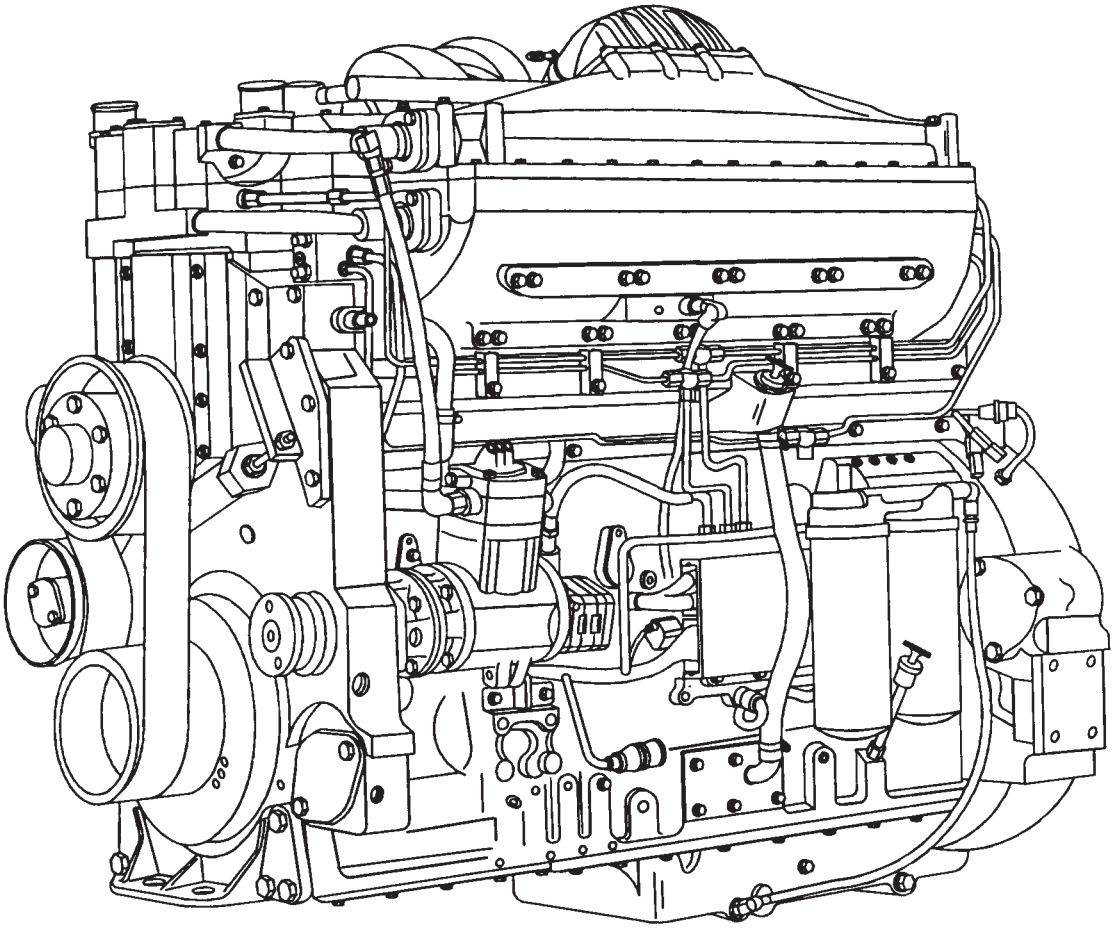
Shop Manual
QSK19 Series
Engines



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Foreword

This manual contains complete rebuild procedures and specifications. Disassembly, cleaning, inspection, and assembly instructions are included. A listing of accessory and component suppliers is located in Section M - Component Manufacturers. 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 Section i - Introduction.

The repair procedures in this manual are based on the engine or component removed from chassis. 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 (for example: Troubleshooting and Repair, Specifications, and Alternative Repair) are available and can be ordered by filling out and mailing the Literature Order Form located in Section L - Service Literature.

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

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

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

Table of Contents

Section i - Introduction

Section Contents

About the Manual

This manual contains information needed to correctly operate and maintain your engine as recommended by Cummins Engine Company, Inc. Additional service literature (Shop Manual, Troubleshooting and Repair Manual, etc.) can be ordered by filling out and mailing the Literature Order Form located in Service Literature, Section L.

This manual does **not** cover vehicle or equipment maintenance procedures. Consult the vehicle or equipment manufacturer for specific maintenance recommendations.

Both metric and U.S. customary values are listed in this manual. The metric value is listed first, followed by the U.S. customary in brackets.

Numerous illustrations and symbols are used to aid in understanding the meaning of the text. Refer to page i-3 through i-6 for a complete listing of symbols and their definitions.

Each section is preceded by a Section Contents to aid in locating information more quickly.

How to Use the Manual

This manual is organized according to the maintenance intervals that are to be performed. A table that states the required intervals and the checks to be made is located in Section 2. Locate the maintenance interval that you are performing and follow all the procedure steps given in that section. In addition, all the previous maintenance interval procedures **must** also be performed.

Keep a record of all the checks and inspections made. A record form for recording date, mileage/kilometer or hours, and what maintenance checks were performed is located in Section 2.

Refer to Section T for a troubleshooting guide to your engine. Follow the Troubleshooting Section Contents for locating and correcting engine problems.

Refer to Section V for specifications recommended by Cummins Engine Company, Inc. for your engine. Specifications and torque values for each engine system are given in that section.

NOTE: Discharge of oil or oily water into or upon the water is a direct violation of today's laws. Violators are subject to a penalty of various monetary charges. Dispose of these substances in accordance with standards set by the EPA.

Symbols

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

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

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

Indicates a **REMOVAL or DISASSEMBLY** step.

Indicates an **INSTALLATION or ASSEMBLY** step.

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

LUBRICATE the part or assembly.

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

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

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

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

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Simbolos

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

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

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

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

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

Se requiere **INSPECCION.**

LIMPIESE la pieza o el montaje.

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

LUBRIQUESE la pieza o el montaje.

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

APRIETESE hasta un par torsor específico.

EJECUTESE una **MEDICION** eléctrica.

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

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

Symbole

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

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

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

AUSBAU bzw. **ZERLEGEN.**

EINBAU bzw. **ZUSAMMENBAU.**

INSPEKTION erforderlich.

Teil oder Baugruppe **REINIGEN.**

DIMENSION - oder **ZEITMESSUNG.**

Teil oder Baugruppe **ÖLEN.**

WERKZEUGGRÖSSE wird angegeben.

ANZUG auf vorgeschriebenes Drehmoment erforderlich.

Elektrische **MESSUNG DURCHFÜHREN.**

Weitere Informationen an anderer Stelle bzw. in anderen Handbüchern.

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

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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 pese 23 kg [50 lb] ou davantage. Pour eviter toute blessure, employer un appariel de levage ou demander de l'aide pour le soulever.

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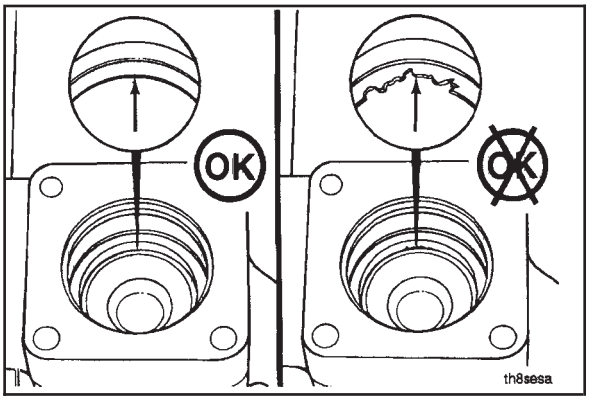
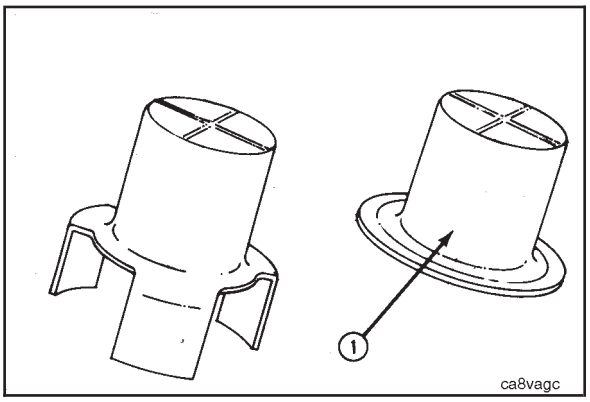


Illustrations

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



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

General Safety Instructions

Important Safety Notice

⚠ WARNING ⚠

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

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

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

General Repair Instructions

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

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

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

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

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

Welding on a Vehicle with Electronic Components

⚠ CAUTION ⚠

Improper welding can destroy the vehicle's electronic components. Before welding, disconnect the negative (-) and then positive (+) battery cables. Attach the welder ground cable within 0.61 meters [2 feet] of the part being welded. Do NOT connect the welder ground cable to any electronic component or component mounting location. Do NOT weld on the engine or engine-mounted components.

General Cleaning Instructions

Solvent and Acid Cleaning

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

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

⚠ WARNING ⚠

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

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

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

Steam Cleaning

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

⚠ WARNING ⚠

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

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

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

Glass or Plastic Bead Cleaning

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

△ CAUTION △

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

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

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

1. Bead size:
   - 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.

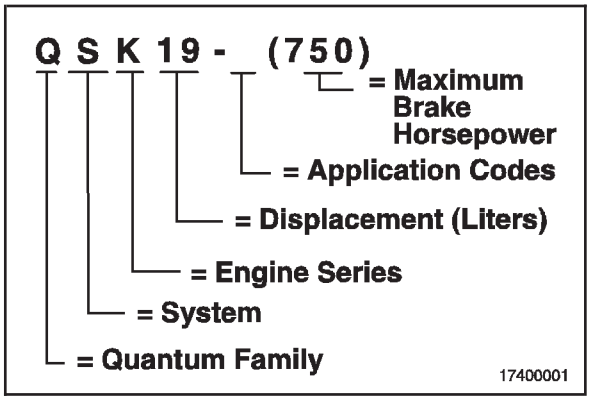
NOTES

Section E - Engine Identification

Section Contents

Engine Identification

Cummins Engine Nomenclature



The model name provides identification data for the engine. Refer to the illustration for the model name identification.

The application codes are:

A = Agricultural

C = Construction

D = Generator Drive

F = Fire Pump

G = Generator Set

L = Locomotive

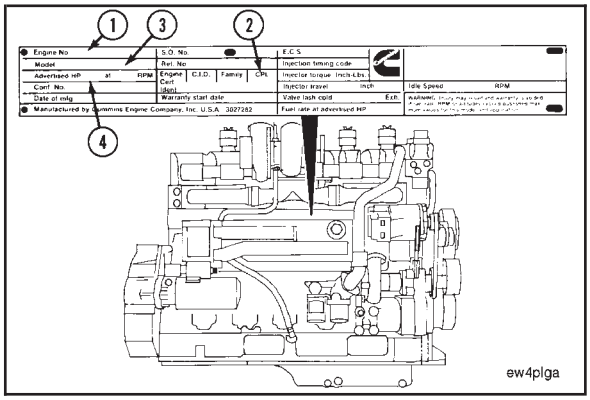
M = Marine

P = Power Unit

R = Railcar

T = Tactical Military

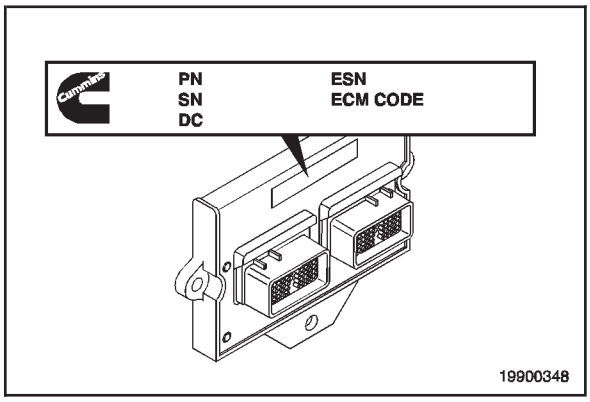
Engine Dataplate



The engine dataplate shows specific information about the engine. The engine serial number (ESN) (1), Control Parts List (CPL) (2), Model (3), and Horsepower and rpm rating (4) provide information for ordering parts and service needs.

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

ECM Dataplate



The external ECM dataplate is located on top on the ECM.

The dataplate contains the following:

- ECM part number (P/N)
- ECM serial number (S/N)
- Manufacturer date code (D/C)
- Engine serial number (ESN)
- ECM code identifying the software in the ECM

Specifications

General Specifications

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

Engine Speed ..... Refer to the fuel pump calibration data for optional speed rating.

Displacement ..... 19 liters [1150 C.I.D.]

Bore and Stroke ..... 158.75 mm x 158.75 mm [6.25 in x 6.25 in]

Engine Weight:
- Dry ..... 1720 kg [3800 lb]
- Wet ..... 2045 kg [4504 lb]

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

Valve and injector settings:
- Intake valve adjustment ..... 0.36 mm [0.014 in]
- Intake valve limits ..... 0.28 to 0.43 mm [0.011 to 0.017 in]
- Exhaust valve adjustment ..... 0.81 mm [0.032 in]
- Exhaust valve limits ..... 0.74 to 0.89 mm [0.029 to 0.035 in]
- Injector OBC Method adjustment (in engine) ..... 19 N•m [165 in-lb]

Compression Ratio:
- 525 HP to 600 HP-Jacket Water Aftercooled (JWAC) 17.0:1
- 600 HP to 750 HP-Low Temperature Aftercooled (LTA) 15.0:1

Crankshaft Rotation (Viewed from the front of the engine) ..... Clockwise

Air Intake System

Maximum Allowable Intake Restriction (at rated speed and load)
- With Clean Filter Element ..... 380 mm H_2O [15 in H_2O]
- With Dirty Filter Element ..... 635 mm H_2O [25 in H_2O]

Electrical System

Maximum Starting Circuit Resistance
- 24 - volt starter ..... 0.00200 Ohms

Battery Cable Sizes - American Wire Gauge (Maximum length in cranking motor circuit)

24 to 32 - volt
- No. 00 ..... 6.1 m [20 ft]
- No. 000 ..... 8.2 m [27 ft]
- No. 0000 or two No. 0* ..... 10.7 m [35 ft]
- Two No. 00 ..... 13.7 m [45 ft]

Minimum Cranking Speed Without Starting Aid ..... 150 rpm

* Two strands of No. 0 cable can be used instead of one No. 0000 cable, providing all connections are carefully made to provide equal current flow in each parallel cable.

NOTE: Starting aids, such as block heaters, lubricating oil pan heaters, etc., are available to aid in cold weather starting.

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

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

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

Fuel System

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

Basic Application Requirements

Engine Idle Speed ..... 600 to 1400 rpm

Fuel Inlet Maximum Restriction:
- Clean Fuel Filter ..... 100 mm Hg [4.0 in-Hg]
- Dirty Fuel Filter ..... 203 mm Hg [8.0 in-Hg]

Fuel Drain Line Restriction:
- With Check Valves ..... 0 to 21 kPa [0 to 3 psi]
- With Check Valves Removed* ..... 14 to 34 kPa [2 to 5 psi]

*All QSK19 engines are built with a check valve.

Fuel Check Valve Between Fuel Pump and Cylinder Head (Integral to Fuel Pump):
- Opening Pressure ..... 21 to 35 kPa [3 to 5 psi]

Engine Minimum Cranking Speed ..... 150 rpm

Fuel Check Valve in Fuel Drain Line:
- Opening Pressure ..... 13 to 25 mm Hg [1/4 to 1/2 psi]

Derate Engine Fuel Rate for High Altitude ..... 4% per 300 m [1000 ft] above 3600 m [12,000 ft]

Derate Engine Fuel Rate for Hot Weather ..... 2% per 11°C above 38°C [1% per 10°F above 100°F]

Shutoff Valve Solenoid Coil Resistance in Ohms 24VDC ..... 28 to 32 Ohms

Fuel Pump Cranking Pressure - Minimum: ..... 172 kPa [25 psi] @ 150 rpm

Fuel Pump Pressure - Minimum:
- 1500 rpm: ..... 1448 kPa [210 psi]
- 1800 rpm: ..... 1655 kPa [240 psi]
- 2100 rpm: ..... 1861 kPa [270 psi]
- 2350 rpm: ..... 1999 kPa [290 psi]

Fuel Filter Specifications (Cummins Engine Company, Inc. Standard No. 14,223)
Efficiency: ..... 98.7% at 10 microns
96.0% at 8 microns
86.0% at 5 microns
Water Removal: ..... Free = 95%
Emulsified = 95%

Lubricating Oil System

Oil Pressure (With 15W-40 Oil at 107° C [225° F])
At Idle (Minimum Allowable) ..... 138 kPa [20 psi]
At No Load Governed Speed ..... 345 to 483 kPa [50 to 70 psi]

Oil Temperature
Maximum ..... 120°C [250° F]

Oil Filter Capacity
Bypass Filter (Spin-On)(LF777 Fleetguard) ..... 2.3 Liters [0.6 U.S. Gallons]
Full-Flow Filter (Spin-On)(LF670 Fleetguard) ..... 2.7 Liters [0.7 U.S. Gallons]
Combination Filter (Two LF3000 Fleetguard) ..... 5.7 Liters [1.5 U.S. Gallons]

	Oil Pan Capacity (Liters)		[U.S. Gallons]	
Oil Pan Part No.	**High**	**Low**	**High**	**Low**
3096460	72	64	19	17
3086096	61	49	16	13
3086097	61	49	16	13
3331695	61	49	16	13
3331568	114	102	30	27

NOTE: When the rear gear train option is specified, add 7.6 liters [2 U.S. gallons] to the oil pan capacity listed above.

Cooling System

Coolant Capacity (Engine Only) ..... 32.2 liters [34 U.S. Quarts]

Standard Modulating Thermostat Range ..... 82°C to 94°C [180°F to 202°F]

Standard LTA Thermostat Range ..... 69°C to 78°C [157°F to 172°F]

Maximum Coolant Pressure (Exclusive of Pressure Cap) ..... 241 kPa [35 psi]

Maximum Allowable Top Tank Temperature ..... 100°C [212°F]

Minimum Recommended Top Tank Temperature ..... 70°C [160°F]

Maximum Allowable Deaeration Time ..... 25 Minutes

Minimum Allowable Drawdown or 20% of System Capacity (whichever is greater) ..... 11 liters [12 U.S. Quarts]

Minimum Allowable Pressure Cap ..... 50 kPa [7 psi]

Exhaust System

Back Pressure - Maximum (at rated speed and load): ..... 75 mm Hg [3.0 in Hg]

Exhaust Pipe Size (Normally Acceptable Inside Diameter):

- All Ratings ..... 152 mm [6.0 in]

Batteries (Specific Gravity)

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

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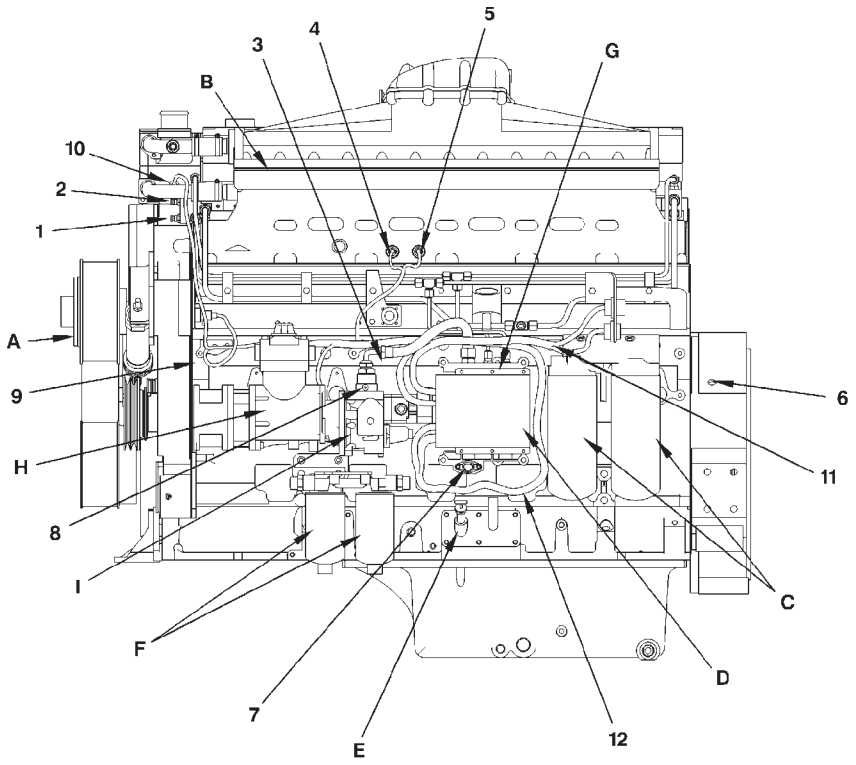
Engine Diagrams

Engine Views

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



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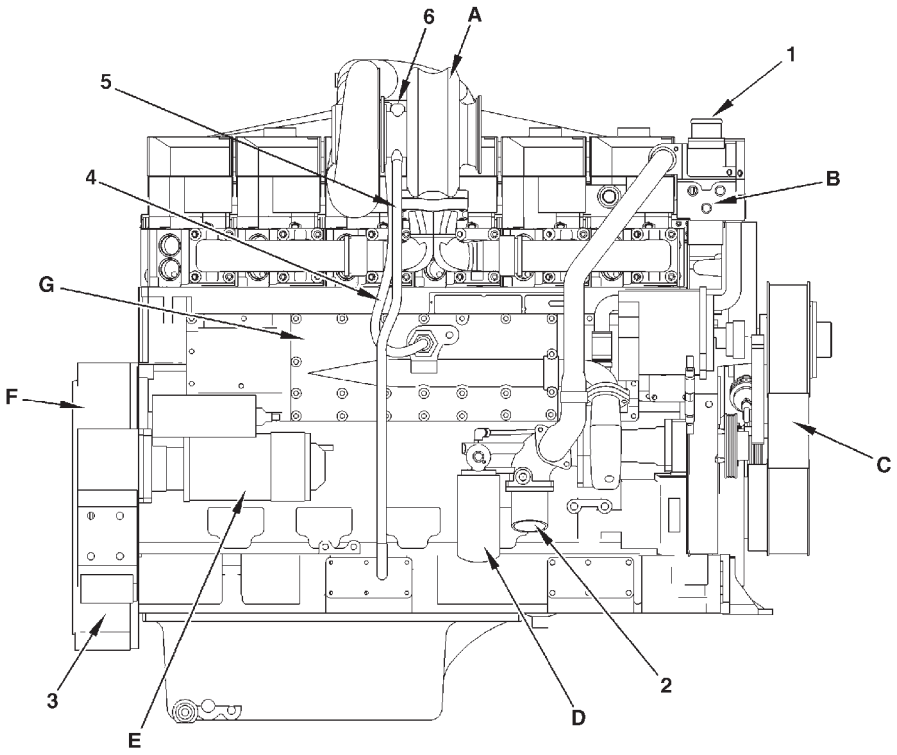
1. Fuel Rail Quick-Disconnect Fitting
2. Timing Rail Quick-Disconnect Fitting
3. Oil Pressure Sensor (OPS)
4. Intake Manifold Temperature Sensor (IMTS)
5. Intake Manifold Pressure Sensor (IMPS)
6. Engine Speed Sensor (ESS)(Generator Drive)
7. Ambient Air Pressure Sensor (AAPS)
8. Fuel Pump Outlet Quick-Disconnect Fitting
9. Engine Speed Sensor (**NOT** Generator Drive)
10. Coolant Temperature Sensor (CTS)
11. OEM Interface Harness
12. Engine Harness

A. Fan Hub
B. Aftercooler Assembly
C. Combination Full Flow/ Bypass Oil Filters
D. Electronic Control Module (ECM)
E. Dipstick
F. Fuel Filters
G. Control Valve Body
H. Air Compressor
I. Fuel Pump



EXHAUST SIDE - QSK19

1. Coolant Outlet
2. Coolant Inlet
3. Alternate Location for Engine Speed Sensor (ESS)(G-Drive ONLY)
4. Coolant Supply to Turbocharger
5. Turbocharger Oil Drain
6. Oil Inlet to Turbocharger

A. Turbocharger
B. Thermostat Housing
C. Fan Idler and Assembly
D. Coolant Filter
E. Starting Motor
F. Flywheel Housing
G. Oil Cooler

NOTES

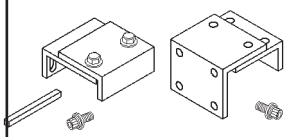
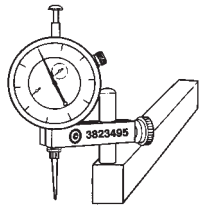
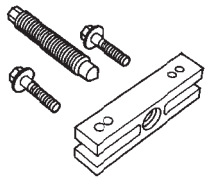
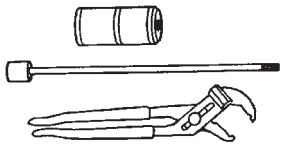
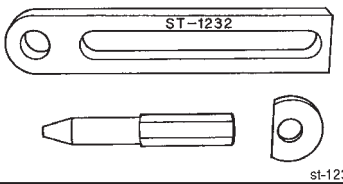
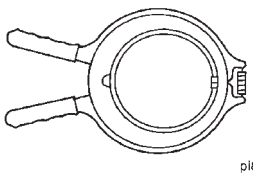
Section 0 - Complete Engine - Group 00

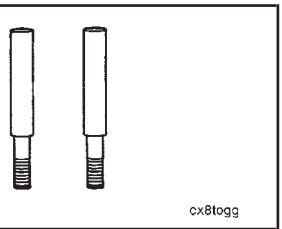
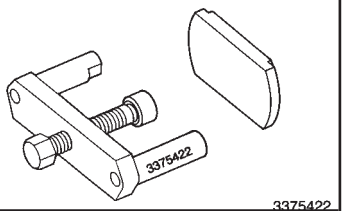
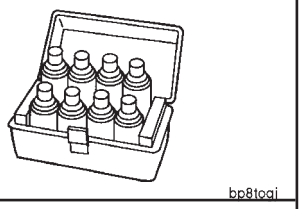
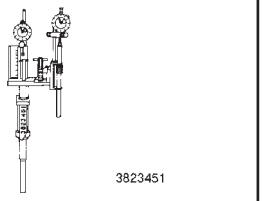
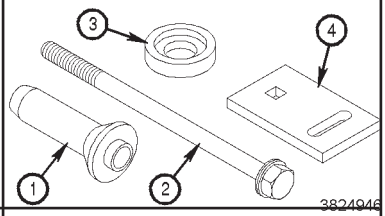
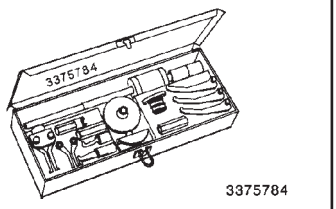
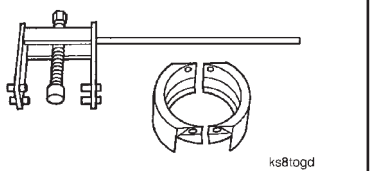
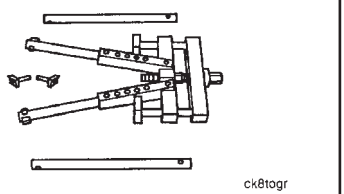
Section Contents

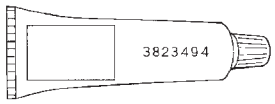
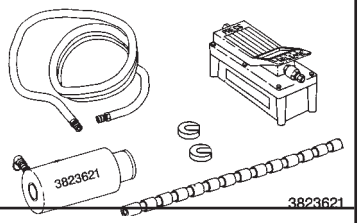
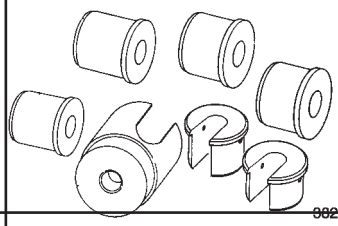
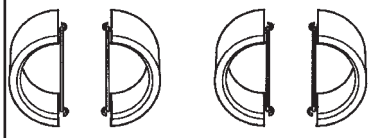
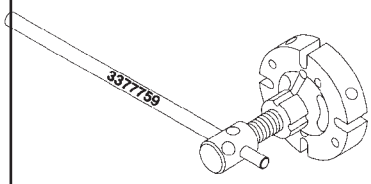
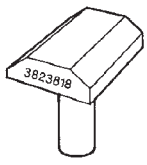
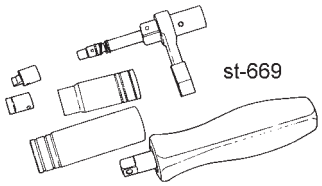
Service Tools

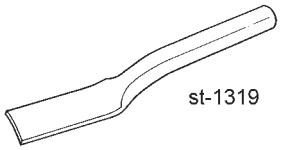
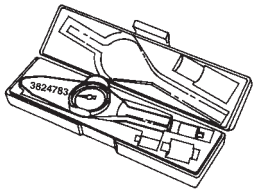
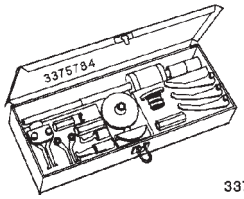
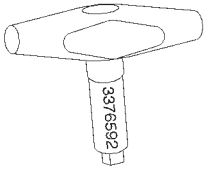
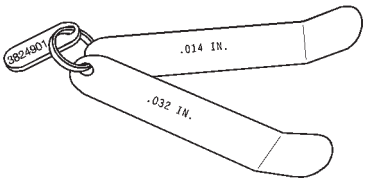
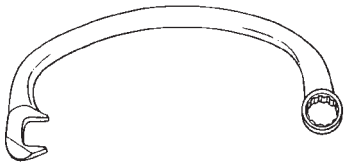
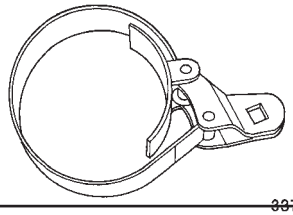
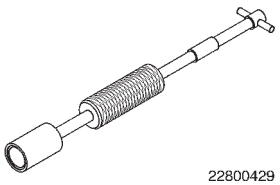
Engine Disassembly and Assembly

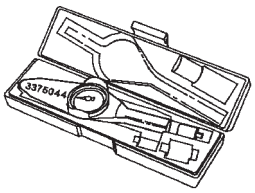
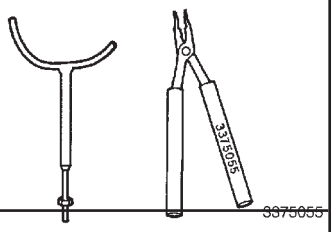
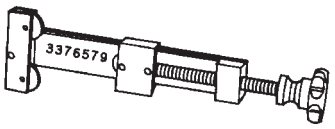
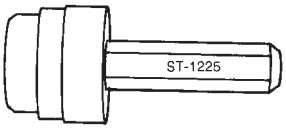
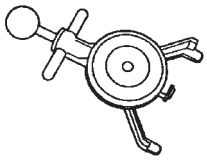
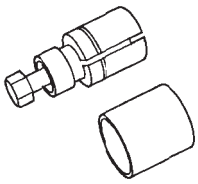
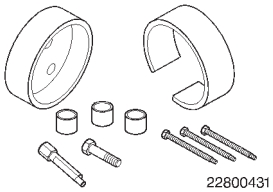
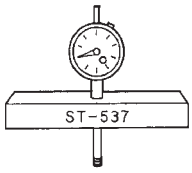
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

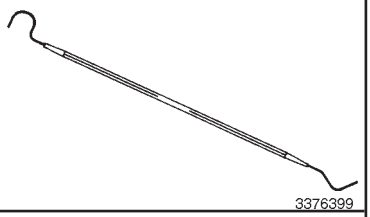
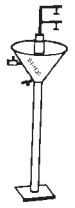
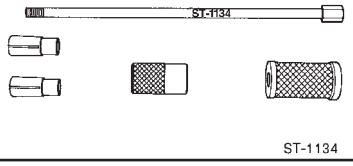
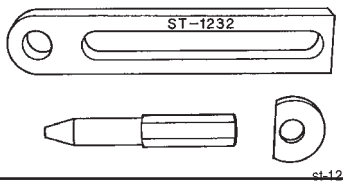
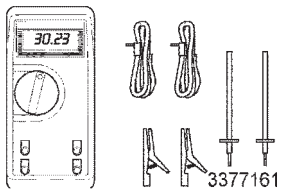
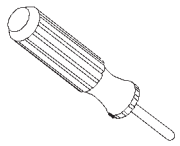
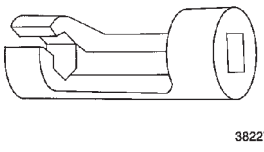
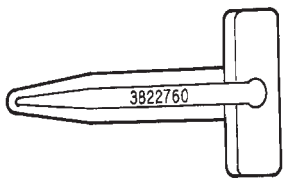
Tool No.	Tool Description	Tool Illustration
3375252	**Engine Support Bracket Kit** Support the front of the engine to allow the front support or oil pan adapter to be removed.	 22800428
3823495	**Depth Gauge Assembly** Measure cylinder liner protrusion and cylinder liner counterbore ledge angle.	 3823495
ST-647	**Puller** Remove the alternator and accessory drive pulleys.	 ad8toga
ST-1178	**Main Bearing Cap Pulley** Used to remove the main bearing caps from the cylinder block.	 mb8toga
ST-1232	**Drill Ream Fixture** Machine dowel hole to install oversize dowels in cylinder block and flywheel housing. Use with a drill, reamer, and the appropriate drill/ream bushing set.	 st-1232
ST-1269	**Piston Ring Expander** Designed to install piston rings on the piston without damaging or distorting the rings.	 pi8togd

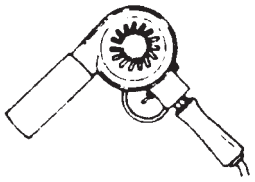
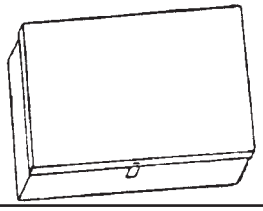
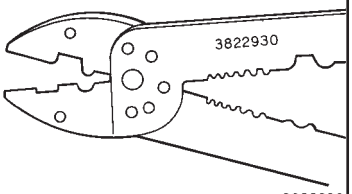
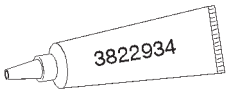
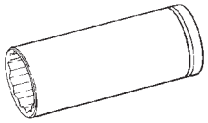
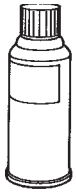
Tool No.	Tool Description	Tool Illustration
3375098	**Connecting Rod Guide Pins** Special nylon pins used to protect the crankshaft journal by guiding the connecting rod during installation or removal.	 cx8togg
3375422	**Liner Installation Tool** Install cylinder liner in engine.	 3375422
3375432	**Crack Detection Kit** Check for cracks in any engine component. Contains cleaner, developer, and penetrant.	 bp8togj
3824942	**Injection Timing Tool** Check injection timing. The timing fixture is designed to determine the push tube travel in relation to the piston travel.	 3823451
3824946	**Universal Injector Timing Tool Fixture Kit Update** Up-Date Kit for the previous Universal Injection Timing Tool, 3823451, to include QSK 19 hardware.	 3824946
3375784	**Light Duty Puller Kit** Remove small bushings, oil seals, and bearings.	 3375784
3375834	**Puller Assembly** Remove the crankshaft front gear from the crankshaft. Use with Part No. 3375835 Puller Jaw.	 ks8togd
3376015	**Universal Liner Puller** Remove cylinder liner from engine.	 ck8togr

Tool No.	Tool Description	Tool Illustration
3376326	**Pulley Installation Tool** Install the alternator and accessory drive pulleys.	 ad8togb
3823494	**Cummins Sealant** Used to prevent coolant or oil leaks. This is one part Room Temperature Vulcanizing (RTV) silicone rubber, adhesive, and sealant material having high heat and oil resistance, and low compression rate.	 3823494
3823621	**Camshaft Bushing Tool Hydraulic Actuator Kit** Hydraulic ram provides the force to install/remove cam bushings when used with installation/removal kit.	 3823621
3824863	**Camshaft Bushing Installation/Removal Kit** Used with the Part No. 3823621 Camshaft Bushing Hydraulic Actuator Kit to remove the camshaft bushing.	 3824842
3825150	**Camshaft Pilot** Install camshaft without damaging the camshaft bushings or camshaft.	 cg8togc
3824900	**Camshaft Gear Puller Kit** Remove camshaft gear from camshaft without removing camshaft from engine.	
3823818	**Main Bearing Roll-out Tool** Used to remove and install main bearing shell.	 3823818
ST-669	**Torque Wrench Adapter** Secures the rocker lever adjusting screw while tightening the lock nut.	

Tool No.	Tool Description	Tool Illustration
ST-1319	**Water Tube Driver** Used to install or remove the water transfer tubes from the rocker housings.	
3824783	**Torque Wrench** A dial-type torque wrench used to accurately adjust injectors in inch-pounds. Use of a clicker-type torque wrench is **not** recommended. 0-35 N•m [0-300 in-lb]	 3824783
3375784	**Light Duty Puller Kit** Used to remove small bushings, oil seals, and bearings.	 3375784
3376592	**Torque Wrench** Inch-pound torque wrench used to tighten the valve lever adjusting screw. Does **not** require screwdriver attachment.	 3376592
3824901	**Valve Setting Gauge Kit** Kit contains two 25.4 mm [1 in] wide feeler gauges for centering under the swivel foot of the rocker lever when setting the valves. The kit contains an intake valve gauge at 0.36 mm [0.014 in] and an exhaust valve gauge at 0.081 mm [0.032 in].	 3824901
3376845	**Fuel Pump/Air Compressor Wrench** Used to reach nuts when removing or installing the fuel pump or air compressor.	 3376845
3375049	**Filter Wrench** Remove spin-on filter.	 3375049
3823580 3824830	**Injector Removal / Installation Tool** Used to remove and install the QSK injector.	

Tool No.	Tool Description	Tool Illustration
3824783	**Torque Wrench** This is a [3/8 inch] drive, [300 in-lb], torque wrench used to set injector preload adjustments on engines with the high pressure fuel injection systems such as the QUANTUM™ Series K19.	
3375055	**Pressure Regulator Removal Tool** Remove retaining ring from lubricating oil pump regulator (on engine).	
3376579	**Filter Cutter** Open spin-on full-flow filter for inspection.	
ST-1225	**Thermostat Seal Mandrel** Install the thermostat seal in the thermostat housing.	
ST-1293	**Belt Tension Gauge** Measure the accessory drive belt tension.	
3376663	**Coupling Puller** Used to remove accessory drive coupling and spline coupling hub.	
3824760	**Oil Seal Remover/Installer** Used to remove small bushings, oil seals, and bearings.	
ST-537	**Dial depth gauge** This gauge is used to check for proper nozzle ring crush or end clearance checks on turbochargers.	

Tool No.	Tool Description	Tool Illustration
3376399	**O-Ring Pick** Use to remove and install o-rings.	
ST-1135	**Lubricating Oil Sampling Filter** Used to monitor oil contamination.	
ST-1134	**Dowel Pin Extractor** Remove dowel pins.	
ST-1232	**Drill Ream Fixture** Machine dowel hole to install oversize dowels in cylinder block and flywheel housing. Use with a drill, reamer, and the appropriate drill/ream bushing set.	
3377161	**Digital Volt-Ohm Meter** Measure electrical circuits; voltage (volts), resistance (ohms), and current (amps).	
3822608	**Weather-Pack Terminal Removal Tool** Used to repair Weather-Pack connectors.	
3822747	**Engine Position Sensor Installation Tool** Used to remove and install the engine position sensor.	
3822760	**Deutsch Terminal Removal Tool** Used to repair Deutsch connectors.	

Tool No.	Tool Description	Tool Illustration
3822860	**Heat Gun** Used to repair connector wires.	
3822926	**Wiring Repair Kit** Contains a variety of connectors, pins, seals, terminals, test leads, and other tools used to repair connectors.	
3284903	**Wire Crimping Pliers** Used when repairing connector wires.	 3822930
3822934	**Lubricant DS-ES** Dielectric lithium grease used to lubricate the pins in the electrical connectors before installation.	 3822934
3823843	**Deep Well Socket (1–1/4 inch)** Used to remove and install sensors and actuators.	 3823843
3824510	**Electrical Contact Cleaner** A non-petroleum cleaner used to clean electrical contacts and connectors.	 oi8togt

Engine Disassembly (000-003)

General Information

General Information

These procedures apply to all QSK19 engines. The differences between engine model due to the application, the optional equipment on an engine, and the year an engine was built are included in the instructions. Omit the steps that do **not** apply to the engine being rebuilt.

⚠ WARNING ⚠

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.

⚠ CAUTION ⚠

All fasteners are given in U.S. Customary measurements. All fasteners have right-handed threads unless a Caution states that a fastener has left-handed threads.

Disassembly

The instructions in this procedure are organized in a logical sequence to **disassemble** an engine. This is **not** the **only** sequence to **disassemble** an 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. Keep these parts if they are needed for a failure analysis.

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

Label, tag, or mark the wiring harness and all components and sensors as they are removed from the engine.

Label, tag, mark, or photograph all special equipment prior to 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 **must** be used when force is required.

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 V) 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.

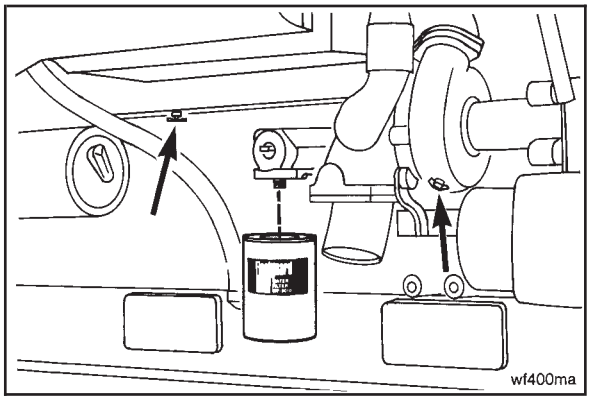
If the capscrew length is not specified, use the formula in the Specifications (Section V) to determine the correct capscrew length. The use of a longer capscrew than the capscrew that is listed can result in damage to the engine.

Disassemble

Remove the Water Filter

Open the draincock on the oil cooler housing and on the water pump.

Remove and discard the coolant filter.



Prepare Engine to be Mounted on Rebuild Stand

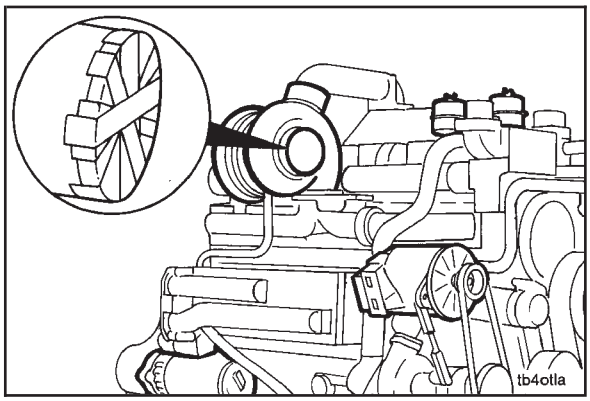
WARNING

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

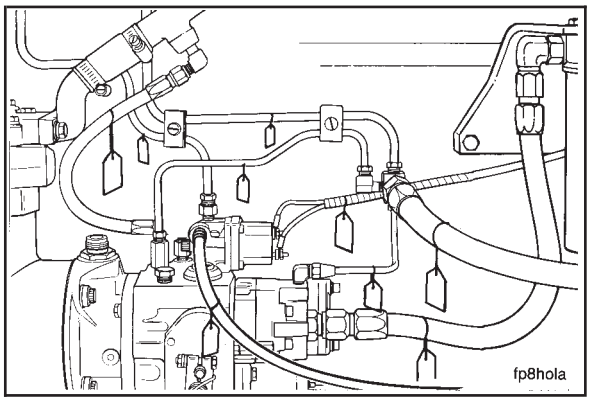
CAUTION

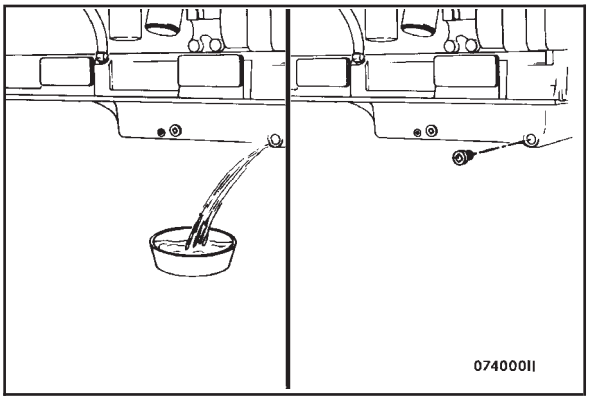
Cover all engine openings and electrical components. This will prevent water damage.

Use steam to clean the heavy dirt from the exterior of the engine.



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





⚠ WARNING ⚠

Hot oil can cause serious personal injury. Drain the oil when the oil temperature is approximately 60°C [140°F].

⚠ 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. Always use the proper procedures to dispose of the oil.

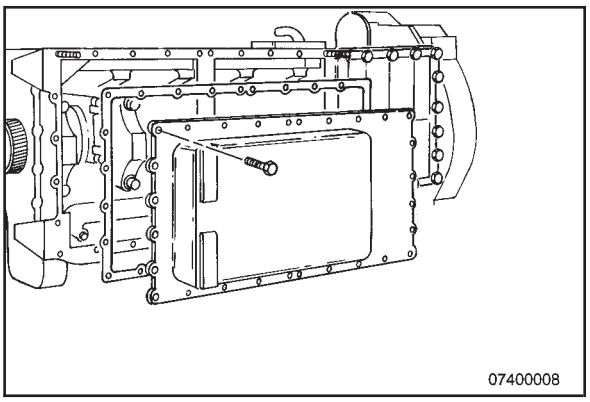
Remove the oil drain plug from the bottom of the oil sump.

Drain the oil.

Install the drain plug.

Tighten the drain plug.

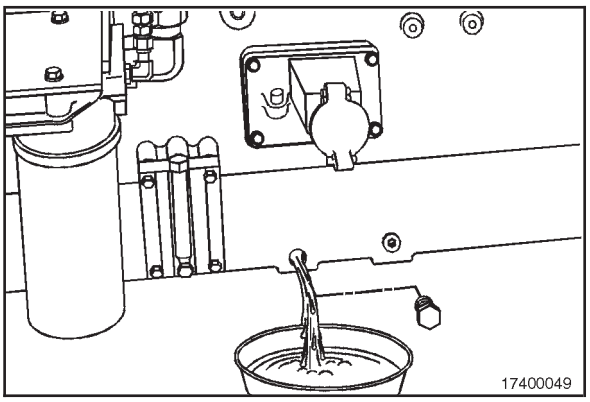
Torque Value: 100 N•m [75 ft-lb]



Remove the 28 capscrews.

Remove the oil pan.

Remove and discard the gasket.



Rail Applications

Remove the lubricating oil drain plug.

Drain the lubricating oil.

Replace the drain plug and tighten.

Torque Value: 100 N•m [75 ft-lb]

Rail Applications

Remove the lubricating oil filters and filter head.

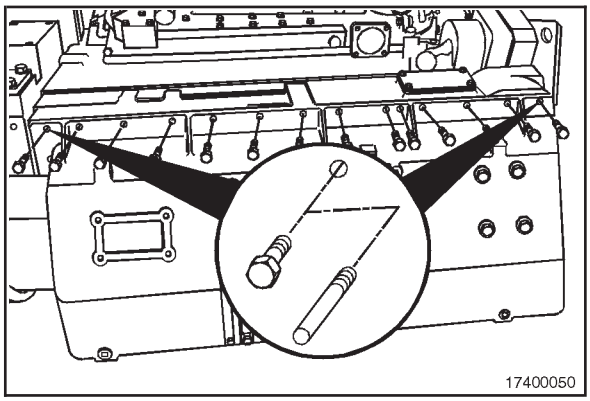
Remove the fuel filter and filter head.

Remove the coolant filter and filter head.

Rail Applications

Remove 15 capscrews on the top of the oil pan.

Install two 3/8 - 16 guide studs in the capscrew holes.

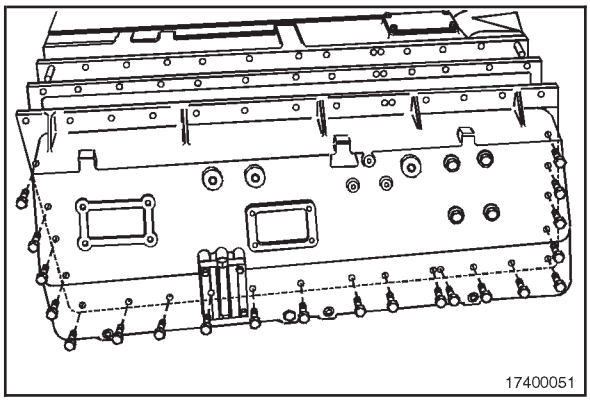


Rail Applications

Remove the remaining 23 capscrews.

Remove the lubricating oil pan.

Remove and discard the gasket.



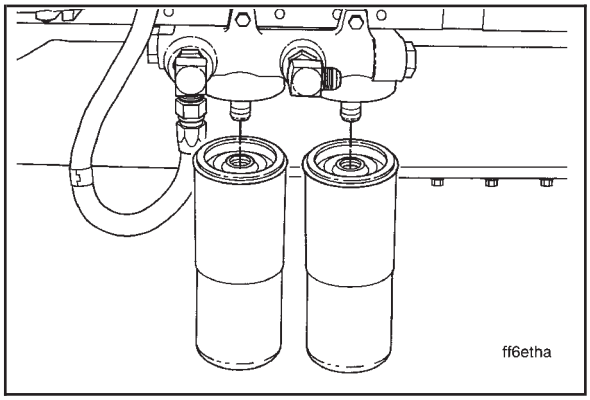
Remove the Fuel Filters

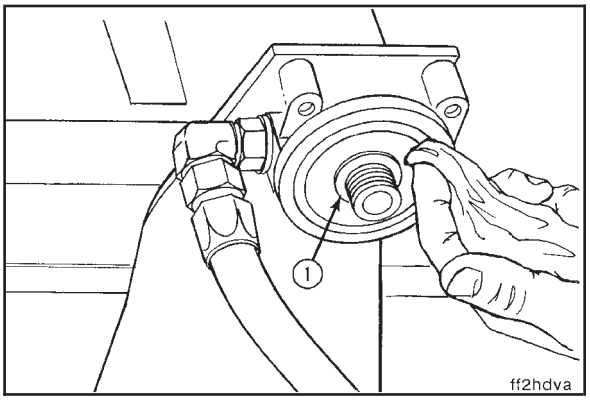
WARNING

Fuel is flammable. Do not allow cigarettes, flames, sparks, arcing switches or equipment, pilot lights, or other ignition sources near the fuel system.

Close the fuel line shutoff valve before changing the fuel filters, or the overhead tank can drain, causing a fuel leak.

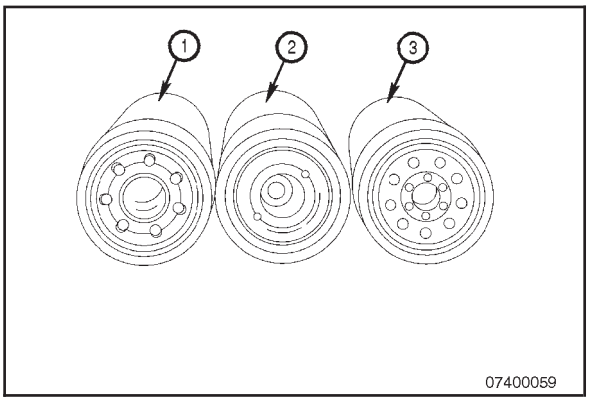
Remove the fuel filter with filter wrench, Part No. 3376807.





Remove the thread adapter sealing ring (1).

Use a clean, lint-free towel to clean the surface of the filter head gasket.



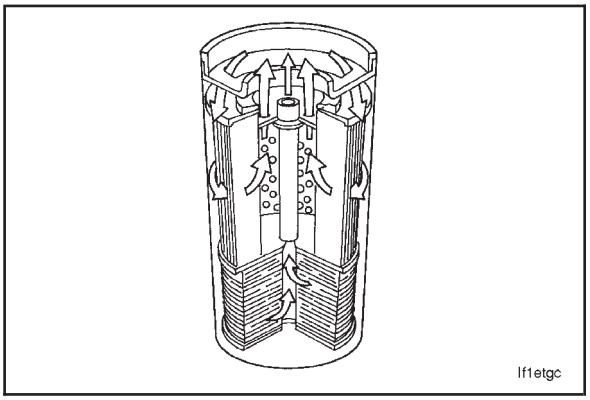
Remove the Oil Filters

The external appearance of the full-flow (1) the bypass (2) and the combination (3) filters are the same. The accompanying picture identifies the differences among the three filters.

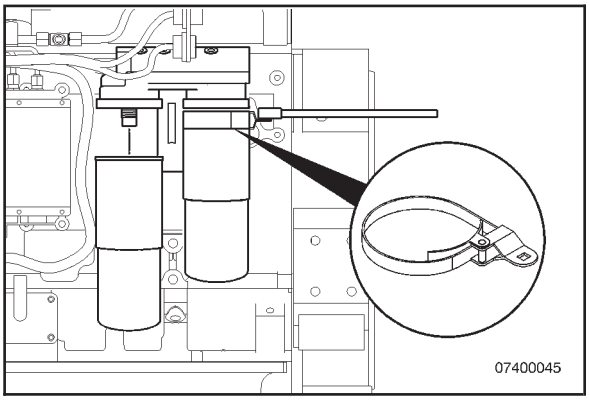
⚠ CAUTION ⚠

The bypass and combination filters both have the same threads. Verify correct filter is used for replacement to avoid damage to the engine.

NOTE: The full-flow filter contains [1 1/2-16 inch] threads. The bypass and combination filters contain [2 1/4-12 inch] threads.



A combination oil filter is used on most engines. The upper section of the filter contains the full-flow filter element while the lower section contain the bypass element.



NOTE: The following illustrations show the combination oil filter. Use the same procedure when changing the remote bypass oil filters.

Use an oil filter wrench, Part No. 3375049, or equivalent. Remove the oil filters.

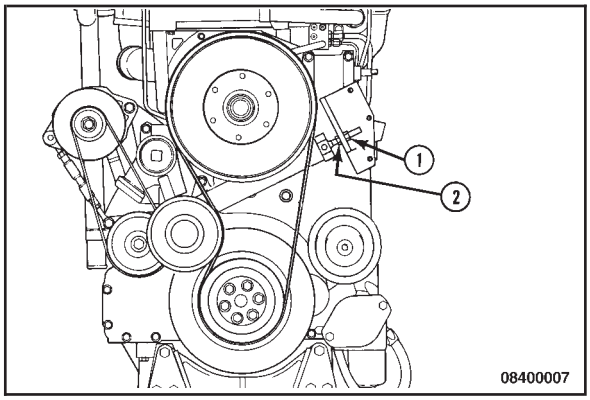
Discard the filters if they are **not** needed for a failure analysis.

Remove the Cooling Fan Drive Belt

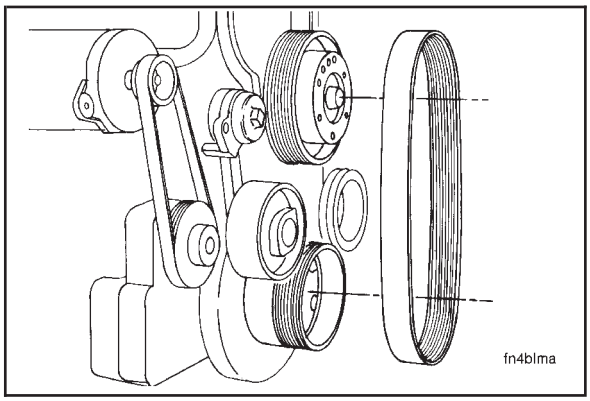
⚠ CAUTION ⚠

The fan belt idler is under tension. Do NOT allow your hands to get between the idler and the belt, or the fan hub. Personal injury can result.

Loosen nuts (1) and (2). Turn nut (1) **counterclockwise** to end of threaded rod to relieve tension on the belt.

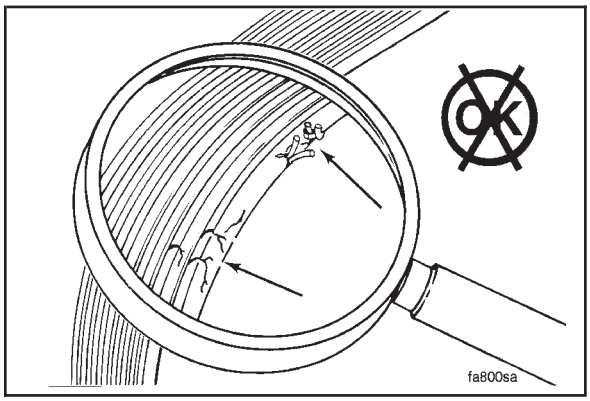


Remove the fan belt.



Check the belt for wear.

If the belt indicates any wear, it **must** be replaced.



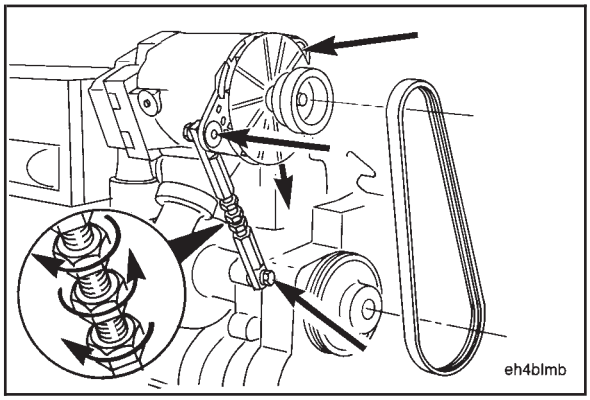
Remove the Alternator Drive Belt

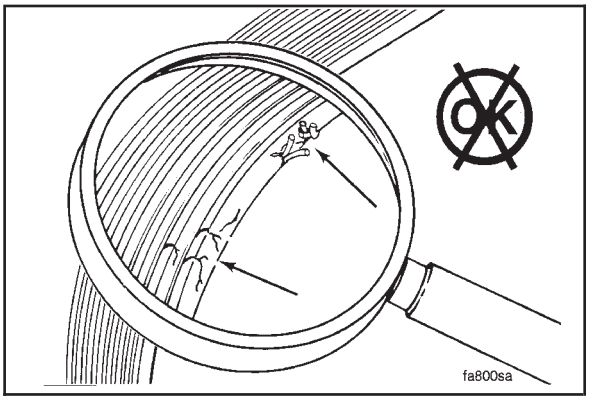
Loosen the adjusting link and the alternator mounting capscrews.

NOTE: The lower jam nut has **left-hand** threads.

Loosen both of the jam nuts. Turn the adjusting screw to relieve the belt tension.

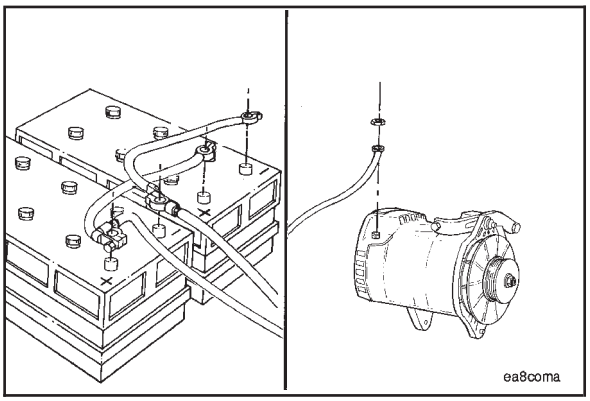
Remove the belt.





Check the belt for wear.

If the belt indicates any wear, it **must** be replaced.



Remove the Alternator

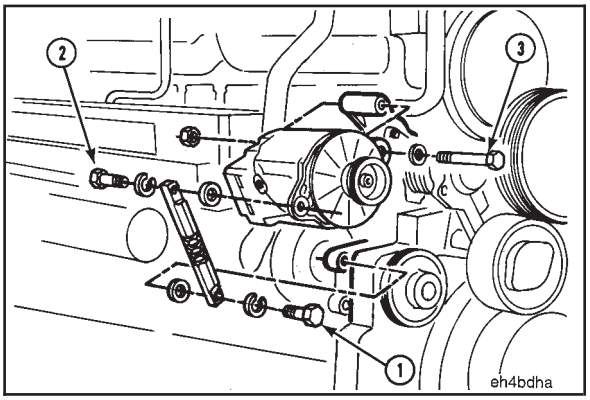
WARNING

Always disconnect the negative (-) cable first to avoid sparks that can ignite explosive battery gases.

WARNING

Batteries emit hydrogen gas. To avoid explosion and personal injury, do not smoke or allow ignition source in area when servicing batteries.

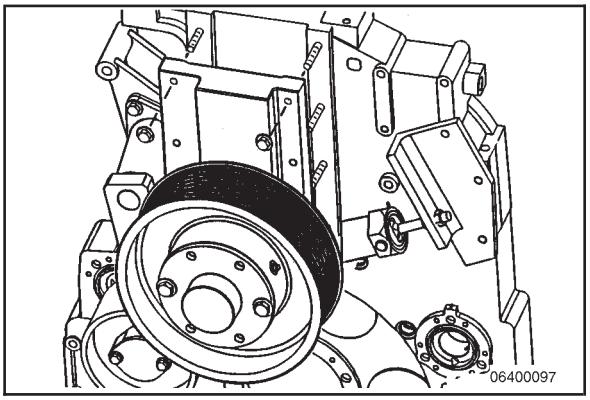
Disconnect the wiring and ground strap from the alternator.



Remove capscrews (1) and (2) and the adjusting link.

Remove capscrew (3) and nut.

Remove the alternator.



Remove the Belt Driven Fan Hub

CAUTION

This assembly weighs more than 23 kg [50 lb]. To avoid personal injury, use a hoist or get personal assistance.

Remove the eight nuts and washers, and the fan hub.

Remove the Fan Drive Idler Arm Assembly

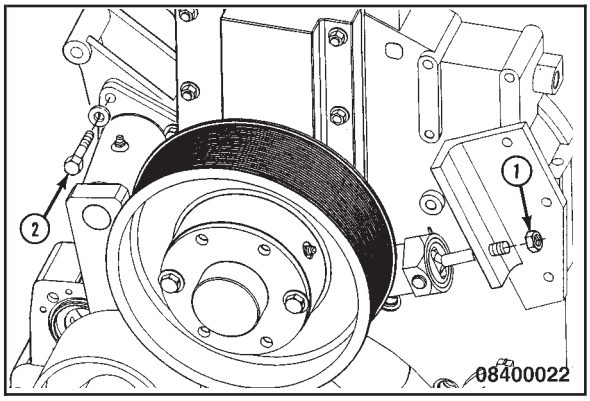
⚠ CAUTION ⚠

The belt tensioner and the pivot arm assembly will rotate during removal. Personal injury can result. To avoid personal injury, use a hoist or get personal assistance to lift the component.

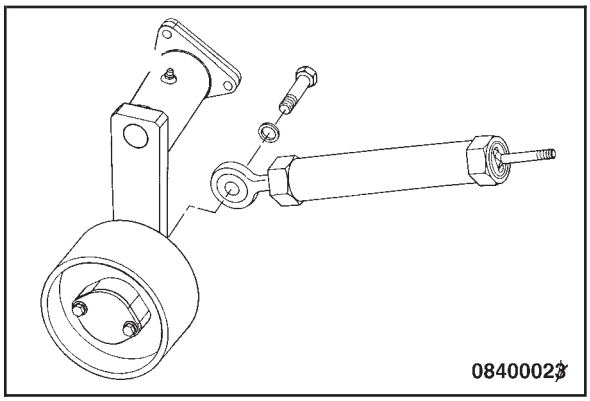
Remove the belt adjusting nut (1) from the tensioner assembly.

Remove the three capscrews (2) from the pivot arm assembly.

Remove the pivot arm and the belt tensioner as an assembly.



Remove the belt tensioner from the idler arm assembly.

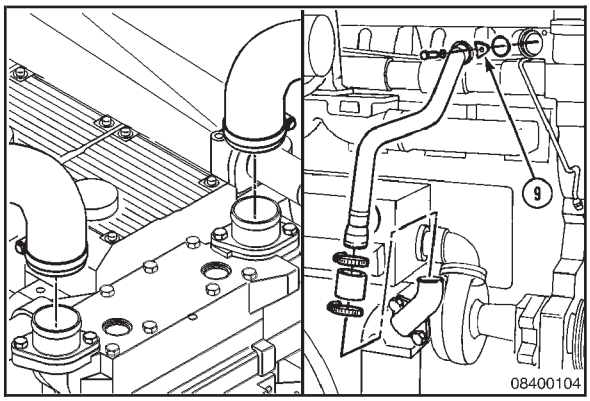


Remove the Coolant Tubes and Hoses - Conventional Aftercooling

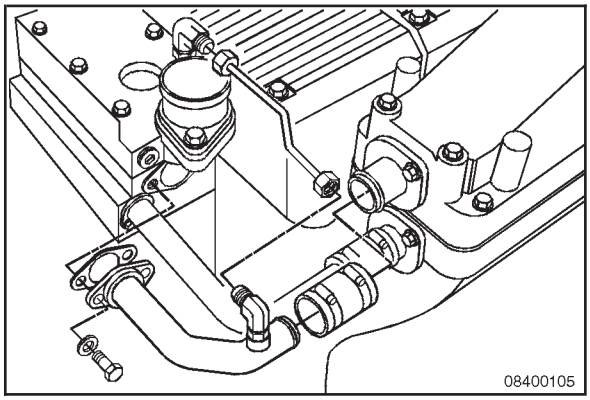
Remove the bypass tube clip (9).

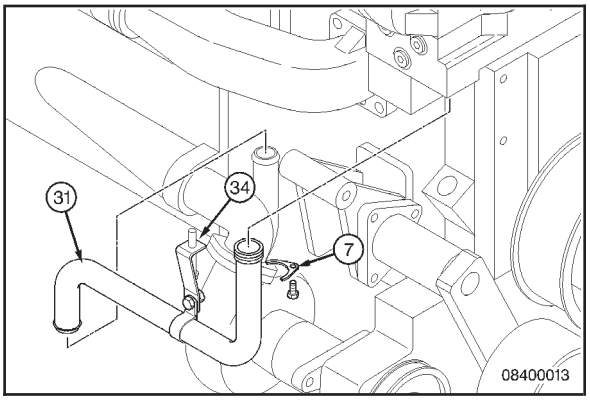
Loosen both hose clamps.

Remove the bypass tube.



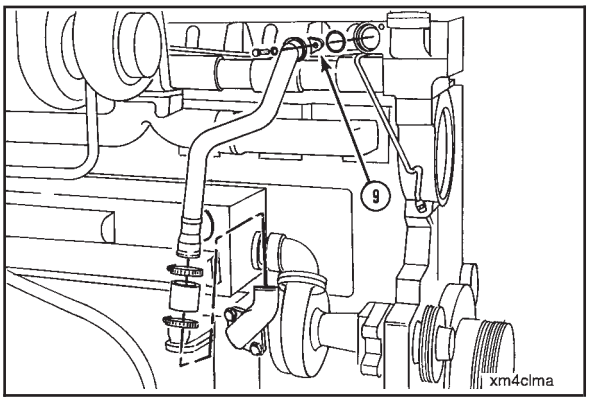
Remove the aftercooler coolant return tube aftercooler coolant supply tube, gaskets and hoses from the thermostat housing support.





Remove the aftercooler water supply tube clip (7). Loosen the hose clamps. Remove the support bracket (34).

Remove the tube (31). Remove and discard the o-ring.

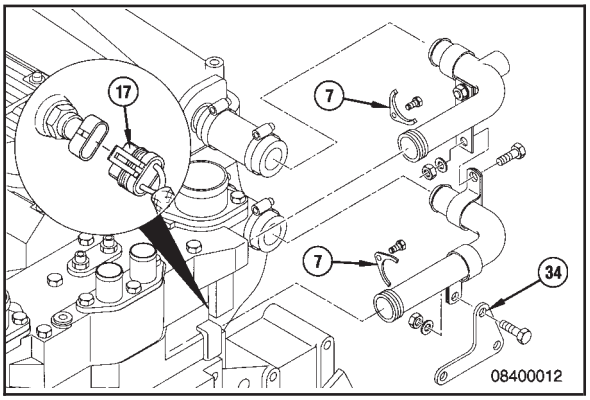


Remove the Coolant Tubes and Hoses - Low Temperature Aftercooling

Remove the bypass tube clamp (9).

Loosen both hose clamps.

Remove the bypass tube, hose, and water connection.



Remove the water inlet and outlet tube clips (7).

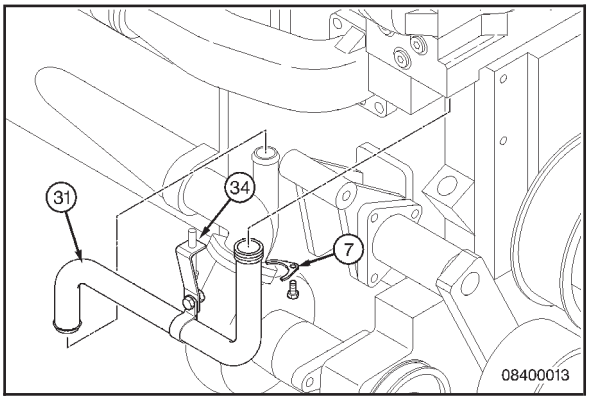
Loosen the hose clamps.

Remove the aftercooler water tube support bracket (34).

Remove the aftercooler water tubes.

Remove and discard the o-rings.

Disconnect the coolant temperature sensor wire (17).



Remove the aftercooler water supply tube clip (7).

Loosen the hose clamps.

Remove the support bracket (34).

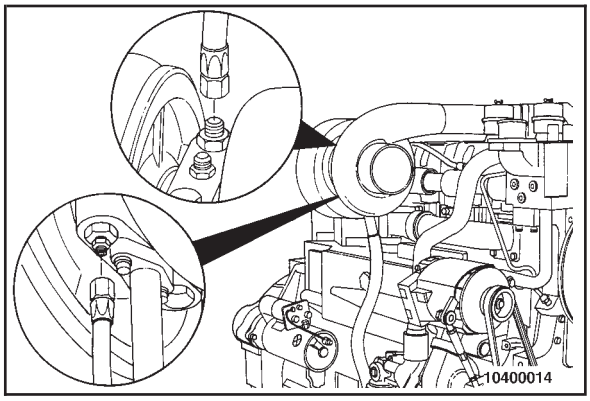
Remove the tube (31).

Remove and discard the o-ring.

Remove the Turbocharger Coolant Supply and Return Hoses

NOTE: This procedure applies to a turbocharger with a water-cooled bearing housing.

Disconnect the coolant supply hose and the coolant return hose from the turbocharger.



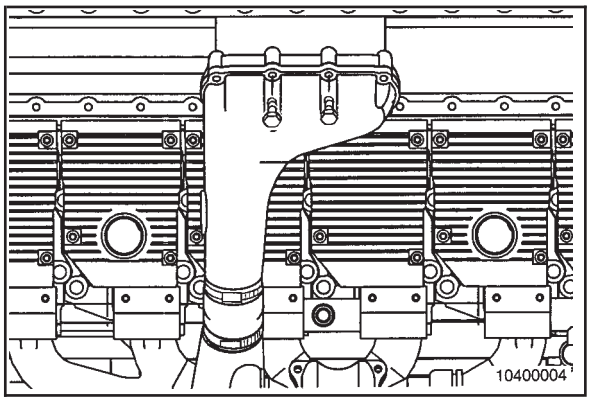
Remove the Crossover Connection

Remove the four mounting capscrews at the top of the air crossover.

Loosen the four capscrews at the bottom of the air crossover until there is clearance between the washer and the crossover.

Remove the air crossover hose clamps and slide the hose down the turbocharger outlet.

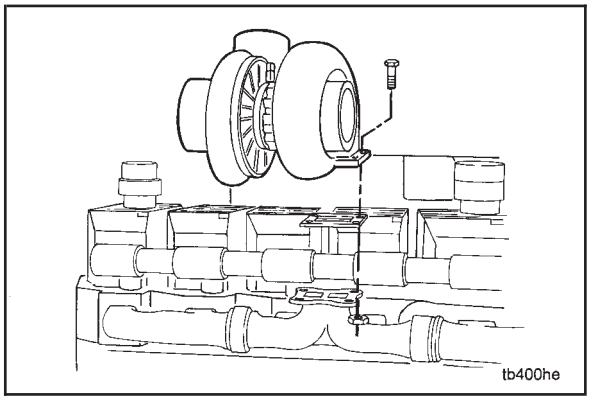
Remove the air crossover.



Remove the Turbocharger

Remove the mounting capscrews, nuts, and the turbocharger.

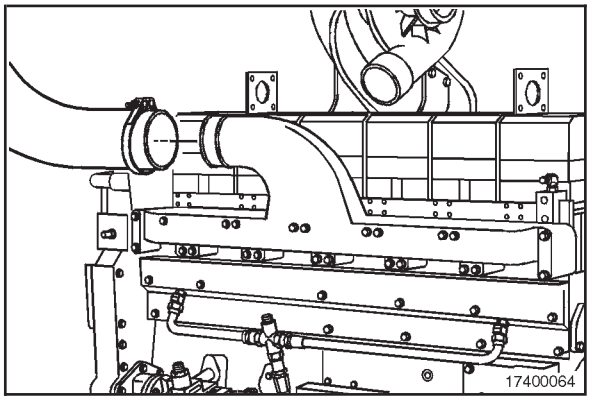
Remove and discard the gasket.

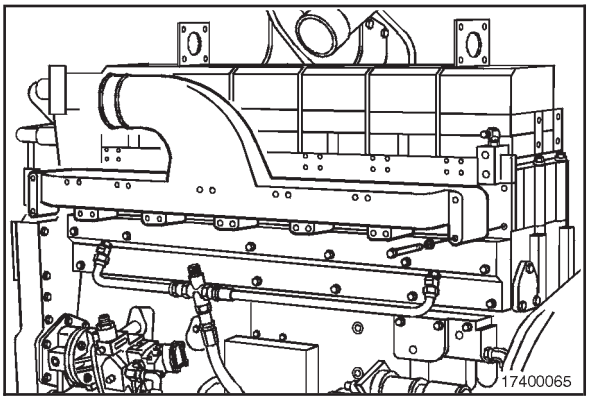


Rail Applications

Remove the turbocharger drain line from the scavenge cross and the turbocharger.

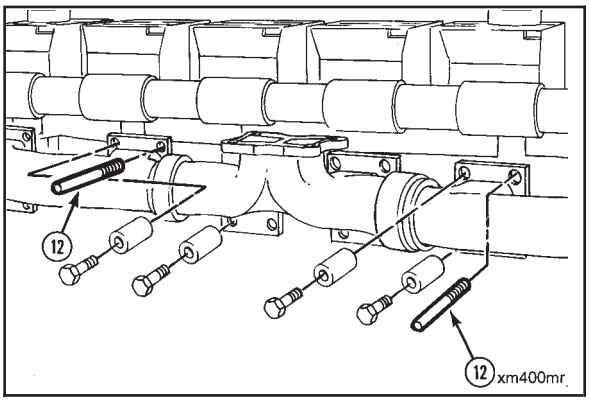
Loosen the hose clamp and remove the hose.





Rail Applications

Remove the 24 capscrews and intake manifold.

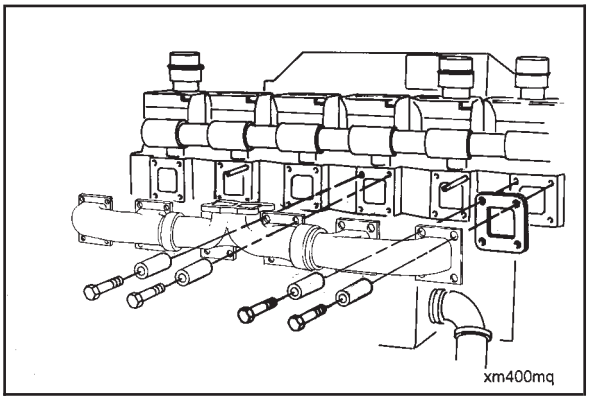


Remove the Exhaust Manifold

Use two [7/16-14x5 in] guide studs (12).

Remove two capscrews as shown.

Install the guide studs as shown.



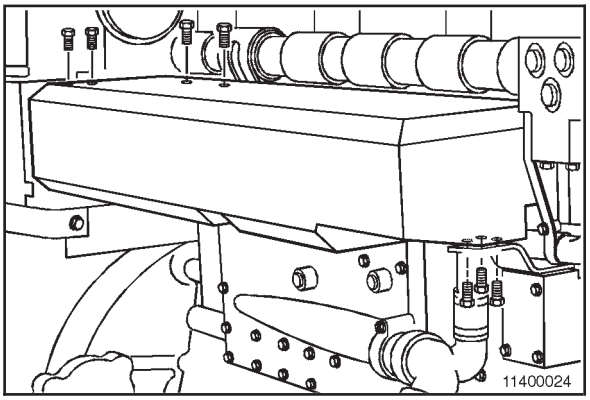
⚠ CAUTION ⚠

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

Remove the remaining capscrews.

Remove the exhaust manifold and the gaskets.

Discard the gaskets.



Marine Applications

NOTE: Do not rip, tear, or damage the insulation of the exhaust manifolds.

Remove the 7 mounting capscrews.

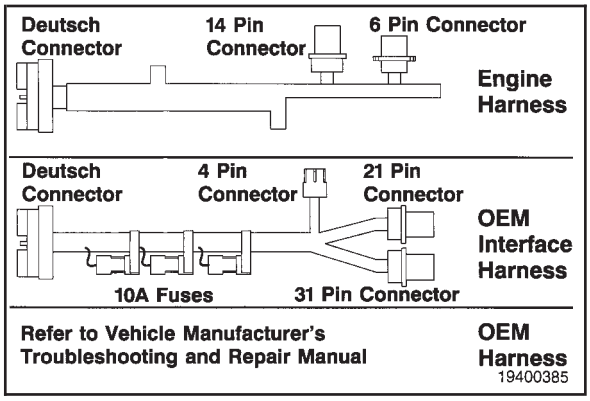
Remove the heat shield.

The heat shield comes straight off the manifold.

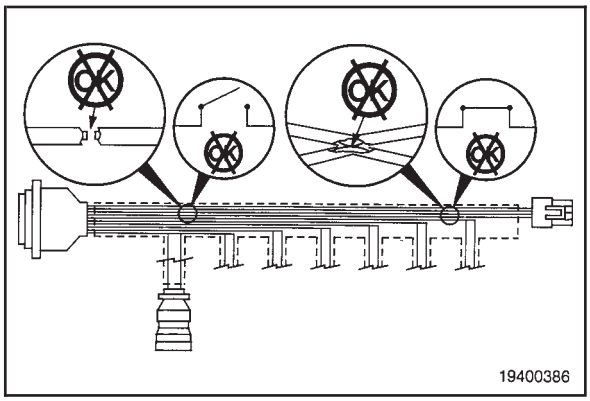
OEM Interface Harness - General Information

The QSK equipped engines use three separate wiring harness to control the engine and some of the vehicle operations.

1. Engine Harness
2. OEM Interface Harness
3. OEM Harness

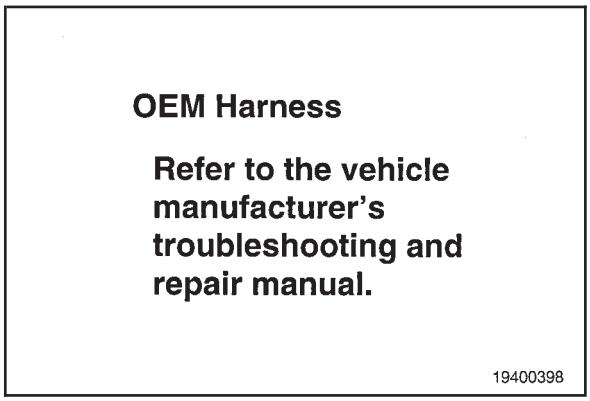


Replace a harness if there is an open circuit or a short circuit found under the protective covering of the harness body.



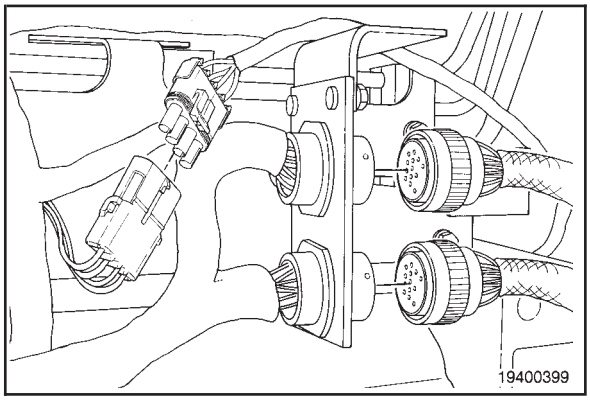
OEM Wiring Harness - General Information

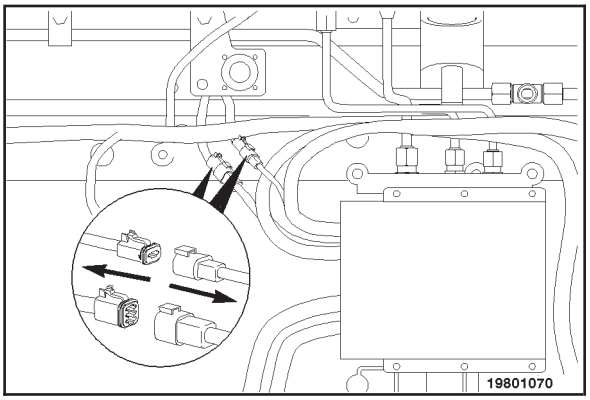
The OEM harness is supplied and installed by the vehicle manufacturer. Follow the vehicle manufacturer's instructions, if replacement is necessary. Refer to the vehicle manufacturer's troubleshooting and repair manual.



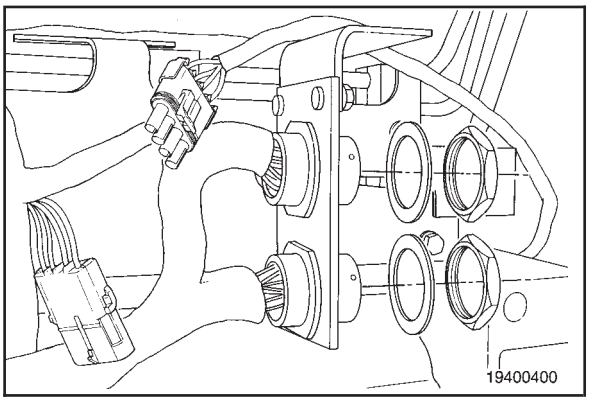
Remove the OEM Interface Harness

Disconnect the 21-pin and 31-pin connectors from the OEM harness.

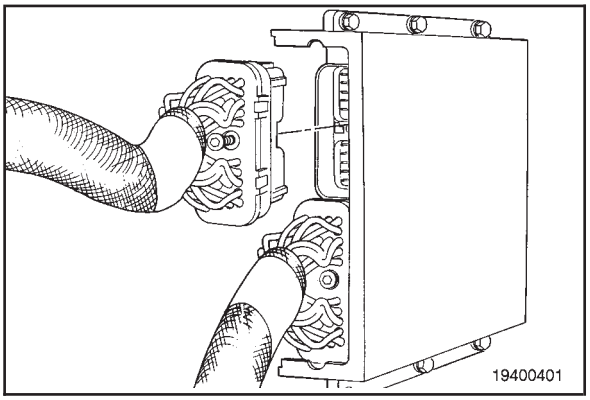




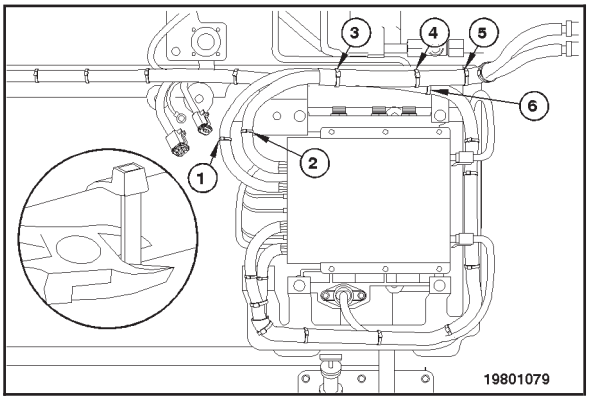
Disconnect the 2-pin and 6-pin Deutsch connectors.



Remove the 21-pin and 31-pin connectors from the harness support brackets.



Use a 4 mm [5/32 in] hex head wrench to disconnect the OEM interface harness Deutsch connector from the ECM.

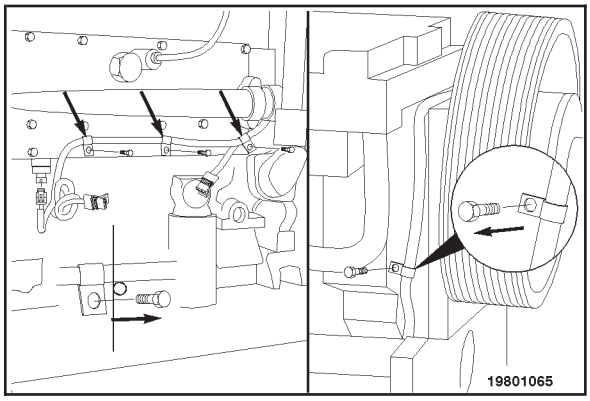


Cut the six wire ties from the harness support bracket and remove the OEM interface harness from the engine.

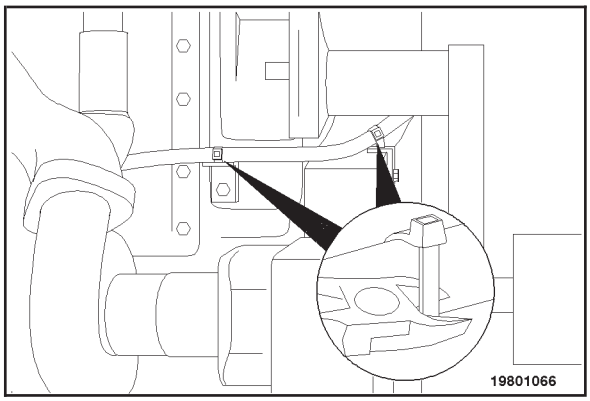
Remove the Engine Wiring Harness

Disconnect the engine harness from the coolant pressure sensor.

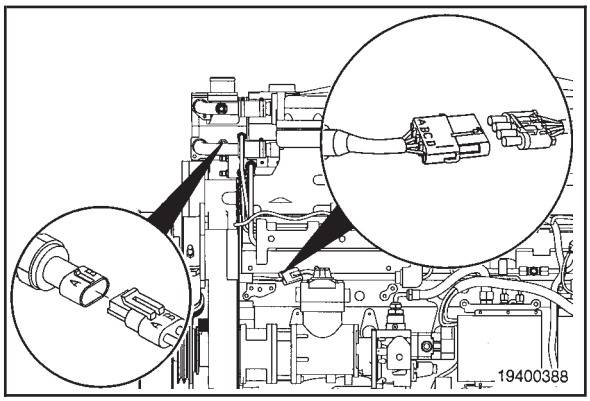
Remove the engine harness clamps.



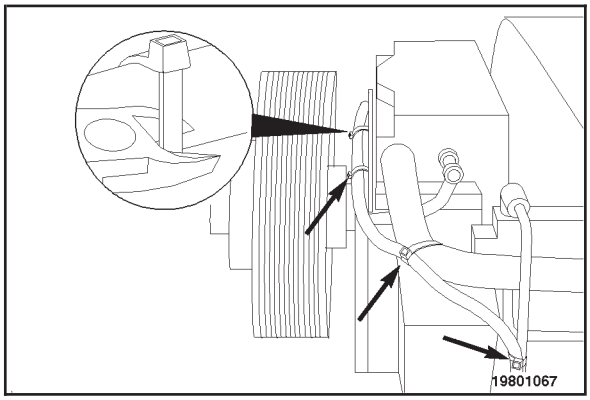
Cut the ties on the alternator bracket and front engine cover bracket.

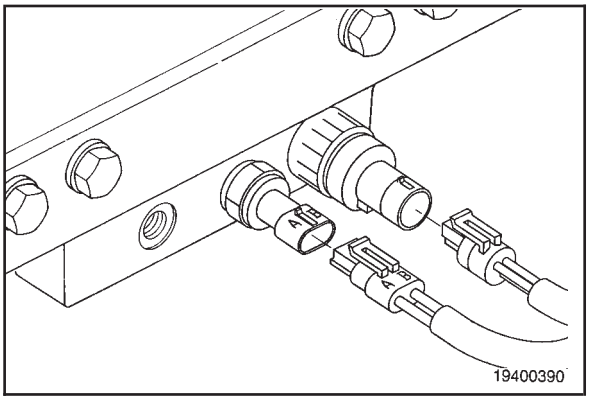


Disconnect the coolant temperature sensor and engine position sensor.

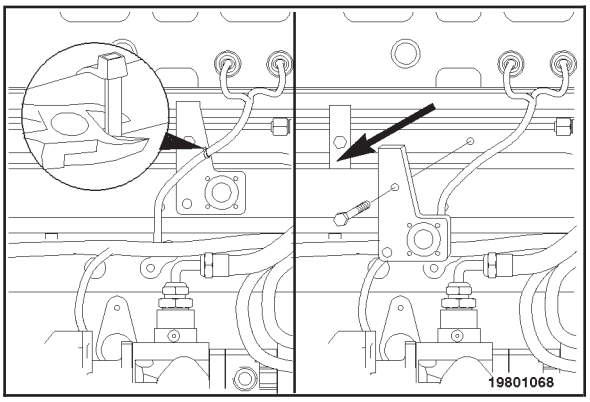


Cut the ties on the thermostat housing bracket, aftercooler tube, and fuel tube.





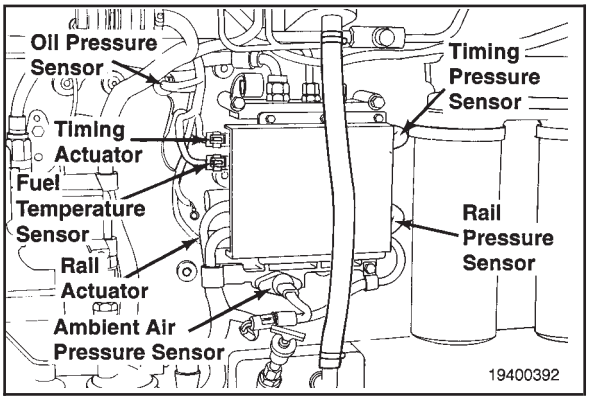
Disconnect the intake manifold temperature sensor and intake manifold pressure sensor.



Cut the tie on the engine datalink connector bracket.

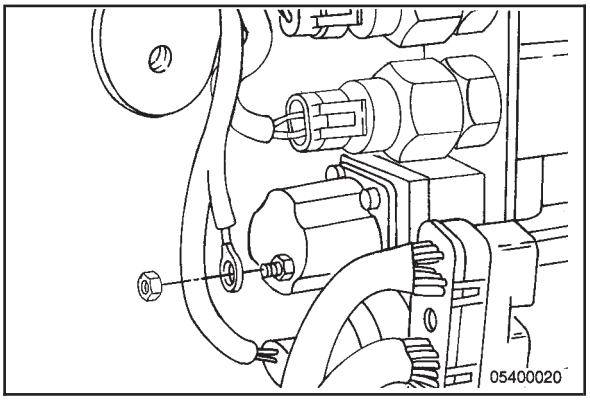
Remove the bracket.

Remove the clamp from the hose.



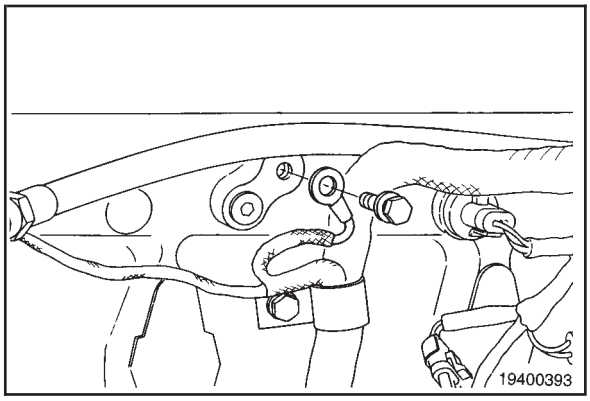
Disconnect the engine harness from the following:

1. Oil pressure sensor
2. Timing actuator
3. Rail actuator
4. Ambient air pressure sensor
5. Rail pressure sensor
6. Timing pressure sensor

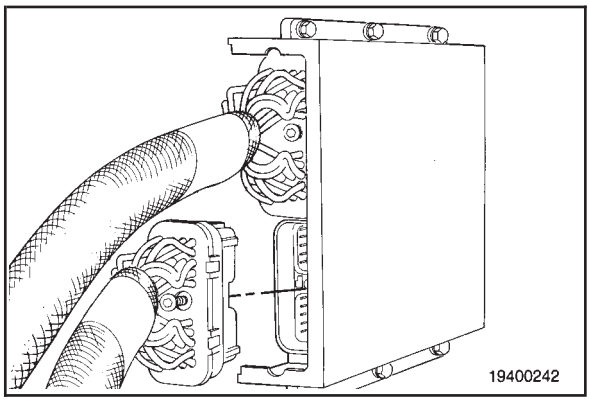


Disconnect the fuel shutoff control wire to the fuel shutoff solenoid.

Disconnect the engine block ground from the block.



Use a 4 mm [5/32 in] hex head wrench to disconnect the engine harness Deutsch connector from the ECM.

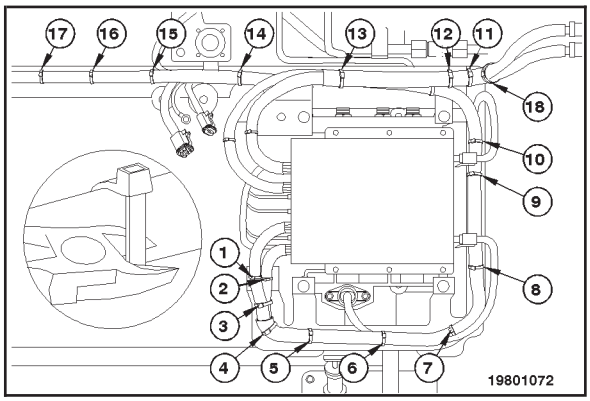


Cut the seventeen ties holding the engine harness to the support bracket.

Cut the corner tie holding the engine harness to the support bracket.

Remove two screws and C-clamps.

Remove the engine harness.

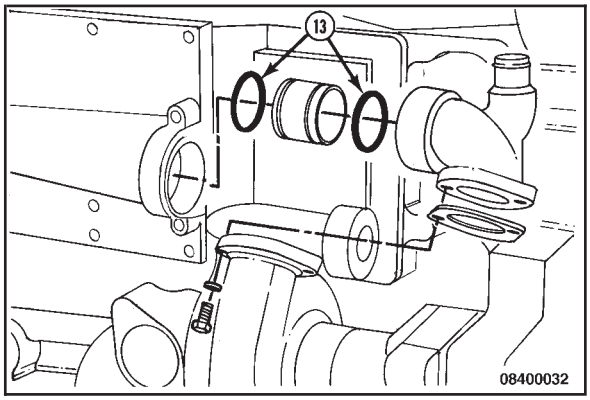


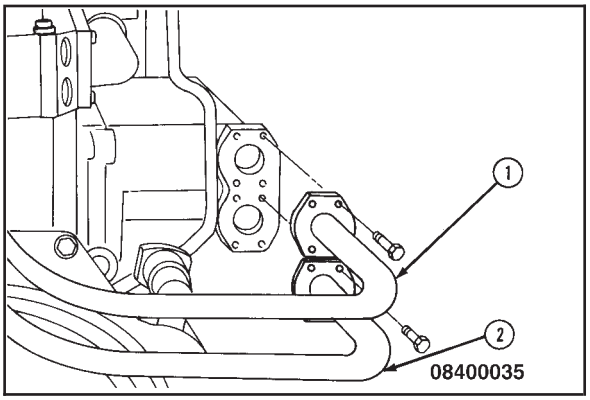
Remove the Water Pump Outlet Connection Assembly

Remove the water pump outlet connection assembly.

Remove the water transfer tube from the water connection.

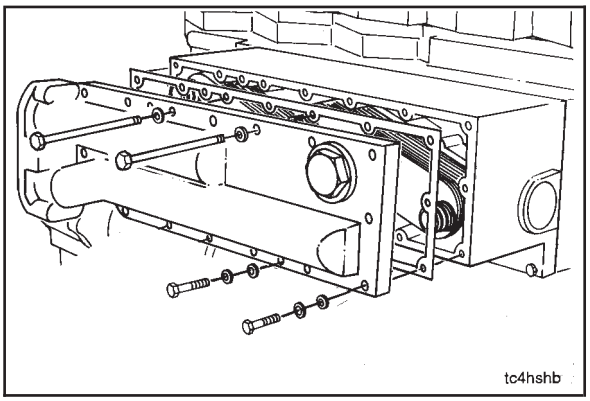
Remove and discard the two o-rings (13) and the gasket.





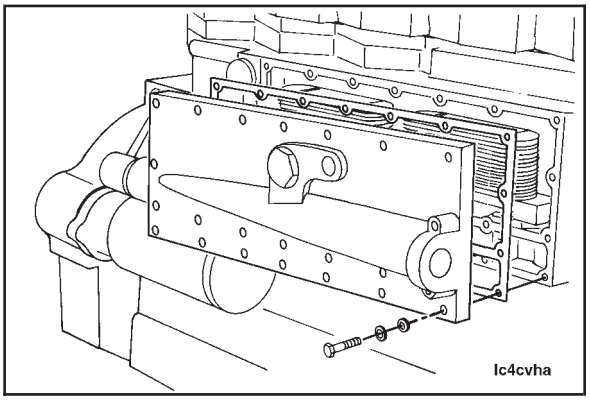
Remove the Torque Converter Cooler Cover (if equipped)

Remove the oil supply (1) and oil return (2) hoses from the torque converter cooler.



Remove the torque converter cooler cover mounting capscrews.

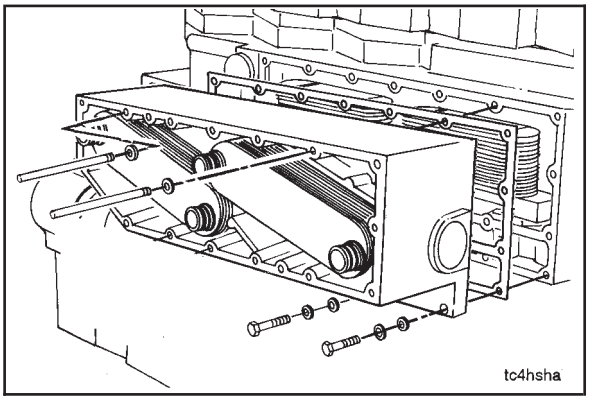
NOTE: The cover must be pried from the housing because of the tight fit between the cover and the o-rings on the elements.



Remove the Oil Cooler Cover (if equipped)

Remove all of the capscrews, the oil cooler cover, and gasket.

Discard the gasket.



Remove the Torque Converter Cooler Housing (if equipped)

⚠ CAUTION ⚠

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

Use two [3/8-16 x 12 in] guide studs to support the housing while the capscrews are being removed.

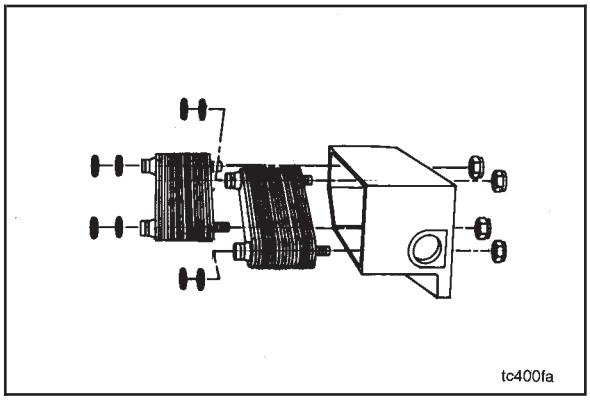
Remove the remaining capscrews, the torque converter cooler housing, and the gasket.

Discard the gasket.

Remove the torque converter cooler element mounting nuts.

Remove the elements.

Remove and discard the o-rings.

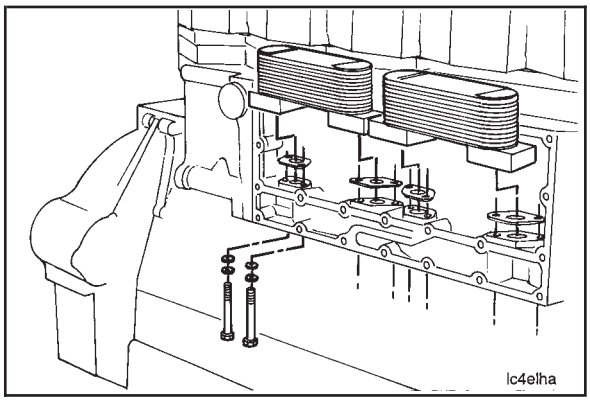


Remove the Oil Cooler Elements

NOTE: There is little clearance between the capscrews and the block on some engines. If necessary, use a drift and a mallet to tap the loosened capscrews from the oil cooler housing.

Remove the eight capscrews and the two oil cooler elements.

Remove and discard the gaskets.



Remove the Water Pump and Water Pump Drive Shaft

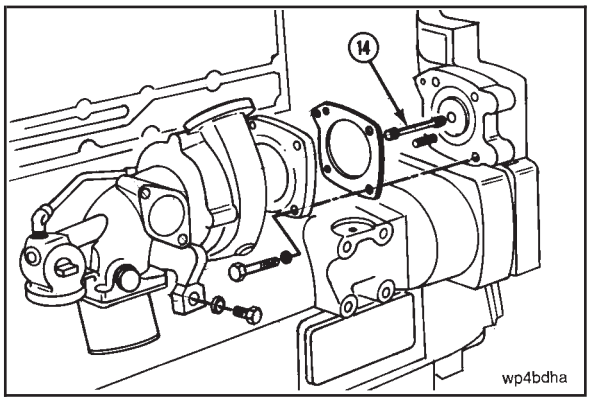
Remove the capscrew from the water pump support bracket.

Remove the three capscrews and the nut from the water pump mounting flange.

Remove the water pump and gasket.

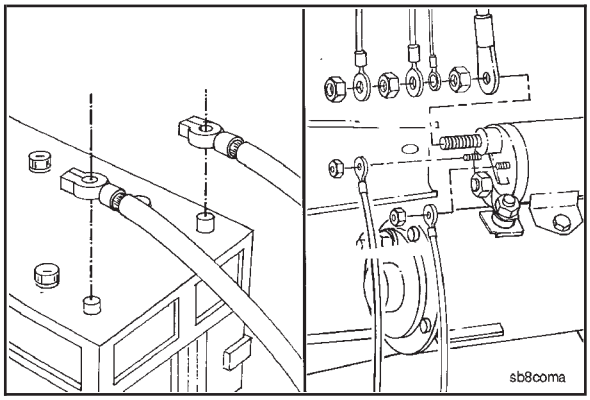
Discard the gasket.

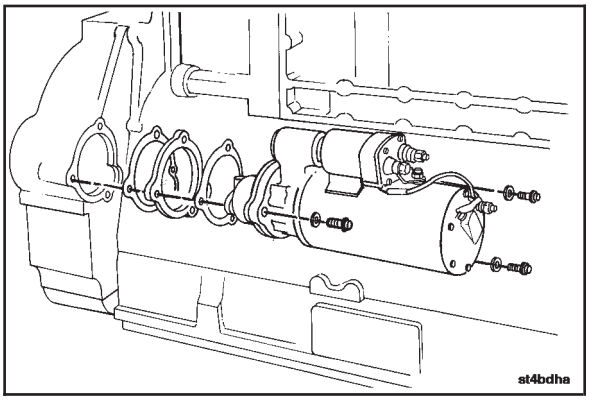
Remove the drive shaft (14).



Remove the Starting Motor

Disconnect the electrical connections from the starting motor.





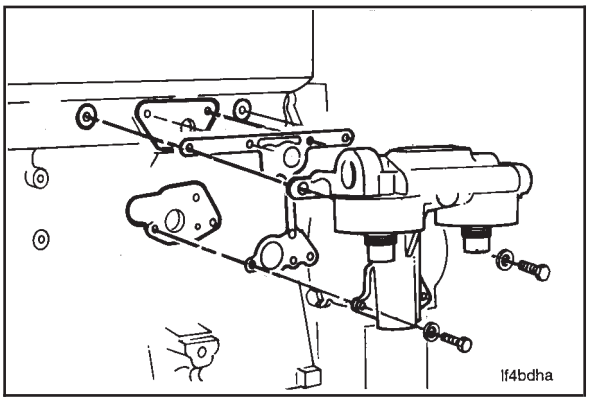
⚠ CAUTION ⚠

This assembly weighs more than 23 kg [50 lb]. To avoid personal injury, use a hoist or get personal assistance.

Remove the starting motor capscrews, the starter, spacers, and the gaskets.

Discard the gaskets.

NOTE: All engines do **not** contain spacers and gaskets.



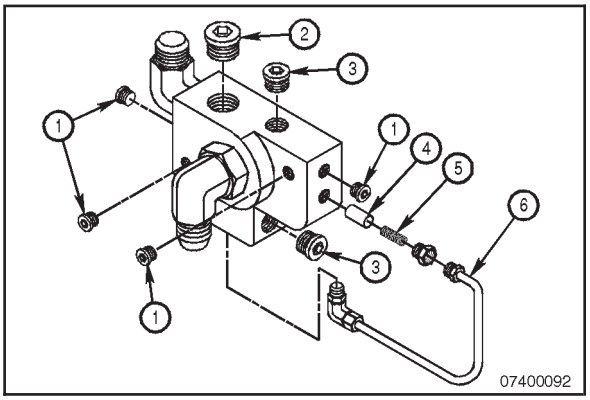
Remove the Oil Filter Head

⚠ 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. Always follow the proper procedures to dispose the used oil.

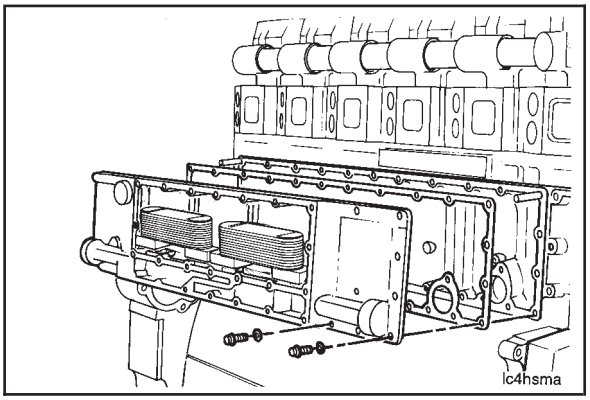
Remove the six capscrews and the filter head assembly.

Remove and discard the gasket.



Lube Oil Transfer Connection Block

Remove the transfer connection block.



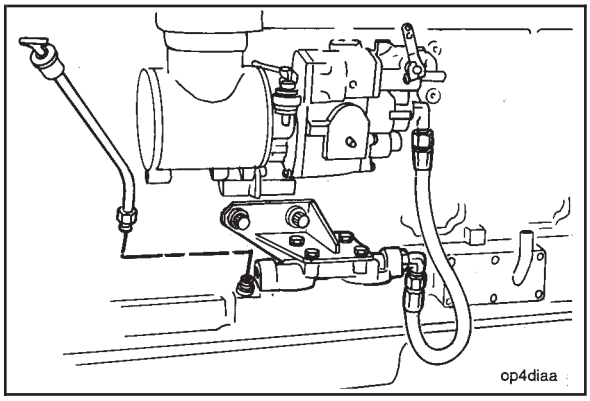
Remove the Oil Cooler Housing

Remove the capscrews and oil cooler housing.

Remove and discard the gaskets.

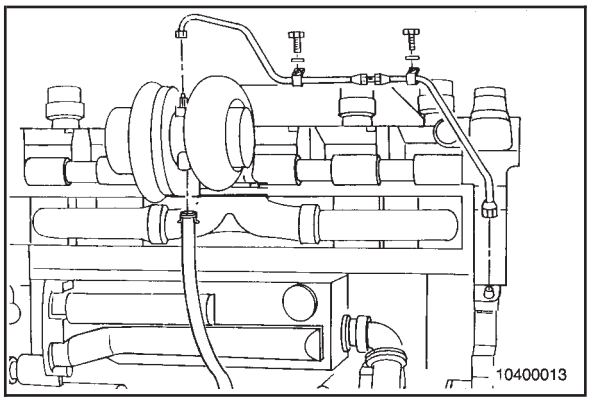
Remove the Dipstick and Dipstick Tube (if equipped on this side of engine)

Remove the dipstick and dipstick tube.



Remove the turbocharger oil supply and drain lines.

Disconnect the oil drain hose and the oil supply hose from the turbocharger.

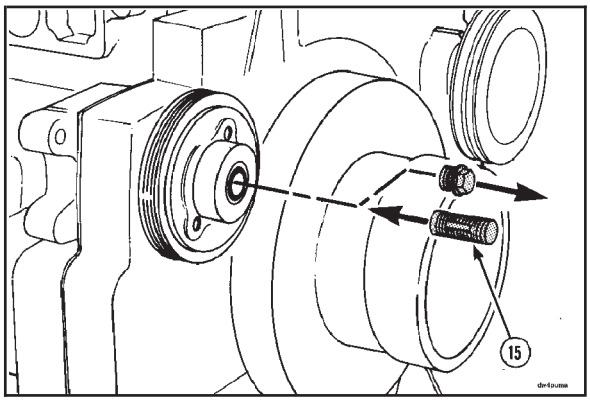


Remove the Alternator Drive Pulley

Remove the plastic plug at the end of the shaft.

Insert the adapter, Part No. 3376089, in the shaft to prevent damage. The adapter is included with the pulley installation tool, Part No. 3376326.

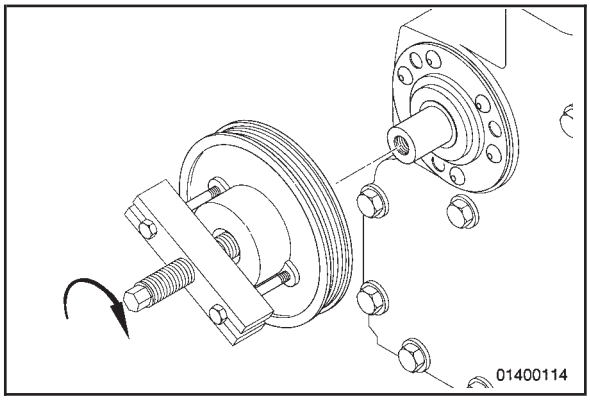
NOTE: If the adapter is **not** available, a [3/4-16 inch] capscrew with a head ground smaller than the pulley I.D. can be used.

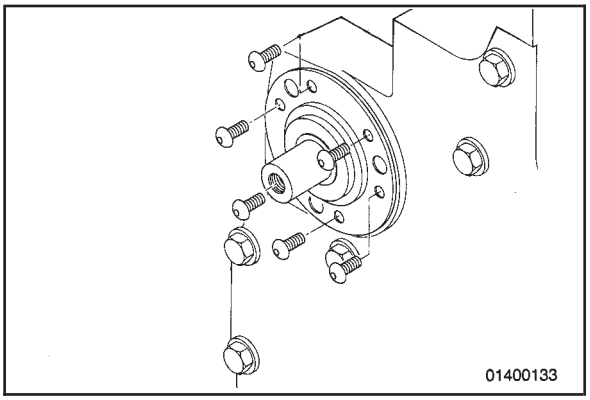


Put the puller on the pulley.

Remove the pulley.

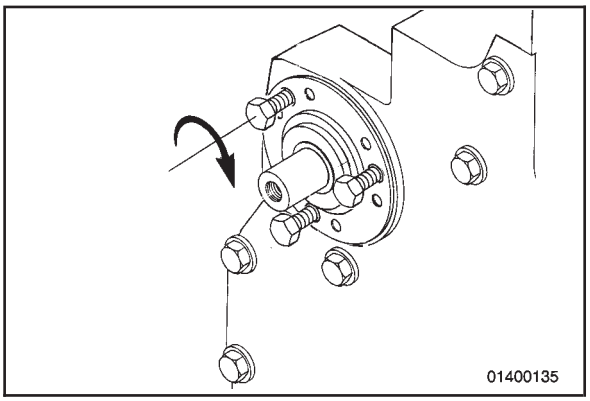
Remove the adapter.





Remove the Alternator Drive Oil Seal

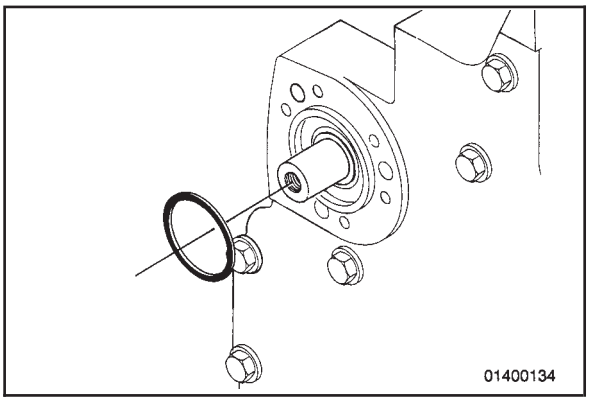
Remove the six button hex head socket capscrews.



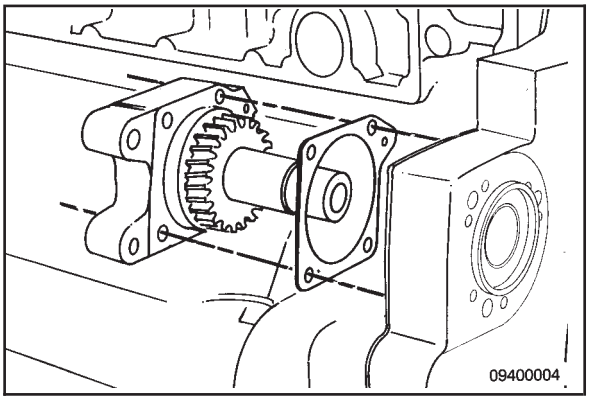
Use three [1/4-20 x 1 in] capscrews to remove the seal from the alternator drive shaft.

Install the three capscrews in the clinch nuts in the seal case.

Tighten the capscrews alternately and evenly to remove the seal.



Remove the o-ring from the groove in the gear cover.



Remove the Water Pump Drive Assembly

Remove the water pump drive assembly.

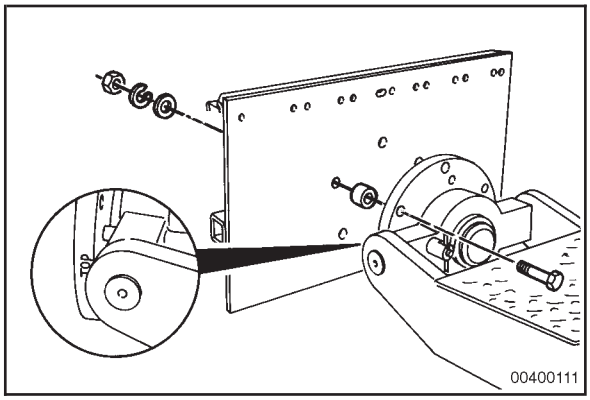
Remove and discard the gasket.

NOTE: If necessary, tap on the end of the shaft with a mallet.

Prepare the Engine Rebuild Stand

The following instructions apply to the Engine Roll over Stand, Part No. 3375194. If another engine stand is used, follow the manufacturer's instructions.

Disengage the locking pin. Turn the swivel plate until the word "TOP" can be seen as shown.



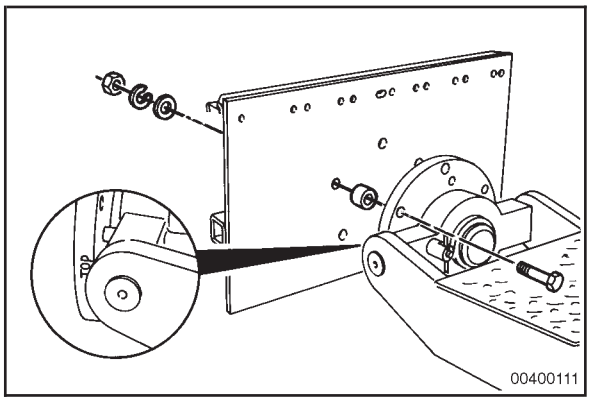
⚠ CAUTION ⚠

Six spacers, 20 mm [3/4 - in] thick are required to prevent the engine form contacting the engine stand. Put the spacers between the adapter plate and the engine stand.

Use six 5/8-18x3-1/4 in Grade 5 capscrews, plain washers, and locknuts.

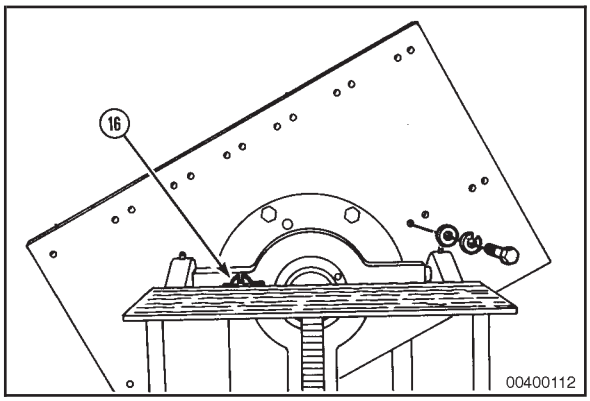
Use the adapter plate, Part No. 3375596. Use the specified mounting hardware to install the adapter plate.

NOTE: It will be necessary to rotate the swivel plate to install all six of the capscrews.



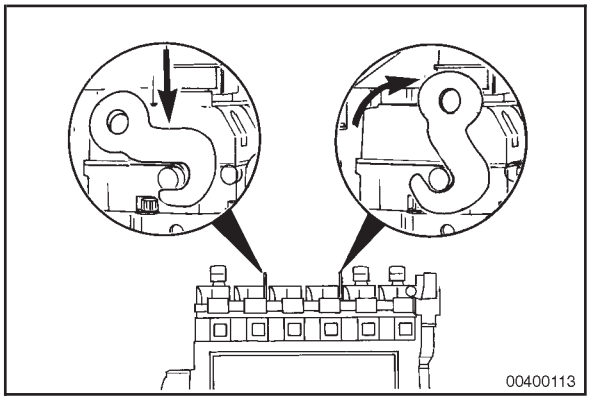
Disengage the locking pin (16). Turn the adapter plate as shown.

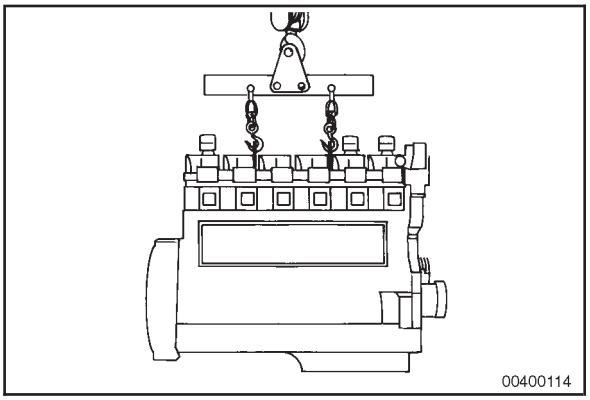
Install one 3/8-16x3-3/4 in capscrew in the location shown.



Put the Engine on the Rebuild Stand

Install engine lifting fixture, Part No. 3822512, to engine lifting brackets.

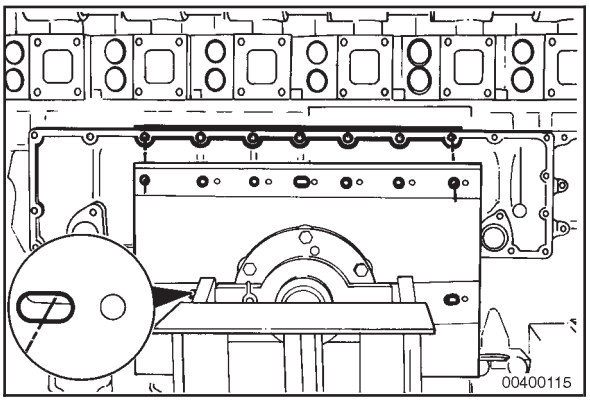




⚠ WARNING ⚠

Engine weighs 2045 kg [4508 lb]. Use a properly rated hoist and engine lifting fixture, Part No. 3822512, to lift the engine.

Lift the engine.



⚠ WARNING ⚠

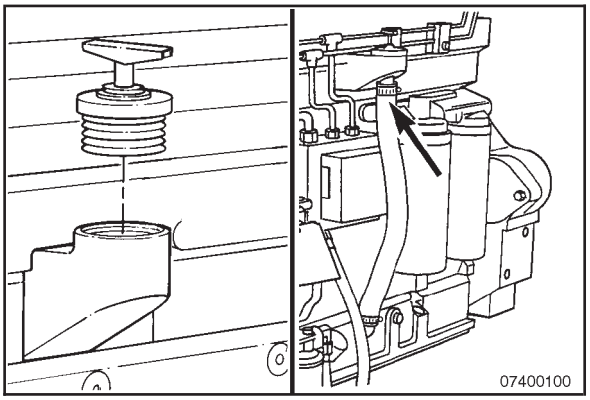
Be sure the locking pin on the engine stand is in the "LOCKED" position before removing the lifting hoist.

Use nine 3/8-16x3-3/4 in Grade 5 capscrews, plain washers, and lockwashers.

Attach the capscrews through the holes as shown.

Torque Value: 45 N•m [35 ft-lb]

Remove the hoist and lifting fixture.

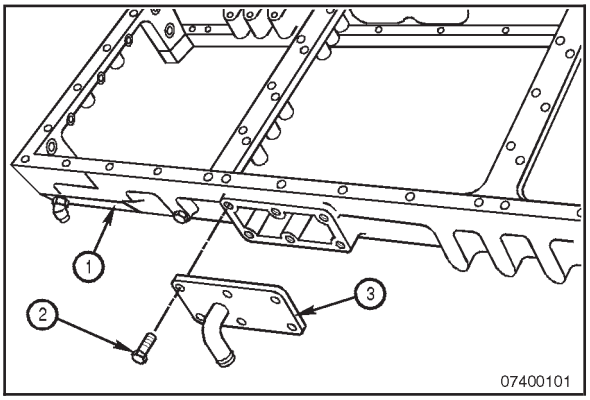


Remove the Oil Filler Cap and Hose

Remove oil filler cap from fill opening.

Remove cap, chain, washer and capscrew from engine.

Loosen the two hose clamps. Remove the hose.



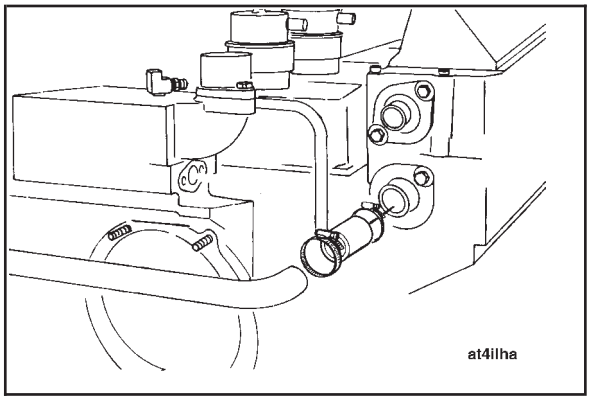
Remove the Hand Hole Cover with Hose Adapter

Remove six capscrews, hand hole cover and gasket.

Discard gasket.

Remove the Aftercooler Assembly

Remove the coolant lines from the aftercooler assembly.



⚠ CAUTION ⚠

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

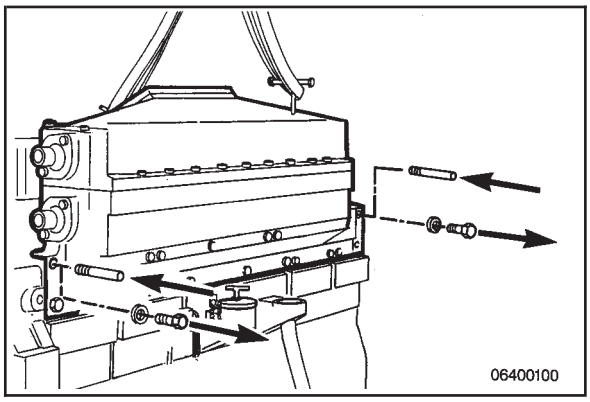
Remove two mounting capscrews. Install two [3/8-16 in] guide studs.

Use a hoist, two tee handles, and a lifting sling. Attach the tee handles, sling, and hoist.

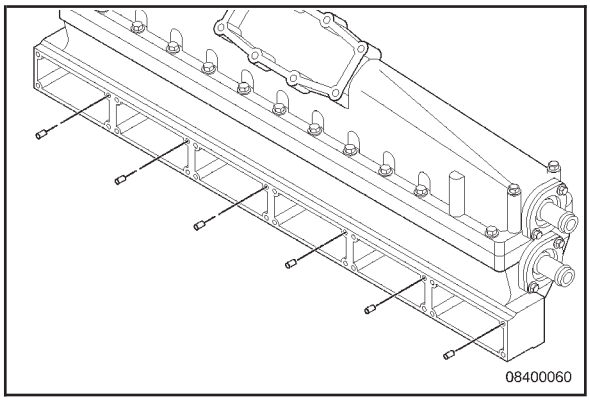
Raise the hoist until there is tension on the sling.

Remove the remaining capscrews and the aftercooler assembly.

Remove and discard the gaskets.



Remove and discard the aftercooler bolt seals from the aftercooler housing.



Remove the Air Compressor Air Inlet Connection and Fuel Supply Tubing

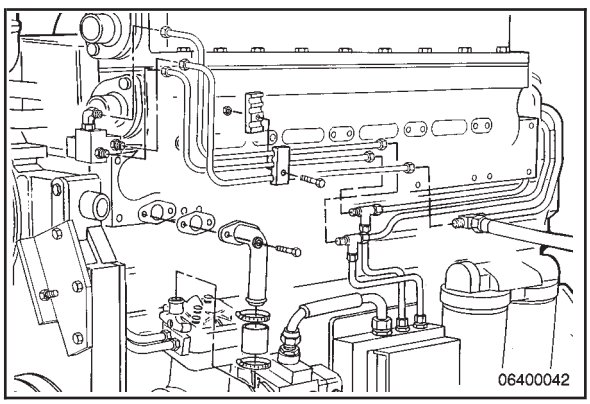
Loosen the two hose clamps and remove the inlet hose.

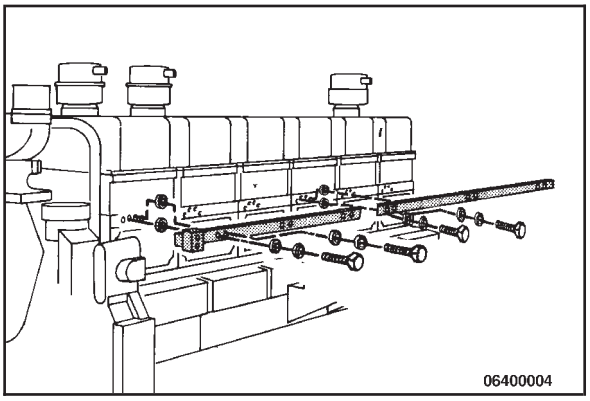
Remove the air compressor air inlet connection.

Remove and discard the hose.

Loosen the fuel tubing nuts at the fuel junction block on the fuel manifold.

Remove the fuel tubing mounting clamp and the fuel tubes.





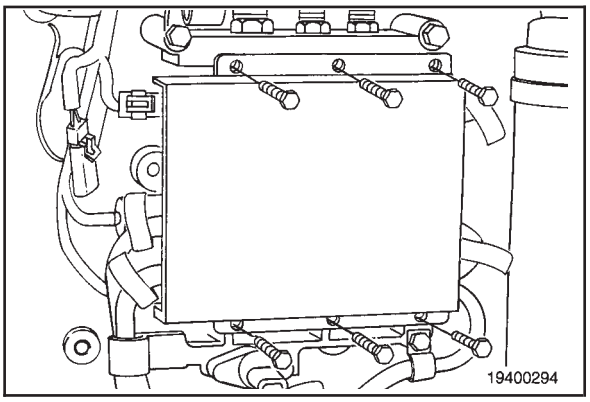
Remove the Fuel Manifold

Remove the 12 capscrews.

Remove the **front** fuel manifold.

Discard the o-rings.

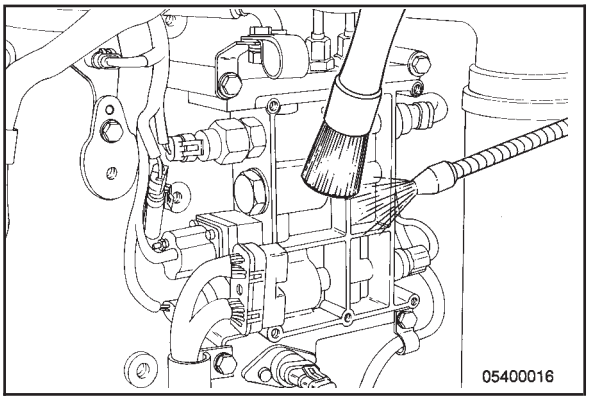
Repeat this process for the removal of the **rear** fuel manifold.



Remove the ECM

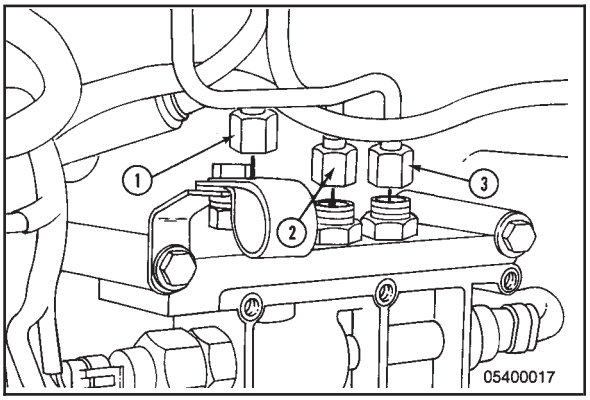
Remove the six capscrews which hold the ECM to the control valve body.

Remove the ECM from the control valve body.



Remove the Fuel Control Valve Body Assembly

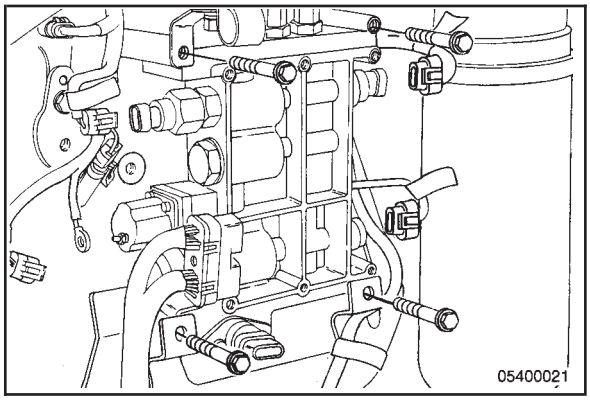
Clean the control valve body and the surrounding area.



Disconnect the fuel supply hose (1).

Remove the four capscrews.

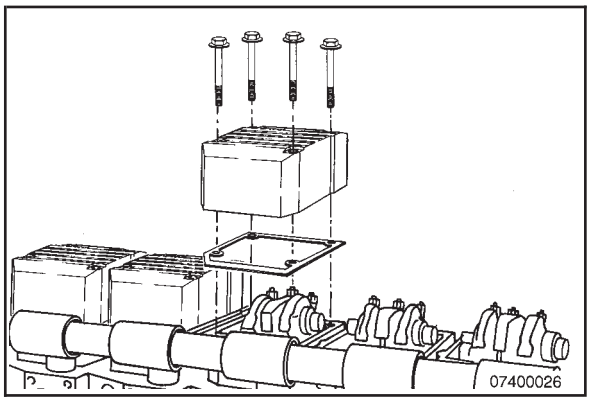
Remove the control valve body assembly.



Remove the Rocker Lever Covers

NOTE: Crankcase breathers can be mounted in any cylinder location. Record the number of breathers and their correct location before mounting.

Remove the rocker lever cover and discard the gasket.

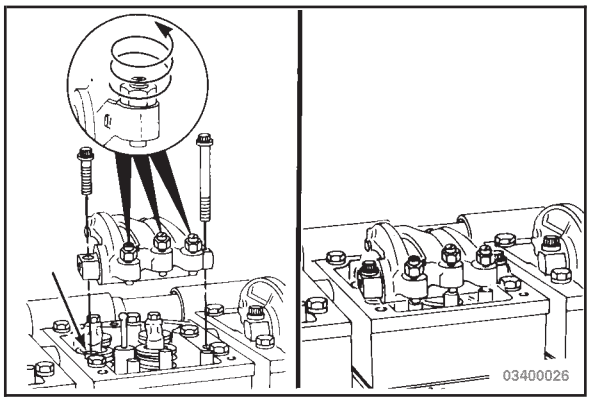


Remove the Rocker Lever Assemblies

NOTE: Do **not** allow the rocker levers to fall off the shaft during removal.

Remove the two capscrews.

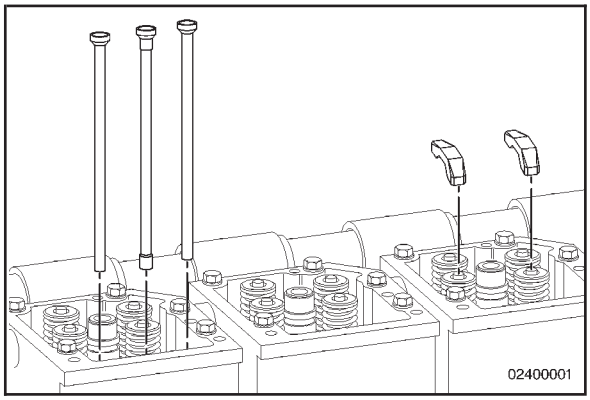
Remove the rocker lever assemblies.

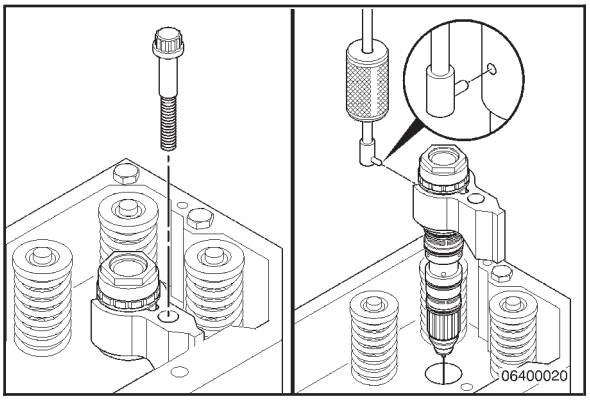


Remove the Push Rods and Crossheads

NOTE: It is a good service practice to mark the push rods so they can be installed in their original position.

Remove the push rods and crossheads.





Remove the Injector and Clamp

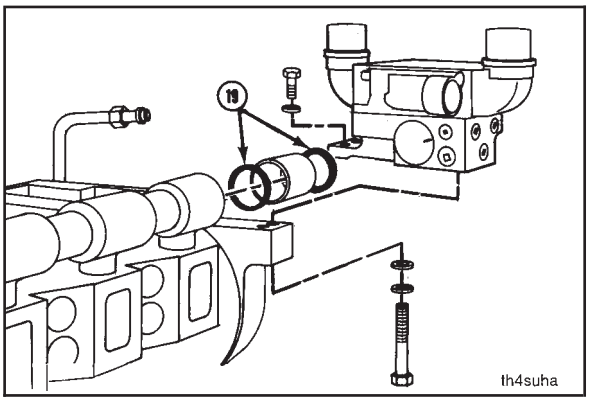
NOTE: The hold-down clamp can **not** be removed until the injector is removed.

Remove the injector hold-down capscrew.

Remove the injector and clamp.

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

If the injector puller mentioned above is **not** available, carefully use a pry bar. Pry **upward** on the injector against the cylinder head.



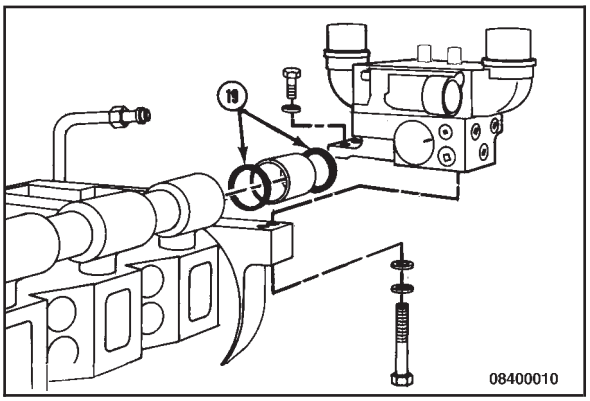
Remove the Thermostat Housing Assembly (Conventional)

Disconnect the air compressor water outlet tube from the thermostat housing.

Remove the four mounting capscrews and the thermostat housing assembly.

Remove the water transfer tube.

Remove and discard the two o-rings (19).



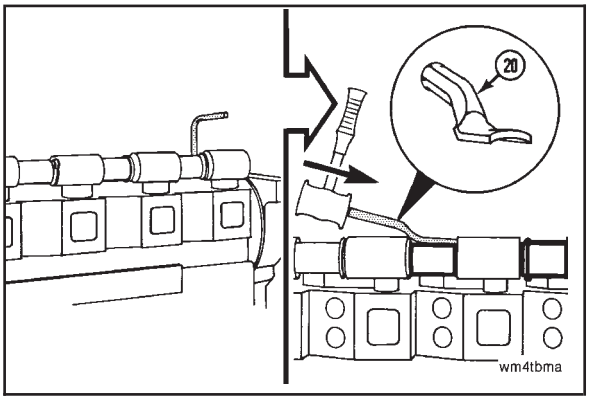
Remove the Thermostat Housing Assembly (LTA)

Remove the four mounting capscrews.

Remove the thermostat housing assembly.

Remove the water transfer tube.

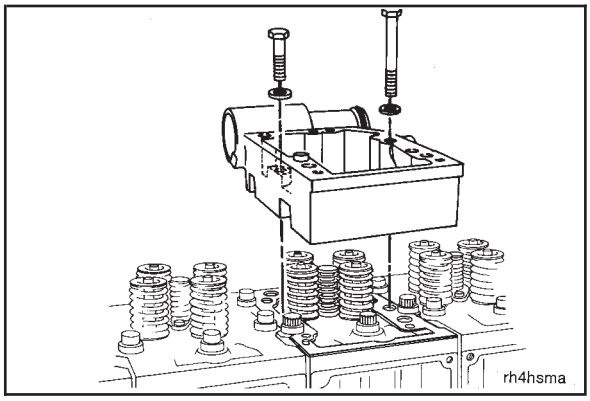
Remove and discard the two o-rings.



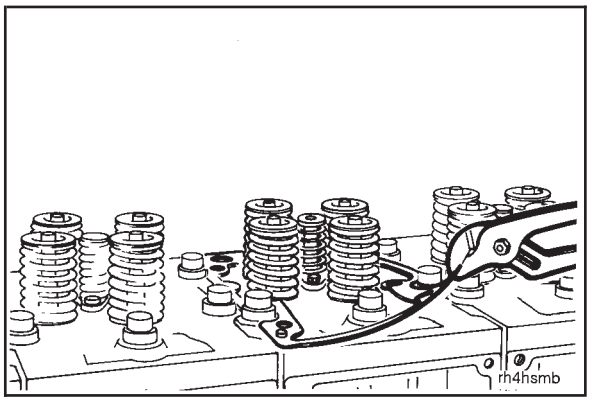
Use the water tube driver, Part No. ST-1319 (20). Use a hammer. Drive the water tube towards the front of the engine until the back part of the tube clears the rocker lever housing as shown.

Remove the Rocker Lever Housing

Remove the seven mounting capscrews and the rocker lever housing.



Remove and discard rocker lever housing gasket.

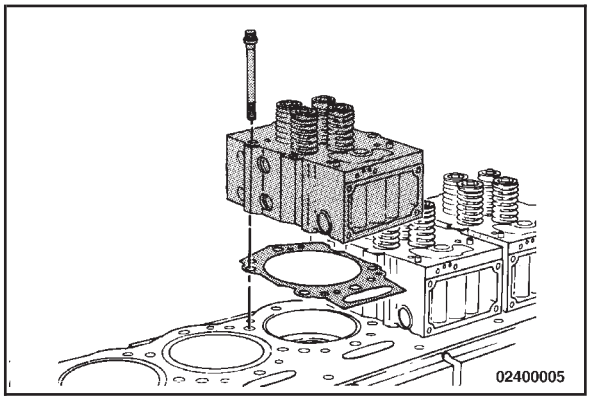


Remove the Cylinder Head

CAUTION

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

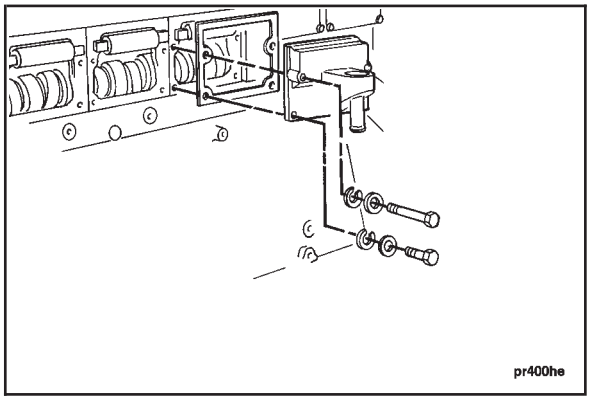
Remove the six capscrews and the cylinder head. Remove and discard the gasket.

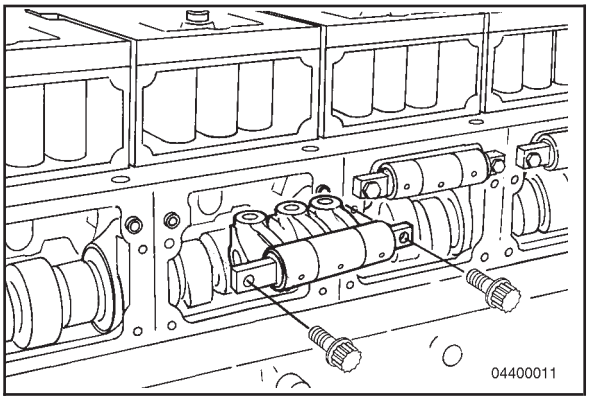


Remove the Cam Follower Assembly

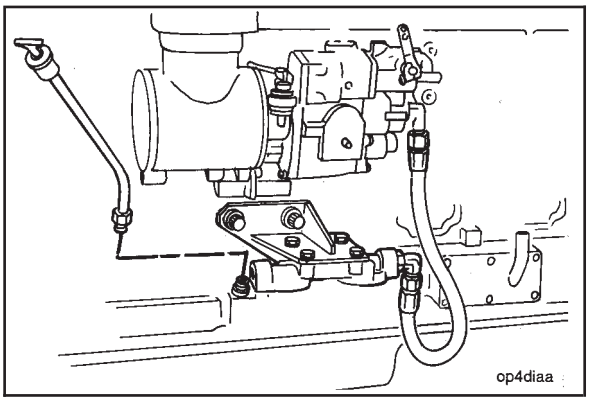
Remove the cam follower cover.

Remove and discard the gasket.



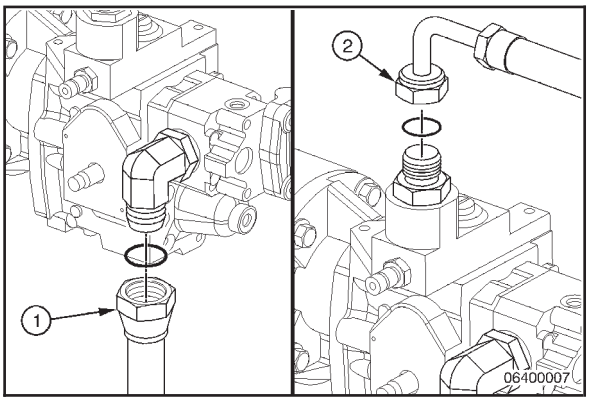


Remove the cam follower assembly. Pull straight out until the shaft is off the ring dowels.



Remove the Dipstick and Dipstick Tube (if equipped on this side of engine)

Remove the dipstick and dipstick tube.



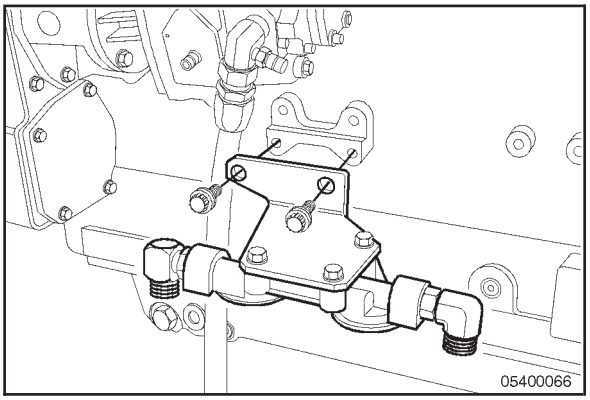
Remove the Fuel Pump

⚠ WARNING ⚠

Fuel is flammable. Do not allow cigarettes, flames, sparks, arching switches or equipment, pilot lights, or other ignition sources near the fuel system.

NOTE: Use two wrenches to remove the fuel tubes and hoses.

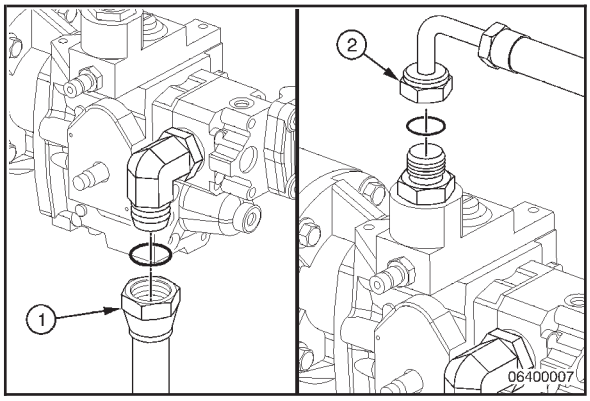
Support the mating fittings with a wrench. Loosen the fuel tube nuts with the other wrench.



Remove the fuel tubes, hoses and o-rings from the fuel pump and fuel filter head.

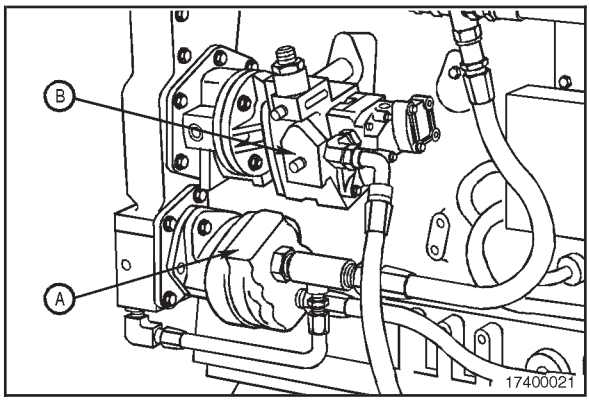
Remove the fuel filter head.

Disconnect the fuel inlet hose (1). Disconnect the electronic fuel control valve supply hose (2). Remove o-rings.



Rail Applications

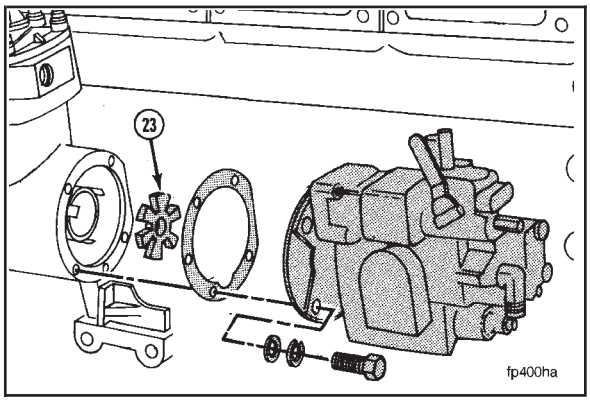
The lubricating oil scavenge pump (A) **must** be removed prior to removing the fuel pump (B) to allow access to the fuel pump mounting capscrews.



Remove the four mounting capscrews, and the fuel pump.

Remove the jaw coupling spider (23).

Remove and discard the gasket.



Remove the Air Compressor (Single Cylinder)

⚠ WARNING ⚠

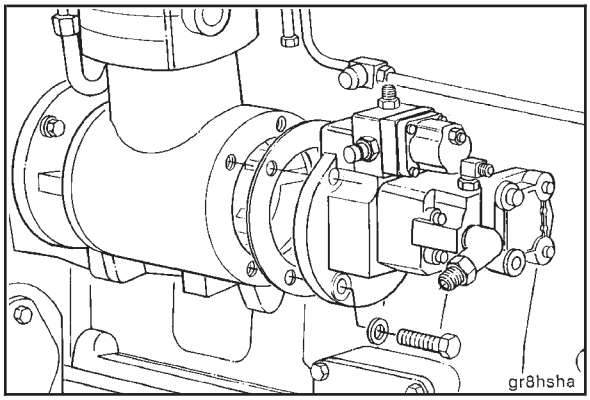
When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam can cause serious personal injury.

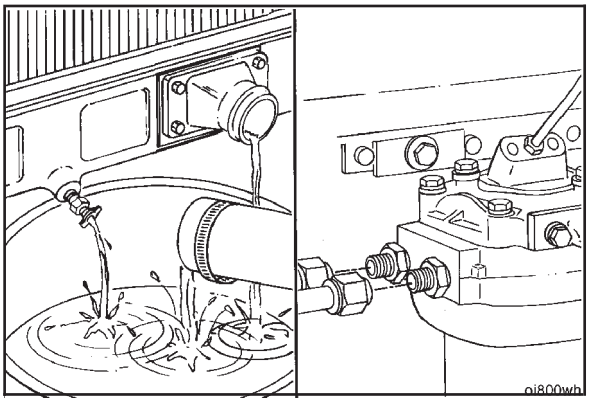
NOTE: The illustrations shown will be the SS model single cylinder air compressor. Differences in procedures for SS, QE and ST Cummins air will be shown where necessary.

Use steam to clean the air compressor.

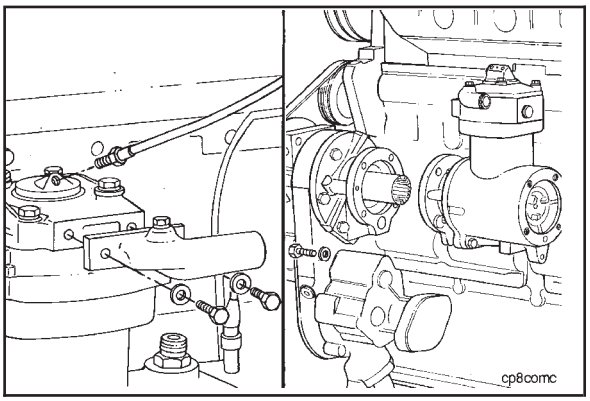
Dry with compressed air.

Remove the fuel pump.





Remove the coolant lines from the air compressor.



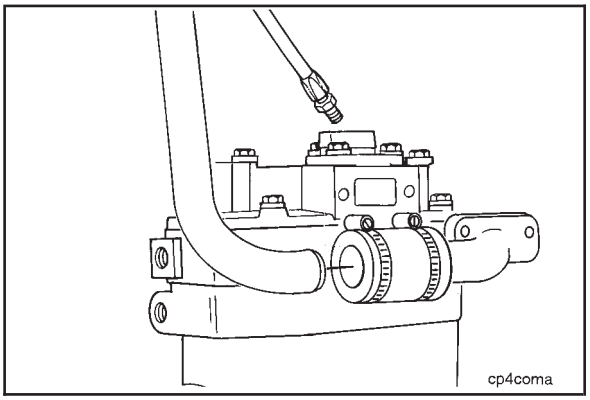
⚠ CAUTION ⚠

This assembly weighs more than 23 kg [50 lb]. Handle securely to avoid dropping.

Remove the air connections from the air compressor.

Remove the air compressor support bracket and capscrews.

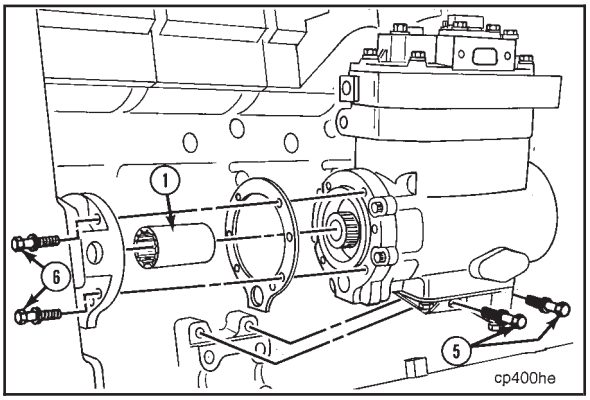
Remove the four capscrews, the air compressor, and splined coupling.



Remove the Air Compressor (Twin Cylinder)

Disconnect the coolant lines from the air compressor.

Remove the air inlet and outlet connections from the air compressor.



Remove the air compressor support mounting capscrews (5).

Remove the four capscrews (6).

Remove the air compressor.

Remove the splined coupling (1).

Remove and discard the gasket.

⚠ CAUTION ⚠

Use a capscrew in the shaft to prevent damage to the shaft threads.

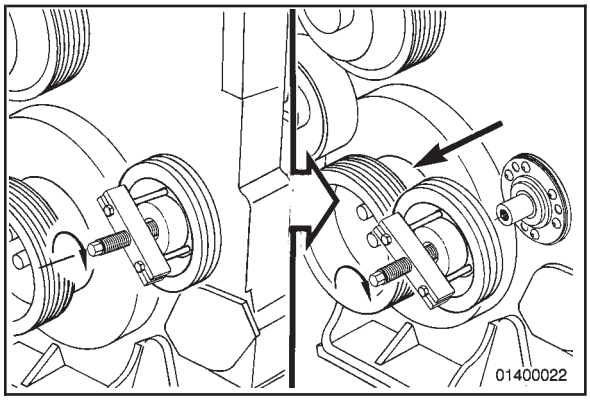
Install a [7/16-20x1 in] capscrew in the shaft.

Use a standard puller, Part No. ST–647, or equivalent. Remove the accessory drive pulley.

Use a brass drift and remove the woodruff key from the shaft.

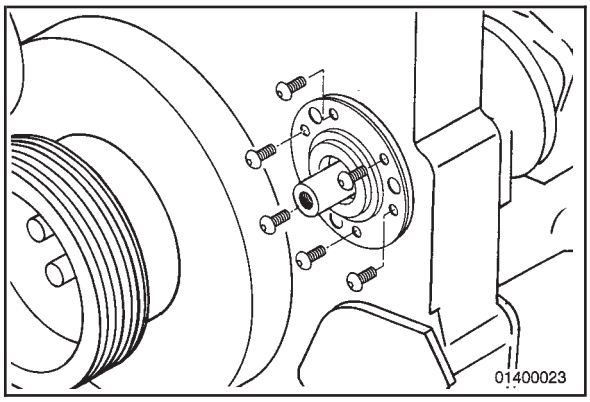
Remove the capscrew from the shaft.

Remove the keyway seal.



Remove the Accessory Drive Seal

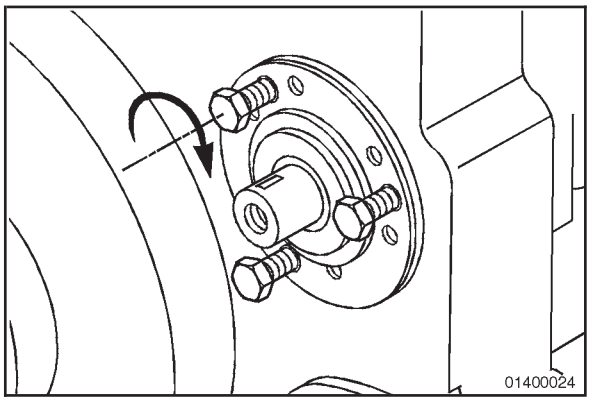
Remove the six button head hex socket capscrews.



Use three [1/4-20 x 1 in] capscrews to remove the seal from the accessory drive shaft.

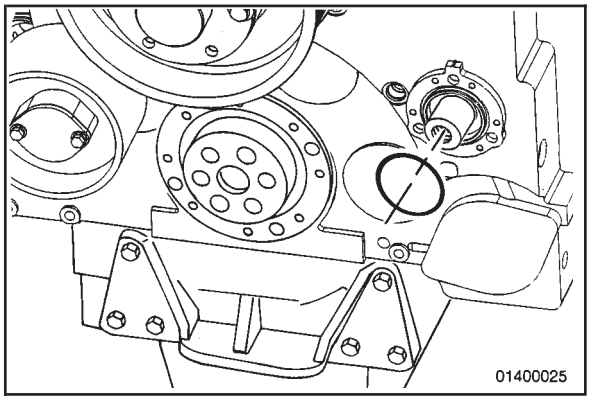
Install the three capscrews in the clinch nuts in the seal case.

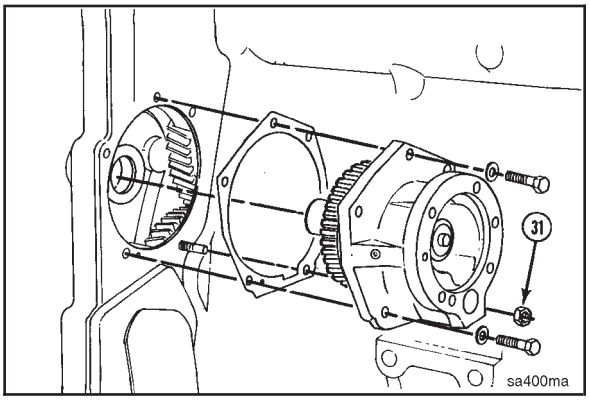
Tighten the capscrews alternately and evenly to remove the seal.



Remove the o-ring from the groove in the gear cover.

NOTE: The crankshaft pulley and damper have been removed for clarity.





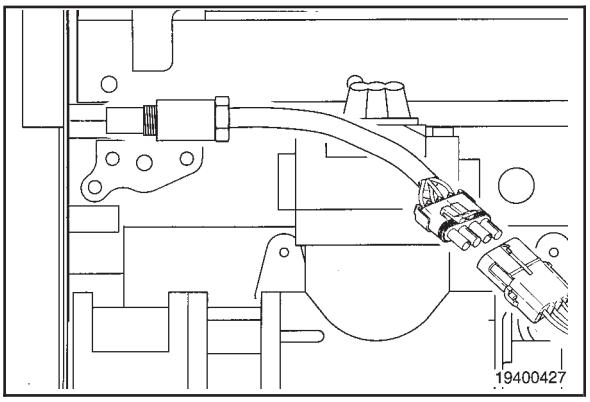
Remove the Accessory Drive Assembly

CAUTION

The woodruff key must be removed before removing the accessory drive assembly. Damage to the bushing can result.

Remove the four capscrews and the nut (31).

Remove the accessory drive assembly.

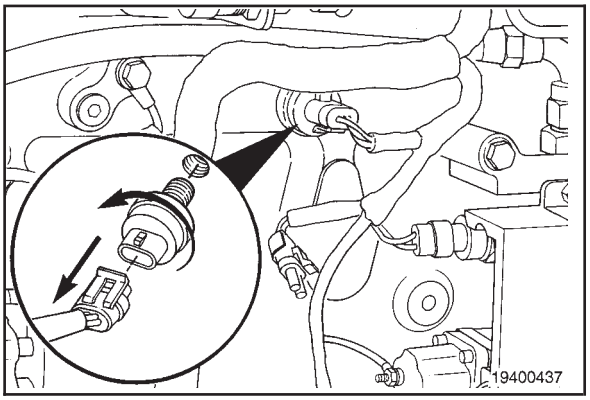


Disconnect the Engine Speed Sensor (ESS)

Disconnect the engine speed sensor (ESS) connectors from the engine harness.

Loosen the locknut.

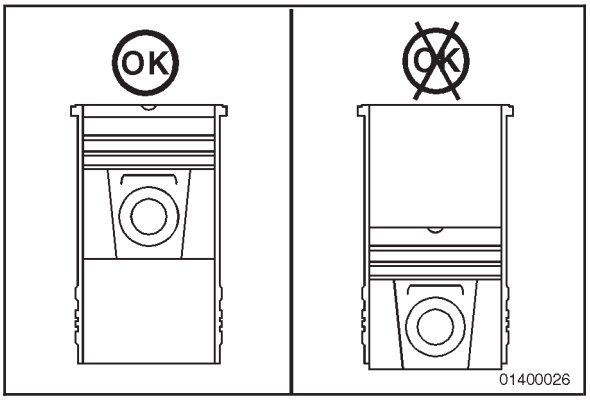
Remove the ESS from the cylinder block.



Disconnect the Lubricating Oil Pressure Sensor

Lift up on the tab and disconnect the connector from the lubricating oil pressure sensor.

Use a deep flank drive socket, Part No. 3823843. Remove the lubricating oil pressure sensor from the engine block.



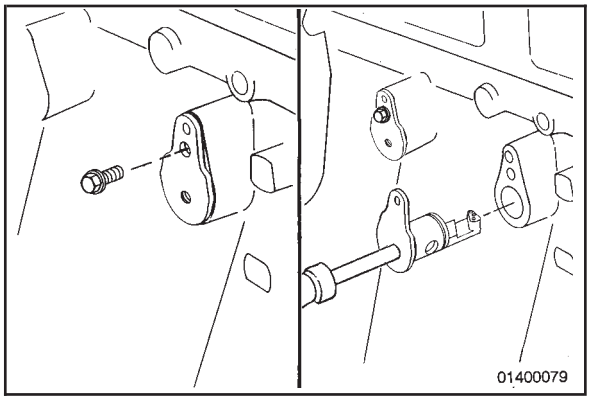
Remove the Piston Cooling Nozzles

CAUTION

Do NOT attempt to remove the piston cooling nozzle when the piston is at BOTTOM DEAD CENTER (BDC). The nozzle will be damaged and can result in piston failure.

Remove the piston cooling nozzle mounting capscrew.

Use a slide hammer with a [3/8 x 16 in] thread to remove the nozzle.



Remove the Vibration Damper and Pulley Assembly

CAUTION

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

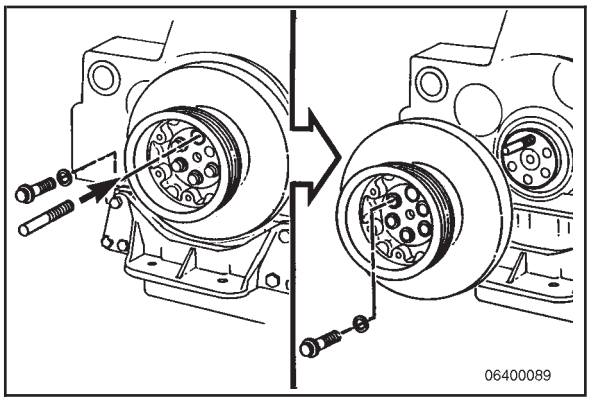
Remove one capscrew and install a [3/4-16x5 in] guide stud.

CAUTION

Do not pry or hammer on the vibration damper. Damage will result.

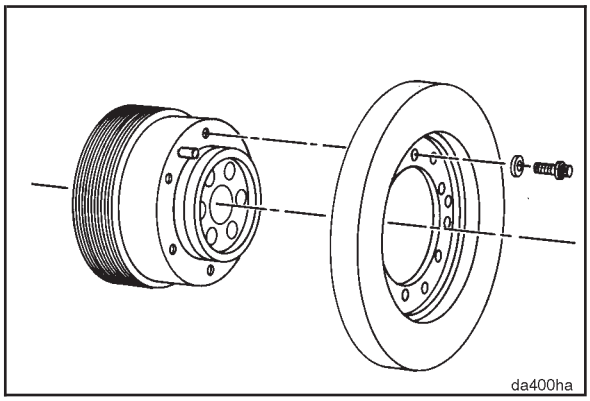
Remove the remaining capscrews, damper and pulley.

Remove the guide stud.



NOTE: Engines that do not have a belt driven fan hub have an adapter instead of the pulley.

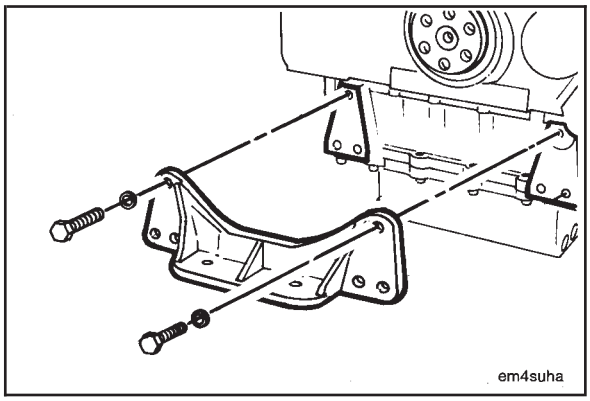
Remove the pulley from the damper.

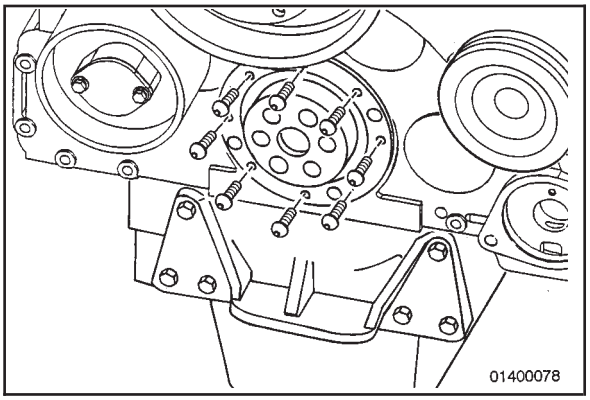


Remove the Front Engine Support

Remove the front engine support.

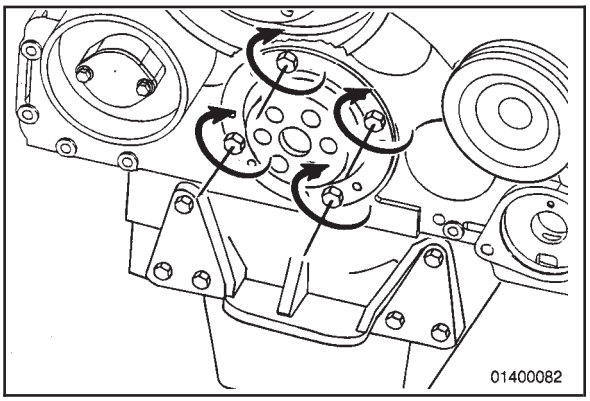
Clean and check the support for reuse. Check for cracks or damage.





Remove the Front Crankshaft Seal

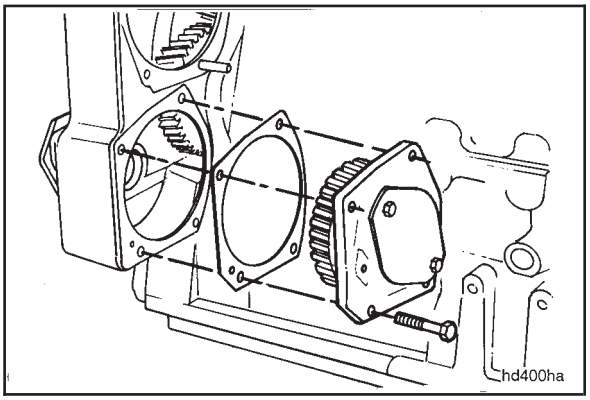
Remove the eight button head hex socket capscrews.



Use four [1/4-20 UNCx1 in] capscrews to remove the seal from the crankshaft.

Install the capscrews into the clinch nuts in the seal case.

Tighten the capscrews alternately and evenly to remove the seal.



Remove the Hydraulic Pump Drive Assembly (if equipped)

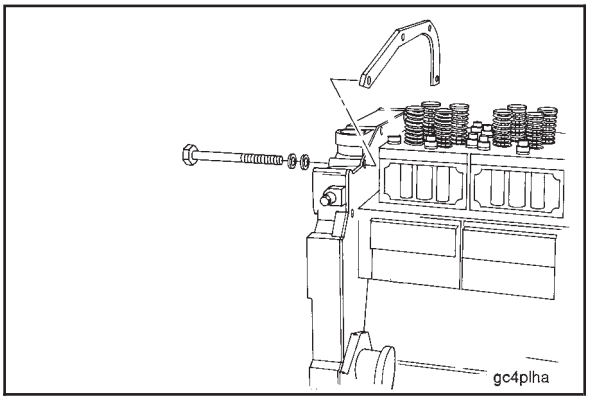
Remove the hydraulic pump drive.

NOTE: Some engines contain a cover plate instead of a hydraulic pump drive assembly.

Remove the four capscrews.

Remove the hydraulic pump drive assembly.

Remove and discard the gasket.

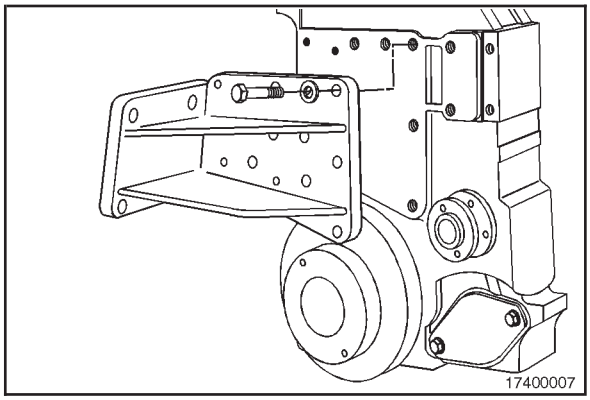


Remove the Gear Cover Clamping Plate

NOTE: Some engines have two plates.

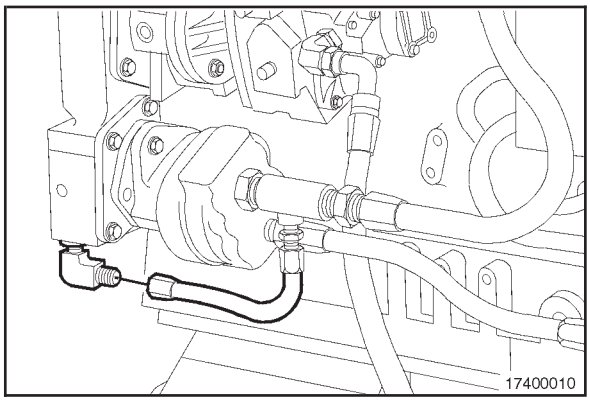
Rail Applications

Remove the front support mounting bracket by removing fifteen capscrews and washers.



Rail Applications

Remove the scavenge line by disconnecting the tube from the 90 degree elbow at the base of the front gear cover.



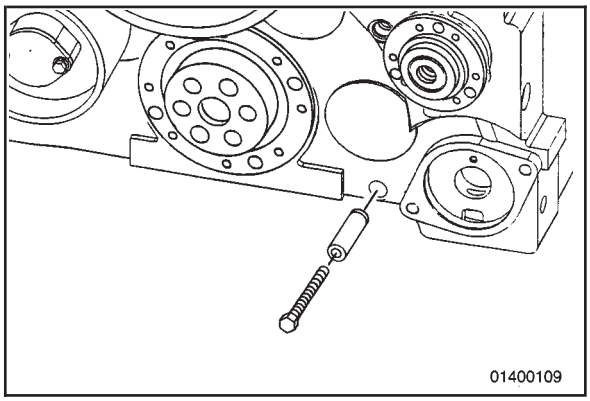
Remove the Front Gear Cover

NOTE: The master dowel **must** be removed before the gear cover can be removed.

Use a 5/16-18 capscrew or a threaded rod. Use an old piston pin or a slide hammer. Remove the dowel.

NOTE: The front cover contains five capscrews on the bottom and three capscrews on back.

Remove the capscrews.



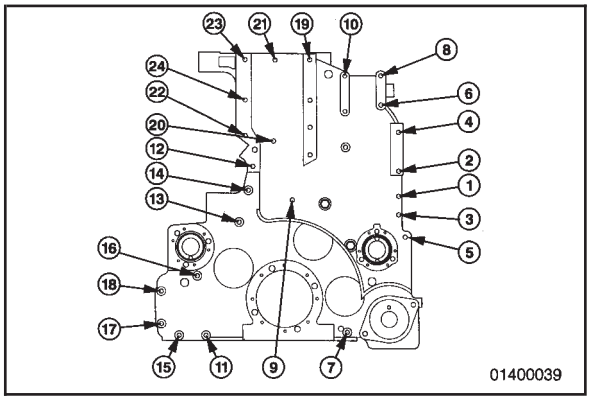
⚠ WARNING ⚠

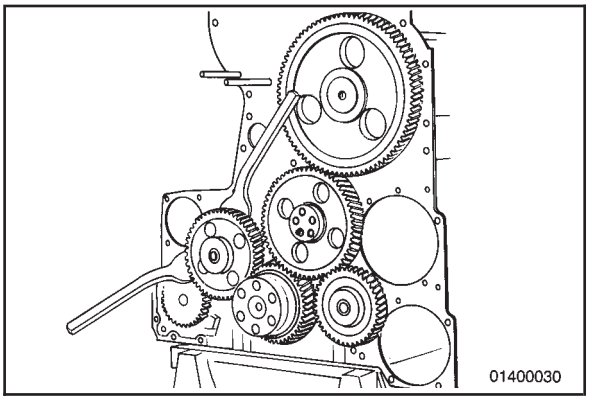
This assembly weighs more than 23 kg. [50lb]. To avoid personal injury, use a hoist or get personal assistance to lift component.

NOTE: The gear cover has 21 capscrews in the front of the cover and three, Nos. 1, 2, and 3, on the back side of the cover.

Remove the 24 capscrews, four nuts, washers, and the gear cover.

Remove and discard the gasket.



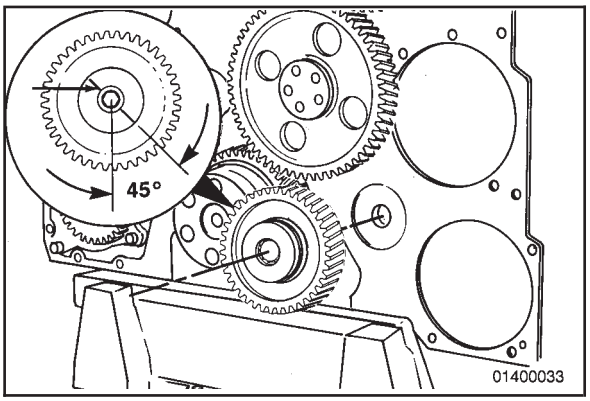


Remove the Water Pump Idler Gear

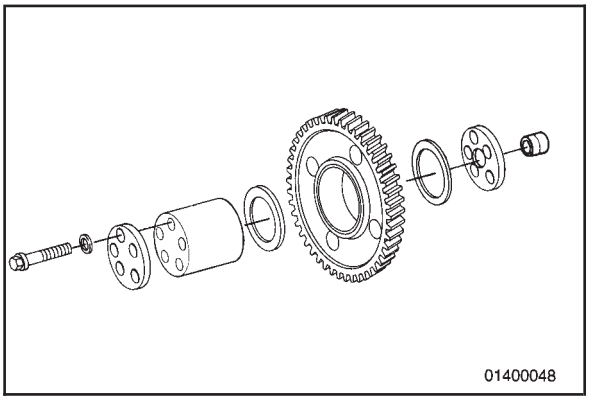
NOTE: The bolt-in idler shafts have a flange that require the shaft, the idler gear, and the thrust washer to be removed as an assembly.

Remove the capscrew from the idler gear.

NOTE: To remove the gear assembly, use two pry bars and pry the gear and the shaft from the block.



Remove the hydraulic pump idler shaft and thrust bearings.

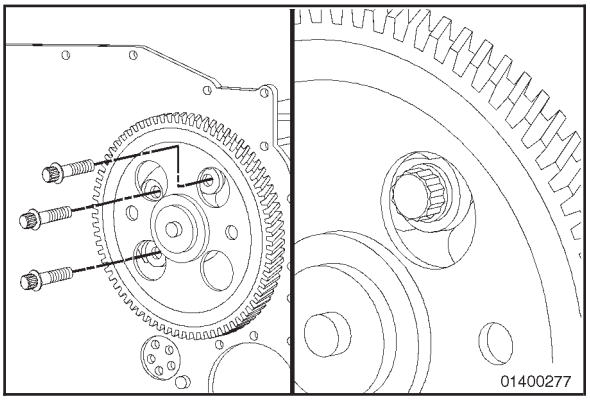


Remove the Camshaft Idler Gear

Remove the five capscrews, the retaining ring, and the front thrust bearing.

Remove the camshaft idler gear.

Remove the rear thrust bearing, the idler shaft, and the thrust bearing wear sleeve.



Remove the Thrust Bearing Plate

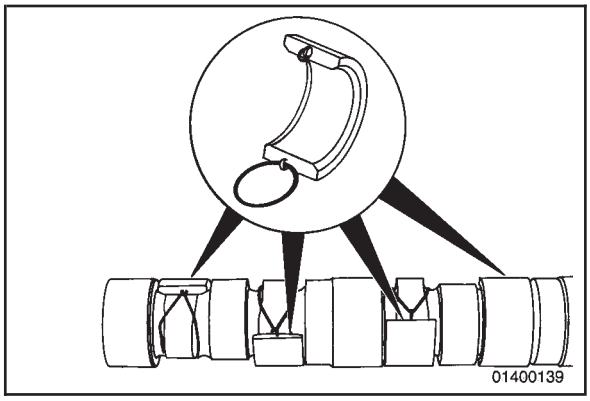
Remove the three 12-point capscrews and thrust bearing plate.

Remove the Camshaft

⚠ CAUTION ⚠

Pilots must be used to prevent damage to the camshaft and the bushings. Be sure the hooks do not damage the camshaft bushings.

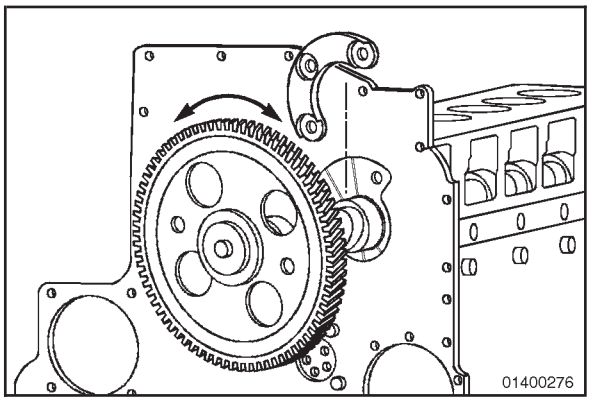
Use camshaft installation pilots, Part No. 3825150. Put the pilots on the inner base circle of the valve lobes for the last two cylinders before removing camshaft from block.



⚠ CAUTION ⚠

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

Rotate the camshaft during removal so that one of the pilots is always on the bottom part of the camshaft bushing.

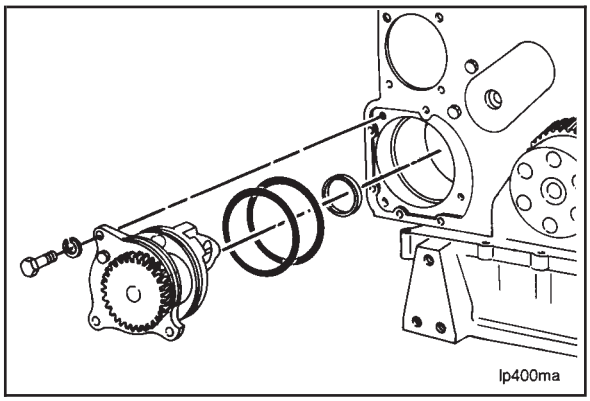


Remove the Lubricating Oil Pump

Remove the three capscrews from the oil pump mounting flange.

Use a pry bar and gently pry the oil pump out of the engine block.

Remove and discard the two o-rings and the seal ring from the pump.

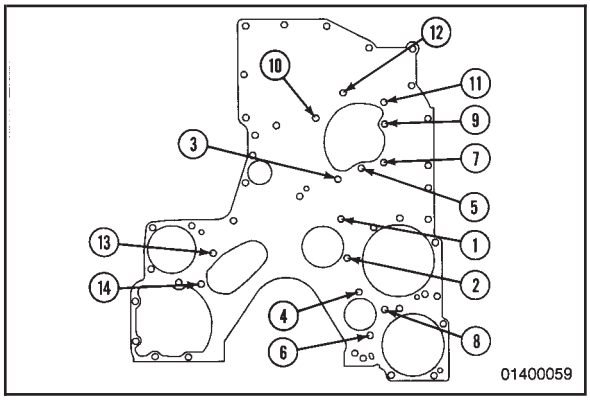


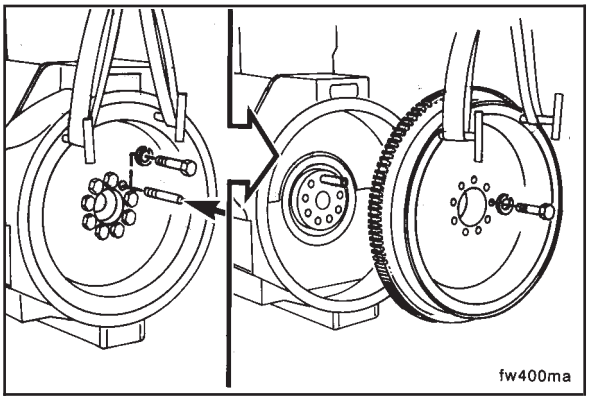
Remove the Front Gear Cover Spacer Plate

Remove the 14 mounting capscrews from the plate.

Remove the plate and discard the gasket.

NOTE: Tag the special mounting capscrews for future identification.





Remove the Flywheel

CAUTION

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

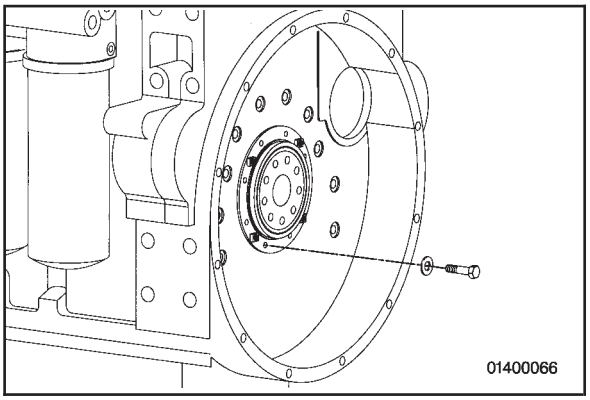
Use two [5/8-18 inch] guide studs to prevent the flywheel from rotating. Remove two capscrews and install the guide studs.

Use a hoist, two tee handles, and a lifting sling. Install the tee handles.

Remove the remaining capscrews.

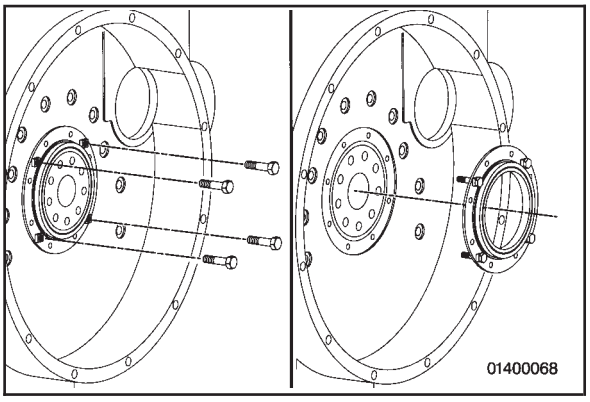
Remove the flywheel.

NOTE: Use a mallet to tap the flywheel from the crankshaft, if necessary.



Remove the Rear Crankshaft Seal

Remove the seal mounting capscrews.



Use four [1/4-20 UNC x 1 inch] capscrews to remove the seal from the crankshaft.

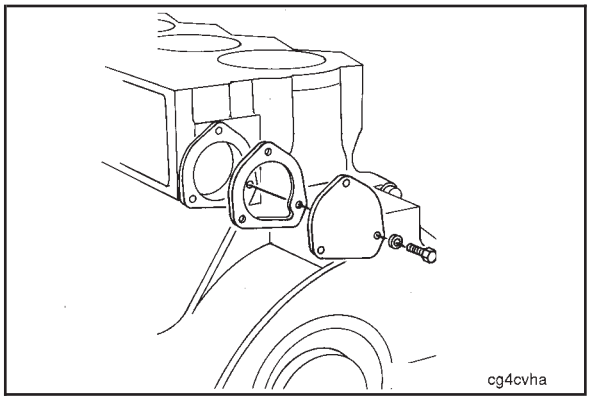
Install the capscrews in the welded nuts in the seal case. Tighten the capscrews alternately and evenly to remove the seal.

Remove the Camshaft Cover Plate

Remove the three capscrews.

Remove the camshaft cover.

Remove and discard the gasket.

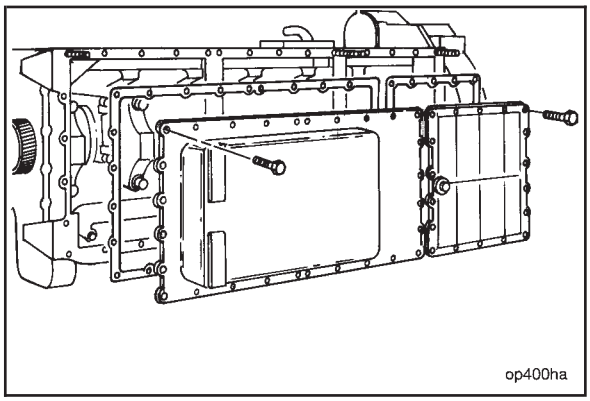


Remove the Lubricating Oil Pan and Lubricating Oil Pan Adapter Cover Plate

Remove the 28 capscrews from the oil pan.

Remove the oil pan.

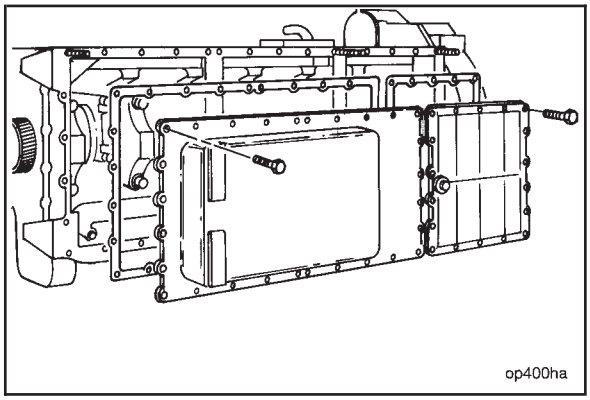
Remove and discard the gasket.



Remove the 18 capscrews from the cover plate.

Remove the cover plate.

Remove and discard the gasket.

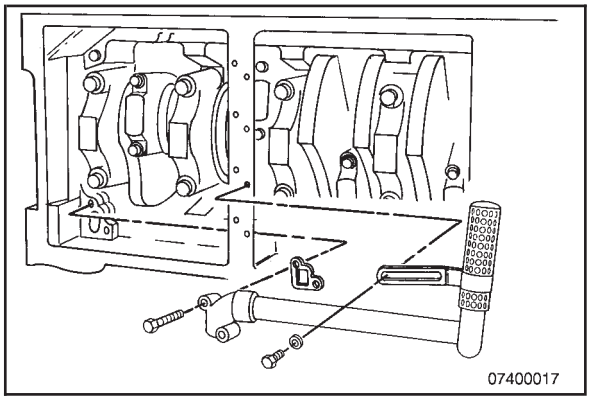


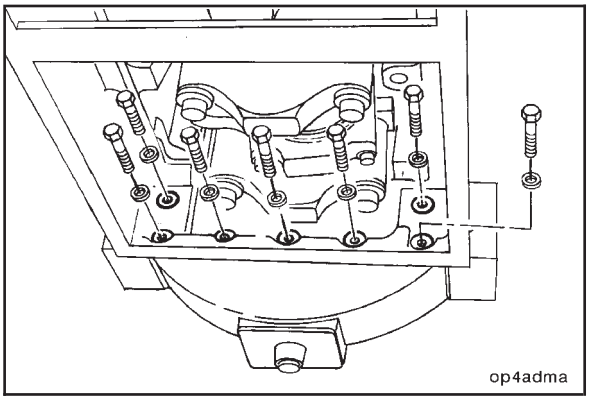
Remove the Lubricating Oil Pan Suction Tube

Remove the three capscrews from the suction tube.

Remove the oil pan suction tube.

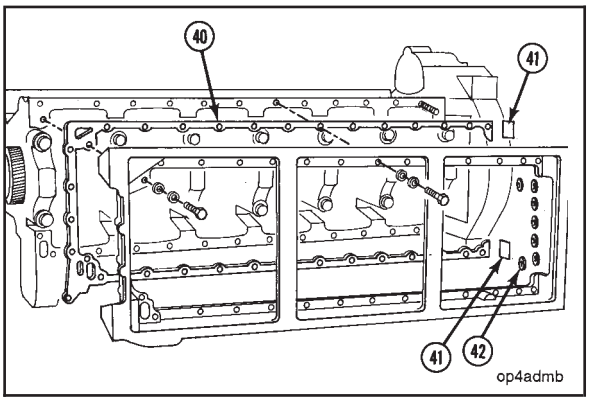
Remove and discard the gasket.





Remove the Lubricating Oil Pan Adapter

Remove the two [7/16-14 inch] capscrews, and the five [3/8-16 inch] capscrews from the flywheel housing.

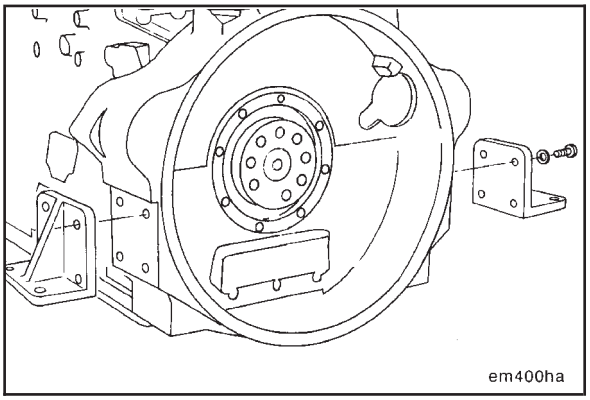


⚠ CAUTION ⚠

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

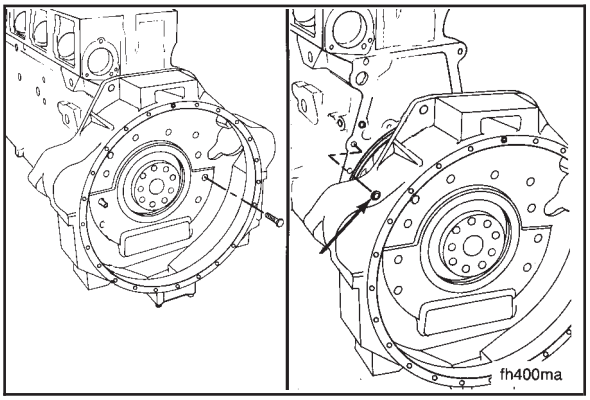
Remove all of the capscrews and the pan adapter.

Remove and discard the gasket (40), the two rectangle seals (41), and the seven bolt seals (42) from the adapter.



Remove the Rear Engine Mounts

Remove the rear engine mounts from the flywheel housing.



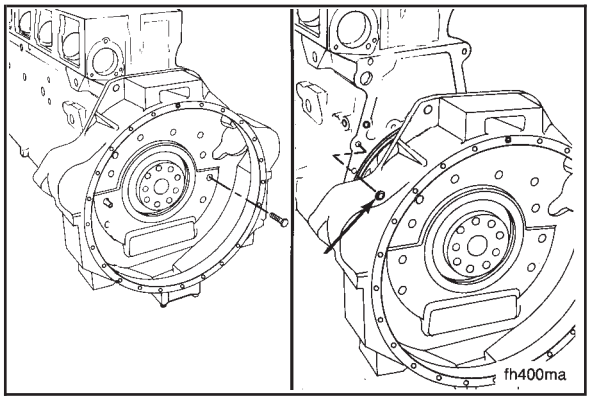
Remove the Flywheel Housing

⚠ CAUTION ⚠

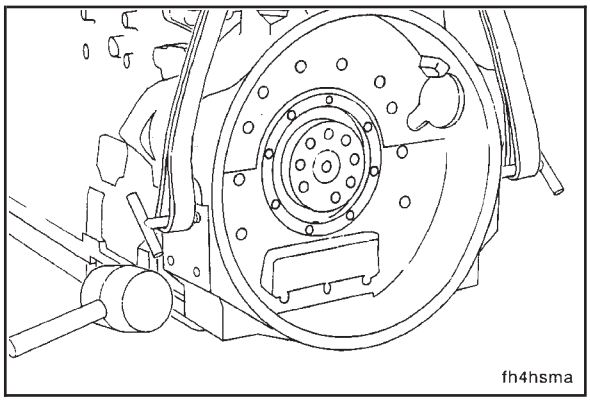
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Use two guide studs to prevent the flywheel housing from rotating during disassembly. Remove two capscrews. Install the guide studs.

Use a hoist, a tee handle, and a lifting sling. Install the tee handle. Adjust the hoist until there is tension in the lifting sling. Remove the remaining capscrews.



Use a mallet and tap the flywheel housing off the two locating dowels. Remove and discard the rectangular seal and the bolt seals.

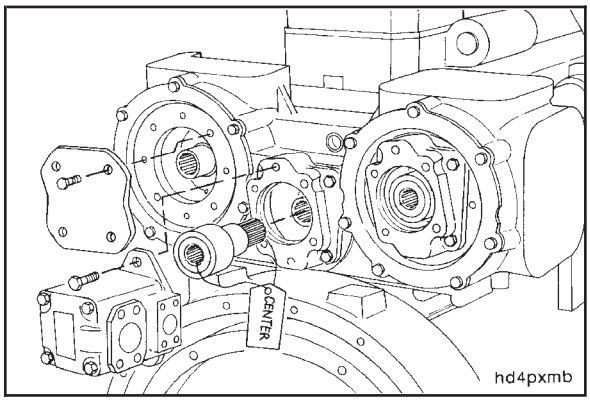


Remove the Rear Gear Drive - Upper Unit

NOTE: The hydraulic pump supports and the hydraulic pump adapters **can** be different. **Mark** the parts for location.

Remove the hydraulic pump support and the hydraulic pump adapters or cover plates.

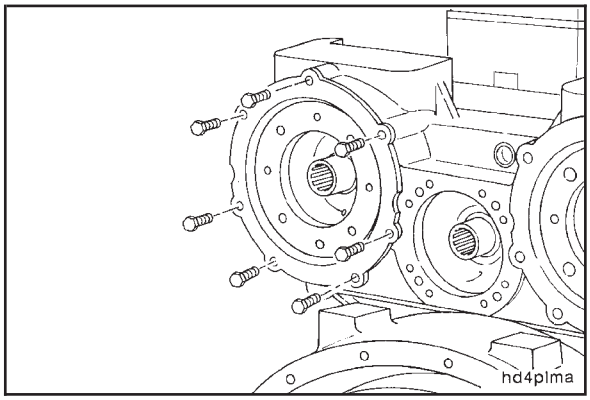
Remove and discard the gaskets.

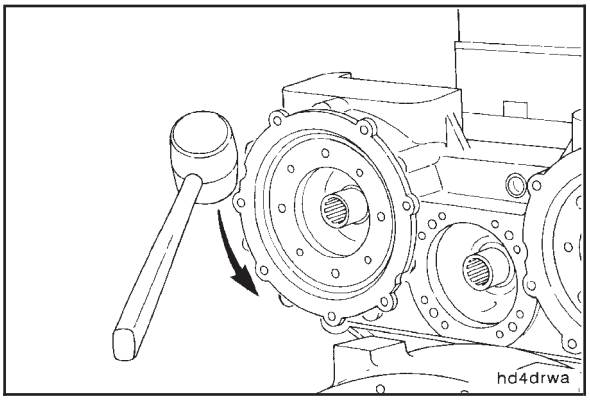


NOTE: Some engines will **not** have an outer hydraulic drive. These engines require a cover plate and a nonsplined shaft, but do **not** use a hydraulic gear.

If using a cover plate, remove the cover plate and nonsplined shaft.

Remove the seven capscrews from each outboard hydraulic drive or cover plate.





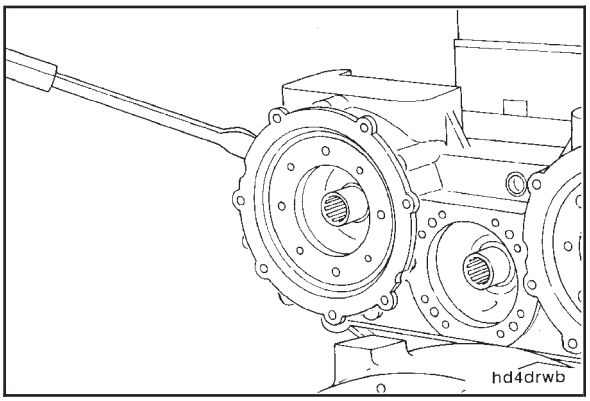
⚠ WARNING ⚠

Care must be taken to avoid possible breakage of the capscrew mounting flanges.

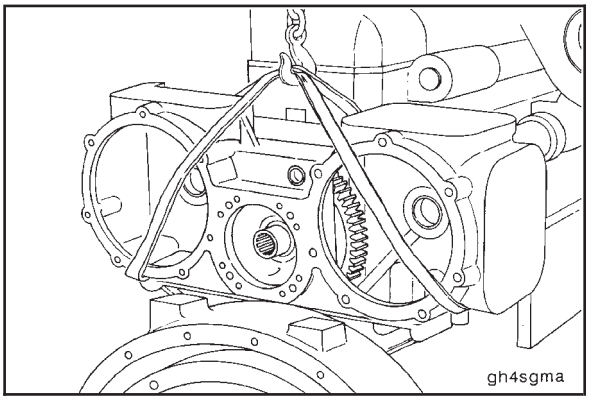
⚠ CAUTION ⚠

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

The outboard hydraulic pump supports must be rotated to remove from the housing. Use a mallet. Carefully tap the side of the support.



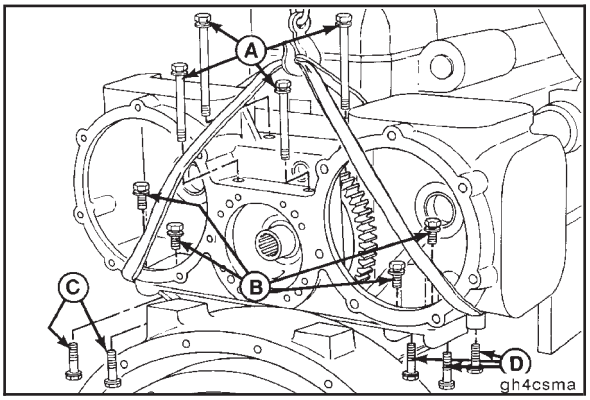
Use a pry bar. Remove both outboard hydraulic pump supports.



⚠ CAUTION ⚠

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

Use a hoist and lifting sling. Install the lifting sling around both sides of the upper housing. Adjust the hoist until there is tension in the lifting sling.



⚠ CAUTION ⚠

The center gear in the drive protrudes from the bottom of the housing. Use wood blocks (2) to level the gear and to prevent the part from being damaged.

Remove the four capscrews from the top of the housing (A), the four internal capscrews (B), the two capscrews from the bottom of the upper housing on the left side (C), and the three capscrews from the bottom on the right side (D).

Remove the rear gear train upper housing from the lower housing.

Remove the gasket. Keep the gasket for future use.

Remove the Rear Gear Drive - Lower Unit

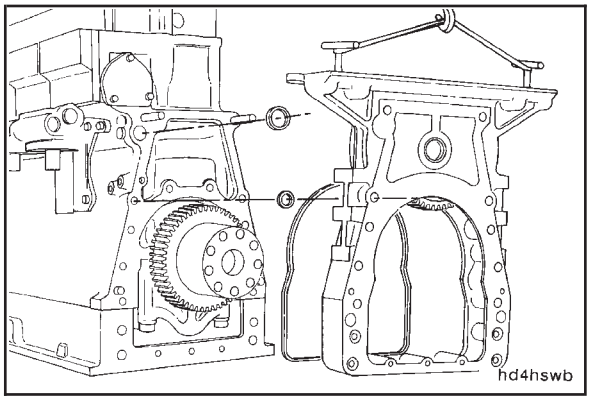
⚠ CAUTION ⚠

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

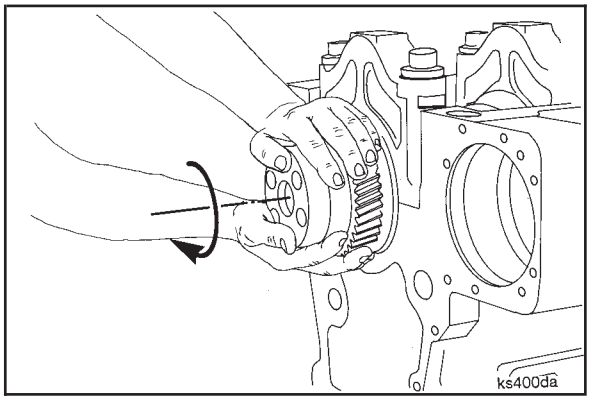
With the flywheel housing removed. Use a hoist, two tee handles, and a lifting sling. Install the tee handles. Adjust the hoist until there is tension in the lifting sling.

Use a mallet. tap the rear gear train lower housing off the two locating dowel pins in the rear face of the cylinder block.

Remove and discard the rectangular seal, bolt seals, and main oil rifle seal.

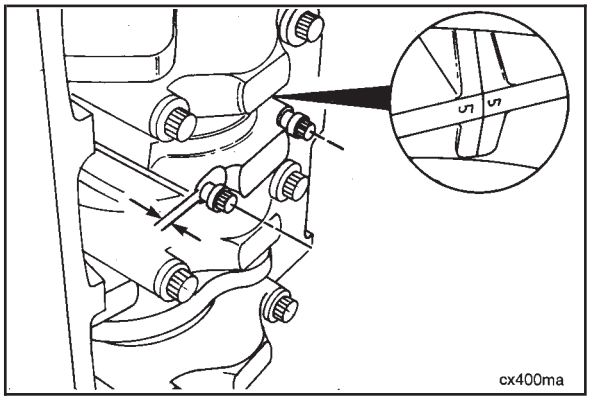


Rotate the crankshaft by hand to position a connecting rod at bottom dead center (BDC).



The connecting rods **must** have the cylinder number marked on both the rod and the cap on the side positioned toward the camshaft. Check the rods for correct markings. Use a steel stamp and mark any rod that is **not** correctly marked.

Loosen the capscrews until there is 6 mm [1/4 inch] of clearance between the rod cap and the capscrew head.

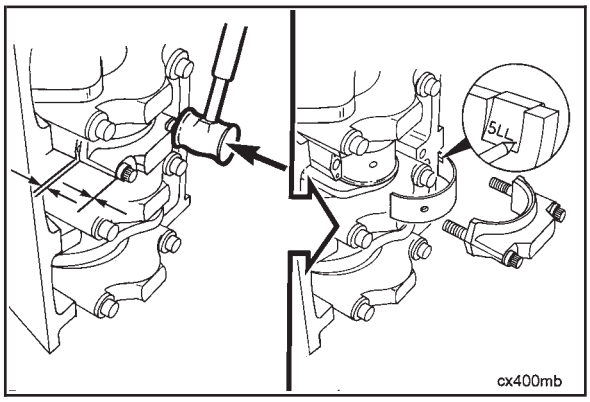


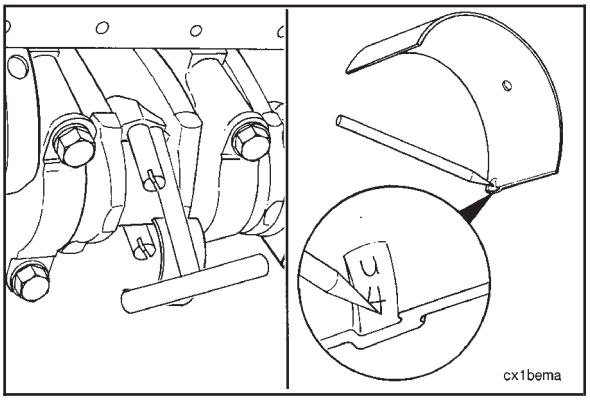
Use a mallet. Tap the connecting rod capscrews until the connecting rod cap and rod separate.

Remove the capscrews and the cap.

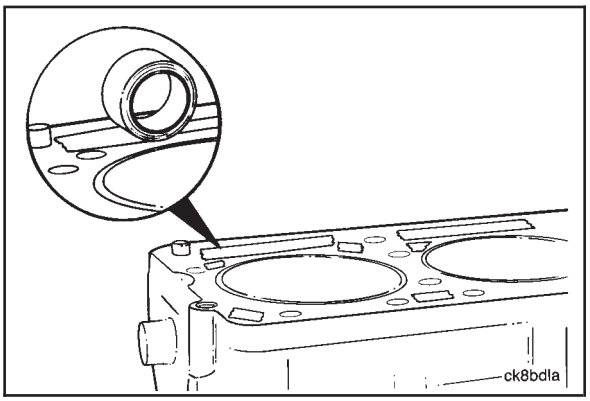
Remove the lower rod bearing. Use a awl and mark the bearing position in the tang area.

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



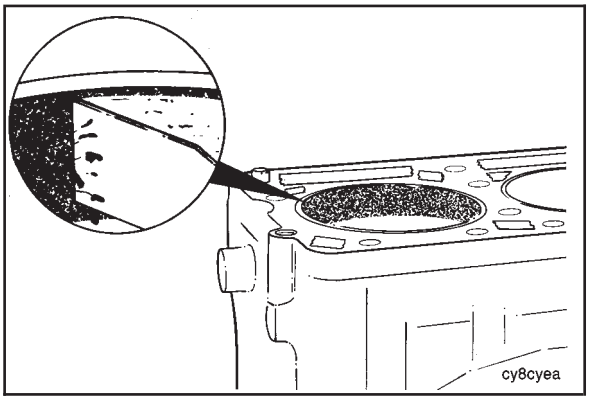


After installing two guide pins, Part No. 3375098, in the connecting rod, push the rod up far enough to allow the upper bearing shell to be removed. Use a “T handle” piston pusher to push the rod away from the crankshaft.



Remove the Piston and Rod Assembly

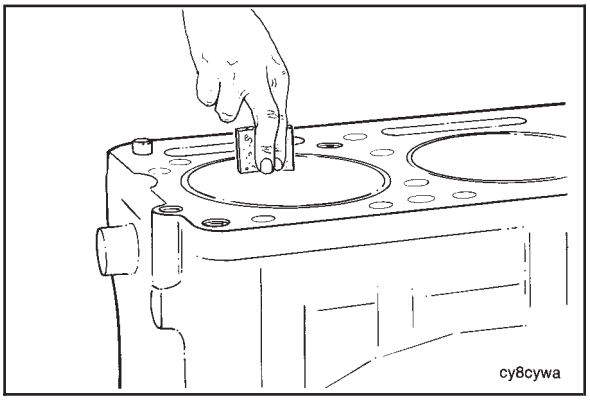
Protect the push rod galleys, coolant passages and oil passages from contamination.



⚠ CAUTION ⚠

Do not use abrasive paper to remove the carbon deposits. Small particles of abrasive paper will cause severe engine damage.

Use a scraper or a similar blunt-edged tool to loosen the carbon deposits.



⚠ CAUTION ⚠

Use extreme care to be sure that no abrasive cleaners or materials are used in the piston ring travel area.

Remove the remaining carbon with a nylon abrasive pad, Scotch-Brite 7448, or equivalent, and solvent. The carbon **must** be removed, but the surface does **not** have to appear like new metal.

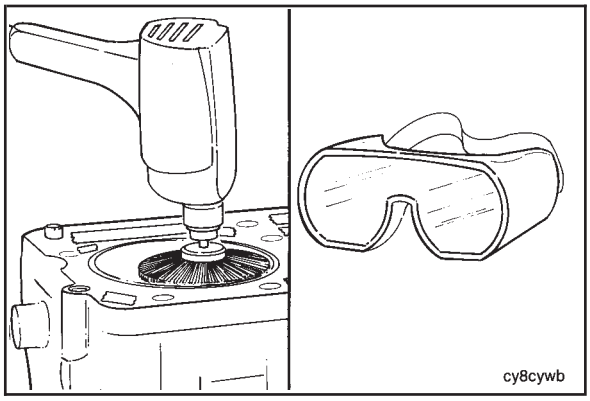
⚠ WARNING ⚠

Wear eye protection to prevent serious eye damage during this operation.

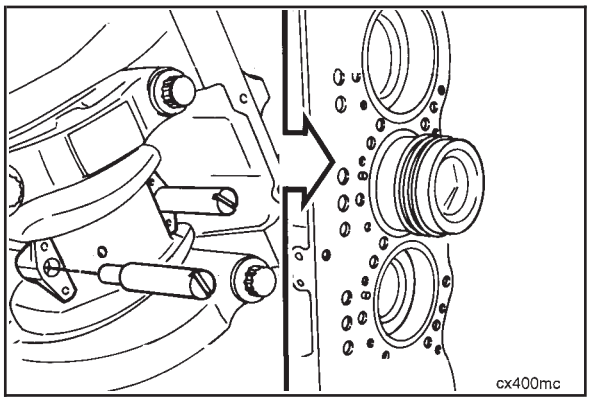
An alternative method to remove the carbon ridge is to use a high quality-steel wire wheel installed in a drill.

NOTE: Do **not** use a steel wire wheel of inferior quality because the wire wheel will lose steel bristles during operation, and cause additional contamination.

NOTE: Do **not** use a steel wire wheel in the piston ring travel area. Operate the wire wheel in a circular motion to remove the deposits.



Use two connecting rod guide pins, Part No. 3375098, or equivalent. Install the guide pins in the connecting rod. Push the piston and connecting rod up until the piston rings are above the cylinder liner.



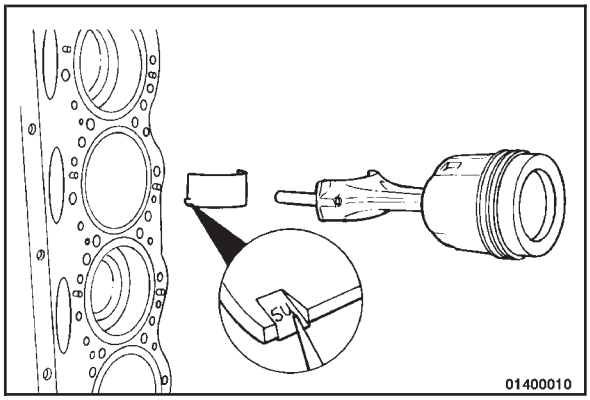
△ CAUTION △

Put the piston and rod assembly in a rack to prevent damage to the piston and rod assembly.

Remove the piston and rod assembly.

Remove the upper connecting rod bearing.

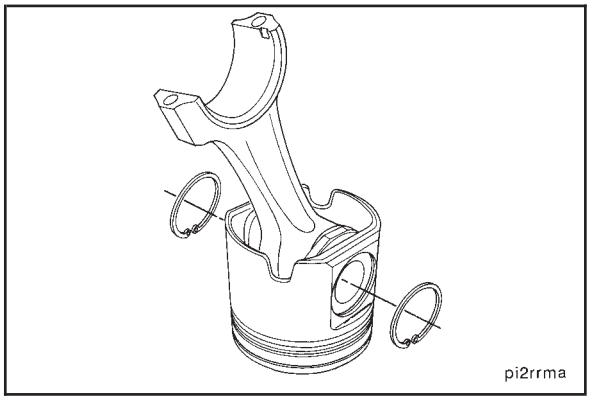
Use an awl and mark the bearing position in the tang area.

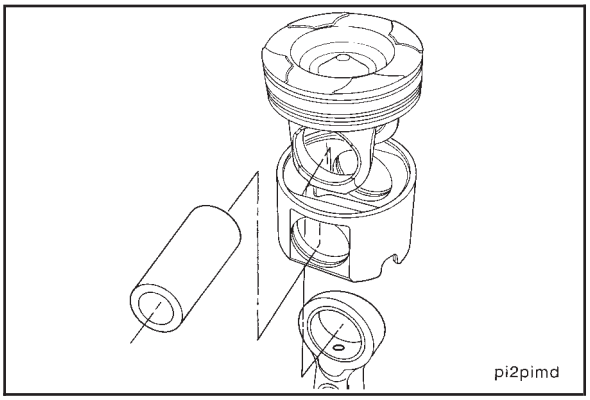


Disassemble the Connecting Rod and Piston

Remove piston rings.

Use internal snap ring pliers. Remove the snap rings from both sides of the piston.





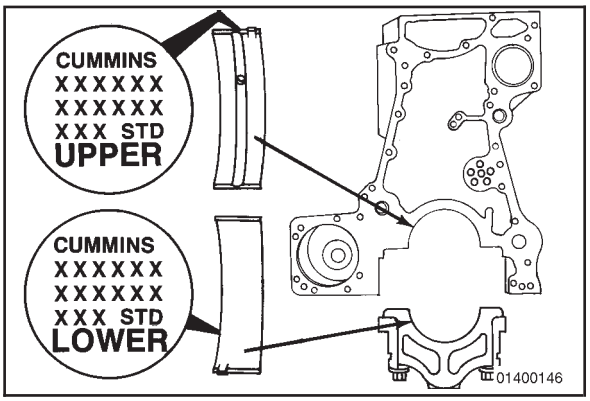
⚠ CAUTION ⚠

To prevent personal injury and damage to the piston, do not drop the piston while removing the piston pin.

When the piston pin is removed from an articulated piston, the skirt will separate from the crown.

The skirts and crowns are interchangeable.

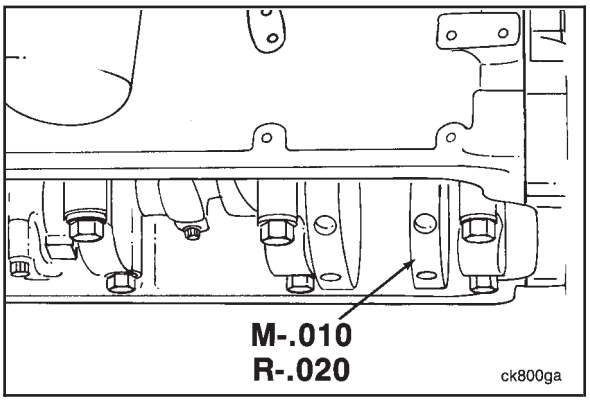
NOTE: It is recommended that these parts be kept together for possible failure analysis.



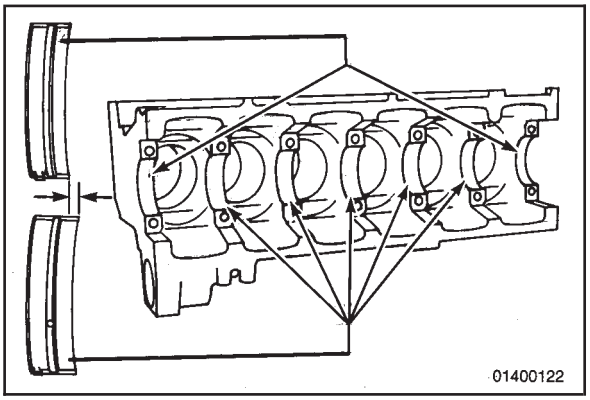
Main Bearings - General Information

NOTE: The **upper** bearings contain an oil hole. The **lower** bearings do **not** have an oil hole. Both bearings are marked on the back side indicating location (UPPER or LOWER) and size (STANDARD [STD] or OVERSIZE [OS]). The amount of OS is indicated in U.S. customary inches.

Use the same size bearing [STD, 0.010, 0.020, or 0.030] that was removed.



The crankshaft will be stamped on the end of the No.1 counterweight to indicate if it has been ground under size. Thrust bearing size is stamped on a crankshaft counterweight adjacent to the thrust location.



NOTE: The location number (No.) of the main bearing caps, beginning at the front, are No. 1 through No. 7.

The main bearings are two widths. The **narrow** main bearings fit locations No. 1 and No. 7. The **wide** bearings fit the remaining locations.

Remove the Lower Main Bearing

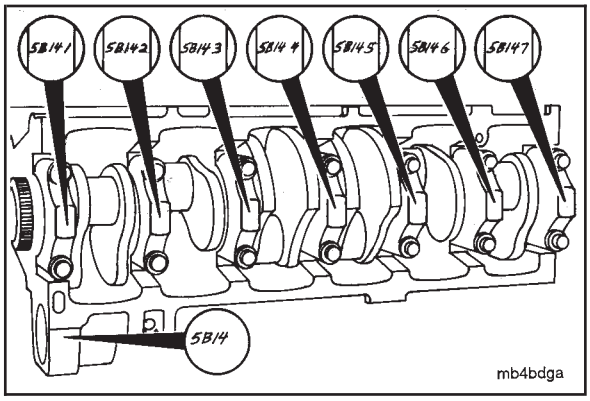
CAUTION

Remove the bearings one pair at a time. Personal injury and damage to the crankshaft can result if the crankshaft falls.

The main bearings caps **must** be marked for position. The last number on each bearing cap identifies the cap location position in the block.

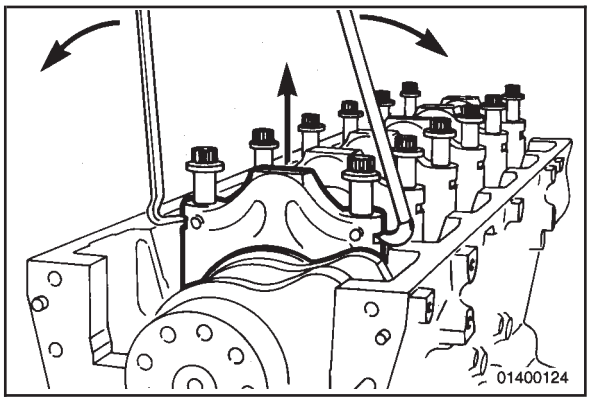
The block and main bearing cap identification numbers **must** be identical.

Use a steel stamp and mark any cap that is **not** marked correctly.



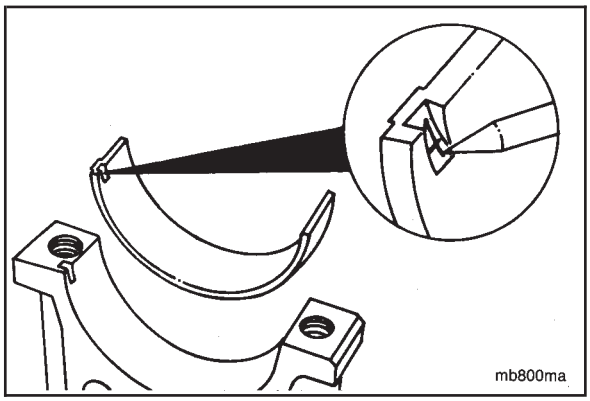
Loosen the main bearing cap capscrews until there is approximately 13 mm [1/2-inch] between the capscrew head and the cap. Use two pry bars to loosen the cap. Put the pry bars in the notches at the sides of the caps.

Remove the cap and capscrews.



Remove the lower bearing. Use an awl and mark the bearing position in the tang area.

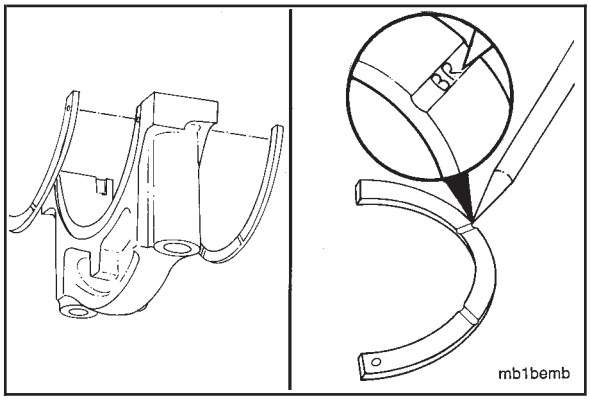
NOTE: Mark the bearing position for future identification or for possible failure analysis.

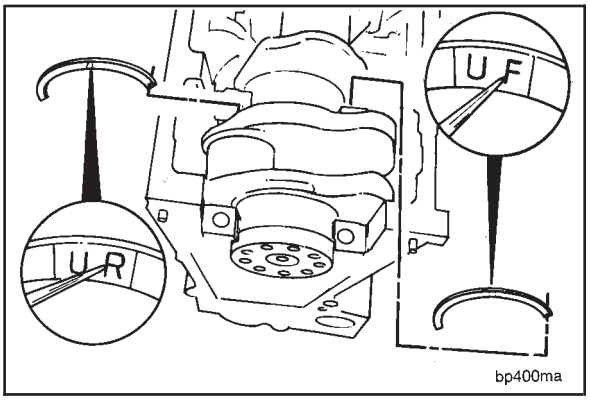


Remove the Lower Thrust Bearings

The No. 6 cap contains two thrust bearings.

Remove and mark them for position in the notched area.

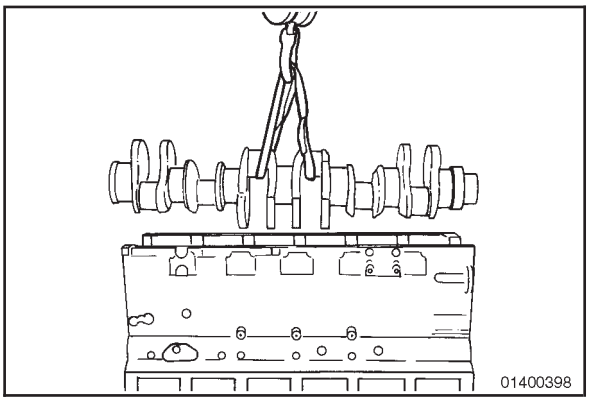




Remove the Upper Thrust Bearings

Remove the upper thrust bearings from the block at the No. 6 location. Mark them for position.

NOTE: If necessary, slide the crankshaft to the front or to the rear to allow the thrust bearings to be removed.



Remove the Crankshaft

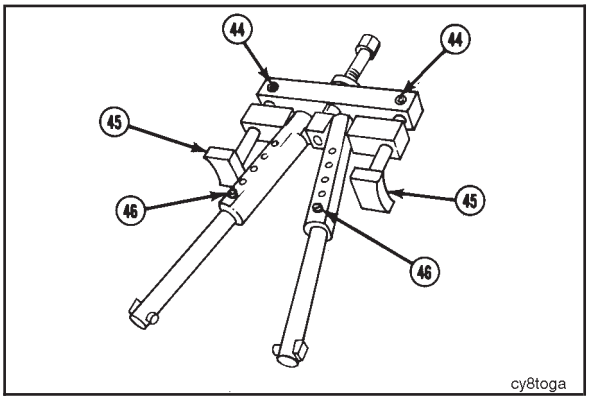
WARNING

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

Remove the main bearing caps and bearings.

Support the weight of the crankshaft with a hoist or lifting device.

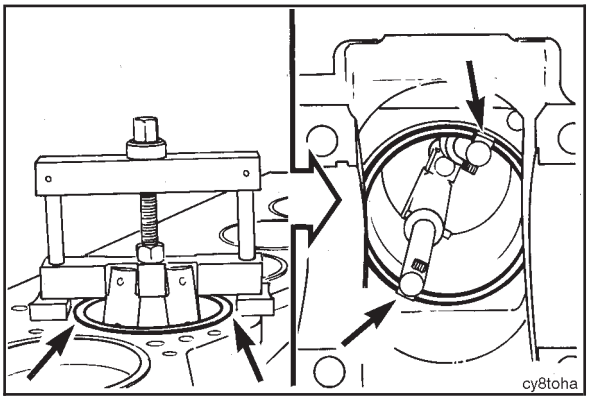
Remove the crankshaft.



Remove the Cylinder Liner

Use the universal liner puller, Part No. 3376015.

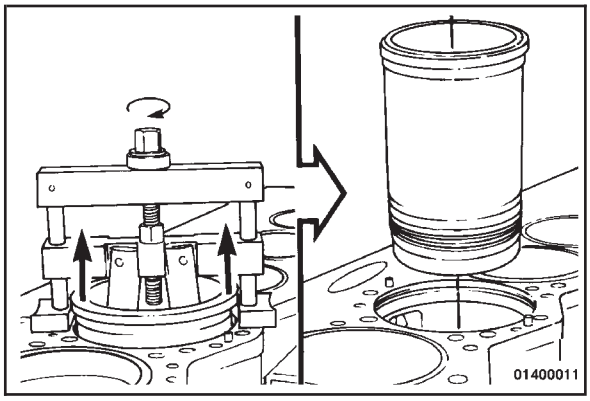
Loosen the set screws (44). Turn the feet (45) of the puller until the curved side turns away from the center as shown. Move the holding pins (46) to the last hole as shown.



Install the tool in the cylinder liner. The puller feet **must not** touch the top of the liner. The puller arms **must** be positioned firmly on the bottom of the liner.

Turn the puller screw until the liner loosens in the block.

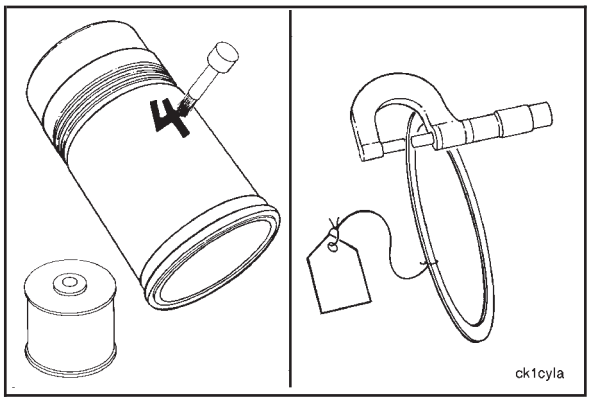
Remove the tool and the liner.

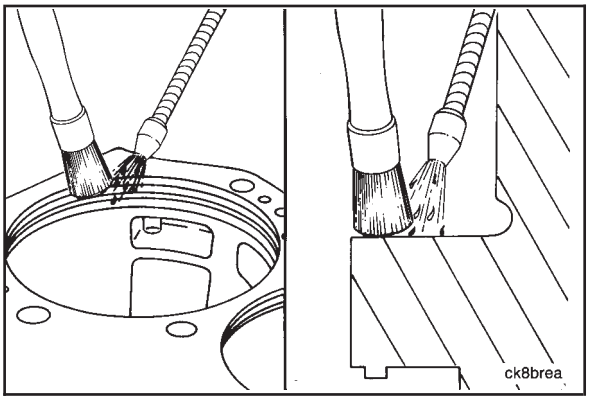


Use a liquid metal marker to mark the cylinder number on each liner.

If sealing rings were used, do the following:

- Use a tag to mark the cylinder number.
- Measure in several places and record the thickness of the sealing rings used in each cylinder. The thickness of the sealing ring is one factor in determining liner protrusion. This information **must** be known when the liners are installed in the engine.

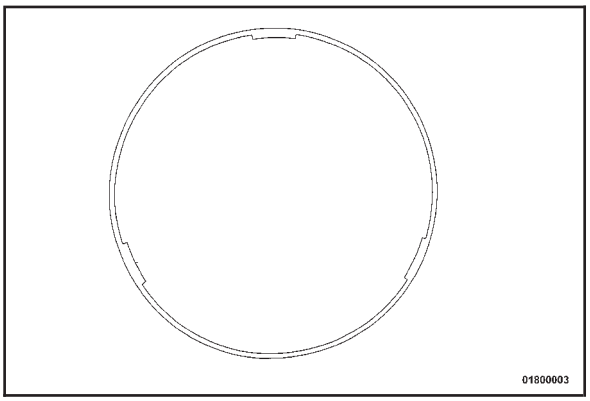




Engine Assembly (000-004)

Assemble

Clean the bottom of the cylinder liner flange with solvent.

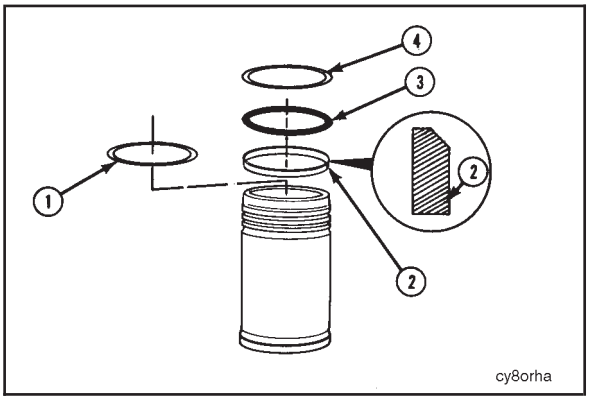


NOTE: The seal rings have three locating tabs on the I.D. The tabs have an interference fit to the liner Lower Press Fit (LPF) diameter to hold the seal ring in place during liner installation.

Install the seal rings.

The seal ring **must** be straight on the liner upon installation. Use your fingers to push the seal ring near the tabs to fit the seal ring down and over the LPF diameter during installation.

This practice during installation of the seal ring will prevent deformation that will result in the seal ring **not** fitting squarely on the bottom of the liner flange.

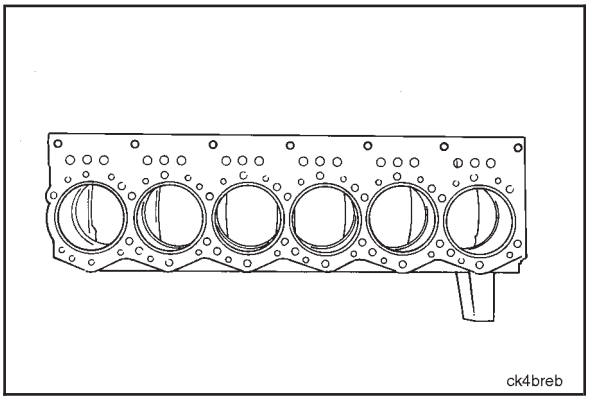


Install the crevice seal. The beveled edge of the crevice seal (2) **must** be positioned as shown.

NOTE: Some o-rings have a ''D'' shape cross section. This type of o-ring **must** be installed with the flat side against the cylinder liner.

Install o-rings in the position shown. Use the mold mark on the o-ring to check if the o-ring is twisted.

(1) Liner, counterbore sealing ring
(2) Crevice seal
(3) Black o-ring
(4) Red o-ring



Use vegetable oil to lubricate the I.D. of the packing ring bores.

Use your hands to push the cylinder liners into the block.

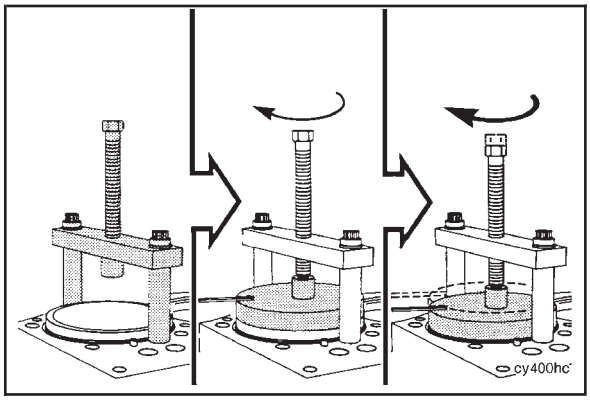
NOTE: Do **not** use RTV or other sealants under liner flange.

Use liner installation tool, Part No. 3375422, or equivalent. Install the bridge assembly and two cylinder head capscrews. Tighten the capscrews.

Torque Value: 65 N•m [50 ft-lb]

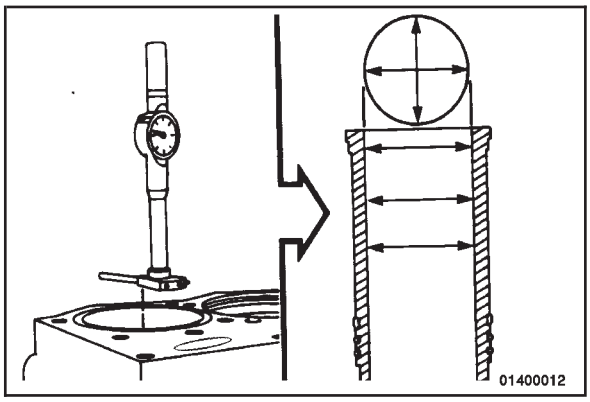
Install the pusher plate in the liner. Be sure it is aligned correctly in the liner. Turn the pusher screw until it touches the plate.

Turn the pusher screw until the liner flange touches the counterbore ledge. Do not use more than 65 N•m [50 ft-lb] of torque. Remove the tool.



NOTE: New cylinder liners can be 0.005 mm to 0.015 mm [0.0002 inch to 0.0006 inch] smaller than the minimum specifications because of the Lubrite® coating.

Use a dial bore gauge and measure the I.D. of the liner at the top, bottom, and middle of the liner.



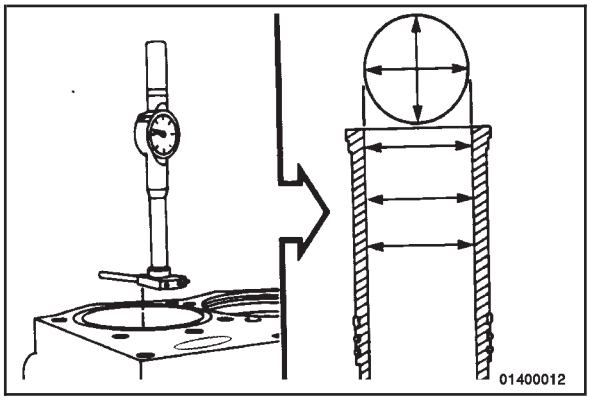
Perform two measurements at each location. The measurements **must** be 90 degrees apart.

Cylinder Liner I.D. (New)		
mm		**in**
158.737	MIN	6.2495
158.775	MAX	6.2510

The I.D. **must** be **no** more than 0.076 mm [0.003 inch] out-of-round at the **top two** measurements.

If the I.D. is more than 0.05 mm [0.002 inch] out-of-round in the **bottom** measurement location, the liner **must** be removed.

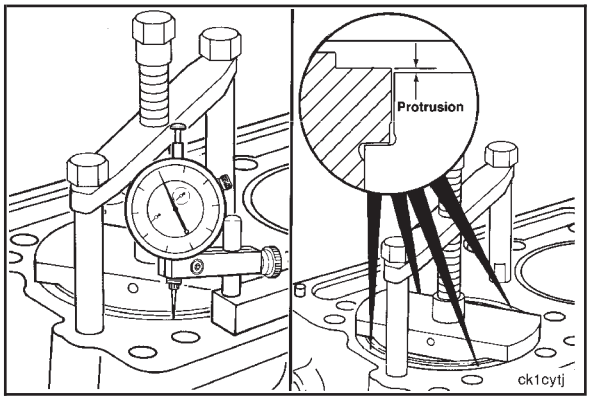
Check for a twisted o-ring.

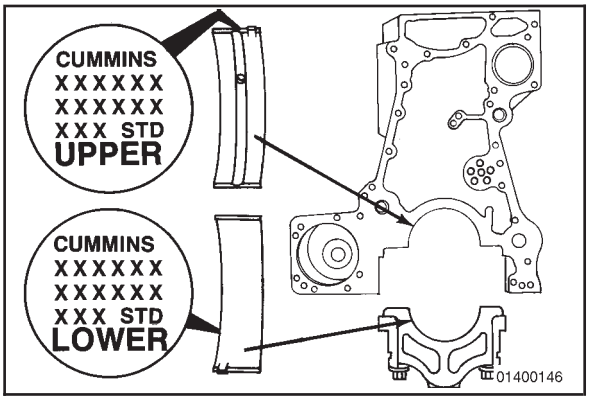


Measure the liner protrusion.

If the protrusion is **not** correct, the liner **must** be removed. The protrusion can be adjusted using seal rings and/or machining the counterbore ledge.

Cylinder Liner Protrusion		
mm		**in**
0.13	MIN	0.003
0.18	MAX	0.007

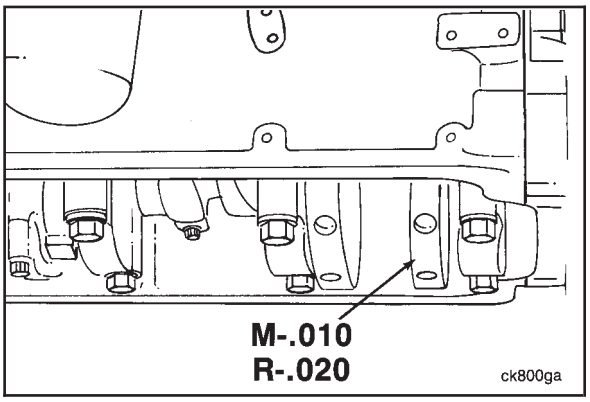




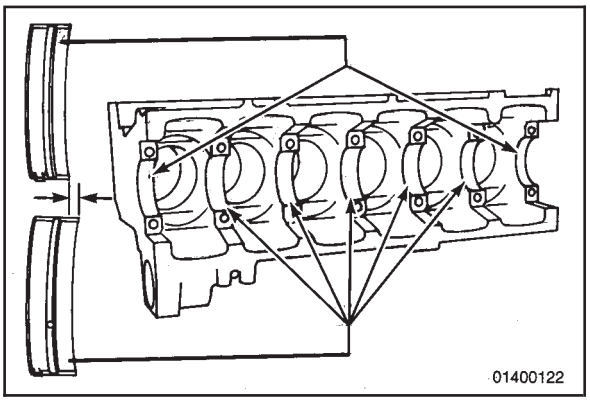
Main Bearings - General Information

NOTE: The **upper** bearings contain an oil hole. The **lower** bearings do **not** have an oil hole. Both bearings are marked on the back side indicating location (UPPER or LOWER) and size (STANDARD [STD] or OVERSIZE [OS]). The amount of OS is indicated in U.S. customary inches.

Use the same size bearing [STD, 0.010, 0.020, or 0.030] that was removed.



The crankshaft will be stamped on the end of the No.1 counterweight to indicate if it has been ground under size. Thrust bearing size is stamped on a crankshaft counterweight adjacent to the thrust location.



NOTE: The location number (No.) of the main bearing caps, beginning at the front, are No. 1 through No. 7.

The main bearings are two widths. The **narrow** main bearings fit locations No. 1 and No. 7. The **wide** bearings fit the remaining locations.

⚠ WARNING ⚠

This part weighs more than 23 kg [50 lb]. Personal injury can result.

Use a lint free cloth. Clean the bearing and the mounting surface.

⚠ CAUTION ⚠

Do not lubricate the back of the bearing.

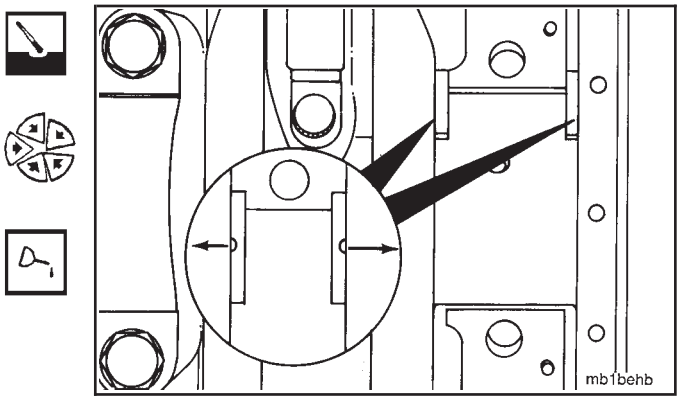
⚠ CAUTION ⚠

Prevent dirt from mixing with the lubricant. Dirty lubricant will cause low mileage failures.

Align the tang in the bearing with the slot in the block. Install the bearings. The end of the bearing **must** be even with the main bearing cap mounting surface.

Use engine oil if the engine will be operated immediately. Use Lubriplate® No. 105, or equivalent if the engine will not be operated immediately. Lubricate the bearings

Use a lint free cloth. Clean the crankshaft bearing journals.

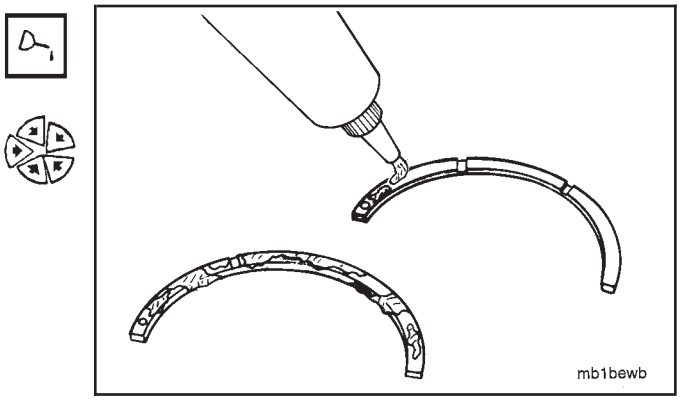


⚠ CAUTION ⚠

Use a lifting strap that will not damage the crankshaft. Do not drop the crankshaft on the bearings.

The end of the crankshaft with the smallest diameter **must** point toward the front of the block. Install the crankshaft.

Use the same lubricant that was used on the upper main bearings. Lubricate the upper thrust bearings.



⚠ CAUTION ⚠

The grooves in the thrust bearings must point toward the crankshaft.

Install the bearings in the No. 6 location.

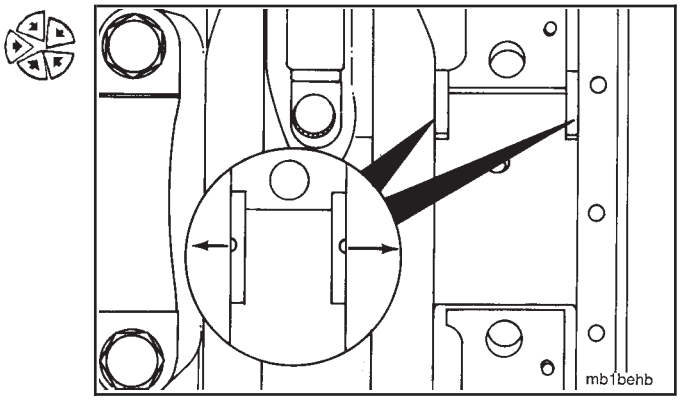
NOTE: Move the crankshaft to the front or rear to install the second thrust bearing.

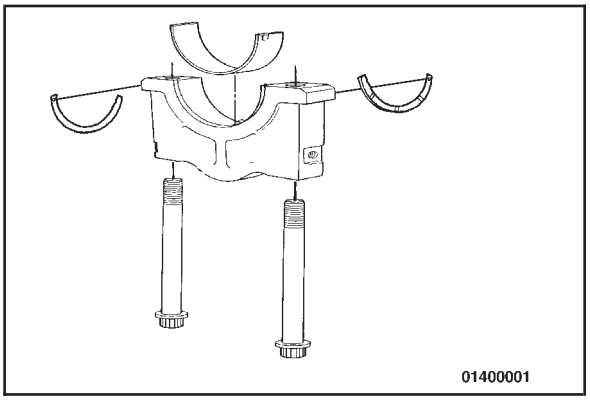
Use a lint-free cloth. Clean the lower main bearings, the lower thrust bearings, and the mounting surfaces.

NOTE: Do **not** lubricate the back of the main bearings.

Align tang (1) in the bearing with the slot (2) in the main bearing cap. Install the bearing. The end of the bearing **must** be even with the main bearing cap mounting surface.

Lubricate the bearing surface with engine oil.





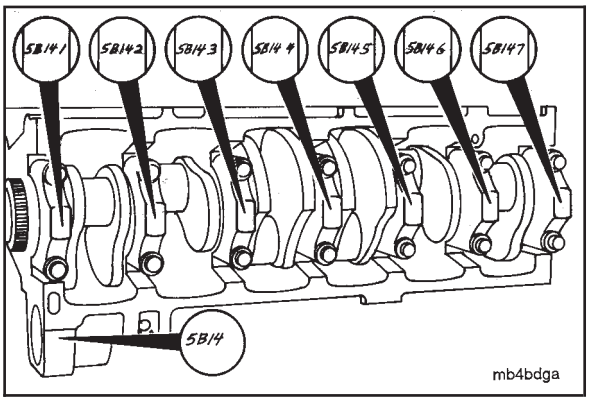
Lubricate the cap screw head and threads with SAE EP 140W oil. Allow excess oil to drip off of the capscrews before installing in the block.

Install capscrews in the cap.

CAUTION

The grooves in the thrust bearing must point toward the crankshaft. The dowels that secure the bearings must not protrude above the housing.

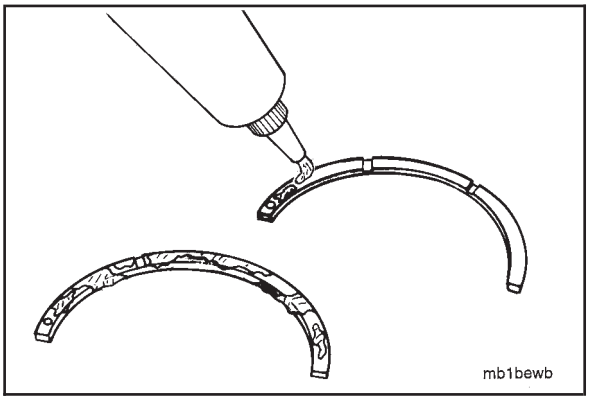
Install the two thrust bearings on No. 6 main bearing cap.



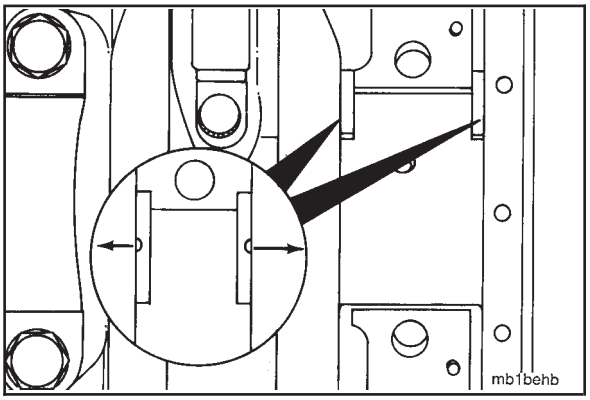
CAUTION

The numbers on the main bearing caps must be the same as the numbers on the block.

Check the numbers on the main bearing caps. The last digit of each number (1 to 7), indicates the correct location.



Use engine oil. Lubricate the upper thrust bearings.



CAUTION

The grooves in the thrust bearings must point toward the crankshaft.

Install the bearings in the No. 6 location.

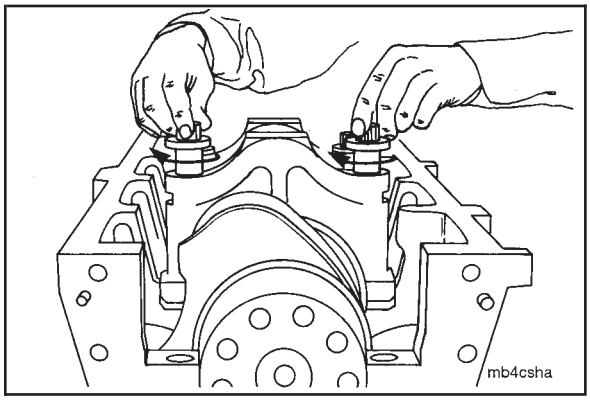
NOTE: Move the crankshaft to the front or to the rear to so the second thrust bearing to be installed.

⚠ CAUTION ⚠

Do not rotate the crankshaft until all of the main bearing caps are pulled to the block. Damage will result if the bearings move out of location.

NOTE: Use your hands to install the capscrews.

Turn each capscrew until it touches the main bearing caps

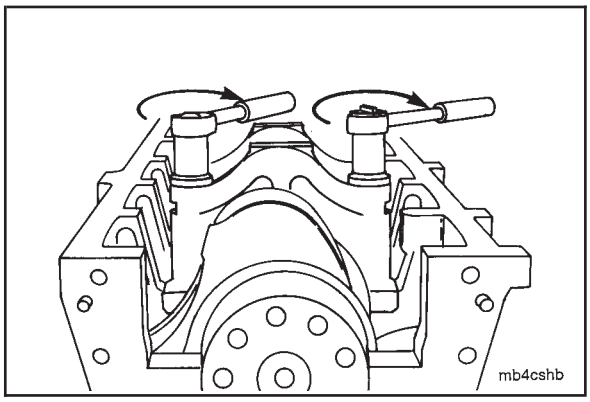


NOTE: Do **not** use an impact wrench. The bearing shells can fall out.

Use both of the capscrews to pull the main bearing cap into position.

Use two wrenches and tighten both capscrews at the same time.

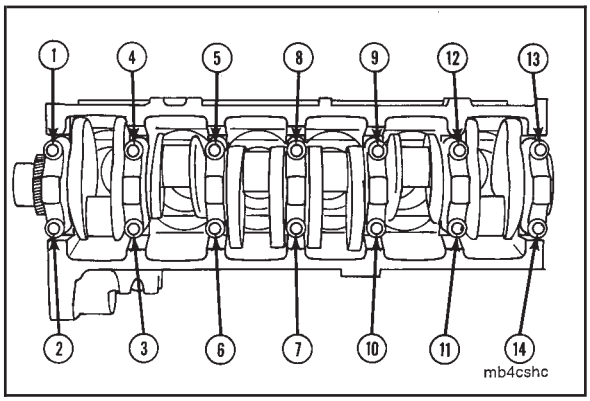
Check to be sure the No. 7 cap is even with the back of the block.



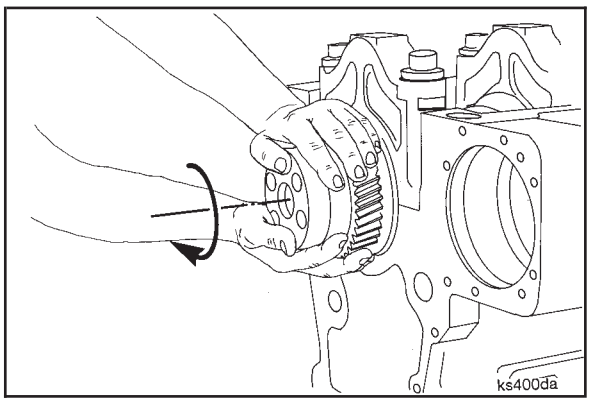
Use the following steps and tighten the capscrews in the sequence shown.

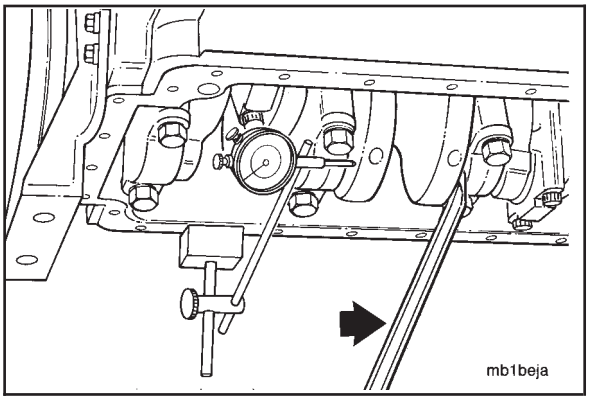
Torque Value:

Main Bearing Cap			
	Step 1	265 N•m	[195 ft-lb]
	Step 2	605 N•m	[445 ft-lb]
	Step 3	Loosen	Loosen
	Step 4	265 N•m	[195 ft-lb]
	Step 5	605 N•m	[445 ft-lb]



NOTE: The crankshaft will turn freely if the main bearings are installed correctly.



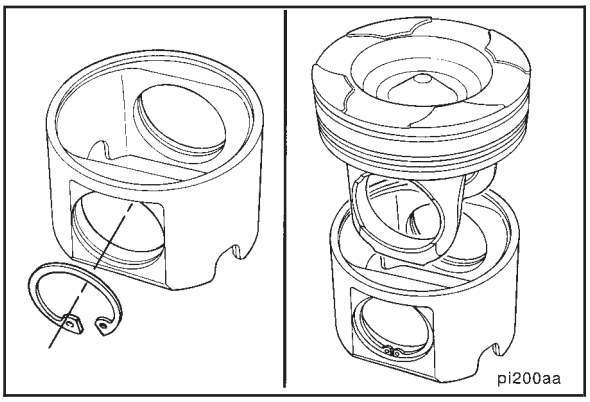


Use a dial indicator and measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		in
0.10	MIN	0.004
0.41	MAX	0.016

If the clearance is not within specifications, check for foreign material. Oversize thrust bearings are available to adjust the end clearance.

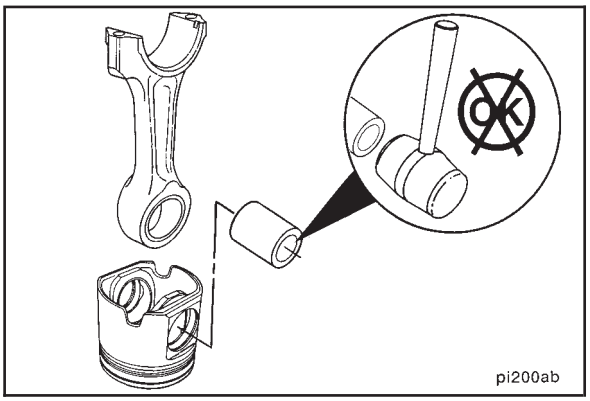
NOTE: The upper and lower thrust bearing on the same side of the main caps must be the same thickness.



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.

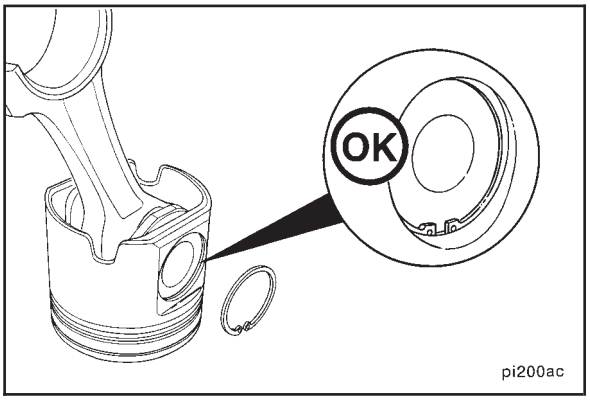


⚠ CAUTION ⚠

Do not use a hammer to install the piston pin. The piston can distort, causing it to seize in the liner.

Use engine oil. Lubricate the piston pin and connecting rod bushing.

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.

NOTE: Do **not** install the piston rings until the pistons are installed of the rods.

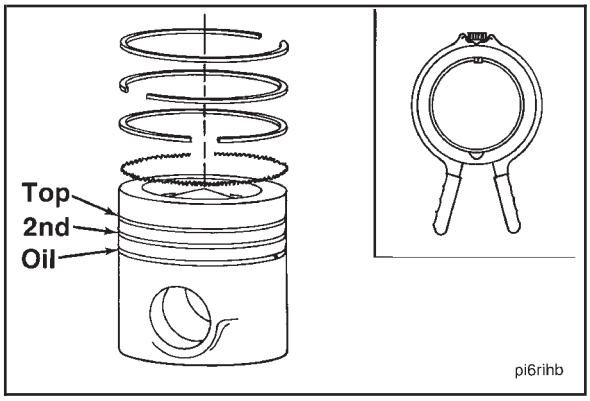
NOTE: The piston rings are marked with the part number. The shipping package is marked with the location. The part number on the ring **must** be positioned toward the **top** of the piston.

Use a ring expander, Part No. ST-1269, or equivalent.

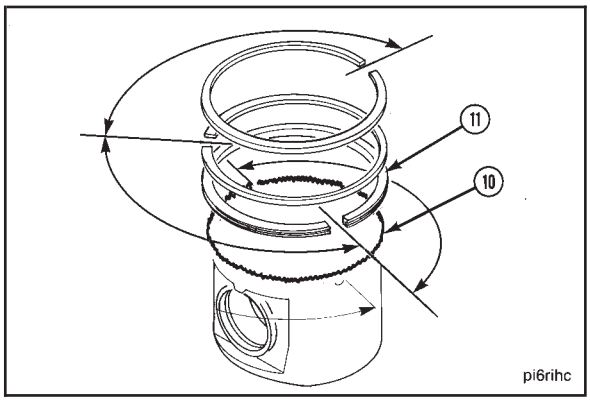
Install piston rings.

NOTE: Do **not** align the gap of a ring with the piston pin bore.

NOTE: The gap in the oil ring expander **must** be turned 180 degrees opposite the gap on the oil ring.



Rotate the rings until the gaps are positioned as shown.



Use a lint-free cloth. Clean the connecting rod and the bearing shells.

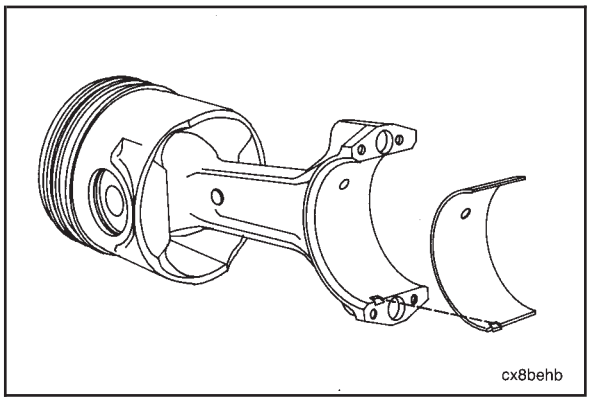
Install the rod bearing. Be sure the tang is positioned as shown. The end of the bearing **must** be even with the cap mounting surface.

⚠ CAUTION ⚠

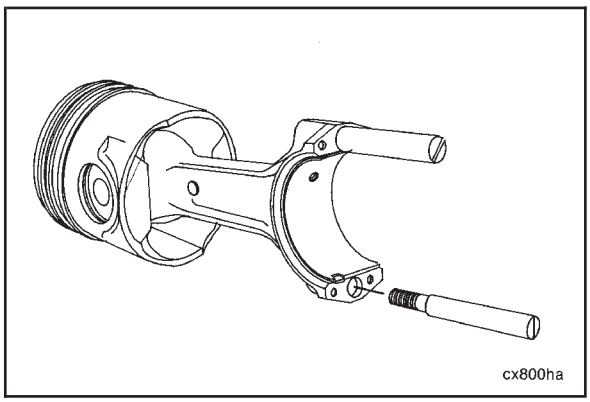
Do not lubricate the back side of the bearing shells.

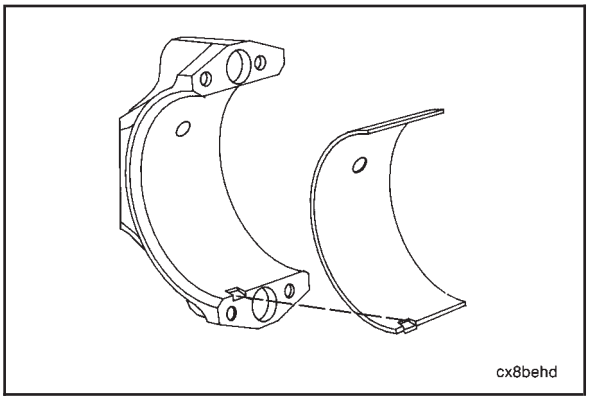
Use engine oil. Lubricate the bearing surface. The bearings **must** be installed in their original location if new bearings are **not** used.

NOTE: All of the rod bearings are identical.



Install two connecting rod guide pins, Part No. 3375098, in the rod. The guide pins will aid the assembly and protect the crankshaft.

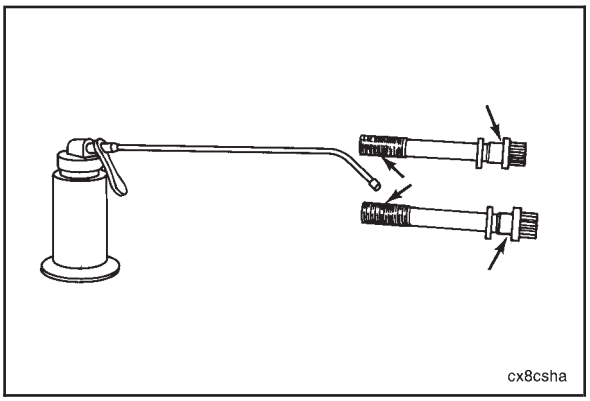




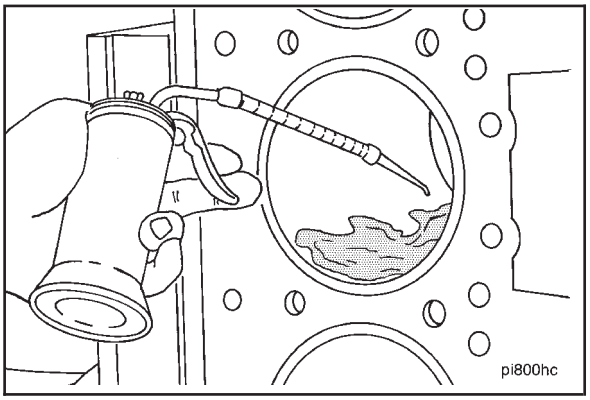
⚠ CAUTION ⚠

The connecting rods and caps are not interchangeable. The rods and the caps are machined as an assembly. Failure will result if they are mixed.

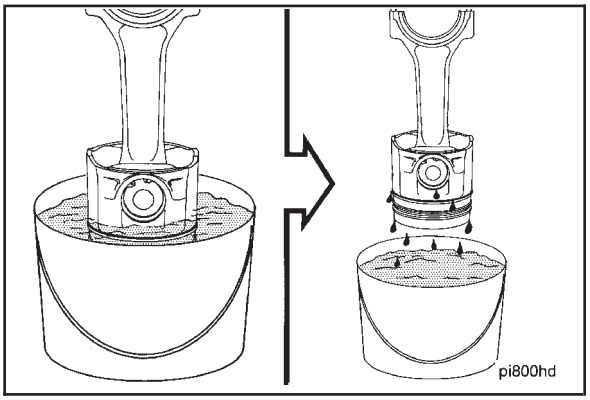
Install the lower bearing shell in the rod cap. Be sure the tang of the bearing shell is in the slot of the cap and the end of the bearing is even with the cap surface.



Use engine oil. Lubricate the connecting rod capscrews and washers as shown. Install the washers and capscrews in the caps.

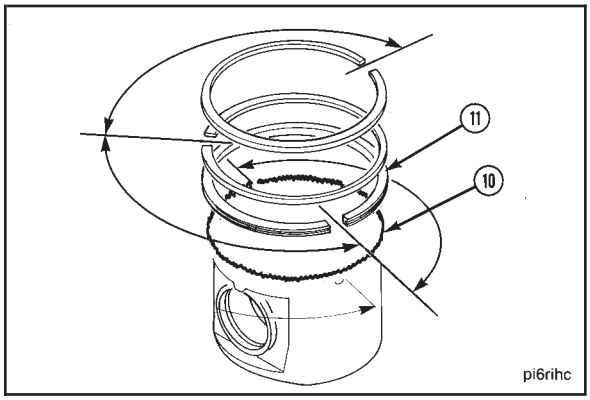


Lubricate the cylinder liner with engine oil. The entire bore **must** be lubricated.



Immerse the piston in engine oil until the rings are covered. Allow the excess oil to drip off of the assembly.

Check to be sure the ring gap position is still correct.

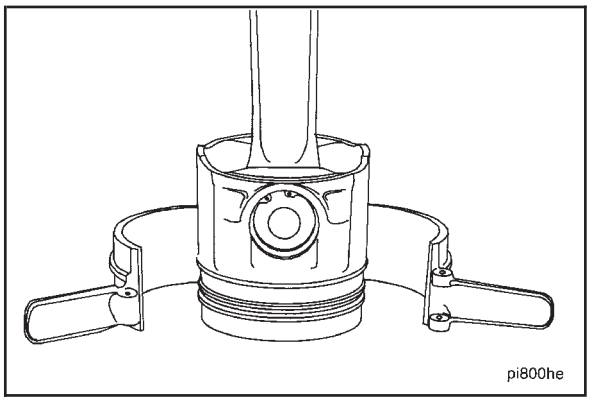


⚠ CAUTION ⚠

Be sure the rings fit correctly in the piston rings.

Use a piston ring compressor, Part No. 3375342, or equivalent. Install the ring compressor on the piston.

NOTE: The ring compressor has a tapered bore. The small end of the taper **must** be positioned toward the piston skirt.



⚠ CAUTION ⚠

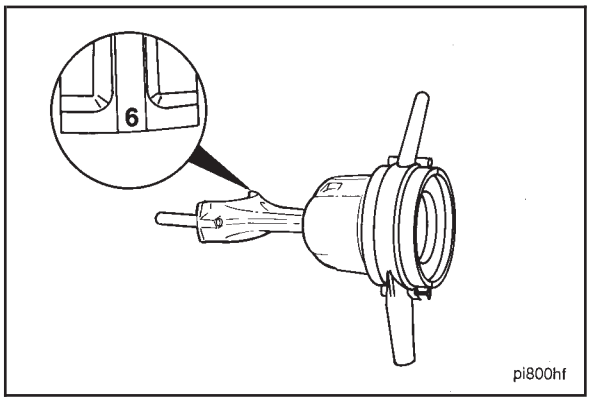
The cylinder number on the rod and cap must be the same.

⚠ CAUTION ⚠

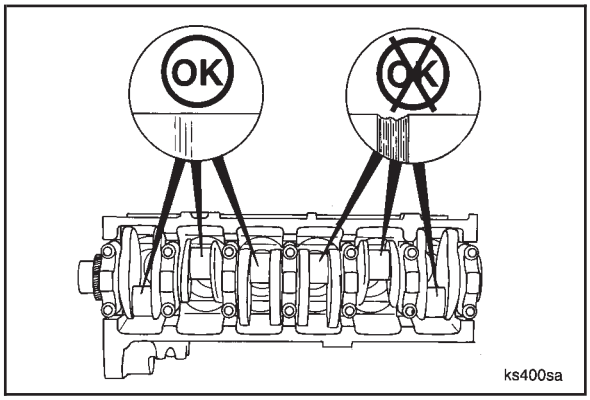
The side of the rod with the cylinder number (bearing tang side) must be toward the camshaft.

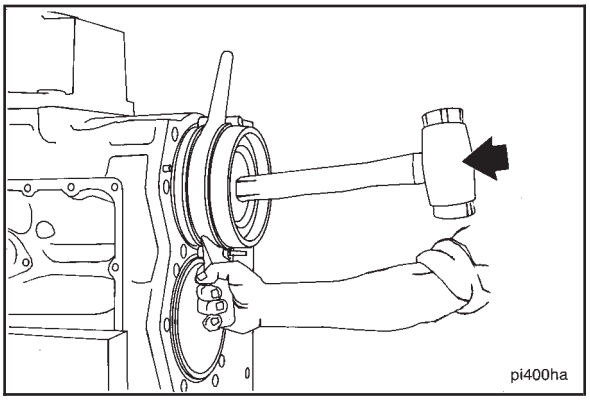
Rotate the crankshaft until the journal for the rod being installed is at bottom dead center (BDC).

NOTE: If the engine has a crankshaft with bolt-on counterweights, the journal **must** be at ‘‘TDC’’ top dead center.



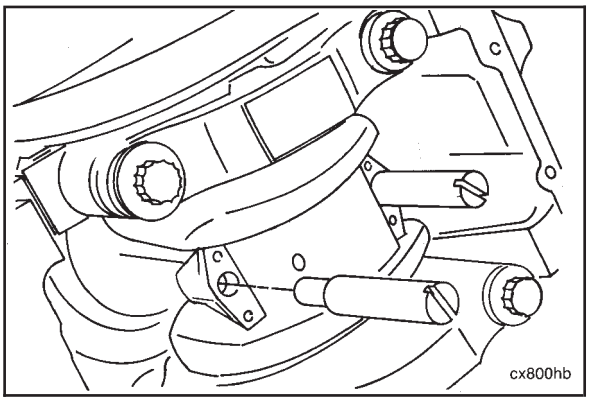
Check the crankshaft rod journals for damage.



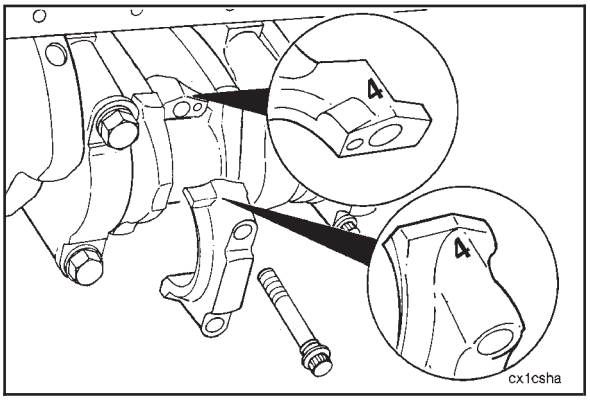


Install the rod and piston until the ring compressor touches the block. Align the rod with the crankshaft journal.

Hold the ring compressor firmly against the block. Use a wooden hammer handle to push the piston into the liner.



Push the piston into the bore until the rod bearing contacts the crankshaft journal. Remove the guide pins.



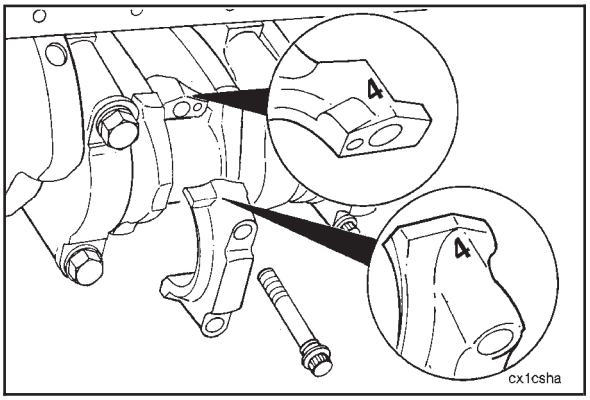
⚠ CAUTION ⚠

The cylinder number on the rod and cap must be the same.

⚠ CAUTION ⚠

The side of the cap with the cylinder number marking (bearing tang side) must be toward the camshaft.

Install the connecting rod cap.



Tighten the capscrews alternately and evenly to pull the cap over the dowel pins. Use the following steps to tighten the capscrews.

Torque Value:

Connecting Rod Capscrews	Step 1	100 N•m	[75 ft-lb]
	2	205 N•m	[150 ft-lb]
	3	339 N•m	[250 ft-lb]
	4	Loosen	Loosen
	5	100 N•m	[75 ft-lb]
	6	205 N•m	[150 ft-lb]
	7	339 N•m	[250 ft-lb]

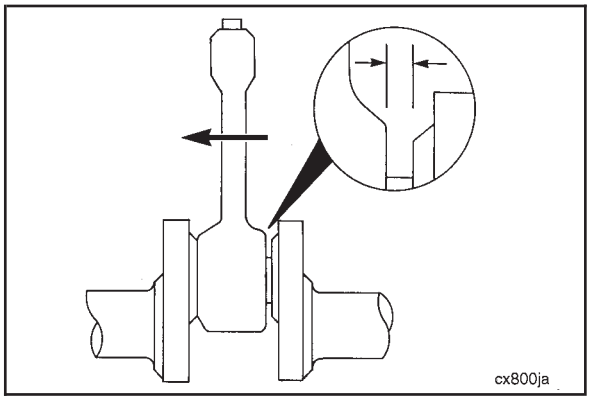
Check the side clearance between the rod and the crankshaft.
The rod **must** move freely from side-to-side.

Measurements over 0.51 mm [0.020 in] must be measured with dial indicator.

Maximum side clearance for used clearance is 5.1 mm [0.200 in].

Connecting Rod and Crankshaft Side Clearance
New or Remanufactured Parts

mm		in
0.20	MIN	0.008
0.35	MAX	0.014



NOTE: Tighten the suction tube to the block capscrews before installing any support bracket capscrews.

NOTE: The suction tube shape can vary from the illustration. All suction tubes attach to the block in the same manner.

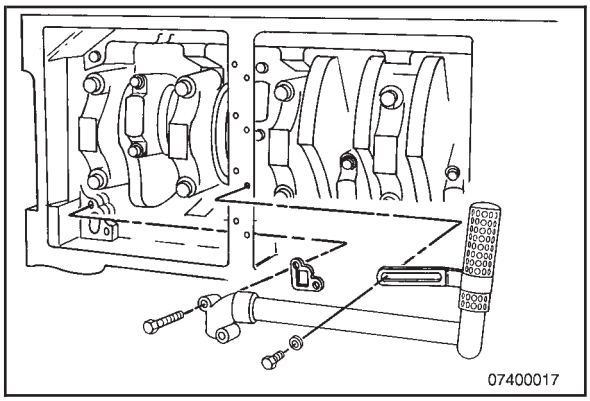
Install the gasket, oil suction tube, washers, and capscrews.

Tighten the capscrews.

Torque Value: 60 N•m [25 ft-lb]

CAUTION

Do not pry or bend the suction tube to get the support bracket capscrew holes to align.



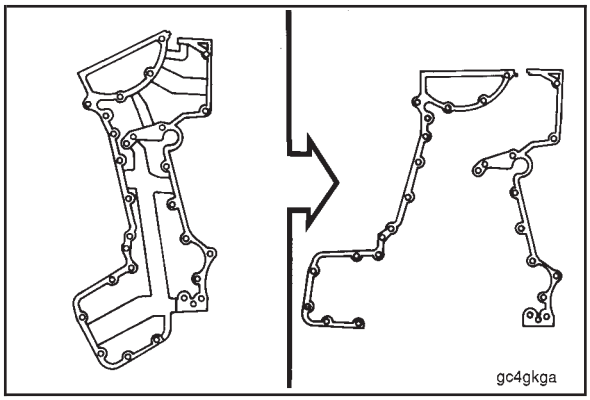
Connect the support bracket to the adapter with the capscrew.

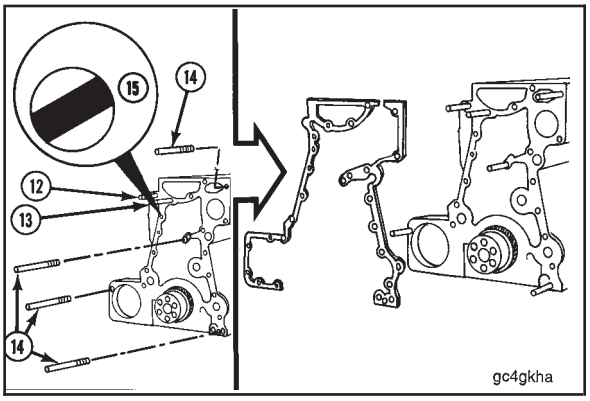
Tighten the capscrews.

Torque Value: 35 N•m [25 ft-lb]

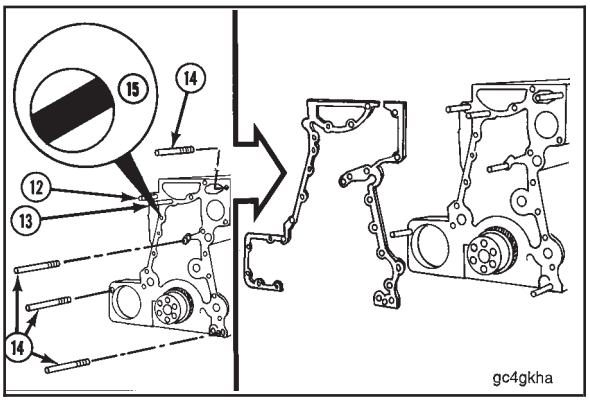
Separate the gasket as shown.

Discard the center tab sections.





The diamond dowel (15) **must** be installed with the flat surface turned toward the master dowel hole at the lower right hand corner of the block. Guide studs (14) will aid the installation.

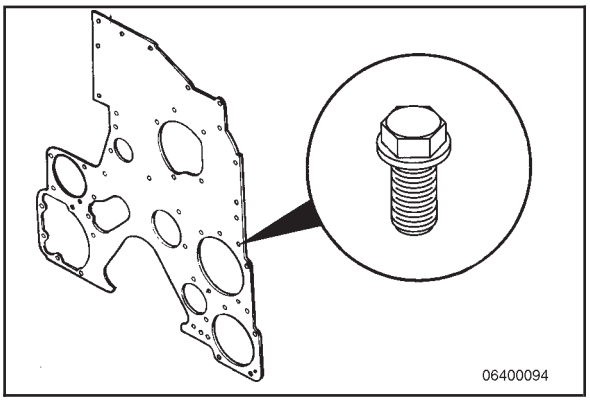


⚠ CAUTION ⚠

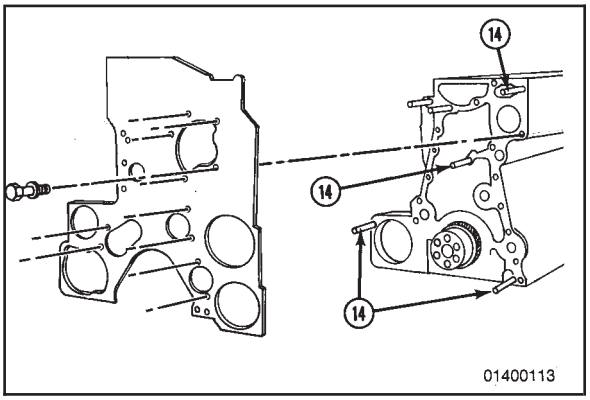
Do not use gasket cement. Damage to the gasket will result.

Use Cummins sealant, Part No. 3823494, or equivalent. Apply a small amount to both sides of the gasket at the butt joint. Install the gasket.

NOTE: The bottom of the gasket **must** be even with the bottom of the block and the spacer plate.



NOTE: Special capscrews are required to attach the spacer plate and the gear housing. The capscrews have a captive, cone-shaped washer to maintain torque.



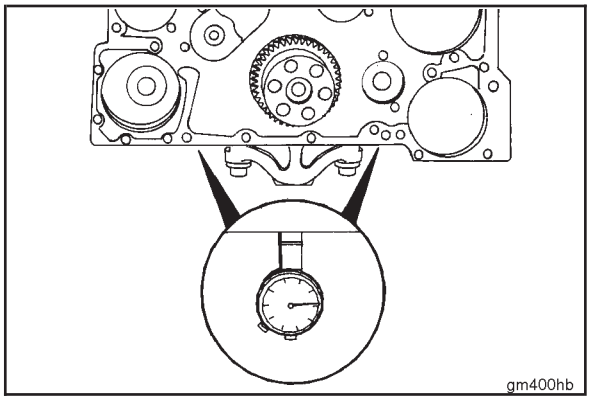
Install the spacer plate and the 11 capscrews as shown. Remove the guide studs (14).

NOTE: If the oil pan adapter is removed, spacer plate alignment **must** be checked. If the oil pan adapter is installed, alignment does **not** require checking.

Use a gauge block, Part No. ST-547, or equivalent, and measure the distance from the bottom of the block to the bottom of the plate.

The bottom of the plate or housing **must** be within 0.05 mm [0.002 inch] of the bottom of the block.

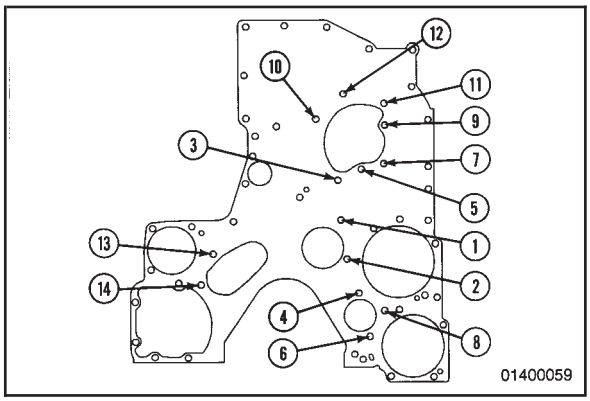
Align the plate or housing with the bottom of the block if necessary.



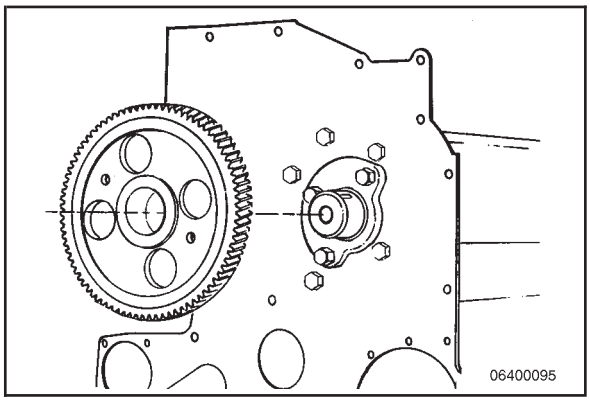
Use the sequence shown and tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]

Measure the plate or the housing to the block alignment again to be sure it is within specifications.



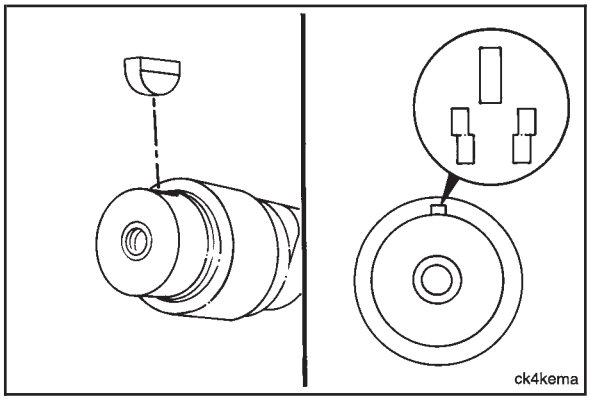
Install the camshaft gear.

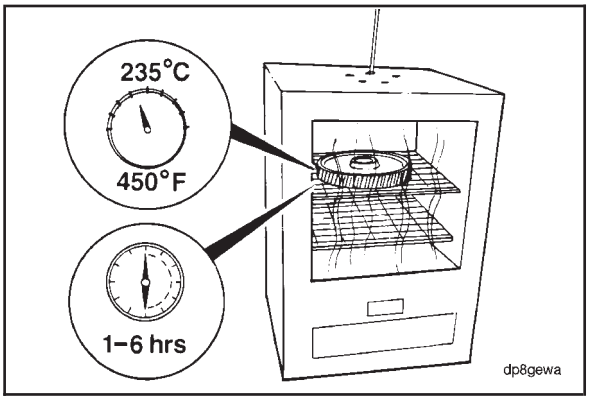


Camshaft keys are available in different sizes (amount of offset). The injection timing is controlled by:

- the selection of the camshaft key.
- the direction of the key offset when compared to the camshaft gear rotation.
- the amount of offset.

Install the same part number key in the same orientation as the key that was removed.





⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

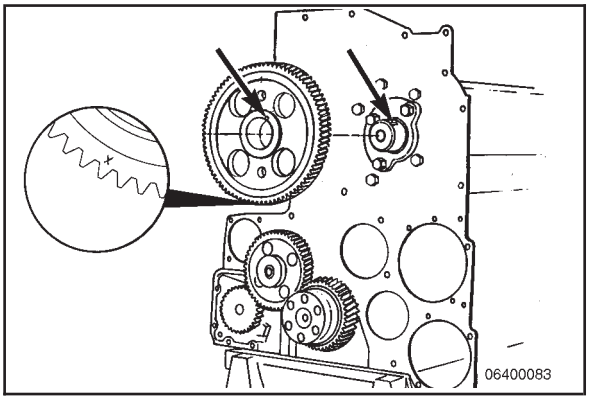
⚠ CAUTION ⚠

Do not exceed the specified time or the temperature. Damage to the gear and the gear teeth will result.

⚠ CAUTION ⚠

Do not attempt to install the gear without using heat.

Use an oven and adjust the heat to 235° C [450° F]. Heat the gear for a minimum of 1 hour, but no more than a maximum of 6 hours. The I.D. of the gear will become larger and will simplify installation.



⚠ CAUTION ⚠

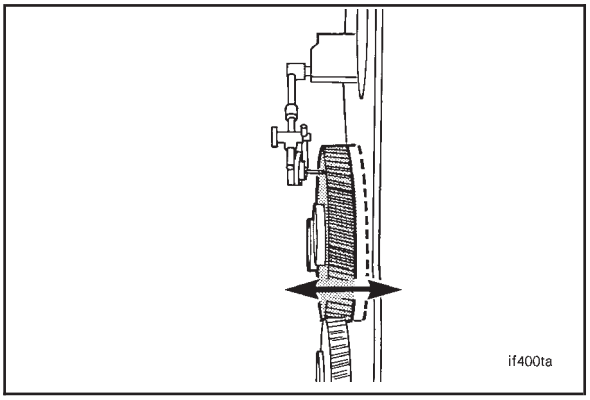
Wear protective clothing to prevent personal injury from burns.

⚠ CAUTION ⚠

Allow the gear to cool slowly. Do not use water or oil to reduce the cooling time. This will cause the gear to crack.

NOTE: The timing mark on the camshaft gear **must** be visible from the front of the gear after it is installed on the camshaft.

Remove the gear from the oven and install on the camshaft. The keyway in the gear **must** be aligned with the key in the camshaft.



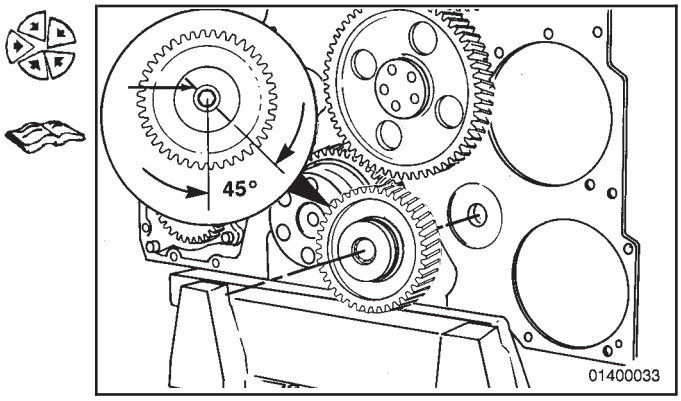
Use a dial indicator and measure the camshaft end clearance.

Camshaft End Clearance

mm		in
0.15	MIN	0.006
0.33	MAX	0.013

If the clearance is too small, check for foreign material or a piece of gasket between the thrust plate and the block.

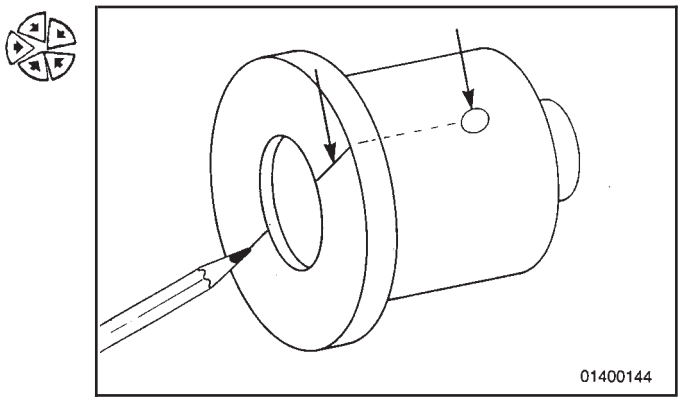
Install the hydraulic pump idler gear.



⚠ CAUTION ⚠

Engines that contain a hydraulic pump must have the oil holes in the hydraulic pump idler shaft as shown. Idler gear bushing failure will result if the oil holes are not aligned correctly.

Mark the flange to show oil hole orientation.

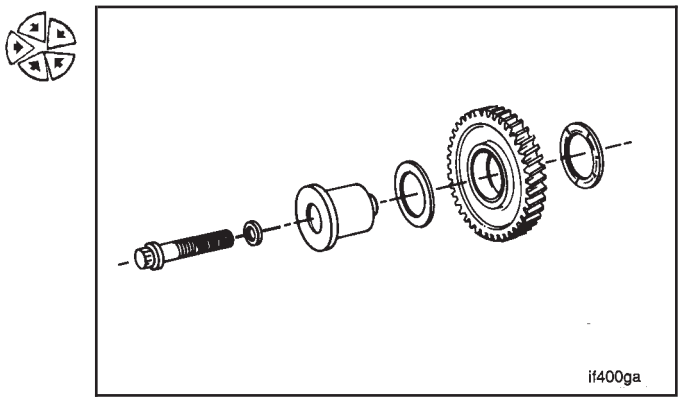


⚠ CAUTION ⚠

The grooves in the thrust washers must be turned toward the gear.

Use Lubriplate® No. 105, or equivalent. Lubricate the gear, bushing, shaft, and the thrust washer.

Use engine oil. Lubricate the capscrew. Assemble the parts as shown.



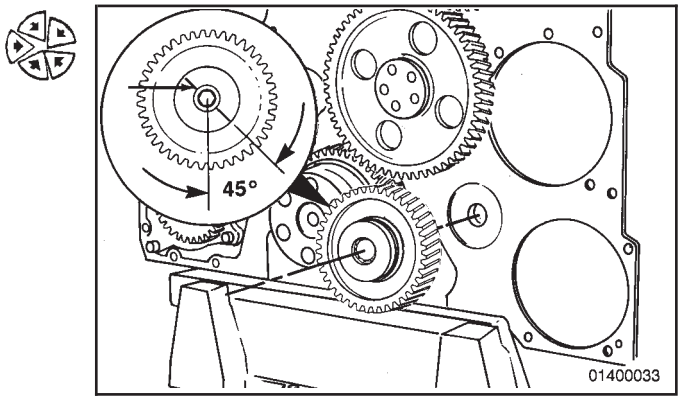
⚠ CAUTION ⚠

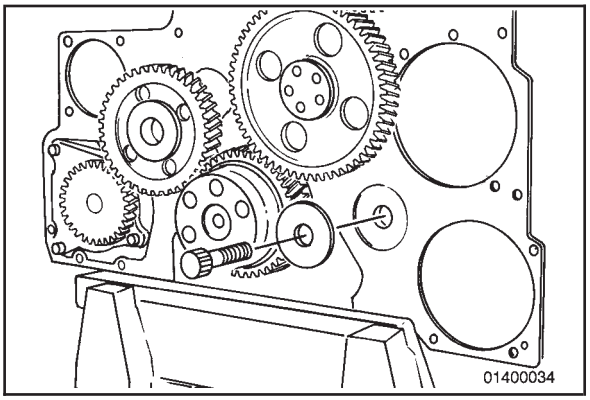
Engines that contain a hydraulic pump must have the oil holes in the hydraulic pump idler shaft oriented as shown. Idler gear bushing failure will result if the oil holes are not aligned correctly.

Align the oil holes in the shaft to an angle 45 degrees to the left of vertical.

Use the capscrew to pull the shaft into the bore. Tighten the capscrew.

Torque Value: 245 N•m [180 ft-lb]





⚠ CAUTION ⚠

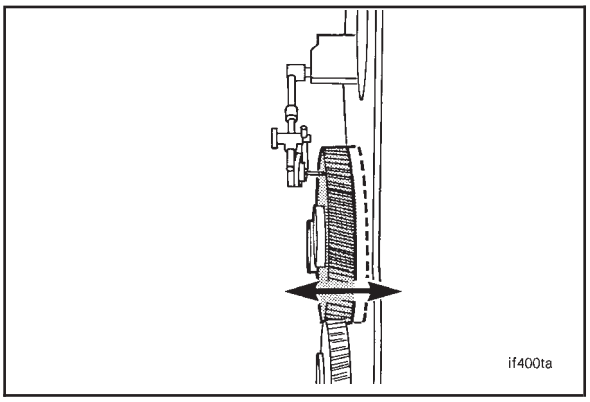
Engines that do not have a hydraulic pump drive must have a plug installed in place of the idler shaft. Low oil pressure will result if the plug is omitted.

⚠ CAUTION ⚠

The capscrew that is used for the lug must not protrude beyond the block.

Use a 9/16–UNF-inch capscrew, lock washer, and a plain washer that is larger than the block bore. Tighten the capscrews.

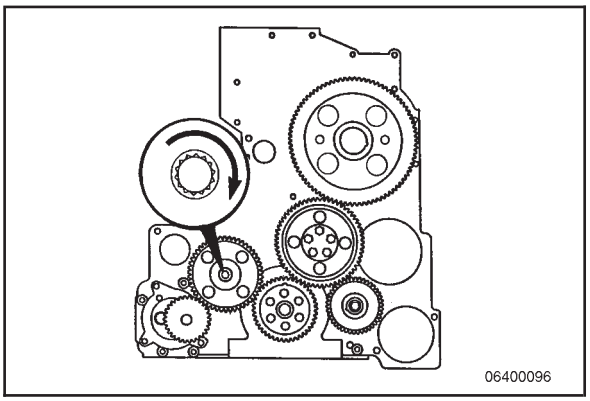
Torque Value: 65 N•m [50 ft-lb]



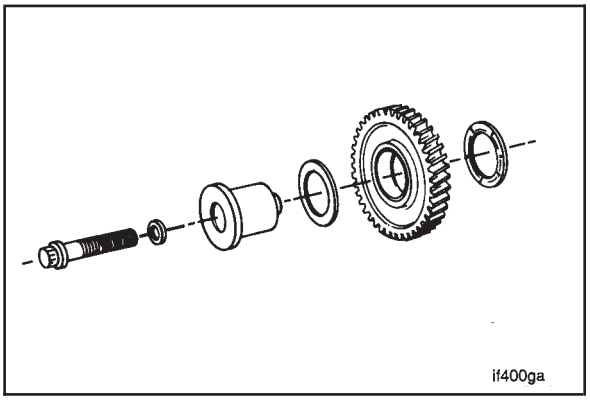
Use a dial indicator and measure the idler gear end clearance.

Hydraulic Pump Idler Gear — End Clearance		
mm		in
0.10	MIN	0.004
0.36	MAX	0.014

NOTE: If the clearance is **not** within specifications, check for foreign material between the parts, or check for proper location of the thrust washers. Oversize thrust washers are available.



Install the water pump idler gear.



⚠ CAUTION ⚠

The grooves in the thrust washers must be turned toward the gear.

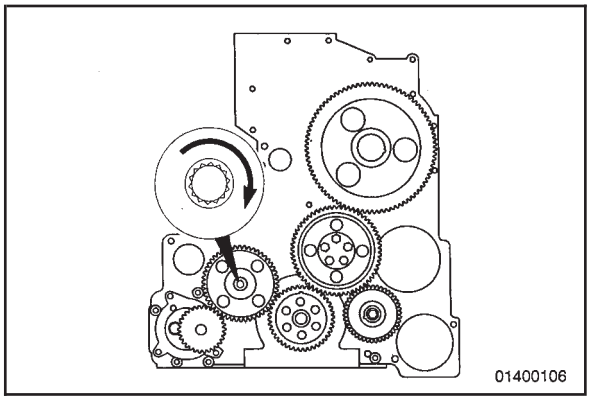
use Lubriplate® No. 105, or equivalent. Lubricate the gear, bushing, shaft, and thrust washer.

Use engine oil. Lubricate the capscrew. Assemble the parts as shown.

Align the oil holes in the shaft to an angle 45 degrees to the left of vertical.

Use the capscrew to pull the shaft into the bore. tighten the capscrew.

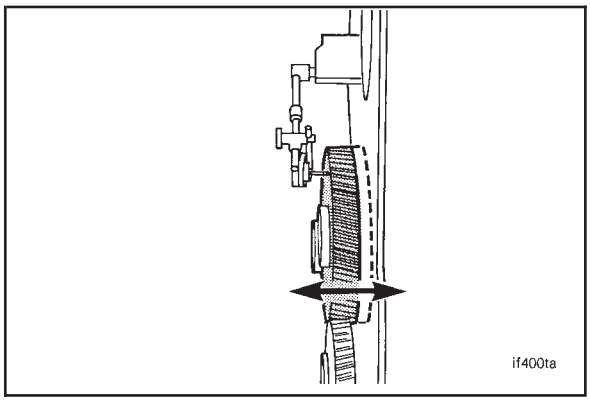
Torque Value: 245 N•m [180 ft-lb]



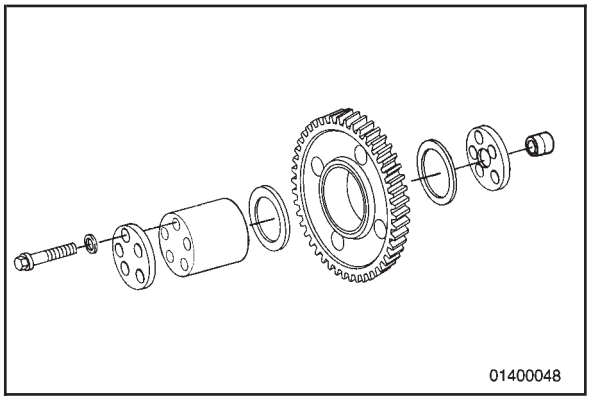
Use a dial indicator and measure the idler gear end clearance.

Water Pump Idler Gear — End Clearance		
mm		in
0.10	MIN	0.004
0.36	MAX	0.014

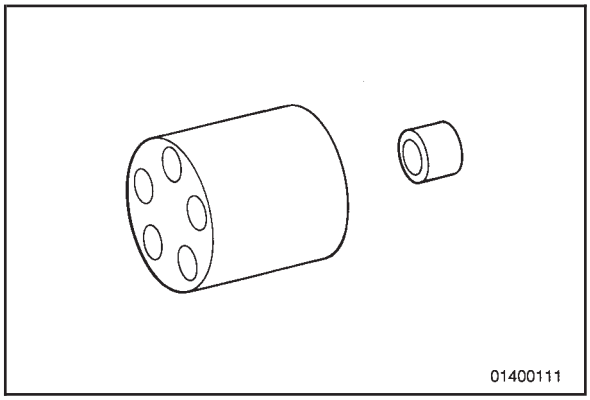
NOTE: If the clearance is **not** within specifications, check for foreign material between the parts, or check for proper location of the thrust washers. Oversize washers are available.

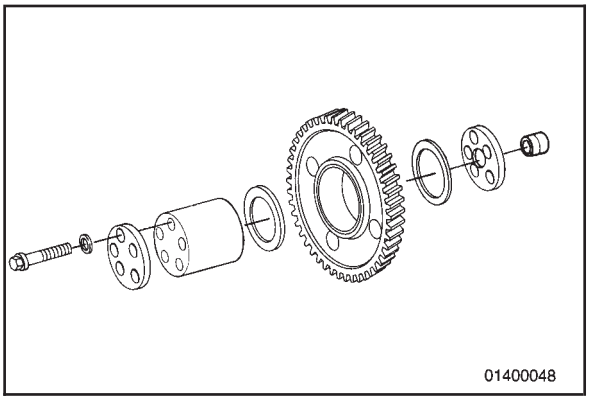


Install the camshaft idler.



NOTE: If the idler shaft ring dowel remained in the cylinder block during disassembly, remove the dowel from the block and install it into the idler shaft. The bore in the thrust bearing wear plate and the O.D. of the dowel are designed to provide a slight press fit to hold the wear plate in position during installation of the idler assembly.





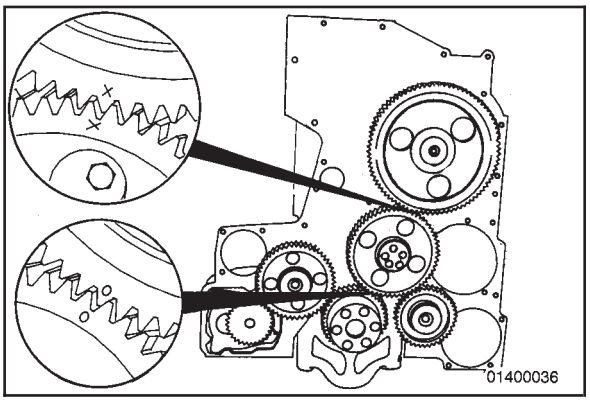
CAUTION

The grooves in the thrust bearing must be positioned toward the gear.

NOTE: The timing marks on the camshaft gear must be visible when the gear is installed.

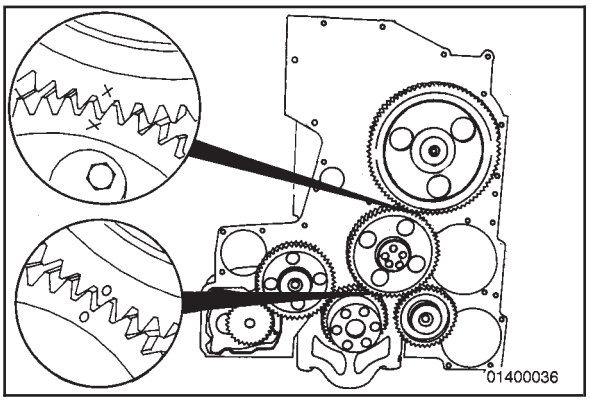
Use Lubriplate® No. 105, or equivalent. Lubricate the gear, bushing, shaft, and thrust washier.

Use engine oil. Lubricate the capscrews. Assemble the parts as shown.



NOTE: The camshaft idler gear is the only idler gear that has timing marks.

Align the “O” on the idler gear with the “O” on the crankshaft gear. Align the “X” on the camshaft gear with the “X” on the idler gear.



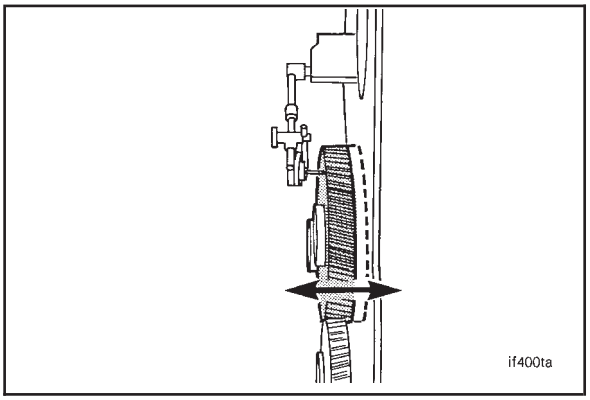
Rotate the idler shaft as necessary to align the mounting capscrew holes.

Use the capscrew to pull the shaft into the bore.

Use the following steps and tighten the capscrews in the sequence shown.

Torque Value:

Step 1	45 N•m	[35 ft-lb]
Step 2	95 N•m	[70 ft-lb]
Step 3	150 N•m	[110 ft-lb]



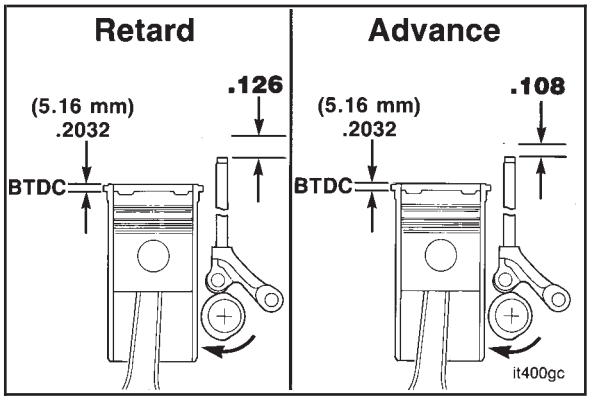
Use a dial indicator. Measure the idler gear end clearance.

Camshaft Idler Gear — End Clearance		
mm		**in**
0.29	MIN	0.012
0.51	MAX	0.020

NOTE: If the clearance is **not** within specifications, check for foreign material between the parts, or check for proper location of the thrust washers. Oversize thrust washers are available.

Static Injection Timing-Check

If the camshaft or camshaft gear was replaced, check the injection timing. Machine tolerances can cause the timing to be out of specifications.

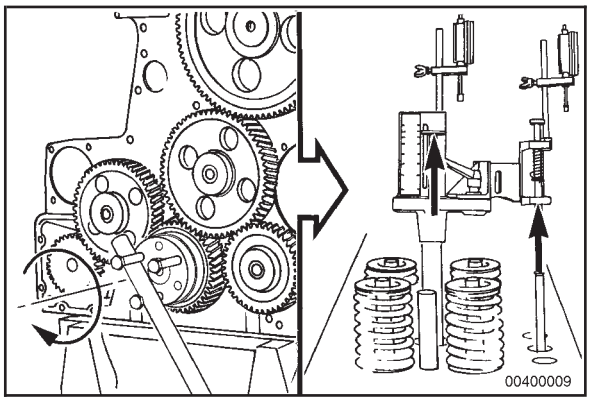


⚠ CAUTION ⚠

Use ONLY the crankshaft to rotate the engine. The use of the gears will result in false measurement. Gear lash must be closed up in the direction of normal rotation.

NOTE: Three guide bolts equally spaced in front of the crankshaft will help rotate the engine.

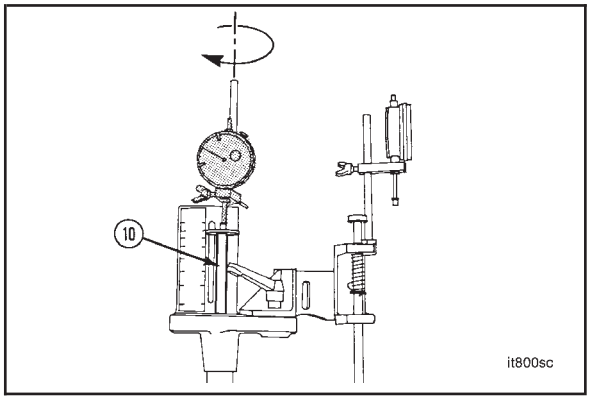
Turn the crankshaft in the direction of normal rotation while observing both of the timing tool plungers. Both plungers will begin moving upward when the cylinder is on the compression stroke.

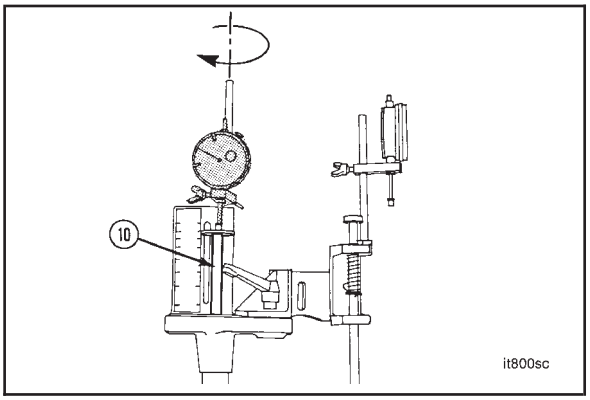


NOTE: Assuming all the gear index marks were aligned when the injection timing process was started, the crankshaft will have to be rotated approximately three-quarters of a revolution to get to the compression stroke for the No. 3 cylinder.

If both plungers are **not** moving **upward** (one **upward**and one **downward**), the engine is on the exhaust stroke. Rotate the crankshaft one revolution to get to the compression stroke.

Establish Top Dead Center (TDC) by slowly rotating the crankshaft in the direction of normal rotation while observing the piston plunger (10). The plunger will move **upward**, STOP, then begin to move **downward**. The STOP point of the plunger is TDC. Rotate the engine **opposite** the direction of normal rotation until the plunger begins to moves **downward**. The cylinder is now **Before Top Dead Center (BTDC)** slightly.

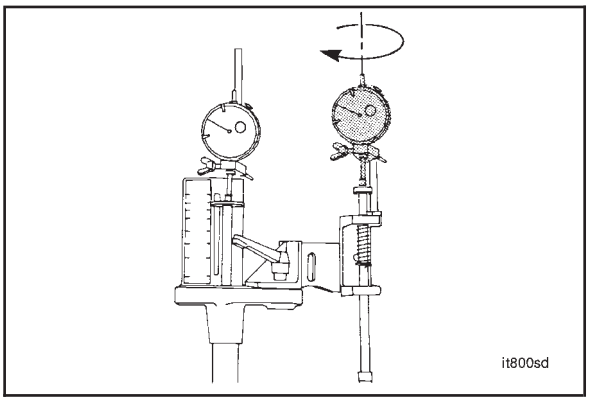




Turn the indicator so that the stem is touching the plunger. Carefully move the indicator **downward** until the needle has turned a minimum of five revolutions 12.7 mm [0.500 inch]. LOCK the indicator in position.

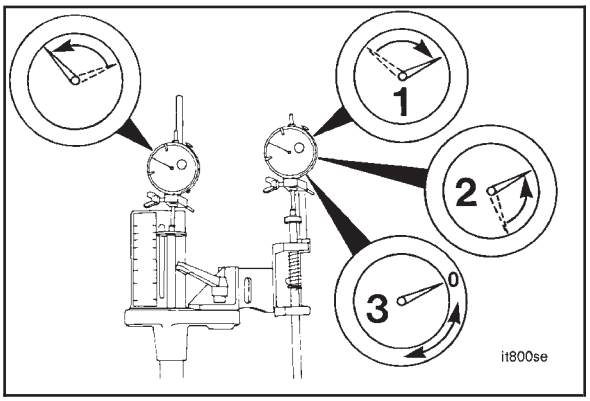
Slowly turn the crankshaft in the direction of normal rotation until the indicator needle STOPS turning **clockwise** (TDC). Move the indicator **downward** until there is ONLY one revolution 2.54 mm [0.100 inch] of travel remaining until the indicator bottoms out.

Adjust the indicator to ZERO.



Turn the push rod indicator so that the stem touches the plunger.

Carefully **lower** the indicator until it bottoms out. **Raise** the indicator when the needle has turned a minimum of three revolutions 7.62 mm [0.300 inch].



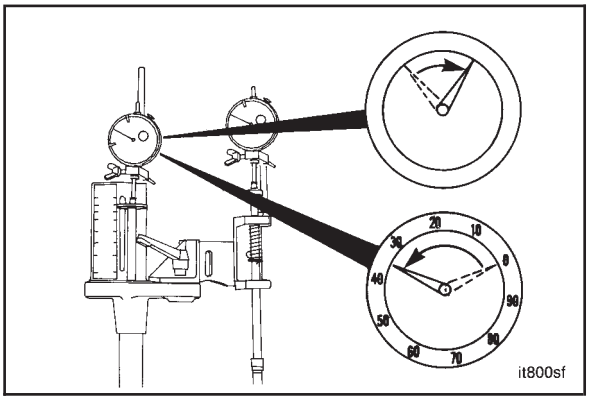
Slowly turn the crankshaft in the direction of normal rotation until the push rod indicator STOPS (1), momentarily **reverses** direction (2) (this is the crush nose on the camshaft), and STOPS again (3). The cam follower is now on the outer base circle of the camshaft. The piston is now approximately 45 degrees After Top Dead Center (ATDC).

CAUTION

It is important to record the amount of travel remaining in the push rod travel indicator for later reference.

Carefully **lower** the push rod travel indicator until it bottoms out. **Raise** the indicator approximately one-half of a revolution 12.7 mm [0.050 inch]. LOCK the indicator in position.

Set the indicator at ZERO.



Set The Piston at 5.1613 mm [0.2032 inch] BTDC

Observe the piston travel indicator as you **slowly** rotate the crankshaft **opposite** the direction of normal rotation.

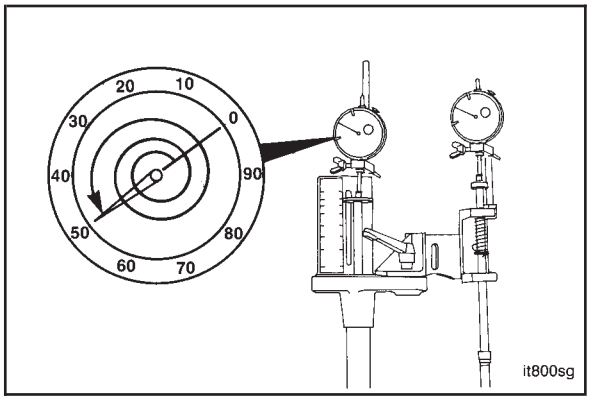
STOP rotating the crankshaft when the piston travel indicator indicates the piston is at TDC (ZERO).

⚠ CAUTION ⚠

The crankshaft must be turned slowly to accurately count the indicator revolutions.

Turn the crankshaft **opposite** the direction of normal rotation until the indicator needle moves two and one-half revolutions 6.35 mm [0.250 inch].

The piston is now 6.35 mm [0.250 inch] BTDC.

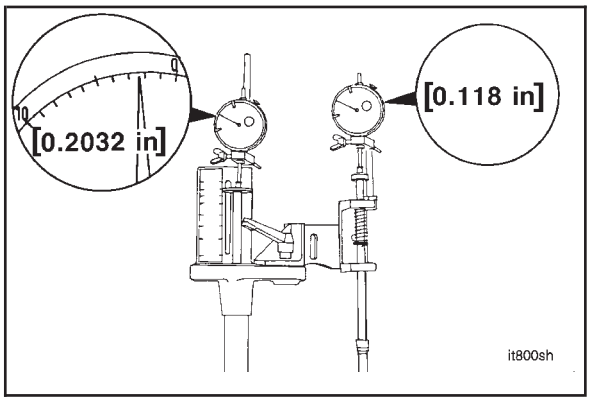


⚠ CAUTION ⚠

ONLY move the piston to 5.1613 mm [0.2032 inch] BTDC by turning the crankshaft in the direction of normal rotation. If you accidently turn the crankshaft too far, you must turn the crankshaft opposite the direction of normal rotation MORE than 5.1613 mm [0.2032 inch] BTDC. Then very slowly turn the crankshaft in the direction of normal rotation until the indicator indicates that the piston is 5.1613 mm [0.2032 inch] BTDC.

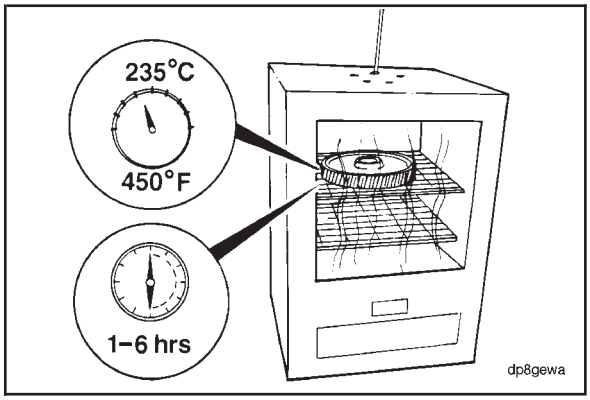
NOTE: Remember that all QSK19 injection timing specifications are **more** than **one** indicator revolution [0.100 inch].

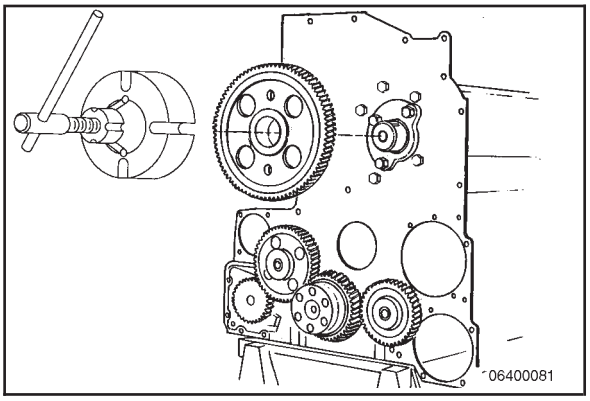
Read the push rod travel indicator **counterclockwise** from ZERO. This is the injection timing measurement to compare to the specification. An example of .354 mm [0.118 inch] is shown.



If you are **not** sure of the number of push rod indicator revolutions, check by carefully **lifting** the indicator stem until the indicator has bottomed out. **Lower** the stem the amount of excess travel you set in the third preceding step. **Lower** the stem to the plunger. Read the indicator.

If the injection timing is within specification and you are using a **slipper-fit** gear, install the **standard** gear. Repeat the injection timing procedure after the camshaft gear has cooled.





If the injection timing is **not** within specification, repeat the measurement procedure to check the tool setup and the ZERO settings.

If the timing is still **not** within specification, the camshaft key **must** be changed.

Record the orientation of any offset of the key. Use the following worksheet to determine an alternate key.

CAUTION

You must confirm the timing measurement after change the key.

TABLE C

S-302	200704	200706	200708	200709	200711	200714	216294	216782	3000491	3000492	3000493	3000494	3000495	New Key Part No.	New Key Direction of Offset
0.0256	0.0351	0.0411	0.0366	0.0326	0.0289	0.0441	0.0273	0.0311	0.0391	0.0436	0.0471	0.0491	0.0512	3000495	Opposite
0.0235	0.033	0.039	0.0345	0.0305	0.0268	0.042	0.0252	0.029	0.037	0.0415	0.045	0.0471	0.0491	3000494	Opposite
0.0215	0.031	0.037	0.0325	0.0285	0.0248	0.040	0.0232	0.027	0.035	0.0395	0.043	0.0441	0.0471	3000493	Opposite
0.0185	0.028	0.034	0.0295	0.0255	0.0218	0.037	0.0202	0.024	0.032	0.0365	0.040	0.042	0.0441	200714	Opposite
0.018	0.0275	0.0335	0.029	0.025	0.0213	0.0365	0.0197	0.0235	0.0315	0.036	0.0395	0.0415	0.0436	3000492	Opposite
0.0155	0.025	0.031	0.0265	0.0225	0.0188	0.034	0.0172	0.021	0.029	0.0335	0.037	0.039	0.0411	200706	Opposite
0.0135	0.023	0.029	0.0245	0.0205	0.0168	0.032	0.0152	0.019	0.027	0.0315	0.035	0.037	0.0391	3000491	Opposite
0.011	0.0205	0.0265	0.022	0.018	0.0143	0.0295	0.0127	0.0165	0.0245	0.029	0.0325	0.0345	0.0366	200708	Opposite
0.0095	0.019	0.025	0.0205	0.0165	0.0128	0.028	0.0112	0.015	0.023	0.0275	0.031	0.033	0.0351	200704	Opposite
0.007	0.0165	0.0225	0.018	0.014	0.0103	0.0255	0.0087	0.0125	0.0205	0.025	0.0285	0.0305	0.0326	200709	Opposite
0.0055	0.015	0.021	0.0165	0.0125	0.009	0.024	0.0072	0.011	0.019	0.0235	0.027	0.029	0.0311	216782	Opposite
0.0033	0.0128	0.0188	0.0143	0.0103	0.006	0.0218	0.005	0.009	0.0168	0.0213	0.0248	0.0268	0.0289	200711	Opposite
0.0017	0.0112	0.0172	0.0127	0.0087	0.0051	0.0202	0.0034	0.0072	0.0152	0.0197	0.0232	0.0252	0.0273	216294	Opposite
0.000	0.0095	0.0155	0.011	0.007	0.003	0.0185	0.0017	0.006	0.0135	0.018	0.0205	0.0235	0.0256	S-302	N/A
0.0017	0.0078	0.0138	0.0093	0.0053	0.0016	0.0168	0.000	0.0038	0.0118	0.0163	0.0198	0.0218	0.0239	216294	Same
0.0033	0.0062	0.0122	0.0077	0.0037	0.000	0.0152	0.0016	0.002	0.0102	0.0147	0.0182	0.0202	0.0223	200711	Same
0.0055	0.004	0.010	0.0055	0.0015	0.002	0.013	0.0038	0.000	0.008	0.0125	0.016	0.018	0.0201	216782	Same
0.007	0.0025	0.0085	0.004	0.000	0.0037	0.0115	0.0053	0.0015	0.0065	0.011	0.0145	0.0165	0.0186	200709	Same
0.0095	0.000	0.006	0.0015	0.0025	0.0062	0.009	0.0078	0.004	0.004	0.0085	0.012	0.014	0.0161	200704	Same
0.011	0.0015	0.0045	0.000	0.004	0.0077	0.0075	0.0093	0.0055	0.0025	0.007	0.0105	0.0125	0.0146	200708	Same
0.0135	0.004	0.002	0.0025	0.0065	0.0102	0.005	0.0118	0.008	0.000	0.0045	0.008	0.010	0.0121	3000491	Same
0.0155	0.006	0.000	0.0045	0.0085	0.012	0.003	0.0138	0.010	0.002	0.0025	0.006	0.008	0.0101	200706	Same
0.018	0.0085	0.0025	0.007	0.011	0.0147	0.0005	0.0163	0.0125	0.0045	0.000	0.0035	0.0055	0.0076	3000492	Same
0.0185	0.009	0.003	0.0075	0.0115	0.0152	0.000	0.0168	0.013	0.005	0.0005	0.003	0.005	0.0071	200714	Same
0.0215	0.012	0.006	0.0105	0.0145	0.0182	0.003	0.0198	0.016	0.008	0.0035	0.000	0.002	0.0041	3000493	Same
0.0235	0.014	0.008	0.0125	0.0165	0.202	0.005	0.0218	0.018	0.010	0.0055	0.002	0.000	0.0021	3000494	Same
0.0256	0.0161	0.010	0.0146	0.0186	0.0223	0.0071	0.0239	0.0020	0.0121	0.0076	0.0041	0.0021	0.000	3000495	Same

06400105

Answer each of the following questions in the spaces provided. The answers to the questions and the use of Tables A, B, and C will determine the timing key required to correct the injection timing.
A working example is attached for your review to illustrate the use of this worksheeet.

1. What is the current timing? _____

2. What is the timing code? _____

3. What is the timing specification for this code? (±0.002 inch) _____

4. Is the current timing a larger or smaller number than the specification? _____

   If larger, advance the timing. _____

   If smaller, retard the timing. _____

5. What is the difference between the current timing (answer to question 1) and the specification (answer to question 3)? _____

6. Does the offset of the current key point in the same or opposite direction that the camshaft normally rotates? _____

7. Use TABLE A to determine the current key part number.
   * What is the amount of the offset of the current key? _____

   * What is the part number of the current key? _____

TABLE A

Timing Key (Part No.)	Offset mm	Offset in
S-302	None	[None]
216294	0.089	[0.0035]
200711	0.179	[0.0070]
216782	0.279	[0.0110]
200709	0.381	[0.0150]
200704	0.500	[0.0197]
200708	0.584	[0.0230]
3000491	0.686	[0.0270]
200706	0.833	[0.0328]
3000492	0.914	[0.0360]
200714	0.991	[0.0390]
3000493	1.092	[0.0430]
3000494	1.194	[0.0470]
3000495	1.295	[0.0510]

8. Use TABLE B to determine how to use TABLE C. Circle or check the appropriate answer.

TABLE B

Answer to Question 4	Answer to Question 6	Beginning Point on TABLE C	
Advance	Same	Top of column	_____
Advance	Opposite	Bottom of column	_____
Retard	Same	Bottom of column	_____
Retard	Opposite	Top of column	_____

9. Answer the following questions BEFORE using TABLE C to determine the new timing key part number.

   * Find the current key part number listed at the TOP of the column on TABLE C.

   * Move up or down the column (the answer to question 8). Do not pass 0.000 (ZERO)*.

   *If you pass 0.000 (ZERO), you will be choosing a key that does the opposite of what you want it to do.

   STOP when you locate the number nearest (±0.002 inch) to the required change in push rod travel (answer to question 5). Remain in this row. Move your finger to the right. The result is the New Key Part No. and the Direction of Offset the timing key must point.

   What is the part number of the new key? _____

   Note: Each column on TABLE C indicates the change in the push rod travel. The change will result if the key at the top of the column is removed and the new key indicated in the second column from the right is installed. The Direction of Offset will be pointing as indicated in the last column to the right on TABLE C.

06400106

Answer each of the following questions in the spaces provided. The answers to the questions and the use of Tables A, B, and C will determine the timing key required to correct the injection timing.
A working example is attached for your review to illustrate the use of this worksheeet.

1. What is the current timing? **0.267**
2. What is the timing code? **JF**
3. What is the timing specification for this code? (±0.002 inch) **0.279**
4. Is the current timing a larger or smaller number than the specification? **Smaller**

   If larger, advance the timing.

   If smaller, retard the timing. **Retard**
5. What is the difference between the current timing (answer to question 1) and the specification (answer to question 3)? **0.012**
6. Does the offset of the current key point in the same or opposite direction that the camshaft normally rotates? **Same**
7. Use TABLE A to determine the current key part number.
   * What is the amount of the offset of the current key? **0.007**
   * What is the part number of the current key? **200711**

TABLE A

Timing Key (Part No.)	Offset mm	Offset in
S-302	None	[None]
216294	0.089	[0.0035]
200711	0.179	[0.0070]
216782	0.279	[0.0110]
200709	0.381	[0.0150]
200704	0.500	[0.0197]
200708	0.584	[0.0230]
3000491	0.686	[0.0270]
200706	0.833	[0.0328]
3000492	0.914	[0.0360]
200714	0.991	[0.0390]
3000493	1.092	[0.0430]
3000494	1.194	[0.0470]
3000495	1.295	[0.0510]

8. Use TABLE B to determine how to use TABLE C. Circle or check the appropriate answer.

TABLE B

Answer to Question 4	Answer to Question 6	Beginning Point on TABLE C	
Advance	Same	Top of column	
Advance	Opposite	Bottom of column	
Retard	Same	Bottom of column	✓
Retard	Opposite	Top of column	

9. Answer the following questions BEFORE using TABLE C to determine the new timing key part number.
   * Find the current key part number listed at the TOP of the column on TABLE C.
   * Move up or down the column (the answer to question 8). Do not pass 0.000 (ZERO)*.

   *If you pass 0.000 (ZERO), you will be choosing a key that does the opposite of what you want it to do.

   STOP when you locate the number nearest (±0.002 inch) to the required change in push rod travel (answer to question 5). Remain in this row. Move your finger to the right. The result is the New Key Part No. and the Direction of Offset the timing key must point.

   What is the part number of the new key? **200706**

   Note: Each column on TABLE C indicates the change in the push rod travel. The change will result if the key at the top of the column is removed and the new key indicated in the second column from the right is installed. The Direction of Offset will be pointing as indicated in the last column to the right on TABLE C.

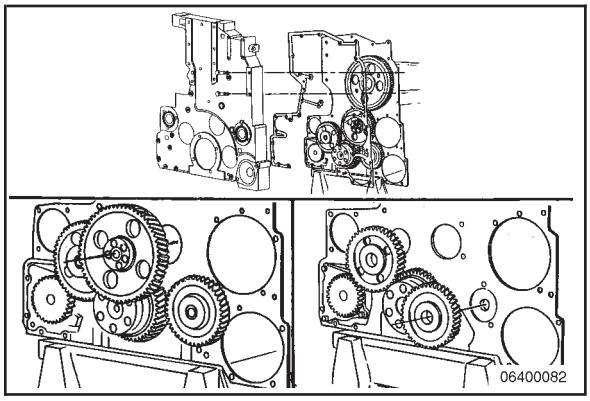
06400108

TABLE C

S-302	200704	200706	200708	200709	200711	200714	216294	216782	3000491	3000492	3000493	3000494	3000495	New Key Part No.	New Key Direction of Offset
0.0256	0.0351	0.0411	0.0366	0.0326	0.0289	0.0441	0.0273	0.0311	0.0391	0.0436	0.0471	0.0491	0.0512	3000495	Opposite
0.0235	0.033	0.039	0.0345	0.0305	0.0268	0.042	0.0252	0.029	0.037	0.0415	0.045	0.0471	0.0491	3000494	Opposite
0.0215	0.031	0.037	0.0325	0.0285	0.0248	0.040	0.0232	0.027	0.035	0.0395	0.043	0.0441	0.0471	3000493	Opposite
0.0185	0.028	0.034	0.0295	0.0255	0.0218	0.037	0.0202	0.024	0.032	0.0365	0.040	0.042	0.0441	200714	Opposite
0.018	0.0275	0.0335	0.029	0.025	0.0213	0.0365	0.0197	0.0235	0.0315	0.036	0.0395	0.0415	0.0436	3000492	Opposite
0.0155	0.025	0.031	0.0265	0.0225	0.0188	0.034	0.0172	0.021	0.029	0.0335	0.037	0.039	0.0411	200706	Opposite
0.0135	0.023	0.029	0.0245	0.0205	0.0168	0.032	0.0152	0.019	0.027	0.0315	0.035	0.037	0.0391	3000491	Opposite
0.011	0.0205	0.0265	0.022	0.018	0.0143	0.0295	0.0127	0.0165	0.0245	0.029	0.0325	0.0345	0.0366	200708	Opposite
0.0095	0.019	0.025	0.0205	0.0165	0.0128	0.028	0.0112	0.015	0.023	0.0275	0.031	0.033	0.0351	200704	Opposite
0.007	0.0165	0.0225	0.018	0.014	0.0103	0.0255	0.0087	0.0125	0.0205	0.025	0.0285	0.0305	0.0326	200709	Opposite
0.0055	0.015	0.021	0.0165	0.0125	0.009	0.024	0.0072	0.011	0.019	0.0235	0.027	0.029	0.0311	216782	Opposite
0.0033	0.0128	0.0188	0.0143	0.0103	0.006	0.0218	0.005	0.009	0.0168	0.0213	0.0248	0.0268	0.0289	200711	Opposite
0.0017	0.0112	0.0172	0.0127	0.0087	0.0051	0.0202	0.0034	0.0072	0.0152	0.0197	0.0232	0.0252	0.0273	216294	Opposite
0.000	0.0095	0.0155	0.011	0.007	0.003	0.0185	0.0017	0.006	0.0135	0.018	0.0205	0.0235	0.0256	S-302	N/A
0.0017	0.0078	0.0138	0.0093	0.0053	0.0016	0.0168	0.000	0.0038	0.0118	0.0163	0.0198	0.0218	0.0239	216294	Same
0.0033	0.0062	0.0122	0.0077	0.0037	0.000	0.0152	0.0016	0.002	0.0102	0.0147	0.0182	0.0202	0.0223	200711	Same
0.0055	0.004	0.010	0.0055	0.0015	0.002	0.013	0.0038	0.000	0.008	0.0125	0.016	0.018	0.0201	216782	Same
0.007	0.0025	0.0085	0.004	0.000	0.0037	0.0115	0.0053	0.0015	0.0065	0.011	0.0145	0.0165	0.0186	200709	Same
0.0095	0.000	0.006	0.0015	0.0025	0.0062	0.009	0.0078	0.004	0.004	0.0085	0.012	0.014	0.0161	200704	Same
0.011	0.0015	0.0045	0.000	0.004	0.0077	0.0075	0.0093	0.0055	0.0025	0.007	0.0105	0.0125	0.0146	200708	Same
0.0135	0.004	0.002	0.0025	0.0065	0.0102	0.005	0.0118	0.008	0.000	0.0045	0.008	0.010	0.0121	3000491	Same
0.0155	0.006	0.000	0.0045	0.0085	0.012	0.003	0.0138	0.010	0.002	0.0025	0.006	0.008	0.011	200706	Same
0.018	0.0085	0.0025	0.007	0.011	0.0147	0.0005	0.0163	0.0125	0.0045	0.000	0.0035	0.0055	0.0076	3000492	Same
0.0185	0.009	0.003	0.0075	0.0115	0.0152	0.000	0.0168	0.013	0.005	0.0005	0.003	0.005	0.0071	200714	Same
0.0215	0.012	0.006	0.0105	0.0145	0.0182	0.003	0.0198	0.016	0.008	0.0035	0.000	0.002	0.0041	3000493	Same
0.0235	0.014	0.008	0.0125	0.0165	0.202	0.005	0.0218	0.018	0.010	0.0055	0.002	0.000	0.0021	3000494	Same
0.0256	0.0161	0.010	0.0146	0.0186	0.0223	0.0071	0.0239	0.0020	0.0121	0.0076	0.0041	0.0021	0.000	3000495	Same

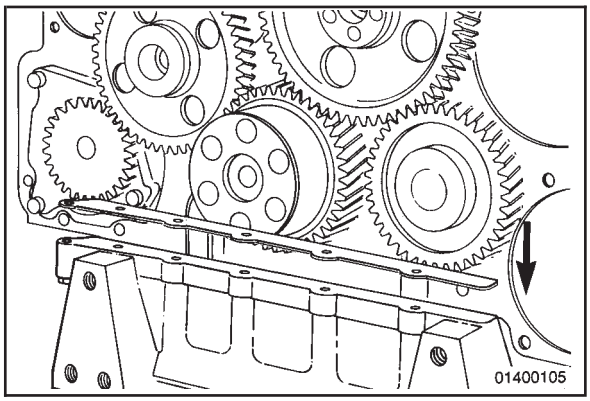
06400107

Install the gear cover and related components.

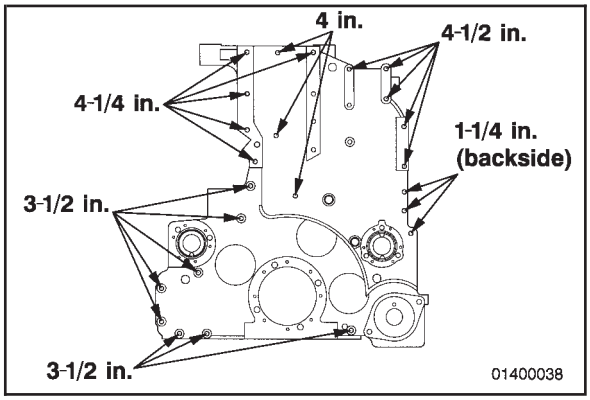


NOTE: Trim the gasket to the correct width since the spacer plate is already installed.

Install the service gasket piece on top of the oil pan adapter. Use a spray adhesive to hold it in position. Use Cummins sealant, Part No. 3823494, at the joints.

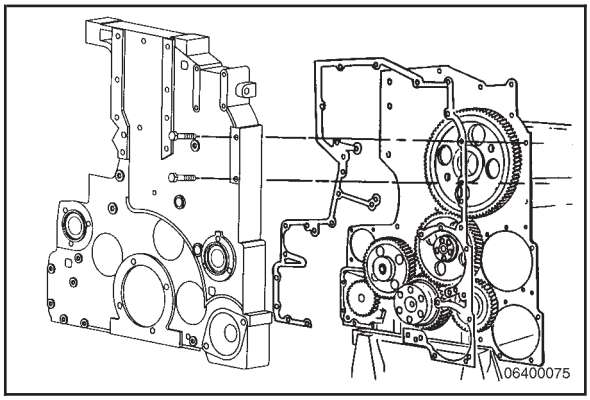


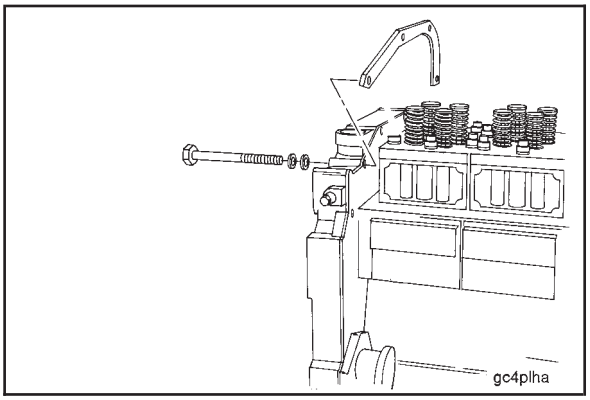
This illustration shows the capscrew length requirements for the front cover.



NOTE: Do **not** tighten the capscrews until the master dowel pin is installed.

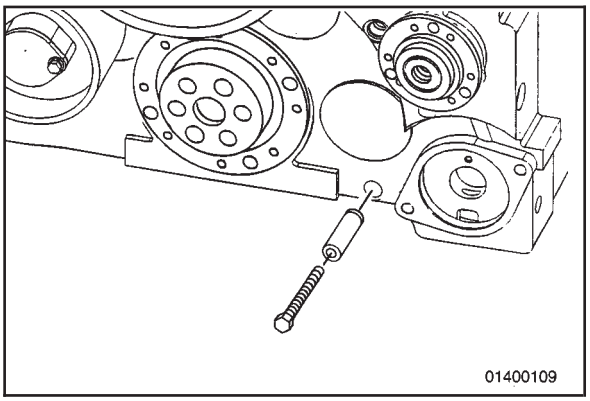
The use of guide bolts will aid the assembly. Install the front cover gasket, cover, and capscrews.



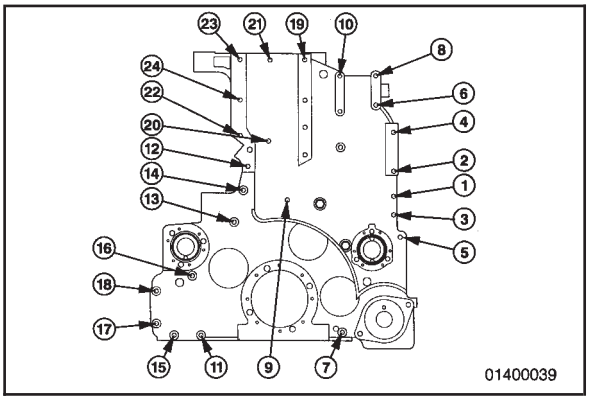


Put the clamping plate in position and begin the installation of the capscrew.

NOTE: The plate **must** remain loose until the fan hub or the cover plate is installed.

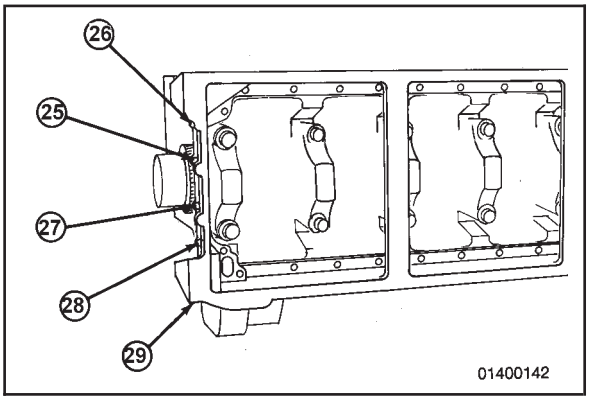


Use a 5/16-8x3 inch capscrew and a mallet. Install the threaded master dowel. Drive the dowel in until it touches the bottom of the hole in the block.



Tighten the mounting capscrews in the sequence shown.

NOTE: Capscrew No. 1, 2, and 3 are located at the back of the spacer plate.



Install the five capscrews that attach to the bottom of the oil pan adapter. Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]

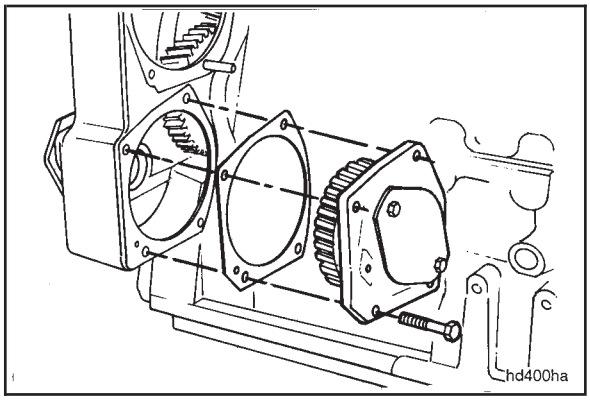
Install the hydraulic pump drive.

Using engine oil, lubricate the bushing in the cover.

Install the gasket, drive or cover, washers, and capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



NOTE: If an SAE 1 flywheel housing option is used, there must be two [5/8–11 x 6 1/2 in] studs, Part No. 3065777, installed in the upper holes of the cylinder block.

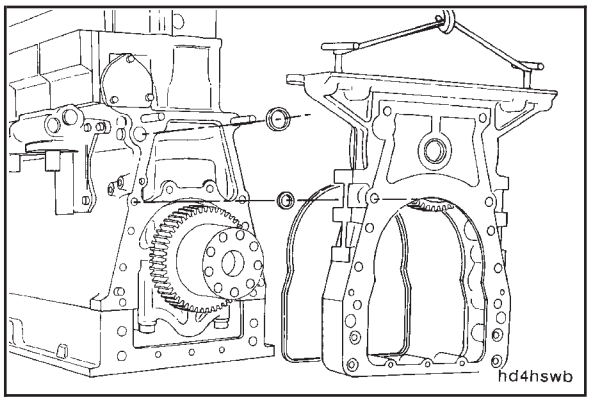
Apply a small amount of Lubriplate® 105 or gasket adhesive on the seal ring groove, the capscrew counterbores, and the dowel counterbores on the block side of the lower housing.

Install the new rectangular seal ring, with the joint at the top into the groove in the lower housing.

Install the ten new capscrew seals into the capscrew counterbores in the lower housing.

Use Lubriplate® 105 or equivalent on the main rifle seal.

Install the main rifle seal into the counterbore surrounding the main rifle drilling.

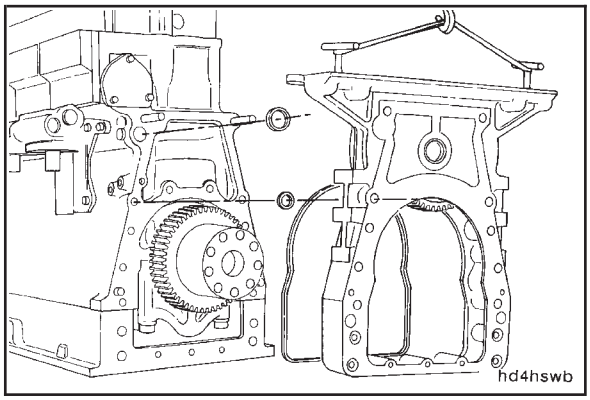


⚠ CAUTION ⚠

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

Install two 5/8-11x1/2 inch guide studs into the rear face of the cylinder block. Use a hoist, two tee handles, and a lifting sling. Install the tee handles.

Lift the lower housing of the rear gear train.

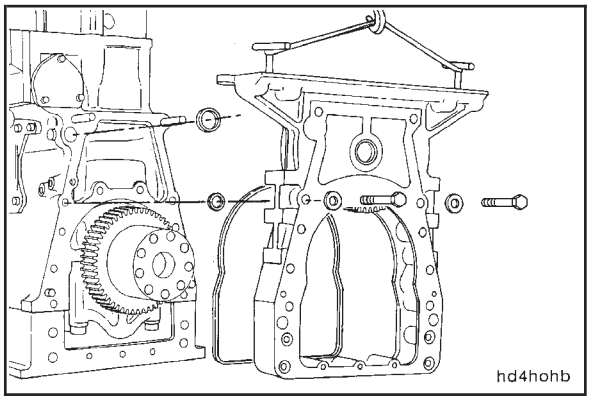


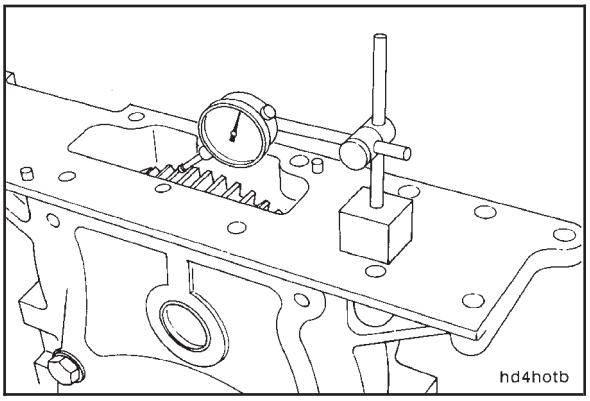
Install the lower housing of the rear gear train onto the dowel pins.

Check the alignment of all capscrews seals, rectangular seal, and the main oil rifle seal.

Use two 5/8-11x5 inch capscrews with flat washers in the locations shown.

Tighten the capscrews alternately to pull the lower housing to the block.





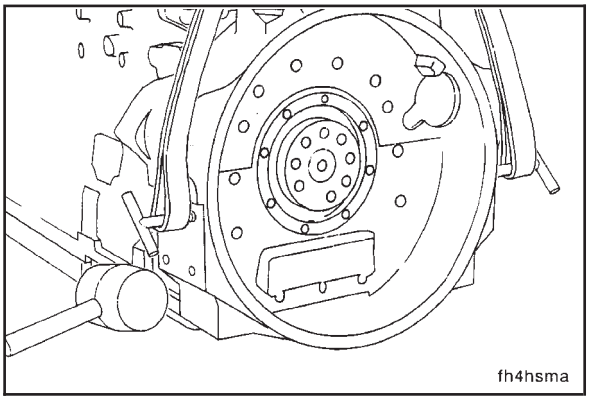
Use a dial indicator. Be sure the two capscrews are holding the lower housing firmly against the cylinder block. Check the gear lash.

Lower Housing-To-Cylinder Block Gear Backlash		
mm		in
0.05	MIN	0.002
0.51	MAX	0.015

If the gear lash is above acceptable limits, the rear gear train lower idler gear or crankshaft gear **must** be replaced.

NOTE: Replace the idler gear first.

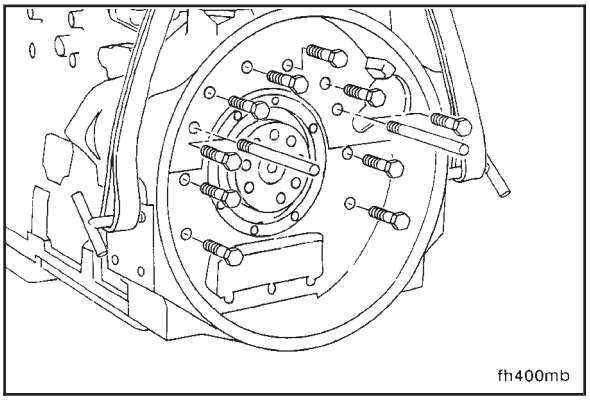
If the gear lash is below acceptable limits (or if the gear replacement does **not** correct the lash), replace the housing.



Use Lubriplate® No. 105 or gasket adhesive on the seal ring groove and the 10 capscrew counterbores on the rear gear train lower housing side of the flywheel housing.

Install the new rectangular seal ring, with the joint at the top, into the groove in the flywheel housing.

Install the new capscrew seals and dowel seals into the counterbores in the lower housing.

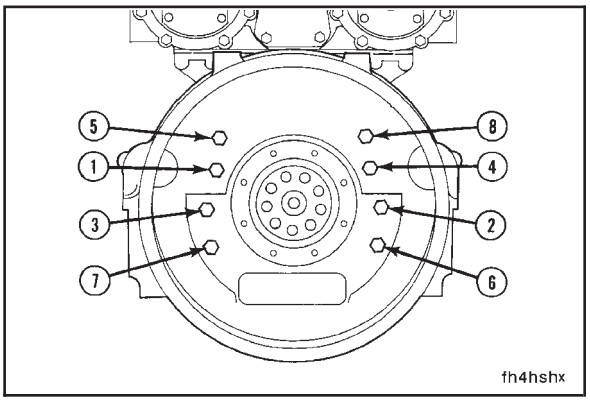


⚠ CAUTION ⚠

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

Use two 5/8-11x6 1/2 inch guide studs. Use a hoist, tee handles, and a lifting sling. Install the flywheel housing onto the dowels in the rear gear train lower housing.

Install the lock washers, capscrews, and nuts.



Use the following steps.

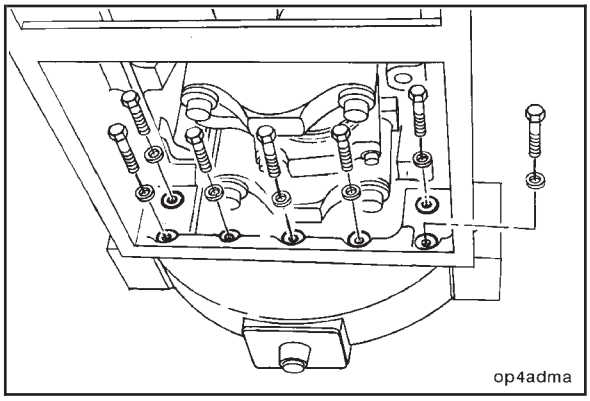
Tighten using the sequence shown.

Torque Value: Step 1 100 N•m [75 ft-lb]
2 205 N•m [150 ft-lb]

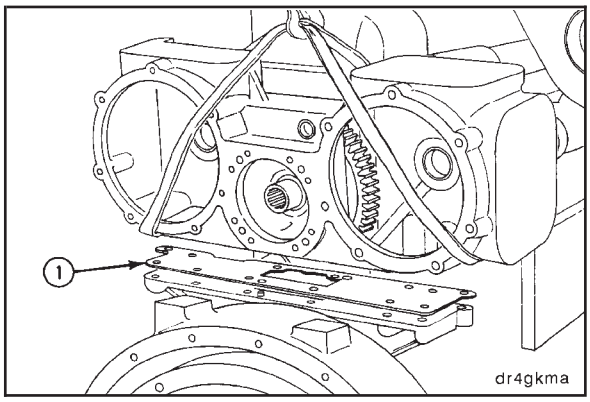
Install the two capscrews 7/16-14x4 3/4 inch, Part No. 190799, and the five capscrews 3/8-16x4 3/4 inch, Part No. S106-C, with flat washers and lockwashers.

Torque Value:

3/8-16 inch	45 N•m	[35 ft-lb]
7/16-14 inch	65 N•m	[50 ft-lb]

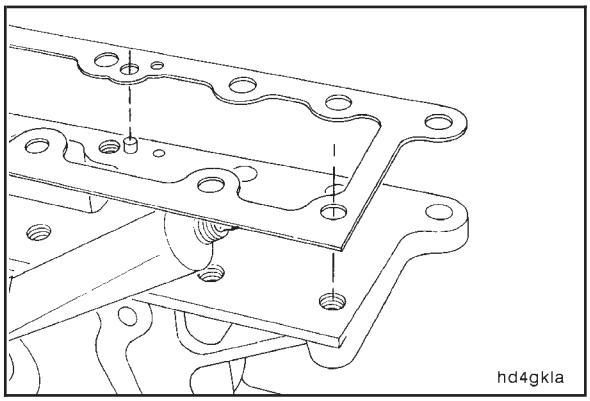


Install the upper housing of the rear gear train.



Use gasket adhesive on the gasket. Do **not** use an excessive amount of adhesive on the gasket.

Align and install the rear gear train upper housing gasket to the rear gear train lower housing.

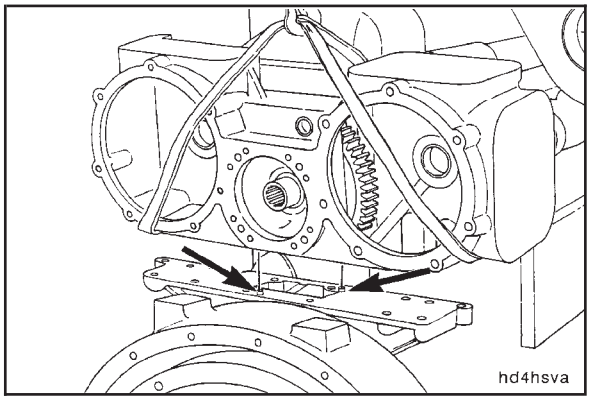


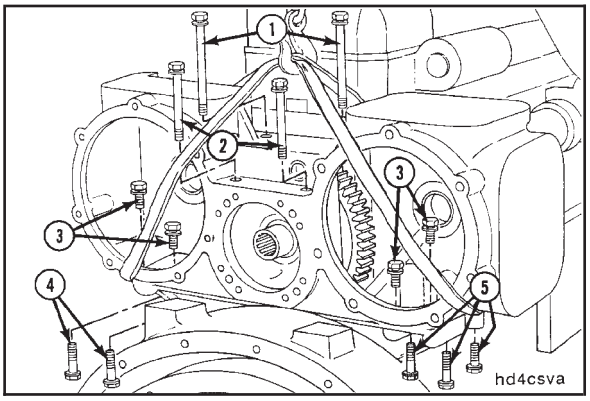
⚠ CAUTION ⚠

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

NOTE: Use extra care when aligning the upper housing onto the lower housing to prevent gasket damage.

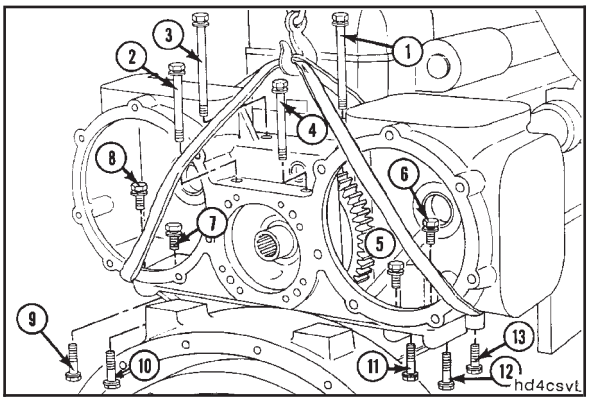
Use the dowel pins to align the **upper** housing onto the **lower** housing.





Use **only** SAE Grade 8 capscrews to install the upper housing. Install the following capscrews according to the table below.

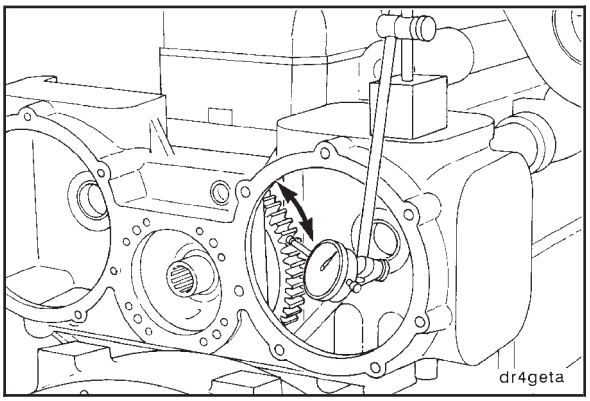
Ref	Location	Part No.	Size [inch]	Qty
1	Top-Front	3202224	1/2-13 x 9 1/4	2
2	Top-Rear	3202223	1/2-13 x 7 1/2	2
3	Internal	1691695	1/2-13 x 1 3/4	4
4	Bottom-Left Side	3202222	1/2-13 x 1 3/4	2
5	Bottom-Right Side	3202222	1/2-13 x 1 3/4	3



Use the sequence shown to tighten the bolts.

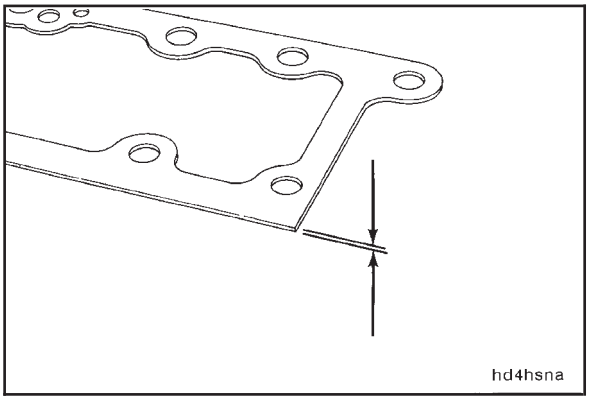
Torque Value:

Step 1	70 N•m	[50 ft-lb]
Step 2	150 N•m	[110 ft-lb]



Use a dial indicator. Be sure the lower idler gear is secure. If the gear is **not** secure, the indicator reading will include the lower idler gear to the crankshaft gear backlash.

Idler Gear Backlash		
mm		**in**
0.05	MIN	0.002
0.51	MAX	0.020

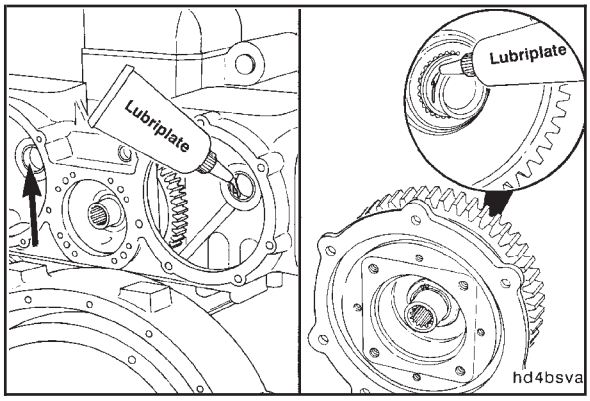


If the gear lash is less than specified limits, thicker gaskets are available. Do **not** use more than two gaskets to correct the backlash.

If the gear lash is greater than the specification and the thinnest gasket is used, the upper and lower gears **must** be replaced.

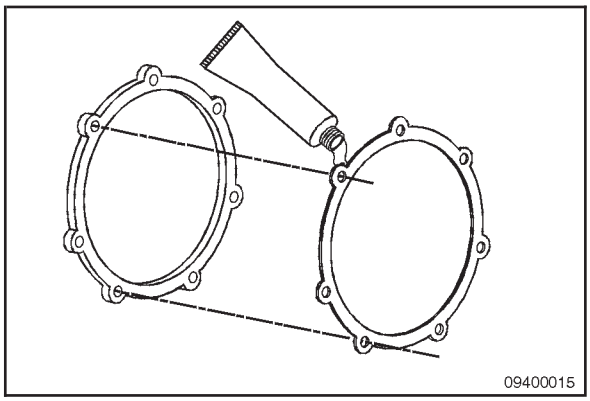
Use Lubriplate® No. 105, or equivalent. Lubricate the outer hydraulic pump support bushing in the upper housing. Lubricate the bushing surfaces on both shafts in the outer hydraulic pump support drive assemblies.

Install the outer hydraulic pump support drive.



NOTE: Some engines will **not** have an outer hydraulic pump support drive. These engines require a cover plate and a non-splined shaft, but do **not** use a hydraulic gear.

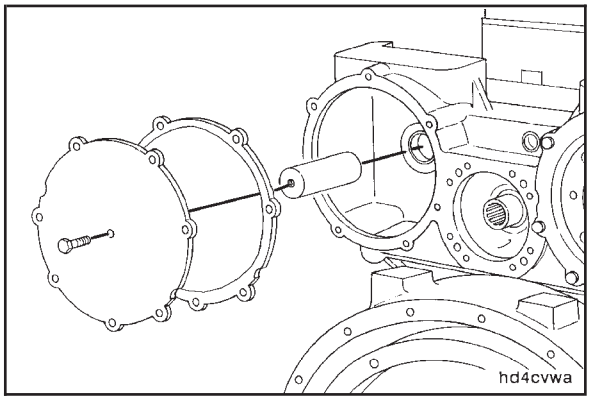
Use gasket adhesive sparingly. Install the hydraulic support housing gaskets to both support mounting flanges on the outer hydraulic pump support drive assemblies.



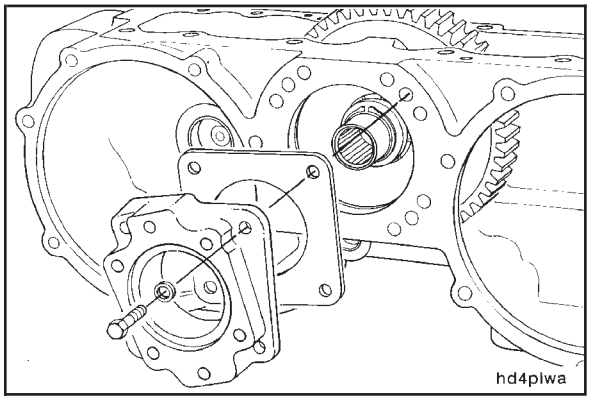
If using the outer hydraulic pump support cover plate, install the non-splined shaft onto the cover plate. Use a 3/8–16 x 1-1/4 inch capscrew.

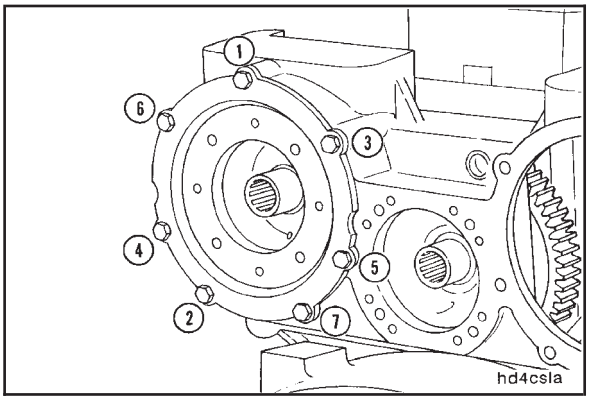
Tighten the capscrew.

Torque Value: 40 N•m [30 ft-lb]



Use three 7/16-14 x 4 inch guide studs. Install one outer hydraulic pump support drive assembly.





Install four capscrews.

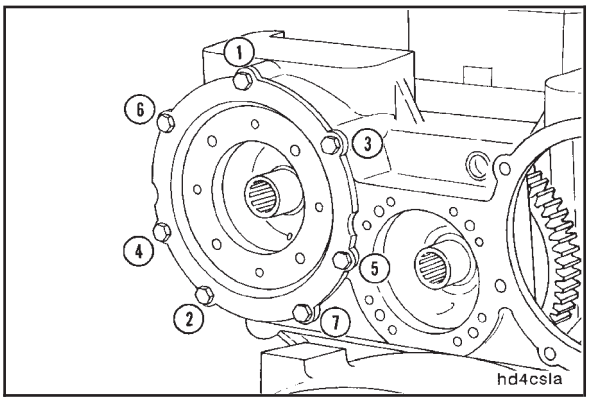
Hand-tighten the capscrews.

Remove the guide studs.

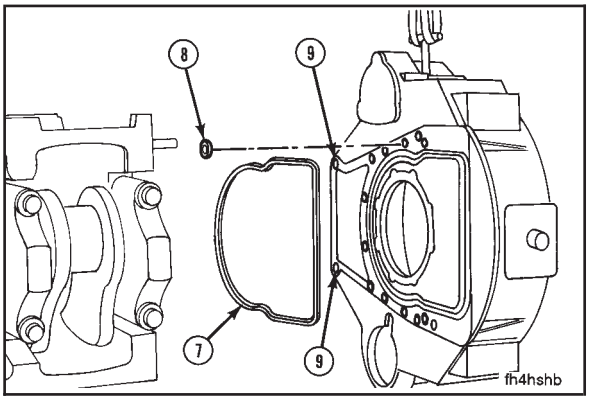
Install the remaining three capscrews. Use the sequence and torque as shown.

Tighten the capscrews.

Torque Value: 70 N•m [50 ft-lb]



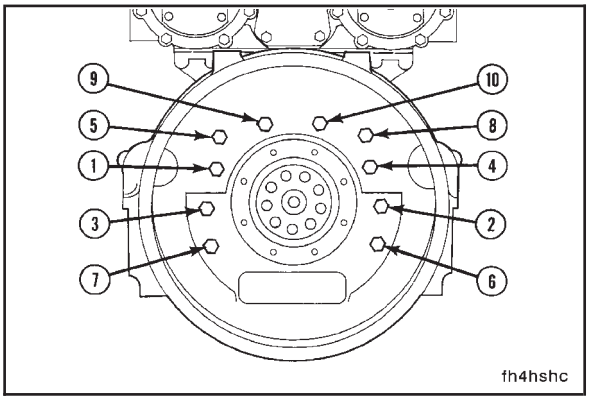
Install the other outer hydraulic pump using the same procedure.



NOTE: Be sure the flywheel housing dowels have been installed in the block.

Install the sealing ring (7) in the groove on the housing. If a wet type is used, install the seals (8) in the counterbores as shown. The holes (9) do **not** require seals.

Use guide bolts to help during alignment. Install the housing and the capscrews.



Torque the flywheel housing capscrews using the sequence shown.

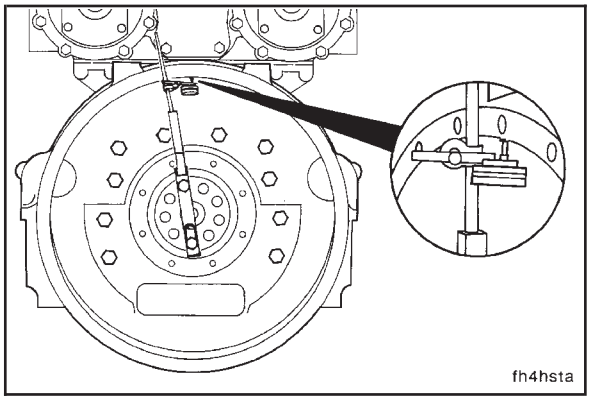
Torque Value:	Step 1	100 N•m	[75 ft-lb]
	2	205 N•m	[150 ft-lb]

Measure the flywheel housing alignment.

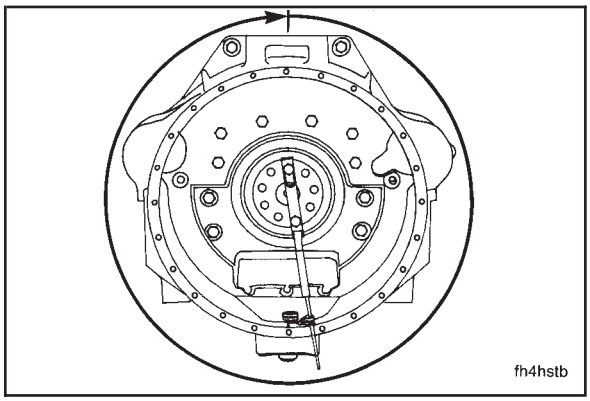
NOTE: The bore and the face of the housing **must** be in alignment with the crankshaft.

NOTE: The indicator arm **must** be rigid for an accurate reading. It **must not** sag.

Attach an indicator to the crankshaft as shown.



Position the indicator at the 12 o'clock position. Adjust the dial until the needle points to ZERO. Rotate the crankshaft one complete revolution (360 degrees). Record the TIR.



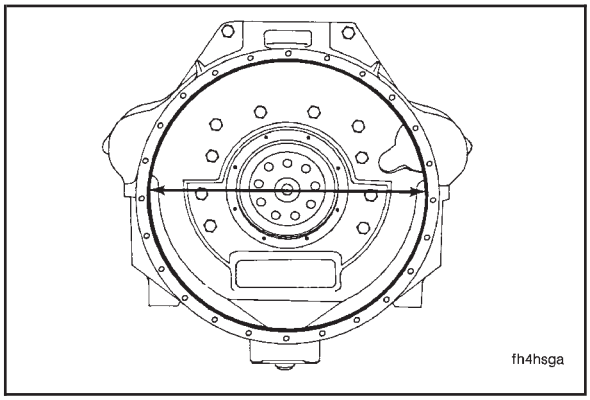
The maximum allowable TIR depends on the diameter of the bore.

Bore Diameter/Maximum TIR

MIN/MAX mm	MIN/MAX in	SAE No.	mm	in
787.4/810.5	[31.00/31.91]	00	0.30	[0.012]
647.7/648.0	[25.50/25.51]	0	0.25	[0.010]
584.2/584.4	[23.00/23.008]	1/2	0.25	[0.010]
511.2/511.3	[20.125/20.13]	1	0.20	[0.008]

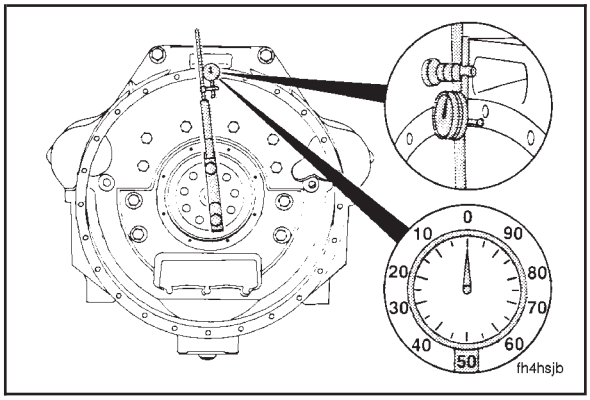
If the alignment is **not** within specifications and the bore is round, the housing can be shifted.

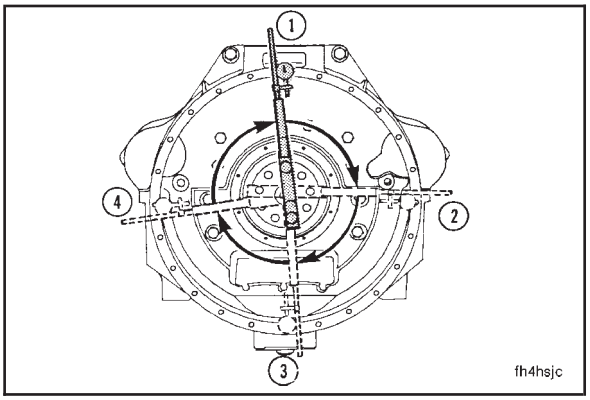
If the alignment is **not** within specifications and the bore is **not** round, the housing **must** be replaced.



NOTE: The crankshaft end clearance **must** be pushed or pulled in the same direction each time a point is measured.

Attach an indicator as shown. Position the indicator at the 12 o'clock position. Adjust the dial until the needle points to ZERO.

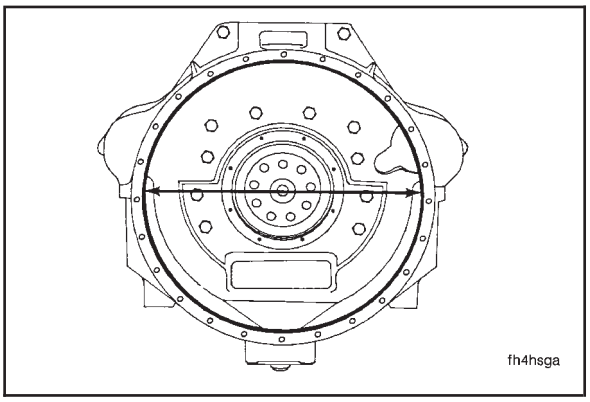




Record the indicator reading at 3 different points; 3 o'clock, 6 o'clock, and 9 o'clock.

Turn backward to the original position. Be sure the needle still points to ZERO. Determine the total indicator runout (TIR).

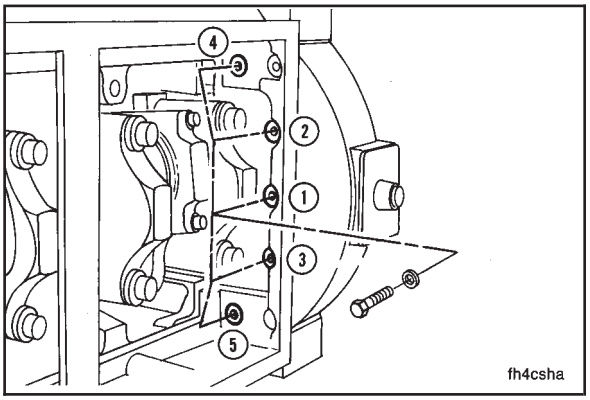
		mm	in
Example:			
	3 o'clock	0.00	[0.00]
	6 o'clock	+ 0.08	[+ 0.003]
	9 o'clock	-0.05	[-0.002]
Equal TIR:		0.13	[0.005]



The maximum allowable TIR depends on the diameter of the bore.

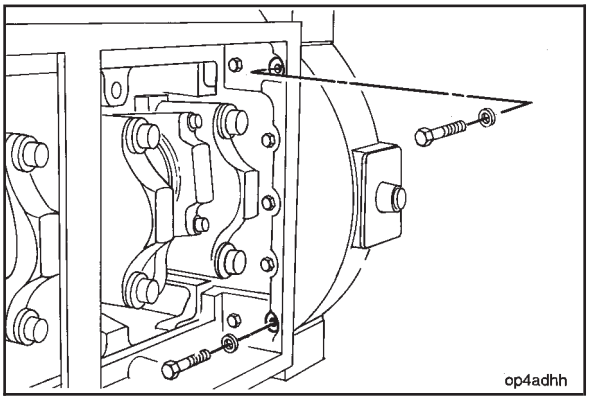
Bore Diameter/Maximum TIR				
MIN/MAX mm	MIN/MAX in	SAE No.	mm	in
787.4/810.5	[31.00/31.91]	00	0.30	[0.012]
647.7/648.0	[25.50/25.51]	0	0.25	[0.010]
584.2/584.4	[23.00/23.008]	1/2	0.25	[0.010]
511.2/511.3	[20.125/20.13]	1	0.20	[0.008]

NOTE: If the alignment is **not** within specifications, remove the housing. Check for nicks, burrs, or foreign material between the block and the housing. Check the alignment again. If the alignment is **not** within specifications, the block or the housing is **not** machined correctly.



Tighten the five [3/8-inch] washers and capscrews in the sequence shown.

Torque Value: Step 1 25 N•m [20 ft-lb]
2 40 N•m [30 ft-lb]
3 45 N•m [35 ft-lb]



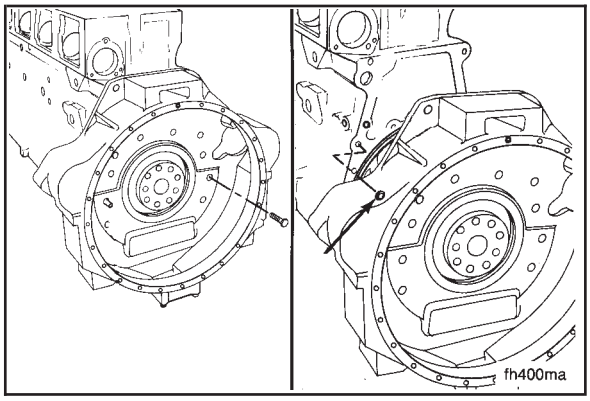
Install the two [7/16-inch] washers and capscrews as shown. Tighten the capscrews.

Torque Value: 65 N•m [50 ft-lb]

Install the flywheel housing mounting capscrews.

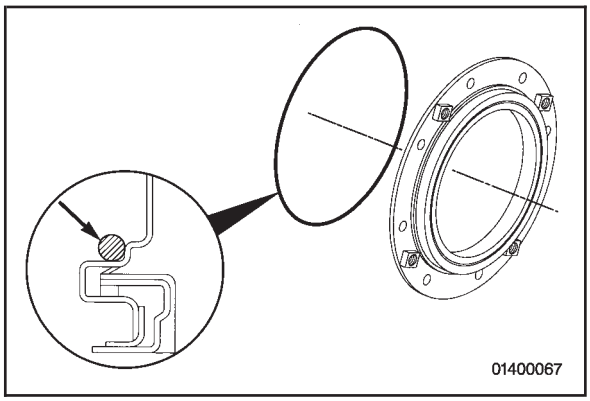
Tighten the capscrews.

Torque Value: 205 N•m [150 ft-lb]



Install a new o-ring on the seal housing.

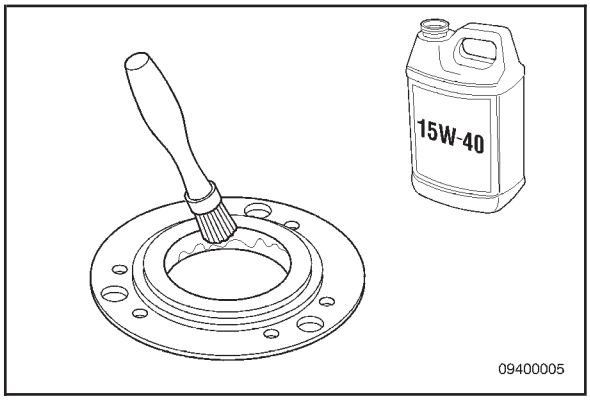
Use vegetable oil to lubricate the o-ring.



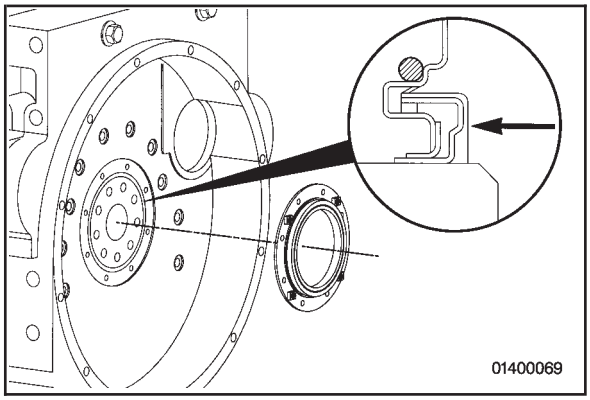
To aid in seal installation, use a small nonmetallic bristle brush to apply a thin film of 15W-40 oil to the inside diameter of the seal case.

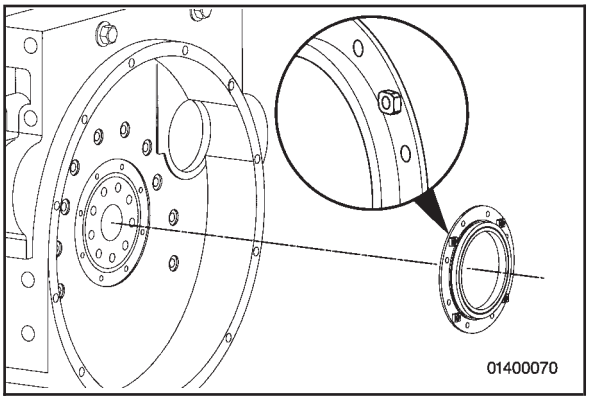
⚠ CAUTION ⚠

Do not allow oil to come in contact with other areas of the seal to avoid damage to sealing surfaces.

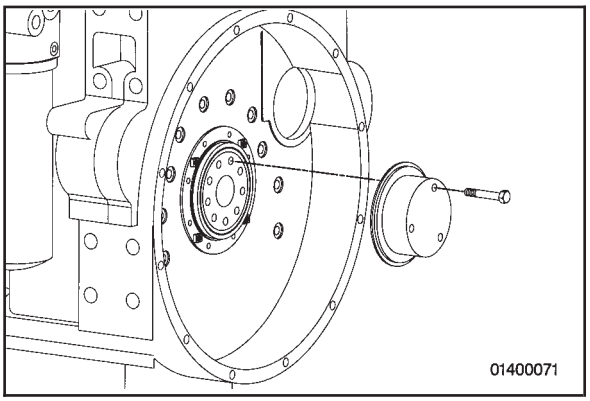


Use hand pressure to push the seal on the crankshaft as far as possible.

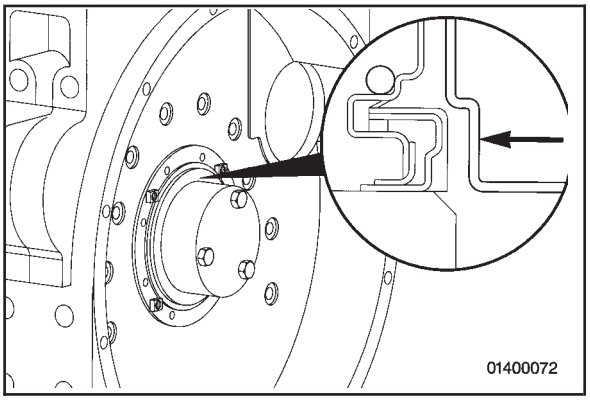




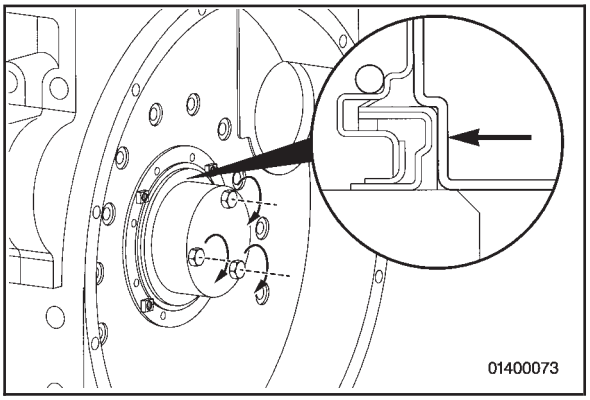
Use the pin supplied in the seal kit to align the seal mounting holes with the mounting capscrew holes in the flywheel housing.



Attach the seal installation tool that is supplied with the seal to the crankshaft, using three flywheel mounting capscrews.

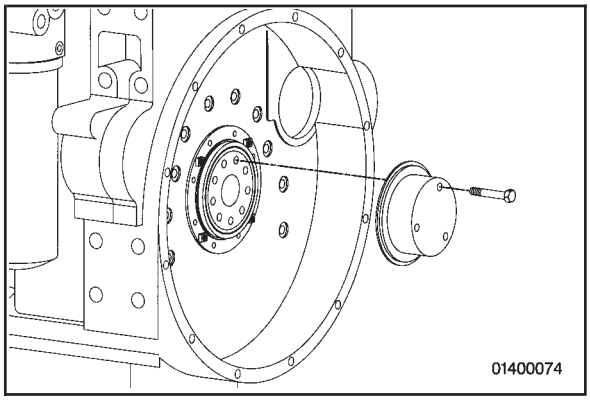


Align the installation tool with the pilot flange on the seal carrier.



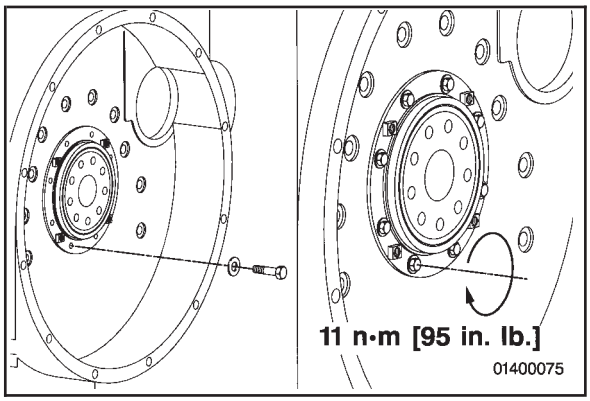
Tighten the three capscrews alternately and evenly in one-half of a turn increments until the seal carrier seats against the flywheel housing.

Remove the seal installation tool.



Install the seal mounting capscrews. Tighten the capscrews.

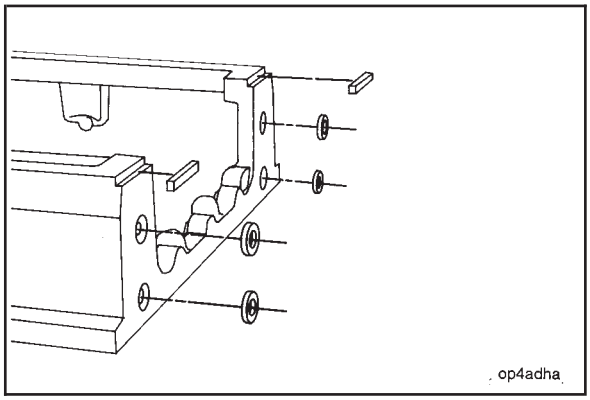
Torque Value: 11 N•m [95 in-lb]



NOTE: Use a contact adhesive such as 3M Spray 77 or 3M 4693 to hold the bolt seals in position.

Install the four bolt seals on the oil pan adapter.

The two rectangular seals have an adhesive on one side. Remove the protective paper strips from the seals. Install the seals on the oil pan adapter.

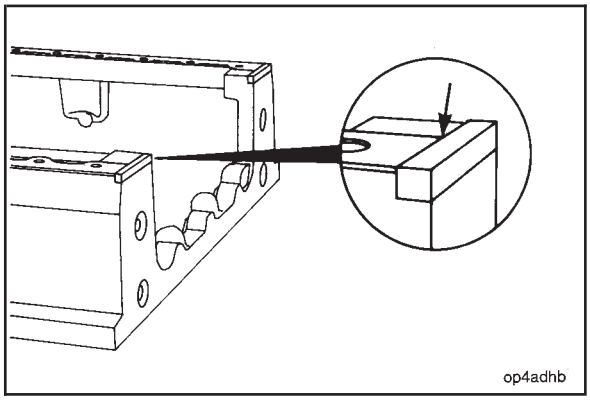


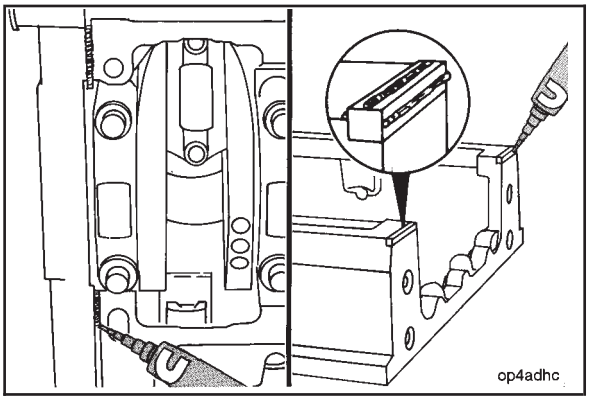
CAUTION

Gasket cement will prevent the gasket from sealing properly.

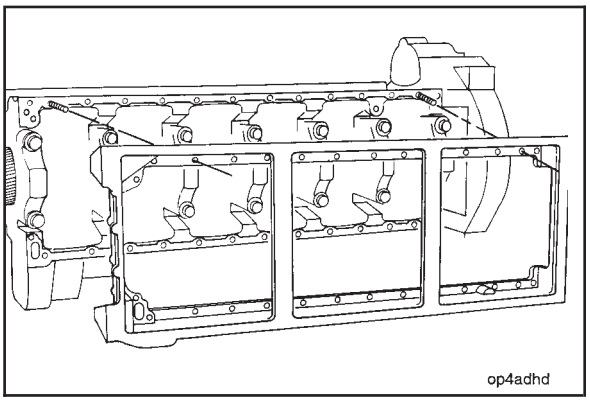
NOTE: Use a contact adhesive such as 3M Spray 77 or 3M 4693 to hold the gasket in position.

Install the gasket. Make sure the gasket touches the rectangular seals.





Use Cummins sealant, Part No.3823494, or equivalent. Apply the sealant as shown.

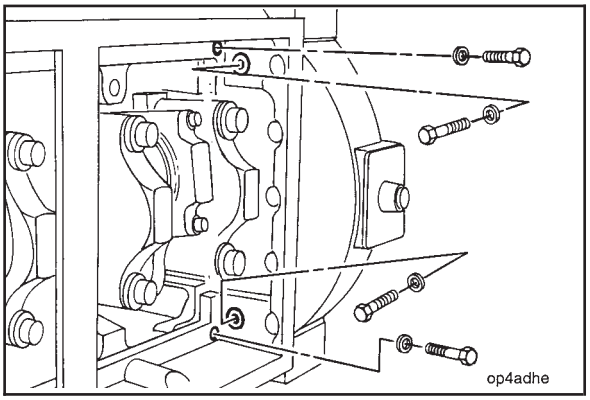


⚠ CAUTION ⚠

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

NOTE: Be sure the seals remain in position when the adapter is installed.

Lift the adapter up against the block surface, and then move it back against the flywheel housing. Hand tighten four capscrews to hold the adapter in position.

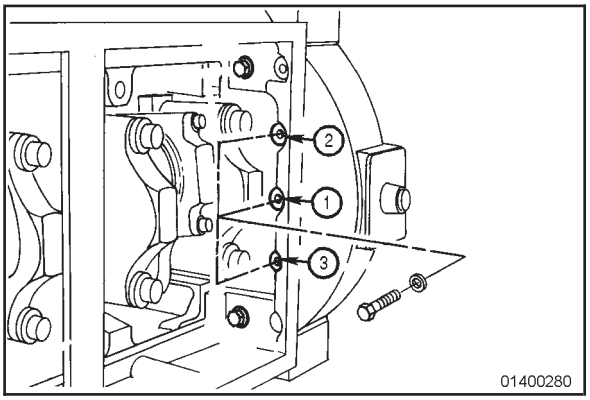


NOTE: The four capscrews shown **must** be tightened alternately and evenly to be sure the adapter is pulled evenly to the block and flywheel housing.

Install the four washers and capscrews as shown. Push the adapter towards the block and flywheel housing while tightening the capscrews.

Use the following steps while tightening the oil pan adapter capscrews.

Torque Value:	Step 1	15 N•m	[10 ft-lb]
	2	25 N•m	[20 ft-lb]
	3	40 N•m	[30 ft-lb]
	4	45 N•m	[35 ft-lb]



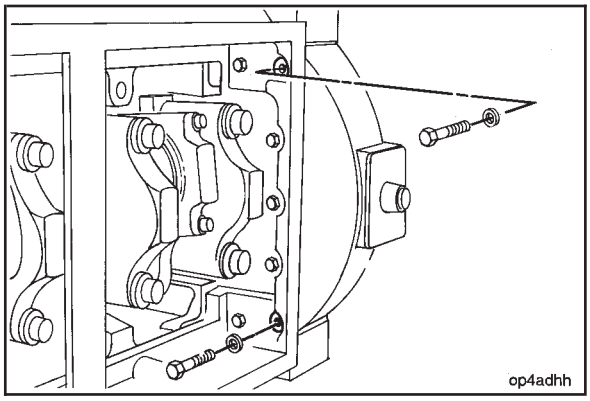
Install the three capscrews located in the center of the flywheel housing and tighten them in the sequence shown. Use the steps and torque values below when tightening the capscrews.

Torque Value:	Step 1	25 N•m	[20 ft-lb]
	2	40 N•m	[30 ft-lb]
	3	45 N•m	[35 ft-lb]

Install the two [7/16-inch] washers and capscrews shown.

Tighten the capscrews.

Torque Value: 65 N•m [50 ft-lb]



NOTE: Capscrews No. 24 through 28 thread into the front cover on engines.

Install capscrews 24 through 28.

Install the remaining [3/8-inch] washers and capscrews (1 through 23).

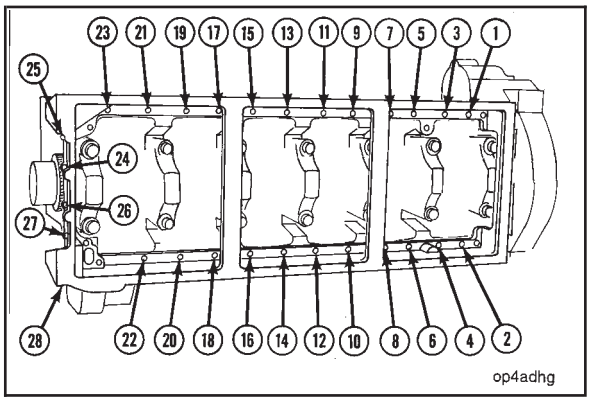
Tighten all the capscrews that thread into the block.

Torque Value:

Capscrews 1 – 23	60 N•m	[45 ft-lb]

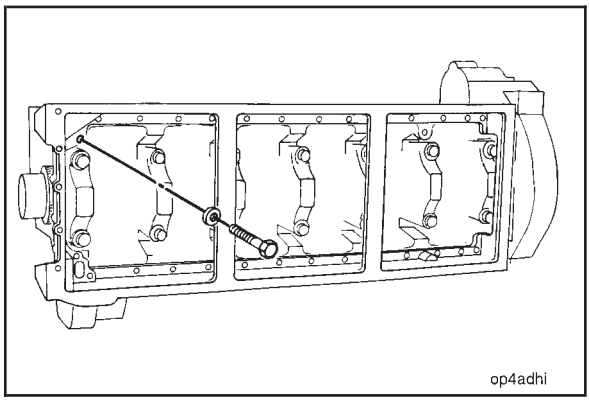
Torque Value:

Capscrews 24 – 28	45 N•m	[35 ft-lb]

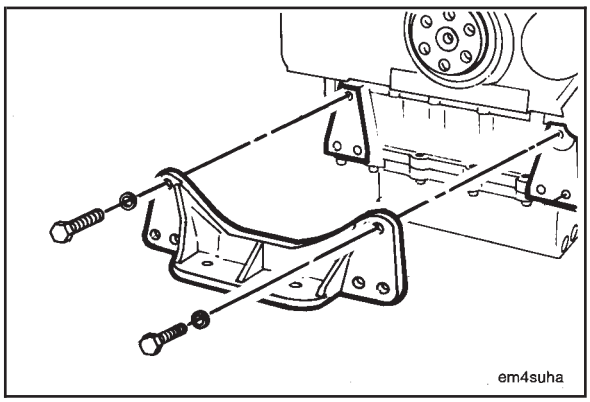


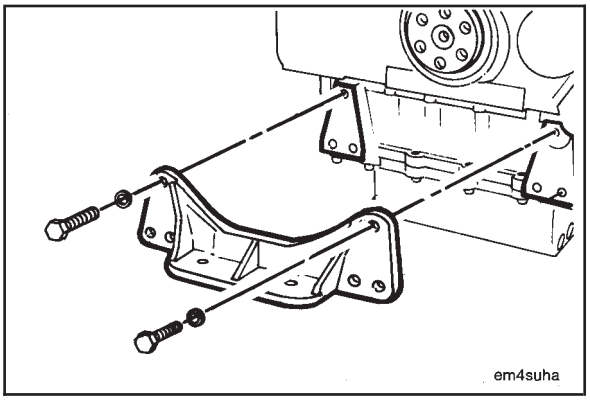
Install the [9/16-inch] washer and capscrew. Tighten the capscrew.

Torque Value: 150 N•m [110 ft-lb]



Install the front engine support bracket.



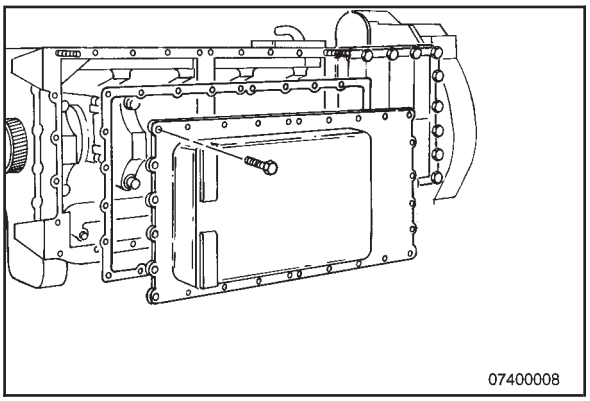


⚠ CAUTION ⚠

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

Install the support, washers, and capscrews. Tighten the capscrews.

Torque Value: 195 N•m [145 ft-lb]

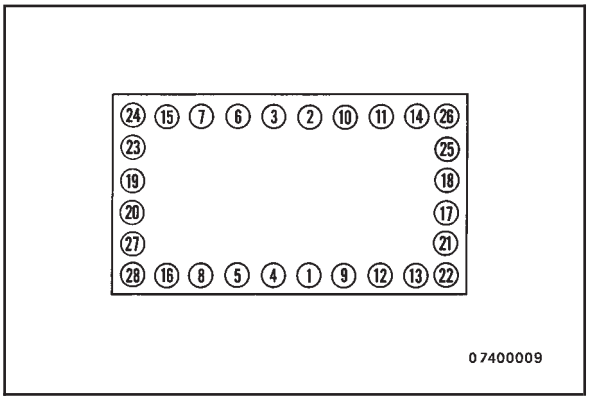


⚠ CAUTION ⚠

Gasket cement will prevent the gasket from sealing properly.

NOTE: Use a contact adhesive such as 3M Spray 77 or 3M 4693 to hold the gasket in position.

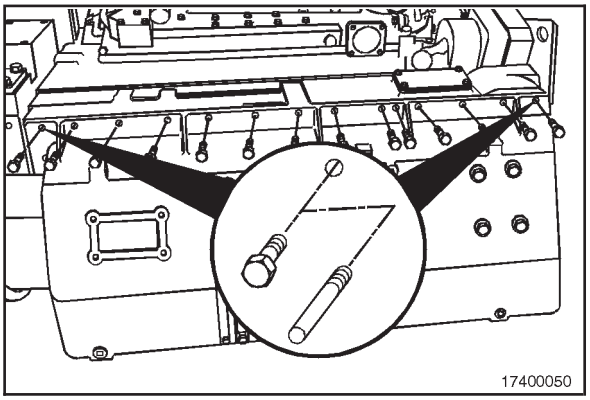
Install the gaskets and oil pan.



Use the sequence shown to install the capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Rail Applications

Install two 3/8 - 16 guide studs in the top row of capscrew holes.

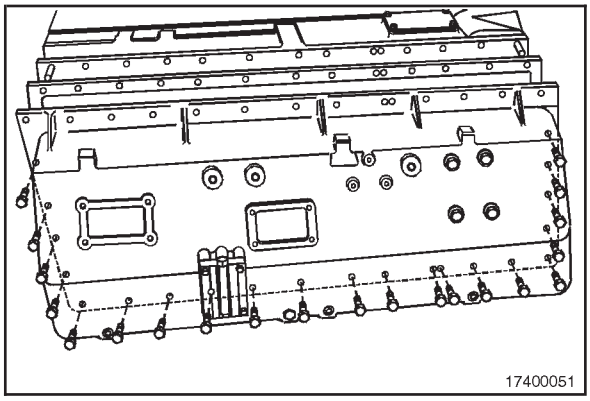
Rail Applications

⚠ CAUTION ⚠

Gasket cement will prevent the gasket from sealing properly.

NOTE: Use a contact adhesive such as 3M Spray 77 or 3M 4693 to hold the gasket in position.

Install the gasket and lubricating oil pan.

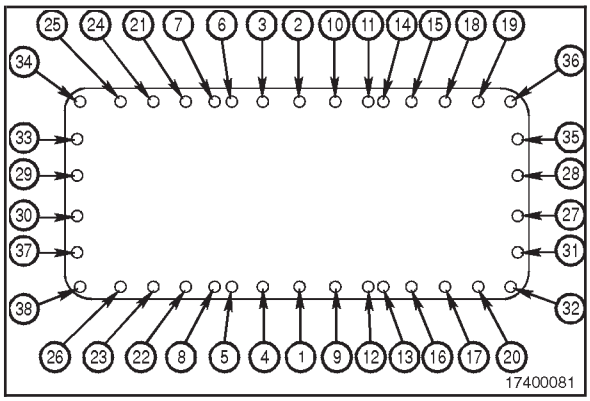


Rail Applications

Use the sequence shown to install the 38 capscrews.

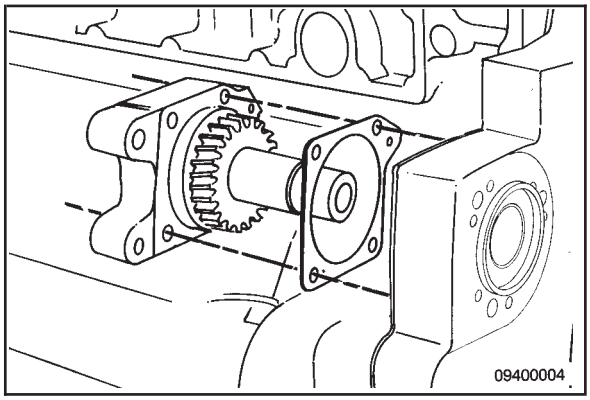
Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]

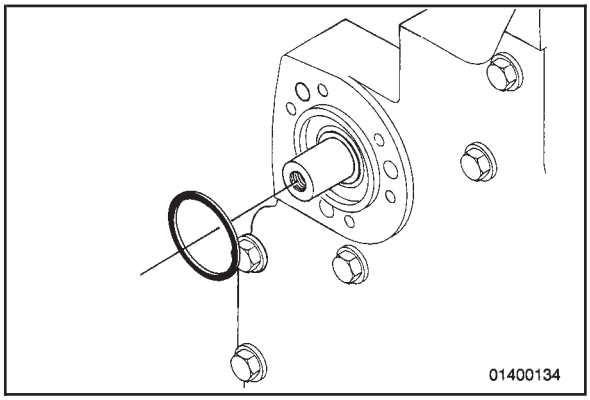


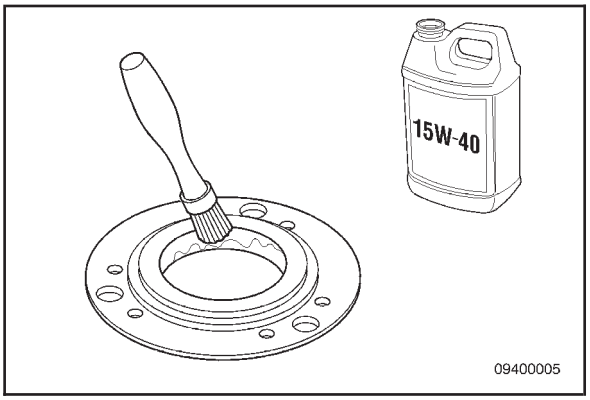
Install the gasket. Install the water pump drive assembly.

The drive will be secured in position by the stud.



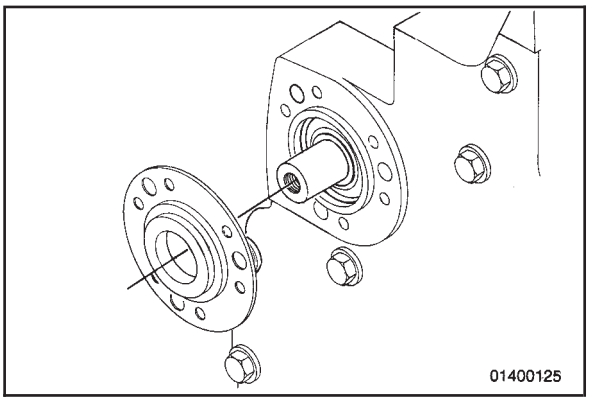
Install the o-ring in the groove in the gear cover.



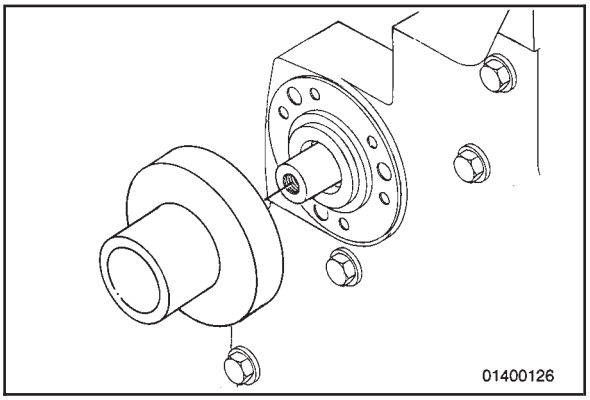


To aid in seal installation, use a small nonmetallic bristle brush to apply a thin film of clean SAE 15W-40 oil to the inside diameter of the seal.

NOTE: Do **not** allow oil to come in contact with other areas of the seal.

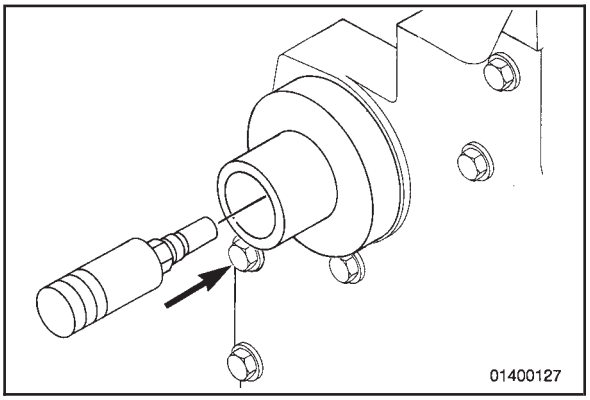


Install the seal on the alternator drive shaft.



Use the seal installation tool that is supplied with the service seal to push the seal on the alternator drive shaft.

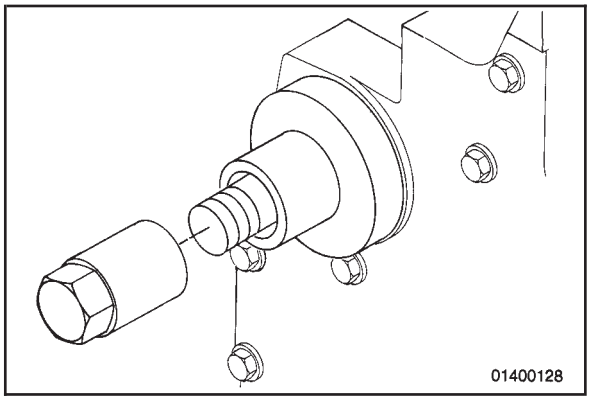
Put the installation tool against the seal.



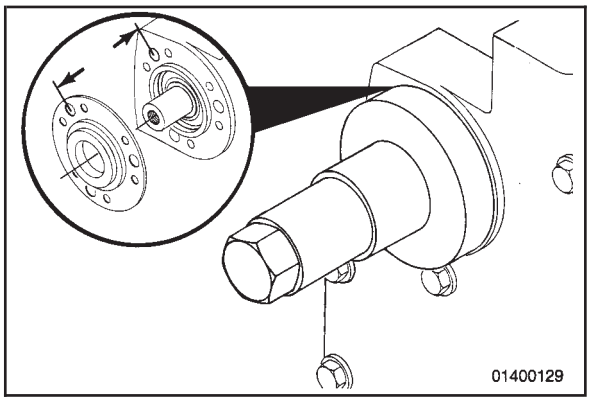
Use the pulley installation tool, Part No. 3376426, to push the seal on the alternator drive shaft.

Position the pulley installer on the accessory drive shaft.

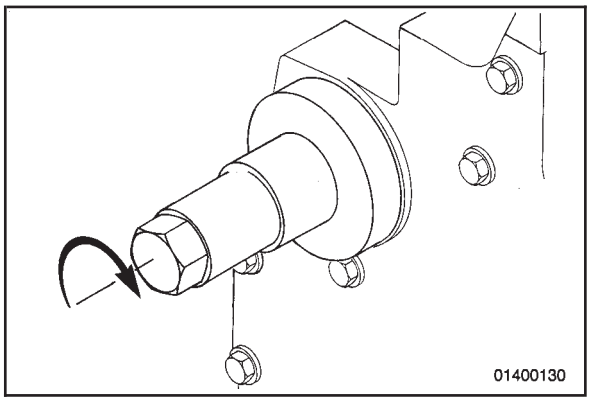
Put the pulley installation housing on the pulley installer.



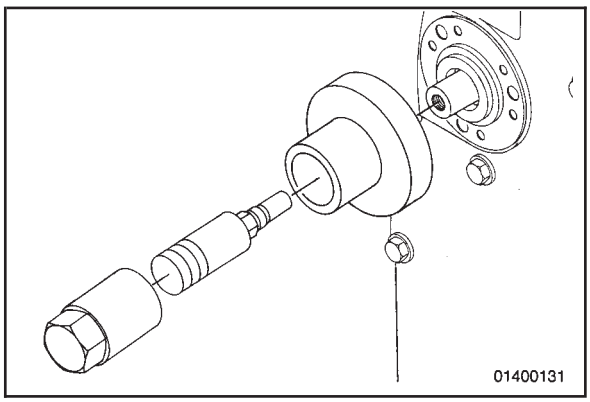
Align the three clinch nuts on the back of the seal carrier flange with the three counterbores in the gear cover seal mounting surface.

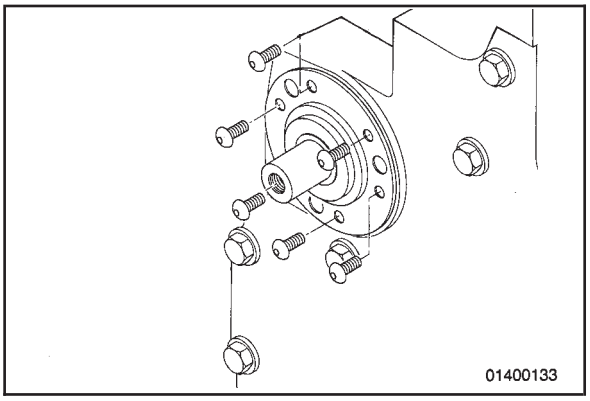


Use the tool to push the seal on the shaft until the seal carrier flange contacts the gear cover.



Remove the pulley installation tool housing, seal installation tool, and pulley installer.

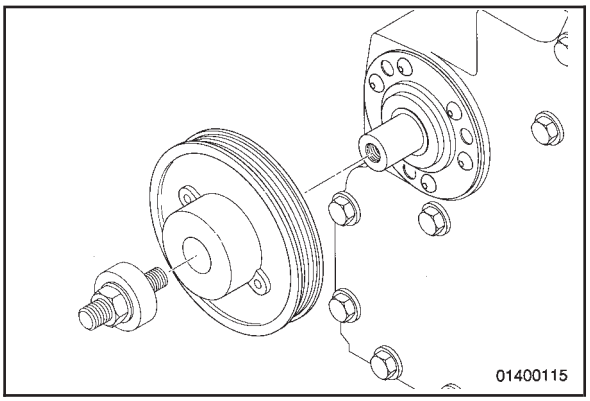




Install the six, button head hex socket capscrews.

Tighten the capscrews alternately and evenly.

Torque Value: 11 N•m [96 in-lb]



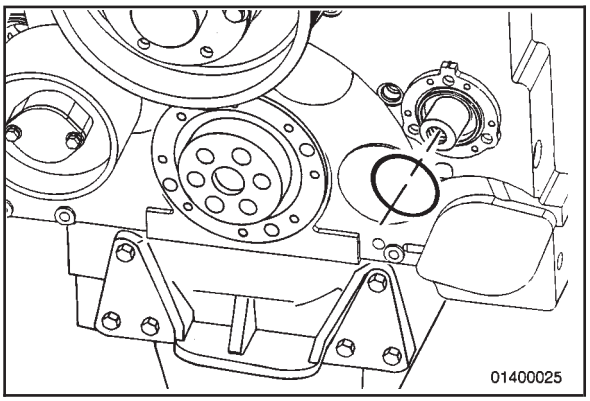
⚠ CAUTION ⚠

Do not use a hammer to drive the pulley into position. The thrust washers will be damaged.

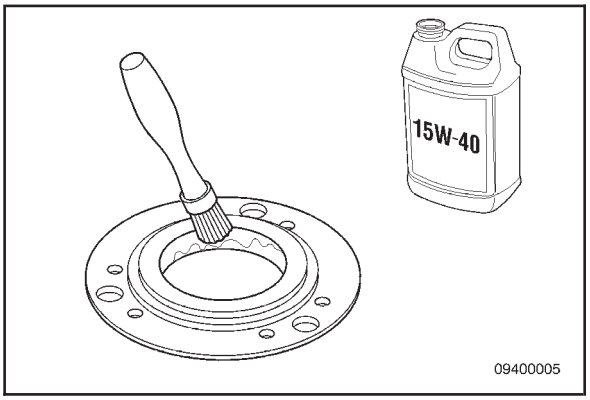
Use the pulley installation kit, Part No. 3376326, or equivalent. Install the correct adapter in the pusher.

Install the pulley on the shaft. The pulley **must** touch the step on the shaft.

Remove the tool and adapter.



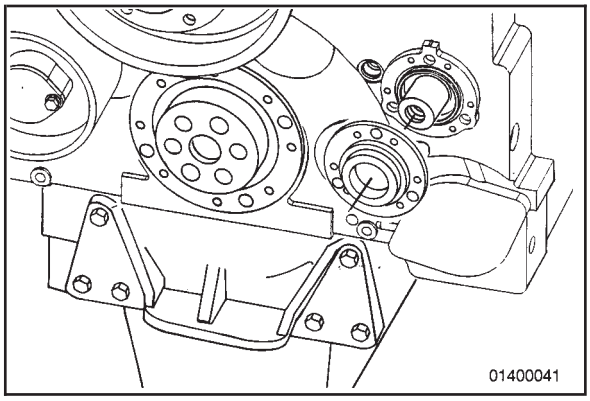
Install the o-ring in the groove in the gear cover.



To aid in seal installation, use a small nonmetallic bristle brush to apply a thin film of clean SAE 15W-40 oil to the inside diameter of the seal case.

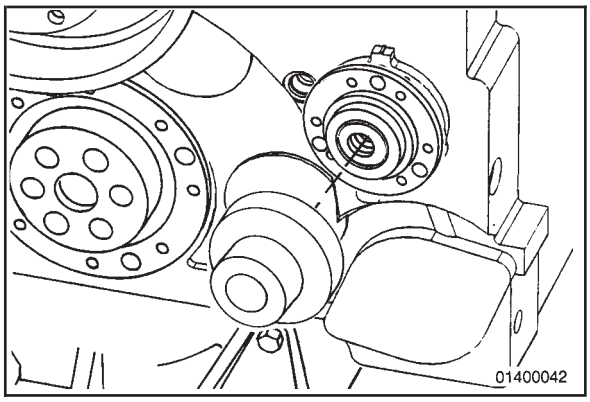
NOTE: Do **not** allow oil to come in contact with other areas of the seal.

Install the seal on the accessory drive shaft.



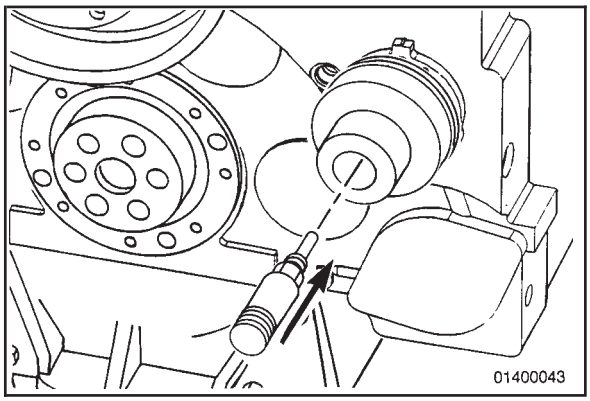
Use the seal installation tool that is supplied with the service seal to push the seal on the accessory drive shaft.

Put the installation tool against the seal.

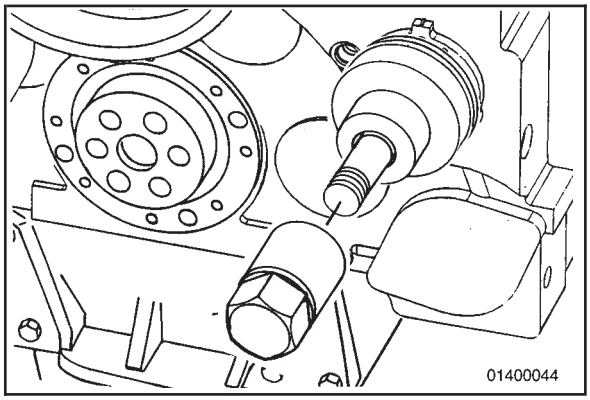


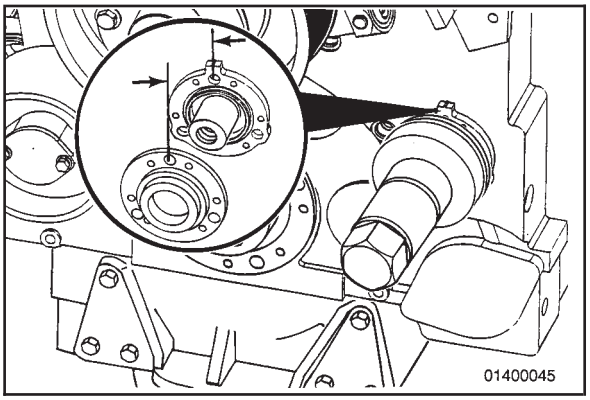
Use the pulley installation tool, Part No. 3376426, to push the seal on the accessory drive shaft.

Position the pulley installer on the accessory drive shaft.

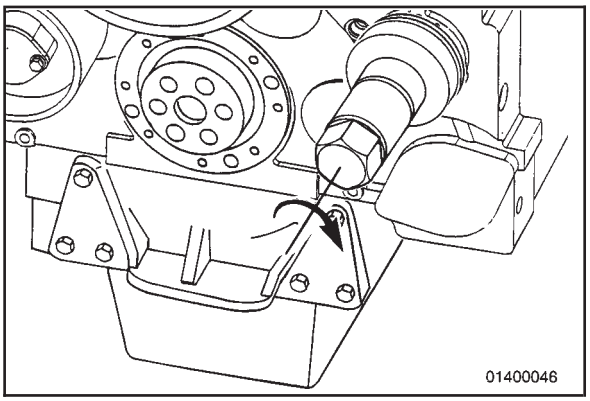


Put the pulley installation housing on the pulley installer.

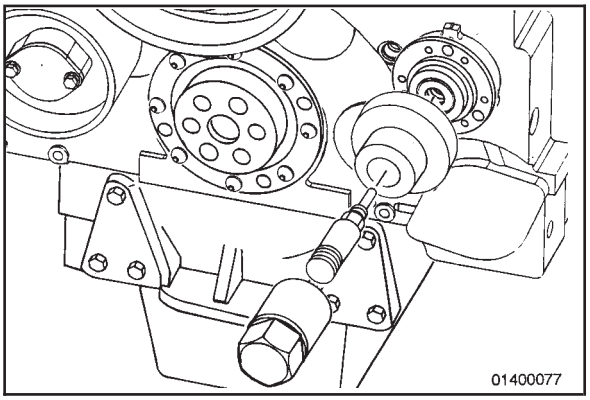




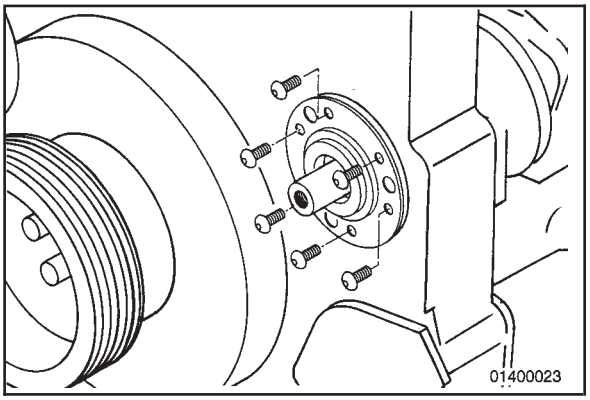
Align the three clinch nuts on the back of the seal carrier flange with the three counterbores in the gear cover seal mounting surface.



Use the tool to push the seal on the shaft until the seal carrier flange contacts the gear cover.



Remove the pulley installation tool housing, seal installation tool, and pulley installer.

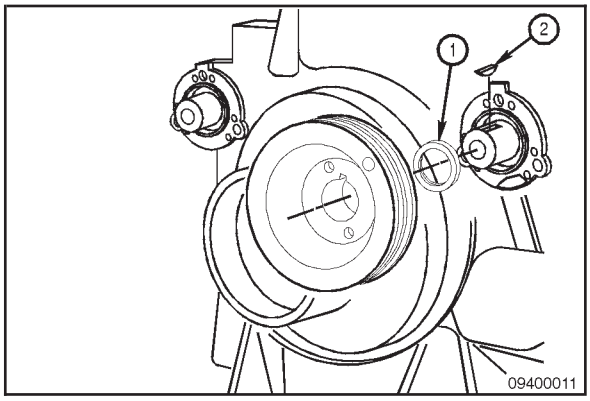


Install the six button head hex socket capscrews. Tighten the capscrews alternately and evenly.

Torque Value: 11 N•m [96 in-lb]

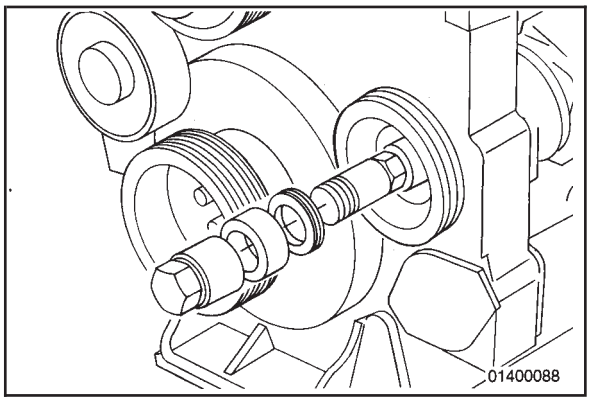
Install the keyway seal.

Install the woodruf key into accessory drive shaft.



NOTE: Keyway seal **must** be installed prior to installation of keyway and accessory drive pulley.

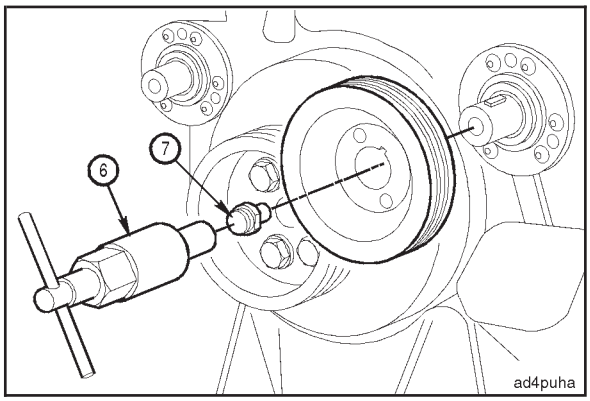
Install the accessory drive pulley.



⚠ CAUTION ⚠

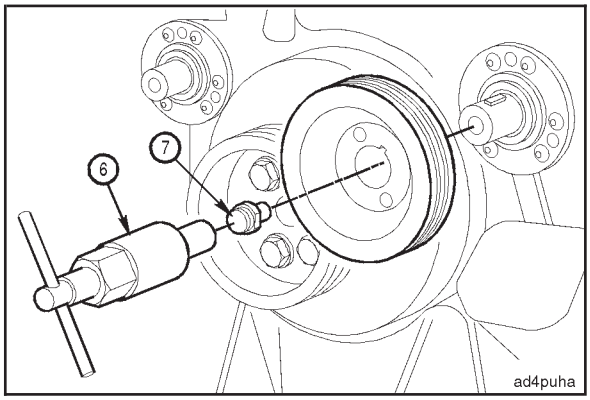
Do not use a hammer to drive the pulley into position. Damage to the thrust bearing will result.

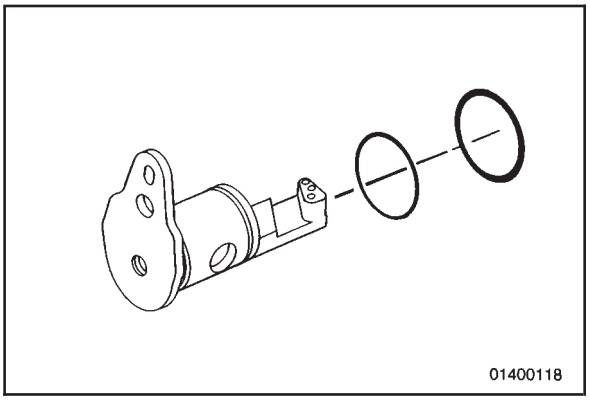
Use a pulley installation tool kit, Part No. 3376326. Insert the appropriate adapter (7) in the pusher.



Lubricate the shaft O.D. and the pulley I.D. with engine oil.

Align the keyway in the pulley with the key in the shaft. Use the tool to push the pulley on the shaft until it touches the step on the shaft.





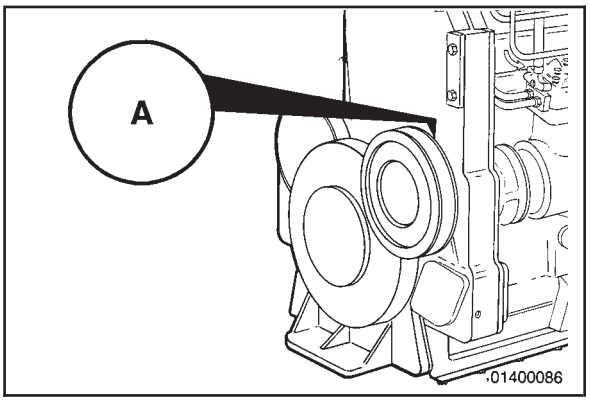
Use vegetable oil to lubricate the new o-ring. Do **not** soak the new o-ring in engine oil.

CAUTION

Use care when handling the piston cooling nozzle. Any damage to the piston cooling nozzle can result in major engine damage.

Install the o-ring in the groove of the piston cooling nozzle that is the **least** distance to the flange.

Install the piston ring type (steel) seal ring in the groove that is the **most distance** from the flange.

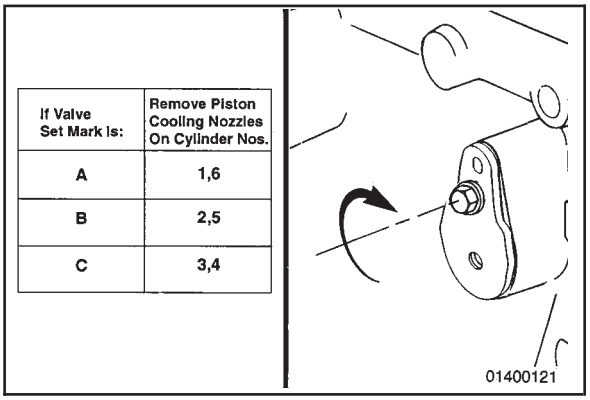


Align one of the valve set marks with the mark cast in the accessory drive seal boss.

If Valve Set Mark Is:	Remove Piston Cooling Nozzles On Cylinder Nos.
A	1,6
B	2,5
C	3,4

01400064

Refer to the sequence chart illustrated to identify the two piston cooling nozzles that can be installed.



CAUTION

Do not use the capscrew to pull the nozzle into the cylinder block. Nozzles and o-ring damage or external oil leaks can result.

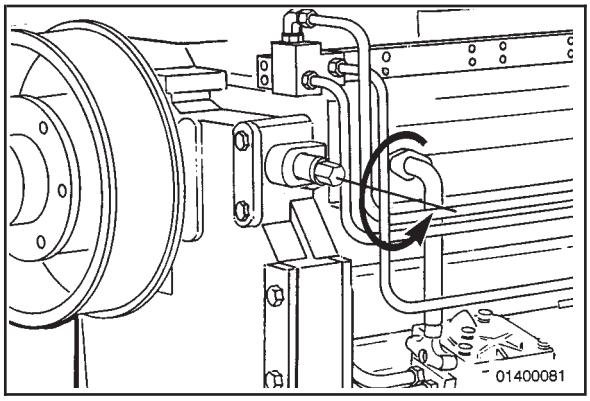
Install the two piston cooling nozzles. Use **only** your hand to push the nozzle into the bore until the flange touches the block.

Install and tighten the capscrew.

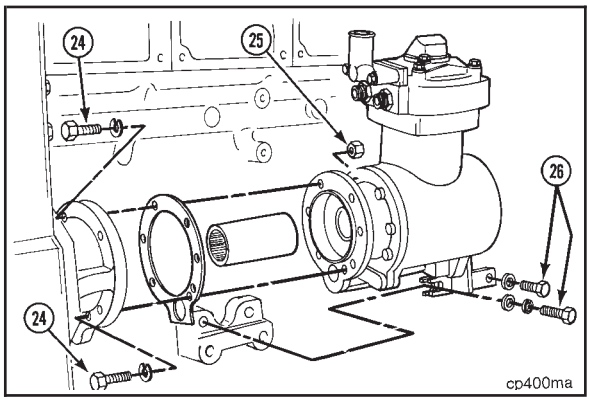
Torque Value 45 N•m [35 ft-lb]

Rotate the barring device and align the next valve set mark with the mark cast into the gear cover.

Repeat the process to install the remaining piston cooling nozzles.



Install the air compressor.



Single Cylinder

Install the splined coupling (1) on the accessory drive shaft.

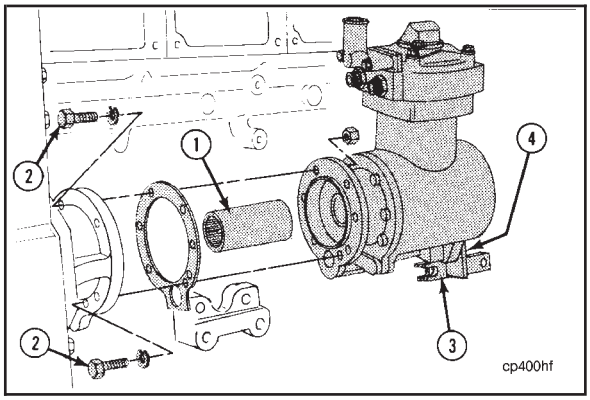
Be sure the gasket surfaces of the accessory drive and air compressor are clean and **not** damaged.

Use a new gasket to install the air compressor.

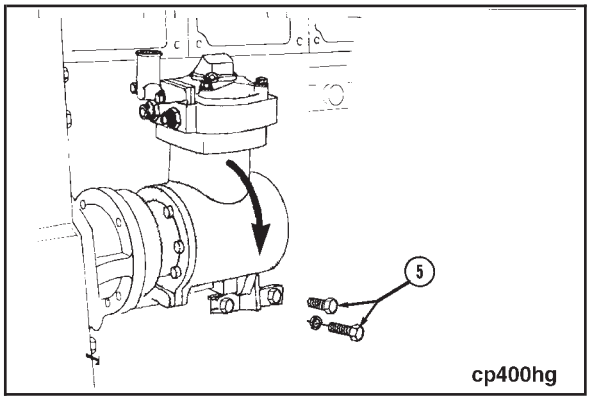
CAUTION

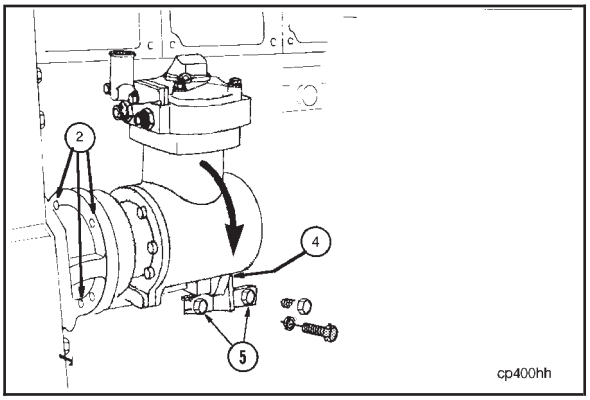
Do not tighten any capscrew until the support bracket is aligned.

Install the four capscrews and two nuts (2). The capscrews (4) **must** be loose.



Install the two capscrews (5) for the bracket. The support bracket **must** be flat against the block. Turn the compressor until the bracket is flat.





Tighten the compressor to the accessory drive capscrews (2).

Torque Value: 60 N•m [45 ft-lb]

Tighten the bracket to the block capscrews (5).

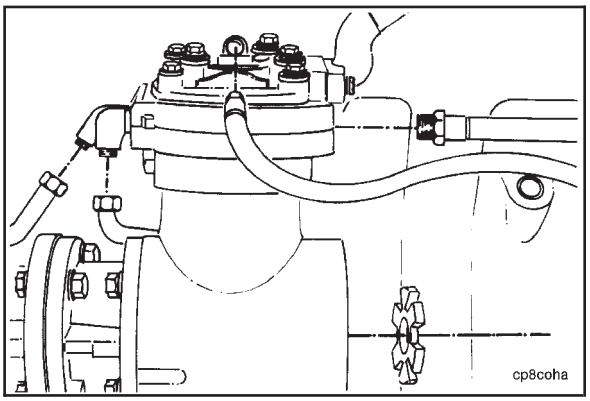
Torque Value: 45 N•m [35 ft-lb]

CAUTION

The bracket MUST be flat against the compressor.

Tighten the bracket to the compressor capscrew (4).

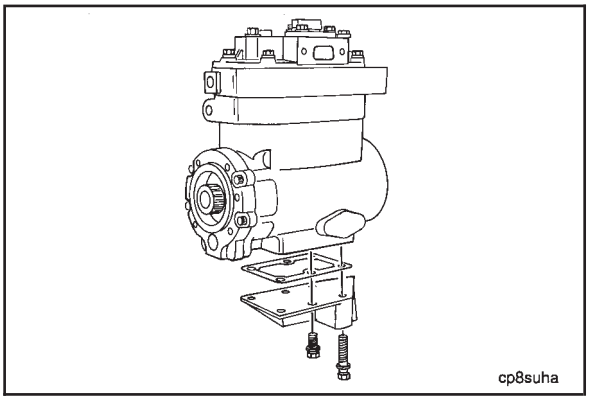
Torque Value: 45 N•m [35 ft-lb]



NOTE: If rubber grommets are used on the coolant lines, be sure they are installed carefully to prevent cuts or tears to the grommets which cause coolant leaks. When flexible tubing is used, make sure that it does **not** rub any other surface.

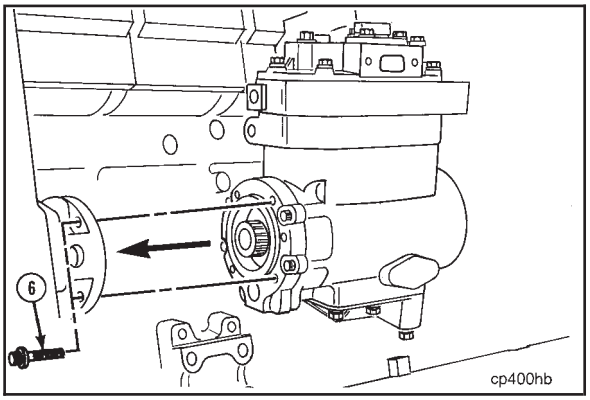
Install the coolant and air lines to the air compressor and tighten.

Install the fuel pump drive coupling on the air compressor.



Install the gasket and the cover plate (support bracket) on the compressor.

Do **not** tighten the six capscrews. The support **must** be adjusted.



NOTE: Do **not** install the splined coupling or the mounting gasket.

Install the compressor on the accessory drive.

Install the four capscrews (6). **Only** tighten the capscrews enough to pull the compressor to the accessory drive. The compressor **must** be turned to align the support bracket.

⚠ CAUTION ⚠

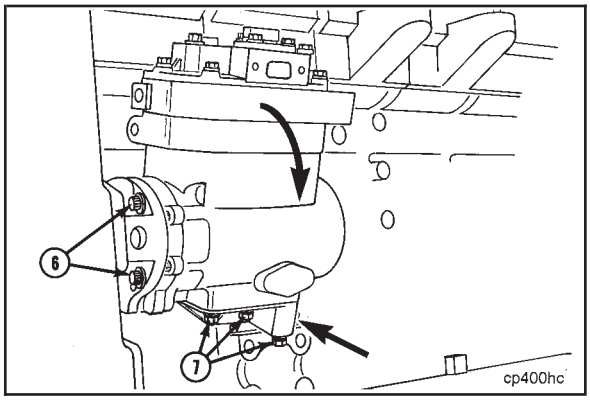
The support MUST be flat against the block. Rotate the compressor until the support is aligned properly against the block. If the support in NOT flat, the compressor and/or accessory drive will fail.

Tighten the four capscrews (6).

Torque Value: 60 N•m [45 ft-lb]

The bracket must remain flat against the block. Tighten the support capscrews (7) that are accessible.

Torque Value: 45 N•m [35 ft-lb]

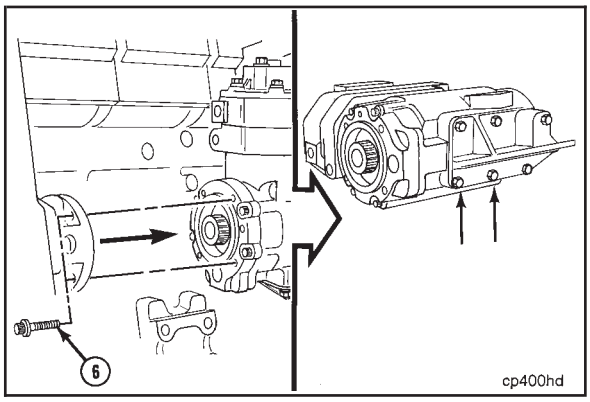


Remove the four capscrews (6).

Remove the compressor.

Tighten the two remaining support to the compressor capscrews.

Torque Value: 45 N•m [35 ft-lb]



Install the splined coupling (1), the gasket, and the compressor.

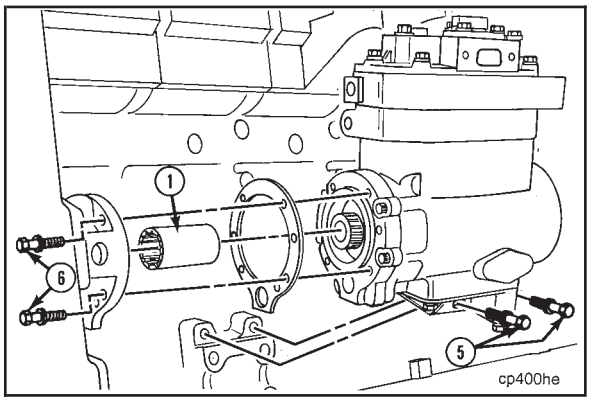
⚠ CAUTION ⚠

The support MUST be flat against the block. Rotate the compressor until the support is aligned properly against the block. If the support is NOT flat, the compressor and/or accessory will fail.

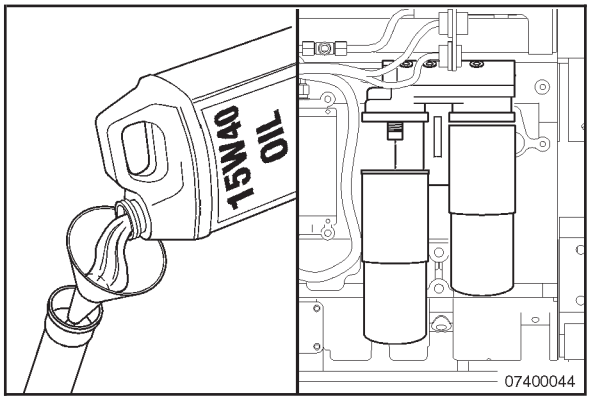
Install the four capscrews (6) and two capscrews (5).

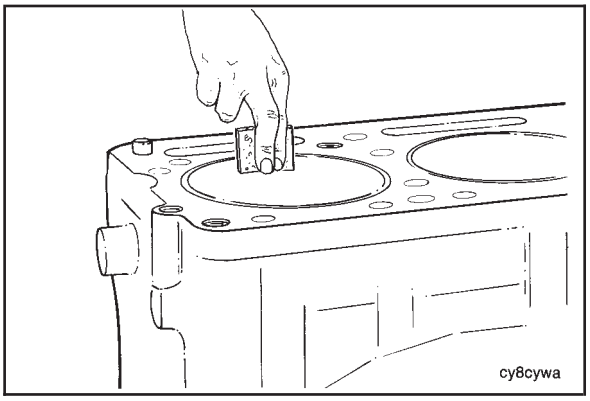
Torque Value:

Capscrew (6)	60 N•m	[54 ft-lb]
Capscrew (5)	45 N•m	[35 ft-lb]



Install the lubricating oil filters.



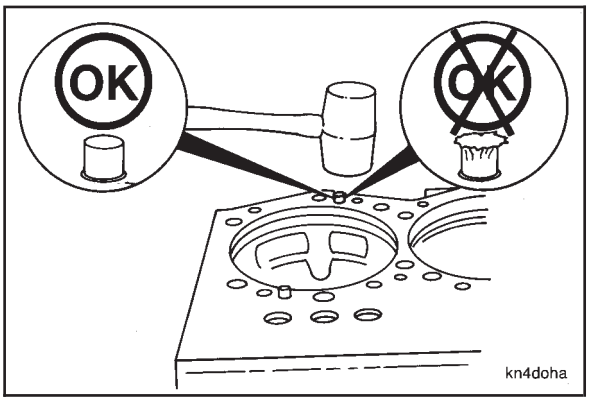


Clean the top of the cylinder block and the cylinder liners.

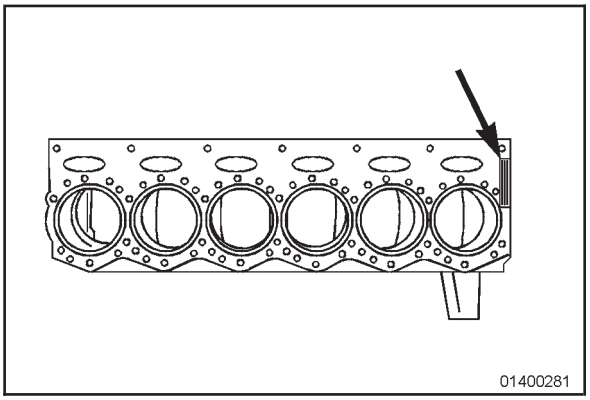
Use a scraper or a fibrous abrasive pad such as Scotch-Brite 7477, or equivalent, and solvent. Clean the top deck surface of the block. Do **not** allow any dirt into the cylinder. The surface **must** be free of dirt, oil, and gasket material, but does **not** have to look like new metal.

NOTE: Check the top surface of the block for wear. If fretting damage is present in an area where a head gasket seal ring or a grommet makes contact, the surface must be repaired. Refer to the Alternative Repair Manual.

NOTE: Fretting damage in any other area is acceptable **only** if it does not change the protrusion measurement of the counterbore or liner.

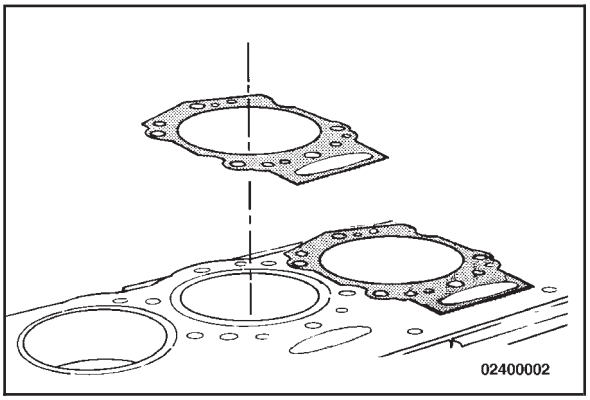


Visually inspect the groove pins for damage. Use the ST-1134 dowel pin extractor, or equivalent to remove the pins.



Inspect the cylinder block to determine if an oversize or a standard size head gasket is required.

NOTE: An oversize head gasket may be required on blocks that have had material removed from the top surface of the block. Check the block for markings indicating an oversized gasket is required.



NOTE: The word TOP stamped on top of the head gasket **must** be visible after the gasket is installed.

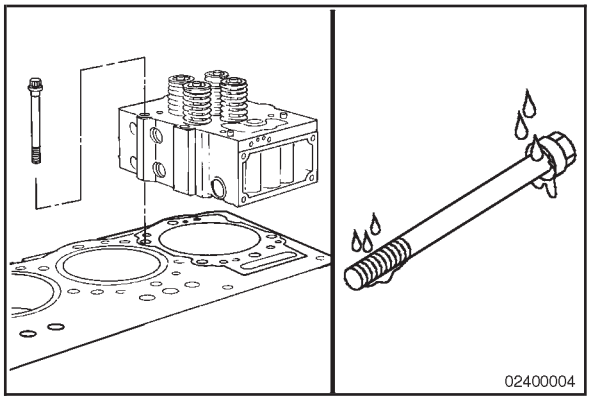
Install the gasket.

Install the cylinder head. It **must** slide easily over the groove pins.

Lubricate the capscrew head flange with SAE EP 140W oil.

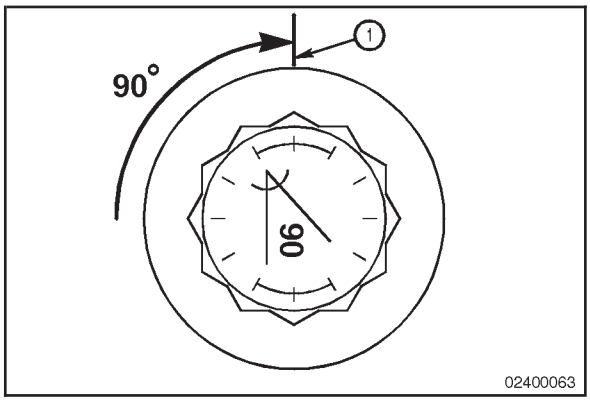
Lubricate the capscrew threads with clean engine oil. Allow excess oil to drip off of the capscrews before installing in the block.

Install the capscrews.

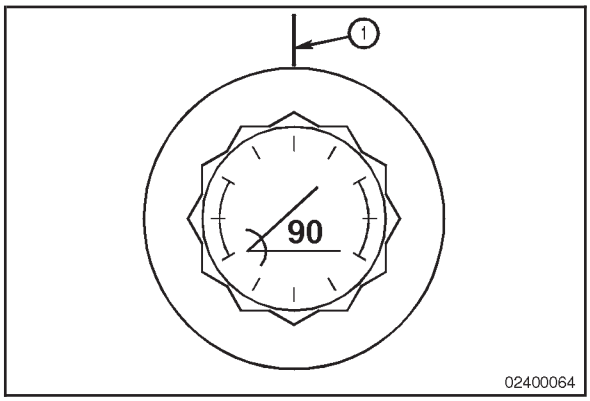


NOTE: When using torque plus angle, the tolerance on the 90 degree angle of rotation is one to two flats (90 degrees ± 30 degrees). If the capscrew is rotated beyond two flats, do **not** loosen the capscrew. The clamp load is still acceptable, however, rotating the capscrew beyond two flats causes additional stretch and reduces the life of the capscrew. With proper torquing, the capscrew can typically be reused for the life of the engine.

After all capscrews on one head have been torqued to 300 N•m [220 ft-lb], they **must** be rotated in the tightening direction an additional 90 degrees. Rotate the capscrew until the mark on the cylinder head(1) is between the next two marks joined by an arc (**more** than one flat and **less** than two flats).

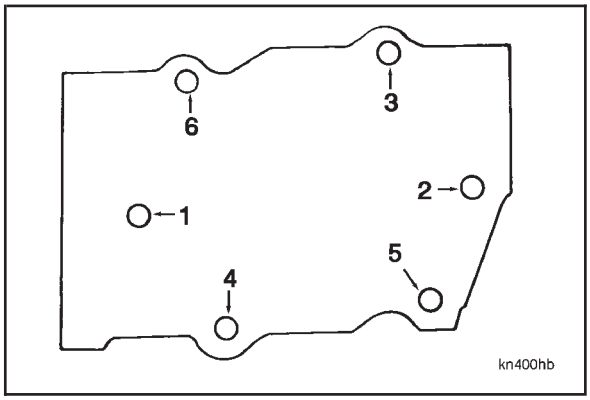


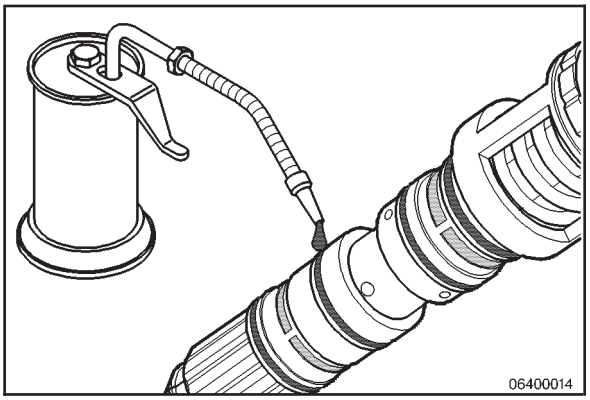
The markings on the head of the flange head capscrews serve as an aid during installation. After torquing the capscrew to 300 N•m [220 ft-lb], mark the cylinder head(1) adjacent to one of the two single marks on the capscrew head.



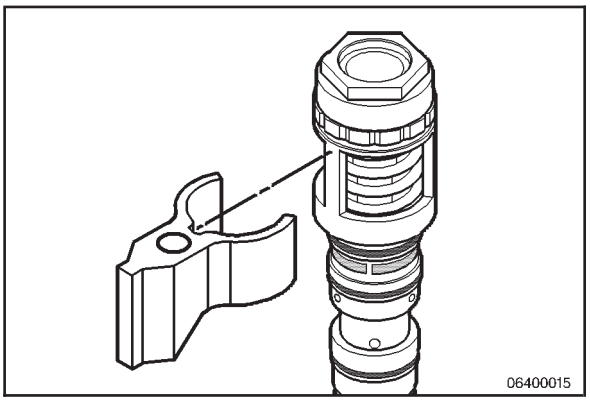
Tighten the capscrews using the following steps and in the sequence shown.

Torque Value: Step 1 68 N•m [50 ft-lb]
2 205 N•m [150 ft-lb]
3 300 N•m [220 ft-lb]
4 Rotate 90 Degrees

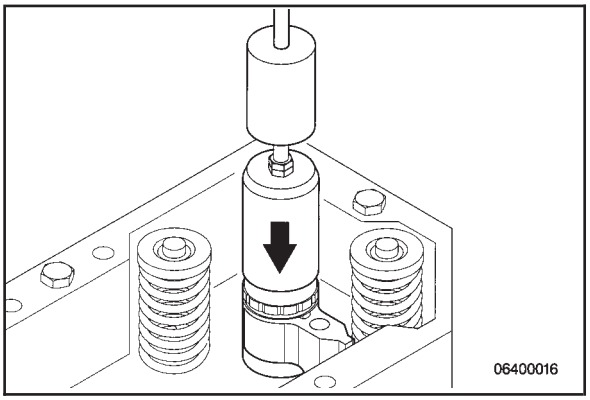




Use clean, 15W-40 oil. Lubricate the o-rings.



Install the hold-down clamp on the side of the injector.

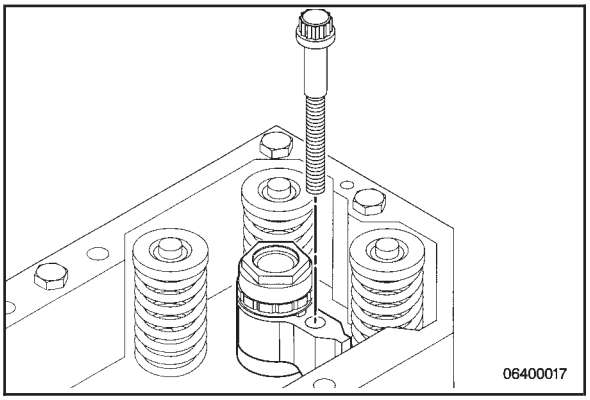


Install the injector and hold-down clamp in the cylinder head.

Use injector installation tool, Part No. 3824830, it set the injector in the bore.

The slide hammer will make a dull sound when the injector is seated properly.

NOTE: If the injector installation tool, Part No. 3824830, is **not** available, use a 40 mm (1 9/16-inch) socket with an extension and a rubber mallet to install the injector.



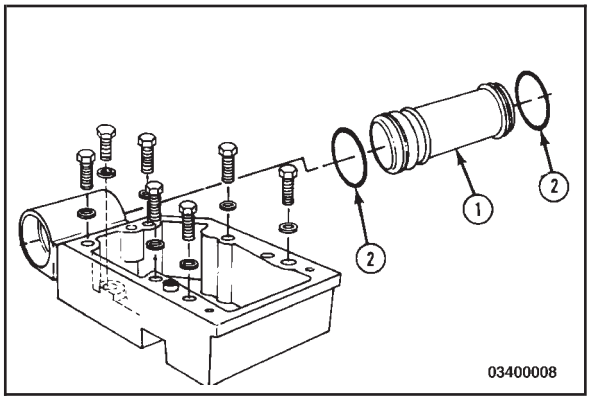
Use clean, engine oil. Lubricate the injector hold-down capscrew.

Install the injector hold-down capscrew.

Torque Value: 54 N•m [40 ft-lb]

Use vegetable oil. Lubricate the o-rings (2). Install the o-rings.

Install the water transfer tube (1).

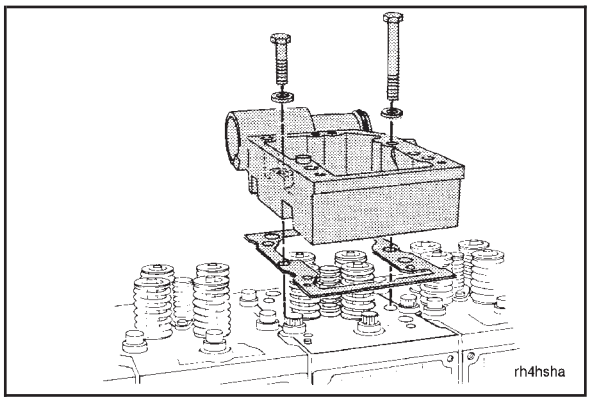


NOTE: The gasket and housing **must** be aligned correctly with the dowel pins.

Install the gasket and the housing.

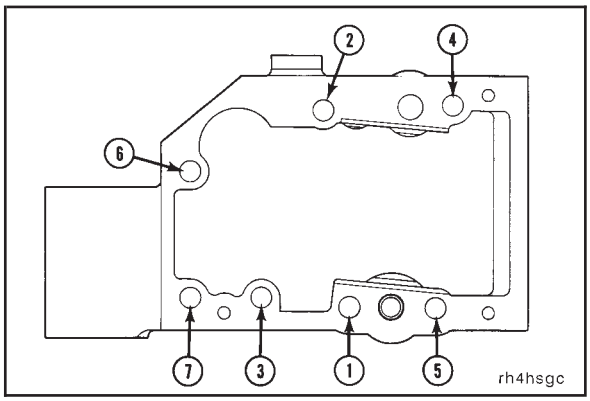
Install the seven capscrews.

Torque Value: 95 N•m [70 ft-lb]



Use the sequence shown to tighten the capscrews.

Torque Value: 95 N•m [70 ft-lb]



NOTE: The push rods **must** be seated correctly in the cam followers.

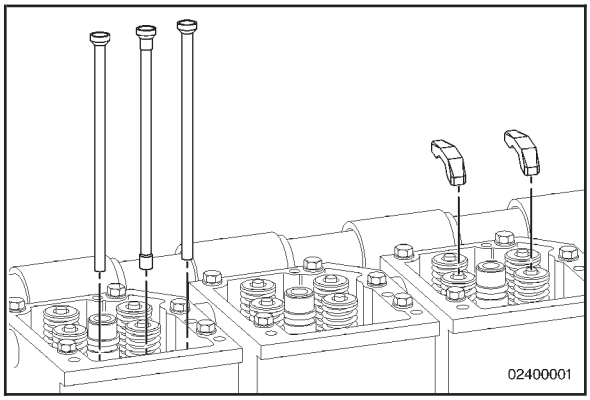
NOTE: The injector push rods are thicker in the middle. The valve push rods are the same for both intake and exhaust.

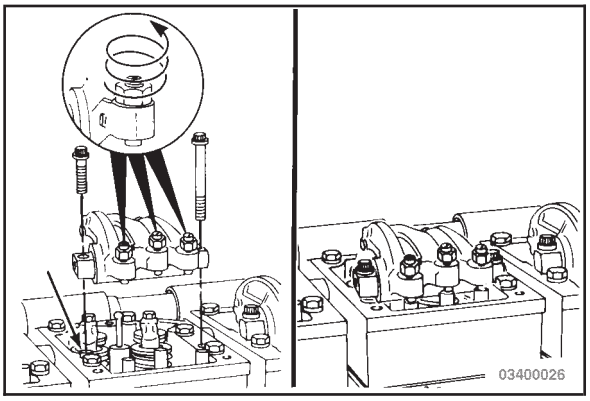
Use engine oil. Lubricate the sockets in the cam followers.

Install the push rods.

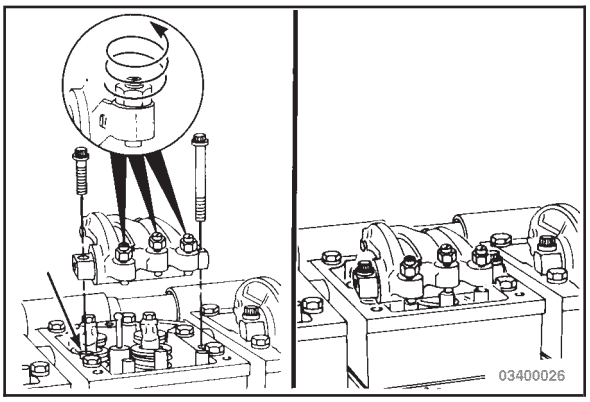
Lubricate the crosshead pockets with clean engine oil.

Install the valve crossheads.





Install the rocker levers.



NOTE: Be sure the ring dowel that aligns the rocker shaft is installed in the housing.

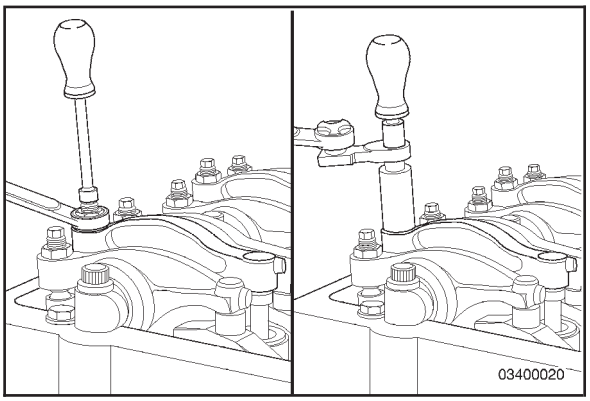
NOTE: Be sure the adjusting screws are loose.

Position the rocker lever assembly on the housing. Install the capscrews 2 or 3 revolutions.

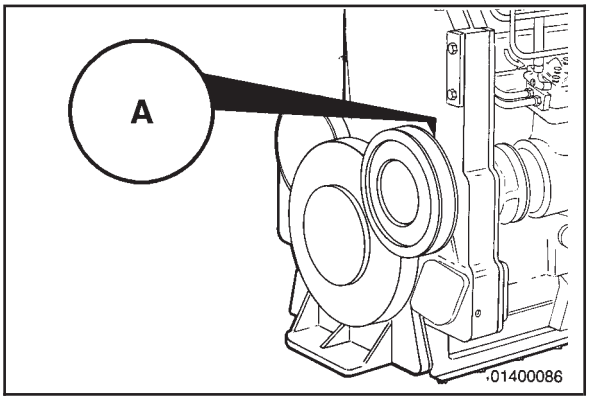
Align the push rod sockets with the adjusting screws.

Tighten the capscrews.

Torque Value: 225 N•m [165 ft-lb]



Adjust the valves and injectors.



NOTE: The barring device shaft turns approximately two revolutions before the engine begins to turn. The device will **not** turn the engine opposite the direction of normal rotation.

Push the shaft in and turn the barring device **counterclockwise** until the ''A'' mark on the pulley is aligned with the mark that is cast into the boss for the accessory drive seal on the front gear cover.

Determine the Cylinder in Position for Valve Set

The valves will be adjusted on the cylinder that has all the valves closed. Use the table to determine the cylinders for valve position.

If Valve Set Mark Is:	Check Valve Position On:
A	1,6
B	2,5
C	3,4

fi400uz

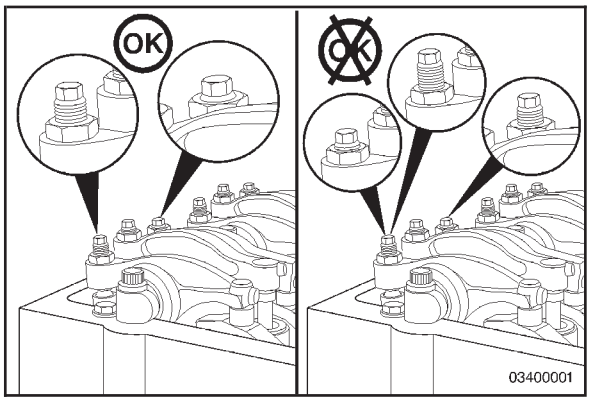
If the rocker lever assemblies have been removed, use this step to determine the cylinder to be set.

NOTE: All adjusting screws **must** be loose on all cylinders, and the push rod **must** remain in alignment.

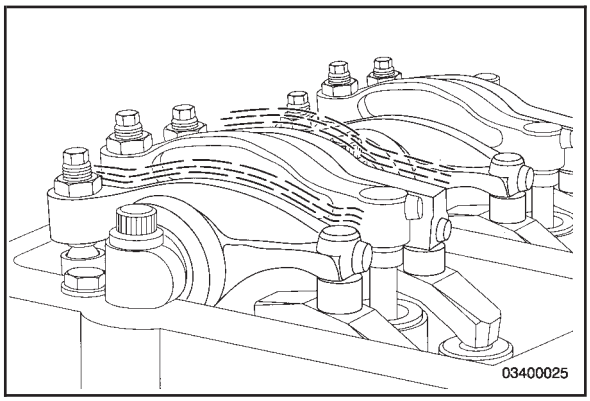
NOTE: Perform this step on both cylinders to be checked.

Hold both rocker levers against the crossheads. Turn the adjusting screws until they touch the push rods. Turn the lock nuts until they touch the levers.

NOTE: The push rods will be the same height above the top of the rocker lever housing on the cylinder ready for valve adjustment.



If the rocker levers have **not** been removed, wiggle the valve rocker levers on the two cylinders in question. Set the valves on the cylinder where both levers feel loose.

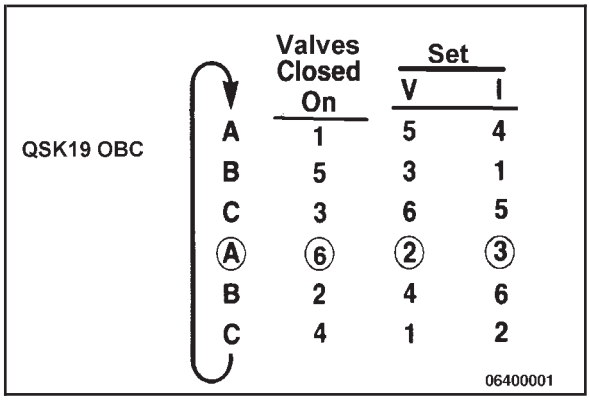


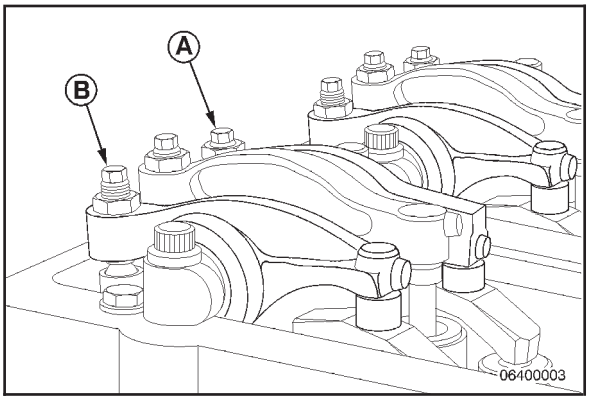
Use the chart to determine the injector that is ready to adjust.

NOTE: Adjustment can begin on any valve set mark.

In our example, assume the A mark is aligned and the push rod heights indicate that the valves on cylinder No. 6 are closed. The chart shows the valves on No. 2 are ready to adjust. The chart shows the injector on cylinder No. 3 is ready to adjust.

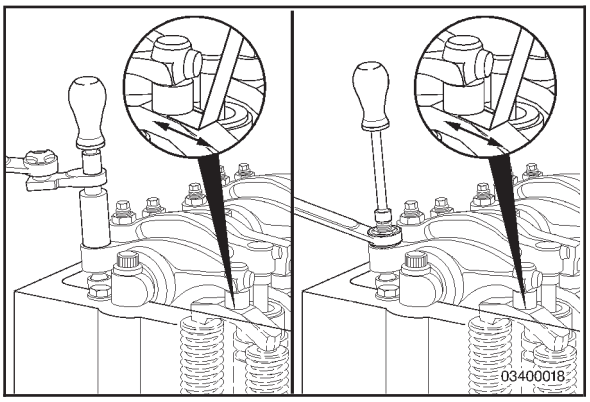
After the adjustment, bar the engine to the B set mark. Adjust the valves on cylinder No. 4 and adjust the injector on cylinder No. 6.





Valves – Setting

Valve Adjustment (Initial Set)			
Reference Point	mm		in
A	0.81	Exhaust	0.032
B	0.36	Intake	0.014

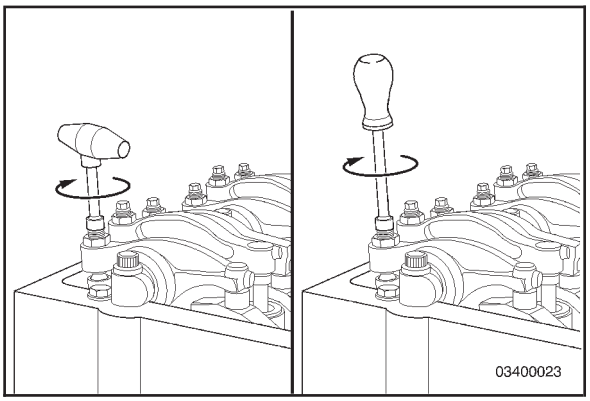


NOTE: To provide a consistent set, lubricate the adjusting screws prior to setting the valves.

NOTE: Be sure the crosshead is firmly in place on the valve stem tips.

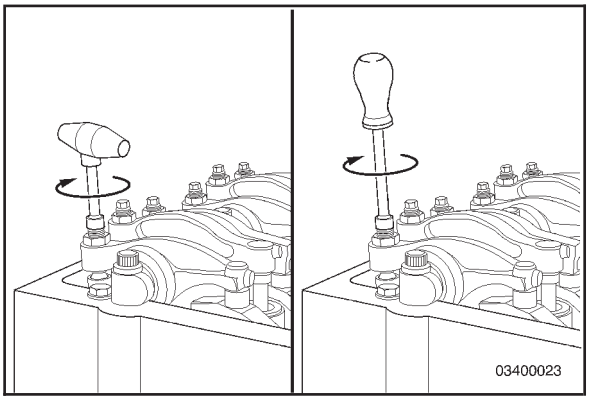
NOTE: Be sure the feeler gauge is under the center of the ball and socket, or the socket can rock or tip, resulting in an incorrect adjustment.

Select a feeler gauge for the correct valve lash specification. Use service tool Part No. 3824901. Insert the gauge (2) between the rocker lever socket and the crosshead.



Two different methods for establishing valve lash clearance are described below. Either method can be used. The torque wrench method has proven to be the most consistent.

- **Torque Wrench Method:** Use Part No. 3376592, Inch Pound Torque Wrench. Tighten the adjusting screw to 1 N•m [6 in-lb] torque.
- **Feel Method:** Use a nut driver and turn the adjusting screw **only** until the lever touches the feeler gauge.



Valve Set — Torque Wrench Method

Hold the torque wrench in a position that allows you to look in a direct line at the dial. This is to be sure that the dial will read accurately.

Be sure the parts are in alignment and squeeze the oil out of the valve and the injector train while tightening the adjusting screw.

After loosening the adjusting screw at least 1 revolution, tighten the adjusting screw again.

Torque Value: 1 N•m [9 in-lb]

NOTE: The feeler gauge **must** slide **backward** and **forward** with only a slight drag.

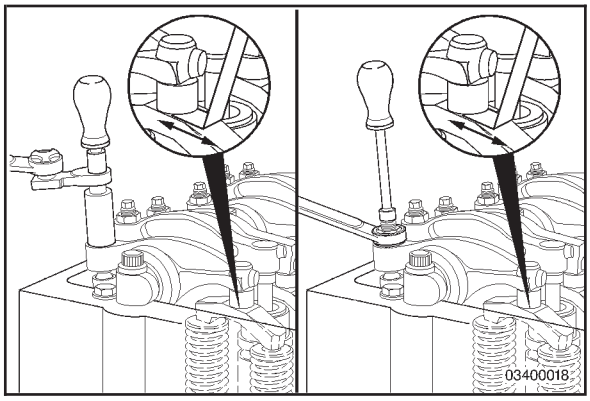
NOTE: The adjusting screw **must not** turn when the lock nut is tightened.

Torque Value:

With Torque Wrench Adapter, Part No. ST-669 (1)	45 N•m	[35 ft-lb]
Without Adapter	60 N•m	[45 ft-lb]

Attempt to insert a feeler gauge that is 0.03 mm [0.001 in] thicker. The valve lash is **not** correct when the thicker gauge will fit.

Repeat the adjustment process until the clearance is correct on both the intake and the exhaust valves.



Injectors — Setting

Use a dial-type torque wrench to tighten the injector rocker lever adjusting screw. If the screw chatters during setting, repair the screw and lever as required.

Hold the torque wrench in a position that allows you to look in a direct line at the dial. This is to be sure the dial will be read accurately.

Be sure the parts are in alignment and squeeze the oil out of the valve and injector train, while tightening the adjusting screw.

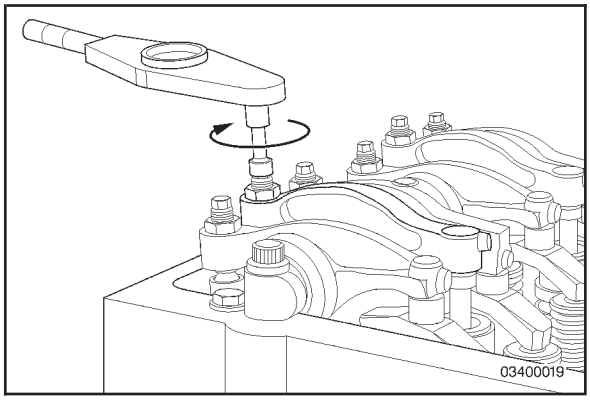
Torque Value: 20 N•m [175 in-lb]

Loosen the adjusting screw at least 1 revolution.

Tighten the adjusting screw again.

Torque Value: 19 N•m [165 in-lb]

NOTE: The torque wrench **must** be calibrated, have a resolution of 0.28 N•m [2.5 in-lb], and have a range of 17 to 23 N•m [150 to 200 in-lb]. Do **not** use a clicker-type torque wrench.



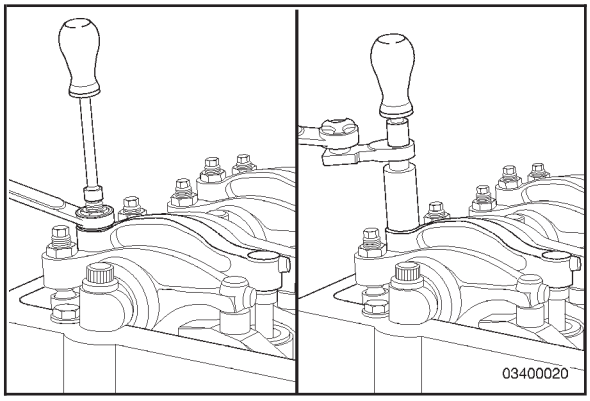
Hold the adjusting screw in this position. The adjusting screw **must not** turn when the lock nut is tightened.

Tighten the lock nut to the following values:

Torque Value:

With Torque Wrench Adapter, Part No. ST-669 (1)	45 N•m	[35 ft-lb]
Without Adapter	60 N•m	[45 ft-lb]

NOTE: To provide a constant set, lubricate the injector adjusting screw prior to setting the injectors.



1. Engine firing order 1-5-3-6-2-4
2. Cylinders are numbered from the front gear cover end of the engine.
3. Two crankshaft revolutions are required to adjust all of the valves and the injectors.
4. One pair of valves and one injector are adjusted at each pulley index mark before rotating the engine to the next index mark.
5. The valves and the injectors on the same cylinder are **not** adjusted at the same mark.
6. Each cylinder has three rocker levers. The lever nearest to the front of the engine is the exhaust lever.

The following chart is useful for recording values.

NOTE: Refer to Procedure 003–006, Overhead Set (OBC), for value and injector adjustment procedures.

Inspection Report for Valve Lash and Injector Torque

Work Sequence	Valves to be Set	Intake	Exhaust	Reset (Y/N)	Crosshead (OK/Reset)	Cylinder No.	Injector Torque	Reset (Y/N)
_____	A-5	_____	_____	_____	_____	4	_____	_____
_____	B-3	_____	_____	_____	_____	1	_____	_____
_____	C-6	_____	_____	_____	_____	5	_____	_____
_____	A-2	_____	_____	_____	_____	3	_____	_____
_____	B-4	_____	_____	_____	_____	6	_____	_____
_____	C-1	_____	_____	_____	_____	2	_____	_____

Customer: .....

Location: .....

Unit No. ..... Hours: ..... Date: .....

Job No.: .....

Engine Model No.: ..... Engine Serial No.: .....

Type of Inspection (Failure, Routine, Complaint):

Inspection Notes: .....

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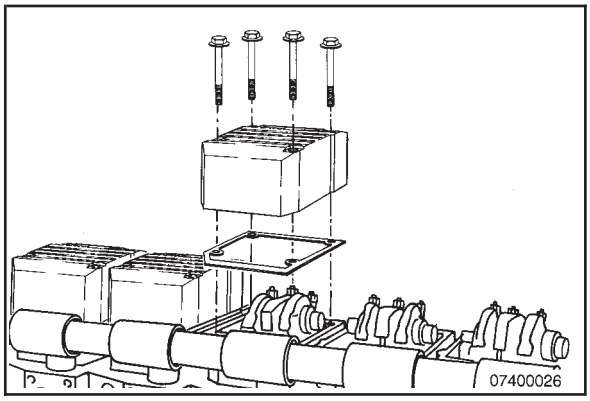
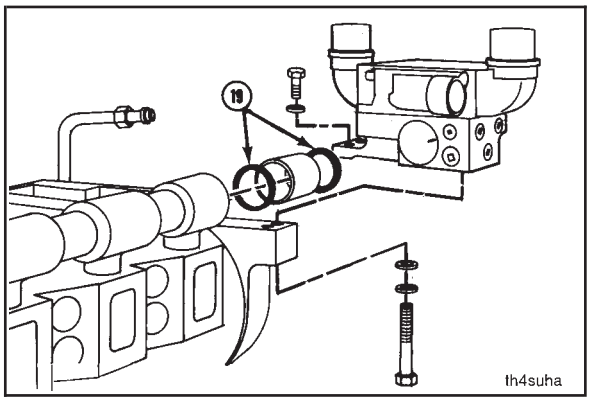
NOTE: Do **not** use gasket cement. It will prevent the gasket from sealing properly.

Install the rocker lever cover, gasket, and capscrews. Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Install the coolant thermostat housing support.

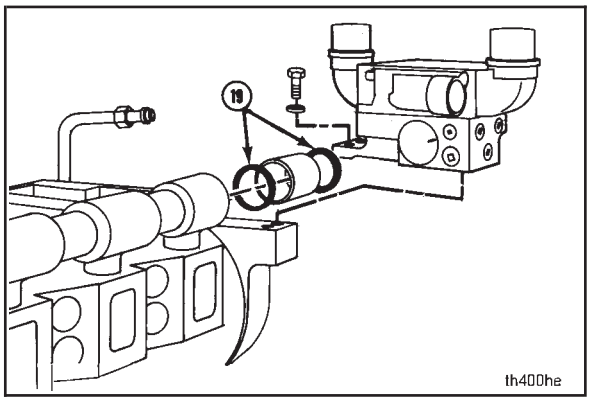


Conventional Aftercooling

Install the o-rings (19) on the water transfer tube.

Use vegetable oil. Lubricate the o-rings. Install the tube in the bore of the rocker lever housing.

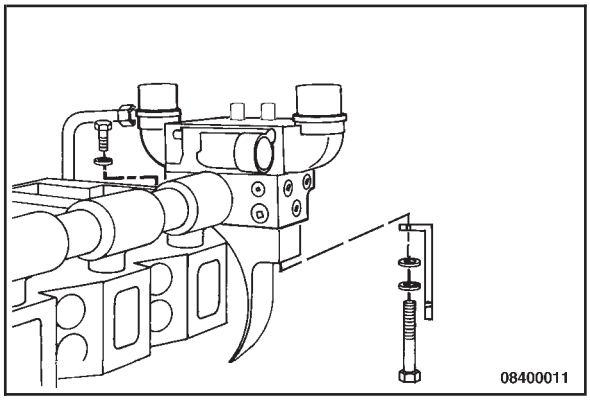
Align the bore in the thermostat housing support with the transfer tube. Push the support into position.

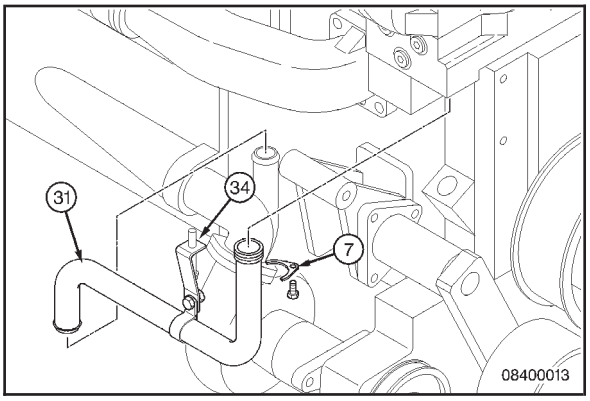


NOTE: The outside capscrew holds a clip for the after-cooler water inlet tube.

Install the four lockwashers and capscrews. Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]





Use vegetable oil to lubricate the o-ring. Install a new o-ring on the aftercooler water supply tube (31).

Install the tube in the bore of the thermostat housing.

Install the retainer clip (7) and capscrew.

Tighten the capscrew.

NOTE: The retainer clip leg should point towards the thermostat housing.

Torque Value:

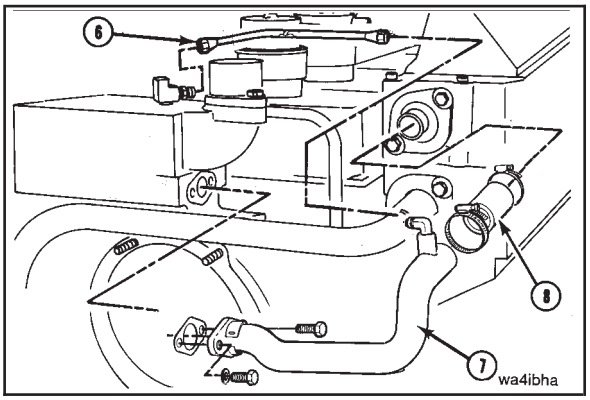
Capscrew	20 N•m	[15 ft-lb]

Tighten the hose clamps.

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]

Attach the support clip to the bracket (34).



Connect the aftercooler coolant return tube (7) and hose(s) to the aftercooler.

Install the gasket and return tube capscrews.

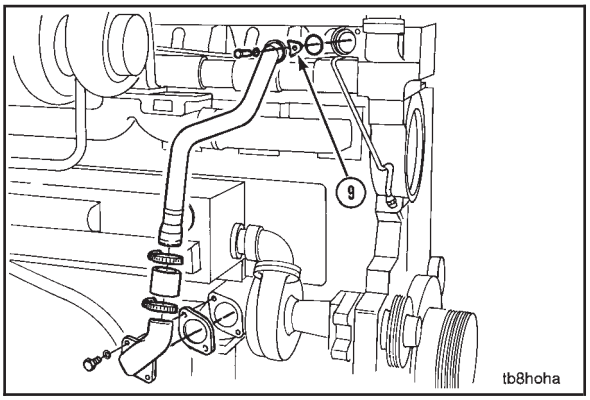
Tighten the capscrews.

Torque Value: 6 N•m [50 in-lb]

Install the vent hose (6).

Connect the coolant temperature sensor wire.

NOTE: If the engine is equipped with an air compressor, install the air compressor coolant return tube.



Use vegetable oil. Lubricate the o-ring on the bypass tube. Install the bypass tube.

Install the retainer (9) and capscrew. Tighten the capscrew.

Torque Value:

Capscrew	45 N•m	[35 ft-lb]

Tighten the hose clamps.

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]

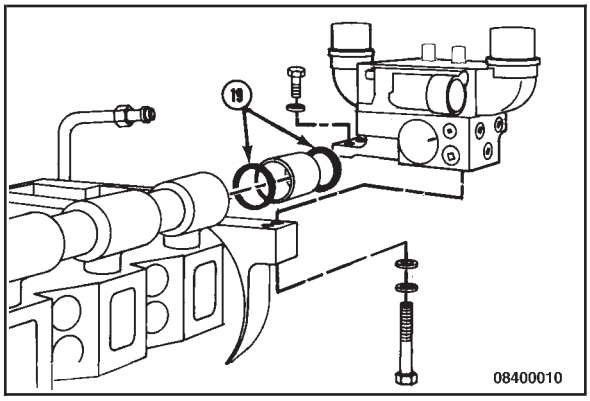
Low Temperature Aftercooling

Install the o-rings (19) on the water transfer tube.

Use vegetable oil. Lubricate the o-rings.

Install the tube in the bore of the rocker lever housing.

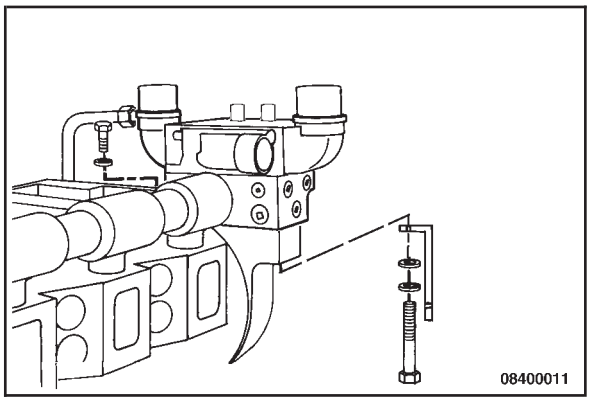
Align the bore in the thermostat housing support with the transfer tube. Push the support into position.



NOTE: The outside capscrew holds a clip for the aftercooler water inlet tube.

Install the four lockwashers and capscrews. Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Use vegetable oil. Lubricate the o-ring on the bypass tube.

Install the bypass tube.

Install the retainer (9) and capscrew.

Tighten the capscrew.

NOTE: The retainer clip leg should point towards the thermostat housing.

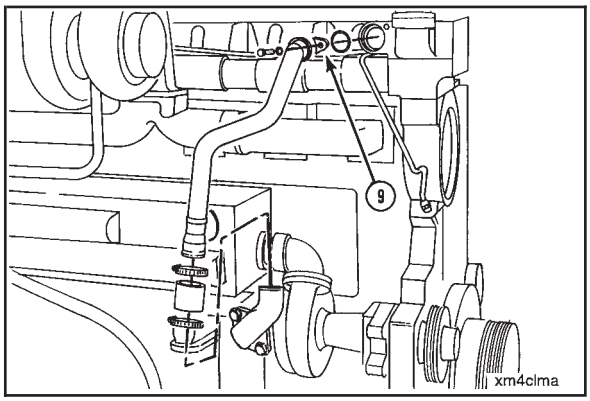
Torque Value:

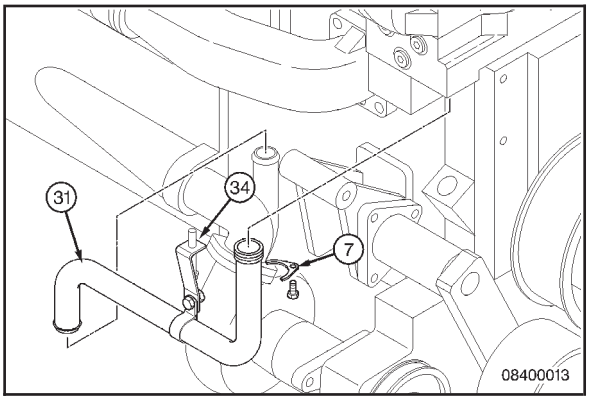
Capscrew	45 N•m	[35 ft-lb]

Tighten the hose clamps.

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]





Use vegetable oil to lubricate the o-ring. Install a new o-ring on the aftercooler water supply tube (31).

Install the tube in the bore of the thermostat housing.

Install the retainer clip (7) and capscrew.

Tighten the capscrew.

NOTE: The retainer clip leg should point towards the thermostat housing.

Torque Value:

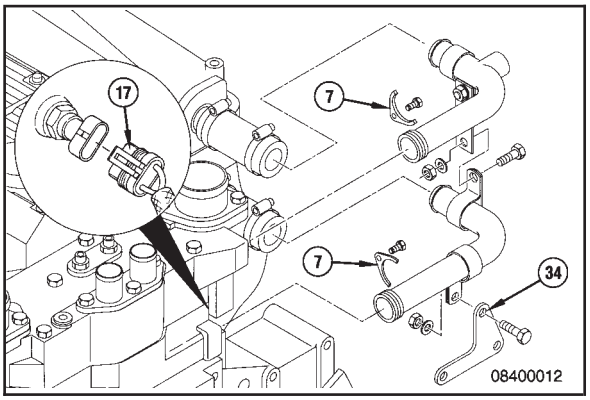
Capscrew	20 N•m	[15 ft-lb]

Tighten the hose clamps.

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]

Attach the support clip to the bracket (34).



Use vegetable oil to lubricate the new o-rings. Install the o-rings on the aftercooler water inlet and outlet tubes.

Install the tubes.

Install the retainer clips (7) and capscrews.

Tighten the capscrews.

Torque Value:

Capscrew	20 N•m	[15 ft-lb]

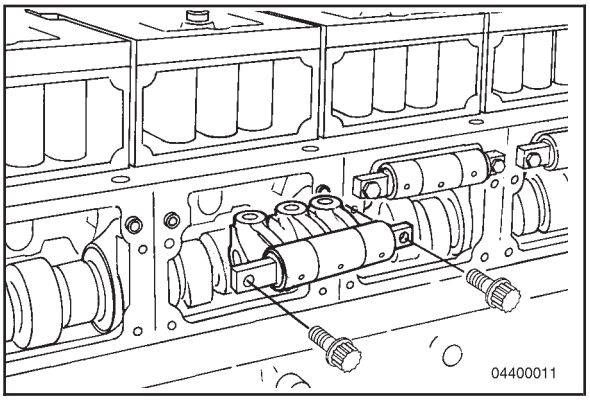
Tighten the hose clamps.

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]

Attach the support clips to the bracket (34).

Connect the coolant temperature sensor wire (17).



NOTE: Service replacement cam followers are coated with a heavy preservative to prevent rust. This preservative **must** be removed completely with solvent before the parts are installed on the engine.

CAUTION

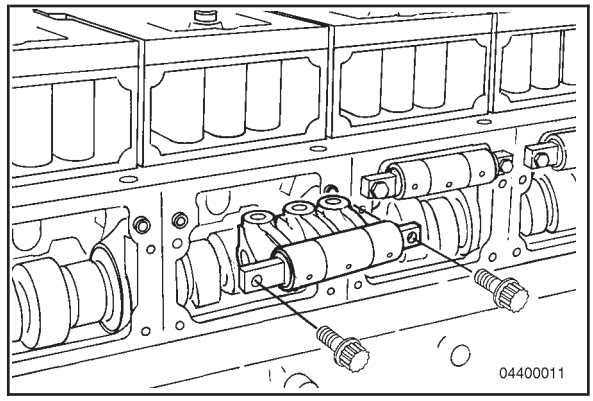
The cam follower mounting capscrews are special 12-point flange heads. Shaft failure will result if standard capscrews are used.

Use engine oil to lubricate the camshaft and cam followers.

Install the cam follower assembly. The shaft **must** fit on both ring dowels.

Install the capscrews.

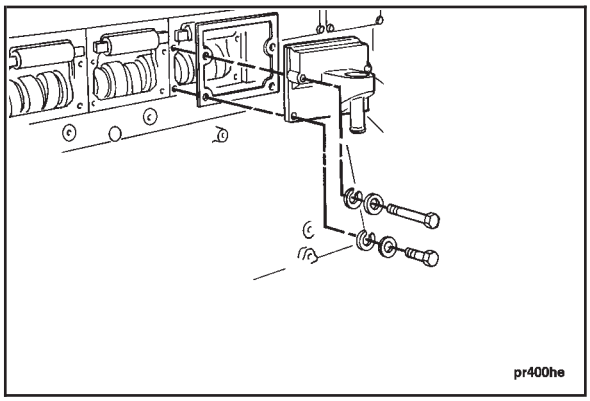
Torque Value: Step 1 55 N•m [40 ft-lb]
2 110 N•m [80 ft-lb]
3 165 N•m [120 ft-lb]



⚠ CAUTION ⚠

The tabs on the cover gasket must be removed before installation.

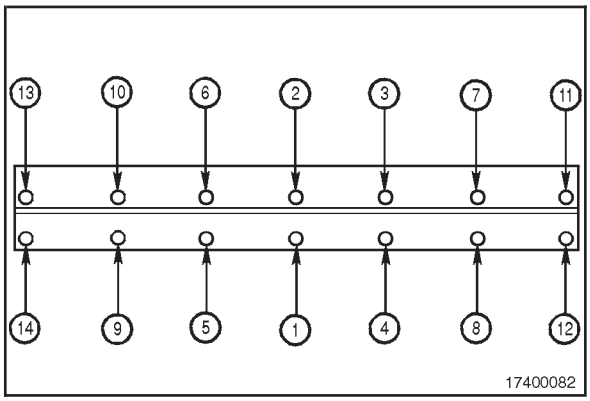
Install the gasket, cover, and capscrews.



Tighten the 14 capscrews in sequence shown.

Torque Value: 27 N•m [20 ft-lb]

Install the crankcase vent hose, fuel supply line, and the wiring harness.

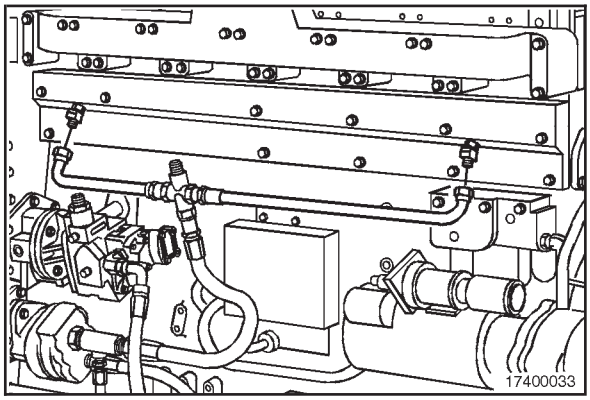


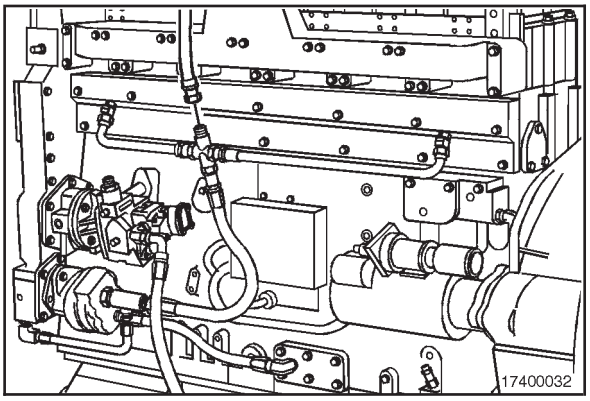
Rail Applications

Install the face seal o-rings.

Install the two scavenging tubes on the fittings of the cam follower cover.

Torque Value: 80 N•m [60 ft-lb]

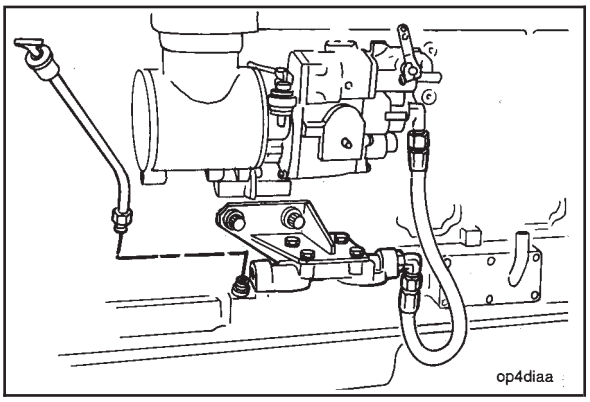




Rail Applications

Connect the turbocharger drain hose to the scavenge cross.

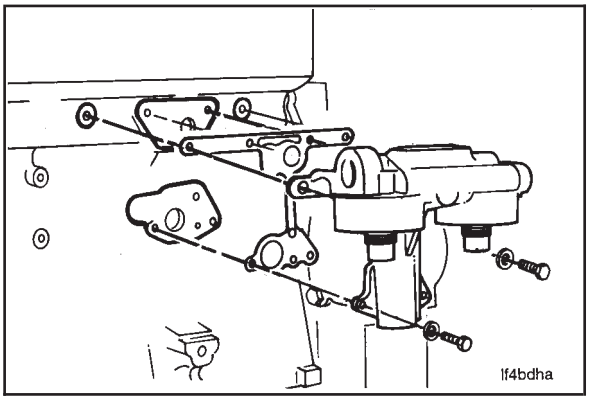
Torque Value: 80 N•m [60 ft-lb]



NOTE: The dipstick tube and fuel filter mounting locations vary depending on the application of the engine.

Install the dipstick tube.

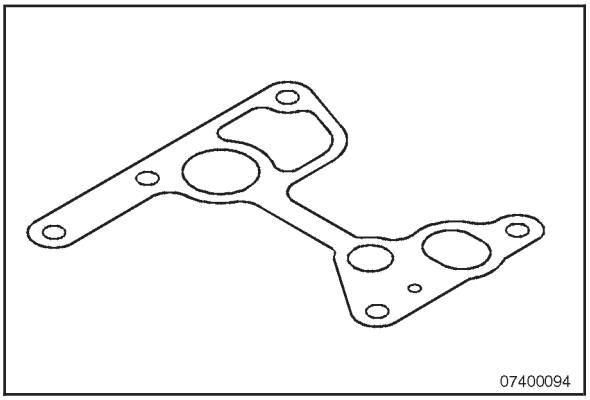
Tighten the nut 3/4 turn to 1 turn after contact with the ferrule.



Install the gasket, filter head and six capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



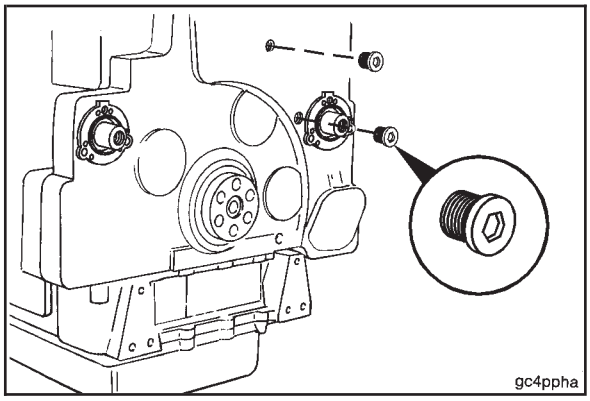
Oil Transfer Connection Block

Install the lube oil transfer connection block gasket, remove tab as shown.

Install the lube oil transfer connection block.

Remove the two straight threaded o-ring plugs from the timing holes in the front cover.

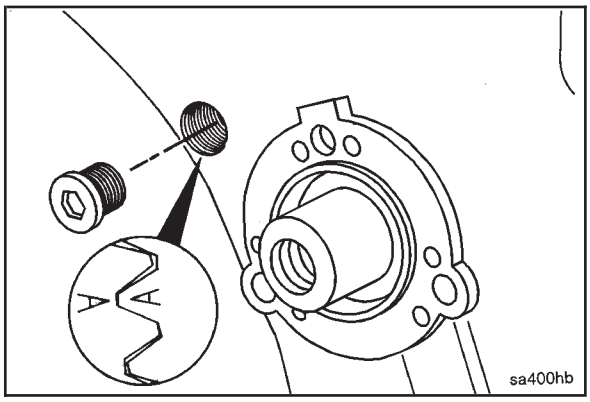
Check the index mark alignment.



⚠ CAUTION ⚠

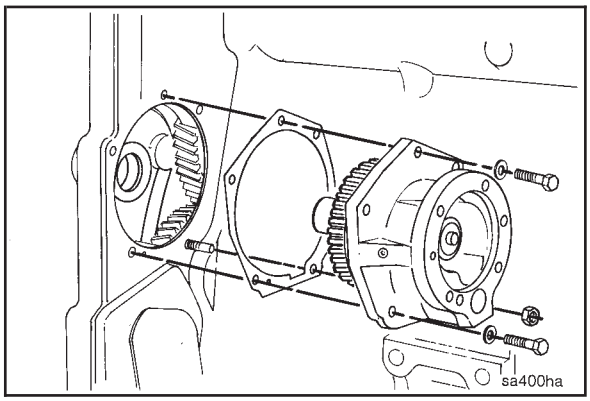
Do not use the ''A'' on the camshaft idler gear for the accessory drive alignment unless the ''X'' marks on the camshaft and the camshaft idler gears are aligned and centered in the upper timing plug hole. If the ''X'' marks are not visible in the upper hole, rotate the engine until the ''X'' marks on the camshaft gear and camshaft idler gear are aligned and centered in the upper timing plug hole.

NOTE: Install the accessory drive so that the ''A'' on the accessory drive gear is centered in the lower timing plug hole.



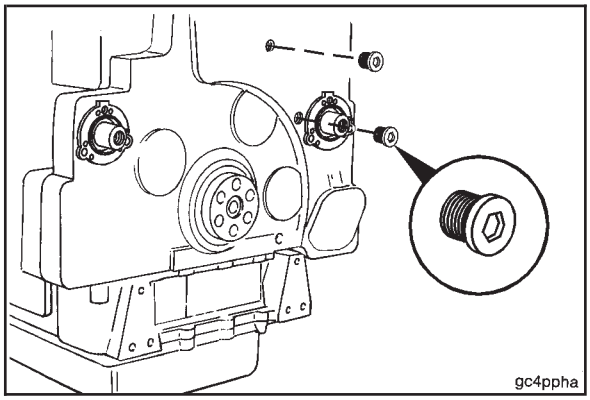
Install the gasket, capscrews, and nut. Tighten the capscrews.

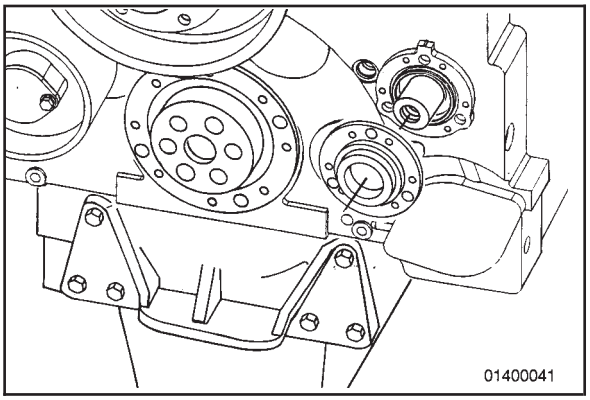
Torque Value: 45 N•m [35 ft-lb]



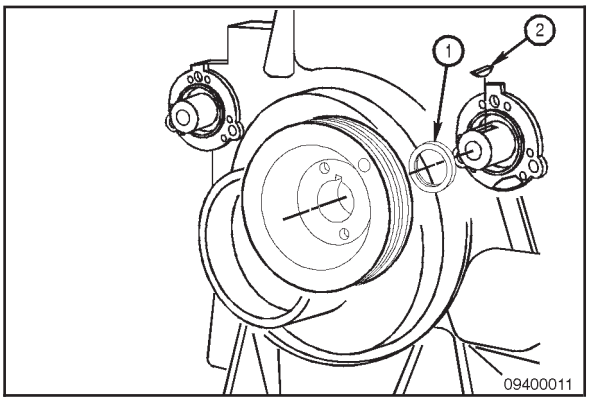
Install the straight threaded o-ring plugs. Tighten the o-ring plugs.

Torque Value: 25 N•m [20 ft-lb]



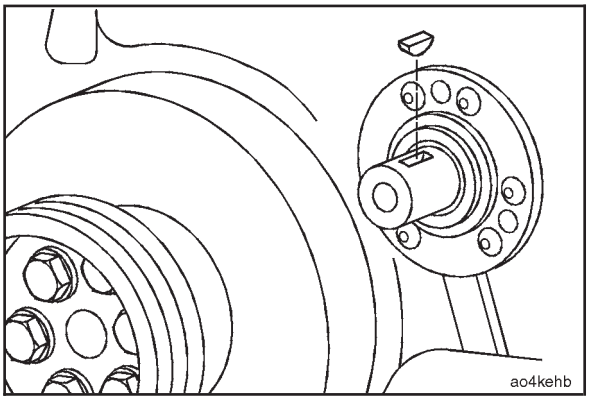


Install the accessory drive seal.

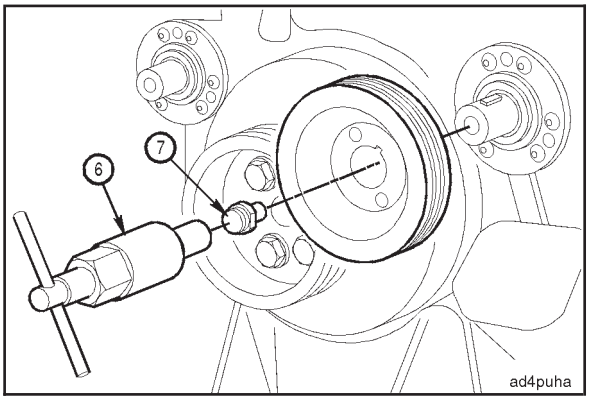


NOTE: The keyway seal must be installed before installing the woodruff key.

Install the keyway seal.



Install the woodruff key.



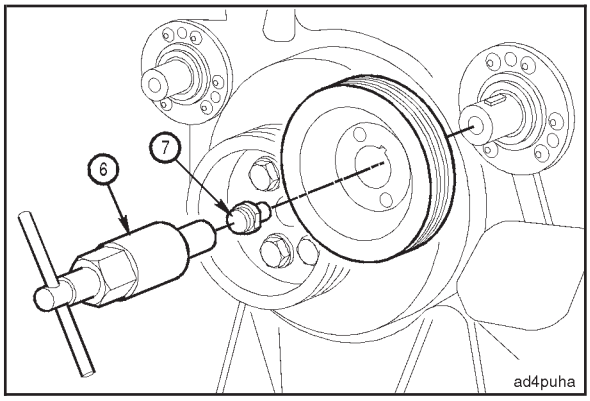
⚠ CAUTION ⚠

Do not use a hammer to drive the pulley into position. Damage to the thrust bearing will result.

Use pulley installation tool kit, Part No. 3376326. Insert the appropriate adapter (7) in the pusher.

Lubricate the shaft O.D. and the pulley I.D. with engine oil.

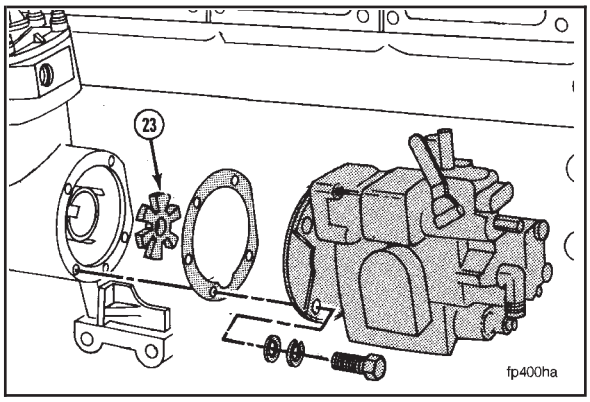
Align the keyway in the pulley with the key in the shaft. Use the tool to push the pulley on the shaft until it touches the step on the shaft.



All QSK19 engines use a light green fuel pump drive coupling.

Install the fuel pump drive coupling (23), gasket, fuel pump, and four capscrews. Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



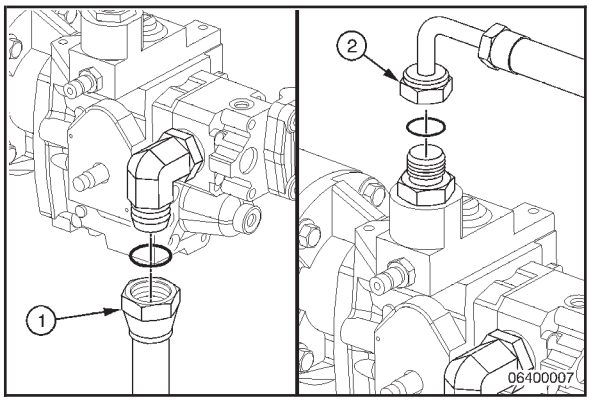
Check for the proper installation of the o-rings in both locations.

Install the fuel pump inlet hose and the fuel supply hose.

Tighten the hoses.

Torque Value:

Fuel Pump Inlet Hose	88 N•m	[65 ft-lb]
Fuel Supply Hose	60 N•m	[45 ft-lb]

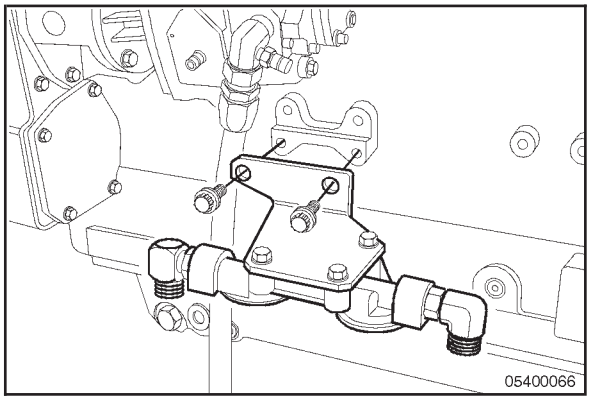


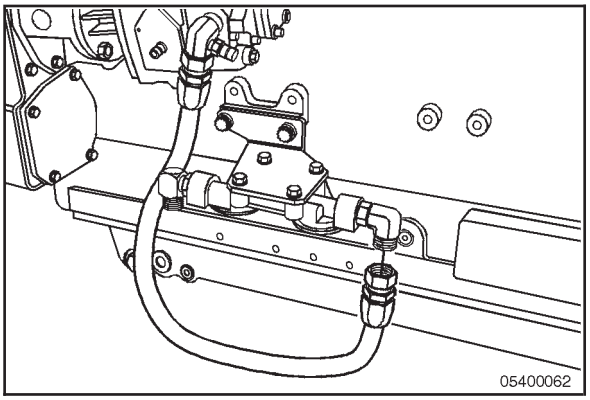
Install the fuel filter head.

Install the two mounting capscrews.

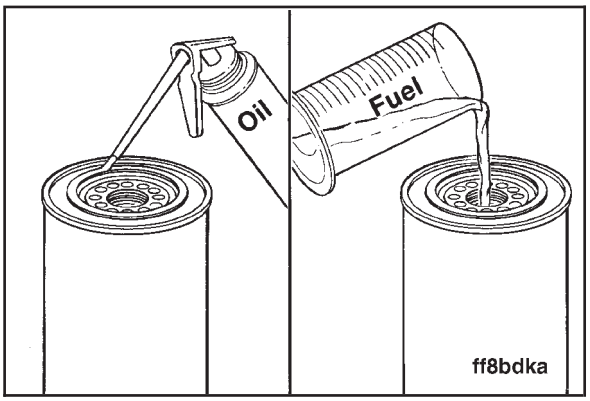
Tighten the capscrews.

Torque Value: 55 N•m [40 ft-lb]





Connect the fuel line to the fuel filter head.

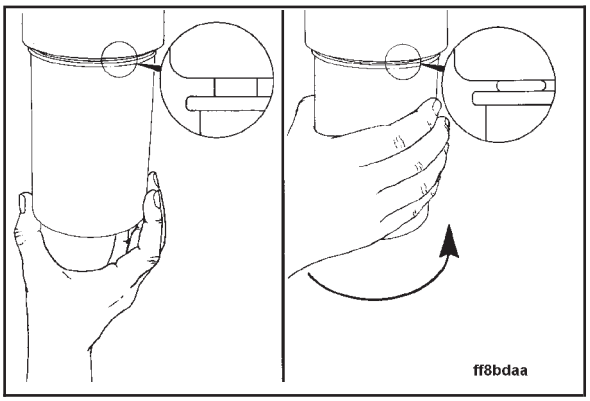


Install a new thread adapter sealing ring supplied with the new filter.

A fuel-water separator or fuel filter and water separator combination **must** be installed.

Apply a light coating of clean engine oil to the surface of the filter gasket.

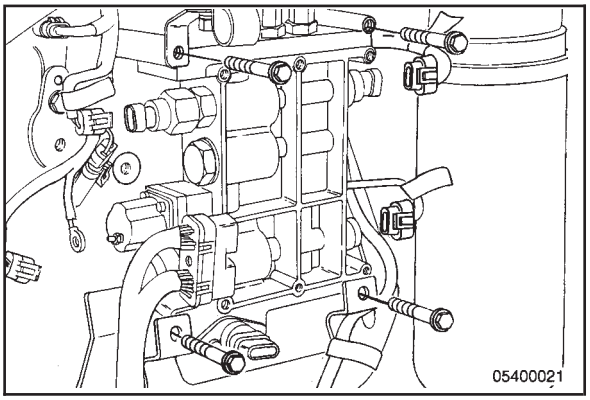
Fill the filter with clean fuel.



Install the filter on the filter head. Turn the filter until the gasket touches the surface of the filter head.

Tighten the filter an additional 1/2 to 3/4 of a turn after the gasket touches the filter head surface.

Open the fuel line shutoff valve and check for leaks.

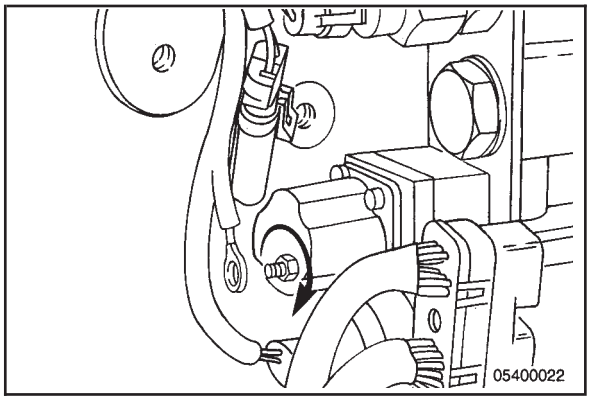


Install the four capscrews to secure the control valve body assembly and the wire harness and brackets.

Torque Value: 45 N•m [35 ft-lb]

Tighten the nut that holds the electrical connection post on the fuel shutoff valve coil.

Torque Value: 3 N•m [25 in-lb]

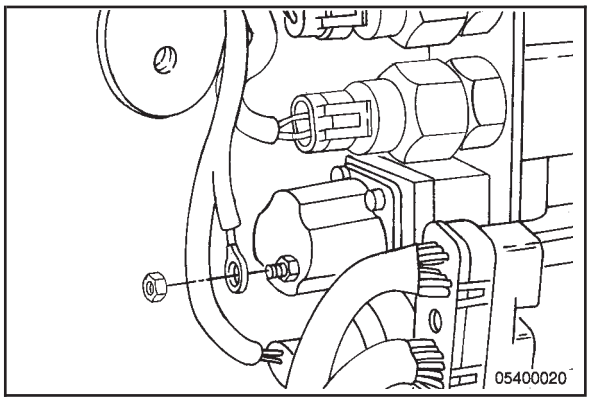


Install the electrical connection on the fuel shutoff valve.

Install the nut on the threaded post of the coil.

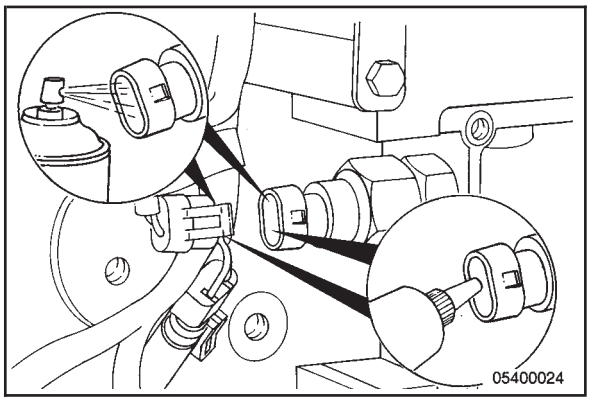
Use two [3/8-inch] wrenches. Hold the post of the nut firmly while tightening the connection nut.

Torque Value: 2 N•m [15 in-lb]



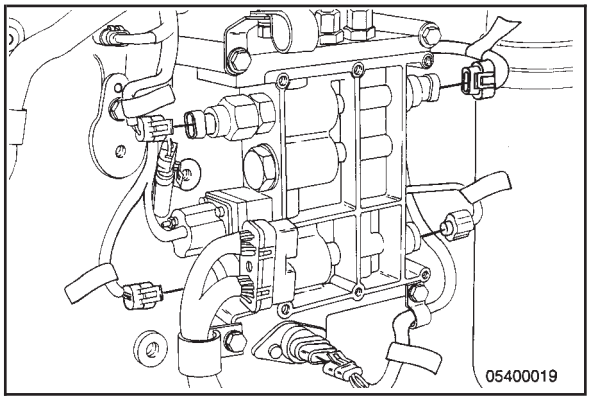
Inspect the actuator and pressure sensor connections for dirt and debris.

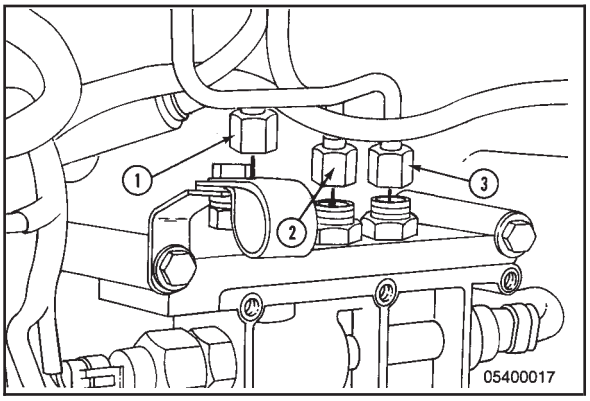
Use dielectric lithium grease, Part No. 3822934, and QD® contact cleaner, Part No. 3824510. Clean and lubricate the connections and actuator if cleaning is required.



NOTE: If the electrical connections were not labeled for identification purposes during disassembly, verify the types of connections on the wiring diagram.

Connect the actuator and pressure sensor connections.





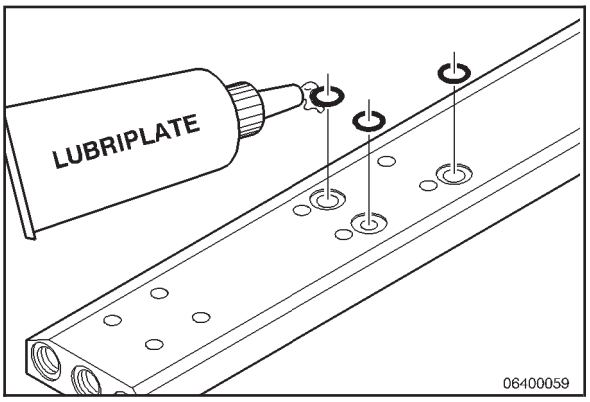
Connect the fuel supply hose (1), the timing rail pressure line (2), and the metering rail pressure lines (3) to the control valve body.

Tighten the fuel supply hose (1).

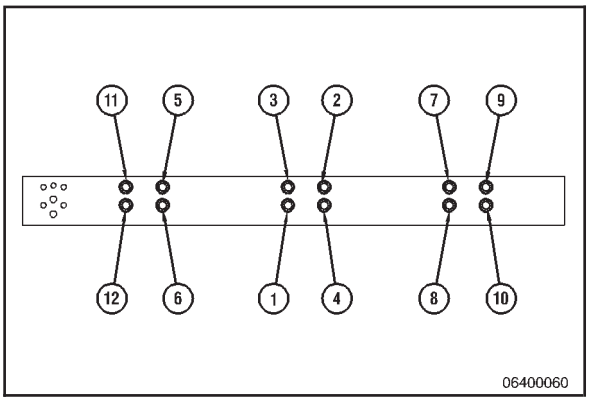
Tighten the timing pressure (2) and rail pressure lines (3).

Torque Value:

Fuel Supply Hose (1)	61 N•m	[45 ft-lb]
Timing and Rail Pressure Lines (2 and 3)	27 N•m	[20 ft-lb]



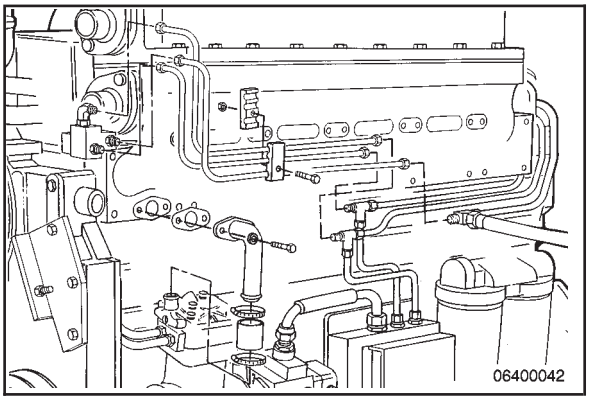
Use Lubriplate® No. 105, or equivalent, to position and secure the o-rings. Install the o-rings.



Install the **front** fuel manifold. Use the sequence illustrated to tighten the 12 capscrews.

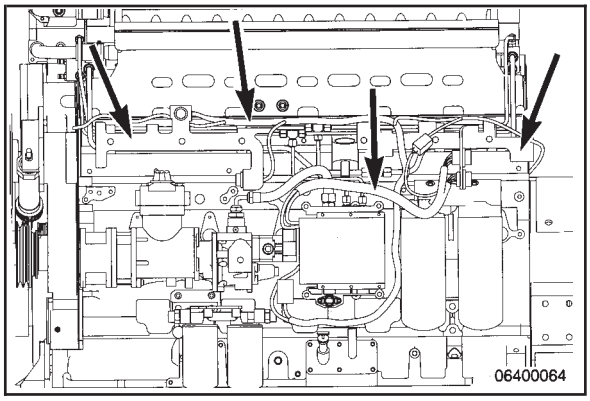
Torque Value: 9.6 N•m [85 in-lb]

Repeat this process for the installation of the **rear** fuel manifold.



On engines equipped with an air compressor, install the air inlet connection hose, and new gasket.

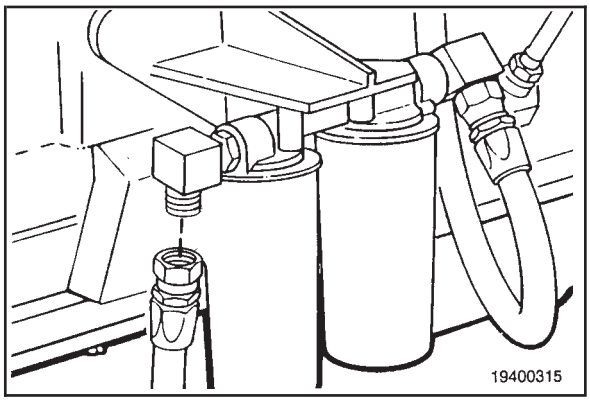
Install the engine wiring harness and brackets.



Fuel Tank-To-Fuel Filter

Install and tighten the fuel inlet line.

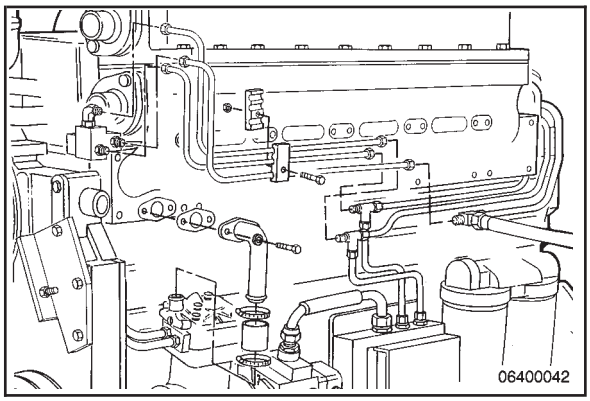
Torque Value: 115 N•m [85 ft-lb]



Fuel Rail Supply Line

Fuel Timing Supply Line

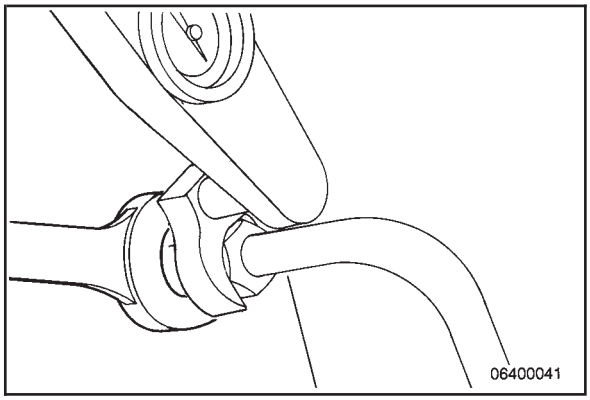
Loosely assemble the fuel tubes and clamps.

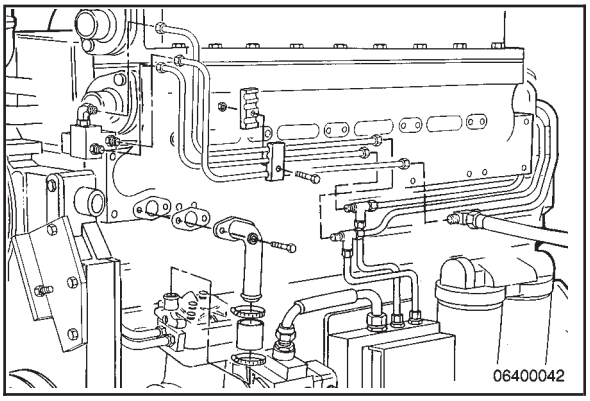


NOTE: It is a good service practice to use two wrenches when tightening the fuel fittings.

Support the fitting. Use a crowfoot wrench and a torque wrench. Tighten the fuel tube nut.

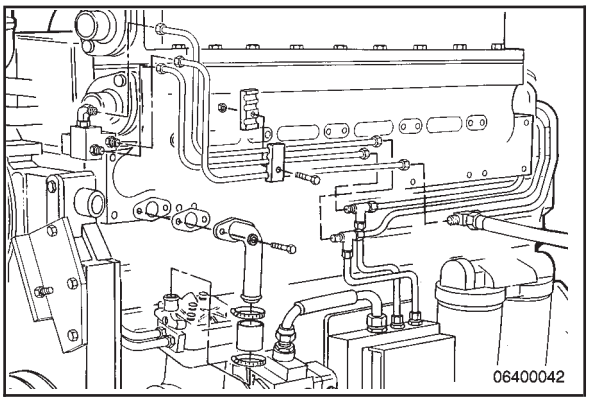
Torque Value: 27 N•m [20 ft-lb]





Tighten the fuel tube clamps.

Torque Value: 27 N•m [20 ft-lb]



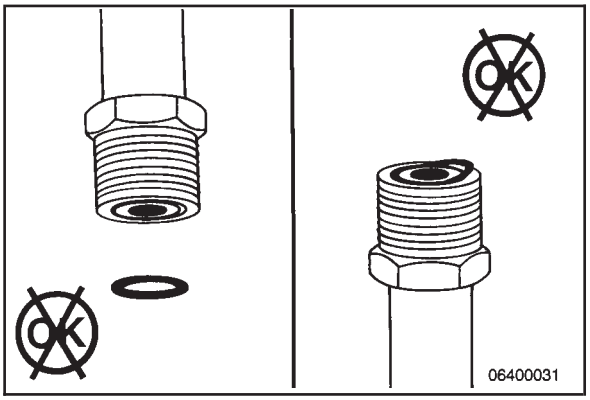
On engines equipped with an air compressor, install the air compressor air inlet connection with a new hose and gasket.

Torque Value:

Flange Capscrew:	4 N•m	[35 in-lb]

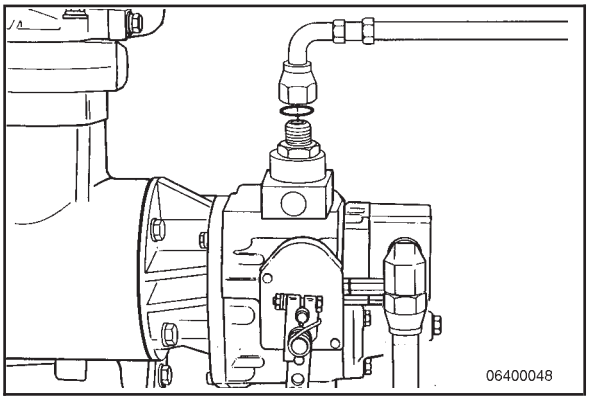
Torque Value:

Clamp:	6 N•m	[50 in-lb]



Fuel Control Supply Lines

Install new o-rings on the control valve body inlet fitting and the fuel pump outlet fitting. Be sure the o-ring is installed properly.

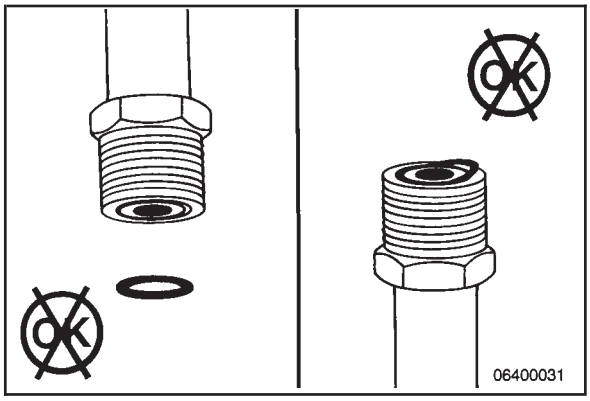


Install and tighten the fuel control valve supply hose.

Torque Value: 61 N•m [45 ft-lb]

Fuel Inlet Line

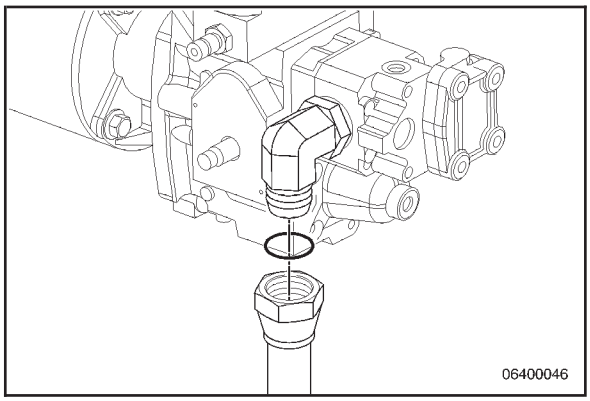
Install new o-rings on the fuel pump inlet fitting and fuel filter head outlet fitting. Check for proper o-ring installation.



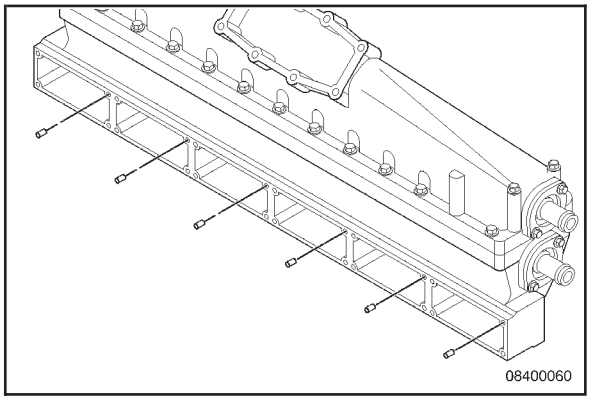
Install the hose at the fuel pump inlet and fuel filter head outlet fitting.

Tighten the hose.

Torque Value: 88 N•m [65 ft-lb]



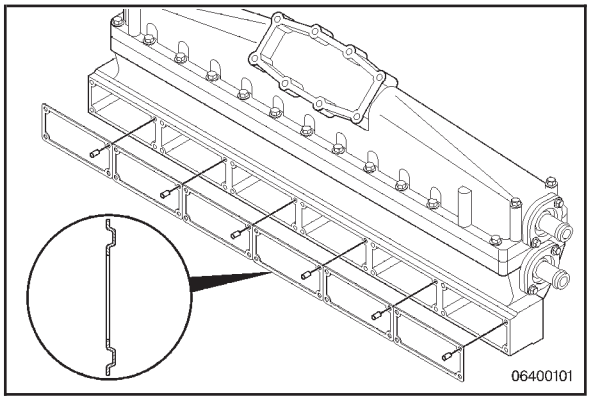
Install the bolt seals in the aftercooler housing.

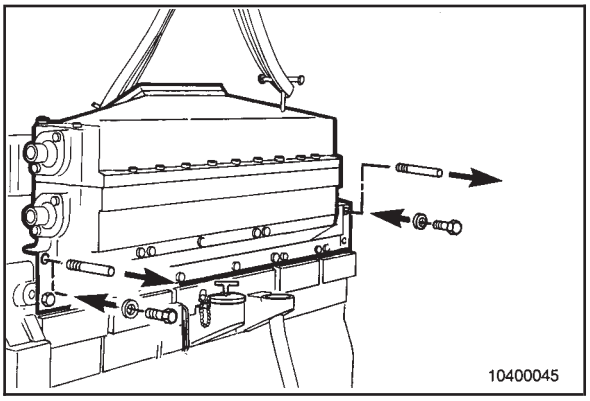


NOTE: Use guide studs long enough to protrude beyond the installed part.

Install 12 guide studs in the upper row of capscrew holes in the cylinder heads.

Install the gaskets on the studs with the raised bead on the gasket toward the cylinder head.



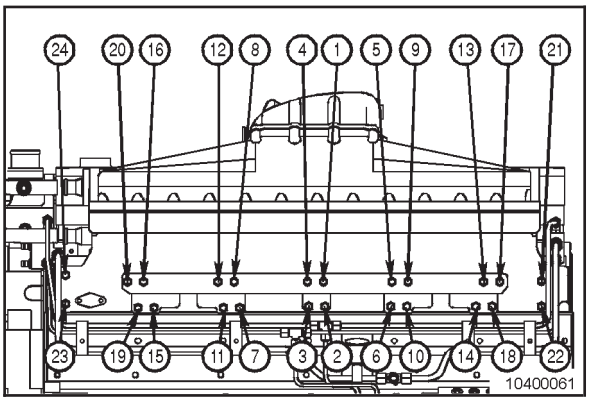


CAUTION

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

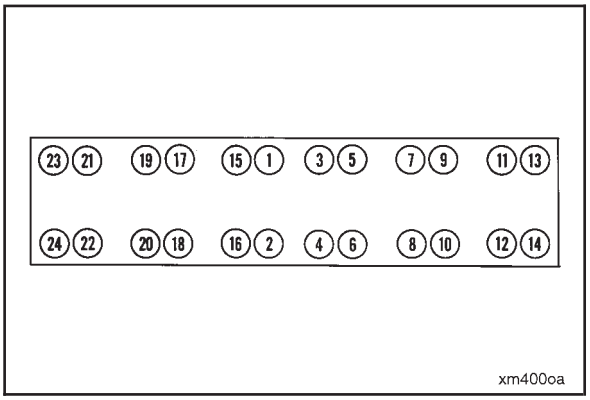
Install the aftercooler and the bottom row of capscrews. Tighten the capscrews **only** enough to hold the part.

Remove the guide studs and install the top row of capscrews.



Use the sequence shown, and the steps and values indicated below to tighten the capscrews.

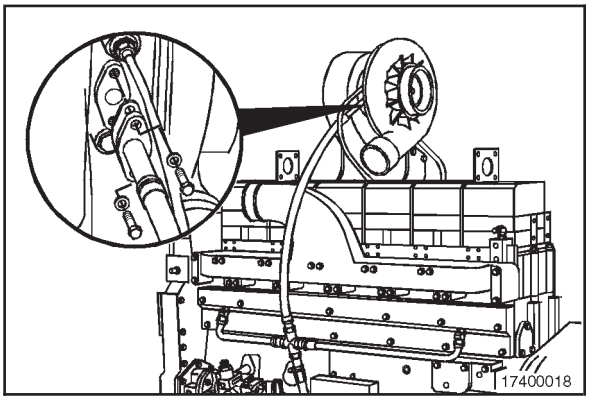
Torque Value: Step 1 25 N•m [20 ft-lb]
2 45 N•m [35 ft-lb]



Rail Applications

Install the intake manifold and 24 capscrews. Tighten the 24 capscrews in the sequence shown.

Torque Value: 45 N•m [35 ft-lb]



Rail Applications

Install the turbocharger drain line to the turbocharger.

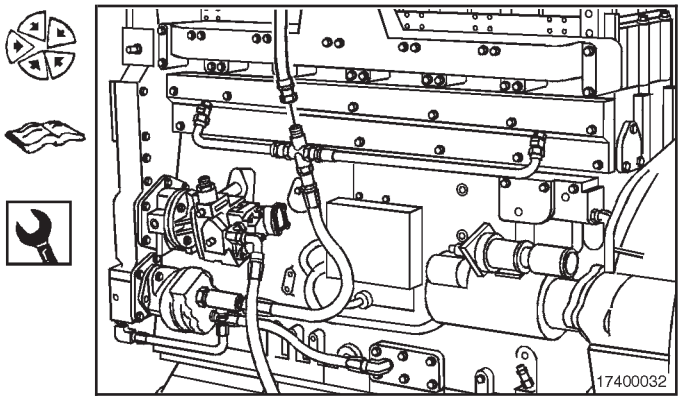
Torque Value: 45 N•m [35 ft-lb]

Rail Applications

Install the face seal o-ring.

Install the turbocharger drain line to scavenge cross.

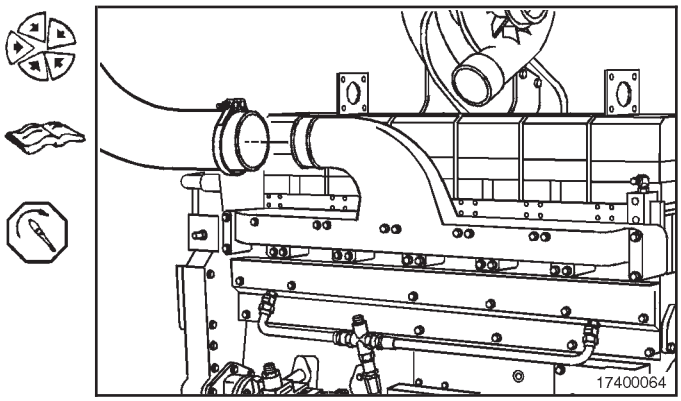
Torque Value: 80 N•m [60 ft-lb]



Rail Applications

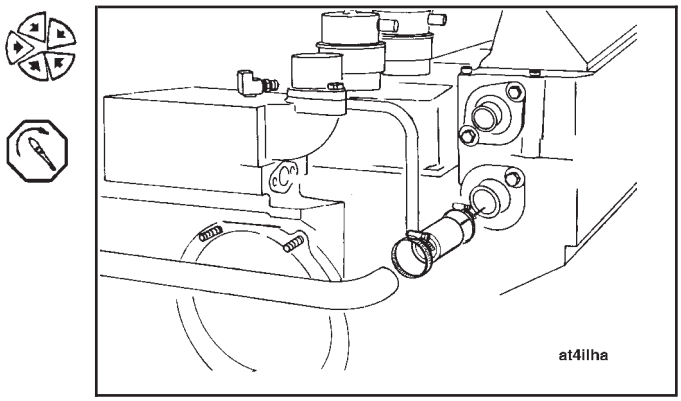
Install hose and tighten hose clamp.

Torque Value: 8 N•m [75 in-lb]



Connect the inlet hose. Tighten the clamps.

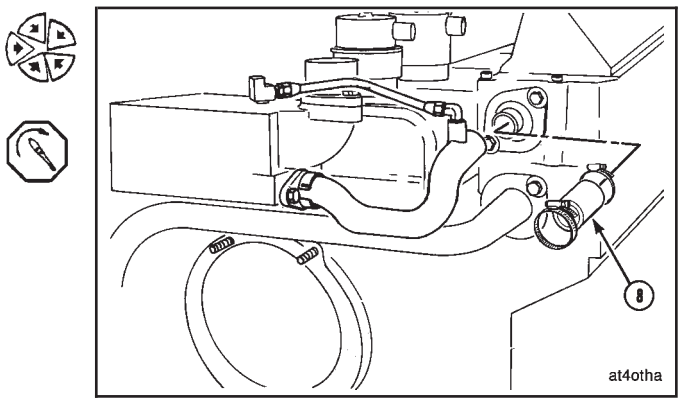
Torque Value 6 N•m [50 in-lb]

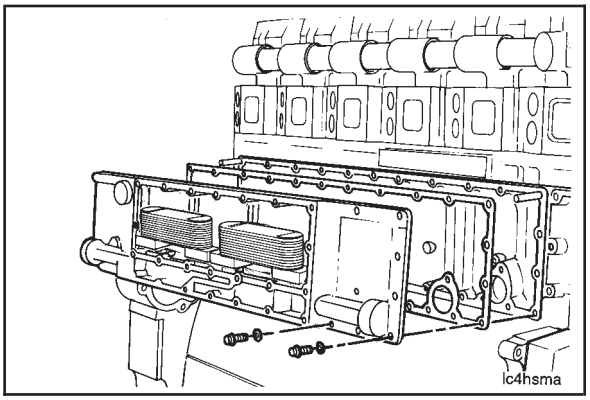


Connect the water outlet hose (8). Tighten the clamps.

Torque Value 6 N•m [50 in-lb]

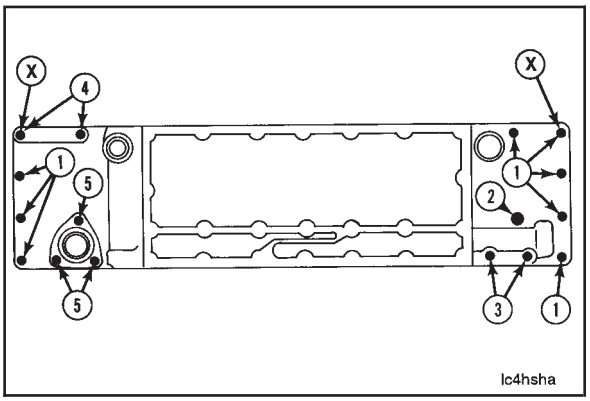
Install the coolant vent and tighten.





Install two guide studs. Put the gasket and housing into position.

Install, but do **not** tighten, capscrews.



⚠ CAUTION ⚠

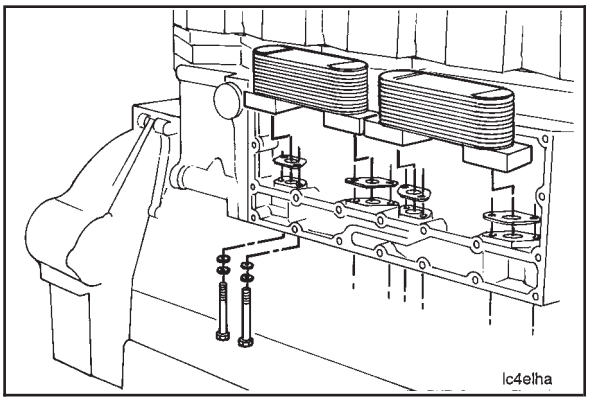
Do not tighten the capscrews until the oil cooler cover or torque converter cooler cover is installed.

Install the capscrews as shown.

⚠ CAUTION ⚠

The two capscrew holes marked ''X'' align with cylinder head capscrews. The cylinder head capscrews will be damaged if the cooler housing capscrews are too long.

Oil Cooler Capscrew Lengths	
Illustration Callout No.	**Without Oil Filter**
1	1-1/4 in
2	1-3/4 in
3	1-5/8 in
4	1-3/4 in
5	1-5/8 in



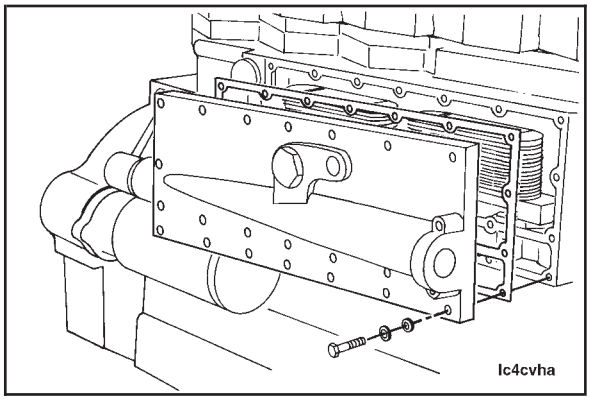
NOTE: Remove the plastic shipping plugs from the new oil cooler elements.

Install the gaskets, oil cooler elements, and capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]

Install the oil cooler cover.

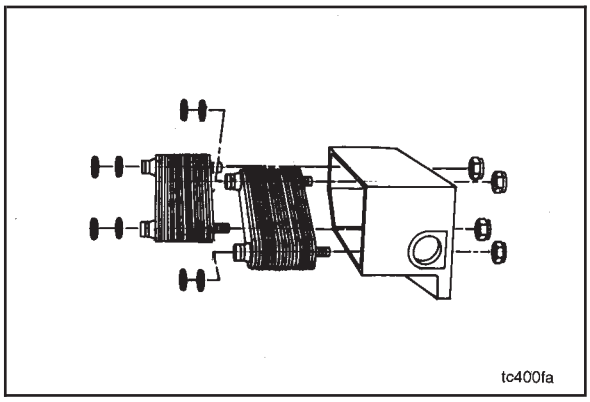


Install the elements.

Tighten the self-locking nuts.

Torque Value: 130 N•m [95 ft-lb]

Use new o-rings. Lubricate the o-rings with vegetable oil. Install the o-rings on the cooler elements.



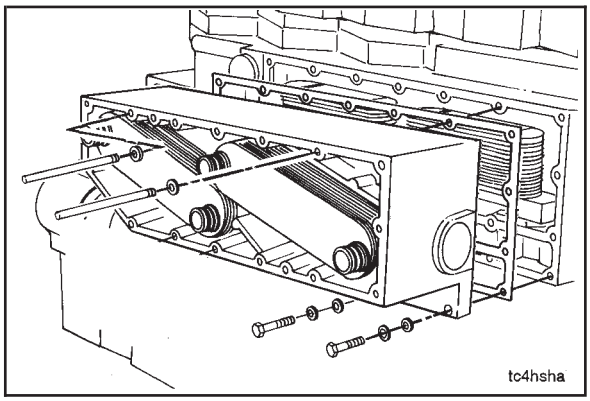
⚠ CAUTION ⚠

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

Use two [3/8-16 x 12 inch] guide studs to support the housing during installation.

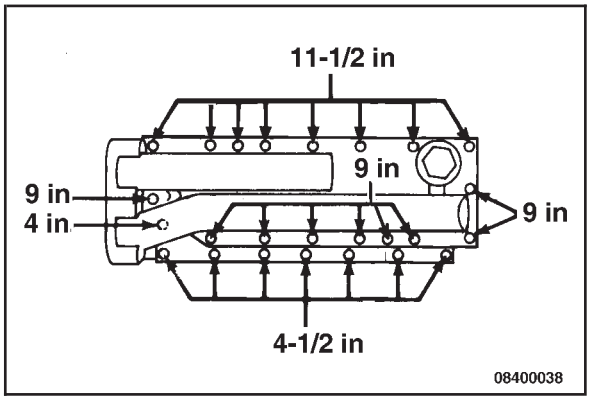
Install the gasket and housing.

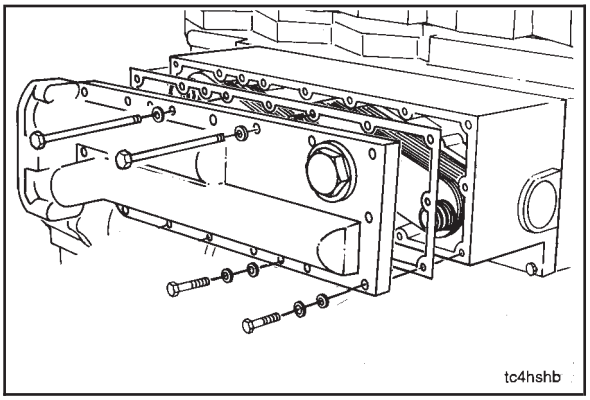
Install the capscrews in the bottom row of holes on the housing. These capscrews are all 101.6 mm [4 in] long.



NOTE: The length and location of all the capscrews on the torque converter cooler and cover are shown. Be sure the capscrews are the correct length.

Do **not** tighten any of the capscrews until all of them have been installed.



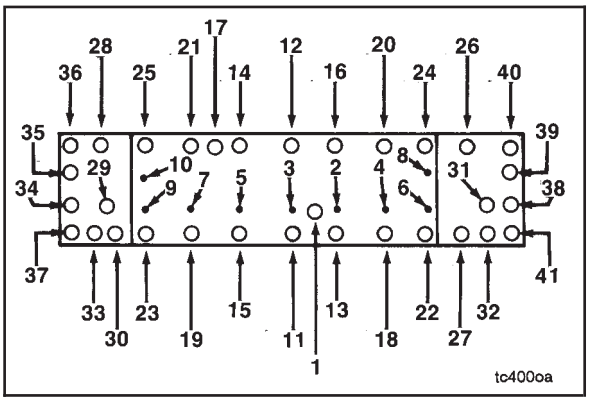


NOTE: Be sure the capscrews are the correct length.

Use vegetable oil to lubricate the o-rings on the cooler element and the bores in the cover.

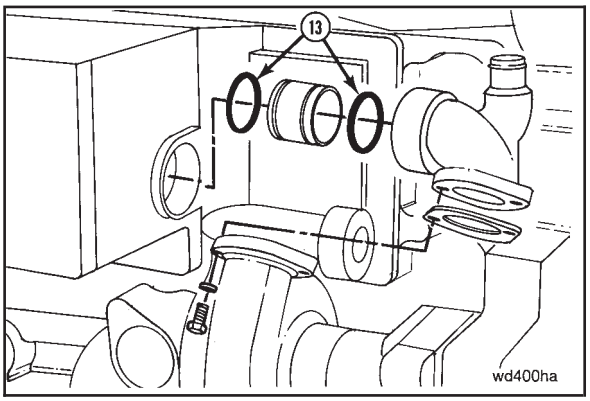
Install the gasket and cover. Push the cover over the o-rings until the cover is against the housing.

Install the remaining capscrews.



Tighten the capscrews in the sequence shown.

Torque Value: 45 N•m [35 ft-lb]



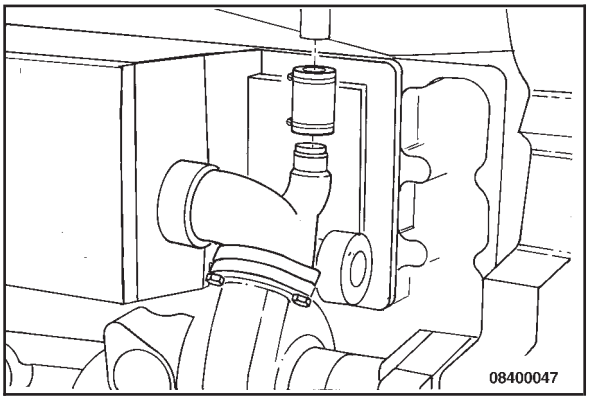
Use vegetable oil. Lubricate the o-rings (13).

Install the transfer tube in the water pump outlet connection.

Install the water pump outlet connection, gasket, and capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Connect the aftercooler supply hose to the water pump outlet connection.

Tighten the clamps.

Torque Value: 5.6 N•m [50 in-lb]

Use vegetable oil. Lubricate the o-ring on the water bypass tube.

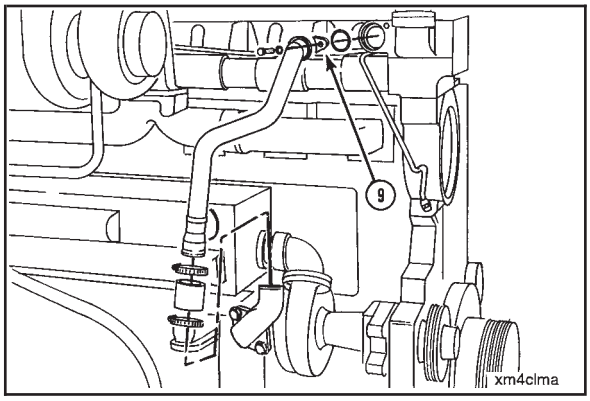
Install the bypass tube.

Install the retainer (9) and capscrew.

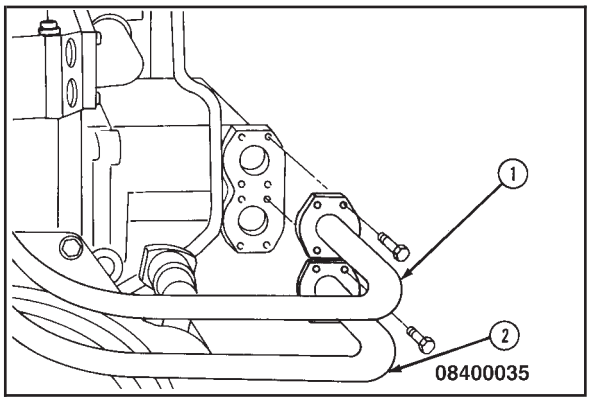
Tighten the capscrew and hose clamp.

Torque Value:

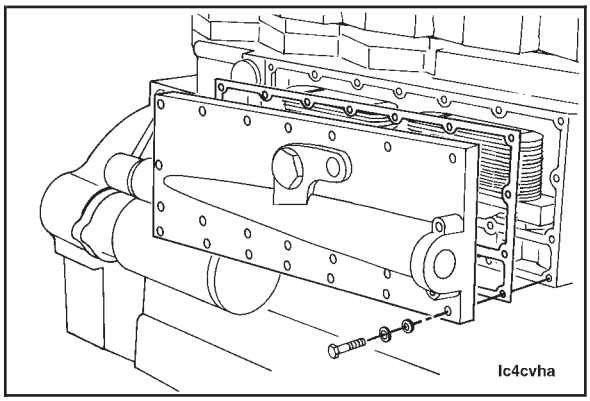
Capscrew	45 N•m	[35 ft-lb]
Clamp	5.6 N•m	[50 in-lb]



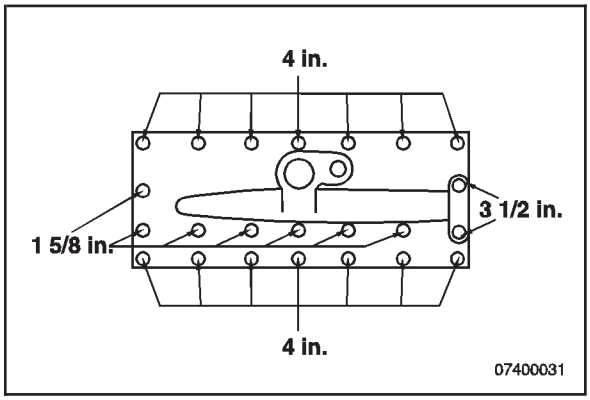
Connect the torque converter oil hoses to the torque converter cooler.

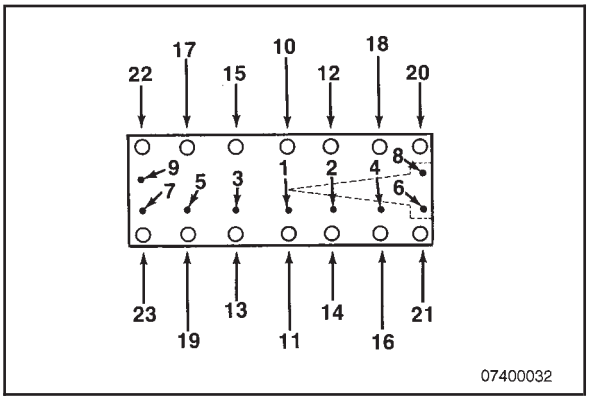


Install the oil cooler cover and new gasket. Use several capscrews to secure the cover in position, but do **not** tighten the capscrews.



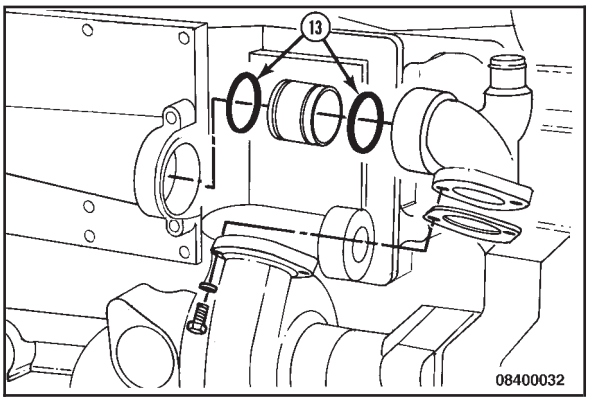
Install the capscrews as shown.





Tighten the capscrews to the values specified and in the sequence shown.

Torque Value: 45 N•m [35 ft-lb]

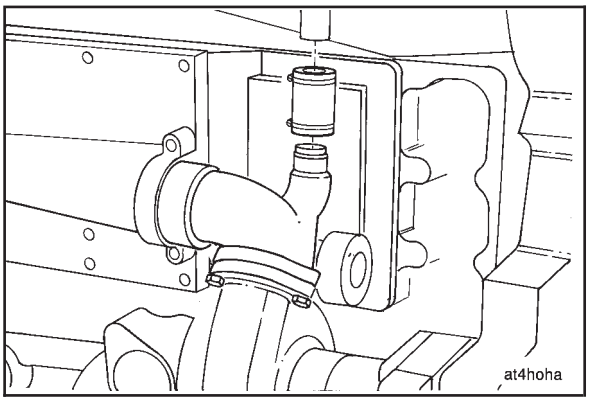


Use vegetable oil. Lubricate the o-rings (13).

Install the transfer tube in the water pump outlet connection.

Install the water pump outlet connection, gasket, and capscrews.

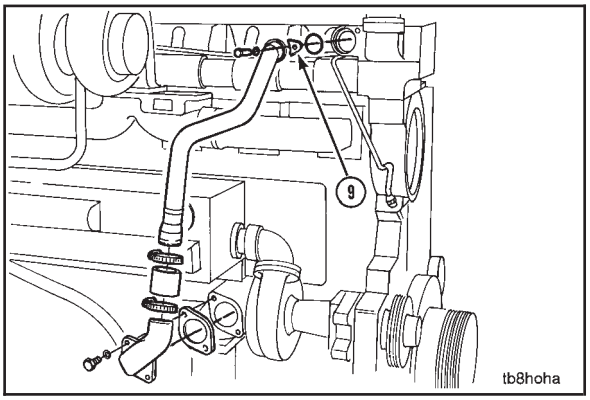
Torque Value: 45 N•m [35 ft-lb]



Connect the aftercooler supply hose to the water pump outlet connection.

Tighten the clamps.

Torque Value: 6 N•m [50 in-lb]



Use vegetable oil. Lubricate the o-ring on the bypass tube. Install the bypass tube.

Install the retainer (9) and capscrew.

Tighten the capscrew and the hose clamps.

Torque Value:

Capscrew	45 N•m	[35 ft-lb]

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]

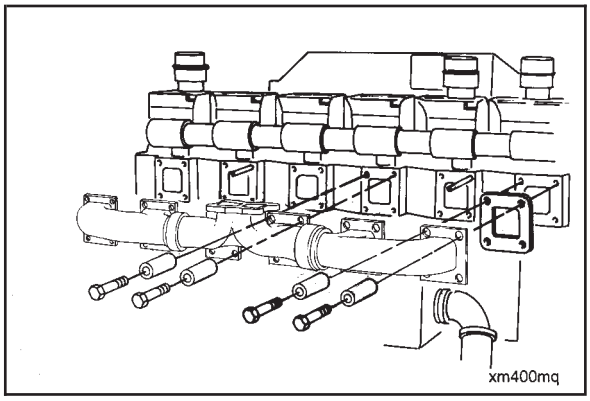
⚠ CAUTION ⚠

Do not use gasket cement or the gasket will fail.

Install the guide studs used during removal.

Use contact adhesive and attach the gasket on the cylinder head exhaust ports.

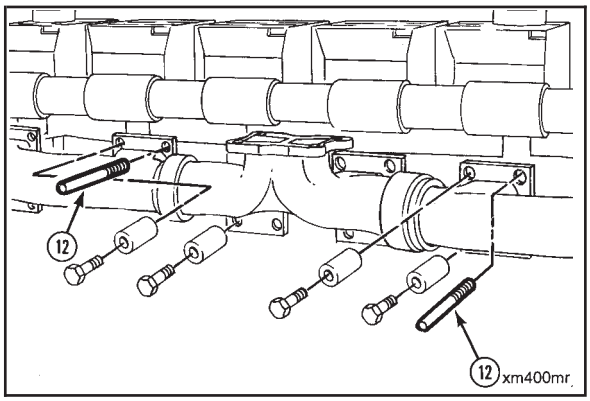
Install the exhaust manifold.



Apply an antiseize compound on the capscrew threads.

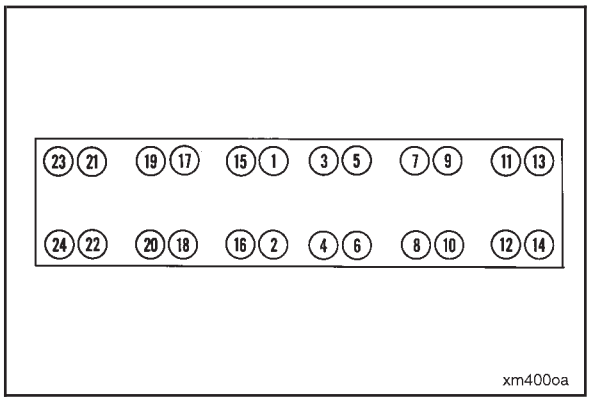
Install the capscrews.

Remove the two guide studs (12) and install the remaining capscrews.



Tighten the capscrews in the sequence shown.

Torque Value: 45 N•m [35 ft-lb]

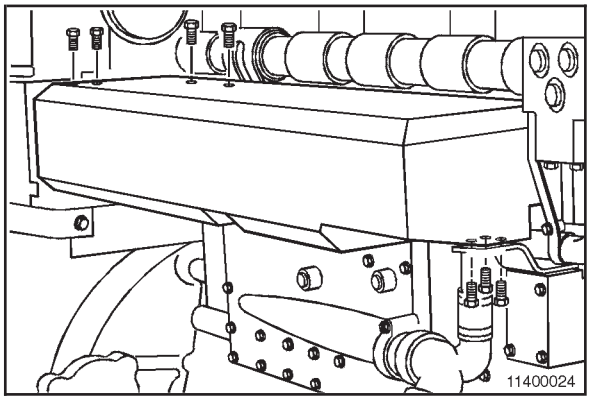


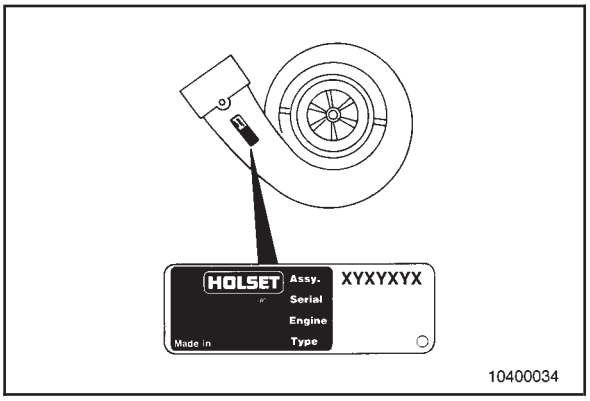
Marine Applications

NOTE: Do not rip, tear, or damage the insulation on the exhaust manifold.

Install the heat shield.

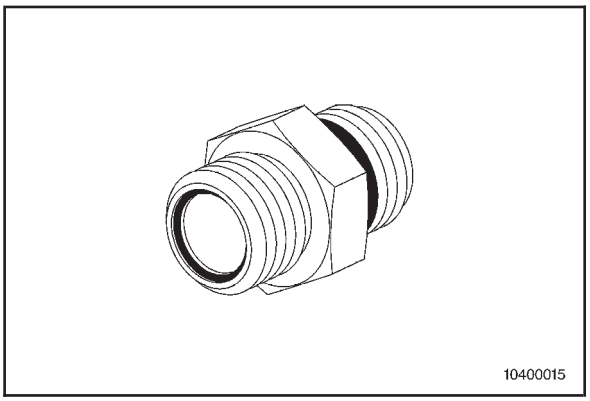
Install the 7 mounting capscrews.





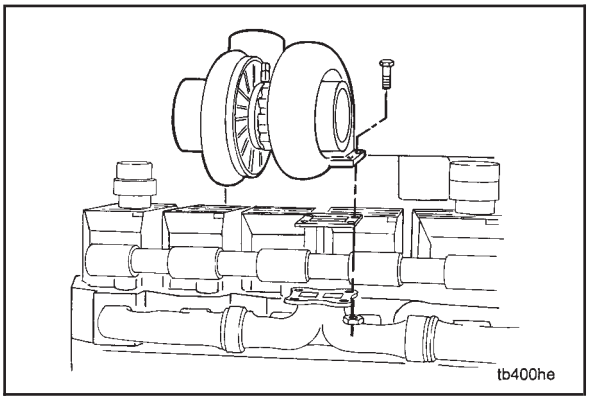
Holset turbocharger(s) are used on the QSK19 engine. Refer to the data tag on the turbocharger to determine the model.

NOTE: The name is also cast on the housing of a turbocharger.



NOTE: All turbocharger fittings are the flat face o-ring type fittings. Be sure the o-ring is in place before attaching the hose(s) to the fittings.

The Holset turbocharger uses a [9/16-18 UNF], straight thread, o-ring type oil supply fitting.



Apply an antiseize compound to the mounting capscrews.

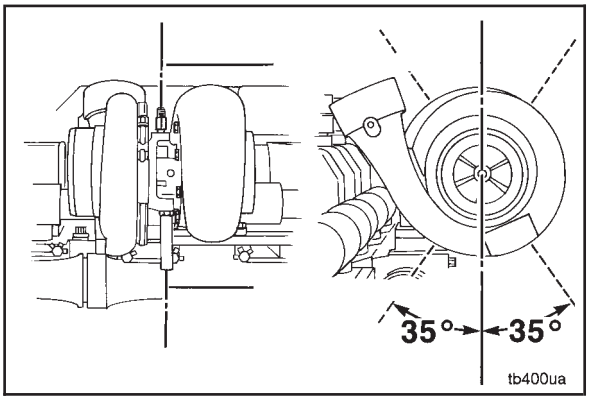
Install the gasket.

NOTE: The word “OUT” **must** be positioned toward the turbocharger or the raised gasket bead.

Install the turbocharger, washers, and nuts.

Tighten the capscrews.

Torque Value: 40 N•m [30 ft-lb]



Position the turbocharger drain tube. The drain tube **must** be within 35 degrees of vertical. Turn the bearing housing to align the tube, if necessary.

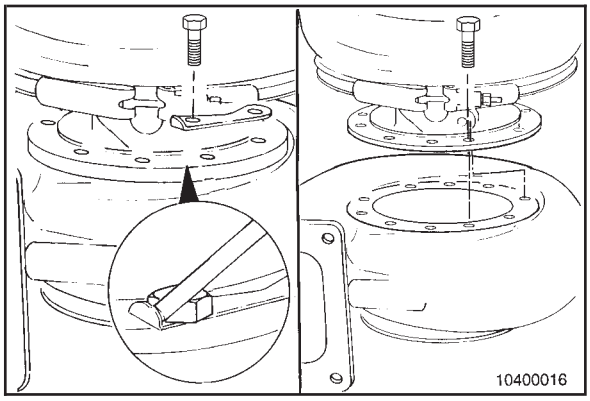
NOTE: The turbocharger uses capscrews to attach the bearing housing to the turbine housing.

Bearing Housing Adjustment

Bend the lockplate off the capscrew heads.

Remove the capscrews.

Rotate the bearing housing. Align the drain tube and the capscrew holes.

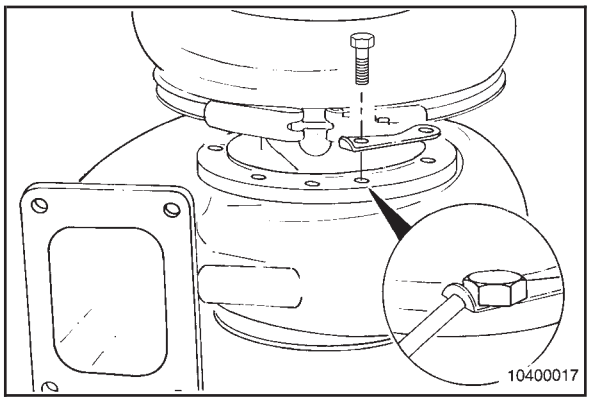


Install the lockplates and capscrews.

Tighten the capscrews.

Torque Value: 20 N•m [180 in-lb]

Bend the lockplate tabs over the capscrews.



⚠ CAUTION ⚠

These parts are a safety-related item. Be sure the parts are clamped correctly to prevent fretting.

Install the oil drain tube and gasket.

Tighten the capscrews.

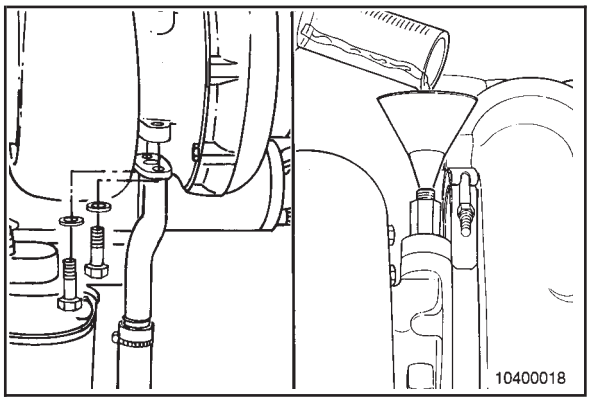
Torque Value: 45 N•m [35 ft-lb]

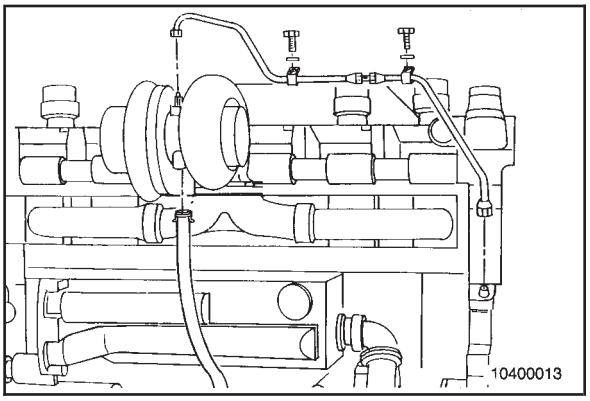
Tighten drain hose swivel to oil pan adapter.

Torque Value: 95 N•m [70 ft-lb]

Pour clean engine oil into the turbocharger oil supply fitting.

Turbocharger Oil Supply
50 to 60 cc
[2.0 to 3.0 oz.]

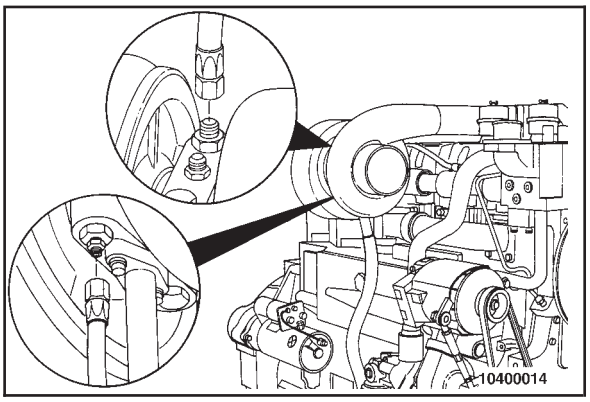




Connect the oil supply hose.

Tighten the hose fitting.

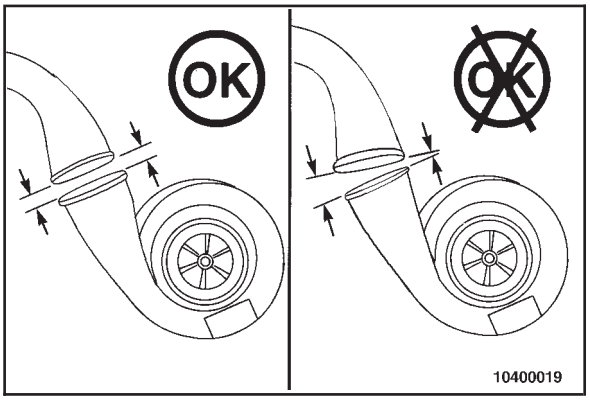
Torque Value: 31 N•m [23 ft-lb]



Connect the coolant supply hose and the coolant return hose to the turbocharger.

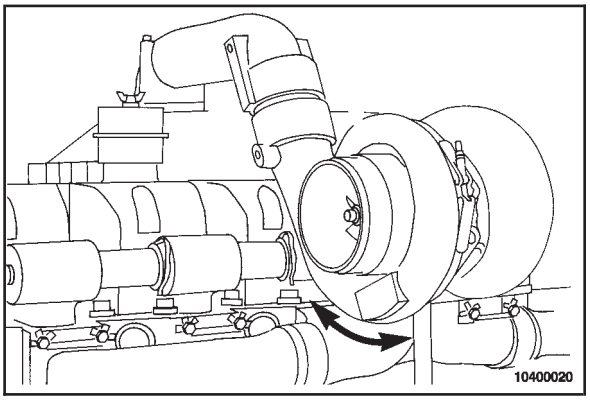
Tighten the hose fittings.

Torque Value: 54 N•m [40 ft-lb]



Check the air crossover-to-turbocharger alignment.

- Install the air crossover on the aftercooler.
- Look at the alignment between the crossover and the turbocharger compressor outlet.
- Remove the crossover and proceed with the assembly if the alignment is correct.
- Proceed to the next step to adjust the compressor housing if the alignment is **not** correct.



To adjust the turbocharger compressor housing alignment:

Loosen the V-band clamp.

Turn the compressor housing to the correct alignment.

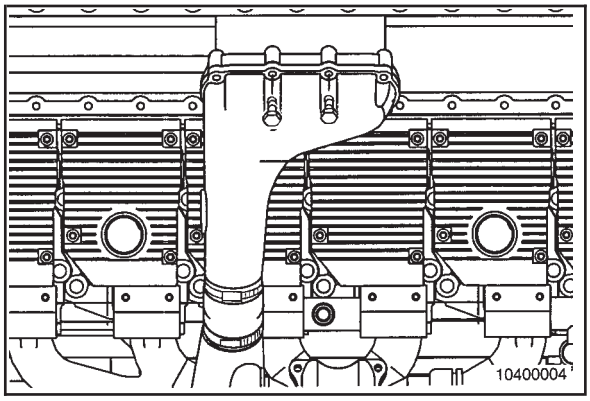
Tighten the clamp.

Torque Value: 8 N•m [75 in-lb]

Tap the clamp with a mallet and tighten the clamp again.

Install the hose and two hose clamps on the air crossover tube.

Install the air crossover. Slide the hose down and over the turbocharger outlet. Install the gasket and capscrews.



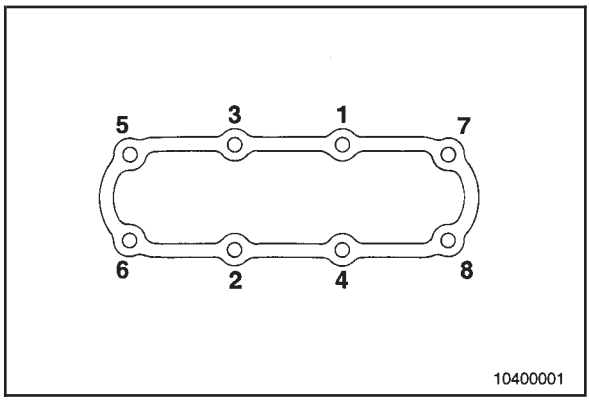
Use the sequence illustrated.

Tighten the capscrews.

Torque Value 45 N•m [35 ft-lb]

Tighten the clamps.

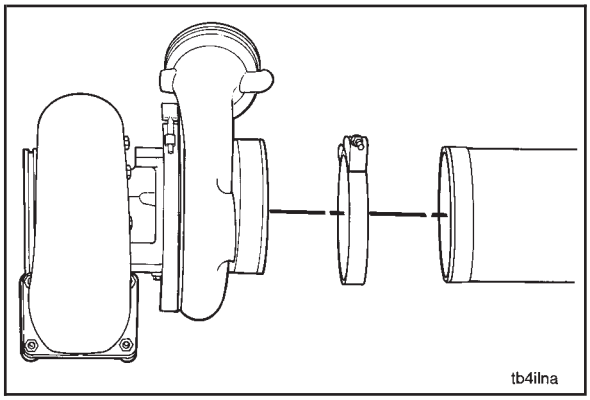
Torque Value 8 N•m [75 in-lb]



Connect the inlet piping to the turbocharger.

Tighten the clamps.

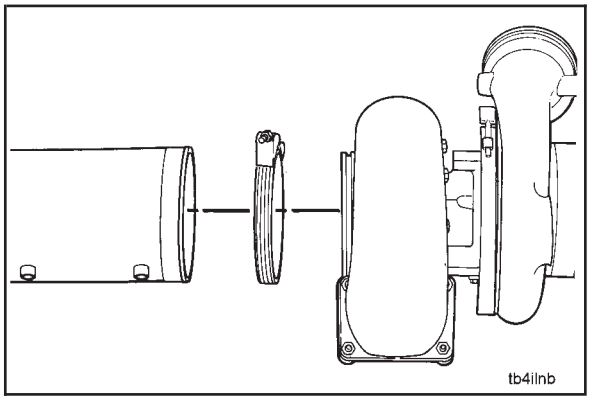
Torque Value: 8 N•m [75 in-lb]

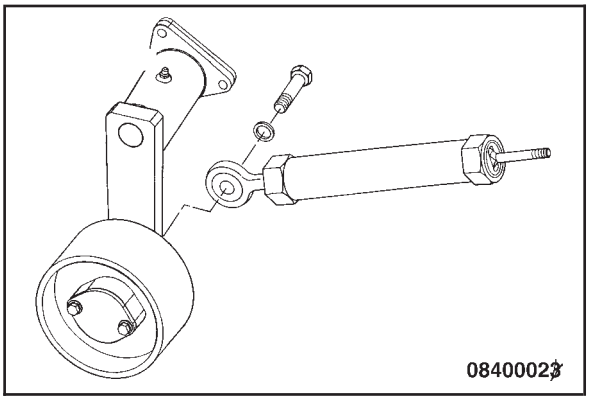


Connect the exhaust piping to the turbocharger.

Tighten the V-band clamp.

Torque Value: 8 N•m [75 in-lb]

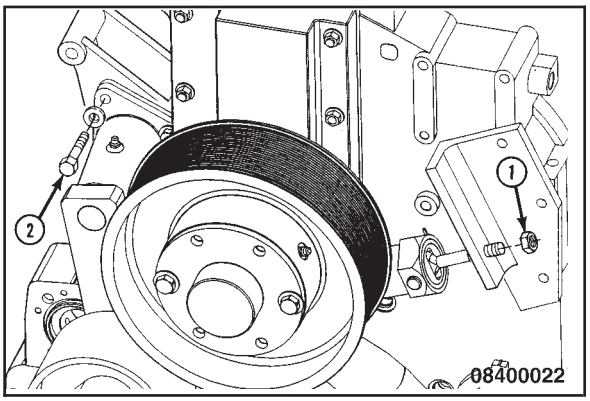




Install the belt tensioner on the idler arm.

Tighten the capscrews.

Torque Value: 201 N•m [75 ft-lb]

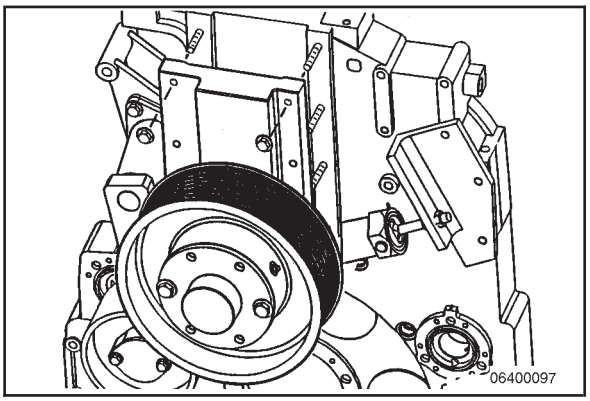


Install the idler arm assembly and capscrews (2).

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]

Install the belt tensioning nut (1). Do **not** tighten the nut.



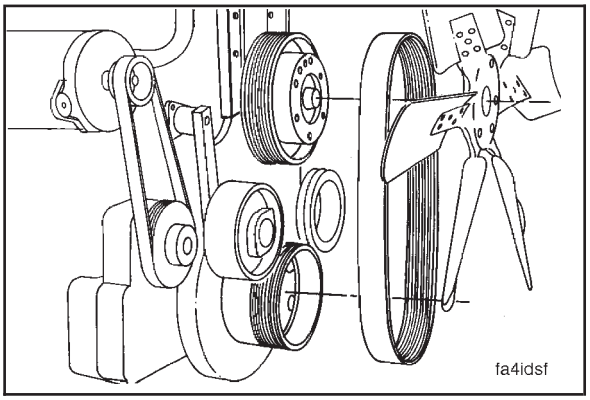
⚠ CAUTION ⚠

This assembly weighs more than 23 kg [50 lb] . To avoid personal injury, use a hoist or get personal assistance.

Install the fan hub, the eight washers and nuts.

Tighten the fan hub nuts.

Torque Value: 34 N•m [25 ft-lb]



Install the fan belt.

Install the fan.

Tighten the belt tensioning nut.

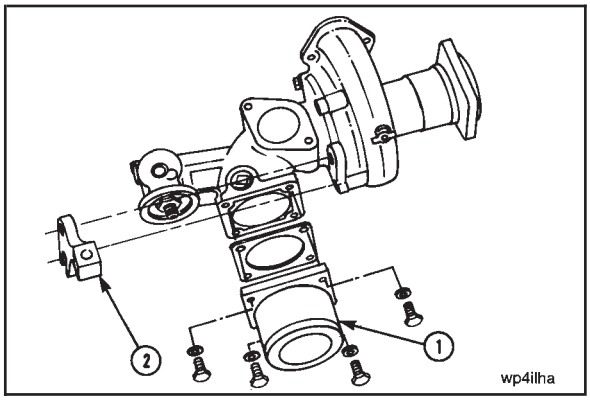
Install the inlet connection (1), gasket, and capscrews.

Tighten the capscrews.

Torque Value: 40 N•m [30 ft-lb]

NOTE: Do **not** tighten the support bracket until the water pump is assembled to the engine. Use a heavy, plain washer on the capscrew that attaches through the slotted hole.

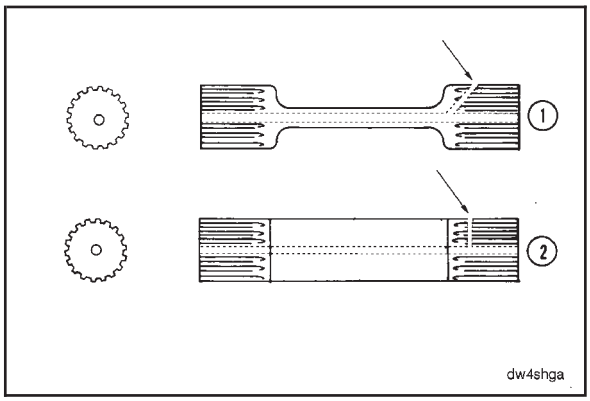
Install the support bracket (2).



NOTE: Failure of the water pump drive shaft will result when the wrong shaft is installed.

Use shaft (1) with cast iron impeller pumps (Marine applications). Use shaft (2) with phenolic (plastic) impeller pumps.

NOTE: Install the shaft with the oil hole at the side of the shaft toward the water pump.



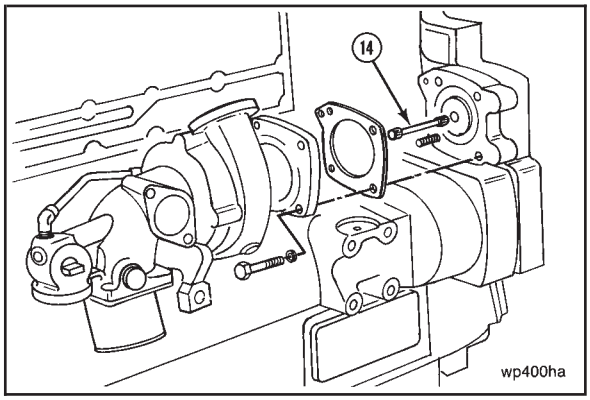
Use engine oil and lubricate the drive shaft (14). Install the shaft in the splined hole in the water pump drive.

NOTE: Do **not** tighten the capscrews and nut until the support bracket is aligned with the cylinder block.

Install the gasket and water pump. Install three capscrews and nuts.

Tighten the capscrews and nuts.

Torque Value: 45 N•m [35 ft-lb]



The support bracket must be flat against the water pump and the cylinder block. Align the bracket before tightening the capscrews.

Install the capscrew through the bracket.

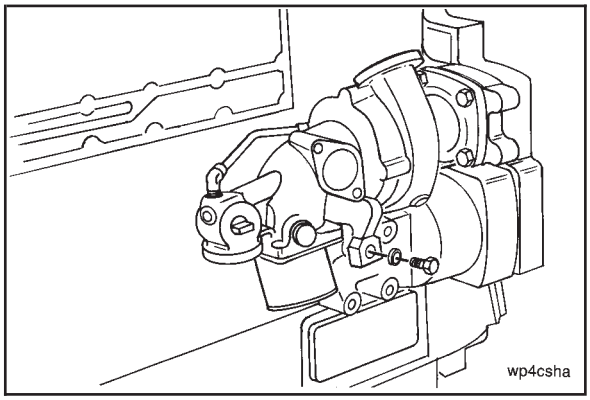
Tighten the capscrew.

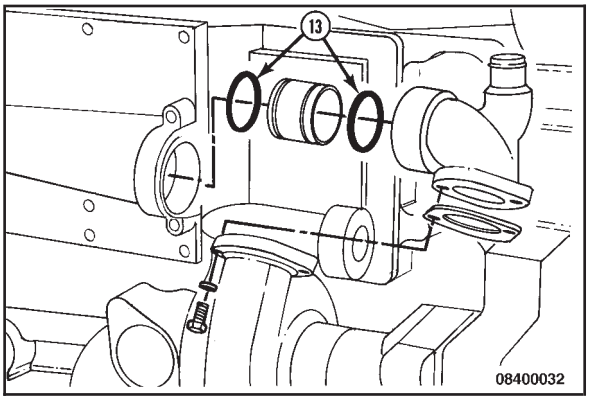
Torque Value: 206 N•m [150 ft-lb]

Check the alignment between the support bracket and the water pump. Loosen the capscrew and adjust if necessary.

Tighten the capscrews holding the support bracket to the water pump.

Torque Value: 45 N•m [35 ft-lb]





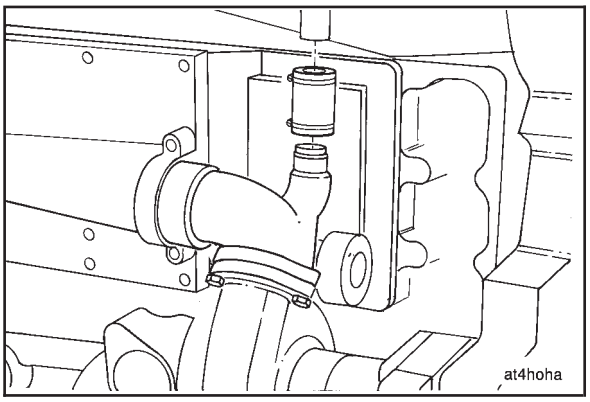
Use vegetable oil and lubricate the o-rings (13).

Install the transfer tube in the water pump outlet connection.

Install the water pump outlet connection, gasket, and capscrews.

Tighten the capscrews.

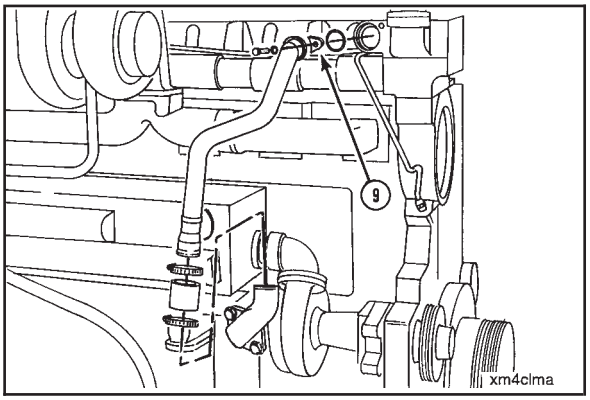
Torque Value: 45 N•m [35 ft-lb]



Connect the aftercooler supply hose to the water pump outlet connection.

Tighten the clamps.

Torque Value: 6 N•m [50 in-lb]



Install the bypass connection gasket.

Tighten the capscrews.

Torque Value: 40 N•m [30 ft-lb]

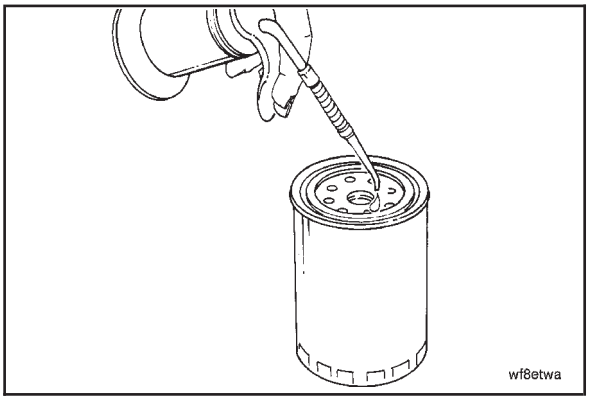
Use vegetable oil and lubricate the o-ring on the bypass tube. Install the bypass tube.

Install the retainer and capscrew.

Tighten the capscrew and the hose clamps.

Torque Value:

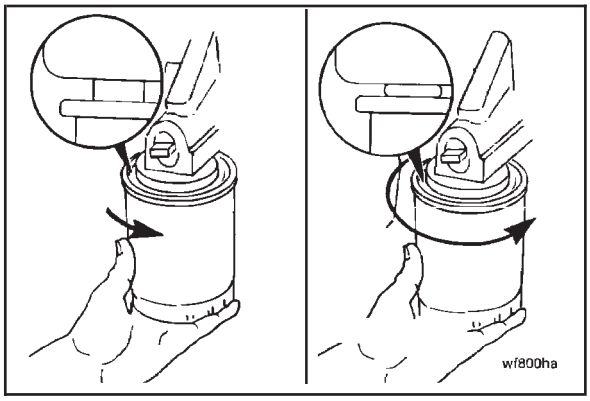
Capscrew	45 N•m	[35 ft-lb]
Hose Clamp	6 N•m	[50 in-lb]



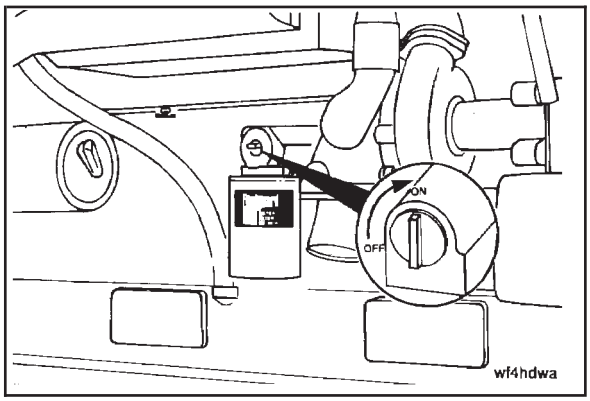
Use engine oil and lubricate the seal on the filter.

NOTE: Do **not** allow oil to get in the filter. It will adversely affect the SCA.

Install the coolant filter. Turn the filter until the seal touches the filter head. Turn an additional 1/2 to 3/4 of a turn after contact.



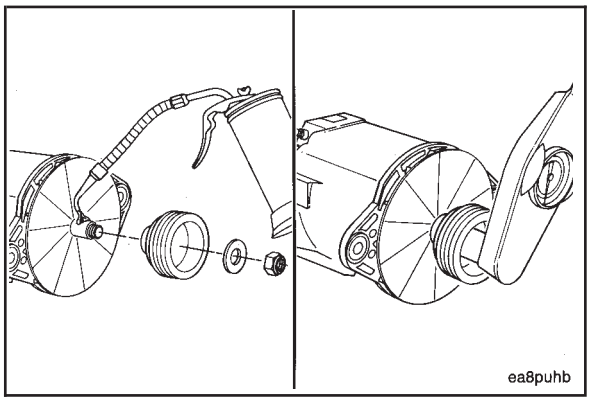
Turn the valve to the ON position.



Lubricate the shaft with engine oil. Install the pulley and nut on the alternator shaft.

Tighten the nut.

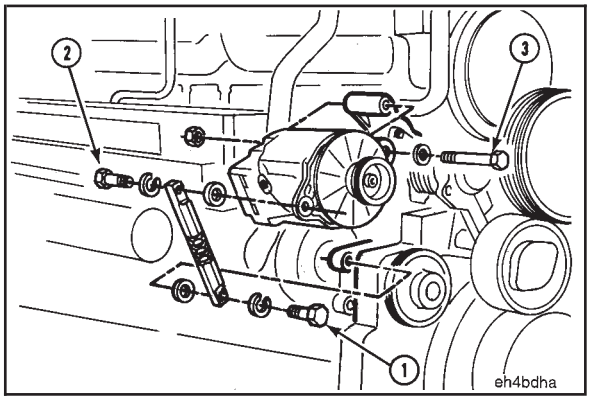
Torque Value: 100 N•m [75 ft-lb]

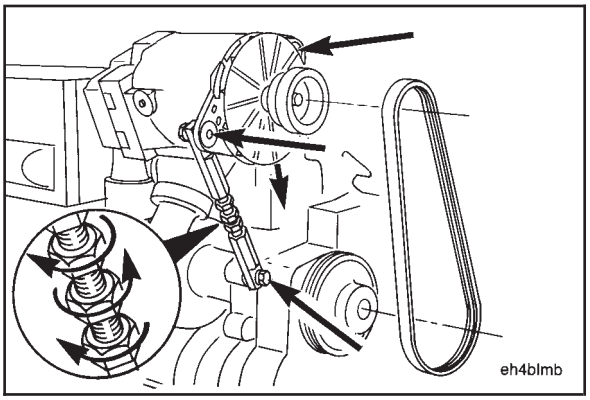


The belt **must** be adjusted before the capscrews are tightened.

NOTE: The end of the adjusting link with the largest area at the capscrew hole **must** be nearest to the alternator.

Install the alternator and the adjusting link as shown.

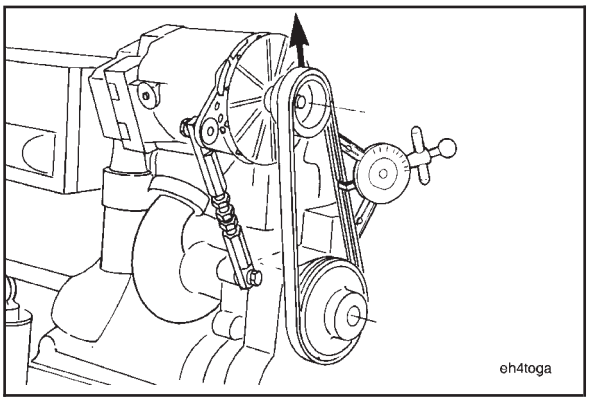




⚠ CAUTION ⚠

Do not attempt to pry the belt on the pulley to avoid damage to pulley and belt.

Install the belt. Turn the adjusting screw **counterclockwise** to shorten the link if necessary.

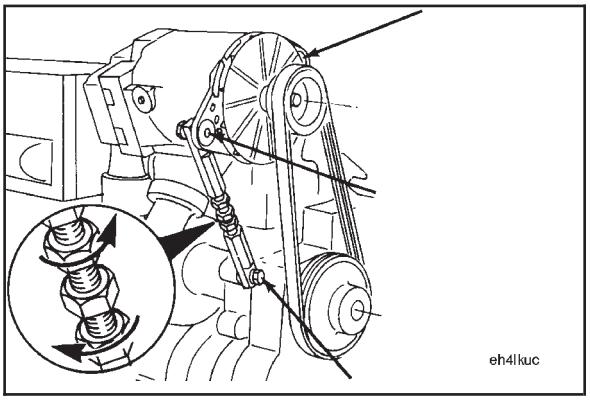


Turn the adjusting screw clockwise to tighten the belt.

Tighten the belt.

Belt Tension 670 N [150 lbf]

Use the (Burroughs) belt tension gauge, Part No. ST-1138, to check the belt tension.



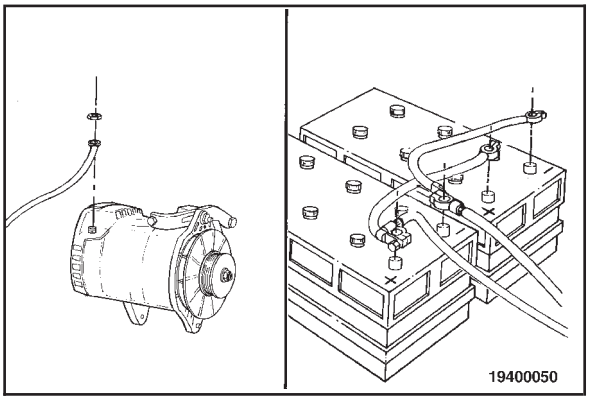
NOTE: The lower jam nut has **left-hand** threads.

Tighten the jam nuts on the adjusting screw.

Tighten the adjusting link and alternator mounting capscrews.

Torque Value:

Jam Nuts	55 N•m	[40 ft-lb]
Alternator Mounting Capscrews	55 N•m	[40 ft-lb]



Connect the wiring to the alternator.

⚠ WARNING ⚠

Always connect the negative (-) cable last to avoid sparks that can ignite explosive battery gases.

⚠ WARNING ⚠

Batteries emit hydrogen gas. To avoid explosion and personal injury, do not smoke or allow ignition source in area when servicing batteries.

Connect the batteries.

NOTE: Not all engines use spacers.

NOTE: The wet type flywheel housing requires gaskets for the starting motor.

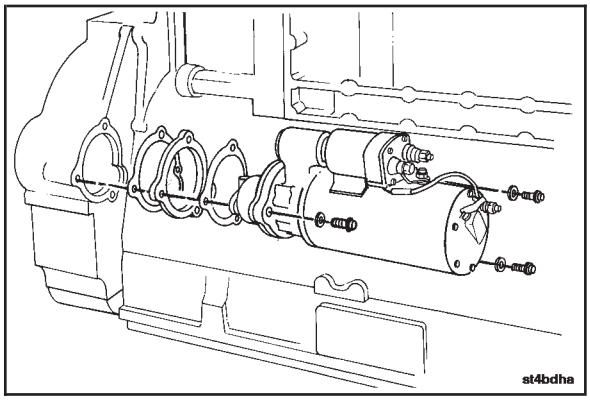
Install any spacer or gaskets.

Install the starting motor and capscrews.

Use the following to tighten the capscrews.

Torque Value:

W/Cast Iron Flywheel Housing	215 N•m	[160 ft-lb]
W/Aluminum Flywheel Housing	195 N•m	[145 ft-lb]



⚠ WARNING ⚠

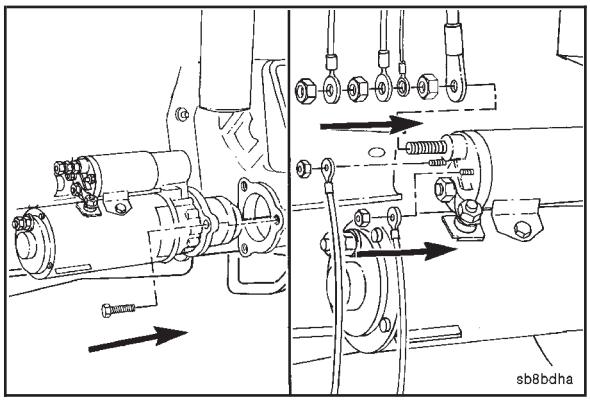
Always connect the negative (-) cable last to avoid sparks that can ignite explosive battery gases.

⚠ WARNING ⚠

Batteries emit hydrogen gas. To avoid explosion and personal injury, do not smoke or allow ignition source in area when servicing batteries.

Install the electrical connections to the starting motor.

Connect the batteries.



NOTES

Section 1 - Cylinder Block - Group 01

Section Contents

Cylinder Block - General Information

General Information

The barring mechanism is inside the front cover. The front cover **must** be removed from the engine to service or rebuild the barring mechanism.

This barring mechanism contains a spring loaded worm gear. The worm gear engages the camshaft gear when the barring shaft is pushed in the front cover and turned in a **counterclockwise** direction. The barring mechanism will **ONLY** turn the engine in the direction of normal rotation. Turn the barring shaft in a **clockwise** direction to disengage the worm gear. If the worm gear remains engaged accidently during the engine **START**, the engine rotation will disengage the parts **without** damage.

The static injection timing is adjusted by using different camshaft **keys**. The selection of a key will change the position of the camshaft lobes in relation to the timing mark on the camshaft gear. The gear **must** be removed to change the injection timing.

The camshaft end clearance is determined by the clearance between the camshaft and the thrust plate. The camshaft gear **must** be removed to adjust the camshaft end clearance.

NOTE: The camshaft does not have to be removed to remove the camshaft gear. Use the Camshaft gear puller, Part No. 3376400.

Camshaft's that are damaged or worn on the injector or the valve lobes **must** be replaced. **Cummins Engine Co., Inc.** does **not** recommend the grinding of camshaft lobes.

The crankshaft uses forged counterweights.

Oversize main bearings and thrust bearings are available for service. **Cummins Engine Co., Inc.**. recommends regrinding **ALL** of the main or the connecting rod journals when **ONE** requires regrinding

The vibration damper controls the twisting or torsional vibration of the crankshaft. A vibration damper is engineered for use on a **specific** engine model.

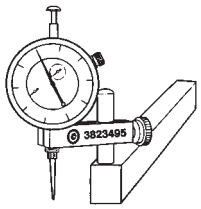
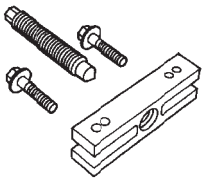
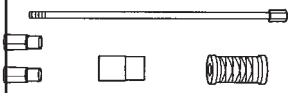
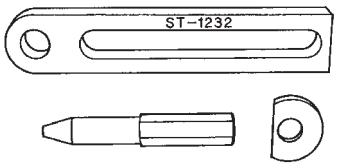
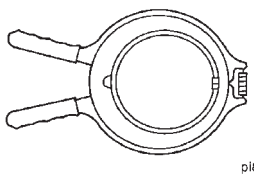
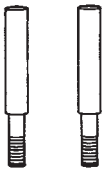
It is not economical to repair a vibration damper in the field. Install a new or a rebuilt vibration damper if the inspection indicates that a damper is defective.

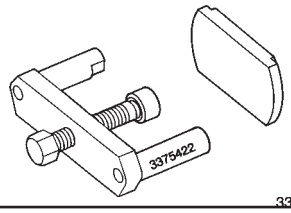
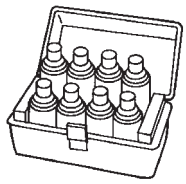
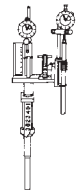
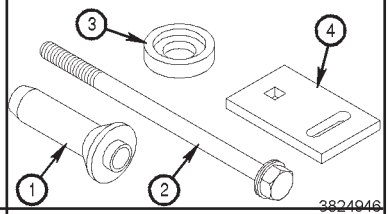
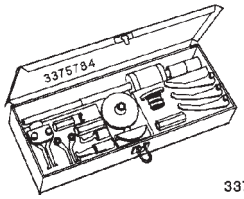
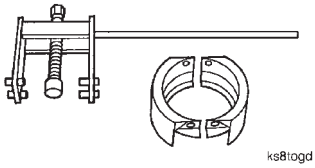
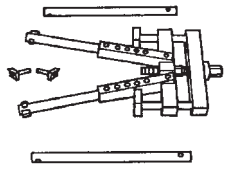
The **viscous** vibration damper has a limited service life. The damper **must** be replaced.

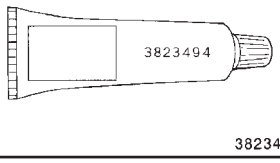
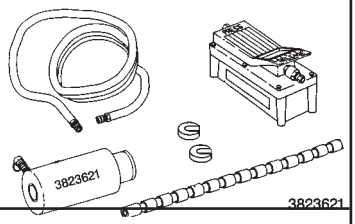
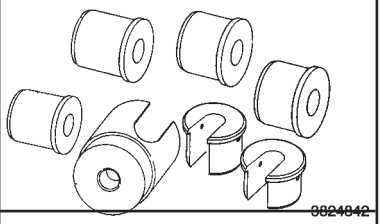
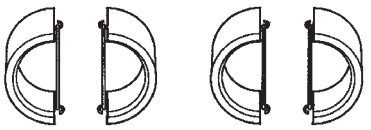
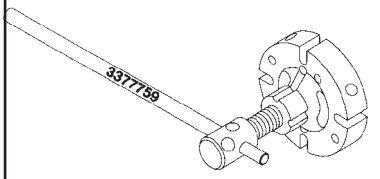
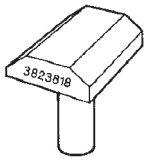
Service Tools

Cylinder Block

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

Tool No.	Tool Description	Tool Illustration
3823495	**Depth Gauge Assembly** Measure cylinder liner protrusion and cylinder liner counterbore ledge angle.	 3823495
ST-647	**Puller** Remove the alternator and accessory drive pulleys.	 ad8toga
ST-1134	**Dowel Pin Extractor** Remove dowel pins and crosshead guides.	 ck8toge
ST-1232	**Drill Ream Fixture** Machine dowel hole to install oversize dowels in cylinder block and flywheel housing. Use with a drill, reamer, and the appropriate drill/ream bushing set.	 st-1232
ST-1269	**Piston Ring Expander** Designed to install piston rings on the piston without damaging or distorting the rings.	 pi8togd
3375098	**Connecting Rod Guide Pins** Special nylon pins used to protect the crankshaft journal by guiding the connecting rod during installation or removal.	 cx8togg

Tool No.	Tool Description	Tool Illustration
3375422	**Liner Installation Tool** Install cylinder liner in engine.	
3375432	**Crack Detection Kit** Check for cracks in any engine component. Contains cleaner, developer, and penetrant.	
3824942	**Injection Timing Tool** Check injection timing. The timing fixture is designed to determine the push tube travel in relation to the piston travel.	
3824946	**Universal Timing Tool Adaptor Kit** This kit includes the hardware needed to upfit the Universal Injector Timing Fixture, Part No. 3823451 to the QSK19 engine.	
3375784	**Light Duty Puller Kit** Remove small bushings, oil seals, and bearings.	
3375834	**Puller Assembly** Remove the crankshaft gear from the crankshaft. Use with Part No. 3375835 Puller Jaw.	
3376015	**Universal Liner Puller** Remove cylinder liner from engine.	
3376326	**Pulley Installation Tool** Install the alternator and accessory drive pulleys.	

Tool No.	Tool Description	Tool Illustration
3823494	**Cummins Sealant** Used to prevent coolant or oil leaks. This is one part Room Temperature Vulcanizing (RTV) silicone rubber, adhesive, and sealant material having high heat and oil resistance, and low compression rate.	 3823494
3823621	**Camshaft Bushing Tool Hydraulic Actuator Kit** Hydraulic ram provides the force to install/remove cam bushings when used with installation/removal kit.	 3823621
3824863	**Camshaft Bushing Installation/Removal Kit** Used with the Part No. 3823621 Camshaft Bushing Hydraulic Actuator Kit to remove the camshaft bushing.	 3824842
3825150	**Camshaft Pilot** Install camshaft without damaging the camshaft bushings or camshaft.	 cg8togc
3824900	**Camshaft Gear Puller Kit** Remove camshaft gear from camshaft without removing camshaft from engine.	
3823818	**Main Bearing Roll-out Tool** Used to remove and install upper main bearing shell.	 3823818

Bearings, Connecting Rod (001-005)

Clean

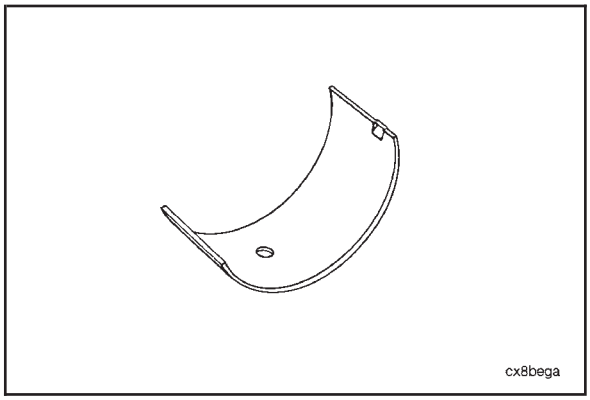
The bearings **must** be marked for location as they are removed for future identification. Each bearing **must** be installed in its original location if the bearing is installed again.

⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacture's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent. Clean the bearings.

Dry with compressed air.



Inspect for Reuse

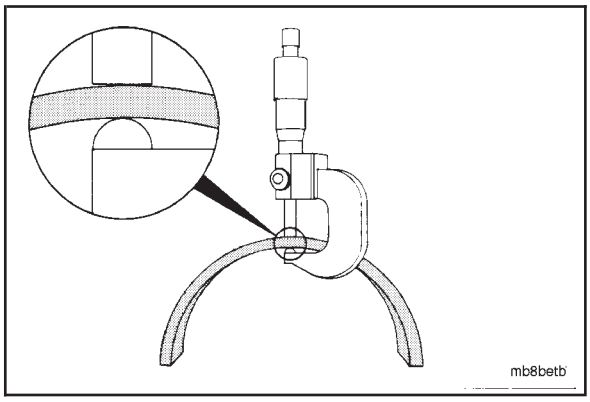
Use a ball-end micrometer.

Measure the thickness of the bearing in the wear location.

Replace the bearing when it is **not** within specifications.

Connecting Rod Bearing Thickness Standard or Oversize (OS)

Size	mm		in
Standard	3.106	MIN	0.1223
	3.157	MAX	0.1243
0.010 (OS)	3.233	MIN	0.1273
	3.284	MAX	0.1293
0.020 (OS)	3.360	MIN	0.1323
	3.411	MAX	0.1343
0.030 (OS)	3.487	MIN	0.1373
	3.538	MAX	0.1393
0.040 (OS)	3.614	MIN	0.1423
	3.665	MAX	0.1443



Bearings, Main (001-006)

Clean

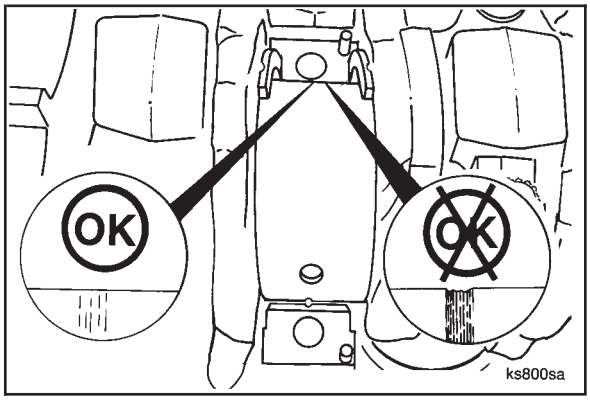
△ CAUTION △

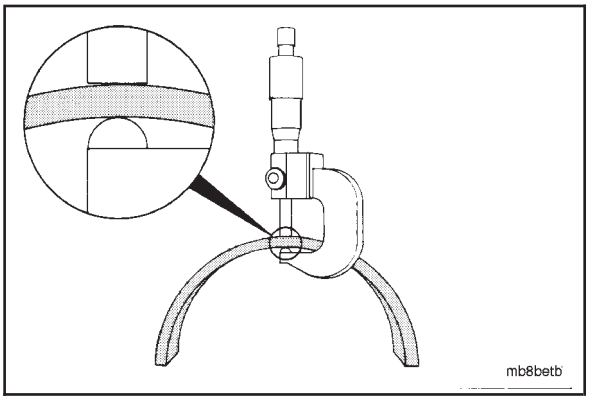
Do not use a scraper or a wire brush.

NOTE: Be sure the bearings are marked for location. The bearings **must** be installed in the original location after rebuild.

Use a lint-free cloth. Clean the crankshaft journals, and connecting rods. Check the crankshaft journal for damage.

Use solvent. Clean the bearings. Dry with compressed air.



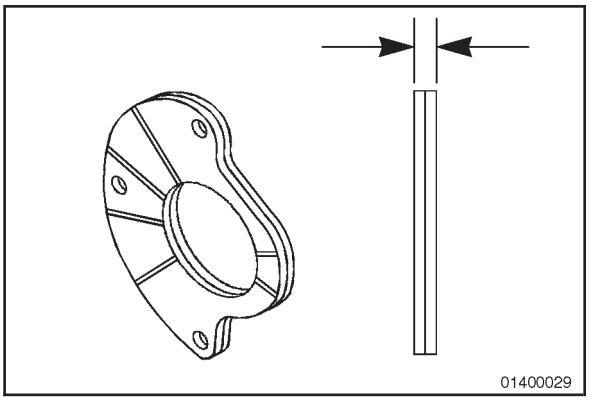


Inspect for Reuse

Use a ball-end micrometer. Measure the bearing thickness at the wear location. The bearing **must** be replaced if it is **not** within specifications.

Main Bearing Thickness
Standard or Oversize (OS)

Size	mm		in
Standard	4.280	MIN	0.1685
	4.336	MAX	0.1707
0.010 (OS)	4.407	MIN	0.1735
	4.463	MAX	0.1757
0.020 (OS)	4.534	MIN	0.1785
	4.590	MAX	0.1807
0.030 (OS)	4.661	MIN	0.1835
	4.717	MAX	0.1857
0.040 (OS)	4.788	MIN	0.1885
	4.844	MAX	0.1907

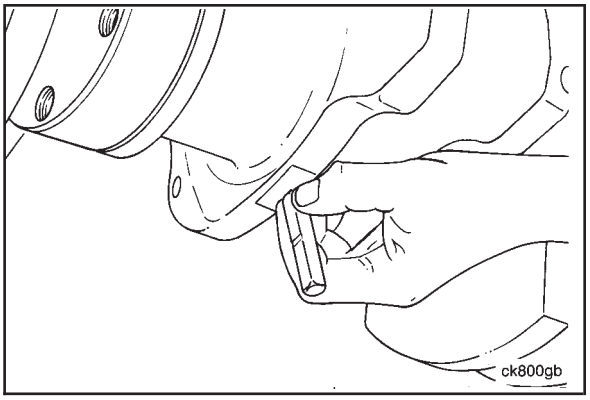


Measure

Measure the thrust bearing thickness. Measure the areas that shine. The shine indicates where the crankshaft has contacted the bearing.

Thrust Bearing Thickness
Standard or Oversize (OS)

	mm		in
Standard	3.82	MIN	0.1505
	3.90	MAX	0.1535
0.010 (OS)	4.08	MIN	0.1605
	4.15	MAX	0.1635
0.020 (OS)	4.33	MIN	0.1705
	4.41	MAX	0.1735



Bearings, Thrust (001-007)

Inspect for Reuse

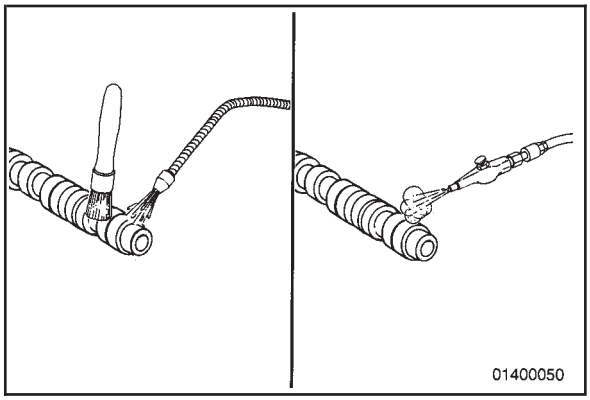
Thrust bearings are available in three sizes: [STD, 0.010, 0.020] OS. The **upper** and **lower** thrust bearings **must** be the **same** size. The **front** and **rear** can be **different** sizes.

Use the same size as those removed. The crankshaft will be marked on a counterweight adjacent to the thrust location if the thrust flange has been machined for oversize thrust bearings.

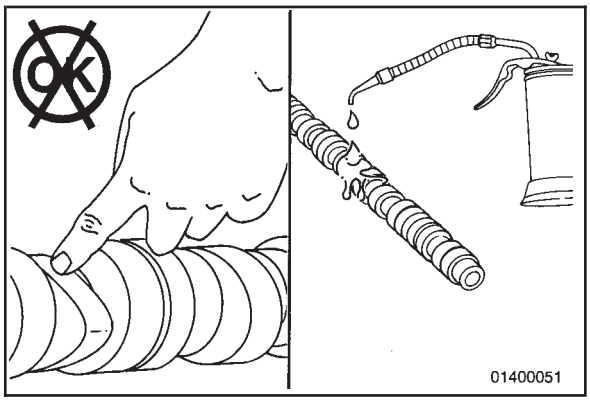
Assemble
Camshaft (001-008)

Clean

Use solvent and compressed air. Clean the camshaft.



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



Inspect for Reuse

CAUTION

Do not repair the camshaft by grinding the valve or the injector lobes.

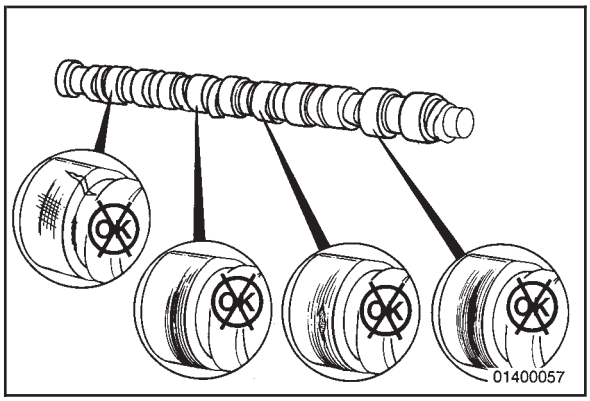
Inspect the camshaft.

Check the valve and the injector lobes for damage.

If the camshaft is damaged, it **must** be replaced.

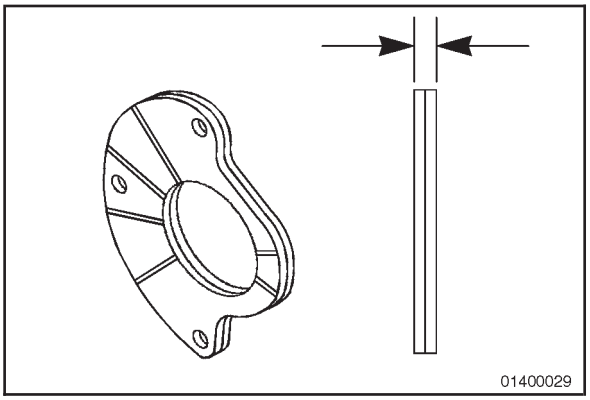
Measure each of the seven bushing journals.

Measure the O.D.

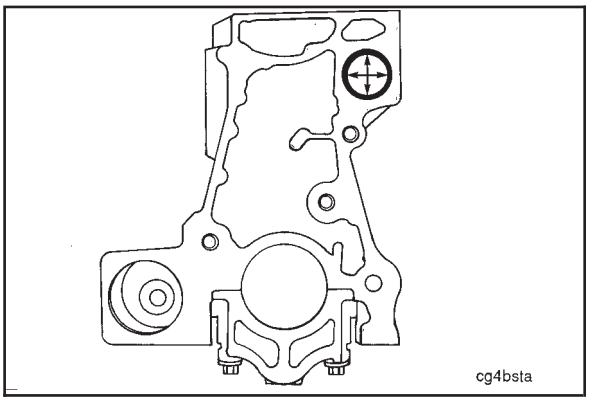


Camshaft Bushing Journal O.D.		
mm		in
76.07	MIN	2.995
76.12	MAX	2.997

If the O.D. is **not** within specifications, the camshaft **must** be replaced.



Inspect the camshaft thrust bearing. .

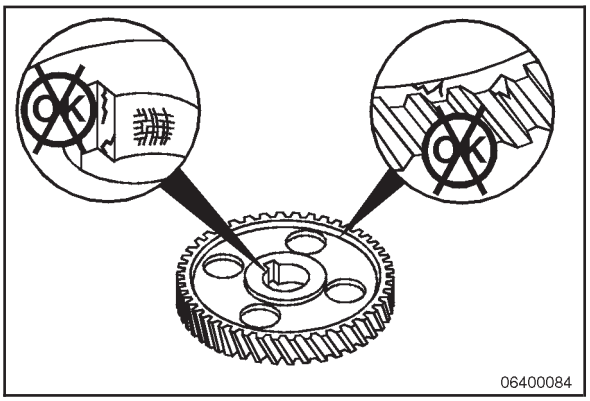


Visually inspect the amount of copper exposure on the camshaft bushing. If it extends more than 180 degrees around the bushing, the bushing **must** be replaced.

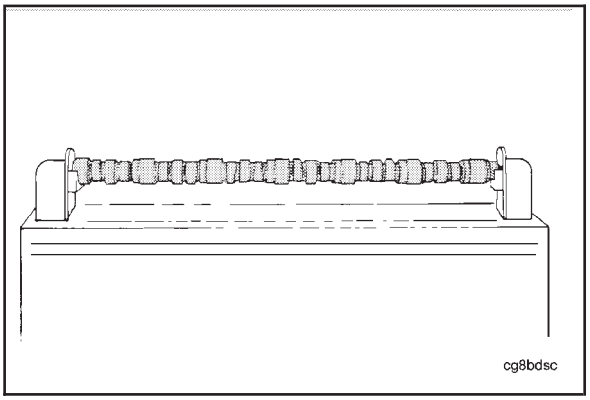
Measure the I.D.

Camshaft Bushing I.D.		
mm		**in**
82.550	MIN	3.2500
82.640	MAX	2.2535

If the bushing is **not** with specifications, the bushing **must** be replaced.



If camshaft requires replacement, inspect the camshaft gear for reuse. Refer to Procedure No. 001-013.



Magnetic Crack Inspect

The gear and the thrust plate must be removed before performing this check.

Use a magnetic particle testing machine. 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.

Check the camshaft for cracks.

⚠ CAUTION ⚠

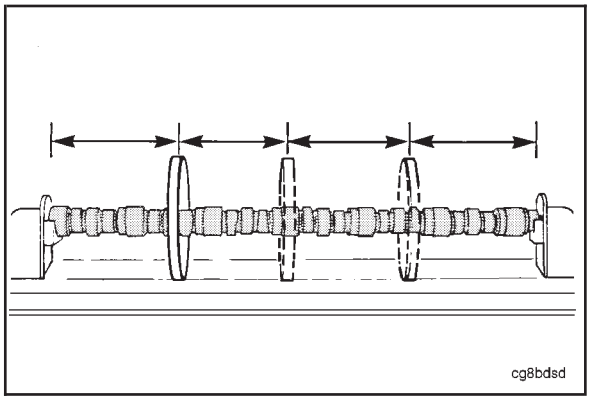
Use the coil shot method. Use a coil that is a minimum of 305 mm [12 in].

Apply coil shot. Use the continuous method.

Amperage	(Ampere Turns)
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.

Check the camshaft for cracks.

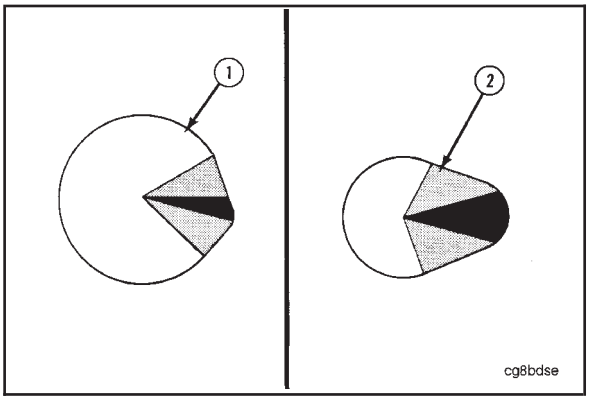


Limits of Acceptance-Bearing Journal

Do **not** use the camshaft if,

- there are 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.
- there is an open indication in a circumferential direction.

NOTE: The camshaft can be used if there are indications below the surface.



Limits of Acceptance- Open Indications

An open indication is visible to the eye after the suspension has been removed. An indication below the surface is **not** visible to the eye after the suspension has been removed.

Do **not** use the camshaft if:

- There is an indication in a circumferential direction.
- There is an indication in the black or shaded areas shown.
- There is an indication that is longer than 6 mm [1/4 inch].
- There is an indication that is closer than 5 mm [3/16 inch] from the edge.
- There are more than two indications on one of the lobes.

Limits of Acceptance- Indications Below the Surface

Do **not** use the camshaft if:

- There are more than two indications in the shaded area shown.
- There is an indication in the shaded area shown that is longer than 16 mm [5/8 inch].
- There are more than three indications in the white area shown.
- There is an indication in the black area on the injector lobe (1).
- There are more than two indications in the black area on the valve lobe (2).
- There is an indication in the black area on the valve lobe that is longer than 3 mm [1/8 inch].

CAUTION

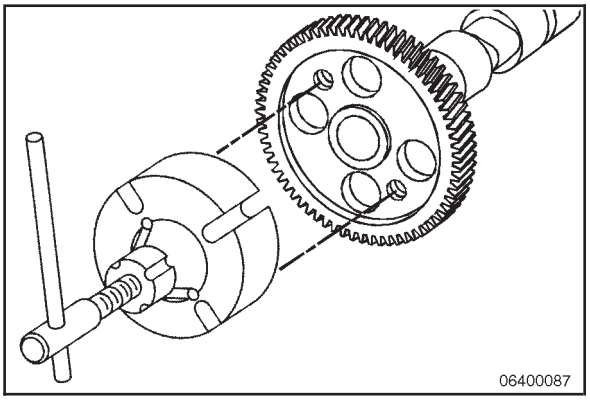
The camshaft must be demagnetized completely and cleaned thoroughly. Small metal particles will cause engine damage.

Demagnetize the camshaft.

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent or steam to clean the camshaft.



Camshaft Gear (Camshaft Removed) (001-013)

Remove

Use a camshaft gear puller, Part No. 3824900, to remove camshaft gear.

Attach the puller to the gear. Remove the gear.

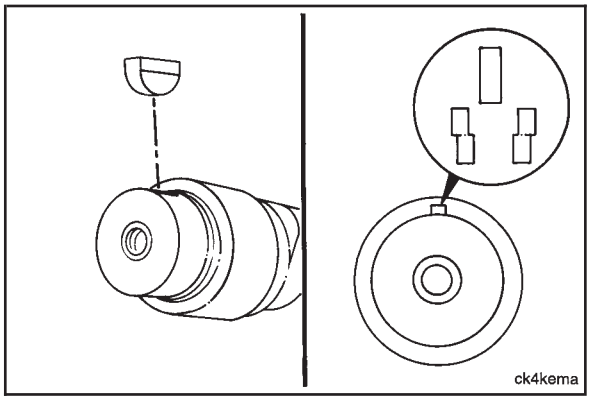
Remove the puller.

NOTE: Camshaft keys area available in different sizes (amount of offset). The injection timing is controlled by:

- The selection of the camshaft key.
- The direction of the key offset when compared to the camshaft gear rotation.
- The amount of offset.

Check and record the direction of the key offset when compared to the camshaft gear rotation (same or opposite).

Remove the key.



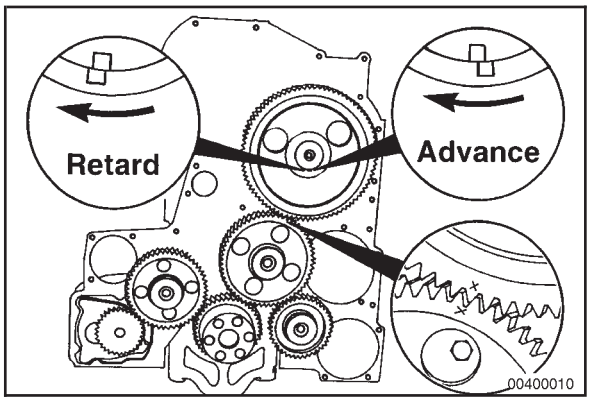
The camshaft key provides a means of indexing the camshaft with the gear.

Offset keys allow the camshaft profile to be rotated slightly while the gear train timing remains the same.

The more the top of the offset is moved in the direction of the camshaft normal rotation, the more the injection timing will be retarded. The push rod travel numerical value will increase.

NOTE: This applies to **ALL** Cummins engines.

NOTE: The direction of normal rotation on a QSK19 engine crankshaft is **clockwise** as viewed from the front of the engine.

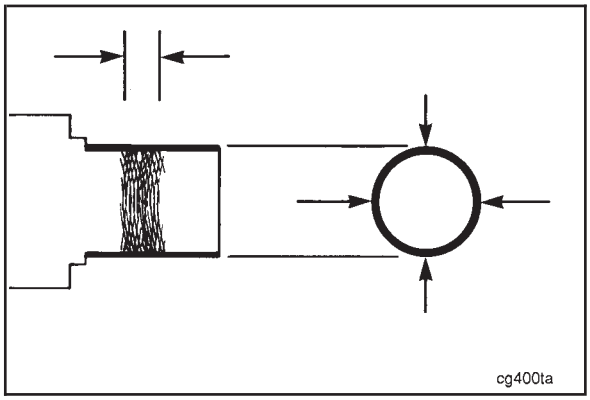


Inspect for Reuse

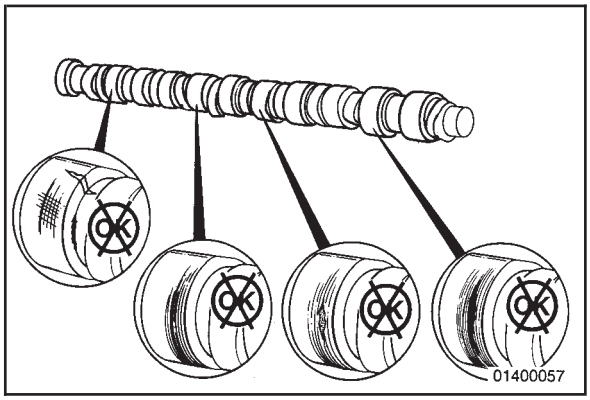
Inspect the camshaft and camshaft gear for reuse. Check for fretting damage. The camshaft **must** be replaced if the fretting damage is more than 3 mm [1/8 inch] wide.

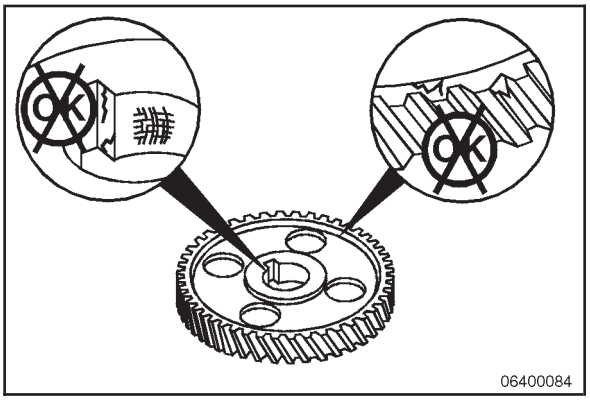
Measure the O.D. of the camshaft.

Camshaft O.D. (Gear Location)		
mm		**in**
57.200	MIN	2.2520
57.210	MAX	2.2525



Visually inspect the camshaft. Refer to Procedure No. 001-008.





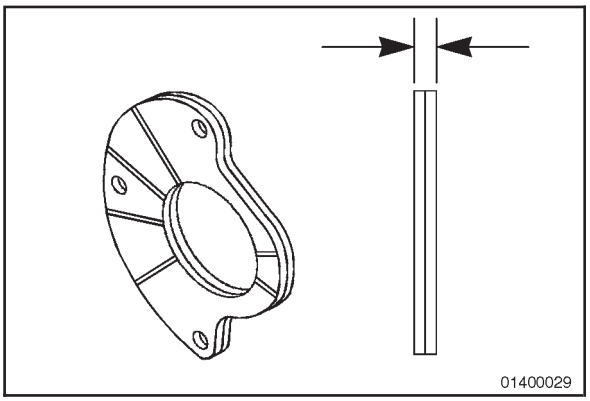
Visually inspect the camshaft gear for cracks, chipped or broken teeth.

Visually inspect the bore of the gear for fretting or burrs.

Measure the I.D.

Camshaft Gear I.D.		
mm		in
57.200	MIN	2.2520
57.210	MAX	2.2525

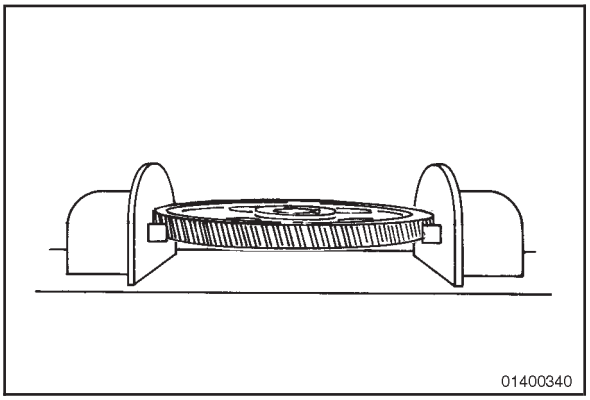
The gear **must** be replaced if the I.D. is **not** within specification.



Visually inspect the thrust bearing for damage.

Measure the thickness.

Thrust Bearing Thickness		
mm		in
9.12	MIN	0.359
9.44	MAX	0.372



Magnetic Crack Inspect

CAUTION

Use a copper braid contact that has neoprene covers to avoid burning the teeth of the gear.

CAUTION

If the gear contains a keyway, position the gear so that the keyway points toward one of the contacts when checking.

Use a magnetic particle testing machine.

Use the residual method to 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 mm to 203 mm [4 inch to 8 inch]	1500
Greater than 203 mm [8 inch]	2000

Check the gear for cracks.

⚠ CAUTION ⚠

If the gear contains a keyway, position the gear so that the keyway points toward the coil.

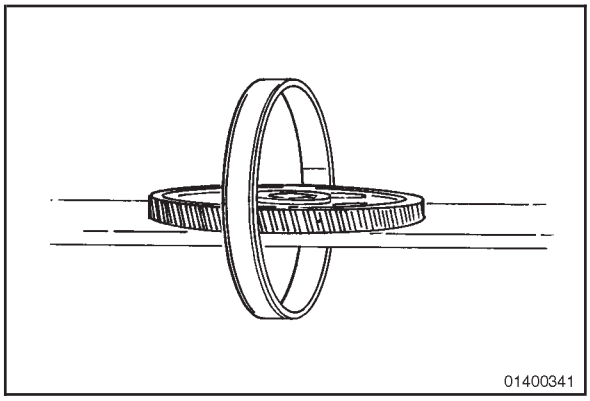
Use the residual method. Apply coil shot amperage.

Adjust the amperage to the specified value.

Gear O.D.	Ampere Turns
Less than 101 mm [4 inch]	4000
101 mm to 203 mm [4 inch 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.

Check the gear for cracks.

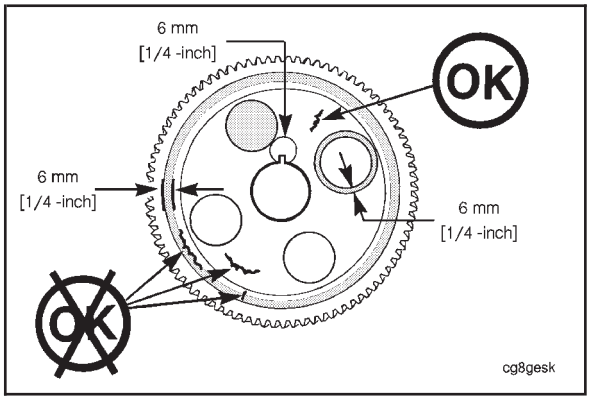


Limits of Acceptance - on Machined Surfaces

An open indication is visible to the eye after the wetting operation has been completed. An indication below the surface is **not** visible to the eye after the wetting operation has been completed. An indication below the surface can be seen with the use of the ultraviolet light that is part of the machine.

Do **not** use the gear if:

- There is an open indication.
- There is an indication below the surface that is in the shaded area as shown.
- There is an indication below the surface that is longer than 6 mm [1/4-in].



Limits of Acceptance - on Forged Surfaces

Do **not** use the gear if:

- There is an open indication that is in a circumferential direction.
- There is an open indication that is longer than 9.5 mm [3/8-in].
- There is an indication below the surface that is in the shaded area.

An indication below the surface in a radial direction is acceptable (OK) if it is in the area that is **not** shaded.

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

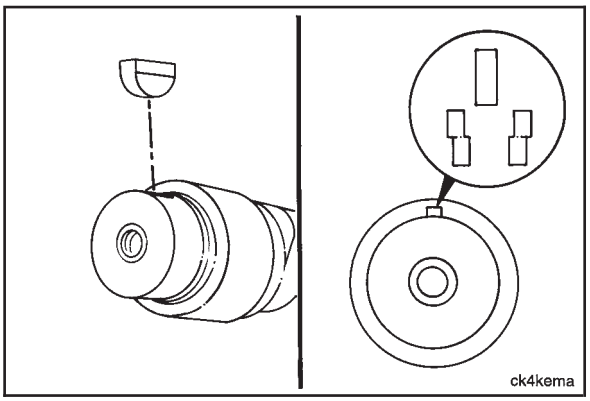
CAUTION

The gear must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the gear.

Use solvent and clean the gear.

Dry with compressed air.



Install

NOTE: The camshaft gear **must** be removed to adjust the injection timing. If the camshaft was replaced, do **not** install the camshaft gear until the injection timing has been verified.

Use a slip-fit gear to adjust injection timing. Refer to Procedure No. 006-025.

The following table lists the recommended camshaft key for each timing code. Machining tolerances on the camshaft and the gear can cause the injection timing not to be within specifications. If the timing is not within specifications, refer to Section 0 for instructions to choose an alternate camshaft key.

The amount of offset is based @ 5.1613 mm (0.2032 inch) of piston travel.

Timing Code	Camshaft Key	Amount of Offset
JF	216294	0.279 Inj.
KG	S-302	0.320 Inj.

⚠ WARNING ⚠

Wear protective clothing to prevent personal injury from burns.

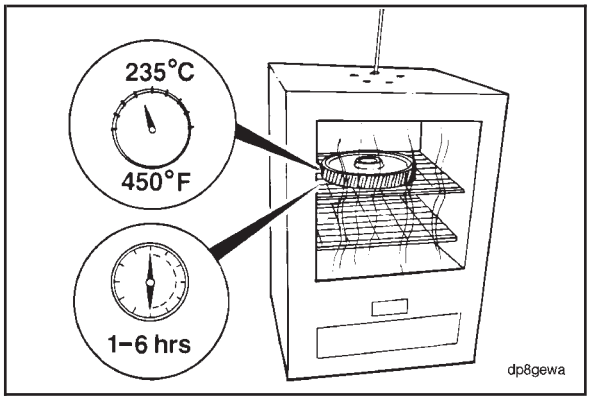
⚠ CAUTION ⚠

Do not exceed the specified time or the temperature. Damage to the gear and the gear teeth will result.

⚠ CAUTION ⚠

Do not attempt to install the gear without using heat.

Use an oven with the temperature adjusted to 235° C [450° F]. Heat the gear in the oven for a **minimum** of one hour but **not** more than a **maximum** of six hours. The I.D. of the gear will become larger and will simplify the installation.

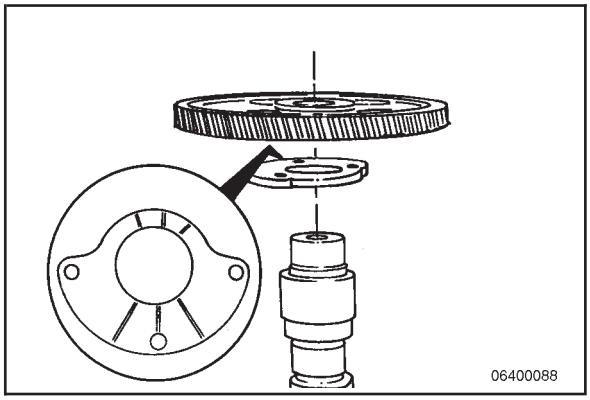


NOTE: The timing marks **must** be visible on the front of the gear after it is installed. The keyway in the gear **must** be aligned with the key.

Install the thrust plate. Install the camshaft gear.

⚠ CAUTION ⚠

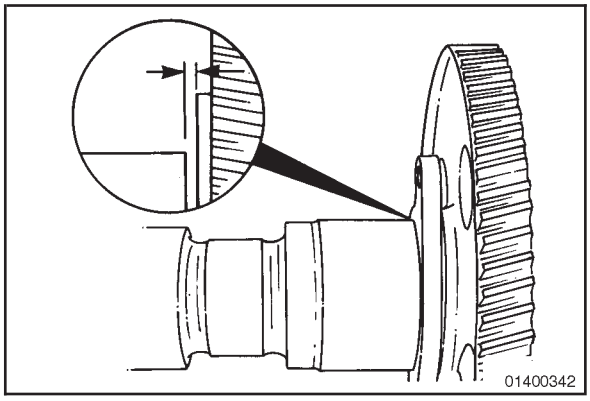
Allow the gear to air cool. Do not use water or oil to reduce the cooling time. It will cause the gear to crack.



Use a feeler gauge. Measure the camshaft thrust clearance.

Camshaft to Camshaft Gear Clearance		
mm		in
0.15	MIN	0.006
0.33	MAX	0.013

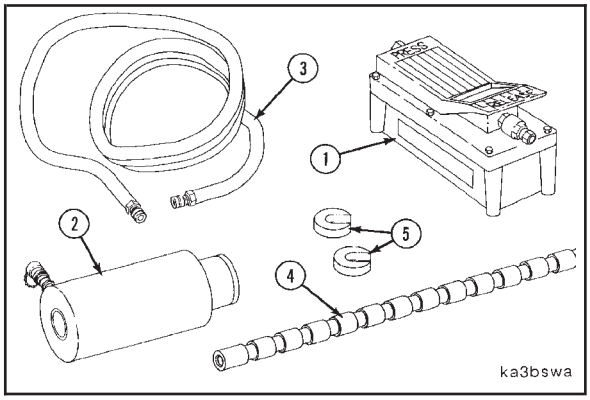
If the clearance is not within specification the gear **must** be removed.

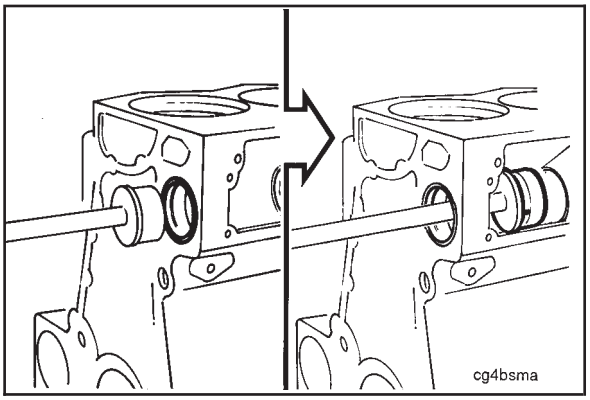


Camshaft Bushings (001-010)

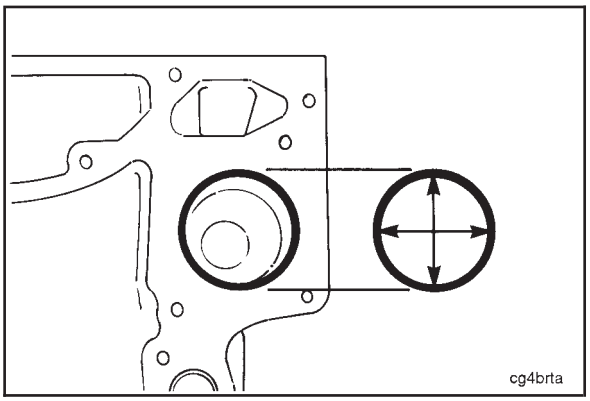
Remove

Use hydraulic actuator kit, Part No. 3823621, and camshaft bushing installation/removal kit, Part No. 3162228, to remove the camshaft bushings.





Remove the camshaft bushings.



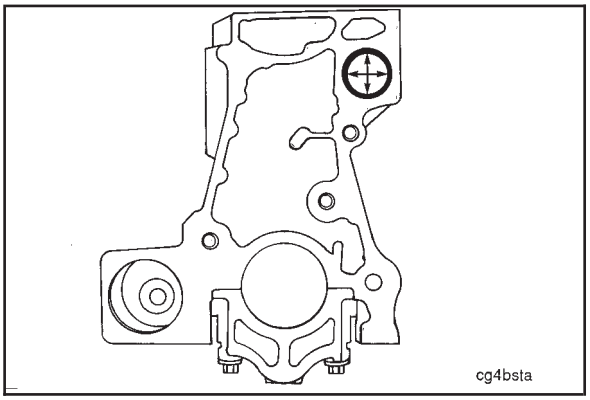
Inspect for Reuse

Inspect the camshaft bores in the block for reuse. Use an emery cloth to remove any burrs and sharp edges from the bore.

Measure the I.D.

Camshaft Bushing Bore in the Block		
mm		**in**
88.989	MIN	3.5035
89.015	MAX	3.5045

If the I.D. is **not** within specifications, install a repair sleeve.

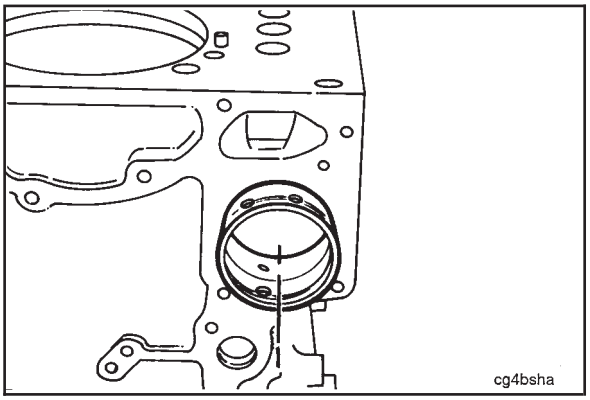


Visually inspect the amount of copper exposure on the camshaft bushing. If it extends more than 180 degrees around the bushing, the bushing **must** be replaced.

Measure the I.D.

Camshaft Bushing I.D.		
mm		**in**
82.550	MIN	3.2500
82.640	MAX	2.2535

If the bushing is **not** within specifications, the bushing **must** be replaced.



Install

Align the oil holes in the bushing with the oil drilling in the block.

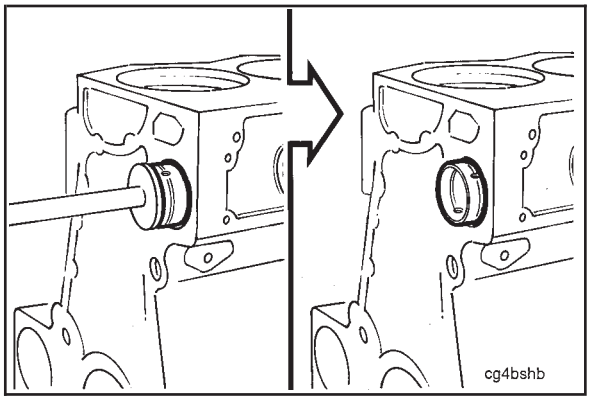
NOTE: The notch in the bushing **must** be positioned toward the front of the block.

⚠ CAUTION ⚠

Clean the oil groove in the back of the camshaft bushing to prevent contamination of the lubrication system.

Use the camshaft bushing driver assembly, Part No. 3376637, and the specified engine kit (mandrel). Install the bushing until the edge of the groove on the back (O.D.) is even with the edge of the block.

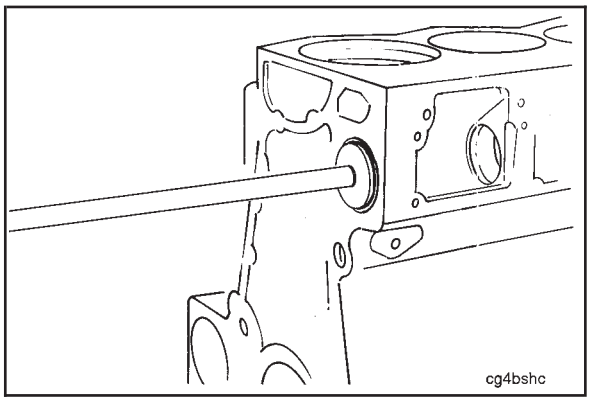
Clean the bushing O.D. Remove any metal shavings from the oil groove.



⚠ CAUTION ⚠

Be sure that the front bushing is below the surface of the block.

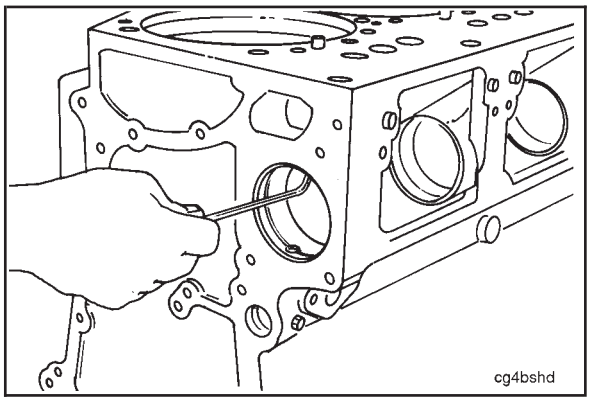
Install the bushing until the oil holes are aligned.

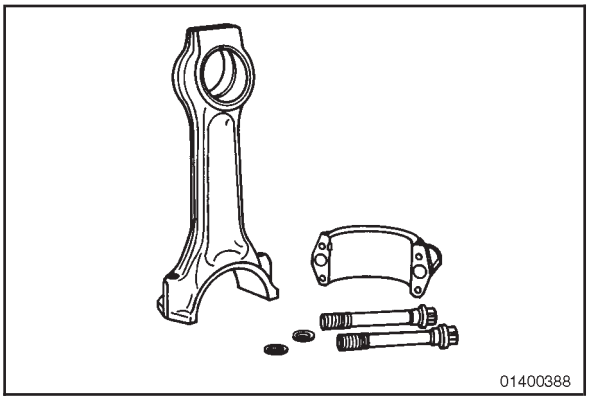


Use a 7 mm [1/4 inch] allen wrench. Check the alignment of the bushing oil holes.

There are three holes in each bushing. **All** holes **must** be aligned **except** on the front bushing.

NOTE: There is no drilling to align with the upper holes on the front bushing.





Connecting Rod (001-014)

Clean

⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacture's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

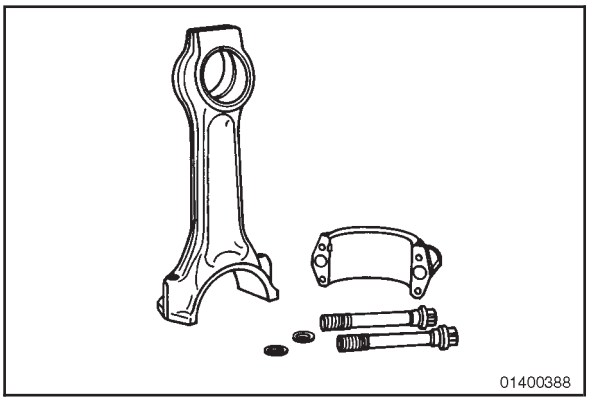
△ CAUTION △

The number on the connecting rod must be the same as the number on the rod cap. NEVER assemble a new cap to an old rod or an old cap to a new rod.

Remove the capscrews, washers, and the cap from the rod.

Use solvent. Clean the parts.

Dry with compressed air.

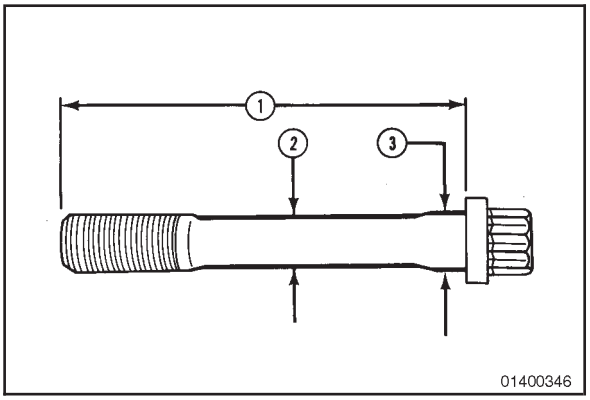


Inspect for Reuse

△ CAUTION △

The connecting rod and connecting rod cap must be replaced as an assembly if any fretting damage is visible on either piece.

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



Check the threads of the connecting rod capscrew for damage. Check under the capscrew head for cracks.

Measure the connecting rod capscrew

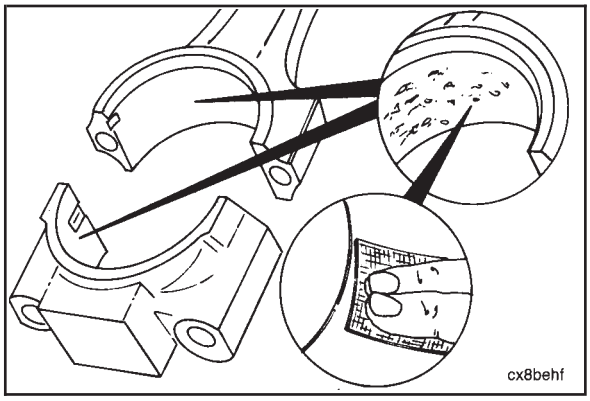
Capscrew Length (1)		
mm		in
117.09	MIN	4.610
117.86	MAX	4.640

Capscrew O.D. (2)		
mm		in
15.26	MIN	0.601
15.37	MAX	0.605

Capscrew O.D. (3)		
mm		in
17.35	MIN	0.683
17.45	MAX	0.687

NOTE: The capscrews **must** be replaced if **not** within specification.

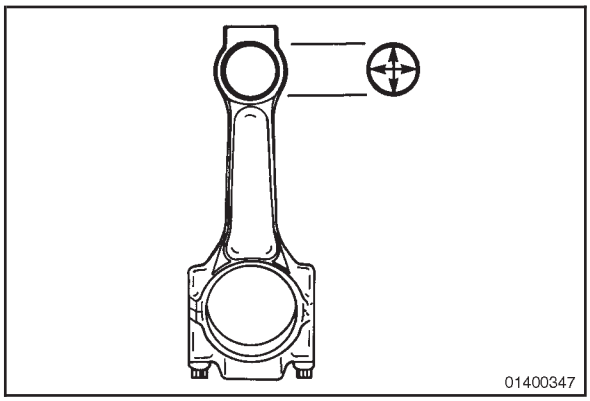
Visually inspect the bearing seating surface for nicks or burrs. If it is **not** possible to remove any nicks or burrs with a fine crocus cloth, the rod **must** be replaced.

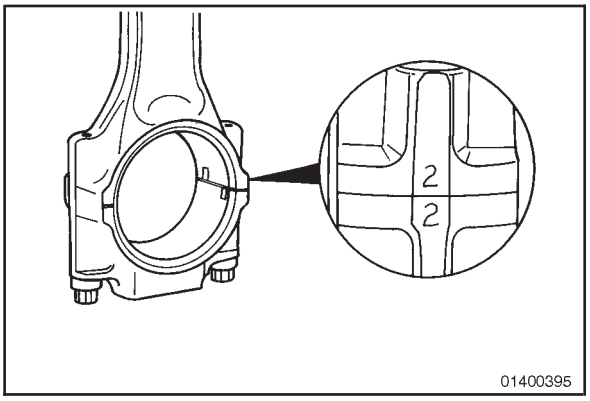


Measure the connecting rod wrist pin bearing I.D.

Connecting Rod Wrist Pin Bearing I.D.		
mm		in
60.99	MIN	2.4010
61.02	MAX	2.4025

The bushing **must** be precision machined after installation. If machining capability is available, the bushing can be replaced. Refer to the Alternative Repair Manual, Bulletin No. 3379035.





⚠ CAUTION ⚠

Use a vise with brass jaws to hold the rod. Notches, scratches, or dents in the I-beam area 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.

⚠ CAUTION ⚠

The connecting rod must be assembled with the capscrews tightened to specifications before stamping the cylinder identification number on the rod. Always stamp a new connecting rod with the cylinder number of the rod being replaced.

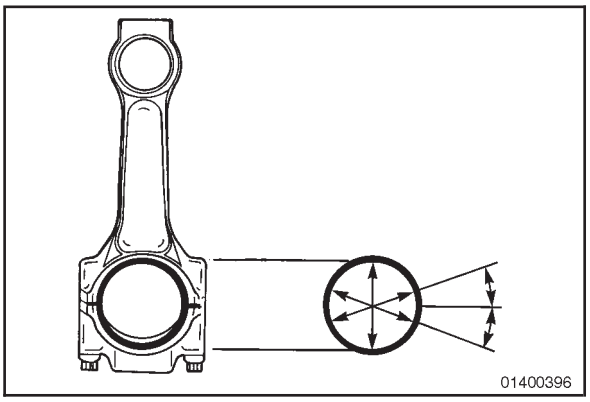
Use engine oil. Lubricate the connecting rod capscrews.

Assemble the rod, cap, washers, and the capscrews.

Tighten the capscrews in the following sequence:

Connecting Rod Capscrew Torque Value Sequence

Step 1.	100 N•m	[75 ft-lb]
Step 2.	200 N•m	[150 ft-lb]
Step 3.	290 N•m	[250 ft-lb]
Step 4. Loosen both capscrews.	mm	[in]
Step 5.	100 N•m	[75 ft-lb]
Step 6.	200 N•m	[150 ft-lb]
Step 7.	290 N•m	[250 ft-lb]



Use a dial bore indicator to measure the I.D. within a 20° arc from each side of the parting line.

Measure the I.D. at 90° from the parting line.

Connecting Rod Bearing Bore I.D.

mm		in
107.995	MIN	4.2518
108.005	MAX	4.2522

If any of the three measurements are **not** within specifications, the rod must be replaced or repaired.

⚠ CAUTION ⚠

The rod cap must be installed and torqued to specification or the measurements will be wrong.

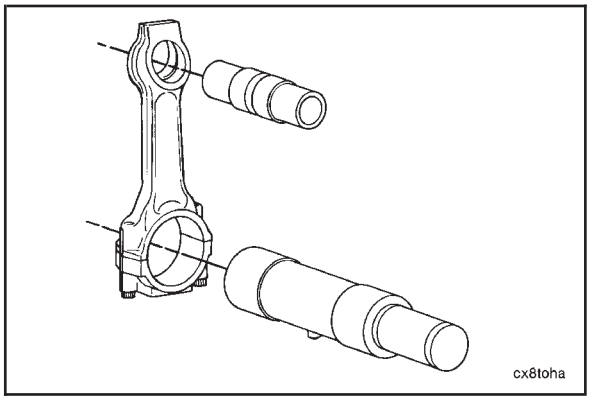
A connecting rod of known length, bend, and twist, called a **master** rod, is required to calibrate the fixture. A **new** connecting rod that the distance from the center of the crank pin to the center of the piston pin end to the center pin end (rod length) is known, can also be used.

Calibrate the Checking Fixture

Install the appropriate mandrel in the piston pin end of the master connecting rod.

NOTE: Be sure the locating pin in the mandrel for the crank pin end is touching the rod cap directly opposite the beam of the rod.

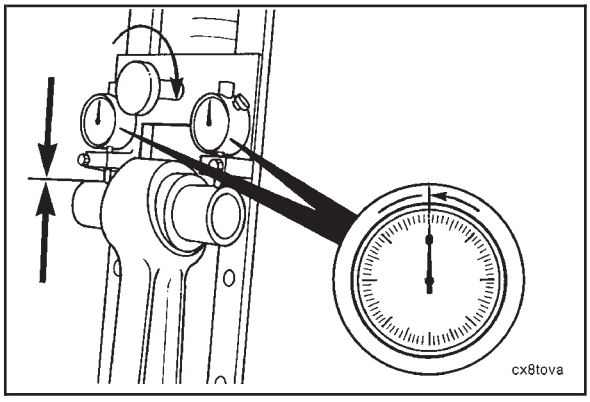
Install the mandrel in the crank pin bore of the master rod. tighten the mandrel so that it is centered in the bore correctly.



Install the master rod in the checking fixture.

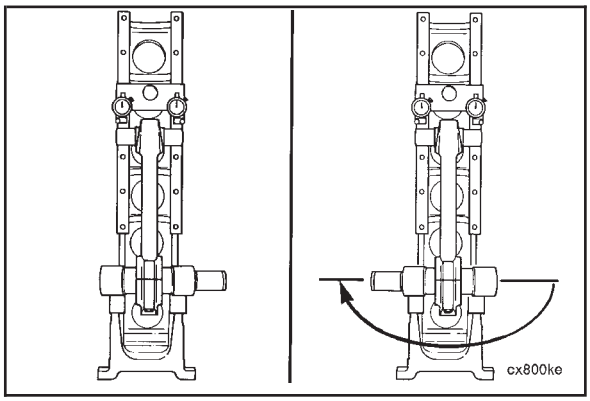
Loosen the knob and move the indicator bracket until both indicators touch the top of the piston pin end mandrel. Move the bracket toward the mandrel until the indicator needles have moved approximately 0.25 mm [0.010 inch]. Turn the knob to tighten the bracket.

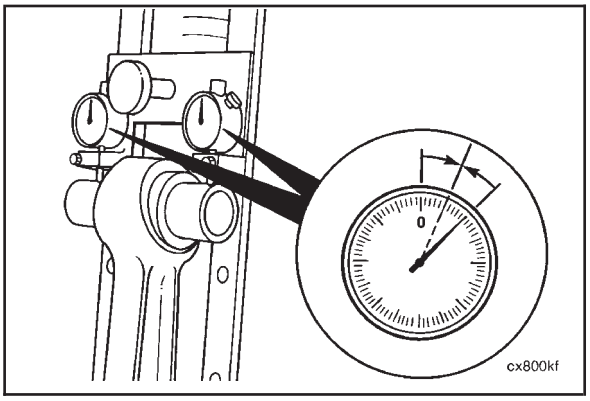
Adjust the indicator needles to “0”. Move the master rod in and out to confirm the “0”.



Remove the master rod from the fixture.

Rotate the rod 180 degrees horizontally and install it in the checking fixture.





Be sure the indicators are at the “0” setting.

If the indicator needles do not return to “0”, adjust the indicator so that the “0” moves 1/2 of the indicated difference from the needle to the “0” established during the previous step.

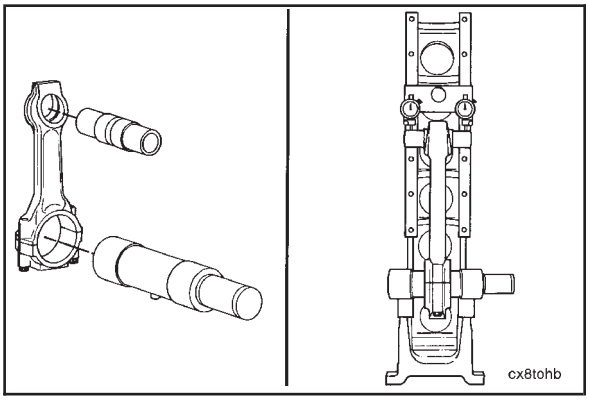
CAUTION

If the needle is more than 0.10 mm [0.004 inch] from the “0” established during the previous step, check for dirt or burrs on the mandrels and fixture. If the “0” is still not within the specification, check the be sure that the master rod is not damaged.

CAUTION

Do not adjust the indicators during this step of the procedure or the measurements will be wrong.

After completing the calibration of the fixture, remove the mandrels from the master rod.

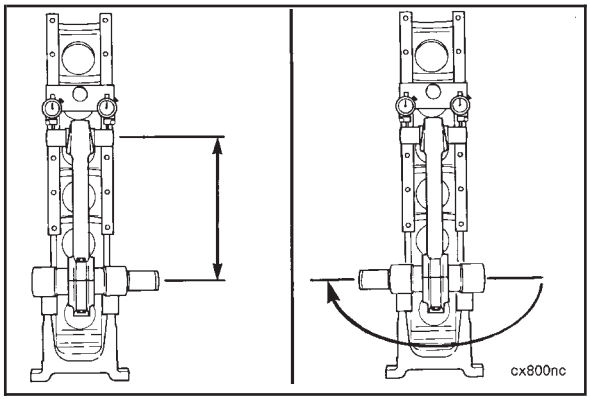


Measure the Connecting Rod Length

Repeat the same steps to install the mandrels in the rod to be measured as you did for the master rod.

Install the rod in the fixture.

Record the indicator reading. The difference of the calibrated “0” of the indicators must be added or subtracted from the known length of the master rod to determine the length of the rod being measured.



Connecting Rod Length		
mm		in
289.69	MIN	11.405
289.74	MAX	11.407

If the connecting rod length is **not** within specifications, the rod **must** be replaced or the piston pin bushing replaced and machined.

Measure the Connecting Rod Bend (Bore Alignment)

CAUTION

Never attempt to straighten a connecting rod useing heat or force. The rod will break eventually and cause extensive engine damage.

Make a note of the indicator readings.

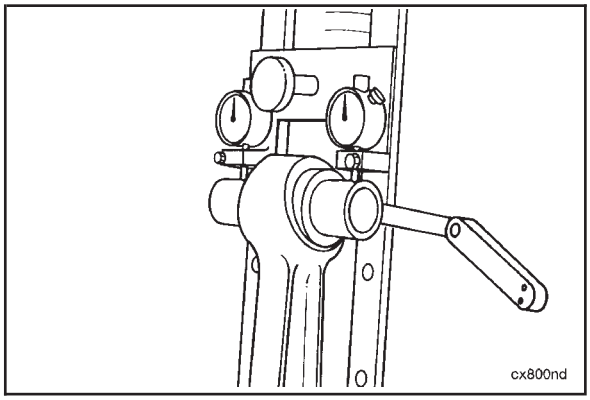
Remove the rod from the fixture. Turn the rod 180 degrees horizontally.

Compare the indicator readings with those noted in the previous step. The difference between the indicator reading is the amount of **bend** in the connecting rod.

Connecting Rod Bend			
	mm		in
	0.01	MAX	0.004
		MAX	0.008

If the connecting rod bend is **not** within specification with the bushing installed, the bushing can be removed and the bend measured again. If the connecting rod is **not** within specifications with the bushing **removed**, the rod **must** be replaced.

Measure the Connecting Rod Twist



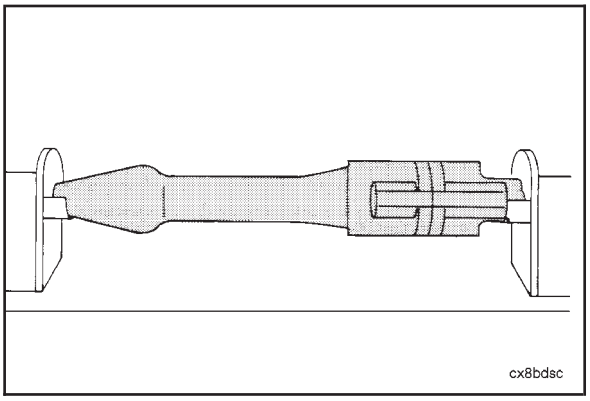
Check the fixture and mandrel in the piston pin end for a gap between the two. If there is any twist in the rod, the mandrel will **only** touch one side of the fixture.

Hold the end of the mandrel that is touching the fixture firmly against the fixture.

Use a feeler gauge to measure the gap between the mandrel and the fixture. The amount of the gap between the mandrel and the fixture is the amount of connecting rod twist.

Maximum Connecting Rod Twist			
	mm		in
Bushing Installed	0.25	MAX	0.010
Bushing Removed	0.51	MAX	0.020

If the connecting rod twist is not within specification with the bushing installed, the bushing can be removed and within specification with the bushing remove the must be replace.



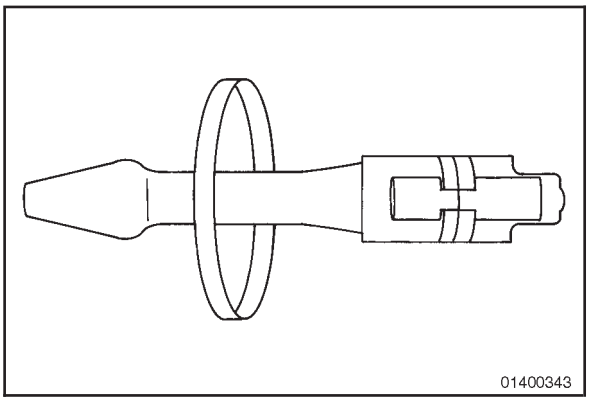
Magnetic Crack Inspect

Use a magnetic particle testing machine.

The connecting rod and cap **must** be assembled during this check.

Use the residual method. Apply head shot amperage. Adjust the amperage to 1500 ampere D.C. or rectified A.C.

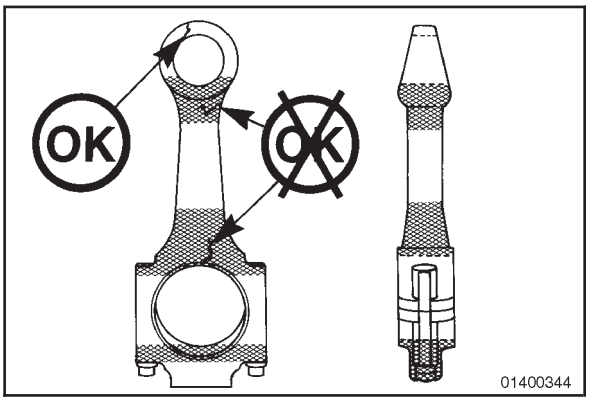
Check for cracks.



Use the residual method. Apply coil shot amperage. Check for cracks.

	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.



The connecting rod **must** be replaced if any indications are visible in the **critical** (shaded) areas.

CAUTION

The rod must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the connecting rod.

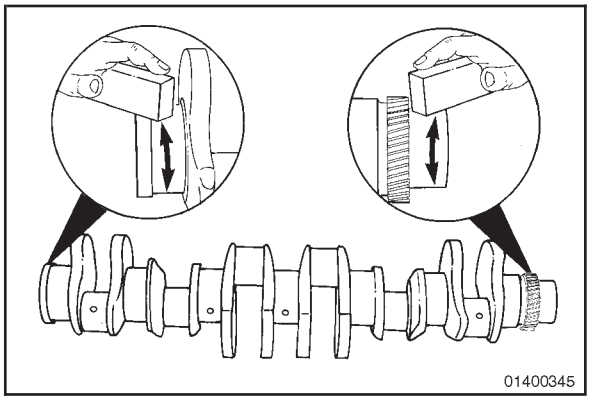
Use solvent or steam. Clean the part.

Crankshaft (001-016)

Clean

NOTE: New crankshafts are coated with a heavy preservative. Use solvent to remove the coating thoroughly. Brush or flush the packing debris from the oil drilling before installing the crankshaft in the engine.

Use a hone stone to remove all small scratches, grooves and to polish the O.D. at the **front** and **rear** oil seal locations, the flywheel mounting location, and the vibration damper location.



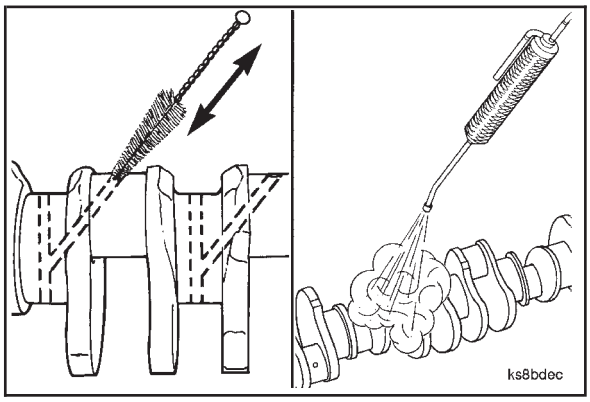
NOTE: Use a light preservative oil to prevent rust during engine rebuild. Place tape over the threaded holes. If the crankshaft is **not** going to be installed immediately, use a **heavy** preservative oil.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

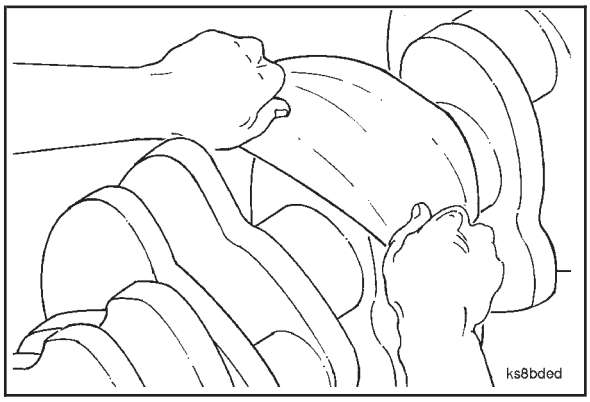
Use solvent to clean the crankshaft.

Dry with compressed air.



NOTE: Make sure to blow out the threaded holes on each end of the crankshaft and the oil drillings. Use a light preservative oil to prevent rust during engine rebuild. Tape over the thread holes.

Use crocus cloth or a 400 grit emery cloth to remove discoloration or light scratches from the machined surfaces.



△ CAUTION △

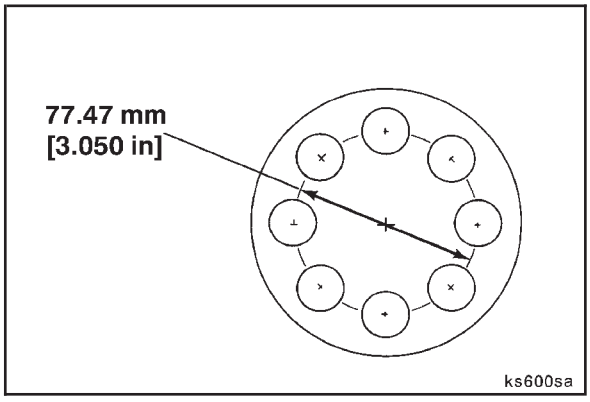
Do NOT chase the threads in the crankshaft, severe engine damage may occur.

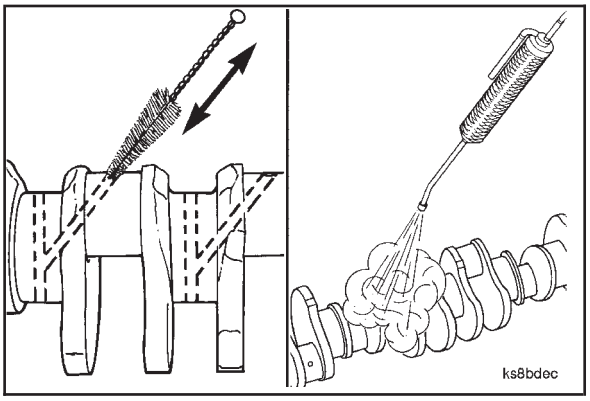
The QSK19 uses rolled threads in the bolt holes in the nose of the crankshaft.

To clean the ROLLED threads, flush with solvent.

Dry the threads with compressed air.

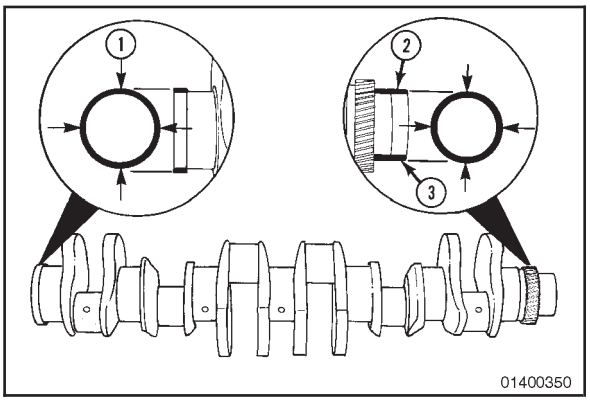
If additional cleaning is required, brush with a nylon bristle brush.





Use a bristle brush and solvent to clean all of the oil drilling.

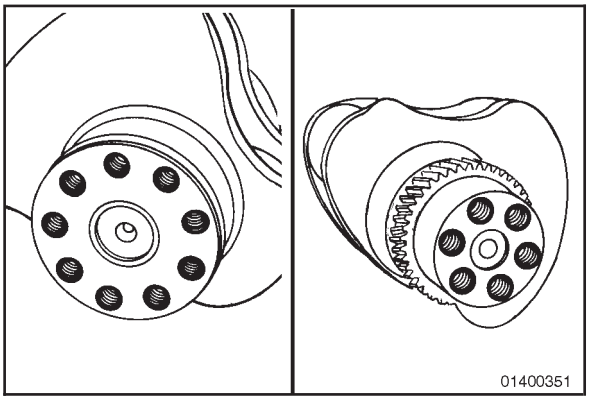
To prevent rust use, a light preservative oil to lubricate the crankshaft.



Inspect for Reuse

Measure the O.D. at the locations shown.

	Crankshaft O.D.		
	mm		in
Location (1)	152.35	MIN	5.998
	152.40	MAX	6.000
Location (2)	111.07	MIN	4.373
	111.13	MAX	4.375
Location (3)	110.74	MIN	4.360
	110.77	MAX	4.361

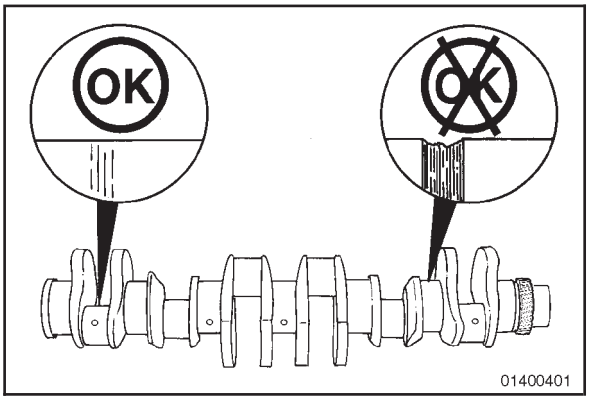


⚠ CAUTION ⚠

Do NOT chase threads on the crankshaft. Severe engine damage may occur.

Check the threads for damage at both ends of the crankshaft.

If necessary refer to Bulletin No. 3379035, Alternative Repair Manual, for repair instructions.



Check the main bearing journals and the rod bearing journals for damage or excessive wear. Minor scratches are OK.

Measure the O.D.

Rod Bearing Journal O.D. (4)		
mm		in
101.524	MIN	3.997
101.600	MAX	4.000

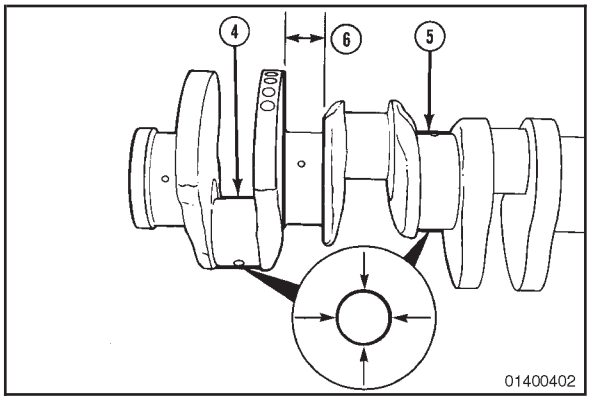
Main Bearing Journal O.D. (5)		
mm		in
139.637	MIN	5.4975
139.700	MAX	5.5000

Measure the thrust distance between the thrust faces on the No. 6 main bearing journal.

Thrust Distance (6)		
mm		in
60.30	MIN	2.374
60.33	MAX	2.375

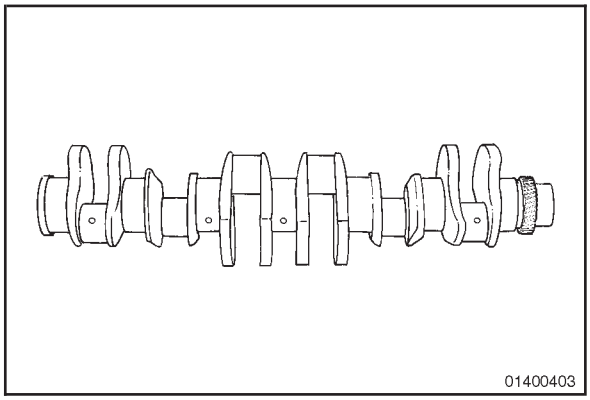
NOTE: The crankshaft **can** be ground undersize if the O.D. is **not** within specifications. **Always** grind **all** of the journals when one is **not** within specifications.

Oversize rod bearings and main bearings are available. Refer to the Alternative Repair Manual, Bulletin No. 3379035, for grinding specifications and instructions.



NOTE: Oversize thrust bearings are available if the thrust distance is **not** within specifications. A 0.25 mm [0.010 inch] and a 0.51 mm [0.020 inch] oversize thrust bearing are available. If the crankshaft **must** be machined to use an oversize thrust bearing, refer to the Alternative Repair Manual, Bulletin No. 3379035, for instructions.

Use a light preservative oil. Lubricate the crankshaft to prevent rust. If the crankshaft is not going to be used immediately, use a heavy preservative oil.



Magnetic Crack Inspect

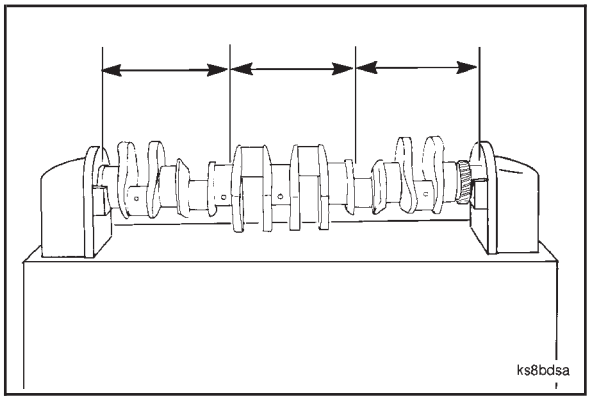
Use a magnetic particle testing machine.

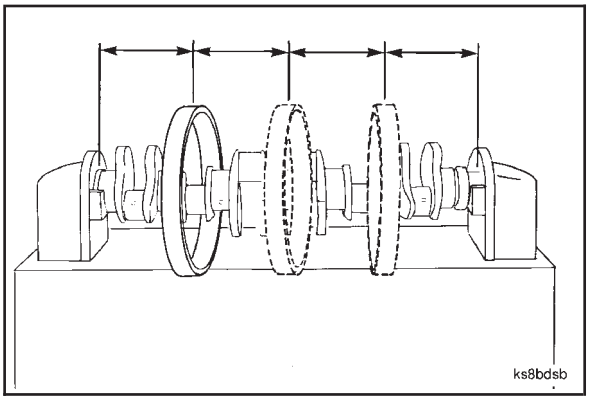
Perform the head shot and inspection method. Then perform the coil shot and inspection method.

Adjust the machine to 1800 ampere D.C. or rectified A.C.

Use the continuous method. Wet **only** 1/3 of the crankshaft at a time.

Check the crankshaft for cracks.





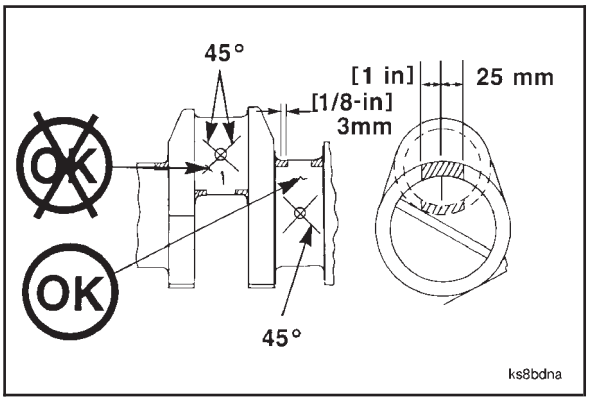
Use the coil shot method. Use a coil that is a minimum of 514 mm [20 1/4-inch] in diameter.

Use the continuous method. Apply coil shot.

Amperage - (Ampere Turns)	
MIN	4500 D.C. or Rectified A.C.
MAX	5000 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.

Check the crankshaft for cracks.

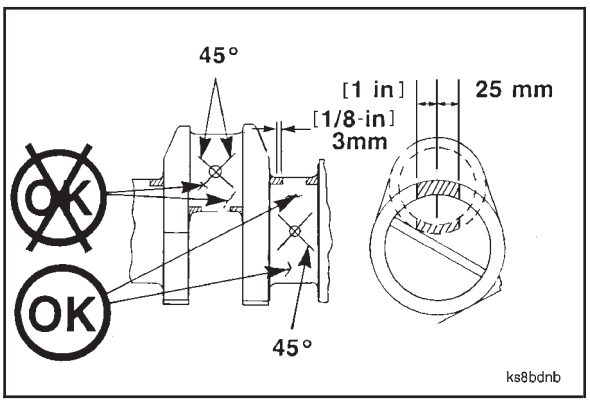


Limits of Acceptance - Open Indications

An open indication is visible to the eye after wetting operation has been completed. An indication below the surface is **not** visible to the eye after the wetting operation has been completed. An indication below the surface can be seen with the use of the ultraviolet light that is part of the machine.

Do **not** use the crankshaft if:

- There is an indication in the fillet or in the shaded area.
- There is an indication that passes through the 45 degree diagonal from the oil hole or goes into the oil hole chamfer.
- There is an indication that is longer than 6 mm [1/4-inch].
- There are more than four indications on one journal.



Limits of Acceptance - Indications Below the Surface

Do **not** use the crankshaft if:

- There is an indication in the fillet or in the shaded area that is in a circumferential direction.
- There is an indication in a circumferential direction that is longer than 25.4 mm [1.0 inch].
- There is an indication in an axial direction that is longer than 9.5 mm [3/8-inch].
- There is an indication that is closer than 1.5 mm [1/16-inch] to an oil hole chamfer.
- There is an indication that passes through the 45 degree diagonal from the oil hole.

CAUTION

The crankshaft must be demagnetized completely and cleaned thoroughly. Small metal particles will cause engine damage.

Demagnetize the crankshaft.

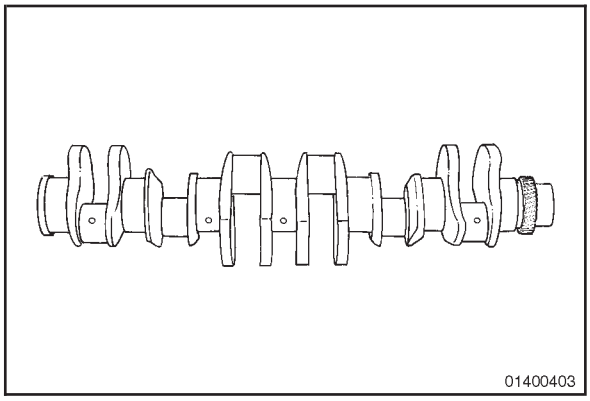
CAUTION

Wear protective clothing to prevent personal injury from burns.

Use steam. Clean the crankshaft and the oil drillings. Refer to the Procedure 001-016.

Use a **light** preservative oil. Lubricate the crankshaft to prevent rust.

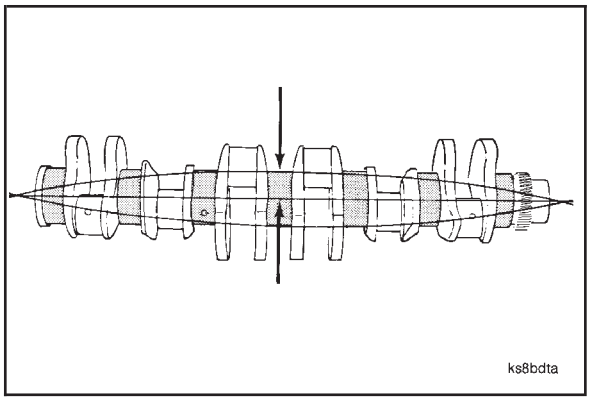
NOTE: Use a **heavy** preservative oil if the crankshaft is **not** going to be installed immediately. Protect the part with a cover to prevent dirt from sticking to the oil.



Bend and Twist Inspect

The crankshaft straightens is determined by the amount of bow and the adjacent journal run out.

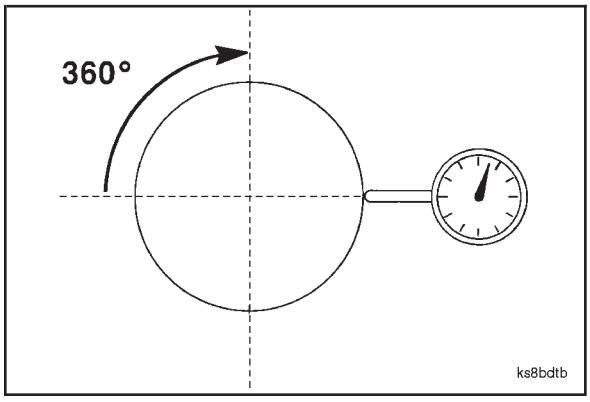
The following definitions will help you understand the procedure.



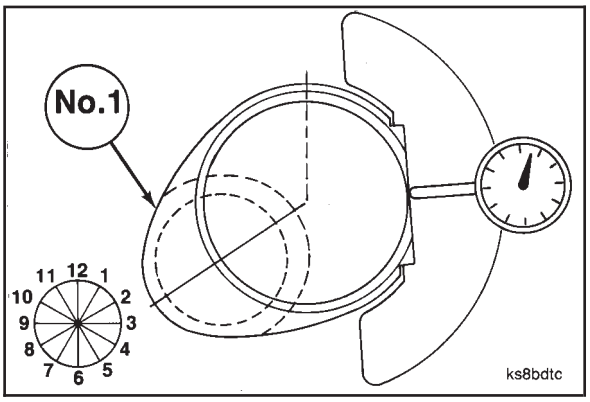
Definitions:

1. Bow:
One-half (1/2) of the TIR measured at the middle bearing journal when the crankshaft is supported on the two end journals. Bow is often referred to as the bend or the full length alignment.

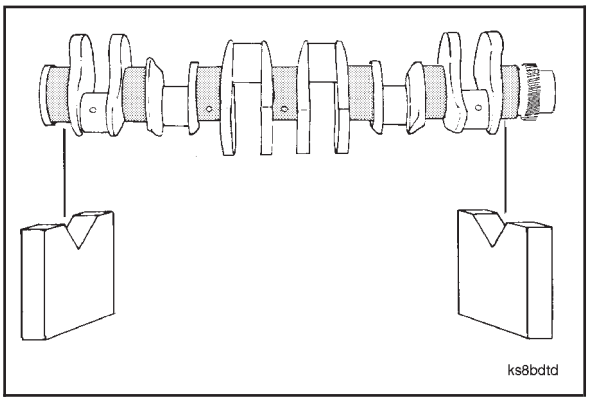
2. Journal Run Out:
The TIR (total sweep of the needle) of the main bearing journal as the crankshaft is rotated one complete revolution (360 degrees).



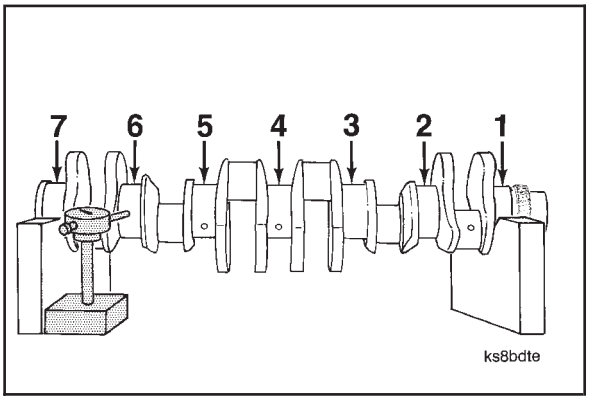
3. Adjacent Journal Run Out:
The relationship of the TIR of a main bearing journal as it is rotated on a common axis to the TIR of an adjacent journal.
Adjacent Journal Run Out is often referred to as the step run out, the bearing-to-bearing run out, or the journal-to-journal run out.



4. Clock Position:
The location of the journal at the highest TIR point. Compare its angular relationship with the No. 1 crankshaft pin as viewed from the front of the crankshaft. In this example, the crankshaft pin is at the 8 o'clock position. This is the clock position of the journal being measured.



Use two vee blocks. Put the vee blocks on a flat surface. Support the crankshaft on the vee blocks at the two end bearing journals.



Use a dial indicator. Position the indicator so the stem touches the bearing journal being measured at the journal centerline.

The point of measurement chosen **must** be used for measuring all bearing journals.

Rotate the crankshaft and measure the TIR at each bearing journal. Record the value and the clock position for each journal.

ITEM	RUNOUT TIR [INCH]	CLOCK POSITION
JOURNAL STEP		
1	[0]	0
2	[0.0021]	12
3	[0.0030]	12
4	[0.0039]	1
5	[0.0025]	1
6	[0.0016]	2
7	[0]	0

ks8bdtf

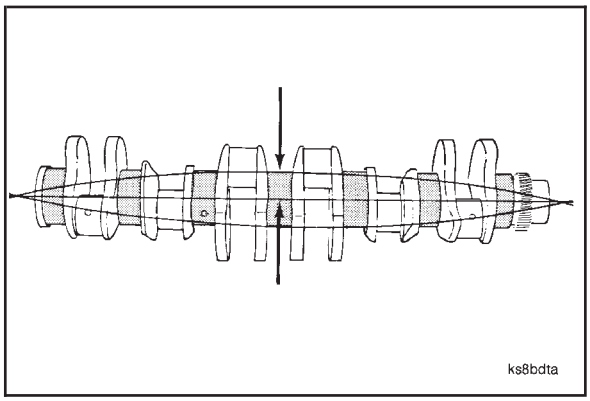
Determine the Crankshaft Bow

Crankshaft bow as specified, is the TIR of the center journal when the crankshaft is rotated thru 360 degrees, while supported on the end of the journals.

Compare the bow to the specifications.

Maximum Crankshaft Bow (TIR)		
mm		in
0.23	FFH	0.009

NOTE: All QSK19 crankshafts are Fully Fillet Hardened.



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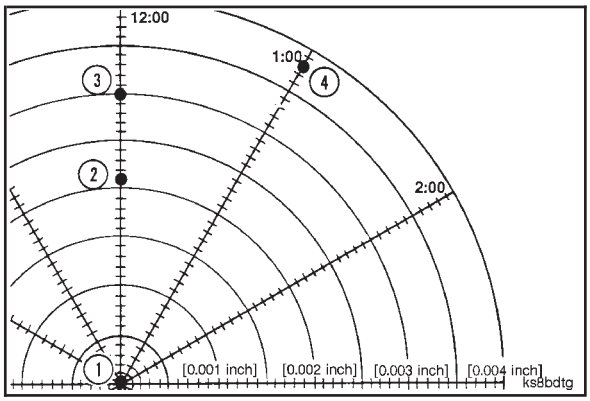
Determine the Adjacent Journal Run Out

For each journal, plot the TIR value at its clock position on a polar chart illustrated on the following page.

The end journals supported by vee blocks **must** be plotted at the center of the chart.

The example illustrates the following plot points.



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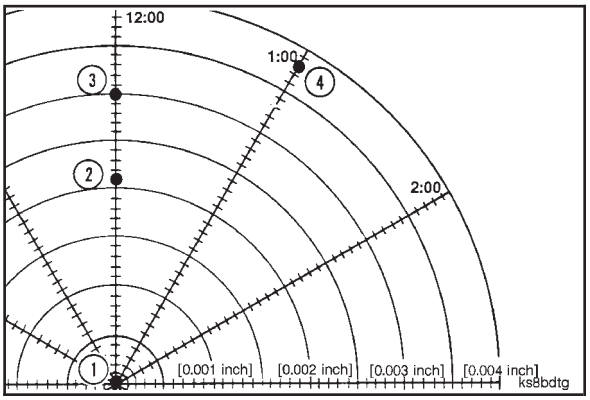
Journal	TIR	Clock Position
1	0	0
2	0.0021	12
3	0.0030	12
4	0.0039	1



Draw a straight line between the plotted points, (from journal No. 1 to No. 2, and from No. 2 to No. 3), until all journals are plotted on the chart.

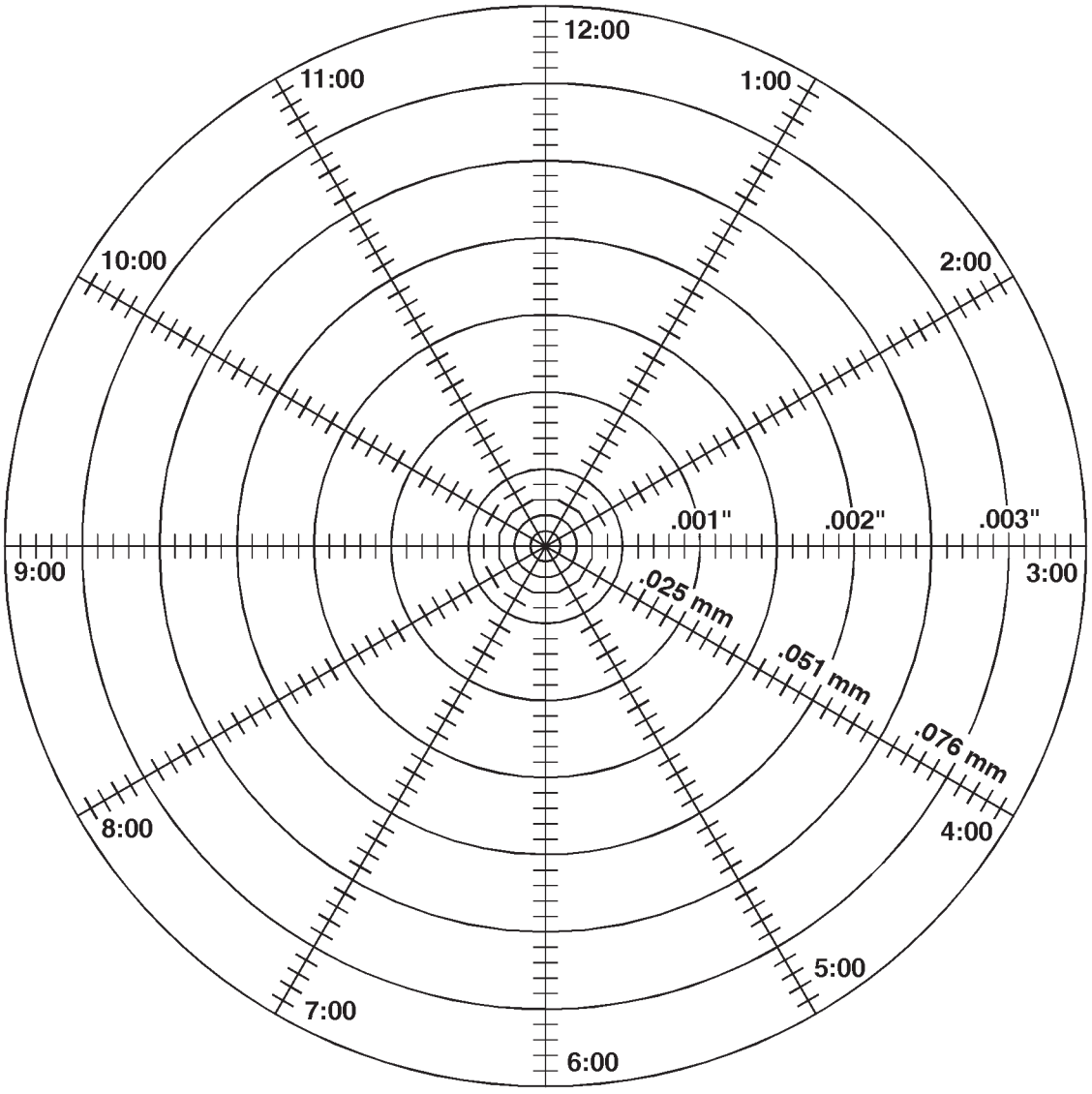
To determine the Adjacent Journal Run Out, measure the length of the line from each journal to its corresponding journal point.

Illustrated as an example, journal No. 3 and No. 4 is 5.1 mm [2 inch]. This represents a run out of 5.1 mm [0.002 inch].

Record the adjacent journal run out for each bearing journal. Compare the adjacent journal run out to specifications.

Maximum Adjacent Journal Run Out		
mm	**QSK19**	**in**
0.089	**FFH**	0.0035

Replace the crankshaft if any measurement is **not** within specifications.



Scale 1" = 0.001"

1mm = 0.001mm

The small graduations are 0.1 of an inch = 0.0001 inch.

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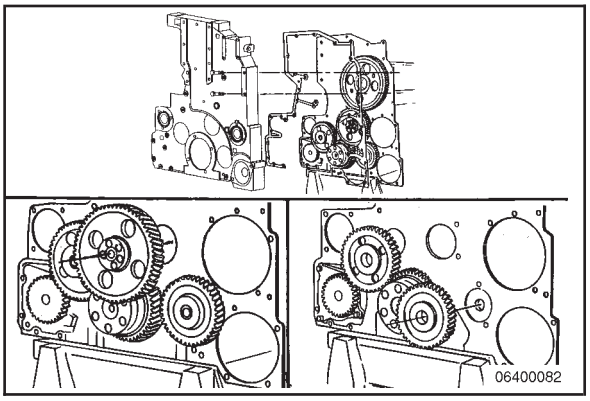
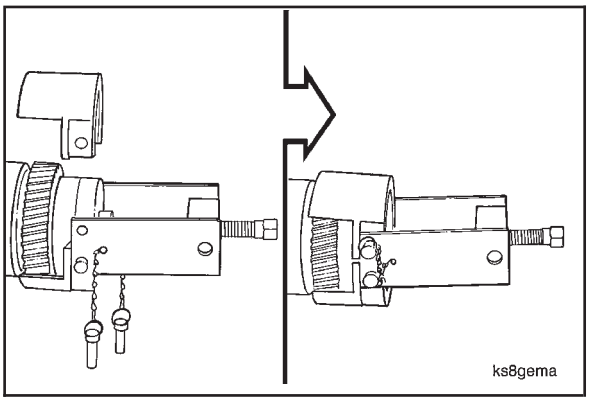


Crankshaft Gear, Front (Crankshaft Installed) (001-018)

Remove

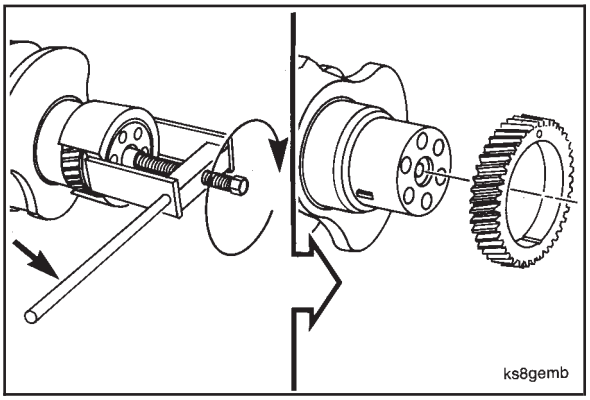
Remove the gear cover and all related components. Refer to the QSK19 Troubleshooting and Repair Manual, Bulletin No. 3666098-01.

Remove the cover spacer plate. Refer to the QSK19 Troubleshooting and Repair Manual, Bulletin No. 3666098-01.



NOTE: ONLY remove the gear when the crankshaft or the gear is damaged.

Use a puller jaw, Part No. 3375835, and bridge assembly, Part No. 3375834. Install the puller jaw and bridge assembly on the gear.



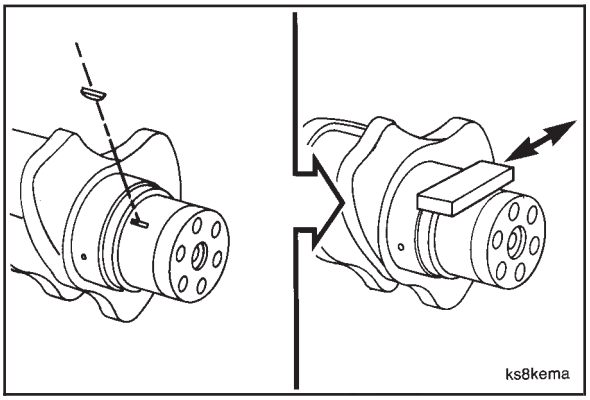
CAUTION

Heat can be used to aid the removal of the gear. Do NOT use a cutting torch. The high temperature of a torch will damage the teeth of the gear.

CAUTION

Do not exceed 475 N•m [350 ft-lb] of torque when turning the jackscrew.

Lubricate the puller jackscrew with engine oil. Hold the pry bar and turn the jackscrew to remove the gear.



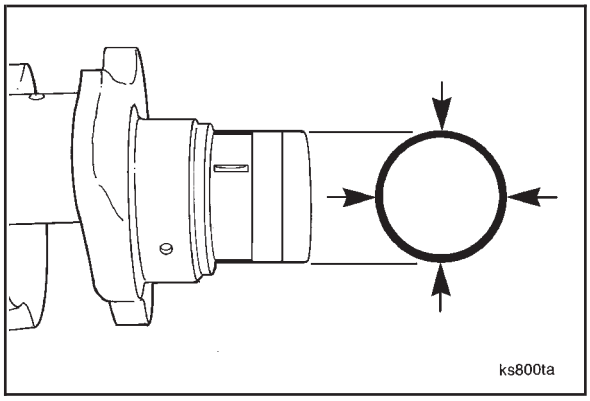
Remove the key.

Use a hone stone and polish the shaft O.D. Remove all of the small scratches, burrs, and small grooves.

Inspect for Reuse

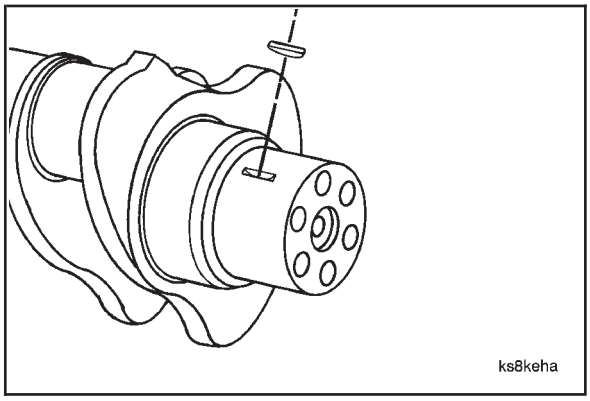
Clean and visually inspect the crankshaft for reuse. Measure the O.D.

Crankshaft O.D. (Gear Location)		
mm		in
111.25	MIN	4.380
111.28	MAX	4.381



Install

Install the key.



⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

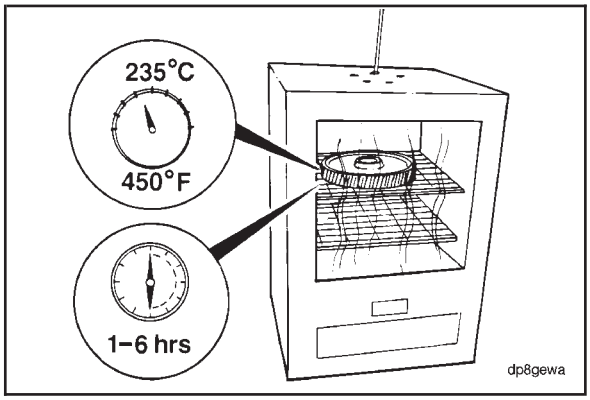
⚠ CAUTION ⚠

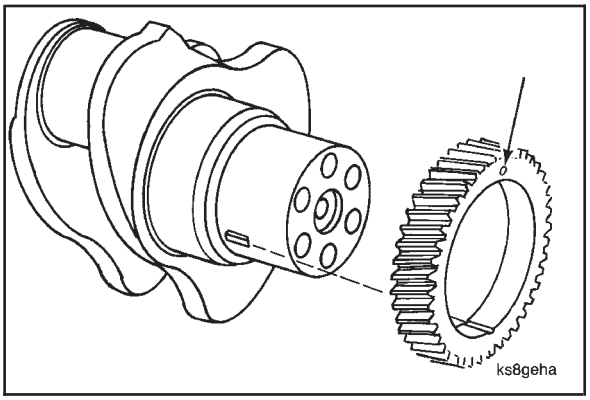
Do not exceed the specified time or the temperature. Damage to the gear and the gear teeth will result.

⚠ CAUTION ⚠

Do not attempt to install the gear without using heat.

Use an oven and adjust the heat to 235°C [450°F]. Heat the gear for a **minimum** of 1 hour, but **no** more than a **maximum** of 6 hours. The I.D. of the gear will become larger and will simplify installation.





⚠ CAUTION ⚠

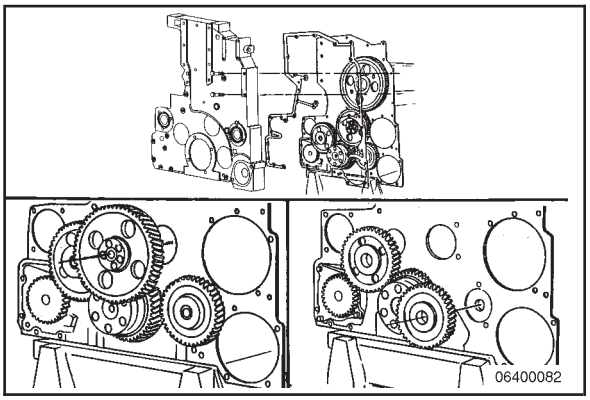
Wear protective clothing to prevent personal injury from burns.

⚠ CAUTION ⚠

Allow the gear to air cool slowly. Do not use water or oil to reduce the cooling time. This will cause the gear to crack.

NOTE: The timing mark on the crankshaft gear **must** be visible from the front of the gear after it is installed on the crankshaft.

Lubricate the O.D. of the crankshaft with Lubriplate® No. 105, or equivalent. Remove the gear from the oven and install it on the crankshaft. The keyway in the gear **must** be aligned with the key in the crankshaft.



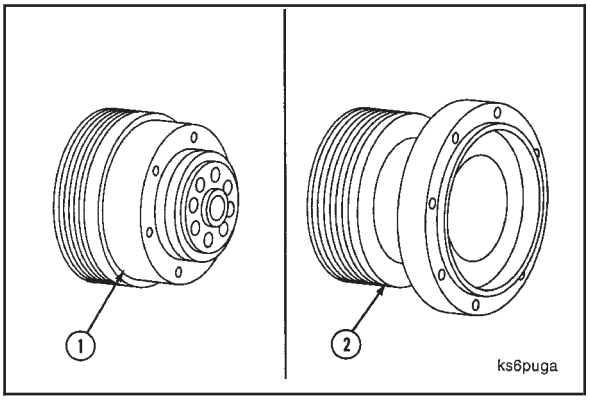
Install the gear cover and related components. Refer to Procedure No. 001-031.

Crankshaft Gear, Rear (Crankshaft Installed) (001-020)

Install

Crankshaft Pulley (001-022)

Clean



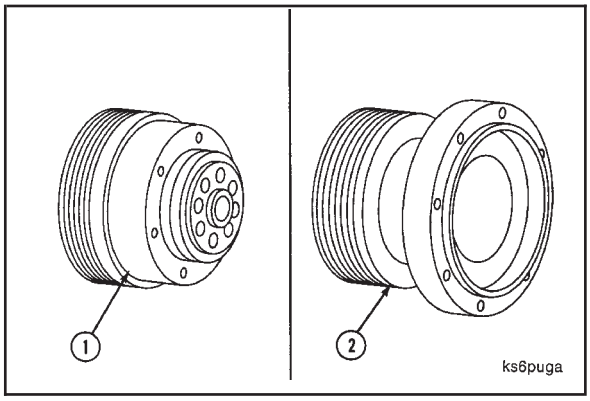
⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacture's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent or steam. Clean the pulley.

Dry with compressed air.

Inspect for Reuse



Check all mounting pilots and surfaces for damage from fretting. If it is **not** possible to remove the damage with a 240 grit abrasive cloth, the part **must** be replaced.

⚠ CAUTION ⚠

The mounting pilots and surfaces control the center and spacing of the pulleys. Do not repair the part by machining. It will cause an out-of-balance condition or a crankshaft failure.

Measure the O.D.

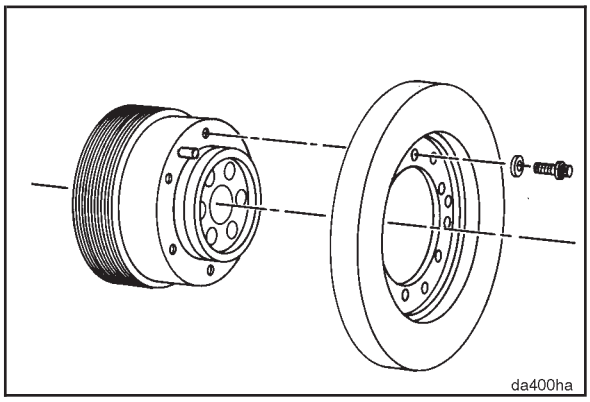
Pully O.D.		
mm		**in**
134.78	MIN	5.3105
135.04	MAX	5.3115

Measure the I.D.

Pully I.D.		
mm		**in**
110.780	MIN	4.3610
110.806	MAX	4.3620

Vibration damper to pulley torque:

Torque Value: 140 N•m [105 ft-lb]



Cylinder Block (001-026)

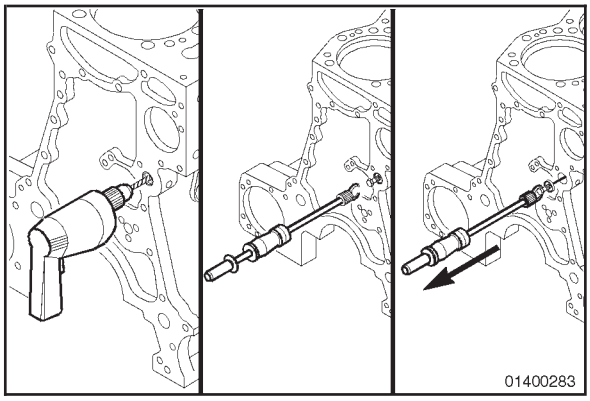
Worksheet

Cylinder Block Inspection Checklist
1. Cylinder Liner Counterbore
a.Upper Bore I.D.
b. Lower Bore I.D.
c. Depth
d. Ledge Flatness
e. Ledge Cracking
2. Packing Ring Bore I.D.
3. Idler Shaft Bore I.D.
4. Head Deck - Damage
5. Water Hole - Damage
6. Idler Shaft Bore I.D.
7. Camshaft Bushing Bore I.D.
8. Main Bearing Bore
a. Alignment
b. I.D.
9. Main Bearing Cup Fit in Block
10. Cylinder Head Capscrew Threads

Clean

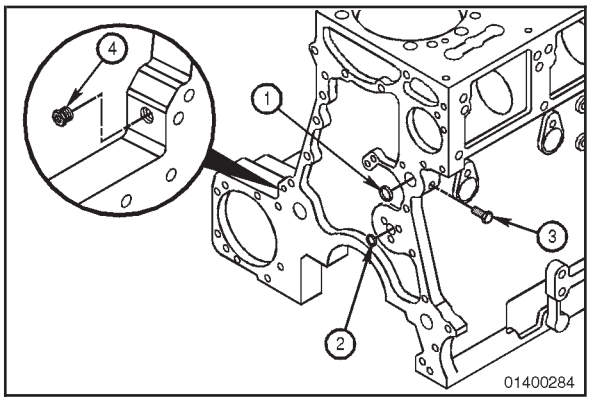
Use a drill, a sheet metal screw, and the following parts from a light duty puller kit, Part No. 3375784:

- Slide hammer
- Hook



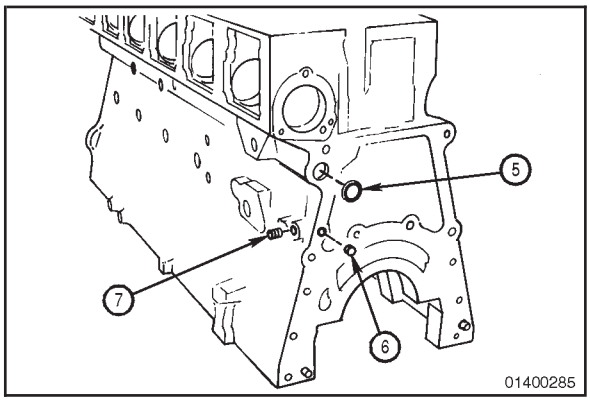
Remove the following cup plugs:

1. Main oil passage cup plug
2. Piston cooling oil passage cup plug
3. Main oil passage cup plug
4. Piston cooling oil passage cup plug

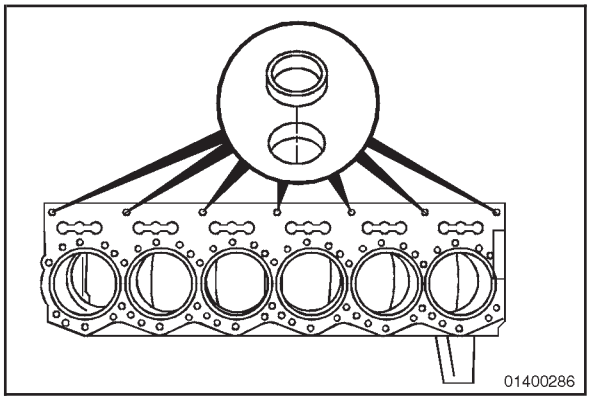


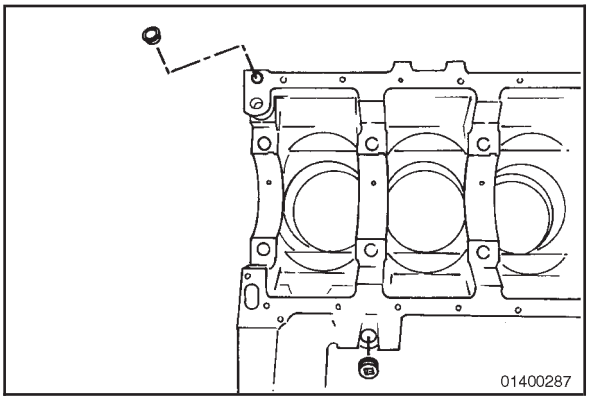
Remove the following straight thread pipe plugs:

5. Main oil passage straight thread pipe plug
6. Water pump idler oil passage straight thread pipe plug
7. Piston cooling oil passage



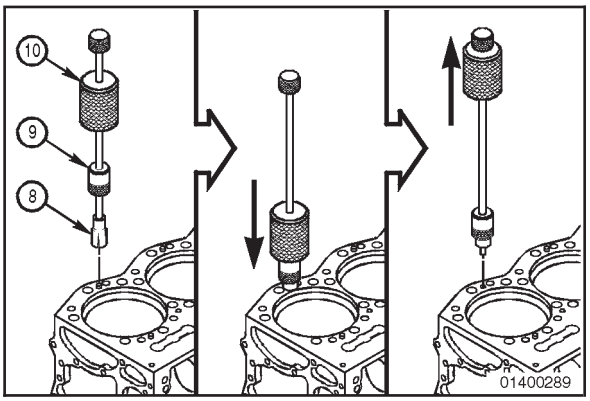
Remove the seven cup plugs from the camshaft oil passages.





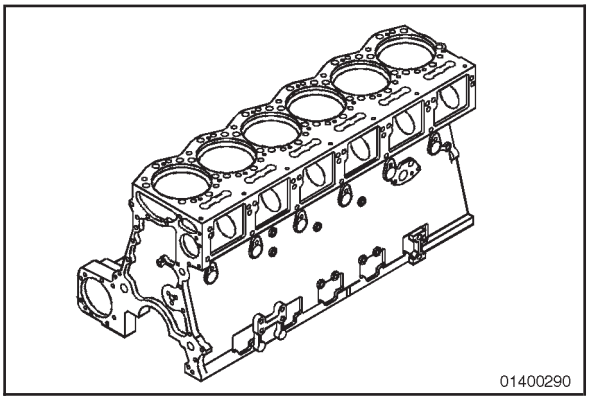
Remove the cup plug from the hydraulic pump idler oil passage.

Remove the straight thread pipe plug from the lubricating pump oil passage.



Use a dowel pin extractor, Part No. ST-1134, or equivalent. Remove the 12 cylinder head groove pins.

- Put the split collet (8) over the groove pin.
- Slide the extractor collar (9) over the split collet.
- Use the slide hammer (10) to push the extractor collar over the split collet tightly.
- Use the slide hammer to remove the groove pin.



⚠ CAUTION ⚠

Do not damage the machined gasket surfaces or the camshaft bushings.

Use a scraper, a wire brush, or a 120-grit emery cloth. Clean all of the heavy dirt deposits off of the cylinder block. Clean:

- all of the gasket surfaces,
- all of the mounting surfaces,
- the cylinder liner counterbore ledge and the press fit areas,
- the cylinder liner packing ring bore,
- the top of the block,
- the main bearing saddles and the caps,
- all of the cup plug bores.

Use a bottle brush with a long handle. Clean all the oil passages.

⚠ WARNING ⚠

Use gloves, an apron, and goggles to prevent personal injury.

⚠ CAUTION ⚠

Use a cleaning solution that will not damage the camshaft bushings.

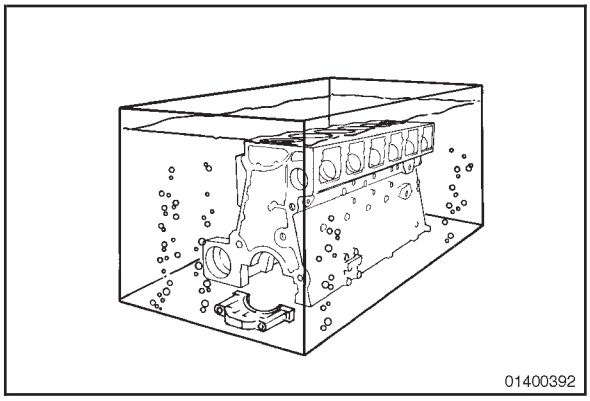
Remove the block from the engine stand.

Follow the instructions of the manufacturer of the cleaning tank and the manufacturer of the cleaning solution.

NOTE: Cummins Engine Co., Inc. does **not** recommend any specific cleaning solution.

Past experience shows that the best results are obtained using a cleaning solution that can be heated from 80°C to 95°C (180°F to 200°F).

A cleaning tank that will mix and filter the cleaning solution will give the best results.



⚠ WARNING ⚠

Use gloves, an apron, and goggles to prevent personal injury.

Remove the block from the cleaning tank.

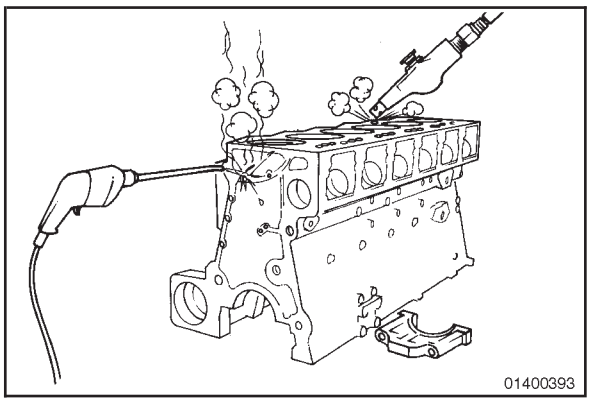
Use a steam cleaner. Be sure all of the oil passages are clean.

⚠ CAUTION ⚠

Be sure all of the water is removed from the capscrew holes and the oil passages.

Use compressed air. Dry the block.

NOTE: If the cylinder block is not going to be used immediately, apply a coating of preservative oil to prevent rust. Cover the block to prevent dirt from sticking to the oil.



Inspect for Reuse

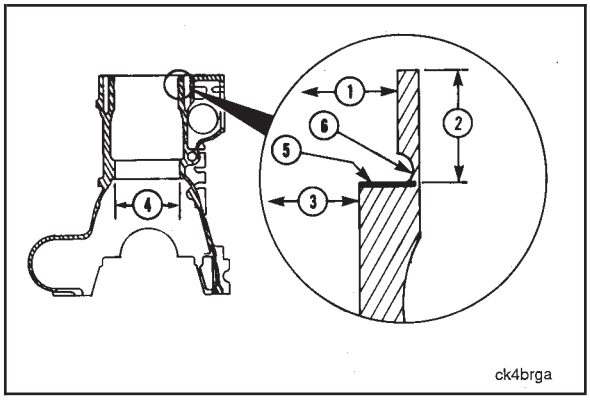
Cylinder Block Surface Condition

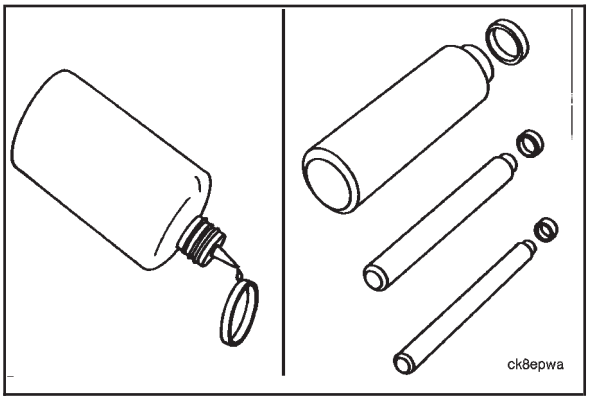
⚠ CAUTION ⚠

All measurements of the cylinder block must be made when the block is positioned on a flat surface. If the block is mounted on an engine stand, distortion will cause the measurements to be wrong.

Definition of numerical terms:

1. Upper Counterbore Inside Diameter
2. Counterbore Depth
3. Lower Counterbore Inside Diameter
4. Packing Ring Bore
5. Counterbore Ledge
6. Counterbore Radius



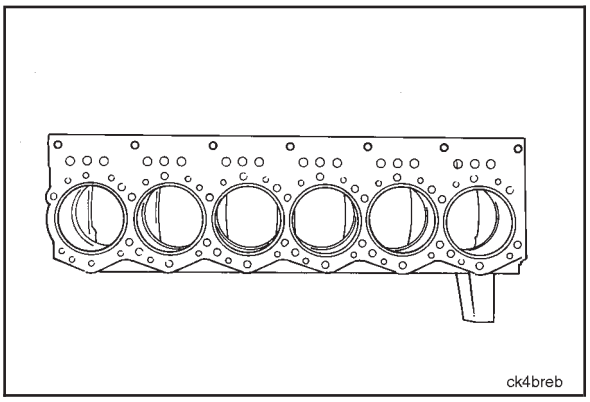


⚠ CAUTION ⚠

Do not install any cup plugs or pipe plugs in the block until the inspection and any necessary repair procedures are completed. This will prevent dirt from being trapped in the oil passages.

Use pipe Loctite sealant, Part No. 3375068, or equivalent, and the correct size cup plug driver.

Use a cup plug driver handle, part No. 3376795 with all cup plug drivers.

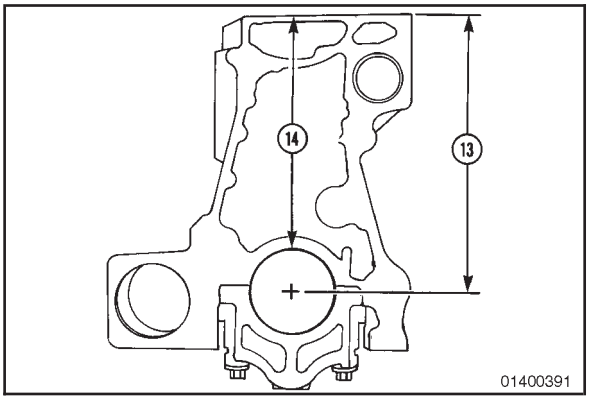


Check the top surface of the block for wear. If fretting damage is present in an area where a head gasket seal ring or a grommet makes contact, the surface **must** be repaired.

Fretting damage in any other area is acceptable if it does **not** change the protrusion measurement of the counterbore or liner.

A newly machined surface **must** be flat within 0.05 mm [0.002 inch] under a cylinder head. Waves on the surface are acceptable as long as they are not more than 0.018 mm [0.0007 inch] high, and the **high** and **low** points of the waves are **not** closer than 25 mm [1.0 inch].

A newly machined surface **must** meet the specifications for block height as stated in the next illustration. If the top surface of the cylinder liner counterbore **must** be machined. Refer to procedure No. 001–058.



⚠ CAUTION ⚠

The parting line of the main bearing cap is not at the same height as the centerline of the main bearing bore.

(13) Cylinder Block Height		
mm		**in**
481.91	MIN	18.9735
482.76	MAX	19.0065

If the height of the block is less than 482.42 mm [18.993 inch], a 0.51 mm [0.020 inch] oversize head gasket **must** be used.

If the checking ring or the centering ring is not available, the height of the block can be measured from the top of the main bearing saddle (14)

(14) Cylinder Block Height- Main bearing Saddle		
mm		**in**
407.70	MIN	16.051
408.53	MAX	16.084

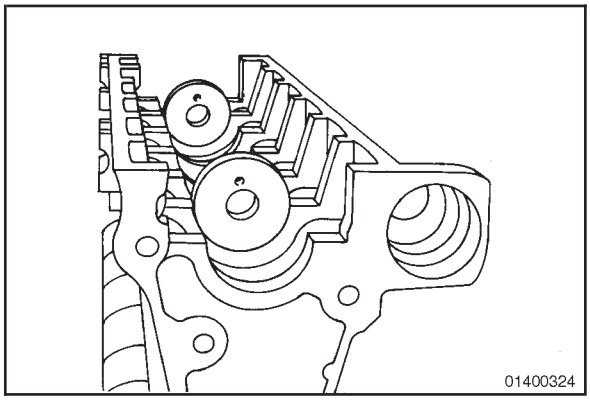
If the block height is less than 408.20 mm [16.071 inch] a 0.51 mm [0.020 inch] oversize head gasket **must** be used.

The height of the block must not vary more than 0.05 mm [0.002 inch] from end to end of the block. If the block height is **not** within specifications, the top surface of the block **must** be **machined** or the block **must** be **replaced.**

NOTE: If the top surface of the block is machined, the ledge depth of the cylinder liner Canterbury must be machined. Refer to procedure number 001-058.

Measure the Main Bearing Bore Alignment

Use two centering rings, Part No. ST-1177-54 [5.846 inch diameter]. Put the rings in the No. 2 and the No. 6 main bearing locations.



⚠ CAUTION ⚠

The main bearing caps are numbered through 7. Install each cap in the correct location. The slot in the cap for the bearing tang must be on the same side as the slot in the block.

Install each capscrew by hand to be sure the capscrew is positioned properly.

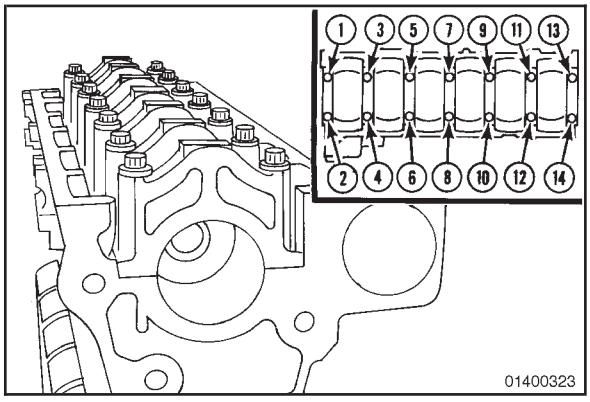
Use a mallet. Install the caps until they touch the block.

If any of the caps do not require force during installation, mark the cap to check the side clearance.

Tighten the main bearing caps using two steps.

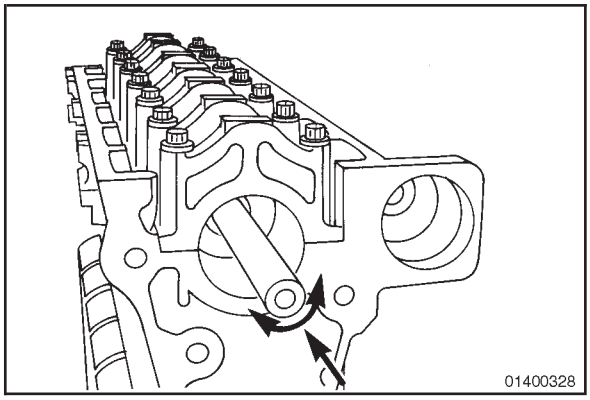
Torque Value:

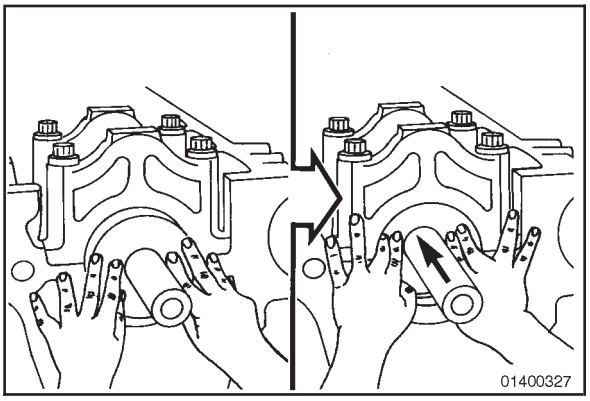
Step 1	270 N•m	[200 ft-lb]
Step 2	610 N•m	[450 ft-lb]



Use engine oil. Lubricate the I.D. of the two centering rings.

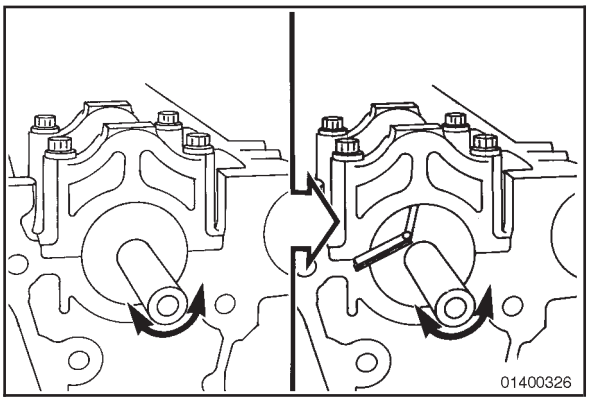
Install the alignment/boring bar, Part No. ST-1177-16, in the two centering rings. The bar **must** turn easily. If the bar does **not** turn easily, check to be sure that the main bearing caps are installed correctly. If they appear to be OK, move one of the centering rings to another bearing location.





Use your hands to install the checking ring in the main bearing bore. If the ring will **not** slide through the bore, check the bore for burrs. If the ring will still **not** slide through the bore, the bore is undersized and **must** be repaired.

Refer to Bulletin No. 337035, Alternative Repair Manual, for repair procedures.



Use a 0.075 mm [0.003 inch] feeler gauge that is not more than 13 mm [0.5 inch] wide.

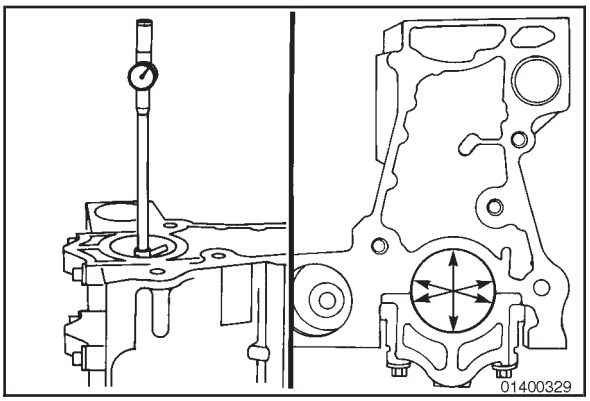
Center the checking ring in the bore. Try to put the feeler gauge between the checking ring and the bore. Rotate the gauge in the bore at both sides of the checking ring.

the bore alignment of the main bearing is OK if:

- The gauge does **not** enter at any point.
- The gauge will enter, but will **not** slide through or around the bore, and the alignment bar will rotate with the gauge inserted.

The bore alignment of the main bearing is **not** OK if:

- The gauge enters and slides around the bore. this means that the bore is oversize and **must** be repaired.
- The gauge will enter on one side only, but can slide around the bore. This means that the bore is tapered and **must** be repaired.



If the tools to check the main bearing bore alignment are not available, use a dial bore indicator.

Measure the I.D. in the three positions shown. The I.D. must be completely round within 0.013 mm [0.0005 inch].

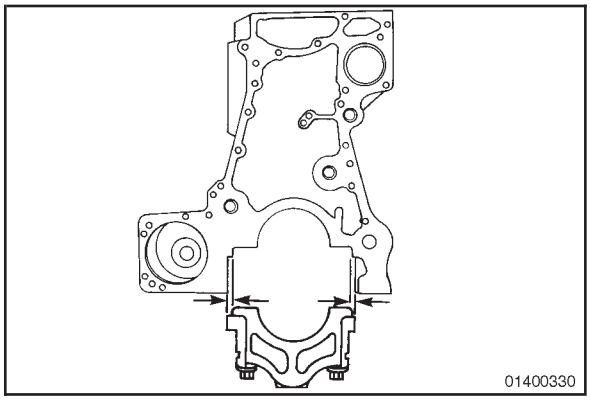
NOTE: Support the rear portion of the block on a flat surface to obtain the most accurate measurement of the I.D.

Check the main bearing caps that are loose. The main bearing cap **must** be replaced if :

- The clearance causes the main bore alignment not to be within specifications.
- The clearance between the block and the cap is more than 0.17 mm [0.007 inch] on either side of the cap when the cap is installed and torqued to specifications.
- There is fretting or heat damage to the cap.

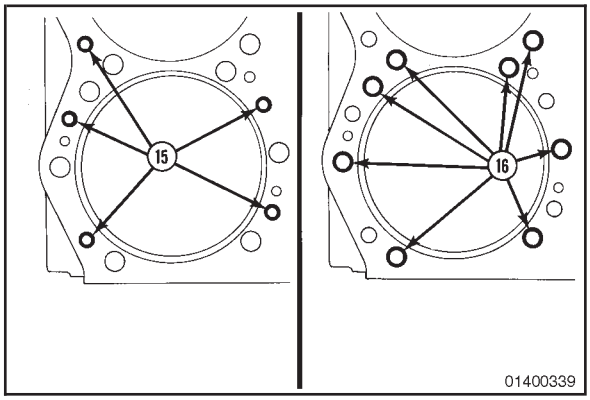
NOTE: On **new** or **reconditioned** blocks, the main bearing cap is 0.00 mm to 0.013 mm [0.00 inch to 0.010 inch] larger than the block. Force **must** be used to install the cap.

Service caps do not have the bore machined to a final specification. If the cap is machined. Use the correct parts of the main bearing boring tool, Part No. ST-1177. Refer to Bulletin No. 3379035, Alternative Repair Manual.



Check the water holes (15). If erosion or pitting is **more** than 0.08 mm [0.003 inch] deep, or extends more than 2.41 mm [0.095 inch] from the edge of the hole, the water hole must be repaired. Refer to Bulletin No. 3379035, Alternative Repair Manual.

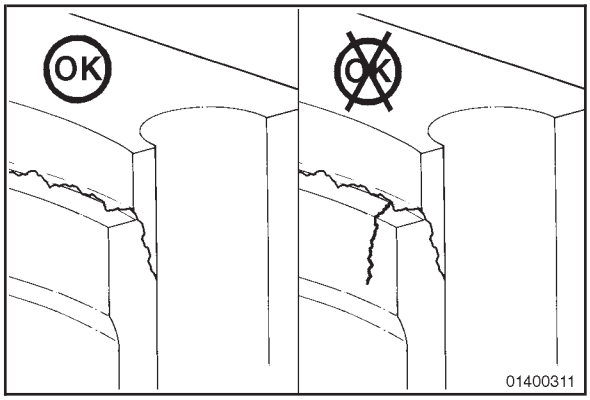
Check the threads of the bolt holes (16) for damage. Use a threaded insert if a damaged bolt hole must be repaired. Refer to bulletin No. 3379035, Alternative Repair Manual.



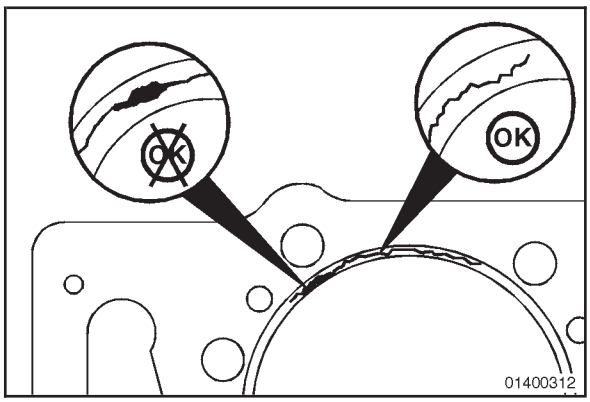
Magnetic Crack Inspect

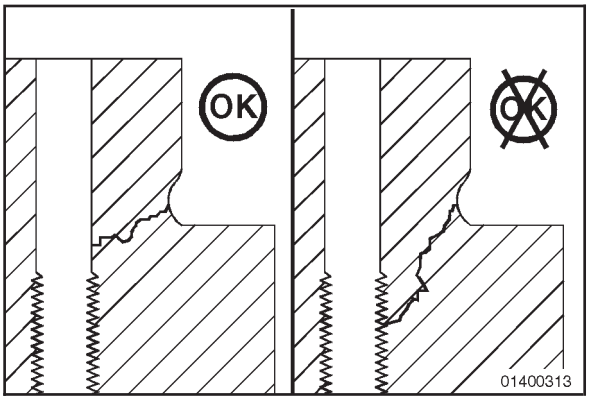
Use a crack detection kit, Part No. 337532, or equivalent, and check the counterbore ledge for cracks.

Circumferential cracks of the counterbore ledge are acceptable if they do **not** extend to or over the edge of the ledge (LPF I.D.). Circumferential cracks in the radius are acceptable if they do **not** extend more than 90 degrees around the radius.



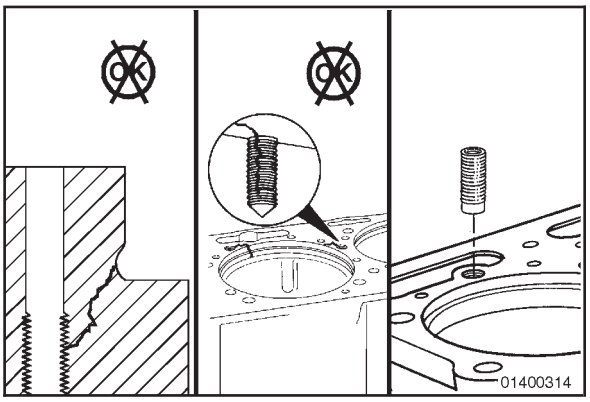
It is **not** necessary to machine the block in an effort to remove ACCEPTABLE cracks. If cracks that are **not** acceptable are found during the initial inspection, the counterbore ledge **must** be machined. Refer to Procedure No. 001-058. If a crack that is **not** acceptable remains after the machining repair procedure is completed, the block is **not** acceptable for reuse.



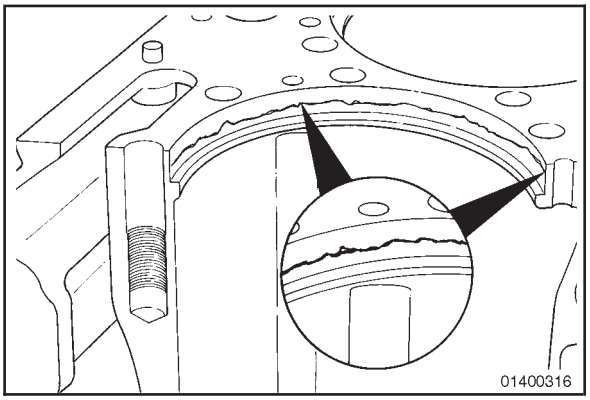


Capscrew Hole Cracks

Cracks that extend from the counterbore wall to the capscrew hole are acceptable for reuse **only** if it **does not** extend into the threaded portion of the hole.

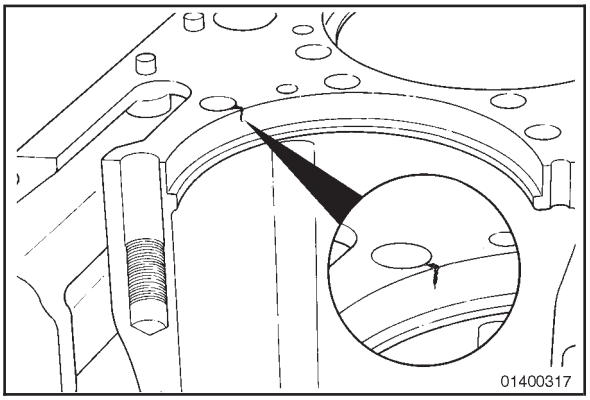


Cracks that extend into threaded portion of the hole require repair with a blind end thread insert. Refer to the Alternative Repair Manual, Bulletin No. 3379035.



Coolant Passage Cracks

If a crack is running horizontally around the counterbore, all the coolant passages that are close to the bore **must** be repaired with coolant passage threaded inserts.

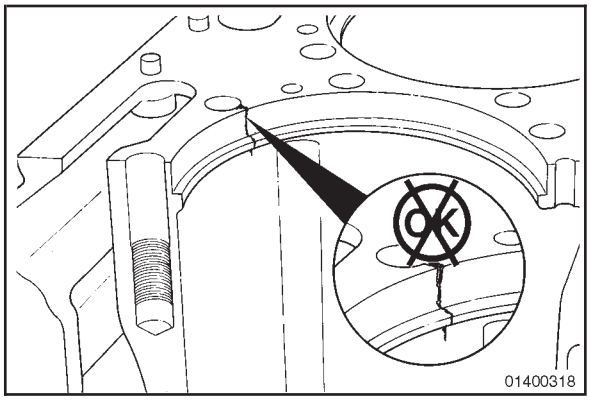


Some cracks will run vertically to a coolant passage or a capscrew hole. Those passages must be repaired with coolant passage threaded inserts.

Use the Coolant Passage Repair Kit, Part No. 3824047, to repair the coolant passages.

NOTE: If the crack extends over the counterbore ledge the block can **not** be repaired.

Cylinder blocks with vertical cracks that extend from a coolant passage down over the counterbore ledge can not be repaired.

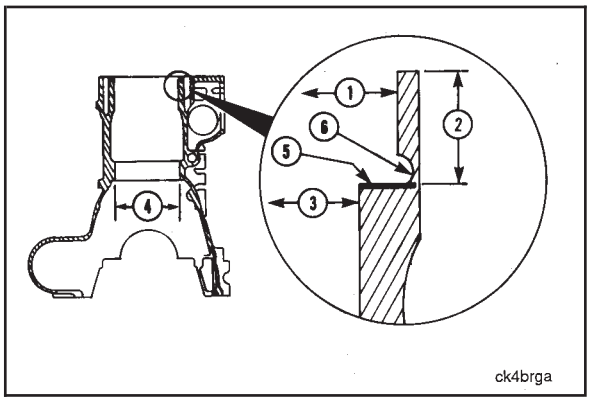


Cylinder Block and Liner Seats (001-027)

General Information

Definition of numerical terms (call-outs):

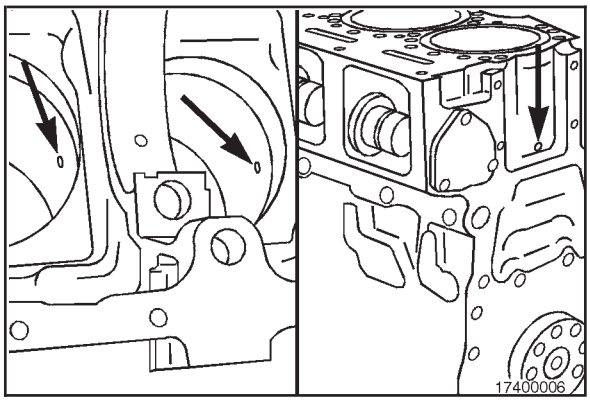
1. Upper counterbore inside diameter
2. Counterbore depth
3. Lower counterbore inside diameter
4. Packing ring bore
5. Counterbore ledge
6. Counterbore radius



Rail Applications

To allow for the proper coolant drainage of the cylinder head and engine block on a horizontally mounted QSK19 Rail engine, a coolant drain drilling was added to the cylinder block. The drilling runs the entire length of the cylinder block and passes through the center of each cylinder liner cavity. The drilling is plugged by a 1/4” pipe plug.

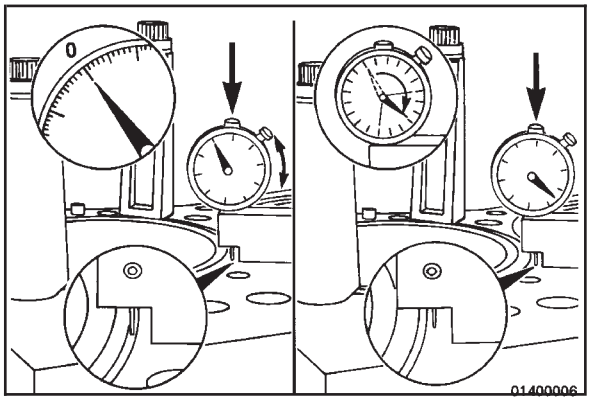
NOTE: Do **not** remove the plug.

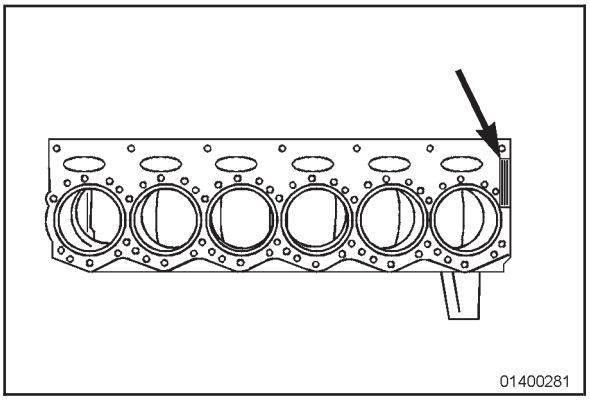


Inspect for Reuse

Measure the liner protrusion. .

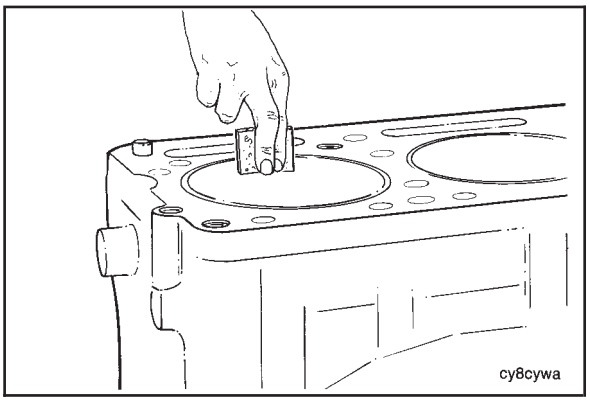
NOTE: If the protrusion is **not** correct, remove the liner. Refer to Procedure 001-064. The protrusion can be adjusted using seal rings, and machining the counterbore ledge.





Inspect the cylinder block to determine if an oversize or a standard size head gasket is required.

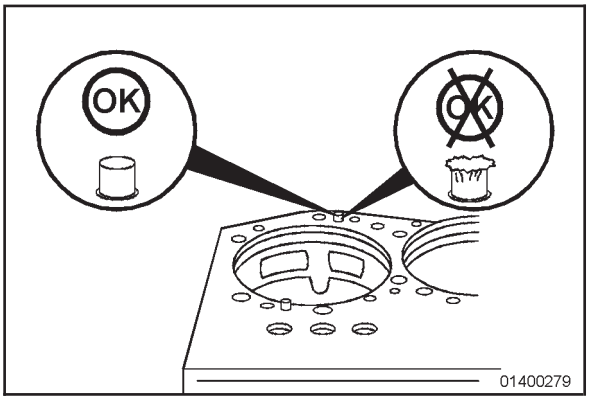
NOTE: An oversize head gasket may be required on blocks that have had material removed from the top surface of the block. Check the block for markings indicating an oversized gasket is required.



Use a scraper or a fibrous abrasive pad such as Scotch-Brite 7477, or equivalent, and solvent. Clean the top deck surface of the block. Do **not** allow any dirt into the cylinder. The surface **must** be free of dirt, oil, and gasket material, but does **not** have to look like new metal.

NOTE: Check the top surface of the block for wear. If fretting damage is present in an area where a head gasket seal ring or a grommet makes contact, the surface **must** be repaired. Refer to the Alternative Repair Manual, Bulletin No. 3379035.

NOTE: Fretting damage in any other area is acceptable **only** if it does not change the protrusion measurement of the counterbore or liner.



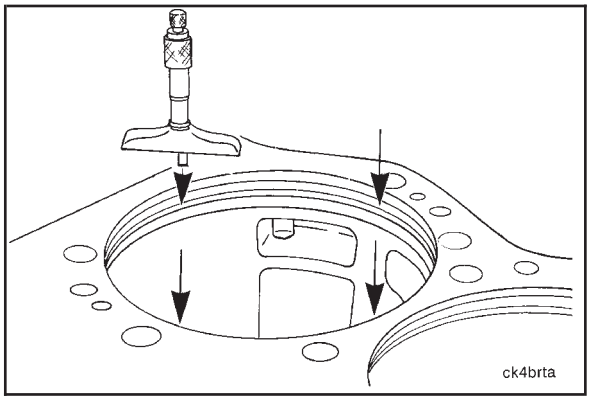
Visually inspect the groove pins for damage. Use the ST-1134 dowel pin extractor, or equivalent, to remove the pins.

Measure

NOTE: Be sure the micrometer contacts the flat surface of the ledge. It **must not** touch the radius.

NOTE: If the counterbore depth does **not** meet specifications, a **thicker** or **thinner** seal ring may have been used in a previous machining bore process. Measure and record the measurement so that the liner protrusion can be determined.

Use a depth micrometer and measure the counterbore depth at the four places shown.

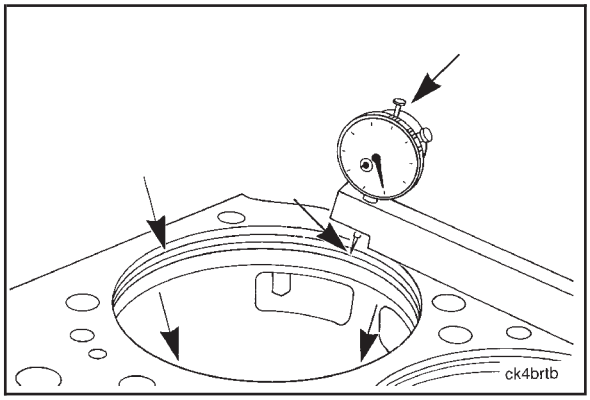


Counterbore Depth		
mm		**in**
13.755	MIN	0.5415
13.805	MAX	0.5435

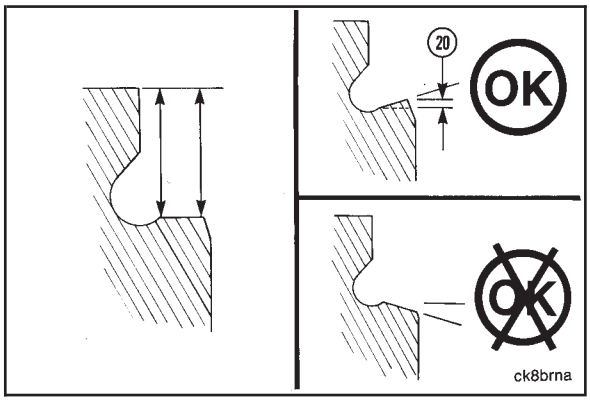
The four measurements **must not** vary more than 0.25 mm [0.001 inch]. If the measurements exceed the specifications, the counterbore ledge **must** be machined.

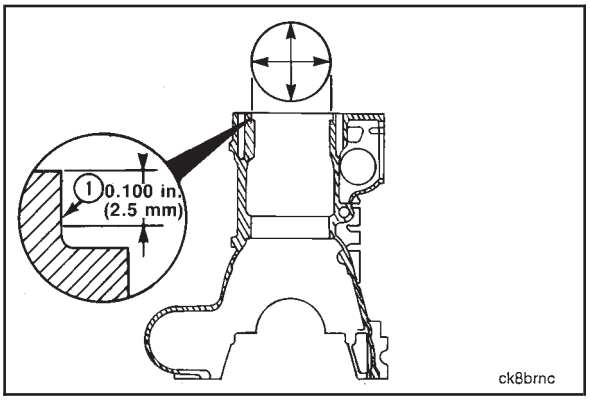
NOTE: Be sure that the indicator does **not** contact the counterbore radius on a block that does **not** have a double undercut.

Use depth gauge assembly, Part No. 3823495. Measure the angle of the counterbore ledge at four places on the counterbore circumference.
The measurement of the ledge depth **must** be as near to the counterbore radius as possible, and as near to the counterbore edge as possible.



The angle (12) of the counterbore ledge is acceptable (OK) if the measurement that is near the counterbore edge is the same or **no** more than 0.036 mm [0.0014 inch] shorter than the measurement near the counterbore radius. If the measurement near the counterbore ledge is longer than the measurement near the counterbore radius, the ledge **must** be machined.





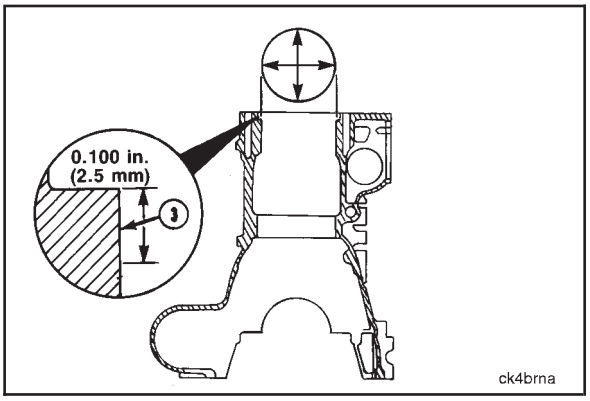
Measure the I.D. of the upper counterbore (1). The point of measurement **must** be within 2.54 mm [0.100 inch] from the top of the block.

Counterbore Diameter - UPPER Press Fit Diameter		
mm		**in**
188.16	MIN	7.409
188.21	MAX	7.410

The I.D. of the upper counterbore **must** be completely round within 0.050 mm [0.002 inch]. If the measurement is **not** within specification, check to see if the block can be machined to use oversize liners.

NOTE: The upper counterbore **must** be **no** more than 0.076 mm [0.003 inch] **larger** than the cylinder liner flange.

NOTE: If the counterbore does **not** meet specifications, an oversize liner may have been used in a previous machining bore process. Measure and record the measurement so that the proper press fit liner can be determined.



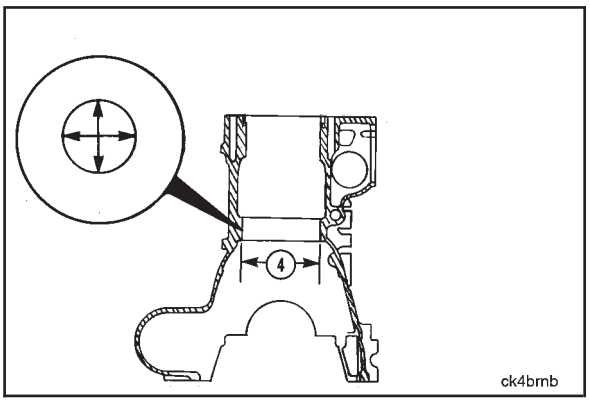
Measure the I.D. of the lower counterbore (3). The point of measurement **must** be within 2.54 mm [0.100 inch] from the top of the counterbore ledge.

Counterbore Diameter - LOWER Press Fit Diameter		
mm		**in**
180.09	MIN	7.090
180.14	MAX	7.092

The I.D. of the lower counterbore **must** be completely round within 0.050 mm [0.002 inch].

NOTE: If the counterbore does **not** meet specifications, an oversize liner may have been used in a previous machining bore process. Measure and record the measurement so that the proper press fit liner protrusion can be determined.

If the block is **not** within specifications, do **not** use the block.



Check the chamfer at the top of the packing ring bore. Excessive pitting **must** be repaired. Refer to the Alternative Repair Manual, Bulletin No. 3379035.

(4) Packing Ring Bore		
mm		**in**
177.34	MIN	6.982
177.40	MAX	6.984

Leak Test
Cylinder Liner (001-028)

Clean

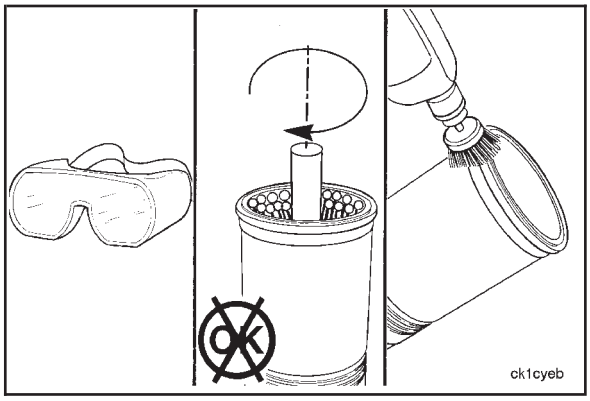
⚠ CAUTION ⚠

Do not use a hone, deglazing, or prebrushing to clean the cylinder liners. Abrasives can damage the finish and the crosshatch pattern and can contaminate the liner.

⚠ WARNING ⚠

Wear eye protection. Make sure the wire brush is rated for the RPM being used if the brush is motor driven.

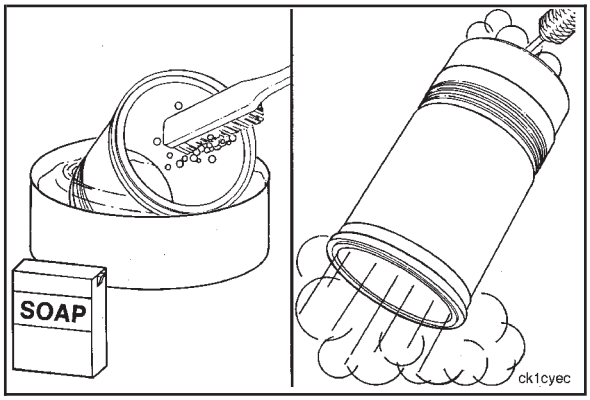
Use a high quality steel wire brush to clean the liner flange seating area.



Use a non-metallic bristle brush, detergent soap, and warm water to clean the inside diameter.

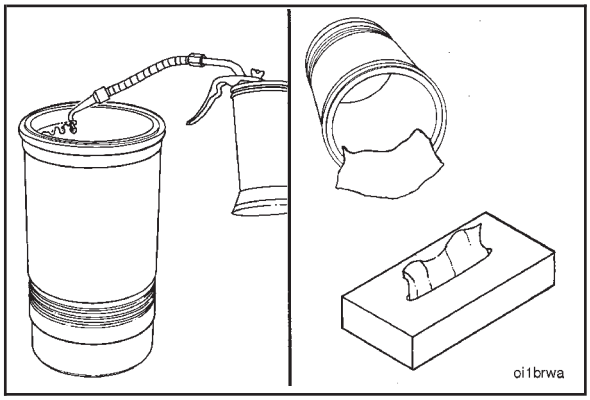
Use a steam cleaner or solvent tank to lean the liners.

Dry with compressed air.



Use clean engine oil. Lubricate the I.D.

Allow the liner to soak for five to ten minutes

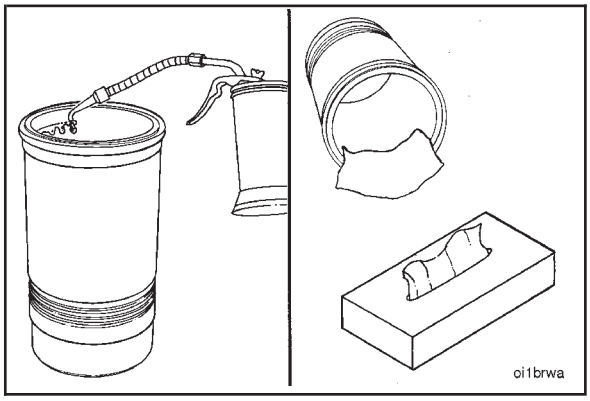


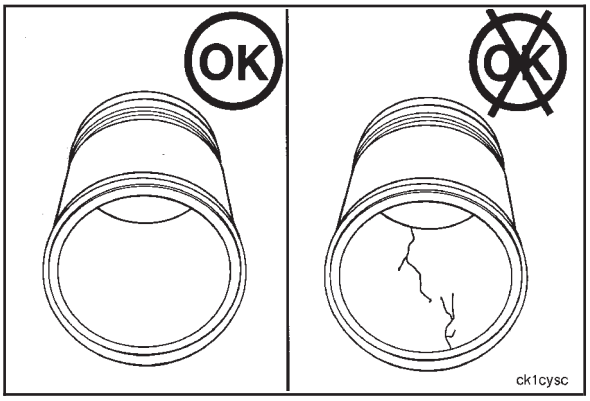
⚠ CAUTION ⚠

Do not use a cloth towel. Lint will cause severe engine damage.

Use a paper towels. Wipe the liner I.D.

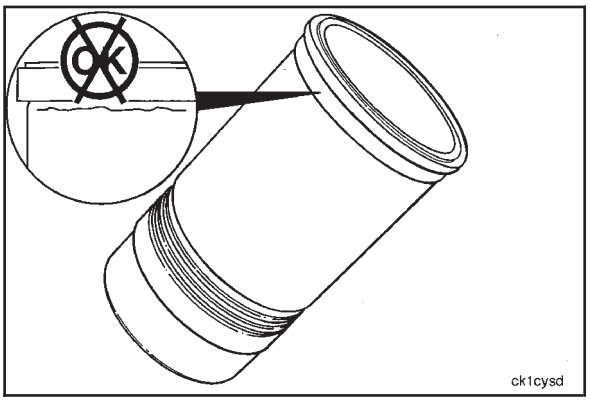
Repeat these three cleaning steps until the paper towel shows **no** gray or black residue.





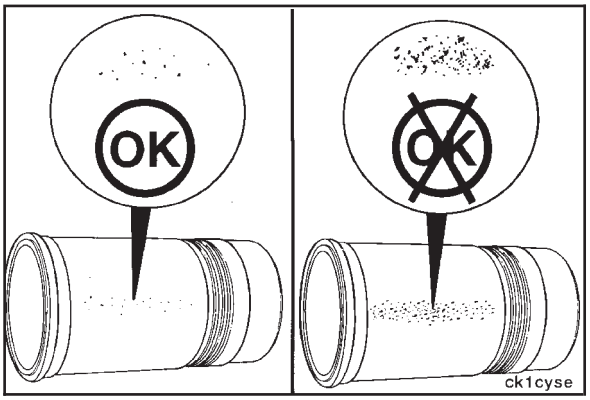
Inspect for Reuse

Visually inspect the liners for cracks on the inside and the outside diameters.



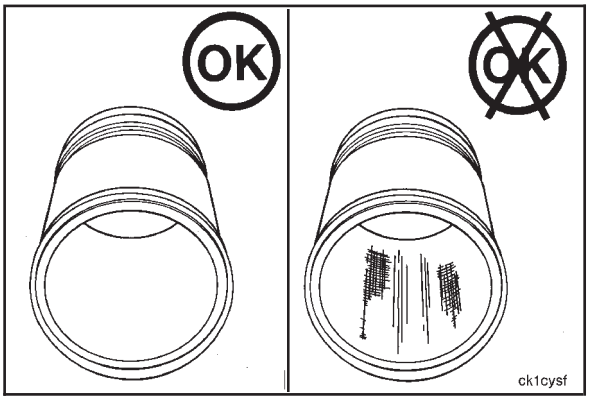
Inspect for cracks under the flange.

NOTE: Cracks can also be detected by using either magnetic inspection or the dye method.



Visually inspect the outside diameter for excessive corrosion or pitting. Pits **must not** be more than 1.6 mm [0.063 in] deep.

Replace the liner if the pits are too deep or if the corrosion **can not** be removed with a fine emery cloth.



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

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

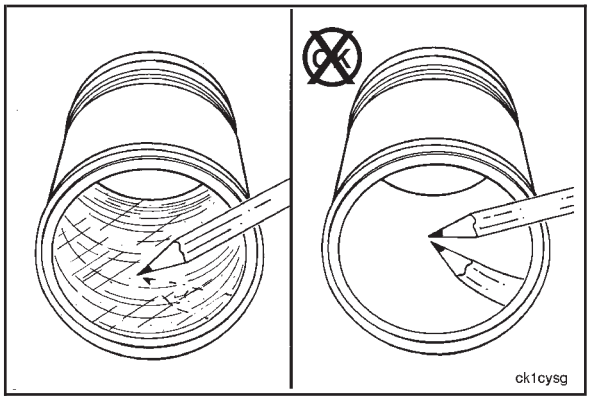
Visually inspect the inside diameter for scuffing or scoring.

Visually inspect the inside diameter for liner bore polishing.

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

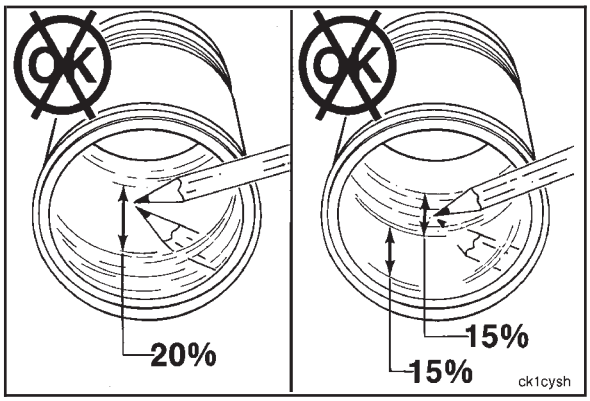
A **heavy polish** produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

NOTE: Refer to Parts Reuse Guidelines, Bulletin No. 3810303, for further information on liner bore polishing.



Replace the liner if:

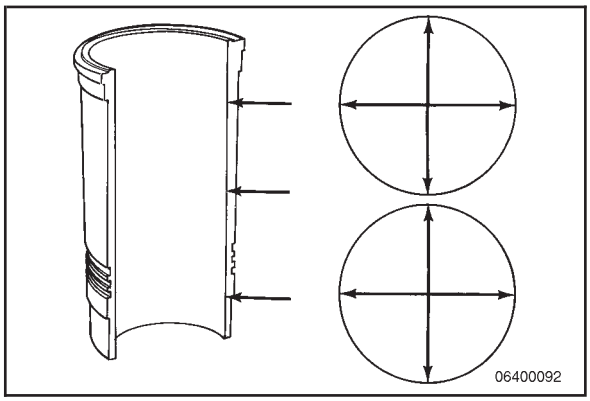
- A heavy polish is present over twenty percent (20%) of the piston ring travel area.
- Thirty percent (30%) of the piston ring travel area has both moderate and heavy polish, and one-half (15 percent) is heavy polish.



Use a dial bore gauge. Measure the I.D. of the liner at the top, the bottom, and the middle of the piston ring travel area. Perform two measurements at each location. The measurements **must** be 90 degrees apart.

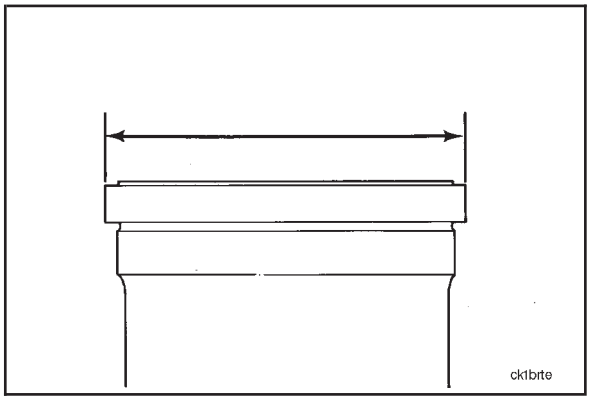
Cylinder Liner I.D.		
mm		**in**
158.737	MIN	6.2495
158.877	MAX	6.2550

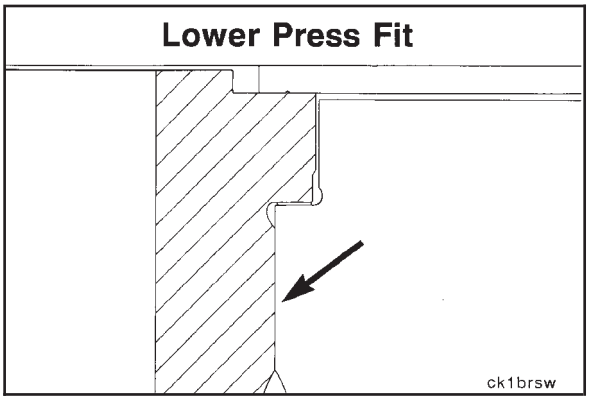
NOTE: The I.D. of a new cylinder liner can be 0.015 mm [0.0006 inch] smaller than specifications because of the Lubrite® coating.



Measure the liner flange outside diameter.

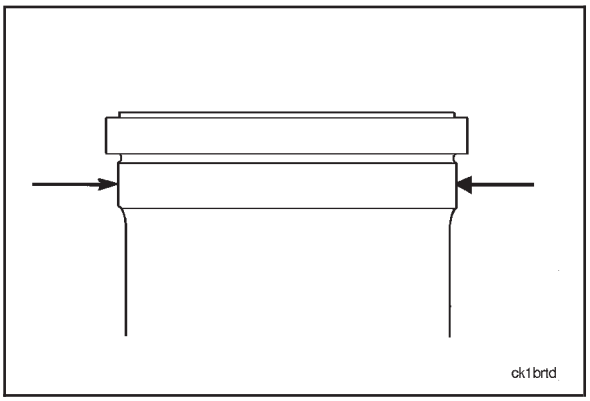
Upper Press Fit Liner Flange Diameter			
	mm		**in**
Standard	188.19	MIN	7.409
	188.24	MAX	7.411
Oversize 20/20	188.70	MIN	7.429
	188.75	MAX	7.431





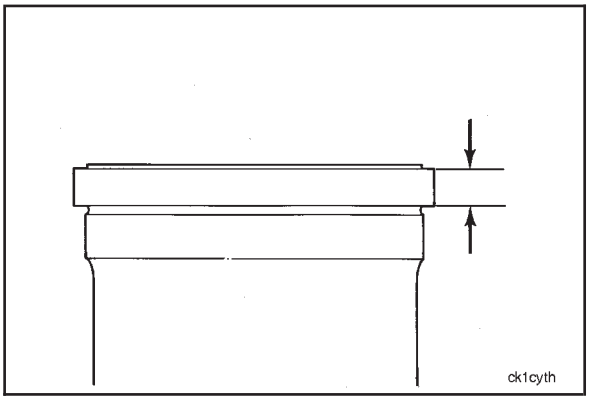
NOTE: The liner design incorporates a press fit between the upper liner bore and the area of the liner directly below the liner flange. This is referred to as the Lower Press Fit (LPF) design.

NOTE: Cylinder liners with standard and oversize press fit diameters are available.



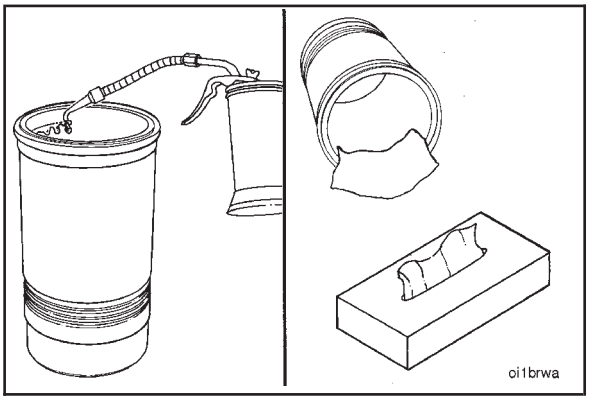
Measure the lower press fit diameter.

Lower Press Fit Area O.D.			
	mm		in
Standard	180.16	MIN	7.093
	180.21	MAX	7.095
Oversize 20/20	180.67	MIN	7.113
	180.72	MAX	7.115



Measure the liner flange thickness.

Liner Flange Thickness		
mm		in
13.398	MIN	0.5275
13.424	MAX	0.5285



Apply a thick film of clean 15W-40 oil to the bores of the liners for final cleaning. Leave the oil on for 5 to 10 minutes.

Use a clean, lint-free paper towel, not cloth, to wipe the oil from the bores until the black and gray deposits are removed.

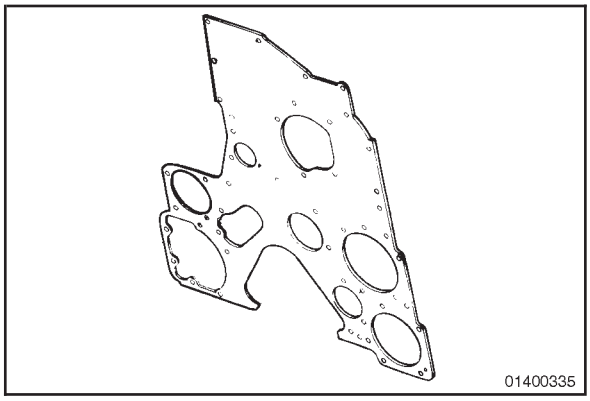
NOTE: Do not set the liners in an area where dirty air flow can contaminate the liners.

Gear Cover Spacer Plate (001-029)

Clean

Use solvent, clean the Gear Cover Spacer Plate.

Dry with compressed air.



Inspect for Reuse

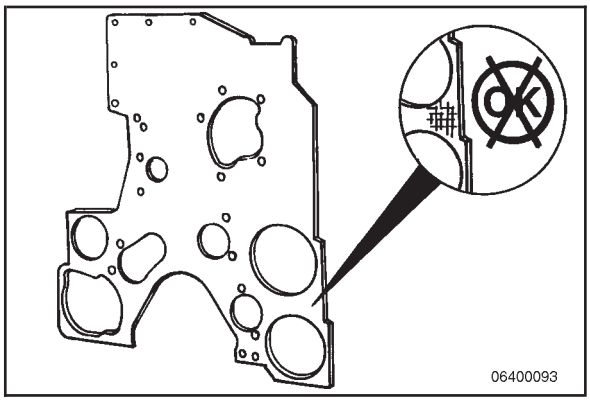
Inspect the plate for reuse. Check for fretting damage on both sides of the gasket surface. Replace the plate if damaged.

Check the mounting stud threads for damage.

Install new studs to the specified height.

Accessory Drive Stud (1)- Installed Height		
mm		in
31.88	MIN	1.255
33.15	MAX	1.305

Water Pump Drive Stud (2) — Installed Height Gear Spacer Plate and Gear Housing		
mm		in
62.99	MIN	2.480
63.75	MAX	2.510



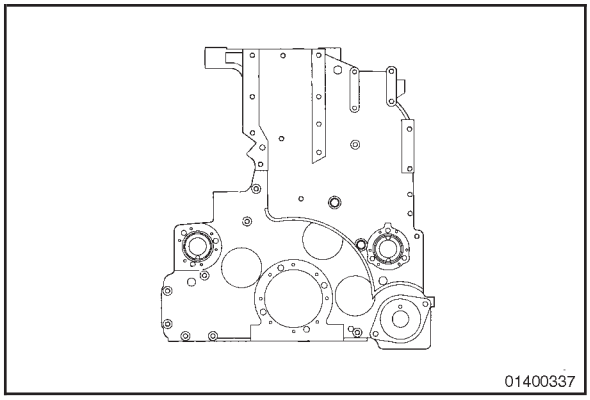
Gear Cover, Front (001-031)

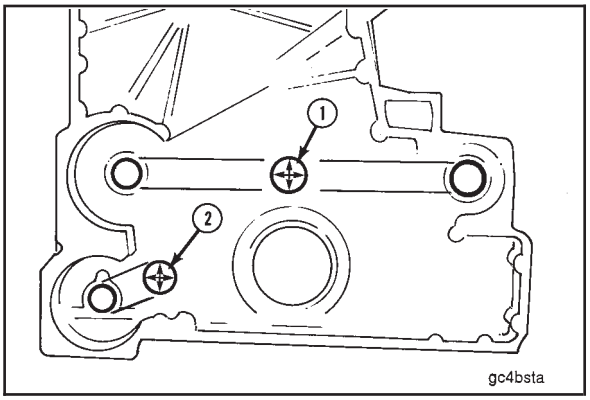
Clean

⚠ WARNING ⚠

When using solvents, acids or alkaline materials or steam for cleaning, follow the manufacture's recommendations for use. Wearing goggles and protective clothing to avoid personal injury.

Use solvent or steam. Clean the front cover and related parts.



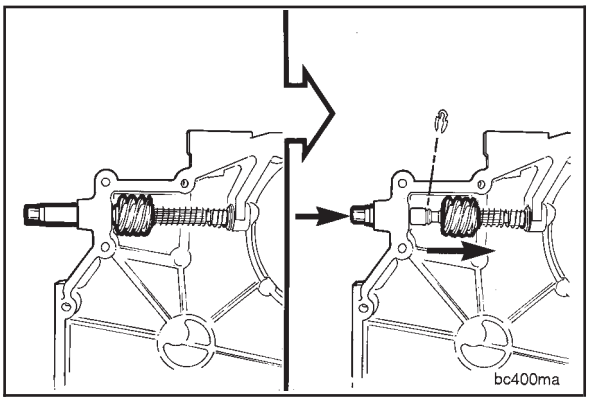


Inspect for Reuse

Measure the I.D. of the bushings. The bushings **must** be replaced if **not** within specifications.

Accessory Drive & Water Pump Drive Bushing I.D.		
mm		in
39.75	MIN	1.565
39.90	MAX	1.571

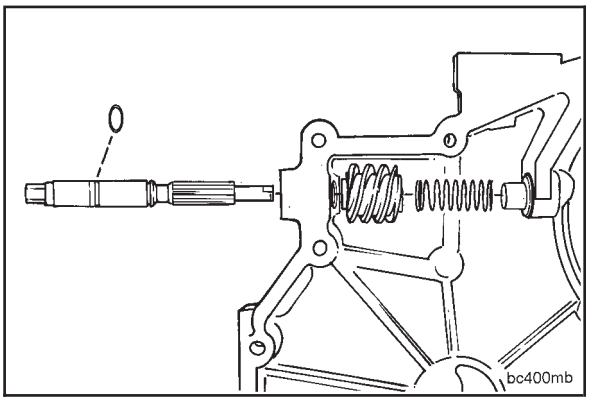
Hydraulic Pump Drive (2) Bushing I.D.		
mm		in
38.13	MIN	1.501
38.25	MAX	1.506



Remove and check the barring mechanism.

Push the shaft in. Hold in position. Slide the worm gear until the spring is compressed.

Use a screwdriver. Remove the retaining ring.



Remove the parts:

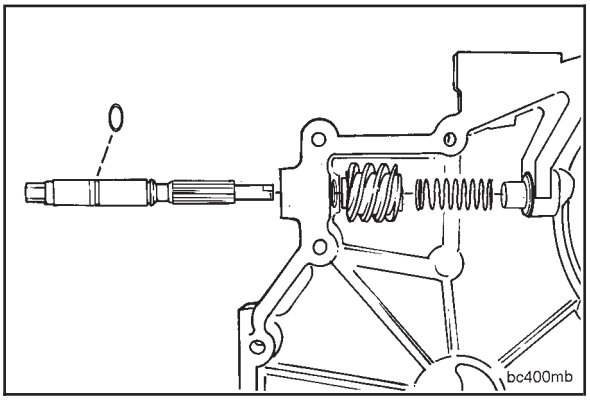
- Shaft
- Spring
- Worm gear

Remove the o-ring from the shaft. Discard the o-ring.

Use solvent to clean the parts. Flush the oil drillings. Dry with compressed air.

NOTE: Some contact marks on gear are acceptable.

Check the parts for severe damage.



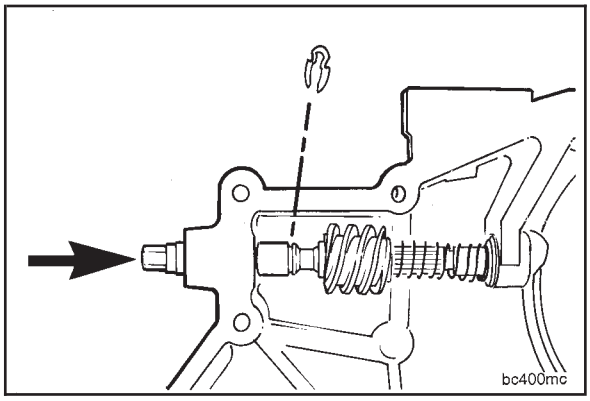
Use vegetable oil to lubricate the o-ring. Install the o-ring on the barring shaft.

Install the parts:

- Worm gear
- Spring
- Shaft

Install the retaining ring.

Rotate the shaft. Check for correct assembly.



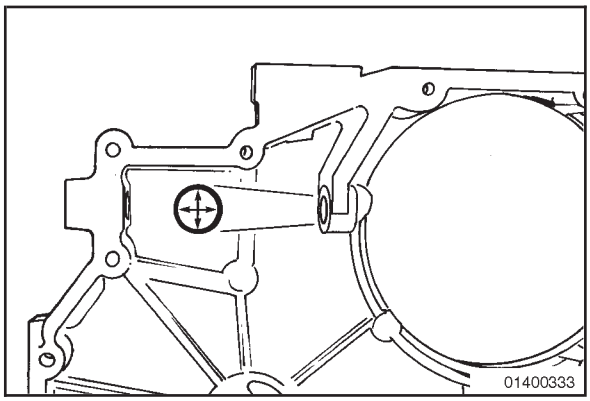
Measure

Barring Mechanism Bushing Bore

Measure the I.D. of the bushing bore.

Barring Mechanism Bushing Bore		
mm		in
18.215	MIN	0.717
18.265	MAX	0.719

The bushing **must** be replaced if **not** within specifications.

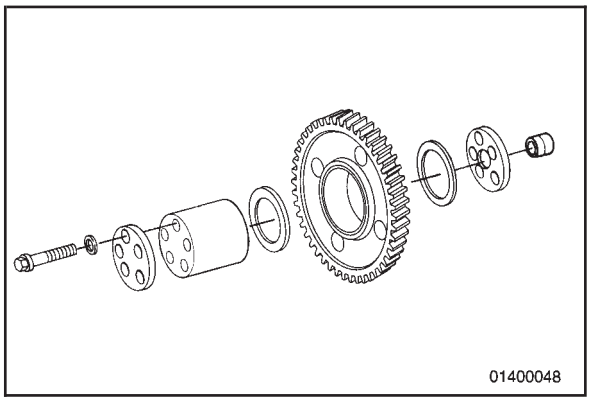


Idler Gear, Camshaft (001-036)

Clean

Use solvent. Clean the idler gear and parts.

Dry with compressed air.



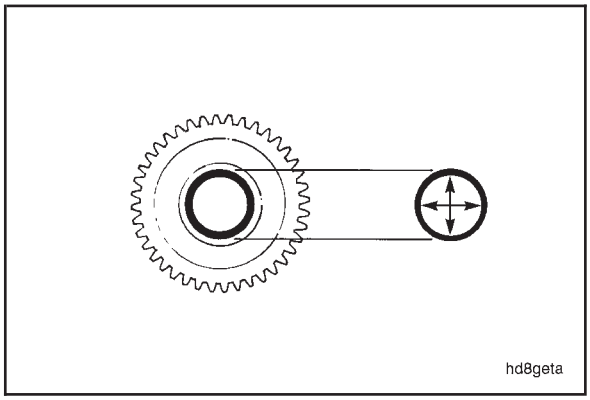
Inspect for Reuse

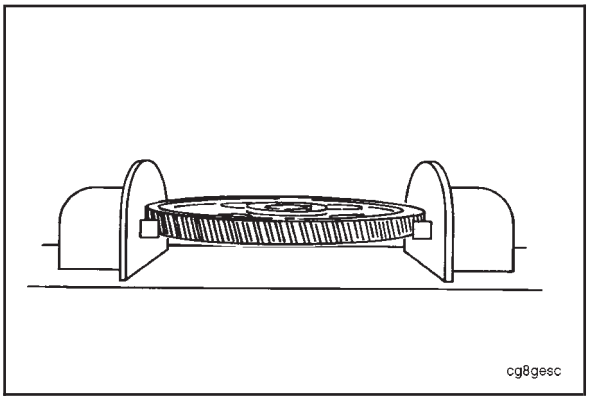
Check the parts for damage.

Measure the I.D. of the idler.

Idler Gear Bushing I.D.		
mm		in
47.638	MIN	1.8755
47.714	MAX	1.8785

NOTE: The bushing in the gear is precision bored after installation. If machining capability is **not** available, replace the bushing and the gear as an assembly.





Magnetic Crack Inspect

⚠ CAUTION ⚠

Use a copper braid contact that has neoprene covers to avoid burning the teeth of the gear.

⚠ CAUTION ⚠

If the gear contains a keyway, position the gear so that the keyway points toward one of the contacts when checking.

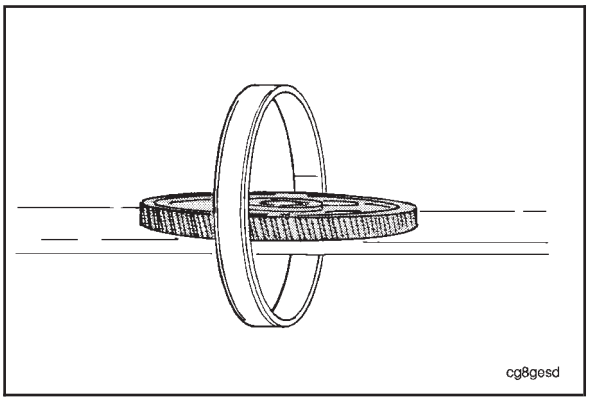
Use a magnetic particle testing machine.

Use the residual method. Apply head shot amperage.

Adjust the amperage to the specified value

Gear O.D.	Amperage D
Less than 101 mm [4 inch]	**1000**
101 mm to 203 mm [4 inch to 8 inch]	1500
Greater than 203mm [8 inch]	2000

Check the gear for cracks.



⚠ CAUTION ⚠

If the gear contains a keyway, position the gear so that the keyway points toward the coil.

Use the residual method. Apply coil shot amperage.

Adjust the amperage to the specified value

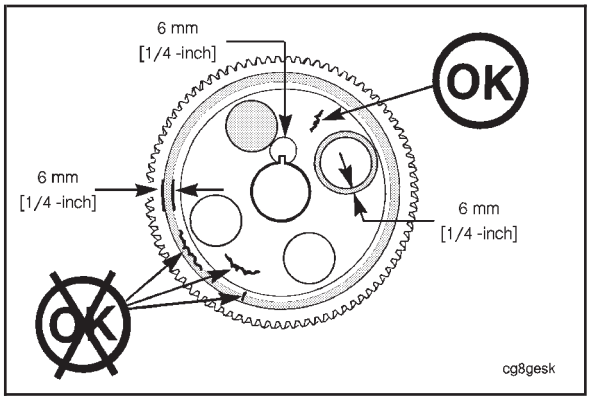
Gear 0.D.	Ampere Turns
Less than 101 mm [4 inch]	**4000**
101 mm to 203 mm [4 inch to 8 inch]	6000
Greater than 203 mm [8 inch]	8000

NOTE: Ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.

Check the gear for cracks.

Limits of Acceptance — on Machined Surfaces

An open indication is visible to the eye after the wetting operation has been completed. An indication below the surface is **not** visible to the eye after the wetting operation has been completed. An indication below the surface can be seen with the use of the ultraviolet light that is part of the machine.



Do **not** use the gear if:

- There is an open indication.
- There is an indication below the surface that is in the shaded area as shown.
- There is an indication below the surface that is longer than 6 mm [1/4 inch].

Limits of Acceptance — on Forged Surfaces

Do **not** use the gear if:

- There is an open indication that is in a circumferential direction.
- There is an open indication that is longer than 9.5 mm [3/8 inch].
- There is an indication below the surface that is in the shaded area.

An indication below the surface in a radial direction is acceptable (OK) if it is in the area that is **not** shaded.

CAUTION

The gear must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the gear.

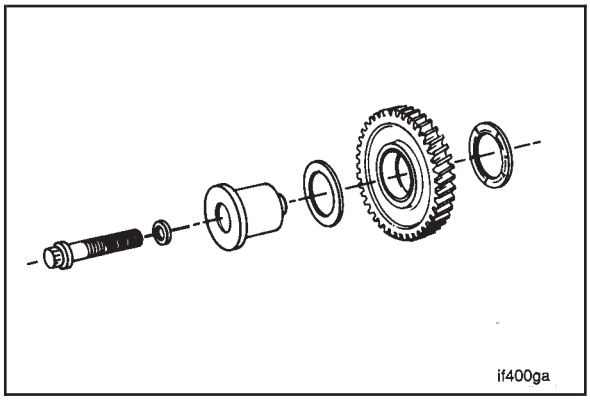
Use solvent or steam. Clean the part.

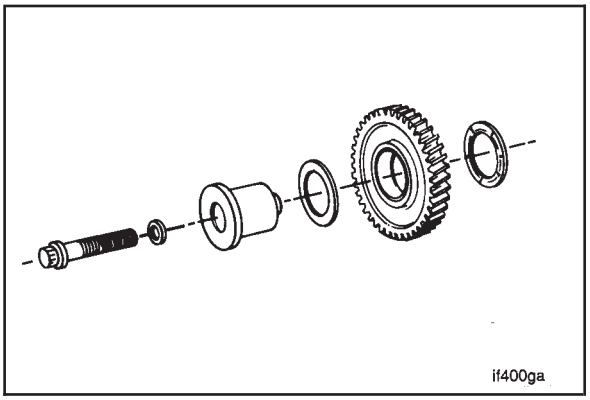
Idler Gear, Hydraulic Pump (001-039)

Clean

Use solvent. Clean the idler gear.

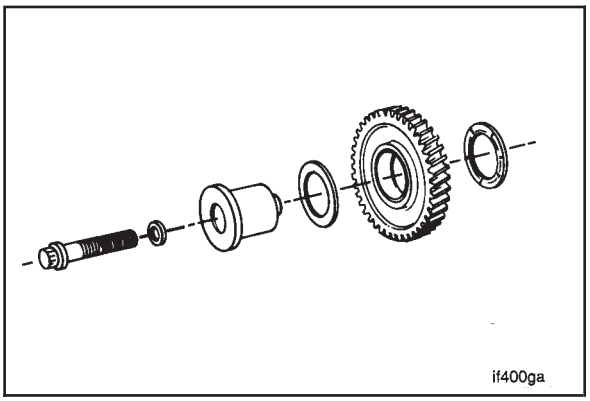
Dry with compressed air.





Inspect for Reuse

Check the gear and parts for any damage.

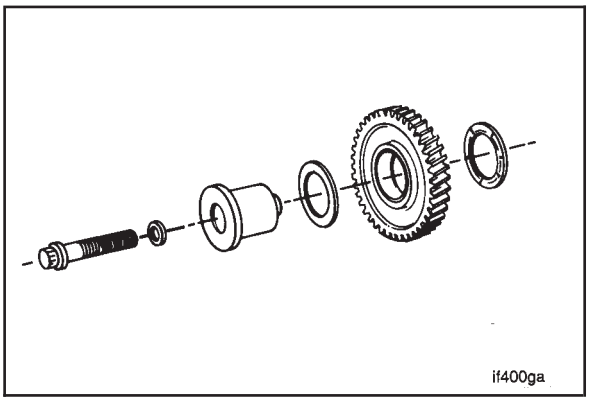


Idler Gear, Water Pump (001-040)

Clean

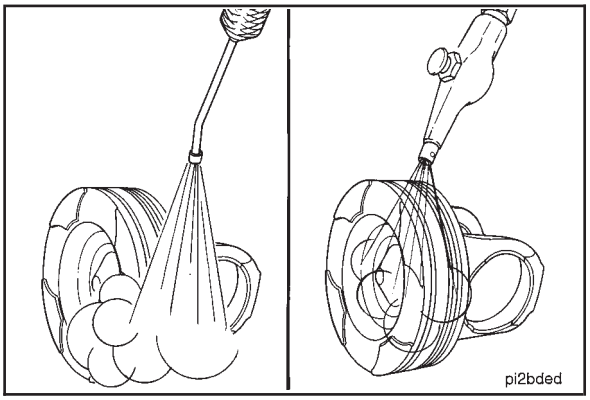
Use solvent clean the part.

Dry with compressed air



Inspect for Reuse

Check all parts for damage.



Piston (001-043)

Clean

⚠ WARNING ⚠

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

Use steam to clean the outer layers of carbon from the piston surface. The bead blast method can be used to clean the top of the piston. If this method is used, cover the ring grooves and skirt securely.

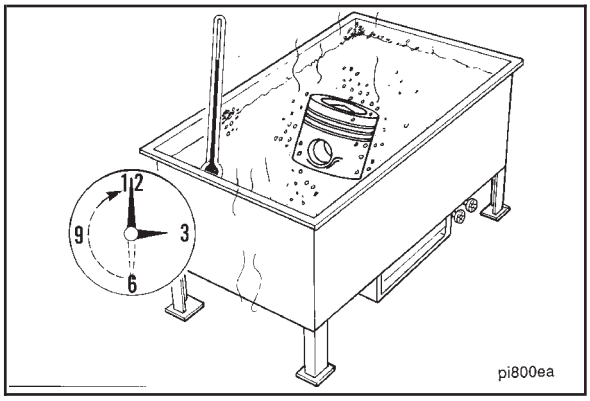
NOTE: It is only necessary to remove the carbon buildup. It is **not** necessary to make the crown appear new.

⚠ CAUTION ⚠

Do not contaminate the wash tank solution with bead blast materials.
Use a kerosene emulsion-based solvent. Do not use a solvent that is higher than 9.5 pH. Do not use a solvent that contains chlorinated hydrocarbons with cresol, phenols, or cresylic components.

Allow the pistons to soak in the solvent a minimum of 30 minutes.

NOTE: For best results soak the pistons several hours or overnight. Use a solvent that can be heated from 90°C to 95°C [194°F to 203°F]. Use a cleaning tank that will circulate and filter the solvent.



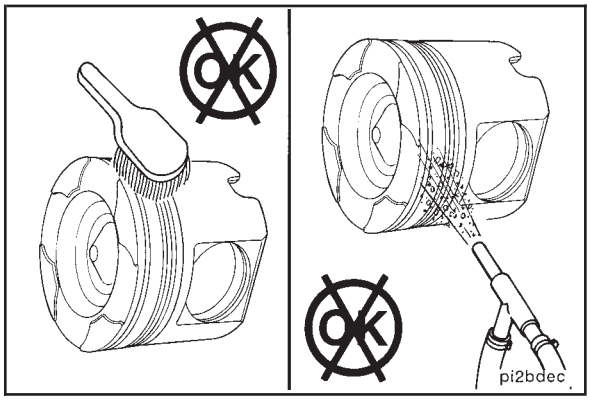
⚠ CAUTION ⚠

Do not use the bead blast method to clean the skirt. The piston skirt will be damaged by blast material being embedded in the aluminum.

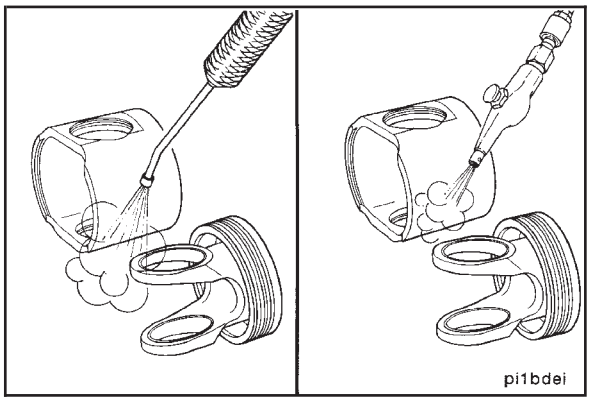
⚠ CAUTION ⚠

Do not use a metal bristle brush to clean the pistons. Damage to the ring grooves will result.

Use a brush to clean the ring grooves. Walnut shell blasting can be used on the piston crown.
Repeat the soaking and scrubbing process until the piston is thoroughly clean.

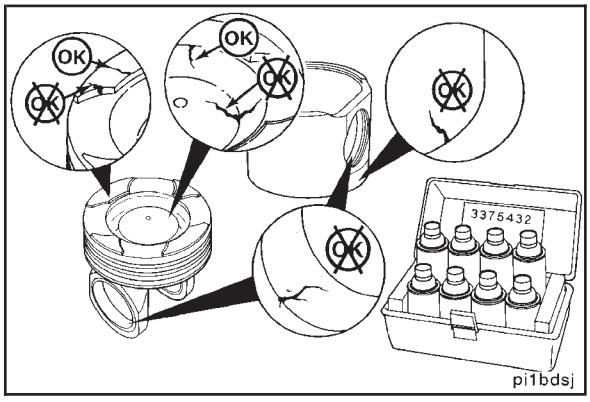


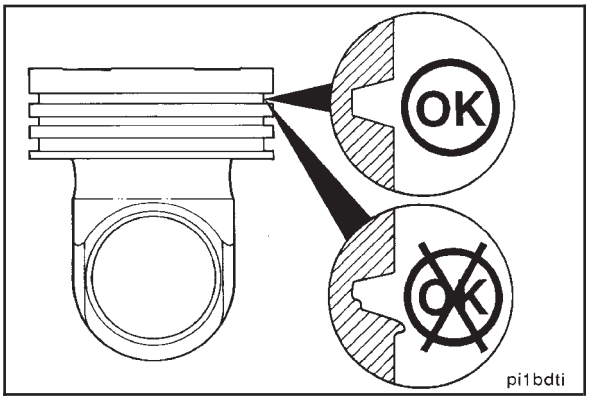
Use steam to rinse the solvent from the pistons. Dry the pistons with compressed air.



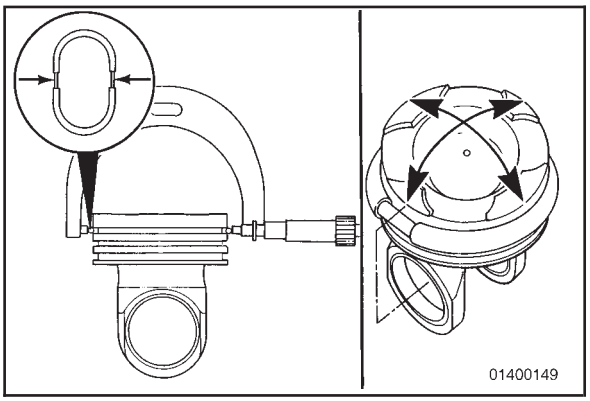
Inspect for Reuse

Visually inspect both the crown and skirt. Do **not** use the crown or skirt if cracks or scuff marks are found. Scratches in the skirt are **not** acceptable if they are visually **not** acceptable. Use crack detection kit, Part No. 3375432, or its equivalent, to check for cracks on the piston crown and in and around the piston pin bore. Do **not** use if cracked or scuffed. If the crown is **not** acceptable, replace the crown and pin.





Visually inspect the ring grooves. The pistons **must** be replaced if there is a visible ridge in the back of the groove. The piston **must** be replaced if a lip has formed on the O.D. of the groove.

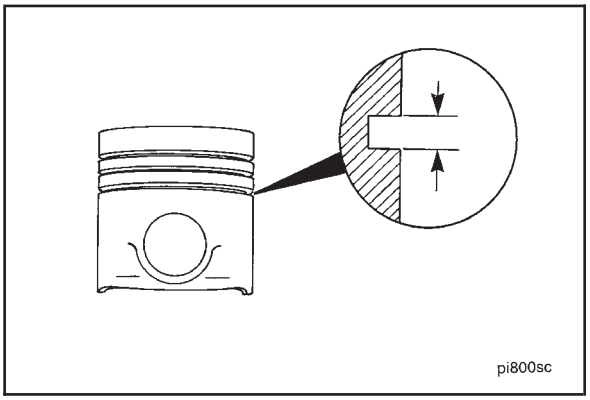


Use piston ring groove wear gauge, Part No. 3824846, and a 6 to 7 inch micrometer to inspect the top groove (compression ring).

NOTE: The piston **must** be replaced if measured dimensions are less than those in the table below.

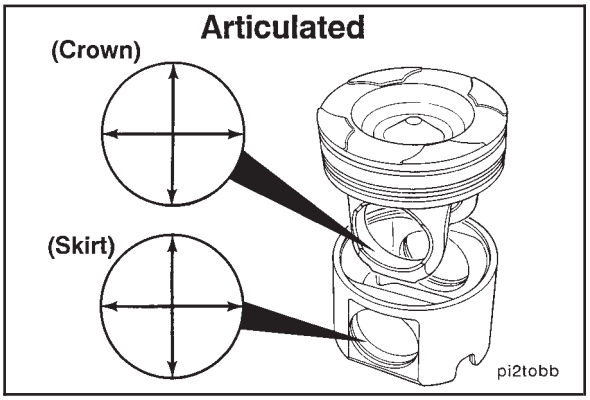
Measure the top and second ring grooves (diameter over pins) when the piston temperature is at 21°C (70°F) in two places 90 degrees apart as shown.

Ring Groove Wear Limits (Diameter Over Pins)			
	mm		in
Top Ring	159.100	MIN	6.2638
Second Ring	159.413	MIN	6.2761



Measure the oil ring groove. The piston must be replaced if it is **not** within specification.

Piston Oil Ring Groove Width		
mm		in
4.788	MIN	0.1885
4.851	MAX	0.1910



Measure the piston pin bore inside diameter.

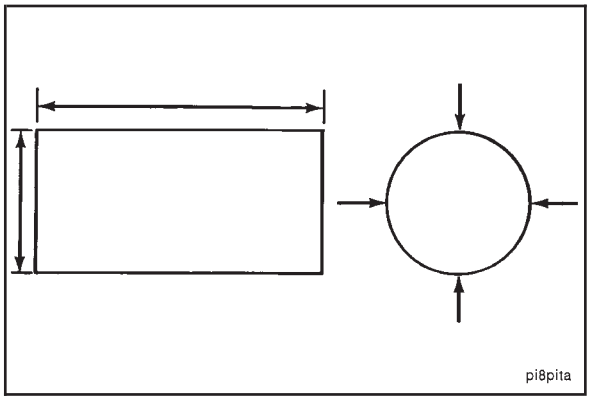
Articulated Piston Pin Bore I.D. (Crown)		
mm		in
60.960	MIN	2.4000
61.059	MAX	2.4039

Articulated Piston Pin Bore I.D. (Skirt)		
mm		in
60.949	MIN	2.3996
60.961	MAX	2.4000

Measure the piston pin outside diameter and length.

Piston Pin O.D.		
mm		in
60.929	MIN	2.3988
60.935	MAX	2.3990

Piston Pin Length		
mm		in
132.59	MIN	5.220
132.85	MAX	5.230



Vibration Damper (001-052)

Clean

Vibration dampers have a limited service life. The damper **must** be replaced after 15,000 hours in service.

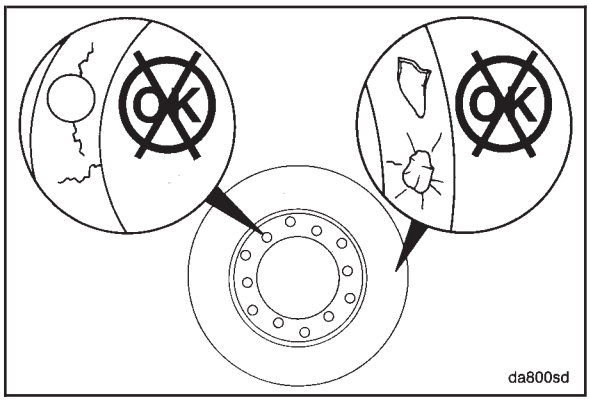
Do **not** repair or balance a viscous damper in the field.

WARNING

When using solvents, acids or alkaline materials for cleaning, follow the manufacture's recommendation for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent. Clean the exterior of the damper.

Dry with compressed air.



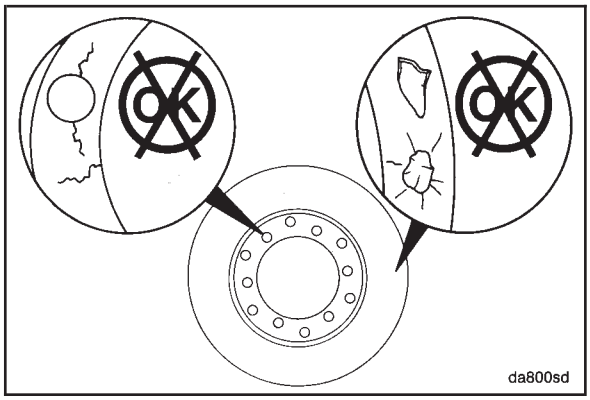
Inspect for Reuse

NOTE: Vibration dampers have a limited service life. The damper **must** be replaced after 576,000 km, [360,000 miles], or 15,000 hours of service.

NOTE: Do **not** repair or balance a viscous damper in the field.

Inspect the damper for reuse. Inspect for cracks on the mounting flange. Inspect for dents or bulges on the housing.

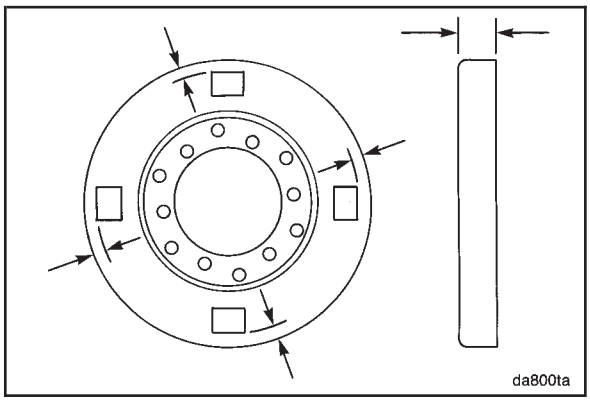
If the damper is damaged, it **must** be replaced.

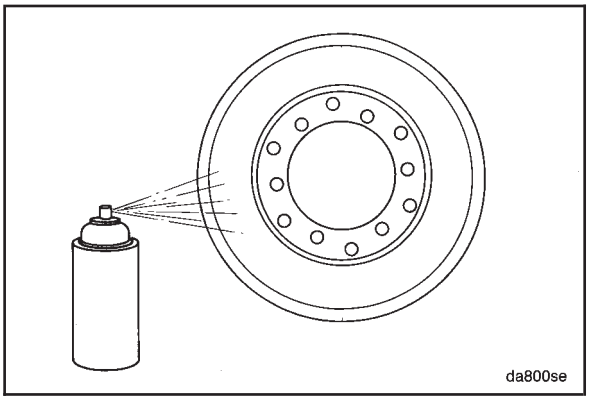


Use a paint solvent and fine crocus cloth. Remove the paint from the front and back of the housing at the four areas shown.

Measure **no** less than 3 mm [1/8 inch] from the O.D. to be sure that the measurement is on a flat surface.

Measure the thickness at four places. If the measurements vary more than 0.25 mm [0.010 inch], or if the thickness exceeds 42.24 mm [1.663 inch], the damper **must** be replaced.

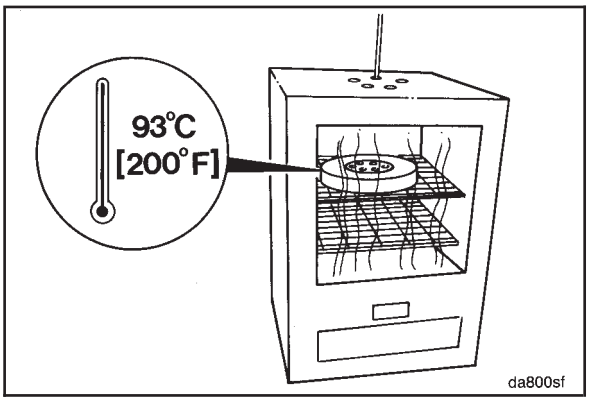




NOTE: The following illustrates the procedure to check the damper for fluid leakage.

Use the crack detection kit, Part No. 3375434, or equivalent, and spray the rolled lip of the damper.

NOTE: The crack detection kit, Part No. 3375434, contains the necessary cleaner, penetrant, and developer to check for cracks using the dye penetrant method.

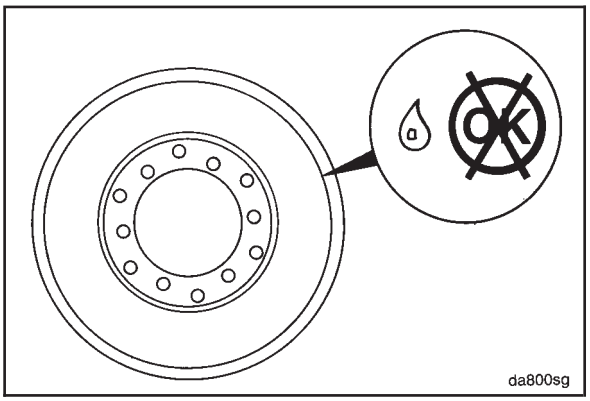


⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

Use an oven with the temperature adjusted to 93°C [200°F].

Put the damper in the oven with the rolled lip down. Heat the damper for two hours.



⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

Remove the damper and check for leakage around the lip. If there is any leakage the damper **must** be replaced.

Cylinder Block Counterbore (001-058)

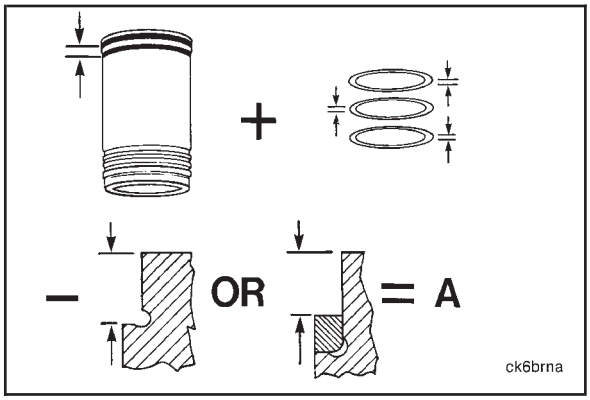
Machine

⚠ WARNING ⚠

Read the complete Procedure before beginning to machine the block.

The counterbore ledge will be machined. Sealing rings will be used to obtain the correct cylinder liner protrusion.

The cylinder protrusion (A) is the **total sum** of the thickness of the liner flange and the sealing rings, **minus** the counterbore depth.

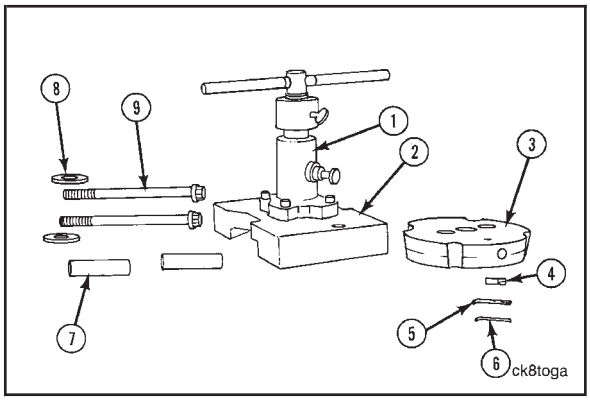


Cylinder Liner Protrusion		
mm		in
0.13	MIN	0.003
0.18	MAX	0.007

NOTE: Some liners are oversize in flange thickness and flange O.D.

If necessary, machine the block for oversize liners before machining the counterbore ledge for depth. Refer to procedure No.

Resurface the block as required before machining the counterbore ledge depth. Refer to Bulletin No. 3379035, Alternative Repair Manual, for machining instructions.

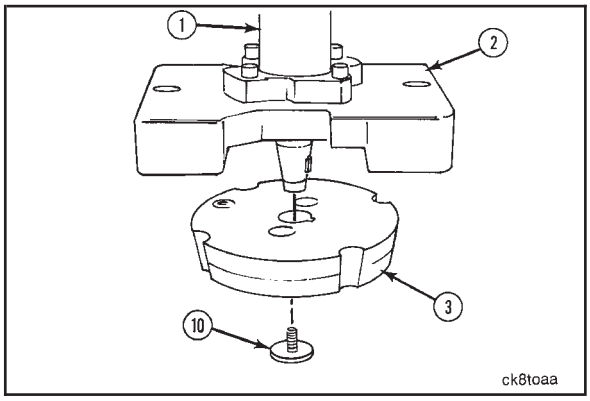


Tools required
1. Drive unit, Part No. 3376685
2. Adapter plate, Part No. 3376684
3. Cutter plate, Part No. 3375980
4. Tool bit
5. Hex wrench [3/16-inch]
6. Hex wrench [3/32-inch]
7. Bolt spacers [3/16-inch I.D. by 3 1/2-inch]
8. Plain washers [3/16 I.D. by 2 inch O.D.]
9. Cylinder head capscrews for the block being machined

NOTE: The cylinder block counterbore tool, Part No. 3376684, contains the tools listed above. The same kit contains the tools to machine the counterbore depth on **all** Cummins engines **except** the L10.

Install the drive unit (1) on the adapter plate (2).

Torque Value: 40 N•m [30 ft-lb]

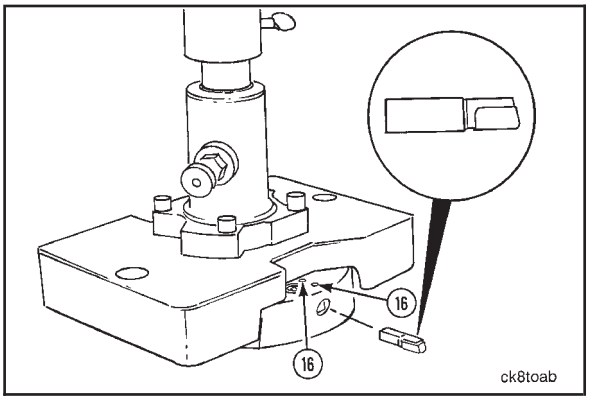


Align the key slot on the cutter plate (3) with the key on the drive unit shaft. Install the plain washer and capscrew (10).

Torque Value: 40 N•m [30 ft-lb]

Use a mallet. Tap the cutter plate. the cutter plate **must** be seated on the shaft.

NOTE: Radius specifications are in inches.



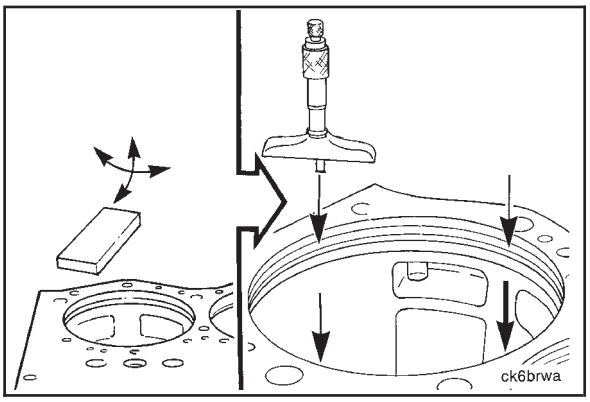
⚠ CAUTION ⚠

Part No. 3377468 must be used to machine the counterbore ledge.

Install the tool bit in the cutter plate. Position the bit so it will cut when the plate is moving **clockwise**.

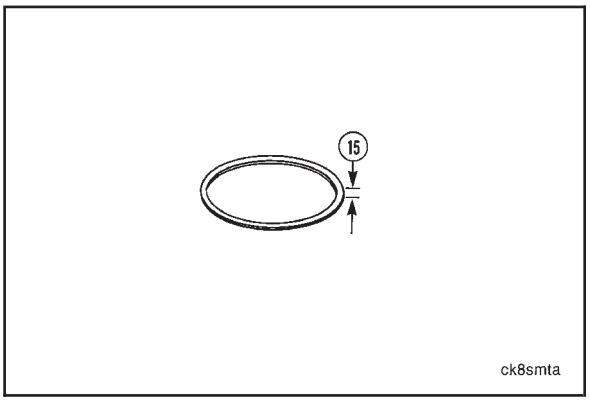
Push the tool bit into the plate until it is **even** with or **below** the O.D. of the plate.

Some resistance can be felt when installing the bit extension device. If the bit will not go in, loosen the two locking screws (16).



Use a fine, India type stone. Remove any nicks and burrs from the head surface and counterbore ledge. Nicks and burrs will prevent the tool from seating correctly.

Use a depth micrometer to measure the counterbore depth. Measure at four equally spaced points. Record the measurements.

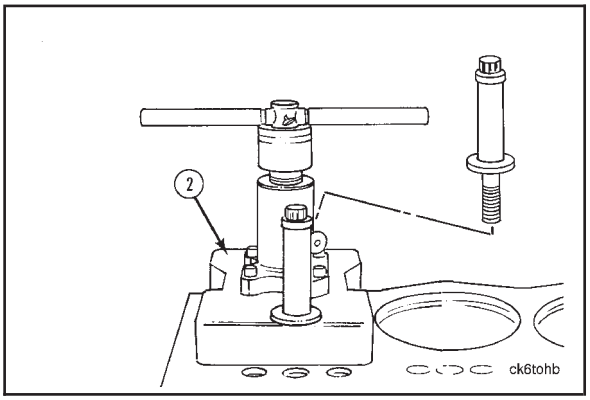


⚠ CAUTION ⚠

Do not use more than three seal rings under one liner. The use of one thick seal ring is better than two thin shims.

Measure the thickness of the sealing rings used with the engine block being machined.

Select the best combination of sealing rings and counterbore ring to achieve the correct protrusion.



⚠ CAUTION ⚠

Do not allow the weight of the cutter plate to cause it to fall. The bit plate will be damaged. Hold up on the shaft when pulling the licking pin.

Set the cylinder block counterbore tool on the block.

Pull the locking pin. Lower the cutter plate until it touches the counterbore ledge. The taper on the cutter plate will center the tool in the cylinder bore.

There **must** be clearance between the stop collar (19) and the housing. Turn the collar until there is clearance.

Turn the shaft **backward** and **forward**. The taper must be positioned squarely in the bore.

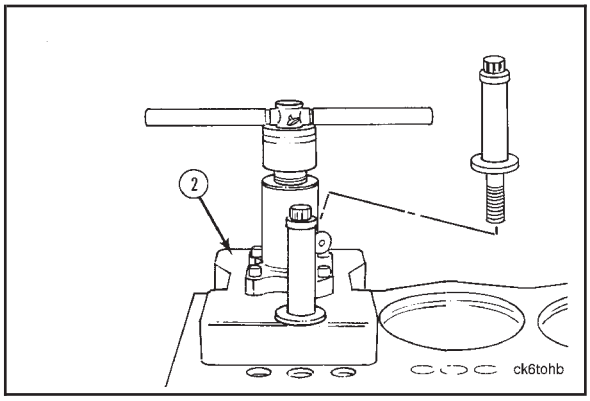
There must be no clearance between the adapter plate mounting surface and the block head surface.

Align the holes in the adapter plate (2) with two cylinder head capscrew holes in the block. Install the plain washers, spacers, and cylinder head capscrews.

Tighten the capscrews.

Torque Value: 70 N•m [50 ft-lb]

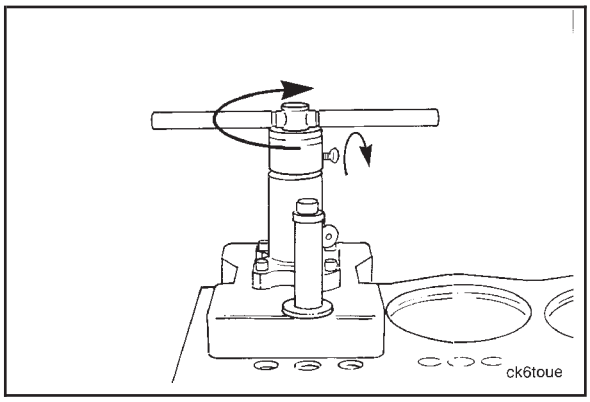
If the tool is **not** aligned correctly it will **not** turn after the capscrews are torqued.



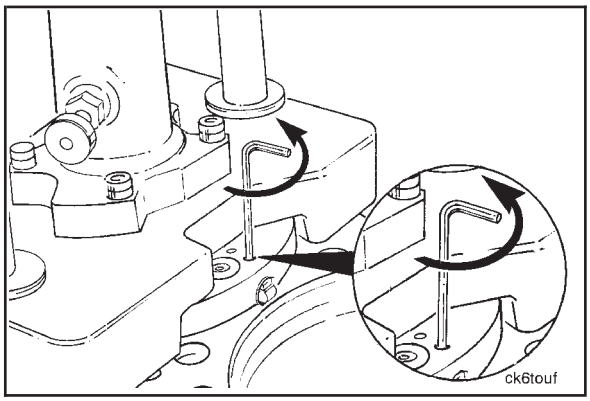
On blocks with a double undercut radius the tool bit **must** be adjusted so it is in the radius.

Use the stop collar to raise the tool bit off the counterbore ledge 0.025 mm to 0.25 mm [0.001 inch to 0.010 inch].

The tool **must** be off the ledge enough to allow the bit extension device to work.

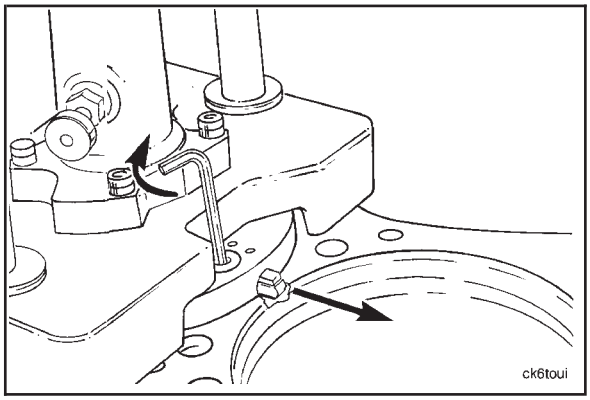


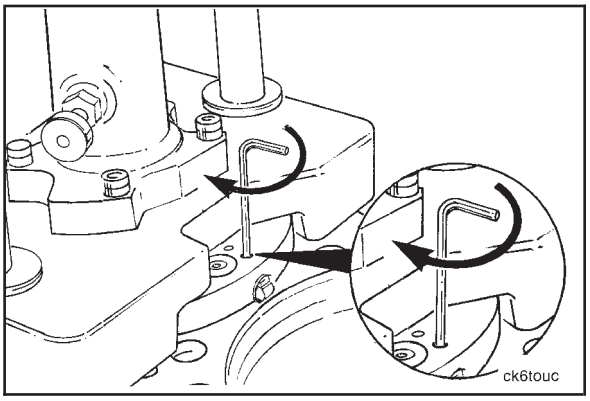
Use a 3/32 inch hex wrench. Loosen the tool bit locking screws **ONLY** enough to allow the extension device to function.



Use the 3/16 inch hex wrench. Turn the bit extension device until the tool bit touches the I.D. of the large radius.

This must be done to be sure the large radius is extended downward as the ledge is machined.





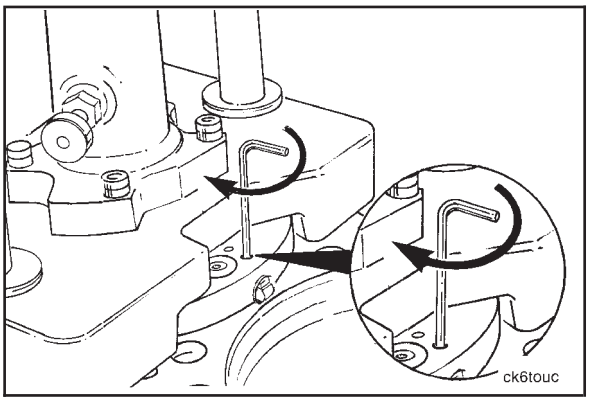
⚠ CAUTION ⚠

Do not turn the handle clockwise. The tool will damage the bore.

Use the handle to turn the tool **counterclockwise**. Listen for the sound of the tool bit scraping the bore wall as it is turned a minimum of 180 degrees.

If the sound does **not** continue through 180 degrees, use the bit extension device to push the tool bit against the bore wall opposite the first position.

Turn another 180 degrees. Listen again for the sound of the bit. Check for a burr if it touches at only one point.

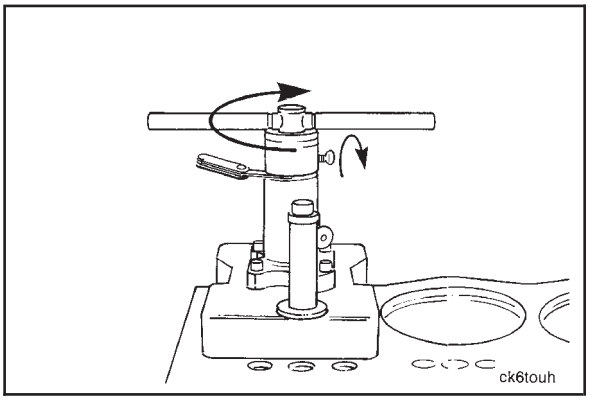


⚠ CAUTION ⚠

Do not attempt to raise the cutter plate with the tool bit extended into the double undercut radius.

Use a 3/32 inch hex wrench. Tighten the two tool bit locking screws.

Turn the stop collar to lower the cutter plate so that the bit touches the ledge.



ADJUSTING THE DEPTH OF MACHINING

Be sure the tool bit is seated on the counterbore ledge.

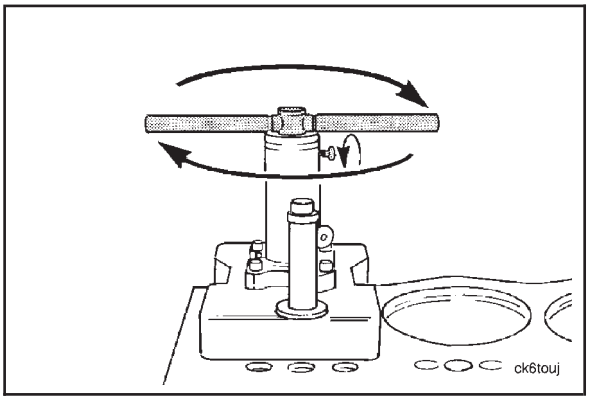
Results will be correct when several 0.05 mm to 0.08 mm [0.002 to 0.003 inch] cuts are made. The tool bit will be damaged by deep cuts. The surface finish will be too rough.

NOTE: Surface finish specification **must** be 80AA or better.

Be sure the tool bit is **not** raised.

Turn the stop collar **clockwise** to adjust the clearance.

Move a feeler gauge around the housing. Clearance **must** be to specification at the **closest** point.



Tighten the thumb screw on the stop collar.

NOTE: Record the depth of each machining. The figures are used to achieve the correct liner protrusion.

Apply **downward** pressure. Turn the handle **clockwise**. Keep the tool bit against the ledge.

Machine the bore until the stop collar contacts the housing. **Not** using pressure, spin the tool two or three times to smooth the surface.

Machine the counterbore in **several** operations until the maximum liner protrusion is achieved.

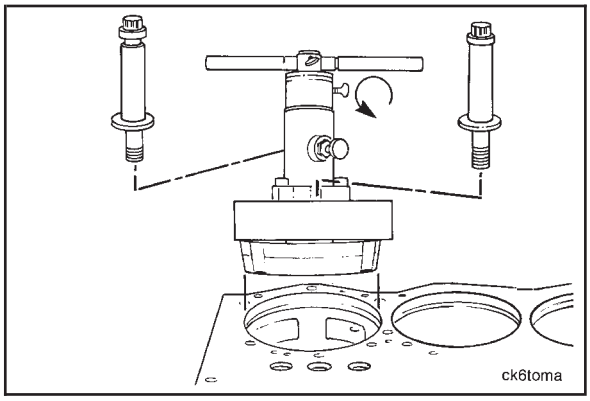
⚠ CAUTION ⚠

Loosen and retract the tool bit before attempting to raise the tool.

Raise the cutter plate.

Remove the tool from the block.

Use a fine, India type stone. Remove any burrs and sharp edges from the counterbore ledge.

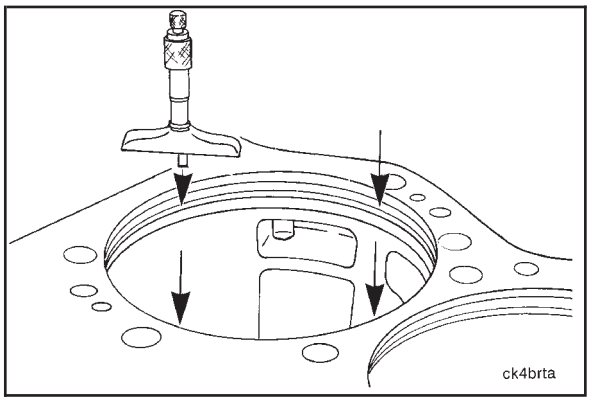


⚠ CAUTION ⚠

Be sure the micrometer does not contact the radius on a block that does not contain a double undercut counterbore radius.

Use a depth micrometer. Measure the counterbore depth in the four places shown.

The four measurements must not vary more than 0.25 mm [0.001 inch]. If the measurements exceed the specification, the counter bore ledge **must** be machined again.

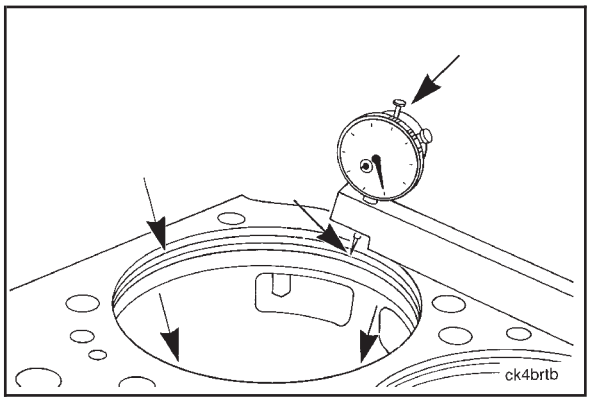


⚠ CAUTION ⚠

Be sure that the indicator does not contact the counterbore radius on a block that does not have a double undercut.

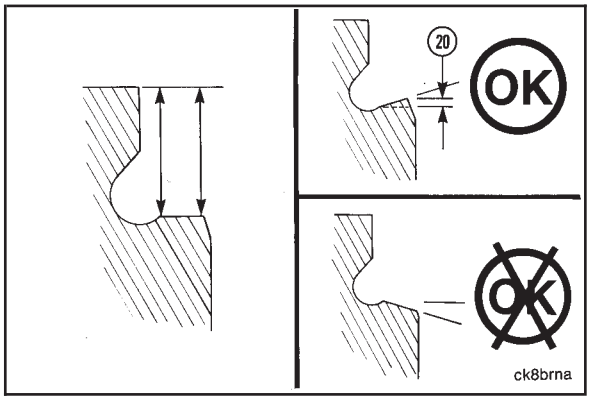
Use a gauge block, Part No. 3823495. Measure the angle of the counterbore ledge at four equally spaced points.

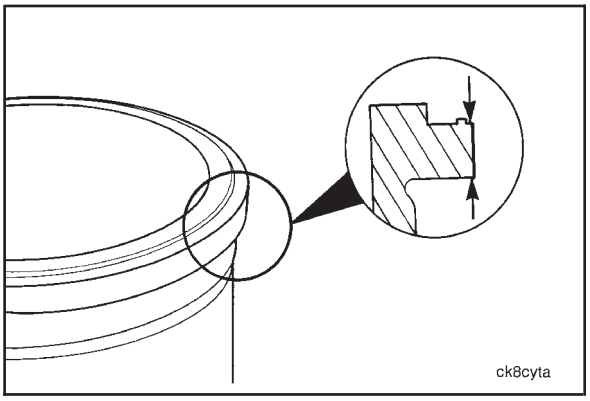
The measurement of the ledge depth **must** be taken as near to the counterbore radius as possible, and as near to the counterbore edge as possible.



The angle (12) is OK if the measurement that is near the counterbore edge is the same or **no** more than 0.036 mm [0.0014 inch] shorter than the measurement near the counterbore radius.

Machine the ledge again if the measurement near the counterbore edge is longer than the measurement near the radius.

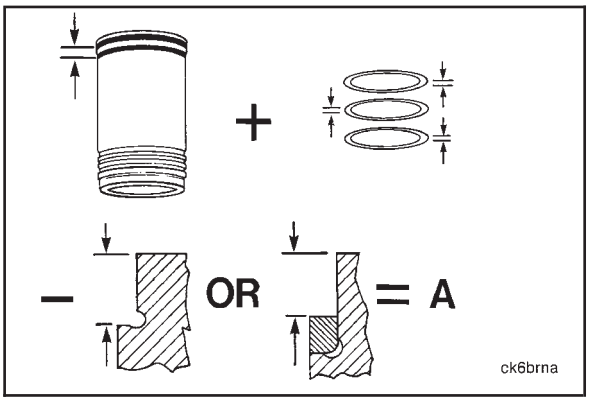




Check the counterbore for cracks.

NOTE: Liners and sealing ring(s) must be identified by cylinder number for proper assembly.

Measure the liner flange thickness at four equally spaced points around the flange.

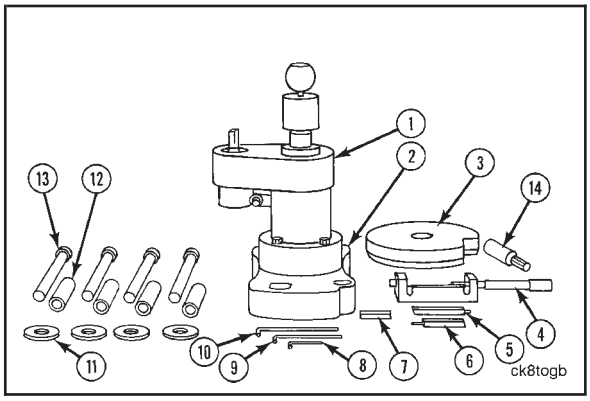


Cylinder liner protrusion (A) is the total sum of the liner flange thickness and sealing ring(s) thickness, minus the depth of the counterbore.

Cylinder Liner Protrusion

mm		in
0.08	MIN	0.003
0.13	MAX	0.006

MACHINE FOR OVERSIZE LINERS



Tools required for this procedure are listed below. They are available separately or in the kits.

LINER COUNTERBORE TOOL KIT, PART NO. ST-1168

1. Main Housing Assembly, Part No. ST-1168-1

8. 3\32 inch Hex Key, Part No. ST-1168-57, or equivalent
9. 5/32 inch Hex Key, Part No. ST-1168-59, or equivalent
10. 3/16-inch Hex Key, Part No. St-1168-60, or equivalent

LINER COUNTERBORE SALVAGE TOOL KIT, PART NO. 3375820

2. Base Plate, Part No.3375827
3. Cutter Plate Assembly, Part No. 3375821
4. Micrometer Assembly, Part No. 3375826
5. Setting Standard, Part No. 3375828
6. Cutter Assembly, Part No. 3822216
7. Depth Spacer Block, Part No. 3376189
11. Plain Washers, four, Part No. 3375830, or equivalent [3/16-inch I.D.], [2-inch O.D.], Standard Adapters, Part No. 3375829, or equivalent, 30.1625 mm I.D. 88.9 mm long [13/16-inch I.D. 3.5 inch long]

The following are also required:

- Four capscrews from the cylinder head
- Drill Motor [10-ampere, 450 rpm, 19 mm [3/4 inch] Chuck.

The user of the following instructions **must** have inspected the cylinder block.

Terms used in this Procedure **must** be understood.

NOTE: After machining both the upper and lower counterbore I.D. for oversized liners, you **must** machine the counterbore ledge. Refer to Procedure, 001-058

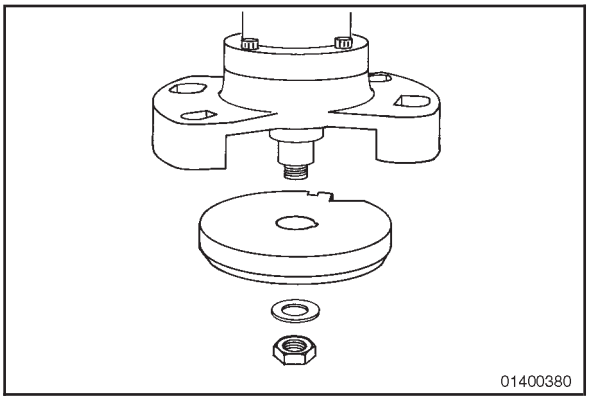
These instructions cover the counterbore depth and the upper counterbore I.D. machining at the same time.

NOTE: Cummins Engine Company, Inc., recommends that the accuracy of the tool be checked before machining the customer's block. If possible, machine a scrap block and check the accuracy of the cut.

If a scrap block is **not** available, adjust the tool to machine a size smaller than required. Check the accuracy of the cut. Make final adjustments before machining to specification.

NOTE: The cylinder liner I.D. is the same on **oversize** liners as that of the **standard** liner.

NOTE: On all QSK19 blocks the upper counterbore I.D. **must be no less** than 0.025 mm [0.001 inch] smaller, and **no more** than 0.076 mm [0.003 inch] larger than the O.D. of the cylinder liner upper flange diameter.



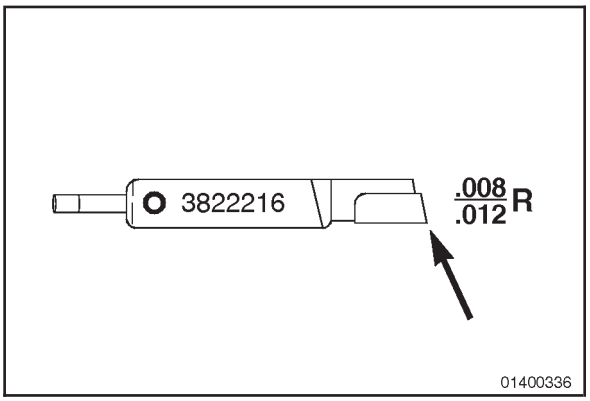
Install the base plate to the main housing. Install the four capscrews.

Torque Value: 40 N•m [30 ft-lb]

Position the cutter plate assembly with the tapered edge away from the housing. Align the keyway in the plate with the key in the shaft.

Install the cutter plate. Install the washer and nut.

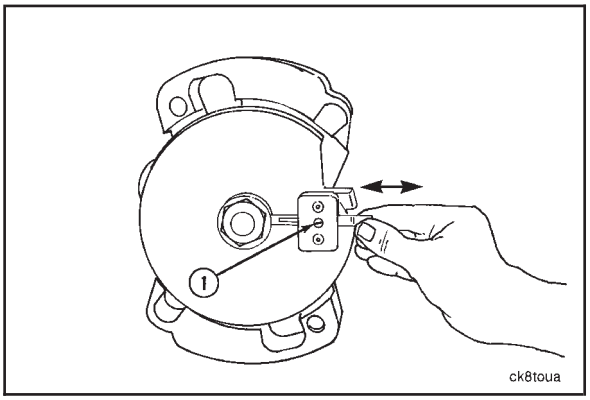
Torque Value: 40 N•m [30 ft-lb]



⚠ CAUTION ⚠

Damage to the cylinder block or interference with the cylinder liner will result if the wrong cutter assembly is used.

The illustration shows the cutter that **must** be used with the QSK19 cylinder block.



ADJUST THE SET SCREW

Put the cutter in the cutter plate assembly. Tighten the set screw until it becomes difficult to slide the cutter in the groove.

Remove the cutter assembly.

Measure the counterbore I.D. and depth. Refer to Procedure No.

⚠ CAUTION ⚠

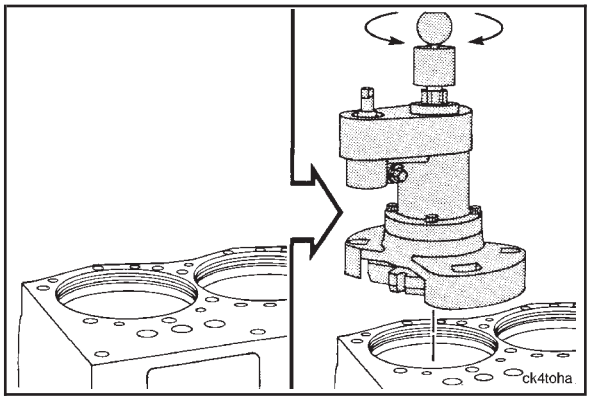
The top of the cylinder block must be clean and free of burrs. The tool must be flat on the block surface to machine the counterbore I.D. correctly.

INSTALL THE TOOL

To “LOCK” the feed mechanism, turn the knob on top **clockwise**.

To “UNLOCK” the feed mechanism, turn the knob **counterclockwise**.

Put the tool on the block.



“UNLOCK” the feed mechanism.

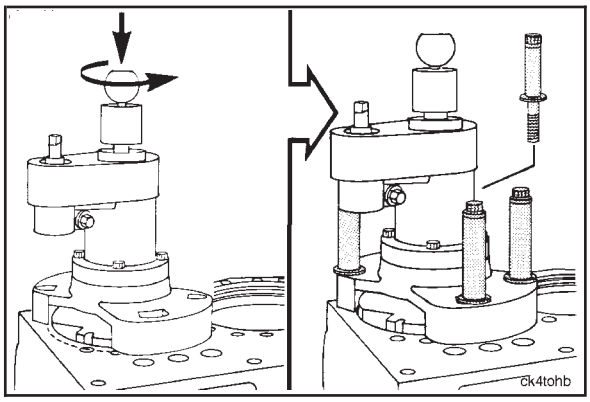
Lower the cutter plate until it contacts the lower counterbore I.D. This will center the tool in the bore.

Be sure the base plate does **not** rock.

Rotate the base plate until the bolt holes align with the cylinder head mounting capscrew locations.

Install the four capscrews, plain washers, and standard adapters.

Torque Value: 45 N•m [35 ft-lb]



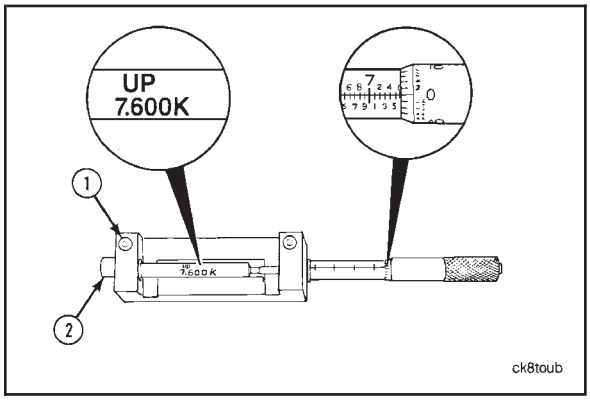
ADJUST THE CUTTER ASSEMBLY

Use the setting standard, Part No. 3375828. Use the micrometer assembly, Part No. 3375826.

Put the setting standard in the micrometer as shown. Measure the length of the standard. In this example, the micrometer reads 193.04 mm (7.600 inch).

If the reading does not agree with the value stamped on the setting standard,

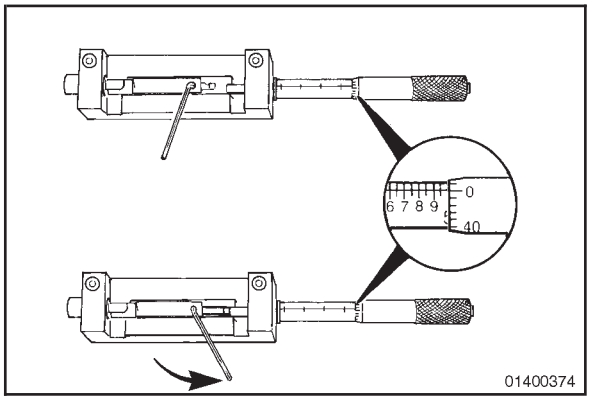
- loosen the set screw (1),
- move the end post (2),
- tighten the set screw (1).

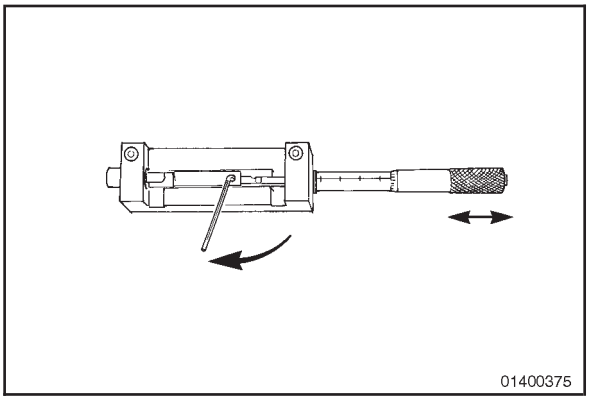


Set the micrometer to the correct dimension for the block being machined.

Put the cutter assembly in the micrometer as shown.

Use a hex key. Loosen the set screw on the cutter assembly. Move the spring loaded plunger until it contacts the micrometer.

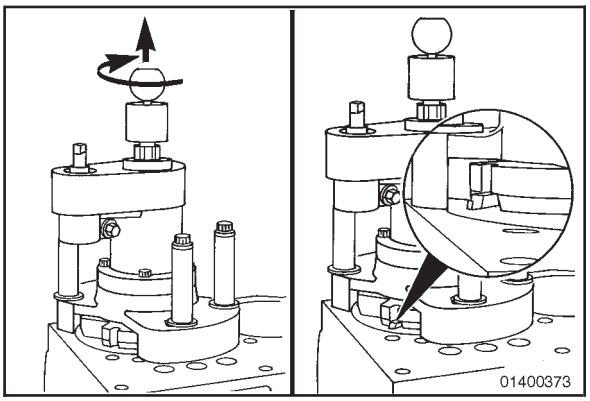




Tighten the set screw.

Move the micrometer to check the setting.

Repeat the setting process until the cutter assembly is accurately set.

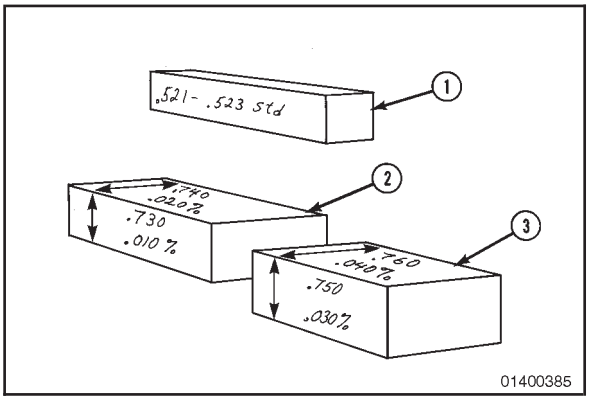


ADJUST MACHINING DEPTH

Raise and “LOCK” the drive assembly.

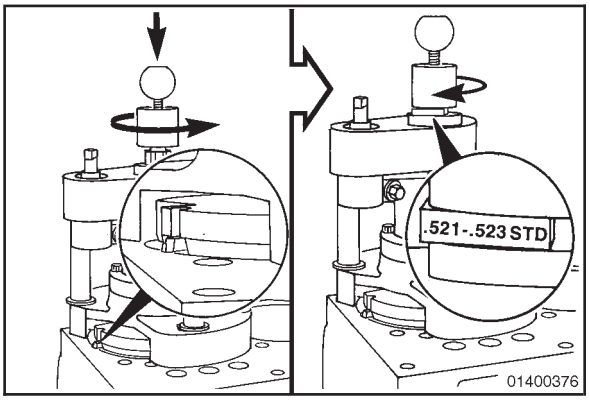
Put the cutter assembly in the cutter plate. It **must** extend a minimum of 6 mm [1/4 inch] over the edge of the counterbore.

Tighten the top set screw for the cutter bit.



On QSK19 cylinder blocks use depth spacer block, Part No. 3376189.

NOTE: The depth spacer block is contained in the liner counterbore salvage tool kit, Part No. 3375820.



“UNLOCK” the drive mechanism. Lower the cutter plate until the cutter touches the block.

Put the depth spacer block, Part No. 3376189, on the tool. The depth of cut dimension **must** be visible [as shown].

Turn the stop collar until it touches the depth spacer block as illustrated.

NOTE: The 0.522 inch depth spacer block is shown as an example **ONLY**.

FINAL ADJUSTMENTS FOR DEPTH

The style of the block being machined determines the next adjustment.

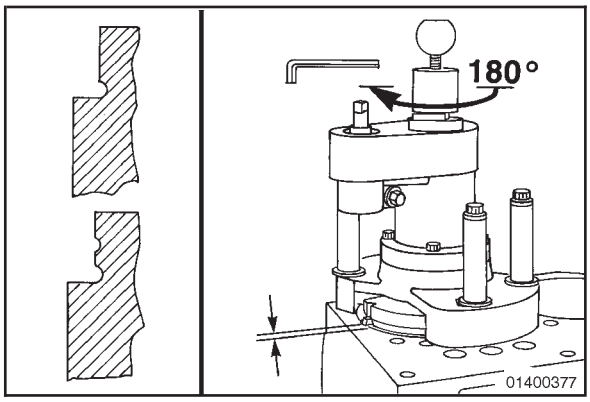
⚠ CAUTION ⚠

Do not cut the counterbore depth with this tool.

Follow these instructions for the QSK19.

Turn the depth stoop collar 1/2 of a turn (180 degrees) **counterclockwise**. The cutting assembly **must** be raised slightly from the counterbore ledge.

Use a hex key. Tighten the set screw on the collar.



MACHINE THE COUNTERBORE I.D.

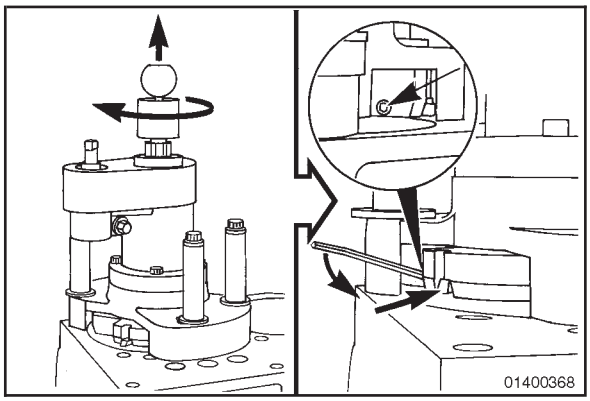
⚠ CAUTION ⚠

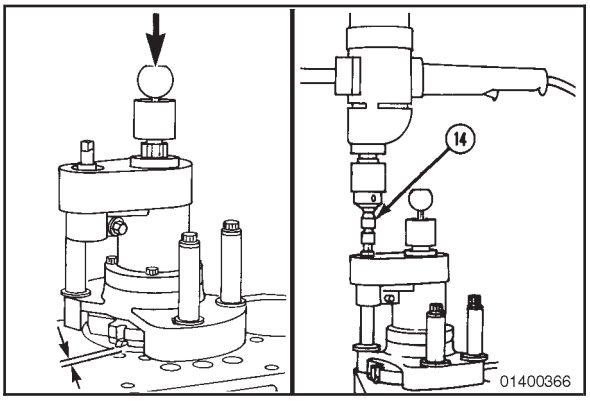
Be sure no dirt or chips are in the cutting assembly groove of the cutter plate.

Raise the cutting plate assembly. “LOCK” the drive mechanism.

Push the cutting assembly into the cutter plate until it touches the shaft.

Use a hex key. Tighten the setscrew.





⚠ WARNING ⚠

Hold the drill firmly. The drill will be hard to hold when the tool first contacts the block.

Lower the cutting plate until the cutting assembly is 1.50 mm [1/16-inch] above the block. “LOCK” the drive mechanism.

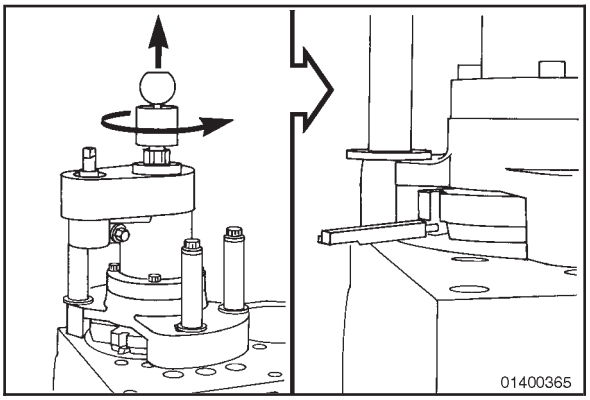
Install the universal drive (14) in the drill.

NOTE: The feed mechanism will automatically control the rate that the cutter is lowered.

START the drill. The cutter plate will freewheel after the depth stop collar has contacted the drive unit.

STOP the drill after the cutter has free wheeled for five to ten revolutions.

Remove the drill.



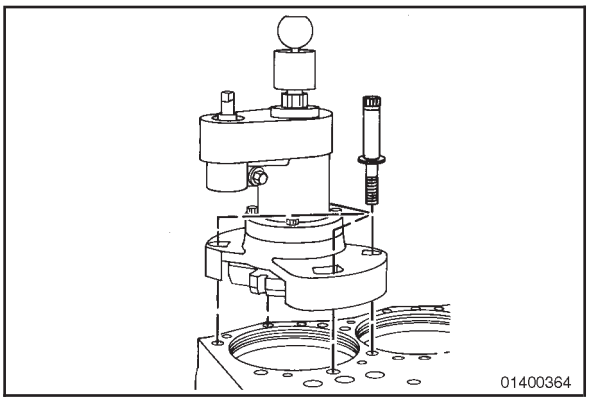
“UNLOCK” the drive mechanism.

Raise the cutter plate.

“UNLOCK” the drive mechanism.

Use a hex key. Loosen the set screw.

Remove the cutter assembly.



Remove the mounting capscrews, adapters, and washers.

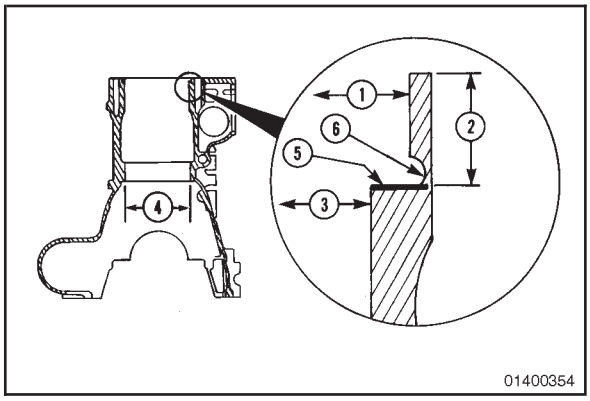
Remove the tool.

Use a hone stone. Remove burrs from the sharp corner of the I.D.

Measure the upper counterbore I.D. (1) in the location shown.

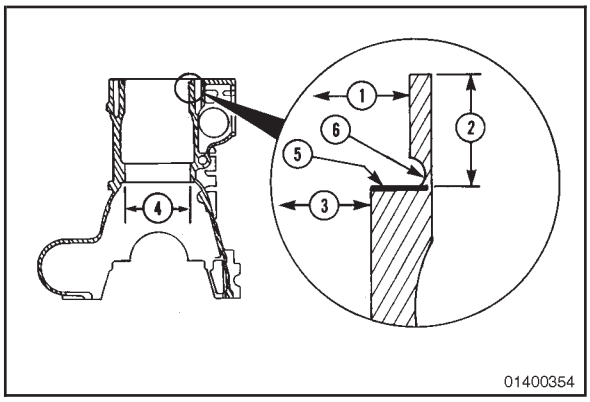
Machine the diameter again if the I.D. is **smaller** than specification.

Machine the block for the next larger size liner when the I.D. is **larger** than specification.



Check the concentricity between the upper counterbore I.D. (1) and the packing ring bore (4).

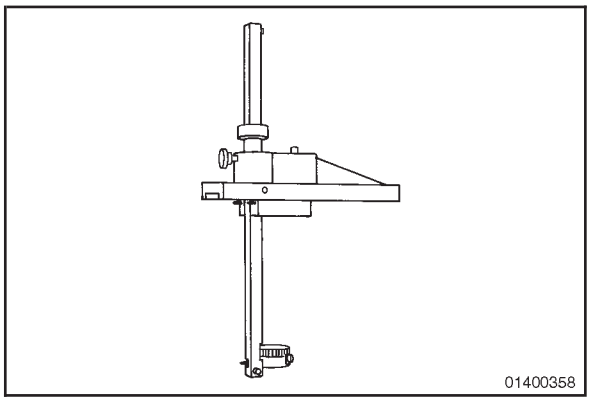
Clean the cylinder block. Refer to Procedure No. 001-026



LINER BORE CONCENTRICITY

Check the concentricity after the repair of the upper counterbore I.D. or the packing ring bore I.D.

Use the concentricity gouge, Part No. ST-1252.



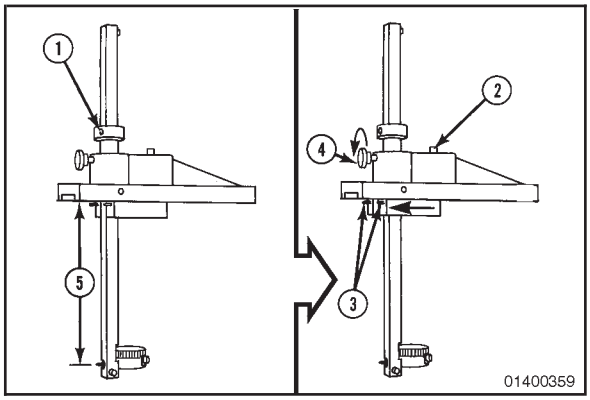
Adjust the contact pins (3) to be as close to the plate as possible. If necessary,

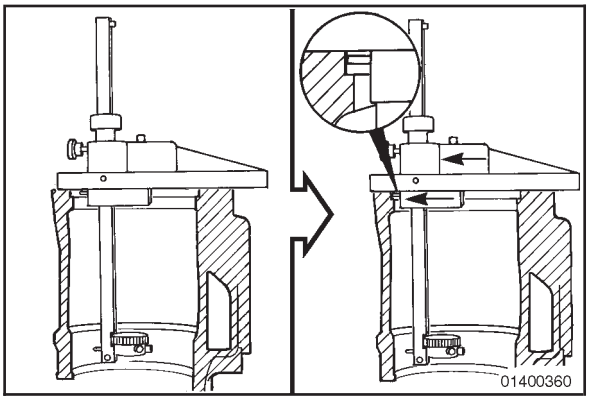
- Remove the set screw (2),
- Remove the plate,
- Turn the plate over,
- Install the plate,
- Install the set screw.

Loosen the indicator arm set screw (1). Move the indicator arm until the distance between the contact pins and the indicator (5) is 254 mm [10 inch].

Loosen the contact plate set screw (2). Slide the contact plate as far toward the indicator arm as possible.

Loosen the adjusting knob (4).





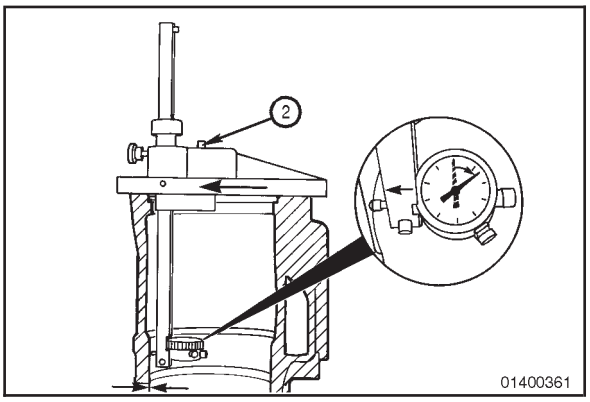
⚠ CAUTION ⚠

The upper counterbore and the top surface of the block must be clean.

Put the tool in the cylinder block liner bore to be checked.

Slide the contact plate until both contact pins touch the upper counterbore I.D.

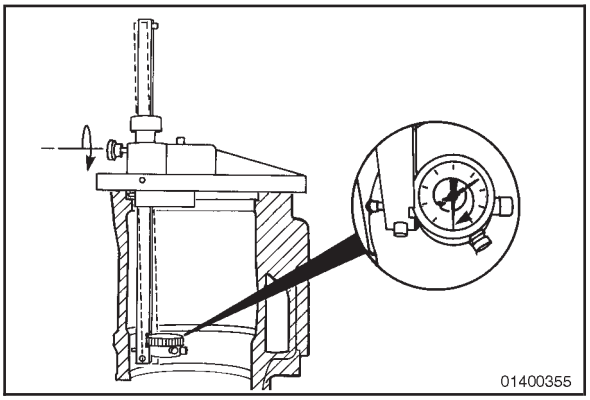
NOTE: The indicator must not touch the packing ring bore at this time.



Hold both contact pins against the upper counterbore I.D.

Slide the base until the indicator tip touches the packing ring bore I.D. Continue to slide the base until the indicator needle has moved 0.0064 mm to 0.254 mm [0.005 inch to 0.010 inch].

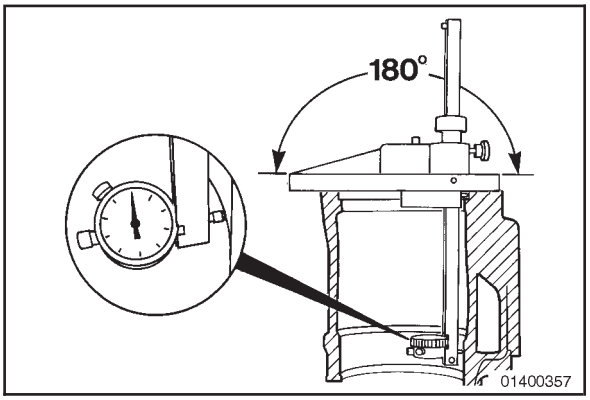
Hold the tool in place and tighten the contact plate set screw (2).



Hold the contact pins against the upper counterbore I.D. Turn the adjusting knob to move the indicator needle a minimum of one revolution. Turn the knob until the needle indicates "**ZERO**".

Slide the tool until the indicator is **not** touching the block. Slide the tool **backward** until both contact pins touch the upper counterbore I.D. The indicator **must** remain at "**ZERO**".

Repeat this step until the indicator continues to read "**ZERO**" after the tool is moved.



Turn the tool 180 degrees from the "ZERO" position. Slide the tool until both contact pins touch the upper counterbore I.D.

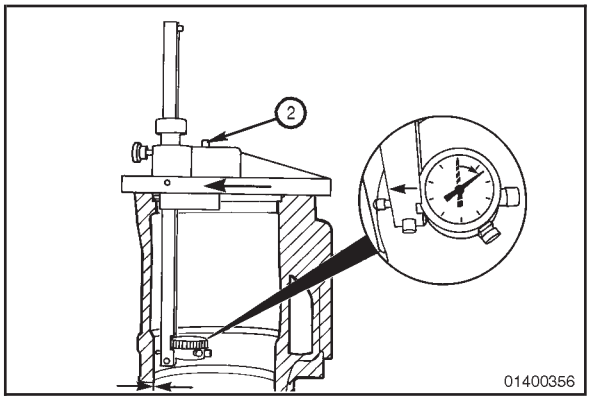
Read the indicator. the bore run out is one-half of the indicator reading.

EXAMPLE:
Indicator reading of 0.2032 mm (0.008 inch)
Actual run out is 0.1016 mm (0.004 inch)

Liner Bore Run Out		
mm		**in**
0.130	MAX	0.005

Move the tool 180 degrees **backward** to the **original** “ZERO” position.

Repeat the measurement procedure when the indicator does **not** read “ZERO”.



⚠ CAUTION ⚠

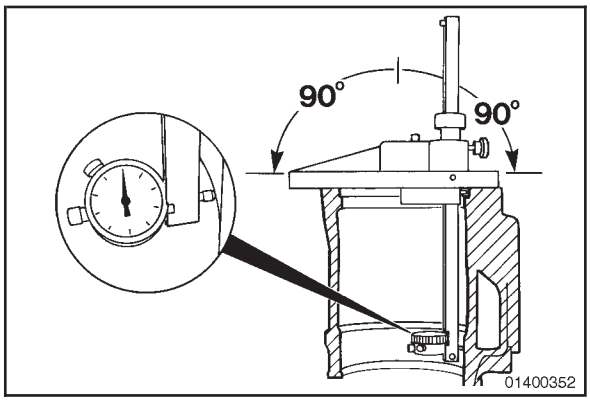
Concentricity must be within specification. Engine damage will result when the liner is not seated correctly in the bore.

Turn the tool until the contact pins are 90 degrees **counterclockwise** from the **original** “ZERO” position. Adjust the indicator to “ZERO” position.

Read the indicator. Compare the reading to the specification.

Repeat this procedure until consistent readings are obtained.

NOTE: The bore **must** be repaired when consistent readings are **not** obtained. Refer to the Alternative Repair Manual, Bulletin No. 3379035.



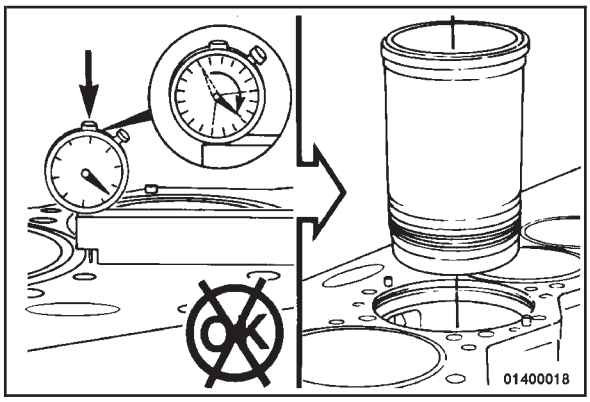
Cylinder Liner Protrusion (001-064)

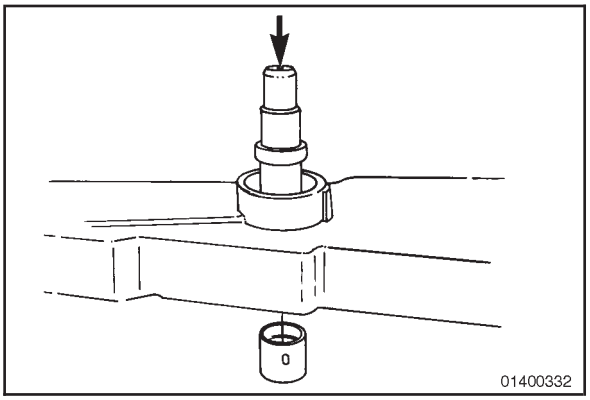
Adjust

If the liner protrusion is **not** correct, the liner **must** be removed.

If liner protrusion needs **increased** add more sealing rings or a thicker sealing ring.

If liner protrusion needs **decreased** machine the counterbore ledge. Refer to Procedure No. 001-058.





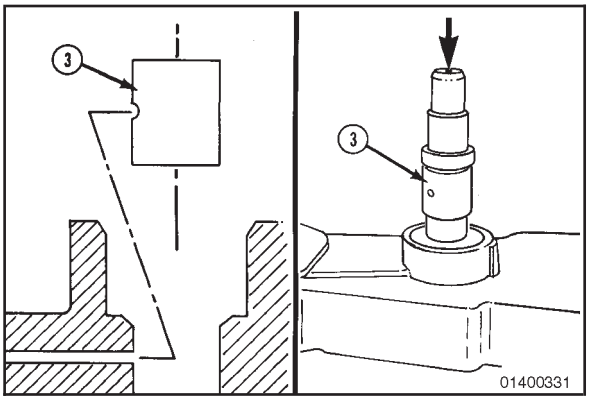
Gear Cover Accessory Drive Bushing (001-066)

Remove

Use the appropriate bushing mandrel and an arbor press. Remove the accessory drive, water pump, and the hydraulic pump drive bushings.

Measure the bore I.D. Replace the front cover when any bore I.D. is **not** within specifications.

Front Cover Bushing Bore I.D.			
	mm		in
Accessory and Water Pump Drive	43.078	MIN	1.696
	43.104	MAX	1.697
Hydraulic Pump Drive	41.275	MIN	1.625
	41.301	MAX	1.626



Install

Use the appropriate bushing mandrel, install the accessory drive, water pump and hydraulic pump.

Use a mallet or an arbor press. Install the bushings.

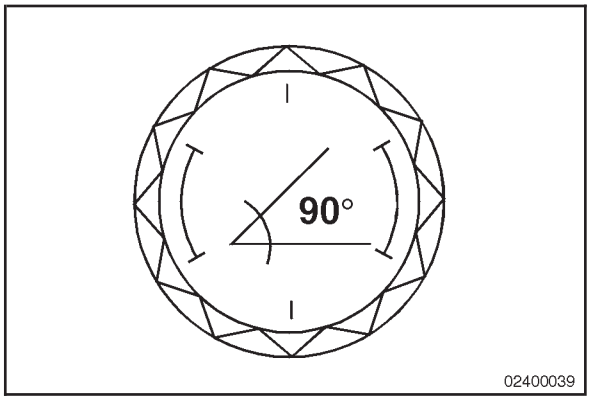
Section 2 - Cylinder Head - Group 02

Section Contents

Cylinder Head - General Information

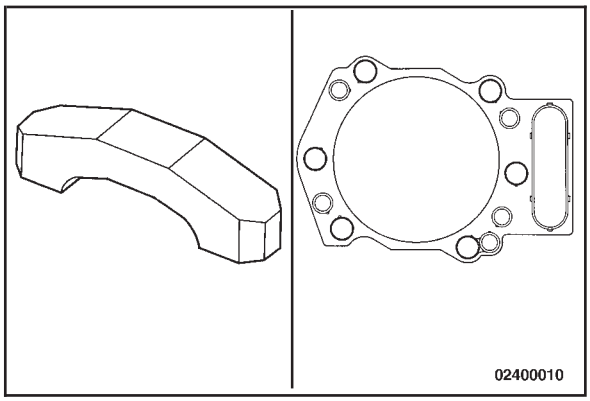
General Information

The QSK19 uses a torque-turn method for torquing all cylinder head capscrews. This method provides better control of the load on the capscrews.



The QSK19 utilizes a stemless crosshead design. This design does **not** require adjustment.

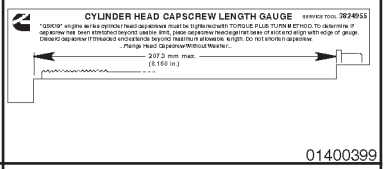
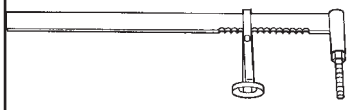
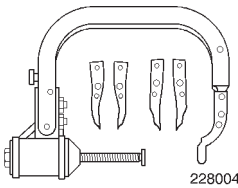
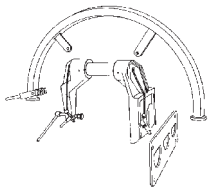
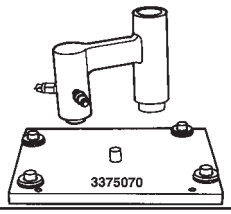
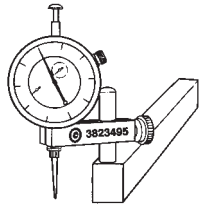
The QSK19 cylinder head gasket has been altered due to changes to the shape of the push tube hole. The grommets have been built into the gasket.

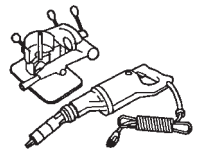
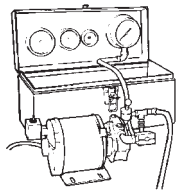
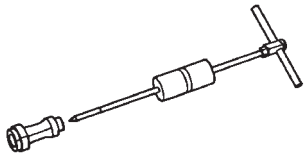
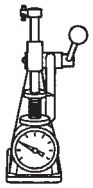
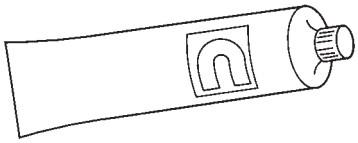
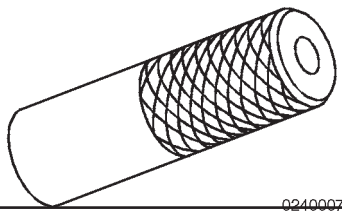


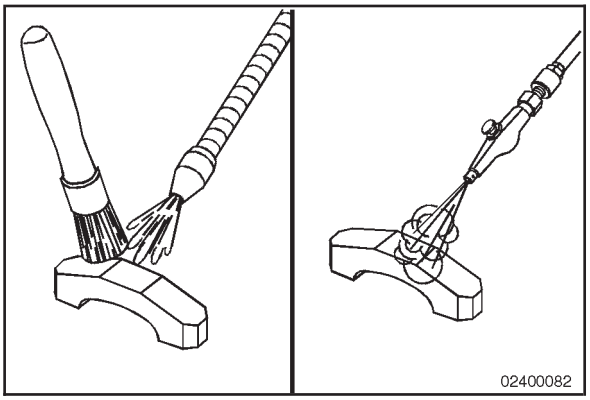
Service Tools

Cylinder Head

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

Tool No.	Tool Description	Tool Illustration
3824955	**Cylinder Head Capscrew Length Gauge** Used to check the length of the cylinder head capscrews.	 01400399
ST-448	**Valve Spring Compressor** Compress the valve spring to allow the valve to be removed or installed.	 ST-448
3375960	**Valve Spring Compressor** Compress the valve spring to allow the valve to be removed or installed. This tool is air-operated.	 22800430
ST-1012	**Hydrostatic Tester** Check for coolant leaks in the cylinder head. Requires shop air, a lifting hoist, a water tank, and the appropriate Test Adapter Plate and o-ring.	
3375070	**Water Test Plates** Check for coolant leaks in the cylinder head. Use with Part No. ST-1012 Hydrostatic Tester. Use with Part No. 3375071 Water Test Plate O-rings.	
3823495	**Depth Gauge Assembly** Measure cylinder liner counterbore ledge angle and injector protrusion.	 3823495

Tool No.	Tool Description	Tool Illustration
ST-685	**Valve Seat Grinding Machine** Used to grind the valve seats.	 kn8togi
ST-1257	**Valve Vacuum Tester** Used to test the valve to valve seat connection.	 kn8togr
ST-1323-1-Exhaust 3376799-Intake	**Valve Seat Extractor** Used to remove the valve seats.	 kn8togx
3375182	**Valve Spring Tester** Used to test the valve springs.	 kn8togs
3375805	**Valve Lapping Compound** An abrasive compound used to lap the valves.	 3377132
3824861	**Valve Head Thickness Gauge** Used to check the intake and exhaust valve head thickness after reconditioning.	 02400079



Crosshead (002-001)

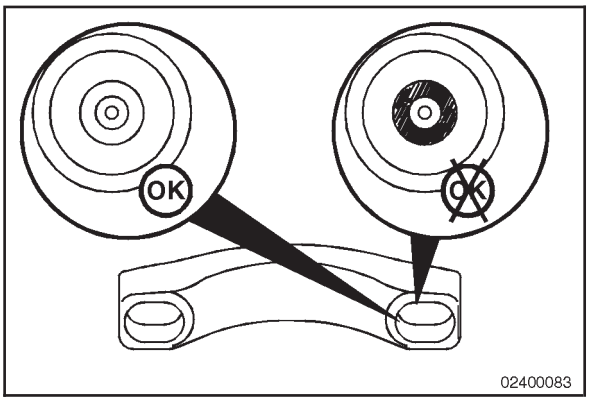
Clean

⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufactures recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent. Clean the parts.

Dry with compressed air.



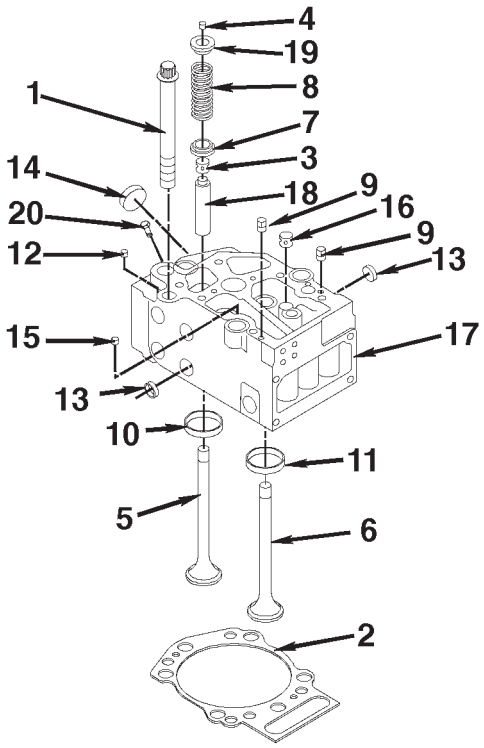
Inspect for Reuse

Check the contact pad (shaded area) for cracks.

Check the valve stem contact area for wear or damage.

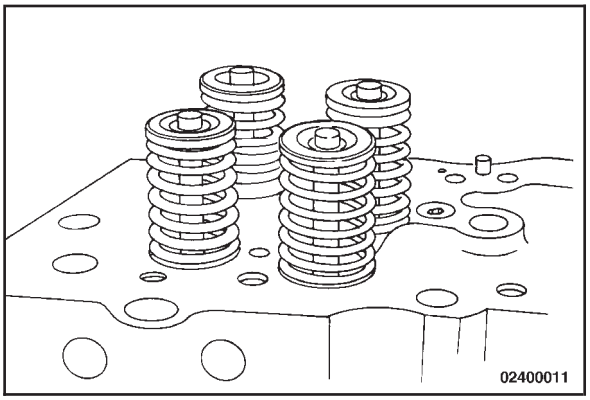
Cylinder Head (002-004)

Exploded View



02400081

1. Screw, Twelve Point Cap
2. Gasket, Cylinder Head
3. Seal, Valve Stem
4. Collet, Valve
5. Valve, Exhaust
6. Valve, Intake
7. Rotator, Valve
8. Spring, Valve
9. Pin, Groove
10. Insert, Valve, Exhaust
11. Insert, Valve, Intake
12. Plug, Expansion
13. Plug, Expansion
14. Plug, Expansion
15. Plug, Threaded
16. Plug, Threaded
17. Head, Cylinder
18. Guide, Valve Stem
19. Retainer, Valve Spring
20. Plug, Pipe



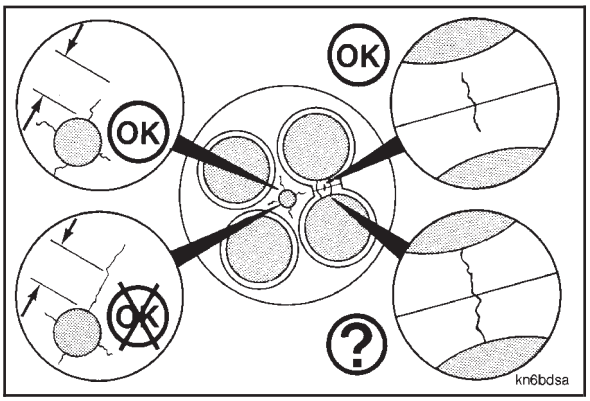
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Clean the heads with solvent.

Check for broken springs or other damage.



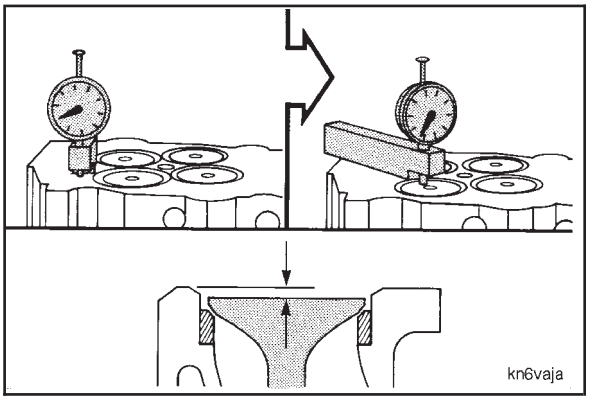
Inspect for Reuse

Check for cracks on the combustion surface.

NOTE: If a crack around the injector bore exceeds the maximum length, the cylinder head **must** be replaced.

Allowable Crack Length		
mm		**in**
6	MAX	0.25

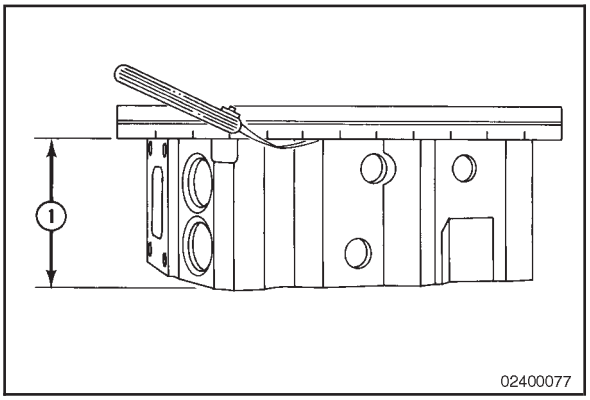
NOTE: Both ends of a crack between the valve **must** be visible. If one end of a crack extends into the valve seat bore (behind the valve seat), the condition of the cylinder is questionable. To be sure that the cylinder head is reusable, remove the valve and valve seat.



Use a depth gauge, Part No. 3823495, or equivalent. Measure the valve head depth.

NOTE: If the valve depth exceeds specifications, the cylinder head **must** be rebuilt.

Allowable Valve Depth from the Combustion Face		
mm		**in**
0.00	MIN	0.000
0.51	MAX	0.020



Use a straight edge to measure the flatness of the head gasket surface.

The head **must** be resurfaced if a feeler gauge larger than 0.08 mm (0.003 in) will fit between the straight edge and the cylinder head.

The head can be resurfaced as long as the head thickness measurement is within specifications.

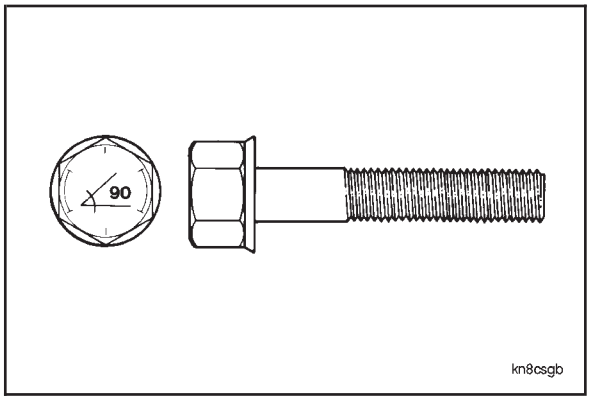
Minimum Head Thickness (1)		
mm		**in**
150.114	MIN	5.910

NOTE: If the head is resurfaced, be sure that the injector protrusion and the valve depth in the head are adjusted properly.

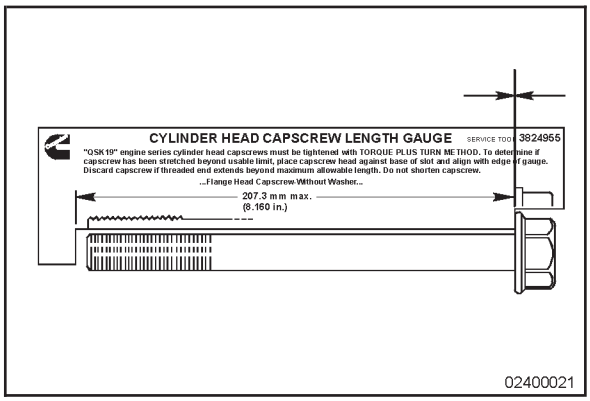
Using flange head capscrews with the torque plus angle method of installation, places the capscrew beyond the yield point and permanently stretches the capscrew. These capscrews can be reused throughout the life of the engine unless the capscrew exceeds the specified free length.

The free length **must** be checked to avoid bottoming in the block during installation.

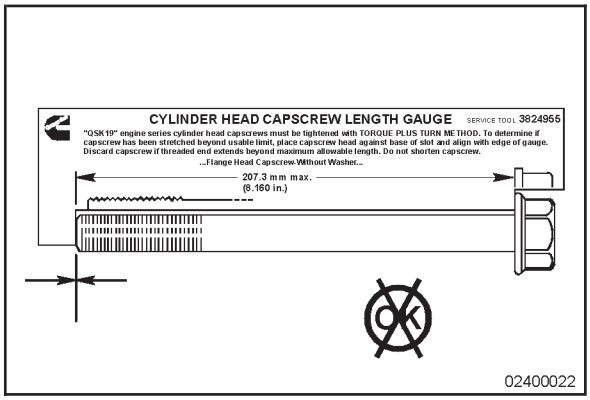
Cylinder head capscrew length gauge, Part No. 3824955, has been developed to check capscrew free length.



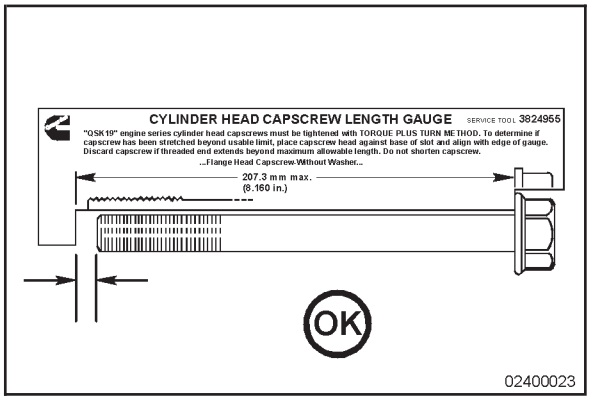
To check the capscrew free length, place the head of the capscrew in the slot, with the flange against the base of the slot.

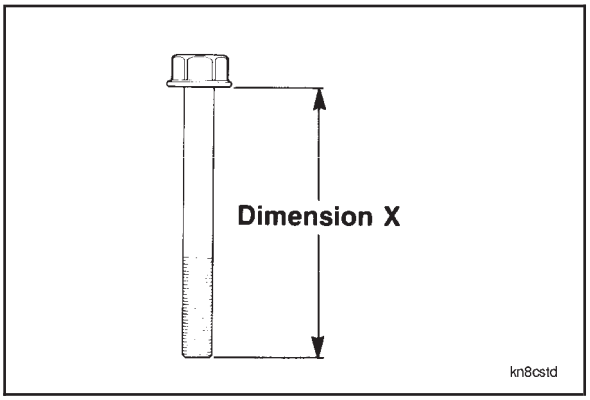


If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.



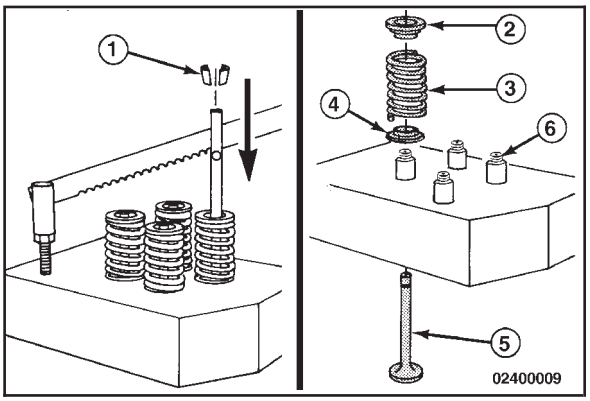
If there is clearance between the end of the capscrew and the bottom base of the tool, the capscrew is OK for reuse.





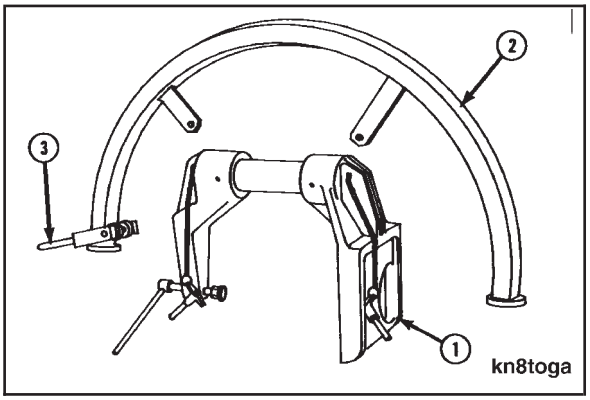
The capscrew can also be checked using a set of calipers. The maximum allowable free length is measured from the bottom of the flange to the end of the capscrew (Dimension X).

Cylinder Head Capscrew Free Length		
mm		in
207.3	MAX	8.160

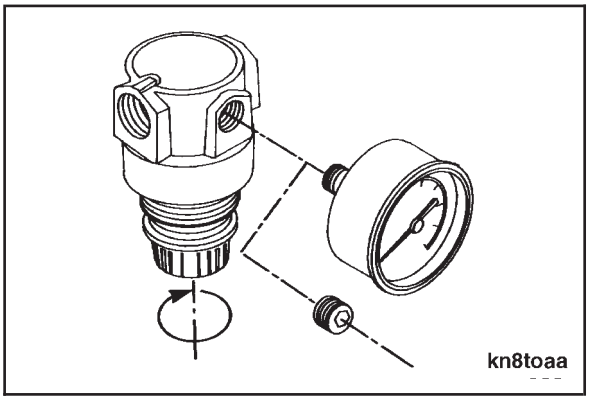


Pressure Test

Remove the valves. Refer to Procedure No. 002-020.



Use a hydrostatic tester, Part No. ST-1012, with water test adapter plate, Part No. 3375070, to test the cylinder head.



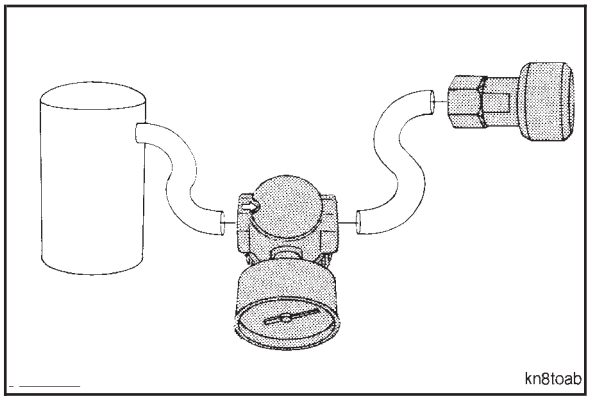
Remove one of the two plugs from the pressure regulator.

Install the pressure gauge in the regulator.

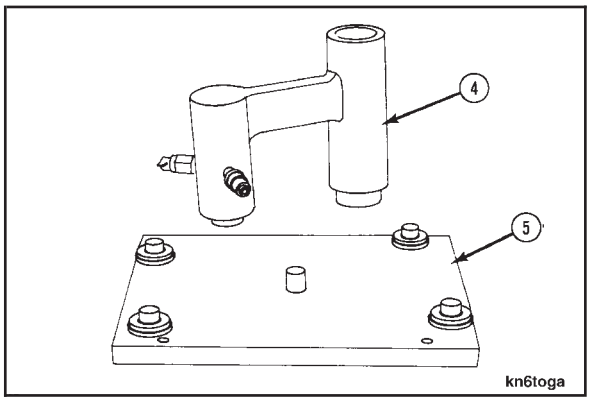
Turn the adjusting knob on the regulator **counterclockwise** as far as it will turn.

Install the pressure regulator between the air supply and the quick disconnect fitting.

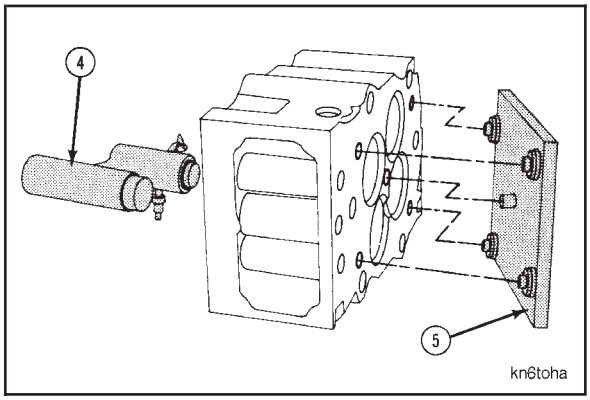
NOTE: The arrow on the top of the pressure regulator **must** point in the direction of the air flow (toward the quick disconnect fitting).



Use adapter plate (4), Part No. 3375070, and plate (5), Part No. 3375071, to test the head.



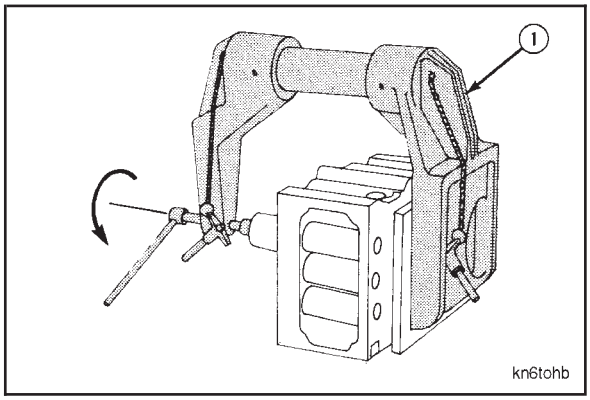
With the head as shown, assemble the adapter plates. The guide pins on the lower plate (5) **must** go in the water passages. The o-ring on the upper plate (4) creates a seal on the upper water passage. The other end of the plate goes into the injector bore.

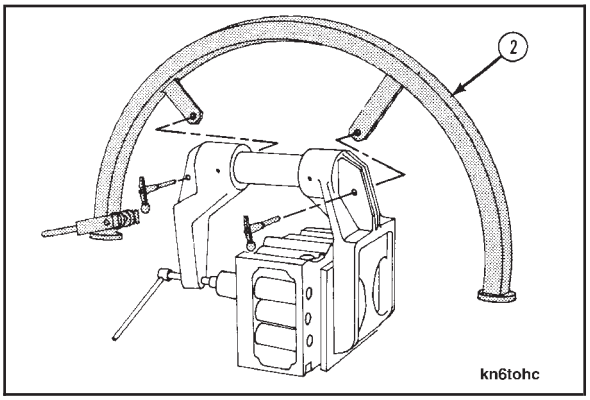


Put the clamping assembly (1) over the head and adapters. The guide pins on the clamp **must** go into the holes in the lower adapter plate.

Tighten the clamp on the head.

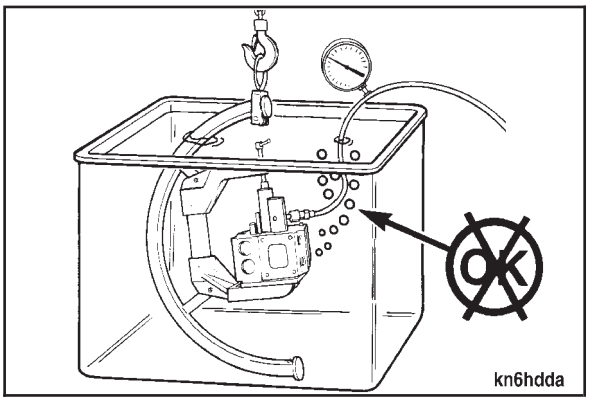
Connect the wire hose to the upper adapter fitting.





Attach the lifting arm (2) to the clamp assembly with the lock pins.

NOTE: One mounting location on each piece is color-coded red.



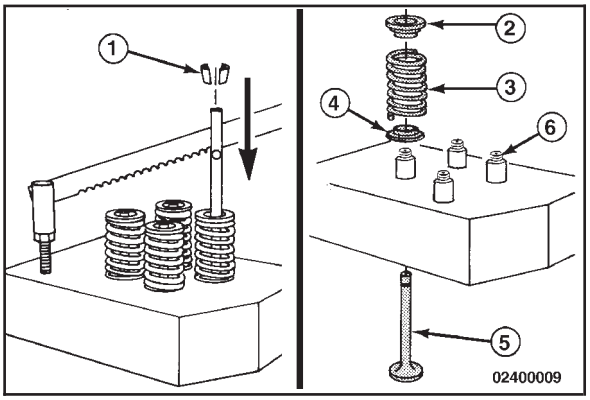
Adjust the air pressure.

Air Pressure		
kPa		**psi**
552	MAX	80

Lower the head into a tank of water.

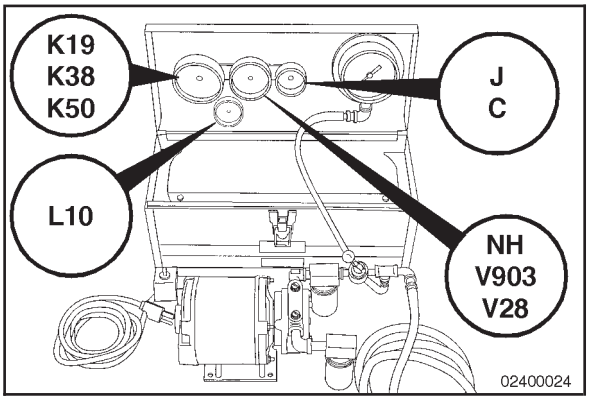
Bubbles will indicate an air leak.

If the cylinder head leaks, it **must** be repaired or replaced.



Install the cylinder head valves. Refer to procedure No. 002-020.

NOTE: Thoroughly lubricate the valve guide I.D. with 140 wt. gear oil before installing the valves.



Vacuum Test

The valve and the valve seats **must** be clean and dry.

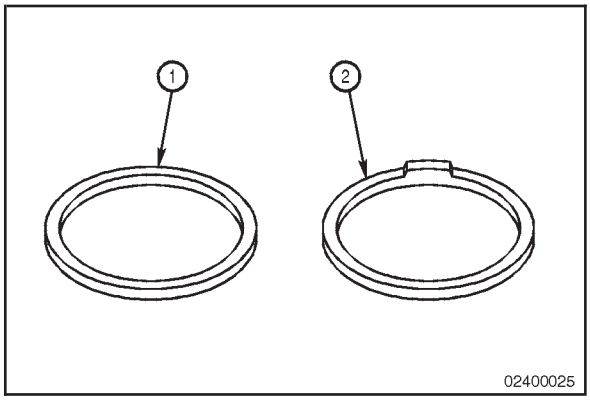
NOTE: The valve vacuum tester, Part No. ST-1257 can be used to test all Cummins' engine models.

Choose the correct cup for the engine model that is to be tested.

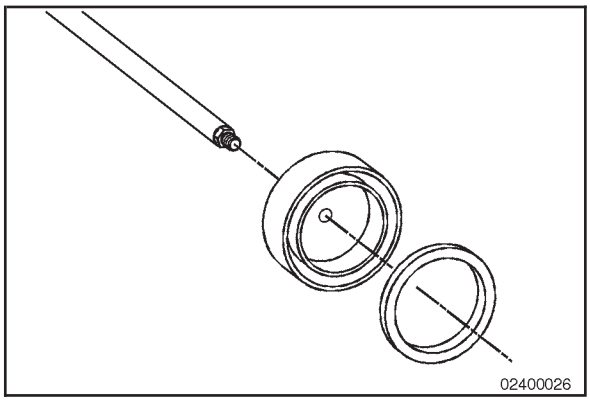
Chose the correct seal.

1. Intake valve
2. Exhaust valve

NOTE: A new seal is available that has the appearance of (1), but is manufactured from a softer material. The new seal is to be used on cylinder heads that are machined with a relief valve between **all four** bores.

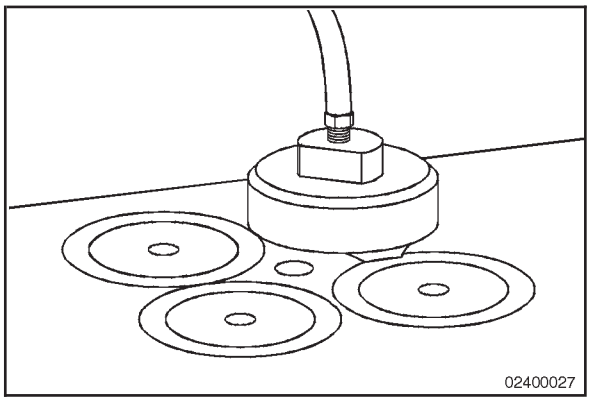


Install the seal and the cup to the vacuum line (hose).



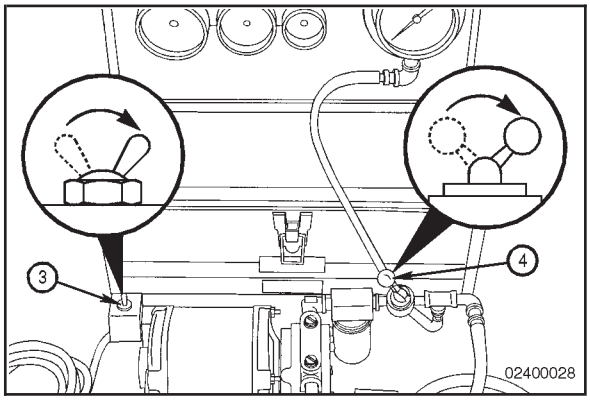
Cover the valve with the cup and the seal. The seal **must** have a tight contact on the cylinder head around the valve.

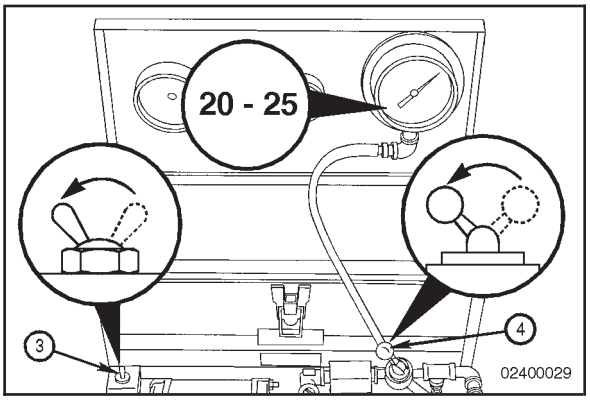
To check the exhaust valves, the seal **must** completely fill the milled area between the exhaust valves.



Move the toggle switch (3) to the “ON” position.

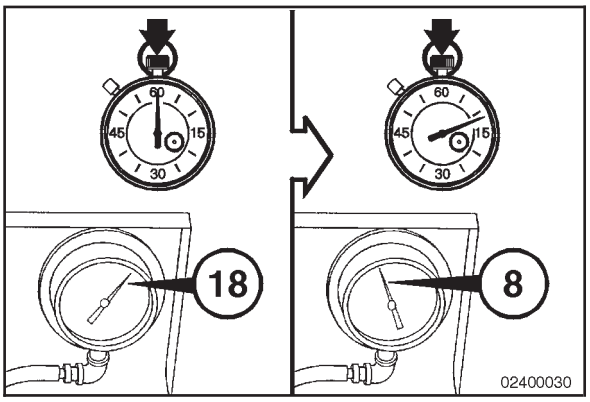
Turn the vacuum control valve (4) to the “OPEN” position.





When the gauge indicates between 20 in-Hg and 25 in-Hg, turn the vacuum control valve (4) to the “CLOSED” or “OFF” position.

Turn the toggle switch (3) to the “OFF” position.



Use a stop watch. As the vacuum gauge needle moves **counterclockwise**, **start** the timing when the needle on the gauge points to 18 in-Hg.

Stop the timing when the needle on the gauge points to 8 in-Hg.

The elapsed time for the gauge to move between the specified 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 functioning properly.
- Use a mallet to hit the valve stem lightly to be sure the valve is sealing. Repeat the test.
- Apply a thin coating of grease on the O.D. of the insert and the valve head. Repeat the vacuum test. The grease pattern will show the point of leakage.
- If the leakage is between the insert and the head, the insert **must** be replaced. Refer to Procedure No.002-019.

CAUTION

The cylinder head must be disassembled and cleaned after any grinding or cutting procedures.

If the leakage is between the valve and the insert, one of the following procedures must be performed:

- Lap Valves to Seat Procedure No. 002-020
- Grind the Valves Procedure No. 002-020
- Grind the Valve Seat Procedure No. 002-019

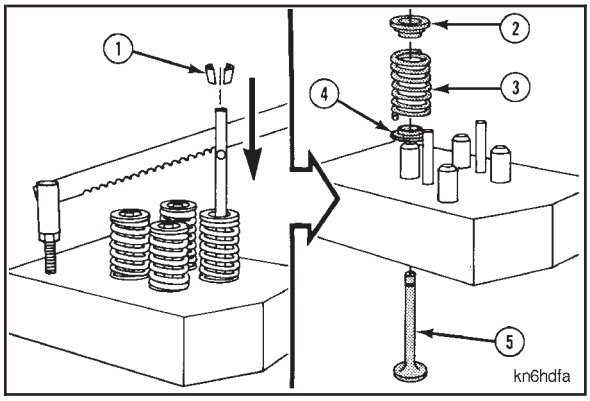
Disassemble

CAUTION

The valve springs are under compression. Be cautious when using the valve spring compressor. Personal injury can result if the tool slips from your hands.

Use a valve spring compressor, Part No. ST-448, or Part No. 3375960, or the equivalent. Valve spring stand, Part No. ST-1022, and the compressor plate, Part No. 3375043 can be used to compress all four springs at the same time.

NOTE: Mark the valves for location prior to removal. The **intake** and **exhaust** valves are **different**. This practice will aid the assembly procedure.



Remove the parts.

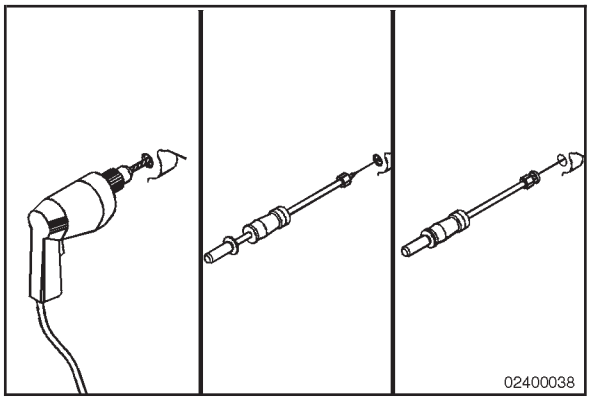
1. Collet, Valve
2. Retainer, Valve Spring
3. Spring, Valve
4. Guide Valve Spring/Rotator Valve
5. Valve

Discard the valve springs, collets and valve rotators.

Refer to Procedure No. 002-004.

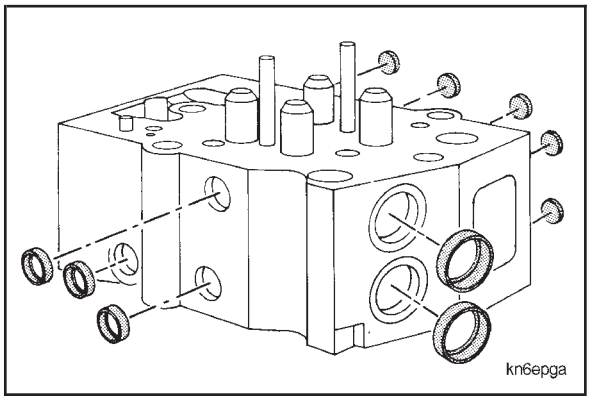
Use a drill, a sheet metal screw, and the following parts from the light duty puller kit, Part No. 3375784, to remove the cup plugs.

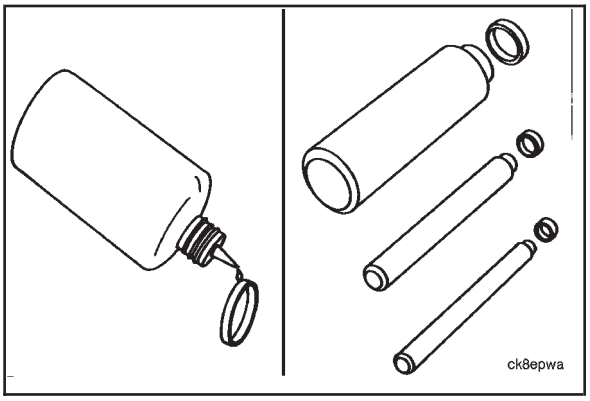
- Slide Hammer
- Hook



Remove and discard the 10 cup plugs.

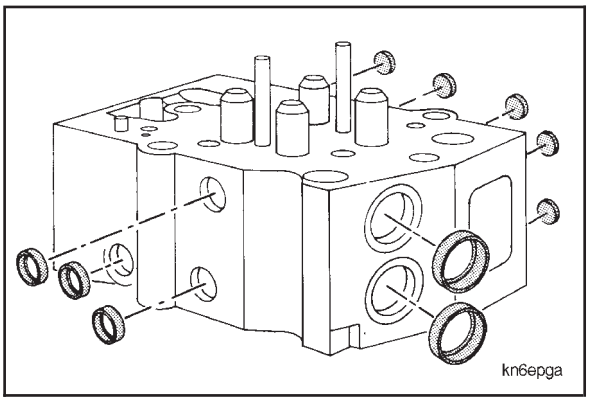
NOTE: Cup plugs **must** be removed from the head casting for cleaning purposes.





Assemble

Use cup plug Loctite® sealant, Part No. 3375068.

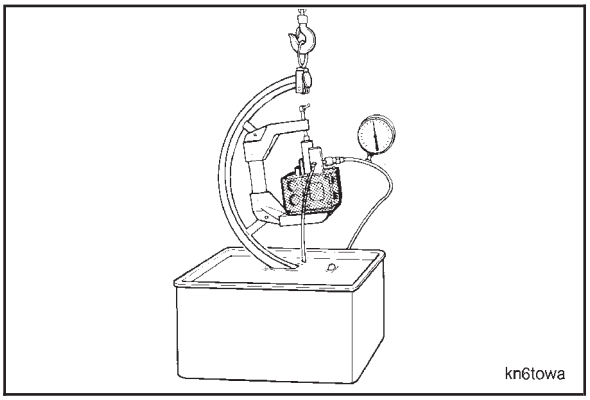


NOTE: Use the correct expansion plug driver to make sure the expansion plugs are installed to the correct depth in the cylinder head. Drive the plug until the shoulder of the driver contacts the cylinder head.

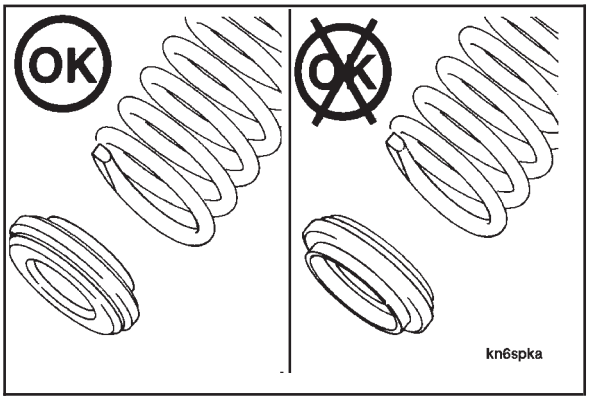
- Part No. 3376813 Expansion Plug Driver
- Part No. 3376814 Expansion Plug Driver

NOTE: A cup plug driver handle, Part No. 3376795, **must** be used with Part No. 3376813 and Part No. 3376814 Expansion Plug Driver.

Install 10 new cup plugs.



Use a hydrostatic tester to check for evidence of leaks around cup plugs. Refer to the Procedure No. 002-004.



NOTE: When turning the rotator by hand, it may turn roughly, appear difficult to turn, or **not** turn at all. This is normal until the rotator is installed, after installation it will rotate freely.

The rotator **must** be soaked in clean engine oil for at least 15 minutes prior to installation.

The rotator **must** be installed over the valve guide with the spring pilot flange face-up as shown in this illustration.

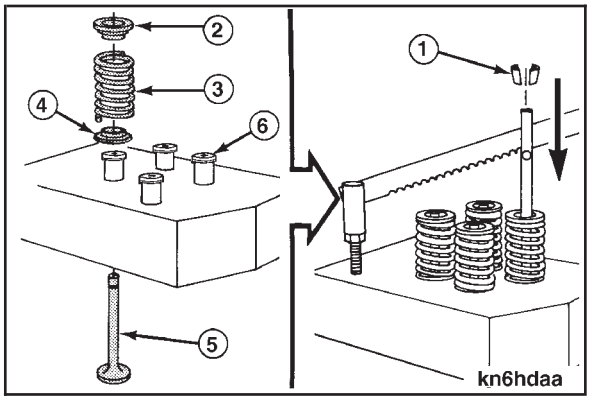
⚠ CAUTION ⚠

The valve springs are under compression. Be cautious when using the valve spring compressor. Personal injury can result if the tool slips from your hands.

Use a valve spring compressor, Part No. ST-448, or Part No. 3375960, or equivalent. Valve spring stand, Part No. ST-1022 and compressor plate, Part No. 3375043 can be used to compress all four springs at the same time.

Install the parts.

1. Valve
2. Rotator, Valve
3. Spring, Valve
4. Retainer, Valve Spring
5. Collet, Valve



NOTE: Thoroughly lubricate the valve guide I.D. with 140 wt. gear oil before installing the valves.

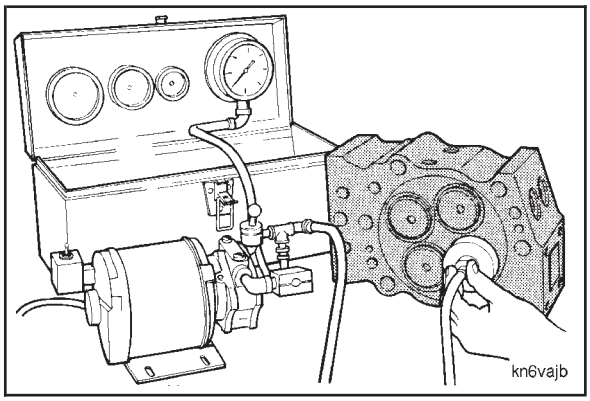
Use a valve vacuum tester, Part No. 3824277, or equivalent.

If the valve to the valve seat contact pattern looks OK and the valve still does **not** pass the vacuum test, perform the following check.

Apply a thin coating of grease on the outside diameter of the insert and the valve head. Repeat the vacuum test. The grease pattern will show the point of leakage.

If the leakage is between the insert and the valve, refer to the Procedure No. 002-020.

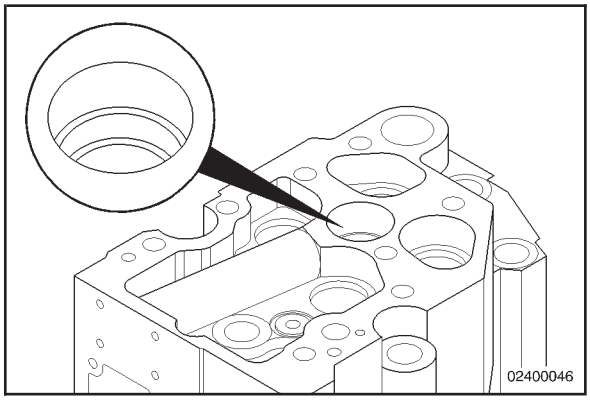
If the leakage is between the insert and the head, the insert **must** be replaced. Refer to the Procedure No. 002-019.

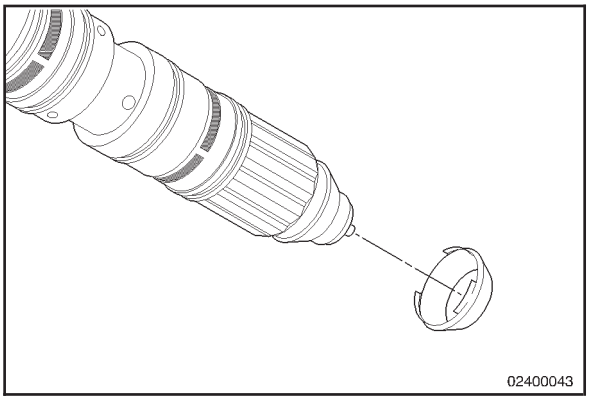


Cylinder Head Injector Bore (002-011)

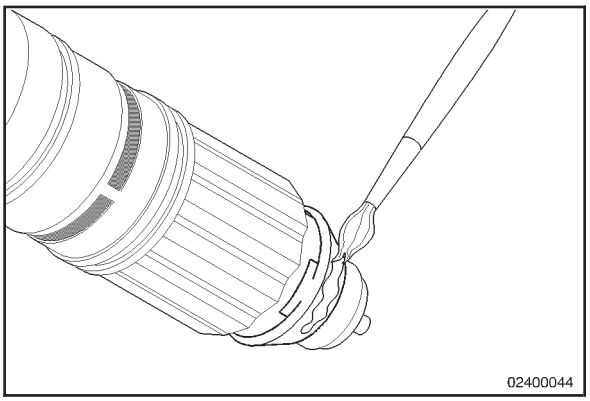
Inspect for Reuse

Inspect the injector bore for cracks or other damage.

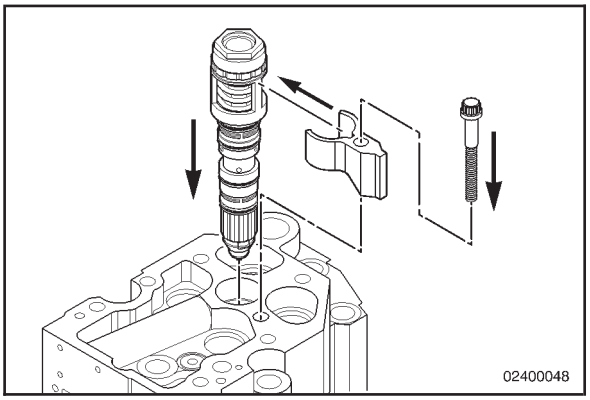




Use a dummy injector with **no** injector o-rings installed.



Use Prussian Blue™, apply a thin coating on the sealing ring.



⚠ CAUTION ⚠

Support the cylinder head to prevent damage to the injector tip that protrudes from the combustion face.

Install the injector and injector hold down clamp.

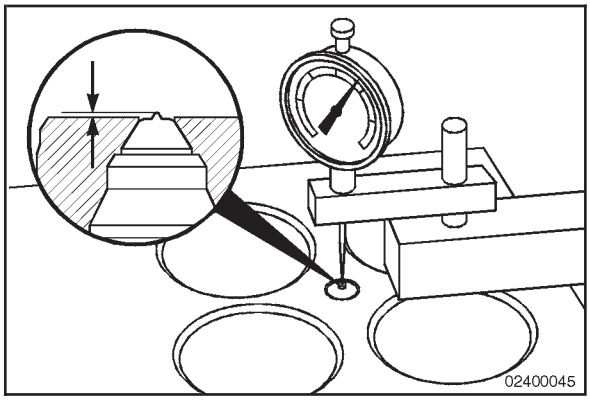
Tighten the hold down clap capscrew.

Torque Value: 16.2 N•m [145 in-lb]

Adjust

Use a gauge block, Part No. ST-547, or equivalent to measure the injector protrusion.

Measure as shown.



Injector Protrusion		
mm		in
2.42	MIN	0.095
2.92	MAX	0.115

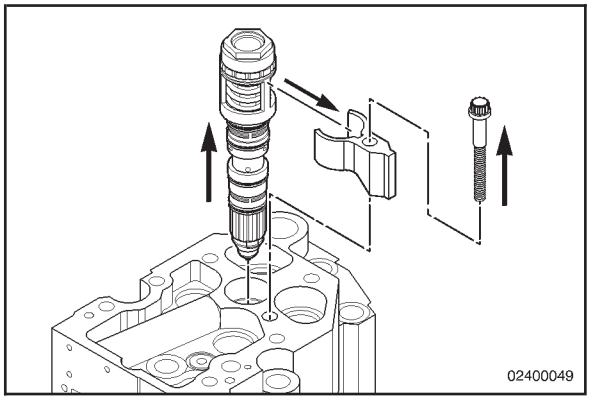
If the protrusion is not within specifications, use an oversize sealing ring. Sealing rings are available in various sizes.

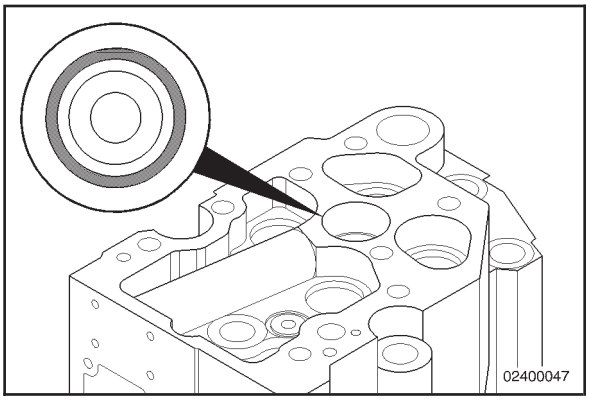
Injector Sealing Rings			
	mm		in
Wall Thickness	0.343	MIN	0.0135
	0.419	MAX	0.0165
Protrusion Change	0.00	NOMINAL	0.000
Wall Thickness	0.470	MIN	0.0185
	0.546	MAX	0.0215
Protrusion Change	0.25	NOMINAL	0.010
Wall Thickness	0.597	MIN	0.0235
	0.673	MAX	0.0265
Protrusion Change	0.51	NOMINAL	0.020
Wall Thickness	0.724	MIN	0.0285
	0.800	MAX	0.0315
Protrusion Change	0.76	NOMINAL	0.030

NOTE: * The 0.343/0.419 mm (0.0135/0.0165 in) is the standard sealing ring.

Remove the injector hold down clamp capscrew.

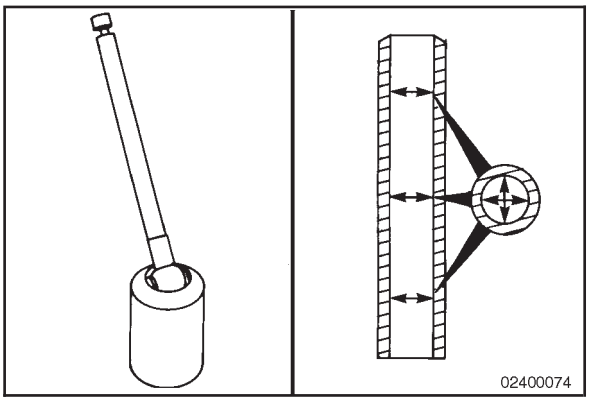
Remove the injector and injector hold down clamp.





Inspect the contact pattern in the injector bore. A blue band 1.52 mm (0.060 in) wide and 360 degrees full circumference minimum **must** be visible.

NOTE: If the pattern does **not** meet the specification, clean the injector bore with a tapered brush. Inspect the seating pattern again. The cylinder head **must** be replaced or repaired if it is not within specifications.



Valve Guide, Cylinder Head (002-017)

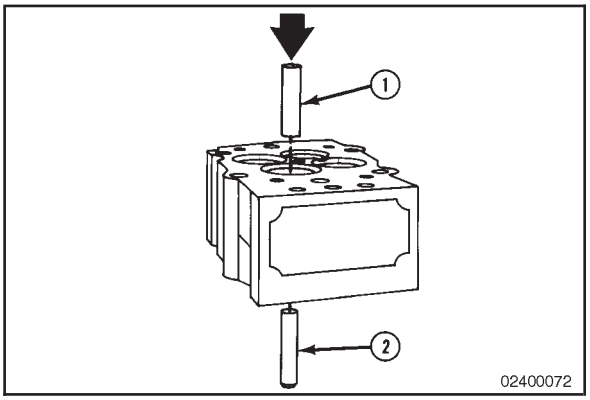
Inspect for Reuse

Inspect the valve guides for chips and cracks.

Use a ball gauge or a dial bore indicator to measure the I.D. of the valve guides.

Measure the I.D.

Valve Guide I.D. (Installed)		
mm		in
10.551	MIN	0.4154
10.589	MAX	0.4169



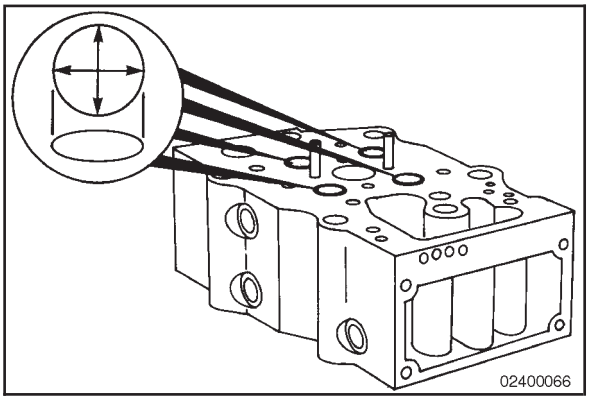
Remove

CAUTION

If a valve guide is replaced, the valve seat insert for the valve guide must be ground, or severe engine damage could result.

NOTE: ONLY replace the valve guide if it is **not** within specifications.

Use an arbor press and a suitable mandrel (1), to remove the worn valve guide (2).



Clean

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the valve guide bores.

Dry with compressed air.

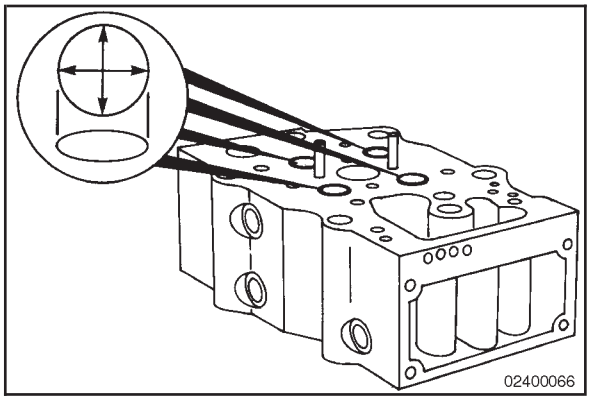
Inspect

Measure the I.D. of the valve guide bore.

Valve Guide Bore I.D.		
mm		in
21.438	MIN	0.8440
21.463	MAX	0.8450

If the bore is not within specifications, ream the bore for oversize valve guides.

NOTE: Valve guides are available in two oversizes; 0.25 mm (0.010 in) and 0.38 mm (0.015 in). Ream the valve guide bore to maintain a press fit within 0.028 mm and 0.067 mm (0.0011 in and 0.0026 in) between the valve guide and the valve guide bore.



Install

CAUTION

Make sure the mandrel does not damage the top of the valve guide. If the guide is damaged, the valves may stick causing severe engine damage.

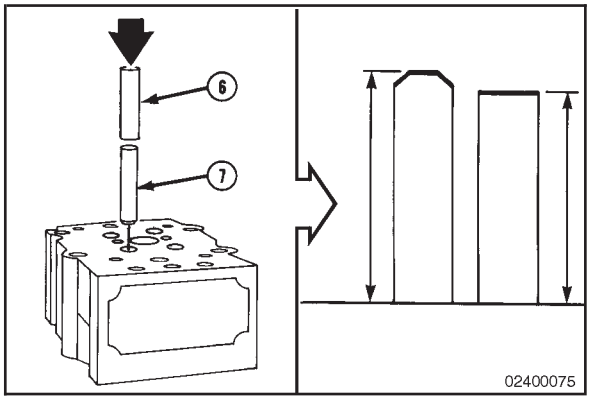
Use an arbor press and a suitable mandrel (6), to install the valve guide.

NOTE: The QSK19 **only** uses the flat top style valve guides with a valve seal.

Install the valve guide (7) to the specified height.

Valve Guide Height (to Spring Pocket)		
mm		in
37.97	MIN	1.495
38.48	MAX	1.515

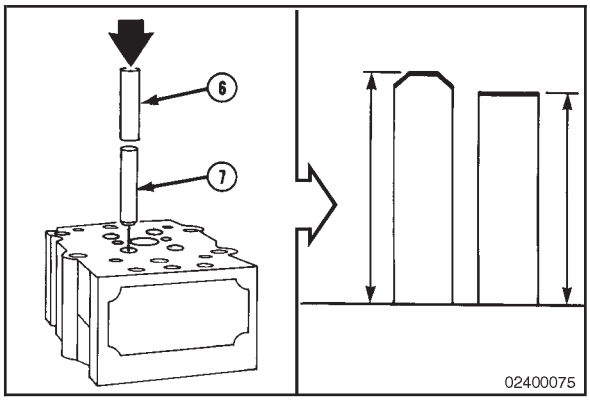
Valve Guide Height (to Top of Head)		
mm		in
13.97	MIN	0.550
14.47	MAX	0.570

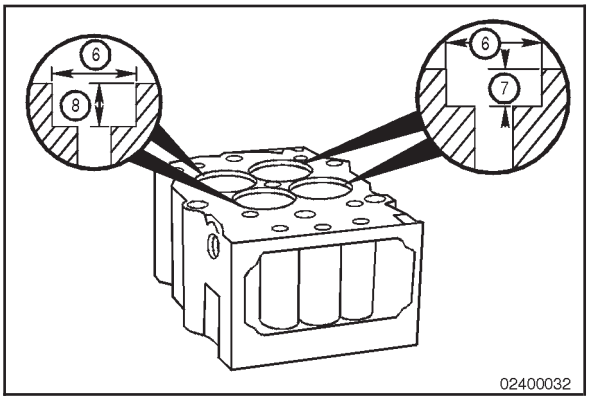


Install the valve guide (7) to the specified height.

Valve Guide Height (to Spring Pocket)		
mm		in
37.97	MIN	1.495
38.48	MAX	1.515

Valve Guide Height (to Top of Head)		
mm		in
13.97	MIN	0.550
14.47	MAX	0.570



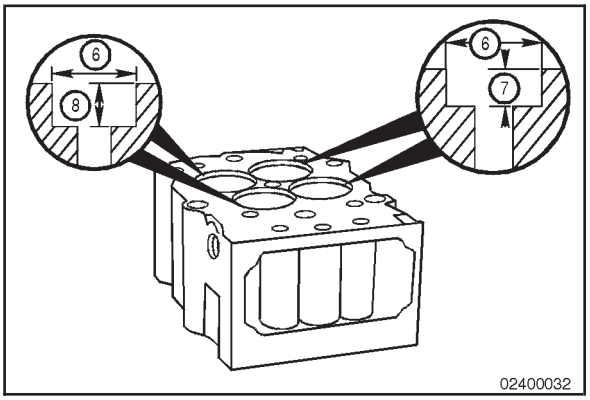


Valve Seat Bore (002-018)

Initial Check

With the valve seats removed, measure the I.D. and the depth of the insert bore in the head

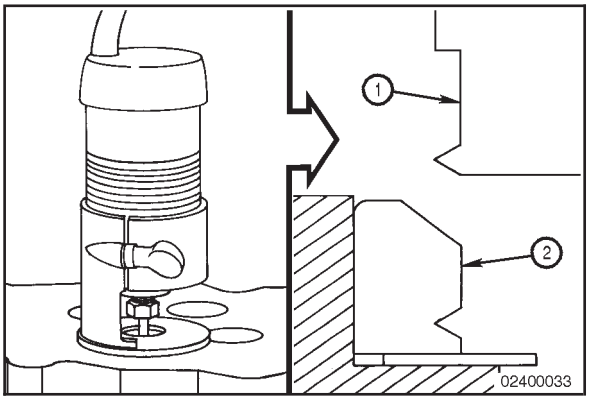
Valve Seat Bore Measurements			
	mm		in
Intake Diameter	60.37	MIN	2.377
	60.40	MAX	2.378
Intake Depth	13.00	MIN	0.492
	13.13	MAX	0.497
Exhaust Diameter	60.37	MIN	2.377
	60.40	MAX	3.378
Exhaust Depth	12.50	MIN	0.492
	12.62	MIN	0.497



If the I.D. is **not** within specifications, use an oversize seat.

NOTE: Oversize valve seat inserts are available in the following sizes. Machine the valve seat insert bore in the head. A press fit within 0.064 mm to 0.114 mm [0.0025 in to 0.0045 in] between the valve seat insert and the valve seat insert bore must be maintained.

O.D. Oversize	Depth (Thickness) Oversize
0.25 mm [0.010 inch]	Standard
0.51 mm [0.020 inch]	0.13 mm [0.005 inch]
0.76 mm [0.030 inch]	0.25 mm [0.010 inch]
1.02 mm [0.040 inch]	0.38 mm [0.015 inch]

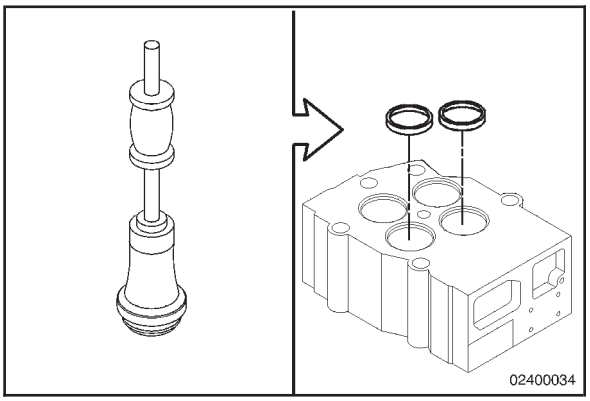


Valve Seat Insert, Cylinder Head (002-019)

Remove

Use a valve seat grooving kit, Part No. 3376405, or equivalent.

Machine a groove in the seat as close to the bottom of the bore as possible. This will allow the valve seat extractor to be used.



Use the specified valve seat extractor. Use an extractor knocker assembly, Part No. 3376617.

- Exhaust seat = Part No. ST-1323–1 Extractor
- Intake seat = Part No. 3376799 Extractor

NOTE: ONLY the intake ports contain anti-swirl plates.

Discard the anti-swirl plate.

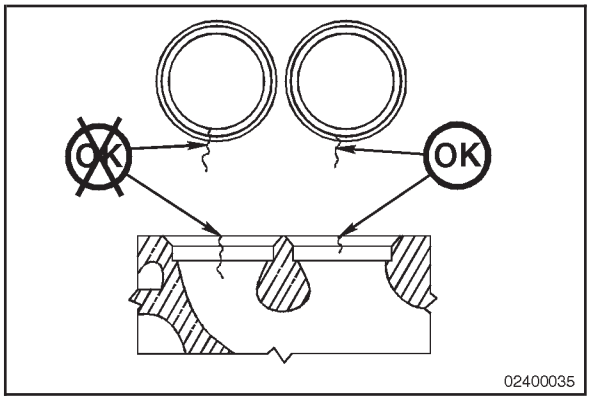
Install

Clean the valve seat insert bore.

Check the length of any cracks extending into the valve seat insert bore.

NOTE: The cylinder head **must** be replaced if a crack extends into the bottom of the bore.

NOTE: At times it is possible to remove the crack by machining the head to use an oversize valve seat insert.

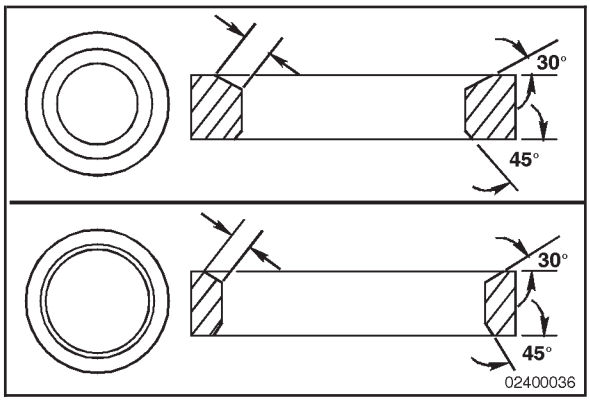


Identify the correct valve seat insert.

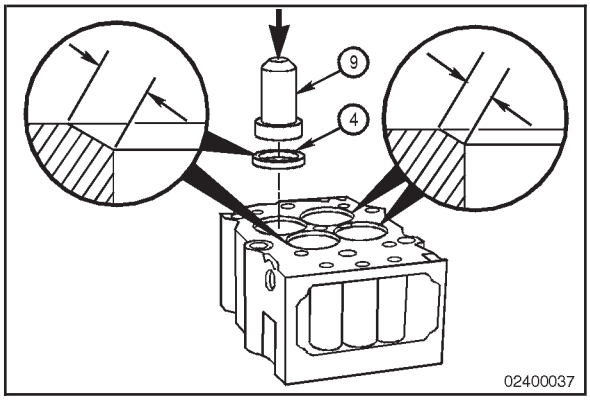
- Top picture: Intake port seat.
- Bottom picture: Exhaust port seat.

Both the **intake** and the **exhaust** port seats **must** be installed with the 30 degree angle positioned as shown.

NOTE: Exhaust seats are color coded blue to identify the 30 degree angle side of the seat.



Use an arbor press, and a mandrel. Install the insert into the head.

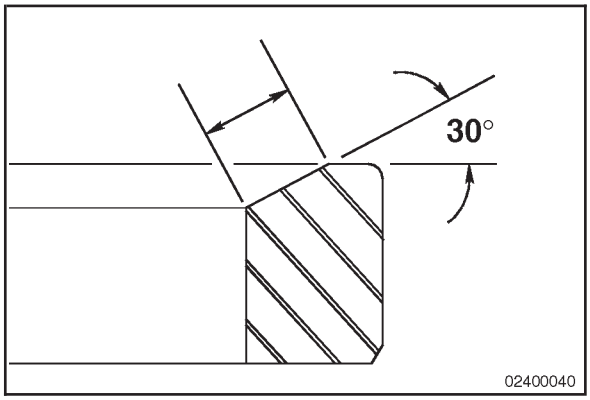


Grind

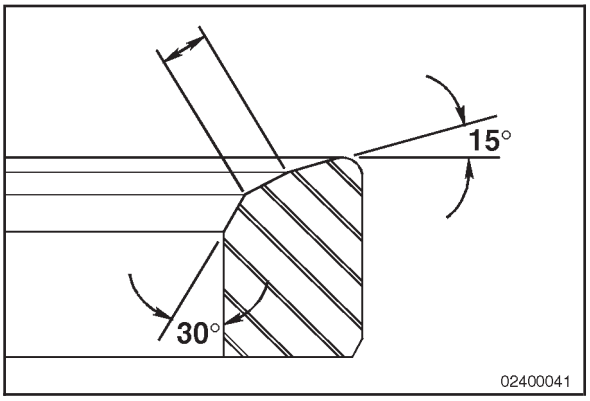
Use a valve seat grinding machine, Part No. ST-685, or equivalent. Use a valve guide arbor set, Part No. 3375946, or equivalent.

Grind the valve seat insert to the angle shown.

Measure the width.

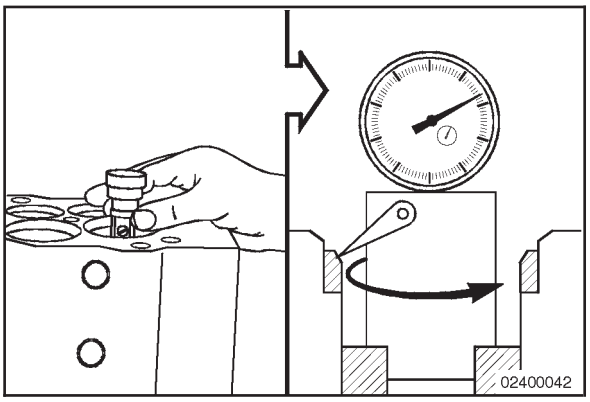


Valve Seat Width			
	mm		in
Intake	3.05	MIN	0.120
	3.55	MAX	0.140
Exhaust	1.52	MIN	0.060
	2.54	MAX	0.100



If the width of the valve seat is **not** within specifications, remove surface material on the I.D. and the O.D. to decrease the width of the seat.

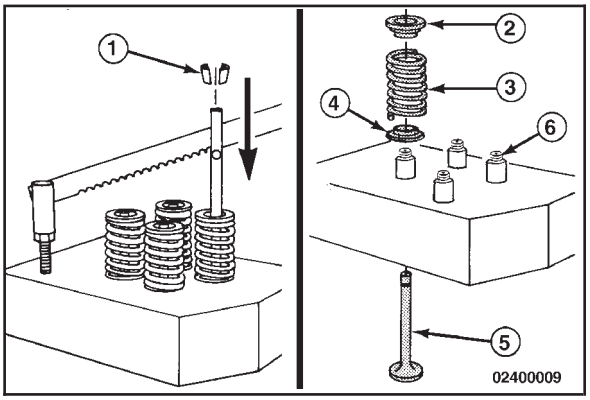
NOTE: If the valve seat specifications are **not** obtained by grinding, the insert **must** be replaced.



Measure the valve seat to the valve guide concentricity.

NOTE: The seat and guide **must** be concentric.

Valve Seat to Guide Concentricity		
mm		in
0.05	MAX	0.002



Valve, Cylinder Head (002-020)

Remove

CAUTION

The valve springs are under compression. Use caution when using the valve spring compressor. Personal injury can result.

Use a valve spring compressor, Part No. ST-448, or Part No. 3375960, or equivalent. Valve spring stand, Part No. ST-1022, and the compressor plate, Part No. 3375043, can be used to compress all four springs at the same time.

Mark the valve for location prior to removal. The intake and exhaust valves are different. The practice will help with future installation identification.

Compress the valve spring and remove the following parts.

1. Valve collets
2. Valve spring retainer
3. Valve spring
4. Valve rotator
5. Valve
6. Valve stem seal

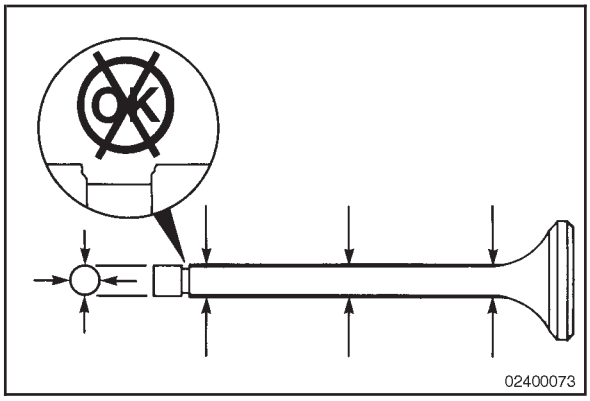
Discard the collets.

Inspect for Reuse

Inspect the collet grooves for wear.

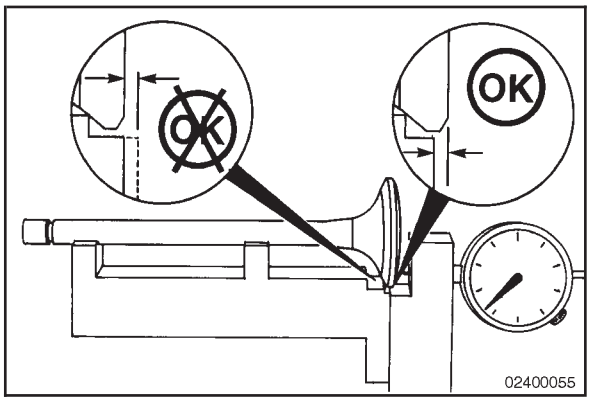
Measure the O.D. of the valve stem.

Valve Stem O.D.		
mm		in
10.490	MIN	0.4130
10.510	MAX	0.4138



Use a valve head checking tool, Part No. 3824861, to measure the head thickness of the valve.

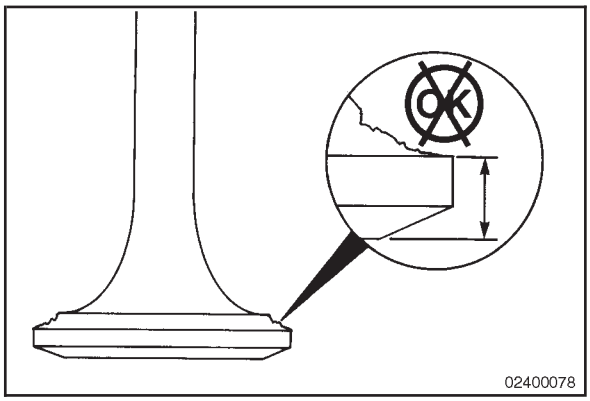
Position the tool over the valve, place on a flat surface, if the bottom of the tool touches the flat surface the valve **must** be replaced.



If a valve head checking tool is **not** available, put the valve on a flat surface. Check the height of the O.D.

Valve Head Thickness (at the O.D.)		
mm		in
3.94	MIN	0.155

NOTE: This type of a check is **not** as accurate as using the valve head checking tool.



Magnetic Crack Inspect

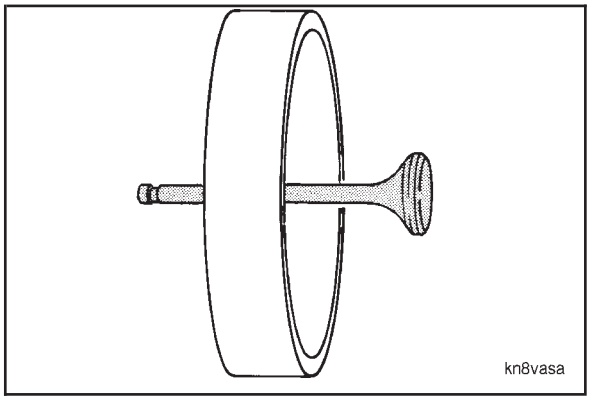
CAUTION

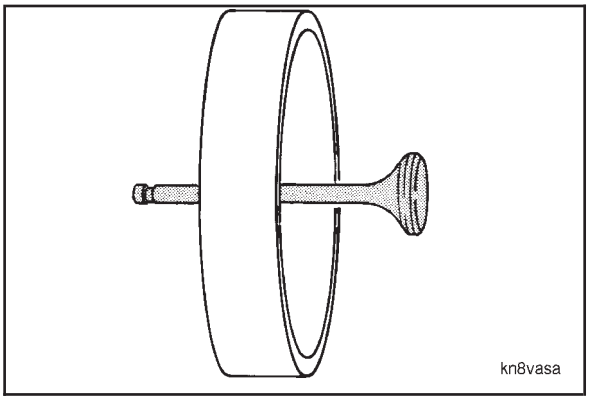
Always demagnetize and clean the parts thoroughly after a magnetic particle inspection. The iron fragments can damage the internal engine components.

Use the magnetic particle residual method. Check the valves for cracks.

NOTE: Check the **intake** valves with the **coil and head shot** methods (the coil shot first). Check the **exhaust** valves with the **coil shot** method.

Use a 305 mm [12 in] minimum diameter coil.

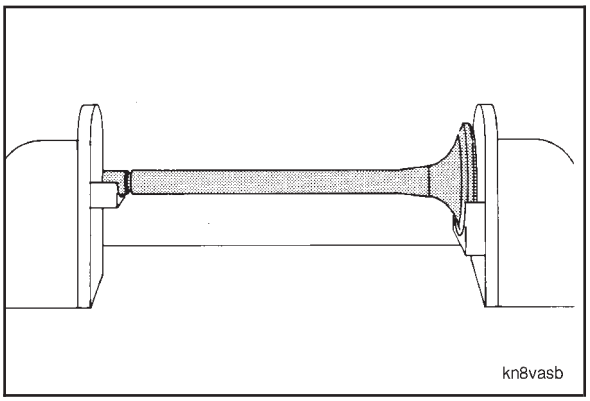




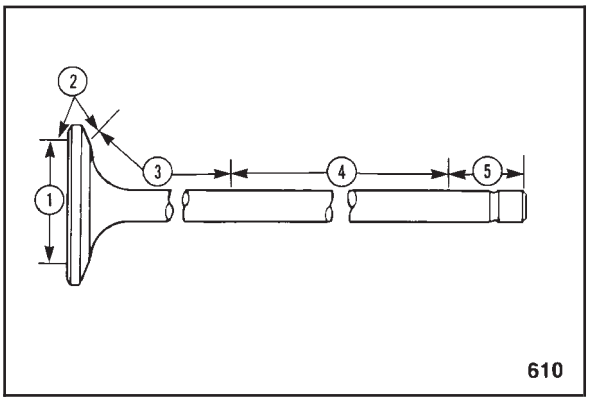
Coil Shot Amperage (Ampere Turns)	
MIN	400 D.C. or rectified A.C.
MAX	800 D.C. or rectified A.C.

NOTE: An ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.

NOTE: A broad fuzzy pattern will appear at the welded joint on the **exhaust** valves. This is normal. If there is a distinct line in the broad fuzzy pattern, the valve **must** be replaced.



Head Shot Amperage (Ampere)	
MIN	500 D.C. or rectified A.C.
MAX	700 D.C. or rectified A.C.



Acceptance Criteria (Intake and Exhaust Valves.

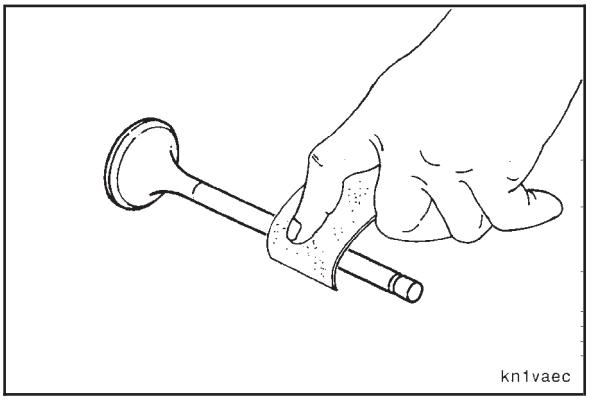
(1). Indications less than 38.1 mm [1.5 in] in length are acceptable. More than five indications, spaced closer than 3 mm [0.118 in], are **not** acceptable.

(2). No indications are acceptable.

(3). ONLY longitudinal indications are acceptable.

(4). ONLY longitudinal indications are acceptable.

(5). No indications are acceptable.



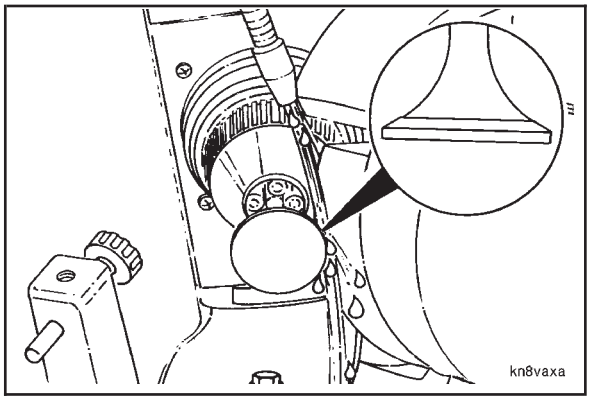
Grind

Use Scotch-Brite®, Part No. 3823258, to clean the valve stems. Clean the valve stems. Clean the carbon deposits from the valve face and the 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.

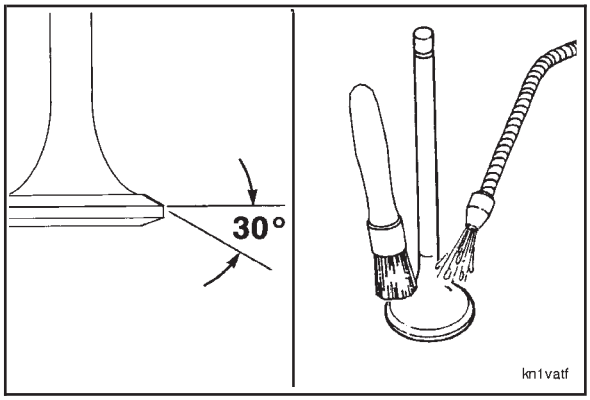
Use a valve facing machine, Part No. 3376256 or equivalent, to grind the face of the valve.

NOTE: Follow the instructions supplied with the valve facing machine for the correct setup before grinding the valves.



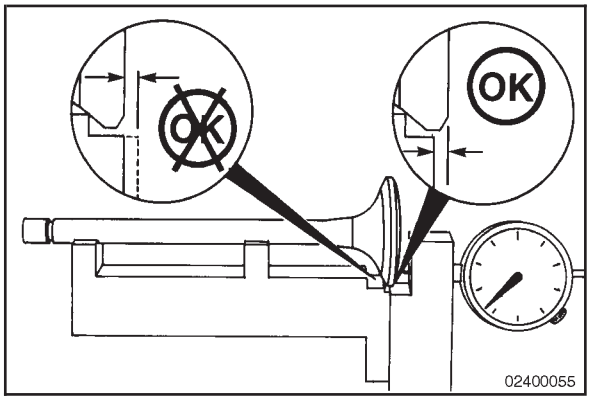
Use solvent to clean the metal particles from the valve.

Dry with compressed air.



Use a valve head checking tool, Part No. 3824861, to measure the head thickness of the valve.

Position the tool over the valve, place on a flat surface, if the bottom of the tool touches the flat surface the valve **must** be replaced.

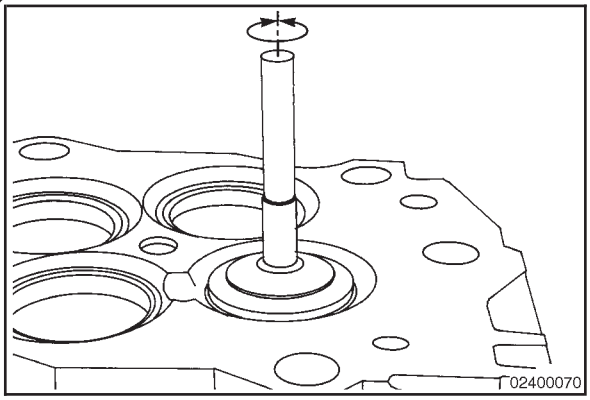


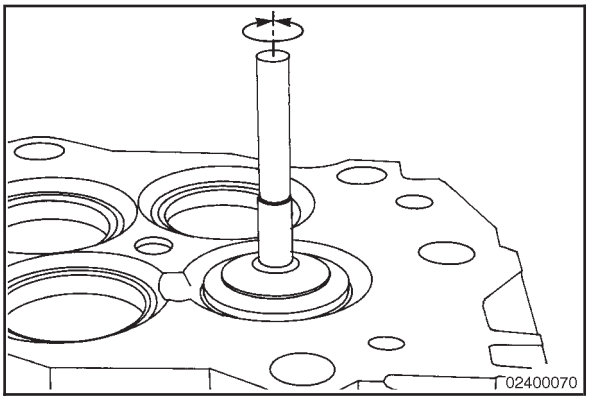
Use a lead pencil or Dykem® to mark across the valve face as shown. Install the valve in the valve guide.

Hold the valve against the valve seat, and rotate the valve backward and forward three or four times.

Correct contact against the valve seat will break the marks on the valve face.

NOTE: Valves and valve seats that are correctly machined do **not** require the use of lapping compound to make an air tight seal. If lapping compound is required, inspect the adjustments of the facing machine and the condition of the grinding stone.



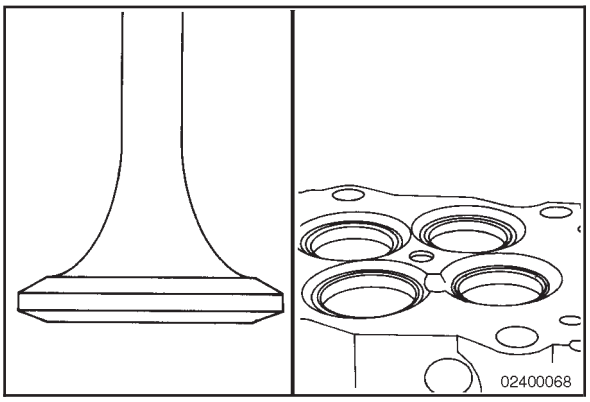


Lap

Use a fine lapping compound, Part No. 3375805, or equivalent. Apply a thin and even coating on the valve.

Use a power or a hand suction lapping tool to provide pressure in the center of the valve.

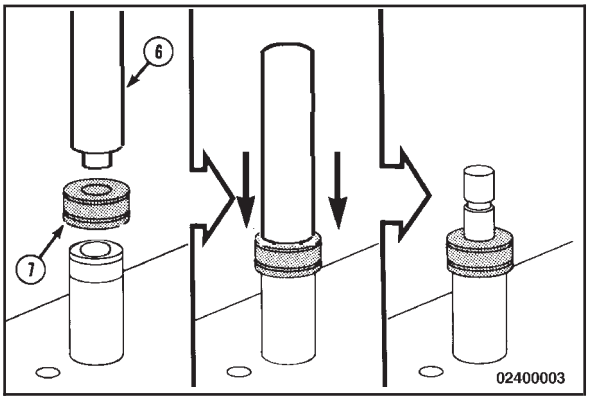
Turn the valve **backward** and **forward**. Continue lapping until the compound shows a continuous contact pattern on **both** the valve seat insert and the valve.



CAUTION

Lapping compound is an abrasive material. Failure will result if the cylinder head, the valves, and the valve seats are not cleaned thoroughly.

Clean the lapping compound from the parts.



Install

CAUTION

Lubricate all the valve guide bores and valve stems with 140W oil. Failure to lubricate guide and stems will result in premature valve guide wear.

Install the seal driver (6) on the valve guide. Push the seal (7) over the seal driver and on the valve guide. Push the seal down on the guide until the lower spring is in the groove on the guide.

Remove the seal driver.

Install the valves.

⚠ CAUTION ⚠

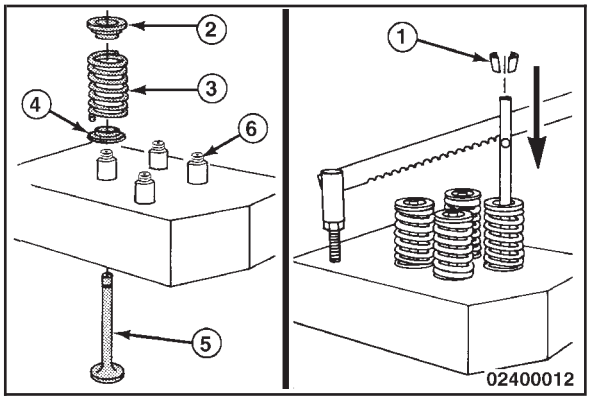
The valve springs are under compression. Use caution when using the valve spring compressor. Personal injury can result.

Use a valve spring compressor, Part No. ST-448, or Part No. 3375960, or equivalent. Valve spring stand Part No. ST-1022 and the compressor plate, Part No. 3375043, can be used to compress all four springs at the same time.

NOTE: The valve rotator **must** be soaked in clean engine oil for at least 15 minutes prior to installation.

Install the following parts:
6. Valve stem seal (already installed)
5. Valve
4. Valve rotator
3. Valve spring

Compress the valve spring and install the following parts:
2. Valve spring retainer
1. New valve collets



NOTES

Section 3 - Rocker Levers - Group 03

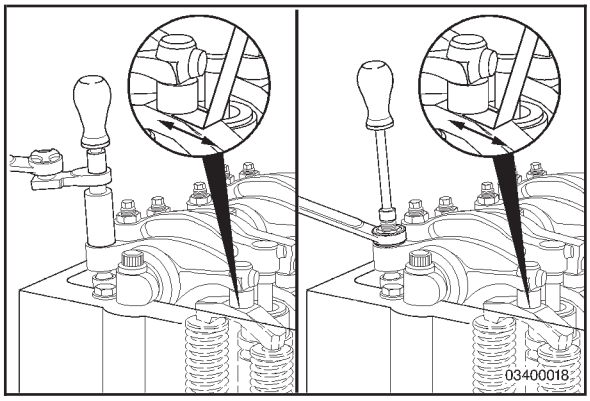
Section Contents

Rocker Levers - General Information

General Information

The QSK19 utilizes the Outer Base Circle (OBC) overhead set procedure.

NOTE: The OBC procedure requires the use of an accurate inch-pound torque wrench. Torque wrench kit, Part No. 3824783, is available. A dial-type torque wrench with a range from 0 to 35 N•m [0 to 300 in-lb] is required. The torque wrench needs to be checked on a routine basis for proper calibration. Use of a clicker-type torque wrench is **not** recommended.

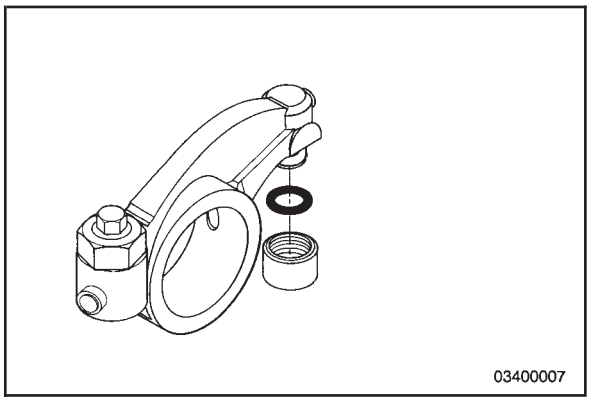


The QSK19 valve rocker lever incorporates a ball and socket to minimize crosshead wear and reduce tipping of the valves.

NOTE: The intake and exhaust rocker levers are **not** interchangeable.

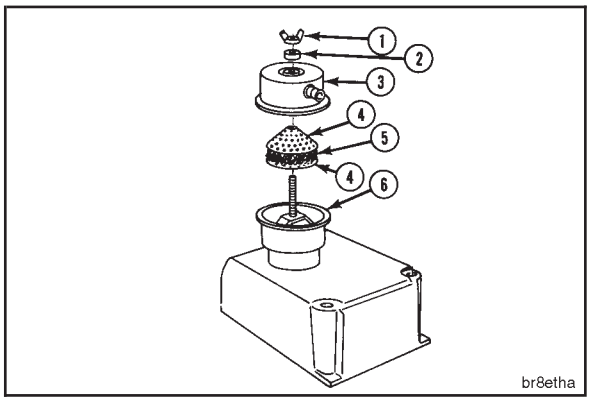
Both the intake and the exhaust levers contain a blind rivet and the injector lever contains a plug ball. The rivets and plug ball plugs, plug the oil drilling in the lever. The rivets and plug ball plug **must** be present.

NOTE: All of the rocker levers contain replaceable bushings.



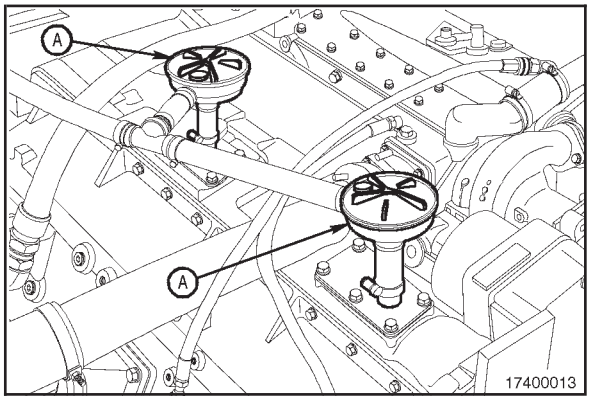
The rocker lever covers are available **with** and **without** crankcase breathers.

The engine should have 3 breathers, but the locations may vary. The rocker covers without breathers should have a service plug (for the injector cut out tool) installed.



Rail Applications

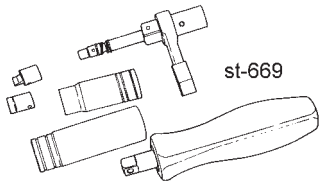
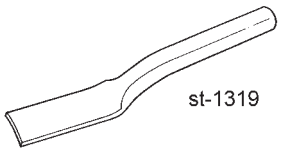
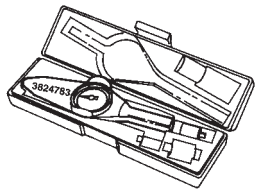
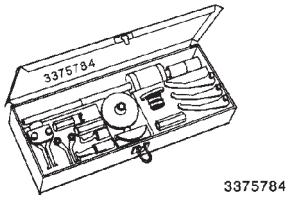
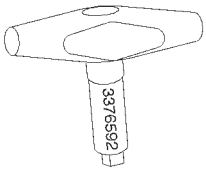
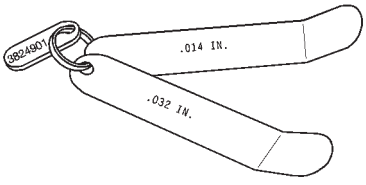
The QSK19 Rail Engine uses a Mann & Hummel™ open crankcase breather system. The two Mann and Hummel™ canisters (A) are mounted on a modified lubricating oil pan adapter hand hole cover.

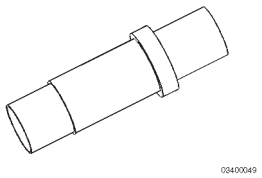


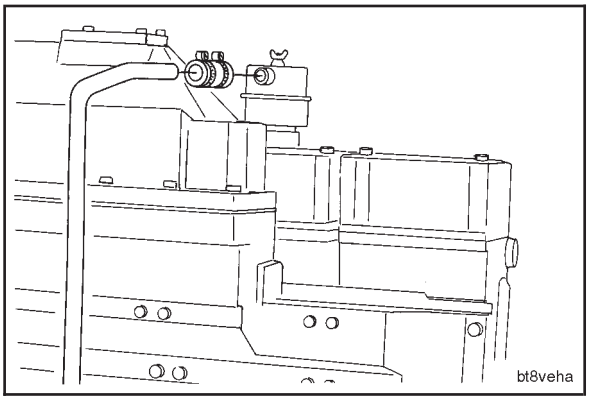
Service Tools

Rocker Levers

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

Tool No.	Tool Description	Tool Illustration
ST-669	**Torque Wrench Adapter** Secures the rocker lever adjusting screw while tightening the lock nut.	
ST-1319	**Water Tube Driver** Used to install or remove the water transfer tubes from the rocker housings.	
3824783	**Torque Wrench** A dial-type torque wrench used to accurately adjust injectors in inch-pounds. Use of a clicker-type torque wrench is **not** recommended. 0-35 N•m [0-300 in-lb]	
3375784	**Light Duty Puller Kit** Used to remove small bushings, oil seals, and bearings.	
3376592	**Torque Wrench** Inch-pound torque wrench used to tighten the valve lever adjusting screw. Does **not** require screwdriver attachment.	
3824901	**Valve Setting Gauge Kit** Kit contains two 25.4 mm [1 in] wide feeler gauges for centering under the swivel foot of the rocker lever when setting the valves. The kit contains an intake valve gauge at 0.36 mm [0.014 in] and an exhaust valve gauge at 0.081 mm [0.032 in].	

Tool No.	Tool Description	Tool Illustration
3162458	**Rocker Lever Bushing Mandrel** Used to install and/or remove the rocker lever bushings	



Crankcase Breather (External) (003-001)

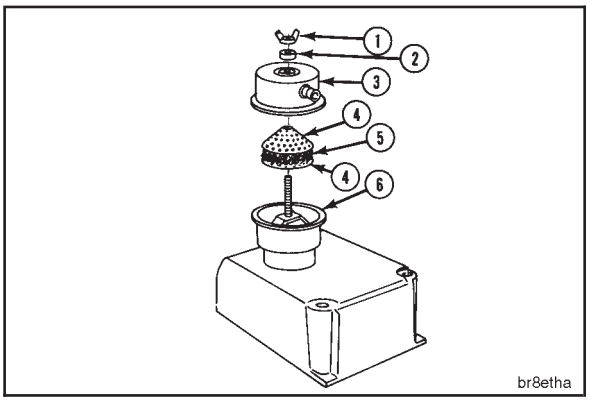
Remove

Loosen the hose clamp at the breather vent tube.

Remove the tube support bracket capscrew and the bracket.

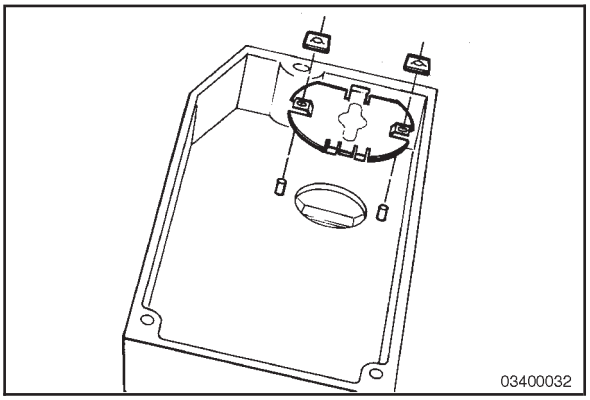
Remove the vent tube and the hose from the engine.

If the vent tube is blocked, it should be cleaned to prevent excess crankcase pressure buildup.



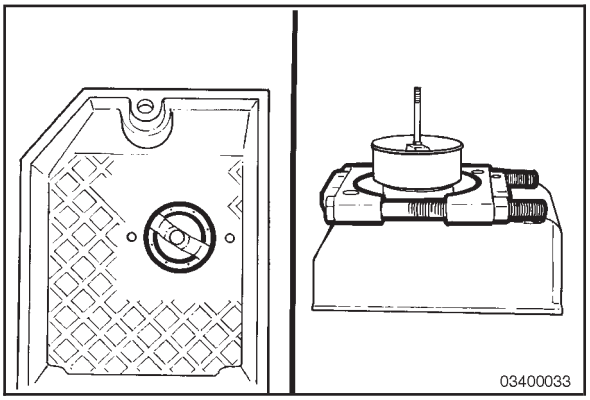
Remove the following parts from the breather body (6).

1. Wing Nut
2. Washer
3. Breather Cap
4. Screen Mesh
5. Element



Remove the push nuts.

Remove the baffle.



⚠ CAUTION ⚠

The mandrel must make contact on the breather body to prevent damage.

Use a water pump bearing separator, Part No. 3375326, or equivalent. Support the cover as close as possible to the breather to prevent cracking of the cover.

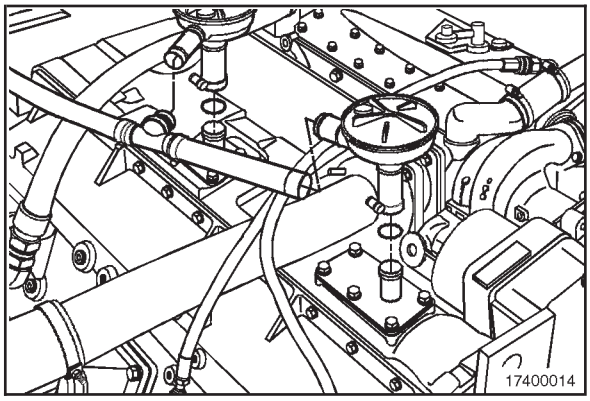
Push the breather out.

Rail Applications

Loosen the hose clamp and remove the crankcase breather hose from breather canister.

Loosen the tube clamp between the breather canister and the hand hole cover.

Remove the breather canister from the hand hole cover.

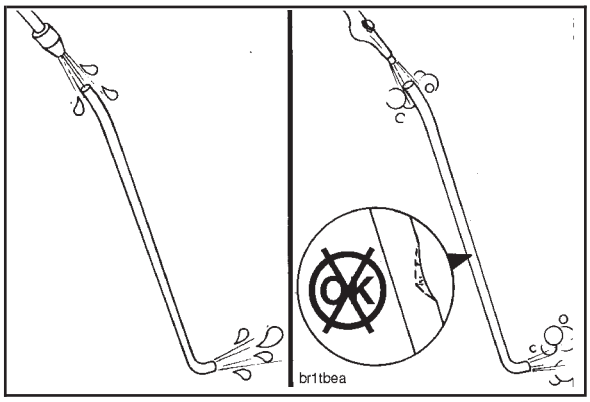


Clean

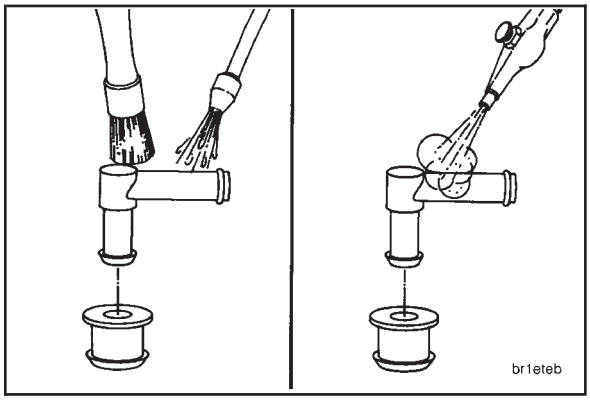
Use solvent to clean the inside of the crankcase breather tube, and dry with compressed air.

Use air pressure to blow through the vent tube.

Replace the vent tube if it is clogged or dented.



Use solvent to clean the breather tube.



Clean the breather cap element and screens in an approved cleaning solvent.

Dry with compressed air.

Wipe out the breather housing (6).

Clean the following parts:

(4) Screen Mesh

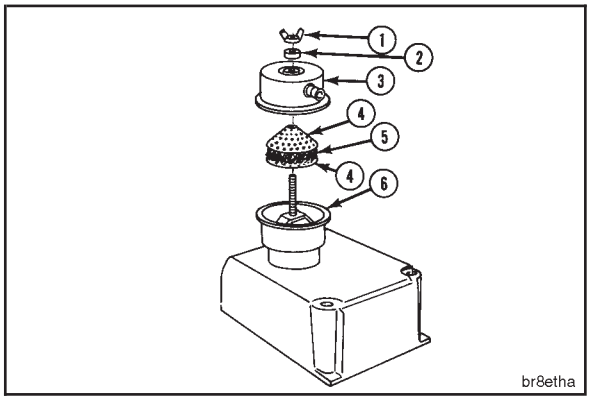
(5) Element

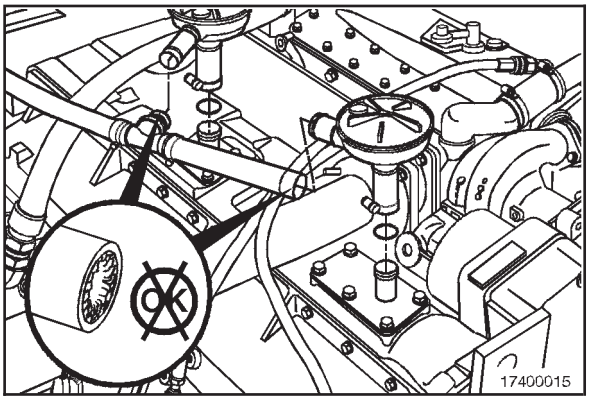
(4) Screen Mesh

(3) Breather Cap

(2) Washer

(1) Wing Nut





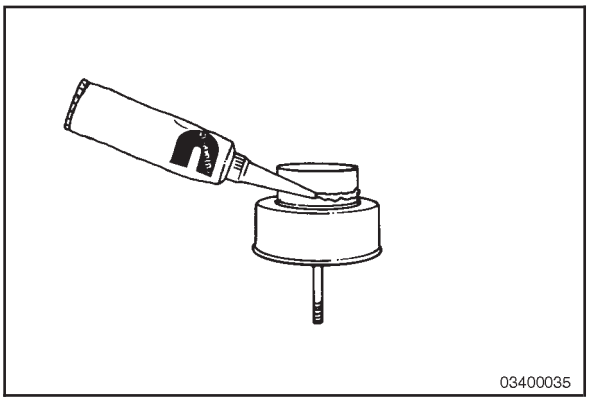
Rail Applications

Loosen the hose clamp and remove the crankcase breather hose from breather canister.

Check hose internally for obstructions or sludge buildup.

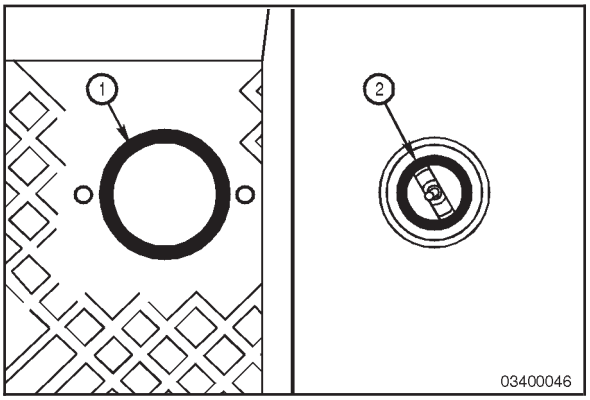
If the hose is blocked, clean it to prevent excess crankcase pressure buildup.

Install the crankcase breather hose on the breather canister. Tighten the hose clamp.



Install

Apply Loctite® 732, or equivalent to the O.D. of the breather.



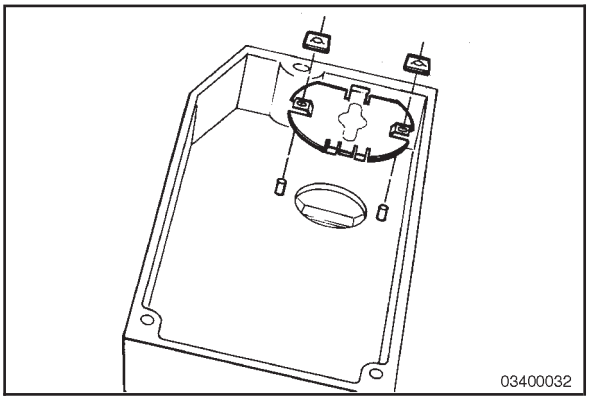
⚠ CAUTION ⚠

The mandrel must contact the breather body in the area shown (2).

⚠ CAUTION ⚠

Excessive force will cause the aluminum cover to crack (1).

Use a mandrel to install the breather.



Install the baffle and new push nuts.

Install the parts in the following order:

(4) Screen Mesh

(5) Element

(4) Screen Mesh

(3) Breather Cap

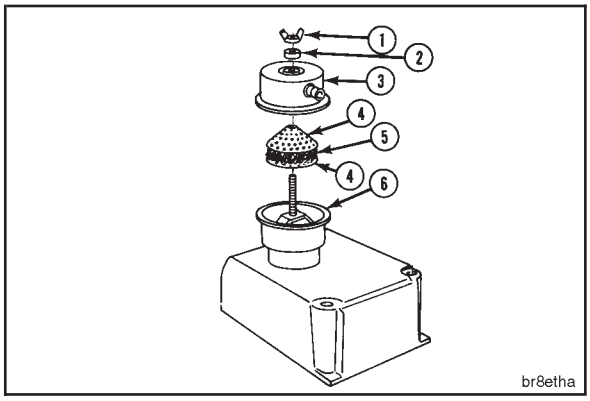
(2) Washer

(1) Wing Nut

If the breather is not used, install the service plug and o-ring.

Tighten the service plug.

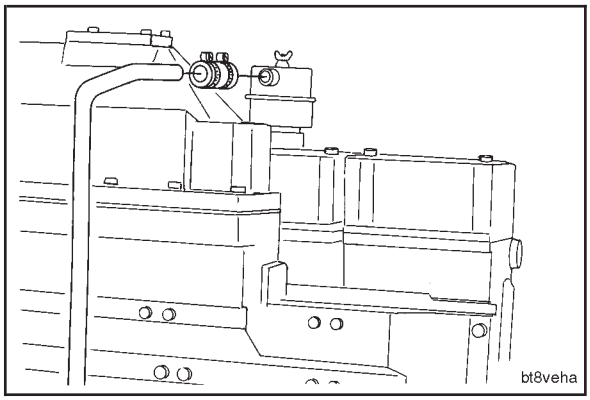
Torque Value: 45 N•m [35 ft-lb]



Install the tube and hose on the engine.

Install the tube support bracket and capscrew.

Tighten the hose clamp at the breather vent tube.



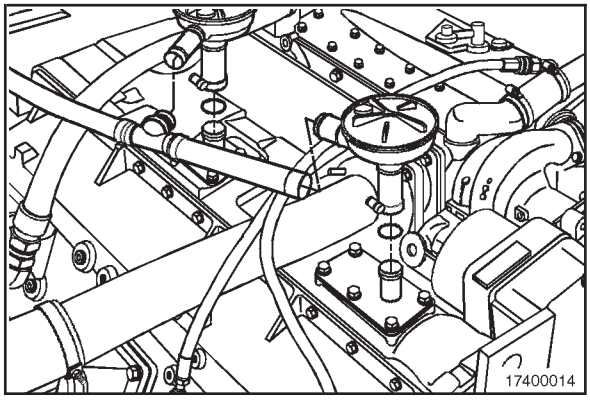
Rail Applications

Install the o-ring and breather canister on the hand hole cover.

Tighten the tube clamp.

Install the crankcase breather hose on the breather canister.

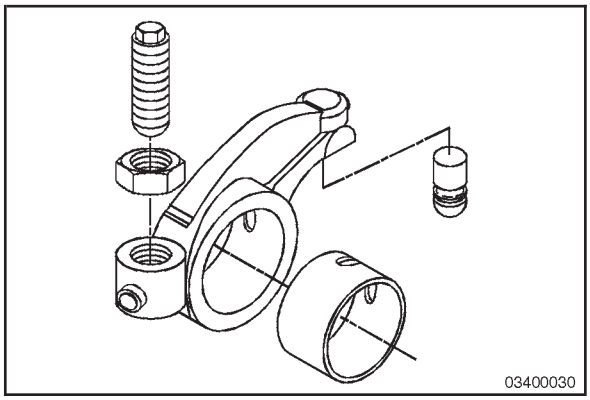
Tighten the hose clamp.

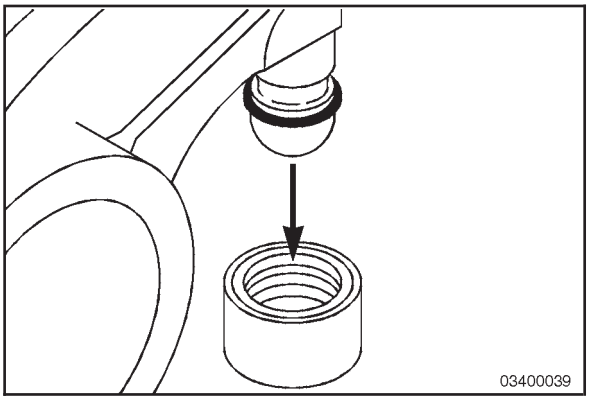


Rocker Lever (003-008)

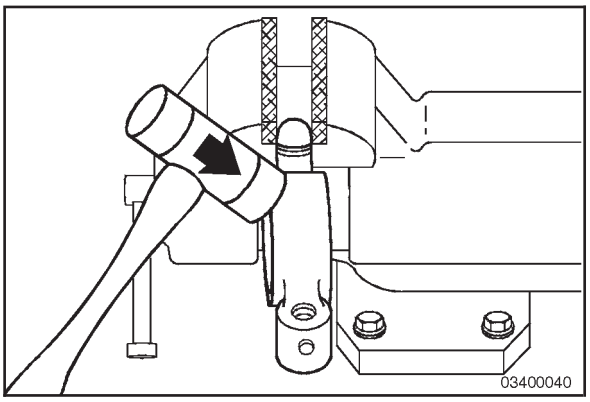
Disassemble

Remove the lock nut and adjusting screw.





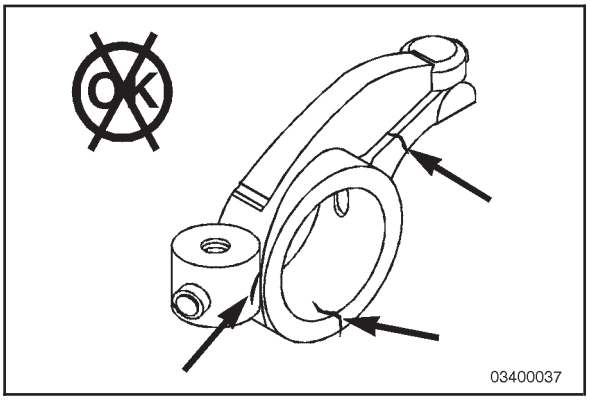
Remove the socket from the ball on the rocker lever shaft.



Place the ball in a vise as shown.

Wiggle the rocker lever until the ball swivels.

Use a mallet to tap the rocker lever until the ball comes out.



Magnetic Crack Inspect

NOTE: The rocker lever must be disassembled to do this inspection.

Use the residual method. Apply coil shot amperage.

Amperage (Ampere Turns)
1200 D.C. or rectified A.C.
2000 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.

The lever **must** be replaced if there is a crack in any location.

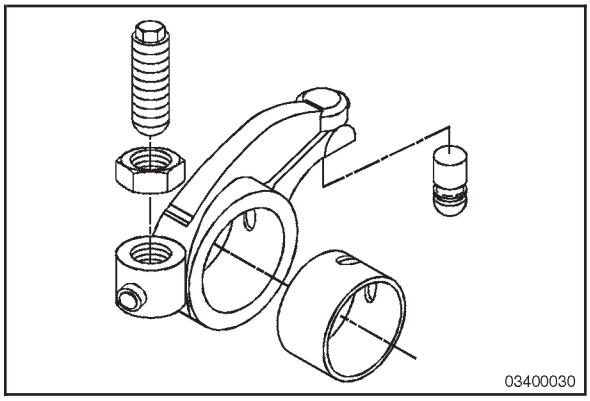
Demagnetize the lever.

Use solvent to clean the rocker lever.

Assemble

Install the adjusting screw and the lock nut in each lever.

Do **not** completely tighten the lock nut until the assembly is installed on the engine.



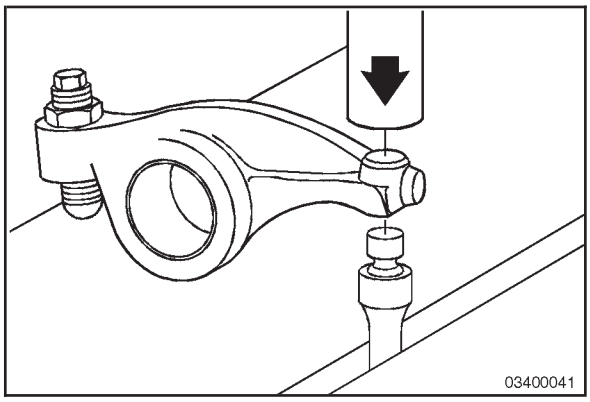
⚠ CAUTION ⚠

Do not overstress the press fit.

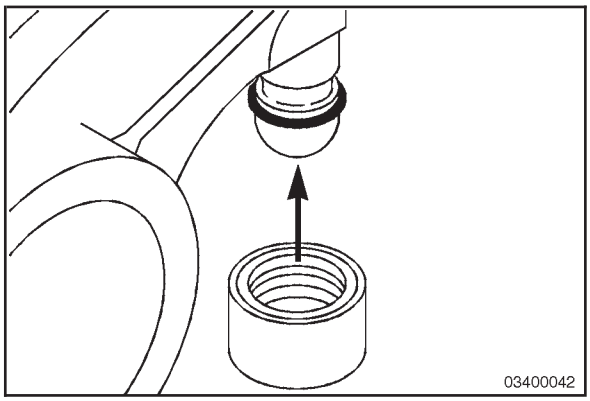
Use a press to seat the new ball into the cavity in the rocker lever.

The lip on the ball must be flush with the surface on the rocker lever.

NOTE: Use an old push tube socket end to help hold and align the ball for proper seating.

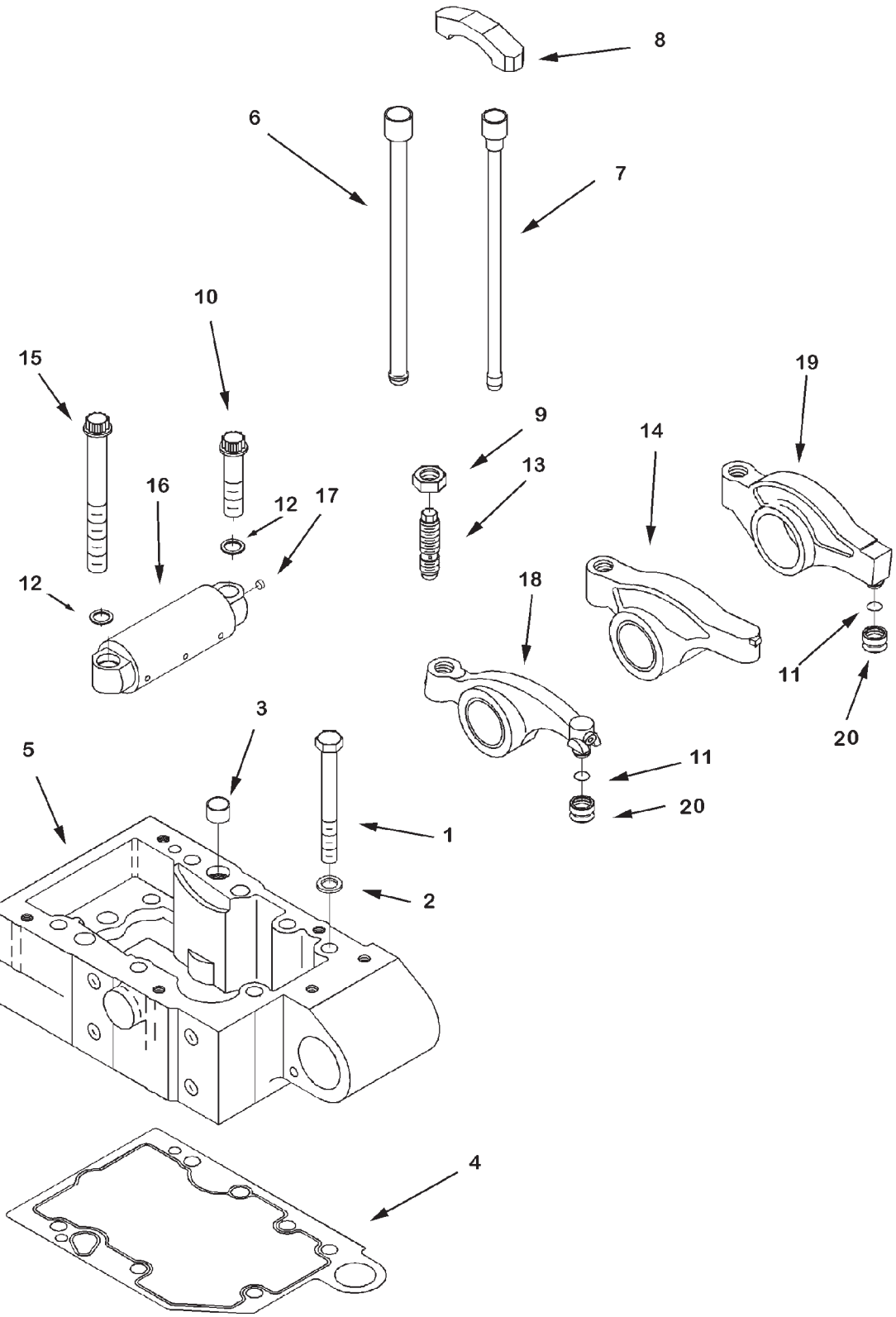


Install the new socket on the ball.

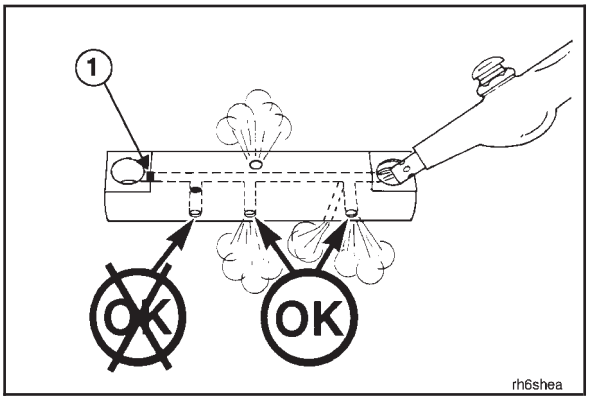


Rocker Lever Assembly (003-009)

Exploded View



1. Screw, Hexagon Head Cap
2. Washer, Plain
3. Dowel, Ring
4. Gasket, Rocker Lever Housing
5. Housing, Rocker Lever
6. Rod, Push
7. Rod, Push
8. Crosshead, Valve
9. Nut Regular Hexagon Jam
10. Screw, Twelve Point Cap
11. Seal, O-ring
12. Washer, Plain
13. Screw, Rocker Lever Adjusting
14. Lever, Rocker
15. Screw, Twelve Point Cap
16. shaft, Rocker Lever
17. Plug, Expansion
18. Lever, Rocker
19. Lever, Rocker
20. Socket, Rocker Lever



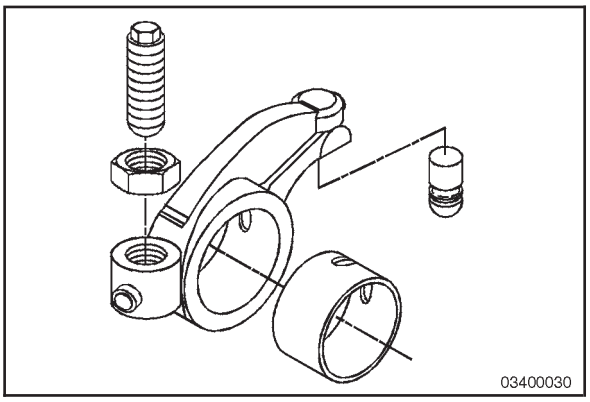
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

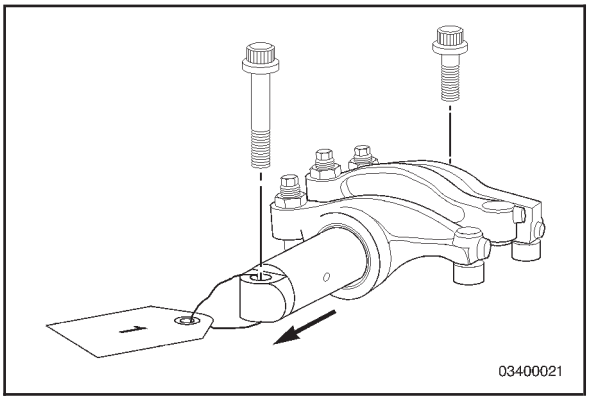
Use solvent. Clean the shaft. Use compressed air to blow through the oil drillings, to be sure that the nine oil holes are not blocked.

The plug (1) in the main oil rifle of the rocker shaft must be installed in the ring dowl end of the shaft (exhaust lever end).



Use solvent to clean the parts.

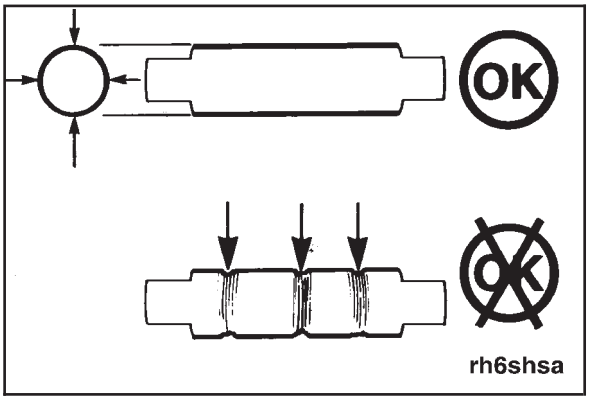
Use compressed air to blow through the oil drillings, to be sure that they are not blocked.



Inspect for Reuse

Remove the capscrews and hardened washers. Pull the shaft out of the rocker levers.

Clean and inspect the parts for damage.



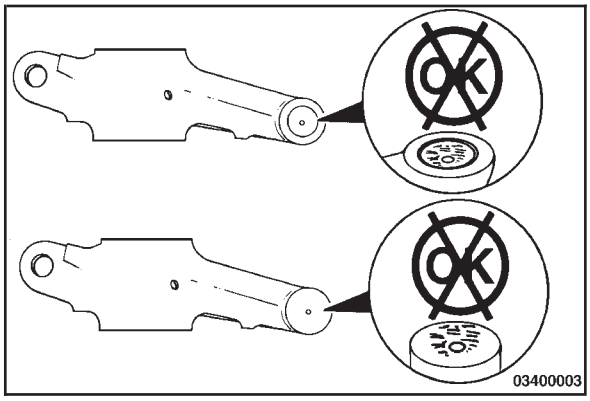
Inspect the shaft for damage or roughness.

Measure the O.D.

Rocker Arm Shaft O.D.		
mm		in
47.592	MIN	1.8737
47.634	MAX	1.8753

Inspect the socket for wear on both the injector and valve sockets. Inspect the crosshead pad for wear.

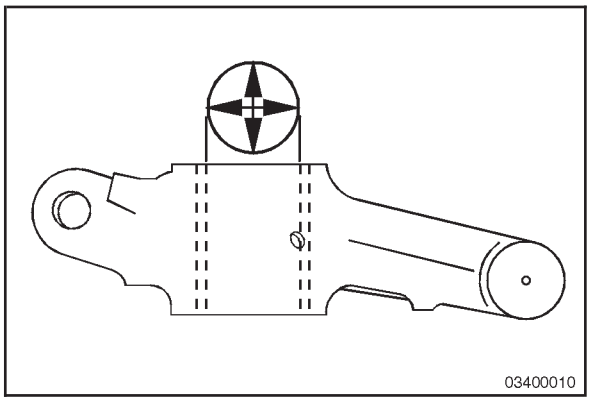
NOTE: If there is damage that can be felt with the fingernail, the parts should be replaced.



Check the bushing wear. Measure the I.D. of the bushing.

Bushing Bore I.D.		
mm		in
47.66	MIN	1.876
47.73	MAX	1.879

NOTE: This specification applies to all rocker levers.



Lubricate the shaft with clean engine oil.

NOTE: The oil drillings in the shaft **must** be in alignment with the oil drillings in the levers.

Slide the levers on the shaft in the sequence shown:

— Exhaust lever (1)

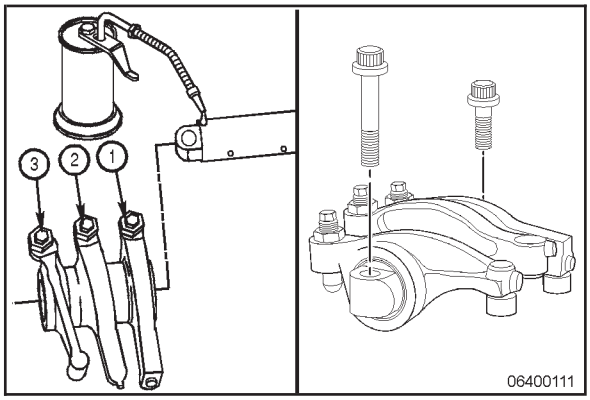
— Injector lever (2)

— Intake lever (3)

NOTE: The plug in the end of the shaft **must** be on the same end as the exhaust rocker lever.

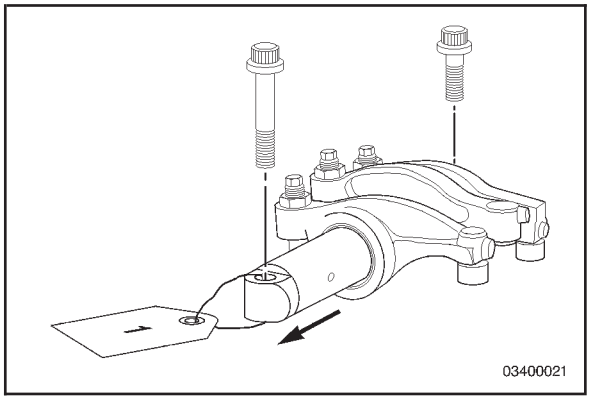
Lubricate threads, rocker sockets, and crosshead pads with clean engine oil.

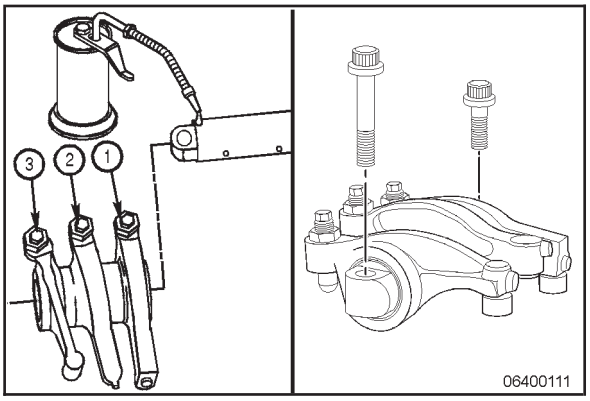
Install the washers and capscrews.



Disassemble

Remove the capscrews. Pull the shaft out. Tag the parts to aid the future assembly procedure.





Assemble

Use clean engine oil to lubricate the shaft.

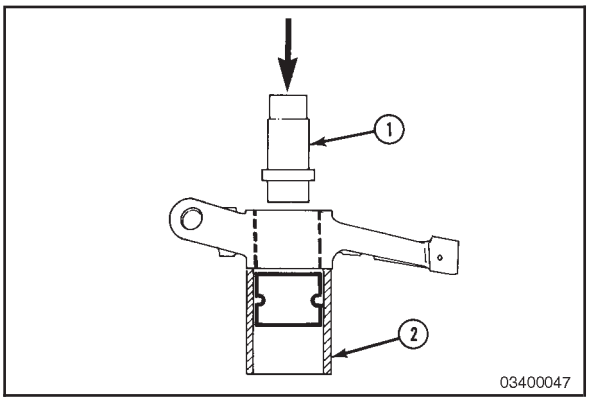
⚠ CAUTION ⚠

The oil drillings in the shaft must be in alignment with the oil drillings in the rocker levers.

The plug (4) in the main oil drilling **must** be nearest to the exhaust lever (1). Slide the levers on the shaft in the sequence shown.

1. Exhaust lever
2. Injector lever
3. Intake lever

Install the capscrews.



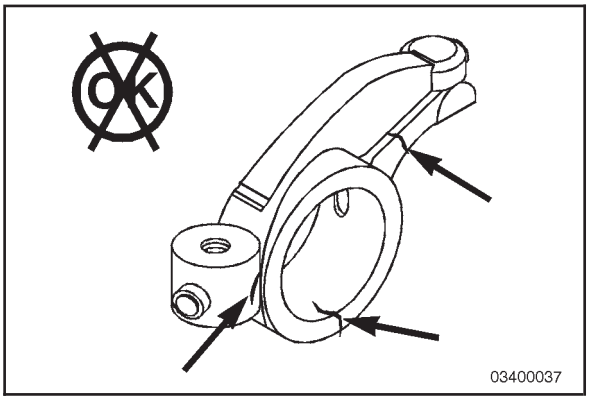
Rocker Lever Bushings (003-010)

Remove

NOTE: Do **not** remove the bushing unless it is damaged or worn.

Support the lever as shown (2). Use an arbor press and rocker lever bushing mandrel, Part No. 3162458 (1), or equivalent.

Remove the bushing.



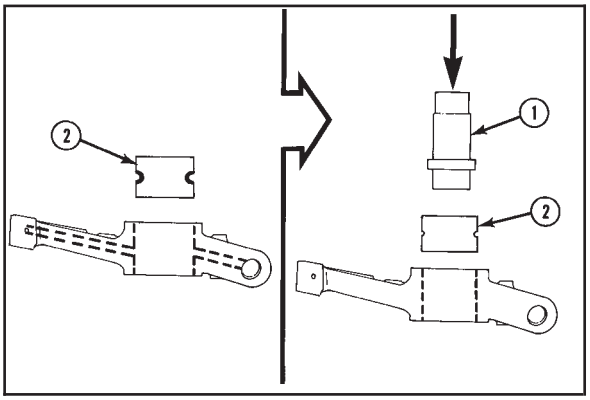
Install

Use a 240 grit, or finer, emery cloth to remove any burrs from the bore of the lever.

If cracks are suspected, use the magnetic particle inspection method. Refer to Procedure 003–008. The lever **must** be replaced if it is worn.

Measure the rocker lever bore I.D.

Lever Bore I.D.		
mm		**in**
49.25	MIN	1.939
49.27	MAX	1.940



⚠ CAUTION ⚠

Refer to Service Tool Instructions for the proper use of Tool No. 3162458. The bushings must be installed and aligned in the bushing bore correctly. A loss of lubricating oil to the shaft will occur if the bushings are incorrectly installed.

Align the oil holes in the bushing (2) with the oil passages in the lever.

Use an arbor press and a rocker lever bushing mandrel, Part No. 3162458 (1), or equivalent. Install the bushing (2).

Rocker Lever Cover (003-011)

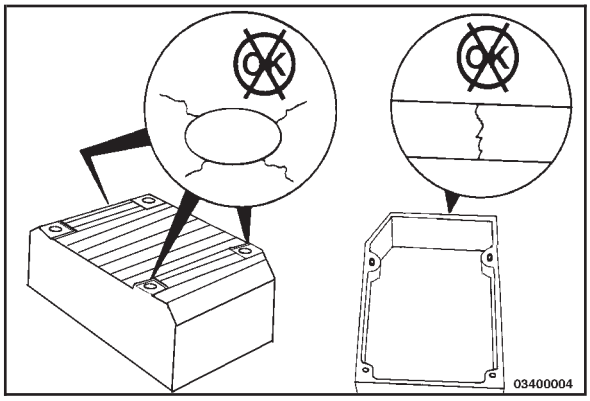
Clean

⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

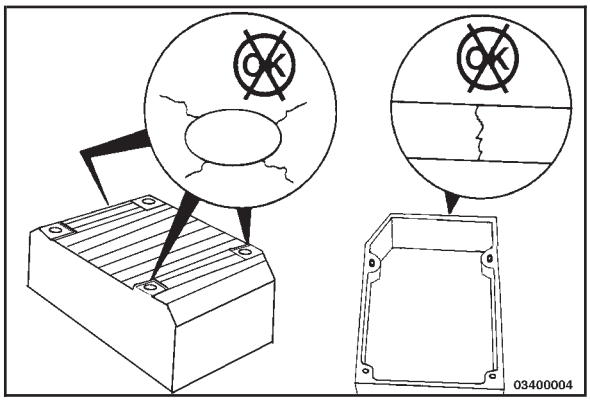
Use solvent to clean the rocker lever covers.

Dry with compressed air.



Inspect for Reuse

Inspect the cover for cracks.



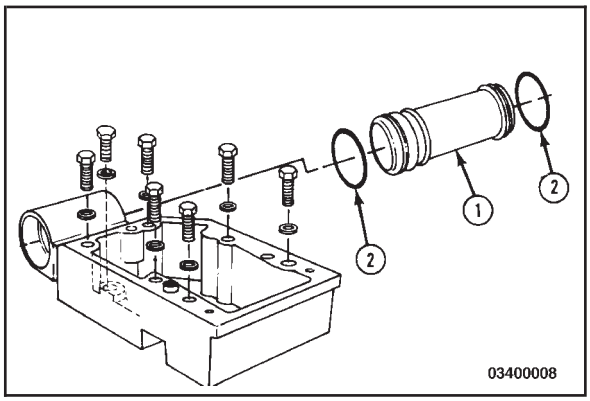
Rocker Lever Housing (003-013)

Clean

Remove the water transfer tube and o-rings.

Discard the o-rings.

Remove the capscrews.

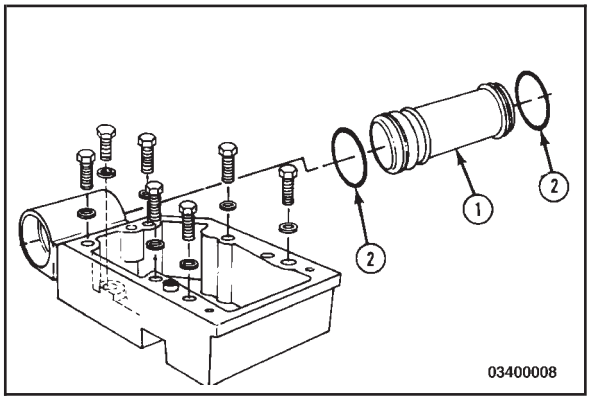


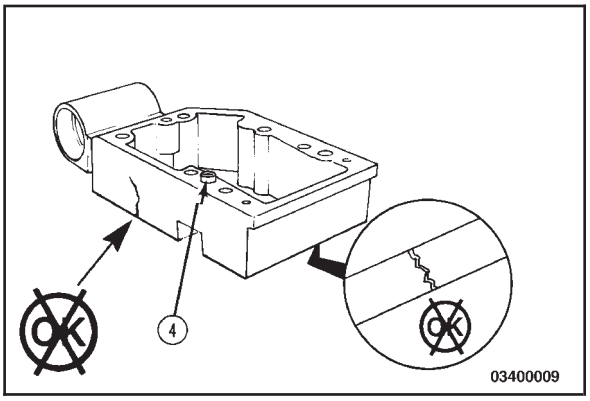
⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the parts.

Dry with compressed air.

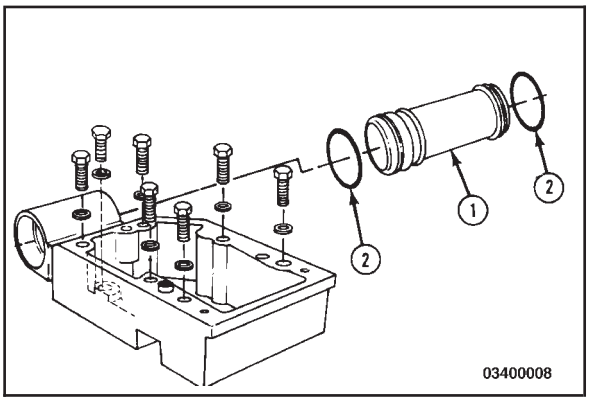




Inspect for Reuse

Inspect the parts for damage. If the ring dowel (4) is damaged, it **must** be replaced. Use a blind hole puller contained in light duty puller kit, Part No. 3375784, or equivalent, to remove the dowel ring.

Use the dye penetrant method to inspect the housing for cracks. If the housing is cracked, it **must** be replaced.



Assemble

Use vegetable oil to lubricate the o-rings (2).

Install the o-rings.

Install the water transfer tube (1).

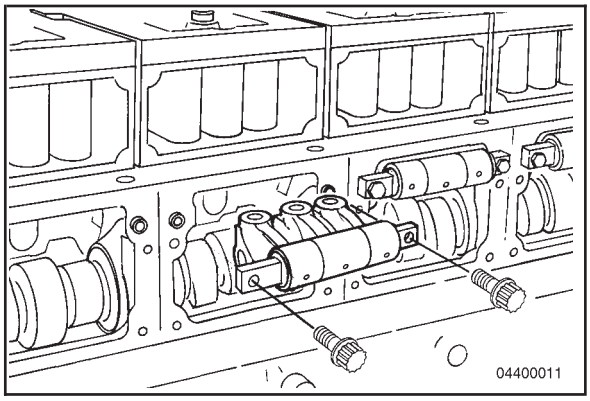
Section 4 - Cam Followers/Tappets - Group 04

Section Contents

Cam Followers/Tappets - General Information

⚠ CAUTION ⚠

The cam follower mounting capscrews are special 12-point flange heads. Failure will result if standard capscrews are used.

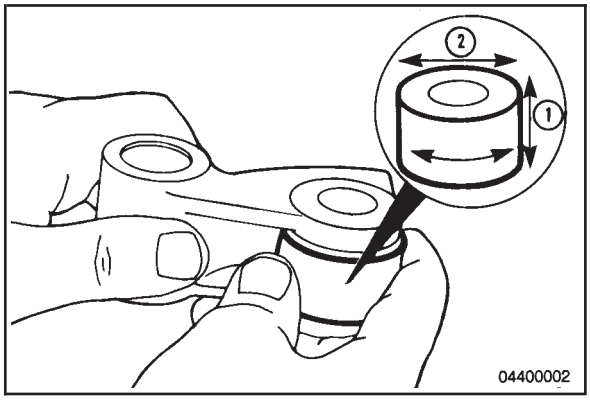


Pressurized engine oil is supplied to each cam follower assembly through an oil cavity around the mounting capscrews of each assembly.

The oil drilling in the shaft has a cup plug at both ends. This means that either end of the shaft can be installed toward the front of the engine. The ring dowel bores **must not** have any burrs to install the assembly by hand. The cup plugs in the end of the shaft keeps the flow of the pressurized oil in the shaft instead of **dumping** the oil into the camshaft cavity in the block. The cup plugs **must** be installed on the ends of the shaft, outside the capscrew hole.

The QSK19 utilizes a one-piece cam follower cover with a steel carrier paper gasket.

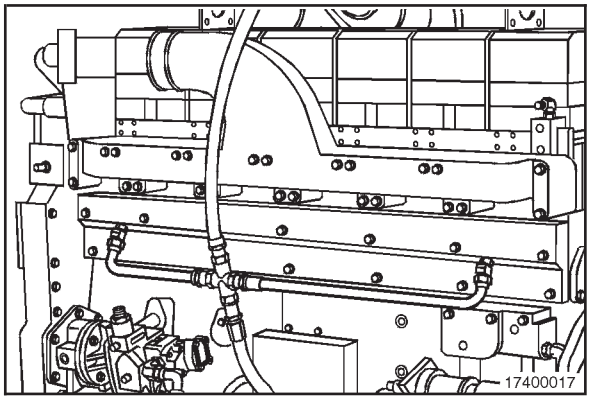
QSK19 cam followers are **not** rebuildable in the field, due to the fit between the pin and lever. Liquid nitrogen is required to shrink the pin sufficiently to slide through the bores in the lever.



New cam follower and roller assemblies are coated with a heavy preservative compound. They **must** be cleaned and lubricated with engine oil before each assembly is installed on the engine.

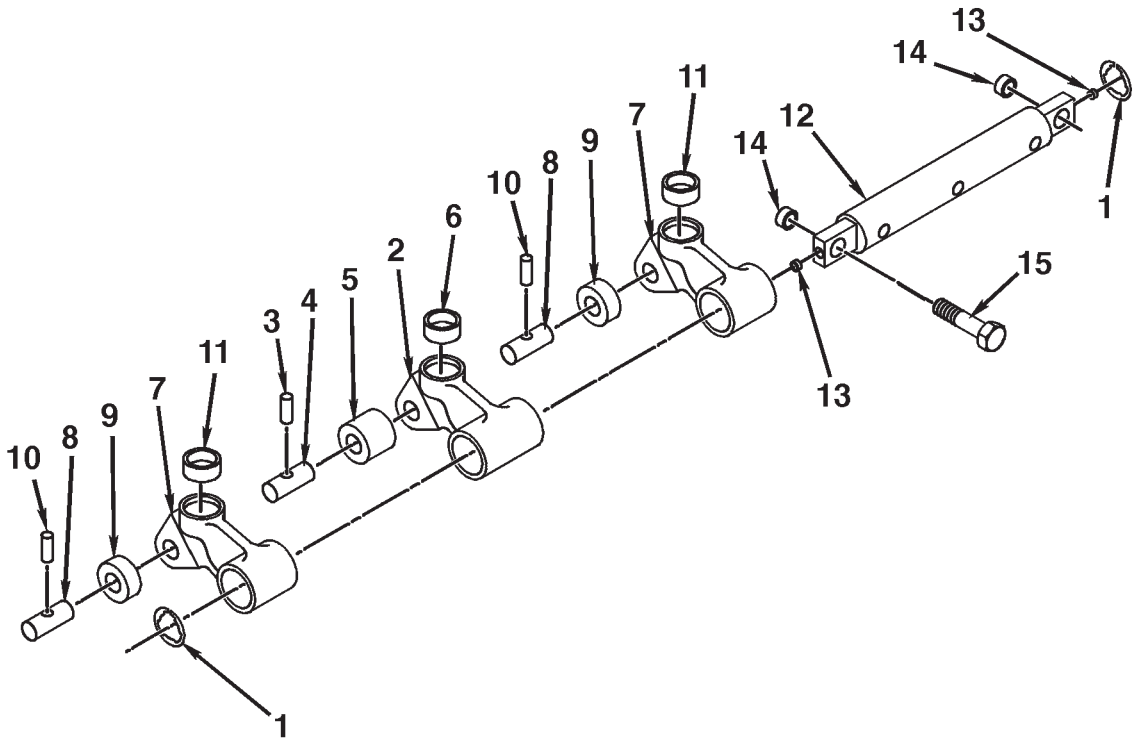
Rail Applications

The QSK19 Rail cam follower cover has been modified to allow two lubricating oil scavenging tubes to be attached. The tubes allow lubricating oil to be scavenged from the cam follower cover to an oil manifold on the suction side of the gear driven scavenge pump.



Cam Follower Assembly (004-001)

Exploded View



04400020

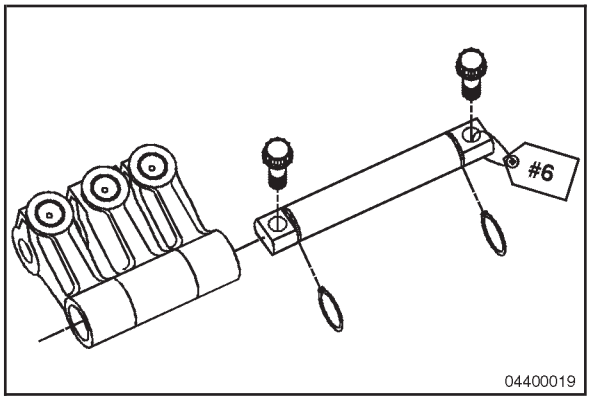
1. Ring, Retaining
2. Lever, Cam Follower
3. Lockwire, Tpt Roller Pin
4. Pin, Cam Follower Roller
5. Roller, Cam Follower
6. Socket, Cam Follower
7. Lever, Cam Follower
8. Pin, Cam Follower Roller
9. Roller, Cam Follower
10. Lockwire, Tpt Roller Pin
11. Socket, Cam Follower
12. Shaft, Cam Follower
13. Plug, Expansion
14. Dowel, Ring
15. Screw, Twelve Point Cap

Disassemble

Remove the 12 point capscrews.

Remove the retaining ring. Pull the shaft out.

Mark and tag the parts for future installation identification.



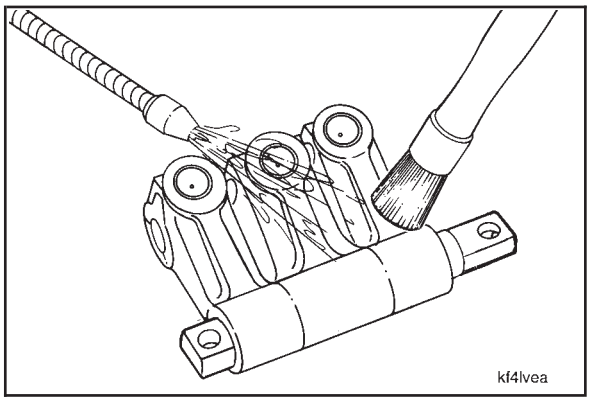
Clean

CAUTION

When using solvents, acids or alkaline materials for cleaning, follow the manufacture's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

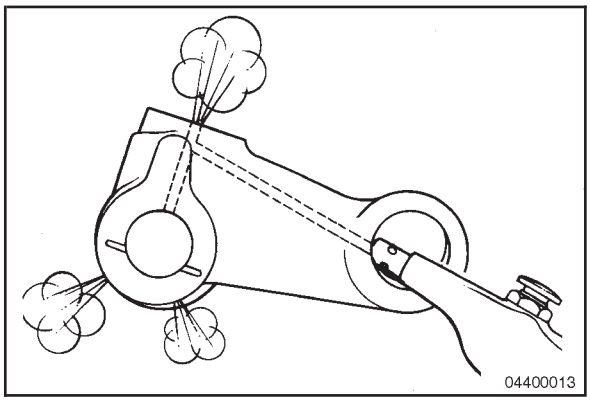
Use solvent, clean the cam follower assemblies.

Use compressed air to dry assemblies.



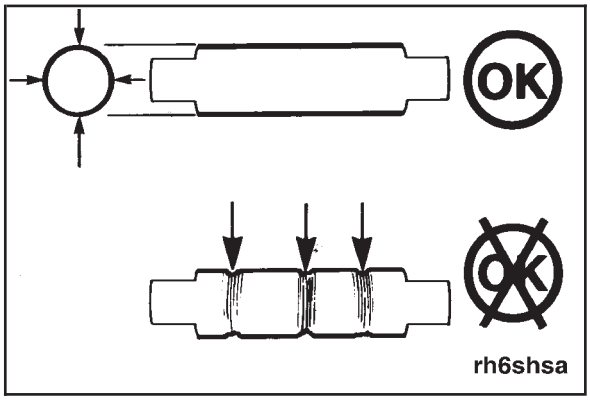
Use solvent, clean the cam followers.

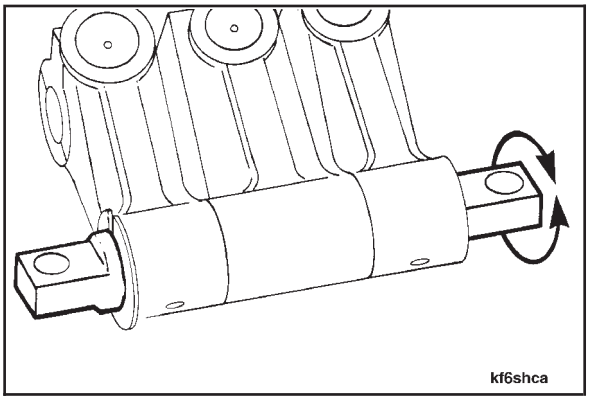
Use compressed air to dry the cam followers and check the oil drillings. Make **sure** the oil drillings are **not** plugged or blocked.



Use solvent, clean the cam follower shaft.

Use compressed air to dry the shaft and check the nine (9) oil drillings. Be **sure** all of the oil drillings are **not** plugged or blocked.

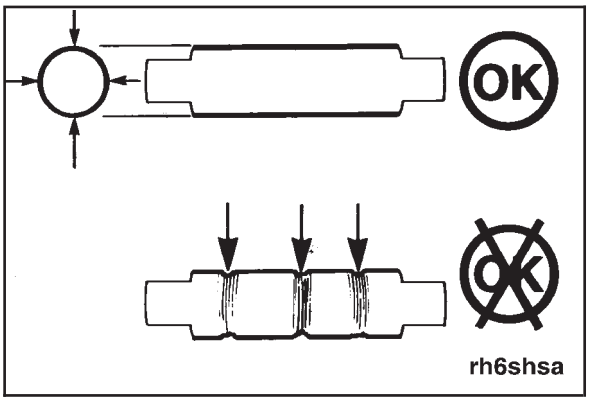




Inspect for Reuse

Inspect the cam follower assembly for reuse.

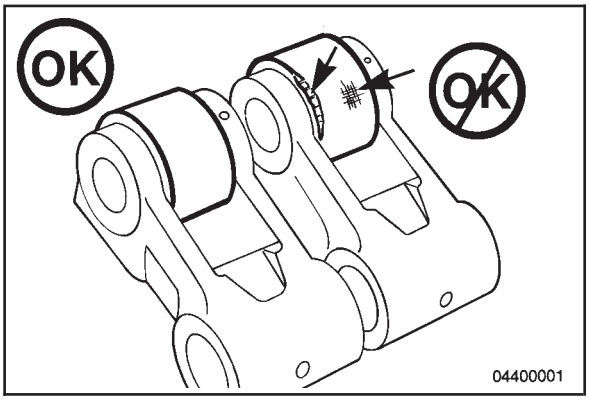
The shaft **must** rotate easily. If resistance is apparent, disassemble and check for burrs on the shaft.



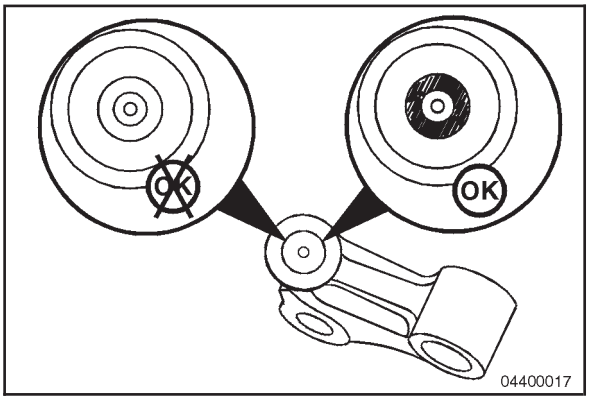
Inspect the cam follower shaft for damage and roughness.

Check the cam follower shaft outer diameter.

Cam Follower Shaft O.D.		
mm		in
28.538	MIN	1.1235
28.575	MAX	1.125



Inspect the cam follower for reuse. The cam follower lever assembly **must** be replaced if damaged.

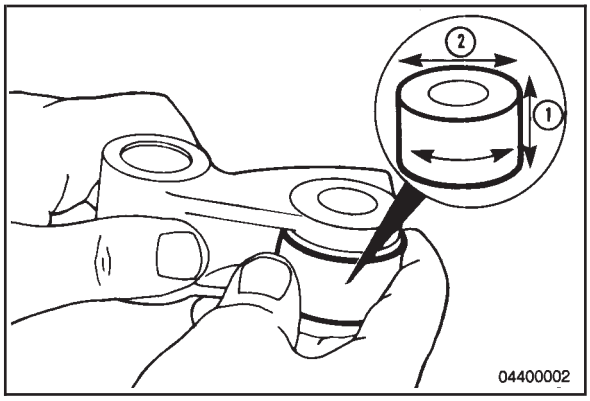


Inspect the push rod socket for damage. If the socket is damaged, the cam follower assembly **must** be replaced.

The roller **must** rotate easily. Check the clearance of the roller.

Cam Follower Roller Clearance			
Reference Point	**mm**		**in**
(1)	0.230	MIN	0.009
	0.610	MAX	0.024
(2)	0.076	MIN	0.003
	0.114	MAX	0.0045

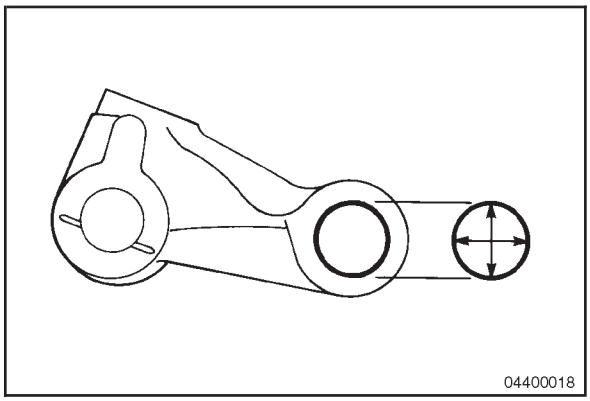
NOTE: If the clearances do **not** meet specifications, the cam follower lever assembly **must** be replaced.



Check the cam follower lever bore inner diameter.

Cam Follower Lever I.D.		
mm		**in**
28.611	MIN	1.1264
28.661	MAX	1.1284

NOTE: If the inner diameter does **not** meet specifications, the cam follower lever assembly **must** be replaced.

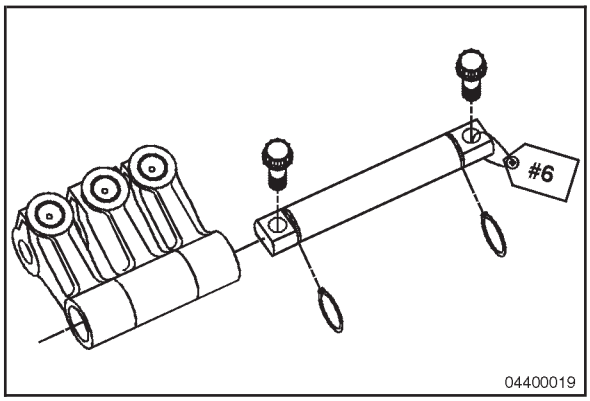


Assemble

Use clean engine oil to lubricate the shaft and bores of the levers.

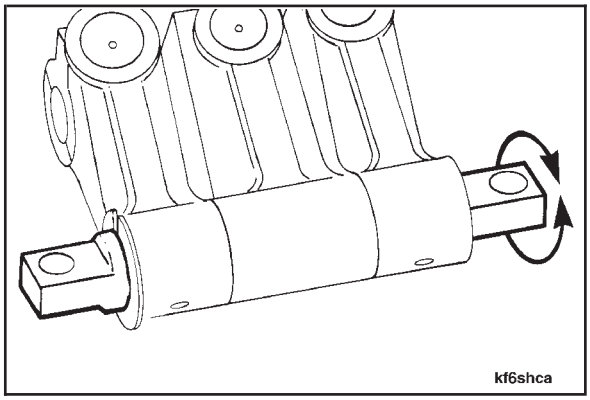
Slide the levers on the shaft.

Install the parts as illustrated.



The shaft **must** rotate easily after assembly.

If resistance is apparent, disassemble and check for burrs on the shaft.

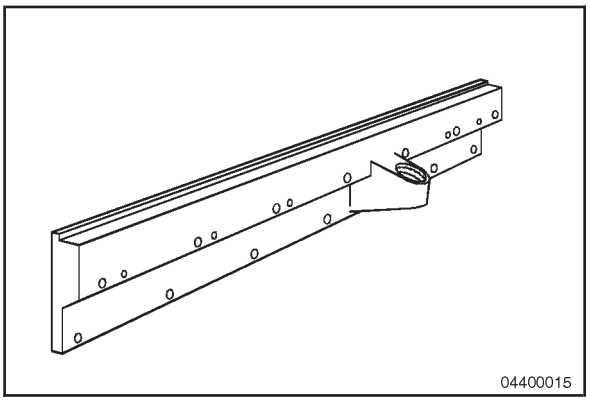


Cam Follower Cover (004-002)

General Information

The QSK19 has a one-piece, aluminum cam follower cover with an oil fill.

NOTE: This is the **only** style of cam follower cover available.



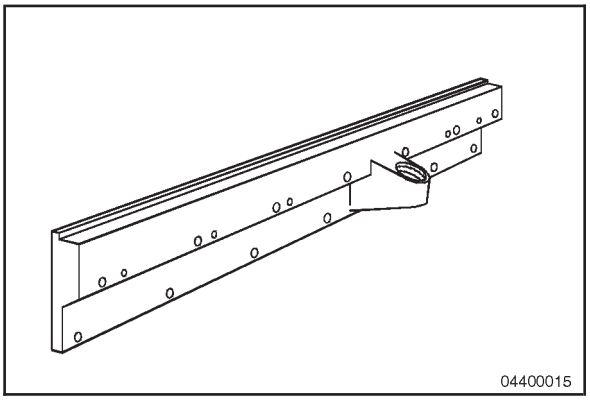
Clean

CAUTION

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent that will **not** harm aluminum to clean the cam follower cover.

Dry with compressed air.



Inspect for Reuse

Check the cover for cracks or damage to the gasket sealing surface.

Push Rods or Tubes (004-014)

General Information

The QSK19 uses push rods that are machined from solid bar stock instead of tubing. The ball end and the socket are machined on the rod.

It is a good service practice to mark the push rods for location when removing them from the engine. The **valve** and **injector** push rods are **not** interchangeable. The cam follower assembly **must** be replaced if the push rod is worn or damaged in the area where it contacts the socket.

NOTE: Replace **both** the rocker lever adjusting screw and the push rod if the socket surface in the rod or on the adjusting screw is damaged.

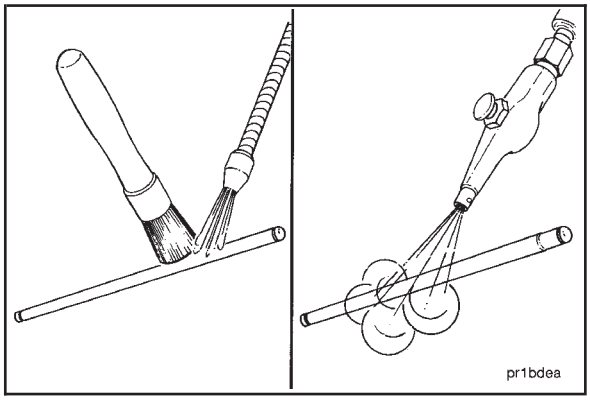
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the push rods.

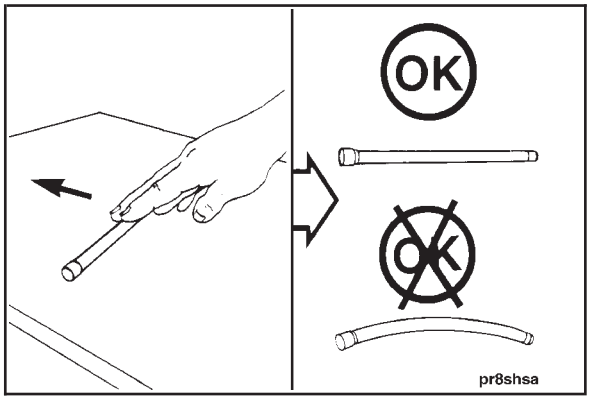
Dry with compressed air.



Inspect for Reuse

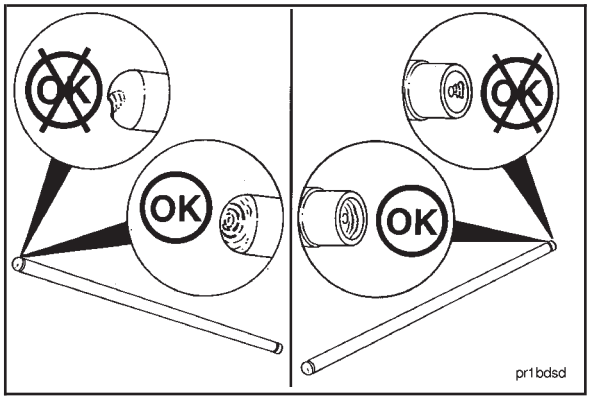
Inspect the straightens of the push rod by rolling it on a level surface. Replace the push rod if it is bent.

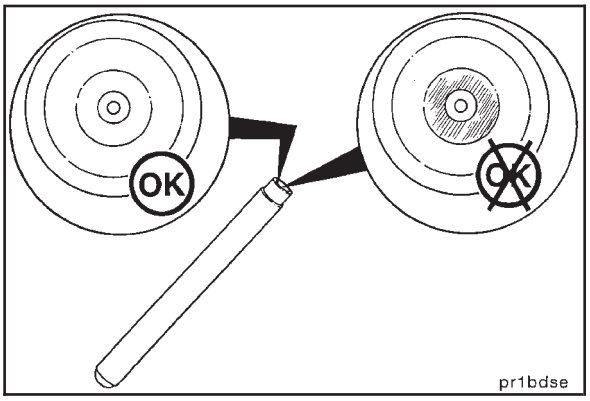
NOTE: Do **not** use or try to straighten a bent push rod.



Inspect **both** ends of the push rod for wear or damage.

NOTE: The cam follower assembly **must** be replaced if the push rod is worn or damaged in the area where it contacts the socket. Replace **both** the rocker lever adjusting screw and the push rod if the socket surface in the push rod or on the adjusting screw is worn or damaged.

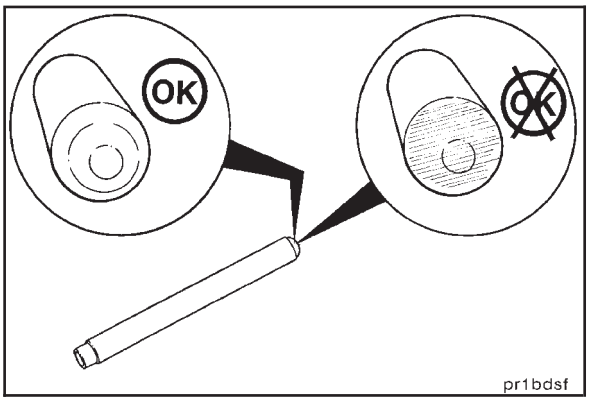




Visually inspect the socket end of the push rod for uneven wear or scratches.

If a worn socket is found, the mating adjusting screw in the rocker lever **must** also be replaced.

When parallel scratches are found in the contact area, the push rod **must** be replaced.



Visually inspect the ball end of the push rod.

The contact area **must** show a smooth seating pattern.

If the ball end of the push rod has parallel grooves and scratches with a raised center, the push rod **must** be replaced.

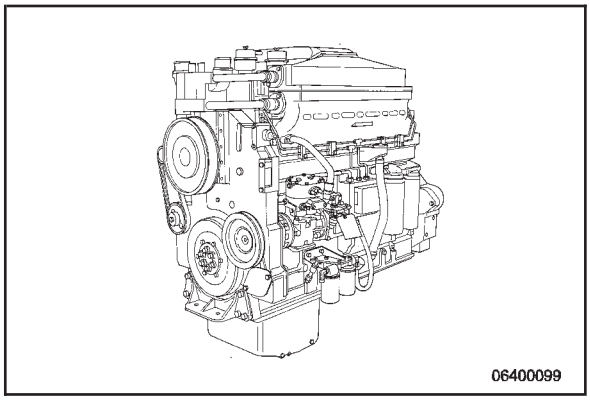
NOTE: If a worn push rod is found, the mating cam follower assembly **must** be replaced.

Section 5 - Fuel System - Group 05

Section Contents

Fuel System - General Information

General Information



⚠ WARNING ⚠

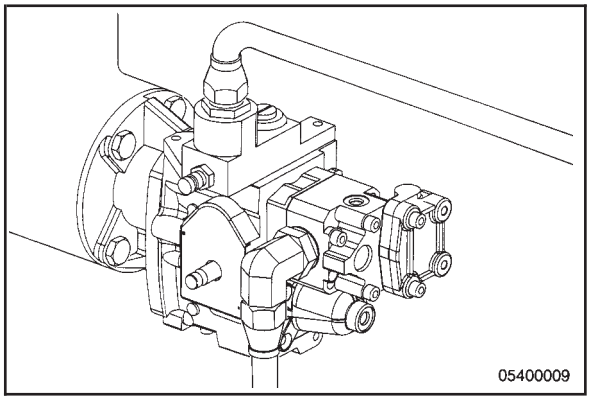
Fuel is flammable. Do not allow cigarettes, flames, sparks, arcing switches or equipment, pilot lights or other ignition sources near the fuel system.

The QSK fuel system is used on the QSK19 engine.

⚠ WARNING ⚠

Tampering with the fuel pump can be a violation of law.

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.

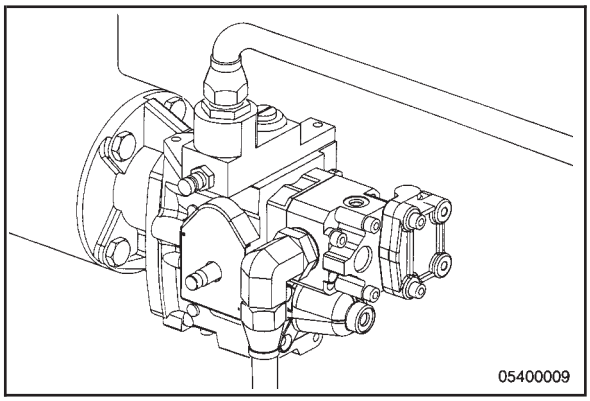


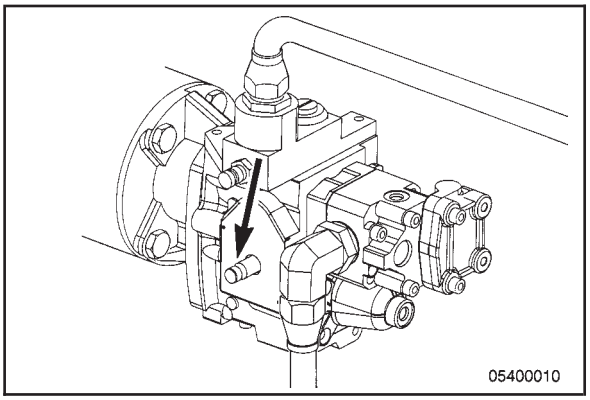
⚠ CAUTION ⚠

Tampering with the fuel pump can void the engine warranty and lower the performance of the engine.

The performance of the engine is defined by the control parts list (CPL) and the fuel pump code. The fuel pump calibration **must** be within published specifications. Fuel pump calibration is certified by several emissions agencies.

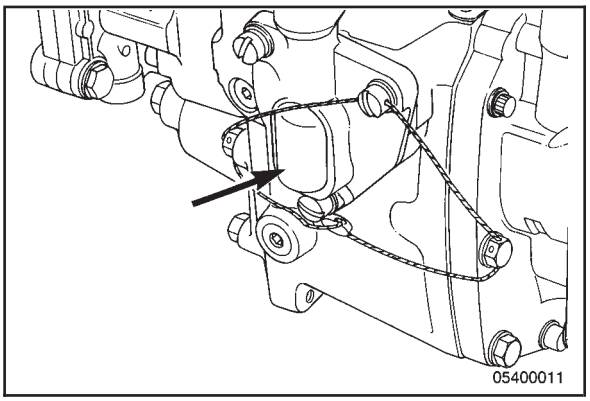
The QSK fuel system uses a PT type fuel pump to supply a linear gear pump pressure from 60 psi at 600 rpm to 280 psi at 2100 rpm to the electronic fuel control valve assembly.



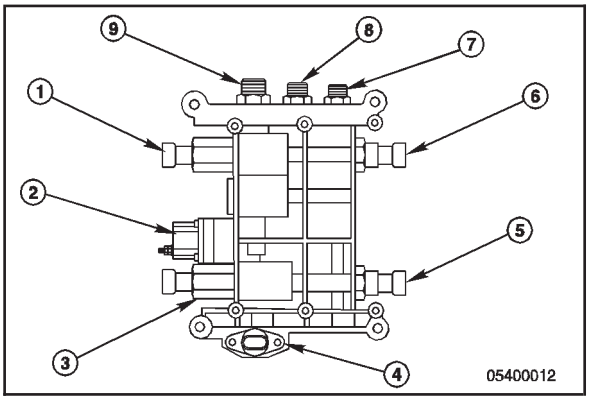


The QSK fuel pump throttle shaft is locked in the full closed position.

There is **no** mechanical throttle on the QSK fuel pump.



The QSK fuel pump does **not** contain an AFC valve. The pump only has an AFC cover plate.



The electronic fuel control valve assembly is located on the fuel pump side of the engine.

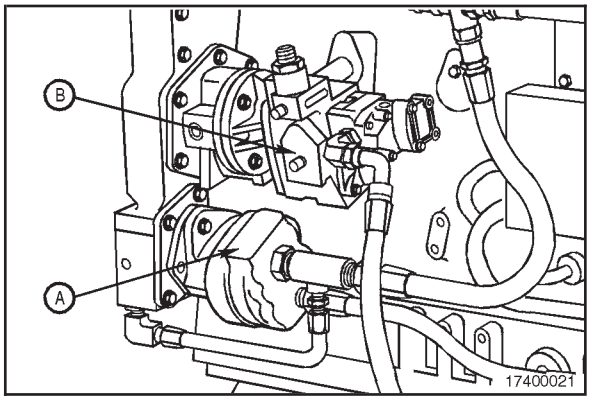
The electronic fuel control valve assembly includes:

1. Timing Actuator
2. Fuel Shut off Valve
3. Rail Actuator
4. Ambient Air Pressure Sensor
5. Rail Pressure Sensor
6. Timing Pressure Sensor
7. Fuel Rail Supply Line Connector
8. Fuel Timing Supply Line Connector
9. Fuel Control Supply Line Connector

Rail Applications

NOTE: The lubricating oil scavenge pump (A) **must** be removed prior to removing the fuel pump (B) to allow access to the fuel pump mounting capscrews.

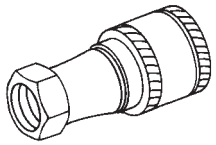
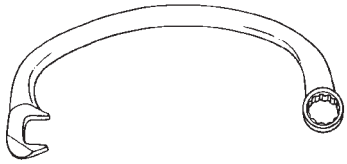
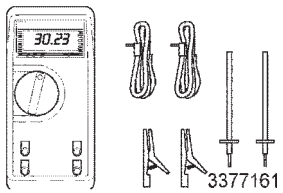
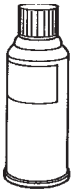
NOTE: The fuel pump (B) **must** be installed prior to installing the lubricating oil scavenge pump (A).

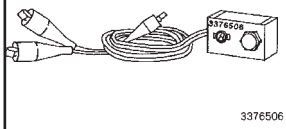
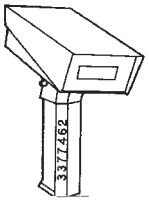
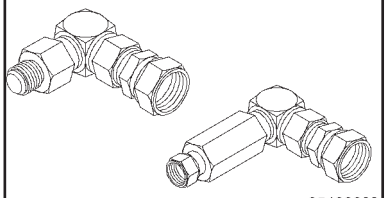


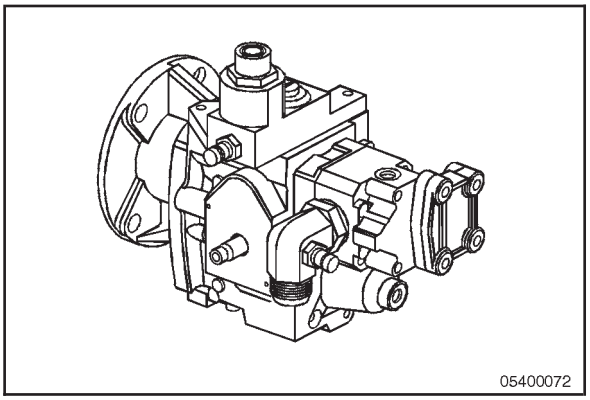
Service Tools

Fuel System

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

Tool No.	Tool Description	Tool Illustration
ST-435-7	**Fitting** Connects gauges when measuring various fuel pressures.	 st-435-7
3824877	**Gauge** Used to measure the fuel pump pressure from 0 to 2758 kPa [0 to 400 psi]. Includes necessary hoses and hardware to attach to a fuel pump.	 eg8togh
3376845	**Fuel Pump/Air Compressor Wrench** Used to reach nuts when removing or installing the fuel pump or air compressor.	 3376845
3377161	**Digital Multimeter** Check resistance of fuel shut-off solenoid.	 3377161
3822934	**Lubricant DS-ES** Dielectric lithium grease used to lubricate the pins in the electrical connectors.	 3377132
3824510	**QD Contact Cleaner** A nonpetroleum cleaner used to clean electrical connections.	 oi8togt

Tool No.	Tool Description	Tool Illustration
3376506	**Remote Starter Switch** Used to crank the engine to measure the cranking fuel pressure.	 3376506
3377462	**Optical Tachometer** Measure engine rpm.	 3377462
3824875	**Adapter S-Tool Kit** Used to hook QSK fuel pump to a fuel pump test stand.	 05400069
3375698	**Fuel Pump Test Stand** Used to check the calibration of the fuel pump.	3375698



Fuel Pump (005-016)

Clean

⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠ CAUTION ⚠

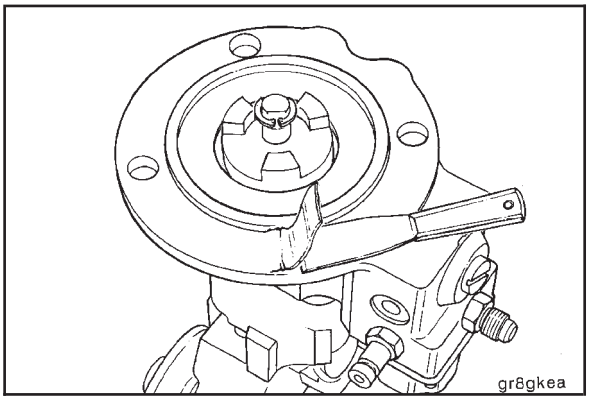
Put plastic cup plugs or tape on all of the openings. If dirt enters the fuel pump, it can cause equipment damage.

⚠ CAUTION ⚠

Use a cleaning solvent that will not harm aluminum.

Use a brush and solvent to clean the fuel pump exterior.

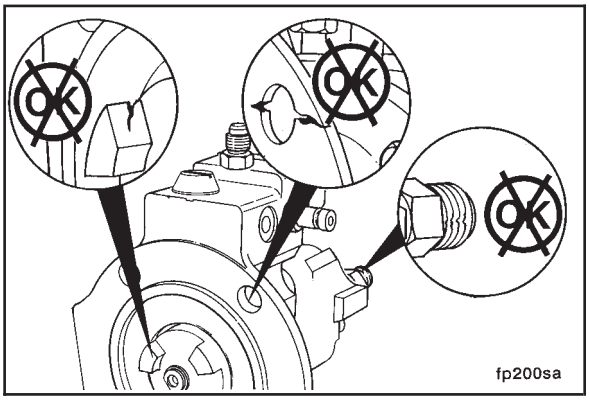
Dry with compressed air.



Inspect for Reuse

Clean the fuel pump and air compressor or accessory drive mounting surfaces.

Inspect the mounting surfaces for damage.

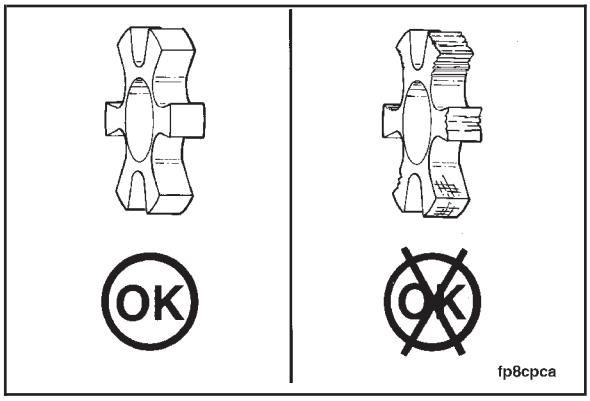


Visually inspect the fuel pump body and front support for cracks or other damage.

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.

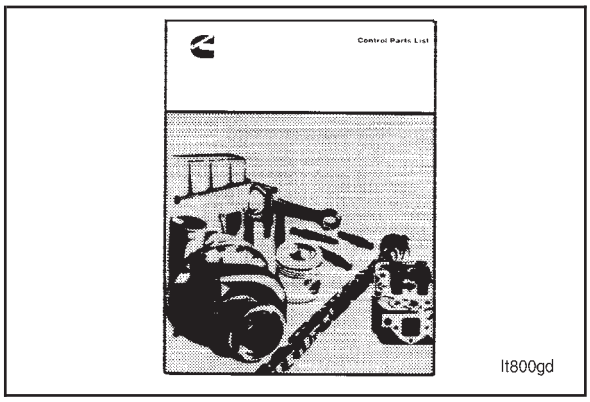
Visually inspect the spider coupling for cracks or damage.



Calibrate

The Control Parts List (CPL), Bulletin No. 3379133, is a listing of the basic parts and timing specifications.

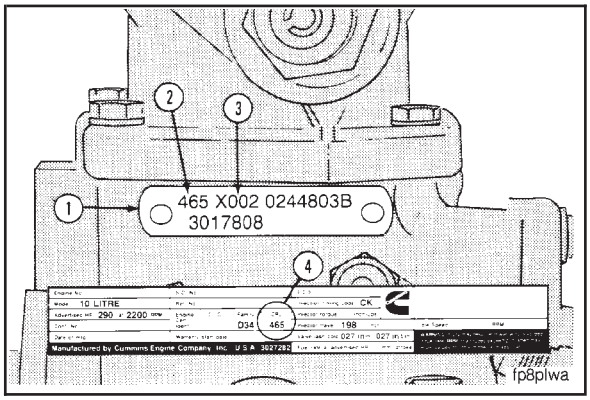
Using the CPL number stamped on the engine dataplate and this list, you can identify the necessary parts within an engine to produce a specific performance.



When removing the fuel pump from the engine, check the fuel pump dataplate (1), which is located on the top of the fuel pump. The CPL number on the **fuel pump dataplate** (2) **must** be the same as the CPL number on the **engine dataplate** (4).

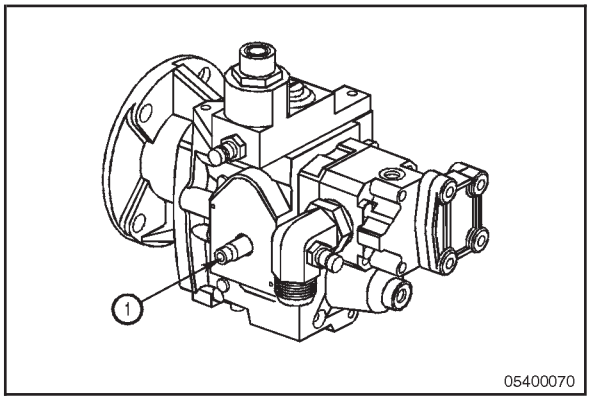
If the numbers do **not** match, do **not** install the fuel pump again until the fuel pump calibration code (3) has been changed to match the requirements of the engine dataplate rating. If the fuel pump calibration is changed, the fuel pump dataplate **must** be changed to indicate the new calibration code and CPL number.

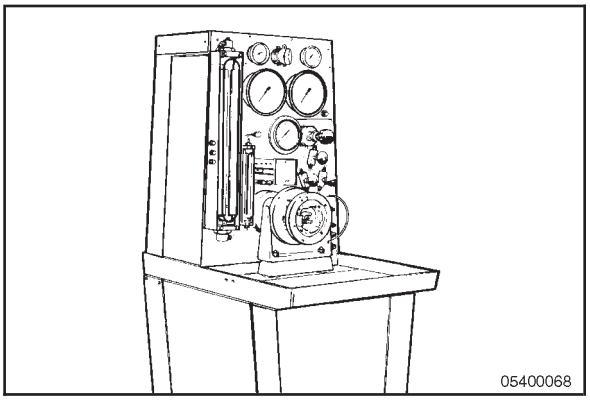
NOTE: Calibration of the fuel pump **must** be performed at a Cummins Authorized Repair location.



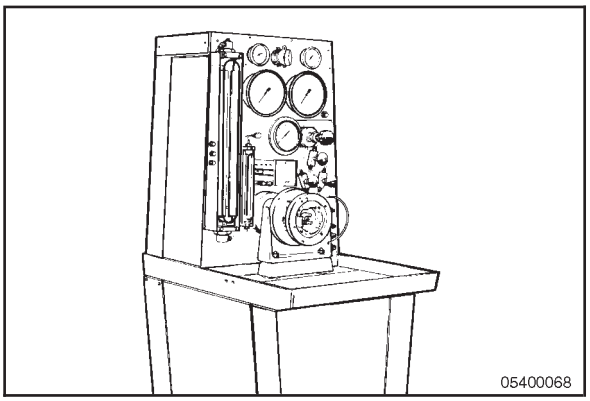
NOTE: The throttle shaft is purposely locked in the closed position. Rotation of the shaft is **not** necessary for pressure checks.

Drain the fuel pump of diesel fuel as completely as possible to avoid contaminating the test stand calibration fluid. Rotation of the drive coupling in a counterclockwise direction will aid in removing fluid held within the pump housing.





Mount the fuel pump on the test stand. Refer to your particular test stand manufacturer's operating and service manual for pump installation instructions.

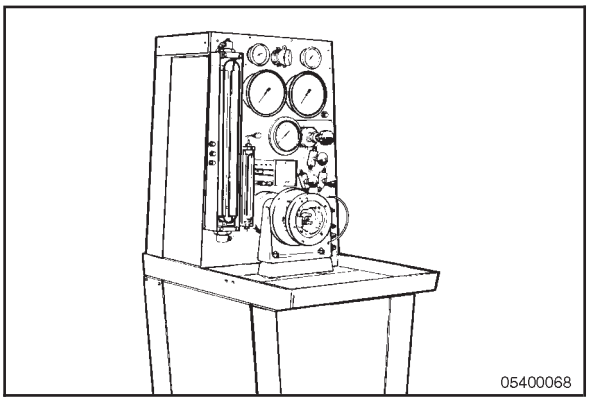


Set the test stand pump drive to 2100 rpm and purge any air from the fuel pump and test stand.

NOTE: The fuel pump test stand fluid must be 32° to 38° C [90° to 100° F] during the re-check procedure.

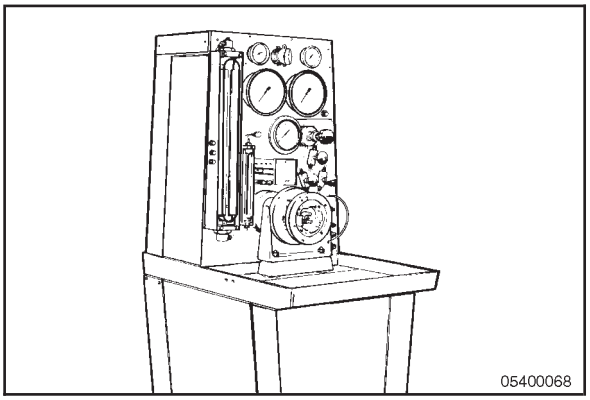
At 2100 rpm, set the flow volume to obtain 1157 pounds per hour (Pph). Adjust the inlet restriction (see note below).

NOTE: The 178 mm (7 in Hg) inlet restriction value **must** be used for all test stands where the vacuum gauge is above the gear pump inner fitting. Use 127 mm (5 in Hg) for vacuum gauges at the same level as the inlet fitting



Check point one

1. Adjust the test stand drive to obtain 2100 rpm.
2. Adjust the flow to obtain 1157 Pph.
3. Record the rpm, flow, and inlet restriction.
4. Read and record the pressure gauge value.
5. The gauge must read 250 to 300 psi.

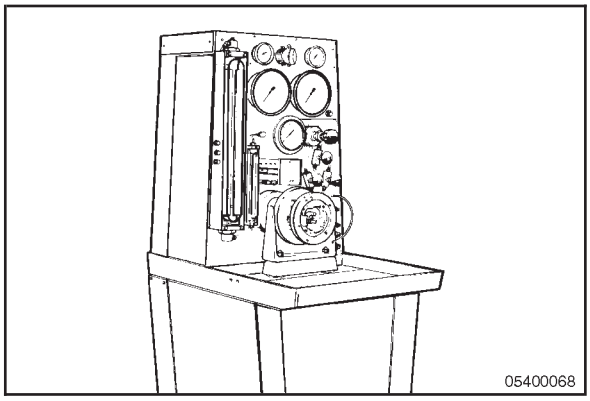


Check point two

1. Reduce the test stand drive speed to 1300 rpm.
2. Adjust the flow volume to obtain 712 Pph.
3. Record the rpm, flow, and inlet restriction.
4. Read and record the pressure gauge value.
5. The pressure valve **must** read 170 to 200 psi.

Check point three

1. Reduce the test stand drive speed to 600 rpm.
2. Adjust the flow to about 286 Pph.
3. Record the rpm, flow, and inlet restriction.
4. Read and record the pressure gauge valve.
5. The pressure value **must** be 55 to 70 psi.

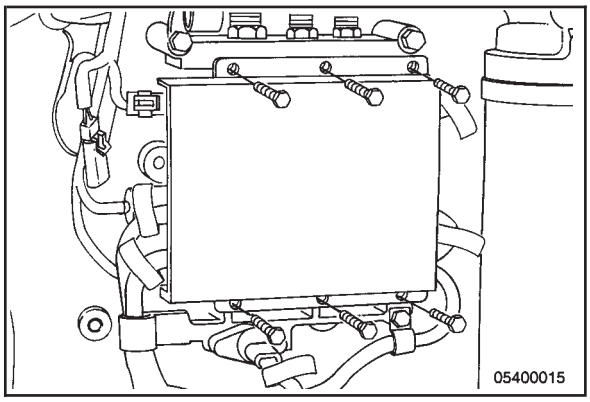


NOTE: The fuel pump can **not** be serviced in the field. If the pressure values are **not** within the given tolerances, a replacement pump **must** be obtained.

Fuel Shutoff Valve (FSOV) (005-043)

Remove

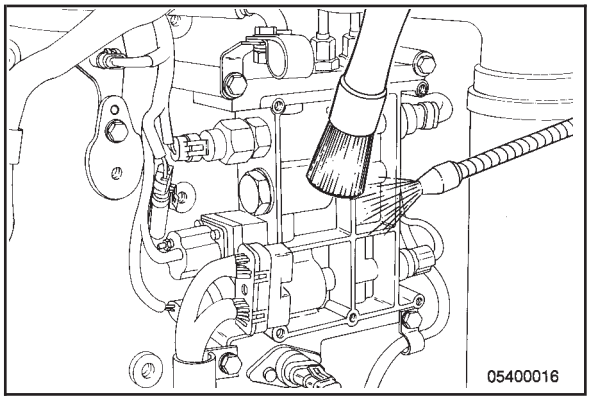
Remove the electronic control module (ECM). Refer to the Troubleshooting and Repair Manual, Bulletin No. 3666098.



⚠ WARNING ⚠

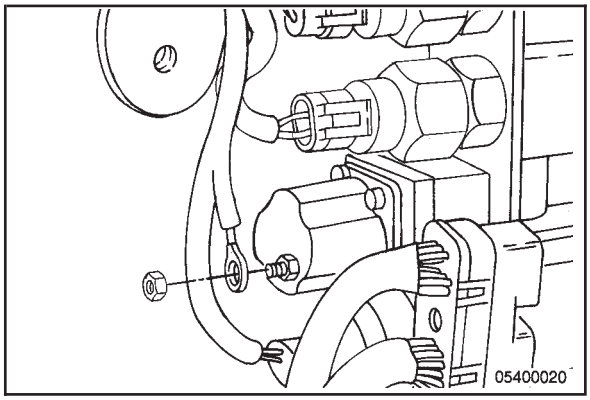
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

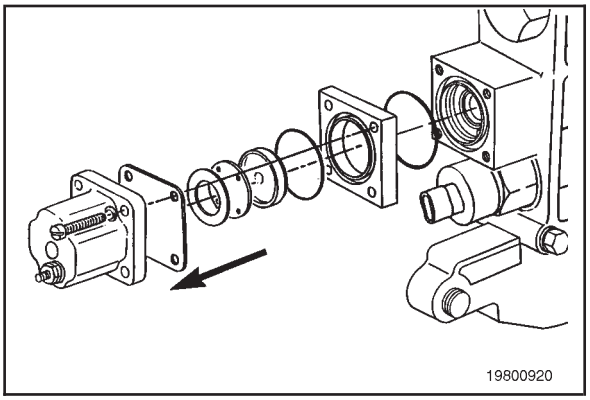
Use solvent to clean the fuel shutoff valve and surrounding area.



Use a 3/8 in wrench to remove the nut holding the electrical connection of the fuel shutoff valve coil.

Remove the connection.





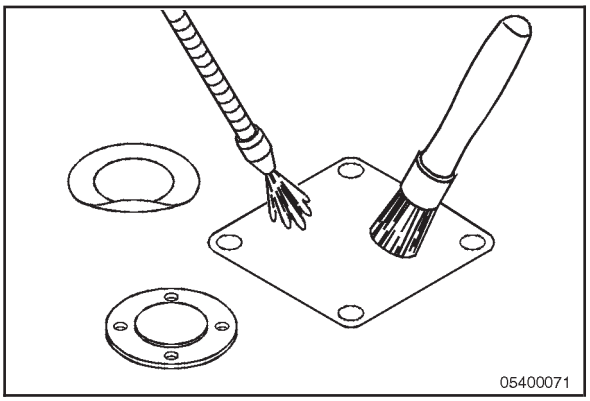
Remove the four capscrews.

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.

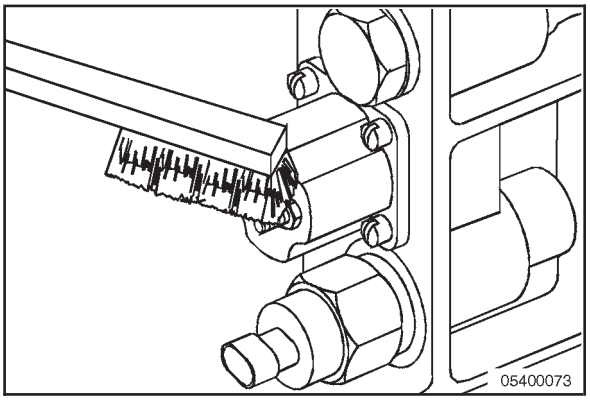
Discard the o-ring.



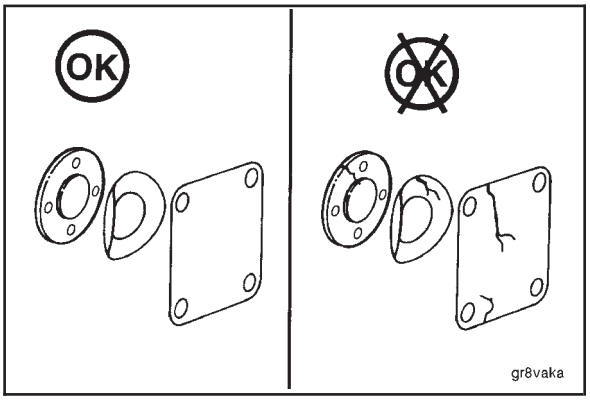
Clean

Use mineral spirits to clean all of the parts **except** the coil assembly.

NOTE: Do **not** get solvent on the coil. Clean the coil with a dry cloth. Use a 200 grit emery cloth and a flat surface to polish the coil surface.



Use a wire brush to clean any corrosion from the coil terminal.



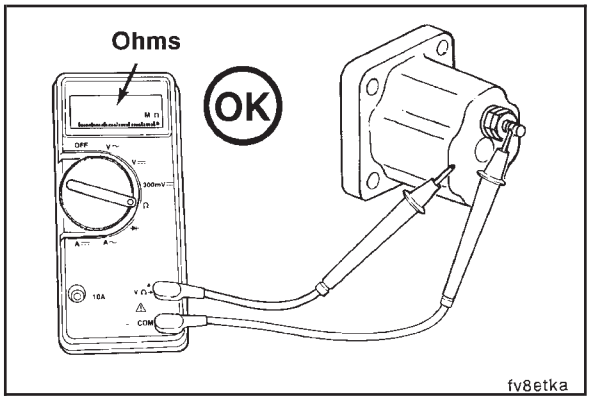
Inspect for Reuse

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 a multimeter.

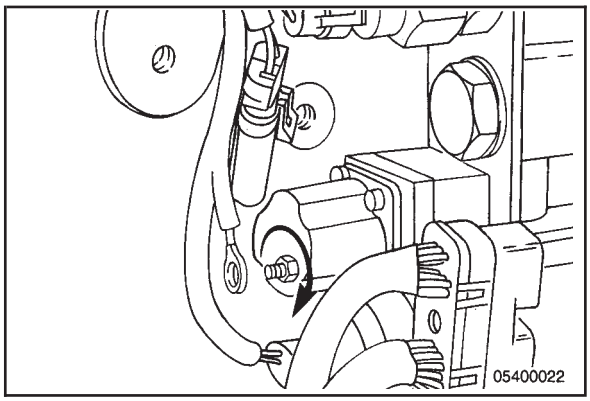
Replace the coil if it does **not** have 28 to 32 Ω of resistance.

NOTE: If the coil assembly shows 0 ohms, there is an electrical short in the coil.



Tighten the nut that holds the electrical connection post on the fuel shutoff valve coil.

Torque Value: 3 N•m [25 in-lb]



Install

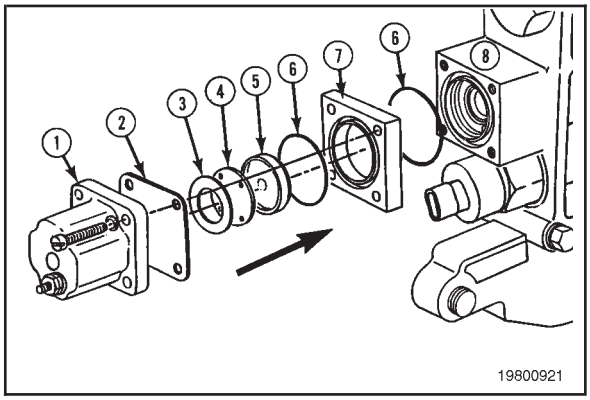
Assemble the shutoff valve as shown. Install these parts as follows.

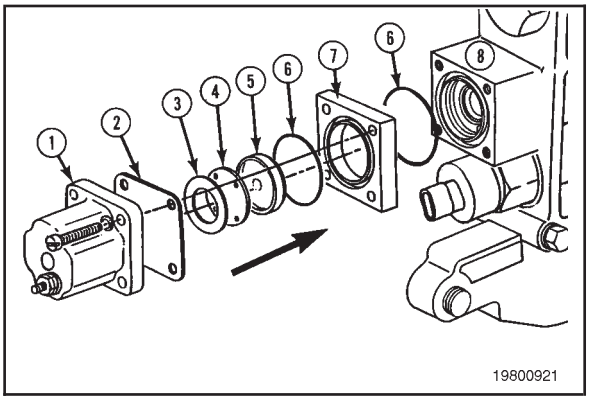
Install a new o-ring (6) between the spacer (7) and the electronic control valve body (8).

Install the spacer (7) o-ring groove toward the coil.

Install the actuator disc (5) with the cup side toward the coil.

Install the spring washer (3) with the cup side toward the coil.





Align the actuator disc (5), spacer (7), and valve disc (4) on the electronic control valve body (8).

Install a new o-ring (6).

Put the spring washer (3) on the valve disc (4), with the cavity side positioned upward.

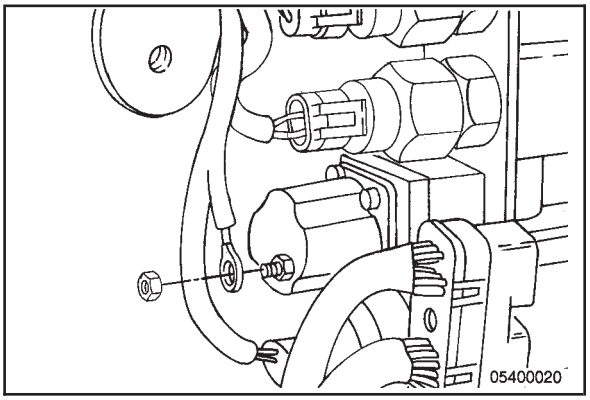
NOTE: The coil **must** be orientated with the electrical connection post on the bottom.

NOTE: Make sure the shutoff valve coil is the correct voltage (24 volts). The coil voltage and part number are cast into the terminal connection end of the coil.

Install the fuel shield (2) and coil (1) on the front cover (8).

Install a new o-ring and tighten the capscrews.

Torque Value: 8 N•m [72 in-lb]

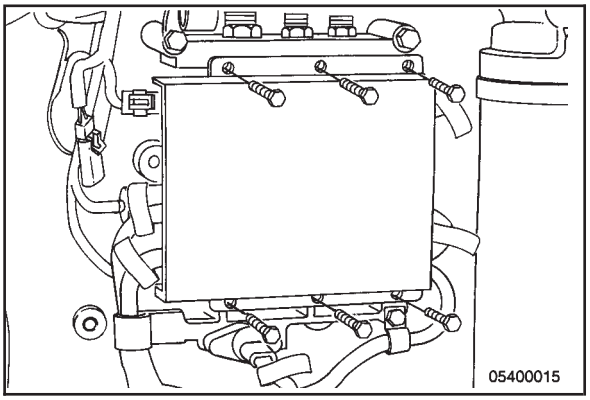


Install the electrical connection on the fuel shutoff valve.

Install the nut on the threaded post of the coil.

Use two 3/8 in wrenches hold the post of the nut firmly while tightening the connection nut.

Torque Value: 2 N•m [15 in-lb]



Install the ECM. Refer to the Troubleshooting and Repair Manual, Bulletin No. 3666098.

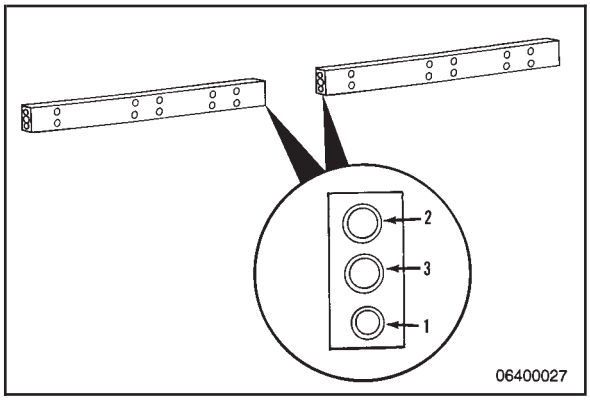
Section 6 - Injectors and Fuel Lines - Group 06

Section Contents

Injectors and Fuel Lines - General Information

General Information

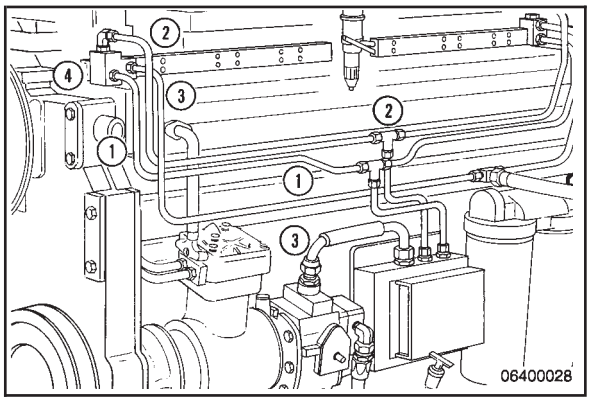
The QSK19 uses a QSK fuel system that requires a split fuel manifold and three fuel circuits. The three circuits are rail (1), timing (2), and drain (3).



⚠ WARNING ⚠

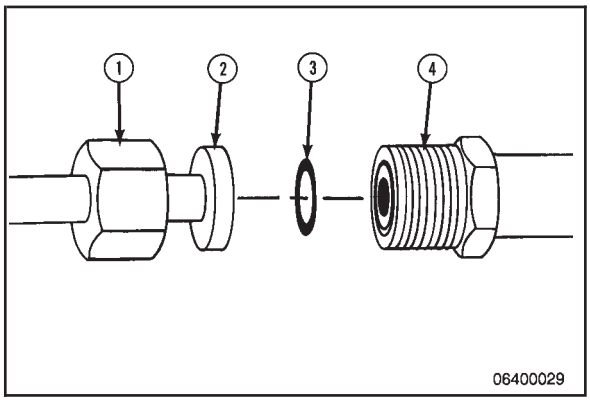
Fuel is flammable. Do not allow cigarettes, flames, sparks, arcing switches or equipment, pilot lights, or other ignition sources near the fuel system.

Fuel is delivered to the fuel blocks (4) at the **front** and **rear** of the engine from the electronic control valve assembly.



The QSK19 uses face seal o-ring fittings, except the fuel filter inlet and the fuel drain connection that are 37 degree flare fittings.

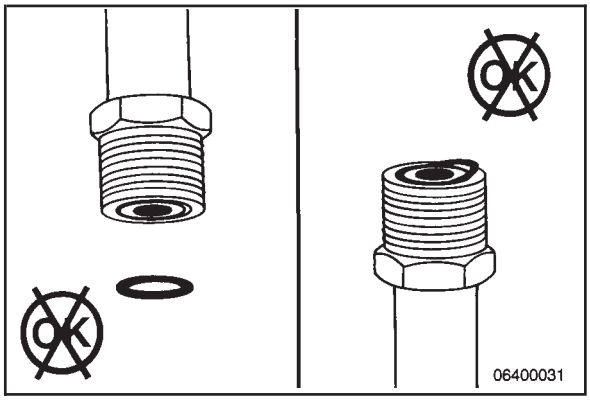
1. Tube nut
2. Tube flare (flat)
3. O-ring
4. Fitting

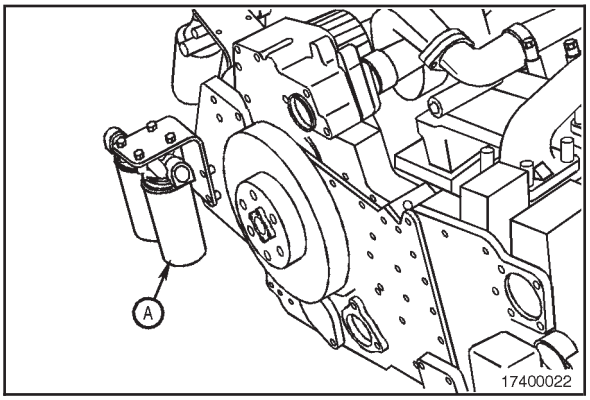


⚠ CAUTION ⚠

If Lubriplate® is not used, the o-ring can fall out or get pinched during assembly and cause a fuel leak.

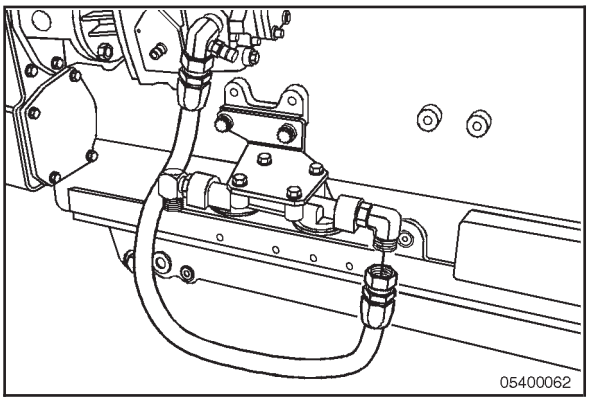
Hold the o-rings in position during assembly using Lubriplate® 105, or equivalent.





Rail Applications

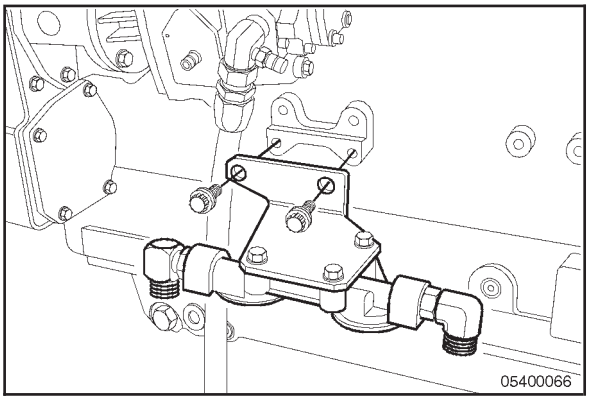
The ten-micron fuel filters/water separators (A) are remote mounted on the lubricating oil pan on the front side of the engine.



Fuel Filter Head (006-017)

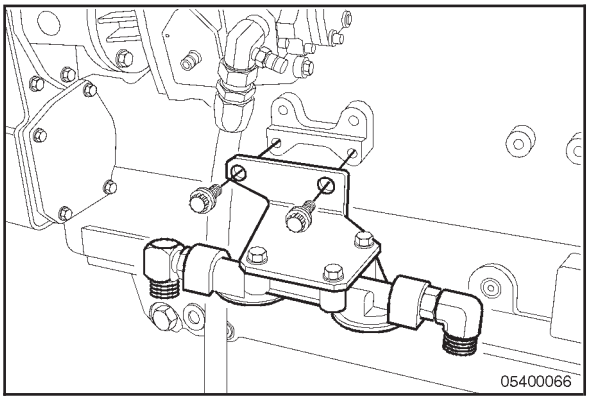
Remove

Disconnect the fuel line from the fuel filter head.



Remove the two mounting capscrews.

Remove the fuel filter head.



Install

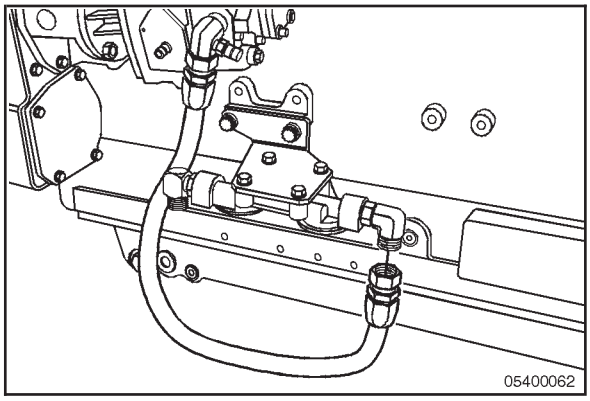
Install the fuel filter head.

Install the two mounting capscrews.

Tighten the capscrews.

Torque Value: 55 N•m [40 ft-lb]

Connect the fuel line to the fuel filter head.



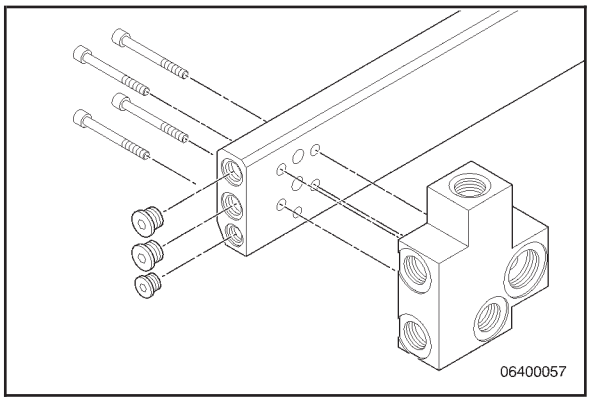
Fuel Manifold (Supply) (006-022)

Clean

Remove the four fuel connection block capscrews.

Remove the fuel connection block.

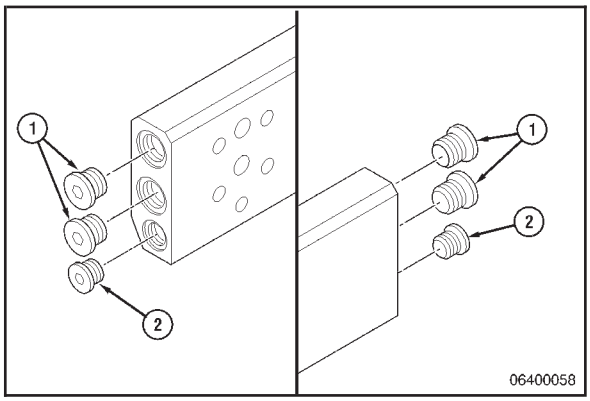
Discard the o-rings.



NOTE: The illustration shows the fuel manifold turned upside down. The small hole is on the bottom of the fuel manifold.

Remove the two 3/8 in plugs (2) and four 1/2 in plugs at the ends of the manifold.

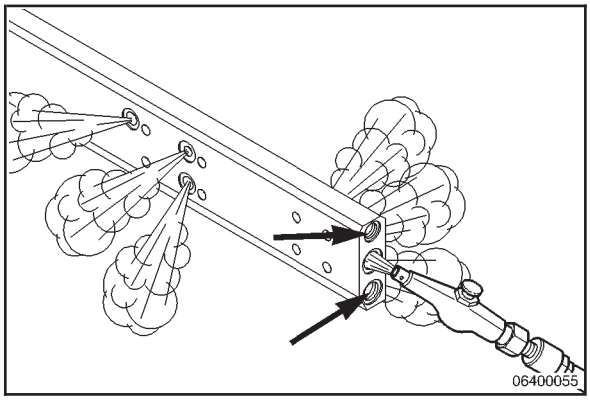
Discard the o-ring if damaged or enlarged.

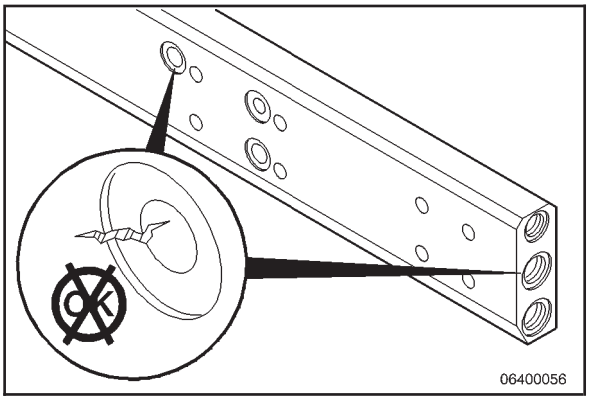


Use solvent to clean the manifold.

Use compressed air to clean all of the drillings.

Be sure all the drillings are clean and open.

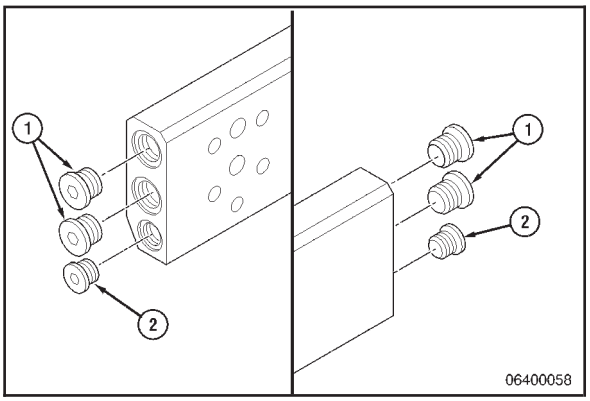




Inspect for Reuse

Check the manifold for cracks in the fuel passages.

The manifold **must** be replaced if damaged.



Use clean engine oil to lubricate the o-rings.

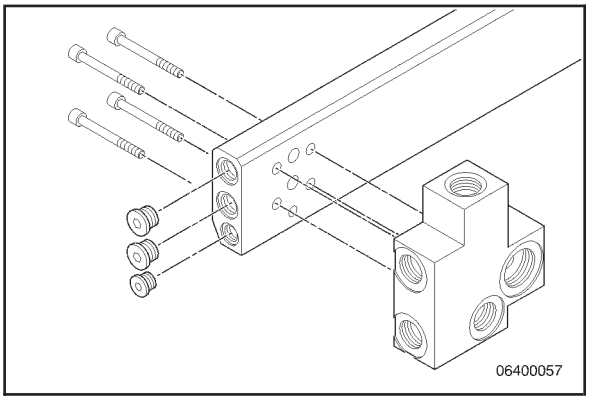
Install the 3/8 in (2) and 1/2 in plugs (1).

Torque Value:

Plug (1):	20 N•m	[180 in-lb]

Torque Value:

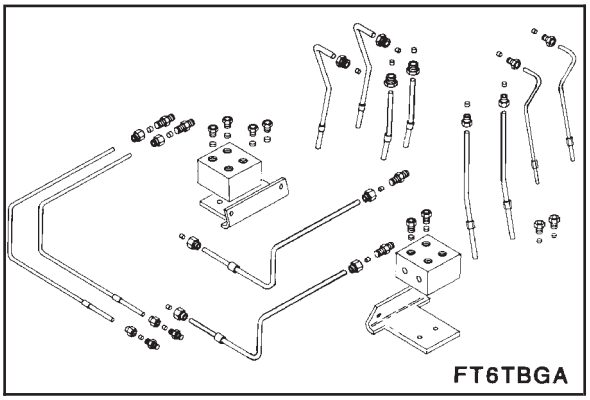
Plug (2):	7 N•m	[60 in-lb]



Use Lubriplate® to secure the o-rings in position.

Install the fuel connection block and the four new o-rings.

Torque Value: 10 N•m [90 in-lb]



Fuel Supply Lines (006-024)

Clean

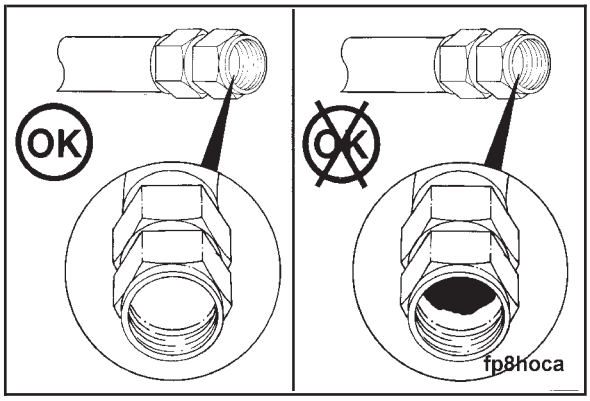
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Remove and discard the ferrule seals.

Use solvent to flush the tubing and fuel block connectors.

Inspect for Reuse



Fuel Tank-To-Fuel Filter

Visually inspect the inside of the hose.

- The inner lining of the hose can separate from the center hose section.
- A separation of flap can cause a restriction in the fuel flow.

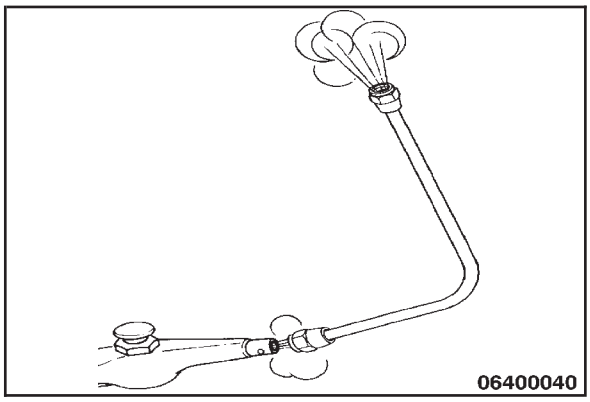
Visually inspect for any pinches in the hose that would obstruct the flow.

Be sure the hose does **not** have pinches or loops that would obstruct the flow.

Fuel Rail Supply Line

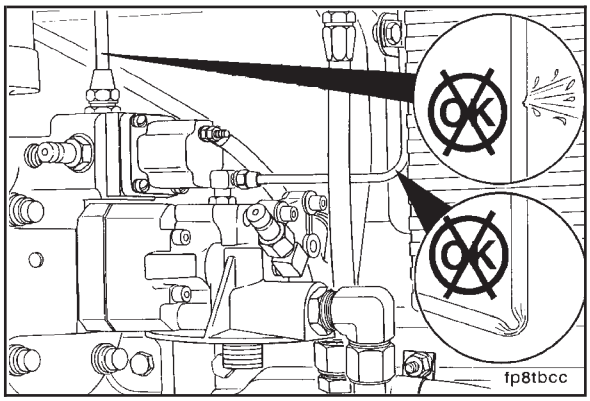
Fuel Timing and Supply Line

Use compressed air. Flush the lines and remove any loose dirt particles.



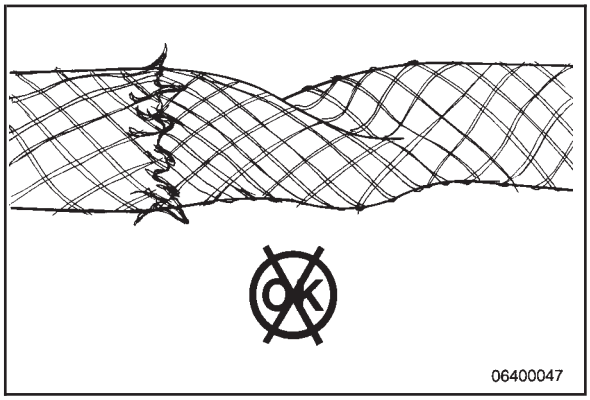
Visually inspect the fuel line for cracks that can cause a loss of pressure.

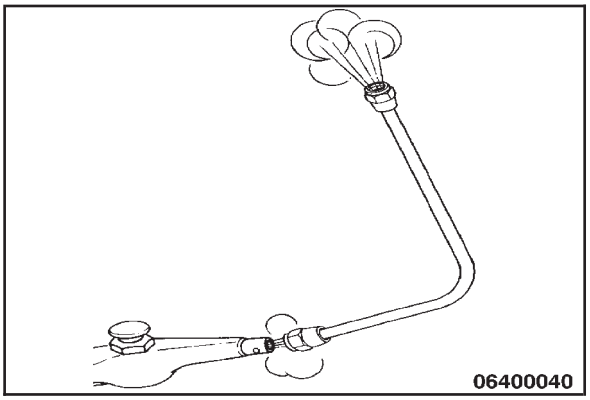
Visually inspect the fuel line for sharp bends that can cause a restriction in pressure.



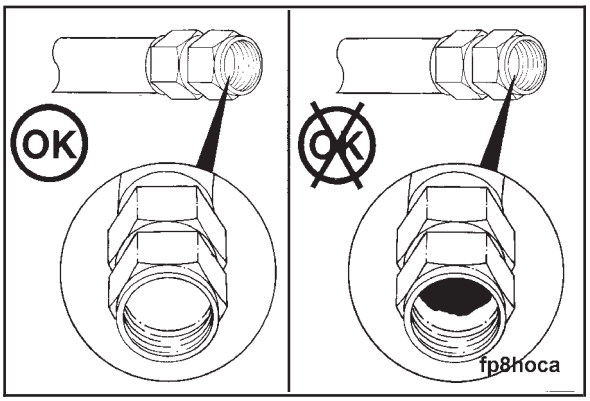
Fuel Control Supply Line

Visually inspect the hose for pinched areas that prevent the proper flow, or frayed mesh. The hose **must** be replaced if damaged.





Use compressed air. Flush the lines and remove any loose dirt particles.

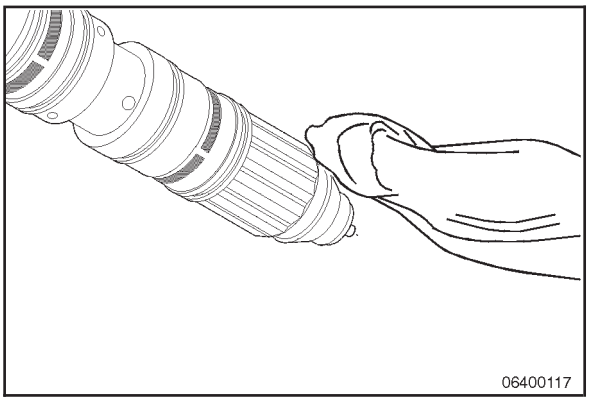


Fuel Inlet Line

Visually inspect the inside of the hose.

- The inner lining of the hose can separate from the center hose section.
- A separation of flap can cause a restriction in the fuel flow.

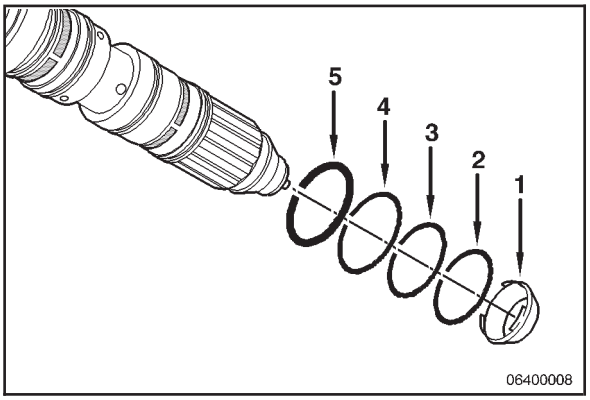
Visually inspect for bends in the line that can restrict the fuel flow.



Injector (006-026)

Clean

Use a lint free cloth to clean the exterior of the injector.



Inspect for Reuse

Remove the sealing ring (1) and note the cylinder location.

NOTE: Sealing rings are available in different thickness sizes to adjust the injector protrusion.

NOTE: The four new o-rings **must** be installed and oriented correctly on the injector. Identify the o-rings to install them in the correct grooves.

Remove the o-rings (2, 3, 4, and 5).

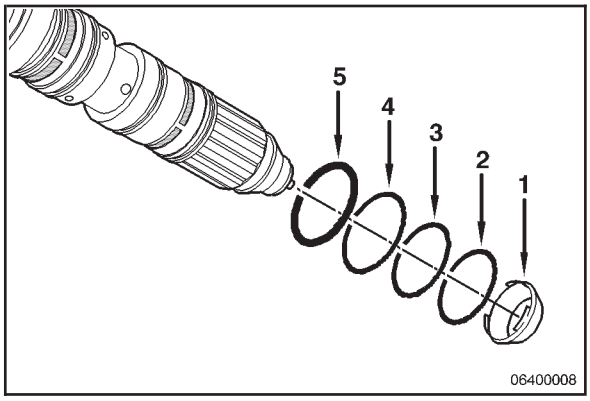
Carefully check the area where the sealing ring touches the injector.

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 the link is damaged or pitting/scoring can be seen or felt, the link **must** be replaced.

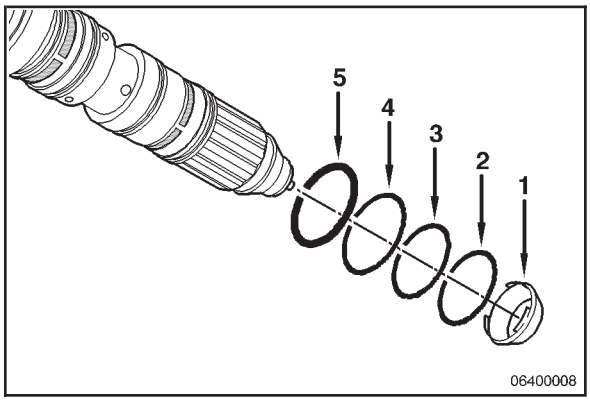


O-ring (2) is brown and is smaller in diameter than the other three.

O-ring (3) is black.

O-ring (4) is brown and is larger in diameter than (2), but has a smaller cross section than o-ring (5).

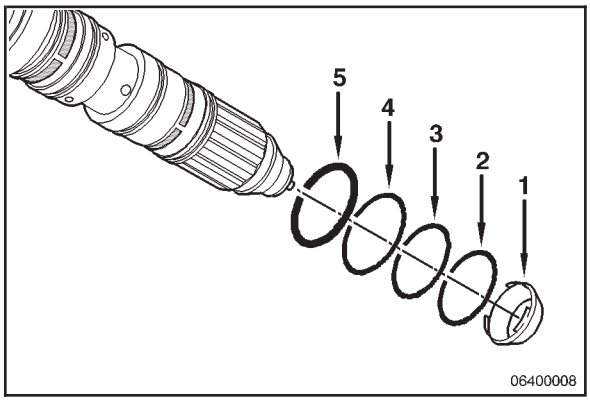
O-ring (5) is brown and is the largest in diameter and cross section.



NOTE: Do **not** lubricate the o-rings until the injector is ready for installation in the cylinder head.

Install four new o-rings on the injector. Do **not** twist the o-rings.

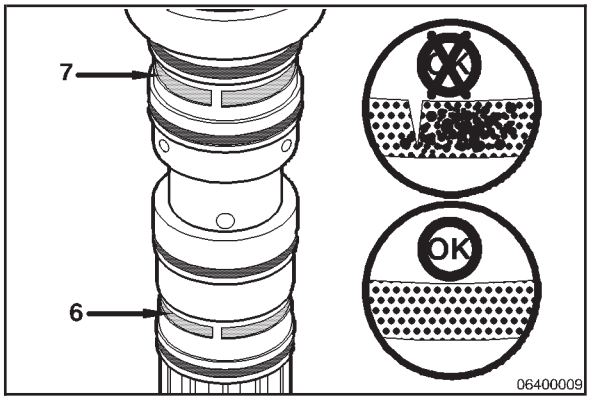
Install the proper size sealing ring (1).

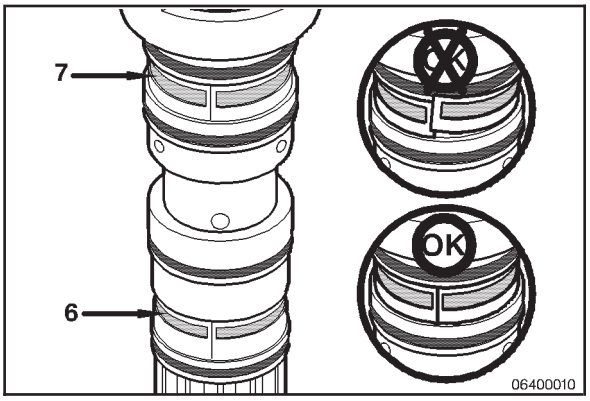


Filter Screen

NOTE: Use solvent when cleaning the filters. The screens **must** be thoroughly dry prior to installation.

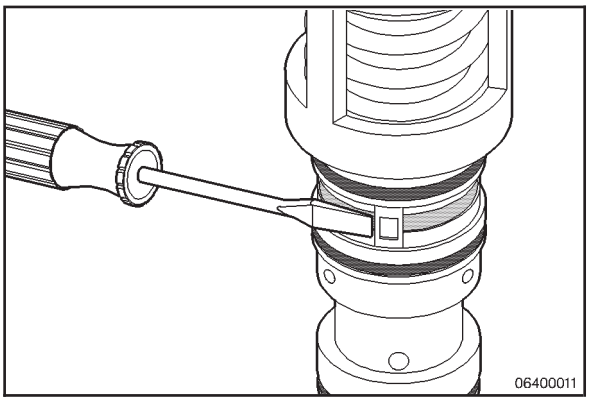
Check the rail (6) and timing (7) filter screens for debris, tears, or punctures. Replace the filter screens if damaged or dirty.



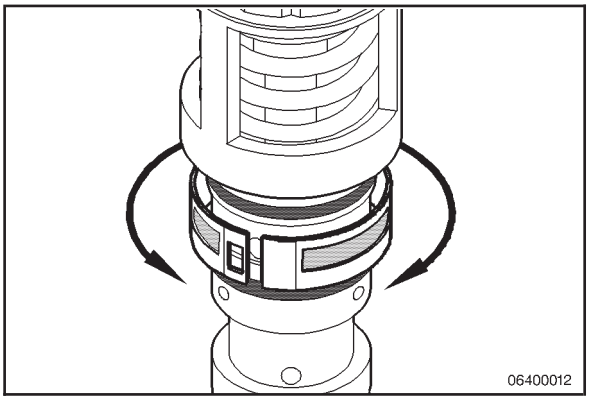


Check the rail (6) and timing (7) filter for proper installation.

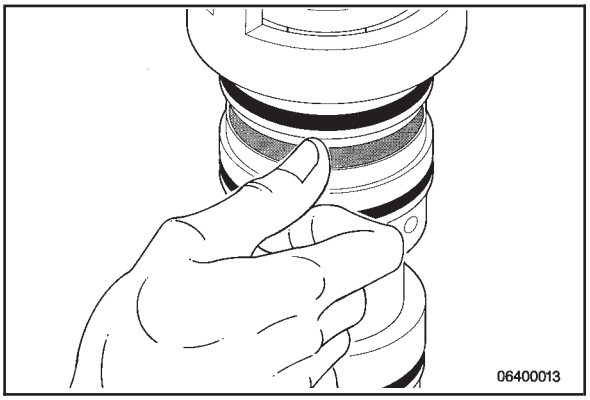
Screens **must** be securely snapped into correct position.



Use a small screwdriver to remove the filter screen by gently prying up on the connector clip.



Wrap the filter screen around the inlet groove.



Apply pressure on the filter screen connector clip.

NOTE: A properly secured connector will create a single, snapping sound.

Section 7 - Lubricating Oil System - Group 07

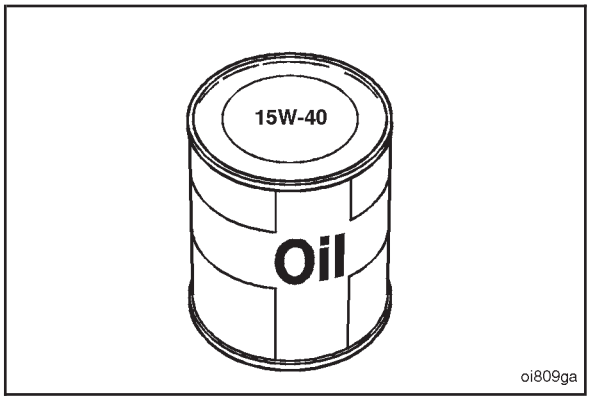
Section Contents

Lubricating Oil System - General Information

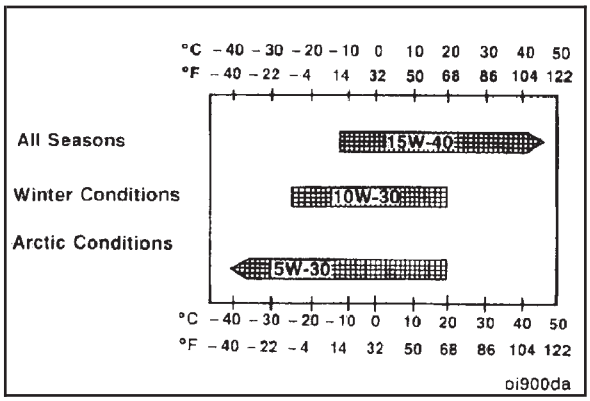
General Information

⚠ 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. Always use the proper procedure to dispose of the used oil.



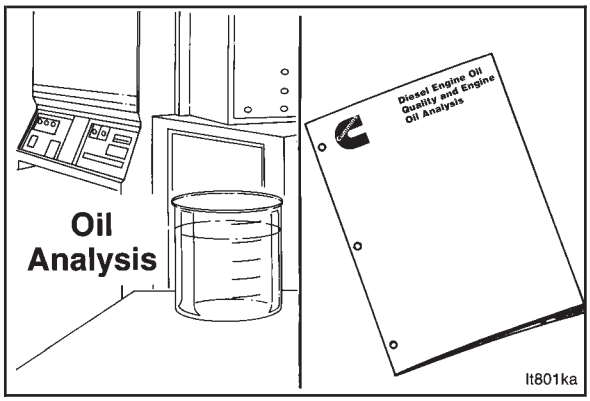
NOTE: The use of low viscosity oil, such as 10W or 10W-30, can be used to aid in starting the engine and in providing sufficient oil flow at ambient temperatures below -5°C [23°F], but continuous use of low viscosity oil can decrease engine life due to wear.



A used oil analysis can help diagnose internal damage and determine if it was caused by one of the following:

- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear

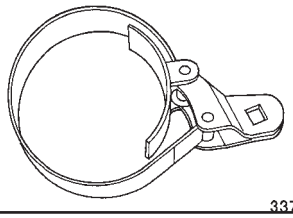
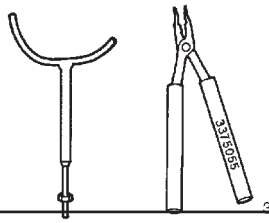
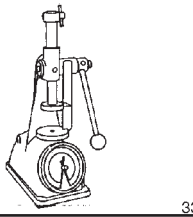
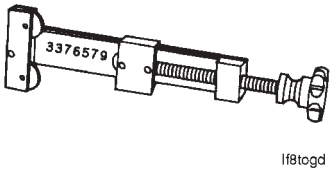
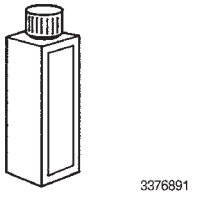
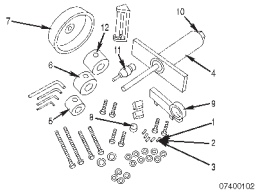
NOTE: Do **not** disassemble an engine for repair based only on the results of an oil analysis. Inspect the oil filter, also. If the filter shows evidence of internal damage, find the source of the problem and repair the damage. Refer to the appropriate section(s) based on the oil filter inspection.



Service Tools

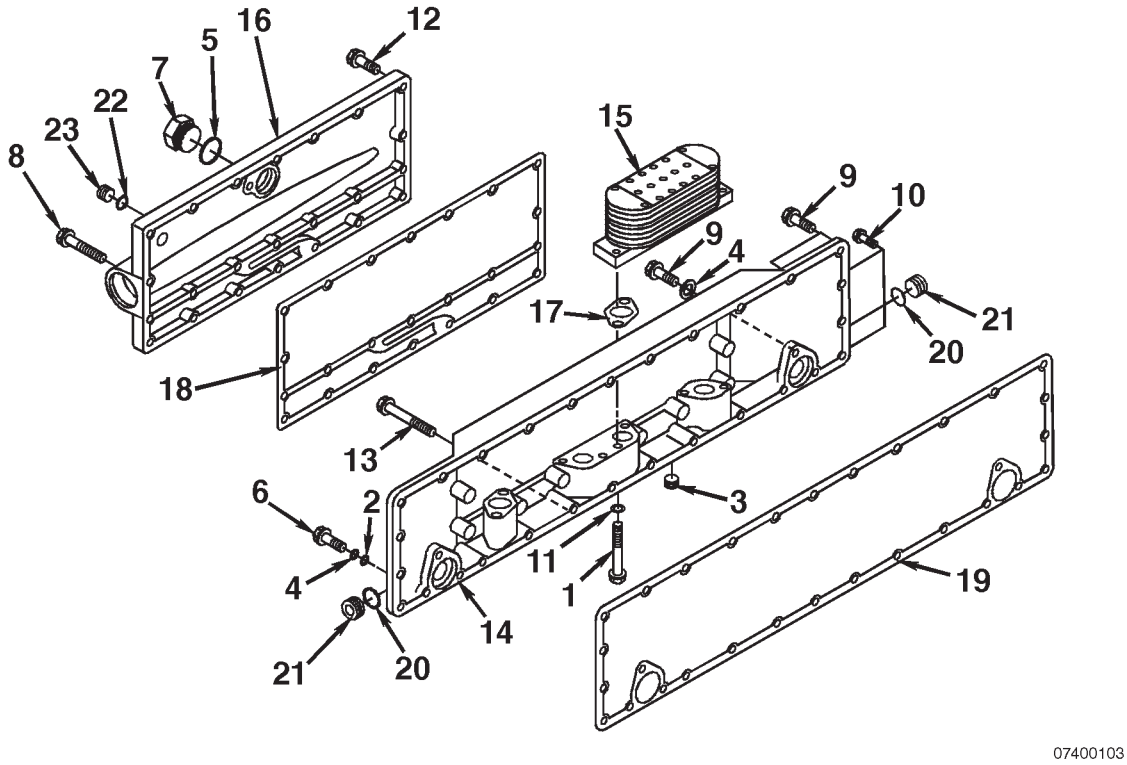
Lubricating Oil System

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

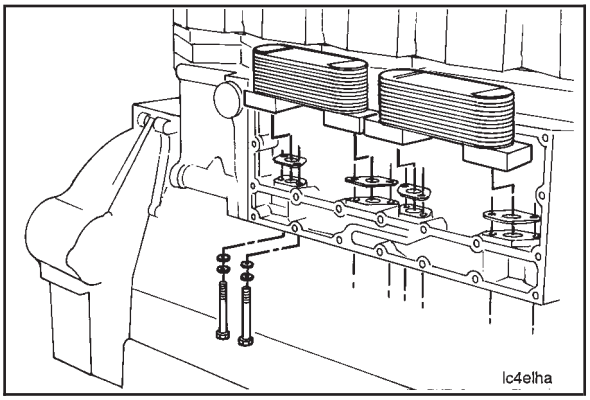
Tool No.	Tool Description	Tool Illustration
3375049	**Oil Filter Wrench** Remove spin-on oil filter.	
3375055	**Pressure Regulator Removal Tool** Remove retaining ring from lubricating oil pump regulator (on engine).	
3375182	**Valve Spring Tester** Measure spring force at a given spring height.	
3376579	**Filter Cutter** Open spin-on full-flow filter for inspection.	
3376891	**Fluorescent Tracer** Add to oil. Use with black light to find oil leaks.	
3375206	**Lube Pump Boring Tool** Used to bore replacement bushings in the lube oil pump.	

Lubricating Oil Cooler (007-003)

Exploded View

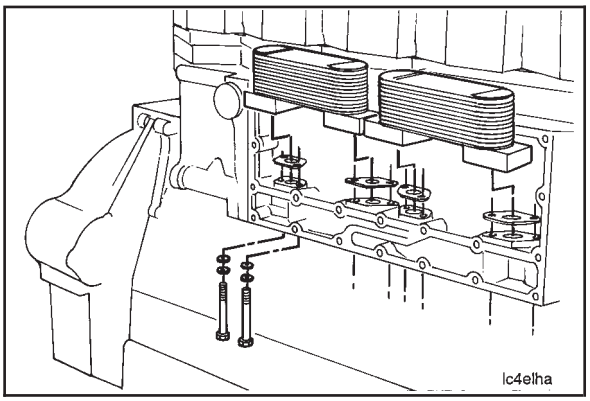


1. Screw, Hexagon Head Cap
2. Washer, Lock
3. Adirondack
4. Washer, Plain
5. Seal, O-ring
6. Screw, Twelve Point Cap
7. Plug, Threaded
8. Screw, Captive Washer Cap
9. Screw, Captive Washer Cap
10. Screw, Captive Washer Cap
11. Washer, Plain
12. Screw, Captive Washer Cap
13. Screw, Captive Washer Cap
14. Housing, Oil Cooler
15. Core, Cooler
16. Cover, Lube Oil Cooler
17. Gasket, Oil Cooler Core
18. Gasket, Tor Converter Oil Cooler
19. Gasket, Lube Oil Cir Hsg
20. Seal, O-ring
21. Plug, Threaded
22. Seal, O-ring
23. Plug, Threaded



General Information

All QSK19 engine oil cooler housings are cast iron.



Clean

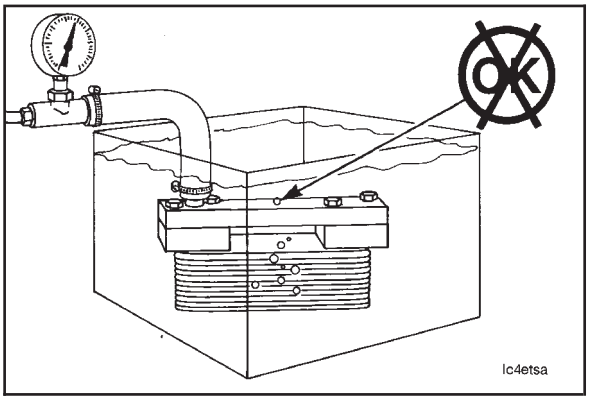
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use a solvent that will not harm copper to clean the oil cooler elements.

NOTE: Replace the elements if any debris is found or the engine has had a debris causing failure.

Use solvent and clean the oil cooler housing and cover.

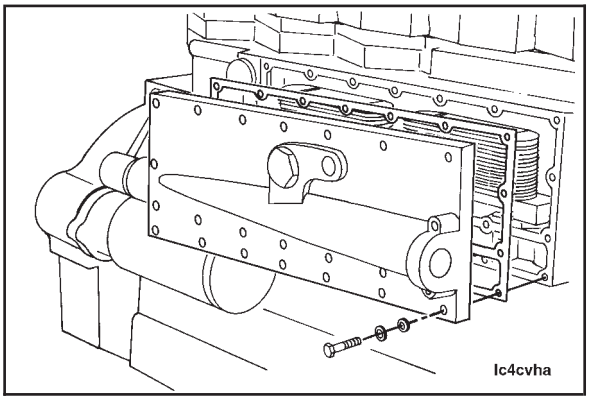


Inspect for Reuse

Pressure test the elements.

Check for leaks.

Torque Value: 415 kPa [60 psi]



Check the cover and housing for cracks. If leaks are suspected, use the dye penetrant method to locate them.

Check the cover and housing for corrosion.

Lubricating Oil Filter Head (007-015)

General Information

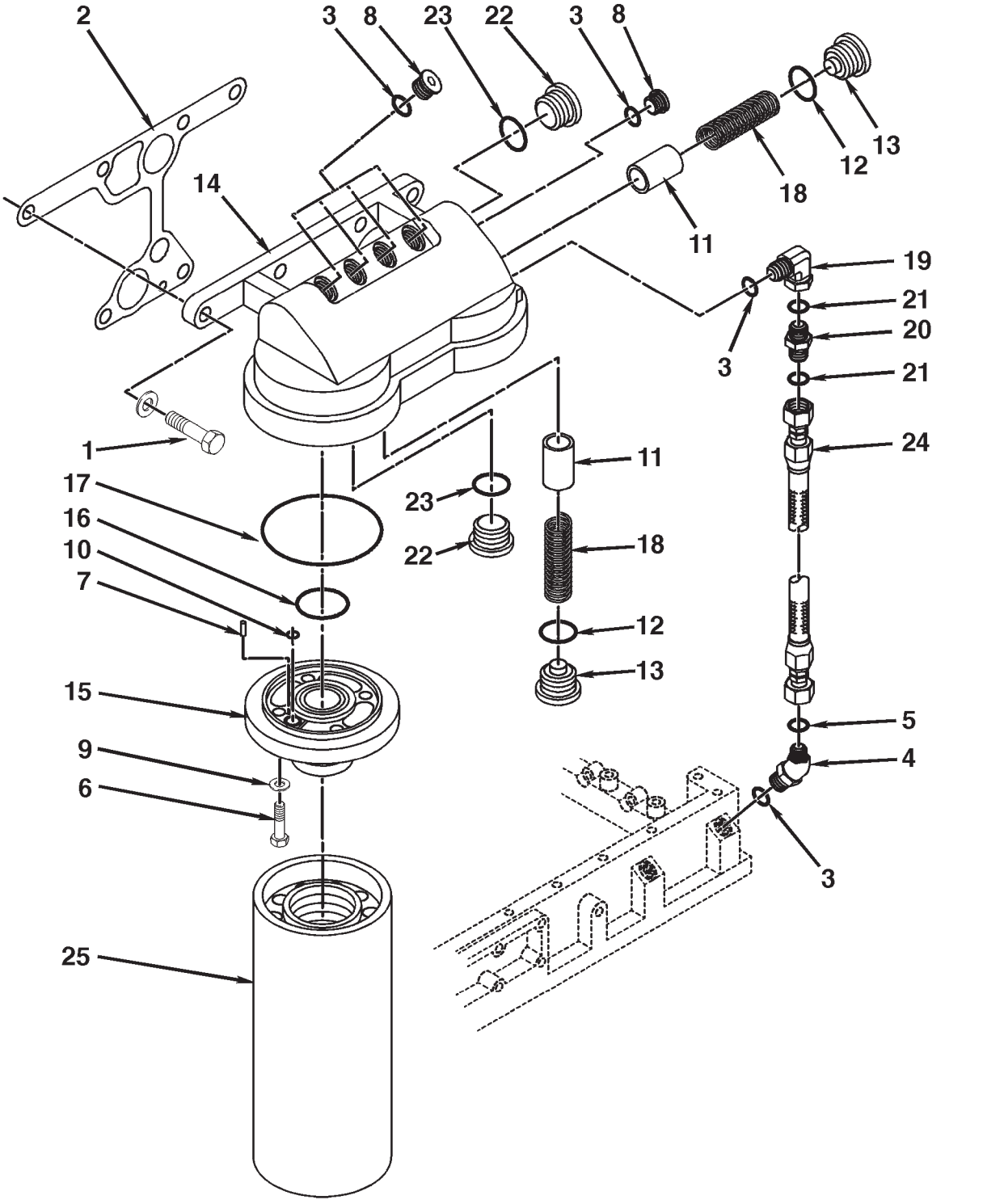
The oil filter head contains two spring loaded plungers. One plunger controls the oil pressure for the piston cooling nozzles. The second spring plunger will bypass oil if a filter element becomes plugged or clogged.

When installing a new filter element, always check to be sure there is no interference between the filter head adapter and the element.

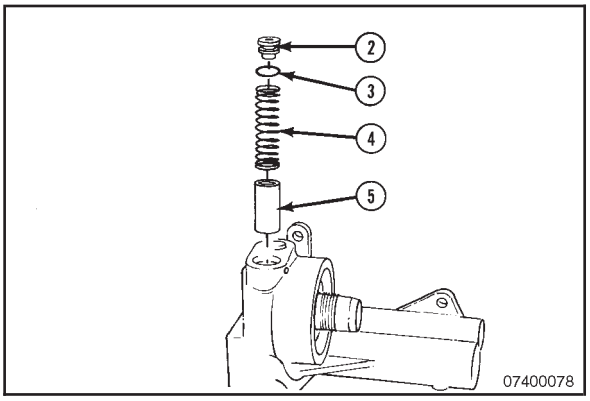
The oil filter remote option has a transfer connection and a remote filter head. The transfer connection is attached to the block in the same manner as the standard filter head. The transfer connection also houses the pressure regulator plunger for the piston cooling nozzles. The remote filter head houses the pressure regulator plunger for the filter bypass.

NOTE: The transfer connection gasket is the same as the filter head gasket, but the tab on the end of the gasket must be removed.

Exploded View



1. Screw, Captive Washer Cap
2. Gasket, Lube Oil Fill Cover
3. Seal, O-ring
4. Elbow, Male Union
5. Seal, O-ring
6. Screw, Hexagon Head Cap
7. Pin, Roll
8. Plug, Threaded
9. Washer, Plain
10. Seal, O-ring
11. Plunger, Filter Head
12. Seal, O-ring
13. Plug, Threaded
14. Head, Lube Oil Filter
15. Adapter, Filter Head
16. Seal, O-ring
17. Seal, O-ring
18. Spring, Valve
19. Elbow, Plain Union
20. Valve, Check
21. Seal, O-ring
22. Plug, Threaded
23. Seal, O-ring
24. Hose, Flexible
25. Element, Lube Oil Filter



Disassemble

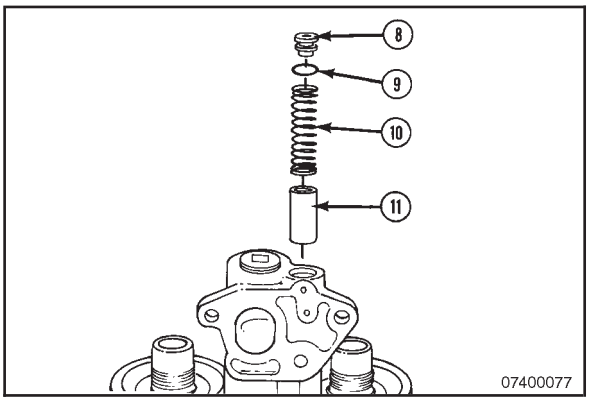
⚠ WARNING ⚠

The threaded plug is under pressure, wear goggles to prevent personal injury.

Remove the bypass regulator plunger and related parts.

2. Regulator plug
3. O-ring
4. Bypass valve spring
5. Bypass valve regulator plunger

Discard the o-ring.



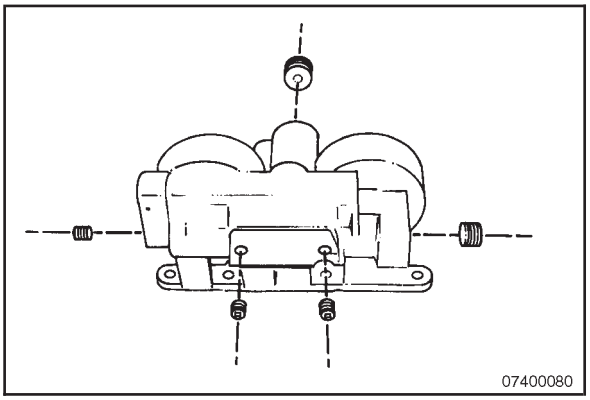
⚠ WARNING ⚠

The threaded plug is under pressure, wear goggles to prevent personal injury.

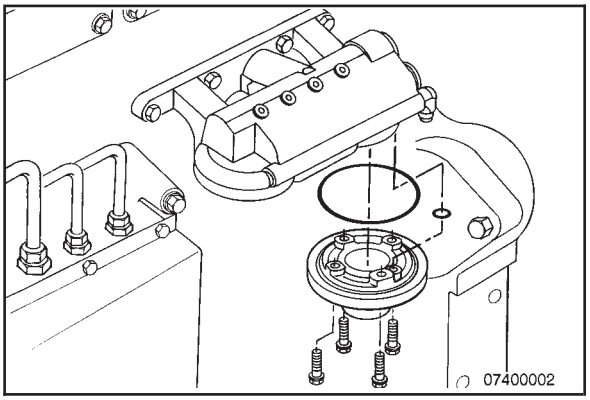
Remove the piston cooling nozzle plunger and parts.

8. Pressure regulator plug
9. O-ring
10. Piston cooling valve spring
11. Piston cooling valve plunger

Discard the o-ring.



Remove the remaining straight threaded o-ring plugs.



LF3000 Filter Head Adapter

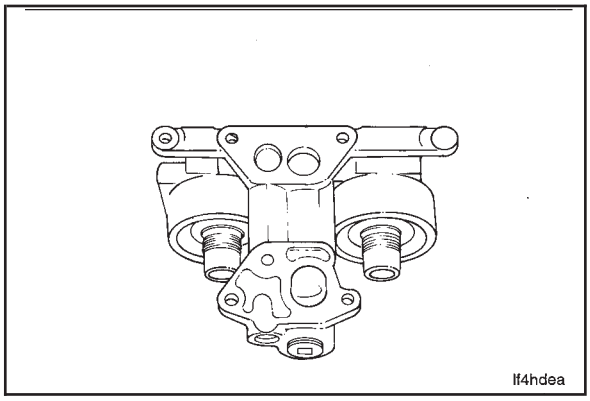
Remove the four capscrews.

Remove the filter head adapter.

Remove and discard the filter head adapter o-rings.

LF670 Filter Head Adapter

Use a 1-1/2 inch socket to remove the adapters.



Clean

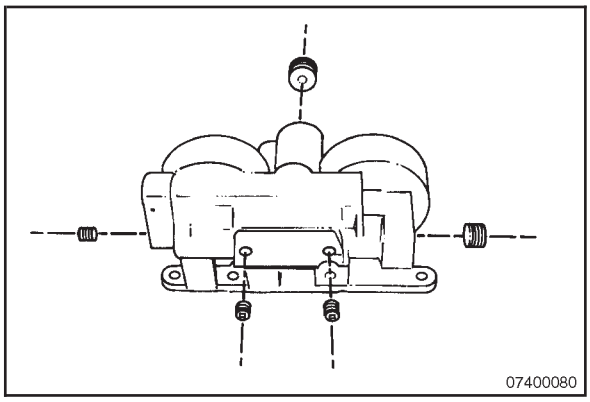
WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use a gasket scraper to remove the two mounting gaskets.

Use solvent to clean the lubricating oil filter head.

Dry with compressed air.

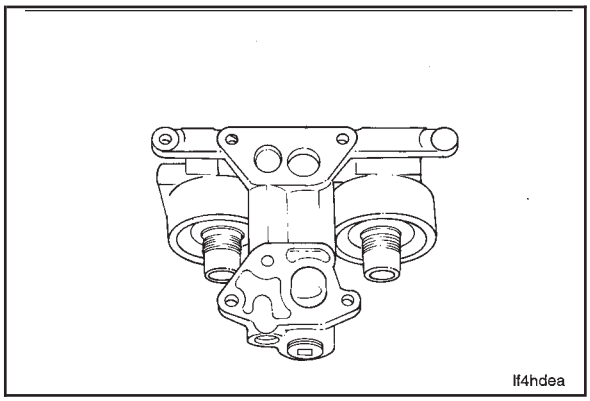


Inspect for Reuse

Check the lubricating oil filter head for cracks or other damage.

Check the visible portion of the valve plungers for signs of scoring or other damage.

If any of the plungers are damaged, the filter head **must** be rebuilt.

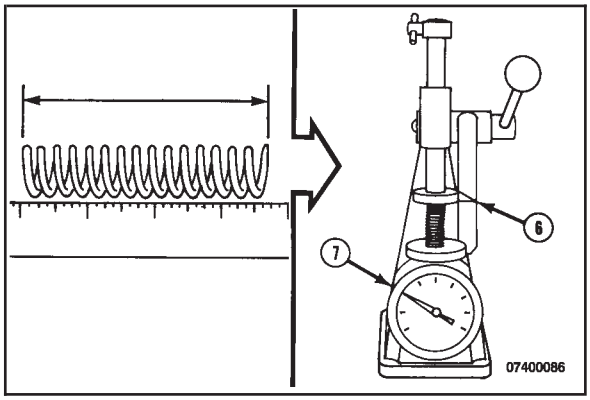


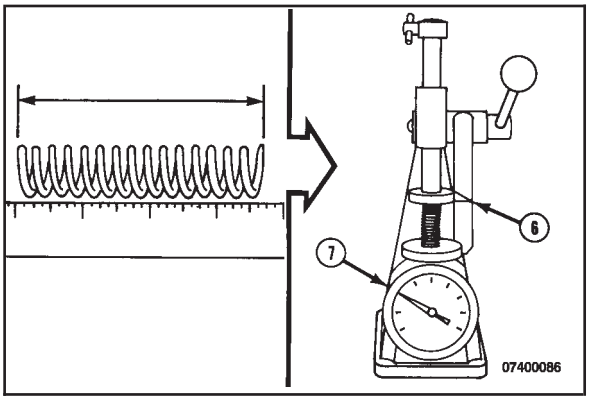
Check the bypass plunger spring.

Bypass Plunger Spring			
	mm		in
Free Length	88.98	MIN	3.500
Working Height (6)	50.80	MAX	2.000

Use a valve spring tester, Part No. 3375182, or equivalent to measure the spring force (7) and the working height (6).

Spring Force (7)		
N•m		ft-lb
26	MIN	19.3
29	MAX	21.3



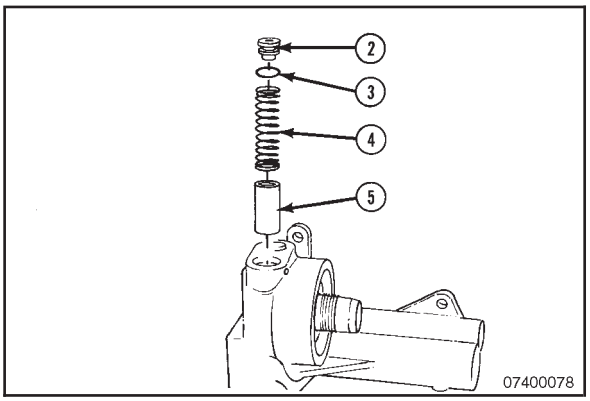


Check the piston cooling nozzle spring.

Piston Cooling Nozzle Spring			
	mm		in
Free Length	88.98	MIN	3.500
Working Height (6)	50.80	MAX	2.000

Use a valve spring tester, Part No. 3375182, or equivalent to measure the spring force (7) and the working height (6).

Spring Force (7)		
N•m		ft-lb
26	MIN	19.3
29	MAX	21.3



Assemble

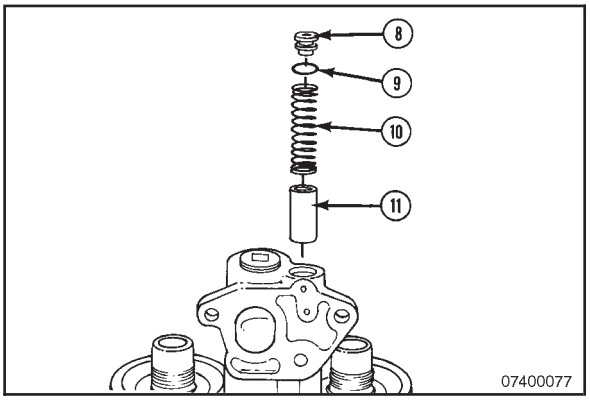
Use engine oil to lubricate the bypass regulator plunger and related parts.

Install the new o-ring (3) on the regulator plug (2).

Install the parts.
5. Bypass valve regulator plunger
4. Bypass valve spring
2. Regulator plug with o-ring (3)

Tighten the regulator plug.

Torque Value: 54 N•m [40 ft-lb]



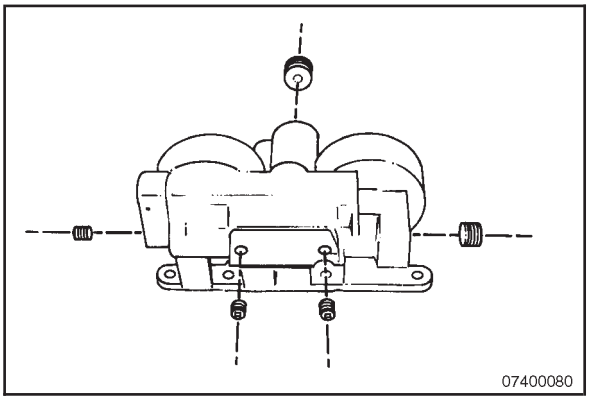
Use clean engine oil and lubricate the piston cooling nozzle plunger and related parts.

Install a new o-ring (9) on the piston cooling nozzle plunger plug (8).

Install the parts.
11. Piston cooling valve plunger
10. Piston cooling valve spring
8. Pressure regulator plug with o-ring (9)

Tighten the piston cooling nozzle plunger plug.

Torque Value: 54 N•m [40 ft-lb]



Tighten the straight threaded o-ringed plugs.

Torque Value:

1-5/16	61 N•m	[45 ft-lb]
9/16	14 N•m	[10 ft-lb]

LF3000 Filter Head Adapter

Lubricate the o-ring (1) and install in the filter head before the adapter.

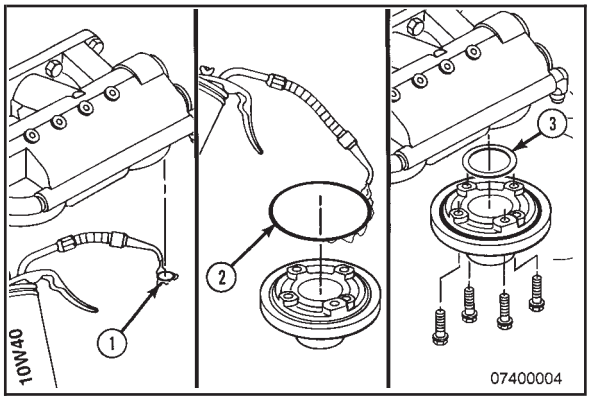
Lubricate the o-rings (2 and 3) and install in the adapter.

NOTE: When installing the filter head adapter, use a locating pin to properly align the filter head adapter to the filter head.

Install the adapter and four capscrews.

Tighten the capscrews.

Torque Value: 23 N•m [17 ft-lb]



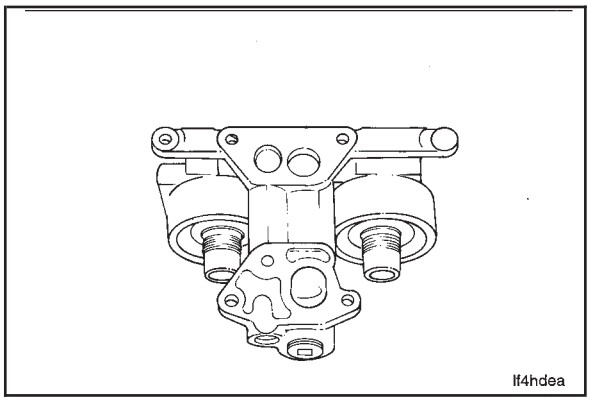
LF670 Filter Head Adapter

Apply Locktite™ 609, or equivalent, to the threads of the adaptor.

Install the adapter into the filter head.

Use a 1-1/2 inch socket to tighten the adapters.

Torque Value: 88 N•m [65 ft-lb]

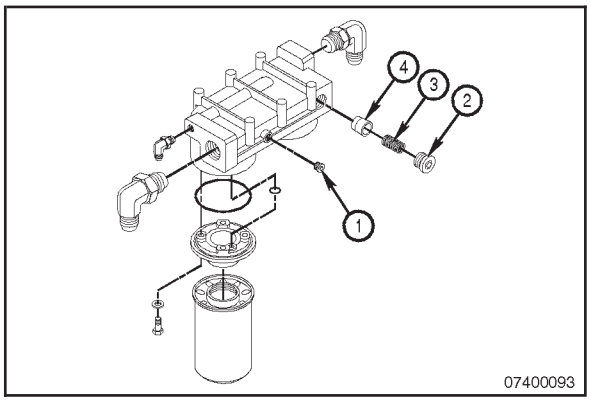


Lubricating Oil Filter Head (Remote-Mounted) (007-017)

Disassemble

Remove the straight thread o-ring plug (1).

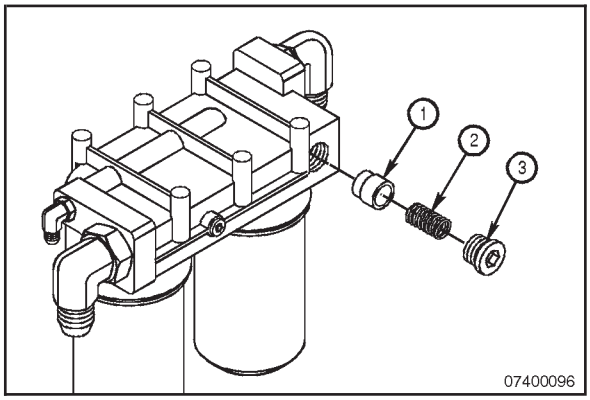
Discard the o-rings.

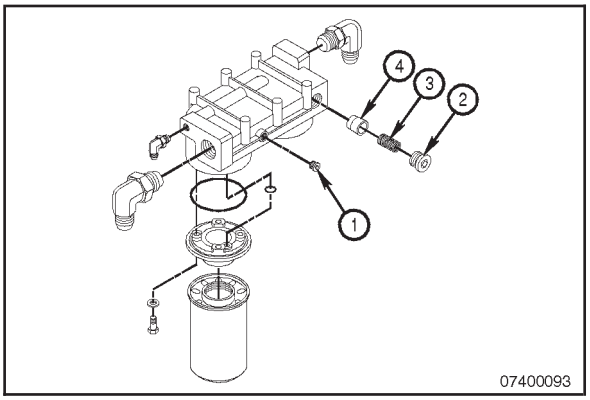


⚠ CAUTION ⚠

The threaded plug (3) is under spring pressure, wear goggles to prevent personal injury.

Remove the straight thread o-ring plug (3), bypass plunger (1), and spring (2).





Clean

⚠ WARNING ⚠

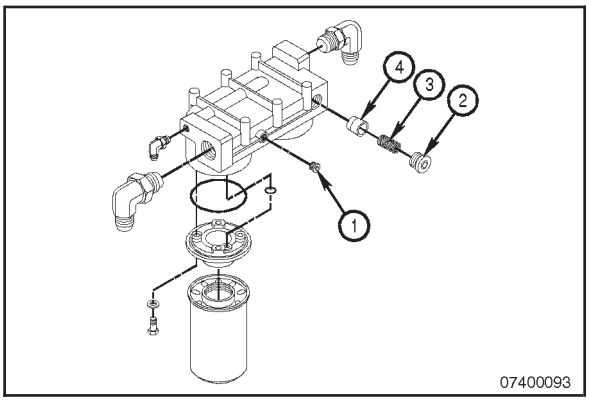
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠ CAUTION ⚠

All solvent must be removed from the filter head or engine damage could result.

Use solvent and clean all of the parts.

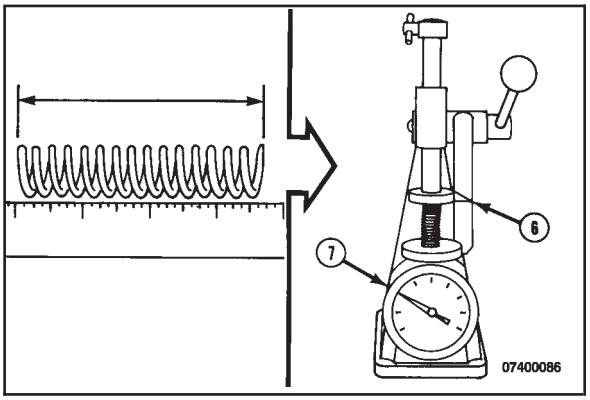
Dry with compressed air.



Inspect for Reuse

Inspect the filter head for crack.

If any cracks are found replace the filter head.

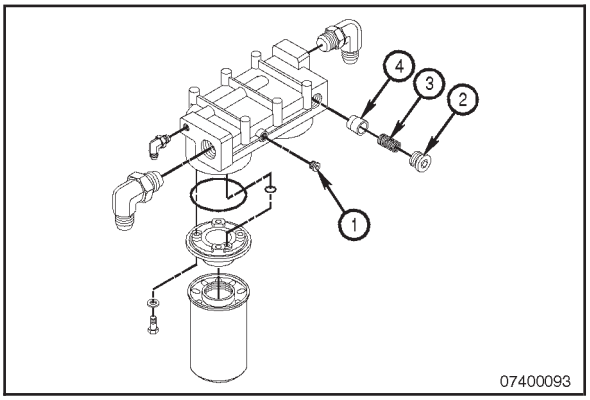


Check the bypass plunger spring.

Bypass Plunger Spring			
	mm		in
Free Length	88.98	MAX	3.500
Working Height (6)	50.80	MAX	2.000

Use a valve spring tester Part No. 3375182, or equivalent. Measure the spring force (7) and the working height (6).

Spring Force (7)		
N•m		ft-lb
26	MIN	19.3
29	MAX	21.3



Assemble

Use clean engine oil to lubricate the parts.

Install the new o-rings on the straight threaded plugs.

Install the plunger and spring.

Install the straight threaded o-ring plugs.

Tighten the plugs.

Torque Value:

9/16 Plug	14 N•m	[10 ft-lb]
1-3/16 Plug	54 N•m	[40 ft-lb]
1-7/8 Plug	95 N•m	[70 ft-lb]

Lubricating Oil Filter Head Adapter (007-018)

General Information

When installing a new filter element, always check to be sure there is no interference between the filter head adapter and the filter element.

Clean

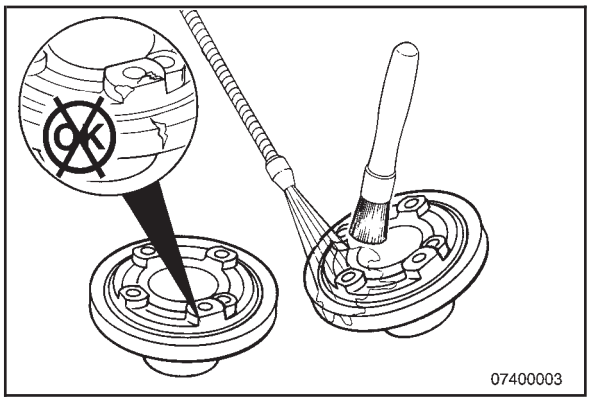
LF3000

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the lubrication oil filter head adapter.

Dry with compressed air.



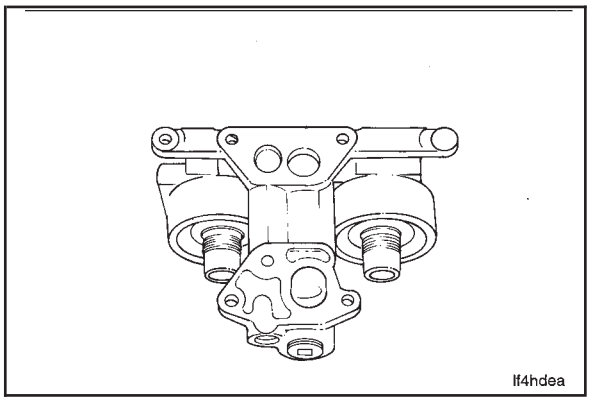
LF670

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the parts.

Dry with compressed air.

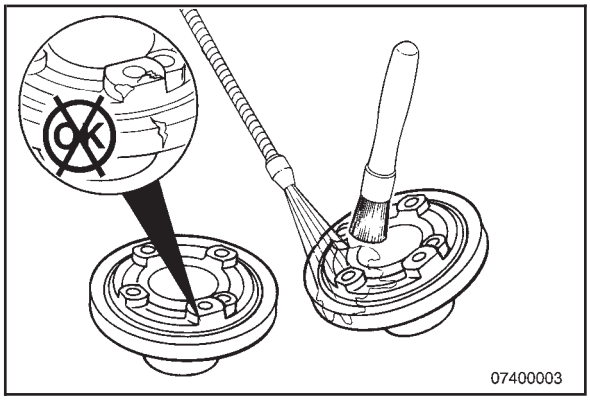


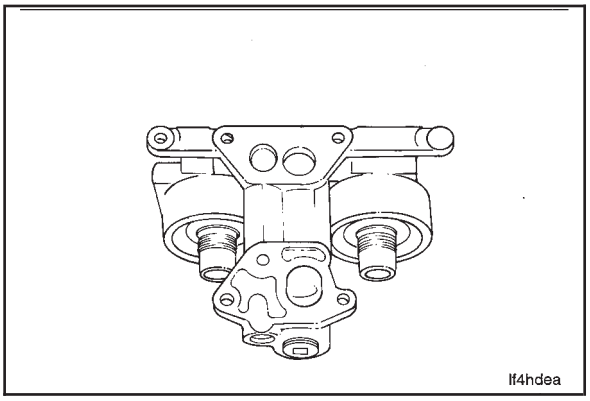
Inspect for Reuse

LF3000

Visually inspect the adapter for cracks or other damage.

Replace if any damage is found.





LF670

Check the threads on the adaptors for damage.

Replace if any damage is found.

Lubricating Oil Pan (007-025)

General Information

Oil pan sumps are available in various capacities. Compare the part number to the chart below to find the correct high and low capacities. When the rear gear train option is specified, add 7.6 liters [2 U.S. gallons] to the sump capacity listed in the table below.

Service dipsticks are available in two types. The first is the locking type. The second is the bottle stopper type that does not lock. When converting from one style to the other, change both the dipstick and the oil gauge tube.

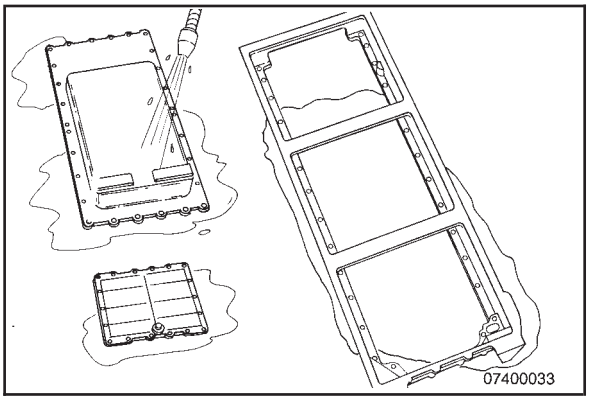
NOTE: Service dipsticks are supplied by length. The dipsticks do **not** have the **high** and **low** marks indicated. Do **not** calibrate the dipstick until the engine is installed in the application that its to be used.

Oil Pan Capacity The following tabulation gives the **low** and **high** STATIC (engine **not** operating) oil level for the pan installed. Use this information when calibrating the oil gauge (dipstick).

NOTE: Only the part number of the oil pan (sump) is given. The part number of the oil pan adapter does **not** change the engine oil capacity.

	Oil Pan Capacities		
	liters		**U.S.gal**
Shallow full length	49	MIN	13
PN 3086097	61	MAX	16
Long (1/3) deep	49	MIN	13
PN 3086096	61	MAX	16
Short (1/3) deep	49	MIN	13
PN 3331695	61	MAX	16
Marine, deep rear	64	MIN	17
PN 3096460	72	MAX	19
Power Generator	102	MIN	27
PN 3331568	114	MAX	30

NOTE: Total system capacity is the summation of the oil pan capacity at the high mark on the dipstick, and the two LF3000 combination full flow/bypass oil filters. On engines with the rear gear train option, add 7.6 L (2 U.S. gal) to both the low and high oil pan capacity listed in the table above.



Lubricating Oil Pan Adapter (007-027)

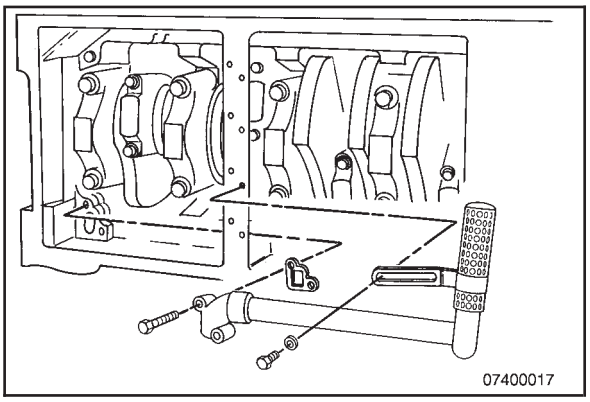
Clean

⚠ WARNING ⚠

Always read and follow the solvent manufacturers safety precautions to avoid severe personal injury or death.

Remove any hand hole covers not previously removed.

Use a solvent that will **not** harm aluminum clean the oil pan adapter and hand hole covers.

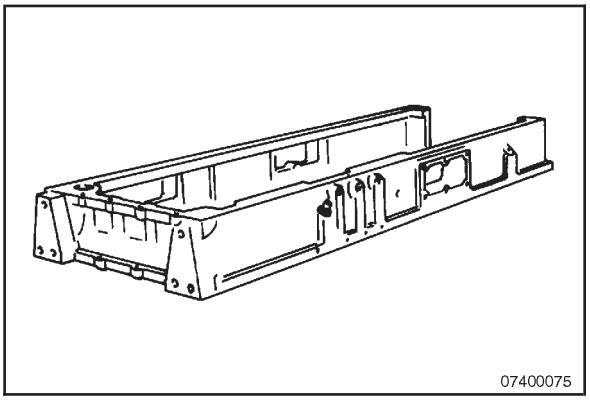


⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the suction tube.

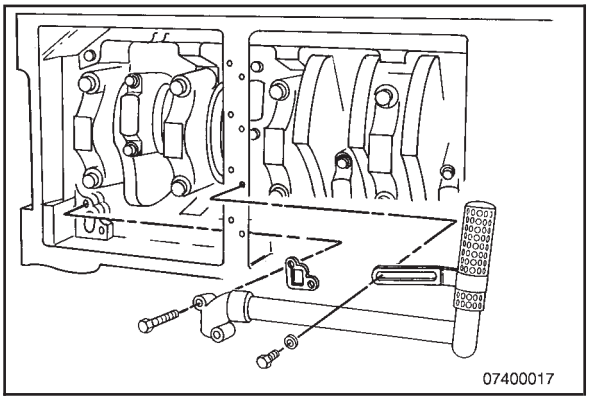
Dry with compressed air.



Inspect for Reuse

Visually inspect the oil pan adapter for cracks or other damage.

If cracks are suspected, use the dye penetrant method. Check the threaded holes for damage.



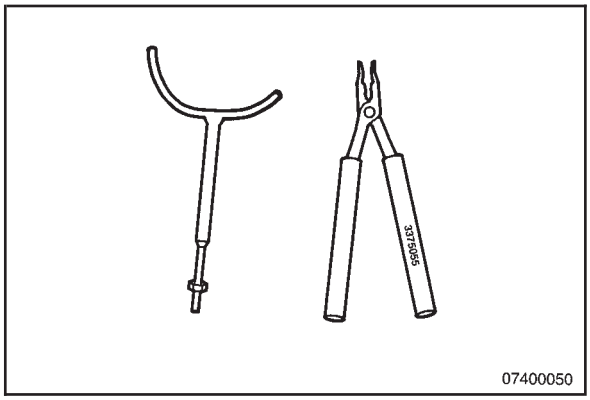
Inspect the suction tube for cracks or other damage.

Lubricating Oil Pump (007-031)

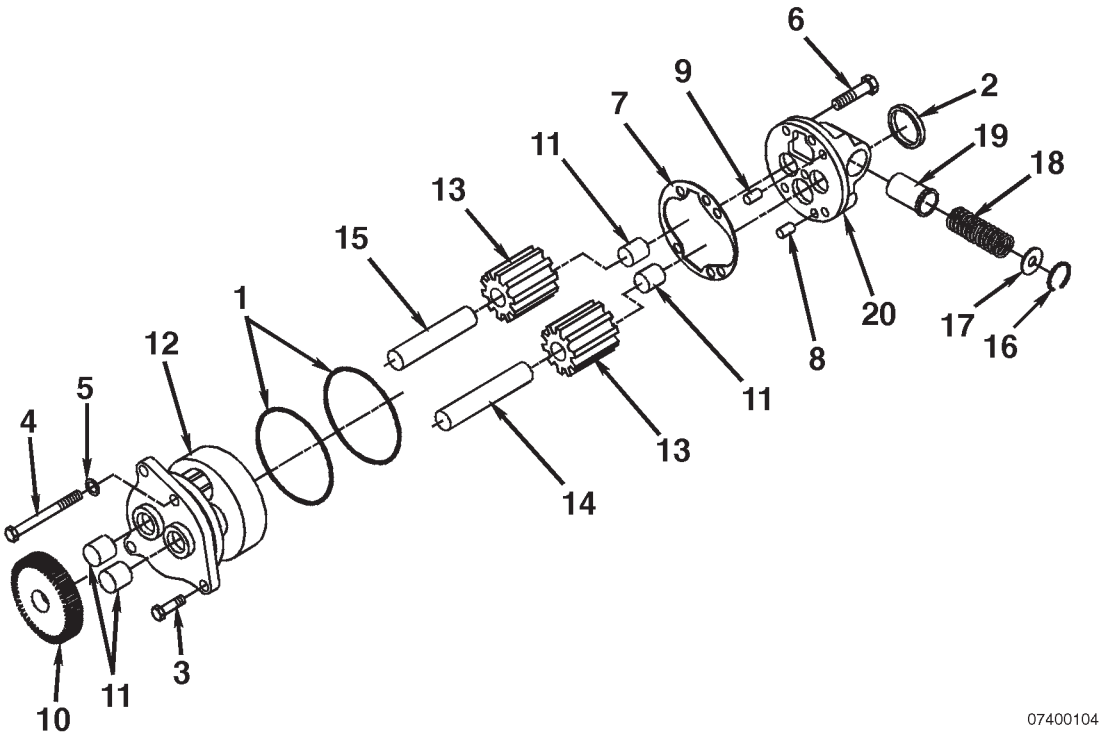
General Information

The QSK19 lubricating oil pump uses a retaining ring to secure the pressure regulator assembly.

Use pressure regulator removal tool, Part No. 3375055, to service the pressure regulator assembly when the lube oil pump is installed in the engine.



Exploded View



1. Seal, O-ring
2. Seal, Rectangular Ring
3. Screw, Captive Washer Cap
4. Screw. Hexagon Head Cap
5. Washer, Lock
6. Screw, Captive Washer Cap
7. Gasket, Lubricating Oil Pump
8. Dowel, Pin
9. Dowel, Diamond
10. Gear, Lubricating Oil Pump
11. Bushing
12. Body Lubricating Oil Pump
13. Gear, Lubricating Oil Pump
14. Shaft, Lubricating Oil Pump Drive
15. Shaft, Idler
16. Ring, Retaining
17. Plug, Retainer
18. Spring, Compression
19. Plunger, Pressure Regulator
20. Cover, Lubricating Oil Pump

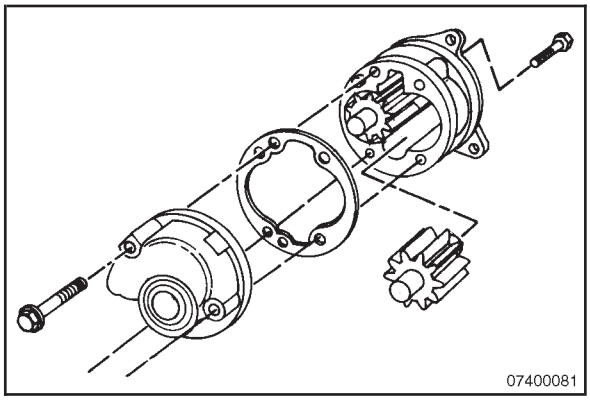
Disassemble

Remove the four capscrews.

Remove the cover from the housing.

Use a mallet to tap on the dowel to separate the cover from the housing.

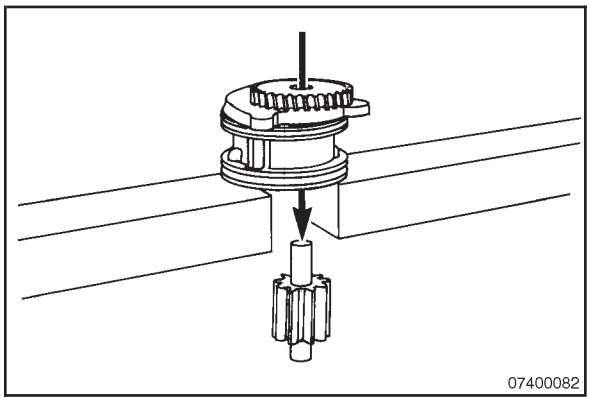
Lift the idler gear and the shaft from the housing.



Support the housing.

Use an arbor press to remove the drive gear, push the shaft through the gear.

Check the parts for damage.



⚠ WARNING ⚠

To prevent personal injury, it is imperative to follow the instructions given below. Wear safety goggles to prevent personal injury.

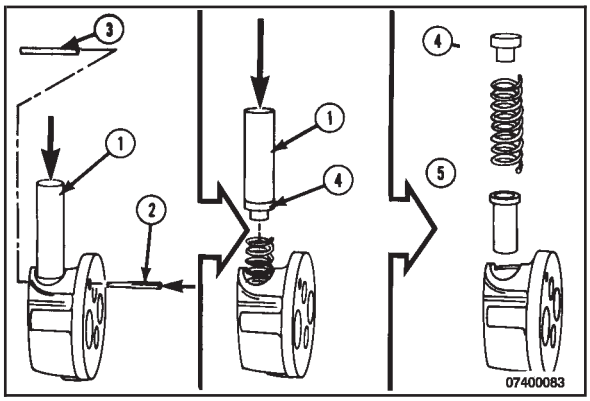
Use an arbor press, and a mandrel (1) to hold the retainer (4) in position.

Remove the retaining ring (3).

Slowly raise the arbor press and allow the spring tension to be relieved.

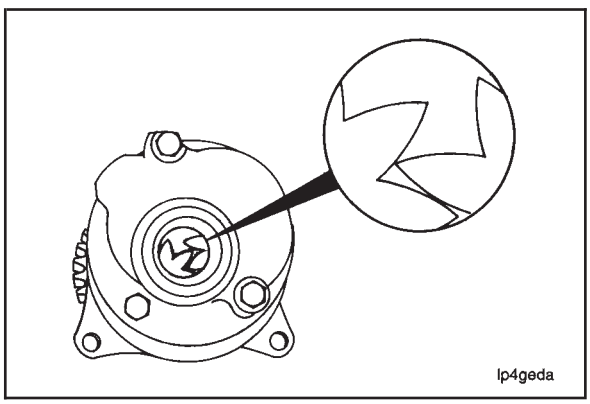
Remove the retainer, the pressure spring, and the pressure regulator plunger.

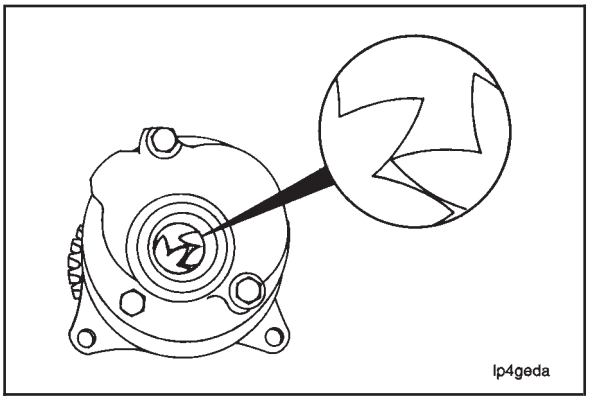
Check the parts for any damage.



Clean

Use solvent to clean and flush the oil pump.





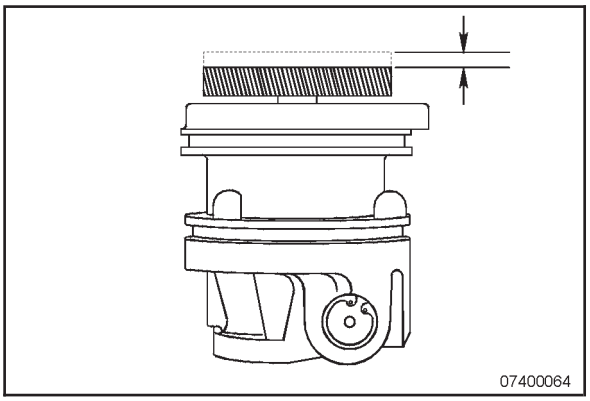
Inspect for Reuse

⚠ 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. Always use the proper procedures to dispose of the oil.

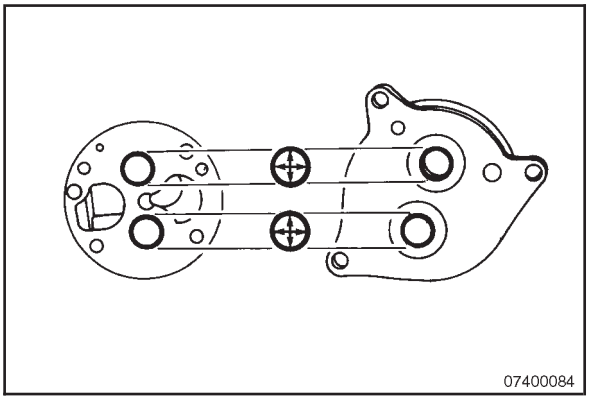
Inspect the lubricating oil pump for reuse, by rotating the drive gear slowly and checking the pump gears for damage.

NOTE: If any of the oil pump parts are damaged, it **must** be rebuilt or replaced.



Measure the oil pump end clearance.

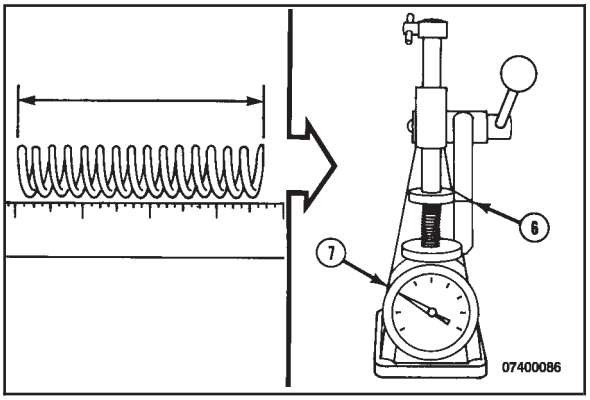
Oil Pump End Clearance		
mm		in
0.1016	MIN	0.004
0.2540	MAX	0.010



Measure the I.D.

Bushing I.D.		
mm		in
22.263	MIN	0.8765
22.324	MAX	0.8785

NOTE: The bushings are bored in position. Lubricating pump bushing boring tool, Part No. 3375206 **must** be used to machine the bushings.



Measure the pressure regulator spring free length.

Pressure Regulator Spring Free Length		
mm		in
95	NOMINAL	3.75

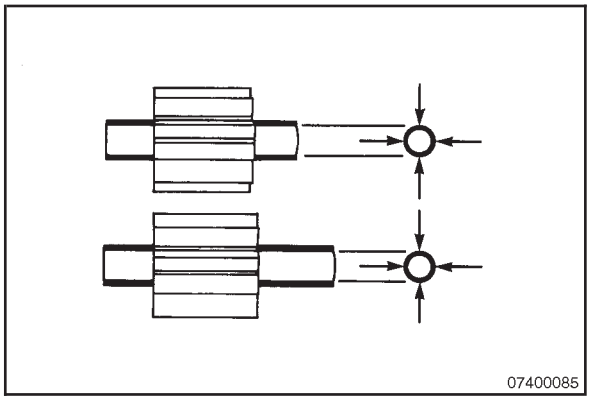
Use a valve spring tester, Part No. 3375182, or equivalent. Measure the spring force (7) at the working height (6).

Spring Force @ 63.88 mm [2.5 in] Working Height		
N		lb
322	MIN	72
344	MAX	77

Check the gears for damage.

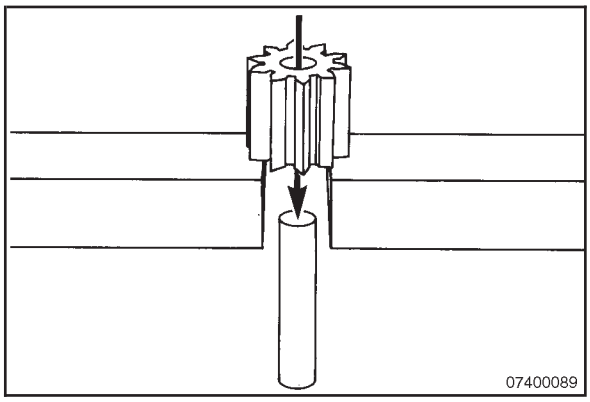
Measure the O.D.

Shaft O.D.		
mm		in
22.212	MIN	0.8745
22.225	MAX	0.8750



Only disassemble when the gear **or** the shaft must be replaced.

Support the gear, use an arbor press to push the shaft through the gear.

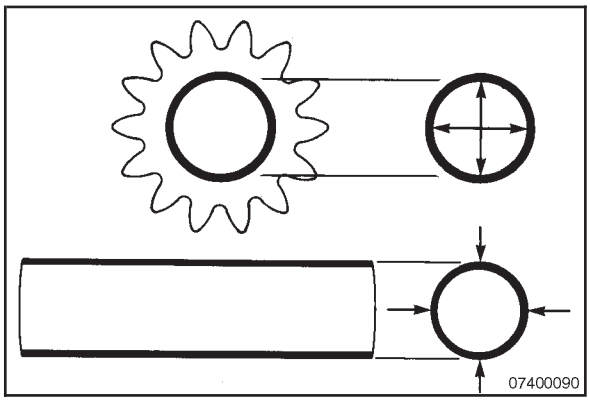


Measure the I.D. of the gear.

Gear I.D.		
mm		in
22.169	MIN	0.8728
22.195	MAX	0.8738

Measure the O.D. of the shaft.

Shaft O.D.		
mm		in
22.212	MIN	0.8745
22.225	MAX	0.8750

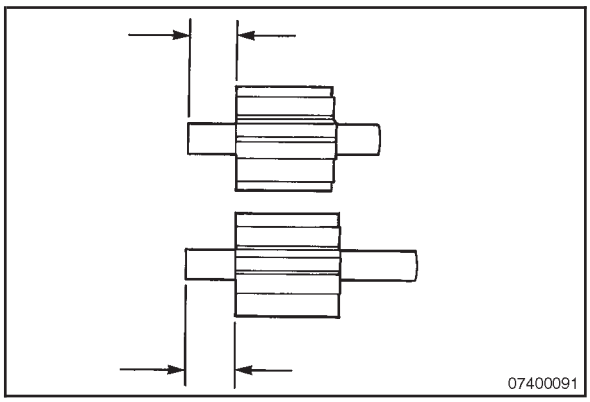


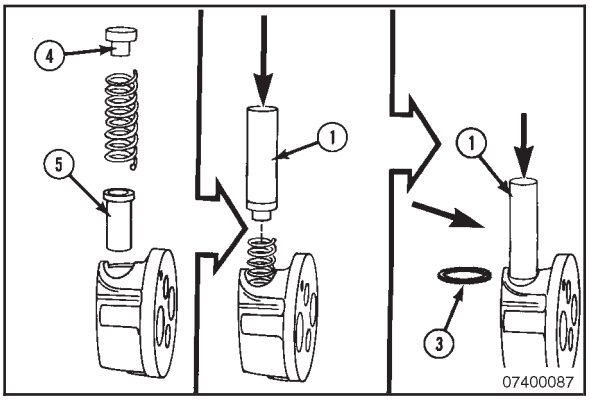
NOTE: Any parts **not** with in the given tolerances **must** be replaced.

Use clean engine oil to lubricate the shaft and the I.D. of the gear.

Use an arbor press to install the gear.

Gear Location on Shaft			
	mm		in
Idler	26.162	MIN	1.03
	26.67	MAX	1.051
Drive	26.162	MIN	1.03
	26.416	MAX	1.040





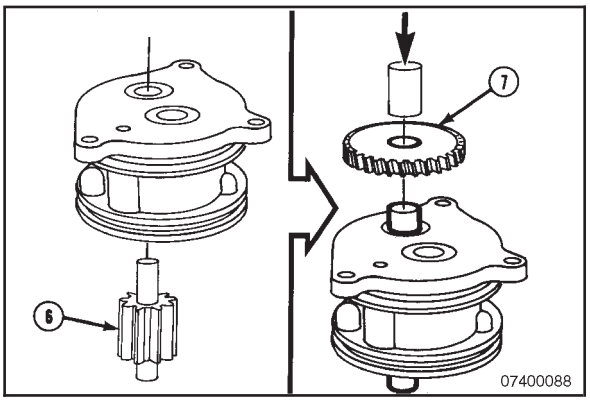
Assemble

Use clean engine oil to lubricate the regulator plunger (5) and the bore.

Install the regulator plunger, spring, and retainer (4).

Use and arbor press, and mandrel (1), to compress the spring, and put the retainer in position.

Install the retaining ring.

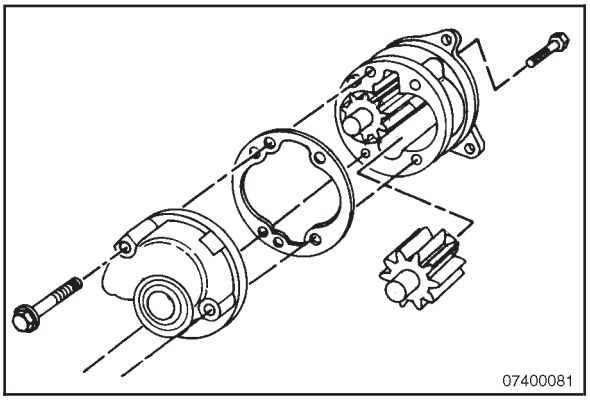


Use clean engine oil and lubricate the shaft and gear inner diameter

Install the gear and the shaft assembly (6), into the housing.

Use an arbor press, support the oil pump shaft. Place the gear over the shaft, and using a mandrel press the gear onto the shaft (7), until the gear is even with the shaft.

NOTE: The part number of the drive gear **must** be positioned up.



Use clean engine oil and lubricate the bushings in the housing cover.

Install the shaft into the housing.

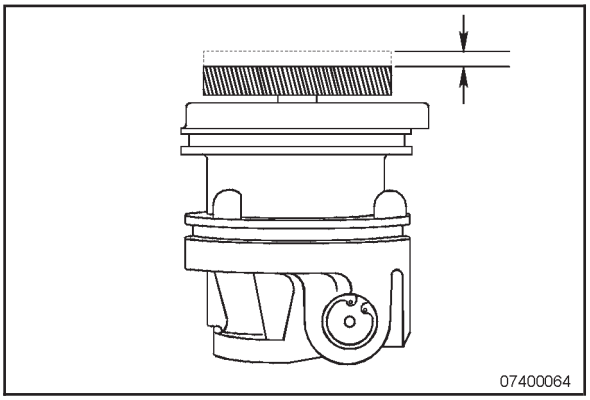
Install the gasket.

Use a mallet. Install the cover over the dowels.

Install the four capscrews.

Torque the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Rotate the assembly.

Measure the end play.

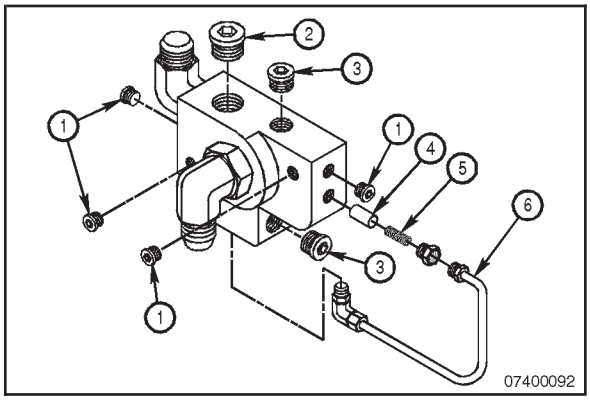
End Play		
mm		in
0.1016	MIN	0.004
0.254	MAX	0.010

Oil Transfer Connection (007-061)

Disassemble

Remove the straight thread o-ring plugs (1), (2), and (3).

Discard the o-rings

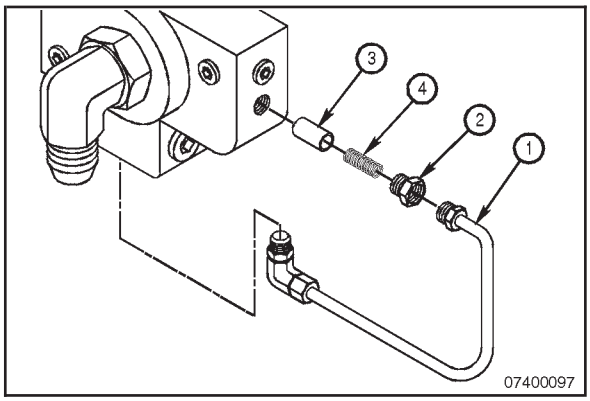


Remove the vent tube (1).

⚠ CAUTION ⚠

The threaded plug (2) is under spring pressure.

Remove the piston cooling nozzle plunger (3) and spring (4).



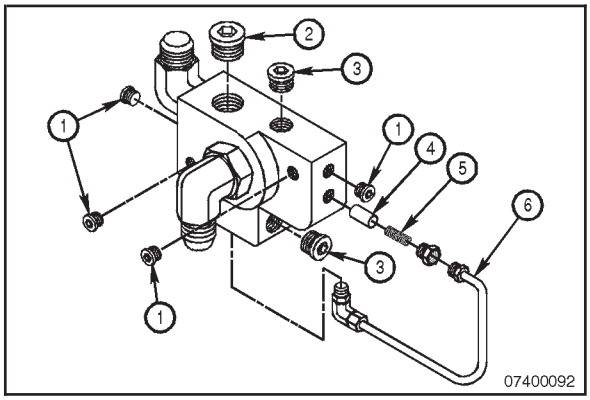
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

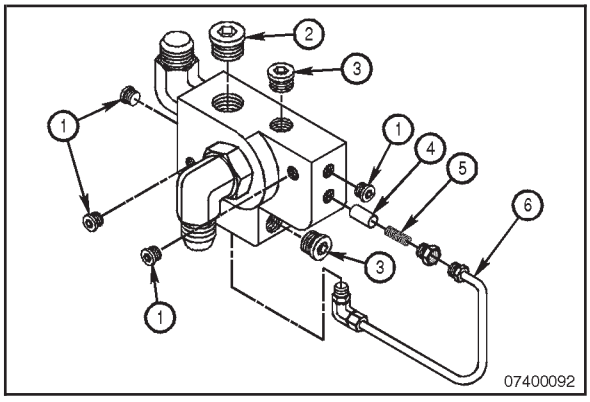
Use solvent to clean the parts.

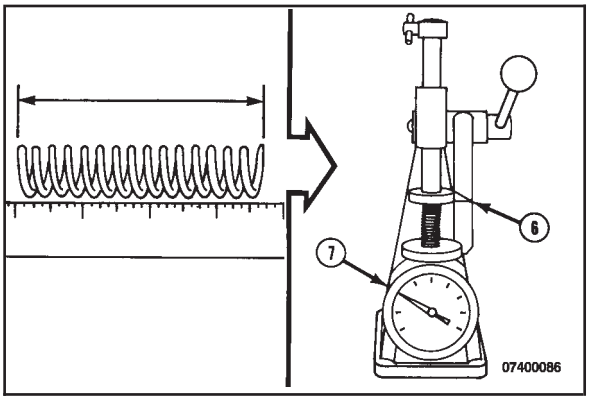
Dry with compressed air.



Inspect for Reuse

Inspect the parts for wear or damage.



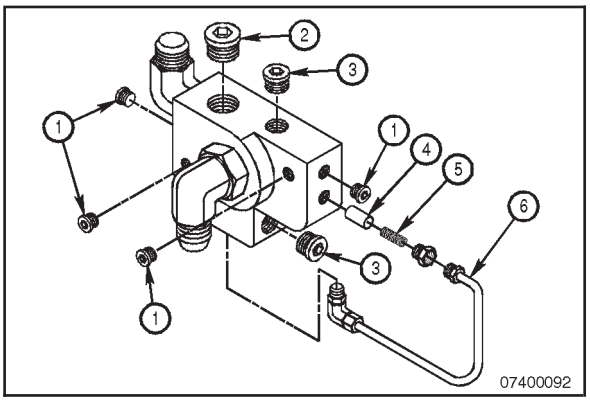


Check the piston cooling nozzle spring.

Piston Cooling Nozzle Spring			
	mm		in
Free Length	88.98	MAX	3.500
Working Height (6)	50.80	MAX	2.000

Use a valve spring tester, Part No. 3375182, or equivelent to measure the spring force and the working height

Spring Force (7)		
N•m		ft-lb
26	MIN	19.3
29	MAX	21.3



Assemble

Use clean engine oil to lubricate the parts.

Install the new o-rings on the plugs.

Install the plunger, spring and vent tube.

Install and tighten the straight threaded o-ring plugs.

Torque Value:

9/16 Plug	14 N•m	[10 ft-lb]
1 3/16 Plug	54 N•m	[40 ft-lb]
1 7/8 Plug	95 N•m	[70 ft-lb]

Section 8 - Cooling System - Group 08

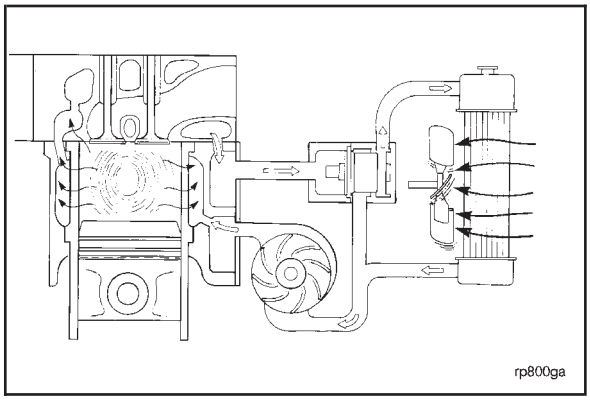
Section Contents

Cooling System - General Information

General Information

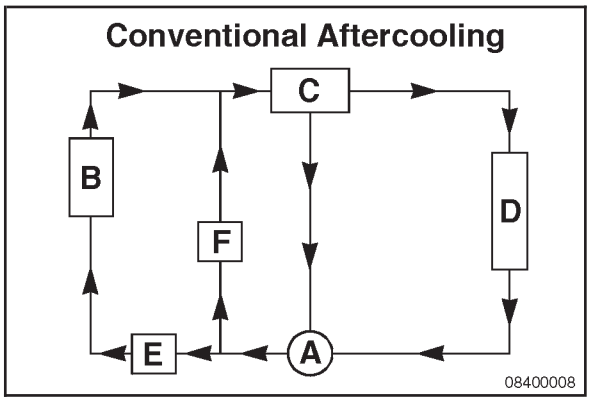
The primary function of the cooling system is to remove heat energy, created by the combustion process, from the engine. The excess heat energy that is **not** removed by the cooling system is carried away by exhaust gases and radiation into the atmosphere.

The QSK19 requires a radiator cap with a minimum pressure rating of 48 kPa [7 psi]. This provides a positive coolant head pressure at the water pump inlet.



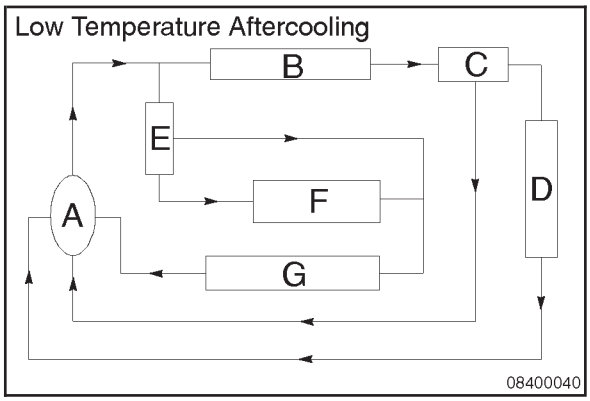
The accompanying chart illustrates the Conventional Aftercooling coolant flow through the engine.

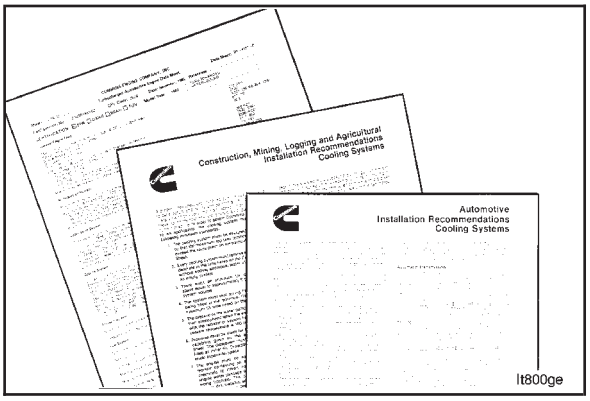
A. Water Pump
B. Base Engine
C. Thermostat, Engine
D. Radiator, Engine
E. Oil Cooler
F. Aftercooler



The accompanying chart illustrates the Low Temperature Aftercooling (LTA) coolant flow through the engine.

A. Water Pump
B. Base Engine
C. Thermostat, Engine
D. Radiator, Engine
E. Low Temperature Aftercooling Thermostat
F. Low Temperature Aftercooling Radiator
G. Aftercooler





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

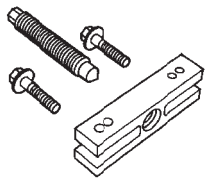
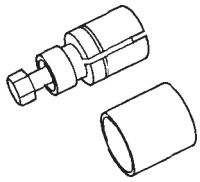
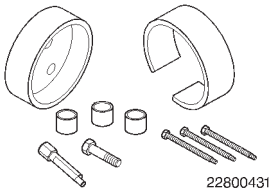
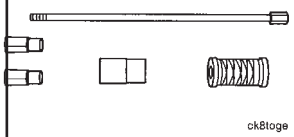
- Automotive Installation Recommendations (Cooling System), Bulletin No. 3382413.
- Construction, Mining, Logging, and Agriculture Installation Recommendations (Cooling System), Bulletin No. 3382171.
- Data Sheets for Construction, Mining, Logging, and Agriculture, Bulletin No. 3381194; for Generator Drive and Generator Set, Bulletin No. 3381174; for Automotive, Bulletin No. 3381237.
- Operation of Diesel Engines in Cold Climates, Bulletin No. 3379009.
- Generator Drive and Generator Set Installation Recommendations (Cooling System), Bulletin No. 3382395.
- Coolant Requirements and Maintenance, Bulletin No. 3666132.

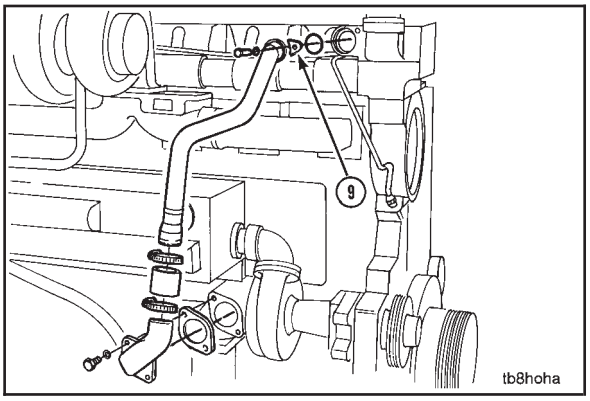
NOTE: Refer to Section L for literature ordering information.

Service Tools

Cooling System

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

Tool No.	Tool Description	Tool Illustration
ST-647	**Gear Puller** Used to remove the drive pulleys and impellers.	 ad8toga
3376326	**Pulley Installation Tool** Used to install drive pulleys.	 ad8togb
3376663	**Coupling Puller** Used to remove accessory drive coupling.	 hp8togg
3824760	**Oil Seal Remover/Installer** Used to remove small bushings, oil seals, and bearings.	 22800431
3375066	**Pipe Sealant** Use when installing pipe plugs or cup plugs on the engine in order to prevent leaks.	 ew8togc
ST-1134	**Dowel Pin Extractor** Used to pull dowel pins.	 ck8toge



Coolant Thermostat (008-013)

Remove

Conventional Aftercooling

⚠ WARNING ⚠

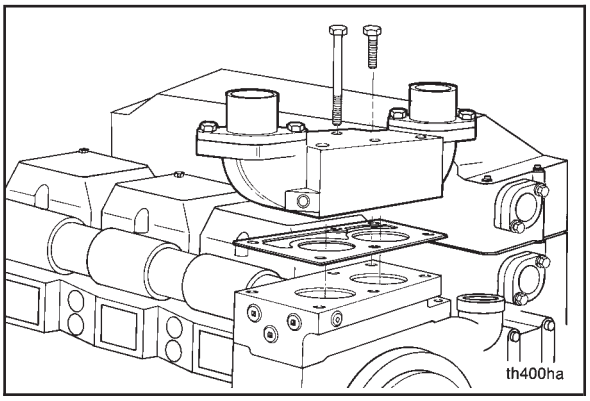
Some coolants are poisonous. Keep away from children and animals. Save for reuse or dispose of in accordance with local authorities.

NOTE: If the engine is equipped with an air compressor, remove the air compressor coolant return tube.

Remove bypass tube clip (9).

Loosen both hose clamps.

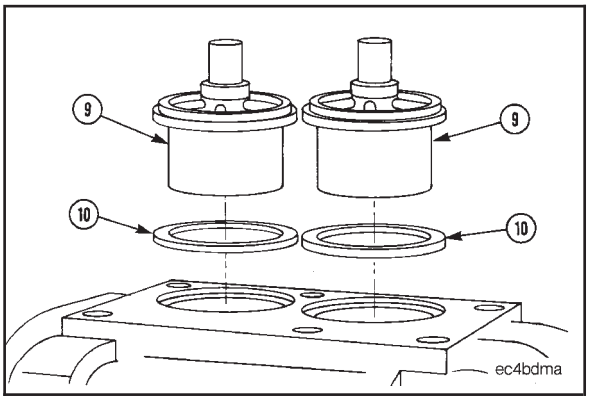
Remove the bypass tube.



Remove the eight long capscrews.

Remove the thermostat housing.

Remove and discard the gasket.



Remove the thermostats (9).

Remove the seals (10).

Low Temperature Aftercooling

⚠ WARNING ⚠

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

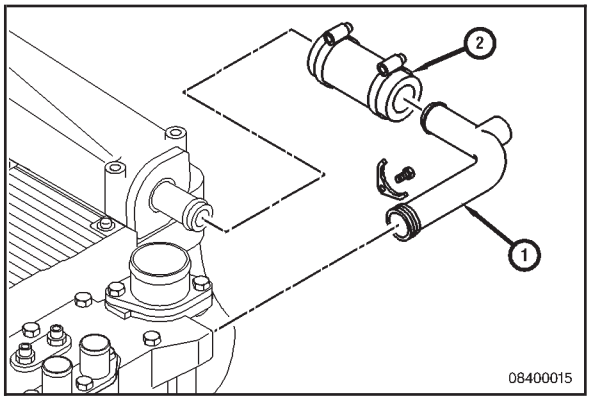
⚠ WARNING ⚠

Some coolants are poisonous. Keep away from children and animals. Save for reuse or dispose of in accordance with local authorities.

Remove the aftercooler return tube clip.

Loosen both hose clamps (2).

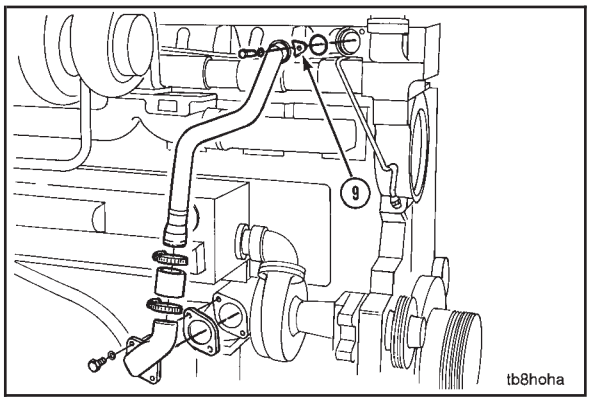
Remove the aftercooler coolant return tube (1).



Remove the bypass tube clip (9).

Loosen both hose clamps.

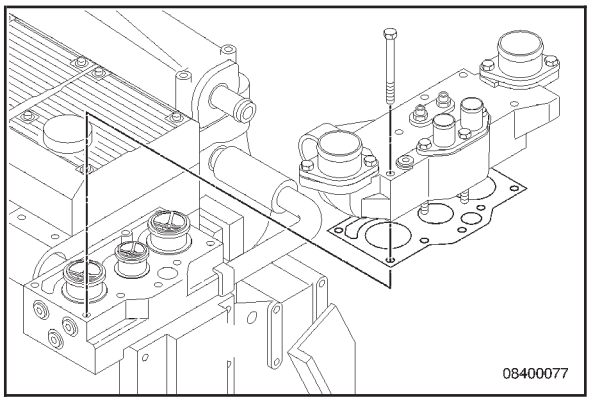
Remove the bypass tube.



Remove the nine long capscrews.

Remove the thermostat housing.

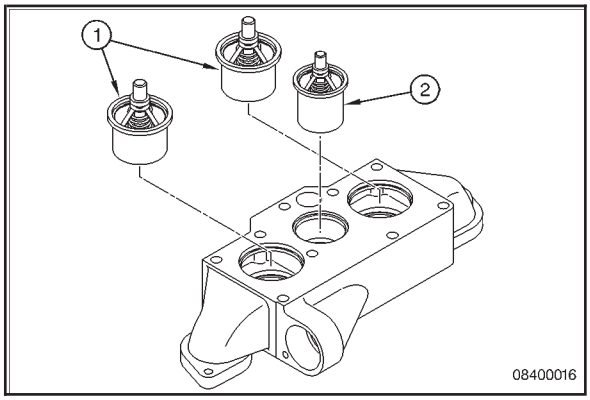
Remove and discard the gasket.

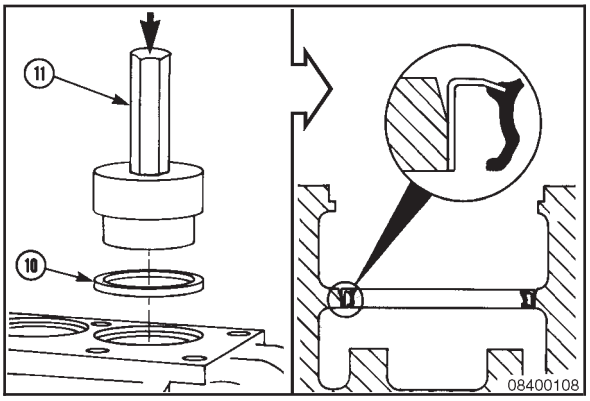


Remove both of the engine thermostats (1).

Remove the Low Temperature Aftercooling thermostat (2).

Remove the seals.





Install

Engine Thermostats

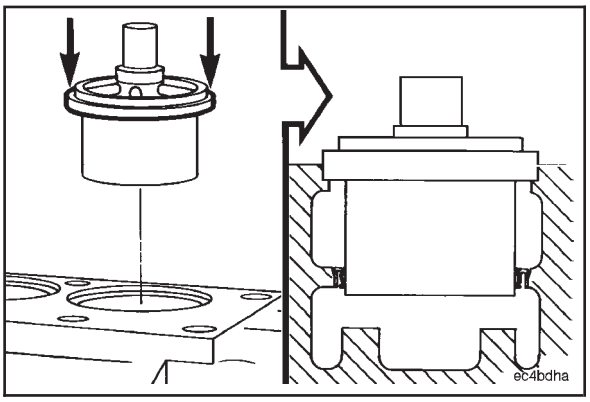
Conventional Aftercooling

⚠ CAUTION ⚠

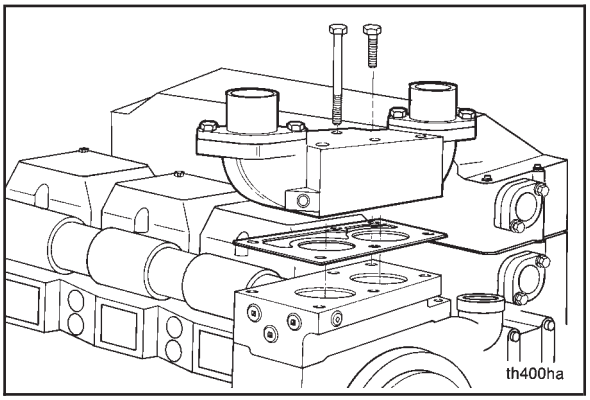
The seal must be installed with the part number pointing up.

Use a mallet and thermostat seal driver, Part No. 3375411, or equivalent. Install the thermostat seal no more than 0.51 mm [0.020 in] below the top of the cast edge.

Install the thermostat seals.



Install the thermostat by pushing on the outer rim.

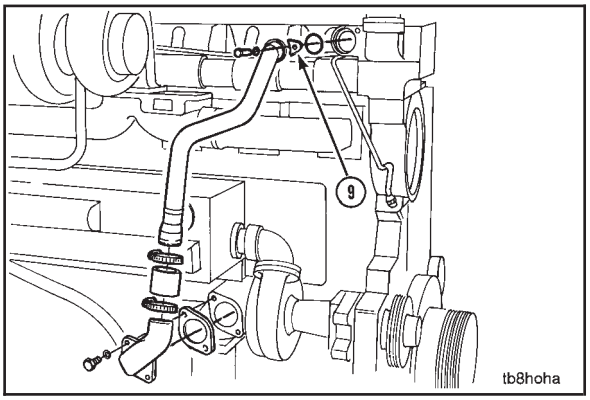


Install a new gasket.

Install the thermostat housing and capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Use vegetable oil to lubricate the o-ring on the bypass tube.

Install the bypass tube.

Install the retainer (9) and capscrew.

Tighten the capscrew and the hose clamps.

Torque Value:

Capscrew	45 N•m	[35 ft-lb]

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]

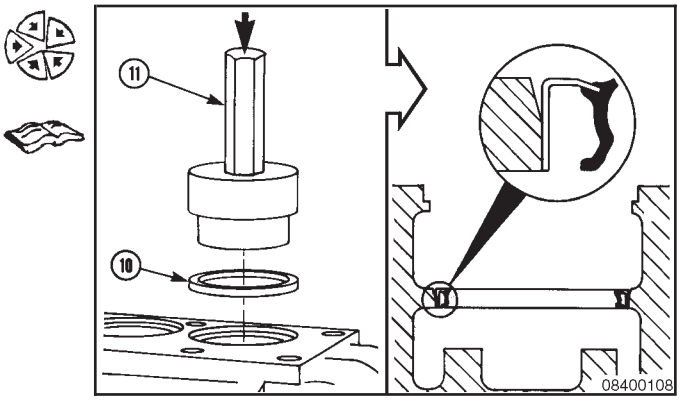
Low Temperature Aftercooling

CAUTION

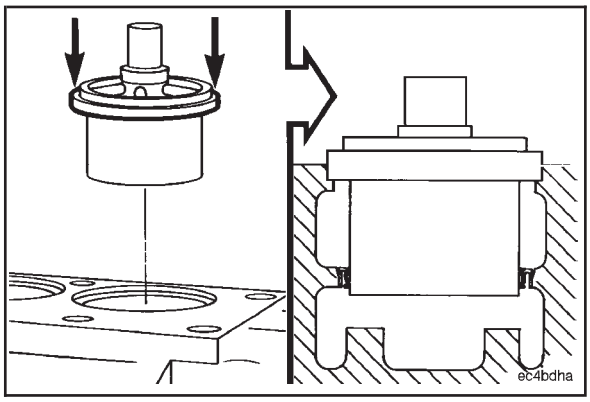
The seal must be installed with the part number pointing up.

Use a mallet and thermostat seal driver, Part No. 3375411, or equivalent. Install the thermostat seal no more than 0.51 mm [0.020 in] below the top of the cast edge.

Install the thermostat seals.



Install the thermostat by pushing on the outer rim.

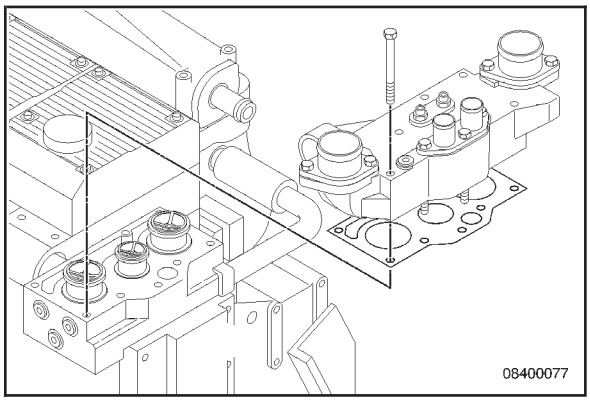


Install a new gasket.

Install the thermostat housing and capscrews.

Tighten the capscrews.

Torque Value: 45 N•m [35 ft-lb]



Use vegetable oil to lubricate the o-ring on the bypass tube.

Install the bypass tube.

Install the retainer (9) and capscrew.

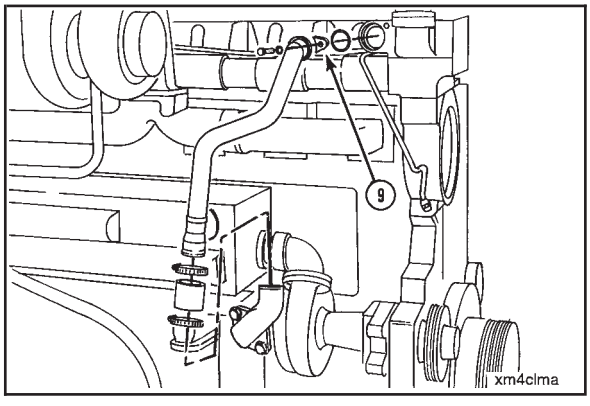
Tighten the capscrew and the hose clamps.

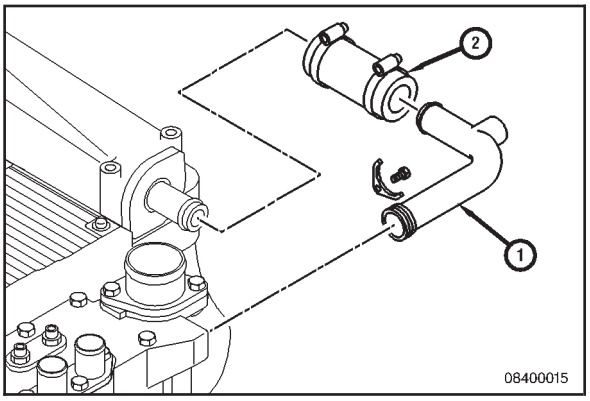
Torque Value:

Capscrew	45 N•m	[35 ft-lb]

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]





Install the aftercooler water return tube (1), tube clip, and capscrew.

Install the connecting hose (2).

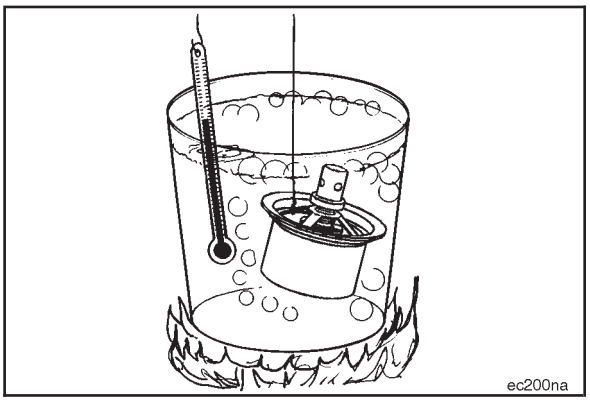
Tighten the hose clamps and capscrew.

Torque Value:

Capscrew	20 N•m	[15 ft-lb]

Torque Value:

Hose Clamp	6 N•m	[50 in-lb]



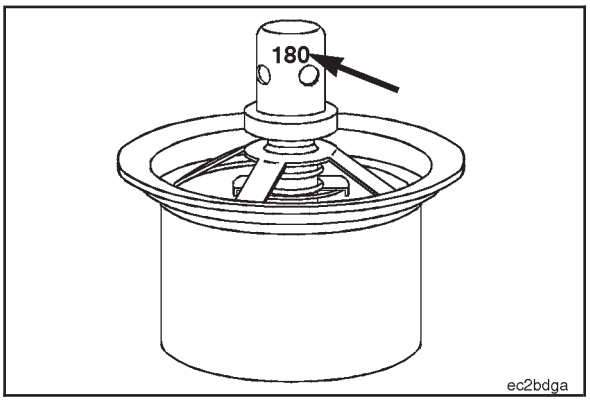
Test

Engine Thermostats

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

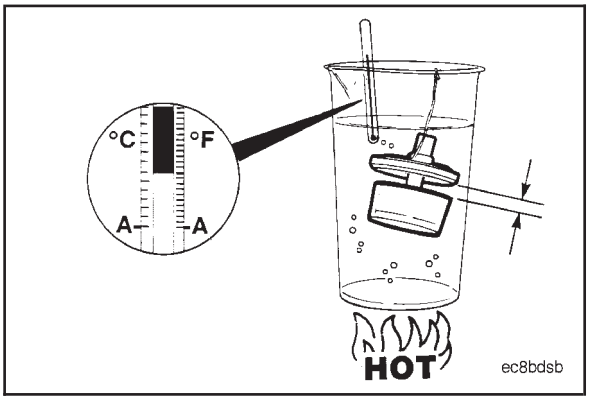
Heat the water and check the thermostat as follows.



The nominal operating temperature is stamped on the thermostat.

- Thermostat **must** begin to open within 2°C [3°F] of nominal temperature.
- Thermostat **must** be fully open at 12°C [22°F] above nominal temperature.

The fully open distance between the thermostat flange and housing is 11.05 mm [0.43 in].



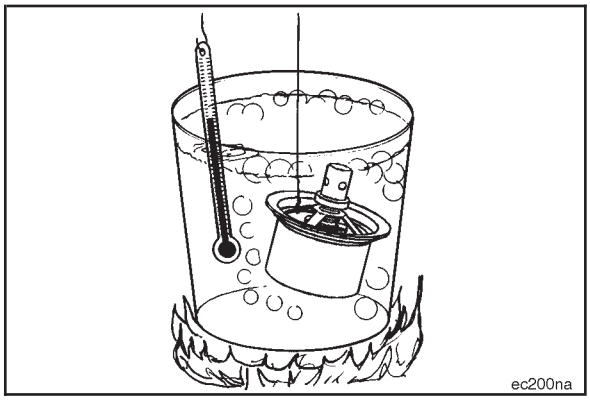
Remove the container from the heat. Check to see if the thermostat returns to the closed position.

Low Temperature Aftercooling Thermostat

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

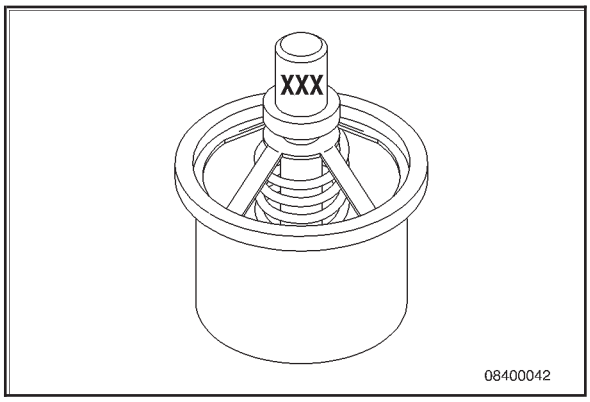
Heat the water and check the thermostat as follows.



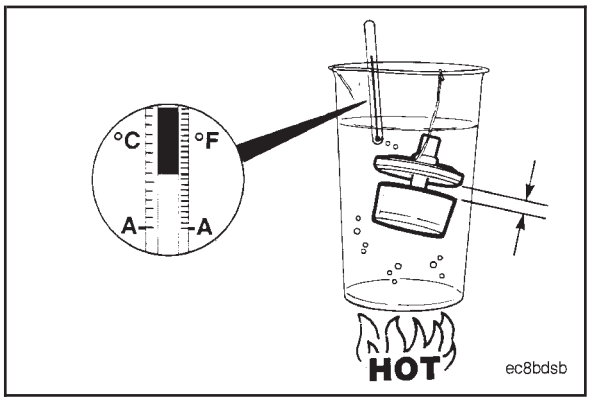
The nominal operating temperature is stamped on the thermostat.

- Thermostat **must** begin to open within 2°C [3°F] of nominal temperature.
- Thermostat **must** be fully open at 8°C [15°F] above nominal temperature.

The fully open distance between the thermostat flange and housing is 7.8 mm [0.3 in].



Remove the container from the heat. Check to see if the thermostat returns to the closed position.



Coolant Thermostat Housing Support (008-015)

General Information

LTA Cooling System The Low Temperature Aftercooling (LTA) arrangement incorporates a dual loop cooling system that shares a single water pump.

Thermostat Support The thermostat assembly contains a support and thermostat housing. The thermostat housing contains two thermostats (conventional aftercooling) or three thermostats (low temperature aftercooling). The support assembly also provides for connection of the water outlet tubing for the cylinder head and the aftercooler.

Thermostat The QSK19 engines **must** have thermostats that do **not** have a vent.

The Low Temperature Aftercooling (LTA) arrangement uses two coolant thermostats and one LTA thermostat. The LTA thermostat is located in the center position between the engine coolant thermostats.

Thermostat Seal Each thermostat has one thermostat seal.

Fan Drive Idler Arm Assembly (008-029)

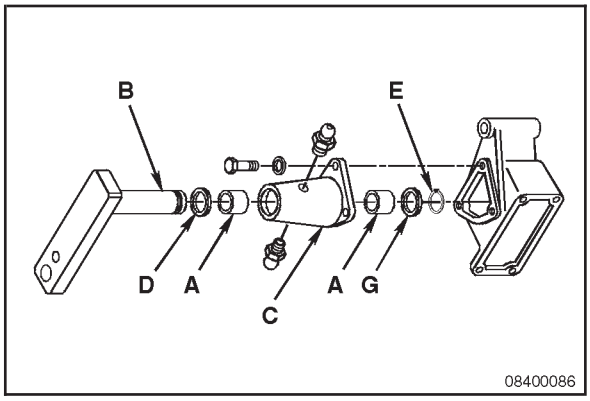
Disassemble

Remove the three mounting capscrews holding the pivot shaft support to the alternator support.

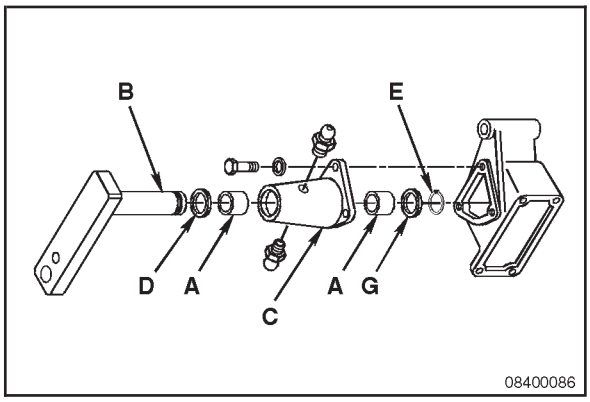
Remove the snap ring from the idler lever.

Remove the idler lever.

Remove the oil seals.



Remove the bushings from the pivot shaft support.



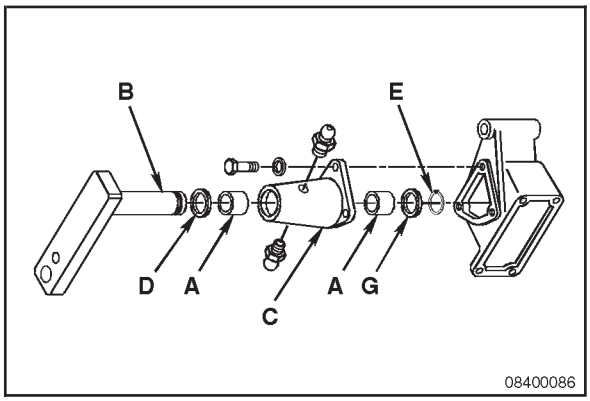
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

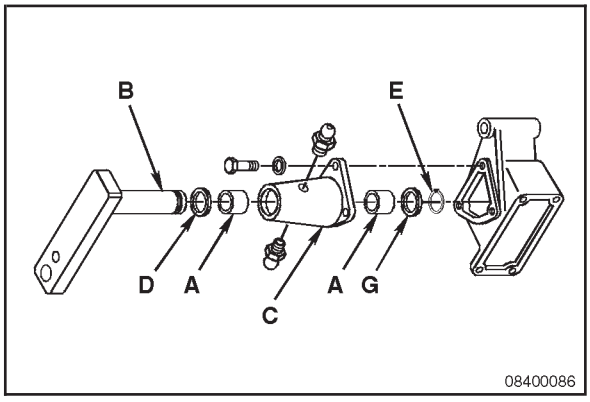
Use solvent to clean the parts.

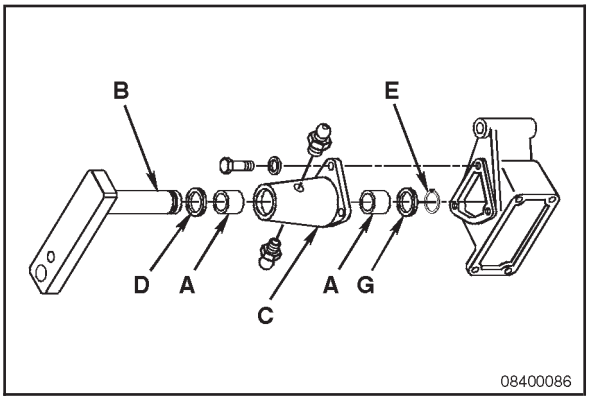
Dry with compressed air.



Inspect for Reuse

Inspect the parts for any damage.

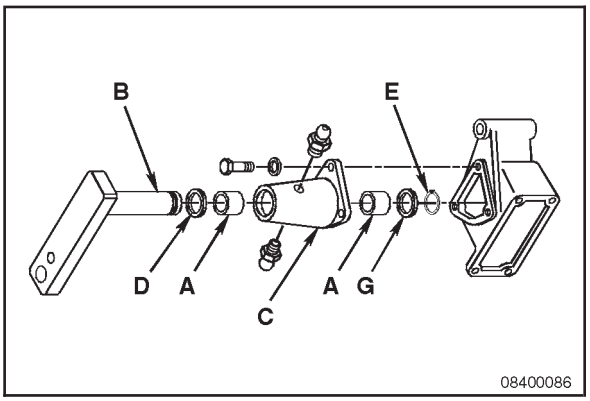




Assemble

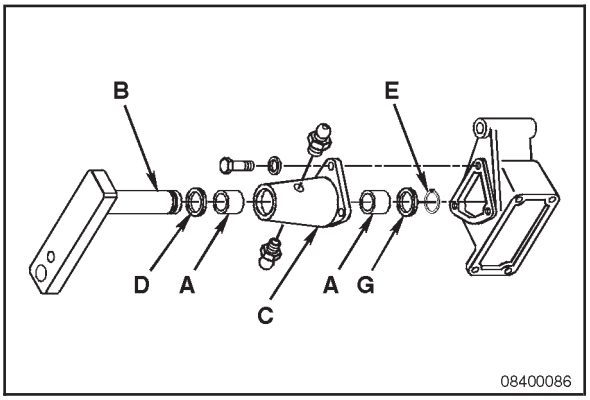
Use an arbor press to install the new bushings.

Install new oil seals.



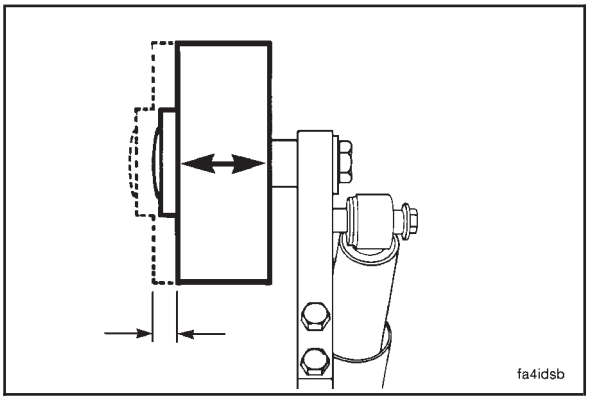
Install the idler lever into the pivot shaft support.

Install the snap ring into the snap ring groove on the idler lever.



Install the pivot shaft support to the alternator support.

Install the mounting capscrews.



Fan Drive Idler Pulley Assembly (008-030)

Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the pulley assembly.

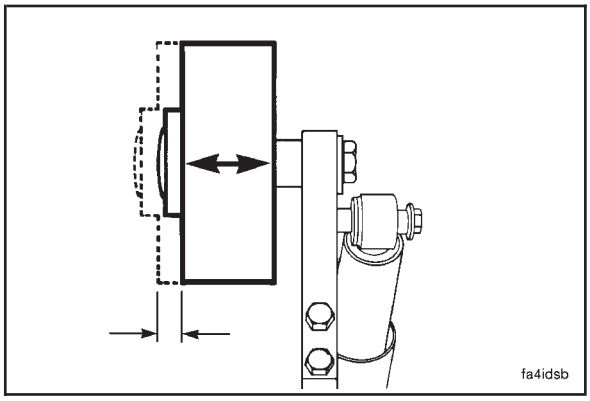
Inspect for Reuse

Check the clearance.

Bearing End Clearance		
mm		in
0.08	MIN	0.003
0.25	MAX	0.010

Rotate the pulley. Check for rough or damaged bearings.

The bearings **must** be replaced if any of the above conditions are found.



Fan Hub, Belt Driven (008-036)

General Information

NOTE: For service and parts information for the fan hub with a clutch, refer to Bulletin No. 3810250, Rockford® Fan Clutch Service and Parts Manual. For rebuild instructions for the fan hub clutch, refer to Bulletin No. 3810251, Rockford® Clutch Overhaul Procedure.

The fan belt is tensioned by the spring loaded idler assembly and does **not** require adjustment.

⚠ CAUTION ⚠

The fan belt is mounted with spring tension. To avoid personal injury from being pinched between the fan hub and fan idler, always release the spring tension before removing or installing the belt.

When the pivot arm cap is aligned properly with the spring, tension is a minimum of 68 N•m [50 ft-lb].

A grease nipple is standard on the pivot arm. The pivot arm **must** be greased at each scheduled maintenance interval *.

Newer engines have a turnbuckle assembly to limit the travel of the idler pulley. **Older** engines have a shock absorber to limit the travel of the idler pulley. The shock absorber can be replaced by the turnbuckle assembly. The adjustment of the turnbuckle **must** be checked at each scheduled maintenance interval *. The shock absorber **must** be checked for fluid leakage and loss of vibration absorption at each scheduled maintenance interval *.

Fan hubs and supports are available in various drive ratios and fan center locations. When replacing the fan hub, **always** check the part number. Be sure the replacement is compatible.

All of the belt driven fan hubs contain anti-friction bearings that are the tapered roller type. Bearing end clearance is controlled by the use of **inner** and **outer** bearing spacers. It is a good service practice to tag the bearings for location during removal. **Always** replace the bearing and the bearing race if either piece requires replacement.

The idler pulley contains two anti-friction bearings that are the tapered roller type. The bearing end clearance is properly set by matching select components in the kit.

⚠ CAUTION ⚠

Always replace the complete bearing kit when any piece of the idler pulley bearing assembly requires replacement.

The kit includes a retaining ring, an inner spacer, two bearings, and two bearing races.

⚠ CAUTION ⚠

Never grease the bearings excessively. Too much grease will cause excessive heating due to the agitation of the grease. Excessive agitation of the grease will result in failure.

The following is the proper method of applying water pump type grease to the fan hub or idler pulley bearings. Do **not** use lithium base grease for fan hub bearings.

Pack both bearings with grease. Fill the cavity between the bearings 2/3-full of grease. Fill the cavity between the front bearing and the end of the hub 2/3-full of grease.

* Recommended maintenance interval refers to every 250 hours, or 6 months of operation.

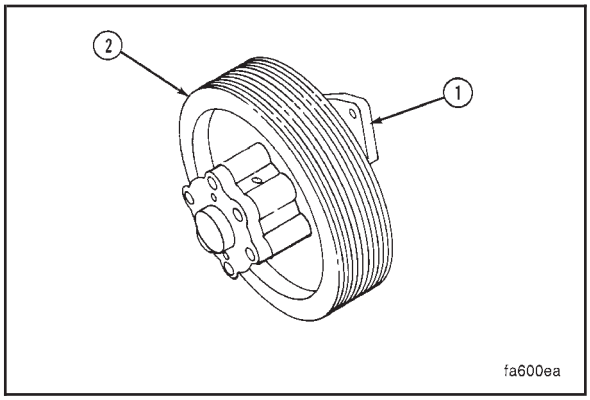
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the fan hub.

Dry with compressed air.



Inspect for Reuse

Inspect the fan hub for reuse. Rotate the pulley to check for rough or damaged bearings.

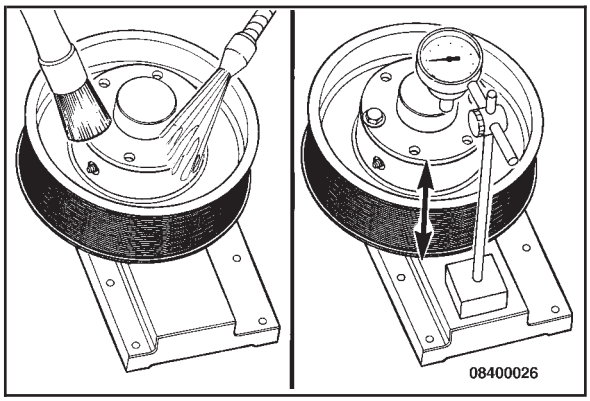
Check bearing end clearance.

Bearing End Clearance		
mm		in
0.03	MIN	0.001
0.25	MAX	0.010

If the clearance is **not** within the specifications, the fan hub **must** be rebuilt.

Rotate the pulley to check for rough or damaged bearings.

If the fan hub does **not** rotate freely, the fan hub **must** be rebuilt.

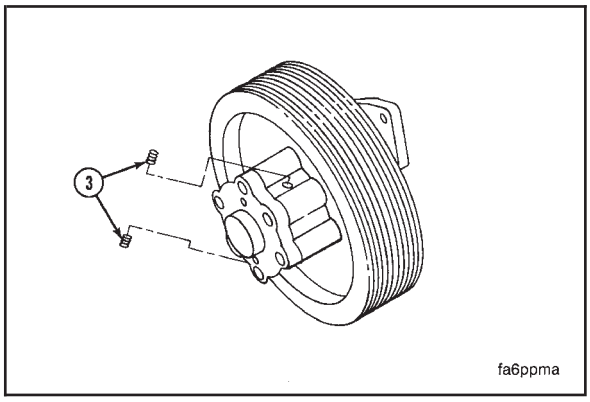


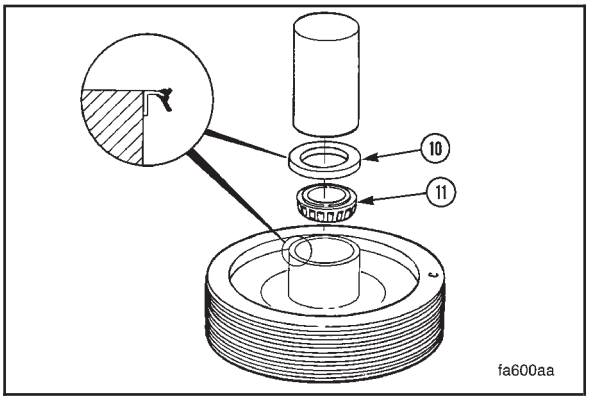
Remove the pipe plugs (3). Install a grease fitting in one of the holes.

Use a grease gun and water pump type grease. Pump grease into the hub until it begins to come out of the open plug hole.

Remove the grease fitting. Install the pipe plugs (3).

Torque Value: 15 N•m [135 in-lb]





Assemble

⚠ CAUTION ⚠

Do not lubricate the seal surface of the shaft. The seal and seal surface must be clean and dry.

Lightly grease the bearing (11) with Mobiplex® 48 grease or equivalent.

NOTE: Excessive grease will affect the end float reading.

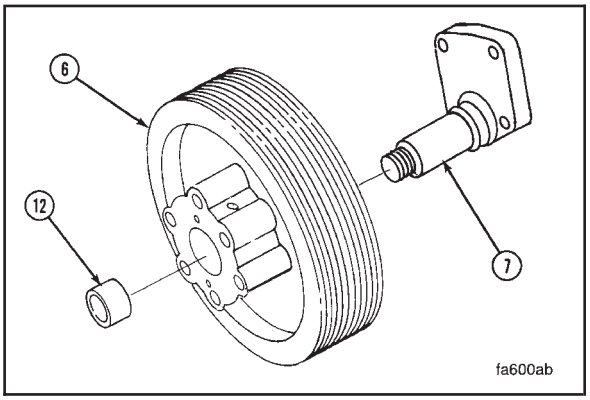
Install the bearing in the hub.

⚠ CAUTION ⚠

Avoid contact with skin.

Apply Loctite® 675 or equivalent to the outside diameter of the seal.

Use a mandrel to install the seal (10). With the flat unseamed face toward the shoulder of the driver, press seal in until it bottoms.



Carefully install the fan hub seal end first over the shaft, ensuring no damage occurs to the seal. The **rear** bearing **must** slide easily on the shaft. If it does **not**, check for chips or burrs.

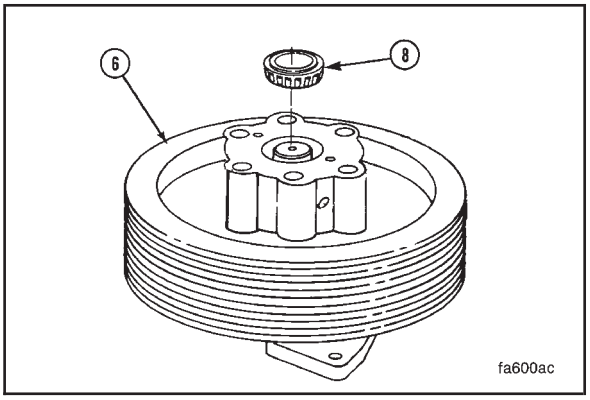
Install the inner bearing spacer (12). The following spacers are available to provide correct end clearance when the fan hub has been assembled.

For two spacer style fan hubs:

a . 3627681
b . 3627682
c . 3627683
d . 3627684

For other fan hubs:

a . 3627677
b . 3627678
c . 3627679
d . 3627680
e . 3628830



Lightly grease the **front** bearing (8).

Install the bearing, it **must** slide easily over the shaft. If it does **not**, check for chips and burrs.

CAUTION

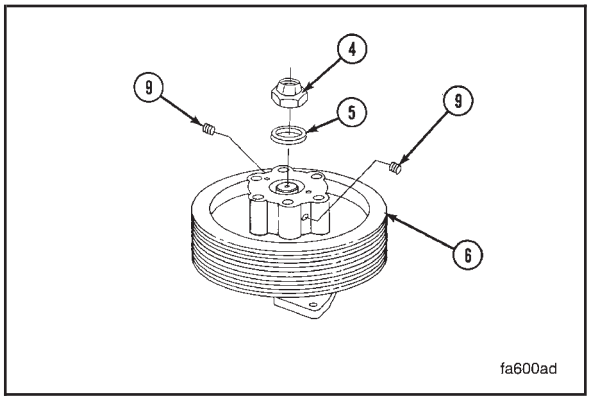
Remove all grease from the threads on the shaft before installing the lock nut. Grease on the threads reduce the torque retention of the lock nut.

Install the hardened washer (5).

Install the lock nut (4).

Tighten the lock nut.

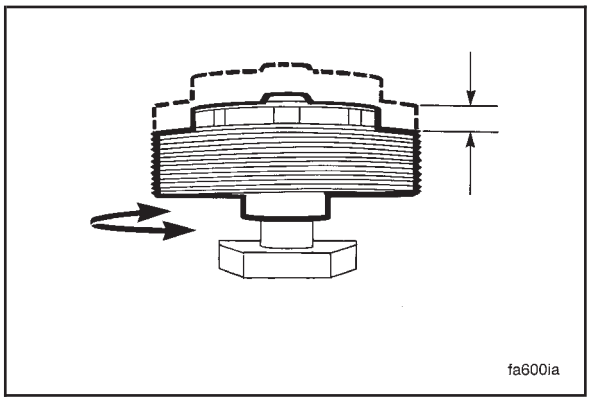
Torque Value: 610 N•m [450 ft-lb]



Use a dial indicator to measure the bearing end clearance.

Bearing End Clearance		
mm		in
0.025	MIN	0.001
0.102	MAX	0.004

If the clearance is **not** within specifications, rebuild the fan hub with a suitable size spacer. Check the bearing end clearance.



CAUTION

Do not use more grease than specified. Too much grease will cause excessive heating and failure.

Use Mobiplex® 48 grease or equivalent and fill the cavity with 120 cc of grease. Grease the inner race, refit the spacer and inner race,

Install the hardened washer (5).

Install the lock nut (4).

Check the bearing end clearance.

Install the o-ring (3) on the fan pilot (2).

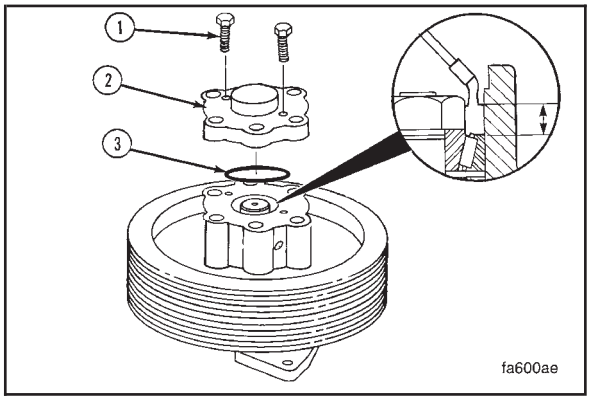
Use vegetable oil to lubricate the o-ring.

Install the fan pilot and o-ring

Install the capscrews (1).

Tighten the capscrews.

Torque Value: 20 N•m [15 ft-lb]



Fan, Cooling (008-040)

General Information

⚠ WARNING ⚠

Never attempt to rotate the engine by pulling or prying on the fan. This practice can result in serious personal injury and damage to the fan. Use only the proper engine barring techniques to manually rotate the engine.

Check the fan for missing balance weights at each regular maintenance interval*. Do **not** attempt to repair broken or bent fans, or fans with missing balance weights.

The majority of equipment that has a Cummins® engine has a radiator and a fan. The radiator and fan transfer heat from the cooling water to the atmosphere. The fan selection process **must** conclude that the fan, the fan mounting arrangement, and the fan drive system are designed and matched for compatibility.

Upon request, Cummins Application Engineering Department will assist in determining the proper selection. Refer any fan changes, other than the direct replacement of a fan with precisely the same Cummins® part number, to the Cummins Application Engineering Department for prior approval.

Examples that require approval are:

- Using an approved fan from one engine model on a different engine model.
- Using an approved fan on an engine with a different fan mounting arrangement.
- Using an approved fan on an engine with a different fan drive arrangement.
- Converting an engine from one market model to another.

  An example is the conversion of a G-drive engine to a power unit application.
- Converting an engine model to a different engine model.

  An example is converting a N-855 to a NT-855 model.

These examples are **not** inclusive. **Always** contact Application Engineering for assistance.

There are times when an existing fan can yield ONLY marginal cooling capability when being considered for a new application.

⚠ WARNING ⚠

Never repitch (bend) the blades to obtain additional air delivery. Bending the blades or spider creates stress in the construction material of the fan. Repitching (bending) will cause fan failure and can cause serious personal injury. The proper diameter fan must be selected. Never modify an existing fan.

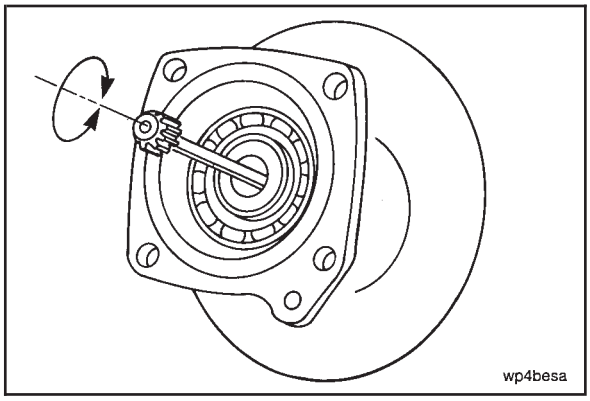
Application Engineering will provide assistance in the selection of a fan with the correct pitch and diameter for proper cooling.

*Recommended maintenance interval refers to every 250 hours or 6 months of operation.

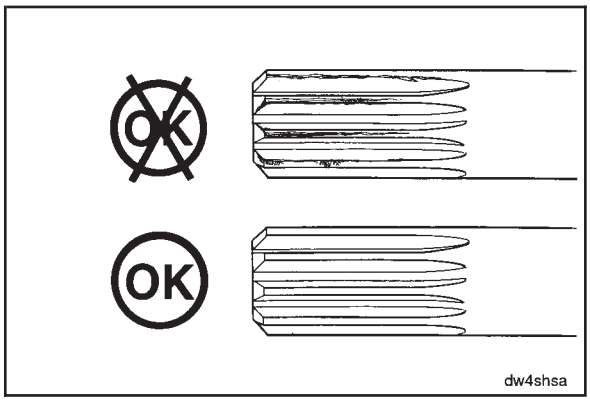
Water Pump (008-062)

Inspect for Reuse

Rotate the shaft and inspect for rough or damaged bearings.

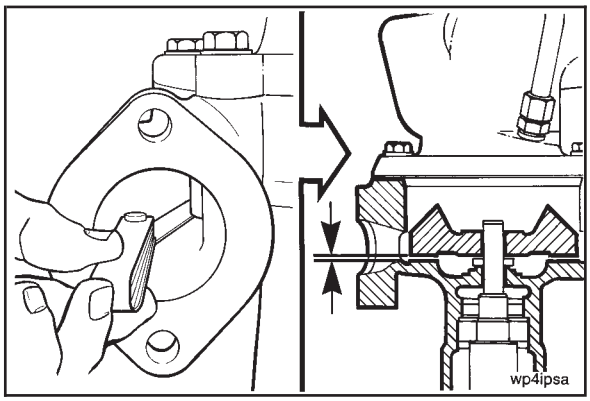


Inspect the drive shaft for wear. If the drive shaft splines are worn, check the female splines in the pump and in the water pump drive.



Use a feeler gauge and measure the impeller-to-pump body clearance.

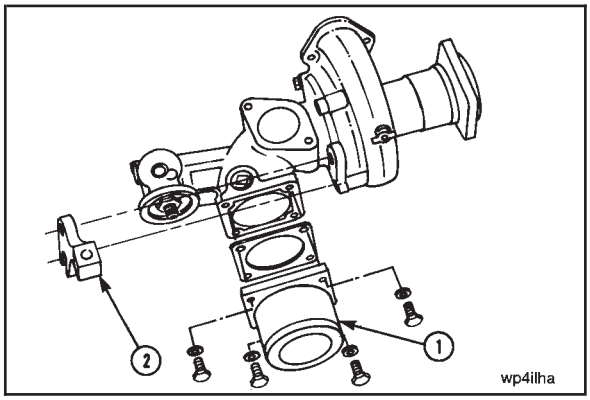
Impeller Vane-To-Body Clearance		
mm		in
0.58	MIN	0.023
0.86	MAX	0.034

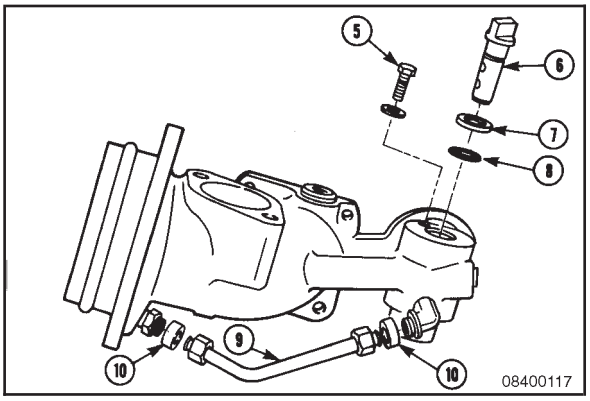


Disassemble

Remove the water inlet connection and gasket (1).

Remove the support bracket (2).

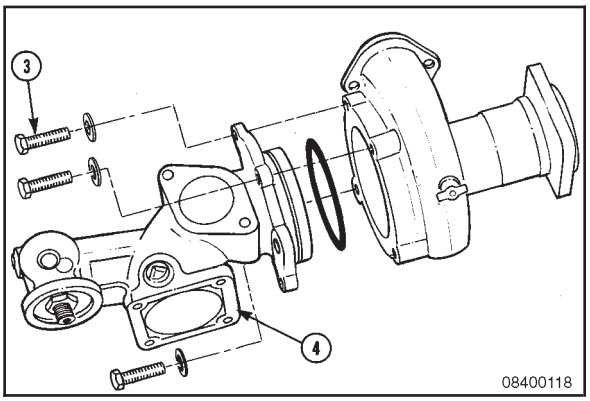




Remove the parts.

5. Shutoff valve capscrew
6. Water shutoff valve
7. Washer
8. O-ring
9. Water transfer tube (Loosen the flare nut at each end.)
10. Grommets

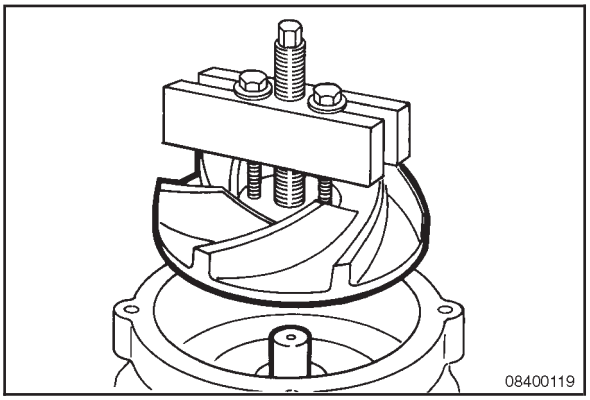
Discard the o-ring and grommets.



Remove the remaining capscrews (3).

Remove the inlet housing and o-ring (4).

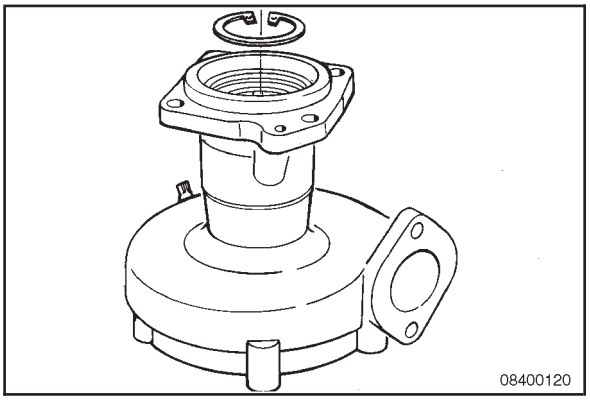
Discard the o-ring.



⚠ CAUTION ⚠

The jack screw in the puller must pass easily through the impeller bore to prevent damage to the impeller.

Use a standard puller, Part No. ST-647, or equivalent and remove the impeller.

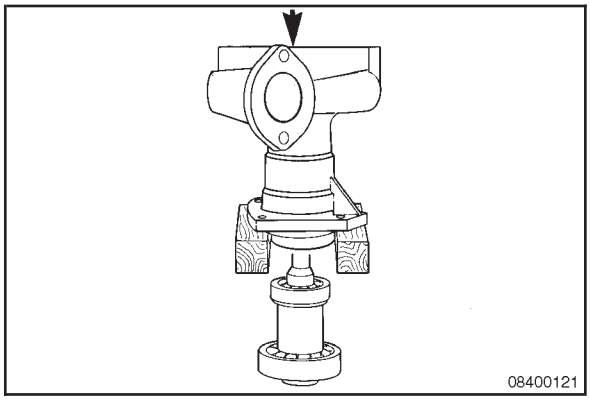


Remove the large retaining ring.

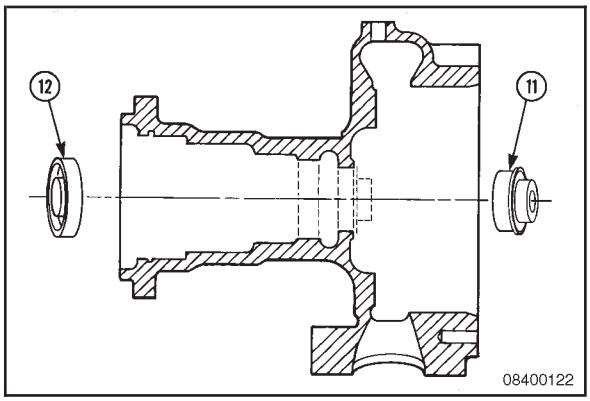
Support the water pump body as shown.

Use an arbor press to push on the impeller end of the shaft. Remove the bearing and shaft assembly.

Discard the water pump seal seat.



Remove and discard the water seal and oil seal.



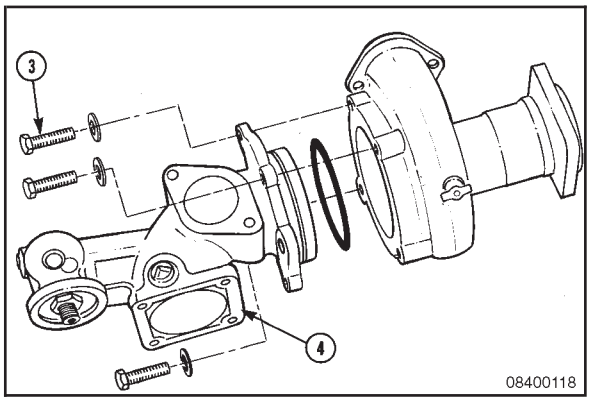
Clean

CAUTION

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendation for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean all the parts.

Dry with compressed air.

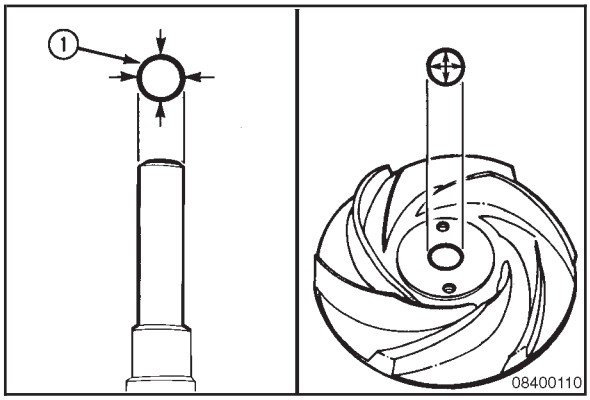


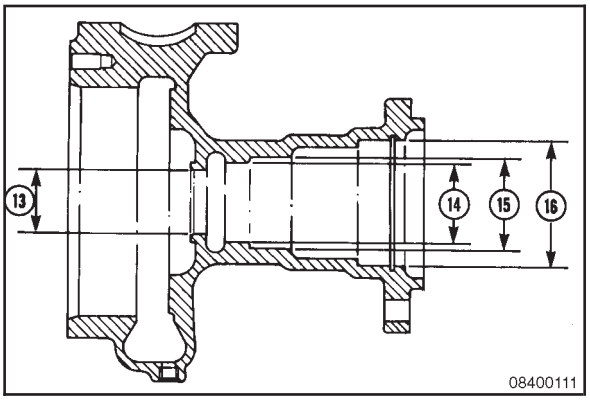
Inspect

Use the following formula to determine the press fit.

Press Fit = Shaft O.D. (1) minus Impeller I.D. (2).

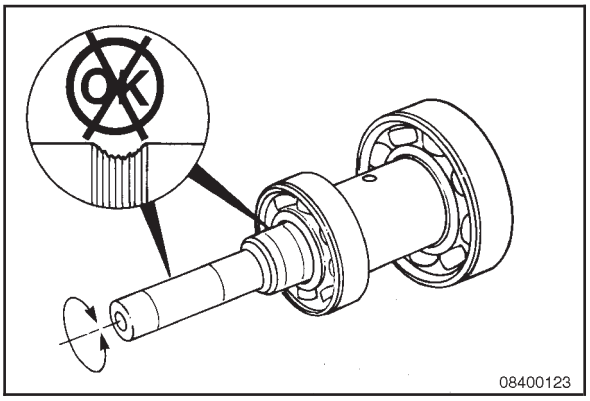
Impeller to Shaft Press Fit		
mm		in
0.03	MIN	0.001
0.07	MAX	0.003





Measure the I.D. of the water pump housing bore.

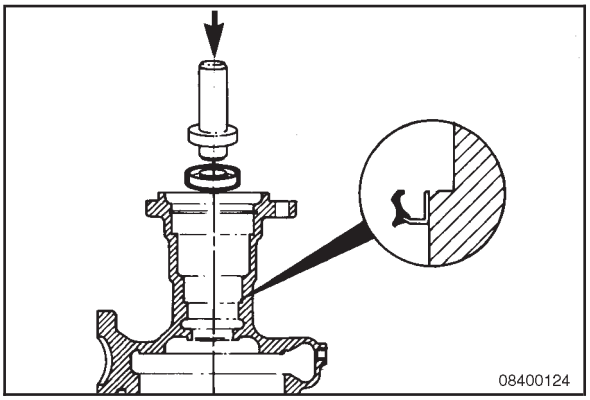
	Housing Bore I.D. mm		in
(13) Water Seal	36.45	MIN	1.435
	36.47	MAX	1.436
(14) Oil Seal	44.43	MIN	1.749
	44.48	MAX	1.751
(15) Rear Bearing	51.996	MIN	2.0471
	52.215	MAX	2.0557
(16) Front Bearing	71.996	MIN	2.8345
	72.215	MAX	2.8431



Inspect the bearing and shaft assembly for wear in the seal areas.

Spin the bearings to check for roughness.

If the bearings or shaft must be replaced refer to Procedure 008-071.



Assemble

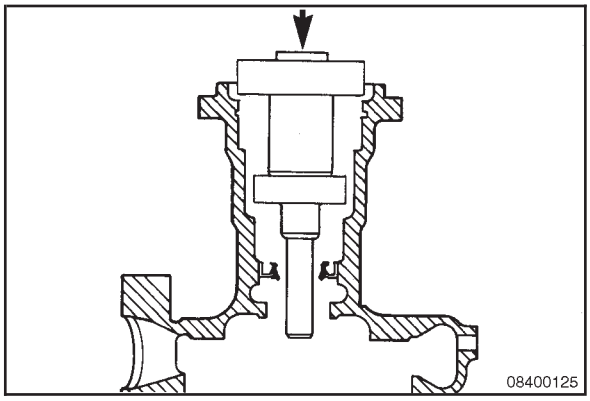
NOTE: The oil seal must be installed with the part number pointing down.

Use a water pump seal mandrel, Part No. 3375320, or equivalent and install the seal.

The seal **must** be **no** more than 0.51 mm (0.020 in.) below the top of the step in the body.

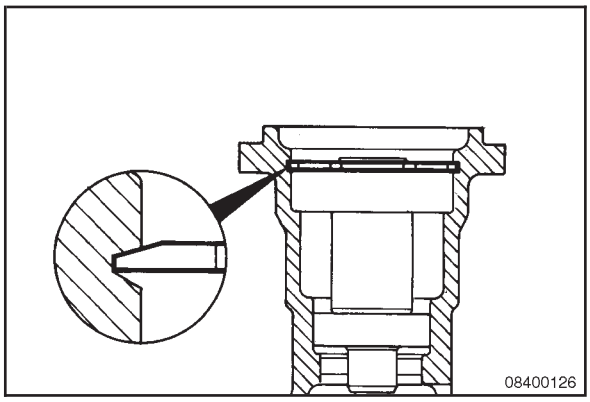
Support the water pump housing.

Use an arbor press and water pump bearing mandrel, Part No. 3375318, or equivalent, or push on the end of the shaft. Install the shaft and bearing assembly.



NOTE: The beveled edge must be positioned as shown.

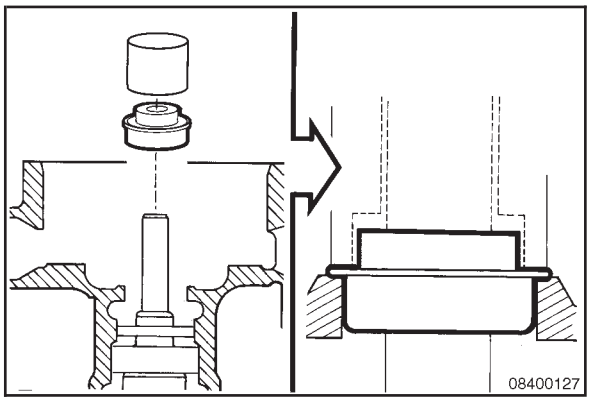
Install the large retaining ring.



Use water pump seal driver, Part No. 3376091, or equivalent and install the water seal.

NOTE: The shoulder on the seal **must** touch the housing.

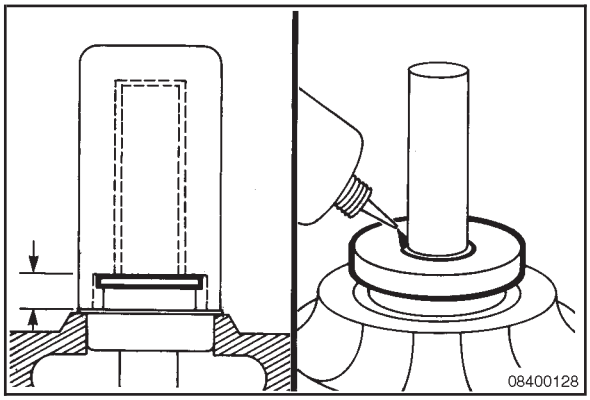
NOTE: This illustration shows the **two-piece** seal. This step is the **same** for the **one-piece** seal. The water pump seal driver **must** be used to adjust the spring tension correctly.



Use an arbor press and water pump seal driver, Part No. 3376091, or equivalent and install the seal seat.

The seat dimension below applies to the **one-piece** and the **two-piece** seal. The seal tension will **not** be correct if the seat dimension is **not** within specifications.

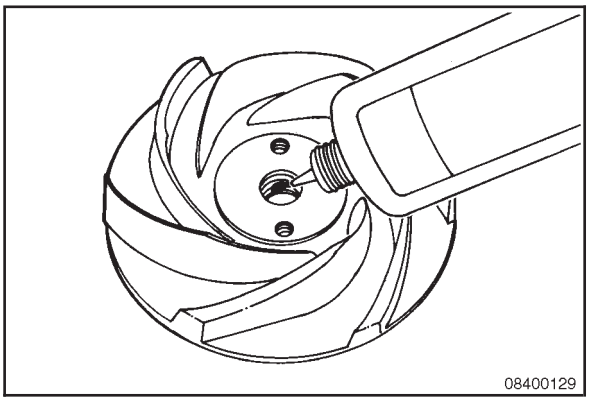
Seat Dimension		
mm		**in**
10.52	MIN	0.414
10.57	MAX	0.416



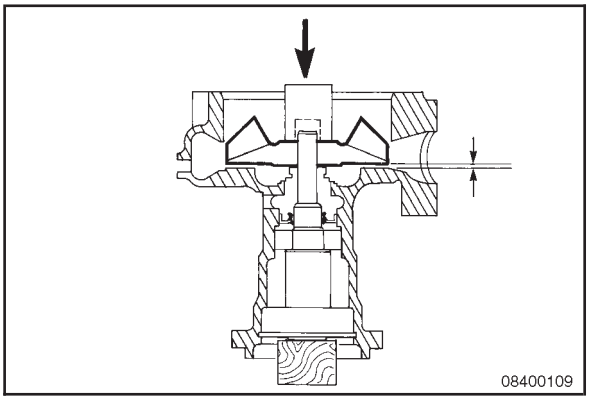
⚠ CAUTION ⚠

More than one drop will glue the faces of the seal together. It can result in damage to the seal.

Apply one drop of Loctite® 290, or equivalent to the seal seat as shown.



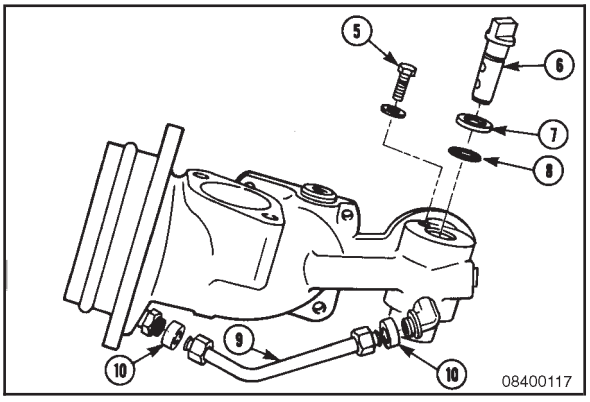
Apply a smooth coating of Loctite® 609, or equivalent to the I.D. of the impeller as shown.



Use an arbor press and a mandrel to install the impeller to the specified clearance.

NOTE: Use a feeler gauge in the water outlet port to measure the clearance.

Impeller Vane to Body Clearance		
mm		**in**
0.58	MIN	0.023
0.86	MAX	0.034



Install the washer (7).

Use vegetable oil to lubricate the o-ring (8). Install the o-ring.

Install the shutoff valve.

Install the capscrew (5).

Torque Value: 20 N•m [15 ft-lb]

Use vegetable oil to lubricate the new grommets (10).

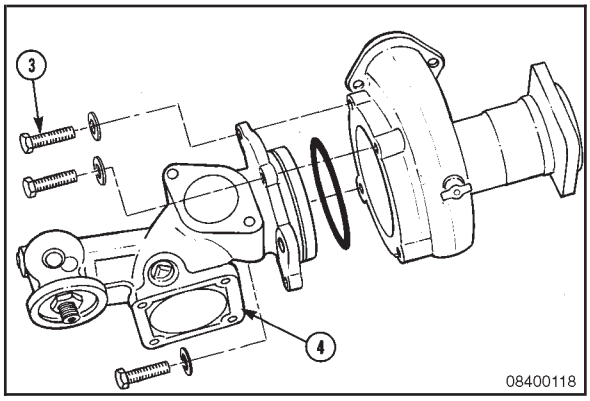
Install the transfer tube.

Use vegetable oil to lubricate the o-ring.

Install the parts as shown.

Install the capscrews.

Torque Value: 45 N•m [35 ft-lb]

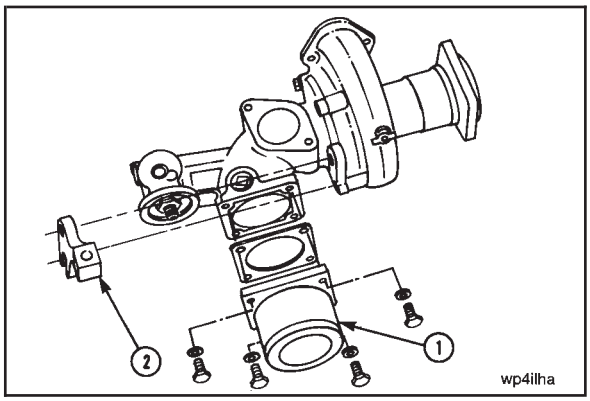


Install the inlet connection (1), gasket, and capscrews.

Torque Value: 40 N•m [30 ft-lb]

NOTE: Do **not** tighten the support bracket until the water pump is assembled to the engine.

Install the support bracket (2).



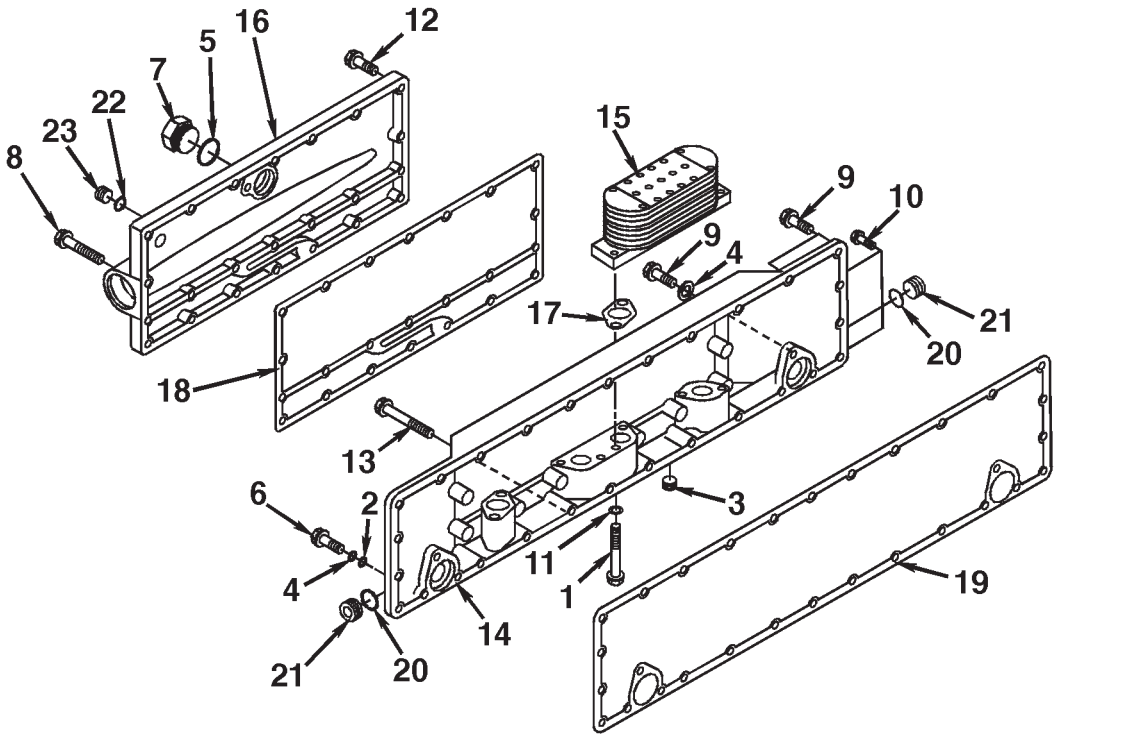
Torque Converter Cooler (008-065)

General Information

The engine mounted torque converter cooler is available as an **option**. This **option** can be added to a **standard** engine by purchasing the torque converter cooler housing, the cooler cover, and the elements.

The location of the turbocharger oil drain line, turbocharger water supply line, and the other components will have to be changed on some engines. The torque converter cooler is mounted and **replaces** the lubricating oil cooler cover. When the torque converter cooler **option** is selected, longer mounting capscrews **must** be used. With the torque converter cooler option, the turbocharger water supply line **must** also be moved from the oil cooler cover to a fitting in the top of the torque converter cooler housing.

Exploded View



07400103

1. Cover, Torque Converter Oil
2. Gasket, Lubricating Oil Cooler Cover
3. O-ring
4. Element, Lubricating Oil Cooler
5. Housing, Torque Converter Cooler
6. Nut, Self-Locking
7. Capscrew, Lock Washer, and Plain Washer
8. Capscrew and Lock Washer
9. Capscrew, Lock Washer, and Plain Washer
10. Capscrew, Lock Washer, and Plain Washer

Inspect for Reuse

NOTE: Heating the water in the tank to 50° C [120° F] will improve the test results.

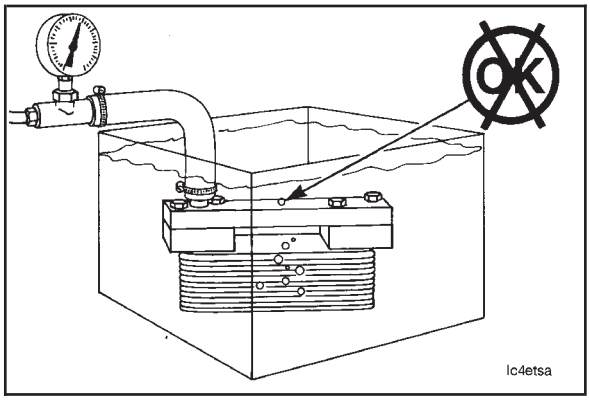
Pressure test the elements.

Apply air pressure, and check for leaks.

NOTE: Discard the elements if any debris is found, the engine has had a debris causing failure, or the torque converter has failed.

Air Pressure		
kPa		psi
415	MAX	60

Discard the elements if any leaks are present.



Assemble

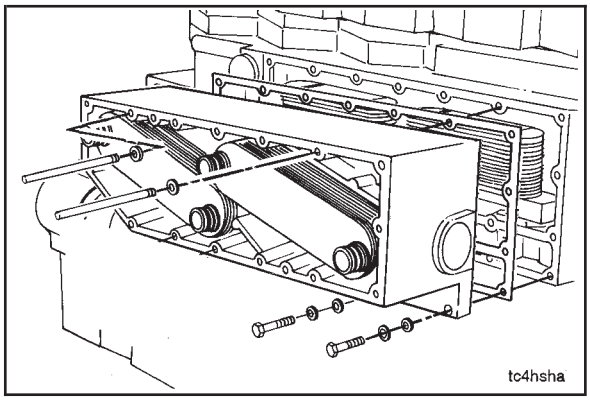
Install the elements.

Torque the self-locking nuts.

Torque Value: 130 N•m [95 ft-lb]

Use vegetable oil adn lubricate the new o-rings.

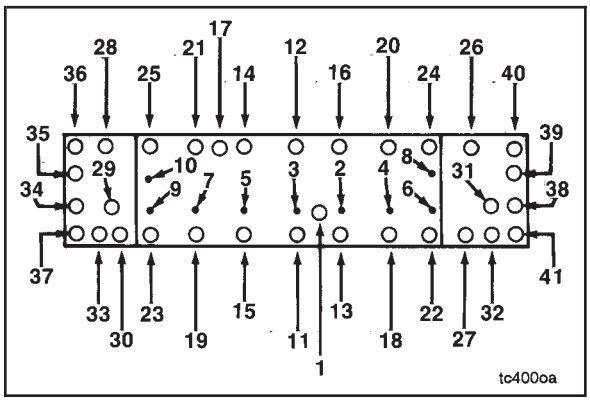
Install the new o-rings.



Install the gasket and cooler cover.

Torque the capscrews in the sequence shown.

Torque Value: 45 N•m [35 ft-lb]

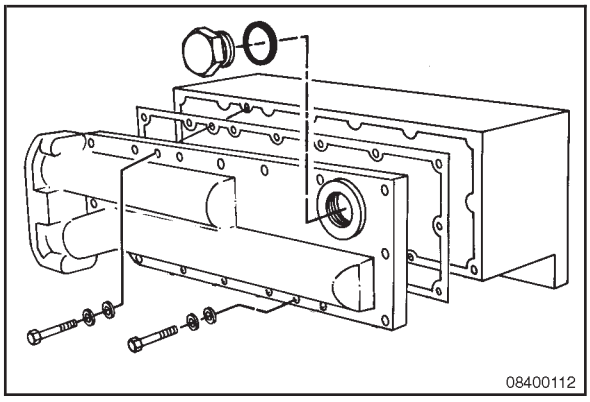


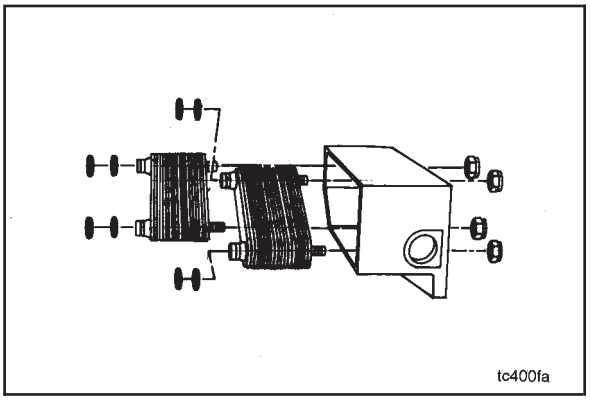
NOTE: Use Loctite 592, or equivalent to seal heater plug.

Apply a smooth coating of sealant to the threads of the heater plug.

Install and torque the heater plug

Torque Value: 75 N•m [55 ft-lb]





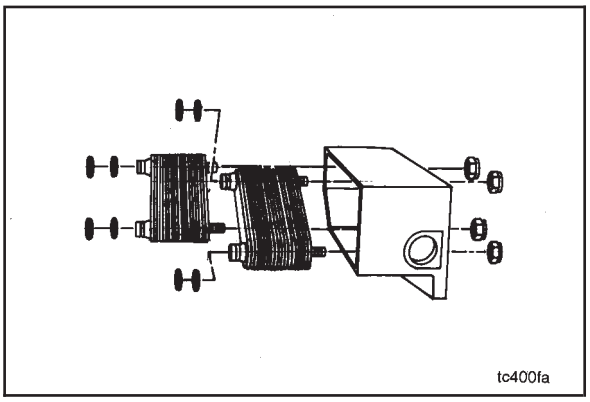
Disassemble

Remove the torque converter cover mounting bolts and cover.

NOTE: The cover **must** be pried from the housing, because of the tight fit between the cover and the o-rings on the elements.

Remove the cooling elements.

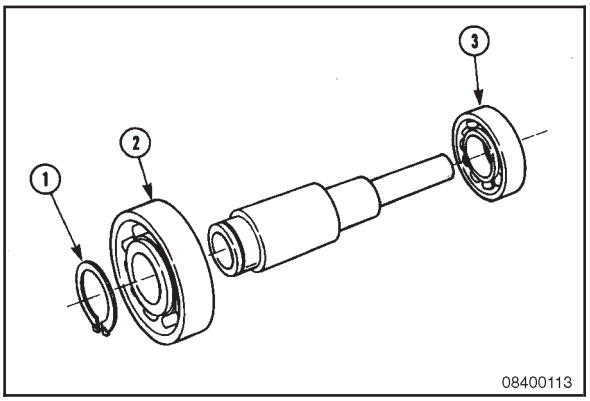
Discard the o-rings.



Clean

Use a solvent that will **not** harm copper and clean the elements.

Use a solvent that will **not** harm aluminum and clean the housing and cover.



Water Pump Bearings (008-071)

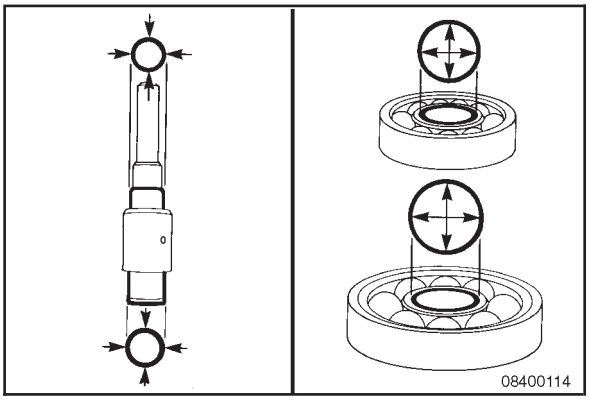
Remove

Use a water pump bearing separator, Part No. 3375326, or equivalent, to disassemble the bearing and shaft assembly.

Remove the retaining ring (1).

Remove the front bearing (2).

Remove the rear bearing (3).



Measure

Measure the shaft O.D. and the bearing I.D. Compare the differences.

Bearing to Shaft Differences			
	mm		in
Clearance	0.003	MAX	0.0001
Interference	0.018	MAX	0.0007

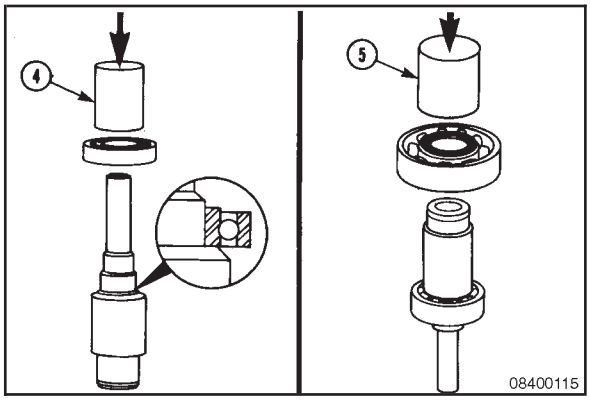
Install

CAUTION

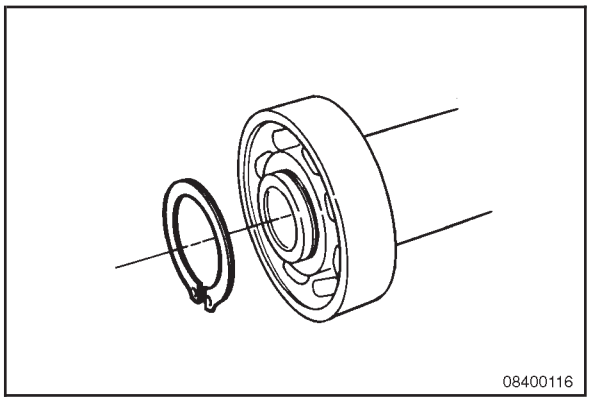
The mandrel must make contact on the inner race of the bearing to prevent damage to the bearing.

Support the shaft.

Use an arbor press and a water pump bearing mandrel, Part No. ST-658 (4), or equivalent, install the bearings.



Install the retaining ring.



NOTES

Section 9 - Drive Units - Group 09

Section Contents

Drive Units - General Information

General Information

The accessory drive housing is manufactured of aluminum. The aluminum housing does **not** contain a bushing, and does **not** require thrust washers.

⚠ CAUTION ⚠

Installation of an air compressor on a fuel pump drive housing will result in failure due to the lack of lubrication.

The housings are available in two designs, **with** and **without** provisions for mounting an air compressor. Those **without** air compressors do **not** have provisions for a compressor oil pressure and drain-back. The fuel pump drive has provisions for a lovejoy coupling. The compressor drive has provisions for a splined sleeve-type coupling. The procedures are identical for both of the designs.

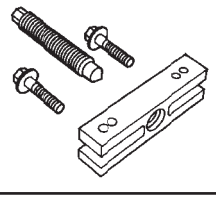
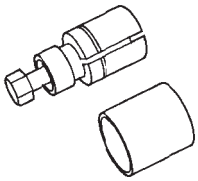
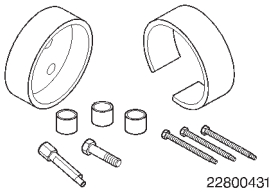
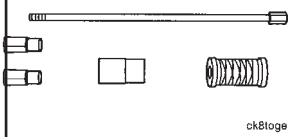
The fuel pump/compressor drive gear has stamped marks. The stamped marks **must** be aligned properly with the camshaft idler gear so that valve and injector adjustment marks on the accessory drive pulley are oriented correctly.

The retainer capscrew on the compressor drive (splined half-coupling) is special. It has a drilling in it that provides lubrications of the splined coupling. The retainer capscrew on the fuel pump drive (lovejoy half-coupling) does **not** have an oil drilling.

Service Tools

Drive Units

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

Tool No.	Tool Description	Tool Illustration
ST-647	**Gear Puller** Used to remove the drive pulleys and impellers.	 ad8toga
3376326	**Pulley Installation Tool** Used to install drive pulleys.	 ad8togb
3376663	**Coupling Puller** Used to remove accessory drive coupling.	 hp8togg
3824760	**Oil Seal Remover/Installer** Used to remove small bushings, oil seals, and bearings.	 22800431
3375066	**Pipe Sealant** Use when installing pipe plugs or cup plugs on the engine in order to prevent leaks.	 ew8togc
ST-1134	**Dowel Pin Extractor** Used to pull dowel pins.	 ck8toge

Accessory Drive Pulley (009-004)

Remove

CAUTION

Use a capscrew in the shaft to prevent damage to the shaft threads.

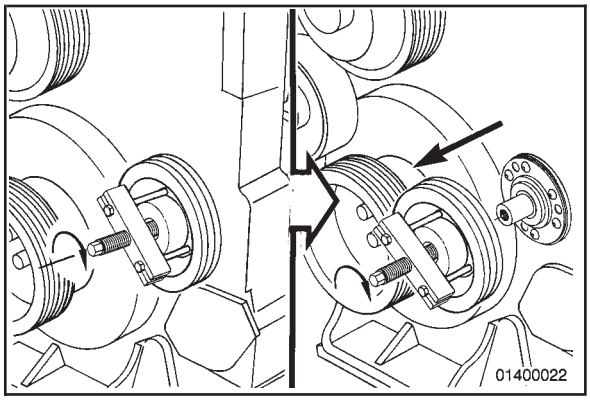
Install a [7/16-20x1 in] capscrew in the shaft.

Use a standard puller, Part No. ST–647, or equivalent. Remove the accessory drive pulley.

Use a brass drift and remove the woodruff key from the shaft.

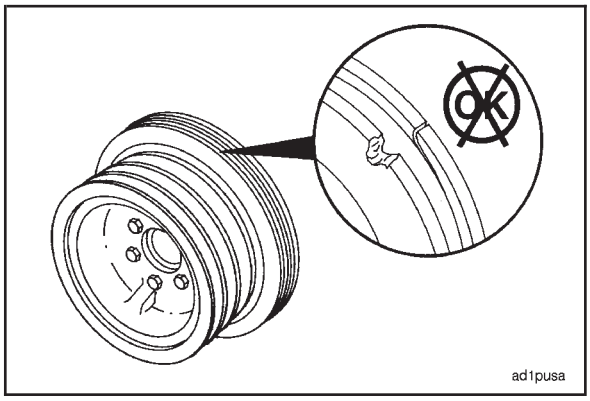
Remove the capscrew from the shaft.

Remove the keyway seal.

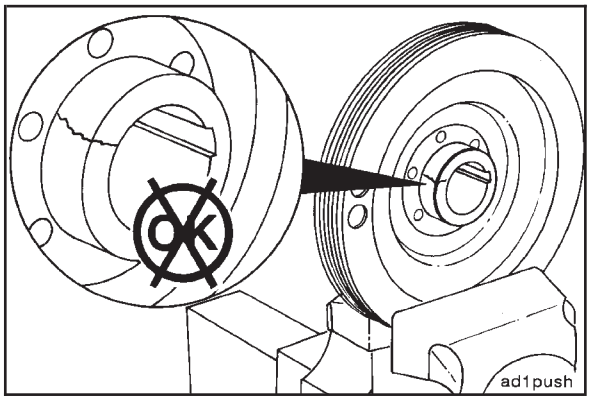


Inspect for Reuse

Visually inspect the pulley for cracks, wear in the belt grooves, or other damage.



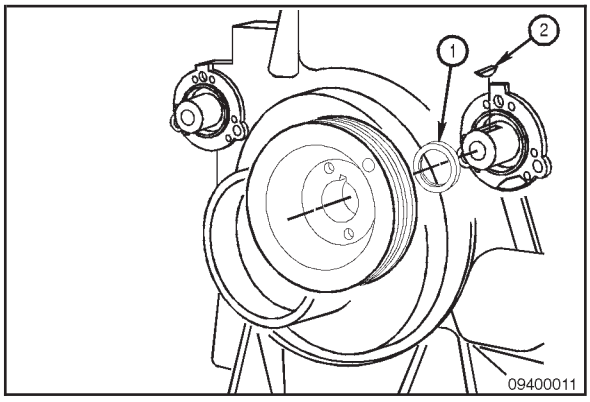
Inspect the mating surface and pulley bore areas for damage.

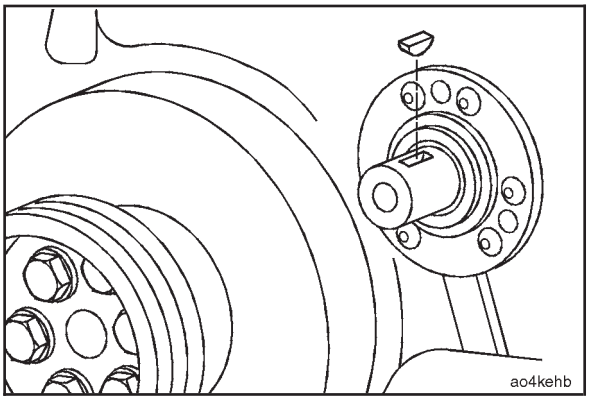


Install

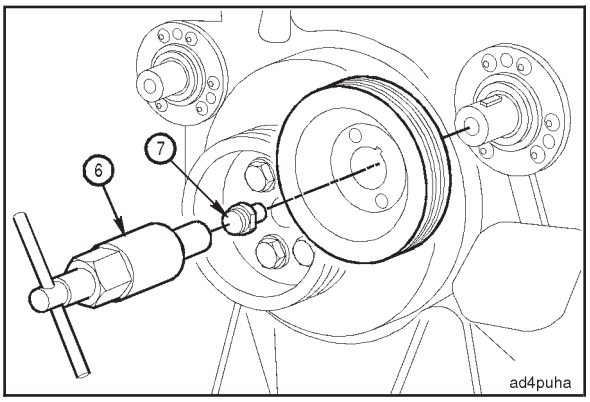
NOTE: The keyway seal must be installed before installing the woodruff key.

Install the keyway seal.





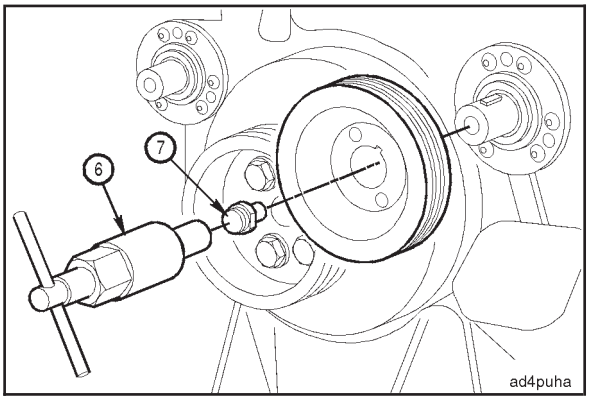
Install the woodruff key.



⚠ CAUTION ⚠

Do not use a hammer to drive the pulley into position. Damage to the thrust bearing will result.

Use pulley installation tool kit, Part No. 3376326. Insert the appropriate adapter (7) in the pusher.



Lubricate the shaft O.D. and the pulley I.D. with engine oil.

Align the keyway in the pulley with the key in the shaft. Use the tool to push the pulley on the shaft until it touches the step on the shaft.

Fuel Pump Drive (009-011)

General Information

The accessory drive housing is manufactured of aluminum. The aluminum housing does **not** contain a bushing, and does **not** require thrust washers.

⚠ CAUTION ⚠

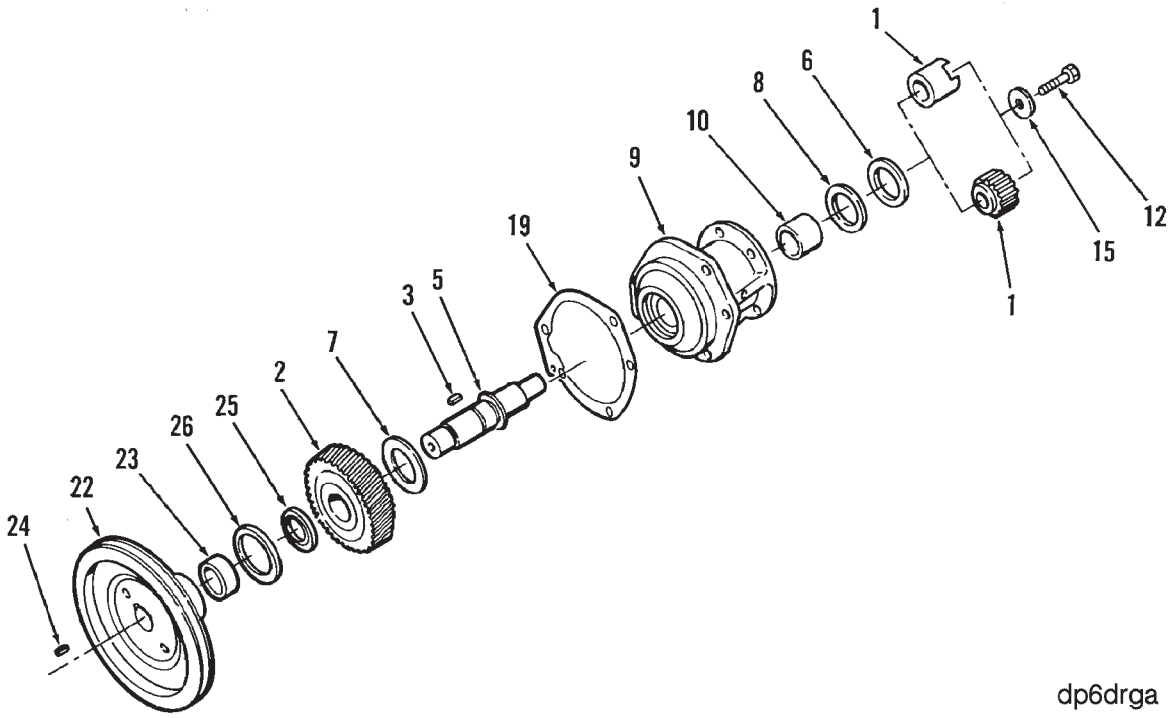
Installation of an air compressor on a fuel pump drive housing will result in failure due to the lack of lubrication.

NOTE: The housings are available in two designs, **with** and **without** provisions for mounting an air compressor. Those **without** air compressors do **not** have provisions for a compressor oil pressure and drain-back. The fuel pump drive has provisions for a lovejoy coupling. The compressor drive has provisions for a splined sleeve-type coupling. The procedures are identical for both of the designs.

The fuel pump/compressor drive gear have stamped marks. The stamped marks **must** be aligned properly with the camshaft idler gear so that valve and injector adjustment marks on the accessory drive pulley are oriented correctly.

The retainer capscrew on the compressor drive (splined half-coupling) is special. It has a drilling in it that provides lubrications of the splined coupling. The retainer capscrew on the fuel pump drive (lovejoy half-coupling) does **not** have an oil drilling.

Exploded View



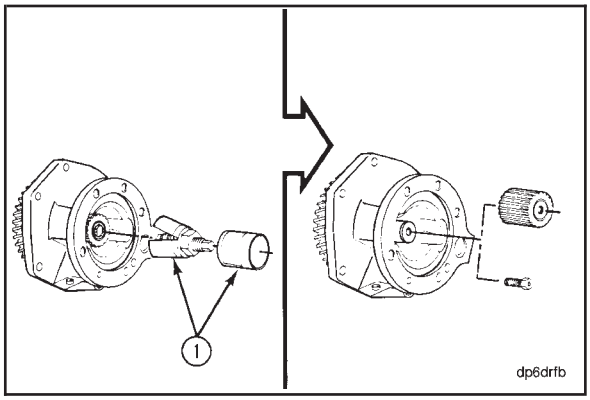
1. Coupling, Lovejoy Type (Upper)
1. Coupling, Spline Type (Lower)
2. Gear, Air Compressor and Fuel Pump Drive
3. Key, Plain Woodruff
5. Shaft, Accessory Drive
6. Washer, Clamping
7. Bearing, Thrust
8. Bearing, Thrust
9. Housing, Accessory Drive
10. Bushing, Accessory Drive
12. Capscrew, Special
15. Washer, Plain
19. Gasket, Accessory Drive Support
22. Pulley, Accessory Drive
23. Sleeve, Wear
24. Key, Plain Woodruff
25. Slinger, Oil
26. Seal, Oil

Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

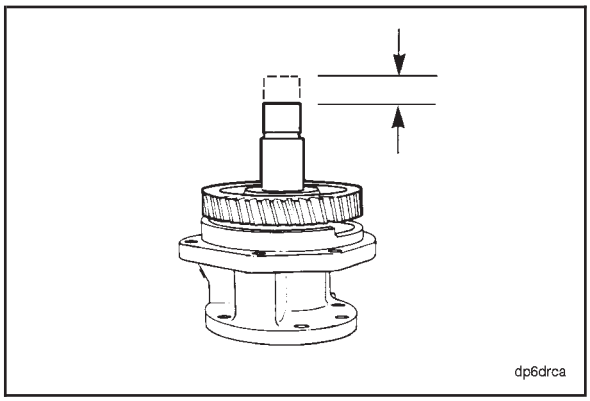
Use solvent to clean the outer housing of the fuel pump drive.



Inspect for Reuse

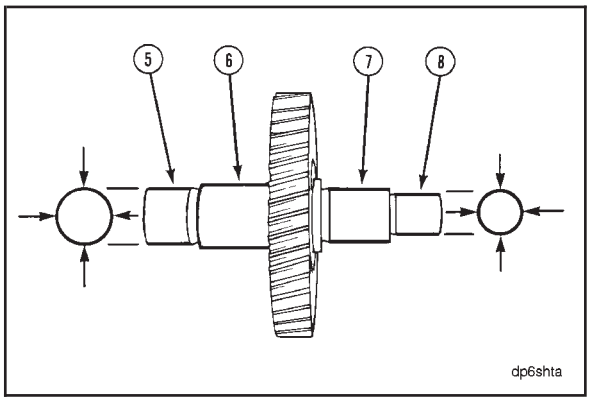
Measure the end clearance.

Fuel Pump/Compressor Drive End Clearance		
mm		in
0.05	MIN	0.002
0.30	MAX	0.012



Check the teeth of the gear for damage.

The coupling washer **must** be positioned tightly between the coupling and the shaft.

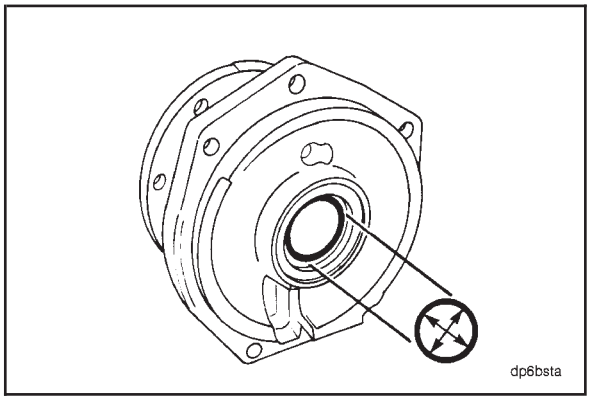


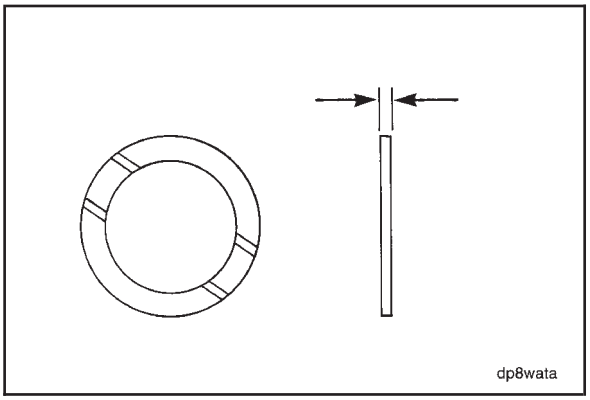
Check the parts for damage.

Measure the I.D. If the bushing must be replaced refer to

Bushing I.D.		
mm		in
33.43	MIN	1.316
33.50	MAX	1.319

NOTE: An **aluminum housing** does **not** contain a bushing. Measure the housing I.D. It **must** be identical to the bushing I.D. in a **cast iron housing**.





Check the grooved surface for damage.

Measure the thickness.

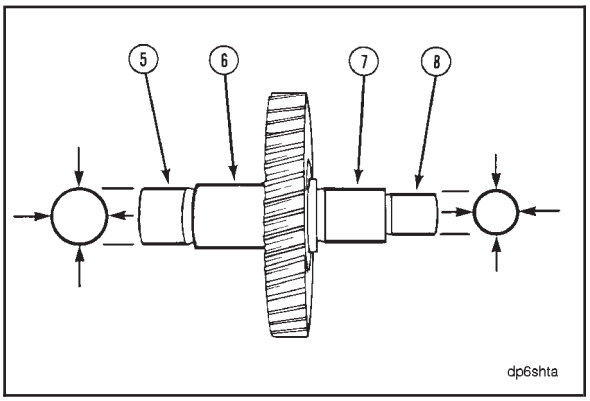
Thrust Bearing Thickness		
mm		in
2.36	MIN	0.093
2.41	MAX	0.095

NOTE: On an aluminum housing **ONLY**, check the two machined thrust surfaces for damage.

Use a depth micrometer.

Measure the thickness.

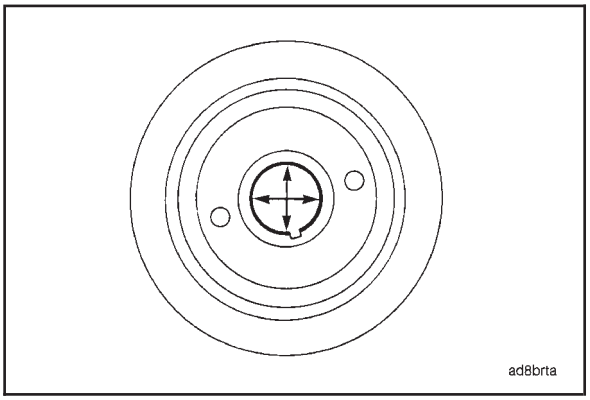
Housing Depth		
mm		in
45.54	MIN	1.793
45.67	MAX	1.798



Check the teeth of the gear for damage.

Shaft O.D.			
	mm		in
(5)	34.963	MIN	1.3765
	34.976	MAX	1.3770
(6)	34.662	MIN	1.5616
	39.674	MAX	1.5620
(7)	33.30	MIN	1.300
	33.33	MAX	1.312
(8)	25.476	MIN	1.0030
	25.489	MAX	1.0035

NOTE: If the gear or shaft must be replaced, refer to Procedure 009–013.



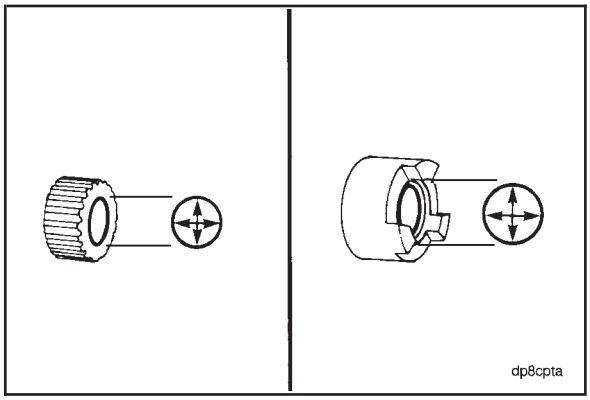
Measure the I.D. of the pulley.

Pully I.D.		
mm		in
34.912	MIN	1.3745
34.938	MAX	1.3755

Measure the I.D. of the coupling.

Lovejoy Coupling I.D.		
mm		in
25.425	MIN	1.0010
25.438	MAX	1.0015

Spline Coupling I.D.		
mm		in
25.400	MIN	1.0000
25.425	MAX	1.0010

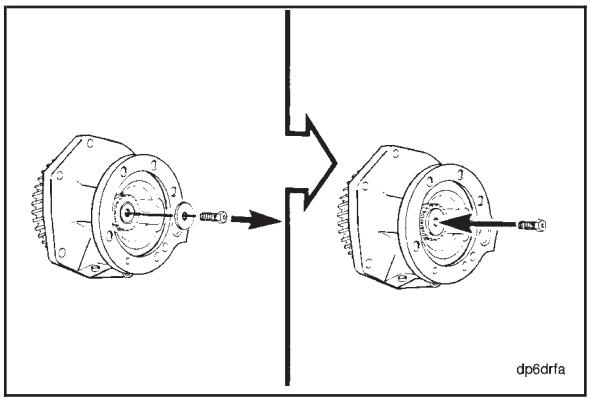


Disassemble

Remove the special capscrew and the washer.

⚠ CAUTION ⚠

Install the capscrew back into the drive unit without the washer until it touches the shaft to prevent damage to the shaft.

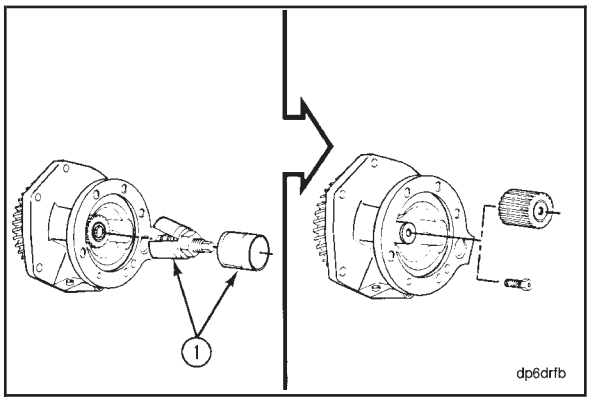


Use a coupling puller (1), Part No. 3376663, or equivalent, to remove the coupling.

Use a 3-jaw puller to remove the lovejoy type coupling.

Remove the coupling.

Remove the capscrew.

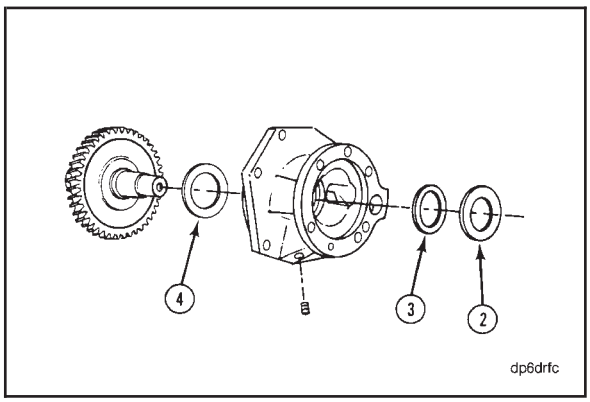


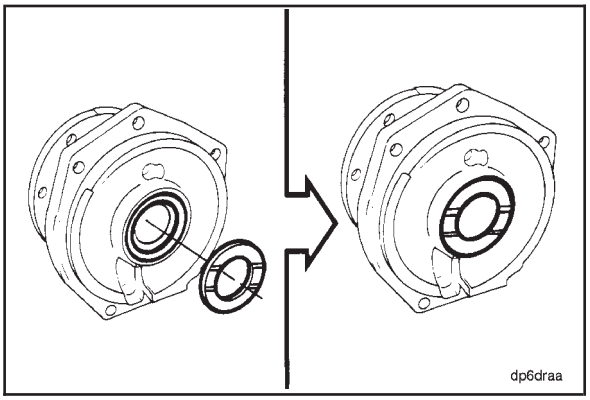
Remove the following:
2. Clamping washer
3. Inner thrust bearing
4. Outer thrust bearing

Remove the gear and the shaft assembly.

Remove the pipe plug from the housing.

NOTE: Aluminum housings do not contain thrust bearings.

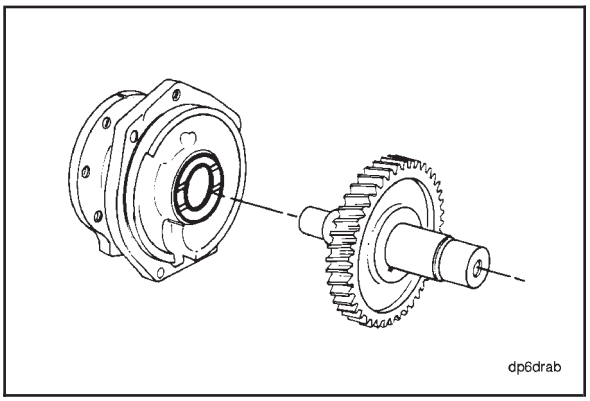




Assemble

Position the grooved surface of the thrust bearing as shown. Install the thrust bearing.

NOTE: An aluminum housing does not contain thrust bearings.

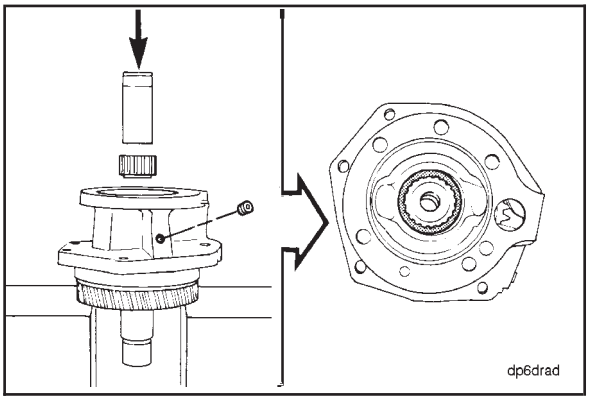


Use Lubriplate® No. 105, or equivalent. Lubricate the grooved surface of the thrust bearing (3).

NOTE: An aluminum housing does not contain thrust bearings. Lubricate the machined thrust surface.

With the grooved surface positioned up, slide the thrust bearing (3) over the shaft.

Before installing the clamping washer (2), the beveled edge **must** be positioned as shown.



Support the gear or the shaft.

Install the coupling.

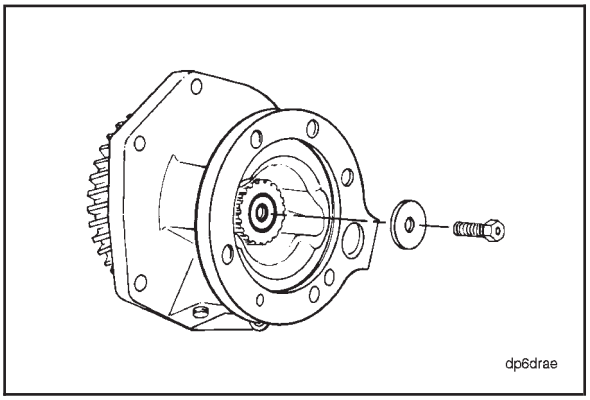
Use an arbor press and a mandrel to push the coupling until it touches the clamping washer.

The clamping washer must be positioned tightly between the coupling and the shoulder of the shaft.

Install the pipe plug into the housing.

Tighten the pipe plug.

Torque Value: 8 N•m [75 in-lb]



⚠ CAUTION ⚠

The capscrew must contain an oil drilling if an air compressor is to be mounted on the engine.

Install the washer and the capscrew.

Check the capscrew size for the correct torque value.

Capscrew Length	Torque
3/8 in	45 Nm [35 ft-lb]
1/2	100 Nm [75 ft-lb]

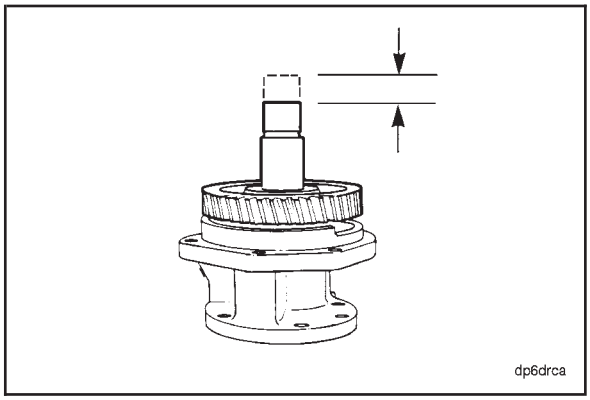
Rotate the shaft to check for correct assembly.

Use a dial indicator. Measure the end clearance.

End Clearance		
mm		in
0.05	MIN	0.002
0.30	MAX	0.012

If the end clearance is not within specifications, be sure the coupling is positioned tightly against the clamping washer.

NOTE: Oversize thrust bearings are available to adjust the end clearance.

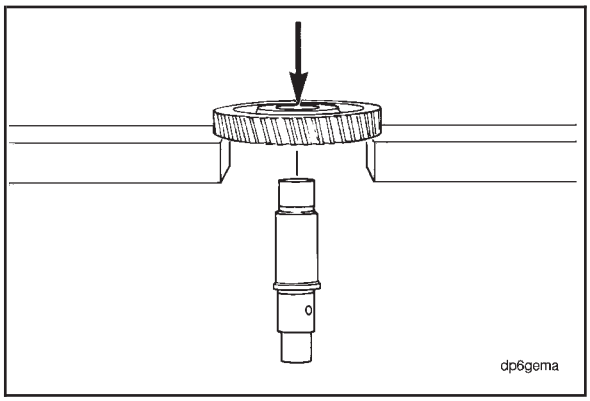


Fuel Pump Drive Gear and Shaft (009-013)

Disassemble

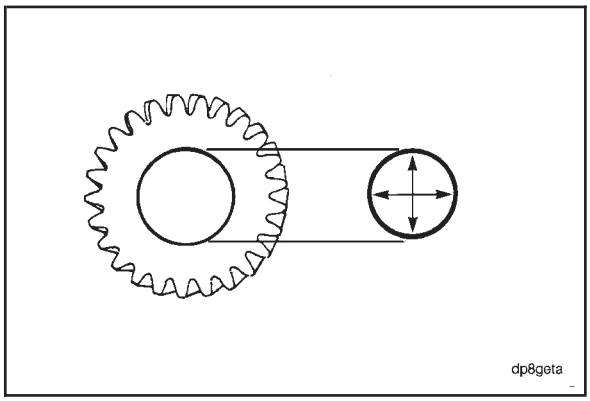
Support the gear.

Use an arbor press to remove the shaft.



Measure the gear I.D.

Gear I.D.		
mm		in
39.73	MIN	1.564
39.75	MAX	1.565

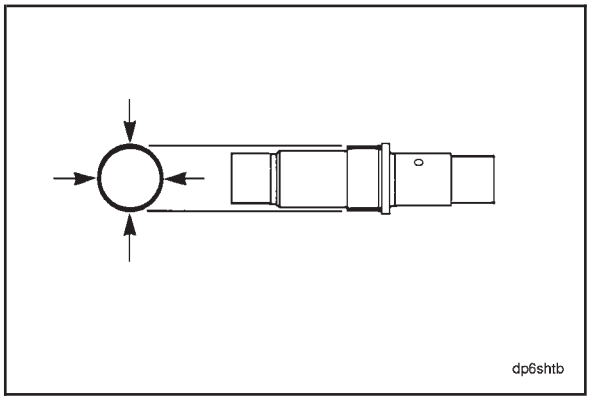


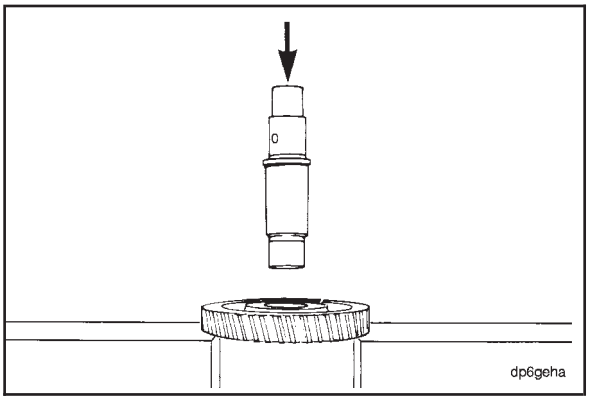
Remove the key and check for damage.

NOTE: If damage is found, the key **must** be replace.

Measure the O.D. at the gear location.

Shaft O.D.		
mm		in
39.789	MIN	1.5665
39.802	MAX	1.5670



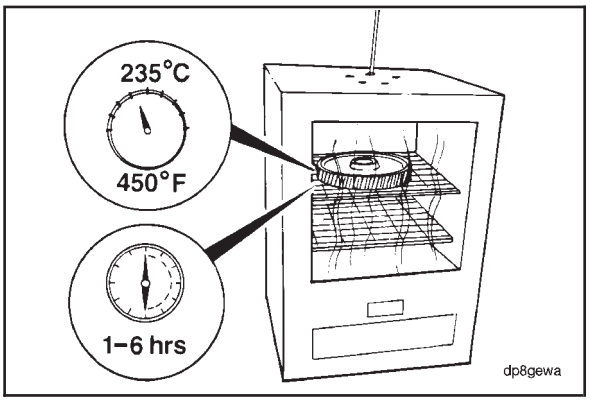


Assemble

Support the gear.

Use engine oil to lubricate the shaft.

Align the key with the key slot in the gear. Use an arbor press to press the shaft through the gear until the shoulder of the shaft touches the gear.



NOTE: If an adequate press is **not** available, an oven can be used.

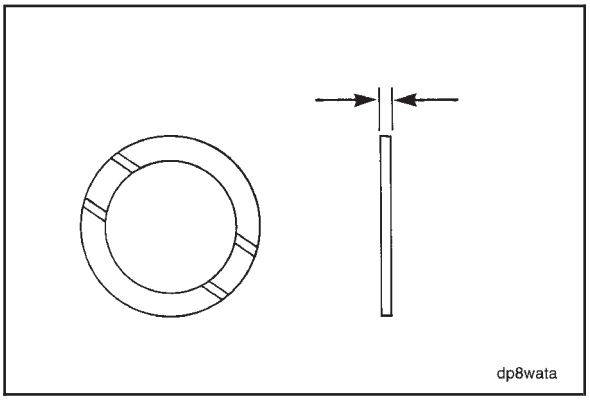
⚠ WARNING ⚠

Wear protective clothing to prevent personal injury from burns.

△ CAUTION △

Do not exceed the specified time or temperature. Damage to the gear teeth will result.

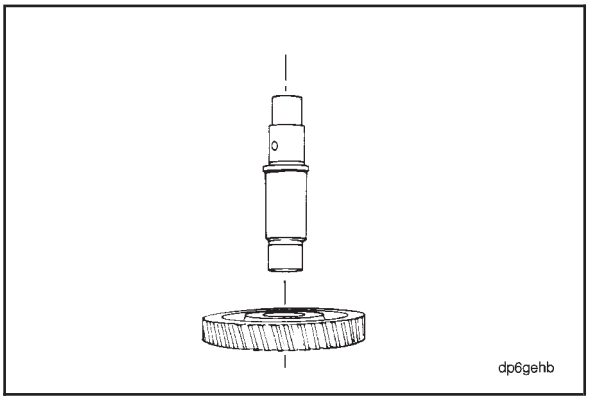
Heat the gear at 235°C (450°F) **no less** than one hour, and **no more** than six hours.



Use Lubriplate® No. 105, or equivalent to lubricate the grooved surface of the thrust bearing.

NOTE: On an aluminum housing **ONLY**, lubricate the grooved area machined in the housing.

Install the shaft and the gear.



⚠ WARNING ⚠

Wear protective clothing to prevent personal injury from burns.

Slide the shaft in the gear.

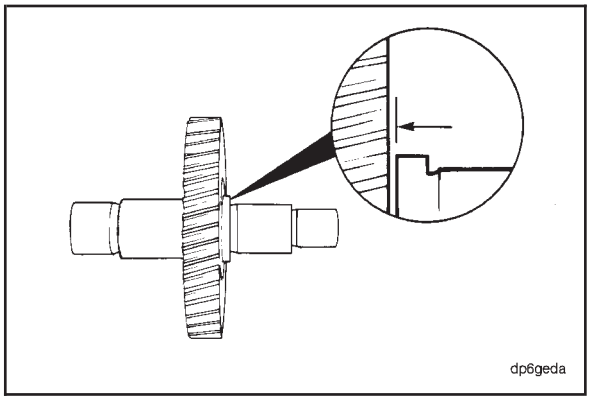
⚠ CAUTION ⚠

Allow the air to cool the gear. Do not use water or oil to reduce the cooling time. Damage to the gear can result.

Use a feeler gauge to measure the distance between the shoulder of the shaft and the gear.

Fuel Pump Drive Gear to Shaft		
mm		**in**
0.05	MAX	0.002

NOTE: If the distance between the gear and the shaft is **not** within specification press the gear on until specifications are meet.



Hydraulic Pump Drive (009-016)

General Information

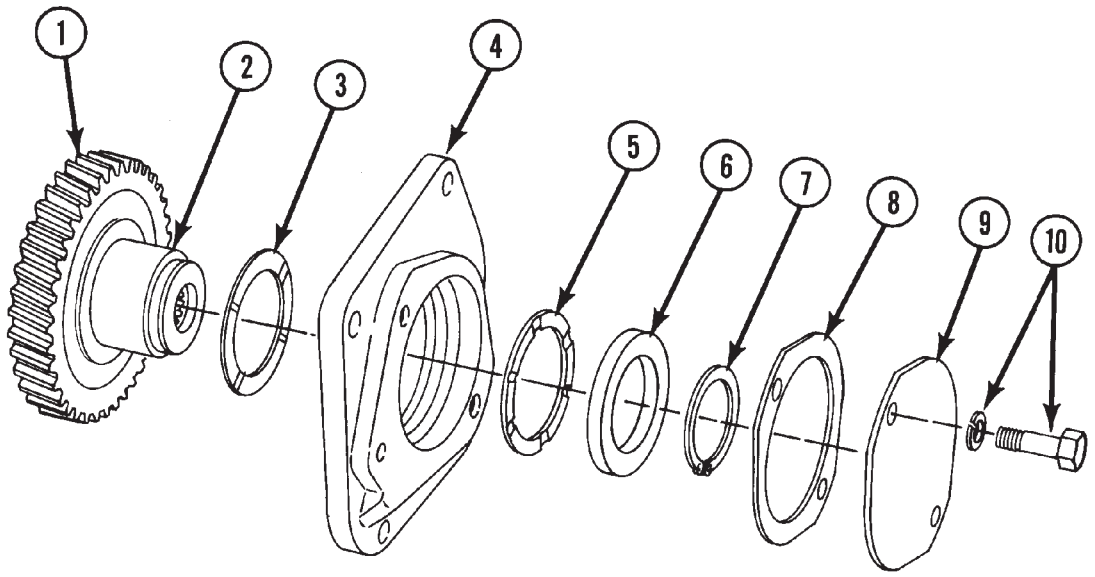
A hydraulic pump can be mounted on the **front** or at the **rear** of the gear cover.

The **SAE A two-bolt** type flange is required to mount a hydraulic pump at the **rear** of the gear cover. The **SAE B four-bolt** type flange is required for a hydraulic pump to be mounted on the **front** of the gear cover. There is a **specific** drive required to match the **different** sizes of spline drives required for the optional hydraulic pumps.

Engines that do **not** have a hydraulic pump drive **must** have parts that block the oil holes in the gear cover and housing for correct engine oil pressure. A **four-bolt** flange that has a blind plug welded to it **must** be installed on the **front** of the gear cover. The blind plug will extend into the bushing, blocking the oil drilling. A **three-bolt** cover that has two o-rings **must** be installed on the **rear** of the gear housing.

A hydraulic pump drive can be installed by removing the blind plug flange and the cover. If only the **rear** drive port is used, a plain **four-bolt** cover and gasket **must** be installed on the **front** of the cover. If only the **front** drive port is used, a **two-bolt** cover and gasket **must** be installed on the **rear** of the pump drive.

Exploded View



09400016

1. Gear, Hydraulic Pump Drive
2. Shaft, Hydraulic Pump Drive
3. Bearing, Thrust
4. Housing, Hydraulic Pump Drive
5. Bearing, Thrust
6. Washer, Clamping
7. Ring, Retaining
8. Gasket
9. Cover, Hydraulic Pump
10. Lock Washer and Locknut

Clean

Remove the capscrews and the lockwashers.

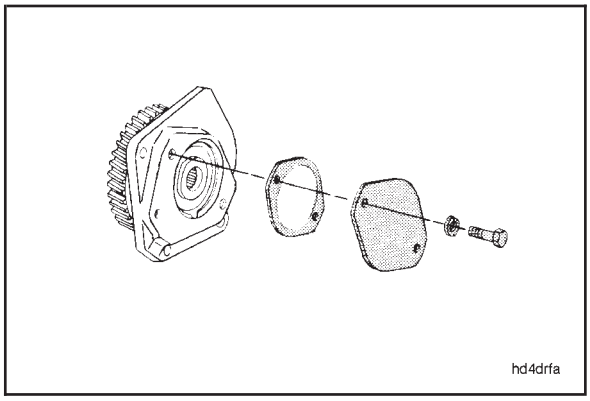
Remove the cover from the pump.

⚠ WARNING ⚠

When using solvents, acids or alkaline materials for cleaning, follow the manufacture's recommendation for use. Wear goggles and protective clothing to avoid personal injury.

Remove adn discard the gasket.

Use solvent to clean the drive.

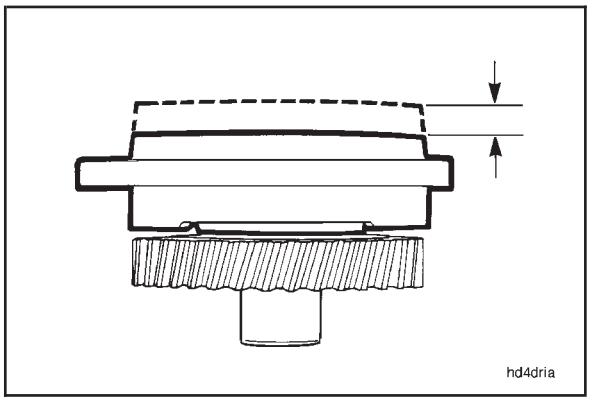


Inspect for Reuse

Measure the clearance.

End Clearance		
mm		in
0.13	MIN	0.005
0.48	MAX	0.019

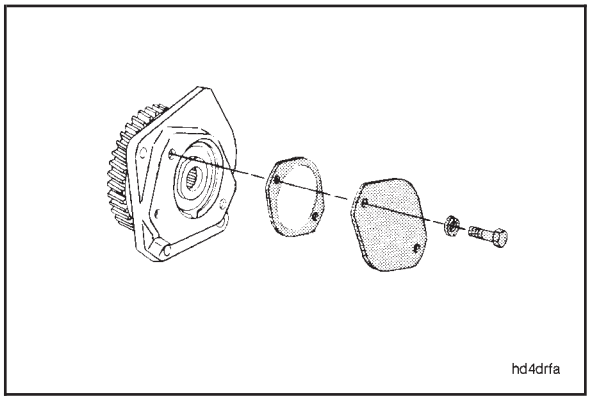
If the end clearance is **not** within specifications, the assembly **must** be rebuilt. Refer to the Procedure, 009-006.



Install a new gasket.

Install the cover on the pump.

Install the lockwashers and the capscrews.

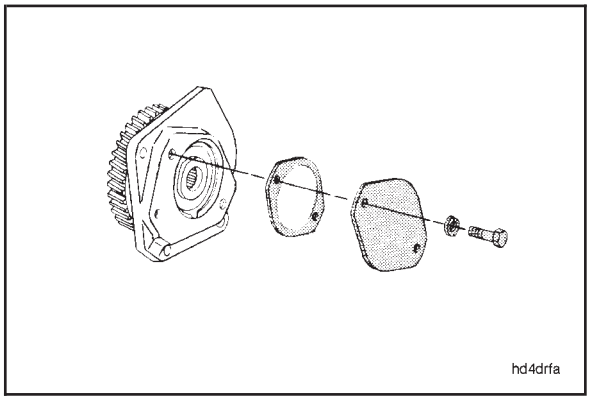


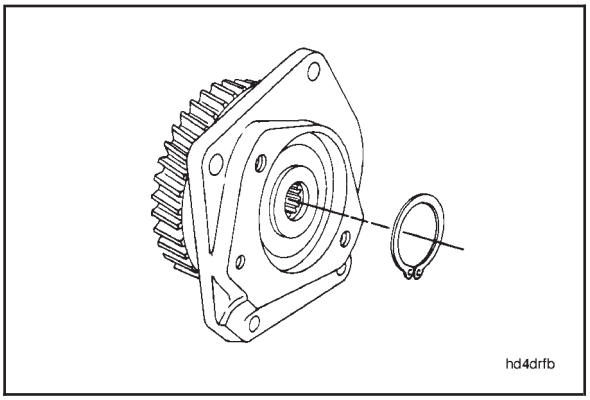
Disassemble

Remove the capscrews and the lockwashers.

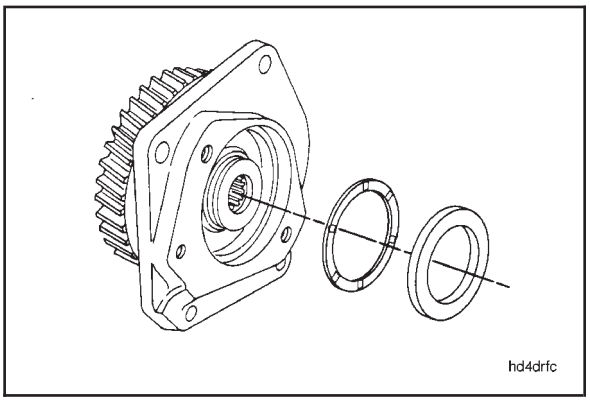
Remove the cover.

Remove and discard the gasket.



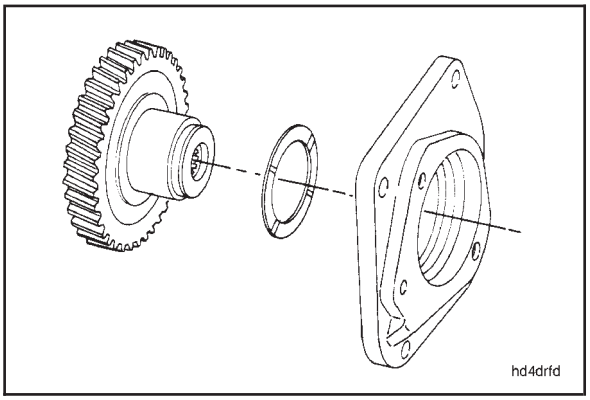


Remove the retaining ring.



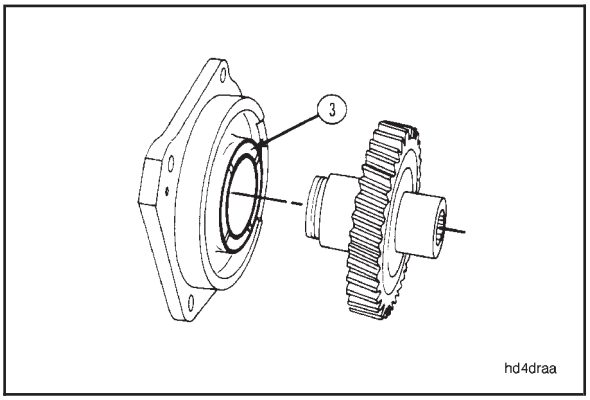
Remove the clamping washer.

Remove the thrust bearing.



Remove the housing.

Remove the thrust bearing.



Assemble

Use Lubriplate® No. 105 or equivalent to lubricate the grooved surface of the thrust bearing.

Position the grooved surface of the thrust bearing as illustrated (3).

Slide the shaft in the housing.

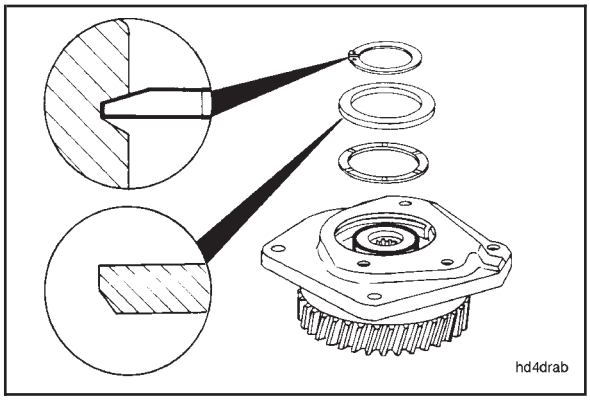
NOTE: The gear **must** touch the thrust bearing.

Use Lubriplate® No. 105 or equivalent to lubricate the grooved surface of the thrust bearing.

With the grooved surface positioned up, slide the thrust bearing over the shaft.

The beveled edge of the clamping washer **must** be positioned against the thrust bearing. Slide the clamping washer over the shaft.

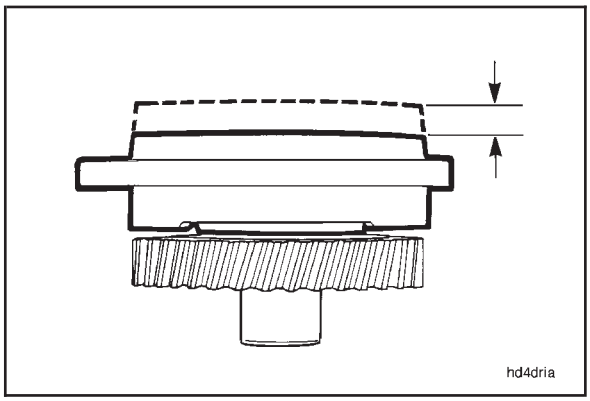
The beveled edge of the retaining ring **must** be positioned as illustrated. Install the retaining ring.



Measure the clearance.

End Clearance		
mm		in
0.13	MIN	0.005
0.48	MAX	0.019

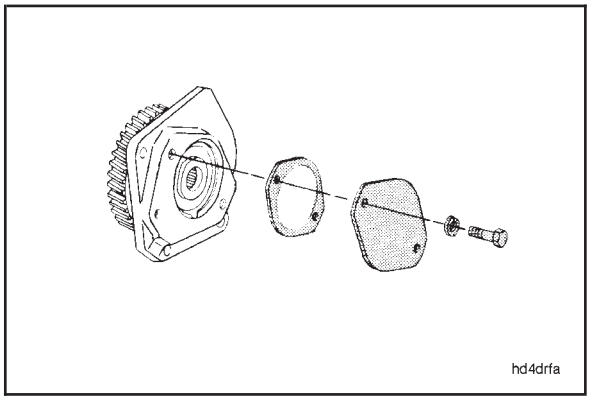
If the end clearance is **not** within specifications, the assembly **must** be rebuilt. Refer to Procedure 009-016.



Install a new gasket.

Install the cover.

Install the lockwashers and the capscrews.

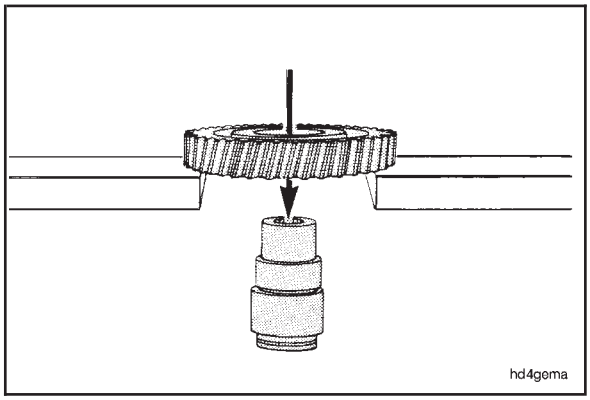


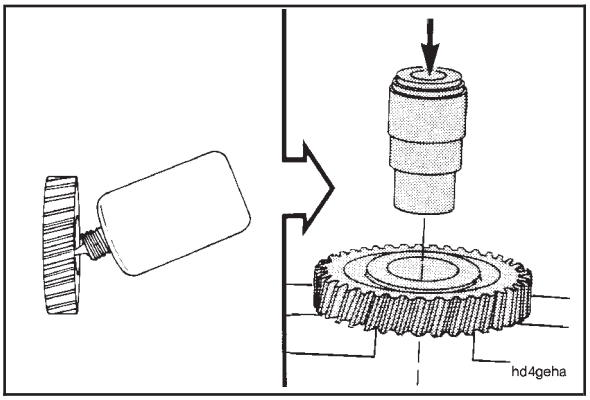
Hydraulic Pump Drive Gear and Shaft (009-019)

Disassemble

ONLY remove the gear from the shaft when the gear **or** the shaft **must** be replaced.

Use an arbor press to remove the gear.



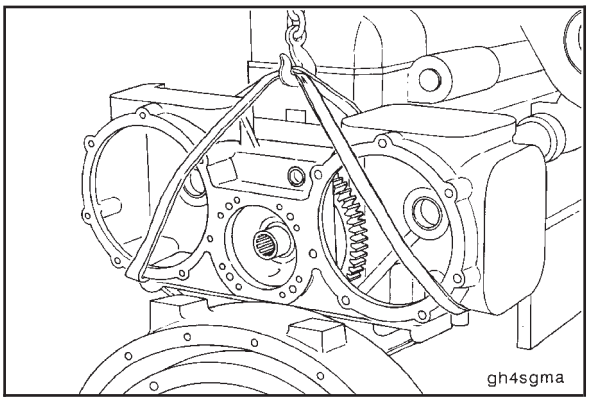


Assemble

Use Loctite® 609 or the equivalent, apply a smooth layer on the I.D. of the gear.

Support the gear and position the part number down.

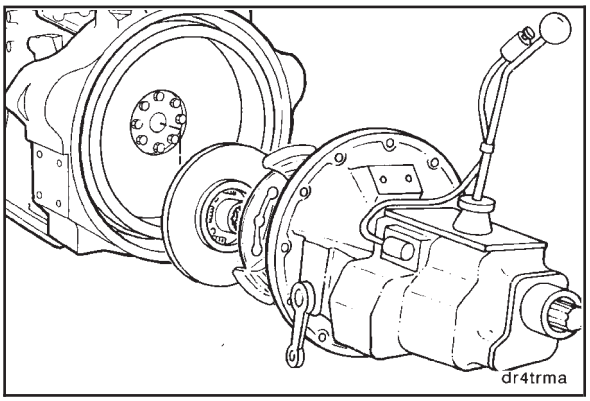
Use an arbor press to press the shaft through the gear until the shaft shoulder touches the gear.



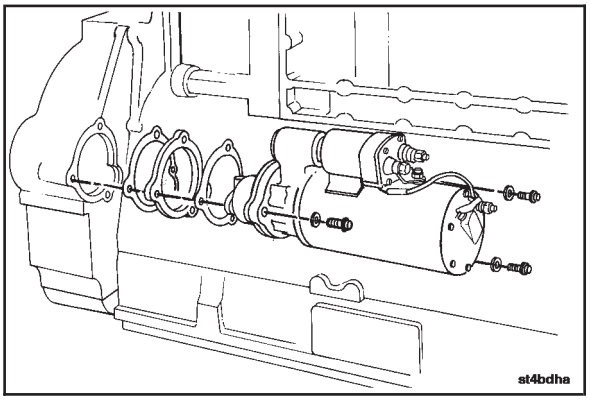
Rear Gear Drive (Lower Assembly) (009-023)

Remove

Remove the upper rear gear drive assembly. Refer to Procedure 009-024.



Remove the transmission, clutch, and all related components. Refer to the equipment manufacturer's instructions.



⚠ CAUTION ⚠

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 starting motor capscrews, starter, spacers, and gaskets.

Discard the gaskets.

NOTE: Not All engines contain spacers. Only engines with wet type flywheel housings contain gaskets.

⚠ CAUTION ⚠

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

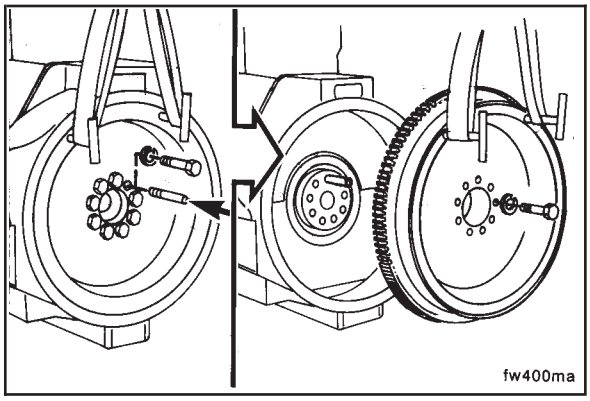
Use a 5/8 in guide stud.

Remove one capscrew and install the guide stud.

Use a hoist, two tee handles, and a lifting sling. Install the tee handles. Remove the remaining capscrews.

Remove the flywheel.

NOTE: Use a mallet to tap the flywheel from the crankshaft if necessary.



⚠ 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. Always use the proper procedure to dispose of the used oil.

⚠ CAUTION ⚠

Hot oil can cause personal injury.

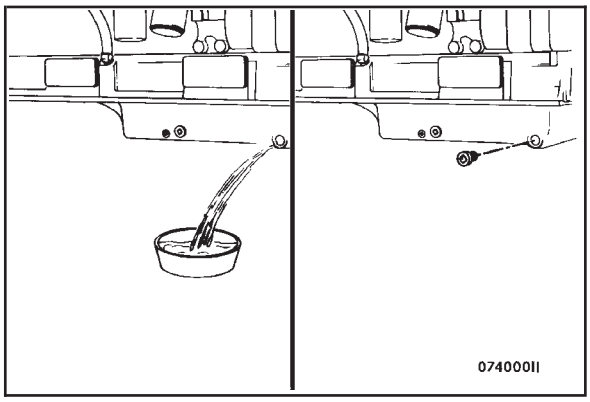
Drain the oil when the oil temperature is less than 60°C [140°F].

Remove the drain plugs from the sump and adapter cover to drain the oil.

Replace the copper washers and plugs.

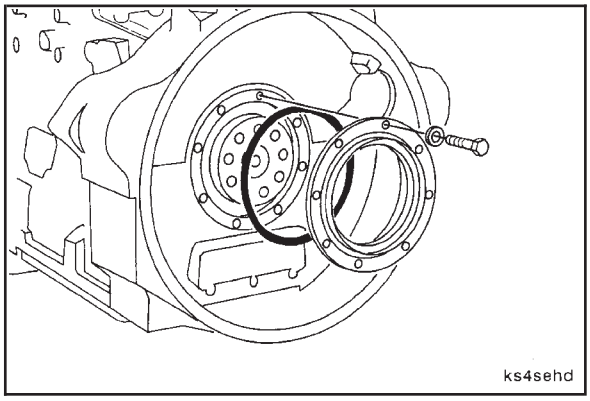
Tighten the drain plugs.

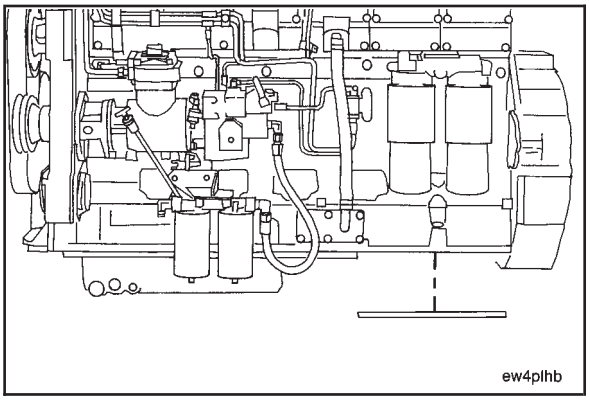
Torque Value: 100 N•m [75 ft-lb]



Remove the capscrews and the rear crankshaft seal.

Remove and discard the o-ring and seal.

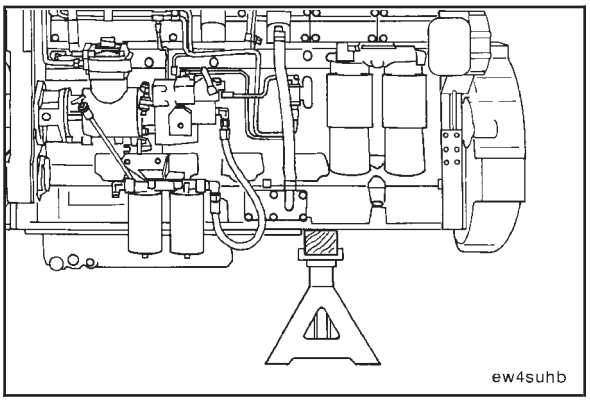




Remove the adapter cover plate or the oil pan (whichever is in the rear position).

Angle the cover plate to allow the oil to drain.

Remove and discard the gasket.

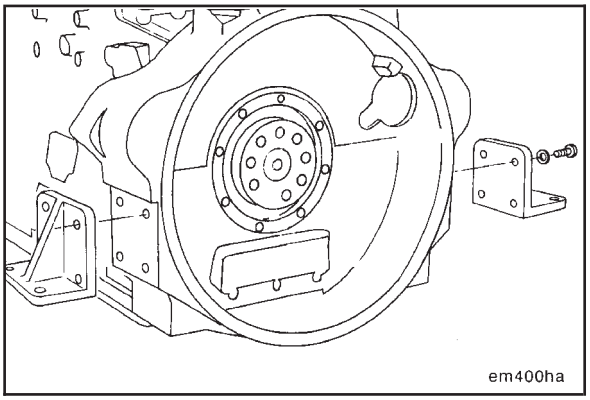


⚠ CAUTION ⚠

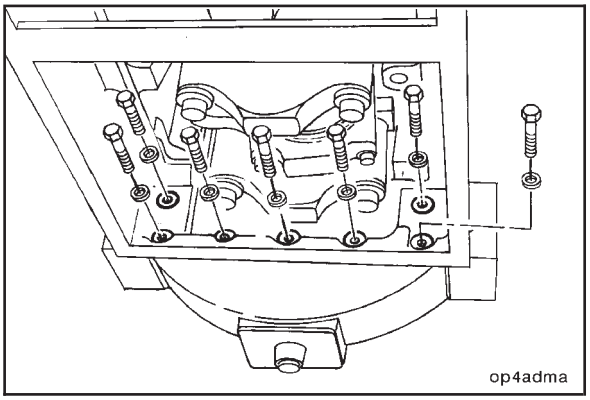
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Put a wooden block the width of the oil pan adapter between the support and the oil pan adapter to prevent damage to the engine.

Use a jack stand or a suitable lifting fixture to support the rear of the engine. Put the support in position to allow access to the capscrews in the oil pan adapter that attach to the flywheel housing.



Remove the rear engine mounts from the flywheel housing if necessary.



Remove the two 7/16 in capscrews and the five 3/8 in capscrews that attach the oil pan adapter to the flywheel housing.

CAUTION

Be sure the rear gear train lower housing is secure BEFORE removing the flywheel housing. The lower housing rests on the guide studs and dowel pins, but is NOT fastened to the block.

CAUTION

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

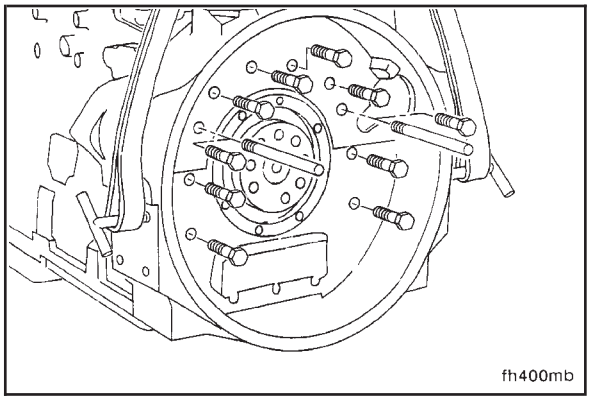
Use two 5/8x6-1/2 in guide studs. Remove two capscrews.

Install the guide studs.

Use a hoist, a tee handle, and a lifting sling. Install the tee handle.

Adjust the hoist until there is tension in the lifting sling.

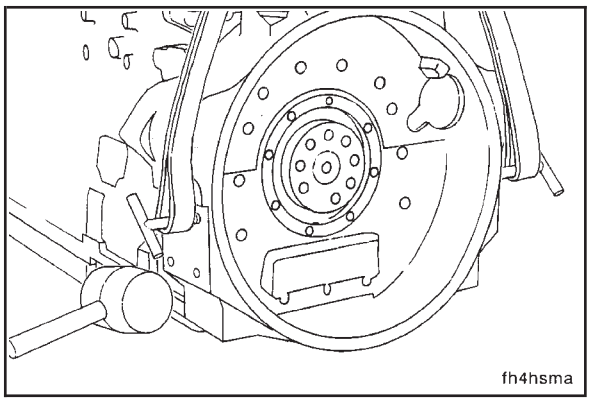
Remove the remaining capscrews, lockwashers, and nuts.



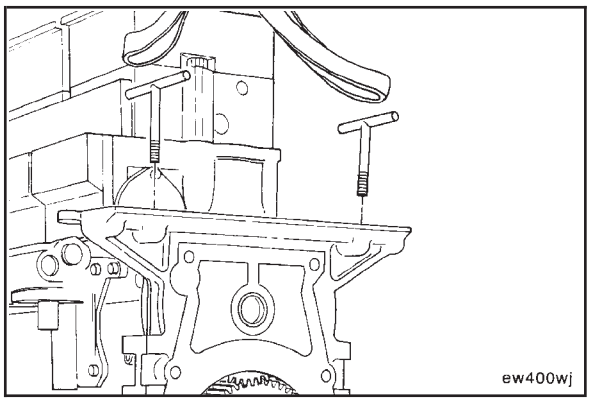
NOTE: Two pry bars can be used to separate the lower housing of the rear gear train from the flywheel housing.

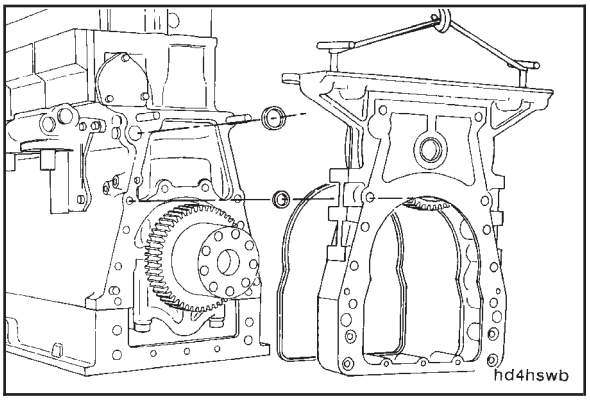
Use a mallet to tap the flywheel housing off the two locating dowels.

Remove and discard the rectangular seal and the bolt seals.



Use a hoist, two tee handles, and a lifting sling. Install the tee handles. Adjust the hoist until there is tension in the lifting sling.

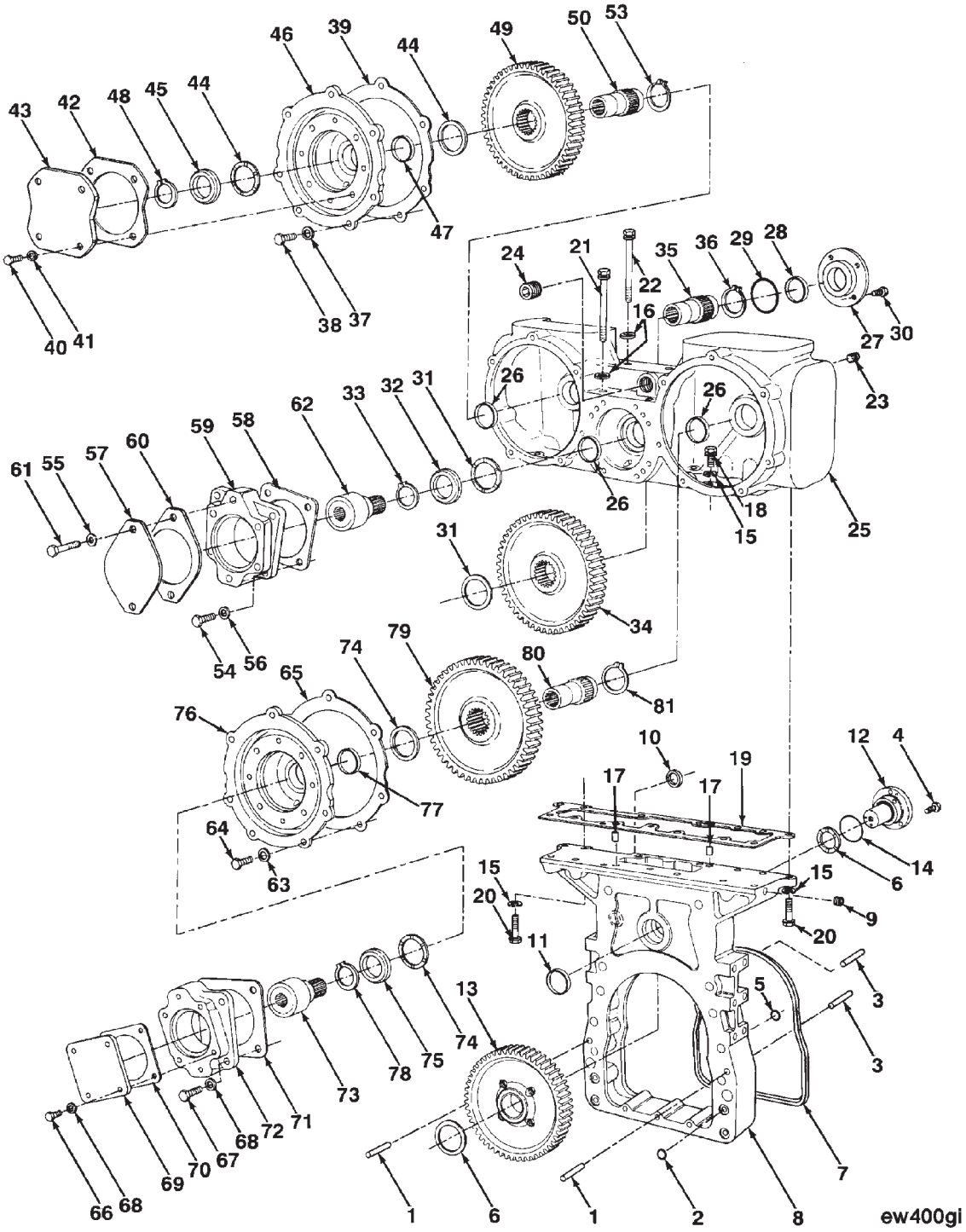




Use a mallet to tap the lower housing of the rear gear train off the two locating dowel pins in the rear face of the cylinder block.

Remove and discard the rectangular seal, bolt seals, and main oil rifle seal.

Exploded View



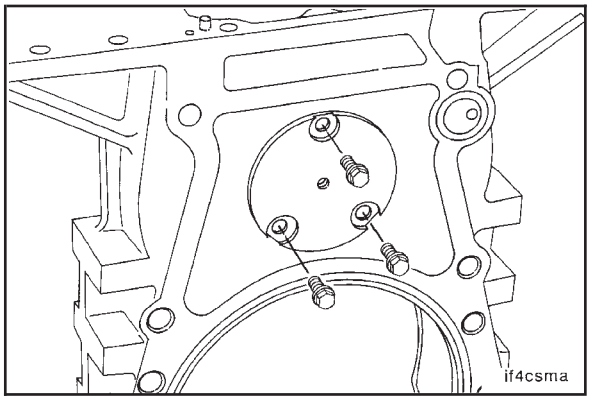
Rear Gear Drive

Rear Gear Drive Exploded View Table

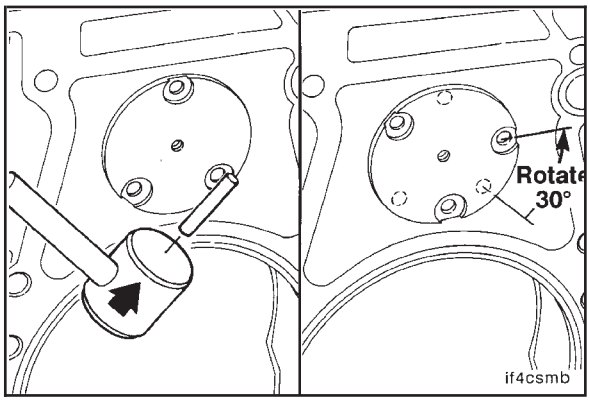
1. Dowel Pin
2. Seal, Rectangular Ring
3. Dowel Pin
4. Capscrew, Hexagon Head
5. Seal, Rectangular Ring
6. Bearing, Thrust
7. Seal, Rectangular Ring
8. Housing, Gear
9. Plug, Pipe
10. Seal, Rectangular Ring
11. Plug, Expansion
12. Shaft, Idler
13. Gear and Bushing, Hydraulic Pump
14. Seal, O-ring
15. Washer, Lock
16. Washer, Plain
17. Dowel Pin
18. Capscrew, Hexagon Head
19. Gasket, Hydraulic Pump
20. Capscrew, Hexagon Head
21. Capscrew, Hexagon Head
22. Capscrew, Hexagon Head
23. Plug, Pipe
24. Plug, Pipe
25. Housing, Hydraulic Drive
26. Bushing
27. Support, Hydraulic Pump
28. Bushing
29. Seal, O-ring
30. Capscrew, Hexagon Head
31. Bearing Thrust
32. Spacer, Bearing
33. Ring, Retaining
34. Gear, Hydraulic Pump
35. Shaft and Plug Assembly
36. Ring, Retaining
37. Washer, Lock
38. Capscrew, Hexagon Head
39. Gasket, Support, Hydraulic
40. Capscrew, Hexagon Head
41. Washer, Lock
42. Gasket, Hydraulic Pump Flange Cover
43. Cover, Hydraulic Pump Flange
44. Bearing, Thrust
45. Spacer, Bearing
46. Support, Hydraulic Pump
47. Bushing
48. Ring, Retaining
49. Gear, Hydraulic Pump
50. Shaft and Plug Assembly
51. Plug, Expansion
52. Ring, Retaining
53. Capscrew, Hexagon Head
54. Washer, Lock
55. Washer, Lock
56. Plate, Cover
57. Gasket, Hydraulic Pump
58. Adapter, Hydraulic Pump
59. Gasket, Hydraulic Pump
60. Capscrew, Hagen Head
61. Adapter, hydraulic Pump
62. Washer, Lock
63. Capscrew, Hexagon head
64. Gasket, Support, Hydraulic
65. Capscrew, Hexagon Head
66. Capscrew, Hexagon Head
67. Washer, Lock
68. Plate, Cover
69. Gasket, Hydraulic Pump
70. Gasket, Hydraulic Pump
71. Adapter, Hydraulic Pump
72. Assembly, Coupling and Adapter
73. Bearing, Thrust
74. Spacer, Bearing
75. Gear, Hydraulic Pump
76. Support, Hydraulic Pump
77. Bushing
78. Ring, Retaining
79. Gear, Hydraulic Pump
80. Shaft and Plug Assembly
81. Ring, Retaining

Disassemble

Remove the three capscrews from the idler shaft.



If the idler shaft has three holes, use a soft punch and a mallet. Rotate the idler shaft 30 degrees until the capscrew holes in the housing are **not** visible through the capscrew holes in the idler shaft.

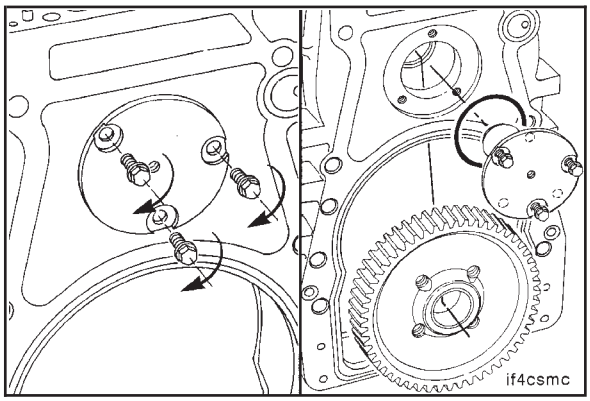


Use three 3/8-24x2 in capscrews. Make sure the idler gear is secure.

Alternately tighten the capscrews to pull the shaft **from** the housing.

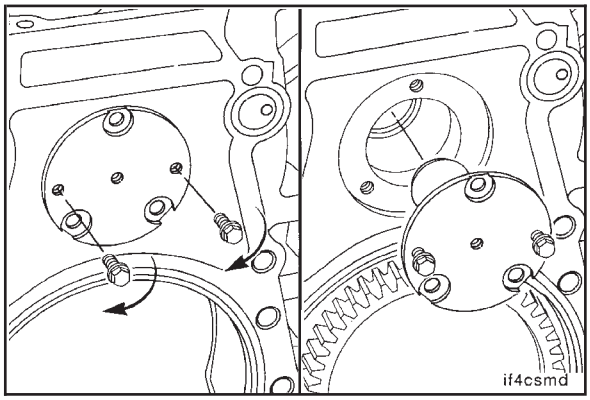
Remove the shaft, thrust washers, and gear.

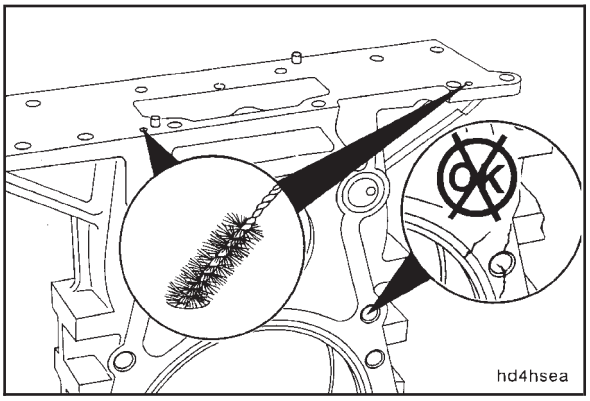
Remove and discard the o-ring.



If the idler shaft has five holes, use two 3/8–24x2 in capscrews. Make sure the idler gear is secure.

Alternately tighten the capscrews to pull the shaft **from** the housing.

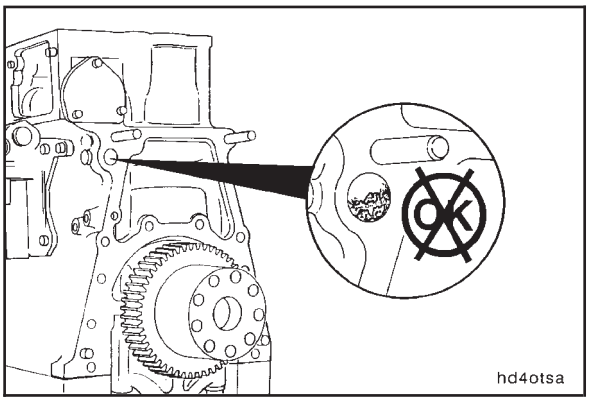




Inspect for Reuse

Remove all pipe plugs and clean all oil drillings. Be sure the oil drillings intersect.

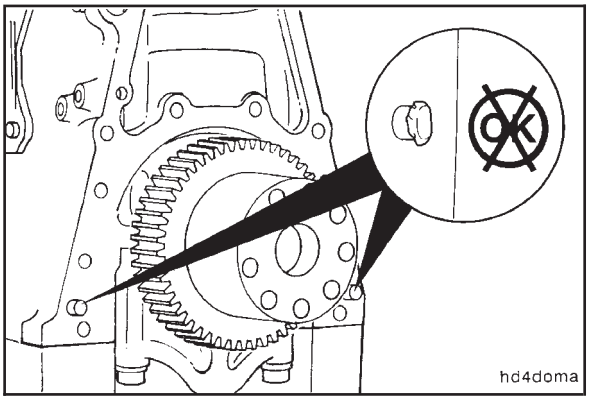
Clean and check the lower housing for damage.



⚠ CAUTION ⚠

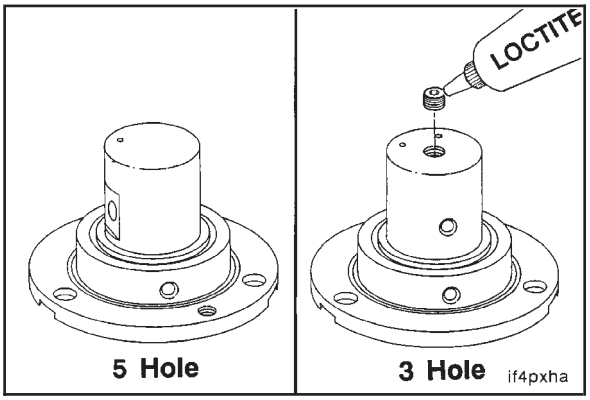
Check for debris in the main oil rifle. Any debris will cause rear gear train damage.

Be sure the 1-1/8 in expansion plug is **not** installed in the end of the main oil rifle in the cylinder block. The main oil rifle **must** be OPEN to allow the oil to the rear gear train.



Inspect the two rear gear train housing dowel pins in the rear face of the cylinder block. Any damaged dowels **must** be replaced.

Use dowel pin extractor, Part No. ST-1143, to remove the dowel pins. Use a brass or lead hammer to install the new dowel pins.



Assemble

The five hole style idler shaft does **not** have a hole for the internal hex pipe plug.

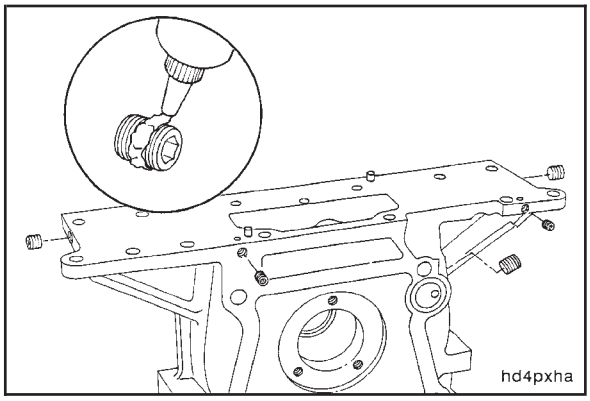
Use Loctite® to install the internal hex pipe plug into the end of the idler shaft.

Torque Value: 11 N•m [8 in-lb]

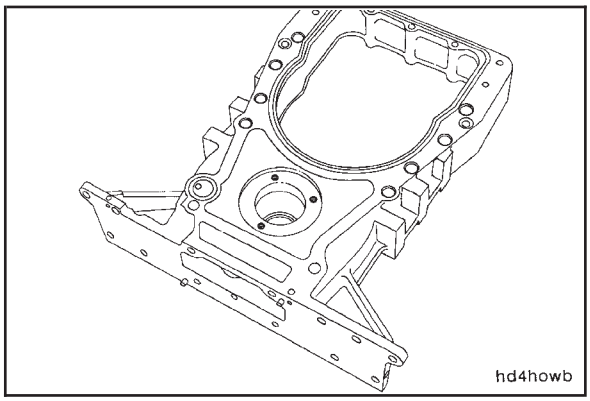
NOTE: Absence of the pipe plug can cause serious engine damage due to a loss in oil pressure to the rear gear train bushings.

Use pipe sealant, Part No. 3375066, or equivalent sealant with liquid Teflon®. Install five 1/8 in internal hex pipe plugs into the lower housing.

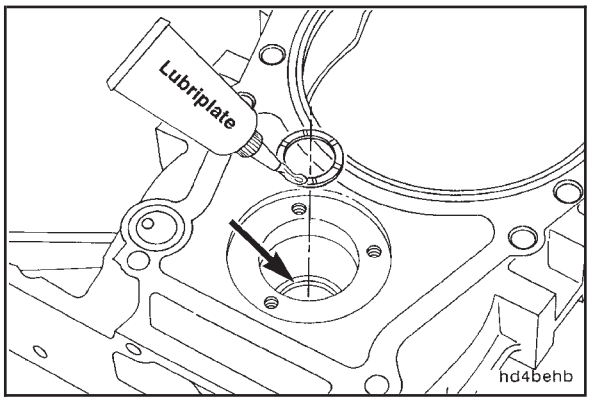
Torque Value: 16 N•m [12 ft-lb]



Position the lower housing horizontally with the block mating surface facing up. Attempting to install the gear and idler shaft with the housing vertical can result in binding of the thrust bearings.

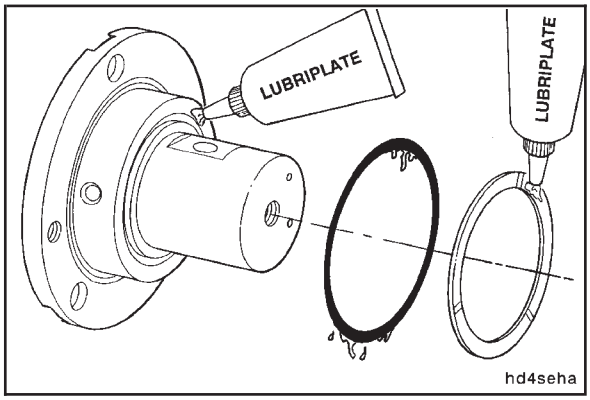


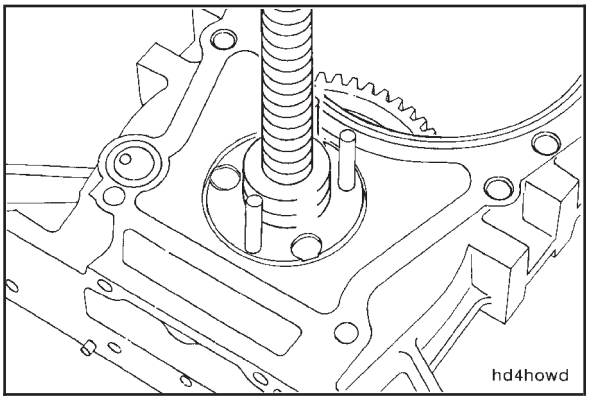
Use Lubriplate® 105 or equivalent. Lubricate one thrust bearing and the counterbore in the lower housing near the expansion plug. Install the thrust bearing into the counterbore with the grooved side facing **away** from the housing.



Install 5/16–18x2 in guide studs.

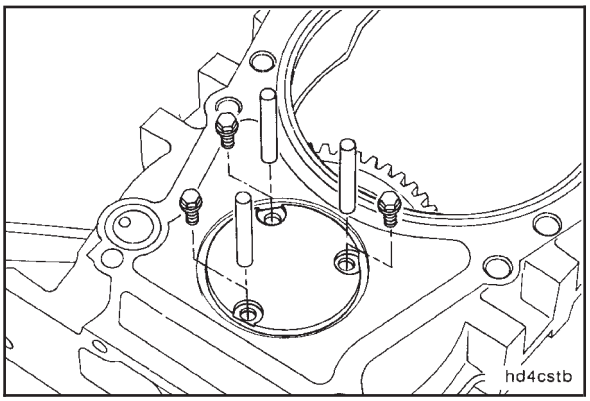
Align the idler gear into the lower housing. Align and install the idler shaft into the idler gear and lower housing until the idler shaft pilot chamfer touches the lower housing.





Make sure the machined surface on the back side of the lower housing is supported to prevent cracking of the housing.

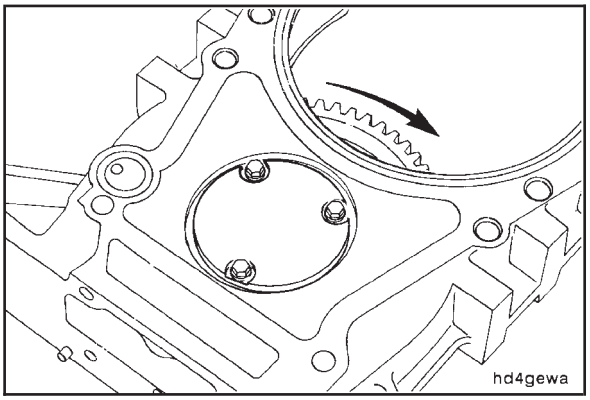
Use an arbor press to press the idler shaft into the lower housing until the mounting flange contacts the housing.



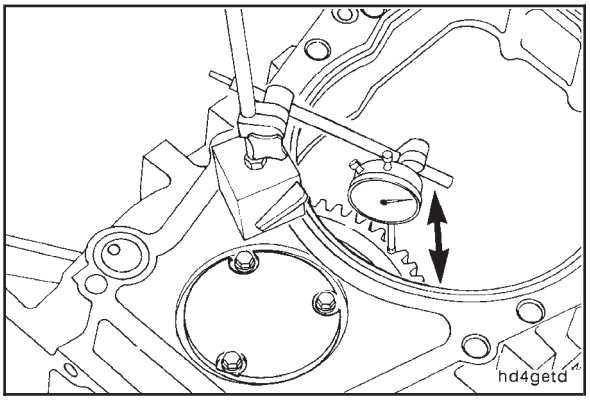
Remove the guide studs and install the three 5/16-18x3/4 in capscrews.

Tighten the three capscrews.

Torque Value: 20 N•m [15 ft-lb]



Rotate the gear to check for binding.



Use a dial indicator.

Measure the idler gear end clearance.

Idler Gear End Clearance		
mm		**in**
0.10	MIN	0.004
0.51	MAX	0.020

NOTE: If the end clearance is **not** within specifications, the thrust bearings must be replaced.

Install

NOTE: If an SAE 1 flywheel housing option is used, there must be two [5/8–11 x 6 1/2 in] studs, Part No. 3065777, installed in the upper holes of the cylinder block.

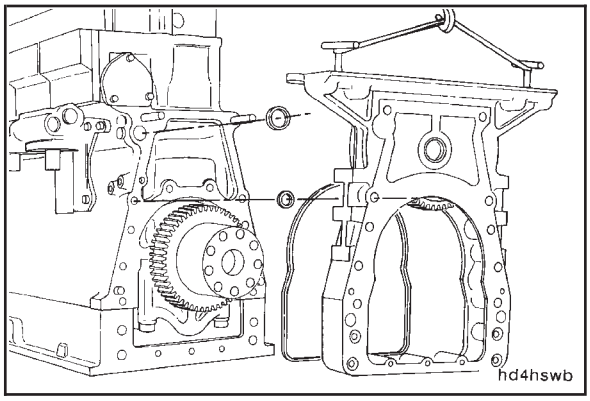
Apply a small amount of Lubriplate® 105 or gasket adhesive on the seal ring groove, the capscrew counterbores, and the dowel counterbores on the block side of the lower housing.

Install the new rectangular seal ring, with the joint at the top into the groove in the lower housing.

Install the ten new capscrew seals into the capscrew counterbores in the lower housing.

Use Lubriplate® 105 or equivalent on the main rifle seal.

Install the main rifle seal into the counterbore surrounding the main rifle drilling.

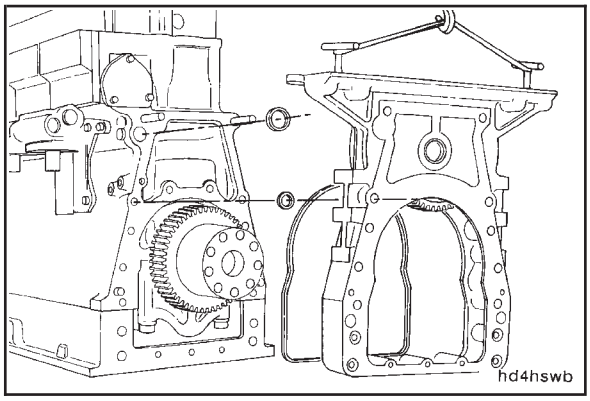


⚠ CAUTION ⚠

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

Install two 5/8-11x1/2 inch guide studs into the rear face of the cylinder block. Use a hoist, two tee handles, and a lifting sling. Install the tee handles.

Lift the lower housing of the rear gear train.

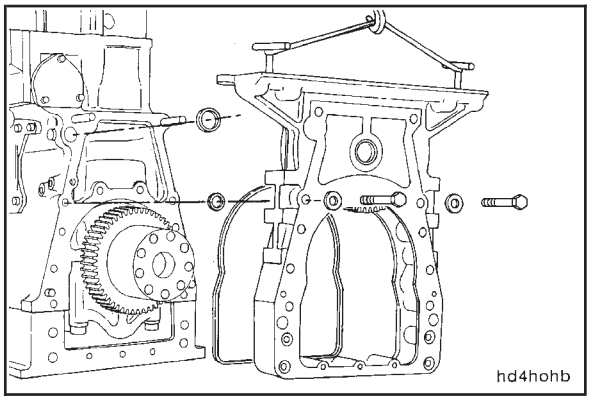


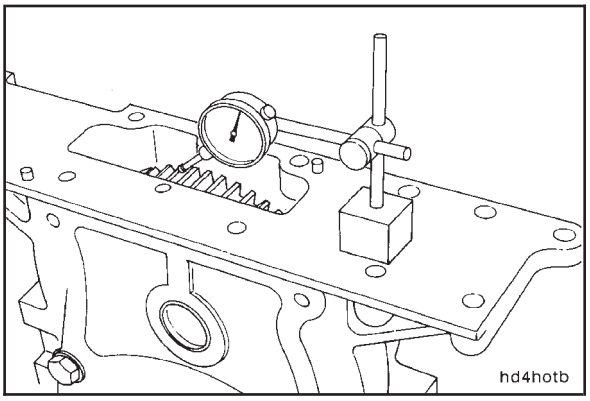
Install the lower housing of the rear gear train onto the dowel pins.

Check the alignment of all capscrews seals, rectangular seal, and the main oil rifle seal.

Use two 5/8-11x5 inch capscrews with flat washers in the locations shown.

Tighten the capscrews alternately to pull the lower housing to the block.





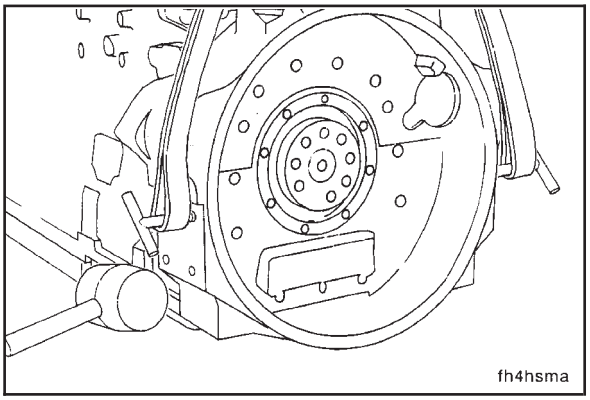
Use a dial indicator. Be sure the two capscrews are holding the lower housing firmly against the cylinder block. Check the gear lash.

Lower Housing-To-Cylinder Block Gear Backlash		
mm		in
0.05	MIN	0.002
0.51	MAX	0.015

If the gear lash is above acceptable limits, the rear gear train lower idler gear or crankshaft gear **must** be replaced.

NOTE: Replace the idler gear first.

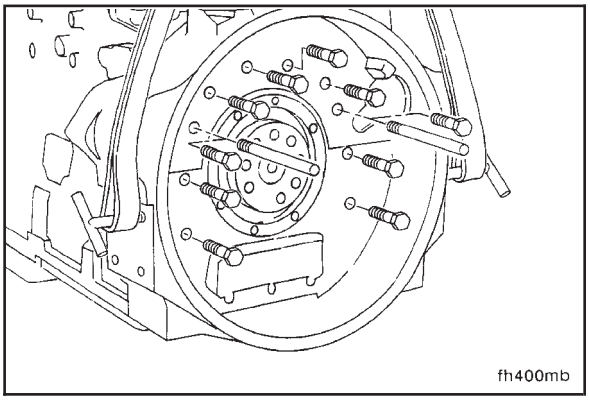
If the gear lash is below acceptable limits (or if the gear replacement does **not** correct the lash), replace the housing.



Use Lubriplate® No. 105 or gasket adhesive on the seal ring groove and the 10 capscrew counterbores on the rear gear train lower housing side of the flywheel housing.

Install the new rectangular seal ring, with the joint at the top, into the groove in the flywheel housing.

Install the new capscrew seals and dowel seals into the counterbores in the lower housing.

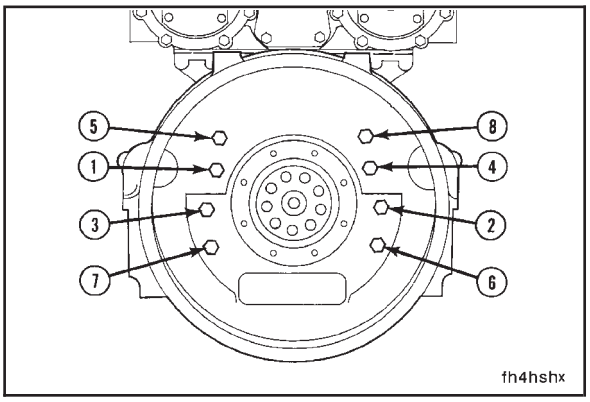


⚠ CAUTION ⚠

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

Use two 5/8-11x6 1/2 inch guide studs. Use a hoist, tee handles, and a lifting sling. Install the flywheel housing onto the dowels in the rear gear train lower housing.

Install the lock washers, capscrews, and nuts.



Use the following steps.

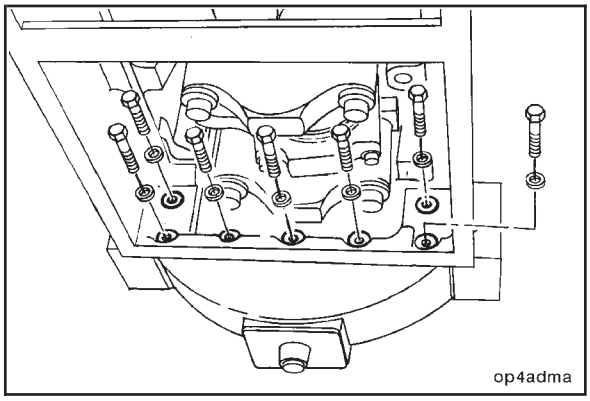
Tighten using the sequence shown.

Torque Value: Step 1 100 N•m [75 ft-lb]
2 205 N•m [150 ft-lb]

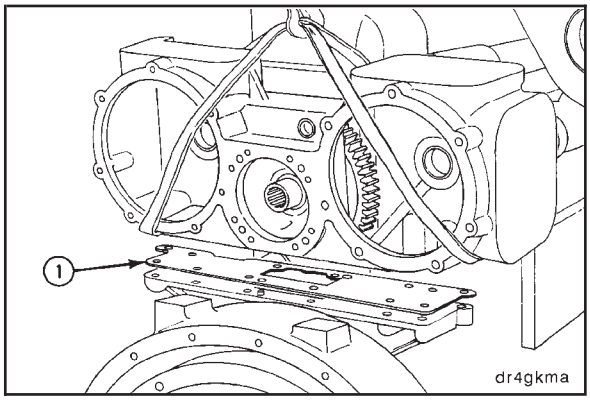
Install the two capscrews 7/16-14x4 3/4 inch, Part No. 190799, and the five capscrews 3/8-16x4 3/4 inch, Part No. S106-C, with flat washers and lockwashers.

Torque Value:

3/8-16 inch	45 N•m	[35 ft-lb]
7/16-14 inch	65 N•m	[50 ft-lb]

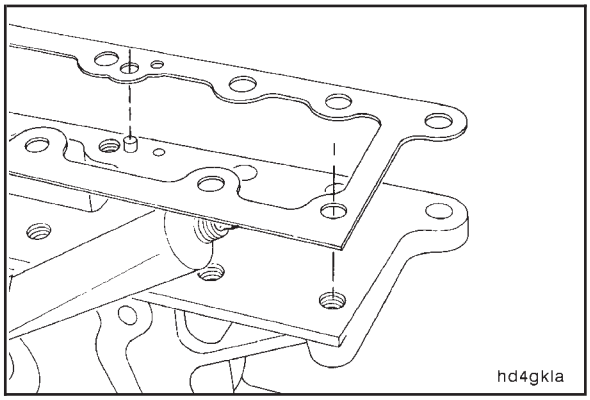


Install the upper housing of the rear gear train.



Use gasket adhesive on the gasket. Do **not** use an excessive amount of adhesive on the gasket.

Align and install the rear gear train upper housing gasket to the rear gear train lower housing.

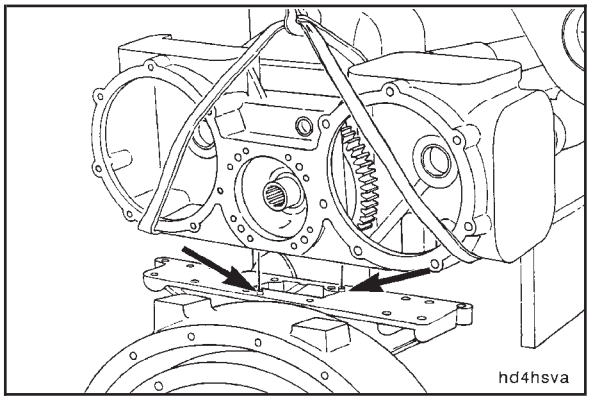


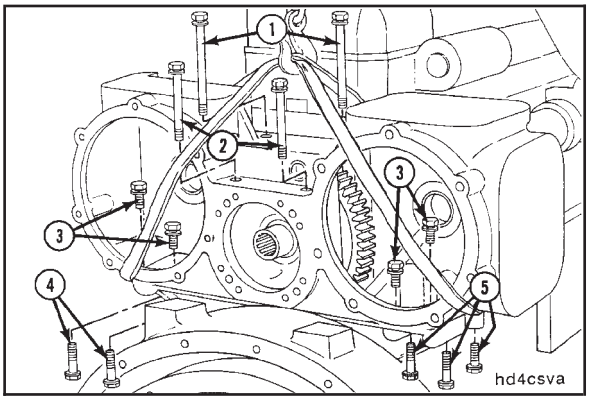
⚠ CAUTION ⚠

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

NOTE: Use extra care when aligning the upper housing onto the lower housing to prevent gasket damage.

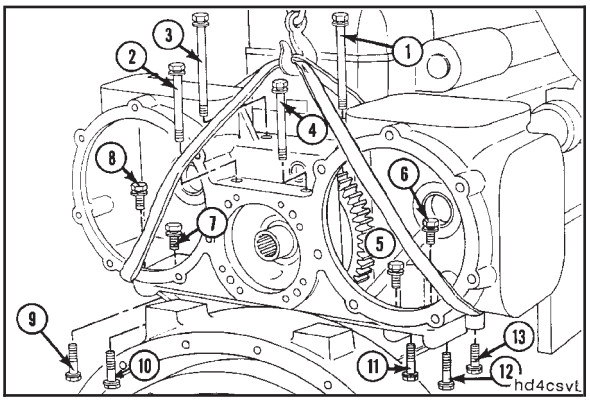
Use the dowel pins to align the **upper** housing onto the **lower** housing.





Use **only** SAE Grade 8 capscrews to install the upper housing. Install the following capscrews according to the table below.

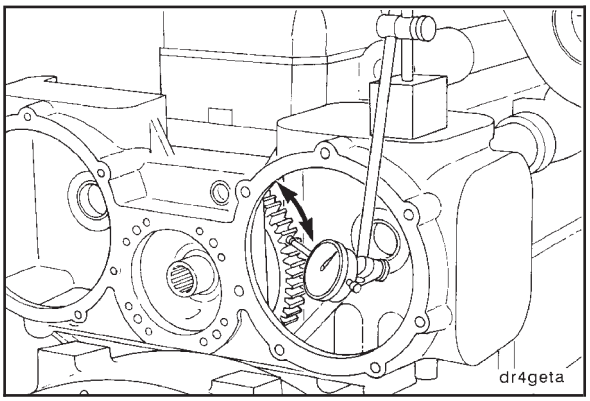
Ref	Location	Part No.	Size [inch]	Qty
1	Top-Front	3202224	1/2-13 x 9 1/4	2
2	Top-Rear	3202223	1/2-13 x 7 1/2	2
3	Internal	1691695	1/2-13 x 1 3/4	4
4	Bottom-Left Side	3202222	1/2-13 x 1 3/4	2
5	Bottom-Right Side	3202222	1/2-13 x 1 3/4	3



Use the sequence shown to tighten the bolts.

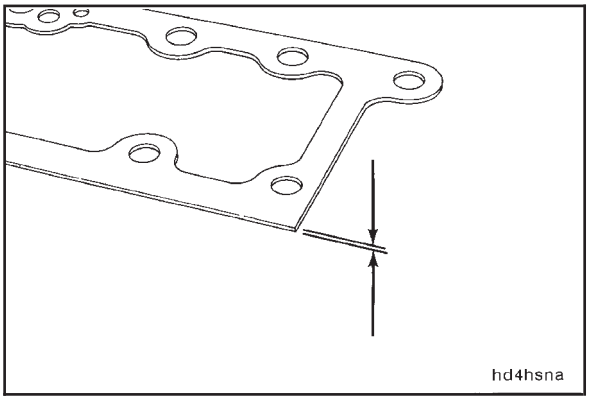
Torque Value:

Step 1	70 N•m	[50 ft-lb]
Step 2	150 N•m	[110 ft-lb]



Use a dial indicator. Be sure the lower idler gear is secure. If the gear is **not** secure, the indicator reading will include the lower idler gear to the crankshaft gear backlash.

Idler Gear Backlash		
mm		**in**
0.05	MIN	0.002
0.51	MAX	0.020

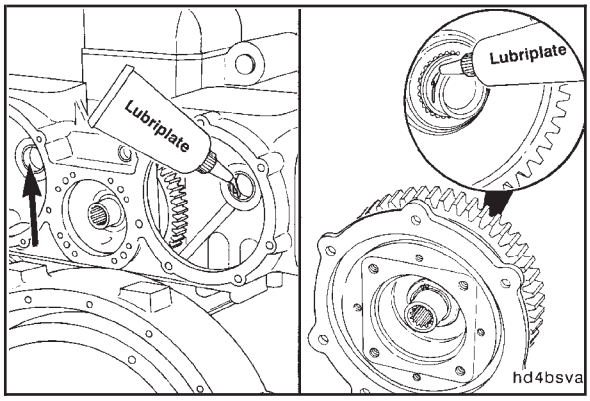


If the gear lash is less than specified limits, thicker gaskets are available. Do **not** use more than two gaskets to correct the backlash.

If the gear lash is greater than the specification and the thinnest gasket is used, the upper and lower gears **must** be replaced.

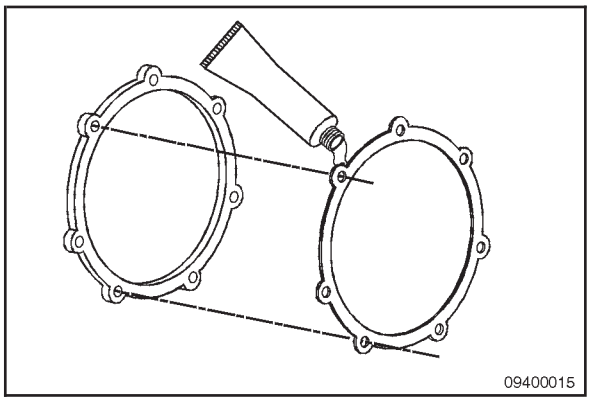
Use Lubriplate® No. 105, or equivalent. Lubricate the outer hydraulic pump support bushing in the upper housing. Lubricate the bushing surfaces on both shafts in the outer hydraulic pump support drive assemblies.

Install the outer hydraulic pump support drive.



NOTE: Some engines will **not** have an outer hydraulic pump support drive. These engines require a cover plate and a non-splined shaft, but do **not** use a hydraulic gear.

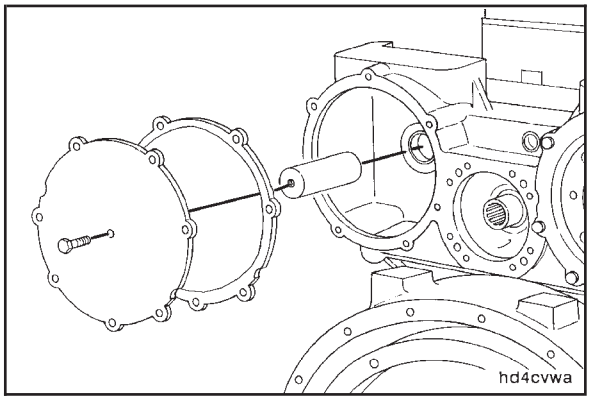
Use gasket adhesive sparingly. Install the hydraulic support housing gaskets to both support mounting flanges on the outer hydraulic pump support drive assemblies.



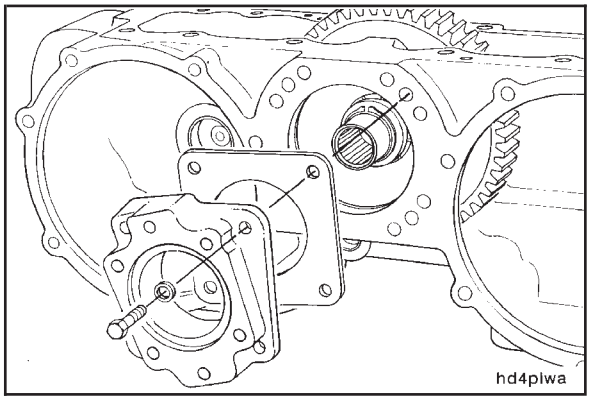
If using the outer hydraulic pump support cover plate, install the non-splined shaft onto the cover plate. Use a 3/8–16 x 1-1/4 inch capscrew.

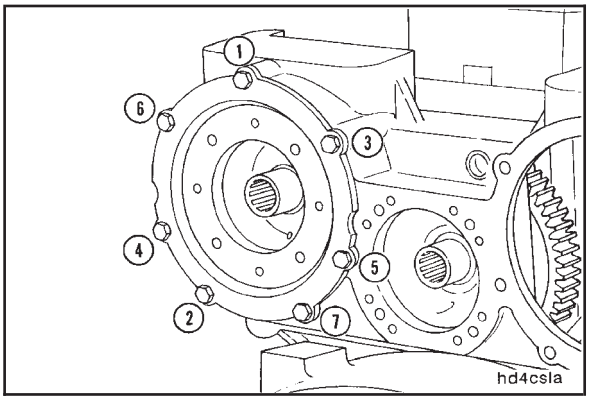
Tighten the capscrew.

Torque Value: 40 N•m [30 ft-lb]



Use three 7/16-14 x 4 inch guide studs. Install one outer hydraulic pump support drive assembly.





Install four capscrews.

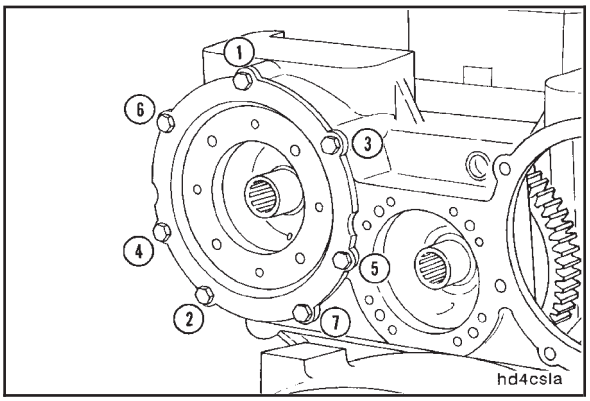
Hand-tighten the capscrews.

Remove the guide studs.

Install the remaining three capscrews. Use the sequence and torque as shown.

Tighten the capscrews.

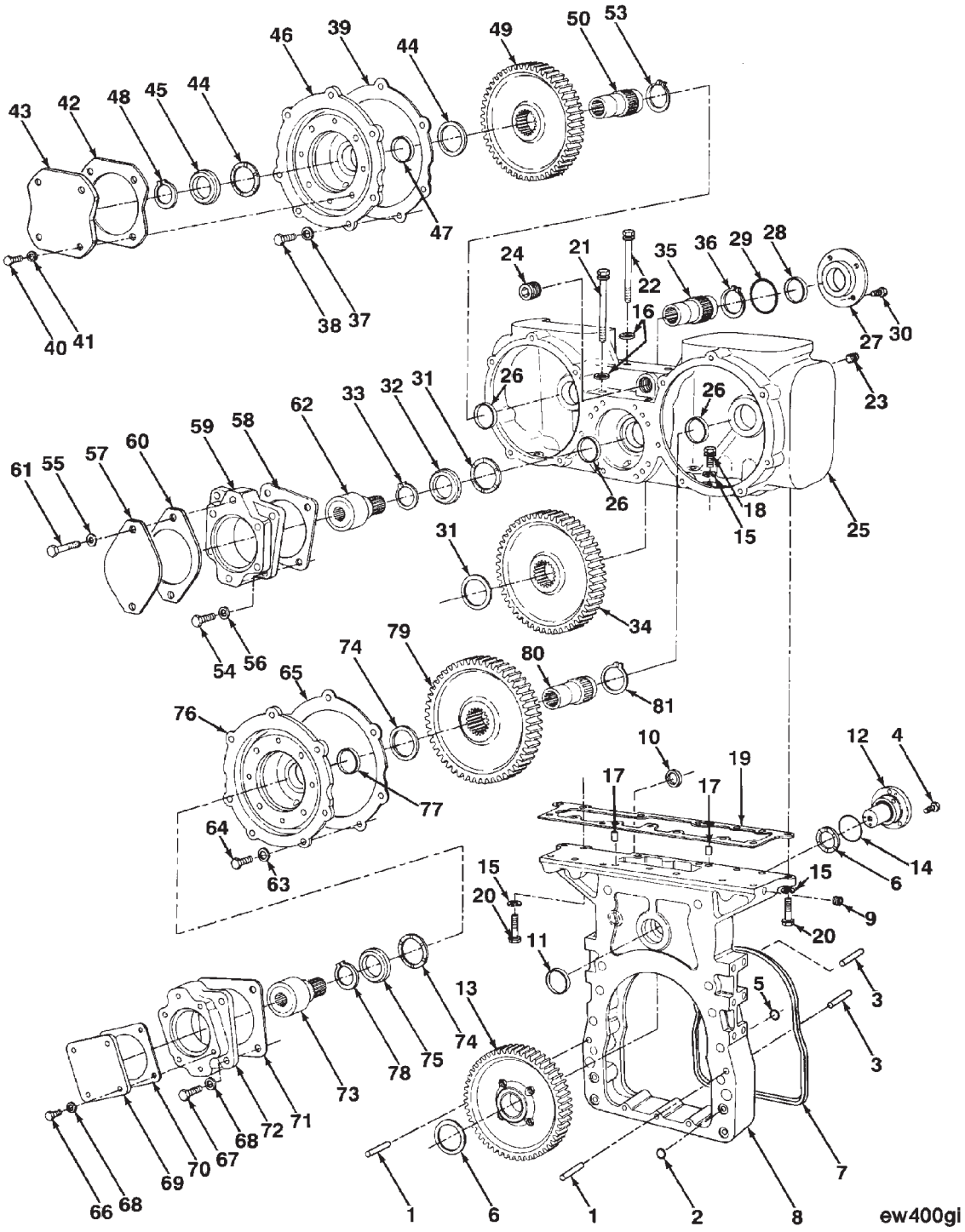
Torque Value: 70 N•m [50 ft-lb]



Install the other outer hydraulic pump using the same procedure.

Rear Gear Drive (Upper Assembly) (009-024)

Exploded View



Rear Gear Drive

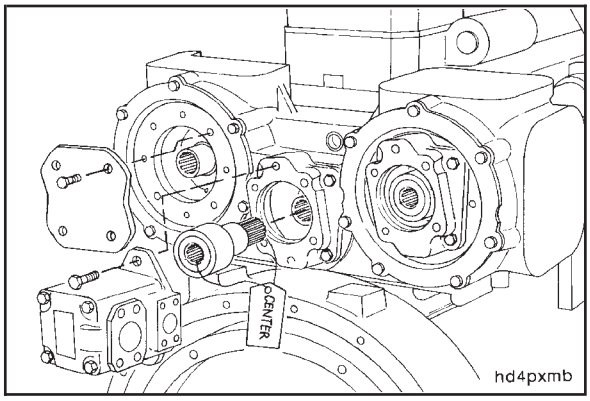
Rear Gear Drive Exploded View Table

1. Dowel Pin
2. Seal, Rectangular Ring
3. Dowel Pin
4. Capscrew, Hexagon Head
5. Seal, Rectangular Ring
6. Bearing, Thrust
7. Seal, Rectangular Ring
8. Housing, Gear
9. Plug, Pipe
10. Seal, Rectangular Ring
11. Plug, Expansion
12. Shaft, Idler
13. Gear and Bushing, Hydraulic Pump
14. Seal, O-ring
15. Washer, Lock
16. Washer, Plain
17. Dowel Pin
18. Capscrew, Hexagon Head
19. Gasket, Hydraulic Pump
20. Capscrew, Hexagon Head
21. Capscrew, Hexagon Head
22. Capscrew, Hexagon Head
23. Plug, Pipe
24. Plug, Pipe
25. Housing, Hydraulic Drive
26. Bushing
27. Support, Hydraulic Pump
28. Bushing
29. Seal, O-ring
30. Capscrew, Hexagon Head
31. Bearing Thrust
32. Spacer, Bearing
33. Ring, Retaining
34. Gear, Hydraulic Pump
35. Shaft and Plug Assembly
36. Ring, Retaining
37. Washer, Lock
38. Capscrew, Hexagon Head
39. Gasket, Support, hydraulic
40. Capscrew, Hexagon Head
41. Washer, Lock
42. Gasket, Hydraulic Pump Flange Cover
43. Cover, Hydraulic Pump Flange
44. Bearing, Thrust
45. Spacer, Bearing
46. Support, Hydraulic Pump
47. Bushing
48. Ring, Retaining
49. Gear, Hydraulic Pump
50. Shaft and Plug Assembly
51. Plug, Expansion
52. Ring, Retaining
53. Capscrew, Hexagon Head
54. Washer, Lock
55. Washer, Lock
56. Plate, Cover
57. Gasket, Hydraulic Pump
58. Adapter, Hydraulic Pump
59. Gasket, Hydraulic Pump
60. Capscrew, Hexagon Head
61. Adapter, hydraulic Pump
62. Washer, Lock
63. Capscrew, Hexagon head
64. Gasket, Support, Hydraulic
65. Capscrew, Hexagon Head
66. Capscrew, Hexagon Head
67. Washer, Lock
68. Plate, Cover
69. Gasket, hydraulic Pump
70. Gasket, Hydraulic Pump
71. Adapter, Hydraulic Pump
72. Assembly, Coupling and Adapter
73. Bearing, Thrust
74. Spacer, Bearing
75. Gear, Hydraulic Pump
76. Support, Hydraulic Pump
77. Bushing
78. Ring, Retaining
79. Gear, Hydraulic Pump
80. Shaft and Plug Assembly
81. Ring, Retaining

Disassemble

NOTE: The hydraulic pump supports and the hydraulic pump adapters **can** be different. **Mark** the parts for location.

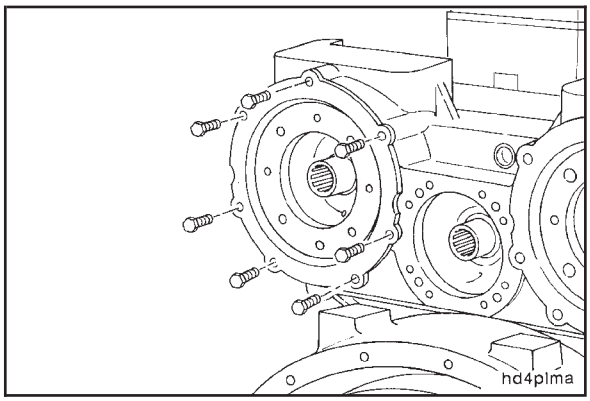
Remove the hydraulic pump support and the hydraulic pump adapters or cover plates. Remove and discard the gaskets.



NOTE: Some engines will **not** have an outer hydraulic drive. These engines require a cover plate and a nonsplined shaft, but do **not** use a hydraulic gear.

If using a cover plate, remove the cover plate and nonsplined shaft.

Remove the seven capscrews from each outboard hydraulic drive or cover plate.



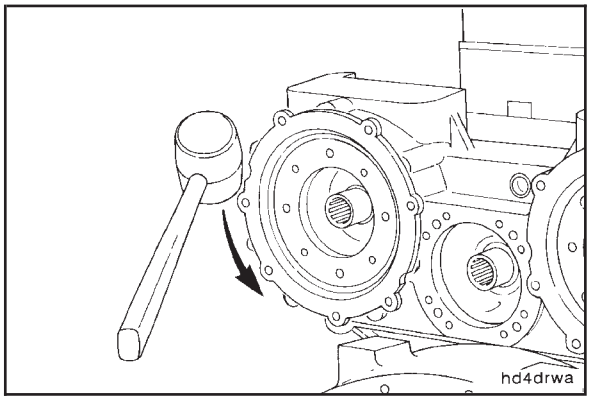
⚠ CAUTION ⚠

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

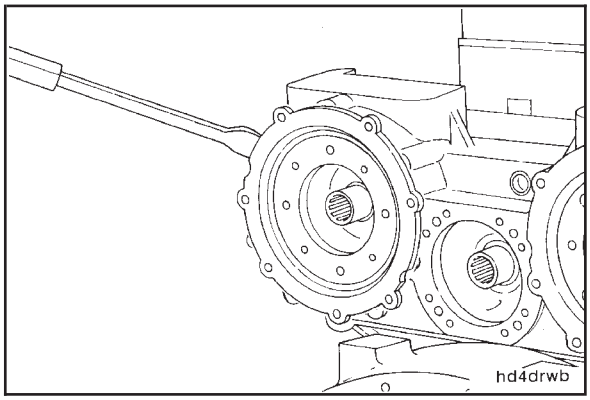
⚠ WARNING ⚠

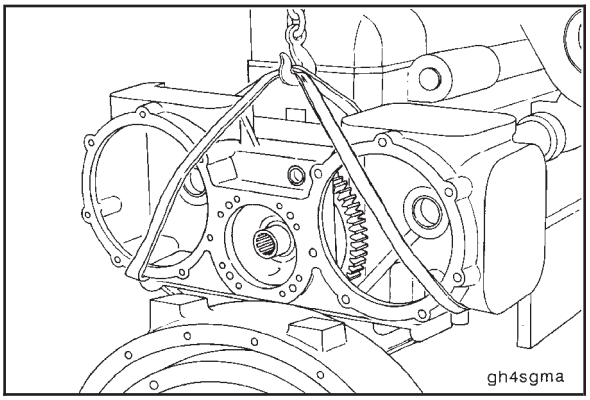
Care MUST be taken to avoid possible breakage of the capscrew mounting flanges.

The outboard hydraulic pump supports must be rotated to remove from the housing. Use a mallet. Carefully tap the side of the support.



Use a pry bar to remove both outboard hydraulic pump supports.

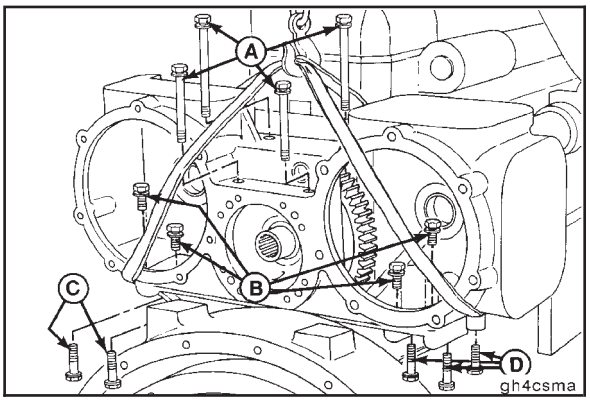




⚠ CAUTION ⚠

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

Use a hoist and lifting sling. Install the lifting sling around both sides of the upper housing. Adjust the hoist until there is tension in the lifting sling.

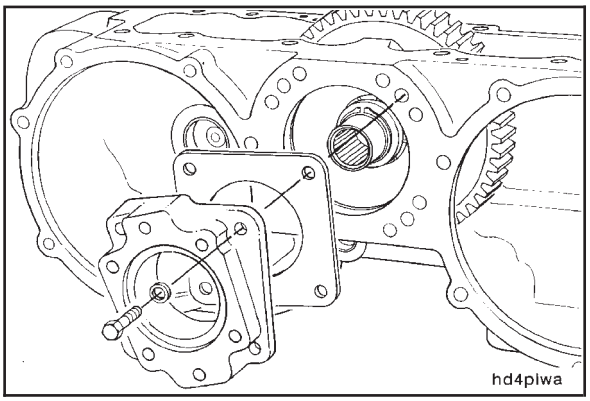


⚠ CAUTION ⚠

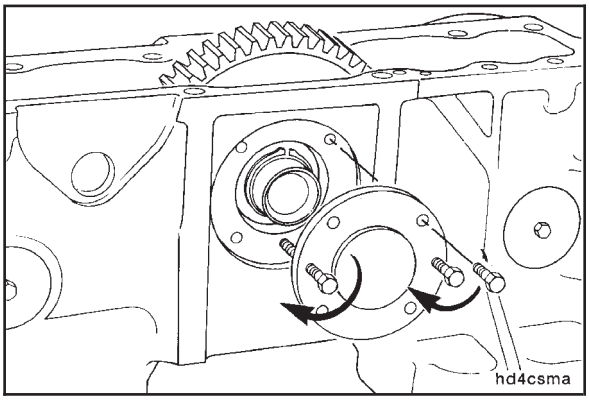
The center gear in the drive protrudes from the bottom of the housing. Use wood blocks to raise the housing and prevent the gear from being damaged.

Remove the four capscrews from the top of the housing (A), the four internal capscrews (B), the two capscrews from the bottom of the upper housing on the left side (C), and the three capscrews from the bottom on the right side (D).

Remove the rear gear train upper housing from the lower housing. Remove the gasket. Keep the gasket for future use.



Remove the center hydraulic pump adapter and/or cover plate. Remove and discard the gaskets.



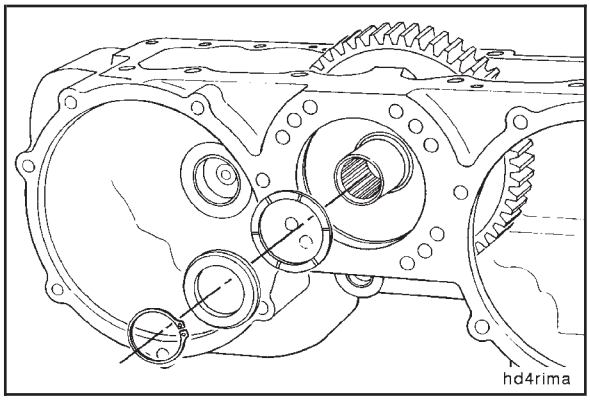
Remove the four capscrews from the hydraulic pump support an the engine side of the upper housing.

Use two 1/4–20x2 inch capscrews. Alternately tighten the capscrews to pull the support plate from the housing.

Remove and discard the o-ring.

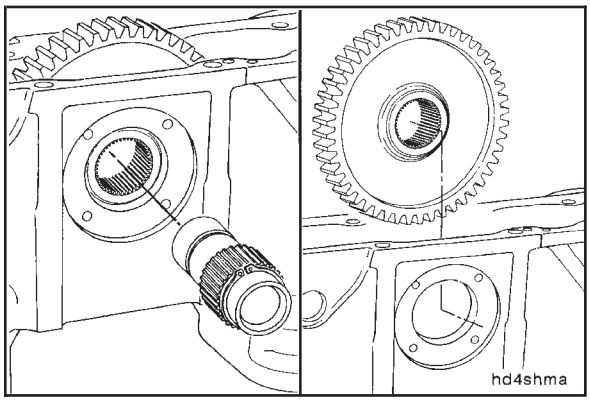
Remove the tapered retaining ring from the hydraulic pump drive shaft on the pump side.

Remove the bearing spacer and the thrust bearing. Check the bearing spacer for wear against the shaft shoulder.

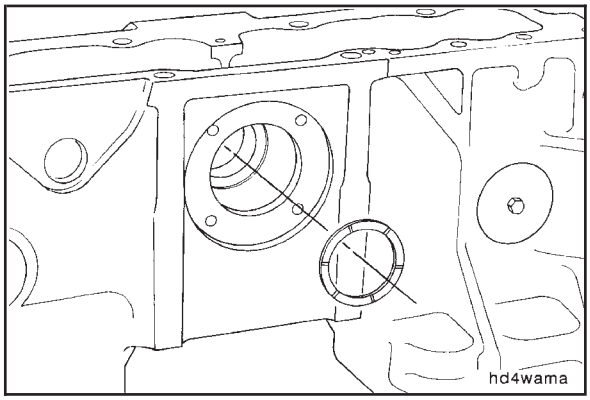


Make sure the center drive gear will **not** drop. Remove the drive shaft from the upper housing.

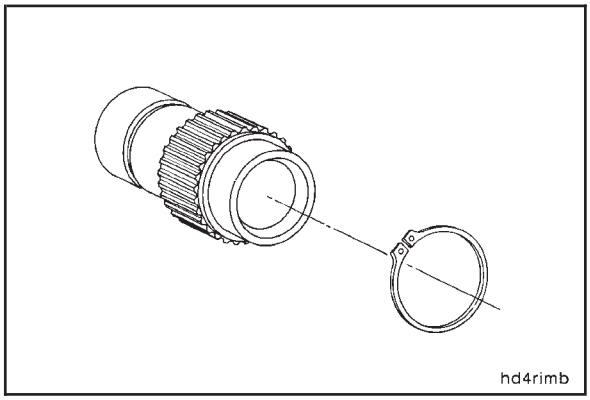
Remove the gear.

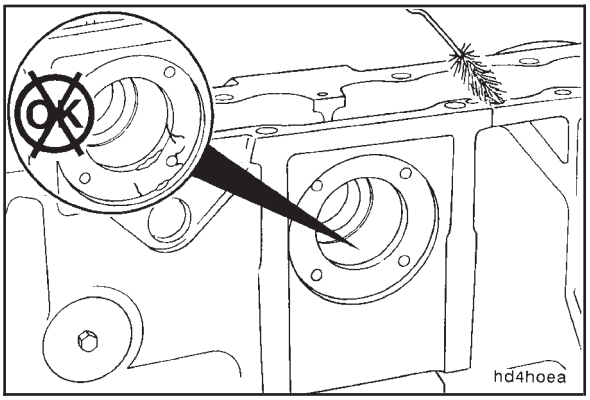


Remove the thrust washer from the counterbore in the upper housing.



Remove the square retaining ring from the drive shaft.

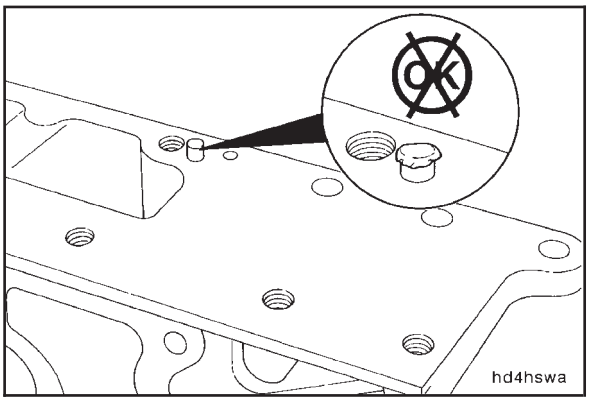




Inspect for Reuse

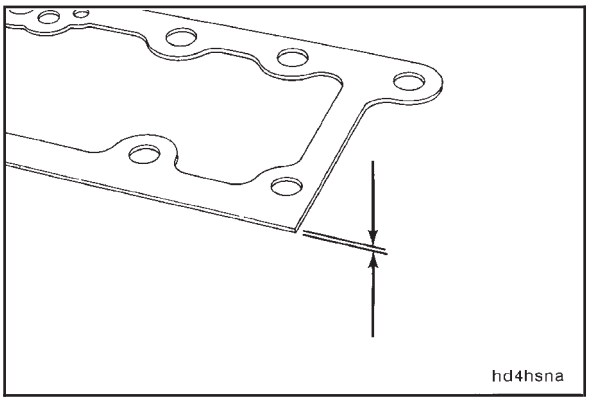
Use a bore cleaning brush and safety solvent. Clean and inspect the upper housing for damage. Clean and inspect all oil drillings for debris.

NOTE: Do **not** remove the 1-inch internal hex pipe plug in the upper housing near the center drive bore. Do **not** remove the 1/8-inch pipe plug that is on the same housings located on the engine side of the housing into the right side outboard hydraulic bushing bore.



Inspect the two rear gear train upper housing dowel pins in the top of the lower housing. Any damaged dowels **must** be replaced.

Use dowel pin remover, Part No. ST-1134, to remove the dowel pins. Use a brass or lead hammer to install the dowel pins.



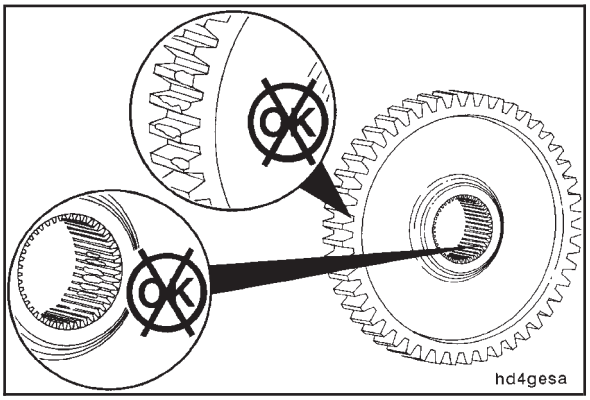
Measure the thickness of the gasket used on the rear gear train upper housing.

Refer to the following table for the part number and dimension.

Upper to Lower Housing Gasket Thickness — Nominal (New*)

	mm		in
Part No. 205723	0.38	NOMINAL	0.015
Part No. 3077231	0.51	NOMINAL	0.020
Part No. 3201852	0.76	NOMINAL	0.030

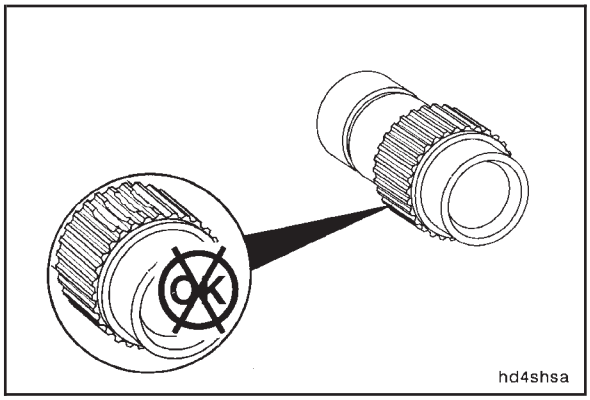
NOTE: * Used gaskets measure thinner.



Clean and check the center gear for damage.

Check the gear teeth for excessive fretting. Check the internal splines for wear.

Check the center drive shaft. Check the external splines for wear.

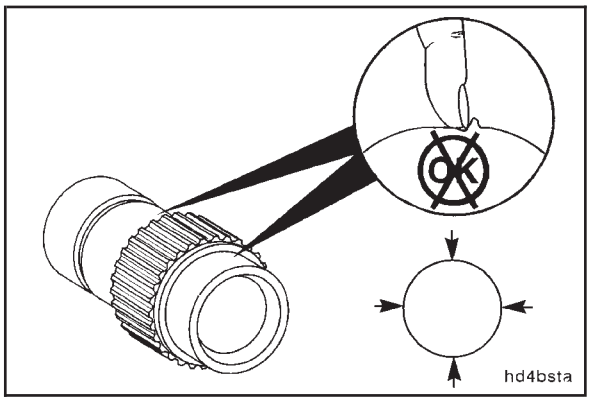


Inspect the bushing diameters on the shaft for wear. If a fingernail will catch on scratches or grooves, replace the shaft.

Measure the shaft of the bushing diameters.

Center Drive Shaft Bushing I.D.		
mm		in
47.536	MIN	1.8715
47.549	MAX	1.8720

NOTE: If the bushing does **not** meet the specifications, the bushing **must** be replaced.



Inspect the thrust bearings.

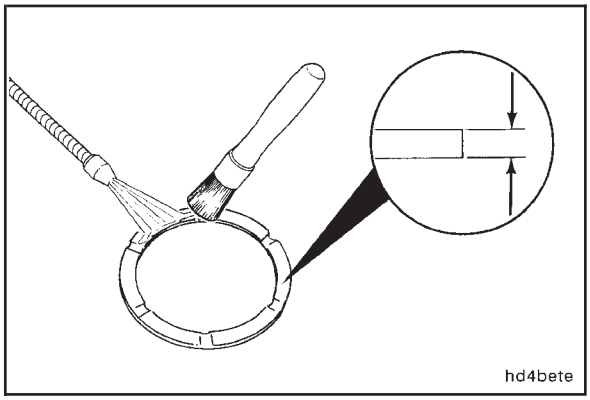
Measure the thrust bearing thickness.

Upper Housing Thrust Bearing Thickness		
mm		in
2.27	MIN	0.085
2.31	MAX	0.091

NOTE: If the thrust bearings do **not** meet the specifications, the bearings must be replaced.

Check the retaining rings for damage.

Check the spacer bearing for damage.

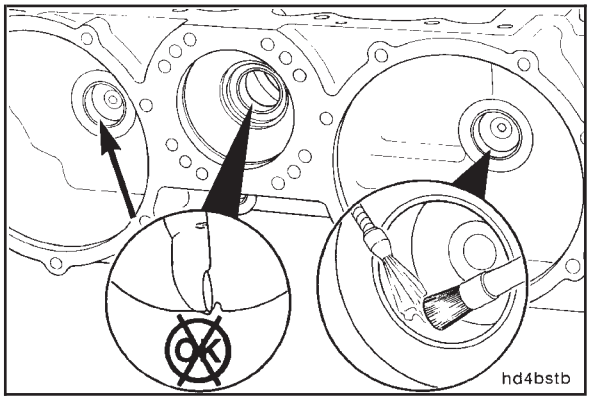


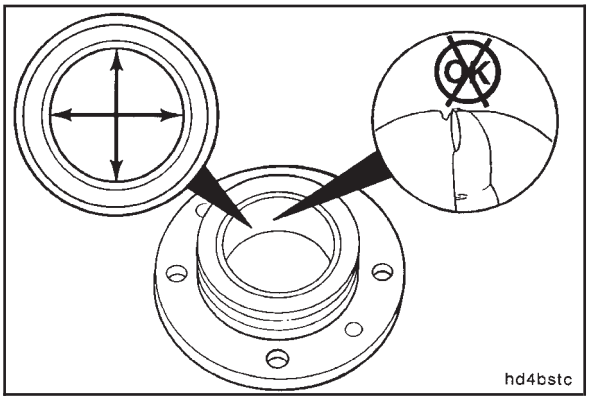
Inspect the three hydraulic pump support bushings in the upper housing. If a fingernail will catch on scratches or grooves, replace the bushing.

Measure the bushing inside diameter.

Hydraulic Drive Housing Bushing I.D.		
mm		in
47.60	MIN	1.874
47.68	MAX	1.877

If the bushing does **not** meet the specifications, the bushing **must** be replaced.



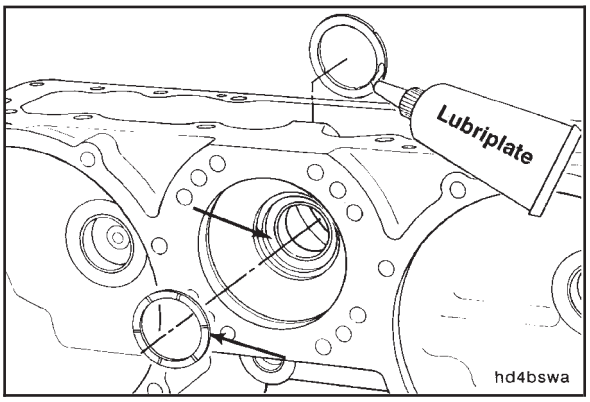


Inspect the hydraulic pump support bushing in the shaft support plate. If a fingernail will catch on the scratches or grooves, replace the bushing.

Measure the bushing inside diameter.

Hydraulic Pump Support Bushing I.D.		
mm		in
47.60	MIN	1.874
47.68	MAX	1.877

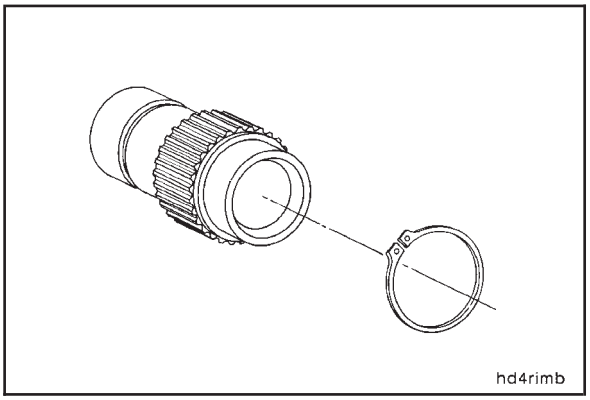
If the bushing does **not** meet the specifications, the bushing **must** be replaced. Refer to Procedure No. 009–037.



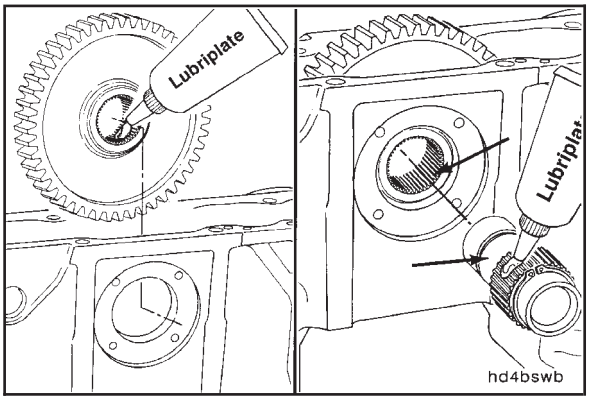
Assemble

Use Lubriplate® 105 or equivalent. Lubricate the center hydraulic shaft bushing, two thrust bearings, and the two counterbores next to the center bushing in the housing.

Install the two thrust bearings with the grooved side facing **away** from the housing into the counterbore.



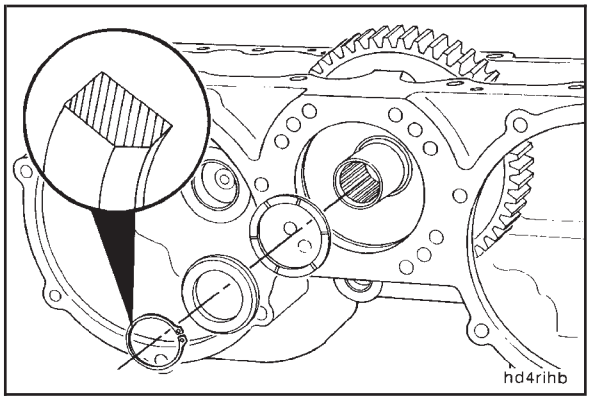
Install the non-tapered retaining ring onto the center drive shaft on the end closest to the external splines.



Use Lubriplate® 105 or equivalent. Lubricate the pump side bushing surface on the center drive shaft, the external splines on the drive shaft, and the internal splines on the gear. Align the gear in the housing.

Install the shaft into the housing and gear from the engine side of the upper housing.

Install the bearing spacers and tapered retaining ring with the beveled side facing the pump side of the drive shaft.

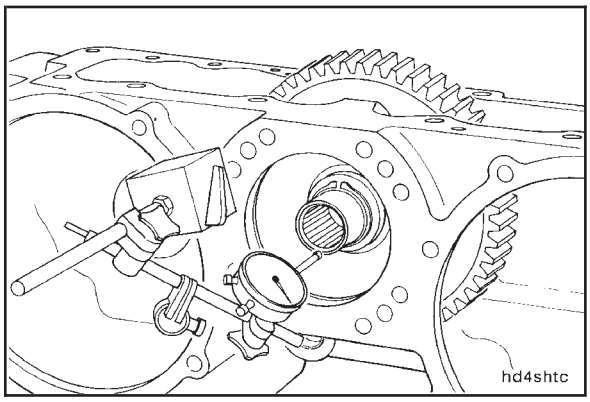


Use Lubriplate® 105 or equivalent. Lubricate the engine side bushing surface on the center hydraulic pump drive shaft and the bushing in the hydraulic pump drive shaft and the bushing in the hydraulic pump drive shaft.

Use clean engine oil to lubricate the o-ring. Install the o-ring into the groove on the support.

Install the hydraulic pump support. Install the four 5/16–18x3/4 inch capscrews. Tighten the capscrews.

Torque Value: 20 N•m [15 ft-lb]

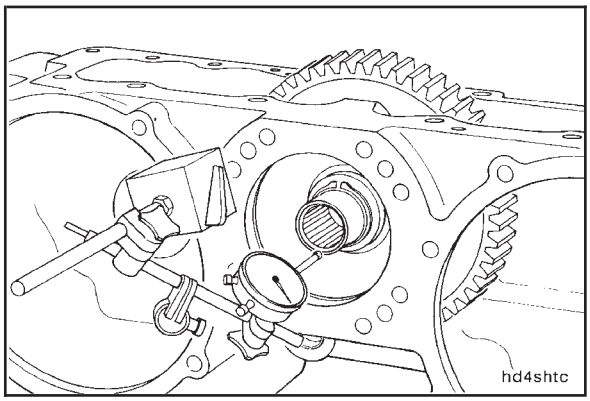


Use a dial indicator.

Measure the end clearance.

Center Drive End Clearance		
mm		**in**
0.10	MIN	0.004
0.51	MAX	0.020

NOTE: If the end clearance is **not** within specifications, the thrust bearings **must** be replaced.

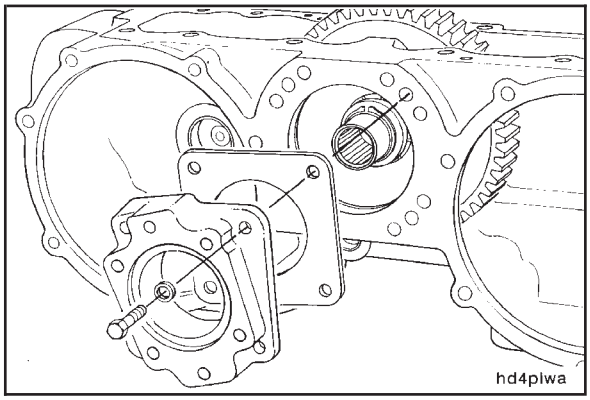


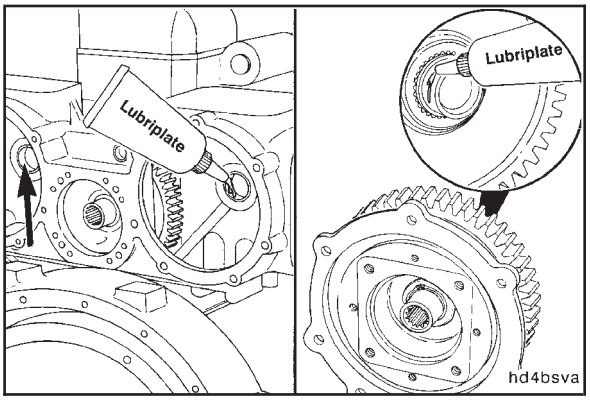
Install the hydraulic pump adapter or cover plate and gasket. Install the four capscrews.

Tighten the adapter or cover plate to the correct torque.

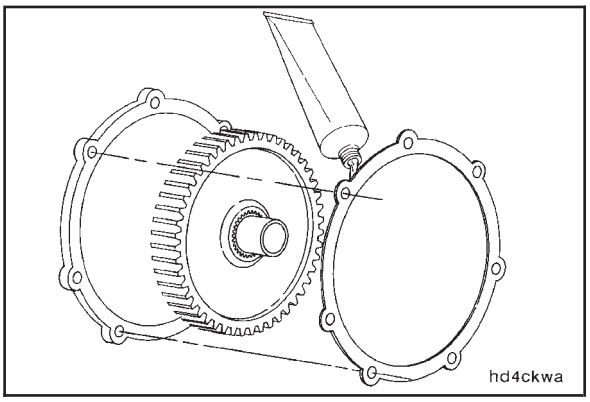
Torque Value:

Adapter Cover Plate SAE C/SAE B Drive	95 N•m	[70 ft-lb]
Cover Plate SAE A Drive	40 N•m	[35 ft-lb]



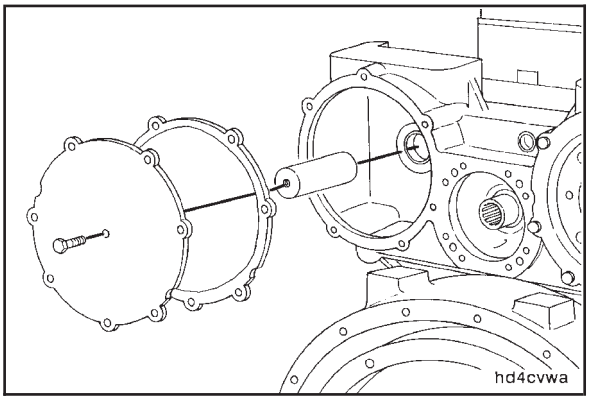


Use Lubriplate® 105 or equivalent. Lubricate the outer hydraulic pump support bushings in the upper housing. Lubricate the bushing surfaces on both shafts in the outer hydraulic pump support drive assemblies.



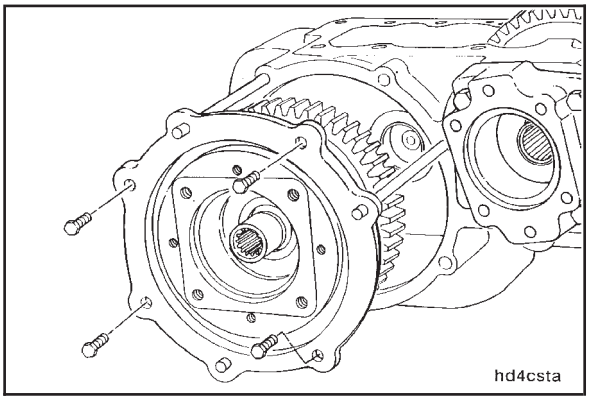
NOTE: Some engines will **not** have an outer hydraulic pump support drive. These engines require a cover plate and a non-splined shaft, but do **not** use a hydraulic gear.

Use a gasket adhesive sparingly. Install the hydraulic support housing gaskets to both support mounting flanges on the outer hydraulic pump support drive assemblies.



If using the outer hydraulic pump support cover plate, install the non-splined shaft onto the cover plate. Use a 3/8-16x1-1/4 inch capscrew.

Torque Value: 40 N•m [30 ft-lb]



⚠ CAUTION ⚠

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

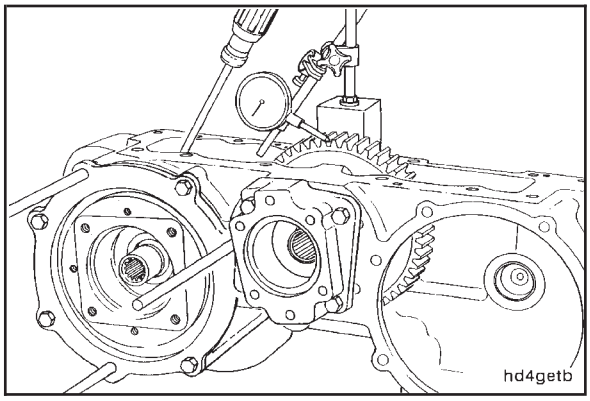
Use three 7/16-14x4 inch guide studs. Install one outer hydraulic pump support drive assembly.

Torque Value: 70 N•m [50 ft-lb]

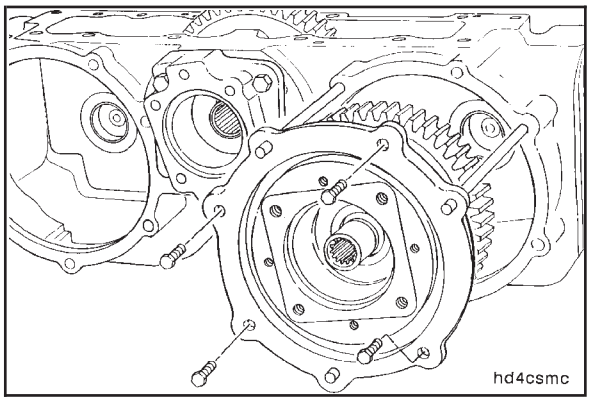
Use a dial indicator. Make sure the outer hydraulic drive shaft will not move. Measure the center drive gear to the outer drive gear backlash.

Center Drive Gear to Outer Drive Gear Backlash		
mm		in
0.10	MIN	0.004
0.51	MAX	0.020

NOTE: If the gear lash is above the specifications, one or both of the gears **must** be replaced.

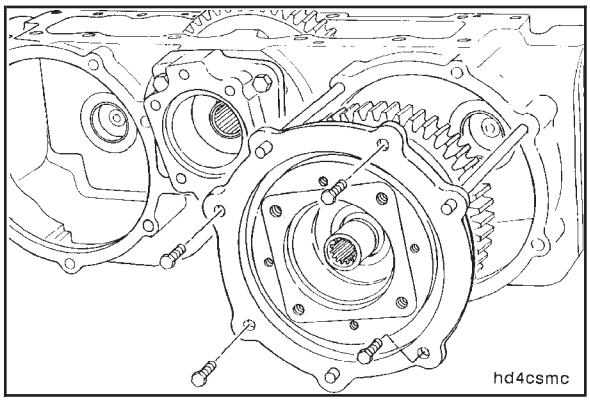


Remove the four capscrews and outer hydraulic drive assembly.



Use three 7/16–14x4 inch guide studs. Install one outer hydraulic pump support drive assembly. Tighten the capscrews.

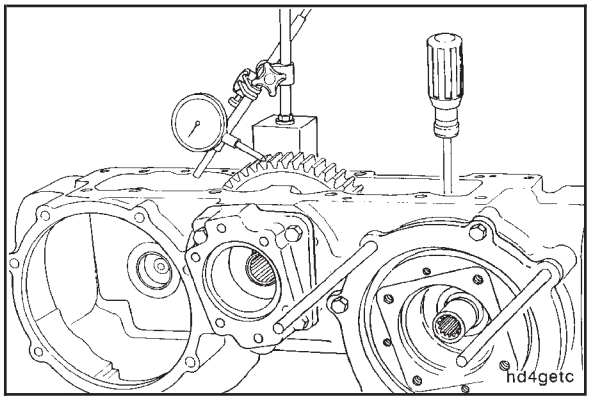
Torque Value: 70 N•m [50 ft-lb]

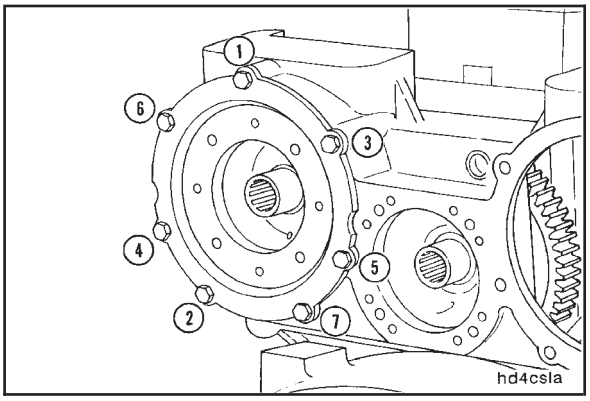


Use a dial indicator. Make sure the outer hydraulic drive shaft will not move. Measure the center drive gear to the outer drive gear backlash.

Center Drive Gear to Outer Drive Gear Backlash		
mm		in
0.10	MIN	0.004
0.51	MAX	0.020

NOTE: If the gear lash is above the specifications, one or both of the gears **must** be replaced.



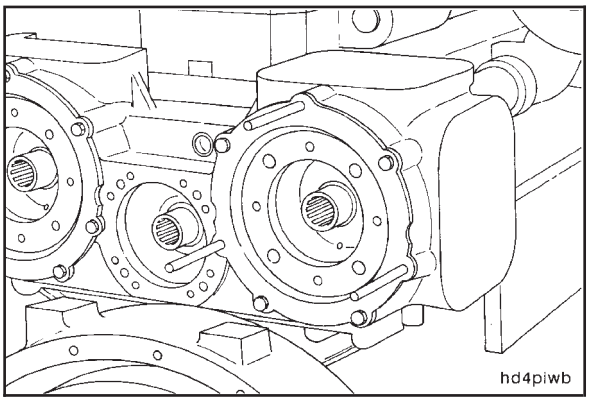


Install four capscrews. Hand tighten the capscrews. Remove the guide studs.

Install the remaining three capscrews.

Use the sequence and tighten as shown.

Torque Value: 70 N•m [50 ft-lb]



Use the same procedures to install the other hydraulic drive assembly. Install the assembly.

The water pump drive is mounted on the front gear housing. It is connected to the water pump with a spline coupling. A pulley on the end of the water pump drive shaft provides power to the vehicle alternator with a belt.

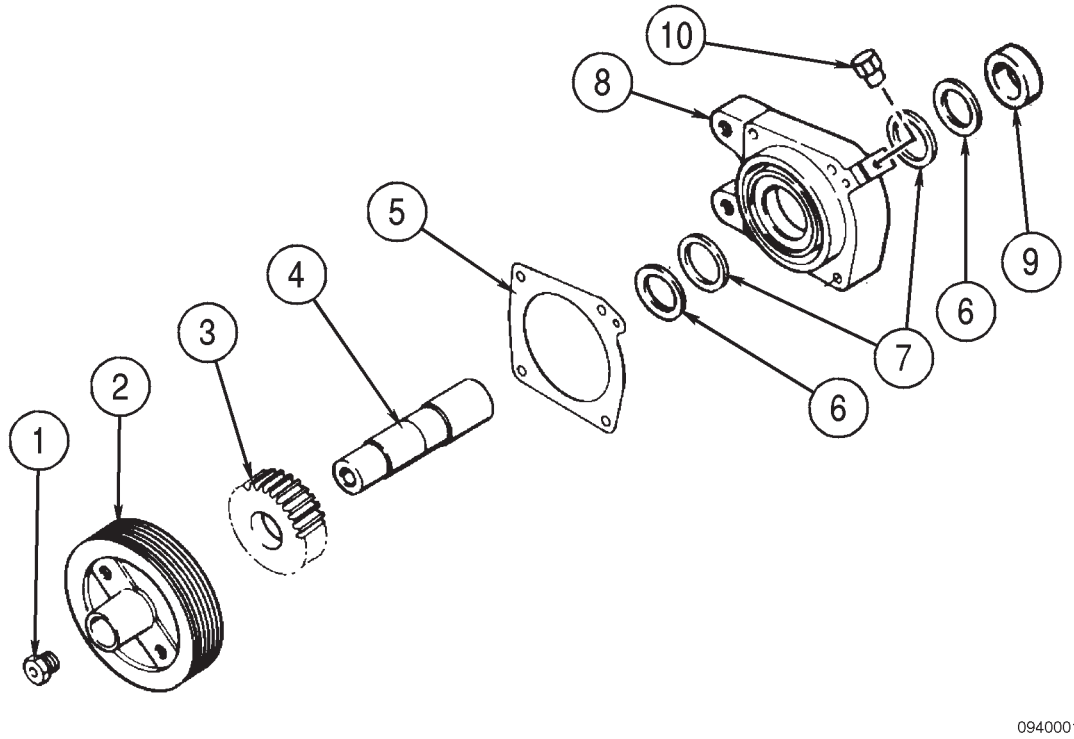
There is a bushing in the front gear cover at the **front** of the water pump drive shaft. There are two bushings in the drive support at the **rear** of the drive shaft. It is **not** necessary to machine the bushings in the support when replacement is required.

Oil is supplied to the bushings in the support through a drilling in the support. Some of the oil that enters the bushing area lubricates the spline coupling through a hole in the shaft. There **must** be an orifice plug in the splined end of the shaft to prevent excessive oil from entering the spline coupling. The oil drilling **must** have an expansion plug that has an orifice to prevent excessive oil from being transmitted to the water pump bearings. The expansion plug is located on the water pump end of the drive.

⚠ CAUTION ⚠

A pulley pusher must be used to install the alternator drive pulley. Do not use a hammer. If a hammer is used to install the pulley, the water pump drive gear will move on the shaft and excessive clearance in the drive will result. Excessive clearance will cause the thrust bearings to fall out and cause the drive to fail.

Exploded View



09400014

1. Plug, Protective
2. Pulley, Alternator Drive
3. Gear, Water Pump and Alternator Drive
4. Shaft, Water Pump and Alternator Drive
5. Gasket, Water Pump Support
6. Bearing, Thrust
7. Bushing, Water Pump Drive
8. Support, Water Pump
9. Retainer
10. Plug, Pipe

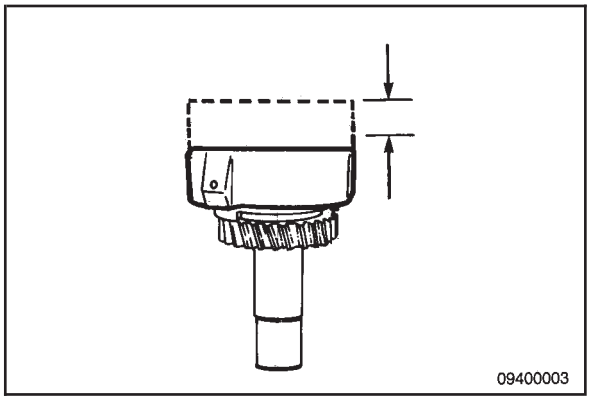
Inspect for Reuse

Measure the water pump drive end clearance.

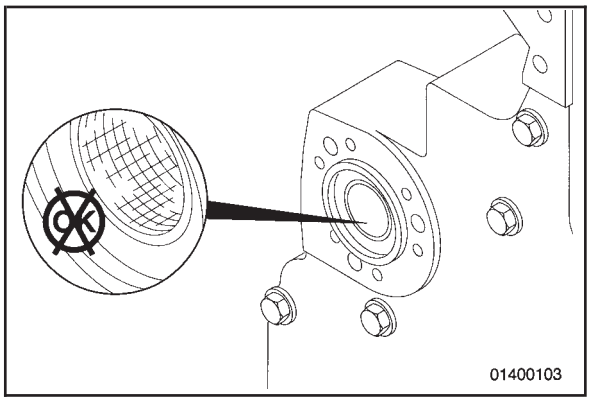
Water Pump Drive End Clearance		
mm		in
0.23	MIN	0.009
0.33	MAX	0.013

If the end clearance is **not** within specifications, replace or rebuild the assembly.

NOTE: Oversize thrust bearings are available to adjust the end clearance.

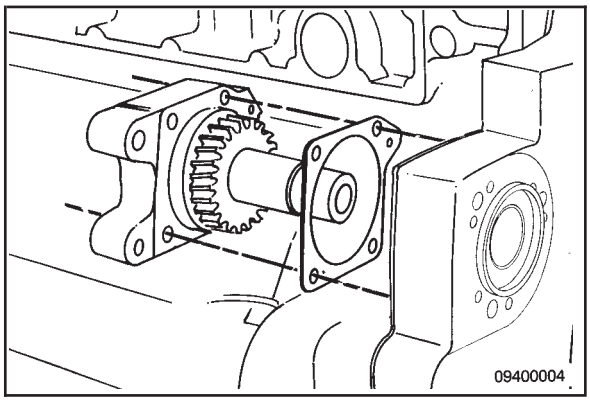


Inspect the water pump drive bushing in the front cover for excessive wear or damage.



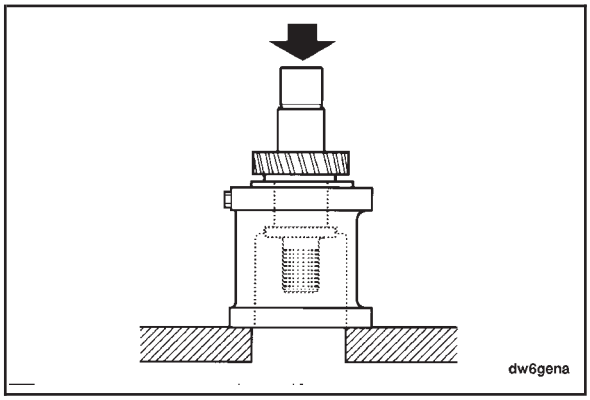
Inspect the alternator drive pulley for reuse. Refer to Procedure 009-004.

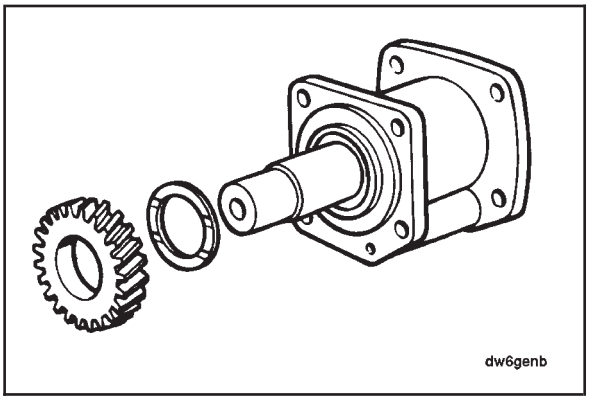
Inspect the water pump for reuse. Refer to Procedure 008-062.



Disassemble

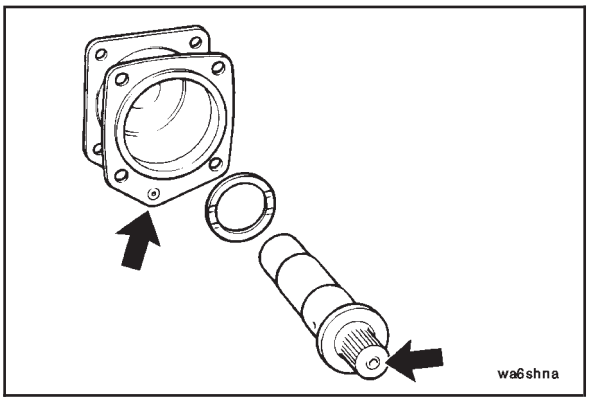
Use a press to remove the gear from the shaft. Support the housing and press the shaft downwards





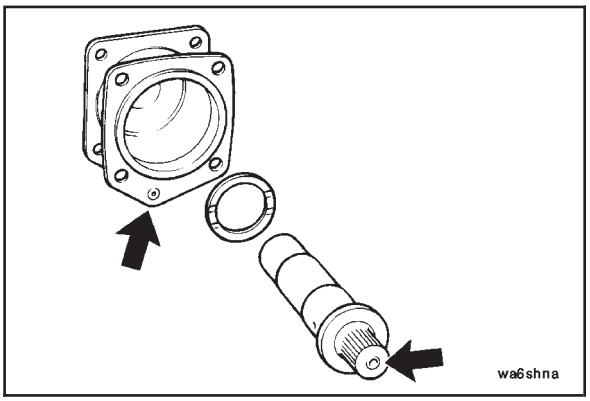
Remove the gear and front thrust bearing.

Remove the pipe plug from the water pump support housing.



Remove the shaft and rear thrust bearing.

Check the water pump support for an orifice expansion plug (A). Check the shaft for an orifice pipe plug (B). The plugs **must** be removed to clean the oil drillings if dirt or debris is found in the main oil passage. Do **not** remove the plugs if the main oil passage is clean.

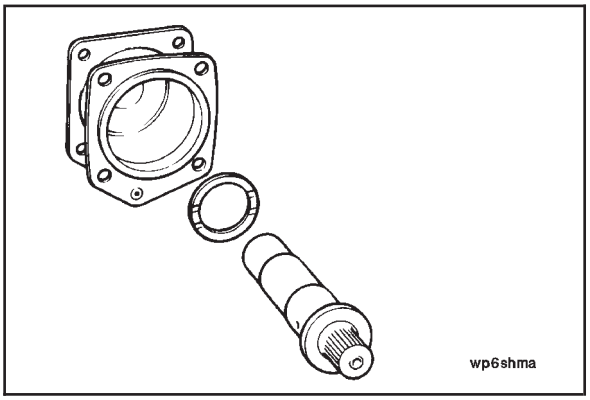


Assemble

If the pipe plug with an orifice was removed, use a driver to install the plug (A). The plug **must** be inserted below the surface of the support housing.

If the orifice pipe plug (B) was removed, install the plug in the shaft.

Torque Value: 15 N•m [135 in-lb]



⚠ CAUTION ⚠

The rear thrust bearing MUST be installed with the oil grooves TOWARD the shaft retainer. Failure will result if the bearing is NOT installed correctly.

Lubricate the oil groove surface of the rear thrust bearing with Lubriplate® No. 105 or equivalent. Install the bearing on the shaft with the grooved surface against the shaft retainer.

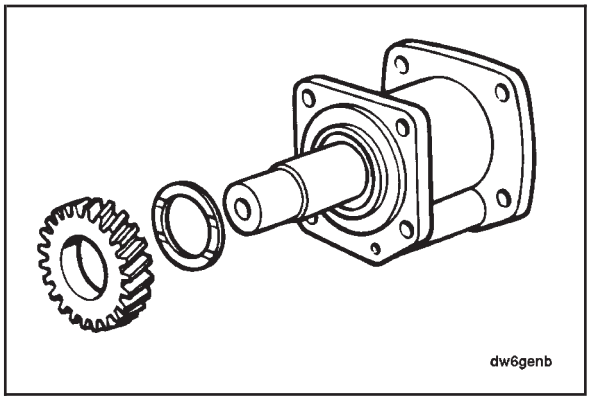
Lubricate both the shaft and the water pump support bushings.

Insert the shaft and rear thrust washer into the water pump support housing.

⚠ CAUTION ⚠

The front thrust bearing MUST be installed with the oil grooves TOWARD the gear. Failure will result if the bearing is NOT installed correctly.

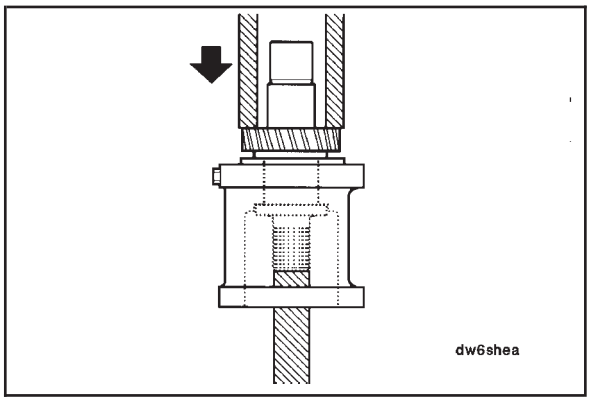
Lubricate the oil groove surface of the front thrust bearing with Lubriplate® No. 105 or equivalent. Install the bearing onto the housing with the grooved surface against the gear.



Support the housing and shaft assembly in a hydraulic press.

Clean any Lubriplate® from the shaft and apply an even coating of Loctite® 609 or equivalent to the inside diameter of the gear.

Press the gear onto the shaft until the gear touches the shoulder of the shaft.



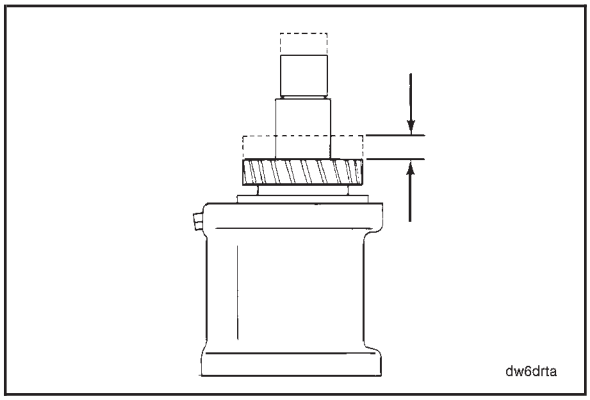
Use a dial indicator. Measure the clearance.

Water Pump Drive End Clearance		
mm		in
0.23	MIN	0.009
0.33	MAX	0.013

If the end clearance is **not** within specifications, check to be sure that both thrust bearings are correctly positioned in the water pump support counterbores.

If the bearings are correct and the end clearance is **not** within specifications, the drive **must** be completely disassembled and the components dimensions checked.

Oversize thrust bearings are available to adjust the end clearance.



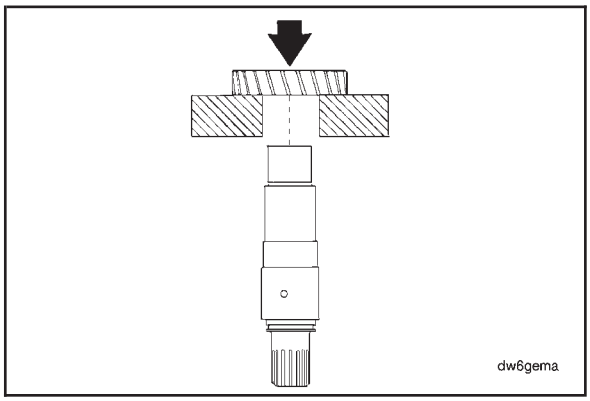
Water Pump Drive Gear and Shaft (009-031)

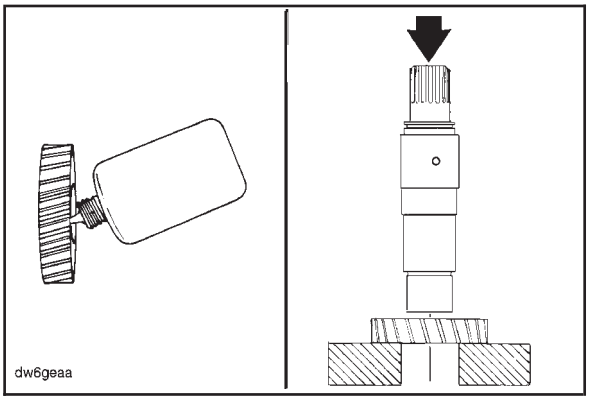
Disassemble

NOTE: The gear should be removed from the shaft **ONLY** when the gear **or** the shaft **must** be replaced.

Support the gear with the oil hole positioned as shown.

Use an arbor press to remove the gear.



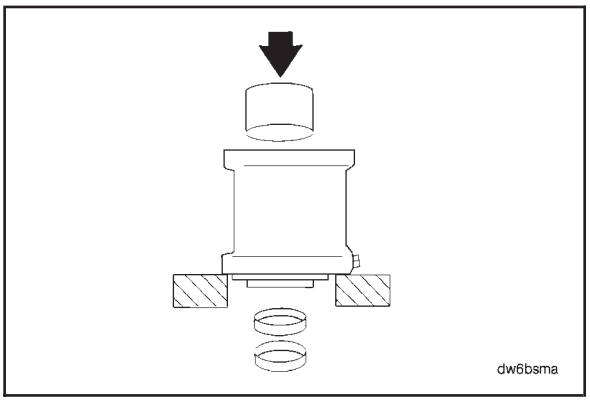


Assemble

Use Loctite® 609 or equivalent. Apply a smooth coating on the I.D. of the gear.

Support the gear.

Use an arbor press to press the shaft in the gear until it touches the shoulder of the shaft.

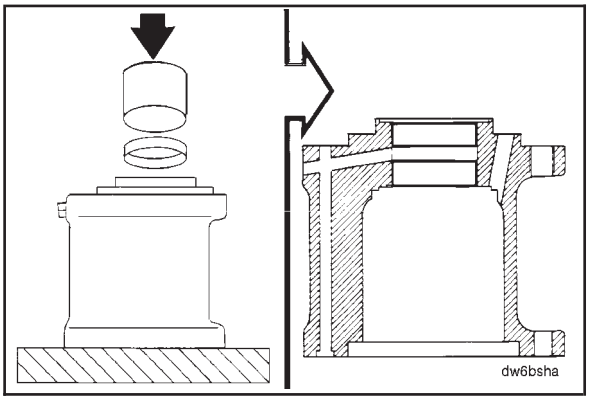


Water Pump Drive Bushing (009-030)

Disassemble

Support the housing.

Use an arbor press and a mandrel to remove the bushings.



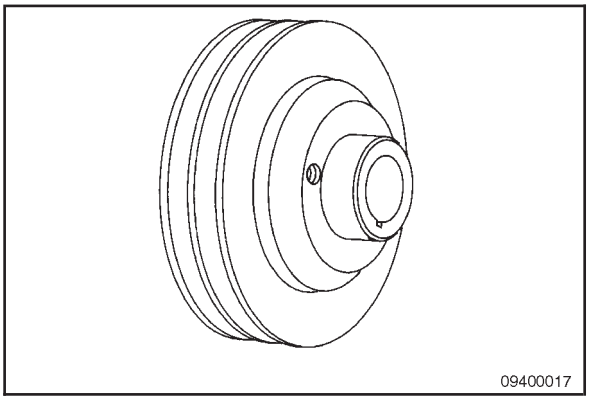
Assemble

Support the housing.

CAUTION

Do not block the oil drilling in the housing.

Use an arbor press and a mandrel to install the bushings. The bushings **must** be even with to a **maximum** of 0.38 mm [0.015 inch] below the housing surface.



Water Pump Drive Pulley (009-032)

Clean

Use solvent to clean the alternator drive and the accessory drive pulley.

Inspect for Reuse

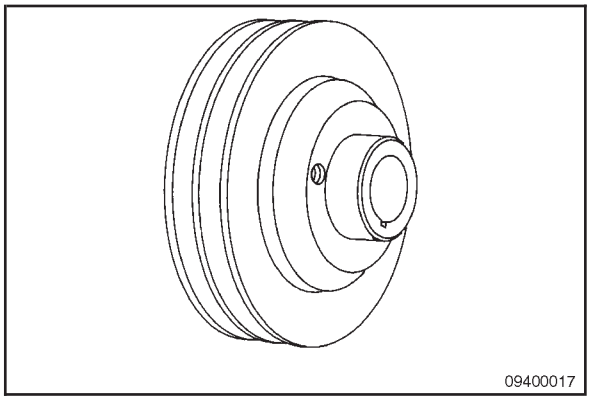
Check the grooves of the pulley for wear.

Check the wear sleeve on the accessory drive pulley.

If the wear sleeve needs replaced, use a chisel and remove the wear sleeve.

Check the Pulley O.D. for damage.

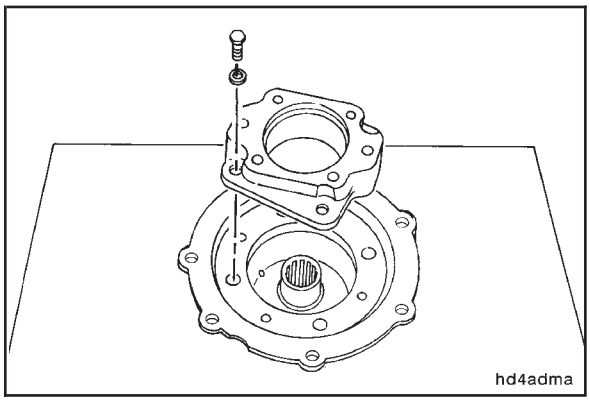
Use an arbor press and a mandrel to install the new wear sleeve even with the end of the pulley.



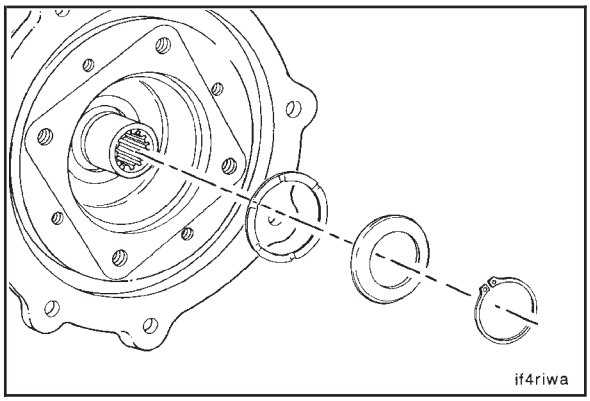
Outer Hydraulic Pump Support Drive (009-036)

Disassemble

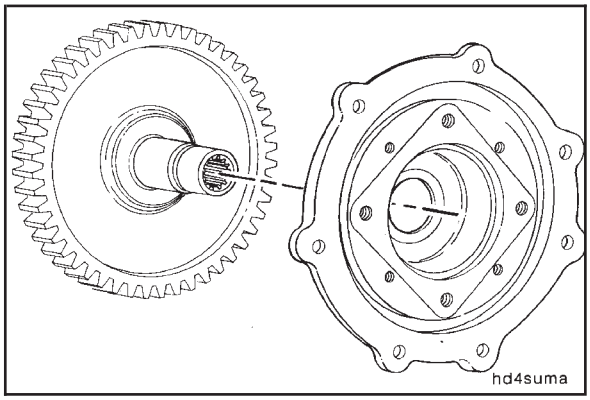
Remove the hydraulic pump adapter and/or cover plate. Remove and discard the gasket

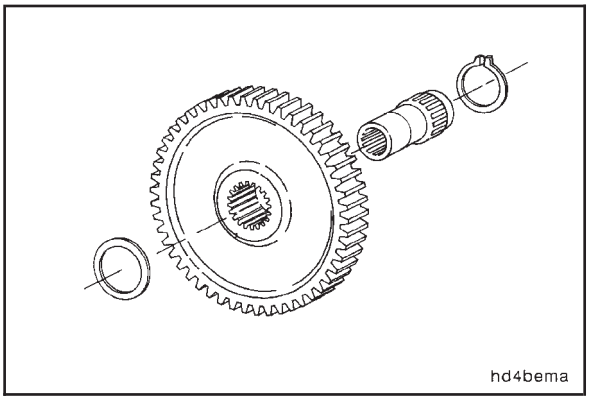


Remove the tapered retaining ring, bearing spacer, and thrust bearing. Check bearing spacer for wear against the shaft shoulder.

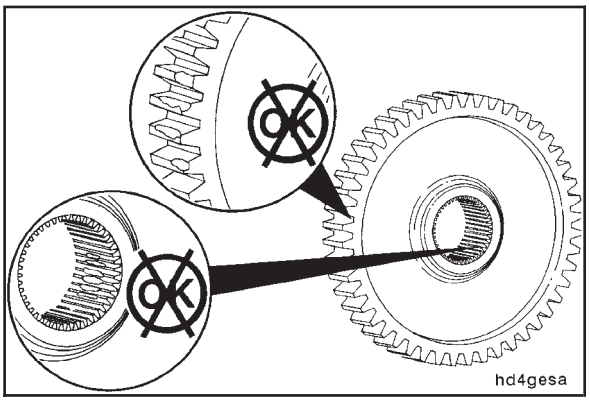


Remove the hydraulic pump support from the splined drive shaft.



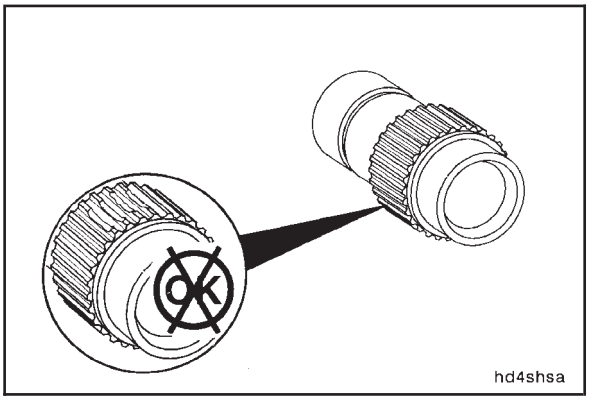


Remove the thrust bearing, gear, and non-tapered retaining ring from the splined drive shaft.

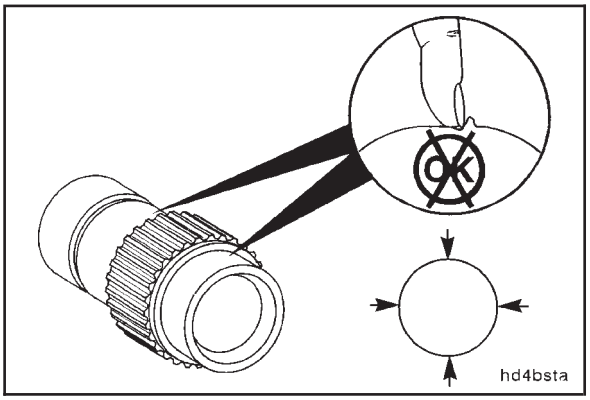


Inspect for Reuse

Visually inspect the idler gear for chipped, broken, or cracked teeth. Check the internal splines for wear.



Check the hydraulic pump drive shaft. Check the external splines for wear.



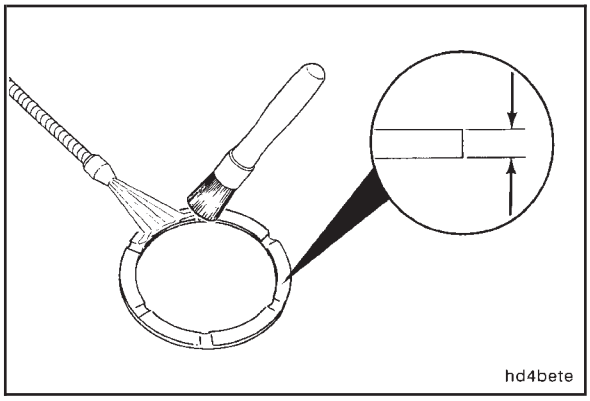
Inspect the bushing diameters on the shaft for wear. If a fingernail will catch on scratches or grooves, then the shaft must be replaced. Measure the shaft in the bushing area.

Drive Shaft Bushing Diameters

mm		in
47.536	MIN	1.8715
47.549	MAX	1.8720

Clean and inspect the thrust bearings. Measure the thrust bearing thickness.

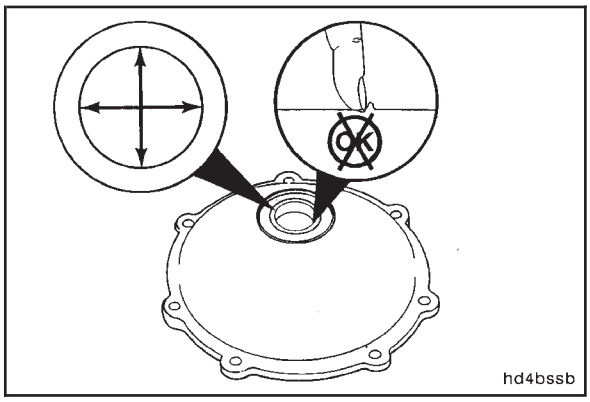
Thrust Bearing Thickness		
mm		in
2.27	MIN	0.085
2.31	MAX	0.091



Check the retaining rings for damage.

Inspect the hydraulic pump support bushing. If a fingernail will catch on scratches or grooves, then the bushing must be replaced. Measure the bushing inside diameter.

Hydraulic Pump Support Bushing I.D.		
mm		in
47.60	MIN	1.874
47.68	MAX	1.877



Install

Install the four capscrews and hand tighten the capscrews.

Remove the guide studs.

Install the remaining three capscrews.

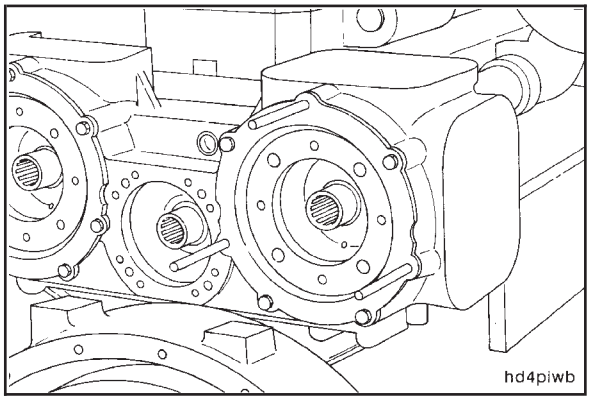
Use the sequence and torque as shown.

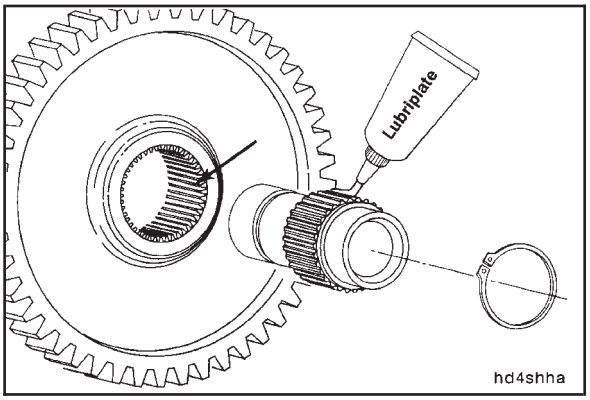
Tighten the capscrews.

Torque Value: 70 N•m [50 ft-lb]

NOTE: The backlash is to be measured during rebuild. Refer to Procedure No. 009-023.

Use the same procedures to install the other outer hydraulic drive assembly. Install the assembly.



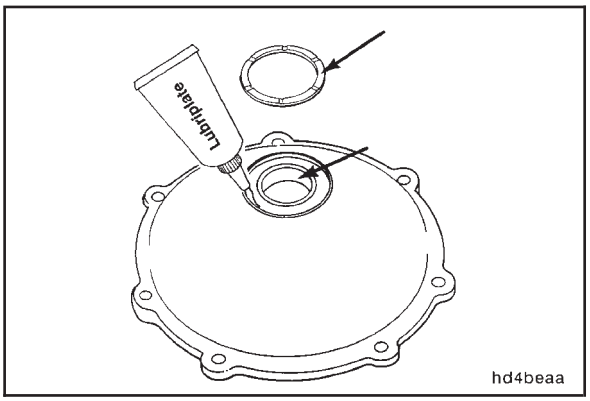


Assemble

Install the non-tapered snap ring onto the drive shaft.

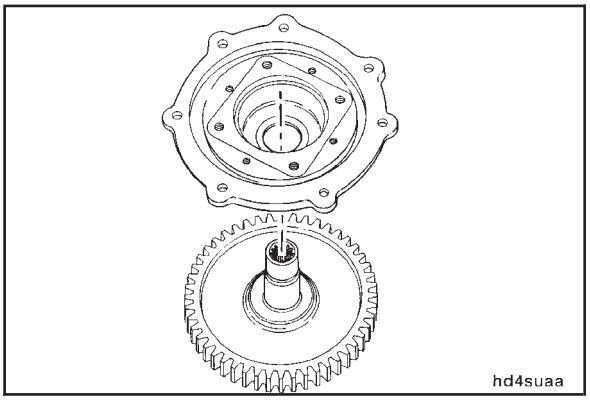
Use Lubriplate® 105 or equivalent. Lubricate the external splines on the drive shaft and the internal splines on the gear.

Align and install the gear onto the drive shaft.

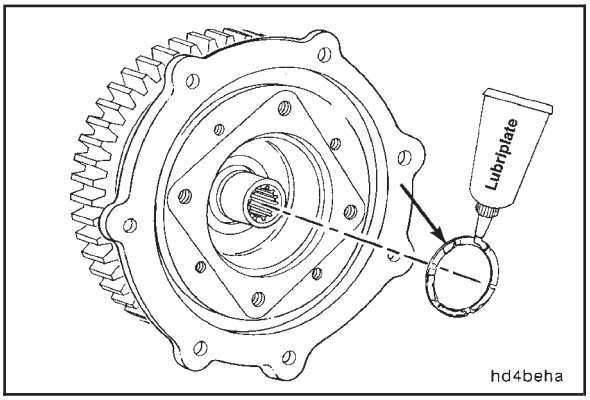


Use Lubriplate® 105 or equivalent. Lubricate the hydraulic pump support bushing, counterbore, and one thrust bearing.

Place the thrust bearing with the groove side up into the counterbore of the cone shaped end of the hydraulic pump support.



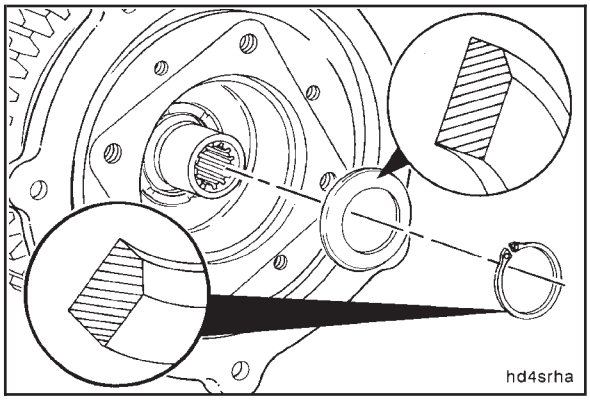
Place the gear and shaft assembly on end with the gear end down. Align and install the hydraulic pump support cone end first onto the drive shaft and gear assembly.



Use Lubriplate® 105 or equivalent. Lubricate one thrust bearing. Install the thrust bearing into the counterbore of the hydraulic pump support with groove side up.

With the beveled side up, install the bearing spacer over the drive shaft.

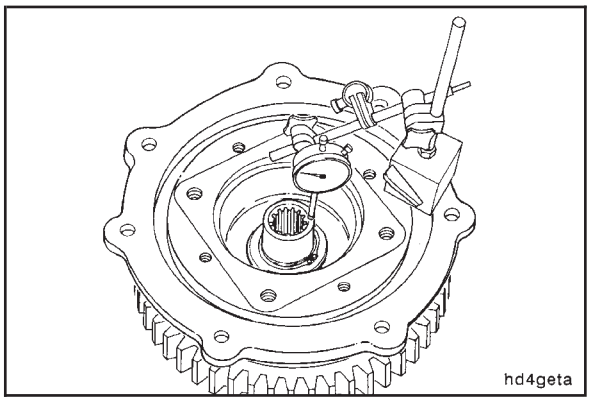
With the beveled side up, install the tapered retaining ring into the groove on the drive shaft.



Measure the gear end clearance.

Hydraulic Drive Gear End Clearance		
mm		in
0.10	MIN	0.004
0.51	MAX	0.020

NOTE: If the end clearance is **not** within specifications, the thrust bearings **must** be replaced.



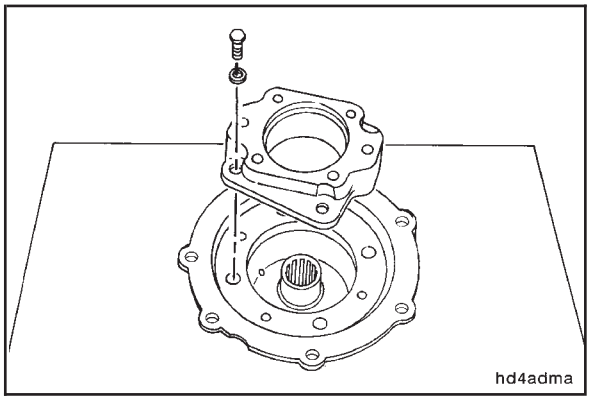
Install the hydraulic pump adapter or cover plate and gasket. Tighten the adapter or cover plate to the correct torque.

Torque Value:

Adapter		95 N•m	[70 ft-lb]

Torque Value:

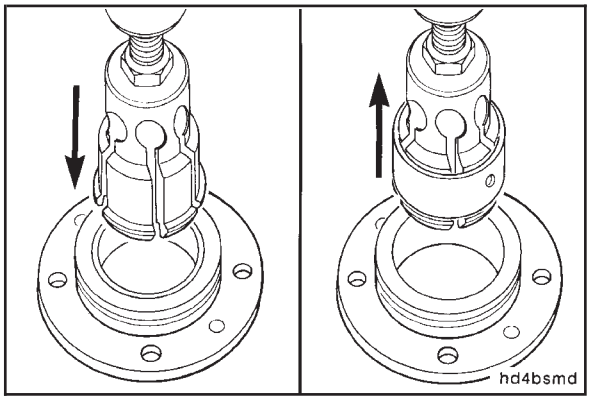
Cover Plate	SAE C/SAE B drive	95 N•m	[70 ft-lb]
SAE A drive	40 N•m	[35 ft-lb]	

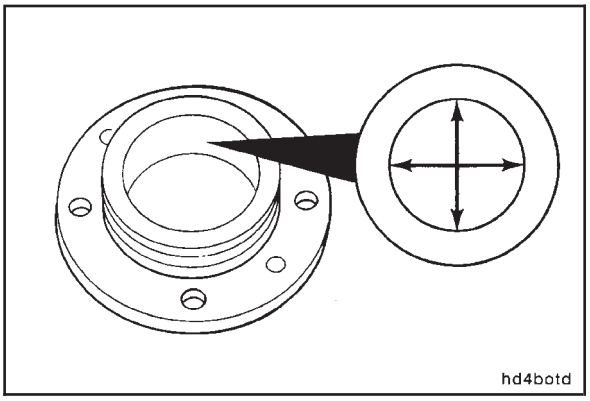


Hydraulic Pump Support Bushing (009-037)

Remove

Use a blind bushing puller to remove the bushing.



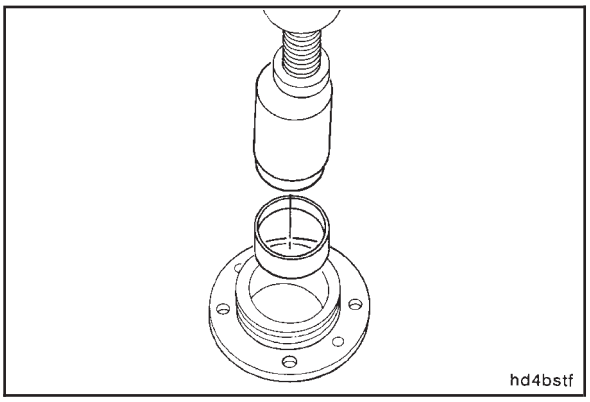


Inspect for Reuse

Measure the bushing bore.

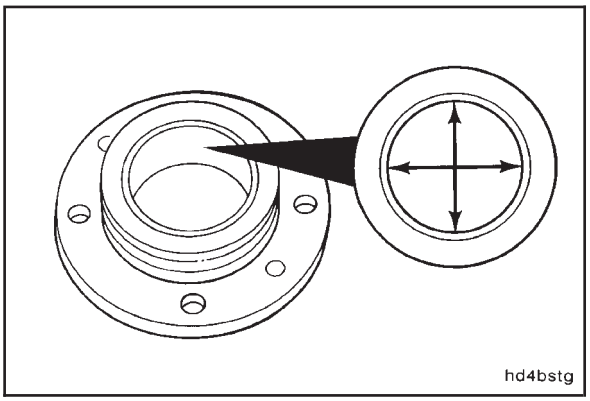
Hydraulic Pump Support Bore I.D.		
mm		in
53.86	MIN	2.121
53.92	MAX	2.123

NOTE: If the bushing bore is **not** within specifications, replace the support.



Install

Use an appropriate bushing mandrel and a press. Install the bushing flush with the support or **no more** than 5.08 mm [0.200 in] below the surface.



Measure the bushing inside diameter again.

Hydraulic Pump Support Bushing Bore I.D.		
mm		in
47.60	MIN	1.874
47.68	MAX	1.877

NOTE: If the bushing is **not** within specifications, replace the support.

Section 10 - Air Intake System - Group 10

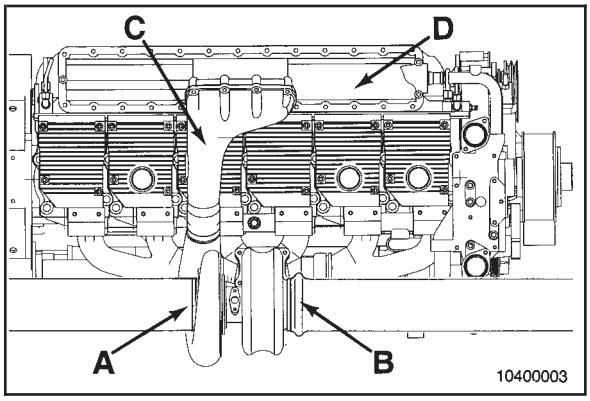
Section Contents

Air Intake System - General Information

Preparatory

The combustion air system consists of air intake system, turbocharger (A), air crossover (C), and aftercooler assembly (D).

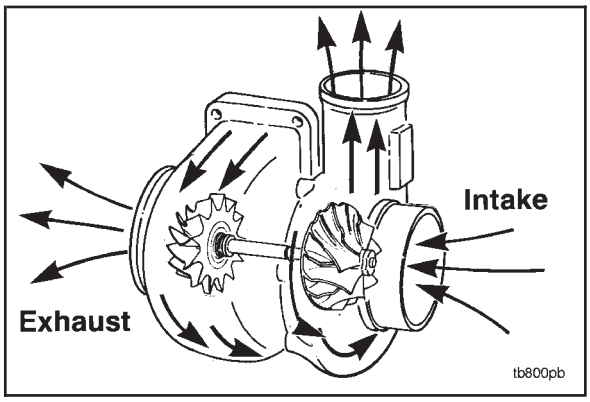
The aftercooler assembly (or intake manifold) to cylinder head mounting capscrews are covered by rubber sleeves. The rubber sleeves are located on the top mounting capscrews at the cylinder head. These sleeves prevent capscrew damage by keeping dirt and water off of the threads. These sleeves **must** be replaced during rebuild.



All QSK19 engines have turbochargers. The turbochargers also have water cooled bearing housings. This gives the turbocharger increased working life by reducing the harm of **hot** shutdowns.

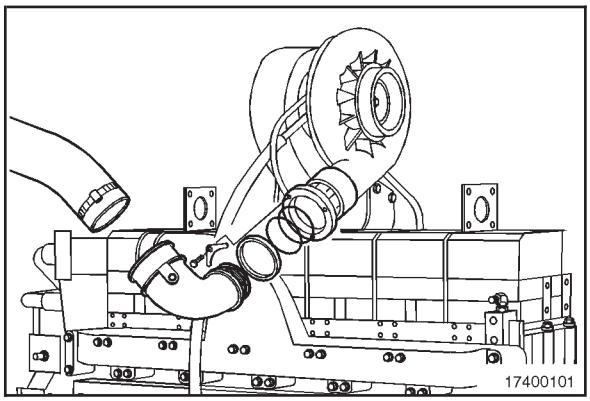
The turbocharger uses exhaust gas energy to turn the turbine wheel. This turbine wheel drives a compressor impeller that provides pressurized air to the engine for combustion.

QSK19 engines can have either JWAC (jacket water after cooled) air cooling systems, or LTA (low temperature aftercooling) air cooling systems. These systems use engine coolant to cool the inlet air between the turbocharger and the engine. Refer to the coolant flow diagrams.



Rail Applications

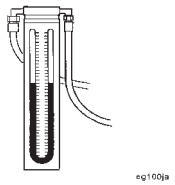
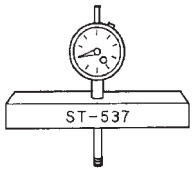
Because the QSK19 Rail engine uses an air-to-air aftercooler, there is **no** aftercooler element in the intake manifold that uses coolant to cool the intake air. The intake housing is a one-piece component that contains an inlet duct. This air-to-air aftercooler has a turbocharger outlet elbow which is unique to all QSK19 air-to-air cooled engines.



Service Tools

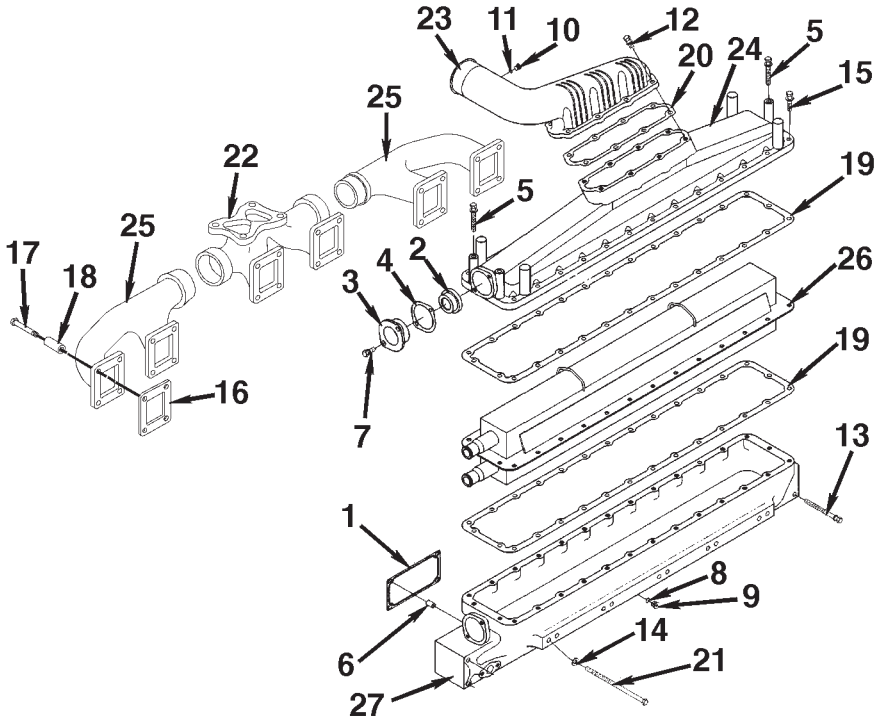
Air Intake System

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

Tool No.	Tool Description	Tool Illustration
ST-1111-3	**Manometer** Used to measure air inlet restriction.	
ST-537	**Dial depth gauge** Used to check for proper nozzle ring crush or end clearance checks on turbochargers.	 ST-537

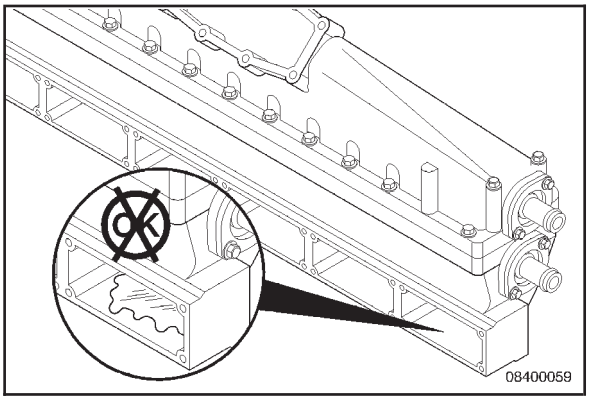
Aftercooler Assembly (010-002)

Exploded View



10400074

1. Gasket, Intake Manifold
2. Seal, Grommet
3. Retainer, Seal
4. Gasket, Connection
5. Screw, Captive Washer Cap
6. Seal, Rectangular Ring
7. Screw, Captive Washer Cap
8. Seal, O-ring
9. Plug, Threaded
10. Plug, Threaded
11. Seal, O-ring
12. Screw, Captive Washer Cap
13. Screw, Captive Washer Cap
14. Washer, Plain
15. Screw, Captive Washer Cap
16. Gasket, Exhaust Manifold
17. Screw, Hex Flange Head Cap
18. Spacer, Mounting
19. Gasket, Aftercooler Housing
20. Gasket, Aftercooler Cover
21. Screw, hexagon Head Cap
22. Manifold, Exhaust
23. Connection, Air Crossover
24. Cover, Aftercooler
25. Manifold, Exhaust
26. Core, Aftercooler
27. Housing, Aftercooler



Clean

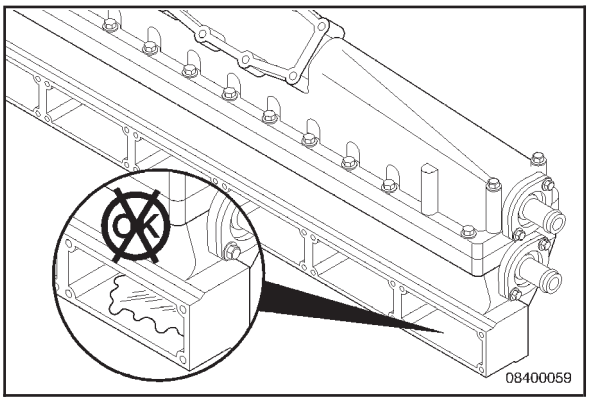
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the exterior of the aftercooler assembly.

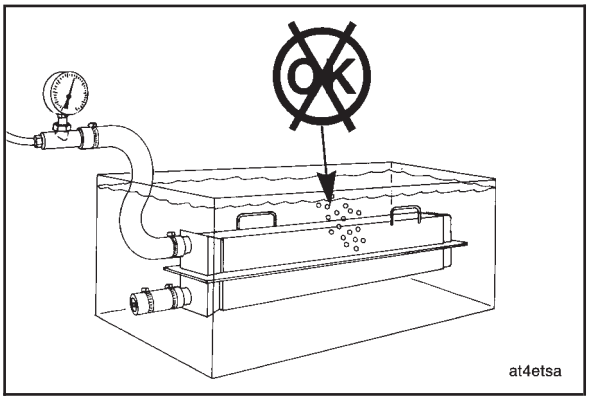
NOTE: Use a solvent that will **not** harm copper.

Use solvent to clean the elements.



Inspect for Reuse

Inspect the aftercooler for reuse. Look into the cylinder head ports and into the aftercooler for indications of coolant leakage.



Use a hose with a plugged with a pipe plug to plug one water tube as shown.

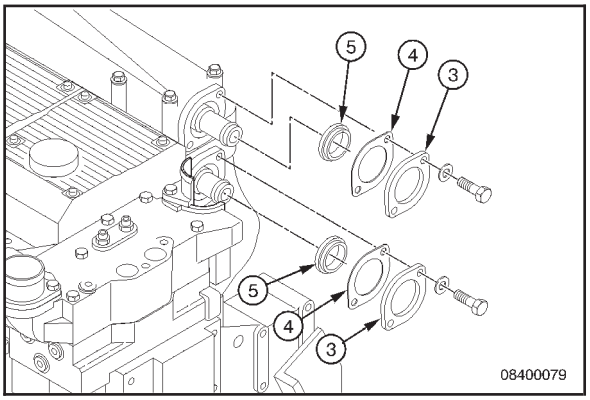
Attach an air line and gauge to the remaining tube.

Pressure check the element.

Apply air pressure and check for leaks.

Air Pressure		
kPa		**psi**
415	MAX	60

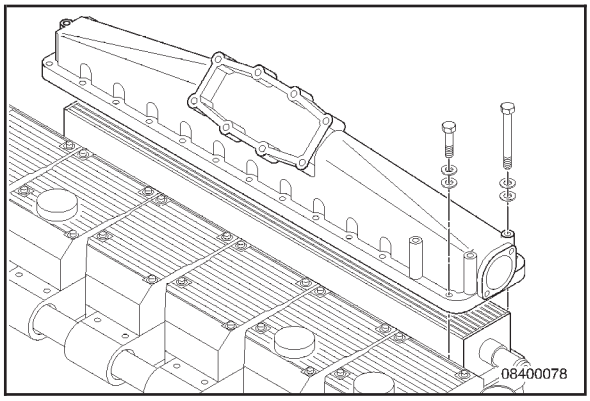
NOTE: Heating the tank water to 50°C (120°F) will improve the test results.



Disassemble

Remove the capscrews, seal retainer (3), gaskets (4), and seals (5). Discard the seals and gaskets.

Remove the aftercooler cover capscrews and cover.

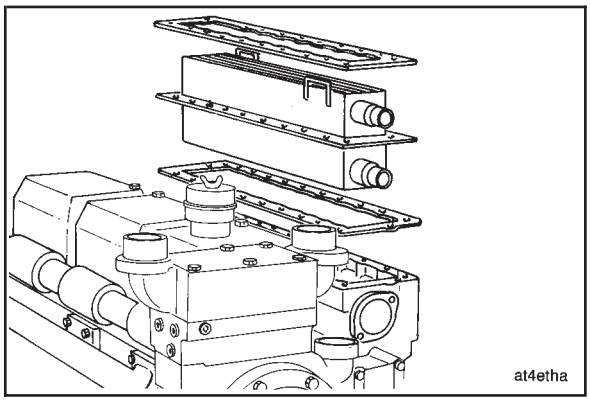


Remove the element and gaskets.

Inspect the cover and intake manifold gasket surfaces for damage.

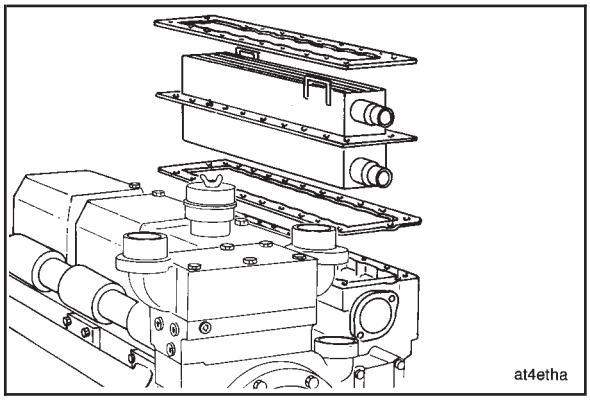
Inspect the threaded holes for damage.

Discard the gaskets.



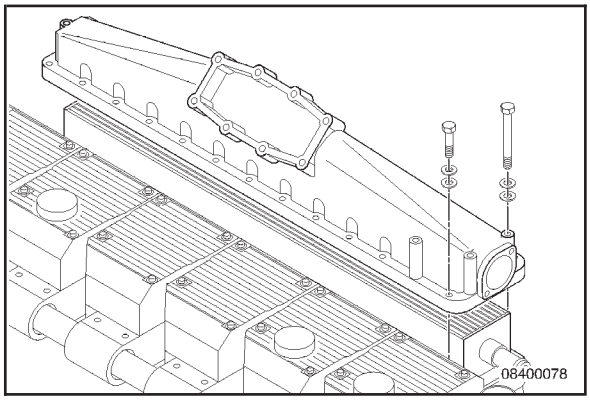
Assemble

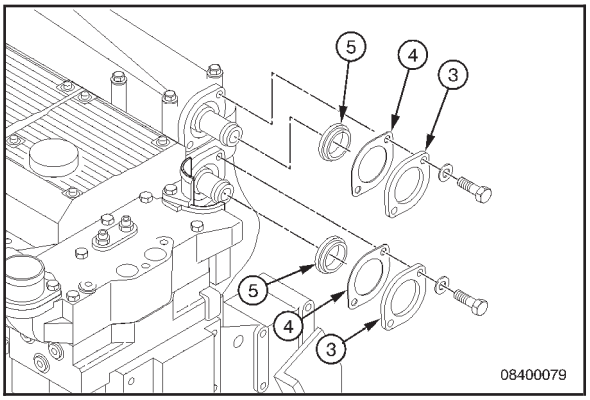
Install the element and two new gaskets.



Install the aftercooler cover and capscrews.

Do not tighten the capscrews until after the seals are installed.





Use engine oil to lubricate the seals.

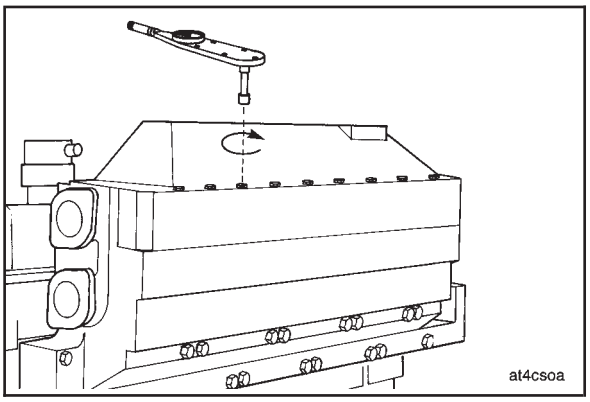
Install the seal on the retainer.

Use clean engine oil to lubricate the O.D. of the water bosses on the aftercooer element.

Slide the gasket on the water bosses. Slide the seal and retainer on the tube.

Install the capscrews, and tighten.

Torque Value: 35 N•m [25 ft-lb]

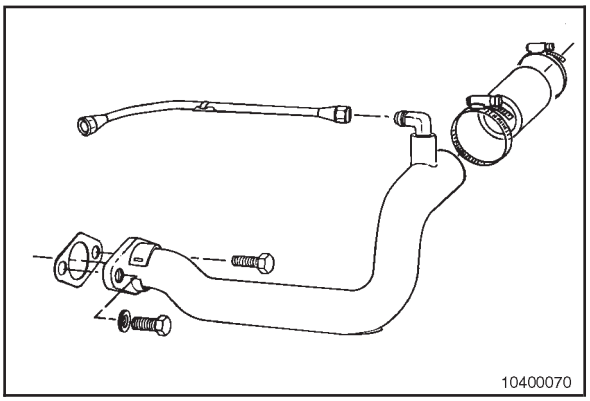


Install the 24 capscrews.

Tighten using the following steps and values.

Torque Value:

Step 1	35 N•m	[25 ft-lb]
Step 2	50 N•m	[35 ft-lb]



Aftercooler Coolant Tube (010-006)

Clean

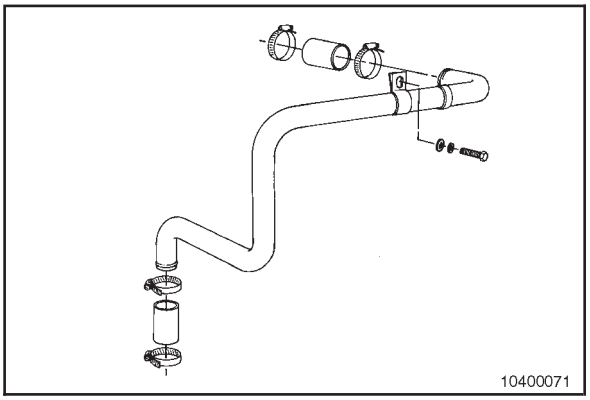
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the aftercooler water inlet and outlet tubes.

Dry with solvent.

Use a wire brush to clean the hose sealing surfaces.



Inspect for Reuse

Inspect the aftercooler water tubes for damage.

Air Crossover (010-019)

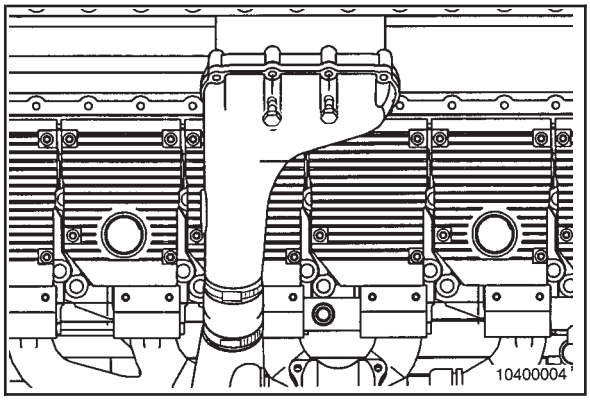
Clean

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the air crossover.

Use compressed air to dry the air crossover.



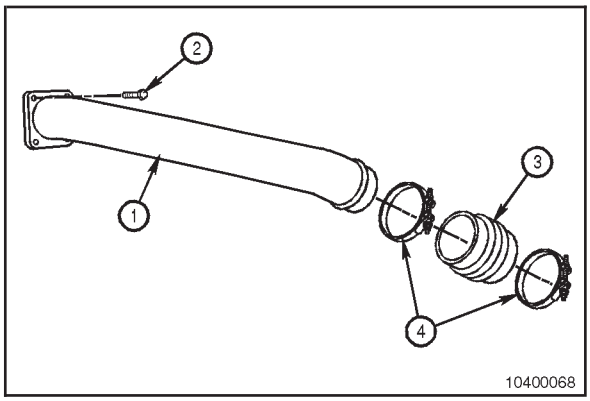
Marine

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

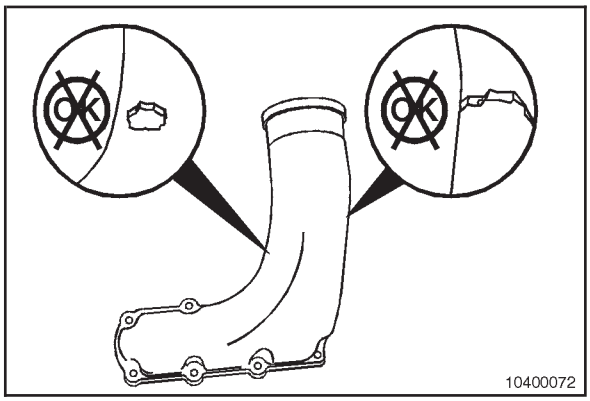
Use solvent to clean the parts.

Use compressed air to dry the parts.



Inspect for Reuse

Inspect the air crossover for cracks, breaks, holes, and worn bolt holes.



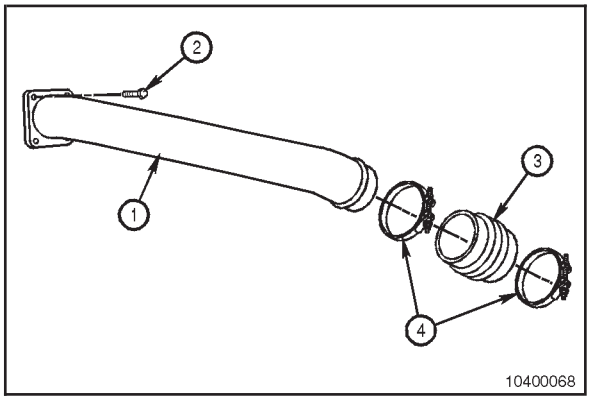
Marine

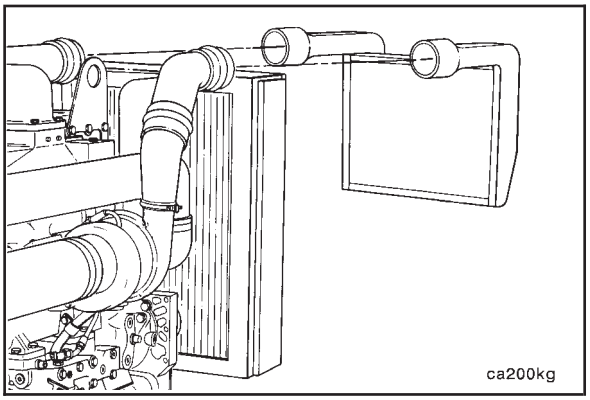
NOTE: The Marine air crossover hose (3) is a different material hose than the standard QSK19 hose.

Inspect the crossover tube for cracks.

Inspect the bore for any blockage.

Inspect the o-ring grove on the mounting flange and the hose clamps (4) for any wear or damage.



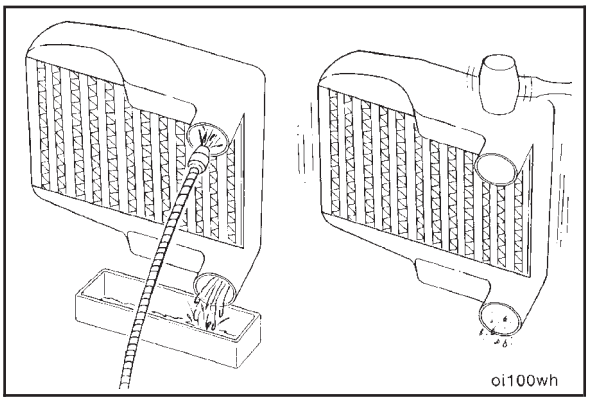


Charge Air Cooler (CAC) (010-027)

Clean

If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the CAC, (charge air cooler) the CAC **must** be cleaned.

Remove the CAC piping and CAC from the vehicle. Refer to the manufacturer's instructions.



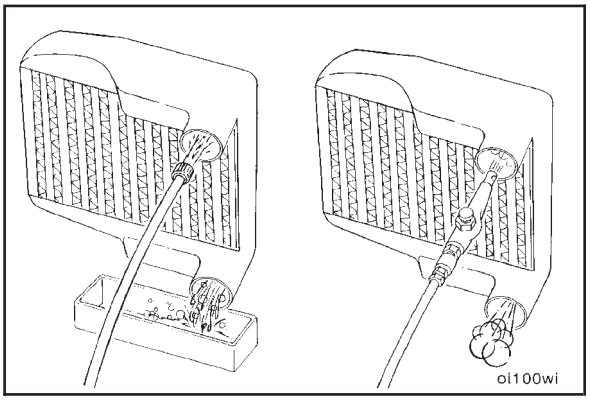
⚠ CAUTION ⚠

Do not use caustic cleaners to clean the CAC. Damage to the CAC will result.

Flush the CAC internally with solvent in the opposite direction of normal air flow. Shake the CAC and **lightly** tap on the end tanks with a rubber mallet to dislodge trapped debris. Continue flushing until **all** debris or oil is removed.

NOTE: Be sure the tubes are in the vertical direction when flushing.

If the debris **cannot** be totally removed from the CAC, the CAC **must** be replaced.

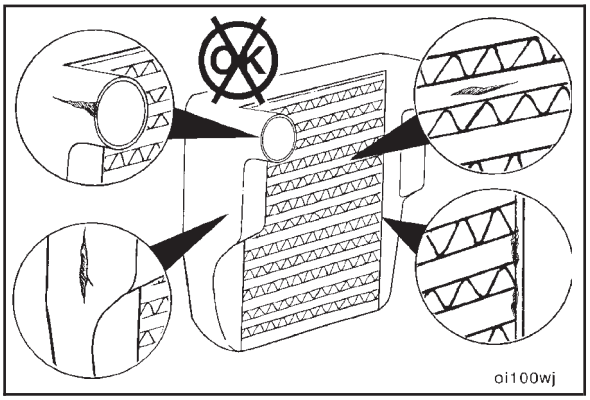


⚠ CAUTION ⚠

The CAC must be rinsed, dried and free of solvent, oil and debris or engine damage will result.

After the CAC has been thoroughly cleaned of all oil and debris with solvent, wash the CAC internally with hot soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

Blow compressed air through the inside of the CAC in the opposite direction of normal air flow until the CAC is dry internally.



Inspect for Reuse

Visually inspect the CAC for cracks, holes or damage.

Inspect the tubes, the fins and the welds for tears, breaks or other damage. If any damage causes the CAC to fail the air leak check, the CAC **must** be replaced.

NOTE: Always clean and inspect the CAC piping and hoses prior to installation.

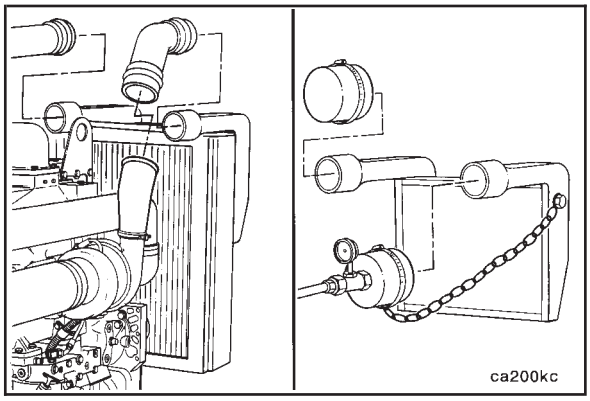
Leak Test

⚠ WARNING ⚠

To prevent possible injury if either plug blows off during the test, secure safety chains on the test plugs to any convenient capscrew on the radiator assembly. This test must not be performed without securely fastened safety chains.

To check the CAC for cracked tubes or header, remove the inlet and outlet hoses from the cooler. The CAC does **not** have to be removed from the chassis.

Install a plug or cap over the outlet side of the cooler. Install a pressure gauge and a regulated shop air supply line with a shutoff valve to the inlet side of the cooler.

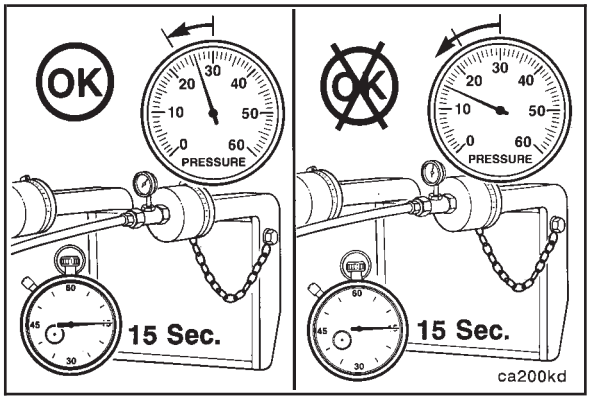


Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shut off the air flow to the cooler and start a stopwatch at the same time. Record the leakage at 15 seconds.

If the pressure drop is 34 kPa [5 psi] or less in 15 seconds, the cooler is okay.

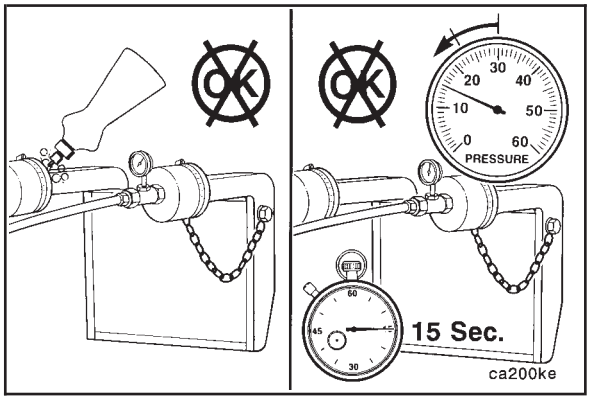
If the pressure drop exceeds 34 kPa [5 psi] in 15 seconds, check all connections again.



Determine if the pressure drop is caused by a leak in the CAC or from a leaky connection. Use a spray bottle filled with soapy water applied to all hose connections, and watch for bubbles to appear at the location of the leak.

If the pressure drop is caused by a leaky connection, repair the connection and repeat the test. If the leak is within the CAC, repeat the test to verify the accuracy of the pressure drop measurement. Similar pressure drop readings **must** be obtained at least three consecutive tests before the reading can be considered accurate.

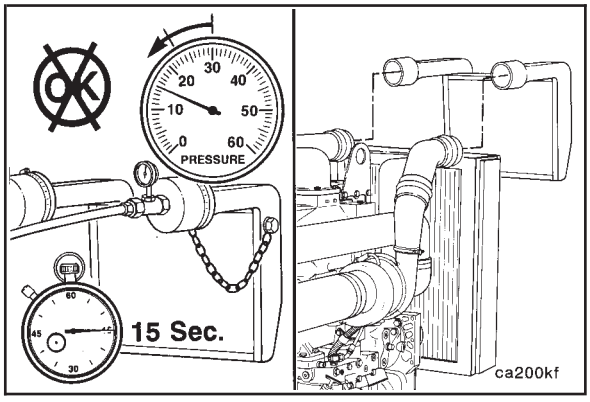
NOTE: If a CAC leaks more than 34 kPa [5 psi] in 15 seconds, it will appear as a major leak in a leak tank.

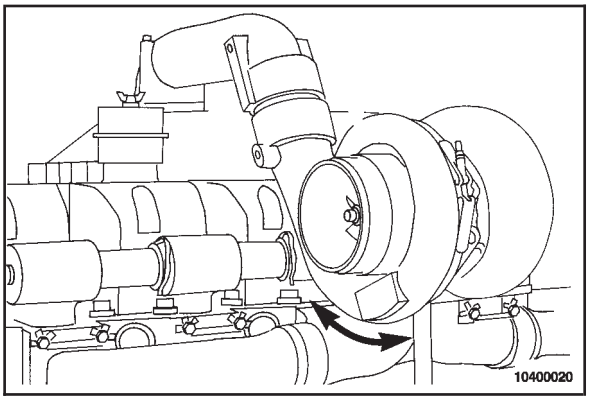


If the pressure drop is greater than 34 kPa [5 psi] in 15 seconds, the CAC **must** be replaced.

Refer to the manufacturer's repair manual for replacement instructions.

NOTE: Charge air coolers are **not** designed to be 100% leak free. If the pressure drop is less than 34 kPa [5 psi] in 15 seconds, then the CAC does **not** need to be replaced.





Turbocharger, Water-Cooled (010-037)

Clean

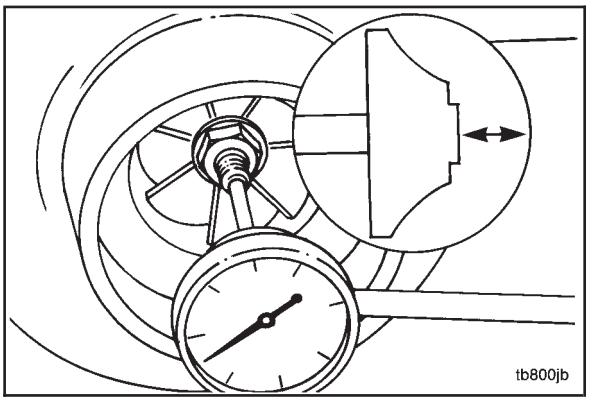
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠ CAUTION ⚠

Tape or plug all openings to prevent solvent or steam from entering the oil cavities in the turbocharger.

Use steam to clean the turbocharger.



Inspect for Reuse

Check the exterior of the turbocharger for damage.

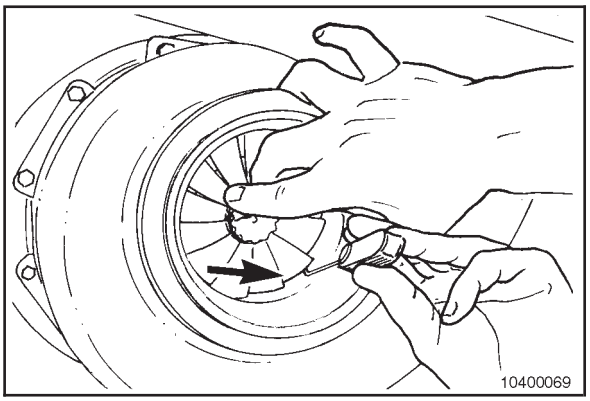
Check the wheel for fretting and broken vanes.

Use a dial indicator to measure the turbocharger end clearance.

Measure the end clearance.

Turbocharger End Clearance		
mm		in
0.05	MIN	0.002
0.13	MAX	0.005

NOTE: If the end clearance exceeds the specifications, the turbocharger **must** be replaced or rebuilt. Refer to the Turbocharger Service Repair Manual, Bulletin No. 3580999, for rebuild instructions.



Use your hand to push the impeller end of the shaft toward the housing.

Use a wire type gauge to measure the clearance between the impeller and the housing at the minimum clearance point.

Holset HX82 Turbocharger			
	mm		in
Compressor Impeller	0.15	MIN	0.006
	0.45	MAX	0.018
Turbine Wheel	0.20	MIN	0.008
	0.55	MAX	0.210

NOTE: If the clearance exceeds the specifications, the turbocharger **must** be replaced or rebuilt. Refer to the Turbocharger Service Repair Manual, Bulletin No. 3580999, for rebuild instructions.

Turbocharger Heat Shield (010-076)

Remove

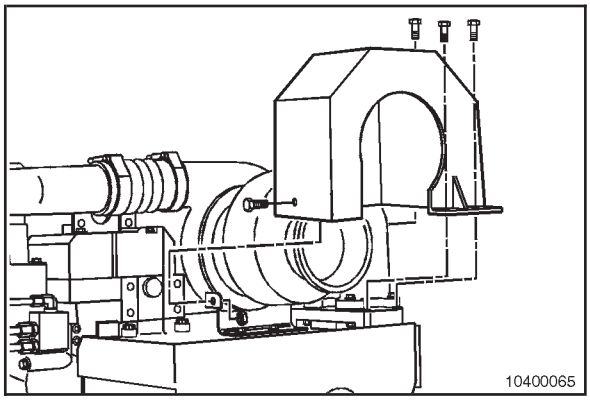
Marine Applications

⚠ CAUTION ⚠

Do not remove insulation from inside of turbocharger heat shield. Insulation is permanently affixed to the heat shield.

Remove the turbocharger heat shield mounting capscrews.

Remove the turbocharger heat shield.



Clean

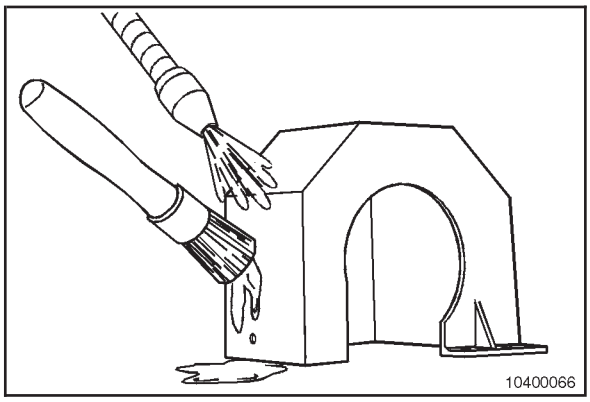
Marine Applications

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the turbocharger heat shield.

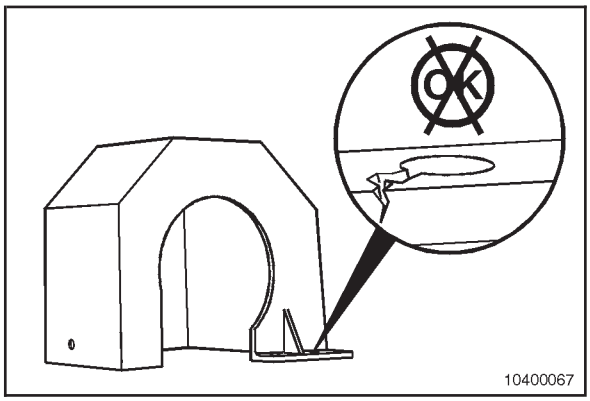
NOTE: Take care **not** to damage the turbocharger heat shield insulation.



Inspect for Reuse

Marine Applications

Inspect the turbocharger heat shield for cracks, holes, and damaged bolt holes.



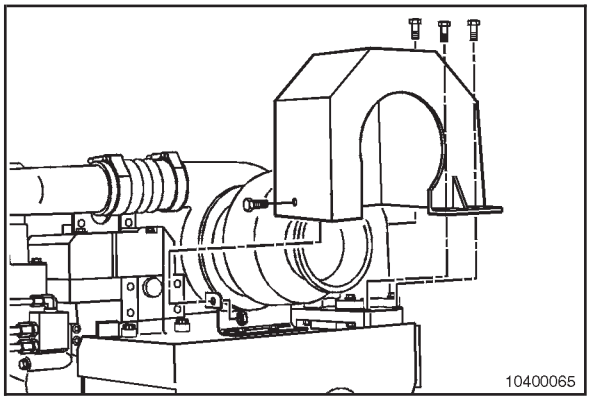
Install

Marine Applications

Install the turbocharger heat shield.

Install and tighten the turbocharger heat shield mounting capscrews.

Torque Value: 35 N•m [25 ft-lb]



NOTES

Section 11 - Exhaust System - Group 11

Section Contents

Exhaust System - General Information

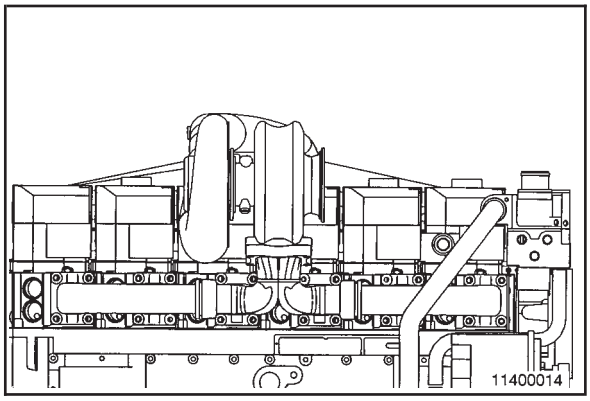
General Information

This section covers **ONLY** those repairs to the exhaust manifold.

Please refer muffler and exhaust pipe repairs to the original equipment manufacturer.

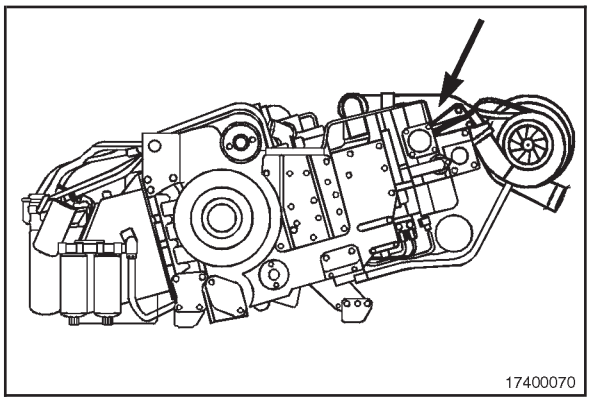
The exhaust system consists of the exhaust manifold and exhaust piping.

NOTE: There is no exploded view pertaining to this section.



Rail Applications

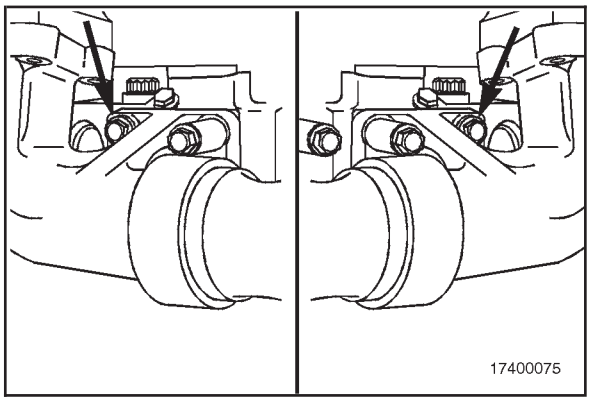
The QSK19 Rail engine exhaust center section has been changed to accommodate the angle of the exhaust transfer connection. The exhaust transfer connection allows the turbocharger to be extended above and over the rocker covers to maintain a low profile design needed in a railcar application. The exhaust transfer connection has two supporting brackets that mount to the No. 2 and No. 3 rocker lever housings



Rail Applications

The two capscrews and spacers for the upper inside capscrew locations on the exhaust center section of the exhaust manifold have been shortened to make it possible to get a wrench on the capscrew heads.

During installation, apply an antiseize compound on the capscrews threads.



Exhaust Manifold, Dry (011-007)

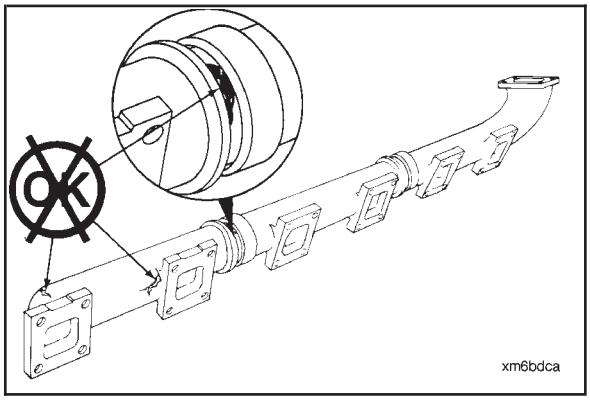
Clean

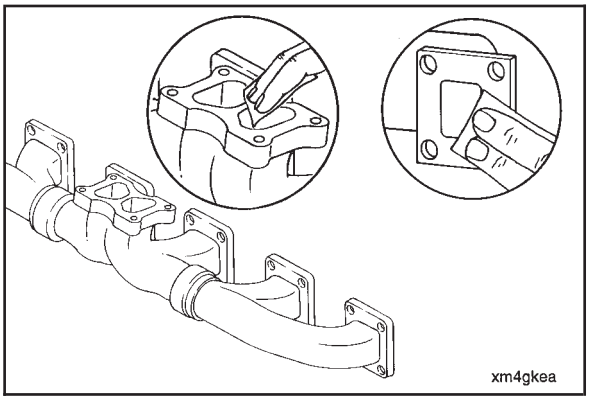
⚠ WARNING ⚠

When using solvents, acids, or alkaline material or steam for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the manifold.

Use a wire brush to clean the sealing joints **inside** and **outside** diameters to remove any scale that has accumulated.





Use a 240 grit emery cloth to clean all of the exhaust manifold gasket surfaces.

Marine Applications

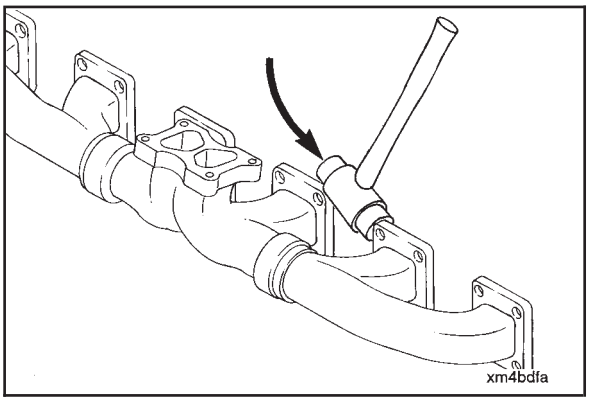
WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing.

CAUTION

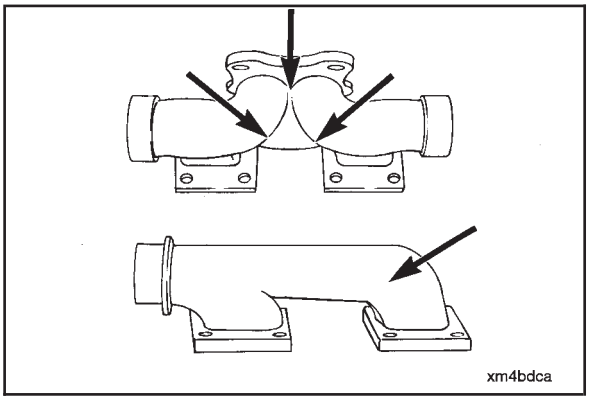
Care must be taken to not destroy the exhaust manifold heat shield insulation while cleaning.

Use solvent to clean the marine exhaust manifold.



Disassemble

Use a mallet to remove the end sections from the exhaust manifold center section.



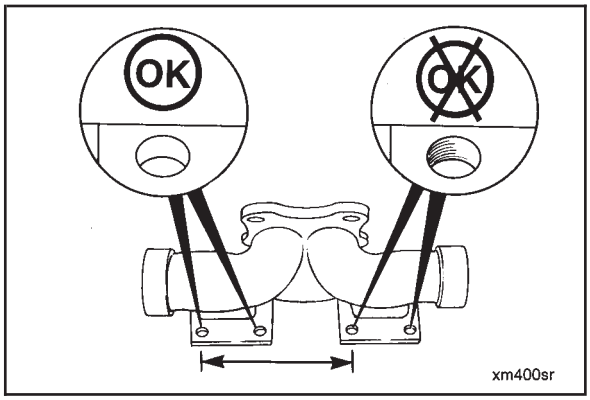
Inspect for Reuse

Inspect for cracks in the areas shown.

Inspect the capscrew holes in the center section for damage.

NOTE: The manifold has been subjected to high temperatures if the capscrew threads are visible on the side of the capscrew holes. High temperature can cause the manifold to shrink.

Measure the center-to-center distance between the same position capscrew holes of the two flanges on the center section and both end sections to determine if the manifold is too short.



Exhaust Manifold Capscrew Holes		
mm		in
191.5	MIN	7.54
193.5	MAX	7.62

Marine Applications

NOTE: Exhaust leaks will show as black soot on the insulation.

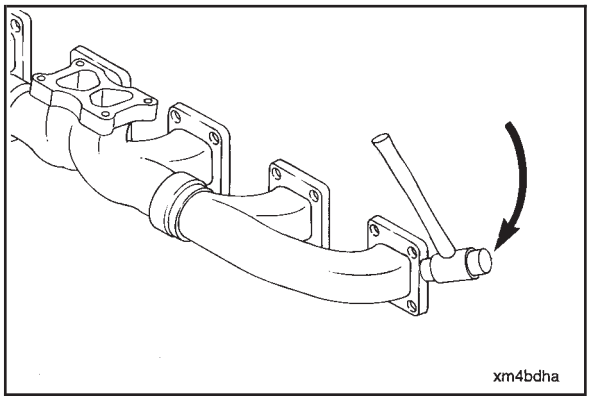
Inspect the heat shield insulation for signs of exhaust leaks.

If exhaust leaks in the manifold are found, the exhaust manifold **must** be replaced.

Assemble

Use an anti-seize compound to lubricate the O.D. of the end section in the area that slides into the center section.

Use a mallet and drive the end section into the center section.



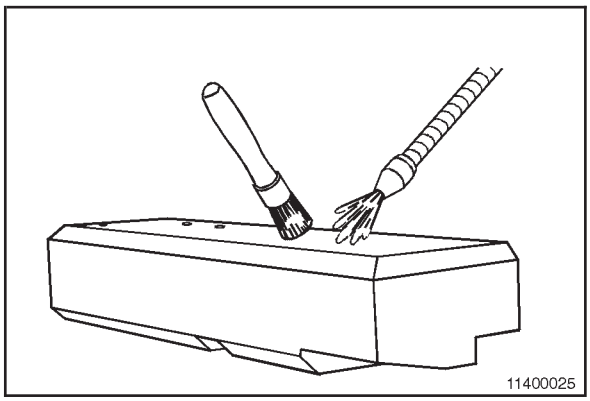
Exhaust Manifold Heat Shield (011-015)

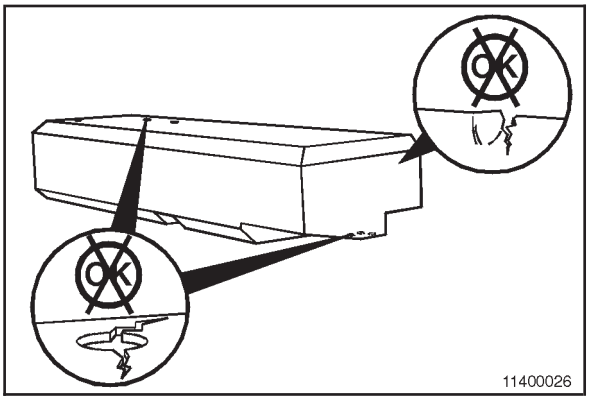
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline material for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the exhaust manifold heat shield.





Inspect for Reuse

Inspect the heat shield for any cracks or damage.

Section 12 - Compressed Air System - Group 12

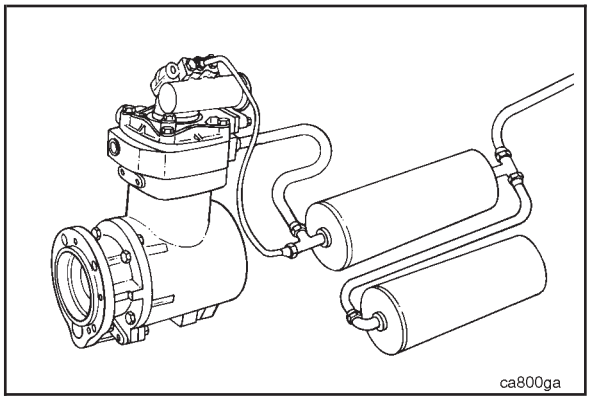
Section Contents

Compressed Air System - General Information

General Information

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

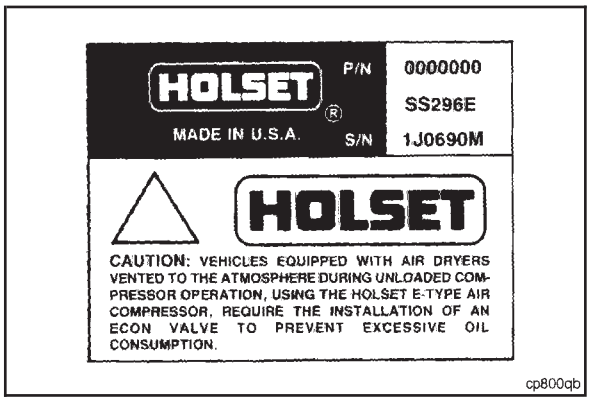
The Holset and Cummins single and two cylinder air compressors are engine-driven, piston-type compressors which supply compressed air to operate air activated devices. The compressor runs continuously, but has a loaded and unloaded operating mode.


ca800ga

E-Type Air Compressor

Holset SS and ST model air compressors built with the E-Type unloader can be identified by the letter "E" (SS296E, SS338E, ST676E, and ST773E), and by the caution on the data plate.

All QE (QE296 and QE338) model air compressors are equipped with the E-Type unloader.

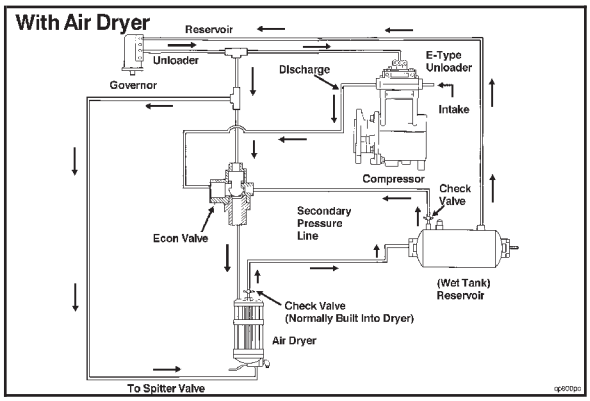


cp800qb

E-Type System With Air Dryer

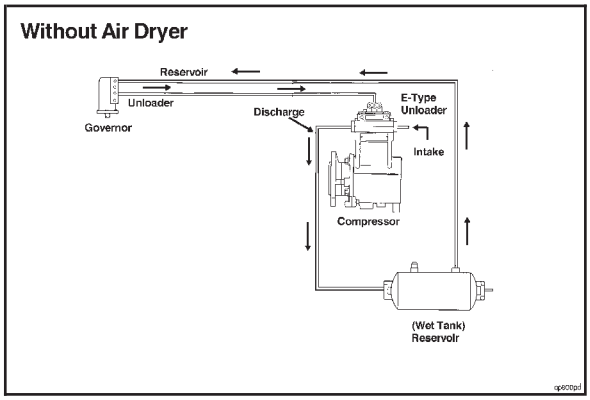
Vehicles equipped with air dryers vented to the atmosphere during unloaded compressor operation, using the Holset E-Type air compressor, require the installation of an econ valve to prevent excessive oil consumption.

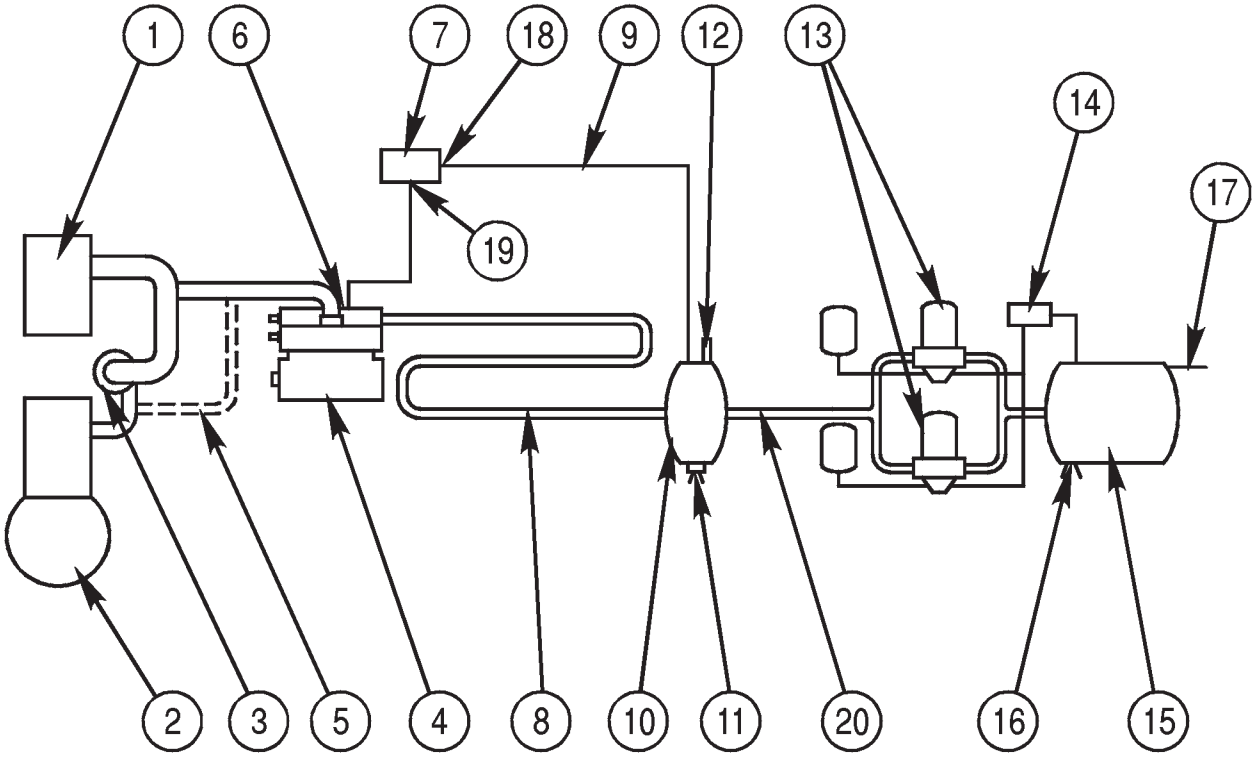
NOTE: Some air dryers can have a built-in econ valve. Check with the manufacturer as to which type is installed.



E-Type System Without Air Dryer

Air systems **without** air dryers, or with air dryers **not** vented to the atmosphere during unloaded compressor operation, can use the Holset E-Type unloader valve without modifying the air system.





12800039

Typical Schematic for Twin Cylinder Air Compressor

1. Engine air filter
2. Engine
3. Turbocharger
4. Holset ST compressor
5. Optional turbo inlet
6. Center unloader valve (std)
7. Compressor governor
8. Exhaust line from compressor to receiver tank is a minimum 457.2 cm [15 ft] of 1 in. nominal
9. Line from governor RES port to receiver tank - minimum 1/4 in. nominal ID
10. 2500 cubic inch receiver tank
11. Heated spitter valve
12. 1206.6 kPa [175 psig] safety valve
13. 2 CR Turbo 2000 air filters
14. Air dryer governor
15. Supply tank
16. Spitter valve
17. 18 scfm maximum system use
18. Governor RES port
19. Governor unload port
20. 3/4 in. nominal line

Section 13 - Electrical Equipment - Group 13

Section Contents

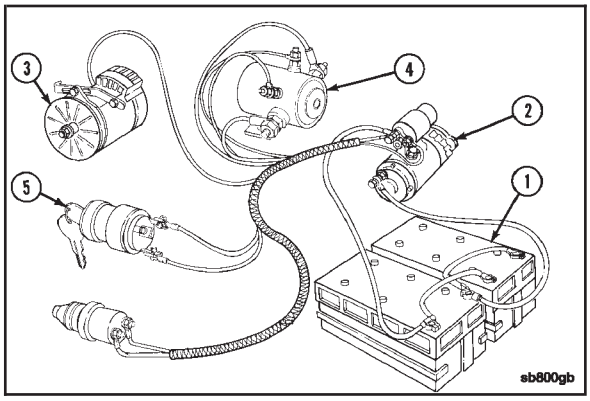
Electrical Equipment - General Information

General Information

The basic heavy-duty electrical system consists of:

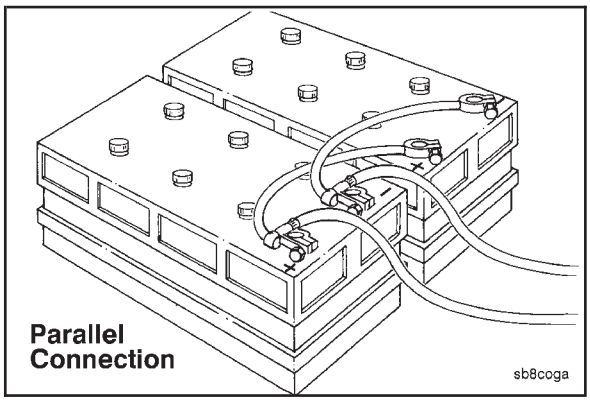
- Batteries (1)
  - — (Usually two or four connected in parallel)
- Starting motor (2)
- Alternator (3)
- Magnetic switch (4)
- Ignition switch (5)
- Necessary wiring

All components **must** be carefully matched.

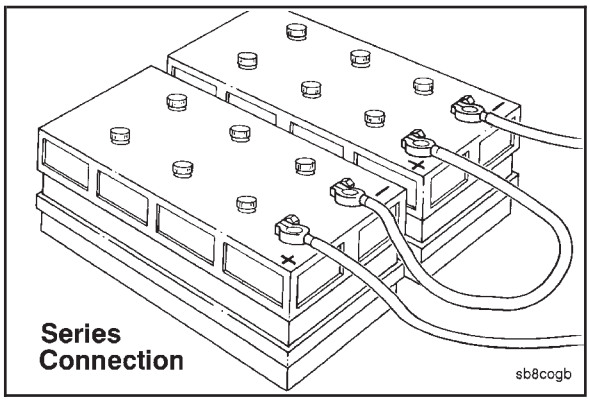


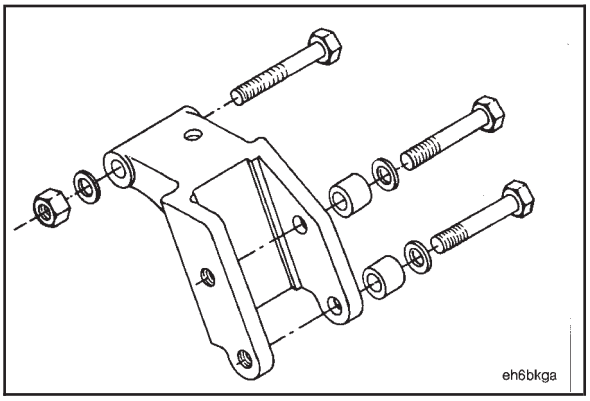
The accompanying illustrations show typical parallel and series battery connections.

- Parallel connection



- Series connection





Alternator Bracket (013-003)

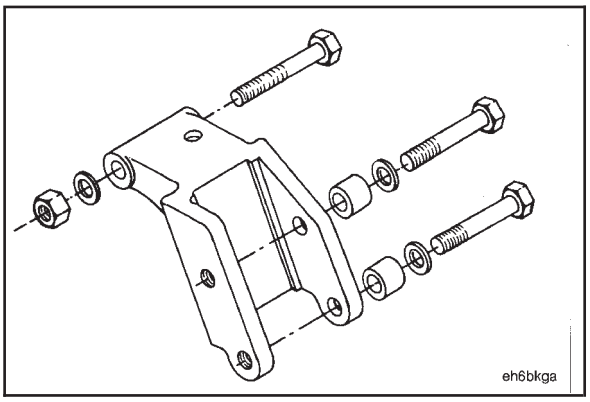
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the parts.

Dry with compressed air.



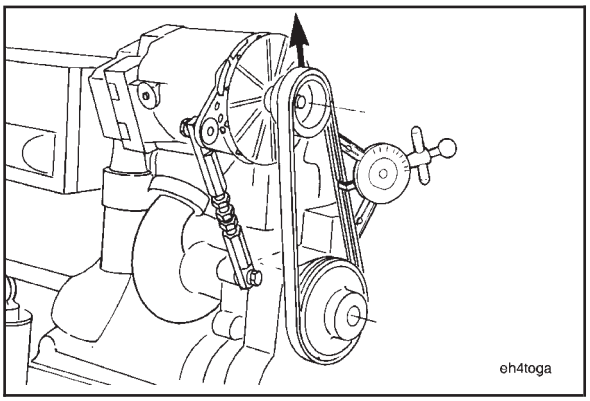
Inspect for Reuse

Check the threads for damage.

Check for cracks.

Check the bores for wear.

NOTE: If any of the above conditions are found, the bracket **must** be replaced.



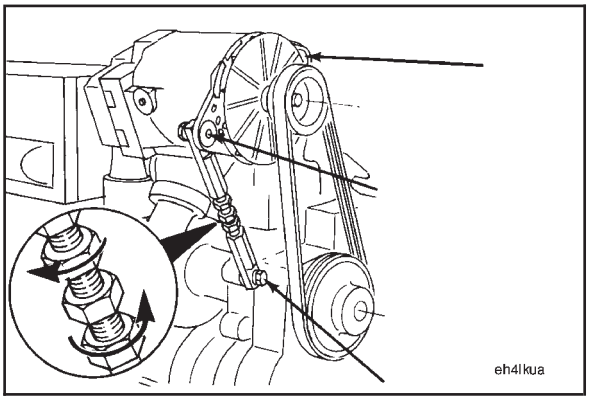
Drive Belt, Alternator (013-005)

Adjust

Use the belt tension gauge, Part No. ST-1138 to check the belt tension.

Belt tension **must** be:

Alternator Belt Tension 670 N [150 lbf]

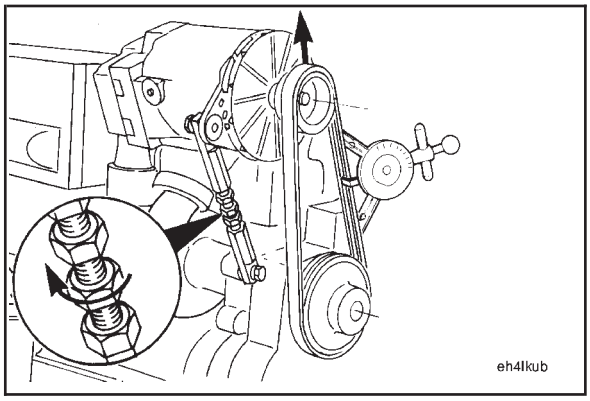


Loosen the alternator and adjusting link mounting capscrews.

NOTE: The lower jam nut has **left-hand** threads.

Loosen the jam nuts on the adjusting screw.

Turn the adjusting screw clockwise to tighten the belt tension.



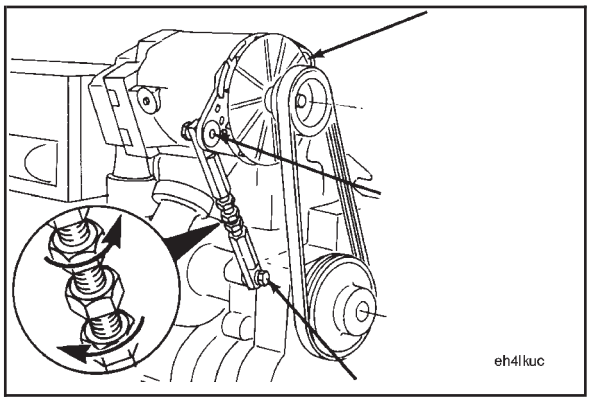
NOTE: The lower jam nut has **left-hand** threads.

Tighten the jam nuts on the adjusting screw.

Tighten the adjusting link and alternator mounting capscrews.

Torque Value:

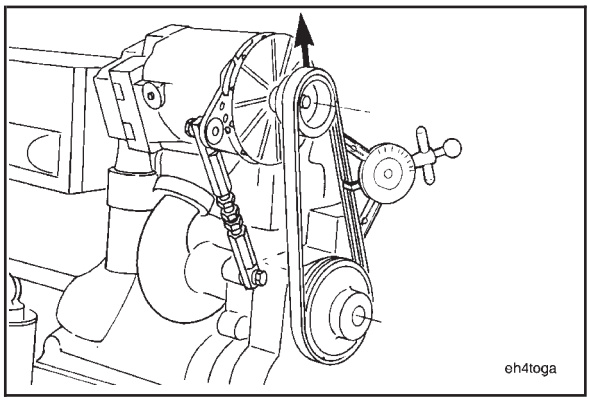
Jam Nuts	55 N•m	[40 ft-lb]
Alternator Mounting Capscrews	55 N•m	[40 ft-lb]



Check the belt tension again to be sure it is correct.

The belt tension **must** be:

Belt Tension 670 N [150 lbf]



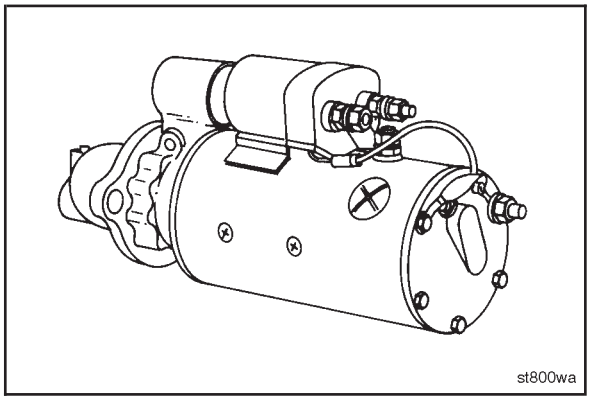
Starting Motor (013-020)

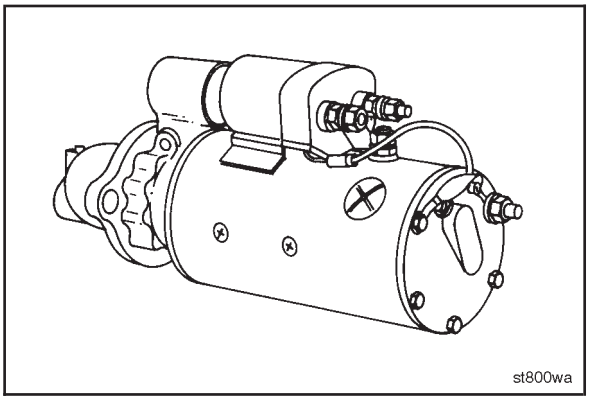
Clean

WARNING

When using steam or hot, high pressure water for cleaning, wear goggles and protective clothing to avoid personal injury.

Use steam to clean the exterior of the starting motor.



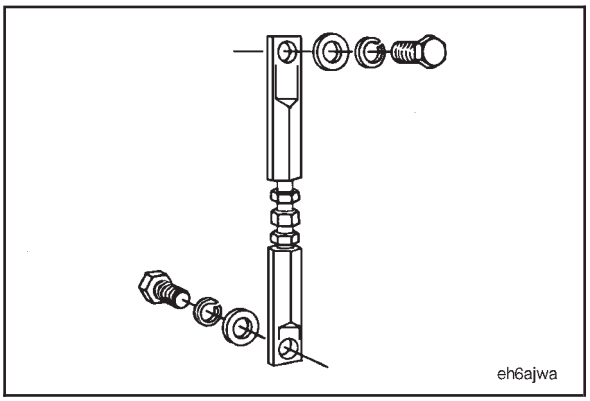


Inspect for Reuse

Inspect the gear, shaft, and the bushing for wear or damage.

Lubricate the bushing with engine oil.

NOTE: A pipe plug **must** be removed to lubricate the bushing on some starter motors.



Alternator Adjusting Link (013-022)

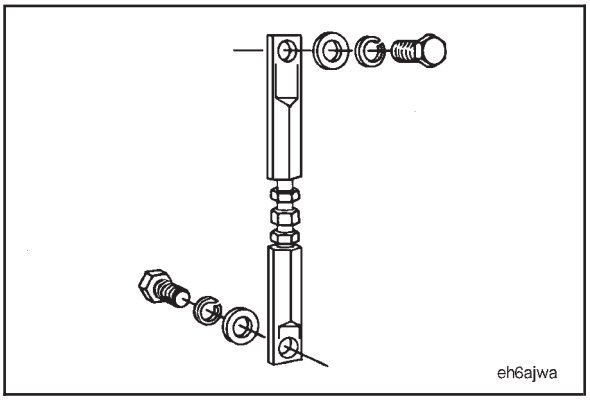
Clean

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent to clean the alternator adjusting link.

Dry with compressed air.



Inspect for Reuse

Check the threads for damage.

Section 14 - Engine Testing - Group 14

Section Contents

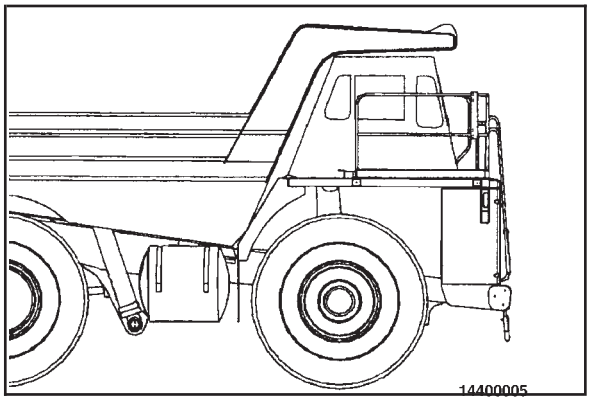
Engine Testing - General Information

General Information

This section outlines engine testing and engine run-in recommendations for QSK19 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 pistons.

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.

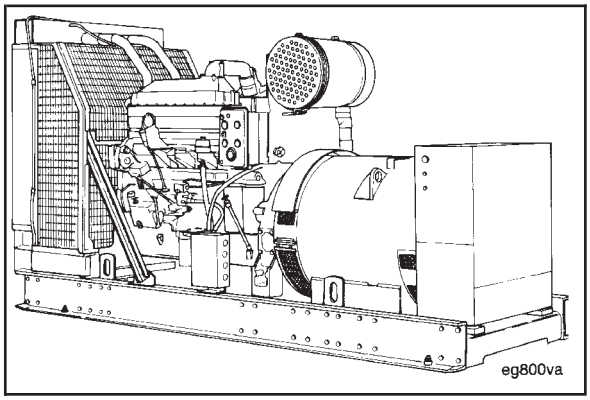
Before running the engine, make sure the engine is filled with the proper coolant. Also, make sure the lubricating oil system is filled and primed.



In-Service Run-In

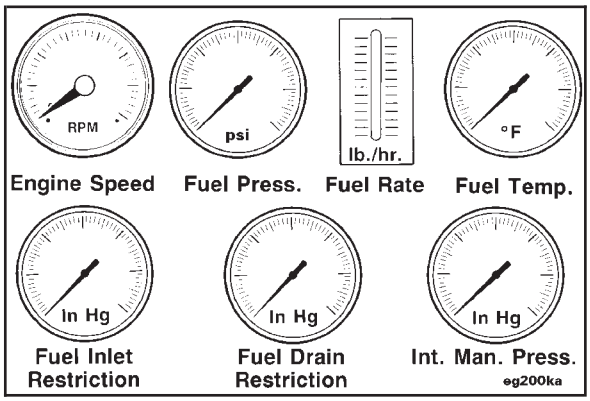
The following in-service run-in guidelines are recommended for QSK19 engines after a repair involving replacement of one or more of the piston ring sets, cylinder liners or pistons where engine or an engine dynamometer and/or chassis dynamometer run-in **cannot** be performed.

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.



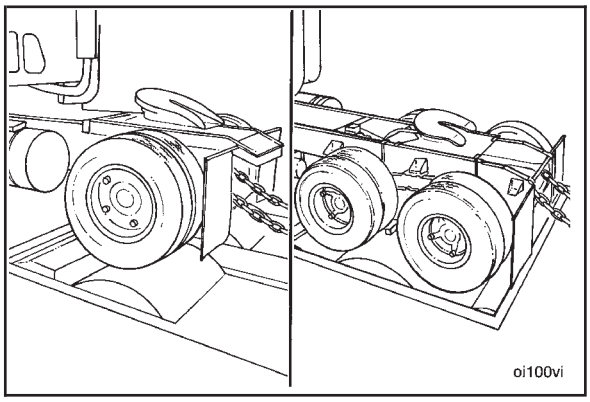
Engine Dynamometer Run-In

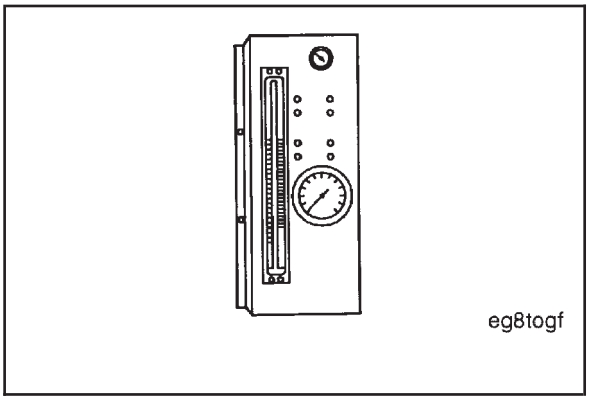
This is the preferred method of run-in for engines that have been rebuilt **out-of-chassis.** It is **not** practical, nor recommended that an engine be removed from the application to conduct the run-in after a rebuild or cylinder repair has been performed in-chassis. There is no requirement, nor is 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 standby generator or fire pump that **cannot** be operated because of customer restrictions, a fire truck that **cannot** be loaded with the water pump, etc.), the engine **must** be run-in on a chassis dynamometer, portable dynamometer or load bank following the recommendations outlined in the attached procedures.





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 available equipment. Below is a description of the fuel measuring device, available from Cummins Engine Company, along with installation and operation recommendations. The fuel measuring device, Part No. 3376375, can be used with either a chassis or engine dynamometer.

Installation

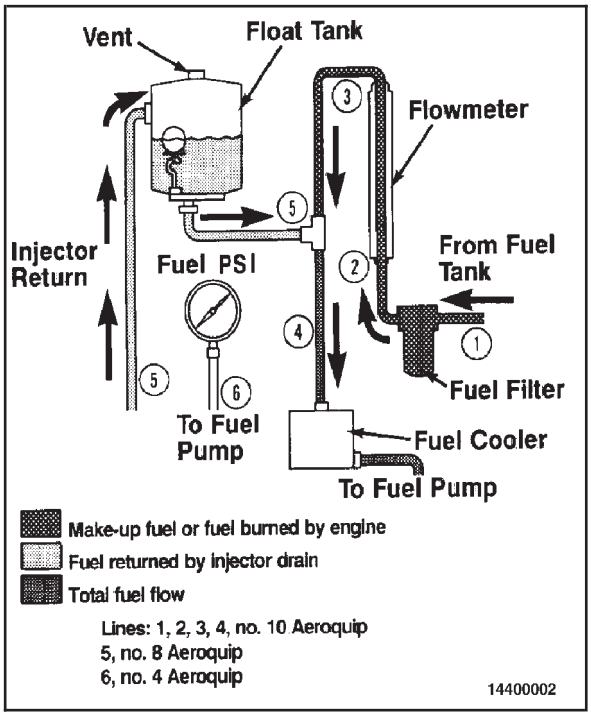
When installing the fuel measuring device, it is important to reduce the amount of air that can be introduced into the system when the device is **not** in use. Therefore, the plumbing used **must** include non-restrictive shutoff valves, such as ballcock valves, to contain fuel in the device after each use. Additional installation considerations are:

- The fuel measuring device, Part No. 3376375, **must** be mounted vertically to ensure accuracy and proper operation.
- A separate fuel supply for use on the dynamometer is recommended. All fuel used in the measuring device **must** be clean for consistent operation.
- Care **must** be taken to reduce fuel line restriction **to** and **from** the engine. Minimum recommended hose sizes are No. 10 for the engine fuel inlet, and No. 8 for the engine fuel drain. The length of either hose **must not** exceed 15 feet.
- For accurate fuel consumption or flow measurement while testing on a chassis dynamometer, it is recommended to use a fuel cooler to maintain inlet temperature to the fuel gear at 49°C [120°F] or below.

Operation

This is a schematic of the fuel measuring device, Part No. 3376375. The device consists of the following components:

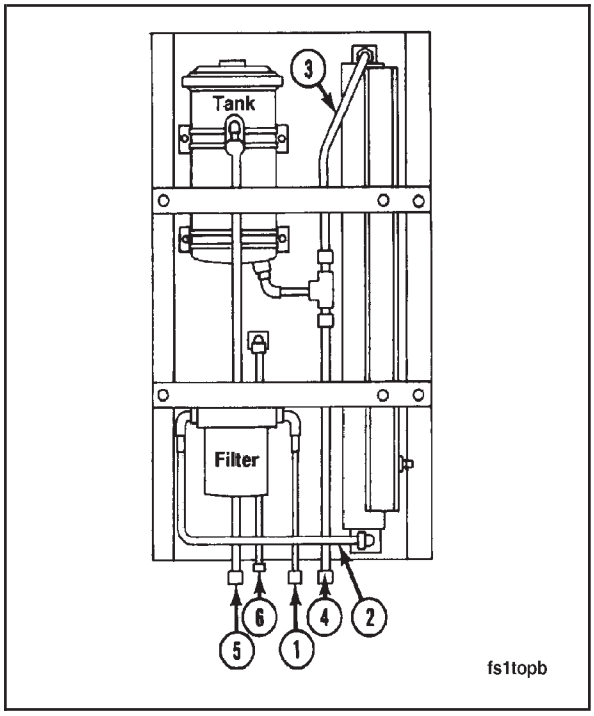
- Fuel Filter
- Flowmeter
- Float Tank
- Fuel Rail Pressure Gauge
- Fuel Cooler is **not** a part of fuel measuring device, Part No. 3376375, however it **must** be used when conducting test with the flow meter.



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

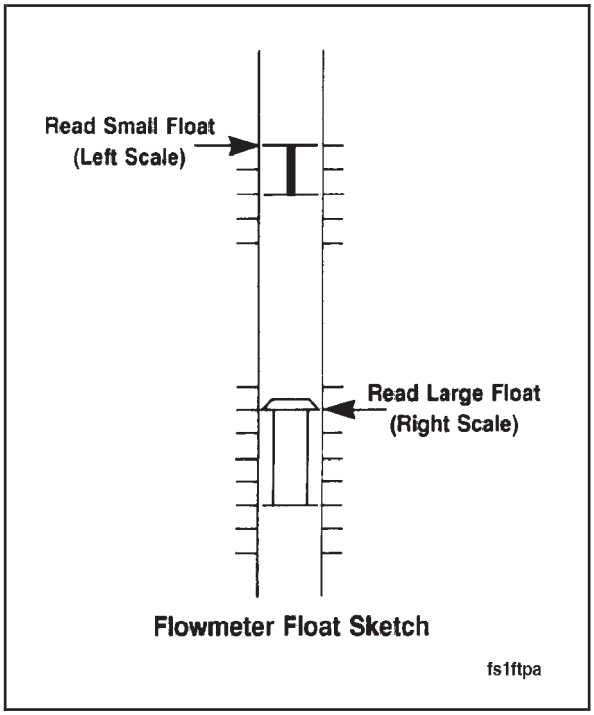
NOTE: The fuel supply tank **must** be below the level of the fuel measuring device to prevent overflow of the float tank. If an overhead fuel supply tank is used, a float controlled reservoir **must** be installed between the fuel supply tank and the fuel measuring device, and below the level of the device.



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.



Flowmeter Float Sketch

fs1ftpa

Specifications

Engine Testing

Maintain the following limits during the engine test/run-in procedures:

Due to variations in ratings of different engine models, refer to the specific ''Engine Data Sheet'' for the particular engine model being tested.

Intake Restriction (Maximum at Advertised Horsepower)
- •Clean Air Filter ..... 381 mm H_20 [15 in. H_2O]
- •Dirty Air Filter ..... 635 mm H_20 [25 in. H_2O]

Exhaust Back Pressure (Maximum at Advertised Horsepower) ..... 75 mm Hg [3 in. Hg]

Blowby* (Maximum at Advertised Horsepower)
- • New or rebuilt engines
  (Maximum) (Less than 160,000 km [100,000 miles] or 3600 hours) ..... See Tables
- •Used Engines
  (Maximum) (Over 160,000 km [100,000 miles] or 3600 hours) ..... See Tables

Oil Pressure (With 15W-40 oil at 107°C [225°F])
- • Low Idle (Minimum Allowable) ..... 138 kPa [20 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 ..... 102 mm [4 in Hg]
- •Dirty Fuel Filter ..... 203 mm [8 in Hg]
- •Maximum Allowable Fuel Inlet Temperature ..... 71°C [160°F]

*Blowby checking tools, Part No. 3822566 - 0.302 inch orifice, Part No. 3823567 - 0.354 inch orifice, and Part No. 3822568 - 0.406 inch orifice, have a special orifice that **must** be used to be certain an accurate reading is obtained.

QSK19 Blowby Limits (using 0.302 inch diameter orifice at rated load and speed)

Engine HP (RPM Rating)	New/Rebuilt	Used Engine Limit
699 HP and Below (1500 - 1900)	305 mm H_2O [12 in H_2O]	762 mm H_2O [30 in H_2O]
699 HP and Below (2000 and above)	355 mm H_2O [14 in H_2O]	889 mm H_2O [35 in H_2O]
700 HP and Above	508 mm H_2O [20 in H_2O]	1270 mm H_2O [50 in H_2O]

QSK19 Blowby Limits (using 0.354 inch diameter orifice at rated load and speed)

Engine HP (RPM Rating)	New/Rebuilt	Used Engine Limit
699 HP and Below (1500 - 1900)	178 mm H_2O [7 in H_2O]	457 mm H_2O [18 in H_2O]
699 HP and Below (2000 and above)	203 H_2O [8 in H_2O]	508 mm H_2O [20 in H_2O]
700 HP and Above	229 mm H_2O [9 in H_2O]	584 mm H_2O [23 in H_2O]

QSK19 Blowby Limits (using 0.406 inch diameter orifice at rated load and speed)

Engine HP (RPM Rating)	New/Rebuilt	Used Engine Limit
All Ratings	127 mm H_2O [5 in H_2O]	330 mm H_2O [13 in H_2O]

Lubricating Oil System

Oil Pressure (With 15W-40 Oil at 107° C [225° F])
- At Idle (Minimum Allowable) ..... 138 kPa [20 psi]
- At No Load Governed Speed ..... 345 to 483 kPa [50 to 70 psi]

Oil Temperature
- Maximum ..... 120°C [250° F]

Oil Filter Capacity
- Bypass Filter (Spin-On)(LF777 Fleetguard) ..... 2.3 Liters [0.6 U.S. Gallons]
- Full-Flow Filter (Spin-On)(LF670 Fleetguard) ..... 2.7 Liters [0.7 U.S. Gallons]
- Combination Filter (Two LF3000 Fleetguard) ..... 5.7 Liters [1.5 U.S. Gallons]

	Oil Pan Capacity (Liters)		[U.S. Gallons]	
Oil Pan Part No.	**High**	**Low**	**High**	**Low**
3096460	72	64	19	17
3086096	61	49	16	13
3086097	61	49	16	13
3331695	61	49	16	13
3331568	114	102	30	27

NOTE: When the rear gear train option is specified, add 7.6 liters [2 U.S. gallons] to the oil pan capacity listed above.

Cooling System

Coolant Capacity (Engine Only) ..... 32.2 liters [34 U.S. Quarts]

Standard Modulating Thermostat Range ..... 82°C to 94°C [180°F to 202°F]

Standard LTA Thermostat Range ..... 69°C to 78°C [157°F to 172°F]

Maximum Coolant Pressure (Exclusive of Pressure Cap) ..... 241 kPa [35 psi]

Maximum Allowable Top Tank Temperature ..... 100°C [212°F]

Minimum Recommended Top Tank Temperature ..... 70°C [160°F]

Maximum Allowable Deaeration Time ..... 25 Minutes

Minimum Allowable Drawdown or 20% of System Capacity (whichever is greater) ..... 11 liters [12 U.S. Quarts]

Minimum Allowable Pressure Cap ..... 50 kPa [7 psi]

Exhaust System

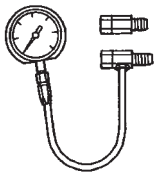
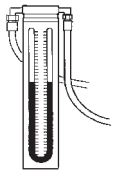
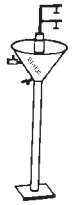
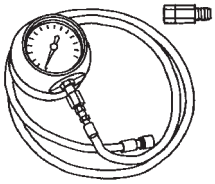
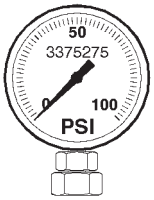
Back Pressure - Maximum (at rated speed and load): ..... 75 mm Hg [3.0 in Hg]

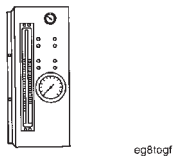
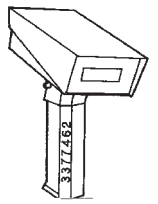
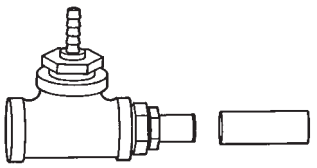
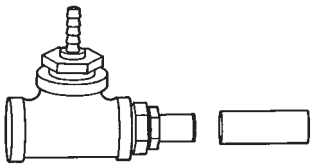
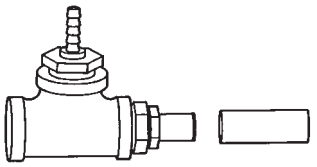
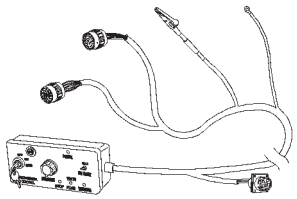
Exhaust Pipe Size (Normally Acceptable Inside Diameter):
- All Ratings ..... 152 mm [6.0 in]

Service Tools

Engine Testing

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

Tool No.	Tool Description	Tool Illustration
ST-434	**Vacuum Gauge** Used to check fuel filter or intake air restriction.	
ST-1111-3	**Manometer** Used with tool, Part No. 3375150, for measuring blowby.	
ST-1135	**Lubricating Oil Sampling Filter** Used to monitor oil contamination.	
ST-1273	**Pressure Gauge [0-75 In-Hg]** Used to measure intake manifold pressure and fuel drain line restriction.	
3375275	**Pressure Gauge [0-100 psi]** Used to measure lubricating oil pressure.	
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.	

Tool No.	Tool Description	Tool Illustration
3376375	**Fuel Measuring Device** Measure the rate of fuel consumption of a Cummins diesel engine.	
3377462	**Digital Optical Tachometer** Used to measure engine speed (RPM).	
3822566 0.302 inch orifice	**Blowby Check Tool** Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.	
3823567 0.354 inch orifice	**Blowby Check Tool** Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.	
3822568 0.406 inch orifice	**Blowby Check Tool** Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.	
3162245	**Engine Dynamometer Control** Used on an engine dynamometer to control the QSK19 engine.	
3824801	**INSITE™ Software Kit** Used to troubleshoot, program, and adjust the QSK Fuel System.	

Dynamometer Worksheet (014-001)

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 psi at Idle	
Fuel Pressure (psi @ rpm)	225 to 250 psi at 1800 rpm	
Fuel Pressure (psi @ rpm)	250 to 300 psi at 2100 rpm	
Fuel Rate (lb/hr)		
Intake Mfd. Pressure (in.Hg)	See Fuel Pump Code	
Intake Mfd. Temperature		
*Intake Air Restriction	25 in. H_2O, Maximum	
*Exhaust Air Restriction	3 in. Hg, Maximum	
*Fuel Inlet Restriction	8 in. Hg (Dirty Filter), Maximum	
*Fuel Drain Line Restriction	3 psi, Maximum	
Engine Blowby	See Tables	
* Recorded at maximum horsepower speed and full load		

Road Speed Limit				Engine High Speed Limit		
Check Oil Level	Low	High	OK	Fuel Quality	OK	Not OK

Engine Speed	Fuel *Rate/Press		Fuel Temp	Turbo Inlet Air Temp	Intake Manifold Temp/Press		Coolant Temp/Press		Engine Blowby	Lube Oil Press	HP or Torque
* Be sure that the fuel rate is corrected for temperature.											

Fuel Temperature	Correction for Flow Rate
Less than 7°C[45°F]	Flow meter **not** accurate
7 to 13°C[45 to 55°F]	Subtract 2% from flow rate reading
13.0 to 20.0°C[55 to 68°F]	Subtract 1% from flow rate reading
20.0 to 29°C[68 to 85°F]	No Correction
29 to 42°C[85 to 108°F]	Add 1% to flow rate reading
42 to 56°C[108 to 132°F]	Add 2% to flow rate reading
56°C above [132°F]	Flow meter **not** accurate.

Pressure Conversions

1 in. H_20 = 0.074 in. Hg = 0.036 psi

1 in. Hg = 13.514 in. H_20 = 0.491 psi

1 psi = 2.036 in. Hg = 27.7 in. H_20

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Engine Testing (Chassis Dynamometer) (014-002)

Setup

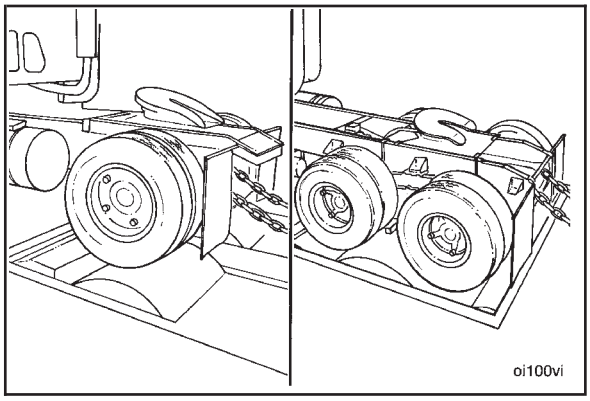
The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

NOTE: 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

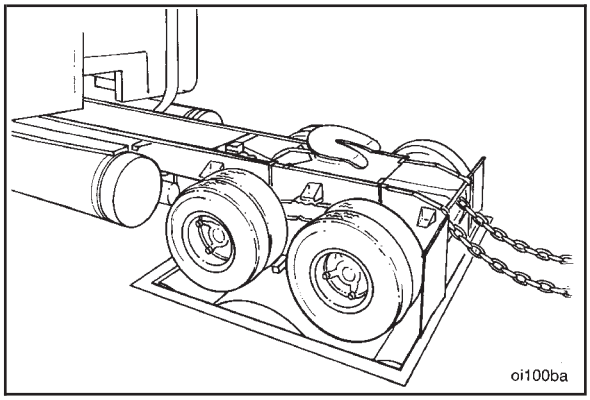
The net horsepower available is called Wheel Horsepower (WHP).

NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 Km/H [55 to 60 MPH].



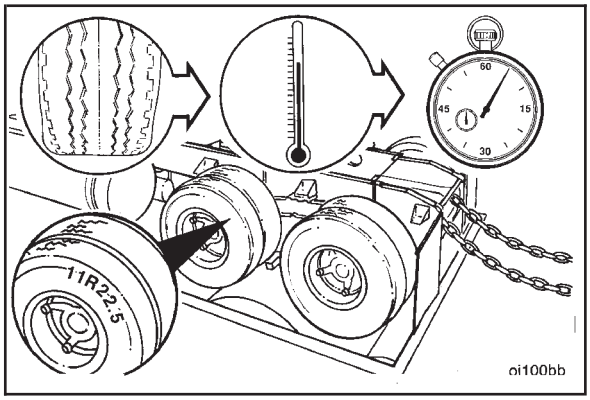
⚠ CAUTION ⚠

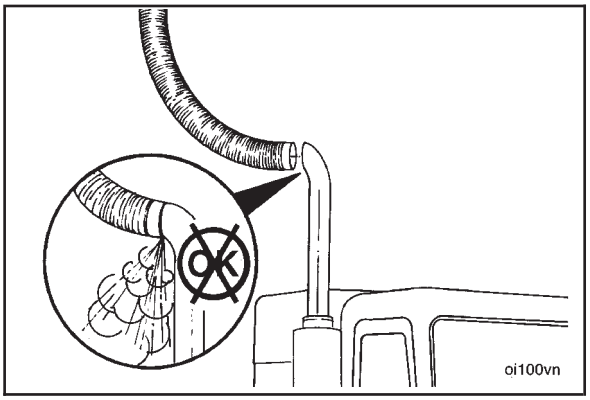
Before installing or operating a vehicle on a chassis dynamometer, follow all the vehicle manufacturer's safety precautions.



⚠ CAUTION ⚠

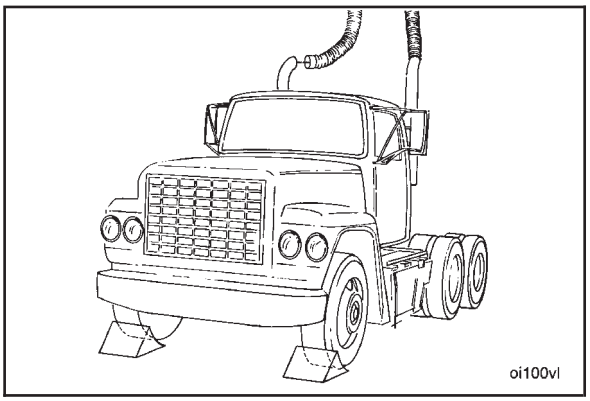
Low profile radial tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



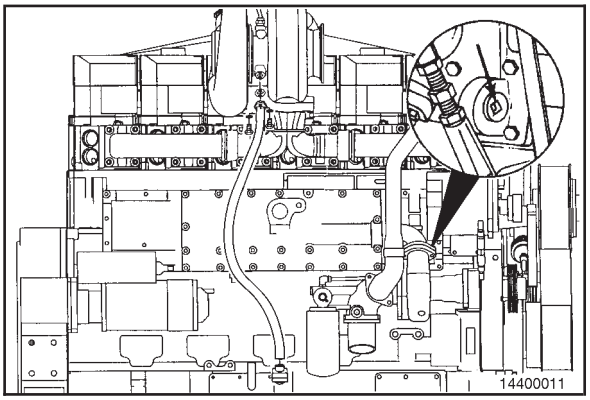


Adjust the vehicle and dynamometer room exhaust system to be sure that all exhaust gases are removed from the room.

Refer to the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.



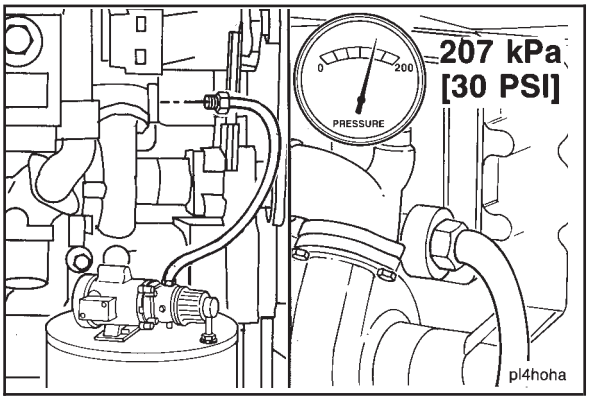
Be sure all instrumentation is removed before removing the vehicle from the dynamometer.



General Engine Test Procedures

NOTE: The lubricating oil system **must** be primed before operating the engine after rebuild to avoid internal component damage. Do **not** prime the system from the bypass filter as the filter will be damaged.

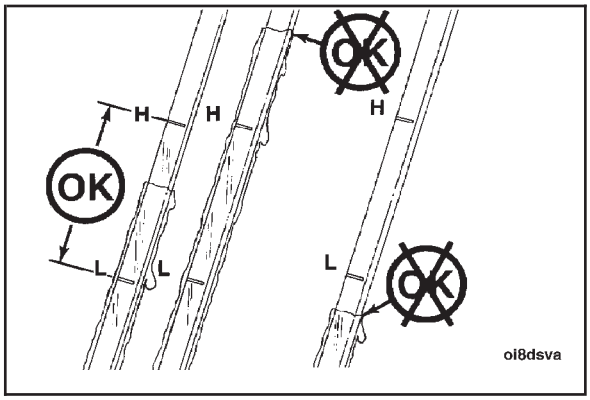
Remove the large plug from the oil cooler housing.



Use a pump capable of supplying 205 kPa [30 psi] continuous pressure. Connect the pump to the front of the engine oil cooler as shown.

Use a supply of clean oil. Turn the pump to the ON position. Check the engine oil pressure gauge. When the gauge indicates oil pressure, begin monitoring the oil level in the oil pan.

Check the engine lubricating oil level to be sure it is filled to the proper level.



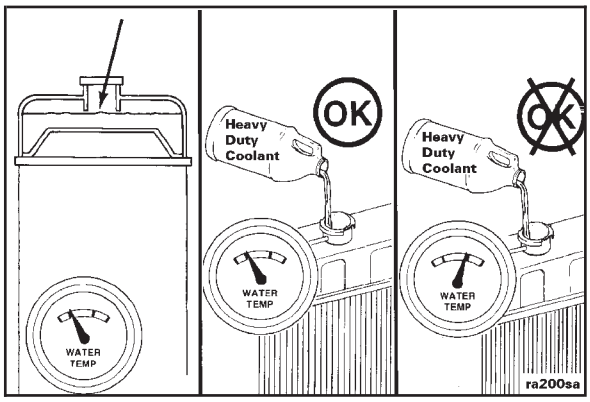
⚠ WARNING ⚠

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.

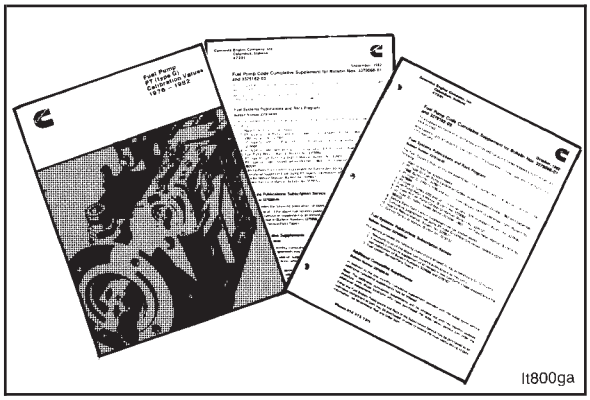
Check the engine coolant level to be sure it is filled to the proper level. Refer to Procedure 008-018.

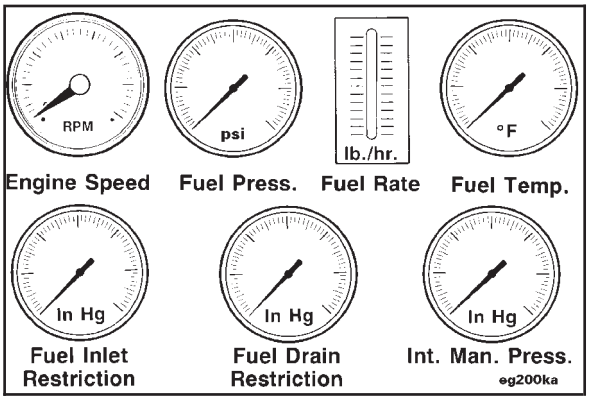


NOTE: Use a known source of good quality No. 2 diesel fuel.

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.).

Engine operating specifications can be found in publications available from your local Cummins Authorized Repair Location.

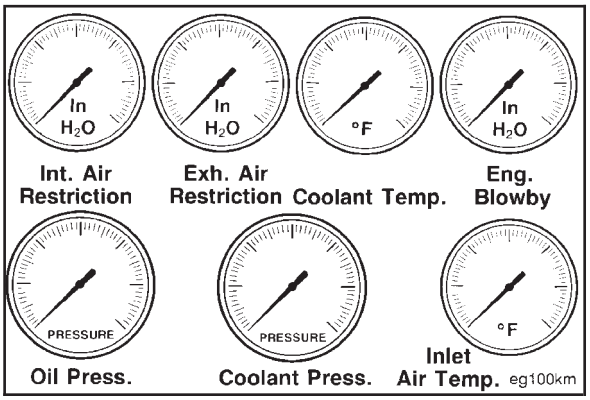




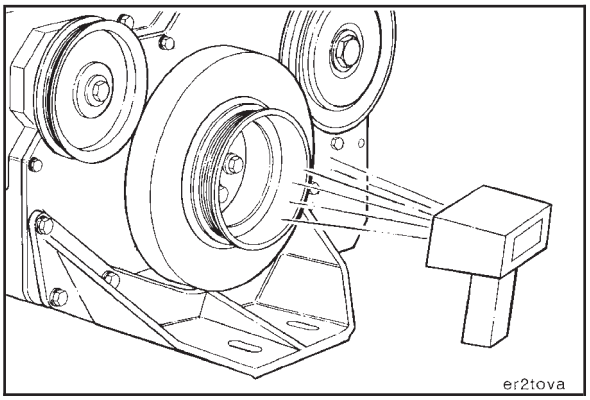
Test

To properly monitor engine performance, record the following parameters. To limit dynamometer operating time, instrument the engine to perform 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

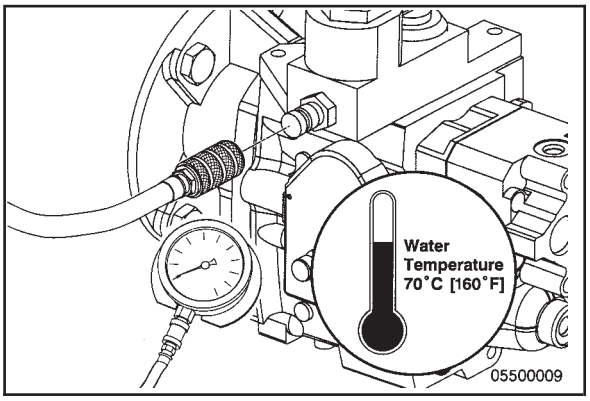


- Intake air restriction
- Exhaust air restriction
- Coolant temperature
- Engine blowby
- Lubricating oil pressure
- Coolant pressure
- Inlet manifold air temperature
- Turbocharger inlet air temperature



Engine Speed (rpm) With a Verified Tachometer

Use digital optical tachometer, Part No. 3377462, to check and verify engine speed.

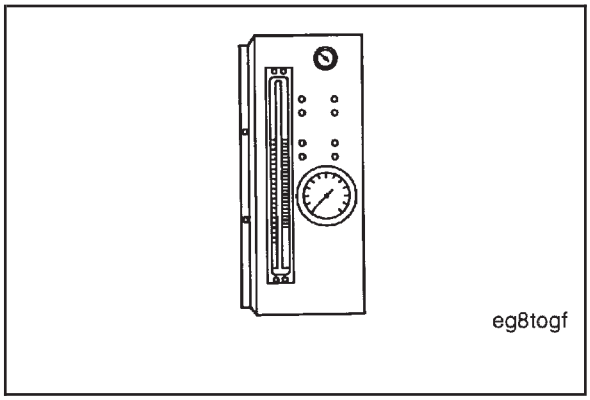


Fuel Supply Pressure

Refer to Procedure 005-016-013.

Fuel Rate

Use fuel measuring device, Part No. 3376375, to measure the rate of fuel consumption. Refer to General Information located in the front of this section.

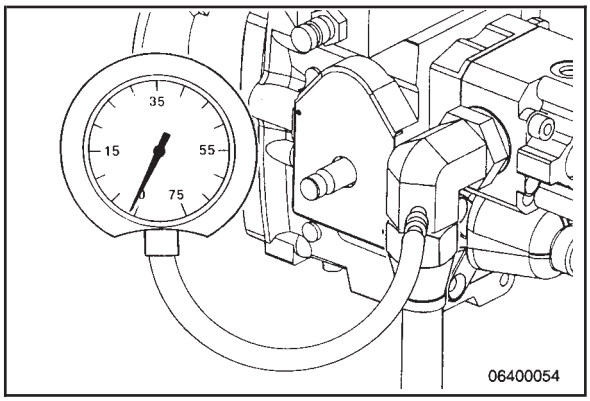


Fuel Inlet Restriction

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.

Refer to Procedure No. 006-020.

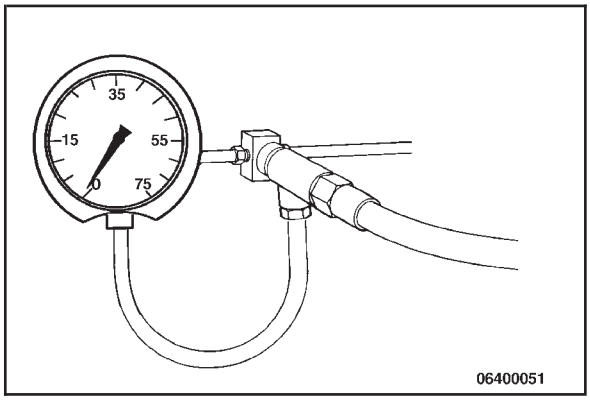


Fuel Drain Line Restriction

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.

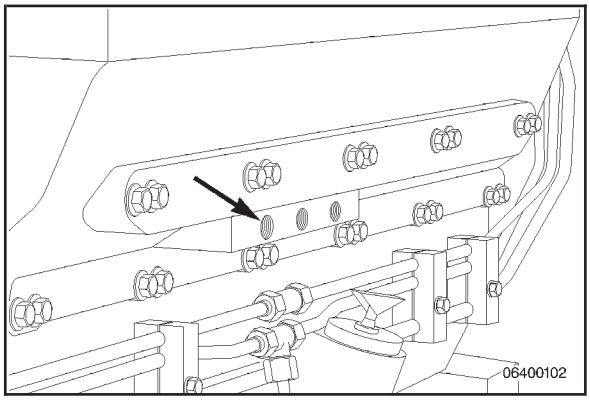
Refer to Procedure No. 006-012.

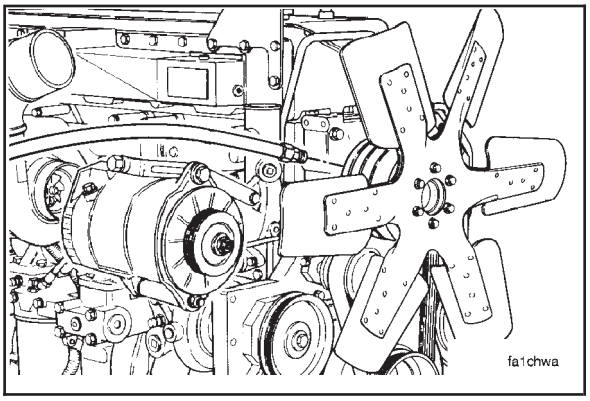


Intake Manifold Pressure

Measure the intake manifold or INSITE™ pressure (turbocharger boost). Install pressure gauge, Part No. ST-1273, in the intake manifold as shown.

Observe the reading on the pressure gauge.

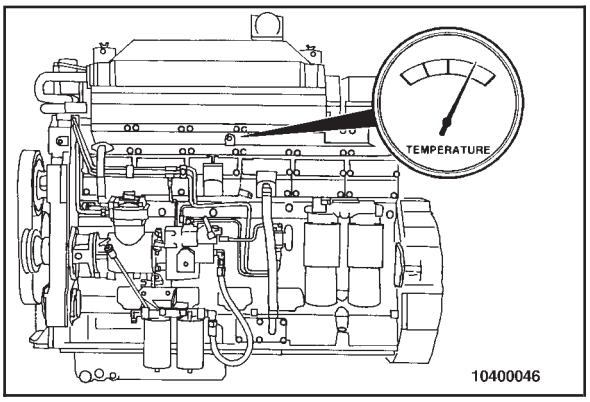




Intake Air Temperature Control - Chassis Dynamometer Test

When operating an engine on a chassis dynamometer, follow these steps for best results and safe operation.

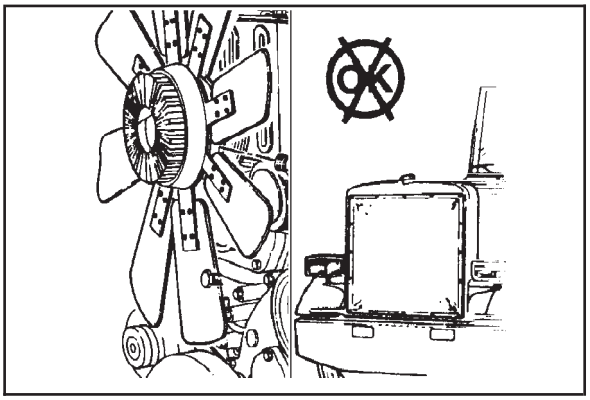
If the engine is equipped with automatic fan, lock the cooling fan in the ON mode. This can be done by installing a jumper across the temperature switch, or by supplying shop air to the control valve. Refer to the fan drive manufacturer for the recommended procedure.



Monitor the intake manifold air temperature using INSITE™ in the monitor mode, or install Fluke digital thermometer, Part No. 3822666, and thermocouple wire kit, Part No. 3822988, into the intake manifold.

The intake manifold air temperature **must not** exceed 77°C [170°F].

Maintain intake manifold air temperature to 66°C [150°F] or below during chassis dynamometer operation.



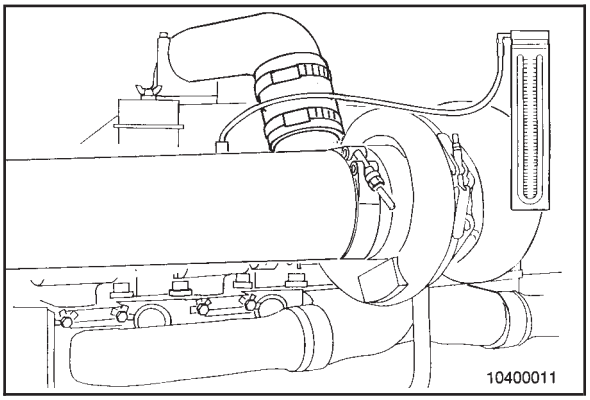
If the intake manifold temperature exceeds 77°C [170°F], shut off the engine. Allow the engine to cool.

Check the fan drive. Be 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.



Intake Air Restriction

Measure the inlet air restriction. Install the vacuum gauge, Part No. ST-434, or a manometer, Part No. ST-1111–3, 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.

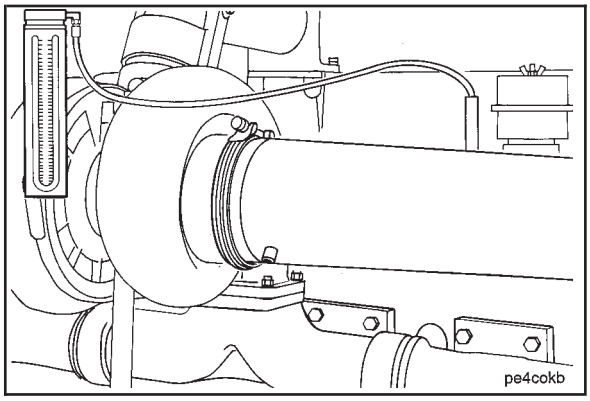
Refer to Procedure No. 010-031-010.

Exhaust Restriction

Measure the exhaust air restriction. Install the pressure gauge, Part No. ST-1273, or a manometer in the exhaust air piping.

The gauge adapter **must** be installed near the turbocharger in a straight section of pipe at the turbine outlet.

Refer to Procedure No. 011-009.



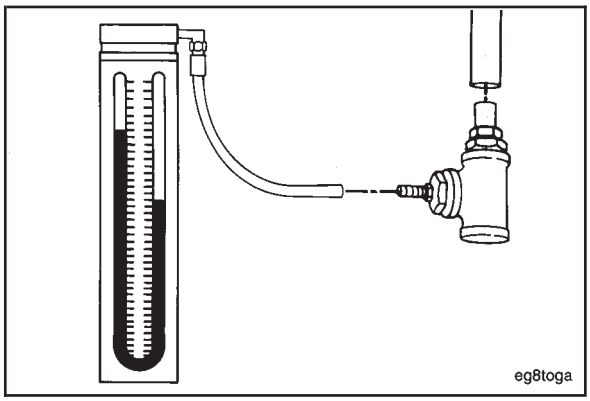
Engine Blowby

NOTE: Excessive blowby indicates an air compressor, a turbocharger, or an engine malfunction, allowing combustion gases or air to enter the crankcase and build a pressure higher than normal.

This procedure describes how to measure crankcase pressure and how to determine the component that is malfunctioning.

Use one of the three blowby service tools and a water manometer Part No. ST-1111-3. Maximum gauge capacity is 1270 mm-H_20 [50 in-H_20].
The engine blowby tools are similar in design. The difference between the tools is in the size of the orifice.

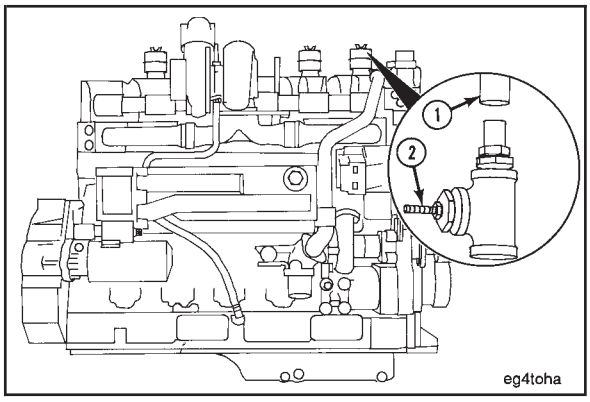
Blowby Tool Part No.	Orifice Size [Inch]
3822566	[0.302]
3822567	[0.354]
3822568	[0.406]

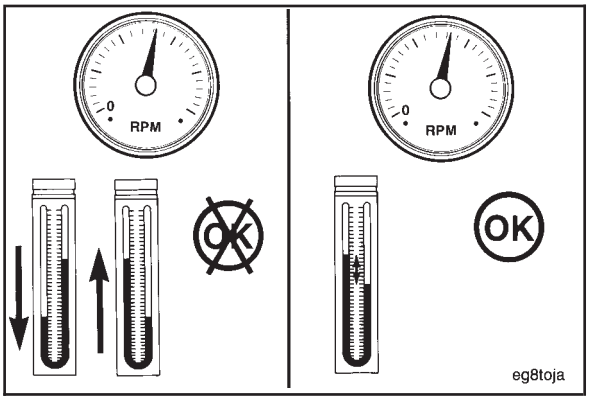


Use a length of hose (1) to attach the blowby tool to one of the crankcase breathers.

Plug all of the other breathers.

Attach a manometer to the location shown (2).





Operate the engine at rated rpm and full load (wide open throttle) until a steady reading is obtained.

Compare the blowby readings to previous readings on the engine. If previous readings for the engine are **not** available, compare the blowby reading to new engine specifications.

NOTE: A sudden increase in blowby indicates a problem. A gradual increase over a period of time is normal (due to wear of internal engine components).

Specifications

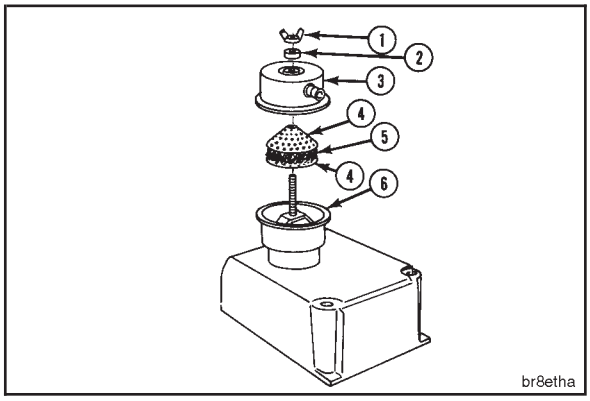
Engine Blowby 7.67 mm [0.302 in] Orifice:	New/Rebuilt		Used	
RPM	**mm H_20**	**[in H_20]**	**mm H_20**	**[in H_20]**
All ratings	508	[20]	1270	[50]
2000 and above	355	[14]	889	[35]
1500 to 1900	305	[12]	762	[30]

Engine Blowby 9.0 mm [0.354 in] Orifice:	New/Rebuilt		Used	
RPM	**mm H_20**	**[in H_20]**	**mm H_20**	**[in H_20]**
All ratings	229	[9]	584	[23]
2000 and above	203	[8]	508	[20]
1500 to 1900	178	[7]	457	[18]

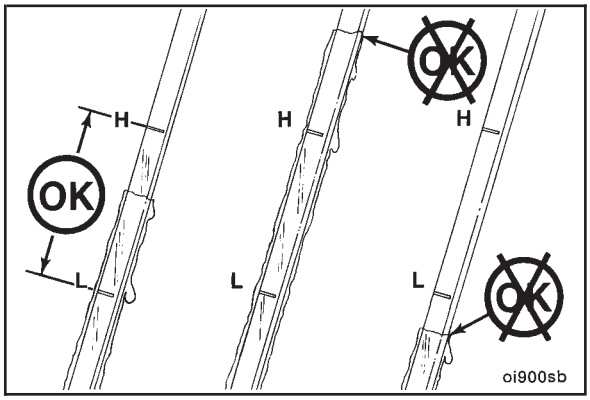
Engine Blowby 10.3 mm [0.406 in] Orifice:	New/Rebuilt		Used	
RPM	**mm H_20**	**[in H_20]**	**mm H_20**	**[in H_20]**
All ratings	127	[5]	330	[13]

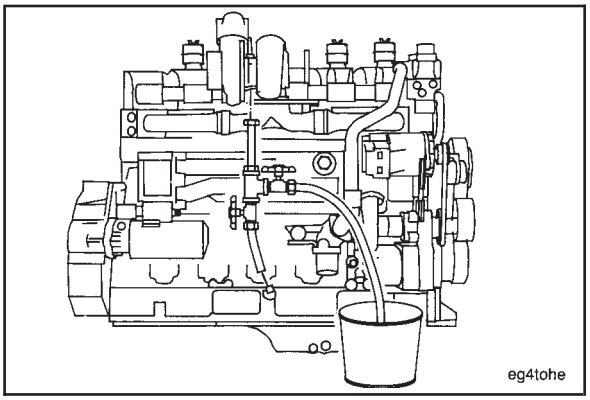
If the blowby is higher than normal, check the crankcase breathers and breather tubes to see if they are plugged.

1. Wing Nut
2. Washer
3. Breather Cap
4. Screen Mesh
5. Breather Element
6. Breather Base



Check the engine oil level. If the level is too high, it can cause a higher than normal crankcase pressure.





Isolate the turbocharger to determine if the high crankcase pressure is due to seal leakage in the turbocharger.

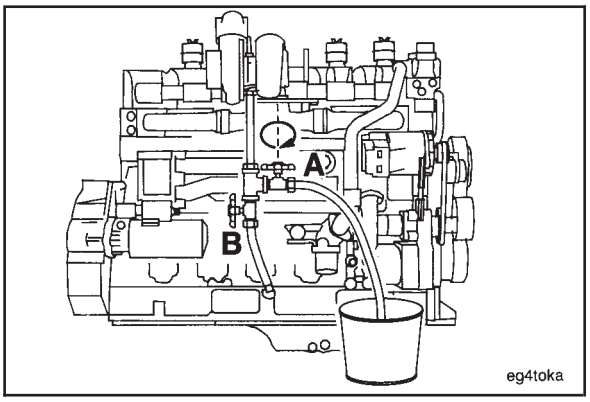
⚠ WARNING ⚠

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. Always use the proper procedures to dispose of the oil.

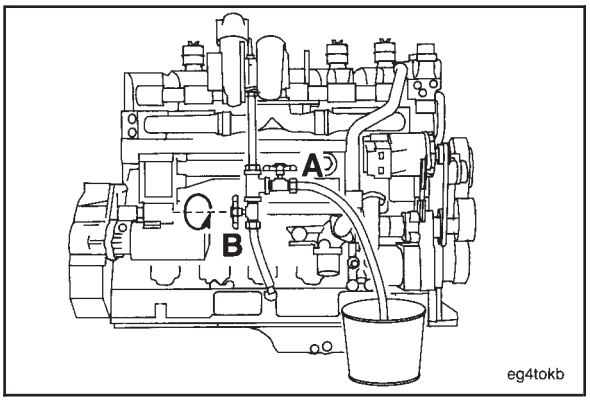
Disconnect the turbocharger drain line from the oil pan adaptor.

Install a hose assembly with the two shutoff valves arranged as shown. Place the other hose in an 8 to 19 liter [2 to 5 gallon] bucket.

NOTE: The valves **must** have a minimum inside diameter of 19 mm [0.75 in].



Close the valve (A) that allows the oil to drain to the bucket.



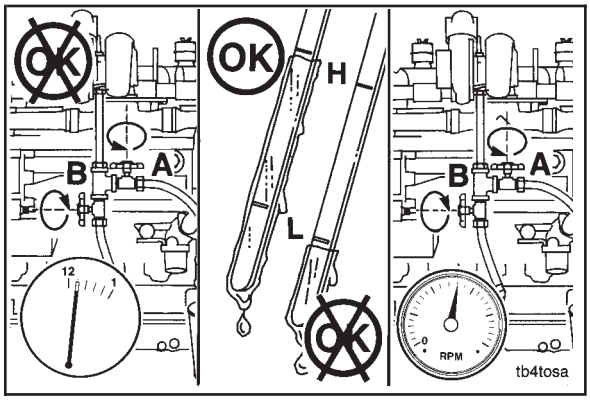
Open the valve (B) that allows the oil to drain into the engine.

Operate the engine at rated speed. Record the blowby value.

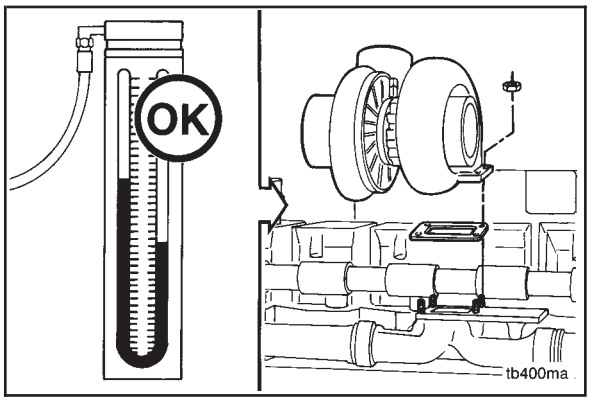
⚠ CAUTION ⚠

Do not operate the engine with valve A open and valve B closed for more than 1 minute. Operation for more than 1 minute can result in severe engine damage.

Continue operating at rated speed and load. Open valve A and close valve B. Record the blowby reading.



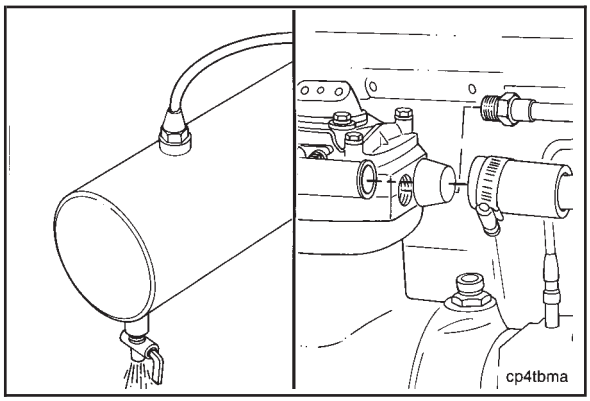
Compare the value to the original reading. If the blowby is **now** acceptable, replace the turbocharger.



Isolate the air compressor to determine if it is malfunctioning and causing the high blowby pressure.

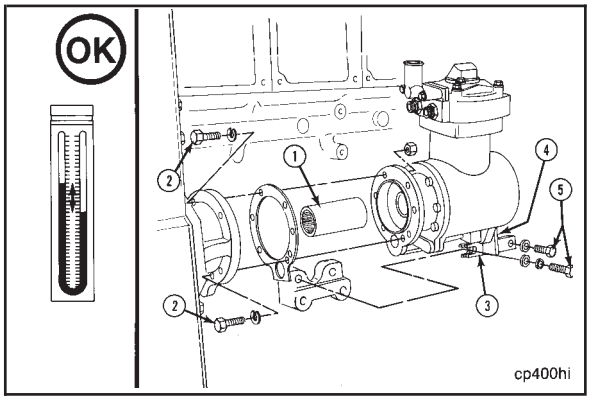
Relieve the air pressure on the first air tank in the system after the air compressor (wet tank).

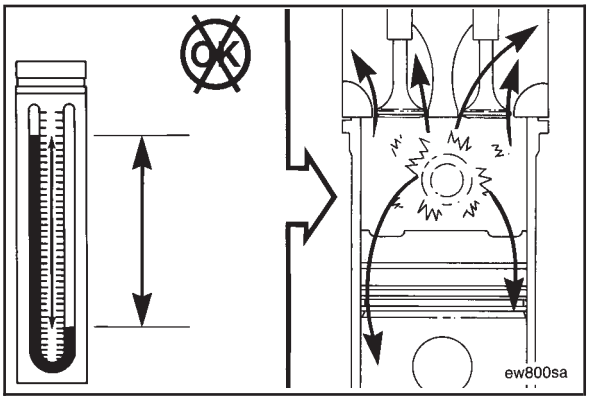
Disconnect the air inlet and outlet connections. Plug the intake manifold or air piping where the inlet connection was removed.



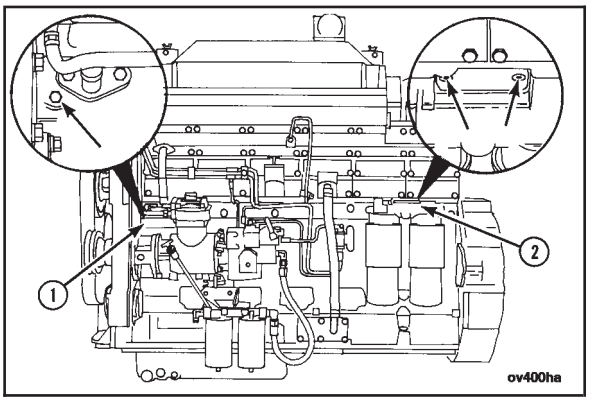
Operate the engine at rated speed and full load (wide open throttle) until a steady blowby reading is obtained.

Compare the blowby readings to the previous value. If the blowby is **now** acceptable, replace the air compressor.





A sudden increase in blowby or a high reading that is **not** steady indicates that there is internal damage in the engine.



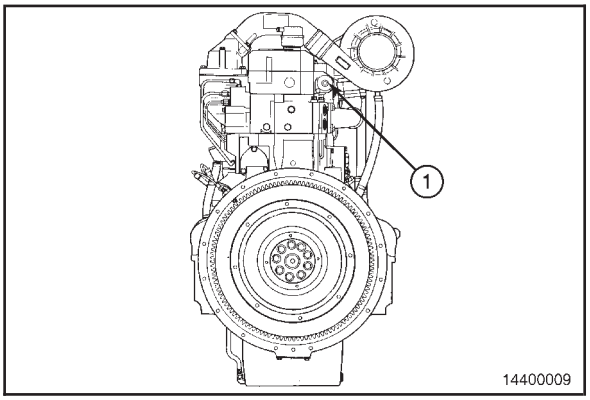
Lubricating Oil Pressure

Use Pressure Gauge, Part No. 3375275, to measure lubricating oil pressure.

Install the pressure gauge to the main oil rifle (1) or oil filter head (2).

Low Idle (minimum allowable) 138 kPa [20 psi]

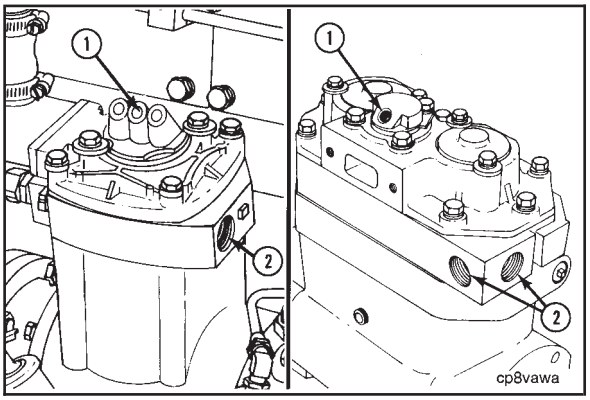
At 1200 rpm (minimum allowable) 207 kPa [30 psi]



Coolant Pressure

Measure the coolant pressure at the water manifold (1).

Maximum Coolant Pressure with Closed Thermostat and No Pressure Cap 241 kPa [35 psi]



Air Compressor

NOTE: All air compressors manufactured by Cummins Engine Company, Inc. **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.

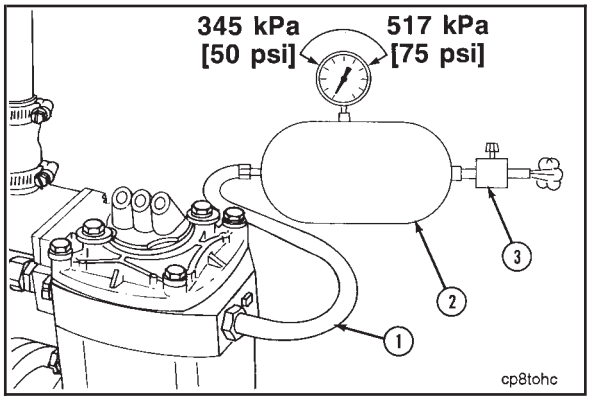
NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).

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) 260 °C [500 °F]

Connect the tube or hose (1) to the air compressor outlet.

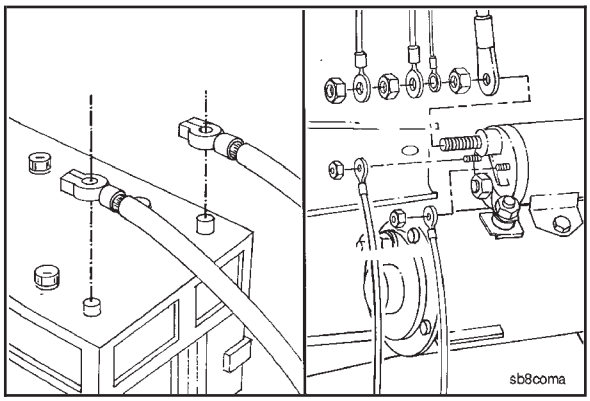


Starting Motor

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.

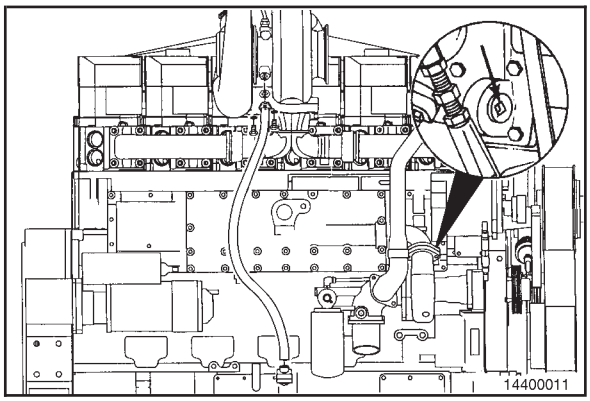


Engine Run-in (Chassis Dynamometer) (014-003)

General Information

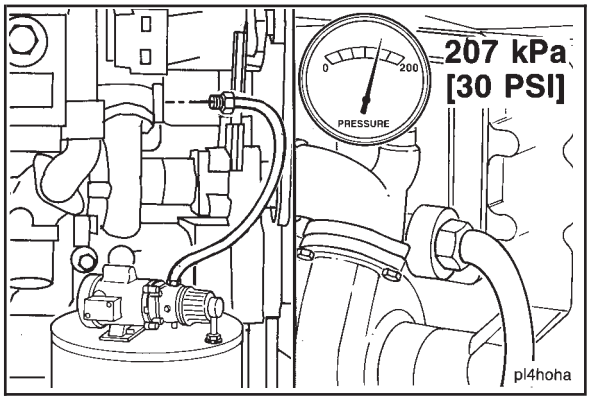
NOTE: The lubricating oil system **must** be primed before operating the engine after rebuild to avoid internal component damage. Do **not** prime the system from the bypass filter as the filter will be damaged.

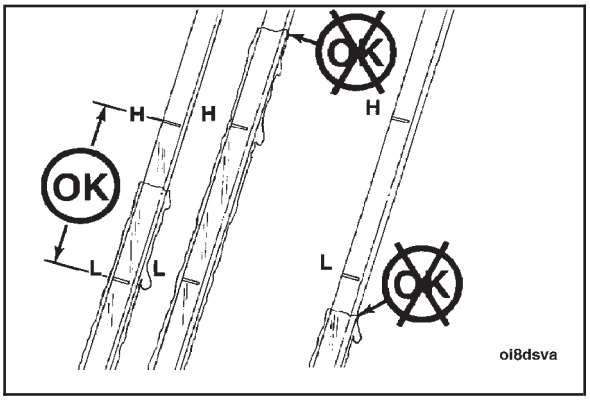
Remove the large plug from the oil cooler housing.



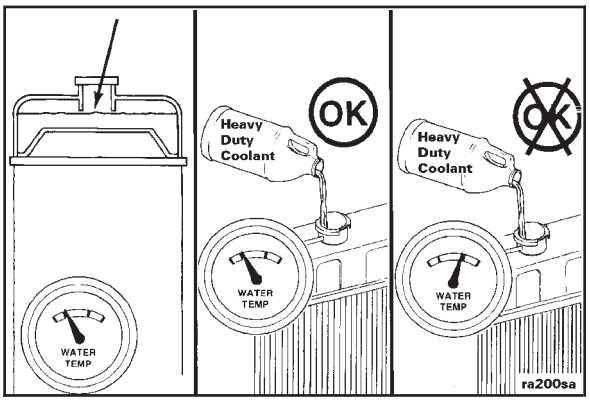
Use a pump capable of supplying 205 kPa [30 psi] continuous pressure. Connect the pump to the front of the engine oil cooler as shown.

Use a supply of clean oil. Turn the pump to the ON position. Check the engine oil pressure gauge. When the gauge indicates oil pressure, begin monitoring the oil level in the oil pan.





Check the engine lubricating oil 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.

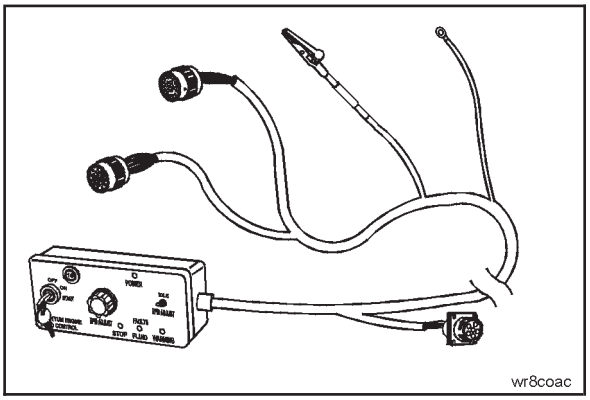
⚠ CAUTION ⚠

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 coolant level to make 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.).



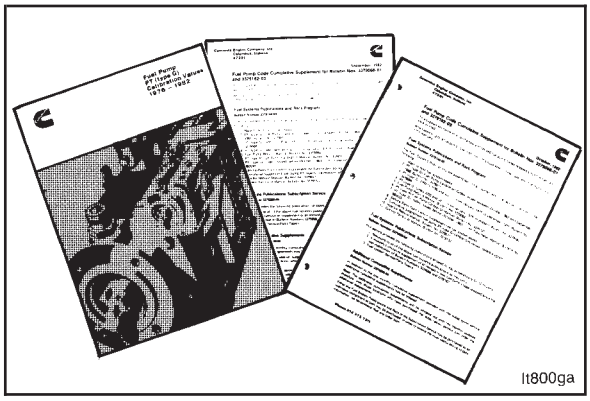
Engine Throttle Control

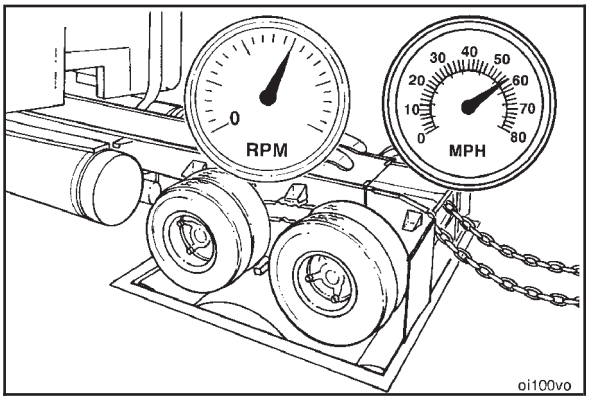
Engines that are run on an engine dynamometer require that the engine harness be installed, and connected to the engine. Additionally, a special engine dynamometer version of the OEM wiring harness and throttle control **must** be installed.

A special wiring harness and throttle control has been developed to enable engine operation out of the chassis.

Engine Dynamometer Kit, Part No. 3162245.

Engine operating specifications can be found in publications available from your local Cummins Authorized Repair Location.





Run-In Instructions

Refer to Chassis Dynamometer - Operation, Procedure No. 014-002, for general operating procedures and safety precautions.

Use this chart to determine the test load.

Example: The test load for a 475 HP engine rated at 2000 rpm with a 15 percent torque rise is 225 ft-lb.

NOTE: This chart assumes the dynamometer constant is 5252. If the dynamometer constant is **not** 5252, use the following formula to determine the correct test load:

Correct test load = (Dynamometer constant) x (Test load) /d 5252.

Example: The dynamometer constant for testing the engine in the above example is 4000.

Correct test load = (4000 x 225) /d 5252 = 171 ft-lb.

NOTE: This chart assumes vehicle run-in on a chassis dynamometer.

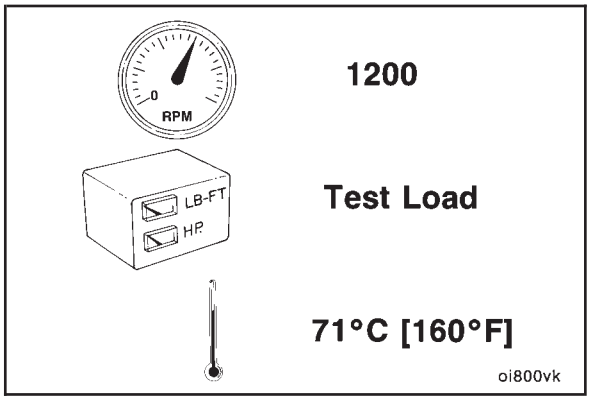
Rated RPM	Rated Horsepower	Torque Rise	Test Load
1200	All	All	305 N•m [225 ft-lb]
1500	All	All	305 N•m [225 ft-lb]
1800	0 to 499	All	305 N•m [225 ft-lb]
1800	500 and ABOVE	All	380 N•m [280 ft-lb]
1900	0 to 474	All	305 N•m [225 ft-lb]
1900	475 and ABOVE	All	380 N•m [280 ft-lb]
2000	0 to 499	0 to 24%	305 N•m [225 ft-lb]
2000	0 to 499	25% and ABOVE	380 N•m [280 ft-lb]
2000	500 and ABOVE	All	380 N•m [280 ft-lb]
2100	0 to 474	0 to 32%	305 N•m [225 ft-lb]
2100	0 to 474	33% Plus	305 N•m [225 ft-lb]
2100	475 to 530	0 to 15%	305 N•m [225 ft-lb]
2100	475 to 530	16% and ABOVE	380 N•m [280 ft-lb]
2100	531 to 649	All	380 N•m [280 ft-lb]
2100	650 and ABOVE	All	405 N•m [300 ft-lb]

Adjust the engine rpm to 1200 rpm. Adjust the dynamometer load to the test load as previously determined. Operate the engine at this setting until the coolant temperature indicates 70°C [160°F].

Check for leaks. Fix all leaks.

Check all of the gauges and record the readings.

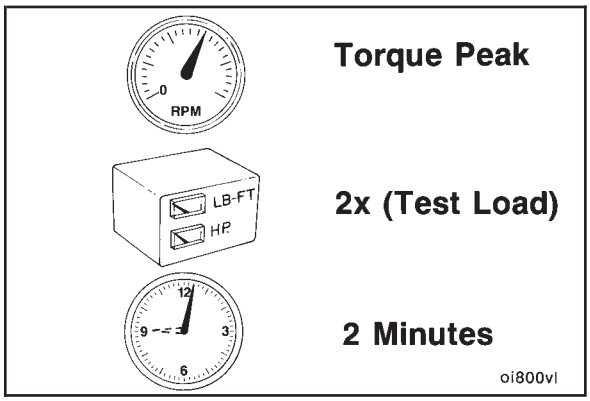
Do **not** proceed to the next step until the blowby becomes stable within specifications.



Adjust the engine rpm to the torque peak rpm. Adjust the dynamometer load to equal two times the test load. Operate the engine for 2 minutes.

Check all the gauges and record the readings.

Do **not** proceed to the next step until the blowby becomes stable within specifications.

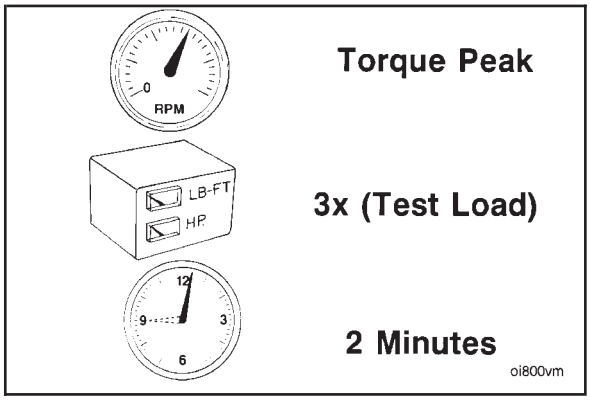


Maintain the engine rpm at torque peak rpm. Increase the dynamometer load to equal three times the test load.

Operate the engine at this load for 2 minutes.

Check all the gauges and record the readings.

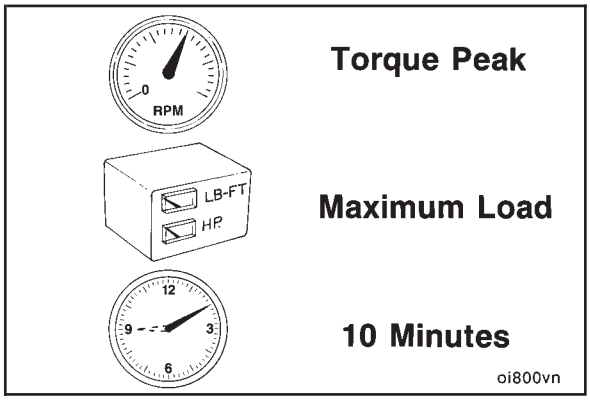
Do **not** proceed to the next step until the blowby becomes stable within specifications.

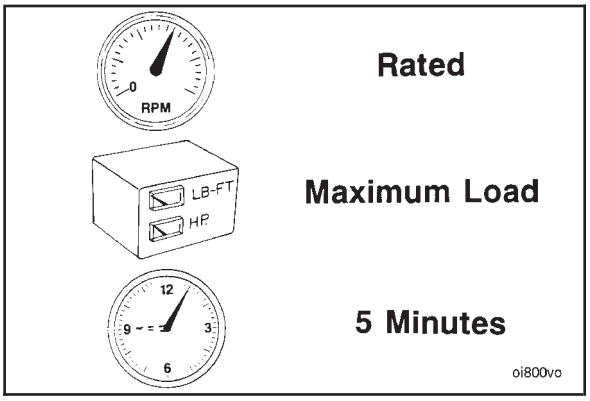


Move the throttle lever to the FULL OPEN position. Increase the load until the engine rpm is at torque peak rpm.

Operate the engine at this setting for 10 minutes or until the blowby becomes stable within specifications.

Check all the gauges and record the readings.

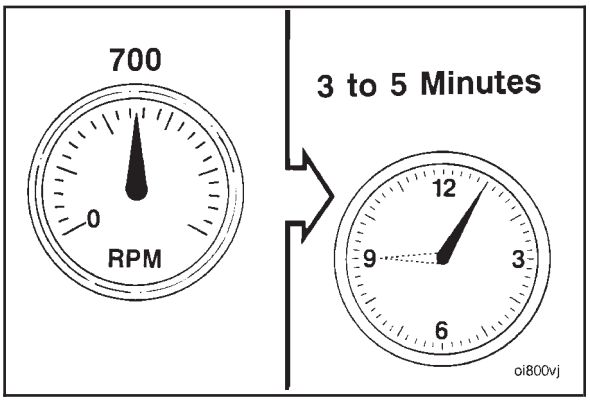




Decrease the dynamometer load until the engine rpm increases to the rated RPM.

Operate the engine at this load for 5 minutes.

Check all the gauges and record the readings.



Decrease the dynamometer load completely.

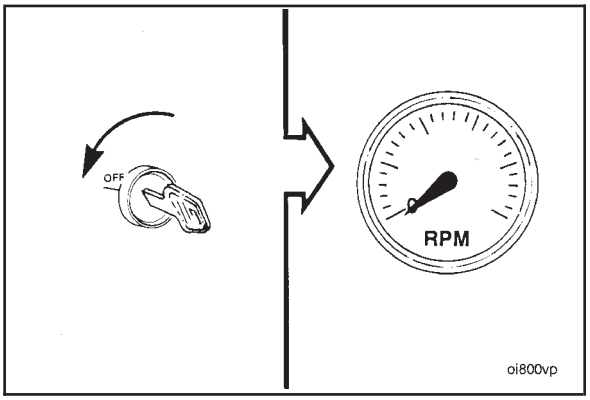
CAUTION

Do not turn the engine OFF immediately. The engine must be allowed to cool or damage to the turbocharger may result.

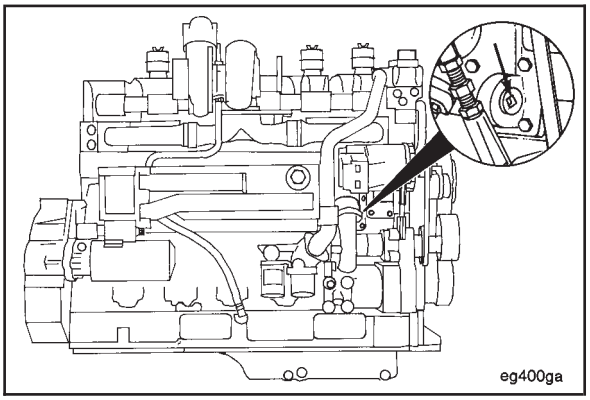
Move the throttle lever to the LOW IDLE position. Operate the engine at this setting for 3 to 5 minutes. This will allow the turbocharger and the other engine components to cool.

CAUTION

Do not operate the engine at IDLE longer than specified. Excessive carbon formation can cause engine damage.



Turn the engine OFF.



Engine Run-in (Without Dynamometer) (014-004)

Preparatory

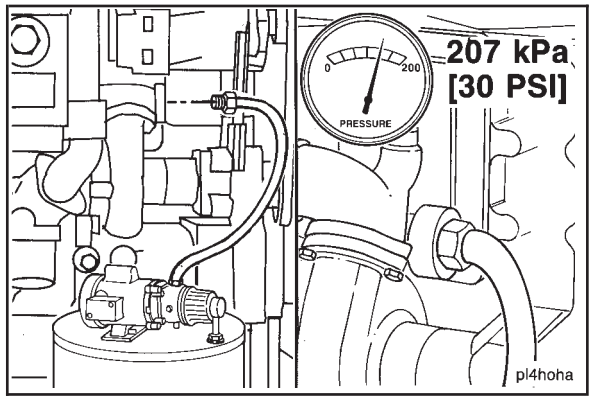
General Engine Test Procedures

NOTE: The lubricating oil system **must** be primed before operating the engine after rebuild to avoid internal component damage. Do **not** prime the system from the bypass filter as the filter will be damaged.

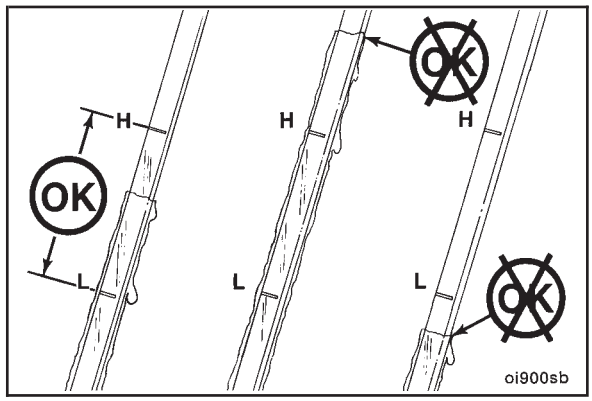
Remove the large plug from the oil cooler housing.

Use a pump capable of supplying 205 kPa [30 psi] continuous pressure. Connect the pump to the front of the engine oil cooler as shown.

Use a supply of clean oil. Turn the pump to the ON position. Check the engine oil pressure gauge. When the gauge indicates oil pressure, begin monitoring the oil level in the oil pan.



Check the engine lubricating oil level to be sure it is filled to the proper level.



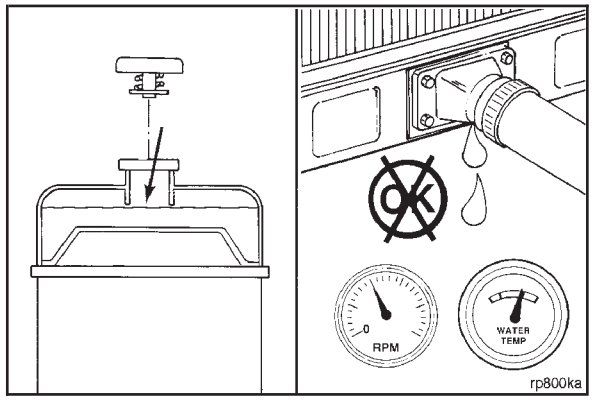
⚠ WARNING ⚠

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 ⚠

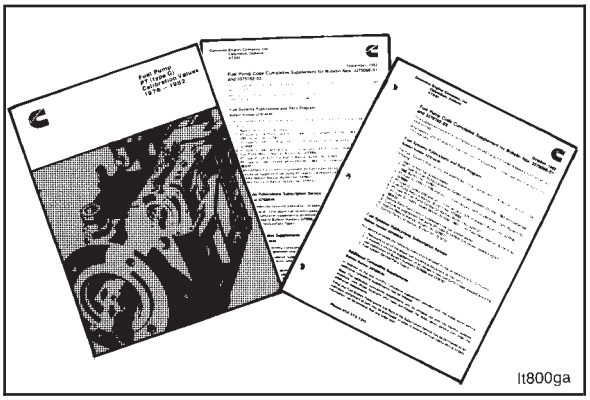
Do not add cold coolant to a hot engine. This can cause engine casting damage. Allow the engine to cool to below 50°C [120°F] before adding coolant.

Check the engine coolant level to make 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.).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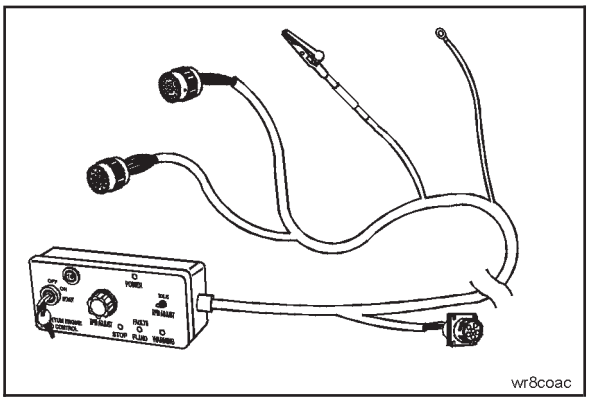
Engine operating specifications can be found in publications available from your local Cummins Authorized Repair Location.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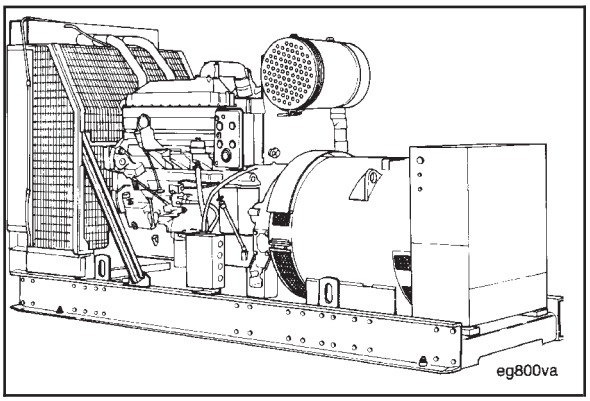
Run-In Instructions

Engines that are run on an engine dynamometer require that the engine harness be installed, and connected to the engine. Additionally, a special engine dynamometer version of the OEM wiring harness and throttle control must be installed.

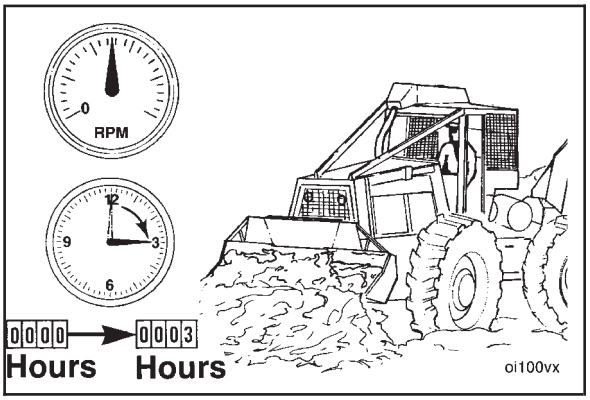
A special wiring harness and throttle control has been developed to enable engine operation out of the chassis.

Engine Dynamometer Kit, Part No. 3162245.


eg800va

Generator Set

Operate the engine in steps, varying the load from 25 to 100 percent, until blowby remains constant.



oi100vx

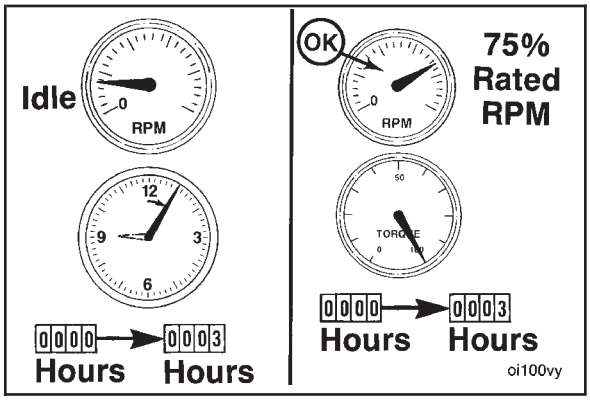
Off-Highway

Operate the equipment in the normal duty cycle at part load during the first 3 hours after rebuild.

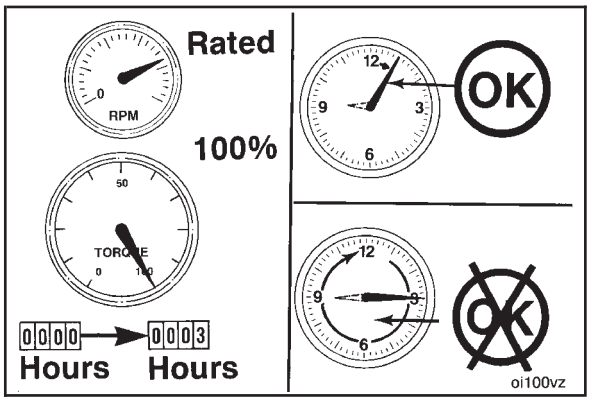
Do **not** idle the engine for more than 5 minutes at any one time.

Do **not** operate the engine at rated rpm. Operate at 75 percent of rated RPM or lower.

Rated RPM	Max RPM for First 3 Hours
2100	1575
2000	1500
1900	1425
1800	1350



Do **not** operate the engine at full load for more than 5 minutes at any one time.



Engine Testing (Engine Dynamometer) (014-005)

Install

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.

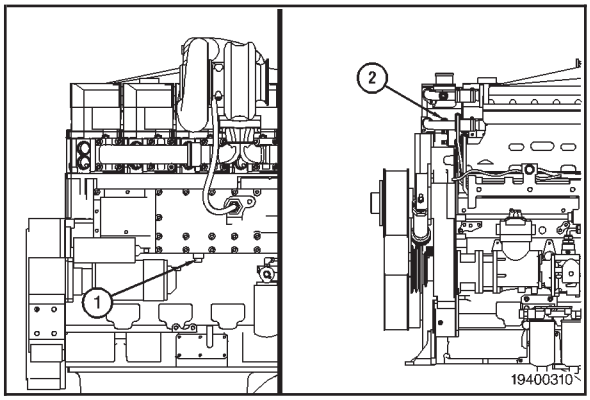
Use engine lifting fixture, Part No. 3822512, to install the engine to the test stand. Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

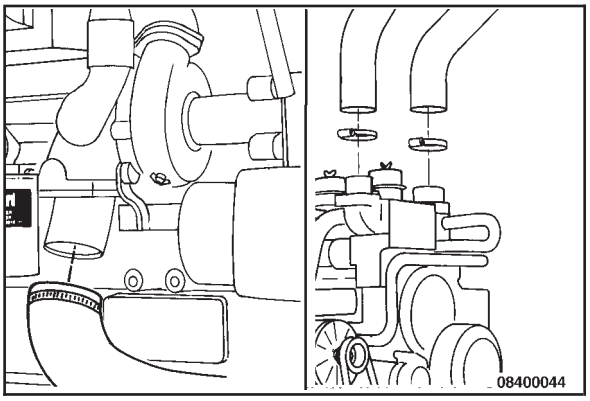
Refer to Service Bulletin No. 3666005, Dynamometer and Road Engine Testing, for detailed instructions on auxiliary aftercooling system attachment.

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).





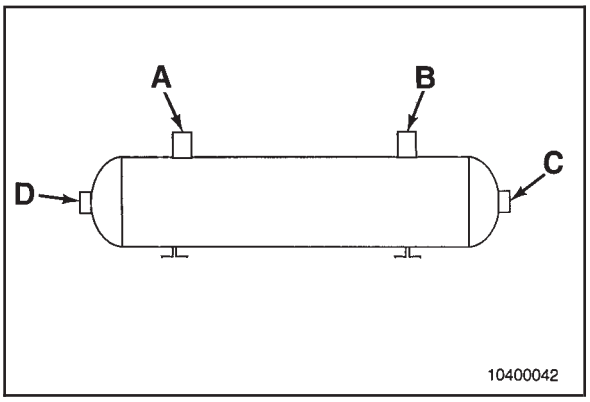
Coolant Plumbing

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.

NOTE: LTA engines require connecting the LTA water lines to a remote heat exchanger.



Intake Air Temperature Control

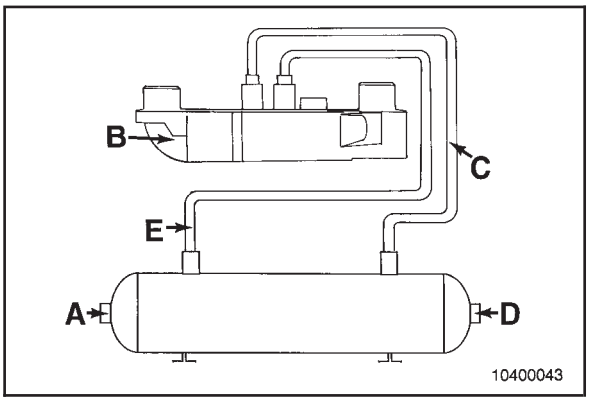
The use of a remote heat exchanger is mandatory whenever a Cummins LTA engine is attached to an engine dynamometer for the purpose of engine run-in, performance testing and engine diagnostics. Do **not** attempt to run a Cummins LTA engine without any means of controlling the intake manifold air temperature.

A = Aftercooler water OUT

B = Aftercooler water IN

C = Water OUT to drain

D = Cool water IN



LTA (Low Temperature Aftercooling)

All QSK19 ratings of 601 HP and above require Low Temperature Aftercooling (LTA) and, therefore, have unique radiator requirements. The ratings of 600 HP and below do **not** require LTA. The LTA is a one-pump, two-loop cooling system.

NOTE: The heat exchanger **must** be sized to maintain 70°C [160°F] maximum intake air temperature at full power.

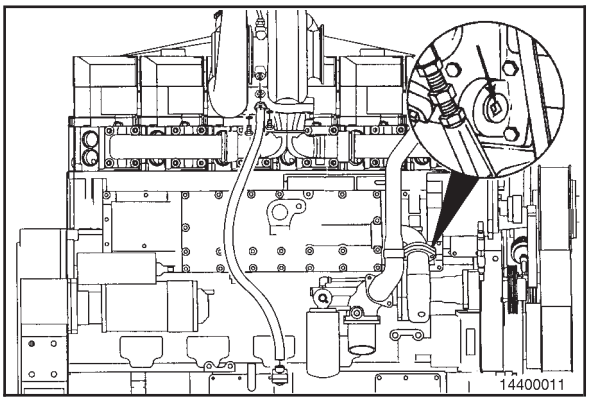
A = Water IN

B = Thermostat housing

C = LTA OUT

D = Water OUT

E = LTA return



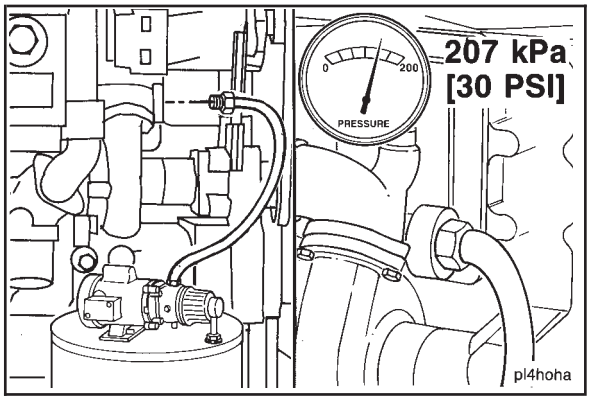
General Engine Test Procedures

NOTE: The lubricating oil system **must** be primed before operating the engine after rebuild to avoid internal component damage. Do **not** prime the system from the bypass filter as the filter will be damaged.

Remove the large plug from the oil cooler housing.

Use a pump capable of supplying 205 kPa [30 psi] continuous pressure. Connect the pump to the front of the engine oil cooler as shown.

Use a supply of clean oil. Turn the pump to the ON position. Check the engine oil pressure gauge. When the gauge indicates oil pressure, begin monitoring the oil level in the oil pan.



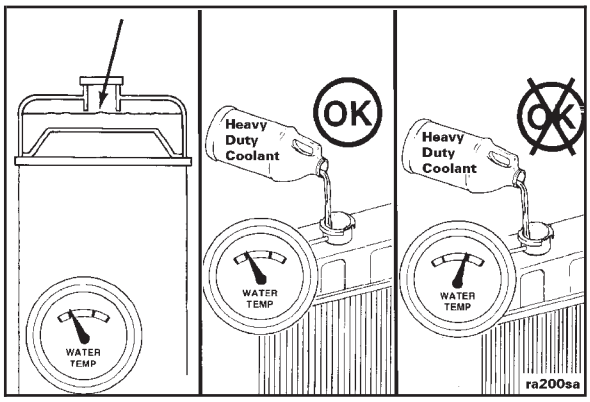
⚠ WARNING ⚠

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.

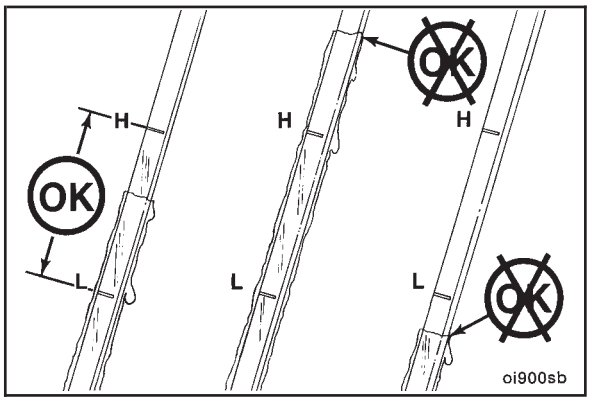
⚠ CAUTION ⚠

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 coolant level to be sure it is filled to the proper level.

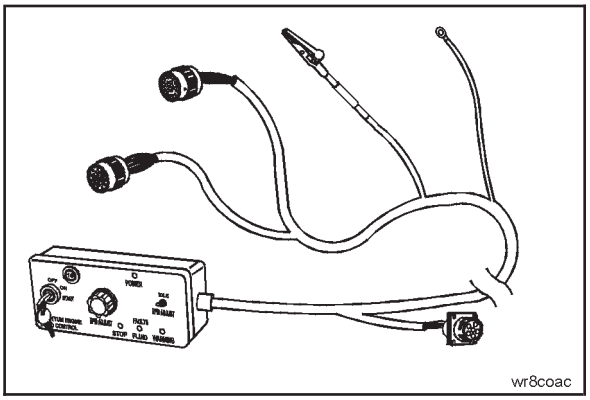


Check the engine lubricating oil level to be sure it is filled to the proper level.



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.).

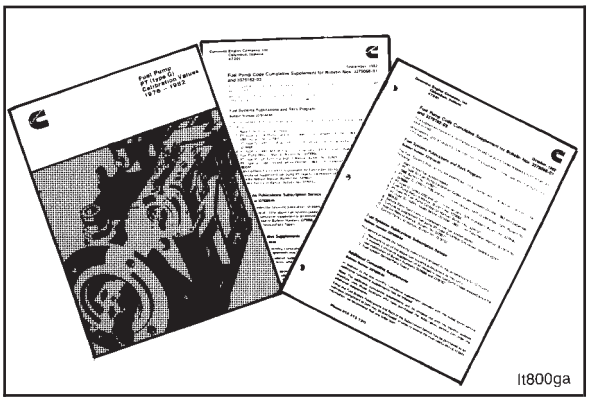


Engine Throttle Control

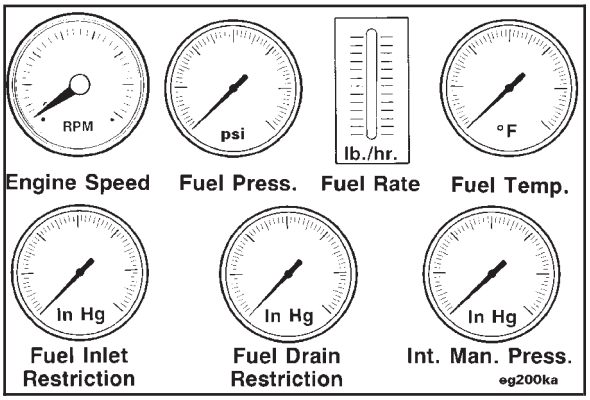
Engines that are run on an engine dynamometer require that the engine harness be installed and connected to the engine. Additionally, a special engine dynamometer version of the OEM wiring harness and throttle control **must** be installed.

A special wiring harness and throttle control has been developed to enable engine operation out of the chassis.

Engine Dynamometer Kit Part No. 3162245.



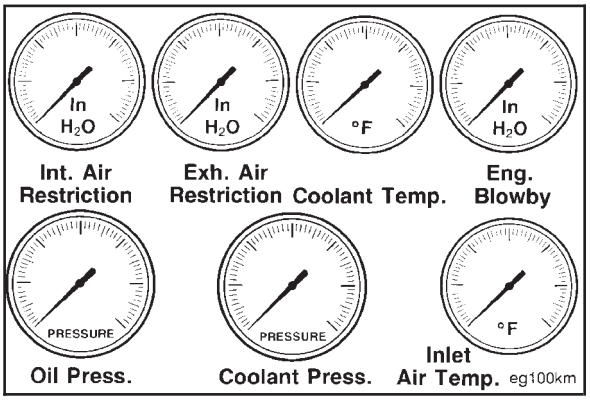
Engine operating specifications are available from your local Cummins Authorized Repair Location.



Test

To properly monitor engine performance, record the following parameters. To limit dynamometer operating time, instrument the engine to make as many checks as possible.

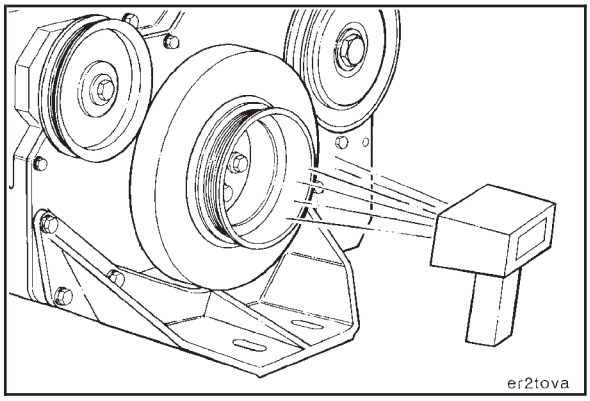
- Engine speed rpm with a verified tachometer
- Fuel pressure
- Fuel rate (Use Service Tool, Part No. 3376375)
- Fuel temperature (if needed to correct fuel rate)
- Fuel inlet restriction
- Fuel drain line restriction
- Intake manifold pressure



- Intake air restriction
- Exhaust air restriction
- Coolant temperature
- Engine blowby
- Lubricating oil pressure
- Coolant pressure
- Inlet manifold air temperature
- Turbocharger inlet air temperature

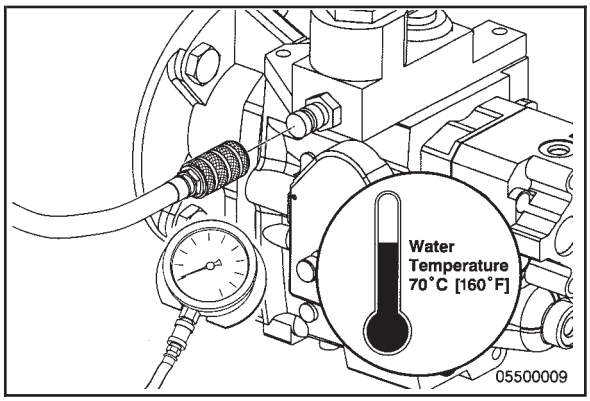
Engine Speed (RPM) With a Verified Tachometer

Use digital optical tachometer, Part No. 3377462, to check and verify engine speed.



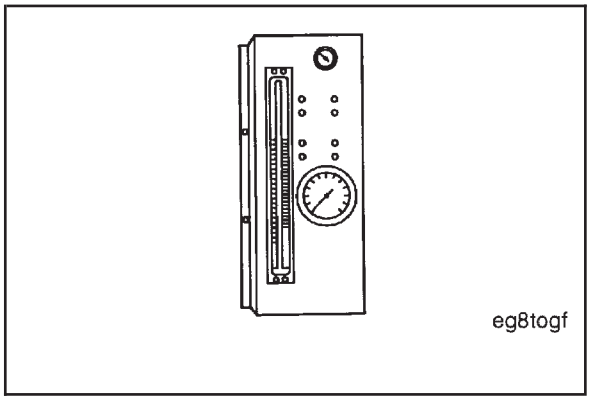
Fuel Supply Pressure

Refer to Procedure 005-016.



Fuel Rate

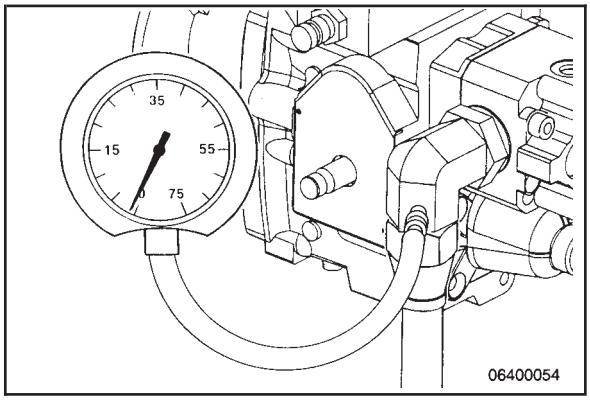
Use fuel measuring device, Part No. 3376375, to measure the rate of fuel consumption. Refer to General Information in the front of this section.

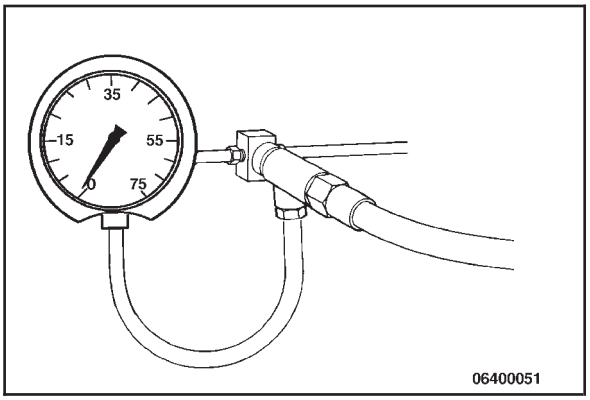


Fuel Inlet Restriction

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.

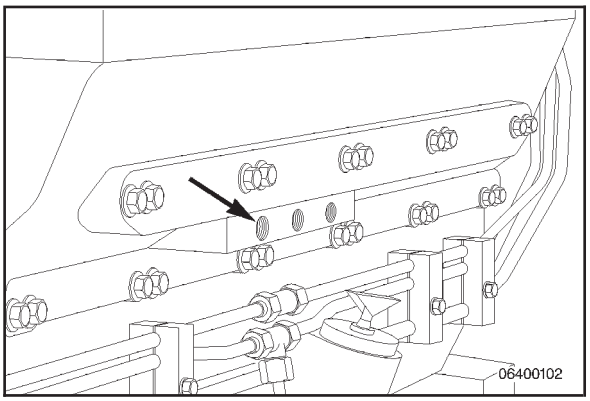




Fuel Drain Line Restriction

Use Pressure Gauge, Part No. ST-1273, to measure fuel drain line restriction.

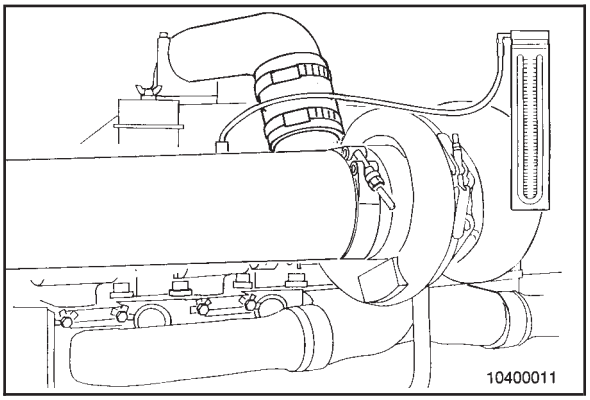
NOTE: Do **not** measure fuel drain line restriction with the fuel measuring device installed. This will **not** measure the drain line restriction of the vehicle's return plumbing.



Intake Manifold Pressure

Measure the intake manifold pressure (turbocharger boost). Install pressure gauge, Part No. ST-1273, in the intake manifold as shown.

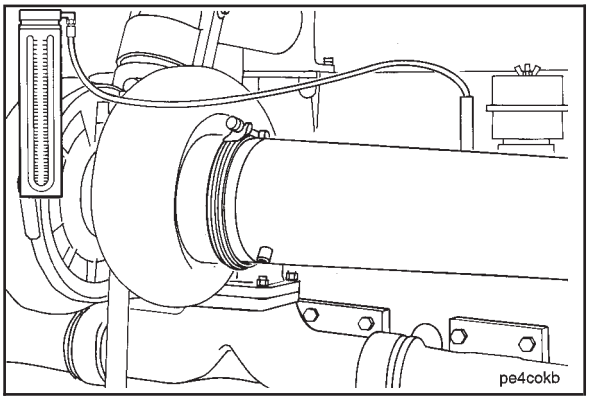
Observe the reading on the pressure gauge.



Intake Air 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.



Exhaust Restriction

Measure the exhaust air restriction. Install the pressure gauge, Part No. ST-1273, or a manometer in the exhaust air piping.

The gauge adapter **must** be installed near the turbocharger in a straight section of pipe at the turbine outlet.

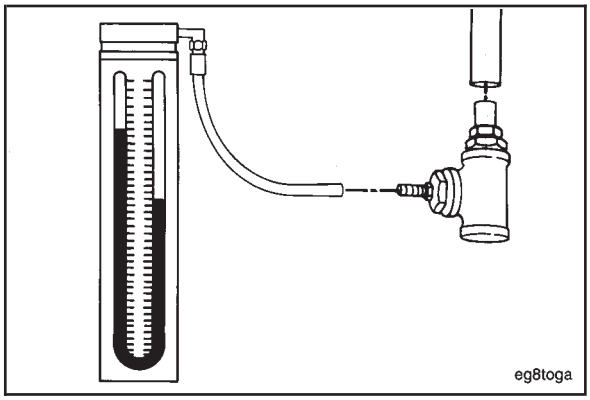
Engine Blowby

NOTE: Excessive blowby indicates an air compressor, a turbocharger, or an engine malfunction, allowing combustion gases or air to enter the crankcase and build a pressure higher than normal.

This procedure describes how to measure crankcase pressure and how to determine the component that is malfunctioning.

Use one of the three blowby service tools and a water manometer, Part No. ST-1111-3. Maximum gauge capacity is 1270 mm-H_20 [50 in-H_20].
The engine blowby tools are similar in design. The difference between the tools is in the size of the orifice.

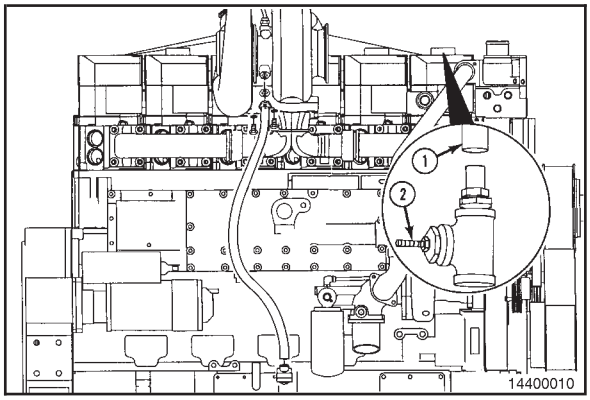
Blowby Tool Part No.	Orifice Size [inch]
3822566	[0.302]
3823567	[0.354]
3822568	[0.406]



Use a length of hose (1) to attach the blowby tool to one of the crankcase breathers.

Plug all of the other breathers.

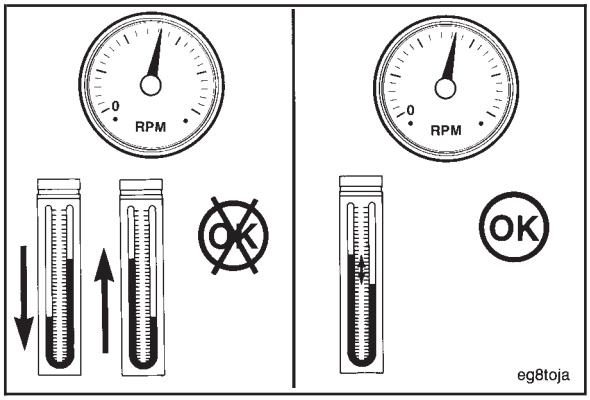
Attach a manometer to the location shown (2).



Operate the engine at rated rpm and full load (wide open throttle) until a steady reading is obtained.

Compare the blowby readings to previous readings on the engine. If previous readings for the engine are **not** available, compare the blowby reading to new engine specifications.

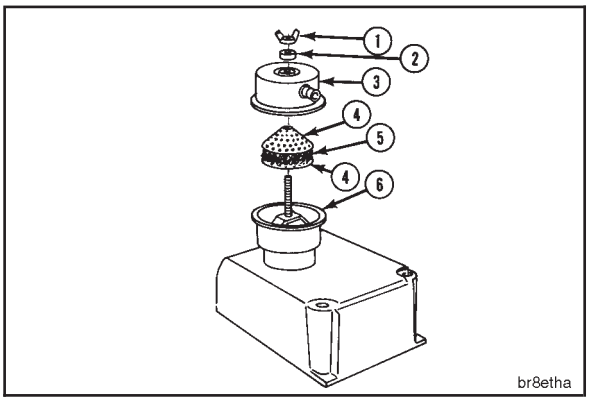
NOTE: A sudden increase in blowby indicates a problem. A gradual increase over a period of time is normal (due to wear of internal engine components).



QSK19 Blowby Limits (using 0.302 inch diameter orifice at rated load and speed)		
Engine HP (RPM Rating)	**New/Rebuilt**	**Used Engine Limit**
699 HP and Below (1500 - 1900)	305 mm H_2O [12 in H_2O]	762 mm H_2O [30 in H_2O]
699 HP and Below (2000 and above)	355 mm H_2O [14 in H_2O]	889 mm H_2O [35 in H_2O]
700 HP and Above	508 mm H_2O [20 in H_2O]	1270 mm H_2O [50 in H_2O]

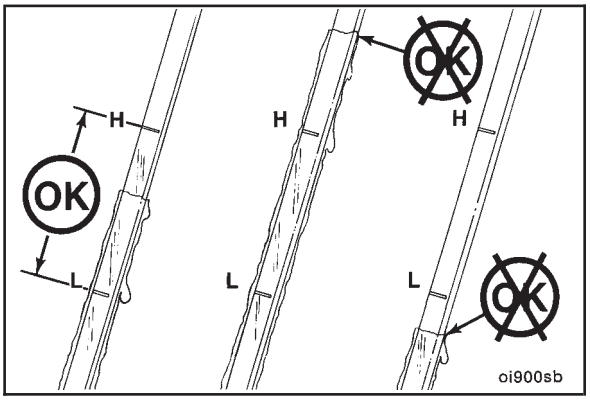
QSK19 Blowby Limits (using 0.354 inch diameter orifice at rated load and speed)		
Engine HP (RPM Rating)	**New/Rebuilt**	**Used Engine Limit**
699 HP and Below (1500 - 1900)	178 mm H_2O [7 in H_2O]	457 mm H_2O [18 in H_2O]
699 HP and Below (2000 and above)	203 mm H_2O [8 in H_2O]	508 mm H_2O [20 in H_2O]
700 HP and Above	229 mm H_2O [9 in H_2O]	584 mm H_2O [23 in H_2O]

QSK19 Blowby Limits (using 0.406 inch diameter orifice at rated load and speed)		
Engine HP (RPM Rating)	**New/Rebuilt**	**Used Engine Limit**
All Ratings	127 mm H_2O [5 in H_2O]	330 mm H_2O [13 in H_2O]



If the blowby is higher than normal, check the crankcase breathers and breather tubes to see if they are plugged.

1. Wing Nut
2. Washer
3. Breather
4. Screen Mesh
5. Breather Element
6. Breather Base



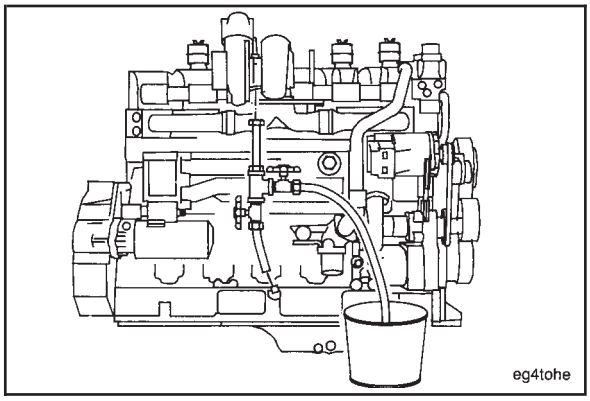
Check the engine oil level. If the level is too high it can cause a higher than normal crankcase pressure.

Isolate the turbocharger to determine if the high crankcase pressure is due to seal leakage in the turbocharger.

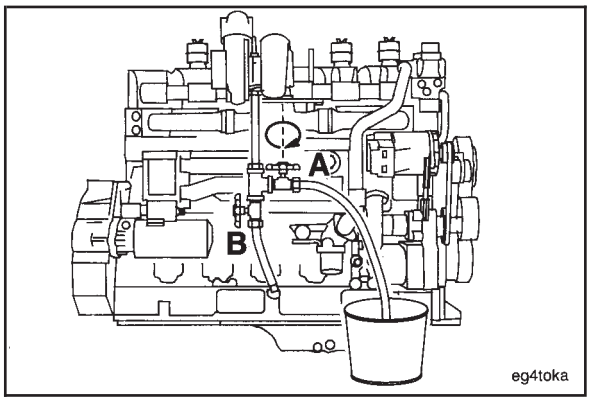
Disconnect the turbocharger drain line from the oil pan adaptor.

Install a hose assembly with the two shutoff valves arranged as shown. Place the other hose in an 8 to 19 liter [2 to 5 gallon] bucket.

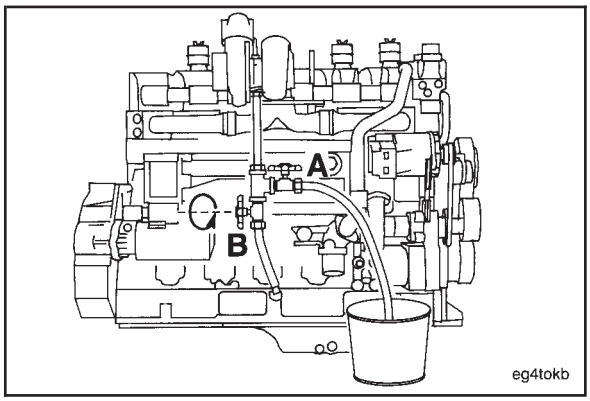
NOTE: The valves **must** have a minimum inside diameter of 19 mm [0.75 inch].



Close the valve (A) that allows the oil to drain to the bucket.



Open the valve (B) that allows the oil to drain into the engine.

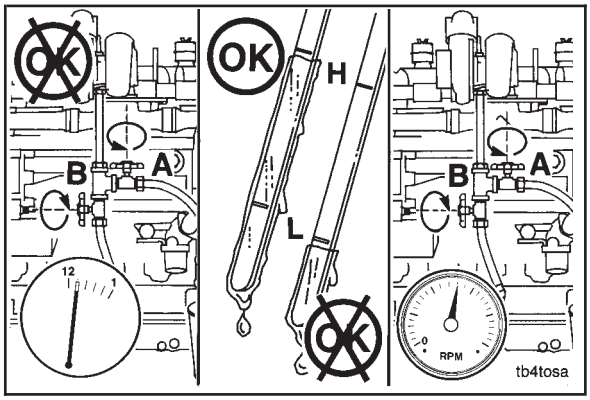


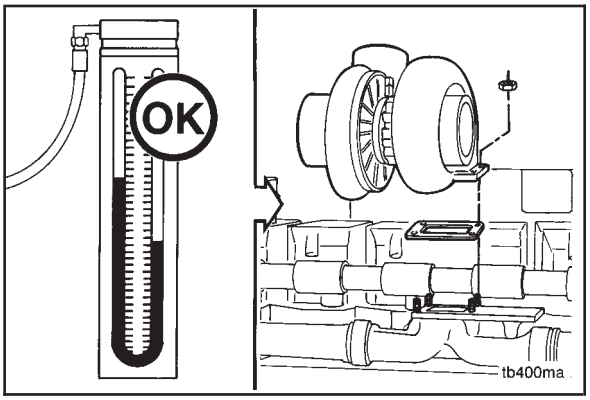
Operate the engine at rated speed.

⚠ CAUTION ⚠

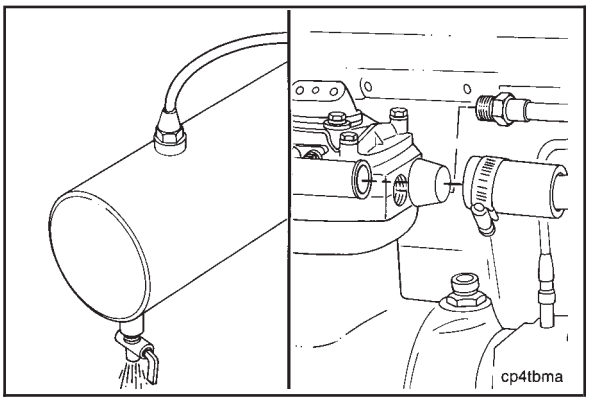
Do not operate the engine with valve A open and valve B closed for more than 1 minute. Operation for more than 1 minute can result in severe engine damage.

Continue operating at rated speed and load. Open valve A and close valve B. Record the blowby reading.





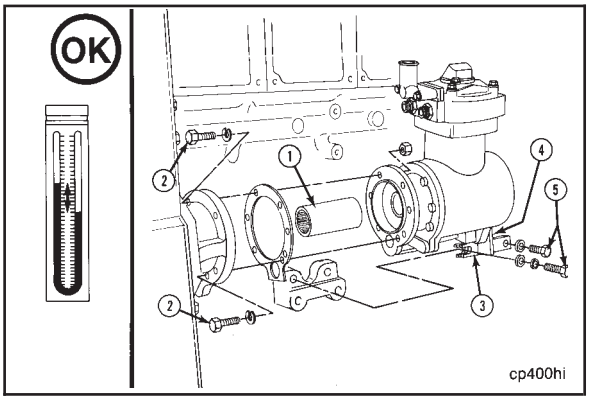
Compare the value to the original reading. If the blowby is now acceptable, replace the turbocharger.



Isolate the air compressor to determine if it is malfunctioning and causing the high blowby pressure.

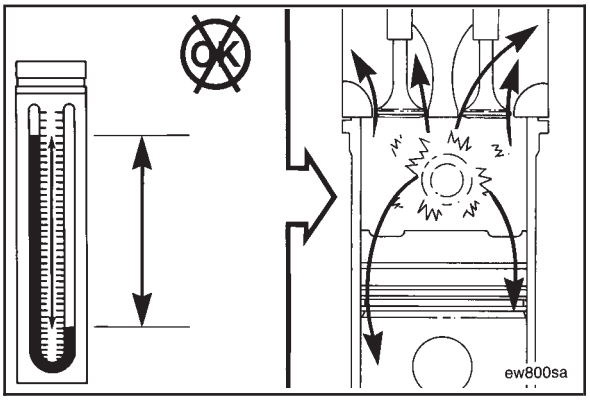
Relieve the air pressure on the first air tank in the system after the air compressor (wet tank).

Disconnect the air inlet and outlet connections. Plug the intake manifold or air piping where the inlet connection was removed.



Operate the engine at rated speed and full load (wide open throttle) until a steady blowby reading is obtained.

Compare the blowby readings to the previous value. If the blowby is now acceptable, replace the air compressor.



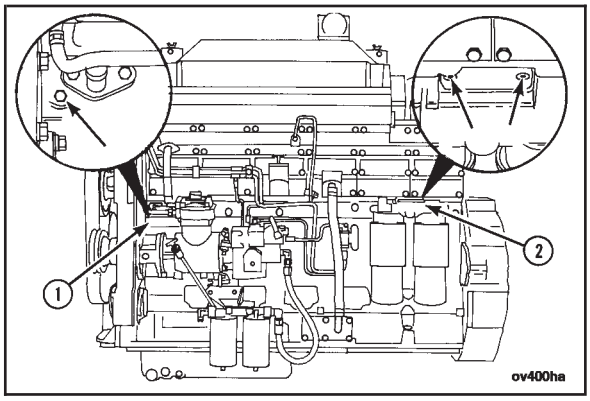
A sudden increase in blowby or a high reading that is **not** steady indicates that there is internal damage in the engine.

Lubricating Oil Pressure

Use Pressure Gauge, Part No. 3375275, to measure lubricating oil pressure.

Install the pressure gauge to the main oil rifle (1) or air filter head (2).

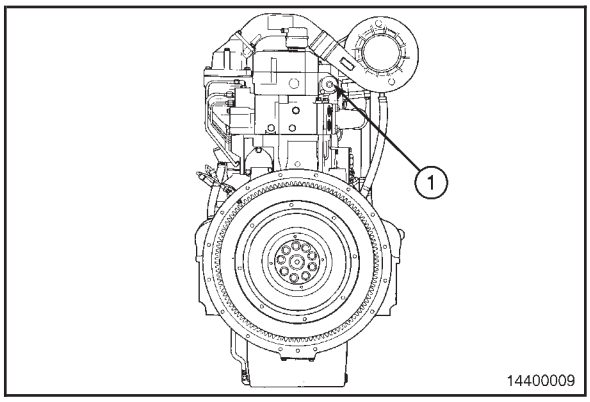
Lubricating Oil Pressure		
kPa		psi
138	MIN	20
207	NOMINAL	30



Coolant Pressure

Measure the coolant pressure at the water manifold (1).

Coolant Pressure		
kPa		psi
241	NOMINAL	35

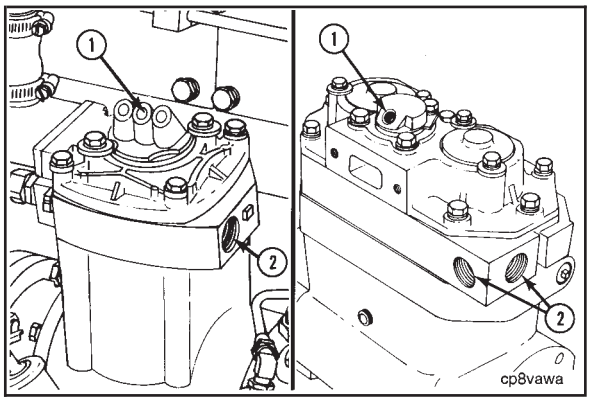


Air Compressor

NOTE: All air compressors manufactured by Cummins Engine Company, Inc. **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).

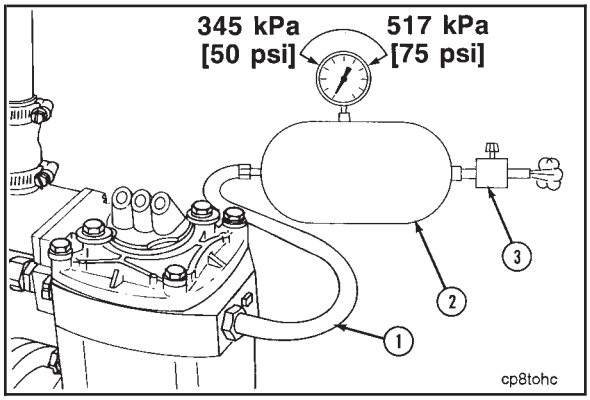


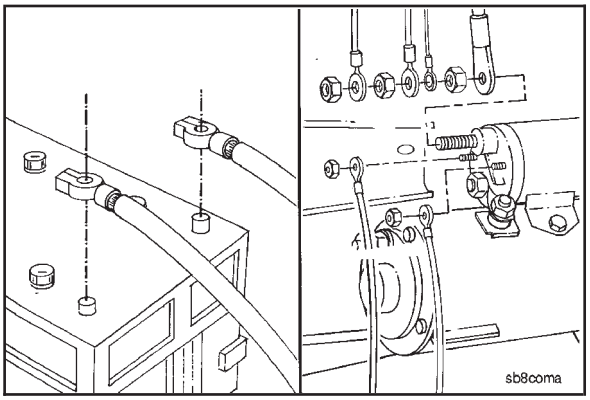
Use an air tank (2). Install an air regulator (3) capable of maintaining 345 to 517 kPa [50 to 75 psi] air pressure at both **minimum** and **maximum** engine rpm.

Install a steel tube or high temperature hose (1).

260°C [500°F].

Connect the tube or hose (1) to the air compressor outlet.



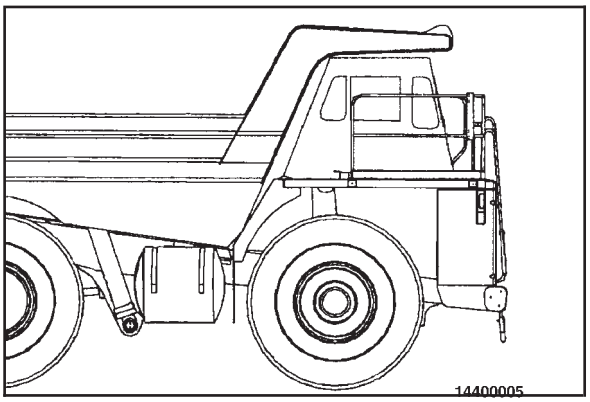


Starting Motor

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 Run-in (Engine Dynamometer) (014-006)

General Information

This section outlines engine testing and engine run-in recommendations for QSK19 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 pistons.

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, make sure the lubricating oil system is filled and primed.

In-Service Run-In

The following in-service run-in guidelines are recommended for QSK19 engines after a repair involving replacement of one or more of the piston ring sets, cylinder liners or pistons where engine or an engine dynamometer and/or chassis dynamometer run-in **cannot** be performed.

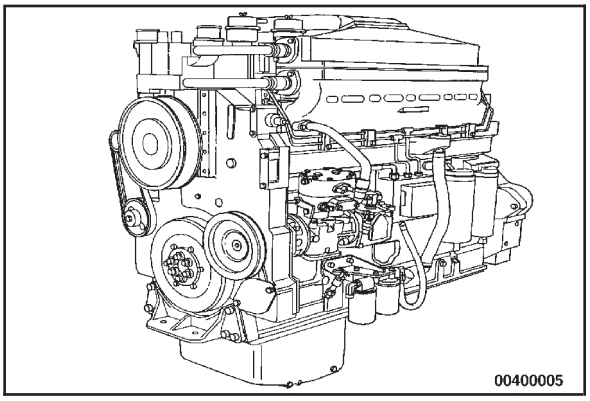
The majority of heavy duty diesel applications will provide sufficient run-in under normal **loaded** operations. However, light load/high rpm operation **must** be avoided during the run-in period.

Engine Dynamometer Run-In

This is the preferred method of run-in for engines that have been rebuilt **out-of-chassis.** It is **not** practical, nor recommended that an engine be removed from the application to conduct the run-in after a rebuild or cylinder repair has been performed in-chassis. There is no requirement, nor is it recommended for an engine that has been run-in and tested on an engine dynamometer to be run-in again after it has been reinstalled in the vehicle or equipment.

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 standby generator or fire pump that **cannot** be operated because of customer restrictions, a fire truck that **cannot** be loaded with the water pump, etc.), the engine **must** be run-in on a chassis dynamometer, portable dynamometer or load bank following the recommendations outlined in the attached procedures.



Run-In Instructions

Refer to Engine Testing-Engine Dynamometer, Procedure No. 014-005, for general operating procedures and safety precautions.

Use this chart to determine the test load.

The run-in test **must** be performed with the engine operating at torque peak rpm. Operate a generator set engine at rated rpm.

Example: The test load for a 475 HP engine rated at 2000 rpm with a 15 percent torque rise is [300 ft-lb].

NOTE: This chart assumes the dynamometer constant is 5252. If the dynamometer constant is **not** 5252, use the following formula to determine the correct test load:

Correct test load = (Dynamometer constant) x (Test load) /d 5252.

Example: The dynamometer constant for testing the engine in the above example is 4000.

Correct test load = (4000 x 300) /d 5252 = [228 ft-lb].

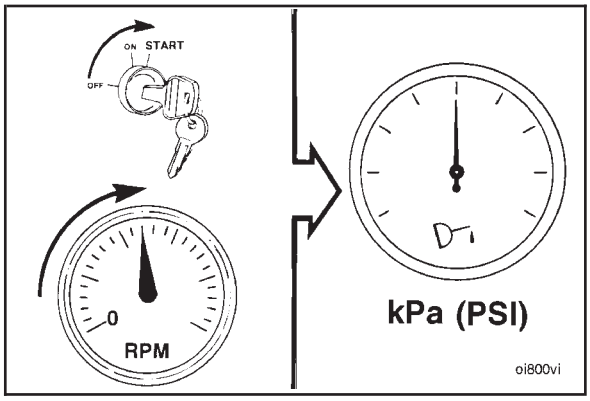
NOTE: This chart assumes vehicle run-in on a chassis dynamometer.

Rated RPM	Rated Horsepower	Torque Rise	Test Load
1200	All	All	405 N•m [300 ft-lb]
1500	All	All	405 N•m [300 ft-lb]
1800	0 to 499	All	405 N•m [300 ft-lb]
1800	500 and ABOVE	All	510 N•m [375 ft-lb]
1900	0 to 474	All	405 N•m [300 ft-lb]
1900	475 and ABOVE	All	510 N•m [375 ft-lb]
2000	0 to 499	0 to 24%	405 N•m [300 ft-lb]
2000	0 to 499	25% and ABOVE	510 N•m [375 ft-lb]
2000	500 and ABOVE	All	510 N•m [375 ft-lb]
2100	0 to 474	0 to 32%	405 N•m [300 ft-lb]
2100	0 to 474	33% Plus	405 N•m [300 ft-lb]
2100	475 to 530	0 to 15%	405 N•m [300 ft-lb]
2100	475 to 530	16% and ABOVE	510 N•m [375 ft-lb]
2100	531 to 649	All	510 N•m [375 ft-lb]
2100	650 and ABOVE	All	540 N•m [400 ft-lb]

⚠ CAUTION ⚠

Do not crank the starting motor for more than 30 seconds. Excessive heat will damage the starter.

START the engine. If the engine does **not** begin operating after 30 seconds, allow two minutes for the starting motor to cool.

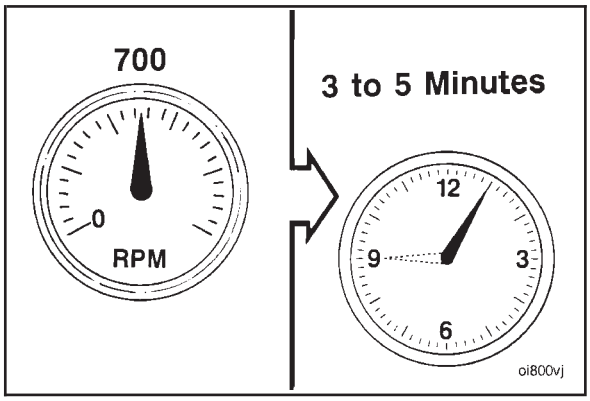


⚠ CAUTION ⚠

If the oil pressure is not within specifications, STOP the engine immediately. Both low and high oil pressure will cause engine damage.

Main Oil Rifle Pressure (At Idle)		
kPa		**psi**
138	MIN	20
483	MAX	70

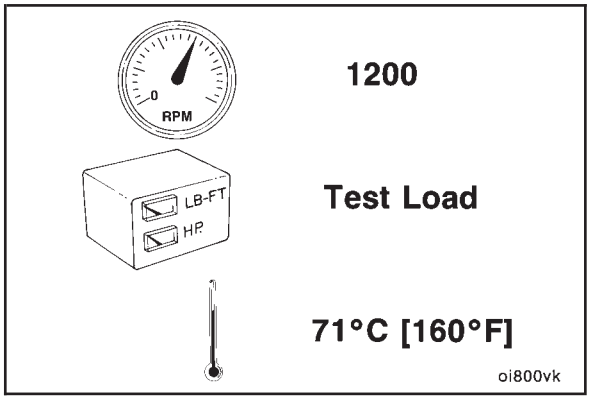
Operate the engine at the IDLE position. Check for leaks.



⚠ CAUTION ⚠

Do not operate the engine at IDLE longer than specified. Excessive carbon formation will cause engine damage.

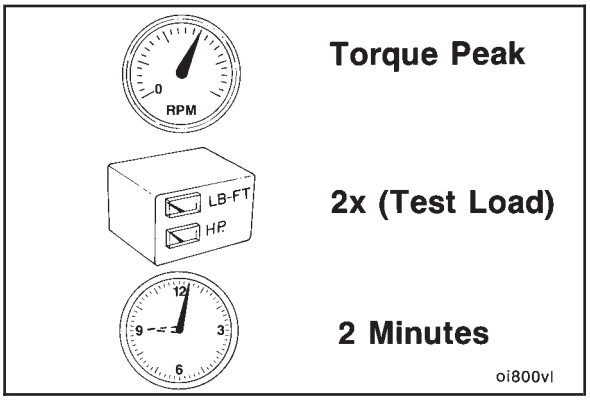
Adjust the engine rpm to 1200 rpm. Adjust the dynamometer load to the test load as previously determined. Operate the engine at this setting until the coolant temperature indicates 70°C [160°F].



Check for leaks. Fix all leaks.

Check all of the gauges and record the readings.

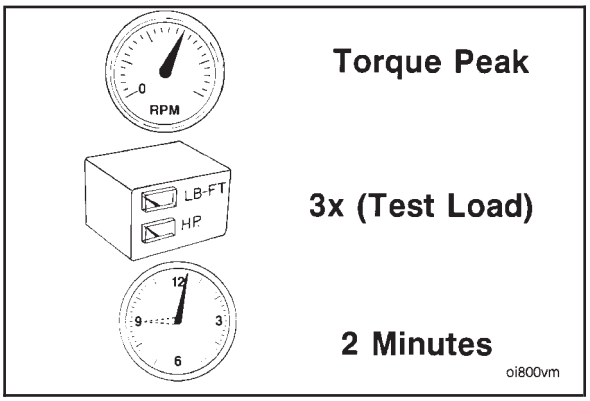
Do **not** proceed to the next step until the blowby becomes stable within specifications.



Adjust the engine rpm to the torque peak rpm. Adjust the dynamometer load to equal two times the test load. Operate the engine for two minutes.

Check all the gauges and record the readings.

Do **not** proceed to the next step until the blowby becomes stable within specifications.

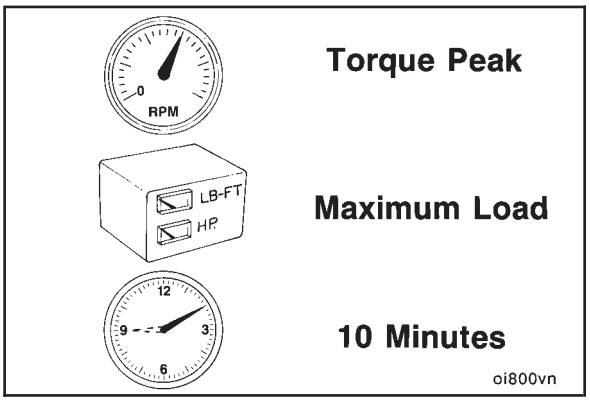


Maintain the engine rpm at torque peak rpm. Increase the dynamometer load to equal three times the test load.

Operate the engine at this load for 2 minutes.

Check all the gauges and record the readings.

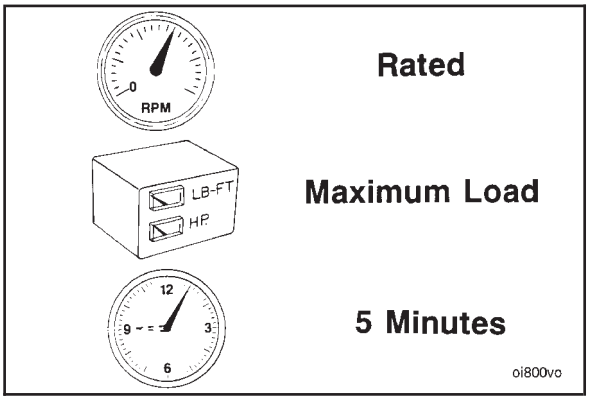
Do **not** proceed to the next step until the blowby becomes stable within specifications.



Move the throttle lever to the FULL OPEN position. Increase the load until the engine rpm is at torque peak rpm.

Operate the engine at this setting for 10 minutes or until the blowby becomes stable within specifications.

Check all the gauges and record the readings.



Decrease the dynamometer load until the engine rpm increases to the rated rpm.

Operate the engine at this load for 5 minutes.

Check all the gauges and record the readings.

Decrease the dynamometer load completely.

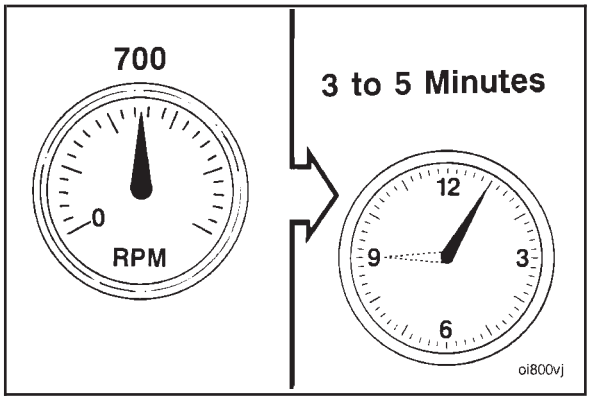
CAUTION

Do not turn the engine OFF immediately. The engine must be allowed to cool.

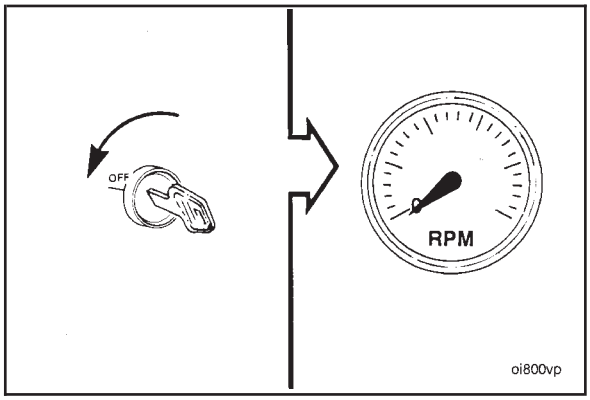
Move the throttle lever to the LOW IDLE position. Operate the engine at this setting for 3 to 5 minutes. This will allow the turbocharger and the other engine components to cool.

CAUTION

Do not operate the engine at IDLE longer than specified. Excessive carbon formation can cause engine damage.



Turn the engine OFF.

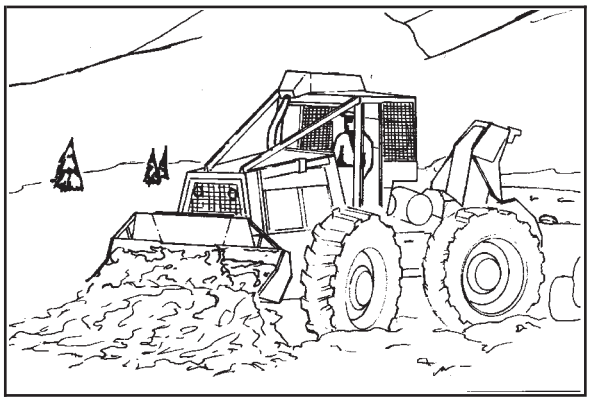


Engine Testing (In Chassis) (014-008)

Stall Speed Check

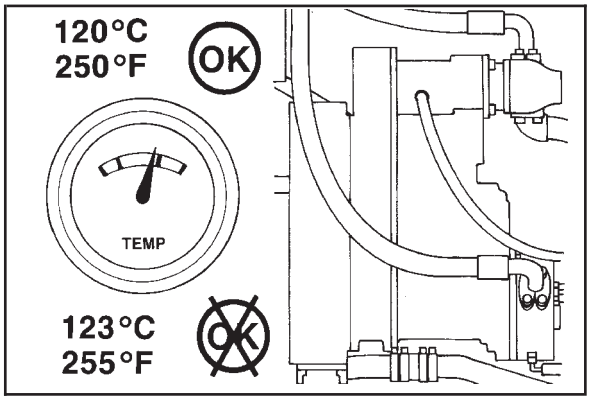
The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

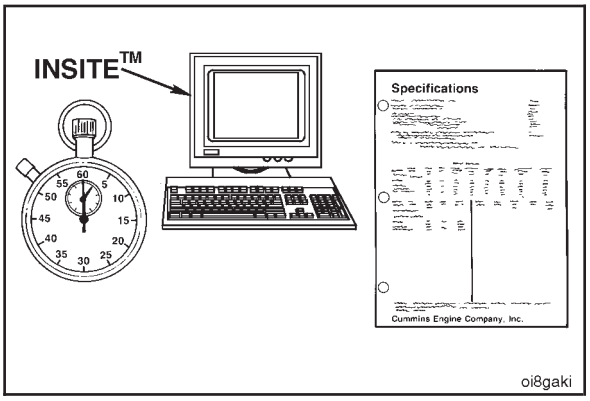
The vehicle brakes do **not** always hold an electronically controlled transmission.



CAUTION

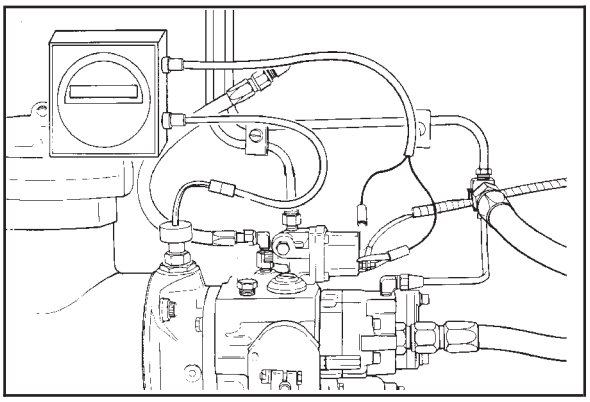
Do not exceed 120°C [250°F] converter oil temperature. If the oil temperature exceeds 120°C [250°F], put the transmission in neutral and operate the engine until the oil temperature is below 120°C [250°F]. Check the converter oil level.



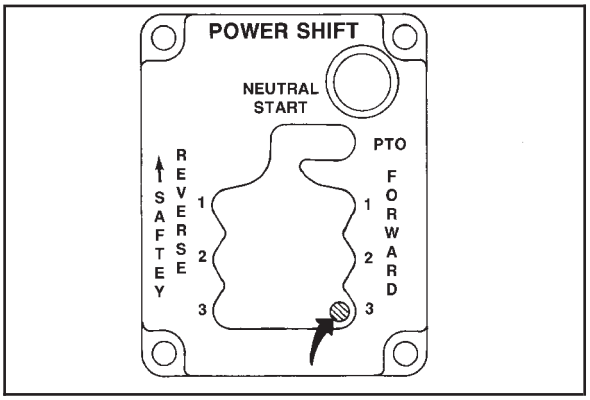


The following equipment is needed for this check:

- Stop watch
- Digital tachometer, Part No. 3375631. or a hand held optical tachometer, Part No. ST-3377462.
- Equipment manufacturer's stall speed and time to stall specifications.

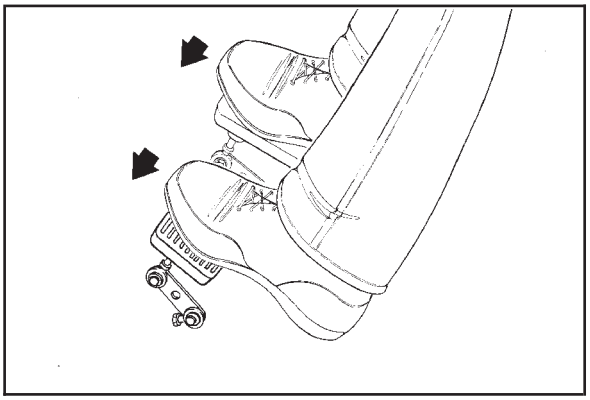


Install the tachometer on the fuel pump.



Put the gear selector in the highest gear or full forward.

In some types of equipment it is also necessary to engage the hydraulics.



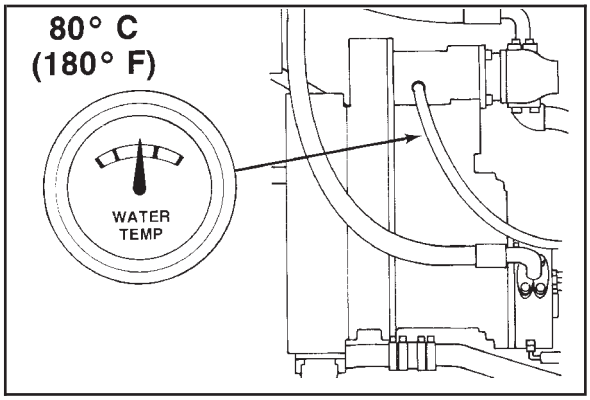
Be sure the vehicle has good brakes and air pressure in the brake system.

The brakes **must** prevent the vehicle from moving when the engine is at full throttle.

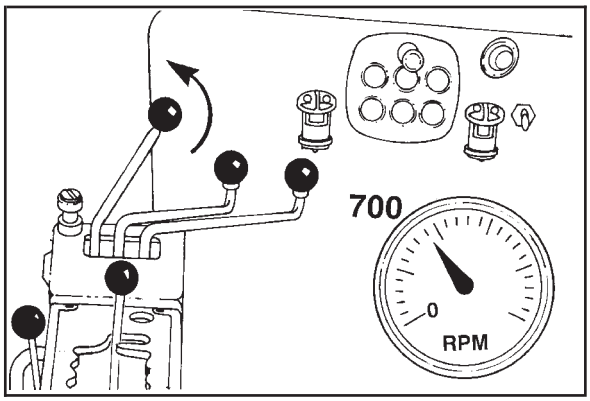
Engage the vehicle brakes or keep the vehicle from moving.

Operate the engine until the coolant temperature is up to 70°C [160°F] and the converter temperature is 80°C [180°F] or above.

Alternately, shift from neutral to the highest speed gear possible and operate at part throttle. This will warm the entire system uniformly.

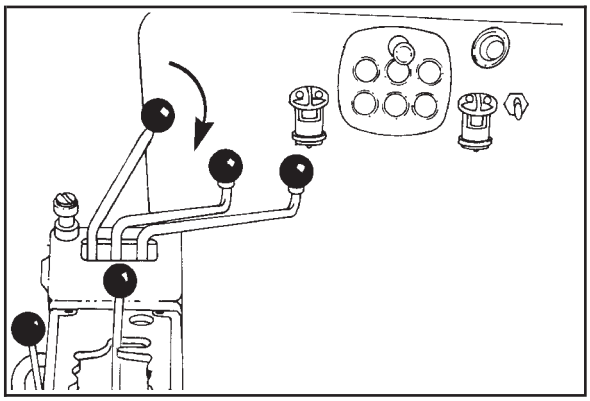


Bring the engine speed back to low idle.



NOTE: Do **not** exceed 120°C [250°F] converter oil temperature.

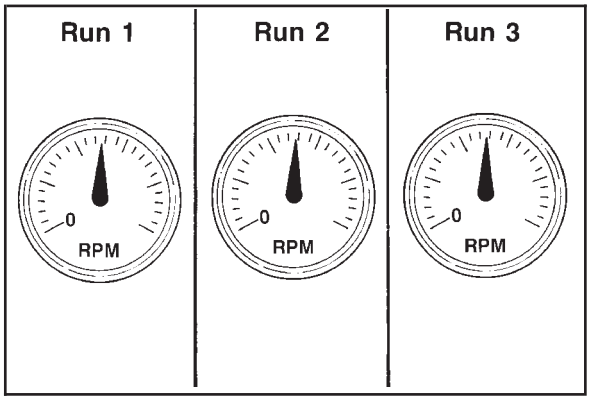
Move the throttle to the full open position. Do **not** perform this test for more than 15 seconds. If the engine speed continues to slowly increase, the torque converter fluid is being overheated.

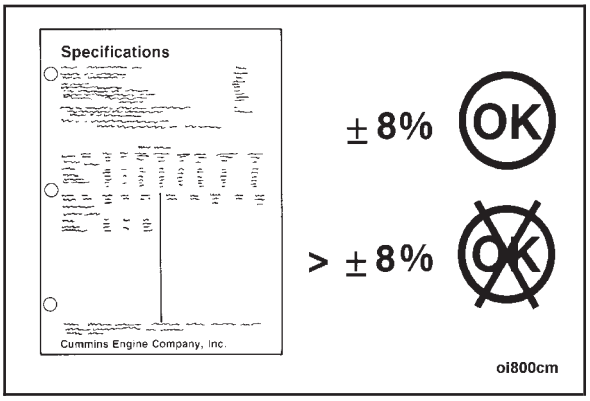


Check the engine speed (rpm) at the point of stall.

Always hold the speed until it is stable.

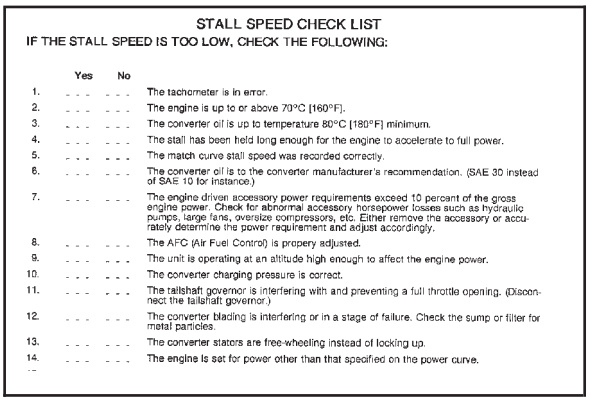
Take several readings. Be sure the reading is accurate.





Check the stall speed (rpm) against the specifications that are for the equipment, converter, or automatic transmission.

NOTE: The stall speed for the engine and converter/transmission can vary plus/minus 8 percent (±8%) from the manufacturer's specifications.



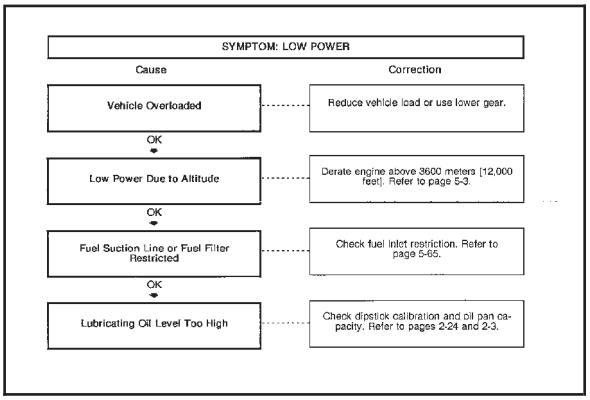
STALL SPEED CHECK LIST

IF THE STALL SPEED IS TOO LOW, CHECK THE FOLLOWING:

	Yes	No	
1.	___	___	The tachometer is in error.
2.	___	___	The engine is up to or above 70°C [160°F].
3.	___	___	The converter oil is up to temperature 80°C [180°F] minimum.
4.	___	___	The stall has been held long enough for the engine to accelerate to full power.
5.	___	___	The match curve stall speed was recorded correctly.
6.	___	___	The converter oil is to the converter manufacturer's recommendation. (SAE 30 instead of SAE 10 for instance.)
7.	___	___	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	___	___	The AFC (Air Fuel Control) is propery adjusted.
9.	___	___	The unit is operating at an altitude high enough to affect the engine power.
10.	___	___	The converter charging pressure is correct.
11.	___	___	The tailshaft governor is interfering with and preventing a full throttle opening. (Disconnect the tailshaft governor.)
12.	___	___	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
13.	___	___	The converter stators are free-wheeling instead of locking up.
14.	___	___	The engine is set for power other than that specified on the power curve.

If the stall speed is **not** within the specifications, refer to the Stall Speed Check List at the end of this section.

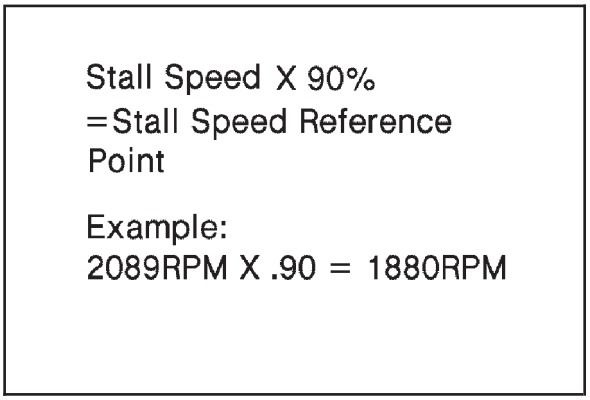
Check the equipment manufacturer's troubleshooting procedures for other reasons for stall speed problems.



SYMPTOM: LOW POWER

Cause	Correction
Vehicle Overloaded	Reduce vehicle load or use lower gear.
OK	
Low Power Due to Altitude	Derate engine above 3600 meters [12,000 feet]. Refer to page 5-3.
OK	
Fuel Suction Line or Fuel Filter Restricted	Check fuel inlet restriction. Refer to page 5-65.
OK	
Lubricating Oil Level Too High	Check dipstick calibration and oil pan capacity. Refer to pages 2-24 and 2-3.

If the cause for the stall speed being too low is low engine power output, refer to the Engine Power Output Low Troubleshooting Chart. Make the correct repair based on the fuel rate, fuel pressure, and intake manifold pressure readings.

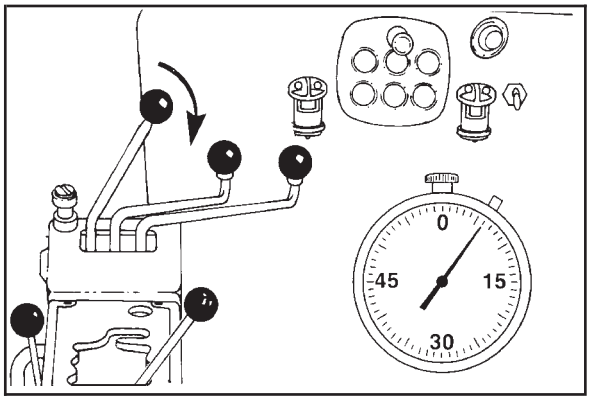


Time Speed Check

After performing the Stall Speed Check through the torque converter fluid being overheated, calculate the engine stall speed.

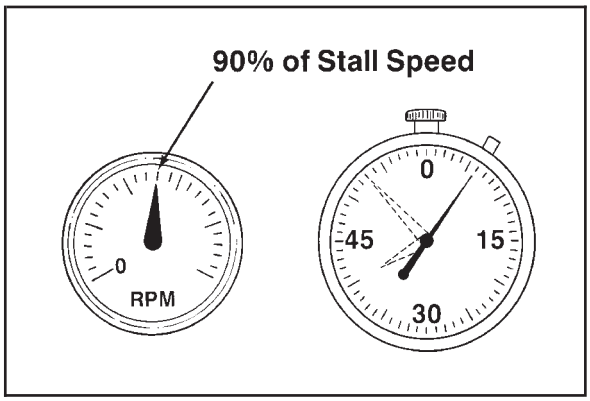
Example: Stall speed 2089 (2089 x .90 = 1880 rpm).

Quickly move the throttle to the full open position and start the stop watch at the same time.



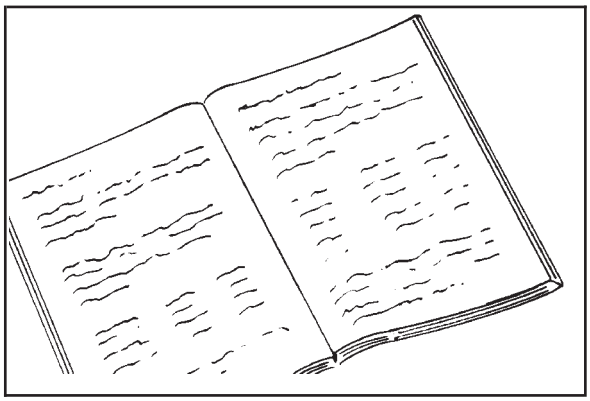
When the engine speed is 90 percent (90%) of the stall speed rpm, stop the stop watch.

NOTE: The type of unit and the stall speed rpm will be different for different types of equipment. Most types have a stall speed between 8 and 12 seconds.



Check the equipment manufacturer's specifications for the time to stall or the acceleration time.

If the time is excessive, refer to Troubleshooting Symptoms Charts, Engine Acceleration/Response Poor.



Stall Speed Check List

If The Stall Speed Is Too Low, Check The Following:

1.	_____	_____	The tachometer is in error.
2.	_____	_____	The engine is up to or above 70°C [160°F].
3.	_____	_____	The converter oil is up to temperature 80°C [180°F].
4.	_____	_____	The stall has been held long enough for the engine to accelerate to full power.
5.	_____	_____	The match curve stall speed was recorded correctly.
6.	_____	_____	The converter oil is to the converter manufacturer's recommendation. Society of Automotive Engineers (Example: SAE 30 instead of SAE 10).
7.	_____	_____	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize, compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	_____	_____	The unit is operating at an altitude high enough to affect the engine power.
9.	_____	_____	The converter charging pressure is correct.
10.	_____	_____	The tailshaft governor is interfering with and preventing a full throttle opening. (Disconnect the tailshaft governor.)
11.	_____	_____	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
12.	_____	_____	The converter stators are free-wheeling instead of locking.
13.	_____	_____	The engine is set for power other than that specified on the power curve.
14.	_____	_____	The converter is wrong, due to improper build or rebuild of unit.
15.	_____	_____	The converter is performing to the published absorption curve.
16.	_____	_____	The engine and converter match is correct. Check the engine and converter models for the proper match.
17.	_____	_____	The engine is matched to an oversized converter. (If this condition is believed to exist, please report the engine-converter-accessory information to the factory.)
18.	_____	_____	The engine power is down. (The engine torque rise could be less than shown on the standard engine curve.) See the fuel setting adjustments and the turbocharger air manifold pressure check.

It is sometimes easier to change the engine fuel rate than to determine the true cause for low stall speed, but the customer ends up with an over-fueled engine that will also negatively affect durability. Do **not** increase the fuel rate as a CURE-ALL.

If The Stall Speed Is Too High, Check The Following:

	Yes	No	
1.	_____	_____	The engine is high in power.
2.	_____	_____	The tachometer is in error.
3.	_____	_____	The accessory power requirements are less than 10 percent of the gross engine power.
4.	_____	_____	The converter oil is aerating (foaming) - check for low oil level, air leaks in suction line, oil does **not** contain a foam inhibitor, or suction screen or filter. (Should be accompanied by a noticeable loss of machine performance.)
5.	_____	_____	The converter is being held at full stall. Check for a slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.
6.	_____	_____	The converter turbine element is beginning to fail and losing blades or the converter was originally built with the wrong size element.
7.	_____	_____	The engine and converter match is correct (due to a revision in the engine rating or the converter performance).
8.	_____	_____	On the transmission-converter units with oil sump in the transmission, if the oil level is too high, it can cause severe aeration due to parts dipping in the oil.
9.	_____	_____	The converter is performing to the published absorption curve.
10.	_____	_____	The converter charging pressure is correct.

The reasons for abnormal stall speeds listed above are some which have been encountered by Cummins representatives and probably do **not** include all possible causes. The correction of the problem is either covered in the vehicle service manual, the converter service manual, or is self-explanatory.

NOTES

Section 16 - Mounting Adaptations - Group 16

Section Contents

Mounting Adaptations - General Information

General Information

The Mounting Adaptations group consists of the flywheel housing, flywheel, and the front engine support.

Flywheel Housing

For various applications, the flywheel housings are available in different styles, sizes, and materials. Check the appropriate parts book and the engine parts listing for the correct part number for the engine application being serviced.

Flywheel and Ring Gear

The flywheel is available **only** as an assembly. The assembly includes the flywheel and the ring gear. The ring gear is available for service.

Flywheel Housing — Redowel To The Cylinder Block

Procedure No. 016-006 Flywheel Housing — Redowel to Cylinder Block, will describe how to install the oversize locating dowel pins in a flywheel housing and a cylinder block.

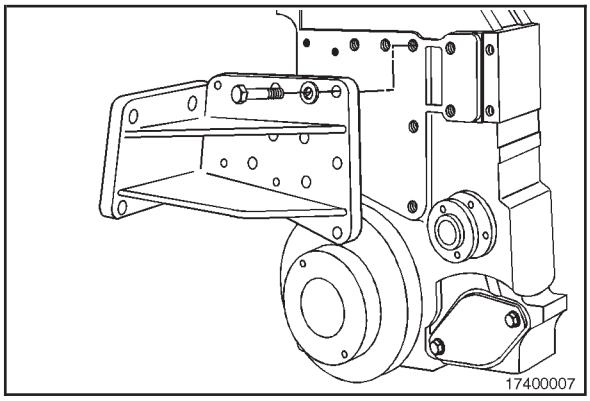
There are two dowel pins in the cylinder block. The pins protrude into holes in the flywheel housing. The pins are used to align the housing properly to the cylinder block when it is installed.

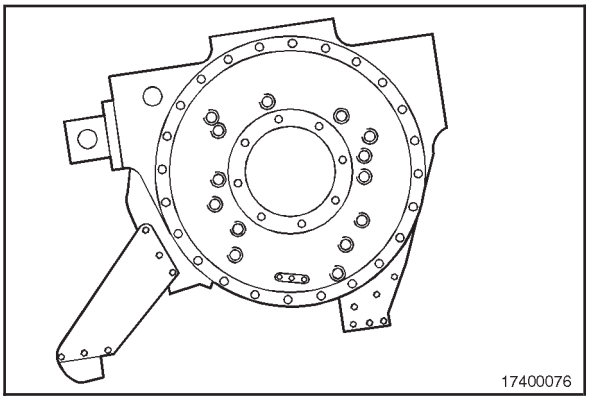
The flywheel housing **must** be in proper alignment. If the housing is **not** in proper alignment, the holes in the flywheel housing and the block **must** be reamed for a bigger dowel.

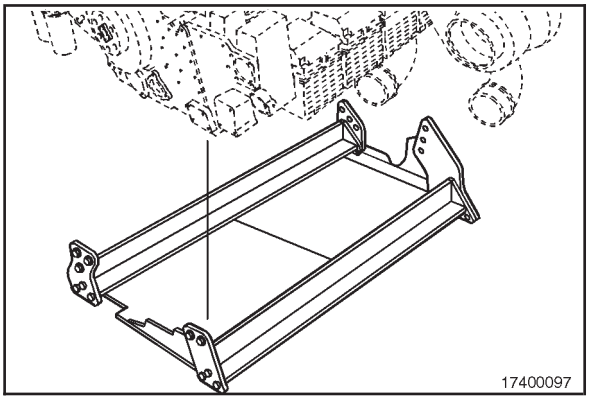
The dowel holes on QSK19 engine blocks and flywheel housings are precision doweled. The holes are machined to 12.7 mm [0.500 in] separately. The parts are assembled and the alignment is checked. If the alignment is **not** within specifications, oversize dowels are installed at the factory. Replacing the block or the flywheel housing does **not** necessarily mean that the flywheel housing and the cylinder block have to be redoweled.

Rail Applications

The rail engine front gear cover is manufactured out of cast iron and has been machined to allow the front engine mount to be installed on the cover.







Rail Applications

The flywheel housing has been modified to allow the engine to be mounted horizontally (intake side down). The intake side starter option in mandatory to keep a low profile design for the railcar applications.

⚠ CAUTION ⚠

The flywheel housing, and the flywheel have metric threads in the capscrew holes where the OEM hardware will mount. The external mounting pads on the flywheel housing have metric threads. Using the wrong capscrews will damage the threads.

NOTE: A 75 degree mounting angle is available by using the front mounting support and flywheel housing. If a 78 degree angle is desired, the OEM will be responsible for modifying their engine supports to achieve a 78 degree tilt.

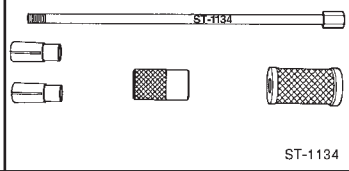
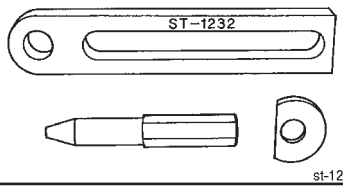
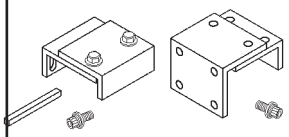
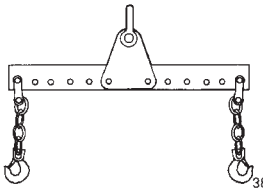
The QSK19 Rail Engine has two rock shields to protect the intake side of the engine. The rock shields are mounted to "T" shaped brackets. The brackets are mounted to the front gear cover and lubricating oil pan adapter on the front of the engine and the flywheel housing on the rear of the engine. The rock shields extend the entire length of the engine.

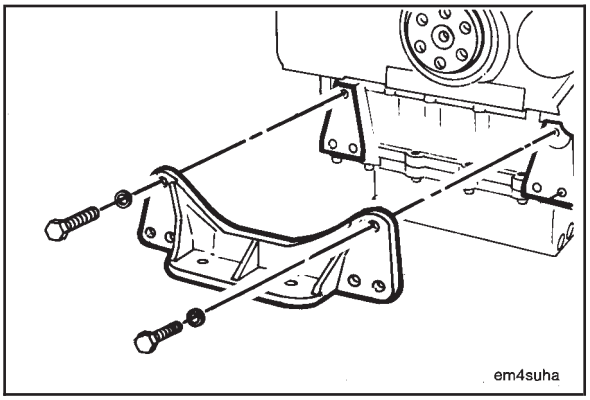
NOTE: The rock shields **must** be removed prior to working on the intake side of the engine. Make certain they are reinstalled after work is completed.

Service Tools

Mounting Adaptations

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

Tool No.	Tool Description	Tool Illustration
ST-1134	**Dowel Pin Extractor** Remove dowel pins.	 ST-1134
ST-1232	**Drill Ream Fixture** Machine dowel hole to install oversize dowels in cylinder block and flywheel housing. Use with a drill, reamer, and the appropriate drill/ream bushing set.	 st-1232
3375272	**Engine Support Bracket** Attaches to the each side of the cylinder block and supports the front of the engine.	 22800428
3822512	**Engine Lifting Fixture** Used to remove and install the engine. Designed to lift 1816 kg [4000 lb].	



Engine Support Bracket, Front (016-002)

Clean

⚠ WARNING ⚠

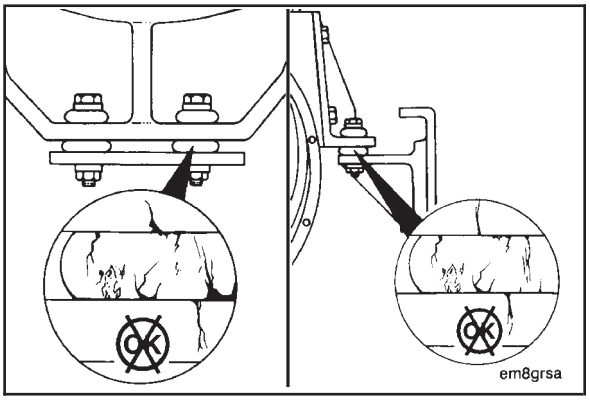
When using steam or hot, high pressure water for cleaning, wear goggles and protective clothing to avoid personal injury.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

Use solvent or steam to clean the engine support bracket.

Dry with compressed air.



Inspect for Reuse

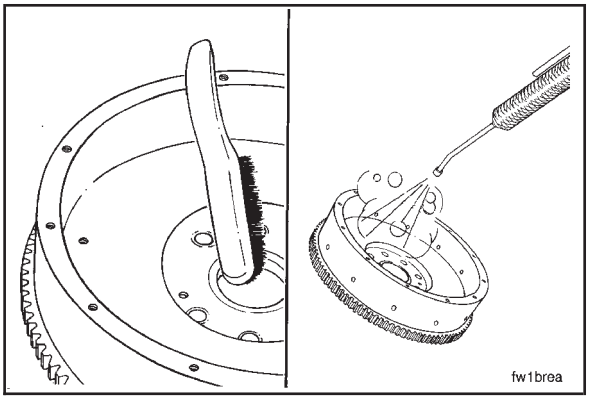
⚠ CAUTION ⚠

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

Clean and inspect the mounts for reuse. Check all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

NOTE: Damaged engine mounts and brackets can cause the engine to move out of alignment, damage the driveline components in the equipment, and result in vibration complaints.



Flywheel (016-005)

Clean

⚠ WARNING ⚠

When using steam or hot, high pressure water for cleaning, wear goggles and protective clothing to avoid personal injury.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠ WARNING ⚠

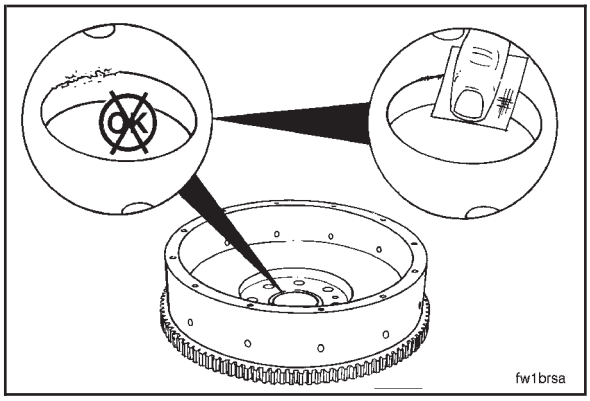
Use solvent or steam to clean the flywheel.

Use a wire brush to clean the crankshaft pilot bore.

Dry with compressed air.

Inspect for Reuse

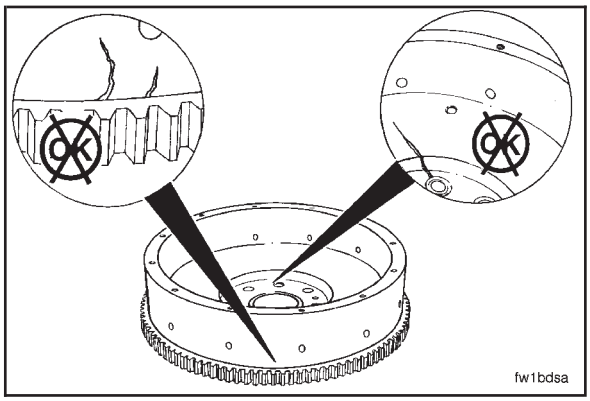
Visually inspect for nicks or burrs. Use a crocus cloth to remove small nicks and burrs.



⚠ WARNING ⚠

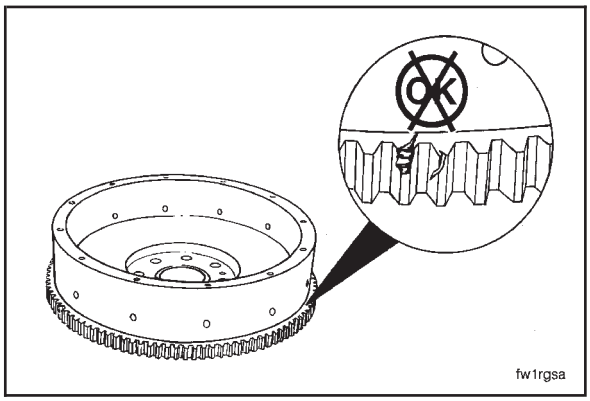
Do not use a cracked flywheel. A cracked flywheel can break or cause serious personal injury.

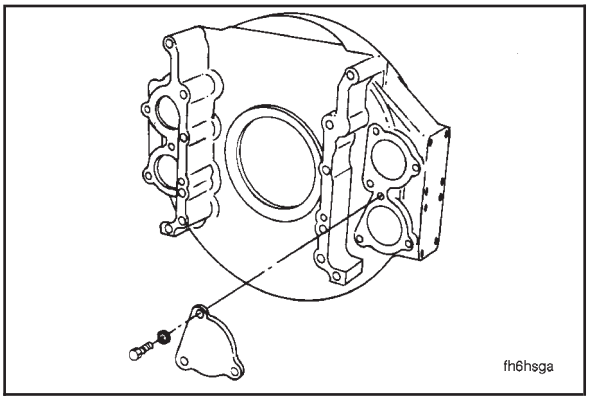
Visually inspect the flywheel for cracks.



Visually inspect the flywheel ring gear teeth for cracks and chips.

NOTE: If the ring gear teeth are cracked or broken, the ring gear **must** be replaced.





Flywheel Housing (016-006)

Clean

⚠ WARNING ⚠

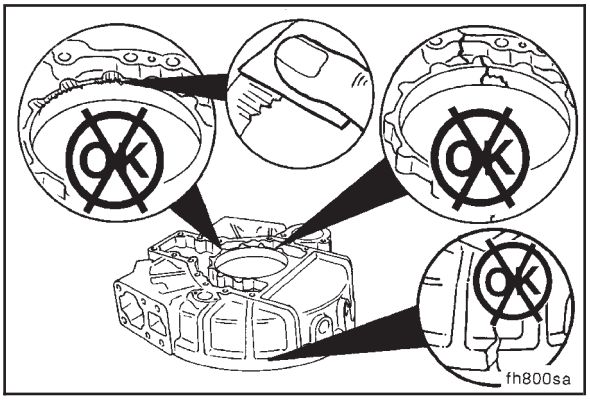
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠ WARNING ⚠

When using steam or hot, high pressure water for cleaning, wear goggles and protective clothing to avoid personal injury.

Use solvent or steam to clean the flywheel housing.

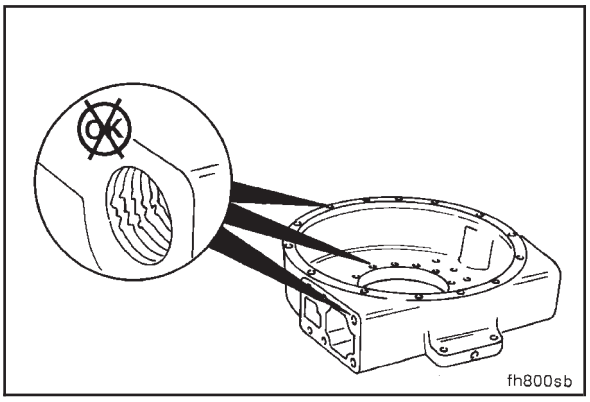
Dry with compressed air.



Inspect for Reuse

Visually inspect all surfaces for nicks, burrs, or cracks.

Use a fine crocus cloth to remove small nicks and burrs.



Visually inspect all threaded capscrew holes for damage.

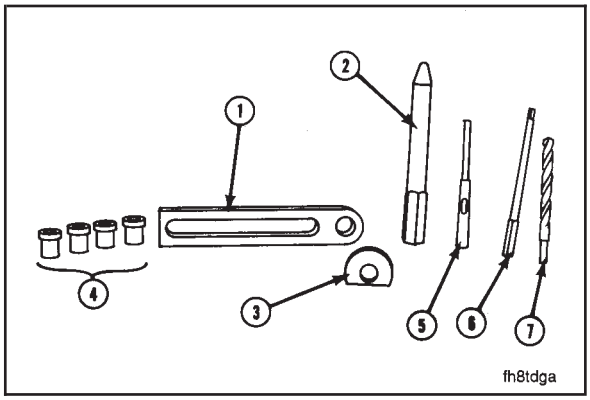
Repair or replace the housing if the capscrew holes are damaged.

Redowel

The tools needed to perform this procedure are:

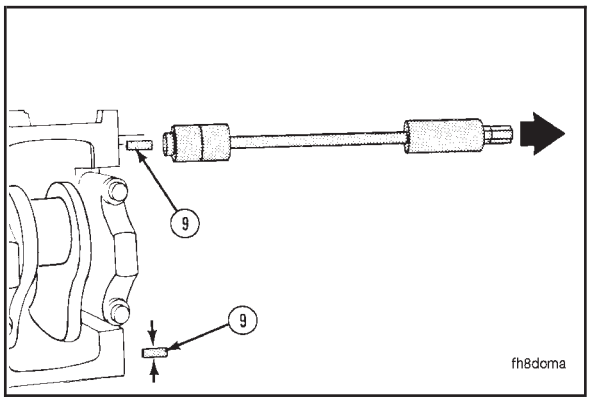
Drill Ream Fixture, Part No. ST-1232, that contains:

1. Plate, Part No. ST-1232-1
2. Locator Pin, Part No. 3375052
3. Spacer Washer, Part No. ST-1232-2
4. Drill/Ream Bushing Set (Actual sizes depend on the dowel size as listed in this Procedure.)
5. Drill Adapter (Locally obtained; use to adapt open (1) shank reamers to drill-chuck)
6. Reamer (Locally obtained)
7. Drill Bit (Locally obtained)



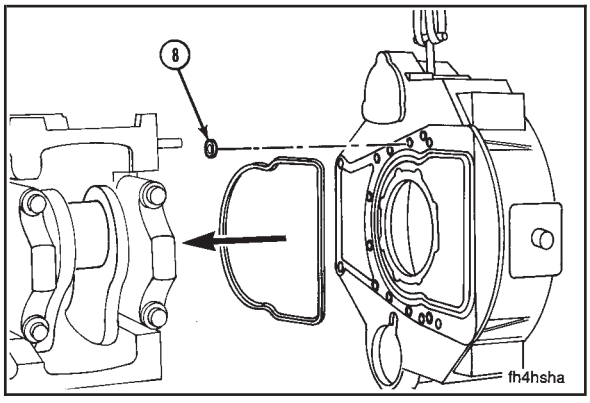
Use a dowel pin extractor, Part No. ST-1134, or equivalent. Remove the two dowels (9) from the block.

Measure a dowel pin that is removed so that an oversize dowel pin can be determined.



NOTE: Do **not** torque the capscrews. The flywheel housing **must** be aligned first.

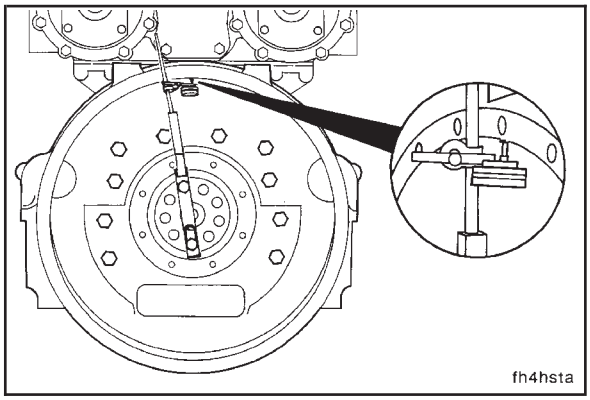
Install the new rectangular seals (8) in the flywheel housing.

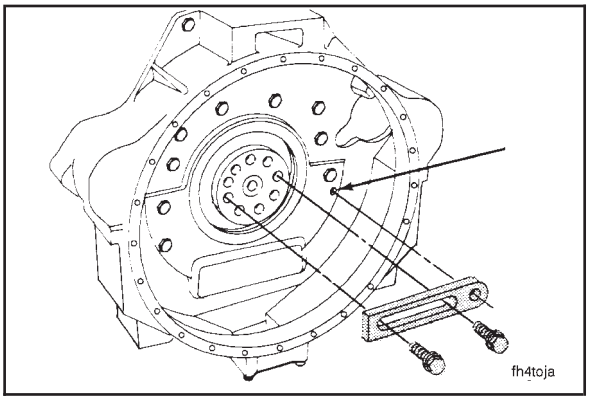


Align the flywheel housing to the crankshaft. for the procedure to measure the housing alignment.

Move the housing with a mallet until the bore is within specification. Check to be sure that the face of the housing is in alignment. When the housing is in alignment, tighten the capscrews. for the capscrew torque.

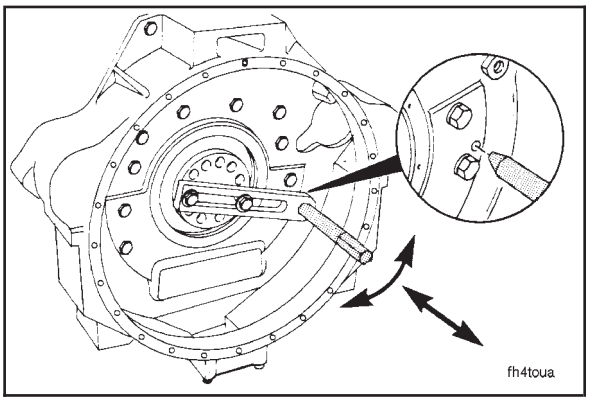
After the capscrews are tightened, check the alignment again.





Use the appropriate size capscrews. Attach the plate, Part No. ST-1232-1, that is contained in Drill Ream Fixture, Part No. ST-1232.

Hand-tighten the capscrews so the plate can be moved.



Use the locator pin to align the plate with the hole for the dowel pin.

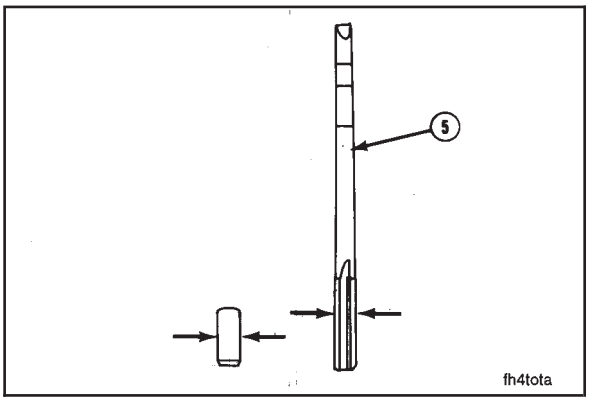
Tighten the capscrews. The taper on the pin **must** engage the dowel pin hole.

The locator pin **must** rotate easily after the capscrews are tightened.

⚠ CAUTION ⚠

Be sure the crankshaft is in the LOCKED position during reaming to prevent damage.

Lock the crankshaft in position. Check to be sure the locator pin is still in alignment and that the locator pin can be rotated easily.



Measure the dowel pins to be installed.

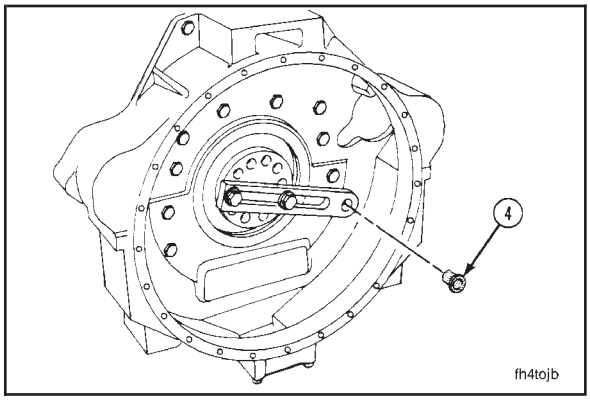
Obtain a reamer (5) that is 0.13 mm to 0.02 mm [0.005 in to 0.001 in] smaller than the dowel.

The dowel **must** be long enough to protrude from the block one-half of the flywheel housing wall thickness.

NOTE: There are three oversize dowel pins available from Cummins Engine Company, Inc.

Oversize Dowel Pin O.D.	
Overall Dimension	**Oversize**
13.08 mm [0.515 in]	0.38 mm [0.015 in]
13.46 mm [0.530 in]	0.76 mm [0.030 in]
13.84 mm [0.545 in]	1.14 mm [0.045 in]

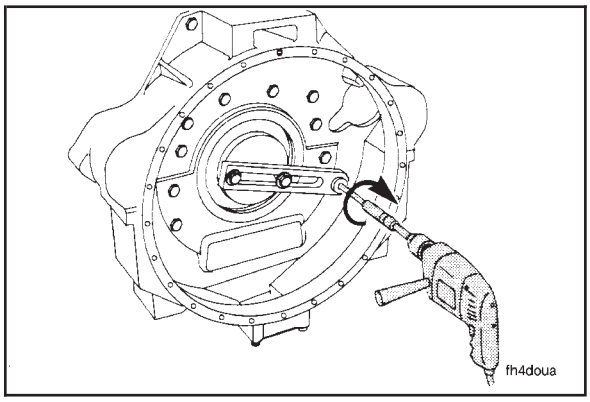
Install the appropriate drill bushings (4). The table shows the bushings available from Cummins Engine Company, Inc.



Drill/Ream Bushing Sets — 25.4 mm [1 Inch] O.D.			
Oversize		Bushing Size	
mm	Inch	mm	Inch
3376495	Special	12.304	[0.4844]
	Standard	12.700	[0.5000]
0.38	[0.015]	13.096	[0.5156]
0.76	[0.30]	13.494	[0.5312]
1.14	[0.045]	13.879	[0.5464]
ST-1234	Standard	14.288	[0.5625]
0.38	[0.015]	14.684	[0.5781]
0.76	[0.030]	15.081	[0.5937]
1.14	[0.045]	15.478	[0.6094]
ST-1235	Standard	15.875	[0.6250]
0.38	[0.015]	16.272	[0.6406]
0.76	[0.030]	16.669	[0.6562]
1.14	[0.045]	17.066	[0.6719]
ST-1236	Standard	17.463	[0.6875]
0.38	[0.015]	17.859	[0.7031]
0.76	[0.030]	18.256	[0.7187]
1.14	[0.045]	18.653	[0.7344]
ST-1237	Standard	19.050	[0.7500]
0.38	[0.015]	19.447	[0.7656]
0.76	[0.030]	19.844	[0.7812]
ST-1238		22.621	[0.8906]
		23.813	[0.9375]

The drill bushing that is used **must** be the same size as the reamer (or the drill) that is used.

If the new dowel pins are more than 0.38 mm [0.015 in] larger than the old dowels, drill the hole to a size that is slightly smaller than the reamer. Then the reamer will **not** have to remove an excess amount of material.



CAUTION

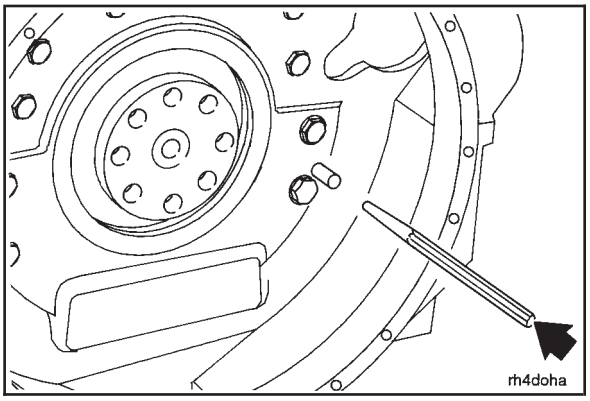
Do not allow metal chips to enter the engine. Damage to the engine will result.

Ream the hole until the reamer touches the bottom of the hole in the block.

Remove the reamer.

Clean the hole and run the reamer through the hold again. The reamer **must** touch the bottom of the hole in the block.

After reaming one hole, turn the plate and align it with the second dowel hole. Repeat the procedure in the second hole.

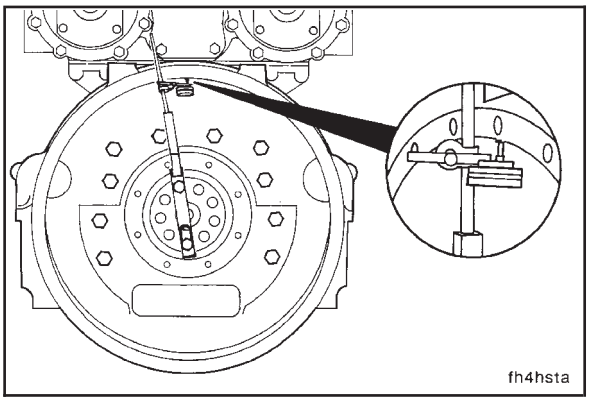


Remove the plate from the crankshaft.

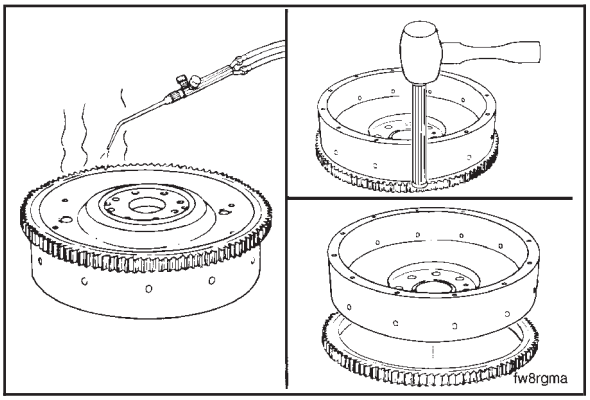
CAUTION

Be sure the dowel hole does not contain any metal chips. Engine damage will result.

Use a square nose drift. Drive each dowel in until it touches the bottom of the hole in the block.



After the dowels are installed, measure the bore and the face alignment again.



Flywheel Ring Gear (016-008)

Disassemble

CAUTION

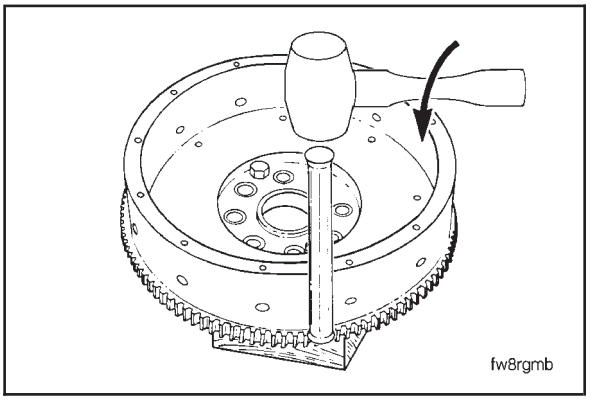
Wear protective clothing to prevent personal injury from burns.

CAUTION

Adjust the torch to a good heating flame. Do not use a cutting flame (a blue flame) to heat the ring gear. Damage to the flywheel can result.

Heat the ring gear.

Use a brass drift and a hammer to remove the hot ring gear.



If a heating torch is **not** available, the ring gear can be removed with a brass drift and a hammer.

NOTE: If this method is used to remove the ring gear from a flexplate assembly, be sure a wooden block is used to support the ring gear adapter.

Assemble

⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

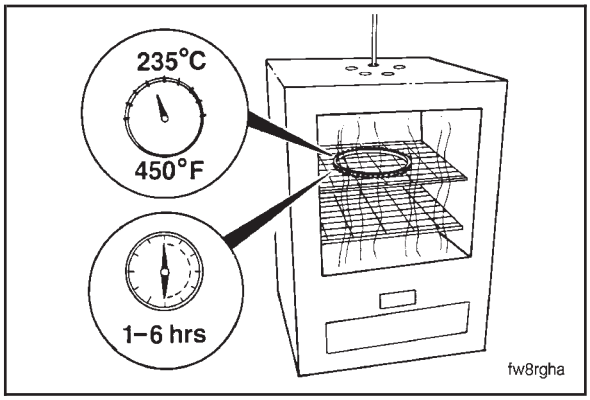
⚠ CAUTION ⚠

Do not exceed the specified time or temperature. Damage to the gear and to the gear teeth will result.

⚠ CAUTION ⚠

Do not attempt to install the gear without using heat. Damage or breakage will result.

Use an oven. Adjust the temperature to 232°C [450°F]. Heat the gear in the oven for a **minimum** of 1 hour, and a **maximum** of 6 hours. The I.D. of the gear will become larger and simplify the installation of the gear on the flywheel.



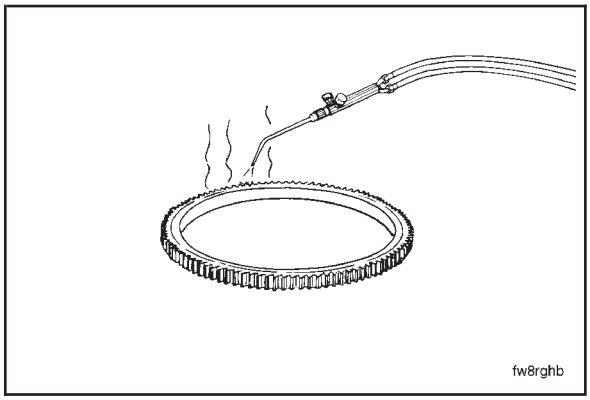
⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

Use a heating flame to heat the gear if an oven is **not** available.

Use a Tempilstik® crayon or equivalent, to check the temperature of the gear.

Heat the gear to 232°C [450°F].



⚠ CAUTION ⚠

Do not exceed 316°C [600°F]. Damage to the ring gear will result from the hardness of the metal being reduced.

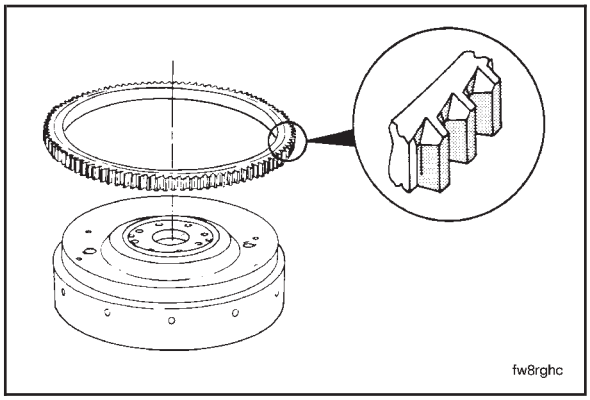
⚠ CAUTION ⚠

Wear protective clothing to prevent personal injury from burns.

Remove the gear from the oven.

Position the gear so the bevel is positioned toward the crankshaft edge of the flywheel as shown.

The part number is on the same side as the bevel.



⚠ CAUTION ⚠

Allow the air to cool the gear. Do NOT use water or oil to reduce the cooling time. Damage to the gear can result.

Install the gear.

NOTES

Section 19 - Electronic Engine Controls - Group 19

Section Contents

Electronic Engine Controls - General Information

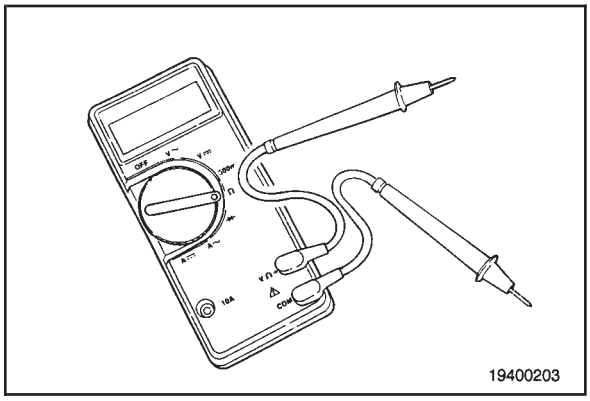
General Information

How To Use A Digital Volt/Ohm Meter

On most meters, the negative (black) meter lead **must** be plugged in the “COM” position and the positive (red) meter lead **must** be plugged into one of the positions marked for current, resistance, or voltage. Refer to the manufacturer’s instructions for more detail.

NOTE: When measuring to a block ground, use a clean unpainted metal surface to ensure a good measurement.

NOTE: If **more** information is needed refer to the QSK19 Troubleshooting and Repair Manual, Bulletin No. 3666098.

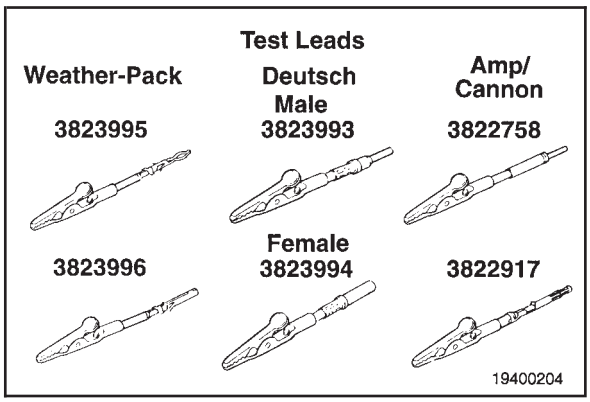


Use of Special Test Leads

CAUTION

To avoid pin and harness damage, use the following test leads when taking a measurement:

- Male Cannon, Metri-Pack and Deutsch test lead, Part No. 3822758
- Female Amp, Metri-Pack and Deutsch test lead, Part No. 3822917
- Male Deutsch test lead, Part No. 3823993
- Female Deutsch test lead, Part No. 3823994
- Male Weather-Pack test lead, Part No. 3823995
- Female Weather-Pack test lead, Part No. 3823996



How To Measure Current

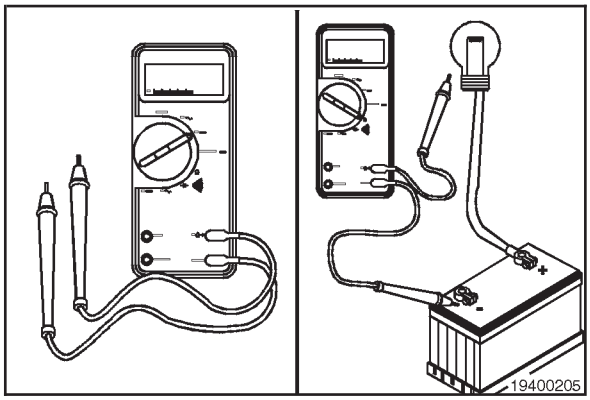
Make an open circuit at the place where the current needs to be measured.

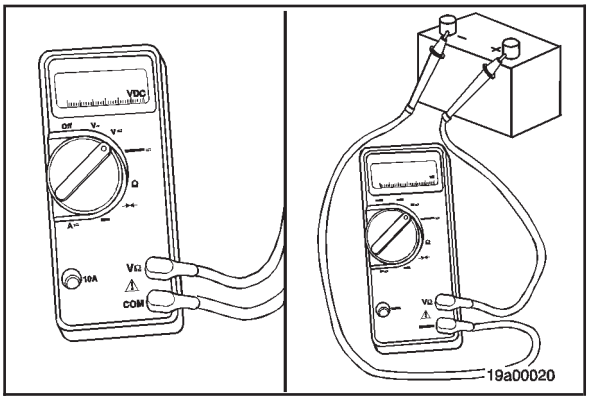
Select the AC current (A ~) or DC current (A –) function on the meter.

Turn on the power in the circuit being measured.

Put the leads of the meter across the open circuit to measure the current.

Read the displayed measurement.



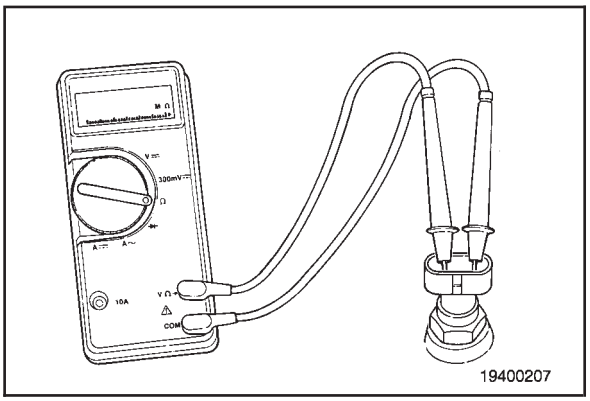


How To Measure Voltage

Select the AC voltage (V ~) or DC voltage (V –) function on the meter.

Turn on the power in the circuit being measured.

Put the leads of the meter in parallel with the component to measure the voltage potential difference between the two points of the component.

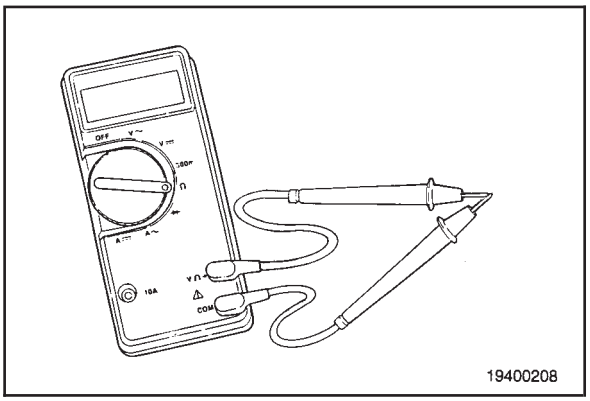


How To Measure Resistance

Select the resistance function on the meter.

Verify that there is no power to the components being tested.

Put the leads of the meter in parallel with the component to measure resistance.



How To Find The Internal Resistance of The Meter

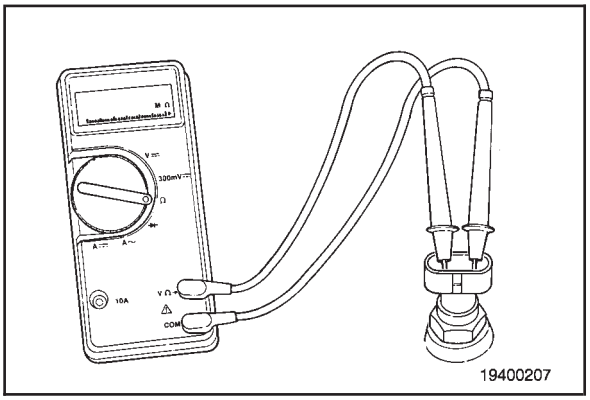
It is important to know the internal resistance of the meter when measuring small resistances. To accurately measure small resistances, the internal resistance of the meter **must** be subtracted from the measured resistance.

Turn the meter “ON”.

Set the meter to the lowest ohm scale.

Measure the resistance across the meter test leads (including special test leads if they are being used).

“ZERO” the meter or subtract this value when taking measurements.



How To Test For Continuity

Select the continuity function on the meter (usually marked with a diode symbol).

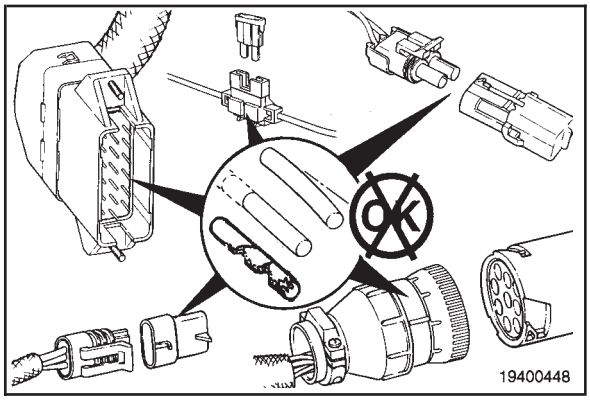
Make sure there is no power to the component being measured.

Put the leads of the meter in parallel with the component to test continuity.

The meter will beep if the resistance is less than about 150 Ohms. If there is an open circuit, the meter will **not** beep.

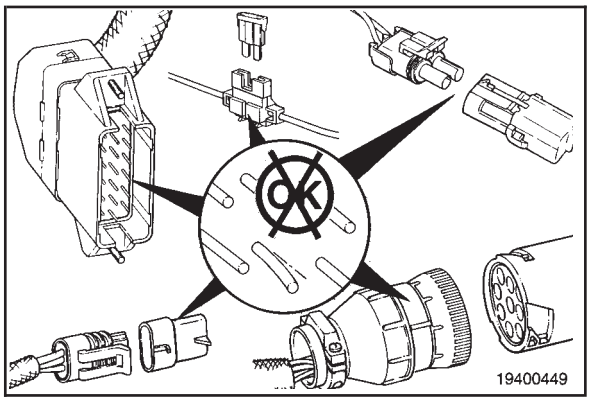
Connector Pins — Checking

When disconnecting connectors during troubleshooting, the pins **must** always be inspected to make sure they are **not** the cause of a bad connection. The three things to look for are bent, corroded, and pushed back pins.



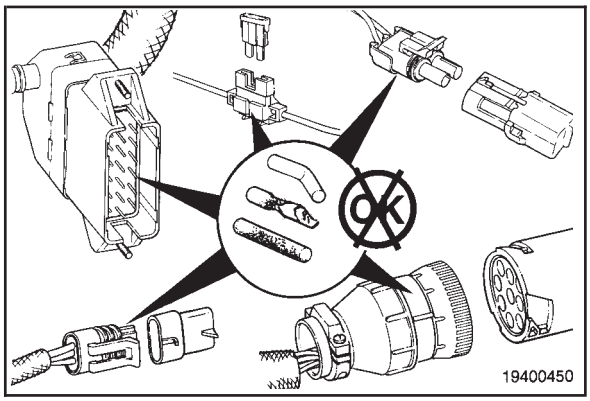
Bent Pins

Inspect the male terminals of the connector. If any of the terminals are bent so that they will **not** easily mate with the other side of the connector, then the pin **must** be replaced. Refer to the connector repair section for the specific connector in question.



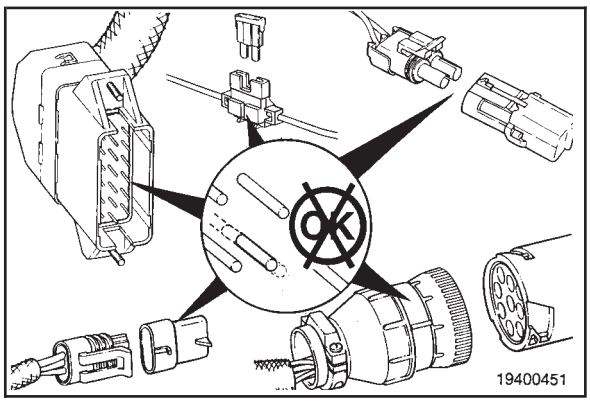
Corroded Pins

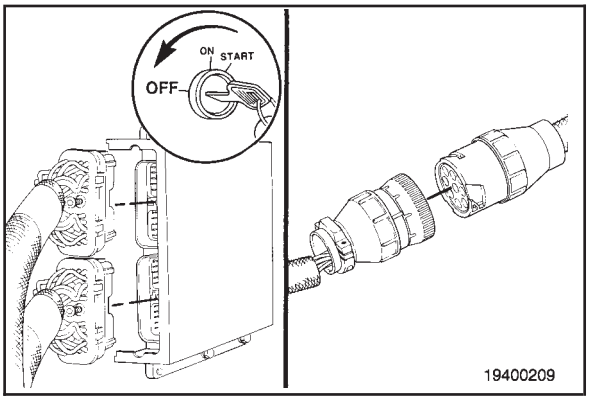
Inspect both the male and female terminals for corrosion which can cause a poor electrical connection within the connector. If any corrosion is evident on the pins then the corroded pins **must** be replaced. Refer to the connector repair section for the specific connector in question.



Pushed Back Pins

Inspect both the male and female terminals for pins that **cannot** be making contact because they are pushed back in the connector. To repair, push the pin into the connector body from the back of the connector. Make sure the terminal locks into place. If the terminal will **not** lock into place then replace it. Refer to the connector repair section for the specific connector in question.





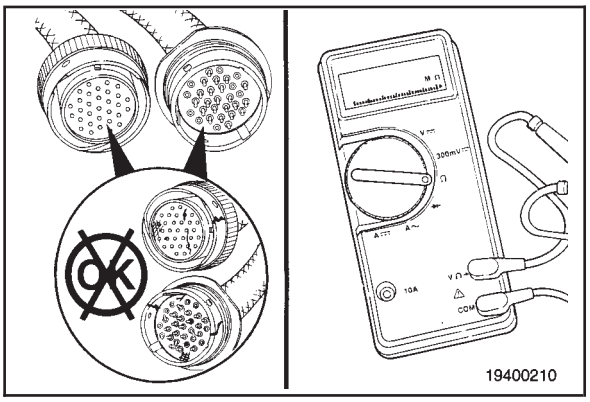
Short Circuit To Ground — Check

Short circuit to ground is a condition where a connection from a wire to ground exists when it is **not** suppose to.

The procedure for checking for a short circuit to ground is as follows:

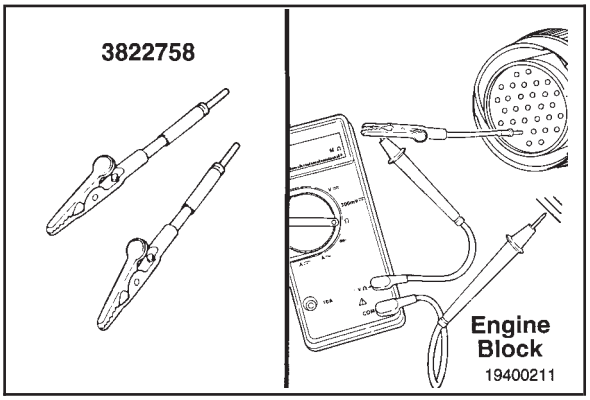
Turn the key switch to the “OFF” position.

Disconnect the connectors that need to be tested. When testing a sensor, the sensor connection only need be disconnected. When testing a harness, the harness connector at the ECM and the connector at the sensor or multiple sensors will need to be disconnected.



Identify the pins that need to be tested.

Turn the dial on the digital VOM to measure resistance.

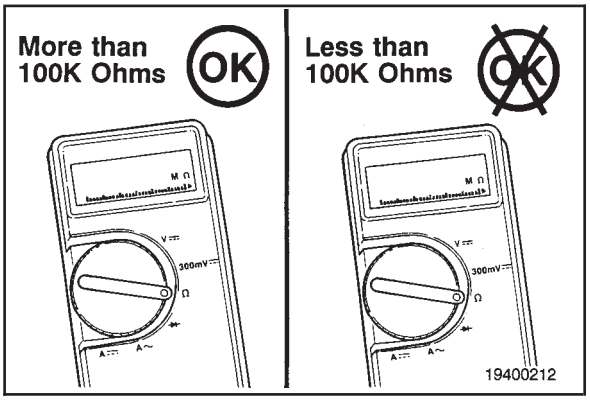


Use the appropriate test leads from the wiring harness repair kit, Part No. 3822926, to avoid damage to the connector pins.

Touch one of the VOM leads to the correct pin to be tested.

Touch the other lead of the VOM to the engine block.

Read the value on the VOM display.



The VOM **must** show greater than 100 K ohms which is an open circuit.

If the circuit is **not** open, the wire being checked has a short to ground or the engine block.

Repair or replace the component or wire.

Short Circuit From Pin To Pin — Check

Short circuit from pin to pin is a condition where an electrical path exists between two pins where it is **not** suppose to exist.

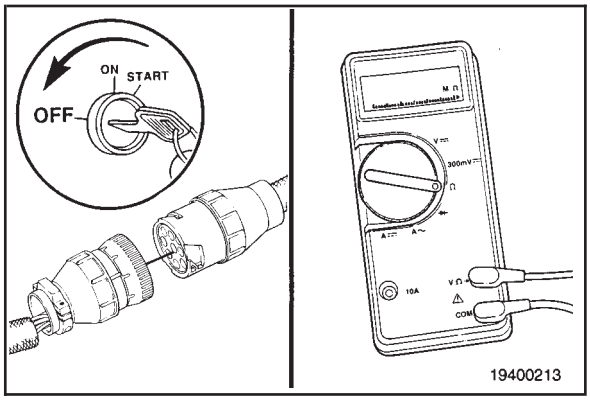
The procedure for checking short circuit from pin to pin is as follows:

Turn the key switch to the “OFF” position.

Disconnect the connector that needs to be tested.

Identify the pins that need to be tested.

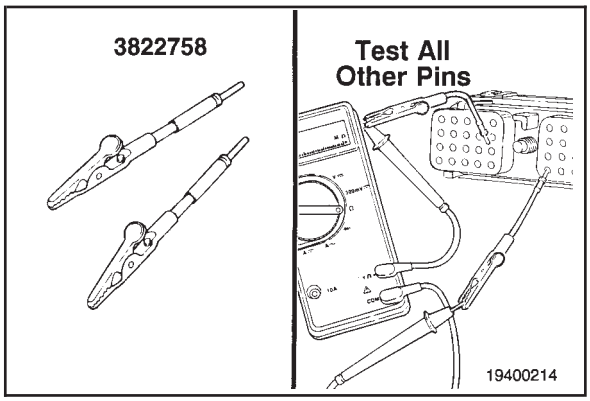
Turn the dial on the digital VOM to measure resistance.



Use the appropriate test leads from the wiring harness repair kit, Part No. 3822926, to avoid damage to the connector pins.

Touch one of the digital VOM leads to the correct pin to be tested on the harness side of the connector.

Touch the other lead of the digital VOM to all other pins on the harness side of this connector.



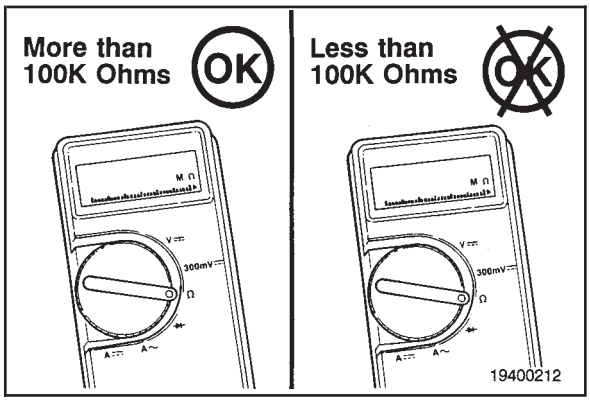
Read the value on the VOM display.

With the wiring harness disconnected from the ECM, theVOM **must** show greater than 100 KΩ which is an open circuit.

If the circuit is **not** open, the pins being checked are electrically connected.

Inspect the harness connectors for water which can cause an electrical connection.

Repair or replace the harness.



Voltage Checking

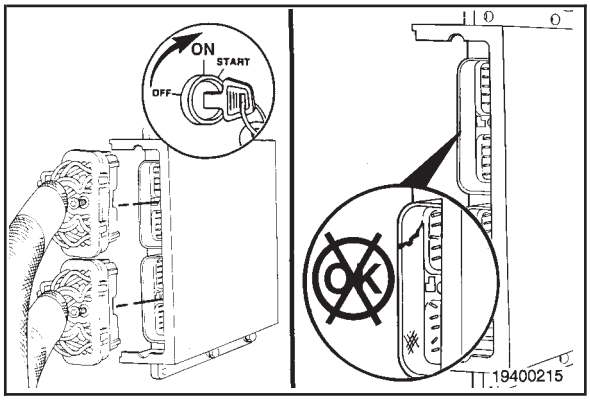
Voltage check is a procedure to measure the difference in voltage potential between two points.

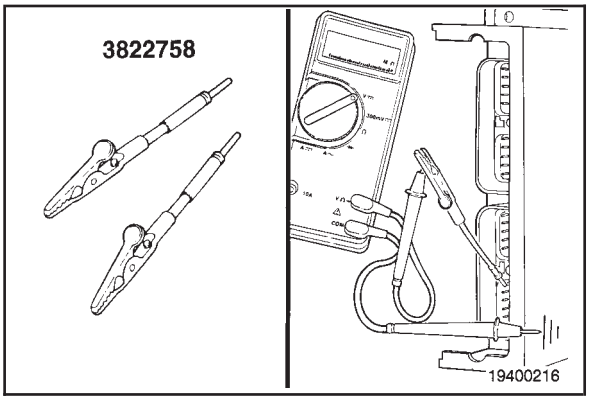
To check voltage, turn the key switch to the “ON” position.

Disconnect the connectors that need to be tested.

Identify the pins that need to be tested.

Turn the dial on the digital VOM to AC voltage (V ~) or DC voltage (V-).

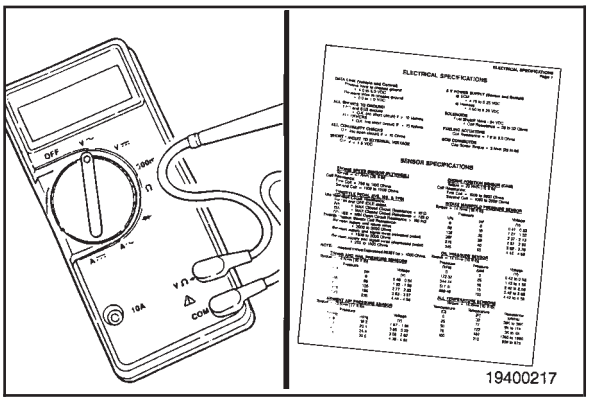




Use the appropriate test leads from the wiring harness repair kit, Part No. 3822926, to avoid damage to the connector pins.

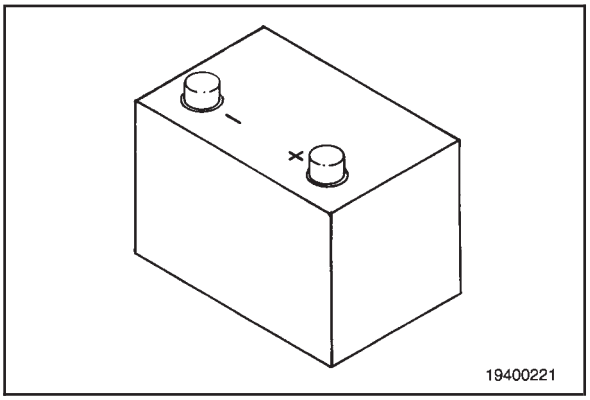
Touch one of the VOM test leads to the correct lead to be tested.

Touch the other lead of the digital VOM to a clean unpainted surface on the engine block.



Read the value on the VOM display. Compare the measured value to the range of voltage given in the specifications.

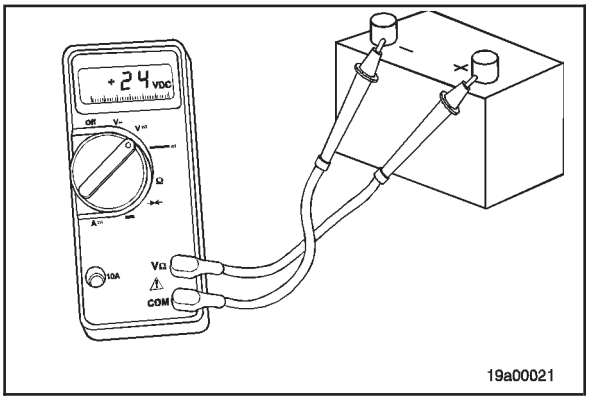
If the measured value falls outside of the specified range, check the QSK Troubleshooting and Repair Manual, Bulletin No. 3666098, for the electrical system that is being checked for the appropriate action.



Polarity Check

A battery will be used as an example to check polarity of a circuit.

The terminals of a battery are marked for polarity. The digital VOM displays the voltage difference of the positive lead (red) to the negative lead (black).



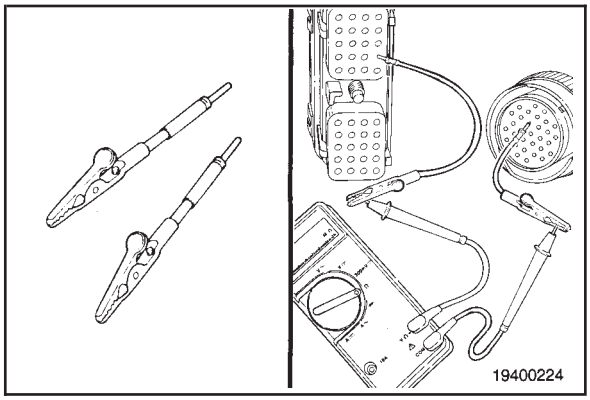
The polarity is correct when the positive (red) lead of the VOM is on the positive terminal of the battery and the negative (black) lead of the VOM is on the negative terminal of the battery.

The VOM will display positive voltage if the polarity is correct.

If the VOM leads are reversed, the VOM will display negative voltage.

Continuity Check

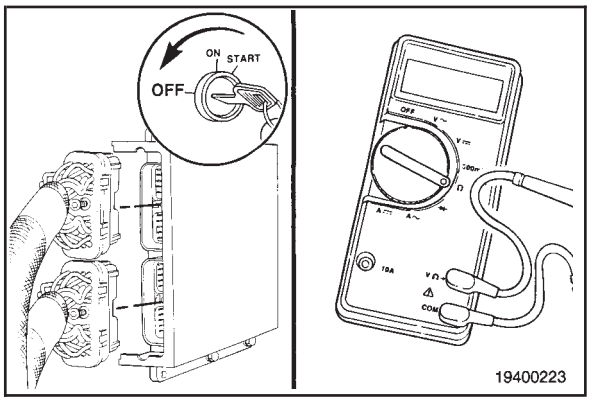
Continuity is an electrical connection between two pins that is less than a certain resistance value. For harness wires, the specification is less than 10 ohms.



Turn the key switch to the “OFF” position.

Disconnect the harness connectors to be tested.

Turn the dial of the digital VOM to measure resistance.



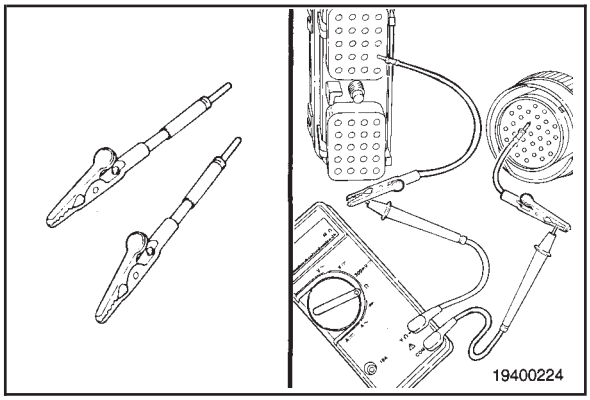
⚠ CAUTION ⚠

Use the appropriate test leads from the wiring harness repair kit, Part No. 3822926, to avoid damage to the connector pins.

Touch one of the VOM test leads to the pin of the wire being tested.

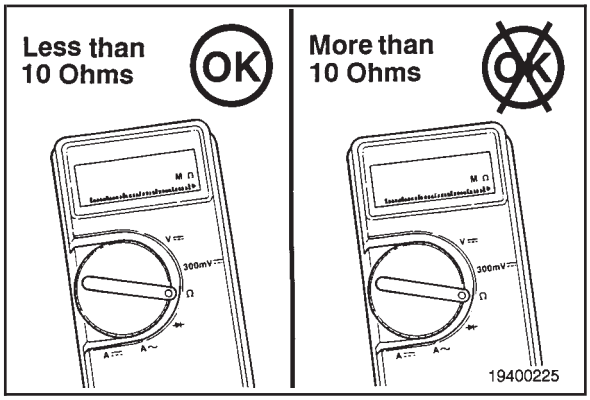
Touch the other lead of the VOM to the pin at the other end of the wire being tested.

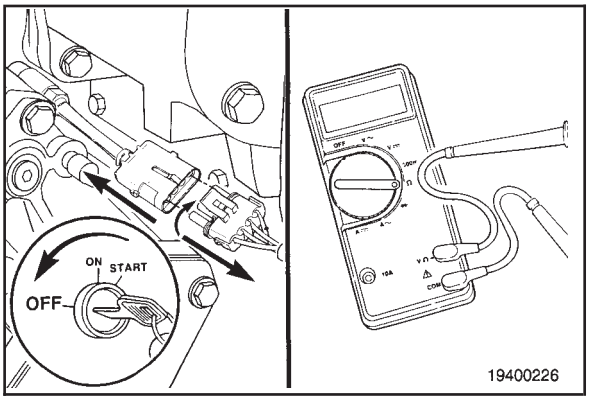
Read the value on the VOM display.



The VOM **must** display less than 10 ohms for wire continuity.

If the VOM displays greater than 10 ohms, the wire **must** be repaired or the harness replaced.



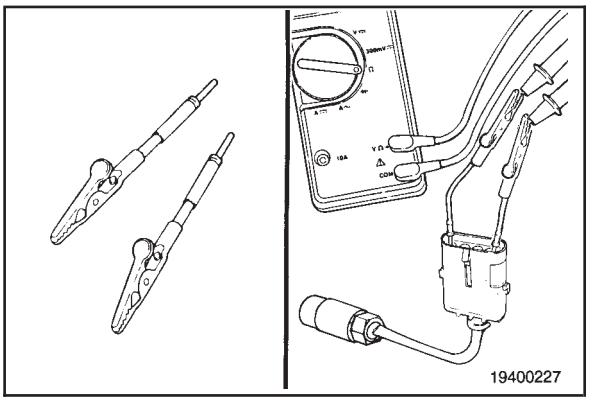


Resistance Check — Coil

Disconnect the harness from the coil.

Turn the dial of the VOM to measure resistance.

Turn the key switch to the “OFF” position.



⚠ CAUTION ⚠

Use the appropriate test leads from the wiring harness repair kit, Part No. 3822926, to avoid damage to the connector pins.

Touch one of the VOM leads to the coil connector pin.

Touch the other test lead to the other coil connector pin.

NOTE: For internally grounded coils, touch one VOM lead to the coil terminal and the other VOM lead to the engine block.

Read the measured resistance on the VOM display.

Engine Position Sensor (CAM)

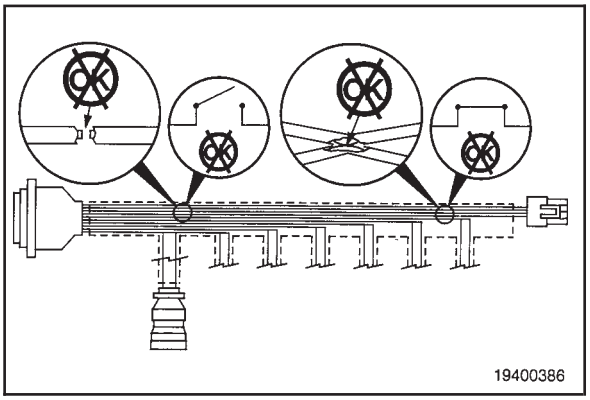
Torque = 20 N•m [15 ft-lb]

Coil Resistance:
First Coil = 1000 to 2000 Ohms
Second Coil = 1000 to 2000 Ohms

19400383

Check the measured resistance against the resistance specification for the coil.

NOTE: The internal resistance of the VOM is significant in some coil resistance checks.



Engine Wiring Harness (019-043)

Inspect for Reuse

Inspect the Engine Wiring Harness.

Check for any open or short circiuts in the wiring harness.

If any open or short circuits are found, the wiring harness **must** be repaired or replaced.

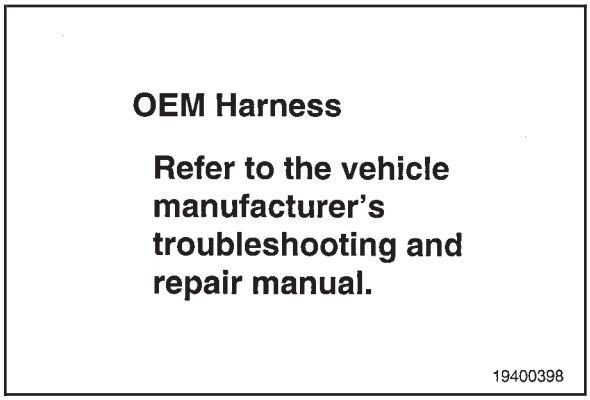
OEM Wiring Harness (019-071)

General Information

The OEM harness is supplied and installed by the vehicle manufacturer.

Follow the vehicle manufacturer's instructions, if replacement is necessary.

Refer to the vehicle manufacturer's troubleshooting and repair manual.

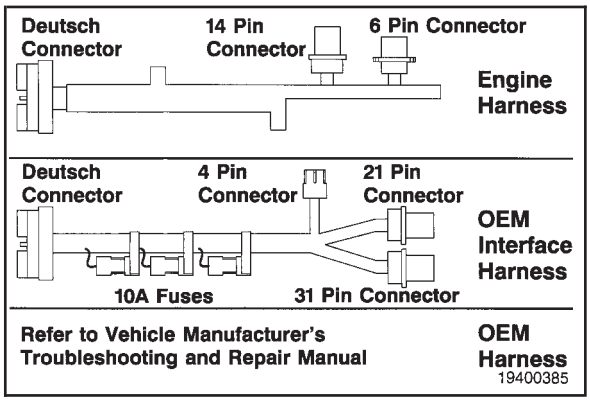


OEM Interface Harness (019-072)

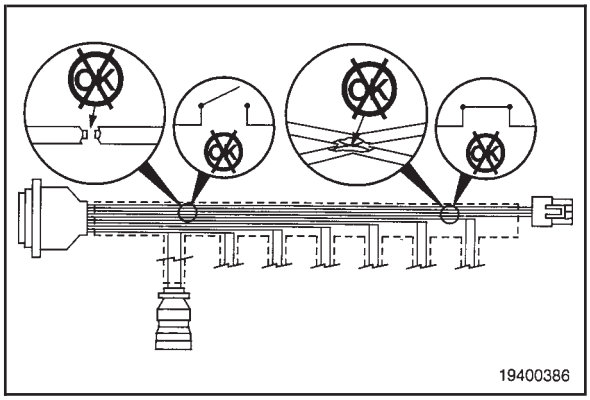
General Information

The QSK equipped engines use three separate wiring harness to control the engine and some of the vehicle operations.

1. Engine Harness
2. OEM Interface Harness
3. OEM Harness



Replace a harness if there is an open circuit or a short circuit found under the protective covering of the harness body.



NOTES

Section L - Service Literature

Section Contents

Additional Service Literature

The following publications can be purchased by filling in and mailing the Literature Order Form:

Bulletin No.	Title of Publication
3666098–01	Troubleshooting and Repair Manual QSK19 Series Engines
3885786	Users Guide Electronic Software and Database Network Version 3.1
3666120	Operation and Maintenance Manual QSK Fuel System/QSK19 Engine Series
3666133	QSK Fuel System Wiring/Fault Code Diagram
3666163	QSK Fuel System Echek™ 1.0 Cartridge Manual
3666148	INSITE™ For QSK Fuel System QUANTUM™ User's Manual
3666113	Troubleshooting and Repair Manual QSK Fuel System/QSK19 Engine Series
3672094	QSK19 Parts Catalog - Construction
3666121	Holset Air Compressor Master Repair Manual
3898170	QUANTUM™ QSK19 Engine Familiarization
3898180	QUANTUM™ QSK19 Fuel System Familiarization

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.

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3					
4					
5					
6					
				Order Total	$

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3					
4					
5					
6					
				Order Total	$

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Country:		

SHIP TO: (Name and address where literature is to be shipped)		
Name:		
Street Address:		
City:	State/Province:	Zip/Postal Code:
Country:		

Please cut on dotted line

Mail the Literature Order Form along with your ship-to address to your nearest Cummins distributor.

FROM:		
Name:		
Street Address:		
City:	State/Province:	Zip/Postal Code:
Country:		

SHIP TO: (Name and address where literature is to be shipped)		
Name:		
Street Address:		
City:	State/Province:	Zip/Postal Code:
Country:		

Section M - Component Manufacturers

Section Contents

Component Manufacturers' Addresses

NOTE: The following list contains addresses and telephone numbers of suppliers of accessories used on Cummins engines. Suppliers can be contacted directly for any specifications **not** covered in this manual.

Air Compressors

Bendix Heavy Vehicles Systems
Div. of Allied Automotive
901 Cleveland Street
Elyria, OH 44036
Telephone: (216) 329-9000

Holset Engineering Co., Inc.
1320 Kemper Meadow Drive
Suite 500
Cincinnati, OH 45240
Telephone: (513) 825-9600

Midland-Grau
Heavy Duty Systems
Heavy Duty Group Headquarters
10930 N. Pamona Avenue
Kansas City, MO 64153
Telephone: (816) 891-2470

Air Cylinders

Bendix Ltd.
Douglas Road
Kingswood
Bristol
England
Telephone: 0117-671881

Catching Engineering
1733 North 25th Avenue
Melrose Park, IL 60160
Telephone: (708) 344-2334

TEC - Hackett Inc.
8909 Rawles Avenue
Indianapolis, IN 46219
Telephone: (317) 895-3670

Air Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
P.O. Box 11245
Spokane, WA 99211-0245
Telephone: (509) 534-6171

Air Starting Motors

Ingersoll Rand
Chorley New Road
Horwich
Bolton
Lancashire
England
BL6 6JN
Telephone: 01204-65544

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone: (708) 530-3875

StartMaster
Air Starting Systems
A Division of Sycon Corporation
9595 Cheney Avenue
P. O. Box 491
Marion, OH 43302
Telephone: (614) 382-5771

Alternators

Robert Bosch Ltd.
P.O. Box 98
Broadwater Park
North Orbital Road
Denham
Uxbridge
Middlesex UD9 5HG
England
Telephone: 01895-833633

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 01908-66001

C. E. Niehoff & Co.
2021 Lee Street
Evanston, IL 60202
Telephone: (708) 866-6030

Delco-Remy America
2401 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 492-1700

Auxiliary Brakes

The Jacobs Manufacturing Company
Vehicle Equipment Division
22 East Dudley Town Road
Bloomfield, CT 06002
Telephone: (203) 243-1441

Belts

Dayco Rubber U.K.
Sheffield Street
Stockport
Cheshire
SK4 1RV
England
Telephone: 061-432-5163

T.B.A. Belting Ltd.
P.O. Box 77
Wigan
Lancashire
WN2 4XQ
England
Telephone: 01942-59221

Dayco Mfg.
Belt Technical Center
1955 Enterprize
Rochester Hills, MI 48309
Telephone: (810) 853-8300

Gates Rubber Company
900 S. Broadway
Denver, CO 80217

Goodyear Tire and
Rubber Company
Industrial Products Div.
2601 Fortune Circle East
Indianapolis, IN 46241
Telephone: (317) 898-4170

Catalytic Convertors

Donaldson Company, Inc.
1400 West 94th Street
P.O. Box 1299
Minneapolis, MN 55440
Telephone: (612) 887-3835

Nelson Division
Exhaust and Filtration Systems
1801 U.S. Highway 51 P.O. Box 428
Stoughton, WI 53589
Telephone: (608) 873-4200

Walker Manufacturing
3901 Willis Road
P.O. Box 157
Grass Lake, MI 49240
Telephone: (517) 522-5500

Coolant Level Switches

Robertshaw Controls Company
P.O. Box 400
Knoxville, TN 37901
Telephone: (216) 885–1773

Clutches

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belguim
Telephone: 067-224941

Twin Disc Incorporated
1328 Racine Street
Racine, WI 53403
Telephone: (414) 634-1981

Coolant Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Drive Plates

Detroit Diesel Allison
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206-0894
Telephone: (317) 242-5000

Electric Starting Motors

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 01744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 0908-66001

Delco-Remy America
2401 Columbus Avenue
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-3528

Leece-Neville Corp.
400 Main Street
Arcade, NY 14009
Telephone: (716) 492-1700

Nippondenso Inc.
2477 Denso Drive
P.O. Box 5133
Southfield, MI 48086
Telephone: (313) 350-7500

Electronic Switches

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449–6600

Engine Protection Controls

Flight Systems Headquarters
Hempt Road
P.O. Box 25
Mechanicsburg, PA 17055
Telephone: (717) 697–0333

The Nason Company
2810 Blue Ridge Blvd.
West Union, SC 29696
Telephone: (803) 638-9521

Teddington Industrial
Equipment
Windmill Road
Sunburn on Thames
Middlesex
TW16 7HF
England
Telephone: 09327-85500

Fan Clutches

Holset Engineering Co. Ltd.
P.O. Box A9
Turnbridge
Huddersfield, West Yorkshire
England HD6 7RD
Telephone: 01484-22244

Horton Industries, Inc.
P.O. Box 9455
Minneapolis, MN 55440
Telephone: (612) 378-6410

Rockford Clutch Company
1200 Windsor Road
P.O. Box 2908
Rockford, IL 61132-2908
Telephone: (815) 633-7460

Fans

Truflo Ltd.
Westwood Road
Birmingham
B6 7JF
England
Telephone: 021-557-4101

Hayes-Albion Corporation
Jackson Manufacturing Plant
1999 Wildwood Avenue
Jackson, MI 49202
Telephone: (517) 782-9421

Engineered Cooling Systems, Inc.
201 W. Carmel Drive
Carmel, IN 46032
Telephone: (317) 846-3438

Brookside Corporation
P.O. Box 30
McCordsville, IN 46055
Telephone: (317) 335-2014

TCF Aerovent Company
9100 Purdue Rd., Suite 101
Indianapolis, IN 46268-1190
Telephone: (317) 872-0030

Kysor-Cadillac
1100 Wright Street
Cadillac, MI 49601
Telephone: (616) 775-4681

Schwitzer
6040 West 62nd Street
P.O. Box 80-B
Indianapolis, IN 46206
Telephone: (317) 328-3010

Fault Lamps

Cutler-Hammer Products
Eaton Corporation
4201 N. 27th Street
Milwaukee, WI 53216
Telephone: (414) 449–6600

Filters

Fleetguard International Corp.
Cavalry Hill Industrial Park
Weedon
Northampton NN7 4TD
England
Telephone: 01327-41313

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Flexplates

Corrugated Packing and
Sheet Metal
Hamsterley
Newcastle Upon Tyne
England
Telephone: 01207-560-505

Allison Transmission
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206-0894
Telephone: (317) 242-5000

Midwest Mfg. Co.
29500 Southfield Road, Suite 122
Southfield, MI 48076
Telephone: (313) 642-5355

Wohlert Corporation
708 East Grand River Avenue
P.O. Box 20217
Lansing, MI 48901
Telephone: (517) 485-3750

Fuel Coolers

Hayden, Inc.
1531 Pomona Road
P.O. Box 848
Corona, CA 91718–0848
Telephone: (909) 736–2665

Fuel Warmers

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Gauges

A.I.S.
Dyffon Industrial Estate
Ystrad Mynach
Hengoed
Mid Glamorgan
CF8 7XD
England
Telephone: 01443-812791

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 01732-359888

Icknield Instruments Ltd.
Jubilee Road
Letchworth
Herts
England
Telephone: 04626-5551

Superb Tool and Gauge Co.
21 Princip Street
Birmingham
B4 61E
England
Telephone: 021-359-4876

Kabi Electrical and Plastics
Cranborne Road
Potters Bar
Herts
EN6 3JP
England
Telephone: 01707-53444

Datcon Instruments
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauges, Inc.
11616 Harry Hines Blvd.
P.O. Box 29242
Dallas, TX 75229
Telephone: (214) 241-2161

Governors

Woodward Governors Ltd.
P.O. Box 15
663/664 Ajax Avenue
Slough
Bucks
SL1 4DD
England
Telephone: 01753-26835

Woodward Governor Co.
P.O. Box 1519
Fort Collins, CO 80522
Telephone: (303) 482-5811
(800) 523-2831

Barber Colman Co.
1354 Clifford Avenue
Loves Park, IL 61132
Telephone: (815) 637-3000

United Technologies
Diesel Systems
1000 Jorie Blvd.
Suite 111
Oak Brook, IL 69521
Telephone: (312) 325-2020

Heat Sleeves

Bentley Harris Manufacturing Co.
100 Bentley Harris Way
Gordonville, TN 38563
Telephone: (313) 348-5779

Hydraulic and Power Steering Pumps

Hobourn Automotive
Temple Farm Works
Priory Road
Strood
Rochester
Kent, England
ME2 2BD
Telephone: 01634-71773

Honeywell Control Systems Ltd.
Honeywell House
Charles Square
Bracknell
Berks RG12 1EB
Telephone: 01344-4245

Sundstrand Hydratec Ltd.
Cheney Manor Trading Estate
Swindon
Wiltshire
SN2 2PZ
England
Telephone: 01793-30101

Sperry Vickers
P.O. Box 302
Troy, MI 48084
Telephone: (313) 280-3000

Z.F.
P.O. Box 1340
Grafvonsoden Strasse
5-9 D7070
Schwaebisch Gmuend
Germany
Telephone: 7070-7171-31510

In-Line Connectors

Pioneer-Standard Electronics, Inc.
5440 Neiman Parkway
Solon, OH 44139
Telephone: (216) 349–1300

Deutsch
Industrial Products Division
37140 Industrial Avenue
Hemet, CA 92343
Telephone: (714) 929–1200

Oil Heaters

Fleetguard, Inc.
1200 Fleetguard Road
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
P.O. Box 11245
Spokane, WA 99211-0245
Telephone: (509) 534-6171

Prelubrication Systems

RPM Industries, Inc.
Suite 109
55 Hickory Street
Washington, PA 15301
Telephone: (412) 228–5130

Radiators

JB Radiator Specialties, Inc.
P.O. Box 292087
Sacramento, CA 95829–2087
Telephone: (916) 381–4791

The G&O Manufacturing Company
100 Gando Drive
P.O. Box 1204
New Haven, CT 06505–1204
Telephone: (203) 562–5121

Young Radiator Company
2825 Four Mile Road
Racine, WI 53404
Telephone: (910) 271–2397

L and M Radiator, Inc.
1414 East 37th Street
Hibbing, MN 55746
Telephone: (218) 263–8993

Throttle Assemblies

Williams Controls, Inc.
14100 SW 72nd Avenue
Portland, OR 97224
Telephone: (503) 684–8600

Torque Converters

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belgium
Telephone: 067-224941

Twin Disc Incorporated
1328 Racine Street
Racine, WI 53403-1758
Telephone: (414) 634-1981

Rockford Powertrain, Inc.
Off-Highway Systems
1200 Windsor Road
P.O. Box 2908
Rockford, IL 61132-2908
Telephone: (815) 633-7460

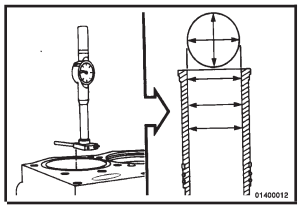
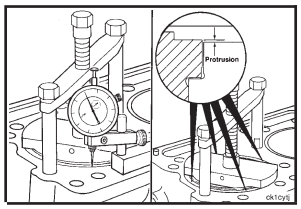
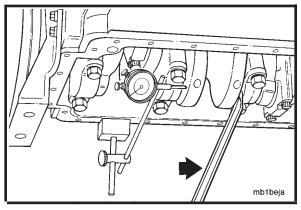
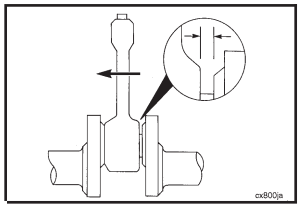
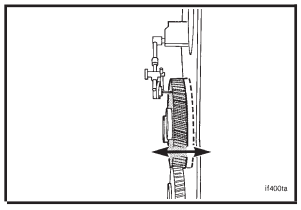
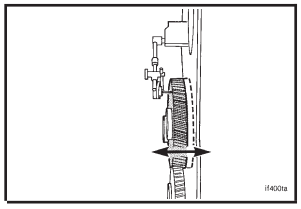
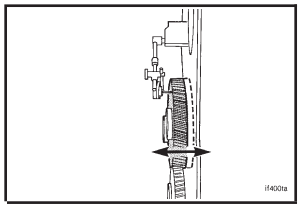
Modine Mfg. Co.
1500 DeKoven Avenue
Racine, WI 53401
Telephone: (414) 636-1640

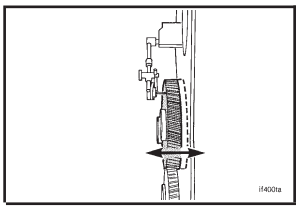
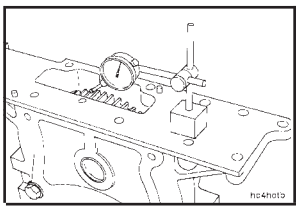
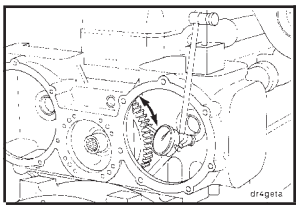
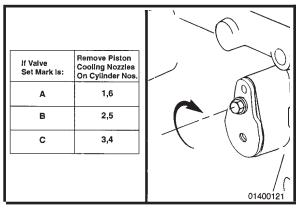
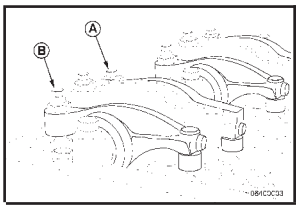
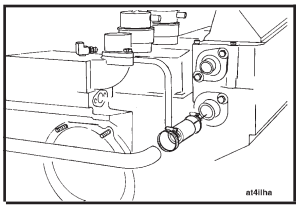
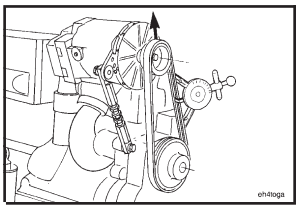
NOTES

Section V - Specifications

Section Contents

Page

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Complete Engine - Specifications					
Engine Assembly (001-058)					
Cylinder Liner I.D. (New)		158.737 mm 158.775 mm	MIN MAX	6.2495 in 6.2510 in	
Cylinder Liner Protrusion		0.13 mm 0.18 mm	MIN MAX	0.003 in 0.007 in	
Crankshaft End Clearance		0.10 mm 0.41 mm	MIN MAX	0.004 in 0.016 in	
Connecting Rod and Crankshaft Side Clearance New or Remanufactured Parts		0.20 mm 0.35 mm	MIN MAX	0.008 in 0.014 in	
Camshaft End Clearance		0.15 mm 0.33 mm	MIN MAX	0.006 in 0.013 in	
Hydraulic Pump Idler Gear End Clearance		0.10 mm 0.36 mm	MIN MAX	0.004 in 0.014 in	
Water Pump Idler Gear End Clearance		0.10 mm 0.36 mm	MIN MAX	0.004 in 0.014 in	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Camshaft Idler Gear End Clearance**		0.29 mm 0.51 mm	MIN MAX	0.012 in 0.020 in
 **Lower Housing-To-Cylinder Block Gear Backlash**		0.05 mm 0.51 mm	MIN MAX	0.002 in 0.015 in
 **Idler Gear Backlash**		0.05 mm 0.51 mm	MIN MAX	0.002 in 0.020 in
 **Piston Cooling Nozzle Mounting Capscrew Torque Value**		45 N•m		35 ft-lb
 **Valve Adjustment (Initial Set)**				
 **Aftercooler Hose Clamp Torque Value**		6 N•m		50 in-lb
 **Alternator Belt Tension**		670 N		150 lbf

If Valve Set Mark Is:	Remove Piston Cooling Nozzles On Cylinder Nos.
A	1,6
B	2,5
C	3,4

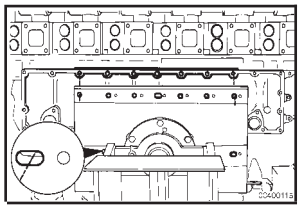
Valve Adjustment (Initial Set)

Valve Adjustment (Initial Set)			
Reference Point	mm		in
A	0.81	Exhaust	0.032
B	0.36	Intake	0.014

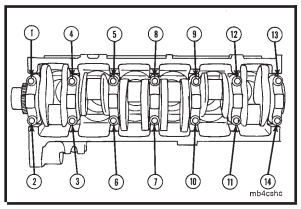
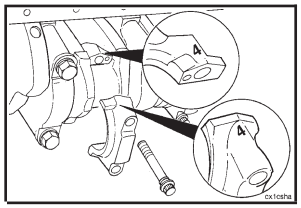
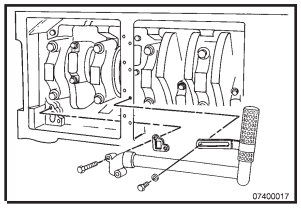
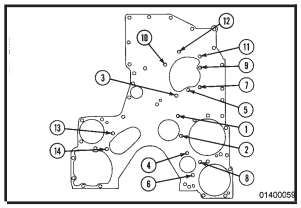
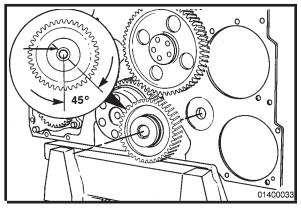
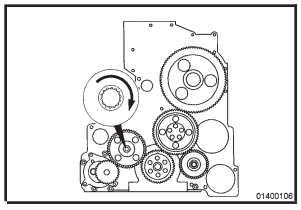
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	

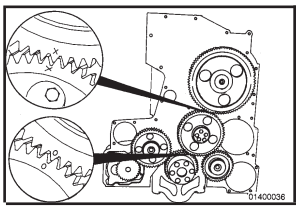
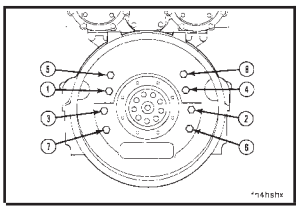
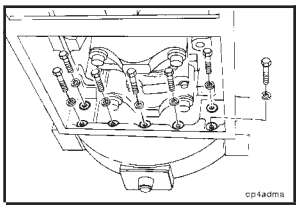
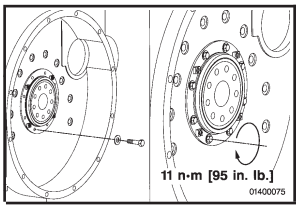
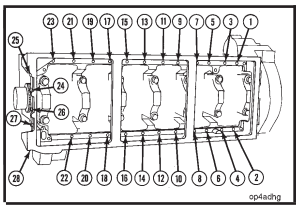
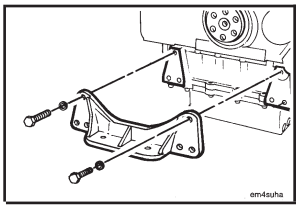
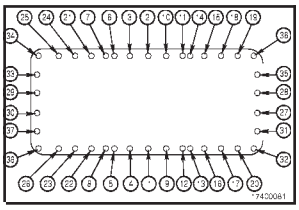
Complete Engine - Torque Values

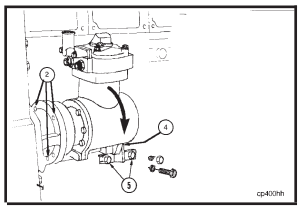
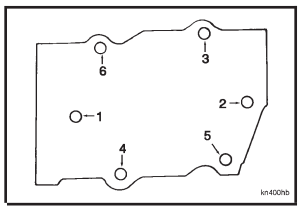
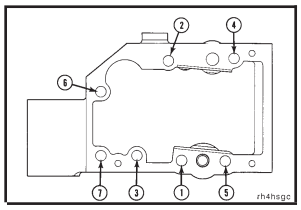
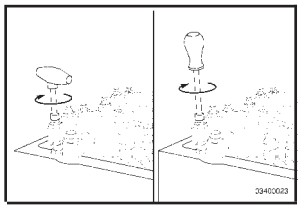
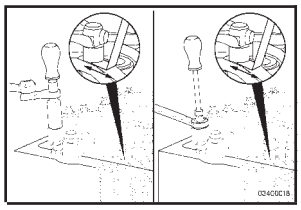
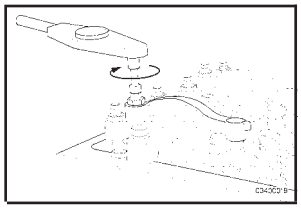
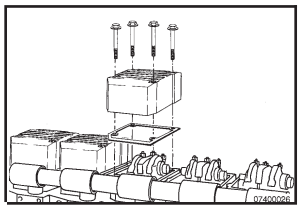
Engine Disassembly (009-029)

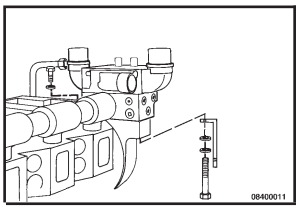
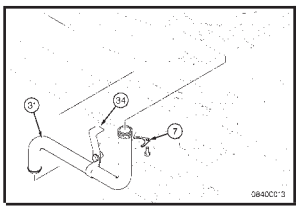
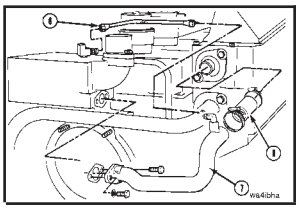
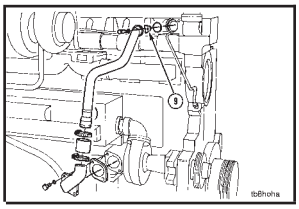
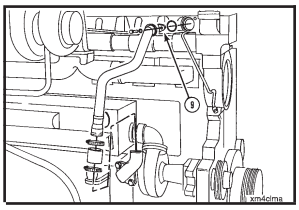
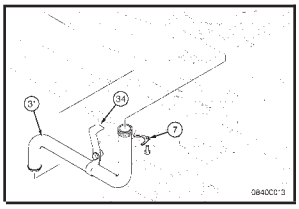
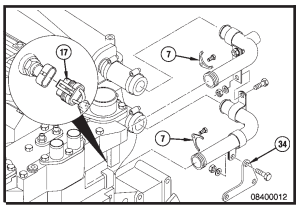
Engine Stand Mounting Capscrews		45 N•m	35 ft-lb	

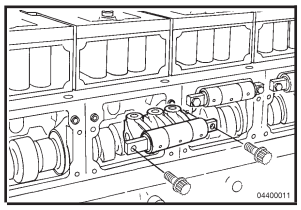
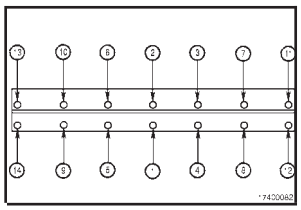
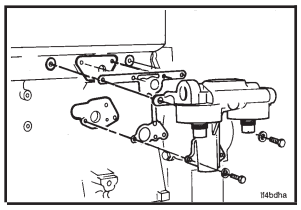
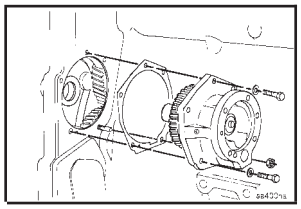
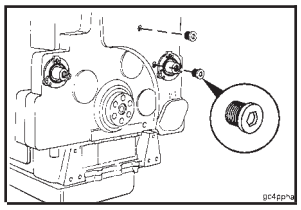
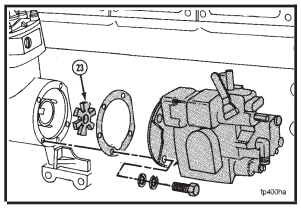
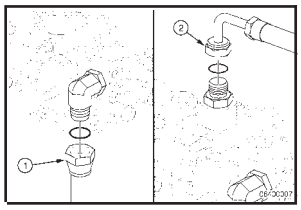
Engine Assembly (001-016)

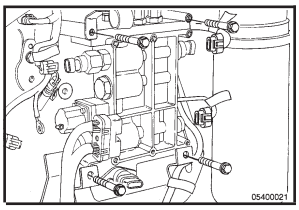
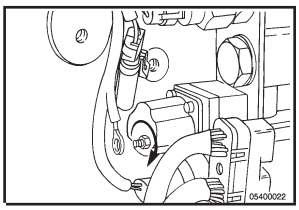
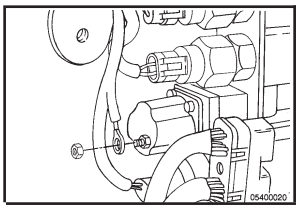
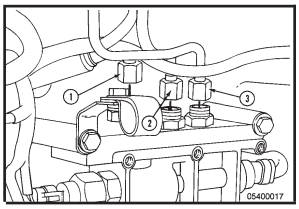
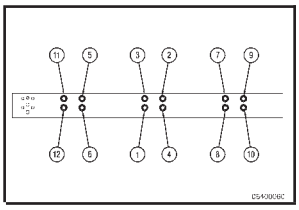
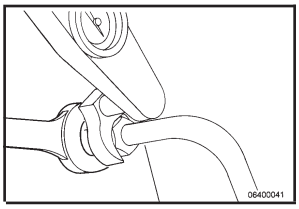
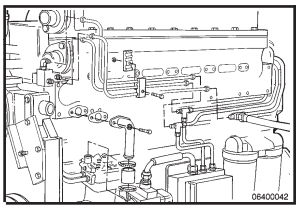
Main Bearing Cap Bolts	1	265 N•m	195 ft-lb	
	2	605 N•m	445 ft-lb	
	3	Loosen	Loosen	
	4	265 N•m	195 ft-lb	
	5	605 N•m	445 ft-lb	
Connecting Rod Capscrews	1	100 N•m	75 ft-lb	
	2	205 N•m	150 ft-lb	
	3	339 N•m	250 ft-lb	
	4	Loosen	Loosen	
	5	100 N•m	75 ft-lb	
	6	205 N•m	150 ft-lb	
	7	339 N•m	250 ft-lb	
Oil Suction Tube Mounting Capscrews		60 N•m	25 ft-lb	
		35 N•m	25 ft-lb	
Gear Cover Spacer Plate Capscrews		45 N•m	35 ft-lb	
Idler Gear		245 N•m	180 ft-lb	
Lube Oil Pump Idler Gear		245 N•m	180 ft-lb	

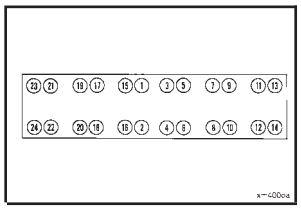
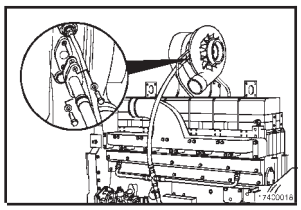
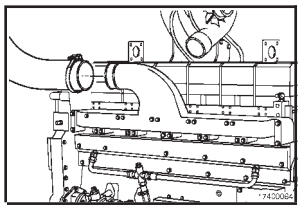
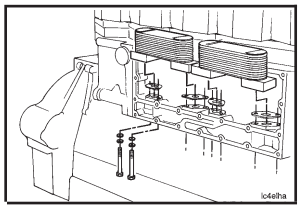
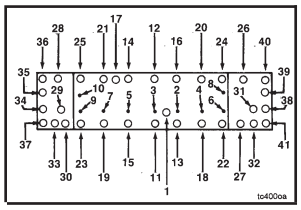
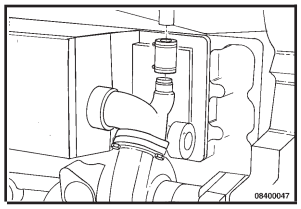
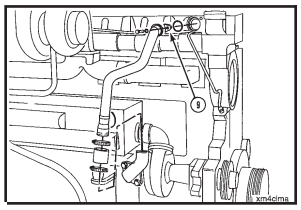
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
			
Camshaft Idler Gear Install			
Camshaft Idler Gear Mountig Capscrew	1	45 N•m	35 ft-lb
	2	95 N•m	70 ft-lb
	3	150 N•m	110 ft-lb
			
Flywheel Housing Mounting Capscrews	1	100 N•m	75 ft-lb
	2	205 N•m	150 ft-lb
			
Lube Oil Pan Adapter Mounting Capscrews			
3/8-16 inch		45 N•m	35 ft-lb
7/16-14 inch		65 N•m	50 ft-lb
			
Rear Main Seal Mounting Capscrews		11 N•m	95 in-lb
			
Oil Pan Adapter Capscrews			
Capscrews 1 – 23		60 N•m	45 ft-lb
Oil Pan Adapter Capscrews			
Capscrews 24 – 28		45 N•m	35 ft-lb
			
Front Engine Mount		195 N•m	145 ft-lb
			
Lube Oil Pan Mounting Capscrews		45 N•m	35 ft-lb

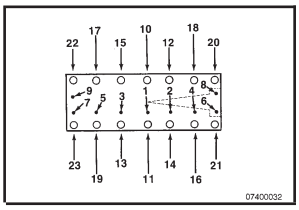
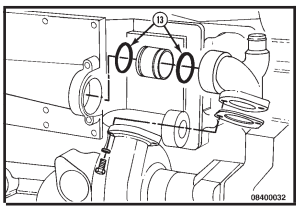
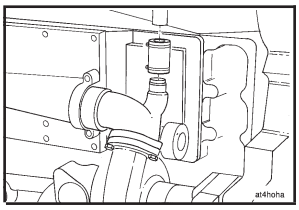
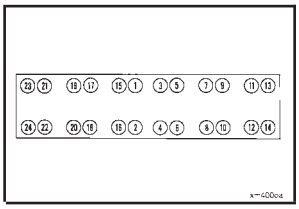
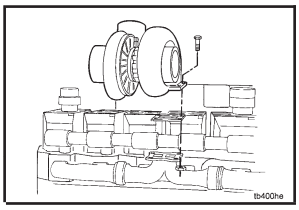
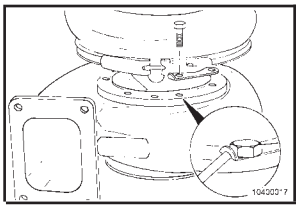
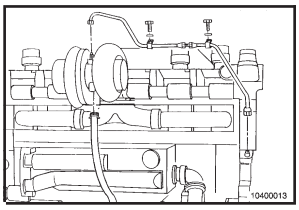
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Air Compressor Mounting Capscrews				
Capscrew 5		60 N•m	45 ft-lb	
Capscrew 4		45 N•m	35 ft-lb	
Capscrew 2		45 N•m	35 ft-lb	
Cylinder Head Capscrews	Step 1	68 N•m	50 ft-lb	
	Step 2	205 N•m	150 ft-lb	
	3	300 N•m	220 ft-lb	
	4	Rotate 90 Degrees		
Rocker Lever Housing Sequence Torque		95 N•m	70 ft-lb	
Valve Adjusting Screw		1 N•m	6 in-lb	
Valve Set-Feel Method				
With Torque Wrench Adapter, Part No. ST-669 (1)		45 N•m	35 ft-lb	
Without Adapter		60 N•m	45 ft-lb	
Valve Adjusting Screw Locknut		20 N•m	250 in-lb	
Valve Adjusting Screw		19 N•m	165 in-lb	
Rocker Lever Cover Capscrews		45 N•m	35 ft-lb	

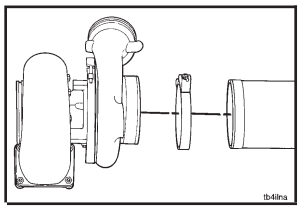
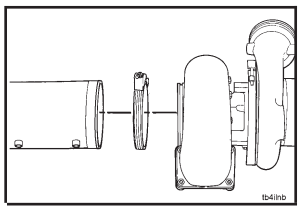
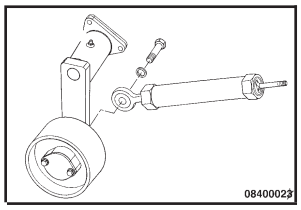
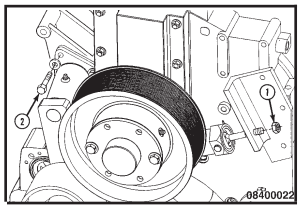
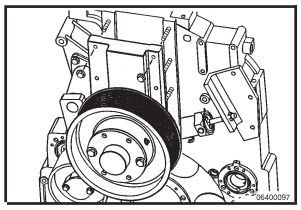
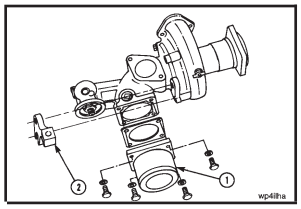
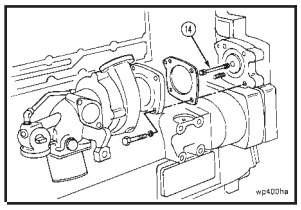
	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Thermostat Housing Support Capscrews**		45 N•m	35 ft-lb
	**Capscrew** **Hose Clamp**		20 N•m 6 N•m	15 ft-lb 50 in-lb
	**Aftercooler Coolant Return Tube Capscrews**		6 N•m	50 in-lb
	**Capscrew** **Hose Clamp**		45 N•m 6 N•m	35 ft-lb 50 in-lb
	**Capscrew** **Hose Clamp**		45 N•m 6 N•m	35 ft-lb 50 in-lb
	**Capscrew** **Hose Clamp**		20 N•m 6 N•m	15 ft-lb 50 in-lb
	**Capscrew** **Hose Clamp**		20 N•m 6 N•m	15 ft-lb 50 in-lb

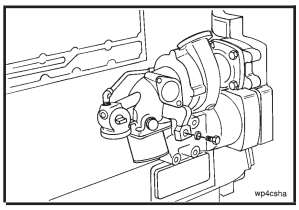
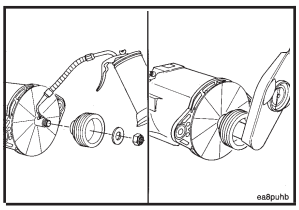
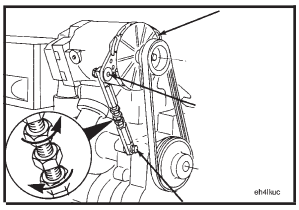
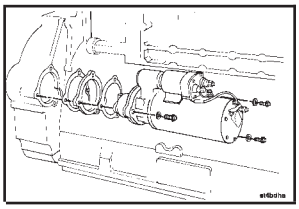
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cam Follower Mounting Capscrews	1	55 N•m	40 ft-lb	
	2	110 N•m	80 ft-lb	
	3	165 N•m	120 ft-lb	
Cam Follower Cover Capscrews		27 N•m	20 ft-lb	
Filter Head Capscrews		45 N•m	35 ft-lb	
Accessory Drive Capscrews		45 N•m	35 ft-lb	
O-Ring Plugs		25 N•m	20 ft-lb	
Fuel Pump Capscrews		45 N•m	35 ft-lb	
Fuel Pump Inlet Hose		88 N•m	65 ft-lb	
Fuel Supply Hose		60 N•m	45 ft-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Fuel Control Valve Body Assembly Capscrew**		45 N•m	35 ft-lb
	**Electrical Connection Post**		3 N•m	25 in-lb
	**Electrical Connection Nut**		2 N•m	15 in-lb
	**Control Valve Body Hoses**			
	Fuel Supply Hose (1)		61 N•m	45 ft-lb
	Timing and Rail Pressure Lines (2 and 3)		27 N•m	20 ft-lb
	**Front Fuel Manifold Capscrews**		9.6 N•m	85 in-lb
	**Fuel Tube Nut**		27 N•m	20 ft-lb
	**Air Inlet Connection Hose**			
	Flange Capscrew:		4 N•m	35 in-lb
	Clamp:		6 N•m	50 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Aftercooler Capscrews	Step 1 2	25 N•m 45 N•m	20 ft-lb 35 ft-lb	
Turbocharger Oil Return Line		45 N•m	35 ft-lb	
Rail Applications, Air Crossover Clamp		8 N•m	75 in-lb	
Oil Cooler Element Capscrews		45 N•m	35 ft-lb	
Torque Converter Cooler Cover Capscrews		45 N•m	35 ft-lb	
Aftercooler Supply Hose Clamp		5.6 N•m	50 in-lb	
Torque Converter Cooler Bypass Tube				
Capscrew		45 N•m	35 ft-lb	
Clamp		5.6 N•m	50 in-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Oil Cooler Cover Capscrews**		45 N•m	35 ft-lb
	**Water Pump Outlet Connection Capscrews**		45 N•m	35 ft-lb
	**Water Pump Outlet Connection Hose Clamps**		6 N•m	50 in-lb
	**Exhaust Manifold Capscrews**		45 N•m	35 ft-lb
	**Turbocharger Capscrews**		40 N•m	30 ft-lb
	**Bearing Housing Capscrews**		20 N•m	180 in-lb
	**Oil Supply Hose Fitting**		31 N•m	23 ft-lb

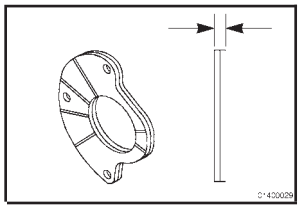
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Turbocharger Inlet Piping Clamp		8 N•m	75 in-lb	
Turbocharger Exhaust Piping Clamp		8 N•m	75 in-lb	
Belt Tensioner Capscrews		201 N•m	75 ft-lb	
Idler Arm Assembly Capscrews		45 N•m	35 ft-lb	
Fan Hub Nuts		34 N•m	25 ft-lb	
Water Pump Inlet Connection Capscrews		40 N•m	30 ft-lb	
Warer Pump Mounting Capscrews and Nut		45 N•m	35 ft-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	**Water Pump Support Bracket Capscrew**		206 N•m	150 ft-lb
	**Alternator Pulley Nut**		100 N•m	75 ft-lb
	**Belt Tensioning**			
	Jam Nuts		55 N•m	40 ft-lb
	Alternator Mounting Capscrews		55 N•m	40 ft-lb
	**Starting Motor Mounting Capscrews**			
	W/Cast Iron Flywheel Housing		215 N•m	160 ft-lb
	W/Aluminum Flywheel Housing		195 N•m	145 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	

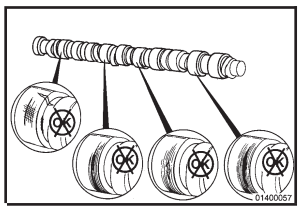
Cylinder Block - Specifications

Bearings, Main (001-006)

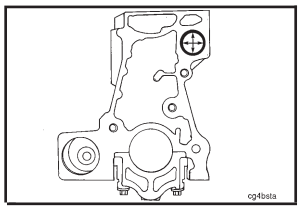


Thrust Bearing Thickness				
Standard or Oversize (OS)				
Standard	3.82 mm	MIN	0.1505 in	
	3.90 mm	MAX	0.1535 in	
0.010 (OS)	4.08 mm	MIN	0.1605 in	
	4.15 mm	MAX	0.1635 in	
0.020 (OS)	4.33 mm	MIN	0.1705 in	
	4.41 mm	MAX	0.1735 in	

Camshaft (001-008)

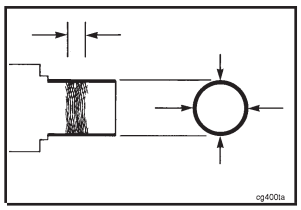


Camshaft Bushing Journal O.D.	76.07 mm	MIN	2.995 in	
	76.12 mm	MAX	2.997 in	

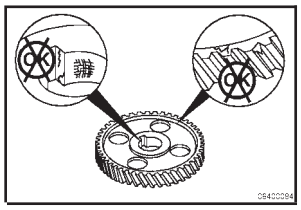


Camshaft Bushing I.D.	82.550 mm	MIN	3.2500 in	
	82.640 mm	MAX	2.2535 in	

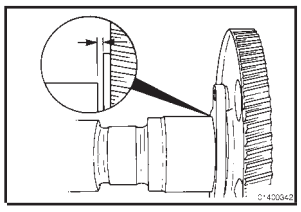
Camshaft Gear (Camshaft Removed) (001-013)



Camshaft O.D. (Gear Location)	57.200 mm	MIN	2.2520 in	
	57.210 mm	MAX	2.2525 in	

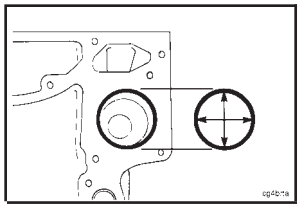


Camshaft Gear I.D.	57.200 mm	MIN	2.2520 in	
	57.210 mm	MAX	2.2525 in	

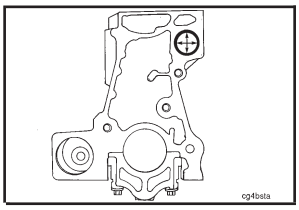
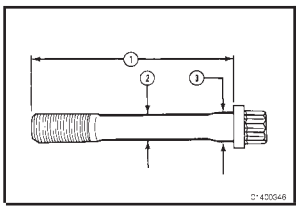
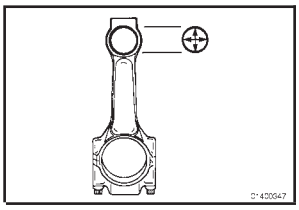
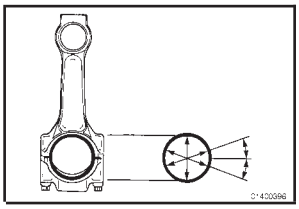
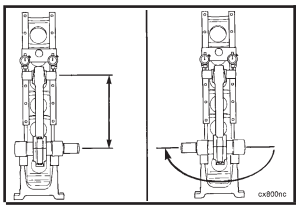
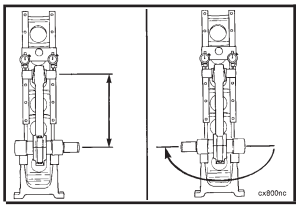


Camshaft to Camshaft Gear Clearance	0.15 mm	MIN	0.006 in	
	0.33 mm	MAX	0.013 in	

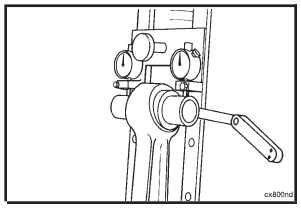
Camshaft Bushings (001-010)

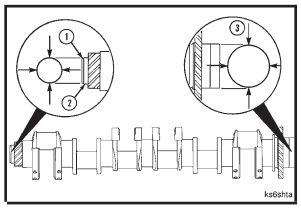


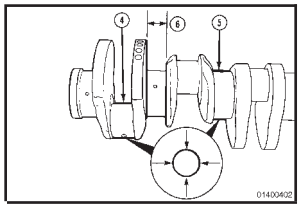
Camshaft Bushing Bore I.D.	88.989 mm	MIN	3.5035 in	
	89.015 mm	MAX	3.5045 in	

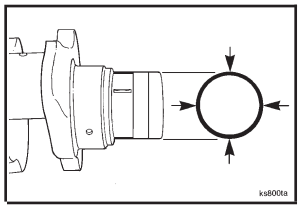
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Camshaft Bushing I.D.**		82.550 mm 82.640 mm	MIN MAX	3.2500 in 2.2535 in
 **Connecting Rod (001-014)**				
Capscrew Length (1)		117.09 mm 117.86 mm	MIN MAX	4.610 in 4.640 in
Capscrew O.D. (2)		15.26 mm 15.37 mm	MIN MAX	0.601 in 0.605 in
Capscrew O.D. (3)		17.35 mm 17.45 mm	MIN MAX	0.683 in 0.687 in
 **Connecting Rod Wrist Pin Bearing I.D.**		60.99 mm 61.02 mm	MIN MAX	2.4010 in 2.4025 in
 **Connecting Rod Bearing Bore I.D.**		107.995 mm 108.005 mm	MIN MAX	4.2518 in 4.2522 in
 **Connecting Rod Length**		289.69 mm 289.74 mm	MIN MAX	11.405 in 11.407 in
Measure the Connecting Rod Bend (Bore Alignment)				
 **Connecting Rod Bend**		0.010 mm 0.195 mm	MAX MAX	0.004 in 0.008 in

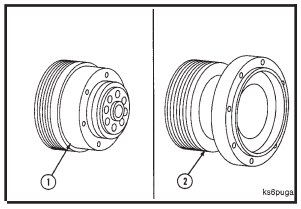
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Measure the Connecting Rod Twist					
Maximum Connecting Rod Twist					
Bushing Installed		0.25 mm	MAX	0.010 in	
Bushing Removed		0.51 mm	MAX	0.020 in	
Crankshaft (001-016)					
Crankshaft O.D.					
Location (1)		152.35 mm	MIN	5.998 in	
		152.40 mm	MAX	6.000 in	
Location (2)		111.07 mm	MIN	4.373 in	
		111.13 mm	MAX	4.375 in	
Location (3)		110.74 mm	MIN	4.360 in	
		110.77 mm	MAX	4.361 in	
Rod Bearing Journal O.D. (4)		101.524 mm	MIN	3.997 in	
		101.600 mm	MAX	4.000 in	
Main Bearing Journal O.D. (5)		139.637 mm	MIN	5.4975 in	
		139.700 mm	MAX	5.5000 in	
Thrust Distance (6)		60.30 mm	MIN	2.374 in	
		60.33 mm	MAX	2.375 in	
Crankshaft Gear, Front (Crankshaft Installed) (001-018)					
Crankshaft O.D. (Gear Location)		111.25 mm	MIN	4.380 in	
		111.28 mm	MAX	4.381 in	
Crankshaft Pulley (001-022)					
Pully O.D.		134.78 mm	MIN	5.3105 in	
		135.04 mm	MAX	5.3115 in	
Pully I.D.		110.780 mm	MIN	4.3610 in	
		110.806 mm	MAX	4.3620 in	
Cylinder Block (001-026)					
(13) Cylinder Block Height		481.91 mm	MIN	18.9735 in	
		482.76 mm	MAX	19.0065 in	
(14) Cylinder Block Height- Main bearing Saddle		407.70 mm	MIN	16.051 in	
		408.53 mm	MAX	16.084 in	
Cylinder Block and Liner Seats (001-027)					
Counterbore Depth		13.755 mm	MIN	0.5415 in	
		13.805 mm	MAX	0.5435 in	

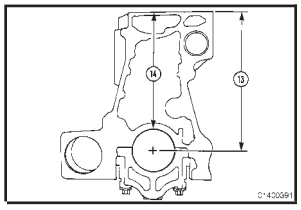


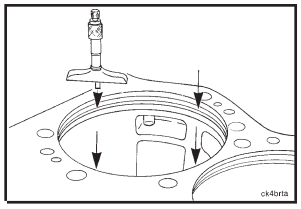


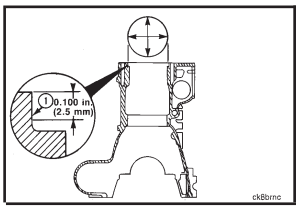
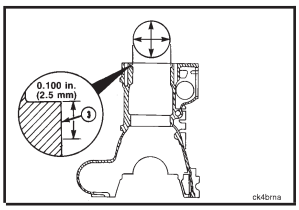
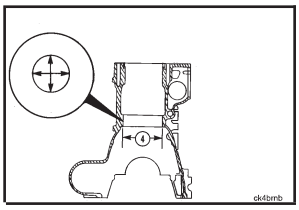
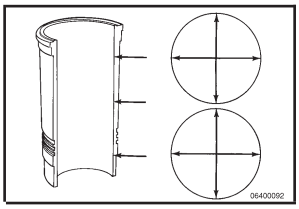
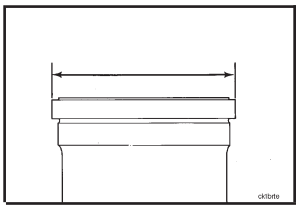
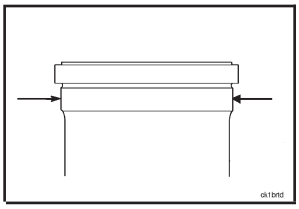
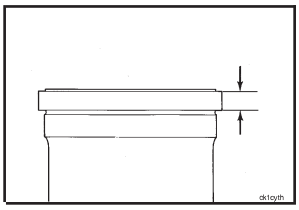


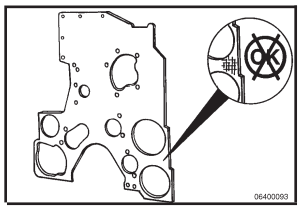
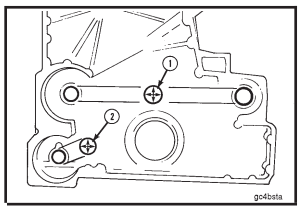
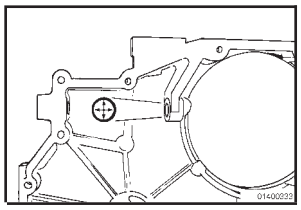
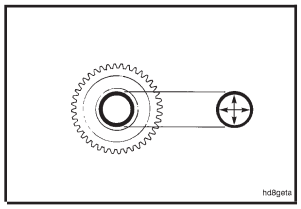
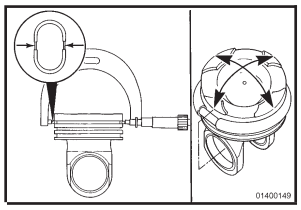
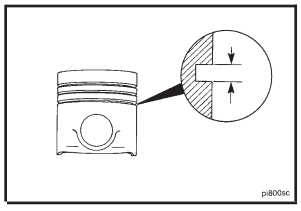
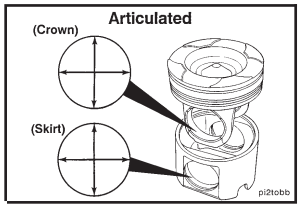


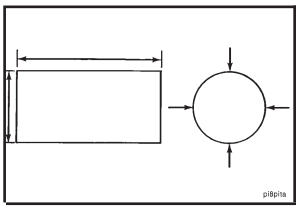
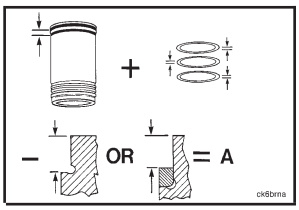
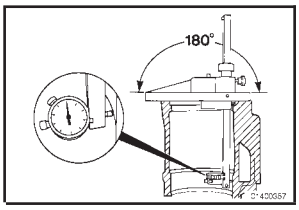
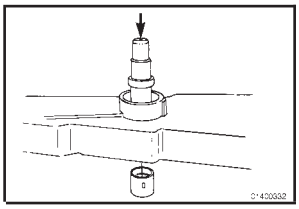






Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	**Counterbore Diameter - UPPER Press Fit Diameter**	188.16 mm 188.21 mm	MIN MAX	7.409 in 7.410 in
	**Counterbore Diameter - LOWER Press Fit Diameter**	180.09 mm 180.14 mm	MIN MAX	7.090 in 7.092 in
	**(4) Packing Ring Bore**	177.34 mm 177.40 mm	MIN MAX	6.982 in 6.984 in
	**Cylinder Liner (001-028)** **Cylinder Liner I.D.**	158.737 mm 158.877 mm	MIN MAX	6.2495 in 6.2550 in
	**Upper Press Fit Liner Flange Diameter** Standard Oversize 20/20	188.19 mm 188.24 mm 188.70 mm 188.75 mm	MIN MAX MIN MAX	7.409 in 7.411 in 7.429 in 7.431 in
	**Lower Press Fit Area O.D.** Standard Oversize 20/20	180.16 mm 180.21 mm 180.67 mm 180.72 mm	MIN MAX MIN MAX	7.093 in 7.095 in 7.113 in 7.115 in
	**Liner Flange Thickness**	13.398 mm 13.424 mm	MIN MAX	0.5275 in 0.5285 in

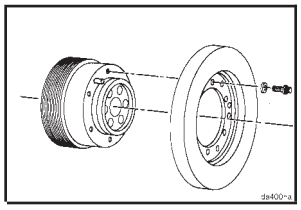
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Gear Cover Spacer Plate (001-029)					
Accessory Drive Stud (1)- Installed Height		31.88 mm 33.15 mm	MIN MAX	1.255 in 1.305 in	
Water Pump Drive Stud (2) — Installed Height Gear Spacer Plate and Gear Housing		62.99 mm 63.75 mm	MIN MAX	2.480 in 2.510 in	
Gear Cover, Front (001-031)					
Accessory Drive & Water Pump Drive Bushing I.D.		39.75 mm 39.90 mm	MIN MAX	1.565 in 1.571 in	
Hydraulic Pump Drive (2) Bushing I.D.		38.13 mm 38.25 mm	MIN MAX	1.501 in 1.506 in	
Barring Mechanism Bushing Bore		18.215 mm 18.265 mm	MIN MAX	0.717 in 0.719 in	
Idler Gear, Camshaft (001-036)					
Idler Gear Bushing I.D.		47.638 mm 47.714 mm	MIN MAX	1.8755 in 1.8785 in	
Piston (001-043)					
Ring Groove Wear Limits (Diameter Over Pins)					
Top Ring		159.100 mm	MIN	6.2638 in	
Second Ring		159.413 mm	MIN	6.2761 in	
Piston Oil Ring Groove Width		4.788 mm 4.851 mm	MIN MAX	0.1885 in 0.1910 in	
Articulated Piston Pin Bore I.D. (Crown)		60.960 mm 61.059 mm	MIN MAX	2.4000 in 2.4039 in	
Articulated Piston Pin Bore I.D. (Skirt)		60.949 mm 60.961 mm	MIN MAX	2.3996 in 2.4000 in	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
				
Piston Pin O.D.		60.929 mm	MIN	2.3988 in
		60.935 mm	MAX	2.3990 in
Piston Pin Length		132.59 mm	MIN	5.220 in
		132.85 mm	MAX	5.230 in
				
Cylinder Block Counterbore (001-058)				
Cylinder Liner Protrusion		0.13 mm	MIN	0.003 in
		0.18 mm	MAX	0.007 in
				
Liner Bore Run Out		0.130 mm	MAX	0.005 in
				
Gear Cover Accessory Drive Bushing (001-066)				
Front Cover Bushing Bore I.D.				
Accessory and Water Pump Drive		43.078 mm	MIN	1.696 in
		43.104 mm	MAX	1.697 in
Hydraulic Pump Drive		41.275 mm	MIN	1.625 in
		41.301 mm	MAX	1.626 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

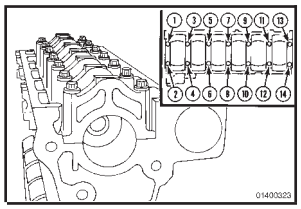
Cylinder Block - Torque Values

Crankshaft Pulley (001-052)



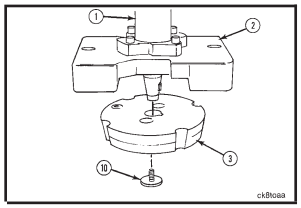
Vibration Damper		140 N•m	105 ft-lb

Cylinder Block (001-026)



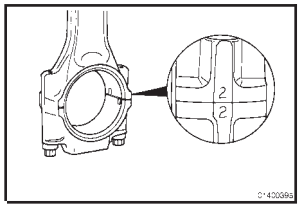
Step 1		270 N•m	200 ft-lb
Step 2		610 N•m	450 ft-lb

Cylinder Block Counterbore (001-058)



Cylinder Block Counter Bore Mechining Tool		40 N•m	30 ft-lb
		40 N•m	30 ft-lb

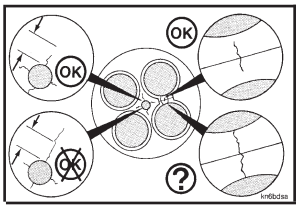
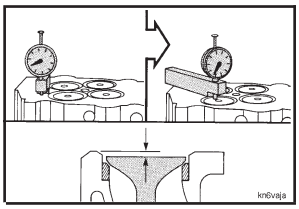
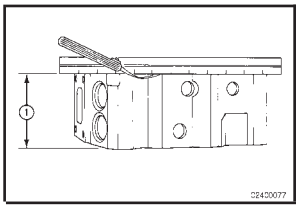
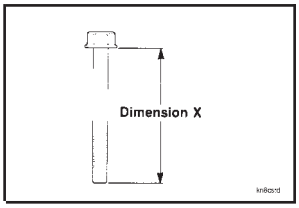
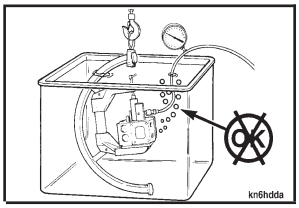
Connecting Rod (001-014)



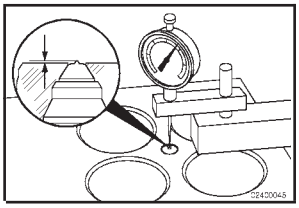
Connecting Rod Capscrew			
	1	100 N•m	75 ft-lb
	2	200 N•m	150 ft-lb
	3	290 N•m	214 ft-lb
Loosen			
Connecting Rod Capscrew			
	5	100 N•m	75 ft-lb
	6	200 N•m	150 ft-lb
	7	290 N•m	214 ft-lb

Cylinder Head - Specifications

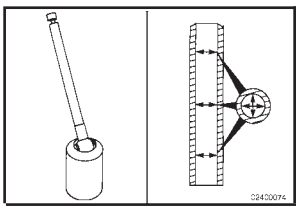
Cylinder Head (002-004)

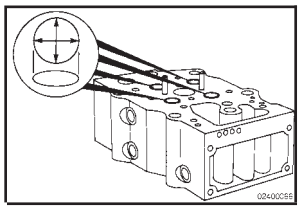
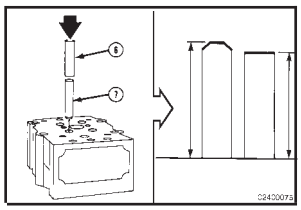
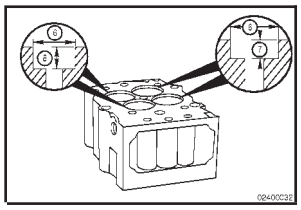
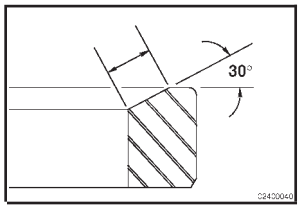
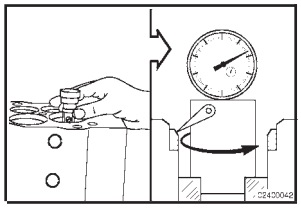
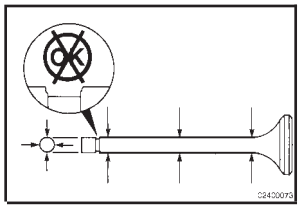
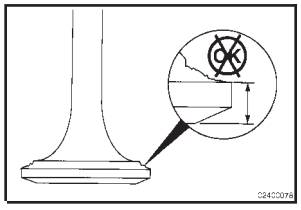
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Allowable Crack Length**		6 mm	MAX	0.25 in
 **Allowable Valve Depth from the Combustion Face**		0.00 mm 0.51 mm	MIN MAX	0.000 in 0.020 in
 **Minimum Head Thickness (1)**		150.114 mm	MIN	5.910 in
 **Cylinder Head Capscrew Free Length**		207.3 mm	MAX	8.160 in
 **Cylilnder Head Pressure Test–Air Pressure**		552 kPa	MAX	80 psi

Cylinder Head Injector Bore (002-011)

 **Injector Protrusion**		2.42 mm 2.92 mm	MIN MAX	0.095 in 0.115 in

Valve Guide, Cylinder Head (002-017)

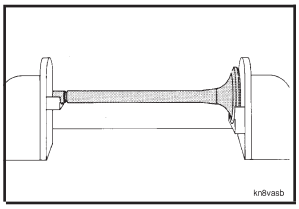
 **Valve Guide I.D. (Installed)**		10.551 mm 10.589 mm	MIN MAX	0.4154 in 0.4169 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Valve Guide Bore I.D.		21.438 mm 21.463 mm	MIN MAX	0.8440 in 0.8450 in	
Valve Guide Height (to Spring Pocket)		37.97 mm 38.48 mm	MIN MAX	1.495 in 1.515 in	
Valve Guide Height (to Top of Head)		13.97 mm 14.47 mm	MIN MAX	0.550 in 0.570 in	
Valve Seat Bore (002-018)					
Valve Seat Bore Measurements					
Intake Diameter		60.37 mm 60.40 mm	MIN MAX	2.377 in 2.378 in	
Intake Depth		13.00 mm 13.13 mm	MIN MAX	0.492 in 0.497 in	
Exhaust Diameter		60.37 mm 60.40 mm	MIN MAX	2.377 in 3.378 in	
Exhaust Depth		12.50 mm 12.62 mm	MIN MIN	0.492 in 0.497 in	
Valve Seat Insert, Cylinder Head (002-019)					
Valve Seat Width					
Intake		3.05 mm 3.55 mm	MIN MAX	0.120 in 0.140 in	
Exhaust		1.52 mm 2.54 mm	MIN MAX	0.060 in 0.100 in	
Valve Seat to Guide Concentricity		0.05 mm	MAX	0.002 in	
Valve, Cylinder Head (002-020)					
Valve Stem O.D.		10.490 mm 10.510 mm	MIN MAX	0.4130 in 0.4138 in	
Valve Head Thickness (at the O.D.)		3.94 mm	MIN	0.155 in	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Coil Shot Amperage

Coil Shot Amperage (Ampere Turns)	
MIN	400 D.C. or rectified A.C.
MAX	800 D.C. or rectified A.C.



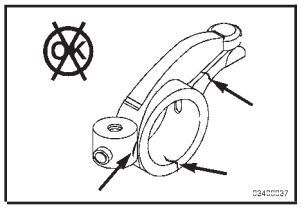
Head Shot Amperage

Head Shot Amperage (Ampere)	
MIN	500 D.C. or rectified A.C.
MAX	700 D.C. or rectified A.C.

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Rocker Levers - Specifications

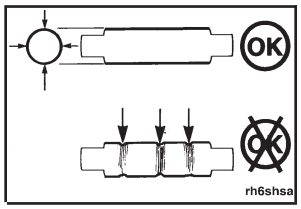
Rocker Lever (003-008)



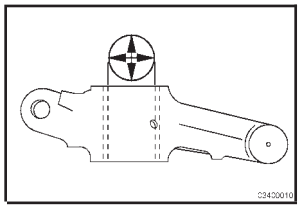
Amperage (Ampere Turns)

Amperage (Ampere Turns)
1200 D.C. or rectified A.C.
2000 D.C. or rectified A.C.

Rocker Lever Assembly (003-009)

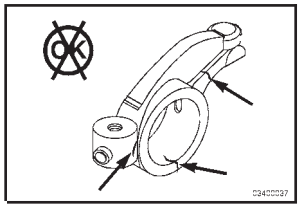


Rocker Arm Shaft O.D.	47.592 mm	MIN	1.8737 in
	47.634 mm	MAX	1.8753 in



Bushing Bore I.D.	47.66 mm	MIN	1.876 in
	47.73 mm	MAX	1.879 in

Rocker Lever Bushings (003-010)

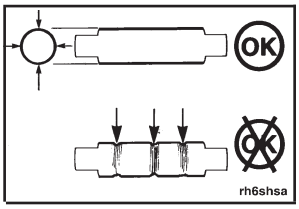


Lever Bore I.D.	49.25 mm	MIN	1.939 in
	49.27 mm	MAX	1.940 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

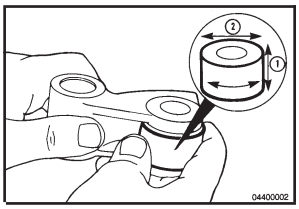
Cam Followers/Tappets - Specifications

Cam Follower Assembly (004-001)



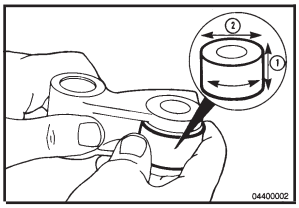
Cam Follower Shaft O.D.

28.538 mm	MIN	1.1235 in
28.575 mm	MAX	1.125 in



Cam Follower Roller Clearance

Cam Follower Roller Clearance			
Reference Point	**mm**		**in**
(1)	0.230	MIN	0.009
	0.610	MAX	0.024
(2)	0.076	MIN	0.003
	0.114	MAX	0.0045



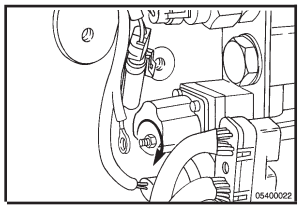
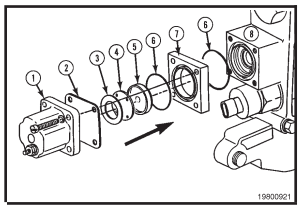
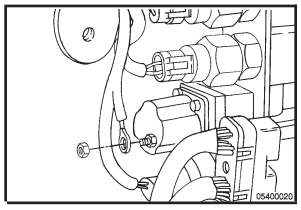
Cam Follower Lever I.D.

28.611 mm	MIN	1.1264 in
28.661 mm	MAX	1.1284 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	

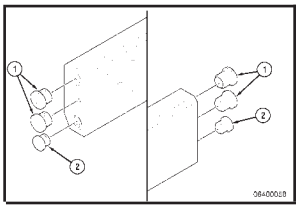
Fuel System - Torque Values

Fuel Shutoff Valve (FSOV) (005-043)

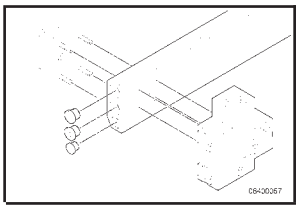
	3 N•m	25 in-lb	
	8 N•m	72 in-lb	
	2 N•m	15 in-lb	

Injectors and Fuel Lines - Torque Values

Fuel Manifold (Supply) (006-022)



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Manifold Plugs			
Plug (1):		20 N•m	180 in-lb
Plug (2):		7 N•m	60 in-lb

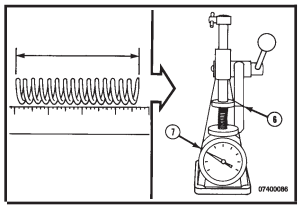


Fuel Connection Block		10 N•m	90 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

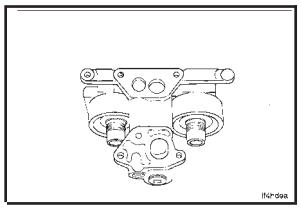
Lubricating Oil System - Specifications

Lubricating Oil Filter Head (007-015)



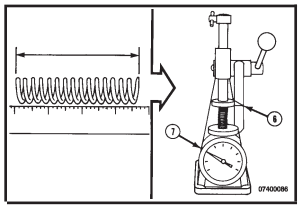
Bypass Plunger Spring			
Free Length	88.98 mm	MIN	3.500 in
Working Height (6)	50.80 mm	MAX	2.000 in
Spring Force (7)	26 N•m	MIN	19.3 ft-lb
	29 N•m	MAX	21.3 ft-lb

Lubricating Oil Filter Head (LF670) (007-015)



LF670 Filter Head Adapter 88 N•m
65 ft-lb

Lubricating Oil Filter Head (Remote-Mounted) (007-017)

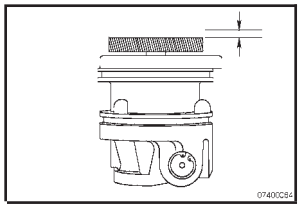


Bypass Plunger Spring			
Free Length	88.98 mm	MAX	3.500 in
Working Height (6)	50.80 mm	MAX	2.000 in
Spring Force (7)	26 N•m	MIN	19.3 ft-lb
	29 mm	MAX	21.3 in

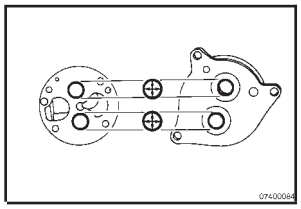
Lubricating Oil Pan (007-025)

Oil Pan Capacities			
Shallow full length	49 liters	MIN	13 U.S.gal
PN 3086097	61 liters	MAX	16 U.S.gal
Long (1/3) deep	49 liters	MIN	13 U.S.gal
PN 3086096	61 liters	MAX	16 U.S.gal
Short (1/3) deep	49 liters	MIN	13 U.S.gal
PN 3331695	61 liters	MAX	16 U.S.gal
Marine, deep rear	64 liters	MIN	17 U.S.gal
PN 3096460	72 liters	MAX	19 U.S.gal
Power Generator	102 liters	MIN	27 U.S.gal
PN 3331568	114 liters	MAX	30 U.S.gal

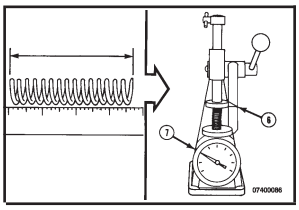
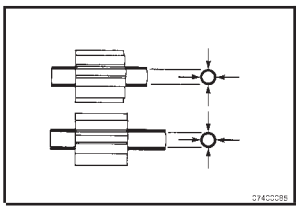
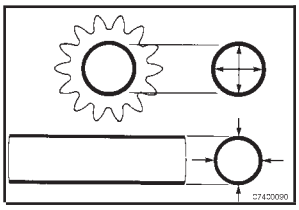
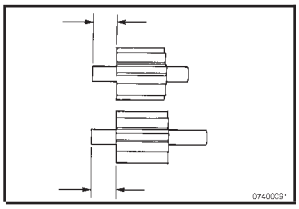
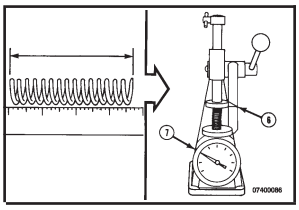
Lubricating Oil Pump (007-031)

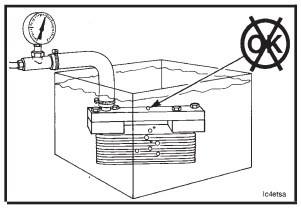
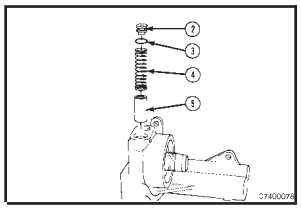
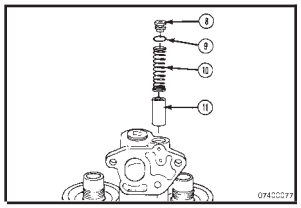
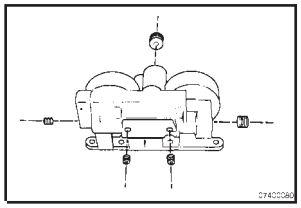
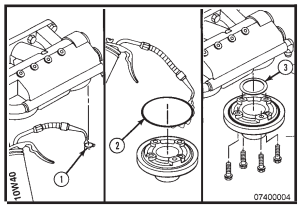
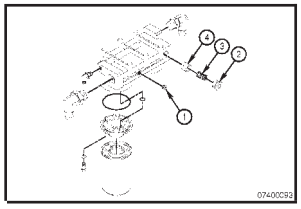
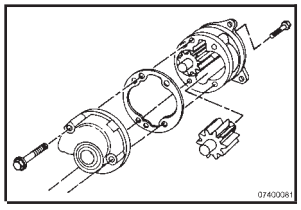


Oil Pump End Clearance	0.1016 mm	MIN	0.004 in
	0.2540 mm	MAX	0.010 in

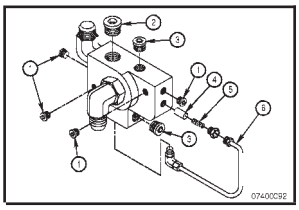


Bushing I.D.	22.263 mm	MIN	0.8765 in
	22.324 mm	MAX	0.8785 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
				
Pressure Regulator Spring Free Length		95 mm	Nominal	3.75 in
Spring Force @ 63.88 mm [2.5 in] Working Height		322 N	MIN	72 lb
		344 N	MAX	77 lb
				
Shaft O.D.		22.212 mm	MIN	0.8745 in
		22.225 mm	MAX	0.8750 in
				
Gear I.D.		22.169 mm	MIN	0.8728 in
		22.195 mm	MAX	0.8738 in
Shaft O.D.		22.212 mm	MIN	0.8745 in
		22.225 mm	MAX	0.8750 in
				
Gear Location on Shaft				
Idler		26.162 mm	MIN	1.03 in
		26.67 mm	MAX	1.051 in
Drive		26.162 mm	MIN	1.03 in
		26.416 mm	MAX	1.040 in
				
Oil Transfer Connection (007-061)				
Piston Cooling Nozzle Spring				
Free Length		88.98 mm	MAX	3.500 in
Working Height (6)		50.80 mm	MAX	2.000 in
Spring Force (7)		26 N•m	MIN	19.3 ft-lb
		29 N•m	MAX	21.3 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Lubricating Oil System - Torque Values				
Lubricating Oil Cooler (007-003)				
Lube Oil Cooler Element Pressure Test		415 kPa	60 psi	
Lubricating Oil Filter Head (007-015)				
Bypass Plunger and Spring		54 N•m	40 ft-lb	
Piston Cooling Nozzle Plunger and Spring		54 N•m	40 ft-lb	
Oil Filter Head Pipe Plugs				
1-5/16		61 N•m	45 ft-lb	
9/16		14 N•m	10 ft-lb	
Lube Oil Filter Head Adapter		23 N•m	17 ft-lb	
Lubricating Oil Filter Head (Remote-Mounted) (007-017)				
9/16 Plug		14 N•m	10 ft-lb	
1-3/16 Plug		54 N•m	40 ft-lb	
1-7/8 Plug		95 N•m	70 ft-lb	
Lubricating Oil Pump (007-031)				
Lube Oil Pump Rear Cover		45 N•m	35 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



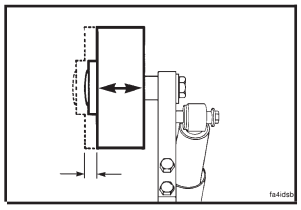
Oil Transfer Connection (007-061)

9/16 Plug	14 N•m	10 ft-lb
1 3/16 Plug	54 N•m	40 ft-lb
1 7/8 Plug	95 N•m	70 ft-lb

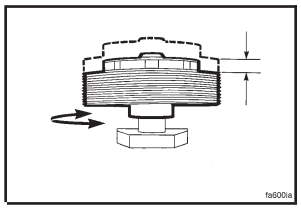
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	

Cooling System - Specifications

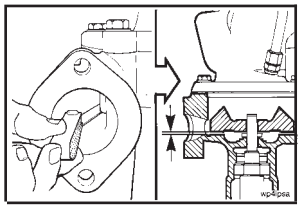
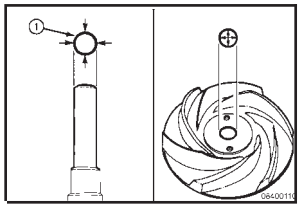
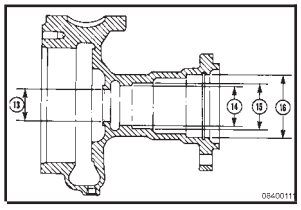
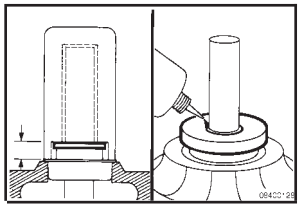
Fan Drive Idler Pulley Assembly (008-030)

Bearing End Clearance	0.08 mm	MIN	0.003 in	
	0.25 mm	MAX	0.010 in	

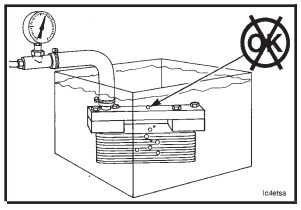
Fan Hub, Belt Driven (008-036)

Bearing End Clearance	0.025 mm	MIN	0.001 in	
	0.102 mm	MAX	0.004 in	

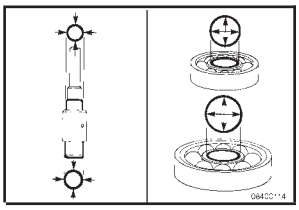
Water Pump (008-062)

Impeller Vane-To-Body Clearance	0.58 mm	MIN	0.023 in	
	0.86 mm	MAX	0.034 in	
Impeller to Shaft Press Fit	0.03 mm	MIN	0.001 in	
	0.07 mm	MAX	0.003 in	
Housing Bore I.D.				
(13) Water Seal	36.45 mm	MIN	1.435 in	
	36.47 mm	MAX	1.436 in	
(14) Oil Seal	44.43 mm	MIN	1.749 in	
	44.48 mm	MAX	1.751 in	
(15) Rear Bearing	51.996 mm	MIN	2.0471 in	
	52.215 mm	MAX	2.0557 in	
(16) Front Bearing	71.996 mm	MIN	2.8345 in	
	72.215 mm	MAX	2.8431 in	
Seat Dimension	10.52 mm	MIN	0.414 in	
	10.57 mm	MAX	0.416 in	

Torque Converter Cooler (008-065)

Air Pressure	415 kPa	MAX	60 psi	

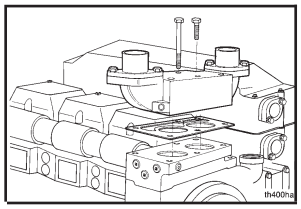
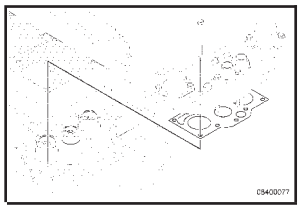
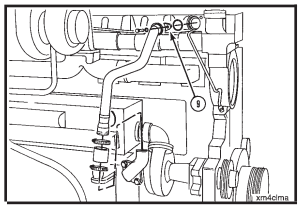
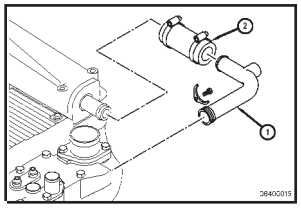
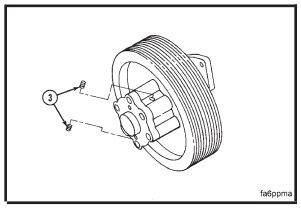
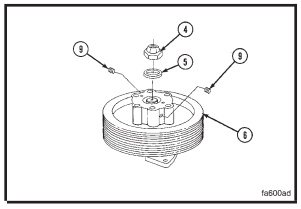
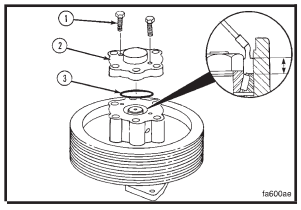
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	

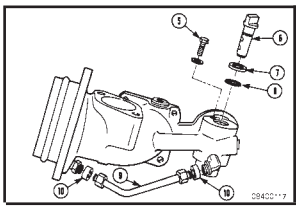
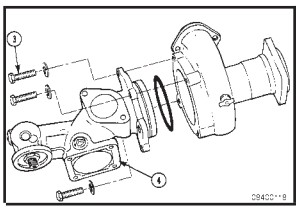
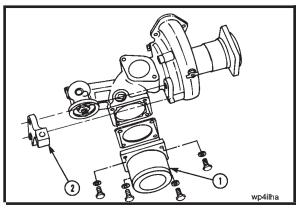
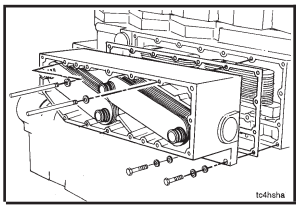
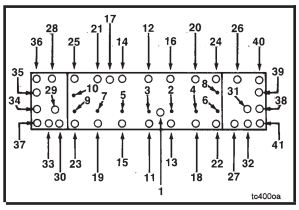
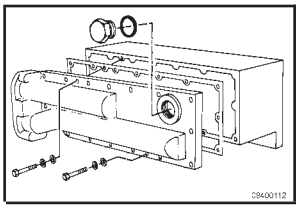


Water Pump Bearings (008-071)

Bearing to Shaft Differences

Clearance	0.003 mm	MAX	0.0001	in
Interference	0.018 mm	MAX	0.0007	in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cooling System - Torque Values				
Coolant Thermostat (008-013)				
Thermostat Housing Capscrews		45 N•m	35 ft-lb	
Thermostat Housing Capscrews		45 N•m	35 ft-lb	
Hose Clamp		6 N•m	50 in-lb	
Hose Clamp		6 N•m	50 in-lb	
Fan Hub, Belt Driven (008-036)				
Fan Hub Grease Fittings		15 N•m	135 in-lb	
Fan Hub Lock Nut		610 N•m	450 ft-lb	
Fan Hub Pilot Capscrews		20 N•m	15 ft-lb	

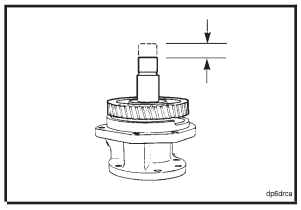
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
		**Water Pump (008-062)**	
	Water Pump Shut Off Valve Capscrew	20 N•m	15 ft-lb
		45 N•m	35 ft-lb
	**Water Pump Inlet Connection Capscrews**	40 N•m	30 ft-lb
		**Torque Converter Cooler (007-018)**	
	Torque Converter Cooler Housing Capscrews	130 N•m	95 ft-lb
	**Torque Converter Cooler Cover**	45 N•m	35 ft-lb
	**Torque Converter Cooler Heater Plug**	75 N•m	55 ft-lb

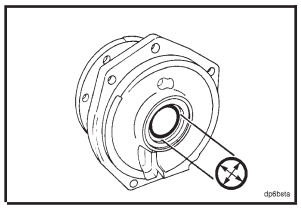
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	

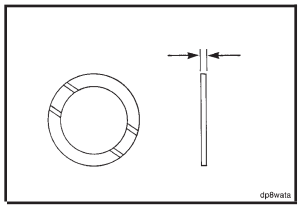
Drive Units - Specifications

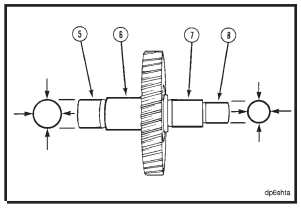
Fuel Pump Drive (009-011)

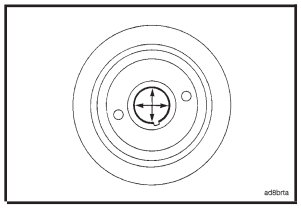
Fuel Pump/Compressor Drive End Clearance		0.05 mm	MIN	0.002 in
		0.30 mm	MAX	0.012 in
Bushing I.D.		33.43 mm	MIN	1.316 in
		33.50 mm	MAX	1.319 in
Thrust Bearing Thickness		2.36 mm	MIN	0.093 in
		2.41 mm	MAX	0.095 in
Shaft O.D.				
	(5)	34.963 mm	MIN	1.3765 in
		34.976 mm	MAX	1.3770 in
	(6)	34.662 mm	MIN	1.5616 in
		39.674 mm	MAX	1.5620 in
	(7)	33.30 mm	MIN	1.300 in
		33.33 mm	MAX	1.312 in
	(8)	25.476 mm	MIN	1.0030 in
		25.489 mm	MAX	1.0035 in
Pully I.D.		34.912 mm	MIN	1.3745 in
		34.938 mm	MAX	1.3755 in
Lovejoy Coupling I.D.		25.425 mm	MIN	1.0010 in
		25.438 mm	MAX	1.0015 in
Spline Coupling I.D.		25.400 mm	MIN	1.0000 in
		25.425 mm	MAX	1.0010 in
End Clearance		0.05 mm	MIN	0.002 in
		0.30 mm	MAX	0.012 in

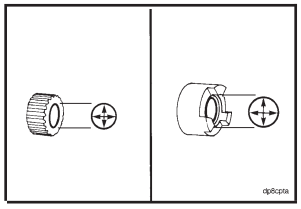


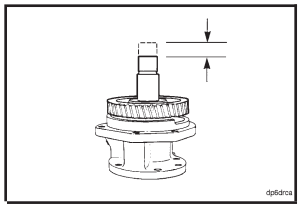


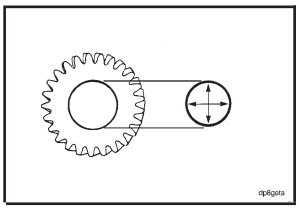
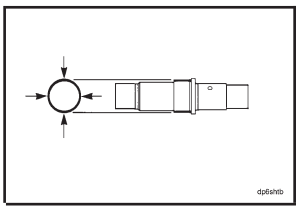
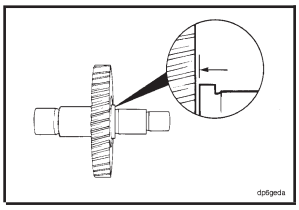
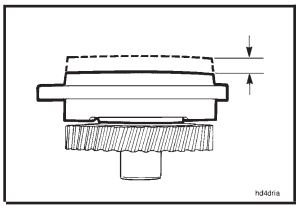
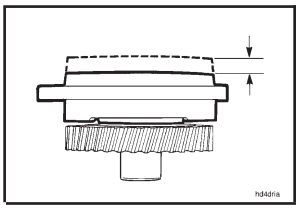
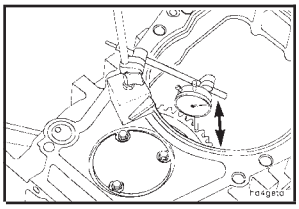
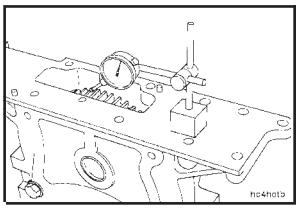


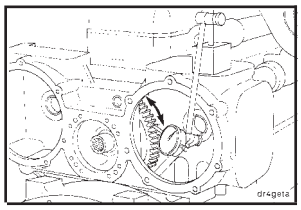




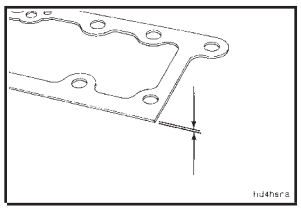




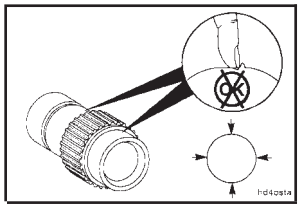
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	**Fuel Pump Drive Gear and Shaft (009-013)**			
	Gear I.D.	39.73 mm 39.75 mm	MIN MAX	1.564 in 1.565 in
	**Shaft O.D.**	39.789 mm 39.802 mm	MIN MAX	1.5665 in 1.5670 in
	**Fuel Pump Drive Gear to Shaft**	0.05 mm	MAX	0.002 in
	**Hydraulic Pump Drive (009-016)**			
	End Clearance	0.13 mm 0.48 mm	MIN MAX	0.005 in 0.019 in
	**End Clearance**	0.13 mm 0.48 mm	MIN MAX	0.005 in 0.019 in
	**Rear Gear Drive (Lower Assembly) (009-023)**			
	Idler Gear End Clearance	0.10 mm 0.51 mm	MIN MAX	0.004 in 0.020 in
	**Lower Housing-To-Cylinder Block Gear Backlash**	0.05 mm 0.51 mm	MIN MAX	0.002 in 0.015 in

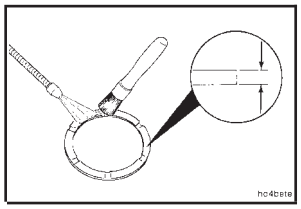
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Idler Gear Backlash		0.05 mm 0.51 mm	MIN MAX	0.002 in 0.020 in	

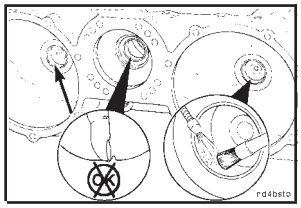
Rear Gear Drive (Upper Assembly) (009-024)

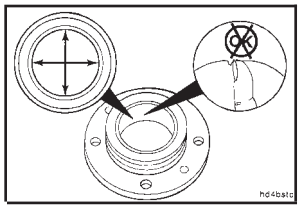


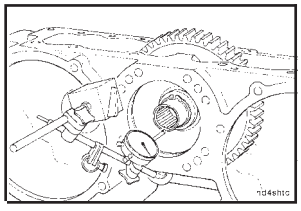
Upper to Lower Housing Gasket Thickness-Nominal (New*)			
Part No. 205723	0.38 mm	Nominal	0.015 in
Part No. 3077231	0.51 mm	Nominal	0.020 in
Part No. 3201852	0.76 mm	Nominal	0.030 in
Center Drive Shaft Bushing I.D.	47.536 mm 47.549 mm	MIN MAX	1.8715 in 1.8720 in
Upper Housing Thrust Bearing Thickness	2.27 mm 2.31 mm	MIN MAX	0.085 in 0.091 in
Hydraulic Drive Housing Bushing I.D.	47.60 mm 47.68 mm	MIN MAX	1.874 in 1.877 in
Hydraulic Pump Support Bushing I.D.	47.60 mm 47.68 mm	MIN MAX	1.874 in 1.877 in
Center Drive End Clearance	0.10 mm 0.51 mm	MIN MAX	0.004 in 0.020 in

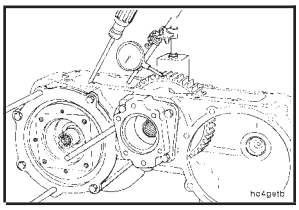
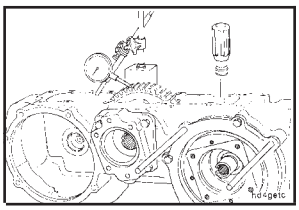
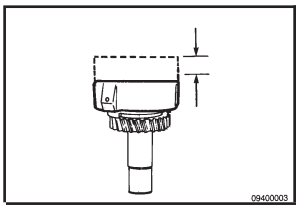
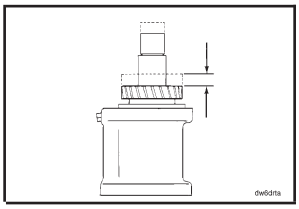
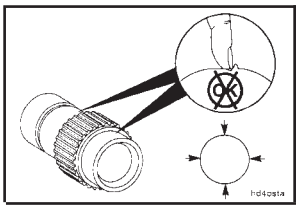
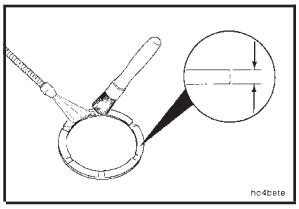
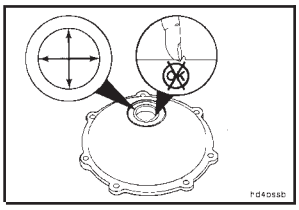


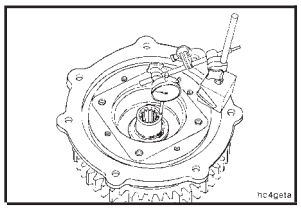




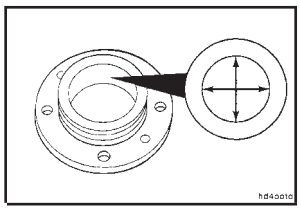
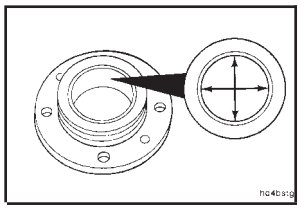




Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
 **Center Drive Gear to Outer Drive Gear Backlash**		0.10 mm 0.51 mm	MIN MAX	0.004 in 0.020 in
 **Center Drive Gear to Outer Drive Gear Backlash**		0.10 mm 0.51 mm	MIN MAX	0.004 in 0.020 in
				
Water Pump Drive (009-029)				
Water Pump Drive End Clearance		0.23 mm 0.33 mm	MIN MAX	0.009 in 0.013 in
 **Water Pump Drive End Clearance**		0.23 mm 0.33 mm	MIN MAX	0.009 in 0.013 in
				
Outer Hydraulic Pump Support Drive (009-036)				
Drive Shaft Bushing Diameters		47.536 mm 47.549 mm	MIN MAX	1.8715 in 1.8720 in
 **Thrust Bearing Thickness**		2.27 mm 2.31 mm	MIN MAX	0.085 in 0.091 in
 **Hydraulic Pump Support Bushing I.D.**		47.60 mm 47.68 mm	MIN MAX	1.874 in 1.877 in

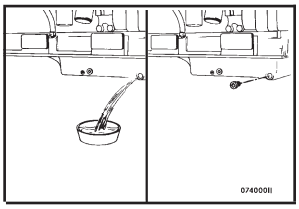
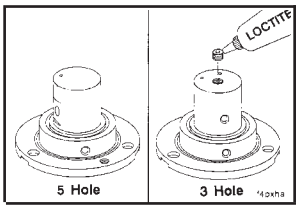
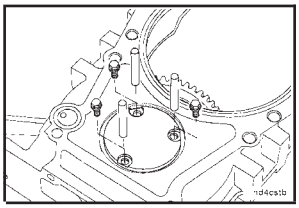
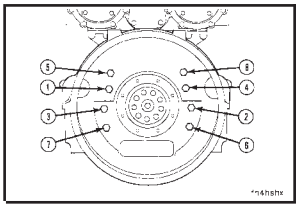
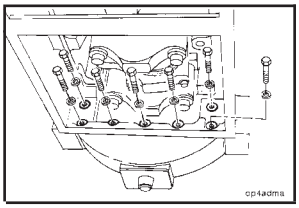
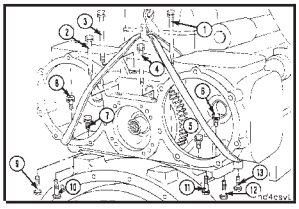
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Hydraulic Drive Gear End Clearance		0.10 mm 0.51 mm	MIN MAX	0.004 in 0.020 in	

Hydraulic Pump Support Bushing (009-037)

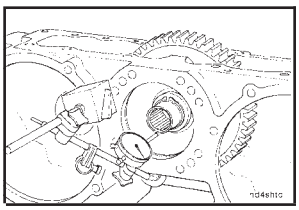
Hydraulic Pump Support Bore I.D.		53.86 mm 53.92 mm	MIN MAX	2.121 in 2.123 in	
Hydraulic Pump Support Bushing Bore I.D.		47.60 mm 47.68 mm	MIN MAX	1.874 in 1.877 in	

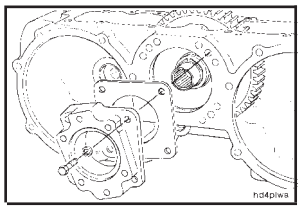
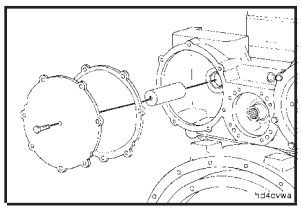
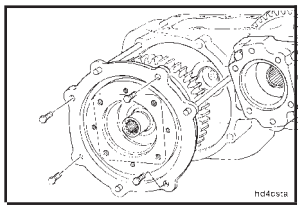
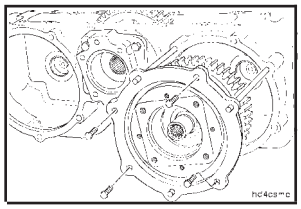
Drive Units - Torque Values

Rear Gear Drive (Lower Assembly) (009-023)

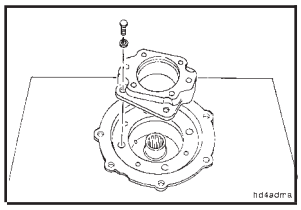
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
 **Drain Plugs**		100 N•m	75 ft-lb
		11 N•m	8 in-lb
		20 N•m	15 ft-lb
 **Rear Gear Drive Capscrews**	Step 1 2	100 N•m 205 N•m	75 ft-lb 150 ft-lb
 **Rear Gear Drive Capscrews** 3/8-16 inch 7/16-14 inch		 45 N•m 65 N•m	 35 ft-lb 50 ft-lb
 **Mounting Capscrews** Step 1 Step 2		 70 N•m 150 N•m	 50 ft-lb 110 ft-lb

Rear Gear Drive (Upper Assembly) (009-024)

		20 N•m	15 ft-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Adapter		95 N•m	70 ft-lb	
Cover Plate SAE C/SAE B Drive		95 N•m	70 ft-lb	
Cover Plate SAE A Drive		40 N•m	35 ft-lb	
		40 N•m	30 ft-lb	
		70 N•m	50 ft-lb	
		70 N•m	50 ft-lb	

Outer Hydraulic Pump Support Drive (009-036)

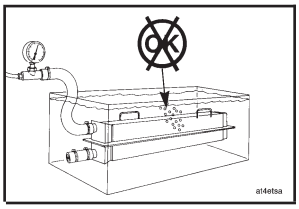


Adapter		95 N•m		70 ft-lb
Cover Plate				
	SAE C/SAE B drive	95 N•m		70 ft-lb
SAE A drive	40 N•m		35 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

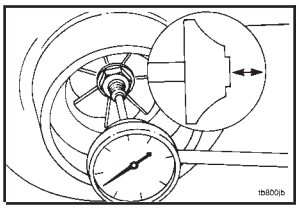
Air Intake System - Specifications

Aftercooler Assembly (010-002)

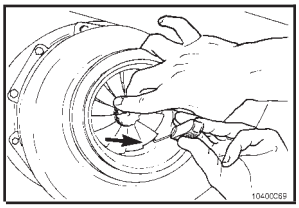


Air Pressure	415 kPa	MAX	60 psi

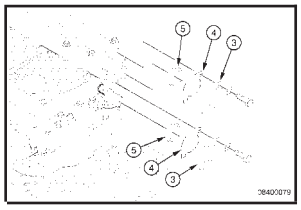
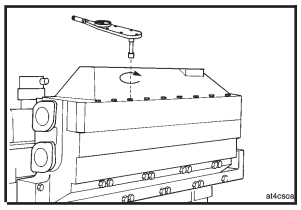
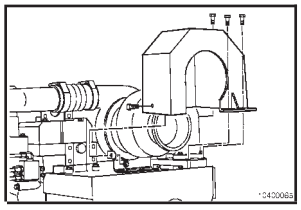
Turbocharger, Water-Cooled (010-037)



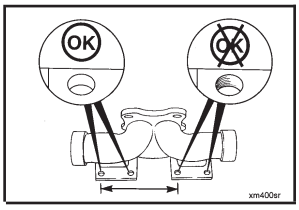
Turbocharger End Clearance	0.05 mm	MIN	0.002 in
	0.13 mm	MAX	0.005 in



Holset HX82 Turbocharger			
Compressor Impeller	0.15 mm	MIN	0.006 in
	0.45 mm	MAX	0.018 in
Turbine Wheel	0.20 mm	MIN	0.008 in
	0.55 mm	MAX	0.210 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Air Intake System - Torque Values				
Aftercooler Assembly (010-002)				
		35 N•m	25 ft-lb	
Step 1		35 N•m	25 ft-lb	
Step 2		50 N•m	35 ft-lb	
Turbocharger Heat Shield (010-076)				
		35 N•m	25 ft-lb	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



Exhaust System - Specifications

Exhaust Manifold, Dry (011-007)

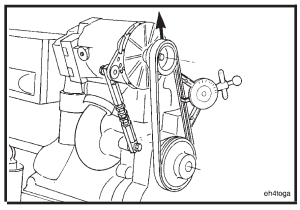
Exhaust Manifold Capscrew Holes	191.5 mm	MIN	7.54 in
	193.5 mm	MAX	7.62 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.

Electrical Equipment - Specifications

Drive Belt, Alternator (013-005)

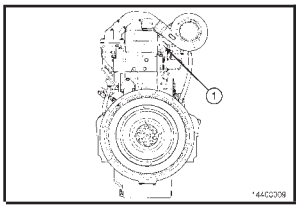
Alternator Belt Tension	670 N	150 lbf



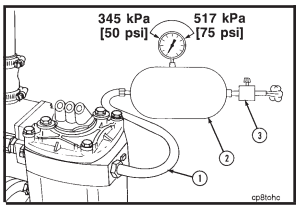
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

Engine Testing - Specifications

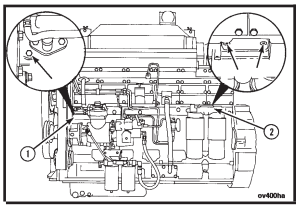
Engine Testing (Chassis Dynamometer) (014-005)



Maximum Coolant Pressure with Closed Thermostat and No Pressure Cap	241 kPa		35 psi



Hose Temperature (Minimum)	260 °C		500 °F



Engine Testing (Engine Dynamometer) (014-005)

Lubricating Oil Pressure	138 kPa	MIN	20 psi
	207 kPa	Nominal	30 psi

Drive Belt Tension

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240

Note: This chart does not apply to automatic belt tensioners.

* A belt is considered used if it has been in service for ten minutes or longer.

* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

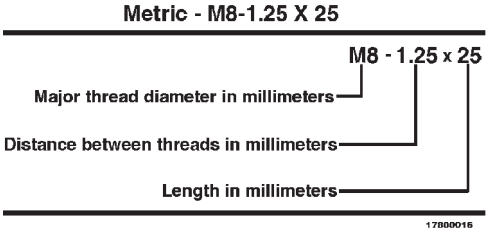
Capscrew Markings and Torque Values

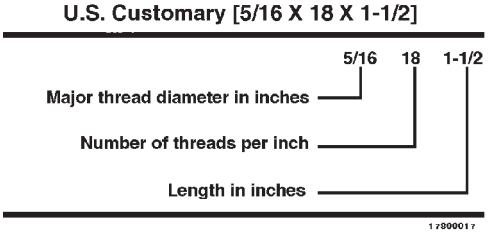
⚠ CAUTION ⚠

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

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

The following examples indicate how capscrews are identified:

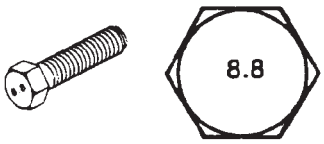
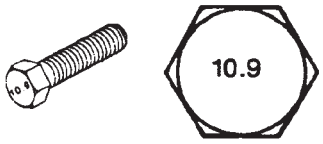
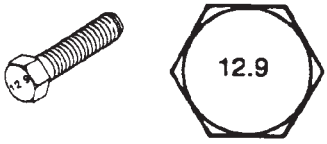




NOTES:

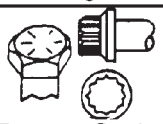
1. **Always** use the torque values listed in the following tables when specific torque values are **not** available.
2. Do **not** use the torque values in place of those specified in other sections of this manual.
3. The torque values in the table are based on the use of lubricated threads.
4. When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

Capscrew Markings and Torque Values - Metric

Commercial Steel Class	8.8	10.9	12.9
Capscrew Head Markings			

Body Size	Torque				Torque				Torque			
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

Fraction, Decimal, Millimeter Conversions

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

Conversion Factor: 1 inch = 25.4 mm

Newton-Meter to Foot-Pound Conversion Chart

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

NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.

Pipe Plug Torque Values

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

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

Tap Size 60%	Tap Size 75%	Drill Size
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size 60%	Tap Size 75%	Drill Size
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size 60%	Tap Size 75%	Drill Size
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
		Z
M12x1.75	M12x1.5	10.50mm
	1/2-13	27/64
M12x1.5	M12x1.25	10.75mm
M12x1.25		11.00mm
1/2-13		7/16
1/4-18NPT		
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size 60%	Tap Size 75%	Drill Size
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
	3/4-10	41/64
	M18x1.5	16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

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Weights and Measures - Conversion Factors

Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbr.	Unit Name	Abbr.		
Area	sq. inch	in^2	sq. millimeters	mm^2	645.16	0.001550
			sq. centimeters	cm^2	6.452	0.155
	sq. foot	ft^2	sq. meter	m^2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H_2O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H_2O	millimeters of water	mm H_2O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) + 32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in^3	liter	l	0.01639	61.02545
	cubic inch	in^3	cubic centimeter	cm^3	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

NOTES

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