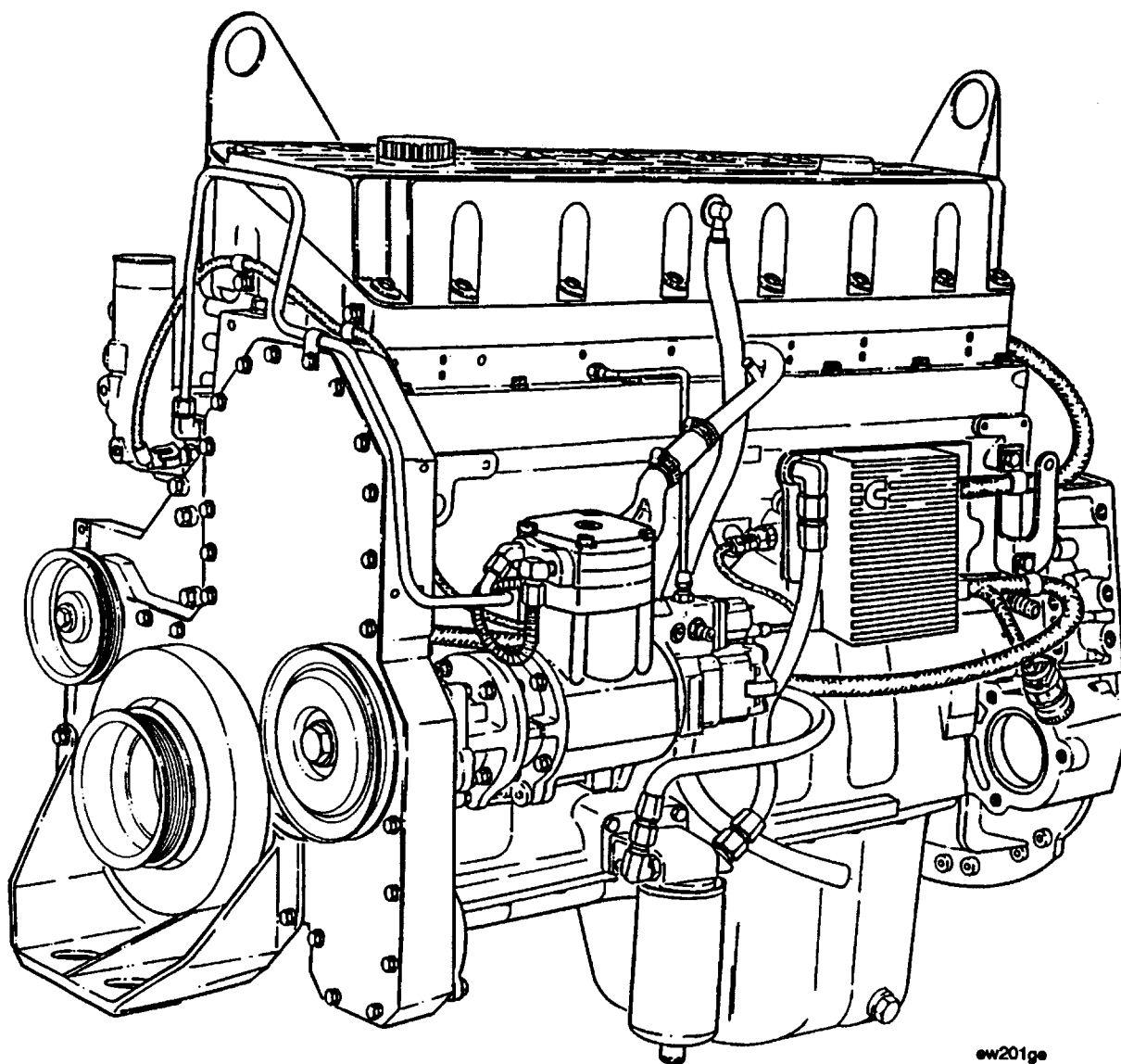




Shop Manual M11 Series Engines



ew201ge

Foreword

This manual contains complete rebuild specifications and information for the M11 model engines, and all associated components manufactured by Cummins Engine Company, Inc. A listing of accessory and component suppliers' addresses and telephone numbers is located in Section C. Suppliers can be contacted directly for any information **not** covered in this manual.

Read and follow all safety instructions. Refer to the WARNING in the General Safety Instructions in this section.

The repair procedures in this manual are based on the engine being installed on an approved engine stand. Some rebuild procedures require the use of special service tools. Make sure the correct tools are used as described in the procedures.

When a specific brand name, number, or special tool is referenced in this manual, an equivalent product can be used in place of the recommended item.

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

Reporting of errors, omissions, and recommendations for improving this publication by the user is encouraged. Please use the postage paid, self-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, a Cummins Division Office, or the factory.

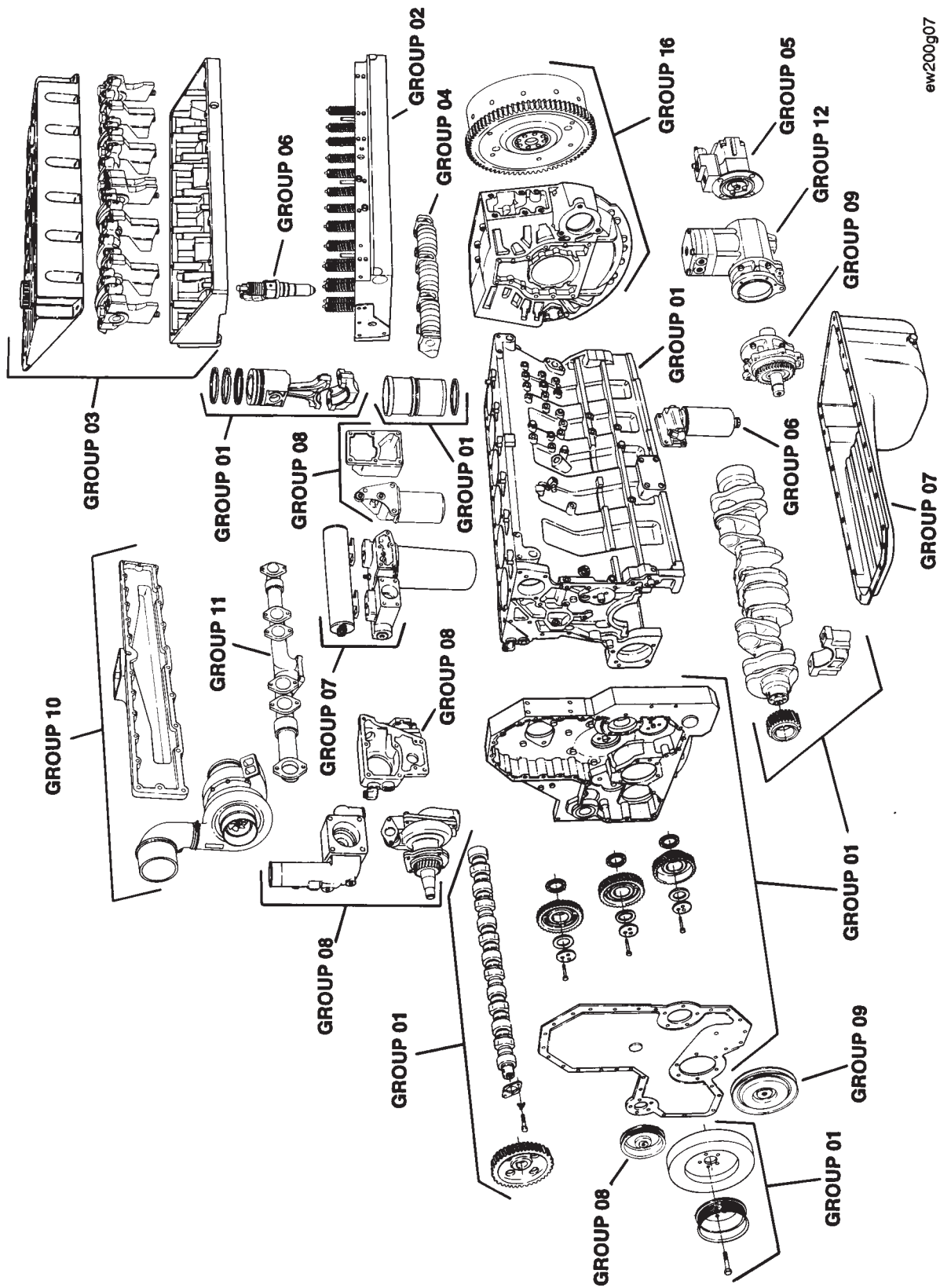
The latest technology and the highest quality components are used to manufacture Cummins engines. When replacement parts are needed, we recommend using only genuine Cummins or ReCon® exchange parts. These parts can be identified by the following trademarks:



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Cummins' 22-Group System Exploded Diagram



Section i - Introduction

Section Contents

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About the Manual

This M11 Shop Manual is intended to aid mechanics in disassembly, inspecting parts for reuse, rebuilding and assembly of components on M11 engines. The manual is divided into sections. Section 0 outlines the disassembly and assembly of the engine while the other sections detail specific components.

How to Use the Manual

This manual is divided in the same group system used for Cummins' filmcard system. Each group is organized in a way that all mechanics, both those who are and are not familiar with the M11 engine models, can reference the manual. Refer to the Table of Contents at the front of the manual to determine the group that details the desired information.

Each group contains the following in sequence:

- Section contents at the beginning of each group to quickly aid in locating the information desired.
- Service tools list with recommended tools needed to rebuild the components.
- General information to aid in rebuilding the component, and an explanation of design change differences.
- Step-by-step rebuild instructions for disassembly, cleaning, inspection and assembly of the component.
- Symbols which represent the action outlined in the instructions. The definitions of the symbols, listed in four languages (English, Spanish, French and German), appear on pages i-3 through i-6.

Topics will be listed alphabetically on the "Section Contents" page. All procedures are described using the "text symbol picture" (TSP) format. In general, each component rebuild will be described through a 3-step sequence of: (1) cleaning and inspection for reuse; (2) rebuild; and (3) replacement. Reference numbers (procedure numbers) are assigned to each process. Reference numbers are constructed with a section number and a two-digit sequenced number.

Both metric and U.S. customary values are used in this manual. The metric value is listed first, followed by the U.S. customary in brackets. An example is 60°C [140°].

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 wiegt 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.



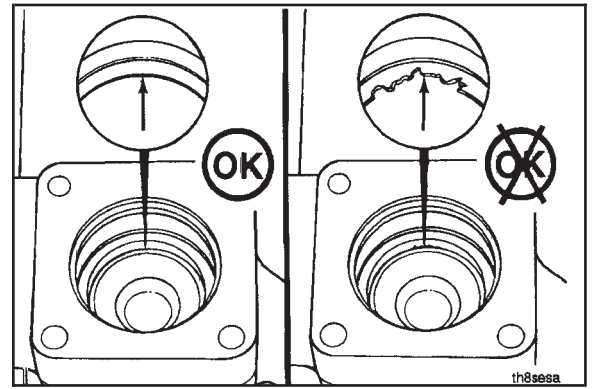
Se reporter à un autre endroit dans ce manuel ou à une autre publication pour obtenir des informations plus complètes.



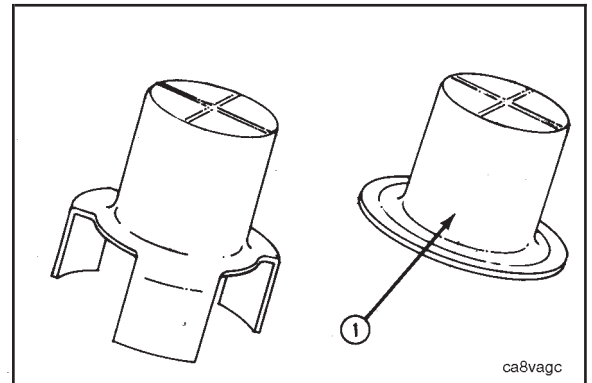
Le composant pèse 23 kg [50 lb] ou davantage. Pour éviter toute blessure, employer un appareil de levage ou demander de l'aide pour le soulever.

Illustrations

The illustrations used in the "Repair Sections" of this manual are intended to give an example of a problem, and to show what to look for and where the problem can be found. Some of the illustrations are "generic" and might **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 illustration can differ from your application, but the procedure given will be the same.



General Safety Instructions

Important Safety Notice



WARNING



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

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

- Make sure the work area surrounding the product is dry, well lit, ventilated; free from clutter, loose tools, parts, ignition sources and hazardous substances. Be aware of hazardous conditions that can exist.
- **Always** wear protective glasses and protective shoes when working.
- Rotating parts can cause cuts, mutilation or strangulation.
- Do **not** wear loose-fitting or torn clothing. Remove all jewelry when working.
- Disconnect the battery (negative [-] cable first) and discharge any capacitors before beginning any repair work. Disconnect the air starting motor if equipped to prevent accidental engine starting. Put a "Do **Not** Operate" tag in the operator's compartment or on the controls.
- Use **ONLY** the proper engine barring techniques for manually rotating the engine. Do **not** attempt to rotate the crankshaft by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s) causing premature fan failure.
- If an engine has been operating and the coolant is hot, allow the engine to cool before you slowly loosen the filler cap and relieve the pressure from the cooling system.
- Do **not** work on anything that is supported **ONLY** by lifting jacks or a hoist. **Always** use blocks or proper stands to support the product before performing any service work.
- Relieve all pressure in the air, oil, 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 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 capture 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 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, Literature, for ordering instructions.

Welding on a CELECT™ Controlled Vehicle



Caution: When welding on a CELECT™ controlled vehicle, to protect the ECM computer circuits, the procedure below **MUST be followed:**

1. Remove all three connectors going to the ECM.
2. Disconnect the negative (-) and positive (+) battery cables from the battery.
3. Do **NOT** connect the welder ground cable to any part of the CELECT™ control system.

General Cleaning Instructions

Solvent and Acid Cleaning

Several solvent and acid-type cleaners can be used to clean the engine parts. **Cummins Engine Company, Inc. does not recommend any specific cleaners. Always** follow the cleaner manufacturer's instructions.

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.



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
2. Wiring
3. Injectors
4. Fuel Pump
5. Belts and Hoses
6. Bearings

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.

Definition Of Terms

A.C.:	Alternating Current
ACT Harness:	The wiring harness used to connect the actuators to the ECM
AFC:	Air Fuel Control; a device in the fuel pump that limits the fuel delivery until there is sufficient intake manifold pressure to allow for complete combustion.
Alligator Clip:	An electrical test clip attached to the end of a wire
API:	American Petroleum Institute
ASA:	Air Signal Attenuator
ASTM:	American Society of Testing and Materials
ATDC:	After Top Dead Center; refers to the position of the piston or the crankshaft rod journal. The piston is moving downward on the power stroke or intake stroke.
BDC:	Bottom Dead Center; refers to the position of the piston or the crankshaft rod journal. The piston is at its lowest position in the cylinder.
BTDC:	Before Top Dead Center; refers to the position of the piston or the crankshaft rod journal. The piston is moving upward on the power stroke or exhaust stroke.
C:	Celsius
CAC:	Charge Air Cooler
CARB:	California Air Resources Board
CELECT™:	A fuel control system that electronically controls the fuel injection to improve fuel economy and to reduce the exhaust emissions. The system does this by controlling the torque and horsepower curve, AFC (smoke) function, engine high speed, engine low idle speed and the road speed. The CELECT™ system also can control fan clutch operation, engine brake enabling and turbocharger wastegating. Additional electronic features include cruise control, PTO, gear down protection, progressive shifting, automotive or VS governor and idle shutoff.
C.I.D.:	Cubic Inch Displacement
Circumferential Direction:	In the direction of a circle in respect to the centerline of a round part or a bore.
Cm:	Centimeter
Compulink™:	A Cummins service tool used for electronic system analysis and to reprogram the system
Concentricity:	A measurement of the difference between the centers of either two or more parts, or the bores in one part.
CPL:	Control Parts List; this listing identifies the specific parts that must be installed on the engine to meet agency certification.
cSt:	Centistokes
Cummins Sealant:	This is a one part Room Temperature Vulcanizing (RTV) silicone rubber, adhesive and sealant material having high heat and oil resistance, and low compression set. Some of the equivalent products are Marston Lubricants, Hylosil, Dow Corning, Silastic 732, Loctite Superflex, General Electric 1473, and General Electric 1470.
D.C.:	Direct Current

Deutsch Connector:	An electrical connector
Dye Penetrant Method:	A method used to check for cracks in a part by using a dye penetrant and a developer. Use Part No. 3375432 Crack Detection Kit, or equivalent.
End Clearance:	The clearance in an assembly determined by pushing the shaft in an axial direction one way , and then pushing the shaft the other way .
ECM:	Electronic Control Module.
E.C.S.:	Emission Control System
EFC:	Electric Fuel Control
EPA:	Environmental Protection Agency
EPS:	Engine Position Sensor
E.S.N.:	Engine Serial Number
ESS:	Engine Speed Sensor
F:	Fahrenheit
ft-lb:	Foot Pound
GPM:	Gallons Per Minute
GVW:	Gross Vehicle Weight
Hammer:	A hand tool consisting of a hard steel head on a handle.
Hg:	Mercury
HP:	Horsepower
H ₂ O:	Water
ID:	Inside Diameter
in-lb:	Inch Pound
kg:	Kilograms
km:	Kilometers
km/l:	Kilometers per Liter
kPa:	Kilopascal
l:	Liter
Loctite 290:	A single component, anaerobic, polyester resin, liquid sealant compound that hardens between closely fitted metal surfaces producing a tough, hard bond with good characteristics. An equivalent product is Perma-Lok HL 126.
Loctite 609:	A single component anaerobic, liquid adhesive that meets or exceeds the requirements of MIL-R-46082A (MR) TYPE 1. Some of the equivalent products are Loctite 601 and Permabond HL 138.
Lubriplate 105:	A mineral oil base grease with calcium soap (2 percent to 6 percent), and zinc oxide (2 percent to 4 percent) additives.
m:	Meter
Magnetic Particle Inspection:	A method of checking for cracks in either steel or iron parts. This method requires a Magnaflux machine, or an equivalent machine that imparts a magnetic field on the part being checked.
Mallet:	A hand tool consisting of a soft head; either wood, plastic, lead, brass, or rawhide on a handle.
MAX:	Maximum allowed
MIN:	Minimum allowed
Mini-Gen:	Speed Sensor

mm:	Millimeter
MPa:	Megapascal
MPH:	Miles Per Hour
MPQ:	Miles Per Quart
N•m:	Newton-meter
No.:	Number
OD:	Outside Diameter
OEM:	Original Equipment Manufacturer
OEM Harness:	The wiring harness used to connect the ECM to the vehicle
OS:	Oversize
PCU:	PACER Control Unit
ppm:	Parts Per Million
Protrusion:	The difference in the height between two parts in the assembled state.
psi:	Pounds Per Square Inch
PTO:	Power Takeoff
REPTO:	Rear Engine Power Takeoff
RPM:	Revolutions Per Minute
S.A.E.:	Society of Automotive Engineers
SCA:	Supplemental Coolant Additive
SEN Harness:	The wiring harness used to connect the engine system sensors to the ECM
STD:	Standard
TC:	Torque Converter; used when referring to the torque converter cooler.
TDC:	Top Dead Center; refers to the position of the piston or the crankshaft rod journal. The piston is at its highest position in the cylinder. The rod journal is pointing straight up toward the piston.
TIR:	Total Indicator Reading; used when measuring the concentricity or the run out. The TIR refers to the total movement of the needle on a dial indicator, from the most negative reading to the most positive reading.
VOM:	Volt Ohm Meter
VS:	Variable Speed
VSS:	Vehicle Speed Sensor
Water Pump Grease:	A premium high temperature grease that will lubricate antifriction bearings continually from minus 40 C [minus 40 F] to plus 150 C [plus 350 F]. Some of the greases meeting this requirement are Aeroshell No. 5, Chevron SRI, Amoco Rykon Premium No. 2, Texaco Premium RB, and Shell Dolium R. Caution: Aeroshell No. 5 is not compatible with the other greases and must not be mixed. Cummins Engine Co., Inc., uses Aeroshell No. 5 on new engines and components.

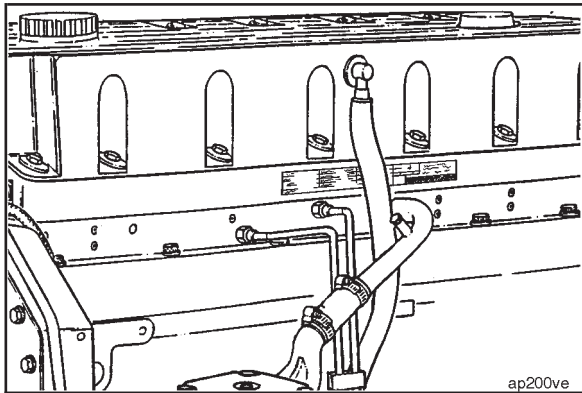
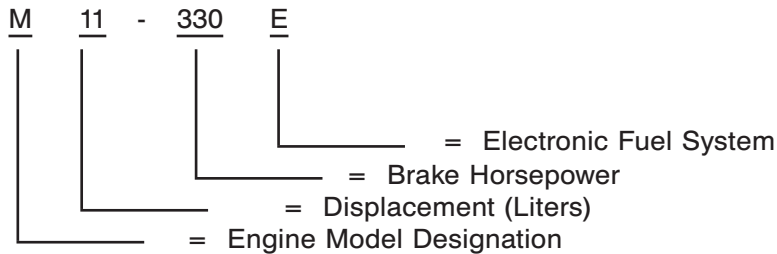
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Section E - Engine Identification
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Engine Identification

The model name provides the following data:



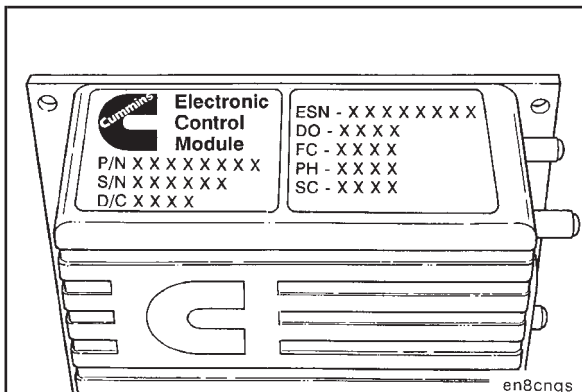
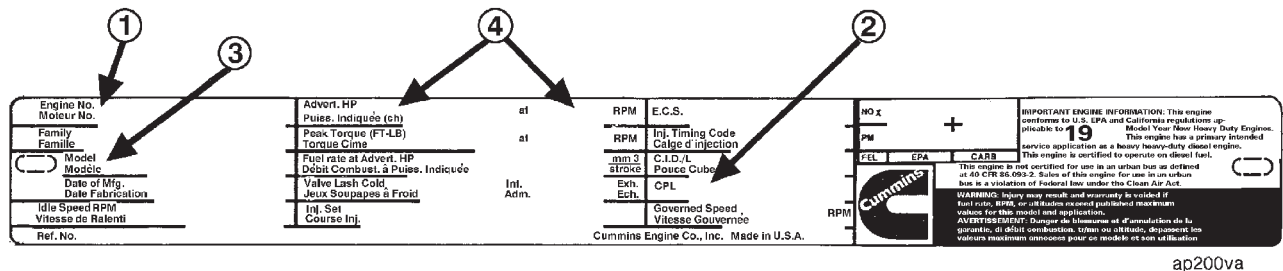
Engine Dataplate

The engine dataplate is located on the fuel pump side of the rocker housing.

The engine dataplate provides model identification as well as other important information about the engine.

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 (E.S.N.)
2. Control Parts List (CPL)
3. Model
4. Horsepower and RPM Rating



Electronic Control Module (ECM) Dataplate

On CELECT™ engines, there are two dataplates on the top of the electronic control module (ECM).

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, fuel code and engine calibration information.

Engine Specifications

Metric [U.S. Customary]

General Engine Data

Horsepower (Refer to the engine dataplate)

Engine speed @ Maximum Output:

- Governed Speed (RPM) - Automotive 1800
- Governed Speed (RPM) - Vocational 2000
- Advertised HP (RPM) 1600

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

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

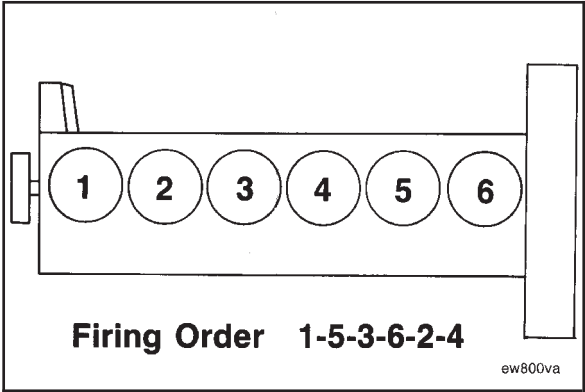
Firing Order 1-5-3-6-2-4

Engine Weight (with Standard Accessories):

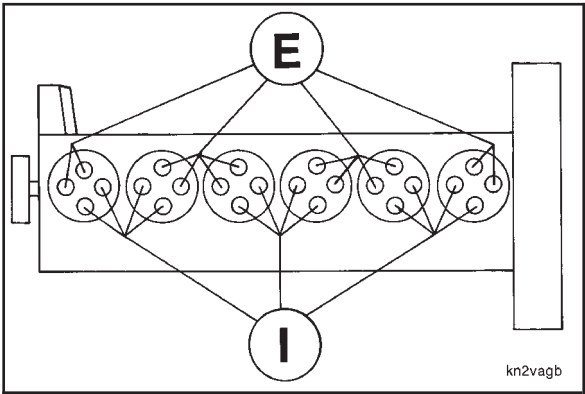
- Dry Weight 940 Kg [2070 lb]
- Wet Weight 996 Kg [2193 lb]

Crankshaft Rotation - (viewed from the front of the engine) Clockwise

Cylinder Location and Firing Order



Intake and Exhaust Valve Locations



Engine Specifications (Continued)

Metric [U.S. Customary]

Air Intake System

Maximum Allowable Intake Restriction with Clean Air Filter Element:

- Heavy Duty Dry Type Cleaner 254 mm H₂O [10 in. H₂O]

Maximum Allowable Intake Restriction with Dirty Air Filter Element 635 mm H₂O [25 in. H₂O]

Maximum Temperature Rise Between Ambient Air and Engine Air Inlet:

- (Ambient Above 0°C [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]

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. gallon]
- Oil Pan (High-Low) 34 to 26.5 liters [9 to 7 U.S. gallon]

Total System Capacity (Including Filter) 39 liters [10.3 U.S. gallon]

Cooling System

Coolant Capacity (Engine Only) 9.5 liters [10 U.S. quarts]

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

Minimum Coolant Cylinder Block Pressure (Pressure Cap Removed):

- Closed Thermostat - 1800 RPM - No Load 138 kPa [20 psi]

Maximum Cylinder Block Coolant Pressure (Pressure Cap Removed):

- Closed Thermostat 275 kPa [40 psi]

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

Minimum Recommended Operating Temperature 70°C [158°F]

Minimum Recommended Pressure Cap 50 kPa [7 psi]

Exhaust System

Maximum Allowable Back Pressure Created by Piping and Silencer:

- Hg 76 mm [3 inch]
- H₂O 1016 mm [40 inch]

Exhaust Pipe Size (Normally Acceptable Inside Diameter) 127 mm [5 inch]

Metric [U.S. Customary]

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: 650 to 800 RPM

Maximum Allowable Fuel Inlet Restriction:

- With **Clean** Filter 152 mm Hg [6 in Hg]
- With **Dirty** Filter 254 mm Hg [10 in Hg]

Maximum Allowable Drain Line Restriction: 89 mm Hg [3.5 in Hg]

Minimum Fuel Pressure:

- During Cranking 172 kPa [25 psi]
- 1200 RPM 827 kPa [120 psi]
- Governed RPM 1034 to 1241 kPa [150 to 180 psi]

Minimum Cranking Speed: 150 RPM

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

Electrical System

Minimum Recommended Battery Capacity

System Voltage	Ambient Temperatures -18°C (0°F)		0°C (32°F)	
	Cold Cranking Amperes	Reserve Capacity * Amperes	Cold Cranking Amperes	Reserve Capacity Amperes
12 Volt	1800	640	1280	480
24 Volt **	900	320	640	240

* The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time which sustained cranking can occur.

** CCA ratings are based on two, 12 volt batteries in series.

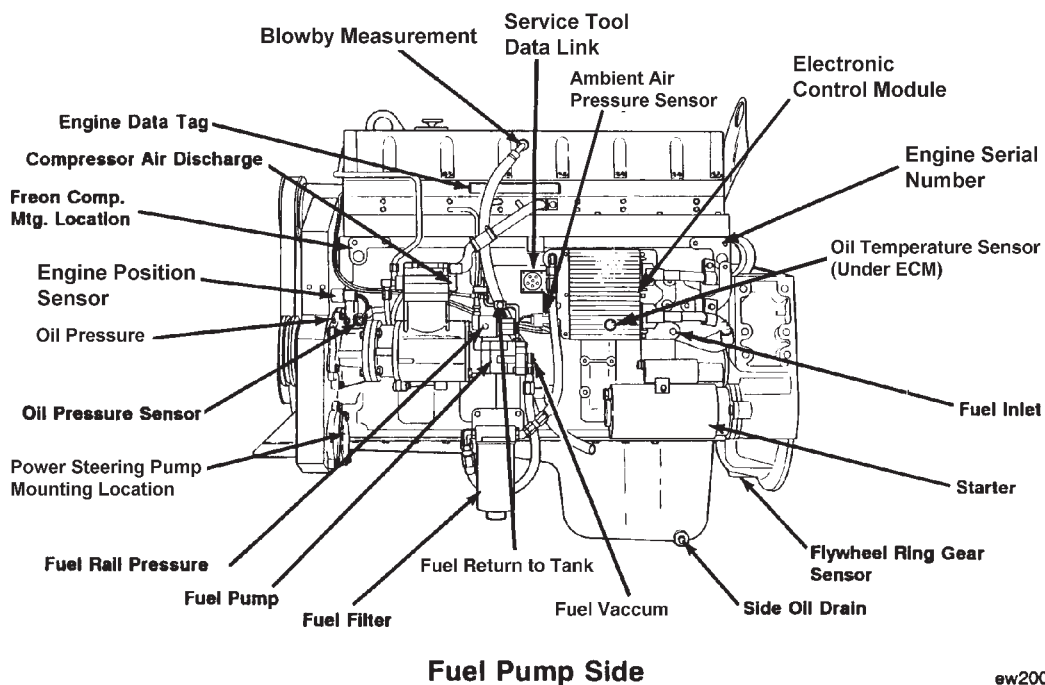
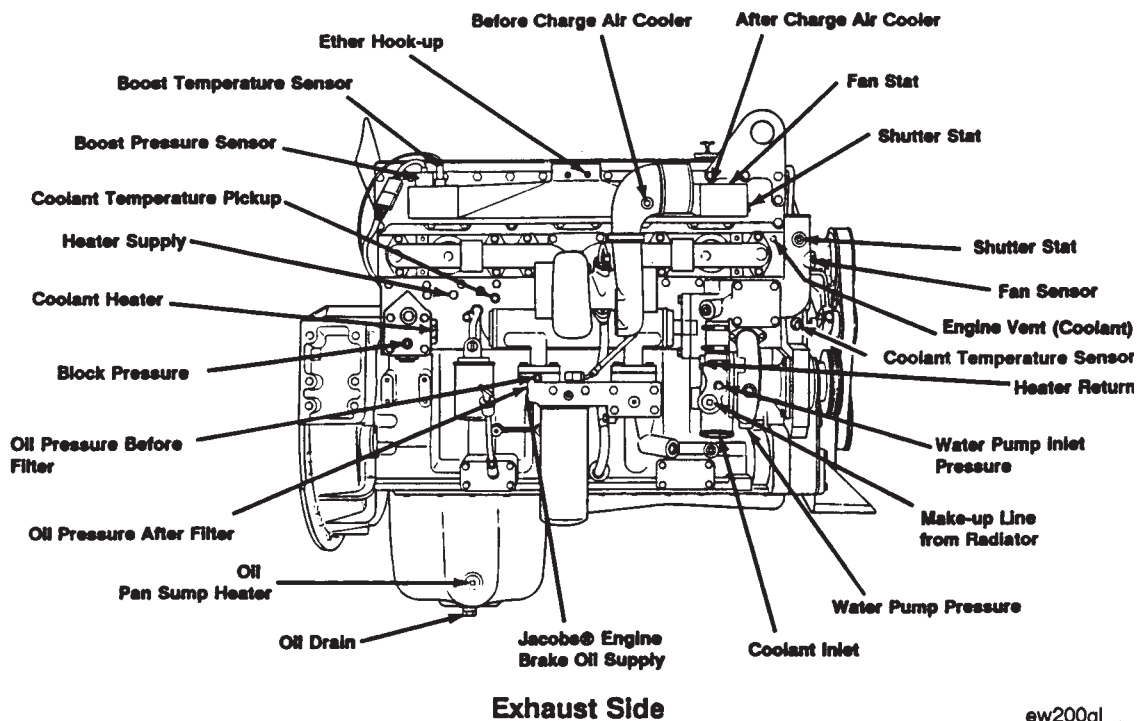
A minimum of 6.5 volts at the three pin connector is required to power up the ECM on CELECT™ engines.

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 provisions 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.



Section 0 - Engine Disassembly and Assembly - Group 00

Section Contents

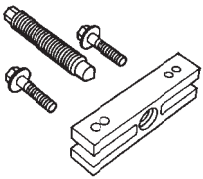
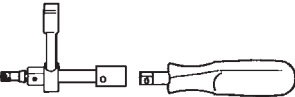
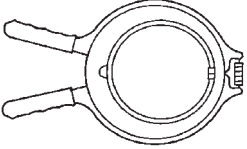
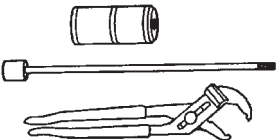
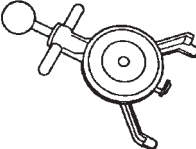
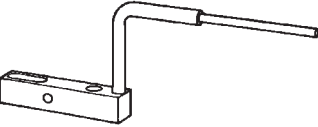
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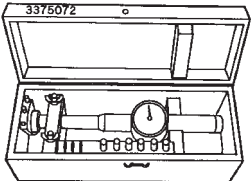
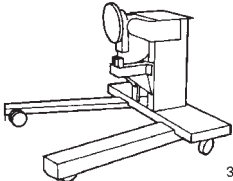
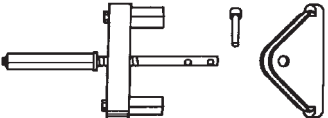
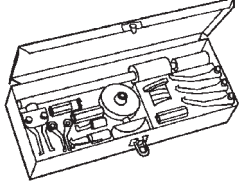
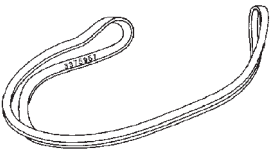
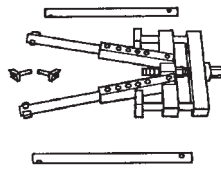
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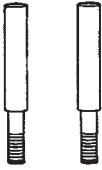
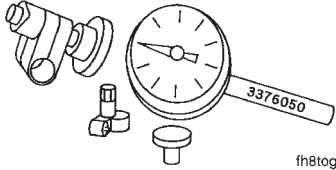
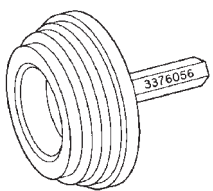
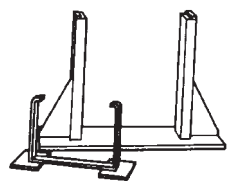
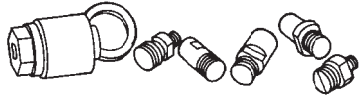
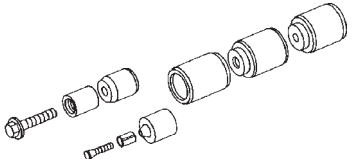
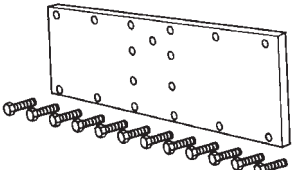
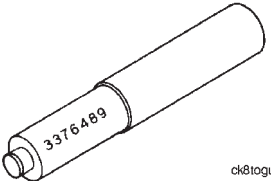
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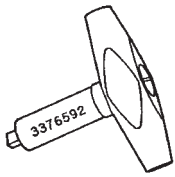
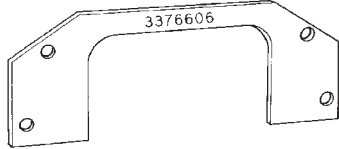
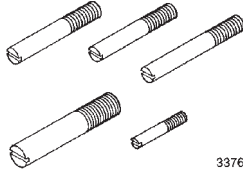
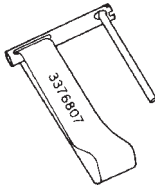
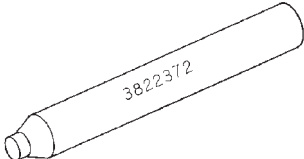
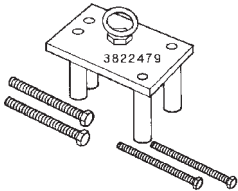
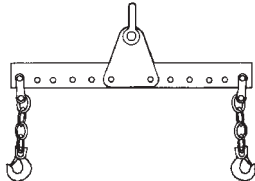
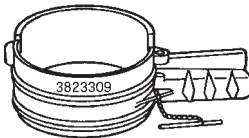
Service Tools - Disassembly and Assembly

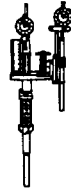
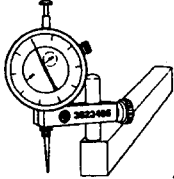
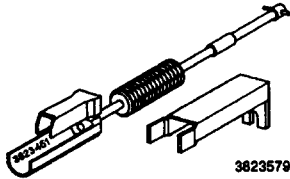
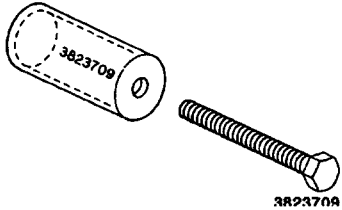
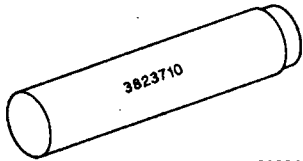
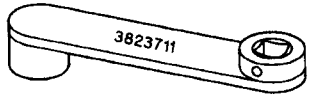
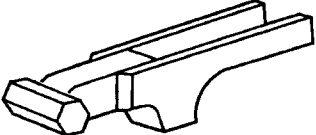
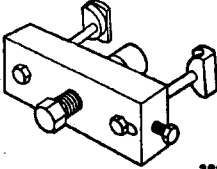
The following special tools are recommended to perform procedures in Group 00. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

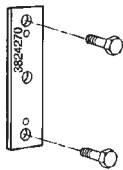
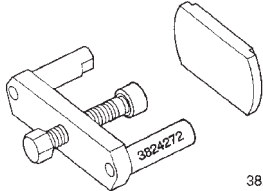
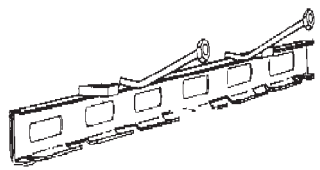
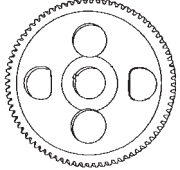
Tool No.	Tool Description	Tool Illustration
ST-647	Standard Puller Remove alternator drive pulley. Use with two (5/16 x 18 x 2 1/2) capscrews.	 ad8toga
ST-669	Torque Wrench Adapter Tighten rocker lever adjusting screws.	 rh8togb
ST-821	Piston Ring Expander Remove and install piston rings on pistons.	 pl8togd
ST-1178	Main Bearing Cap Puller Remove main bearing caps.	 mb8toga
ST-1293	Belt Tension Gauge Measure drive belt tension.	 fa8togc
ST-1325	Dial Gauge Attachment Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial indicator gauge, Part No. 3376050.	 fh8togb

Tool No.	Tool Description	Tool Illustration
3375049	Oil Filter Wrench Used to remove and install lubricating oil filter.	 lf8togb
3375066	Pipe Sealant Used to prevent leaks when installing pipe plugs or fittings.	 bp8togh
3375072	Dial Bore Gauge Kit Used to measure inside diameters.	 oi8togu
3375194	Engine Rebuild Stand Support cylinder block during engine rebuild. Used with adapter plate, Part No. 3376432.	 3375194
3375629	Universal Cylinder Liner Puller Remove cylinder liners from cylinder block. Requires cylinder liner puller plate, Part No. 3376049.	 ck8togq
3375784	Light Duty Puller Kit Remove high oil pressure regulator retainer plug.	 ck8togi
3375957	Nylon Lifting Sling Aid in removal and installation of crankshaft, flywheel and other components which weigh more than 23 kg [50 lb].	 3375957
3376015	Universal Cylinder Liner Puller Remove cylinder liners from the cylinder block. Requires two puller arm extension feet, Part No. 3376649.	 ck8togr

Tool No.	Tool Description	Tool Illustration
3376038	Connecting Rod Guide Pins Guide connecting rods over crankshaft during removal or installation of connecting rods.	 cx8togg
3376050	Dial Indicator and Sleeve Assembly Use with dial gauge attachment, Part No. ST-1325 to measure flywheel and flywheel housing runout. Use with magnetic base, Part No. 3377399, and extension, Part No. ST-537-4, to measure gear end clearance and backlash.	 fh8togc
3376056	Cylinder Liner Driver Install cylinder liner in cylinder block.	 3376056
3376057	Engine Support Stand Support engine when not in-chassis or on the engine rebuild stand.	 3376057
3376326	Pulley Installation Tool Install drive pulleys. Use pulley pusher adapter, Part No. 3377401, to install the alternator drive pulley.	 ad8togb
3376388	Camshaft Guide Pilot Aid in removal and installation of the camshaft in cylinder block.	 3376388
3376432	Engine Stand Adapter Plate Adapt M11 cylinder block to the engine rebuild stand, Part No. 3375194. Requires 12 (M10-1.5 X 80) hex head capscrews, Part No. 3376434, and lockwashers.	 3376432
3376489	Regulator Retainer Plug Driver Install the high oil pressure regulator retainer plug in the cylinder block to a specified depth.	 ck8togu

Tool No.	Tool Description	Tool Illustration
3376592	Inch Pound Torque Wrench Required to make consistent settings of the injector. Screwdriver socket, Part No. ST-669-13, must be used with this tool.	 fi8togi
3376606	Flywheel Housing Alignment Plate Align flywheel housing with cylinder block.	
3376695	Guide Pin Kit Aid during installation of flywheel, flywheel housing, vibration damper, and air manifold. The kit contains two each of guide pins, Part Nos. 3376488, 3376638, 3376696, 3376697, and 3376698.	 3376695
3376807	Filter Wrench Used to remove or tighten spin on fuel filter(s) and coolant filter.	 3376807
3822372	Expansion Plug Driver Install expansion plug to specified depth. Use with expansion plug driver handle, Part No. 3376795.	 3822372
3822479	Cylinder Head Lifting Bracket Remove and install cylinder head to the cylinder block.	
3822512	Engine Lifting Fixture Used for lifting the engine.	 3822512
3823309	Piston Ring Compressor Compress piston rings on pistons during installation of pistons in the cylinder block.	 3823309

Tool No.	Tool Description	Tool Illustration
3823451	Static Injection Timing Tool Check static injection timing.	 3823451
3823495	Gauge Block Measure cylinder liner protrusion on the cylinder block, flywheel and gear housing protrusion below the cylinder block.	 3823495
3823579	Injector Puller Used to remove and install injectors in CELECT™ engines.	 3823579
3823709	Idler Shaft Puller and Capscrew Used to remove the idler shaft from the idler gear and flywheel housing on engines equipped with a rear engine power takeoff	 3823709
3823710	Cup Plug Driver Used to install the cup plug in a REPTO flywheel housing.	 3823710
3823711	Offset Wrench Use to loosen or tighten four hidden flywheel housing mounting capscrews on engines equipped with a rear engine power take-off.	 3823711
3823771	Rocker Lever Actuator Used to check injector adjustments on engines with or without engine brakes.	 3375790
3824106	Camshaft Gear Puller Used to remove the camshaft gear from the camshaft.	 3824106

Tool No.	Tool Description	Tool Illustration
3824270	Engine Barring Tool Used to bar the engine by hand. Also used with a slide hammer to remove the hydraulic drive adapter.	 3824270
3824272	Cylinder Liner Clamping Tool Used to seat the liner in the cylinder block while measuring cylinder liner protrusion.	 3824272
3824519	Cam Follower Assembly Removal and Installation Tool Used to remove and install the cam follower assemblies.	 3824519
3824652	Slip Fit Camshaft Gear Used for checking static injection timing during engine assembly.	 3824652

Engine Disassembly and Assembly - General Information

These procedures apply to M11 engines. The differences between engine models, due to the application and optional equipment on an engine, is included in the instructions. Omit the steps that do **not** apply to the engine being rebuilt.

1. A **Warning** statement is included for any component or assembly that weighs more than 23 Kg [50 lb]. To avoid personal injury, use a hoist or get assistance from more than one person when removing or installing these parts.
2. Most of the capscrews used on the M11 engine are metric. Some components, such as the air compressor and fuel pump, are installed using U.S. Customary capscrews. All fasteners have right-hand threads unless a **Caution** states that a fastener has left-hand threads.

Disassembly

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.

The instructions in this procedure are organized in a logical sequence to disassemble the M11 engine. This is **not** the only sequence to disassemble a M11 engine. Certain parts **must** be removed in the sequence indicated. Use this sequence until you become familiar with the engine.

Discard all gaskets, seals, hoses, filters, and o-rings unless these parts are needed for a failure analysis.

Label, tag, or mark the parts for location as they are removed. This will help find all of the parts that can be involved in a failure, and simplify the assembly procedure.

Label, tag, mark, or photograph all special equipment prior to the removal from an engine. This engine assembly procedure does **not** include the installation of special optional equipment.

Force **must** be used to remove certain parts. A mallet can be used when force is required. All of the fasteners **must** be removed before using force.

Avoid as much dirt as possible during disassembly. The accumulation of additional dirt will make it more difficult to clean the components.

Assembly

This procedure assumes that all of the components and assemblies have been cleaned, replaced, or rebuilt and are ready to be installed on the engine.

Torque values are listed in each step. If a torque value is **not** specified, use the chart listed in the specifications section, Group 18, to determine the correct torque value.

Many of the gaskets and o-rings are manufactured from a material designed to absorb oil. These gaskets will enlarge and provide a tight seal after coming in contact with oil. Use **ONLY** a recommended contact adhesive or a vegetable based oil to install these parts.

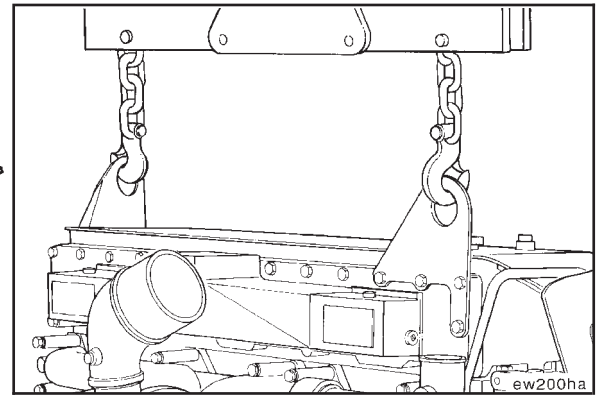
Always use a capscrew of the same system, metric or U.S. Customary, the same dimension and the same grade as the capscrew removed. The use of a longer capscrew than the capscrew that is listed can result in damage to the engine.

Engine Lifting Brackets

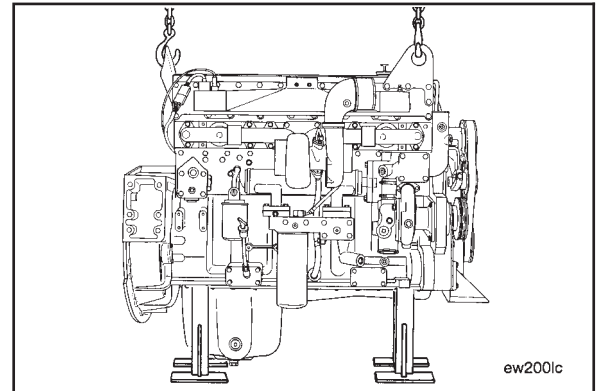
Warning: The engine lifting equipment must be designed to safely lift the engine as an assembly.

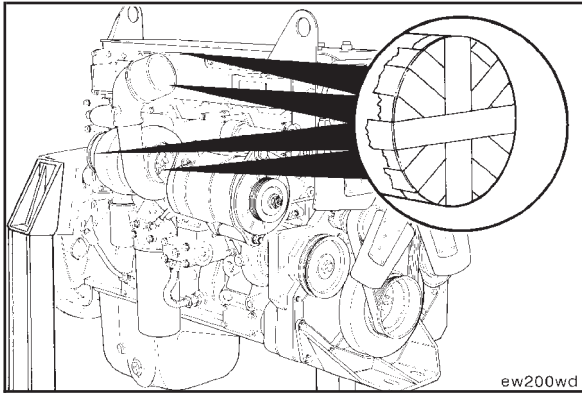
Use a properly rated hoist and engine lifting fixture, Part No. 3822512, attached to the engine mounted lifting brackets to lift the engine.

Refer to Section E for the weight of the engine you are working on.



Install the engine on two engine support stands, Part No. 3376057.





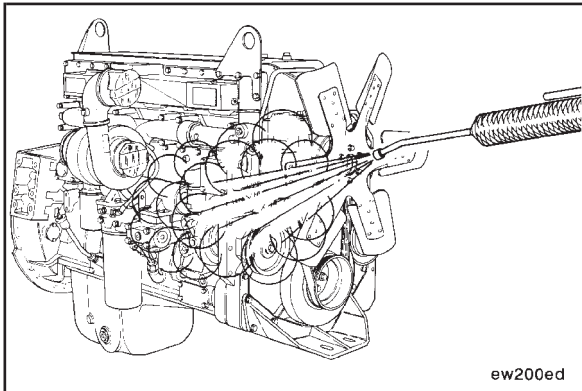
Engine Disassembly (0-01)

Engine - Preparation for Cleaning



Install caps or tape on all engine openings to prevent moisture and dirt from entering the engine:

Protect all electrical components and wiring from the full force of the cleaner spray nozzle.



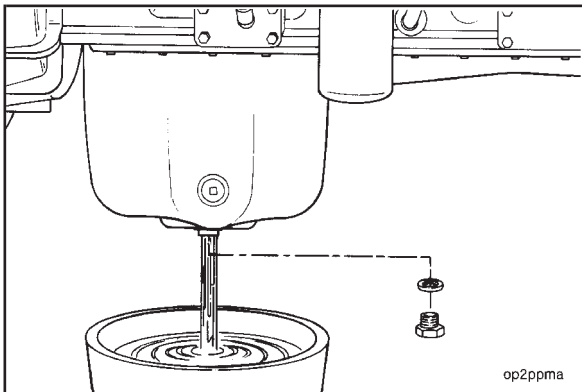
Engine - Cleaning



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



Steam clean and dry with compressed air.



Lubricating Oil - Draining

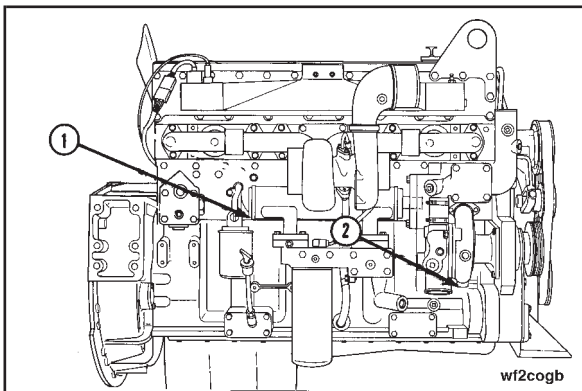


Warning: Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

The oil pan capacity is 34 Liters [9.0 U.S. gallons].

Remove the oil drain plug from the bottom of the oil pan.

Drain the oil into a suitable container.



Coolant - Draining



Remove the plugs from the following points:

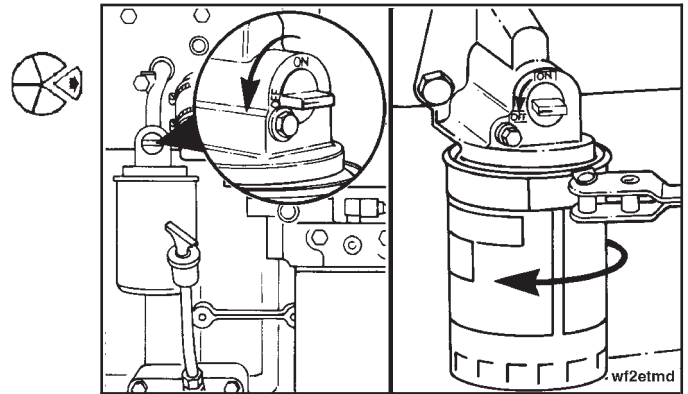
- Lubricating oil cooler (1)
- Water pump (2)

Drain the coolant into a suitable container.

Coolant Filter - Removal

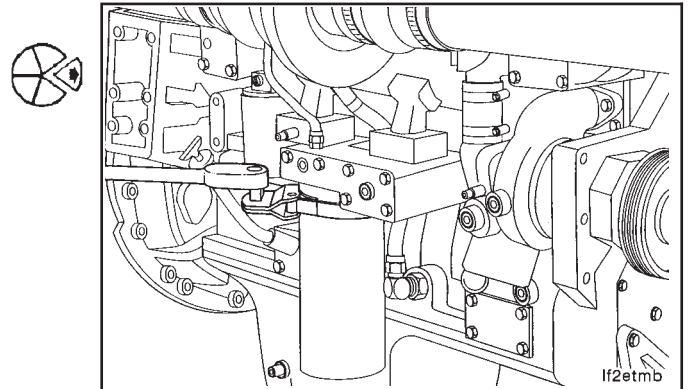
Turn the coolant valve to the “OFF” position before the filter is removed.

Use fuel and water filter wrench, Part No. 3376807, to remove the coolant filter.



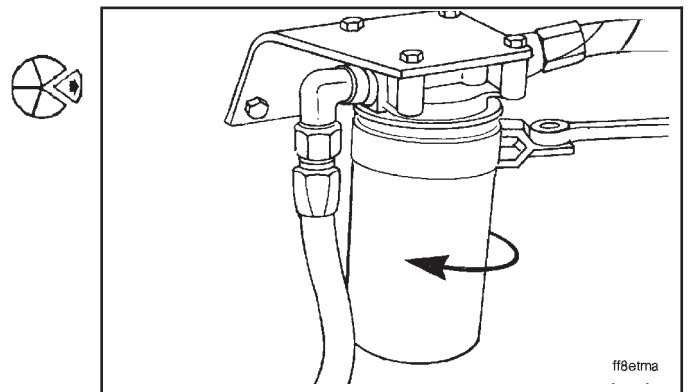
Lubricating Oil Filters - Removal

Use oil filter wrench, Part No. 3375049, to remove the oil filter.



Fuel Filter - Removal

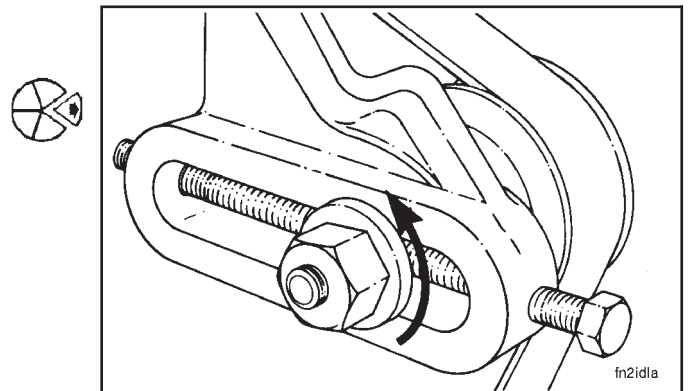
Use fuel and water filter wrench, Part No. 3376807, to remove the fuel filter.

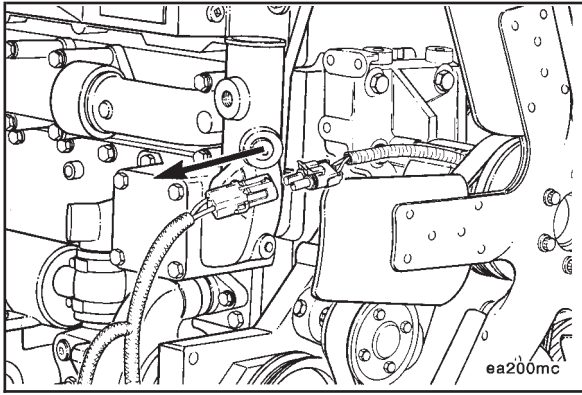


Fan Drive Belt - Removal

Loosen the idler pulley shaft locknut.

Turn the adjusting screw **counterclockwise** to release tension, and remove the belt.

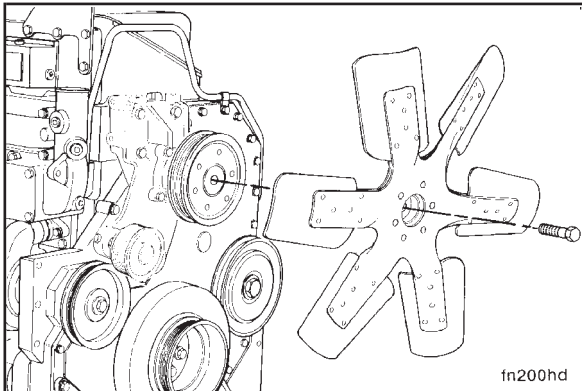




Fan and Fan Hub - Removal



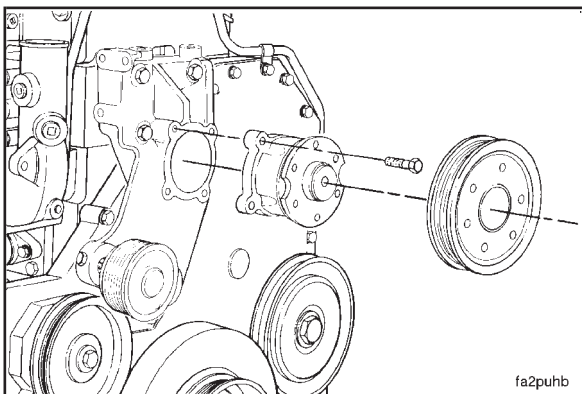
If an electric fan clutch is used, disconnect the fan clutch connector from the base wiring harness.



Remove the six capscrews and the fan.



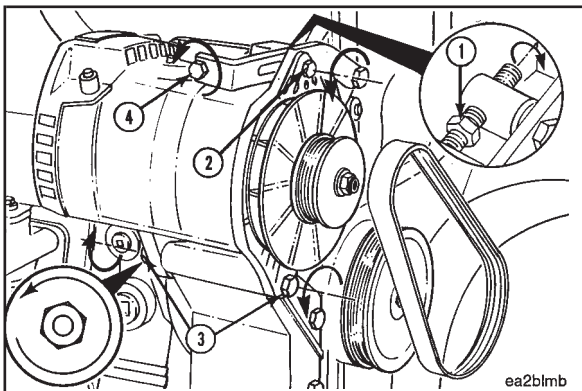
NOTE: The six capscrews also hold the fan drive pulley in position. Do **not** allow the pulley to fall.



Remove the fan drive pulley.



Remove the four capscrews and the fan hub.



Alternator Belt (Non Bus Applications) - Removal



Loosen the adjusting screw locknut (1).

Loosen the adjusting link capscrew (2).

Loosen the pivot capscrew and nut (3).

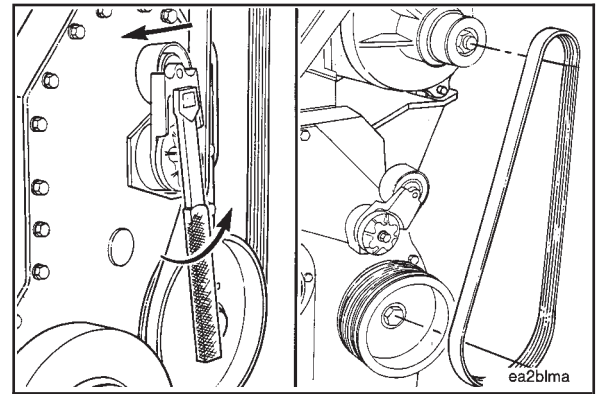
Turn the adjusting screw (4) to release tension, and remove the belt.

Alternator Belt (Bus Applications) - Removal

Insert a 3/8 inch breaker bar into the space provided on the tensioner.

Rotate the tensioner away from the belt until it stops.

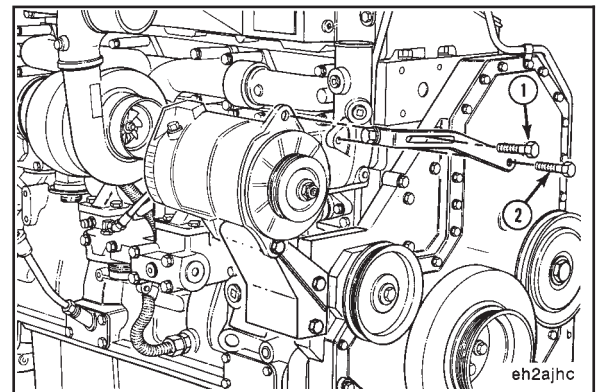
Remove the alternator belt while holding the tensioner back.



Alternator Adjusting Link (Non Bus Applications) - Removal

Remove the capscrew (1) from the alternator.

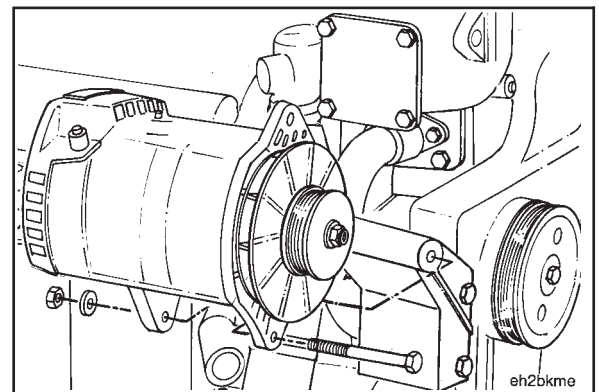
Remove the capscrew (2) from the thermostat housing and the adjusting link.



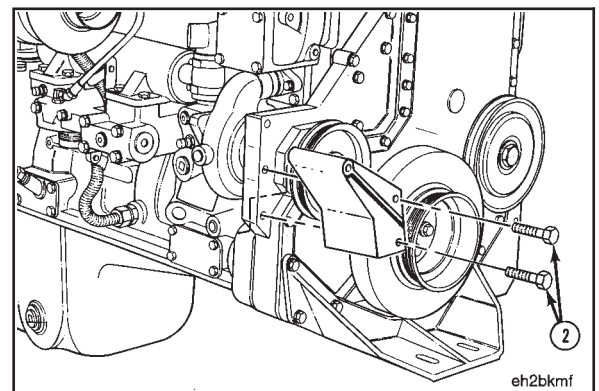
Alternator and Bracket (Non Bus Applications) - Removal

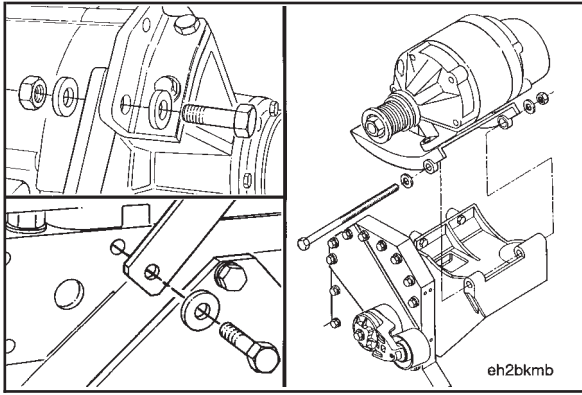
Remove the nut from the alternator mounting pivot bolt.

Remove the pivot bolt and alternator.



Remove the mounting capscrews, the bracket, and the spacers.



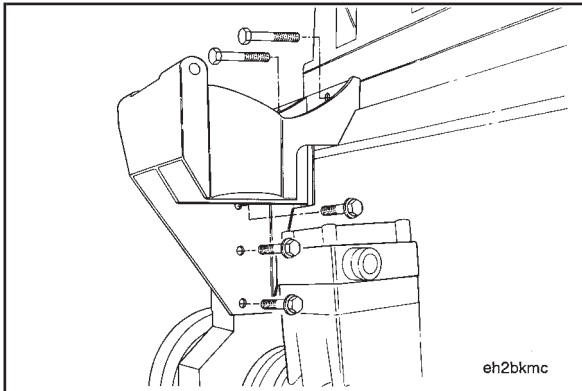


Alternator and Brackets (Bus Applications)

Loosen the alternator pivot mounting capscrew.

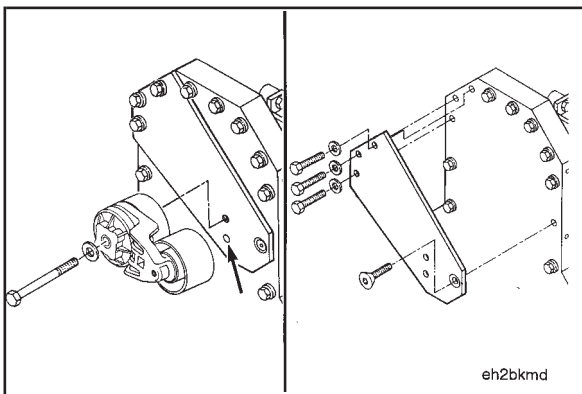
Remove the alternator brace link.

Remove the alternator pivot capscrew and the alternator.



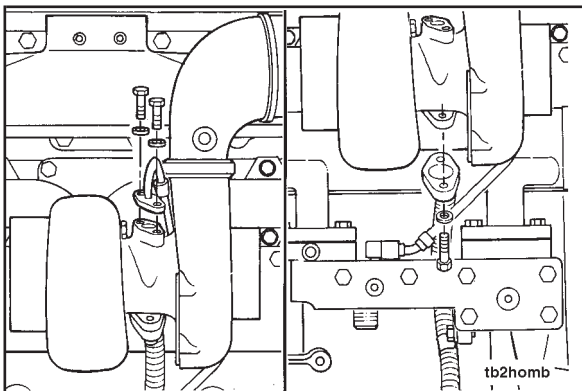
Remove the mounting nut from the rear of the gear housing and the four cylinder block mounting capscrews from the lower alternator mounting bracket.

Remove the lower alternator mounting bracket.



Remove the belt tensioner from the front of the engine.

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



Turbocharger - Removal

Remove the oil supply line and gasket from the top of the turbocharger.

Remove the other end of the supply line from the lubricating oil filter head.

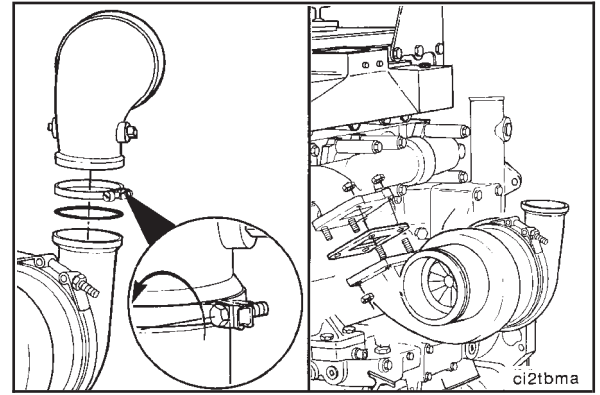
Remove the oil drain line and gasket from the bottom of the turbocharger.

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.

Plug the supply and drain holes in the turbocharger.



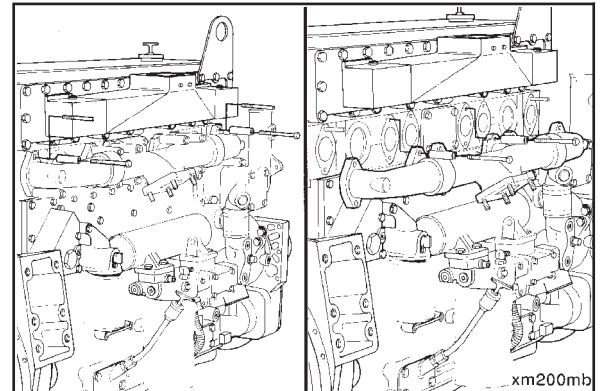
Exhaust Manifold - Removal

Caution: The exhaust manifold assembly has three sections which can separate and fall causing personal injury during removal. Hold the assembly on each end to remove it.

Remove one capscrew from each end section of the exhaust manifold and install two guide pins, Part No. 3376488.

Remove the remaining capscrews.

Remove the exhaust manifold, gaskets and the two guide pins.



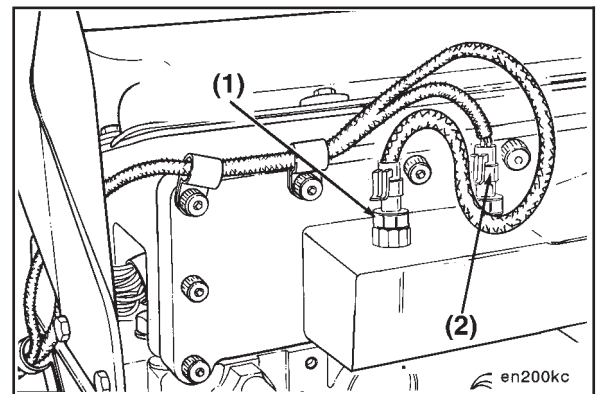
Air Intake Manifold - Removal

Remove the intake manifold pressure sensor and the intake manifold temperature sensor wire connectors from the top rear end of the intake manifold.

Tag the wires as they are removed for future identification.

Remove the boost pressure sensor (1) and the intake manifold temperature sensor (2) from the manifold.

Remove the wire clamps holding the harness to the manifold.



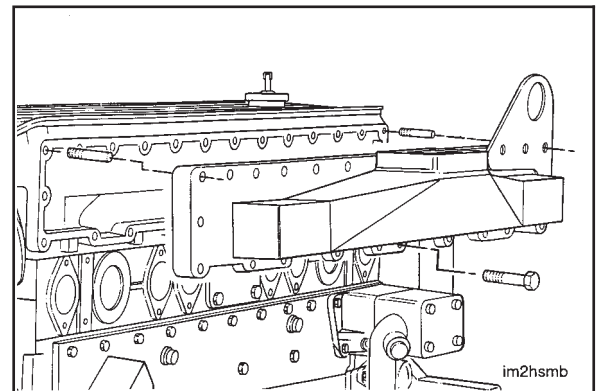
Remove the air intake connection and gasket from the top of the manifold.

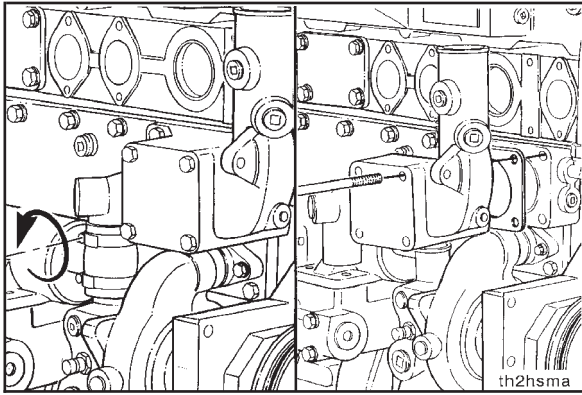
Remove two of the mounting capscrews and install two guide pins, Part No. 3376488.

Remove the remaining capscrews, beginning at the ends and moving toward the center, intake manifold and gasket. Remove the guide pins.

Use four (M10 x 25) capscrews and install the front lifting bracket on the rocker lever housing.

Torque Value: 47 N•m [35 ft-lb]





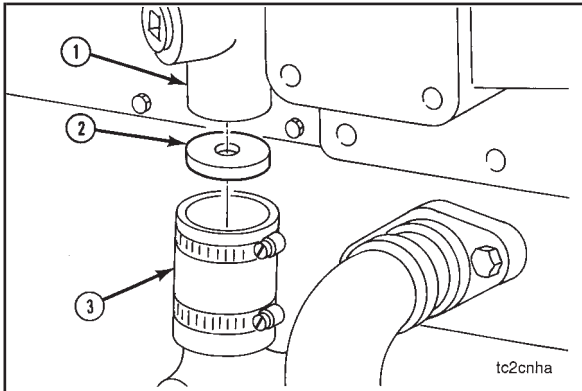
Thermostat Housing - Removal

Loosen the bottom coolant bypass hose clamp.



NOTE: If the housing is stuck, hit the housing with a mallet to loosen it.

Remove the four capscrews, the housing, and the thermostat.

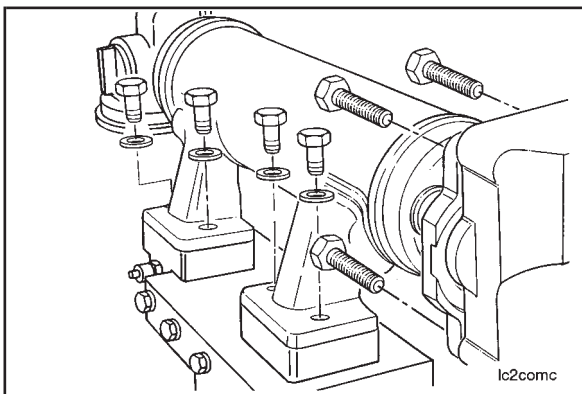


Torque Converter Cooler Disc - Removal

The torque converter cooler disc (2) restricts the water flow through the thermostat housing (1) to water pump bypass hose (2). This allows coolant to be circulated through a remote mounted torque converter oil cooler.



Remove the disc (2) from the thermostat housing to water pump bypass hose connection.



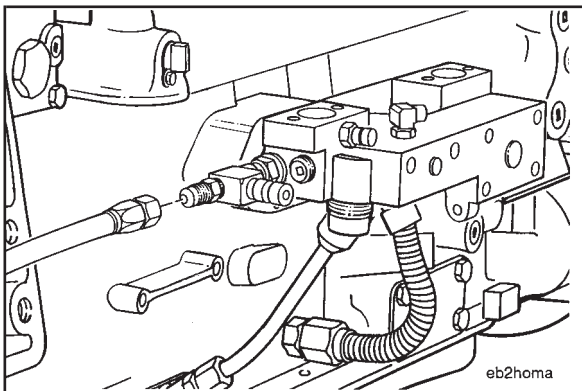
Lubricating Oil Cooler - Removal

Remove the four oil cooler to thermostat housing support flange mounting capscrews.



Remove the four oil cooler to lubricating oil filter head mounting capscrews, oil cooler and gaskets.

Remove the oil cooler water inlet and outlet tubes and the mounting flange.



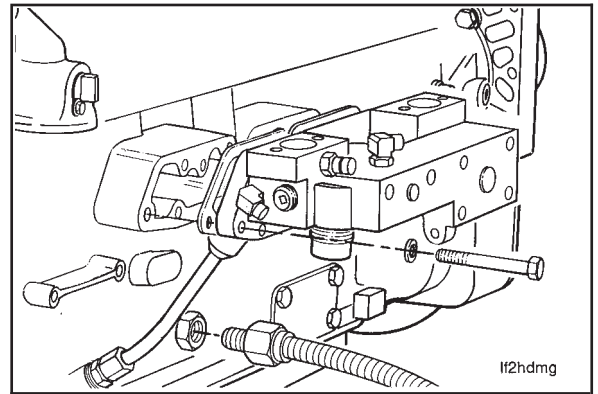
Lubricating Oil Filter Head - Removal

Remove the Jacobs® engine brake oil supply line, if equipped.

Remove the capscrew from the turbocharger drain line bracket.

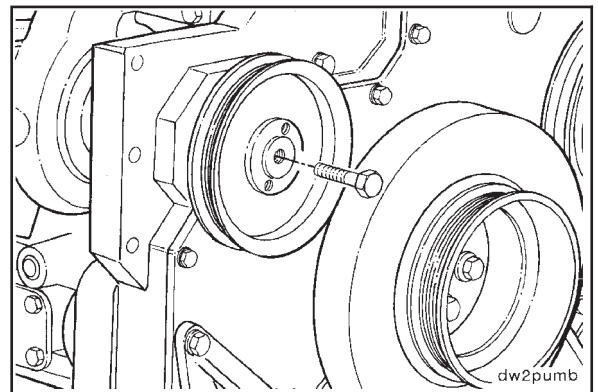
Remove the nine capscrews, oil filter head and gasket.

Remove the turbocharger oil drain line from the cylinder block drain connection.

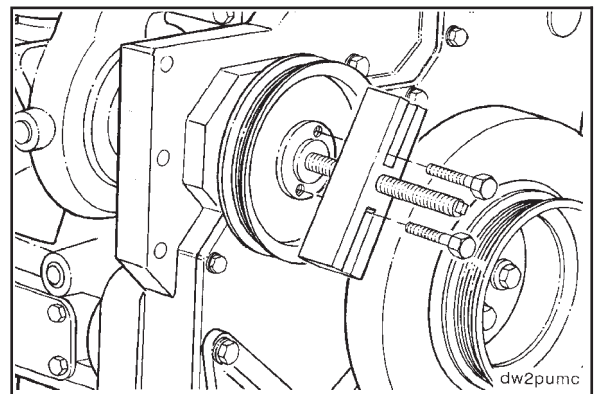


Alternator Drive Pulley - Removal

Remove the pulley retainer capscrew.

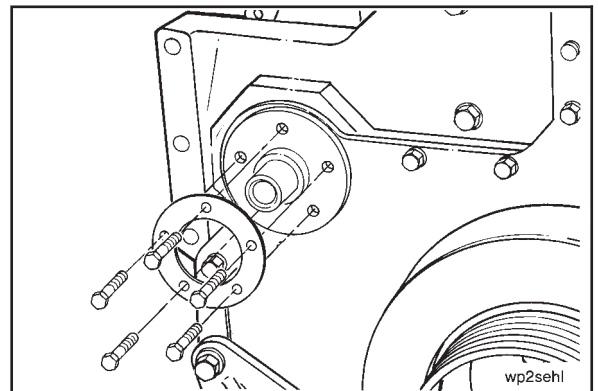


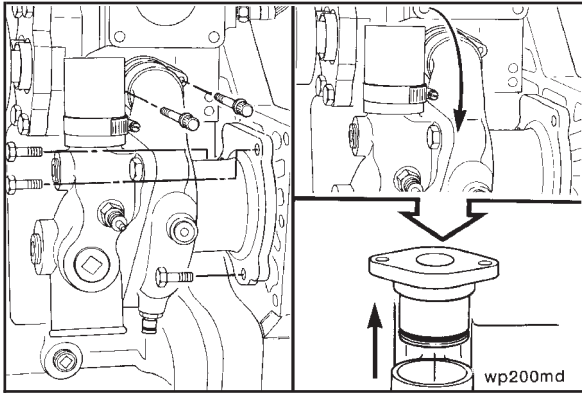
Use standard puller, Part No. ST-647, and two capscrews, (5/16-18 x 2 1/2), to remove the pulley.



Alternator Drive Oil Seal - Removal

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





Water Pump - Removal

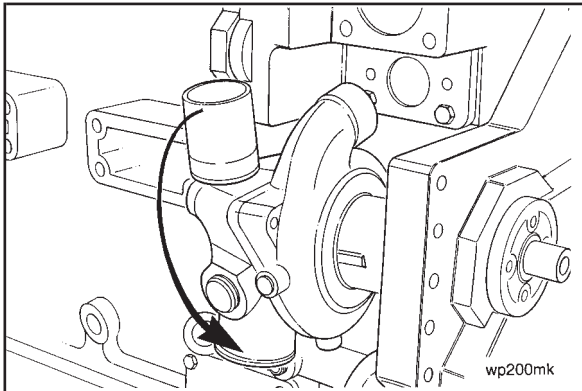


Remove the two water transfer connection capscrews.

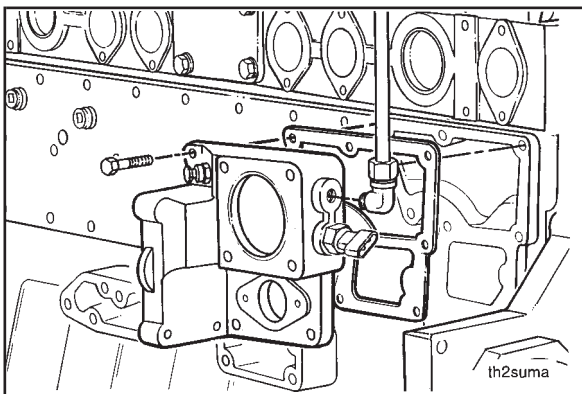
Remove the three water pump mounting capscrews.

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.



Twist the water 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 while being removed.



Thermostat Housing Support - Removal

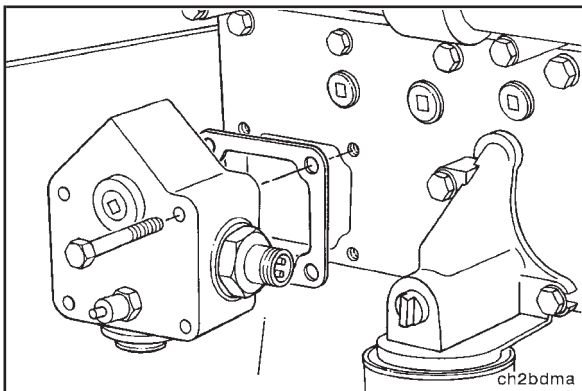


Remove the wiring harness from the coolant temperature sensor. Tag the harness connection for future identification.

Loosen the air compressor water return tube connection (1).

NOTE: If the support is stuck, hit the support with a mallet to loosen it.

Remove the four capscrews (2) and the support.



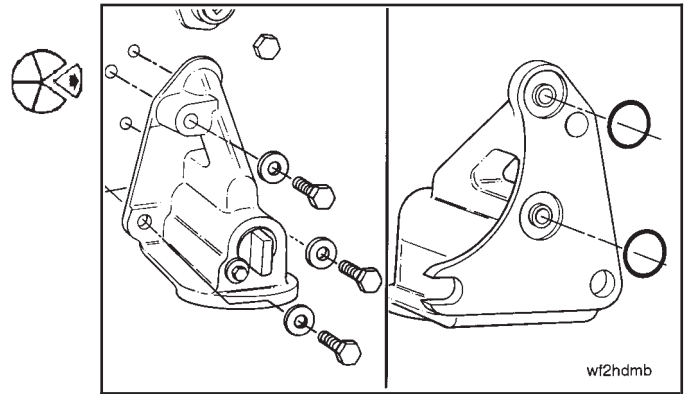
Water Heater Housing - Removal



Remove the four mounting capscrews, the housing and gasket.

Water Filter Head - Removal

Remove the three capscrews, filter head and the two o-rings.



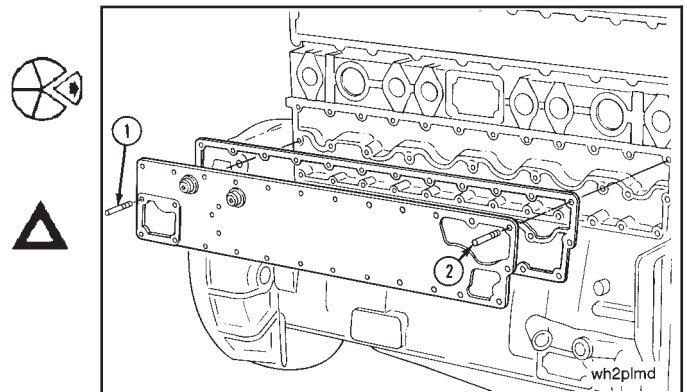
Water Header Plate - Removal

Remove capscrews (1) and (2), and install two guide pins, Part No. 3376488.

Remove the remaining capscrews beginning at the ends and moving toward the center of the plate.

Caution: Care must be taken to ensure no surface scratches occur on the water header plate or cylinder block mounting surfaces. Scratches on these surfaces will cause future leak paths.

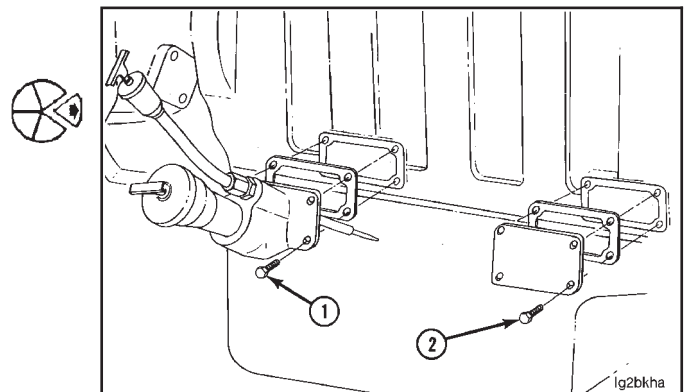
Remove the water header plate, gasket and guide pins.



Hand Hole Cover and Dipstick Tube Bracket - Removal

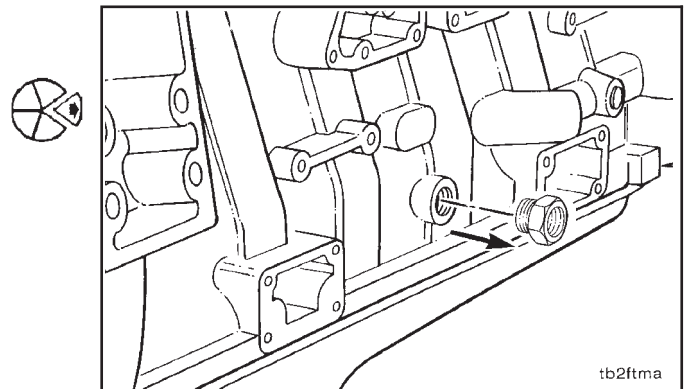
Remove the four capscrews (1), the dipstick tube bracket and gasket.

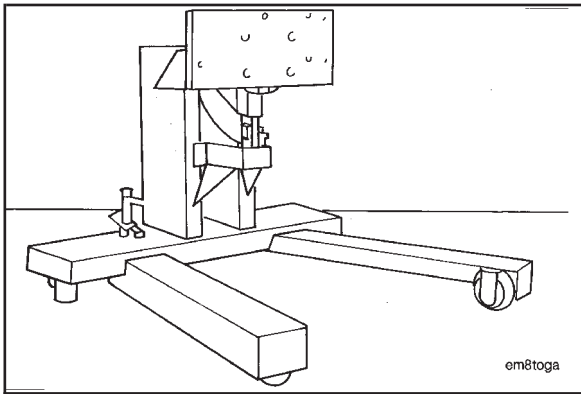
Remove the four capscrews (2), the hand hole cover and gasket.



Turbocharger Oil Drain Connection - Removal

Remove the turbocharger oil drain tube connection fitting from the side of the cylinder block.





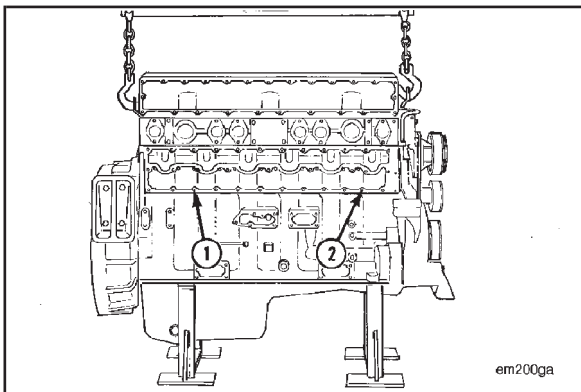
Engine - Installation On Rebuild Stand

Use the engine rebuild stand, Part No. 3375194, and adapter plate, Part No. 3376432.



Use five capscrews (5/8—11 X 2 inch) grade 5 capscrews to install the adapter plate to the rebuild stand.

Torque Value: 180 N•m [135 ft-lb]



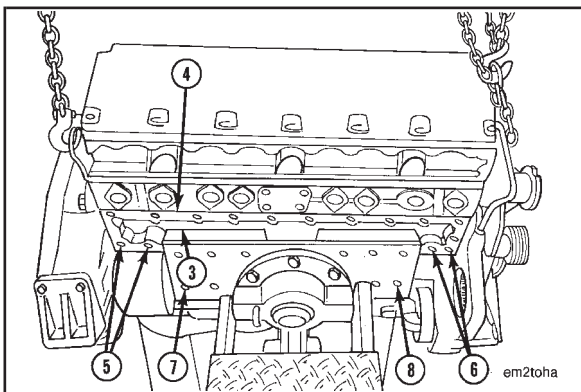
Install two guide pins, Part No. 3376488, in the water header plate mounting capscrew holes at points (1) and (2) (No. 3 capscrew hole from each end).



Warning: To avoid personal injury, use a properly rated hoist to lift the engine. The engine weighs approximately 940 kg [2070 lb].

Use the engine lifting fixture, Part No. 3822512, to lift the engine.

Install the exhaust side of the engine to the adapter plate of the rebuild stand.



Align the top of the adapter plate (3) to the top row of the water header plate mounting capscrews holes (4).

The cylinder block **must** be positioned so two capscrew holes (5) and (6) in the bottom row will show on each side of the adapter plate.



Align the guide pins with the bottom row of holes in the adapter plate at points (7) and (8).



Use eight capscrews, Part No. 3376434, to install the adapter plate to the engine block.

Torque Value: 47 N•m [35 ft-lb]

Remove the guide pins and install two capscrews, Part No. 3376434.

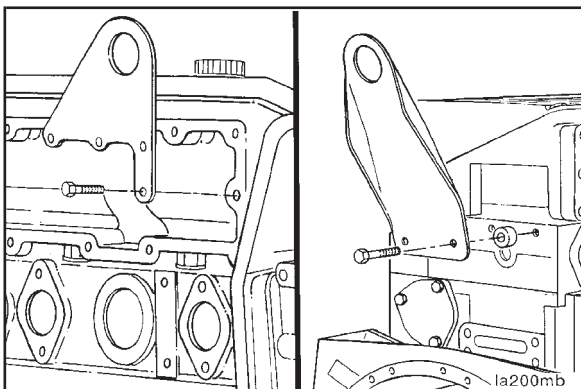
Torque Value: 47 N•m [35 ft-lb]

Lifting Brackets - Removal



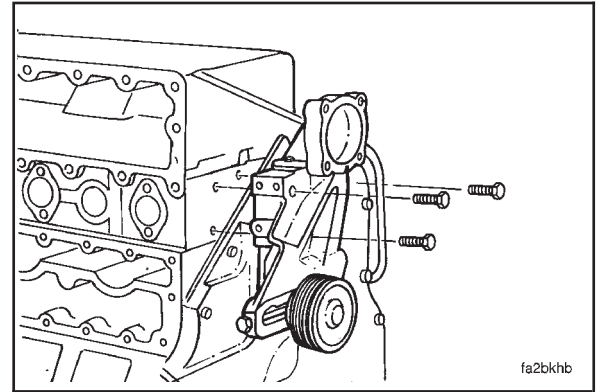
Remove the front lifting bracket.

Remove the rear lifting bracket.



Fan Hub Support - Removal

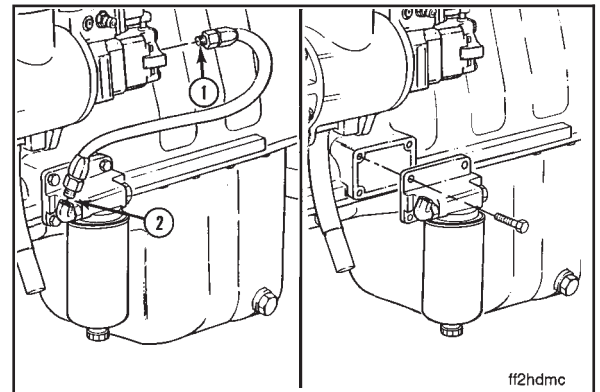
Remove the three mounting capscrews and the support.



Fuel Supply Hose and Filter Head - Removal

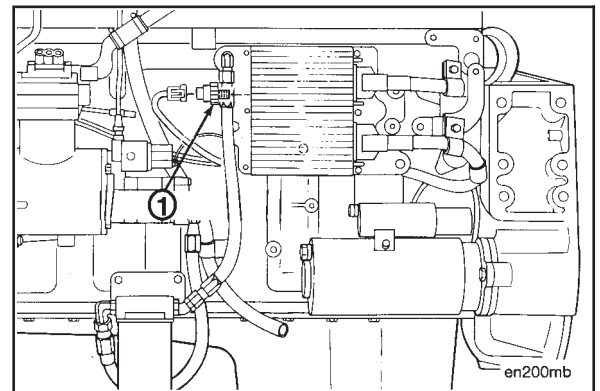
Remove the fuel supply hoses at points (1) and (2).

Remove the fuel filter head.



Electronic Control Module - Removal

Remove the ambient air pressure sensor wire connector and the ambient air pressure sensor (1), if equipped, from the front electronic control module (ECM) mounting bracket.

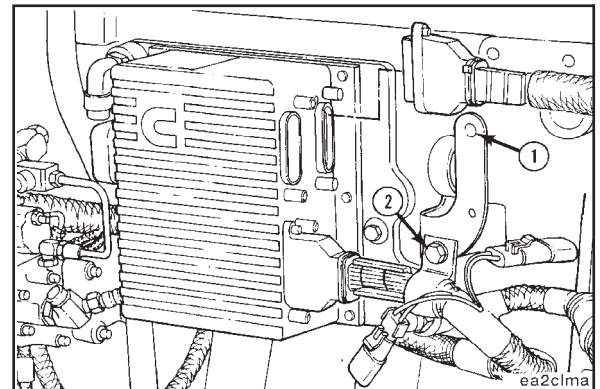


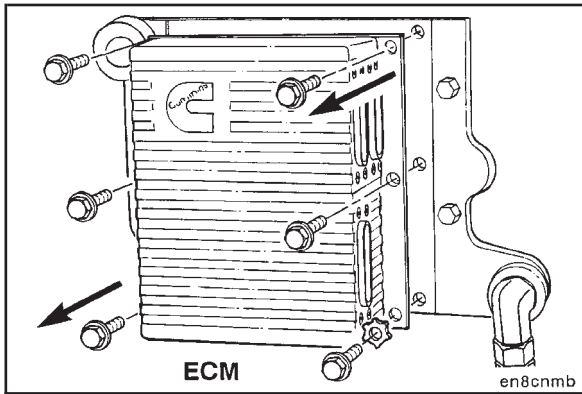
Remove the harness wire clamps from the support bracket at points (1) and (2).

Loosen the AMP connector mounting capscrews from the actuator harness and the sensor harness. Remove the actuator and sensor harness connectors from the ECM.

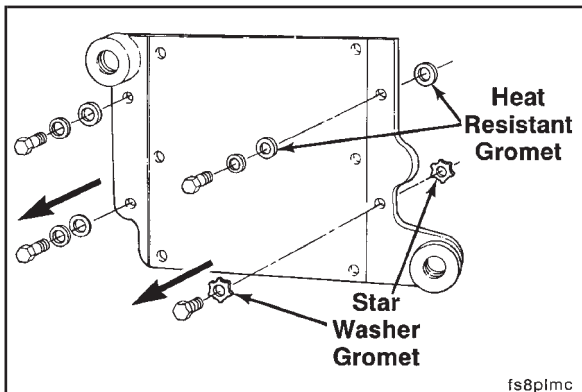
NOTE: The actuator harness is the top connector nearest the engine, and the sensor harness is the bottom connector.

Tag the connectors as they are removed for future identification.



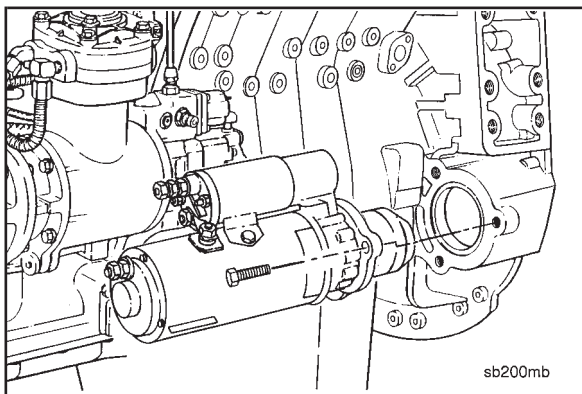


Remove the six ECM mounting capscrews, star washers and the ECM.



Electronic Control Cooling Plate - Removal

Remove the four mounting capscrews, the electronic control cooling plate and the mounting brackets.



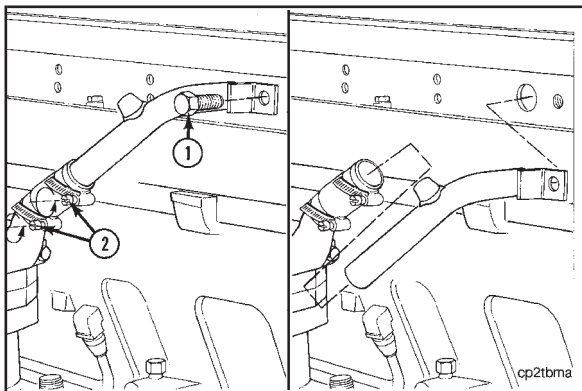
Starting Motor - Removal

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

The starter mounting capscrews can be one of several different sizes. These sizes could be in metric or U.S. Customary. Use the correct wrench size to avoid damage to the capscrews.



Remove the three capscrews and the starting motor.



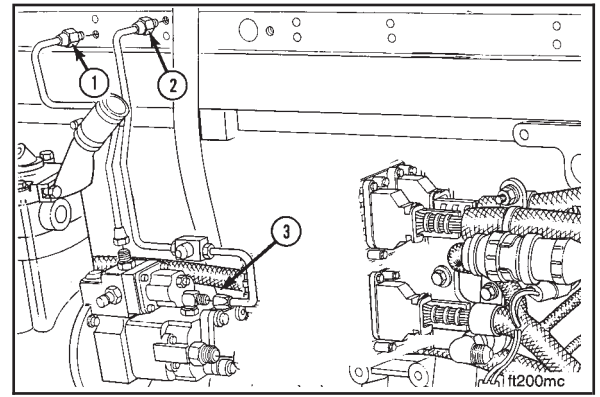
Air Compressor Air Supply Tube - Removal

Remove the capscrew (1), loosen the two hose clamps (2) and remove the tube.

Fuel Lines - Removal

Remove the fuel supply tube (1) and the fuel drain tube (2) from the cylinder head.

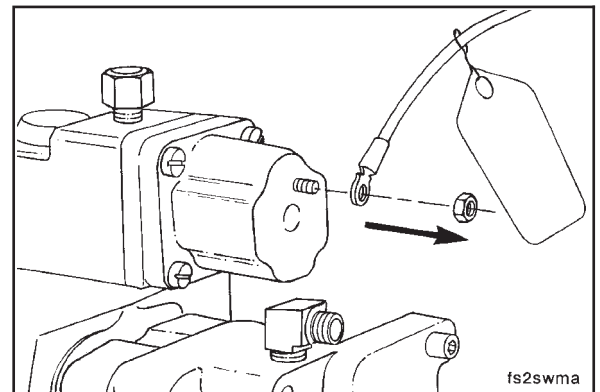
Remove the fuel pump gear pump cooling tube (3).



Fuel Pump - Removal

Remove the actuator harness wire from the fuel shutoff valve.

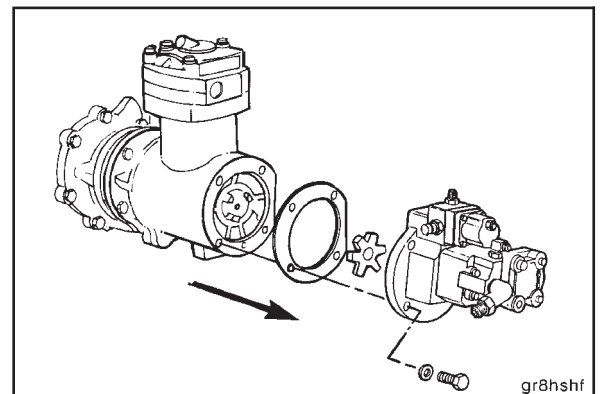
Tag the wire for future identification.



Remove the two support bracket capscrews.

Remove the four fuel pump mounting capscrews, fuel pump and gasket.

Remove the coupling spider.

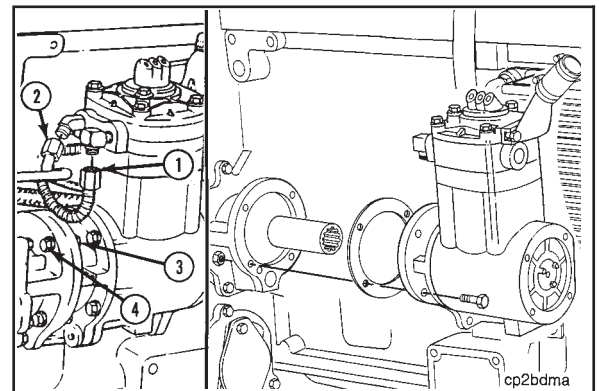


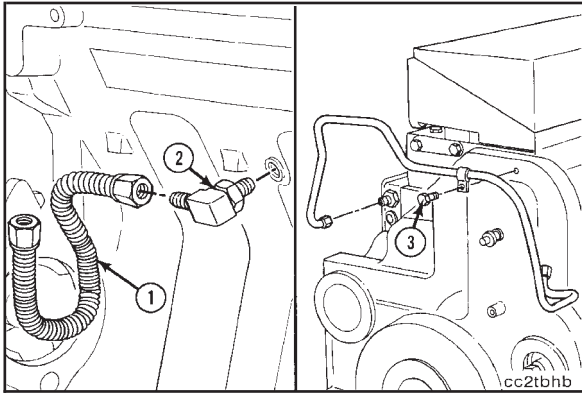
Air Compressor - Removal

Remove the coolant inlet tube (1) and coolant outlet tube (2) from the air compressor.

Remove the nuts (3) from the two top mounting capscrews.

Remove the four air compressor mounting capscrews (4), air compressor and splined coupling.



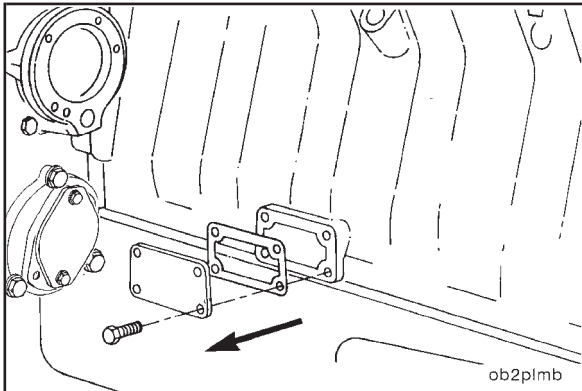


Air Compressor Coolant Tubes - Removal



Remove the inlet tube (1) and fitting (2).

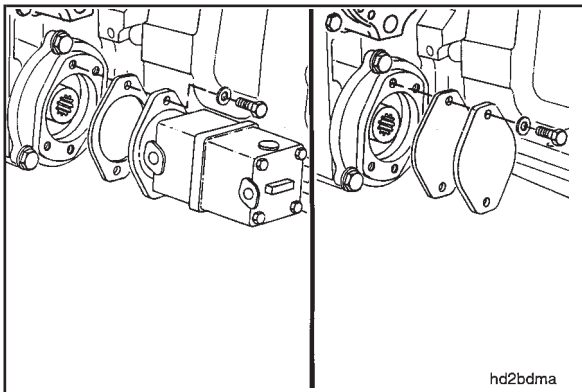
Remove the outlet tube clamp capscrew (3) and the tube.



Hand Hole Cover (Fuel Pump Side) - Removal



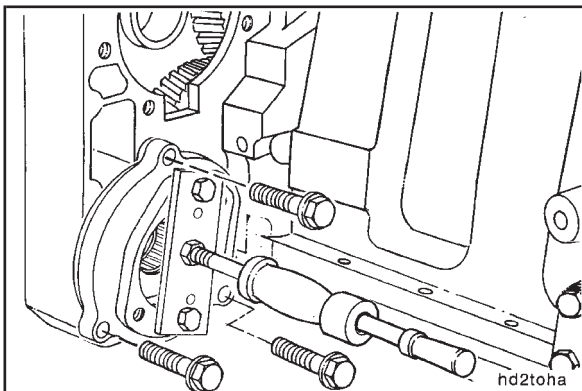
Remove the four capscrews, the cover and gasket.



Hydraulic Pump or Cover - Removal



Remove the two capscrews, the pump and gasket.



Hydraulic Pump Drive - Removal

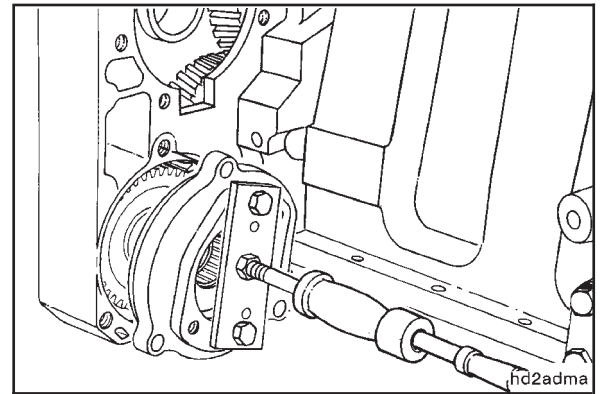


Remove the three pump drive adapter mounting capscrews.

Install a slide hammer and the engine barring tool, Part No. 3824270, to the hydraulic drive adapter. Use two (M10-1.50 x 30) capscrews, Part No. 3335003, for SAE "A" drives. Use two (M12-1.75 x 40) capscrews, Part No. 3018671, for SAE "B" drives.

Caution: Do not allow the hydraulic drive gear to slide out of the adapter or the gear housing during removal. Damage to the gear will result.

Remove the hydraulic drive adapter, o-ring, and hydraulic drive gear.



Sensor Harness and Sensors - Removal

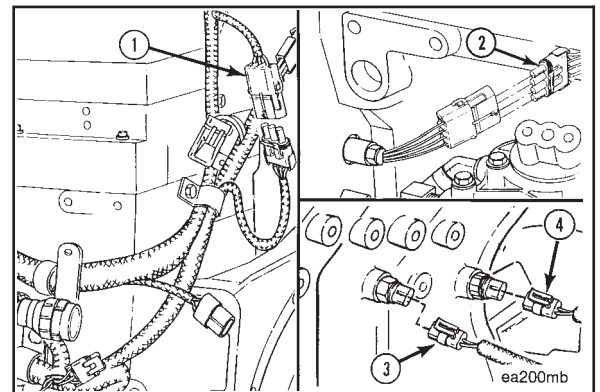
Tag all connections as they are removed for future identification.

Disconnect the connector (1) that connects the sensor and actuator harnesses.

Remove the sensor harness connectors from the following sensors:

- engine position sensor (2) (back of gear housing),
- oil temperature sensor (3) (fuel pump side of block),
- oil pressure sensor (4) (fuel pump side of block).

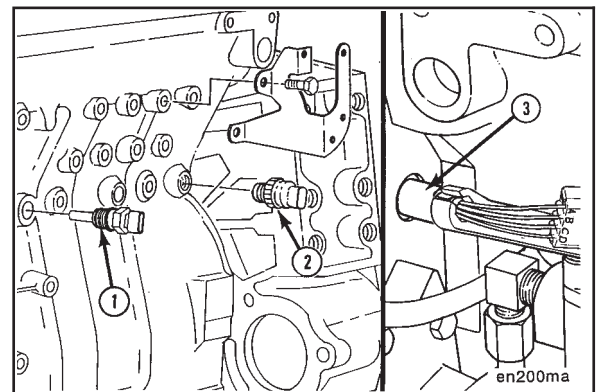
Remove all the sensor wiring harness clamps from the engine and the sensor wiring harness.



Remove the harness bracket from the cylinder block.

Remove the oil temperature sensor (1) and oil pressure sensor (2) from the cylinder block.

Remove the engine position sensor (3) from the rear of the gear housing.

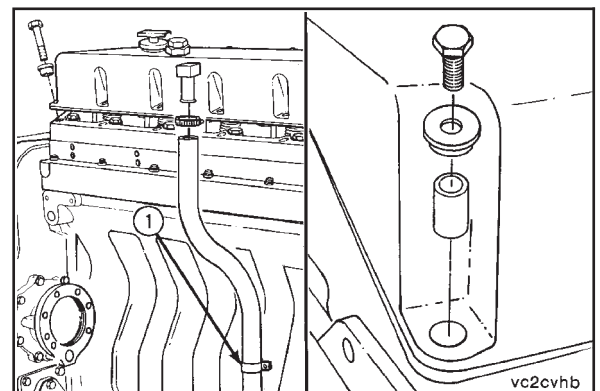


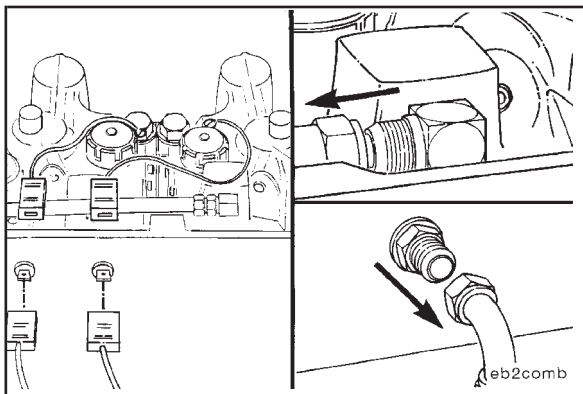
Rocker Lever Cover - Removal

Remove the breather tube and the tube retaining clip (1) from the side of the cylinder block.

Remove the 16 capscrews, isolators and spacers from the cover.

Remove the cover and gasket.





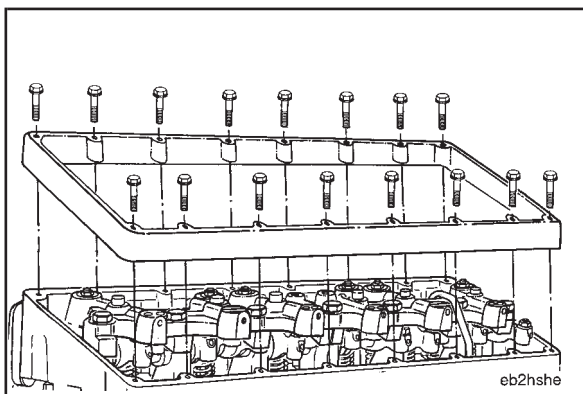
Rocker Lever Housing Spacer - Removal



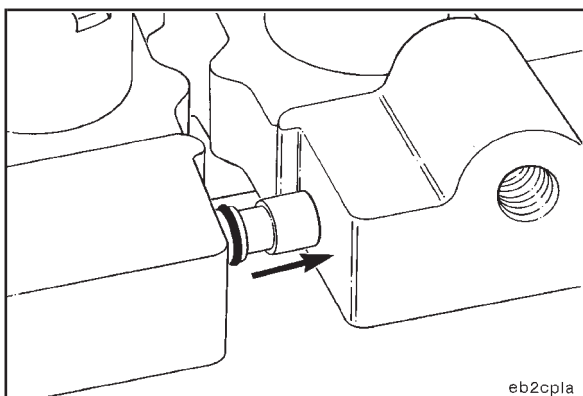
If the engine is equipped with a Jacobs® Engine Brake, disconnect the two electrical connections from the terminals on the inside and outside of the spacer.

Disconnect the oil supply hose connection.

Remove the oil supply hose.



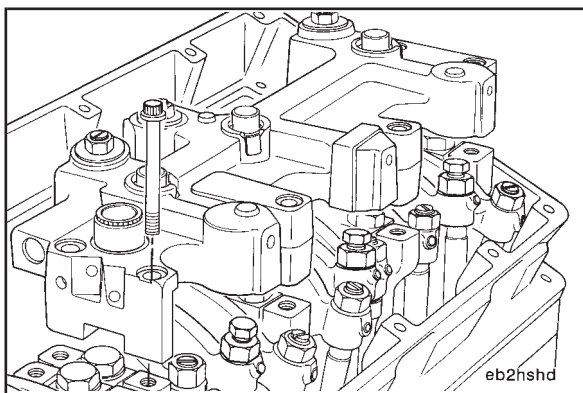
Remove the 16 capscrews and spacer.



Jacobs® Engine Brake - Removal



If the engine is equipped with a Jacobs® Engine Brake, press the connector into the front housing to allow clearance for housing removal.



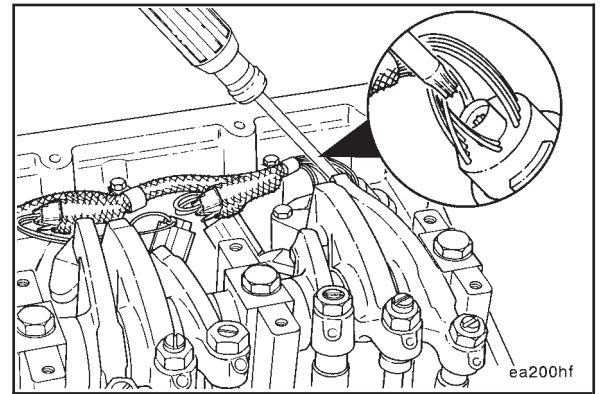
Remove the mounting capscrews and remove the Jacobs® engine brake, if equipped, from the engine.

Internal Actuator Harness - Removal

Use a Torx screwdriver (T25) to loosen the screw which secures the two sections of the actuator harness together at the rear of the rocker lever housing.

The screw head is accessible from inside the rocker lever housing.

Disconnect the two sections of the actuator harness.

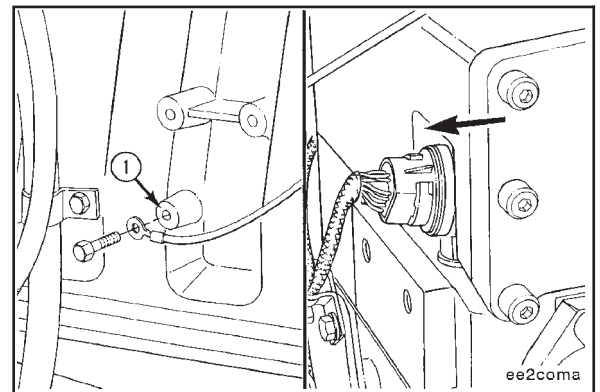


Disconnect the ground wire connection of the actuator harness (1) from the engine.

Tag the end for future identification.

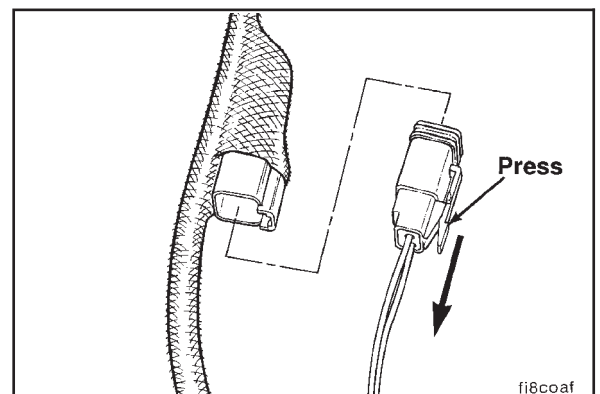
Remove the external section of the actuator harness.

Use care **not** to damage the plug as it is being removed from the rocker housing.

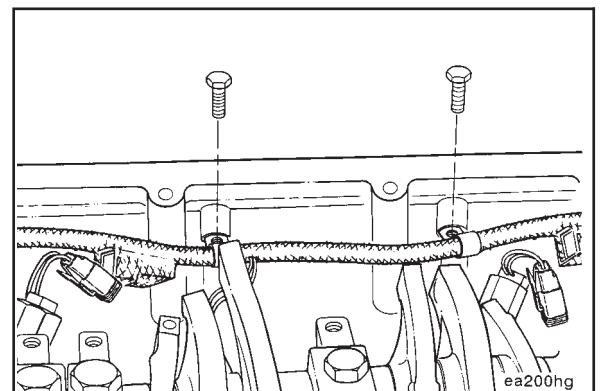


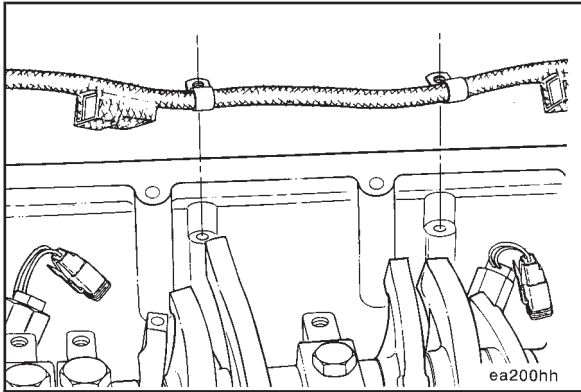
Disconnect the wire connectors from the injectors.

Tag the connectors for future identification. The connectors **must** be connected to the same injector as they were removed from when the engine is reassembled.

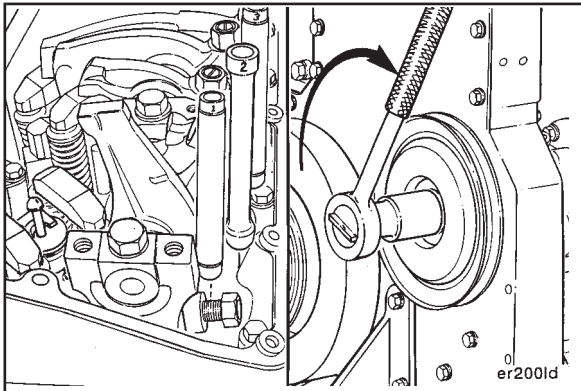


Remove the five capscrews and wire clamps which hold the harness section to the rocker housing.





Remove the internal section of the actuator wiring harness.



Push Rods - Removal

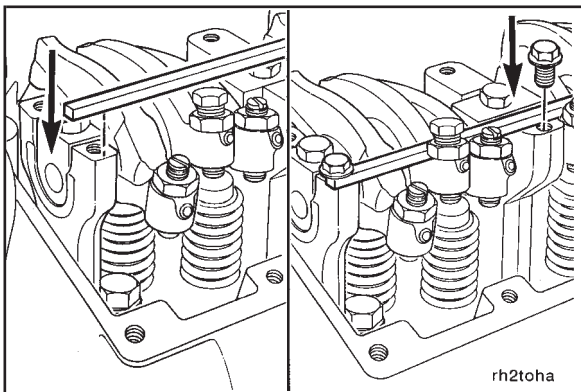


Mark the location of the valve push tubes and injector push rods as they are removed. The push tubes and push rods **must** be installed in the same location when the engine is assembled.

Loosen the 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.

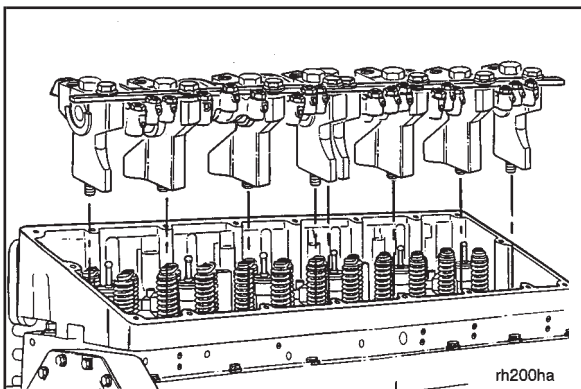


Rocker Lever Assemblies - Removal



Install a piece of one-quarter inch key stock 18 inches long on top of the four front rocker lever assembly supports. Use four (M10-1.5 x 25) flange head capscrews to secure the bar stock to the supports.

The two capscrews on the end supports will fasten on one side of the bar stock to the engine brake mounting holes. The two capscrews on the center supports will fasten on the opposite side of the bar stock to the engine brake mounting holes.



Loosen, but do **not** remove, the eight rocker shaft capscrews. The capscrews hold the rocker lever assemblies together.

Grasp hold of the bar stock and lift the front rocker lever assembly from the engine.

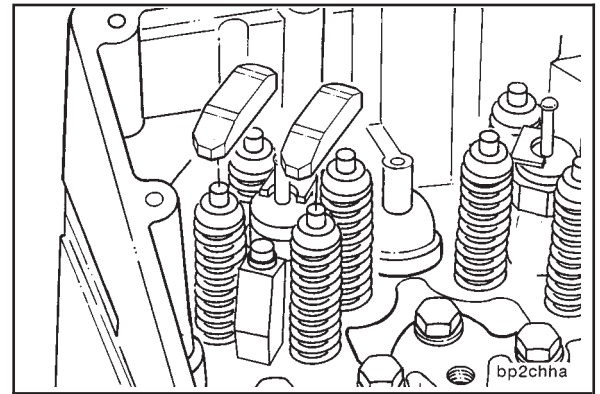
Repeat the process to remove the rear rocker lever assembly.

Crossheads - Removal

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 from when the engine is assembled.

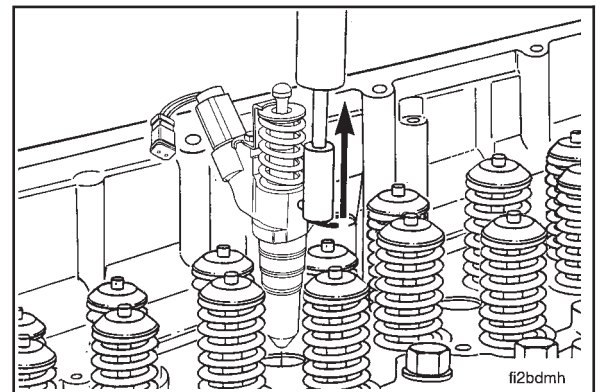


Injectors - Removal

Remove the injector hold down capscrews and hold down clamps.

Use injector puller, Part No. 3823579, to remove the injectors from the engine. Insert the pin of the tool into the hole provided in the body of the injector.

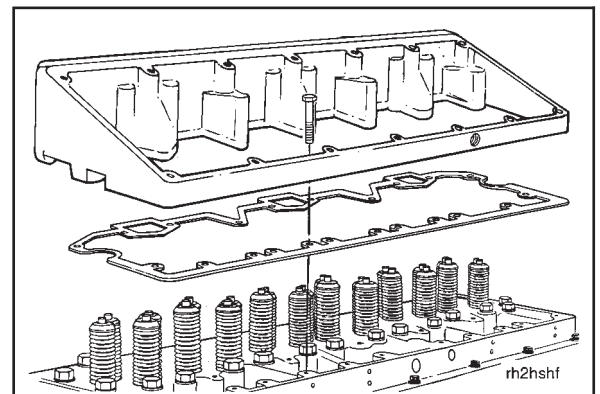
Number each injector with the cylinder number as it is removed.



Rocker Lever Housing - Removal

NOTE: Do not drop the capscrew washers into the engine.

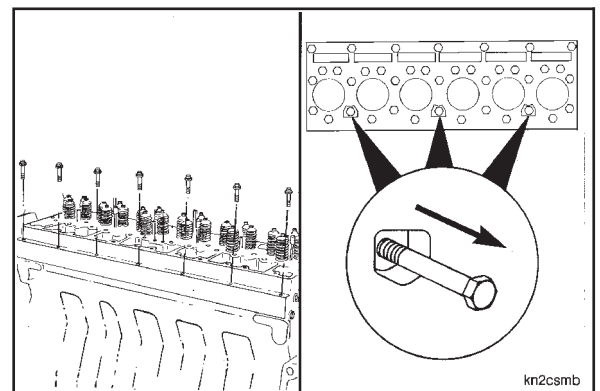
Remove the capscrews, washers, rocker lever housing, and gasket.

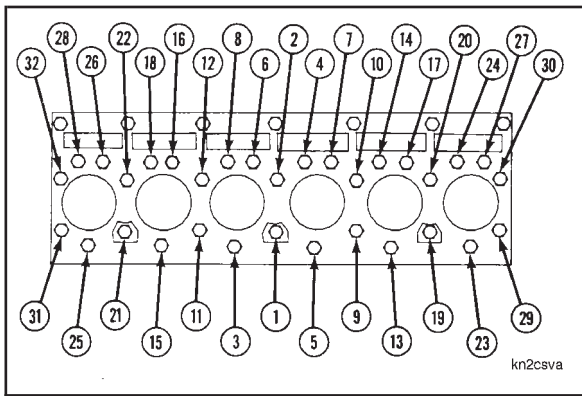


Cylinder Head - Removal

Remove the seven 12 point capscrews from the camshaft side of the cylinder head.

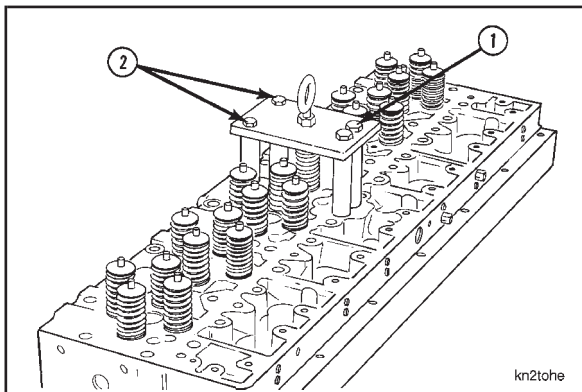
Remove the three capscrews inside the intake ports.





Remove the remaining 32 capscrews starting from the ends and moving toward the center.

NOTE: The illustration shown is for torquing the cylinder head during installation. Reverse the order for removal.

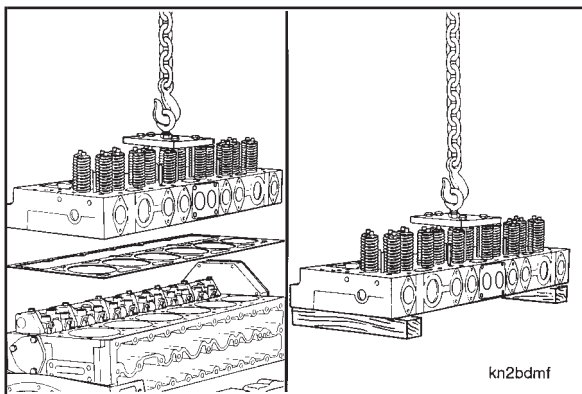


Install cylinder head lifting bracket, Part No. 3822479, on the center of the cylinder head.

NOTE: If the capscrews are **not** available from the kit, install two rocker lever support capscrews (M14—2.00 x 135) (1) and two rocker lever housing capscrews (M10—1.50 x 115) (2).



Torque Value: 47 N•m [35 ft-lb]



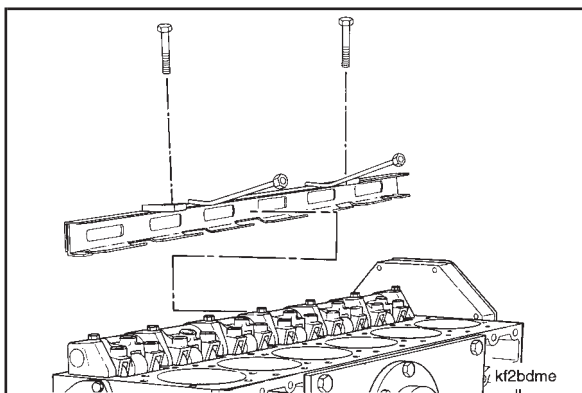
The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

To prevent damage to the cylinder head, lift it straight up. The cylinder head is doweled to the cylinder block. To prevent damage to the combustion face of the cylinder head, place it on wooden blocks after removal.



Use a hoist or hydraulic arm to remove the cylinder head.

Remove the gasket.



Cam Follower Assemblies - Removal

Remove the nuts and washers from the seven supports. **Do not** allow the nuts or washers to fall into the engine.



NOTE: The cam follower assembly consists of two shaft assemblies with a common center support.

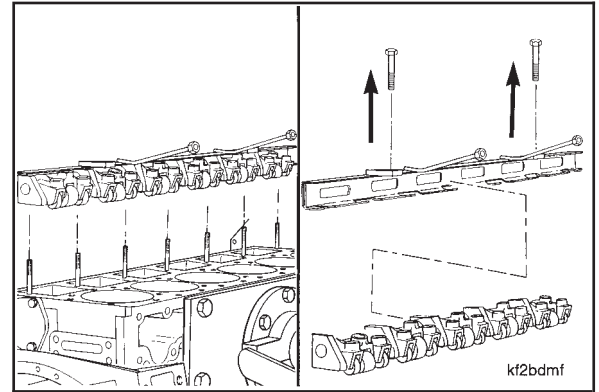


Slide the cam follower removal and installation tool, Part No. 3824519 under the cam follower and around the supports. If necessary, bump the dowel supports to loosen.

Slide the tool forward until the adjusting screws on the top of the tool can be finger tightened in to the socket of the injector cam followers.

Lift the cam follower assemblies to remove them from the engine.

Remove the tool from the cam follower assemblies.



Lubricating Oil Pan - Removal

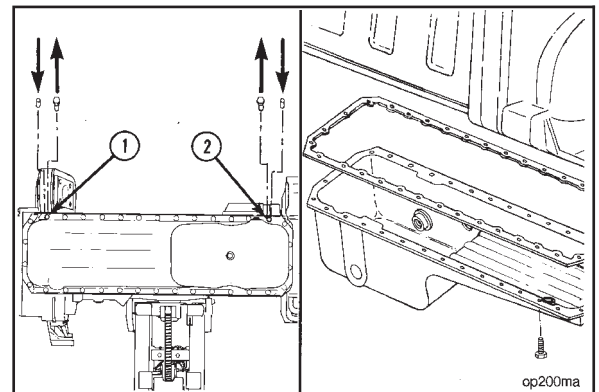
Rotate the engine on the rebuild stand to position the engine on its side.

Remove two capscrews at points (1) and (2) and install two guide pins, Part No. 3376488.

Remove the remaining 32 capscrews and oil pan.

Use a mallet to loosen the oil pan if it is stuck.

Remove the guide pins.

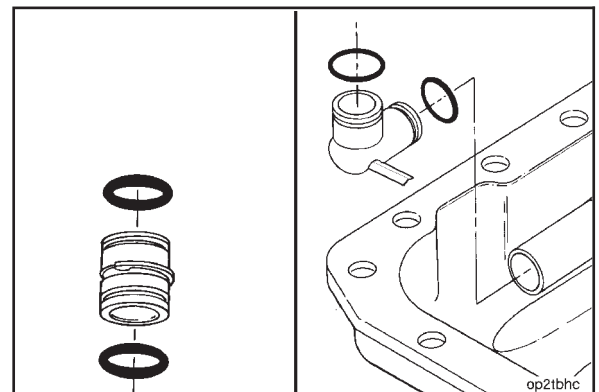


Lubricating Oil Transfer Tube - Removal

Remove the oil transfer tube from the oil pan on rear sump lubricating oil pans.

NOTE: The straight transfer tube is used on some aluminum front sump oil pan applications.

Remove and discard the two o-rings from the transfer tube.

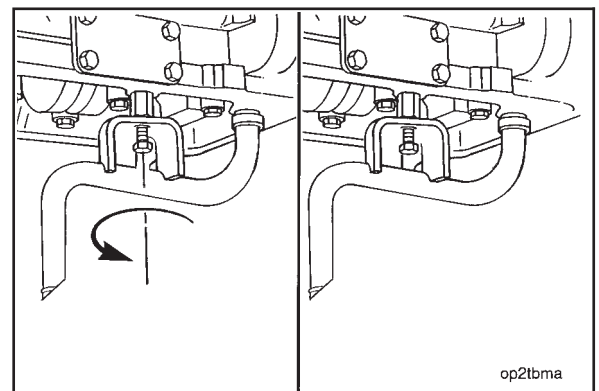


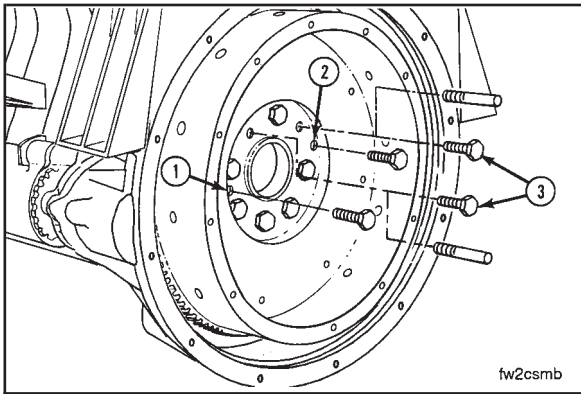
Block Mounted Front Sump Suction Tube - Removal

If the engine is equipped with a block mounted front sump suction tube, remove the suction tube retaining capscrew from the cylinder block.

Remove the suction tube from the cylinder block.

Remove and discard the o-ring from the suction tube.





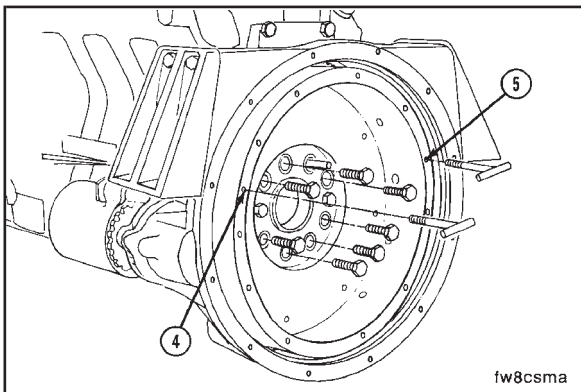
Flywheel - Removal



Install two capscrews (M10-1.50 x 40) at points (1) and (2).

Remove two mounting capscrews (3) and install two guide pins, Part No. 3376696.

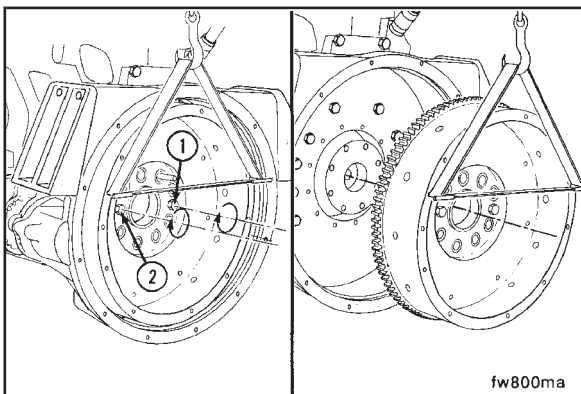
NOTE: On engines equipped with a rear engine power take-off (REPTO), two guide pins, Part No. 3376696, are required to support the crankshaft gear until the rear crankshaft oil seal is removed.



The clutch pressure plate capscrew holes are U.S. Customary threads. They can be (3/8-16), (7/16-14), or (1/2-13). Make sure to measure a pressure plate mounting capscrew before installing the "T-handles" for lifting to prevent damage to the flywheel.

Install two "T-handles" (4) and (5) into the flywheel.

Remove the remaining seven mounting capscrews from the flywheel.



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

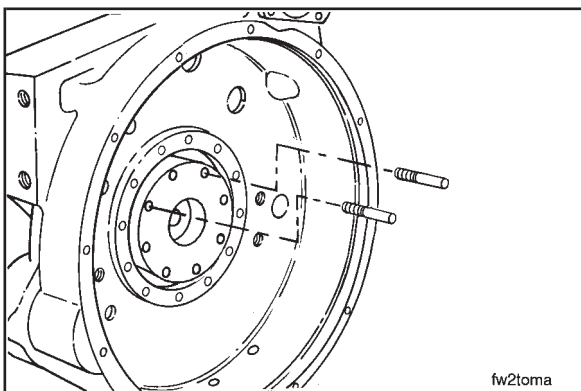


Install the nylon lifting sling, Part No. 3375957, on the two "T-handles" and attach a hoist to the lifting sling.

Tighten capscrews (1) and (2) in alternating sequence to loosen the flywheel.



Use a hoist to remove the flywheel.



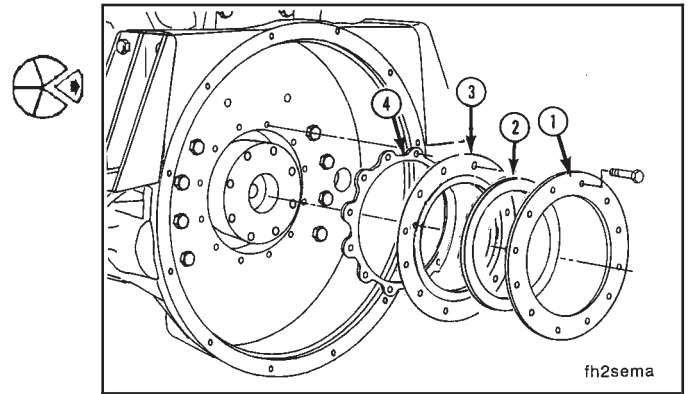
Remove the capscrews (1) and (2) and the guide pin.

Crankshaft Rear Oil Seal - Removal

Remove the 12 capscrews and clamping ring (1),

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

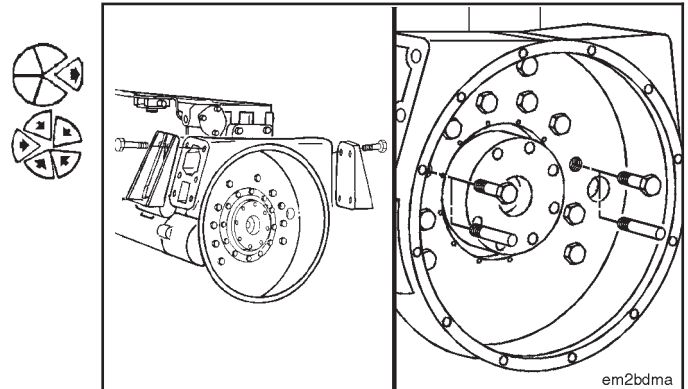
Remove the gasket (4).



Flywheel Housing - Removal

Remove the capscrews and both rear engine mounts.

Remove capscrews (1) and (2) and install two flywheel housing guide pins, Part No. 3376697.

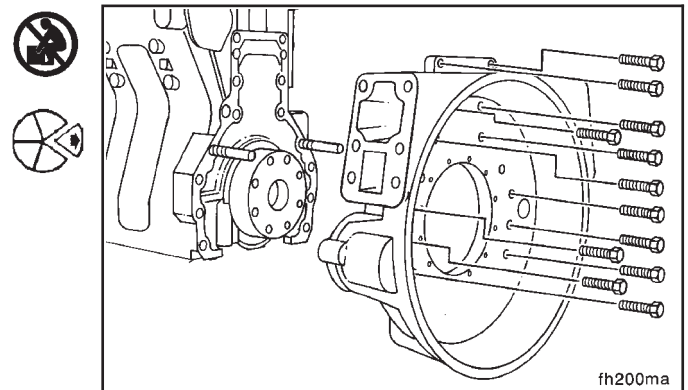


The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Remove the remaining 12 capscrews and the flywheel housing.

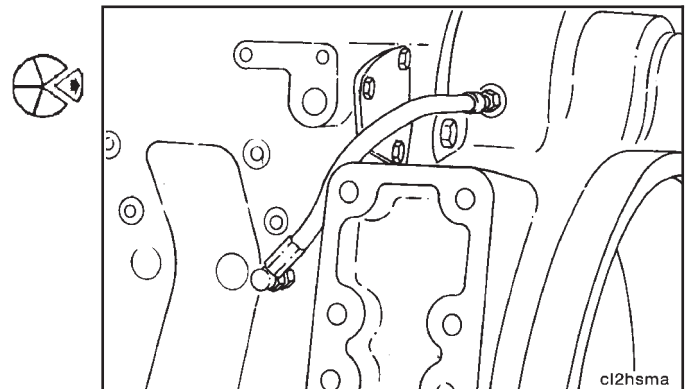
Use a mallet to loosen the housing if it is stuck.

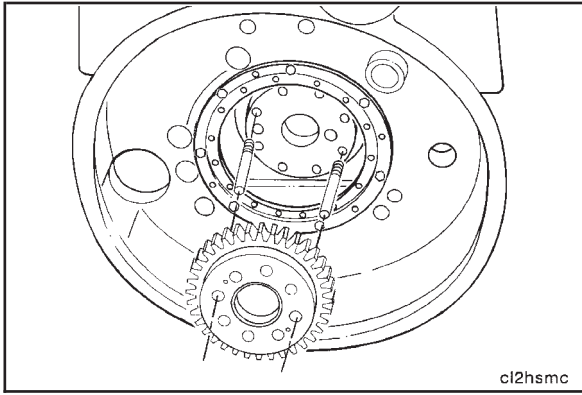
Remove the guide pins.



Flywheel Housing, REPTO - Removal

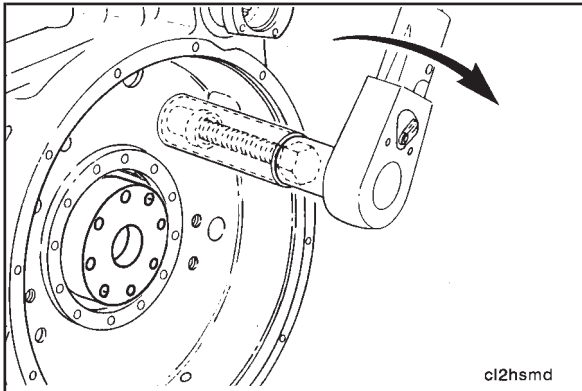
Remove the REPTO oil supply line from the flywheel housing and the oil galley connection.





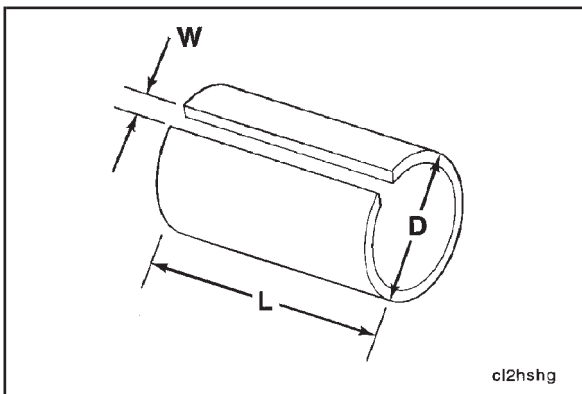
Remove the crankshaft drive gear.

Remove the two guide pins from the crankshaft.



Remove the idler shaft retaining capscrew.

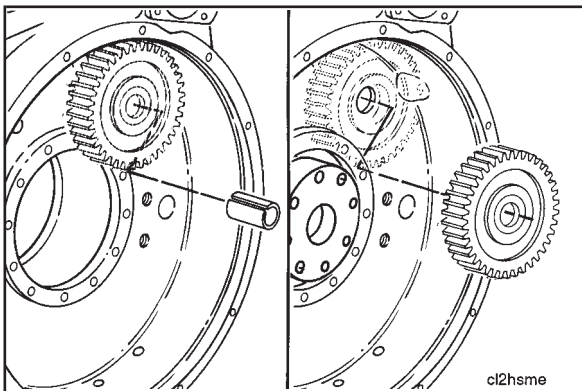
Use idler shaft puller, Part No. 3823709, to remove the idler shaft.



Manufacture a sleeve from 38.1 mm O.D. [1.50 inch O.D.] (D) PVC, aluminum, or equivalent, to the following dimensions:

Length (L): 25.4 mm [1.00 in]

Slot (W): 6.3 mm [0.25 in]



Caution: Do not drop the idler gear bearings as the idler gear is removed. Damage to the bearings can result.



Install the tool into the idler gear bore through the idler shaft bore to hold the idler gear and bearings together while they are removed.



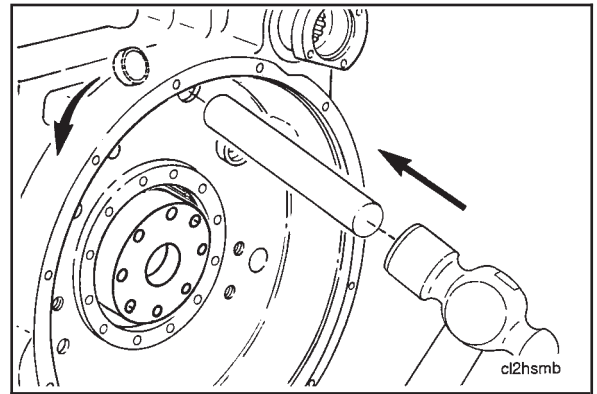
Remove the idler gear to gain access to the rest of the housing capscrews.

Caution: 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.

To gain access to the housing capscrews, use a drift to drive the cup plugs straight through into the housing.

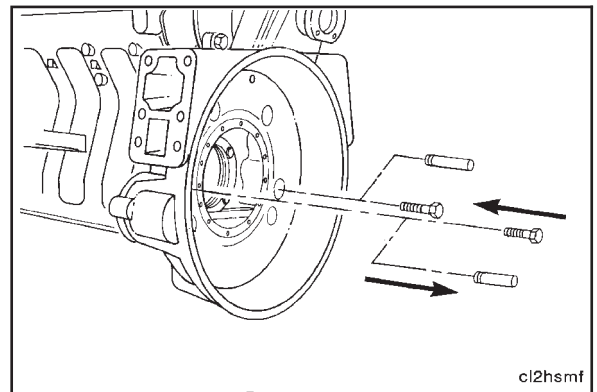
Retrieve the plugs from inside of the housing.

NOTE: Do **not** reuse the cup plugs that are removed. The cup plugs **must** be replaced with new ones.



Remove two of the mounting capscrews and install two guide pins, Part No. 3376697, to support the housing during removal.

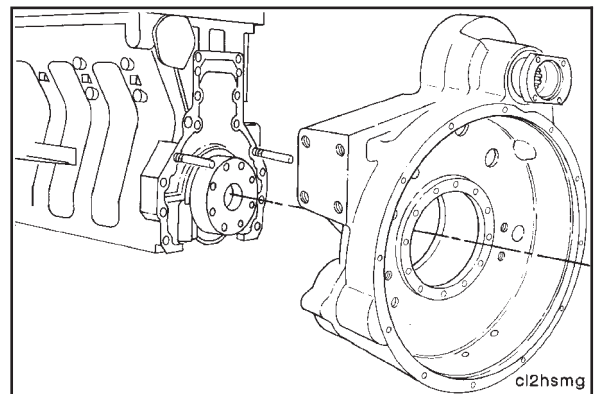
Use offset wrench, Part No. 3823711, to remove the capscrews which are **not** in view.



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

Remove the remaining capscrews. Use a rubber hammer to loosen the housing.

Remove the housing and the guide pins.



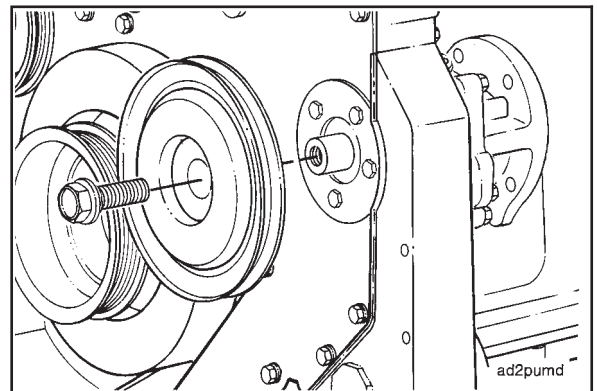
Accessory Drive Pulley - Removal

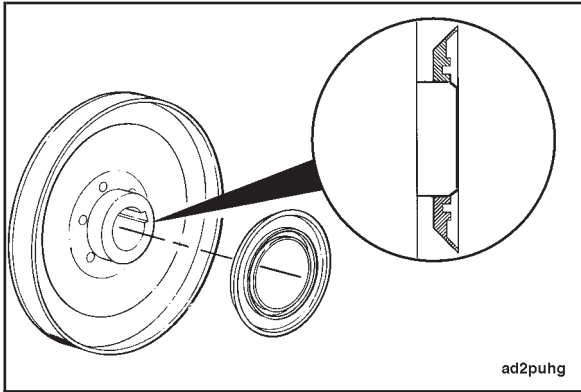
Remove the pulley retaining capscrew.

The crankshaft **must** be held in position to allow the capscrew to be removed.

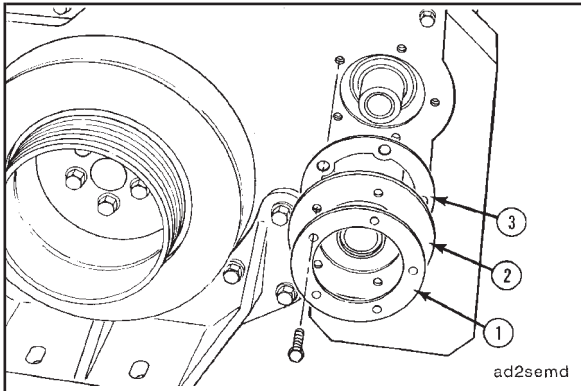
NOTE: This is a slip fit pulley and does **not** require the use of a puller.

Remove the pulley.



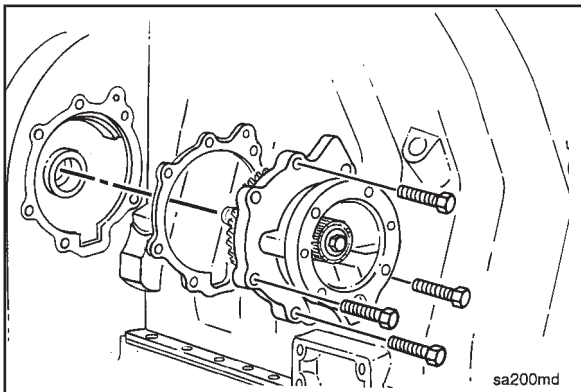


NOTE: Some pulleys have an oil seal dust seal installed on the pulley hub. If a dust seal is installed, remove the dust seal from the pulley. The dust seal can be slipped off the hub by hand.



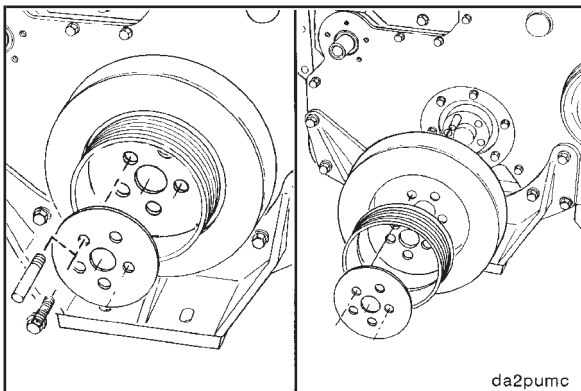
Accessory Drive Oil Seal - Removal

Remove the five capscrews, clamping ring (1), seal (2), and gasket (3).



Accessory Drive Assembly - Removal

Remove the six mounting capscrews, accessory drive assembly, and gasket.



Crankshaft Pulley and Vibration Damper - Removal

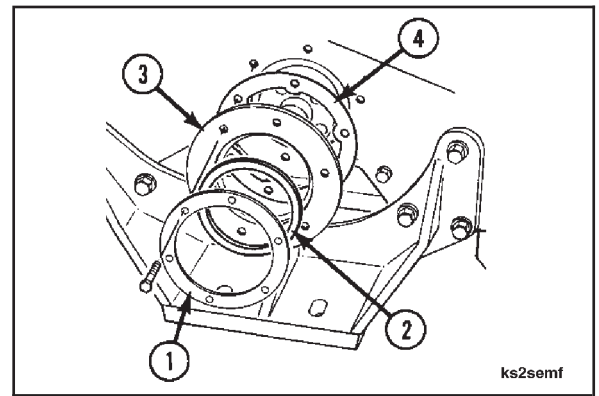
Remove one of the damper mounting capscrews and install guide stud, Part No. 3376696 in the hole.

Remove the remaining capscrews, pulley, and damper.

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

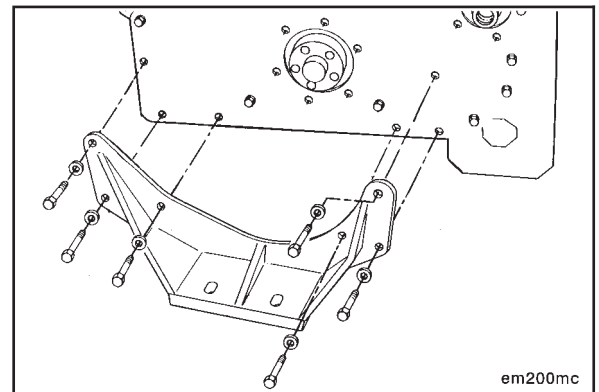
Crankshaft Front Oil Seal - Removal

Remove the six capscrews, the clamping ring (1), the oil seal (3) and dust seal (2) together, and the gasket (4).



Front Engine Support Bracket - Removal

Remove the six capscrews and bracket.

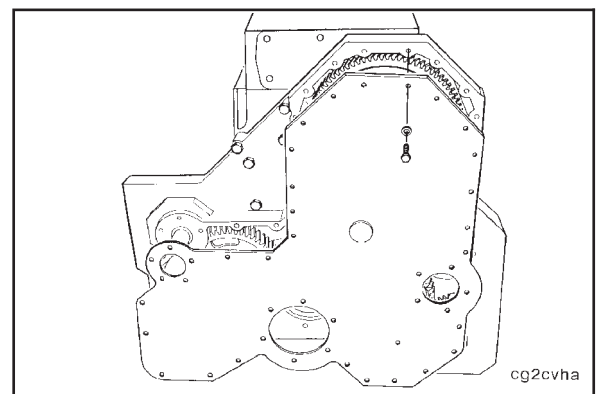


Gear Cover - Removal

Six of the gear cover capscrews were removed with the front support bracket.

Remove the remaining 14 capscrews and the gear cover.

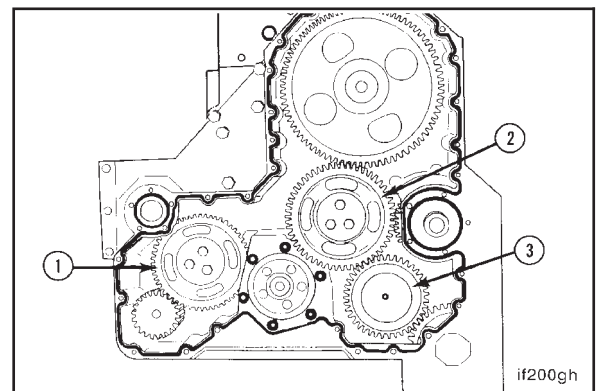
Remove the rectangular seals from the grooves around the mounting surfaces of the gear housing.

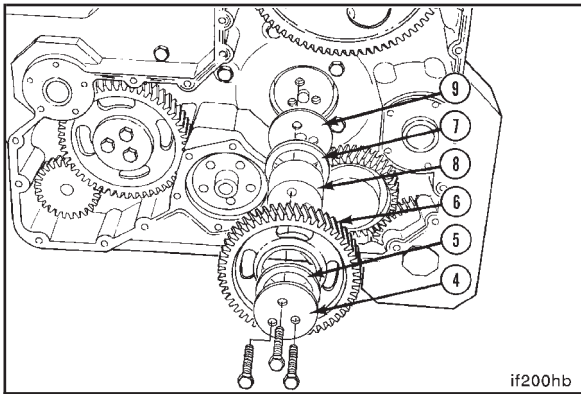


Idler Gear Assemblies - Removal

Three idler gear assemblies are used:

- water and lube pump idler gear (1),
- camshaft idler gear (2),
- hydraulic pump idler gear (3).

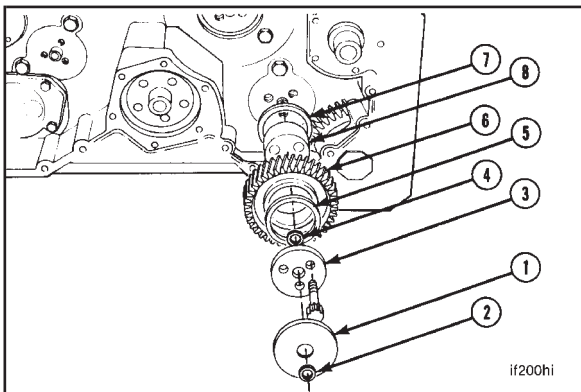




To remove the camshaft and water pump idler gear assemblies, remove:

- the three retaining capscrews,
- the gear retainer (4),
- the front thrust bearing (5),
- the idler gears (6),
- the rear thrust bearing (7),
- the idler gear shafts (8),
- the camshaft idler gear assembly includes a wear plate (9).

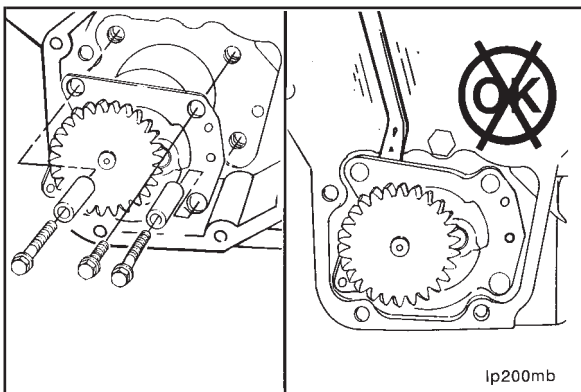
NOTE: If SAE "B" hydraulic drive is used, mark the idler gear shafts for position as they are removed. Each shaft **must be** installed in the same position it was removed from.



To remove the hydraulic drive idler gear assembly, remove:

- mounting spacer (1),
- rectangular seal (2),
- three retaining 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.



Lubricating Oil Pump - Removal

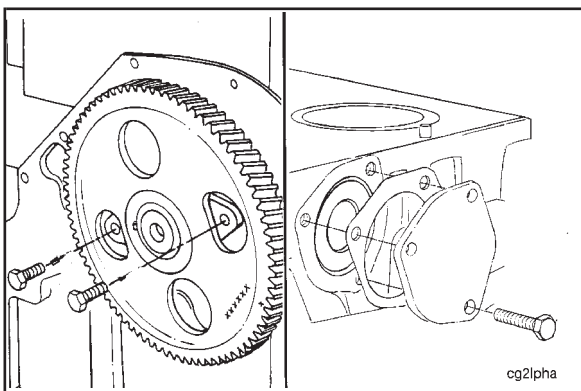


Caution: Do not pry on the gear pump flange when removing the oil pump. This can result in damage to the pump.



Remove the three mounting capscrews, and two spacers if applicable.

Use both hands to pull, or insert two capscrews (M8-1.25) into the puller holes to push the pump from the engine.



Camshaft - Removal



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

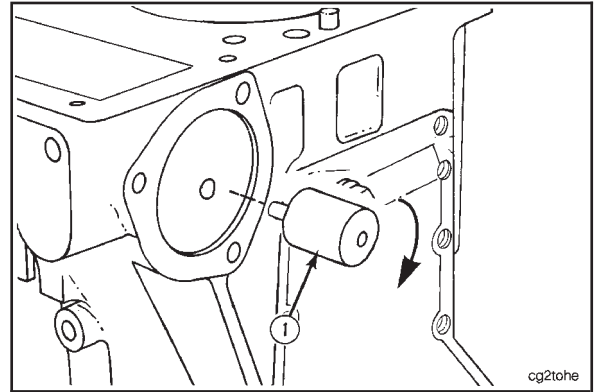


Remove the two capscrews.

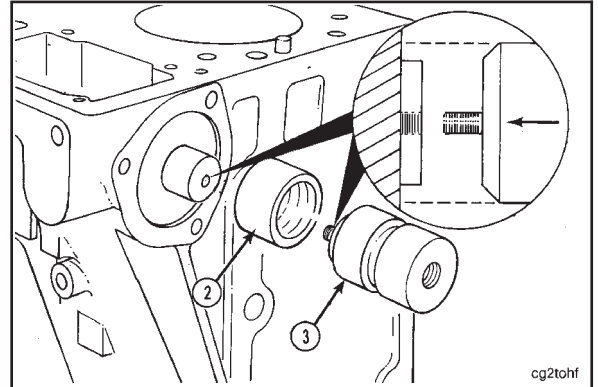
Remove the three capscrews, the rear cover plate and gasket.

Install camshaft installation pilot, Part No. 3376388.

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

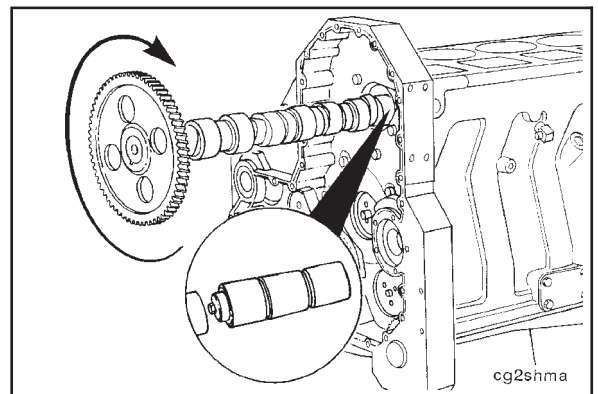


3. Install the arbor sleeve (2) over the expander.
4. Install the locating pilot extensions (3) to the expander.



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.

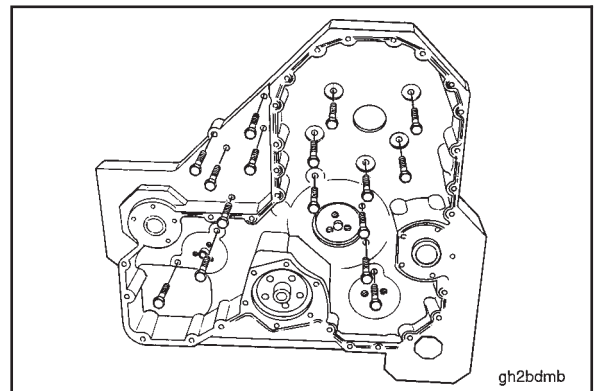
Remove the camshaft pilot tool.

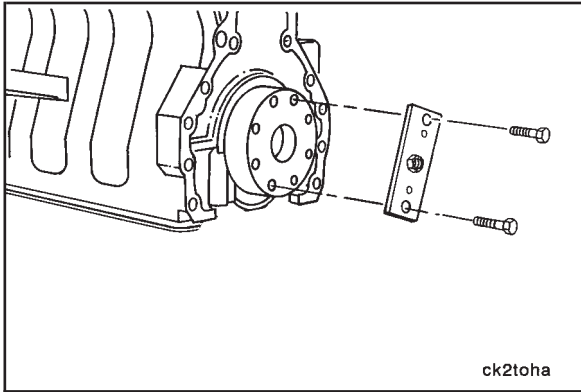


Gear Housing - Removal

Remove the gear housing mounting capscrews and the housing.

Remove the rectangular seal from the back side of the housing.

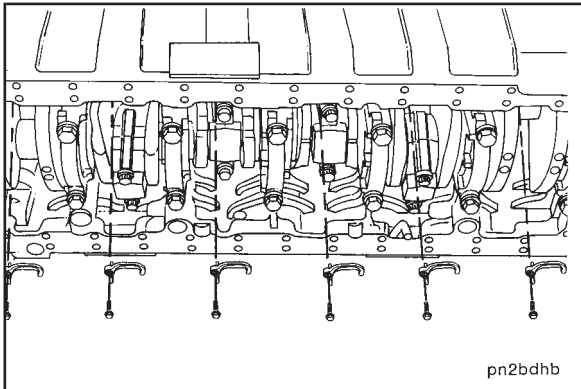




Engine Barring Tool - Installation



Use two flywheel mounting capscrews (M14—1.50 x 40) to install the engine barring tool, Part No. 3824270, to the flywheel end of the crankshaft.



Piston Cooling Nozzles - Removal

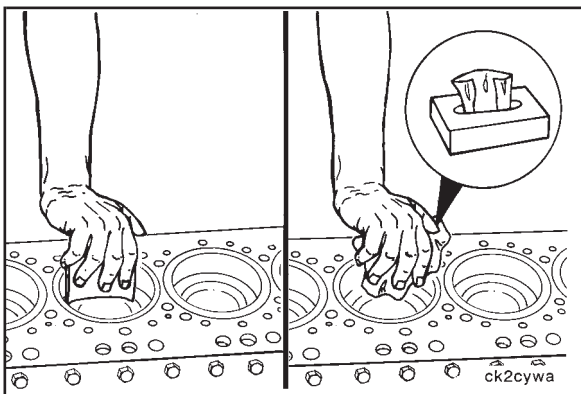


Caution: The nozzles must be removed before the piston and rod assemblies to avoid damage to the nozzles.

The crankshaft **must** be rotated to allow access to remove all the nozzles.



Remove each retaining capscrew and nozzle.



Pistons and Connecting Rods - Removal

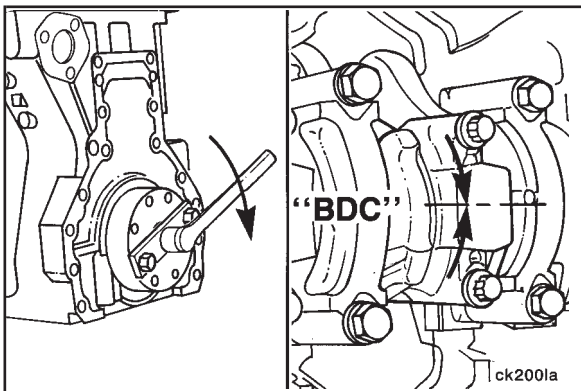


Caution: Do not use emery cloth or sandpaper to remove carbon from the cylinder liners and cylinder block top deck surface. Aluminum oxide or silicon particles from emery cloth or sandpaper can cause serious engine damage.



Rotate the crankshaft to expose the carbon ridge above the ring travel area in the cylinder liner.

Use a fine fibrous abrasive pad such as Scotch-Brite® 7448, Part No. 3823258 or equivalent, and solvent to remove the carbon.



Use the barring tool to rotate the crankshaft to position the rod caps at "bottom dead center" (BDC) for removal.

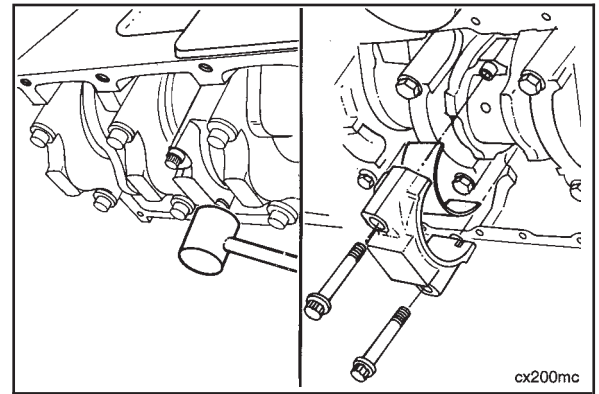
Loosen the connecting rod capscrews.

Do **not** remove the capscrews from the rods until the caps have been loosened.

Hit the heads of connecting rod capscrews with a mallet to loosen the caps from the dowel rings.

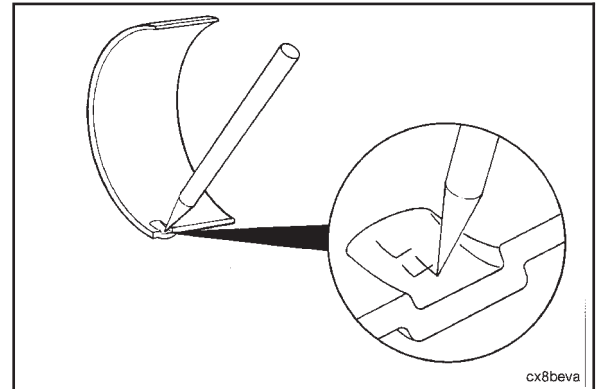
Do **not** drop the bottom bearing shell when the cap is removed.

Remove the connecting rod capscrews and caps.



Caution: Do not mark on the bearing to crankshaft mating surface. Damage to the engine can occur if bearings are used again.

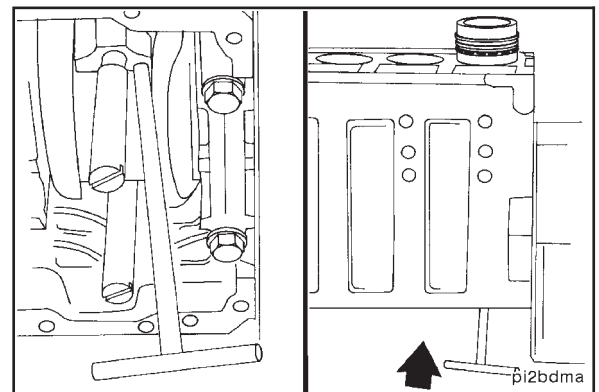
Mark the cylinder number and the letter “L” in the flat surface of the bearing tangs.



Install two connecting rod guide pins, Part No. 3376038, in the rod capscrews holes.

Use a wooden dowel, hammer handle or equivalent to push the rod away from the crankshaft.

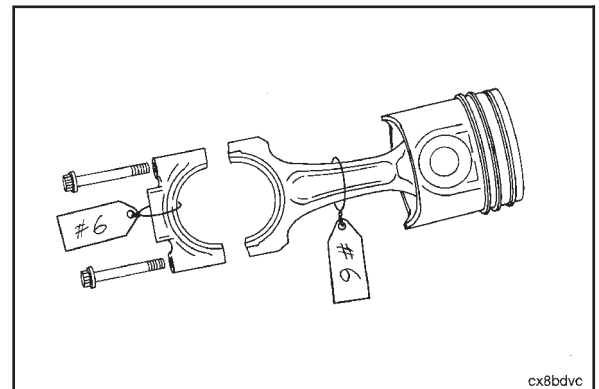
Push the rod until the piston rings are outside of the block.

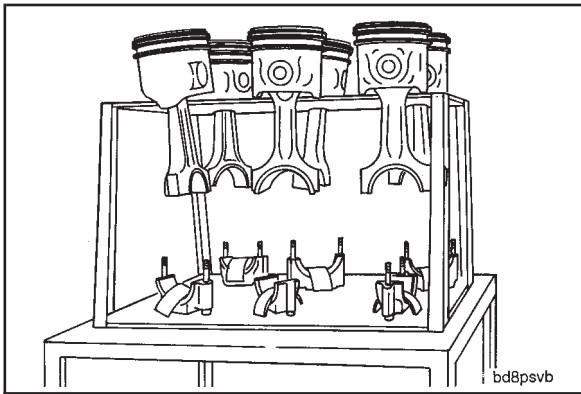


Use both hands to remove the piston and rod assembly.

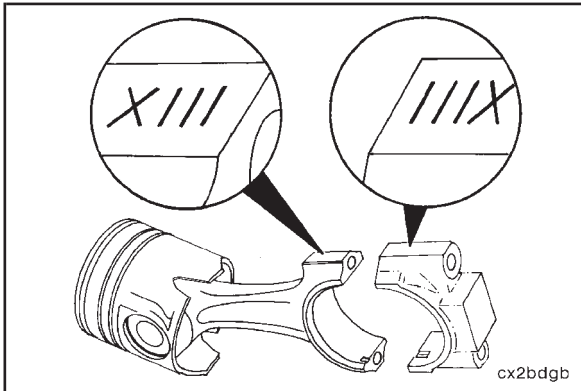
The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to insure proper fit of worn mating surfaces if parts are used again.

Use a tag to mark the cylinder number each piston and rod assembly was removed from.

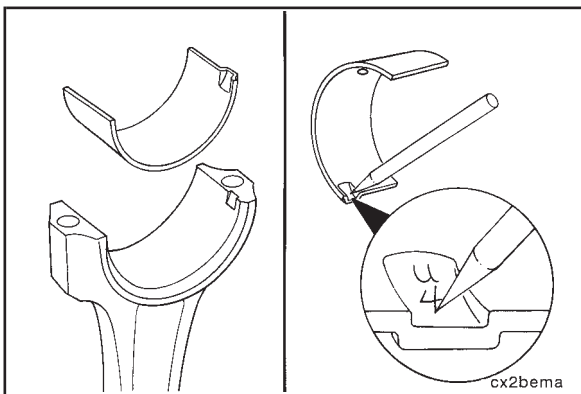




Place the rod and piston assemblies into a container to protect them from damage.



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.

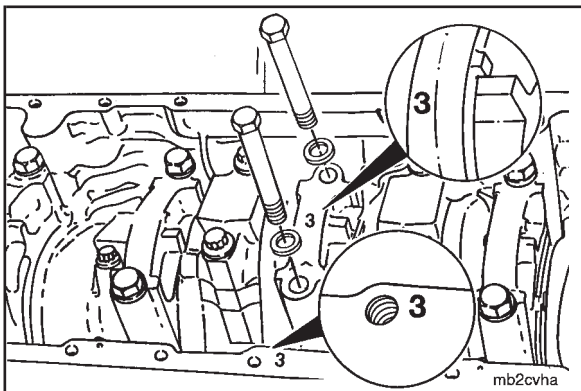


Remove the upper rod bearing.



Caution: Do not mark on the bearing to crankshaft mating surface. Damage to the engine can occur if the bearings are used again.

Mark the cylinder number and the letter "U" in the flat surface of the bearing tangs.



Main Bearing Caps, Lower Bearing Shells and Thrust Bearings - Removal

Rotate the engine on the rebuild stand to position the oil pan mounting flange facing up.

The main bearing caps are marked for position as shown. The caps **must** be installed with the number on the cap matching the number on the oil pan flange of the cylinder block. The caps **must** be oriented so they are lock tang to lock tang.

Use a steel stamp to mark any caps without a number before the cap is removed.

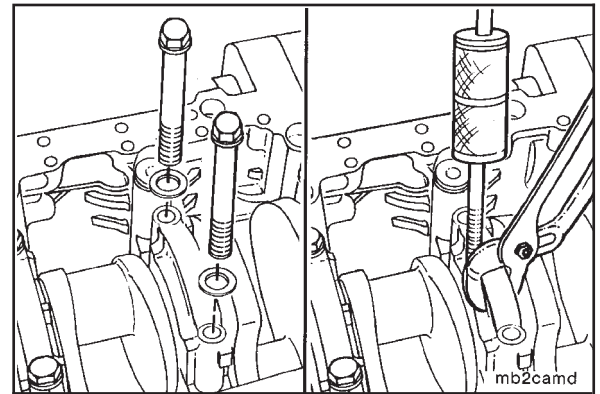
Caution: The number “4” main bearing cap is doweled to the block. To avoid damage to the cylinder block, do not rock the cap to remove, pull straight up.

Remove the main bearing cap capscrews.

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

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

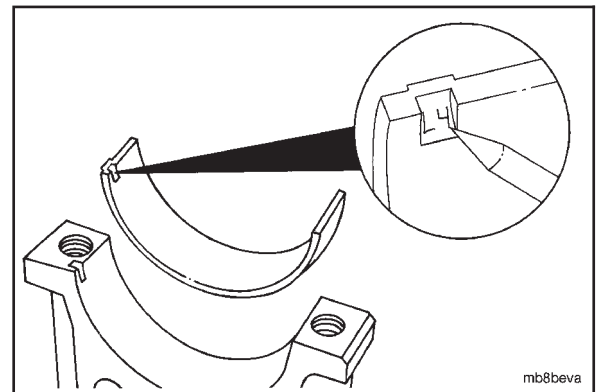
NOTE: The No. 4 main bearing cap has thrust bearings.



Remove the lower main bearing shells from the caps.

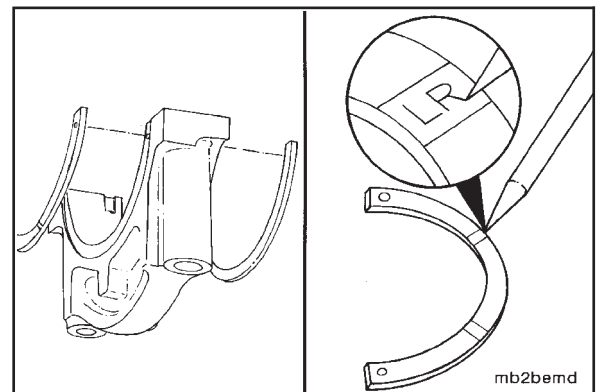
Caution: Do not mark on the bearing to crankshaft mating surface. Damage to the engine can result if the bearings are used again.

Mark the bearing shells with the journal number they were removed from in the flat surface of the bearing tang.



Remove the thrust bearings from the number “4” cap.

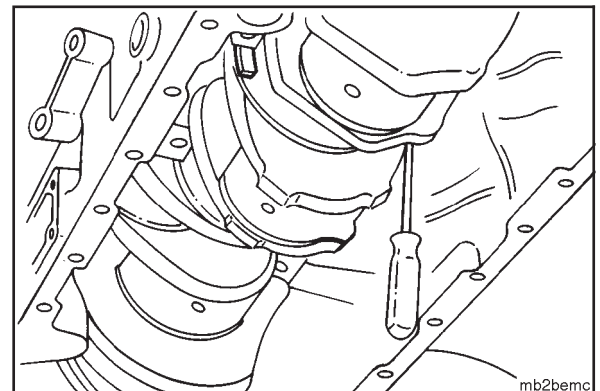
Mark the thrust bearings with the letter “L” and front or rear.

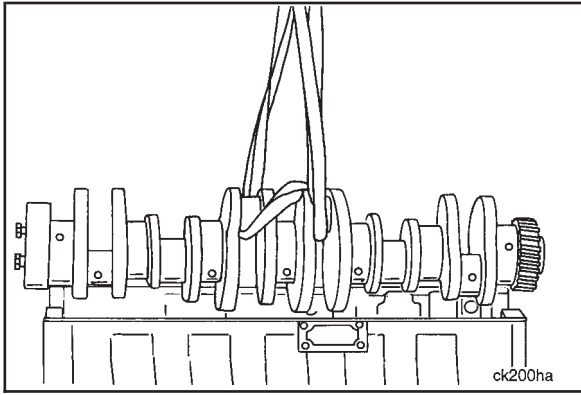


Caution: Do not damage the crankshaft when removing the thrust bearings.

Use a blunt tool to remove the upper thrust bearings from the number “4” main bearing journal.

Mark these bearings with the letter “U” and front or rear.





Crankshaft and Upper Main Bearing Shells - Removal



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

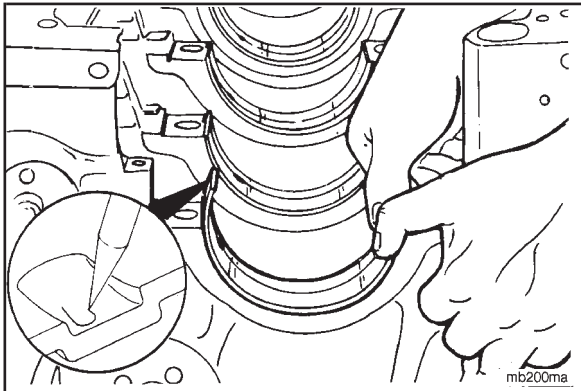
Lift the crankshaft straight up to avoid damage to the crankshaft or cylinder block.



Install nylon lifting sling, Part No. 3375957, around the number "3" and "4" rod bearing journals.



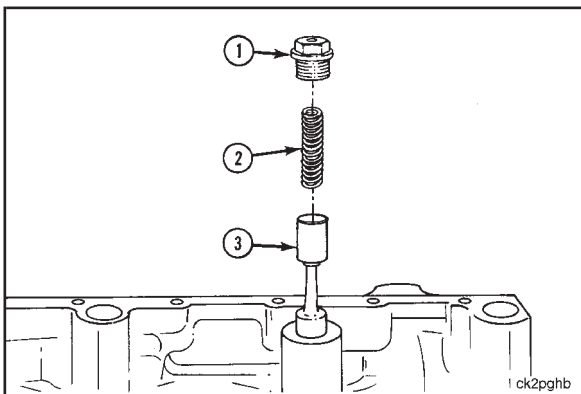
Attach the sling to a hoist and remove the crankshaft.



Use both thumbs to remove the upper bearing shells.

Mark these bearing shells with the journal number they were removed from in the flat surface of the bearing tang.

Do **not** mark on the bearing to crankshaft mating surface. Damage to the engine can result if the bearings are used again.



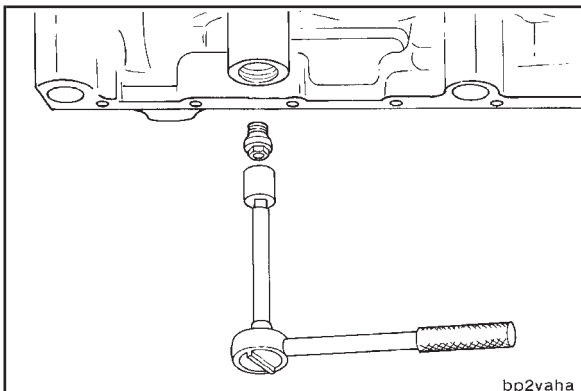
Main Oil Pressure Regulator - Removal



Warning: Use caution while removing the retainer plug (1). The pressure regulator spring (2) is under compression. Wear face and eye protection.



Remove the retainer plug (1), the pressure regulator spring (2) and plunger (3).



Viscosity Sensor - Removal



Remove the viscosity sensor with a 7/16 inch socket, an extension and ratchet.



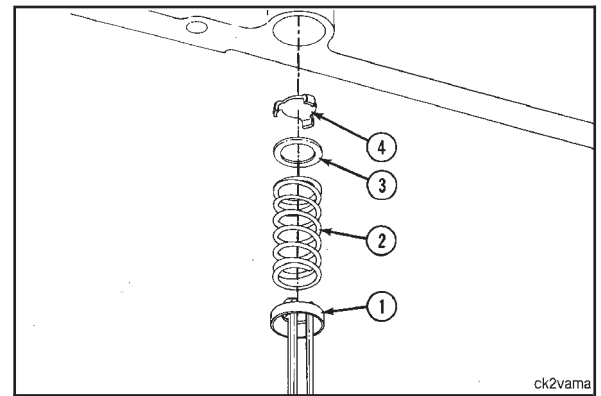
High Oil Pressure Regulator - Removal

Warning: Use caution while removing the retainer plug (1). The pressure regulator spring (2) is under compression. Wear face and eye protection.

Use light duty puller kit, Part No. 3375784, to remove the retainer plug (1).

Remove the pressure regulator spring (2), washer (3), and valve disc (4).

NOTE: The high oil pressure regulator seat will remain in the cylinder block.



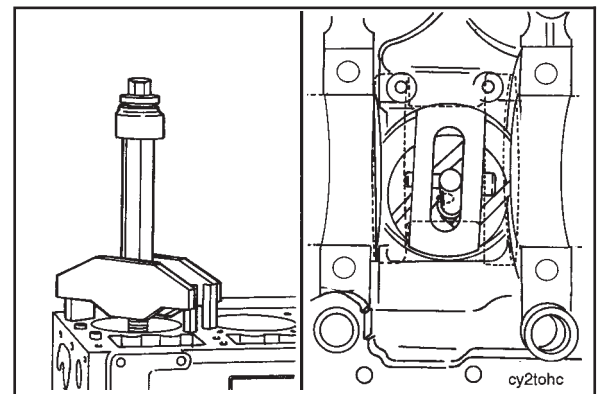
Cylinder Liners - Removal

Rotate the engine on the rebuild stand so the head deck is facing up.

Use universal liner puller, Part No. 3375629, with plate, Part No. 3376049, to remove the cylinder liners.

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.

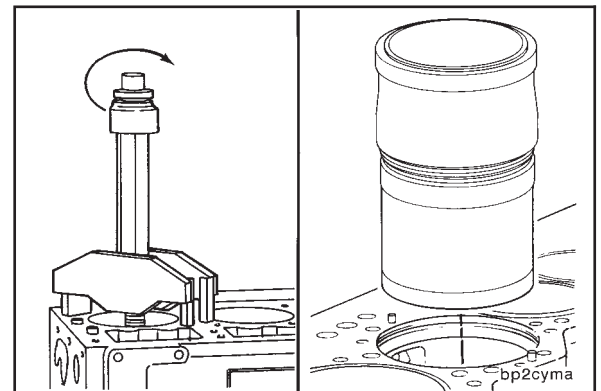
Remove the liners with universal liner puller, Part No. 3375629.

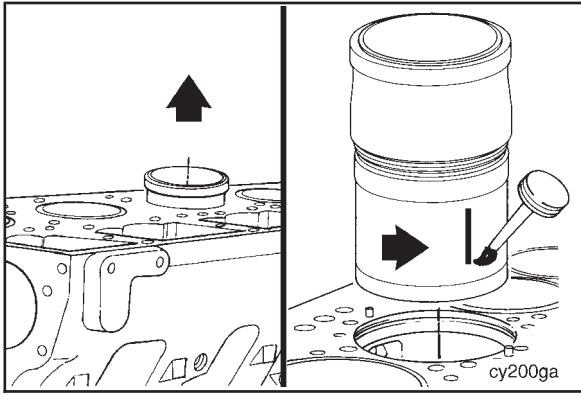


The liner puller **must** be centered on the top of the cylinder block to prevent damage to the cylinder block.

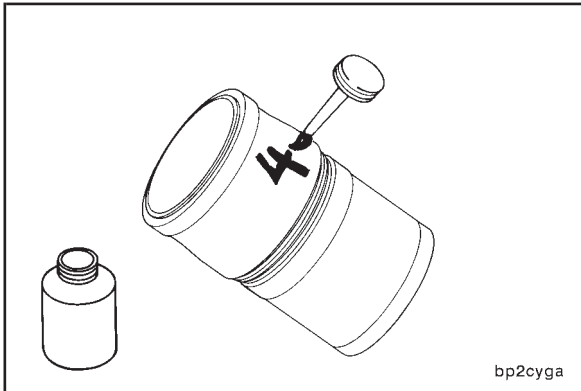
Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liners.

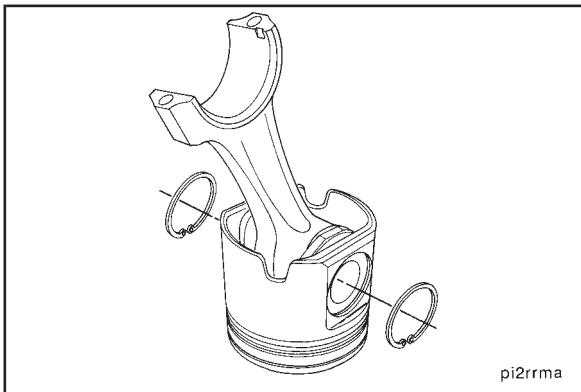




When the liner is removed from the cylinder block, use Dykem® or equivalent, to place a mark on the camshaft side of the liner to show liner orientation.



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



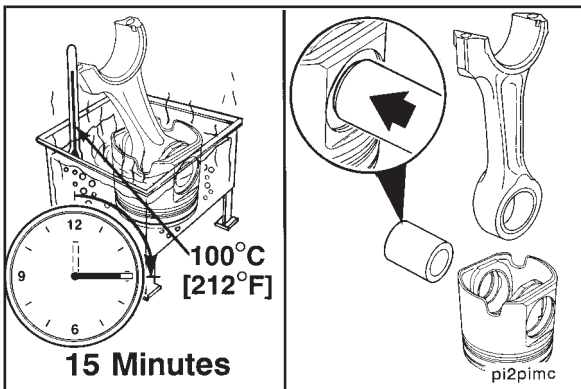
Pistons and Connecting Rods - Disassembly



Caution: The piston pin can fall from the piston assembly when the retainer snap rings are removed. The piston and pin can be damaged.



Use internal snap ring pliers to remove the retainer snap rings from both sides of the piston.



Caution: Do not use a hammer to remove the piston pins. The piston can be distorted and damaged.

If the pin **cannot** be removed by hand:

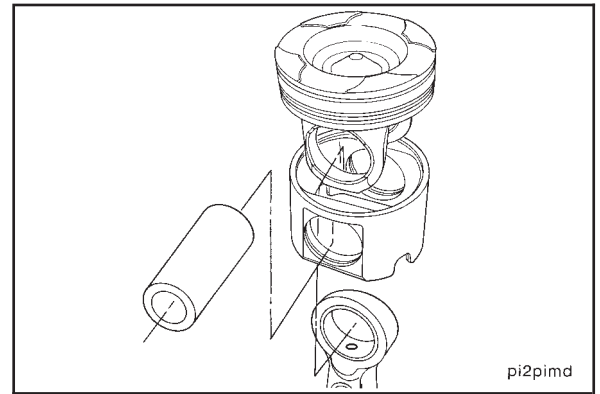


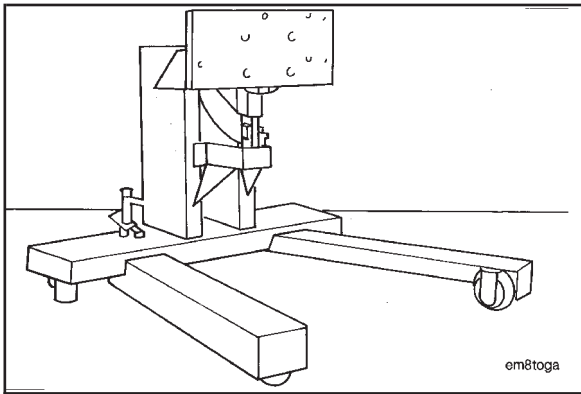
- install the piston and rod assembly in a container of water,
- heat the piston in boiling water for 15 minutes,
- use a blunt tool to push the piston pin from the piston and rod assembly.



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.





Engine Assembly (0-02)

Cylinder Block - Installation On Rebuild Stand

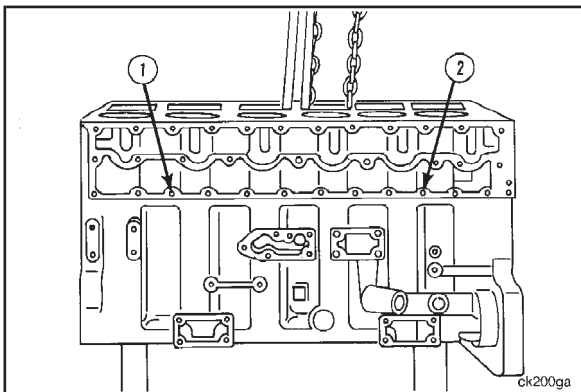


Use adapter plate, Part No. 3376432, with the engine rebuild stand, Part No. 3375194, to assemble the engine.



Use ten (5/8 - 11 x 1 3/4) grade 5 capscrews to install the adapter plate to the rebuild stand.

Torque Value: 180 N•m [135 ft-lb]



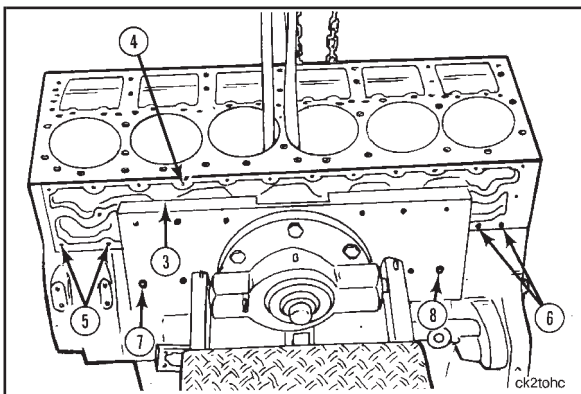
Install two guide pins, Part No. 3376488, into the water header plate mounting capscrew holes (1) and (2).



The 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 and engine lifting sling, Part No. 3375957, to lift the cylinder block.

Install the exhaust side of the cylinder block to the adapter plate of the rebuild stand.



Align the top of the adapter plate (3) with the top row of water header plate mounting capscrew holes (4).

The cylinder block **must** be positioned so two capscrew holes (5) and (6) in the bottom row will show on each side of the adapter plate.



Align the guide pins with the bottom row of holes in the adapter plate at points (7) and (8).

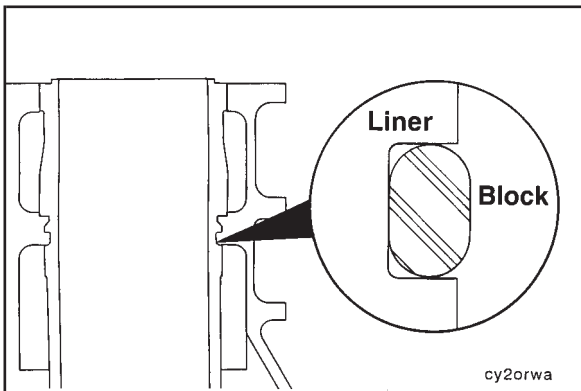


Use eight capscrews, Part No. 3376434, to install the adapter plate to the cylinder block.

Remove the guide pins and install two capscrews, Part No. 3376434.



Torque Value: 47 N•m [35 ft-lb]



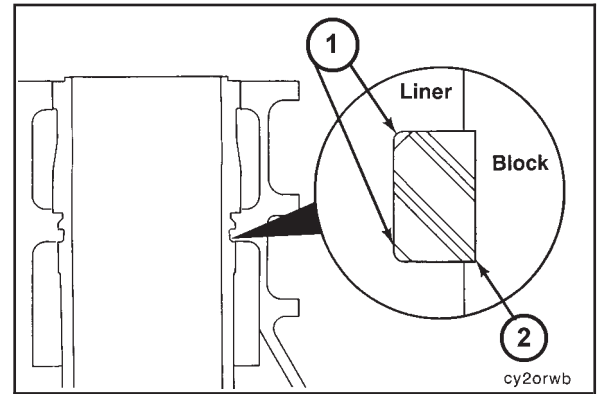
Cylinder Liners - Installation

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 symmetric 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.

- A lathe cut o-ring which has a straight outside with sharp corners and the inside which has two 45 degree chamfers, so there are no sharp corners next to the liner. This o-ring **must** be installed with the straight side 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.

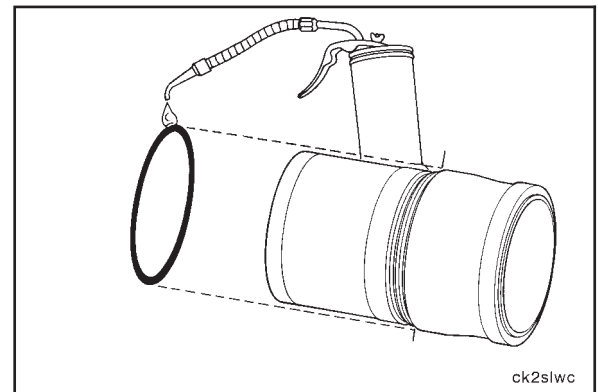


Make sure the cylinder block and all parts are clean before assembly.

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.

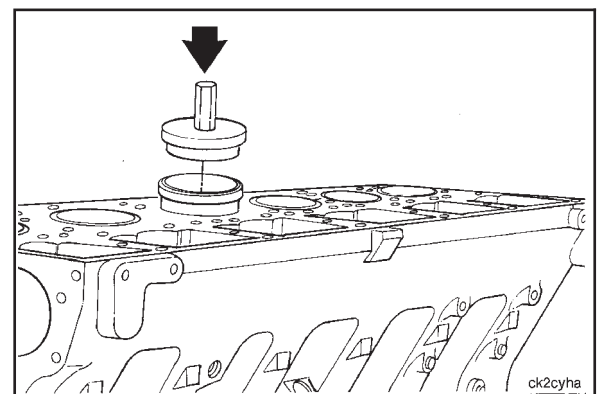


Install the liner into the cylinder block.

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.

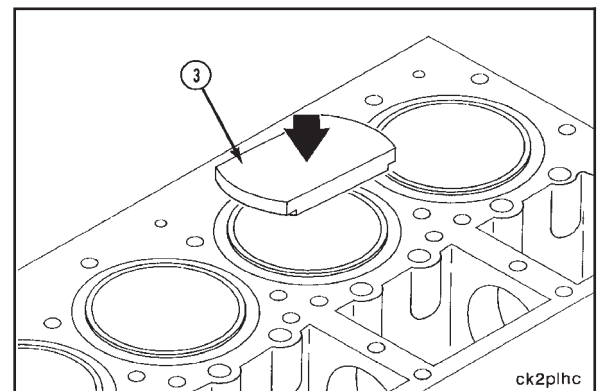
Use the cylinder liner driver, Part No. 3376056, and a leather mallet to drive the liner into the cylinder block bore.

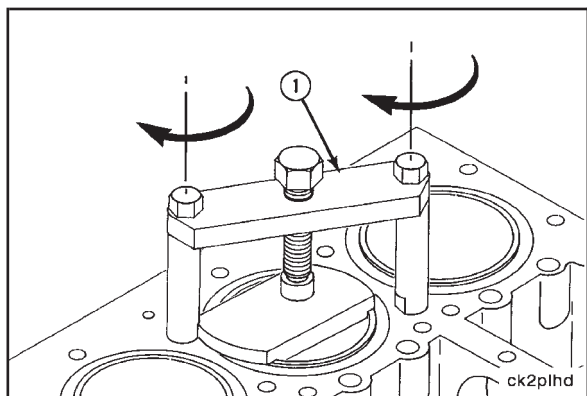
If the liner does **not** seat properly, remove the liner. Inspect the counterbore seat and liner for nicks, burrs, or dirt. Install the liner again.



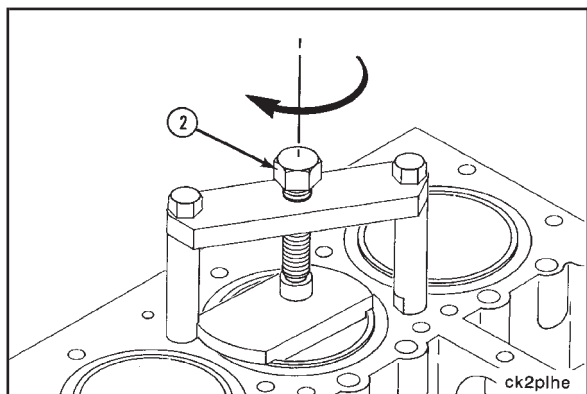
Use cylinder liner clamping tool, Part No. 3824272, to seat the liner into the cylinder block.

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.

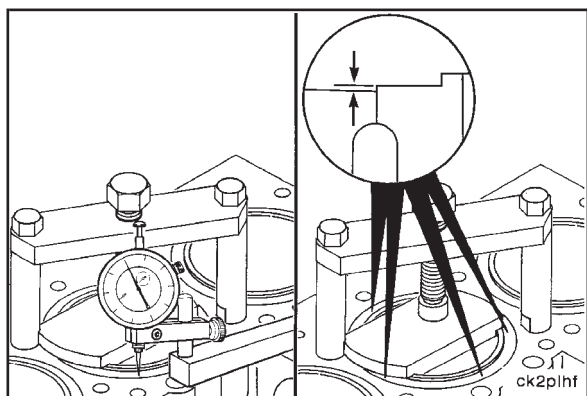


Tighten the forcing screw (2).



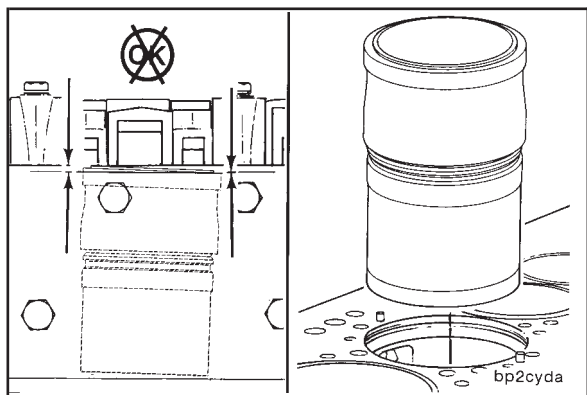
Torque Value: 136 N•m [100 ft-lb]

Check for correct protrusion.



Use a depth gauge, Part No. 3823495, to measure the liner protrusion at four points 90 degrees apart.

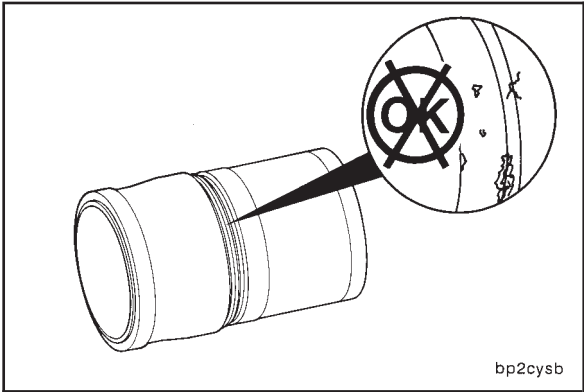
Cylinder Liner Protrusion		
mm		in
0.00	MIN	0.000
0.13	MAX	0.005



If the protrusion varies more than 0.025 mm [0.0010 inch]:

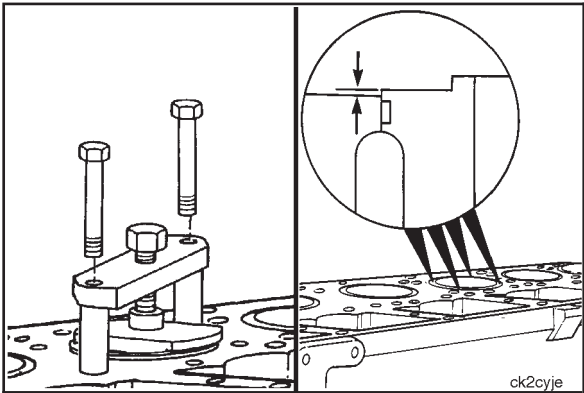
- Remove the liner.

- Inspect the liner seating edge for burrs, dirt or damage.
- Replace the liner if it is damaged.



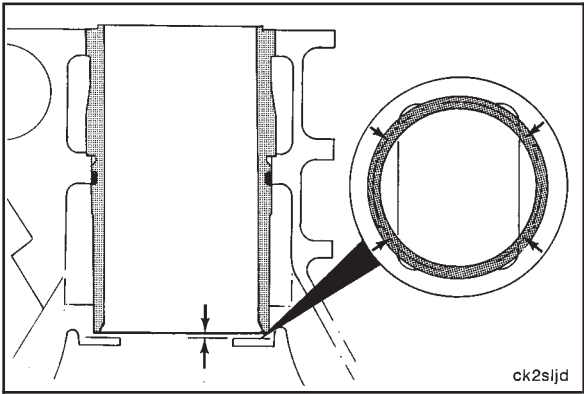
- Install the liner again.
- Measure the liner protrusion.

If the liner protrusion still does **not** meet the specifications, use counterbore ledge tool, Part No. 3823558, to cut the cylinder block liner bore for shims. Refer to the Alternative Repair Manual, Bulletin No. 3810310, for the correct procedure.



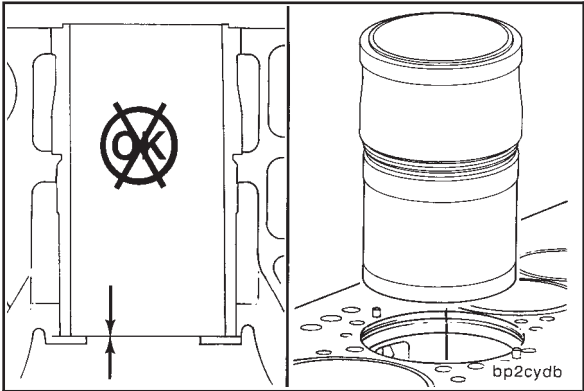
Use a feeler gauge to measure the liner to block clearance at the four block casting points.

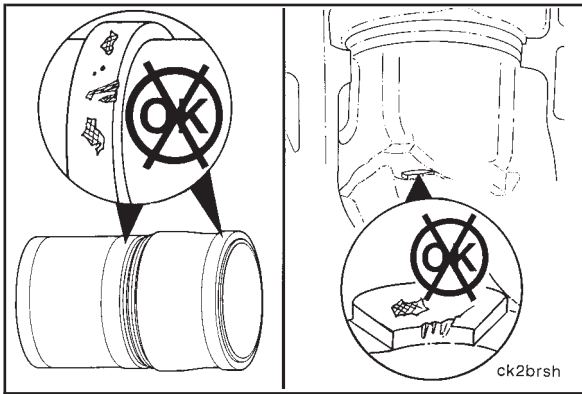
Cylinder Liner to Block Clearance		
mm		in
0.25	MIN	0.010



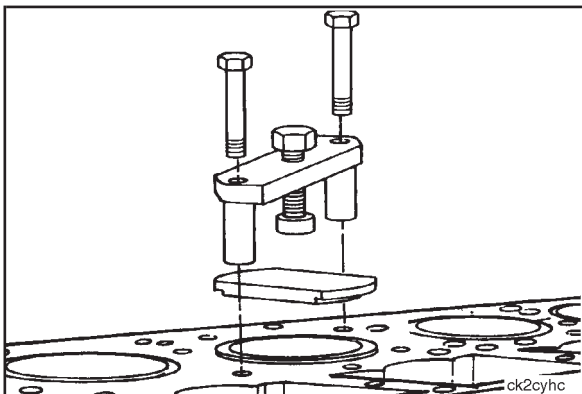
If the clearance is less than 0.25 mm [0.010 inch]:

- Remove the liner.

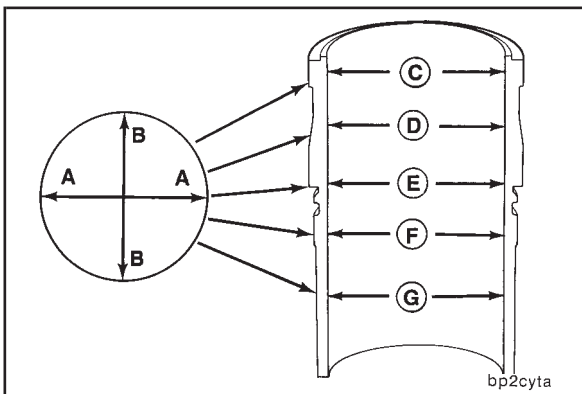




- Inspect the liner and cylinder block for dirt or damage.

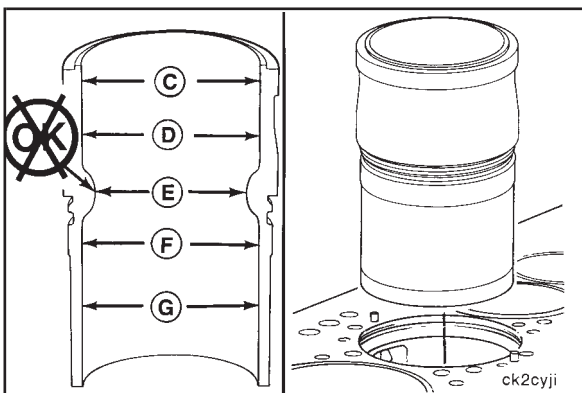


- Replace the liner if it is damaged.
- Install the liner again.



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.

NOTE: The cylinder block can be distorted when mounted on the engine rebuild stand. If the liner bore does **not** meet the specifications, remove the engine from the engine rebuild stand and set it on a clean flat surface. Measure the liner bore out-of-roundness again.



If the liner bore is more than 0.10 mm [0.004 inch] out-of-round with the engine on a flat surface:

- 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 I.D. (A)		
mm		in.
145.900	MIN	5.7441
146.027	MAX	5.7491

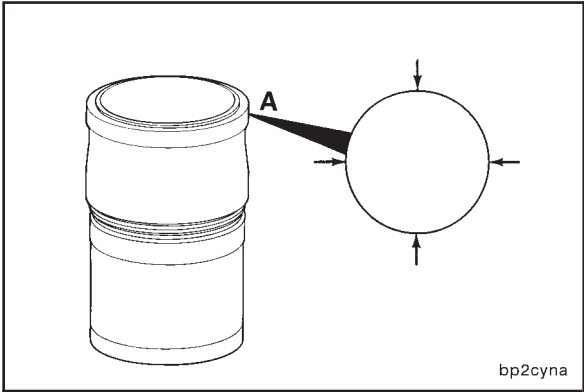
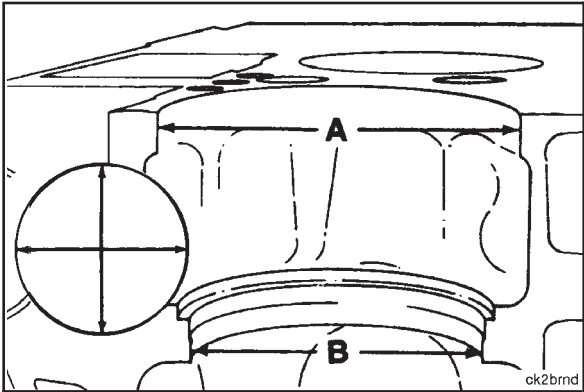
- Measure the cylinder block liner seal seat bore (B) 8.0 to 13.5 mm [0.32 to 0.53 inch] below the counterbore.

Cylinder Block Liner Seal Seat Bore I.D. (B)		
mm		in.
138.063	MIN	5.4355
138.113	MAX	5.4375

- Measure the liner outside diameter (A).

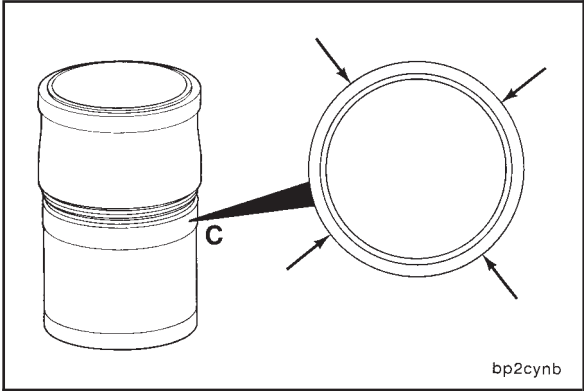
Cylinder Liner Top Press Fit O.D. (A)		
mm		in.
145.938	MIN	5.7456
145.976	MAX	5.7471

NOTE: The cylinder block liner counterbore flange diameter is **not** a critical dimension and does **not** need to be measured.

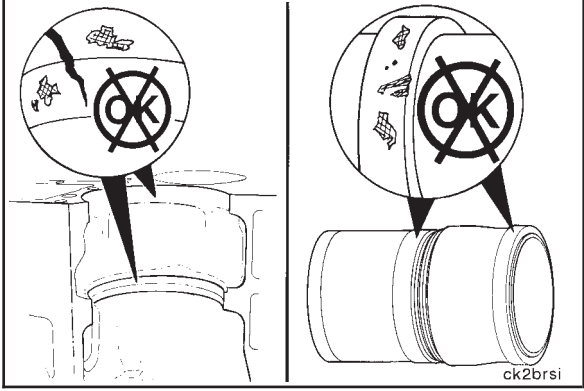


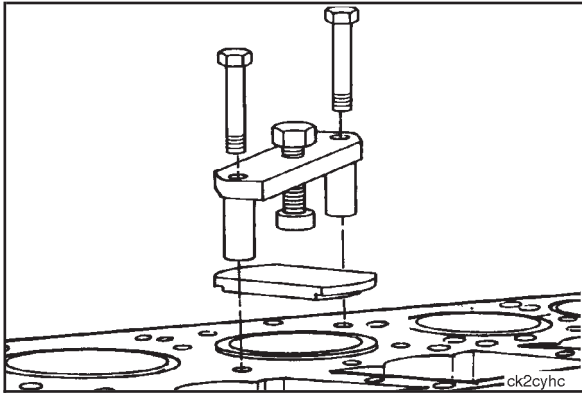
Measure the liner outside diameter (C).

Cylinder Liner Seal Seat Bore Fit O.D. (C)		
mm		in.
137.937	MIN	5.4306
138.013	MAX	5.4336

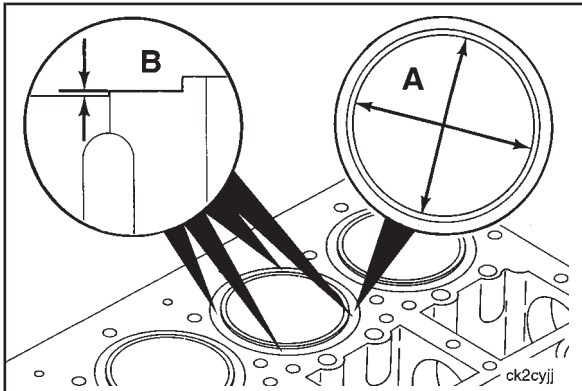


- Inspect the cylinder block liner bore and liner for burrs, dirt or damage.



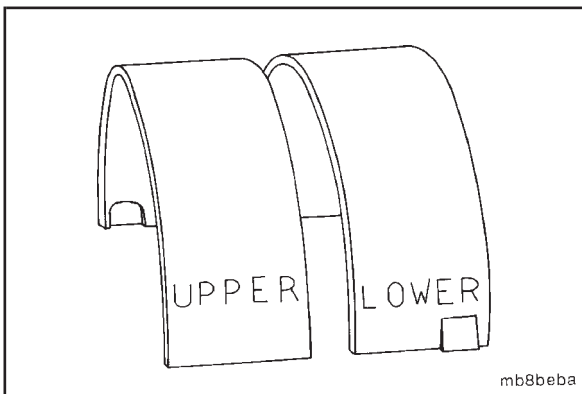


Replace the liner if it is damaged.



Inspect the liner bore (A) and measure the protrusion (B) again.

Replace the liner if it does **not** meet the specifications.

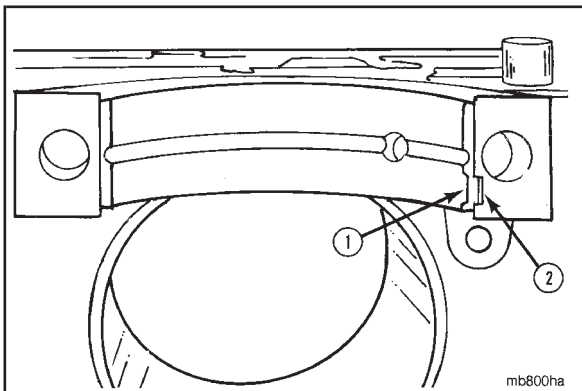


Upper Main Bearing Shells - Installation



Caution: The bearing shells are marked with the words “upper” and “lower”. Each must be installed in the correct location to prevent engine damage.

If used bearing shells are to be installed, each **must** be installed in its original location in the engine. The bearing journal numbers should have been marked in the bearing tangs during disassembly.

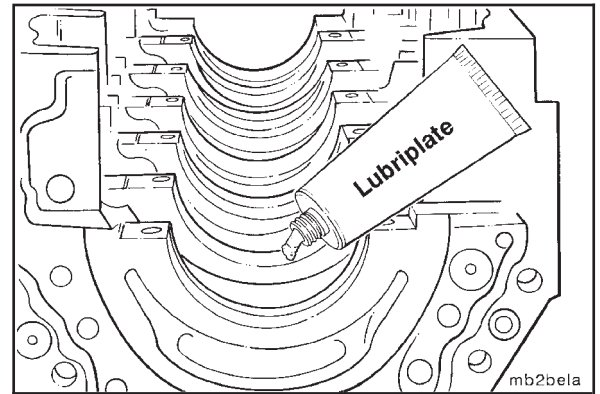


Caution: The tang (1) on the bearing shell must be in the slot (2) of the bearing saddle to correctly position the bearing and prevent engine damage.



Install the upper main bearing shells.

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



Crankshaft - Installation

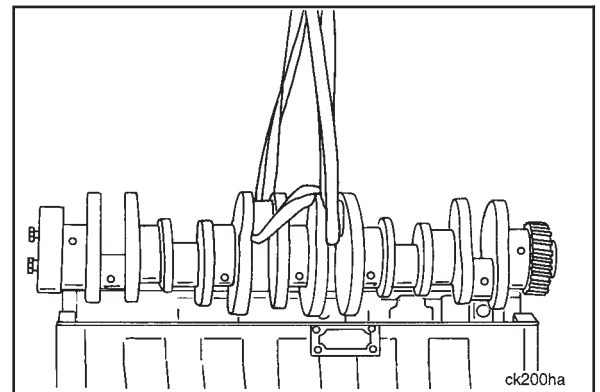
The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Use a hoist and nylon lifting sling, Part No. 3375957.

Install the sling around the numbers “3” and “4” rod bearing journals.

Do not damage or move the bearing shells when the crankshaft is installed.

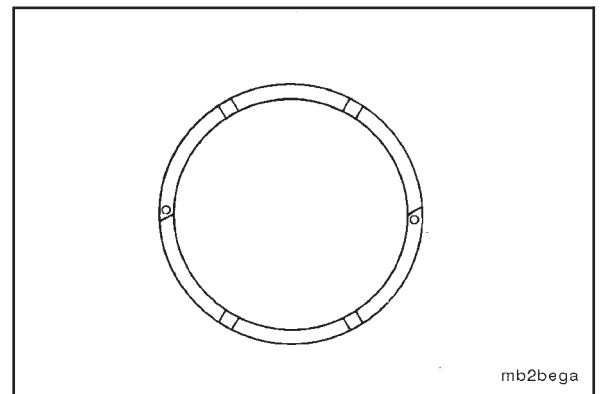
Install the crankshaft.



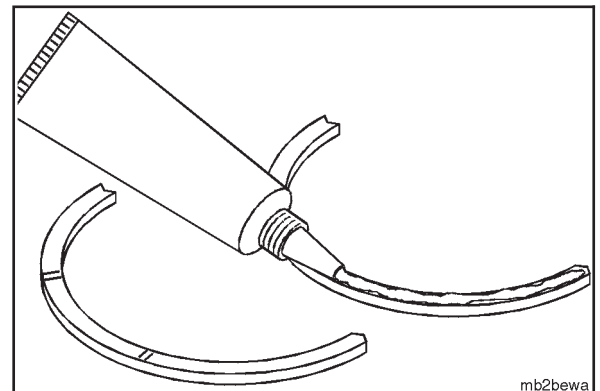
Thrust Bearings, Lower Bearing Shells and Main Bearing Caps - Installation

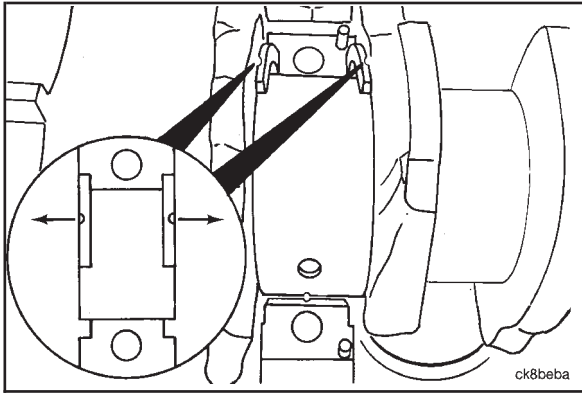
Production thrust bearings, Part No. 3822062, include an interlocking design to make sure the bearings are installed correctly.

NOTE: 0.25 mm [0.010 inch] oversize thrust bearings, Part No. 3050589, are available if required.



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



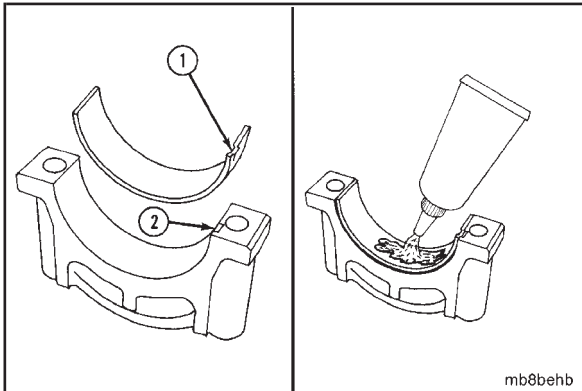


Push the crankshaft toward the rear of the engine to install the rear thrust bearing, and to the front to install the front thrust bearing.



The grooves in the thrust bearings **must be** installed toward the crankshaft to prevent damage to the crankshaft and cylinder block during engine operation.

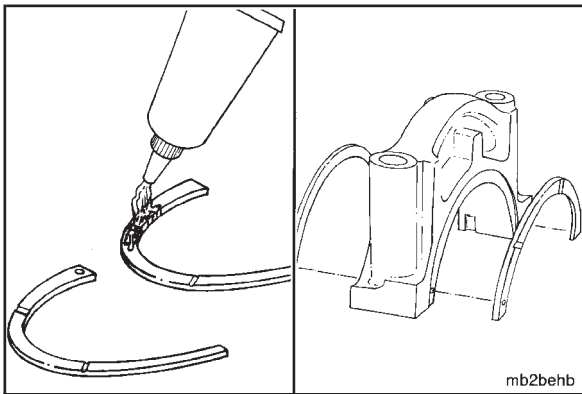
Install the upper thrust bearings into the number "4" main bearing saddle.



Install the lower main bearing shells with the 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.



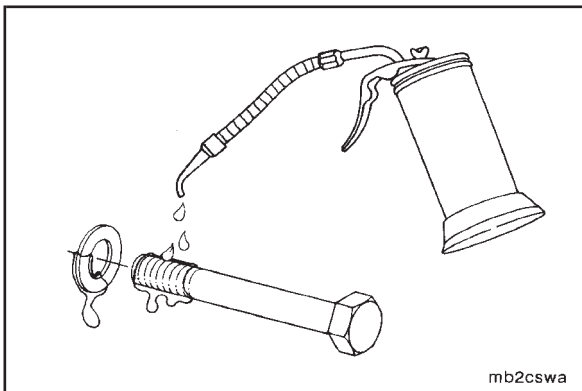
Use Lubriplate® 105, or equivalent, to coat the lower thrust bearings.



Caution: The grooves of the thrust bearing must be facing out from the bearing cap to prevent damage to the crankshaft and cylinder block during engine operation. The locating dowels must not protrude above the thrust bearing surface.



Install the thrust bearings to the number "4" main bearing cap.



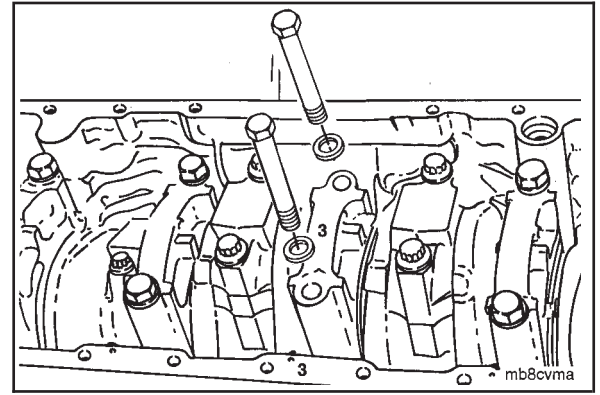
Use clean 15W-40 oil to coat the main bearing capscrew threads and on both sides of the washers.



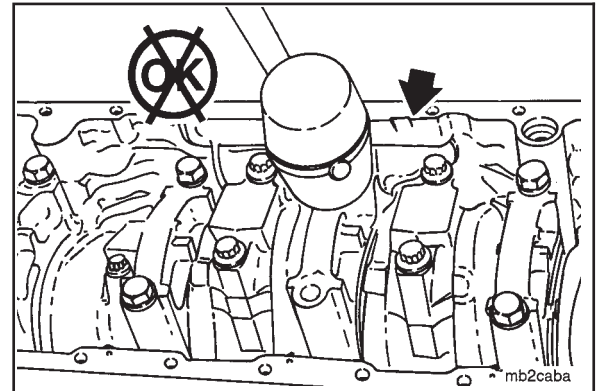
Drain the excess oil from the capscrews before installing them in the cylinder block to prevent hydraulic lock and possible engine damage during engine operation.

The main bearing caps are numbered. The caps **must** be installed with the number on the cap matching the number on the oil pan flange of the cylinder block. The caps **must** be oriented so they are lock tang to lock tang.

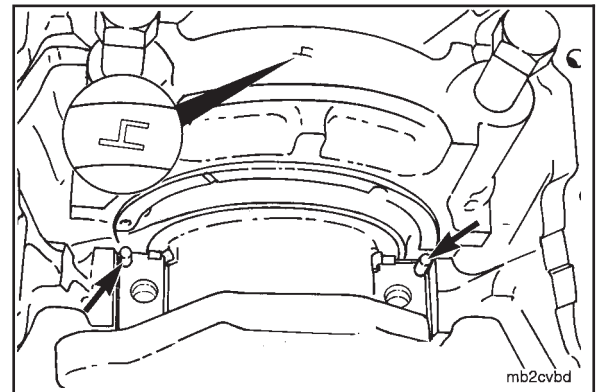
Install the main bearing caps, capscrews and washers.



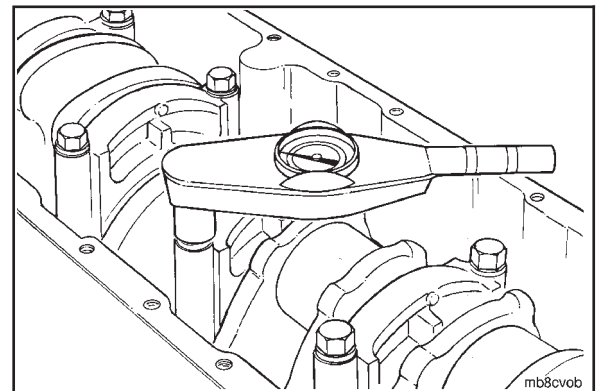
Caution: Do not hit the main bearing caps with a hammer. The main bearing cap and bearings can be damaged.

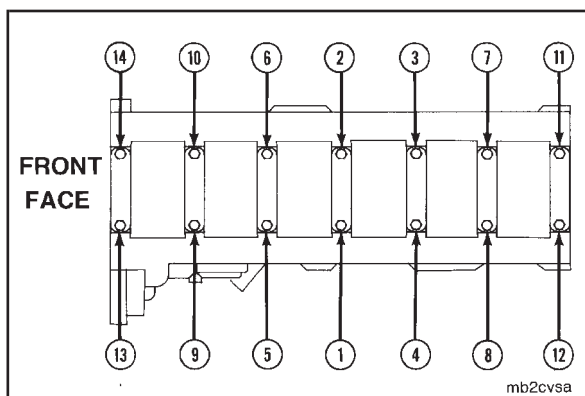


Caution: The number “4” main bearing cap must be aligned with the dowel pins in the bearing saddle. If the dowel pins and main bearing cap are not in alignment, the cylinder block and main bearing cap will be damaged when the capscrews are tightened.



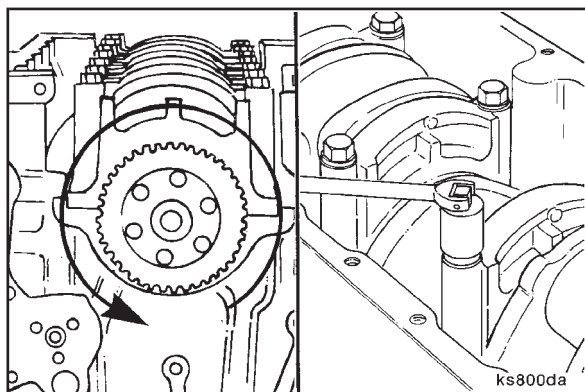
Caution: Do not use an impact wrench to tighten the capscrews; the capscrews must be tightened alternately and evenly in specific steps to the correct torque values to prevent damage to the cylinder block, main bearing caps and crankshaft.





Complete the following steps to tighten the capscrews in the sequence shown:

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 - 68 N•m [50 ft-lb]
6 - 142 N•m [105 ft-lb]
7 - 210 N•m [155 ft-lb]

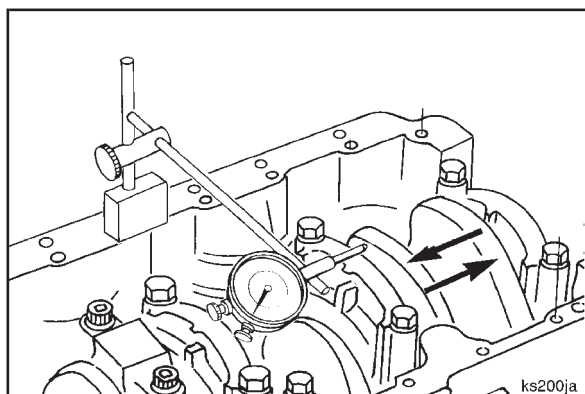


Use your hands to turn the crankshaft. If it does **not** turn freely, loosen the main bearing capscrews one at a time to locate the bearing that is too tight.

If a tight bearing is found, remove the cap and bearing.

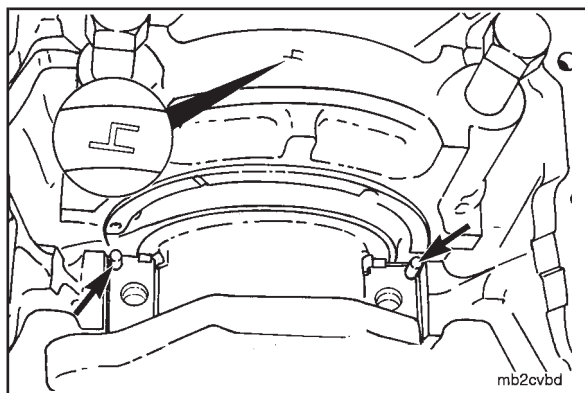
Check for dirt, dings and proper fit.

Replace the bearing if necessary.



Use dial indicator, Part No. 3376050, and base, Part No. 3377399, to measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.10	MIN	0.004
0.56	MAX	0.022

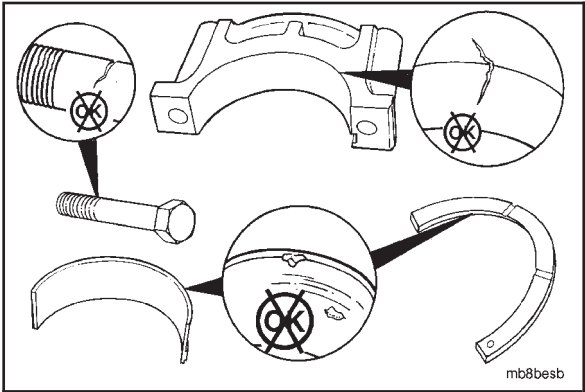


If the end clearance is **not** within specifications, complete the following steps:

- Remove the number "4" main bearing cap and thrust bearings.

- Inspect for burrs, dirt or damage.

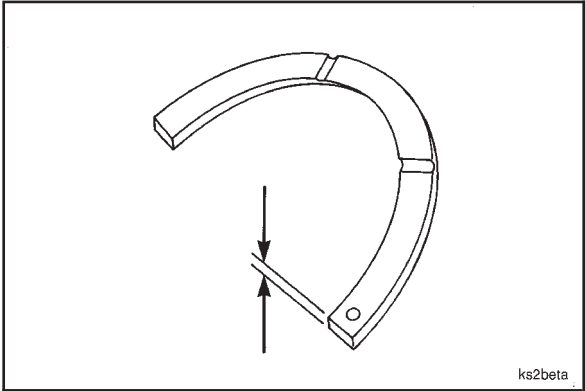
If nicks or burrs **cannot** be removed with fine crocus cloth, the cap and bearings **must** be replaced.



Measure the thrust bearing thickness and replace the bearings if they are **not** within specifications.



Crankshaft Thrust Bearing Thickness		
mm		in
4.83	MIN	0.1902
4.89	MAX	0.1925



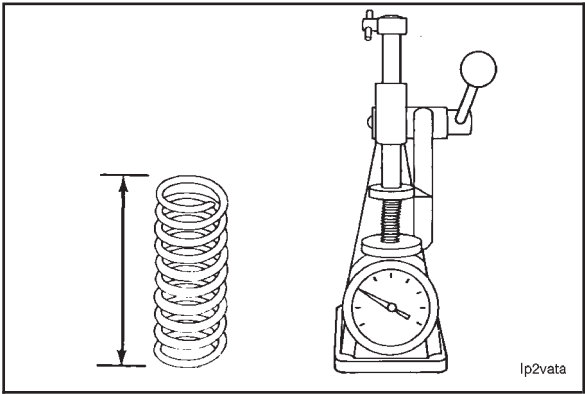
High Oil Pressure Regulator - Installation

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.



Force Required to Compress Regulator Spring		
Newton		lbf
263	MIN	59
322	MAX	72



If the spring does **not** meet the above specifications, it **must** be replaced.

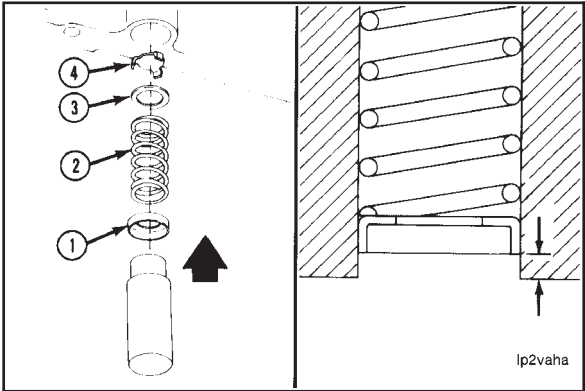
Install the valve disc (4), washer (3) and regulator spring (2).

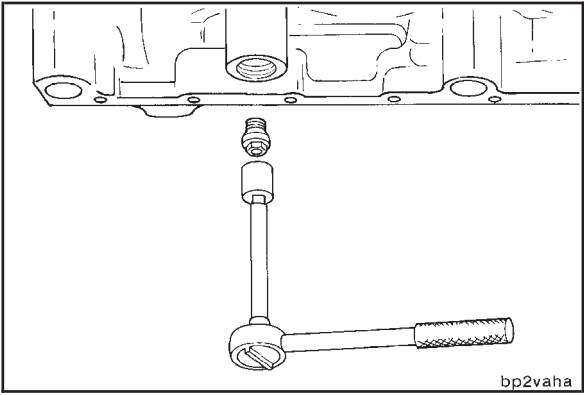
Use plug driver, Part No. 3376489, to install the new retainer cup plug (1).

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

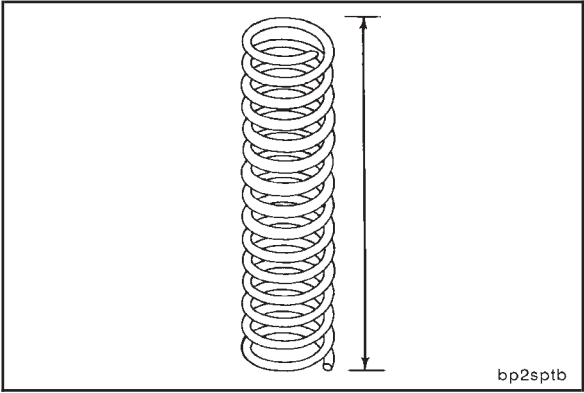




Viscosity Sensor - Installation

Install the viscosity sensor in the cylinder block.

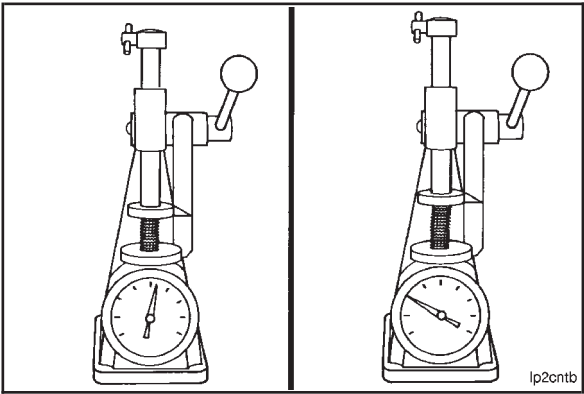
Torque Value: 24 N•m [18 ft-lb]



Main Oil Pressure Regulator - Installation

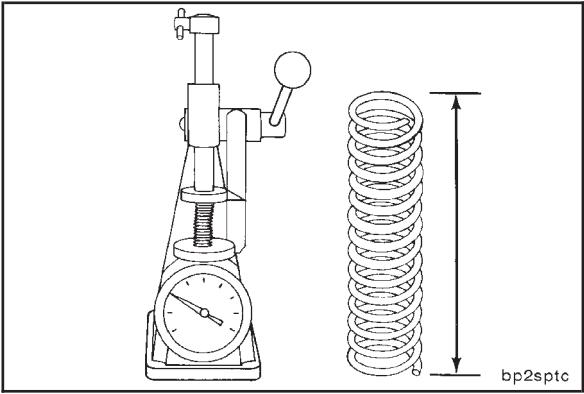
Measure the free length of the regulator spring.

Regulator Spring Free Length	
mm	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.



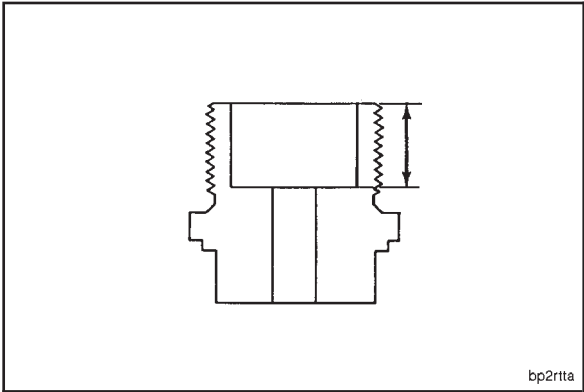
Main Oil Pressure Regulator Spring Load at 48.3 mm
[1.90 in]

mm		in
91.1	MIN	20.50
94.7	MAX	21.30

Measure the retainer plug to determine if it is defective.



Main Oil Pressure Regulator Retainer Plug		
mm		in
11.1	MIN	0.44
13.4	MAX	0.53



bp2rta

Warning: The regulator spring must be compressed to install the retainer plug (1). 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.



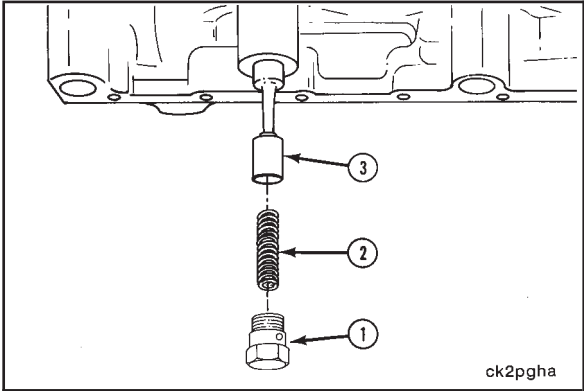
Install the plunger (3) and spring (2). Install and tighten the retainer plug (1).

Rear Sump Oil Pan Retainer

Torque Value: 75 N•m [55 ft-lb]

Block Mounted Front Sump Suction Tube (BMFSST)

Torque Value: 122 N•m [90 ft-lb]



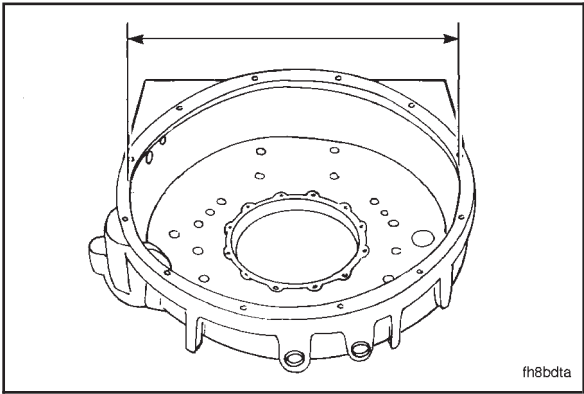
ck2pgha

Flywheel Housing - Installation

Measure the inside diameter of the housing bore to determine the SAE number and size of the housing being used.



Flywheel Housing Maximum Bore I.D.		
mm	SAE No.	in
787.7	00	31.01
648.0	0	25.51
584.4	1/2	23.01
511.3	1	20.13
447.8	2	17.63
409.7	3	16.13

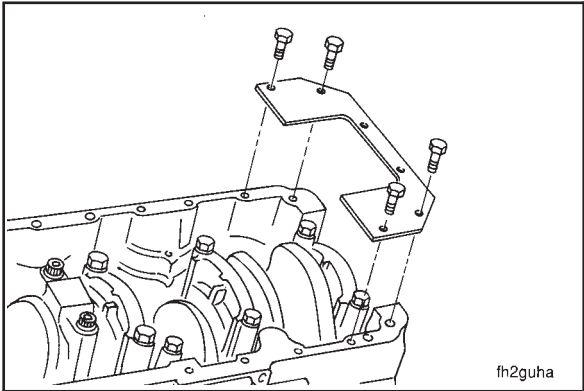


fh8bda

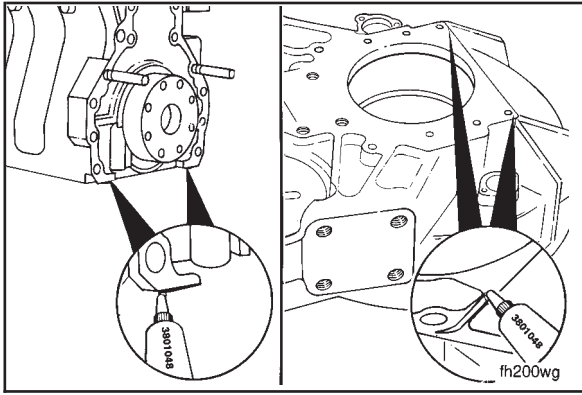
Use four oil pan capscrews (M10-1.50 x 25) to install the flywheel housing alignment plate, Part No. 3376606, to the oil pan flange at the rear of the cylinder block.



Torque Value: 47 N•m [35 ft-lb]



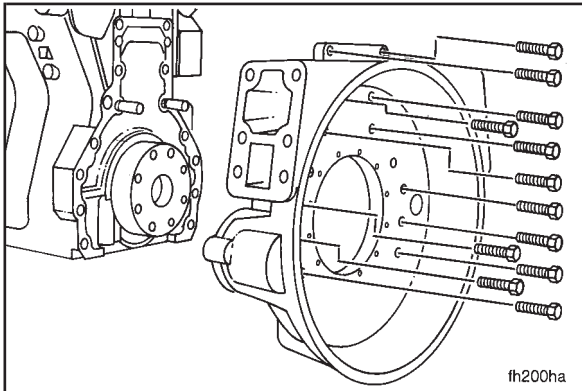
fh2guha



Rotate the engine on the rebuild stand to position the cylinder head mounting surface facing up.

Install two guide pins, Part No. 3376697, into the flywheel housing mounting holes of the cylinder block.

Apply a 2 mm [1/16 inch] bead of silicone sealant, Part No. 3823494, on the mounting surface of the housing and around each of the mounting capscrew holes.



Install the flywheel housing over the guide pins.

Install the ten capscrews (M16-2.00 x 55).

Remove the guide pins and install the remaining two capscrews (M16-2.00 x 55).

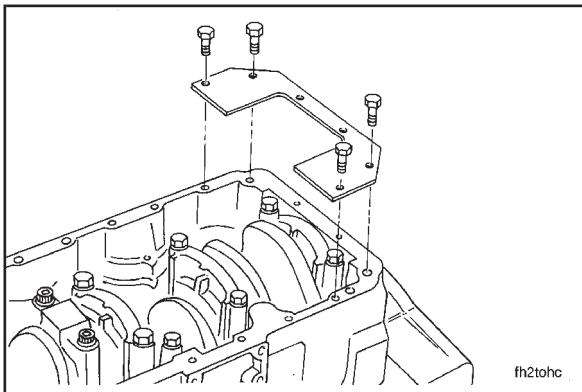


Tighten the capscrews to the following value:

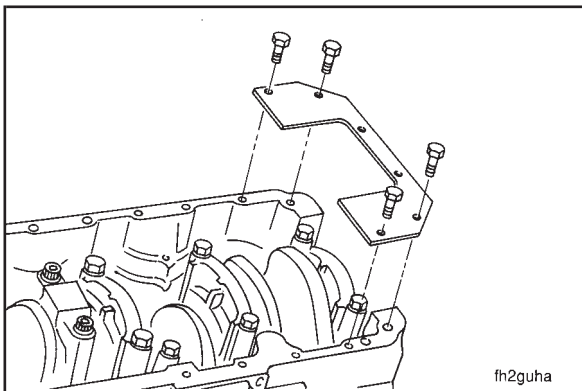
Torque Value: 7 N•m [60 in-lb]



NOTE: This is **not** the final torque value. The flywheel housing bore **must** be aligned with the crankshaft. The capscrews will be tightened to the final torque value after the flywheel housing is aligned.



Remove the four alignment plate capscrews and the alignment plate.



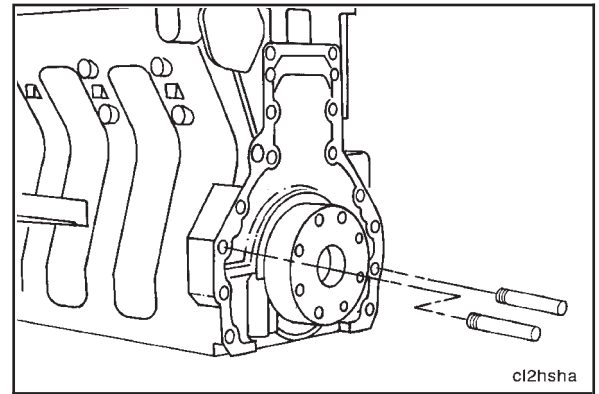
Flywheel Housing, REPTO - Installation

Use four oil pan capscrews (M10-1.50 x 25) and install the flywheel housing alignment plate, Part No. 3376606, to the oil pan flange at the rear of the cylinder block.

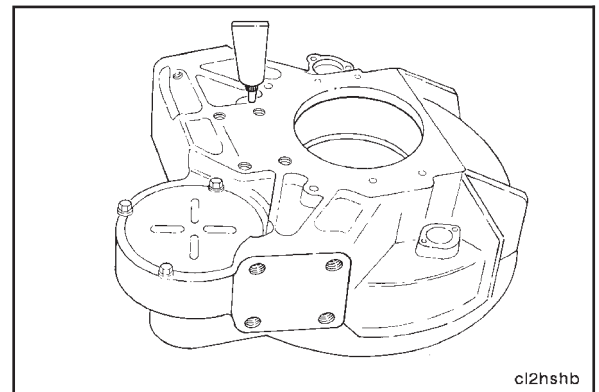
Torque Value: 47 N•m [35 ft-lb]

Rotate the engine on the rebuild stand to position the cylinder head mounting surface facing up.

Install two guide pins, Part No. 3376697, into the flywheel housing mounting holes of the cylinder block.

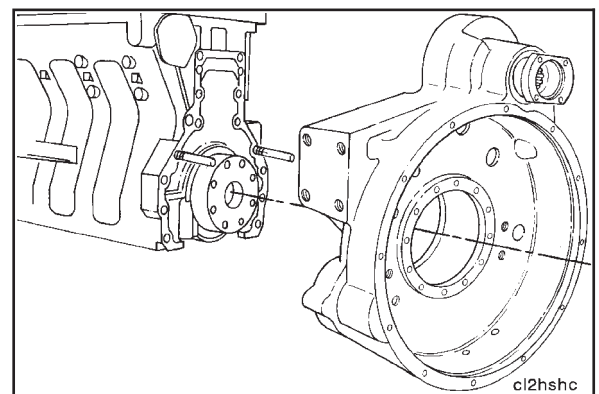


Apply a 2 mm [1/16 inch] bead of sealant, Part No. 3823494, on the mounting surface of the housing and around each of the mounting capscrew holes.



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 REPTO flywheel housing over the guide pins.



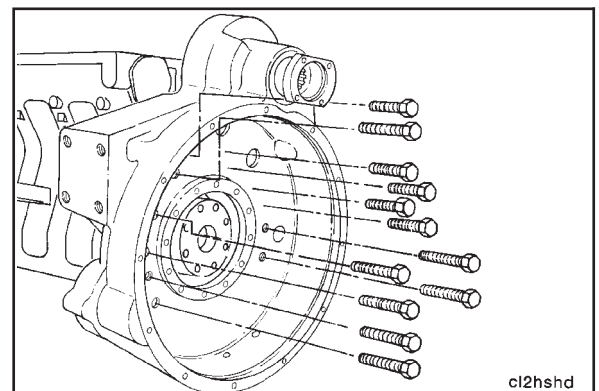
Install the five of the seven long capscrews (M16-2.00 x 130) and the five short capscrews (M16-2.00 x 60).

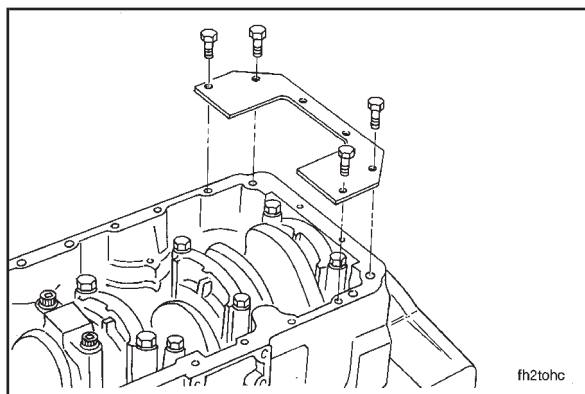
Remove the two guide pins and install the two remaining (M16-2.00 x 130) capscrews.

Tighten the capscrews to the following value:

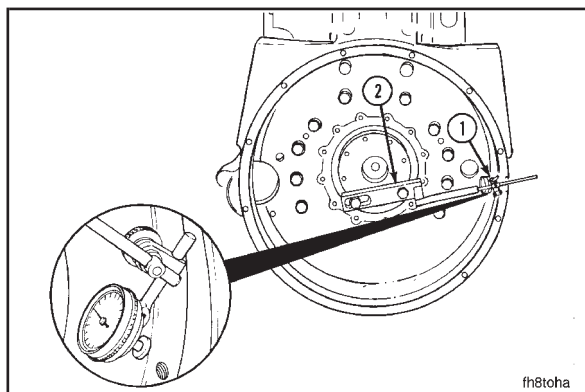
Torque Value: 7 N•m [60 in-lb]

NOTE: This is **not** the final torque value. The flywheel housing bore **must** be aligned with the crankshaft. The capscrews will be tightened to the final torque value after the flywheel housing is aligned.





Remove the four alignment plate capscrews and the alignment plate.



Flywheel Housing Bore Alignment - Measurement

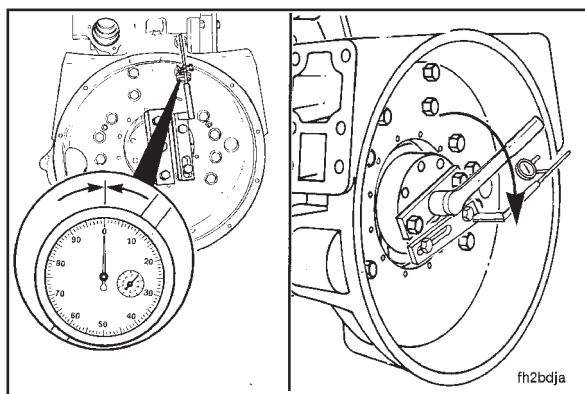


NOTE: On REPTO flywheel housings, dial gauge attachment, Part No. ST-1325, **must** be spaced out from the flywheel and longer mounting capscrews used. An alternative method is to use a magnetic base with the dial indicator gauge.

Use dial indicator gauge, Part No. 3376050, (1) and dial gauge attachment, Part No. ST-1325, (2) to measure the bore alignment.

Install the attachment and gauge as shown.

Install the engine barring tool, Part No. 3824270, to rotate the crankshaft.

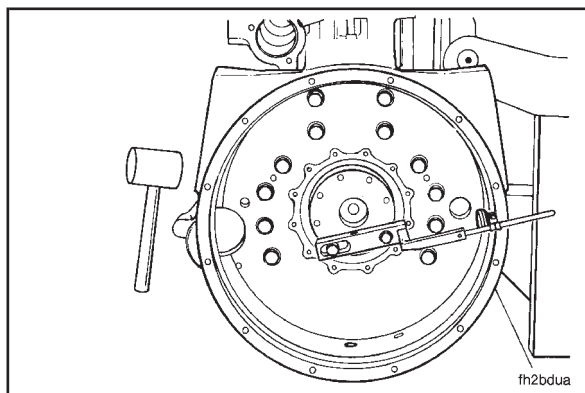


Position the indicator at the 12 o'clock position. Adjust the gauge dial to "0" (zero).



Rotate the crankshaft one complete revolution (360 degrees) and record the TIR.

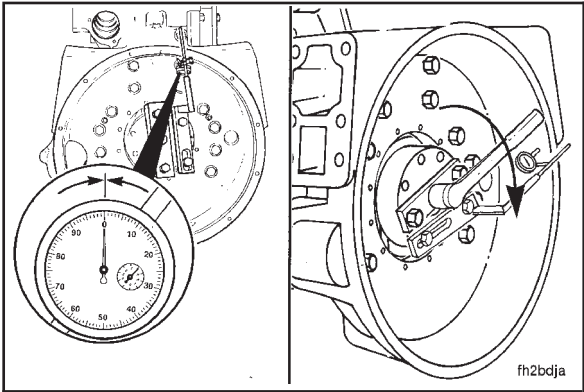
Flywheel Housing Bore Alignment Maximum TIR		
mm	SAE No.	in
0.31	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008



If the maximum bore alignment does **not** meet the specifications, use a mallet to move the housing in the necessary direction.

Repeat the above steps until the maximum bore TIR is within specifications for the determined housing size.

NOTE: If the bore alignment is **not** within specifications and the bore is **not** round, the housing **must** be replaced.



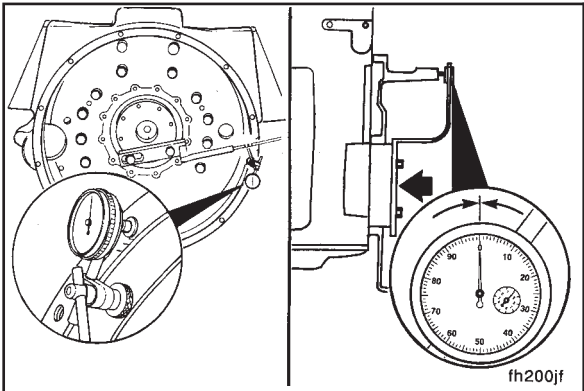
Flywheel Housing Face Alignment - Measurement

Caution: If the tip of the gauge enters the capscrew holes, the gauge will be damaged.

Position the contact tip of the gauge against the flywheel housing face.

Push the crankshaft toward the front of the engine.

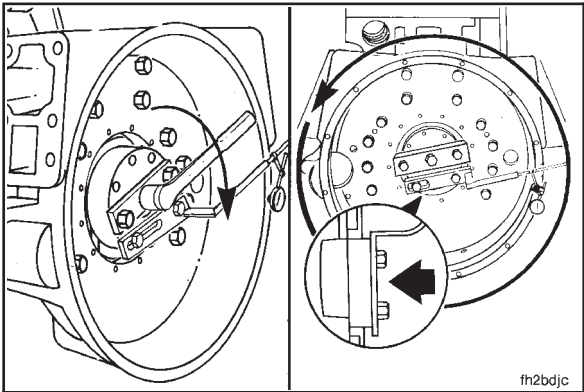
Adjust the gauge dial to "0" (zero).



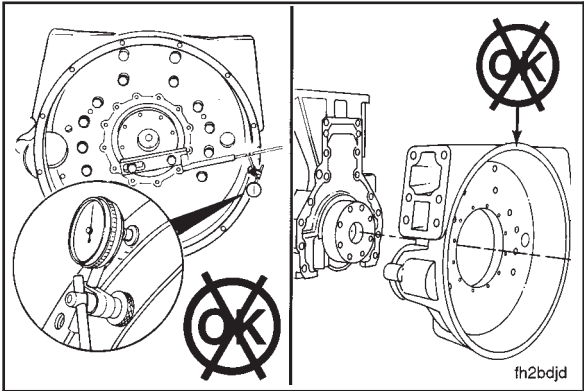
Rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward, and record the TIR.

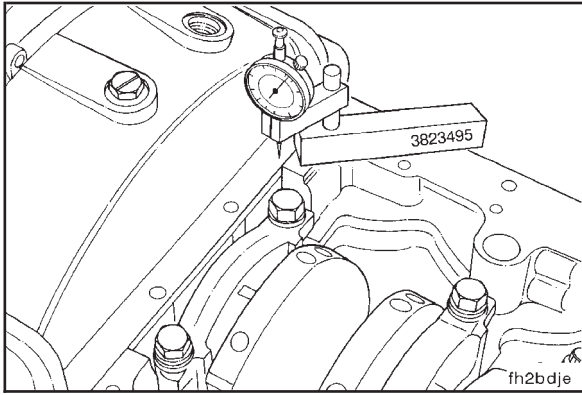


Flywheel Housing Face Alignment Maximum TIR		
mm	SAE No.	in
0.31	00	0.012
0.25	0	0.010
0.25	1/2	0.010
0.20	1	0.008
0.20	2	0.008
0.20	3	0.008



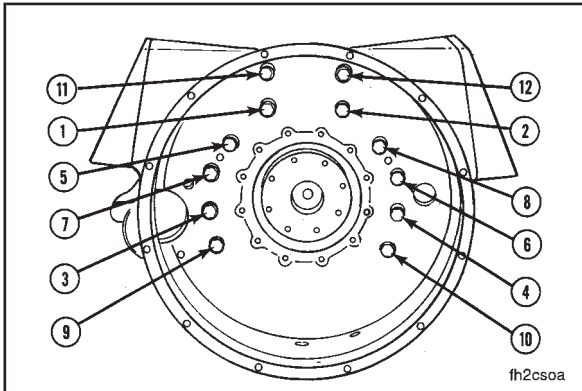
If the maximum face alignment does **not** meet the specifications, check for nicks, burrs and foreign material between the cylinder block mounting face and the flywheel housing mounting surface. If none is found, the housing **must** be replaced.





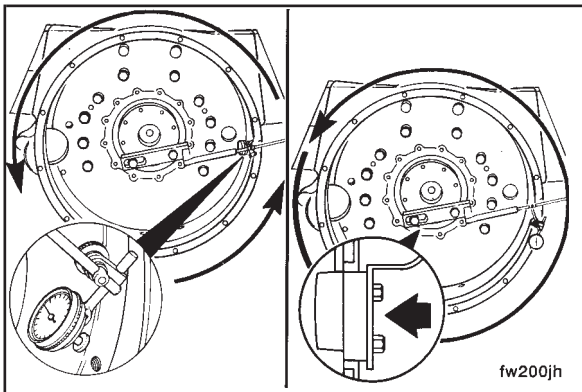
Use the gauge block, Part No. 3823495, to measure the alignment of the oil pan mounting flange of the housing with the oil pan mounting flange of the cylinder block.

The housing flange **must** be even with the cylinder block flange within ± 0.15 mm [0.006 inch]. If it does **not** meet these specifications, the bore and face **must** be realigned.



Complete the following steps to tighten the 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]

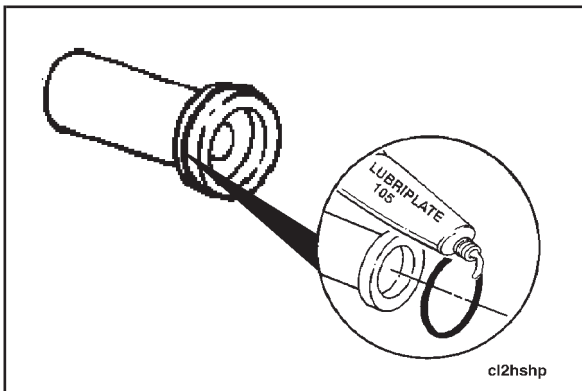


Measure the bore and face alignment again.

NOTE: If the bore and face alignment does **not** meet the specification, loosen the housing capscrews, tighten the capscrews again, and measure the bore and face alignment again.



Remove the barring tool and flywheel housing alignment measuring tool from the crankshaft.



Idler Gear (REPTO) - Installation

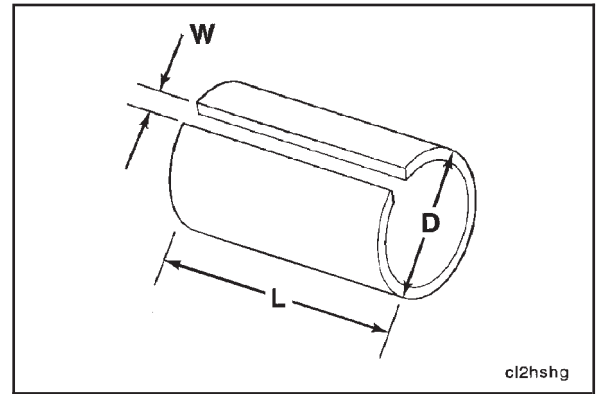
Use Lubriplate® 105, or equivalent, to lubricate the idler shaft o-ring and install the o-ring onto the shaft.



Manufacture a sleeve from 38.1 mm O.D. [1.50 in O.D.] (D) PVC, aluminum, or equivalent, to the following dimensions:

Length (L): 25.4 mm [1.00 in]

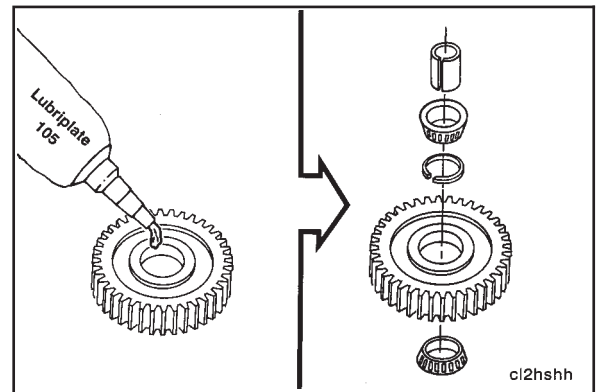
Slot (W): 6.3 mm [0.25 in]



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.

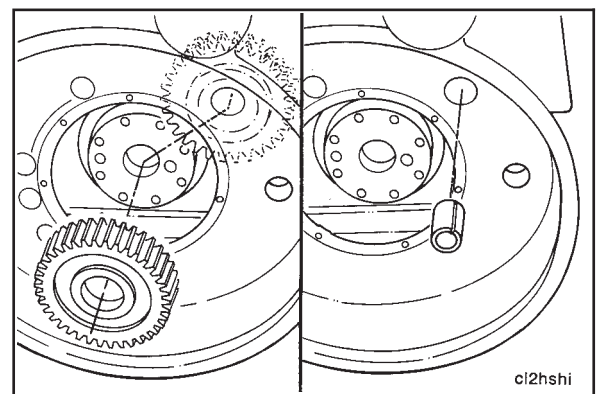
Install the bearing and spacer into the idler gear. Use the manufactured sleeve to hold the bearing assembly together when installing the idler gear assembly.



Apply a thin film of Lubriplate® 105, or equivalent, into the idler shaft bore of the housing and on the idler shaft.

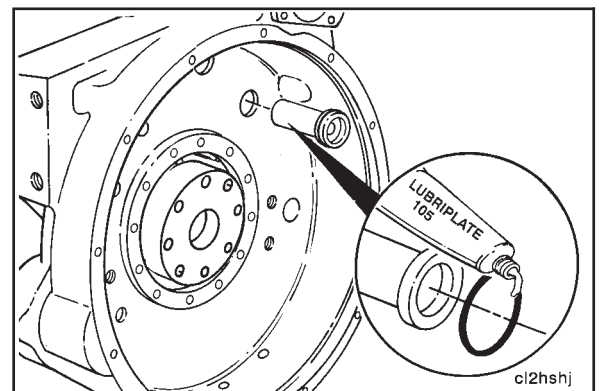
Install the idler gear assembly into the flywheel housing.

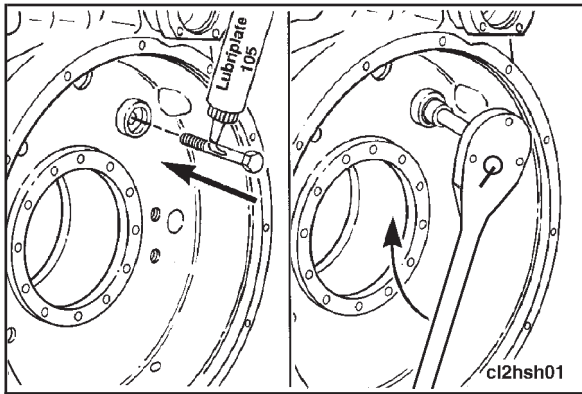
Hold the idler gear and bearings in place and remove the plastic sleeve.



Caution: Do not use a hammer when installing the idler shaft and capscrew, or the part can be damaged.

Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.

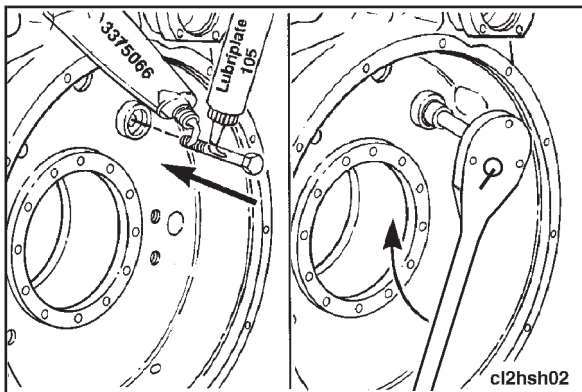




NOTE: Check the gear for freedom of rotation while using the cap screw to install the shaft. If the gear does **not** turn freely, it can indicate misalignment between the bore and the shaft. Remove the idler shaft and install it again.



Apply Lubriplate® 105 under the head of the idler shaft cap screw. Insert the cap screw through the idler shaft. Tighten the installation cap screw to draw the shaft into the bore.

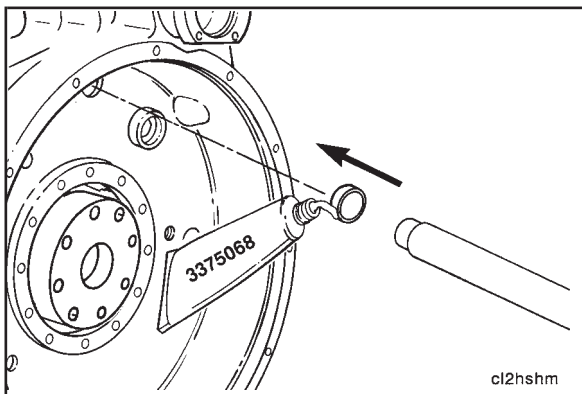


After the idler shaft has been seated, remove the cap screw.



Apply pipe sealant, Part No. 3375066, to the threads of the idler shaft cap screw. Apply Lubriplate® 105 under the head of the cap screw. Install the cap screw and tighten to its final torque value.

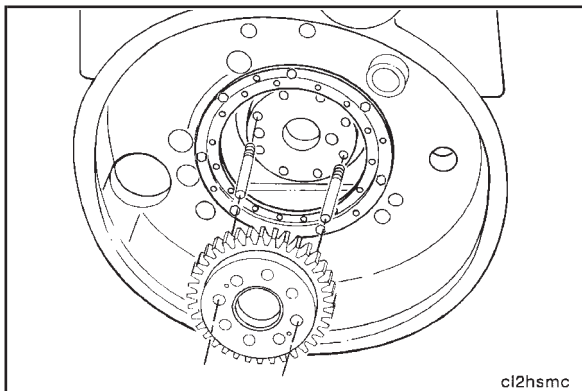
Torque Value: 102 N•m [75 ft-lb]



NOTE: New cup plugs **must** be used. Do **not** use the cup plugs that were removed from the housing.

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.

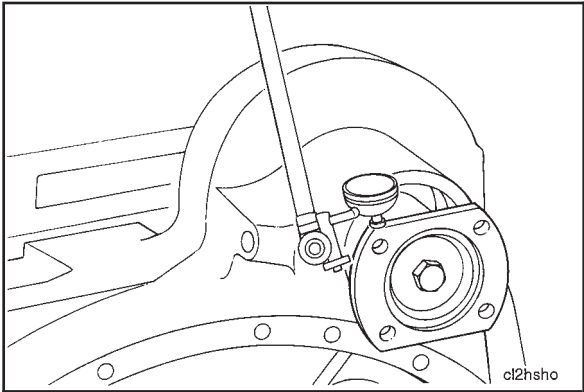


Install two guide pins, Part No. 3822784, into the crankshaft flywheel mounting flange 180 degrees apart.

Make sure the crankshaft and crankshaft gear are clean.

Install the crankshaft gear on the guide pins. Use flat washers as a spacer and install the gear with two cap screws (M14-1.50 x 110).

Use a magnetic base and dial indicator gauge, Part No. 3376050, to measure the idler gear backlash from the output shaft. Mount the gauge so the tip of the gauge is reading at the outmost edge of the output shaft.



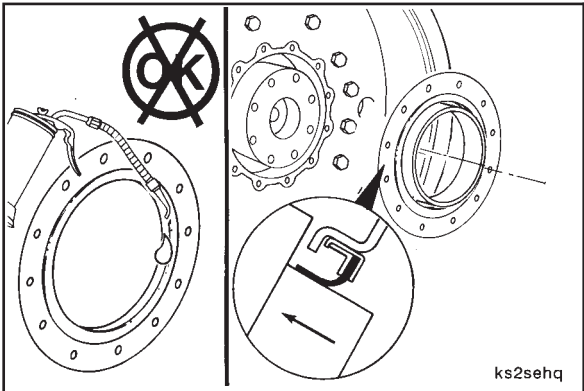
REPTO Idler Gear Backlash		
mm		in
0.15	MIN	0.006
0.38	MAX	0.015

Rear Crankshaft Oil Seal - Installation

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

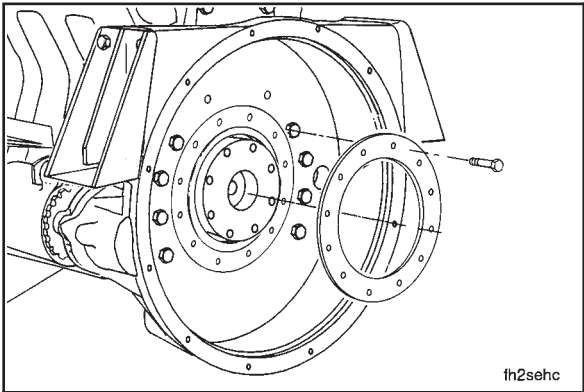
The oil seal **must** be installed with the lip of the seal and the crankshaft clean and **dry** to provide a proper oil sealing surface.

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



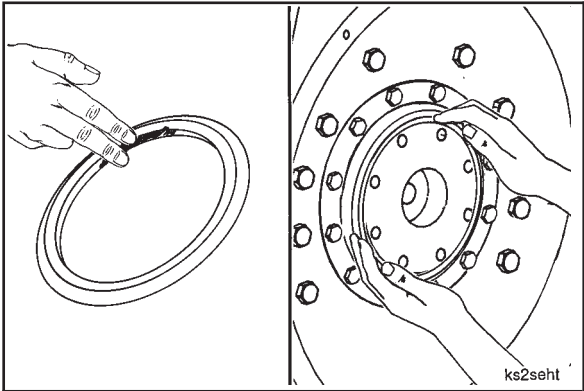
Install clamping ring using the 12 capscrews (M8-1.25 x 20). Tighten in a star pattern.

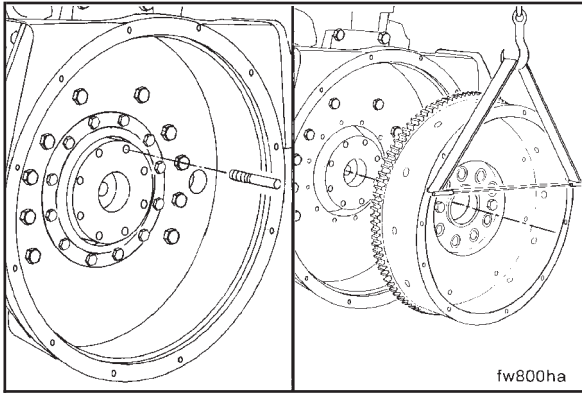
Torque Value: Step 1 - 7 N•m [60 in-lb]
2 - 20 N•m [180 in-lb]



Place a light film of oil or anti-freeze 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.





Flywheel - Installation



Install one guide pin, Part No. 3376696, into the crankshaft flange.

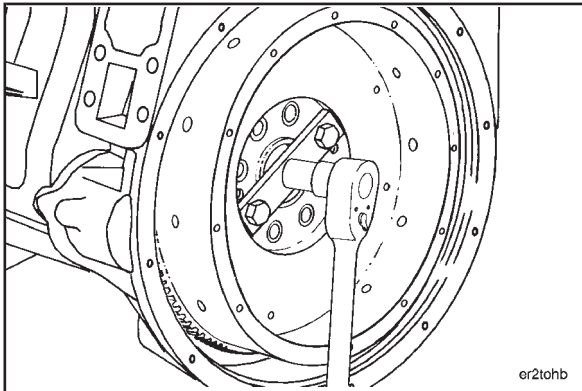
NOTE: On REPTO units, install the crankshaft gear on the guide pin before installing the flywheel.



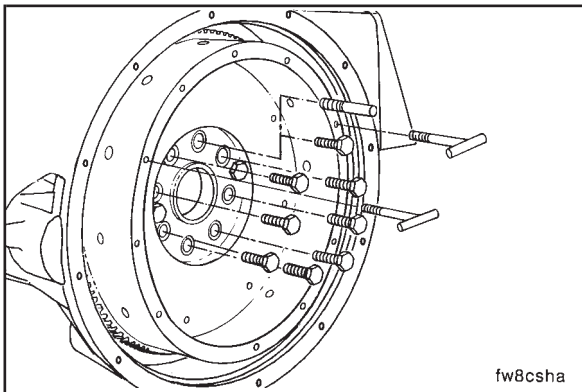
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

The crankshaft flange **must** be clean and free of damage.

Install the flywheel on the guide pin.



Install the engine barring tool, Part No. 3824270, to the flywheel.



Caution: Capscrew length is critical. Capscrews of different length can result in loss of flywheel integrity that can cause engine damage and personal injury.



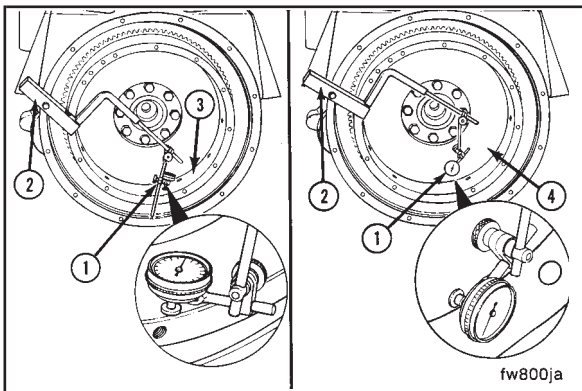
Install seven capscrews:

- **Standard Flywheel Housing** (M14-1.50 x 35)
- **REPTO Flywheel Housing** (M14-1.50 x 110)



Remove the guide pin and install the one remaining capscrew. Tighten the capscrews in a star pattern.

Torque Value: 183 N•m [135 ft-lb]



Flywheel Bore Runout - Measurement

Use the dial indicator gauge (1), Part No. 3376050, and the dial gauge attachment (2), Part No. ST-1325, to check the flywheel bore (3) and face (4) runout.



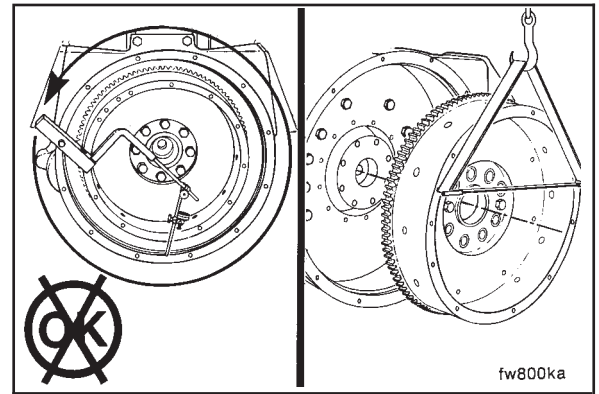
Install the attachment to the flywheel housing. Install the gauge on the attachment. Install the contact tip of the indicator against the inside diameter of the flywheel bore.

Rotate the crankshaft one complete revolution (360 degrees).

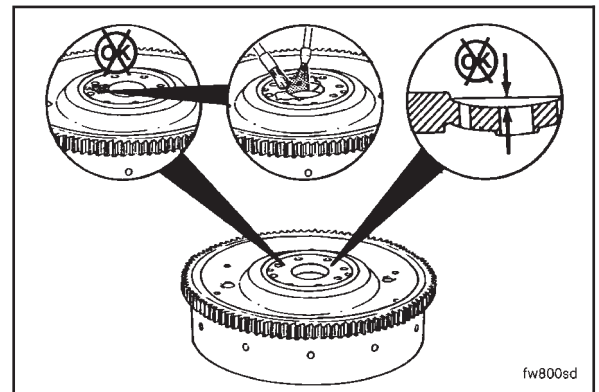
The maximum TIR **must not** exceed 0.127 mm [0.0050 inch].

If the TIR exceeds the specifications:

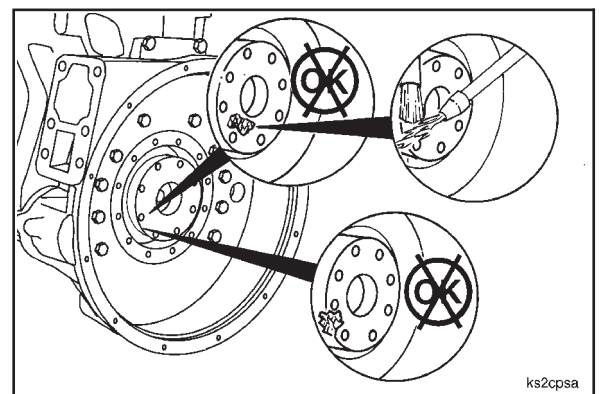
- Remove the flywheel.



- Inspect the flywheel mounting surface for burrs, dirt or damage.
- If burrs **cannot** be removed with crocus cloth, or the flywheel is damaged, it **must** be replaced.

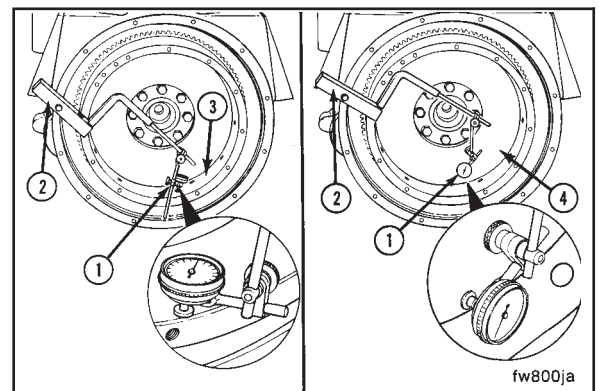


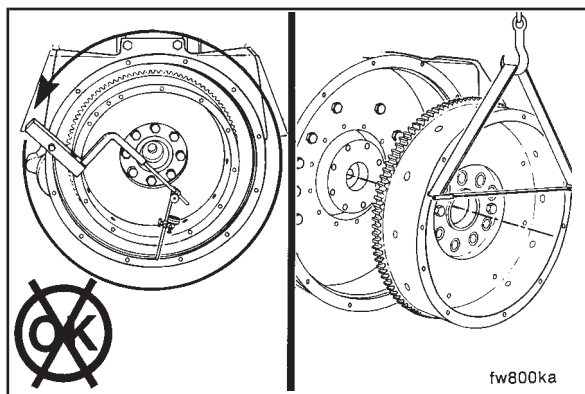
- Inspect the crankshaft flange for burrs, dirt or damage.
- If burrs **cannot** be removed with crocus cloth, or the crankshaft is damaged, refer to the Alternative Repair Manual, Bulletin No. 3810310.



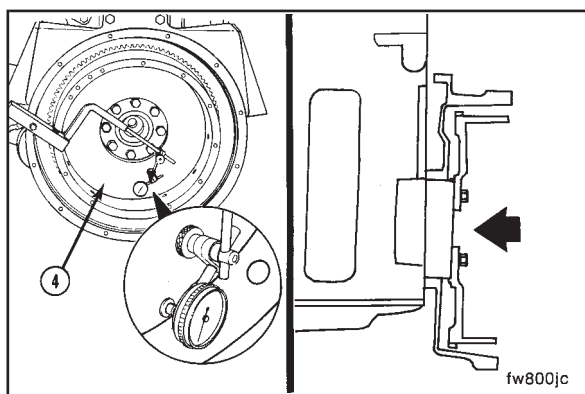
Install the flywheel and tighten the capscrews to the correct torque value.

Measure the bore runout again.





If the TIR still exceeds the specification, the flywheel **must** be replaced.

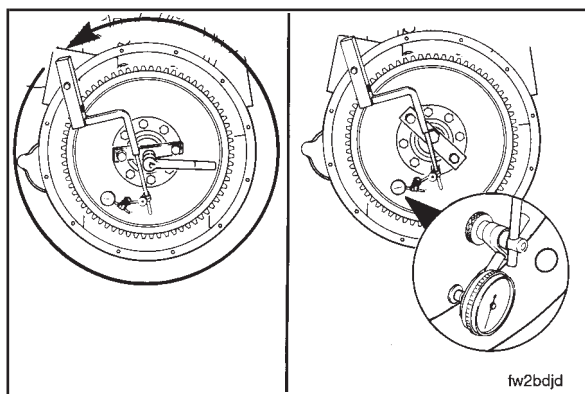


Flywheel Face Runout - Measurement

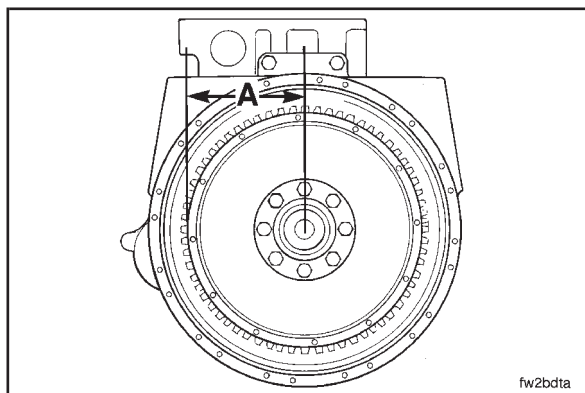


Install the contact tip of the indicator against the flywheel face as close as possible to the outside diameter to measure the face (4) runout.

Push the flywheel forward to remove the crankshaft end thrust.



Rotate the crankshaft one complete revolution (360 degrees) while keeping the crankshaft end thrust pushed forward.



The maximum TIR **must not** exceed the following specifications.

Flywheel Face Runout			
Radius (A)		Maximum TIR	
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

If the face runout does **not** meet these specifications, the flywheel **must** be replaced.

Piston and Connecting Rod - Assembly

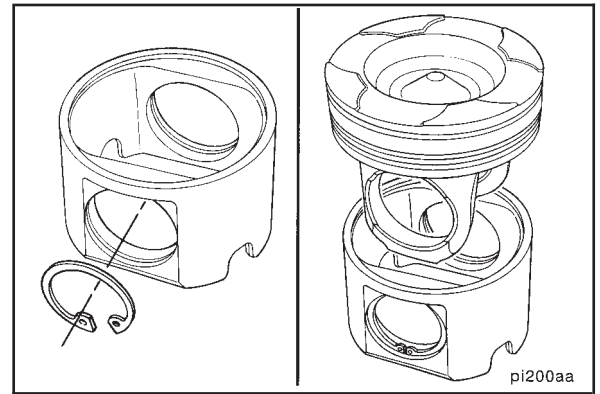
Articulated Piston

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.

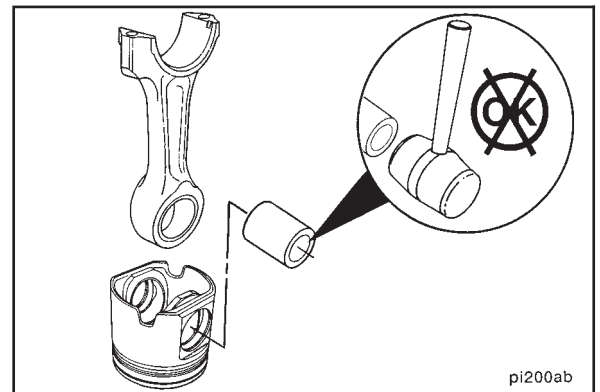
Position the skirt over the piston crown.

NOTE: It is not necessary to heat the articulated pistons before assembly. The piston pin is slip fit.



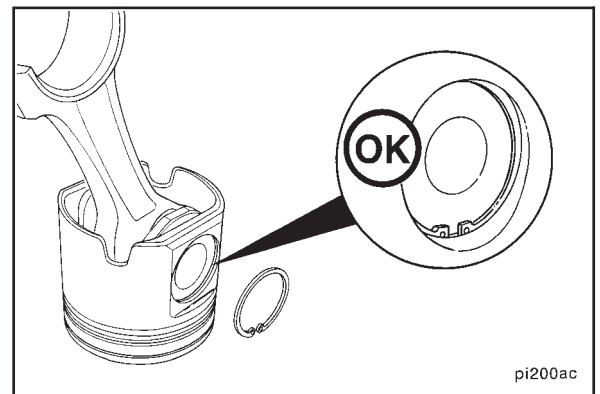
Caution: Do not use a hammer to install the piston pin. The piston can be distorted and damaged.

Align the pin bore of the rod with the pin bore of the piston skirt and crown, and install the piston pin.



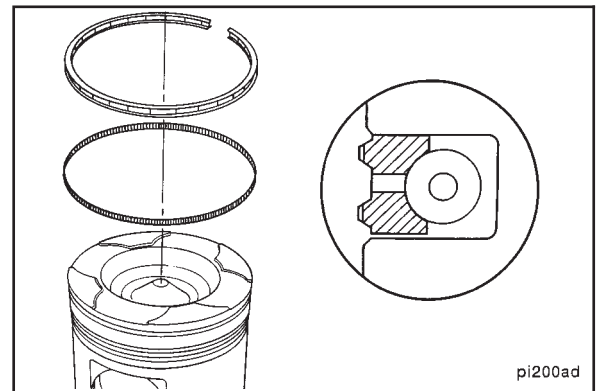
The snap ring **must** be seated completely in the piston groove to prevent engine damage during engine operation.

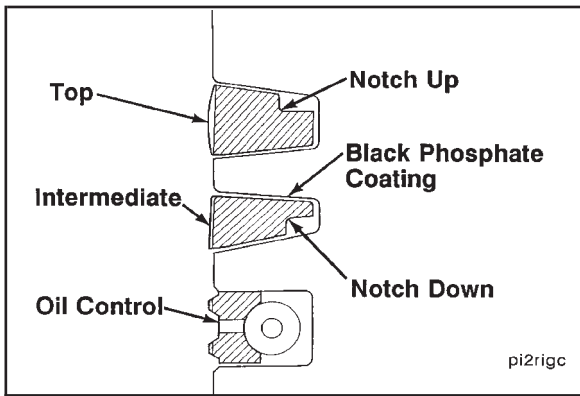
Install a new snap ring in the piston pin bore.



A cross sectional 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.

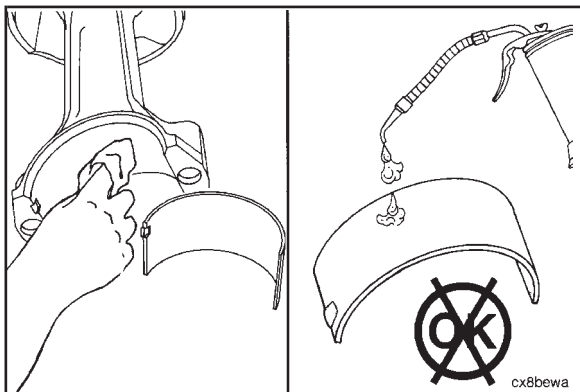




Use piston ring expander, Part No. ST-821, to install the rings on the piston.

The top piston ring is a positive twist design that has a cutback notch on the top side of the ring.

The intermediate ring is a negative twist design with a cutback notch on the bottom side and a two degree taper face. It also has a black phosphate coating which helps to readily distinguish it from the top ring.

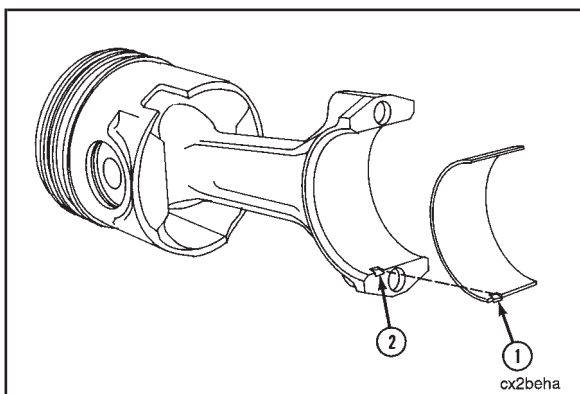


Piston and Connecting Rod - Installation



Use a clean "lint free" cloth to clean the connecting rods and bearing shells.

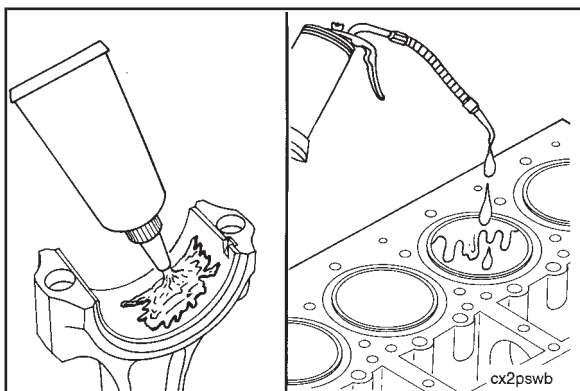
Do not lubricate the back of the bearing shells. The operating clearance of the bearing will be reduced and the bearing can be damaged during engine operation.



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.



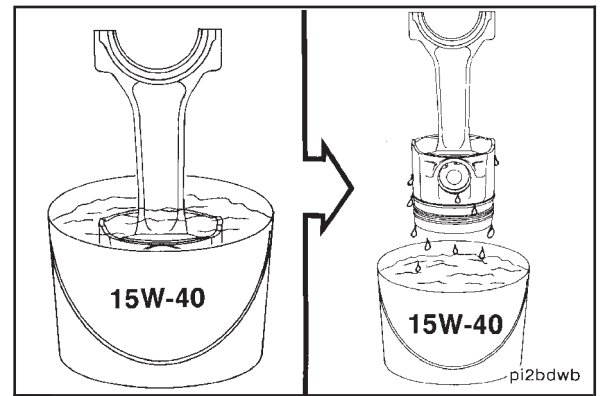
Use Lubriplate® 105, or equivalent, to coat the bearing shell.

Apply a heavy film of 15W-40 oil to the cylinder liner bore.

Install the piston and ring assembly into a container of clean 15W-40 oil.

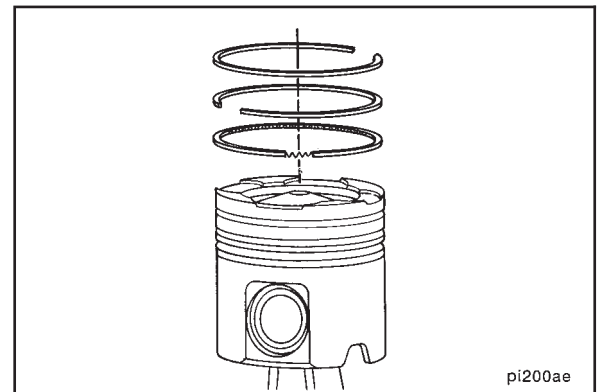


Remove the piston and ring assembly from the container and let the excess oil drain from the piston.



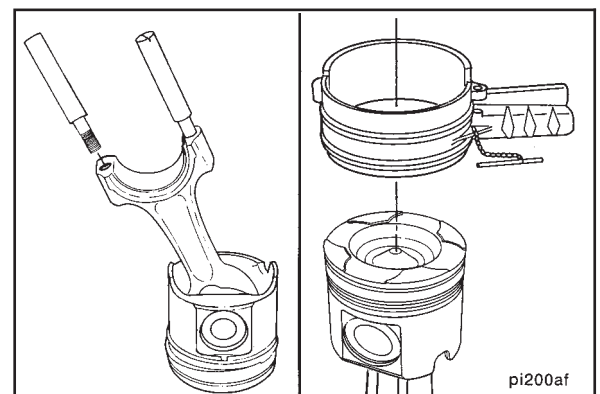
Rotate the rings to position the ring gaps as shown.

NOTE: The ring gap of each ring **must not** be aligned with the piston pin or with any other ring gap. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.



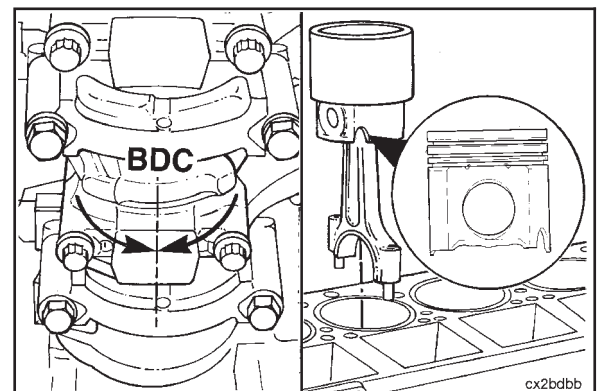
Install the connecting rod guide pins, Part No. 3376038, into the connecting rod.

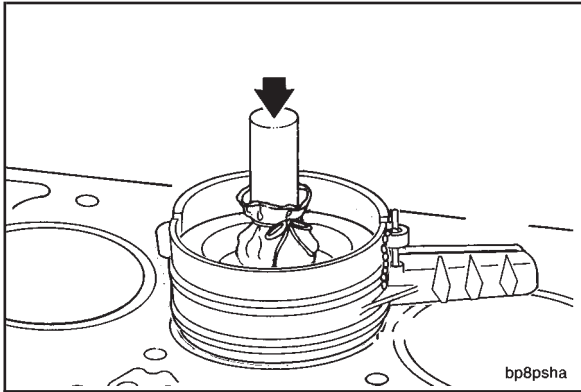
Use piston ring compressor, Part No. 3823309, to compress the rings.



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 until the ring compressor contacts the top of the liner.



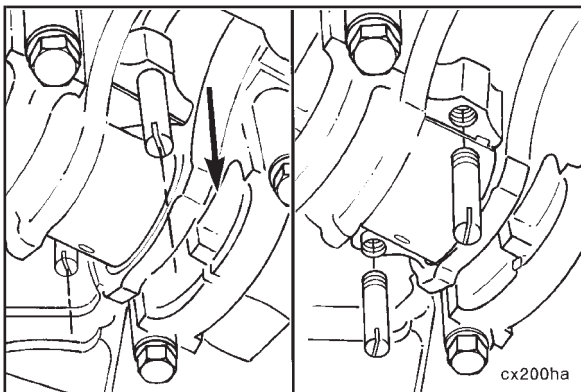


Caution: Do not use a metal object to push the piston into the liner. The piston, rings or cylinder liner can be damaged.



Hold the ring compressor against the cylinder block. Push the piston through the ring compressor and into the cylinder liner. Push the piston until the top ring is completely inside the cylinder liner.

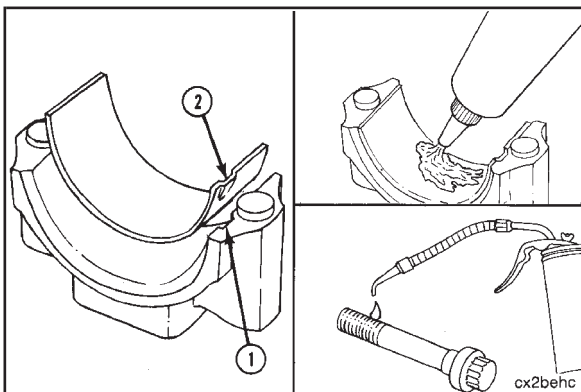
NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



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.



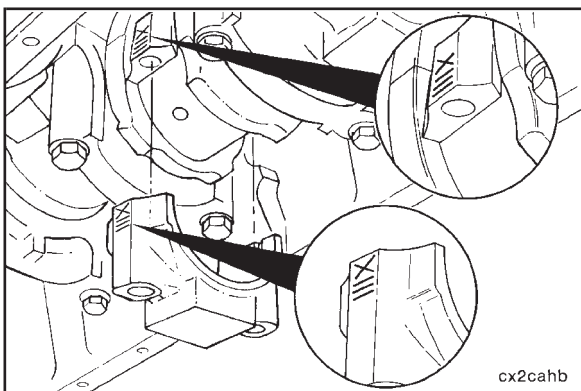
Install the bearing in the connecting rod cap.

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 coat the connecting rod capscrews.

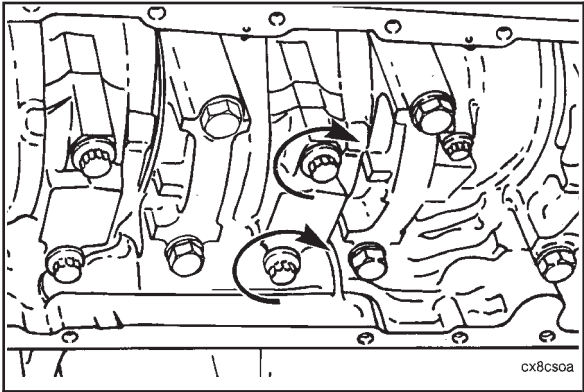


The connecting rod and cap **must** have the same number, and **must** be installed in the proper cylinder. The connecting rod cap and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.

Install the connecting rod caps and capscrews.

Complete the following steps to tighten the 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

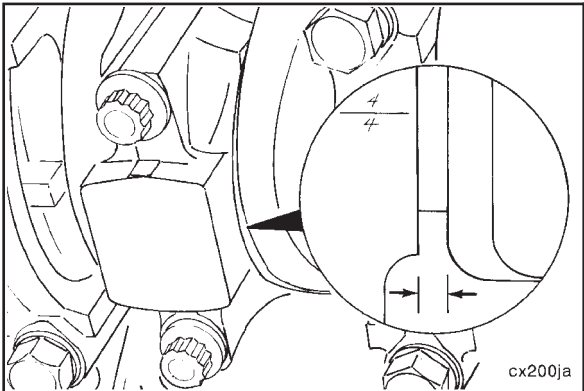


Connecting Rod Side Clearance Measurement

Use a feeler gauge to measure the connecting rod side clearance.

Connecting Rod Side Clearance		
mm		in.
0.10	MIN	0.004
0.30	MAX	0.012

The rod **must** move freely from side-to-side.



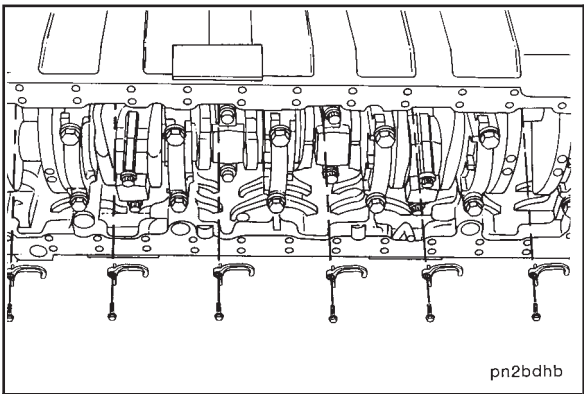
Piston Cooling Nozzle - Installation

The piston and connecting rod assemblies **must** be installed before the piston cooling nozzles are installed.

Rotate the crankshaft to position the connecting rod journal toward the exhaust side of the engine.

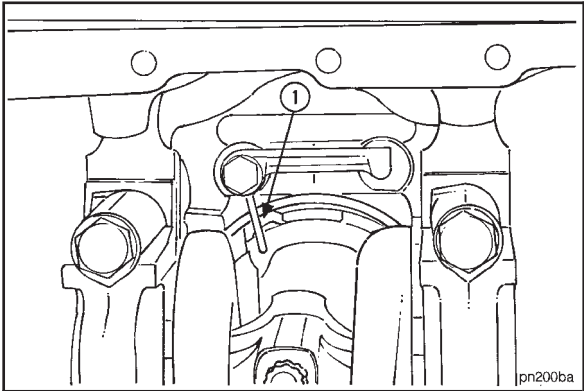
Install the nozzles and the special capscrews.

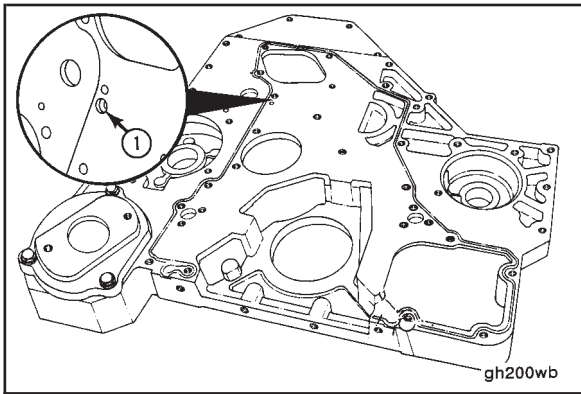
Torque Value: 24 N•m [18 ft-lb]



The nozzle **must** be in alignment with the center of the notch in the piston skirt (1).

NOTE: Rotate the crankshaft to be sure the pistons do **not** hit the nozzles. If the pistons hit the nozzles, the nozzles and engine will be damaged during engine operation.





Gear Housing - Installation



Caution: Avoid the use of excessive amounts of sealant which could result in blocked oil passages in the engine.



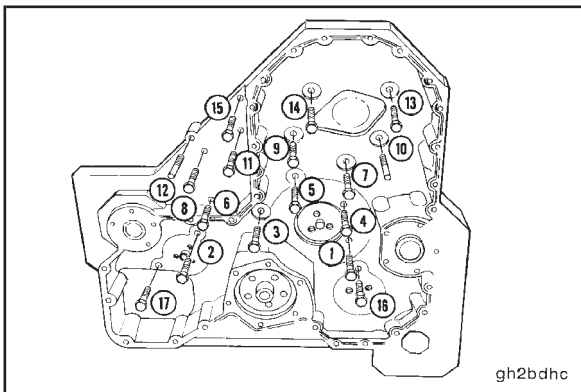
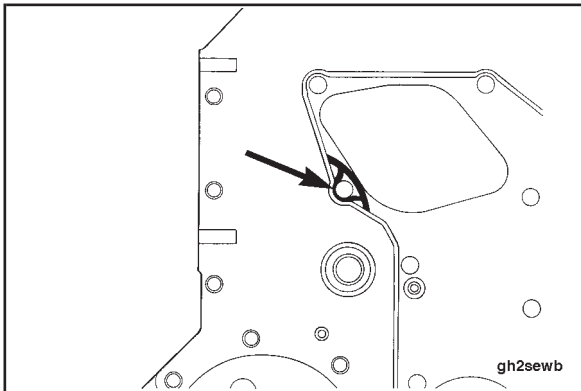
Install a new o-ring, Part No. 3883150, into the rear of the gear housing at the oil jumper gallery (1) for the accessory drive support. Be sure to keep sealant from the hole.

NOTE: Sealant requires assembly in ten minutes or less. It is best to apply the sealant and then immediately assemble the parts.

Apply a bead of silicone 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.

NOTE: Sealant requires assembly in ten minutes or less. It is best to apply the sealant and then immediately assemble the parts.

Apply additional sealant in the area shown in the graphic.



Install two guide pins, Part No. 3376488, in the cylinder block.

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.

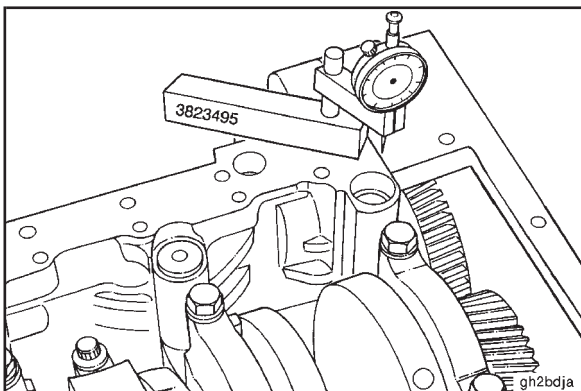


Remove the two guide pins and install the two remaining capscrews (M10-1.50 x 25).



Tighten the capscrews in the sequence shown.

Torque Value: Step 1 - 20 N•m [15 ft-lb]
2 - 68 N•m [50 ft-lb]



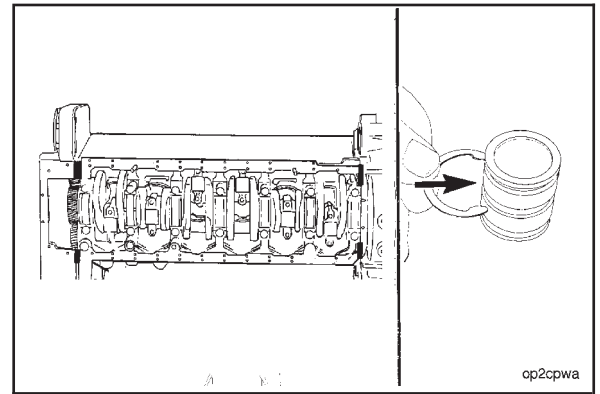
Measure the gear housing protrusion below the oil pan rail. The maximum allowable protrusion is 0.15 mm [0.006 in].

If the protrusion is beyond the allowable limit, remove the housing and check the idler gear dowel pin O.D.

Lubricating Oil Pan - Installation

Rotate the engine on the rebuild stand.

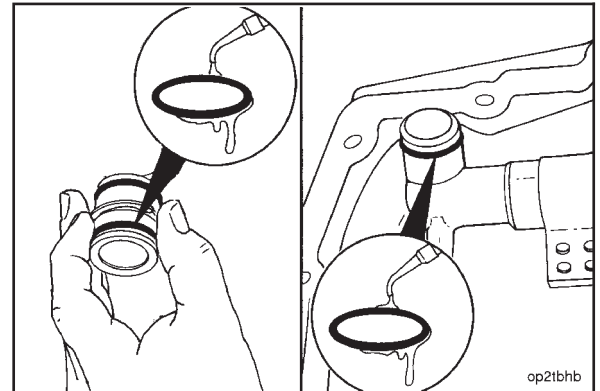
If a front sump aluminum oil pan is used, install the spring clip on the oil transfer tube.



Install a new o-ring(s) on the oil transfer tube.

Use clean 15W-40 oil to lubricate the o-rings.

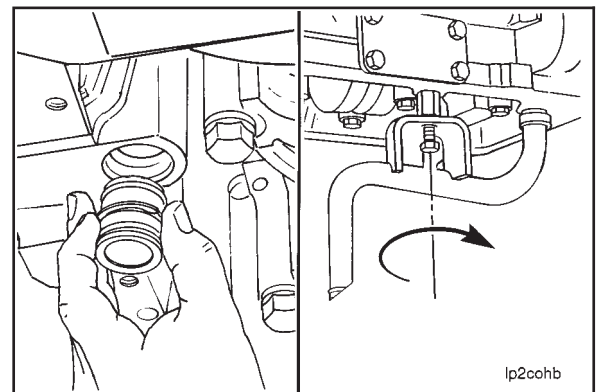
Install the oil transfer tube into the oil pan on rear sump oil pans.



On front sump aluminum oil pans, install the straight transfer tube into the cylinder block.

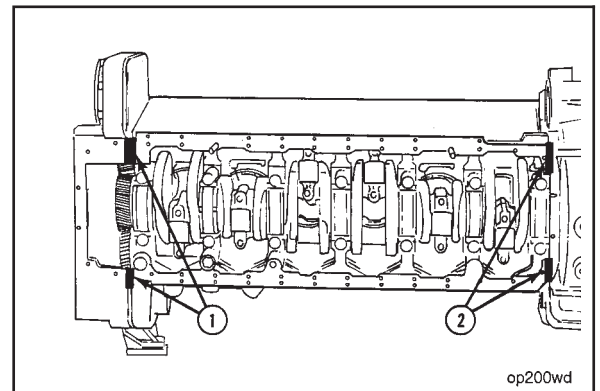
On front sump oil pans with block mounted suction tube, install the suction into the cylinder block by hand. Install the retaining capscrew.

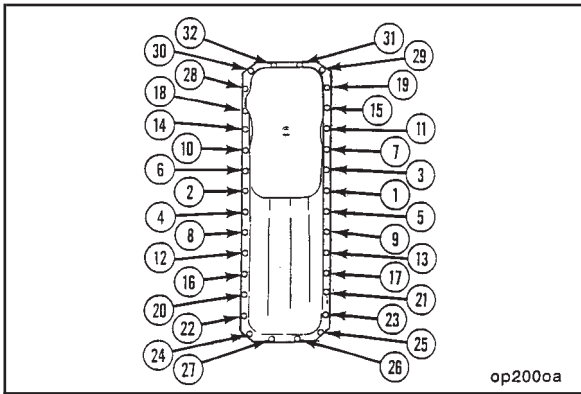
Torque Value: 61 N•m [45 ft-lb]



Apply a bead of silicone sealant, Part No. 3823494, to the oil pan mounting surfaces of the cylinder block to gear housing joint (1) and flywheel housing to cylinder block joint (2).

Install two guide pins, Part No. 3376488, into the cylinder block.

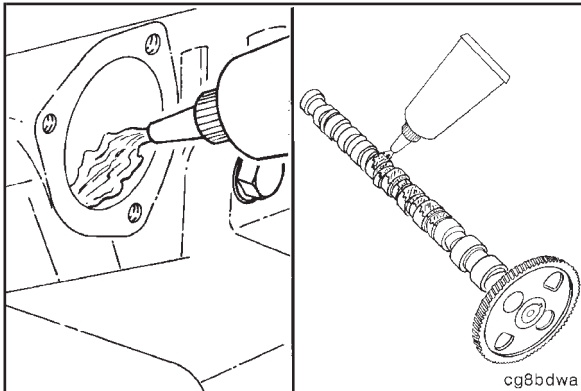




NOTE: Make sure the transfer tube is aligned with the cylinder block suction tube hole when installing the oil pan.

Install and tighten the 32 capscrews (M10-1.50 x 25) in the sequence shown.

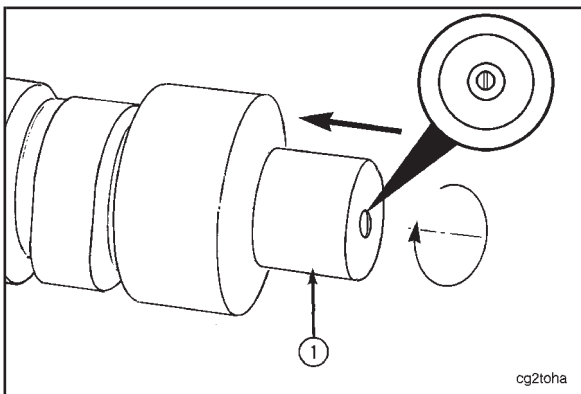
Torque Value: 47 N•m [35 ft-lb]



Camshaft and Gear Assembly - Installation

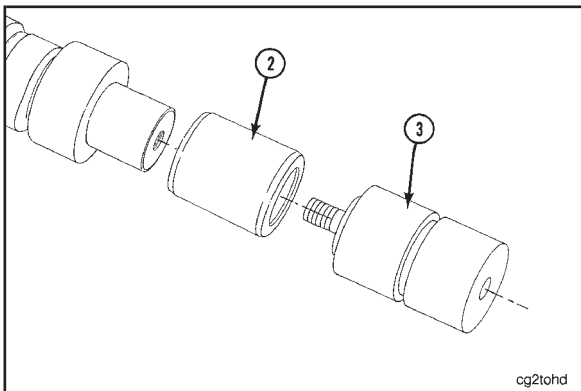


Use Lubriplate® 105, or equivalent, to coat the camshaft bushings and camshaft.



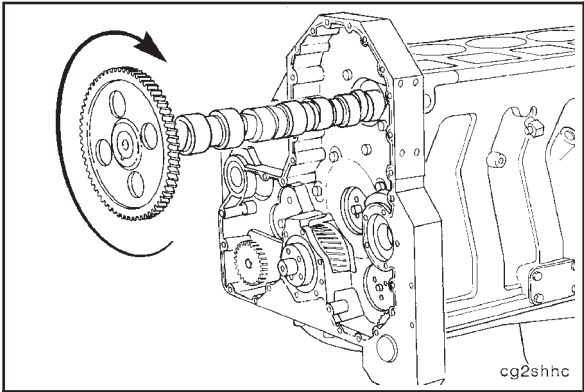
Install the camshaft installation pilot, Part No. 3376388.

- Install the expander, Part No. 3376923, (1).
- 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 into the cylinder block.



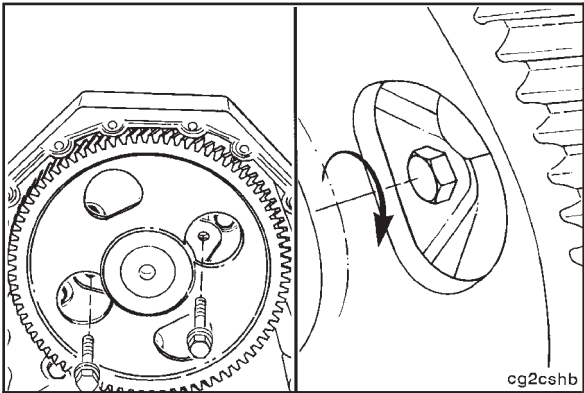
Rotate the camshaft to align the holes in the camshaft gear with the thrust plate capscrew holes in the cylinder block.



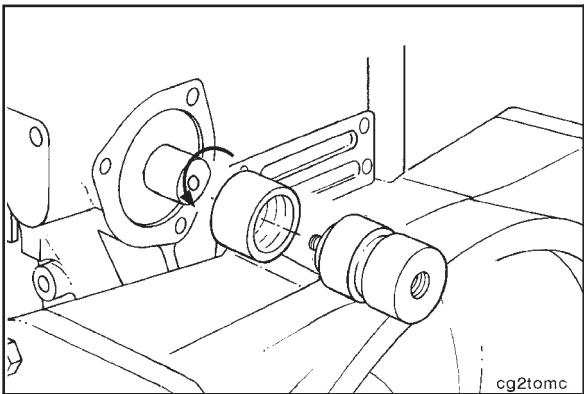
Align the capscrew holes in the thrust plate with the cylinder block capscrew holes.

Install the two capscrews (M10-1.50 x 25) with a nylon locking patch on the threads, or apply retaining compound, Part No. 3823682, to the threads.

Torque Value: 47 N•m [35 ft-lb]



Remove the camshaft pilot.

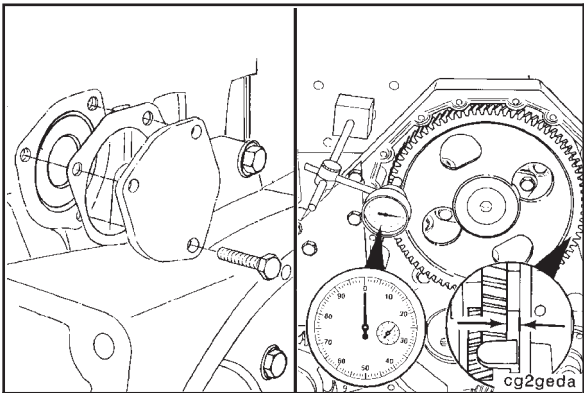


Use a new gasket and install the camshaft rear cover plate. Tighten the three capscrews (M10-1.50 x 22).

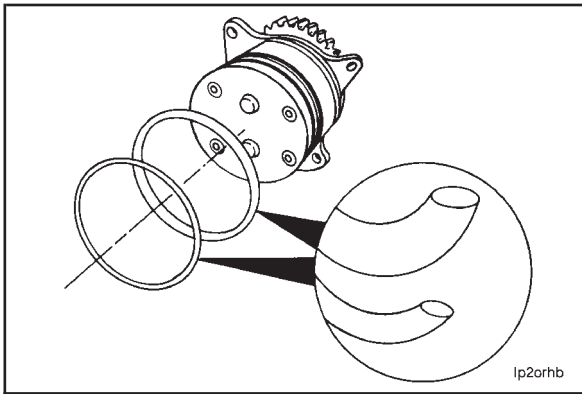
Torque Value: 47 N•m [35 ft-lb]

Use a dial indicator gauge and a magnetic base to measure the camshaft end clearance.

Place the contact tip of the gauge against the face of the gear.



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



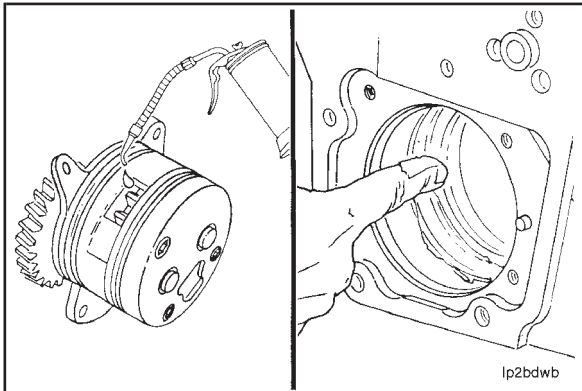
Lubricating Oil Pump - Installation

NOTE: Do **not** lubricate the two oil pump body o-rings. The o-rings will swell and the pump **cannot** be installed.



Install two new o-rings on the oil pump body.

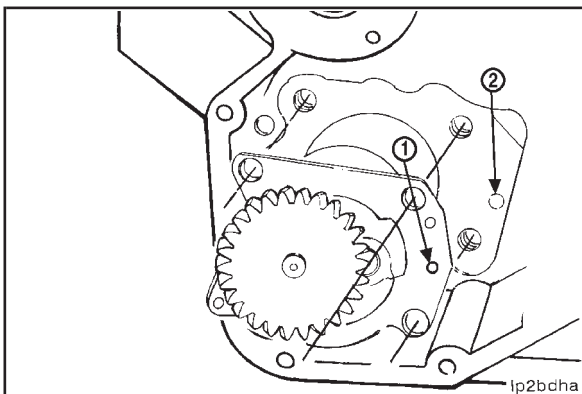
Install the thickest o-ring into the groove nearest to the oil pump drive gear.



Use clean 15W-40 oil to lubricate the oil pump gears.

Apply a film of Lubriplate® 105 to the oil pump bore in the cylinder block.

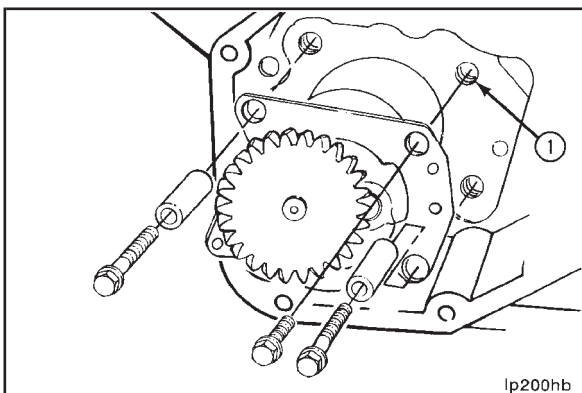
NOTE: Be sure the threaded oil pump mounting holes in the cylinder block are clean and free of oil or dirt. If they are **not**, use solvent to clean them before installing the oil pump.



Caution: The dowel pin bore in the oil pump flange (1) must be aligned with the dowel pin (2) in the cylinder block 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.



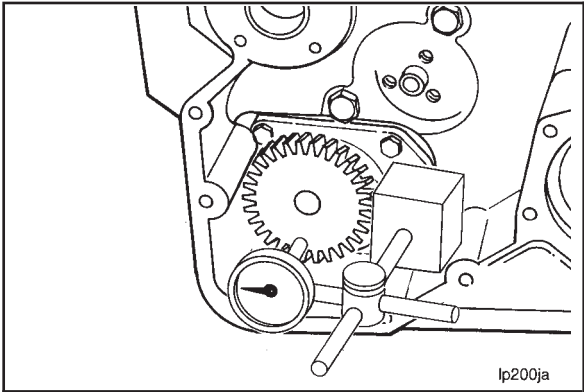
Install the three capscrews and spacers. Use the short flange head capscrew in the upper right hand mounting hole (1). Use the longer flange head capscrews and spacers in the other two holes.

Torque Value: 41 N•m [30 ft-lb]

Use a dial indicator gauge assembly, Part No. 3376050, with extension, Part No. ST-537-4 and a magnetic base, Part No. 3377399, to measure the oil pump gear end clearance.

Place the contact tip of the gauge against the face of the oil pump drive gear.

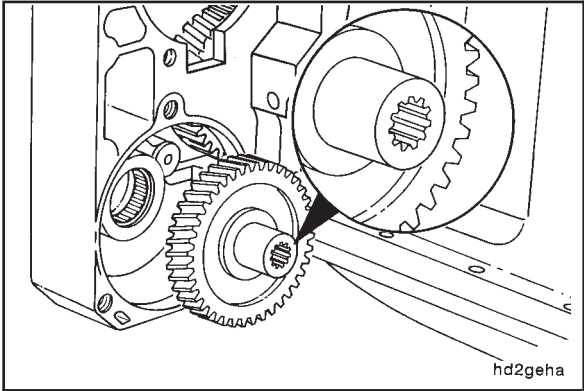
Lubricating Oil Pump Gear End Clearance		
mm		in
0.064	MIN	0.0025
0.270	MAX	0.0106



Hydraulic Pump Drive - Installation

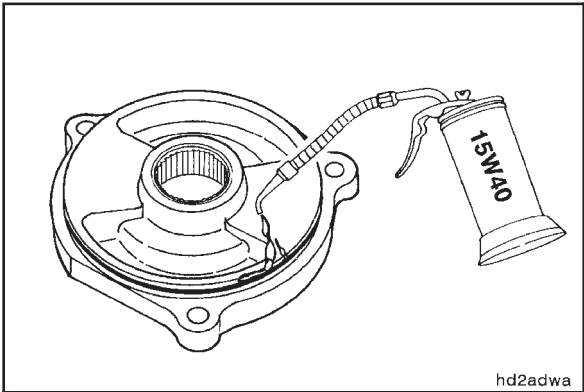
Use Lubriplate® 105, or equivalent, to lubricate the front and rear needle bearings.

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 bore with clean 15W-40 oil.



Align the hydraulic drive adapter over the shaft and gear assembly.

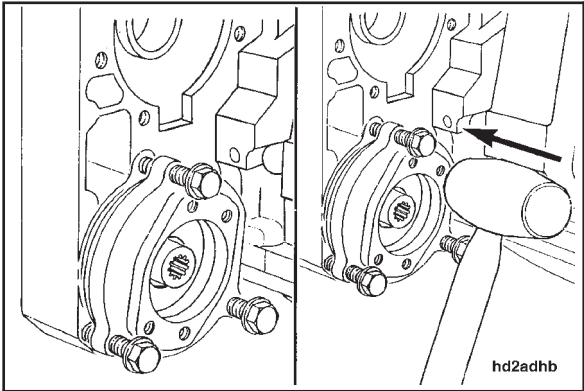
Start the three mounting capscrews (M10-1.50 x 35) by hand to align the hydraulic drive adapter with the gear housing.

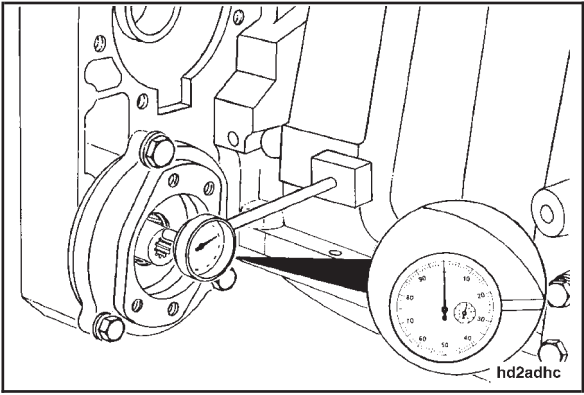
Use a rubber mallet to install the adapter.

NOTE: Use care **not** to damage the o-ring during installation.

Tighten the mounting capscrews.

Torque Value: 47 N•m [35 ft-lb]

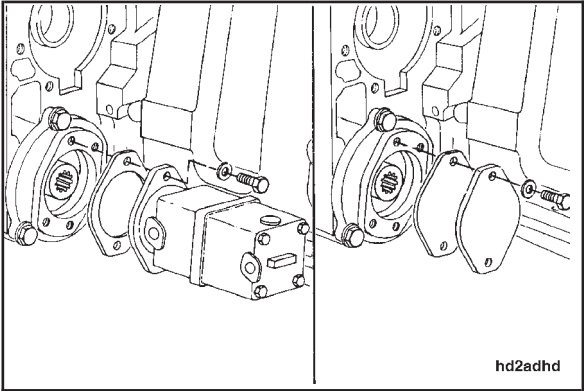




Measure the drive shaft end clearance.

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	0.0030
0.635	MAX	0.0250

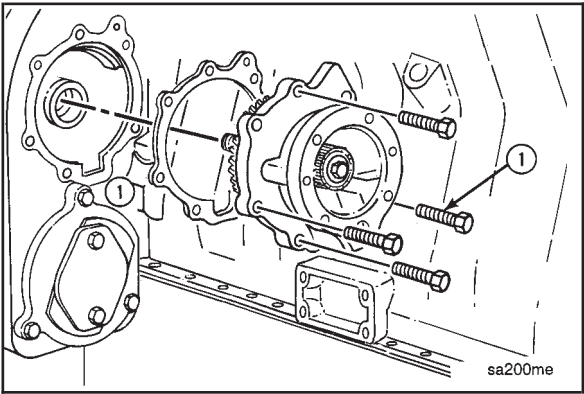


Use a new gasket and install the hydraulic pump, if equipped, or the cover plate.

Install the two mounting capscrews (M10-1.50 x 20) and tighten.



Torque Value: 27 N•m [20 ft-lb]



Accessory Drive Assembly - Installation

Install two guide pins, Part No. 3376488, in the accessory drive mounting capscrew holes of the gear housing.

Use a new gasket and install the accessory drive assembly.

NOTE: Make sure the "V" stamped on the accessory drive gear is in the 9 o'clock position, so it will easily align with the camshaft idler gear when it is installed. The capscrew located in the lower corner nearest the cylinder block (1) **must** be installed with a new copper sealing washer and sealant, Part No. 3375068 or equivalent, applied to the threads.



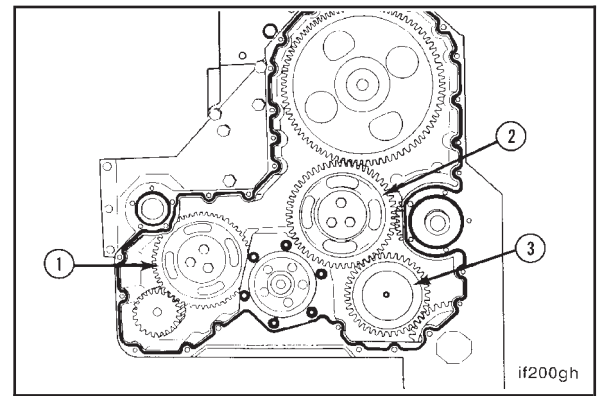
Install the five capscrews (M10-1.50 x 40) and plain washers, and one capscrew (M10-1.50 x 35) with copper washer and tighten.

Torque Value: 47 N•m [35 ft-lb]

Idler Gear Assemblies - Installation

Three idler gear assemblies are used:

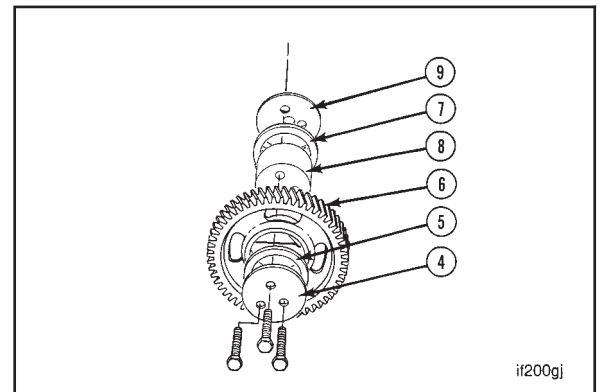
- water pump/lube pump idler gear (1),
- camshaft idler gear (2),
- hydraulic pump idler gear (3).



Each idler gear assembly consist of:

- three retaining capscrews,
- gear retainer (4),
- front thrust bearing (5),
- idler gear (6),
- rear thrust bearing (7),
- idler gear shaft (8).

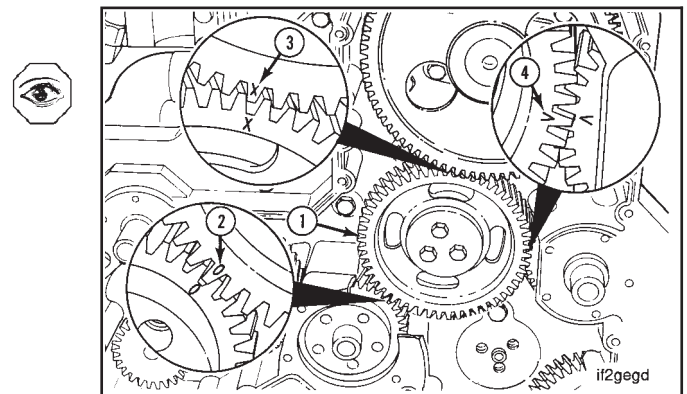
The camshaft idler gear assembly includes a wear plate (9).



Camshaft Idler - Installation

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.

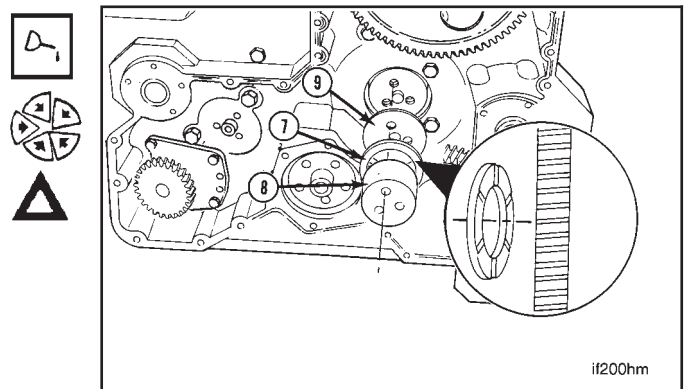


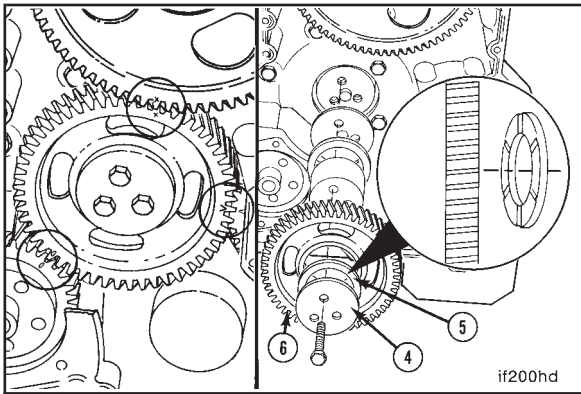
Use Lubriplate® 105, or equivalent, to lubricate the wear plate, thrust bearing and idler gear.

Install the camshaft idler gear wear plate (9).

Caution: The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

Install the idler gear shaft (8) and rear thrust bearing (7).





Caution: The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

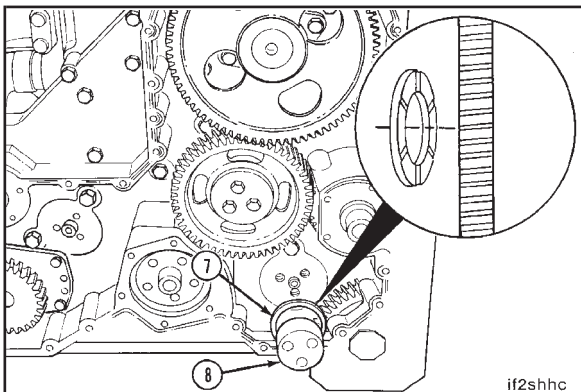


Align the timing marks and install the idler gear (6), front thrust bearing (5) and gear retainer (4).



Install the three retaining capscrews (M10-1.50 x 60) and tighten.

Torque Value: 61 N•m [45 ft-lb] plus 60 degrees



Hydraulic Drive Idler - Installation



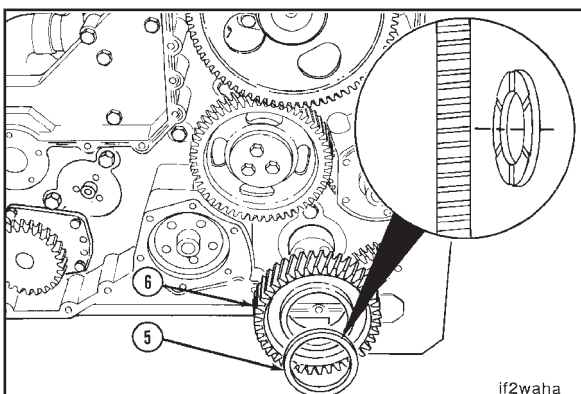
Use Lubriplate® 105, or equivalent, to lubricate the thrust bearing and idler gear.



Caution: The grooved side of the rear thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.



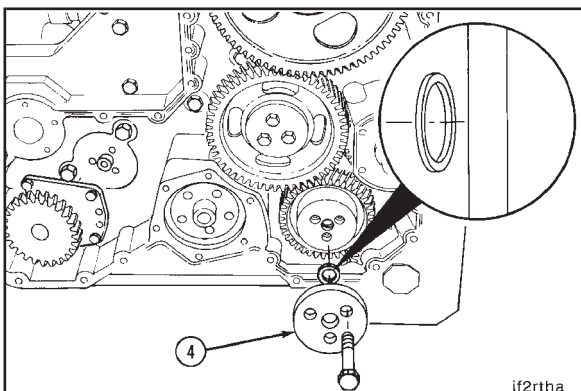
Install the idler gear shaft (8) and rear thrust bearing (7).



Caution: The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.



Install the idler gear (6) and front thrust bearing (5).



NOTE: On SAE "B" drives, install a new rectangular seal on the rear surface of the gear retainer (4) before installation.



Install the gear retainer (4).



Install the three retaining capscrews (M10-1.50 x 60) and tighten.

Torque Value: 61 N•m [45 ft-lb] plus 60 degrees

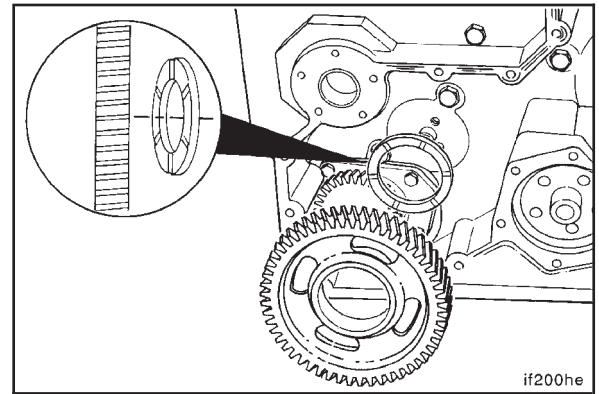
Water Pump/Lube Pump Idler - Installation

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.

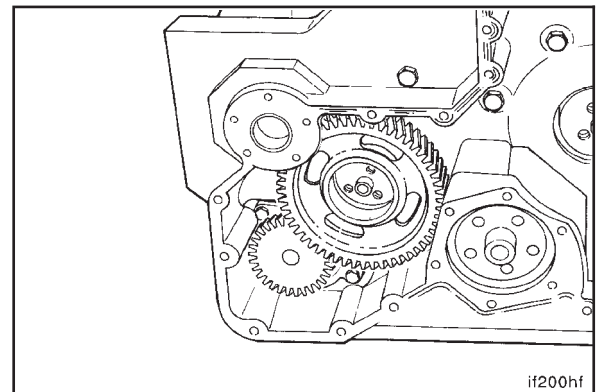
Use Lubriplate® 105, or equivalent, to lubricate the thrust bearings and idler gear shaft.

Install the rear thrust bearing.

Install the idler gear without the shaft.

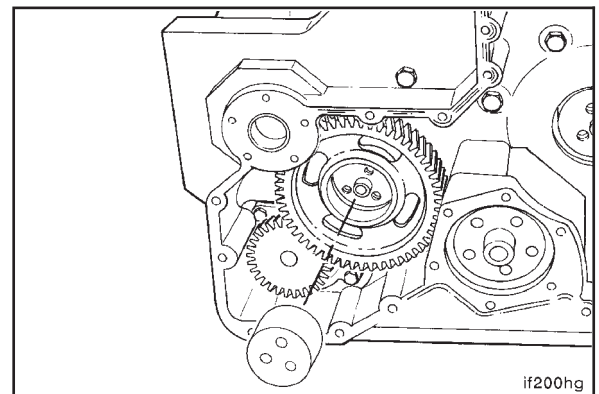


Align the inside diameter of the rear thrust bearing with the inside diameter of the idler gear.



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 that the shaft is **not** properly piloted into the rear thrust bearing.

Install the shaft into the gear bore.



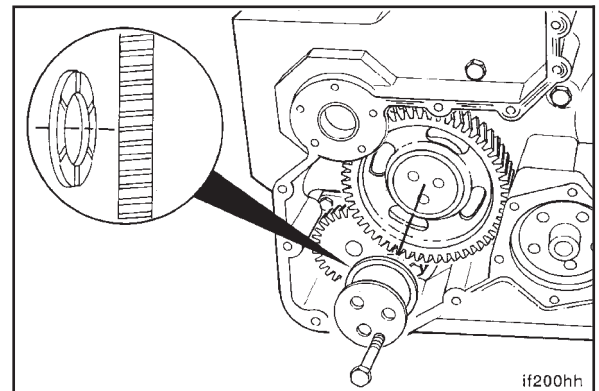
Caution: The grooved side of the front thrust bearing must be facing toward the gear to prevent damage to the gear and engine during engine operation.

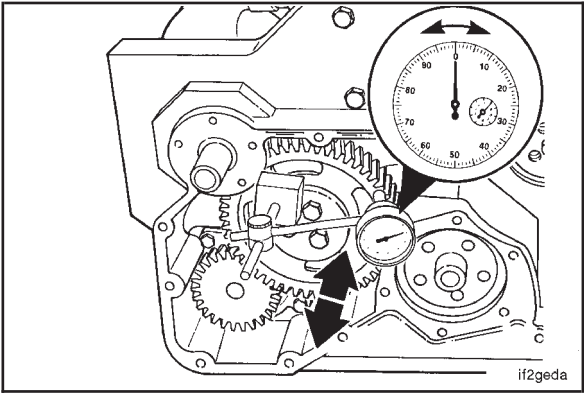
Install the front thrust bearing.

Install the gear retainer.

Install the three retaining capscrews (M10-1.50 x 60) and tighten.

Torque Value: 61 N•m [45 ft-lb] plus 60 degrees





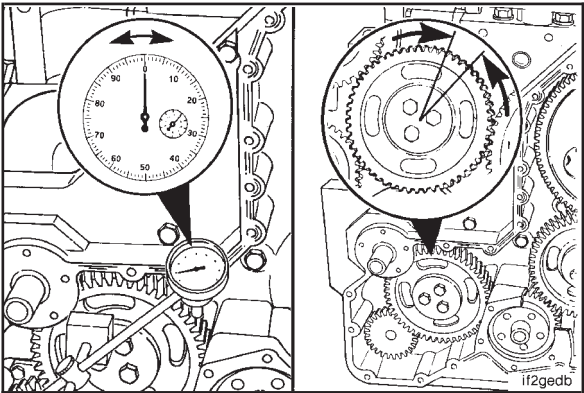
NOTE: The following idler gear end clearance and backlash checks applies to all three idler gears.



Use a dial indicator gauge assembly, Part No. 3376050, with extension, Part No. ST-537-4, and a magnetic base, Part No. 3377399, 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

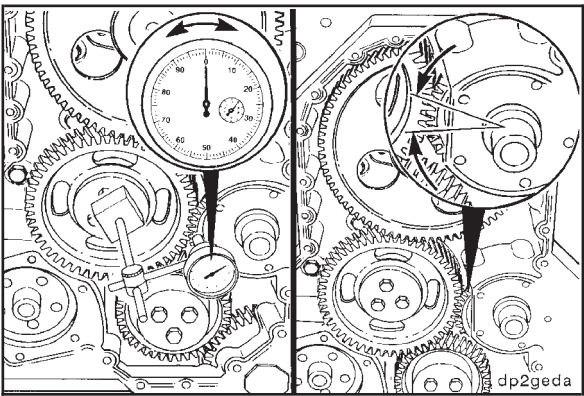


Use the dial indicator gauge with the magnetic base to measure the idler gear backlash.

Place the contact tip of the gauge against a tooth on the idler gear.

Do **not** allow the mating gears to move while measuring the backlash.

Idler Gear Backlash		
mm		in
0.08	MIN	0.003
0.41	MAX	0.016

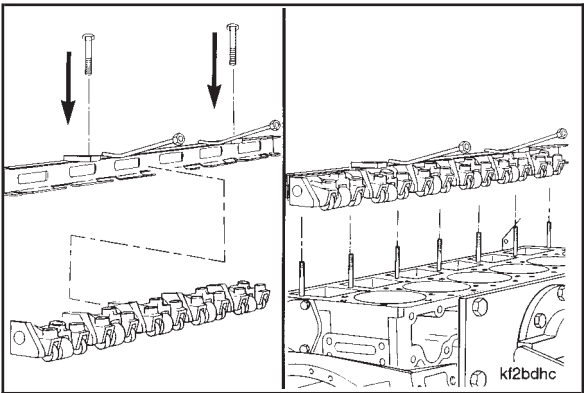


Use the dial indicator gauge to measure the accessory drive gear backlash.

Place the contact tip of the gauge against a tooth of the accessory drive gear.

Do **not** allow the mating gear to rotate while measuring the backlash.

Accessory Drive Gear Backlash		
mm		in
0.08	MIN	0.003
0.41	MAX	0.016



Cam Follower Assemblies - Installation

NOTE: Before installing the cam follower assemblies, the cylinder head deck **must** be clean.

Install the cam follower assembly while in the cam follower installation and removal tool, Part No. 3824519.

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.

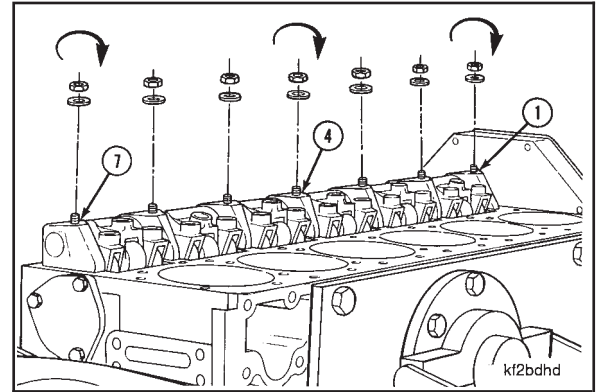
Loosen the two installation tool cam follower retaining screws and remove the service tool.

Install the washers and nuts on each stud.

Tighten nuts on supports (1), (4) and (7) only.

Torque Value: 47 N•m [35 ft-lb]

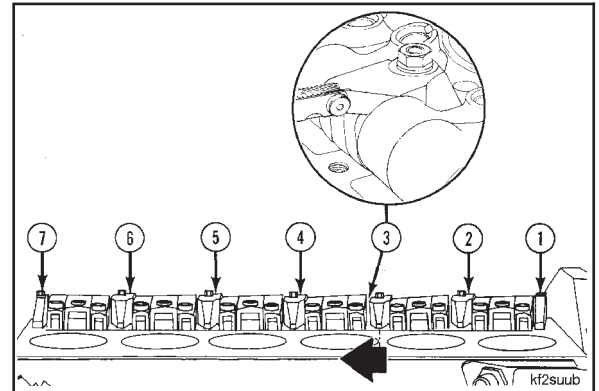
NOTE: The side clearance **must** be adjusted before the remaining nuts are tightened.



Install a 0.76 mm [0.030 inch] feeler gauge between the number seven lever and the number three support. Push the number three support toward the number four support.

Tighten the number **three** support nut.

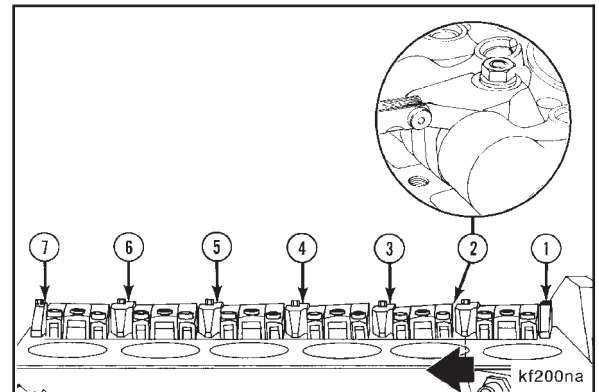
Torque Value: 47 N•m [35 ft-lb]



Install a 0.76 mm [0.030 inch] feeler gauge between the number four lever and the number two support. Push the number two support toward the number three support.

Tighten the number **two** support nut.

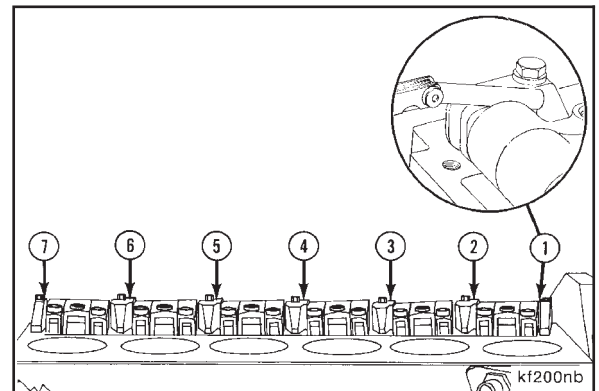
Torque Value: 47 N•m [35 ft-lb]

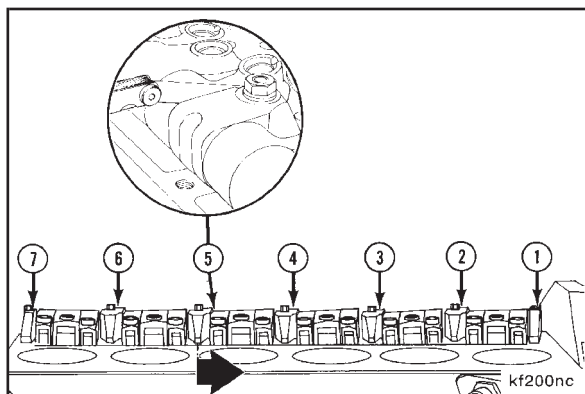


Measure the side clearance between the number one support and the number one lever.



Cam Follower Side Clearance Between Supports		
mm		in
0.76	MIN	0.030



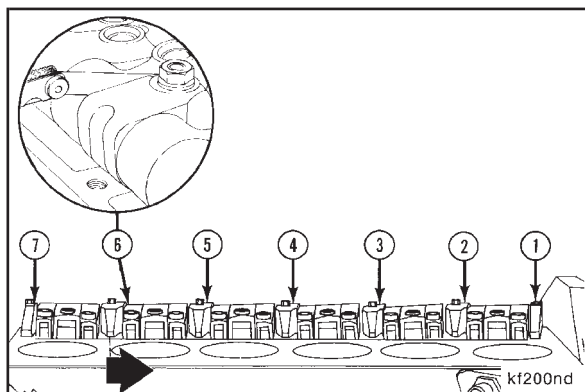


Install the 0.76 mm [0.030 inch] feeler gauge between the number 12 lever and the number five support. Push the number five support toward the number four support.



Tighten the number **five** support nut.

Torque Value: 47 N•m [35 ft-lb]

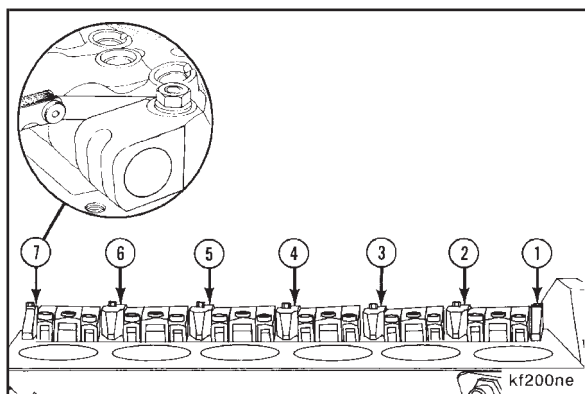


Install the 0.76 mm [0.030 inch] feeler gauge between the number 15 lever and the number six support. Push the number six support toward the number five support.



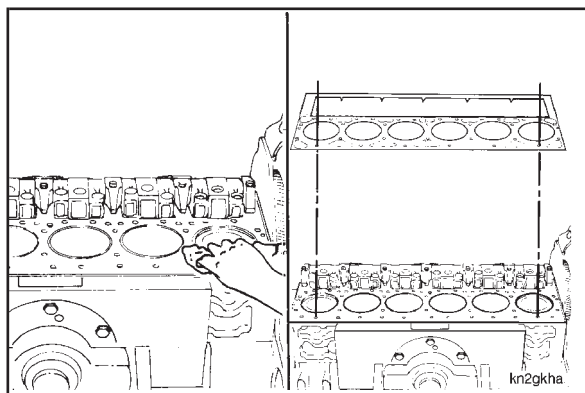
Tighten the number **six** support nut.

Torque Value: 47 N•m [35 ft-lb]



Measure the side clearance between the number 18 lever and seven support.

Cam Follower Side Clearance Between Supports		
mm		in
0.76	MIN	0.030



Cylinder Head - Installation

Use a “lint-free” cloth to clean and dry the cylinder head surfaces. Make sure all cylinder head capscrew holes are cleaned out.

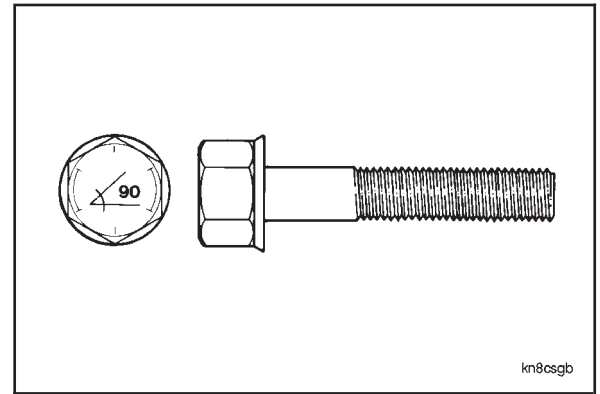


Install a new cylinder head gasket on the cylinder block.

NOTE: The gasket can be installed with either side up.

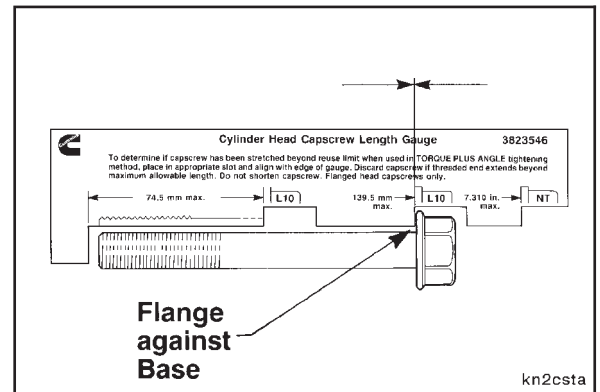
Reuse Guidelines - Flange Head Capscrews

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.

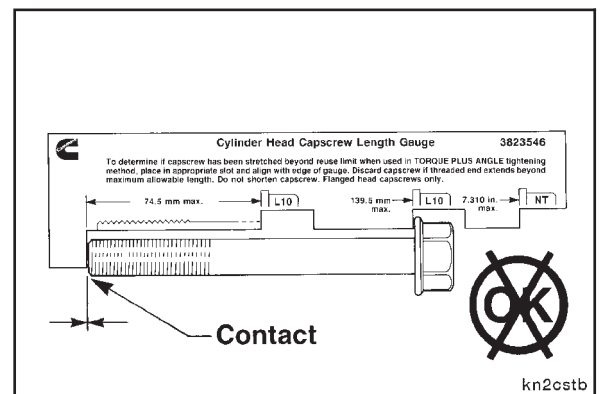


Cylinder head capscrew length gauge, Part No. 3823546, has been developed to check capscrew free length.

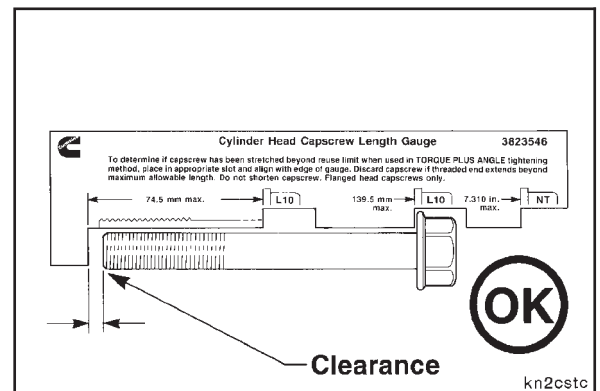
To check the capscrew free length, place the head of the capscrew in the appropriate slot, long or short, with the flange against the base of the slot.

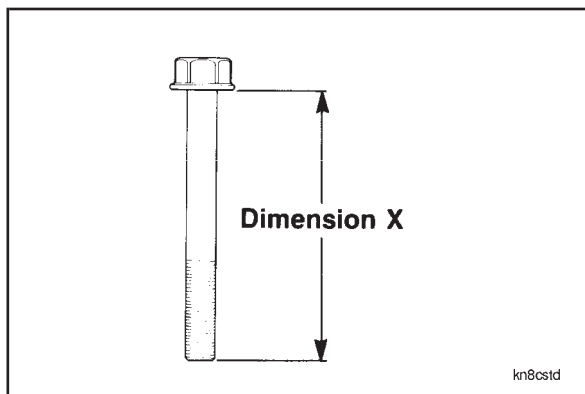


If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.



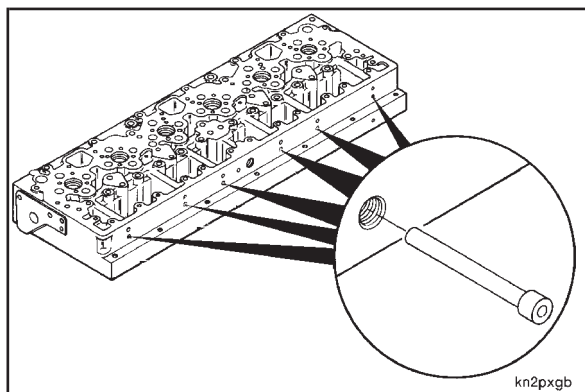
If there is clearance between the end of the capscrew and the bottom base of the tool, the capscrew is OK for reuse.





The capscrew can also be checked using a set of calipers. The maximum allowable free length is measured from the bottom of the flange to the end of the capscrew (Dimension X).

Part No.	Maximum Free Length
3045849	74.5 mm [2.933 in]
3045850	139.5 mm [5.492 in]

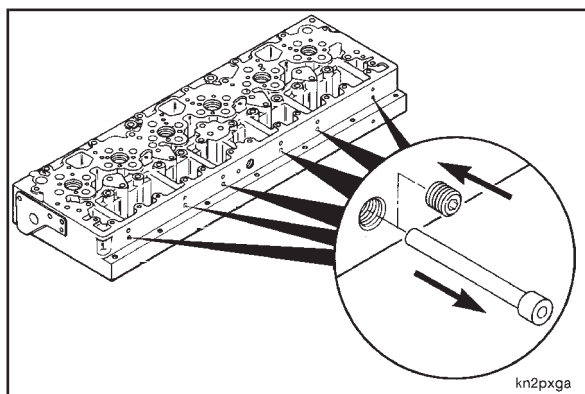


Installation



A plastic insert is installed in all fuel inlet passages on new and ReCon® cylinder heads.

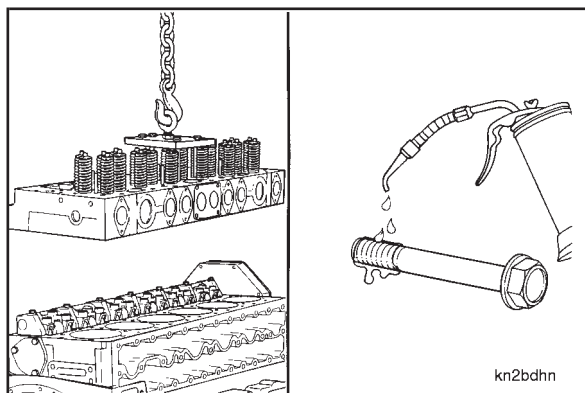
NOTE: The fuel inlet passages are the lower row of drillings.



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.

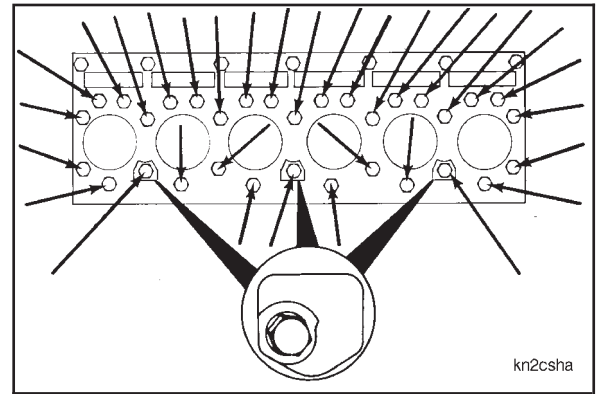


Use clean 15W-40 oil to lightly coat the cylinder head capscrew threads and bottom of the flange.

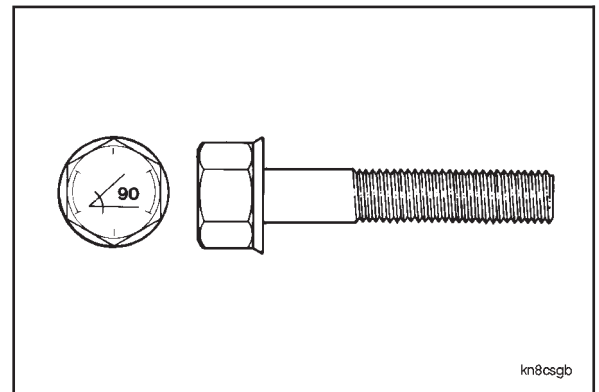
Allow the excess oil to drain from the capscrew threads.

Install the three capscrews (M14-1.50 x 75) in the cylinder head intake ports.

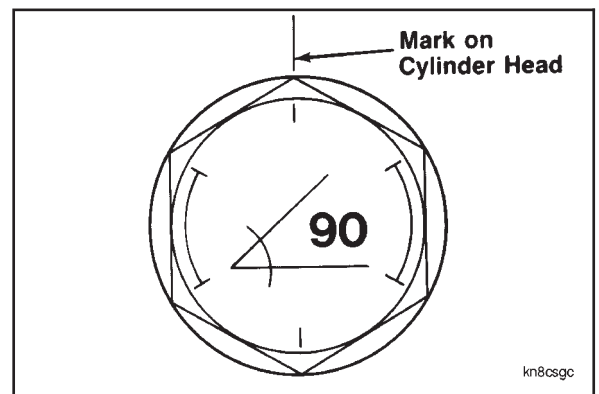
Install the remaining 29 capscrews (M14-1.50 x 140).



The markings on the head of the flange head capscrews serve as an aid during installation.

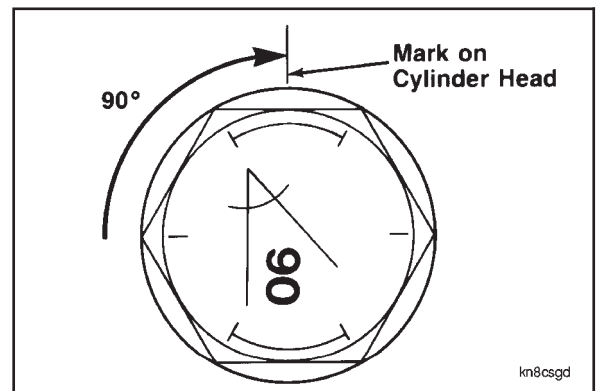


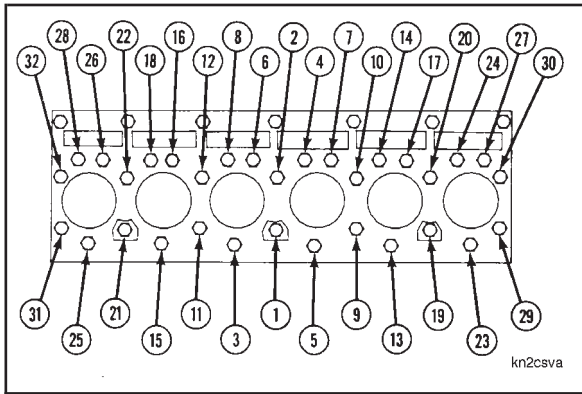
After torquing to Step 2, mark the cylinder head adjacent to one of the two single marks on the cap screw head.



After all 32 capscrews have been torqued to Step 2, they **must** be rotated 90 degrees. Rotate the cap screw 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 cap screw is unintentionally rotated beyond two flats, do **not** loosen the cap screw. The clamp load is still acceptable; however, rotating the cap screw beyond two flats reduces the number of reuses.

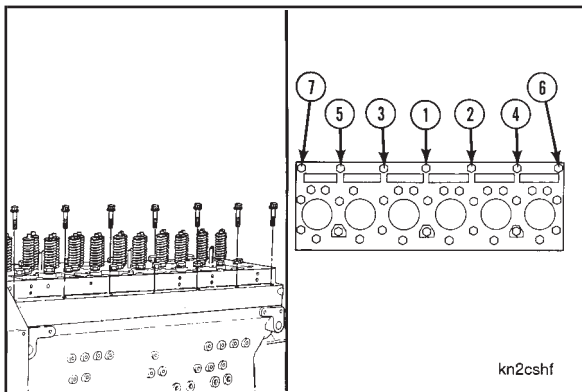




Tighten the capscrews in the sequence shown to the specified values:

Torque Value: Step 1 - 136 N•m [100 ft-lb]
2 - 217 N•m [160 ft-lb]
3 - Rotate 90 Degrees

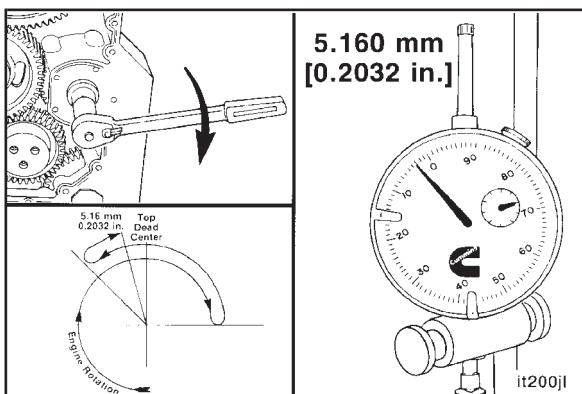
NOTE: Rotate at least one flat, but **not** more than two.



Use new copper sealing washers and install the seven capscrews (M10-1.50 x 75) on the fuel pump side of the cylinder head.

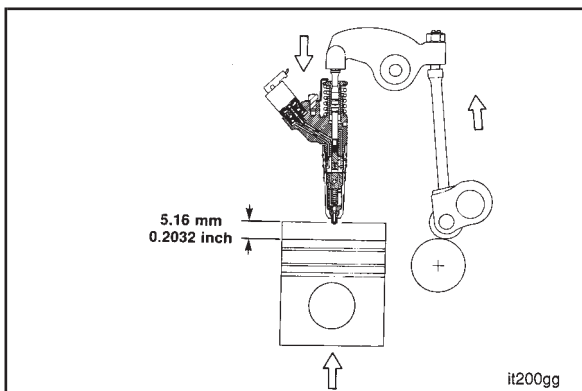
Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



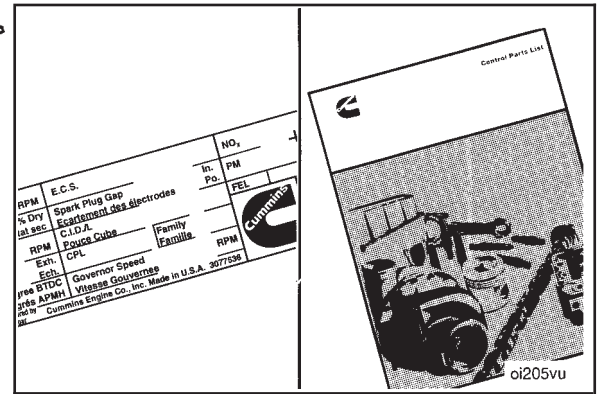
Static Injection Timing - General Information

The static injection timing **must** be correct to achieve the best performance, fuel economy and lowest emissions. The static injection timing **must** be checked when the engine is rebuilt and when a component of the gear train is replaced or removed and installed again.



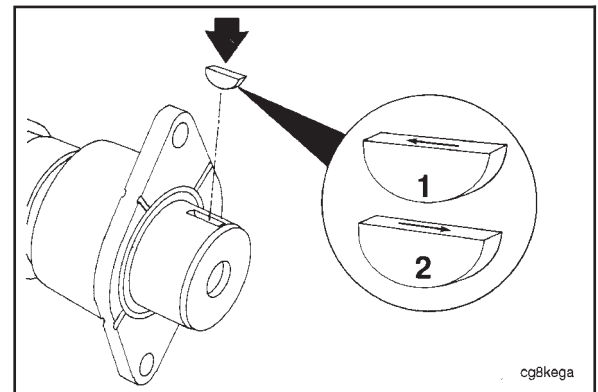
Static injection timing refers to injecting fuel in the combustion chamber at the correct time during the compression stroke. The static timing **must** be checked when the piston is on the compression stroke at 5.16 mm [0.2032 inch] before top dead center (BTDC). When the piston is at this position, measure the amount of travel left in the injector push rod with injector timing tool, Part No. 3823451.

To verify the correct static injection timing for a particular engine, check the control parts list (CPL) number on the engine dataplate, then refer to the CPL Bulletin No. 3379133. Timing codes are listed as two letter alpha characters, for example, an "HZ" code indicates a nominal setting of 5.97 mm [0.235 in]. Refer to the accompanying chart.



M11 static injection timing can be adjusted by removing the camshaft gear and changing the camshaft key. The camshaft key controls the position of the camshaft lobes during the operating cycles of the engine.

If an offset camshaft key is installed with the arrow marked on the top of the key pointing toward the engine (1), the timing will be **retarded**. If the offset key is installed with the arrow pointing away from the engine (2), the timing will be **advanced**.



Retarded timing (1) begins the fuel injection process **later** and advanced timing (2) begins the fuel injection process **earlier** relative to the "TDC" position of the piston.

Refer to the accompanying chart for a list of offset keys by part number and degree of offset.

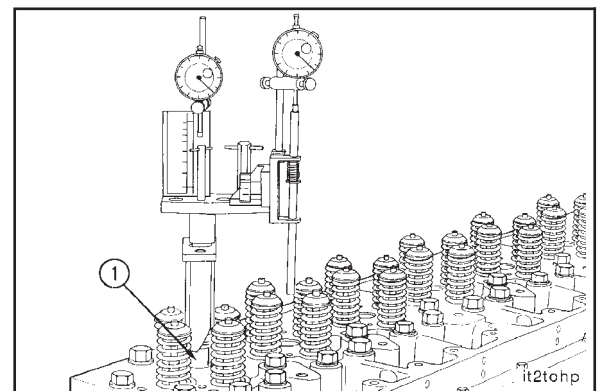


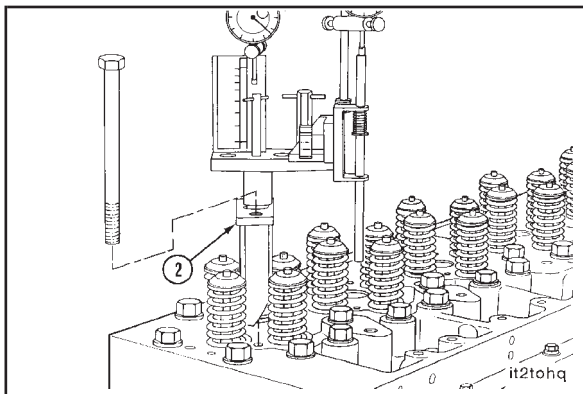
Camshaft Keys			
Key Part No.	Degree of Offset (To the Camshaft)	Change in Push Rod Travel	
		mm	In.
3009953	0.00	0.000	0.0000
3030893	0.25	0.051	0.0020
3009948	0.50	0.102	0.0040
3030894	0.75	0.152	0.0060
3009949	1.00	0.203	0.0080
3030895	1.25	0.254	0.0100
3009950	1.50	0.305	0.0120
3030896	1.75	0.356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

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Static Injection Timing - Checking

Install the piston plunger rod (1) of the injection timing tool, Part No. 3823451, into the injector bore of the number one cylinder.

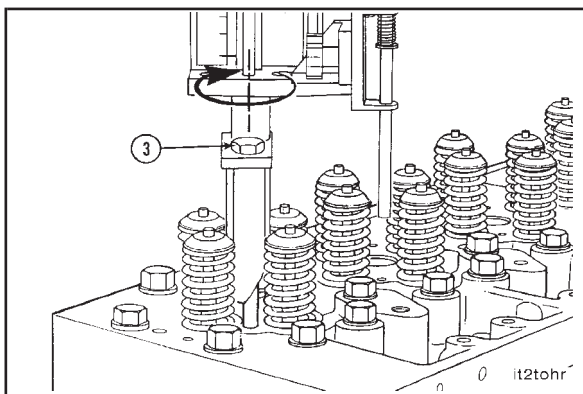




Align the swivel bracket (2) with the injector hold down cap screw hole.

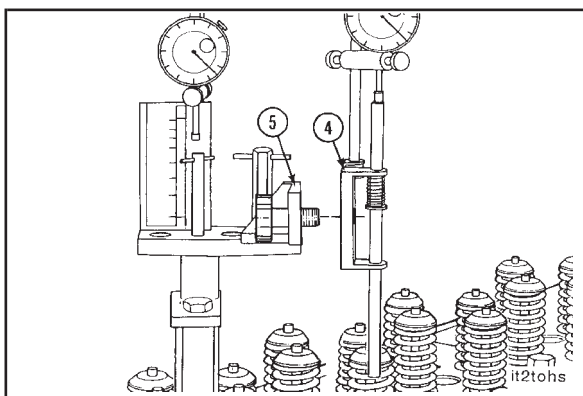


Install cap screw, Part No. 3823600, through the swivel bracket. The cap screw is included in the timing tool kit.

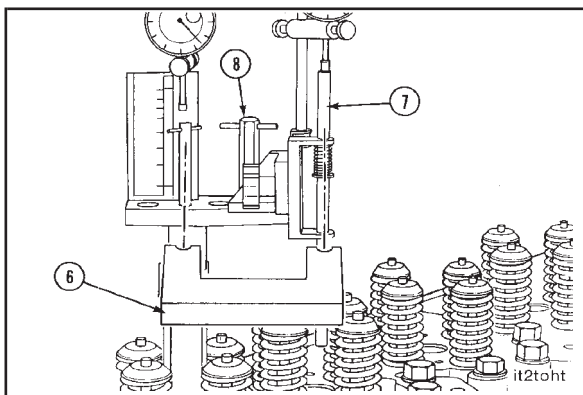


NOTE: If the cap screw (3) is tightened too tight, it will restrict the piston rod travel.

Tighten the cap screw (3) enough to hold the timing fixture rigid.



Position the timing tool push rod plunger bracket (4) on the back side of the center bracket (5).



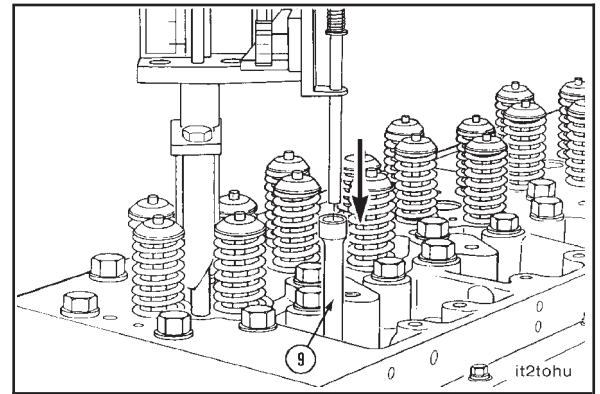
Use the alignment tool (6) to align the push rod plunger rod (7).

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.



NOTE: The push rod **must** be aligned properly to attain a correct reading.



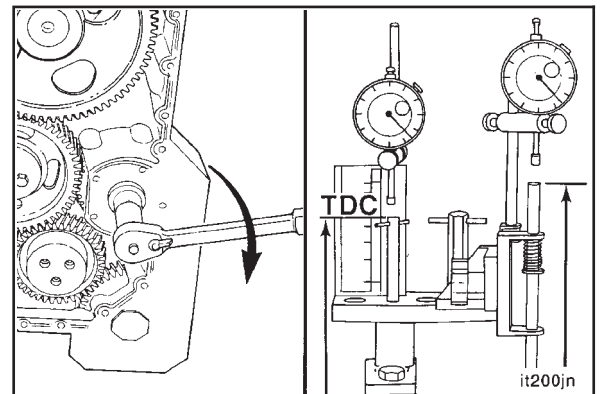
Caution: Always use the accessory drive shaft to rotate (bar) the crankshaft for checking the static injection timing. Using any other method will cause an error in the static injection timing or can damage the engine.

NOTE: The accessory drive pulley capscrew will need to be installed to rotate the crankshaft.

Determine the piston top dead center (TDC) on the compression stroke by rotating the accessory drive shaft in the direction of engine rotation **clockwise**.

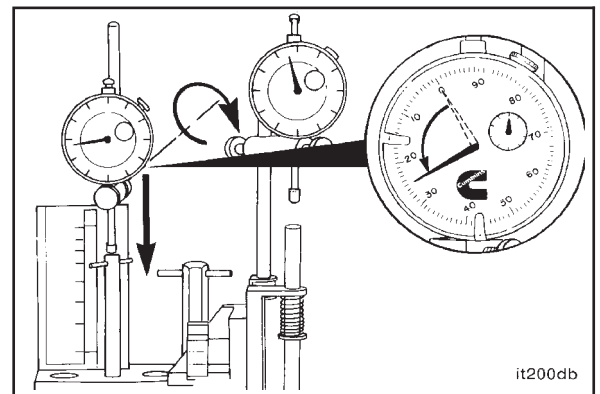


The piston is on the compression stroke when both plungers move in an upward direction at the same time. TDC is indicated by the maximum **clockwise** indicator position of the piston travel indicator pointer.

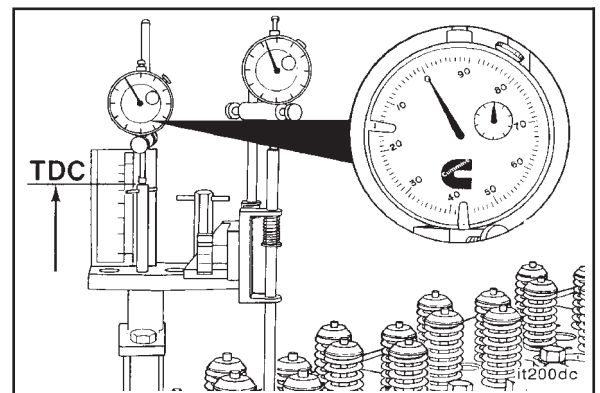


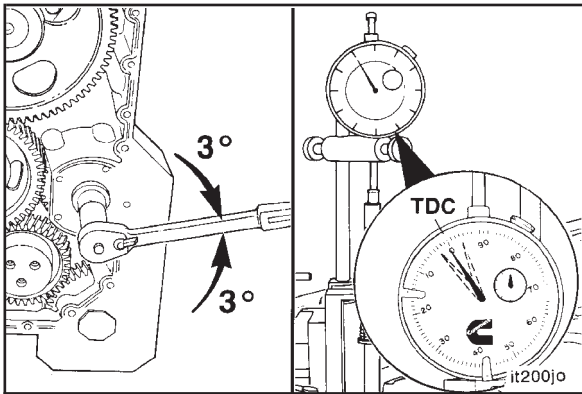
Caution: Both indicators must have a travel range of at least 6.35 mm [0.250 inch] or the indicators will be damaged.

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.

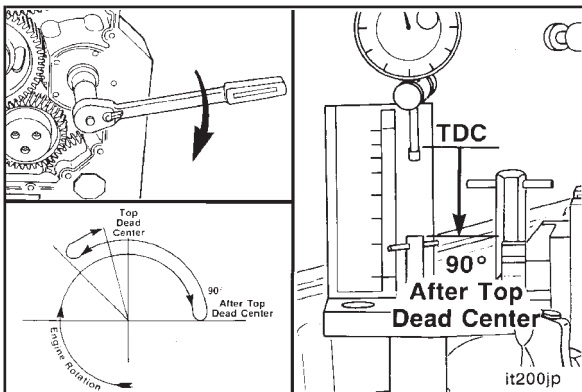


Set the dial indicator over the piston plunger rod to "0" (zero) when the piston plunger rod has reached maximum upward movement TDC.



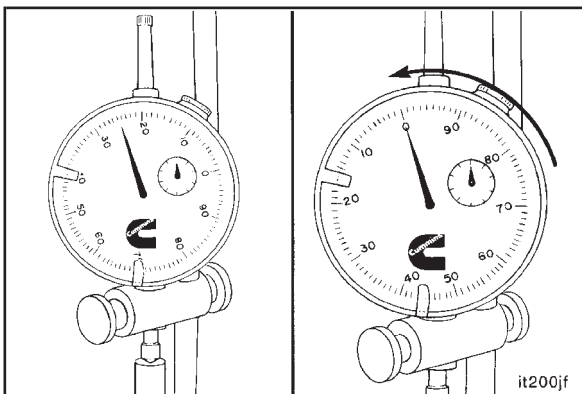


Rotate the accessory drive shaft back and forth (before and after) the “0” (zero) indicator reading for approximately 3 degrees to be sure the piston is at TDC.



Rotate the accessory drive shaft in the direction of engine rotation **clockwise** to 90 degrees after top dead center (ATDC).

The piston plunger will be at the “L10 90 degree” mark on the timing fixture.



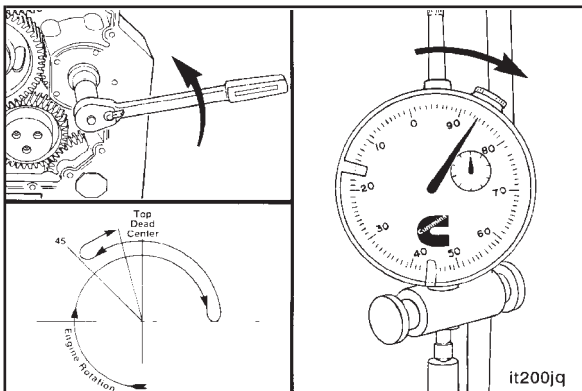
Position the push rod dial indicator contact tip in the center of the plunger rod and lower the gauge to within 0.63 mm [0.025 inch] of the fully compressed position.



Set the push rod dial indicator to “0” (zero).



Rotate the accessory drive shaft in the opposite direction of crankshaft rotation **counterclockwise** to TDC.



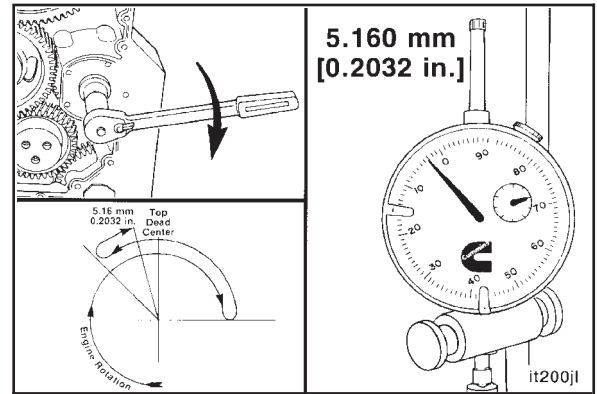
Continue to rotate the accessory drive shaft **counterclockwise** until the crankshaft is at 45 degrees before top dead center (BTDC).



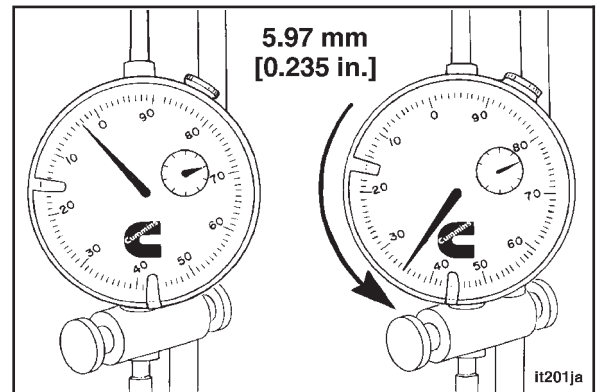
NOTE: This step is necessary to remove gear backlash in the engine.

NOTE: 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.

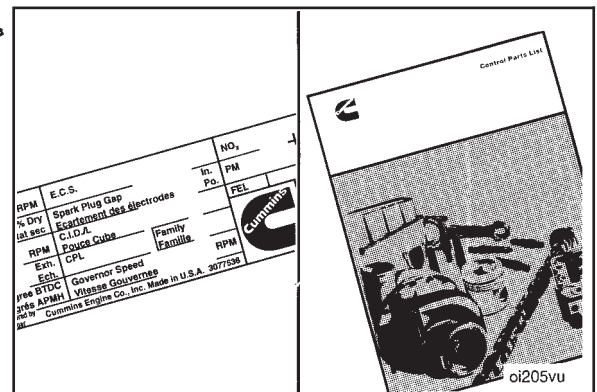
Rotate the accessory drive shaft **clockwise** slowly until the piston travel gauge is at 5.160 mm [0.2032 inch] BTDC.



Read the push rod travel gauge **counterclockwise** from "0" (zero). This travel represents the static injection timing value. In the example shown, the value is 5.97 mm [0.235 inch].

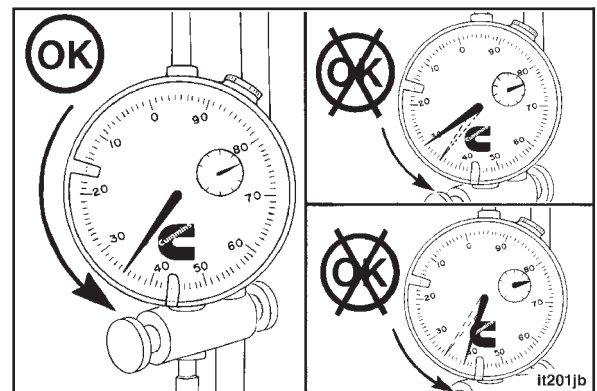


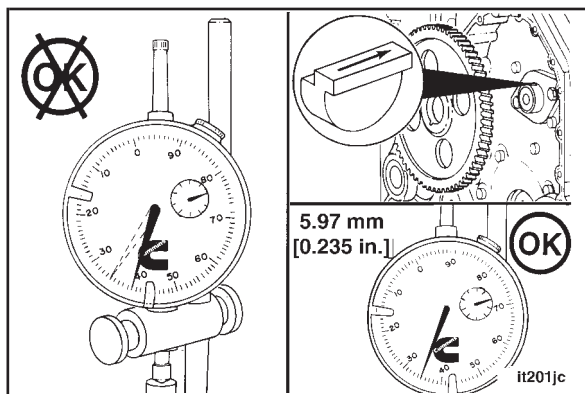
To verify the correct static injection timing for a particular engine, check the CPL number on the engine dataplate then refer to the Control Parts List, Bulletin No. 3379133. Timing codes are listed as two letter alpha characters. An example is a "HM" code which indicates a nominal setting of 5.08 mm [0.199 inch]. Refer to the accompanying chart.



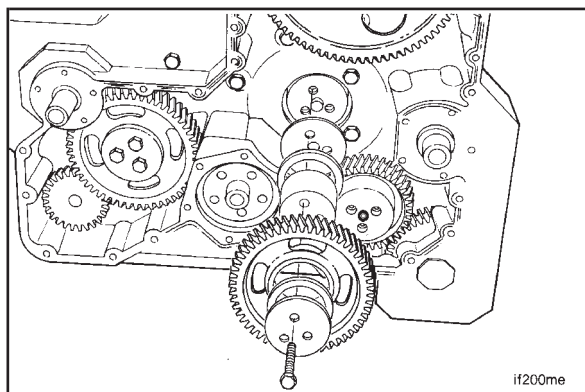
If the indicator reading is higher than the specification, the timing is **retarded**.

If the indicator reading is lower than the specification, the timing is **advanced**.

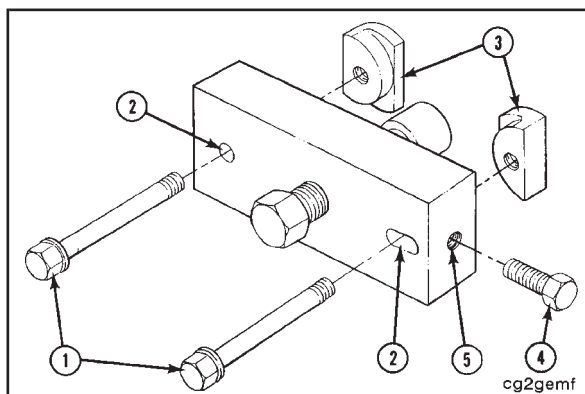




Static injection timing can be changed by removing the camshaft gear and installing an offset key.



To change the static injection timing, remove the camshaft idler gear. Refer to "Idler Gears - Removal, Procedure 0-01".



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). 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 the assembled camshaft gear puller on to 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.

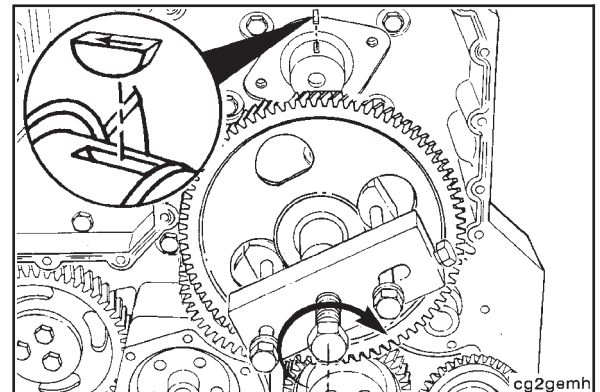
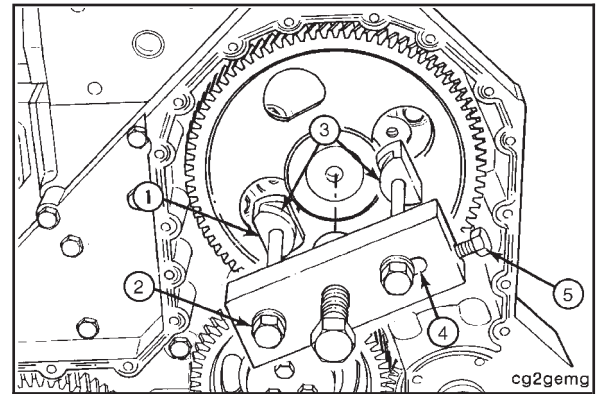
While holding the puller in place with one hand, tighten the capscrew on the end of the puller plate (5). Make certain the puller adapters are hooked completely over the camshaft gear. Torque the capscrew (5).

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.



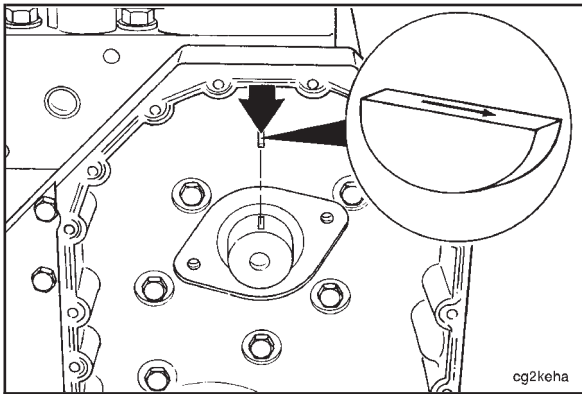
The accompanying table lists offset keys by part number and degree of offset.

Never advance static injection timing beyond the specification limits. The engine durability will be affected.

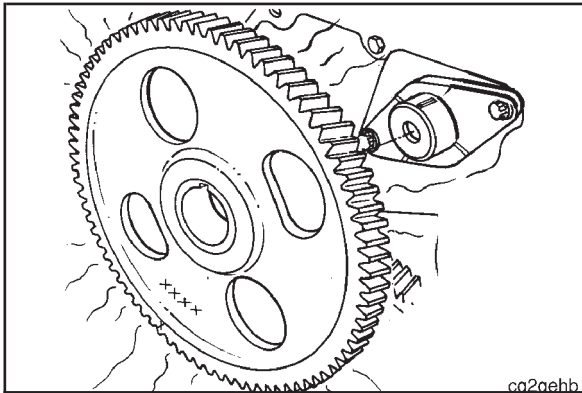
Camshaft Keys

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

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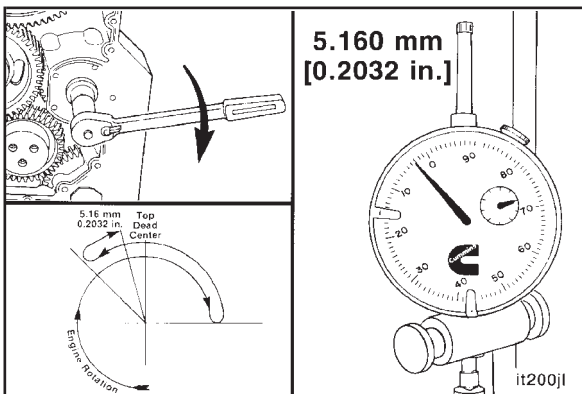


Use a leather hammer to install the camshaft gear key.
NOTE: Gear housing clearance makes key installation more difficult. Use care when installing the key.



Use master camshaft gear, Part No. 3824652, for checking the static injection timing again. This is a slip fit gear which can be installed without heating the gear and removed without the camshaft gear puller.

Install the gear onto the camshaft.

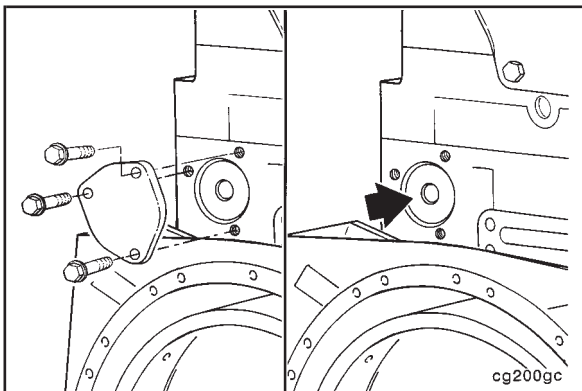


Caution: Failure to check the engine timing can cause severe engine damage.



Check the engine timing again.

When the correct static timing value is reached, remove the master camshaft gear.

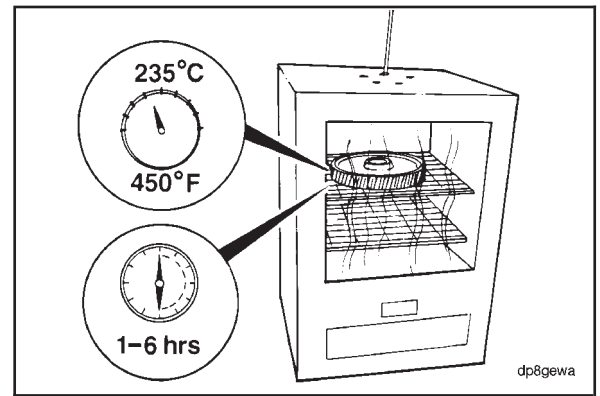


It can be necessary to remove the camshaft rear cover plate and apply pressure to the end of the camshaft to hold it in the forward position while the camshaft gear is being installed.

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

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

Temperature: 235°C [450°F]

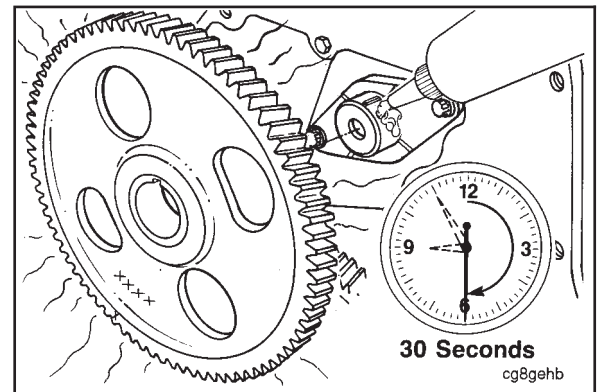


Use Lubriplate® 105, or equivalent, to coat the camshaft nose before installing the camshaft gear.

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

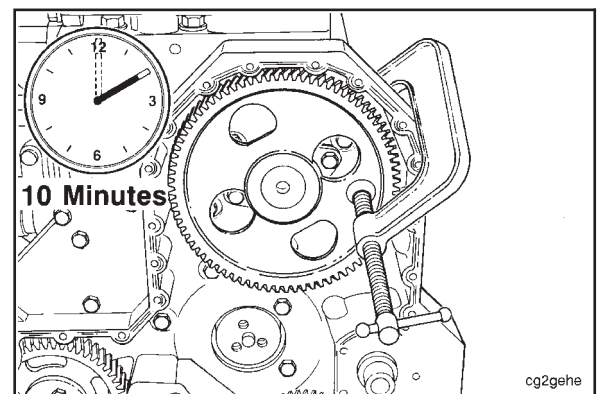
NOTE: Install the gear on the camshaft within 30 seconds after it is removed from the oven.

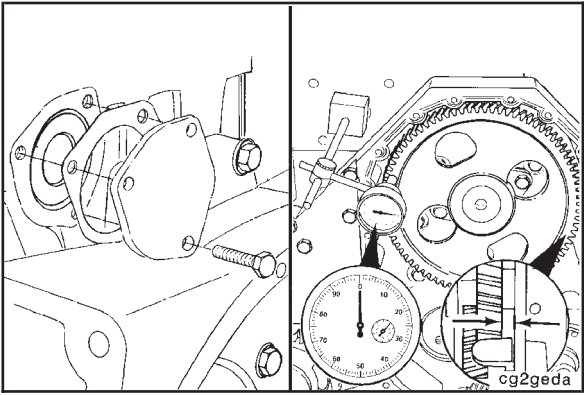
Remove the gear from the oven. Align the gear keyway with the key in the camshaft and install the gear on the camshaft.



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

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





Use a new gasket and install the camshaft rear cover plate. Tighten the three capscrews (M10-1.50 x 22).



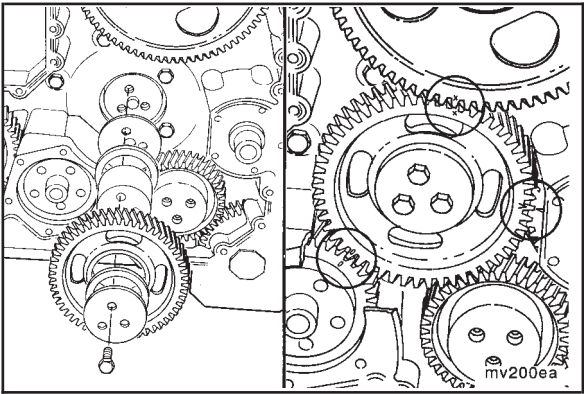
Torque Value: 47 N•m [35 ft-lb]

Use a dial indicator gauge assembly, Part No. 3376050, with an extension, Part No. ST-537-4, and a magnetic base, Part No. 3377399, to measure the camshaft end clearance.

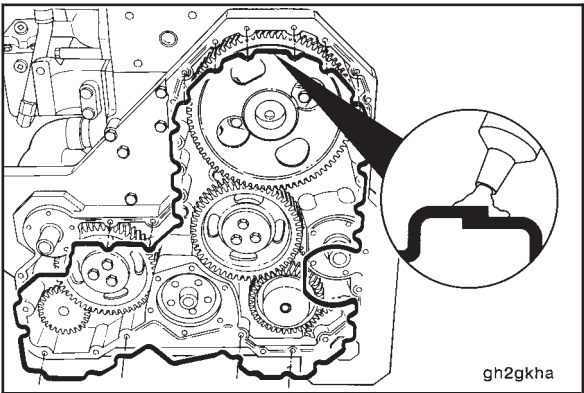


Place the contact tip of the gauge against the face of the gear.

Camshaft End Clearance		
mm		in
0.13	MIN	0.005
0.33	MAX	0.013



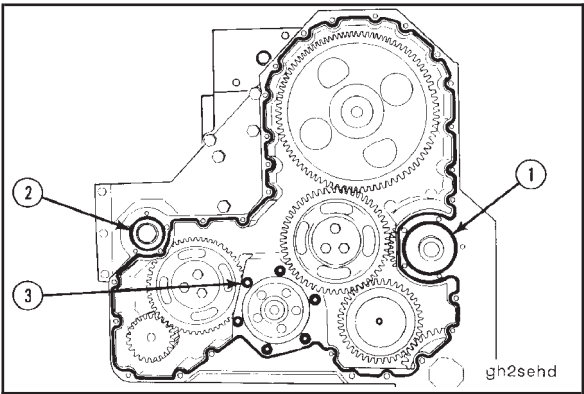
Install the camshaft idler gear. Refer to “Idler Gear Assemblies - Installation” earlier in this procedure.



Gear Cover - Installation

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

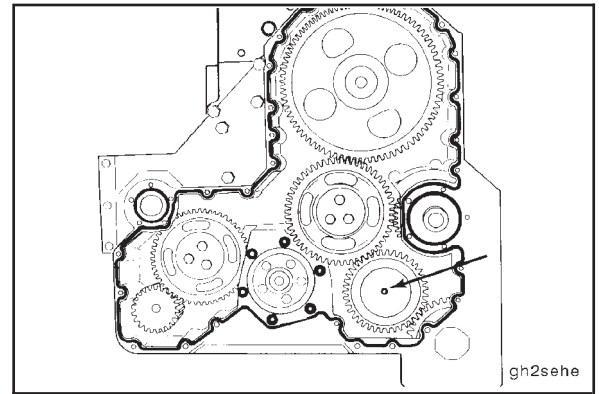
Apply silicone sealant, Part No. 3823494, to the overlap joint.



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

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

Install a new o-ring at the front of the hydraulic drive idler retainer mounting spacer. The spacer **must** be in the proper position.



Install the gear cover and 22 mounting capscrews (M8-1.25 x 20).

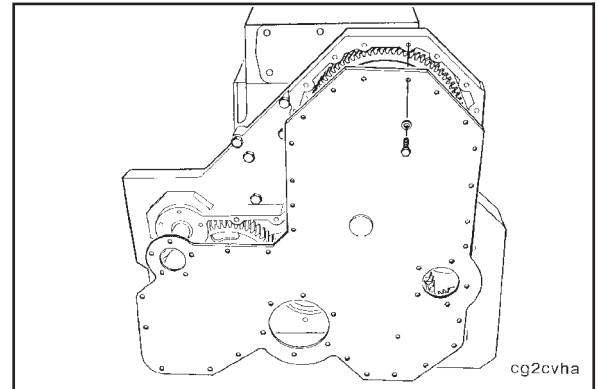
NOTE: Do **not** install the front engine support capscrews at this time.

NOTE: Applications equipped with an automatic belt tensioner refer to the next block of text for installation of the belt tensioner bracket before tightening the mounting capscrews.

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

Tighten the capscrews.

Torque Value: 6 N•m [55 in-lb]

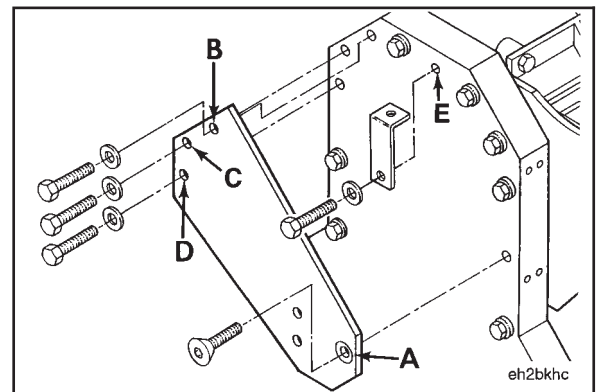


If the engine is equipped with an automatic belt tensioner, install the belt tensioner bracket with the countersunk hole (A) facing away from the gear cover. Use flat head capscrew (M8 x 25) at location (A).

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

Tighten the capscrews. Capscrew (A) **must** be tightened before (B, C and D).

Torque Value: 6 N•m [55 in-lb]



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

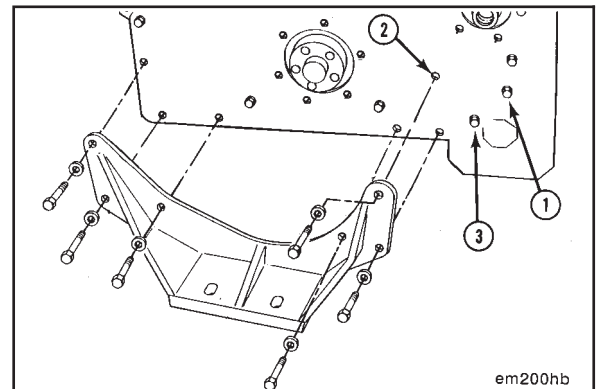
Install the front engine support with five mounting capscrews (M10-1.50 x 100) and one mounting capscrew (M10-1.50 x 35).

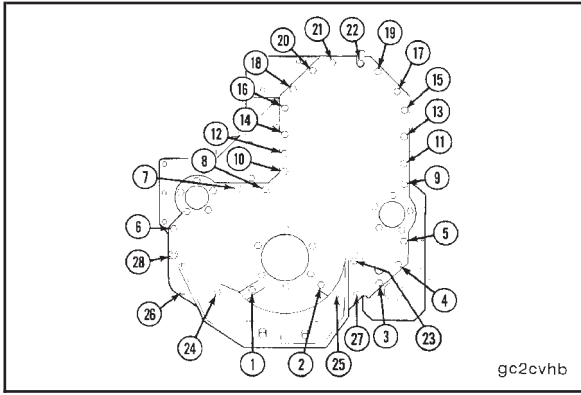
NOTE: The capscrew (M10-1.50 x 35) is used in the mounting hole aligned with the hydraulic drive idler gear.

Tighten the capscrews.

Torque Value: 6 N•m [55 in-lb]

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





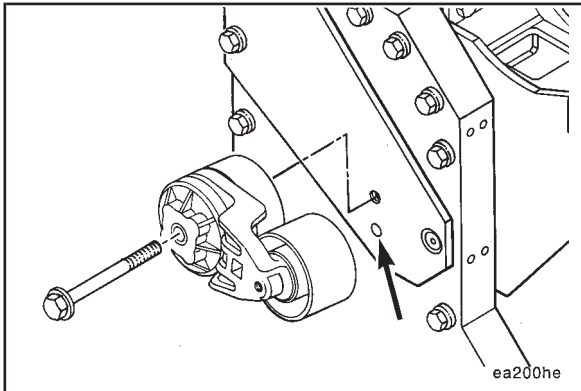
Tighten the gear cover capscrews in the sequence shown.

For capscrews 1 through 22:

Torque Value: 20 N•m [15 ft-lb]

For capscrews 23 through 28:

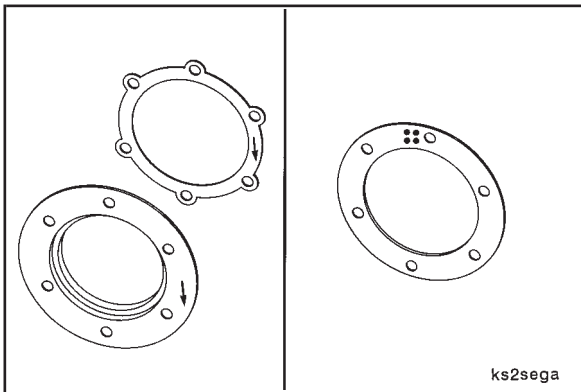
Torque Value: 68 N•m [50 ft-lb]



Automatic Belt Tensioner - Installation

Install the 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]

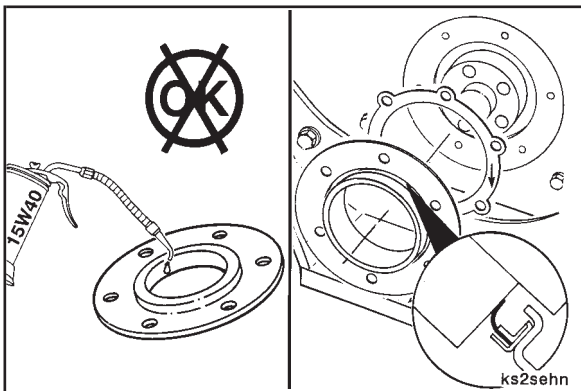


Front Crankshaft Oil Seal - Installation

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 o'clock location.

The clamping ring is marked with four punch marks which locate at approximately the 11:30 o'clock location.



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 in the new seal kit to install the new seal and gasket.

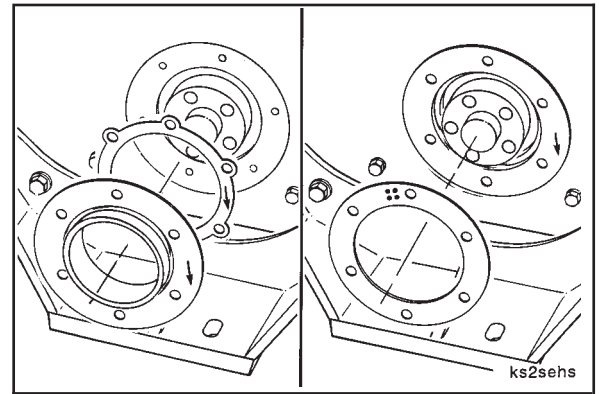


Orient the four punch marks on the clamping ring at the 11:30 o'clock location.

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

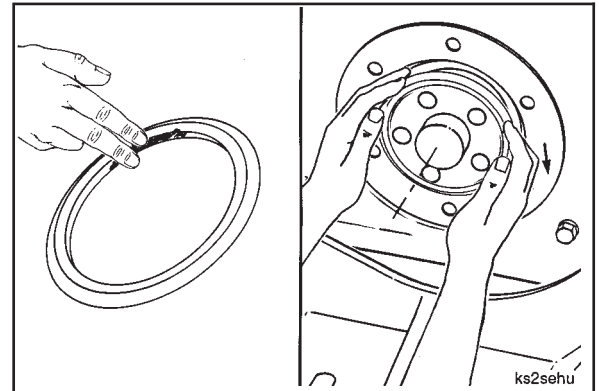
Install the six seal capscrews (M8-1.25 X 20) and washers. Tighten the capscrews in a star pattern in two steps.

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



Place a light film of oil or anti-freeze on the inside diameter of the 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.

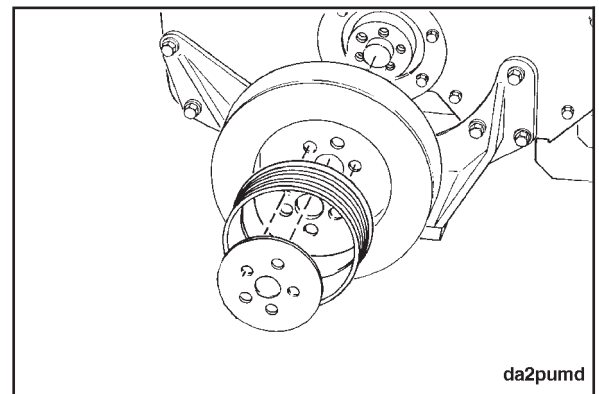


Vibration Damper and Crankshaft Pulley - Installation

Make sure the mounting surfaces of the crankshaft nose, vibration damper and 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 spacer on the guide studs.

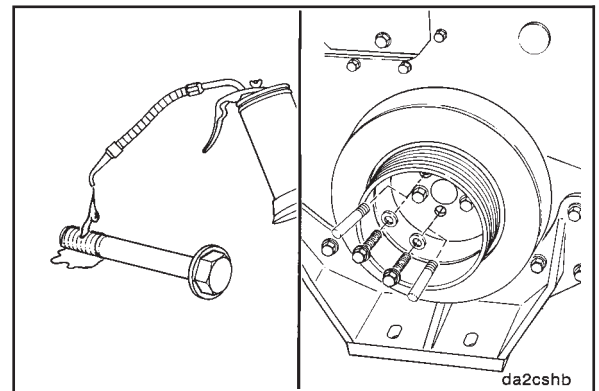


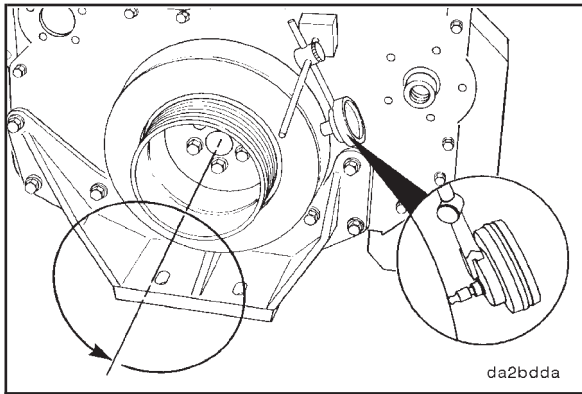
Use clean 15W-40 oil to lubricate the capscrew threads and under the flange head.

Install three of the mounting capscrews (M14-1.50 x 50).

Remove the two guide studs and install the remaining capscrews.

Torque Value: 203 N•m [150 ft-lb]





Vibration Damper Eccentricity - Measurement

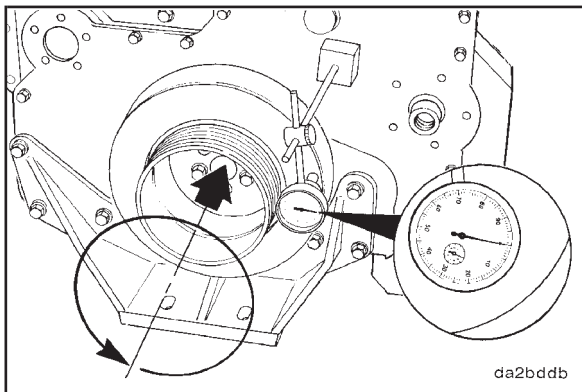


Install dial indicator assembly, Part No. 3376050, with magnetic base, Part No. 3377399, in the center of the vibration damper outside diameter to measure eccentricity (out-of-round).

Rotate the crankshaft with the accessory drive shaft one complete revolution (360 degrees).

Maximum eccentricity **must not** exceed 0.28 mm [0.011 inch] TIR.

Replace the damper if the eccentricity exceeds these specifications.



Vibration Damper Face - Runout Measurement



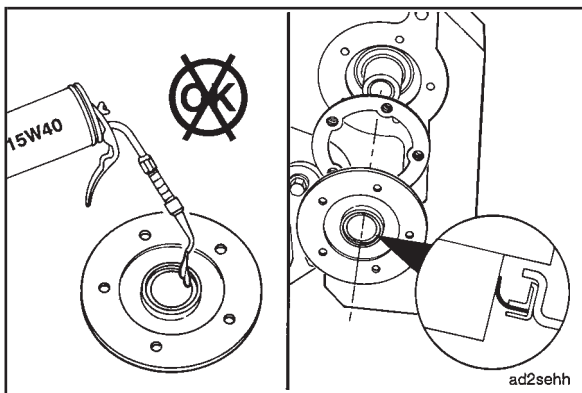
Install the dial indicator gauge against the face of the vibration damper to measure the runout.

Push the crankshaft toward the front or the rear of the engine.

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 runout exceeds 0.28 mm [0.011 inch].

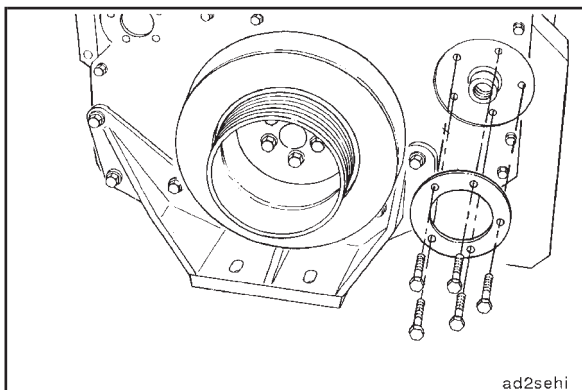


Accessory Drive Oil Seal - Installation

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 in the new seal to install the seal and gasket.



Install the clamping ring and five capscrews (M8-1.25 X 20).

Tighten the capscrews in a star pattern in two steps.



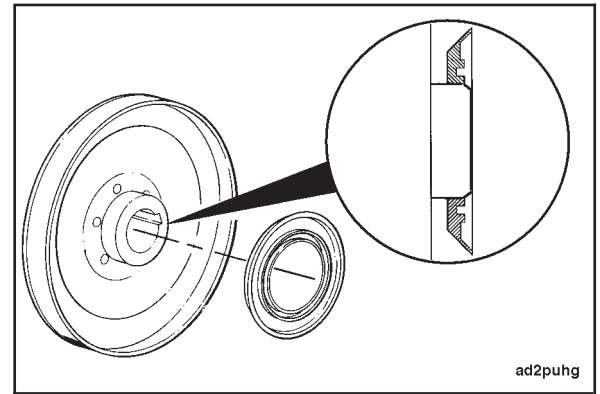
Torque Value: Step 1 - 7 N•m [60 in-lb]
2 - 19 N•m [170 in-lb]

Accessory Drive Pulley - Installation

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 anti-freeze 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.



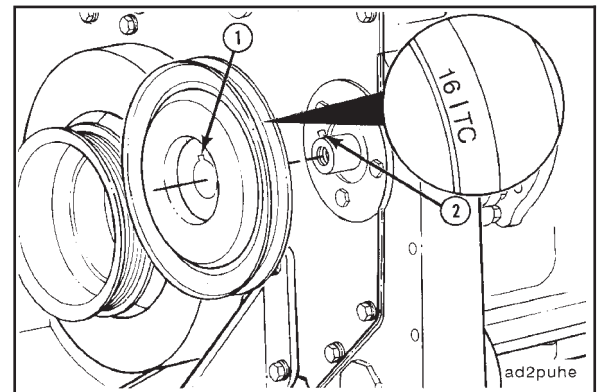
ad2puhg

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. It does **not** require the use of an installation tool.

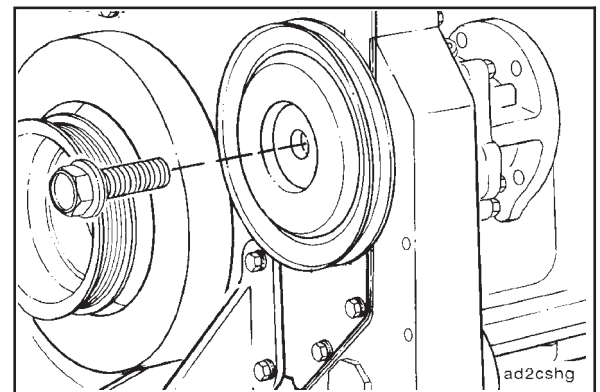
Install the pulley on the accessory drive shaft by hand.



ad2puhe

Install the pulley retaining capscrew (M20-2.50 X 50).

Torque Value: 542 N•m [400 ft-lb]

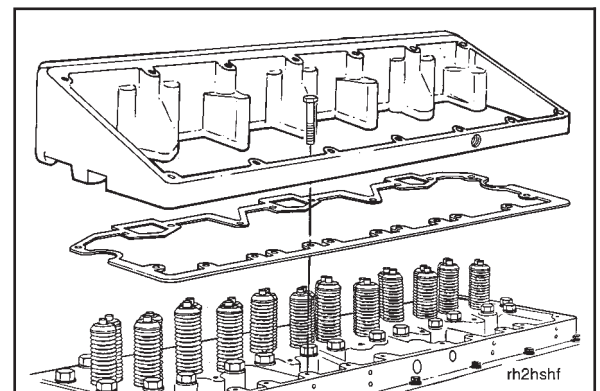


ad2cshg

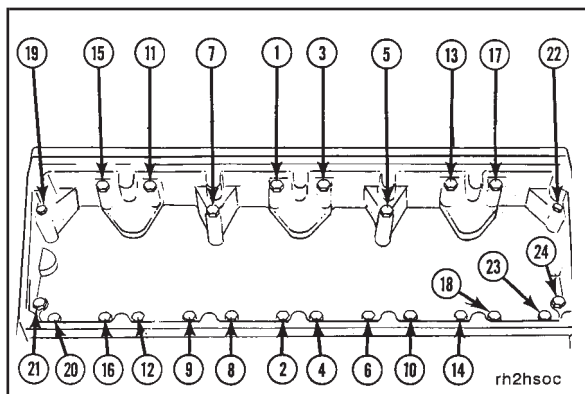
Rocker Lever Housing - Installation

The rocker lever housing **must** be installed before the injectors on M11 engines.

Use a new gasket and install the rocker lever housing using four mounting capscrews (M10-1.50 x 100) and 20 mounting capscrews (M10-1.50 x 35).

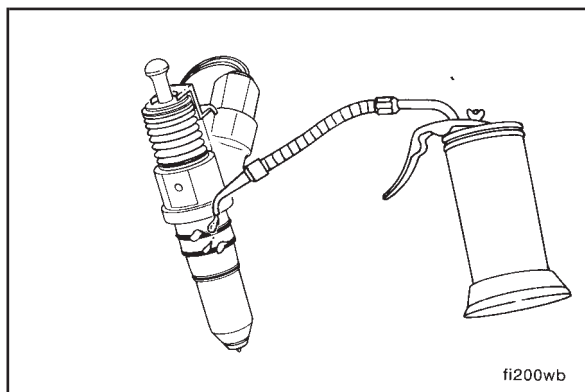


rh2hshf



Tighten the capscrews, in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]



Injectors - Installation



Do **not** stretch the o-rings as they are installed. The o-rings **must** be correctly installed in the grooves to prevent leaks.

NOTE: It is important that the three injector o-rings be installed in the correct orientation. Install the three new o-rings as follows:

Part No.	Location	Color Code
3070136	Top	Black or Red
3070137	Middle	Brown or White
3070138	Bottom	Black with White Dot or Light Blue



Lubricate the o-rings with clean 15W-40 oil just before installation.

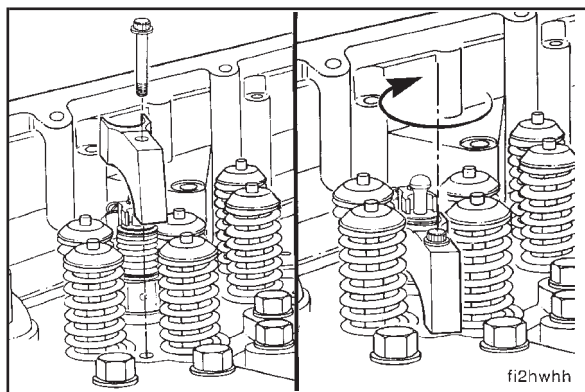
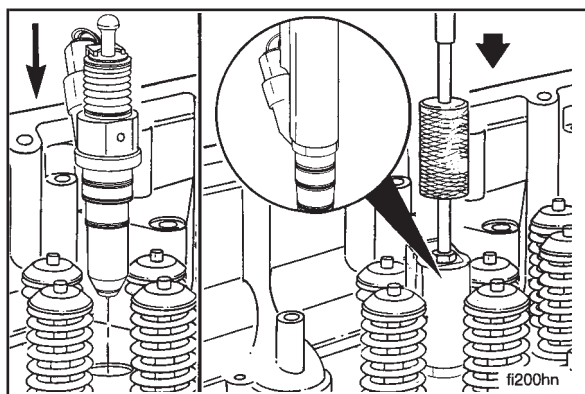


Place the injector in the cylinder head injector bore with the injector solenoid valve toward the intake port. Align the injector equally between the valve springs.



Caution: Do not drive the injector in by striking the top stop or 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.



Install the hold down clamp and capscrew (M10-1.25 x 75). Tighten the capscrew.

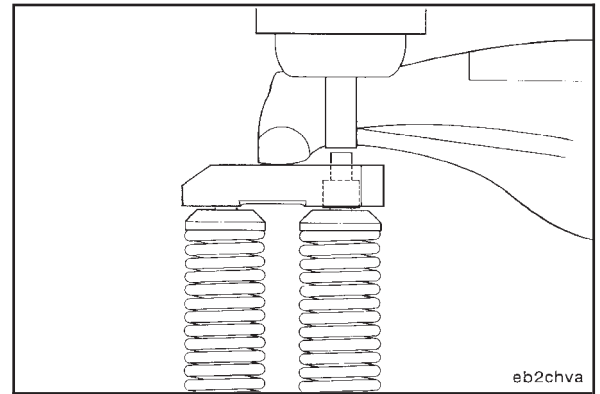


Torque Value: 75 N•m [55 ft-lb]

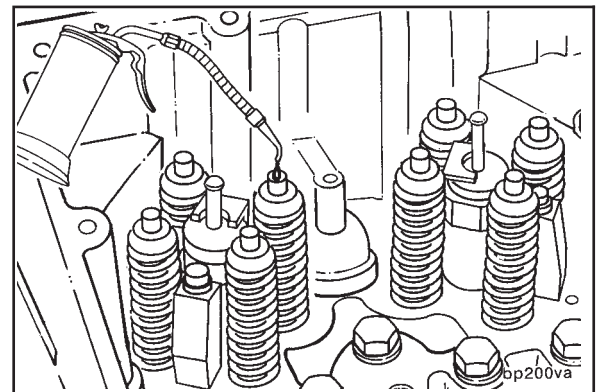
Crossheads - Installation

If the engine is equipped with a Jacobs® Engine Brake, special guideless crossheads **must** be installed on the exhaust valve stems.

Install the crosshead with the pin over the exhaust valve stem closest to the center of the cylinder head.

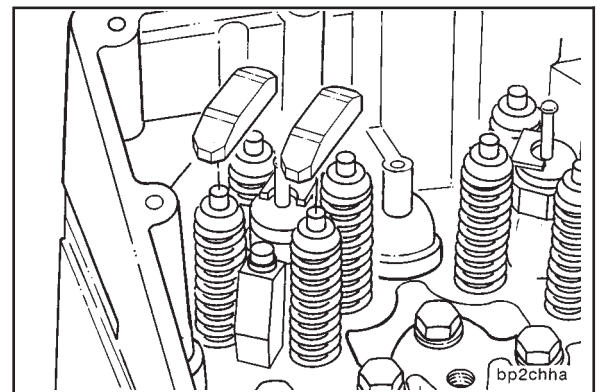


Use clean 15W-40 oil to lubricate the end of the valve stems.



If the same crossheads are used, they **must** be installed in the same location as from which they were removed.

Install the crossheads on the valve stems.

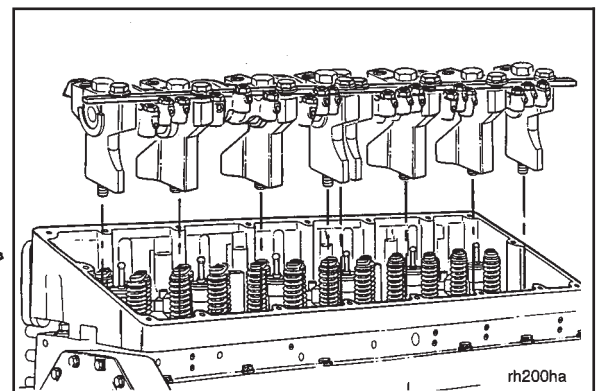


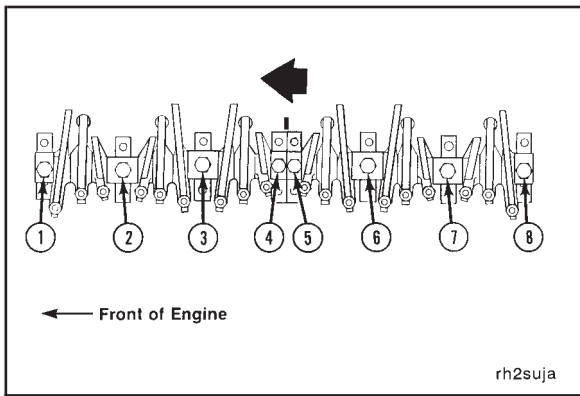
Rocker Lever Assemblies - Installation

The rocker lever assemblies **must** be installed in the engine so they are in the same position as they were removed from.

Install the assemblies on the engine.

Only snug the mounting capscrews. Do **not** tighten the capscrews to more than 5 N•m [45 in-lb] torque at this time. The rocker lever side clearance **must** be adjusted before the capscrews are tightened to their final torque value.





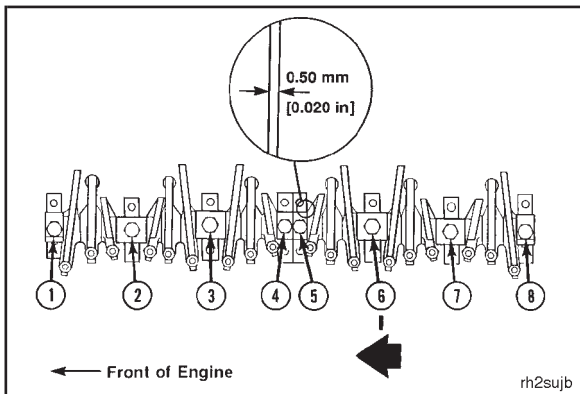
Rocker Lever Side Clearance - Adjustment



Push the number five rocker lever support toward the front of the engine and tighten the support capscrew.



Torque Value: 122 N•m [90 ft-lb]

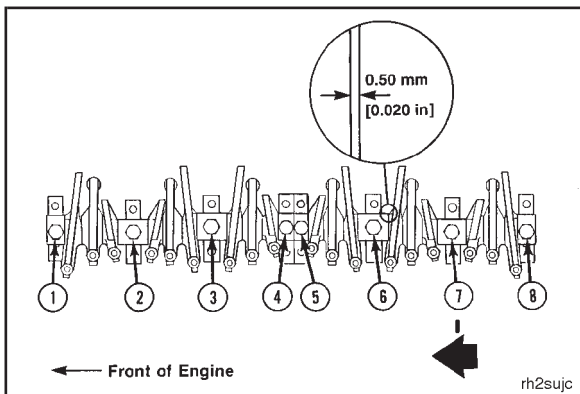


Install a 0.55 mm [0.022 inch] feeler gauge between the number five support and the intake lever for the number four cylinder.

Push the number six support toward the front of the engine and tighten the support capscrew.



Torque Value: 122 N•m [90 ft-lb]

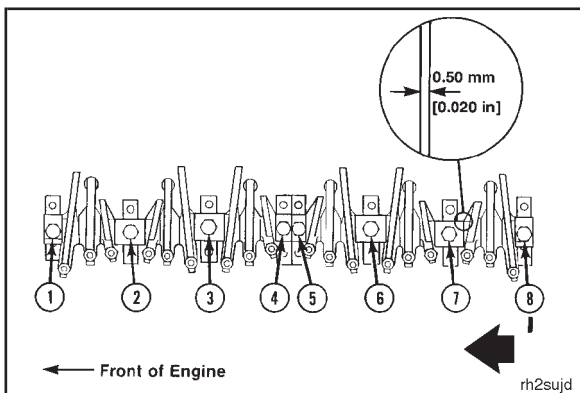


Install a 0.55 mm [0.022 inch] feeler gauge between the number six support and the exhaust lever for the number five cylinder.

Push the number seven support toward the front of the engine and tighten the support capscrew.



Torque Value: 122 N•m [90 ft-lb]



Install a 0.55 mm [0.022 inch] feeler gauge between the number seven support and the intake lever for the number six cylinder.

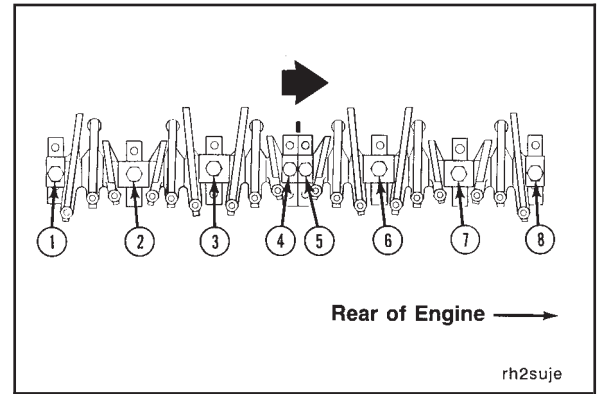
Push the number eight support toward the front of the engine and tighten the support capscrew.



Torque Value: 122 N•m [90 ft-lb]

Push the number four support toward the rear of the engine and tighten the support capscrew.

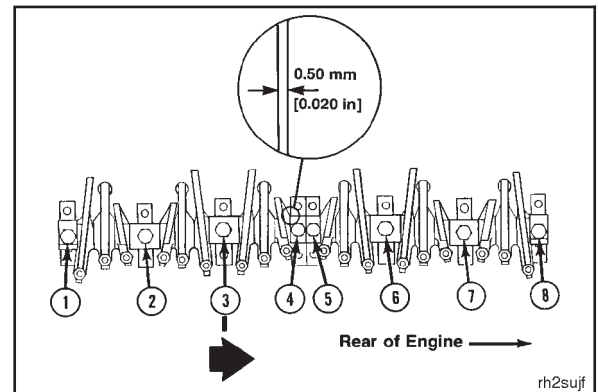
Torque Value: 122 N•m [90 ft-lb]



Install a 0.55 mm [0.022 inch] feeler gauge between the number four support and the intake lever for the number three cylinder.

Push the number three support toward the rear of the engine and tighten the support capscrew.

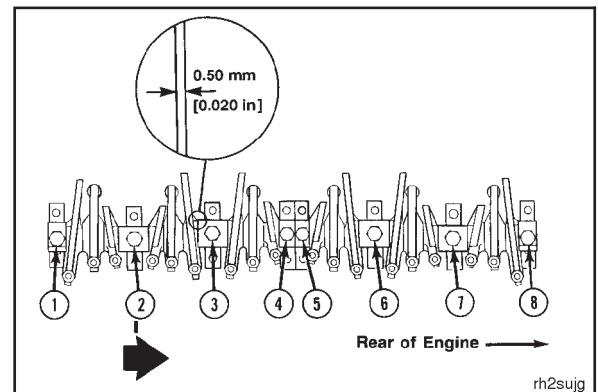
Torque Value: 122 N•m [90 ft-lb]



Install a 0.55 mm [0.022 inch] feeler gauge between the number three support and the exhaust lever for the number two cylinder.

Push the number two support toward the rear of the engine and tighten the support capscrew.

Torque Value: 122 N•m [90 ft-lb]

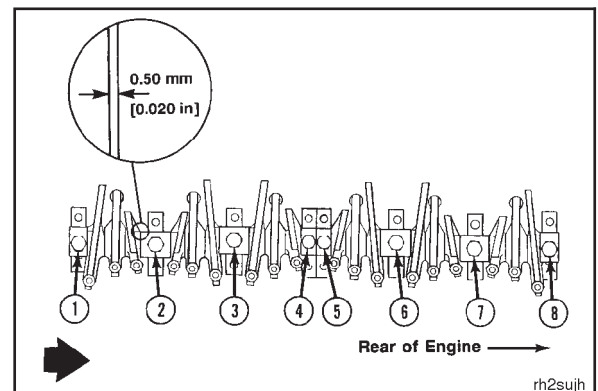


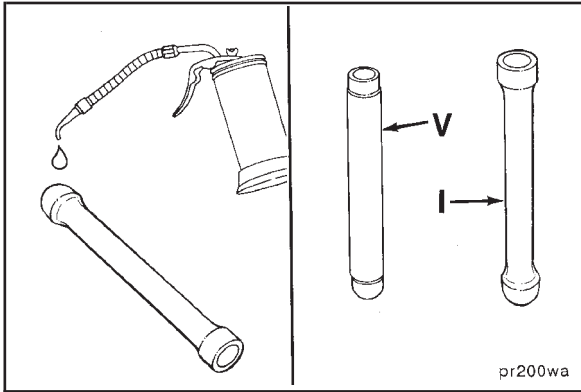
Install a 0.55 mm [0.022 inch] feeler gauge between the number two support and the intake lever for the number one cylinder.

Push the number one support toward the rear of the engine and tighten the support capscrew.

Torque Value: 122 N•m [90 ft-lb]

Check the front and rear assemblies for correct clearance. Check the support capscrews for the correct torque value.





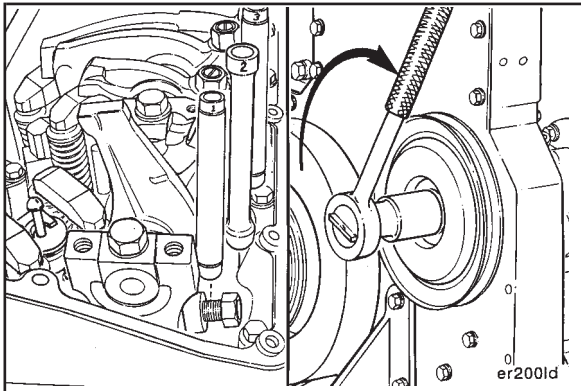
Push Rods and Tubes - Installation



Use clean 15W-40 oil to coat the ball end of the push rods and push tubes.



The injector push rods (I) are longer than the valve push tubes (V).



Do **not** allow the push rods or push tubes to fall into the engine. They can be damaged.

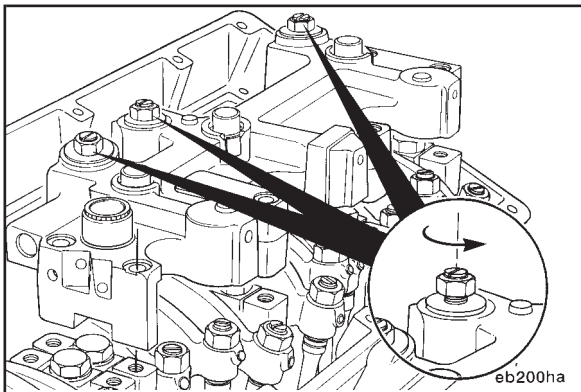


The crankshaft **must** be rotated to install all the push rods and push tubes. The push rods and tubes **must** be installed in the same location as from which they were removed.

Install the injector push rods and valve push tubes.

Position the push rods and push tubes under the rocker lever adjusting screws.

Tighten the adjusting screws enough to hold the push rods and push tubes in position.

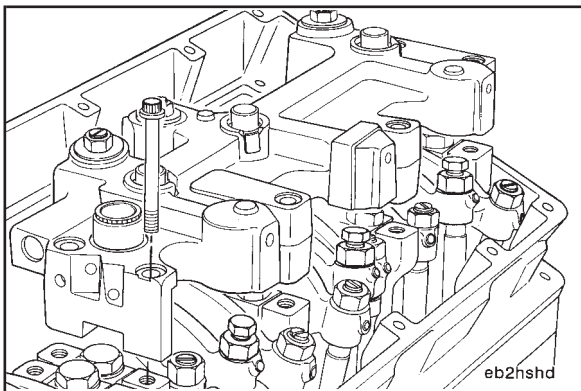


Jacobs® Engine Brake - Installation

If the engine is equipped with a Jacob® Engine Brake, loosen the locknuts on the slave pistons.

Make sure the slave pistons are fully retracted.

Install the rear Jacobs® 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.

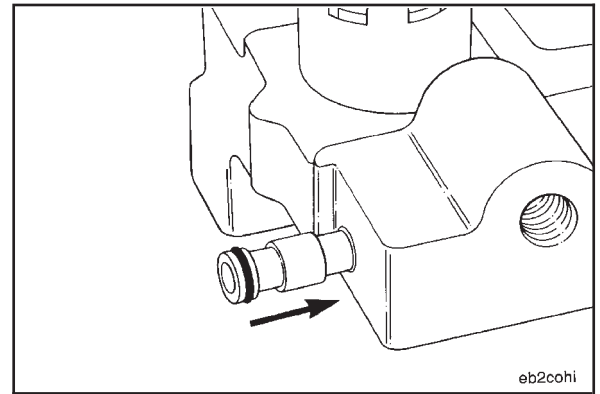
Install the capscrews in the rocker lever supports.

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.

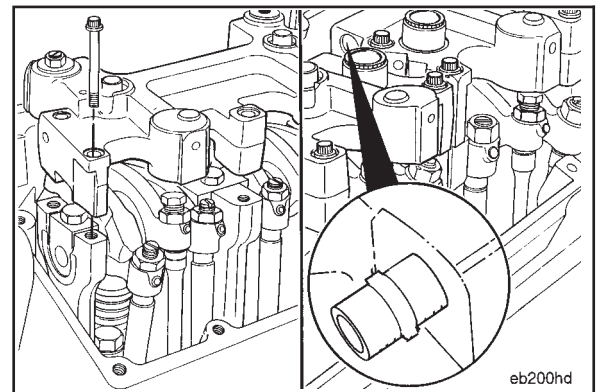
When installing the front housing, be sure the oil connector and o-ring are in position to be pushed into the rear housing.



eb2cohi

Install the front Jacobs® Engine Brake housing on the front rocker lever supports.

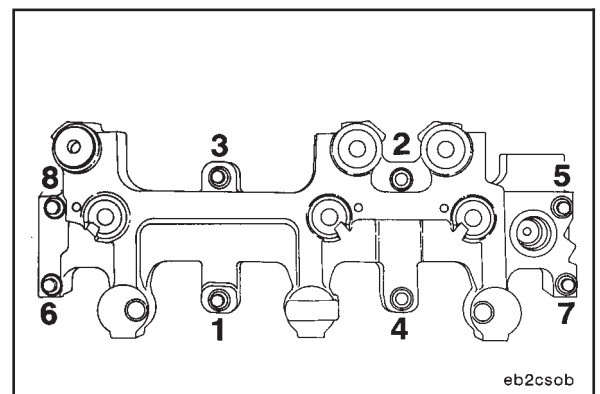
Center the oil connector between the front and rear housings before tightening the capscrews.



eb200hd

Tighten the capscrews in the sequence shown.

Torque Value: 81 N•m 60 ft-lb]



eb2csob

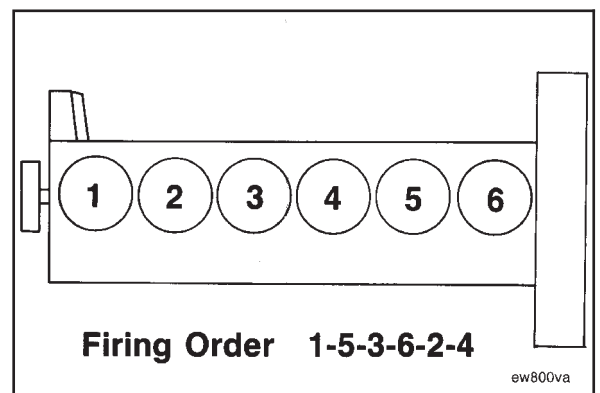
Overhead - Adjustment

This procedure describes the valve and injector adjustment procedures for CELECT™ engines.

The crankshaft rotation is **clockwise** when viewed from the front of the engine.

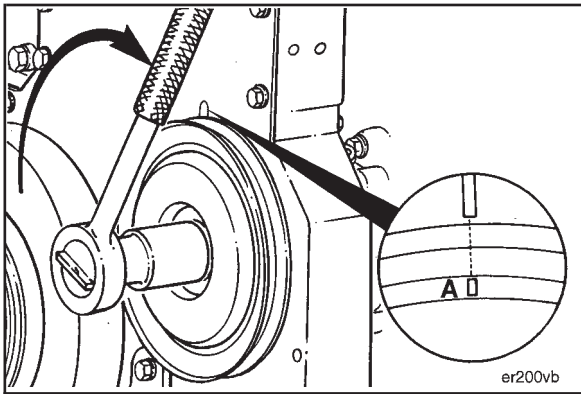
The cylinders are numbered from the front gear housing end of the engine.

The engine firing order is 1-5-3-6-2-4.



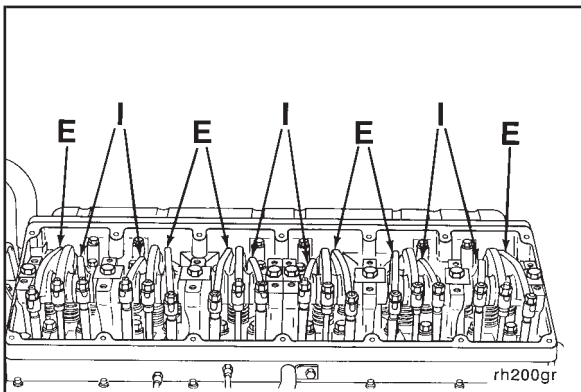
Firing Order 1-5-3-6-2-4

ew800va



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.



Each cylinder has three rocker levers.

1. The long rocker lever (E) is the exhaust lever.
2. The center rocker lever is the injector lever.
3. The short rocker lever (I) is the intake lever.



Refer to the accompanying chart for valve rocker lever locations.

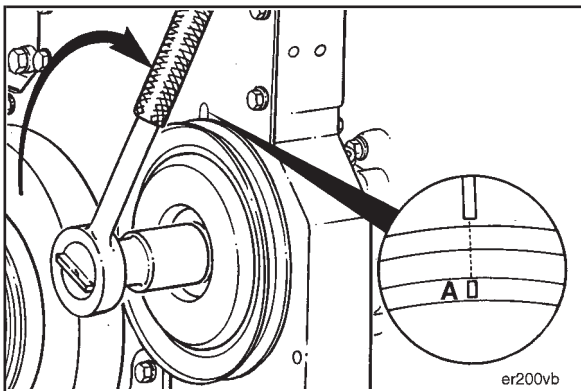
CELECT™ Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4
Firing Order: 1-5-3-6-2-4			

oi200vh

On CELECT™ engines, the valves and injectors on the same cylinders are adjusted at the same index mark on the accessory drive pulley.

One pair of valves and one injector are adjusted at each pulley index mark before rotating the accessory drive to the next mark.

Two crankshaft revolutions are required to adjust the valves and injectors.

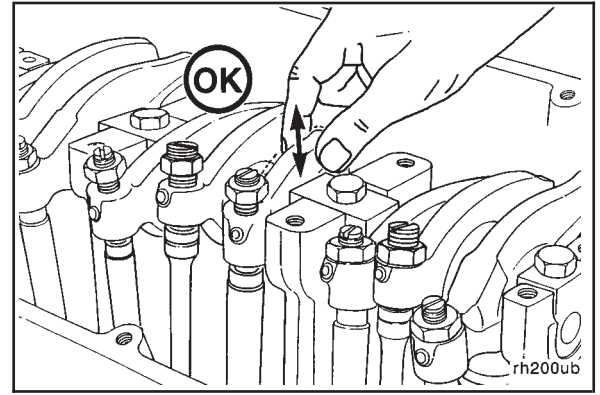


The adjustment can begin on any valve set mark. In the following example, the adjustment will begin on the 'A' valve set mark with cylinder number one ready for adjustment.

Rotate the accessory drive **clockwise** until the 'A' valve set mark on the 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 **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 by hand.

Both valves are closed when both rocker levers are loose and can be moved from side to side.



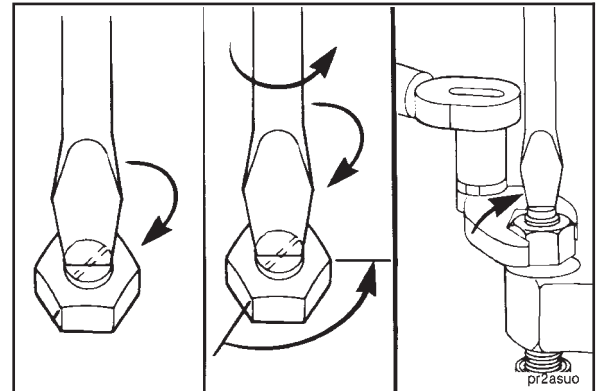
Loosen the injector adjusting screw locknut. Using a screwdriver or box end wrench, and the adjusting screw, bottom the injector plunger three or four times to remove the fuel.

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]

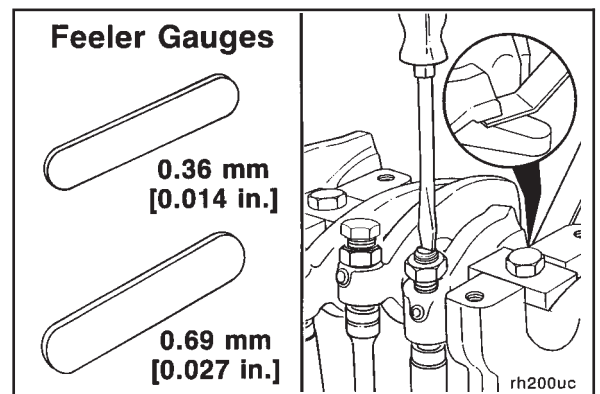


After adjusting the injector, set the valves on the same cylinder.

Select a feeler gauge for the correct valve lash specification.

Valve Lash Specifications		
	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.

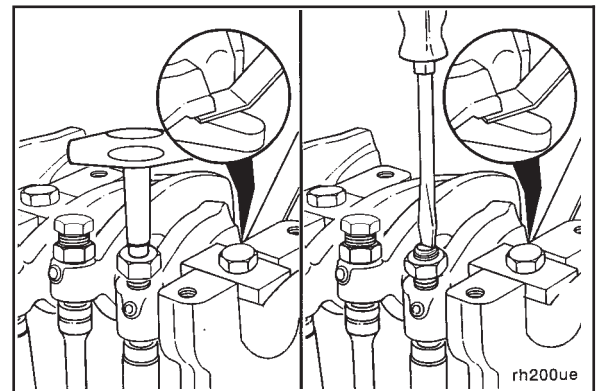


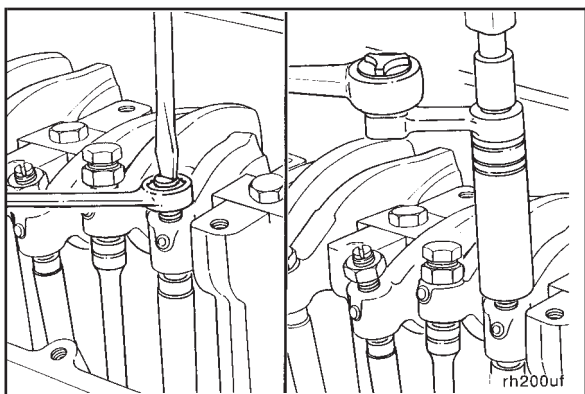
Two different methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent. It eliminates the need to feel the drag on the feeler gauge.

- **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: 1 N•m [6 in-lb]

- **Touch Method:** Tighten the adjusting screw until a slight drag is felt on the feeler gauge.





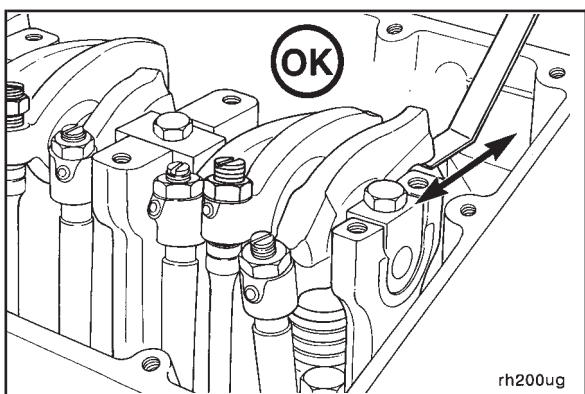
Hold the adjusting screw in this position. The adjusting screw **must not** turn when the locknut is tightened.

Without Adapter:

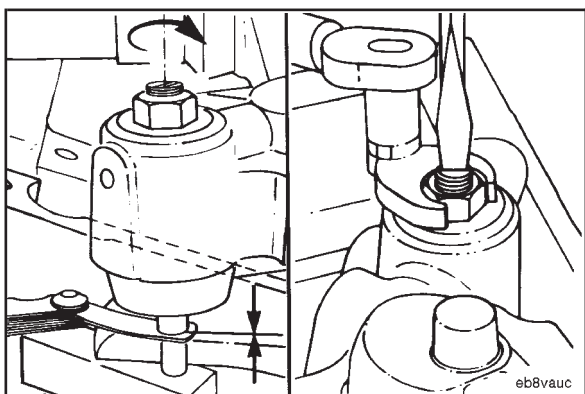
Torque Value: 61 N•m [45 ft-lb]

With Adapter:

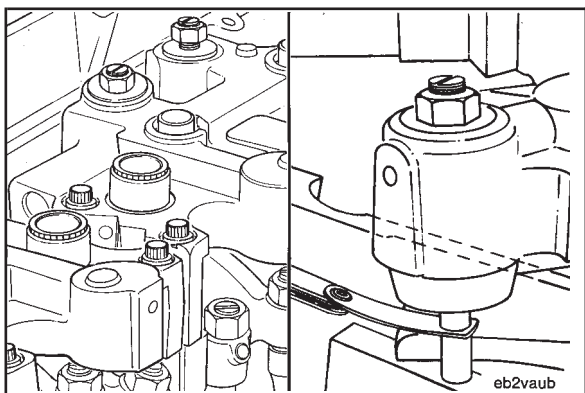
Torque Value: 47 N•m [35 ft-lb]



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.



After adjusting the injector and valves on the appropriate cylinder, it is necessary to adjust the slave piston clearance if the engine is equipped with engine brakes.



Caution: To obtain maximum brake operating efficiency and prevent engine damage by piston-to-valve contact, complete the following instructions carefully.



Install an 0.38 mm [0.015 inch] feeler gauge between the slave piston and the actuating pin in the crosshead.

Turn the slave piston adjusting screw down until it touches the feeler gauge.

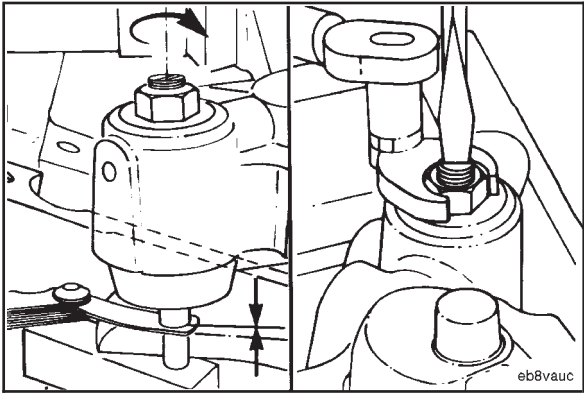
Hold the adjusting screw in position and tighten the locknut.

Without Adapter:

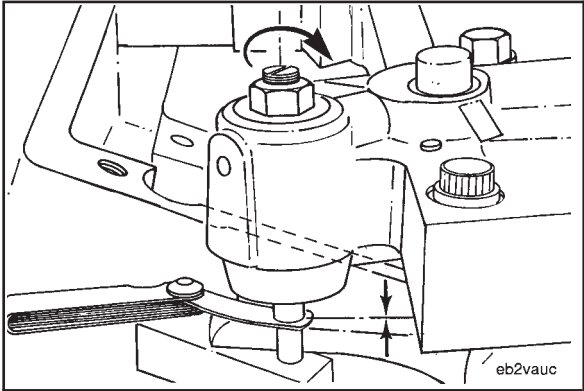
Torque Value: 34 N•m [25 ft-lb]

With Adapter:

Torque Value: 30 N•m [22 ft-lb]



Caution: After the slave piston adjusting screw locknut is tightened to the correct torque value, measure the clearance with a feeler gauge again. Do not tighten the adjusting screws too tight. The engine can be damaged.



Adjust the appropriate injector and valves following the injector and valve adjustment sequence chart.

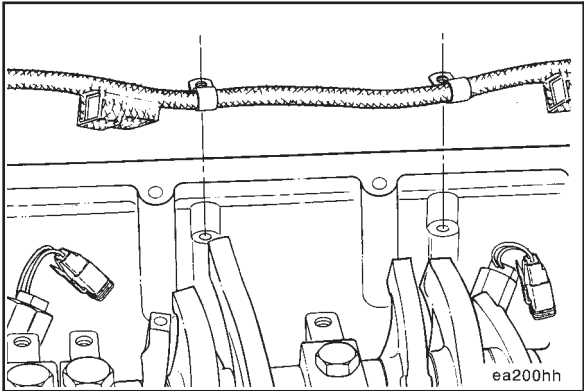
Repeat the process to adjust all injectors, valves and slave pistons correctly.

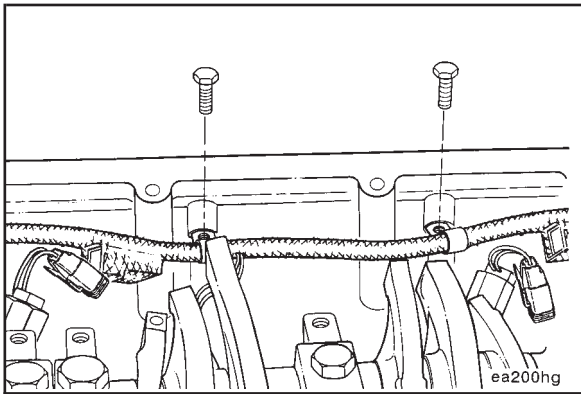
CELECT™			
Injector and Valve Measurement Sequence			
Bar Engine in Direction of Rotation	Pulley Position	Set Cylinder Injector	Valve
Start	A	1	1
Advance to	B	5	5
Advance to	C	3	3
Advance to	A	6	6
Advance to	B	2	2
Advance to	C	4	4
Firing Order: 1-5-3-6-2-4			
oi200vh			

Actuator Harness - Installation

Install the internal actuator wiring harness on the engine.

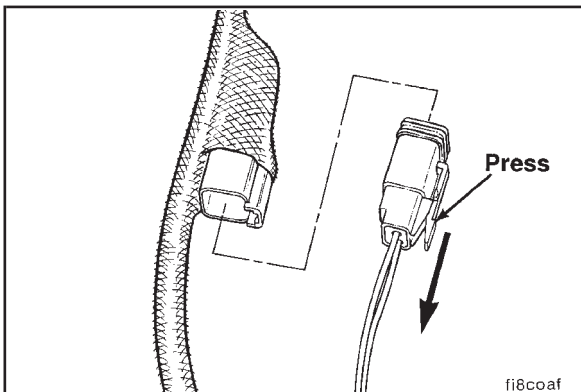
The harness and connectors **must** be clear of any moving parts so the wires will **not** be damaged during engine operation.





Use five wire clamps and capscrews (M8-1.25 x 20) to install the inside section of the actuator harness to the inside of the rocker housing. The harness and the connectors **must be** clear of any moving parts, so the wires will **not** be damaged during engine operation.

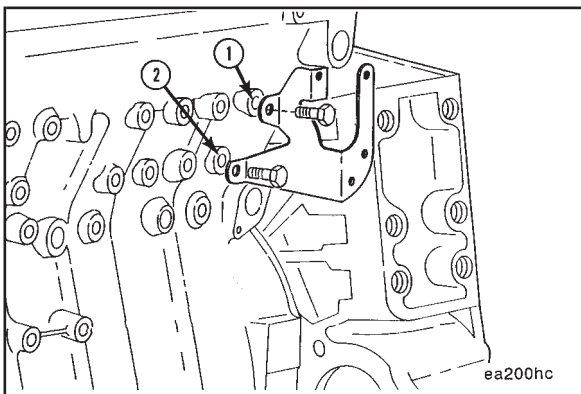
Torque Value: 20 N•m [15 ft-lb]



Lubricate the connector ends with lubricant DS-ES, Part No. 3822934.

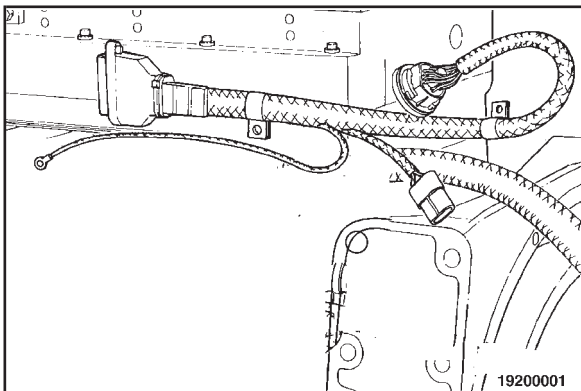


Connect the Deutsch two pin connectors from the internal actuator harness to the same injector as they were removed from.



Install the harness wire bracket to the cylinder block at points (1) and (2). Use two capscrews (M10-1.50 x 20).

Torque Value: 41 N•m [30 ft-lb]



Install the external actuator harness on the engine.

Install the harness holding clamps to the support bracket and to the rear of the engine block.



Tighten the capscrew.

Torque Value: 20 N•m [15 ft-lb]

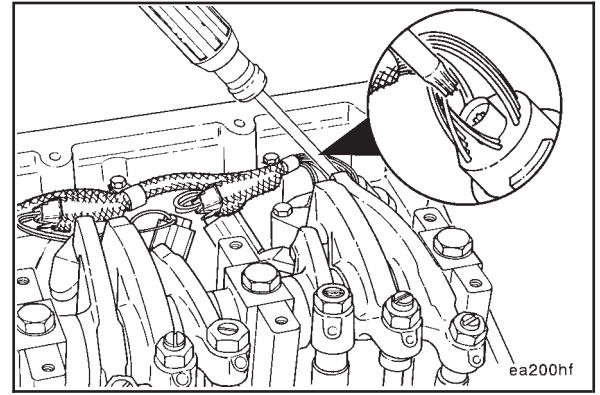
Install new o-ring seals on the connector ends of the internal and external actuator harness where it passes through the rocker lever housing.

Lubricate the connector with lubricant DS-ES, Part No. 3822934.

Install the ends through the rear end of the rocker lever housing.

Using a Torx® screwdriver (T-25), tighten the locking capscrew. The screw head is on the inside plug of the harness.

Torque Value: 1 N•m [11 in-lb]



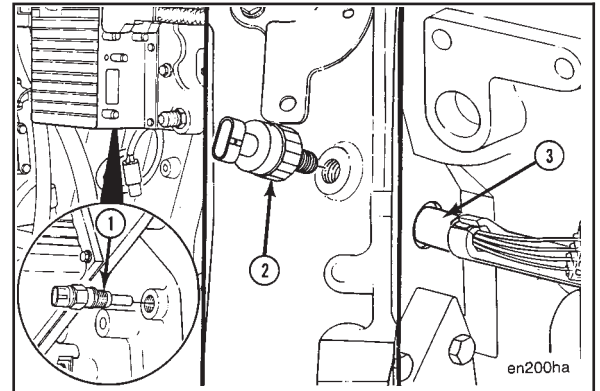
Install the oil temperature sensor (1) and the oil pressure sensor (2) to the cylinder block.

Torque Value:

- Temperature Sensor 34 N•m [25 ft-lb]
- Pressure Sensor 30 N•m [22 ft-lb]

Install the engine position sensor (3) to the rear of the gear housing.

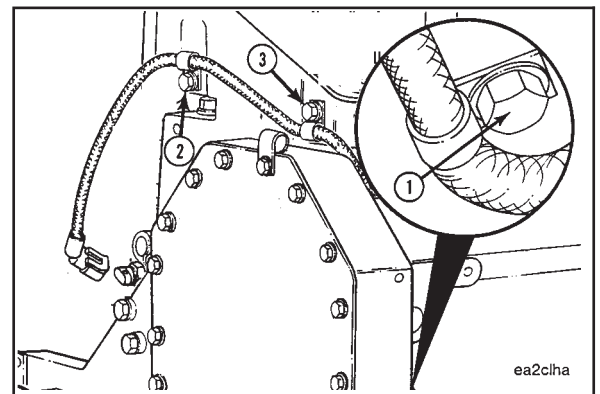
Torque Value: 34 N•m [25 ft-lb]



Sensor Harness - Installation

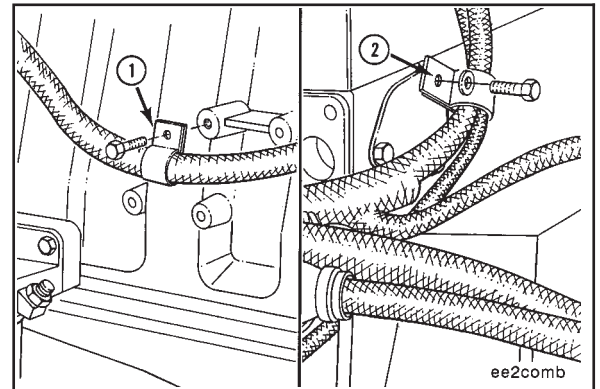
Install the sensor wire harness.

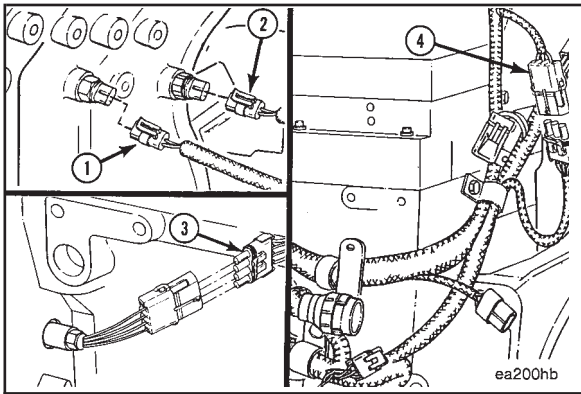
Use wire clamps to fasten the coolant temperature sensor lead to the gear housing (1), and to the front of the rocker lever housing (2) and (3).



Install a wire clamp around the sensor harness and actuator fuel shutoff solenoid wire, and fasten the clamp to the cylinder block at point (1).

Install another wire clamp around the intake temperature and boost pressure sensor wires and actuator harness, and fasten them to the camshaft rear cover plate (2).





NOTE: Care **must** be used when matching connectors with sensors. Each sensor has its own unique connection.

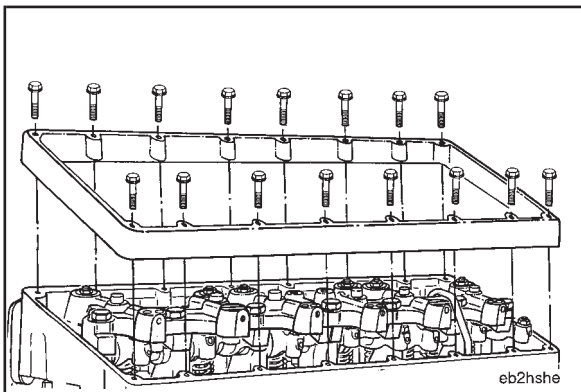


Lubricate the sensor harness wire connectors with lithium grease.

Connect the correct sensor harness wire connectors to the following sensors:

- oil temperature sensor (1),
- oil pressure sensor (2),
- engine position sensor (3).

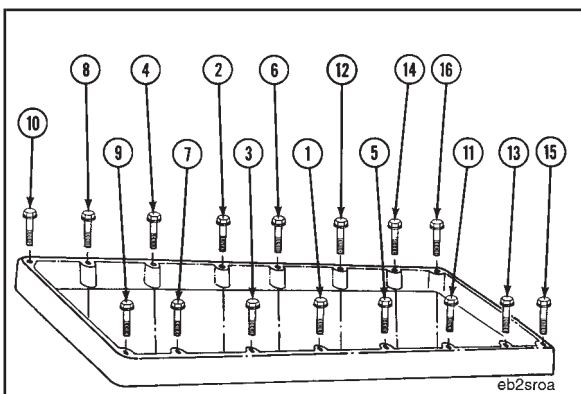
Connect the sensor and actuator harnesses together with Weather Pack connector (4).



Jacobs® Brake Housing Spacer - Installation

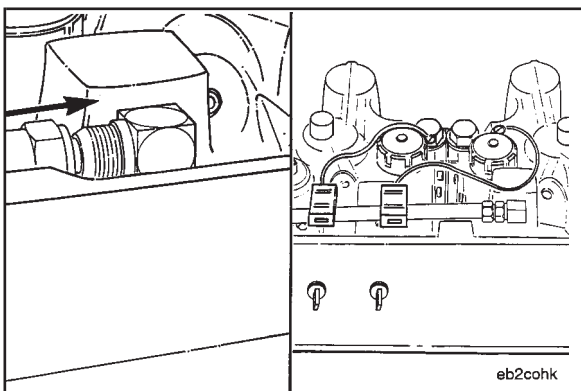
If the engine is equipped with Jacobs® Engine Brakes, apply a bead of sealant, Part No. 3823494 or equivalent, to the top of the rocker lever housing.

Install the spacer using 18 capscrews (M8-1.25 x 25) and washers provided with the Jacobs® Brakes.



Tighten the capscrews in the sequence shown.

Torque Value: 25 N•m [18 ft-lb]



Install and tighten the oil supply hose fitting to the front brake housing.

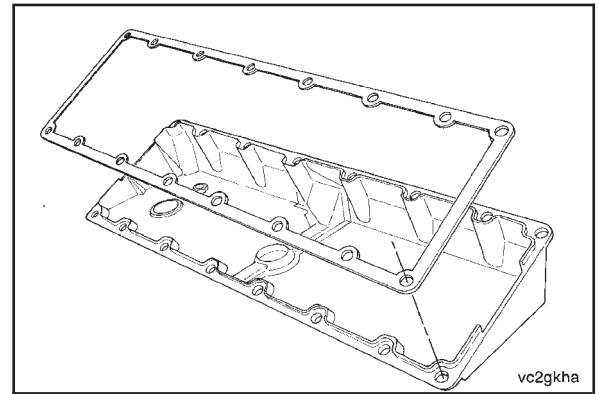
NOTE: Install the oil supply hose to the lubricating oil filter head after the filter head is installed.

Install the Jacobs® terminal lead outs in the spacer.

Connect the two solenoid electrical wires to the terminals on the inside of the spacer.

Rocker Lever Cover - Installation

Install a new gasket on the cover.



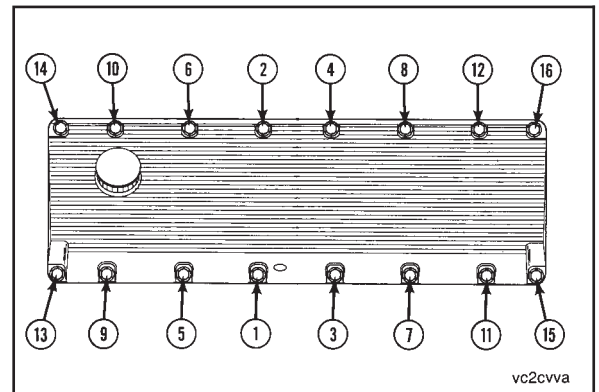
Install the cover on the rocker lever housing.

Install the 16 isolators and capscrews (M8-1.25 x 40) in the cover.

Tighten the capscrews in the sequence shown.

Torque Value: 15 N•m [130 in-lb]

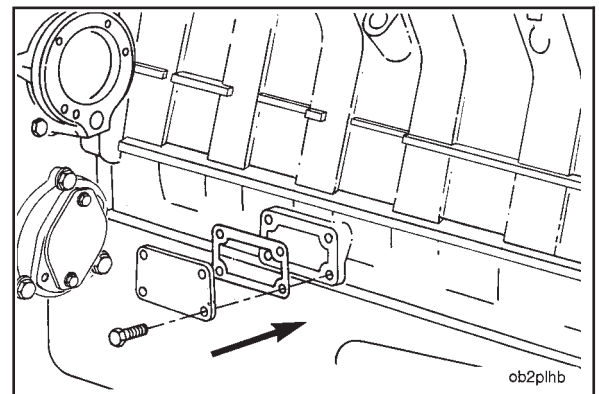
Install the breather hose and retaining clip.



Hand Hole Cover (Fuel Pump Side of Engine) - Installation

Use a new gasket and install the hand hole cover and the four capscrews (M10-1.50 x 20).

Torque Value: 47 N•m [35 ft-lb]



Air Compressor Coolant Inlet Tube Fitting - Installation

Loosen the locknut so there is space between the nut and o-ring.

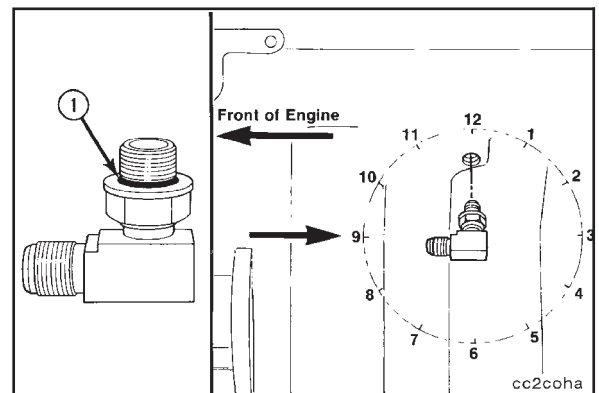
Apply a thin coat of oil to the o-ring.

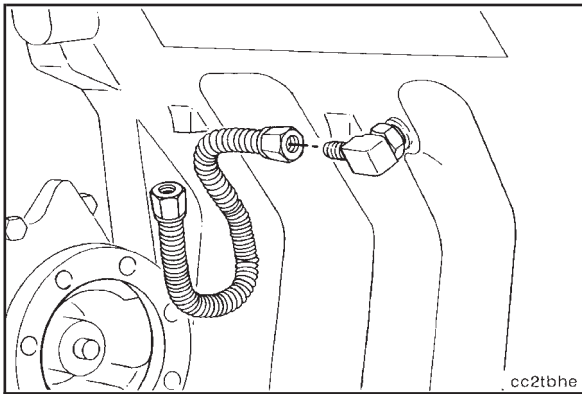
Install the fitting into the cylinder block until the o-ring contacts the block.

NOTE: The fitting must be installed with the threaded end at the 9:00 o'clock position.

Tighten the locknut.

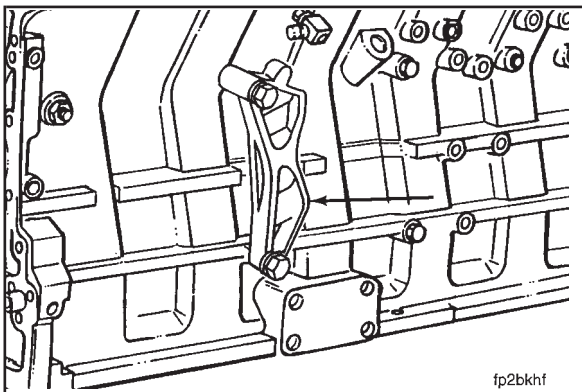
Torque Value: 47 N•m [35 ft-lb]





Install and tighten the coolant inlet tube to the fitting.

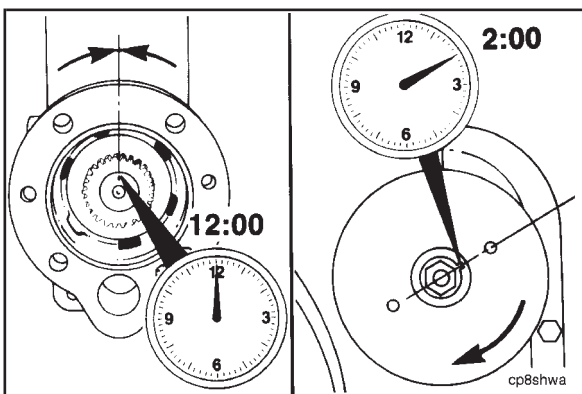
Torque Value: 40 N•m [30 ft-lb]



Fuel Pump Support Bracket - Installation

Install the fuel pump support bracket to the cylinder block with two mounting capscrews (M10-1.50 x 40).

Torque Value: 47 N•m [35 ft-lb]

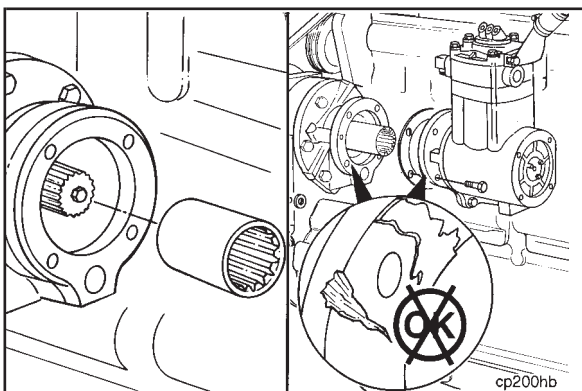


Air Compressor - Installation

NOTE: To reduce noise and vibration, the air compressor **must** be timed with the accessory drive.

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 (accessory drive pulley at TDC) position as viewed from the front of the engine.



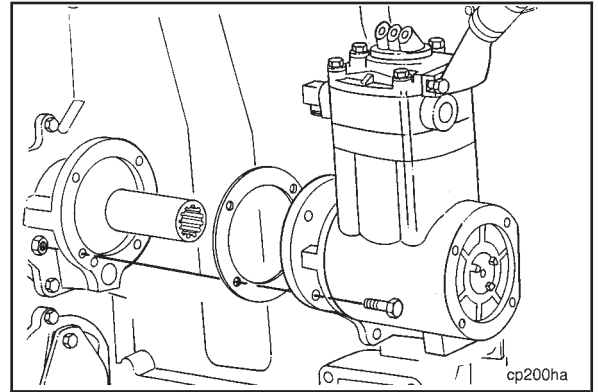
Install the spline coupling on the accessory drive shaft.

The gasket surfaces of the accessory drive and air compressor **must** be clean and free of damage.



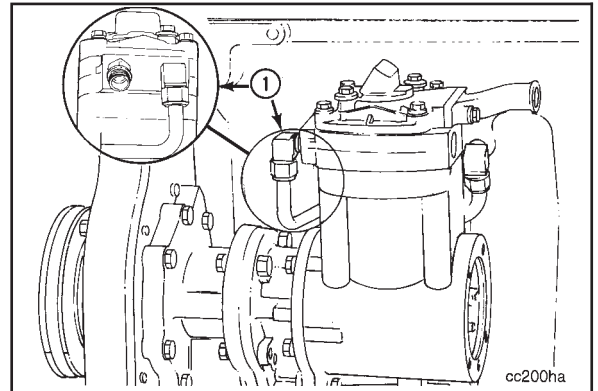
Use a new gasket and install the air compressor using four capscrews (7/16 - 14 x 1 7/8 inch) and two nuts (7/16 x 14).

Torque Value: 65 N•m [50 ft-lb]



Install the coolant inlet hose on the air compressor fitting (5) and tighten.

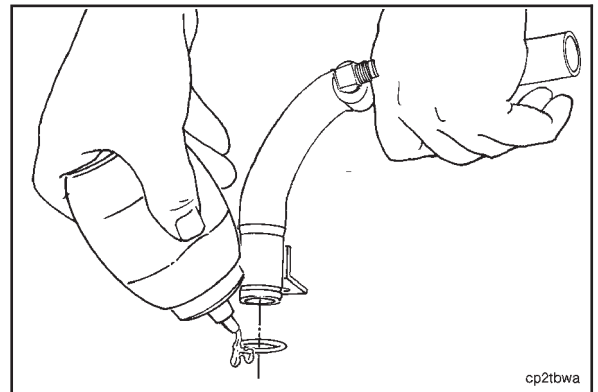
Torque Value: 40 N•m [30 ft-lb]



Air Compressor Air Supply Tube - Installation

Install the o-ring on the air supply tube.

Use vegetable oil to lubricate the o-ring.



Install a new hose (1) and two new hose clamps 1-3/4 inch (2) on the tube.

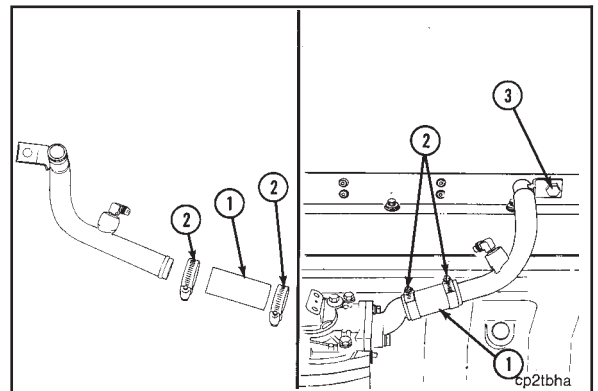
Use one capscrew (M10-1.50 x 20) to install the tube into the side of the cylinder head at location (3).

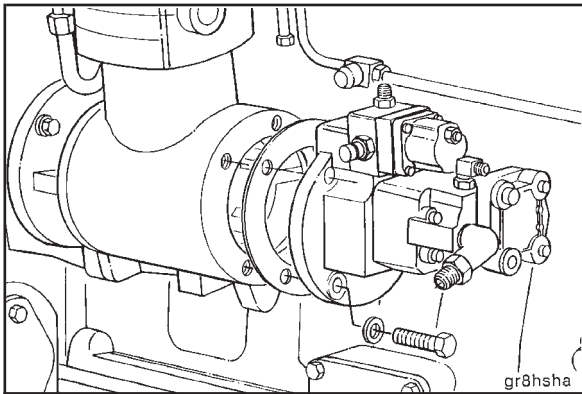
Torque Value: 47 N•m [35 ft-lb]

Install the hose (1) on the air compressor air supply connection.

Tighten the hose clamps (2).

Torque Value: 5 N•m [40 in-lb]





Fuel Pump (With Air Compressor) - Installation

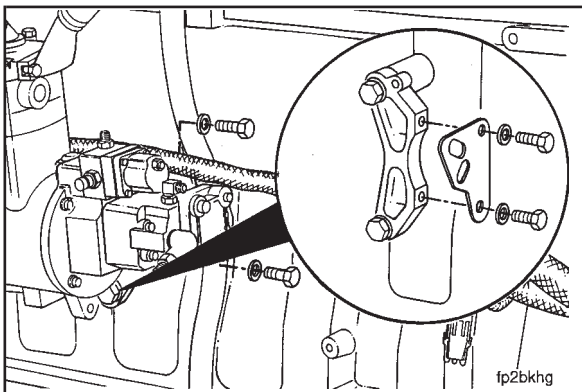


Install the spider coupling to the end of the air compressor crankshaft.

Use a new gasket to install the fuel pump.



Install the two outside 12 point mounting capscrews (7/16-14 x 1-1/4).



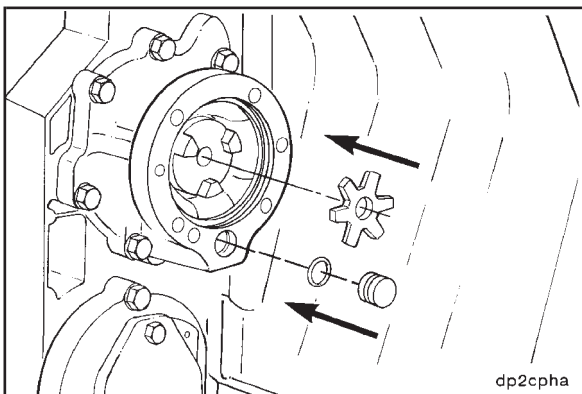
Install the two fuel pump support bracket capscrews (3/8-16 x 1) to the cylinder block bracket. Tighten the four fuel pump mounting capscrews.



Torque Value: 45 N•m [35 ft-lb]

Tighten the two support bracket to cylinder block mounting capscrews.

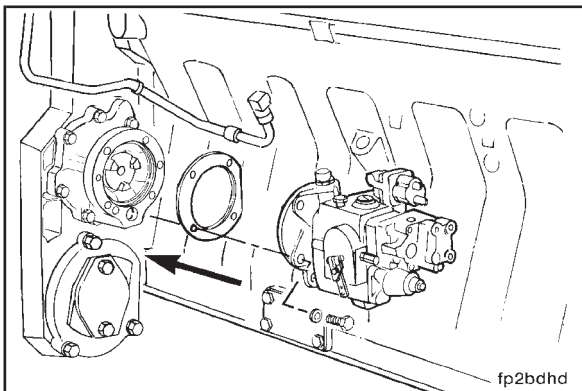
Torque Value: 45 N•m [35 ft-lb]



Fuel Pump (Without Air Compressor) - Installation

Install the spider coupling to the end of the accessory drive shaft.

Install the new o-ring on the accessory drive oil drain plug and install the plug into the accessory drive.



Use a new gasket and install the fuel pump on the accessory drive.

Install four capscrews (M10-1.50 x 45) and four nuts (M10-1.50).



Torque Value: 47 N•m [35 ft-lb]

Electronic Control Cooling Plate - Installation

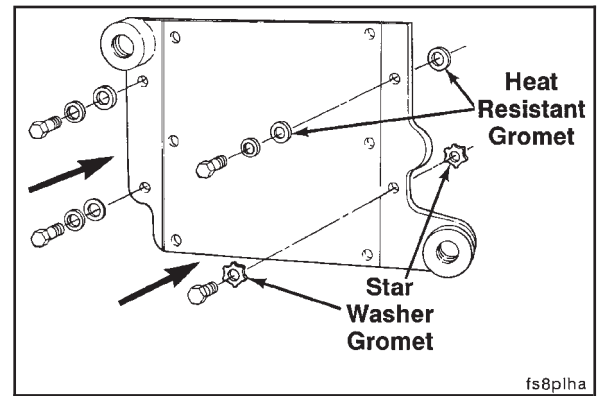
Install the electronic control cooling plate and the two mounting brackets. Use two capscrews (M10-1.50 x 100) in the bottom mounting holes and two capscrews (M10-1.50 x 60) in the upper mounting holes.

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]



Electronic Control Module - Installation

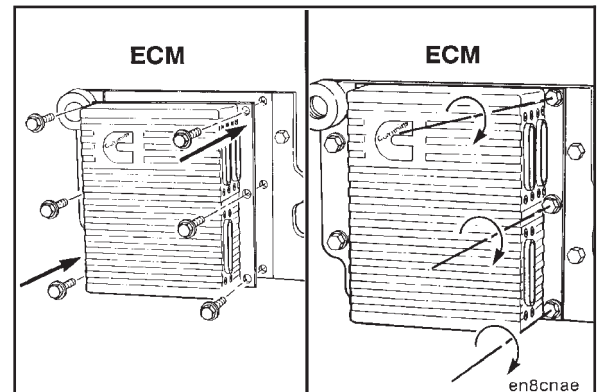
Caution: Do not paint the back side of the ECM. Make sure there is no grease or dirt between the ECM and the cooling plate.

Install the ECM to the electronic control cooler plate using six capscrews (M6-1.00 x 20).

Torque Value: 7 N•m [62 in-lb]

Make sure the star washer is installed under one of the capscrews.

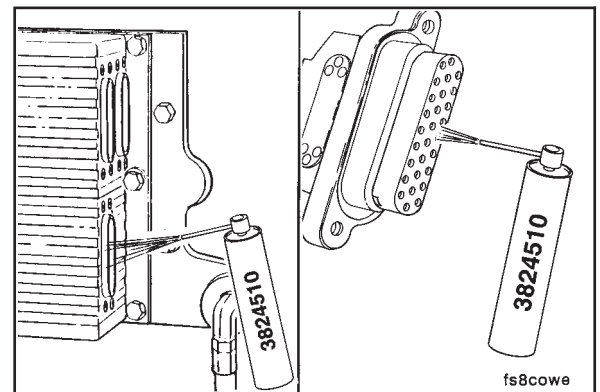
NOTE: Be sure the pins for the wire harness connectors in the ECM are **not** bent or damaged.



Caution: Do not blow compressed air onto the ECM ports or connectors. Compressed air can contain moisture due to condensation.

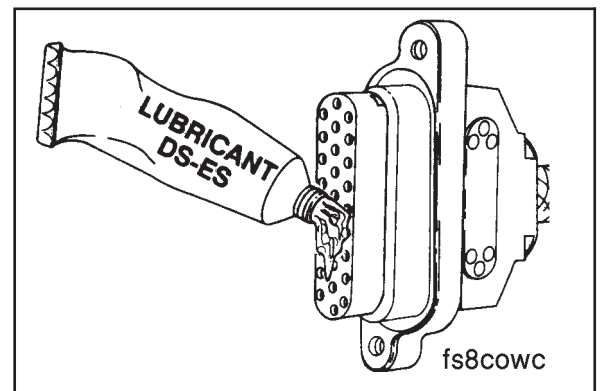
Remove all dirt and moisture from the ECM connector ports and the harness connector by spraying each with electronic contact cleaner, Part No. 3824510.

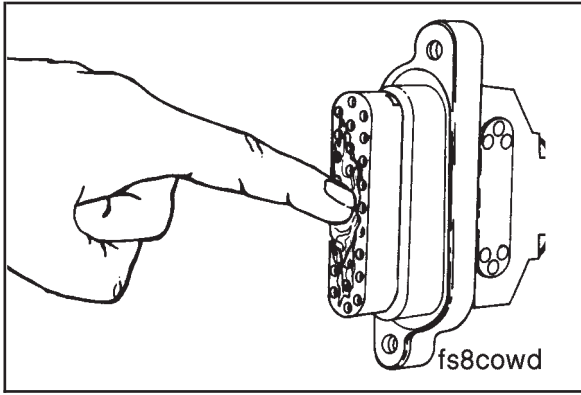
Allow the ports and connectors to dry.



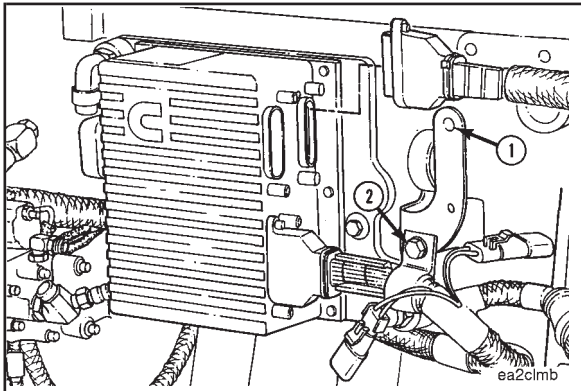
Caution: Use only Cummins recommended lubricant DS-ES, Part No. 3822934. Other lubricants such as lubricating oil or grease in the connectors can cause ECM damage, poor engine performance or premature connector pin wear.

Apply a thin coating of lubricant to the connector nose piece.





Spread the lubricant across the connector nose piece so it enters every pin hole and lubricates the contacts. Lubricant **must not** be visible on the surface of the nose piece.



Install the actuator wiring harness connector to the upper plug nearest the engine on the ECM.

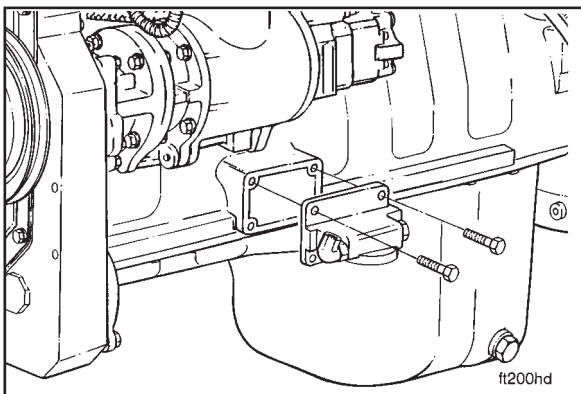


Install the sensor wiring harness connector to the lower plug on the ECM.

Tighten the connector capscrews.

Torque Value: 2.0 N•m [18 in-lb]

Use two wire clamps and two capscrews (M6-1.00 x 16) to fasten the actuator harness to the bracket at point (1) and the sensor harness to the bracket at point (2).



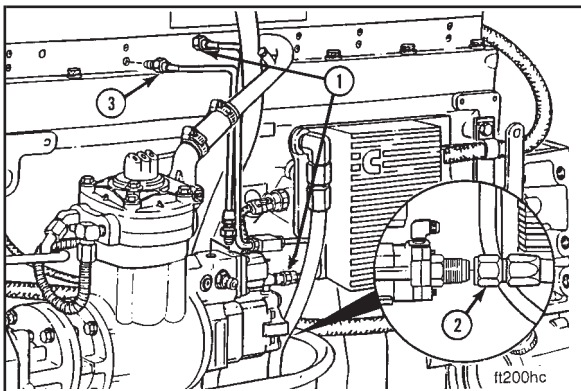
Fuel Filter Head and Bracket - Installation

Different engine applications can have the fuel filter bracket and filter head mounted at different locations on the engine. Some engines have a pump mounted filter head. Install the bracket and filter head in the same location it was removed from.



Use four capscrews (M10-1.50 x 25) to install the filter head to the engine.

Torque Value: 47 N•m [35 ft-lb]



Fuel Pump Plumbing - Installation

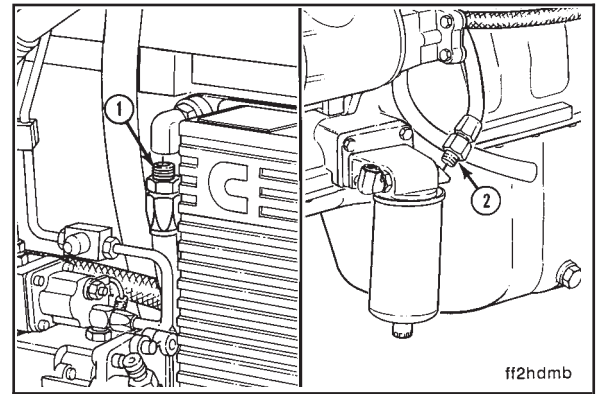


Install the fuel lines:

- fuel drain from T-block connection (1),
- fuel pump supply (2),
- fuel supply to injectors (3).

Install the correct actuator harness wire connector to the fuel shutoff valve.

Install the fuel suction line from the electronic control cooling plate (1) to the filter head (2).



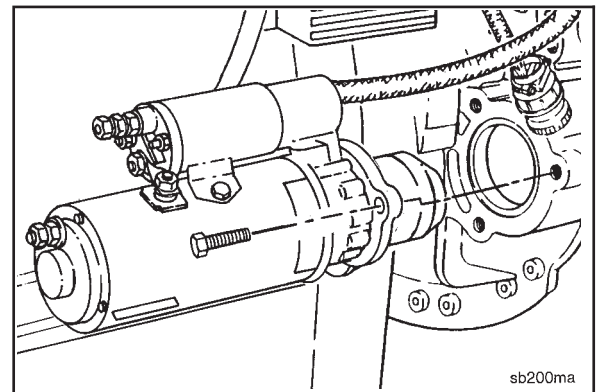
Starting Motor - Installation

The mounting capscrews for the starting motor will be metric (M16-2.00 x 45) 12 point, or U.S. Customary (5/8-11 x 3/4) hex head, depending on the flywheel housing used. Make sure to use the correct capscrews to avoid damage to the threaded holes in the flywheel housing.

Install the spacer if required.

Install the starting motor into the flywheel housing bore with the three capscrews.

Torque Value: 90 N•m [140 ft-lb]



Air Compressor Coolant Outlet Tube - Installation

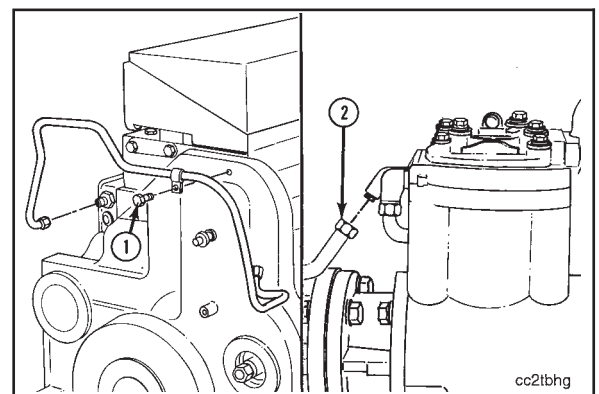
Remove capscrew (1) from the gear cover.

Use the capscrew to install the coolant outlet clamp and tube to the engine.

Torque Value: 20 N•m [15 ft-lb]

Install a new rubber grommet on the air compressor tube, and install and tighten the tube connection to the air compressor fitting (2).

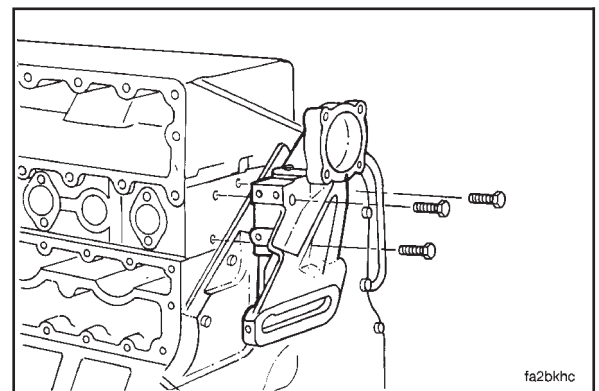
Torque Value: 20 N•m [15 ft-lb]

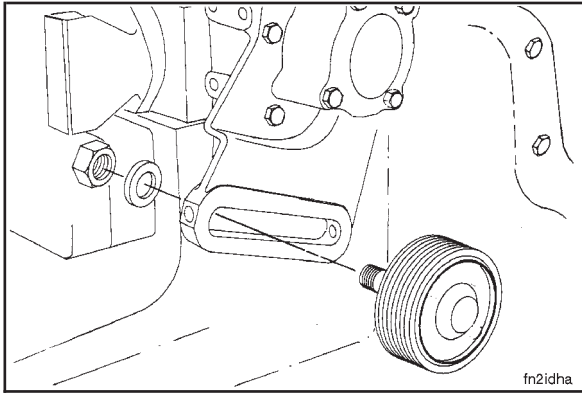


Fan Hub Support - Installation

Install the fan hub support with three capscrews (M12-1.75 x 80).

Torque Value: 75 N•m [55 ft-lb]





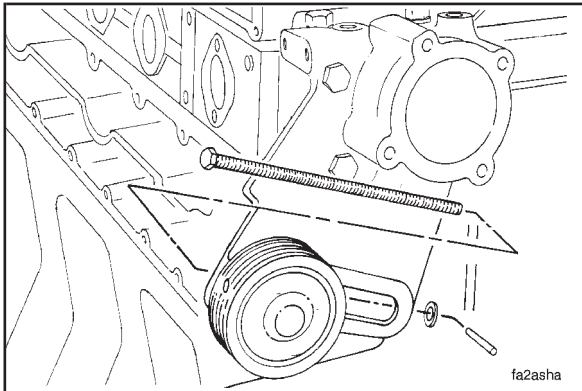
Fan Idler Pulley - Installation



Install the idler pulley into the fan hub support bracket.

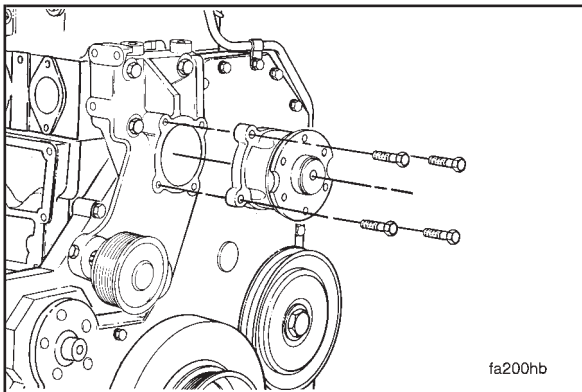
Install the washer and locknut on the idler pulley shaft.

Do not tighten the locknut until the fan drive belt has been installed and adjusted.



Install the adjusting screw (M10-1.50 x 170) into the idler pulley shaft.

Turn the adjusting screw in far enough to install the washer and roll pin into the shaft at the bottom of the fan hub support bracket.



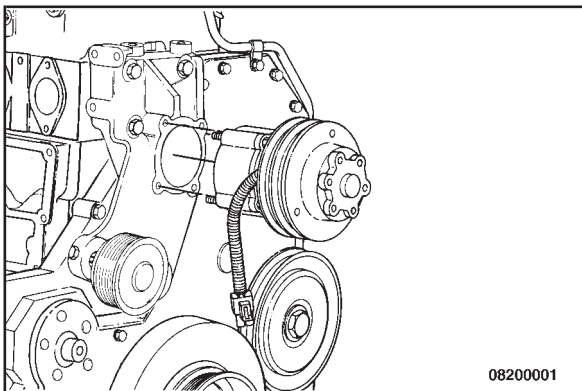
Fan Hub (Belt Driven) - Installation



Install the fan hub on the fan hub support bracket with four cap screws (M10-1.50 x 30).



Torque Value: 47 N•m [35 ft-lb]



Electric Fan Clutch (Cummins) - Installation



Install the fan hub, clutch, and cap screws. Tighten the cap screws alternately and evenly.



Torque Value: 47 N•m [35 ft-lb]

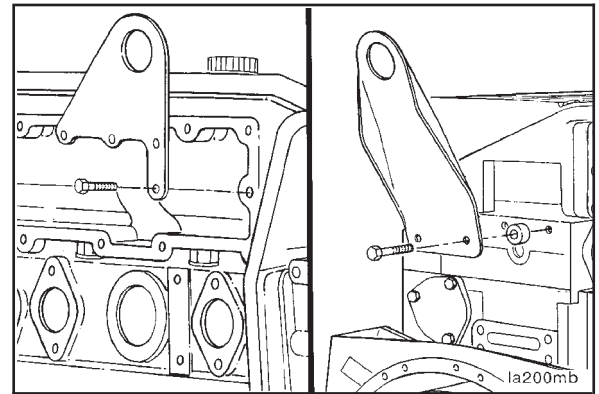
Connect the fan clutch connector on the base wiring harness to the fan clutch.

Engine - Removal From The Rebuild Stand

Use four capscrews (M10-1.50 x 40) and temporarily install the front lifting bracket to the rocker lever housing.

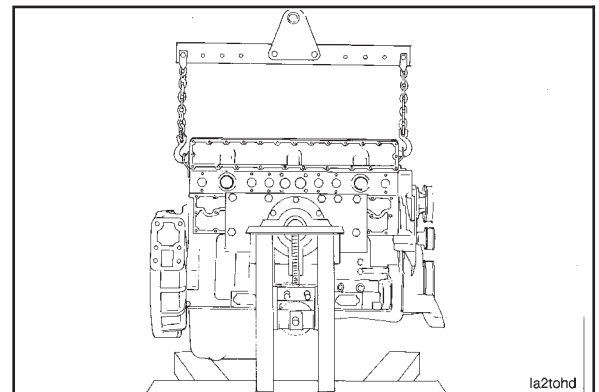
Use two capscrews (M12-1.75) and fasten the rear lifting bracket to the cylinder head.

Torque Value: 70 N•m [55 ft-lb]



Warning: To prevent personal injury, use a properly rated hoist to lift the engine. The engine weighs approximately 940 kg [2070 lb].

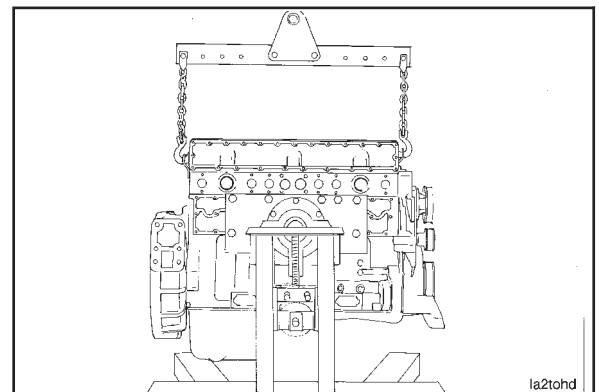
Use lifting fixture, Part No. 3822512, and a hoist with a minimum lifting capacity of 1.8 M ton [2.0 tons] to lift the engine.



Warning: The engine can move or drop a small distance as it is being removed from the rebuild stand. Use extreme care to prevent personal injury.

Use the hoist and lifting fixture to apply lifting tension to the engine.

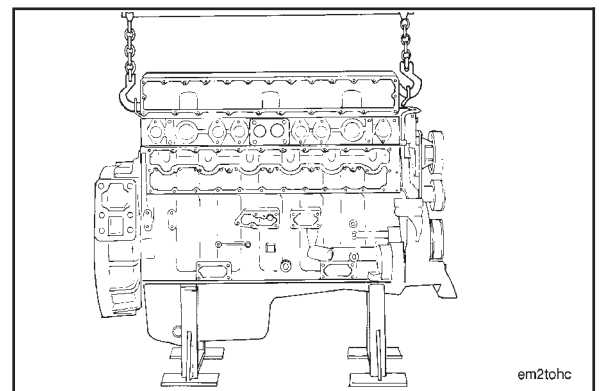
Remove the ten capscrews that hold the engine to the adapter plate.

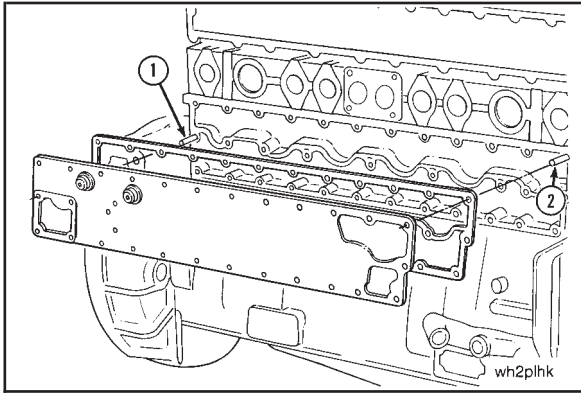


Lower the engine to the engine support stands, Part No. 3376057, or a shipping skid with the hoist.

Remove the hoist and lifting fixture from the engine.

Remove the front lifting bracket.





Water Header Plate - Installation



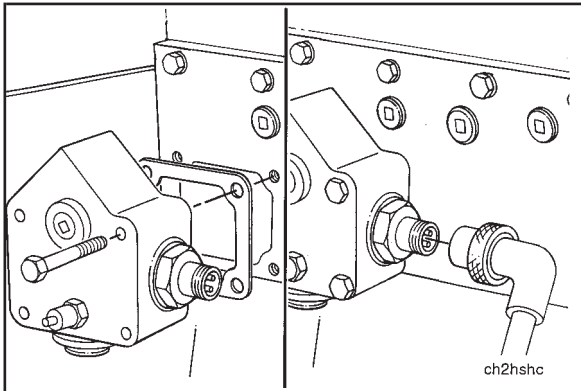
Install two guide pins, Part No. 3376488, in the side of the cylinder block at locations (1) and (2).

Use a new gasket and install the water header plate with 18 capscrews (M10-1.50 x 25).

NOTE: The capscrews are not tightened to their final torque value at this time.



Torque Value: 20 N•m [15 ft-lb]



Water Heater Housing - Installation

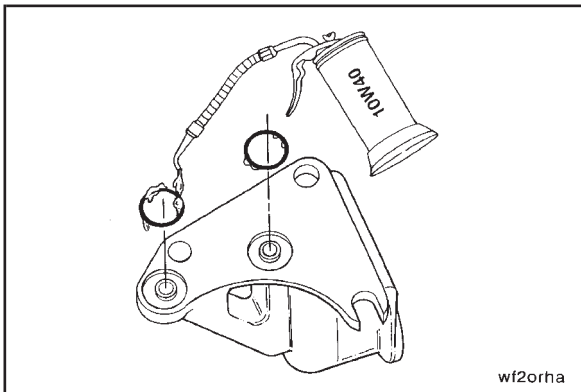


Use a new gasket and install the water heater housing with four capscrews (M10-1.50 x 90).

NOTE: The capscrews are **not** tightened to their final torque value at this time.



Torque Value: 20 N•m [15 ft-lb]

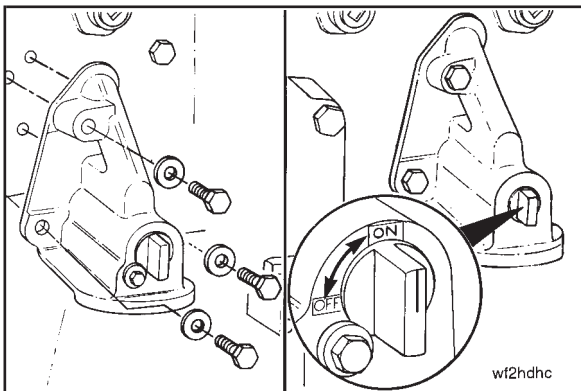


Water Filter Head - Installation



Use clean 15W-40 oil to lubricate the two new o-rings.

Install the o-rings into the filter head.



Install the filter head with two capscrews (M10-1.50 x 35) and one capscrew (M10-1.50 x 65).

NOTE: The capscrews are **not** tightened to their final torque value at this time.



Torque Value: 20 N•m [15 ft-lb]



Caution: The control valve must be in the "ON" position to prevent engine damage.

Turn the control valve to the "ON" position.

Thermostat Housing Support - Installation

Use a new gasket and install the support with four capscrews (M10-1.50 x 35).

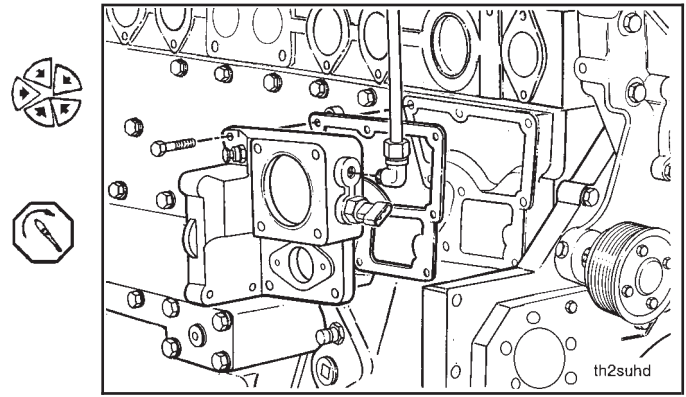
NOTE: The capscrews **are not** tightened to their final torque value at this time.

Torque Value: 20 N•m [15 ft-lb]

Install the air compressor water outlet tube to the fitting on the thermostat housing support.

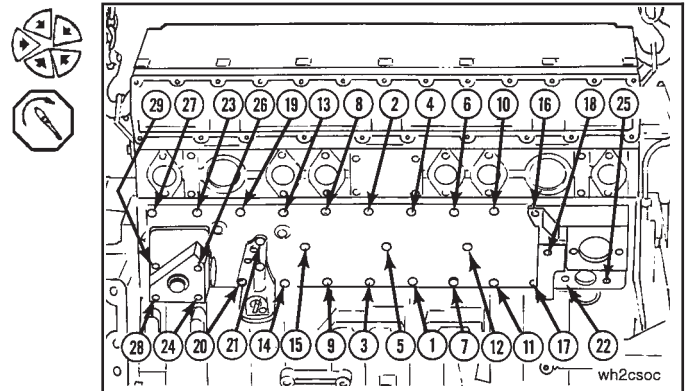
Torque Value: 20 N•m [15 ft-lb]

Install the sensor harness coolant temperature sensor connector to the coolant temperature sensor.



Tighten the water header plate capscrews in the sequence shown.

Torque Value: 55 N•m [40 ft-lb]

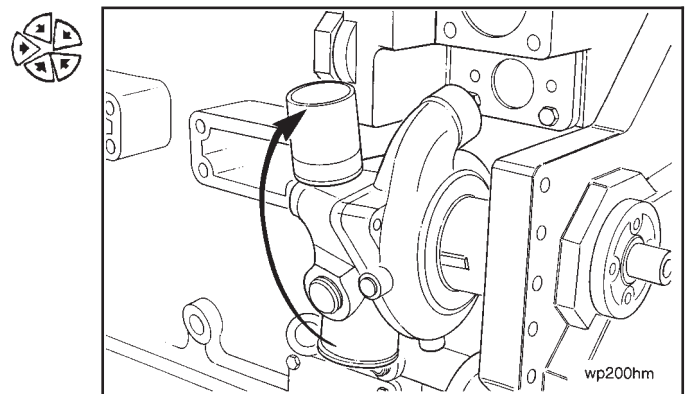


Water Pump - Installation

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.

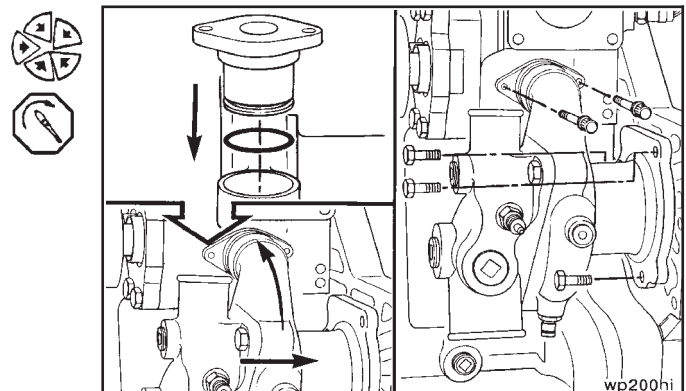
Install the connection into the water pump.

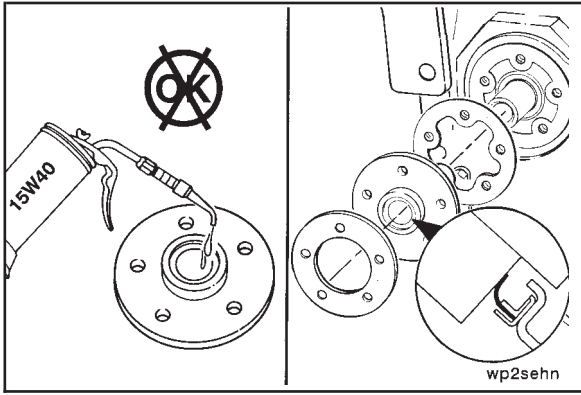
Twist the water pump inward and install the three water pump mounting capscrews.

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]





Alternator Drive Seal - Installation



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.

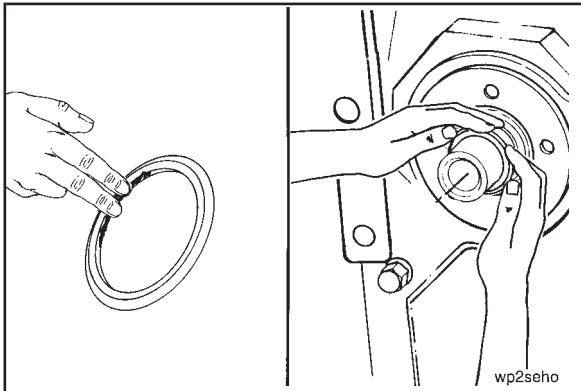
Use the installation sleeve provided in the seal kit to install the new seal and gasket.

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 in two steps.

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



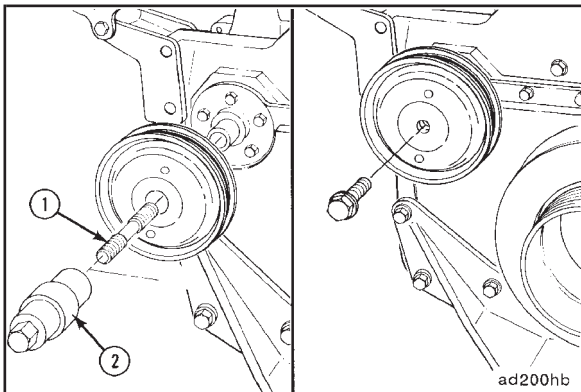
Place a light film of oil or anti-freeze on the inside diameter of the oil seal dust seal.



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.



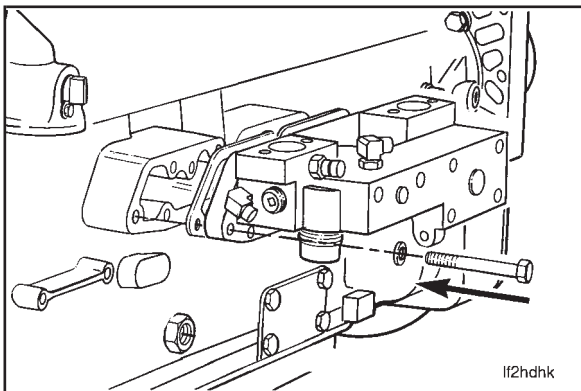
Alternator Drive Pulley - Installation



Use pulley pusher adapter (1), Part No. 3377401, and pulley installation tool (2), Part No. 3376326, to install the pulley.

Install the pulley retainer capscrew (M12-1.75 x 40).

Torque Value: 75 N•m [55 ft-lb]



Lubricating Oil Filter Head - Installation



Use a new gasket and install the filter head with six capscrews (M10-1.50 x 170) and three capscrews (M10-1.50 x 30).



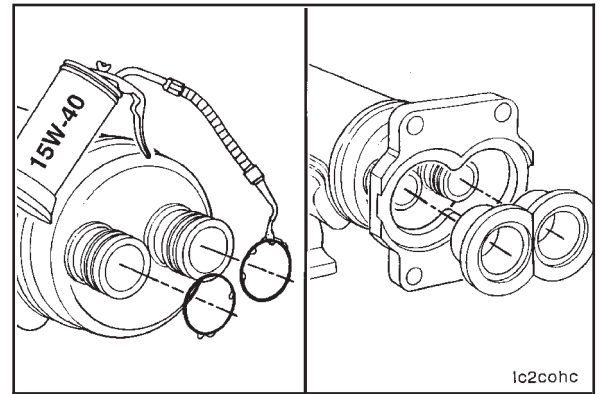
Torque Value: 47 N•m [35 ft-lb]

Lubricating Oil Cooler - Installation

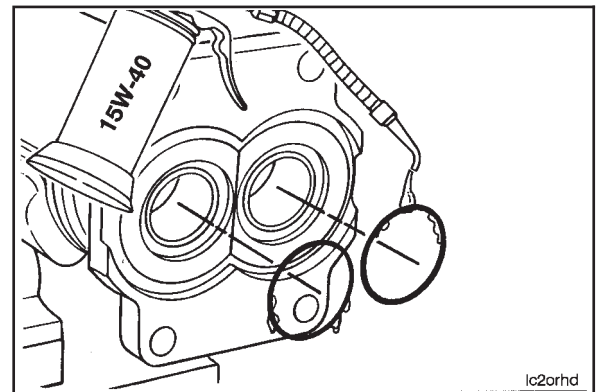
Install two new o-rings on the water inlet and outlet transfer tube ends of the oil cooler.

Lubricate the o-rings with clean 15W-40 engine oil.

While holding the retainer connection in place, install both o-ring adapters onto the oil cooler tube ends as far as possible. The straight edges of the o-ring adapters **must** face each other when installed.



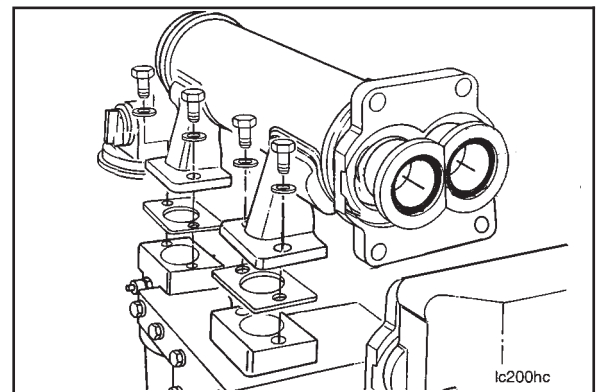
Install two new o-rings on the ends of the o-ring adapters.
Lubricate the o-rings with clean 15W-40 engine oil.



Install two new gaskets on the lubricating oil filter head.
Install the oil cooler on the engine with mounting capscrews (M10-1.50 x 30).

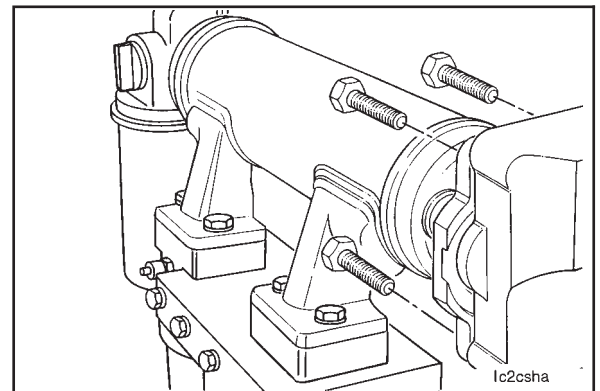
Tighten the capscrews alternately and evenly.

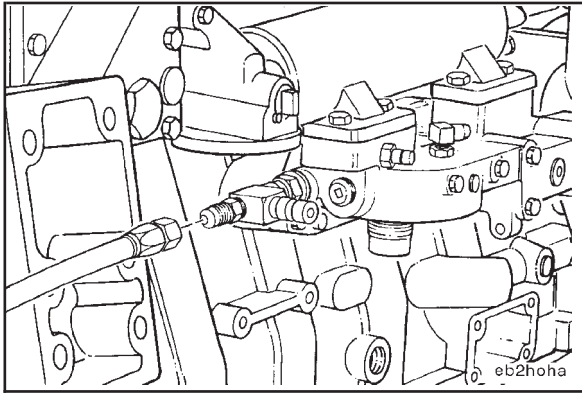
Torque Value: 47 N•m [35 ft-lb]



Install the four retainer connection mounting capscrews.
Tighten the capscrews alternately and evenly.

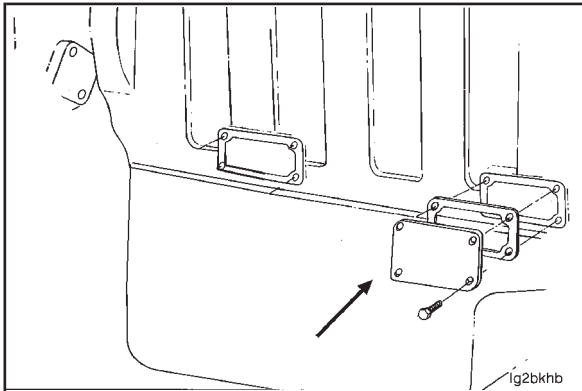
Torque Value: 47 N•m [35 ft-lb]





Jacobs® Brake Oil Supply Hose - Installation

Install and tighten the oil hose on the oil filter head and Jacobs® Brake connections.

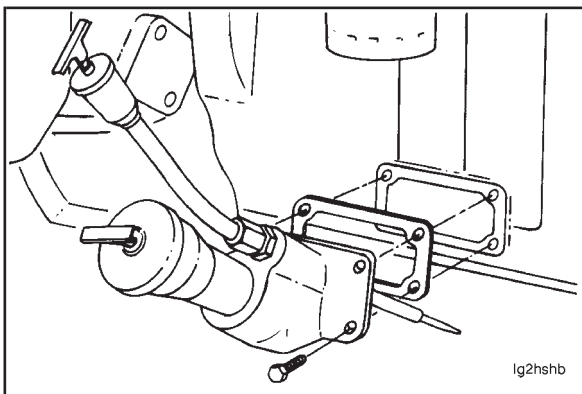


Hand Hole Cover (Exhaust Side of Engine) - Installation

Use a new gasket and install the cover with four capscrews (M10-1.50 x 20).



Torque Value: 47 N•m [35 ft-lb]

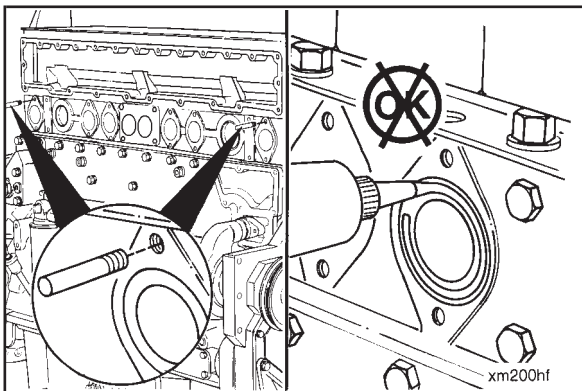


Dipstick Tube Bracket - Installation

Use a new gasket and install the tube bracket with four capscrews (M10-1.50 x 20).



Torque Value: 47 N•m [35 ft-lb]



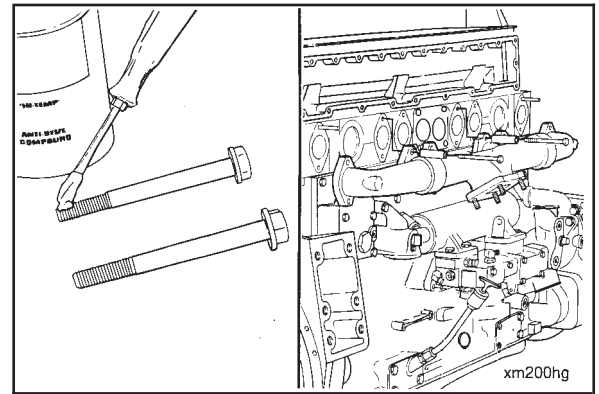
Exhaust Manifold - Installation

Install two guide pins, Part No. 3376488, into the cylinder head.

The gaskets can be installed with either side facing out. **Do not** use an adhesive to hold the gaskets in place on the cylinder head.

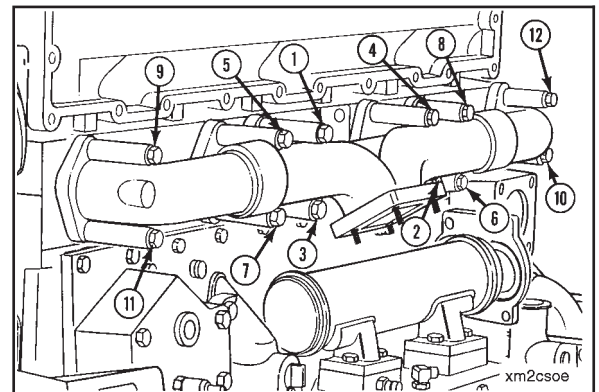
Use high temperature anti-seize compound, Part No. 3823097 or equivalent, to coat the capscrew threads, this will aid future capscrew removal.

Install the exhaust manifold with twelve capscrews (M10-1.50 x 100) and tubular spacers.



Tighten the capscrews in the sequence shown.

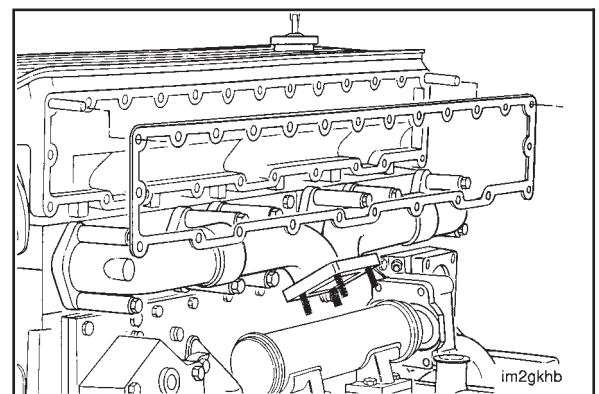
Torque Value: Step 1 - 27 N•m [20 ft-lb]
2 - 47 N•m [35 ft-lb]



Air Intake Manifold - Installation

Install two guide pins, Part No. 3376696, into the rocker lever housing.

Install a new gasket.



Install the intake manifold.

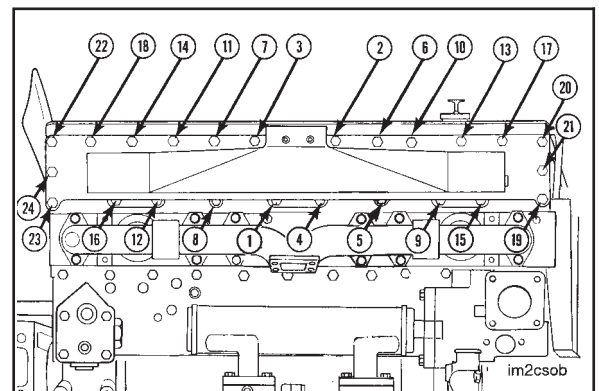
Install the front lifting bracket using three capscrews (M10-1.50 x 50) in locations 17, 20 and 21. Install one capscrews (M10-1.50 x 48) capscrew in location 13.

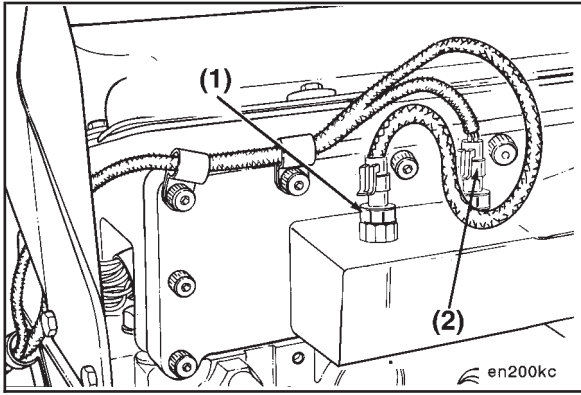
Install the two sensor harness wire clamps at locations 18 and 24.

Install the remaining capscrews (M10-1.50 x 40).

Tighten the capscrews in the sequence shown.

Torque Value: 47 N•m [35 ft-lb]





Install a new sealing ring and the boost pressure sensor and the intake manifold temperature sensor.

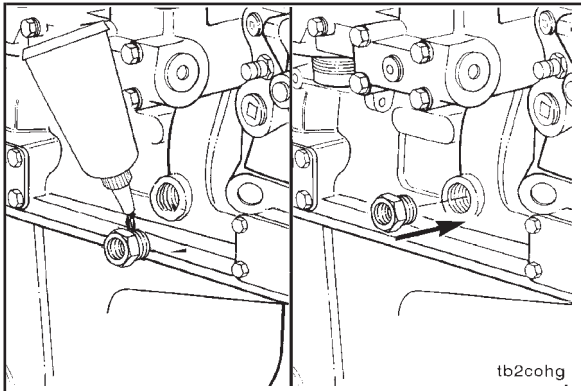
Torque Value: 27 N•m [20 ft-lb]



Install the correct sensor harness wire connectors to the sensors.

Use a new gasket and install the air connection to the intake manifold. Use four capscrews (M10-1.50 x 22).

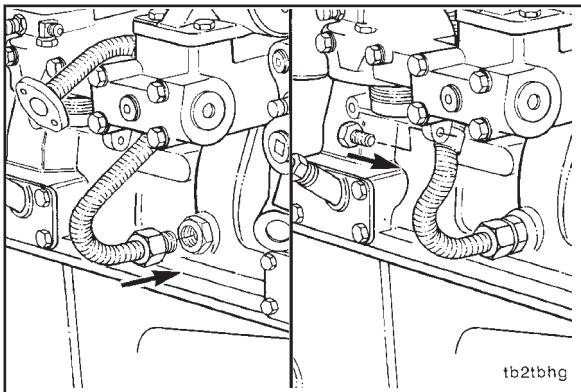
Torque Value: 41 N•m [30 ft-lb]



Turbocharger Drain Fitting - Installation

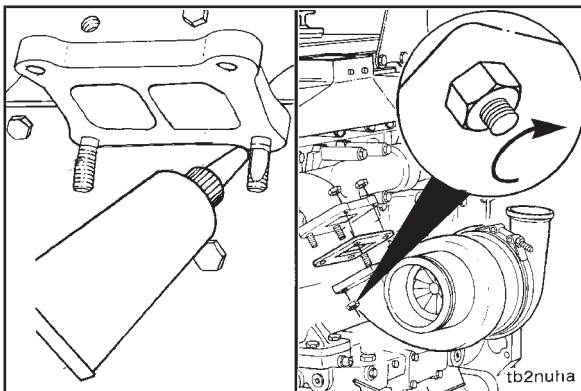
Apply a film of pipe sealant, Part No. 3375066, to the threads of the drain fitting.

Install and tighten the fitting into the cylinder block.



Insert the flexible turbo oil drain tube behind the filter head and install on the fitting.

Install the clamp and capscrew.



Turbocharger - Installation

Install a new gasket on the exhaust manifold.

Apply a film of high temperature anti-seize compound to the turbocharger mounting studs.



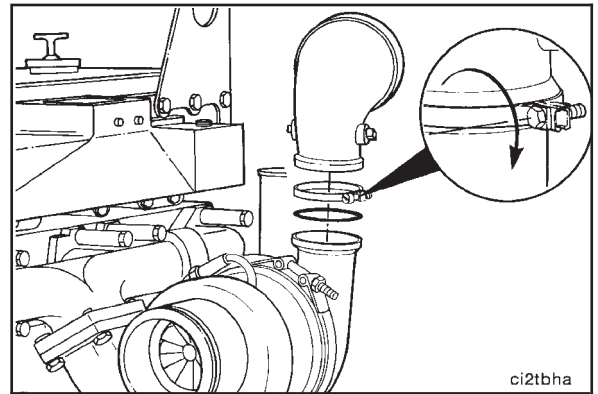
Install the turbocharger and four mounting nuts.

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.

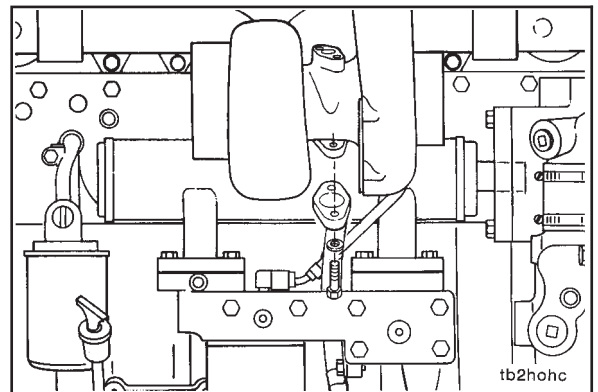
Tighten the clamp.

Torque Value: 8 N•m [75 in-lb]



Install and tighten the oil drain line.

Torque Value: 27 N•m [20 ft-lb]

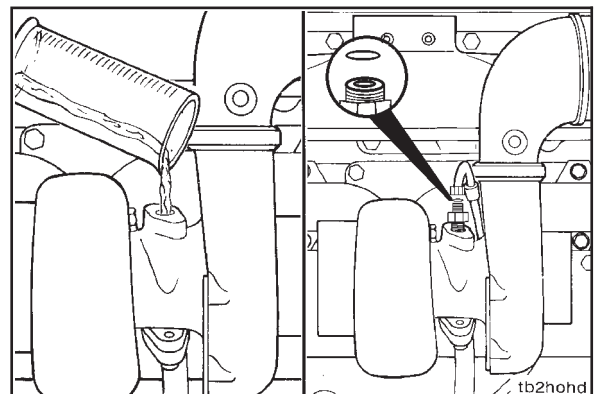


Pour 50 to 60 cc [2.0 to 3.0 ounces] of clean engine oil in the oil supply hole of the turbocharger.

Install the oil supply line to the turbocharger with two capscrews (M8-1.25 x 20).

Torque Value: 20 N•m [15 ft-lb]

Install the other end of the supply line to the lubricating oil filter head and tighten.

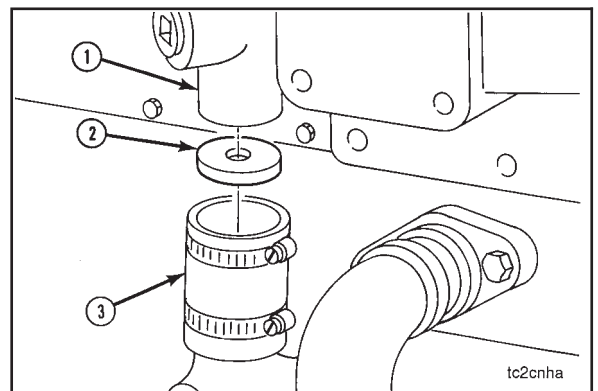


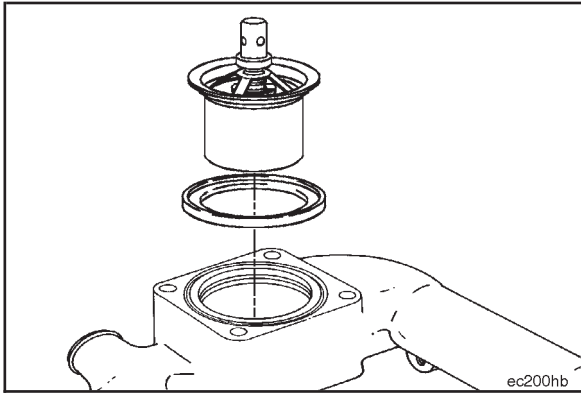
Torque Converter Cooler Disc - Installation

Install the water pump bypass hose (3) and two hose clamps onto the water pump. Do **not** tighten the hose clamps at this time.

Install the disc (2) into the water pump bypass hose.

Install the top hose clamp for the thermostat housing connection (1).



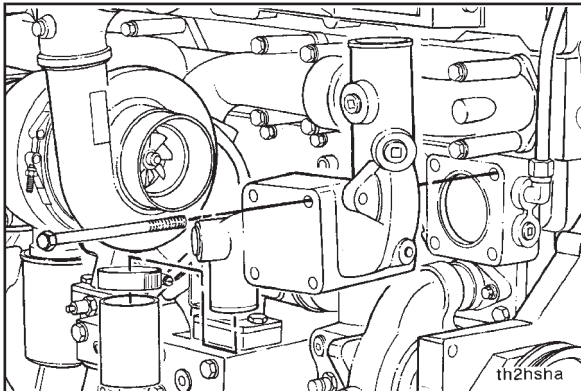


Thermostat Housing - Installation



Install the thermostat into the housing.

Install a new seal in the groove on the thermostat housing mounting surface.



Install the thermostat housing with four capscrews (M10-1.50 x 145).

Torque Value: 54 N•m [40 ft-lb]

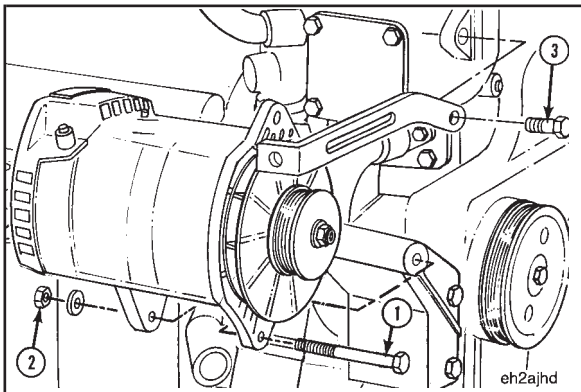


Evenly space the bypass hose on the water pump and thermostat housing connections.



Tighten the hose clamps.

Torque Value: 3 N•m [30 in-lb]



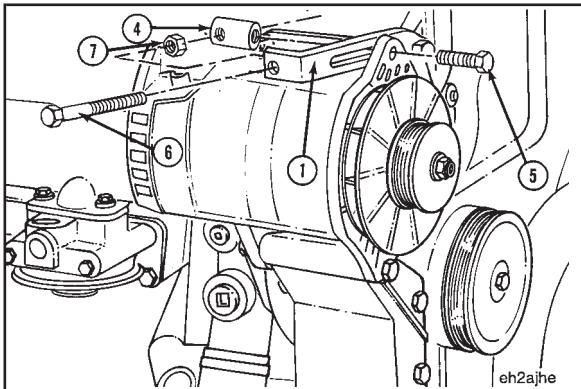
Alternator - Installation



NOTE: Do not tighten any of the capscrews and nuts to their final torque value until the alternator belt is installed and adjusted.

Install the alternator with one (1/2-20 x 6.0) capscrew (1) and a (1/2 x 20) nut (2) with washer.

Install the adjusting link to the thermostat housing with one (M12-1.75 x 30) capscrew (3).



Install the adjusting screw retainer (4) and capscrew (5) through the adjusting link and alternator mounting support.

Install the (1/2-13 x 5.75) adjusting screw (6) into the adjusting link (1).

Install a (1/2 x 13) locknut (7) on the adjusting screw (6).

Install the adjusting screw (6) into the retainer (4).

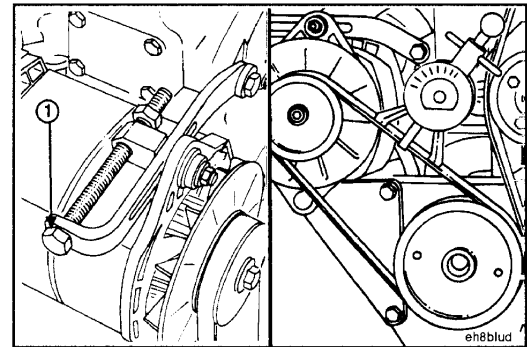
Alternator Belt (Non Bus Applications) - Installation

Install a new belt on the water pump and alternator pulleys.

Turn the adjusting screw (1) **clockwise** to increase the belt tension.

Use belt tension gauge, Part No. ST-1293, to measure the belt tension.

NOTE: Refer to the belt tension chart in Section V for the correct belt adjustment.



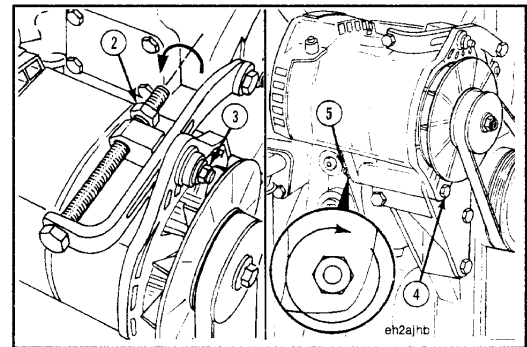
Tighten the adjusting screw locknut (2) against the retainer.

Tighten adjusting link locknut (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]



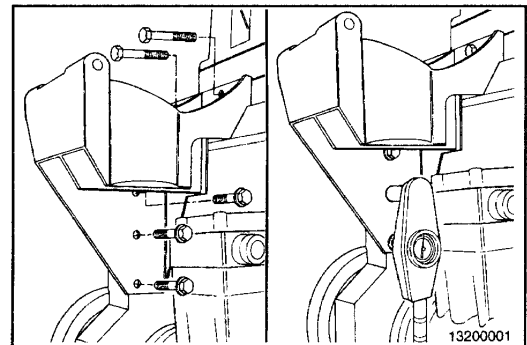
Alternator and Bracket (Bus Applications) - Installation

Install the lower alternator bracket on the engine using the capscrews that were removed. The two longer capscrews are used in the bracket to cylinder head mounting holes.

Check to be sure the bracket is flat against the gear housing, the cylinder block, and the cylinder head before torquing the capscrews.

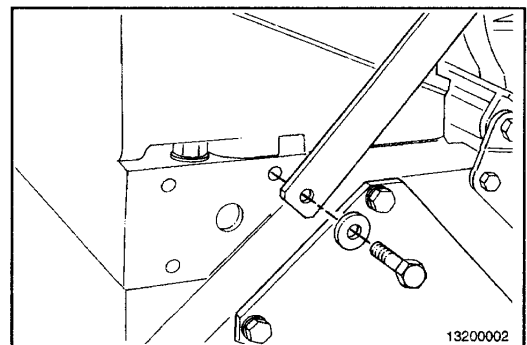
Alternately and evenly, tighten the alternator bracket mounting capscrews.

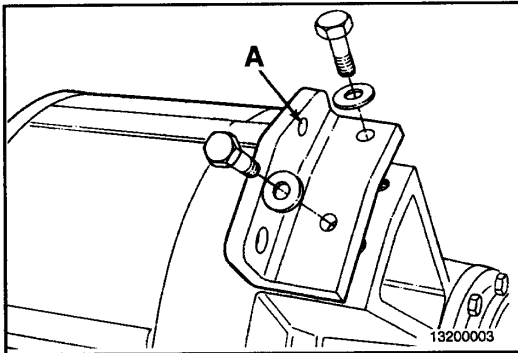
Torque Value: 47 N•m [35 ft-lb]



Install one end of the alternator link to the cylinder head using a (M12-1.75 x 30) capscrew with a hardened plain washer. Do **not** torque the capscrew at this time.

Twist the link back out of the way until the alternator is mounted.





Caution: A (3/8-16) tapped hole (A) is provided for customer use as a grounding location. Do not place ground straps under mounting cap screws. This will cause the cap screws to lose torque, and can lead to alternator and bracket damage.

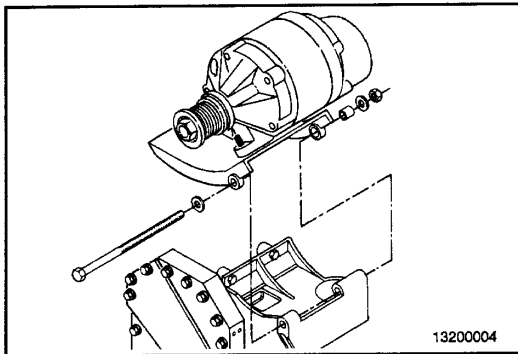


Install the alternator top bracket to the alternator using two cap screws (3/8-16 x 1 inch) and two hardened plain washers.



Torque the two cap screws.

Torque Value: 54 N•m [0 ft-lb]



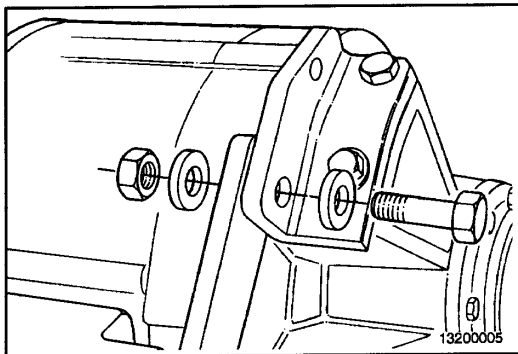
NOTE: Use one washer under the head of the cap screw and one under the locknut.



Install the alternator and upper bracket onto the lower alternator bracket loosely using the pivot cap screw (1/2-13 x 7 inch), if **not** damaged, and two hardened plain washers.

NOTE: Do **not** torque the cap screw at this time.

Use a prevailing-torque locknut (1/2-13).

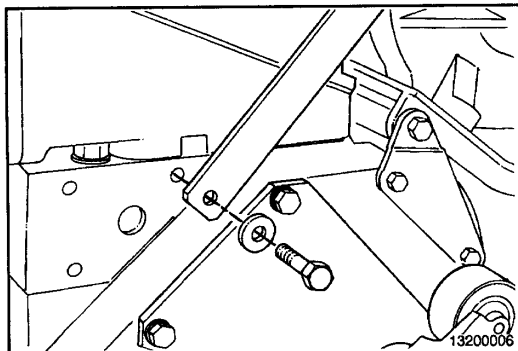


Install the unattached end of the alternator top link to the back side of the top alternator bracket using cap screw (1/2-13) and locknut (1/2-13). Use one hardened plain washer under the head of the cap screw and one under the nut.



Torque the cap screw and locknut.

Torque Value: 128 N•m [95 ft-lb]



Torque the top link to cylinder head mounting cap screw.

Torque Value: 102 N•m [75 ft-lb]

Torque the alternator pivot mounting cap screw.

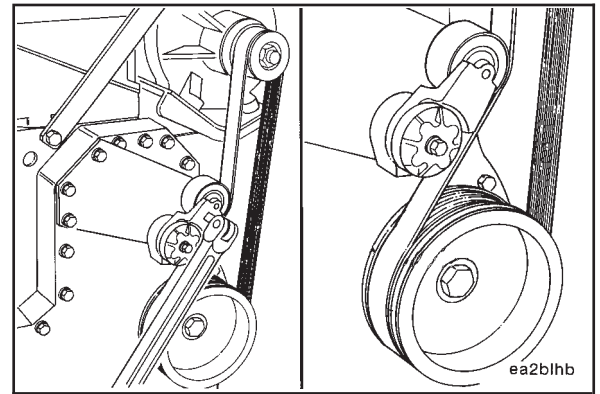
Torque Value: 128 N•m [95 ft-lb]

Alternator Drive Belt (Bus Applications) - Installation

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.



Fan Pulley and Fan - Installation

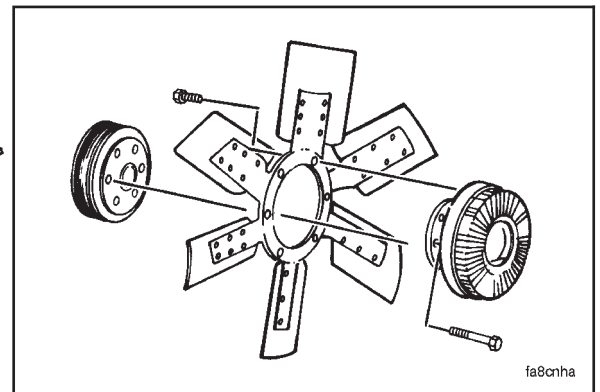
NOTE: Use six capscrews (3/8-16 x 1.25) to install the pulley on the fan hub if a fan is **not** installed.

Install the fan on the fan clutch assembly if equipped. Tighten the mounting nuts to the fan clutch manufacturer's specifications.

Install the fan assembly and pulley on the fan hub with six minimum SAE grade 8 capscrews (3/8-16).

NOTE: Capscrew length will vary with the type of fan assembly used.

Torque Value: 47 N•m [35 ft-lb]



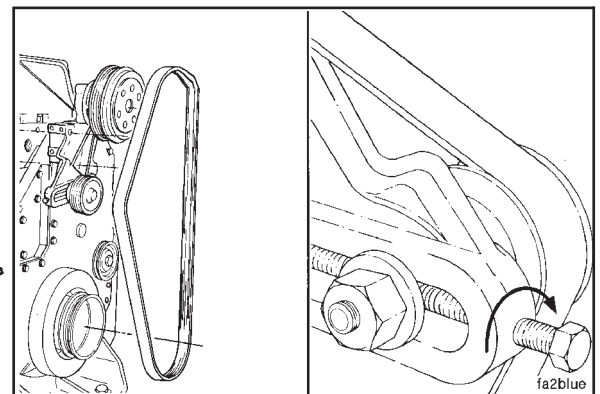
Fan Belt - Installation

Install a new belt on the crankshaft and fan drive pulleys.

Use belt tension gauge, Part No. ST-1293, to measure the belt tension.

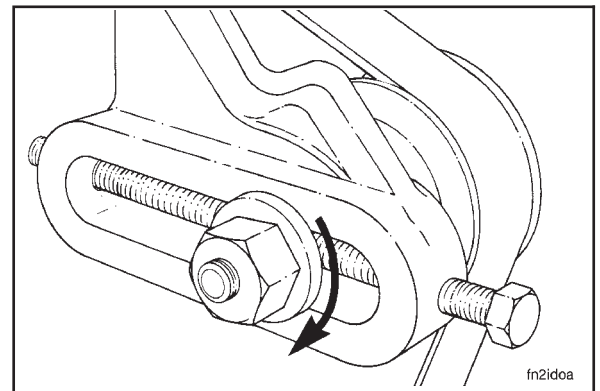
Turn the idler pulley adjusting screw **clockwise** to increase the belt tension.

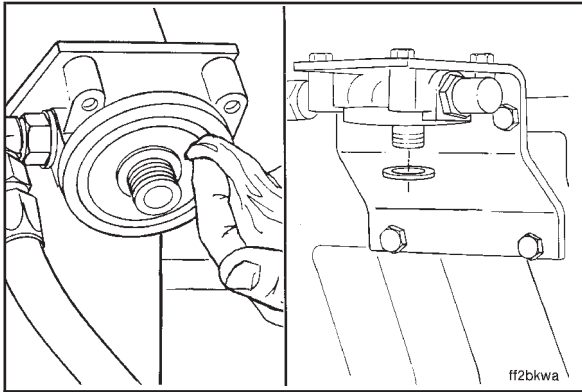
Refer to the belt tension chart in Section V for the correct belt tension for your application.



Tighten the idler pulley shaft locknut.

Torque Value: 190 N•m [140 ft-lb]





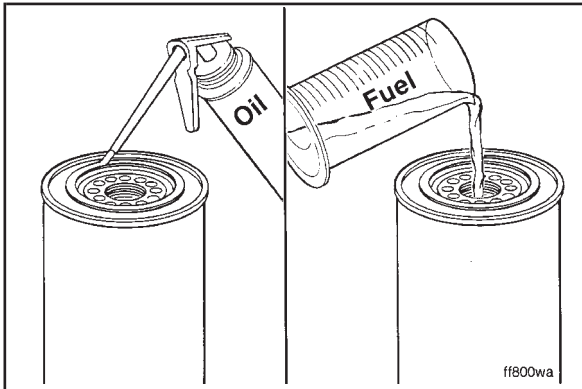
Fuel Filter - Installation



Use a clean, “lint-free” towel to clean the filter head gasket surface.

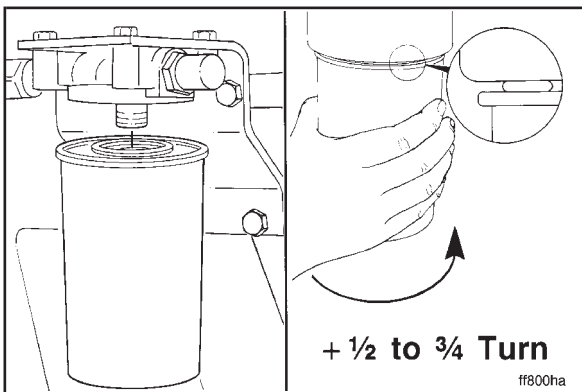


Install a new o-ring on the filter head fitting.



Use clean 15W-40 oil to lubricate the filter gasket surface.

Use clean No. 2 diesel fuel to fill the filter.



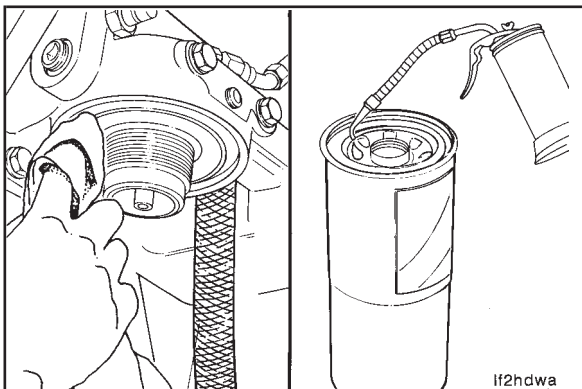
Install the filter by hand.

Tighten the filter until the gasket contacts the filter head surface.



Caution: To prevent damage to the filter threads or filter head, do not over-tighten the filter.

Tighten the filter an additional one-half to three-fourths (1/2 to 3/4) turn after the gasket contacts the filter head surface.



Lubricating Oil Filter - Installation



Use a clean “lint-free” cloth to clean the oil filter head surface.



Use clean 15W-40 oil to lubricate the gasket surface of the filter.

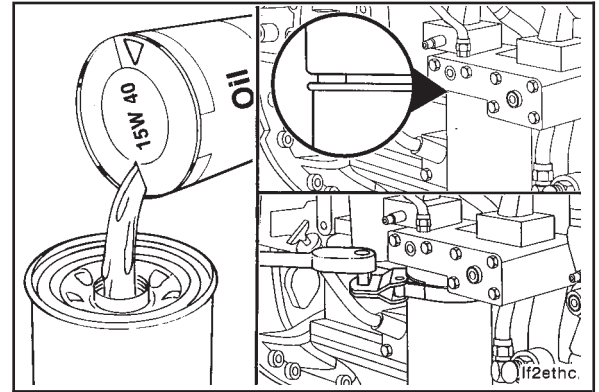
Fill the filter with clean 15W-40 oil.

Install the filter on the filter head.

Caution: To prevent damage to the filter threads or filter head, do not over-tighten the filter.

Tighten the filters until the gasket contacts the filter head surface.

Use oil filter wrench, Part No. 3375049, to tighten the filter an additional three-fourths to one ($3/4$ to 1) turn or follow the instructions supplied with the filter.



Coolant Filter - Installation

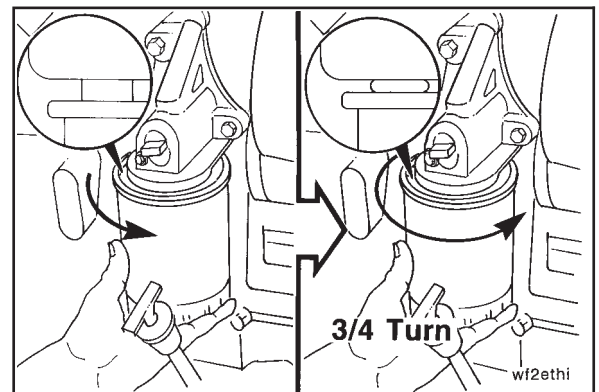
Use clean 15W-40 oil to lubricate the filter sealing ring.



Caution: To prevent damage to the filter threads or filter head, do not over-tighten the filter.

Install the new filter and tighten until the sealing ring contacts the filter head surface.

Tighten the filter an additional one-half to three-fourths ($1/2$ to $3/4$) turn or refer to the filter manufacturer's instructions.

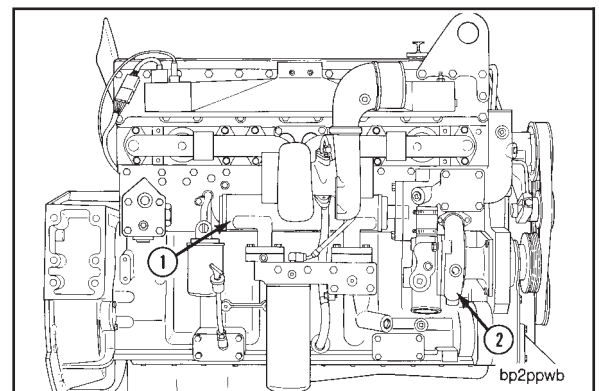


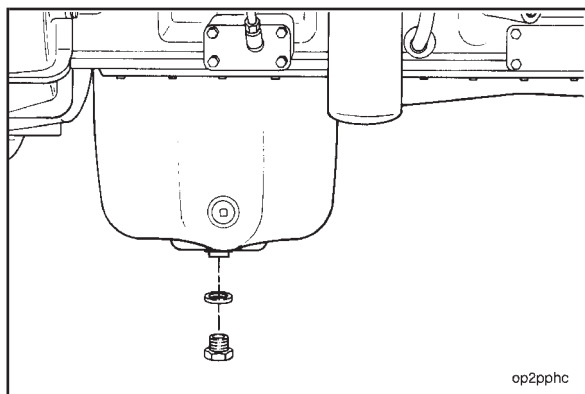
Drain Plugs - Inspection

Inspect the coolant and oil drain plugs to make sure they are tightened to the correct torque value.

Tighten the plug in the end of the lubricating oil cooler, thermostat housing and the bottom of the water pump housing.

Torque Value: 20 N•m [15 ft-lb]





Tighten the drain plug in the oil pan.

Torque Value: 90 N•m [65 ft-lb]



NOTE: Refer to “Engine Test” or “Engine Storage”, Section 14, after the engine is assembled.

Section 1 - Cylinder Block - Group 01

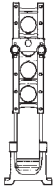
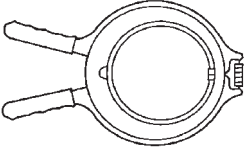
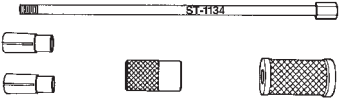
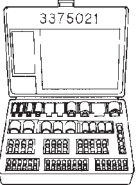
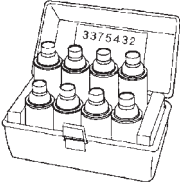
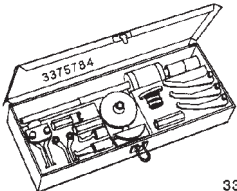
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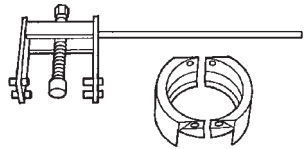
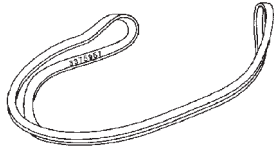
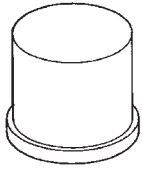
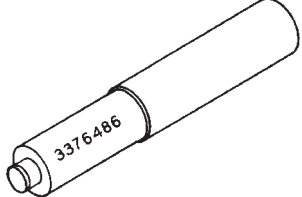
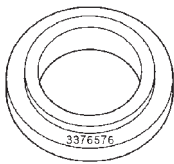
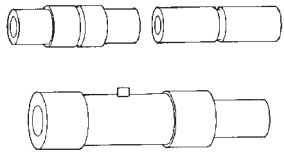
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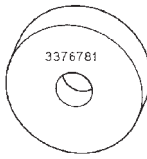
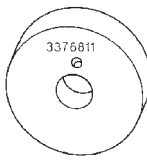
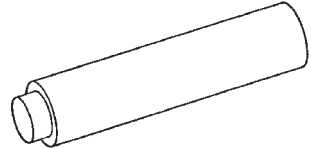
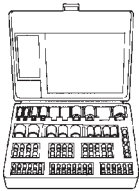
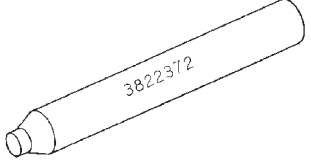
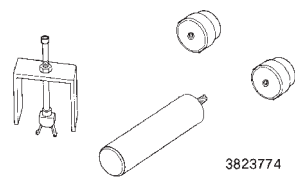
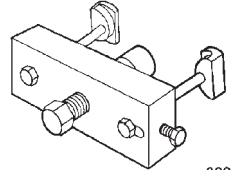
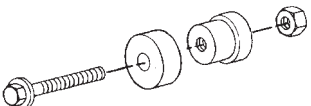
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Service Tools - Cylinder Block

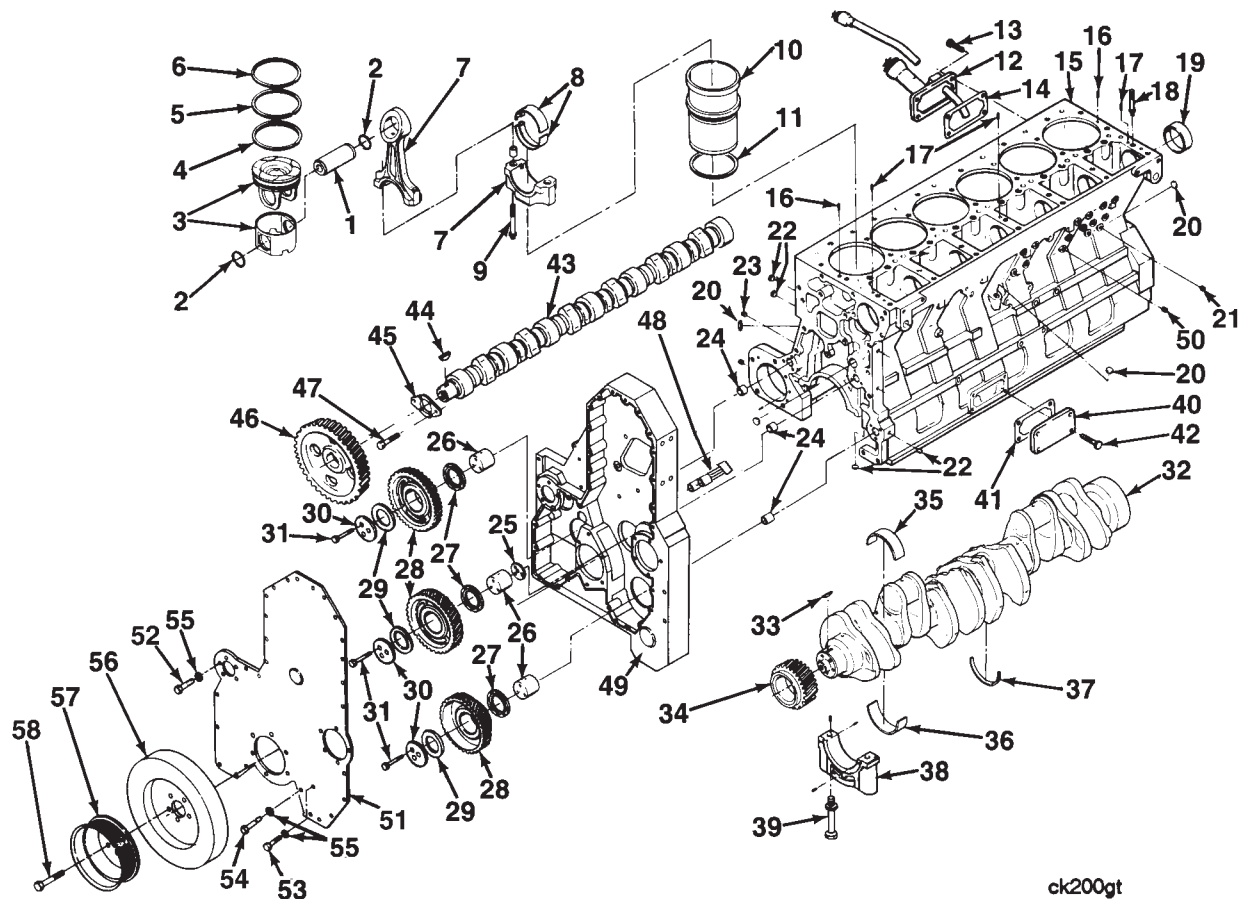
The following special tools are recommended to perform procedures in Group 01. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-561	Connecting Rod Checking Fixture Measure connecting rod bend and twist.	 ST-561
ST-821	Piston Ring Expander Replace piston rings on pistons.	 pi8togd
ST-1134	Dowel Pin Extractor Remove dowel pins.	 ST-1134
3375021	Threaded Insert Kit Repair damaged threads.	 3375021
3375432	Crack Detection Kit Inspect components for cracks.	 3375432
3375784	Puller Kit Remove the idler gear ring dowels.	 3375784

Tool No.	Tool Description	Tool Illustration
3375840	Gear Puller Remove the crankshaft gear. Requires jaw, Part No. 3375839, to be used.	 ks8togd
3375957	Lifting Strap Lift the cylinder block or crankshaft.	 3375957
3376069	Guide Replace cylinder block camshaft bushings. Used with camshaft bushing driver set, Part No. 3376637.	 ck8togj
3376070	Driver Replace cylinder block camshaft bushings. Used with camshaft bushing driver set, Part No. 3376637.	 ck8togk
3376486	Regulator Valve Seat Driver Used to install the high oil pressure seat in the cylinder block.	 3376486
3376576	Master Ring Gauge Use to set dial indicator gauge to measure cylinder block main bearing bore.	 3376576
3376637	Camshaft Bushing Driver Set Replace cylinder block camshaft bushings. Used with guide, Part No. 3376069, and driver, Part No. 3376070.	 ck8togg
3376690	Connecting Rod Mandrel Set Used to measure bend and twist with connecting rod checking fixture, Part No. ST-561. Mandrel, Part No. 3376691, used for crankshaft end of connecting rod. Mandrel, Part No. 3376692, used for piston pin end without bushing. Mandrel, Part No. 3376693, used for piston pin end with bushing.	 3376690

Tool No.	Tool Description	Tool Illustration
3376781	Centering Rings Used to check cylinder block main bearing bore alignment. Used with checking bare, Part No. ST-1177-16.	 3376781
3376811	Checking Ring Used to check cylinder block main bearing bore alignment. Used with checking bar, Part No. ST-1177-16.	 3376811
3376816	Expansion Plug Driver Used with handle, Part No. 3376795, to install expansion plugs.	 ck8togo
3376881	Threaded Insert Kit (Metric) Used to repair damaged threads.	 3376881
3822372	Expansion Plug Driver Install expansion plugs.	 3822372
3823774	Needle Bearing Kit Used to remove and install the hydraulic drive needle bearings in the gear housing.	 3823774
3824106	Camshaft Gear Puller Kit Used to remove the camshaft gear from the camshaft.	 3824106
3824117	Bearing Installation Tool Used to install the water pump needle bearing in the gear housing.	 3824117

Cylinder Block - Exploded View



ck200gt

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Pin, Piston	6	21	Oil Pressure Sensor	1	39	Capscrew and Washer, Main Bearing	14
2	Ring, Retaining	12	22	Plug, Expansion (9.83 mm) [0.387 inch]	8	40	Cover, Hand Hole	2
3	Piston	6	23	Plug, Pipe [1/2 inch]	1	41	Gasket, Hand Hole	2
4	Ring, Oil	6	24	Dowel, Ring [19.23]	3	42	Capscrew, [10-1.50x20]	8
5	Ring, Compression	6	25	Plate, Thrust Bearing Wear	1	43	Camshaft	1
6	Ring, Compression	6	26	Shaft, Idler	3	44	Key, Offset	1
7	Rod, Connecting	6	27	Bearing, Thrust	3	45	Support, Camshaft Thrust	1
8	Bearing, Connecting Rod	12	28	Assembly, Idler Gear	3	46	Gear, Camshaft	1
9	Capscrew, 12 point [14-1.5x91.25]	12	29	Bearing, Thrust	3	47	Capscrew	2
10	Liner, Cylinder	6	30	Gear Retainer	3	48	Engine Position Sensor	1
11	O-ring, Liner	6	31	Capscrew [10-1.50x60]	9	49	Gear Housing	1
12	Housing, Dipstick	1	32	Crankshaft	1	50	Oil Temperature Sensor	1
13	Capscrew [10-1.50x20]	4	33	Key, Plain Woodruff	1	51	Cover, Gear	1
14	Gasket, Dipstick Housing	1	34	Gear, Crankshaft	1	52	Capscrew [10-1.50x60]	12
15	Cylinder Block	1	35	Bearing, Main (upper)	7	53	Capscrew [10-1.50x30]	1
16	Dowel, Pin [7/16x1 inch]	2	36	Bearing, Main (lower)	7	54	Capscrew [10-1.50x50]	1
17	Dowel, Pin [6.000x12.00]	3	37	Bearing, Thrust (No. 4 Main)	4	55	Washer, Plain	15
18	Stud [10-1.50x50]	7	38	Cap, Main Bearing	7	56	Damper, Vibration	1
19	Bushing, Camshaft	7				57	Pulley, Crankshaft	1
20	Plug, Expansion [1.00 Dia]	3				58	Capscrew [14-1.50x50]	5

Cylinder Block - General Information

These procedures apply to M11 engines. The differences between engine models, due to the application and the optional equipment, is included in the instructions. Omit the steps that do **not** apply to the engine being rebuilt.

1. A Warning statement is included for any component or assembly that weighs more than 23 kg [50 lb]. To avoid personal injury, use a hoist or get assistance from more than one person when removing or installing these parts.
2. Most of the capscrews used on the M11 engine are metric. All fasteners have right-hand threads unless a "Caution" states that a fastener has left-hand threads.

Discard all gaskets, seals and o-rings unless they are needed for a failure analysis.

Label, tag, or mark the parts for location as they are removed. This will help in finding all of the parts that can be involved in a failure, and simplify the assembly procedure. Some parts can also be used again.

Force **must** be used to remove certain parts. A mallet can be used when force is required. All of the fasteners **must** be removed before using force.

Avoid as much dirt as possible during disassembly. The accumulation of dirt will make it more difficult to clean the components.

Torque values are listed in each assembly step. If a torque value is **not** specified, use the chart listed in the specifications section, Group 18, to determine the correct torque value.

Many of the gaskets and o-rings are manufactured from a material designed to absorb oil. These gaskets will enlarge and provide a tight seal after coming in contact with oil. Use only a recommended contact adhesive or a vegetable based oil to install these parts.

Always use a capscrew of the same system, metric or U.S. Customary, the same dimension and the same grade as the capscrew removed. The use of a longer capscrew than the capscrew that is listed can result in damage to the engine.

Cylinder Block (1-01)

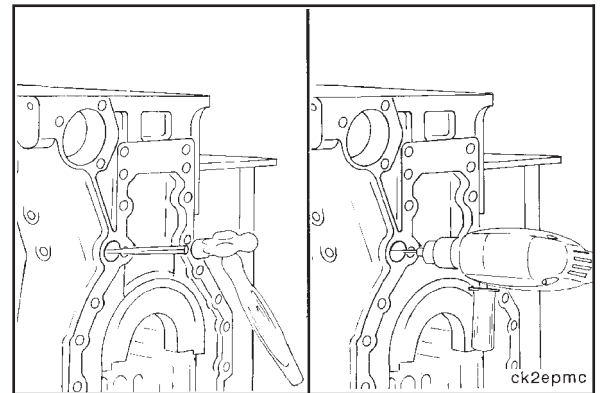
Disassembly

Cup Plugs - Removal

Use the following procedure to remove all cup plugs from the cylinder block.

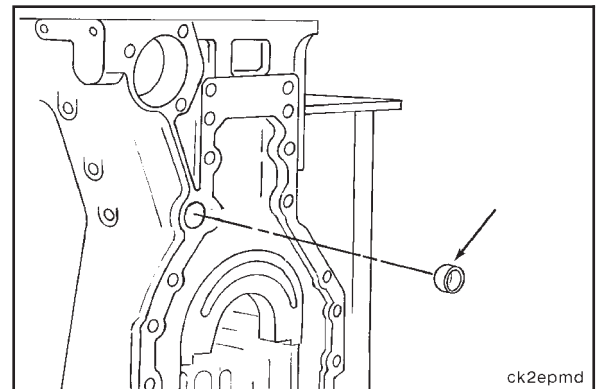
Use a center punch to mark the cup plugs for drilling.

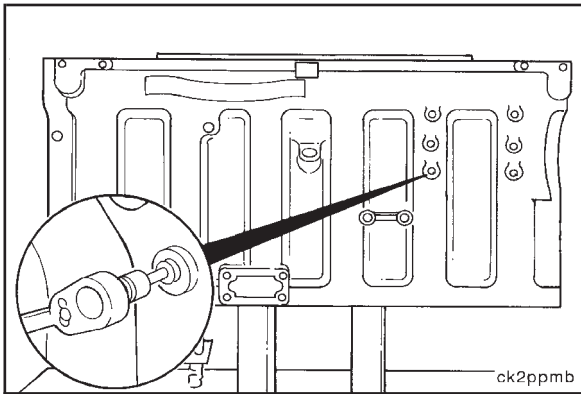
Drill a 3mm [1/8 inch] hole in the cup plugs.



Use a dent puller to remove the cup plugs.

Discard all used cup plugs.

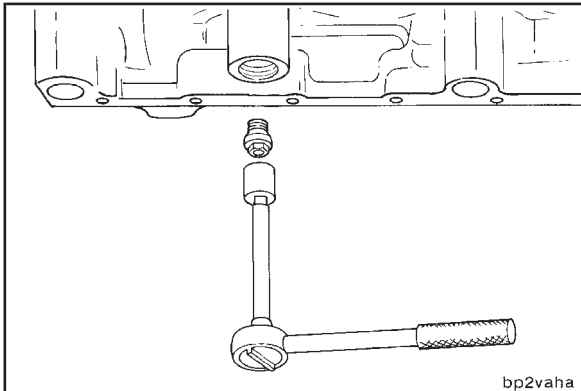




Pipe Plugs - Removal

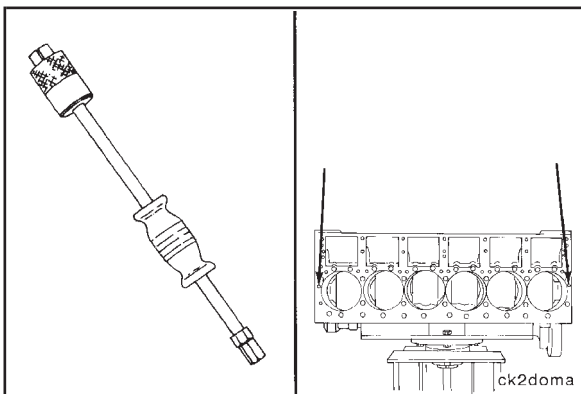


Use the appropriate size hex key wrench to remove all of the pipe plugs.



Viscosity Sensor - Removal

If the viscosity sensor was **not** removed during engine disassembly, use a 7/16 inch socket with a ratchet and extension and remove the viscosity sensor.

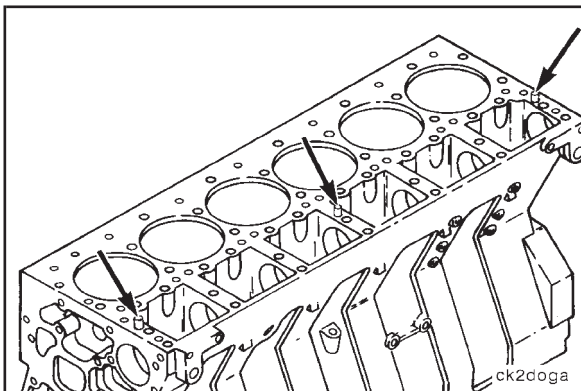


Dowel Pins - Removal



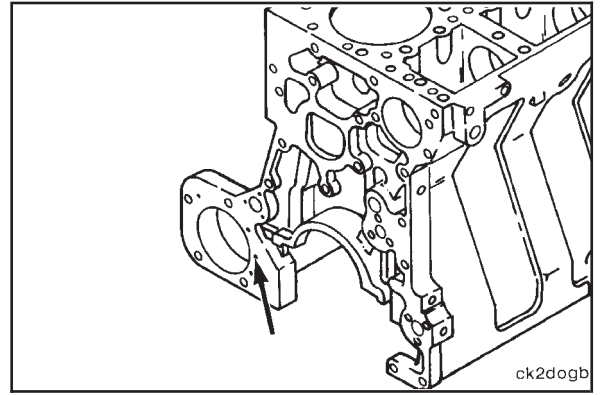
Use dowel pin extractor, Part No. ST-1134, to remove the following dowel pins:

- Two cylinder head alignment dowel pins



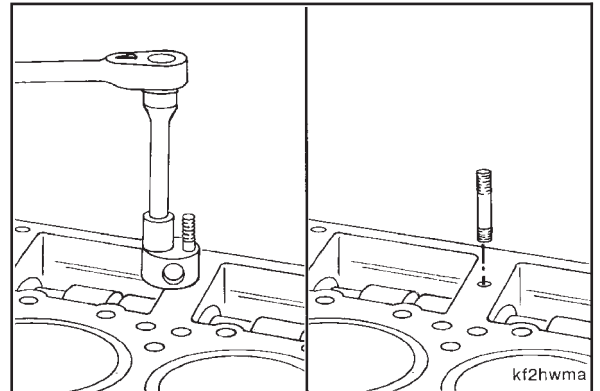
- Three cam follower alignment dowel pins

- Lubricating oil pump alignment dowel pin



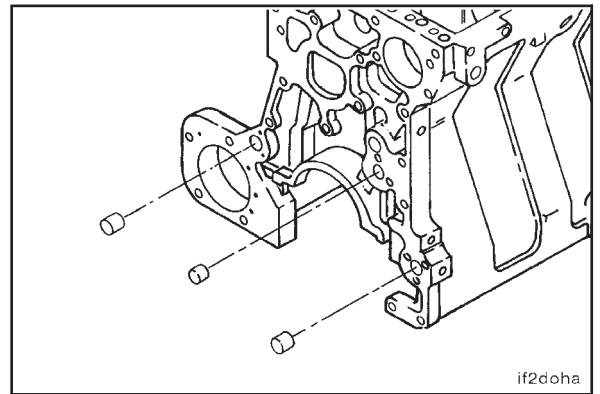
Cam Follower Studs - Removal

Use a 11 to 13 mm [7/16 to 1/2 inch] stud extractor to remove the seven cam follower studs.



Idle Shaft Ring Dowels - Removal

Use puller kit, Part No. 3375784, to remove the three idler gear ring dowels.

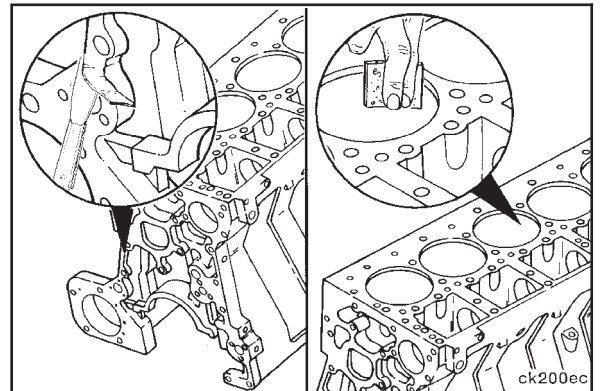


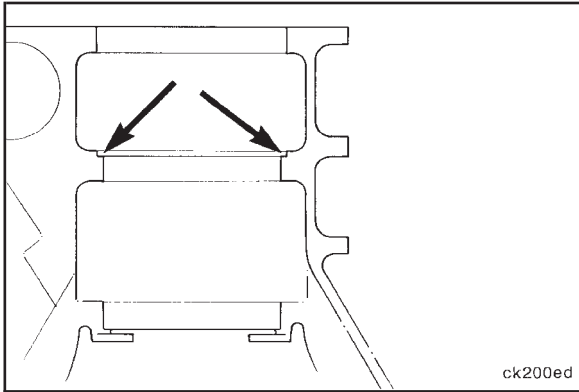
Cleaning

Caution: Do not damage the machined surfaces when using a wire brush or gasket scraper.

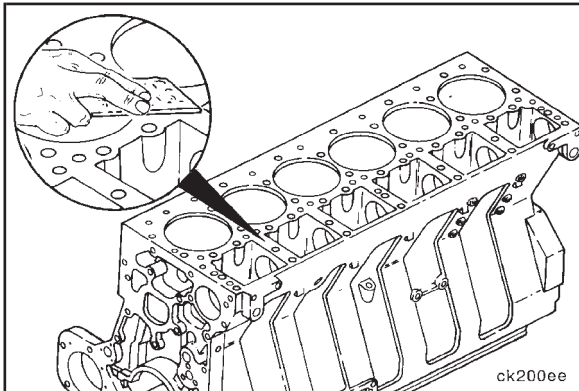
Use a Scotch-Brite® pad, emery cloth, or gasket scraper to clean the following cylinder block areas:

- Gasket surfaces
- Cylinder liner bores

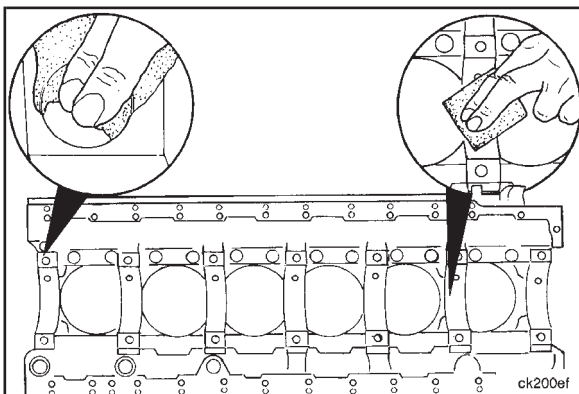




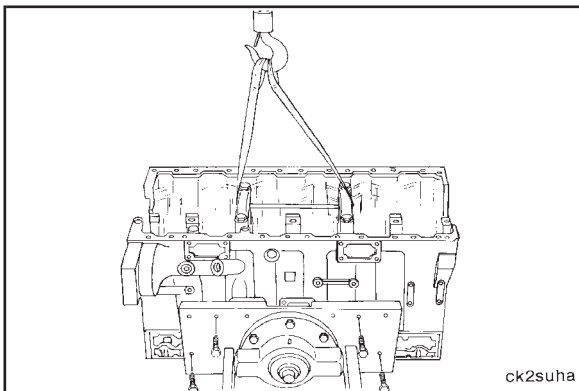
- Cylinder liner counter bore



- Cylinder head deck surface



- Cup plug bores
- Main bearing saddles and caps



Cylinder Block - Removal from the Rollover Stand



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



Install the numbers “3” and “5” main bearing caps and tighten the cap screws.

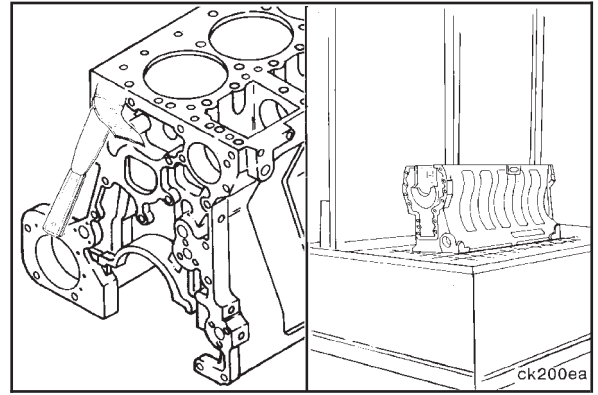
Use the lifting strap, Part No. 3375957, and a hoist to support the cylinder block.



Remove the twelve cap screws holding the cylinder block to the rollover stand adapter plate.

Use a gasket scraper to remove all gasket material and heavy dirt from the cylinder block.

Place the cylinder block into a cleaning or soak tank.

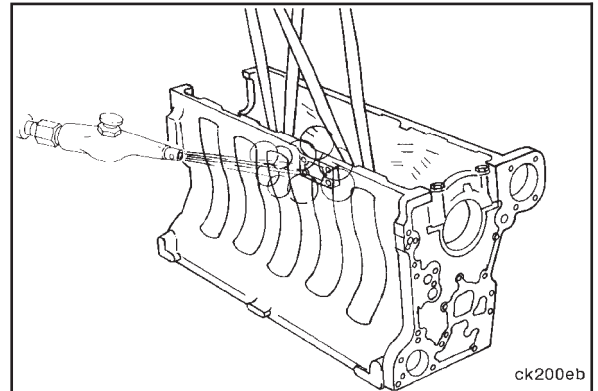


Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.

Steam clean the cylinder block and dry with compressed air.

Make sure to blow out all oil drillings, pipe plug bores, and capscrew threads.

If the cylinder block is **not** going to be used immediately, apply a coating of light preservative oil to prevent rust. Cover the block to prevent dirt from sticking to the oil.

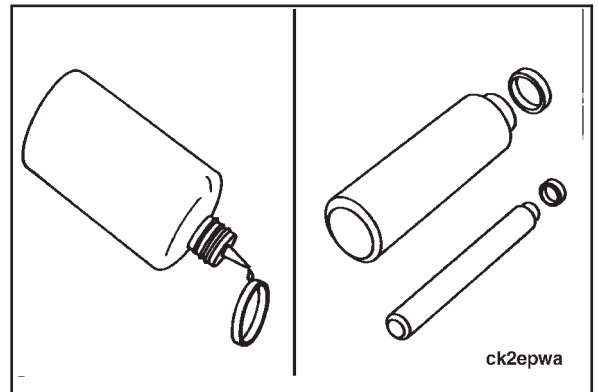


Assembly

Cup Plugs - Installation

NOTE: Do not install any cup or pipe plugs until the inspection and any necessary repair procedures are completed. This will prevent dirt from being trapped in the oil passages. Refer to Procedure 1-02 for inspection.

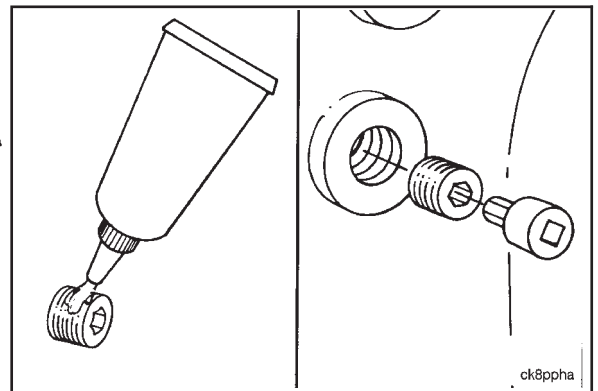
Use cup plug sealant, Part No. 3375068, to coat the outside diameter of the cup plugs. Use expansion plug driver, Part No. 3376816 or Part No. 3822372, to install the cup plugs.

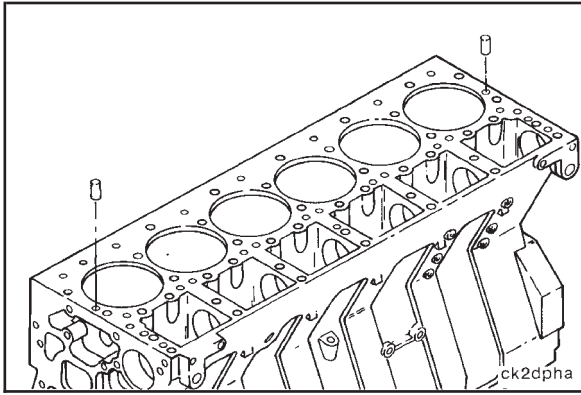


Pipe Plugs - Installation

Use pipe sealant, Part No. 3375066, to coat the pipe plug threads.

Refer to the "Pipe Plug Torque Values" chart in Section V at the back of this manual for the correct torque values.



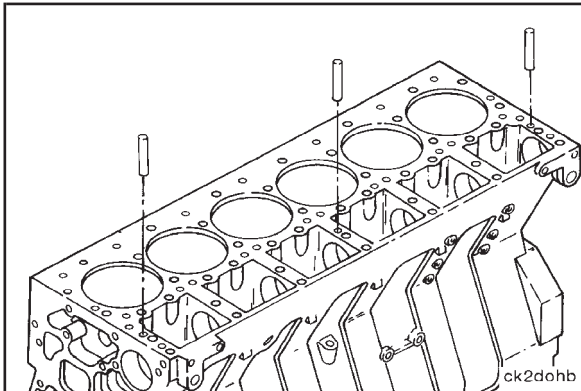


Dowel Pins - Installation

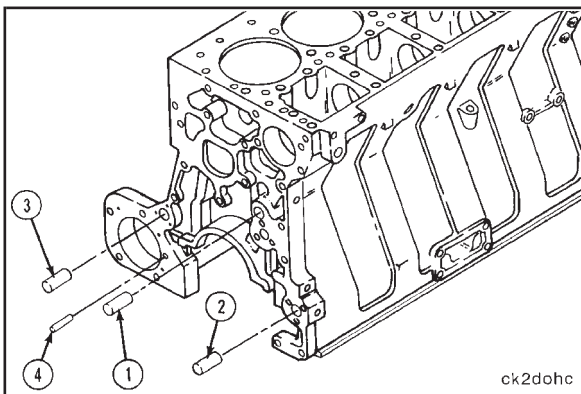


Use a hard plastic hammer to install the following dowel pins:

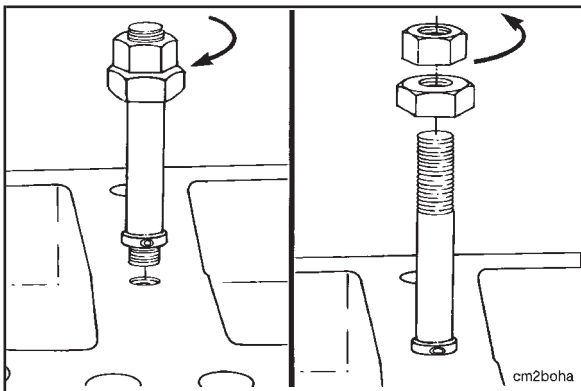
- Two cylinder head dowel pins



- Three cam follower support dowel pins



- Idler gear ring dowels (1), (2), and (3)
- Lubricating oil pump dowel pin (4)



Cam Follower Studs - Installation



Install the seven cam follower studs with two nuts (M10x1.5) tightened together.

Torque Value: 34 N•m [25 ft-lb]

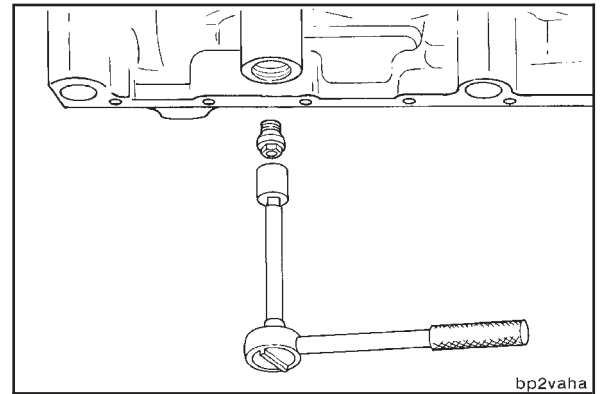


Remove the two nuts after the studs are torqued.

Viscosity Sensor - Installation

Use a 7/16 inch socket, extension and ratchet to install the viscosity sensor.

Torque Value: 24 N•m [18 ft-lb]



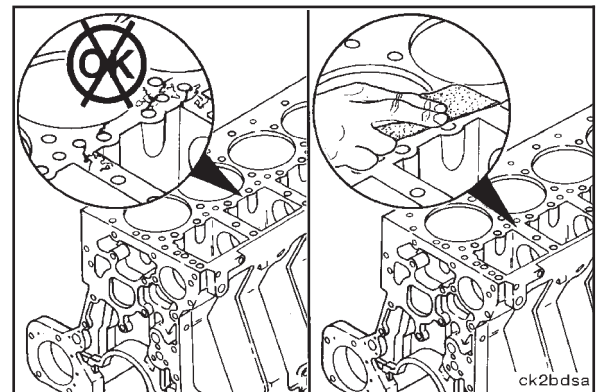
Cylinder Block - Inspection for Reuse (1-02)

NOTE: All measurements of the cylinder block **must** be made when the block is positioned on a flat surface. If the block is mounted on the engine stand, the measurements can be wrong because of distortion.

Inspect all gasket surfaces.

Visually inspect for burrs or damage.

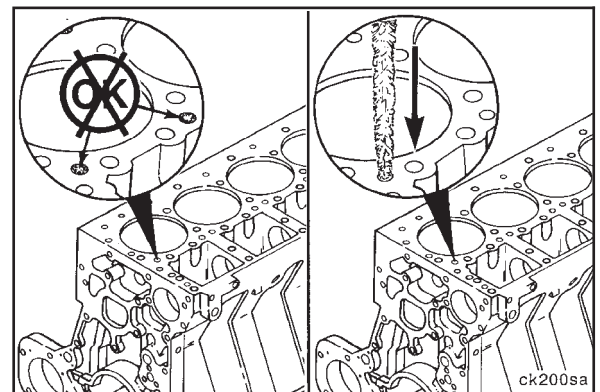
Use a medium grit hone or crocus cloth to remove burrs.



Visually inspect the water passages for rust or restriction.

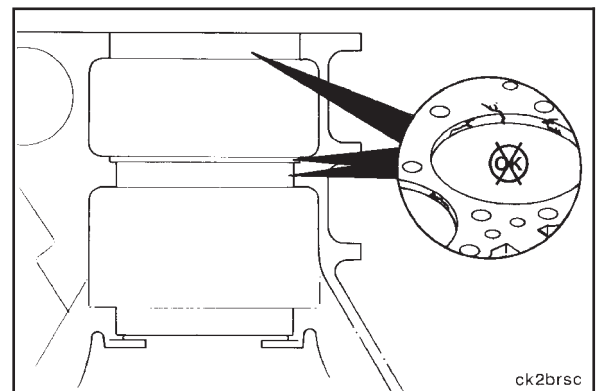
Use bristle brushes to clean the water passages.

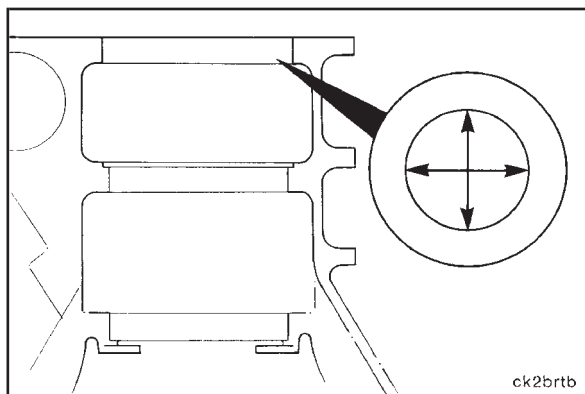
If rust or restriction **cannot** be removed with bristle brushes, the cylinder block **must** be cleaned with a chemical bath.



Cylinder Liner Bores - Inspection

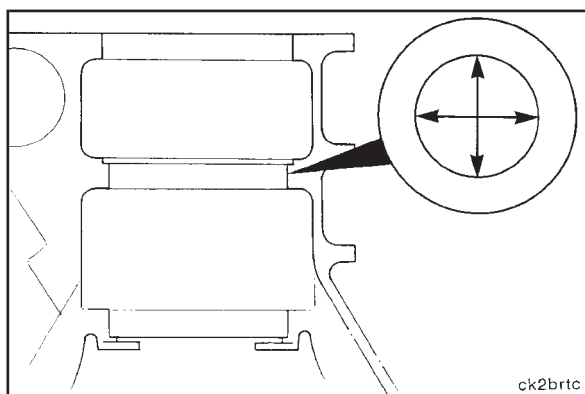
Visually inspect the cylinder head mounting surface, upper liner bore, the liner counter bore and the lower liner bore for cracks or damage.





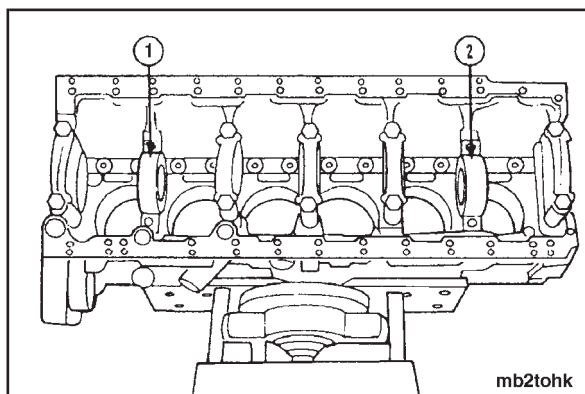
Measure the upper liner bore inside diameter.

Cylinder Block Upper Liner Bore I.D.		
mm		in
145.900	MIN	5.7441
146.027	MAX	5.7491



Measure the liner seal bore Inside diameter 8.0 to 13.5 mm [0.32 to 0.53 inch] below the counterbore.

Cylinder Block Liner Seal Bore I.D.		
mm		in
138.063	MIN	5.4355
138.113	MAX	5.4375



Main Bearing Bore Alignment - Inspection

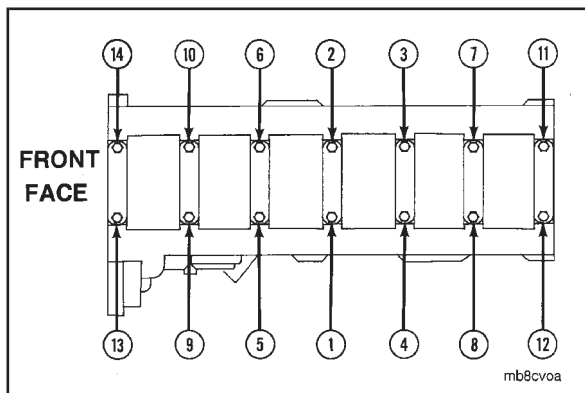
Install main bearing cap numbers "1", "3", "4", "5", and "7".



NOTE: The main bearing caps are numbered. The numbers on the caps **must** match the numbers stamped on the cylinder block. The caps **must** be installed with lock tang to lock tang.

Install the centering rings, Part No. 3376781, (1) and (2) in the numbers "2" and "6" main bearing saddles.

Install the main bearing cap numbers "2" and "6".



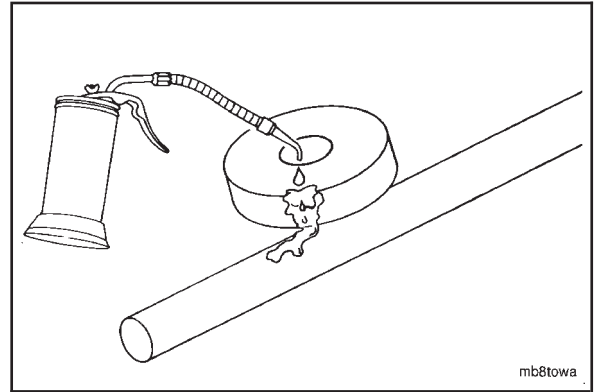
Tighten the main bearing caps in the sequence shown.

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

Section 1 - Cylinder Block - Group 01
M11

Cylinder Block - Inspection for Reuse (1-02)
Page 1-15

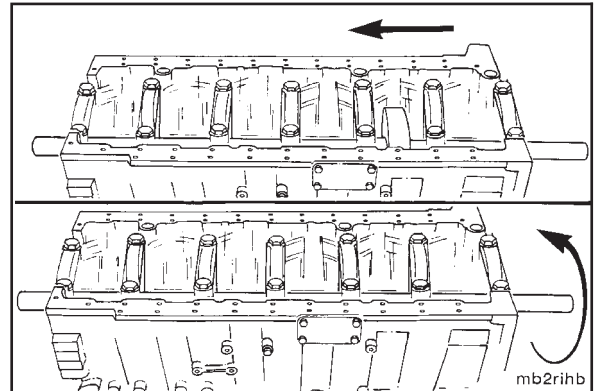
Use clean 15W-40 oil to lubricate the checking ring, Part No. 3376811, and the checking bar, Part No. ST-1177-16.



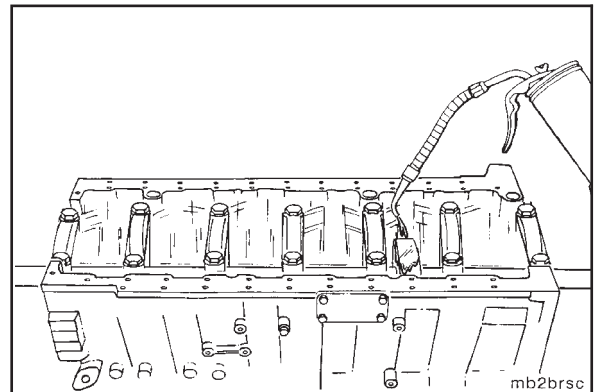
Slide the checking bar through one of the centering rings.
Install the checking ring, Part No. 3376811, on the checking bar.



Slide the checking bar through the other centering ring.
Inspect the checking bar for freedom of rotation.



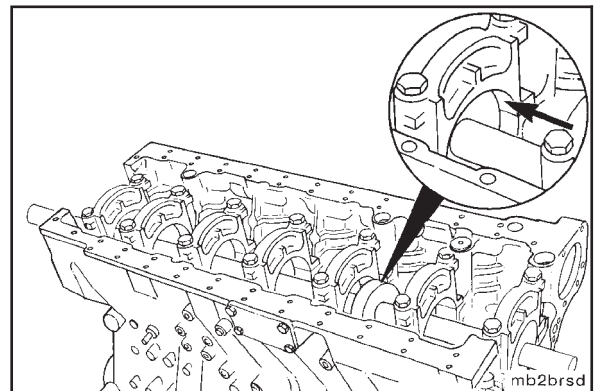
Use clean 15W-40 oil to lubricate the outside diameter of the checking ring.

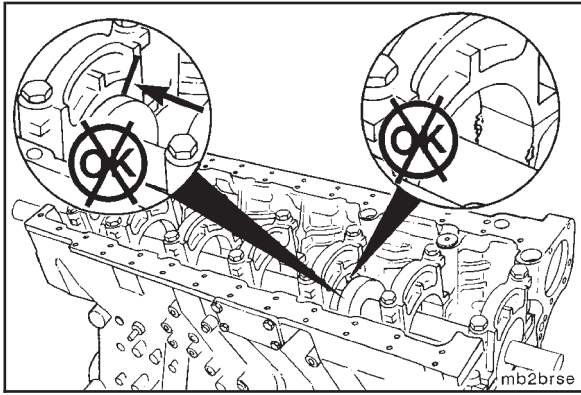


Push the checking ring through the bores to be inspected using light finger pressure on each side of the checking ring.

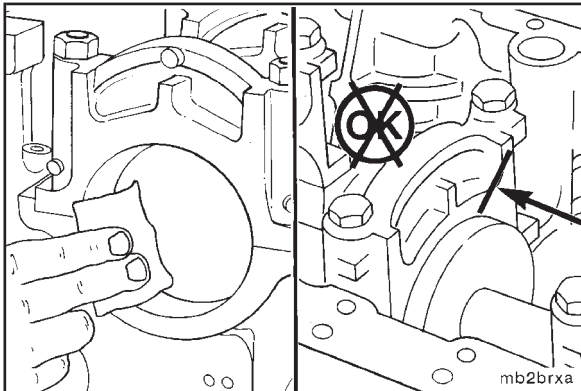


The checking ring **must** pass through each bore with slight resistance.

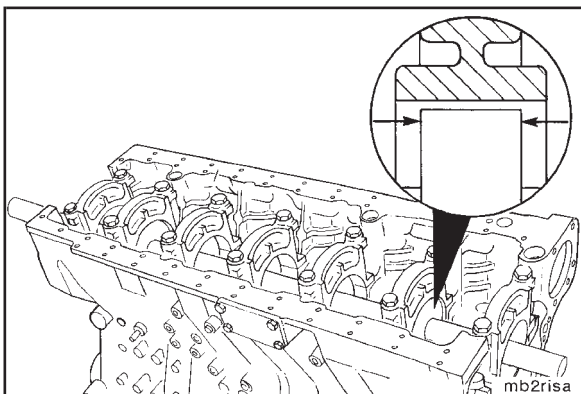




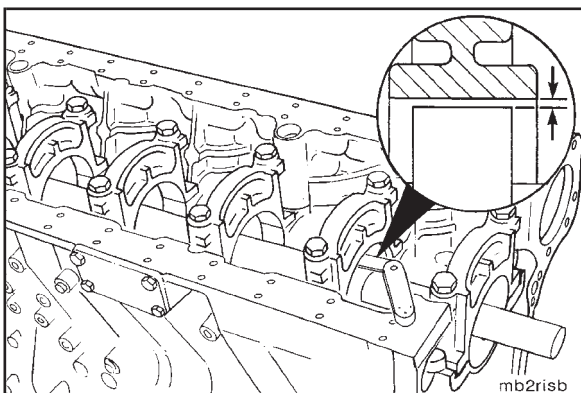
If the checking ring will **not** go through the bore, visually inspect the bore for burrs and other obstructions.



After removing any burrs, if the checking ring still will **not** go through the bore, mark the bore for repair.



If the checking ring will pass through the bore without any resistance, center the checking ring in the bore.

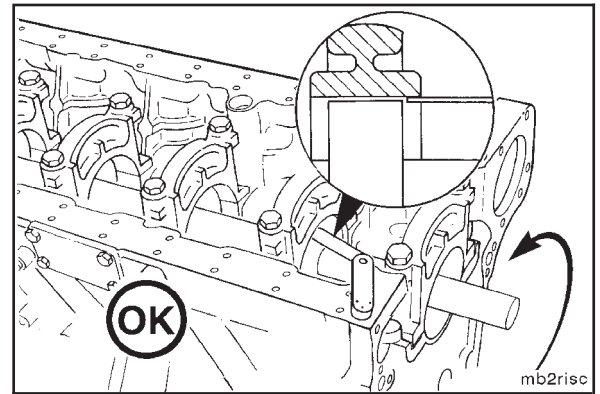


Use a feeler gauge 0.08 mm [0.003 inch] that is **not** more than 12.7 mm [1/2 inch] wide. Insert the feeler gauge between the checking ring and the cylinder block.

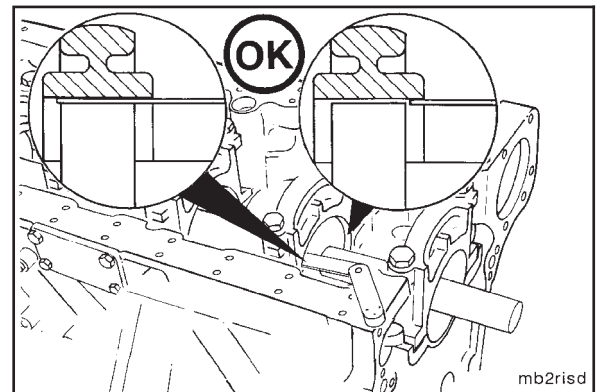
Rotate the feeler gauge completely around both sides of the checking ring.

Evaluate the main bearing bore alignment inspection as follows:

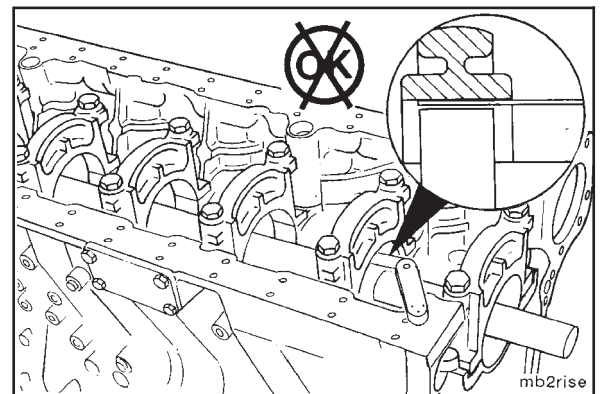
- If the feeler gauge will **not** go in the bore at any point and the checking bar rotates freely, the main bearing bore is acceptable.



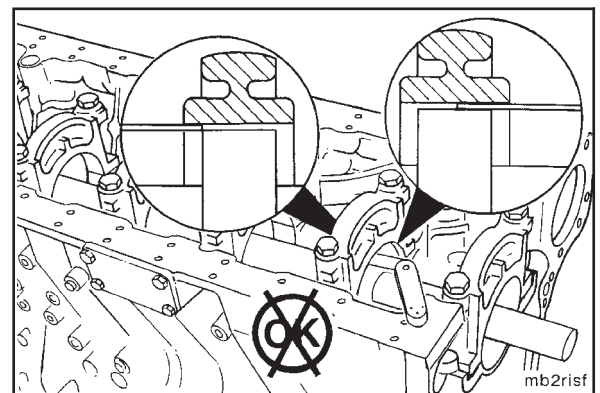
- If the feeler gauge will enter the bore at one point on one side of the checking ring, but will **not** enter the bore 180 degrees from that point on the same side and the checking bar rotates freely, there is a slight misalignment but the main bearing bore is acceptable.

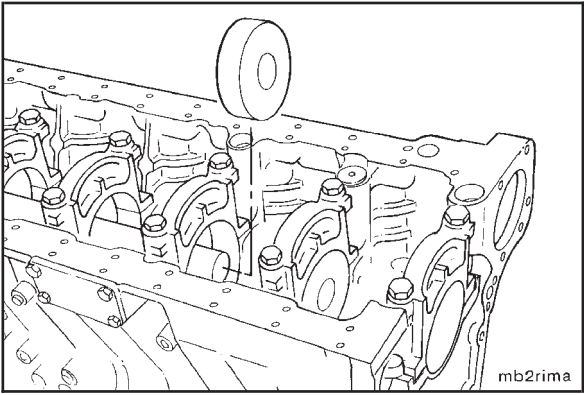


- If the feeler gauge is loose in the bore, the bore is oversize and **not** acceptable. Mark the main bearing bore to be repaired.



- If the feeler gauge will enter the bore all the way around on one side of the checking ring, but will **not** enter the bore on the other side, the bore is tapered and **not** acceptable. Mark the main bearing bore to be repaired.

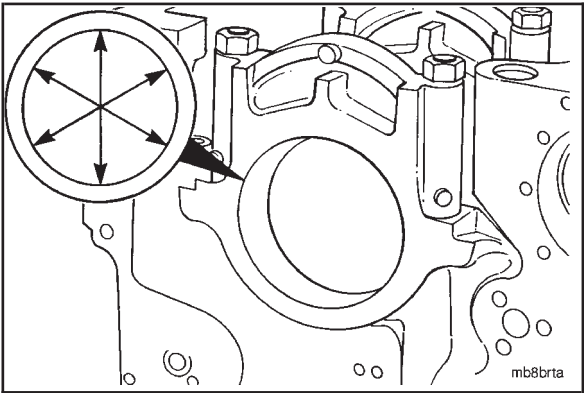




Remove the checking ring.

NOTE: Leave the centering rings and checking bar in place if any bores are to be repaired.

Refer to the Alternative Repair Manual, Bulletin No. 3810310, for salvage procedures.

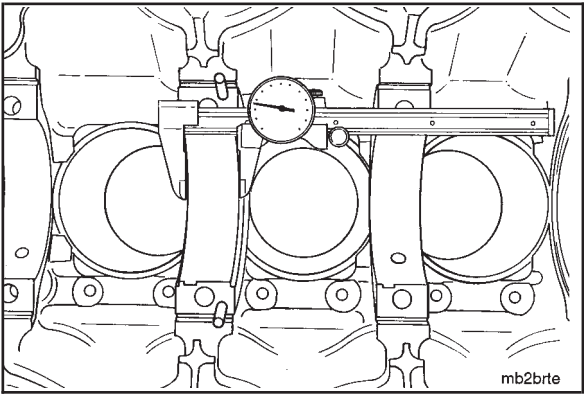


Main Bearing Bore Inside Diameter - Measurement

Use master ring gauge, Part No. 3376576, to set up the dial bore gauge.

Measure the inside diameter of all seven bores at three points.

Main Bearing Bore I.D.		
mm		in
121.990	MIN	4.8028
122.015	MAX	4.8037



Thrust Bearing Surface Width - Measurement

Measure the width of the cylinder block between the front and rear thrust bearing surfaces.

Cylinder Block Thrust Bearing Surface Width		
mm		in
39.95	MIN	1.573
40.05	MAX	1.577

NOTE: One original undamaged thrust bearing surface point is required as a reference point for this measurement.

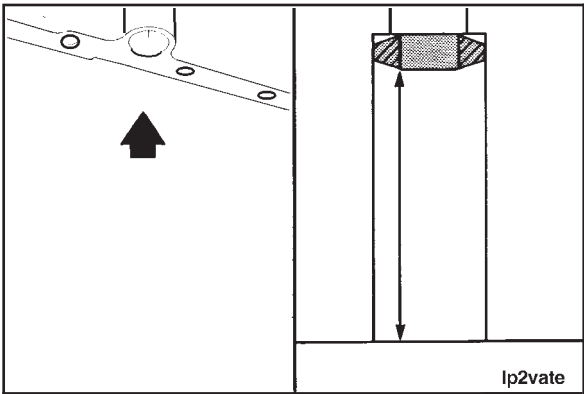
High Oil Pressure Regulator Seat Depth - Measurement

Measure the relief valve seat depth in the cylinder block.

High Oil Pressure Relief Valve Seat Depth		
mm		in
62.62	MIN	2.465
63.62	MAX	2.505

NOTE: 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.

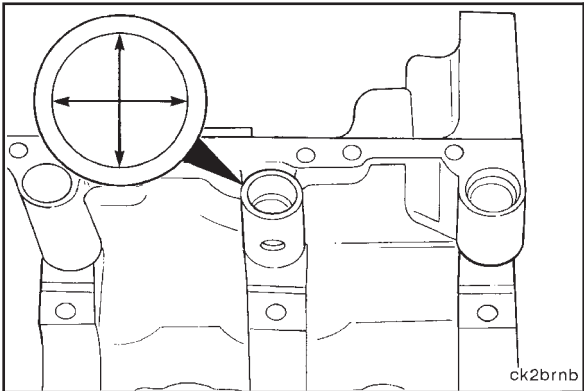
If the seating surfaces are free of indentations, the seat can be reused. If the surfaces have indentations, the seat **must** be replaced. Use regulator valve seat driver, Part No. 3376486, to install the seat.



Main Oil Pressure Regulator Valve Bore - Measurement

Measure the inside diameter of the main oil pressure regulator valve bore.

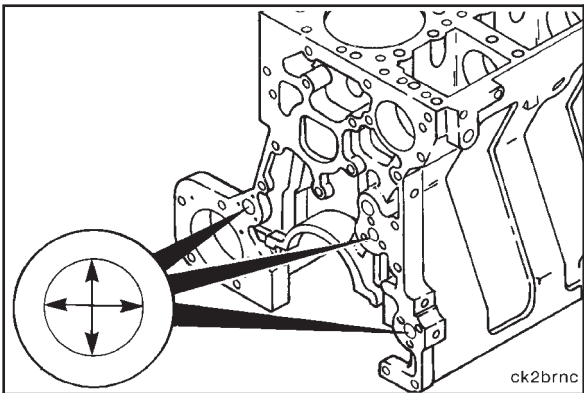
Main Oil Pressure Regulator Valve Bore I.D.		
mm		in
22.226	MIN	0.8750
22.301	MAX	0.8780

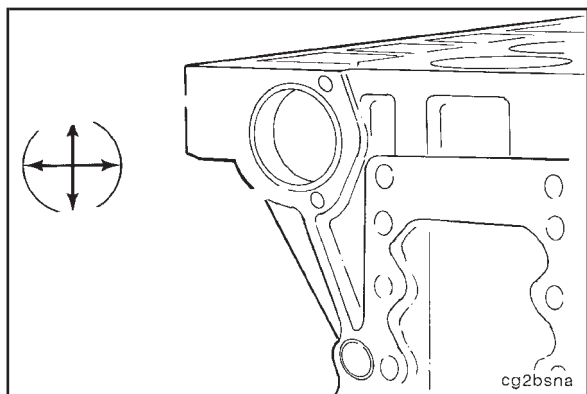


Idler Gear Ring Dowel Bore - Measurement

Measure the inside diameter of the three idler gear ring dowel bores.

Idler Gear Ring Dowel Bore I.D.		
mm		in
19.175	MIN	0.7549
19.215	MAX	0.7565



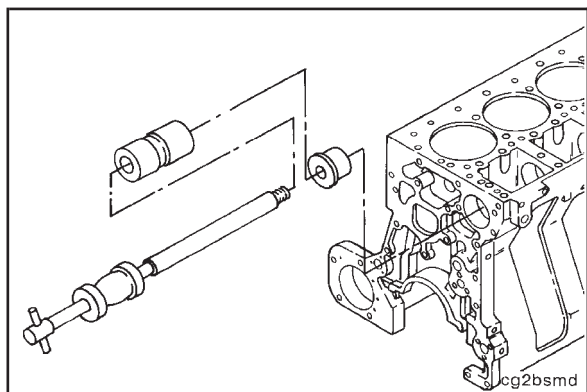


Camshaft Bushing Inside Diameter - Measurement

Measure the inside diameter of the camshaft bushings when installed.

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

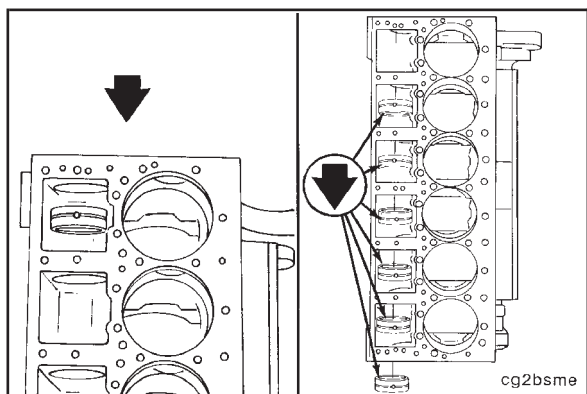
NOTE: If one of the bushings exceeds the maximum specifications, all bushings **must be** replaced.



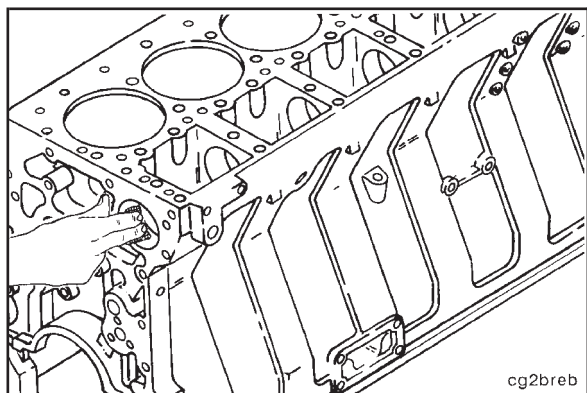
Camshaft Bushing - Replacement (1-03)

Removal

Use the camshaft bushing driver, Part No. 3376070, bushing driver assembly, Part No. 3376637, and the guide, Part No. 3376069, to remove the camshaft bushings.



Remove the number one bushing first.
Remove the six remaining bushings.



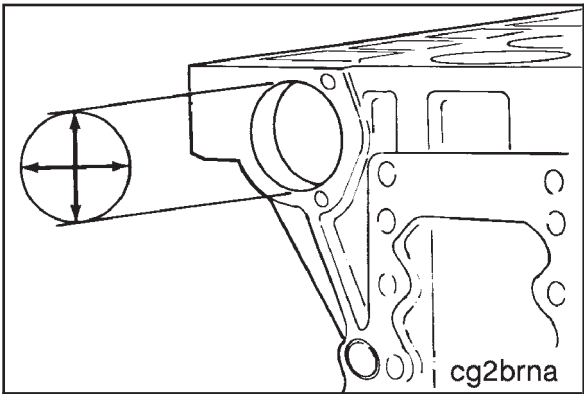
Cleaning

Use fine emery cloth to remove burrs and sharp edges from the camshaft bores.

Inspection

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



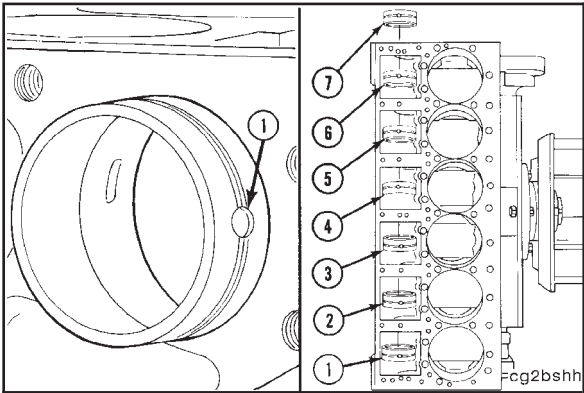
Installation

Caution: Remove any metal chips from the camshaft bushing oil groove to prevent the lubricating system from being contaminated and causing engine damage.

Use camshaft bushing driver, Part No. 3376070, and the bushing driver assembly, Part No. 3376637, to install the camshaft bushings.

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

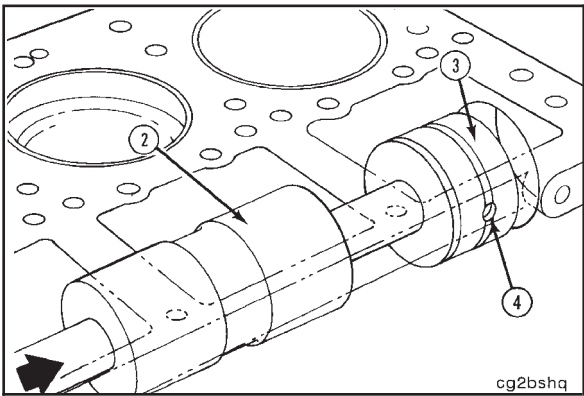
Install the bushings in the following order; number “7”, “6”, “5”, “4”, “3”, “2”, and “1”.



To install the number “7” bushing, install the guide (2), Part No. 3376069, between the number “6” and number “5” bores.

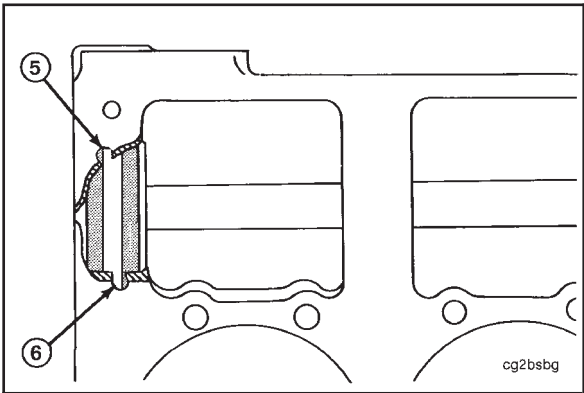
Install a new bushing (3) on the driver with the oil hole (4) at the 3 O'clock position viewed from the front of the engine.

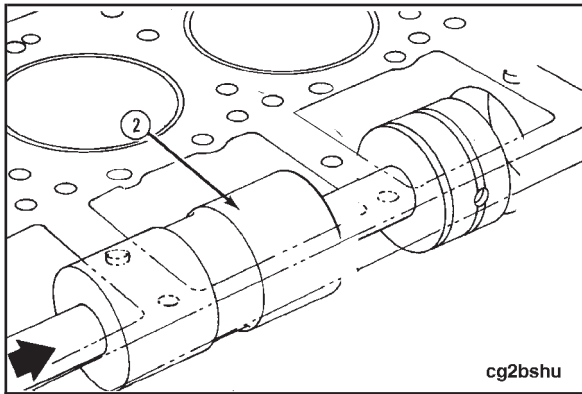
Drive the bushing in the bore.



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 cylinder block as the bushing is installed.



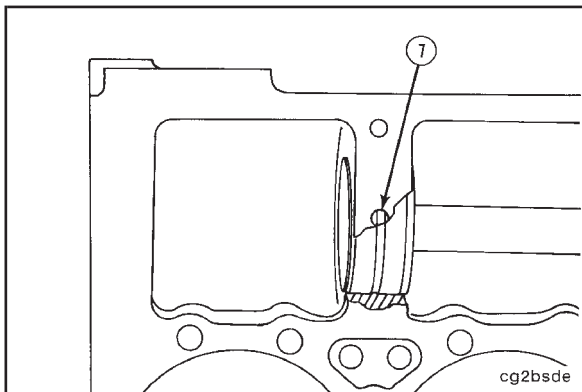


Use the same procedure to install the numbers “6”, “5”, “4”, “3”, and “2” bushings.

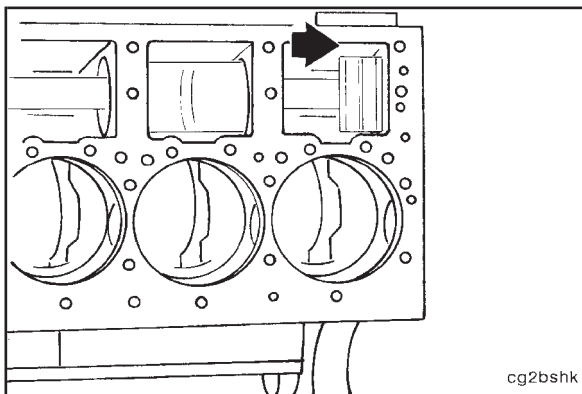
Install the guide (2) into the correct position.

Install the bushing on the driver with the oil hole at the 3 O'clock position viewed from the front of the engine.

Drive the bushing in the bore.

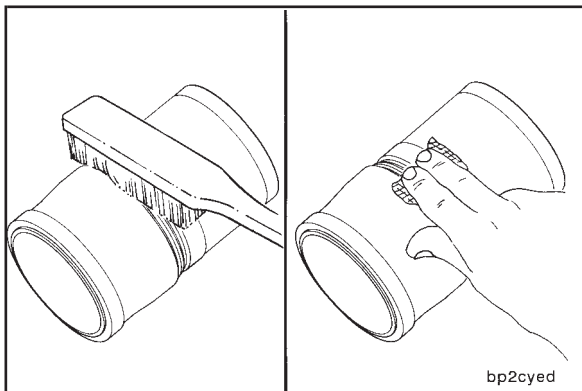


Caution: Visually inspect the position of the camshaft bushing oil groove through the cam follower stud holes (7). The bushing oil groove must be visible to prevent engine damage.



Follow the procedure used to install the number “7” bushing to install the number “1” bushing.

NOTE: Visually inspect the bushing oil groove alignment for the number “1” bushing also. The oil groove **must** align in the same way as the number “7” bushing does.



Cylinder Liner - Cleaning and Inspection for Reuse (1-04)

Cleaning

Caution: To prevent cylinder liner damage, 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.

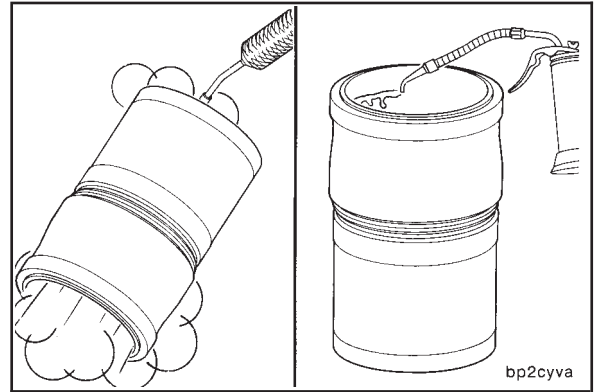
Use a fine fibrous abrasive pad such as; Scotch-Brite® 7448, Part No. 3823258 or equivalent, to remove the remaining scale and rust.

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 liner and dry with compressed air.

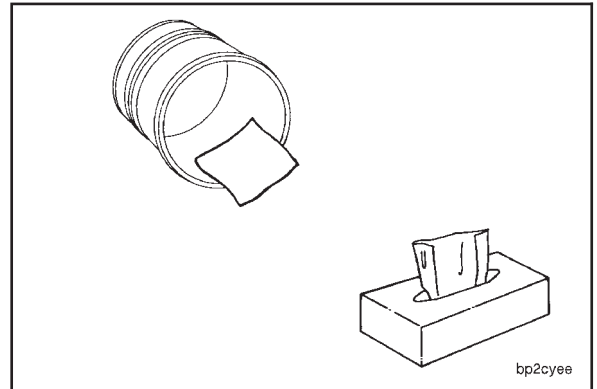
Use clean 15W-40 oil to lubricate the inside diameter of the liner.

Allow the oil to soak in the liner for five to ten minutes.



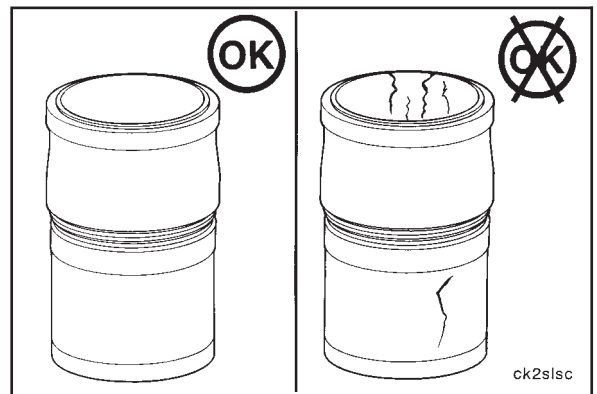
Use “lint-free” paper towels to wipe the oil from the inside of the liner.

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



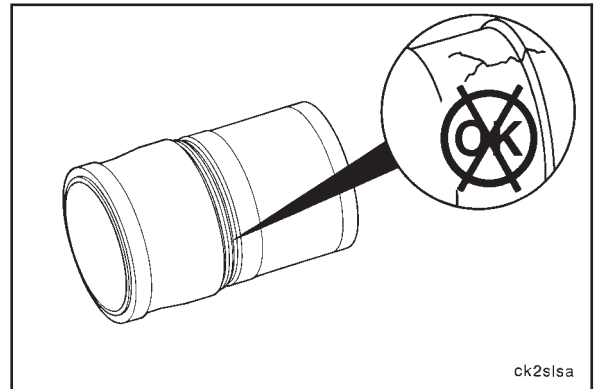
Inspection

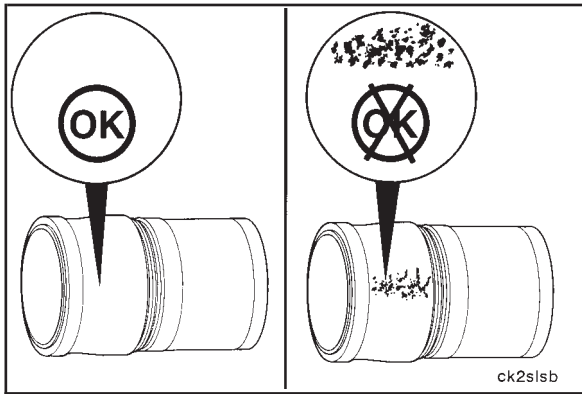
Visually inspect for cracks on the inside and the outside of the liner.



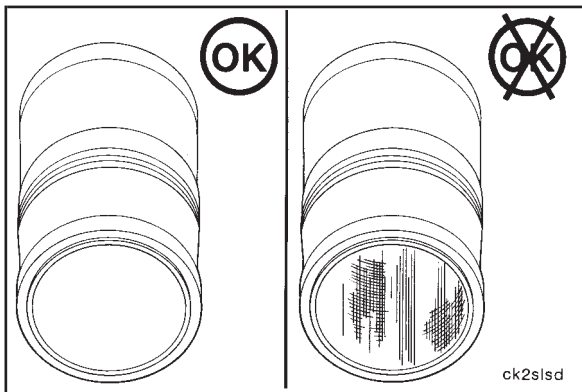
Visually inspect for cracks under the liner flange.

NOTE: Cracks in the liner can also be detected by using either magnetic inspection or the dye penetrant method.





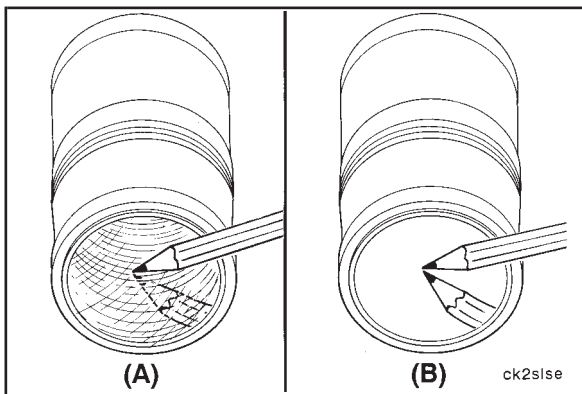
Visually inspect the outside diameter of the liner for excessive corrosion or pitting. Liners with pitting generally **cannot** be reused. However, if the pitting is light and can be removed with fine emery cloth, the liner can be reused.



Visually inspect the liner 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 liner inside diameter for scuffing or scoring.

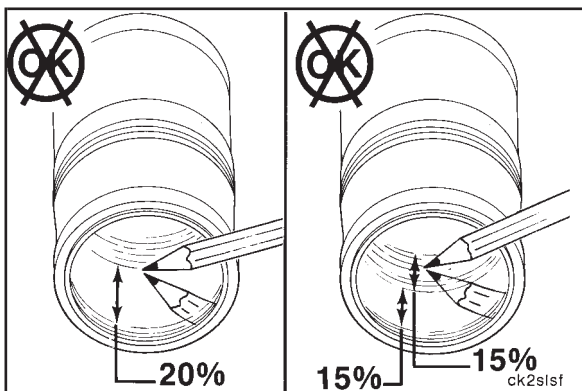


Visually inspect the liner inside diameter for liner bore polishing.

NOTE: M11 cylinder liners are **not** lubrited.

A moderate polish (A) produces a 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.

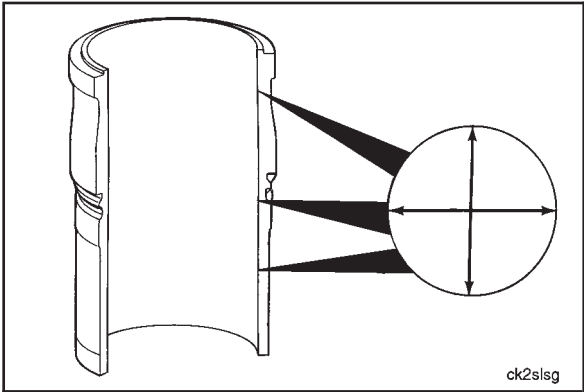


Replace the liner if either of the following conditions apply:

- 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.

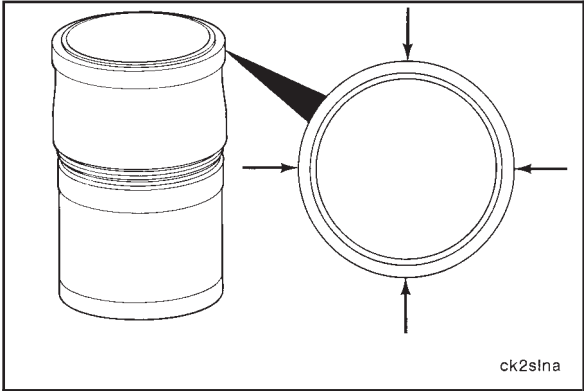
Use a dial bore gauge to measure the liner inside diameter 90 degrees apart at the top, middle, and bottom of the piston travel area.

Cylinder Liner Inside Diameter		
mm		in
125.000	MIN	4.9213
125.095	MAX	4.9250



Measure the liner top press fit area outside diameter.

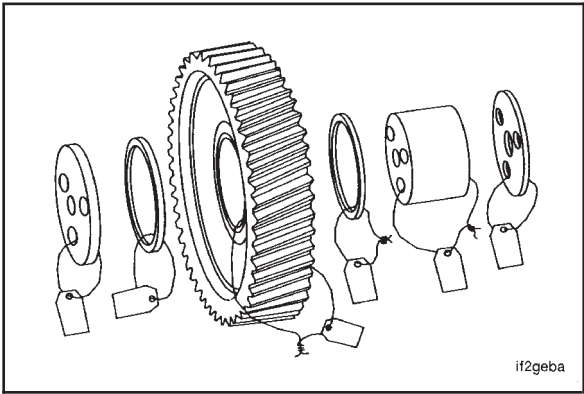
Cylinder Liner Top Press Fit O. D.		
mm		in
145.938	MIN	5.7456
145.976	MAX	5.7471



Idler Gear Assembly - Cleaning and Inspection for Reuse (1-05)

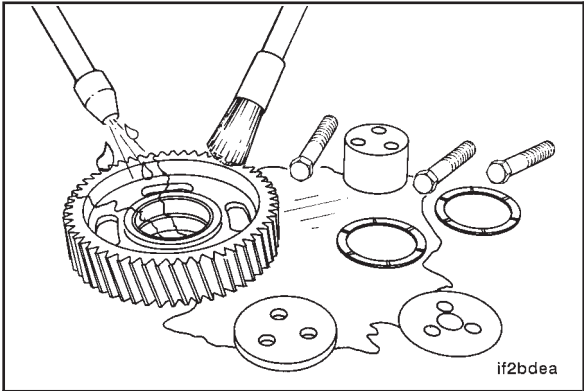
Use the following procedure to clean and inspect all three Idler gear assemblies.

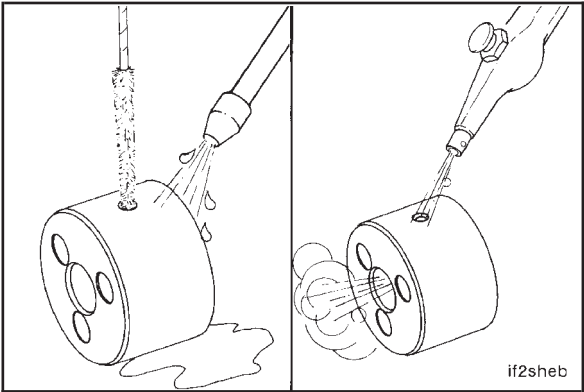
Keep each individual idler gear assembly tagged together to be sure the assemblies are installed in the correct location.



Cleaning

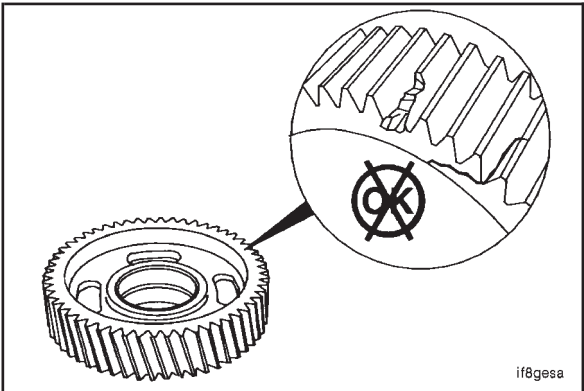
Use solvent to clean the assembly and dry with compressed air.





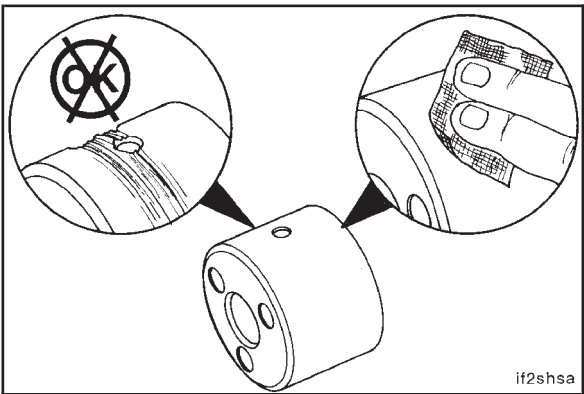
Use a soft bristle brush to clean the oil drilling in the idler gear shaft.

Use compressed air to blow out the oil drilling.



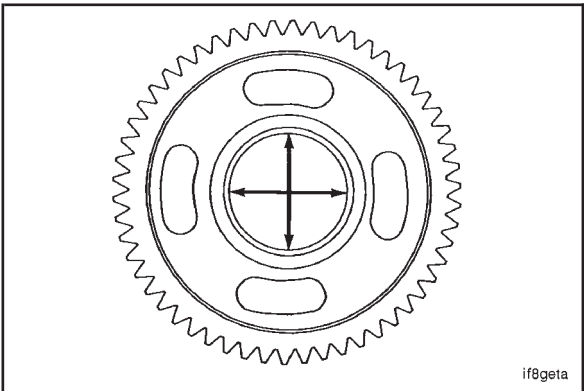
Inspection

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



Visually inspect the shaft for damage.

Use crocus cloth to remove any burrs.

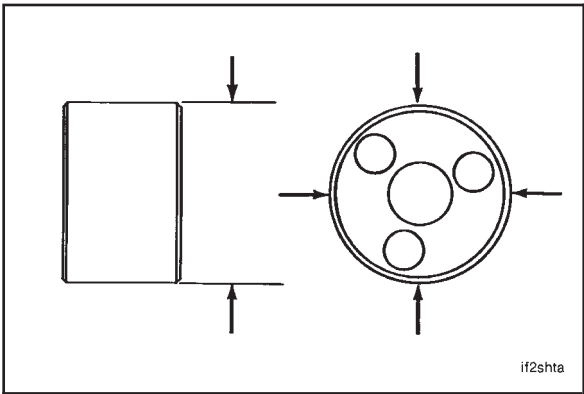


Measure the idler gear bushing bore inside diameter.

Idler Gear Bushing Bore I. D.		
mm		in
60.045	MIN	2.3640
60.100	MAX	2.3661

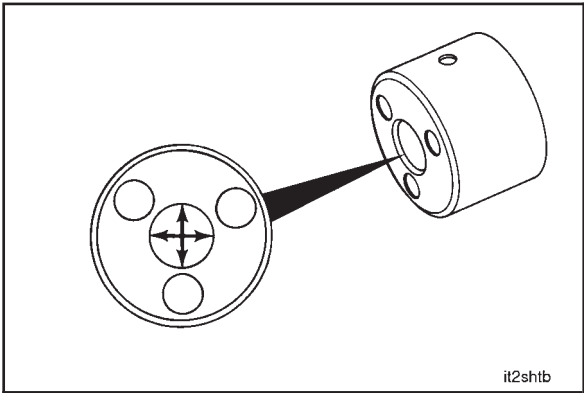
Measure the idler gear shaft outside diameter.

Idler Gear Shaft O. D.		
mm		in
59.975	MIN	2.3612
60.008	MAX	2.3625



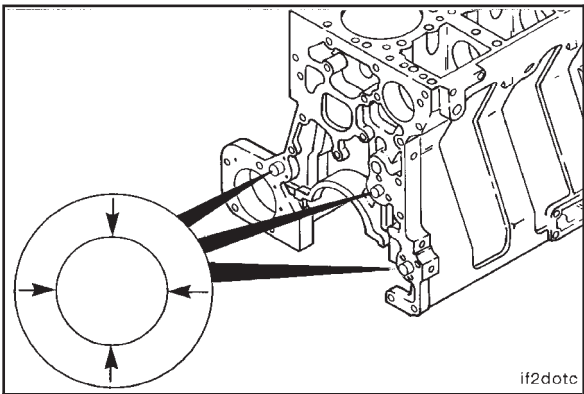
Measure the idler gear shaft ring dowel bore inside diameter.

Idler Gear Shaft Ring Dowel Bore I.D.		
mm		in
19.245	MIN	0.7577
19.265	MAX	0.7585



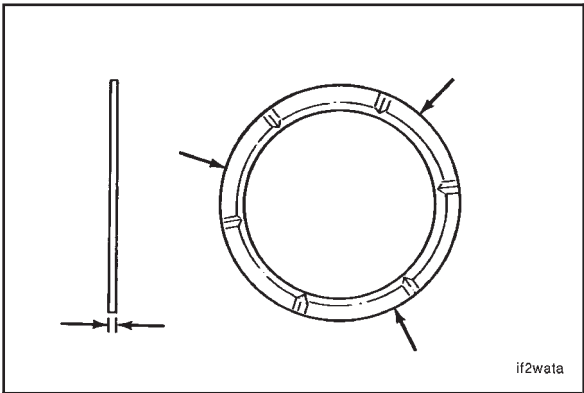
Measure the idler gear ring dowel outside diameter.

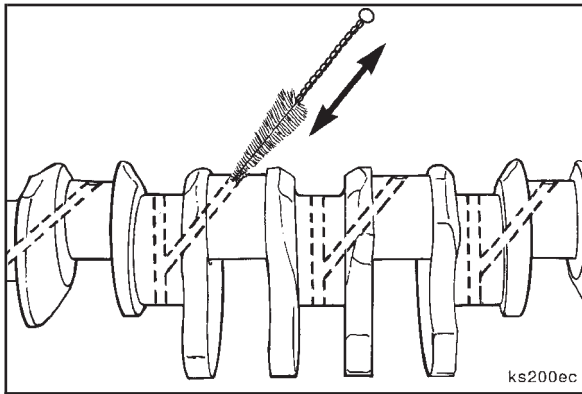
Idler Gear Ring Dowel O. D.		
mm		in
19.217	MIN	0.7566
19.243	MAX	0.7576



Measure the idler gear thrust washer thickness in three places 120 degrees apart.

Idler Gear Thrust Washer Thickness		
mm		in
2.400	MIN	0.0945
2.470	MAX	0.0972





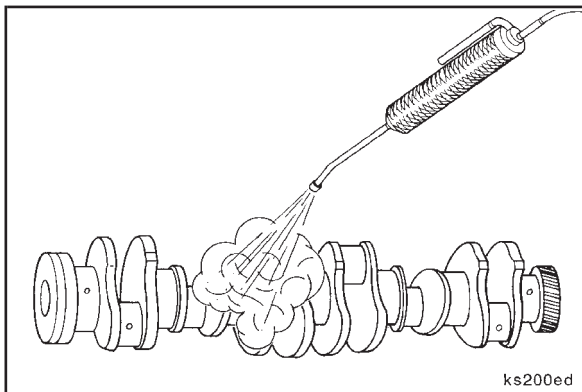
Crankshaft - Cleaning and Inspection For Reuse (1-06)

Cleaning



Use crocus cloth to polish the machined surfaces.

Use a bristle brush to clean the oil drillings.

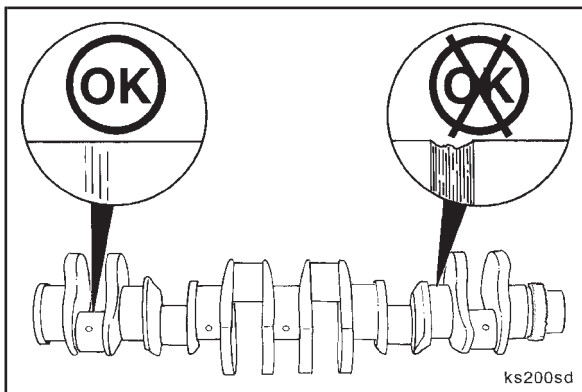


Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.



Steam clean the crankshaft and dry with compressed air.

Make sure to blow out the threaded holes on each end of the crankshaft and the oil drillings.



Inspection

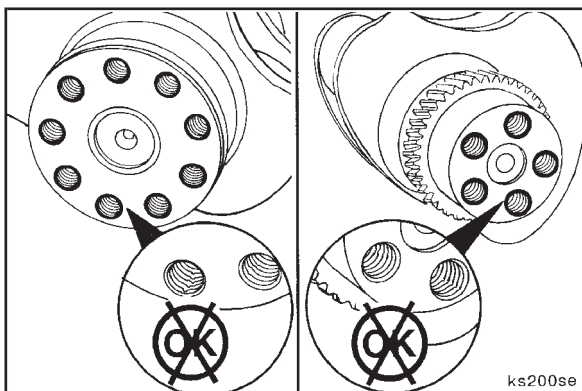


Visually inspect the machined surfaces for scratches or nicks.



Use crocus cloth to remove the nicks and scratches.

If scratches or nicks can be felt with a fingernail after the crankshaft has been polished with crocus cloth, the crankshaft **must be** replaced or reconditioned. Refer to the Alternative Repair Manual, Bulletin No. 3810310.



Visually inspect the threaded capscrew holes for damage.

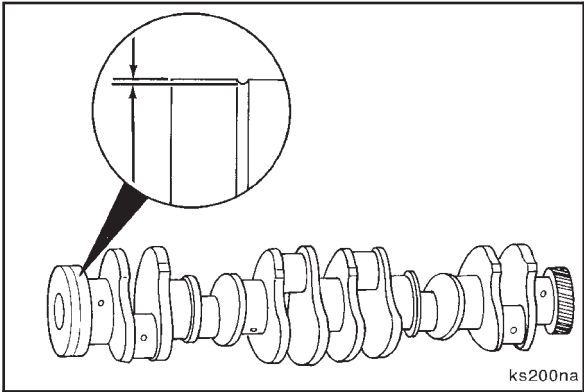
Use one of the following methods to repair any threaded holes:

- Chase the threads
- Use threaded insert kit, Part No. 3376881

NOTE: If more than three threaded holes are damaged in one end, the crankshaft **must be** replaced.

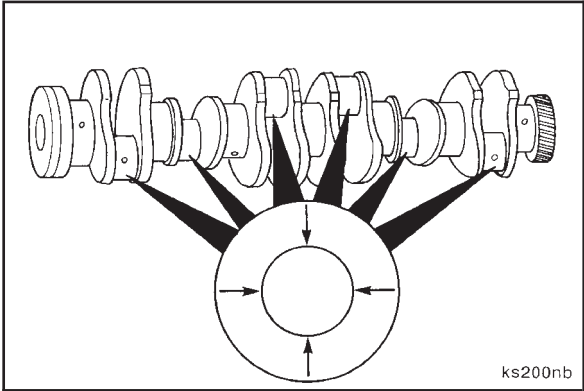
Measure the front and rear oil seal wear grooves.

Crankshaft Rear Oil Seal Wear Groove		
mm		in
0.25	MAX	0.0098



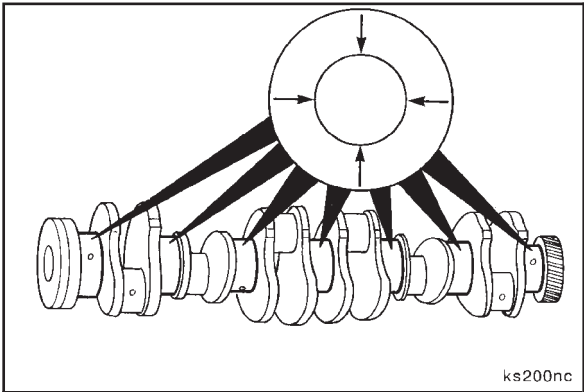
Measure the connecting rod journals outside diameter.

Crankshaft Connecting Rod Journal O.D.		
mm		in
78.950	MIN	3.1083
79.013	MAX	3.1107



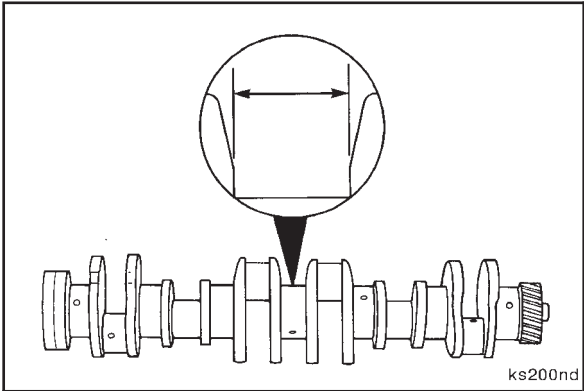
Measure the main bearing journals outside diameter.

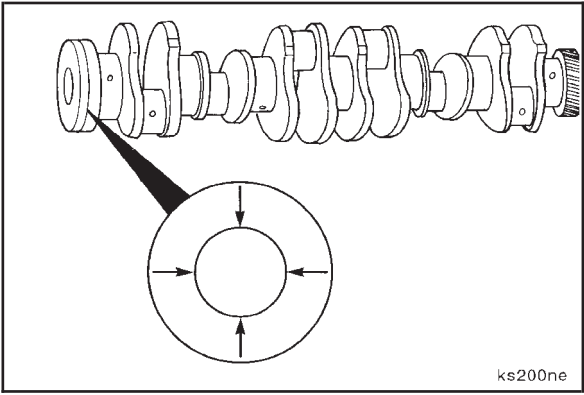
Crankshaft Main Bearing Journal O.D.		
mm		in
114.015	MIN	4.4888
114.055	MAX	4.4903



Measure the thrust face width.

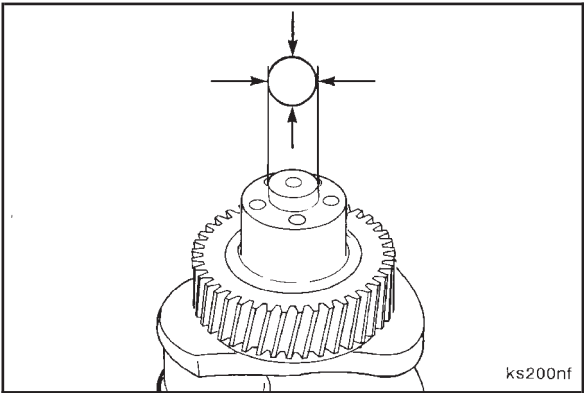
Crankshaft Thrust Face Width		
mm		in
49.975	MIN	1.9675
50.100	MAX	1.9724





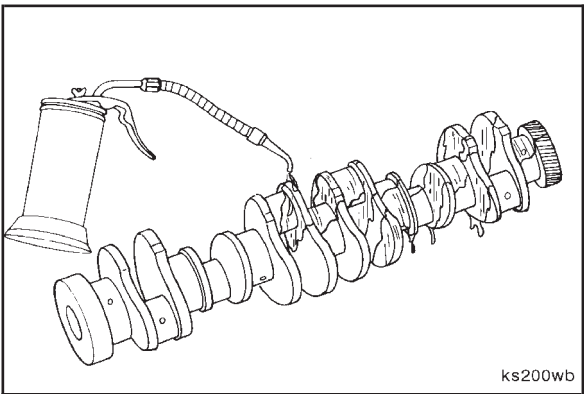
Measure the rear oil seal flange outside diameter.

Crankshaft Rear Oil Seal Flange O.D.		
mm		in
164.965	MIN	6.4947
165.035	MAX	6.4974

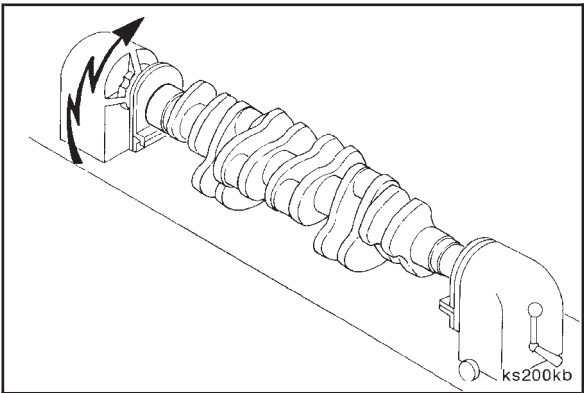


Measure the damper pilot outside diameter.

Crankshaft Damper Pilot O.D.		
mm		in
32.01	MIN	1.2602
32.04	MAX	1.2614



Use clean 15W-40 oil to coat the entire crankshaft to prevent rust.



Crankshaft Magnetic Crack Inspection (1-07)

The crankshaft **must be** tested by the 'Continuous Method'. The entire surface **must be** wetted with the magnetic bath solution before and during the flow of the magnetic current through the crankshaft.

Head Shot (Longitudinal Magnetization)

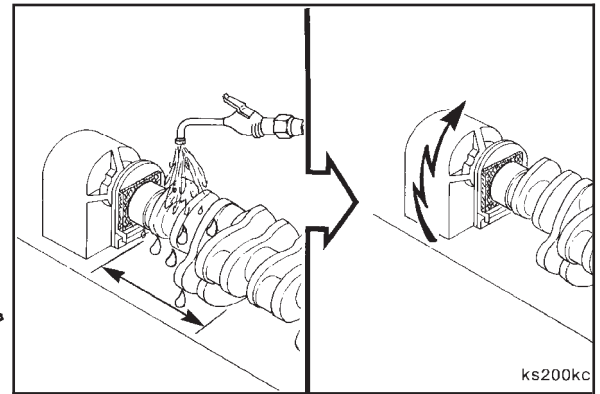
Apply the magnetic bath solution to the crankshaft and use 3800 amperes with direct current or rectified A.C. to magnetize the crankshaft.

A minimum of three successive head shots are required for each section of the crankshaft.

Flow the bath solution over the first one-third length of the crankshaft and apply three head shots of magnetizing current.

NOTE: Turn off the flow of bath solution before the third head shot of current is completed to prevent washing the metal particles from the crankshaft.

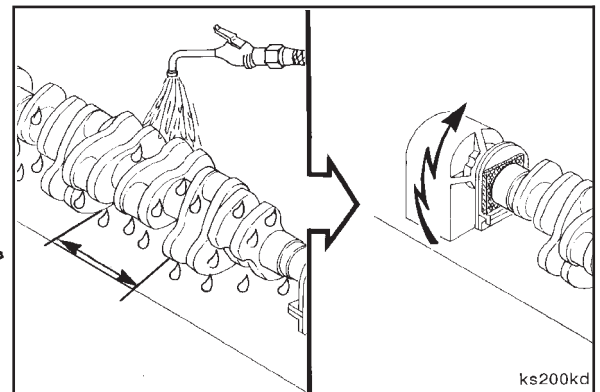
Inspect the first one-third section of the crankshaft. Refer to "Magnetic Inspection" in this procedure for reuse guidelines.



Flow the bath solution over the second one-third length of the crankshaft and apply three head shots of magnetizing current.

NOTE: Turn off the flow bath before the third head shot of current is completed to prevent washing the metal particles from the crankshaft.

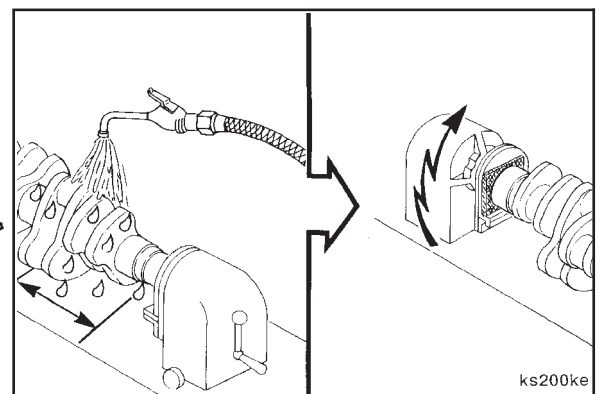
Inspect the second one-third section of the crankshaft. Refer to "Magnetic Inspection" in this procedure for reuse guidelines.



Flow the bath solution over the last one-third length of the crankshaft and apply three head shots of magnetizing current.

NOTE: Turn off the flow of bath solution before the third head shot of current is completed to prevent washing the metal particles from the crankshaft.

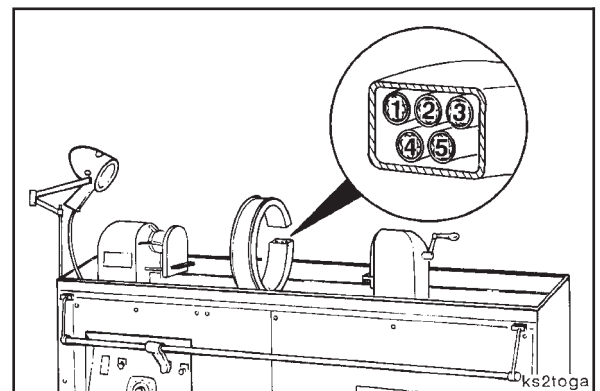
Inspect the last one-third section of the crankshaft. Refer to "Magnetic Inspection" in this procedure for reuse guidelines.

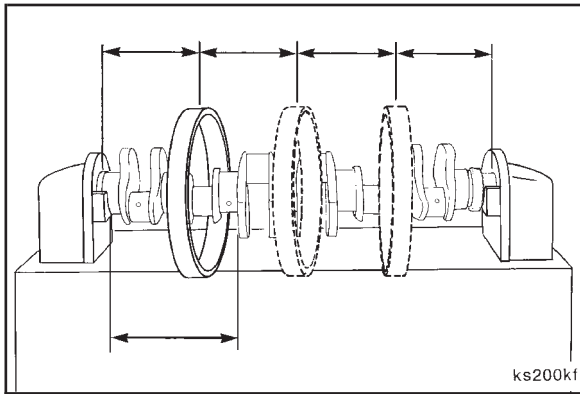


Coil Shot (Circumferential Magnetization)

Apply the magnetic bath solution and magnetize the crankshaft in a 514.35 mm [20.249 inch] inside diameter coil or equivalent using 3600 to 4000 ampere-turns with direct current or rectified A.C.

NOTE: Ampere-turn is the amperage flowing through the coil multiplied by the number of turns in the coil.





A minimum of three coil shots are required for each 18 inch length to correctly magnetize the crankshaft.

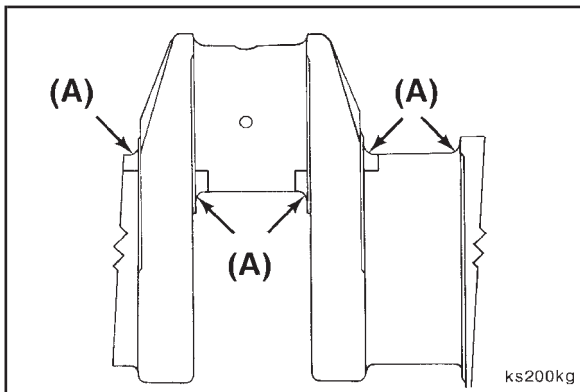


Flow the magnetic bath solution over the crankshaft in one third sections.

Apply three coil shots after each wetting with the coil placed at quarter-length points along the crankshaft.

NOTE: Turn off the flow of bath solution before the third coil shot is completed to prevent washing the metal particles from the crankshaft.

Inspect each 18 inch section after the third coil shot is completed.



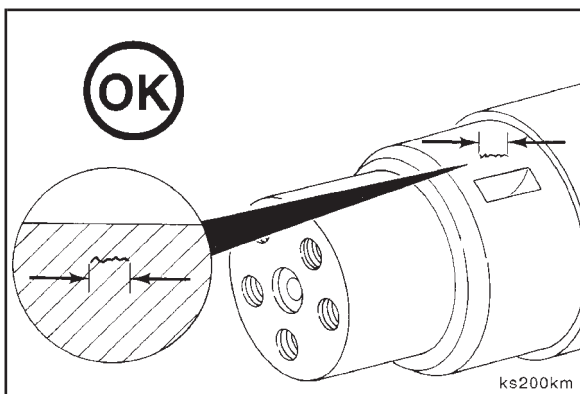
Magnetic Inspection - Limits of Acceptance



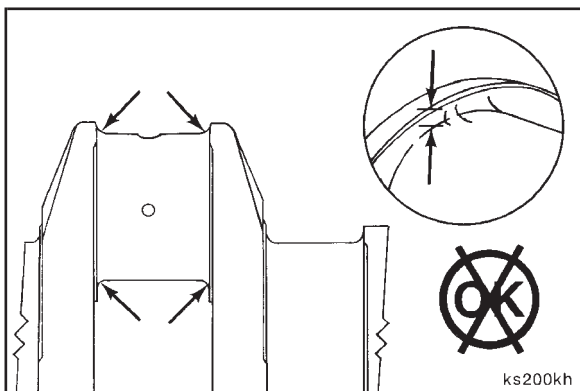
Visually inspect for open indications.

An open indication is a crack open to the surface that can be seen without using optical enhancement. An open indication can sometimes be felt with a fingernail. Do **not** mistake forging trim lines for crack indications.

If open indications are seen in the hardened fillet area or the critical areas shown (A), refer to the Alternative Repair Manual, Bulletin No. 3810310..

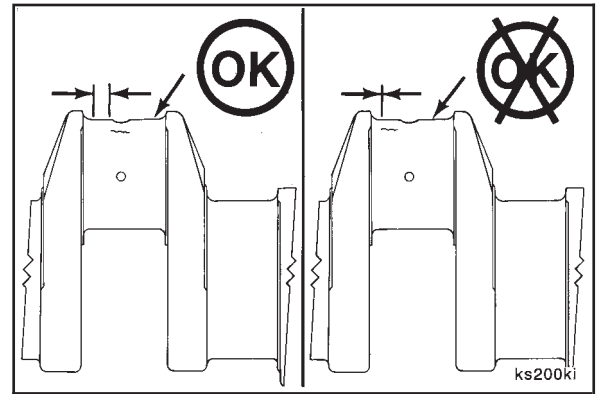


Open indications longer than 6 mm [1/4 inch] long are **not** acceptable.



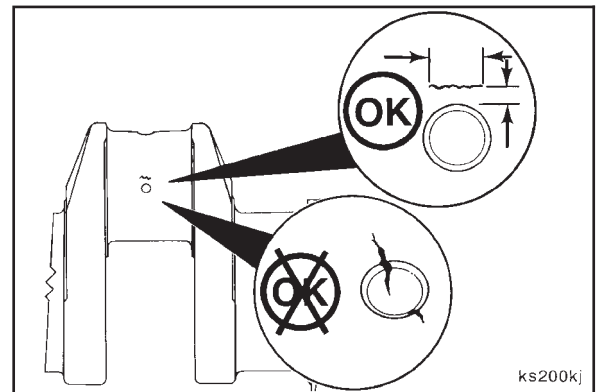
No open indications are permissible in any fillets or the critical areas.

Open indications on the crankpin or main bearing journal surfaces that extend closer than 3 mm [1/8 inch] to the fillet but **do not** enter the fillet are acceptable.

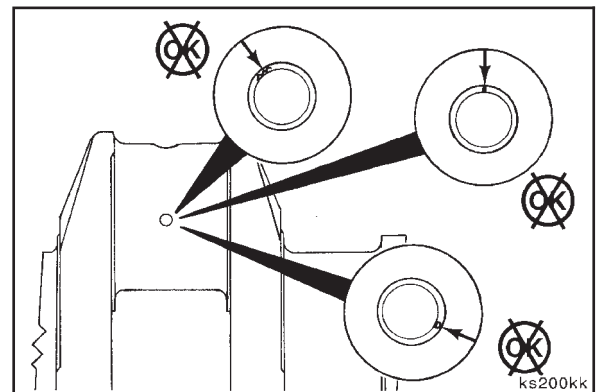


Open indications in the longitudinal direction up to 12 1/2 mm [1/2 inch] long, but **not** closer than 3 mm [1/8 inch] to the oil hole chamfer are acceptable.

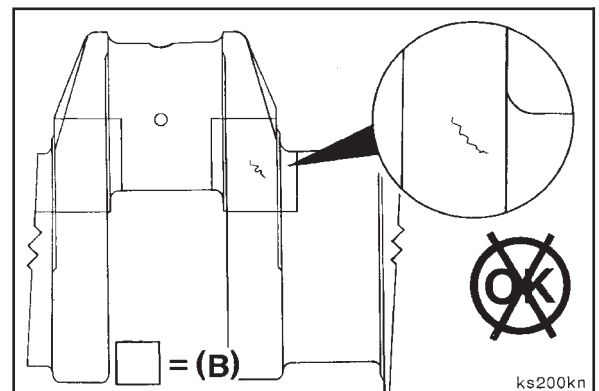
Open indications that enter the oil hole chamfer or intersect the oil hole at 45 degrees (plus or minus 10 degrees) are **not** acceptable.

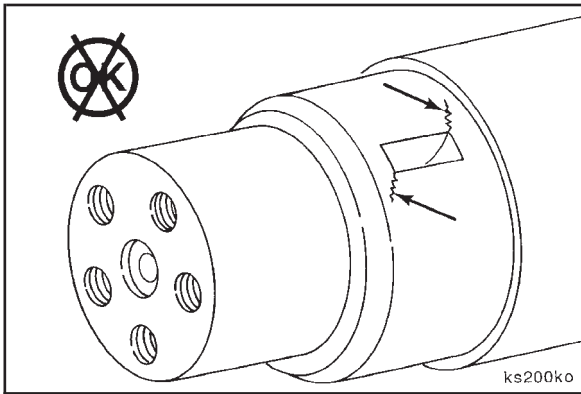


Any open indication in the crankpin bearing oil hole entrance chamfer is **not** acceptable.

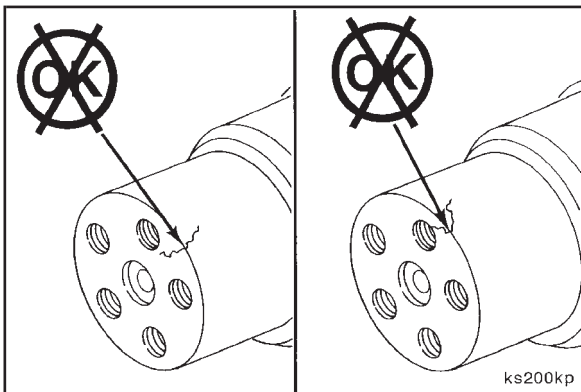


Open indications on the counterweights inside of the critical area (B) are **not** acceptable.

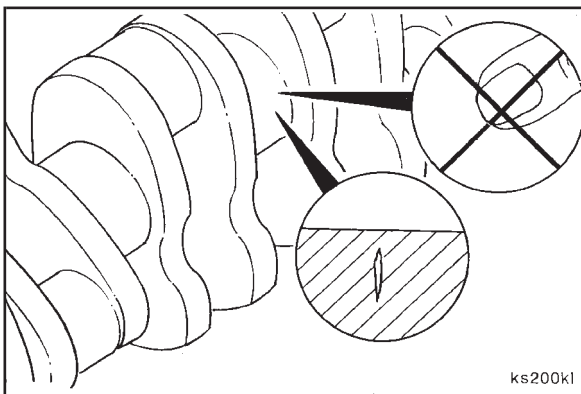




Open indications on the gear step diameter that enter the crankshaft keyway are **not** acceptable.

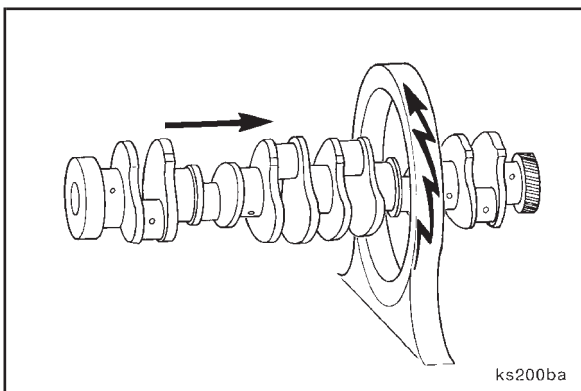


Open indications that extend over the face of the crankshaft or extend into the damper mounting capscrew holes are **not** acceptable.



Subsurface indications **cannot** be seen with the naked eye after the magnetic particles have been removed. These are indications of open areas or foreign objects below the surface.

Inspect for subsurface indications.



Caution: All magnetism must be removed from the crankshaft completely and the crankshaft cleaned thoroughly. Small metal particles will cause engine damage.



Remove all magnetism from the crankshaft.

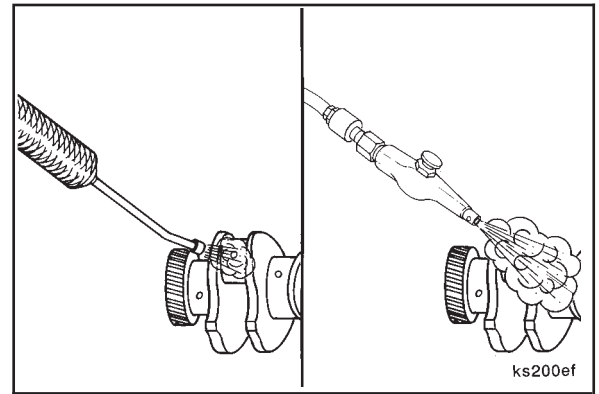
The maximum residual magnetic field on any pin or main bearing journal is 8 gauss.

NOTE: It can be necessary to use reverse D.C.-30 point step down equipment, or equivalent, to remove the magnetism.

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

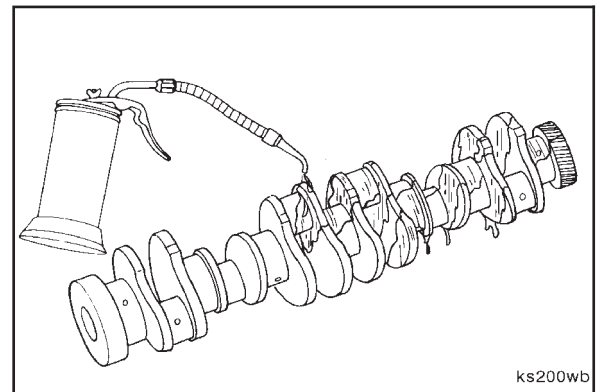
Use steam to clean the crankshaft and oil drillings.

Dry with compressed air.



Use a light preservative oil to lubricate the crankshaft to prevent rust.

If the crankshaft is **not** going to be used immediately, protect the part with a plastic cover to prevent dirt from sticking to the oil.



Main Bearings - Cleaning and Inspection for Reuse (1-08)

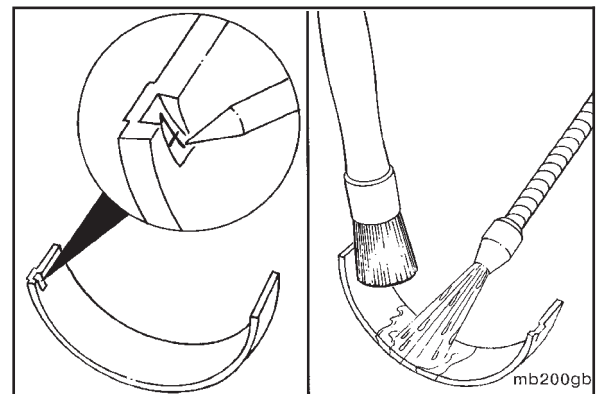
Make sure the bearings are marked for location. The bearings **must be** installed in their original location if used again.

Cleaning

Caution: Do not use a scraper or a wire brush. The bearings can be damaged.

Use solvent and a soft bristle brush.

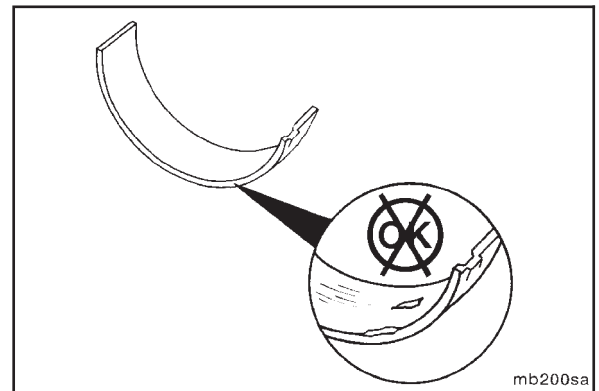
Dry with compressed air.

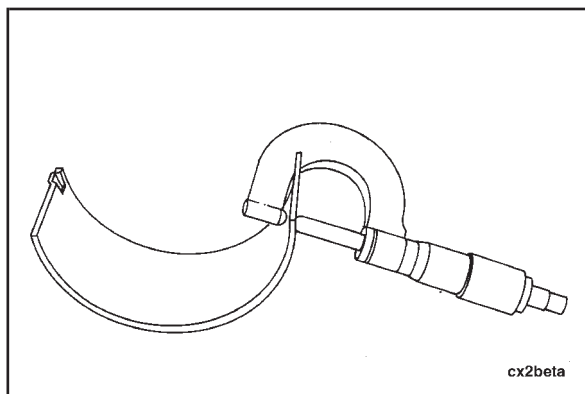


Inspection

Visually inspect the bearings for nicks, scratches or damage.

For more detailed information of bearing reuse guidelines, refer to Parts Reuse Guidelines, Bulletin No. 3810303.

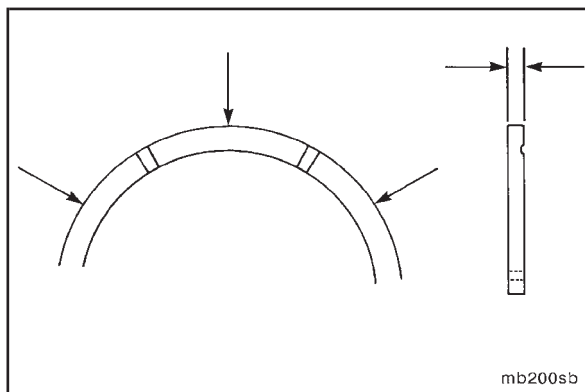




Measure the bearing shell thickness with a ball micrometer.



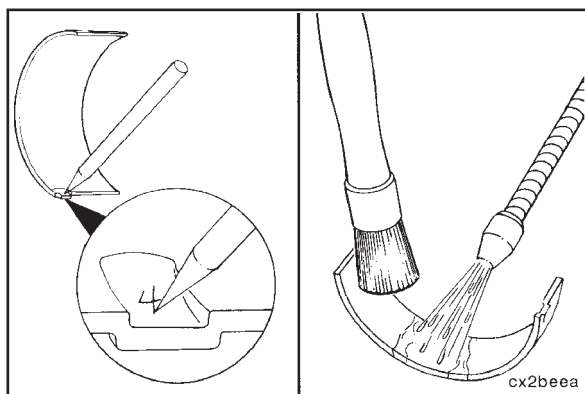
Main Bearing Shell Thickness (Standard)		
mm		in
3.895	MIN	0.1533
3.944	MAX	0.1553



Measure the thrust bearing thickness in three locations.



Thrust Bearing Thickness		
mm		in
4.75	MIN	0.1870
4.89	MAX	0.1925



Connecting Rod Bearings - Cleaning and Inspection for Reuse (1-09)

The bearings **must** be marked for location as they are removed for future identification. Each bearing **must** be installed in its' original location if the bearing is used again.

Cleaning

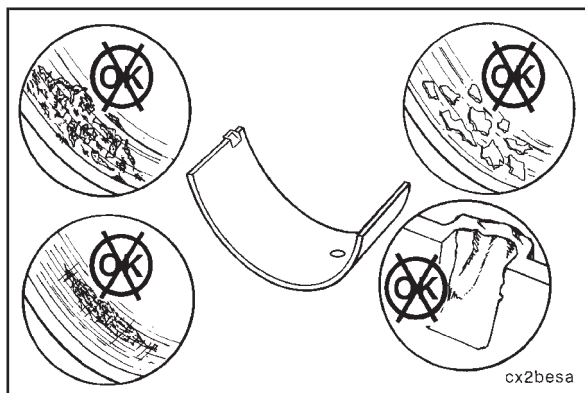


Caution: Do not use a scraper or a wire brush. The bearings can be damaged.



Use solvent and a soft bristle brush.

Dry with compressed air.



Inspection



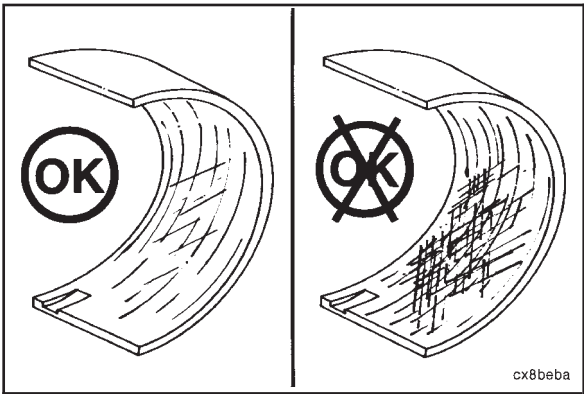
Visually inspect the bearings for damage.

Replace bearings with any of the following damage:

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

For more detailed information of bearing reuse guidelines, refer to Parts Reuse Guidelines, Bulletin No. 3810303.

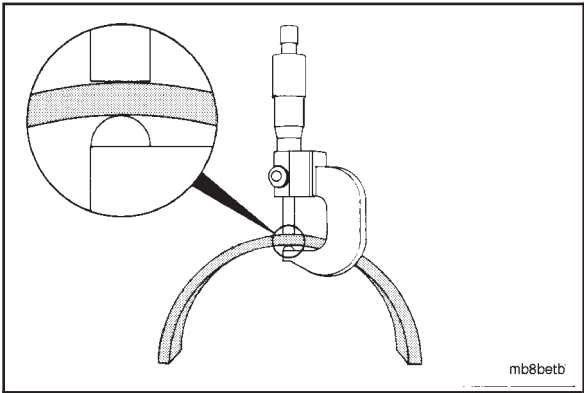
Normal bearing wear produces a smooth finish which will wear into the copper lining. Exposed copper does **not** always indicate worn bearings.



Measure the bearing thickness using a ball micrometer. Measure the thickness at three locations on each edge of the bearing.



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

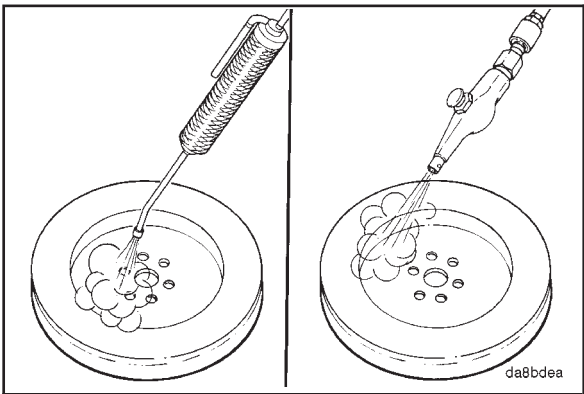


Vibration Damper (Viscous) - Cleaning and Inspection for Reuse (1-10)

Cleaning

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

Steam clean the damper and dry with compressed air.

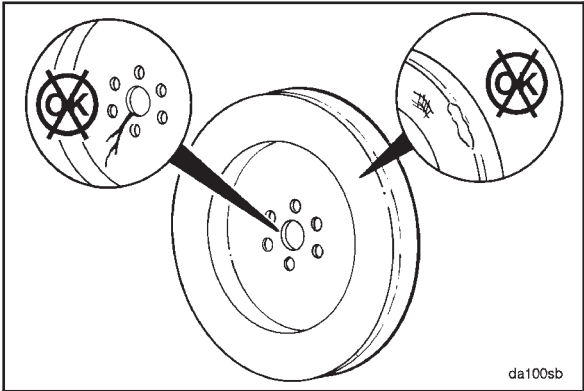


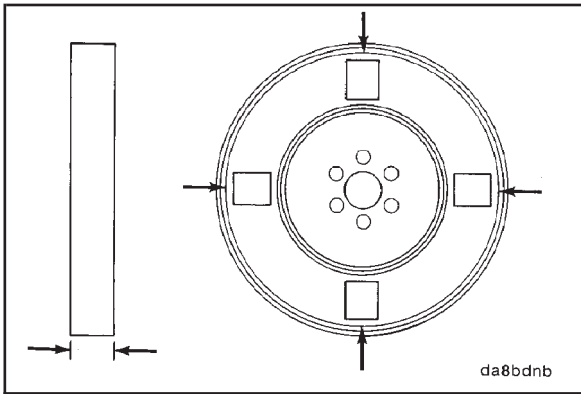
Inspection

Check the mounting area for cracks.

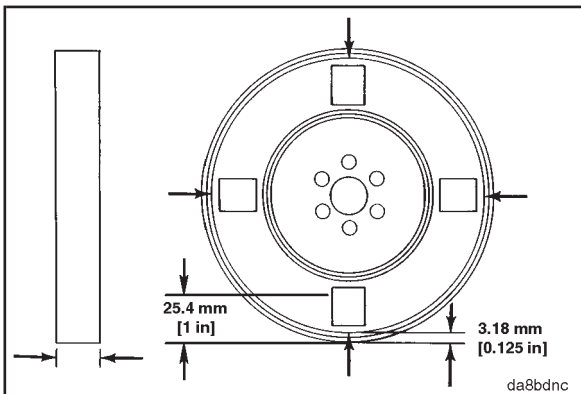
Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.





Remove the paint on **both** sides of the damper in four locations spaced 90 degrees apart.

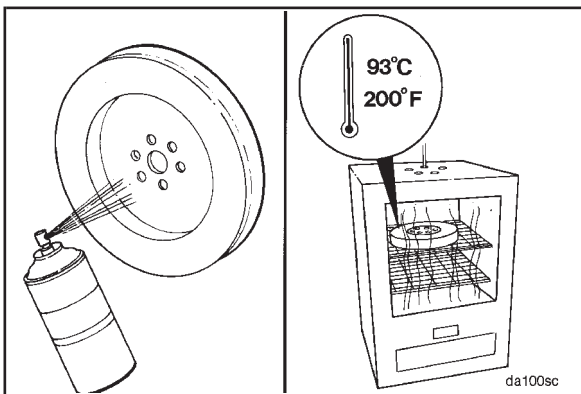


Measure and record the thickness at two points on each of the four locations as follows:

- Measure the thickness at 3.18 mm [0.125 inch] from the outer lip.
- Measure the thickness at 25.4 mm [1.0 inch] from the outer lip.

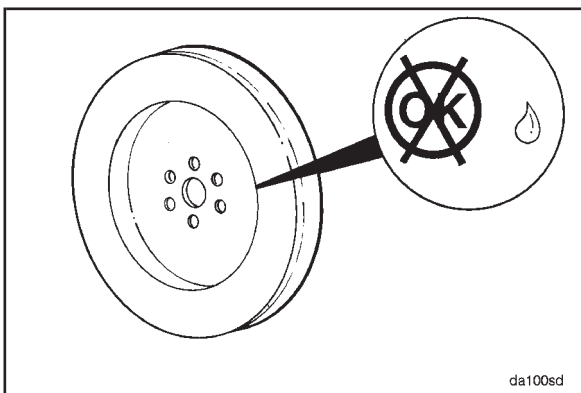
NOTE: This step will result in a total of eight measurements.

If the variations between any of the eight measurements exceeds 0.25 mm [0.010 inch], or if the thickness at any point exceeds the maximum thickness dimensions of 45 mm [1.772 inch], replace the damper.



Spray the rolled lip of the damper with crack detection developer, Part No. 3375434 or equivalent.

Heat the damper in an oven (rolled lip side down) at 93°C [200°F] for two hours.



Caution: Wear protective gloves when handling parts that have been heated to prevent personal injury.

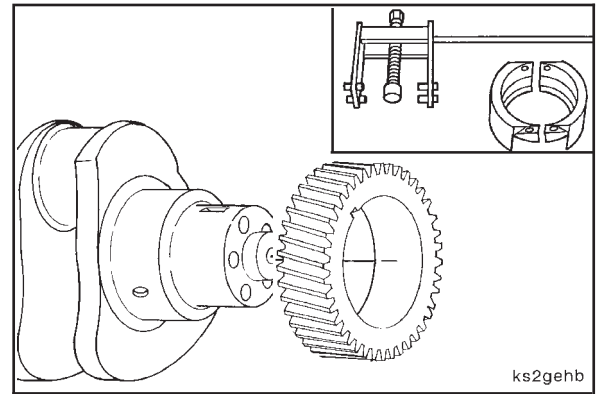


Remove the damper from the oven and check for fluid leakage around the rolled lip. If there is leakage, replace the damper.

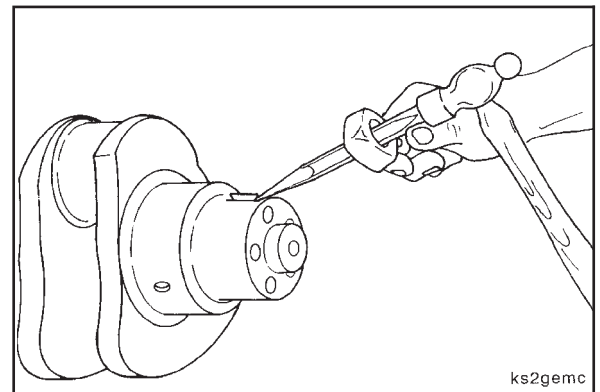
Crankshaft Gear - Replacement (1-11)

Removal

Use gear puller, Part No. 3375840, with jaws, Part No. 3375839, to remove the crankshaft gear.



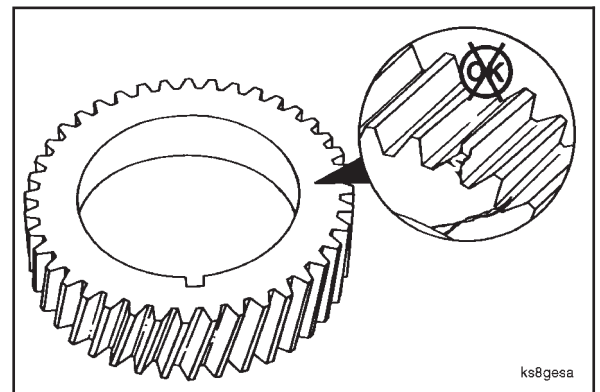
Use a flat chisel and a hammer to remove the key.



Inspection

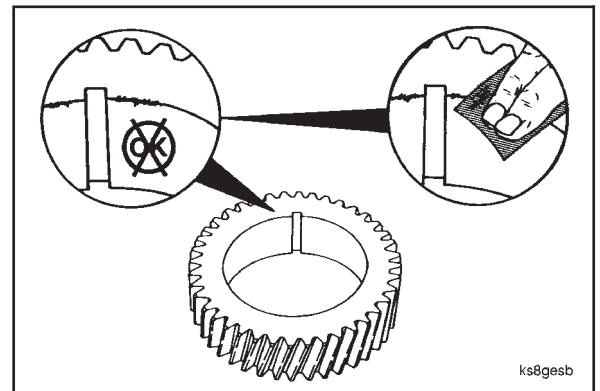
Visually inspect the crankshaft gear for cracks and broken or chipped teeth.

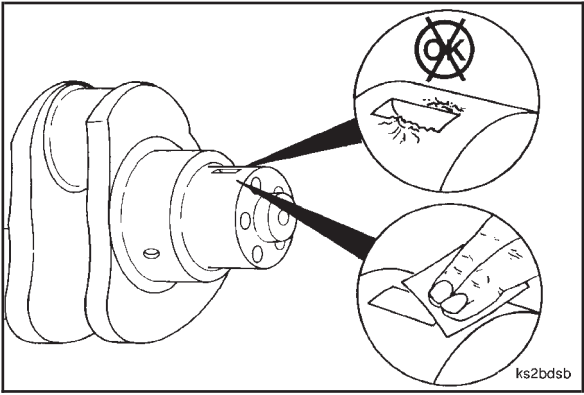
The gear **must** be replaced if it is damaged.



Visually inspect the gear and keyway for nicks or burrs.

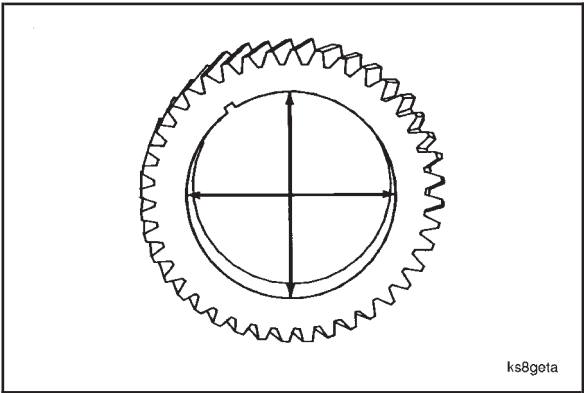
Use crocus cloth to remove nicks and burrs.





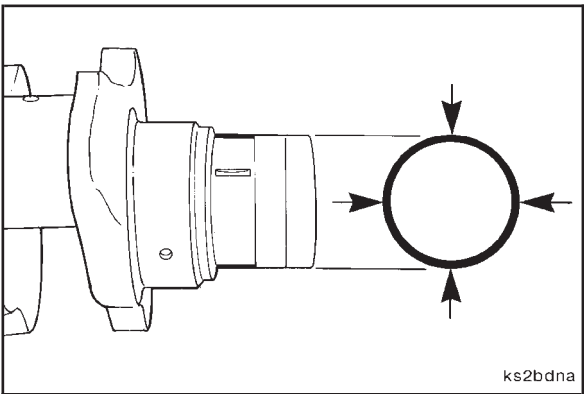
Visually inspect the crankshaft gear journal for burrs or damage.

Use crocus cloth to remove burrs.



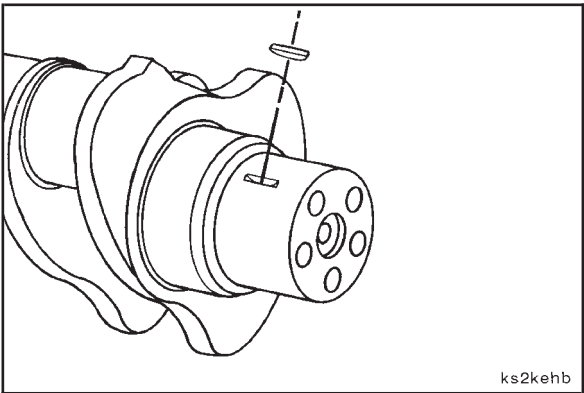
Measure the crankshaft gear inside diameter.

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

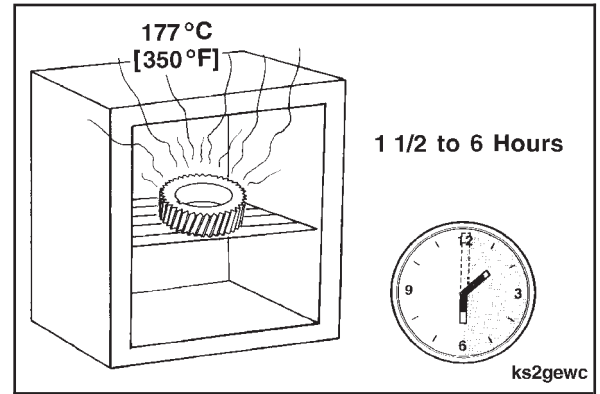


Installation

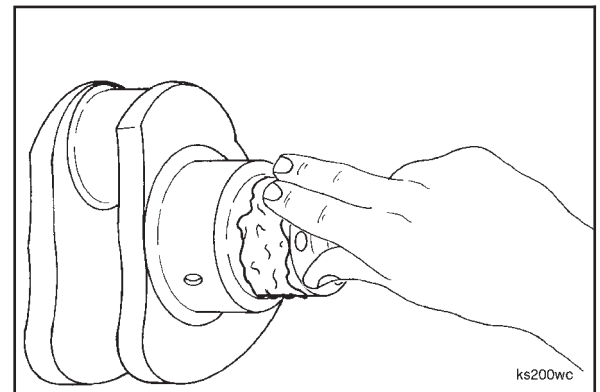
Use a soft hammer to install the key in the crankshaft keyway.

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

Heat the gear in an oven heated to 177°C [350°F] for a minimum of 1 1/2 hours, but **not** more than 6 hours.



Use Lubriplate® No. 105, or equivalent, to lubricate the outside diameter of the crankshaft gear journal.



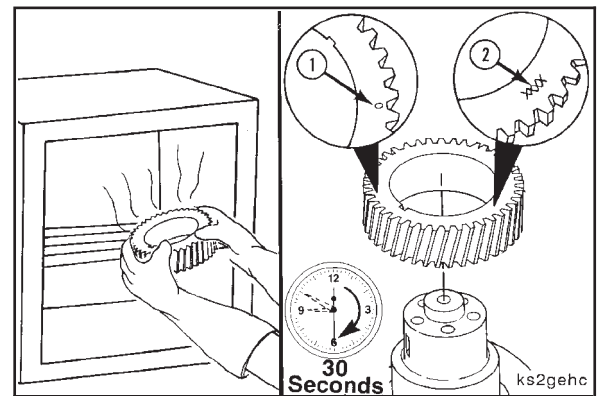
Caution: Use insulated gloves, Part No. 3823730, when handling heated parts. Personal injury can result.

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.

Remove the gear from the oven.

Caution: Do not use water or oil to reduce the cooling time. The gear can crack. Allow the air to cool the gear.

Align the keyway of the gear with the key in the crankshaft and install the gear within 30 seconds.



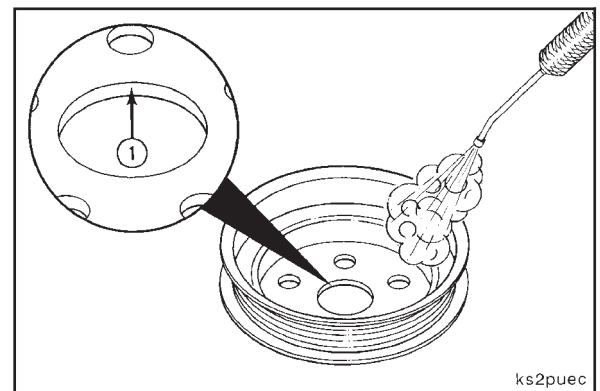
Crankshaft Pulley - Cleaning and Inspection for Reuse (1-12)

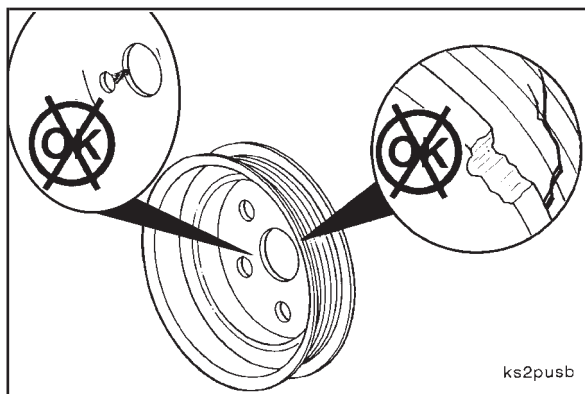
Cleaning

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

Use Scotch-Brite® to polish the crankshaft pilot bore (1).

Steam clean and dry with compressed air.

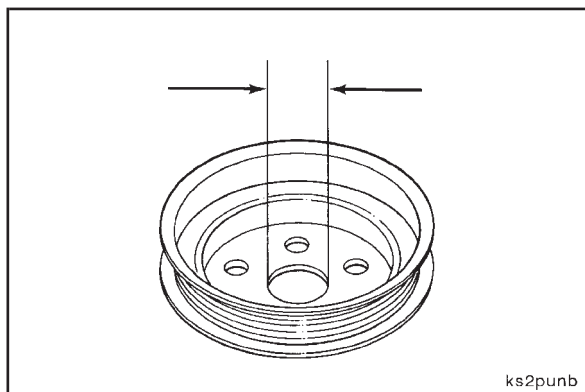




Inspection



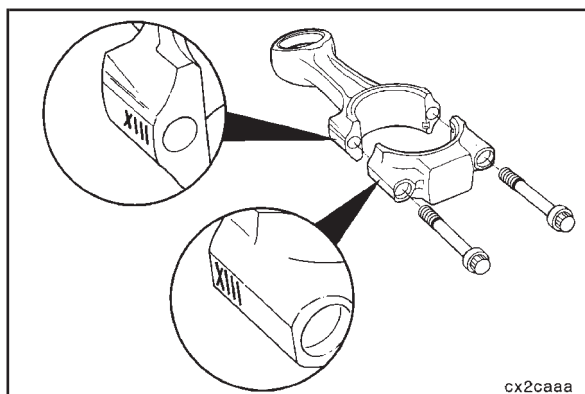
Visually inspect the pulley for broken pieces, cracks, or excessive wear in the belt grooves. Replace the pulley if any of these conditions exist.



Measure the pulley crankshaft pilot bore inside diameter.



Crankshaft Pulley Crankshaft Pilot Bore I. D.		
mm		in
32.05	MIN	1.2618
32.10	MAX	1.2638



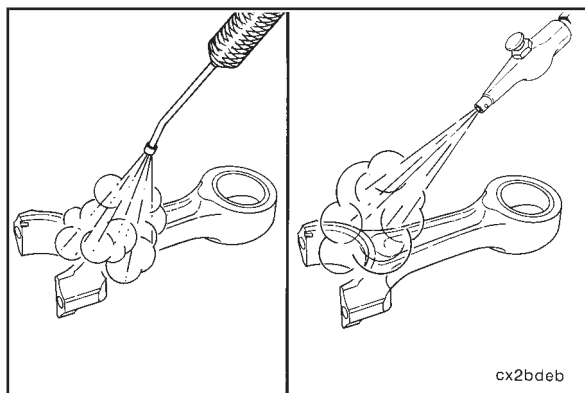
Connecting Rod - Cleaning and Inspection for Reuse (1-13)

Cleaning

NOTE: The number on the connecting rod cap **must** be the same as the number on the rod. Do **not** assemble a new cap to a used rod or a used cap to a new rod.



Remove the capscrews and cap from the rod.



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

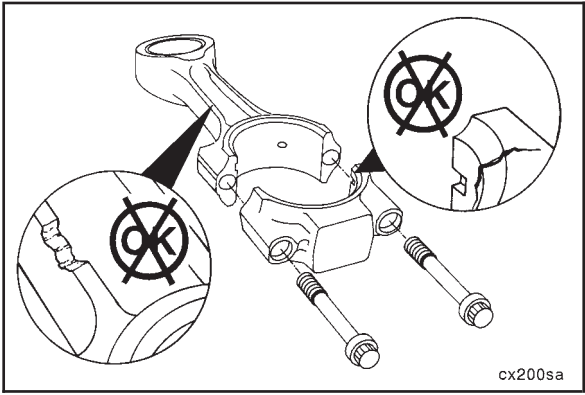


Use solvent or steam to clean the rod.

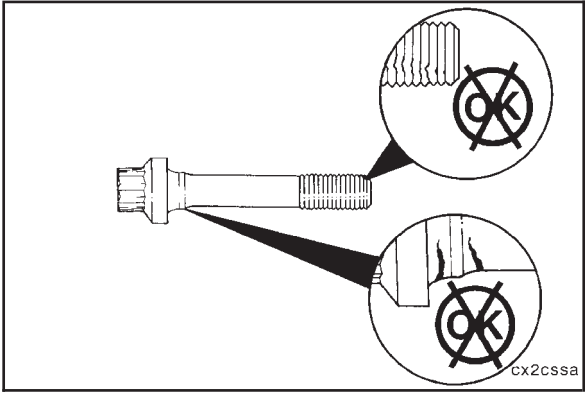
Dry with compressed air.

Inspection

Visually inspect the rod and cap for damage.
Replace the rod if the “I-Beam” is nicked or damaged.

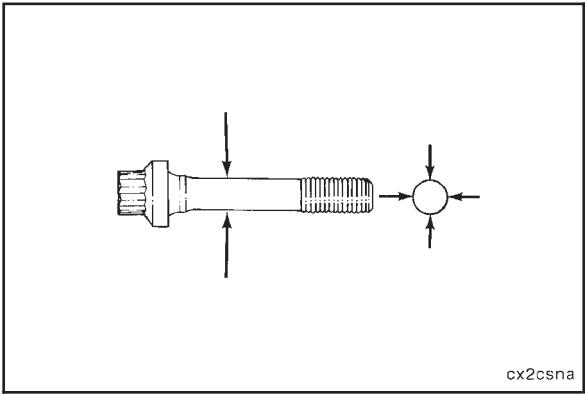


Visually inspect the connecting rod capscrew threads for damage.
Visually inspect under the capscrew heads for cracks.

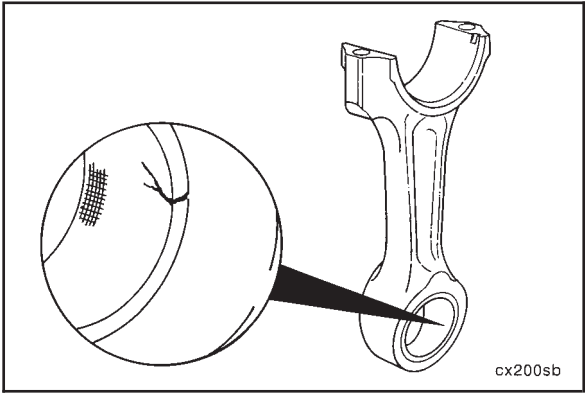


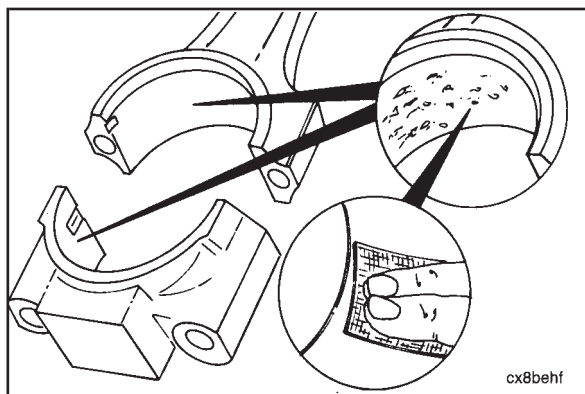
Measure the capscrew outside diameters.

Connecting Rod Capscrew O. D.		
mm		in
12.600	MIN	0.4961
12.800	MAX	0.5039



Visually inspect the piston pin bore for damage.

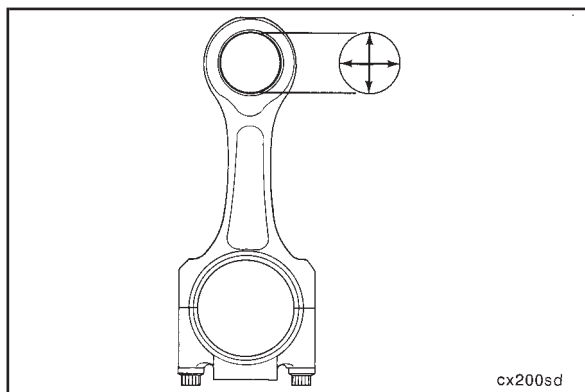




Visually inspect the bearing seating surface for nicks or burrs.



If burrs **cannot** be removed with crocus cloth, the rod **must be** replaced.

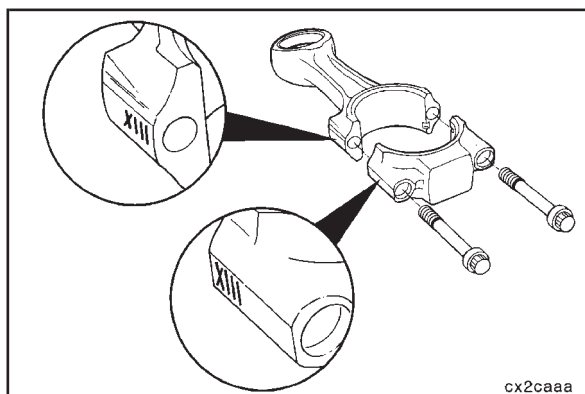


Measure the connecting rod piston pin bushing installed inside diameter.



Connecting Rod Piston Pin Bushing I. D. (Installed)

mm		in
54.054	MIN	2.1281
54.099	MAX	2.1299



Caution: Use a vise with brass jaws to hold the rod. Notches, scratches, or dents in the "I-Beam" will cause engine failure.

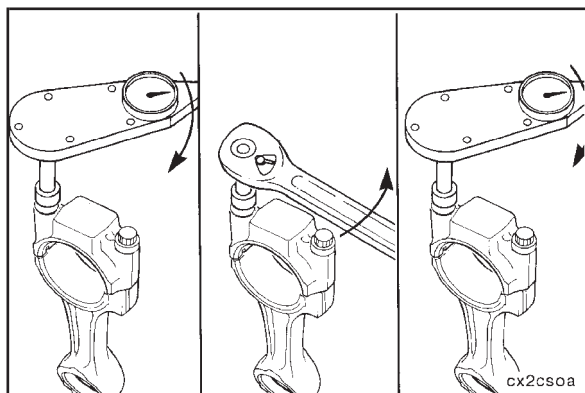
Caution: The number on the connecting rod must be the same as the number on the rod cap. Never assemble a new cap to a used rod or a used cap to a new rod. The engine can be damaged.



Use clean 15W-40 oil to lubricate the connecting rod capscrews.



Assemble the rod, cap, and capscrews.



Tighten the capscrews in the following sequence to the specified 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

Section 1 - Cylinder Block - Group 01
M11

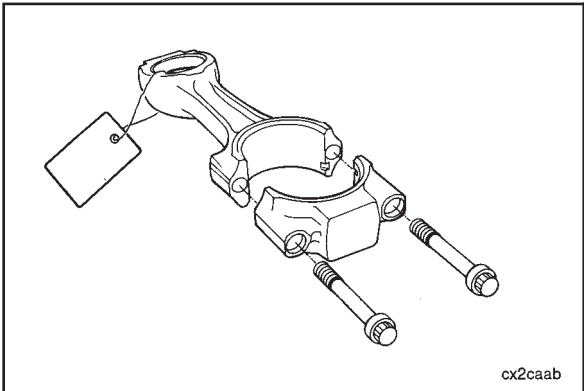
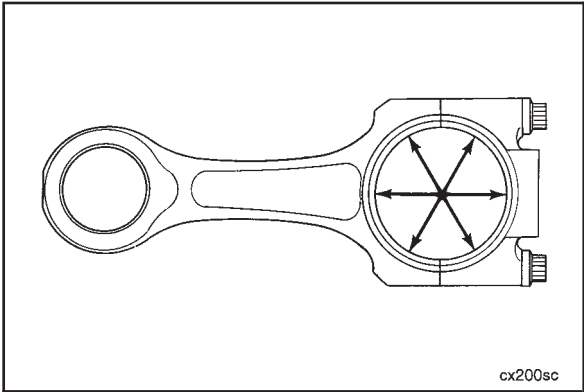
Measure the connecting rod bearing bore inside diameter at 45 degrees and at 90 degrees from the parting line.

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

If any of the three measurements are **not** within the specifications, the rod **must** be repaired or replaced.

Always tag a new connecting rod with the cylinder number of the rod being replaced.

Connecting Rod - Magnetic Inspection (1-14)
Page 1-45



Connecting Rod - Magnetic Crack Inspection (1-14)

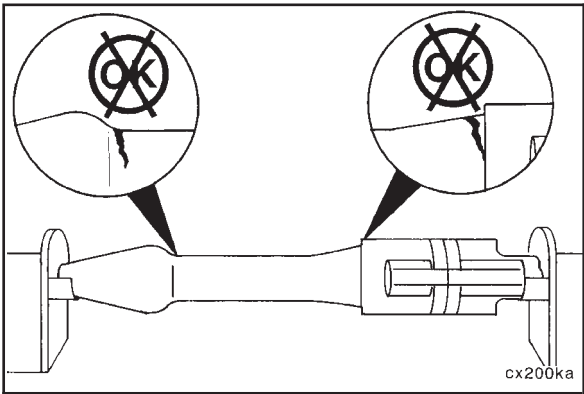
Use a magnetic particle testing machine to check the connecting rod for cracks.

NOTE: The connecting rod and cap **must** be assembled.

Use the residual method and apply head shot amperage.

Apply the amperage to 1500 ampere D.C. or rectified A.C..

Visually inspect the connecting rod for cracks.

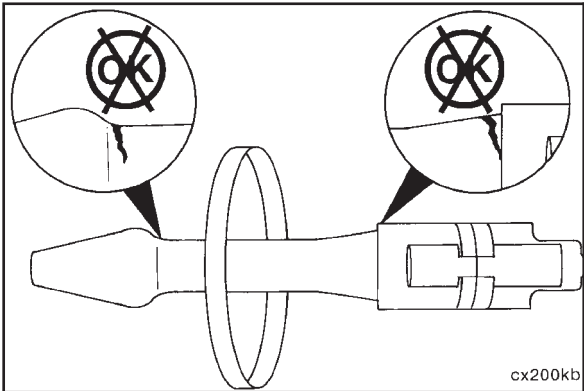


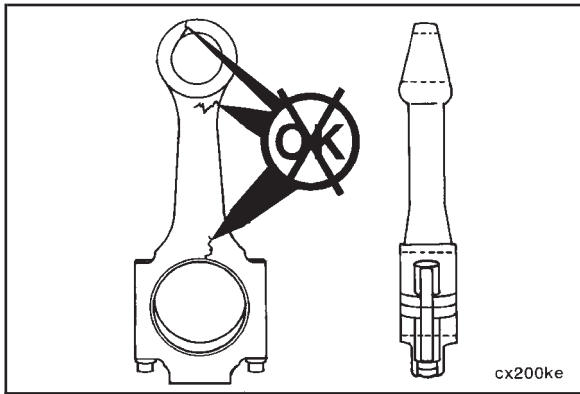
Use the residual method and apply coil shot amperage.

	Amperage (Ampere Turns)
MIN	2600 D.C. or rectified A.C.
MAX	2800 D.C. or rectified A.C.

NOTE: Ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.

Visually inspect the connecting rod for cracks.

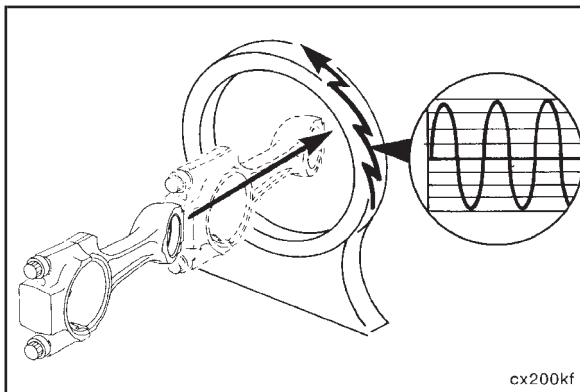




Connecting Rod - Limits of Acceptance

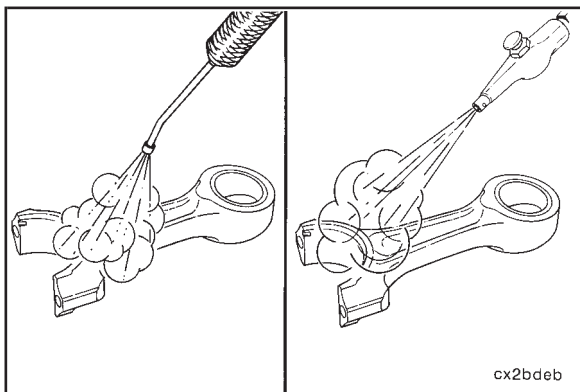
An indication is open if it can be seen with the naked eye in a well lighted area. Many times an open indication can be felt with a fingernail.

The connecting rod **must** be replaced if any indications are visible in the critical areas shown.



NOTE: The connecting rod **must** have all magnetism removed completely and cleaned thoroughly.

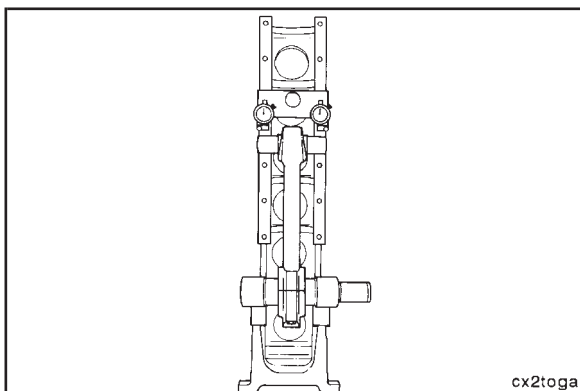
Remove all magnetism from the connecting rod.



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 connecting rod and dry with compressed air.



Connecting Rod - Bend and Twist Inspection (1-15)

Fixture Calibration

Use checking fixture, Part No. ST-561, and mandrel set, Part No. 3376690, to inspect the bend and twist of the connecting rod.

Calibrate the checking fixture with a new rod that has been measured for correct center to center length, 217.975 to 218.025 mm [8.5817 to 8.5836 inch].



Assemble the connecting rod cap to the rod. Refer to Procedure 1-13.

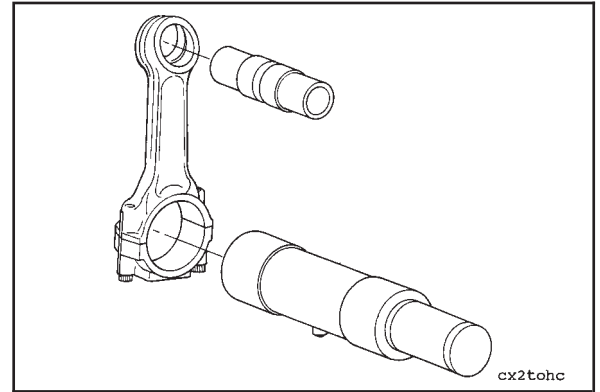
Section 1 - Cylinder Block - Group 01
M11

Connecting Rod - Bend and Twist Inspection (1-15)
Page 1-47

Install the piston pin mandrel, Part No. 3376693, from the mandrel set, Part No. 3376690, into the piston pin bore.

Install the mandrel, Part No. 3376691, in the piston crankshaft bore and expand the mandrel.

Make sure the pin on the mandrel is down and locked in position in the center of the connecting rod.

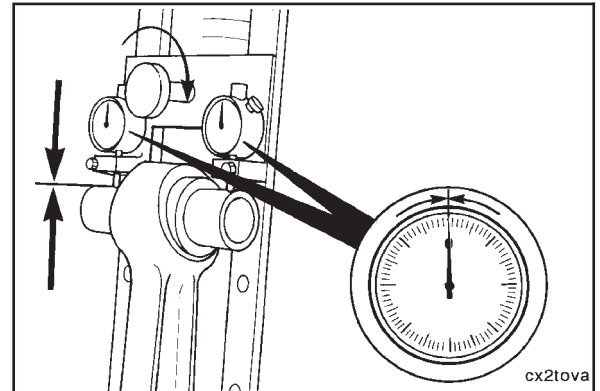


Install the connecting rod into the fixture.

Move the dial holder to position the contact points of the indicators on the mandrel in the piston pin bore.

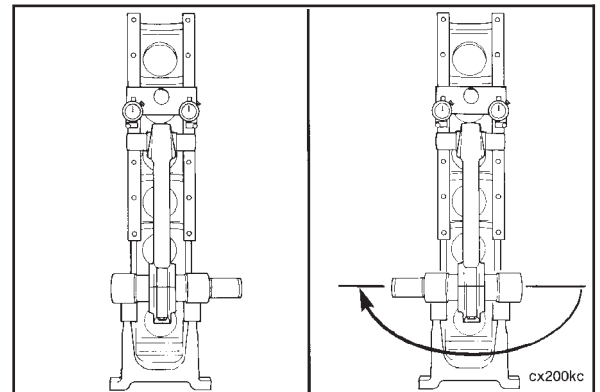
Tighten the bracket to hold the indicators in position.

Set the dial indicators to zero, "O".



Remove the connecting rod from the fixture.

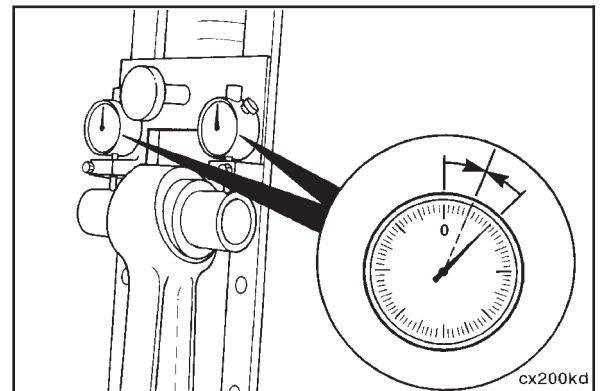
Turn the rod 180 degrees horizontally and install the rod into the fixture again.

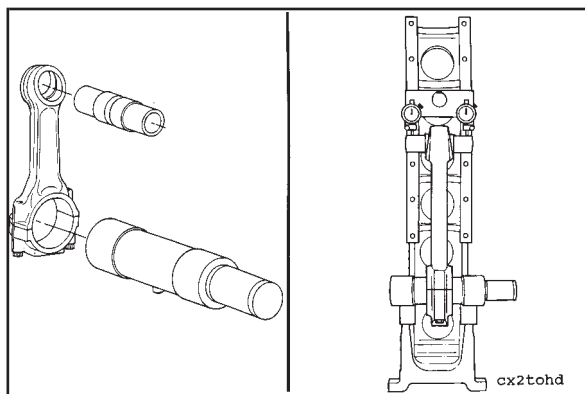


Check the dial indicators for zero, "O" position again.

If the dial indicators show any change from zero, "O", adjust the dials to half the indicated reading.

The fixture is now calibrated to allow the connecting rod to be installed into the fixture in either direction and the dials will indicate an equal deflection on either side of zero, "O".



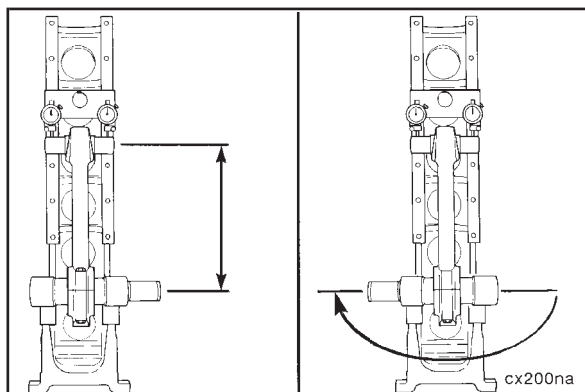


Alignment Inspection



Install the mandrel and arbor into the connecting rod to be inspected.

Install the connecting rod into the fixture.

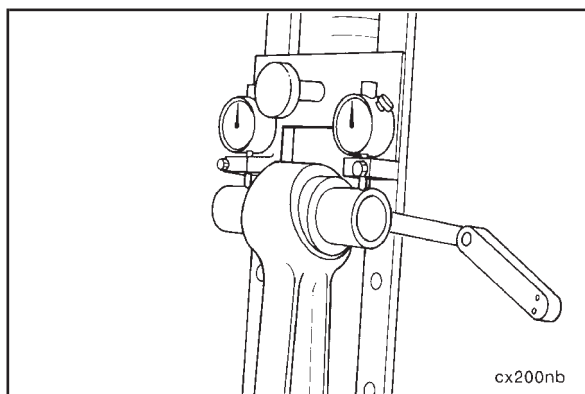


Measure the rod length and bend (alignment).



Connecting Rod Length			
	mm		in
	217.975	MIN	8.5817
	218.025	MAX	8.5836

Connecting Rod Alignment			
	mm		in
Bushing Installed	0.10	MAX	0.004

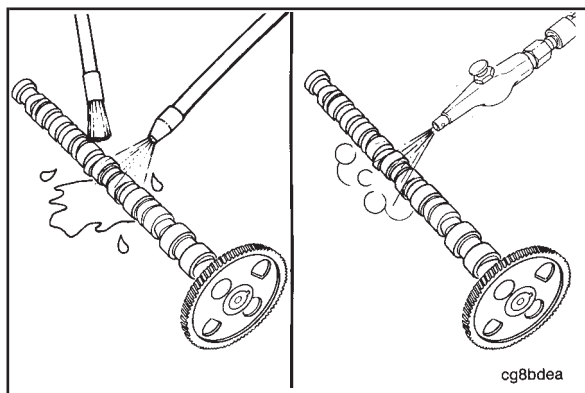


Twist Inspection

Install a feeler gauge between the mandrel and the dial indicator holding plate as shown.



Connecting Rod Twist			
	mm		in
Bushing Installed	0.25	MAX	0.010



Camshaft - Cleaning and Inspection for Reuse (1-16)

Cleaning



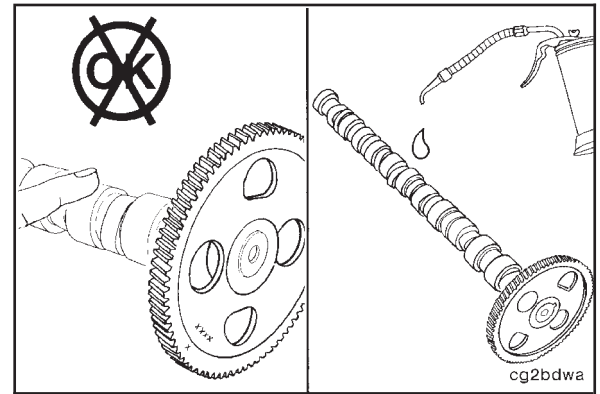
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.



Use solvent or steam clean the camshaft and dry with compressed air.

After the camshaft has been steam cleaned, do **not** touch the machined surfaces with bare hands. This will cause rust to form.

Use clean 15W-40 oil to lubricate the camshaft.

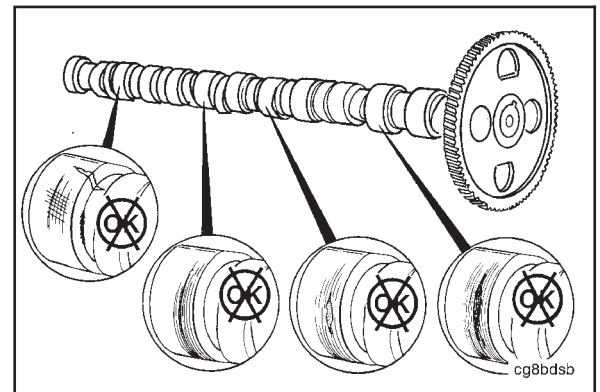


Inspection

Visually inspect the valve and injector lobes for damage.

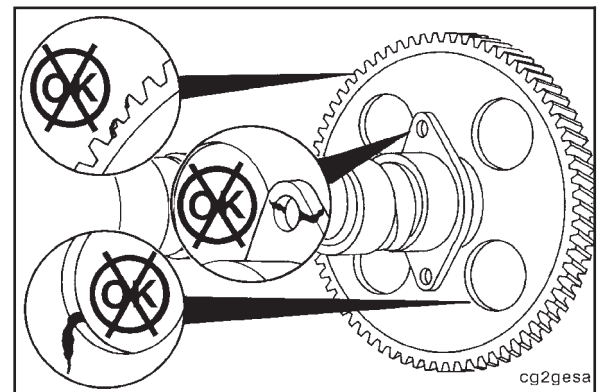
NOTE: Cummins Engine Co., Inc., does **not** recommend repairing camshafts by grinding the valve or injector lobes.

If the camshaft is damaged, it **must** be replaced.



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

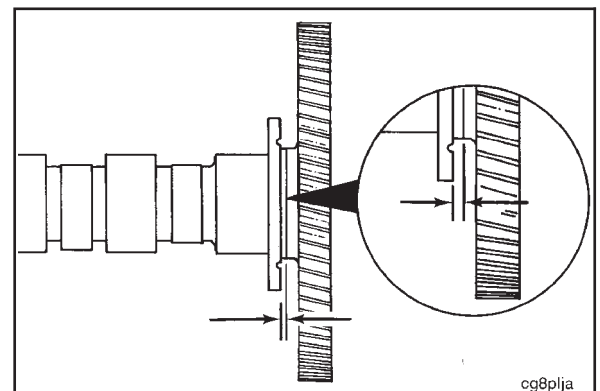
Visually inspect the thrust bearing for cracks.

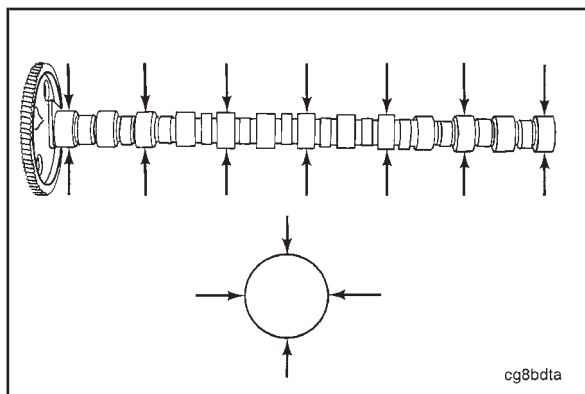


Measure the camshaft thrust plate clearance.

Camshaft Thrust Plate Clearance		
mm		in
0.180	MIN	0.0070
0.330	MAX	0.0130

If the clearance is **not** within specifications, check for proper gear seating against the camshaft. Remove the gear and check for burrs.



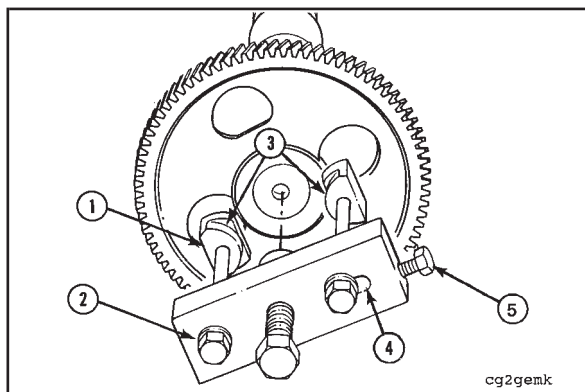


Measure the seven camshaft bushing journals.



Camshaft Bushing Journal O. D.		
mm		in
71.987	MIN	2.8341
72.013	MAX	2.8352

If the bushing journal outside diameters are **not** within specifications, the camshaft **must** be replaced.



Camshaft Gear - Replacement (1-17)



Removal

Use camshaft gear puller kit, Part No. 3824106, to remove the camshaft gear from the camshaft.

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.

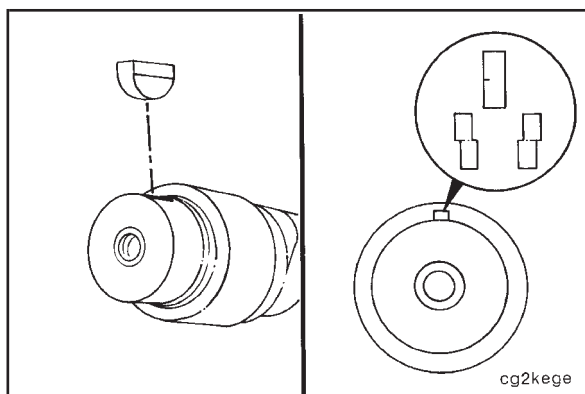
Slide the capscrew and adapter of the slotted end of the puller plate (4) toward the end of the puller plate and insert the adapter onto the camshaft gear. The adapter pulling surface (3) **must** point toward the center of the camshaft gear.

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

Torque Value: 7 N•m [60 in-lb]

Camshaft keys are available in different sizes (amount of offset). Static injection timing is controlled by the following:

- Amount of key offset.
- Key offset direction compared to camshaft gear rotation.

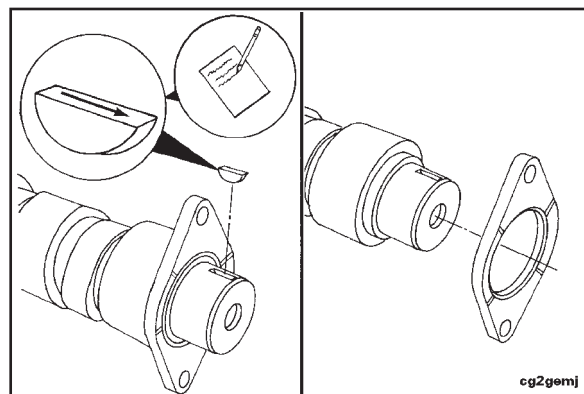


Record the size (amount of offset) and part number of the key.

Record the direction the arrow on the key is pointed (toward or away from the camshaft) for future reference.

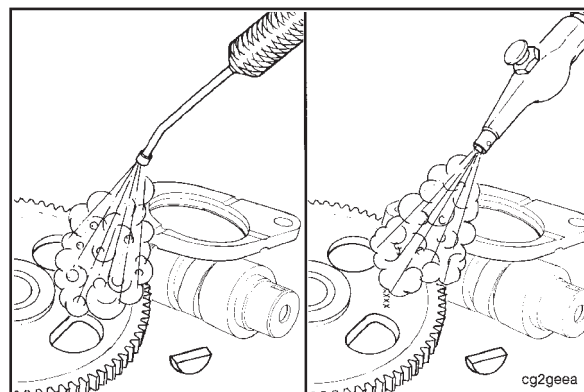
Use a flat chisel and hammer to remove the camshaft key.

Remove the thrust plate.



Cleaning

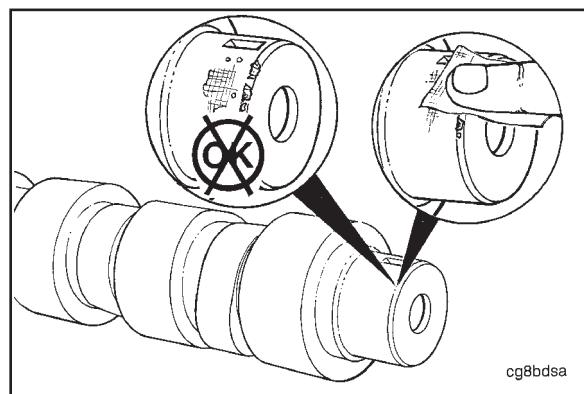
Use solvent to clean the parts and dry with compressed air.



Inspection

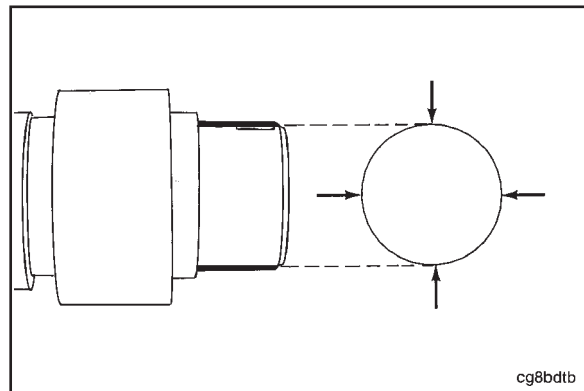
Visually inspect the camshaft nose for fretting or burrs.

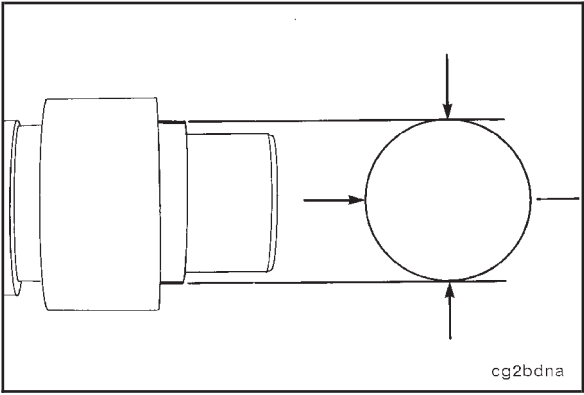
NOTE: The camshaft **must** be replaced if the fretting damage is more than 3 mm [0.125 inch] wide.



Measure the camshaft nose (gear mounting surface) outside diameter.

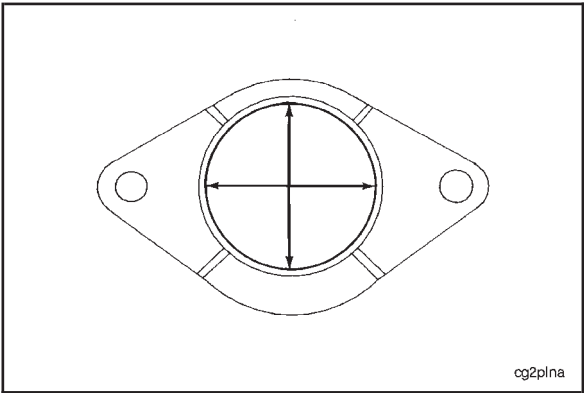
Camshaft Gear Mounting Surface O.D.		
mm		in
46.987	MIN	1.8499
47.013	MAX	1.8509





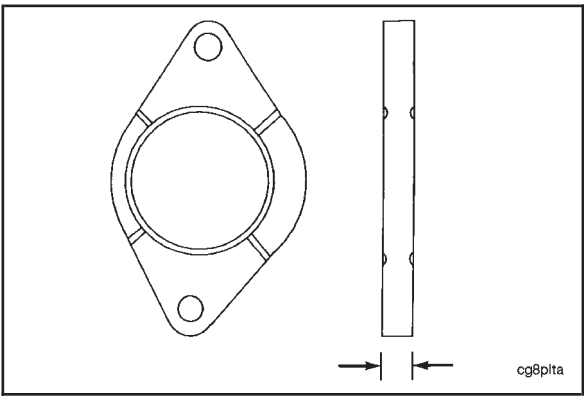
Measure the camshaft thrust bearing journal outside diameter.

Camshaft Thrust Bearing Journal O.D.		
mm		in
54.800	MIN	2.1575
55.200	MAX	2.1732



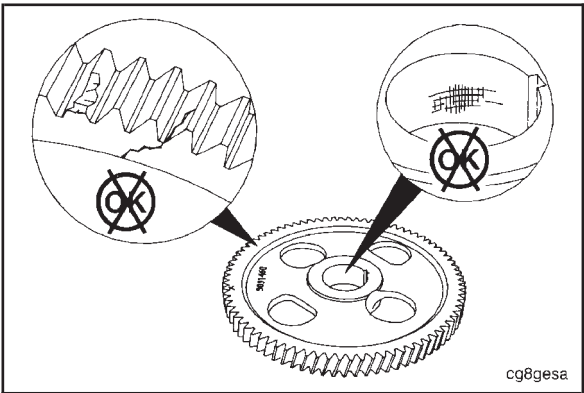
Measure the camshaft thrust plate inside diameter.

Camshaft Thrust Plate I.D.		
mm		in
55.60	MIN	2.1890
56.61	MAX	2.2287



Measure the camshaft thrust plate thickness.

Camshaft Thrust Plate Thickness		
mm		in
8.960	MIN	0.3528
9.040	MAX	0.3559



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



Visually inspect the gear bore and keyway for fretting or burrs.

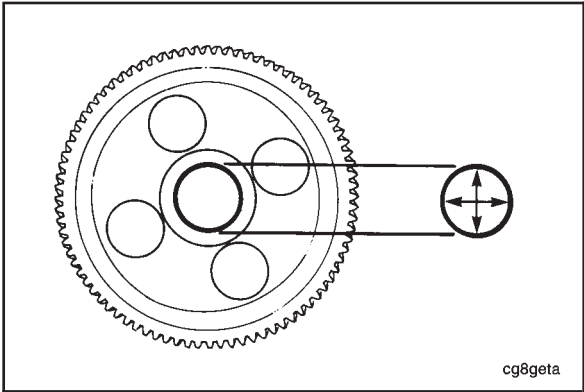


Use crocus cloth to remove burrs.

NOTE: The gear **must** be replaced if the fretting is more than 3 mm [0.125 inch] wide.

Measure the camshaft gear bore inside diameter.

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



cg8geta

Installation

If the same camshaft and gear are used again, install a key with the same part number as the one that was removed. Make sure the arrow on the key is pointing in the same direction as it was when it was removed. Refer to the “Static Injection Timing” in Section “O” if the static injection timing is to be changed. Refer to the following list of offset keys to change static injection timing.

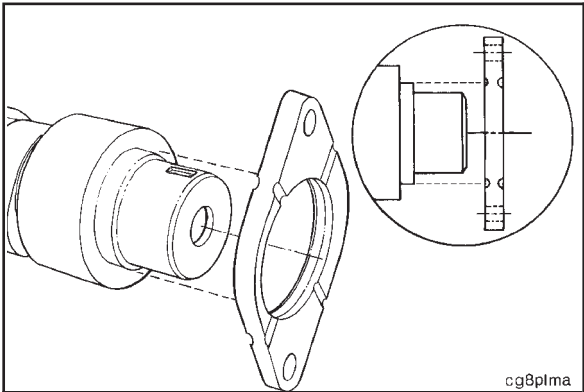
The accompanying table list offset keys by part number and degree of offset.



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

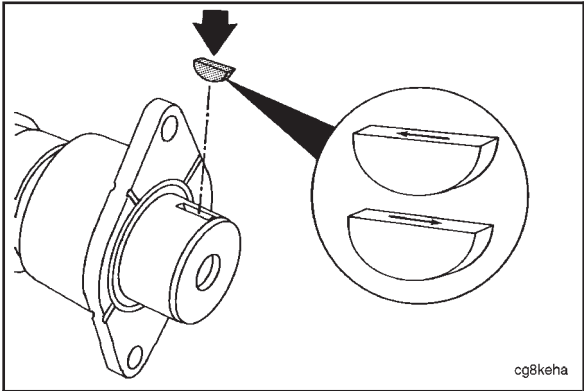
It200nb

Install the thrust plate on the camshaft.

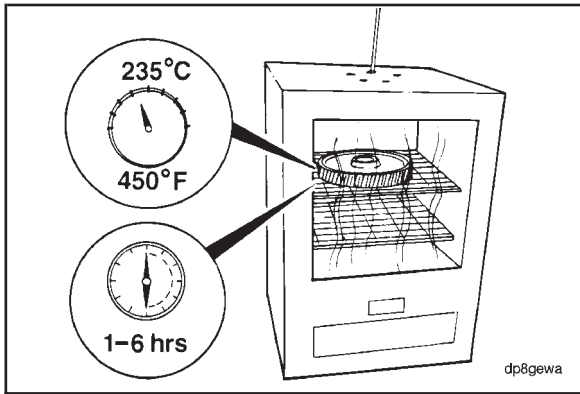


cg8plma

Use a soft hammer to install the camshaft key with the arrow pointing in the same direction as when it was removed.



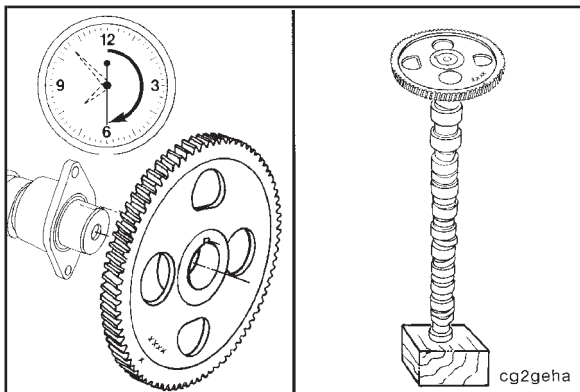
cg8keha



Caution: Do not exceed the temperature or time limits with the gear in the oven. The gear will be damaged.



Put the camshaft gear into an oven heated to 235°C [450°F] for a minimum of one hour but **not** longer than six hours.



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



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

Use Lubriplate® No. 105, or equivalent to lubricate the camshaft gear mounting surface.

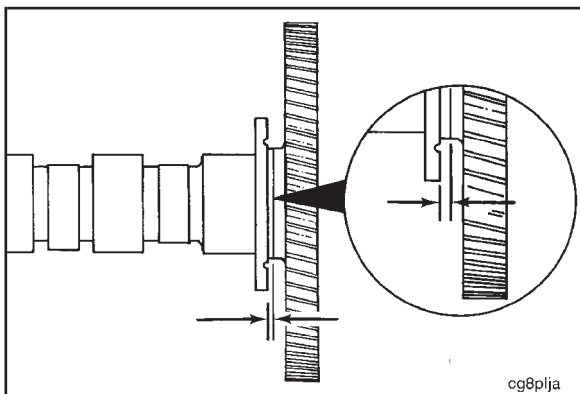


Caution: Keep the camshaft in a vertical position until the gear has cooled. Do not use water to reduce the cooling time, the gear will crack.



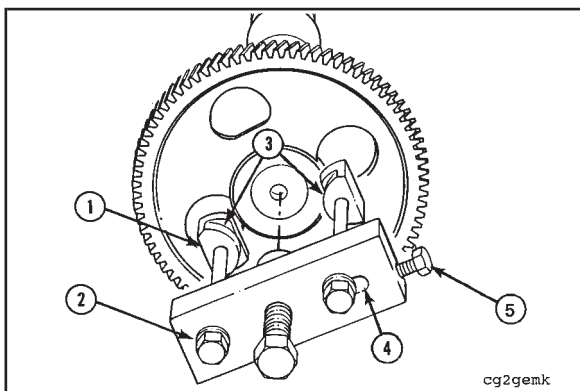
Remove the gear from the oven, align the keyway in the gear with the key in the camshaft and install the gear on the camshaft within 30 seconds.

Measure the camshaft thrust plate clearance.



Camshaft Thrust Plate Clearance

mm		in
0.13	MIN	0.005
0.33	MAX	0.013



Camshaft - Magnetic Crack Inspection (1-18)



The camshaft gear and thrust plate **must** be removed before performing this inspection. Refer to Procedure 1-17, to remove the camshaft gear and thrust plate.

Section 1 - Cylinder Block - Group 01 M11

Use a magnetic particle testing machine to check the camshaft for cracks.

Use the head shot method.

Adjust the machine to 2000 ampere D.C. or rectified A.C..

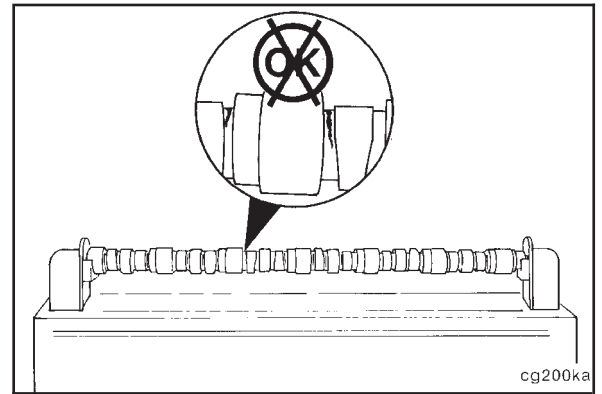
Use the continuous method.

Do **not** wet more than one-third of the camshaft at a time.

Visually inspect the camshaft for cracks.



Camshaft - Magnetic Crack Inspection (1-18) Page 1-55

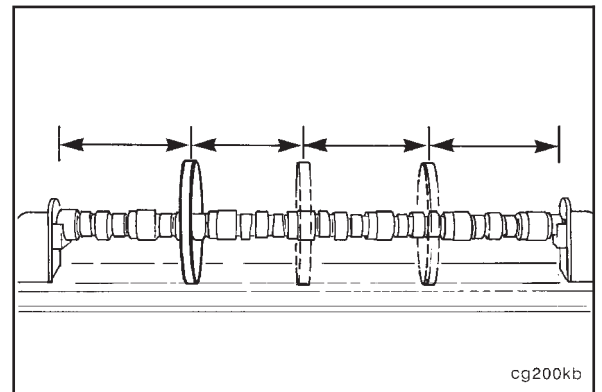


Use the coil shot continuous method that is a minimum of 305 mm [12 inch].

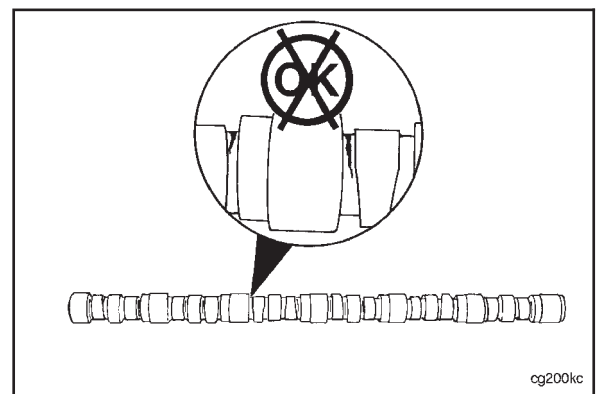
Apply the coil shot.

	Amperage (Ampere Turn)
MIN	3600 D.C. or rectified A.C.
MAX	4000 D.C. or rectified A.C.

NOTE: Ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.



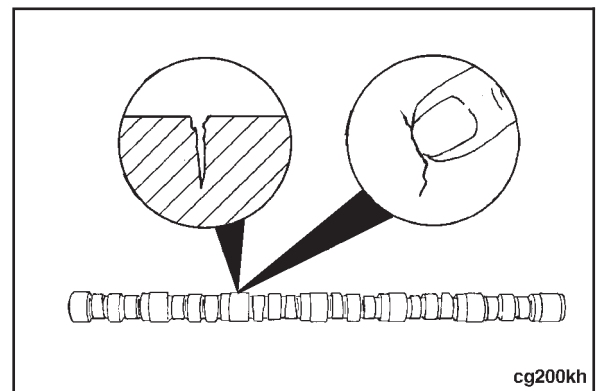
Visually inspect the camshaft for cracks.

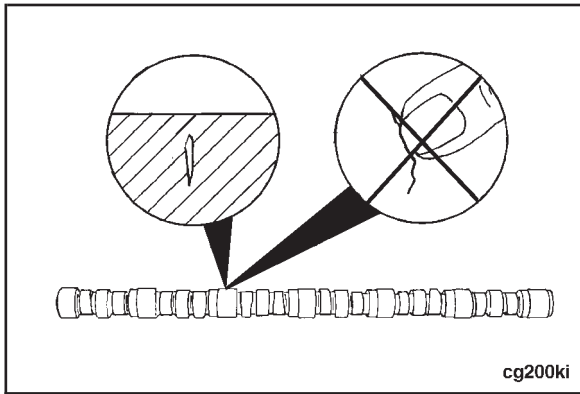


Definitions of Indications

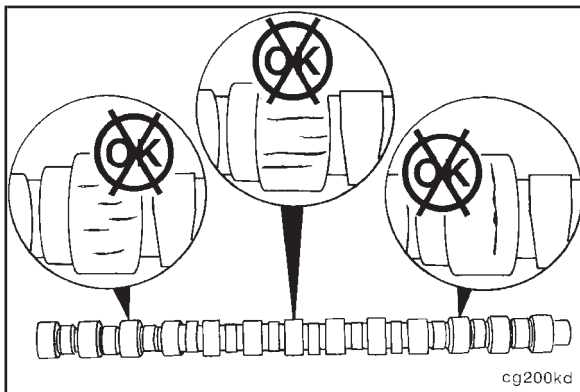
Definitions of indications are as follows:

Open indication - An indication is open if, when wiped clean of magnetic particle bath, it can be seen with the naked eye in a well lighted area. Many times an open indication can be felt with a fingernail.





Subsurface indications - An indication is subsurface if, when wiped clean of magnetic particle bath, it **cannot** be seen with the naked eye in a well lighted area. Subsurface indications are often “voids” or “non-metallic inclusions” which are present in the raw material.

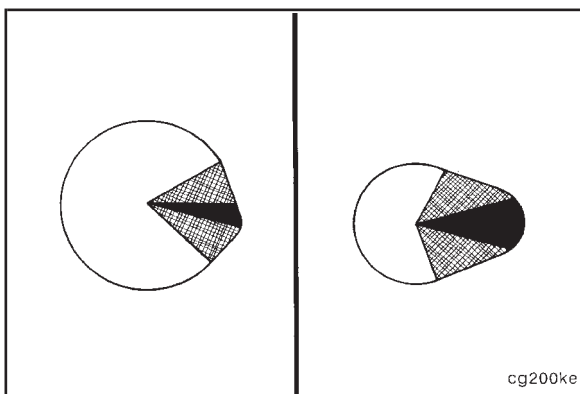


Bearing Journal - Limits of Acceptance

Do **not** use the camshaft if:

- More than four open indications in an axial direction on one of the bearing journals.
- More than one-half of the open indications extend more than half the distance across the bearing journals.
- An open indication in a circumferential direction.

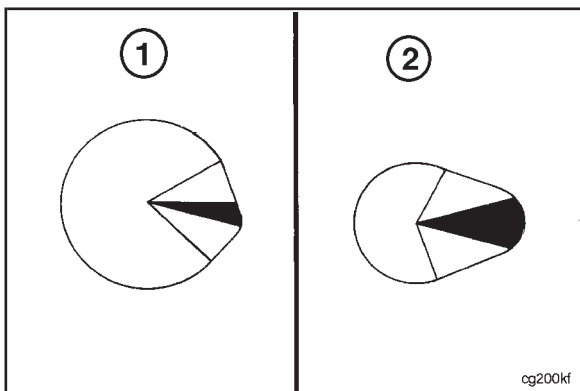
NOTE: The camshaft can be used if there are subsurface indications.



Valve and Injector Lobe - Limits of Acceptance

Do **not** use the camshaft if there is:

- An indication in a circumferential direction.
- An indication in the black or shaded areas shown.
- An indication longer than 6 mm [0.250 inch].
- An indication closer than 5 mm [0.188 inch] from the edge.
- More than two open indications on one of the lobes.



Do **not** use the camshaft if:

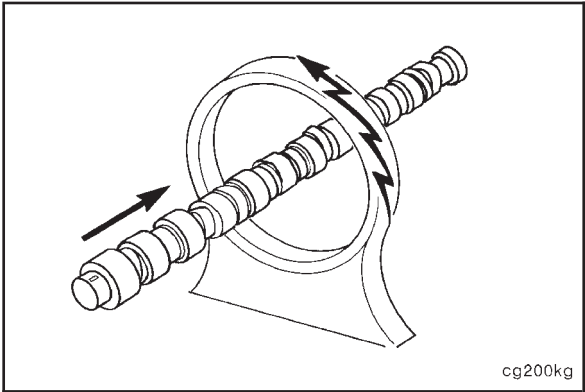
- More than two indications are in the shaded area shown.
- An indication in the shaded area shown is longer than 16 mm [0.625 inch].
- More than three indications are in the white area shown.
- An indication is in the black area on the injector lobe (1).
- More than two indications are in the black area on the valve lobe (2).
- An indication in the black area on the valve lobe is longer than 3 mm [0.125 inch].

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

Caution: The camshaft must have all magnetism removed completely and cleaned thoroughly. Small metal particles will cause engine damage.

Remove all magnetism from the camshaft.

Use solvent or steam clean the camshaft and dry with compressed air.



Camshaft or Idler Gear - Magnetic Crack Inspection (1-19)

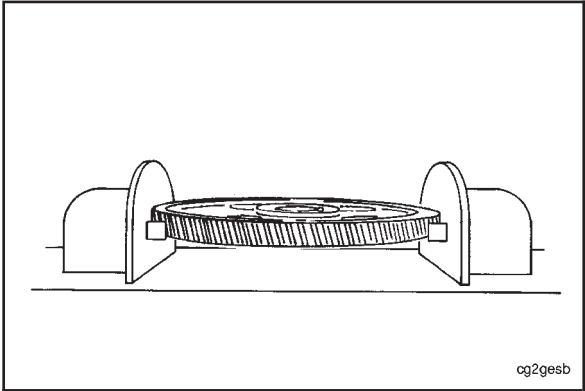
Caution: Use a copper braid contact that has neoprene covers to avoid burning the teeth of the gear.

Position the gear keyway toward one of the contacts when inspecting.

Use a magnetic particle testing machine.

Use the residual method.

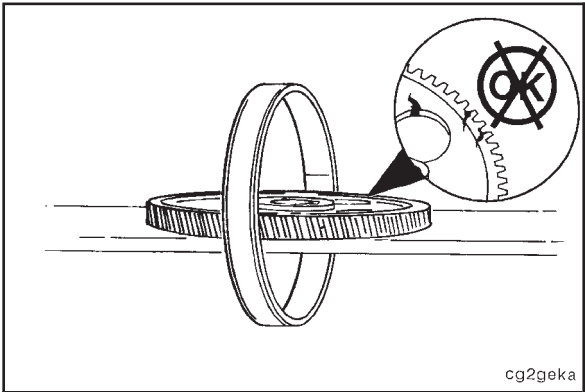
Apply head shot amperage.



Adjust the amperage to the specified value.

Gear O. D.	Amperage D.C.
Less than 101 mm [4 inch]	1000
101 to 203 mm [4 to 8 inch]	1500
Greater than 203 mm [8 inch]	2000

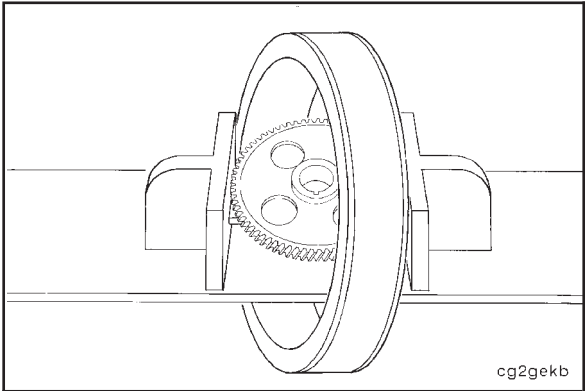
Visually inspect the gear for cracks.

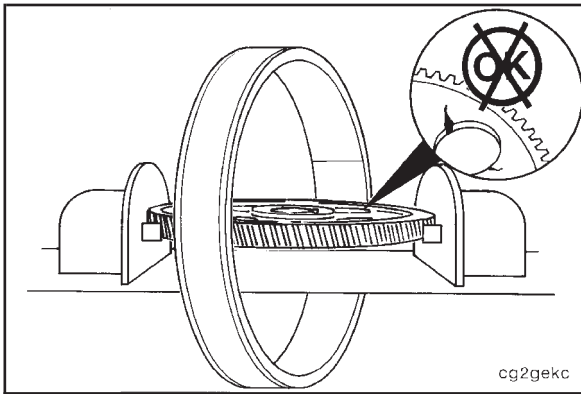


Position the gear keyway toward one of the contacts when inspecting.

Use the residual method.

Apply coil shot amperage.





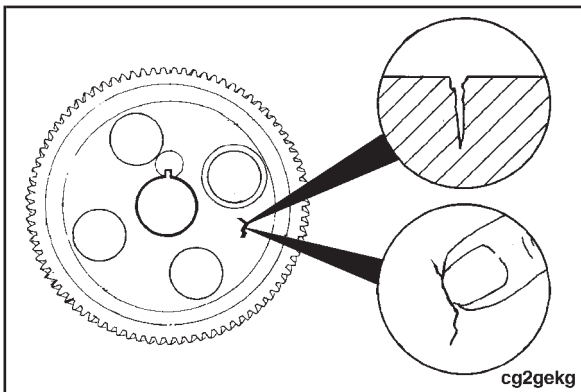
Adjust the amperage to the specified value.

Gear O.D.	Ampere Turns
Less than 101 mm [4 inch]	4000
101 to 203 mm [4 to 8 inch]	6000
Greater than 203 mm [8 inch]	8000

NOTE: Ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.

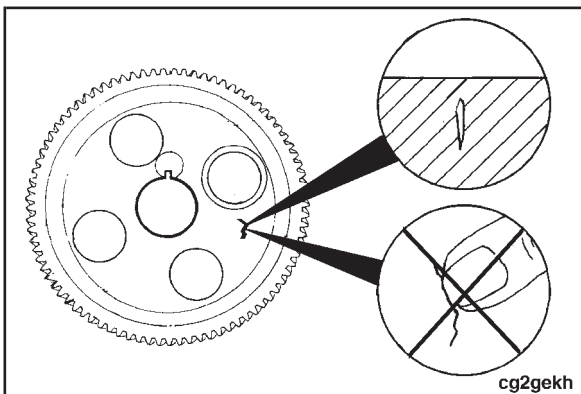


Visually inspect the gear for cracks.

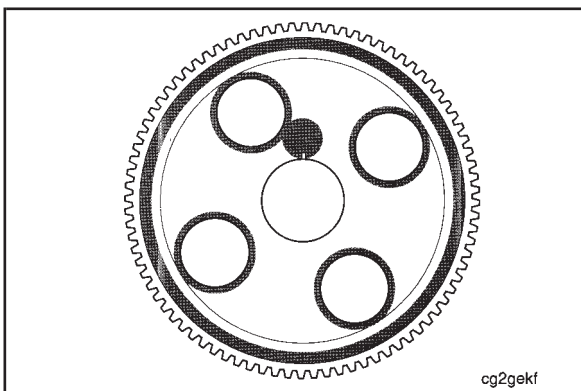


Definitions of Indication

Open Indication - An indication is open if, when wiped clean of magnetic particle bath, it can be seen with the naked eye in a well lighted area. Many times an open indication can be felt with a fingernail.



Subsurface Indication - An indication is subsurface if, when wiped clean of magnetic particle, it **cannot** be seen with the naked eye in a well lighted area. Subsurface indications are often "voids" or "non-metallic inclusions" which are present in the raw material.



Camshaft or Idler Gear - Limits of Acceptance



Do **NOT** use a camshaft gear if:

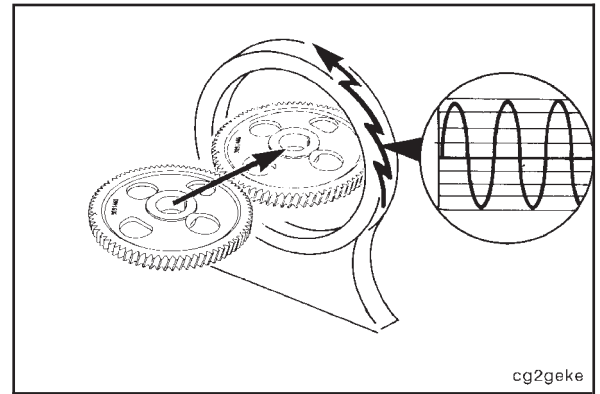
- There are open indications in any direction.
- There are any subsurface indications in the shaded area.
- There are subsurface indications longer than 6 mm [1/4 inch] in the non-shaded area.

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

Caution: The gear must have all magnetism removed completely and cleaned thoroughly. The small metal particles will cause engine damage.

Remove all magnetism from the gear.

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

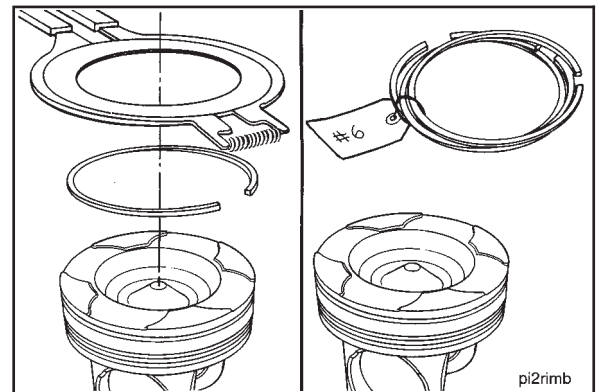


Piston - Cleaning and Inspection for Reuse (1-20)

Piston Rings - Removal

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.

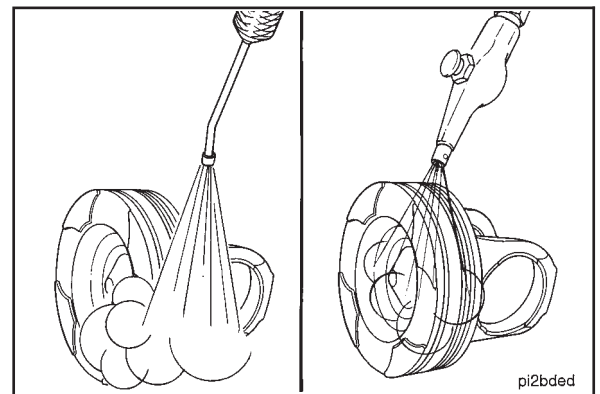


Cleaning

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

Use steam to clean the carbon from the piston.

NOTE: A plastic bead media, Part No. 3822735, has been released for cleaning the piston dome or crown and the ring grooves. Do **not** bead blast the piston skirt.



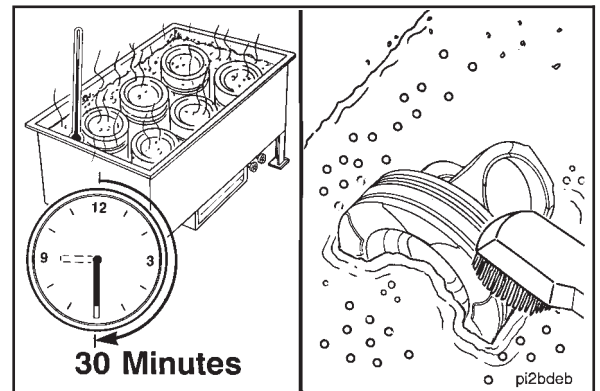
Caution: The cleaning solvent must be approved for aluminum to prevent damage to the pistons.

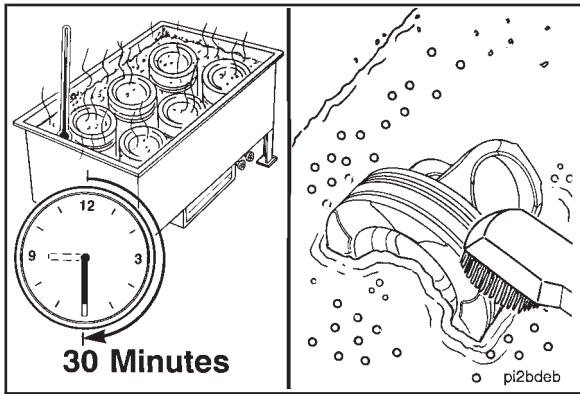
Use a kerosene emulsion based solvent that can be heated to 95°C [200°F] and a cleaning tank that will constantly mix and filter the solvent.

NOTE: Do **not** use a solvent that has a pH higher than 9.5, or a solvent that contains chlorinated hydrocarbons with cresols, phenols, or cresylic components.

Put the pistons into the solvent and allow them to soak for a minimum of 30 minutes.

NOTE: Soak the pistons several hours or overnight for best results.



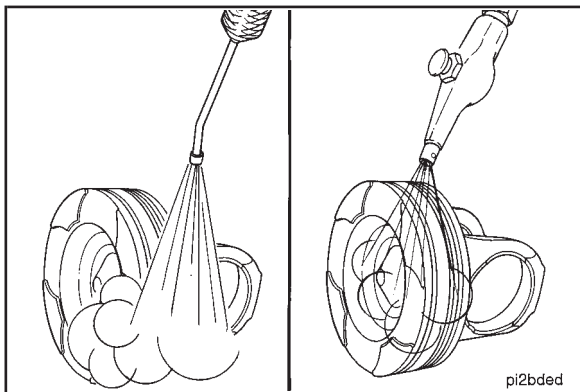


Caution: Do not use a metal brush to clean the piston. The ring grooves will be damaged. Do not use glass beads to clean the grooves. Walnut shell or plastic bead, Part No. 3822735, blasting can be used on ring grooves on the dome and crown of the piston. Use the minimum effective pressure, and do not concentrate the spray in one area for an extended period of time.



Use a brass or non-metallic brush to clean the piston ring grooves.

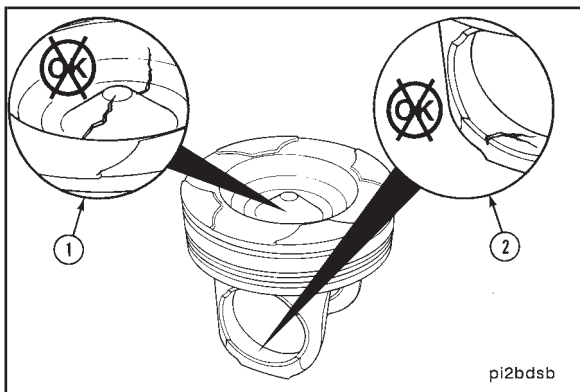
Repeat the soaking and scrubbing process until the piston is cleaned thoroughly.



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



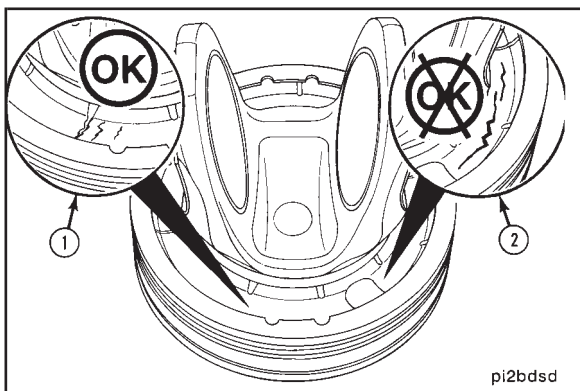
Use steam to clean the solvent from the piston and dry with compressed air.



Inspection

Visually inspect the piston bowl (1) and crown piston pin bore (2) for cracks or damage.

Do **not** use a piston with cracks.



Visually inspect the piston gallery cover plate in the piston crown for cracks.

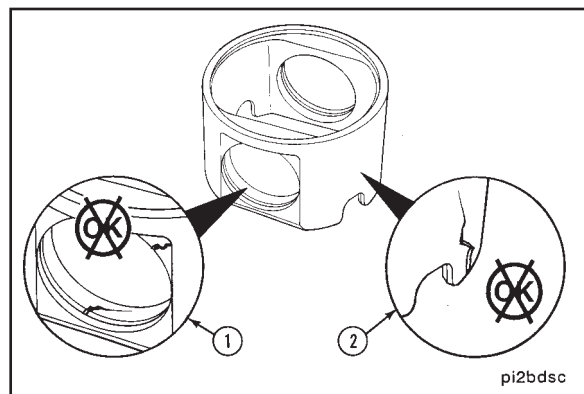
If the cover plate has a radial crack (1), the crown can be reused.

If the cover plate has a circumferential crack (2), the piston crown **must** be replaced.

Section 1 - Cylinder Block - Group 01 M11

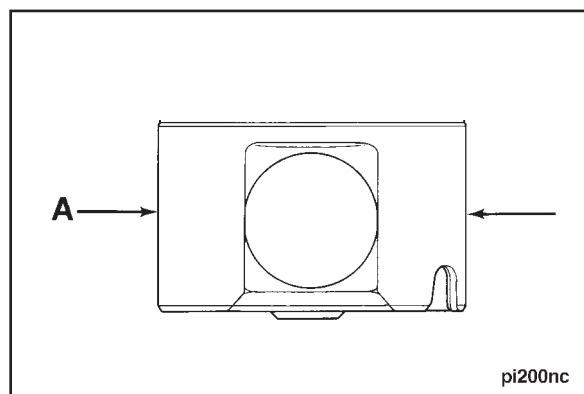
Visually inspect the piston skirt pin bore (1) and sides (2) for cracks or damage.

Do **not** use pistons with cracks. If the skirt is cracked, it **must** be replaced.



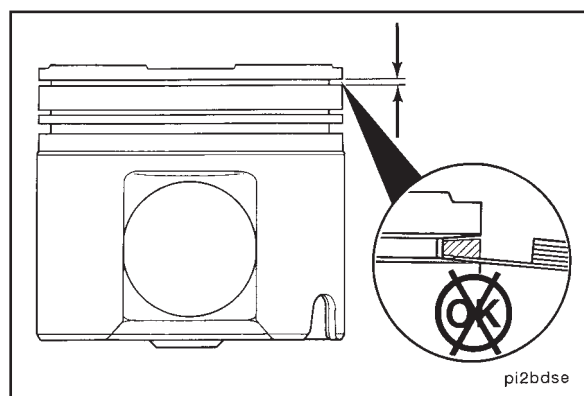
Measure the piston skirt outside diameter at room temperature 21°C [70°F].

Piston Skirt O.D.			
	mm		in
(A)	124.939	MIN	4.9189
	124.983	MAX	4.9206



The ring groove can be inspected with a new ring and a feeler gauge.

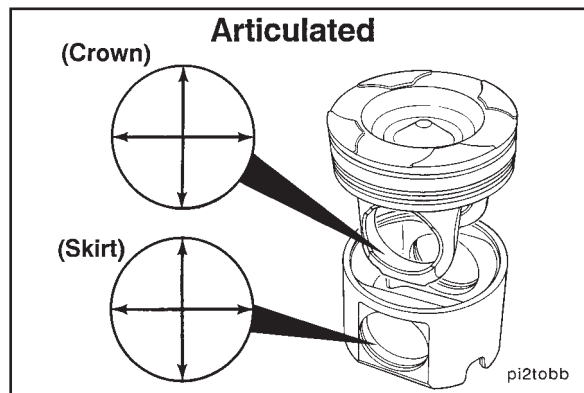
Hold a new ring in the groove even with the outside diameter of the piston. Install a 0.15 mm [0.006 inch] feeler gauge. If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.

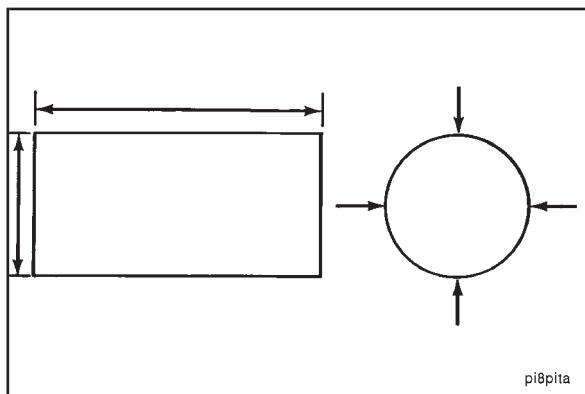


Measure the piston pin bore inside diameter.

Articulated Piston Pin Bore I.D. (Crown)			
	mm		in
	54.040	MIN	2.1276
	54.055	MAX	2.1281

Articulated Piston Pin Bored I.D. (Skirt)			
	mm		in
	54.007	MIN	2.1263
	54.015	MAX	2.1266

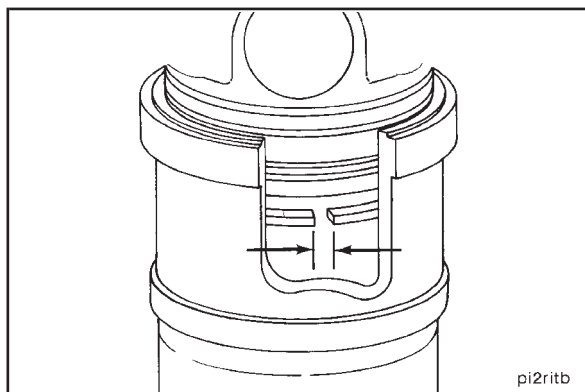




Measure the piston pin outside diameter and length.

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

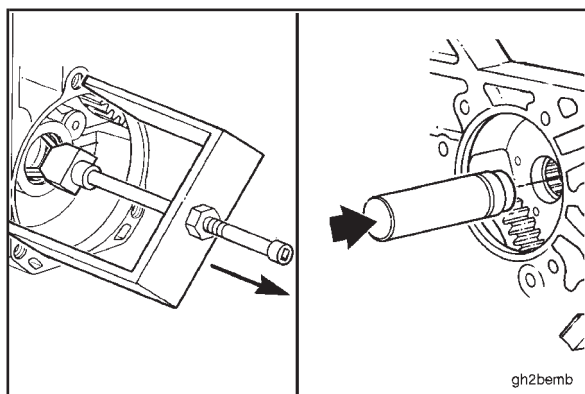


To check the ring gap, install the piston rings in the wear area of the cylinder liner in which they will be used.



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

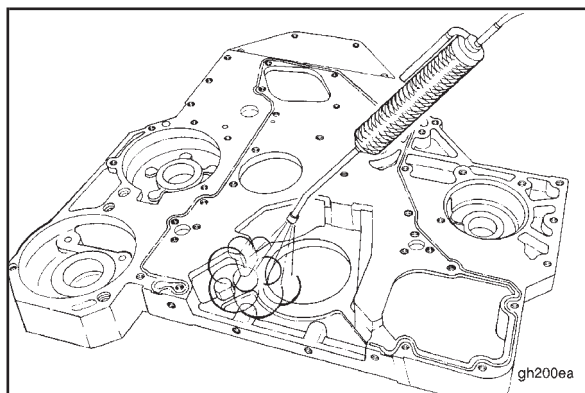


Gear Housing - Cleaning and Inspection for Reuse (1-21)

Cleaning

Use bearing puller kit, Part No. 3823774, to remove the hydraulic pump needle bearing from the gear housing.

Use bearing driver kit, Part No. 3824117, to remove the water pump drive needle bearing.



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.

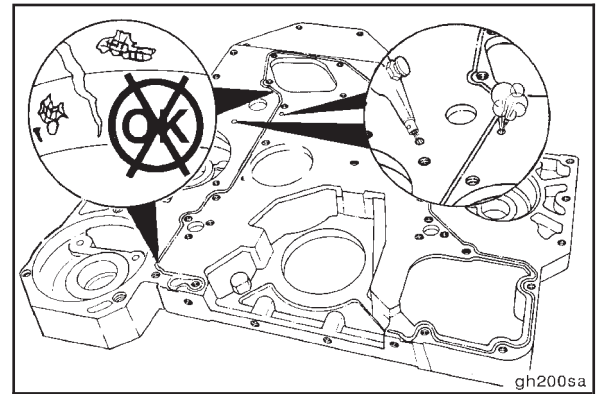
Inspection

Visually inspect the gear housing for cracks or damage.

Inspect the seal grooves on both sides of the housing for debris or damage.

Inspect the o-ring groove at the accessory drive oil jumper gallery for cracks or damage.

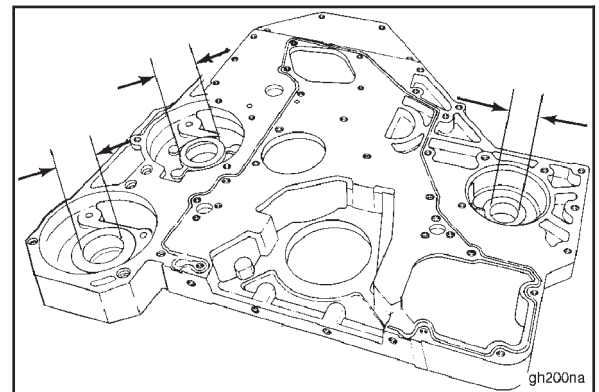
Use compressed air to make sure the oil jumper gallery to the accessory drive is free of any obstructions.



Measure the inside diameter of the bearing bores at the accessory drive, water pump drive, and hydraulic drive.



Bore Location	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

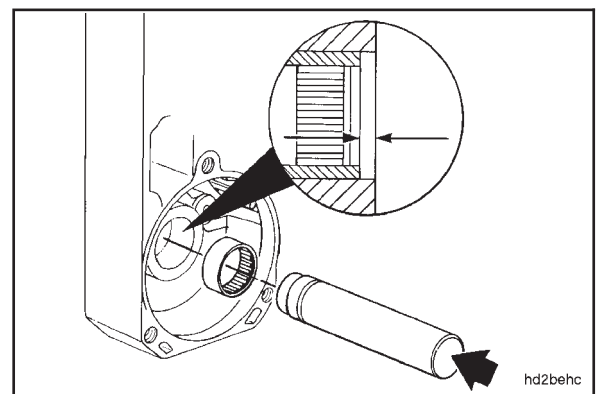


Needle Bearing Installation

Use bearing installation tool, Part No. 3823776, to install a new needle bearing in the hydraulic pump bore of the gear housing.

Tap the bearing gently until it comes into contact with the shoulder in the housing.

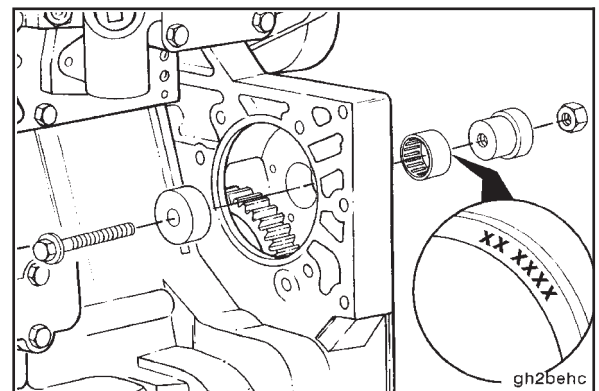
The bearing **must** be 0.25 to 0.76 mm [0.010 to 0.030 inch] below the edge of the gear housing.

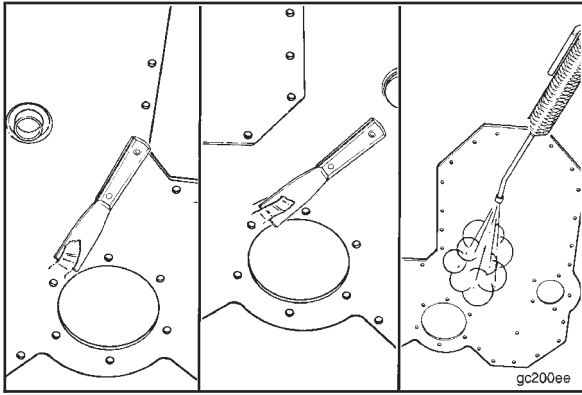


Use bearing driver kit, Part No. 3824117, to install a new needle bearing in the water pump drive bore of the gear housing.

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 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.





Gear Cover - Cleaning and Inspection for Reuse (1-22)

Cleaning

Use a gasket scraper to remove all gasket material.

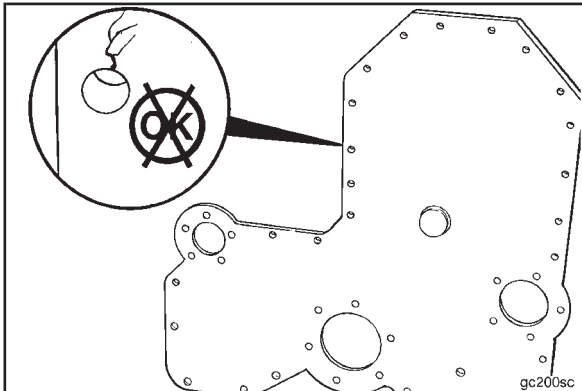
Use crocus cloth to remove burrs from the capscrew holes and gasket surface.



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



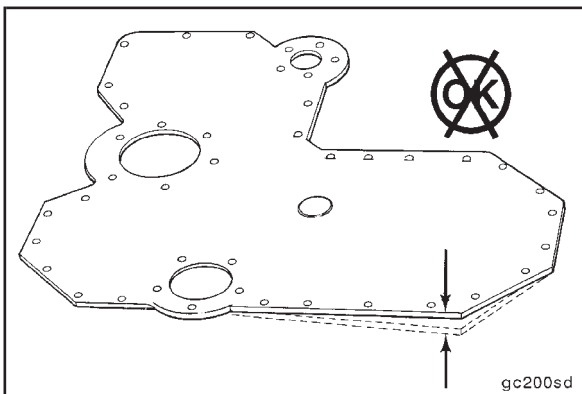
Steam clean the gear cover and dry with compressed air.



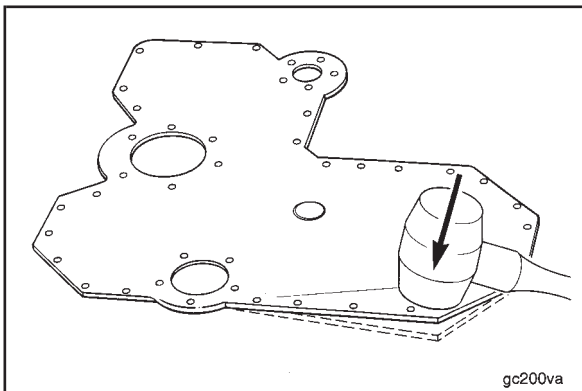
Inspection

Visually inspect the gear cover for cracks or damage.

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



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.

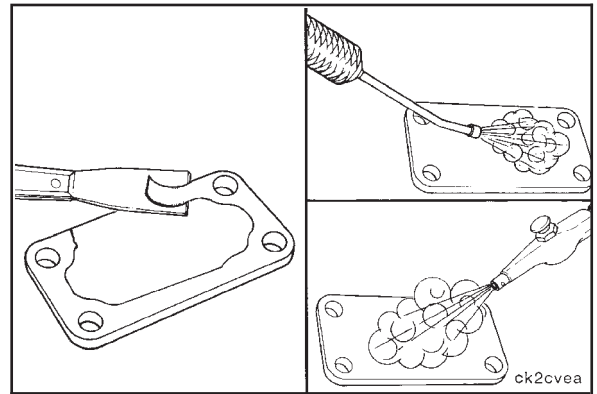
Hand Hole Cover - Cleaning and Inspection for Reuse (1-23)

Cleaning

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

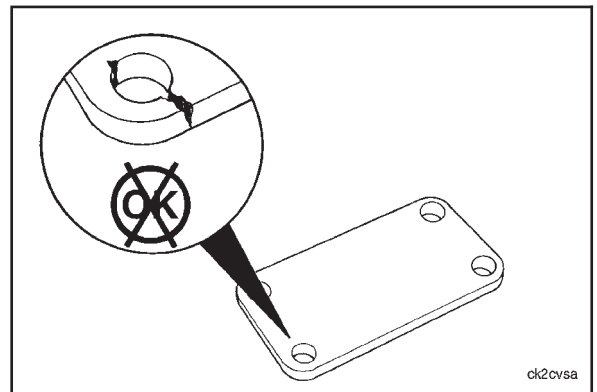
Use a gasket scraper to remove all gasket material.

Steam clean the covers and dry with compressed air.

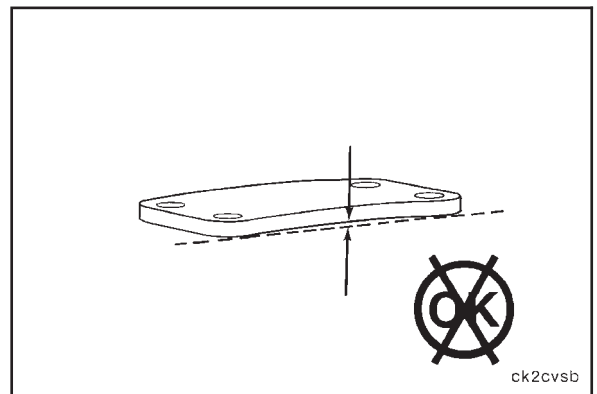


Inspection

Visually inspect the cover for cracks or damage.



Visually inspect the cover for flatness.



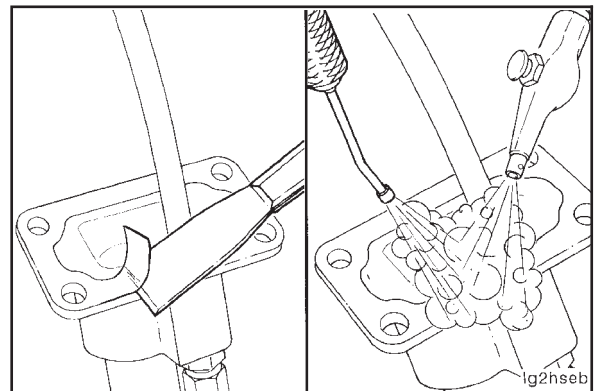
Dipstick Tube Bracket - Cleaning and Inspection for Reuse (1-24)

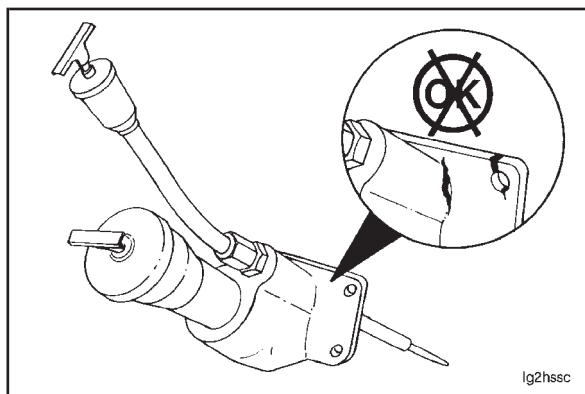
Cleaning

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

Use a gasket scraper to remove all gasket material.

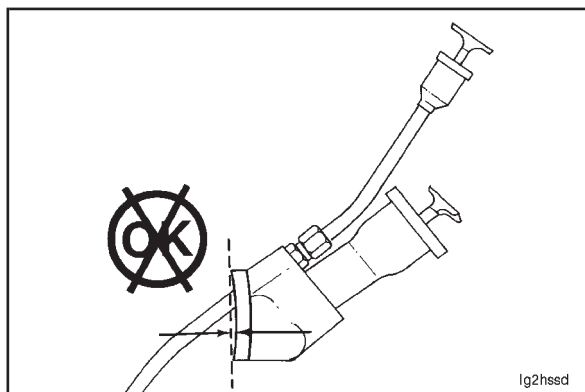
Steam clean the bracket and dry with compressed air.





Inspection

Visually inspect the bracket for cracks or damage.



Visually inspect the bracket for flatness.

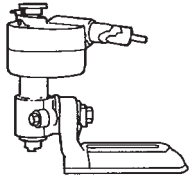
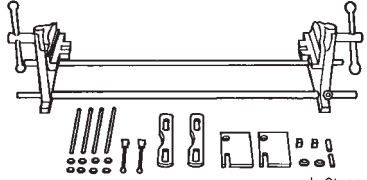
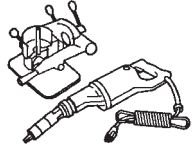
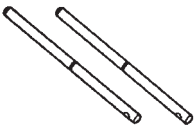
Section 2 - Cylinder Head - Group 02

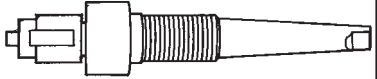
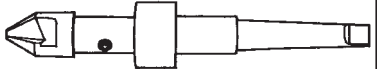
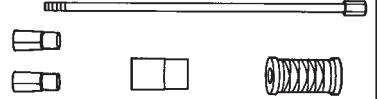
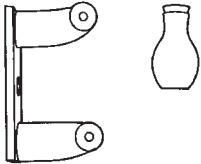
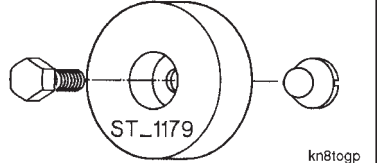
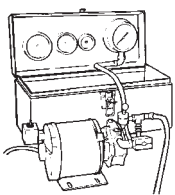
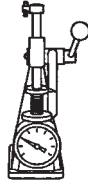
Section Contents

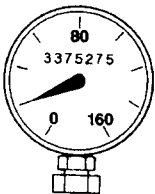
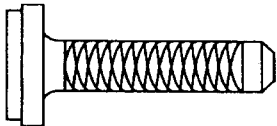
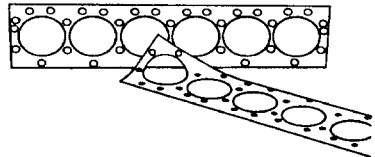
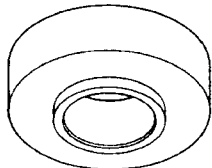
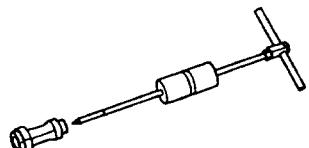
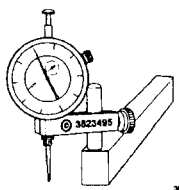
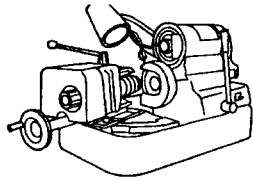
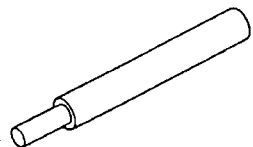
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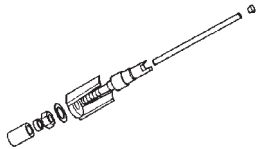
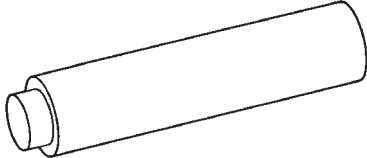
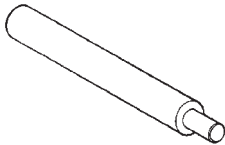
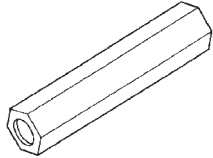
Service Tools - Cylinder Head

The following special tools are recommended to perform procedures in Group 02. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

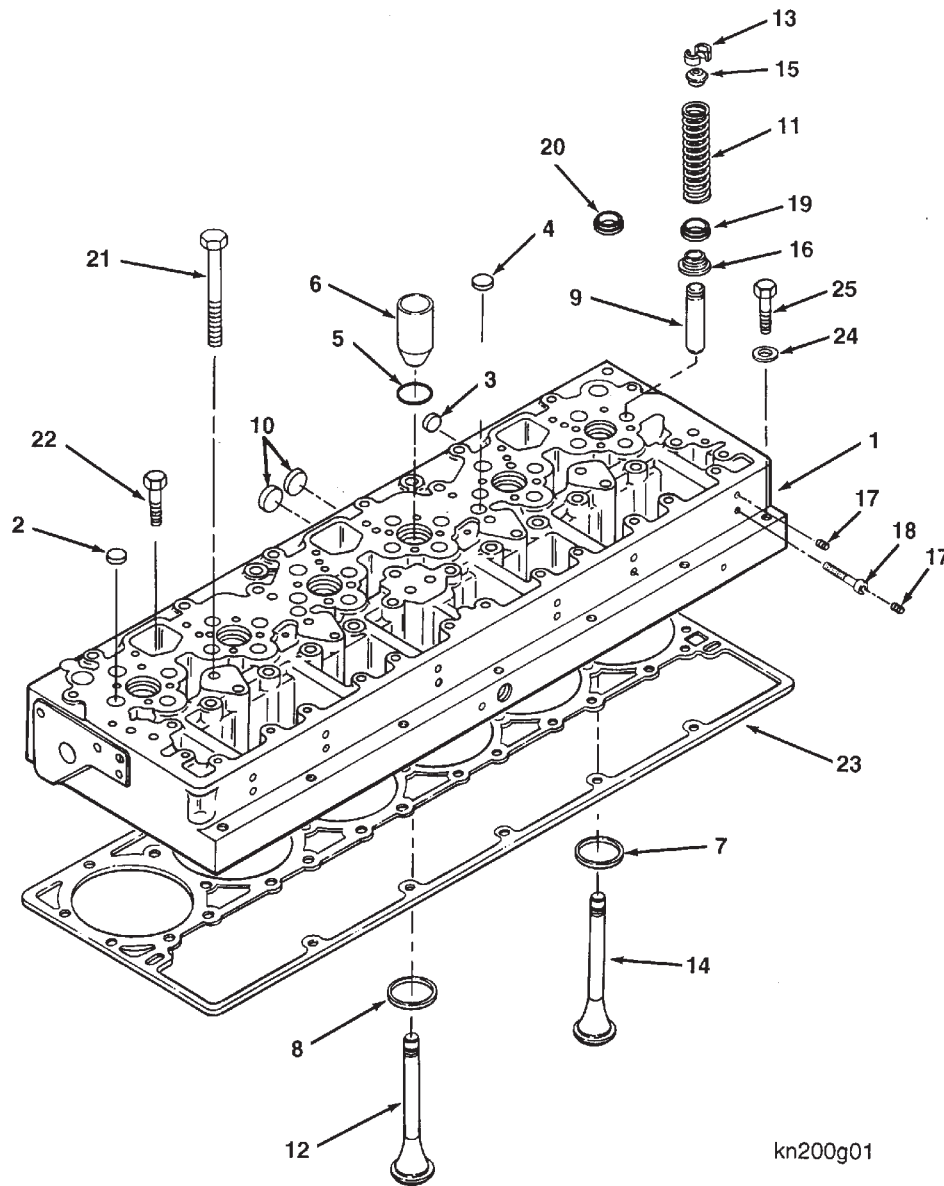
Tool No.	Tool Description	Tool Illustration
ST-257	Valve Seat Insert Tool Cut valve seat counterbores for oversize valve seat inserts. Used with valve guide set, Part No. ST-804, and valve guide insert cutter, Part No. 3376595.	 kn8toge
ST-448	Valve Spring Compressor Used with threaded adapter, Part No. 3376850, and adapter, Part No. 3376851, to compress the valve spring while removing or installing the valve collets.	 kn8togf
ST-583	Head Holding Fixture Hold and revolve the cylinder head during repair and assembly.	 kn8togg
ST-685	Valve Seat Grinding Machine Grind the valve seats in the cylinder head. Used with valve guide arbor set, Part No. ST-804, and valve seat grinding wheel, Part No. 3376077.	 kn8togi
ST-804	Valve Guide Arbor Set Used with valve seat insert tool, Part No. ST-257, and valve seat grinding machine, Part No. ST-685. ST-804-1 Arbor (3/8 in. + .006 in.) ST-804-2 Arbor (3/8 in. + .007 in.)	 kn8togj
ST-876	Fuel Passage Cleaning Brush Clean the internal fuel passages in the cylinder head.	 kn8togk

Tool No.	Tool Description	Tool Illustration
ST-880	Injector Sleeve Expander Roll and seal the upper portion of the injector sleeve in the cylinder head.	 kn8togl
ST-884-1	Injector Seat Cutter Used with pilot, Part No. ST-379-2, and cutter, ST-884-3, to machine the injector sleeve seat to the proper depth to allow the specified injector protrusion through the cylinder head.	 kn8togm
ST-1134	Dowel Pin Extractor Remove the dowel pins from the cylinder head.	 kn8togn
ST-1166	Magnetic Crack Detector Used to inspect the cylinder head combustion face for cracks in the injector bore and valve seat areas. The kit includes powder spray bulb, Part No. ST-1166-7, used for spraying the metal powder, ST-1166-8.	 kn8togo
ST-1179	Injector Sleeve Holding Tool Hold the injector sleeve in place when rolling the upper portion of the sleeve and testing the cylinder head.	 kn8togp
ST-1227	Injector Sleeve Driver Install the injector sleeve into the cylinder head.	 kn8togq
ST-1257	Valve Vacuum Tester Used with vacuum cup, Part No. 3376100. Vacuum test the cylinder head to determine if the valves are properly seated.	 kn8toqr
3375182	Valve Spring Tester Measure the cylinder head valve spring tension.	 kn8togs

Tool No.	Tool Description	Tool Illustration
3375275	Pressure Gauge [0-160 psi] Used to measure air pressure.	 3375275
3376058	Expansion Plug Driver Install the 2.263 inch diameter expansion plugs in the cylinder head.	 bp8togc
3376082	Cylinder Head Water Test Fixture The test fixture contains the nuts, Part No. 3376083, the gasket, Part No. 3376084, and the test plate, Part No. 3376658, used to perform a leak check to the cylinder head.	 kn2togv
3376105	Valve Seat Driver Mandrel Used with the adapter sleeve and seat driver in the valve seat insert tool, Part No. ST-257.	 3376105
3376146	Valve Seat Extractor Used with slide hammer assembly, Part No. 3376617 to remove the valve seat inserts from the cylinder head.	 kn8togx
3823495	Gauge Block Used to measure the injector protrusion and valve recess in the cylinder head.	 3823495
3376256	Valve Facing Machine Grind cylinder head valves and resurface valve stems.	 kn8togz
3376398	Valve Guide Driver Remove the valve guides from the cylinder head.	 3376398

Tool No.	Tool Description	Tool Illustration
3377079	Injector Sleeve Puller Remove the injector sleeves from the cylinder head. This tool is designed for use with an air impact wrench.	
3376816	Expansion Plug Driver Install the 1.010 inch diameter expansion plugs in the cylinder head. Use with handle, Part No. 3376795.	 bp8toge
3823946	Valve Seal Driver Used to install valve seals onto the valve guides.	 3823946
3823947	Valve Guide Driver Used to install valve guides requiring valve seals to the proper assembled height in the cylinder head.	 3376061

Cylinder Head - Exploded View



kn200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Cylinder Head	1	14	Valve, Exhaust	12
2	Plug, Expansion	2	15	Retainer, Valve Spring	24
3	Plug, Expansion	2	16	Guide, Spring	24
4	Plug, Expansion	8	17	Plug, Pipe	16
5	Seal, O-ring	6	18	Plug, Orifice	5
6	Sleeve, Injector	6	19	Seal, Intake Valve Guide	12
7	Insert, Exhaust Valve	12	20	Seal, Exhaust Valve Guide	12
8	Insert, Intake Valve	12	21	Screw, Hex Flange Head Cap	29
9	Guide, Valve Stem	24	22	Screw, Hexagon Head Cap	3
10	Cup Plugs	2	23	Gasket, Cylinder Head	1
11	Spring, Valve	24	24	Washer, Plain	7
12	Valve, Intake	12	25	Screw, Twelve Point Cap	7
13	Collet, Valve	24			

Cylinder Head - General Information

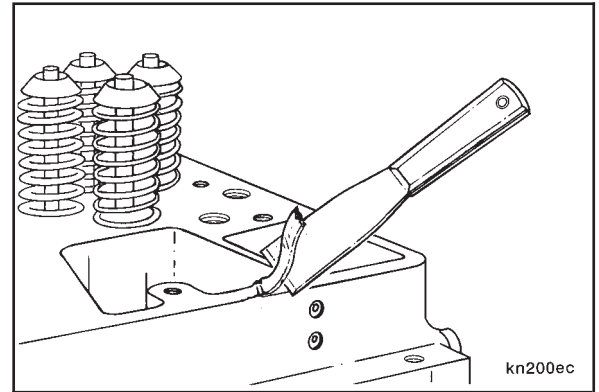
The Cylinder Head Group consists of the cylinder head, valves, valve guides, valve springs, valve seat inserts, crossheads, and the injector sleeves. The exhaust valves are manufactured from a material that is capable of operating at a higher temperature than the intake valves. The exhaust valves can be installed in the intake valve location. Do **not** install the intake valves in the exhaust valve location. The valve seat inserts are the same for both the exhaust and intake valves. The intake spring is the same as the exhaust spring. The springs are interchangeable.

Mark, label or tag the cylinder head parts such as crossheads, valves, and valve springs with the cylinder number and location from which they were removed. This practice will be a valuable aid in diagnosing any cylinder head or part failures. Install the acceptable parts in their original locations.

Cylinder Head - Cleaning and Inspection for Reuse (2-01)

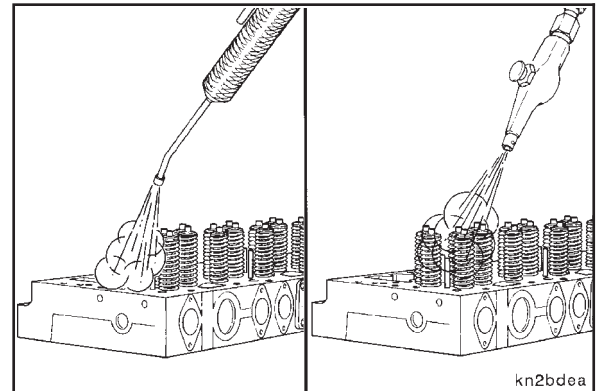
Cleaning

Remove the gasket material from the rocker lever housing surface.

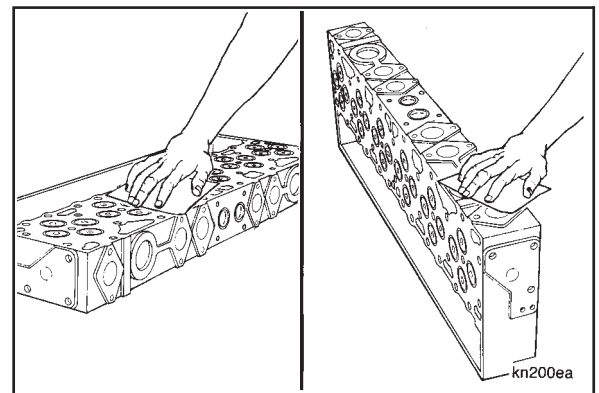


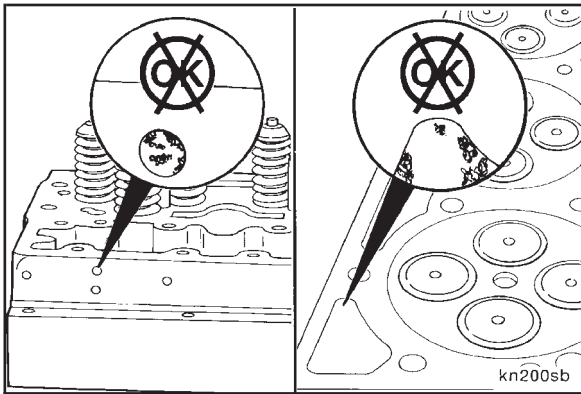
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.

Use steam to clean the cylinder head. Dry with compressed air.



Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to clean the cylinder head combustion face and the exhaust manifold gasket surface.



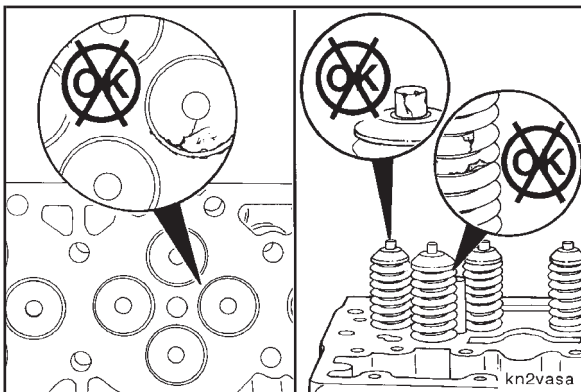


Inspection



Visually inspect the fuel drillings and water passages for restrictions or foreign material.

Remove any obstructions.

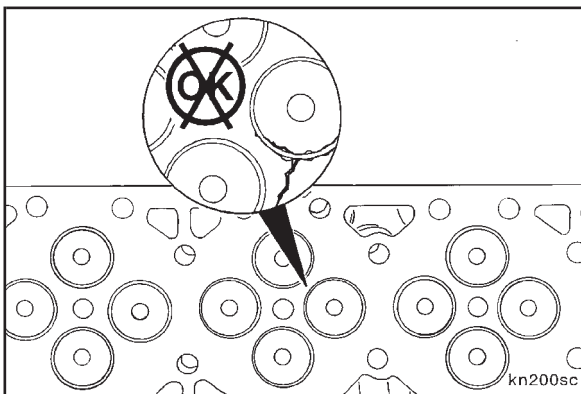


Visually inspect the valves and valve springs for cracks, bent or broken valve stems, broken valve spring collets or other damage.

Visually inspect the valves for indications of leakage or burning.



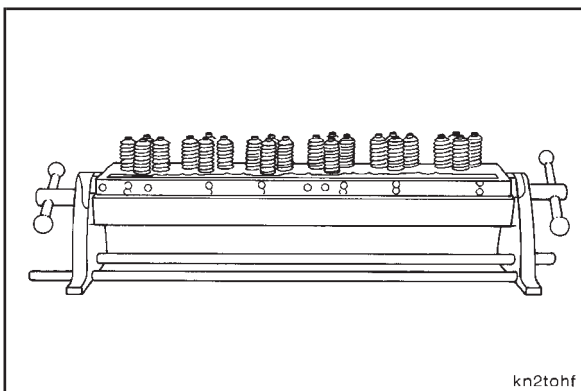
If cracked or damaged parts, or indication of leakage or burning is found, the cylinder head **must** be rebuilt. Refer to Cylinder Head - Rebuild (2-02).



Visually inspect the cylinder head for cracks or damage.



If cracks or leaks in the cylinder head are suspected, refer to Cylinder Head - Pressure Test for Reuse (2-08).



Cylinder Head - Rebuild (2-02)

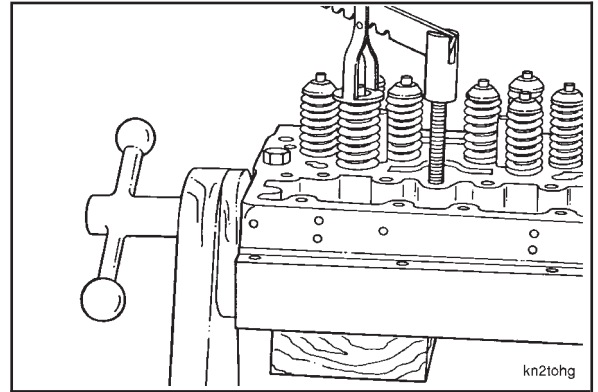
Disassembly



Install the cylinder head in the head holding fixture, Part No. ST-583, as shown.

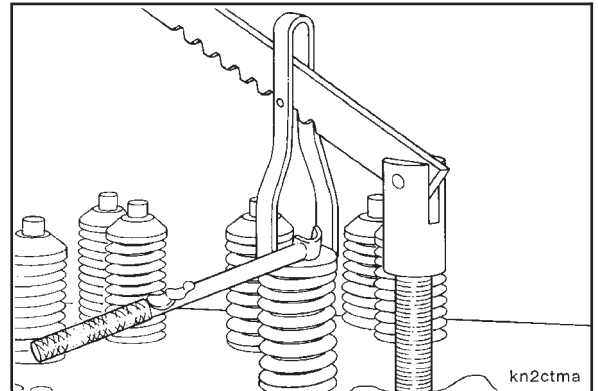
Install a wood block between the valves and head holding fixture to support the valves.

Use the valve spring compressor, Part No. ST-448, the compressor threaded adapter, Part No. 3376850, and the compressor adapter, Part No. 3376851, to compress the valve springs.



Use a pencil magnet to remove the valve collets. Discard the valve collets.

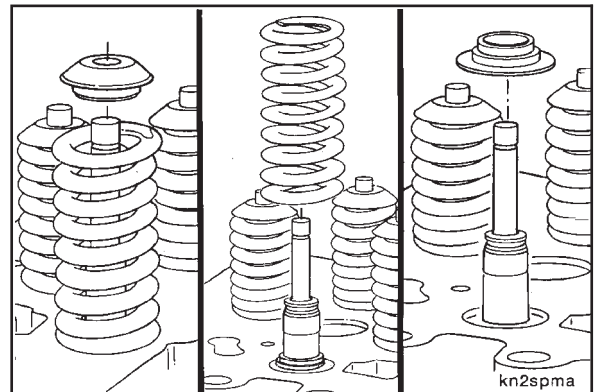
Slowly release the pressure on the valve spring.



Remove the valve spring retainer.

Remove the valve spring.

Remove the valve spring wear plate.

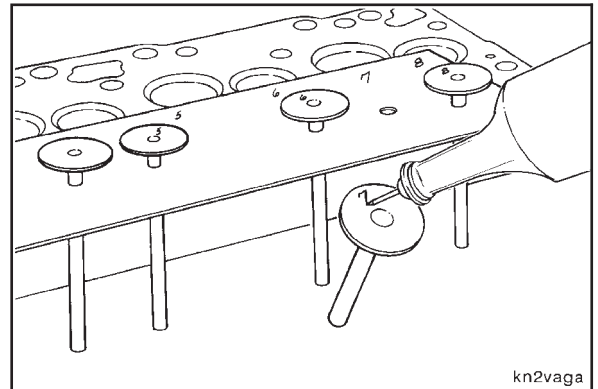


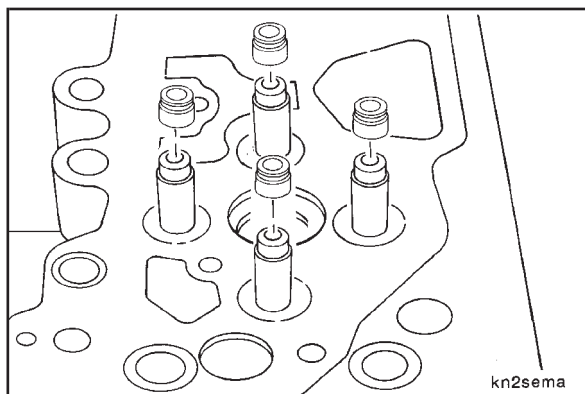
Remove the valve.

Mark the valves with an electric pencil (engraving tool) for location as they are removed.

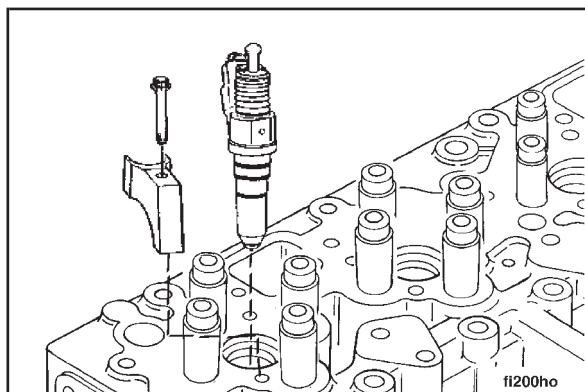
NOTE: The intake and exhaust valves are manufactured from different materials and are **not** interchangeable.

Repeat the procedure to remove the remaining valve collets, retainers, springs, wear plates and valves.





Remove the valve seals from the valve guides.



Inspection

Use clean 15W-40 oil to lubricate the injector o-rings.



Install a set of injectors with new o-rings in the cylinder head.

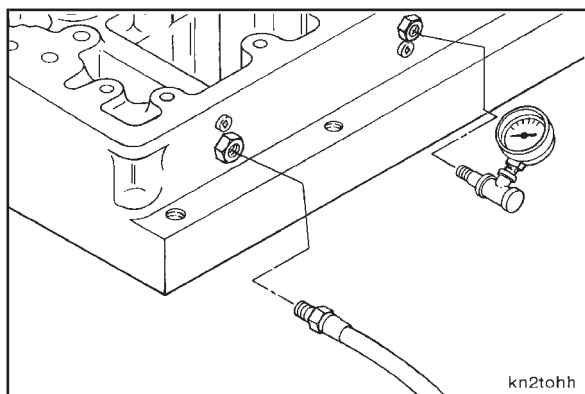


Refer to Section 0 for proper o-ring orientation.

Install the injector holddown clamps and mounting capscrews.



Torque Value: 75 N•m [55 ft-lb]



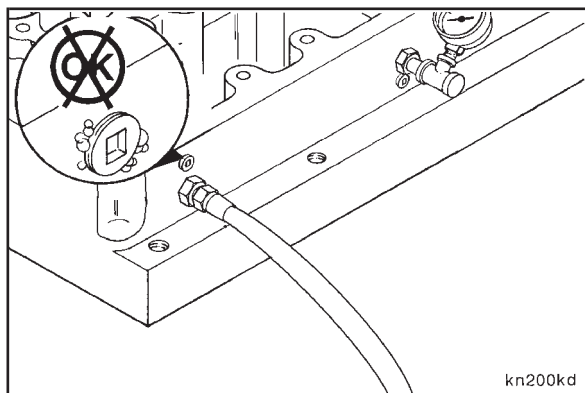
Install a 0-160 psi pressure gauge, Part No. 3375275, to the fuel outlet fitting.



Install an air supply line to the fuel inlet fitting.

Apply air pressure to the cylinder head.

Air Pressure		
kPa		psi
550	MIN	80
690	MAX	100



Close the air supply valve and visually inspect the fuel passages for leaks.

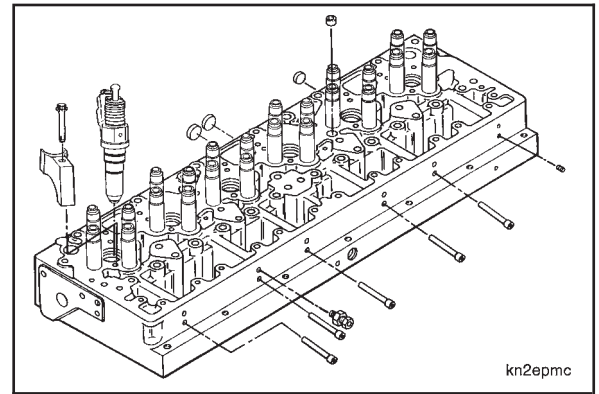
Record the air pressure on the gauge. The air pressure **must not** decrease on the gauge for at least fifteen seconds.

If the air pressure decreases, use a solution of soap and water on the fuel passage areas and pipe plugs to find the leaks.

Remove the injectors from the cylinder head.

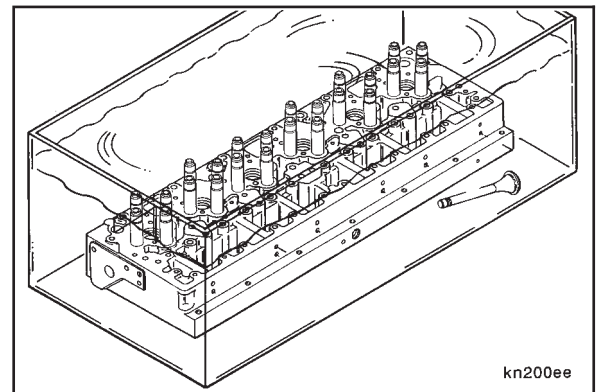
Remove the pipe plugs, fuel passage plugs and fuel fittings from the cylinder head.

Use a dent puller to remove the expansion plugs



Install the cylinder head and parts in a tank of cleaning solution.

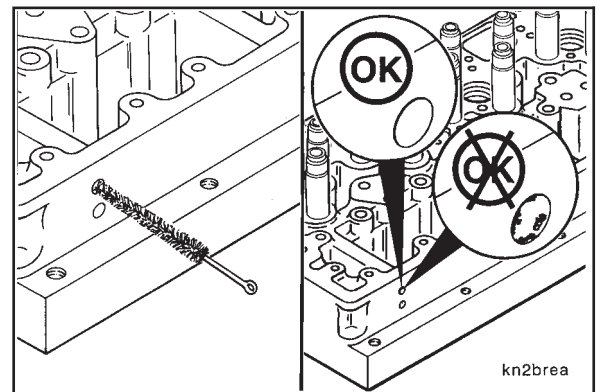
NOTE: Be sure to follow the cleaning solution manufacturer's instructions when cleaning the parts.



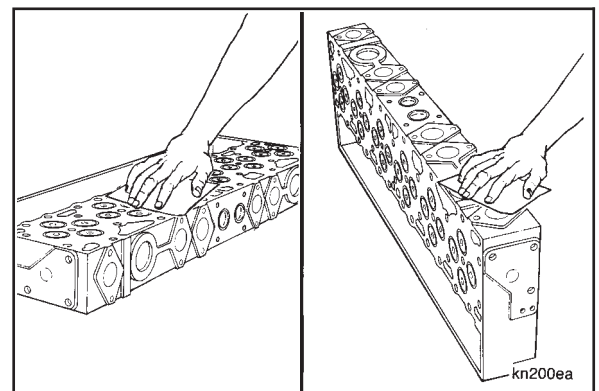
Remove the cylinder head and parts from the cleaning tank.

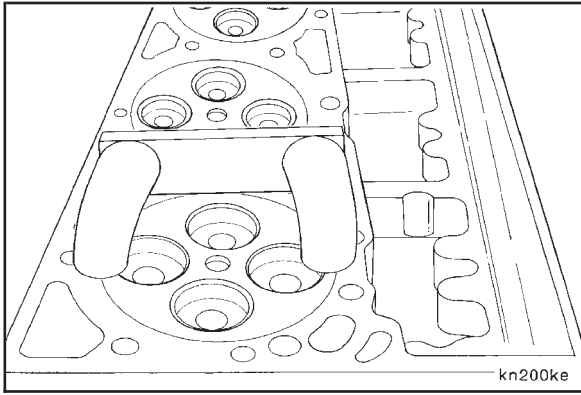
Use fuel passage cleaning brush, Part No. ST-876, to clean the fuel and oil passages with solvent. Dry with compressed air.

Visually inspect the fuel and oil passages to make sure they are clean.



Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to clean the cylinder head combustion face and the exhaust manifold gasket surface.

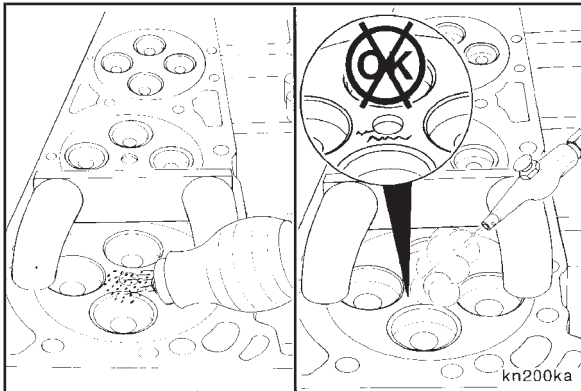




Use magnetic crack detector, Part No. ST-1166, to find cracks in the combustion face, in areas around the valve ports and the injector bores.



Place the magnetizing head on the combustion face as shown, to check for cracks that run across the cylinder head.



Fill the powder spray bulb one-third (1/3) full with metal powder.

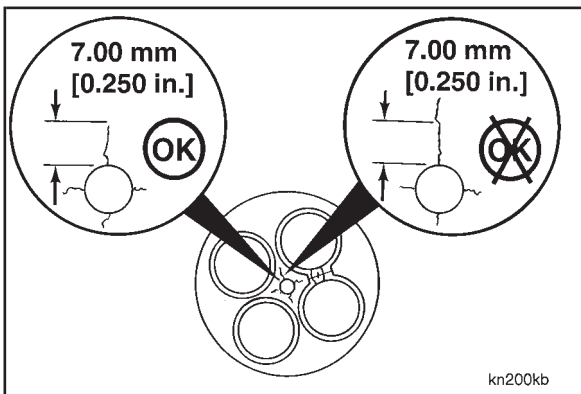


Spray the powder lightly onto the combustion face.

Use compressed air to remove the excess metal powder.

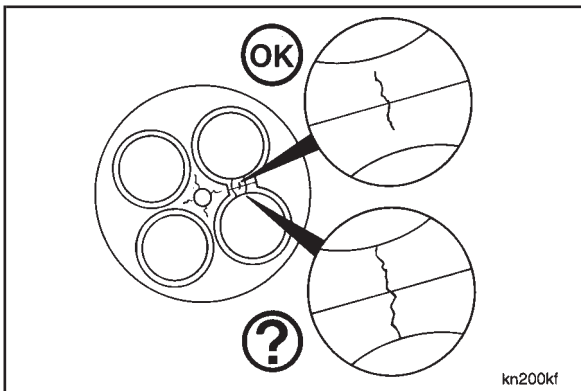
Air Pressure: 276 kPa [40 psi]

NOTE: The powder will remain in the cracks, if present, and show as a white line.



Visually inspect the cylinder head for cracks in the combustion face.

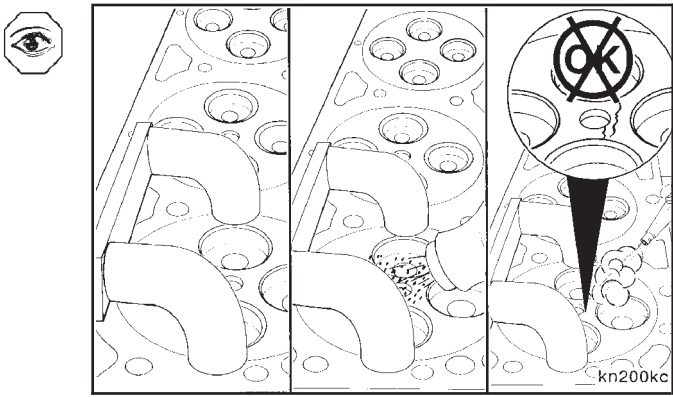
If any cracks around the injector bore are longer than 7 mm [0.250 inch], the cylinder head **must** be replaced.



Both ends of a crack between the valves **must** be visible. If one end of a crack extends into the valve seat insert bore behind the valve seat insert, then the condition of the cylinder head is questionable. To be sure that the cylinder head is in good condition, remove the valve seat insert. Refer to Cylinder Head Valve Seat Insert - Replacement (2-04).

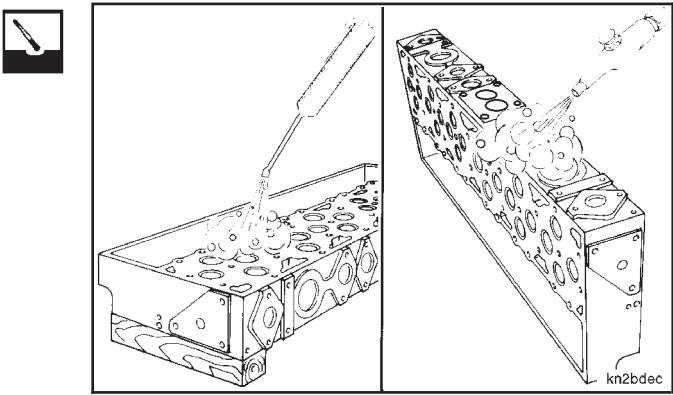
Place the magnetizing head on the combustion face as shown to check for cracks that run lengthwise of the cylinder head.

Repeat the procedure as outlined above.



Remove all magnetism and use solvent to clean the cylinder head. Dry with compressed air.

NOTE: The cylinder head **must** be thoroughly cleaned after using the magnetic crack detector to remove all of the iron fragments.



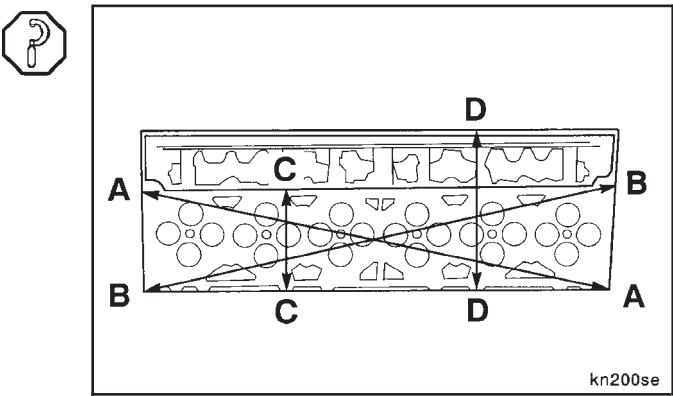
Measure the flatness of the cylinder head gasket surface as follows:

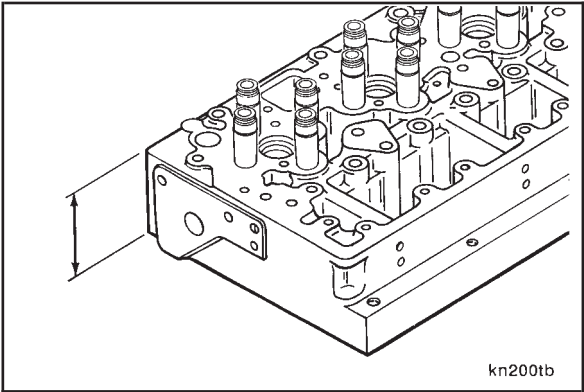
- AA and BB (corner to corner)
- CC (across combustion face)
- DD (across entire head surface)

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

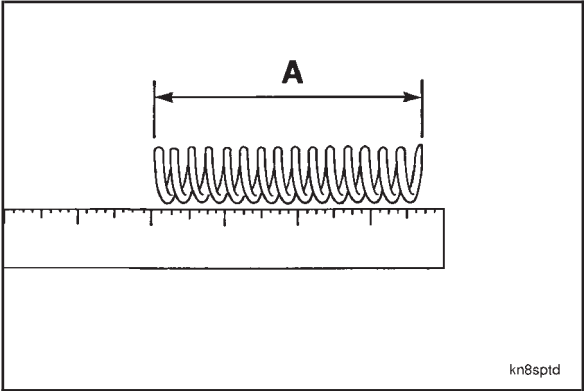
If the cylinder head combustion face is pitted, grooved or worn, the cylinder head surface **must** be machined or cut. Refer to the Alternative Repair Manual, Bulletin No. 3810310.





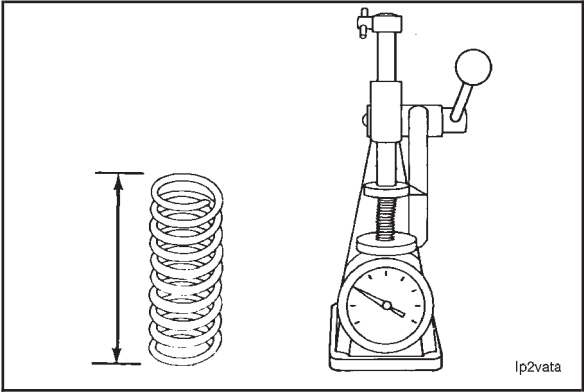
Measure the thickness of the cylinder head.

Cylinder Head Thickness		
mm		in
99.24	MIN	3.907
100.25	MAX	3.947



Measure the valve spring free height.

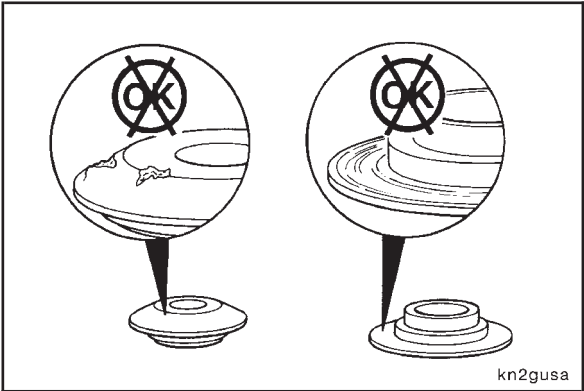
Valve Spring Free Height (A)		
mm		in
103.30	Nominal	4.0669



Use valve spring tester, Part No. 3375182, to measure the valve spring load at the valve spring working height.

Valve Spring Load at 71.48 mm [2.8142 in]		
N		lbf
1252	MIN	281
1584	MAX	356

If the valve spring load for the working height is less than the minimum specified, the valve spring **must** be replaced.



Visually inspect the valve spring retainers and valve spring guides for damage or worn areas.

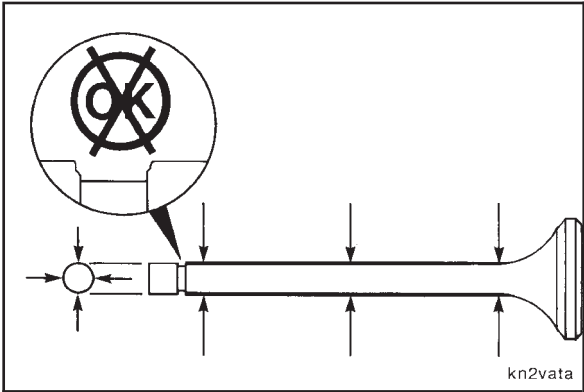
Discard damaged and worn parts.

Visually inspect the valves for damage and the collet grooves for wear.

Measure the outside diameter of the valve stem.

Valve Stem O.D.		
mm		in
9.580	MIN	0.3772
9.633	MAX	0.3793

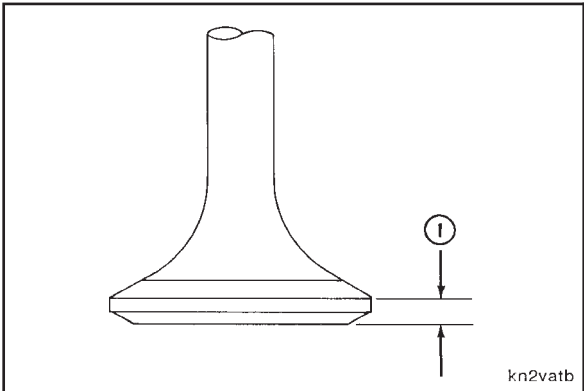
If the valves are damaged or the stems are worn smaller than the minimum specified, the valves **must** be replaced.



Place the valve on a flat surface and measure the head thickness (1) at the outside diameter.

Valve Head Thickness (at O.D.)		
mm		in
3.15	MIN	0.124
3.62	MAX	0.143

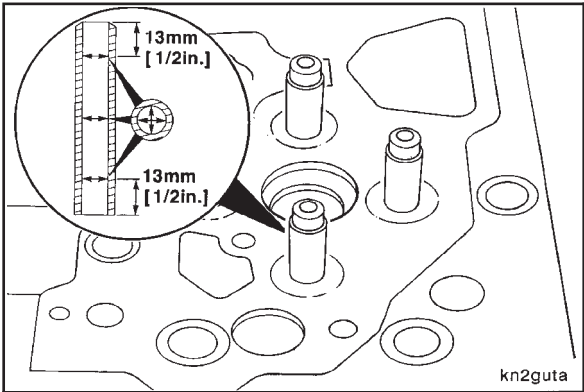
If the valve head is worn thinner than the minimum specified, the valve(s) **must** be replaced.



Visually inspect the valve guides for chips or cracks.

Measure the inside diameter of the valve guides in locations 13mm [1/2 inch] from each end and at the center as shown.

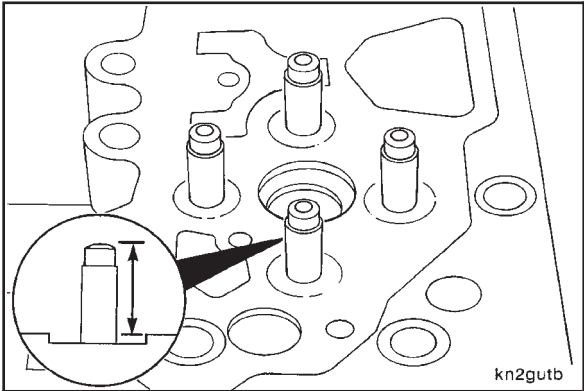
Used Valve Guide I.D. (Installed)		
mm		in
9.670	MIN	0.3807
9.730	MAX	0.3831

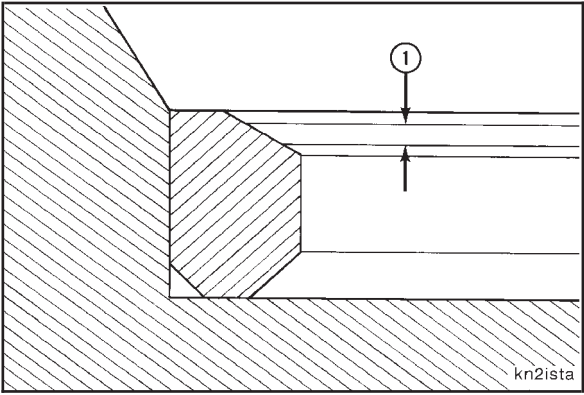


Measure the valve guide installed height.

Valve Guide Height (Installed)		
mm		in
27.15	MIN	1.069
27.65	MAX	1.089

If damage is found or the valve guide(s) do **not** meet the limits specified, the valve guide(s) **must** be replaced. Refer to Cylinder Head Valve Guide - Replacement (2-03)



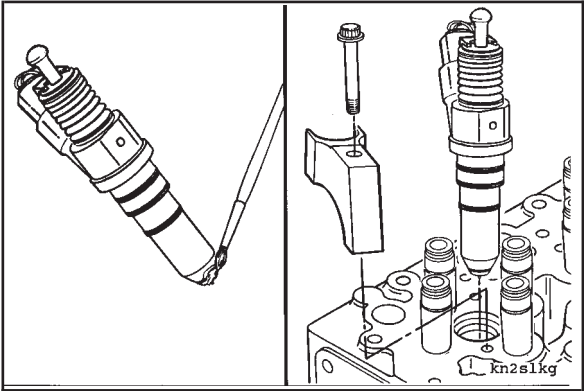


Measure the width of the valve seat area (1) of the valve seat inserts.



Valve Seat Area (Width)		
mm		in
1.63	MIN	0.064
2.69	MAX	0.106

If the valve seat area is worn wider than the maximum specified, refer to Grind the Valve Seats following in this procedure, or Cylinder Head Valve Seat Insert - Replacement (2-04).



Caution: Support the cylinder head in the Part No. ST-583 Head Holding Fixture to prevent damage to the injector tip that protrudes from the combustion face.

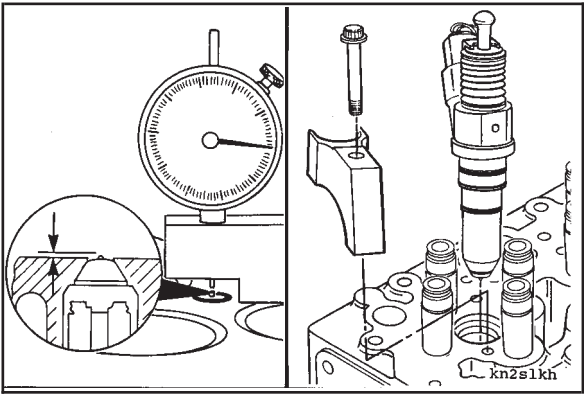


Apply a bluing compound to the outside diameter of the injector at the injector sleeve seat area.



Install the injectors into the cylinder head without o-rings.

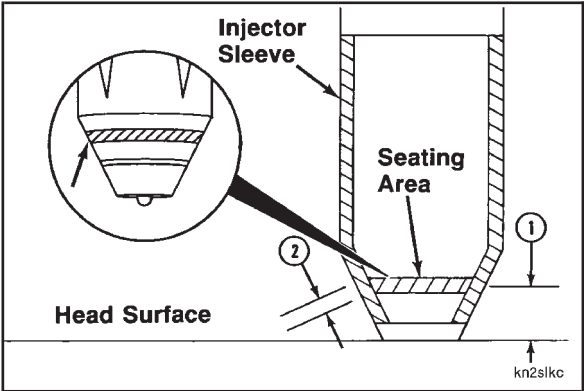
Torque Value: 75 N•m [55 ft-lb]



Turn the cylinder head over and use depth gauge, Part No. 3823495, to measure the injector tip protrusion.

Injector Tip Protrusion		
mm		in
2.28	MIN	0.090
2.65	MAX	0.104

Remove the injectors from the cylinder head.



The bluing pattern of the injector seating area (1) **must** be approximately 13 mm [0.50 inch] from the cylinder head combustion face surface.



The injector bore seating width (2) **must** be a minimum of 1.52mm [0.060 inch].



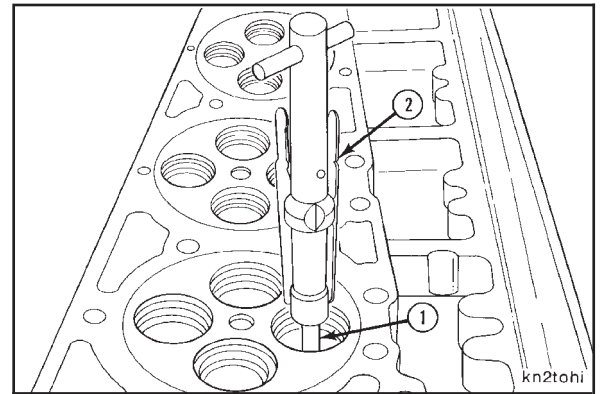
If the injector protrusion is more than the maximum specified or the injector sleeve bluing pattern does **not** meet the specifications given, the injector sleeve(s) **must** be replaced. Refer to Cylinder Head Injector Sleeve - Replacement (2-07).

Valve Seats - Grinding

Use valve seat grinding machine, Part No. ST-685, and valve guide arbor set, Part No. ST-804, when grinding the valve seat inserts.

Install the valve guide arbor (1) in the valve guide with the arbor puller (2).

Rotate the arbor to be sure that it is installed correctly.

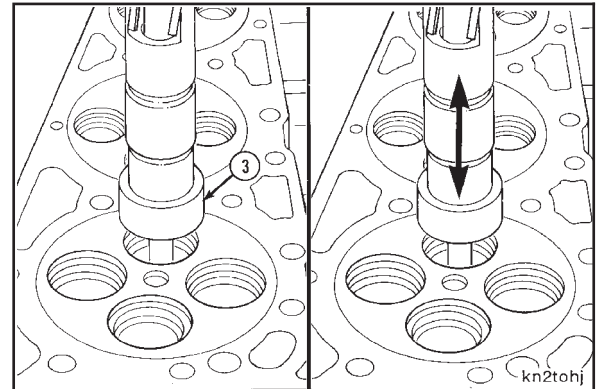


Install the valve seat grinding stone (3), Part No. 3376077, on the driver.

Install the grinder unit on the arbor.

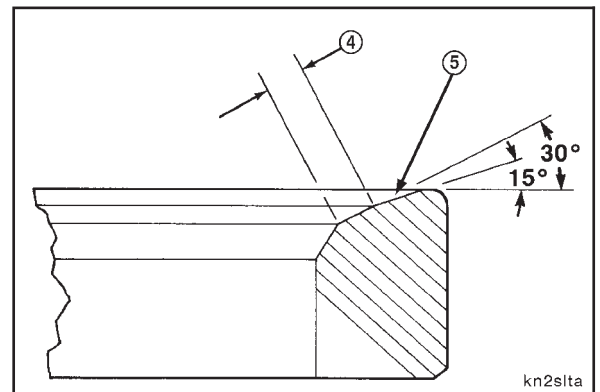
NOTE: The grinding stone (3) **must not** be touching the valve seat insert when the drive unit motor is started.

Hold the drive unit in a vertical position and use an “up and down” movement of 13 mm [0.50 inch] travel and light pressure to grind the insert.



If the area (4) is wider than 2.69mm [0.106 inch], use a grinding stone with a 15 degree angle to narrow the width (5).

Remove the grinder unit from the arbor.

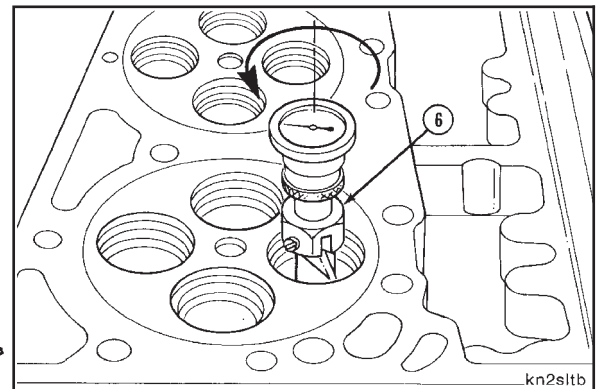


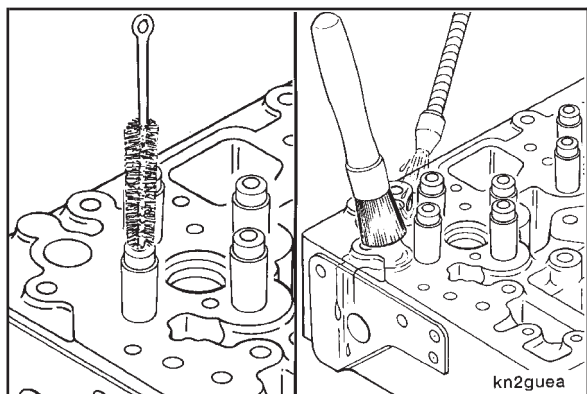
Install eccentricimeter gauge (6), Part No. ST-685-4, on the arbor.

Measure the valve seat to valve guide concentricity.

Concentricity (Per 360 Degrees)		
mm		in
0.05	MAX	0.002

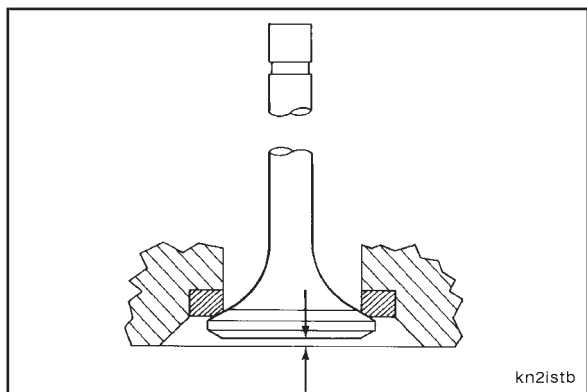
If the valve seat concentricity does **not** meet the specifications, grind the valve seat again. If the specifications **cannot** be met, replace the valve seat insert. Refer to Cylinder Head Valve Seat Insert - Replacement (2-04).





After grinding the valve seats, use a 13 mm [0.50 inch] bristle brush to clean the inside diameter of the valve guides.

Use solvent to clean the cylinder head. Dry with compressed air.



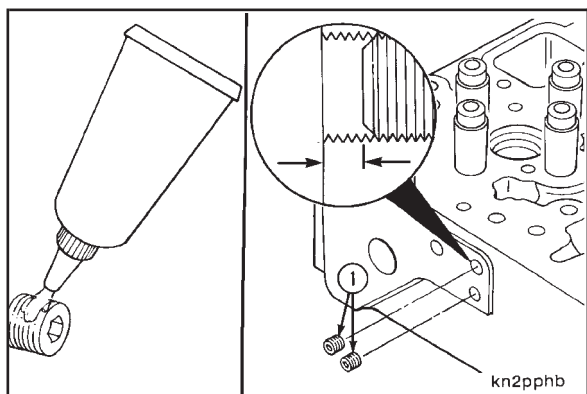
Install a new or reconditioned valve in the valve guide. Hold the valve firmly against the valve seat insert.



Use depth gauge, Part No. 3823495, to measure the valve recess in the cylinder head.

Valve Recess		
mm		in
0.76	MIN	0.030
1.17	MAX	0.046

If the valve recess does **not** meet the specifications given, the valve seat **must** be ground again or replaced. Refer to Cylinder Head Valve Seat Insert - Replacement (2-04).

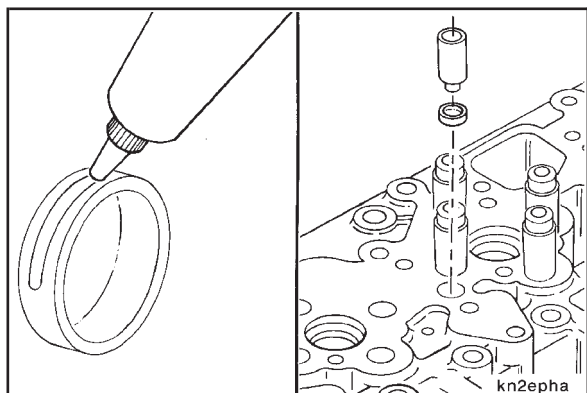


Assembly

Apply a coat of cup plug sealant, Part No. 3375068, to the pipe plug threads. Install the pipe plugs.

NOTE: The pipe plugs (1) located in the front of the cylinder head **must** be installed below the surface of the cylinder head.

Torque Value: 10 N•m [8 ft-lb]



Apply a coat of cup plug sealant, Part No. 3375068, to the outside diameter of the expansion plugs.

Use expansion plug drivers, Part No's. 3823372, 3376058, and 3376816, to install the expansion plugs in the cylinder head.

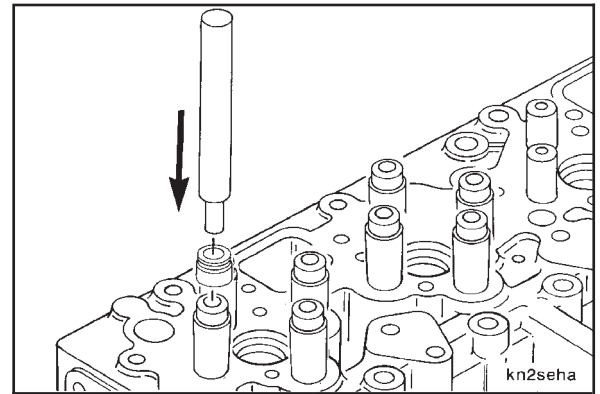
NOTE: The correct expansion plug driver will install the expansion plugs to the correct depth in the cylinder head.

Caution: Do not use excessive force or the seal will be damaged.

Use valve seal driver, Part No. 3823946, to install the valve seals on the valve guides.

Position the seal on the tool arbor.

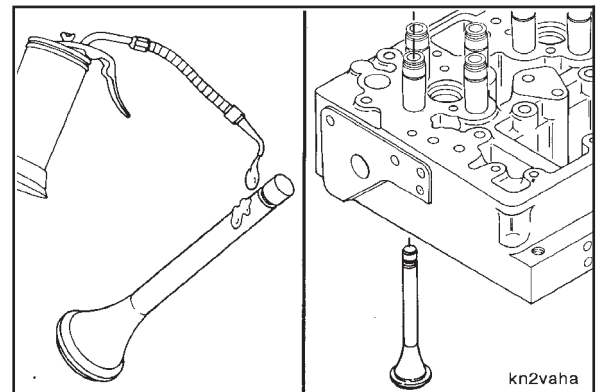
Insert the arbor into the top of the guide and tap the tool with a plastic mallet to seat the bottom of the seal against the machined step on the valve guide.



Use clean 80W, or higher, gear lube with EP additives to lubricate the valve stems.

Install the valves in the valve guides.

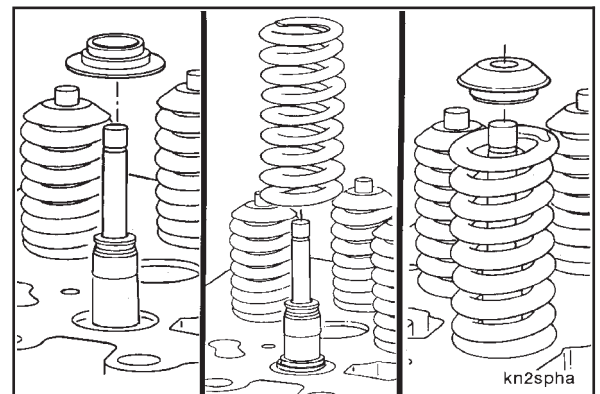
After the valves are installed, place the cylinder head on a flat surface that will **not** damage the cylinder head surface.



Install the valve spring wear plates.

Install the valve springs.

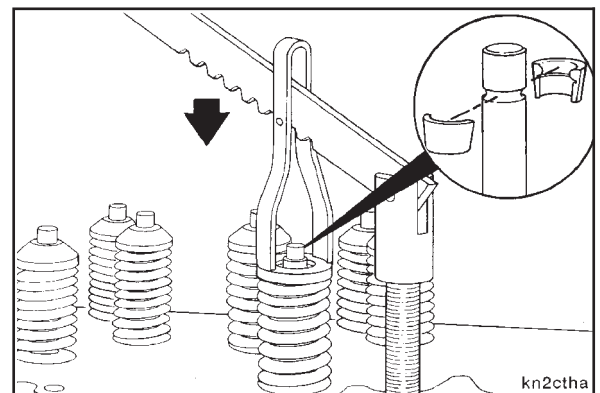
Install the valve spring retainers.

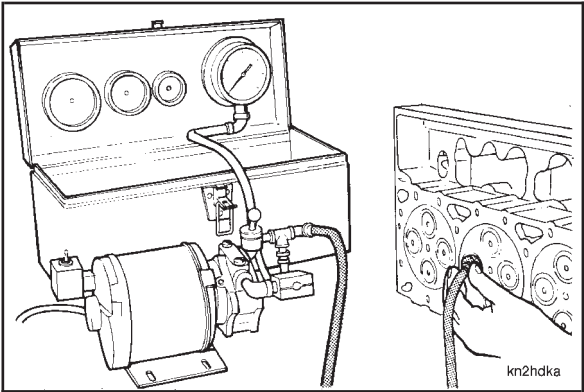


Use valve spring compressor, Part No. ST-448, compressor thread adapter, Part no. 3376850, and compressor adapter, Part No. 3376851, to compress the valve springs.

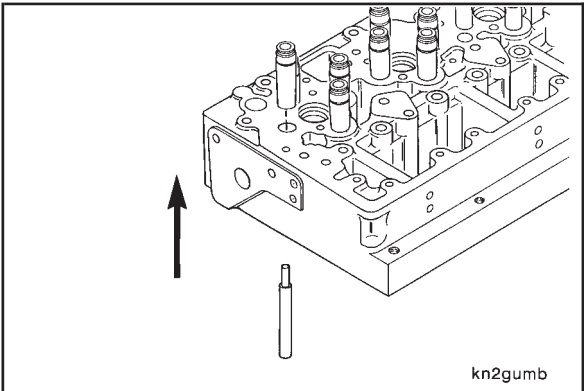
NOTE: Always use new collets when rebuilding the cylinder head.

Install the new valve spring retainer collets.





Use vacuum tester, Part No. ST-1257, with vacuum cup, Part No. 3376100, to vacuum test the valve seating. Refer to Cylinder Head - Vacuum Test Valve Seating (2-10).

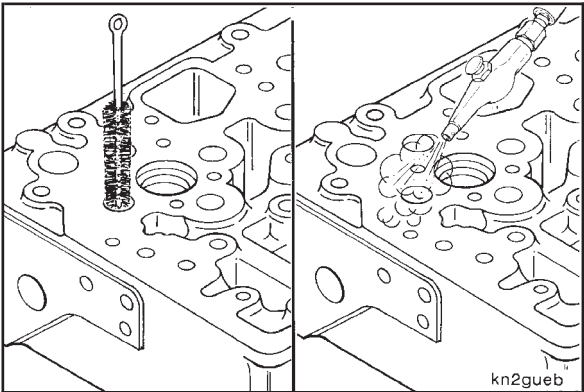


Cylinder Head Valve Guide - Replacement (2-03)

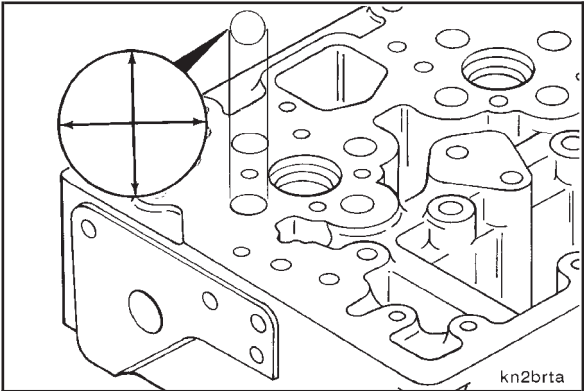
Disassembly



Use valve guide driver, Part No. 3376398, to remove the old valve guides.



Use a flexible brush and solvent to clean the valve guide bores in the cylinder head. Dry with compressed air.



Inspection

Measure the inside diameter of the valve guide bore in the cylinder head.

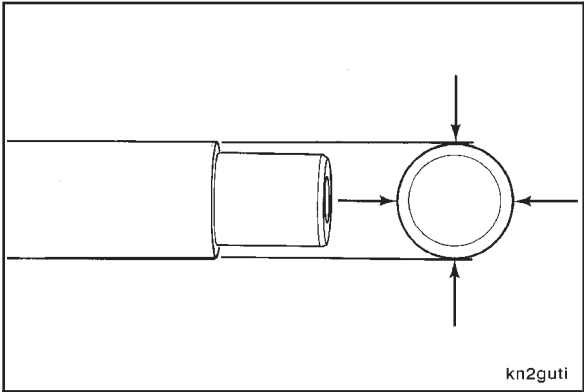
Valve Guide Bore I.D.		
mm		in
16.480	MIN	0.6488
16.500	MAX	0.6496

If the valve guide bore is worn larger than the maximum specified, the valve guide bore can be machined, and a 0.51mm [0.020 inch] oversize valve guide installed. Refer to the Alternative Repair Manual, Bulletin No. 3810310.



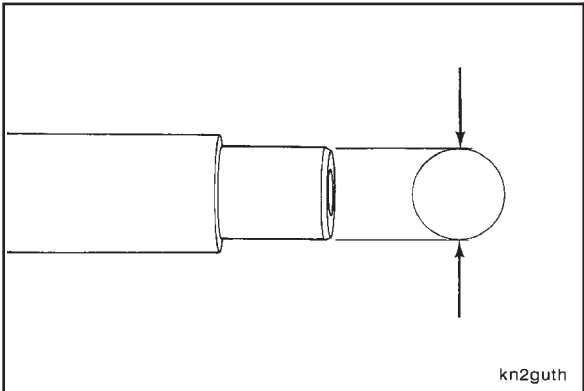
Measure the outside diameter of the base of the valve guide.

Valve Guide O.D. of Base		
mm		in
16.513	MIN	0.6501
16.526	MAX	0.6506



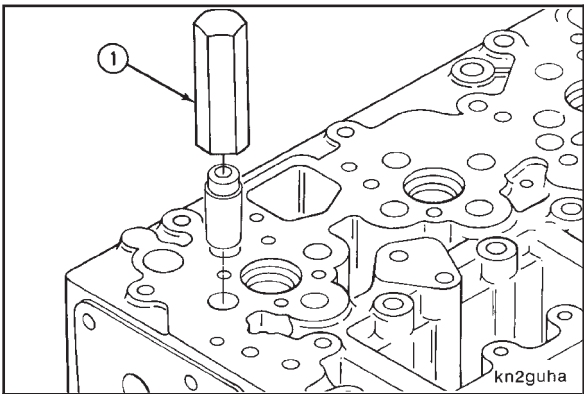
Measure the outside diameter of the seal area of the valve guide.

Valve Guide O.D. of Seal Area		
mm		in
14.25	MIN	0.561
14.37	MAX	0.566



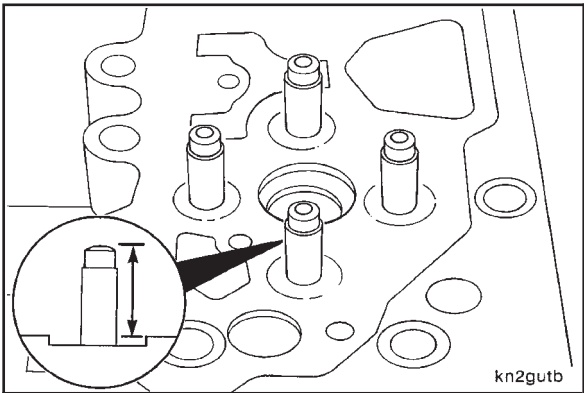
Assembly

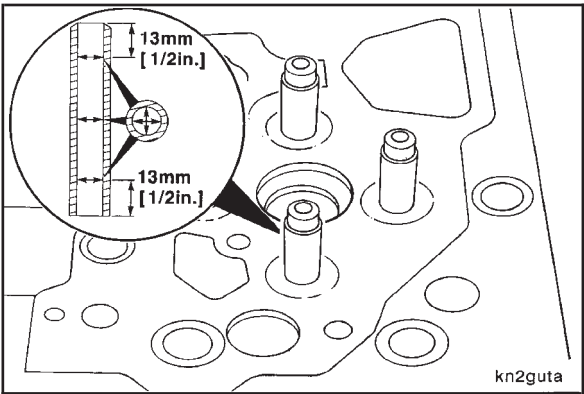
Use valve guide driver (1), Part No. 3823947, to install the new valve guides.



Measure the valve guide installed height above the cylinder head top deck surface.

Valve Guide Height (Installed)		
mm		in
27.15	MIN	1.069
27.65	MAX	1.089

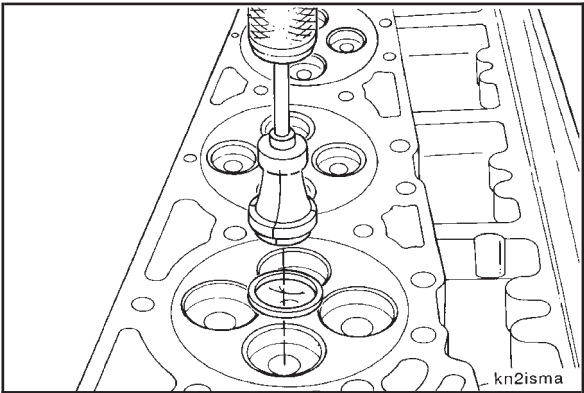




Measure the valve guide inside diameter.

New Valve Guide I.D. (Installed)		
mm		in
9.670	MIN	0.3807
9.695	MAX	0.3817

If the valve guide is **not** within the specifications given, the valve guide **must** be replaced.

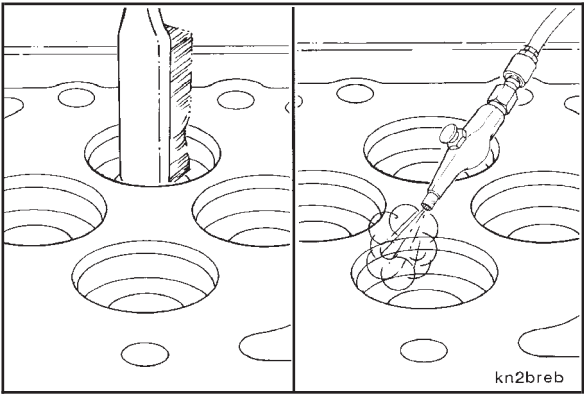


Cylinder Head Valve Seat Insert - Replacement (2-04)

Disassembly

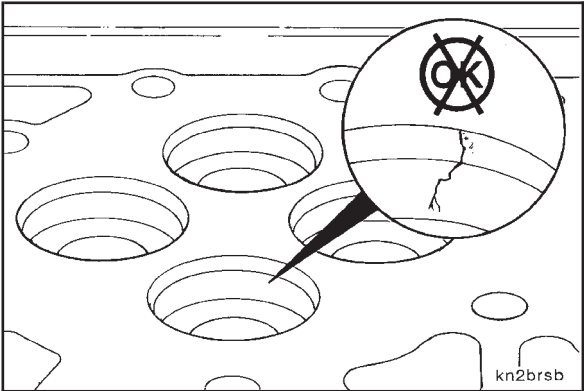


Use slide hammer assembly, Part No. 3376617, and valve seat extractor, Part No. 3376146, to remove the valve seat inserts from the cylinder head.



Use a wire brush and solvent to clean the deposits from the valve seat insert bores.

Use solvent to clean the cylinder head. Dry with compressed air.



Inspection

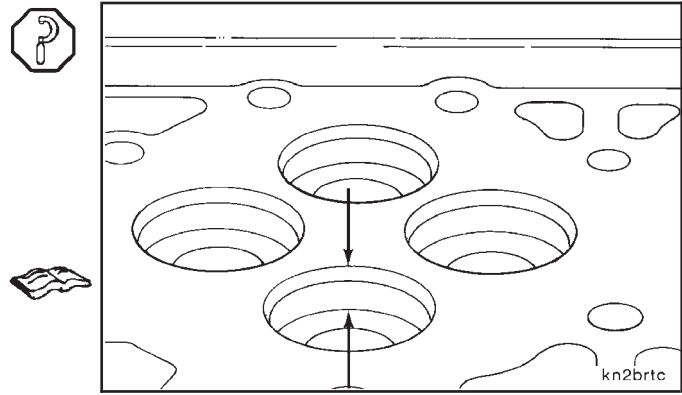
Visually inspect the insert bore for cracks or damage.

If cracks or damage is found, it is possible to repair the cylinder head by machining the insert bore for oversize valve seat inserts. Refer to the Alternative Repair Manual, Bulletin No. 3810310.

Measure the valve seat insert bore depth in the cylinder head.

Insert Bore Depth (Standard Insert)		
mm		in
9.40	MIN	0.370
9.50	MAX	0.374

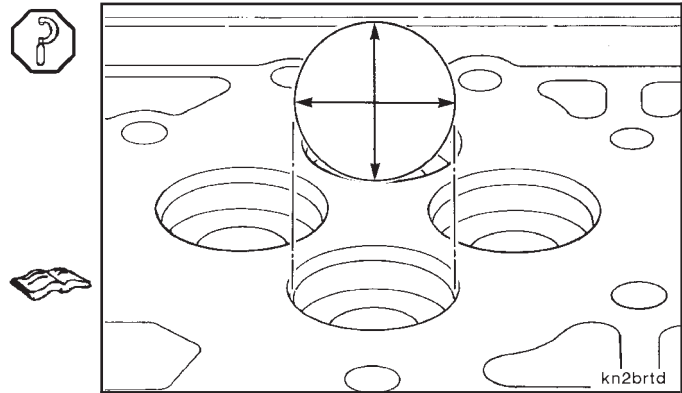
If the valve seat insert bore depth does **not** meet the specifications given, refer to Cylinder Head Oversize Valve Seat Insert - Installation (2-05).



Measure the inside diameter of the valve seat insert bore in the cylinder head.

Insert Bore I.D. (Standard Insert)		
mm		in
45.920	MIN	1.8073
45.935	MAX	1.8085

If the valve seat insert bore inside diameter does **not** meet the specifications given, refer to Cylinder Head Oversize Valve Seat Insert - Installation (2-05)



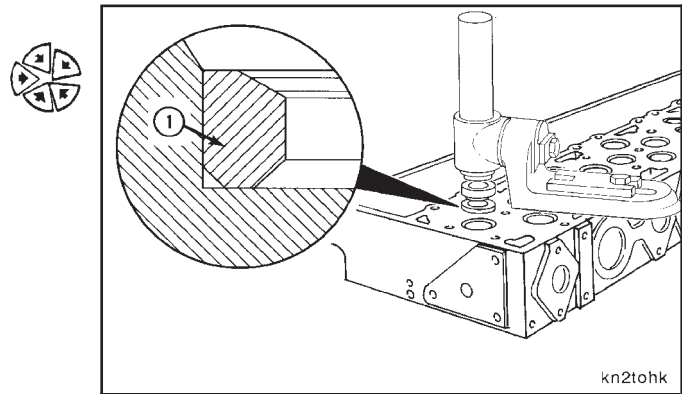
Assembly

Install the base and swivel of valve seat insert tool, Part No. ST-257, on the cylinder head to guide the valve seat driver. Install valve guide arbor, Part No.ST-804-1.

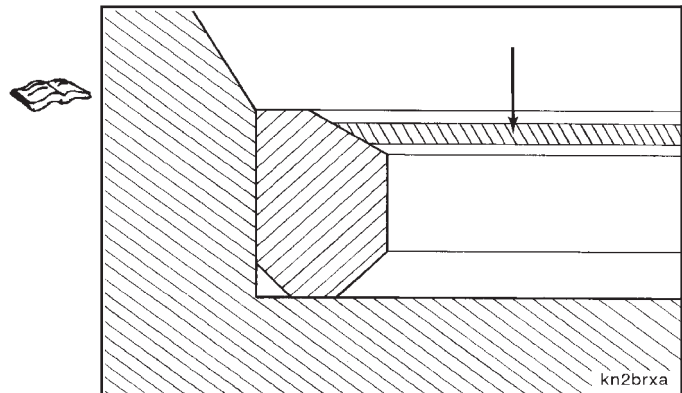
NOTE: The insert chamfer (1) **must** be installed toward the bottom of the counterbore.

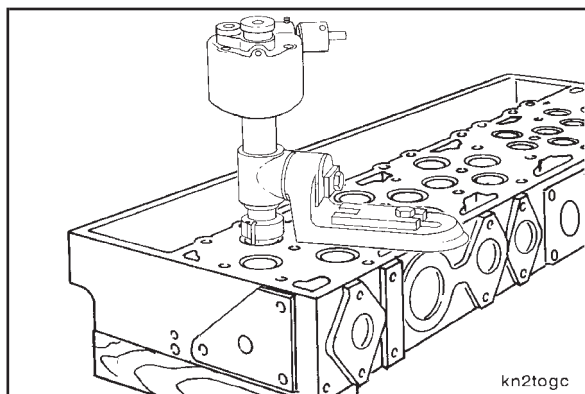
Use valve seat driver, Part No. 3376105, to drive the valve seat insert into the counterbore.

Make sure the insert is at the bottom of the counterbore.



Use valve seat grinding machine, Part No. ST-685, and valve guide arbor set, Part No. 804, to grind the new valve seat inserts. Refer to Valve Seats - Grinding in Procedure (2-02).





Cylinder Head Oversize Valve Seat Insert - Installation (2-05)



Valve seat inserts that are oversize on both the outside diameter and thickness are available to repair cylinder heads that are worn or damaged in the valve seat insert counterbore. The insert bore depth and inside diameter of the standard and oversize valve seat inserts are listed below. For complete instructions for machining the counterbore for oversize inserts, refer to the Alternative Repair Manual, Bulletin No. 3810310.

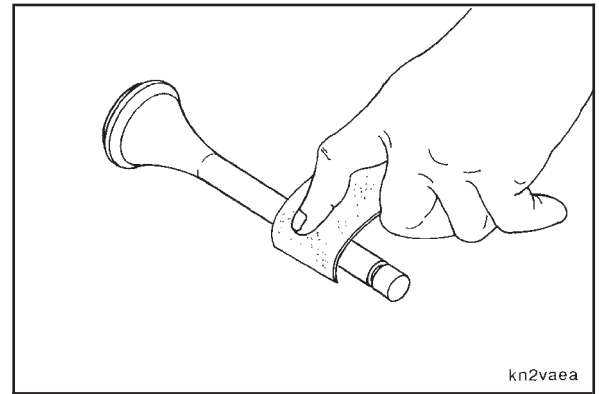
The valve seat insert cutter set, Part No. 3376595, consists of the oversize cutters listed below.

Valve Seat Inserts					
Valve Insert Part No.	Valve Seat Insert Cutter Part No.	Cylinder Head Valve Insert Bore Depth Nominal	Cylinder Head Valve Insert Bore Diameter Nominal	Valve Insert O.D. Oversize	Valve Insert Thickness Oversize
3027060 STD		9.45 mm	45.920 mm	STD mm	STD mm
		0.344 in	1.8079 in	STD in	STD in
3028071	3376596	8.75 mm	46.170 mm	0.25 mm	STD mm
		0.344 in	1.8177 in	0.010 in	STD in
3028072	3376597	8.88 mm	46.420 mm	0.50 mm	0.13 mm
		0.349 in	1.8276 in	0.020 in	0.005 in
3028073	3376598	9.00 mm	46.670 mm	0.75 mm	0.25 mm
		0.354 in	1.8374 in	0.030 in	0.010 in
3028074	3376599	9.13 mm	46.920 mm	1.00 mm	0.38 mm
		0.359 in	1.8472 in	0.040 in	0.015 in

Cylinder Head - Valve Grinding (2-06)

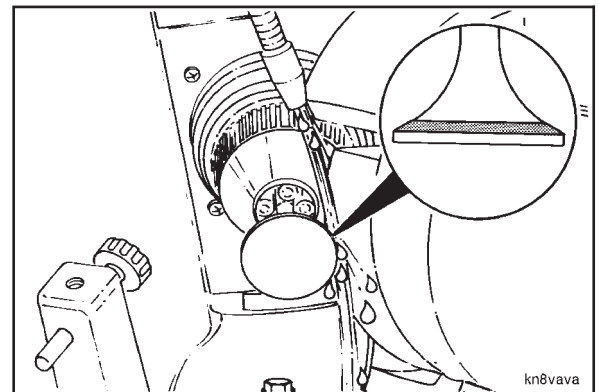
Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to clean the valve stems. Clean the carbon deposits from the valve face and head.

NOTE: The valves **must** be clean and free of carbon deposits before they are ground. Valves can be cleaned by the bead blasting method in the **head area only**.



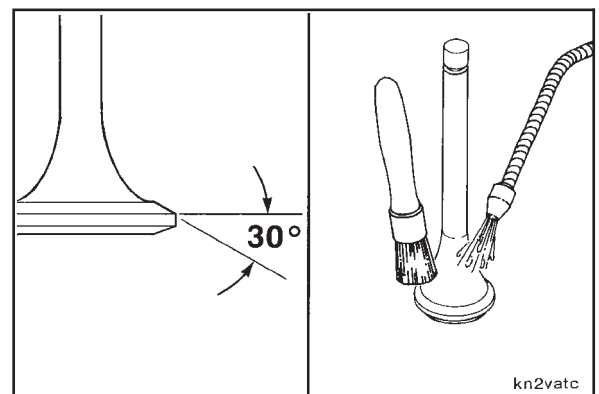
Use valve facing machine, Part No. 3376256, to grind the face of the valve.

Follow the instructions supplied with valve facing machine for the correct setup before grinding the valves.



Grind the intake and exhaust valves to the angle shown.

Use solvent to clean the metal particles from the valve. Dry with compressed air.



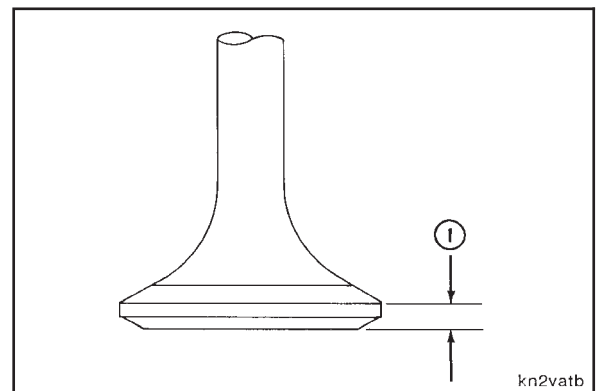
Inspection

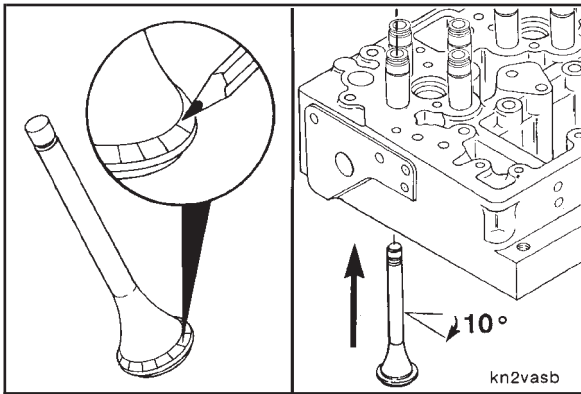
Place the valve on a flat surface and measure the head thickness (1) at the outside diameter.



Valve Head Thickness (at O.D.)		
mm		in
3.15	MIN	0.124
3.62	MAX	0.143

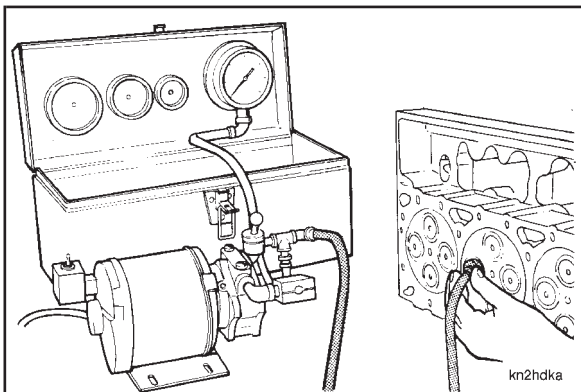
If the valve head is worn thinner than minimum specified, the valve(s) **must** be replaced.





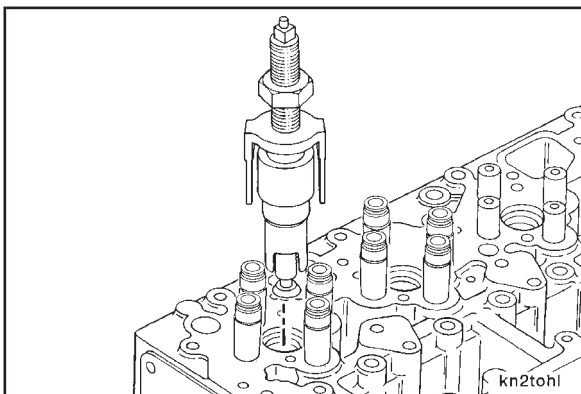
Use a lead pencil to mark across the valve face, as shown. Install the valve into the valve guide.

Hold the valve against the valve seat and rotate the valve at least 10 degrees. Correct contact against the valve seat will break the marks on the valve face.



Install the valves in the cylinder head. Refer to Cylinder Head - Rebuild - Assembly (2-02).

Use valve vacuum tester, Part No. ST-1257, with vacuum cup, Part No. 3376100, to vacuum test the valve seating. Refer to Cylinder Head - Vacuum Test Valve Seating (2-09).

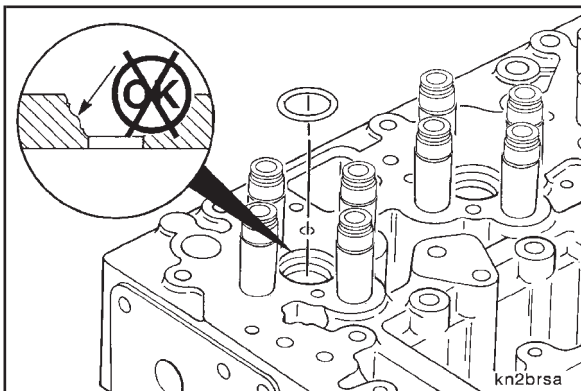


Cylinder Head Injector Sleeve - Replacement (2-07)

Disassembly

Use injector sleeve puller, Part No. 3377079, to remove the injector sleeves from the cylinder head.

Follow the directions supplied with the tool to remove the sleeves.



Inspection

Remove the injector sleeve o-ring from the injector bore in the cylinder head. Discard the o-ring.

Use solvent to clean the injector bore. Dry with compressed air.

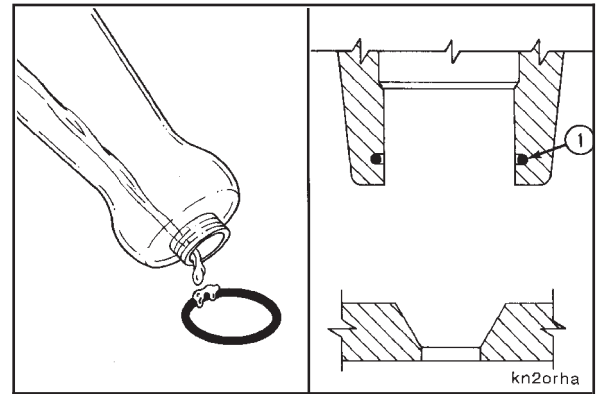


Visually inspect the injector seat surface in the bottom of the injector bore.

If the bead in the cylinder head is **not** smooth the injector bore **must** be repaired. Refer to the Alternative Repair Manual, Bulletin No. 3810310.

Assembly

Use vegetable oil to lubricate the injector sleeve o-rings.
Install the o-ring (1) in the groove of the injector sleeve bore.



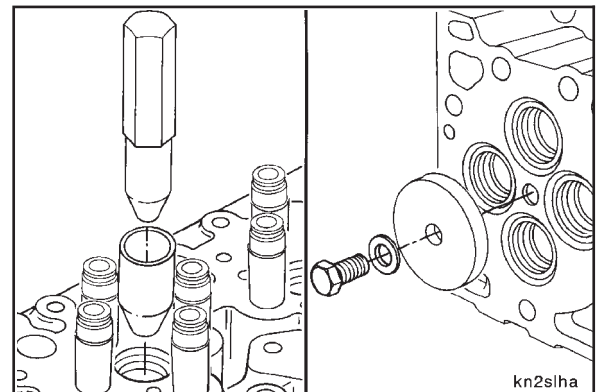
Use injector sleeve driver, Part No. ST-1227, to install the injector sleeve into the cylinder head. Remove the sleeve driver.



Install injector sleeve holding tool, Part No. ST-1179, in the injector sleeve.



Torque Value: 50 N•m [38 ft-lb]



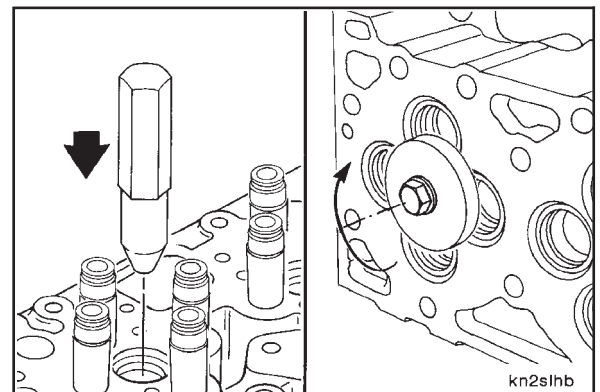
Install the injector sleeve driver.

Hit the driver with a mallet to seat the sleeve in the bore.

Remove the driver and tighten the injector sleeve holding tool capscrew again.



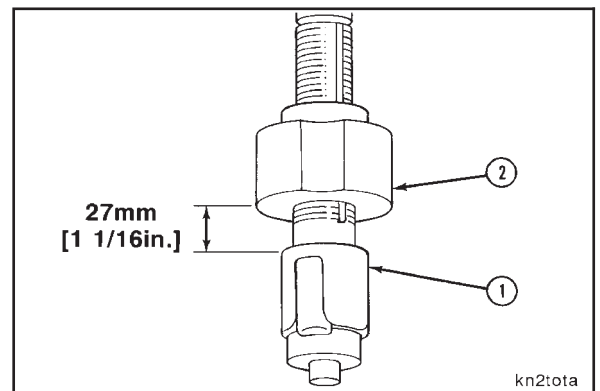
Torque Value: 50 N•m [38 ft-lb]

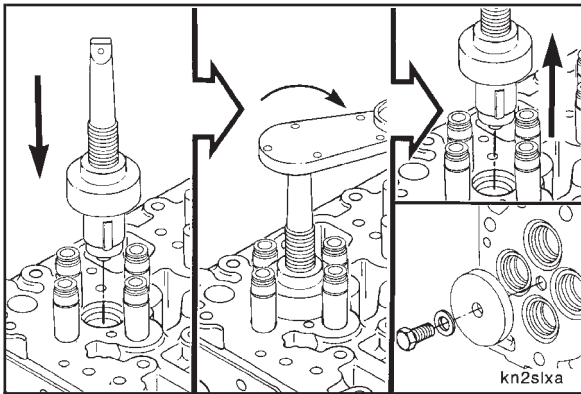


Use injector sleeve expander, Part No. ST-880, to expand the upper section of the injector sleeve.

Adjust the expander roller edge (1) and collar (2) to the clearance specified.

Clearance: 27 mm [1-1/16 in.]



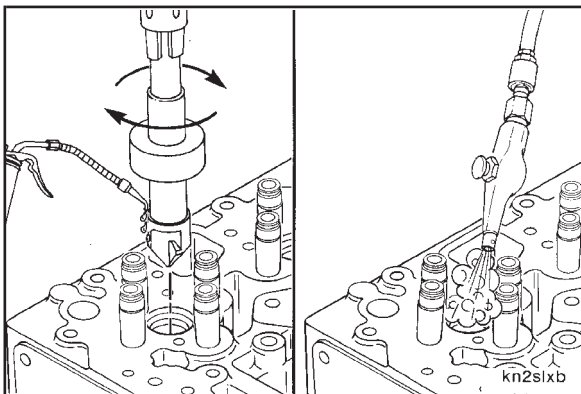


Install the expander into the injector sleeve and turn the mandrel with a 1/2 inch socket and an inch pound torque wrench.



Torque Value: 9 N•m [75 in-lb]

Remove the expander and holding tool from the injector sleeve.



Use pilot, Part No. ST-379-2, holder, Part No. ST-884-1, and injector seat cutter, ST-844-3, to cut the injector seat.



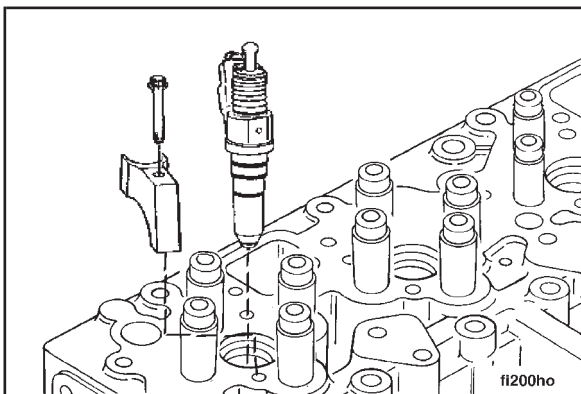
Install the injector sleeve cutter and the cylinder head in a drill press.

Use a cutting oil to lubricate the cutter head.

Carefully machine the injector sleeve until the sealing area is smooth.



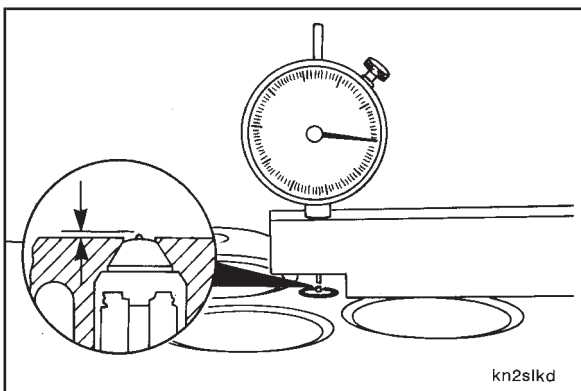
Clean the metal particles from the injector sleeve bore and fuel passages.



Caution: Support the cylinder head in the Part No. ST-583 Head Holding Fixture to prevent damage to the injector tip that protrudes from the combustion face.

Install the injector into the cylinder head without the o-rings.

Torque Value: 75 N•m [55 ft-lb]



Turn the cylinder head over and use depth gauge, Part No. 3823495, to measure the injector tip protrusion.

Injector Tip Protrusion (New Injector Sleeve)

mm		in
2.28	MIN	0.090
2.54	MAX	0.100

If the injector tip protrusion does **not** meet the specifications given, the injector sleeve **must** be machined again.

Section 2 - Cylinder Head - Group 02 M11

Remove the injectors and apply a bluing compound to the outside diameter of the injector at the injector seat area.

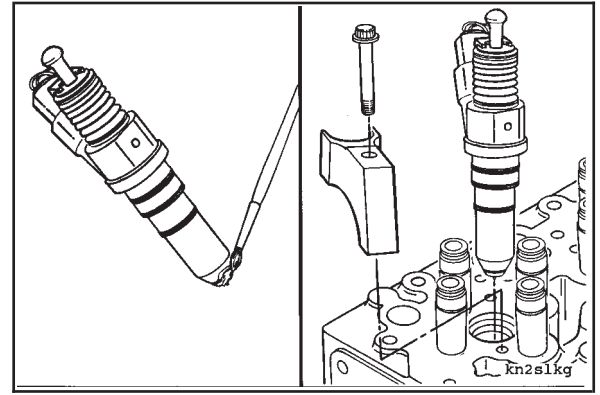
Install the injectors into the cylinder head **without** the o-rings.

Torque Value: 75 N•m [55 ft-lb]

Remove the injectors from the cylinder head.



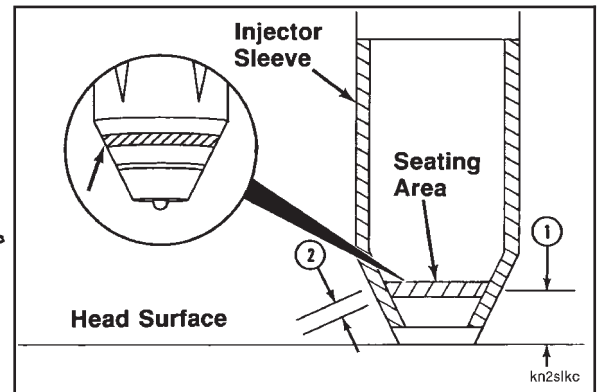
Cylinder Head - Pressure Test for Reuse (2-08) Page 2-29



The bluing pattern of the injector seating area (1) **must** be approximately 13mm [0.50 inch] from the cylinder head surface.

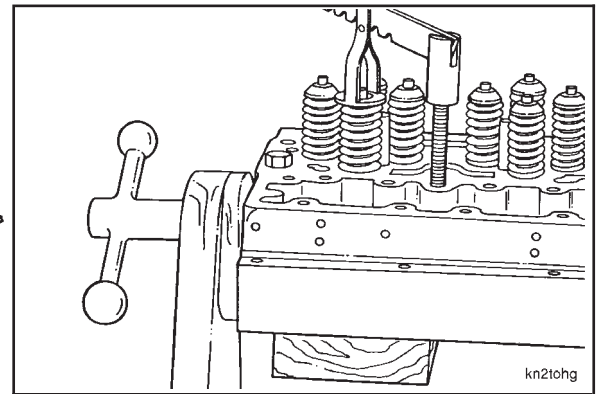
The injector bore seating width (2) **must** be a minimum of 1.52mm [0.060 inch].

Inspect the cylinder head for leaks after the new injector sleeves have been installed. Refer to Cylinder Head - Pressure Test for Reuse (2-08).



Cylinder Head - Pressure Test for Reuse (2-08)

Caution: Do not pressure test the cylinder head with the valves and valve springs installed. Water entering the cylinder head cannot be dried thoroughly and will damage the valve guides and valve stems. Refer to Cylinder head - Rebuild - Disassembly (2-02)

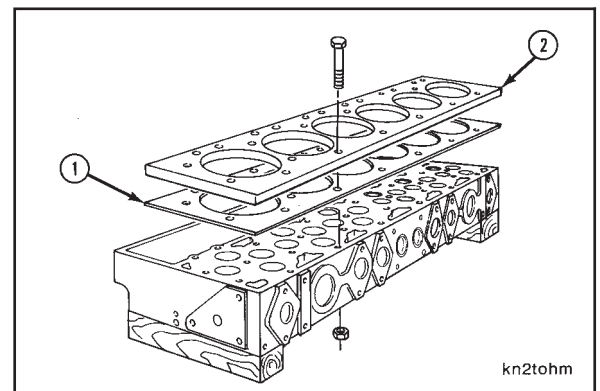


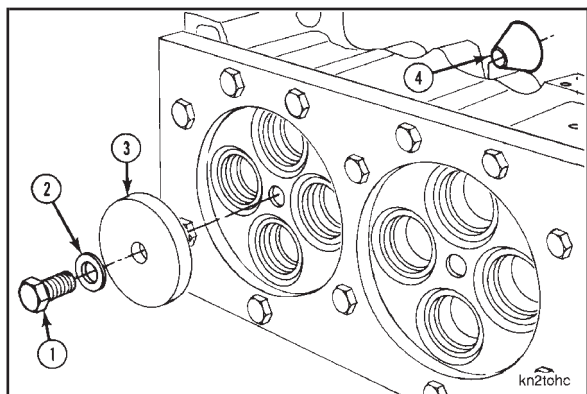
Use cylinder head water test fixture, Part No. 3376082.

Install the gasket (1), Part No. 3376084, and the test plate (2), Part No. 3376658.

Install the cylinder head capscrews and nuts.

Torque Value: 45 N•m [35 ft-lb]

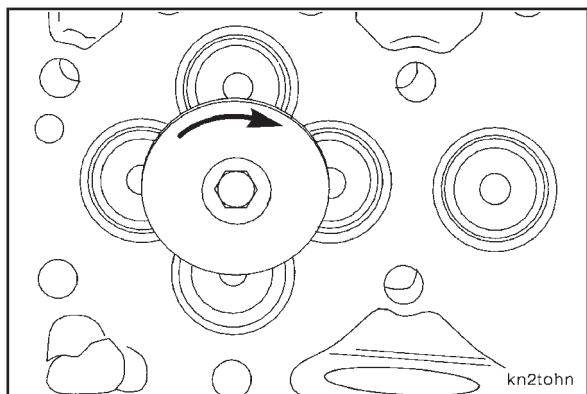




Use six of the injector sleeve holding tools, Part No. ST-1179.



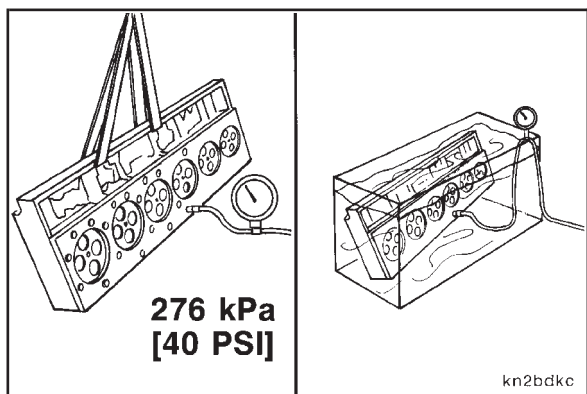
Install the cap screw (1), flat washer (2), anvil (3), Part No. ST-179-4, and mandrel (4), Part No. ST-1179-2, in each injector bore as shown.



Tighten the six injector sleeve holding tool cap screws.



Torque Value: 75 N•m [55 ft-lb]



Connect a regulated air supply hose to test fixture plate.

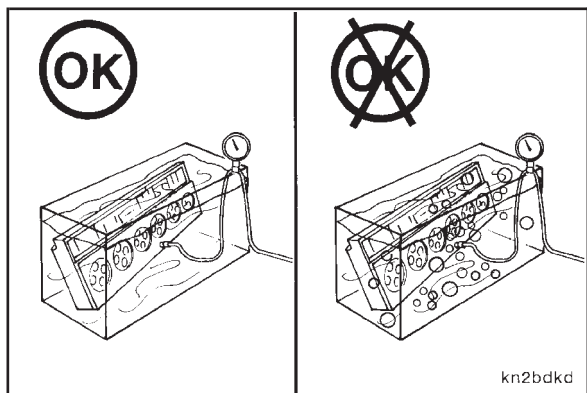


Air Pressure: 276 kPa [40 psi]



Completely submerge the cylinder head in a tank of warm water.

Temperature: 60°C [140°F]



Visually inspect the cylinder head for air leakage.

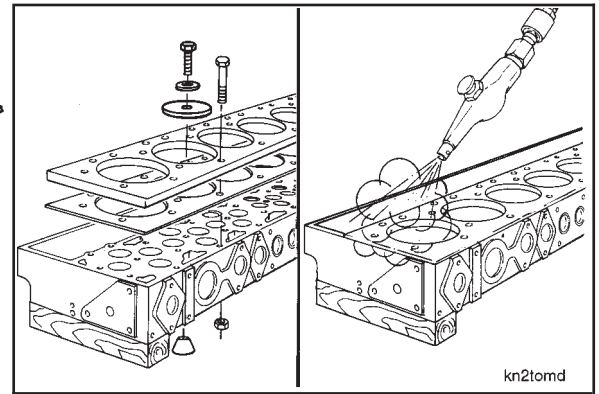


If air is leaking into the water the cylinder head **must** be replaced or rebuilt. Refer to Cylinder Head - Rebuild (2-02)

Remove the test equipment.

Use compressed air to dry the cylinder head.

Assemble the cylinder head. Refer to Cylinder Head - Rebuild - Assembly (2-02)



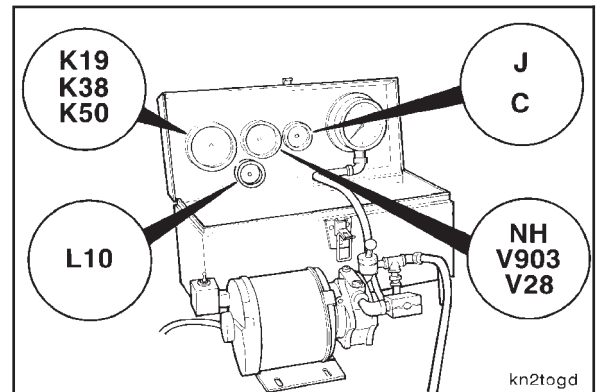
kn2tomd

Cylinder Head - Vacuum Test Valve Seating (2-09)

Use valve vacuum tester, Part No. ST-1257, to inspect the seal between the valve and the valve seat.

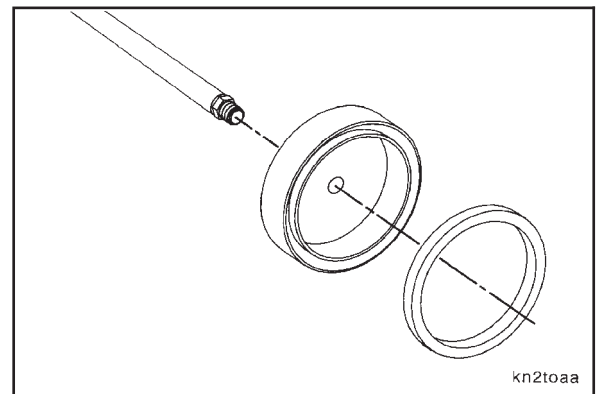
NOTE: The valve vacuum tester is **not** recommended for use on used heads. Refer to Procedure 7-07 in the M11 Troubleshooting and Repair Manual, Bulletin No. 3666074, for the recommended procedure to check used heads.

NOTE: The valve vacuum tester can be used to test all Cummins engine models. The seal ring, Part No. ST-1257-35, and vacuum cup, Part No. 3376100, are used on the M11 cylinder heads.



kn2togd

Install the seal ring and vacuum cup to the vacuum line (hose).

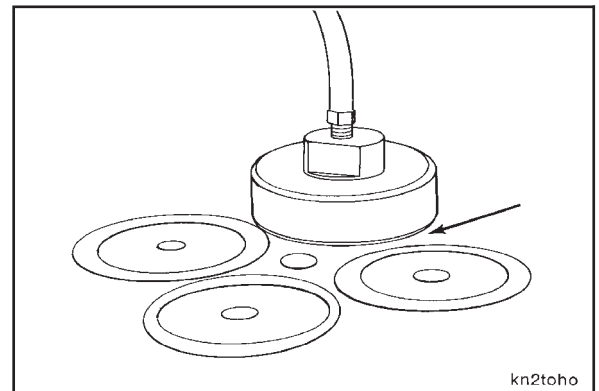


kn2toaa

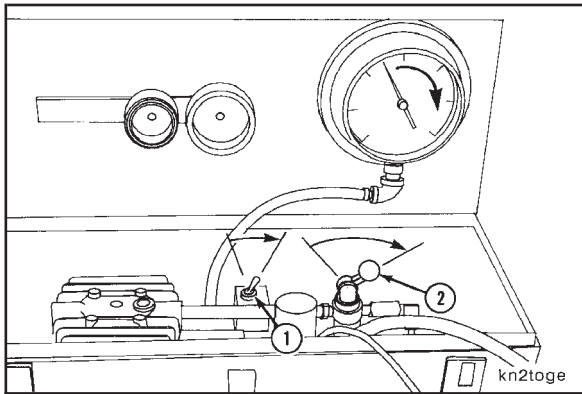
The valves and valve seats **must** be clean and dry when vacuum testing.

Cover the valve with the cup and seal.

NOTE: The seal **must** make a tight contact on the cylinder head around the valve.



kn2toho

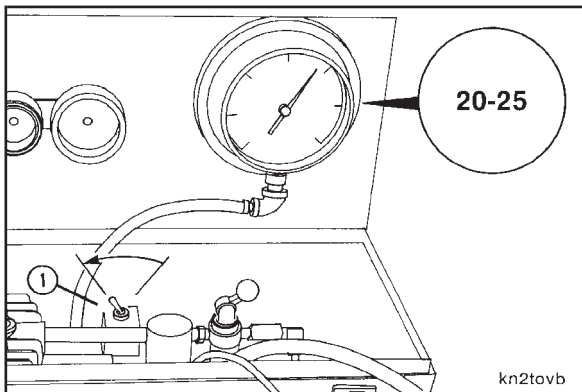


Move the toggle switch (1) to the "ON" position.

Turn the vacuum control valve (2) to the "OPEN" position.



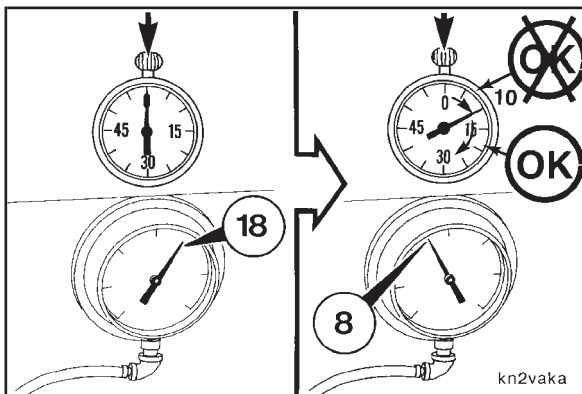
NOTE: The vacuum control valve is in the "OPEN" position if the vacuum gauge needle moves **clockwise**.



Operate the vacuum pump until the gauge indicates the specified vacuum.

Valve to Valve Seat Vacuum		
mm-Hg		in-Hg
508	MIN	20
685	MAX	25

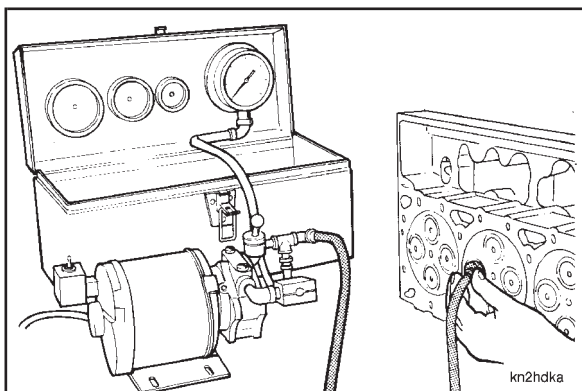
Turn the toggle switch (1) to the "OFF" position.



Use a stopwatch and start timing when the needle on the gauge indicates 457mm-Hg [18 in.Hg].

Stop timing when the needle on the gauge indicates 203mm Hg [8 in.Hg].

The elapsed time for the needle to move between the specified gauge readings **must** be 10 seconds or more.



If the elapsed time is **less** than 10 seconds perform the following checks:

- Repeat the test to be sure the equipment is operating properly.
- Use a mallet to hit the valve stem lightly to make sure the valve is seated. Repeat the test.
- Apply a thin layer of grease on the outside diameters of the insert and the valve head. Repeat the test. The grease pattern will show the point of leakage.



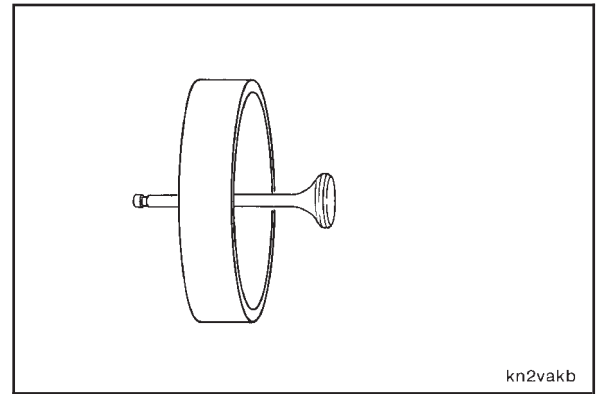
A break in the grease seal pattern will indicate leakage between the valves and valve seat or the valve seat insert and the cylinder head. Refer to Cylinder Head - Rebuild (2-02).

Cylinder Head Valves - Magnetic Crack Inspection (2-10)

Use the magnetic particle residual method to inspect the valves for cracks.

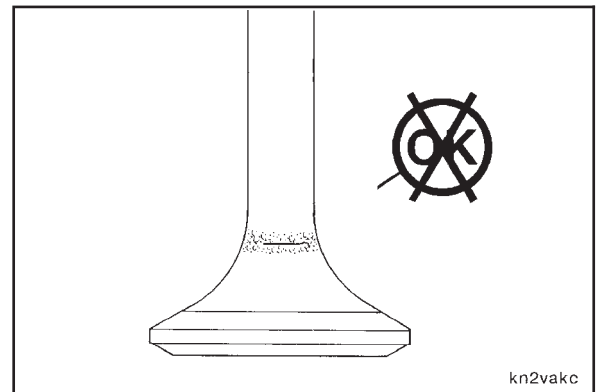
The exhaust valves contain two types of metal, and **must** be inspected by the coil shot method. There will be a magnetic leakage apparent at the point where the two metals are welded together. The leakage will appear as a wide pattern of magnetic particles.

Magnetize the valves in a coil of 100 to 200 amperes.



Inspect the valves with residual magnaglo.

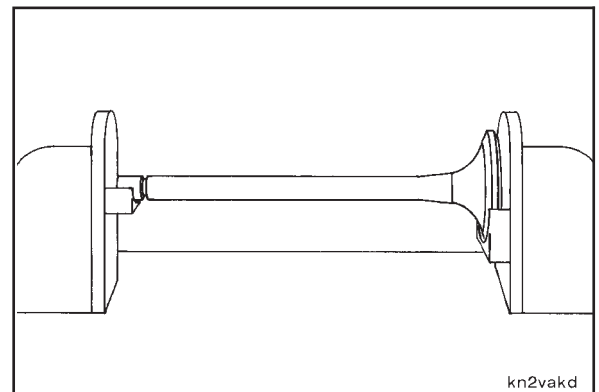
A broad fuzzy pattern will appear at the welded joint on the exhaust valves. If there is a distinct line in the pattern, the valve **must** be replaced.



The intake valves contain only one type of metal, and **must** be magnetized and inspected in two directions. Use the magnetic coil method and inspect with residual magnaglo the same as exhaust valves.

Magnetize the intake valves again with a headshot at 500 to 700 amperes.

Inspect the valves again with residual magnaglo.



Acceptance Criteria (Exhaust and Intake Valves)

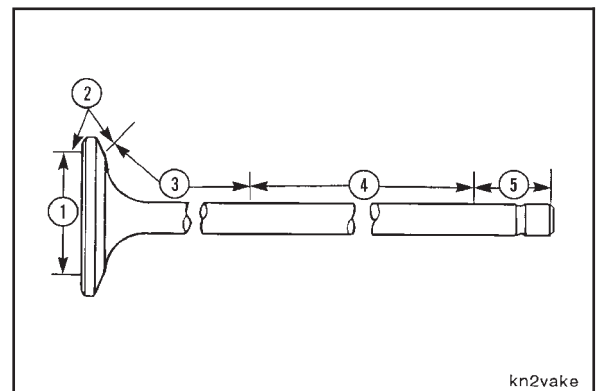
NOTE: "Visible" means an indication of a crack can be seen through a three power magnifying glass after the magnetic particle suspension is removed.

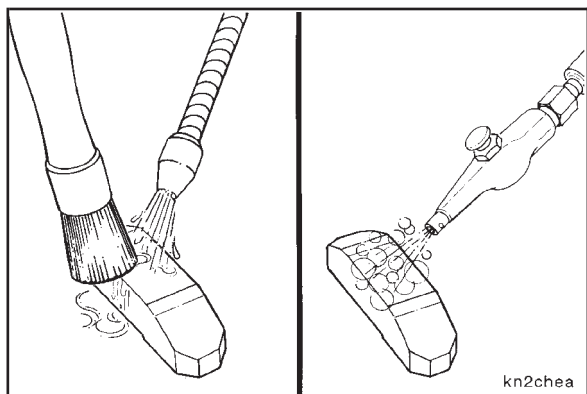
Area (1), **no** indication longer than 12.70mm [0.500 inch].

NOTE: There **must** be no more than five indications or no indications closer together than 3.18mm [0.125 inch].

Areas (2, 3, 4 and 5) **must not** have any magnetic indications or visible indications.

Remove all magnetism and clean the acceptable valves.



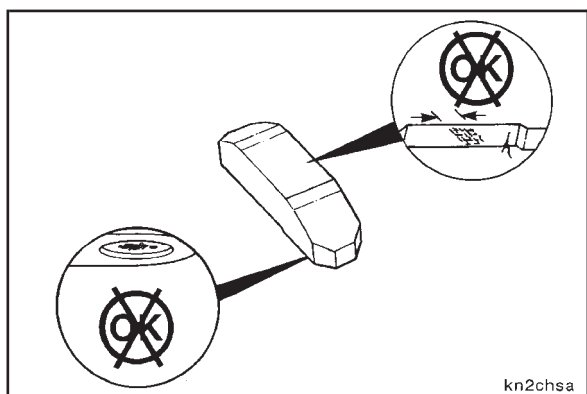


Valve Crosshead - Cleaning and Inspection for Reuse (2-11)



Cleaning

Use solvent to clean the parts. Dry with compressed air.

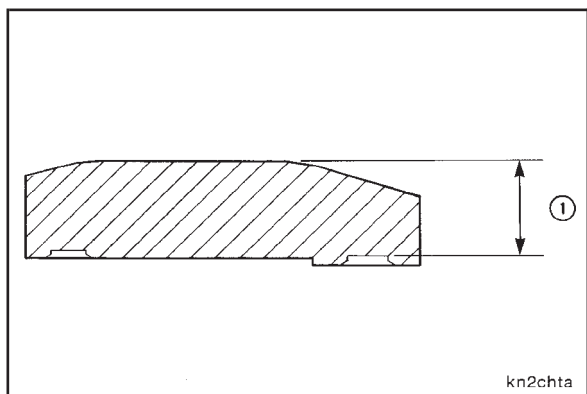


Inspection



Visually inspect the rocker lever contact pad for wear, cracks or damage.

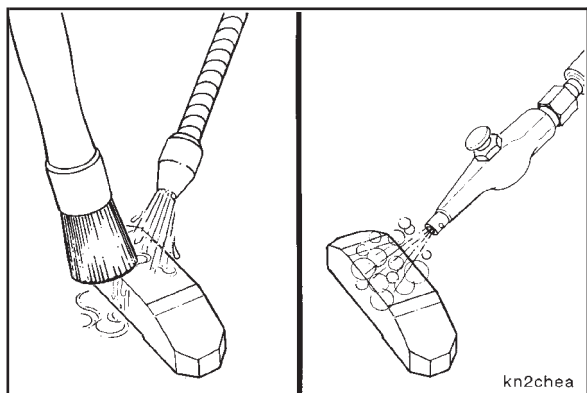
Wear in the pad contact area **must not** exceed 7mm [0.250 inch] in width.



Measure the valve stem pocket depth from the valve stem pocket to the rocker pad face (1).

Stem Pocket to Pad Face		
mm		in
12.05	MIN	0.474
12.55	MAX	0.494

If damaged parts are found or the pocket depth is **not** within the limits specified, the parts **must** be replaced. If cracks are suspected, refer to Valve Crosshead - Magnetic Crack Inspection (2-12).



Valve Crosshead - Magnetic Crack Inspection (2-12)

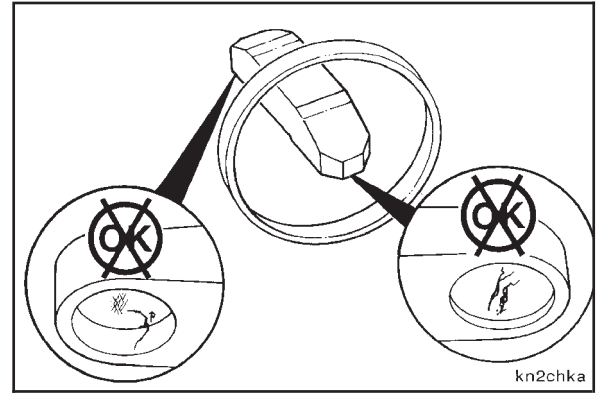


Use solvent to clean the crossheads. Dry with compressed air.

Magnetize the crosshead and inspect it with residual magnaglo.

Cracks will be indicated by a bright line. The primary location for cracks will be the valve stem pocket area.

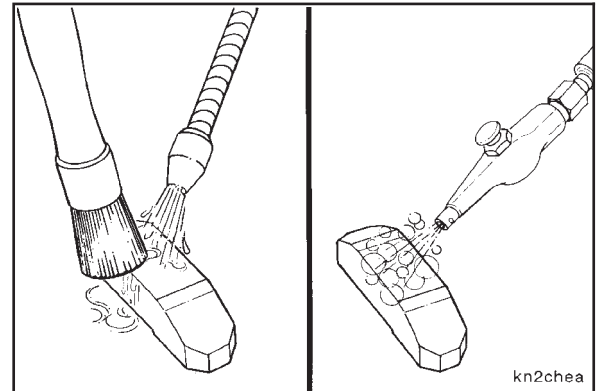
If cracks are found, the crosshead **must** be replaced.



Remove all magnetism.

Use solvent to clean the crossheads.

Dry with compressed air.



NOTES

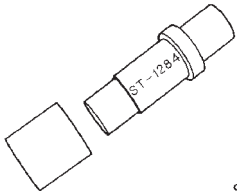
Section 3 - Rocker Levers - Group 03

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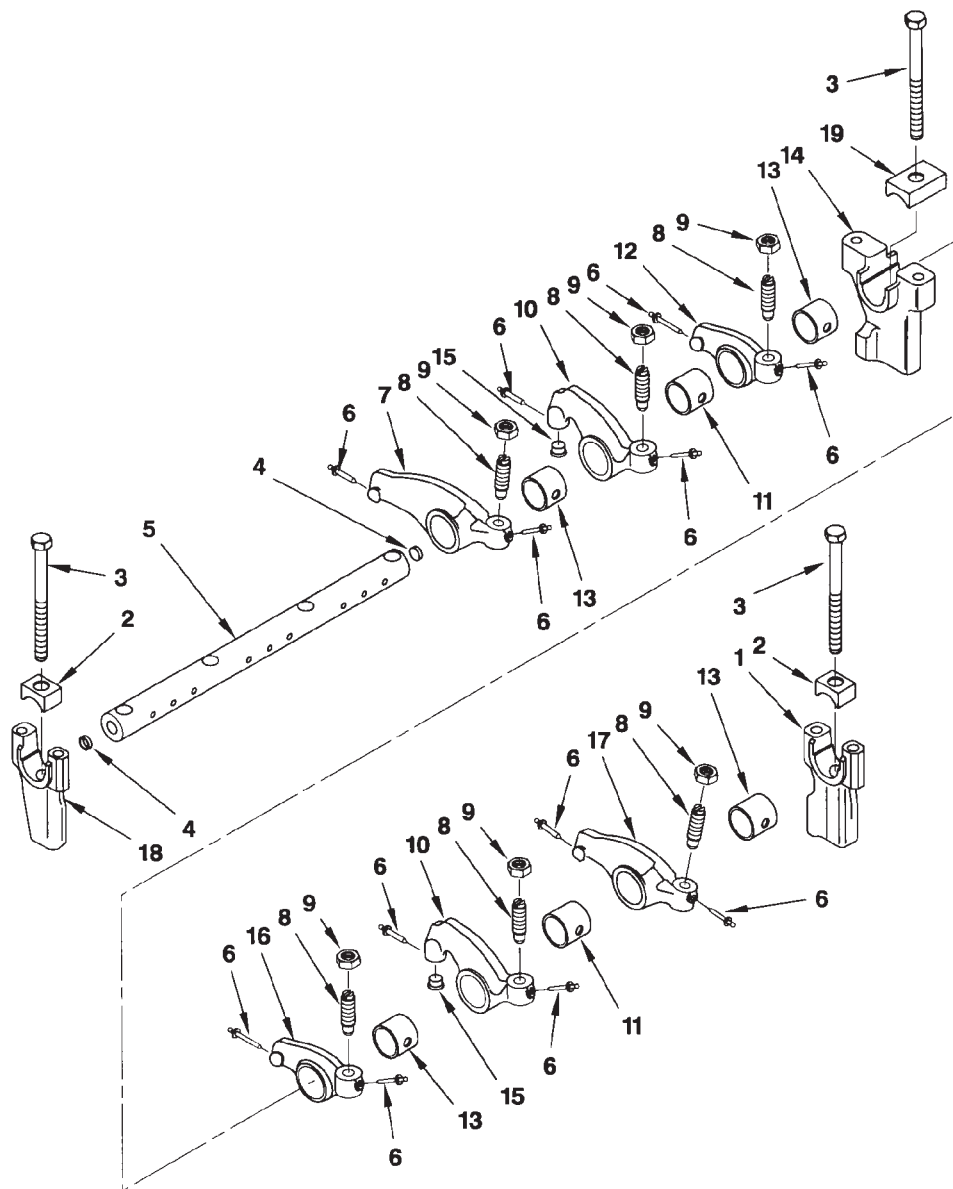
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Service Tools - Rocker Levers

The following special tools are recommended to perform procedures in Group 03. 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-1284	Rocker Lever Bushing Mandrel Install and remove the rocker lever bushings in the rocker levers.	 ST-1284

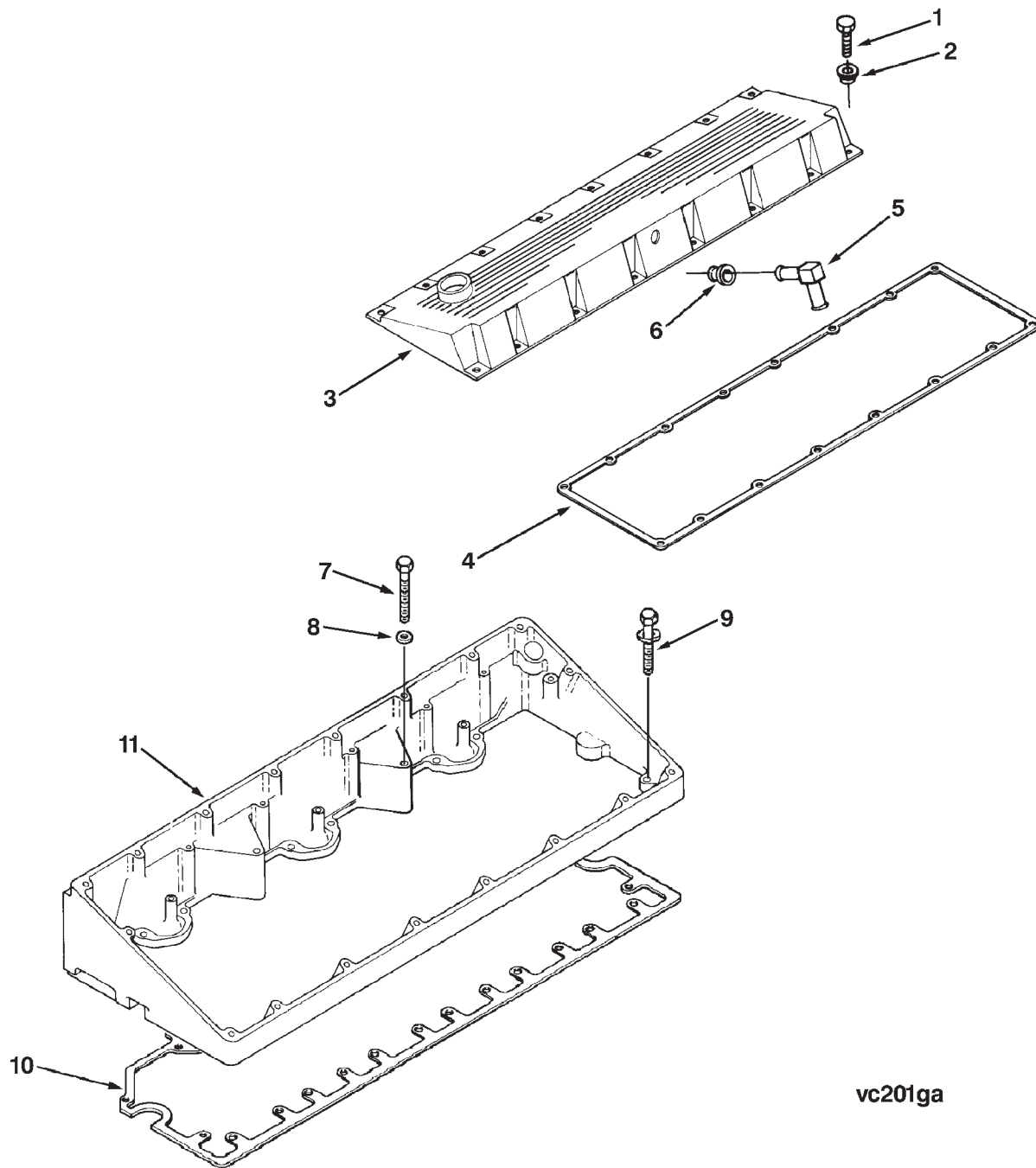
Rocker Levers - Exploded View



rh200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Support, Rocker Lever	2	11	Bushing, Injector Rocker Le- ver	6
2	Clamp, Retaining	4	12	Rocker Lever, Intake	3
3	Capscrew	8	13	Bushing, Rocker Lever	12
4	Plug, Drive	4	14	Support, Rocker Lever	4
5	Shaft, Rocker Lever	2	15	Socket, Tappet	6
6	Rivet	36	16	Rocker Lever, Intake	3
7	Rocker Levers, Exhaust	3	17	Rocker Lever, Exhaust	3
8	Screw, Slotted Set	18	18	Support, Rocker Lever	2
9	Nut, Adjusting	18	19	Clamp, Retaining	4
10	Rocker Lever, Injector	6			

Rocker Housing and Cover (Automotive) - Exploded View



Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Capscrew	16	7	Capscrew	4
2	Isolator, Noise	16	8	Washer, Plain	4
3	Cover, Rocker Housing	1	9	Capscrew	20
4	Gasket, Rocker Cover	1	10	Gasket, Rocker Lever Housing	1
5	Breather Tube	1	11	Housing, Rocker Lever	1
6	Seal, Grommet	1			

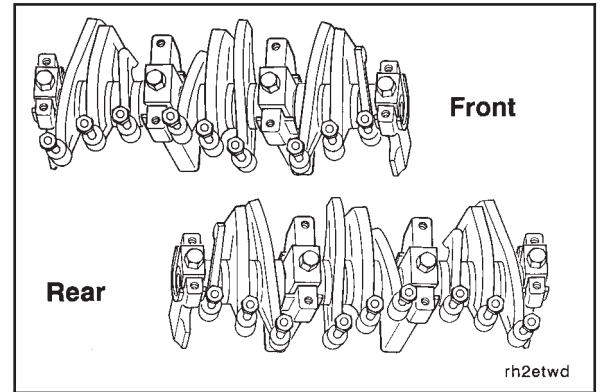
Rocker Levers - General Information

The rocker lever group consists of the rocker lever assembly, rocker lever housing, rocker housing cover, and the crankcase breather. The rocker levers contain replaceable bushings. Both the intake and exhaust rocker levers contain blind rivets to plug the oil drilling holes in the levers. The rocker lever pad on the intake and exhaust rocker lever is precision ground and **must not** be repaired.

Rocker Lever Assembly - Cleaning and Inspection for Reuse (3-01)

Disassembly

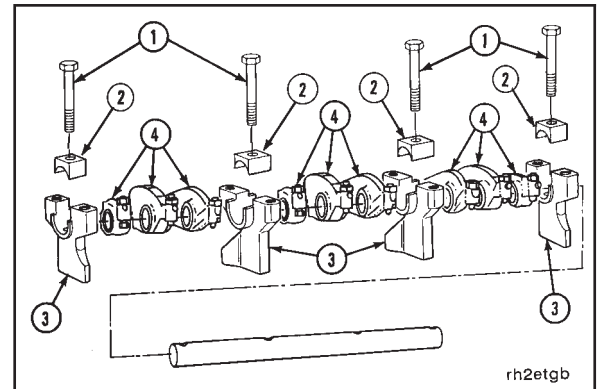
Label the rocker lever shaft assemblies “front” and “rear” when they are removed from the engine. Label the rocker levers and supports with their relative position to each other as they are removed from the shafts. The rocker lever assemblies **must** be installed in the same position they were removed from.



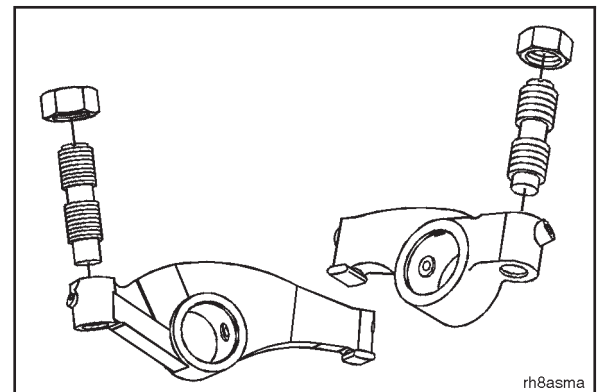
Remove the rocker shaft capscrews (1) and retaining clamps (2).

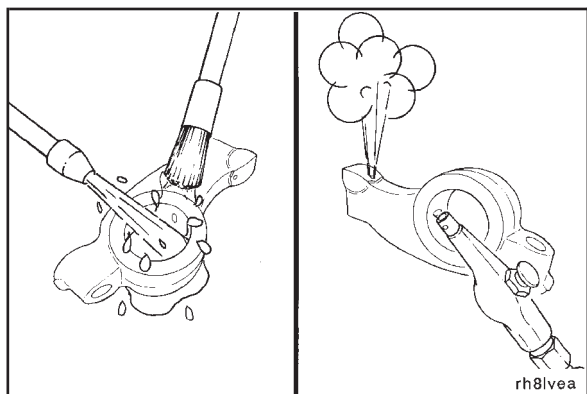
Lift the shaft and levers out of the supports (3).

Remove the rocker levers (4) from both shaft assemblies.

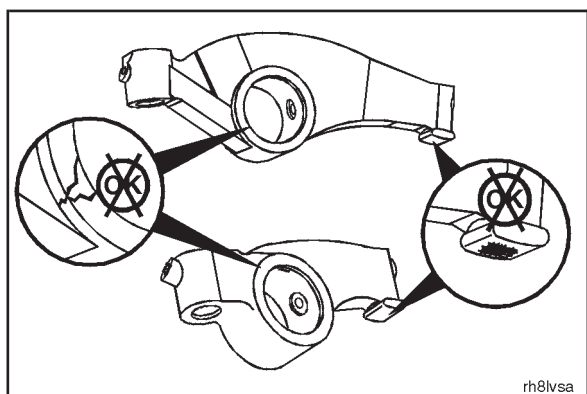


Remove the locknut and adjusting screw from each rocker lever.





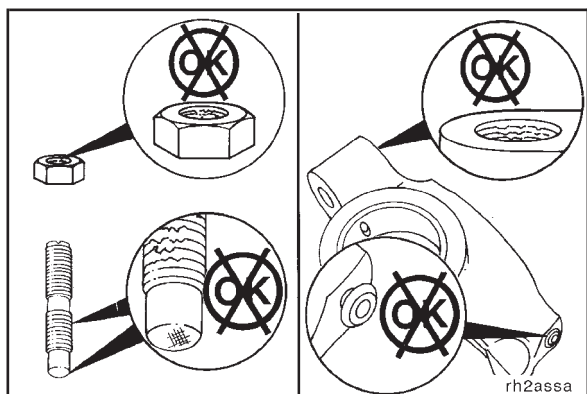
Use solvent to clean the parts. Dry with compressed air.
Use compressed air to make sure the oil passages are **not** blocked.



Inspection

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.

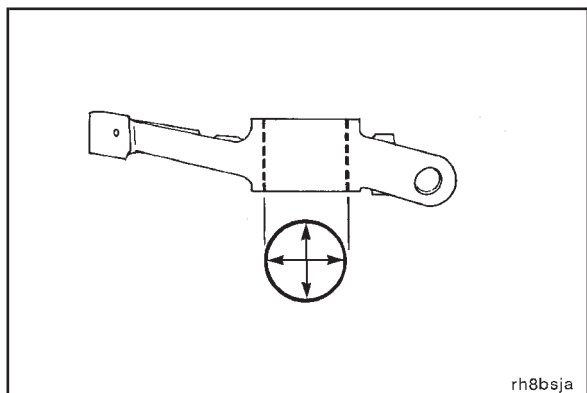


Visually inspect the adjusting screws and locknuts for damaged threads.

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 the inside diameter of the rocker lever bushing bore.

Rocker Lever Bushing Bore I.D.		
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 the outside diameter of the rocker lever shafts.

Rocker Lever Shaft O.D.		
mm		in
34.837	MIN	1.3715
34.864	MAX	1.3726

Refer to 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 Rocker Lever Assembly - Rebuild (3-02).

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 shaft supports for cracks or damage.

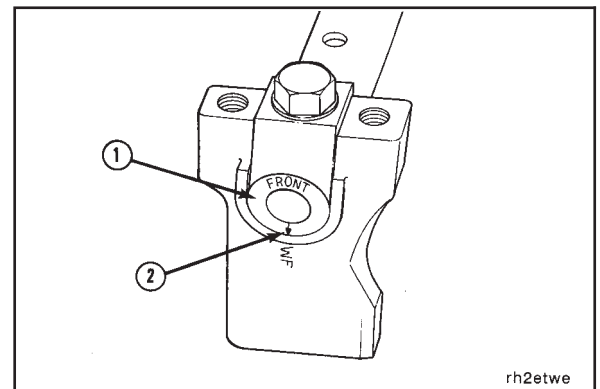
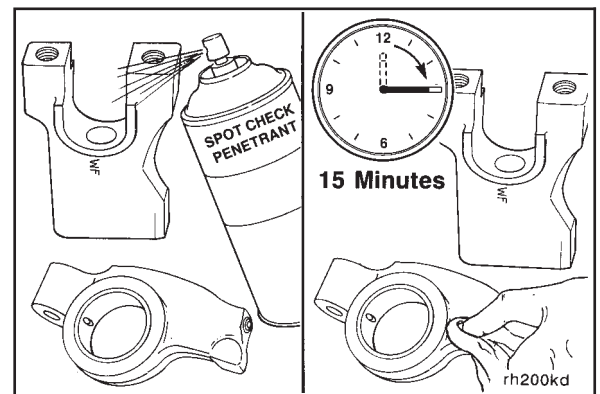
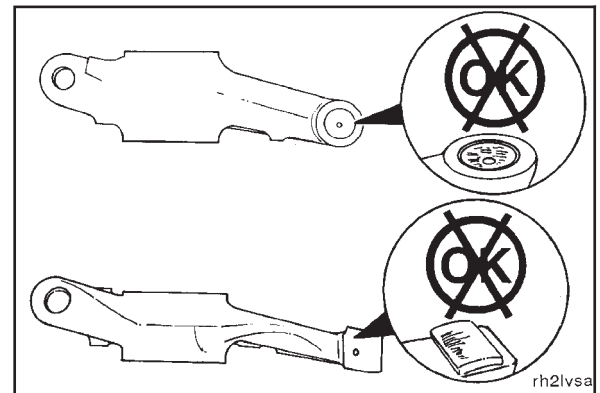
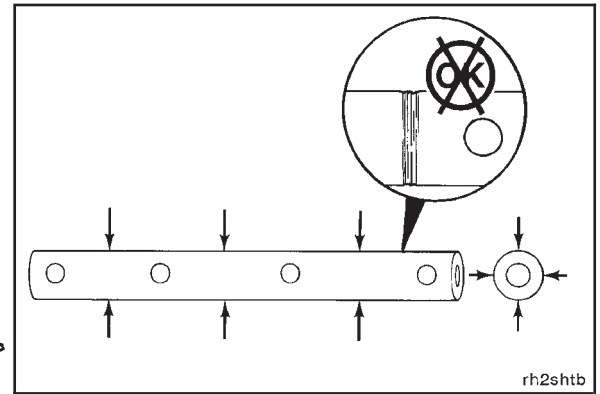
If cracks or damage is found, the rocker lever shaft support **must** be replaced.

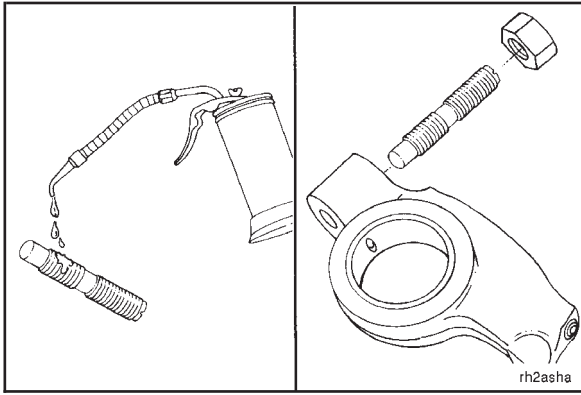
Assembly

Caution: 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 arrow (2) on the end of the shaft **must** be pointed downward to ensure an oil flow to the rocker levers.

The shaft end supports are **not** interchangeable.





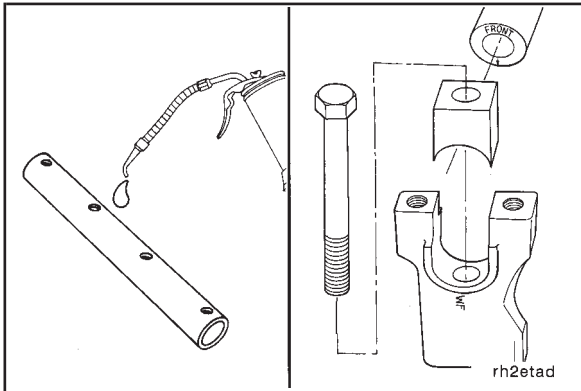
Use clean 15W-40 oil to lubricate the threads of the adjusting screws.



Install the adjusting screws into the rocker levers.

Install the locknuts on the adjusting screws.

NOTE: If the engine is equipped with Jacobs® Brakes, a special hex head adjusting screw **must** be used. Install the locknut on the adjusting screw before installing the adjusting screw in the rocker lever.

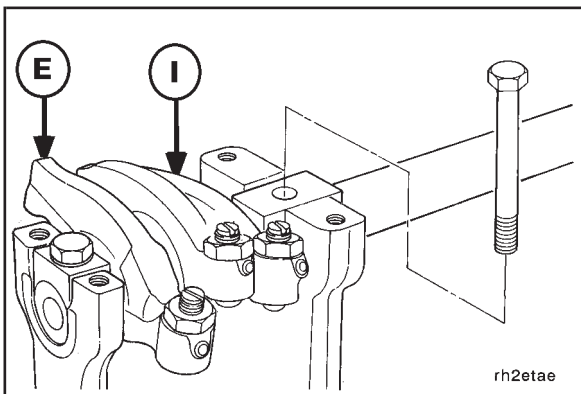


Use clean 15W-40 oil to lubricate both rocker lever shafts.

Install the front end support on each shaft.



Install the retaining clamps and support mounting capscrews through the end supports.

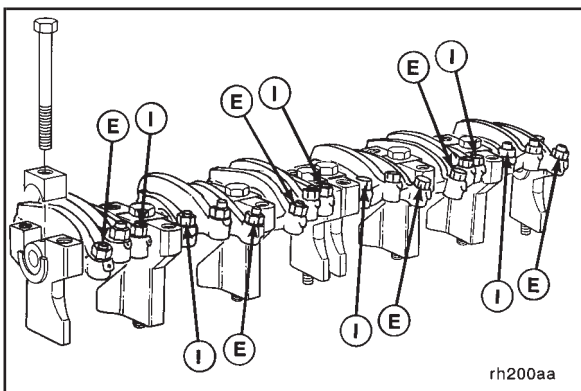


Install the rocker levers on the front rocker lever shaft in the correct sequence as shown.

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 clamp and support mounting capscrew through the center support.



Install the remaining levers and the supports with the intake (I) and the exhaust (E) valve rocker levers in the correct position as shown.

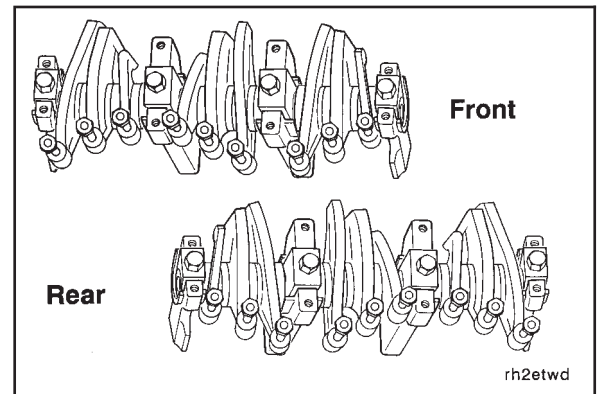
Install the retaining clamps and the support mounting capscrews.

Use the same procedure to install the rocker levers and supports on the rear shaft.

Rocker Lever Assembly - Rebuild (3-02)

Disassembly

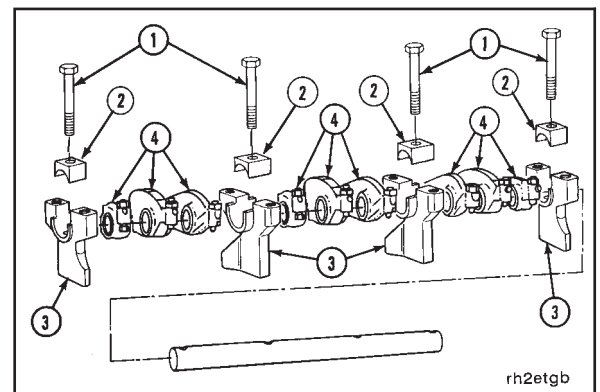
Label the rocker lever shaft assemblies “front” and “rear” when they are removed from the engine. Label the rocker levers and supports with their relative position to each other as they are removed from the shafts. The rocker lever assemblies **must** be installed in the same position they were removed from.



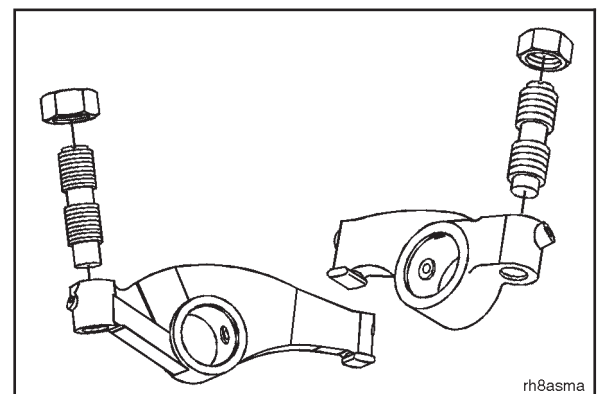
Remove the rocker lever shaft capscrews (1) and retaining clamps (2).

Lift the shaft and levers out of the supports (3).

Remove the rocker levers (4) from both shaft assemblies.



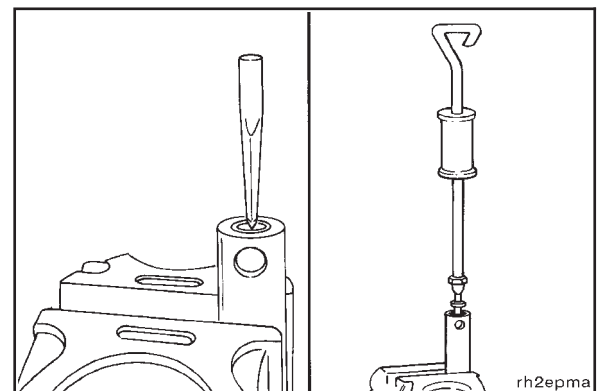
Remove the locknut and adjusting screw from each rocker lever.

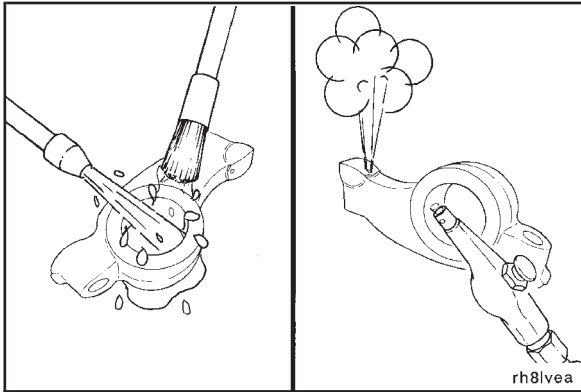


Install the rocker lever shafts in a vise with brass jaws.

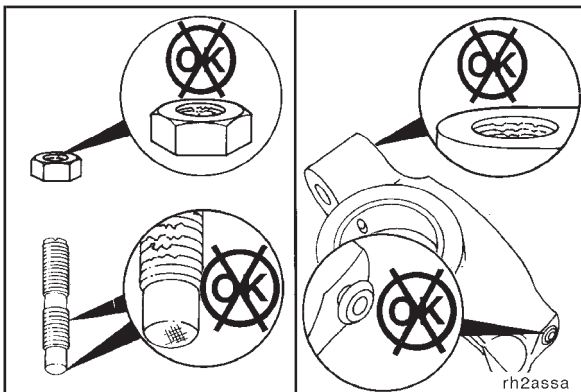
Center punch the plugs in the ends of the shafts.

Drill a 1/8 inch hole in the plugs, and use a standard dent puller to remove the plugs from the shafts.





Use solvent to clean the parts. Dry with compressed air.
Use compressed air to make sure the oil passages are **not** blocked.



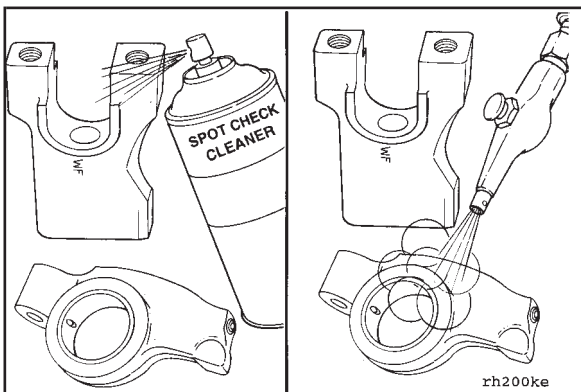
Inspection

Visually inspect the adjusting screws and locknuts for damaged threads.

Visually inspect the adjusting screws for wear on the ball end.

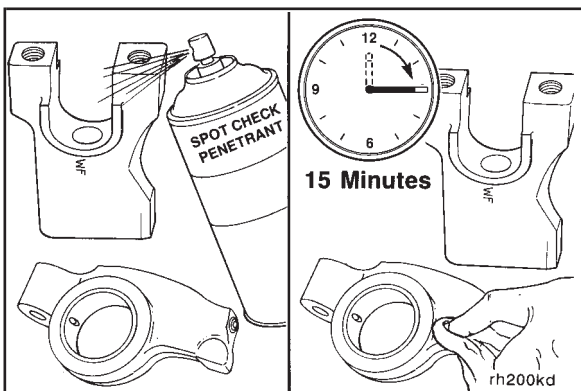
Visually inspect the adjusting screw threads in the rocker levers for damaged threads.

Visually inspect the rocker levers for loose rivets.



Use crack detection kit, Part No. 3375432, to inspect the rocker levers and rocker lever shaft supports for cracks.

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.

Section 3 - Rocker Levers - Group 03
M11

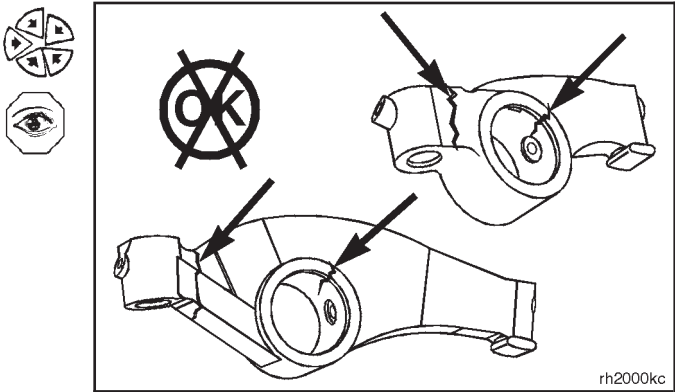
Use crack detection developer, Part No. 3375434, to spray the rocker levers and shaft supports.

Visually inspect the levers and supports.

Cracks will appear as a solid bright line.

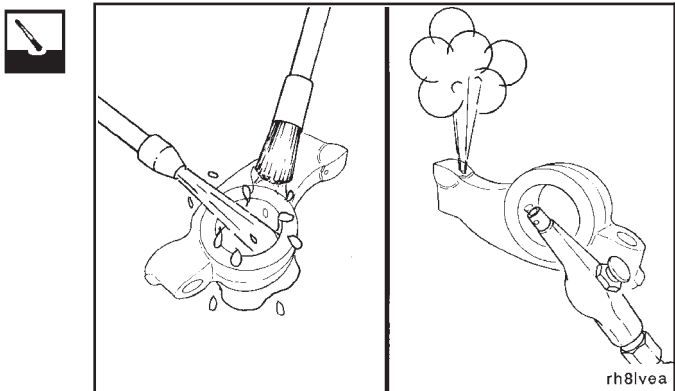
Cavitation in the casting will appear as a small round mark.

If cracks or cavitation are found, the part **must** be replaced.



Use solvent to clean the serviceable levers and supports.

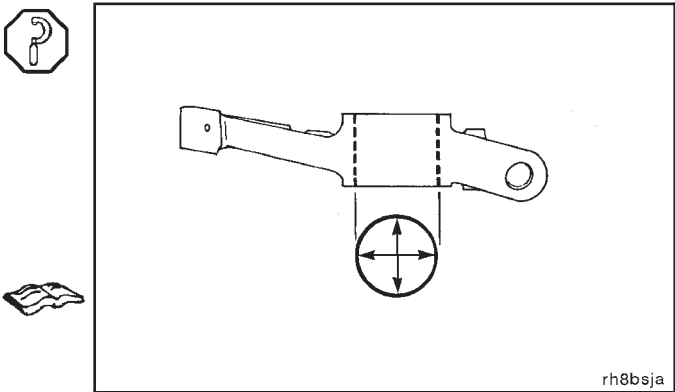
Dry with compressed air.



Measure the inside diameter of the rocker lever bushing bore.

Rocker Lever Bushing Bore I.D.		
mm		in
34.887	MIN	1.3735
34.990	MAX	1.3776

If the bushing is worn larger than the maximum specification it **must** be replaced. Refer to Rocker Lever Bushing - Replacement (3-03).

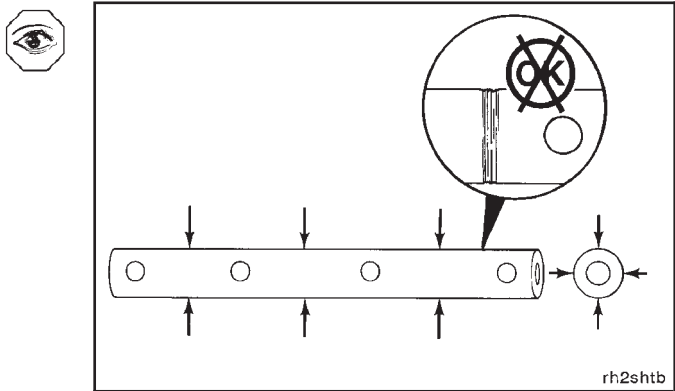


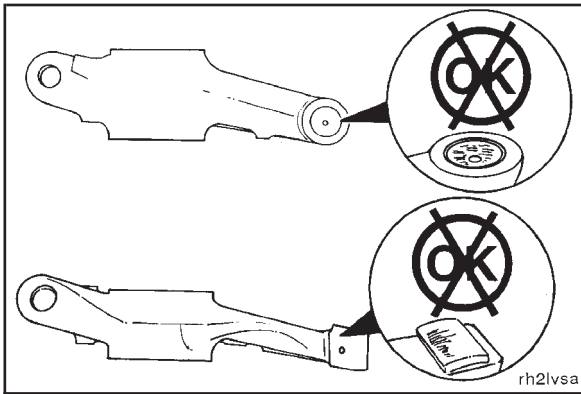
Visually inspect the rocker lever shafts for pitting, scoring or other damage.

Measure the outside diameter of the rocker lever shafts.

Rocker Lever Shaft O.D.		
mm		in
34.837	MIN	1.3715
34.864	MAX	1.3726

If the shaft is damaged or worn smaller than the minimum specification, it **must** be replaced.

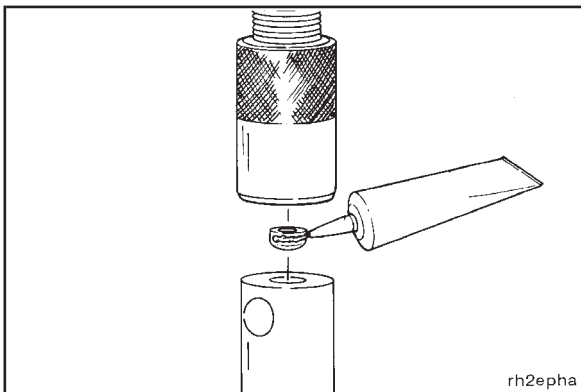




Visually inspect the sockets in the injector rocker levers for wear or damage.

Visually inspect the valve rocker lever pads for wear, cracks or other damage.

If wear, cracks or other damage is found the rocker lever(s) **must** be replaced.



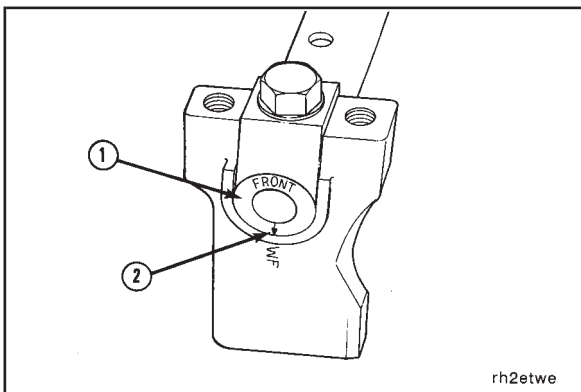
Assembly

Apply a coat of cup plug sealant, Part No. 3375068, to the outside diameter of the drive plugs.



Install the shaft in an arbor press.

Press the plug into the shaft until it is level with the end of the shaft.

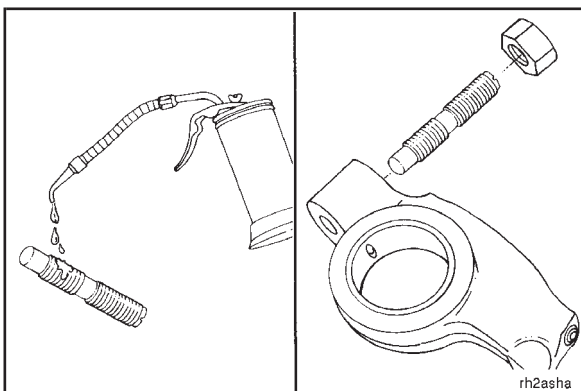


Caution: Ensure that the rocker lever shafts are installed with the arrow on the end of the shafts pointed downward. Failure to do so will prevent oil from lubricating the rocker levers.



The rocker lever shafts are labeled front and rear on the end of the shafts (1). The arrow (2) on the end of the shaft **must** be pointed downward to ensure an oil flow to the rocker levers.

The shaft end supports are **not** interchangeable.



Use clean 15W-40 oil to lubricate the threads of the adjusting screws.

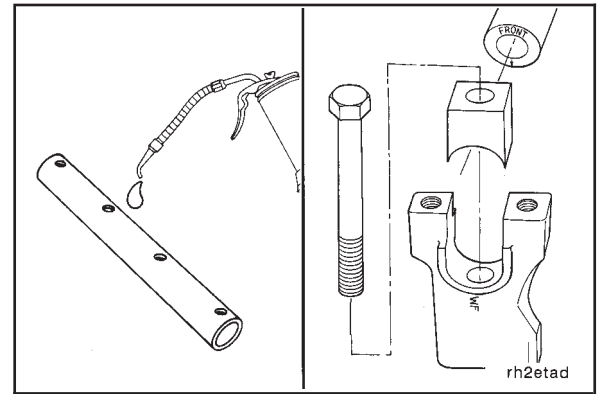


Install the adjusting screws into the rocker levers.

Install the locknuts on the adjusting screws.

Section 3 - Rocker Levers - Group 03 M11

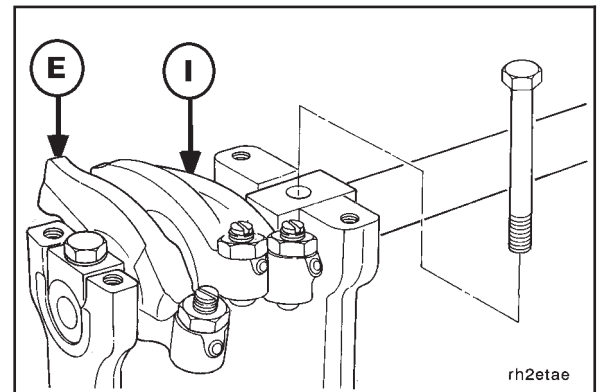
Use clean 15W-40 oil to lubricate both rocker lever shafts.
Install the front end support on each shaft.
Install the retaining blocks and support mounting capscrews through the end supports.



Install the rocker levers on the front rocker lever shaft 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.

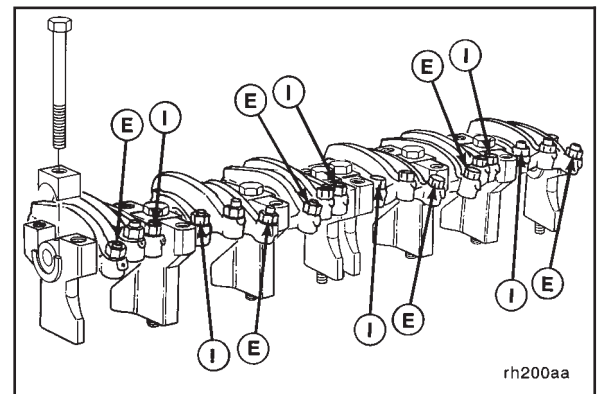
Install one of the two shaft center supports on the shaft.
Install the center support capscrew.



Install the remaining levers and supports with the intake (I) and the exhaust (E) valve rocker levers in the correct position as shown.

Install the support mounting capscrews.

Use the same procedure to install the rocker levers and supports on the rear shaft.

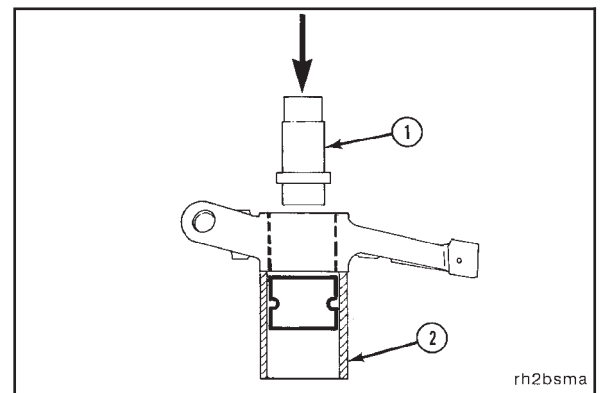


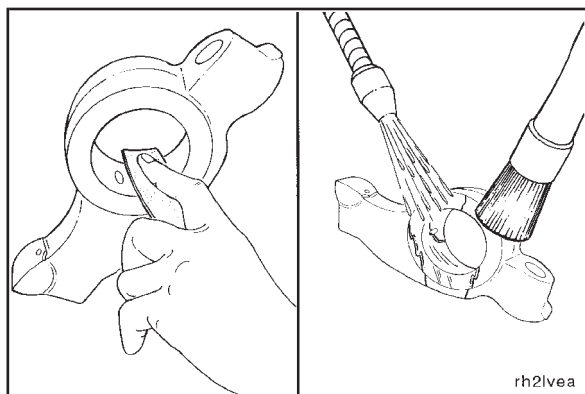
Rocker Lever Bushing - Replacement (3-03)

Disassembly

Install the rocker lever in an arbor press.

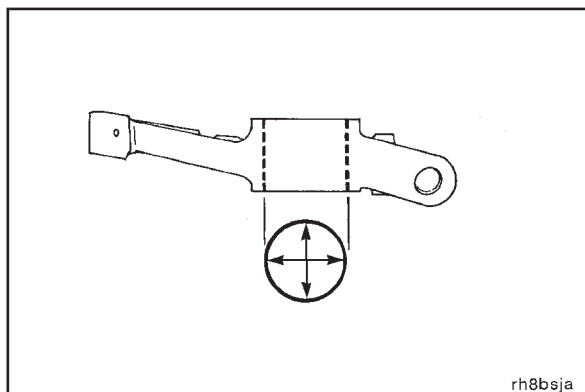
Use rocker lever bushing mandrel (1), Part No. ST-1284, and a support (2) to push the bushing out of the rocker lever.





Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to remove any rough edges or burrs from the bore of the rocker lever.

Use solvent to clean the rocker levers. Dry with compressed air.



Inspection



If cracks in the rocker lever are suspected, refer to Rocker Lever - Magnetic Crack Inspection (3-04)

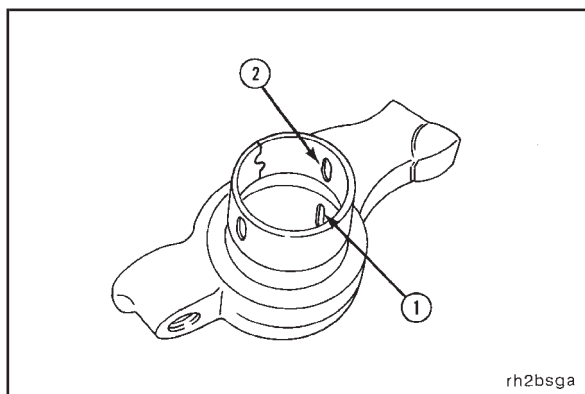


Measure the inside diameter of the rocker lever bore.

Rocker Lever Bore I.D.

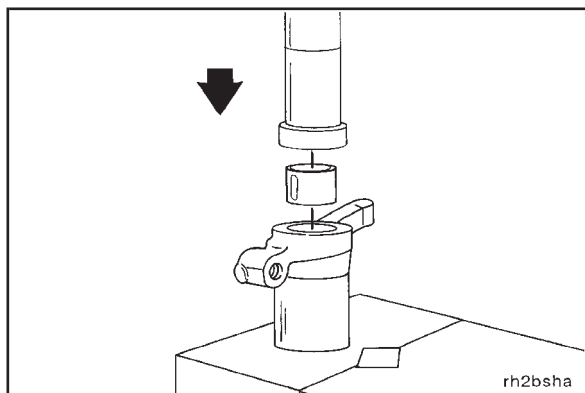
mm		in
36.474	MIN	1.4359
36.499	MAX	1.4370

If the rocker lever bore is worn larger than the maximum specification the rocker lever(s) **must** be replaced.



Assembly

The oil hole in the rocker lever bore (1) and the oil hole in the bushing (2) **must** be aligned correctly to supply oil to the rocker lever and rocker lever shaft.



Install the rocker lever in an arbor press.

Use rocker lever bushing mandrel, Part No. ST-1284, and a support to push the bushing into the rocker lever.

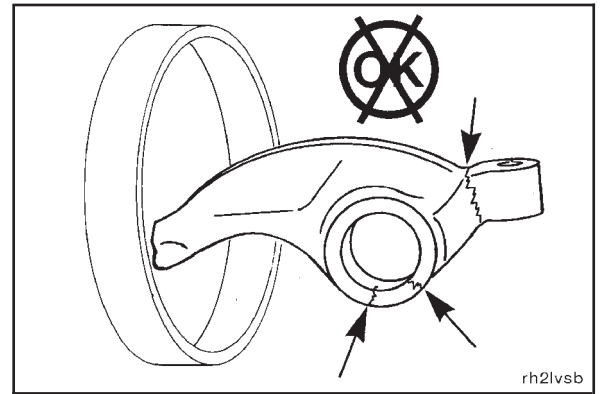
Rocker Lever - Magnetic Crack Inspection (3-04)

Use coil magnetization with residual magnaglow to magnetize the rocker levers.

Magnetize the rocker levers in a coil of 300 to 500 amperes.

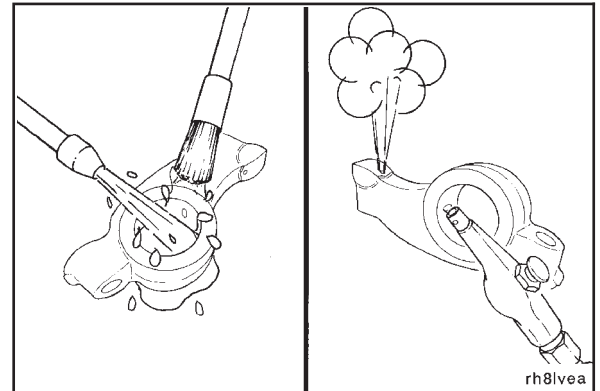
Visually inspect the levers for cracks.

Cracks will appear as a solid bright line. Discard cracked levers.



Use a demagnetizer to remove the magnetism.

Use solvent to clean the rocker levers. Dry with compressed air.



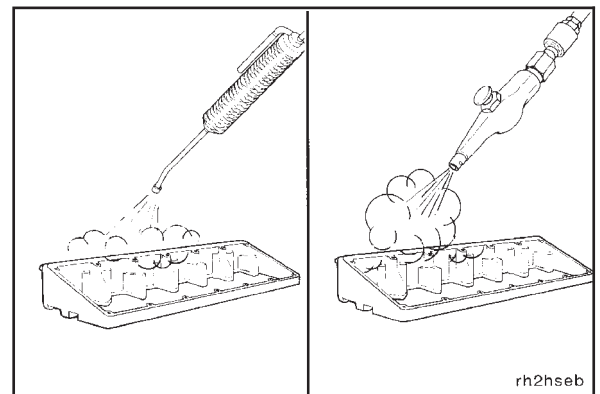
Rocker Lever Housing - Cleaning and Inspection for Reuse (3-05)

Cleaning

Remove all gasket material from the gasket sealing surfaces.

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 to clean the intake manifold ports and the rocker lever housing. Dry with compressed air.

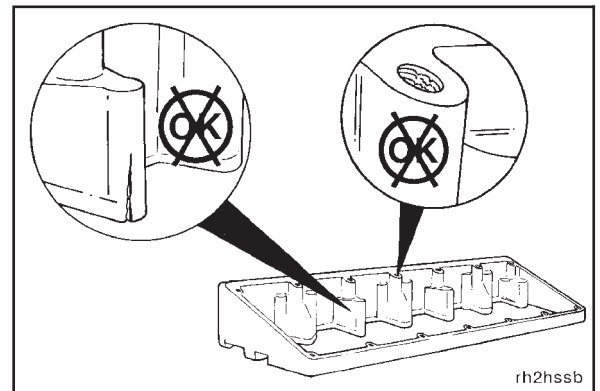


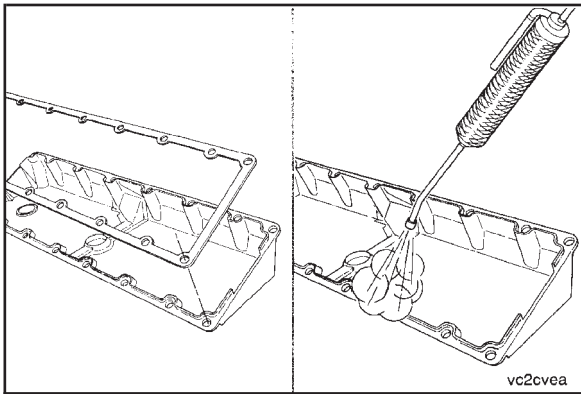
Inspection

Visually inspect the intake manifold ports and rocker lever housing for cracks or damage.

Visually inspect the threaded holes for damaged threads.

If cracks or damage is found, the housing **must** be replaced. Use thread inserts to repair damaged threads.





Rocker Lever Cover - Cleaning and Inspection for Reuse (3-06)

Cleaning



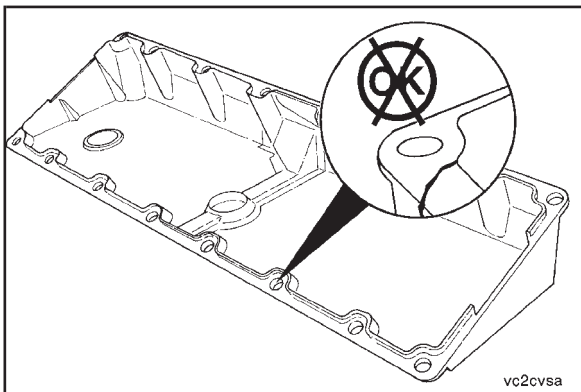
Remove all gasket material from the gasket sealing surface.



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 to clean the rocker lever cover. Dry with compressed air.

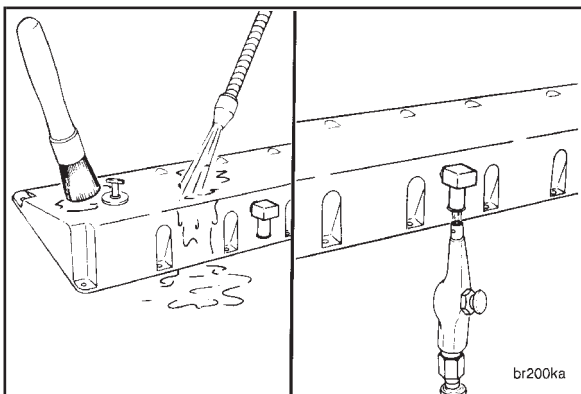


Inspection



Visually inspect the cover for cracks or damage

If cracks or damage is found, the cover **must** be replaced.



Crankcase Breather (Internal) - Cleaning and Inspection (3-07)



Use solvent to clean the cover and crankcase breather cavity. Dry with compressed air.

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.

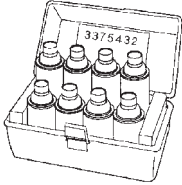
Section 4 - Cam Follower Assembly - Group 04

Section Contents

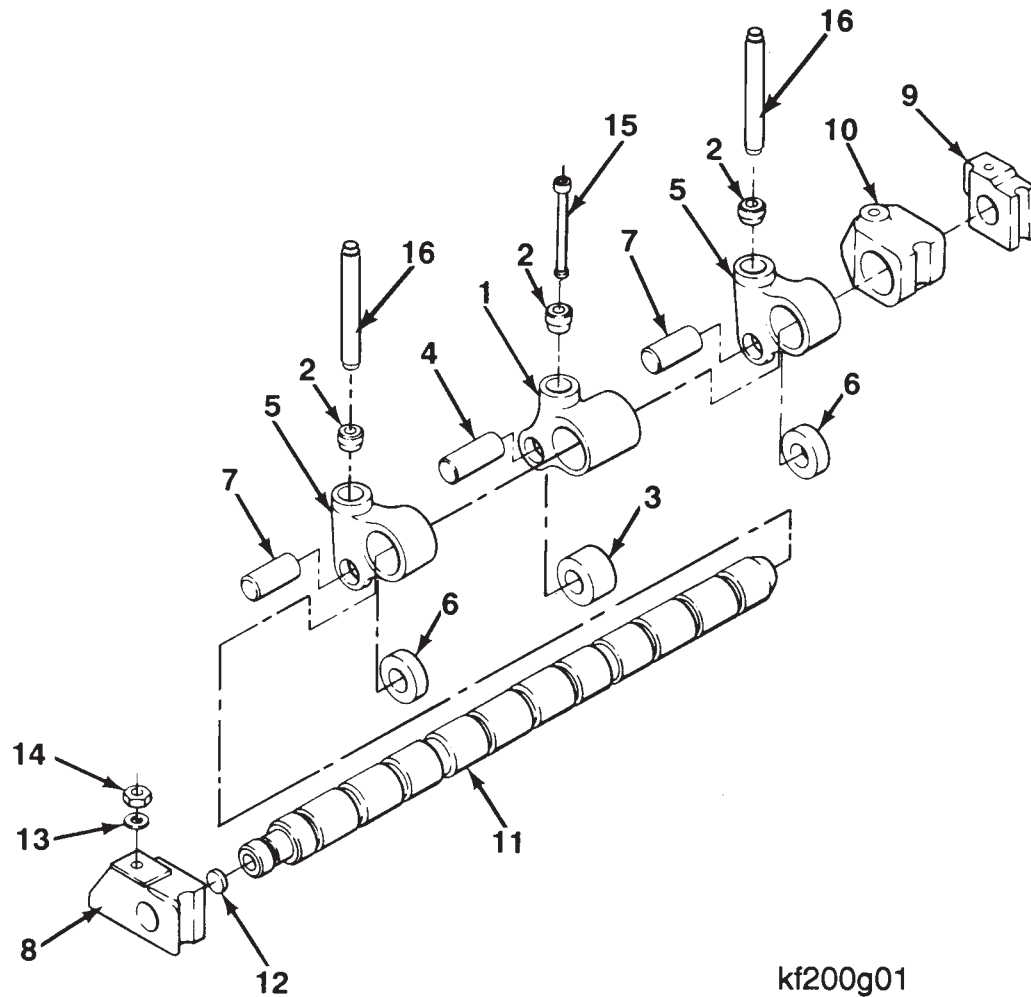
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Service Tools - Cam Follower Assembly

The following special tools are recommended to perform procedures in Group 04. 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
3375068	Cup Plug Sealant Used to seal plugs in cam follower shafts.	 bp8togk
3375432	Crack Detection Kit Inspect components for cracks.	 3375432

Cam Follower Assembly - Exploded View



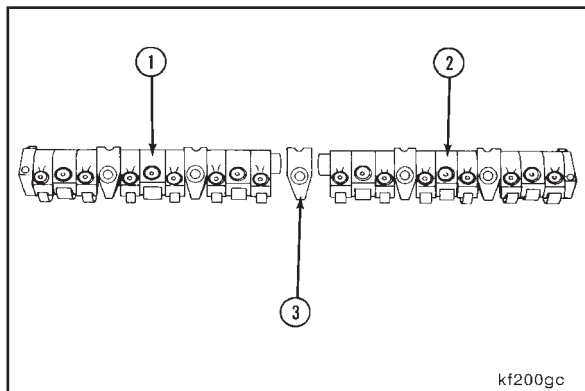
kf200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Lever, Injector Cam Follower	6	9	Support, Cam Follower Shaft	1
2	Socket, Tappet	18	10	Support, Cam Follower Shaft	5
3	Roller, Injector Cam Follower	6	11	Shaft, Cam Follower	2
4	Pin, Injector Cam Follower	6	12	Plug, Drive	4
5	Lever, Valve Cam Follower	12	13	Washer, Plain	7
6	Roller, Valve Cam Follower	12	14	Nut	7
7	Pin, Valve Cam Follower	12	15	Rod, Injector Push	6
8	Support, Cam Follower Shaft	1	16	Tube, Valve Push	12

Cam Follower Assembly - General Information

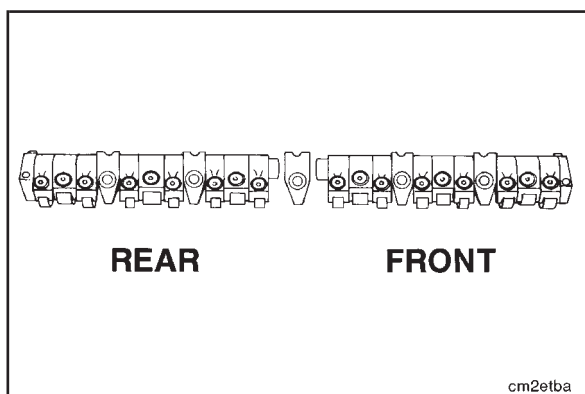
The cam follower group consists of the injector and valve cam followers, cam follower shafts and supports, valve push tubes and injector push rods.

Label or tag all of the cam follower parts with the engine cylinder number and their relative position to the other parts as they are removed from the engine. Many of the cam follower parts are interchangeable; however, due to established wear patterns, they **must** be installed in the same position they were removed from.



Cam Follower Assembly - Cleaning and Inspection for Reuse (4-01)

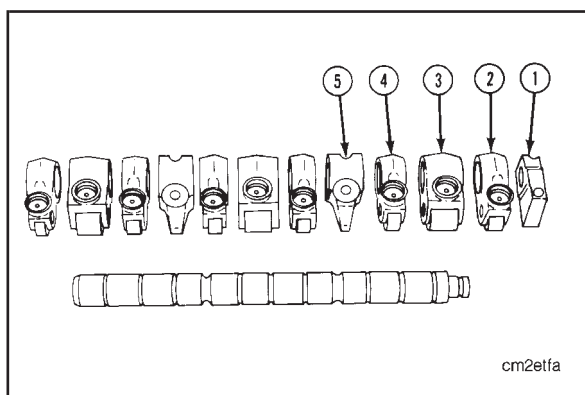
The cam follower assembly consists of two shaft assemblies (1) and (2) installed on the engine with a common center support (3).



Disassembly



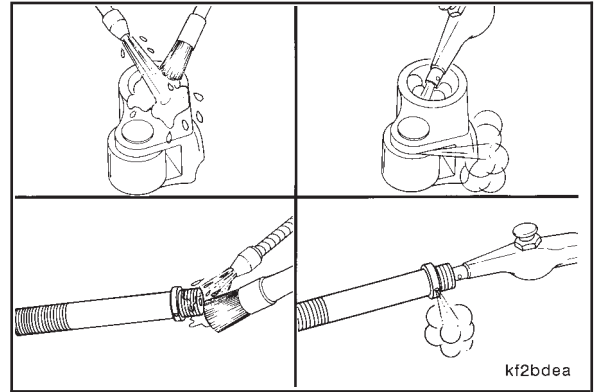
The cam follower levers have established wear patterns and **must** be installed in the same position they were removed from. Mark the end supports, front and rear, and all of the cam followers to identify their position when they are removed. The end supports are **not** interchangeable.



Remove the end supports (1) from the shaft.

Remove the valve cam followers (2), the injector cam followers (3), the valve cam followers (4), and the shaft supports (5).

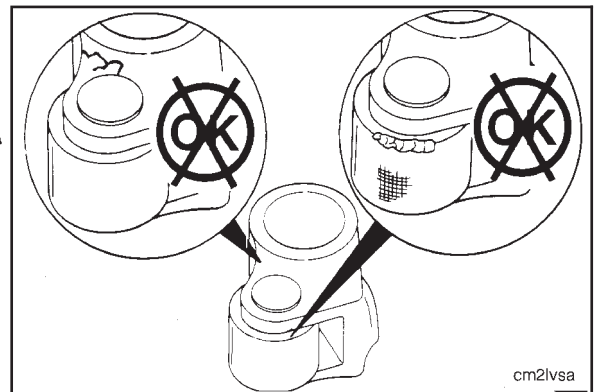
Clean the cam follower parts with solvent. Dry with compressed air.



Inspection

Visually inspect the cam followers for cracks, scoring or other damage.

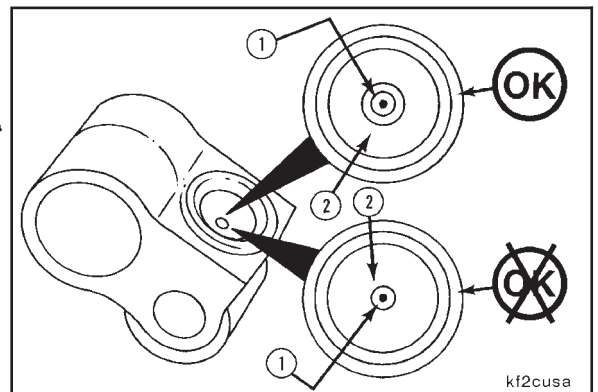
Refer to Camshaft Reuse Guidelines, Bulletin No. 3666052, for visual inspection criteria of cam follower rollers.



Visually inspect the sockets for excessive wear.

If the seating pattern extends down into the oil drain hole chamfer (1), or if pitting or scratches in the seating pattern (2) can be seen or felt, the socket(s) **must** be replaced. Refer to Cam Follower Socket - Replacement (Roller Removed) (4-05).

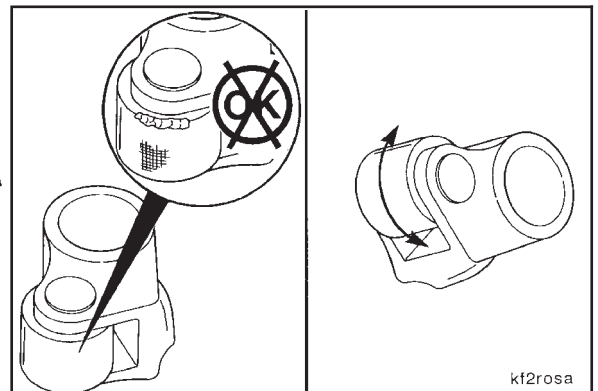
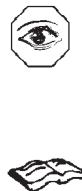
NOTE: If a socket is replaced, the mating push rod **must** also be replaced.

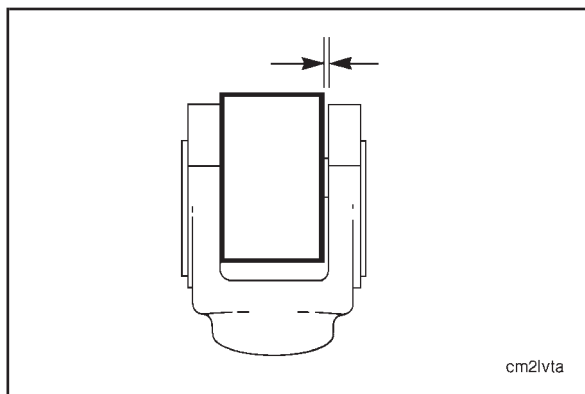


Visually inspect the cam follower rollers for flat spots, scuff marks or other damage.

Turn the rollers by hand to make sure they rotate freely.

If the cam follower rollers are damaged or do **not** rotate freely, the rollers **must** be replaced. Refer to Cam Follower Lever - Roller Replacement (4-03).





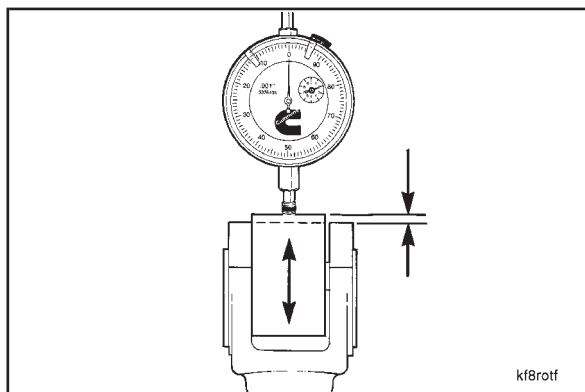
Measure the cam follower roller side clearance.

Roller Side Clearance

mm		in
0.19	MIN	0.007
0.65	MAX	0.026



If the roller side clearance is **not** within these specifications, the roller **must** be replaced. Refer to Cam Follower Lever - Roller Replacement (4-03).



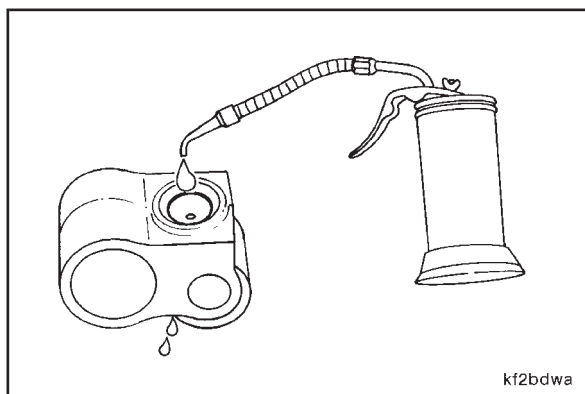
Use a dial indicator to measure the cam follower roller to pin clearance.

Roller to Pin Clearance

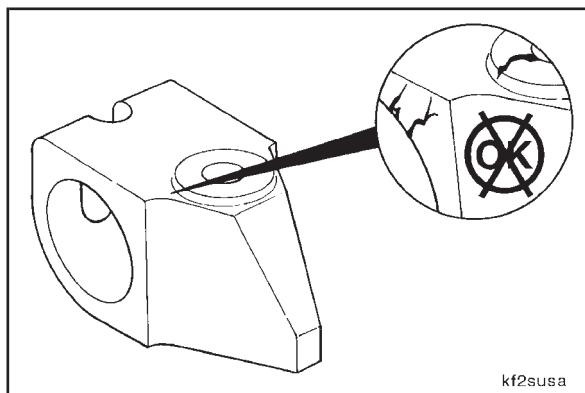
mm		in
0.08	MIN	0.003
0.20	MAX	0.008



NOTE: If the roller to pin clearance is **not** within these specifications, the roller and pin **must** be replaced. Refer to Cam Follower Lever - Roller Replacement (4-03).



Use clean 15W-40 oil to check the oil flow through the cam followers.

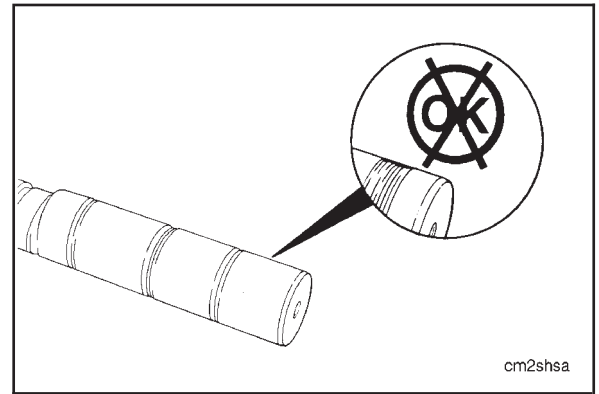


Visually inspect the cam follower shaft supports for cracks or damage.

If cracks or damage is found, the shaft supports **must** be replaced.

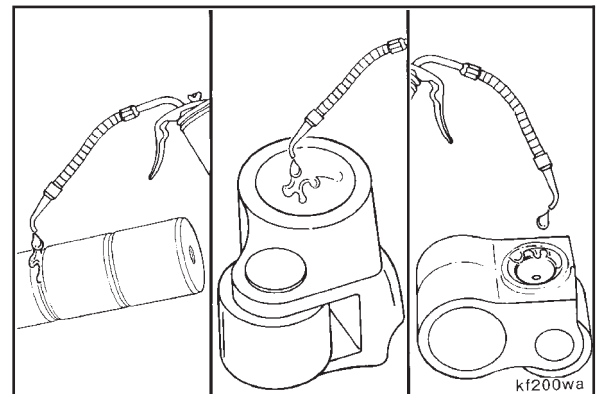
Visually inspect the cam follower shafts for scoring or damage.

If scoring or damage is found, the cam follower shaft(s) **must** be replaced.



Assembly

Use clean 15W-40 oil to lubricate the cam follower shafts and the injector and valve cam followers.

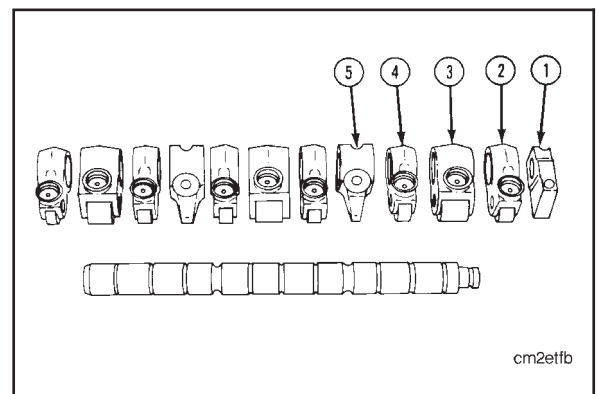


The cam follower levers, supports and shafts have established wear patterns and **must** be installed in the same position from which they were removed. The shaft end supports are **not** interchangeable.

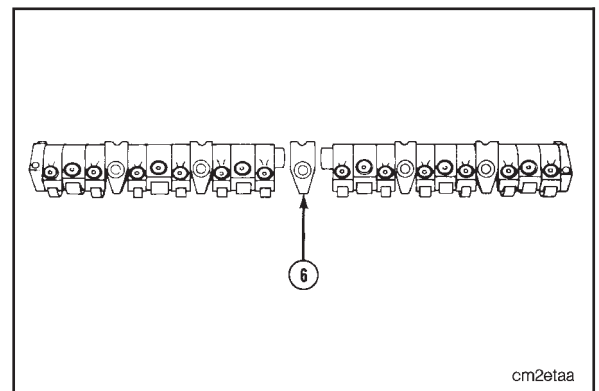
Install the end support (1) on the shaft.

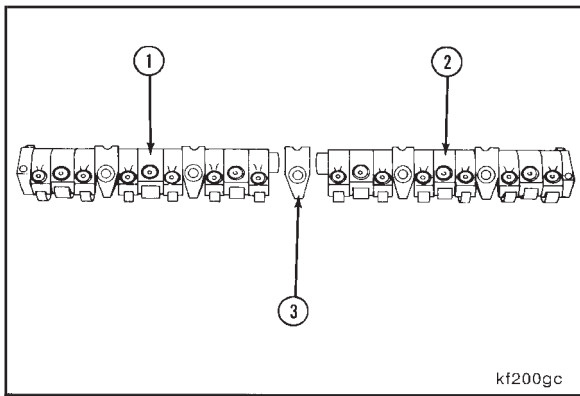
Install the valve cam follower (2), the injector cam follower (3), the valve cam follower (4), and the shaft support (5) on the shaft.

Install the remaining cam followers and supports in the same sequence.



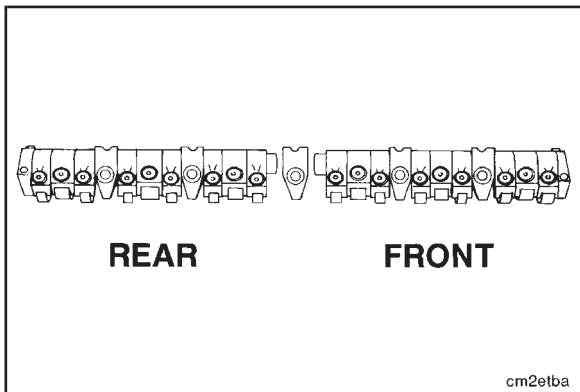
Install the two cam follower shaft assemblies in the common center support (6).





Cam Follower Assembly - Rebuild (4-02)

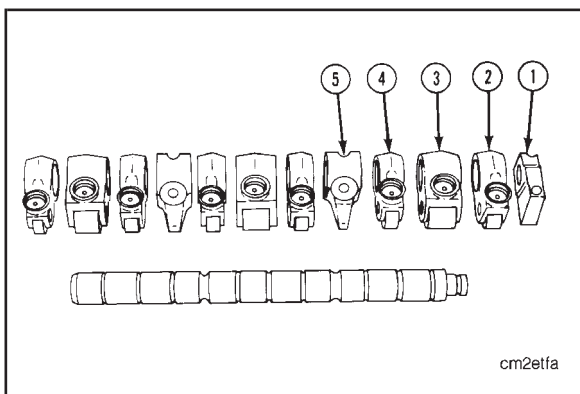
The cam follower assembly consists of two shaft assemblies, (1) and (2), installed on the engine with a common center support (3).



Disassembly

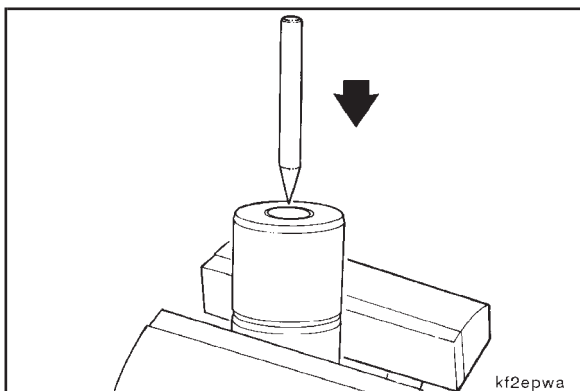


The cam follower levers have established wear patterns and **must** be installed in the same position they were removed from. Mark the end supports and all of the cam followers to identify their position, front and rear, when they are removed. The end supports are **not** interchangeable.



Remove the end supports (1) from the shafts.

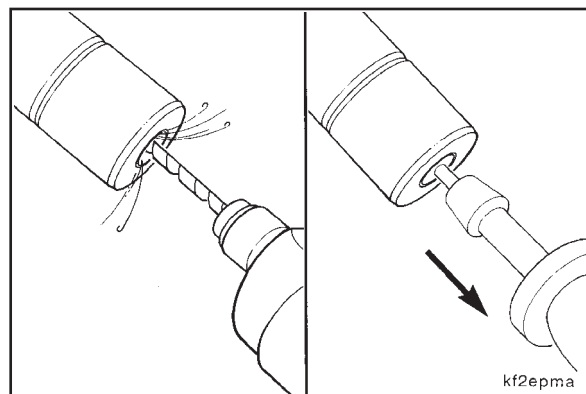
Remove the valve cam followers (2), injector cam followers (3), valve cam followers (4), and shaft supports (5).



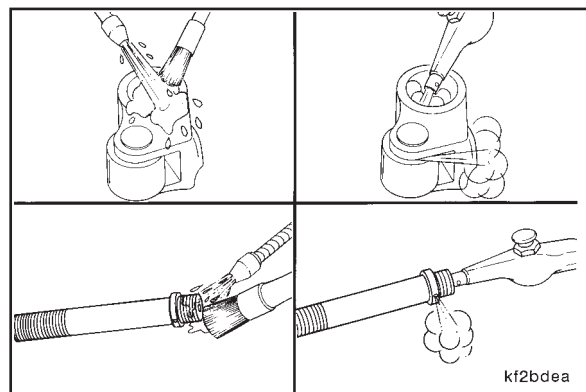
Install the cam follower shafts in a vise with brass jaws.

Center punch the plugs in the ends of the shafts.

Drill a 1/8 inch hole in the plugs and use a standard dent puller to remove the plugs from the shafts.

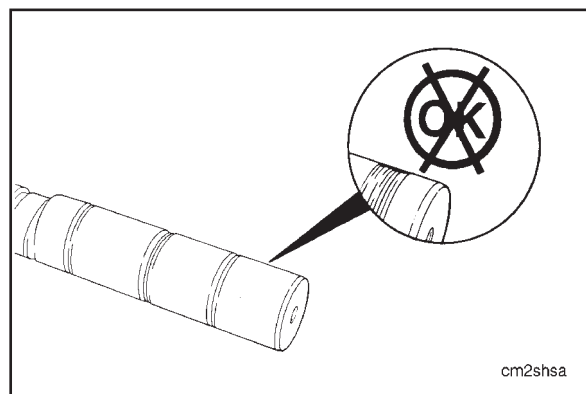


Clean the cam follower parts with solvent. Dry with compressed air.



Inspection

Visually inspect the cam follower shafts for scoring or damage.

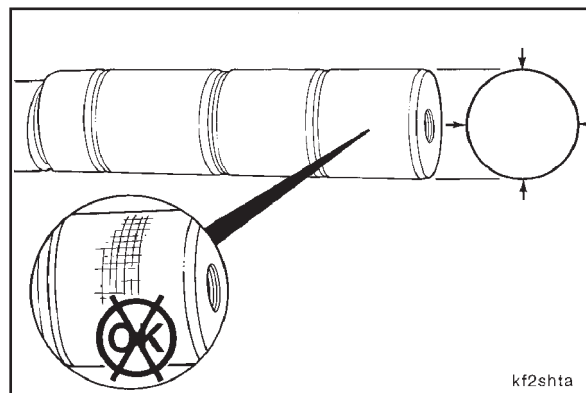


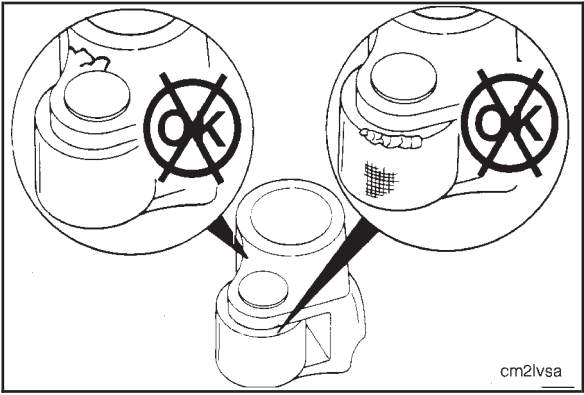
Measure the outside diameter of the cam follower shaft journals.



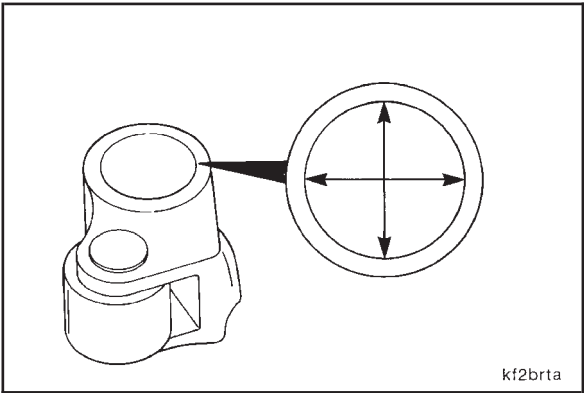
Shaft Journals O.D.		
mm		in
33.991	MIN	1.3382
34.009	MAX	1.3389

If scoring or damage is found or the shafts are **not** within the specifications, the shaft(s) **must** be replaced.





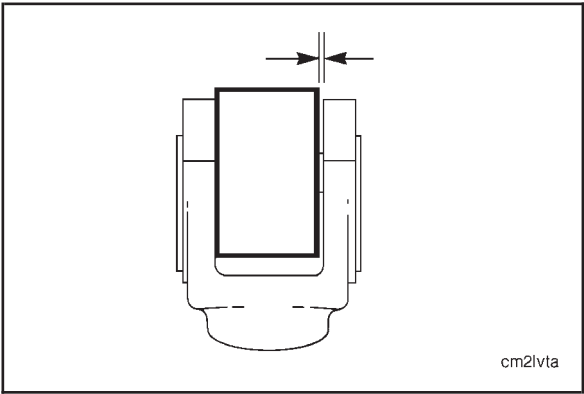
Visually inspect the cam follower levers for cracks or damage.



Measure the inside diameter of the shaft bore in the cam follower levers.

Shaft Bore I.D.		
mm		in
34.086	MIN	1.3420
34.116	MAX	1.3431

If the cam follower lever is damaged or the shaft bore is **not** within the maximum specification, the lever(s) **must** be replaced.

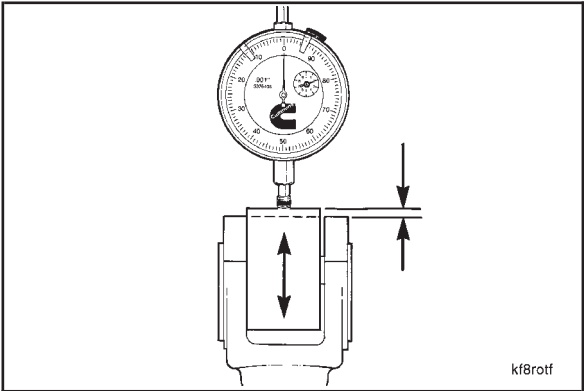


Measure the cam follower roller side clearance.

Roller Side Clearance		
mm		in
0.19	MIN	0.007
0.65	MAX	0.026



If the roller side clearance is **not** within the specifications, the roller **must** be replaced. Refer to Cam Follower Lever - Roller Replacement (4-03).



Use a dial indicator to measure the cam follower roller to pin clearance.

Roller to Pin Clearance		
mm		in
0.08	MIN	0.003
0.20	MAX	0.008

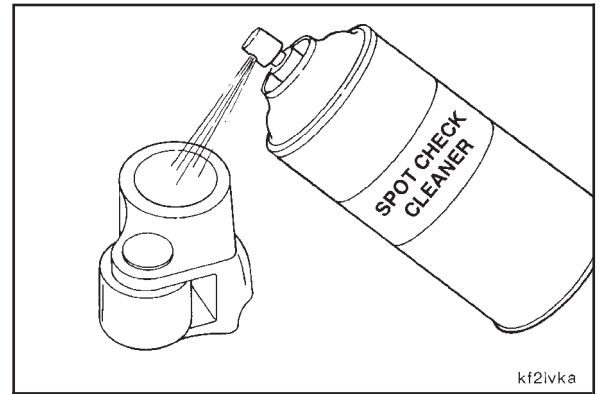


NOTE: If the roller to pin clearance is **not** within these specifications, the roller and pin **must** be replaced. Refer to Cam Follower Lever - Roller Replacement (4-03).

Section 4 - Cam Follower Assembly - Group 04 M11

Use the crack detection kit, Part No. 3375432, to inspect the cam follower levers and supports for cracks.

Use the crack detection cleaner, Part No. 3375433, to clean the levers and supports. Dry with compressed air.

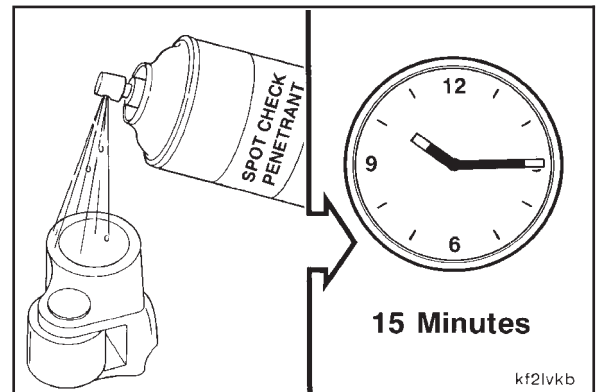


Use the crack detection penetrant, Part No. 3375435, to spray the levers and supports.

NOTE: Do **not** dry the penetrant with compressed air.

Allow the penetrant to dry for 15 minutes.

Remove the excess penetrant with a dry cloth.



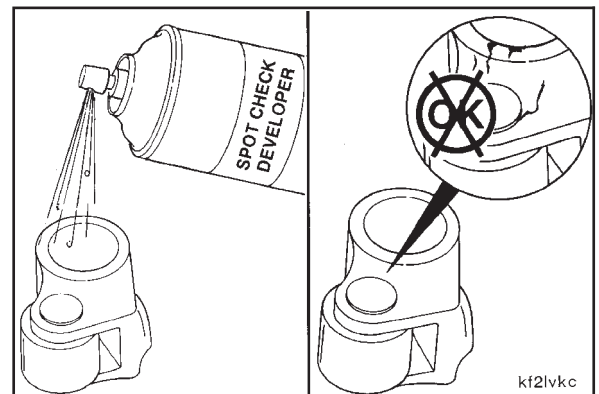
Use the crack detection developer, Part No. 3375434, to spray the levers and supports.

Visually inspect the levers and supports.

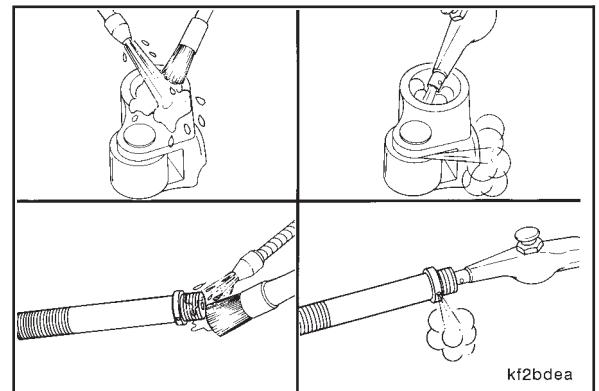
Cracks will appear as a solid bright line.

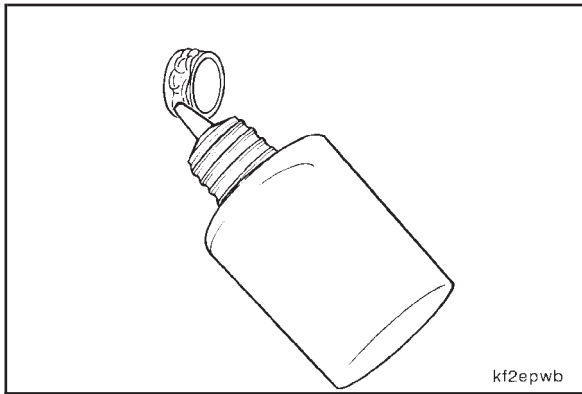
Cavitation in the casting will appear as a small round mark.

If cracks or cavitation are found the part **must** be replaced.



Use solvent to clean the acceptable levers and supports.
Dry with compressed air.

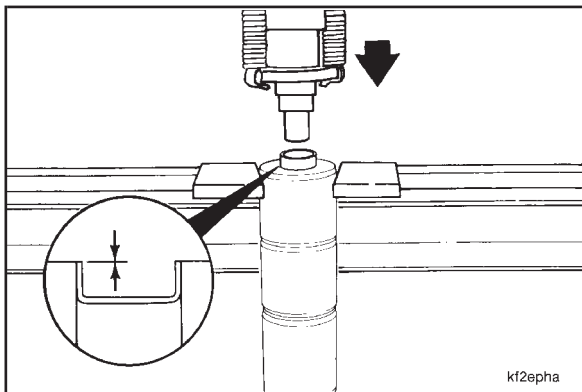




Assembly



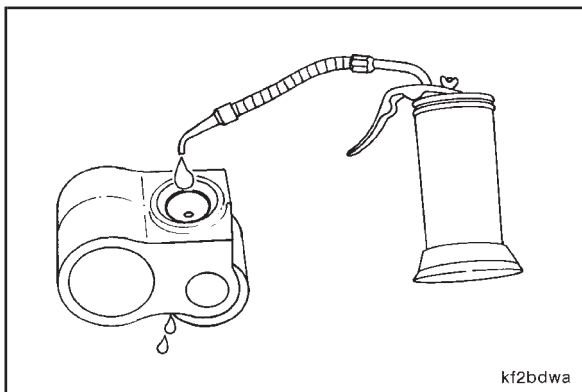
Apply a coat of cup plug sealant, Part No. 3375068, to the outside diameter of the shaft plugs.



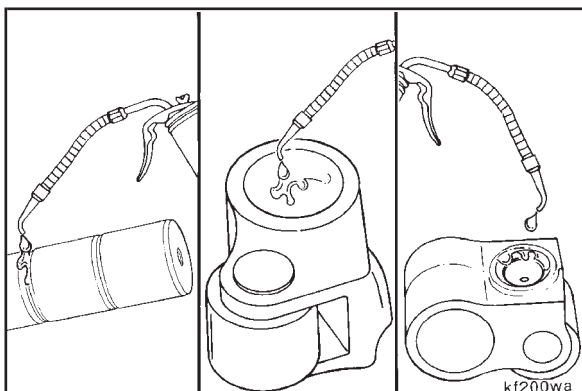
Install the shaft in an arbor press.

NOTE: Make sure the end of the shaft is supported.

Press the plug into the shaft until it is level with the end of the shaft.



Use clean 15W-40 oil to check the oil flow through the cam followers.



Use clean 15W-40 oil to lubricate the cam follower shafts, and the injector and valve cam followers.

Section 4 - Cam Follower Assembly - Group 04 M11

The cam follower levers, supports, and shafts have established wear patterns and **must** be installed in the same position from which they were removed. The shaft end supports are **not** interchangeable.

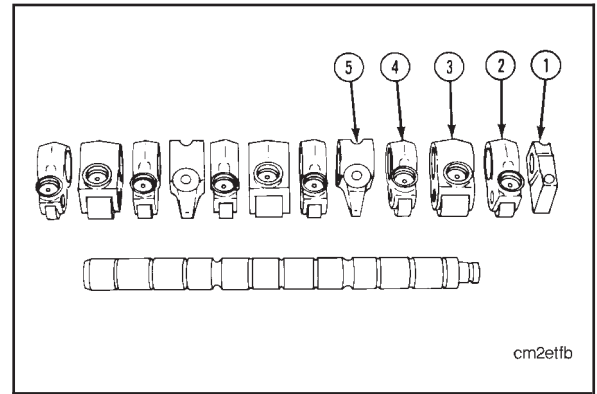
Install the end support (1) on the shaft.

Install the valve cam follower (2), injector cam follower (3), valve cam follower (4), and shaft support (5) on the shaft.

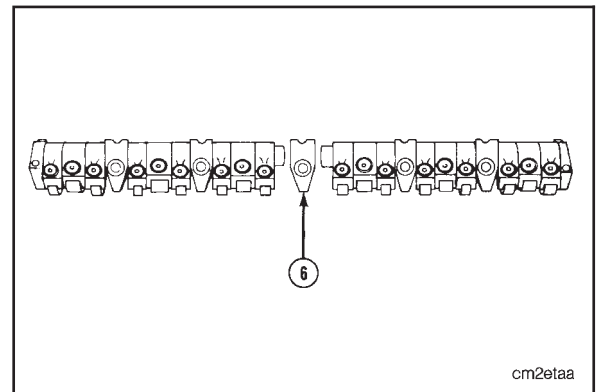
Install the remaining cam followers and supports in the same sequence.



Cam Follower Lever - Roller Replacement (4-03) Page 4-13



Install the two cam follower shaft assemblies into the common center support (6).



Cam Follower Lever - Roller Replacement (4-03)

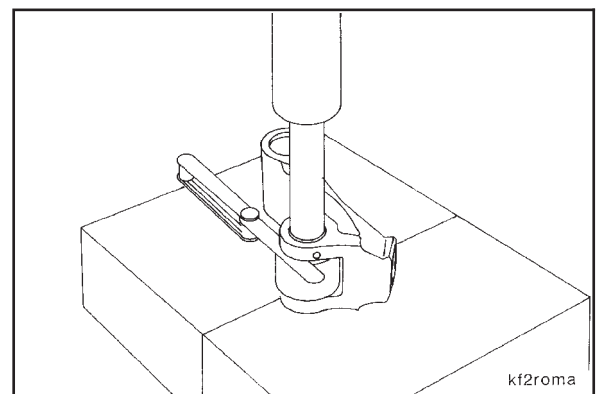
Disassembly

Install the cam follower lever in an arbor press.

Caution: Use the largest feeler gauge that will fit between the roller and the lever to prevent damage when removing the roller pin.

Install a feeler gauge between the roller and the leg of the lever.

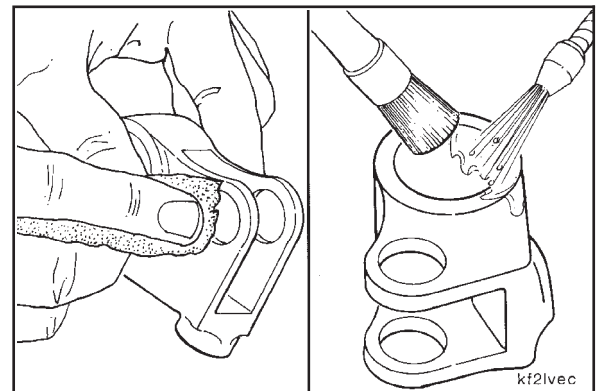
Push the roller pin from the cam follower lever. Discard the unacceptable rollers and roller pins.

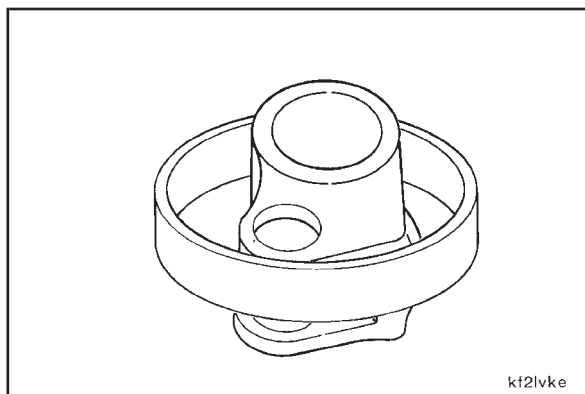


Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to remove any burrs from the edges of the pin bore holes.

NOTE: Do **not** burnish the inside diameter of the pin bore holes.

Use solvent to clean the levers. Dry with compressed air.

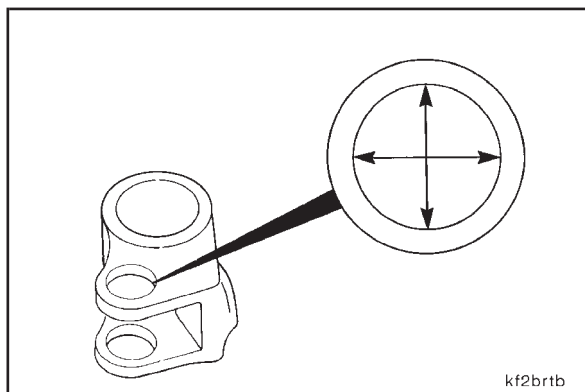




Inspection

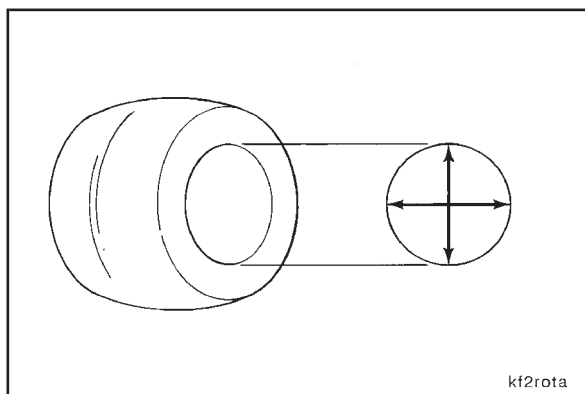


Use the magnetic crack inspection method to inspect the cam follower levers for cracks. Refer to Cam Follower - Magnetic Crack Inspection (Roller Removed) (4-04)



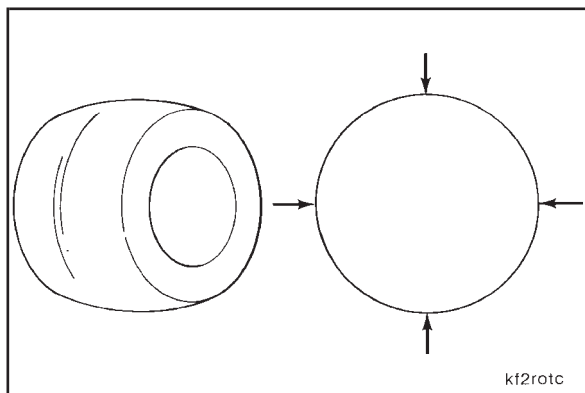
Measure the inside diameter of cam follower lever roller pin bore.

Roller Pin Bore I.D.		
mm		in
19.043	MIN	0.7497
19.055	MAX	0.7502



Measure the inside diameter of the new cam follower lever roller bore.

Roller Bore I.D.		
mm		in
19.151	MIN	0.7540
19.177	MAX	0.7550

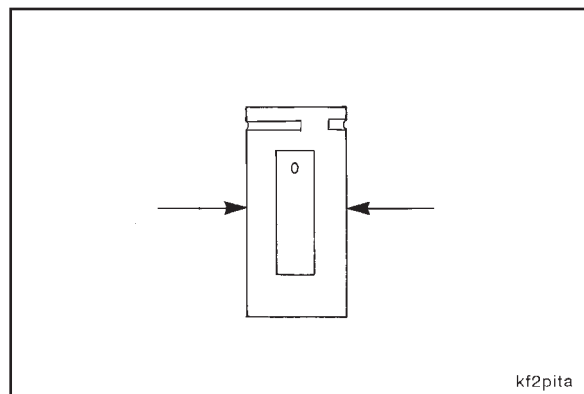


The crowned roller **must** be measured in the middle of the roller outside diameter.

Crowned Roller O.D.		
mm		in
41.237	MIN	1.6235
41.287	MAX	1.6255

Measure the outside diameter of the new roller pin.

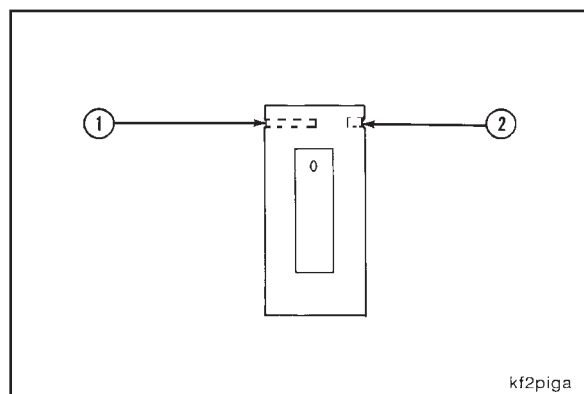
Roller Pin O.D.		
mm		in
19.065	MIN	0.7506
19.073	MAX	0.7509



kf2pita

Assembly

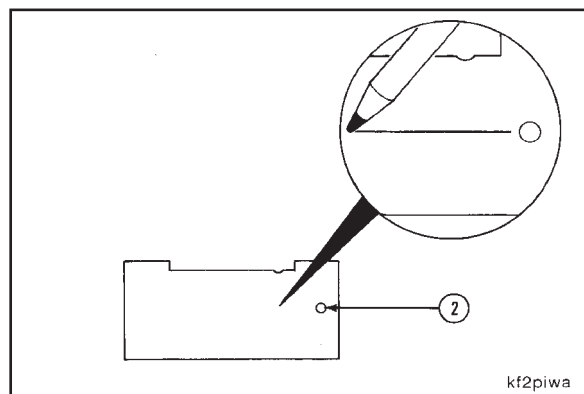
The roller pin **must** be installed correctly to be sure the cam follower roller and roller pin are supplied with oil. Inspect the new roller pin as shown to determine the oil feed passage (1) and the alignment hole (2) locations. The oil feed passage is approximately three times as deep as the alignment hole.



kf2piga

Use a grease pencil or similar marker to draw a line on the side of the roller pin that is parallel to the alignment hole (2).

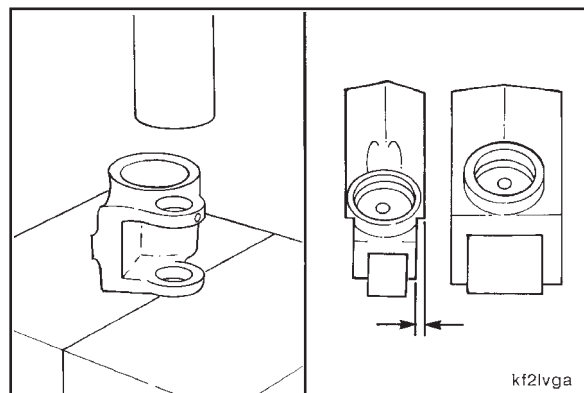
NOTE: The line will help align the roller pin correctly in the cam follower lever.



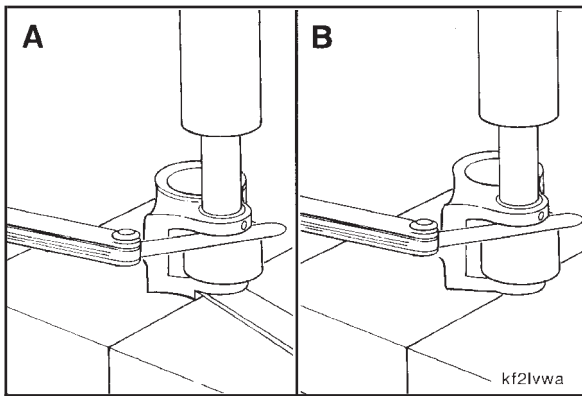
kf2piwa

Install the cam follower lever in an arbor press so the leg with the alignment hole is towards the top.

NOTE: Because of the offset on the valve cam follower levers, it is necessary to install a 1.6 mm [1/16 inch] shim under the lever. This will prevent leg deflection and keep the lever perpendicular to the roller pin.



kf2lvga



Install the roller in the cam follower lever.

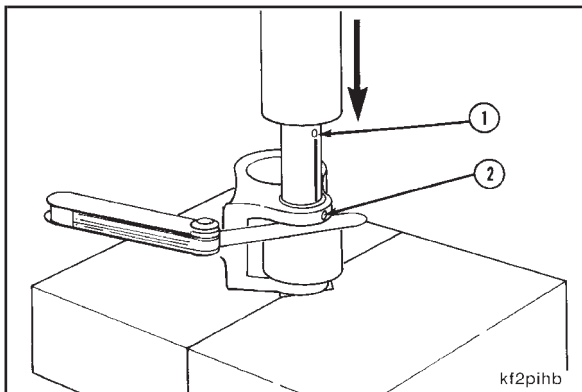


Caution: Use the largest feeler gauge that will fit between the roller and the lever to prevent leg deflection when installing the roller pin. This will reduce shaving of the bronze roller pin and prevent leg breakage.



Install a feeler gauge between the roller and the leg of the lever.

- Valve cam follower lever (A)
- Injector cam follower lever (B)

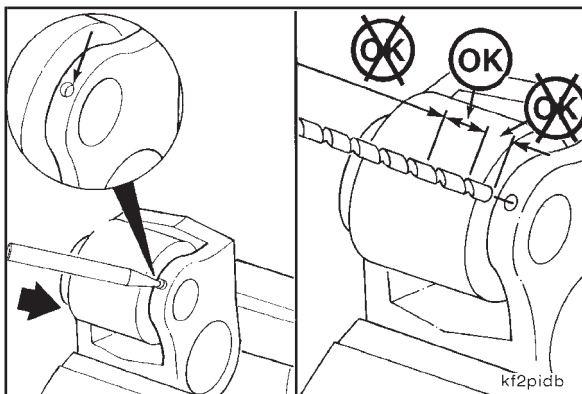


NOTE: Freezing the roller pin will simplify it's installation.

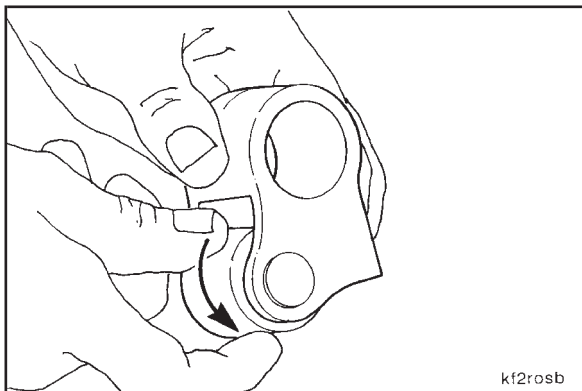
Use clean 15W-40 oil to lubricate the roller pin.



Install the roller pin. Make sure the pin alignment hole (1) is correctly aligned with the alignment hole (2) in the lever before pushing the roller pin into the cam follower lever.



Cam followers can be checked for correct roller pin installation by using a 5/64-inch drill bit. If the drill bit enters 10.2 mm [0.40 inch] the roller pin **is** installed correctly. If the drill bit enters only 5.1 mm [0.20 inch] or goes in 18.0 mm [0.70 inch] the roller pin is installed incorrectly. Roller pins that are **not** installed correctly **must** be removed and new roller pins installed.

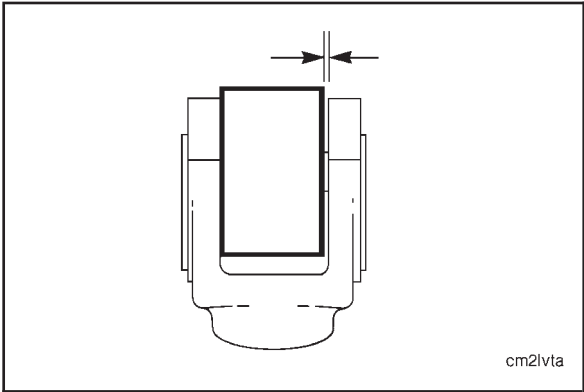


Turn the roller by hand to make sure it rotates freely.

Measure the cam follower roller side clearance.

Roller Side Clearance		
mm		in
0.19	MIN	0.007
0.65	MAX	0.026

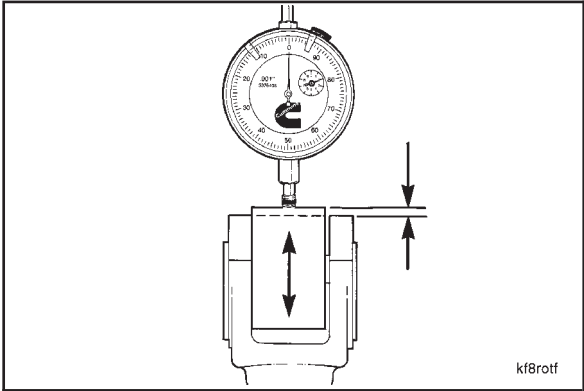
If the roller does **not** rotate freely or the side clearance does **not** meet the specifications, the cam follower lever **must** be rebuilt again.



Use a dial indicator to measure the cam follower roller to pin clearance.

Roller to Pin Clearance		
mm		in
0.08	MIN	0.003
0.20	MAX	0.008

NOTE: If the roller to pin clearance is **not** within these specifications, the roller and pin **must** be replaced. Refer to Cam Follower Lever - Roller Replacement (4-03).



Cam Follower Lever - Magnetic Crack Inspection (Roller Removed) (4-04)

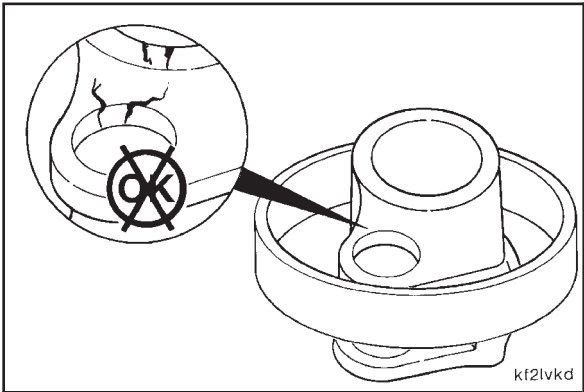
Use coil magnetization with residual magnaglow to magnetize the cam follower levers.

Amperage

300 Ampere Turns min.
500 Ampere Turns max.

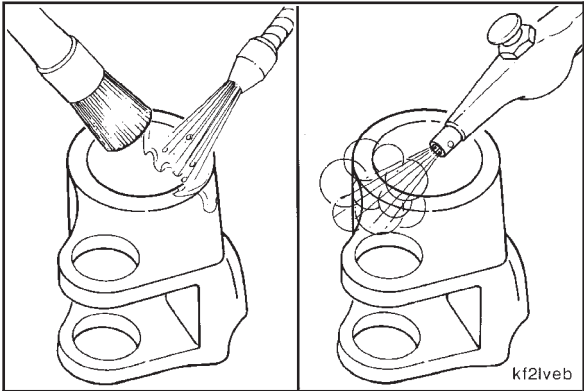
Visually inspect the levers for cracks.

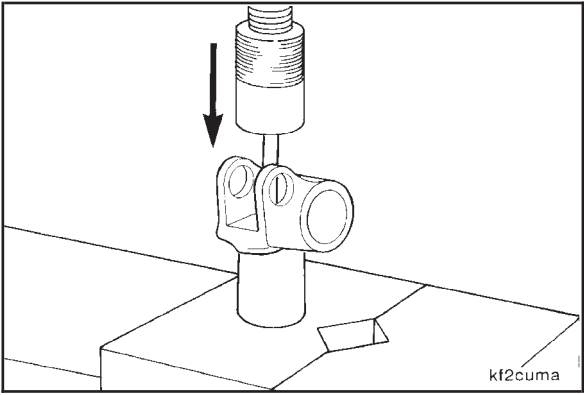
Cracks will appear as a solid bright line. Discard cracked levers.



Use a demagnetizer to remove the magnetism.

Use solvent to clean the cam follower levers. Dry with compressed air.





Cam Follower Lever Socket - Replacement (Roller Removed) (4-05)

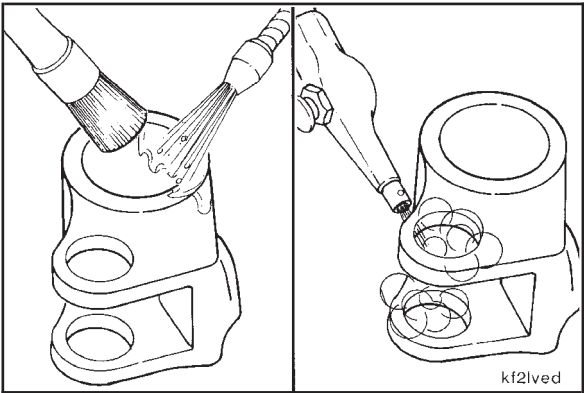
Disassembly



Install the cam follower lever in an arbor press, as shown.
Press the socket from the lever.

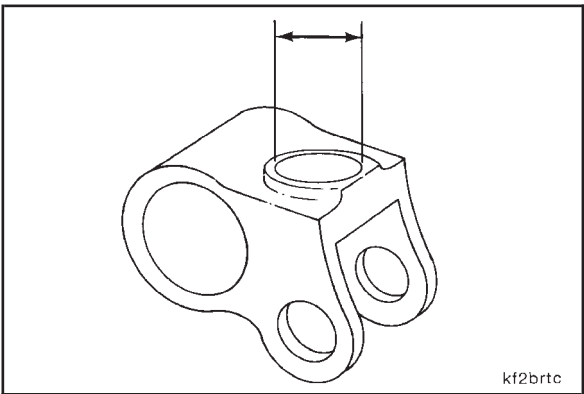


NOTE: If a socket is replaced, the mating push rod **must** also be replaced.



Use solvent to clean the cam follower lever. Dry with compressed air.

Use compressed air to blow any debris from the oil passages.



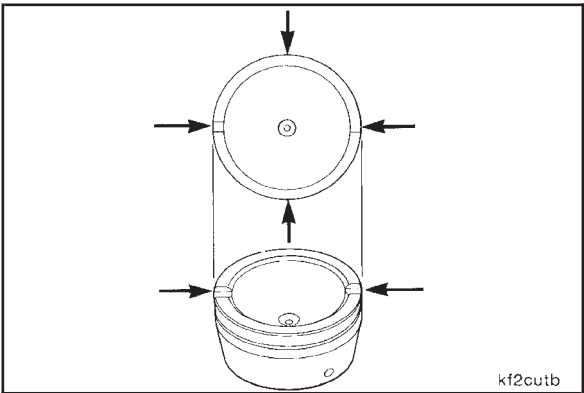
Inspection



Measure the inside diameter of the cam follower lever socket bore.

Socket Bore I.D.		
mm		in
19.024	MIN	0.7490
19.050	MAX	0.7500

If the cam follower lever socket bore does **not** meet the specifications. The lever **must** be replaced.

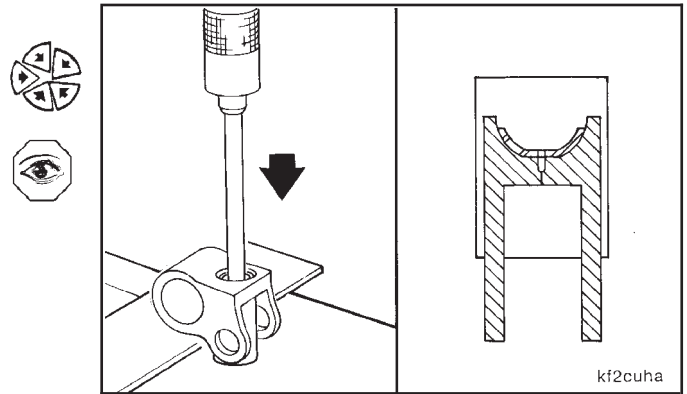


Measure the outside diameter of the new cam follower lever socket.

Socket O.D.		
mm		in
19.062	MIN	0.7505
19.088	MAX	0.7515

Assembly

Install the cam follower lever in an arbor press, as shown. Use a used push rod to press the new socket into the lever. Visually inspect the bottom side of the socket through the oil passage hole in the lever. The socket **must** be completely seated.

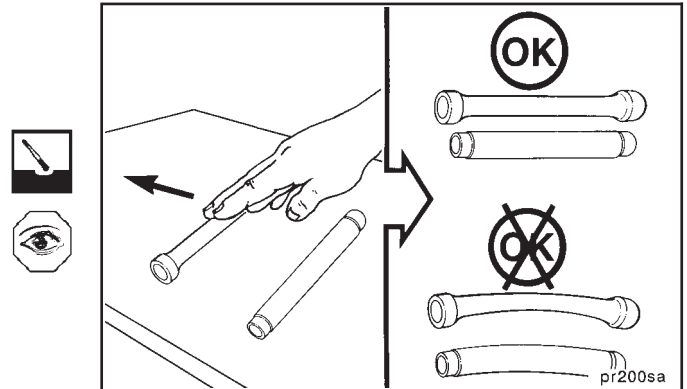


Push Rods and Tubes - Cleaning and Inspection for Reuse (4-06)

Inspection

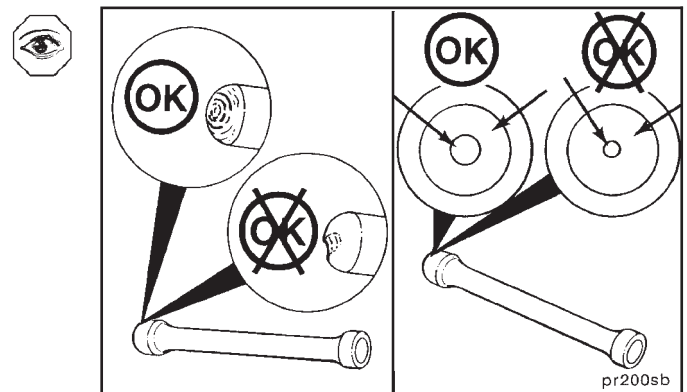
Use solvent to clean the push rods and push tubes. Dry with compressed air.

Visually inspect the straightness of the push rods and tubes by rolling them on a level surface.



Visually inspect the ball end for pitting, uneven wear, or scratches.

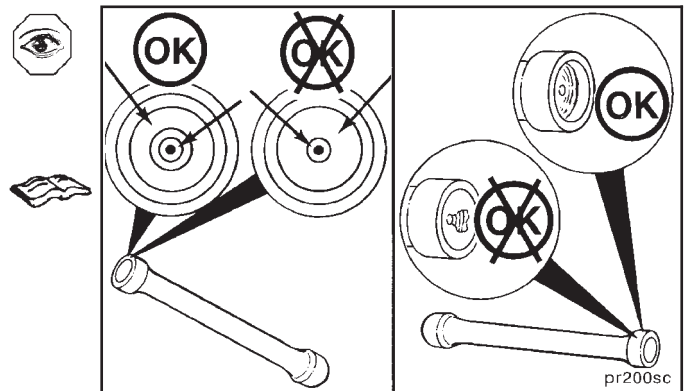
NOTE: If a push rod or push tube is replaced because of pitting, uneven wear, or scratches the mating cam follower **must** also be replaced.



Visually inspect the seating pattern in the socket for pitting, uneven wear, or scratches.

If an excessively worn push rod or push tube is found, the mating rocker lever adjusting screw **must** be replaced also.

Refer to the Overhead Reuse Guidelines, Bulletin No. 3810388, to identify wear patterns and excessive wear.



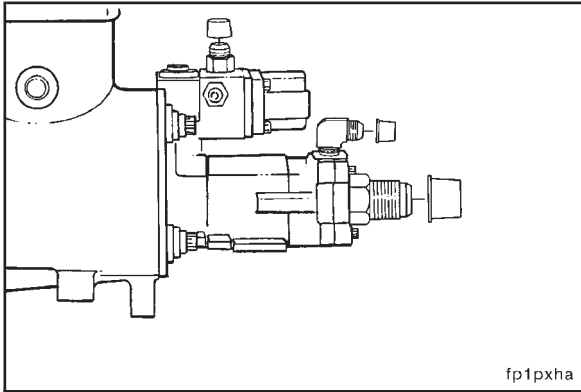
NOTES

Section 5 - Fuel System - Group 05
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Fuel Damper - Assembly	5-11
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Fuel Shutoff Valve - Assembly	5-12
Fuel Shutoff Valve - Cleaning and Inspection.....	5-12
Fuel Shutoff Valve - Disassembly	5-11
Fuel Supply Pump - Test.....	5-13
Inspection	5-6

Fuel Pump - General Information

NOTE: Warranty repairs are **not** to be made to the fuel pump unless the work is performed in a shop meeting all requirements established by Cummins Engine Company, Inc. to accurately calibrate, test and repair the fuel systems on Cummins engines.

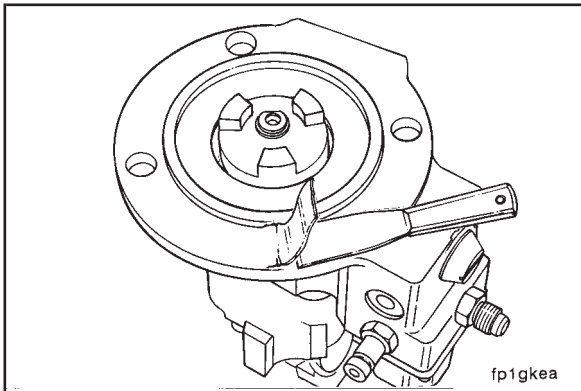


Fuel Pump - Cleaning and Inspection for Reuse (5-01)

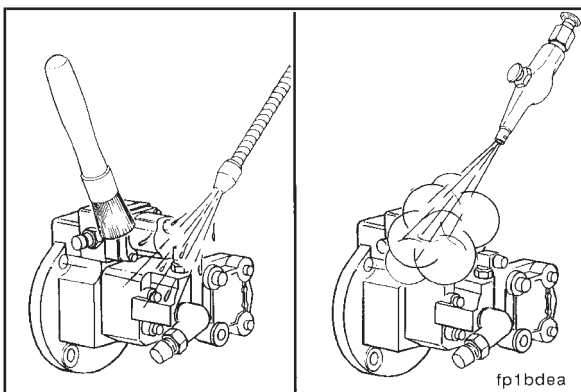
Cleaning



Install plastic cup plugs or tape on all openings of the fuel pump to prevent dirt or cleaning solvent from entering the pump.



Remove the gasket material from the front cover gasket sealing surface.



Caution: Use a cleaning solvent approved for cleaning aluminum to prevent damage to the fuel pump.



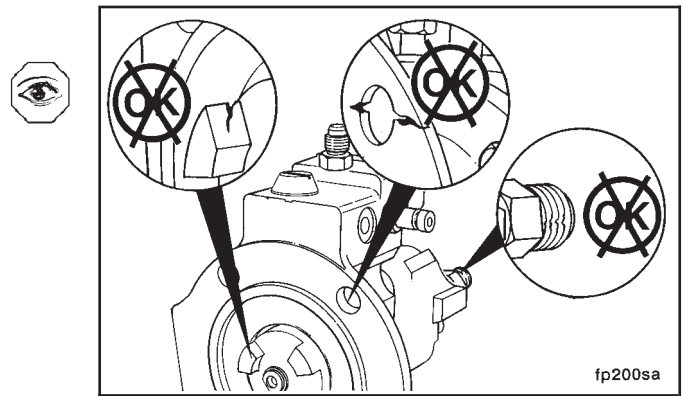
Use a brush and solvent to clean the fuel pump exterior. Dry with compressed air.

Inspection

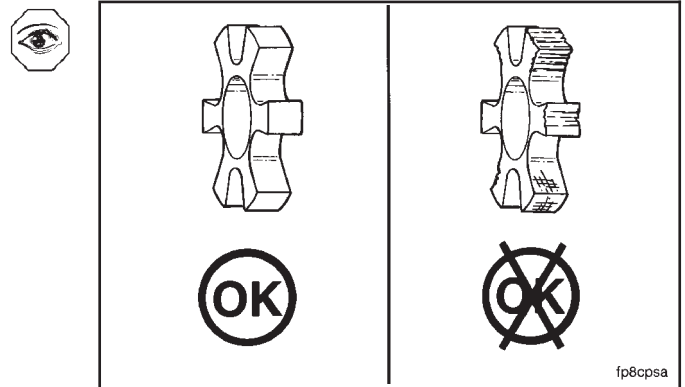
Visually inspect the fuel pump body and front support for cracks or other damage.

Visually inspect the fuel pump assembly for damaged capscrews and damaged or loose fuel fittings.

Visually inspect the drive coupling lugs for excessive wear or damage.

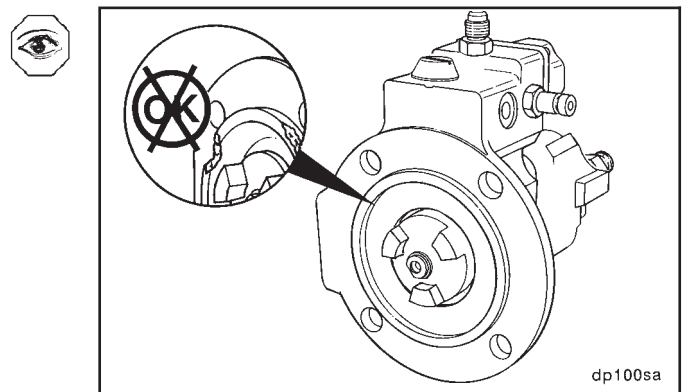


Visually inspect the drive coupling spider for cracks or other damage.



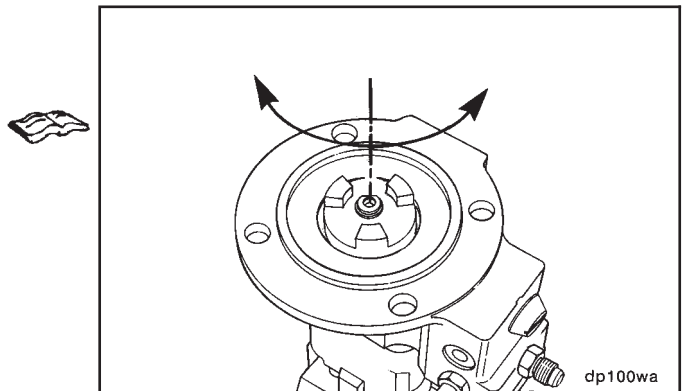
Visually inspect the front support pilot to make sure the pilot is continuous without cracks or gaps.

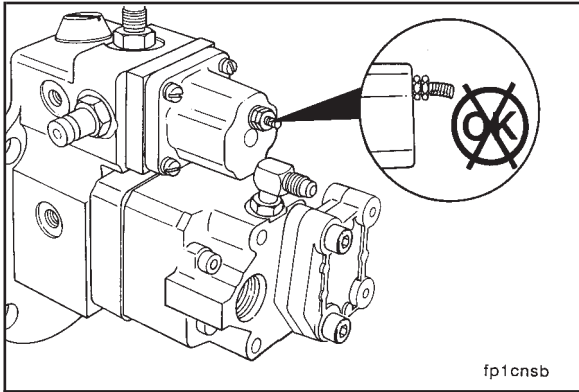
Check the relative motion between the coupling and shaft using the indicator level and angle service tool, Part No. 3375855. Hold the drive shaft stationary, and record the difference between angular values obtained at the extremes of motion. If the relative motion exceeds 15 degrees, then replace the coupling and shaft.



Turn the fuel pump shaft by hand. The shaft **must** rotate freely.

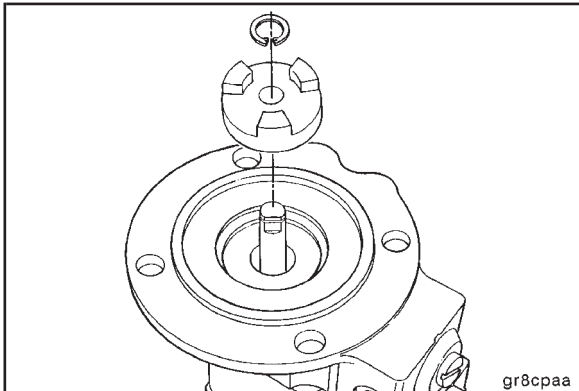
NOTE: If the shaft does **not** rotate freely, the pump **must** be disassembled for further inspection. Refer to Fuel Pump - Rebuild (5-02).





Visually inspect the fuel pump shutoff valve for loose or damaged electrical terminals.

Torque Value: 3 N•m [25 in-lb]



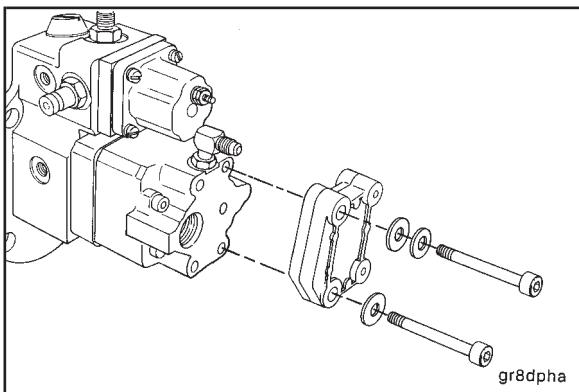
Fuel Pump - Rebuild (5-02)

Disassembly

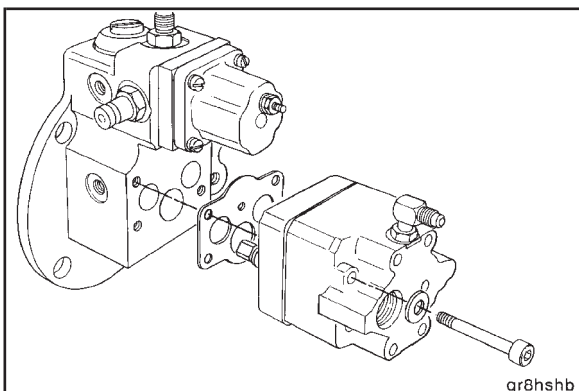


Remove the snap ring and the drive coupling.

NOTE: The coupling is a slip fit D shape coupling.



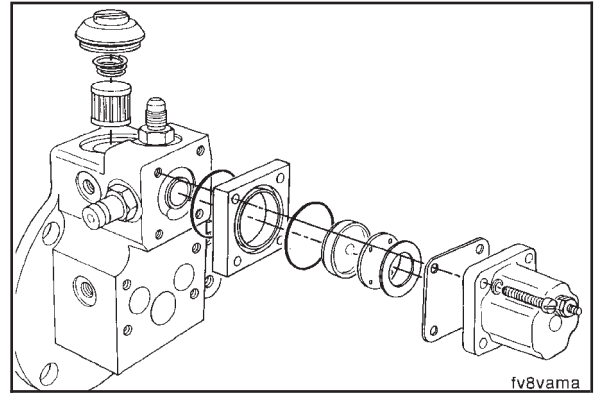
Remove the fuel inlet connection and pulsation damper, or the filter head damper assembly. Discard the rubber o-rings.



Remove the four capscrews that hold the gear pump to the support.

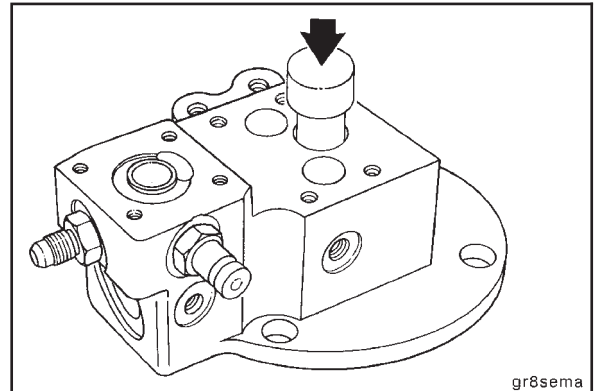
Hold the gear pump housing in a vise and tap the support with a plastic hammer to loosen.

Remove the shutoff valve, discard the o-ring. Remove the filter screen cap and the filter screen.

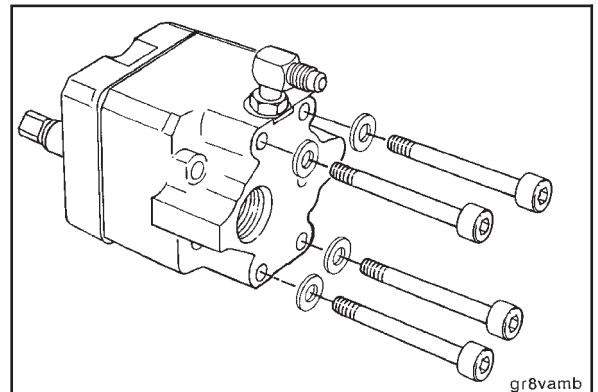


Press both of the drive shaft seals out of the support.
Press the seals in the direction of the drive coupling.

Use seal removal tool, Part No. 3823239.

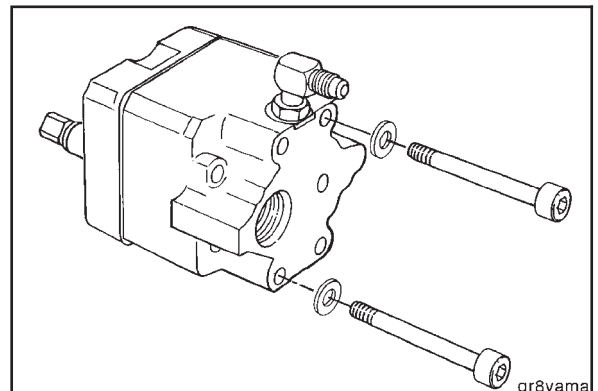


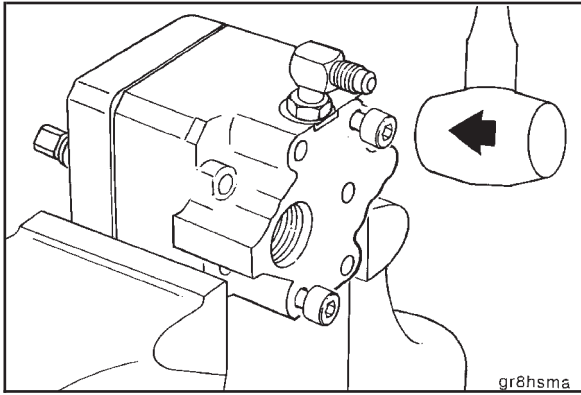
Remove the four capscrews that hold the gear cover to the gear housing.



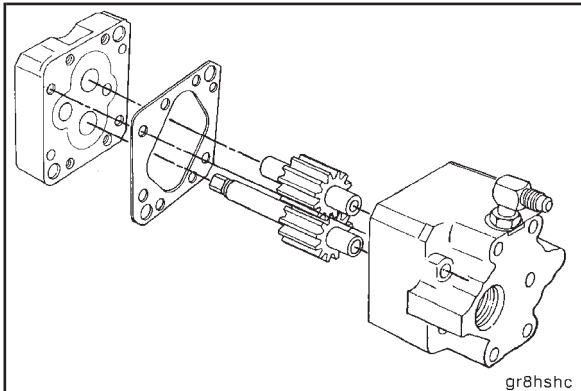
Install two capscrews that are 100 mm [4 inches] long into the gear pump cover. Install these capscrews in the cover holes that are near the dowel pins.

NOTE: Install capscrews at locations nearest to the alignment dowel pins.

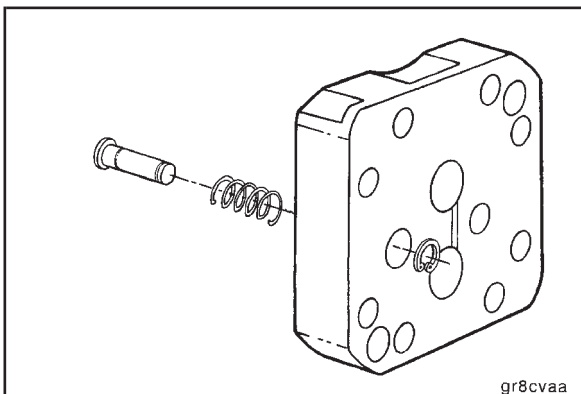




Clamp the gear pump housing in a vise. Gently tap alternately on the head of the capscrews to loosen the gear pump cover.

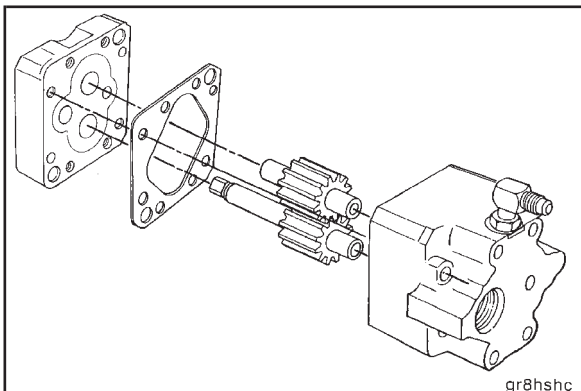


Remove the gear pump cover, drive gear and the idler gear. Discard the gasket.



Remove the regulator retaining snap ring.

Remove the regulator plunger and the spring from the gear pump cover.



Inspection

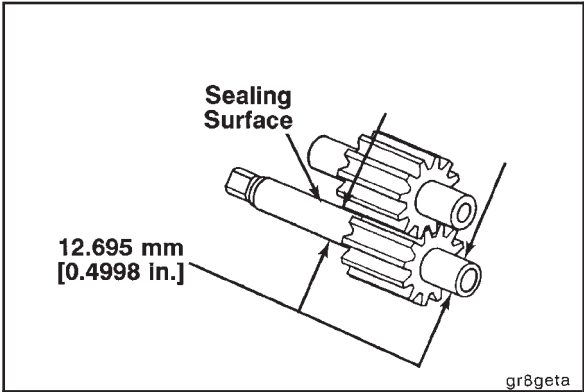
The gear pump components **must** be inspected for damage and wear.

If the gear pump body, gear pump cover, or either of the gear pump gears are damaged or out of specification, replace the gear pump assembly. If one or both of the shafts are damaged or out of specification, replace the shaft(s) as required.

Check the gear pump shafts. Discard them if they are damaged. Replace the shaft if the bearing surface is worn smaller than 12.695 mm [0.4998 in] in diameter.

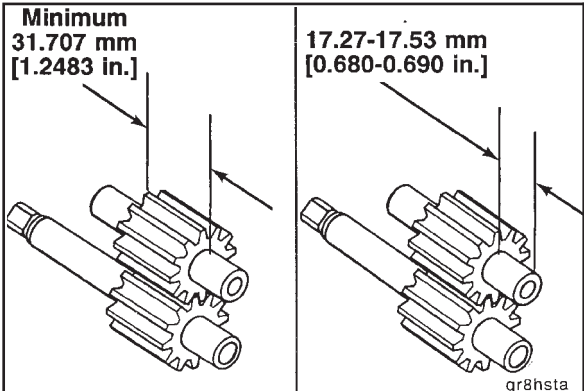
Replace the drive shaft if there is measurable wear on the sealing surface.

NOTE: If the shaft feels rough when a fingernail is moved across the sealing surface, replace the shaft.



Visually inspect the gears for damage and replace them if needed. Check the gear width. Discard any gear worn smaller than 31.707 mm [1.2483 in].

Press the gears on the shaft 17.27 to 17.533 [0.680 to 0.690 inch] from the body end of the shaft, if removed. Put a coating of clean engine lubricating oil on the shaft before assembly.

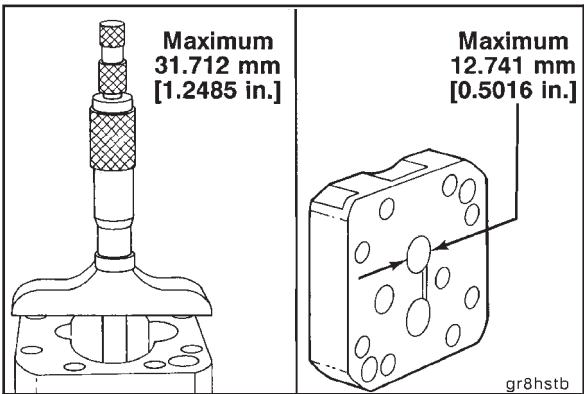


Visually inspect the gear body and cover for damage and replace them if needed. Check the gear hole depth.

Gear Hole Depth		
mm		in
31.704	MIN	1.2482
31.712	MAX	1.2485

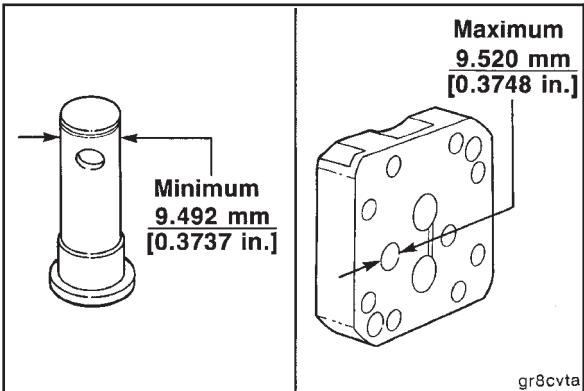
Check the shaft bores in the cover and the body.

Shaft Bores		
mm		in
12.733	MIN	0.5013
12.741	MAX	0.5016

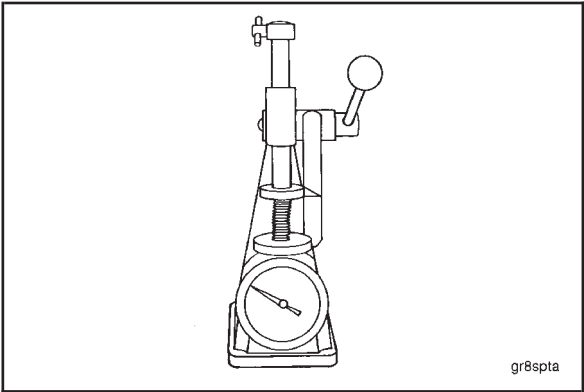


Visually inspect the regulator plunger for binding or scuffing and replace if needed. Check the regulator outside diameter. Replace the regulator if worn smaller than 9.492 mm [0.3737 inch].

Check the regulator bore.



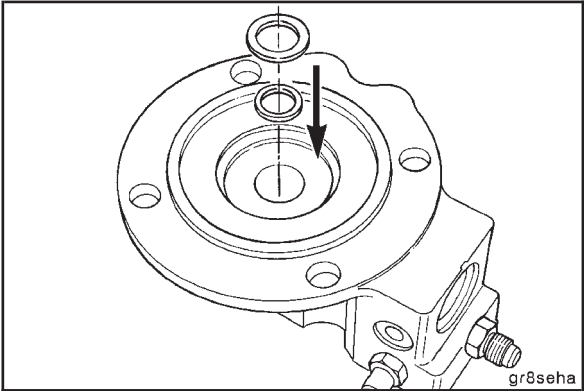
Regulator Bore		
mm		in
9.510	MIN	0.3744
9.520	MAX	0.3748



Inspect the regulator spring for damage and replace if needed. The spring **must** meet the specifications as shown in the table.

Regulator Spring Specifications					
Part No.	Wire Dia. mm [inch]	No. Coils	Load Kg [lb]	Length mm [inch]	Free Length mm [inch]
3068424	1.52 [.060]	5.25	4.0 [8.9]	16.0 [.631]	21.16 [.8337]

Check and clean all of the flow passages in the cover, housing and gears. Dry with compressed air.

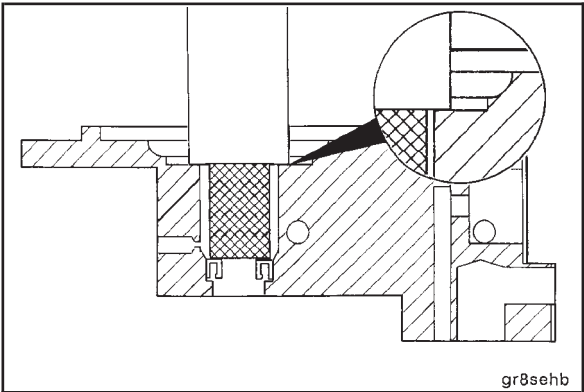


Assembly



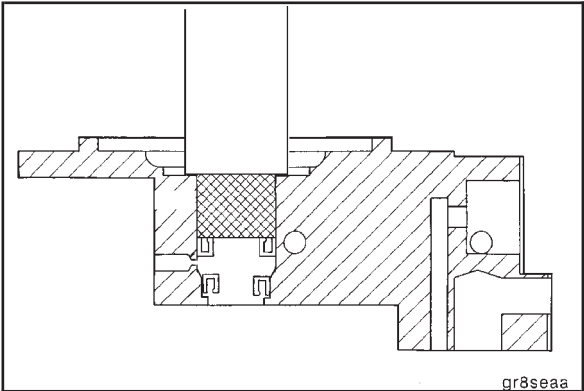
Install the two seals into the support housing, from the drive coupling side.

NOTE: The seal nearest the gear pump has a smaller outside diameter than the seal on the drive coupling side.



Install the fuel seal first. This is the seal nearest to the gear pump. The seal lip **must** be toward the gear pump.

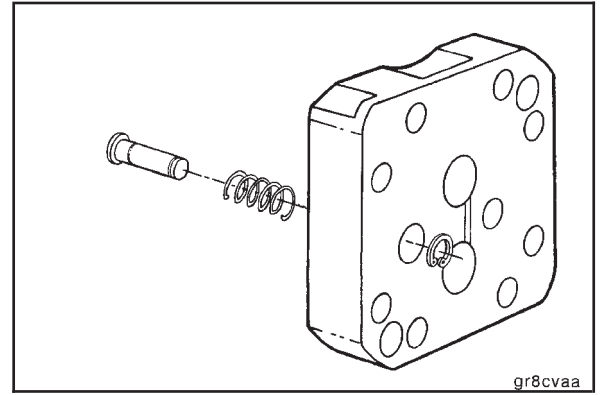
Use driver, Part No. 3823240, to install the seal. Press the seal in until the driver shoulder seats against the front support.



Install the oil seal. The seal lip **must** be away from the gear pump side.

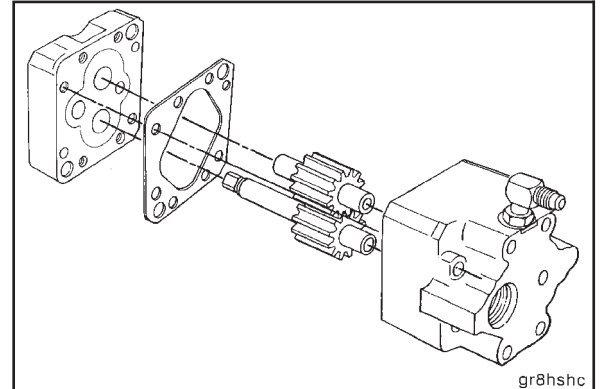
Use driver, Part No. 3823250, to install the seal. Press the seal in until the driver shoulder seats against the front support.

Install the regulator spring on the regulator plunger. Install the regulator assembly in the gear pump cover. Install the plunger retaining ring. Make sure the retaining ring is securely located in the snap ring groove of the regulator plunger.

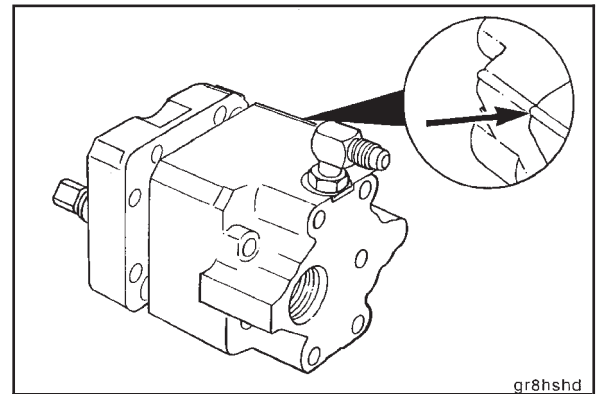


Lubricate with clean engine oil and install the shafts and the gears into the body. Make sure the parts are clean.

Position a new gasket on the dowel pins. Install the cover on the body. Align the location notches.

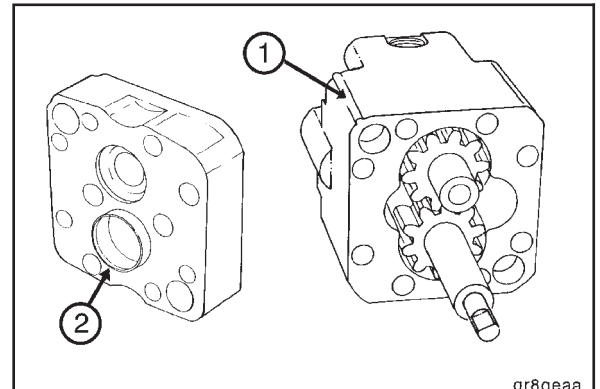


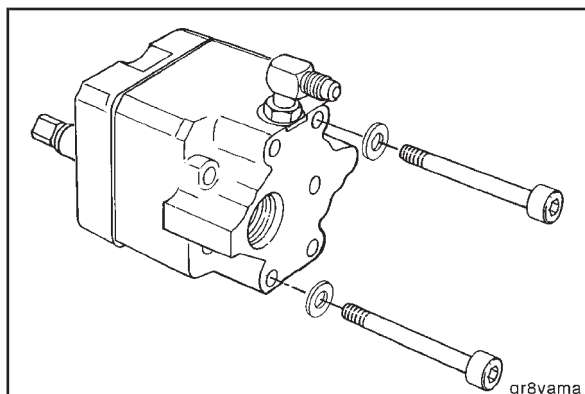
NOTE: The location of the notches and the drive gear shaft determines the rotation of the pump.



Assemble a right hand rotation pump as follows:

- Place the driven gear shaft of the pump in the body nearest the **location notches** (1).
- Place the driving gear shaft in the opposite hole.
- The ring dowel (2) **must** be around the drive shaft.

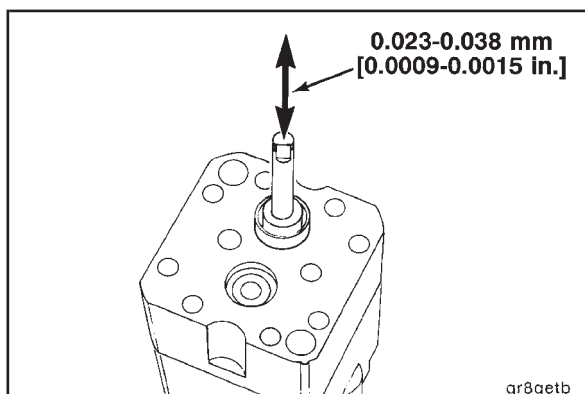




Align the cover and body with the dowels. Tighten the four cover to body capscrews evenly.

Check that the pump rotates freely with finger pressure.

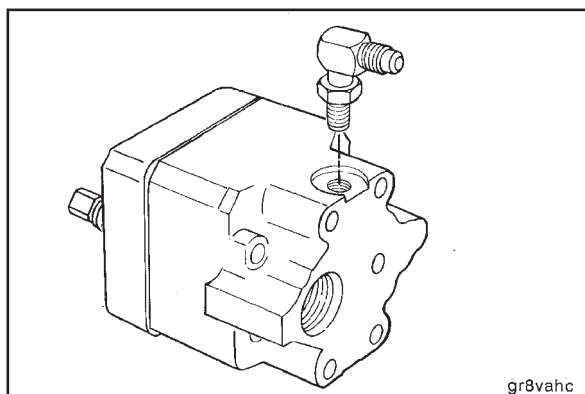
Torque Value: 18 N•m [13 ft-lb]



Shaft End Clearance

mm		in
0.023	MIN	0.0009
0.038	MAX	0.0015

NOTE: Gaskets are available in 0.51 mm [0.0020 inch] (red) and 0.038 mm [0.0015 inch] (purple). If the end clearance is **not** correct or the pump does **not** rotate freely, check for an error in the assembly procedure.



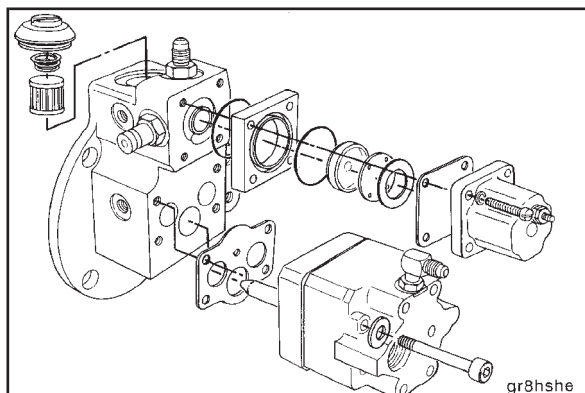
Install the check valve elbow.



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]

NOTE: If the check valve in the elbow is stuck open or closed, replace the elbow.



Place the seal expander that is included in the seal kit over the gear pump drive shaft. Use a new gasket, install the pump support on the gear pump housing. Tighten the capscrews.

Torque Value: 18 N•m [13 ft-lb]



Install the filter screen in the top of the front support. Install the shutoff valve assembly onto the pump assembly. Tighten the capscrews.

Torque Value: 18 N•m [13 ft-lb]



NOTE: Refer to solenoid rebuild instructions at the end of this section for parts orientation details.

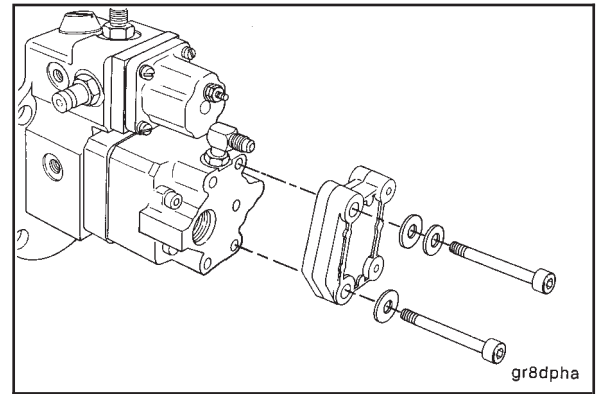
Remove the two damper mounting capscrews. Install the damper assembly with a new o-ring on the gear pump. Tighten the capscrews.

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 pump.

Check for free rotation of the gear pump.

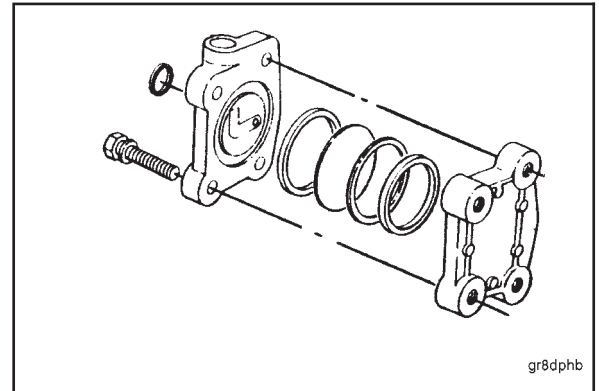


Fuel Damper - Disassembly and Inspection

Remove the housing from the cover. Remove the spring steel diaphragm. Discard the o-rings. Inspect the nylon washer, discard if 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.



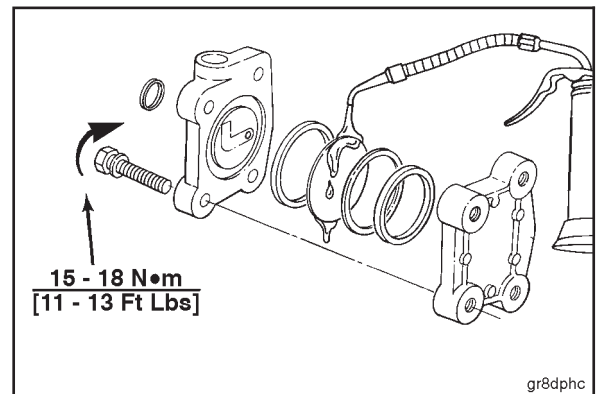
Fuel Damper - Assembly

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.

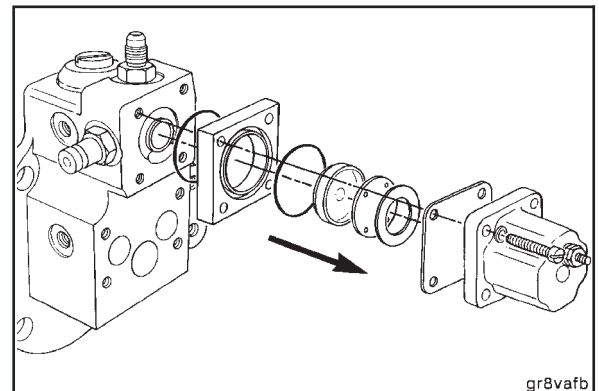
Torque Value: 18 N•m [13 ft-lb]

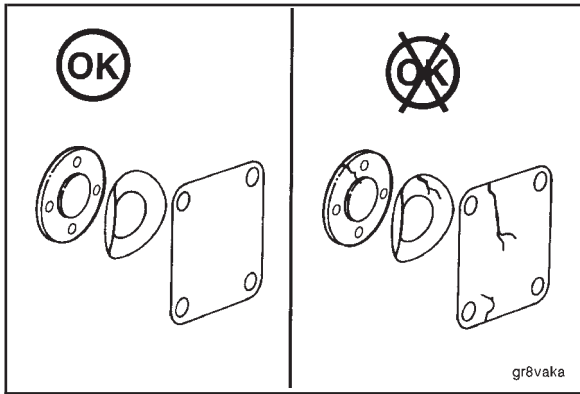


Fuel Shutoff Valve - Disassembly

Remove the coil housing and the fuel shield. Discard the o-ring.

Remove the spring washer, valve disc, actuator disc, and actuator spacer from the valve housing. Discard the o-ring.



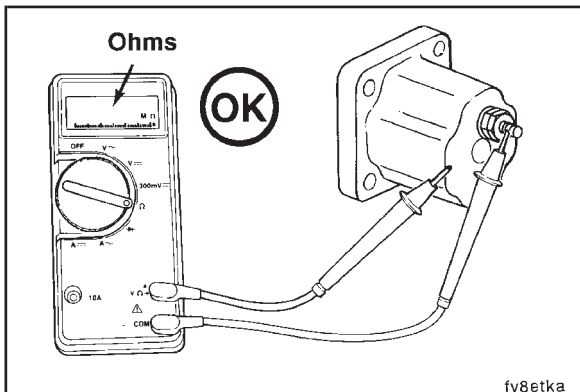


Fuel Shutoff Valve - Cleaning and Inspection

Clean all of the parts except the coil assembly in mineral spirits.

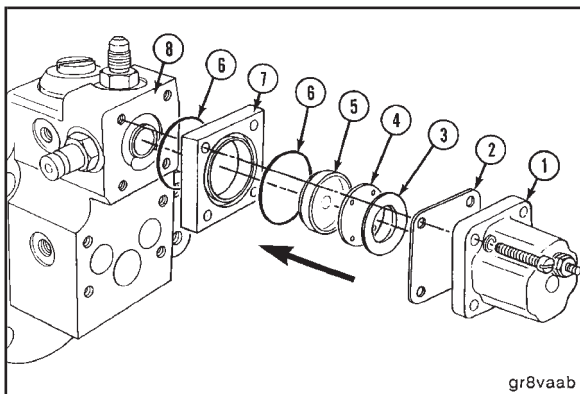
NOTE: Do **not** get the coil wet with solvent. Clean the coil with a dry cloth. Polish the coil face with a 200 grit emery cloth on a flat surface.

Visually check the valve disc, valve seat, and actuator disc for dirt, metal parts, bonding separation, corrosion, cracks or wear. Replace if necessary.



Check the coil assembly with an ohm meter. Replace the coil if it is **not** between 7 and 8 ohms resistance.

NOTE: If the coil assembly shows zero ohms, there is electrical short in the coil.



Fuel Shutoff Valve - Assembly

Assemble the shutoff valve as shown. Install these parts as follows:

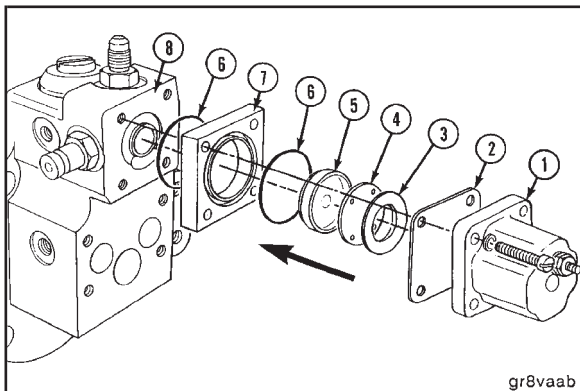
Place the pump support side down. Install a new o-ring (6).

Install the actuator disc (5) with cup side toward the coil.

Install the valve disc (4) with raised area up.

Install the spring washer (3) with cup side toward the coil.

Install the spacer (7) o-ring groove toward the coil.



Install the fuel shield (2) and coil (1) on the front cover (8). Hold the assembly together, insert the capscrews and tighten.

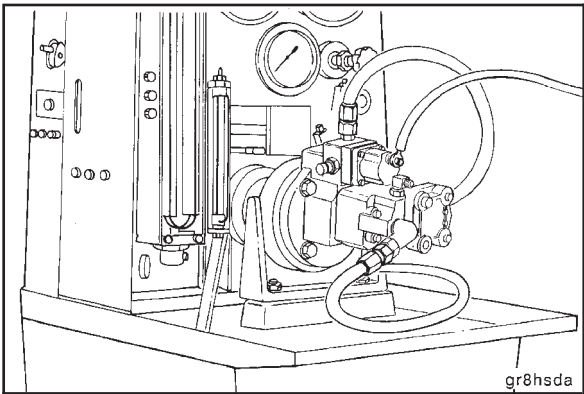


Torque Value: 3 N•m [30 in-lb]

Fuel Supply Pump - Test

Description of Test

The fuel supply pump **must** pass the specification tests. The self-priming capacity **must** be high enough to start the engine. The operating flow **must** be correct. The supply pressure **must** be regulated for fault-free fuel injector performance. The safety shutoff valve **must** stop the fuel flow at excessive pressures.

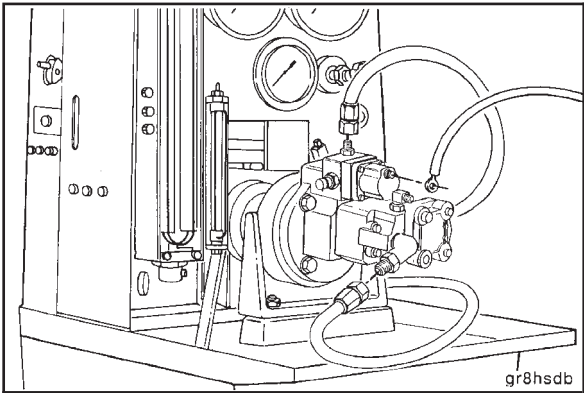


Installation

Install the supply pump assembly on the test stand, Part No. ST-848 or 3375698, with four capscrews.

The plumbing of the test stand **must** be as shown. The minimum size of the supply line is No. 10 with a maximum length of 70 inches. The minimum size of the drain is No. 5.

Connect the correct voltage to operate the shutoff valve.



Gear Pump Test

Operate the system with the inlet and outlet valves open to remove the air from the pump and the system.

Adjust the speeds and the inlet and outlet values according to the table. Check the pump flow.

NOTE: The fuel supply **must** follow the minimum and maximum pressure guidelines for the correct injector performance.

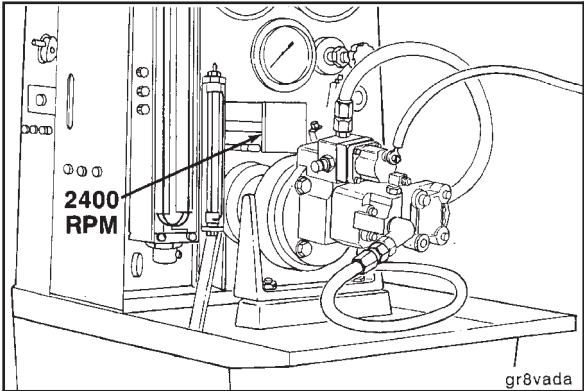
Gear Pump Flow Test			
RPM	Flow kg/hr [lb/hr]	Inlet Restriction mm Hg [in Hg]	Outlet Pressure kPa [psi]
600		51 [2.0]	
1200	236 [520]	127 [5.0]	[130-160]
2100	295 [650]	127 [5.0]	[150-180]

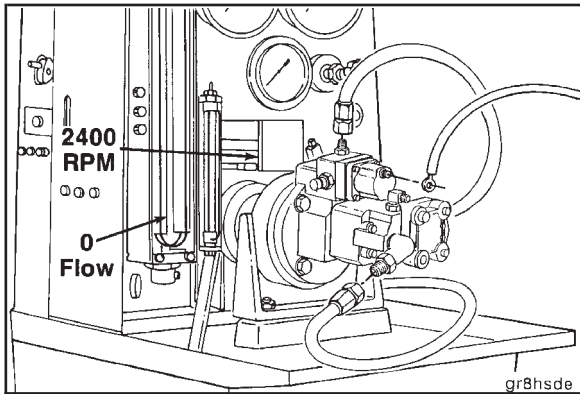
Shutoff Valve Test

Remove the air from the pump and system.

Open the inlet restriction and low control valve.

Adjust the pump speed to 2400 rpm.





Disconnect the voltage from the shutoff valve.

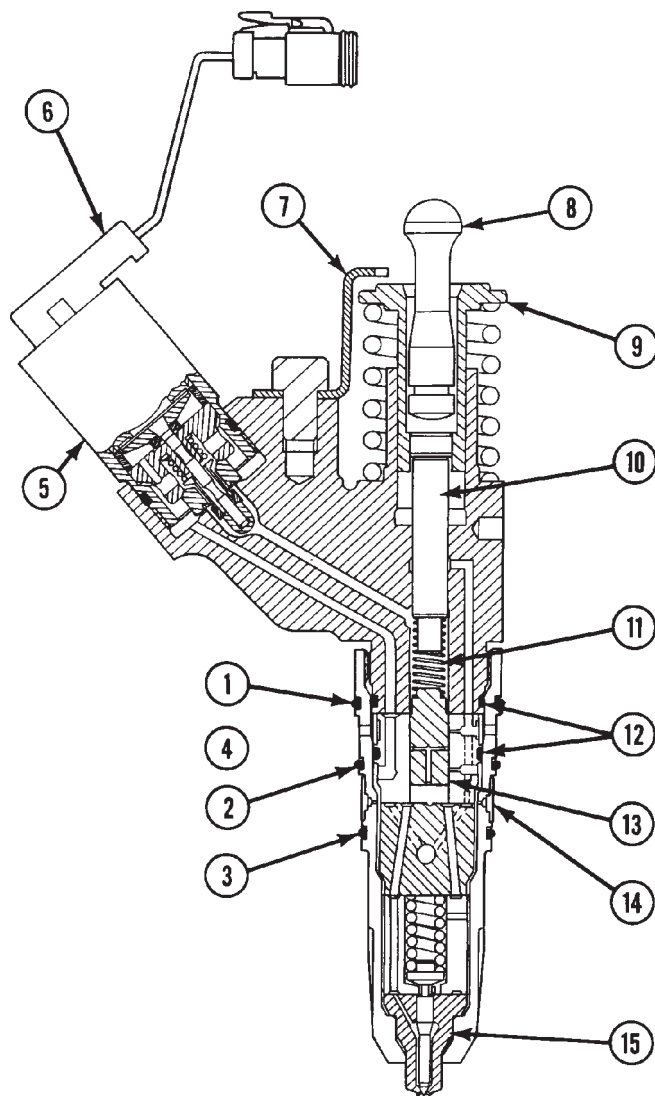
Check the outlet for leakage. No leakage **must** be evident.

NOTE: Do **not** operate the pump at 0 flow for more than 1 minute.

Section 6 - Injectors and Fuel Lines - Group 06
Section Contents

	Page
Fuel Tubes, Fittings and Mounting Parts - Cleaning and Inspection for Reuse.....	6-6
Inspection	6-6
Injector - CELECT™ - Exploded View	6-2
Injectors - Calibration	6-5
Injectors - Cleaning and Inspection for Reuse	6-4
Inspection	6-4
Injectors - General Information	6-3
Injectors - Rebuild	6-5

Injector - CELECT™ - Exploded View



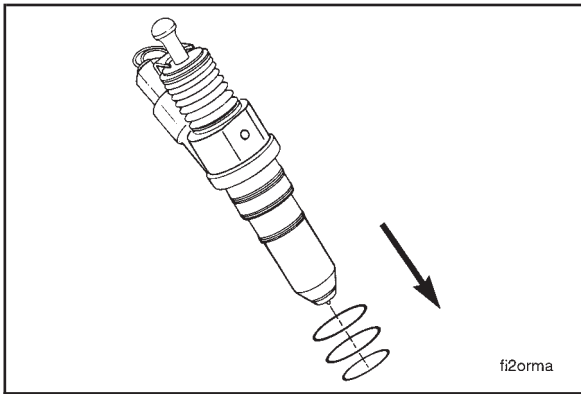
fi200g03

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1.	Seal, O-ring Top (Red)	1	9.	Coupling	1
2.	Seal, Oring Middle (White)	1	10.	Plunger, Timing	1
3.	Seal, Oring Bottom (Blue)	1	11.	Spring, Bias	1
4.	Drain, Fuel	1	12.	Seal, O-ring	2
5.	Solenoid Valve	1	13.	Plunger, Metering	1
6.	Connection, Wire Harness	1	14.	Port, Fuel Inlet	8
7.	Coupling Retainer	1	15.	Nozzle (or Cup)	1
8.	Link, Injector	1			

Injectors - General Information

The CELECT™ system allows an engine to have variable timing, depending on load, engine temperature, environmental conditions, etc. The timing and fueling rate are controlled electronically.

The injectors used in CELECT™ engines are electronically controlled, closed nozzle unit injectors.



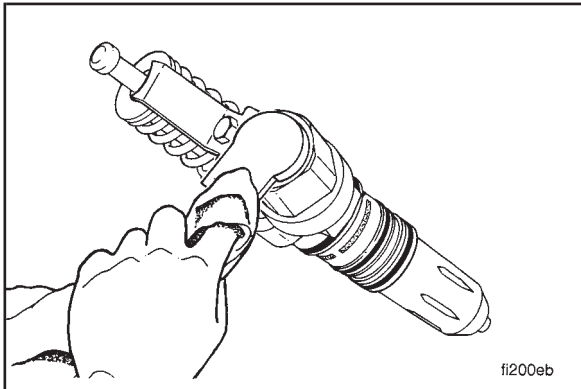
Injectors - Cleaning and Inspection for Reuse (6-01)



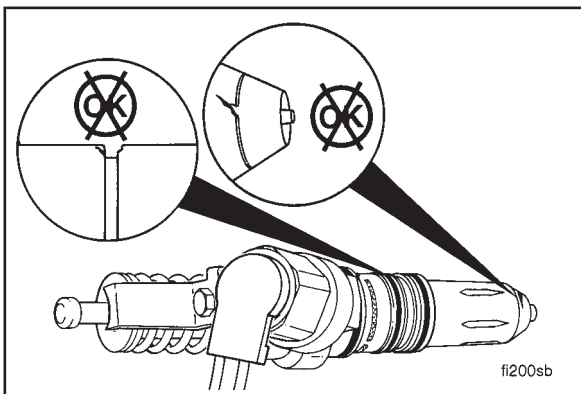
Caution: Do not remove the injector plungers or allow the plungers to fall out of the injector body. Injector plungers and barrels have a very precise fit and are damaged easily.



Remove and discard the three injector o-rings.



Use a clean, lint free cloth to clean the exterior of the injectors.

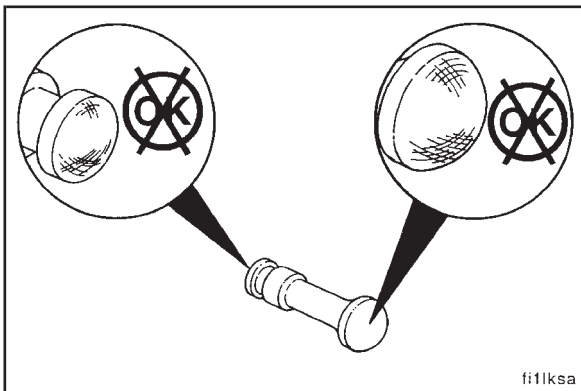


Inspection



Visually inspect the o-ring grooves for damage.

Visually inspect the injector body and cup retainer for cracks or other damage.



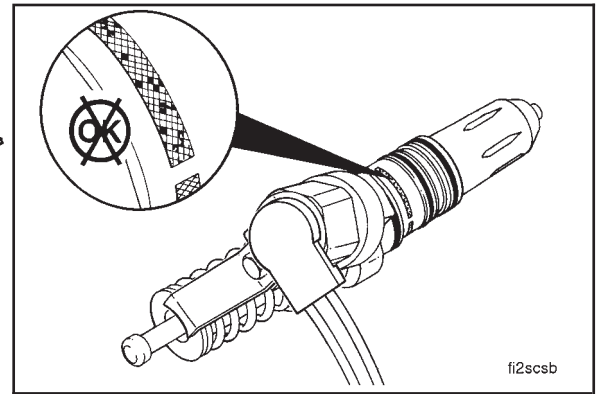
Visually inspect the injector links for damage, excessive wear, and pitting or scoring on the ball ends.

NOTE: If link damage, or the pitting or scoring can be seen or felt, the links **must** be replaced.

Visually inspect the orifice screen for damage, contamination or metal particles.

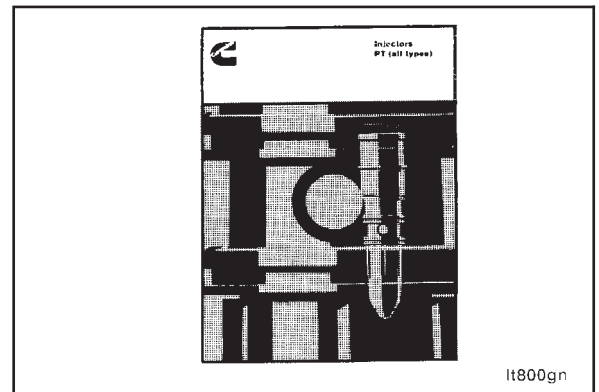
If damaged or contaminated parts are found, the injectors **must** be replaced.

NOTE: Some CELECT™ injectors do **not** contain an orifice screen.



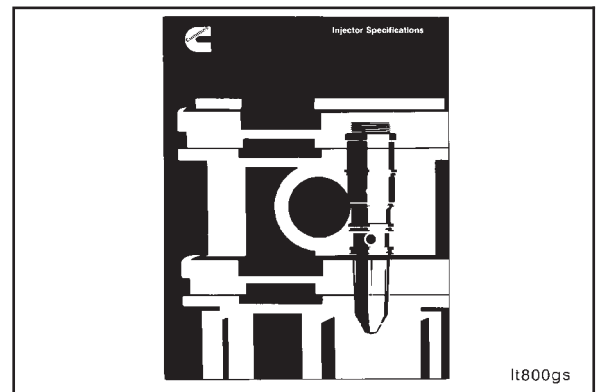
Injectors - Rebuild (6-02)

CELECT™ injectors **cannot** presently be rebuilt. They **must** be replaced with new injectors.

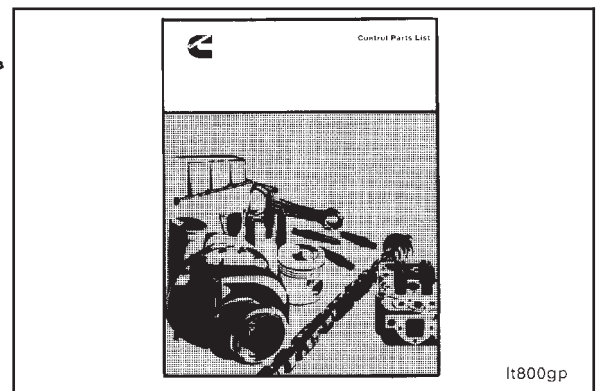


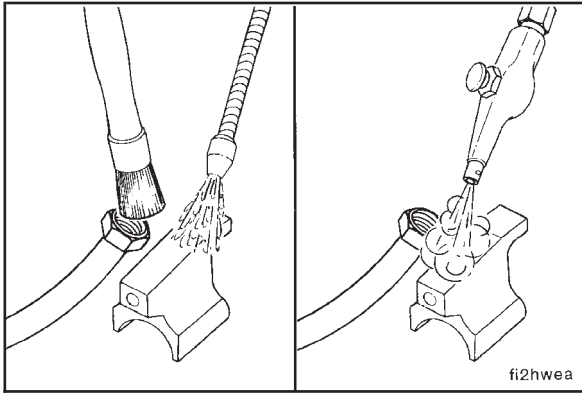
Injectors - Calibration (6-03)

NOTE: CELECT™ injectors do **not** require flow calibration.



The CPL (Control Parts List) Manual, Bulletin No. 3379133 is a listing of basic engine parts and static timing specifications which are necessary to produce a given engine performance. The CPL number stamped on the engine dataplate is used to identify parts within the engine, including the injectors.

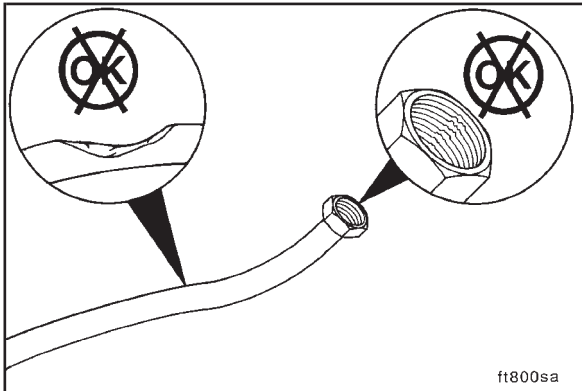




Fuel Tubes, Fittings and Mounting Parts - Cleaning and Inspection for Reuse (6-04)



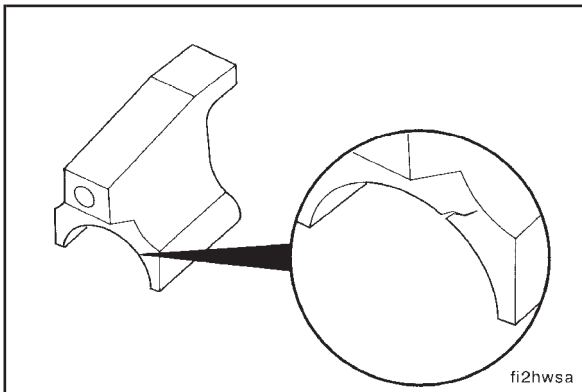
Use solvent to clean the fuel tubes, fittings and parts. Dry with compressed air.



Inspection



Visually inspect the fuel tubes for cracks or locations where the tubing is crushed. Do **not** attempt to repair fuel tubing.



Visually inspect the injector hold down clamps for cracks or other damage.

NOTE: If cracked or damaged parts are found the parts **must** be replaced.

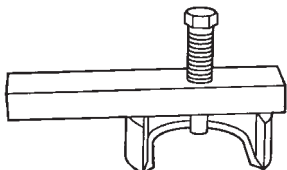
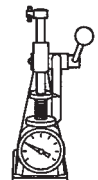
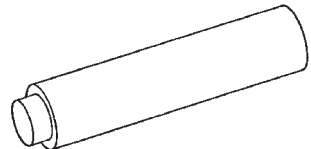
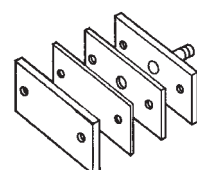
Section 7 - Lubricating Oil System - Group 07

Section Contents

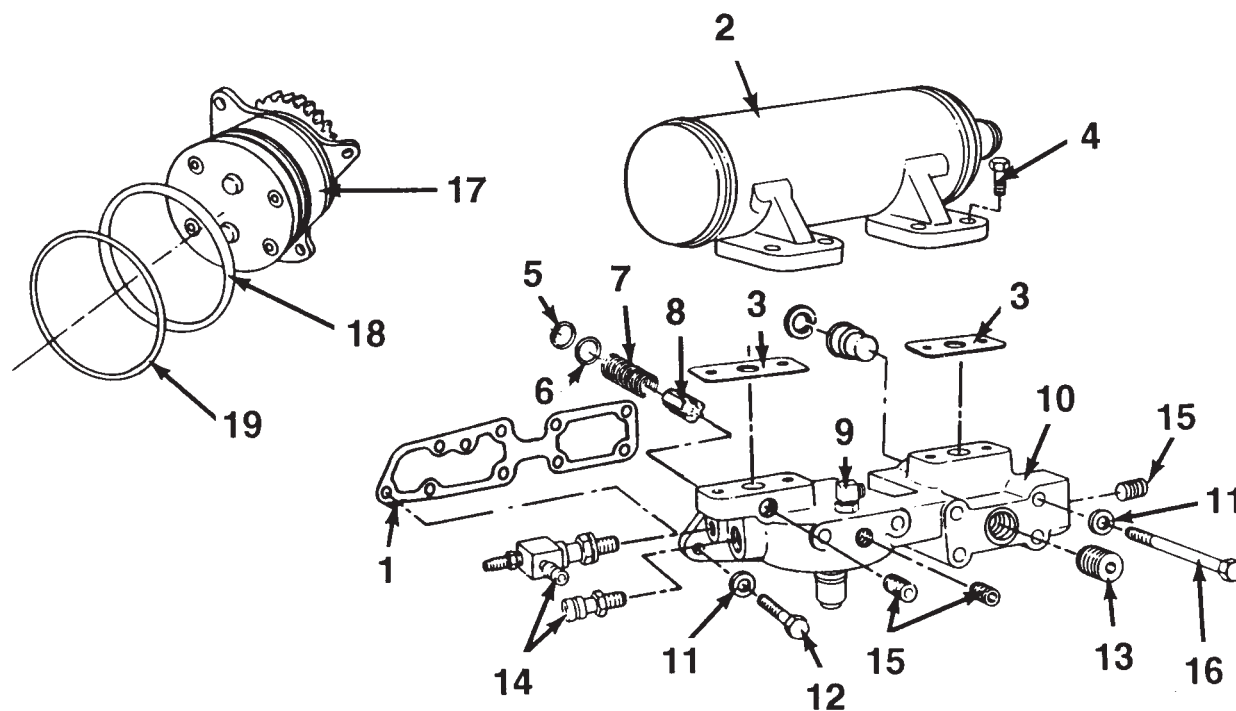
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Service Tools - Lubricating Oil System

The following special tools are recommended to perform procedures in Group 07. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

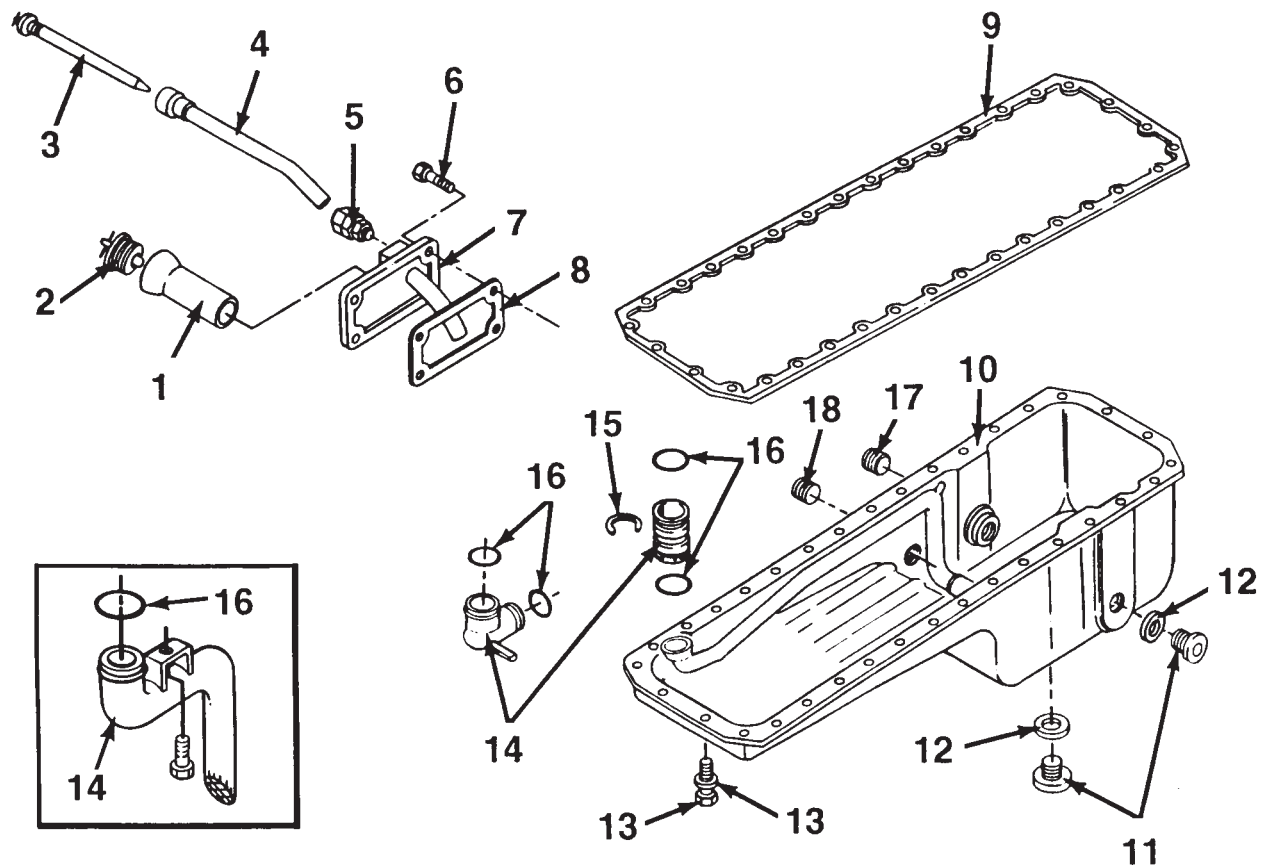
Tool No.	Tool Description	Tool Illustration
3375082	Lubricating Oil Pump Gear Puller Remove the lubricating oil pump main drive gear.	 lp2toga
3375182	Valve Spring Tester Measure the tension of the oil filter head bypass valve spring.	 kn8togs
3376816	Expansion Plug Driver Install the bypass valve regulator assembly expansion plug. Used with expansion plug driver handle, Part No. 3376795.	 ck8toga
3376861	Lubricating Oil Cooler Pressure Test Kit Pressure test the lubricating oil cooler element. Test Kit consists of: test plate 3376889, test plates 3376890 (2), and test gasket 3376866.	 lc2toga

Lubricating Oil System - Exploded View



lp200g03

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Gasket, Filter Head	1	11	Washer, Plain	9
2	Cooler, Lubricating Oil	1	12	Capscrew	3
3	Gasket	2	13	Plug	1
4	Capscrew	4	14	Compuchek®	2
5	Ring, Snap	1	15	Plug	2
6	Washer	1	16	Capscrew	5
7	Spring, Compression	1	17	Pump, Lubricating Oil	1
8	Bypass Valve	1	18	O-ring	1
9	Turbocharger Supply Fitting	1	19	O-ring	1
10	Head, Lubricating Oil Filter	1			



lp200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Tube, Oil Filler	1	10	Pan, Oil	1
2	Cap, Oil Filler	1	11	Plug, Oil Pan	2
3	Dipstick	1	12	Washer, Plain	1
4	Tube, Oil Gauge	1	13	Capscrew, Captive Washer	32
5	Connector, Tube	1	14	Tube, Oil Transfer	1
6	Capscrew	4	15	Ring, Retaining	1
7	Cover, Handhole	1	16	O-ring, Seal	2
8	Gasket, Handhole Cover	3	17	Plug, Pipe	1
9	Gasket, Oil Pan	1	18	Plug, Pipe	1

Lubricating Oil System - General Information

The lubricating oil system group consists of the oil pan, the oil pan transfer tube, the oil dipstick and tube, the oil filter head, the oil cooler and the lubricating oil pump.

Service replacement oil dipsticks do **not** have the high and low oil level marks indicated on the dipstick. The dipstick **must** be calibrated after the engine is installed in the chassis.

Instructions for pressure testing the lubricating oil cooler element are included in this manual. The oil cooler does **not** have a replaceable element and **cannot** be rebuilt in the field.

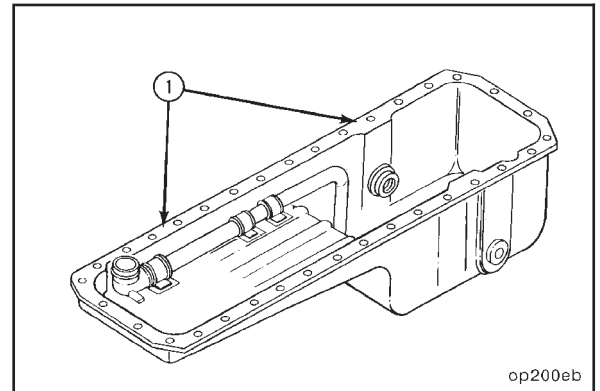
The M11 engine uses capscrews in both metric and U.S. Customary dimensions. In some cases, the capscrews are almost identical in dimensions and appearance. Be sure to install the capscrews in the same location they were removed from.

The pipe plugs and hose clamps installed in the lubricating system are U.S. Customary dimensions.

Lubricating Oil Pan - Cleaning and Inspection for Reuse (7-01)

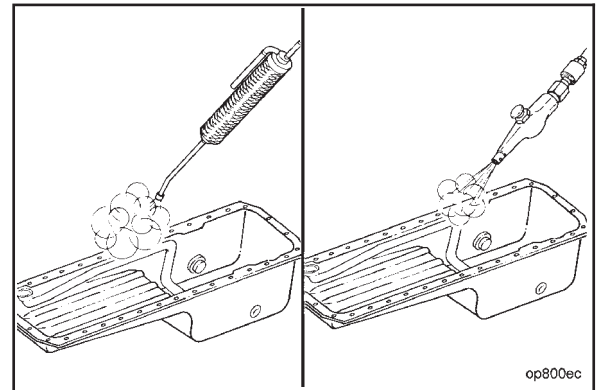
Cleaning

Remove all gasket material from the oil pan gasket sealing surface (1).



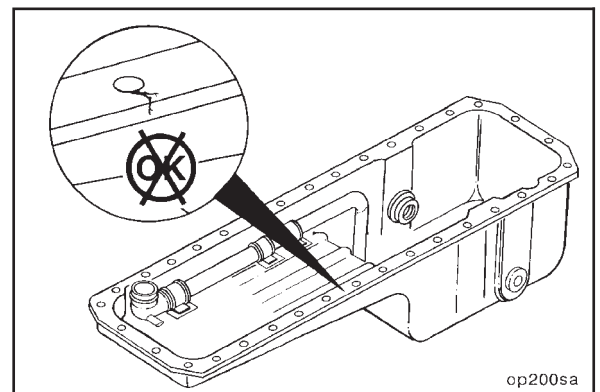
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.

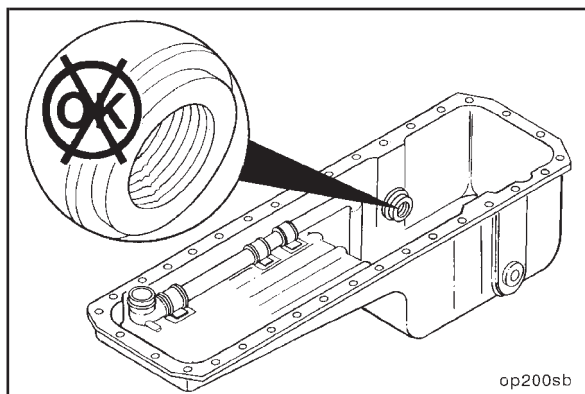
Use steam to clean the oil pan. Dry with compressed air.



Inspection

Visually inspect the oil pan for cracks or damage.

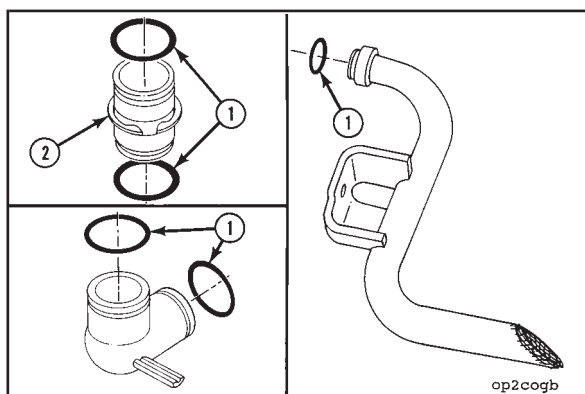




Visually inspect the threaded holes for damage. Damaged threads can be chased with the following taps.

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 oil pan is cracked or damaged, or if the threaded holes **cannot** be repaired with the taps listed above, the oil pan **must** be replaced.



Lubricating Oil Pan Transfer Tube - Cleaning and Inspection for Reuse (7-02)

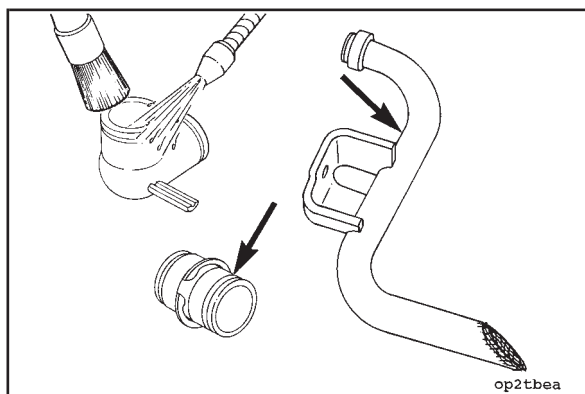
Cleaning



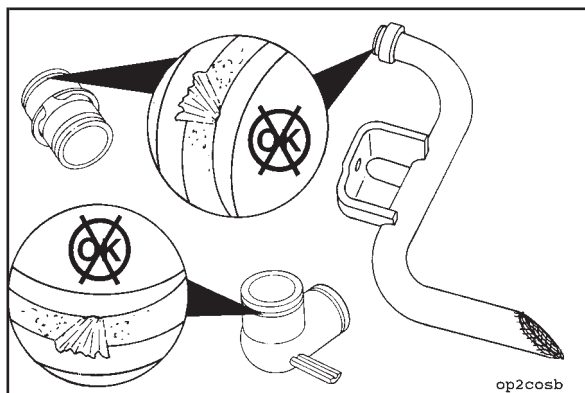
Three styles of transfer tubes are used. Front sump pans use the straight transfer tube or the block mounted suction tube. Rear sump pans use a "L" shaped tube.

Remove the o-rings (1) from the oil transfer tube.

The snap ring (2) is used to locate the straight style oil transfer tube correctly between the oil pan and the cylinder block during assembly.



Use solvent to clean the oil transfer tube. Dry with compressed air.



Inspection

Visually inspect the oil transfer tube for cracks or damage. Visually inspect the o-ring grooves for cavitation or damage.

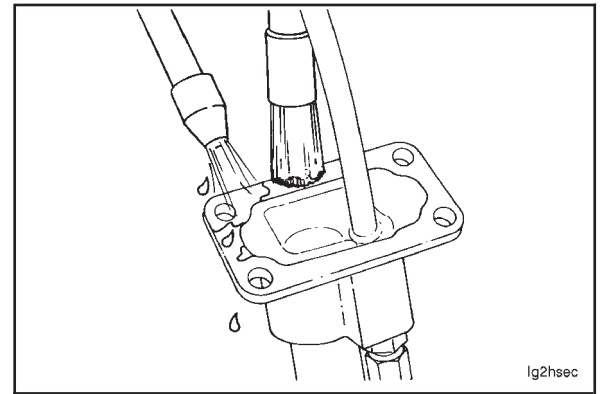
If cracks, damage or cavitation is found, the oil transfer tube **must** be replaced.

Lubricating Oil Dipstick and Dipstick Tube - Cleaning and Inspection for Reuse (7-03)

Cleaning

Remove all gasket material from the gasket sealing surface.

Use solvent to clean the dipstick and filler tube assembly. Dry with compressed air.

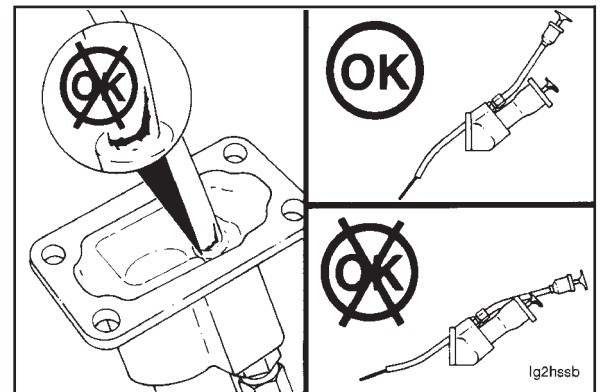


Inspection

Visually inspect the dipstick tube, filler tube and hand hole cover for cracks or damage.

Visually inspect the dipstick tube angle.

If cracks or damage is found or the dipstick tube does **not** angle downward into the oil pan, the damaged parts or dipstick tube **must** be replaced.



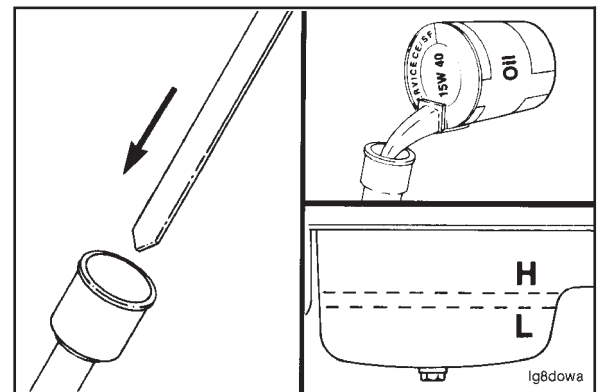
Lubricating Oil Dipstick - Calibration (7-04)

Install the dipstick in the dipstick tube.

NOTE: Be sure the engine is level. Begin this procedure with the oil pan empty.

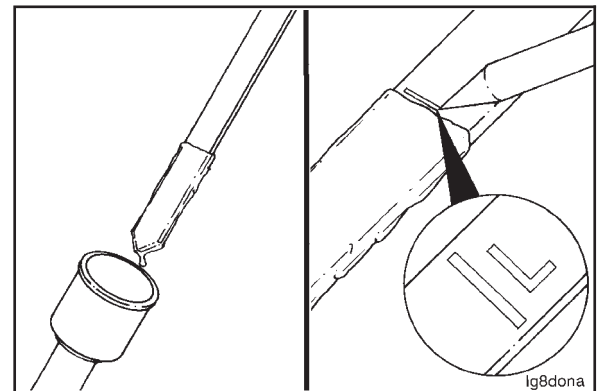
Use clean 15W-40 oil to fill the oil pan to the specified "Low" oil pan capacity level.

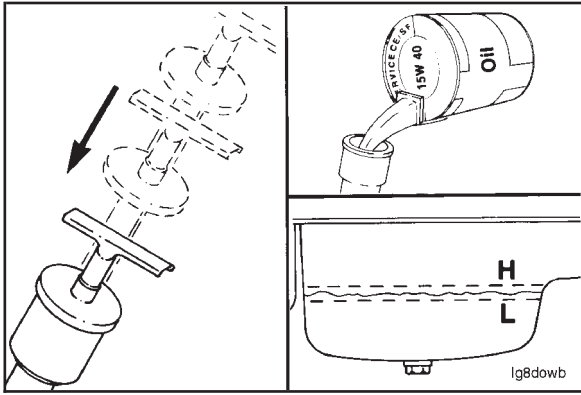
Oil Pan Capacity		
Litres		U.S. Gallons
	Automotive	
26.5	Low	7.0
34.0	High	9.0



Remove the dipstick and scribe a line across the dipstick. Mark the low oil level with an "L".

Cut the new dipstick off approximately 38 mm [1.5 inch] below the "Low" oil level mark.

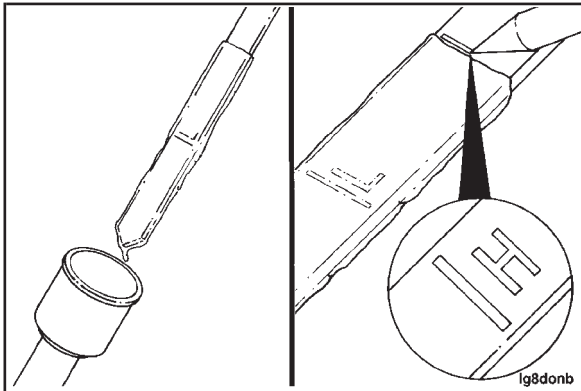




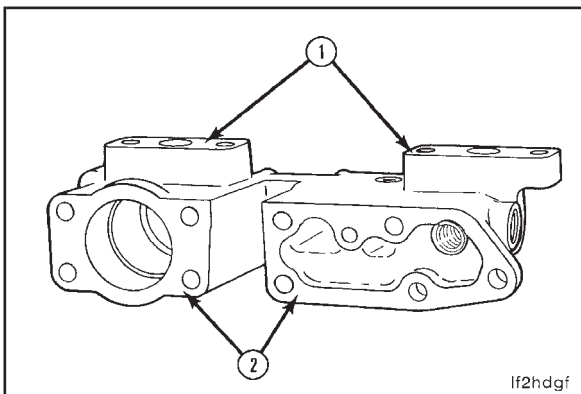
Install the dipstick in the dipstick tube.

Add enough clean 15W-40 oil to fill the oil pan to the specified "High" oil pan capacity level.

Refer to the preceding oil pan capacity table for the oil required.



Remove the dipstick and scribe a line across the dipstick. Mark the "High" oil level with an "H".

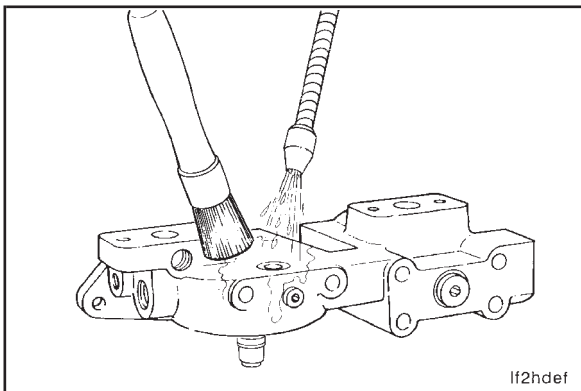


Lubricating Oil Filter Head - Cleaning and Inspection for Reuse (7-05)

Cleaning

Remove the gaskets from surfaces (1).

Remove the filter head mounting gasket material from surface (2).

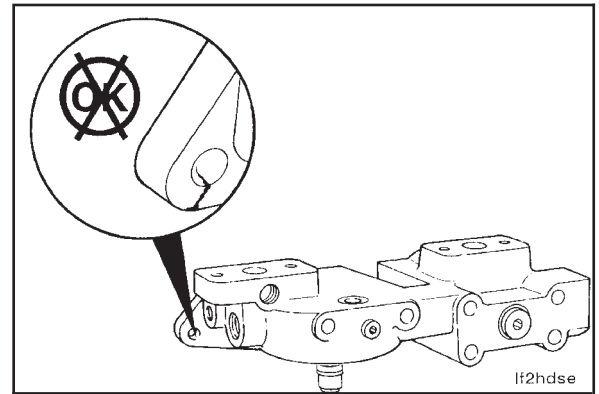


Use solvent to clean the exterior of the filter head. Dry with compressed air.

Inspection

Visually inspect the filter head for cracks or other damage.

If cracks or damage is found, the filter head **must** be replaced.



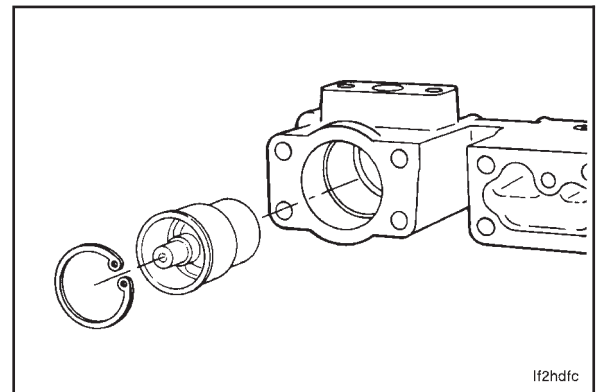
If2hdse

Lubricating Oil Filter Head - Rebuild (7-06)

Disassembly

Using snap ring pliers, remove the snap ring in the thermostat bore.

Remove the oil thermostat.



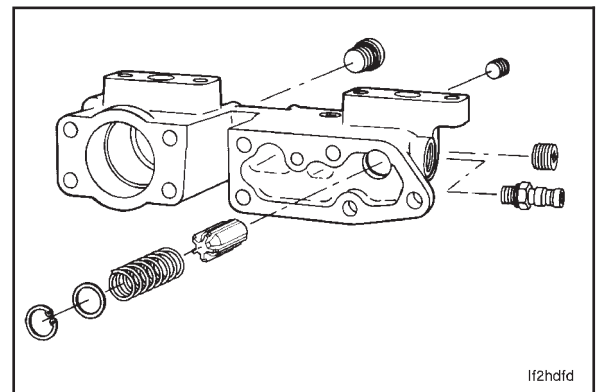
If2hdfc

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.

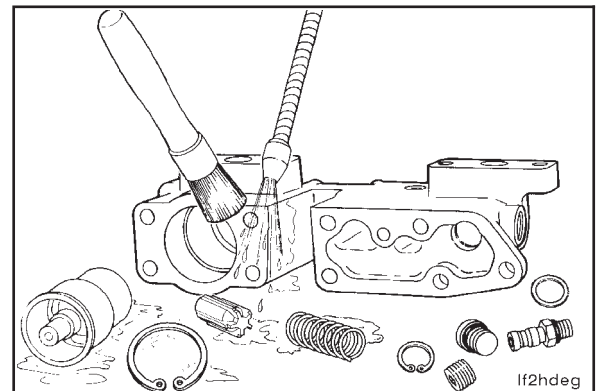
Remove the remaining plugs and fittings from the filter head.



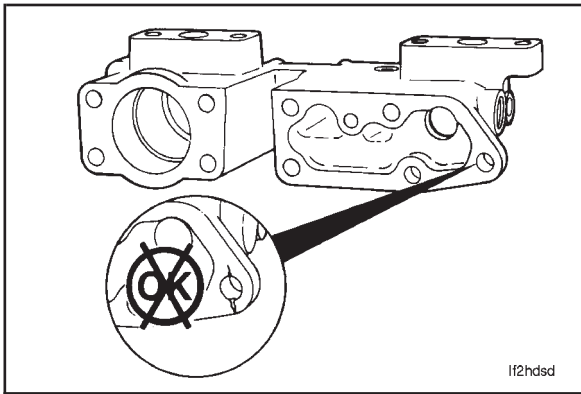
If2hdfd

NOTE: Do **not** allow dirt or gasket material to enter the oil passages when cleaning the oil filter head.

Use solvent to clean the filter head and associated parts.

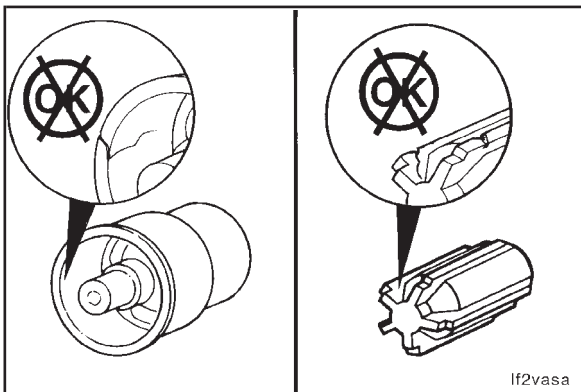


If2hdeg



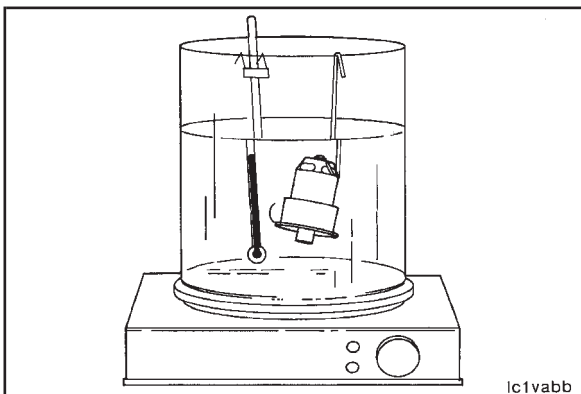
Visually inspect the filter head for cracks or other damage.

If cracks or damage is found, the filter head **must** be replaced.



Visually inspect the thermostat and bypass valve for cracks or other damage.

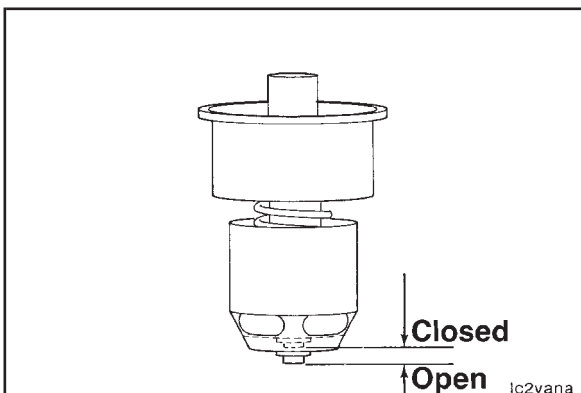
If the bypass valve is damaged, it **must** be replaced.



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.

Caution: 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.

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 115°C [240°F].

Replace the thermostat if it does **not** operate as described.

Use valve spring tester, Part No. 3375182, to inspect the operating condition of the bypass valve spring.

Spring Specifications (Free Length)		
mm		in
37.68	MIN	1.483
38.52	MAX	1.517

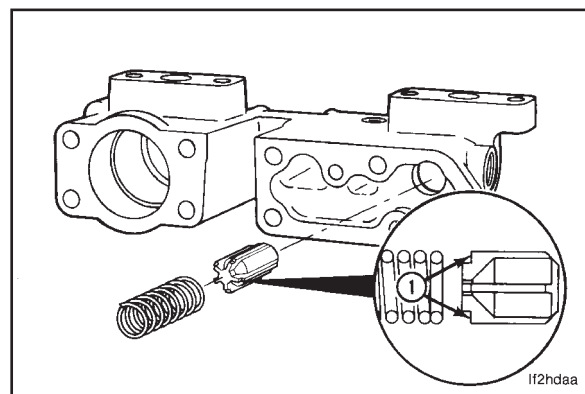
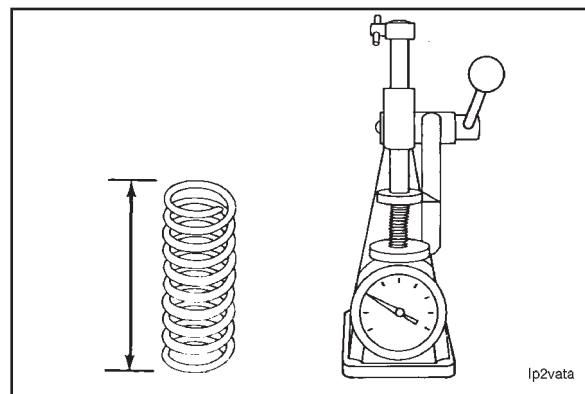
Spring Specifications at 29.65 mm [1.167 in] Load		
N		lbf
110.1	MIN	24.751
121.7	MAX	27.359

If damaged parts are found, or the bypass spring is **not** within the specifications given, the parts **must** be replaced.

Assembly

Install the bypass valve into the filter head. The notched end of the valve (1) **must** face the engine side of the filter head.

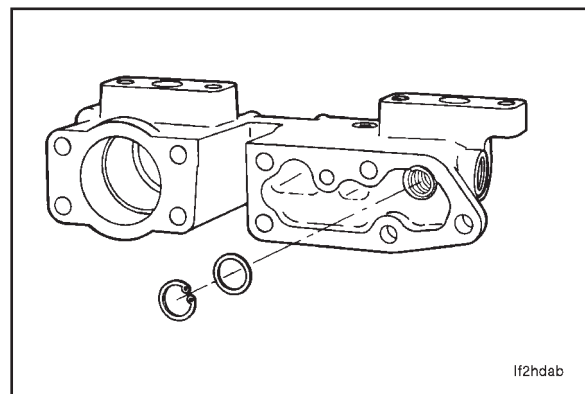
Insert the spring into the bore. Check to be sure the spring is properly located over the notched end of the valve (1).



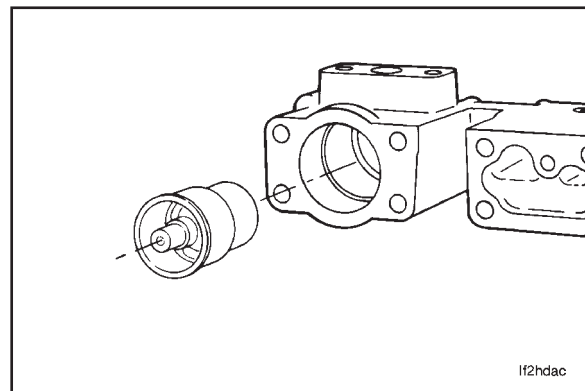
Caution: The valve spring must be compressed to install the snap ring. To avoid personal injury, wear face and eye protection.

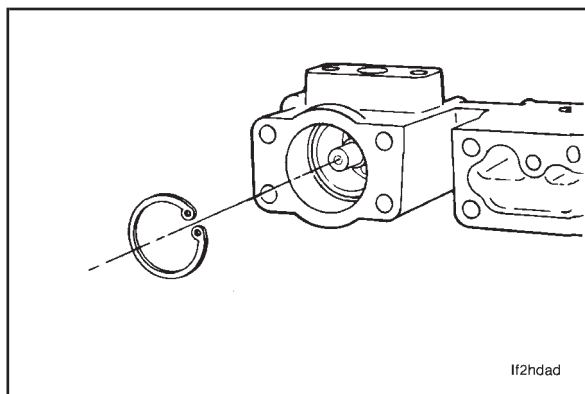
Place the washer on top of the spring.

Using snap ring pliers, install the snap ring into the groove inside the bore.

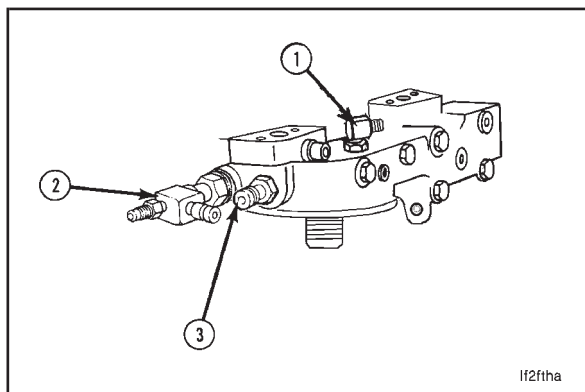


Insert the thermostat into the filter head as shown.





Using snap ring pliers, install the snap ring into the groove inside the bore.



Install the following fittings:

- Turbocharger oil supply fitting (1)

Torque Value: 12 N•m [105 in-lb]

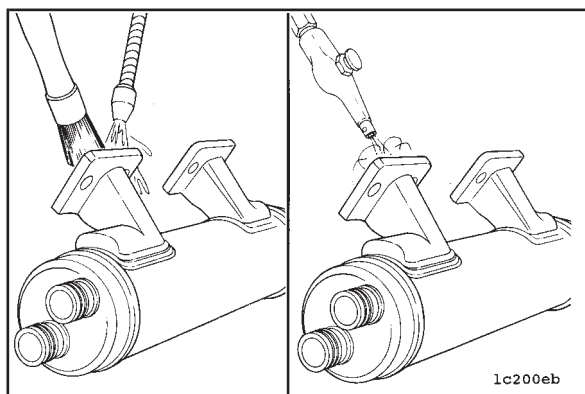
- Jacobs® brake supply fitting (2)

Torque Value: 12 N•m [105 in-lb]



- Compuchek® fitting (3).
- Remaining plugs

Torque Value: 25 N•m [20 ft-lb]

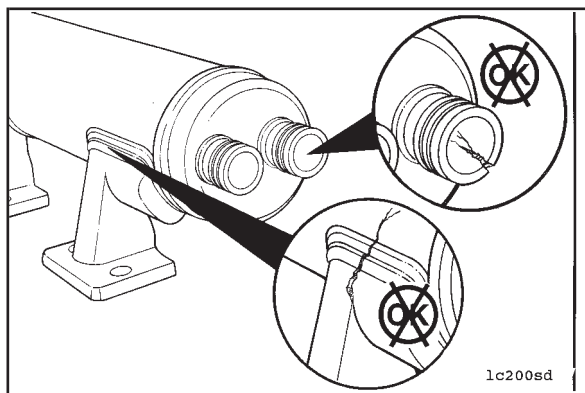


Lubricating Oil Cooler - Cleaning and Inspection for Reuse (7-07)

Cleaning



Use solvent to clean the outside of the oil cooler assembly. Dry with compressed air.



Inspection

Caution: Do not reuse an oil cooler after a progressive damage failure has resulted in metal particles in the lube oil filter. There is no practical method to clean the oil cooler core, and metal particles can be circulated through the lubricating system and cause engine damage after a repair.



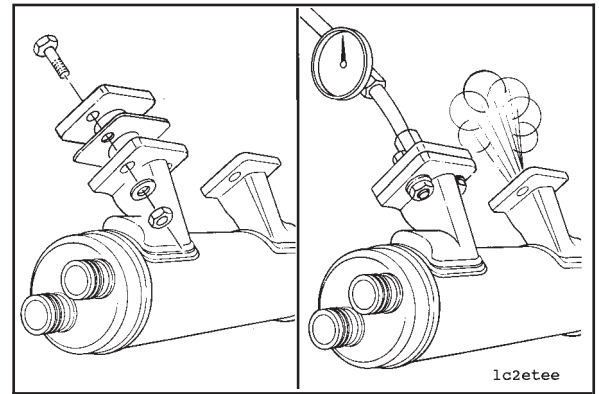
Visually inspect the oil cooler for cracks or damage.

If cracks or damage are found, the oil cooler **must** be replaced.

Use the lubricating oil cooler pressure test kit, Part No. 3376861, to seal the oil passage.

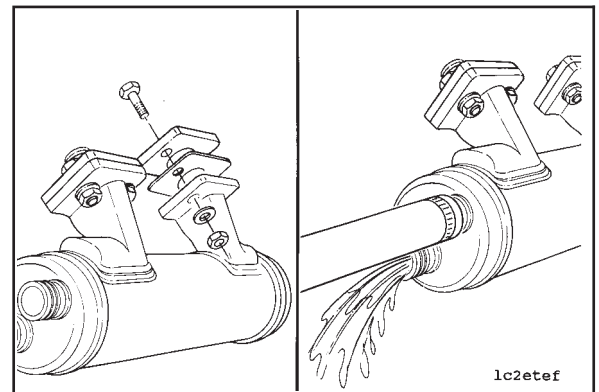
Install one of the pressure test plates on one of the oil passage openings.

Use air pressure to blow the moisture from inside the oil passages.



Use a cooling system cleaner attached to the coolant outlet side of the housing to flush the coolant passages.

If the oil or coolant passages are contaminated by foreign material, the oil cooler **must** be replaced.



Pressure Test the Oil Cooler Element

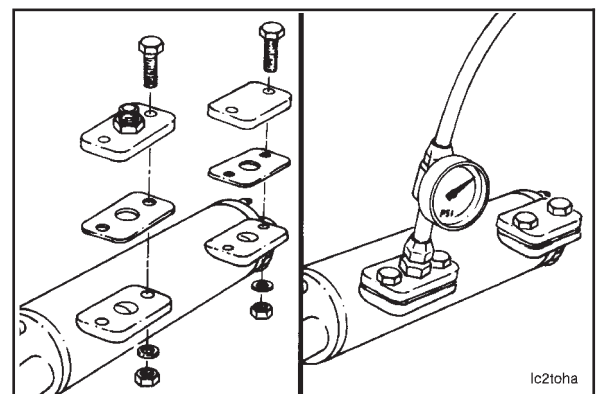
Use the lubricating oil cooler pressure test kit, Part No. 3376861, to pressure test the oil cooler element.

Install the two gaskets and test plates to the oil passage openings.

Install a regulated air pressure line to the Part No. 3376869 Test Plate.

Apply air pressure.

Air Pressure: 414 kPa [60 psi]

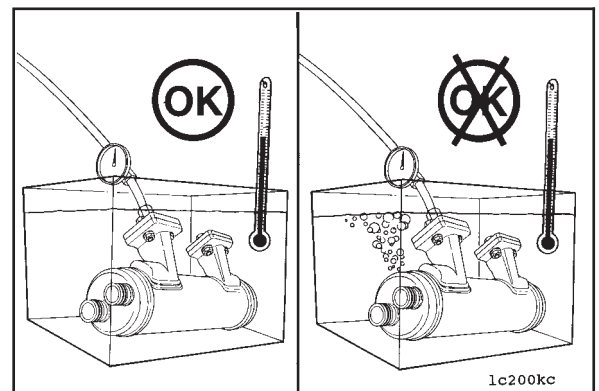


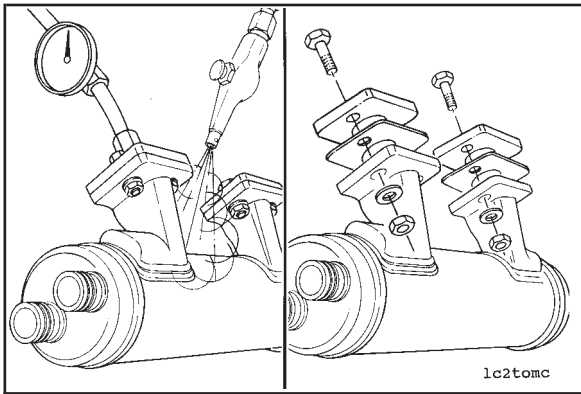
Install the oil cooler in a tank of water.

Temperature: 82°C [180°F]

Check for leaks.

If leaks are found in the oil cooler element, the oil cooler **must** be replaced.





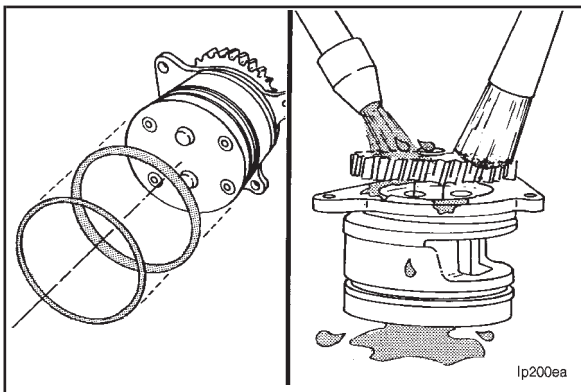
Remove the oil cooler from the tank of water.



Remove the pressure test equipment.

Use compressed air to dry the oil cooler.

Cover all of the openings with tape to prevent dirt from entering the element when the oil cooler is **not** in use.



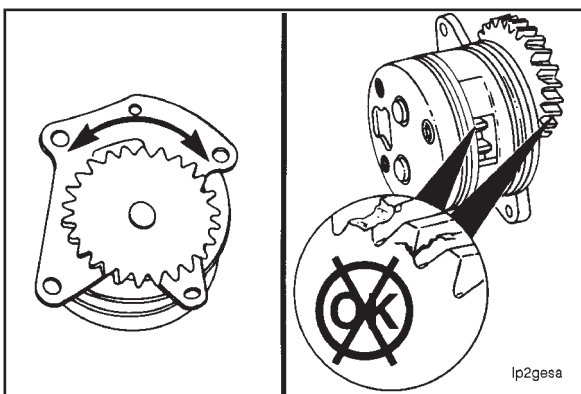
Lubricating Oil Pump - Cleaning and Inspection for Reuse (7-08)

Cleaning

Remove the two sealing o-rings. Discard the o-rings.



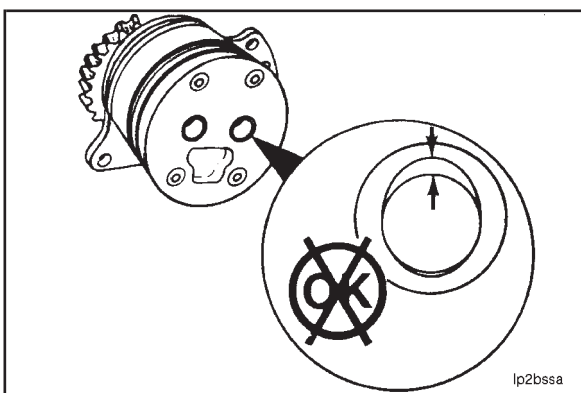
Use solvent to clean the oil pump. Dry with compressed air.



Inspection

Turn the main drive gear by hand to inspect the external gear for freedom of rotation.

Visually inspect the gear for cracked or broken teeth.

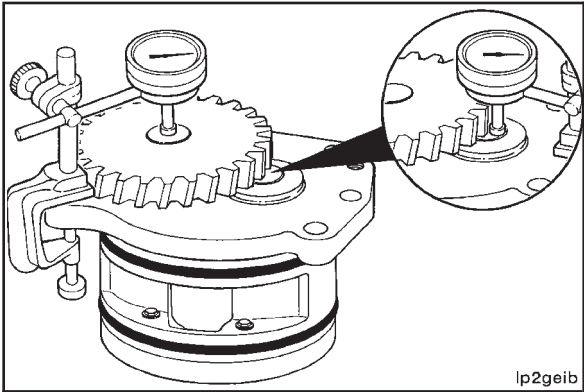


Visually inspect the rear cover plate shaft bores for excessive wear or discoloration due to overheating or shaft seizure.

Measure the drive shaft end clearance in two locations 90 degrees apart.

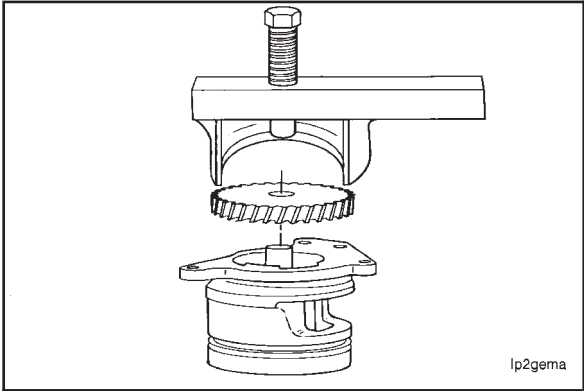
Shaft End Clearance		
mm		in
0.064	MIN	0.0025
0.269	MAX	0.0106

If the main drive gear does **not** turn freely by hand, cracked or broken gear teeth are found, or the shaft end clearance is **not** within the specifications given, the oil pump **must** be disassembled for further inspection.



Disassembly

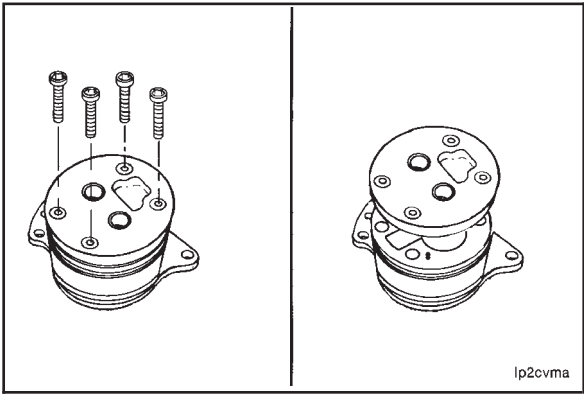
Use the lubricating oil pump gear puller, Part No. 3375082, to remove the main drive gear.



Remove the rear cover plate capscrews.

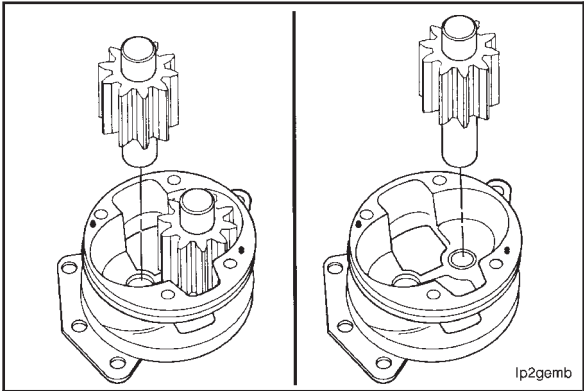
Remove the rear cover plate.

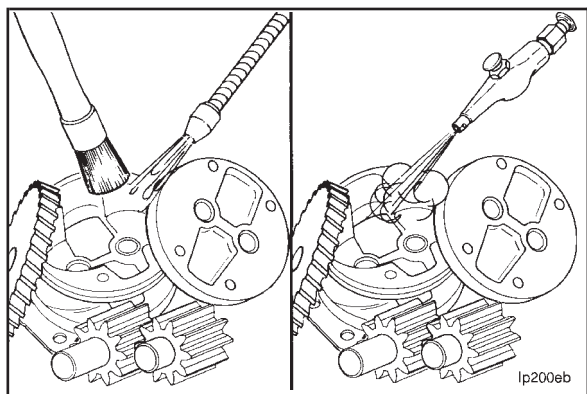
The cover is located with dowel pins. Use care **not** to damage or break the dowels.



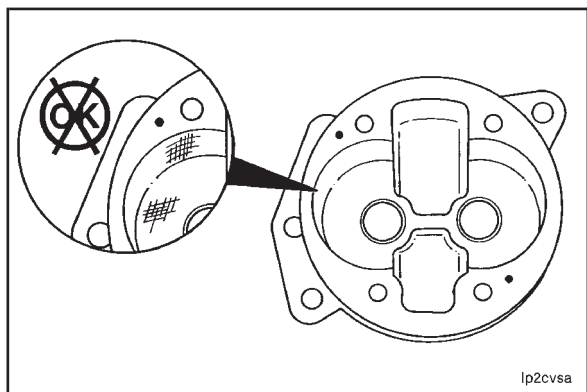
Remove the driven gear and shaft from the pump body.

Remove the drive gear and shaft from the pump body.





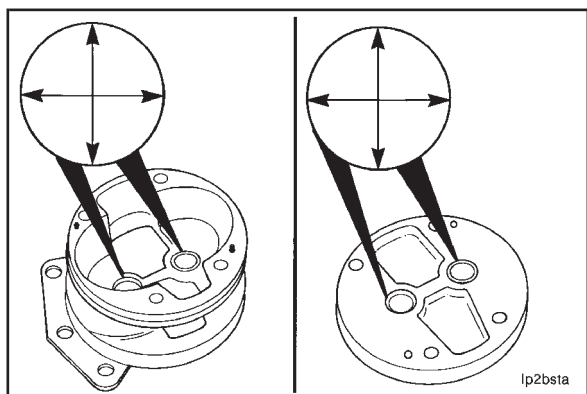
Use solvent to clean the oil pump parts. Dry with compressed air.



Inspection

Visually inspect the gear pockets in the pump body for excessive wear or scoring.

If excessive wear or scoring is found, the oil pump **must** be replaced.

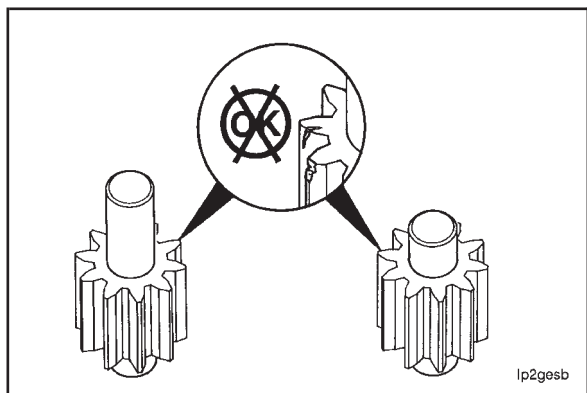


Caution: To avoid oil pump failure and engine damage, do not attempt to drill and ream the oil pump body and cover plate.



Measure the inside diameter of the shaft bores in the oil pump body and cover plate.

Shaft Bore I.D.		
mm		in
18.720	MIN	0.7370
18.746	MAX	0.7380



Visually inspect the internal oil pump gears for cracked or broken teeth and excessive wear.

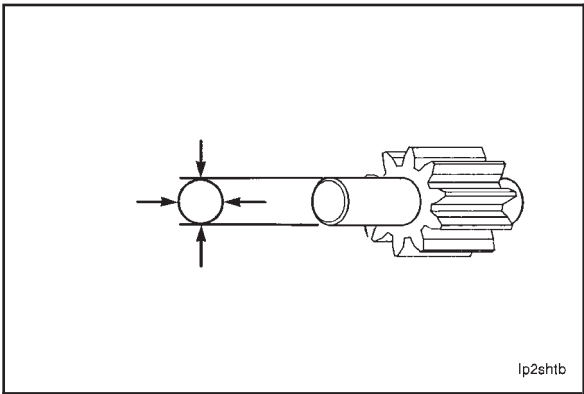
If cracked or broken teeth or excessive wear is found, the gear(s) **must** be replaced.

Measure the outside diameter of the oil pump gear shafts.



Gear Shafts O.D.		
mm		in
18.669	MIN	0.7350
18.681	MAX	0.7355

If the gear shafts are worn beyond the minimum limit specified, the shaft(s) **must** be replaced.

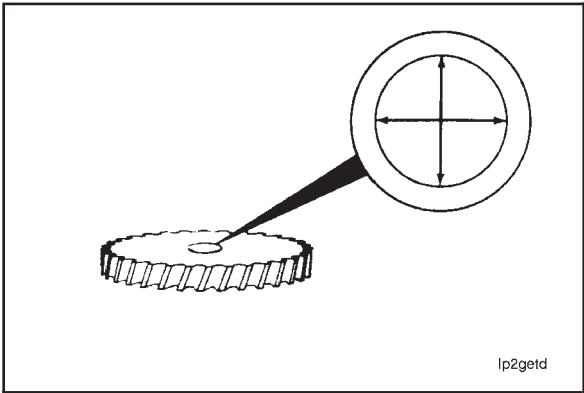


Measure the inside diameter of the drive gear bore.



Drive Gear Bore I.D.		
mm		in
18.600	MIN	0.7323
18.625	MAX	0.7333

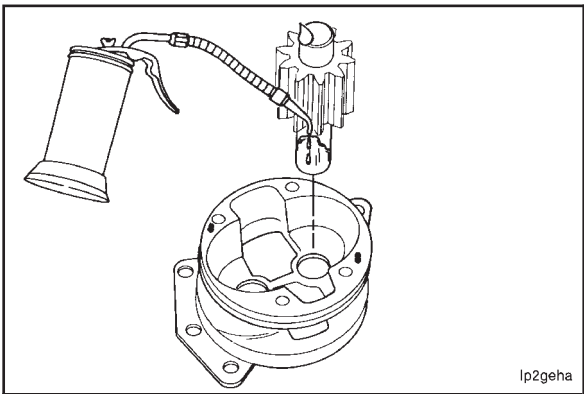
If the drive gear bore is worn beyond the maximum limit, the drive gear **must** be replaced.



Assembly

Use clean 15W-40 oil to lubricate the internal drive gear and shaft.

Install the drive gear and shaft in the oil pump body.

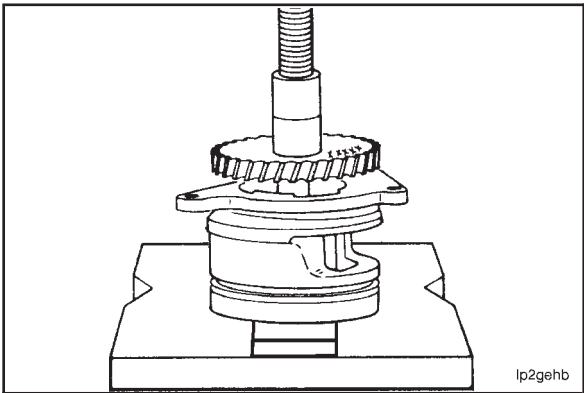


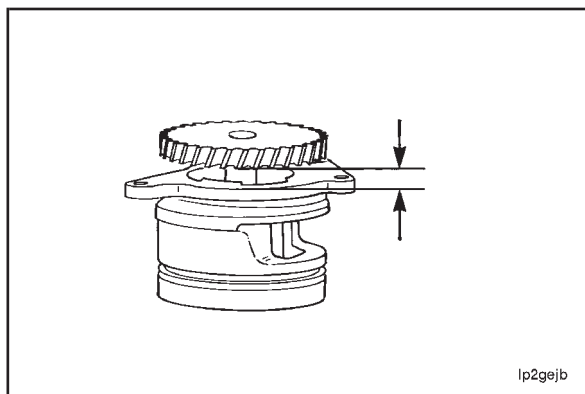
Install the oil pump body in an arbor press with the front of the body facing up. Make sure the flat surface of the pump body, and **not** the dowel pins, is resting against the press table.

Make sure the end of the drive shaft is supported.

Install the drive gear on the shaft with the part number facing up.

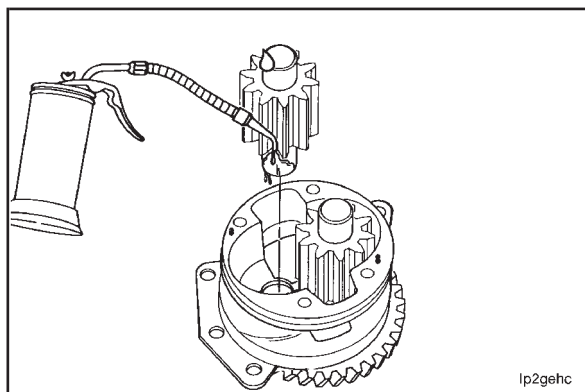
Press the gear on the shaft far enough to leave the specified clearance between the gear and pump body.





Measure the drive gear to pump body clearance.

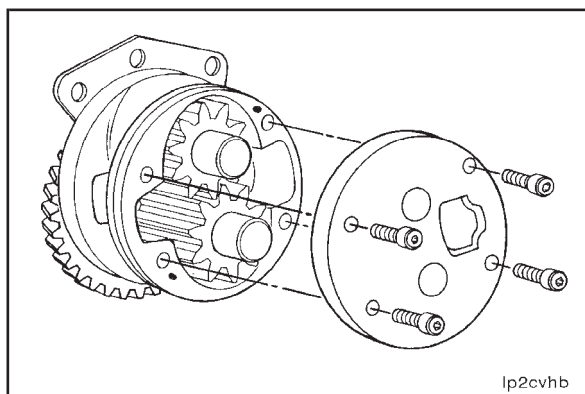
Gear to Body Clearance		
mm		in
9.50	MIN	0.37
12.00	MAX	0.47



Use clean 15W-40 oil to lubricate the driven gear and shaft.



Install the driven gear and shaft into the oil pump body.

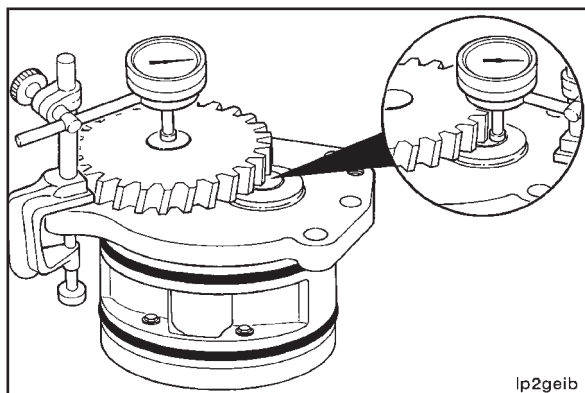


Align the dowel pins in the body with the locating holes in the cover. Install the rear cover plate and the four hex head capscrews.



Alternately tighten the four hex head capscrews.

Torque Value: 20 N•m [18 ft-lb]



Turn the drive gear by hand to check the shafts and gears for freedom of rotation.

Measure the drive shaft end clearance in two locations 90 degrees apart.

Shaft End Clearance		
mm		in
0.064	MIN	0.0025
0.270	MAX	0.0106

If the end clearance does **not** meet the specifications, the pump **must** be disassembled, inspected and assembled again.

Lubricating Oil Pump - Rebuild (7-09)

Caution: The lubricating oil pump body cannot be drilled and reamed due to the highly precise and sophisticated drilling and reaming required. Attempting to rebuild the oil pump can cause oil pump failure and future engine damage.



NOTES

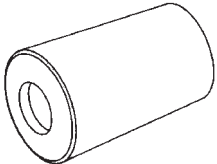
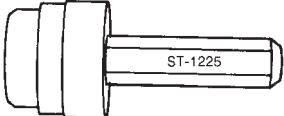
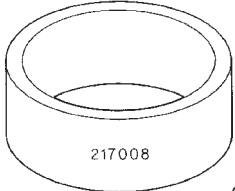
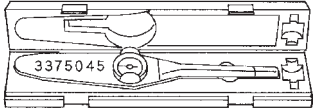
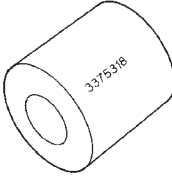
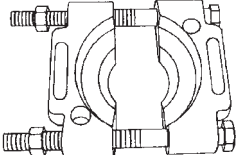
Section 8 - Cooling System - Group 08

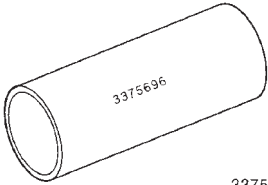
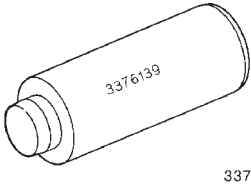
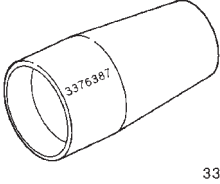
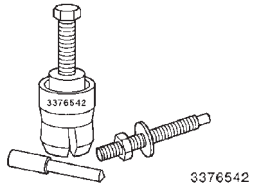
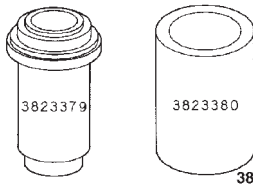
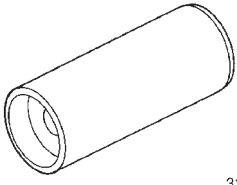
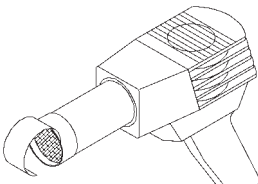
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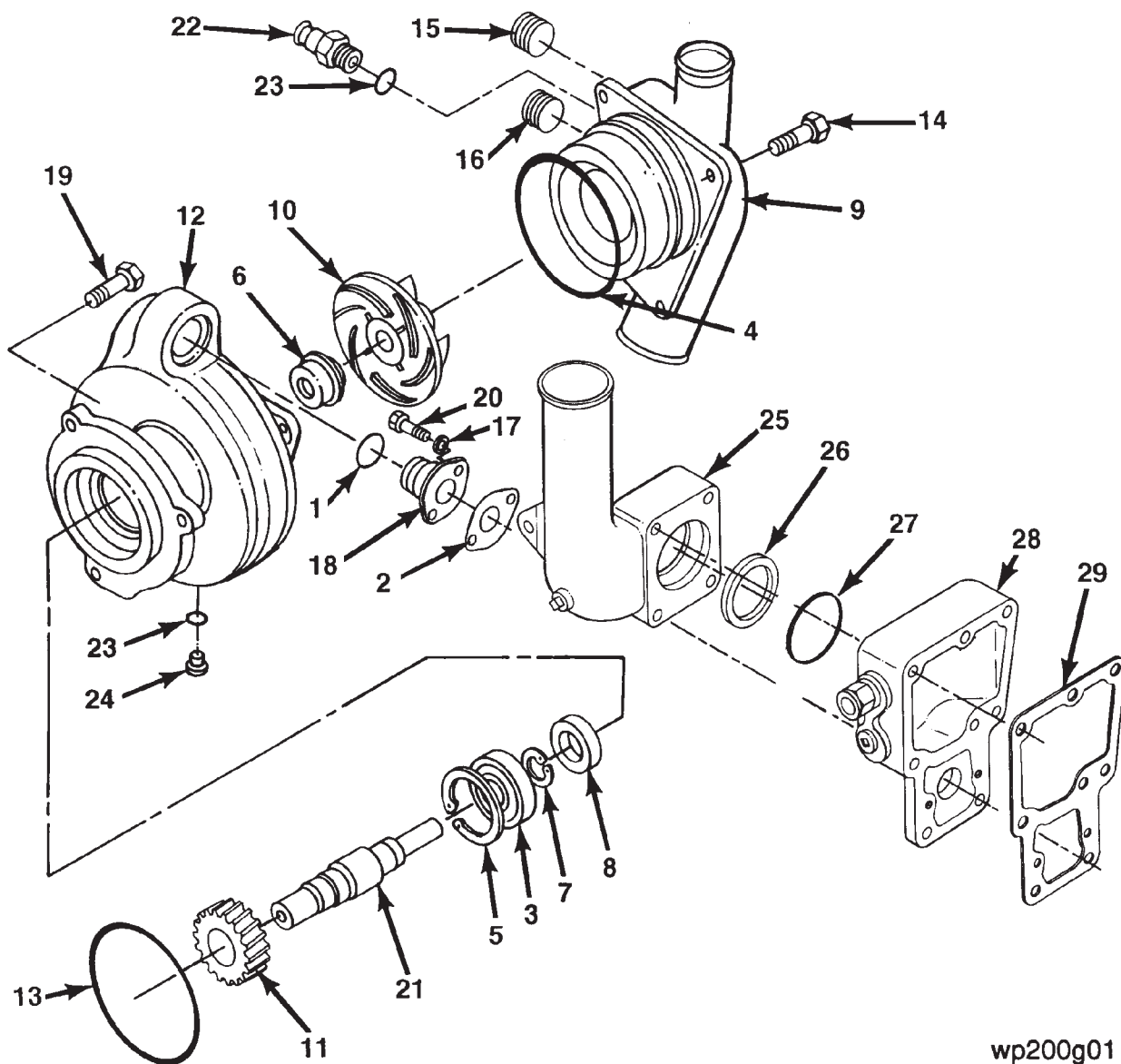
Service Tools - Cooling System

The following special tools are recommended to perform procedures in Group 08. 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-658	Water Pump Bearing Mandrel Install the water pump bearing on the shaft.	 st-658
ST-1225	Thermostat Seal Mandrel Install the thermostat seal in the thermostat housing.	 th2togb
217008	Spacer Used to support fan hub shaft during assembly when the shaft is shorter than 95.2 mm [3.75 in].	 217008
3375045	Torque Wrench Used to torque water pump cover capscrews.	 3375045
3375318	Water Pump Bearing Mandrel Install the water pump bearing on the shaft.	 3375318
3375326	Water Pump Bearing Separator Remove the water pump bearings from the shaft.	 3375326

Tool No.	Tool Description	Tool Illustration
3375696	Bearing Driver Install the bearing races in the fan idler pulley.	
3376139	Water Pump Oil Seal Driver Install the water pump oil seal in the water pump body.	
3376387	Water Pump Oil Seal Expander Install the water pump shaft assembly into the water pump body.	
3376542	Water Pump Impeller Puller Kit Remove or install the water pump impeller. The kit consists of: spacer pin, Part No. 3376543, puller sleeve, Part No. 3376544, compression sleeve, Part No. 3376545, pressure screw, Part No. 3376546, pusher screw, Part No. 3376547, friction puller, Part No. 3376548, puller halves, Part No. 3376549 (two required) and spacer pin, Part No. 3822296.	
3823378	Fan Hub Rebuild Kit Used to remove or install new bearings during a fan hub rebuild. Kit contains bearing driver, Part No. 3823379, and disassembly pot, Part No. 3823380.	
3823815	Water Pump Seal Driver Install the water pump seal in the water pump body.	
3823851	Water Pump Gear Mandrel Install the water pump shaft into the water pump gear.	

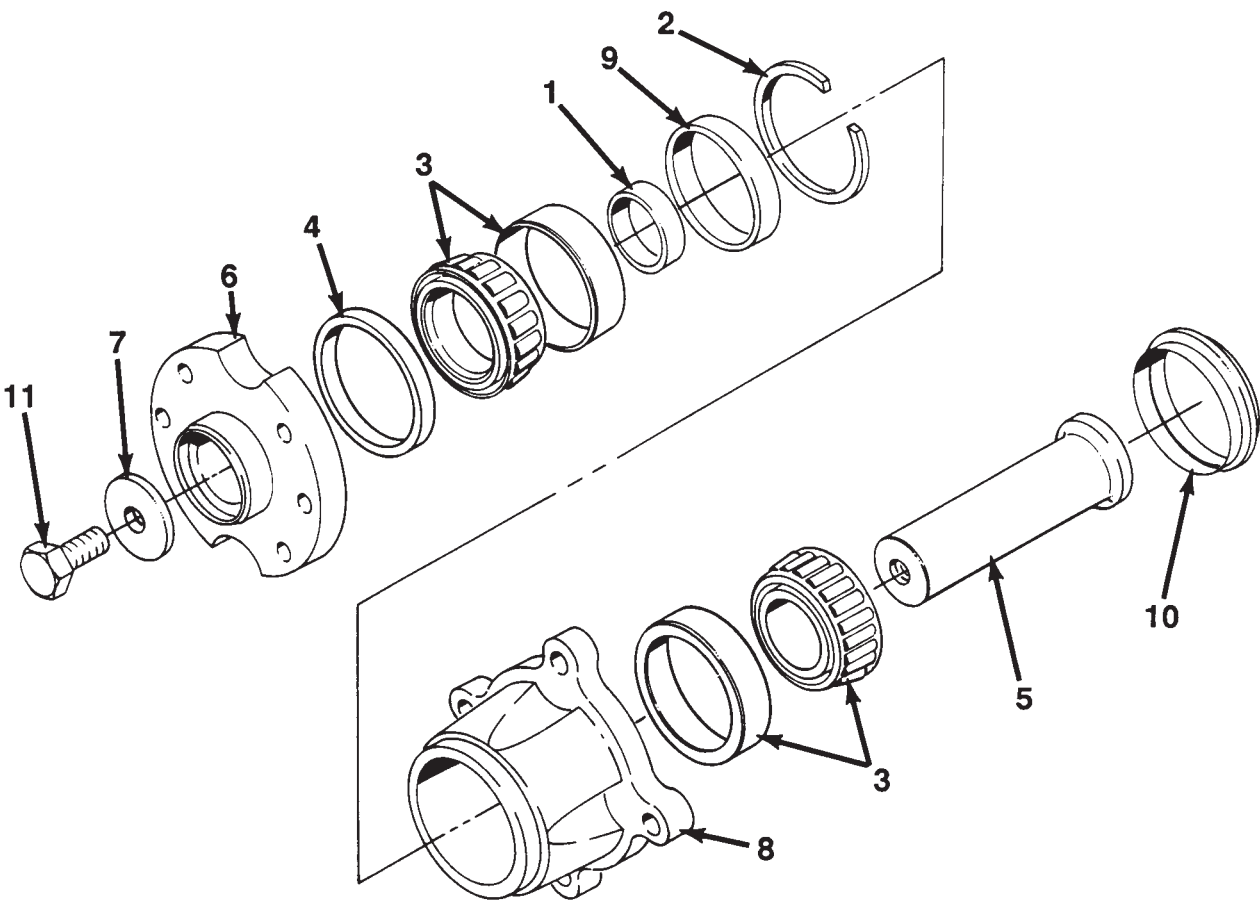
Water Pump Assembly - Exploded View



wp200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Seal, O-ring	2	16	Plug, Pipe	1
2	Gasket, Connection	1	17	Washer, Plain	2
3	Bearing, Ball	1	18	Connection, Water Transfer	1
4	Seal, O-ring	1	19	Capscrew	4
5	Ring, Retaining	1	20	Capscrew	2
6	Seal, Water Pump	1	21	Shaft, Water Pump	1
7	Ring, Retaining	1	22	Compuchek® Fitting	1
8	Seal, Oil	1	23	Seal, O-ring	2
9	Cover, Water Pump	1	24	Threaded Plug	1
10	Impeller, Water Pump	1	25	Thermostat Housing	1
11	Gear, Water Pump	1	26	Thermostat Housing Seal	1
12	Body, Water Pump	1	27	Seal, O-Ring	1
13	Seal, O-ring	1	28	Thermostat Housing Support	1
14	Capscrew	3	29	Gasket	1
15	Plug, Pipe	1			

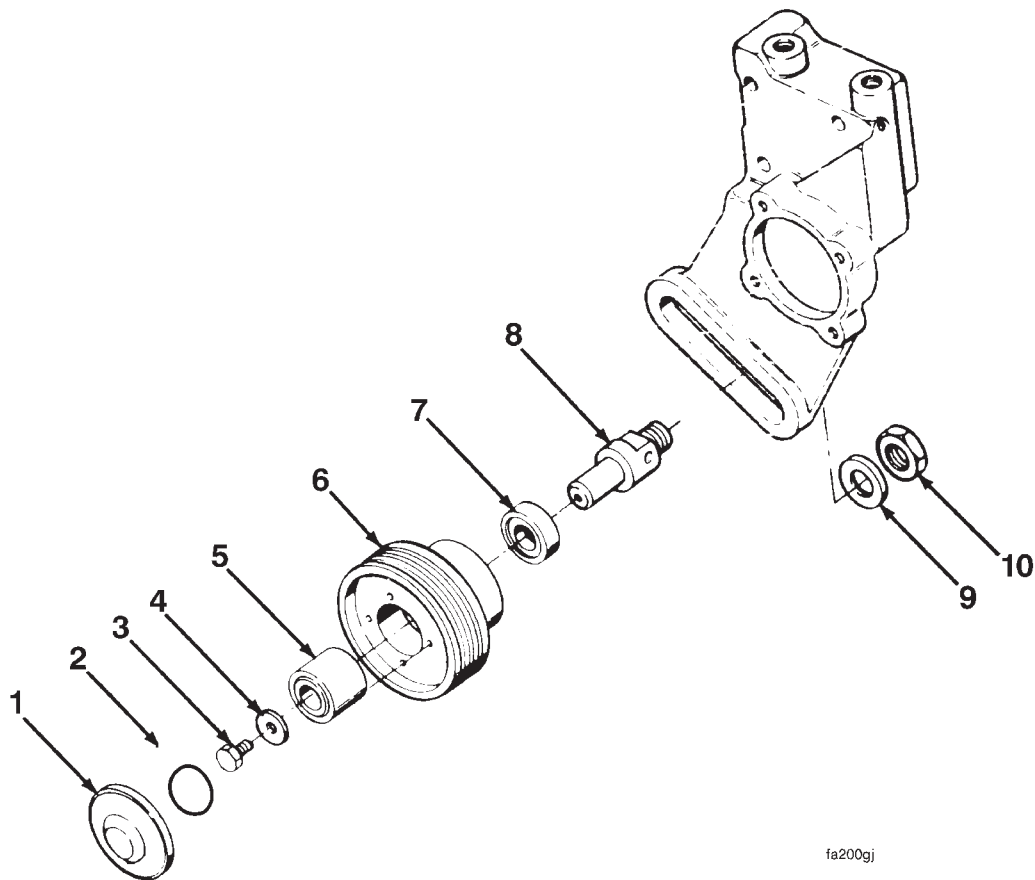
Fan Hub - Exploded View



fa200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Spacer, Bearing (Small)	1	7	Washer, Plain	1
2	Ring, Retaining	1	8	Hub, Fan	1
3	Bearing, Roller	2	9	Spacer, Bearing (Large)	1
4	Seal, Grease	1	10	Cover, Fan Hub	1
5	Shaft, Fan Hub	1	11	Screw, Hexagon Head	1
6	Flange	1			

Fan Idler Pulley and Bracket - Exploded View



Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Plate Cover	1	6	Pulley, Idler	1
2	Seal, O-ring	1	7	Seal, Oil	1
3	Capscrew	1	8	Shaft, Idler	1
4	Washer, Plain	1	9	Washer, Plain	1
5	Bearing, Roller	1	10	Nut	1

Water Pump Assembly - General Information

The M11 engine water pump is a centrifugal type pump with a phenolic impeller. The water pump is gear driven from an idler gear in the front gear train. The water pump contains an oil seal and a unitized water seal. The water pump bearing, gear and shaft receive lubrication from engine oil in the front gear train.

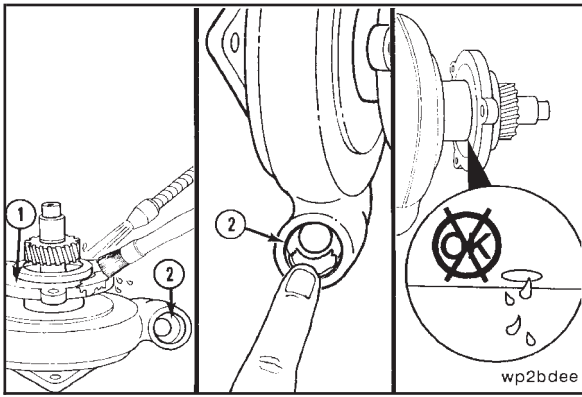
The M11 engine uses both metric and U.S. Customary capscrews. In some cases, capscrews in metric and U.S. Customary threads are almost identical in appearance. Be sure to install the capscrews in the same location they were removed from.

Pipe plugs used in the cooling system are U.S. Customary dimensions.

Fan Hub and Fan Idler Pulley - General Information

The fan belt tension is adjusted by an adjusting screw and idler pulley in the fan hub support.

The fan idler pulley contains two anti-friction tapered roller type bearings. The idler pulley end clearance is set properly by two bearing race spacers. **Always** replace the complete bearing set if any one piece requires replacement.



Water Pump - Cleaning and Inspection for Reuse (8-01)

Cleaning



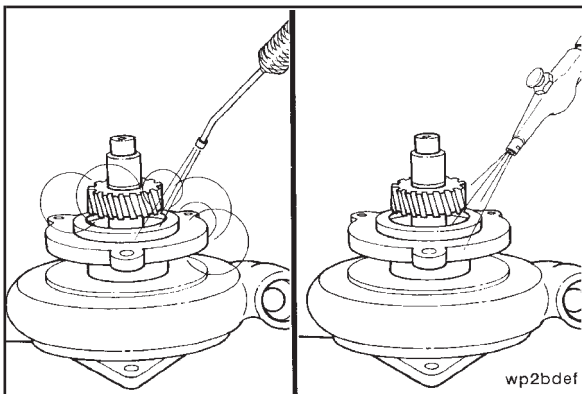
Remove the o-ring and clean surface (1).

Use Scotch-Brite® 7448, Part No. 3823258, to clean surface (2).



Visually inspect the water pump weep hole for indication of leakage.

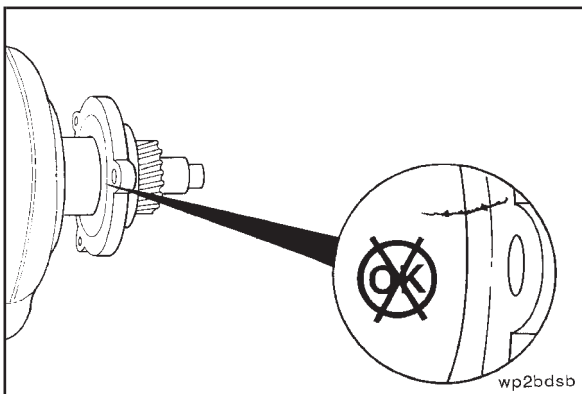
NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement. If a steady flow of coolant or oil is observed, replace or rebuild the water pump.



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



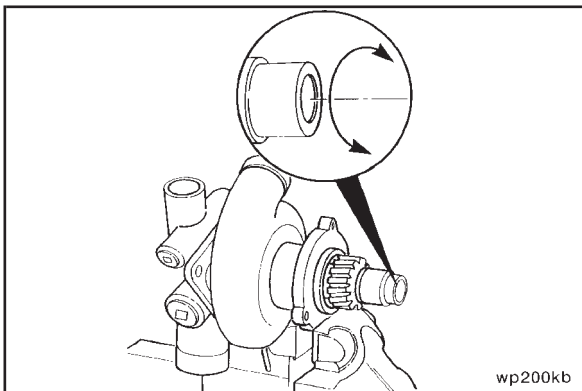
Use solvent or steam to clean the water pump exterior. Dry with compressed air.



Inspection



Visually inspect the water pump body for cracks or damage.



Turn the water pump shaft by hand to inspect the bearings and impeller for freedom of rotation.

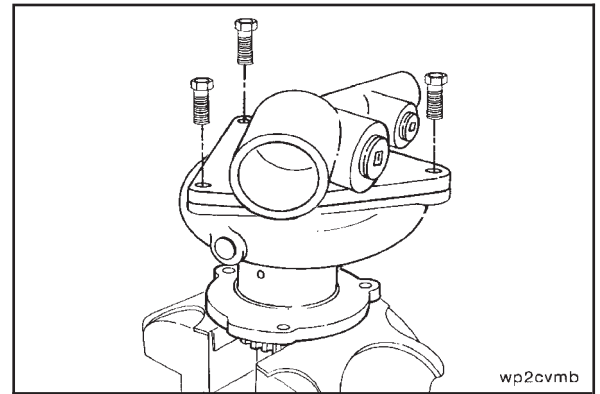
If damaged parts are found or the shaft does **not** rotate freely in the water pump body, the water pump **must** be rebuilt or replaced. Refer to Water Pump - Rebuild (8-02).

Water Pump - Rebuild (8-02)

Disassembly

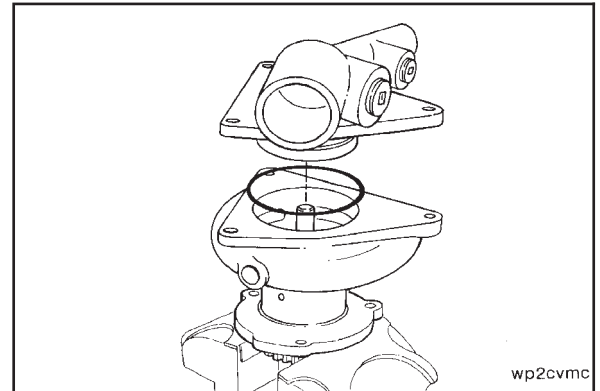
Install the water pump in a vise with brass jaws with the inlet cover facing up.

Remove the three capscrews.



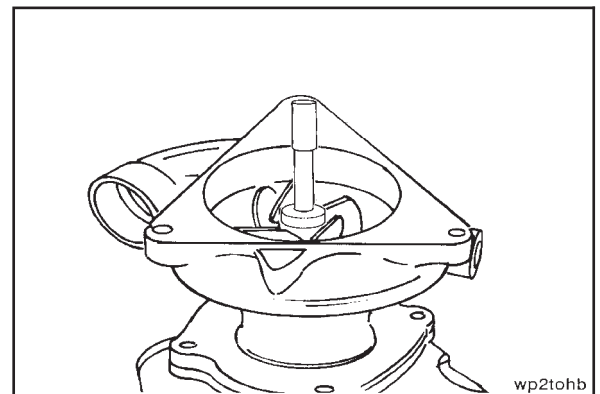
Use a mallet to loosen the cover. Remove the inlet cover from the water pump body.

Remove the o-ring from the cover. Discard the o-ring.

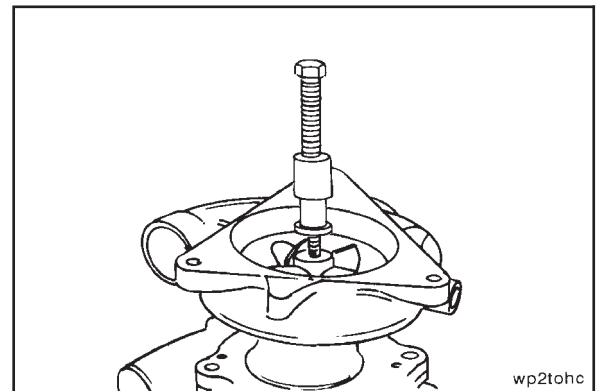


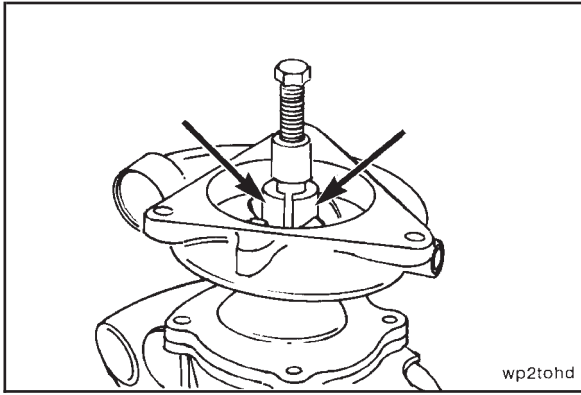
Use the water pump impeller puller kit, Part No. 3376542, to remove the impeller.

Install the spacer pin, Part No. 3822296, into the bore of the water pump impeller.

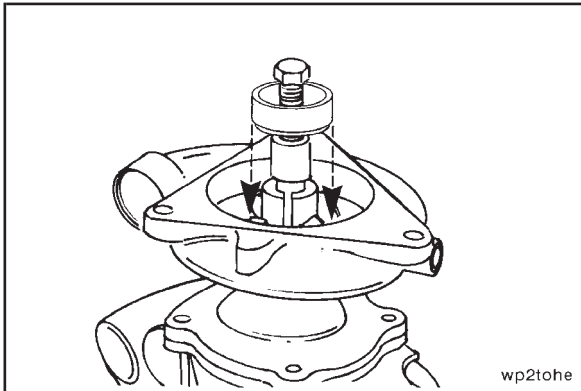


Install the puller sleeve, Part No. 3376544, and the pressure screw, Part No. 3376546, over the spacer pin.

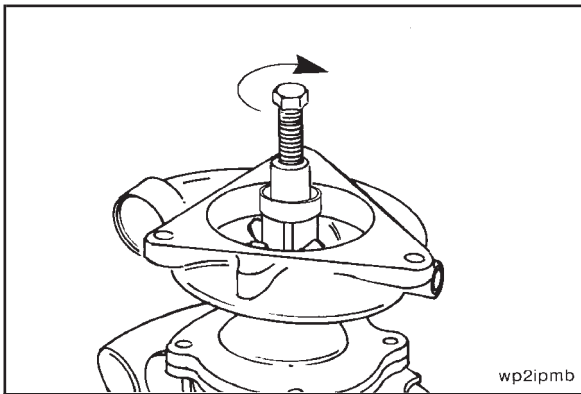




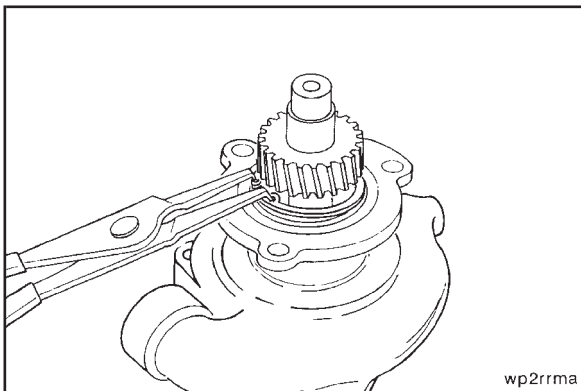
Install the puller halves, Part No. 3376549, on the threaded sleeve assembly.



Install the compression sleeve, Part No. 3376545, over the two puller halves.



Hold the puller sleeve with an adjustable wrench.
Turn the pressure screw **clockwise** to remove the impeller.



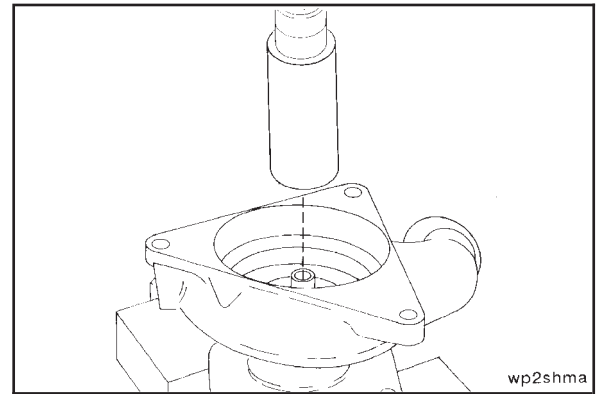
Caution: The retainer ring will be bent or broken if it is removed before the bearing is removed from the shaft.



Use a pair of long nose angle snap ring pliers to remove the front bearing retainer ring from the ring groove in the water pump body.

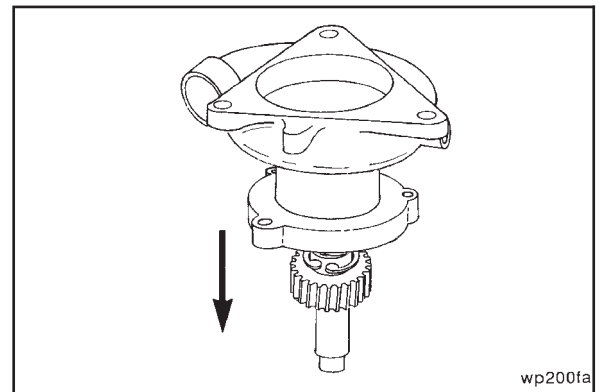
Leave the retainer ring loose on the shaft until the bearing is removed.

Install the water pump in an arbor press with the front mounting surface facing down.



Caution: To avoid damage to the water pump shaft, do not allow the shaft assembly to fall when pushed from the water pump body.

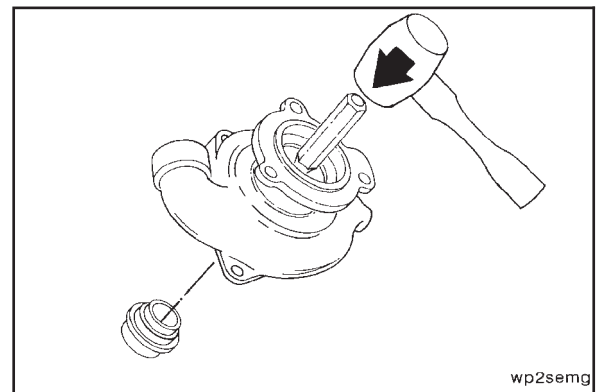
Press the shaft assembly from the water pump body.



Caution: To prevent future water pump failure, do not damage the water seal bore when removing the water seal.

Install the water pump body on a bench with the front mounting surface facing up.

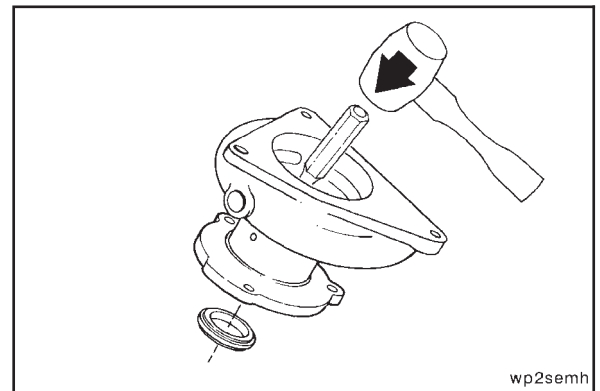
Use a punch and hammer to remove the water seal. Discard the seal.

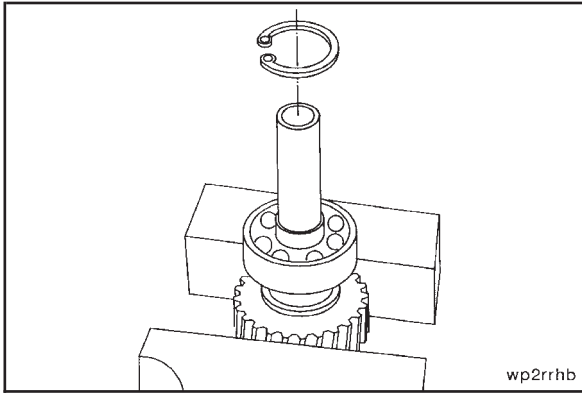


Turn the water pump body over with the front mounting surface facing down.

Caution: To prevent future water pump failure, do not damage the oil seal bore when removing the oil seal.

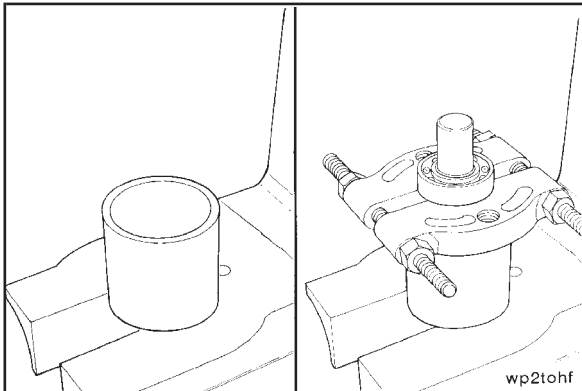
Use a punch and hammer to remove the oil seal.





Install the water pump shaft assembly in a vise with brass jaws.

Use a pair of long nose angle snap ring pliers to remove the rear bearing retainer ring from the shaft.

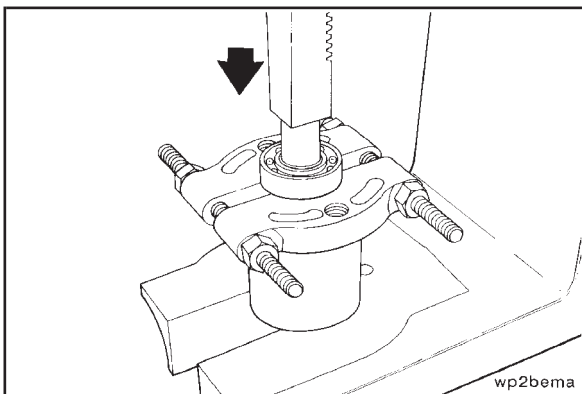


Install a section of pipe (3-1/2 inch O.D. x 3 inch I.D. x 3-1/2 inch Length) in an arbor press to support the bearing separator.



Caution: The bearing separator halves must be under the inner race of the bearing to prevent personal injury or bearing damage when the shaft is pushed from the bearing.

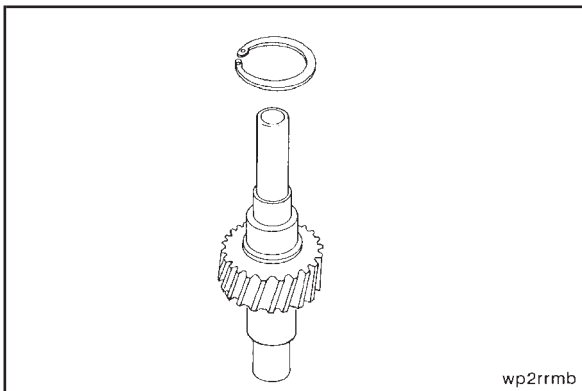
Install the shaft assembly through the section of pipe in the arbor press with the rear bearing inner race supported by bearing separator, Part No. 3375326.



Caution: To avoid damage to the shaft or personal injury, do not allow the shaft to fall when pressed from the bearing.



Press the shaft from the bearing.



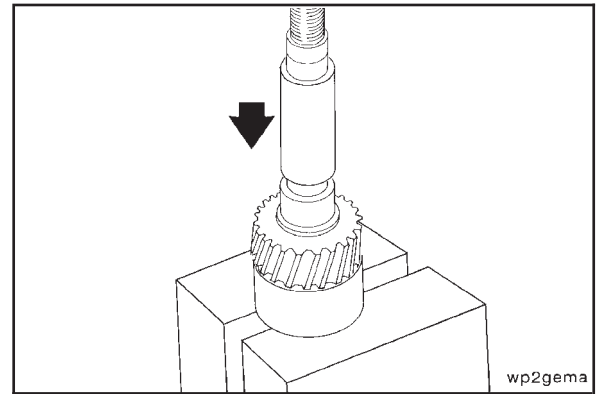
Remove the rear bearing to water pump body retainer ring from the shaft.

NOTE: Be sure the gear surface and **not** the shoulder of the shaft is resting on the arbor press.

Install the shaft and gear in an arbor press with the largest outside diameter end of the shaft up.

Caution: Do not allow the shaft to fall when pressed from the gear. Damage to the shaft or personal injury can occur.

Press the shaft from the gear.

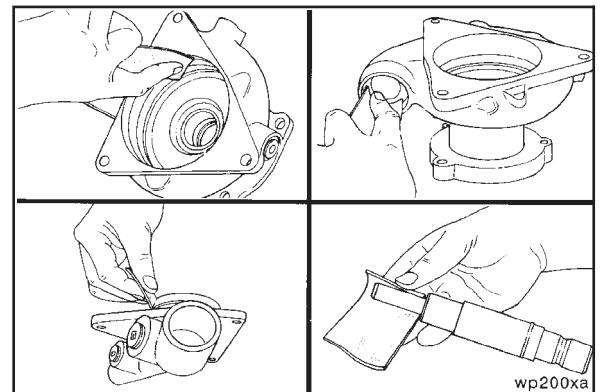


wp2gema

Cleaning

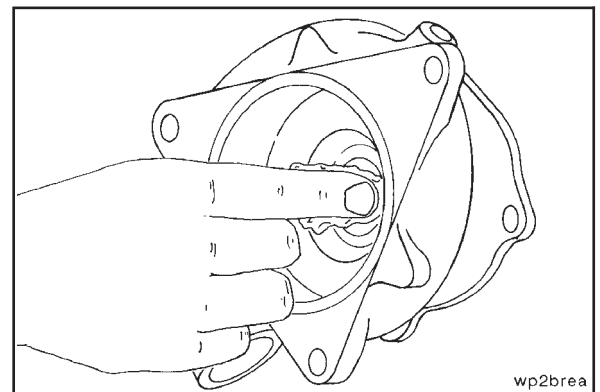
Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to clean the o-ring bores and grooves in the water pump body and cover.

Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to clean the water pump shaft.



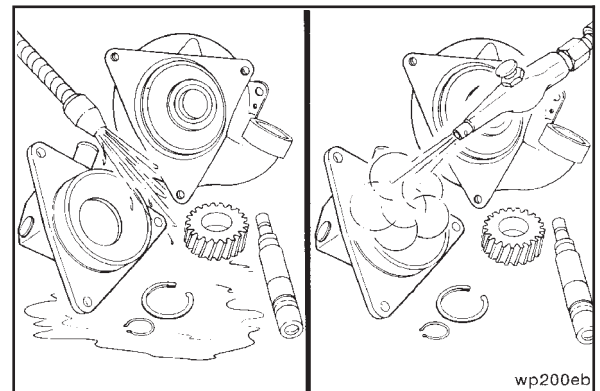
wp200xa

Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to clean the bearing bores in the water pump body.

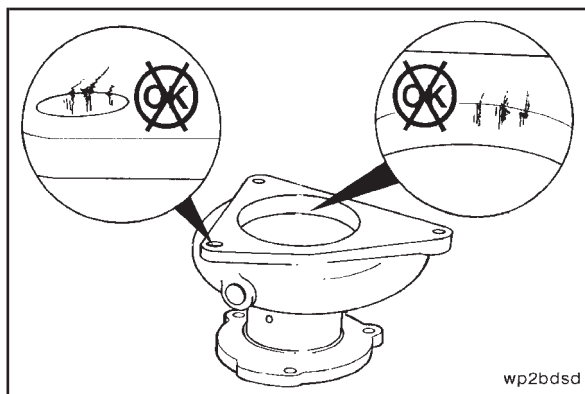


wp2brea

Use solvent to clean the water pump parts. Dry with compressed air.



wp200eb

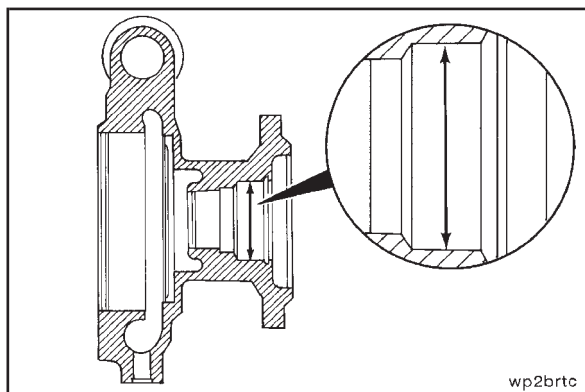


Inspection

If the part being inspected does **not** meet the specifications given, or is damaged and no alternative is given, the part **must** be replaced.

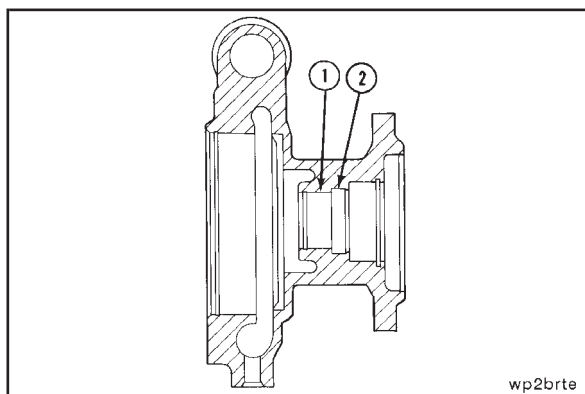


Visually inspect the water pump body for cracks, porosity or excessive corrosion.



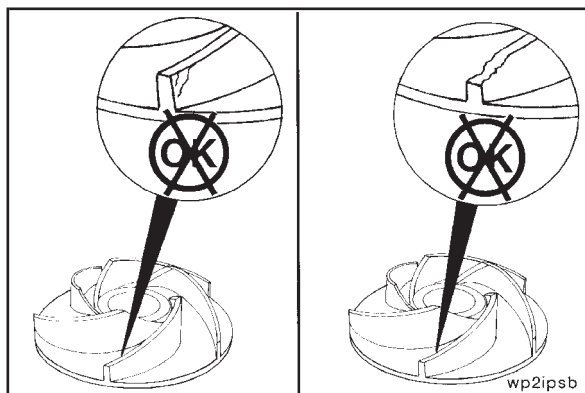
Measure the water pump body bearing bore inside diameter.

Water Pump Body Bearing Bore I.D.			
	mm		in
	51.996	MIN	2.0471
	52.011	MAX	2.0477



Measure the water seal bore inside diameter (1).
Measure the oil seal bore inside diameter (2).

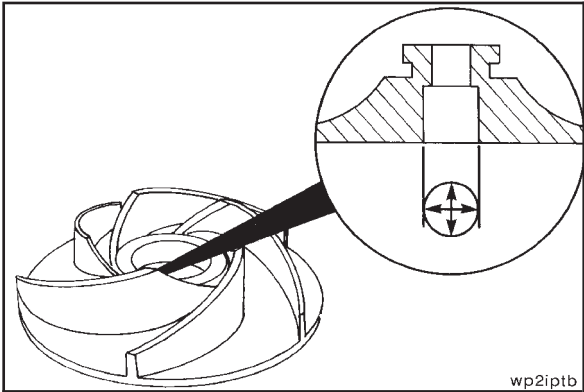
Seal Bore I.D.			
Point	mm		in
1	36.450	MIN	1.4350
	36.475	MAX	1.4360
2	40.975	MIN	1.6132
	41.025	MAX	1.6152



Visually inspect the water pump impeller for cracks or damage.

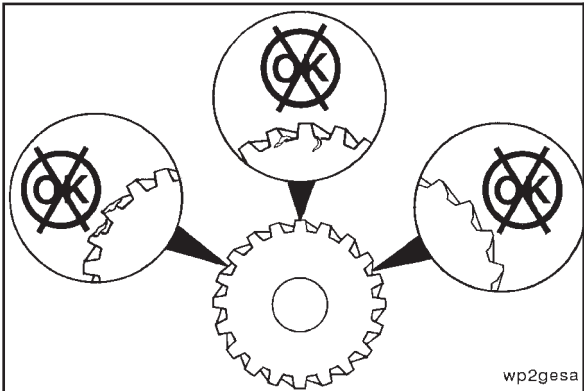
Measure the water pump impeller bore inside diameter.

Impeller Bore I.D.		
mm		in
15.339	MIN	0.6039
15.365	MAX	0.6049



wp2iptb

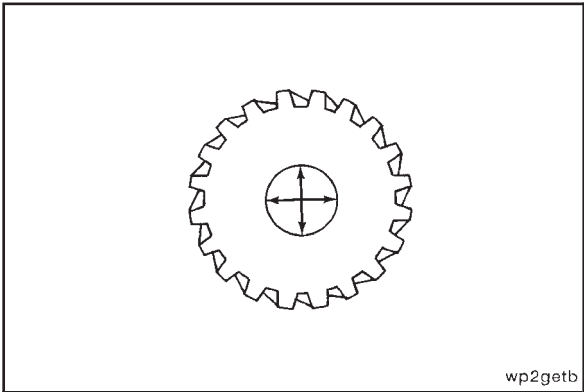
Visually inspect the water pump drive gear for broken teeth, cracks or excessive or uneven tooth wear.



wp2gesa

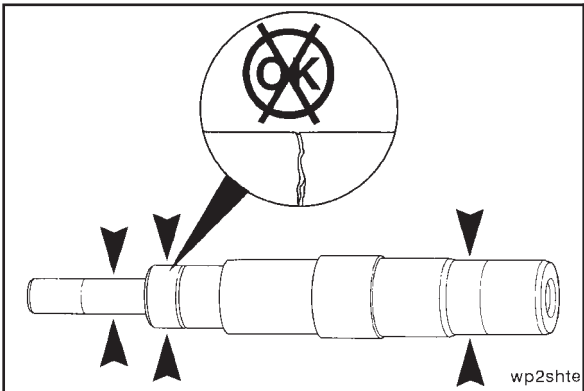
Measure the water pump drive gear bore inside diameter.

Drive Gear Bore I.D.		
mm		in
33.900	MIN	1.3346
33.925	MAX	1.3356

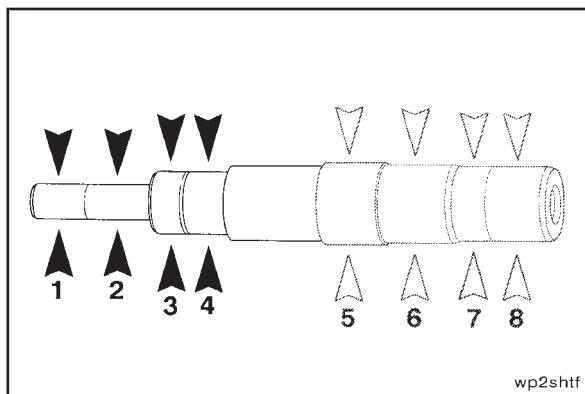


wp2getb

Inspect the seal surfaces of the water pump shaft for large grooves, nicks or damage.

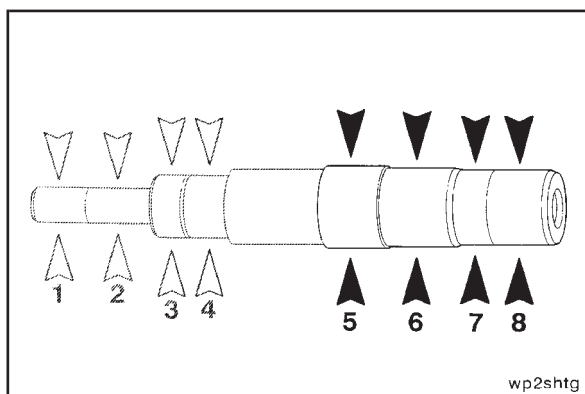


wp2shte

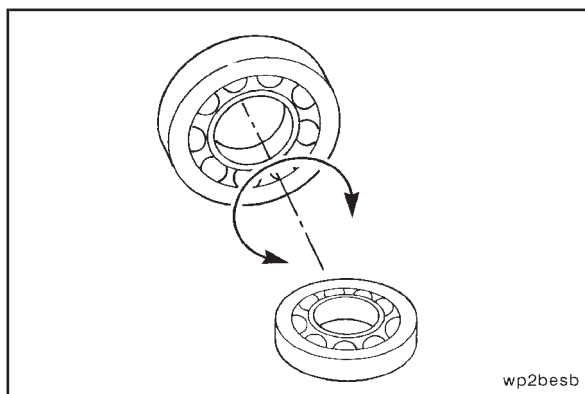


Measure the water pump shaft journal outside diameters.

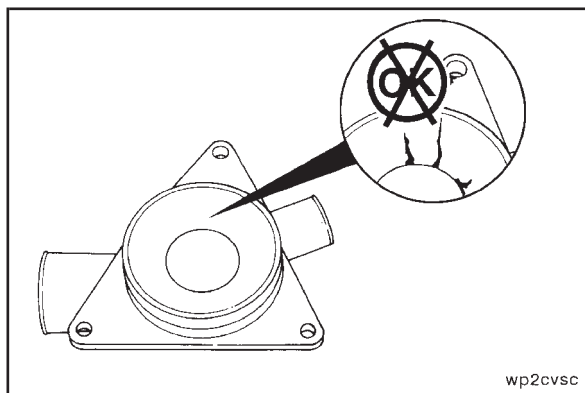
Point	Shaft Journals O.D.		
	mm		in
1	15.389	MIN	0.6059
	15.402	MAX	0.6064
2	15.897	MIN	0.6259
	15.910	MAX	0.6264
3	24.999	MIN	0.9842
	25.009	MAX	0.9846
4	24.999	MIN	0.9842
	25.009	MAX	0.9846



Point	Shaft Journals O.D. (Cont'd.)		
	mm		in.
5	33.951	MIN	1.3366
	33.976	MAX	1.3376
6	29.987	MIN	1.1806
	30.000	MAX	1.1811
7	27.975	MIN	1.1014
	28.025	MAX	1.1033
8	27.887	MIN	1.0979
	27.900	MAX	1.0984

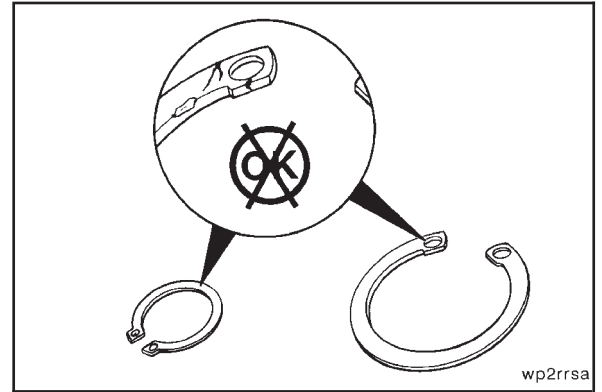


Turn the water pump bearing by hand to inspect for freedom of rotation.



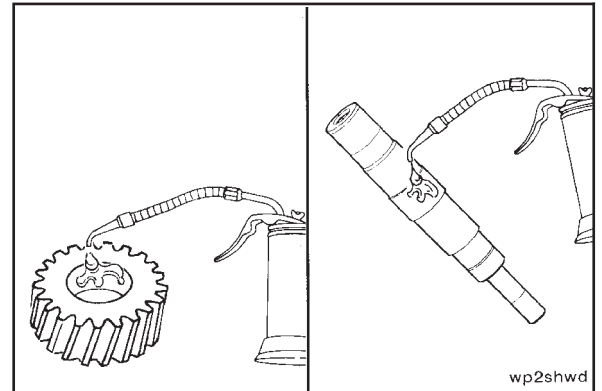
Visually inspect the water inlet cover for cracks or excessive corrosion.

Visually inspect the bearing retainer rings for nicks or cracks.

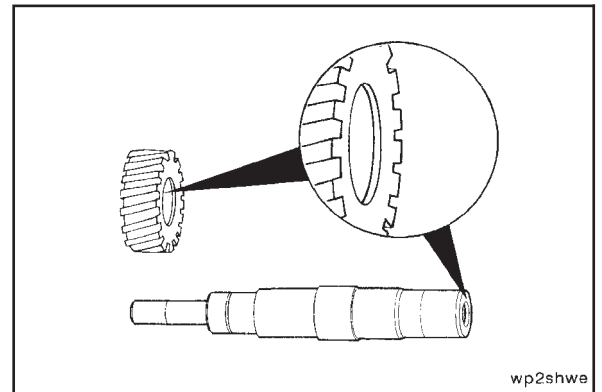


Assembly

Use clean 15W-40 oil to lubricate the drive gear bore and the shaft.



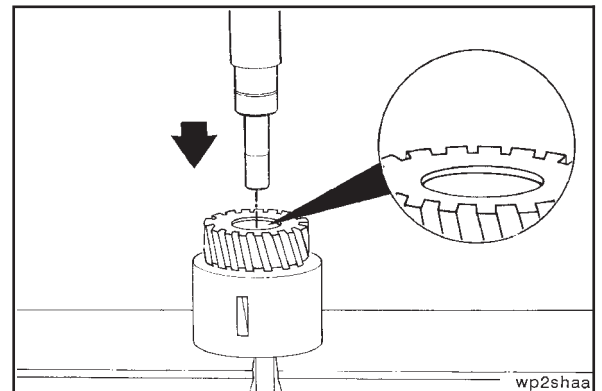
Caution: The chamfered side of the drive gear bore must be installed toward the large diameter end of the shaft to prevent damage to the gear when the water pump is installed on the engine.

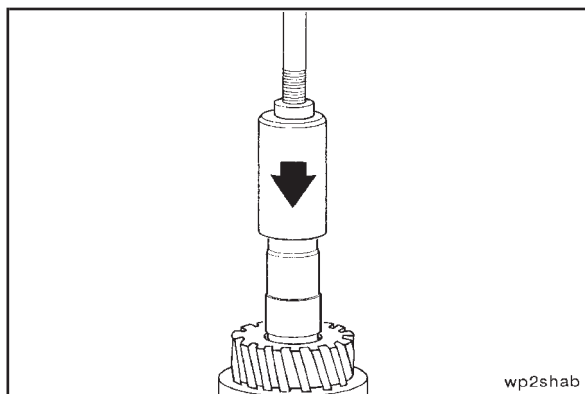


Install the gear in an arbor press with the chamfered side of the gear bore facing up.



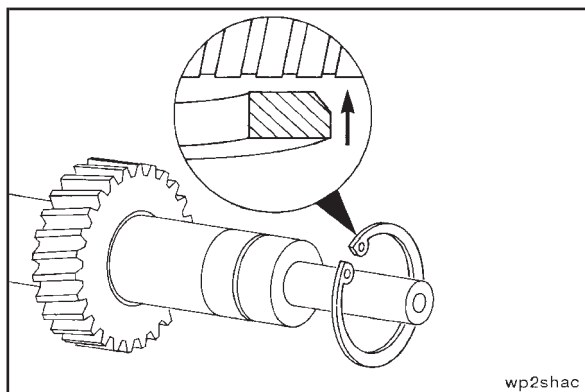
Insert the impeller end (smallest diameter) of the shaft through the top of the gear bore.





Use the water pump gear mandrel, Part No. 3823851, to press the shaft into the gear.

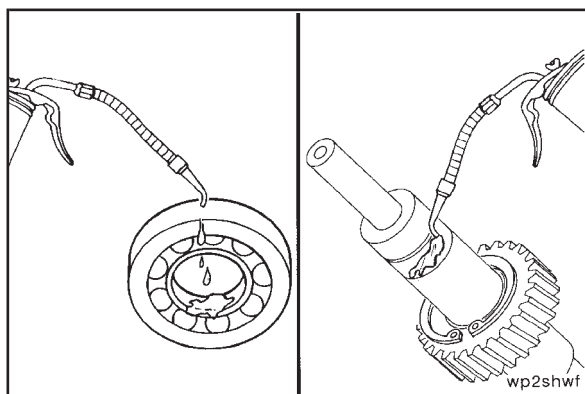
NOTE: Press the shaft through until the tool contacts the gear surface.



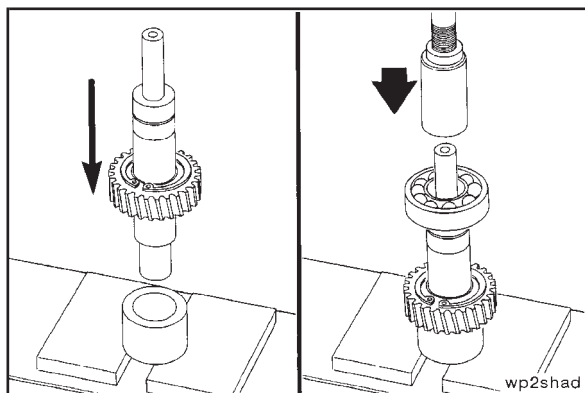
Caution: To prevent future water pump damage, the beveled side of the retainer ring must be installed toward the drive gear.



Install the front bearing to water pump body retainer ring on the shaft.



Use clean 15W-40 oil to lubricate the bearing and shaft bearing journal.



Install the shaft assembly in an arbor press. Use the water pump bearing mandrel, Part No. 3375318, to support the shaft assembly.



Caution: Press against the inner race of the bearing to prevent personal injury or bearing damage.

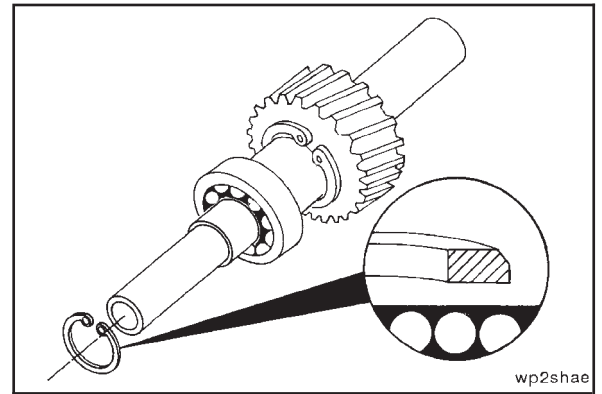


Use the water pump bearing mandrel, Part No. ST-658, to press the bearing on the shaft until the bearing contacts the shoulder on the shaft.



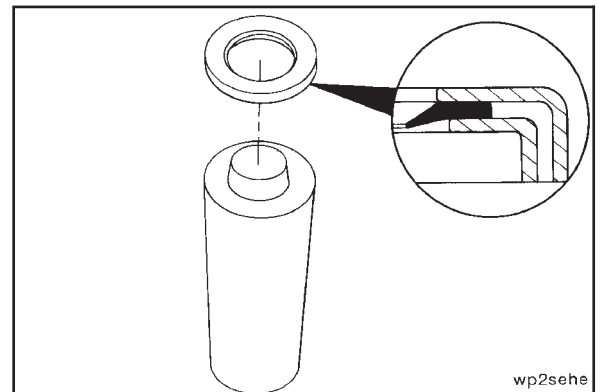
The flat side of the retainer ring **must** be installed toward the bearing.

Use a pair of snap ring pliers to install the bearing retainer ring into the groove on the shaft.



The sealing lip of the oil seal **must** be installed toward the seal driver.

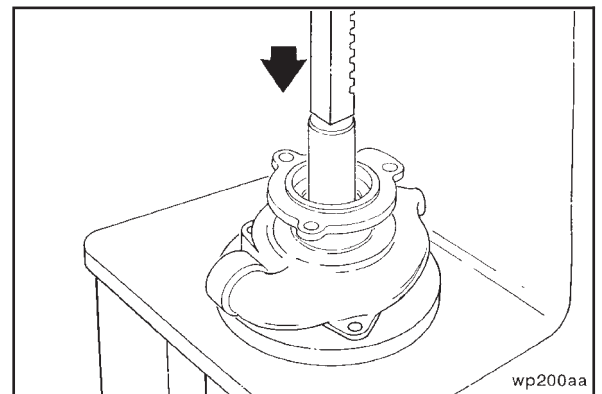
Install the oil seal on the water pump oil seal driver, Part No. 3376139.



Install the water pump body in an arbor press with the oil seal bore (water pump mounting surface) facing up.

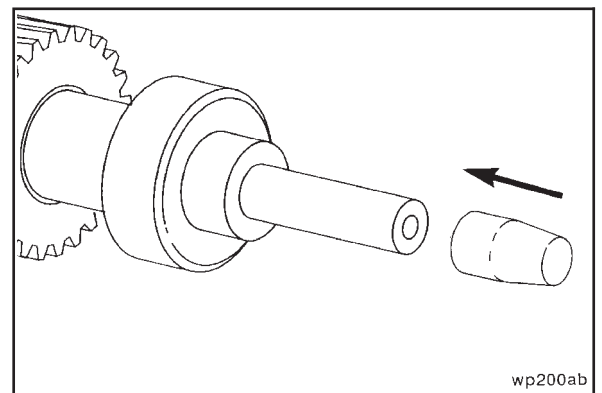
Install the oil seal and oil seal driver into the oil seal bore.

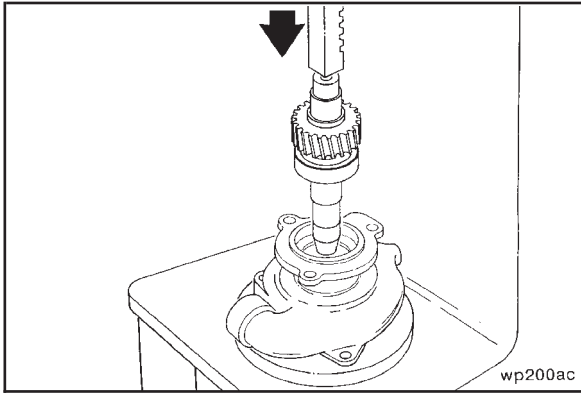
Press the oil seal into the oil seal bore until the seal driver contacts the water pump body.



Do **not** lubricate the oil seal. The oil seal **must** be installed with the lip of seal and the shaft clean and dry to provide a proper sealing surface and prevent future water pump and engine damage.

Install the water pump oil seal expander, Part No. 3376387, on the impeller end of the shaft.





Install the water pump body in an arbor press with the front mounting surface facing up.

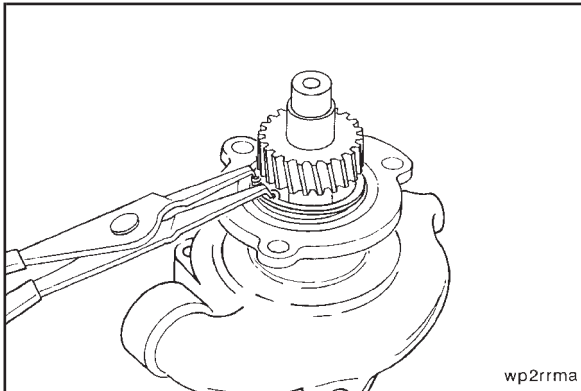


Caution: To avoid deformation of the seal lip and water pump leakage, water pump oil seal expander, Part No. 3376387, must be used when installing the shaft assembly.

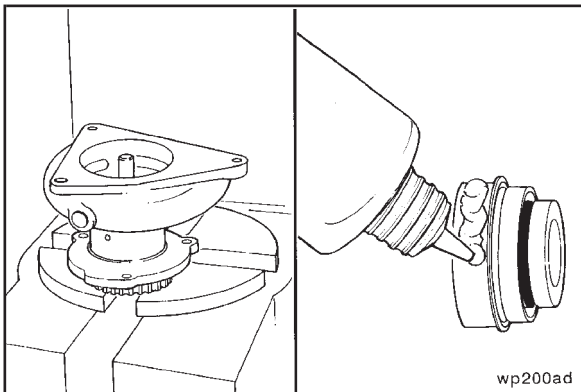
Press the shaft assembly and oil seal expander into the water pump body. Remove the oil seal expander.



NOTE: The shaft assembly **must** be pressed into the body far enough to install the rear bearing retainer ring into the groove of the body.



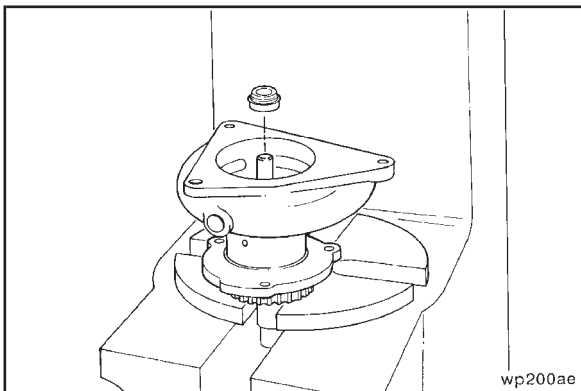
Use a pair of long nose angle snap ring pliers to install the front bearing retainer ring into the groove of the water pump body.



Install the water pump assembly in an arbor press. Support the pump assembly on the drive side of the body with the impeller end of the water pump shaft facing up.



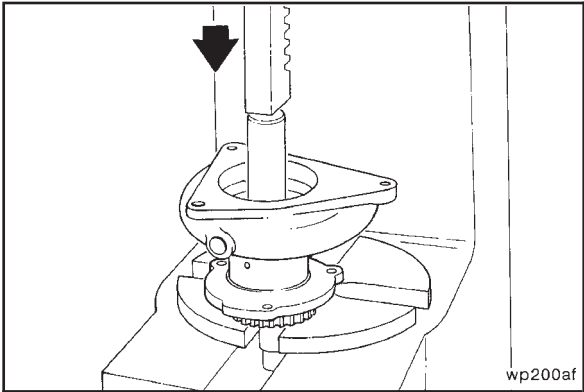
Apply a coat of pipe sealant, Part No. 3375066, to the outside diameter of the new water seal.



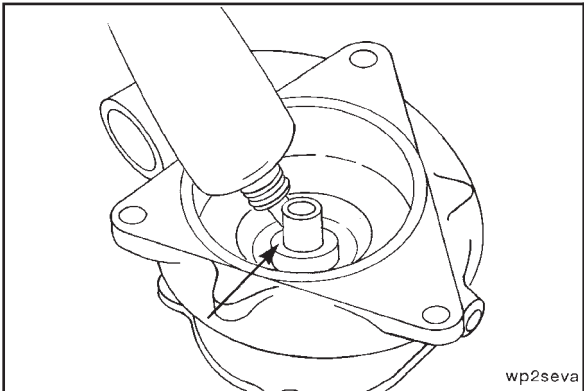
Install the water seal over the shaft.

Caution: The use of any tool other than Part No. 3823815 can result in seal damage.

Use the water pump seal driver, Part No. 3823815, to press the seal into the water pump body.

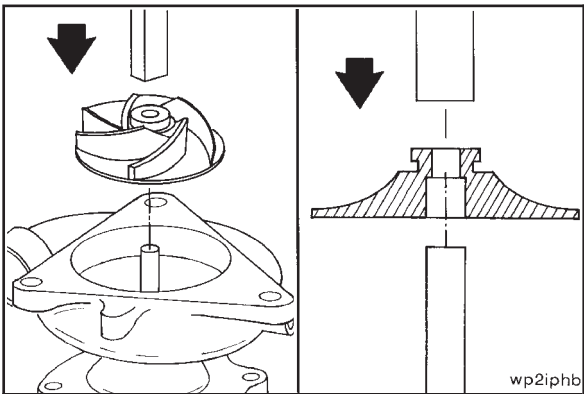


Apply one drop of Loctite 290™, Part No. 3823682 or equivalent, to the joint between the water pump shaft and the water pump seal.



Install the water pump body in an arbor press with the impeller end of the shaft facing up. Support the bottom end of the shaft.

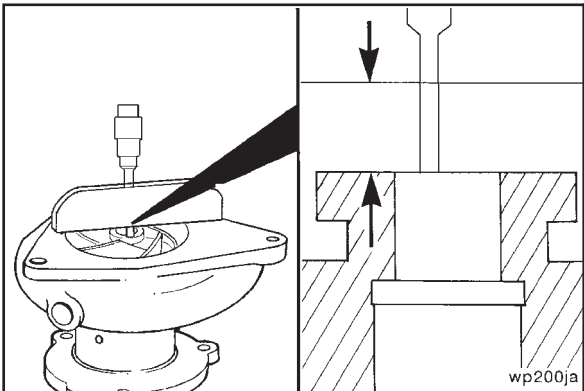
Press the impeller on the shaft until the step inside the impeller bore contacts the shaft.

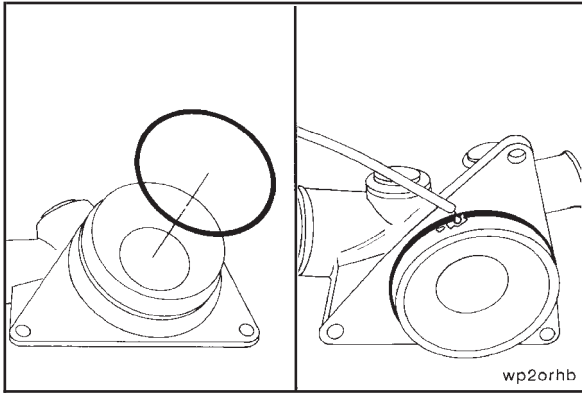


Use a dial depth gauge to measure the distance from the impeller hub to the water pump body surface.

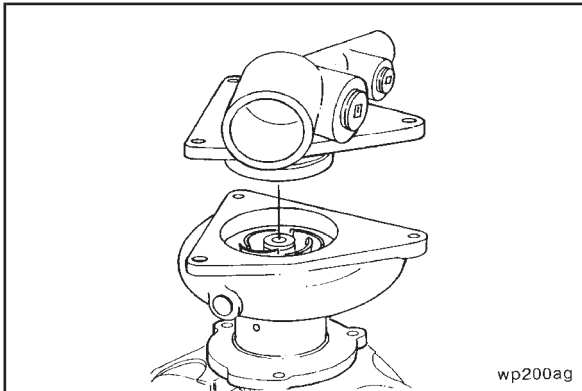
Impeller Hub to Body Surface		
mm		in
13.52	MIN	0.532
13.72	MAX	0.540

If the distance from the impeller hub to the body surface is greater than the maximum specification, use the water pump impeller puller kit, Part No. 3376542, to move the impeller to the correct distance.

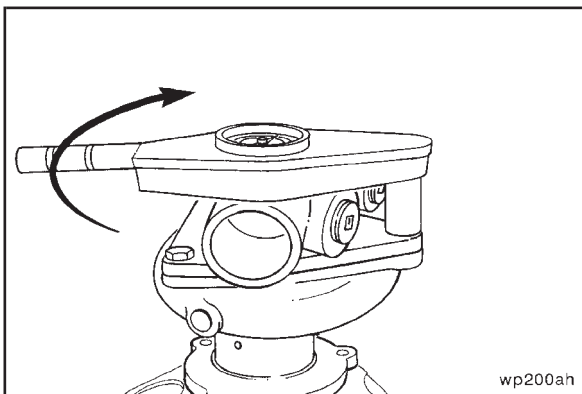




Install the new o-ring on the water inlet cover.
Use clean vegetable oil to lubricate the o-ring.



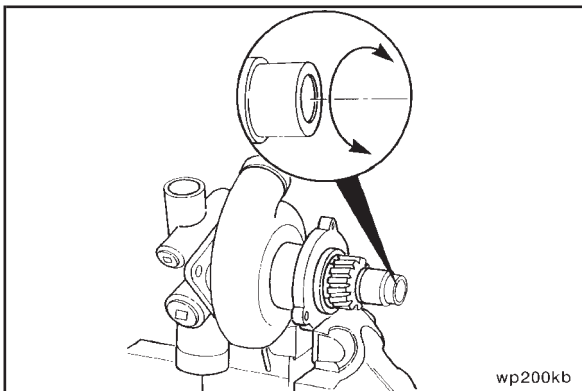
Install the water inlet cover on the water pump body.



Install three (M10-1.50 x 25) capscrews in the water pump body.



Torque Value: 47 N•m [35 ft-lb]



Turn the water pump shaft by hand to inspect the bearings and impeller for freedom of rotation.

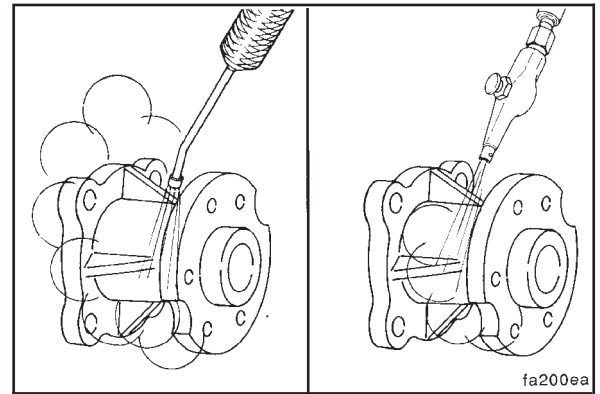
If the water pump shaft does **not** rotate freely in the water pump body, the water pump **must** be disassembled, inspected and assembled again.

Fan Hub - Cleaning and Inspection for Reuse (8-03)

Cleaning

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 to clean the fan hub exterior. Dry with compressed air.

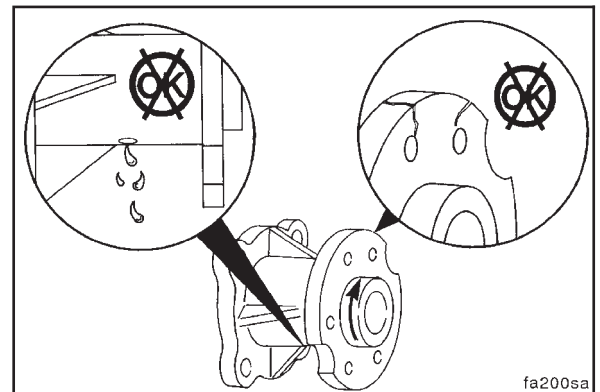


Inspection

Visually inspect the fan hub for indication of oil seal leakage.

Visually inspect the fan hub for cracks or damage.

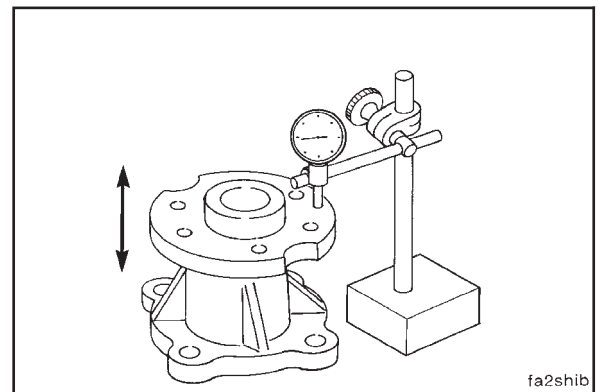
Turn the fan hub shaft by hand to inspect the fan hub for freedom of rotation.



Measure the fan hub shaft end clearance.

Shaft End Clearance		
mm		in
0.076	MIN	0.0030
0.406	MAX	0.0160

If damaged parts are found, the shaft does **not** rotate freely or the shaft end clearance is **not** within the specifications, the fan hub **must** be rebuilt or replaced.

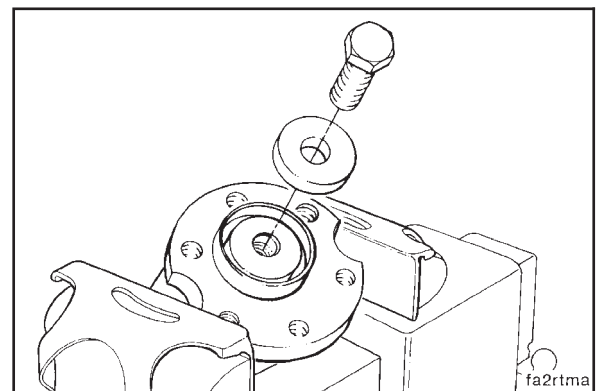


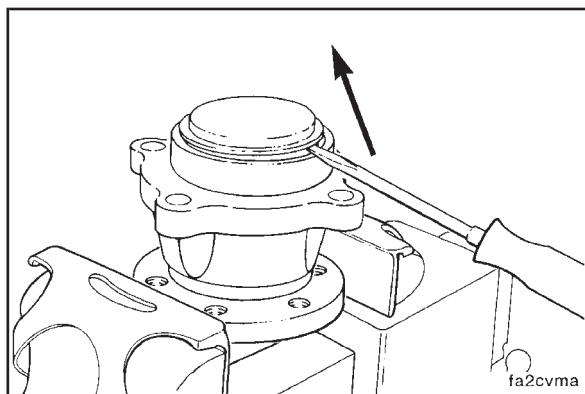
Fan Hub (Belt Driven) - Rebuild (8-04)

Disassembly

Install the flange in a vise with brass jaws, and with the fan mounting flange face up.

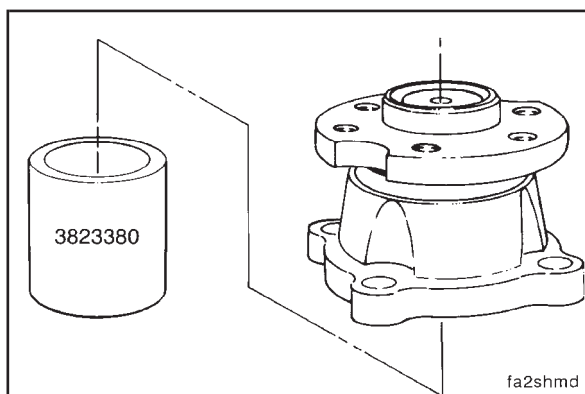
Remove the retaining capscrew and washer.





Loosen the vise and turn the fan hub assembly over so the back side of the assembly is facing up.

Insert a screwdriver blade under the cover flange and pry the cover out of the fan hub. Save the cover for reuse.

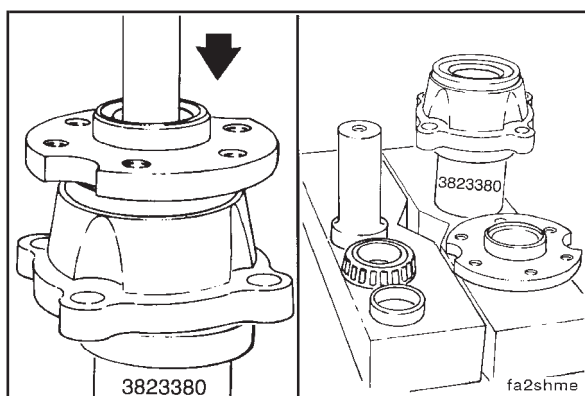


Caution: The shaft will be damaged if the rear bearing inner race is not supported when removing the shaft.

Use disassembly pot, Part No. 3823380, to support the bearing inner race.



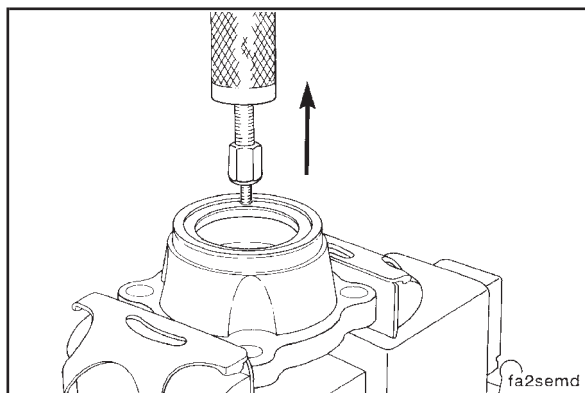
Place the support on an arbor press with the fan hub assembly on top of the support. The fan mounting flange **must** be facing up.



Press the shaft through the flange.



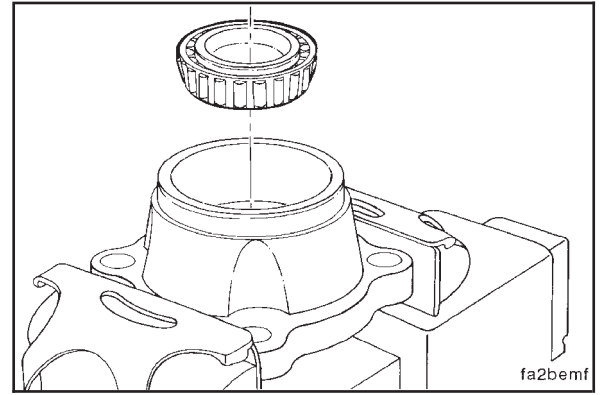
Remove the flange, shaft, small bearing spacer and rear bearing.



Place the hub in a vise with brass jaws, and the fan side up.

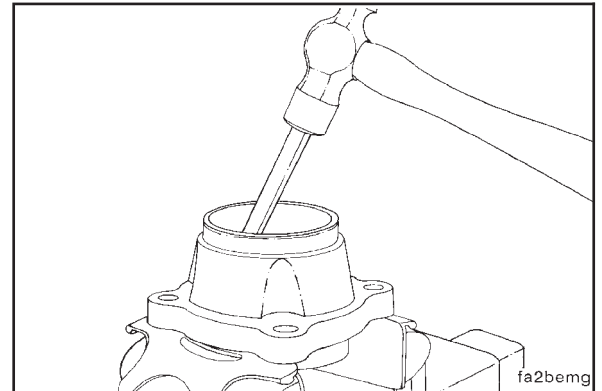
Use a seal puller, or equivalent, to remove the front grease seal. Discard the seal.

Remove the front bearing.



Use a punch and hammer to remove the rear bearing outer race.

NOTE: Use care **not** to damage the inside bore of the hub as the bearing race is removed.

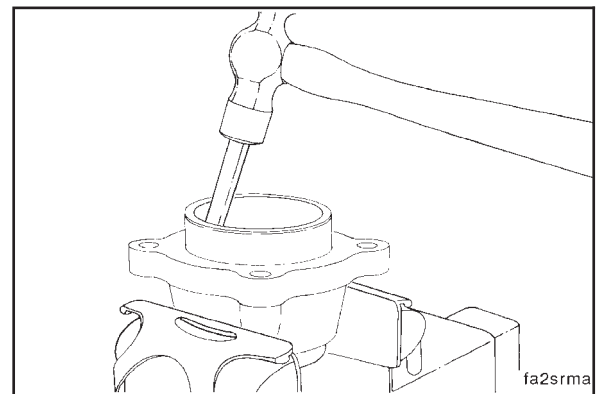


Turn the hub over in the vise so the back side is facing up.

NOTE: Use care **not** to damage the inside bore of the hub when removing the race.

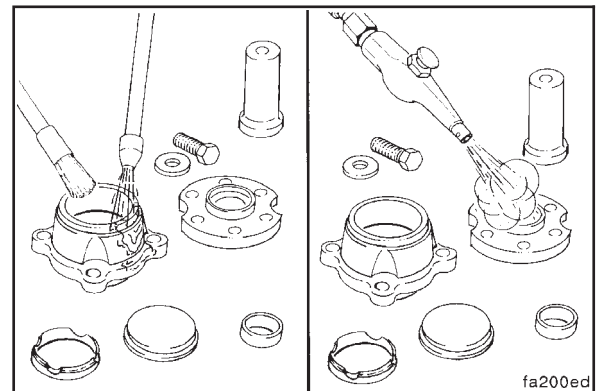
Use a hammer and punch to remove the front bearing outer race and large bearing spacer.

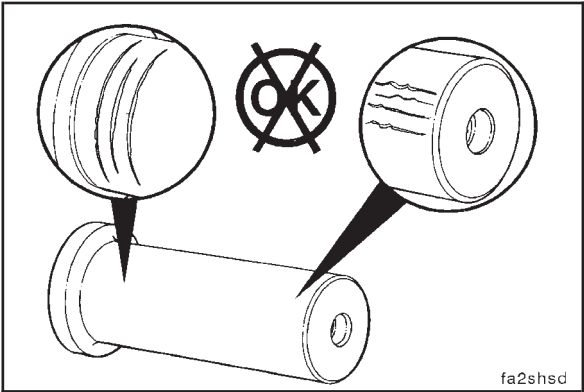
NOTE: Inspect the bearing retaining ring. If the ring is **not** damaged, it does **not** need to be removed.



Cleaning

Use solvent to clean the fan hub assembly parts. Dry with compressed air.

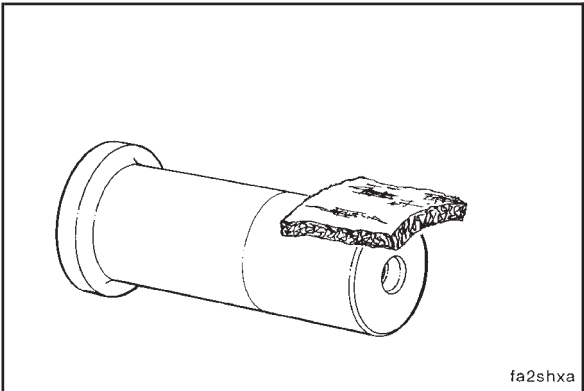




Inspection



Visually check the shaft for grooves, scoring, cracks or any other types of damage.

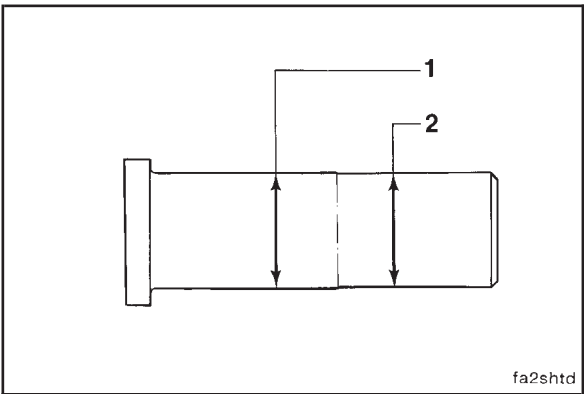


NOTE: When removing flaws with Scotch-Brite® or other material, the shaft O.D. specifications **must** be maintained, or the shaft **must** be replaced.

Use Scotch-Brite® 7448, Part No. 3823258, or equivalent, to remove any minor flaws from the shaft.

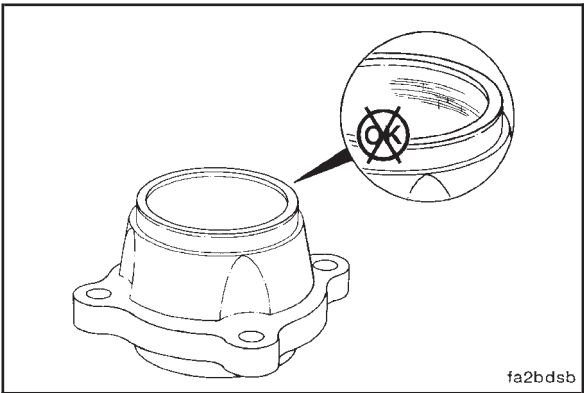


Use solvent to clean the shaft. Dry with compressed air.



Measure the outside diameter of the shaft at points (1) and (2).

Point	Fan Hub Shaft O.D.		
	mm		in
1	34.590	MIN	1.3760
	34.963	MAX	1.3765
2	34.912	MIN	1.3745
	34.925	MAX	1.3750

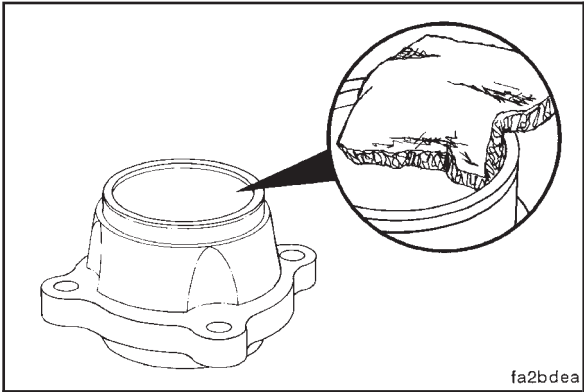


Visually check the hub bore for scoring, nicks, scratches or any other type of damage.

NOTE: When removing nicks or scratches from the hub, the inside diameter **must** be maintained, or the hub **must** be replaced.

Use Scotch-Brite® 7448, Part No. 3823258 or equivalent, to remove any minor damage from the hub bore.

Use solvent to clean the hub and dry with compressed air.

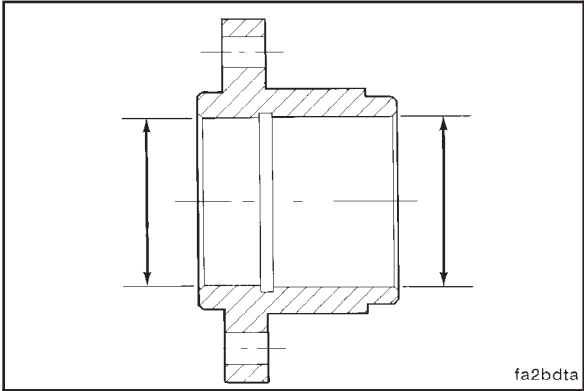


fa2bdea

Measure the inside diameter of the hub bearing bores.

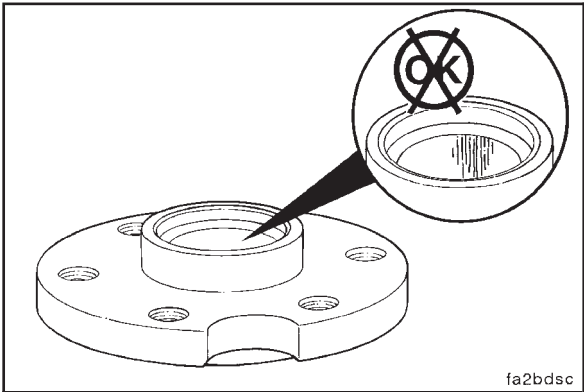


Hub Bearing Bore I.D.		
mm		in
65.038	MIN	2.5605
65.076	MAX	2.5620



fa2bdta

Visually check the flange bore for grooves, scratches or any type of damage.

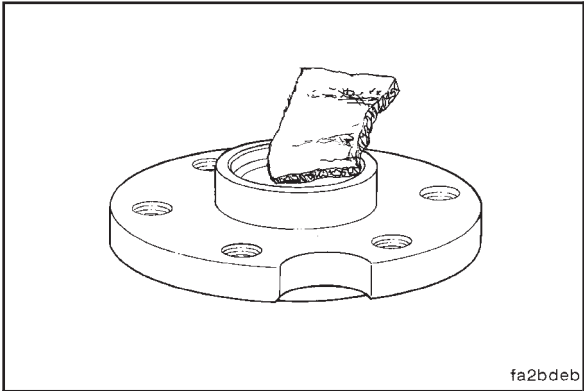


fa2bdsc

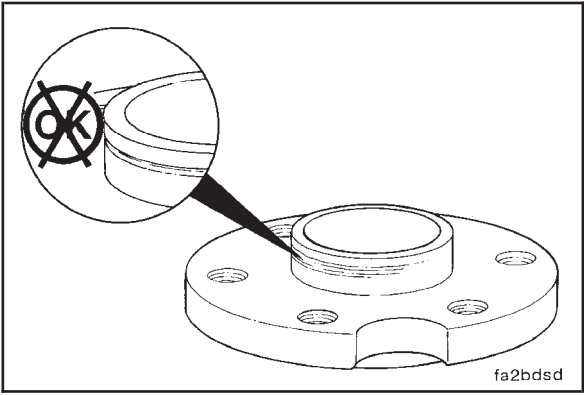
NOTE: When removing nicks or scratches from the flange, the inside diameter **must** be maintained, or the flange **must** be replaced.

Use Scotch-Brite® 7448, Part No. 3823258 or equivalent to remove any minor damage from the flange bore.

Use solvent to clean the flange and dry with compressed air.

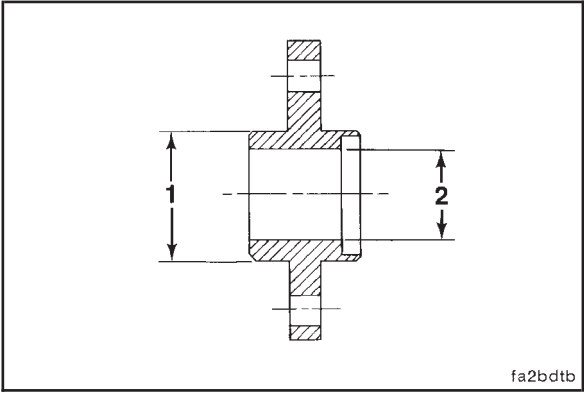


fa2bdeb



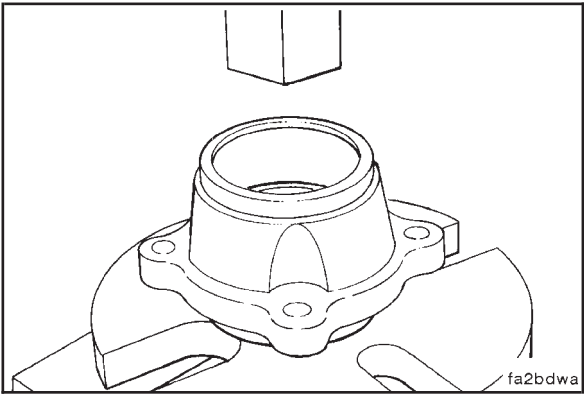
Visually check the grease seal contact area on the flange.

The grease seal contact area **must not** be grooved more than 0.25 mm [0.010 inch] deep on the flange. If the groove is deeper than specified, the flange **must** be replaced.



Measure the outside diameter (1) and inside diameter (2) of the flange.

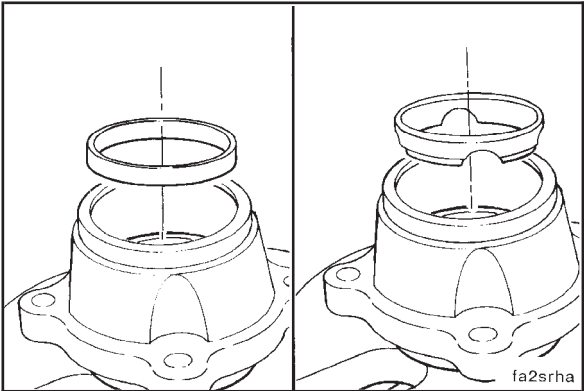
Point	Flange O.D. and I.D.		
	mm		in
1	48.975	MIN	1.9281
	49.000	MAX	1.9291
2	34.849	MIN	1.3720
	34.875	MAX	1.3730



Assembly



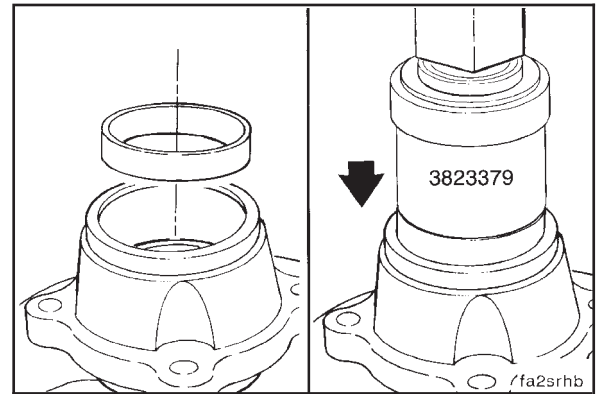
Position the hub in an arbor press with the fan side of the hub facing up.



NOTE: If a spacer **without** slots is used, either end of the spacer can be installed against the retaining ring. If a slotted spacer is used, install the slotted end of the spacer against the retaining ring.

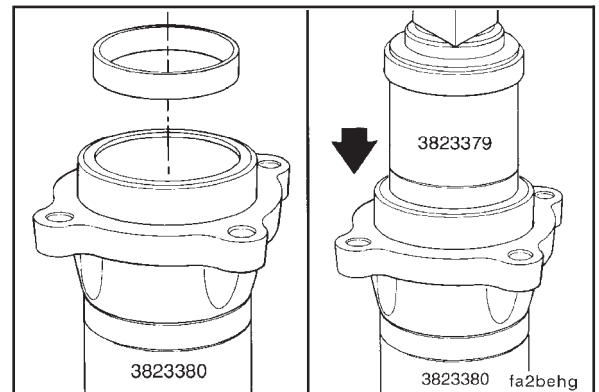
Install the large bearing spacer into the front of the hub.

With the large inside diameter of the bearing race facing up, use the small end of bearing driver, Part No. 3823379, to press a new front bearing race into the hub until it contacts the bearing spacer.

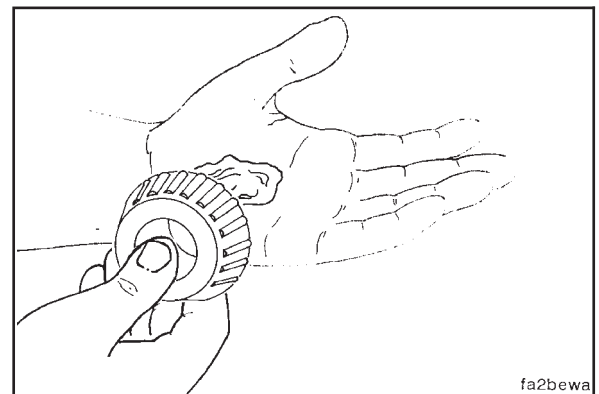


Turn the fan hub over and support the front bearing race with disassembly pot, Part No. 3823380.

With the large inside diameter of the bearing race facing up, use bearing driver, Part No. 3823379, to press a new rear bearing race into the hub until it contacts the bearing spacer.



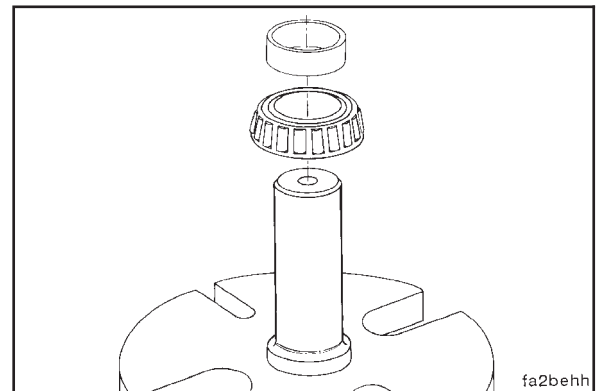
Use Chevron SRI grease, or equivalent, to pack both bearings.

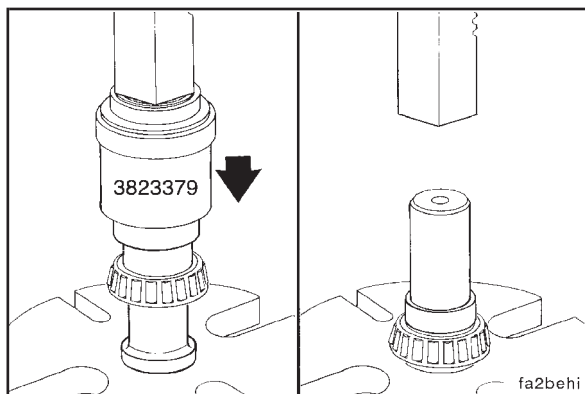


Place the shaft on the arbor press table with the small end pointed up.

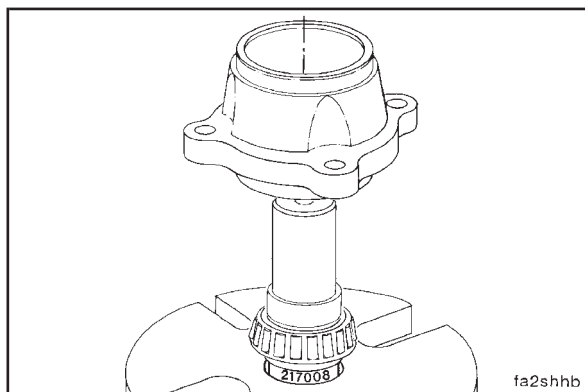
Install the rear bearing on the shaft with the small outside diameter of the bearing on top.

Install the small bearing spacer on top of the bearing.



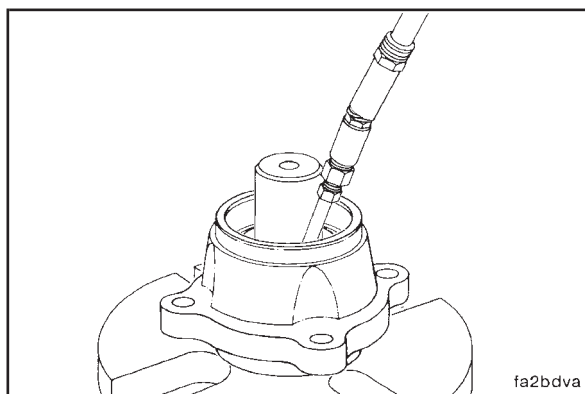


Use the small end of the bearing driver, Part No. 3823379, to press the spacer and bearing onto the shaft until it contacts the shaft shoulder.

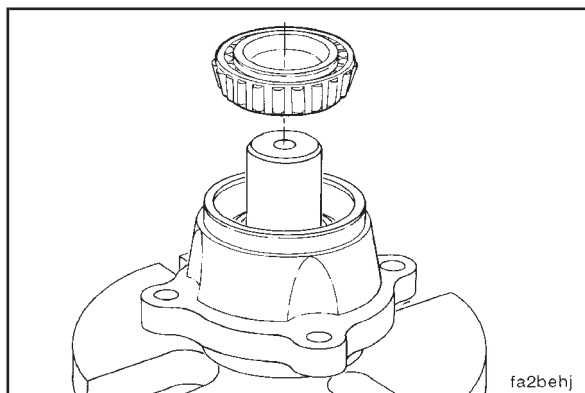


If the shaft is shorter than 95.2 mm [3.75 inch], support the shaft with spacer, Part No. 217008 or equivalent.

With the tapered (fan mounting) end of the fan hub facing up, place the hub over the shaft and bearing assembly.

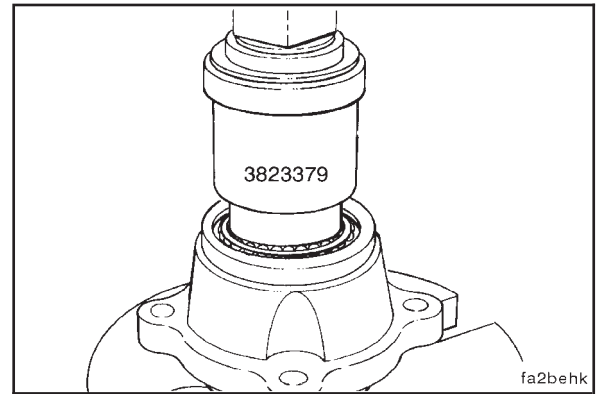


Use Chevron SRI grease, or equivalent, to fill the hub to the top of the bearing spacer.

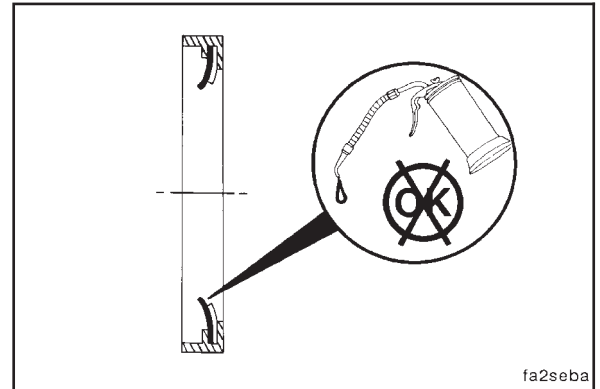


With the small outside diameter of the bearing facing down, install the front bearing on the shaft.

Use the small end of bearing driver, Part No. 3823379, to press the front bearing onto the shaft until the inner race of the bearing contacts the bearing spacer.



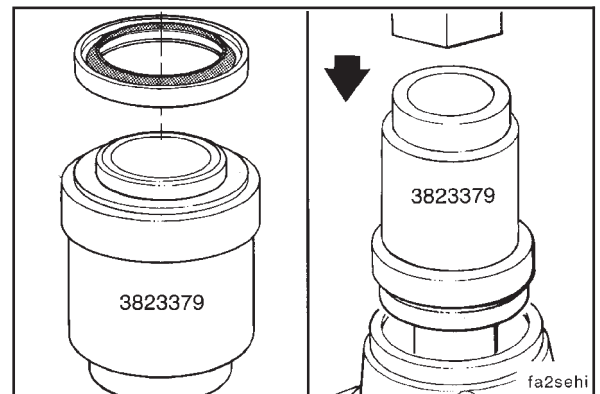
Caution: Do not lubricate the grease seal. The seal must be installed with the lip of the seal clean and dry to provide a proper sealing surface and prevent hub damage. Make sure the seal installation tool and flange are clean and dry when the fan hub is assembled.



The sealing lip of the grease seal **must** be installed away from the seal driver.

Place the seal on the large end of bearing driver, Part No. 3823379, with the open side of the seal facing away from the driver.

Press the seal into the hub until the driver contacts the hub.

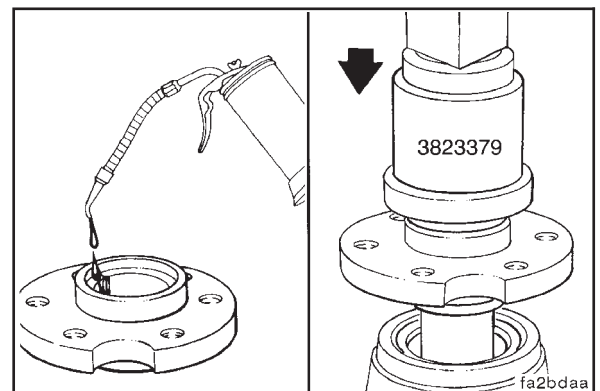


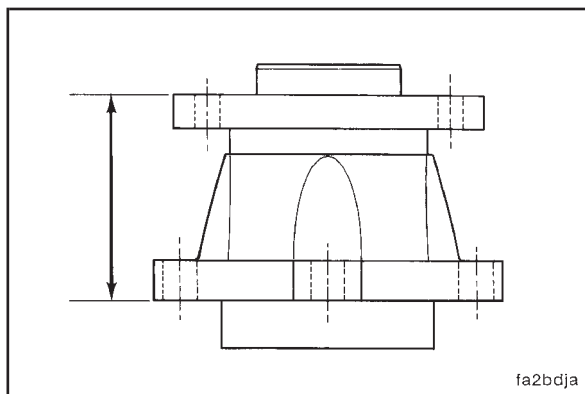
If the shaft is shorter than 95.2 mm [3.75 inch], support the shaft with spacer, Part No. 217008 or equivalent.

Place the hub on an arbor press with the tapered (fan mounting) end facing up.

Apply a thin film of oil into the bore of the fan hub flange.

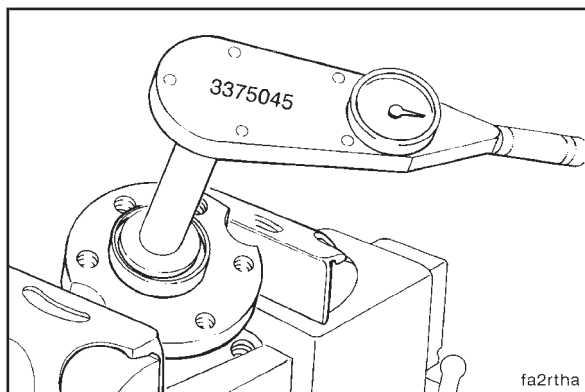
Use the large end of bearing driver, Part No. 3823379, to press the flange onto the shaft until it contacts the front bearing.





Measure the distance between the fan hub mounting faces.

Face to Face Distance		
mm		in
73.4	MIN	2.890
74.0	MAX	2.913

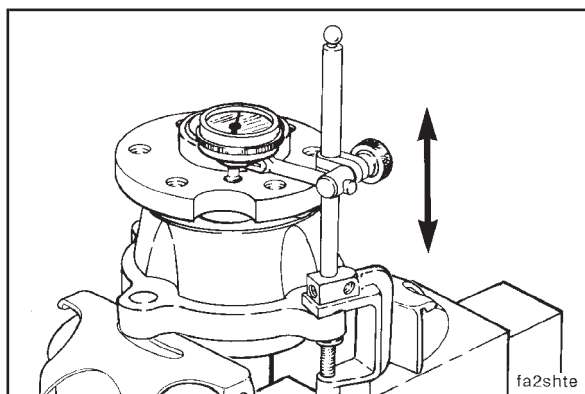


Install the fan hub in a vise with the fan mounting flange facing up.

Install the flat washer and the (M10-1.50 x 25) capscrew.



Torque Value: 61 N•m [45 ft-lb]



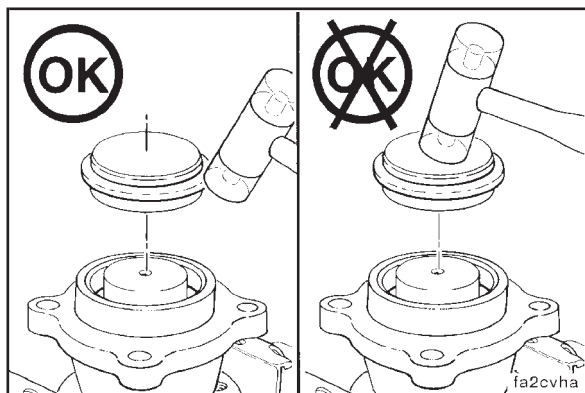
Install the fan hub in a vise so the shaft end clearance can be measured.



Shaft End Clearance		
mm		in
0.076	MIN	0.0030
0.406	MAX	0.0160



If the shaft end clearance is **not** within the specifications, disassemble and inspect for incorrect assembly.



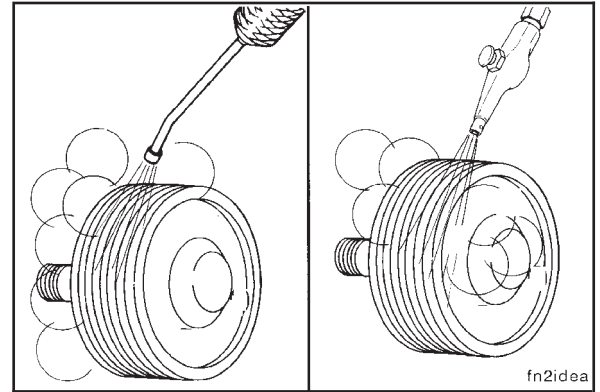
Use a leather hammer to install the cover. Do **not** hit in the center of the cover.

Fan Idler Pulley - Cleaning and Inspection for Reuse (8-05)

Cleaning

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

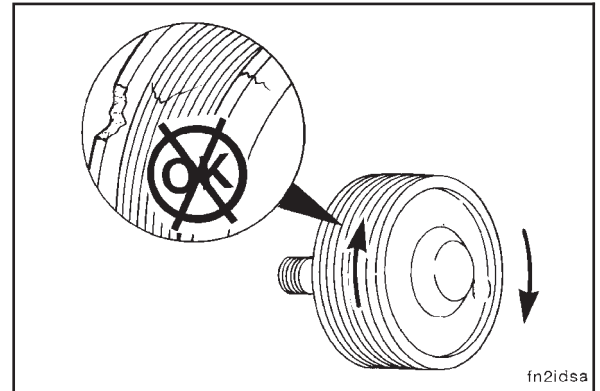
Use solvent or steam to clean the fan idler pulley exterior. Dry with compressed air.



Inspection

Visually inspect the idler assembly for cracked, chipped or broken pulley grooves.

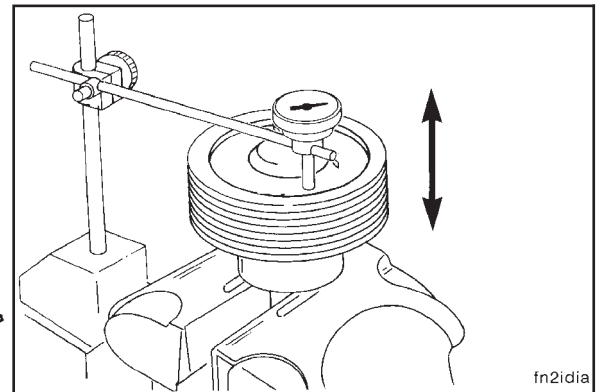
Turn the idler pulley by hand to inspect the shaft for freedom of rotation.



Measure the idler pulley end clearance.

Pulley End Clearance		
mm		in
0.05	MIN	0.002
0.25	MAX	0.010

If damaged parts are found, the pulley does **not** rotate freely or the pulley end clearance is **not** within the specifications, the idler pulley **must** be replaced or rebuilt. Refer to Fan Idler Pulley - Rebuild (8-06).

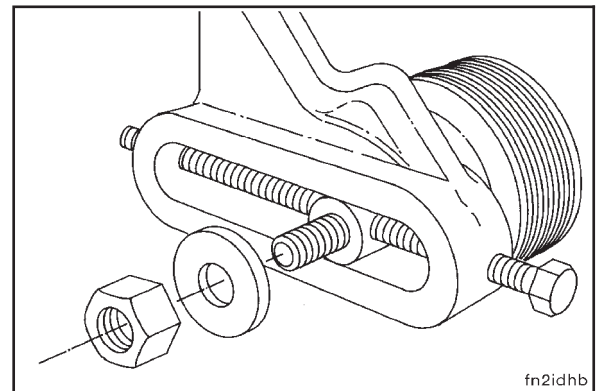


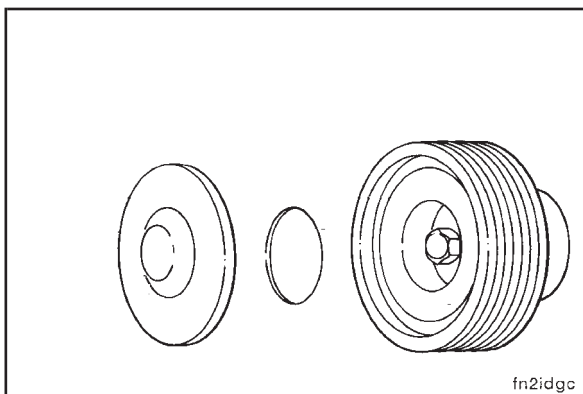
Fan Idler Pulley - Rebuild (8-06)

Disassembly

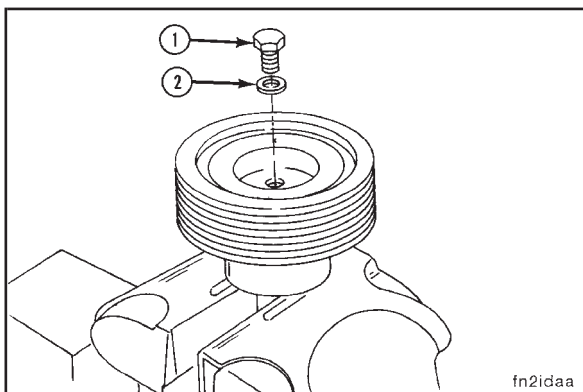
Install the fan hub support in a vise with brass jaws.

Remove the idler pulley from the fan hub support.

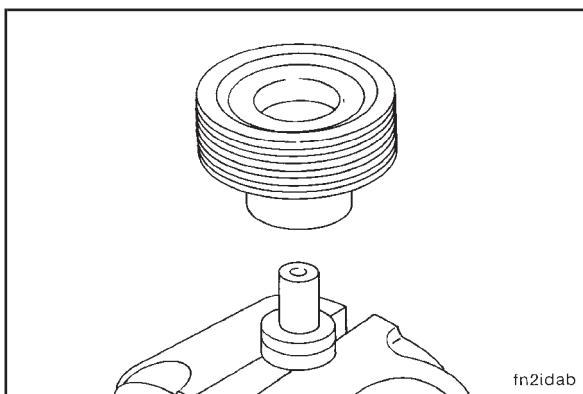




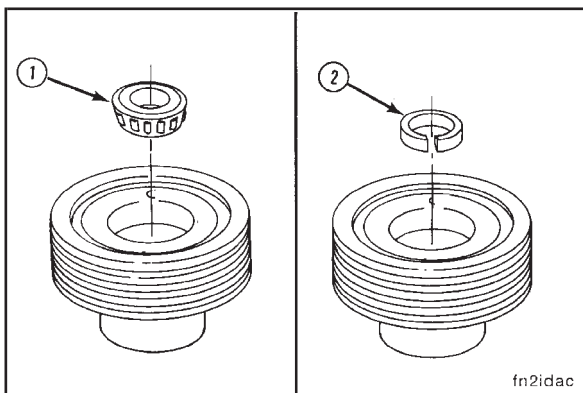
Remove the cover plate and o-ring from the idler pulley.
Discard the o-ring.



Install the pulley shaft in a vise with brass jaws.
Remove the cap screw (1) and washer (2) from the pulley shaft.



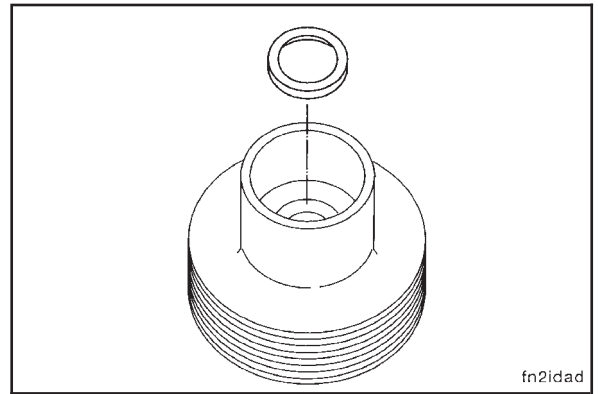
Remove the idler pulley from the shaft.



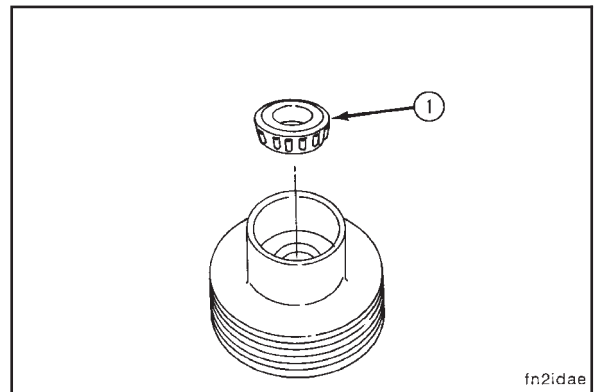
Remove the front bearing (1) from the idler pulley.
Remove the bearing spacer (2) from the idler pulley.

Caution: Do not damage the pulley bore when removing the rear grease seal. The idler pulley can fail.

Use a “flat tip” screwdriver or pry bar to remove the rear grease seal.



Remove the rear bearing (1) from the idler pulley.

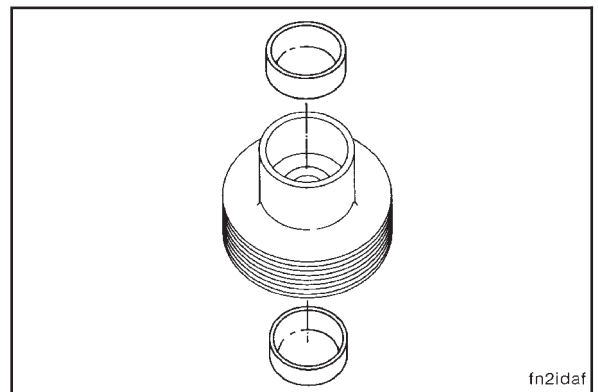


NOTE: The bearing races do **not** need to be removed during the inspection and rebuild procedure if they are **not** damaged. See Inspection following, if damage is found:

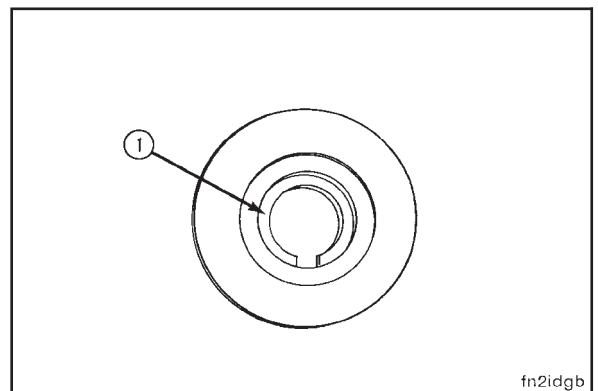
Install the idler pulley mounting flange in a vise with brass jaws.

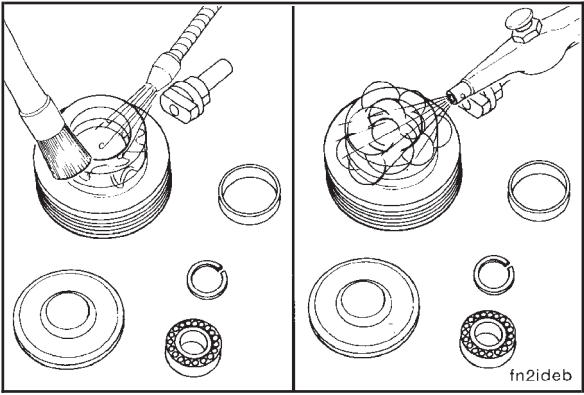
Caution: Do not damage the pulley bore when removing the bearing races. The idler pulley can fail.

Use a punch and hammer to remove the front and rear bearing races.



If the bearing race spacer (1) is **not** worn or damaged, it does **not** need to be removed during the inspection and rebuild procedure.

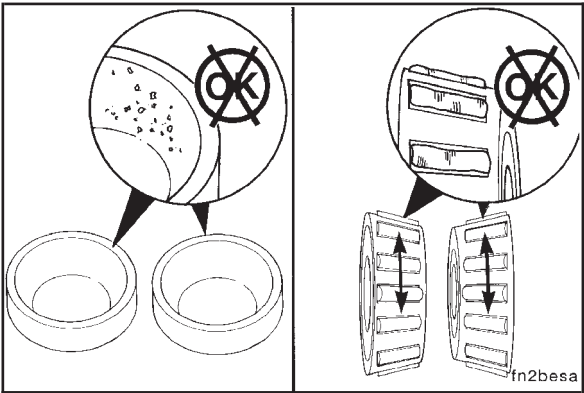




Cleaning



Use solvent to clean the idler pulley parts. Dry with compressed air.

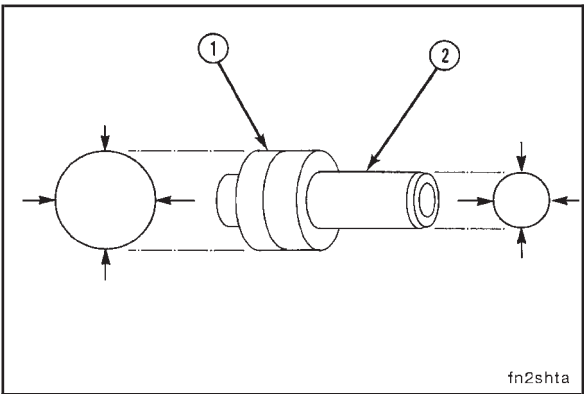


Inspection

The new idler pulley roller bearing set consists of two bearings, two races, an inner spacer and an outer spacer. To prevent future idler pulley failure, the bearings **must** be replaced as a complete set and **not** individual parts. Bearings and races that are to be used again **must** also be kept in sets.

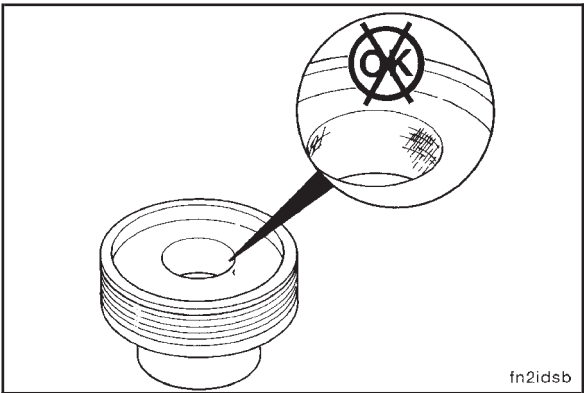


Visually inspect the bearing races for pitting or scoring.
Visually inspect the bearings for freedom of movement or damage.



Measure the outside diameter of the seal (1) and bearing (2) surfaces of the idler pulley shaft.

Point	Idler Pulley Shaft O.D.		
	mm		in
1	32.975	MIN	1.2982
	33.000	MAX	1.2992
2	19.037	MIN	0.7495
	19.050	MAX	0.7500

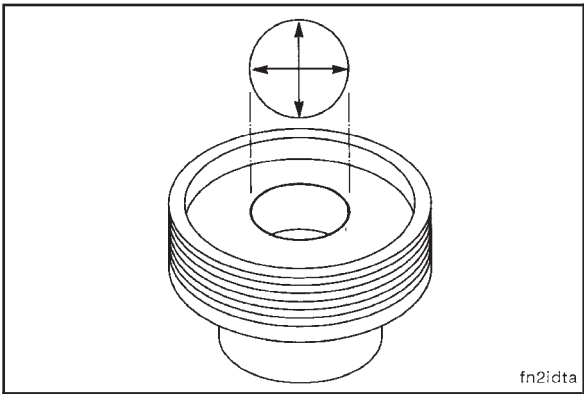


Visually inspect the idler pulley bore for scoring, nicks or scratches.

Measure the inside diameter of the idler pulley bearing bores.



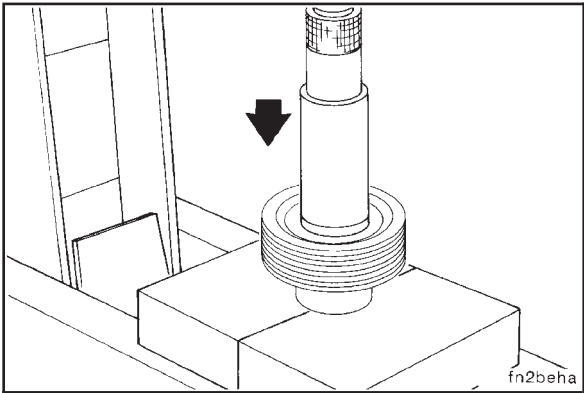
Front and Rear Bearing Bores I.D.		
mm		in
45.199	MIN	1.7795
45.224	MAX	1.7805



Assembly

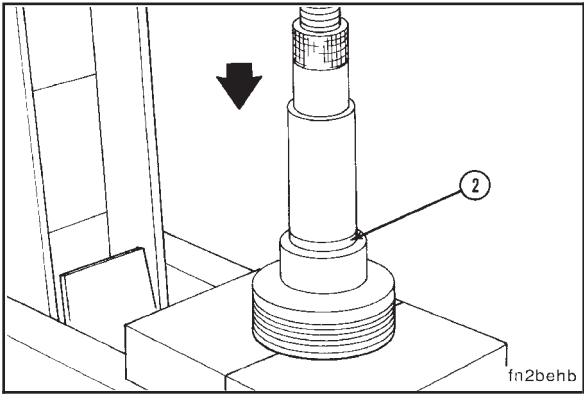
Install the idler pulley in an arbor press with the mounting flange facing down.

Use the bearing driver, Part No. 3375696, to press the front bearing race (1) into the pulley until it touches the spacer ring.



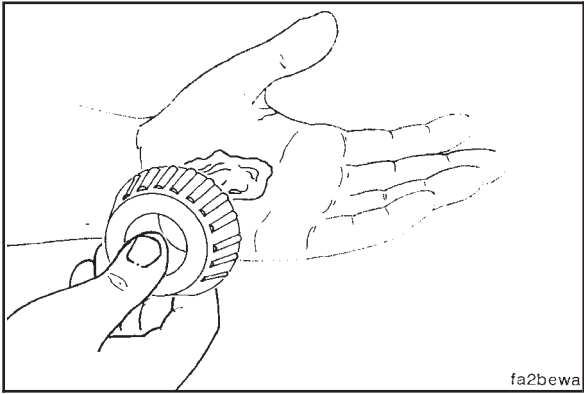
Turn the pulley over with the mounting flange facing up in the arbor press.

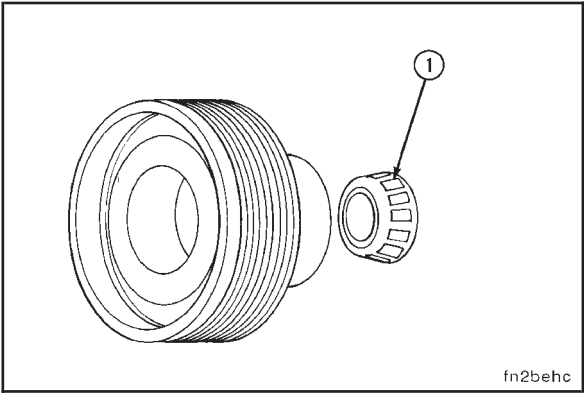
Use the bearing driver, Part No. 3375696, to press the rear bearing race (2) into the pulley until it touches the spacer ring.



Use clean Chevron SRI, or equivalent to lubricate the front and rear bearings.

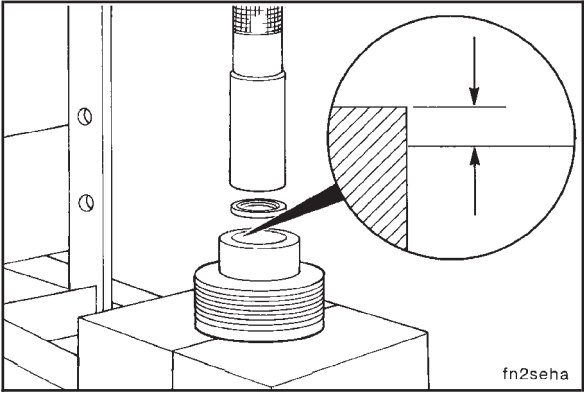
NOTE: Fill the space between the two bearings with grease when assembling the idler pulley.





Install the rear bearing (1) into the mounting flange end of the pulley.

The rear bearing **must** be seated in the rear bearing race.



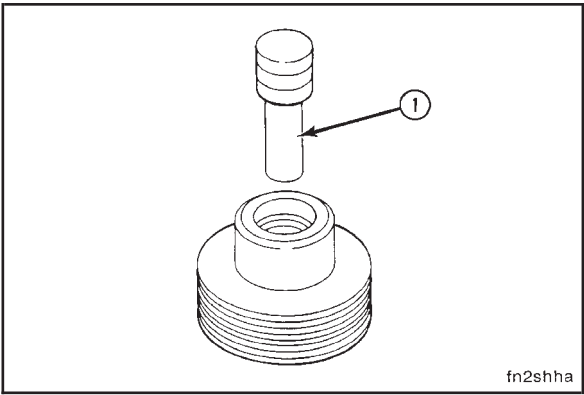
Install the idler pulley in an arbor press with the mounting flange facing up.

Caution: Do not lubricate the seal. The oil seal must be installed with the lip of the seal clean and dry to provide a proper oil sealing surface and prevent future idler pulley damage.

Install the seal into the pulley bore with the lip of the seal facing down.

Use the bearing driver, Part No. 3375696, to press the oil seal into the pulley bore to the specified depth from the mounting flange surface.

Oil Seal Installed Depth		
mm		in
0.00	MIN	0.000
0.25	MAX	0.010



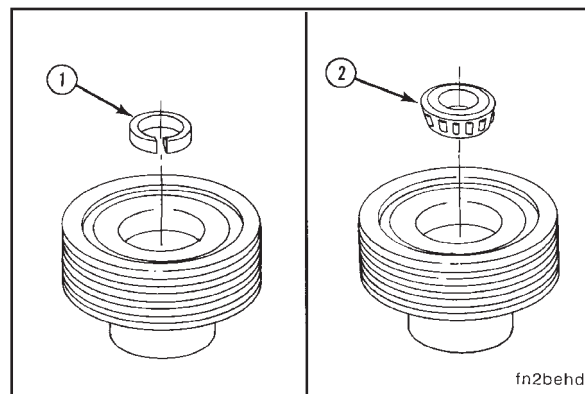
Caution: Do not allow the dust lip on the seal to roll under when installing the idler pulley shaft. The dust seal must be correctly installed to prevent contamination and future idler pulley failure.

Install the idler pulley shaft (1) into the bore of the pulley with the large end of the shaft seated in the mounting flange.

Install the front bearing spacer (1) into the idler pulley bore.

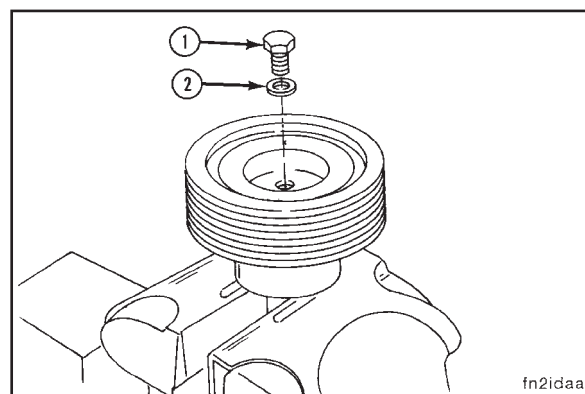
Install the front bearing (2) into the idler pulley bore.

The front bearing **must** be seated in the front bearing race.



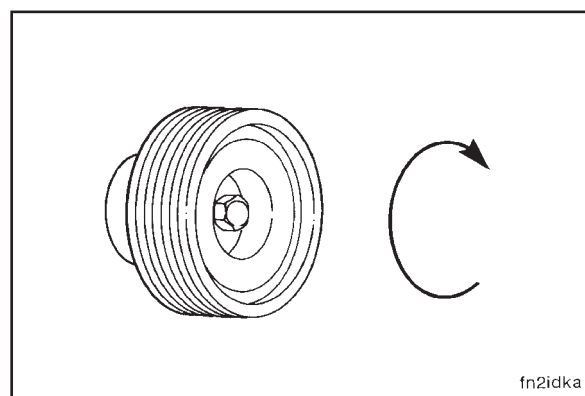
Install the capscrew (1) and washer (2) into the idler pulley shaft.

Torque Value: 47 N•m [35 ft-lb]



Turn the idler pulley by hand to inspect the shaft for freedom of rotation.

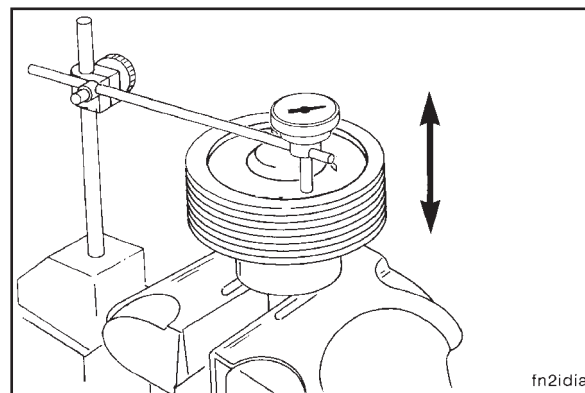
If the idler pulley does **not** rotate freely, disassemble and inspect for incorrect assembly.

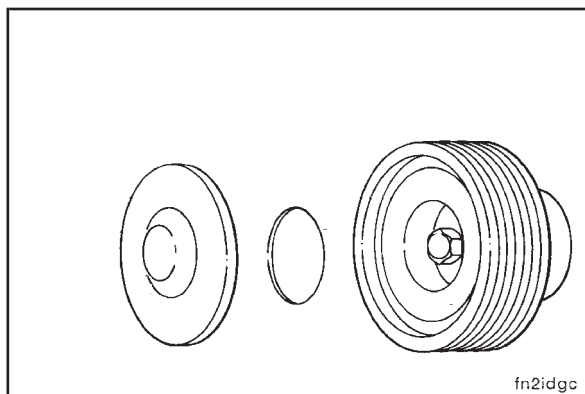


Measure the idler pulley end clearance.

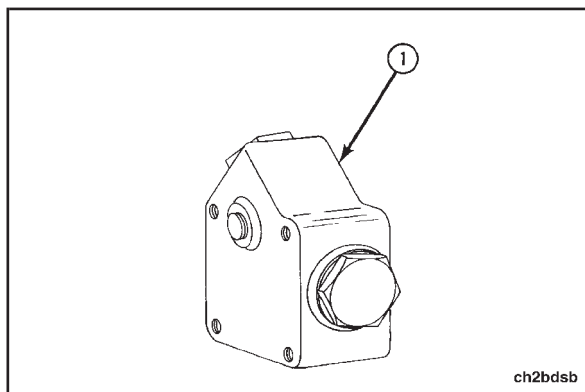
Pulley End Clearance		
mm		in
0.05	MIN	0.002
0.25	MAX	0.010

If the idler pulley end clearance is **not** within the specifications, disassemble and inspect for incorrect assembly.





Install a new o-ring and the cover plate.

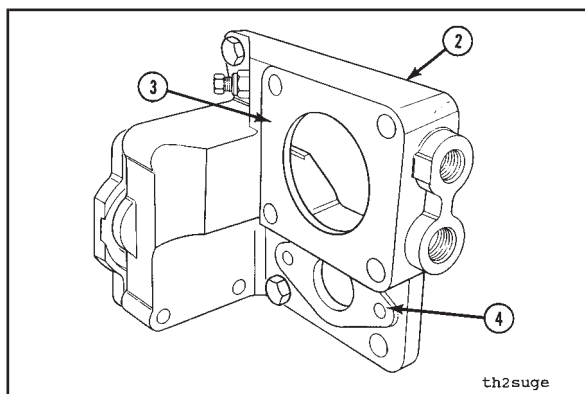


Heater Housing, Thermostat Support and Water Header Cover - Cleaning and Inspection (8-09)

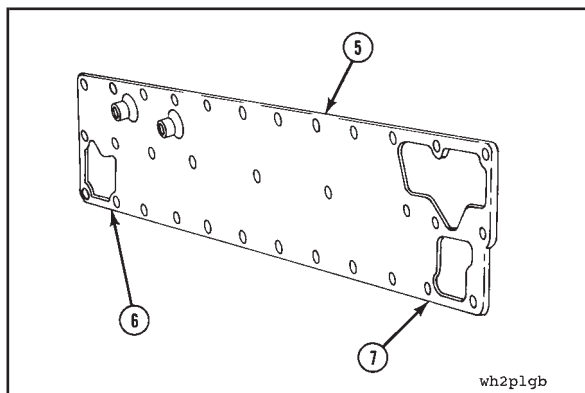
Cleaning



Remove the gasket material from the engine heater housing surface (1).

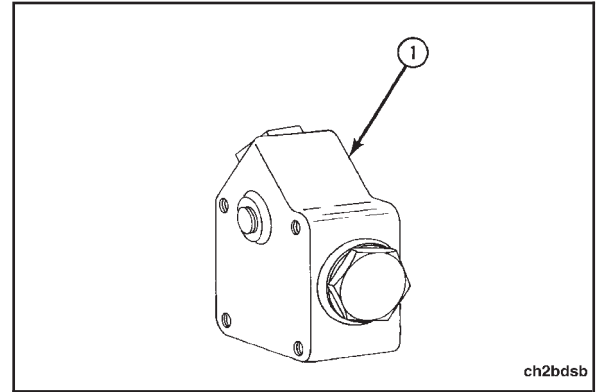


Remove the gasket material from the thermostat support surfaces (2, 3 and 4).

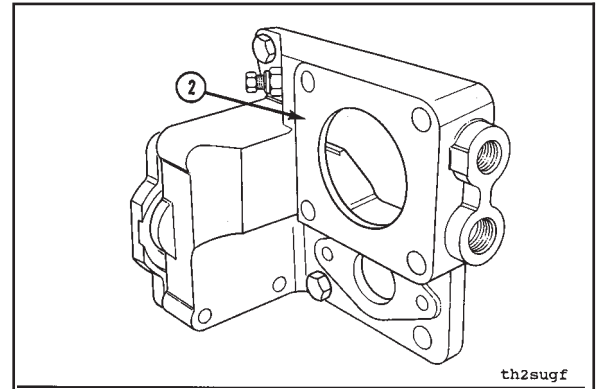


Remove the gasket material from the water header cover surfaces (5, 6 and 7).

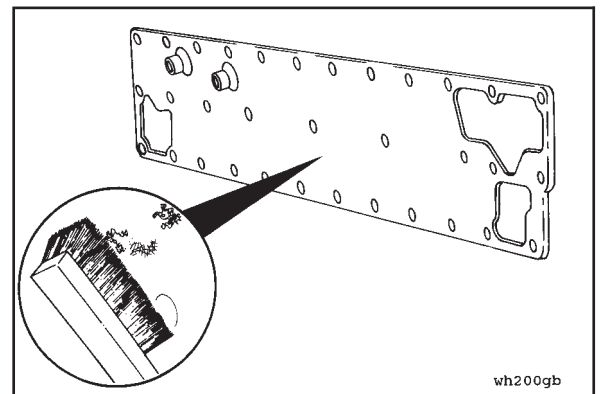
Use a wire brush to remove the rust and corrosion from the engine heater housing surface (1).



Use a wire brush to remove the rust and corrosion from the thermostat support surface (2).

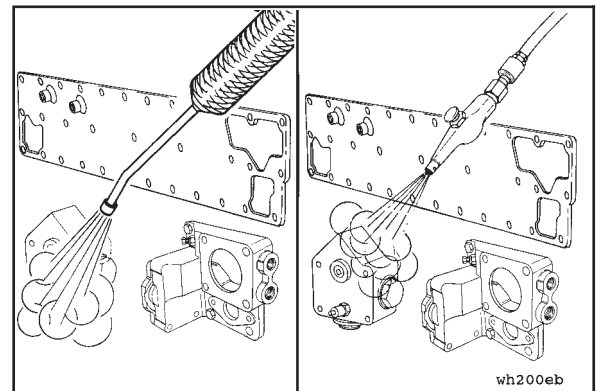


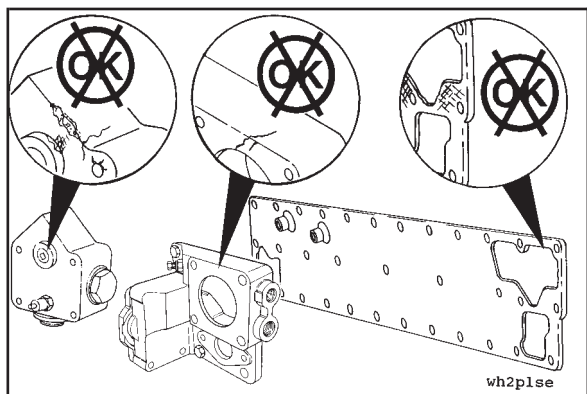
Use a wire brush to remove the rust and corrosion from the water header cover surfaces (3 and 4).



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

Use steam to clean the parts. Dry with compressed air.



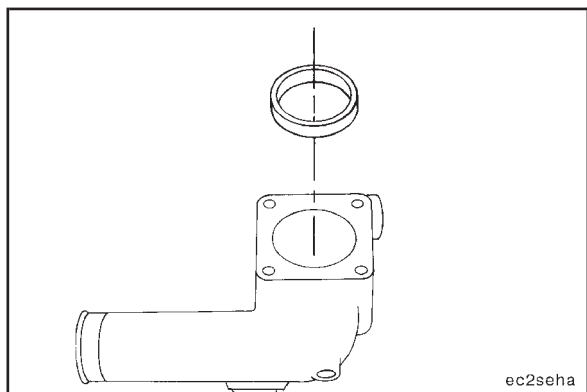


Inspection



Visually inspect the parts for cracks, damage or excessive corrosion.

If damaged parts or excessive corrosion is found the part **must be** replaced.



Thermostat Housing Assembly - Rebuild (8-10)

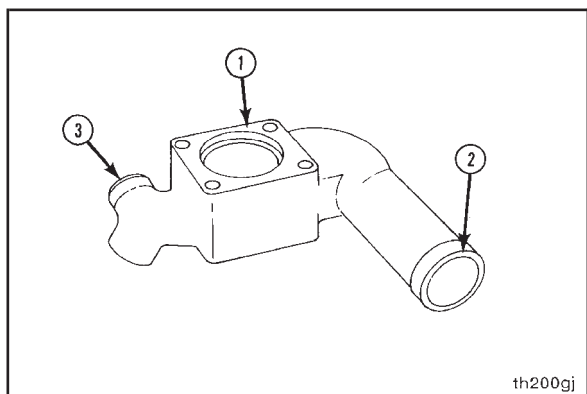
Disassembly



Caution: To prevent future engine damage, do not damage the thermostat housing when removing the thermostat water seal.



Use a punch and hammer to remove the thermostat water seal.

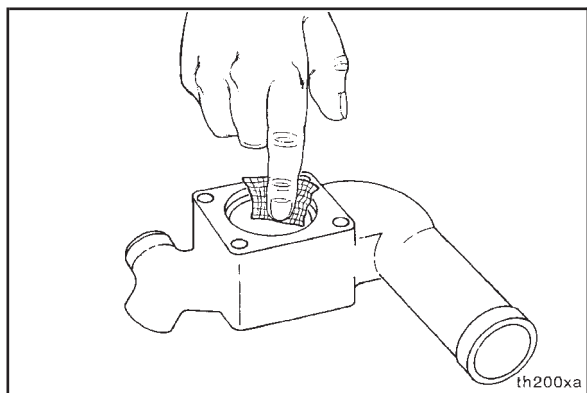


Cleaning



Use a gasket scraper to remove all gasket material from surfaces (1).

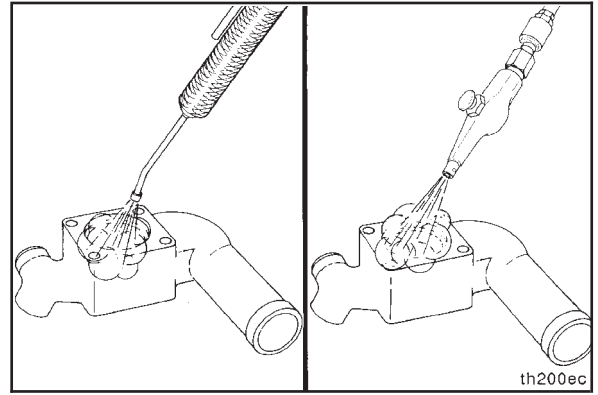
Use a wire brush to clean the hose sealing surfaces (2 and 3).



Use Scotch-Brite® 7448, Part No. 3823358 or equivalent, to remove the corrosion from the thermostat housing bore.

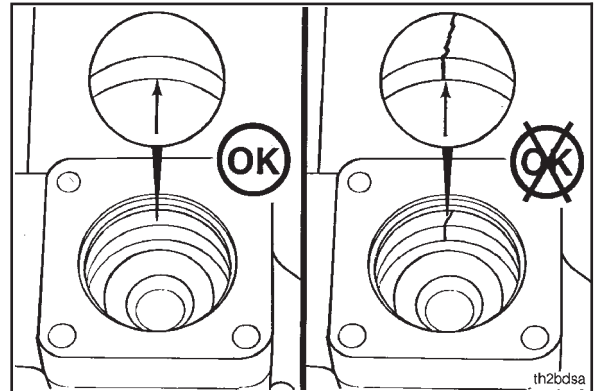
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.

Use steam to clean the parts. Dry with compressed air.



Inspection

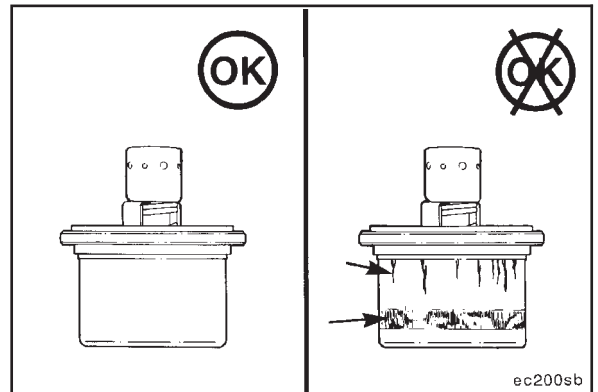
Visually inspect the parts for excessive corrosion, cracks or damage.



Visually inspect the thermostat for cracks or other damage.

If excessive corrosion, cracks or other damage is found the part **must** be replaced.

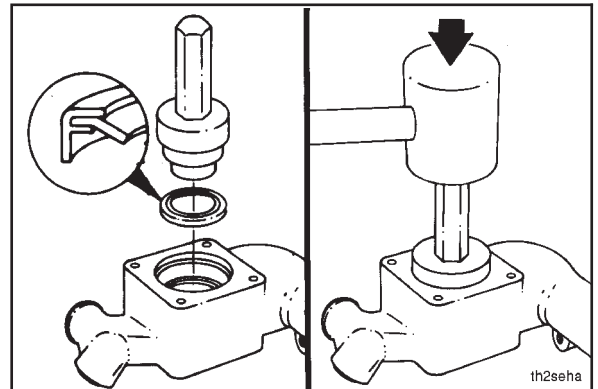
Refer to Thermostat - Check Operating Temperature (8-11).

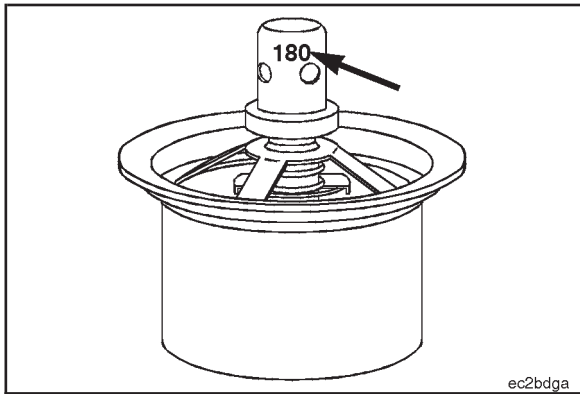


Assembly

When installing the thermostat water seal, the flat side of the seal **must be** facing the thermostat seal mandrel.

Use the thermostat seal mandrel, Part No. ST-1225, and a mallet to install the new seal.



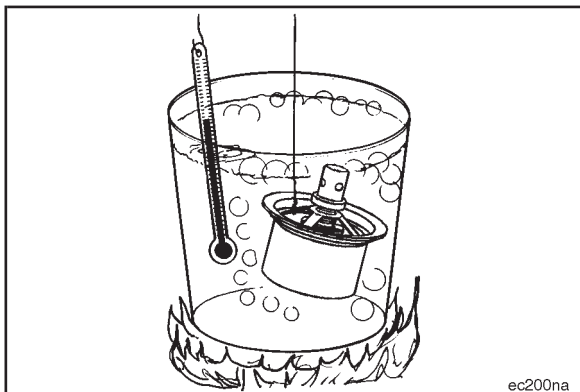


Thermostat - Operating Temperature Inspection (8-11)

Test



Check the temperature marked on the thermostat to see when the thermostat is designed to open. Record the nominal opening temperature.

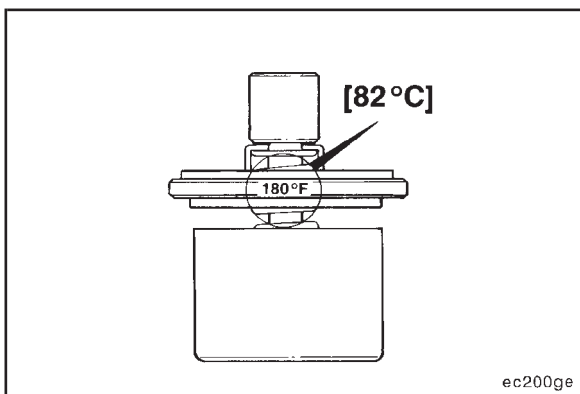


NOTE: Do not allow the thermostat or thermometer to touch the side of the container.



Suspend the thermostat and a thermometer in a container of water.

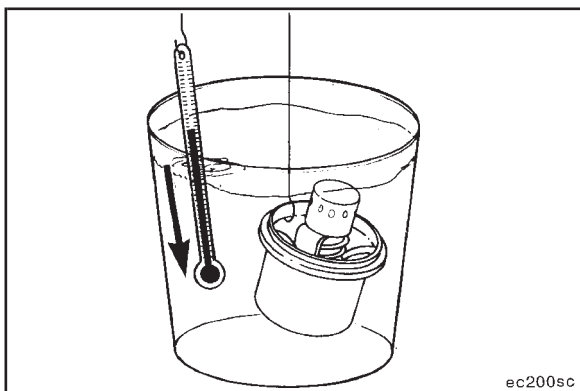
Heat the water. Check the temperature when the thermostat starts to open.



The thermostat **must** operate within the following specifications.



Initial Opening Temperature		
Degree °C		Degree °F
81°C	MIN	178°F
83°C	MAX	182°F
Fully Open Temperature		
93°C	MAX	200°F
Maximum Open Distance		
mm		in.
9.52	MAX	0.375



Remove the container from the heat.



The thermostat **must** begin to close as the temperature drops below the nominal temperature marked on the thermostat.

If the thermostat fails to open at the specified temperature or does **not** completely close after the water temperature has dropped below the nominal operating temperature, the thermostat **must** be replaced.

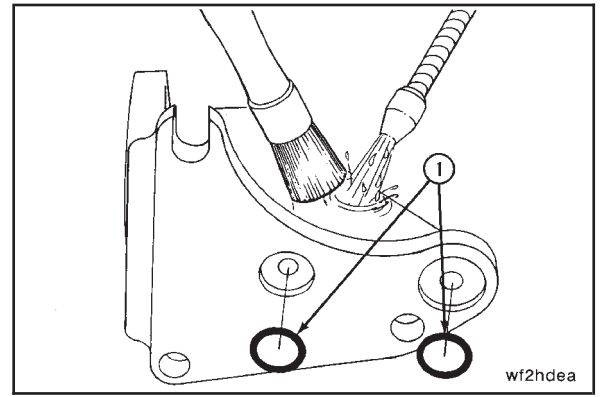
Water Filter Head Assembly - Cleaning and Inspection for Reuse (8-12)

Cleaning

Remove the o-ring seals (1) from the mounting flange.

Discard the o-ring seals.

Use solvent to clean the filter head assembly. Dry with compressed air.

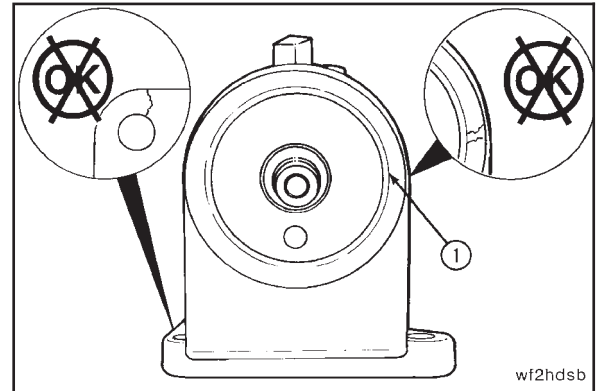


Inspection

Visually inspect the filter head assembly for cracks or damage.

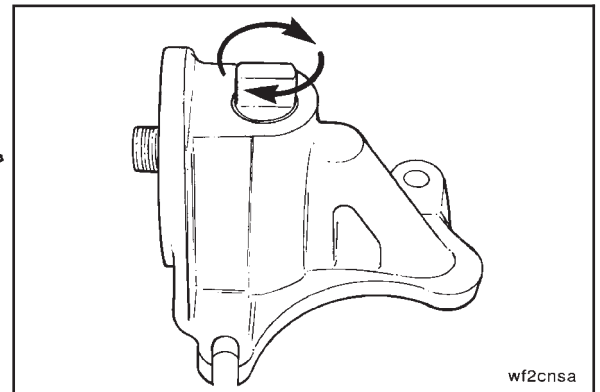
Visually inspect the water filter element sealing surface (1) for cracks or damage.

If cracks or damage are found, the filter head assembly **must** be replaced.



Turn the shutoff valve shaft from the "ON" to the "OFF" position and back to the "ON" position again to inspect for freedom of movement.

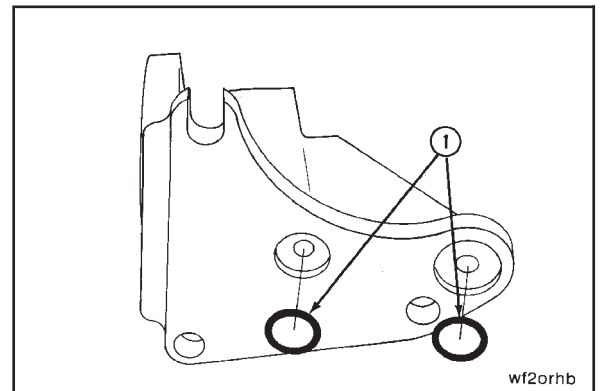
If the shut-off valve shaft does **not** turn freely by hand, the filter head assembly **must** be rebuilt. Refer to Water Filter Head Assembly Rebuild (8-13).

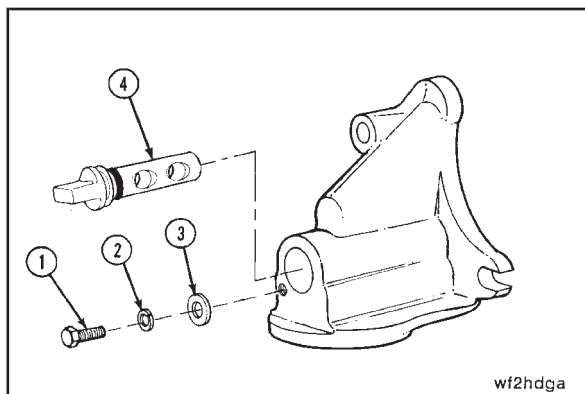


Water Filter Head Assembly - Rebuild (8-13)

Disassembly

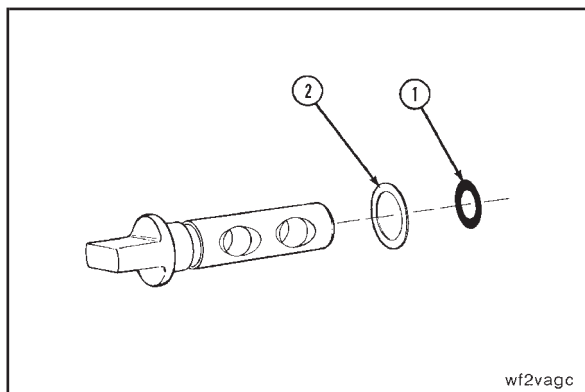
Remove the o-ring seals (1) from the mounting flange. Discard the o-rings.



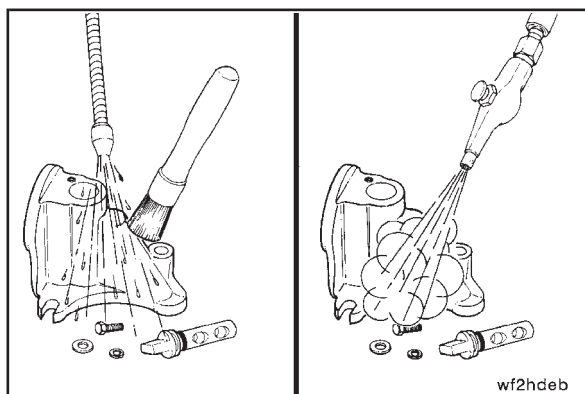


Remove the capscrew (1), and the washers (2 and 3) from the filter head.

Use a pair of pliers to remove the shutoff valve shaft (4) from the filter head.

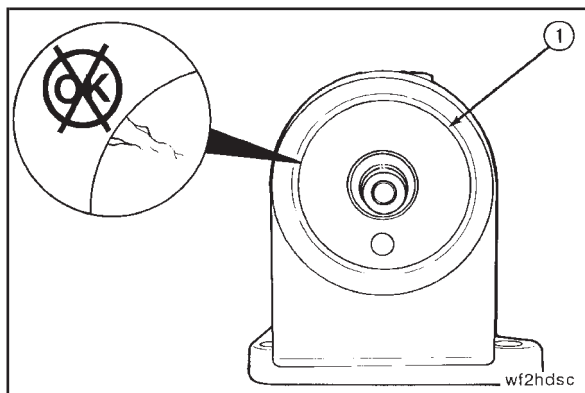


Remove the o-ring (1) and spring washer (2) from the shutoff valve shaft.



Cleaning

Use solvent to clean the parts. Dry with compressed air.



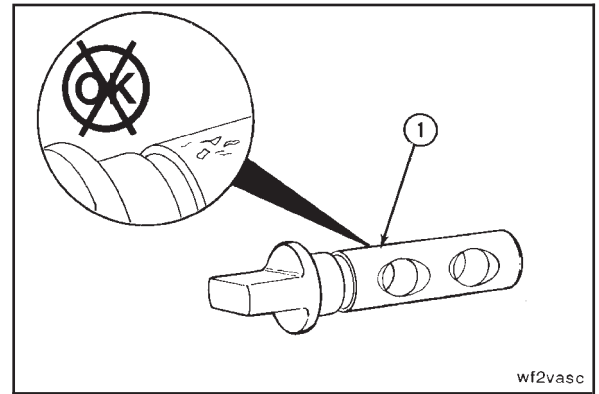
Inspection

Visually inspect the filter head and water filter element sealing surface (1) for cracks or damage.

Visually inspect the water passages in the shutoff valve shaft (1).

Visually inspect the shaft for corrosion or pitting. Use 240 grit aluminum oxide paper to remove the corrosion.

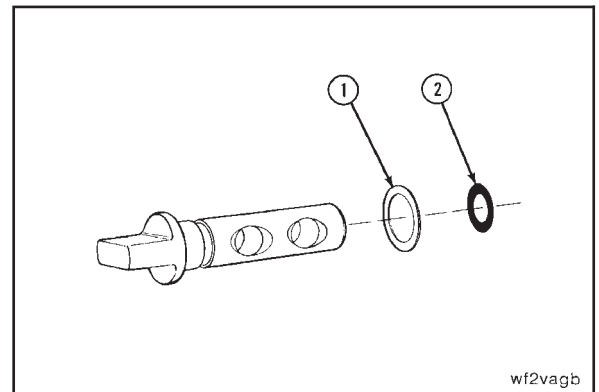
If the parts are cracked or damaged, the filter head assembly **must** be replaced.



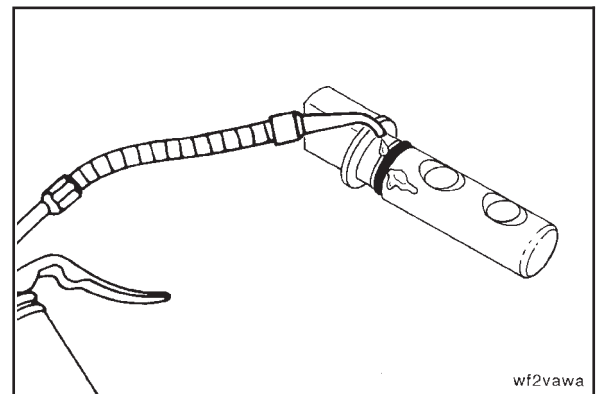
Assembly

Install the spring washer (1) on the shutoff valve shaft.

Install a new o-ring (2) in the groove of the shaft.



Use anti-seize to lubricate the shaft and o-ring.

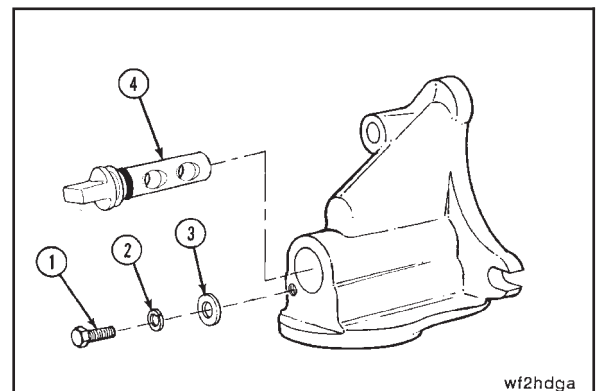


Install the shutoff valve shaft (4) in the filter head.

NOTE: Make sure the flat washer (3) is a hardened steel washer.

Install the hardened flat washer (3), lockwasher (2) and clamping capscrew (1) in the filter head.

Torque Value: 10 N•m [60 in-lb]



NOTES

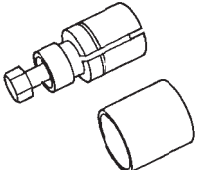
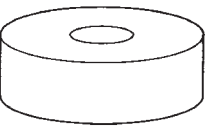
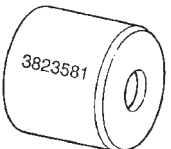
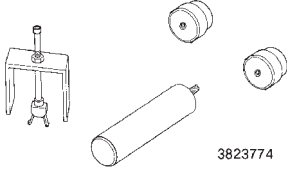
Section 9 - Drive Units

Section Contents

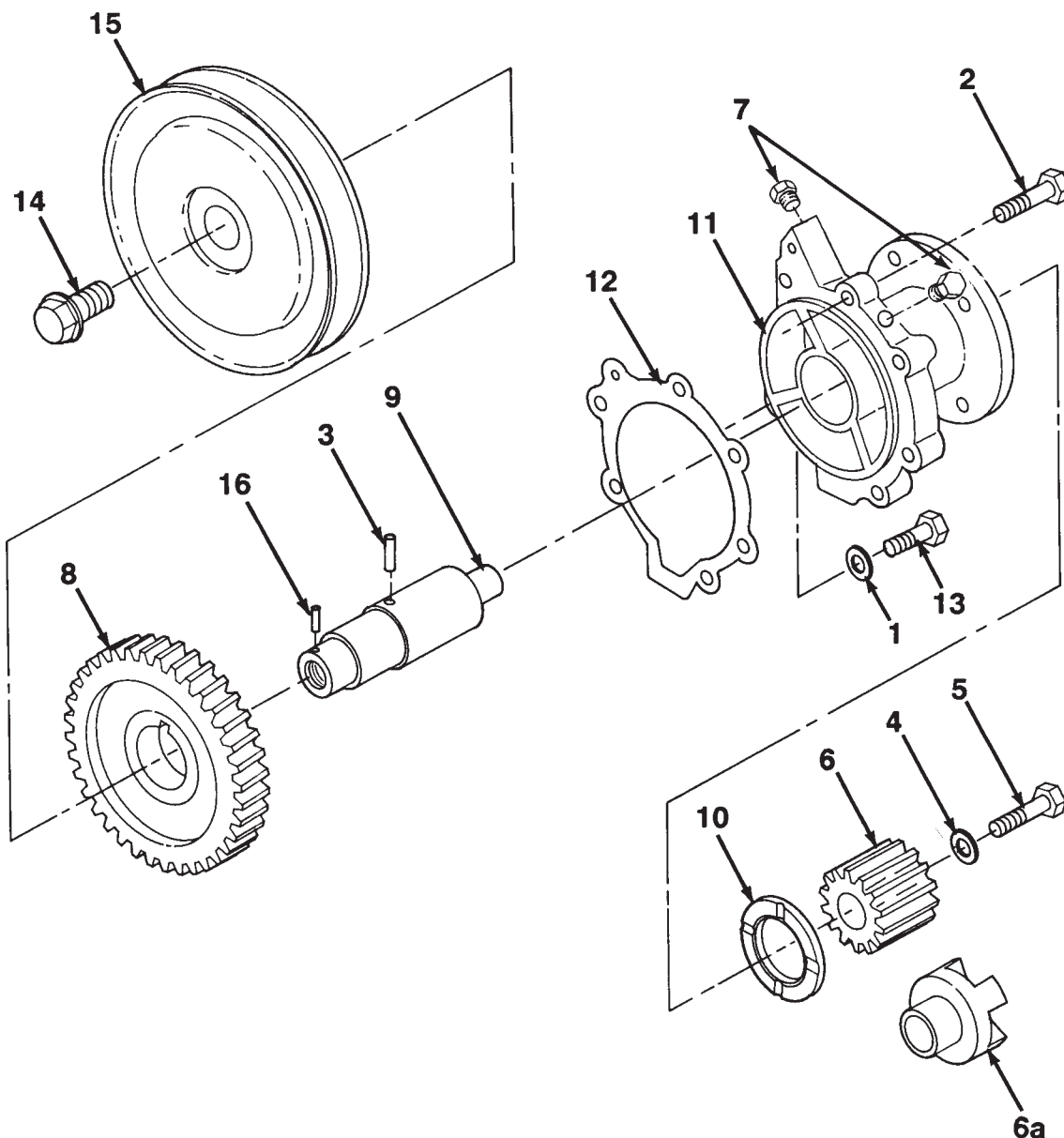
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Service Tools - Drive Units

The following special tools are recommended to perform procedures in Group 09. 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
3376663	Coupling Puller Remove the splined coupling gear from the compressor drive.	 bp81cgg
3376820	Hydraulic Drive Gear Driver Install the hydraulic pump drive gear on the drive shaft.	 3376820
3823581	Fuel Pump Drive Gear Driver Install the fuel pump drive gear on the drive shaft.	 3823581
3823774	Needle Bearing Removal and Installation Kit Used to remove needle bearings in the hydraulic pump adapter. Use mandrel, Part No. 3823776, and handle, Part No. 3823775, to install hydraulic pump needle bearings.	 3823774

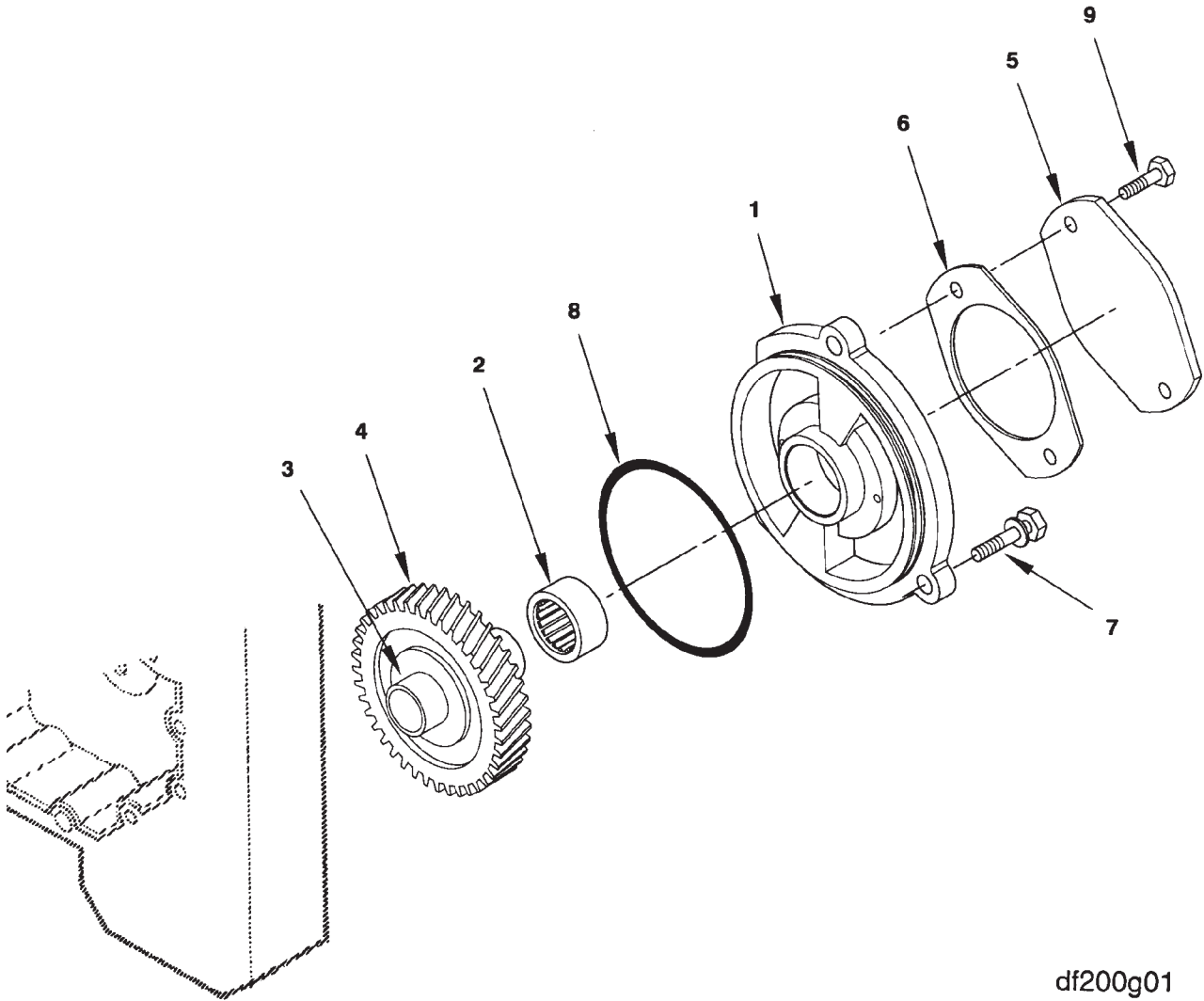
Fuel Pump and Compressor Drive - Exploded View



sa200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1.	Washer, Copper Sealing	1	9.	Shaft, Accessory Drive	1
2.	Capscrew	5	10.	Bearing, Thrust	1
3.	Pin, Groove	1	11.	Support, Accessory Drive	1
4.	Washer, Plain	1	12.	Gasket, Accessory Drive Support	1
5.	Capscrew	1	13.	Capscrew	1
6.	Gear, Splined Coupling	1	14.	Capscrew, Captive Washer	1
6a.	Coupling, Hub	1	15.	Pulley, Accessory Drive	1
7.	Plug, Straight Thread O-ring	2	16.	Pin, Dowel	1
8.	Gear, Fuel Pump and Compressor Drive	1			

Hydraulic Pump Drive - Exploded View



df200g01

Ref. No.	Description	Qty.
1.	Adapter, Hydraulic Pump	1
2.	Bearing, Needle	1
3.	Adapter, Spline	1
4.	Gear, Hydraulic Pump	1
5.	Plate, Cover	1

Ref. No.	Description	Qty.
6.	Gasket, Hydraulic Pump	1
7.	Screw, Captive Washer Cap	2
8.	Seal, O-ring	1
9.	Screw, Hex Flange Head Cap	2

Drive Units - General Information

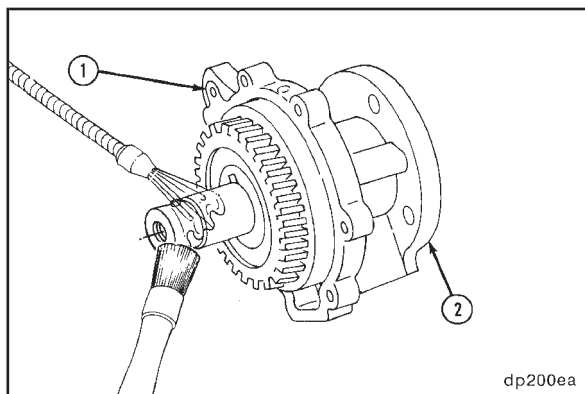
Fuel Pump and Compressor Drive

The fuel pump and compressor drive housings are available in two designs, **with** and **without** hardware for mounting an air compressor. The fuel pump drive assembly has hardware for a hub or spider coupling. The compressor drive assembly has hardware for a **splined sleeve** coupling. The rebuild procedures are the same for both designs.

The M11 Engine uses both metric and U.S. Customary capscrews. In some cases, capscrews in metric and U.S. Customary threads are almost identical in appearance. Be sure to install the capscrews in the same location they were removed from.

Hydraulic Pump Drive

The hydraulic pump is gear driven from an idler gear in the front gear train. The drive gear and shaft are contained in the gear housing and rear support by two roller bearings. The bearings, gear and shaft receive lubrication from engine oil in the front gear train.



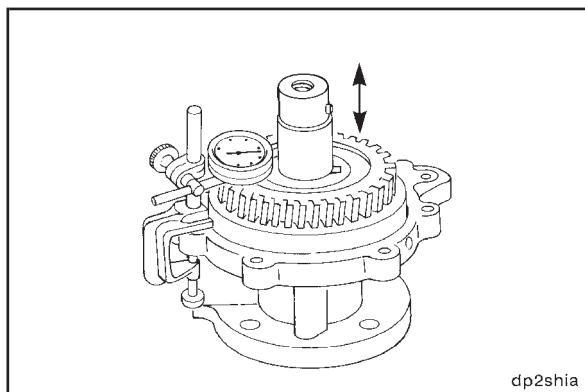
Fuel Pump and Compressor Drive - Cleaning and Inspection for Reuse (9-01)

Cleaning



Remove all gasket material from surfaces (1 and 2).

Clean the exterior of the drive with solvent, dry with compressed air.



Inspection

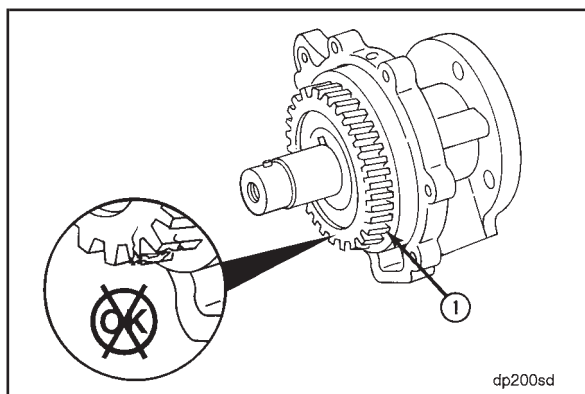


Measure the driveshaft end clearance.

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 Fuel Pump and Compressor Drive - Rebuild (9-02).

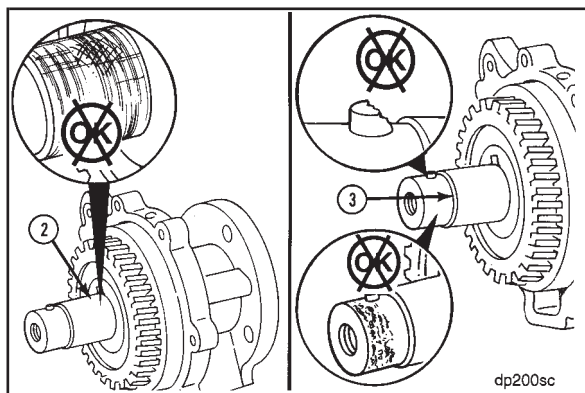


Visually inspect the housing for cracks and non-uniform front and rear gasket sealing surfaces.

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.

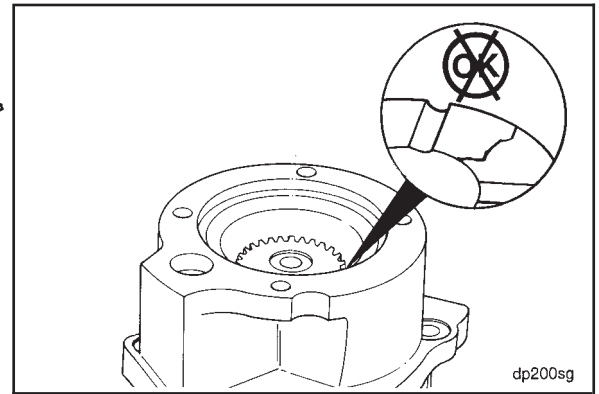


Visually inspect the shaft surface (2). Pay special attention to the pulley hub to shaft shoulder contact area (3). Replace the shaft if scratches, scoring, or fretting is found.

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 Fuel Pump and Compressor Drive - Rebuild (9-02).

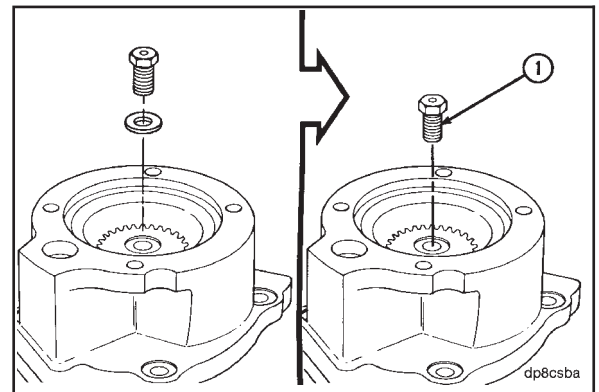


Fuel Pump and Compressor Drive - Rebuild (9-02)

Disassembly

Remove the capscrew and washer.

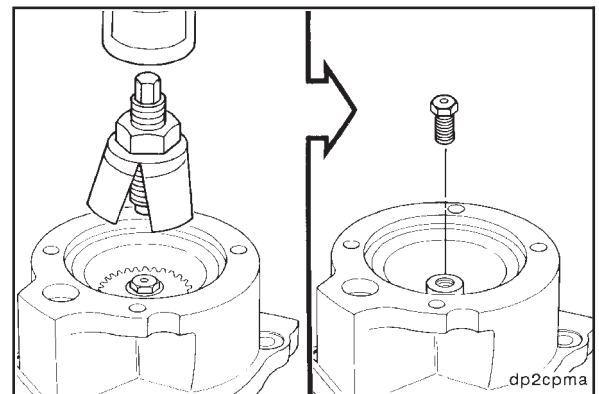
Caution: Install the retainer capscrew (1), without the washer to prevent damage to the shaft while the gear is being removed.



The thrust bearing will be damaged if a hydraulic press is used to remove the spline or hub coupling from the shaft.

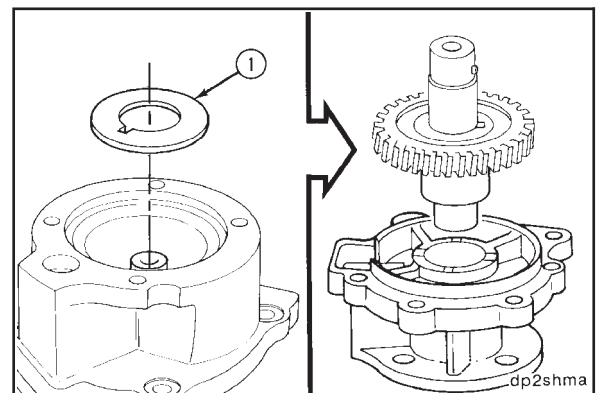
Use the coupling puller, Part No. 3376663, to remove the splined coupling, or a three jaw puller to remove the hub coupling.

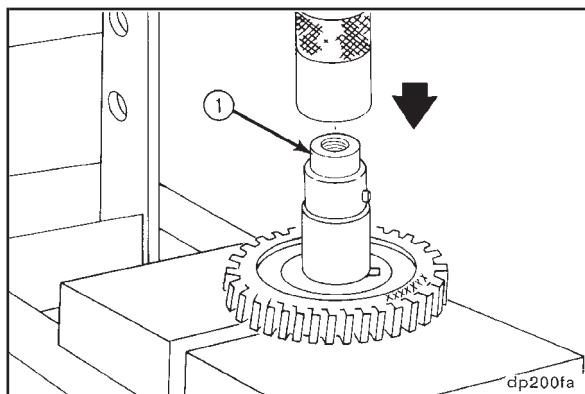
Remove the capscrew.



Remove the thrust bearing (1).

Remove the shaft and gear assembly.





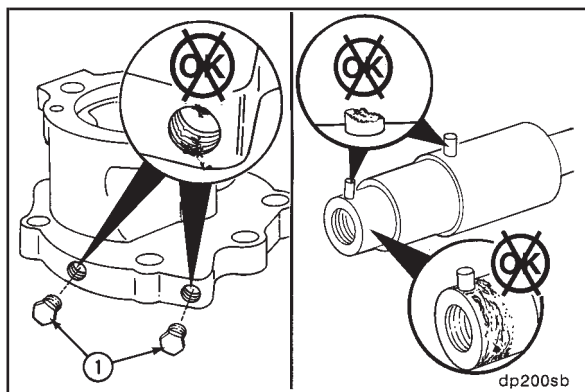
Install the shaft and gear assembly in an arbor press with the part number side of the gear facing up.



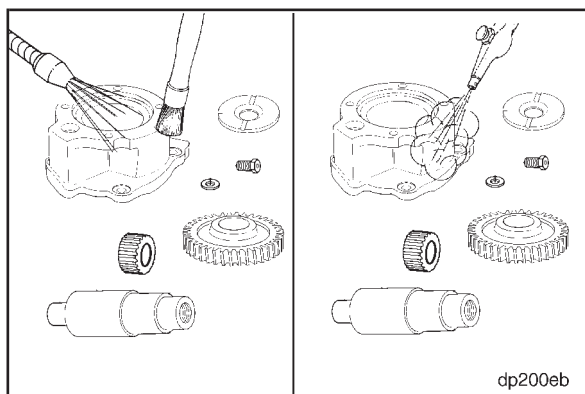
Caution: Do not let the shaft fall when removing it from the drive gear. Damage to the shaft or personal injury can occur.



Press the shaft from the gear.

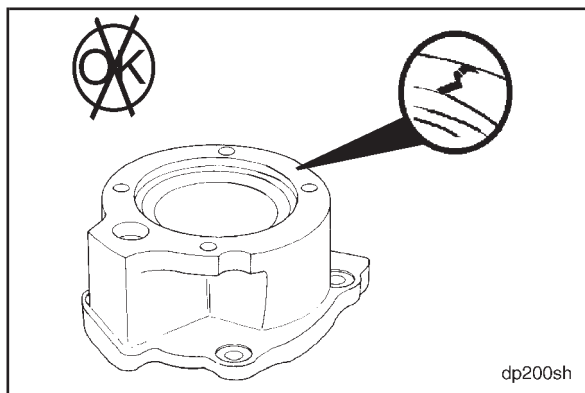


Remove the straight thread o-ring plugs (1) from the drive housing.



Cleaning

Clean the parts with solvent. Clean the oil passages in the housing with solvent. Dry all the parts and blow out the oil passages with compressed air.



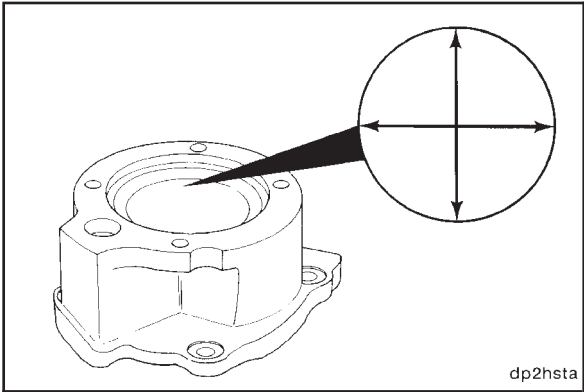
Inspection

Visually inspect the housing for cracks and non-uniform front and rear gasket sealing surfaces.

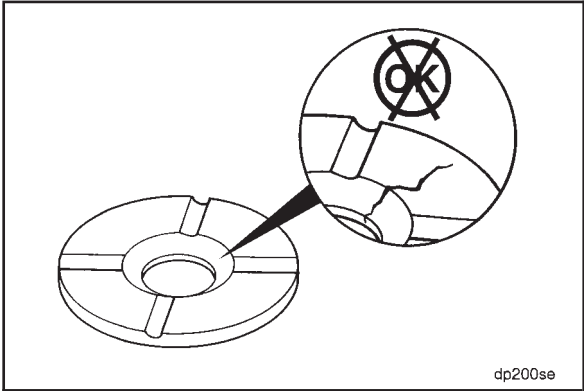
Replace the housing if cracks are found, or the gasket sealing surfaces **cannot** be made uniform using Scotch-Brite® or its equivalent.

Measure the inside diameter of the bearing bore in the drive housing.

Drive Housing Bearing Bore I.D.		
mm		in
47.676	MIN	1.8770
47.775	MAX	1.8809

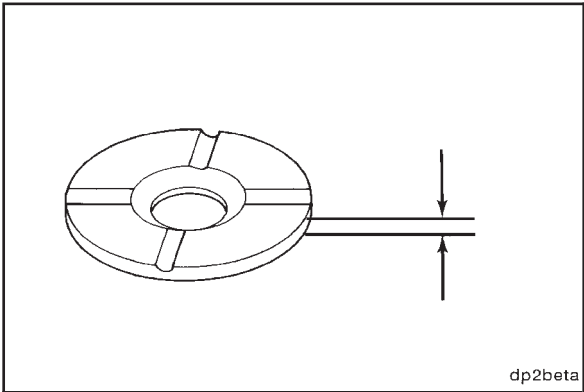


Visually inspect the thrust washer for cracks or other damage. Replace the washer if it is cracked or damaged.

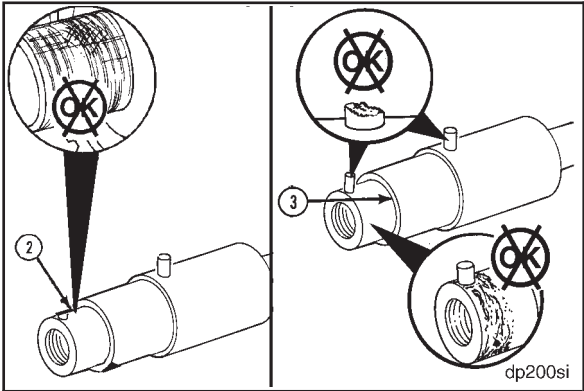


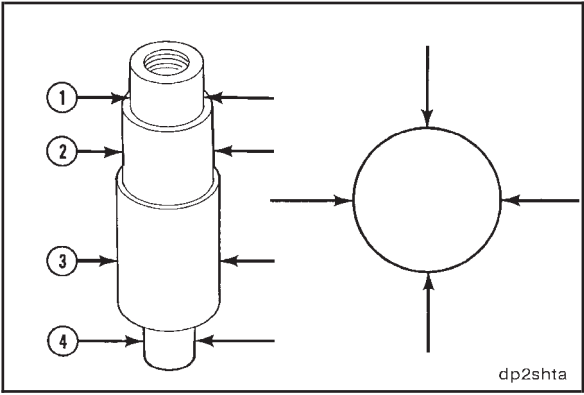
Measure the thrust bearing thickness.

Thrust Bearing Thickness		
mm		in
6.084	MIN	0.2395
6.312	MAX	0.2485

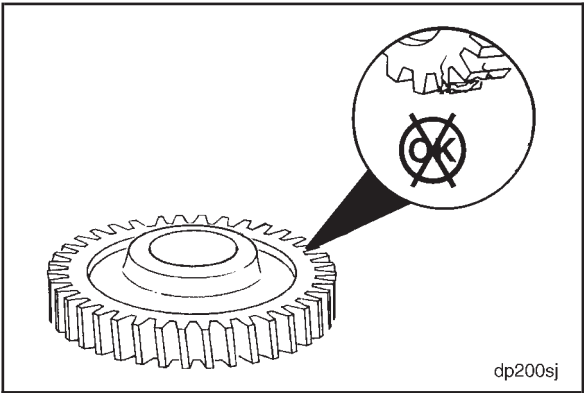


Visually inspect the shaft surface (2). Pay special attention to the pulley hub to shaft shoulder contact area (3). Replace the shaft if scratches, scoring, or fretting is found. Inspect the dowel pin for damage. Replace if required.

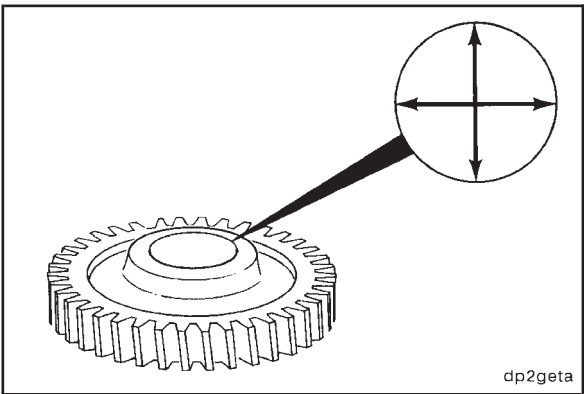




Drive Shaft Journal O.D.			
Point	mm		in
(1)	34.984	MIN	1.3773
	35.000	MAX	1.3779
(2)	44.975	MIN	1.7706
	45.000	MAX	1.7716
(3)	47.554	MIN	1.8722
	47.570	MAX	1.8728
(4)	25.476	MIN	1.0030
	25.489	MAX	1.0035

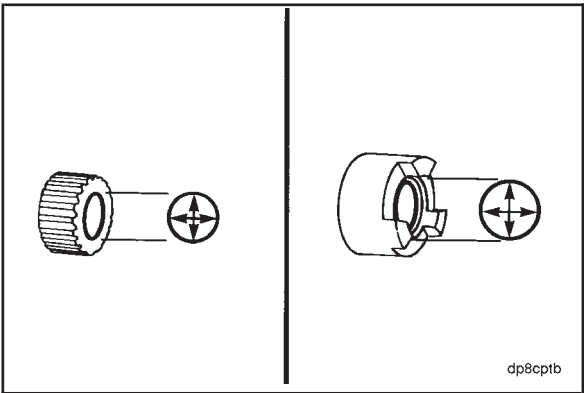


Visually inspect the drive gear for cracked or severely worn teeth. Replace the drive gear if it is cracked or abnormally worn teeth are found.



Measure the inside diameter of the drive gear.

Drive Gear Bore I.D.		
mm		in
47.484	MIN	1.8694
47.509	MAX	1.8704



Measure the inside diameter of the splined coupling gear or hub coupling.

Splined Coupling I.D.		
mm		in
25.400	MIN	1.0000
25.425	MAX	1.0010

Hub Coupling I.D.		
mm		in
25.425	MIN	1.0010
25.438	MAX	1.0015

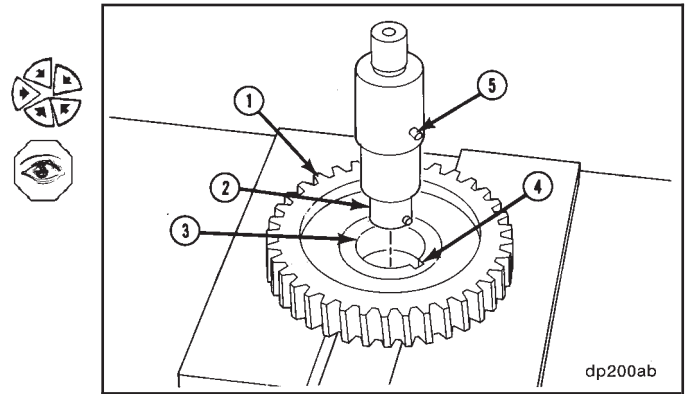
Assembly

Install the drive gear (1) in an arbor press. Support the gear as shown.

NOTE: Make sure the part number side of the gear faces down.

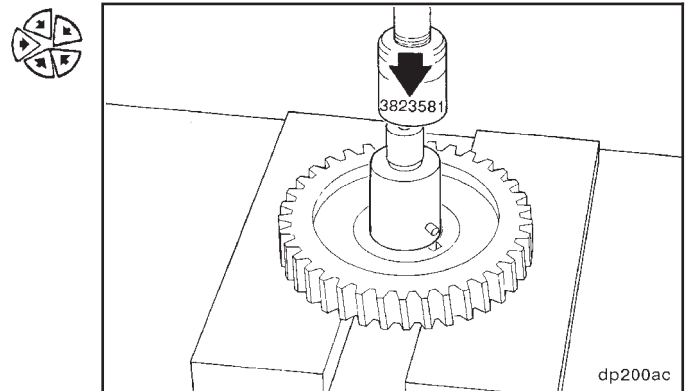
Install the largest diameter end of the shaft (2) through the gear bore (3).

Align the keyway in the gear (4) with the dowel pin in the shaft (5).



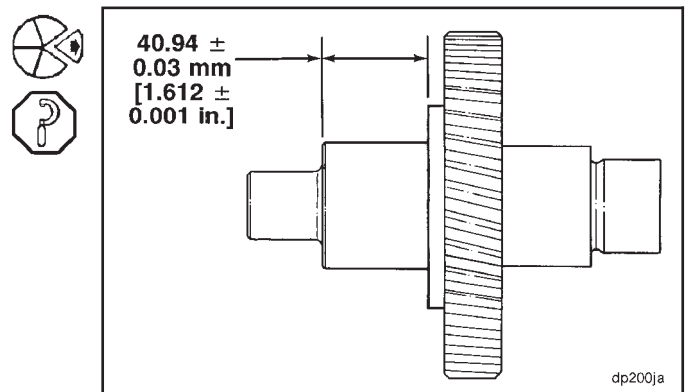
Place accessory drive assembly tool, Part No. 3823581, over the top (smaller diameter) end of the shaft.

Use the arbor press to press the shaft into the gear until the tool comes into contact with the gear surface.



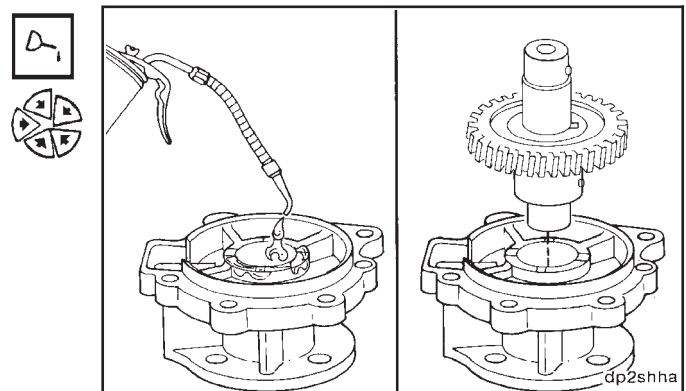
Remove the tool and measure the shaft as shown to be sure the gear is at the correct location on the shaft.

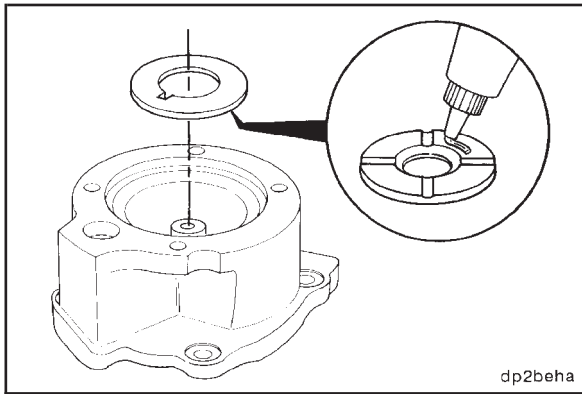
Drive Gear/Shaft Installation Depth		
mm		in
40.91	MIN	1.611
40.97	MAX	1.613



Use clean 15W-40 oil to lubricate the shaft bore and thrust bearing surface of the housing.

Install the shaft and gear assembly into the housing.





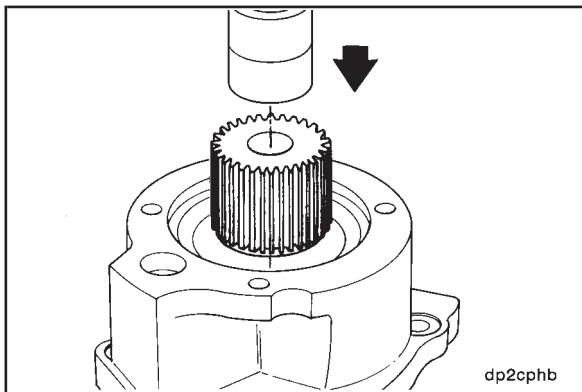
Caution: The grooved surface of the thrust bearing must be facing the thrust surface of the housing to provide proper lubrication and prevent damage to the drive assembly.



Use Lubriplate® No. 105, or equivalent to lubricate the grooved surface of the thrust bearing.



Install the thrust bearing over the shaft.



Install the Spline Coupling Gear



Use clean 15W-40 oil to lubricate the bore of the splined coupling gear.



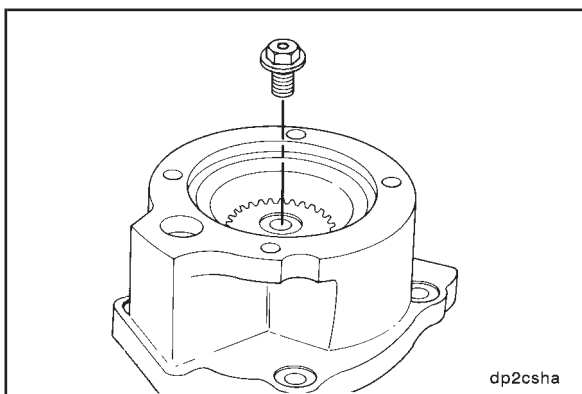
NOTE: Make sure the end of the drive shaft is supported.

Install the drive assembly in an arbor press with the drive gear facing down.



The splined teeth are recessed from one end of the gear to aid in removal of the gear. Install this end of the gear on the shaft.

Press the gear onto the shaft.



Caution: The retainer capscrew must have an oil drilling if an air compressor is to be used. The oil drilling will lubricate and prevent damage to the coupling.

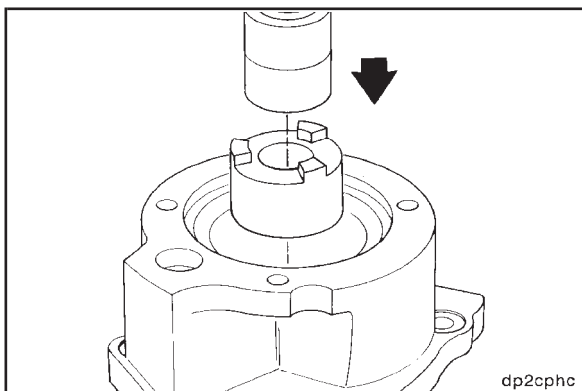


Install the splined coupling gear retainer washer and capscrew.



Tighten the capscrew.

Torque Value: 47 N•m [35 ft-lb]



Install the Hub Coupling



Use clean 15W-40 oil to lubricate the bore of the coupling.

Install the drive assembly in an arbor press with the drive gear facing down.



NOTE: Make sure the end of the drive shaft is supported.

Press the coupling onto the shaft.

Install the washer and capscrew.

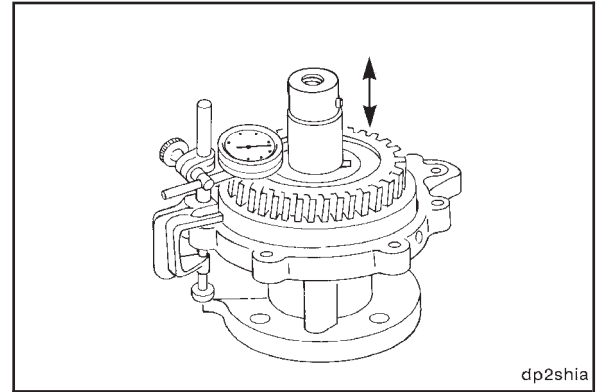


Torque Value: 47 N•m [35 ft-lb]

Rotate the drive shaft to check for correct assembly.
Measure the drive shaft end clearance.

Drive Shaft End Clearance		
mm		in
0.10	MIN	0.004
0.30	MAX	0.012

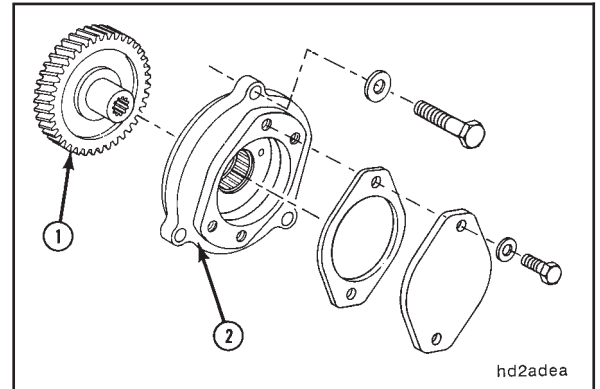
If the drive shaft end clearance does **not** meet these specifications, disassemble the drive and inspect the gear and thrust bearing positions. If the drive gear and thrust bearing are within specifications, the fuel pump and compression drive housing **must** be replaced.



Hydraulic Pump Drive - Cleaning and Inspection for Reuse (9-03)

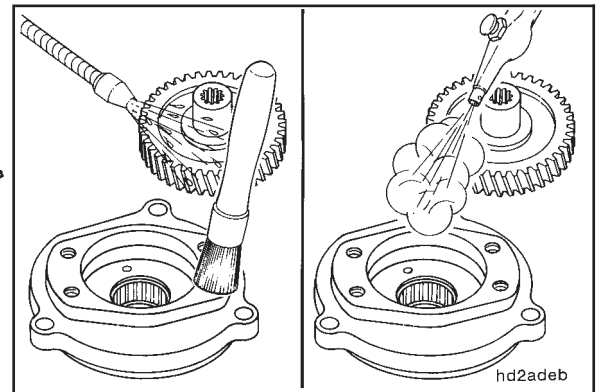
Cleaning

Remove all gasket and o-ring material from surfaces (1) and (2). Discard the gaskets and o-ring.



Clean the parts with solvent, dry with compressed air.

NOTE: Do not remove the gear from the shaft. If the parts are damaged refer to Hydraulic Pump Drive - Rebuild (9-04).



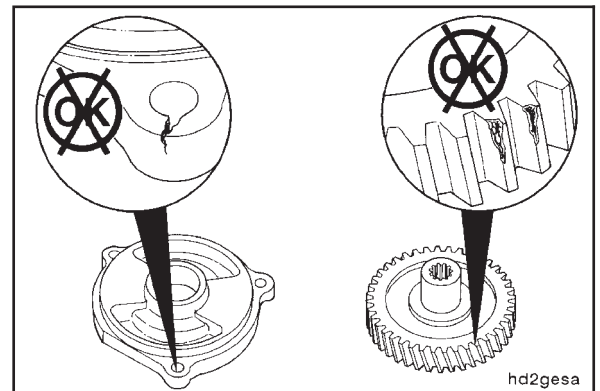
Inspection

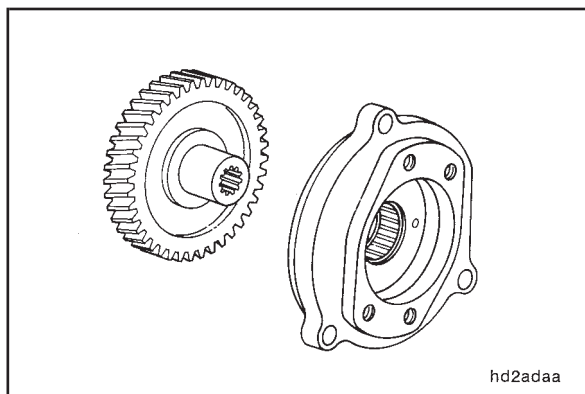
Visually inspect the hydraulic pump drive and rear adapter for cracks and fretting on the pump flange mounting surface.

Visually inspect the gear for broken or abnormally worn teeth.

Inspect the shaft inner spline for wear.

Replace any parts that are damaged.



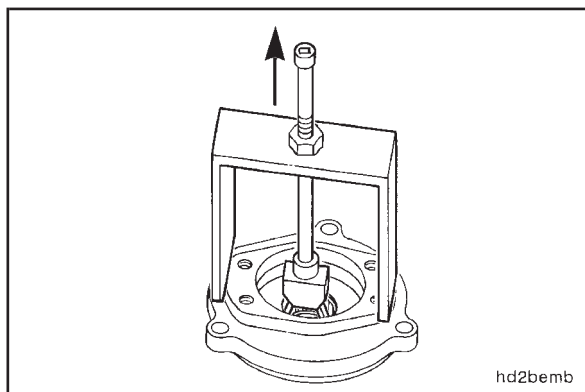


Hydraulic Pump Drive - Rebuild (9-04)

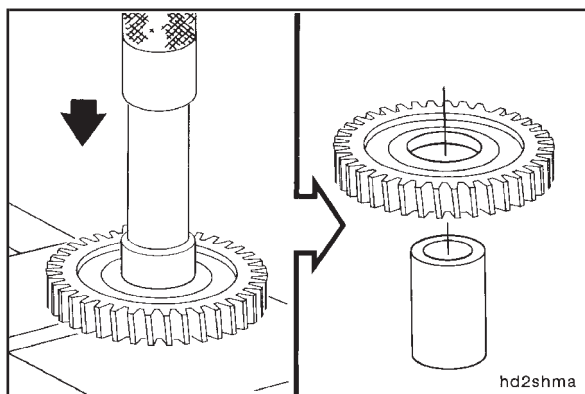
Disassembly



Remove the shaft and gear assembly from the rear adapter.



Use needle bearing kit, Part No. 3823774, to remove the needle bearing from the hydraulic pump adapter.



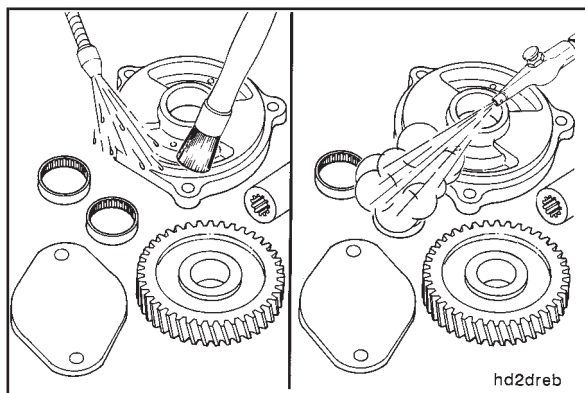
Install the shaft and gear assembly in an arbor press with the part number side of the gear facing down.



Caution: Do not allow the shaft to fall when removing it from the gear. Personal injury or damage to the shaft can result.



Press the shaft from the gear.



Cleaning

Clean the parts with solvent, dry with compressed air.

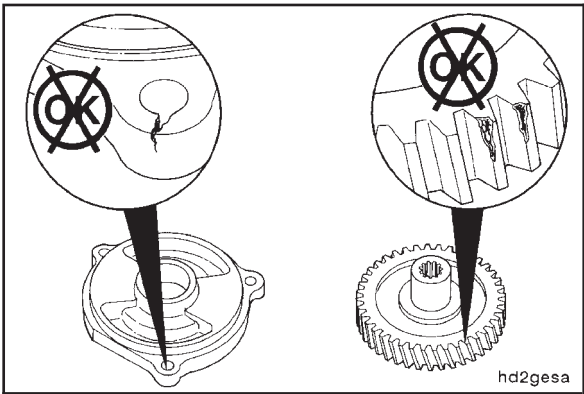
Inspection

Visually inspect the hydraulic pump drive and rear adapter for cracks and fretting on the pump flange mounting surface.

Visually inspect the gear for broken or abnormally worn teeth.

Inspect the shaft inner splines for wear.

Replace any parts that are damaged.

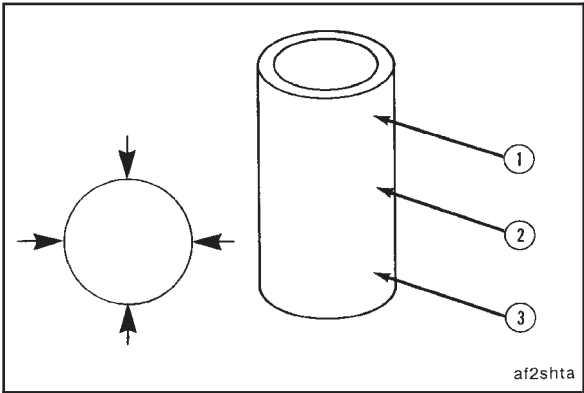


If the part being inspected **does not** meet the specifications given, the part **must** be replaced.

Measure the drive shaft outside diameter in two positions 90 degrees apart at points (1, 2 and 3).



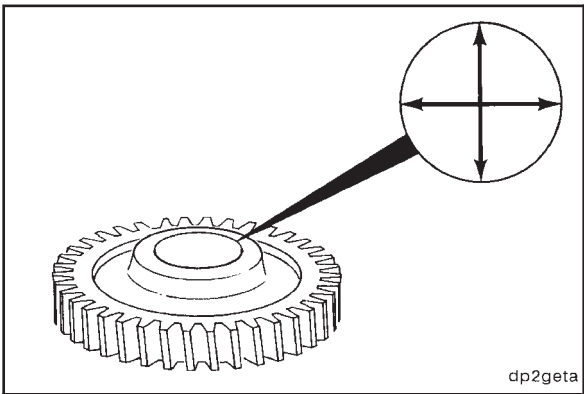
Drive Shaft O.D.		
mm		in
34.984	MIN	1.3773
35.000	MAX	1.3780



Measure the inside diameter of drive gear bore.



Drive Gear Bore I.D.		
mm		in
34.925	MIN	1.3750
34.950	MAX	1.3760



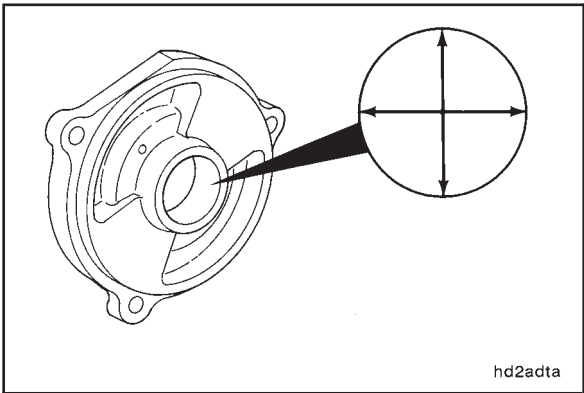
Visually inspect the rear adapter thrust surface for scoring, excessive wear or other damage.

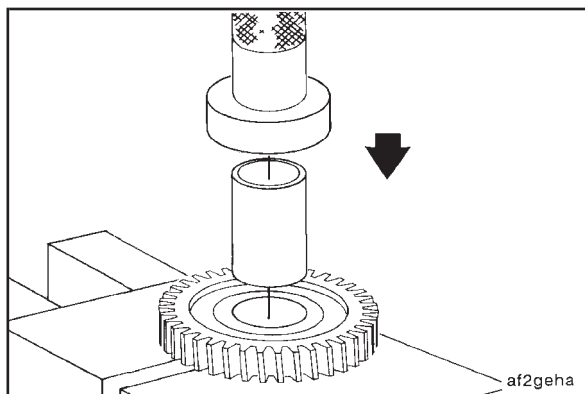
Measure the inside diameter of the rear adapter bore.



Rear Adapter Bore I.D.		
mm		in
41.967	MIN	1.6522
41.992	MAX	1.6532

If scoring, excessive wear or damage is found or the bore inside diameter is **not** within the specifications given, the adapter **must** be replaced.





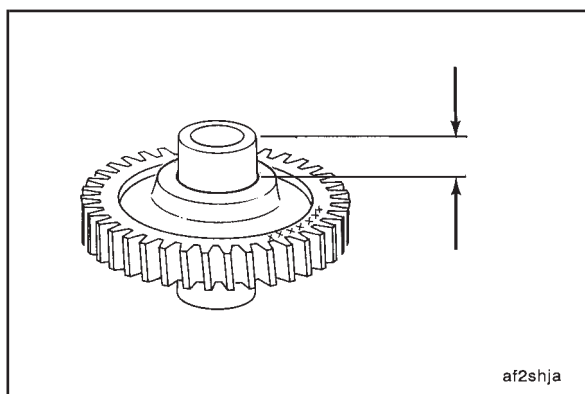
Assembly

Install the drive gear in an arbor press with the part number side of the gear facing down.

Install the shaft into the gear.

NOTE: The splined end of the shaft **must** be facing up (toward the **non**-part number side of the gear).

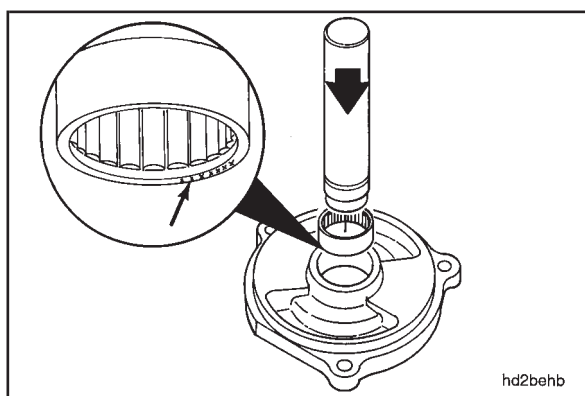
Use the hydraulic drive gear driver, Part No. 3376820, to push the shaft into the gear until the gear driver touches the gear.



Measure the installed height of the shaft in the drive gear from the part number side of the gear. If the shaft does **not** meet the specifications, remove the shaft from the gear and install the shaft to the specified height.

Drive Shaft Installed Height

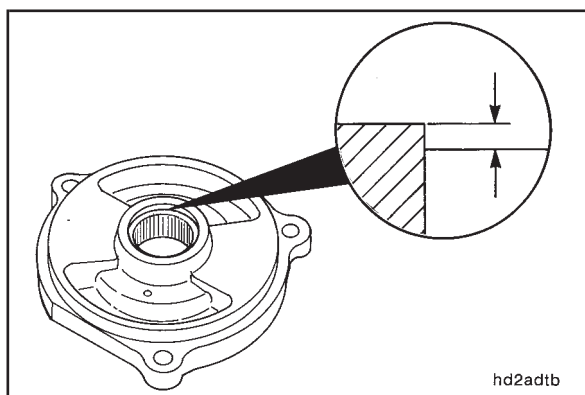
mm		in
18.50	MIN	0.728
19.50	MAX	0.768



Caution: The numbered side of the bearing must face the drive gear. Press against the outer race or numbered side of the bearing to prevent personal injury or damage to the bearing.

Install the front support in an arbor press with the mounting flange facing up.

Use the bearing mandrel, Part No. 3823776, with handle, Part No. 3823775, included in needle bearing removal and installation kit, Part No. 3823774 to press the bearing into the support until the specified depth is reached.



Check the installed depth of the bearing.

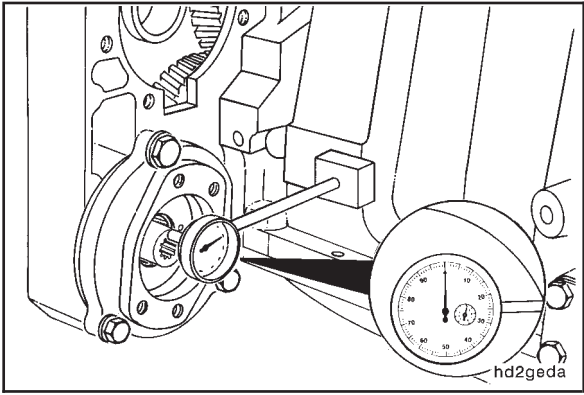
Bearing Depth in Housing Bore

mm		in
0.254	MIN	0.0100
0.762	MAX	0.0300

The drive shaft end clearance **must** be checked with the hydraulic pump drive assembly installed on the engine. Measure the drive shaft end clearance.

Drive Shaft End Clearance		
mm		in
0.076	MIN	0.0030
0.635	MAX	0.0250

If the drive shaft end clearance does **not** meet the specifications, the front and rear support thrust surfaces are worn excessively. Replace the rear supports and recheck. If the end clearance is still excessive, the gear housing **must** be replaced.



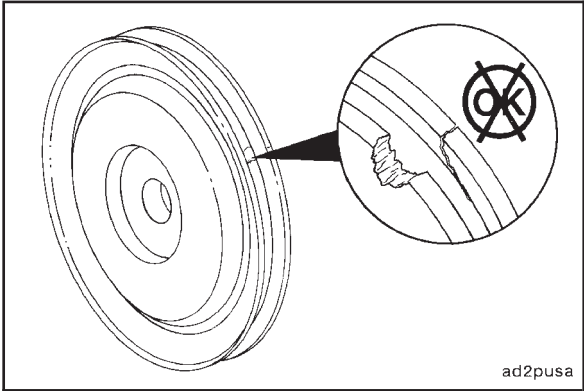
Accessory Drive Pulley - Cleaning and Inspection for Reuse (9-05)

Cleaning

Clean the accessory drive pulley with solvent, dry with compressed air.

Inspection

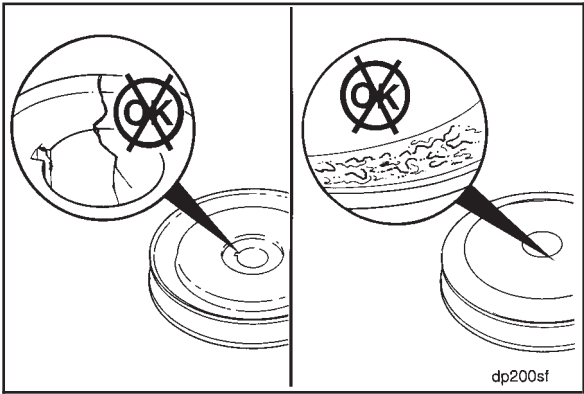
Visually inspect the entire pulley for cracks, dents and severe wear. Pay special attention to the belt groove area.



Visually inspect the pulley bore, keyway and pulley hub on the back side of the pulley.

Visually inspect the pulley hub to shaft shoulder contact area for fretting.

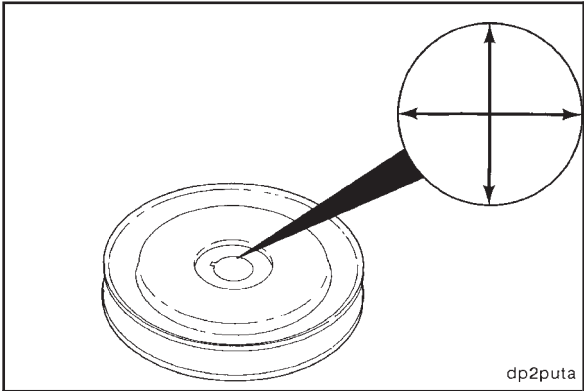
The pulley **must** be replaced if any of the above conditions are found.



Measure the inside diameter of the pulley bore.

Drive Pulley Bore I.D.		
mm		in
35.060	MIN	1.3803
35.098	MAX	1.3818

The pulley **must** be replaced if the pulley bore does **not** meet the specifications given.



NOTES

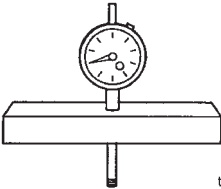
This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Section 10 - Air Intake System
Section Contents

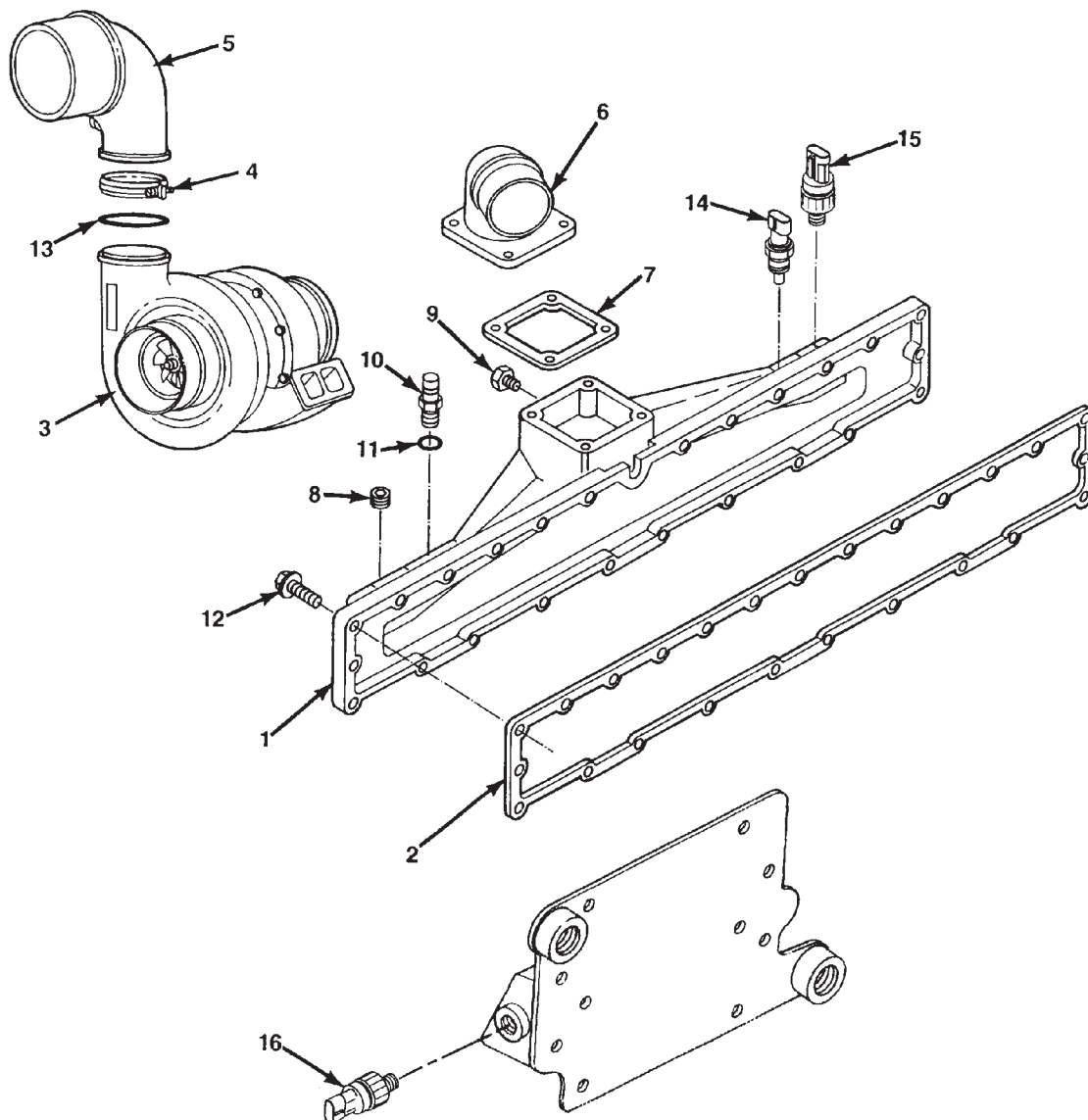
	Page
Air Intake System - General Information	10-4
CAC Air Intake System - Exploded View	10-3
Intake Manifold - Cleaning and Inspection for Reuse	10-6
Cleaning	10-6
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Service Tools - Air Intake System	10-2
Turbocharger - Cleaning and Inspection for Reuse	10-5
Cleaning	10-5
Inspection	10-5

Service Tools - Air Intake System

The following special tools are recommended to perform procedures in Group 10. 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 the turbocharger axial motion.	 tb8togf

CAC Air Intake System - Exploded View



ci200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1.	Manifold, Intake	1	10.	Compuchek® Fitting	1
2.	Gasket, Intake Manifold	1	11.	Seal, O-ring	1
3.	Turbocharger	1	12.	Capscrews	21
4.	Clamp, V-Band	1	13.	O-ring	1
5.	Connection, Turbo Discharge Air	1	14.	Sensor, Intake Manifold Temperature	1
6.	Connection, Air Intake	1	15.	Sensor, Intake Manifold Pressure	1
7.	Gasket, Connection	1	16.	Sensor, Ambient Air Pressure	1
8.	Plug, Pipe	2			
9.	Plug, Pipe	2			

Air Intake System - General Information

The Air Intake System Group consists of the intake manifold, charge air cooler and turbocharger.

The charge air cooler uses ram air with the aid of the cooling fan to cool the intake air between the turbocharger and the intake manifold during engine operation. Refer to the OEM for information on the maintenance procedures for the charge air cooler.

The turbocharger is cooled and lubricated with engine oil from the engine lubricating oil system.

The M11 engine uses capscrews in both metric and U.S. Customary dimensions. In some cases, the capscrews are almost identical in dimensions and appearance. Be sure to install capscrews in the same location as they were removed from.

The pipe plugs and hose clamps installed in the intake system are U.S. Customary dimensions.

Turbocharger - Cleaning and Inspection for Reuse (10-01)

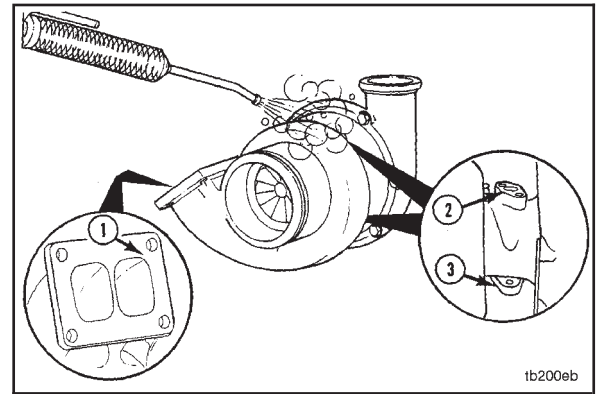
Cleaning

Remove all carbon deposits and gasket material from surfaces (1), (2) and (3).

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

Caution: Tape or plug all openings to prevent solvent or steam from damaging the oil cavities in the turbocharger.

Use solvent or steam to clean the exterior of the turbocharger. Dry with compressed air.



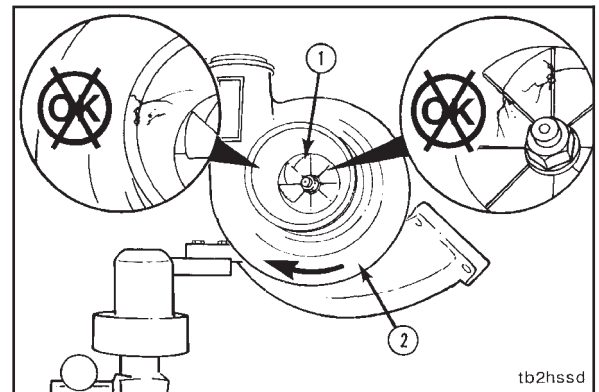
Inspection

Visually inspect the housings for damage.

Visually inspect the turbine wheel and compressor impeller (1) for fretting, cracked or broken vanes.

Turn the impeller in the direction shown with arrow (2), to inspect the turbine shaft for freedom of rotation. The shaft **must** rotate freely.

Replace damaged parts.

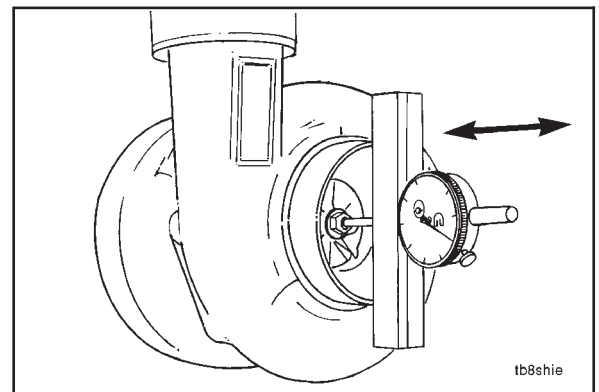


Measure the turbocharger shaft axial movement with the dial depth gauge, Part No. ST-537.

Push the rotor assembly away from the gauge.

Set the gauge on zero.

Push the rotor assembly toward the gauge and record the data.



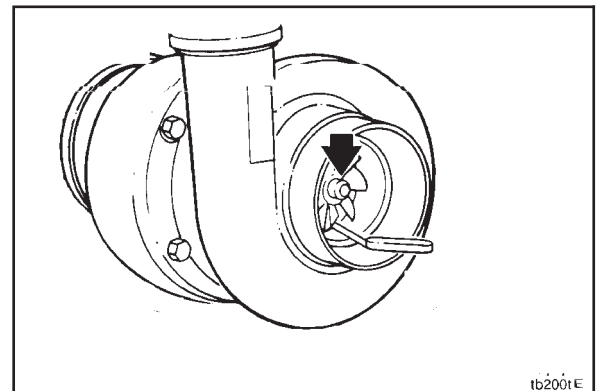
Turbocharger Shaft Axial Movement

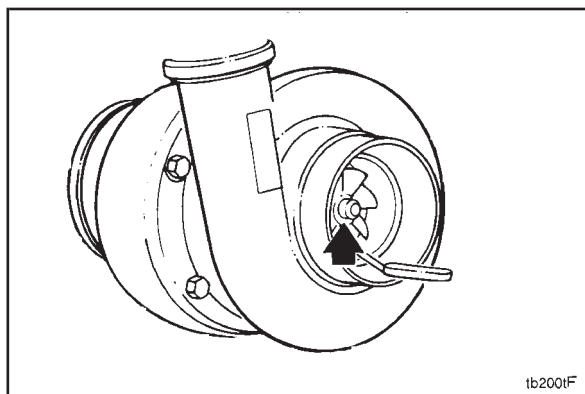
mm		in
0.038	MIN	0.0015
0.089	MAX	0.0035

Push the compressor impeller by hand toward the compressor housing.

Install a wire feeler gauge, at the minimum clearance point, between the impeller and the housing to measure the clearance.

Record this clearance.





With the feeler gauge in the same location, push the compressor wheel by hand away from the compressor housing.



Install a wire feeler gauge, at the same point.

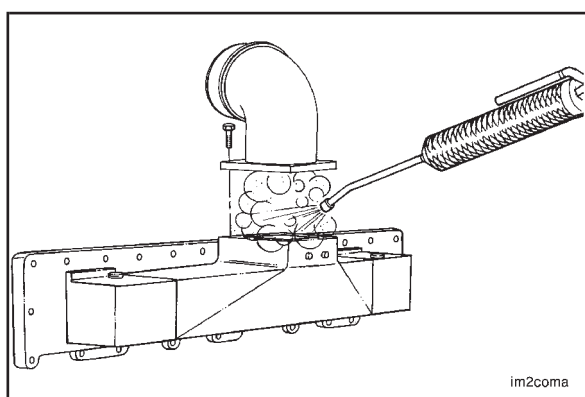
Record this clearance.

Subtract the smaller from the larger clearance.

Compressor Wheel Radial Clearance		
mm		in
0.15	MIN	0.006
0.64	MAX	0.025



If the radial clearance does **not** meet the above specifications, the turbocharger **must** be rebuilt. Refer to Turbocharger Component Shop Manual, Bulletin No. 3379461, for rebuild instructions.



Intake Manifold - Cleaning and Inspection for Reuse (10-02)

Cleaning



Remove the air inlet housing.

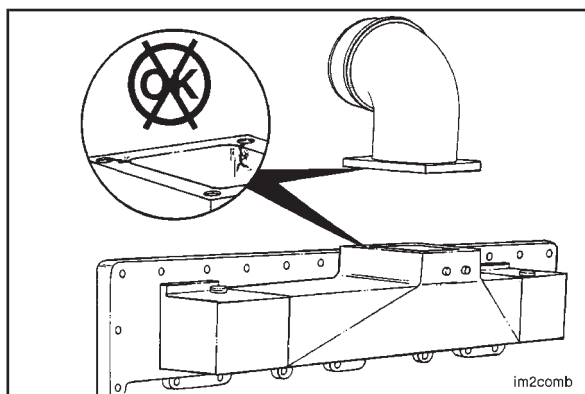
Remove all gasket material.



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 to clean the parts. Dry with compressed air.



Inspection



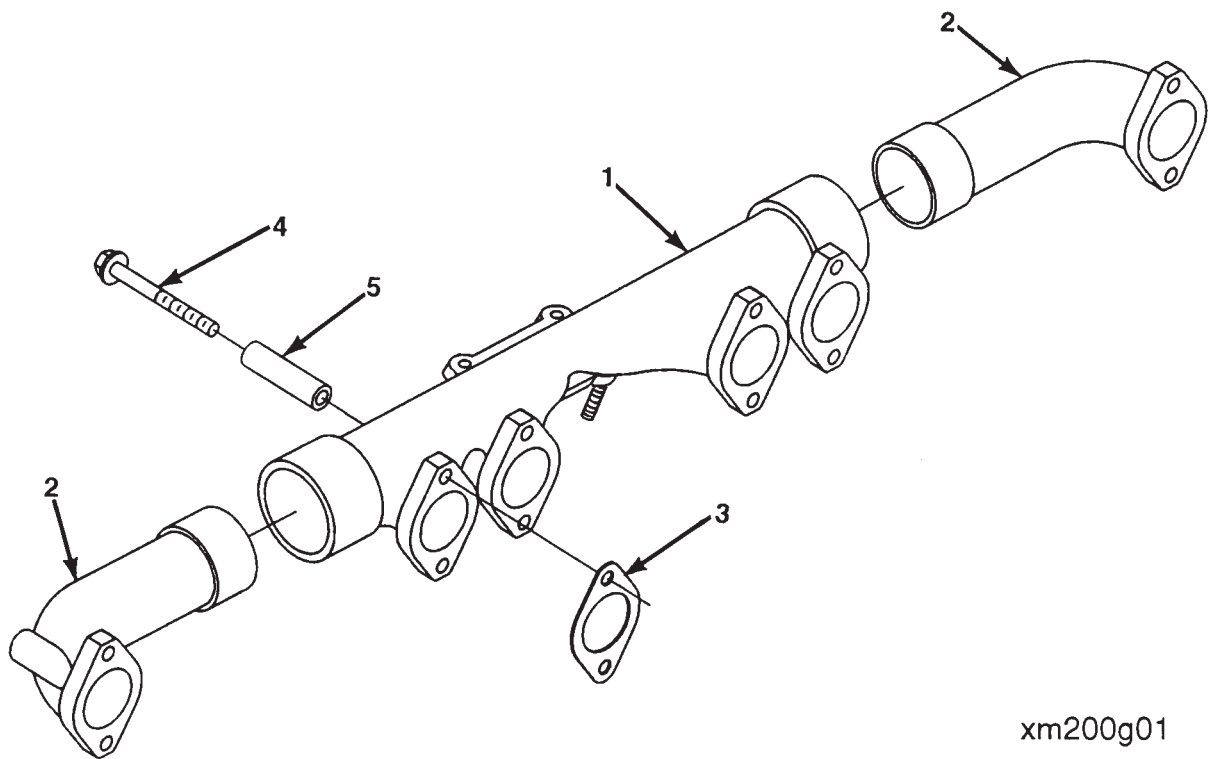
Visually inspect the intake manifold and inlet housing for cracks or damage.

Replace damaged parts.

Section 11 - Exhaust System
Section Contents

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Exhaust Manifold - Cleaning and Inspection for Reuse	11-3
Cleaning	11-3
Disassembly	11-3
Inspection	11-4
Exhaust System - Exploded View	11-2
Exhaust System - General Information	11-3

Exhaust System - Exploded View



xm200g01

Ref. No.	Description	Qty.
1.	Manifold, Exhaust, Center	1
2.	Manifold, Exhaust, End	2
3.	Gasket, Exhaust Manifold	6

Ref. No.	Description	Qty.
4.	Capscrew	12
5.	Spacer, Mounting	12

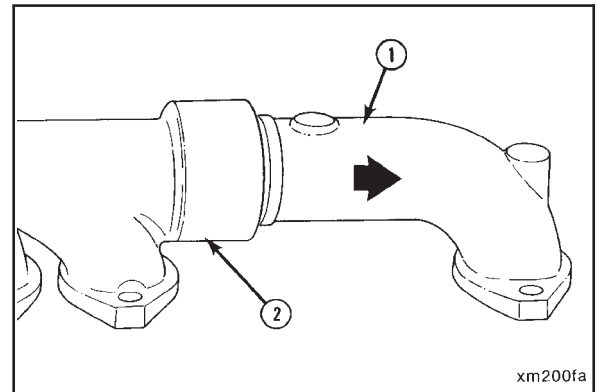
Exhaust System - General Information

The exhaust manifold group consists of the exhaust manifolds and the turbocharger mounting studs.

Exhaust Manifold - Cleaning and Inspection for Reuse (11-01)

Disassembly

Use a mallet to remove the two end sections (1) from the center section (2).



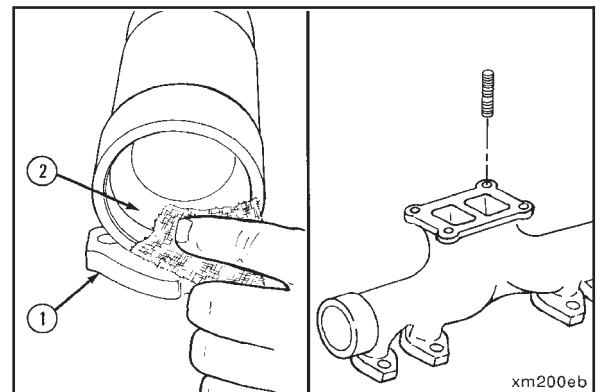
Cleaning

Use Scotch-Brite®, or its equivalent, to remove the carbon from the gasket sealing surfaces (1).

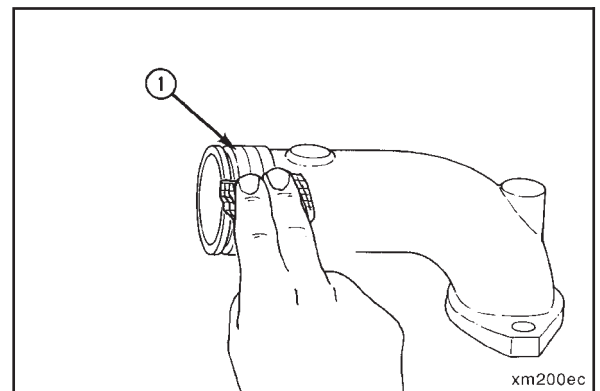


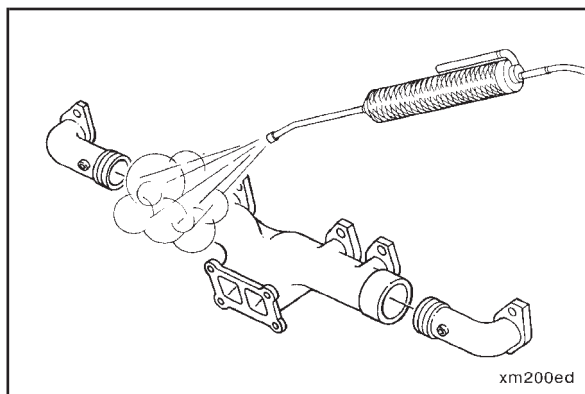
Use Scotch-Brite®, or its equivalent, to remove the carbon from the center section sealing surface bores (2).

Use a standard stud extractor to remove the four turbocharger mounting studs from the center section.



Use Scotch-Brite®, or its equivalent, to remove the carbon from the connection surface (1) of both end sections.

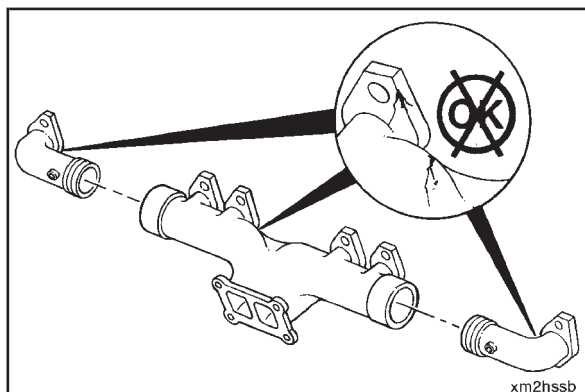




Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.



Use steam to clean the manifold sections. Dry with compressed air.



Inspection

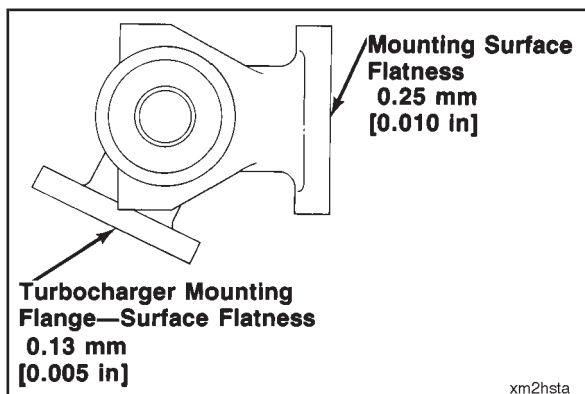
Visually inspect the manifold sections for cracks or damage.



Visually inspect the sealing connection surfaces for damage.

Visually inspect the center section for damaged threads in the turbocharger mounting stud holes.

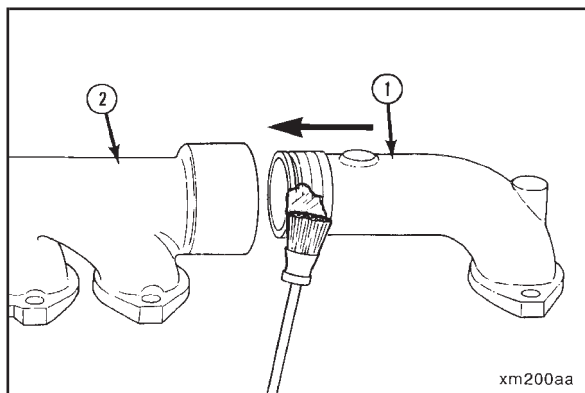
Replace damaged parts.



Inspect the mounting surfaces for flatness. The exhaust manifold mounting surface **must** be flat to within 0.25 mm [0.010 in]. The turbocharger mounting flange **must** have a surface flatness of 0.13 mm [0.005 in].



If these surfaces are not within the flatness specifications, refer to the Alternative Repair Manual, Bulletin No. 3810310.



Apply a coat of anti-seize compound to the outside diameter of both end sections in the area that enters the center section.



Install the end sections (1) in the center section (2).

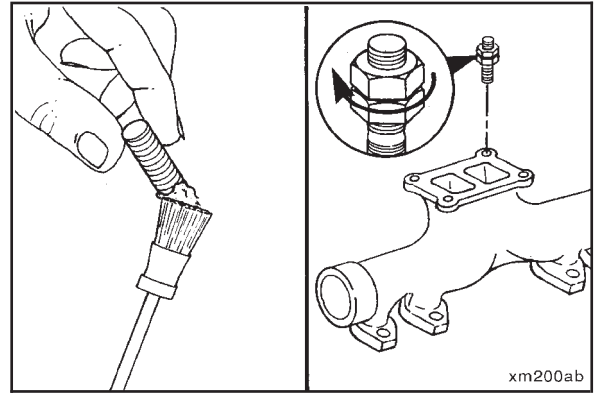
Apply a coat of anti-seize compound to the threads.

NOTE: Install the **shorter** threaded end of the turbocharger mounting stud in the exhaust manifold flange.

Install the studs in the mounting flange.

Use two mounting nuts locked together to tighten the studs.

Torque Value: 65 N•m [50 ft-lb]



[illegible]

Section 12 - Air Equipment - Group 12
Section Contents

	Page
Air Compressor - Cleaning and Inspection for Reuse	12-6
Cleaning.....	12-6
Inspection.....	12-6
Air Equipment - General Information	12-2
Compressed Air System Flow Diagrams	12-5

Air Equipment - General Information

The air equipment group consists of Cummins single and two cylinder air compressors, compressor check valves and air and coolant piping. It also includes air activated cranking motors.

The air compressor is lubricated by engine lubricating oil which enters the compressor through a drilling in the support. The oil lubricates the air compressor connecting rod bearings and the crankshaft. The oil then flows to the air compressor crankcase and returns to the engine through a drain passage located in the support.

The air compressor is cooled by the engine coolant. Only the cylinder head is cooled on the single cylinder air compressor. Both the cylinder head and cylinders are cooled on the two cylinder air compressor.

Service information, specifications, and repair of Cummins air compressors are contained in the following publications:

- Single Cylinder Air Compressor - Shop Manual, Bulletin No. 3810242
- SS338E Single Cylinder Air Compressor - Shop Manual, Bulletin No. 3810457
- ST676 Two Cylinder Air Compressor - Shop Manual, Bulletin No. 3810257
- ST773 Two Cylinder Air Compressor - Shop Manual, Bulletin No. 3810347

Instructions for testing and repairing air cranking motors and air compressors **not** manufactured by Cummins, **can** be obtained from the original equipment manufacturers.

The following list contains the addresses of suppliers of air equipment for use on Cummins engines:

U.S.A.

Bendix H.V.S.G.
901 Cleveland St.
Elyria, OH 44036
Attention: Technical Services Dept.

Engine Starting Systems
Allen and Martinsville Rd.
P.O. Box 1776
Liberty Corner, NJ 07938

Midland Brake, Inc.
490 South Chestnut St.
Owosso, MI 48867

Canada

Bendix H.V.S.G.
P.O. Box 5712
1005 Wilton Grove Rd.
London Ontario, Canada N6A4S8
Attention: Technical Services Dept.

International

Bendix H.V.S.G. Europe Ltd.
66 Grosvenor St.
London, England W1X90B
Attention: Technical Services Dept.

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

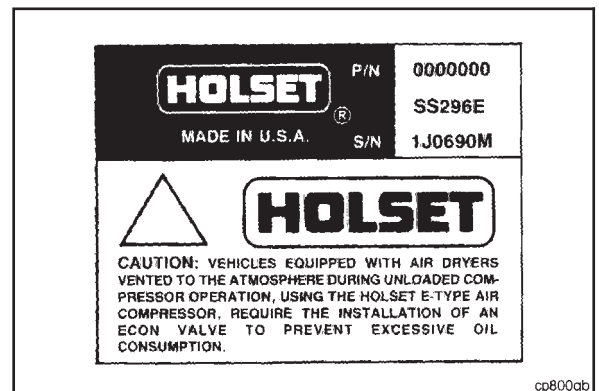
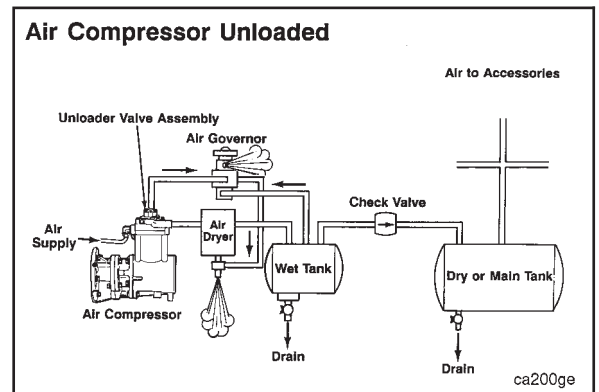
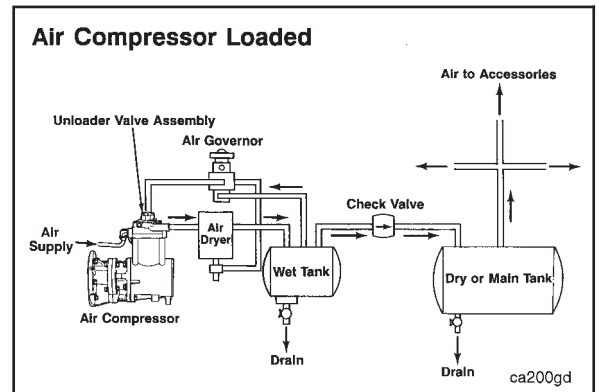
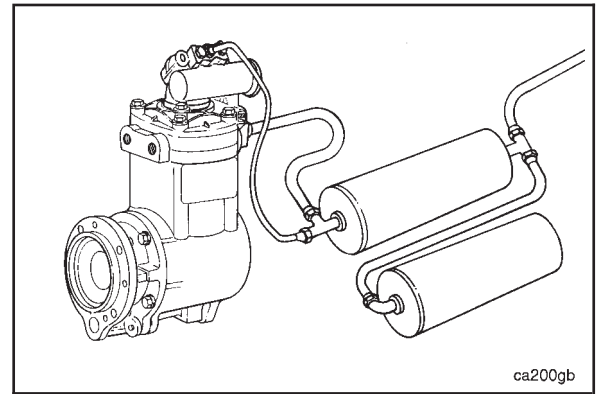
The Holset single and two cylinder air compressors are engine-driven piston-type compressors which supply compressed air to operate air activated devices. The compressor runs continuously but has a loaded and unloaded operating mode.

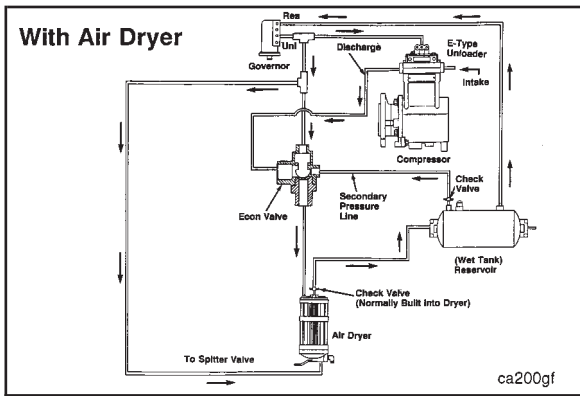
The operating mode is controlled by a pressure-activated governor and the compressor unloading assembly. When the air system reaches a predetermined pressure, the governor applies an air signal to the air compressor unloader assembly causing the unloader valve to hold the compressor intake valve open and 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

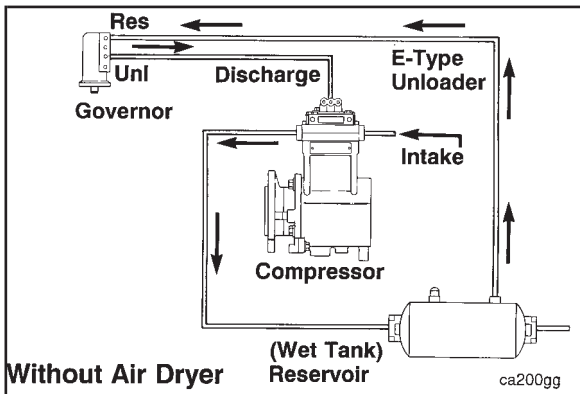
Air compressors built with the E-Type unloader can be identified by the letter "E" (SS296E), and by the caution on the dataplate.





E-Type System With Air Dryer

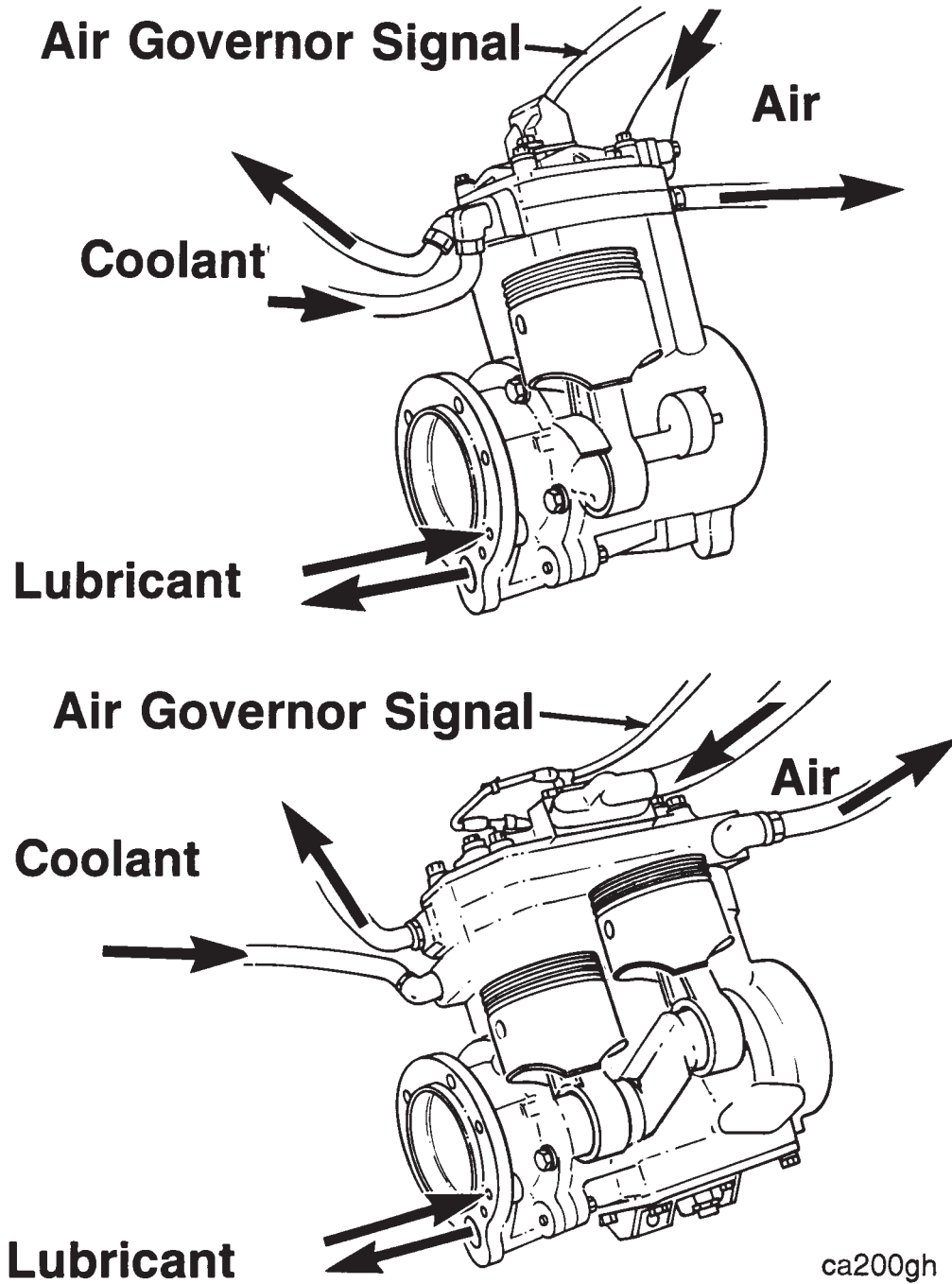
Vehicles equipped with air dryers vented to the atmosphere during unloaded compressor operation, using the Holset E-Type air compressor, require the installation of an econ valve to prevent excessive oil consumption.

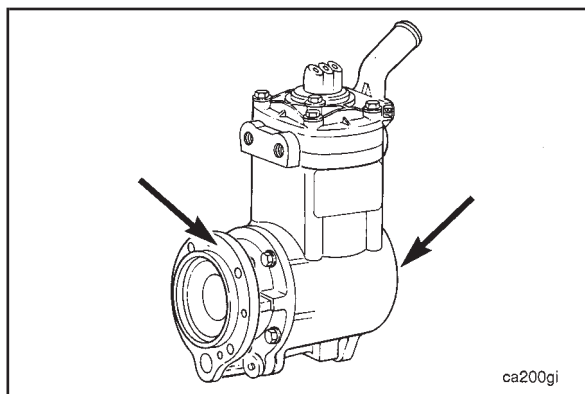


E-Type System Without Air Dryer

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.

Compressed Air System Flow Diagrams



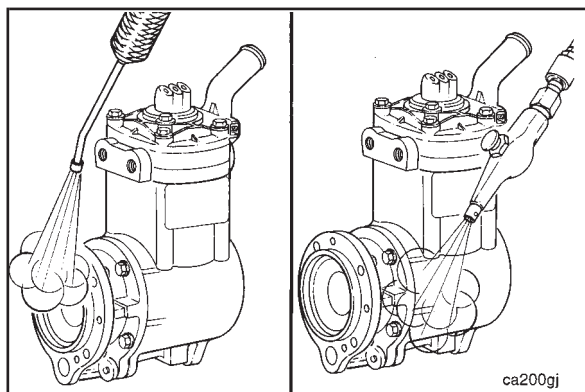


Air Compressor - Cleaning and Inspection for Reuse (12-01)

Cleaning



Remove all gasket material from the sealing surfaces.



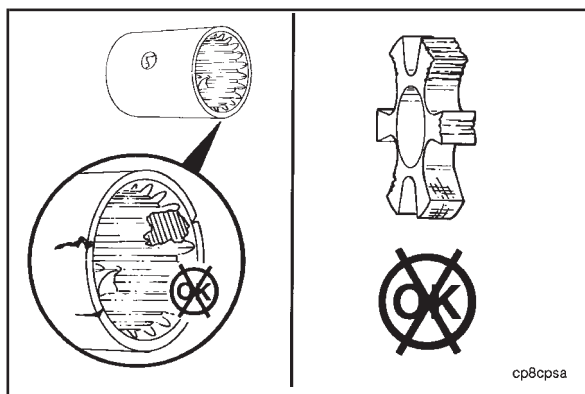
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.



Caution: Seal all openings with tape to prevent damage from solvent or steam entering the oil passages in the air compressor.



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

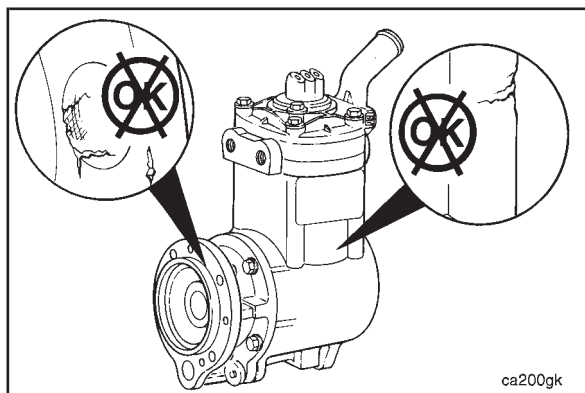


Inspection



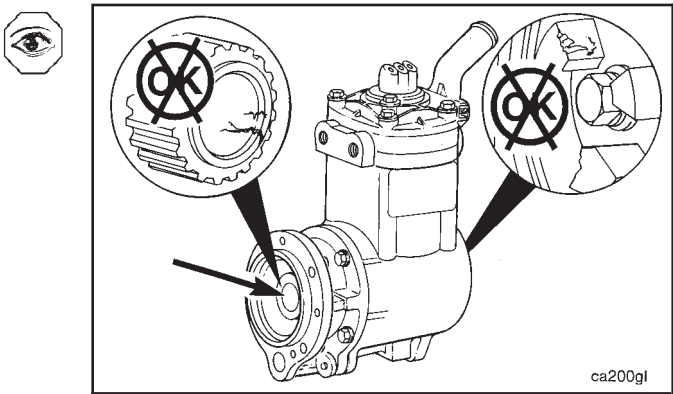
Visually inspect the compressor drive splined coupling for cracks or broken splines.

Visually inspect the fuel pump drive hub or spider coupling for wear or damage.



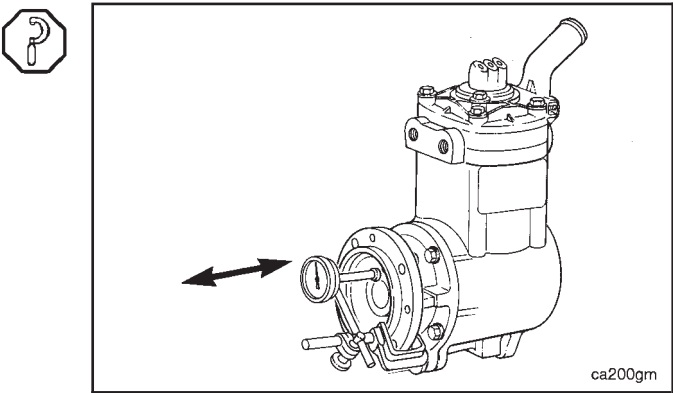
Visually inspect the compressor housing for cracks or damage.

Visually inspect the compressor drive gear and the fuel pump “hub type” drive coupling for wear or damage.



Measure the single cylinder air compressor crankshaft end clearance.

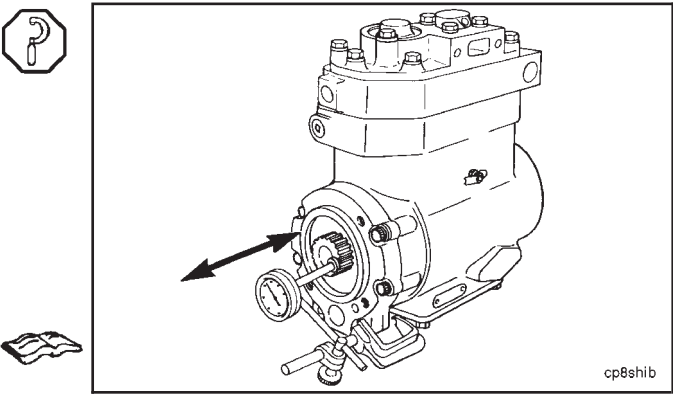
Crankshaft End Clearance		
mm		in
0.05	MIN	0.002
0.15	MAX	0.006



Measure the two cylinder air compressor crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.05	MIN	0.002
0.19	MAX	0.008

If cracked or damaged parts are found or the end clearance exceeds the limits specified, the air compressor **must** be rebuilt or replaced. Refer to Shop Manual, Bulletin No. 3810242 or 3810457, for single cylinder. Refer to Bulletin No. 3810257 for ST676, or Bulletin No. 3810347 for ST773 two cylinder air compressor rebuild instructions.



NOTES

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Electrical Equipment - General Information

The electrical equipment used on the M11 engine is **not** manufactured by Cummins Engine Company, Inc. Complete instructions for adjusting, testing, and repairing the electrical equipment **can** be obtained from the equipment manufacturer. The following list contains the suppliers of the electrical equipment used on Cummins engines.

Alternators

Robert Bosch Ltd.
P.O. Box 166
Rhodes Way
Watford
WD2 41B
England
Telephone: 0923-44233

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 0744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.V. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 0908-66001

Delco-Remy
P.O. Box 2439
Anderson, IN 46018
U.S.A.
Telephone: (317) 646-7838

Leece-Neville Corp.
1374 E. 51st St.
Cleveland, OH 44013
U.S.A.
Telephone: (216) 431-0740

C E Niehoff
2021 Lee St.
Evanston, ILL 60202
Telephone: (708) 866-6030

* Air Starting Motors

Ingersoll Rand
Chorley New Road
Horwich
Bolton
Lancashire
England
BL6 6JN
Telephone: 0204-65544

Ingersoll-Rand
Engine Starting Systems
651 Part Avenue
King of Prussia, PA 19406
U.S.A.
Telephone: (215) 337-5900

Electric Starting Motors

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 0744-21663

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

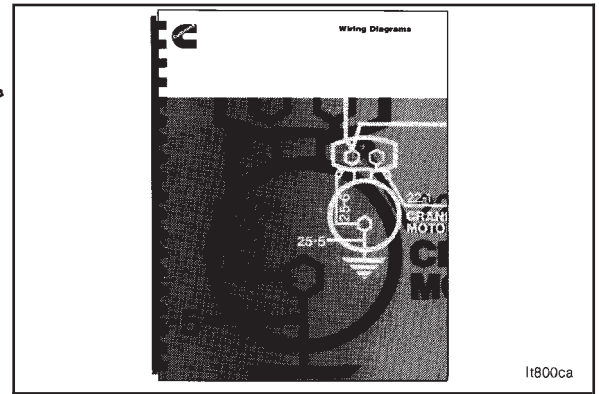
Delco-Remy
P.O. Box 2439
Anderson, IN 46018
U.S.A.
Telephone: (317) 646-7838

Leece-Neville Corp.
1374 E. 51st Street
Cleveland, OH 44013
U.S.A.
Telephone: (216) 431-0740

* Non Electrical Equipment Suppliers

Wiring Diagrams

A complete collection of electrical wiring diagrams, as applied to all Cummins engines, is contained in Wiring Diagrams, Bulletin No. 3379099.



Alternator Bracket - Cleaning and Inspection for Reuse (13-01)

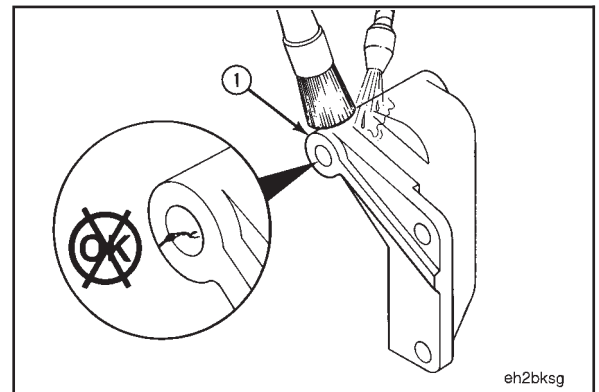
Inspection

Use solvent to clean the bracket. Dry with compressed air.

Visually inspect the bracket area (1) for cracks. Inspect the bracket for other damage.

Discard damaged parts.

NOTE: The cylinder block mounting surface **must** be clean and free of paint to provide a proper electrical ground for the alternator.



Alternator Adjusting Link - Cleaning and Inspection for Reuse (13-02)

Inspection

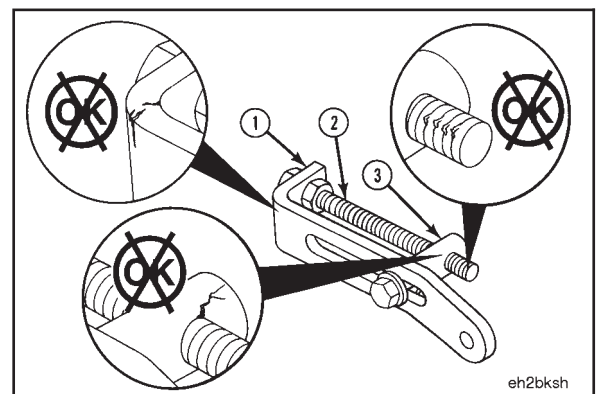
Use solvent to clean the adjusting link. Dry with compressed air.

Some parts can vary in design.

Visually inspect the adjusting link (1), capscrew (2), and the adjusting retainer (3) for damage.

NOTE: The capscrew (2) **must** turn freely in the retainer (3).

Discard damaged parts.

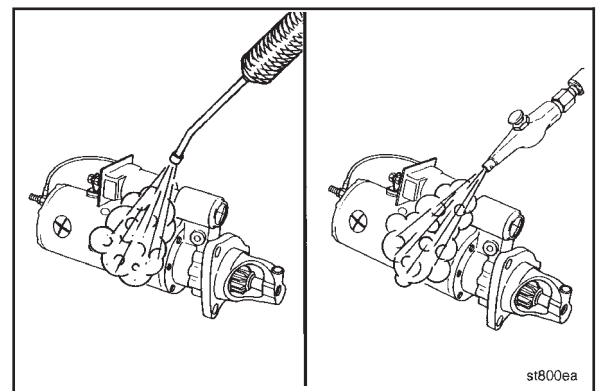


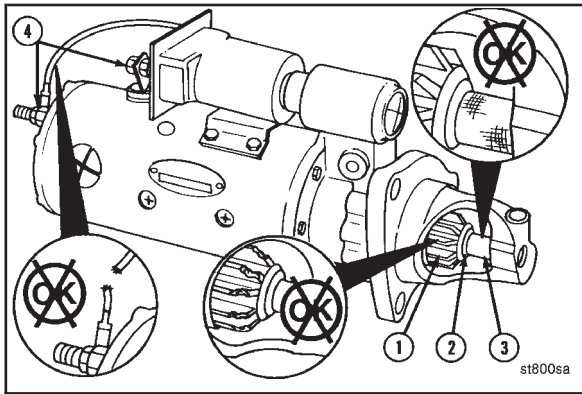
Starting Motor - Cleaning and Inspection for Reuse (13-03)

Cleaning

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

Use steam to clean the starting motor. Dry with compressed air.





Inspection

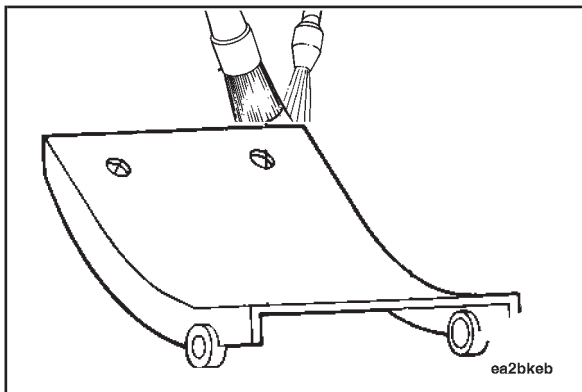


Visually inspect the gear (1) for cracked or broken teeth.

Visually inspect the drive bushing (2) and the gear shaft (3) for excessive wear or damage.

Visually inspect the terminal posts (4) for loose or broken connections.

If the starting motor parts are damaged or the posts are loose or damaged, the starting motor **must** be repaired or rebuilt. Refer to the electrical equipment manufacturers specifications to rebuild the starting motor.

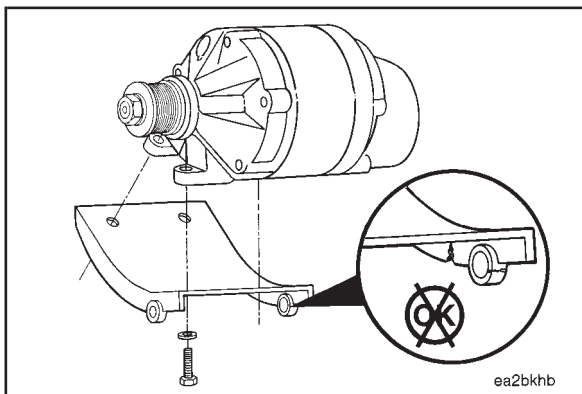


Alternator Bracket (Bus Applications) - Cleaning and Inspection for Reuse (13-04)

Cleaning



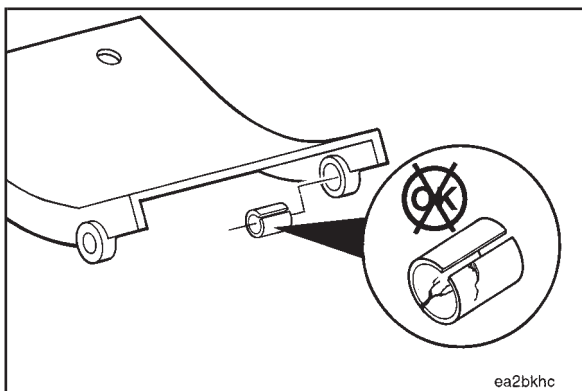
Use solvent to clean the upper and lower alternator brackets. Dry with compressed air.



Inspection



Inspect the upper bracket for cracks. If the bracket is cracked, it **must** be replaced.



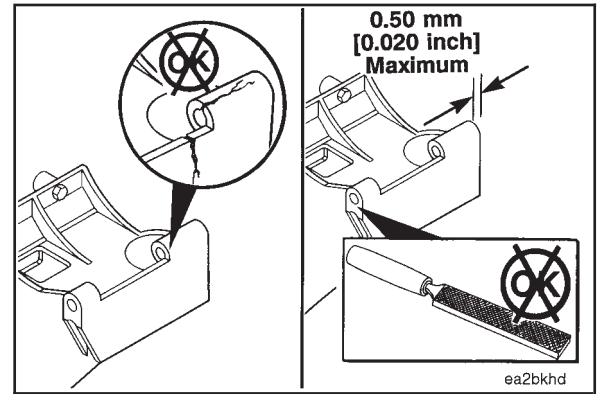
Inspect the pivot bushing for cracks and a tight fit in the upper bracket.

If the bushing is cracked, but the bracket appears undamaged, replace the bushing with bushing, Part No. 3883412.

If the bracket is damaged and the old bushing no longer fits securely, replace the bracket and the bushing.

Inspect the lower bracket and mounting capscrews. If the bracket is cracked, it **must** be replaced.

The front and rear faces of the lower bracket, where the lower bracket and upper bracket contact, **must** be flat and parallel. If these surfaces are **not** flat, the rear face **ONLY** can be re-faced by milling a maximum of 0.50 mm [0.020 inch] deep to clean up. However, the minimum dimension allowed from the front to rear contact faces of the lower bracket is 210.7 mm [8.30 inch]. **Do not** re-face the front surface. If the front surface needs re-faced, or the dimension is less than the minimum allowed, the bracket **must** be replaced.

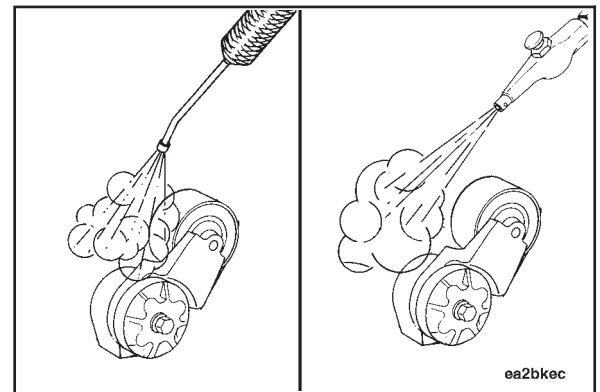


Automatic Belt Tensioner (Bus Applications) - Cleaning and Inspection for Reuse (13-05)

Cleaning

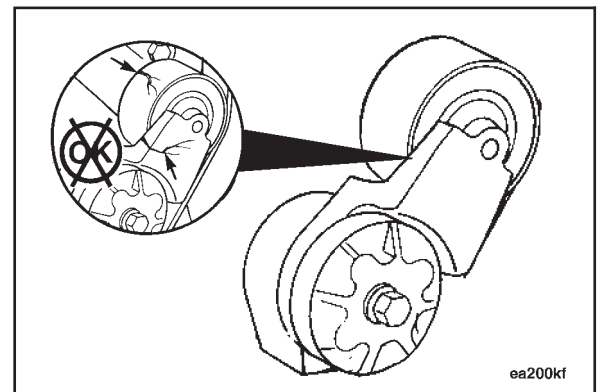
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.

Steam clean the automatic belt tensioner. Dry with compressed air.

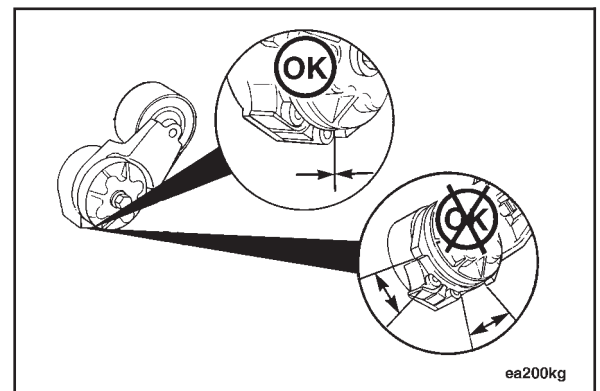


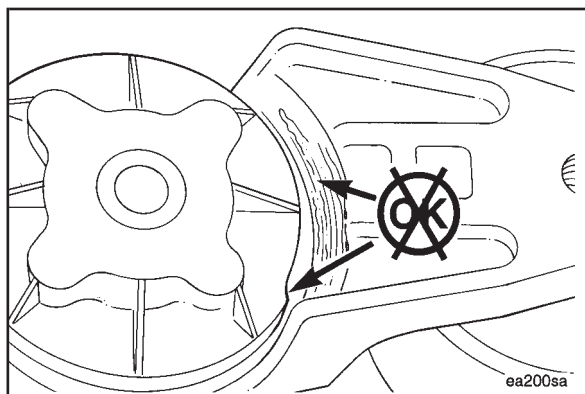
Inspection

Check the tensioner pulley and body for cracks. If any cracks are noticed, the tensioner **must** be replaced.

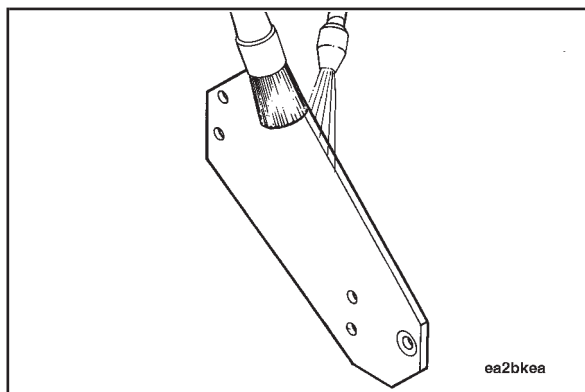


Check that the bottom tensioner arm stop is in contact with the bottom tensioner arm stop boss on the tensioner body. If these two are **not** contacting, the tensioner **must** be replaced.





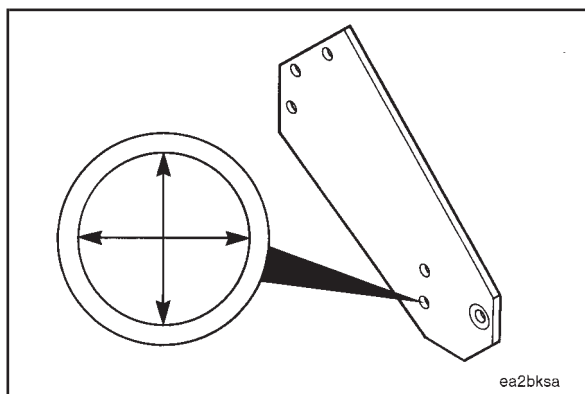
Inspect the tensioner for evidence of the pivoting tensioner arm contacting the stationary circular base. If there is evidence of these two areas contacting, the pivot tube bushing has failed and the tensioner **must** be replaced.



Automatic Belt Tensioner Bracket (Bus Applications) - Cleaning and Inspection for Reuse (13-06)

Cleaning

Use solvent to clean the tensioner bracket. Dry with compressed air.



Inspect the bracket for cracks around the capscrew mounting and tensioner locator holes.



Measure the tensioner locator hole inside diameter at two locations 90 degrees apart.

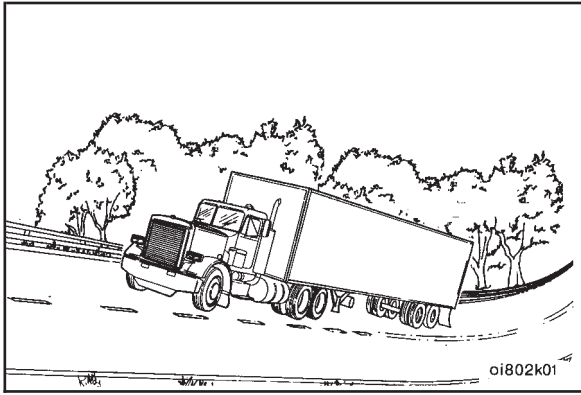
Tensioner Locator Hole I.D.		
mm		in
4.00	MIN	0.354
4.50	MAX	0.374

Replace the bracket if the locator hole inside diameter is **not** within the specifications given.

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 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 installed in the vehicle or equipment.

Chassis Dynamometer, Portable Dynamometer or Load Bank Run-In

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 stand-by 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 attached procedures.

Definition of Terms On Engine Performance Curve

Cummins M11 Heavy Duty Engine Operating Curve Definitions:

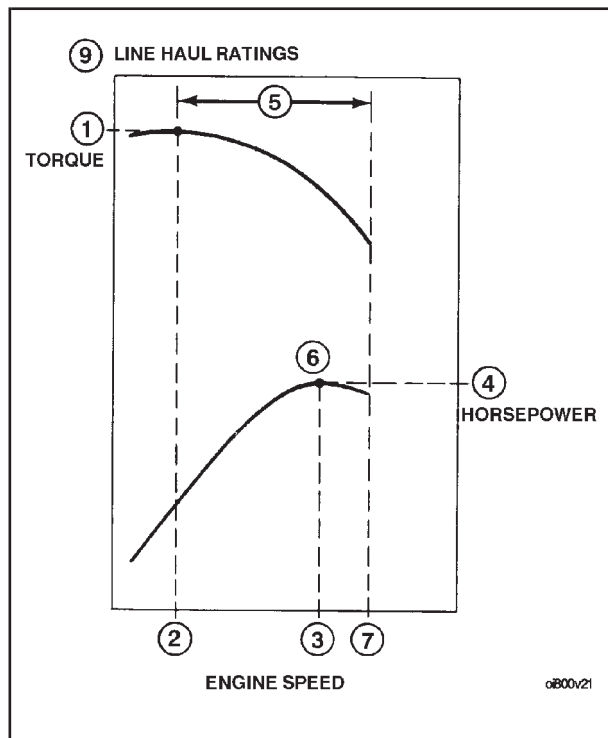


Fig. 1

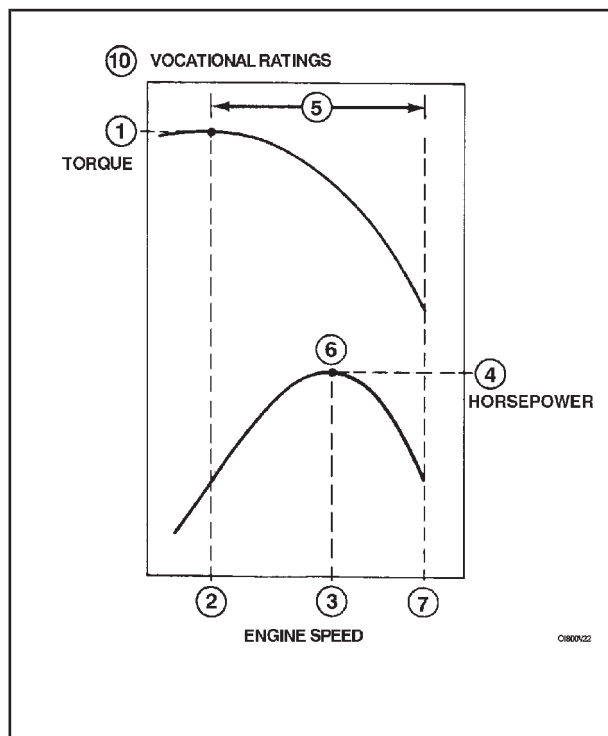
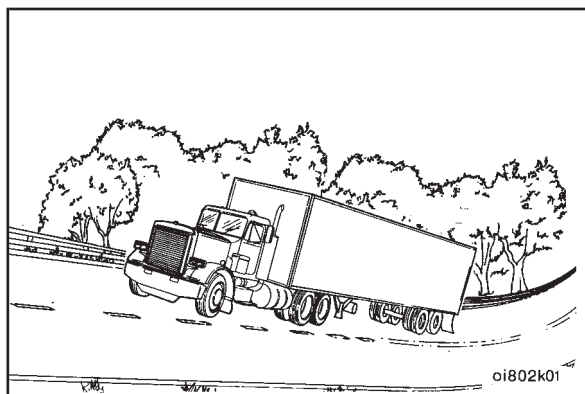


Fig. 2

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 (RPM)** - Engine speed at which peak torque is generated. This is listed on the engine data plate.
3. **Maximum HP RPM (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 (RPM)** - 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 (RPM)** - 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 (RPM)** - (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.



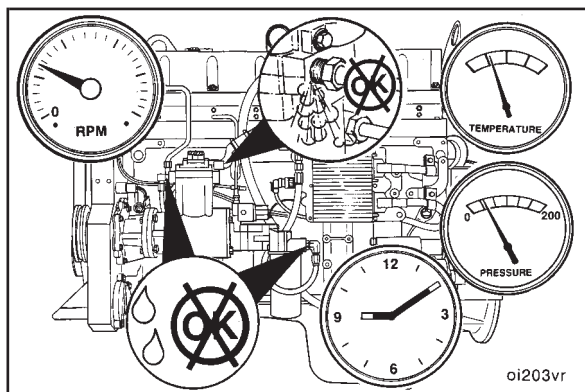
General Run-In Procedures



Caution: Refer to General Engine Test Specifications in this section before operating the engine to avoid internal component damage.

The amount of time specified for the following engine run-in phases are minimums.

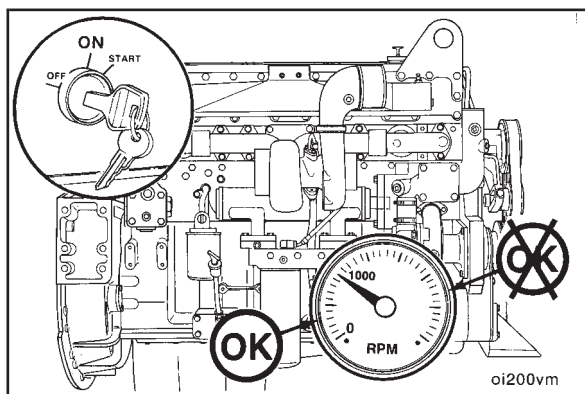
The engine can be operated for longer periods of time at each operating range or phase with the exception of engine idling which **must** be kept to 5 minutes or less.



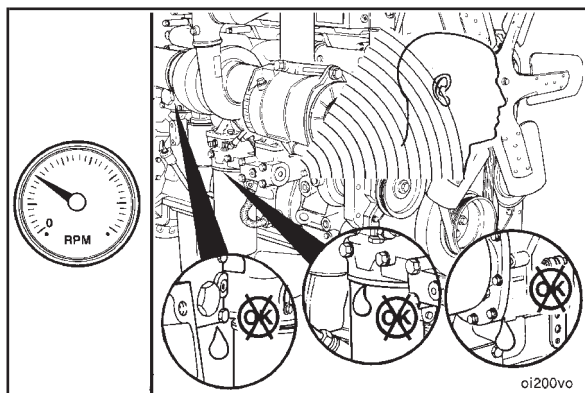
Start the engine and idle for initial check.

Avoid long idle periods. Operate the engine at low idle only long enough (5 minutes maximum) to check for correct oil pressure and any fuel, oil, water, or air leaks.

Do **not** operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will occur and cause damage to the engine.



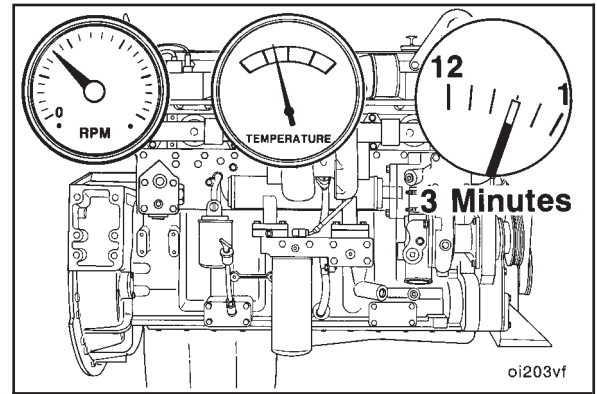
To avoid internal component damage, do **not** allow the engine speed to exceed 1,000 RPM before run-in.



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.



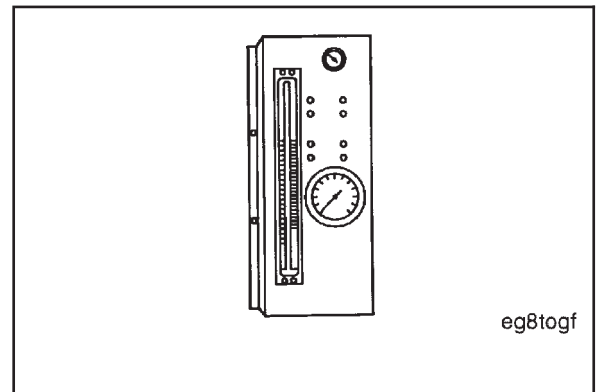
Fuel Flow Measurement on Engine or Chassis Dynamometer

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

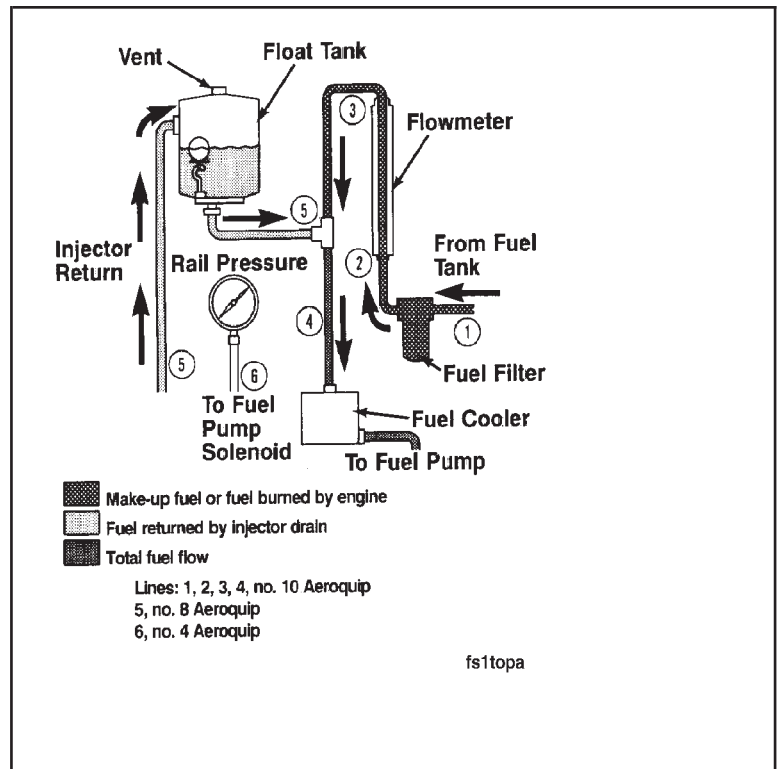
When installing the fuel measuring device, it is important to reduce the amount of air that can be introduced into the system when the device is **not** in use. Therefore, the plumbing used **must** include non-restrictive shutoff valves, such as ballcock valves, to contain fuel in the device after each use. Additional installation considerations are:

- The fuel measuring device, Part No. 3376375, **must** be mounted vertically to provide 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.



This is a schematic of the fuel measuring device, Part No. 3376375. The device consists of the following components:

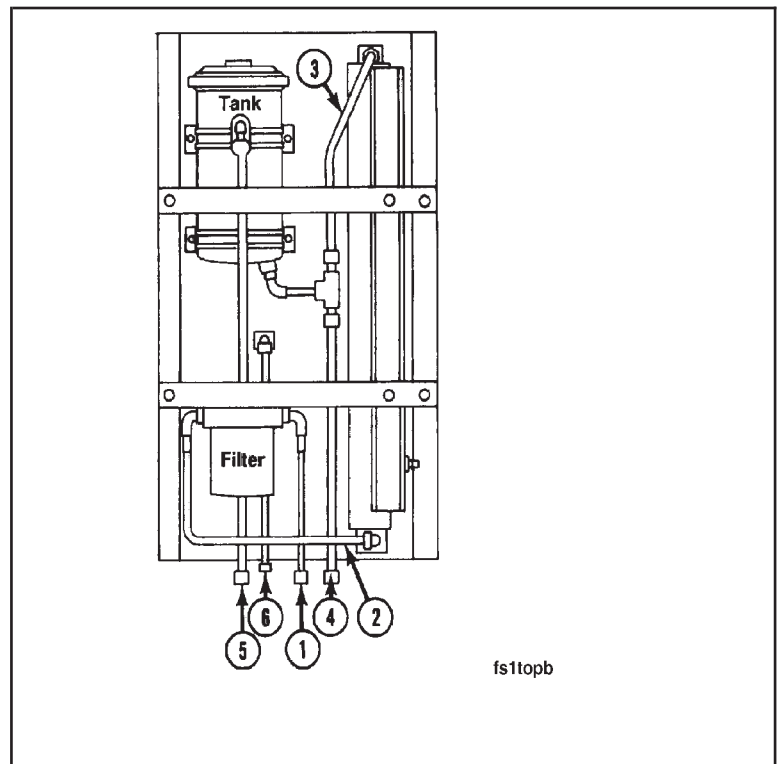
- Fuel Filter
- Flowmeter
- Float Tank
- Fuel Rail Pressure Gauge
- Fuel Cooler is not a part of fuel measuring device, Part No. 3376375; however, **must** be used when conducting test with the flow meter.

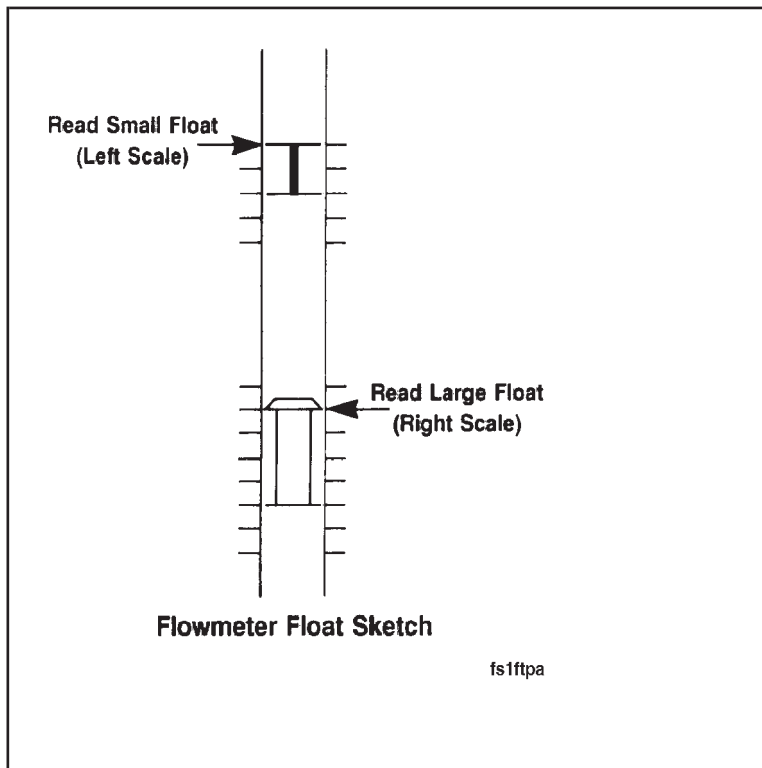


The fuel measuring device recirculates return fuel to the engine fuel inlet by routing the return fuel to the top side of the float tank. The fuel is deaerated as it passes through the baffling in the float tank. A ball float valve at the bottom of the float tank maintains an adequate volume in the tank 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™ engines, the engine fuel inlet line **must** flow through the ECM cooling plate to provide 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.

Intake Manifold Boost Pressure Correction Factors

Boost pressure measured in the intake manifold is directly related to the ambient temperature, the temperature rise across the air cleaner and turbocharger, and the pressure drop across the charge air cooler. Typically when the ambient temperature rises, the boost pressure measured in the intake manifold decreases. Conversely, higher boost pressure measured in the intake manifold can be obtained with falling ambient temperature.

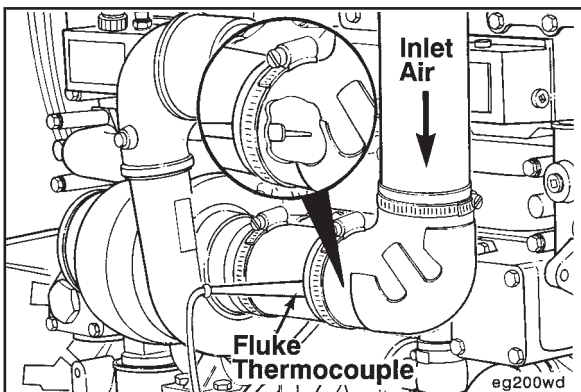
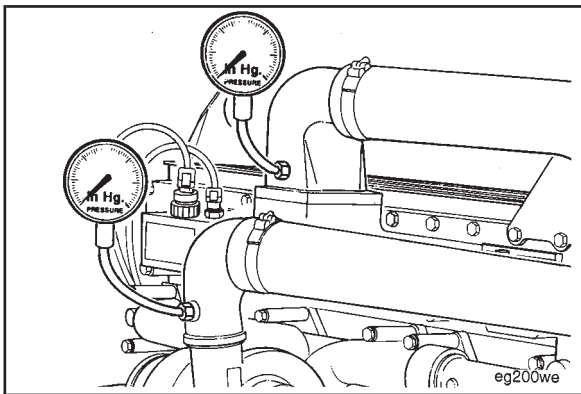
Refer to the following procedure and boost pressure correction factor charts to aid in the determination of engine performance output. The charts define power output by modifying boost pressure as a function of intake manifold air temperature.

To use the charts, first determine which chart is appropriate for your engine. Select the proper chart based on the local area altitude and the engine horsepower stamped on the dataplate. With the engine running at full load and full throttle at maximum horsepower RPM, the following data **must** be taken.

Two pressure measurements are required:

1. Measure the turbocharger compressor outlet pressure (boost) between the turbocharger and the charge air cooler using a calibrated pressure gauge.
2. Measure the intake manifold pressure at the 1/8 inch NPT tap in the intake manifold connection with the air horn using a calibrated pressure gauge.

NOTE: The most accurate and reliable readings are obtained using the same pressure gauge to measure both the turbocharger compressor outlet pressure and the intake manifold pressure.

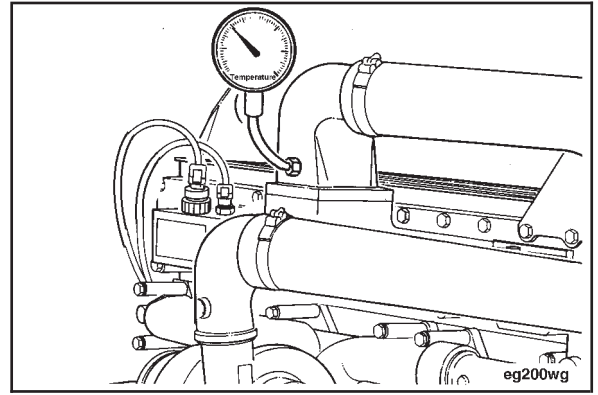


Two temperature measurements are required:

1. Measure the turbocharger compressor inlet temperature by inserting a Fluke digital thermometer, Part No. 3822666, and thermocouple wire kit, Part No. 3822988, underneath the intake air inlet elbow which is between the air cleaner and the turbocharger.

2. Measure the intake manifold temperature at the 1/8 inch NPT tap near the air horn connection with the intake manifold. Measure this temperature as close as possible to the inlet of the intake manifold.

Alternately, intake air temperature can be measured by using Compulink™ in the “monitor” mode.



TEST DATA FOR BOOST CORRECTION CHART

Altitude: _____ Engine Horsepower: _____ Date: _____
Customer: _____ Truck Unit: _____ Vehicle Make/Model: _____
ESN: _____ CPL: _____ Mileage: _____

RPM	Fuel Rate lb/hr	Turbo Outlet Press (in Hg)	Intake Mfd Press (in Hg)	Turbo Comp Inlet Temp (°F)	Intake Mfd Temp (°F)

Once the data has been obtained and the table filled, plot the data on the chart specific for your engine. On the horizontal axis, mark a vertical line (A) so that it intersects the axis at the measured compressor inlet temperature which is that temperature measured between the air cleaner and the turbocharger. For this example, let the compressor inlet temperature equal 34.4°C [94°F].

Altitude = sea level

Typical Restrictions Assumed:

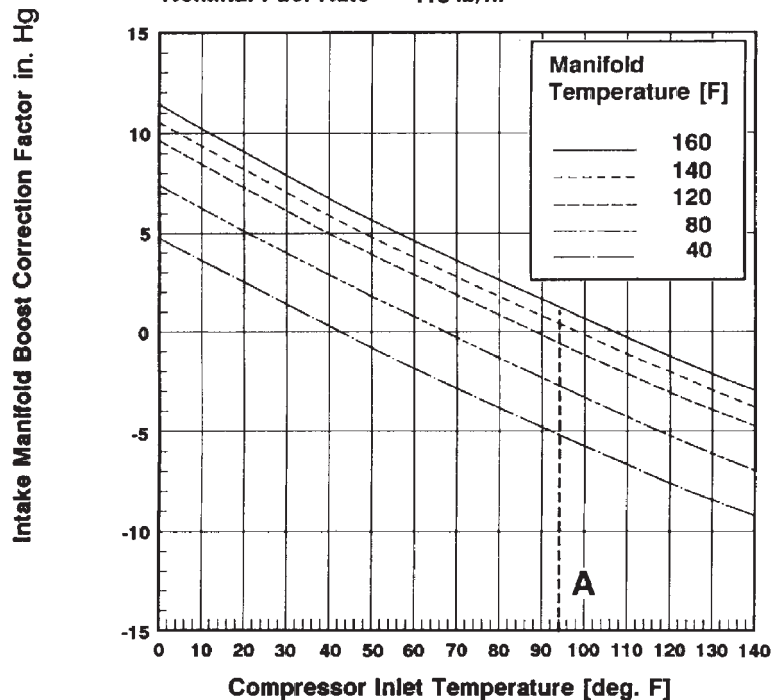
CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 110 lb/hr



Base Intake Manifold Boost Pressure
Specification Range = 48 to 58 in. Hg [gage]

oi200kl

Next, find the curved line in the graph (B) closest to the measured intake manifold temperature recorded during the test. If the measured intake manifold temperature is for example 130°F, put a mark in the middle of the curved lines representing 49°C and 60°C [120°F and 140°F] intake manifold temperature. This mark **must** intersect the vertical line (A) drawn through the measured compressor inlet temperature. Draw a horizontal line (C) from this mark to the vertical axis. Where it crosses the vertical axis, the number obtained will be either a positive number, a negative number or zero. The charts provide correction factors from -15 to +15 in-Hg. This number now **must** be added or subtracted to each end of the boost specification range. This example yielded a zero (0) correction factor.

Altitude = sea level

Typical Restrictions Assumed:

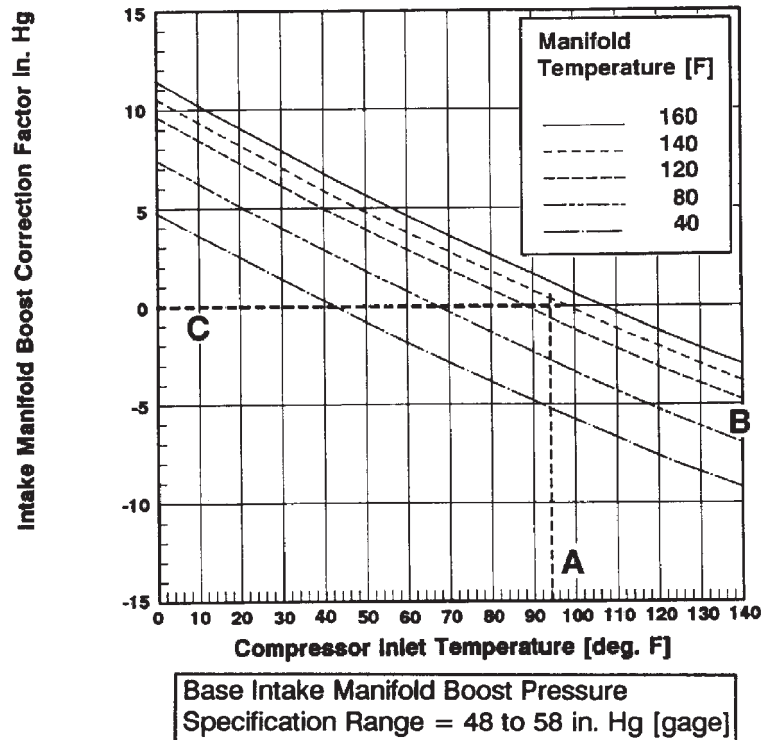
CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 110 lb/hr



Consider another example:

The turbocharger compressor inlet temperature measured between the air cleaner and the turbocharger is 70°F and the intake manifold temperature is 49°C [120°F]. At the intersection of the 49°C [120°F] intake manifold temperature curve (B), and the vertical line (A) for 21.1°C [70°F] compressor inlet temperature, draw a horizontal line (C) to the vertical axis and record the boost correction factor. In this example, the intake manifold boost correction factor is 2.0. This added to each end of the base intake manifold boost specification range gives 53 to 62 in-Hg as the new acceptable boost range. Now, what this new range says is that the engine is generating the expected power and is **not** suffering from low power if the measured intake manifold pressure is actually between 53 and 62 in-Hg.

Altitude = sea level

Typical Restrictions Assumed:

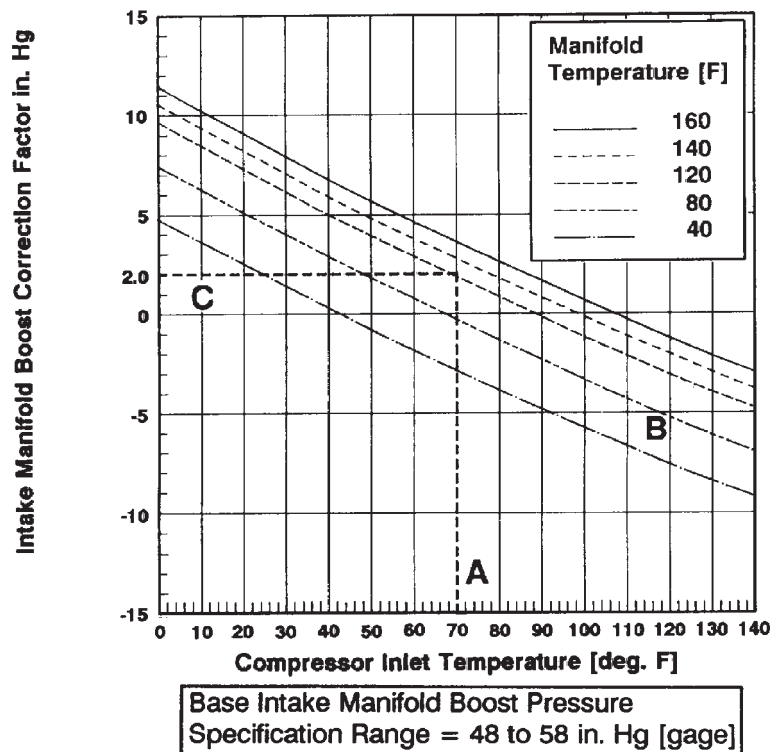
CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

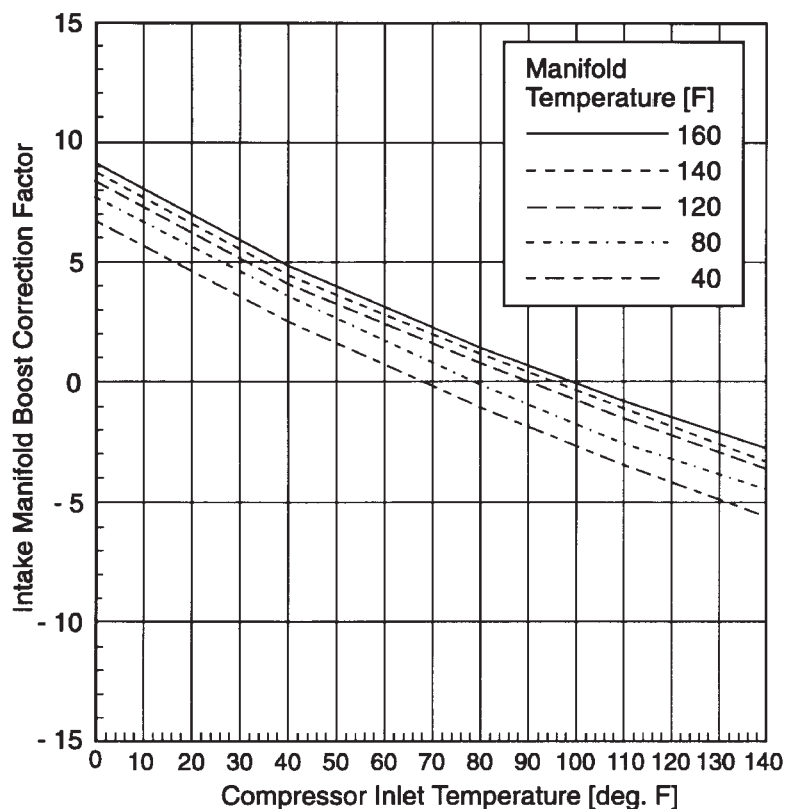
Engine Speed = 1600 rpm

Nominal Fuel Rate = 110 lb/hr



oi200kn

M11-280E



Altitude = sea level

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

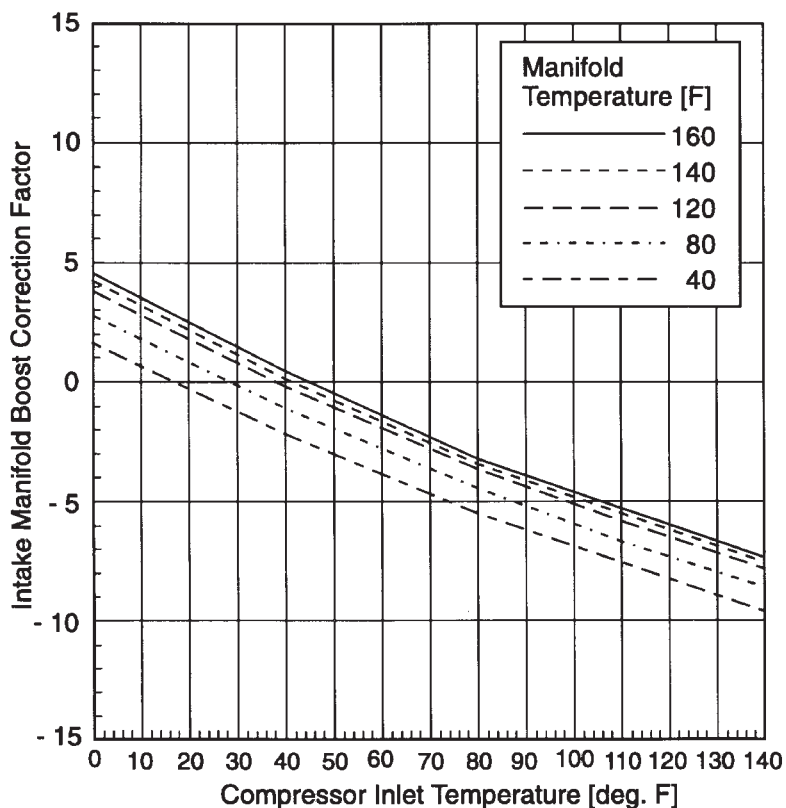
Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 83 - 92 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 28 to 38 in. Hg [gage]



Altitude = 5,000 feet

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

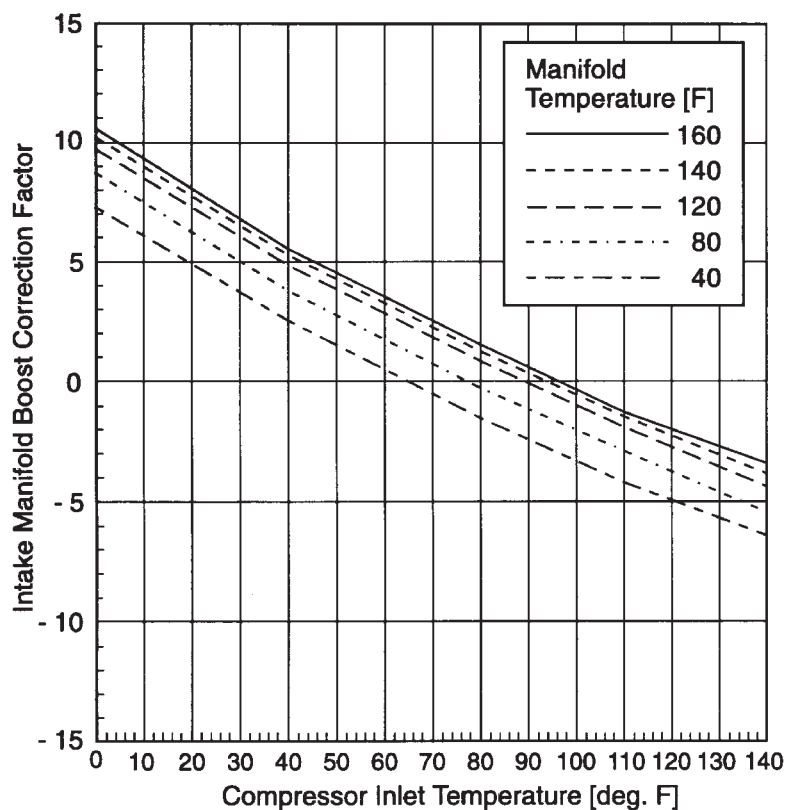
Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 83 - 92 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 28 to 38 in. Hg [gage]

M11-310E



Altitude = sea level

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

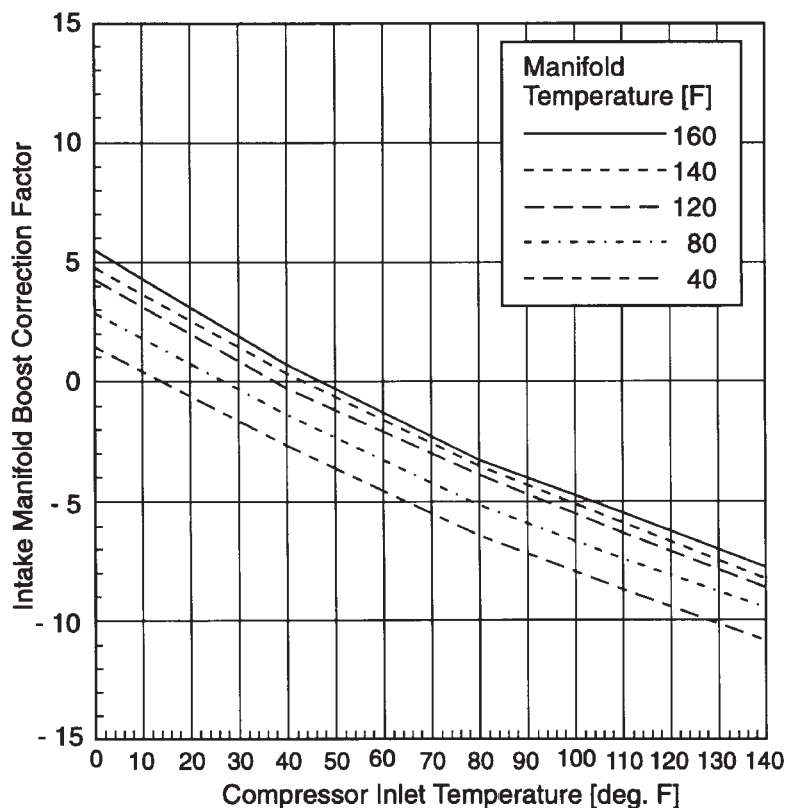
Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 92 - 102 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 33 to 45 in. Hg [gage]



Altitude = 5,000 feet

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

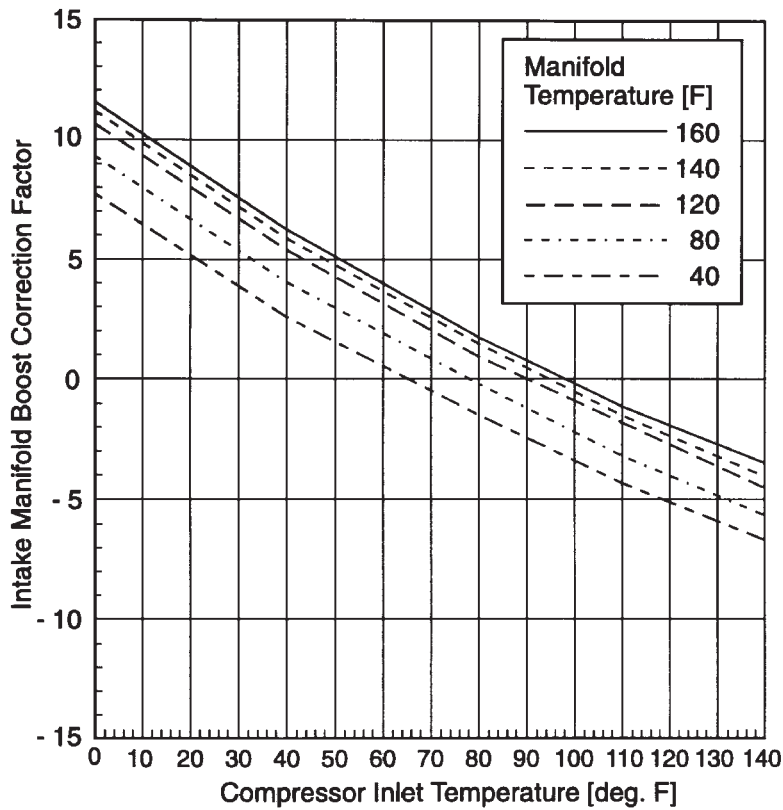
Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 92 - 102 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 33 to 45 in. Hg [gage]

M11-330E



Altitude = sea level

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

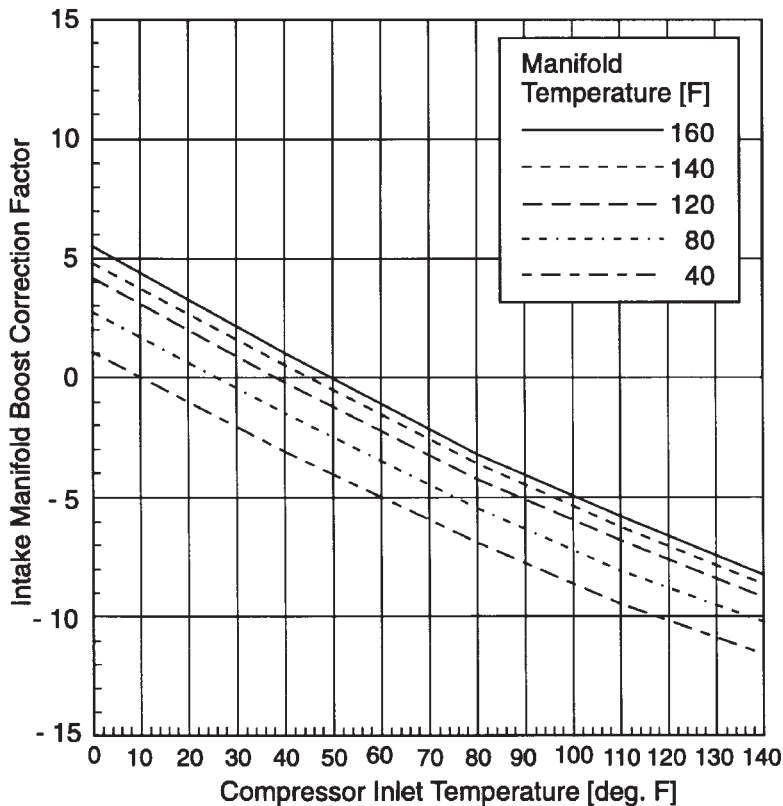
Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 98 - 108 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 37 to 47 in. Hg [gage]



Altitude = 5,000 feet

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

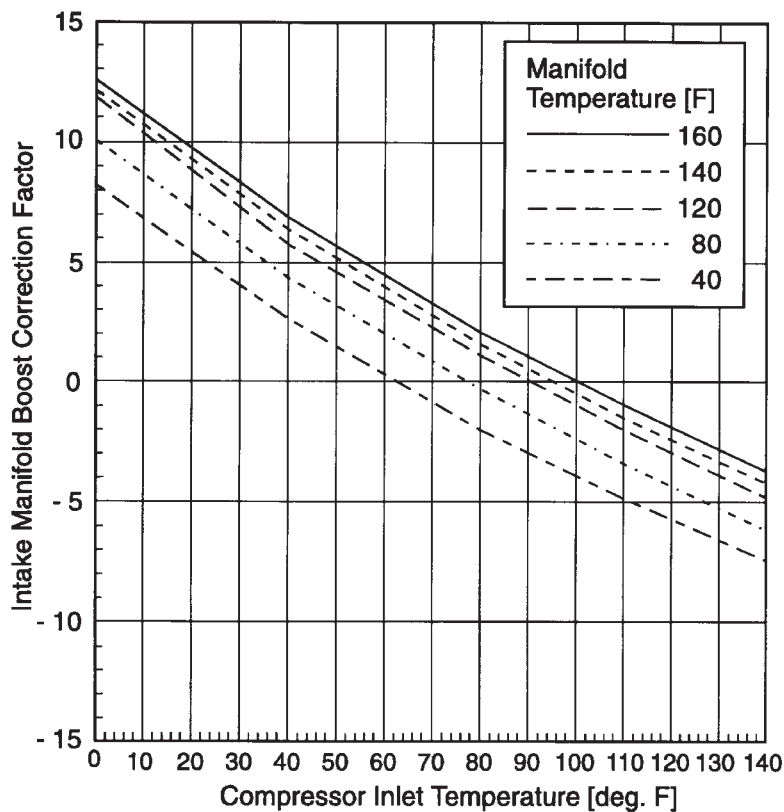
Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 98 - 108 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 37 to 47 in. Hg [gage]

M11-350E



Altitude = sea level

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

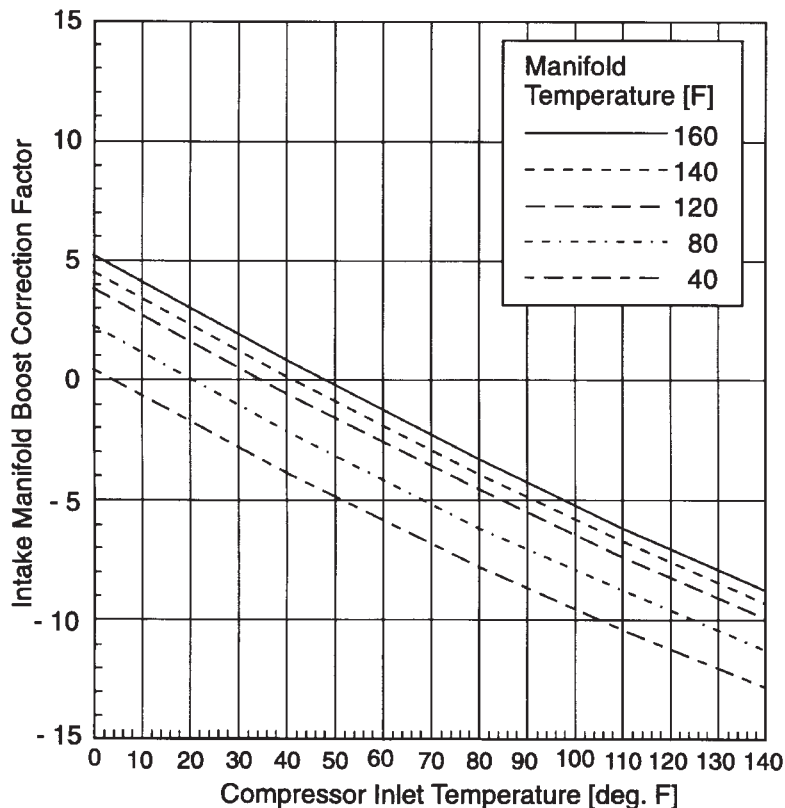
Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 105 - 116 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 41 to 51 in. Hg [gage]



Altitude = 5,000 feet

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

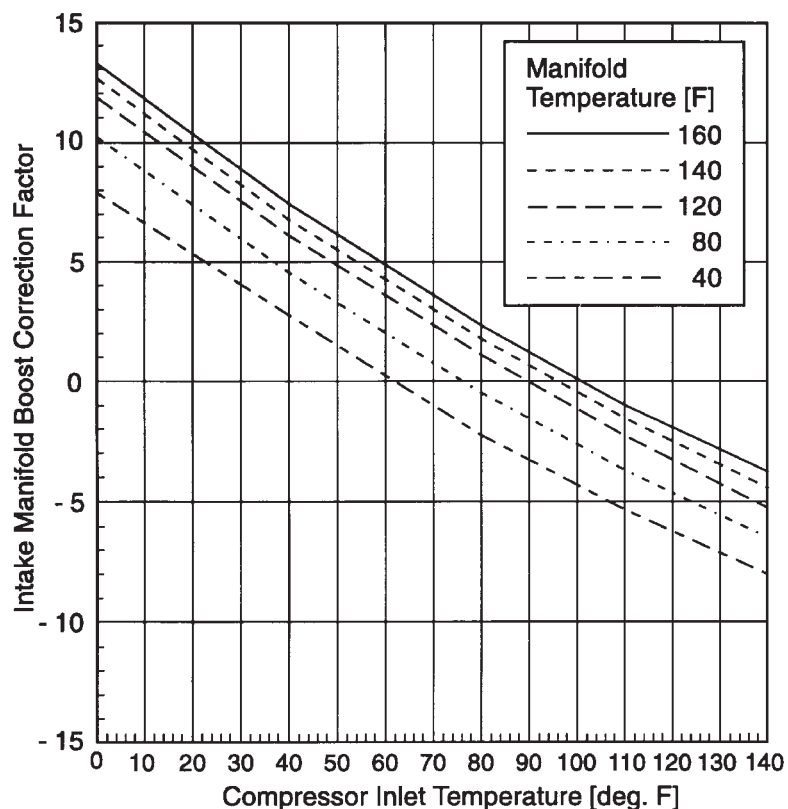
Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 105 - 116 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 41 to 51 in. Hg [gage]

M11-370E



Altitude = sea level

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

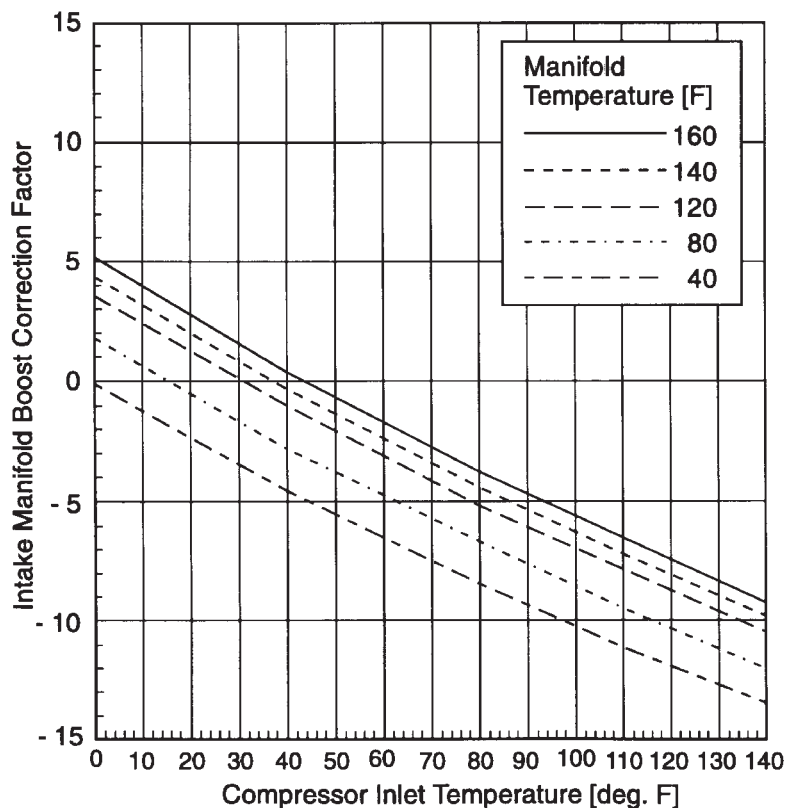
Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 111 - 123 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 45 to 55 in. Hg [gage]



Altitude = 5,000 feet

Typical Restrictions Assumed:

CAC Pressure Drop = 3 in. Hg

Intake Air Restriction = 15 in. H₂O

Exhaust Restriction = 3 in. Hg

Engine Speed = 1600 rpm

Nominal Fuel Rate = 111 - 123 lbs/hr

Base Intake Manifold Boost Pressure
Specification Range = 45 to 55 in. Hg [gage]

Engine Testing - Specifications

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) 152 mm Hg [6.0 in. Hg]
21 kPa [3.0 psi]

Intake Restriction (Maximum at Advertised Horsepower)

- Clean Air Filter 254 mm H₂O [10.0 in. H₂O]
- Dirty Air Filter 635 mm H₂O [25.0 in. H₂O]

Exhaust Back Pressure (Maximum at Advertised Horsepower) 75 mm Hg [3.0 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 [12.0 in. H₂O]
- Used Engines
(maximum) (over 160,000 km [100,000 miles] or 3600 hours) 460 mm H₂O [18.0 in. H₂O]

Oil Pressure

- Low Idle (minimum allowable) 69 kPa [10.0 psi]
- At 1200 RPM or Torque Peak (minimum allowable) 207 kPa [30 psi]

Fuel Inlet Restriction measured at fuel pump inlet (Maximum at Advertised Horsepower)

- Clean Fuel Filter 152 mm [6.0 in Hg]
- Dirty Fuel Filter 254 mm [10.0 in Hg]
- Maximum Allowable Fuel Inlet Temperature 71°C [160°F]

Fuel Drain Line Restriction (Maximum at Advertised Horsepower) 89 mm Hg [3.5 in Hg]

- Due to variations in ratings of different engine models, refer to the specific “Engine Data Sheet” for the particular engine model being tested.
- Blowby checking tool, Part No. 3822566, have a special 7.67 mm [0.302-inch] orifice that **must** be used to be certain an accurate reading is obtained.

Dynamometer Worksheet

Date _____ Repair Order No. _____ Operator _____
 ESN _____ CPL _____ Fuel Pump Code _____
 Complaint _____ SC Code _____

PARAMETER	CODE SPECIFICATIONS	ACTUAL READING
Fuel Pressure (psi @ RPM)	150 to 180 at Governed	
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	10 in. Hg (Dirty Filter), Maximum	
*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	Horse power or Torque

* Be sure that the fuel rate is corrected for temperature.

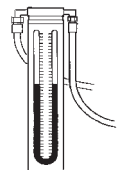
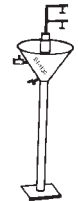
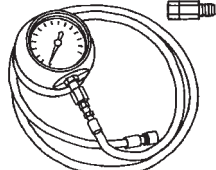
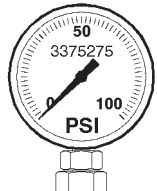
Fuel Temperature	Correction for Flow Rate
Less than 7°C[45°F]	Flow meter not accurate
7 to 13°C[45 to 55°F]	Subtract 2% from flow rate reading
13.0 to 20.0°C[55 to 68°F]	Subtract 1% from flow rate reading
20.0 to 29°C[68 to 85°F]	No Correction
29 to 42°C[85 to 108°F]	Add 1% to flow rate reading
42 to 56°C[108 to 132°F]	Add 2% to flow rate reading
56°C above [132°F]	Flow meter not accurate.

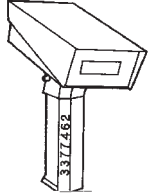
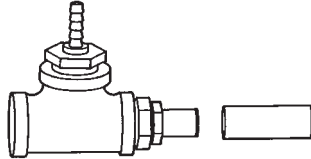
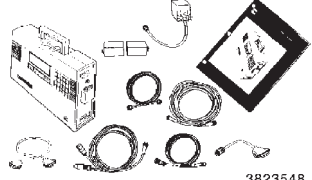
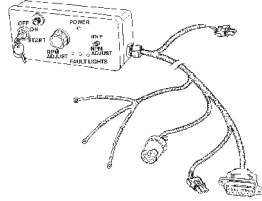
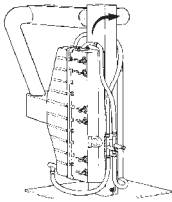
Pressure Conversions
1 in. H ₂ O = 0.074 in. Hg = 0.036 psi
1 in. Hg = 13.514 in. H ₂ O = 0.491 psi
1 psi = 2.036 in. Hg = 27.7 in. H ₂ O

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Service Tools - Engine Testing

The following special tools are recommended to perform procedures in Section 8. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-434	Vacuum Gauge Used to check fuel filter or intake air restriction.	 eg8togc
ST-1111-3	Manometer Used with tool, Part No. 3375150 and 3822556, for measuring blowby.	 eg100ja
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
3375932	Pressure Gauge (0-300 psi) Used to measure fuel pressure. Includes necessary hoses and hardware to attach to a fuel pump. Part No. ST-435-1 is the hose and Part No. ST-435-6 is the pressure gauge.	 eg8togh

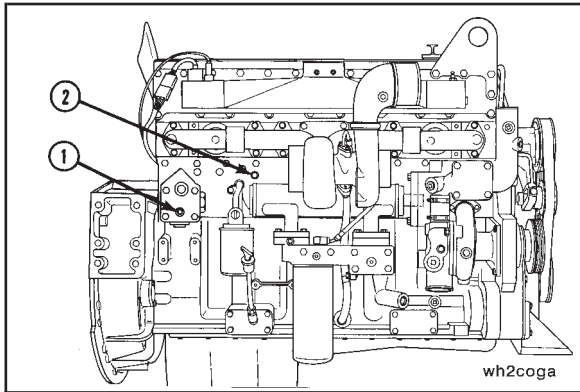
Tool No.	Tool Description	Tool Illustration
3376375	Fuel Measuring Device Measure the rate of fuel consumption of a Cummins diesel engine.	 eg8togf
3377462	Digital Optical Tachometer Used to measure engine speed (RPM).	 3377462
3822566	Blowby Check Tool Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.	 eg8toge
3823548	Compulink™ Kit Used to program and adjust CELECT™ system. Kit includes Compulink™ and all necessary cables.	 3823548
3823948	CELECT™ Engine Dyno Control Used on an engine dyno to control the CELECT™ engine.	 3823948
3823978	Dyno-Room Charge Air Cooler Used to cool intake air when an air to air engine is used on a engine dyno.	 3823978

Engine Dynamometer - Install Engine (14-01)

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.

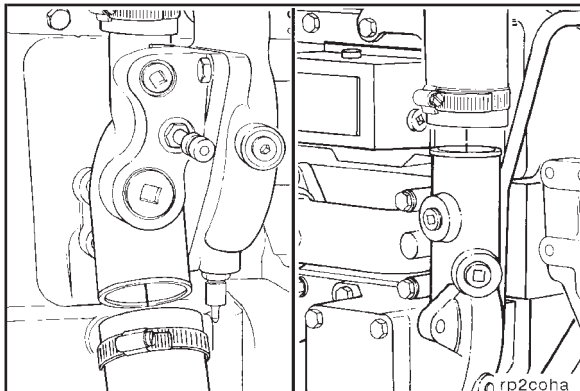


NOTE: Some engines are equipped with fittings used for Compuchek® testing sensors. The sensor probes used for Compuchek® and dynamometer testing are **not** compatible. If the same location is used, remove the Compuchek® fitting and install adapters for the dynamometer sensor.



Install the coolant pressure sensor (1).

Install the coolant temperature sensor (2).



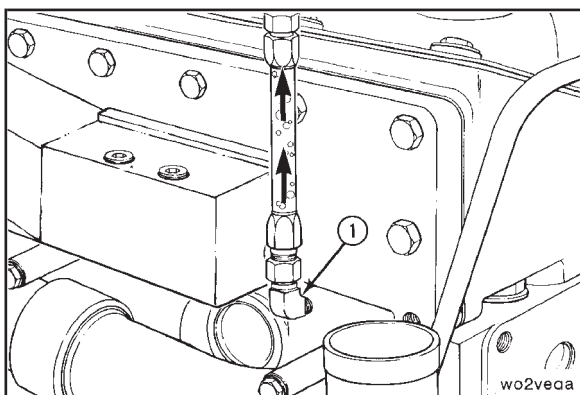
Coolant Plumbing



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 Big Cam III 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]).

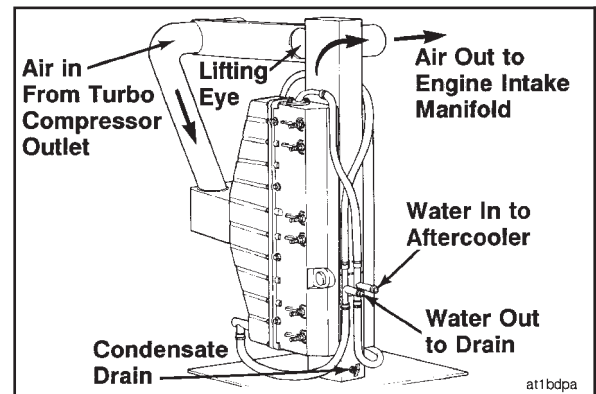
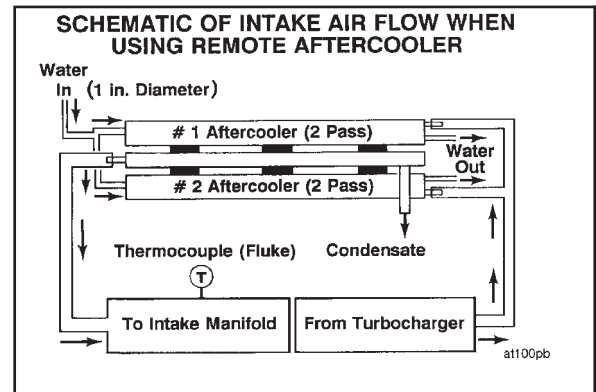
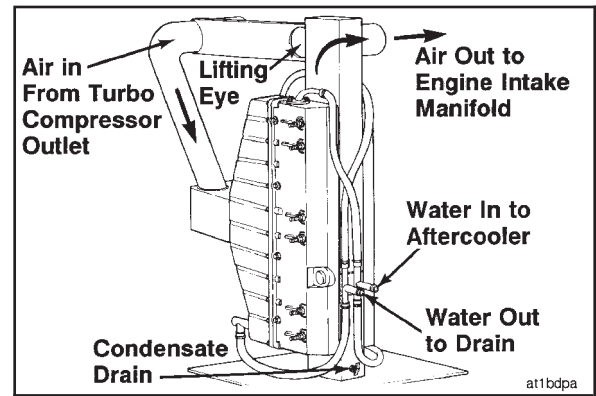
The remote aftercooler removes energy from the intake air which is compressed and heated by the turbocharger to temperatures as high as 210°C [410°F] then cooled to temperatures of 66°C [150°F] using city water at 16°C [60°F].

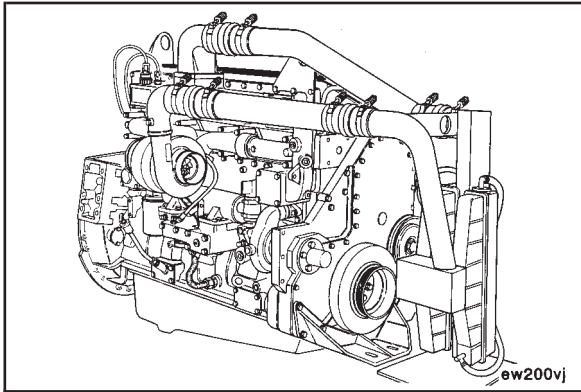
Water from a city tap line flows to the aftercoolers via a one inch I.D. neoprene hose. Testing has shown the 12 GPM city water flow is required (6 GPM per aftercooler core) to adequately cool the intake air. A typical garden hose is **not** suitable for this flow due to the excessive restriction. A 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.

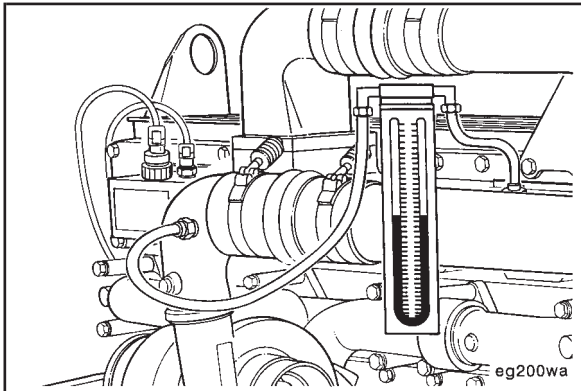
The condensate that will develop, as the intake air is cooled in the remote aftercooler, is allowed to drain at all times through a hole at the bottom of the tubular steel manifold between the aftercoolers. This fitting **must** remain unobstructed throughout each use of the aftercoolers.

NOTE: Some air flow will escape through the condensate drain opening, but it is insignificant compared to the total air flow.





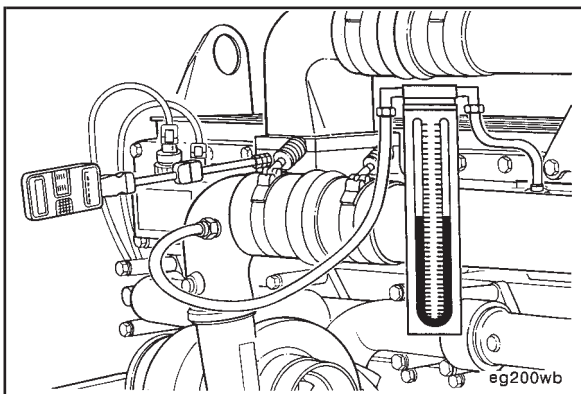
The air flow piping requires 4 inch I.D. aluminized steel piping. The flow circuit **must** have as few bends as possible maximizing the length of straight sections. However, when bends are required, use long elbows. Do **not** use mitered elbows, or anything that changes the air flow direction quickly. 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.

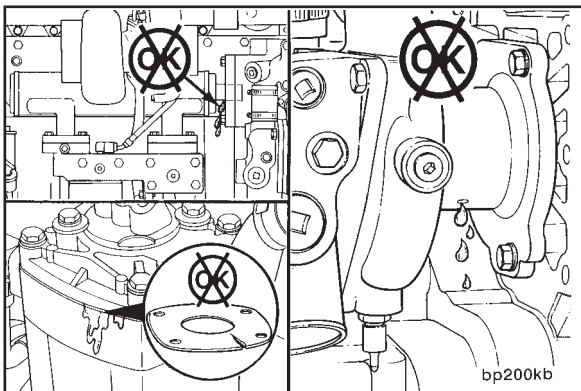


The pressure drop between these two locations **must not** be greater than 102 mm Hg [4 in Hg]. If the pressure drop is greater than 102 mm [4 in Hg], check the remote aftercoolers and air flow piping for plugging. Clean and replace if necessary.



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.

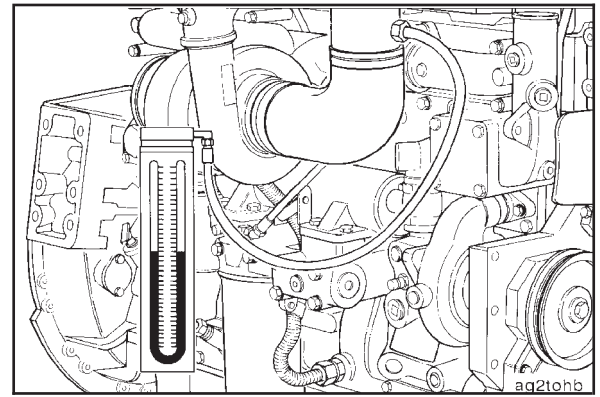
Air Inlet Restriction

Connect 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].

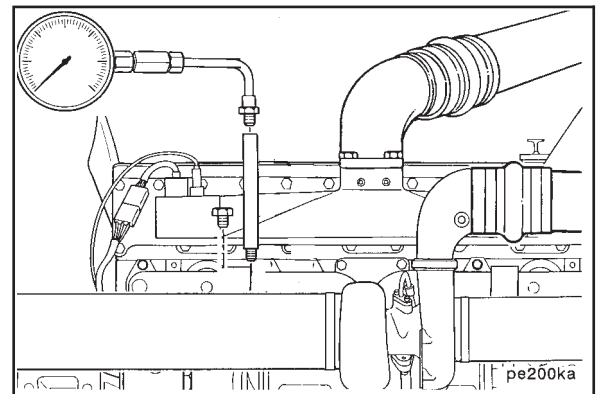


Exhaust Restriction

Connect a mercury manometer to a straight section of the exhaust piping one pipe diameter from the turbocharger outlet to measure exhaust restriction.

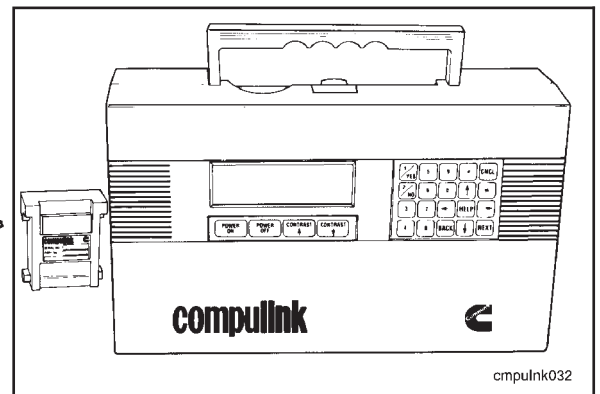
Protect the hose from heat by using a 305 mm [12 in] minimum length of metal tubing leading from the exhaust pipe connection.

Minimum Gauge Capacity: 254 mm Hg [10 inches Hg].



Lubricating Oil Temperature

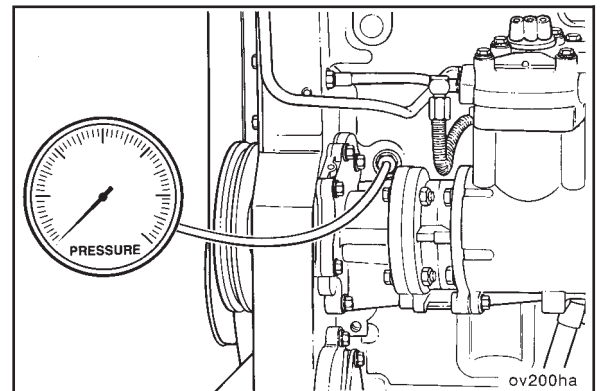
Use a Compulink™ to monitor the lubricating oil temperature. Refer to the Compulink™ Manual, Bulletin No. 3810472, for correct operation.

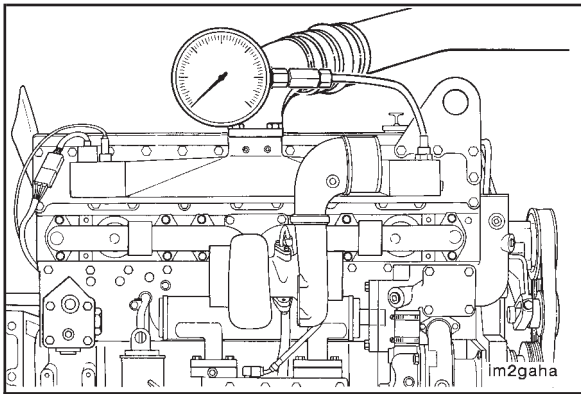


Lubricating Oil Pressure

Remove the pipe plug from the main oil rifle drilling in the cylinder block.

Install the lubricating oil pressure gauge, Part No. 3375275.

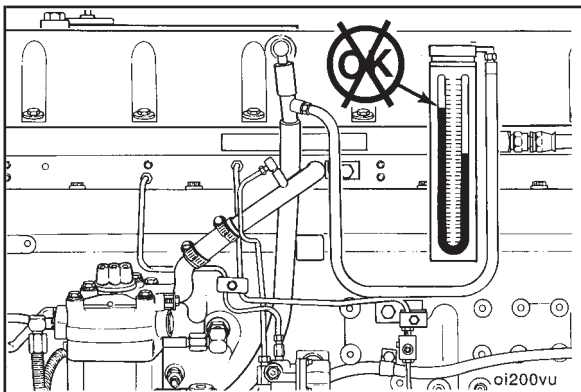




Intake Manifold Pressure



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.



Engine Blowby



Install the Part No. 3822566, Engine Blowby Tool, to the breather on the rocker lever cover to measure engine crankcase pressure.

Install a water manometer, Part No. ST-1111-3, to the engine blowby tool.

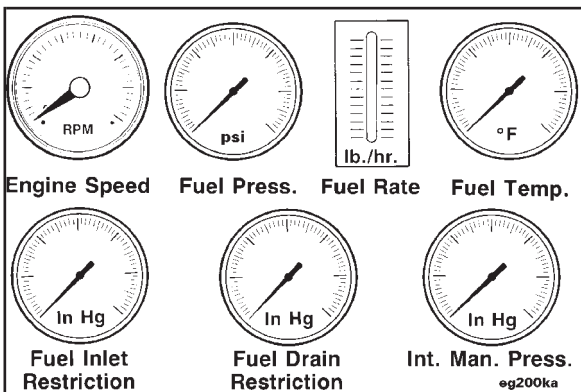
NOTE: A pressure gauge can be used to record the engine blowby.

Blowby Specifications

New, Rebuilt Engines*	30.5 cm H ₂ O [12 in H ₂ O]
Used Engines**	46.0 cm H ₂ O [18 in H ₂ O]

* Less than 160,000 km [100,000 mi] or 3600 hours.

** Over 160,000 km [100,000 mi] or 3600 hours.



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

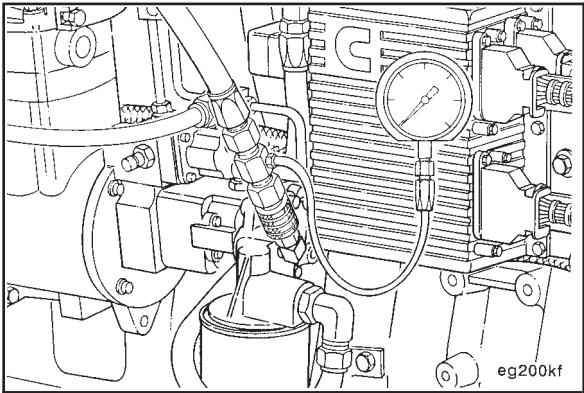
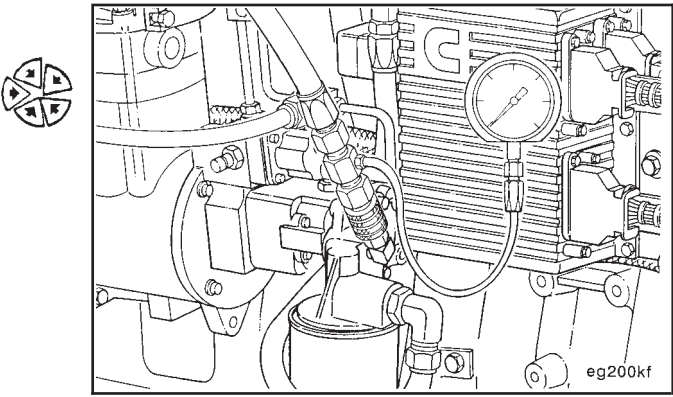
Measure the fuel inlet restriction. Install a vacuum gauge, Part No. ST-434, between the fuel filter and the gear pump inlet.

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.

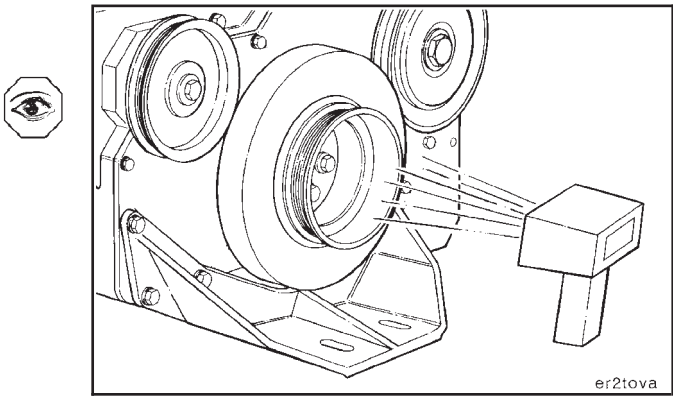
NOTE: The gauge will **not** measure the correct vacuum if the gauge is **not** held at the same level as the gear pump.

Fuel Inlet Restriction (plus ECM Cooling Plate)			
	mm Hg		in Hg
Clean Filter	152	MAX	6
Dirty Filter	254	MAX	10



Engine Speed (RPM) With a Verified Tachometer

Use digital optical tachometer, Part No. 3377462, to check and verify engine speed.

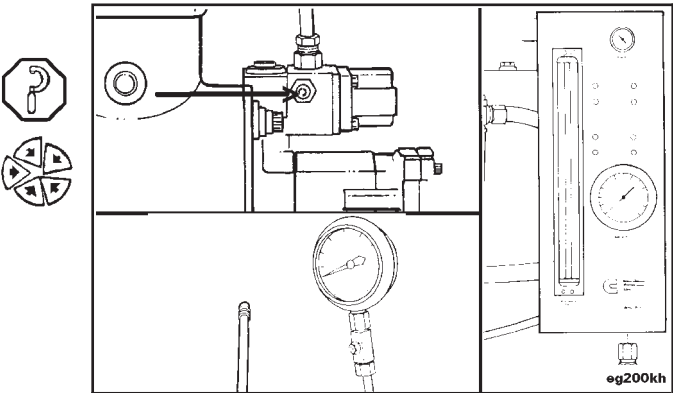


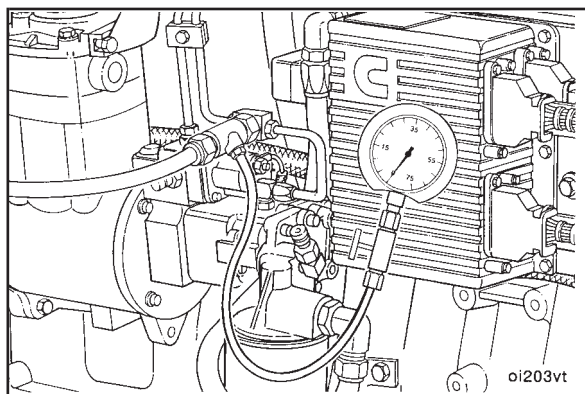
Fuel Pressure

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 Pressure at Governed RPM		
kPa		psi
1034	MIN	150
1241	MAX	180

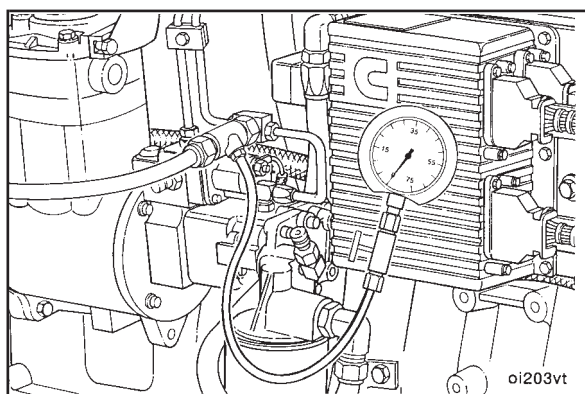




Fuel Drain Line Restriction

Use pressure gauge, Part No. ST-1273, to measure fuel drain line restriction.

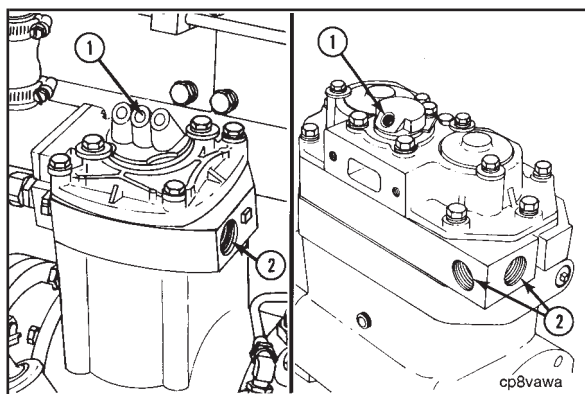
NOTE: Do **not** measure fuel drain line restriction with the fuel measuring device installed. This will **not** measure the drain line restriction of the vehicle's return plumbing.



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.

Fuel Drain Line Restriction		
mm Hg		in Hg
89	MAX	3.5



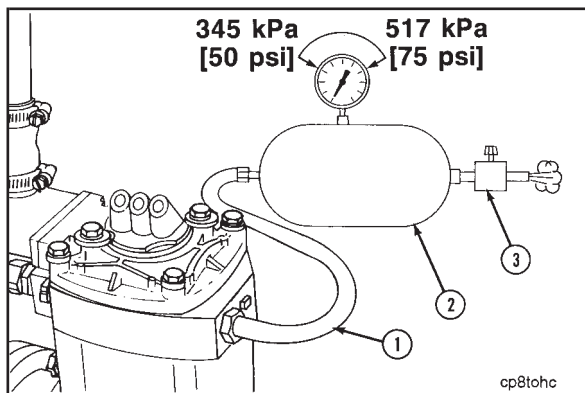
Air Compressor

NOTE: All air compressors manufactured by HolsetTM **must** be operating during the engine run-in. During the performance check, all air compressors **must** be in the unload or non-operating mode.



Connect a source of compressed air capable of producing 665 kPa [95 psi] to the air compressor unloader (1). This air line **must** contain a valve between the source and the unloader.

NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).



Use an air tank (2). Install an air regulator (3) capable of maintaining 345 to 517 kPa [50 to 75 psi] air pressure at both minimum and maximum engine RPM.

Install a steel tube or high temperature hose (1).

Hose Temperature (Minimum): 235°C [500°F].

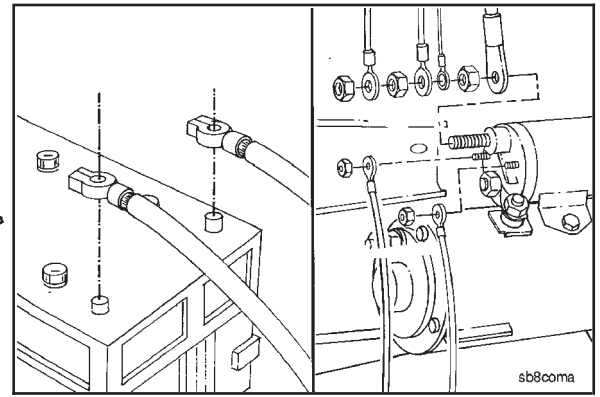
Connect the tube or hose (1) to the air compressor outlet.

Starting Motor

Inspect the voltage rating on the starting motor before installing the electrical wiring.

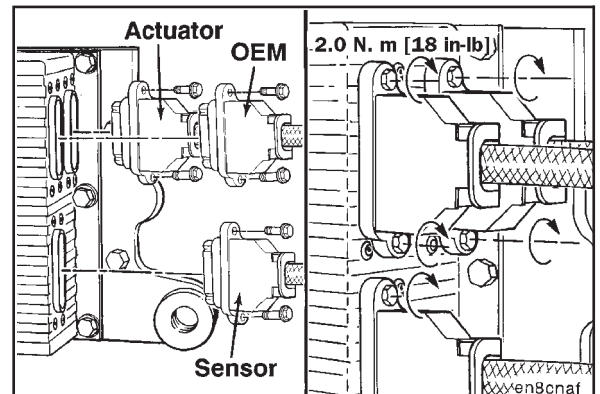
Install the electrical wiring to the starting motor and batteries, if used.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

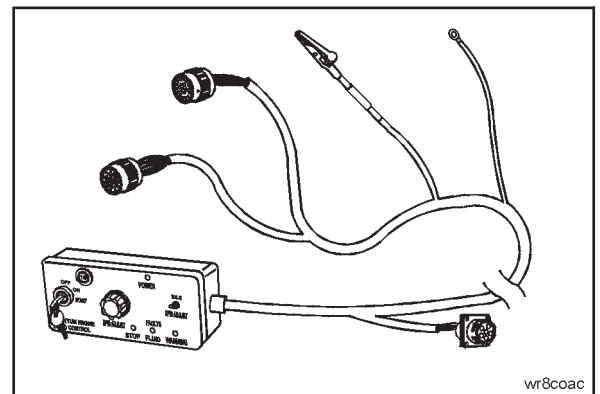


Engine Throttle Control

Engines which are run on an engine dynamometer require that the sensor and actuator 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.

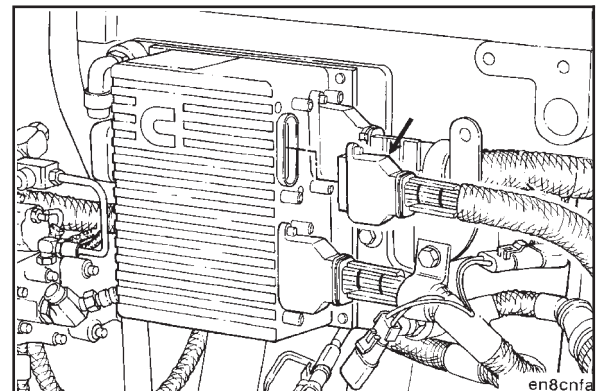


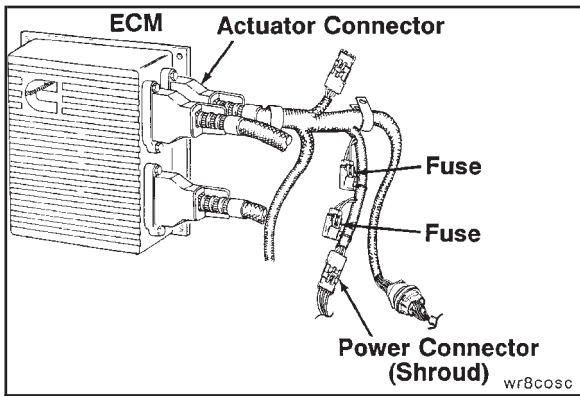
A special wiring harness and throttle control, Part No. 3823948, has been developed to enable engine operation out of chassis.



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]



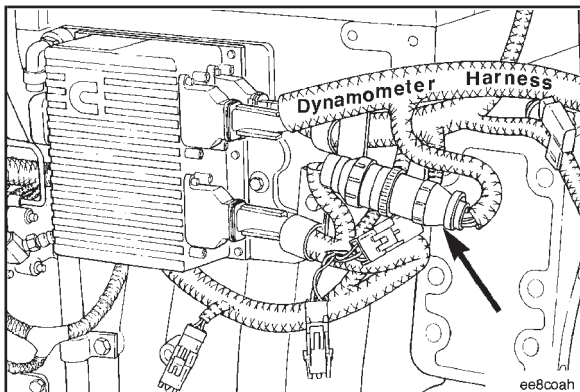


Connect the dynamometer test OEM wiring harness pin connector to the actuator harness power connector (shroud).

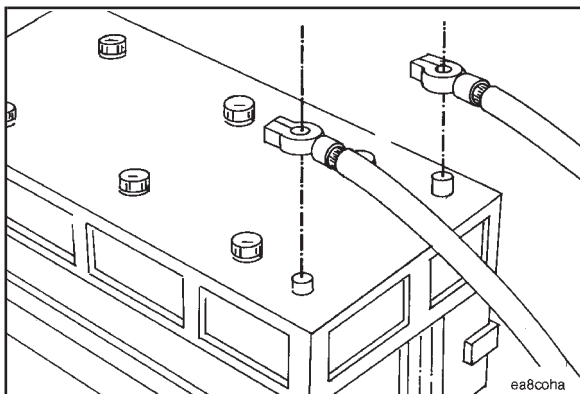


To save, adjust, and write parameters to and from the ECM, refer to the **CELECT™ Compulink™ Cartridge Manual**, Bulletin No. 3810472.

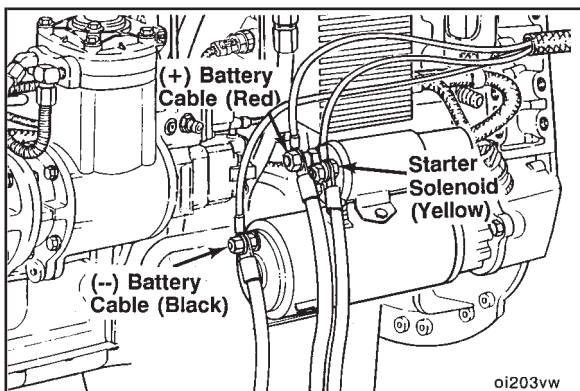
NOTE: Parameters **must** be returned to their original value when the test or run-in is completed.



Connect the dynamometer test OEM wiring harness 9 pin connector to the sensor harness 9 pin connector.



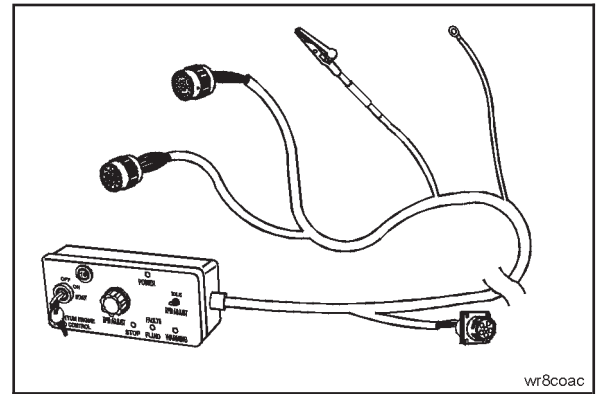
Connect battery power to the starter.



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.

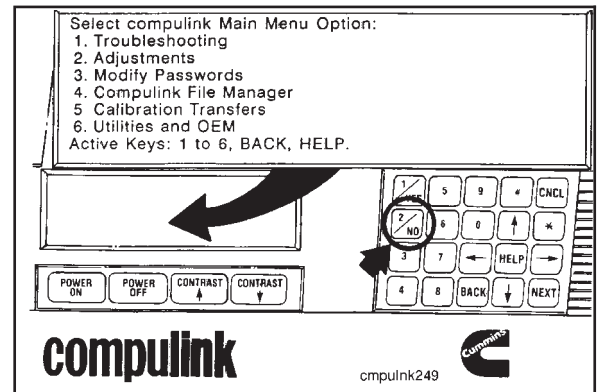
Connect the keyswitch panel datalink cable to the Compulink™.

Depress the “POWER ON” button on the Compulink™.



If the “Progressive Shift Feature” is turned “ON”, it **must** be turned “OFF” during the engine test to allow the engine to accelerate through its RPM range.

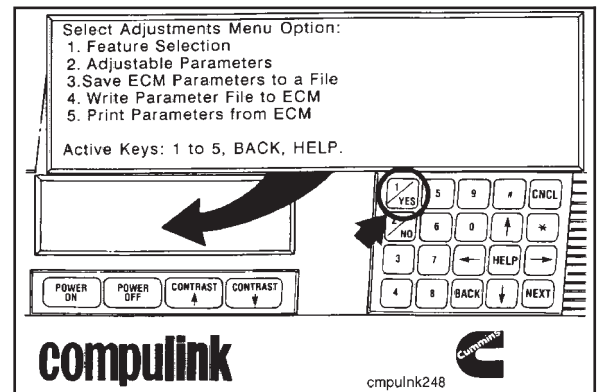
Select the “Adjustments” option from the main menu screen by depressing the number “2” on the Compulink™ keypad.



Select the “Feature Selection” from the menu options by depressing the number “1” on the keypad.

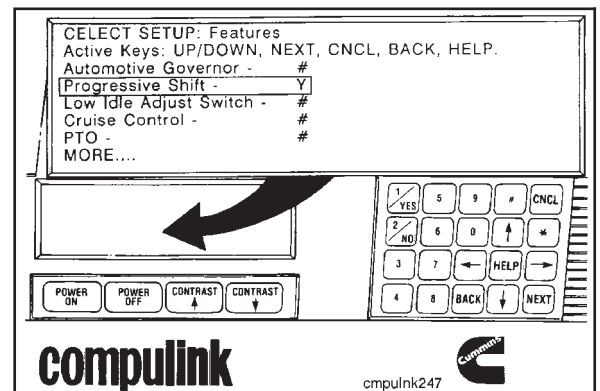
NOTE: If the password procedure has **not** been disabled, a password **must** be entered before any features can be changed. Enter the master password, user password or ECM password depending on which password is enabled. Refer to the CELECT™ Compulink™ Cartridge Manual, Bulletin No. 3810472, for instructions to enter a password.

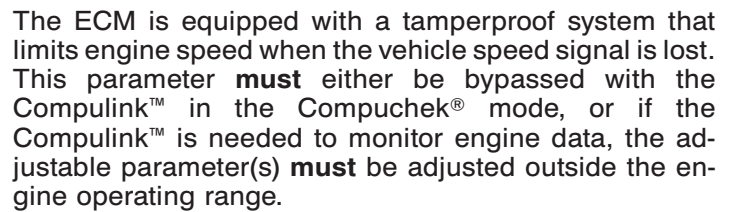
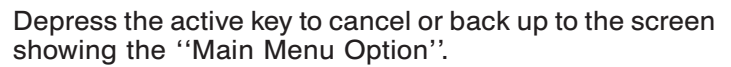
The next screen will show if the “Progressive Shift Feature” is turned “ON” or “OFF”.



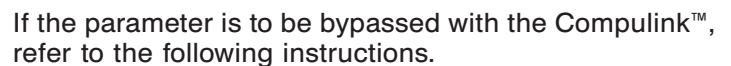
Check the “Progressive Shift Feature”. If “Y” is displayed, depress the number “2” key on the keypad to display “N” and turn off the “Progressive Shift”.

NOTE: Turn the “Progressive Shift Feature” back to “ON” when the test is completed.

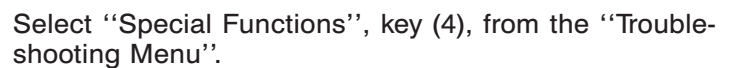




NOTE: Parameter(s) **must** be returned to their original value when the test or run-in is completed.



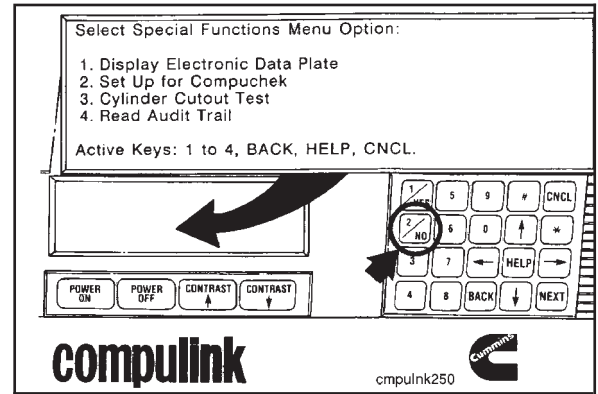
Select “Troubleshooting”, key (1), from the “Main Menu Option” screen.



Select “Set Up for Compuchek®” from the “Special Functions Menu”. The Compulink™ **must** be left in this mode throughout the test. Future generations of Compulink™ cartridge software will allow Compulink™ in the monitor mode while running tests with parameters bypassed.

The setup is now completed, and the auto/manual throttle control can be used to control engine speed.

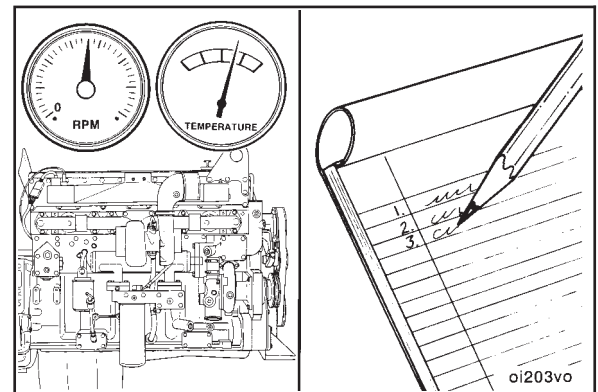
Use the active keys to cancel or back up the Compulink™ when the test is complete.



Engine Run-In Procedure - Engine Dynamometer (14-02)

Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period. Engine measurements taken are:

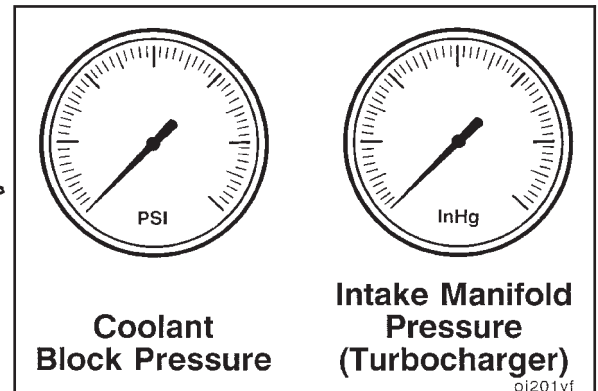
- Engine speed
- Engine torque
- Lube oil pressure
- Coolant out temperature
- Fuel pressure
- Crankcase blowby
- Fuel rate (using Service Tool, Part No. 3376375)
- Intake manifold air temperature
- Intake manifold pressure
- Turbocharger inlet air temperature

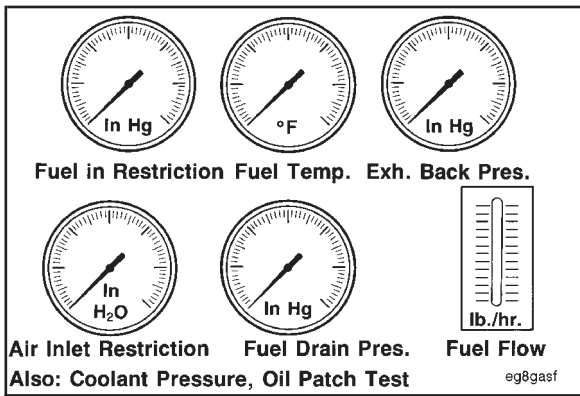


Refer to the Engine Dynamometer Worksheet in this section.

NOTE: Intake manifold pressure (turbocharger boost) **must** be corrected for variances due to intake air temperature. Use the ‘Boost Pressure Correction Factors’ explained in “Engine Testing - General Information”.

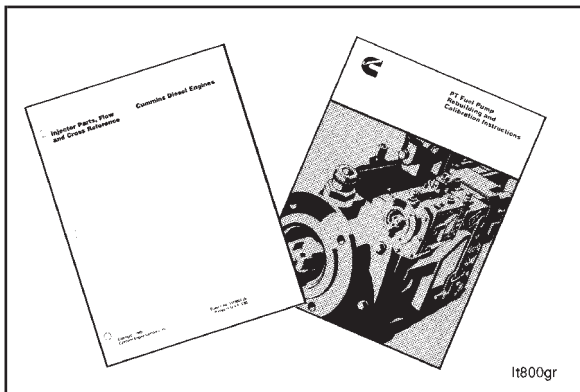
It is recommended to monitor block coolant pressure during run-in to aid in early indication of a cooling system problem.





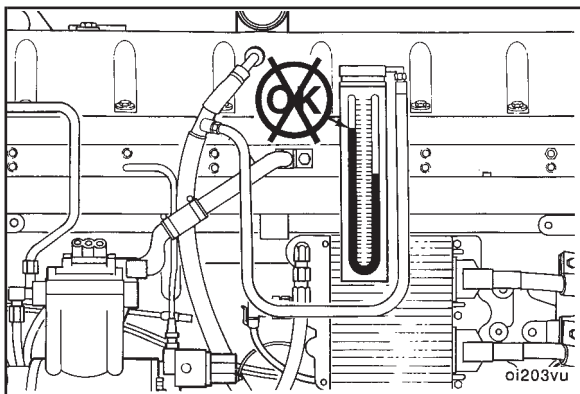
It is a good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for underperformance. The measurements taken are:

- 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
- Compulink™ for CELECT™ equipped engines



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:

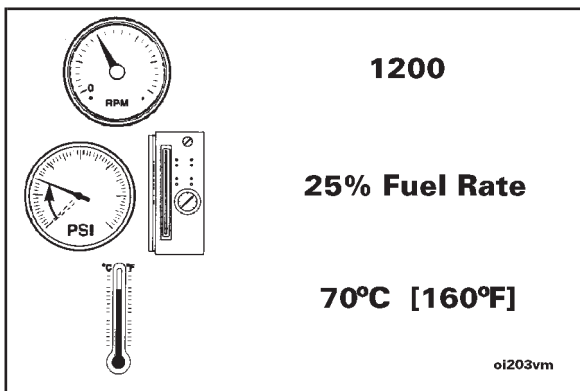
1. Fuel Pump Calibration Values, Bulletin No. 3379352.
2. Injector Parts Flow and Cross Reference, Bulletin No. 3379664.
3. Engine Data Sheets.



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.

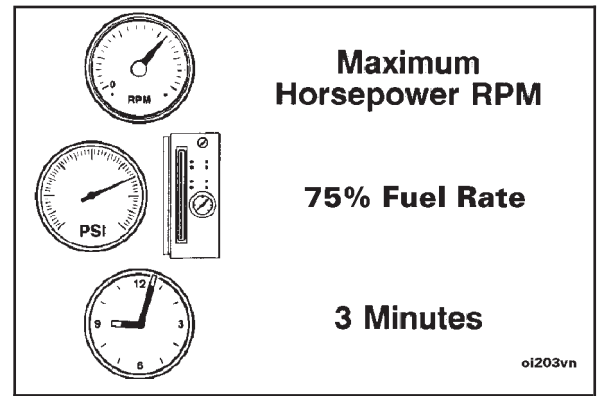
Move the throttle to obtain 1200 RPM engine speed, and apply a test load sufficient to develop 25 percent fuel rate.

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.

Open the throttle to obtain speed at which maximum horsepower is developed and adjust the dynamometer load to achieve 75 percent of fuel rate. Operate the engine at this speed and load level for 3 minutes.

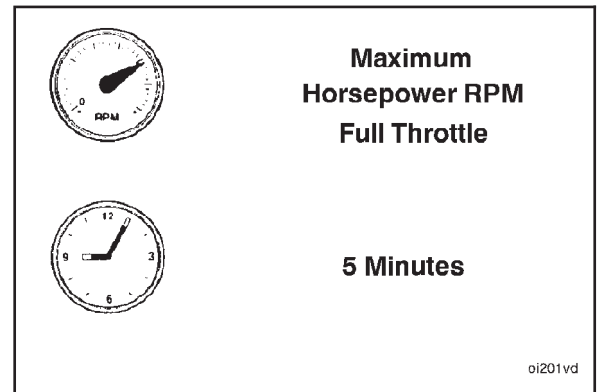
Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



Move the throttle lever to its fully opened position, and increase the dynamometer load until 100 percent fuel flow is developed. Operate the engine at this condition and load level for 5 minutes, or until the blowby becomes stable within specifications.

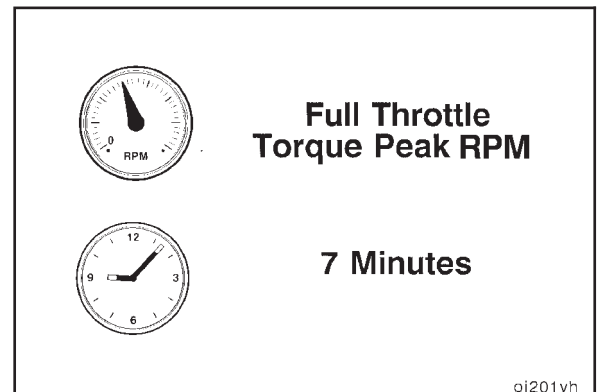
Check all gauges and record the data.



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.

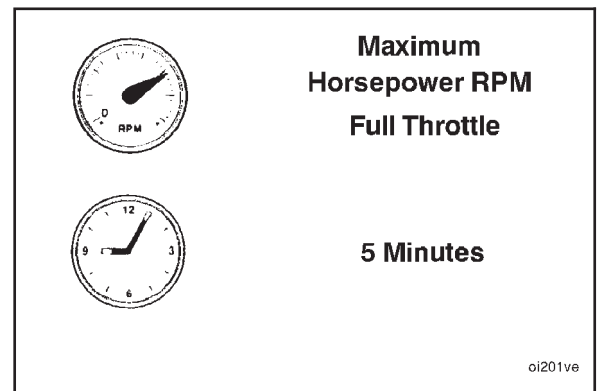


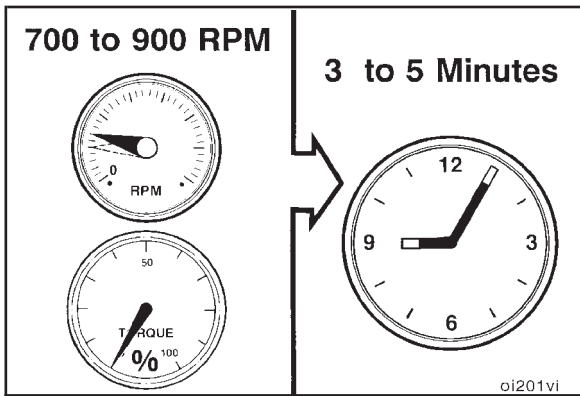
Reduce the dynamometer load until the engine speed increases to the engine's maximum horsepower RPM.

Operate the engine at maximum horsepower RPM for 5 minutes.

Check all gauges and record the data.

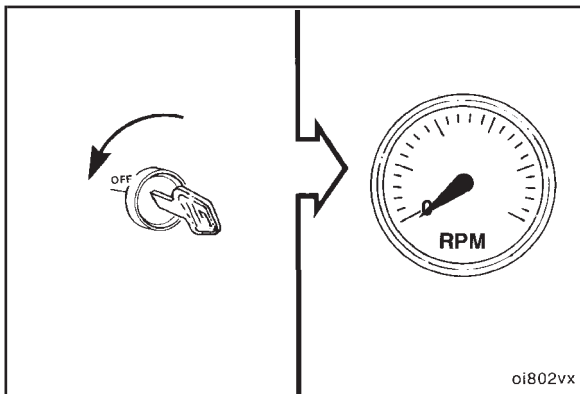
Compare the readings to the specifications listed earlier in this section.



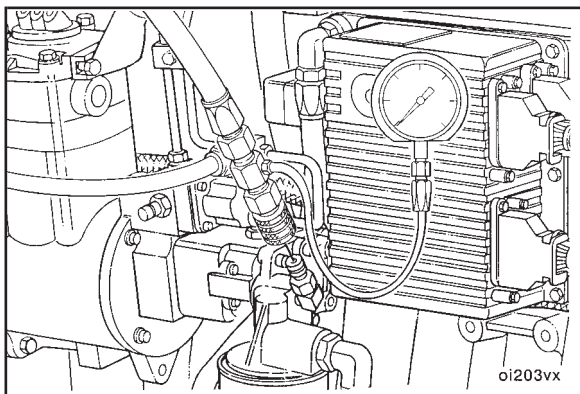


Caution: Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

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 engine dynamometer.

Chassis Dynamometer (14-03)

Operation

The performance of an engine installed in “on-highway” vehicles can be tested on a chassis dynamometer.

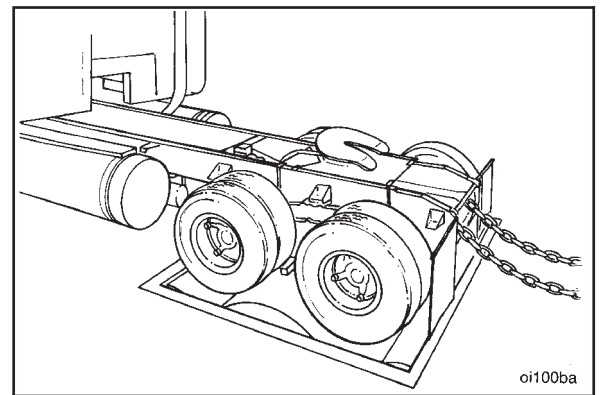
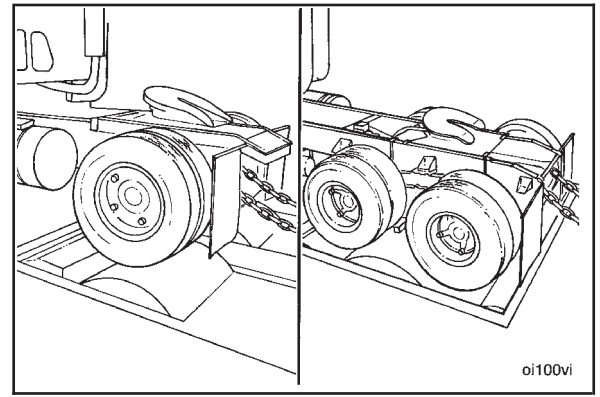
NOTE: Due to driveline inefficiencies and engine-driven accessories, the rated horsepower will be reduced by approximately:

- 20 percent for single axle vehicles
- 25 percent for tandem axle vehicles

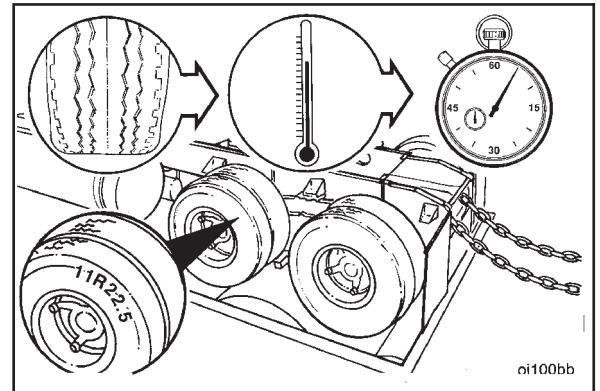
The net horsepower available is called wheel horsepower (WHP).

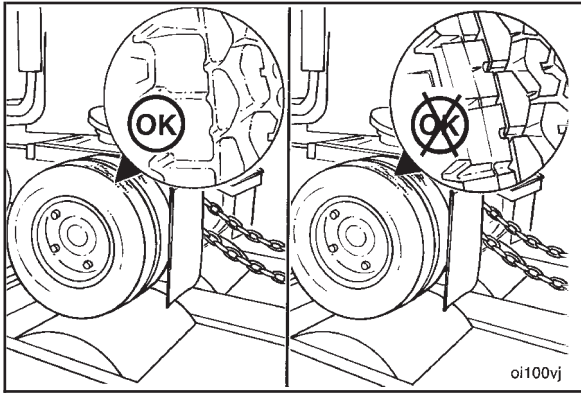
NOTE: These percentages are used for engine run-in only and are **not** to be used as absolute figures.

Caution: Before installing or operating a vehicle on a chassis dynamometer, follow all the vehicle manufacturer’s safety precautions.



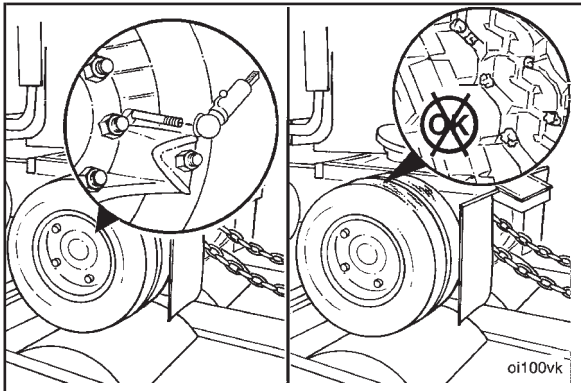
Caution: Low profile radial tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage tires due to overheating. Check the tire manufacturer’s recommendations for the maximum allowable chassis dynamometer operating time.



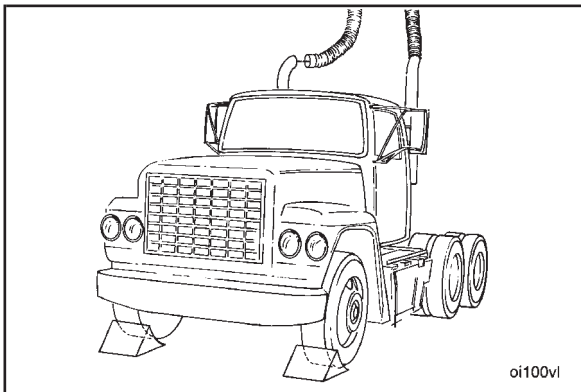


The following are general safety precautions to be observed while operating the chassis dynamometer.

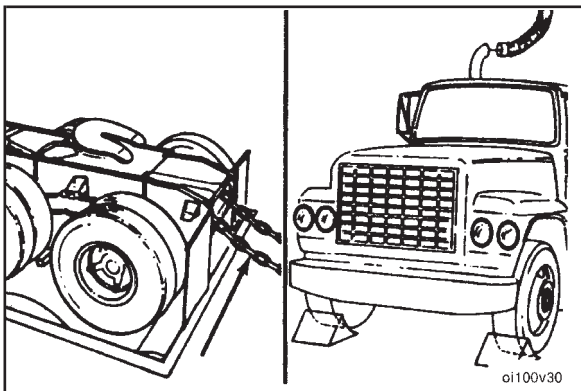
- Use tires that have more than 160 kilometers [100 miles] on them. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- 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.



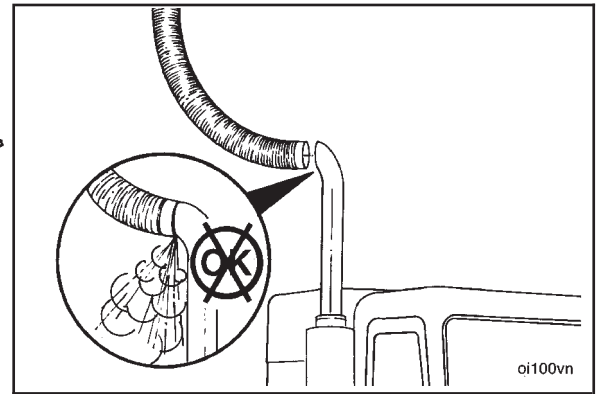
- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.



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.

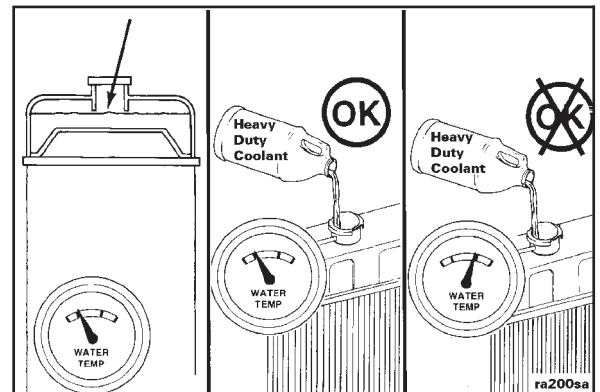


General Test Procedure

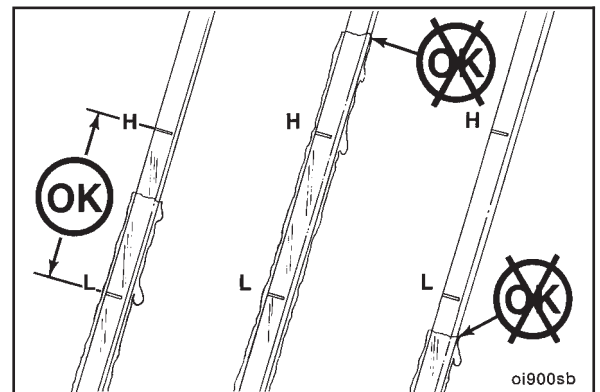
Check the engine coolant level to be sure it is filled to the proper level.

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.

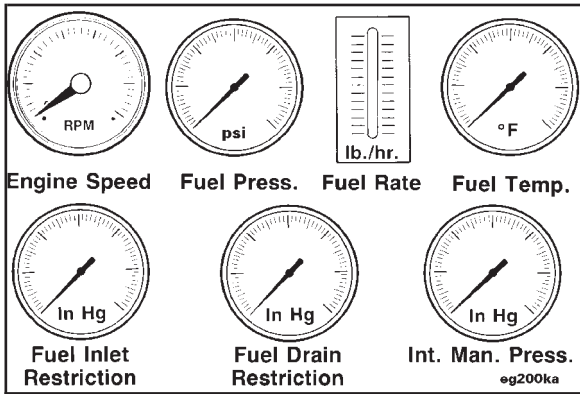
Caution: Do not add cold coolant to a hot engine. This can cause engine casting damage. Allow the engine to cool to below 50°C [120°F] before adding coolant.



Check the engine lubricating oil level to be sure it is filled to the proper level.

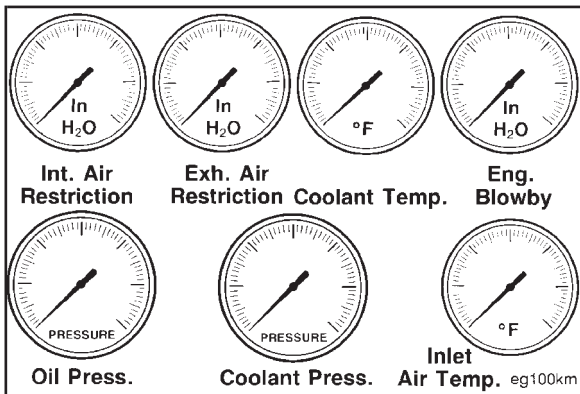


NOTE: Use a known source of “good” quality No. 2 diesel fuel. This is very important since No. 1 diesel fuels, along with most other alternate fuels, are lighter (lower specific gravity, higher API gravity) than No. 2 diesel fuel. The lighter the fuel, the lower the energy content (BTU) per gallon (liter, etc).

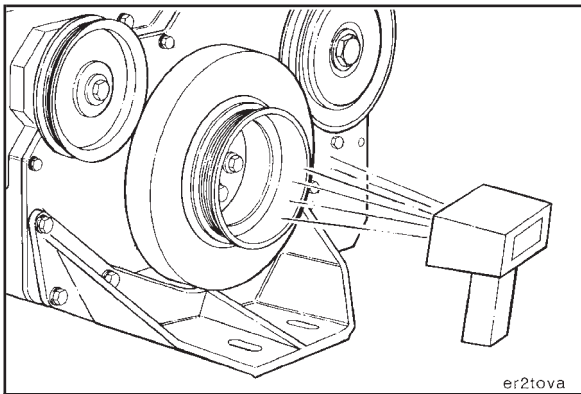


To properly monitor engine performance, record the following parameters. To limit dynamometer operating time, instrument the engine to make as many checks as possible.

- 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



Engine Speed (RPM) With a Verified Tachometer

Use digital optical tachometer, Part No. 3377462, to check and verify engine speed.

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.

Fuel Inlet Temperature		
°C		°F
15.5	MIN	60
48.9	MAX	120

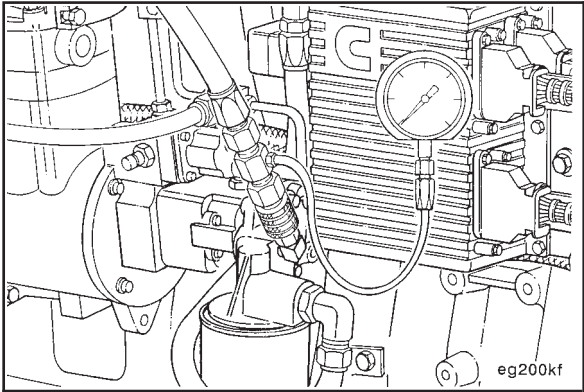
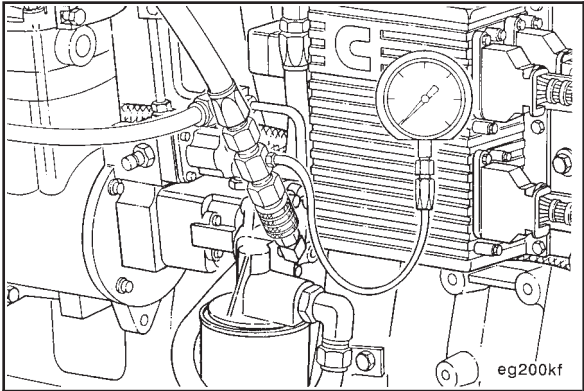
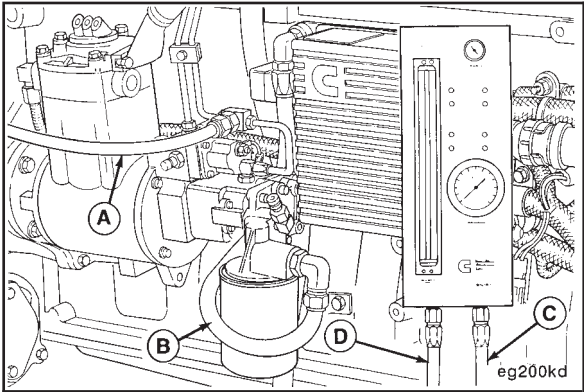
Fuel Inlet Restriction

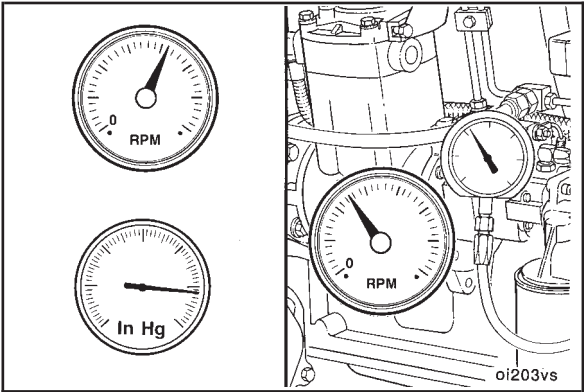
Measure the fuel inlet restriction. Install a vacuum gauge, Part No. ST-434, between the fuel pump inlet and the gear pump inlet.

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 and Advertised Horsepower.

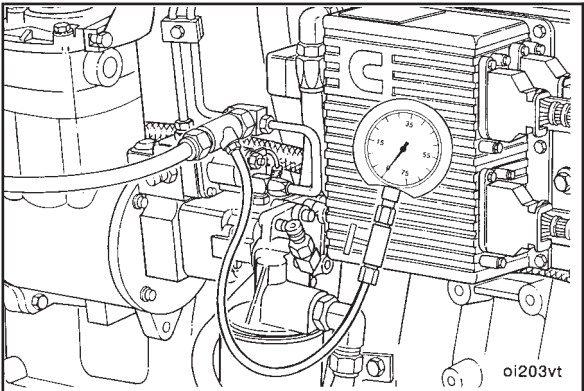


Observe the reading on the gauge.

NOTE: The maximum fuel inlet restriction is as follows:

Fuel Inlet Restriction (plus ECM Cooling Plate)			
	mm Hg		in Hg
Clean Filter	152	MAX	6
Dirty Filter	254	MAX	10

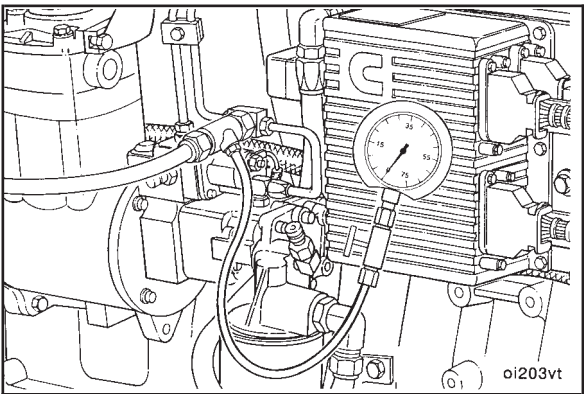
Correct the restriction or replace the fuel filter.



Fuel Drain Line Restriction

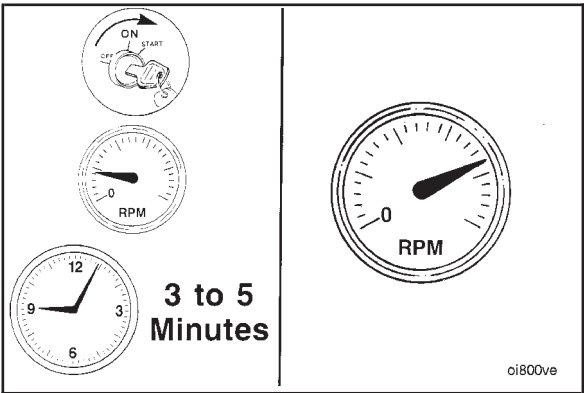
Use Pressure Gauge, Part No. ST-1273, to measure fuel drain line restriction.

NOTE: Do **not** measure fuel drain line restriction with the fuel measuring device installed. This will **not** measure the drain line restriction of the vehicle's return plumbing.



Hold the gauge at the same level as the connection.

NOTE: The gauge will **not** measure the correct pressure if the gauge is **not** held at the same level as the connection.



Operate the engine at maximum horsepower RPM and Advertised Horsepower.

Observe the reading on the gauge.

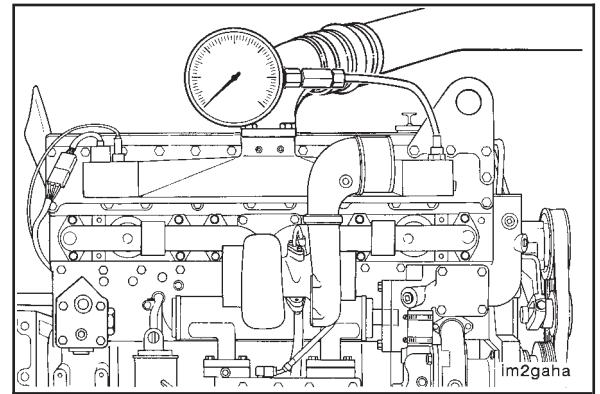
Fuel Drain Line Restriction		
mm Hg		in Hg
89	MAX	3.5

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.

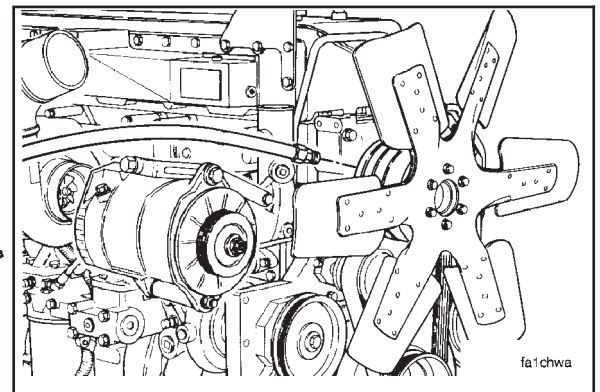
NOTE: Intake manifold pressure (turbocharger boost) **must** be corrected for variances due to intake air temperature. Use the 'Boost Pressure Correction Factor's explained in "Engine Testing - General Information".



Intake Air Temperature Control - Chassis Dynamometer Test

When operating an engine on a chassis dynamometer, follow these steps for best results and safe operation.

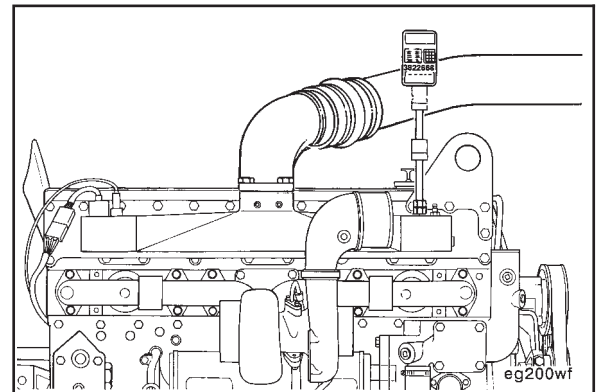
Lock the cooling fan in the "ON" mode. This can be done by installing a jumper across the temperature switch, or by supplying shop air to the control valve. Refer to the fan drive manufacturer for the recommended procedure.



Monitor the intake manifold air temperature using Compulink™ 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 77°C [170°F]. The engine protection system will disrupt performance if the temperatures exceed this level.

Maintain intake manifold air temperature to 66°C [150°F] or below during chassis dynamometer operation.



If the intake manifold temperature exceeds 77°C [170°F], shut off the engine. Allow the engine to cool.

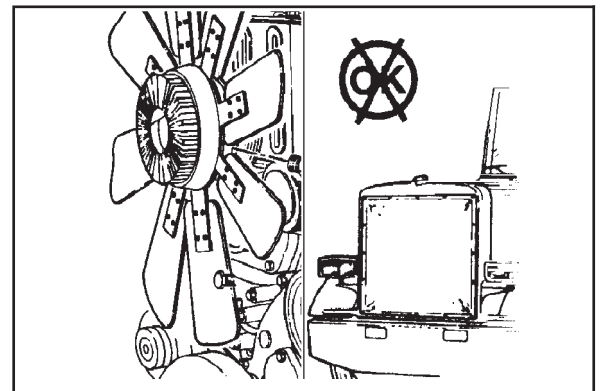
Inspect the CAC fins for obstructions to the air flow.

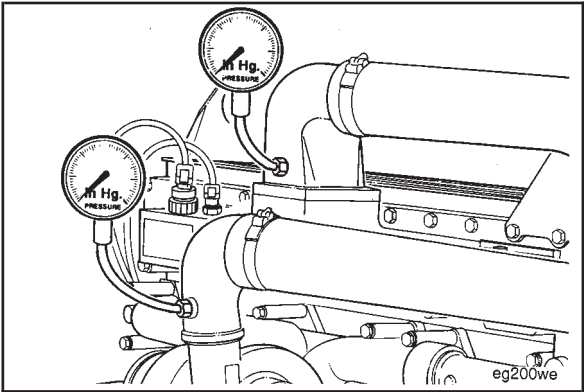
Check the fan drive. Make sure the fan is locked in the "ON" mode.

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.





Charge Air Cooler Restriction

Measure the intake pressure drop across the charge air cooler.

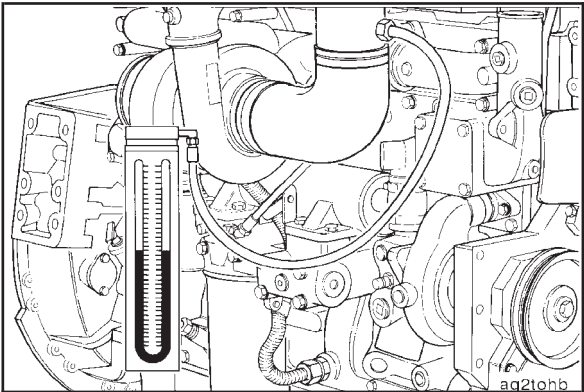
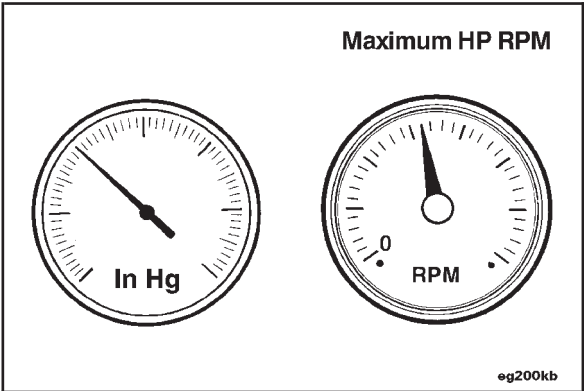
This test can be done with a mercury manometer or two separate gauges, Part No. ST-1273. If two gauges are being used, calibrate both gauges on a common pressure source to ensure consistency.

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 the 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.

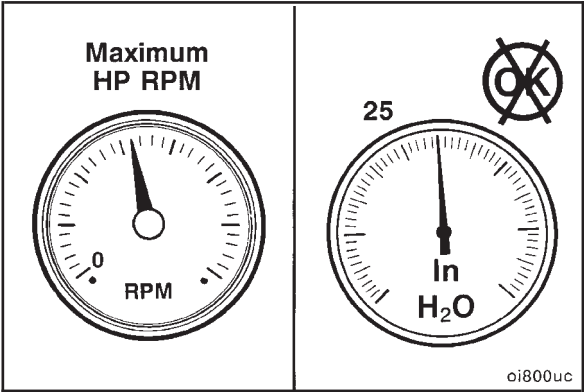
NOTE: The gauge adapter **must** be installed at a 90 degree angle to the air flow in a straight section of pipe at a minimum of one pipe diameter before the turbocharger.



Operate the engine at maximum horsepower RPM and advertised horsepower and RPM.

Observe the reading on the gauge or manometer.

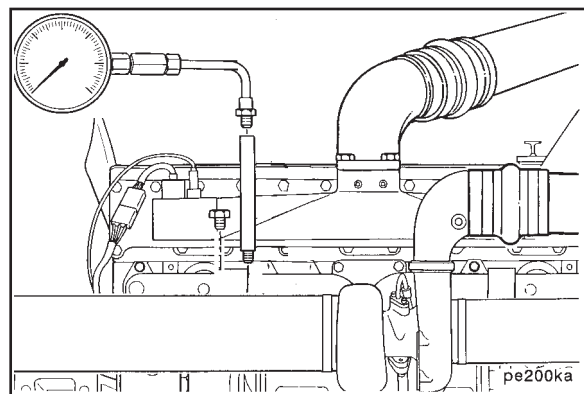
Intake Air Restriction		
mm H ₂ O		in H ₂ O
635	MAX	25



Exhaust Air Restriction

Measure the exhaust air restriction. Install the pressure gauge, Part No. ST-1273, or a manometer in the exhaust air piping.

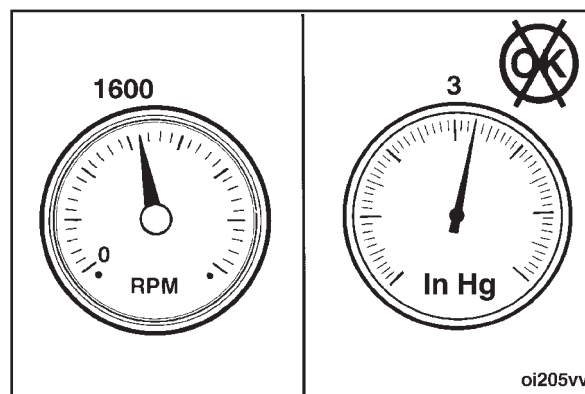
The gauge adapter **must** be installed near the turbo-charger in a straight section of pipe at the turbine outlet.



Operate the engine at advertised horsepower.

Observe the gauge or manometer.

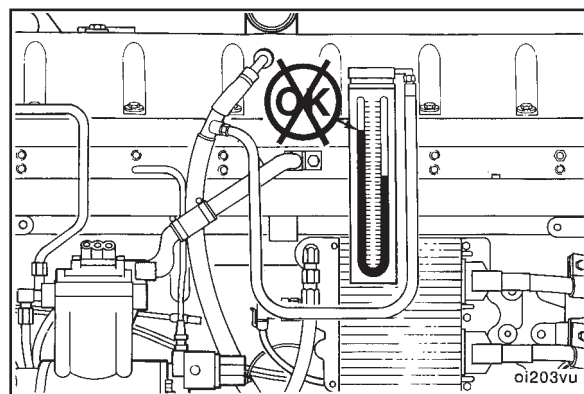
Pressure **must not** exceed 75 mm Hg [3.0 inches Hg].



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.

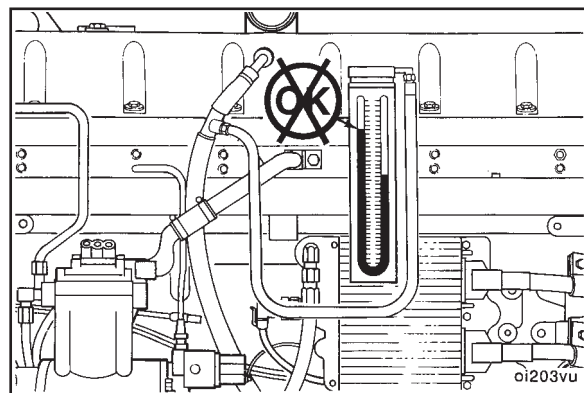
Engine blowby **must not** exceed the following specifications:

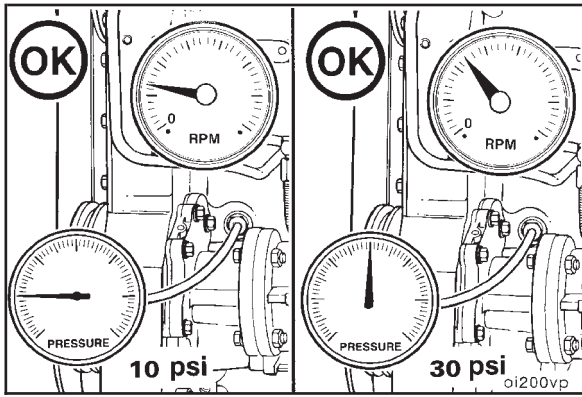
Blowby Specifications

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.

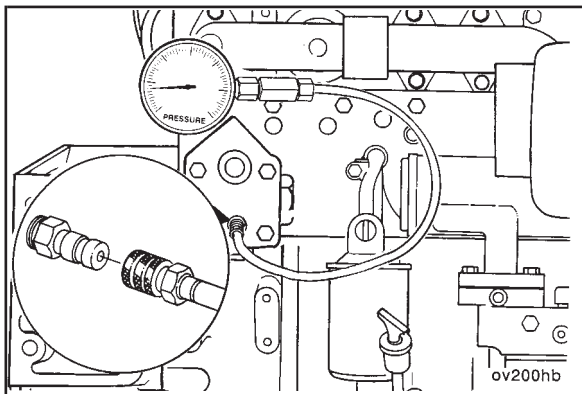


Install the pressure gauge to the main oil rifle and observe the oil pressure.



Low Idle (minimum allowable) 69 kPa [10 psi]

At 1200 RPM (minimum allowable) 207 kPa [30 psi]

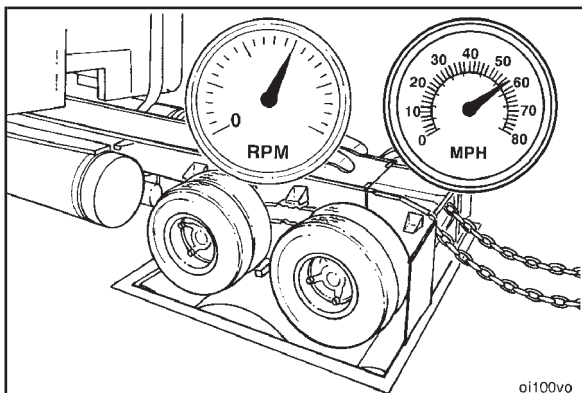


Coolant Pressure



Use a vacuum gauge to measure engine coolant pressure.

Maximum coolant pressure (pressure cap removed) with closed thermostat is 317 kPa [46 psi] at rated RPM.

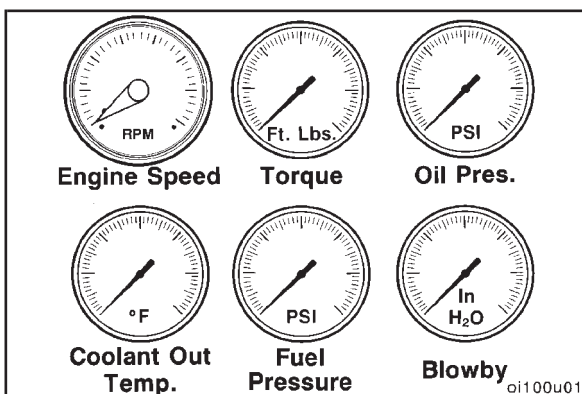


Engine Run-In Procedure - Chassis Dynamometer (14-04)



Refer to Chassis Dynamometer - Operation, Procedure 14-03, for general operating procedures and safety precautions.

Operate the vehicle in a gear that produces a road speed of 90 to 100 km/h [55 to 60 mph] at maximum horsepower RPM.



Install a Compulink™ on CELECT™ engines for monitoring engine performance variables, system pressures, temperatures etc.

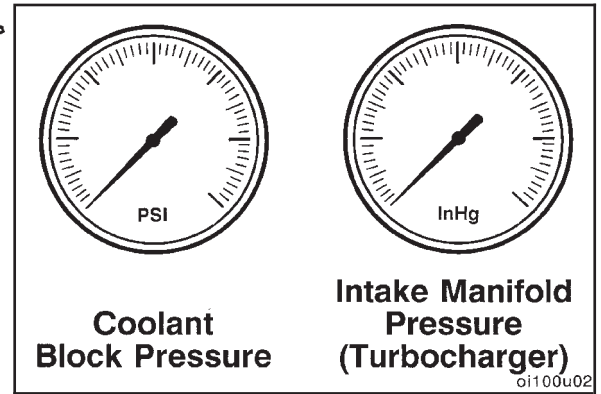
Monitor and record the following measurements during run-in:

- Lubricating oil pressure
- Coolant temperature
- Fuel pressure
- Engine Torque
- Crankcase Blowby
- Engine speed (RPM)
- Fuel rate (Use service tool, Part No. 3376375)
- Intake manifold air temperature
- Intake manifold pressure
- Turbocharger inlet air temperature

Refer to the Engine Dynamometer Worksheet in this section.

Intake manifold pressure (turbo boost) **must** be corrected for variances due to intake air temperature. Use the 'Boost Pressure Correction Factors' explained in "Engine Testing - General Information".

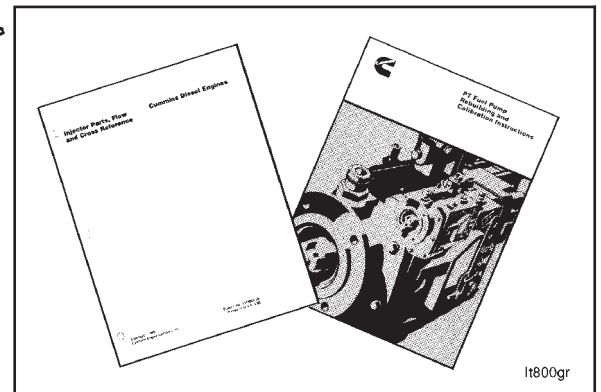
It is recommended to monitor block coolant pressure during run-in to aid in early indication of a cooling system problem.



Obtain CPL number from the engine dataplate and the fuel pump code from the fuel pump data plate.

Engine performance specifications and fuel system calibration values are listed for specific engine CPL and fuel pump codes in the following publications:

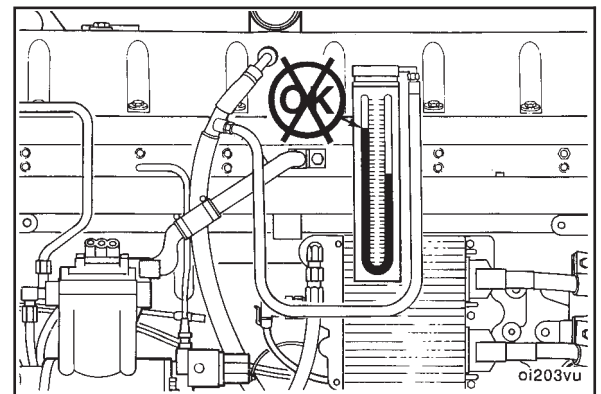
1. Fuel Pump Calibration Values, Bulletin No. 3379352.
2. Injector Parts Flow and Cross Reference, Bulletin No. 3379664.
3. Engine Data Sheets



If a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in, 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, acceptable blowby reading is obtained.

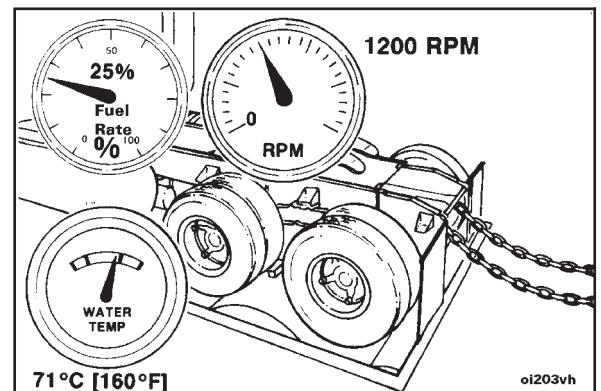
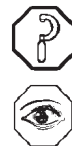
NOTE: Blowby **must** be measured by using Service Tool, Part No. 3375150 or 3822566 with manometer, Part No. ST-1111-3, or equivalent. Service Tool, Part No. 3375150, as shown, utilizes a chamfered 7.67 mm [0.302 in] orifice.

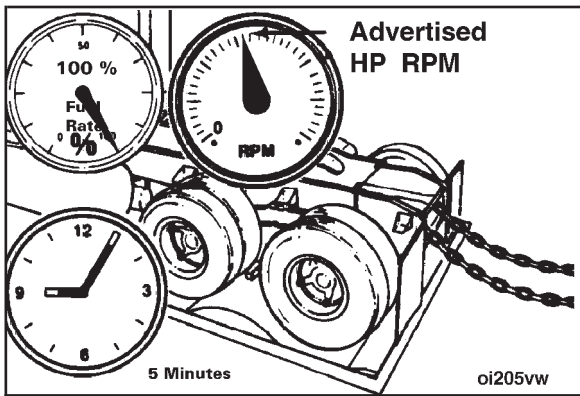


Move the throttle to obtain 1200 RPM engine speed, and apply a test load sufficient to develop 25 percent fuel rate.

Operate the engine at this speed and load level until the coolant temperature reaches 71°C [160°F].

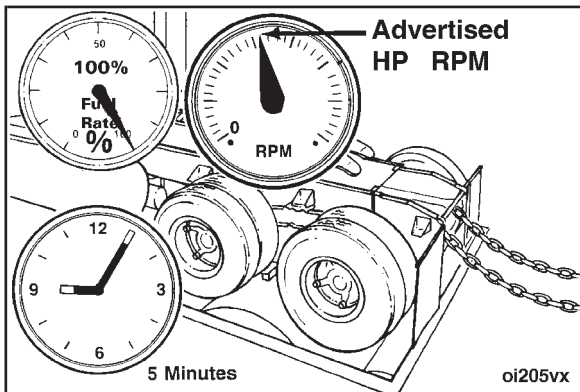
Check all gauges and record the data.



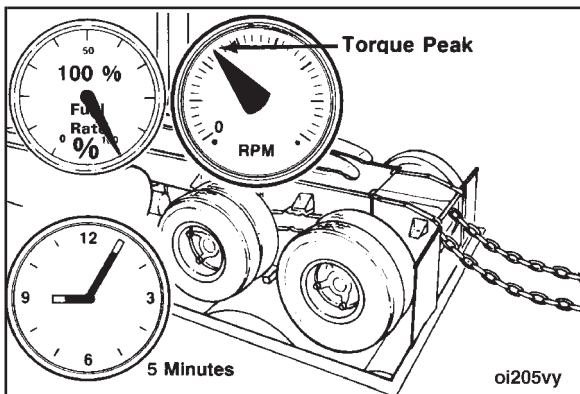


Operate the engine at advertised horsepower RPM and 75 percent fuel rate. Check the gauges, and record the readings.

Do **not** proceed to the next step until a steady, acceptable blowby reading is obtained.

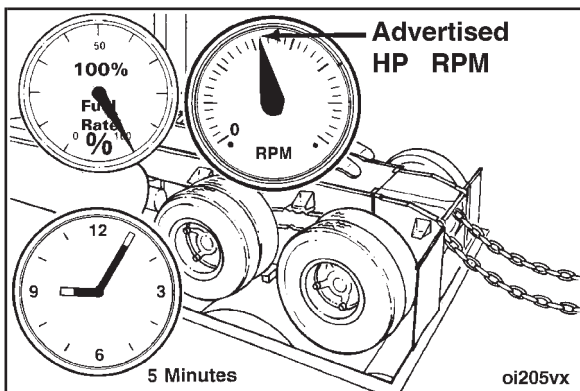


Operate the engine at advertised horsepower RPM with a wide open throttle, for 5 minutes. Check the gauges, and record the readings.



Operate the engine at torque peak RPM, full load, wide open throttle, for 5 minutes. Check the gauges, and record the readings.

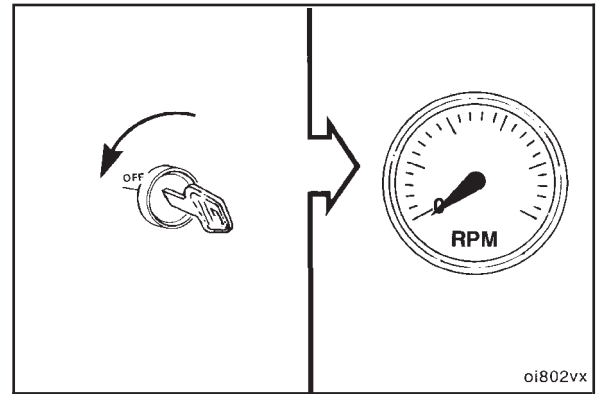
Refer to the engine "Data Sheet" for the torque peak RPM of the engine model being tested.



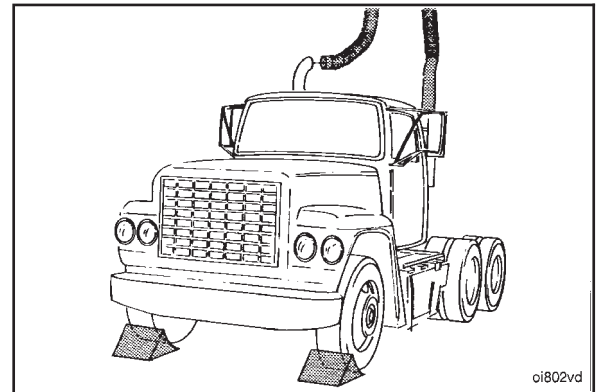
Operate the engine at advertised horsepower RPM with a wide open throttle for 5 minutes. Check the gauges, and record the readings. Compare the readings to those published on the appropriate engine "Data Sheet".

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.



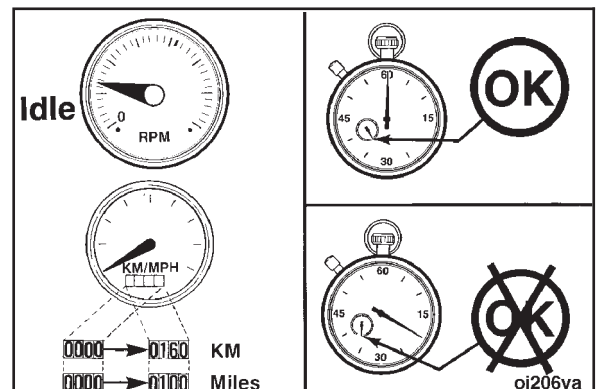
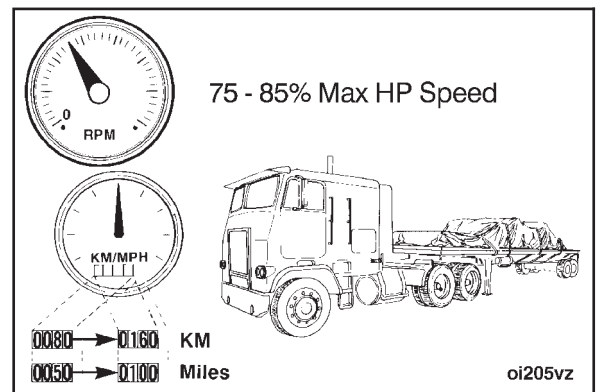
Engine Run-In Procedure - Without Dynamometer (14-05)

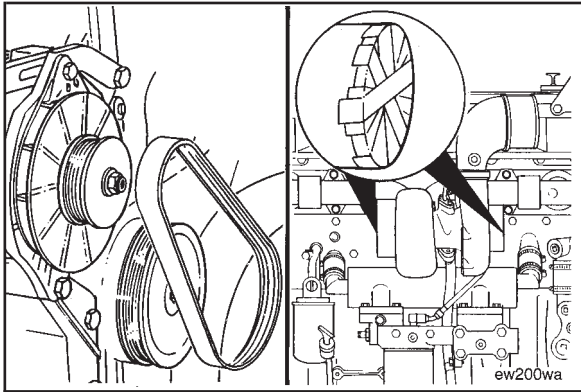
On-Highway

Caution: Refer to “Engine Testing - General Information” and “Engine Testing - Specifications” at the front of this section before operating the engine to avoid internal component damage.

Operate the vehicle pulling heaviest available trailer allowed for the first 80 to 160 km [50 to 100 miles] after rebuild. Operate vehicle in 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.



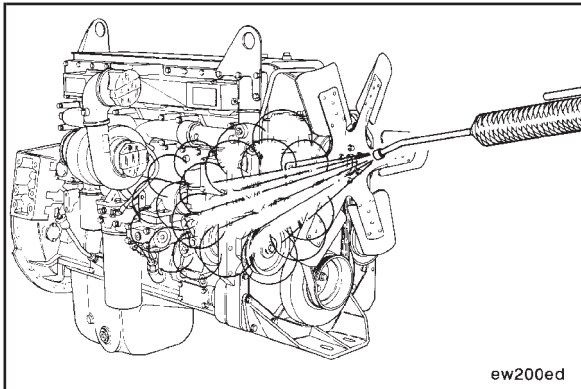


Engine Painting (14-06)

Remove all belts from the engine.

Cover the following:

- Exhaust and intake openings
- Electrical components
- Fuel inlet and drain connections
- Any exposed fittings, threads and electrical wire terminals

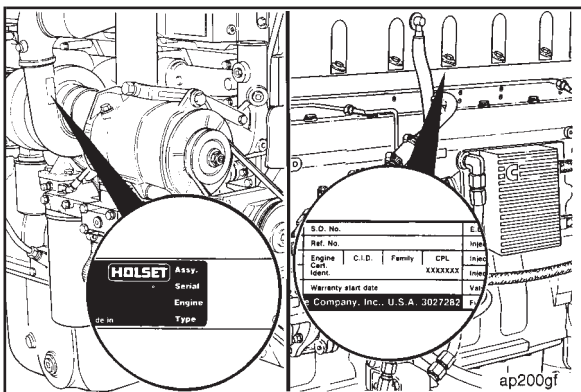


Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.



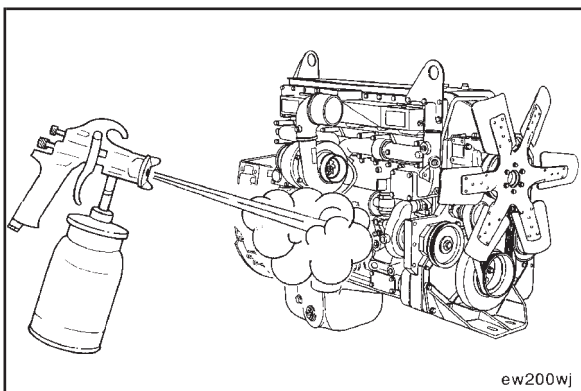
Use steam to clean the engine. Dry with compressed air.

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



Cover the following:

- All dataplates
- Valve and injector set marks
- Exhaust manifold
- Turbocharger turbine housing
- Flywheel
- Flywheel housing transmission mounting surface



Paint the engine.

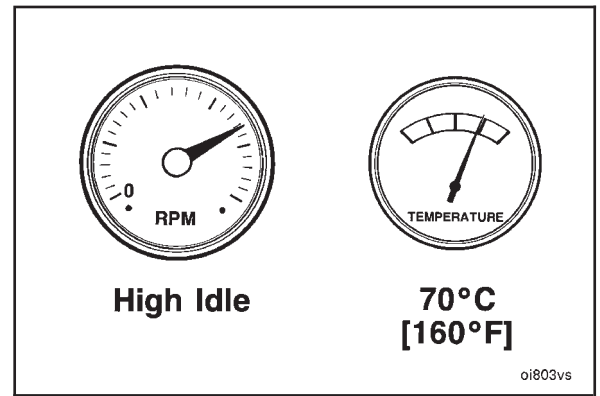
Engine Storage - Short Term (14-07)

This procedure describes the proper method to prepare an engine for short term storage (one to six months).

Operate the engine at “High Idle” speed until the coolant temperature indicator reaches:

Temperature: 70°C [160°F]

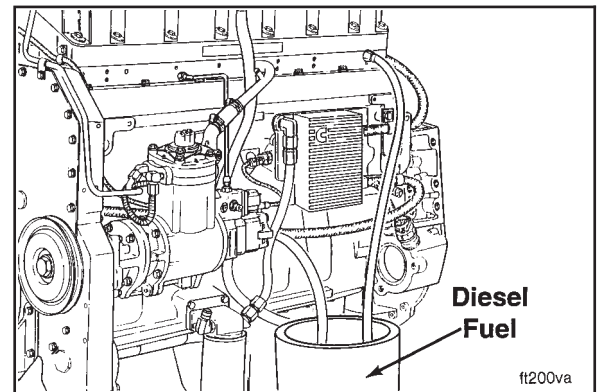
Shut off the engine.



Remove the fuel lines to the engine fuel filter and the injector return line.

Use Daubert Chemical NoxRust No. 518 Preservative Oil, or equivalent. The oil **must** meet Military Specification MIL-L-644 Type P-9.

Fill two containers, one with diesel fuel, the second with preservative oil. Install both fuel lines in the container of diesel fuel.

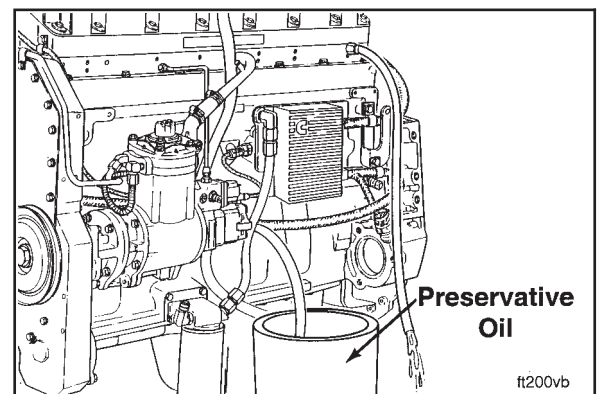


Start the engine.

After the engine is operating smoothly, transfer the fuel supply line to the container of preservative oil. Operate the engine until the preservative oil is coming out of the injector return line.

Shut off the engine.

Install the fuel lines to the fuel filter and the injector return line fitting.

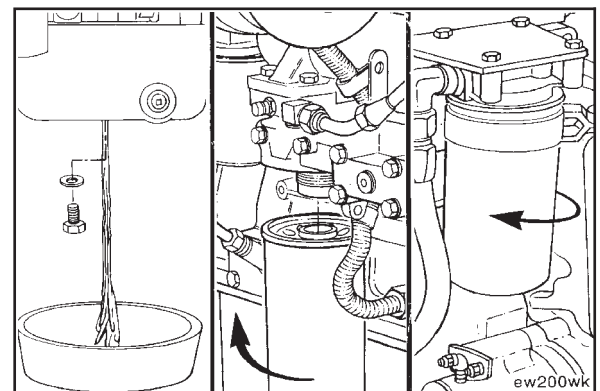


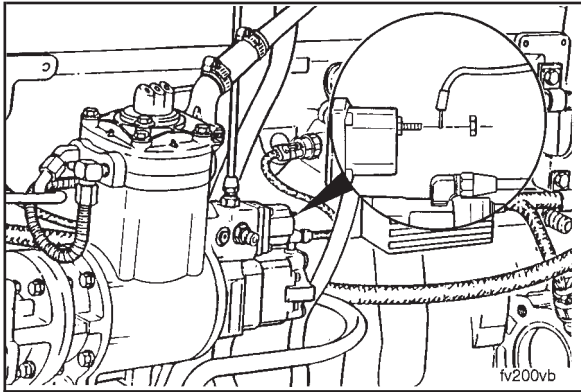
Drain the lubricating oil pan, the oil filters and the fuel filter.

Install the drain plug in the oil pan.

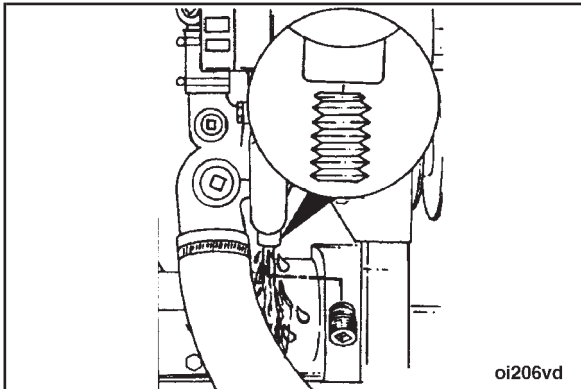
Torque Value: 90 N•m [65 ft-lb]

NOTE: The oil pan **can** remain empty until the engine is ready to use.



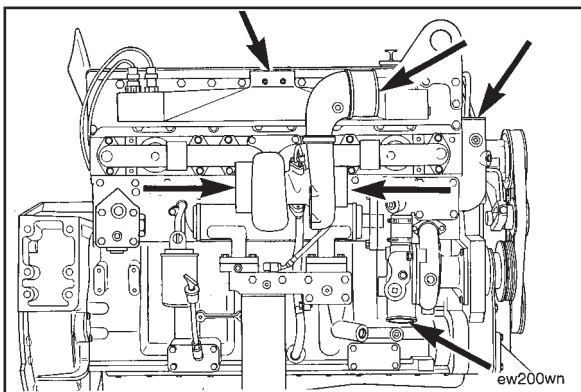


Remove the electrical wiring from the fuel pump solenoid.



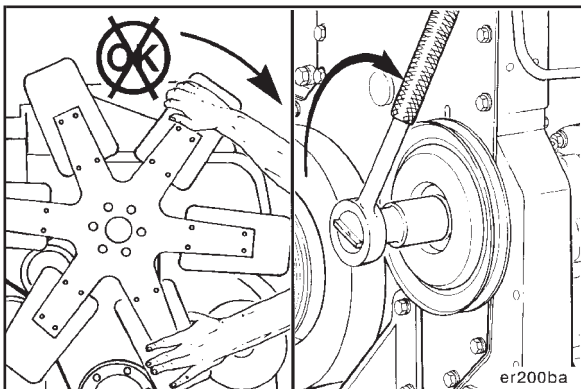
Drain the cooling system.

NOTE: It is **not** necessary to drain the coolant if it is a permanent type antifreeze with a rust inhibitor. Do **not** drain the coolant if the engine is installed in a vehicle.



Cover **all** openings with tape to prevent dirt and moisture from entering the engine.

Install a warning tag on the engine. The tag **must** indicate that the engine does **not** contain oil and **must** not be operated.



Store the engine in an area that is dry and has a constant temperature.

Warning: Do not pull or pry on the fan to manually rotate the engine. 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.

Use the accessory drive shaft to rotate the crankshaft two to three revolutions every **three to four** weeks.

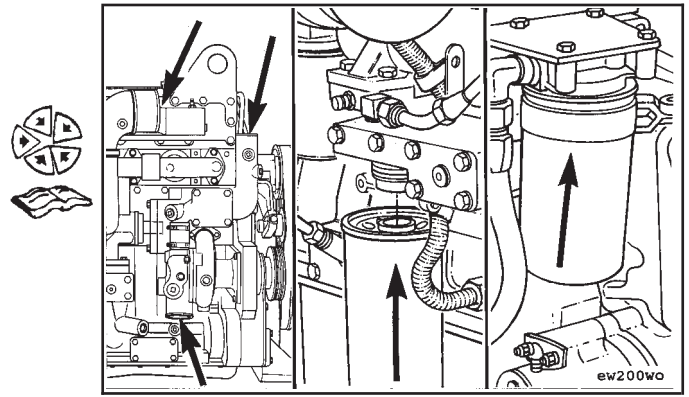
Remove the Engine From Short Term Storage

Remove the tape from the openings. Remove the warning tag.

Replace the oil, water and fuel filters.

Prime the lubricating oil system.

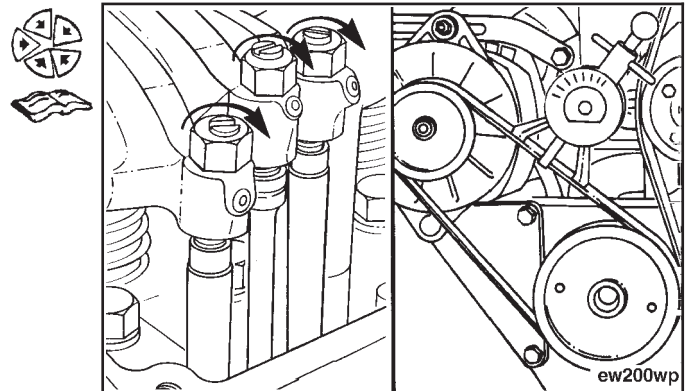
Use clean diesel fuel to flush the preservative oil from the fuel system.



Fill the cooling system (if necessary).

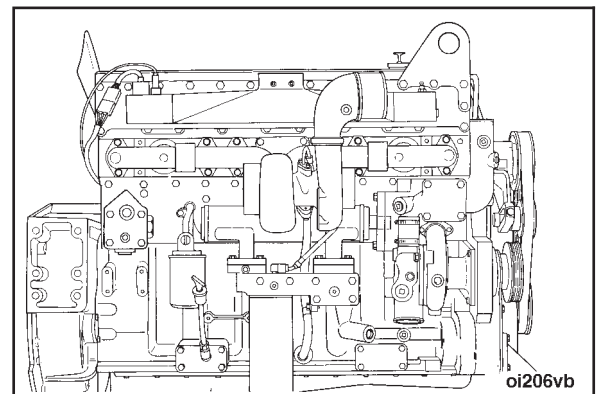
Adjust the injector and valve clearance. Refer to Engine Assembly (00-02).

Adjust the belt tension. Refer to Engine Assembly (00-02).



Engine Storage - Long Term (14-08)

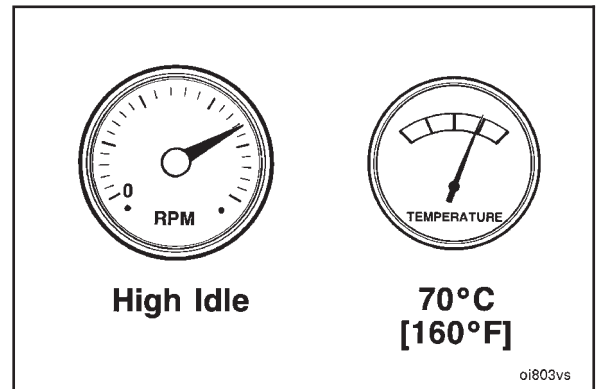
This procedure describes the proper method to prepare an engine for long term storage (six to 24 months).

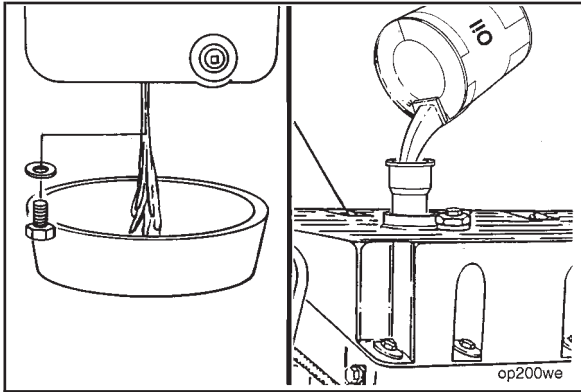


Operate the engine at “High Idle” speed until the coolant temperature indicator reaches:

Temperature: 70°C [160°F]

Shut off the engine.





Drain the lubricating oil pan. Install the drain plug.

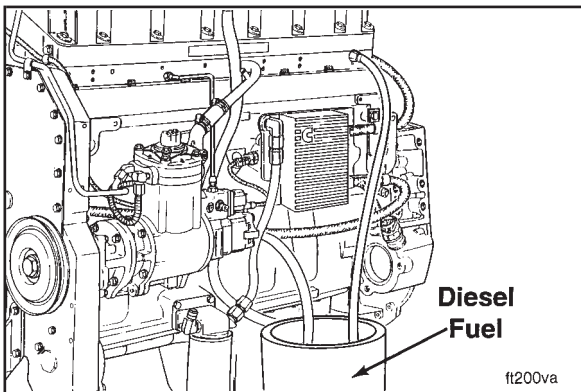
Torque Value: 90 N•m [65 ft-lb]



Fill the oil pan to the “High” level mark with preservative oil.



Use Shell 66202, or an equivalent preservative oil. The oil **must** meet Military Specification MIL-L-21260 Type R10 Grade 2 SAE 30.

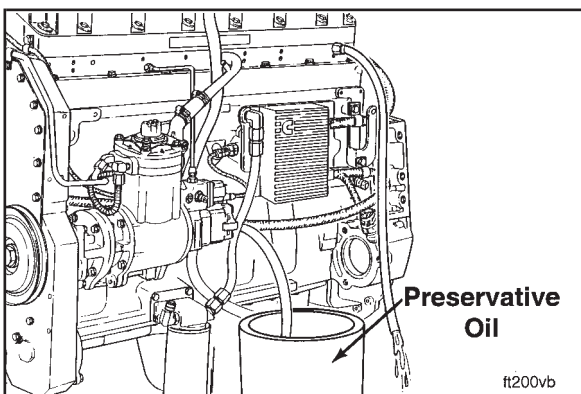


Remove the fuel lines to the engine fuel filter and the injector return line.

Use Daubert Chemical NoxRust No. 518 Preservative Oil, or equivalent. The oil **must** meet Military Specification MIL-L-644 Type P-9.



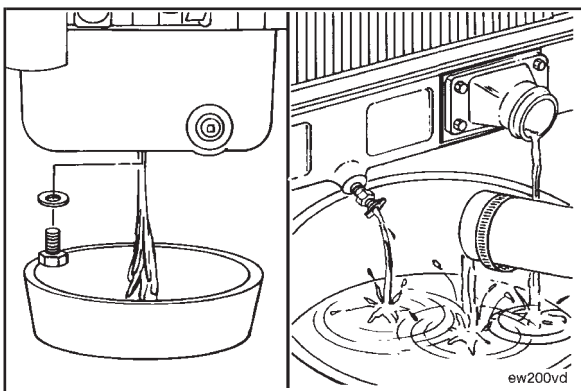
Fill two containers, one with diesel fuel, the second with preservative oil. Install both fuel lines in the container of diesel fuel.



Start the engine.

After the engine is operating smoothly, transfer the fuel supply line to the container of preservative oil. Operate the engine until the preservative oil is coming out of the injector return line.

Install the fuel lines to the fuel filter and the injector return line fitting.



Drain the preservative oil from the lubricating oil pan and the oil filters.



Install the drain plug.

Torque Value: 90 N•m [65 ft-lb]



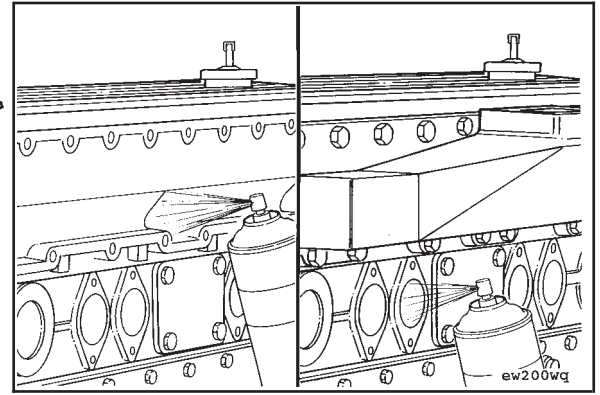
Drain and flush the cooling system.

NOTE: Use a rust inhibitor that will mix with water.

Remove the intake manifold. Remove the exhaust manifold. Refer to Engine Disassembly (0-01).

Spray Shell 66202, or an equivalent preservative oil, into the intake and exhaust ports in the cylinder head and into the aftercooler housing and exhaust manifold.

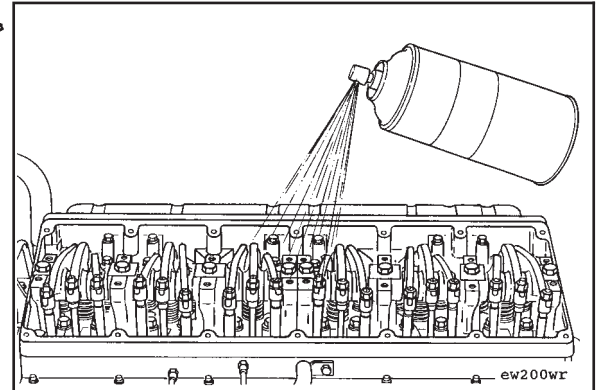
Install the intake manifold. Install the exhaust manifold. Refer to Engine Assembly (00-02).



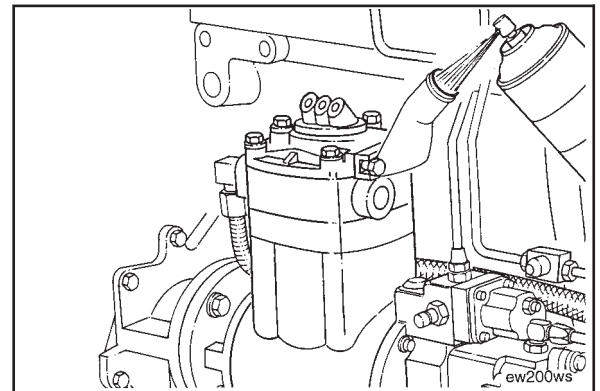
Remove the rocker housing cover. Refer to Engine Disassembly (0-01).

Spray the rocker levers, crossheads, valve springs, valve stems, valve guides, and the push rods with preservative oil.

Install the rocker housing cover. Refer to Engine Assembly (0-02).

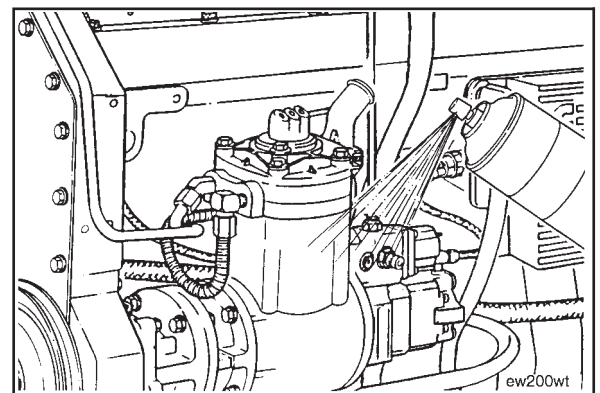


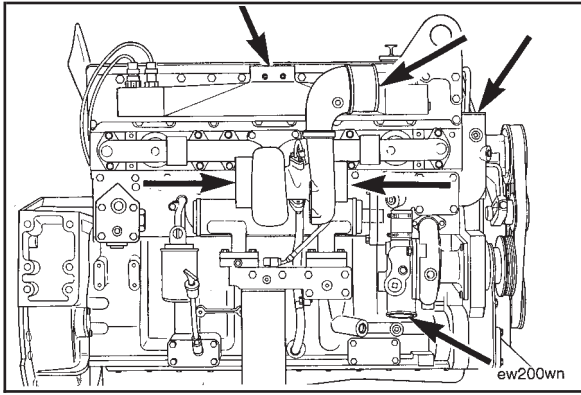
Spray preservative oil into the intake port on the air compressor.



Brush or spray preservative compound on all of the exposed surfaces that are not painted.

NOTE: Use a rust preservative compound that meets Military Specification MIL-C-16137C Type P-2 Grade 1 or 2.



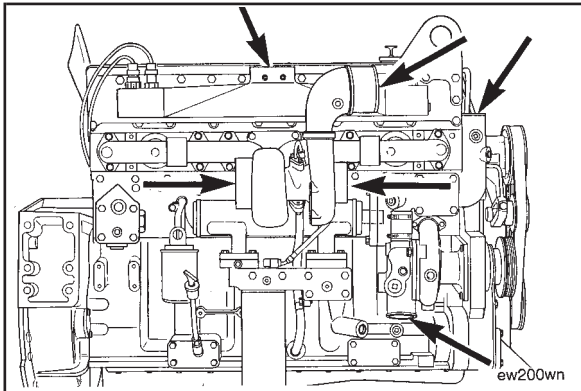


Cover **all** of the openings with heavy paper and tape to prevent dirt and moisture from entering the engine.

Install a warning tag on the engine. The tag **must** indicate:

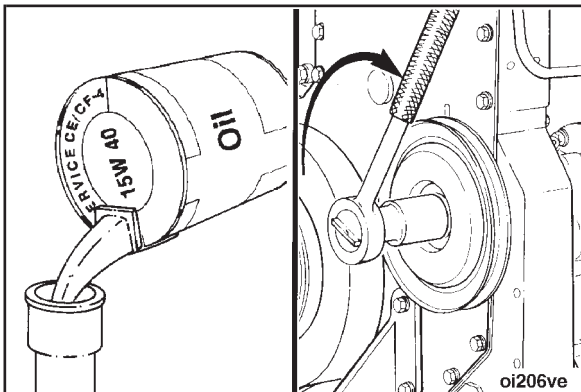
- The date the engine was treated with preservatives.
- The coolant and oil have been drained.
- Do **not** operate the engine.

Store the engine in an area that is dry and has a constant temperature.



Remove the Engine From Long Term Storage

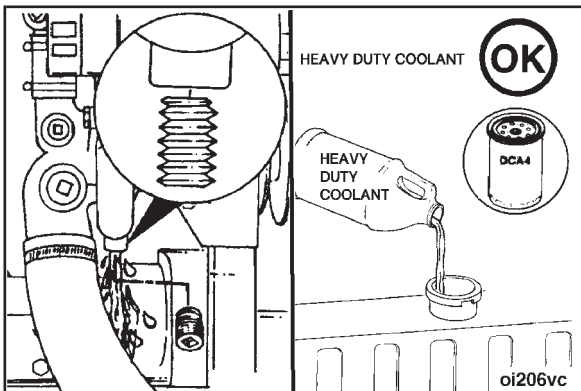
Remove the heavy paper and tape from the openings.
Remove the warning tag.



Remove a plug from the main oil rifle drilling. Use a clean 15W-40 engine oil to flush the preservative oil from the engine.

Use the accessory drive shaft to rotate the crankshaft three to four revolutions during the flushing procedure.

After flushing the preservative oil from the engine, install a new oil filter.



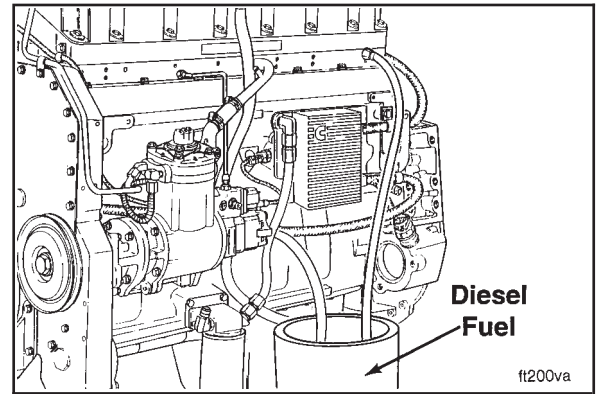
Drain and flush the cooling system.

Fill the cooling system with heavy duty coolant.

Install a new coolant filter.

Use clean diesel fuel to flush the preservative oil from the fuel system.

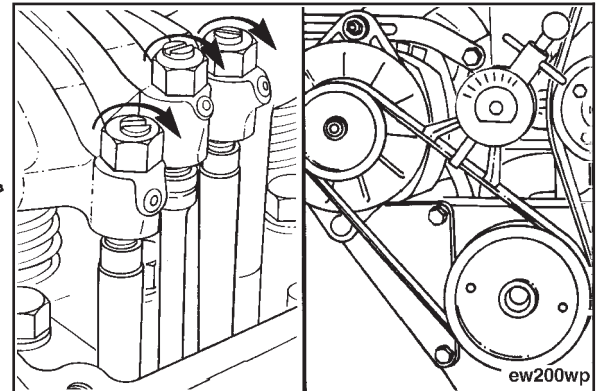
After operating the engine to flush out the preservative oil, install a new fuel filter(s).



Adjust the injector and valve clearance. Refer to Engine Assembly (0-02).

Adjust the belt tension. Refer to Engine Assembly (0-02).

Tighten the intake manifold cover capscrews. Tighten the exhaust manifold capscrews. Refer to Engine Assembly (0-02).



NOTES

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Instruments and Controls - General Information

The instruments and control group consists of the gauges, speed switch, safety controls, cold weather operating aids, etc. used on Cummins engines.

Gauges that indicate the coolant temperature, oil pressure, and oil temperature will provide the operator information on the condition of the engine. Overheating and low or high oil pressure indicate a malfunction that requires mechanical correction.

Cold weather operating aids provide cold weather protection and better starting conditions for the engine.

The instruments and controls used on the M11 engine are not manufactured by Cummins Engine Company, Inc. The following list contains the suppliers of the instrumentation used on Cummins engines.

Air Heaters

Fleetguard, Inc.
Route 8
Cookeville, TN 38501
Telephone: (615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone: (509) 534-6171

Coolant Heaters

Fleetguard, Inc.
Route 8
Cookeville, TN 38501
Telephone: (615) 526-9551

Service Products Company, Inc.
635 S. Mapleton Street
Columbus, IN 47201
Telephone: (812) 377-8178

Fuel Warmers

Fleetguard, Inc.
Route 8
Cookeville, TN 38501
Telephone: (615) 526-9551

Service Products Company, Inc.
635 S. Mapleton Street
Columbus, IN 47201
Telephone: (812) 377-8178

Gauges

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 0732-359888

Icknield Instruments Ltd.
Jubilee Road
Letchworth
Herts
England
Telephone: 04626-5551

Gauges (Cont'd)

Superb Tool and
Gauge Co.
21 Princip Street
Birmingham
B4 61E
England
Telephone: 021-359-4876

Smiths Industries
50 Oxgate Lane
Cricklewood
London
NW2 7JB
England
Telephone: 01-452-3333

Kabi Elec. and Plastics
Cranborne Road
Potters Bar
Herts
EN6 3JP
England
Telephone: 0707-53444

Datcon Instrument Co.
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauge of Texas
11637 Denton Drive
Dallas, TX 75229
Telephone: (214) 241-2161

Oil Heaters

Fleetguard, Inc.
Route 8
Cookeville, TN 38501
Telephone: (615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone: (509) 534-6171

Service Products Company, Inc.
635 S. Mapleton Street
Columbus, IN 47201
Telephone: (812) 377-8178

Safety Controls

Teddington Ind. Equip.
Windmill Road
Sunburn on Thames
Middlesex
TW16 7HF
England
Telephone: 09327-85500

The Nason Company
10388 Enterprise Drive
Davisburg, MI 48019
Telephone: (313) 625-5381

NOTES

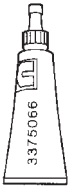
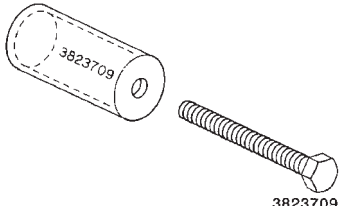
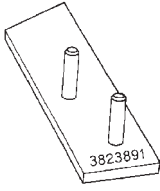
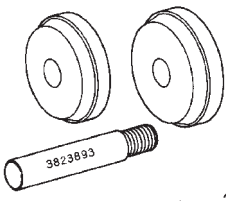
Section 16 - Mounting Adaptations - Group 16

Section Contents

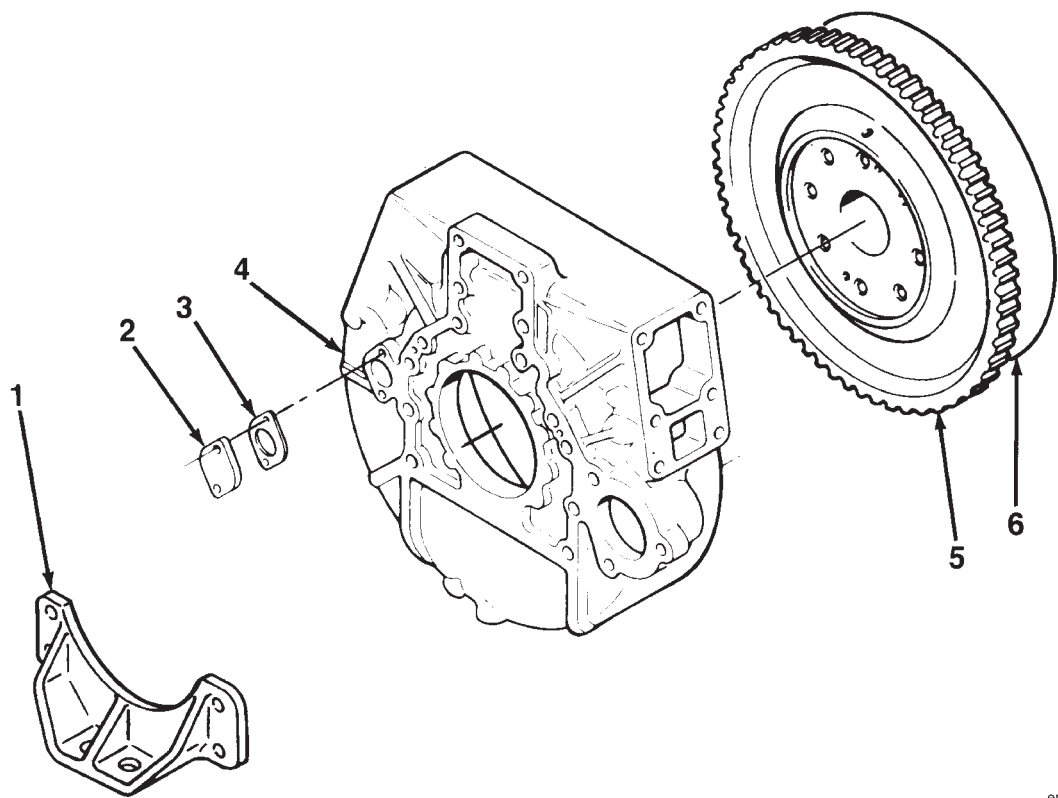
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Service Tools - Mounting Adaptations

The following special tools are recommended to perform procedures in Group 16. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3375066	Pipe Sealant Use on capscrew threads and pipe plugs.	 3375066
3823709	Idler Shaft Puller and Capscrew Remove idler shaft from idler gear and flywheel housing.	 3823709
3823891	Gear Locking Tool Used to prevent rotation of the PTO output shaft while tightening the output flange capscrew.	 3823891
3823893	Bearing Race Driver Used to install the output shaft bearing races.	 3823893

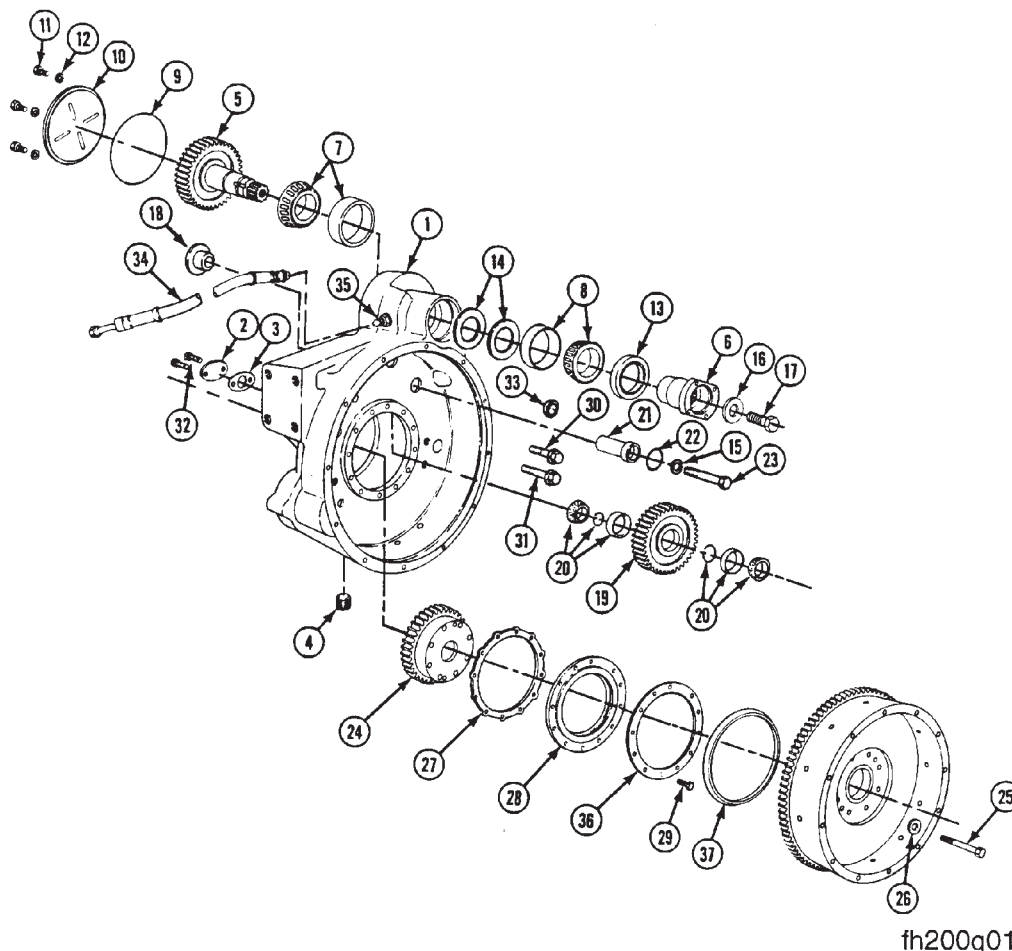
Mounting Adaptations - Exploded View



em200gd

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Support, Front Engine	1	4	Housing, Flywheel	1
2	Cover, Access Hole	1	5	Gear, Ring	1
3	Gasket, Cover Plate	1	6	Flywheel	1

Rear Engine Power Takeoff - Exploded View



fh200g01

Ref. No.	Description	Qty.	Ref. No.	Description	Qty.	Ref. No.	Description	Qty.
1	Housing, Flywheel	1	13	Seal, Oil (Output Shaft)	1	25	Screw, Hexagon Head Cap	8
2	Cover, Access Hole	1	14	Shims (See note below)		26	Washer, Plain	8
3	Gasket, Cover Plate	1	15	Washer, Plain	1	27	Gasket, Carrier	1
4	Plug, Threaded Drain	1	16	Washer, Plain (PTO Flange)	1	28	Kit, Seal	1
5	Shaft, Accessory Drive Output	1	17	Screw, Hexagon Head Cap	1	29	Screw, Captive Washer Cap	12
6	Flange, Power Takeoff	1	18	Retainer, Shaft	1	30	Screw, Hexagon Head Cap	5
7	Bearing, Roller (Large)	1	19	Gear, Idler	1	31	Screw, Hexagon Head Cap	7
8	Bearing, Roller (Medium)	1	20	Assembly, Bearing and Race	1	32	Screw, Hexagon Head Cap	2
9	Seal, Rectangular Ring (Tetra)	1	21	Shaft, Idler	1	33	Plug, Expansion	1
10	Plate, Cover (Ribbed)	1	22	Seal, O-ring	2	34	Hose, Flexible Oil Supply	1
11	Capscrew	4	23	Screw, Hexagon Head Cap	1	35	Connection, Male Oil Supply	1
12	Washer, Plain	4	24	Gear, Crankshaft	1	36	Ring, Clamping	1
						37	Seal, Dust	1

NOTE: There are 7 shims available. A given REPTO could have any combination of these shims.

Ref. No.	Description	mm	in
14	Shim	0.127	0.005
14	Shim	0.254	0.010
14	Shim	0.381	0.015
14	Shim	0.051	0.002
14	Shim	0.076	0.003
14	Shim	0.508	0.020
14	Shim	1.016	0.040

Mounting Adaptations - General Information

The mounting adaptations group consists of the flywheel housing, flywheel, flywheel ring gear, pilot bearing, and the front engine support.

The flywheel is available **only** as an assembly with the ring gear installed; however, the ring gear is available for service replacement.

Flywheel - Cleaning and Inspection for Reuse (16-01)

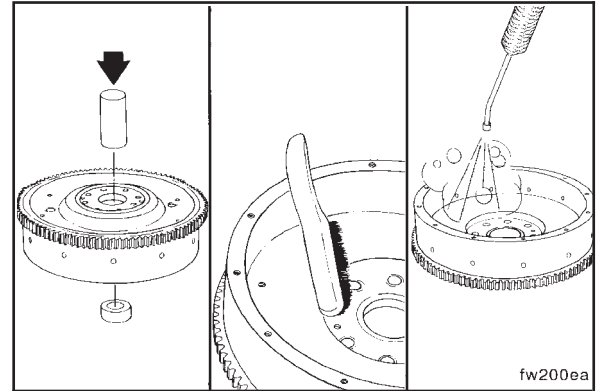
Disassembly

Use a mandrel and hammer to remove the pilot bearing.

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

Use a wire brush to clean the crankshaft pilot bore.

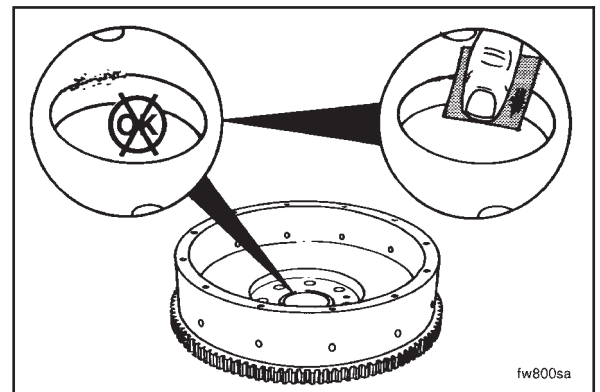
Use solvent or steam to clean the flywheel assembly. Dry with compressed air.



Inspection

Visually inspect the pilot bore for nicks or burrs.

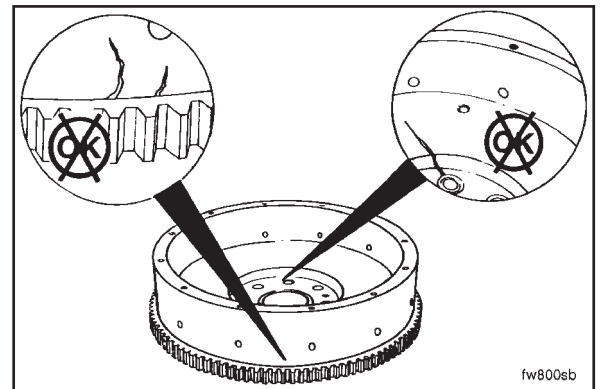
Use 240 grit emery cloth to remove small nicks and burrs.

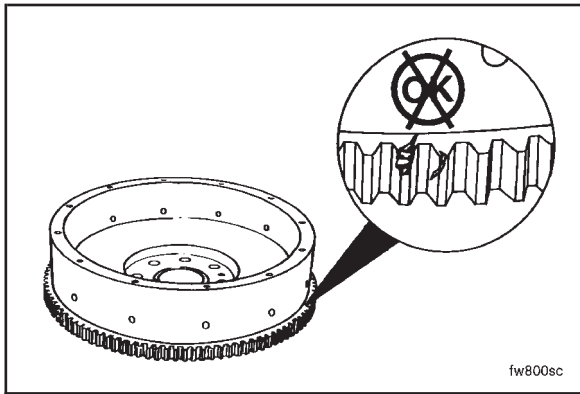


Warning: Do not use a cracked flywheel. A cracked flywheel can break and cause serious personal injury or property damage.

Visually inspect the flywheel and the clutch mounting surface for cracks.

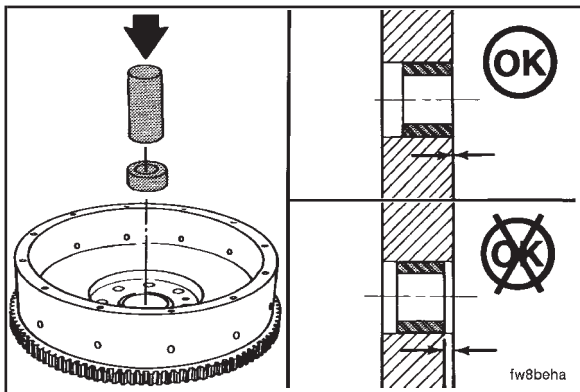
Visually inspect the clutch mounting holes for damaged threads.





Visually inspect the flywheel ring gear for chipped, cracked or broken teeth.

If the ring gear teeth are damaged, the ring gear **must** be replaced. Refer to Flywheel Ring Gear - Replacement (16-02).

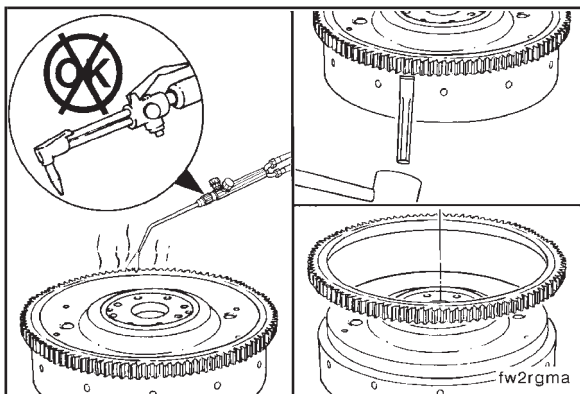


Assembly

Use a new pilot bearing when installing a new or rebuilt clutch. The pilot bearing **must** be installed flush with the pilot bore surface.



Use a mandrel and hammer to install the pilot bearing.



Flywheel Ring Gear - Replacement (16-02)

Disassembly

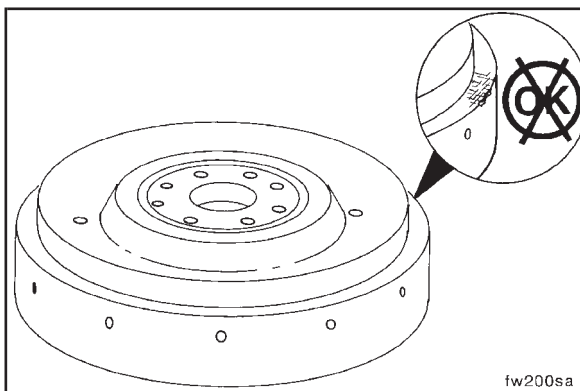


Caution: Do not use a cutting torch to heat the ring gear, the flywheel can be damaged.



Use a heating torch to heat the outside diameter of the ring gear.

Use a blunt chisel and hammer to remove the ring gear from the flywheel.



Inspection

Visually inspect the flywheel outside diameter for damage at the ring gear location.



Use 240 grit emery cloth to remove small nicks and burrs.

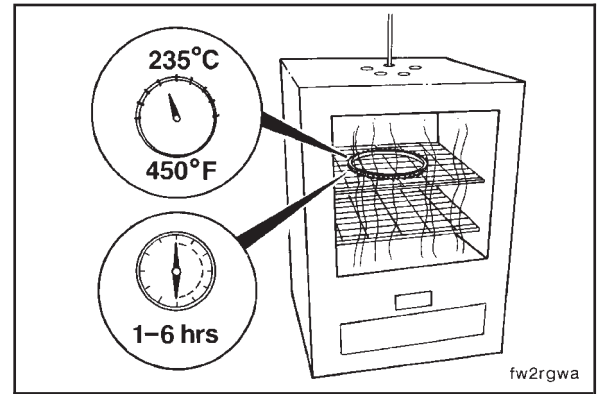
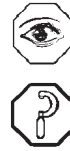
Assembly

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]

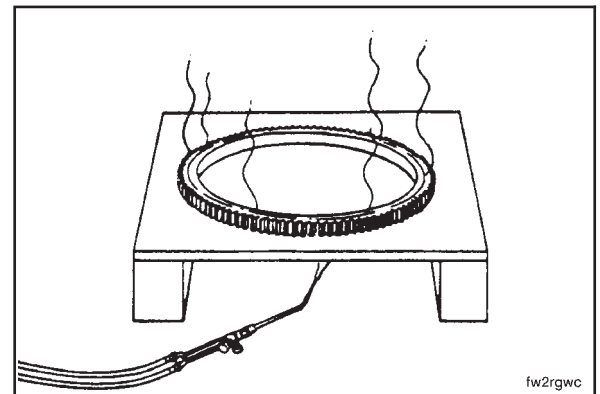
NOTE: Do **not** exceed the specified time or temperature.



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.

Temperature: 235°C [450°F]

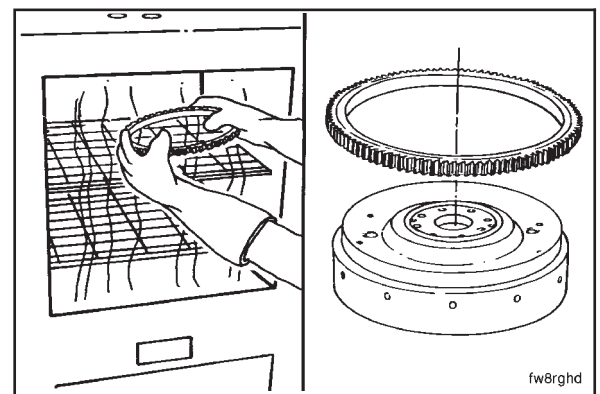
NOTE: A more even temperature is obtained by placing the ring gear on a metal plate, then heating the bottom side of the plate with the torch. Do **not** exceed the specified temperature.



Caution: Wear protective gloves when handling parts that have been heated to prevent 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.

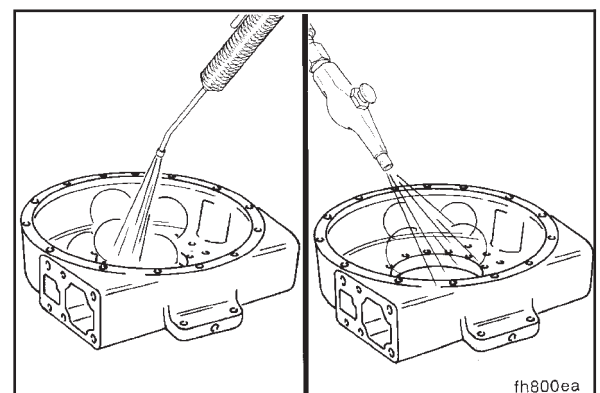


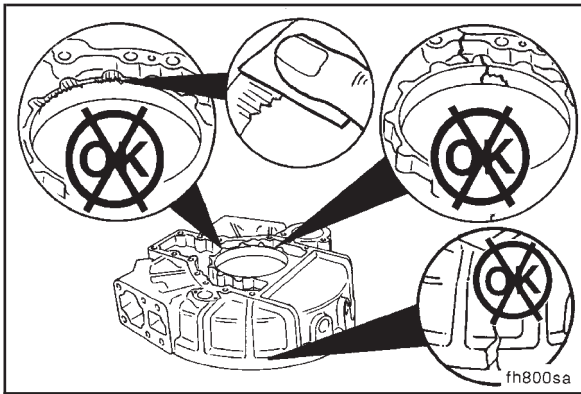
Flywheel Housing - Cleaning and Inspection for Reuse (16-03)

Cleaning

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 to clean the flywheel housing. Dry with compressed air.





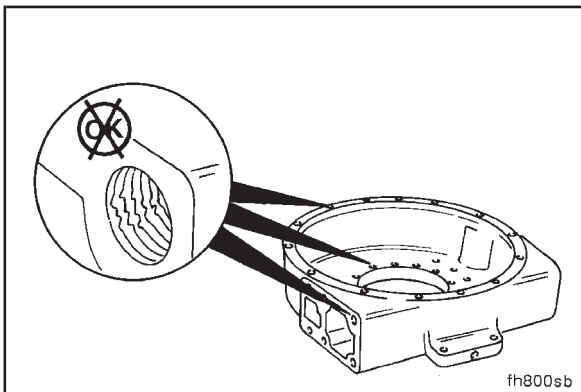
Inspection



Visually inspect all surfaces of the flywheel housing for nicks, burrs or cracks.

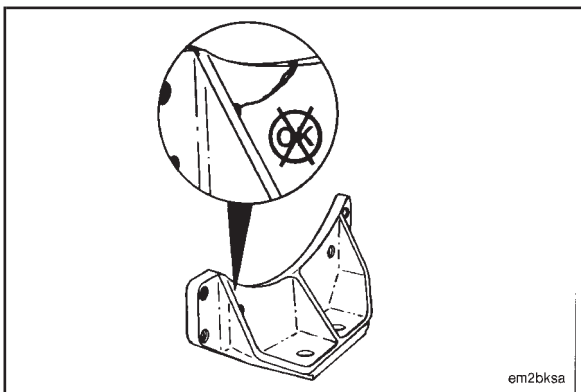


Use 240 grit emery cloth to remove small nicks and burrs.



Visually inspect all threaded capscrew holes for damage.

If cracks are found, the flywheel housing **must** be replaced. Damaged or distorted capscrew threads **can** be repaired with thread inserts.



Front Engine Support - Cleaning and Inspection (16-04)



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

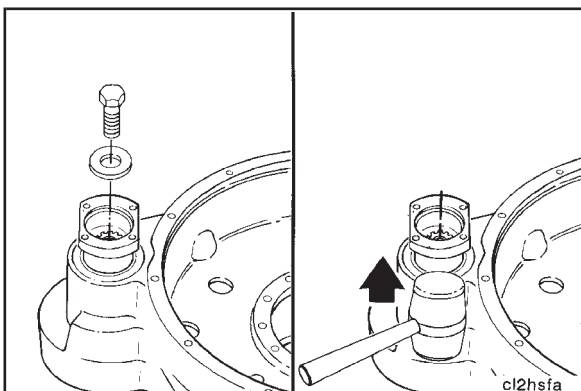


Use solvent or steam to clean the front engine support. Dry with compressed air.



Visually inspect the support for cracks or damage.

If cracks or damage is found, the front engine support **must** be replaced.



Rear Engine Power Takeoff (REPTO) - Rebuilding (16-05)

Disassembly

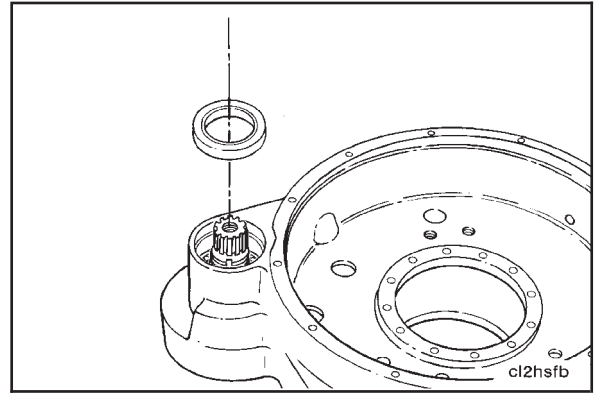


NOTE: Use gear locking tool, Part No. 3823891, to prevent the output shaft from turning when removing the retainer cap screw.

Remove the cap screw that secures the output flange to the output shaft.

Use a rawhide hammer to remove the output flange and flat washer from the output shaft.

Use a dent puller to remove the seal. Do **not** damage the surface of the housing or the seal bore.

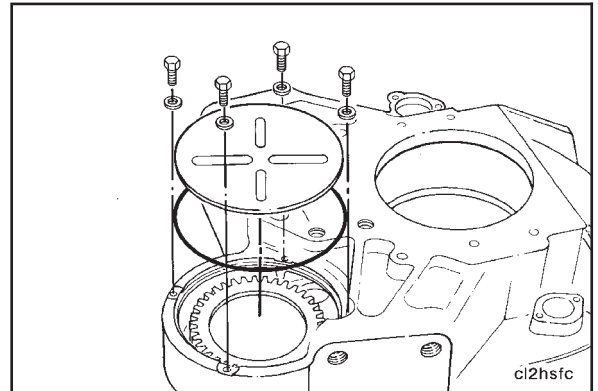


NOTE: When the housing is turned over, the bearing will fall out. Do **not** allow the bearing to become damaged.

Turn the housing over so the four cover plate capscrews are accessible. Be careful not to damage the output shaft.

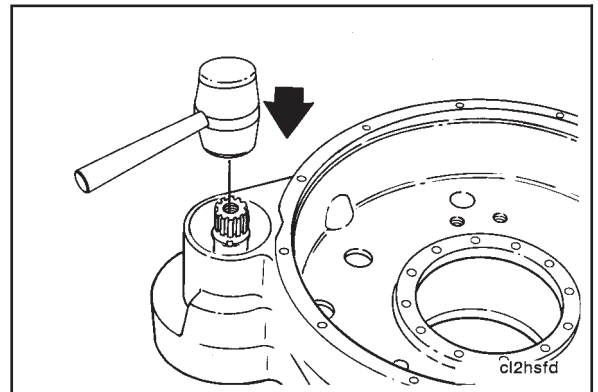
Remove the capscrews and the ribbed cover plate from the output gear housing.

Remove and discard the square cut o-ring seal.

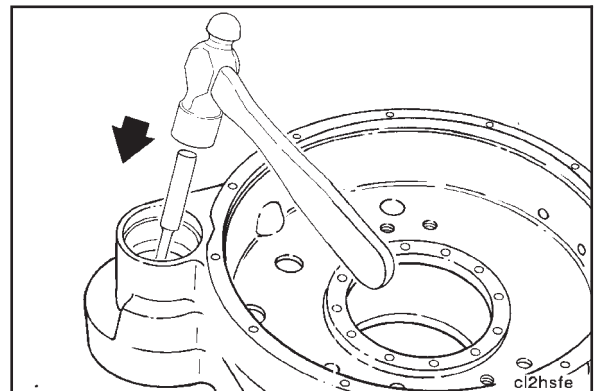


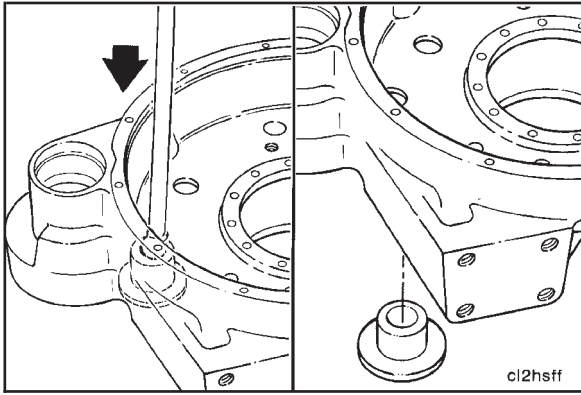
NOTE: Save the original shims for rebuild purposes. They will be used to set the proper end clearance on the output shaft and bearing assembly.

Turn the housing over and use a rawhide hammer to hit the end of the output shaft to remove the output subassembly from the REPTO housing.



With the housing positioned so the cylinder block mating surface is down, use a hammer and brass punch to drive the bearing outer races out of the output shaft housing bore.

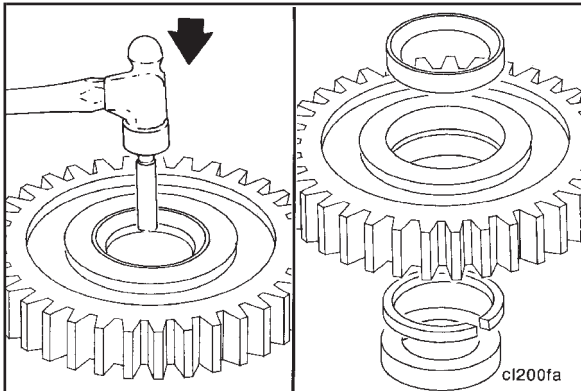




Support the housing in a press with the cylinder block mating surface down.

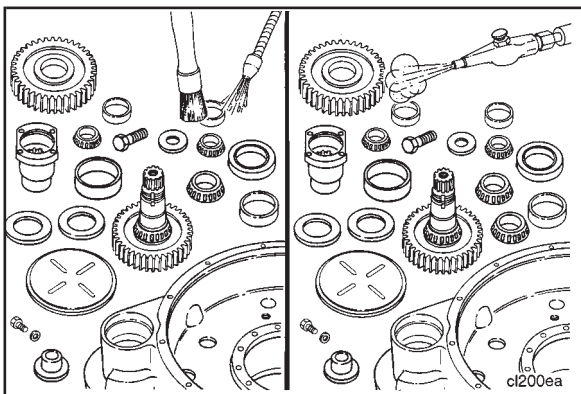


With a long mandrel, press out the idler shaft bushing.
Remove and discard the o-ring.



Use a hammer and a brass drift to remove the two bearing outer races from the bore of the idler gear. Discard the outer races.

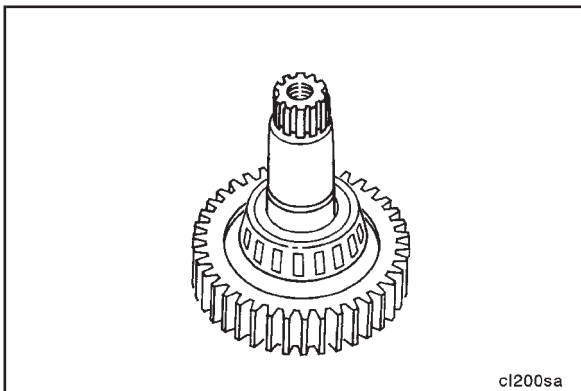
Remove the large spacer ring from the center groove of the gear. Discard the spacer ring.



Cleaning



Use solvent to clean all the parts. Dry with compressed air.



Inspection

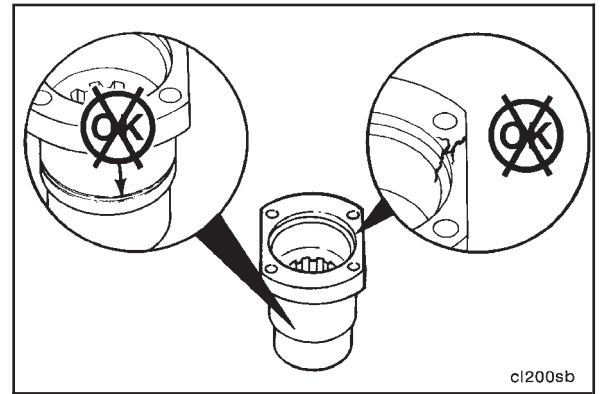
Inspect the output shaft and bearings for wear.

Inspect the output gear for damage.

Replace any defective parts.

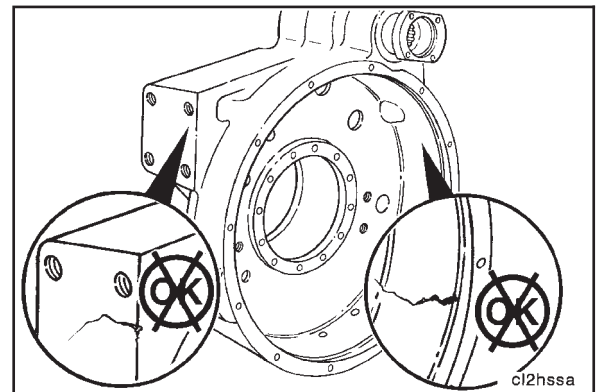
Inspect the output flange for damage or wear grooves from the oil seal.

Replace the flange if it is defective.



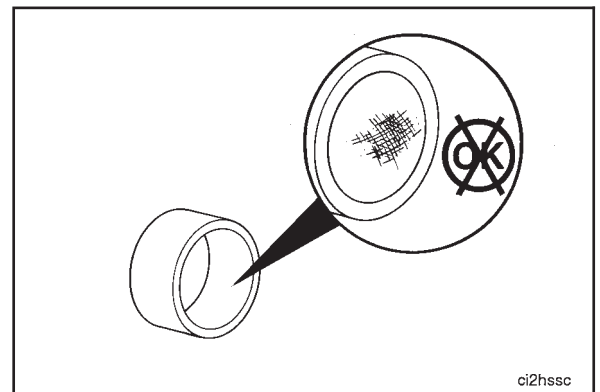
Inspect the REPTO housing for cracks at the rear engine mounting surfaces and the flywheel bore.

Replace the housing if it is cracked.



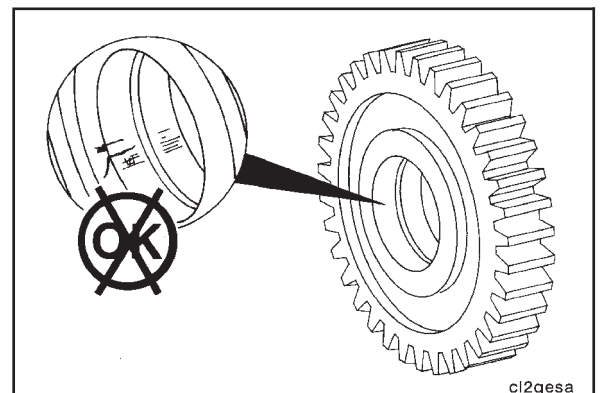
Inspect the idler shaft bushing for wear.

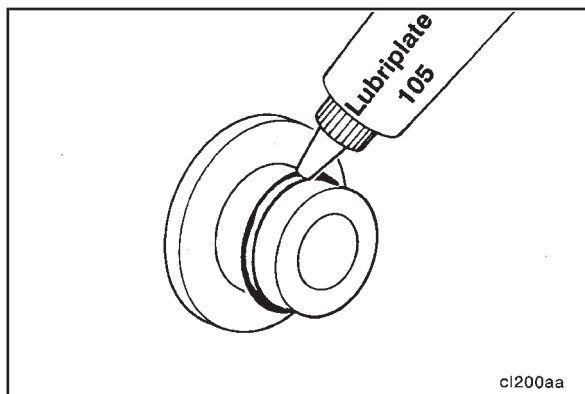
Replace the bushing if it is worn.



Closely inspect the bore, the side faces and the teeth of the idler gear.

Replace the gear if there are cracks, discoloration from excessive heat or other damage.

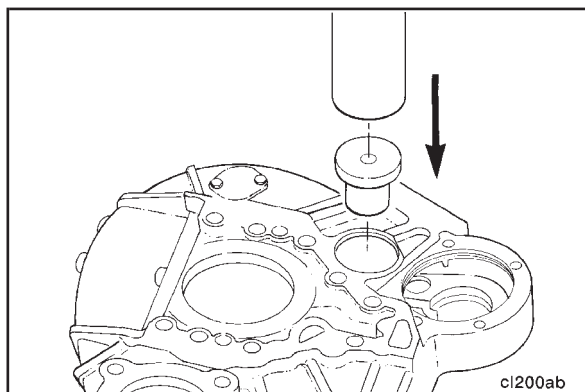




Assembly

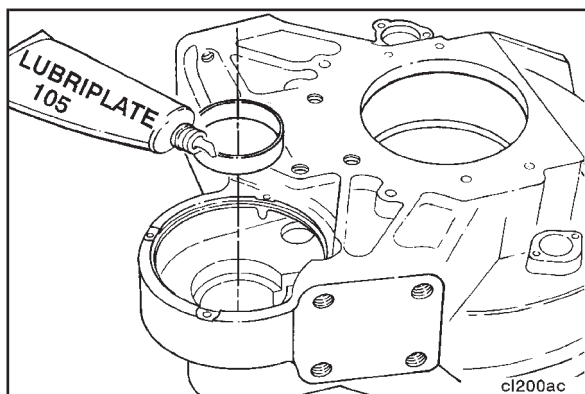


Install a new o-ring on the idler shaft bushing.
Use Lubriplate to lubricate the o-ring.

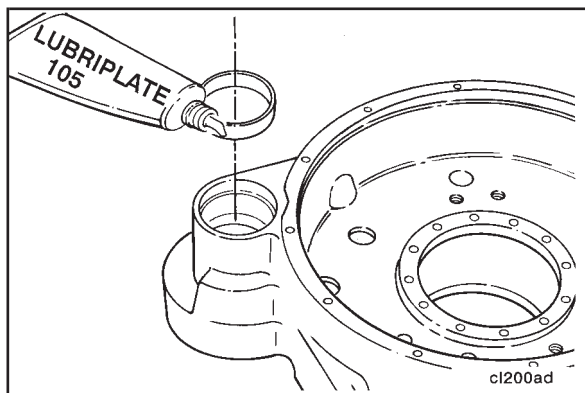


Support the housing evenly with the engine mating surface up.

Press the new bushing into the housing until it is below the surface of the cylinder block mating surface.



Use Lubriplate® 105 to lubricate the larger bearing race.
Use the larger end of driver, Part No. 3823893, to press the bearing race to the shoulder in the housing.



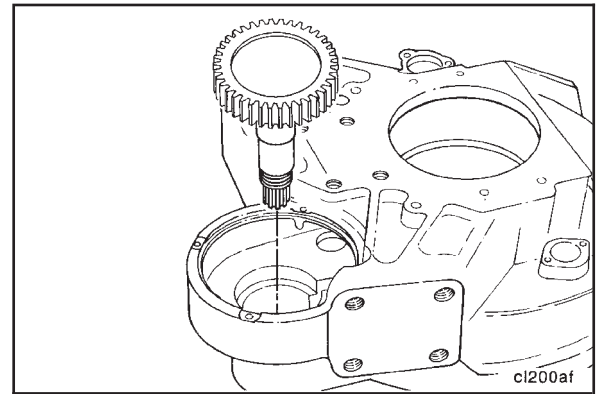
Turn the housing over and support it evenly in the press.

Use Lubriplate™ 105 to lubricate the smaller bearing race.
Use the smaller end of driver, Part No. 3823893, to press the bearing race to the shoulder in the housing.



Position the housing on the table so the cylinder block mating surface is up.

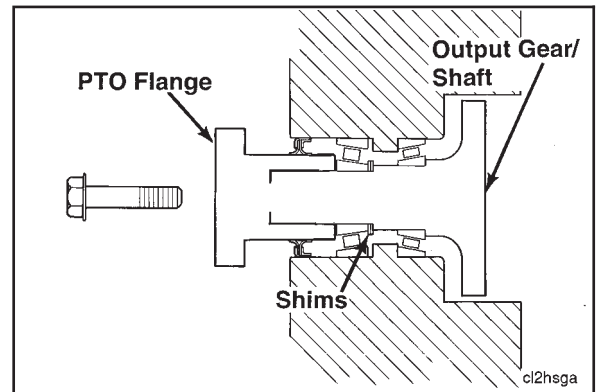
Install the output shaft assembly into the housing.



The correct shaft end clearance (rolling resistance) is determined by the number and thickness of shims used between the two bearings.

When the shim thickness is increased, there is more shaft end clearance and less rolling resistance.

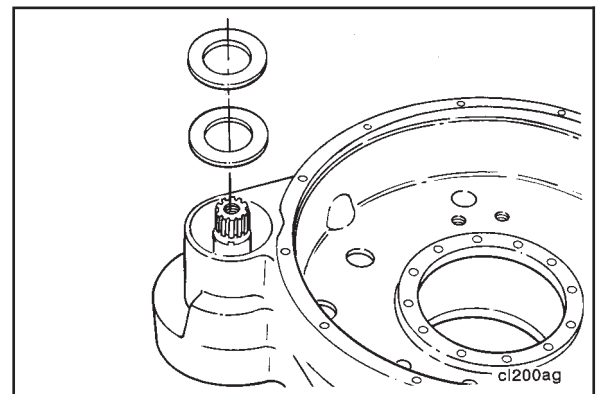
When the shim thickness is decreased, there is less shaft end clearance and more rolling resistance.



Turn the housing over with engine mating surface down while holding the output shaft and gear in place.

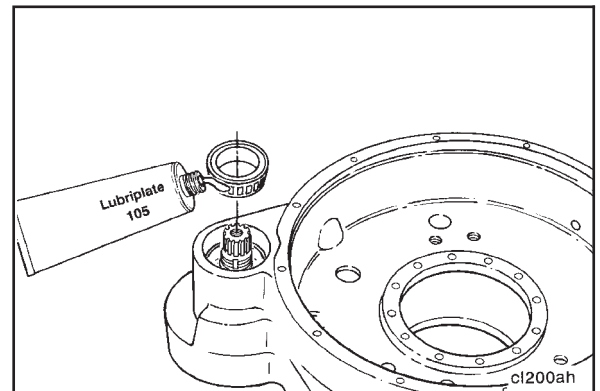
NOTE: If the original thickness of shims is **not** available for reuse, a beginning thickness of 1.47 mm [0.058 inch] can be used as a starting point.

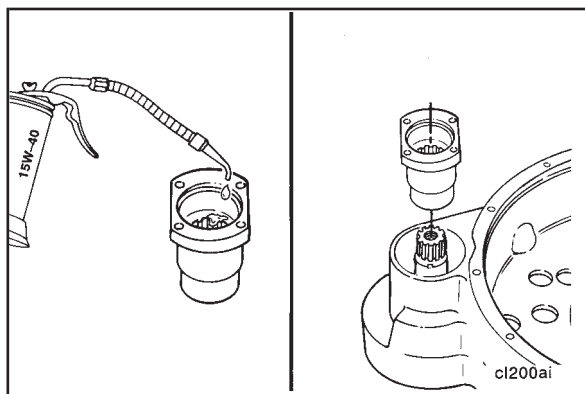
Install the original thickness of shims.



Use Lubriplate 105 to lubricate the smaller bearing.

Install the smaller bearing onto the shaft.

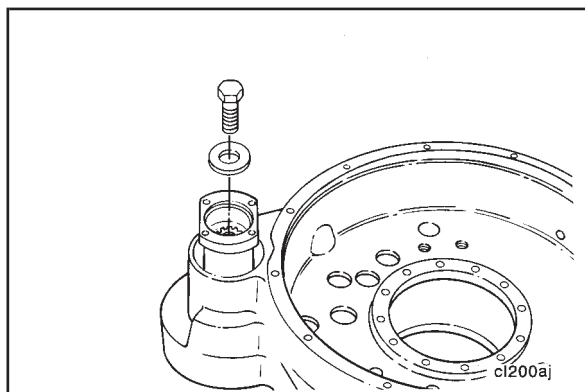




Temporarily install the output flange before installing the oil seal.



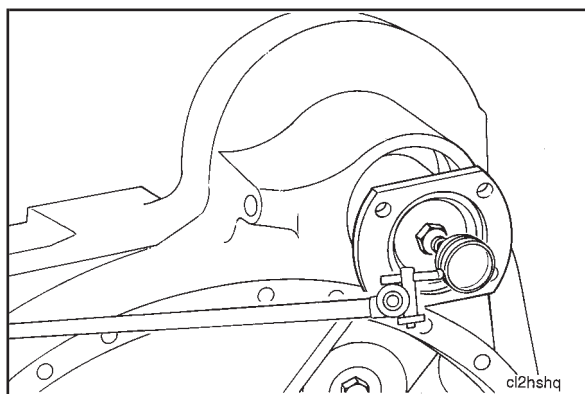
Use clean 15W-40 oil to lubricate the splines.



Install the flat washer and capscrew. Use gear locking tool, Part No. 3823891, to hold the output shaft while tightening the capscrew.

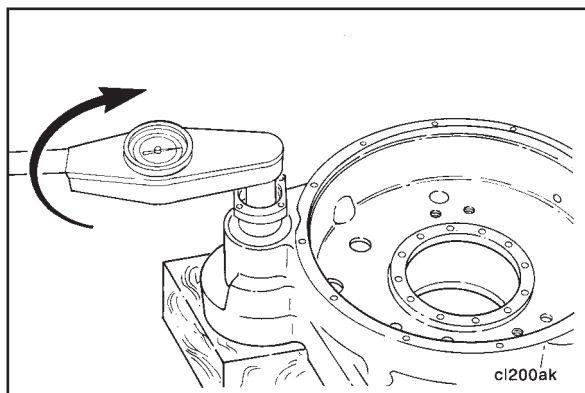


Torque Value: 205 N•m [150 ft-lb]



Measure the shaft end play.

REPTO Shaft End Play		
mm		in
0.00	MIN	0.000
0.03	MAX	0.001



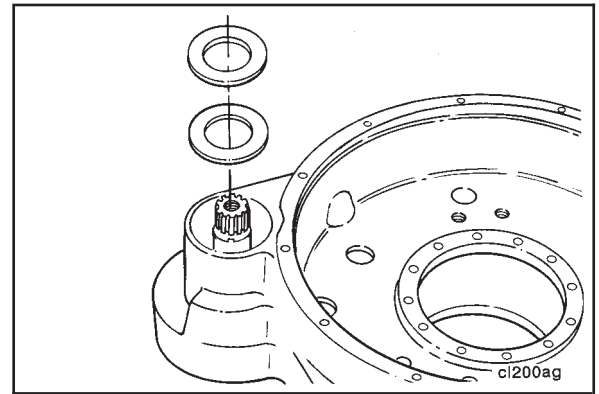
Check the output shaft rolling resistance with a torque wrench.

The rolling resistance **must** be between 0.6 to 1.1 N•m [5 to 10 in-lb].

If the rolling resistance is **not** within the specifications, remove the output flange and smaller bearing.

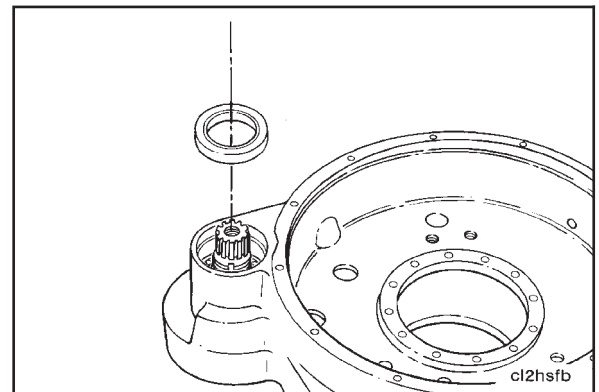
Add or subtract shims to obtain the correct rolling resistance.

NOTE: Adding more shims will decrease the resistance, and removing shims will increase resistance. Any combination of shims can be used.



Once the correct rolling resistance is obtained, remove the output flange and install a new oil seal.

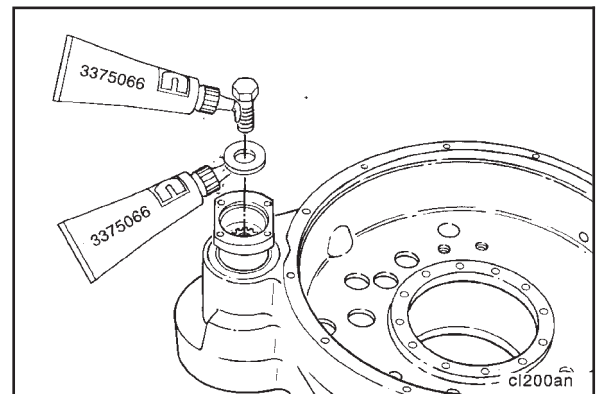
Press the oil seal flush with the housing surface.



Apply pipe sealant, Part No. 3375066, to the output flange capscrew and under the washer.

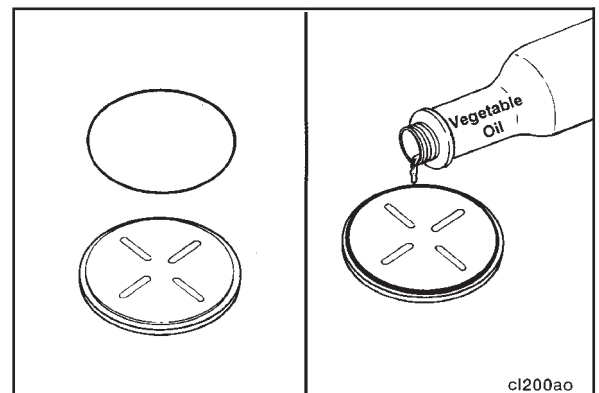
Install the output flange flat washer and capscrew. Torque the capscrew.

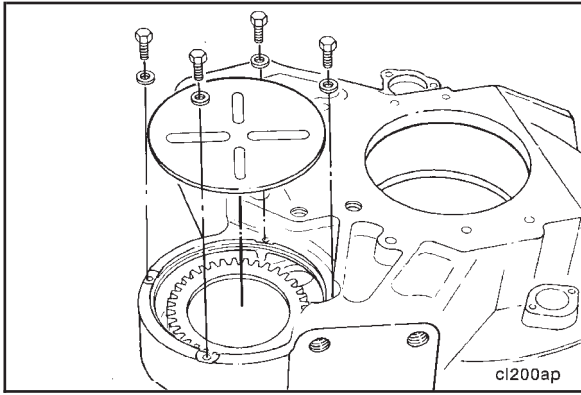
Torque Value: 205 N•m [150 ft-lb]



Install a new o-ring on the bearing housing cover.

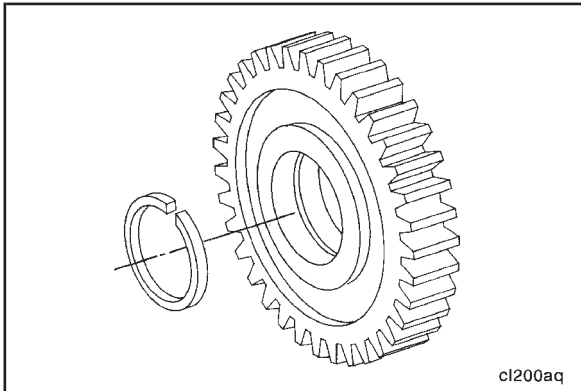
Use clean vegetable oil to lubricate the o-ring.



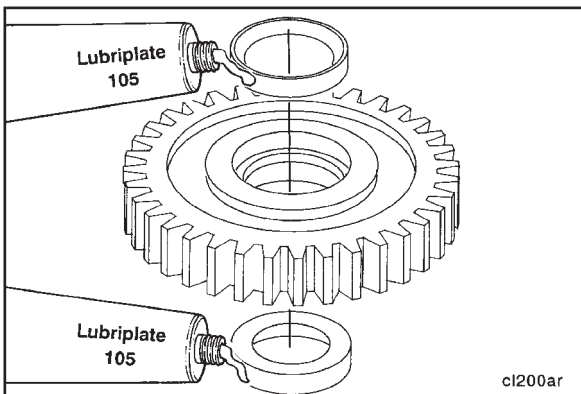


Install the cover and four capscrews.

Torque Value: 18 N•m [14 ft-lb]

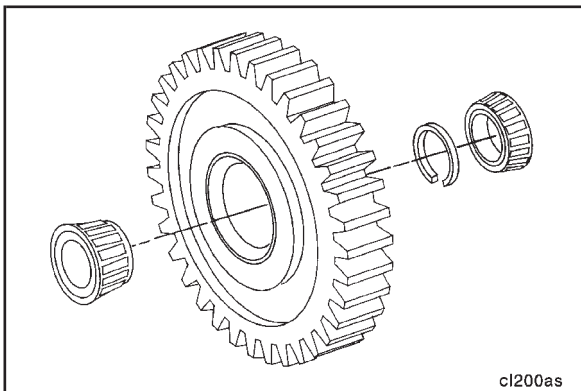


Insert a new spacer ring into the bore of the idler gear. Push it in until it snaps into place in the center groove.



Use Lubriplate 105 to lubricate the bearing outer races.

Press the two new bearing outer races into the bore of the idler gear. The larger side of the taper **must** face toward the outside of the gear.



NOTE: Do **not** interchange individual parts that make up the idler gear bearing assembly. Rebuild the idler gear with bearings that are packaged together.

Keep the two roller bearing assemblies and the spacer ring with the idler gear.

Section V - Specifications - Group 18

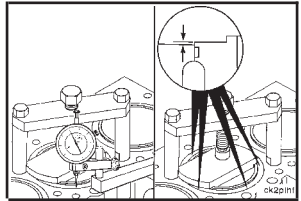
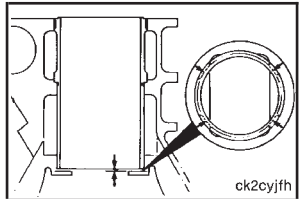
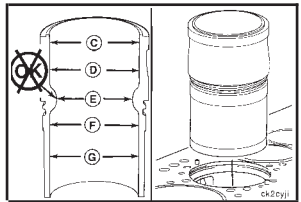
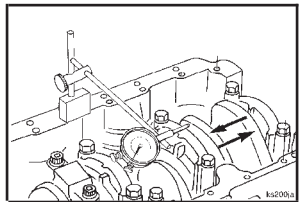
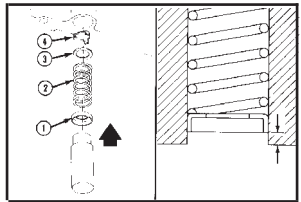
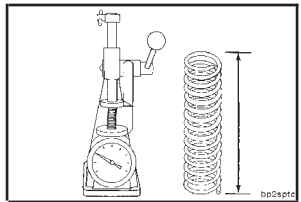
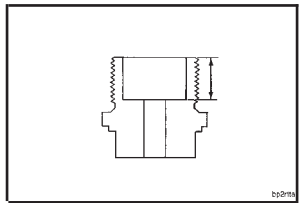
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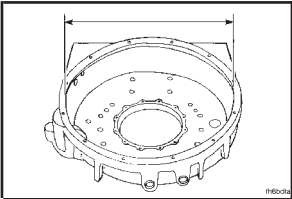
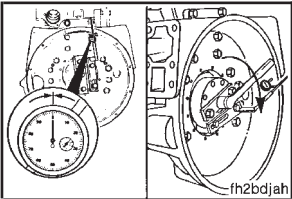
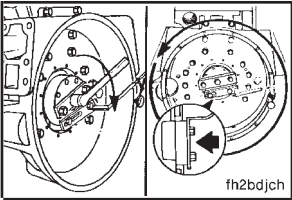
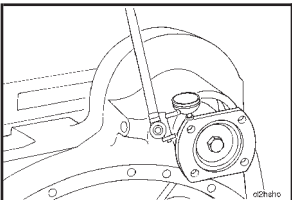
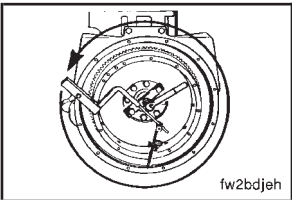
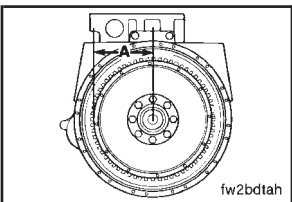
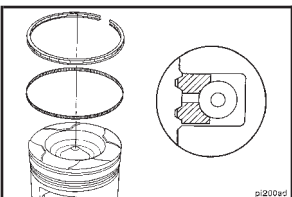
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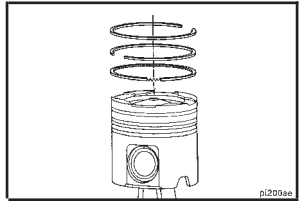
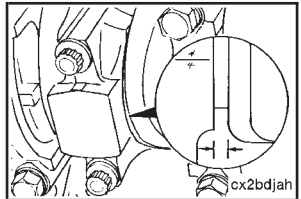
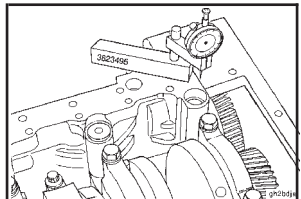
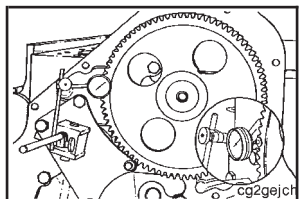
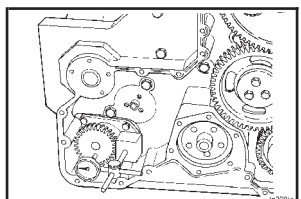
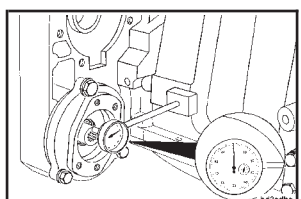
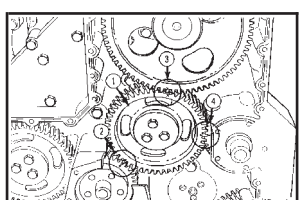
Specifications - General Information

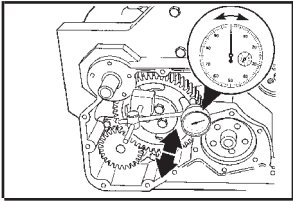
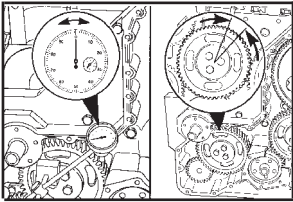
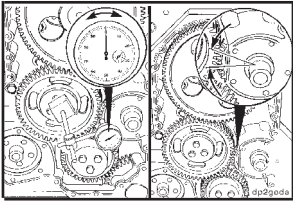
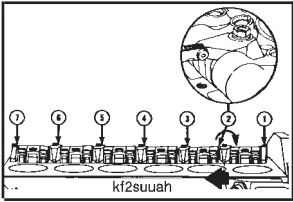
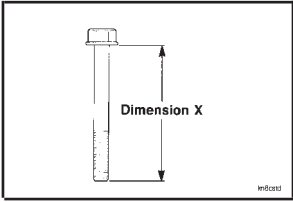
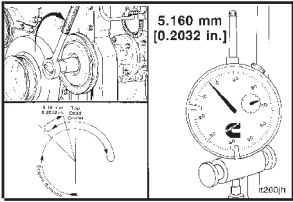
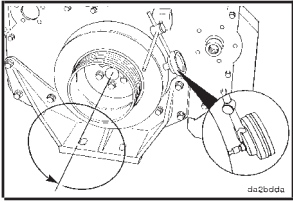
The specifications in this section are organized in the same sequence used in each group of this manual. The minimum and maximum tolerance limit specifications are listed in both metric and U.S. Customary dimensions. The assembly and rebuild specifications and torque values are provided to assure that the parts are correctly assembled, fit properly and are secured with the correct torque value.

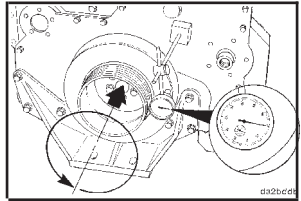
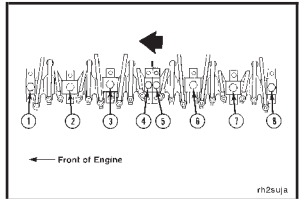
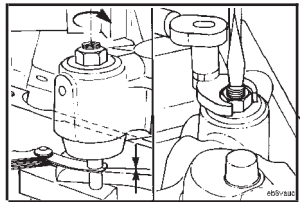
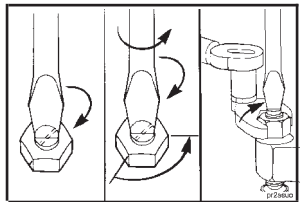
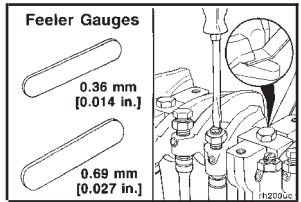
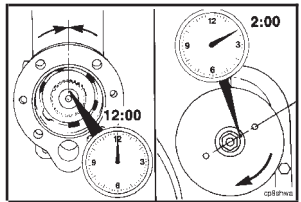
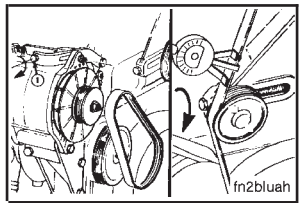
Most of the capscrews used to assemble the M11 engine are metric. Some components, such as the air compressor and the fuel pump, are installed using U.S. Customary capscrews. Capscrew torque values are listed in metric and U.S. Customary values. If a torque value is not listed, use the standard torque value for the capscrew. Refer to Capscrew Markings and Torque Values at the back of this section.

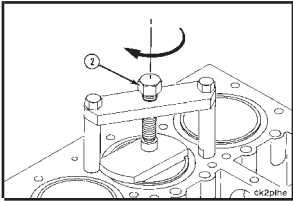
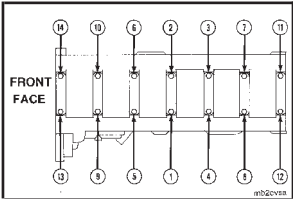
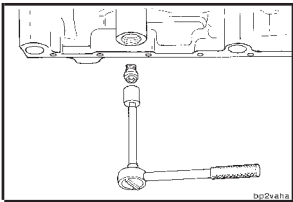
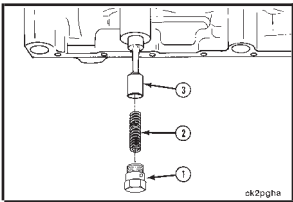
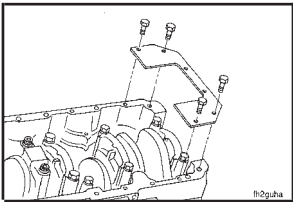
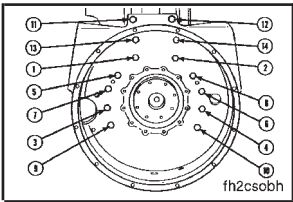
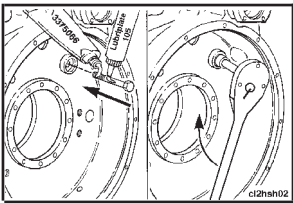
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Component Specifications and Torque Values Engine Assembly - Specifications				
Cylinder Liner Protrusion		0.00 mm 0.13 mm	MIN MAX	0.000 in 0.005 in
Note: Liner protrusion is measured with Part No. 3823495 Cyliner Liner Clamp Set installed.				
Cylinder Liner to Block Clearance		0.25 mm	MIN	0.010 in
				
Cylinder Liner Out of Round		0.10 mm	MAX	0.004 in
				
Crankshaft End Clearance		0.10 mm 0.56 mm	MIN MAX	0.004 in 0.022 in
				
High Oil Pressure Regulator Retainer Plug		8.03 mm 8.53 mm	MIN MAX	0.316 in 0.336 in
				
Main Oil Pressure Regulator Spring Free Length		84.1 mm		3.31 in
Spring Load at 48.3 mm [1.90 in]		91.1 N 94.7 N	MIN MAX	20.50 lbf 21.30 lbf
				
Main Oil Pressure Regulator Retainer Plug		11.1 mm 13.4 mm	MIN MAX	0.44 in 0.53 in
				

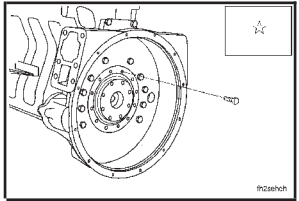
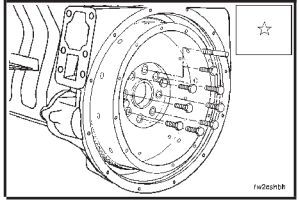
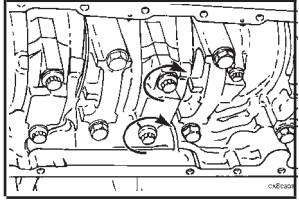
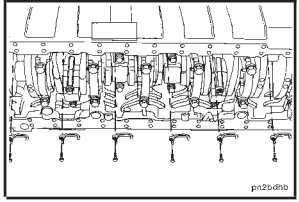
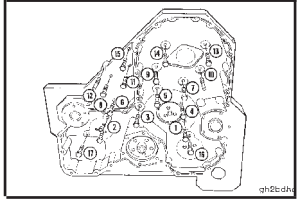
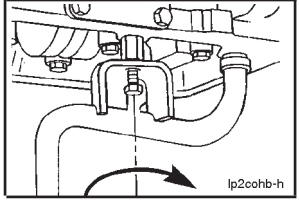
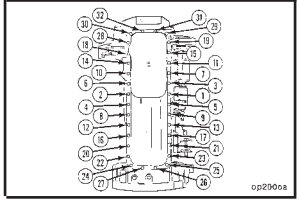
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.		
	SAE No.				
	00	787.7 mm	MAX	31.01 in	
	0	648.0 mm	MAX	25.51 in	
	1/2	584.4 mm	MAX	23.01 in	
	1	511.3 mm	MAX	20.13 in	
	2	447.8 mm	MAX	17.63 in	
	3	409.7 mm	MAX	16.13 in	
	SAE No.				
	00	0.31 mm	MAX	0.012 in	
	0	0.25 mm	MAX	0.010 in	
	1/2	0.25 mm	MAX	0.010 in	
	1	0.20 mm	MAX	0.008 in	
	2	0.20 mm	MAX	0.008 in	
	3	0.20 mm	MAX	0.008 in	
	SAE No.				
	00	0.31 mm	MAX	0.012 in	
	0	0.25 mm	MAX	0.010 in	
	1/2	0.25 mm	MAX	0.010 in	
	1	0.20 mm	MAX	0.008 in	
	2	0.20 mm	MAX	0.008 in	
	3	0.20 mm	MAX	0.008 in	
		0.15 mm	MIN	0.006 in	
		0.38 mm	MAX	0.015 in	
		0.127 mm	MAX	0.0050 in	
	Radius (A)				
	mm	in			
	203	8	0.203 mm	MAX	0.008 in
	254	10	0.254 mm	MAX	0.010 in
	305	12	0.305 mm	MAX	0.012 in
	356	14	0.356 mm	MAX	0.014 in
	406	16	0.406 mm	MAX	0.016 in
	Oil Control Ring End Gap				
	The two-piece oil ring must be installed with the expander gap 180 degrees from the oil ring gap.				

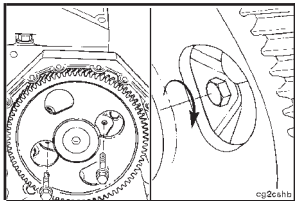
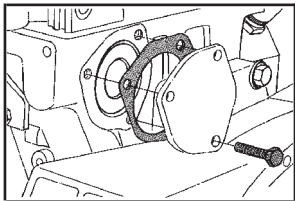
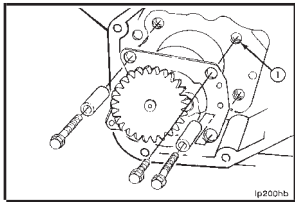
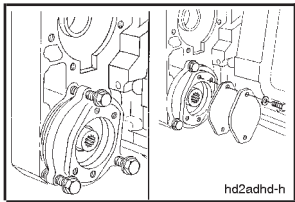
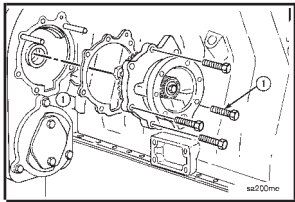
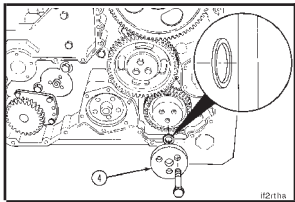
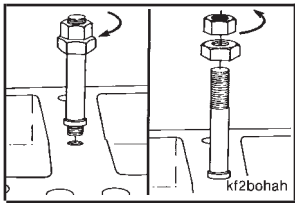
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Piston Ring End Gap The ring gaps must not be aligned with the piston pin bore. Rotate the rings to position the gaps as shown.				
Connecting Rod Side Clearance Note: The rod must move freely from side-to-side.		0.10 mm 0.30 mm	MIN MAX	0.004 in 0.012 in
				
Gear Housing Protrusion (below the cylinder block oil pan rail)		0.15 mm	MAX	0.006 in
				
Camshaft End Clearance		0.13 mm 0.33 mm	MIN MAX	0.005 in 0.013 in
				
Lubricating Oil Pump Gear End Clearance		0.064 mm 0.270 mm	MIN MAX	0.0025 in 0.0106 in
				
Hydraulic Pump Drive Shaft End Clearance		0.076 mm 0.635 mm	MIN MAX	0.0030 in 0.0250 in
				
Engine Timing Note: The timing marks on the camshaft idler gear must align with the timing marks on the accessory drive, crankshaft and camshaft gears to make sure the engine timing is set correctly.				

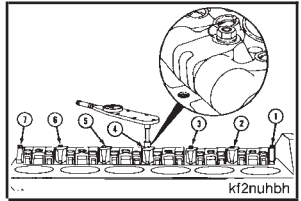
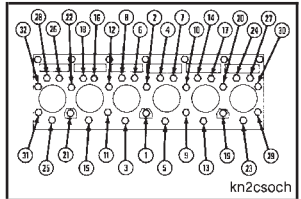
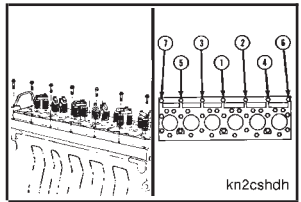
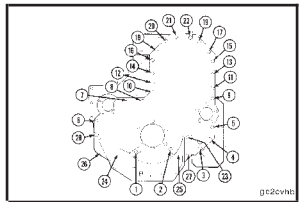
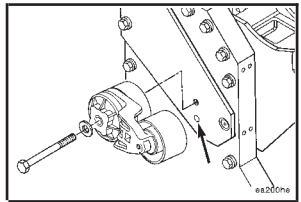
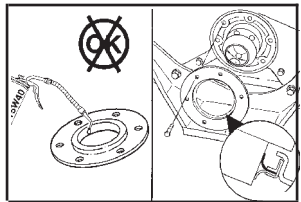
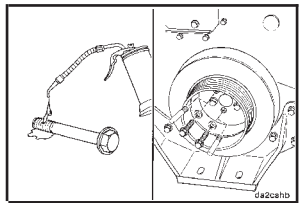
	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Idler Gear End Clearance		0.30 mm 0.53 mm	MIN MAX	0.012 in 0.021 in
	Idler Gear Backlash		0.08 mm 0.41 mm	MIN MAX	0.003 in 0.016 in
	Accessory Drive Gear Backlash		0.08 mm 0.41 mm	MIN MAX	0.003 in 0.016 in
	Cam Follower Side Clearance Between Supports		0.76 mm	MIN	0.030 in
	Cylinder Head Capscrew Free Length Part No. 3045849 Part No. 3045850		74.5 mm 139.5 mm	MAX MAX	2.933 in 5.492 in
	Static Injection Timing To verify the correct injection timing for a particular engine refer to the engine dataplate. Refer to Group 00, Engine Assembly, Injection Timing for complete instructions.				
	Vibration Damper Eccentricity TIR		0.28 mm	MAX	0.011 in

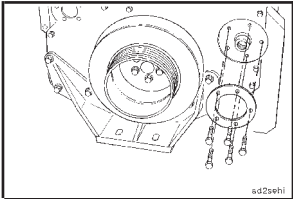
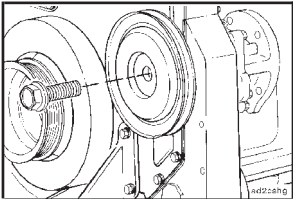
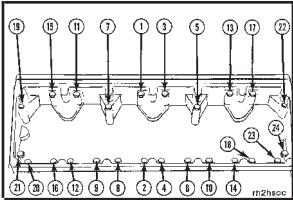
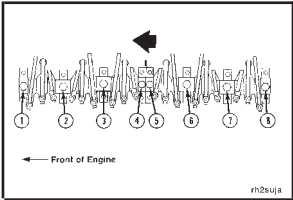
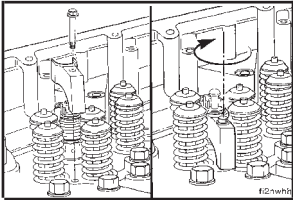
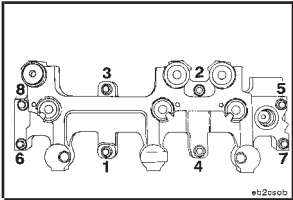
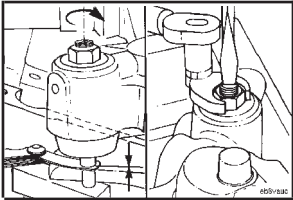
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Vibration Damper Face Runout - Measurement		0.28 mm	MAX 0.011 in	
Rocker Lever Side Clearance		0.55 mm	MIN 0.022 in	
Jacobs® Brake Slave Piston Clearance		0.38 mm	MIN 0.015 in	
Injector Adjustment 1. Bottom plunger 2. Loosen adjusting screw 2 flats and torque locknut. Note: Do not use excess force when bottoming plunger.				
Intake Valve Clearance Exhaust Valve Clearance		0.36 mm 0.69 mm	MIN MIN 0.014 in 0.027 in	
Air Compressor to Accessory Drive Timing Position the air compressor crankshaft timing mark at the 12:00 o'clock position. Position the accessory drive shaft dowel pin at the 2:00 o'clock position.				
Alternator Belt Tension Refer to the belt tension chart in this section.				

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Engine Assembly - Capscrew Torque Values		
	Cylinder Liner Clamping Plate Forcing Screw	136 N•m	100 ft-lb
	Main Bearing		
	Note: Tighten the capscrews in the sequence shown.		
	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen All	
	5	68 N•m	50 ft-lb
	6	142 N•m	105 ft-lb
	7	210 N•m	155 ft-lb
	Viscosity Sensor	24 N•m	18 ft-lb
	Main Oil Pressure Regulator Retainer Plug		
	Rear Sump Oil Pan Block Mounted Front Sump Suction Tube	75 N•m 122 N•m	55 ft-lb 90 ft-lb
	Flywheel Housing Alignment Plate	47 N•m	35 ft-lb
	Flywheel Housing		
	Note: Tighten the capscrews in the sequence shown.		
	1	68 N•m	50 ft-lb
	2	129 N•m	95 ft-lb
	3	197 N•m	145 ft-lb
	REPTO Idler Shaft Capscrew	102 N•m	75 ft-lb

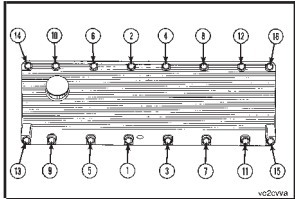
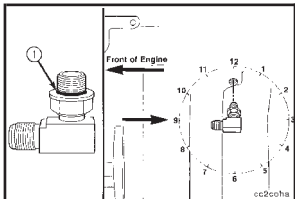
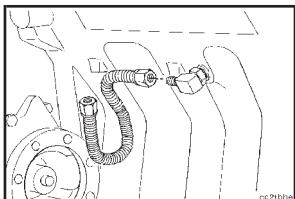
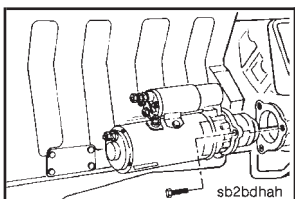
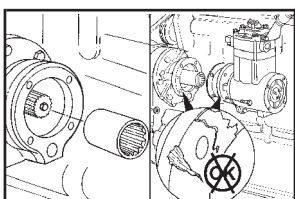
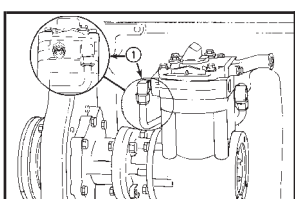
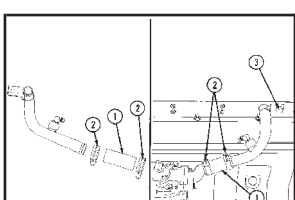
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Crankshaft Rear Oil Seal Note: Tighten in a star pattern.	1 2	7 N•m 20 N•m	60 in-lb 180 in-lb	
Flywheel Note: Tighten the capscrews in a star pattern.		183 N•m	135 ft-lb	
Connecting Rod	1 2 3 4 5 6 7	68 N•m 142 N•m 210 N•m Loosen All 68 N•m 142 N•m 210 N•m	50 ft-lb 105 ft-lb 155 ft-lb 50 ft-lb 105 ft-lb 155 ft-lb	
Piston Cooling Nozzle		24 N•m	18 ft-lb	
Gear Housing Note: Tighten the capscrews in sequence shown	1 2	20 N•m 68 N•m	15 ft-lb 50 ft-lb	
Block Mounted Front Sump Suction Tube Retainer		61 N•m	45 ft-lb	
Lubricating Oil Pan Note: Tighten the capscrews in the sequence shown.		47 N•m	35 ft-lb	

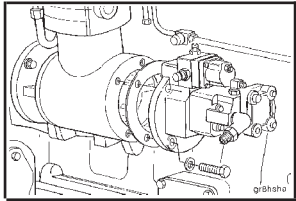
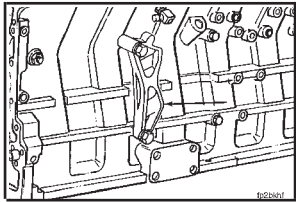
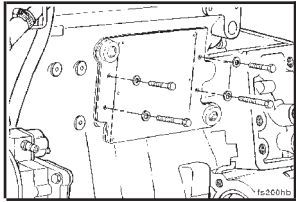
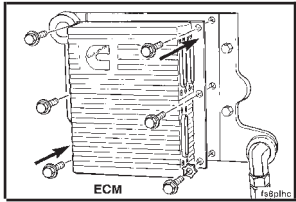
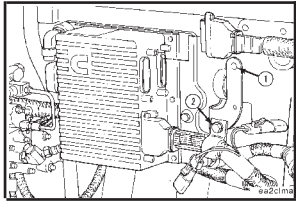
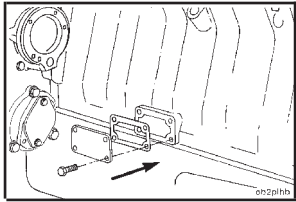
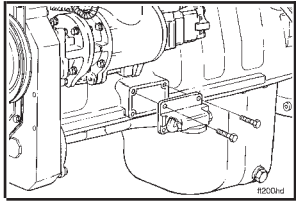
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Camshaft Thrust Plate		47 N•m	35 ft-lb
	Camshaft Rear Cover Plate		47 N•m	35 ft-lb
	Lubricating Oil Pump		41 N•m	30 ft-lb
	Hydraulic Drive Adapter Hydraulic Drive Cover Plate		47 N•m 27 N•m	35 ft-lb 20 ft-lb
	Accessory Drive Assembly		47 N•m	35 ft-lb
	Idler Gear Cover Retainer:		61 * N•m	45* ft-lb * Plus 60 degrees
	Cam Follower Support Studs Note: Install the cam follower support studs with two (M10X1.5) nuts tightened together. Remove the nuts after the studs are tightened.		34 N•m	25 ft-lb

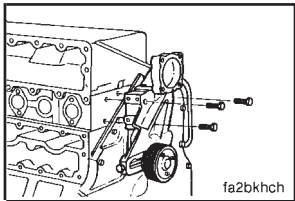
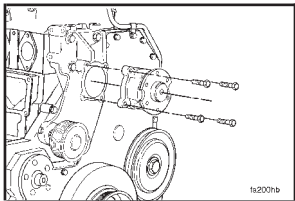
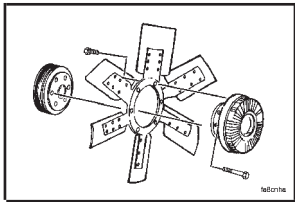
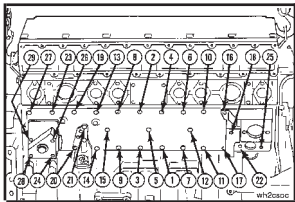
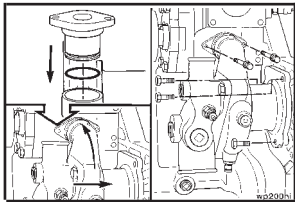
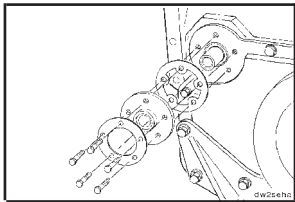
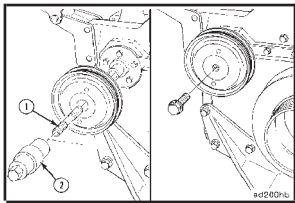
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cam Follower Support Nuts		47 N•m	35 ft-lb	
Cylinder Head Note: Tighten the cylinder head capscrews in the sequence shown. Note: Rotate at least one flat, but not more than two.	1 2 3	136 N•m 217 N•m	100 ft-lb 160 ft-lb Rotate 90 Degrees	
Cylinder Head (Fuel Pump Side) Tighten the capscrews in the sequence shown.		47 N•m	35 ft-lb	
Gear Cover Capscrews 1 through 22 Capscrews 23 through 28 Note: Tighten the capscrews in the sequence shown.		20 N•m 68 N•m	15 ft-lb 50 ft-lb	
Automatic Belt Tensioner		43 N•m	32 ft-lb	
Front Crankshaft Oil Seal	1 2	7 N•m 20 N•m	60 in-lb 180 in-lb	
Vibration Damper and Crankshaft Pulley Note: Tighten the capscrews in a star pattern.		203 N•m	150 ft-lb	

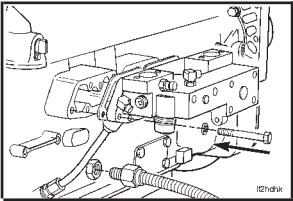
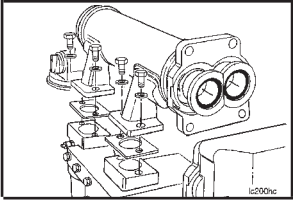
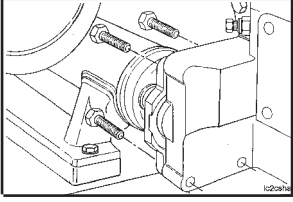
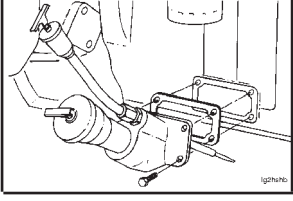
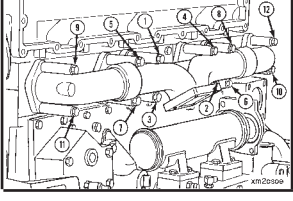
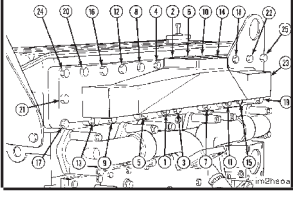
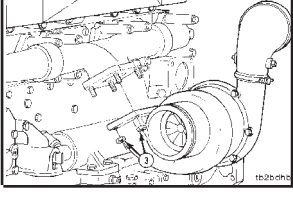
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Accessory Drive Oil Seal	1 2	7 N•m 20 N•m	60 in-lb 175 in-lb
	Accessory Drive Pulley		542 N•m	400 ft-lb
	Rocker Lever Housing Note: Tighten the capscrews in the sequence shown.		47 N•m	35 ft-lb
	Rocker Lever Assembly		122 N•m	90 ft-lb
	Injector Hold Down Clamp		75 N•m	55 ft-lb
	Jacobs® Brake		81 N•m	60 ft-lb
	Jacobs® Brake Slave Piston Adjusting Srew Locknut: • (Without Torque Wrench Adapter) • (With ST-669 Torque Wrench Adapter)		34 N•m 30 N•m	25 ft-lb 22 ft-lb

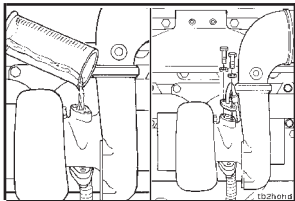
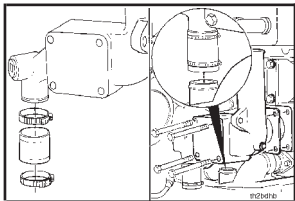
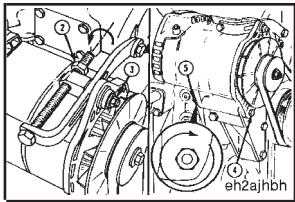
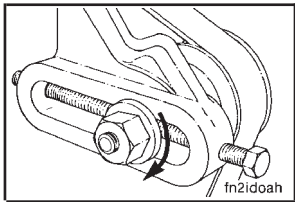
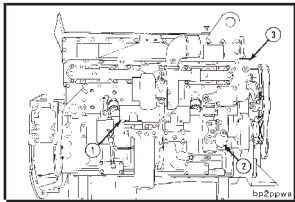
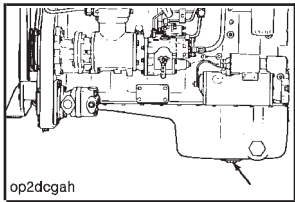
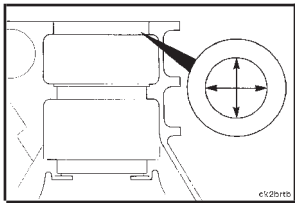
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Injector Lever Adjusting Screw Locknut: (Without Torque Wrench Adapter) (With ST-669 Torque Wrench Adapter)		61 N•m 47 N•m	45 ft-lb 35 ft-lb	
Valve Lever Adjusting Screw Locknut: (Without Torque Wrench Adapter) (With ST-669 Torque Wrench Adapter)		61 N•m 47 N•m	45 ft-lb 35 ft-lb	
Jacobs® Brake Housing Spacer Note: Tighten the capscrews in the sequence shown.		25 N•m	18 ft-lb	
CELECT™ Wiring Harness Bracket		41 N•m	30 ft-lb	
Internal Actuator Harness Clamps		20 N•m	15 ft-lb	
Internal/External Actuator Harness Connector		1 N•m	11 in-lb	
CELECT™ Sensors - Oil Temperature - Oil Pressure - Engine Position - Boost Pressure - Intake Manifold Temperature		34 N•m 30 N•m 34 N•m 14 N•m 14 N•m	25 ft-lb 22 ft-lb 25 ft-lb 10 ft-lb 10 ft-lb	

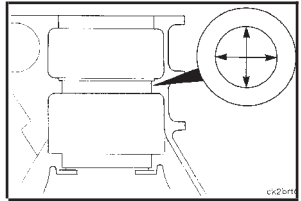
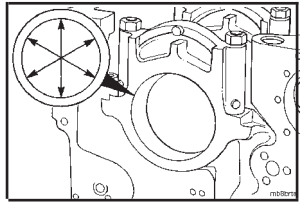
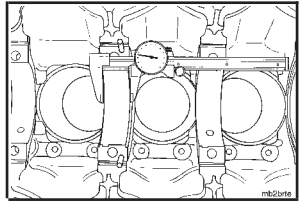
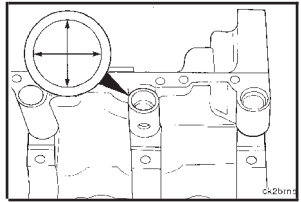
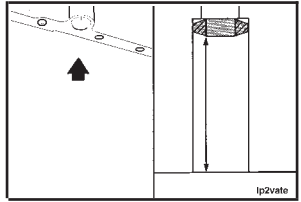
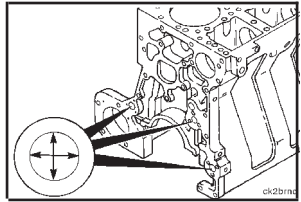
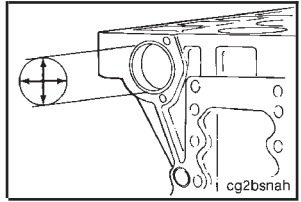
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Rocker Lever Cover Note: Tighten the capscrews in the sequence shown.		15 N•m	130 in-lb
	Air Compressor Coolant Inlet Tube Fitting Locknut		47 N•m	35 ft-lb
	Air Compressor Coolant Inlet Tube		40 N•m	30 ft-lb
	Starting Motor Mounting		90 N•m	140 ft-lb
	Air Compressor Mounting		65 N•m	50 ft-lb
	Air Compressor Coolant Hoses		40 N•m	30 ft-lb
	Air Compressor Air Supply Tube Air Compressor Air Tube Hose Clamps	47 N•m 5 N•m	35 ft-lb 40 in-lb	

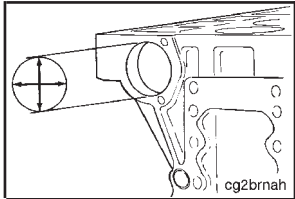
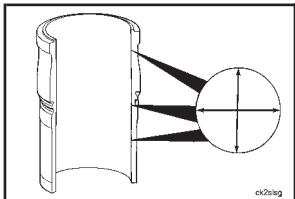
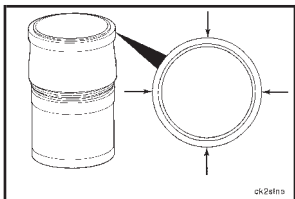
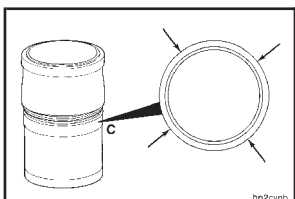
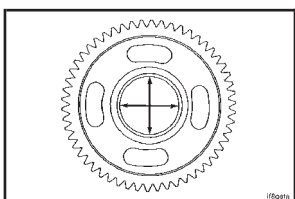
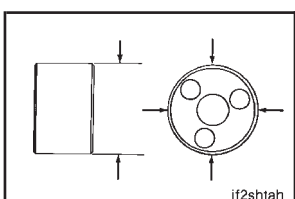
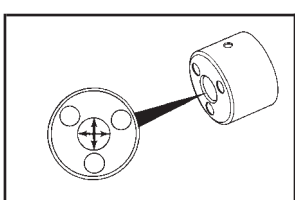
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Fuel Pump Mounting		47 N•m	35 ft-lb	
Fuel Pump Support Bracket Fuel pump housing mounting Cylinder block mounting		47 N•m 47 N•m	35 ft-lb 35 ft-lb	
Electronic Control Cooling Plate		40 N•m	30 ft-lb	
Electronic Control Module		7 N•m	62 in-lb	
ECM Wiring Harness Connector		2 N•m	18 in-lb	
Hand Hole Cover		47 N•m	35 ft-lb	
Fuel Filter Head		47 N•m	35 ft-lb	

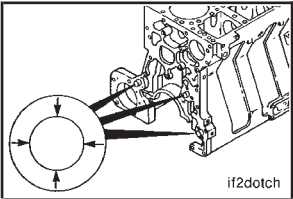
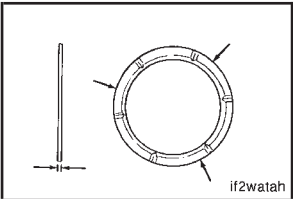
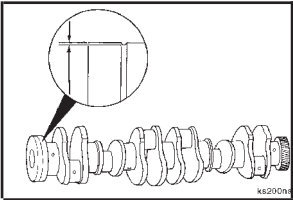
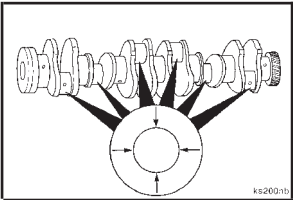
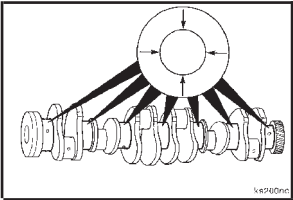
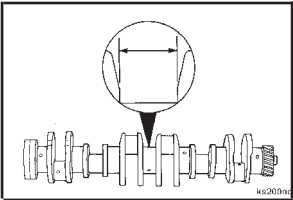
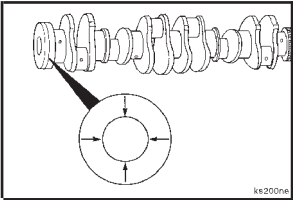
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Fan Hub Support		75 N•m	55 ft-lb
	Fan Hub		47 N•m	35 ft-lb
	Fan Pulley and Fan		47 N•m	35 ft-lb
	Water Header Plate Note: Tighten the capscrews in the sequence shown.		54 N•m	40 ft-lb
	Water Pump Mounting Water Transfer Connection		47 N•m 25 N•m	35 ft-lb 18 ft-lb
	Water Pump Oil Seal Note: Tighten the capscrews in a star pattern	1 2	7 N•m 20 N•m	60 in-lb 180 in-lb
	Alternator Drive Pulley		75 N•m	55 ft-lb

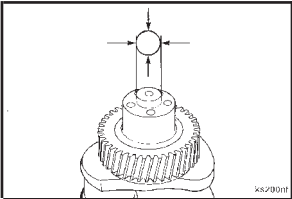
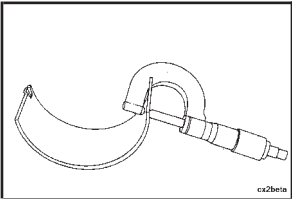
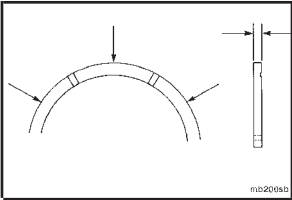
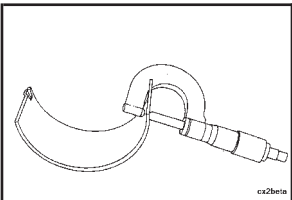
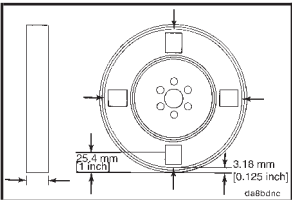
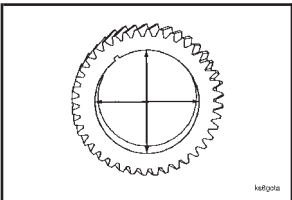
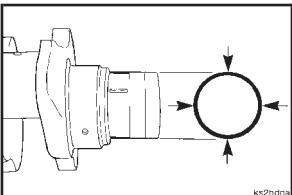
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Lubricating Oil Filter Head		47 N•m	35 ft-lb	
Lubricating Oil Cooler Mounting		47 N•m	35 ft-lb	
Oil Cooler Thermostat Support Mounting Flange		47 N•m	35 ft-lb	
Dipstick Tube and Housing		47 N•m	35 ft-lb	
Exhaust Manifold Note: Tighten the capscrews in the sequence shown.	1 2	27 N•m 47 N•m	20 ft-lb 35 ft-lb	
Air Intake Manifold Note: Tighten the capscrews in the sequence shown.		47 N•m	35 ft-lb	
Turbocharger - Mounting Nuts		61 N•m	45 ft-lb	

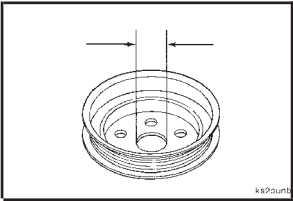
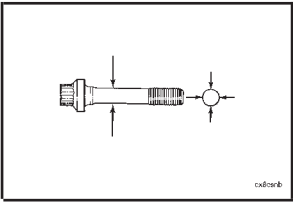
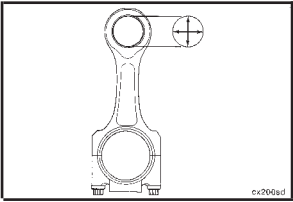
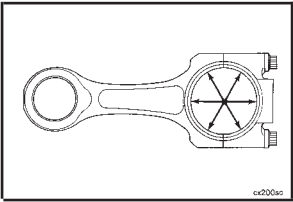
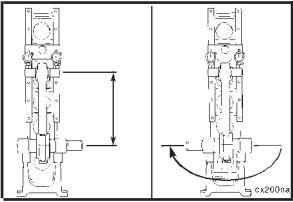
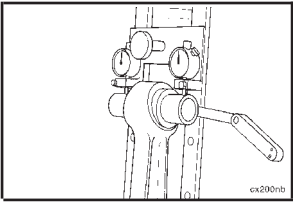
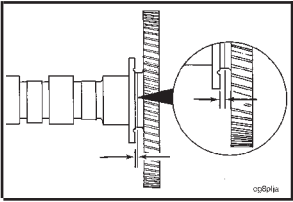
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Turbocharger Oil Supply		20 N•m	15 ft-lb
	Turbocharger Oil Drain		27 N•m	20 ft-lb
	Thermostat Housing		54 N•m	40 ft-lb
	Hose Clamps		3 N•m	30 in-lb
	Alternator Adjusting Screw Locknuts		80 N•m	60 ft-lb
	Alternator Mounting Bracket		47 N•m	35 ft-lb
	Idler Pulley Shaft Locknut		190 N•m	140 ft-lb
	Drain Plugs (Coolant)		20 N•m	15 ft-lb
	Drain Plug (Lubricating Oil Pan)		90 N•m	65 ft-lb
	Cylinder Block - Rebuild Specifications			
	Cylinder Block Upper Liner Bore I.D.		145.900 mm	MIN 5.7441 in
			146.027 mm	MAX 5.7491 in

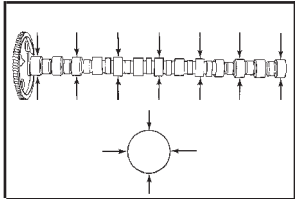
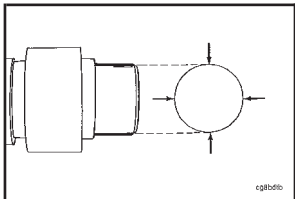
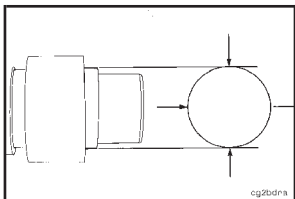
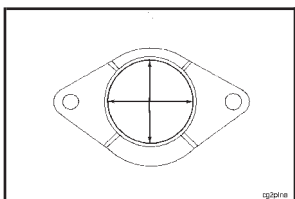
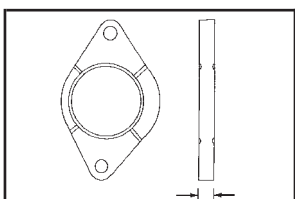
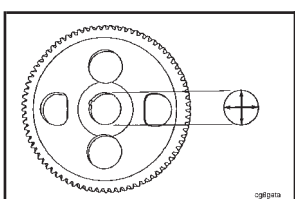
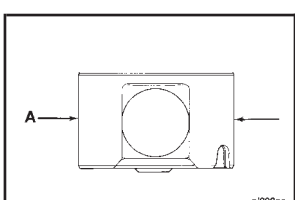
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cylinder Block Liner Seal Seat Bore I.D.		138.063 mm 138.113 mm	MIN MAX 5.4355 in 5.4375 in	
Main Bearing Bore I.D.		121.990 mm 122.015 mm	MIN MAX 4.8028 in 4.8037 in	
Cylinder Block Thrust Bearing Surface Width		39.95 mm 40.05 mm	MIN MAX 1.573 in 1.577 in	
Main Oil Pressure Regulator Valve Bore I.D.		22.226 mm 22.301 mm	MIN MAX 0.8750 in 0.8780 in	
High Oil Pressure Relief Valve Seat Depth		62.62 mm 63.62 mm	MIN MAX 2.465 in 2.505 in	
Idler Gear Ring Dowel Bore I.D.		19.175 mm 19.215 mm	MIN MAX 0.7549 in 0.7565 in	
Camshaft Bushing I.D. (Installed)		72.078 mm 72.142 mm	MIN MAX 2.8377 in 2.8402 in	
Note: If one of the bushings exceeds the specifications, all of the bushings must be replaced.				

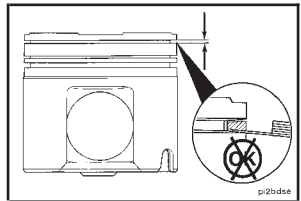
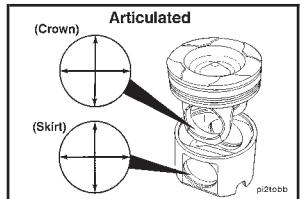
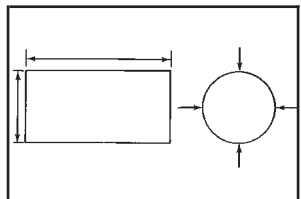
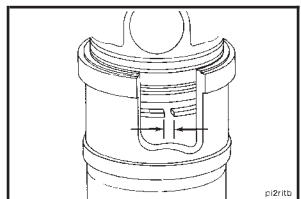
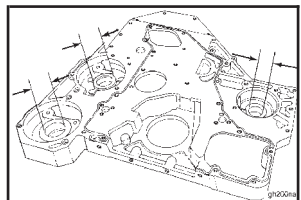
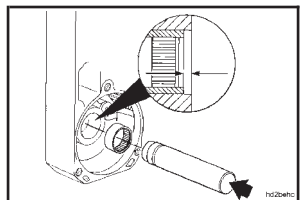
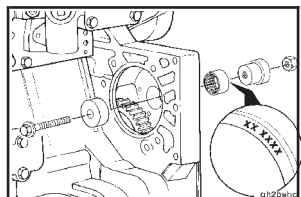
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	MIN MAX	U.S.
	Cylinder Block Camshaft Bore I.D.		76.987 mm 77.040 mm	MIN MAX	3.0310 in 3.0331 in
	Cylinder Liner I.D.		125.000 mm 125.095 mm	MIN MAX	4.9213 in 4.9250 in
	Cylinder Liner Top Press Fit O.D.		145.938 mm 145.976 mm	MIN Max	5.7456 in 5.7471 in
	Cylinder Liner Seal Seat O.D.	C	137.937 mm 138.013 mm	MIN MAX	5.4306 in 5.4336 in
	Idler Gear Bushing Bore I.D.		60.045 mm 60.100 mm	MIN MAX	2.3640 in 2.3661 in
	Idler Gear Shaft O.D.		59.975 mm 60.008 mm	MIN MAX	2.3612 in 2.3625 in
	Idler Gear Shaft Ring Dowel Bore I.D.		19.245 mm 19.265 mm	MIN MAX	0.7577 in 0.7585 in

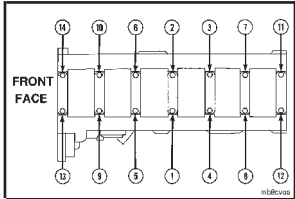
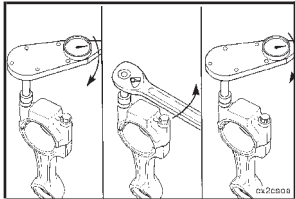
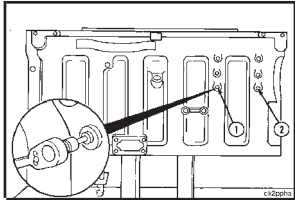
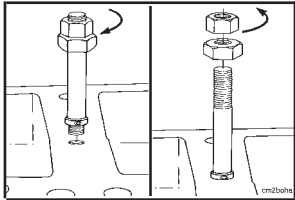
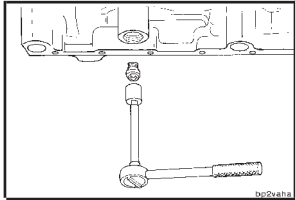
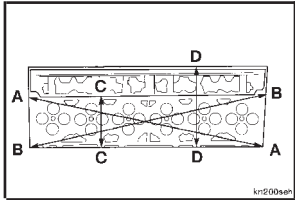
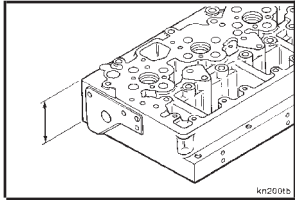
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Idler Gear Ring Dowel O.D.		19.217 mm 19.243 mm	MIN MAX 0.7566 in 0.7576 in	 if2dotch
Idler Gear Thrust Washer Thickness		2.400 mm 2.470 mm	MIN MAX 0.0945 in 0.0972 in	 if2watah
Crankshaft Rear Oil Seal Wear Groove		0.25 mm	MAX 0.0098 in	 ks200ne
Crankshaft Connecting Rod Journal O.D.		78.950 mm 79.013 mm	MIN MAX 3.1083 in 3.1107 in	 ks2001b
Crankshaft Main Bearing Journal O.D.		114.015 mm 114.055 mm	MIN MAX 4.4888 in 4.4903 in	 ks200ne
Crankshaft Thrust Face Width		49.975 mm 50.100 mm	MIN MAX 1.9675 in 1.9724 in	 ks2001a
Crankshaft Rear Oil Seal Flange O.D.		164.965 mm 165.035 mm	MIN MAX 6.4947 in 6.4974 in	 ks200ne

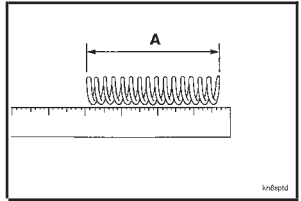
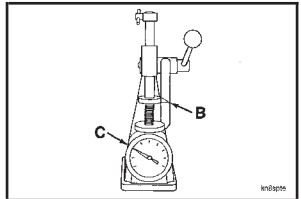
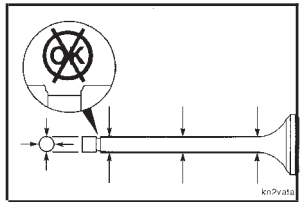
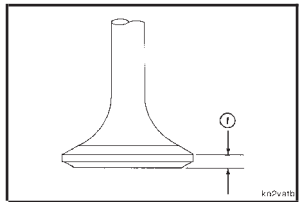
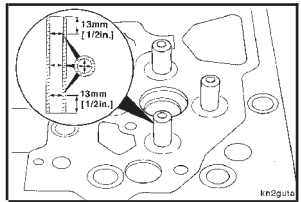
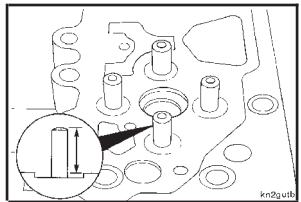
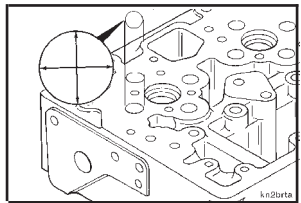
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Crankshaft Damper Pilot O.D.	32.01 mm 32.04 mm	MIN MAX	1.2602 in 1.2614 in
	Main Bearing Shell Thickness (Standard)	3.895 mm 3.944 mm	MIN MAX	0.1533 in 0.1553 in
Note: For visual inspection criteria, refer to the Parts Reuse Guidelines, Bulletin No. 3810303.				
	Crankshaft Thrust Bearing Thickness	4.75 mm 4.89 mm	MIN MAX	0.1870 in 0.1925 in
	Connecting Rod Bearing Thickness (Standard)	2.430 mm 2.473 mm	MIN MAX	0.0957 in 0.0974 in
Note: For visual inspection criteria, refer to the Parts Reuse Guidelines, Bulletin No. 3810303.				
	Vibration Damper Thickness Variation	0.25 mm 45.00 mm	MAX MAX	0.010 in 1.772 in
	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

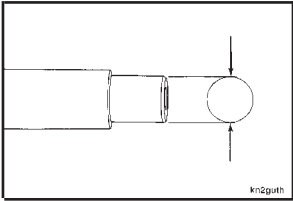
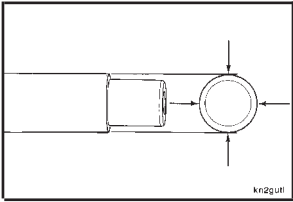
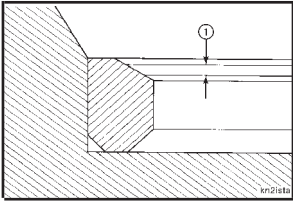
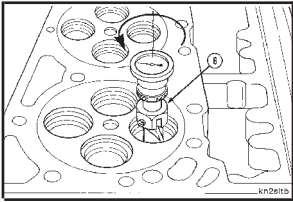
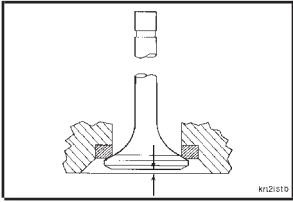
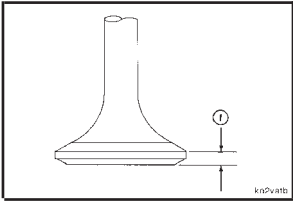
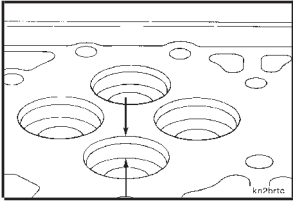
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Crankshaft Pulley Crankshaft Pilot Bore I.D.		32.05 mm 32.10 mm	MIN MAX	1.2618 in 1.2638 in
				
Connecting Rod Capscrew O.D.		12.600 mm 12.800 mm	MIN MAX	0.4961 in 0.5039 in
				
Connecting Rod Piston Pin Bushing I.D. (Installed)		54.054 mm 54.099 mm	MIN MAX	2.1281 in 2.1299 in
				
Connecting Rod Bearing Bore I.D.		83.975 mm 84.025 mm	MIN MAX	3.3061 in 3.3080 in
				
Connecting Rod - Length		217.975 mm 218.025 mm	MIN MAX	8.5817 in 8.5836 in
Connecting Rod - Alignment:				
• (With Bushing)		0.10 mm	MAX	0.004 in
				
Connecting Rod - Twist:				
• (With Bushing)		0.25 mm	MAX	0.010 in
				
Camshaft Thrust Plate Clearance		0.180 mm 0.330 mm	MIN MAX	0.0070 in 0.0130 in
				

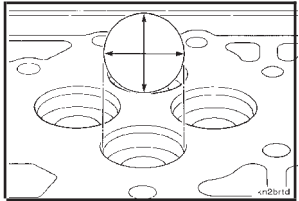
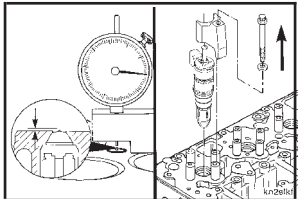
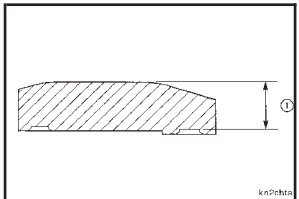
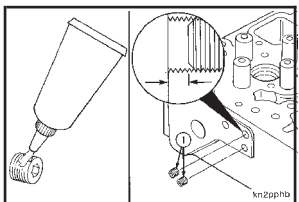
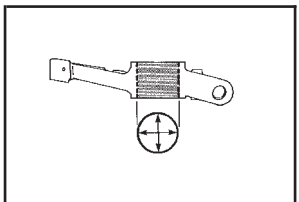
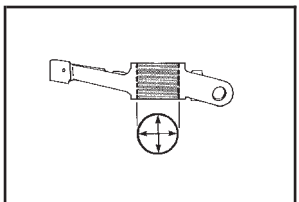
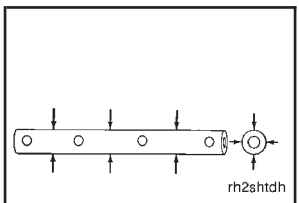
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	MIN MAX	U.S.
	Camshaft Bushing Journal O.D.		71.987 mm 72.013 mm	MIN MAX	2.8341 in 2.8352 in
	Camshaft Gear Mounting Surface O.D.		46.987 mm 47.013 mm	MIN MAX	1.8499 in 1.8509 in
	Camshaft Thrust Bearing Journal O.D.		54.800 mm 55.200 mm	MIN MAX	2.1575 in 2.1732 in
	Camshaft Thrust Plate I.D.		55.60 mm 56.61 mm	MIN MAX	2.1890 in 2.2287 in
	Camshaft Thrust Plate Thickness		8.960 mm 9.040 mm	MIN MAX	0.3528 in 0.3559 in
	Camshaft Gear Bore I.D.		46.912 mm 46.938 mm	MIN MAX	1.8469 in 1.8479 in
	Piston Skirt O.D.	(A)	124.939 mm 124.983 mm	MIN MAX	4.9189 in 4.9206 in

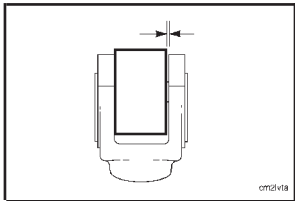
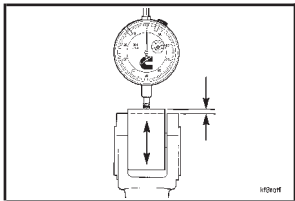
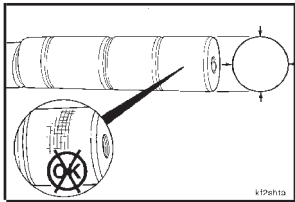
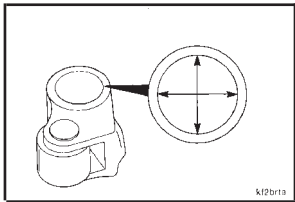
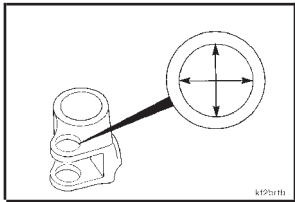
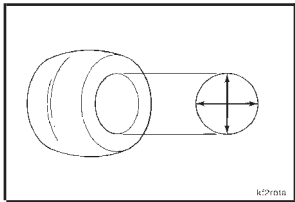
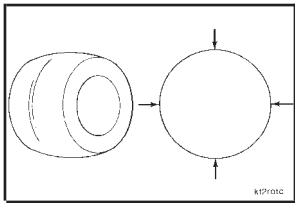
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Piston Ring Groove Width				
Use a new ring and a 0.15 mm [0.006 inch] feeler gauge. If the feeler gauge enters the groove without resistance the piston must be replaced.				
				
Piston Pin Bore I.D.				
• Articulated Crown		54.040 mm 54.055 mm	MIN MAX	2.1276 in 2.1281 in
• Articulated Skirt		54.007 mm 54.015 mm	MIN MAX	2.1263 in 2.1266 in
				
Piston Pin Length				
		101.700 mm 102.000 mm	MIN MAX	4.0039 in 4.0157 in
Piston Pin O.D.				
		53.997 mm 54.003 mm	MIN MAX	2.1259 in 2.1261 in
				
Piston Ring Gap				
Top		0.46 mm 0.71 mm	MIN MAX	0.018 in 0.028 in
Intermediate		0.76 mm 1.14 mm	MIN MAX	0.030 in 0.045 in
Oil		0.25 mm 0.64 mm	MIN MAX	0.010 in 0.025 in
				
Gear Housing Bearing Bore I.D.				
Hydraulic Drive		41.967 mm 41.992 mm	MIN MAX	1.6522 in 1.6532 in
Water Pump Drive		36.967 mm 36.992 mm	MIN MAX	1.4553 in 1.4564 in
Accessory Drive		45.100 mm 45.125 mm	MIN MAX	1.7756 in 1.7766 in
				
Hydraulic Pump Needle Bearing Installed Depth				
		0.25 mm 0.76 mm	MIN MAX	0.010 in 0.030 in
				
Water Pump Needle Bearing Installed Depth				
The bearing must be installed with the part number side of the bearing against the installation tool to prevent bearing damage during installation. Use bearing driver kit, Part No. 3824117, to install to the correct specification.				
				

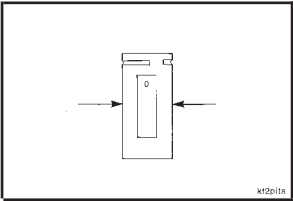
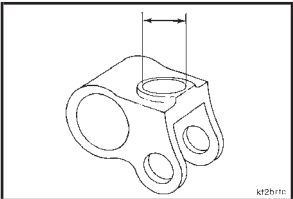
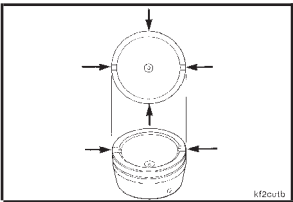
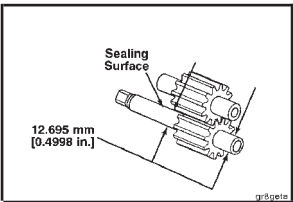
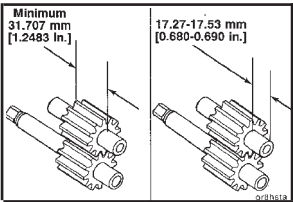
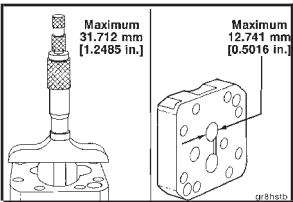
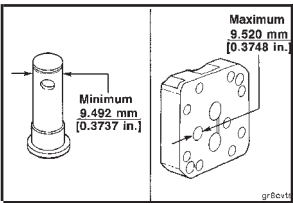
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Cylinder Block - Torque Values		
	Main Bearing Capscrews		
	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen All	
	5	68 N•m	50 ft-lb
	Connecting Rod Capscrews		
	1	68 N•m	50 ft-lb
	2	142 N•m	105 ft-lb
	3	210 N•m	155 ft-lb
	4	Loosen All	
	5	68 N•m	50 ft-lb
	6	142 N•m	105 ft-lb
	Cylinder Block Pipe Plugs		
	Refer to "Pipe Plug Torque Value Table" at the rear of this section for torque value of various plug sizes.		
	Cam Follower Studs	34 N•m	25 ft-lb
	Viscosity Sensor	24 N•m	18 ft-lb
	Cylinder Head - Rebuild Specifications		
	Cylinder Head Flatness		
	AA and BB (Corner to Corner)	0.200	MAX 0.008
	CC (Across Combustion Face)	0.076	MAX 0.003
	Cylinder Head Thickness	99.24 mm	MIN 3.907 in
		100.25 mm	MAX 3.947 in

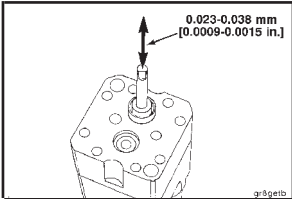
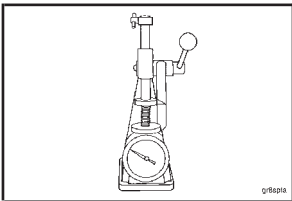
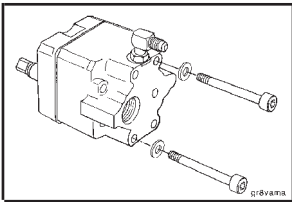
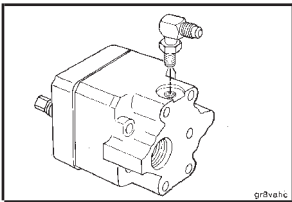
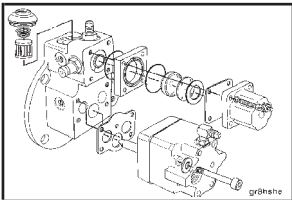
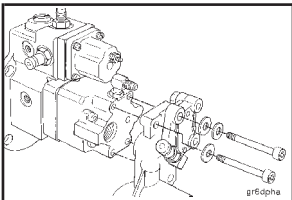
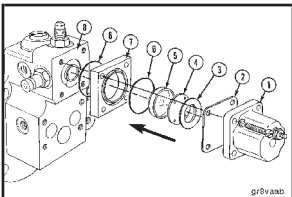
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Valve Spring Free Height:	A	103.300 mm	Nominal	4.0669 in	
Valve Spring Working Height:	B	71.48 mm	Nominal	2.8142 in	
Load for Working Height at 71.48 mm [2.8142 in]:	C	1252 N 1584 N	MIN MAX	281 lbf 356 lbf	
Valve Stem O.D.		9.580 mm 9.633 mm	MIN MAX	0.3772 in 0.3793 in	
Valve Head Thickness at O.D.	1	3.15 mm 3.62 mm	MIN MAX	0.124 in 0.143 in	
Valve Guide I.D. (Installed) Used		9.670 mm 9.730 mm	MIN MAX	0.3807 in 0.3831 in	
New/Rebuilt		9.670 mm 9.695 mm	MIN MAX	0.3807 in 0.3817 in	
Valve Guide Height (Installed)		27.15 mm 27.65 mm	MIN MAX	1.069 in 1.089 in	
Valve Guide Bore I.D.		16.480 mm 16.500 mm	MIN MAX	0.6488 in 0.6496 in	

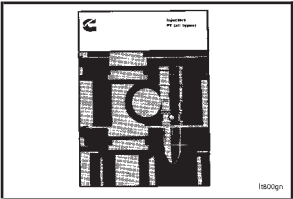
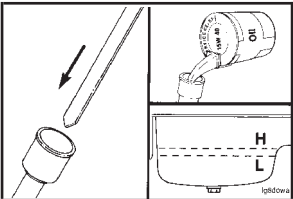
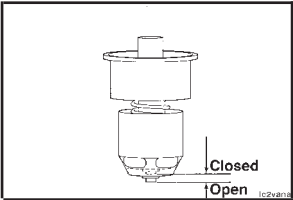
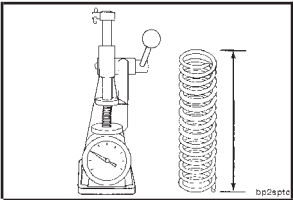
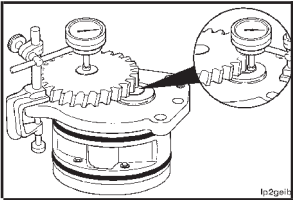
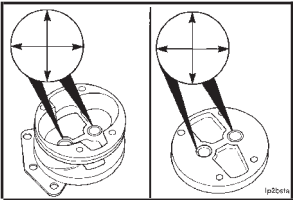
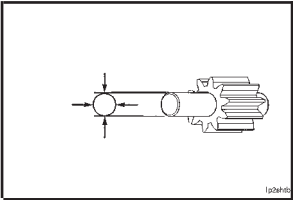
	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Valve Guide O.D. (Seal Area)		14.25 mm 14.37 mm	MIN MAX	0.561 in 0.566 in
	Valve Guide O.D. (Base)		16.513 mm 16.526 mm	MIN MAX	0.6501 in 0.6506 in
	Valve Seat Area Width	1	1.63 mm 2.69 mm	MIN MAX	0.064 in 0.106 in
	Valve Seat to Valve Guide Concentricity (Per 360 Degrees)		0.05 mm	MAX	0.002 in
	Valve Recess in Cylinder Head	1	0.76 mm 1.17 mm	MIN MAX	0.030 in 0.046 in
	Valve Head Thickness (at. O.D.)		3.15 mm 3.62 mm	MIN MAX	0.124 in 0.143 in
	Valve Insert Bore Depth (Standard Insert)		9.40 mm 9.50 mm	MIN MAX	0.370 in 0.374 in

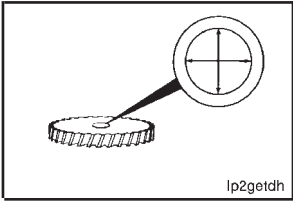
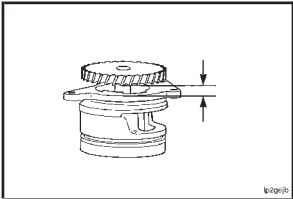
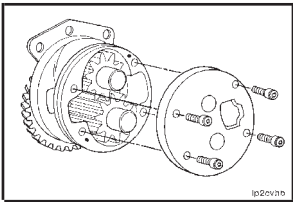
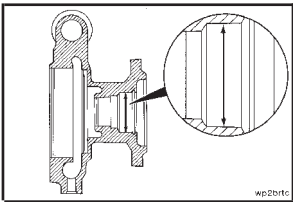
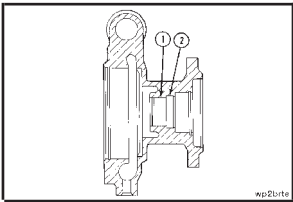
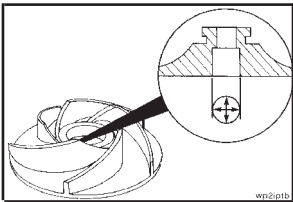
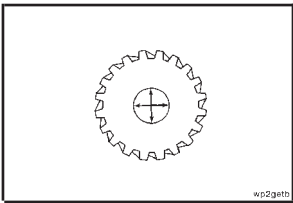
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Valve Insert Bore I.D. (Standard Insert) Note: Refer to Cylinder Head - Oversize Valve Seat Installation (2-05) for oversize valve insert dimensions.		45.920 mm 45.935 mm	MIN MAX 1.8073 in 1.8085 in	
Injector Tip Protrusion: • (Used Injector Sleeve) • (New Injector Sleeve)		2.28 mm 2.65 mm 2.28 mm 2.54 mm	MIN MAX MIN MAX 0.090 in 0.104 in 0.090 in 0.100 in	
Crosshead Stem Pocket to Pad Face		12.05 mm 12.55 mm	MIN MAX 0.474 in 0.494 in	
Cylinder Head - Torque Values Cylinder Head Pipe Plugs Note: The pipe plugs (1) located in the front of the cylinder head must be installed below the surface of the cylinder head.		10 N•m	8 ft-lb	
Rocker Lever Assembly - Rebuild Specifications				
Rocker Lever Bushing Bore I.D.		34.887 mm 34.990 mm	MIN MAX 1.3735 in 1.3776 in	
Rocker Lever Bore I.D.		36.474 mm 36.499 mm	MIN MAX 1.4359 in 1.4370 in	
Rocker Lever Shaft O.D.		34.837 mm 34.864 mm	MIN MAX 1.3715 in 1.3726 in	

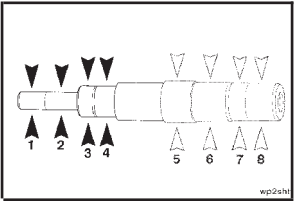
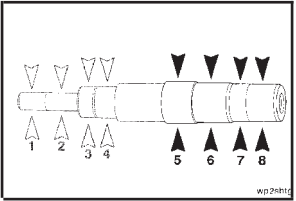
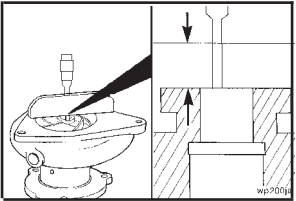
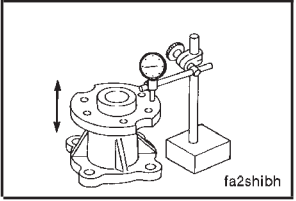
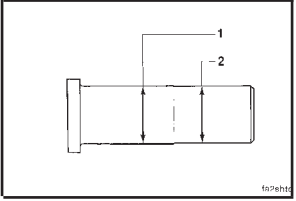
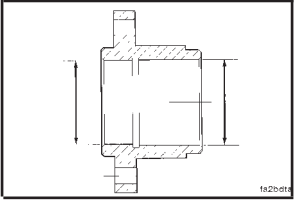
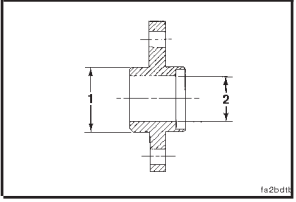
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Cam Follower Assembly - Rebuild Specifications			
	Cam Follower Roller Side Clearance		0.19 mm 0.65 mm	MIN MAX 0.007 in 0.026 in
	Cam Follower Roller to Pin Clearance		0.08 mm 0.20 mm	MIN MAX 0.003 in 0.008 in
	Cam Follower Shaft Journal O.D.		33.991 mm 34.009 mm	MIN MAX 1.3382 in 1.3389 in
	Cam Follower Lever Shaft Bore I.D.		34.086 mm 34.116 mm	MIN MAX 1.3420 in 1.3431 in
	Cam Follower Lever Roller Pin Bore I.D.		19.043 mm 19.055 mm	MIN MAX 0.7497 in 0.7502 in
	Cam Follower Lever Roller Bore I.D.		19.151 mm 19.177 mm	MIN MAX 0.7540 in 0.7550 in
	Cam Follower Crowned Roller O.D.		41.237 mm 41.287 mm	MIN MAX 1.6235 in 1.6255 in

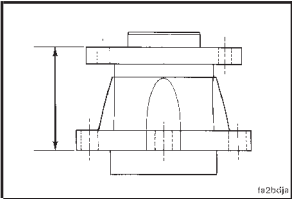
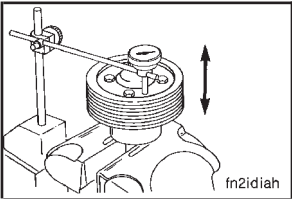
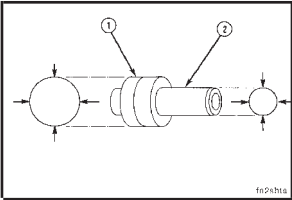
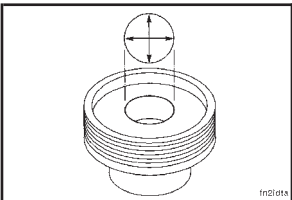
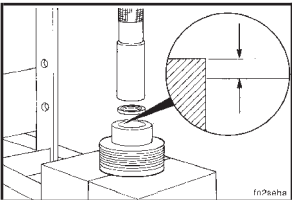
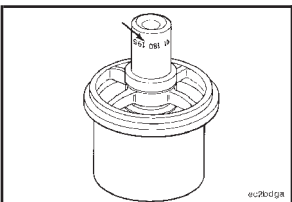
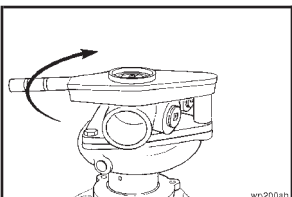
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cam Follower Roller Pin (New) O.D.		19.065 mm 19.073 mm	MIN MAX	0.7506 in 0.7509 in
				
Cam Follower Lever Socket Bore I.D.		19.024 mm 19.050 mm	MIN MAX	0.7490 in 0.7500 in
				
Cam Follower Lever Socket (New) O.D.		19.062 mm 19.088 mm	MIN MAX	0.7505 in 0.7515 in
				
Fuel Pump - Rebuild Specifications				
Gear Pump Shaft Bearing Surface O.D.		12.695 mm	MIN	0.4998 in
				
Gear Width		31.707 mm	MIN	1.2483 in
Gear Installed Depth		17.270 mm 17.533 mm	MIN MAX	0.6799 in 0.6903 in
Note: Measure from the body end of the shaft.				
				
Body Gear Hole Depth		31.704 mm 31.712 mm	MIN MAX	1.2482 in 1.2485 in
Body Shaft Bore I.D.		12.733 mm 12.741 mm	MIN MAX	0.5013 in 0.5016 in
				
Body Regulator Bore I.D.		9.510 mm 9.520 mm	MIN MAX	0.3744 in 0.3748 in
				

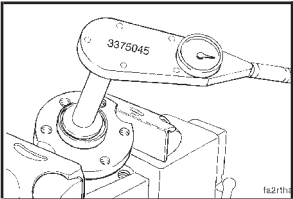
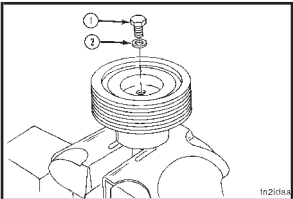
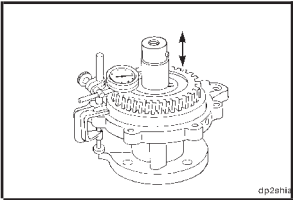
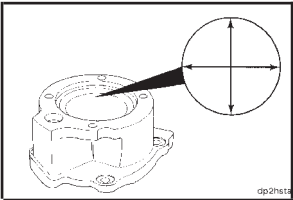
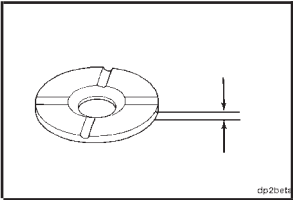
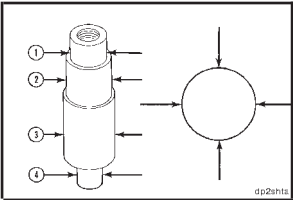
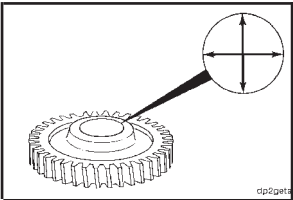
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.																			
	Shaft End Clearance	0.023 mm 0.038 mm	MIN MAX	0.0009 in 0.0015 in																		
	<table><thead><tr><th colspan="6">Regulator Spring Specifications</th></tr><tr><th>Part No.</th><th>Wire Dia. mm [inch]</th><th>No. Coils</th><th>Load Kg [lb]</th><th>Length mm [inch]</th><th>Free Length mm [inch]</th></tr></thead><tbody><tr><td>3068424</td><td>1.52 [.060]</td><td>5.25</td><td>4.0 [8.9]</td><td>16.0 [.631]</td><td>21.16 [.8337]</td></tr></tbody></table>				Regulator Spring Specifications						Part No.	Wire Dia. mm [inch]	No. Coils	Load Kg [lb]	Length mm [inch]	Free Length mm [inch]	3068424	1.52 [.060]	5.25	4.0 [8.9]	16.0 [.631]	21.16 [.8337]
Regulator Spring Specifications																						
Part No.	Wire Dia. mm [inch]	No. Coils	Load Kg [lb]	Length mm [inch]	Free Length mm [inch]																	
3068424	1.52 [.060]	5.25	4.0 [8.9]	16.0 [.631]	21.16 [.8337]																	
	Fuel Pump - Torque Values Cover to Body Capscrews	18 N•m		13 ft-lb																		
	Check Valve Elbow	6 N•m		50 in-lb																		
	Support to Pum Filter Screen	18 N•m 18 N•m		13 ft-lb 13 ft-lb																		
	Damper Assembly	18 N•m		13 ft-lb																		
	Fuel Shutoff	3 N•m		30 in-lb																		

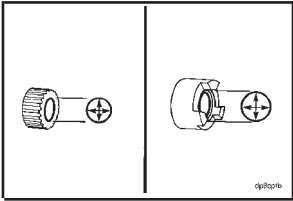
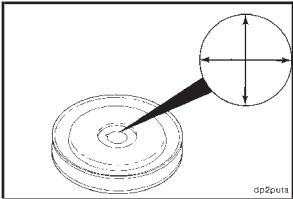
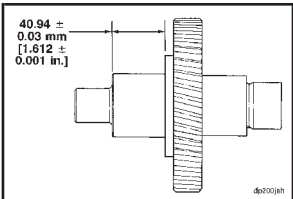
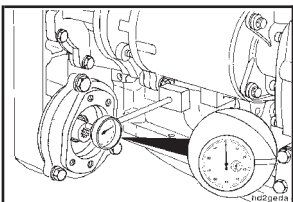
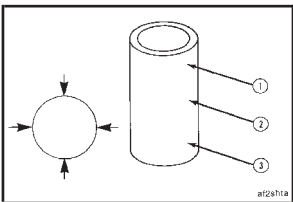
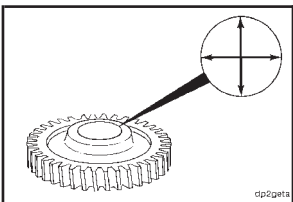
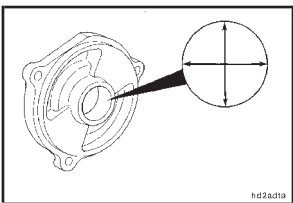
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Injectors - Rebuild Specifications				
CELECT™ injectors cannot presently be rebuilt.				
				
Lubricating Oil System - Specifications				
Oil Pan Capacity:				
• Automotive		26.5 litres 34.0 litres	Low High	7.0 gal. 9.0 gal.
				
Lubricating Oil Thermostat				
• Initial Opening Temperature		106°C 108°C	MIN MAX	223°F 227°F
• Fully Open Temperature		115°C	MAX	240°F
• Maximum Opening Distance		6.35 mm	MAX	0.250 in
				
Lubricating Oil Filter Head Bypass Valve Spring:				
• Free Length		37.68 mm 38.52 mm	MIN MAX	1.483 in 1.517 in
• Load at 29.65 mm [1.167 inch]		110.1 N 121.7 N	MIN MAX	24.751 lbf 27.359 lbf
				
Lubricating Oil Pump Shaft End Clearance				
		0.064 mm 0.269 mm	MIN MAX	0.0025 in 0.0106 in
				
Lubricating Oil Pump Body and Cover Shaft Bore I.D.				
		18.720 mm 18.746 mm	MIN MAX	0.7370 in 0.7380 in
				
Lubricating Oil Pump Gear Shaft O.D.				
		18.669 mm 18.681 mm	MIN MAX	0.7350 in 0.7355 in
				

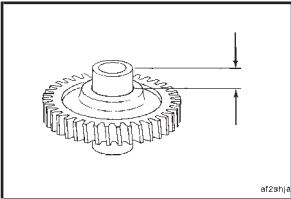
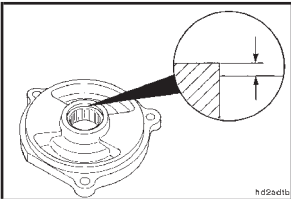
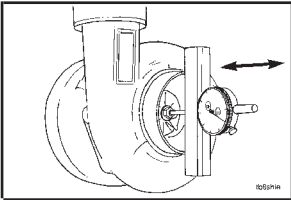
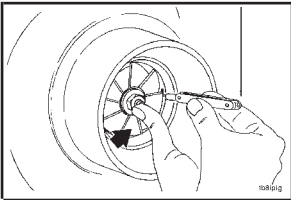
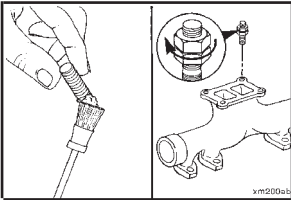
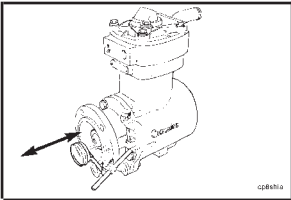
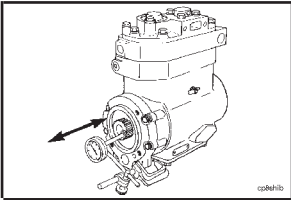
	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Lubricating Oil Pump Drive Gear Bore I.D.		18.600 mm	MIN	0.7323 in
			18.625 mm	MAX	0.7333 in
	Lubricating Oil Pump Gear to Body Clearance		9.50 mm	MIN	0.37 in
			12.00 mm	MAX	0.47 in
	Lubricating Oil System - Torque Values Rear Cover Plate		20 N•m		18 ft-lb
	Cooling System - Rebuild Specifications Water Pump Body Bearing Bore I.D.		51.996 mm	MIN	2.0471 in
			52.011 mm	MAX	2.0477 in
	Water and Oil Seal Bore I.D.:	1	36.450 mm	MIN	1.4350 in
			36.475 mm	MAX	1.4360 in
		2	40.975 mm	MIN	1.6132 in
			41.025 mm	MAX	1.6152 in
	Water Pump Impeller Bore I.D.		15.339 mm	MIN	0.6039 in
			15.365 mm	MAX	0.6049 in
	Water Pump Drive Gear Bore I.D.		33.900 mm	MIN	1.3346 in
			33.925 mm	MAX	1.3356 in

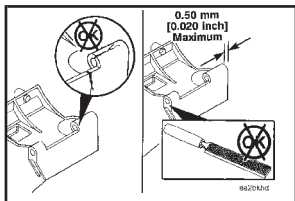
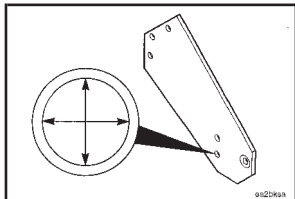
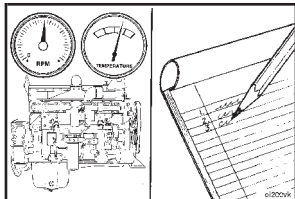
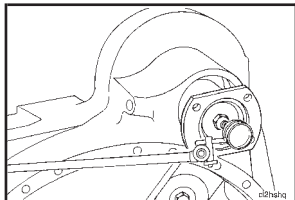
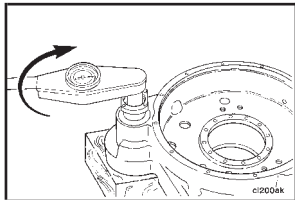
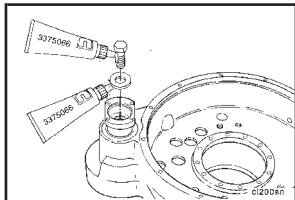
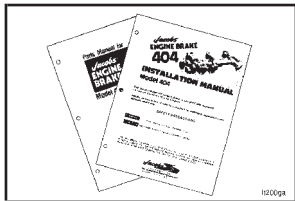
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.		
Water Pump Shaft Journals O.D.	1	15.389 mm 15.402 mm	MIN MAX	0.6059 in 0.6064 in		
	2	15.897 mm 15.910 mm	MIN MAX	0.6259 in 0.6264 in		
	3	24.999 mm 25.009 mm	MIN MAX	0.9842 in 0.9846 in		
	4	24.999 mm 25.009 mm	MIN MAX	0.9842 in 0.9846 in		
Water Pump Shaft Journals O.D. (Cont'd.)	5	33.951 mm 33.976 mm	MIN MAX	1.3366 in 1.3376 in		
	6	29.987 mm 30.000 mm	MIN MAX	1.1806 in 1.1811 in		
	7	27.975 mm 28.025 mm	MIN MAX	1.1014 in 1.1033 in		
	8	27.887 mm 27.900 mm	MIN MAX	1.0979 in 1.0984 in		
Water Pump Impeller Hub To Body Surface Distance		13.52 mm 13.72 mm	MIN MAX	0.532 in 0.540 in		
Fan Hub Shaft End Clearance		0.076 mm 0.406 mm	MIN MAX	0.0030 in 0.0160 in		
Fan Hub Shaft O.D.	1	34.590 mm 34.963 mm	MIN MAX	1.3760 in 1.3765 in		
	2	34.912 mm 34.925 mm	MIN MAX	1.3745 in 1.3750 in		
Fan Hub Bearing Bore I.D.		65.038 mm 65.076 mm	MIN MAX	2.5605 in 2.5620 in		
Fan Hub Flange O.D. and I.D.	1	48.975 mm 49.000 mm	MIN MAX	1.9281 in 1.9291 in		
	2	34.849 mm 34.875 mm	MIN MAX	1.3720 in 1.3730 in		

	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Fan Hub Face to Face Distance		73.4 mm	MIN	2.890 in
			74.0 mm	MAX	2.913 in
	Fan Idler Pulley End Clearance		0.05 mm	MIN	0.002 in
			0.25 mm	MAX	0.010 in
	Fan Idler Pulley Shaft O.D.:	1	32.975 mm	MIN	1.2982 in
			33.000 mm	MAX	1.2992 in
		2	19.037 mm	MIN	0.7495 in
			19.050 mm	MAX	0.7500 in
	Fan Idler Pulley Bearing Bore I.D.		45.199 mm	MIN	1.7795 in
			45.224 mm	MAX	1.7805 in
Note: The front and rear bearing bores are the same inside diameter.					
	Fan Idler Pulley Bore Oil Seal Installed Depth		0.00 mm	MIN	0.000 in
			0.25 mm	MAX	0.010 in
Note: Measure depth from the mounting flange surface, as shown.					
	Thermostat, Coolant - Operating Temperature		81°C	MIN	178°F
			83°C	MAX	182°F
			93°C	MAX	200°F
			9.52 mm	MAX	0.375 in
	Cooling System - Torque Values		47 N•m		35 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Fan Hub Retaining Capscrew		61 N•m	45 ft-lb	
Fan Idler Pulley Assembly Retaining Capscrew		47 N•m	35 ft-lb	
Drive Units - Rebuild Specifications				
Accessory Drive Shaft End Clearance		0.10 mm 0.30 mm	MIN MAX 0.004 in 0.012 in	
Accessory Drive Housing Bearing Bore I.D.		47.676 mm 47.775 mm	MIN MAX 1.8770 in 1.8809 in	
Accessory Thrust Bearing Thickness		6.084 mm 6.312 mm	MIN MAX 0.2395 in 0.2485 in	
Accessory Drive Shaft Journal O.D.	1	34.984 mm 35.000 mm	MIN MAX 1.3773 in 1.3779 in	
	2	44.975 mm 45.000 mm	MIN MAX 1.7706 in 1.7716 in	
	3	47.554 mm 47.570 mm	MIN MAX 1.8722 in 1.8728 in	
	4	25.476 mm 25.489 mm	MIN MAX 1.0030 in 1.0035 in	
Accessory Drive Gear Bore I.D.		47.484 mm 47.509 mm	MIN MAX 1.8694 in 1.8704 in	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	Accessory Drive Splined Coupling I.D.		25.400 mm 25.425 mm	MIN MAX	1.0000 in 1.0010 in
	Accessory Drive Hub Coupling I.D.		25.425 mm 25.438 mm	MIN MAX	1.0010 in 1.0015 in
	Accessory Drive Pulley Bore I.D.:		35.060 mm 35.098 mm	MIN MAX	1.3803 in 1.3818 in
	Drive Shaft Installed Height in the Drive Gear		40.91 mm 40.97 mm	MIN MAX	1.611 in 1.613 in
	Hydraulic Pump Drive Shaft End Clearance		0.076 mm 0.635 mm	MIN MAX	0.0030 in 0.0250 in
	Note: The hydraulic pump drive must be mounted to the engine to check the drive shaft end clearance.				
	Hydraulic Pump Drive Shaft O.D.		34.984 mm 35.000 mm	MIN MAX	1.3773 in 1.3780 in
	Note: Measure the drive shaft outside diameter in two positions 90 degrees apart at points (1, 2 and 3).				
	Hydraulic Pump Drive Gear Bore I.D.		34.925 mm 34.950 mm	MIN MAX	1.3750 in 1.3760 in
	Hydraulic Pump Drive Rear Adapter Bore I.D.		41.967 mm 41.992 mm	MIN MAX	1.6522 in 1.6532 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Hydraulic Pump Drive Shaft Installed Height in the Drive Gear		18.50 mm 19.50 mm	MIN MAX	0.728 in 0.768 in
				
Hydraulic Pump Drive Rear Adapter Bore Bearing Depth		0.254 mm 0.762 mm	MIN MAX	0.0100 in 0.0300 in
				
Air Intake System - Inspection Specifications				
Turbocharger Shaft Axial Movement		0.038 mm 0.089 mm	MIN MAX	0.0015 in 0.0035 in
				
Compressor Wheel Radial Clearance		0.15 mm 0.64 mm	MIN MAX	0.006 in 0.025 in
Note: Specifications and instructions for rebuilding the turbocharger are provided in the Turbocharger Component Shop Manual, Bulletin No. 3379461.				
Exhaust System - Torque Values				
Exhaust Manifold Flange To Turbocharger Mounting Stud Torque		65 N•m		50 ft-lb
Note: Apply a coat of anti-seize compound to the threads. Use two mounting nuts locked together to tighten the studs.				
Air Equipment - Inspection Specifications				
Single Cylinder Air Compressor Crankshaft End Clearance		0.05 mm 0.15 mm	MIN MAX	0.002 in 0.006 in
Note: Specifications and instructions for rebuilding the single cylinder air compressor are provided in the Air Equipment Rebuild Manual, Bulletin No. 3810457.				
Two Cylinder Air Compressor Crankshaft End Clearance		0.05 mm 0.19 mm	MIN MAX	0.002 in 0.008 in
Note: Specifications and instructions for rebuilding the two cylinder air compressor are provided in the Air Equipment Rebuild Manual, Bulletin No. 3810347.				

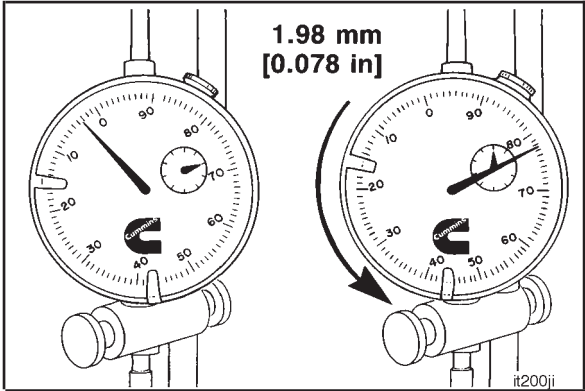
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Electrical Equipment - Inspection Specifications				
	Alternator Bracket (Bus Applications) Lower Bracket Front to Rear Mounting Surface	210.7 mm	MIN	8.30 in
	Automatic Tensioner Bracket Locator Hole I.D.	4.00 mm 4.50 mm	MIN MAX	0.354 in 0.374 in
Engine Testing - Test Specifications				
	Note: The specifications and instructions for testing the engine are provided in this manual. Refer to Engine Testing - Group 14.			
Mounting Adaptations - Rebuild Specifications				
	REPTO Shaft End Play	0.00 mm 0.03 mm	MIN MAX	0.000 in 0.001 in
	REPTO Rolling Resistance	0.6 N•m 1.1 N•m	MIN MAX	5 in-lb 10 in-lb
	REPTO Output Flange Capscrew	205 N•m		150 ft-lb
Vehicle Braking - Rebuild Specifications				
	Note: The specifications and instructions for rebuilding the Jacobs® Brake are provided in the Jacobs® Brake Installation Manual. Refer to Vehicle Braking - Group 20.			

Injection Timing Codes

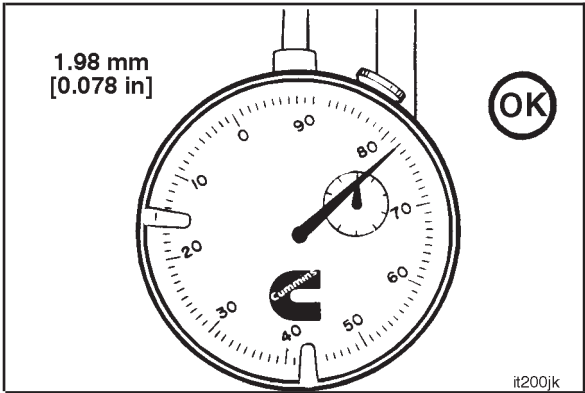
Note: Injection timing is measured at 5.161 mm [0.2032 inch] BTDC piston travel.

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]

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
.380 in.	3822524		620	140	270 to 490	60 to 110
.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

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

CONVERSION FACTOR: 1 INCH = 25.4MM

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	2.3527	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



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

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

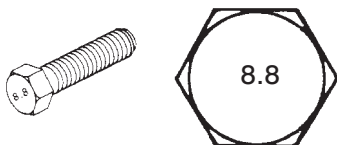
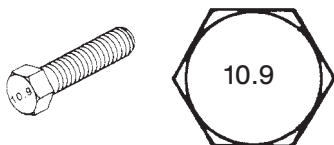
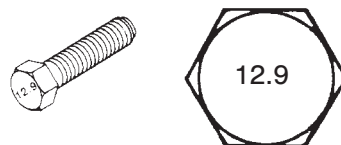
The following examples indicate how capscrews are identified:

Metric - M8-1.25 X 25			U.S. Customary [5/16 X 18 X 1-1/2]		
M8	1.25	25	5/16	18	1-1/2
Major Thread Diameter in Millimeters	Distance Between Threads in Millimeters	Length in Millimeters	Major Thread Diameter in Inches	Number Threads per Inch	Length in Inches

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, give consideration to converting the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values - Metric

Commercial Steel Class													
8.8					10.9				12.9				
Capscrew Head Markings													
													
Body Size	Torque				Torque				Torque				
Diam.	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum		
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	
6	9	5	7	4	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 in	Actual Thread O.D. in	In Aluminum Components		In Cast Iron or Steel Components	
		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

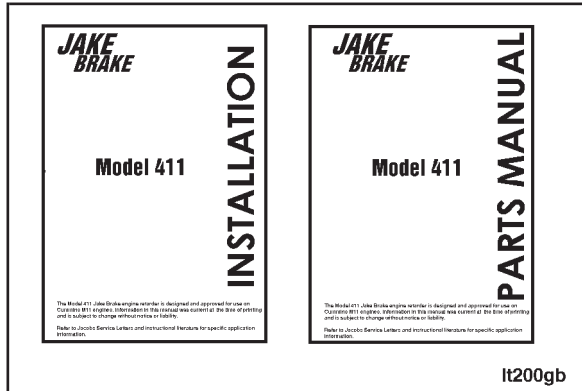
NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power.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

Section 20 - Vehicle Braking - Group 20
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Vehicle Braking - General Information

For installation and adjustment of the Jacobs® Engine Brake, Model 411, refer to the installation and parts manuals. The Installation Manual, Form No. 018874, and the Parts Manual, Form No. 018875, can be purchased from a Jacobs® Engine Brake dealer, or refer to the manufacturer at the following address:



The Jacobs® Manufacturing Company
Vehicle Equipment Division
22 East Dudley Town Road
Bloomfield, CT 06002
U.S.A.
Telephone: (203) 243-1441

Section L - Service Literature
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Additional Service Literature

The following publications can be purchased by filling in and mailing the Literature Order Form:

BULLETIN NO.	TITLE OF PUBLICATION
3377710	¹ Service Products Catalog
3379133	Control Parts List
3387137	Troubleshooting Driveability Complaints
3387245	Troubleshooting Excessive Fuel Consumption
3387266	Cold Weather Operation
3810303	Parts Reuse Guidelines
3666083	Standard Repair Times, M11 Series Engines
3810387	Analysis and Prevention of Bearing Failures
3810388	Overhead Reuse Guidelines, L10 Series Engines
3666084	Troubleshooting and Repair Manual, CELECT™ System
3666075	Shop Manual
3666076	Specifications Manual, M11 Series Engines
3810490	Shop and Installation Manual, Rear Engine Power Takeoff
3666072	Operation and Maintenance Manual

¹ This publication is available only from Service Products Company, Inc. Refer to the Service Literature Ordering Locations on the following page.

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 or (for U.S.A. and Canada) by calling Cummins Toll Free Number 1-800-DIESELS (1-800-343-7357).

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, contact 1-800-DIESELS (1-800-343-7357) (for U.S.A. and Canada).

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, contact 1-800-DIESELS (1-800-343-7357) (for U.S.A. and Canada).

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: _____ Zip Code: _____

Country: _____

SHIP TO: (Name and address where literature is to be shipped)

Name: _____

Street Address: _____

City: _____ State: _____ Zip Code: _____

Country: _____

Please cut on dotted line

Mail the Literature Order Form along with your ship-to address to your nearest Cummins distributor.

FROM:

Name: _____

Street Address: _____

City: _____ State: _____ Zip Code: _____

Country: _____

SHIP TO: (Name and address where literature is to be shipped)

Name: _____

Street Address: _____

City: _____ State: _____ Zip Code: _____

Country: _____

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Component Manufacturers' Addresses

NOTE: The following list contains addresses and telephone numbers of suppliers of accessories used on Cummins engines. Suppliers may 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. Pomona Avenue
Kansas City, MO 64153
Telephone: (816) 891-2470

Air Cylinders

Bendix Ltd.
Douglas Road
Kingswood
Bristol
England
Telephone: 0272-671881

Catching Engineering
2101 Roberts Drive
Broadview, IL 60153
Telephone: (312) 344-2334

Air Heaters

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone: (509) 534-6171

Air Starting Motors

Ingersoll Rand
Chorley New Road
Horwich
Bolton
Lancashire
England
BL6 6JN
Telephone: 0204-65544

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone: (312) 530-3800

StartMaster
Air Starting Systems
A Division of Sycon Corporation
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: 0895-833633

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 0744-21663

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

C. E. Niehoff
2021 Lee Street
Evanston, IL 60202
Telephone: (708) 866-6030

Delco-Remy
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-7838

Leece-Neville Corp.
1374 E. 51st St.
Cleveland, OH 44013
Telephone: (216) 431-0740

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. Ind. Products
P.O. Box 77
Wigan
Lancashire
WN2 4XQ
England
Telephone: 0942-59221

Dayco Corp.
Belt Technical Center
P.O. Box 3258
Springfield, MO 65804
Telephone: (417) 881-7440

Gates Rubber Company
5610 Crawfordsville Road
Suite 2002
Speedway, IN 46224
Telephone: (317) 248-0386

Goodyear Tire and
Rubber Company
49 South Franklin Road
Indianapolis, IN 46219
Telephone: (317) 898-4170

Catalytic Convertors

Donaldson Company, Inc.
1400 West 94th Street
P.O. Box 1299
Minneapolis, MN 55440
Telephone: (612) 887-3131

Nelson Industries, Inc.
Exhaust and Filtration Systems
Highway 51 West, P.O. Box 428
Stoughton, WI 53589
Telephone: (608) 873-4373

Walker Manufacturing
3901 Willis Road
P.O. Box 157
Grass Lake, MI 49240
Telephone: (517) 522-5500

Clutches

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belguim
Telephone: 067-224941

Twin Disc Clutch Co.
Racine, WI 53403
Telephone: (414) 634-1981

Coolant Heaters

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Drive Plates

Detroit Diesel Allison
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206
Telephone: (317) 244-1511

Electric Starting Motors

Bute Electric
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 0744-21663

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
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-7838

Leece-Neville Corp.
1374 E. 51st Street
Cleveland, OH 44013
Telephone: (216) 431-0740

Nippondenso Sales, Inc.
24777 Denso Drive
P.O. Box 5133
Southfield, MI 48086-5133
Telephone: (313) 350-7500

Nippondenso of Los Angeles, Inc.
3900 Via Oro Avenue
Long Beach, CA 90810
Telephone: (310) 834-6352

Engine Protection Controls

Teddington Industrial
Equipment
Windmill Road
Sunburn on Thames
Middlesex
TW16 7HF
England
Telephone: 09327-85500

The Nason Company
10388 Enterprise Drive
Davisburg, MI 48019
Telephone: (313) 625-5381

Fan Clutches

Holset Engineering Co. Ltd.
P.O. Box 9
Turnbridge
Huddersfield
England
Telephone: 0484-22244

Horton Industries, Inc.
P.O. Box 9455
Minneapolis, MN 55440
Telephone: (612) 378-6410

Rockford Division
Borg-Warner Corporation
1200 Windsor Road
P.O. Box 7007
Rockford, IL 61125-7007
Telephone: (815) 633-7460

Transportation Components Group
Facet Enterprises, Inc.
Elmira, NY 14903
Telephone: (607) 737-8212

Fans

Truflo Ltd.
Westwood Road
Birmingham
B6 7JF
England
Telephone: 021-557-4101

Hayes-Albion
1999 Wildwood Avenue
Jackson, MI 49202
Telephone: (517) 782-9421

Engineering Cooling Systems
201 W. Carmel Drive
Carmel, IN 46032
Telephone: (317) 846-3438

Brookside
McCordsville, IN 46055
Telephone: (317) 335-2014

Aerovent
8777 Purdue Rd.
Indianapolis, IN 46268
Telephone: (317) 872-0030

Kysor
1100 Wright Street
Cadillac, MI 49601
Telephone: (616) 775-4681

Schwitzer
1125 Brookside Avenue
P.O. Box 80-B
Indianapolis, IN 46206
Telephone: (317) 269-3100

Filters

Fleetguard International Corp.
Cavalry Hill Industrial Park
Weedon
Northampton NN7 4TD
England
Telephone: 0327-41313

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Flexplates

Corrugated Packing and
Sheet Metal
Hamsterley
Newcastle Upon Tyne
Telephone: 0207-560-505

Allison Transmission
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206
Telephone: (317) 244-1511

Allison Transmission
Division of General Motors
36501 Van Born Road
Romulus, MI 48174
Telephone: (313) 595-5711

Midwest Mfg. Co.
30161 Southfield Road
Southfield, MI 48076
Telephone: (313) 642-5355

Wohlert Corporation
708 East Grand River Avenue
Lansing, MI 48906
Telephone: (517) 485-3750

Fuel Warmers

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Gauges

A.I.S.
Dyffon Industrial Estate
Ystrad Mynach
Hengoed
Mid Glamorgan
CF8 7XD
England
Telephone: 0443-812791

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 0732-359888

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: 0707-53444

Datcon Instrument Co.
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauge of Texas
11637 Denton Drive
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: 0753-26835

Woodward Governor Co.
1000 E. Drake Road
Fort Collins, CO 80522
Telephone: (303) 482-5811

Barber Colman Co.
1300 Rock Street
Rockford, IL 61101
Telephone: (815) 877-0241

United Technologies
Diesel Systems
1000 Jorie Blvd.
Oak Brook, IL 60521
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 Eaton Ltd.
Priory Road
Stroud
Rochester
Kent
ME2 2BD
Telephone: 0634-71773

Honeywell Control Systems Ltd.
Honeywell House
Charles Square
Bracknell
Berks RG12 1EB
Telephone: 0344-424555

Sundstrand Hydratec Ltd.
Cheney Manor Trading Estate
Swindon
Wiltshire
SN2 2PZ
England
Telephone: 0793-30101

Sperry Vickers
1401 Crooks Road
Troy, MI 48084
Telephone: (313) 280-3000

Z.F.
P.O. Box 1340
Grafvonsoden Strasse
5-9 D7070
Schwaebisch Gmuend
West Germany
Telephone: 7070-7171-31510

Oil Heaters

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone: (509) 534-6171

Torque Converters

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belgium
Telephone: 067-224941

Twin Disc Clutch Co.
Racine, WI 53403
Telephone: (414) 634-1981

Rockford Division
Borg-Warner Corporation
1200 Windsor Road
P.O. Box 7007
Rockford, IL 61125-7007
Telephone: (815) 633-7460

Modine
1500 DeKoven Avenue
Racine, WI 53401
Telephone: (414) 636-1640

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