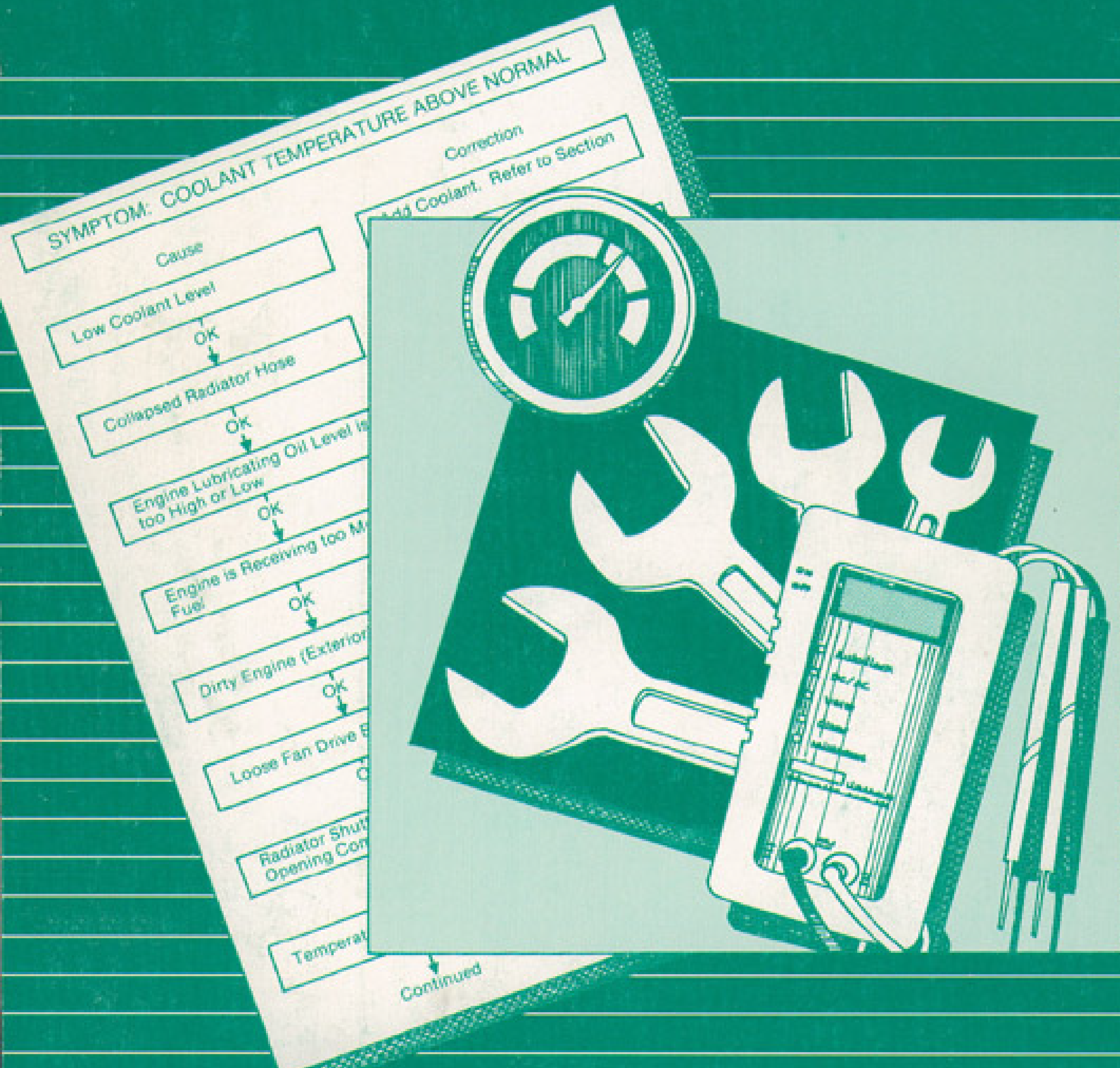
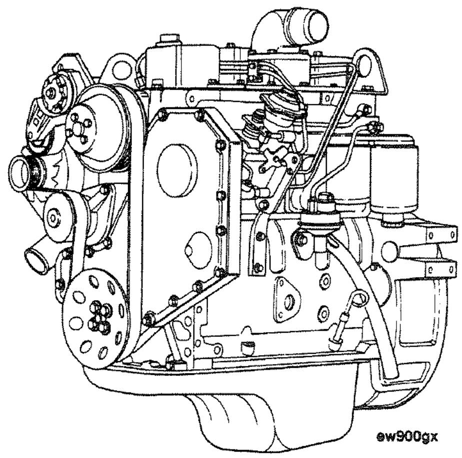
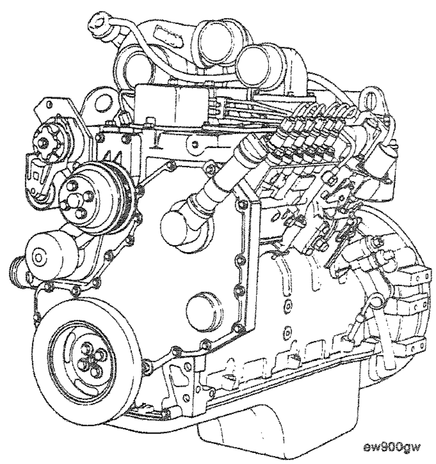
Troubleshooting and Repair Manual B Series Engines 1991 and 1994 Certification Levels



Troubleshooting and Repair Manual B Series Engines



Four Cylinder



Six Cylinder

Bulletin 3666087
Printed 11/93

Foreword

This manual provides instructions for troubleshooting and repairing the B Series Engine in the chassis. Component and assembly rebuild procedures are provided in the B Series Engine Shop Manual. Refer to Page i-2 in the Introduction for instructions on how to use this manual. The procedures given in this manual are applicable for the B Series engines produced in 1991 and newer. Refer to Bulletin No. 3810207 to find the procedures applicable to B Series engines introduced prior to 1991.

The manual is organized to guide a service technician through the logical steps of identifying and correcting problems related to the engine.

This manual does **not** cover vehicle or equipment problems. Consult the vehicle or equipment manufacturer for repair procedures.

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

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

Reporting of errors, omissions, and recommendations for improving this publication by the user is encouraged. Please use the postage paid, self-addressed Literature Survey Form in the back of this manual for communicating your comments.

The specifications and rebuild information in this manual is based on the information in effect at the time of printing. Cummins Engine Company, Inc. reserves the right to make any changes at any time without obligation. If differences are found between your engine and the information in this manual, contact a Cummins Authorized Repair Location, a Cummins Division Office, or the factory.

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

Table of Contents

NOTES

Section i - Introduction

Section Contents

About the Manual

This B Series Troubleshooting and Repair Manual is intended to aid in determining the cause of engine-related problems and to provide recommended repair procedures. The manual is divided into sections by system. Each section provides general information, specifications, diagrams, and service tools, where applicable. The specific repair procedures are referenced in the Troubleshooting Logic Charts.

How to Use the Manual

The manual is organized to provide an easy flow from problem identification to problem correction. A list of troubleshooting symptoms containing the most common engine problems is on Page T-2 in the Troubleshooting Section. Complete the following steps to locate and correct the problem:

(STEP 1.) Locate the symptom on the list.

Reference is made to the procedure number where the "Troubleshooting Logic Chart" is found.

(STEP 2.) The left column of the "Troubleshooting Logic Chart" indicates a probable cause, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult.

The right column provides a brief description of the corrective action with the reference number for the repair.

(STEP 3.) Locate the probable cause in the left column, and then turn to the procedure number in the right column.

The repair procedures are listed by system (Cooling, Lubricating Oil, Combustion Air, Compressed Air, Fuel, Electrical, and Base Engine Components).

(STEP 4.) The Troubleshooting Logic Charts are based on the following assumptions:

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

Symbols

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

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

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

Indicates a **REMOVAL or DISASSEMBLY** step.

Indicates an **INSTALLATION or ASSEMBLY** step.

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

LUBRICATE the part or assembly.

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

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

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

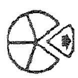
The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Simbolos

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

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

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



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

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

Se requiere **INSPECCION.**

LIMPIESE la pieza o el montaje.

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

LUBRIQUESE la pieza o el montaje.

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

APRIETESE hasta un par torsor específico.

EJECUTESE una **MEDICION** eléctrica.

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

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

Symbole

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


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


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


AUSBAU bzw. **ZERLEGEN.**


EINBAU bzw. **ZUSAMMENBAU.**


INSPEKTION erforderlich.

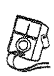

Teil oder Baugruppe **REINIGEN.**


DIMENSION - oder **ZEITMESSUNG.**


Teil oder Baugruppe **ÖLEN.**


WERKZEUGGRÖSSE wird angegeben.


ANZUG auf vorgeschriebenes Drehmoment erforderlich.


Elektrische **MESSUNG DURCHFÜHREN.**


Weitere Informationen an anderer Stelle bzw. in anderen Handbüchern.


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

Symboles

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

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

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

Indique une opération de **DEPOSE.**

Indique une opération de **MONTAGE.**

L'INSPECTION est nécessaire.

NETTOYER la pièce ou l'ensemble.

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

GRAISSER la pièce ou l'ensemble.

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

SERRER à un couple spécifique.

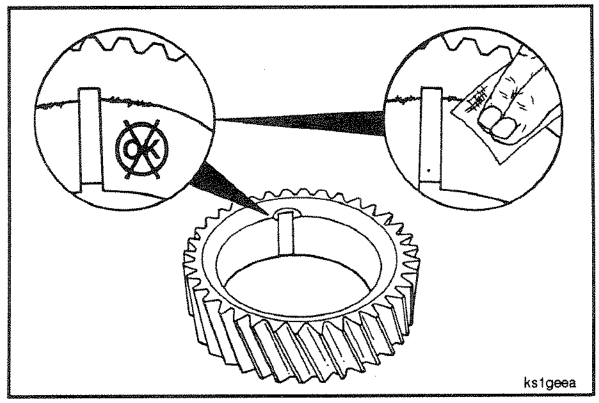
EFFECTUER une **MESURE** électrique.

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

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

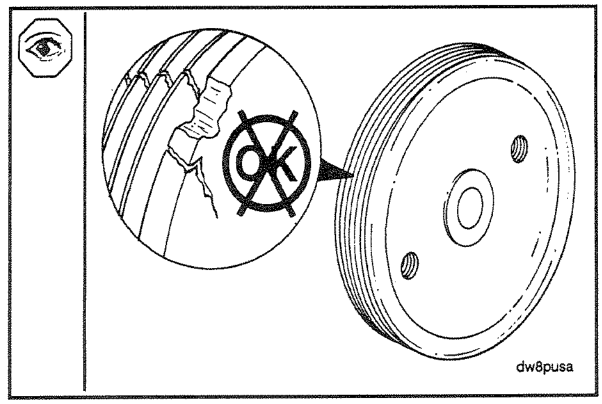
Illustrations

The illustrations used in the "Repair Sections" of this manual are intended to give an example of a problem, and to show what to look for and where the problem can be found. Some of the illustrations are "generic" and will **not** look exactly like the engine or parts used in your application. Some illustrations contain symbols to indicate an action required, and an acceptable or **not** acceptable condition.



ks1geea

The illustrations are intended to show repair or replacement procedures with the engine "in-chassis." The illustration can differ from your application, but the procedure given will be the same.



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Definition of Terms

AFC	Air Fuel Control
API	American Petroleum Institute
ASA	Air Signal Attenuator
ASTM	American Society of Testing and Materials
C	Celsius
CARB	California Air Resources Board
C.I.D.	Cubic Inch Displacement
Cm	Centimeter
CPL	Control Parts List
cSt	Centistokes
DCA	Diesel Coolant Additive
ECM	Electronic Control Module
E.C.S.	Emission Control System
EPA	Environmental Protection Agency
EPS	Engine Position Sensor
F	Fahrenheit
ft-lb	Foot Pound
GVW	Gross Vehicle Weight
Hg	Mercury
HP	Horsepower
H_20	Water
in-lb	Inch Pound
kg	Kilograms
km	Kilometers
km/l	Kilometers per Liter
kPa	Kilopascal
l	Liter
m	Meter
mm	Millimeter
MPa	Megapascal
MPH	Miles Per Hour
MPQ	Miles Per Quart
N•m	Newton-meter
OEM	Original Equipment Manufacturer
ppm	Parts Per Million
psi	Pounds Per Square Inch
PTO	Power Takeoff
RPM	Revolutions Per Minute
S.A.E.	Society of Automotive Engineers
STC	Step Timing Control
VS	Variable Speed
VSS	Vehicle Speed Sensor

General Safety Instructions

Important Safety Notice

WARNING

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 safe. Be aware of hazardous conditions that can exist.
- **Always** wear protective glasses and protective shoes when working.
- Do **not** wear loose-fitting or torn clothing. Remove all jewelry when working.
- Disconnect the battery 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 engine by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s) causing premature fan failure.
- If an engine has been operating and the coolant is hot, allow the engine to cool before you slowly loosen the filler cap and relieve the pressure from the cooling system.
- Do **not** work on anything that is supported ONLY by lifting jacks or a hoist. **Always** use blocks or proper stands to support the product before performing any service work.
- Relieve all pressure in the air, oil, and the cooling systems before any lines, fittings, or related items are removed or disconnected. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do **not** check for pressure leaks with your hand. High pressure oil or fuel can cause personal injury.
- To prevent suffocation and frostbite, wear protective clothing and ONLY disconnect liquid refrigerant (freon) lines in a well ventilated area.
- To avoid personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lb] or more. Make sure all lifting devices such as chains, hooks, or slings are in good condition and are of the correct capacity. Make sure hooks are positioned correctly. **Always** use a spreader bar when necessary. The lifting hooks **must not** be side-loaded.
- Corrosion inhibitor contains alkali. Do **not** get the substance in your eyes. Avoid prolonged or repeated contact with skin. Do **not** swallow internally. In case of contact, immediately wash skin with soap and water. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. IMMEDIATELY CALL A PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
- Naptha and Methyl Ethyl Ketone (MEK) are flammable materials and **must** be used with caution. Follow the manufacturer's instructions to provide complete safety when using these materials. KEEP OUT OF REACH OF CHILDREN.
- To avoid burns, be alert for hot parts on products that have just been turned OFF, and hot fluids in lines, tubes, and compartments.
- **Always** use tools that are in good condition. Make sure you understand how to use them before performing any service work. Use ONLY genuine Cummins or Cummins Recon® replacement parts.
- **Always** use the same fastener part number (or equivalent) when replacing fasteners. Do **not** use a fastener of lessor quality if replacements are necessary.

General Cleaning Instructions

Solvent and Acid Cleaning

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

Experience has shown that the best results can be obtained using a cleaner that can be heated to 90 to 95 degrees Celsius [180 to 200 degrees Fahrenheit]. A cleaning tank that provides a constant mixing and filtering of the cleaning solution will give the best results.

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

Warning: The use of acid can be extremely dangerous to personnel, and can damage the machinery. Always provide a tank of strong soda water as a neutralizing agent.

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

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

Steam Cleaning

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

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

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

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

Glass or Plastic Bead Cleaning

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

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

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

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

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

General Repair Instructions

This engine incorporates the latest diesel technology; 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. 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

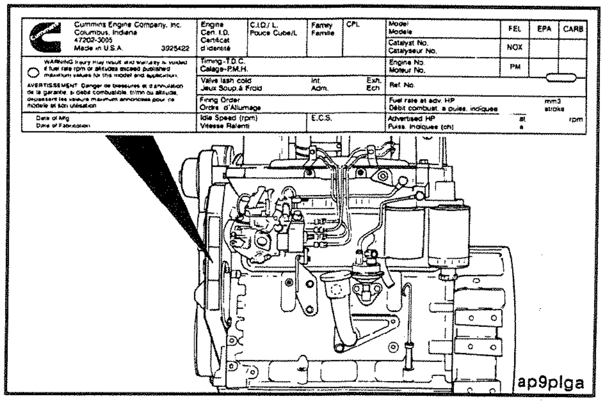
- **Follow All Safety Instructions Noted in the Procedures.**
  - Follow the manufacturer's recommendations for cleaning solvents and other substances used during the repair of the engine. **Always** use good safety practices with tools and equipment.
- **Provide A Clean Environment and Follow the Cleaning Instructions Specified in the Procedures**
  - The engine and its components **must** be kept clean during any repair. Contamination of the engine and components will cause premature wear.
- **Perform the Inspections Specified in the Procedures.**
- **Replace all Components or Assemblies Which are Damaged or Worn Beyond the Specifications**
- **Use Genuine Cummins New or ReCon® Service Parts and Assemblies**
  - The assembly instructions have been written to use again as many components and assemblies as possible. When it is necessary to replace a component or assembly, the procedure is based on the use of new Cummins or Cummins ReCon® components. All of the repair services described in this manual are available from all Cummins Distributors and most Dealer locations.
- **Follow The Specified Disassembly and Assembly Procedures to Avoid Damage to the Components.**

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

NOTES

Section E - Engine Identification

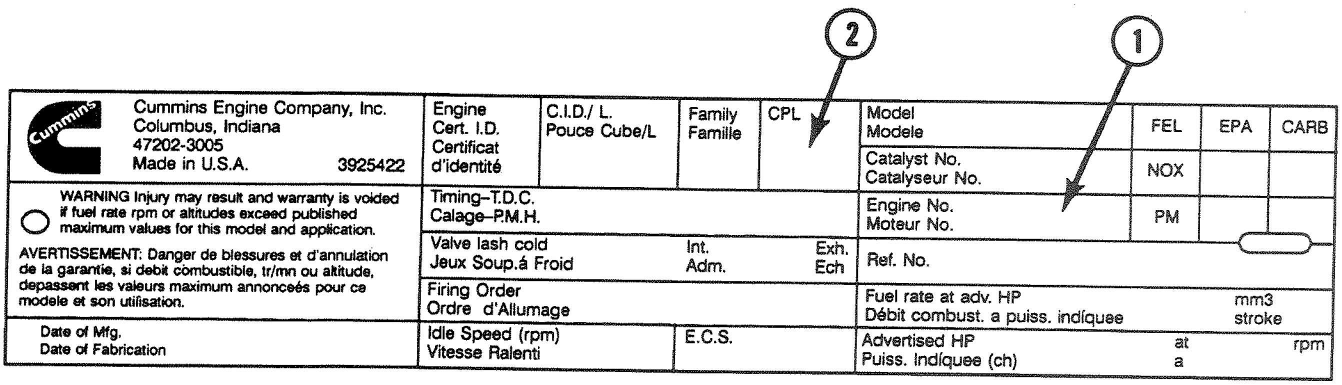
Section Contents



Engine Identification

Engine Dataplate

The engine dataplate shows specific information about your engine. The engine serial number (1) and Control Parts List (CPL) (2) provide information for ordering parts and service needs.



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Engine Nomenclature

The model name for engines in automotive applications provides the data shown in the example.

Example

B 3.9-105

- 105 — Rated Horsepower
- 3.9 — Displacement in Liters
- B — Engine Series

The following example shows a model name of an engine for non-automotive applications.

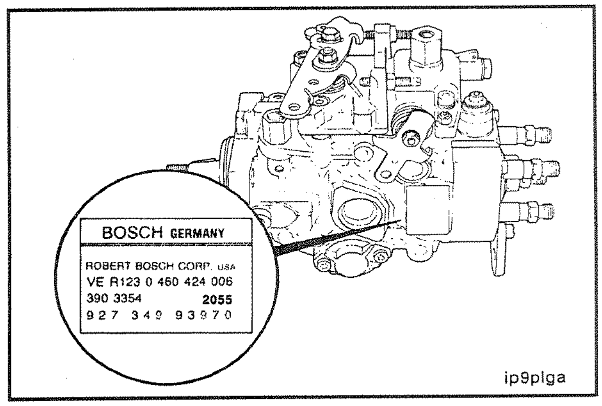
Example

4 B T A 3.9

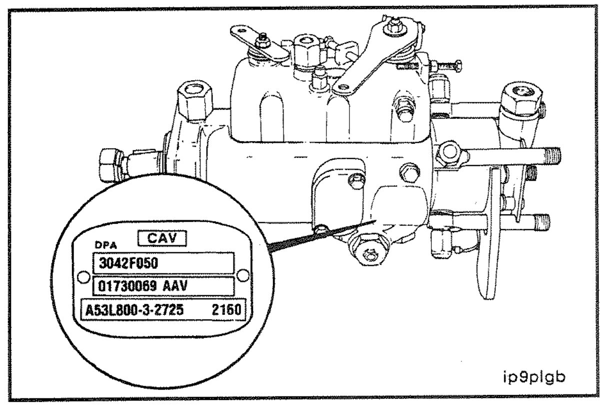
- 3.9 — Displacement in Litres
- A — Aftercooled
- T — Turbocharged
- B — Engine Series
- 4 — Number of Cylinders

Fuel Pump Dataplate (Nameplate)

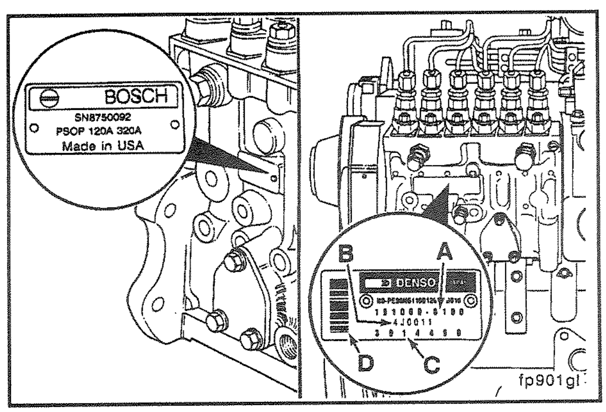
The fuel pump dataplate is located on the side of the fuel pump. It provides information for fuel pump calibration. This illustration shows the dataplate location on a Bosch rotary injection pump.



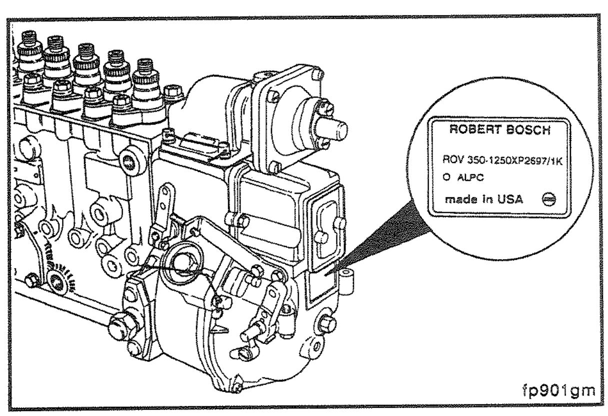
This illustration shows the dataplate location and a Lucas CAV rotary injection pump.



This illustration shows the dataplate location on a Bosch in-line injection pump. The Nippondenso EP-9 dataplate is located in approximately the same location as the illustrated Bosch dataplate.



The Cummins part number for the in-line pump and governor combination is located on the governor dataplate.



Automotive Engine Specifications

General Engine Data

	B3.9	B5.9
Bore - mm [in.]	102 [4.02]	
Stroke - mm [in.]	120 [4.72]	
Displacement - litre [in.^{3}]	3.9 [239]	5.9 [359]
Engine Weight (Dry) Less Flywheel and Electrics-kg [lbs]	308-329 [680-725]	388-411 [855-905]
Firing Order	1.3.4.2	1.5.3.6.2.4
Valve Clearances		
-Intake- mm [in.]	0.25 [0.010]	
-Exhaust- mm [in.]	0.51 [0.020]	
Compression Ratio	(Rotary Pump) 17.6:1	(In-Line Pump) 17.9:1
Rotation, viewed from the Front of the Engine	Clockwise	
Aspiration		
- Turbocharged	X	X
-Charge Air Cooled	X	X

Lubrication System

	B3.9	B5.9
Lubricating Oil Pressure at Idle - (Minimum Allowable) kPa [PSI]	69 [10]	
Lubricating Oil Pressure at Rated - (Minimum Allowable) kPa [PSI]	207 [30]	
Regulating Valve Opening Pressure kPa [PSI]	449 [65]	
Differential Pressure to Open the Bypass Valve - kPa [PSI]	138 [20]	
Lubricating Oil Capacity		
Standard Pan Only - Liter [U.S. Quarts]	9.5 [10]	14.2 [15]
Total System - Liter [U.S. Quarts]	11 [11.6]	16.4 [17.3]
Number of Liters [U.S. Quarts] from Low to High	0.9 [1]	1.9 [2]

Cooling System

	B3.9	B5.9
Coolant Capacity (Engine Only) - Litre - [U.S. Qts.]	7. [7.4]	10.5 [11.1]
Standard Modulating Thermostat - Range - °C [°F]	Start 83 [181]	Fully Open 95 [203]
Pressure Cap (kPa [PSI])		
104°C [220°F] Systems	103 [15]	
99°C [210°F] Systems	48 [7]	

	B3.9	B5.9
Air Induction System		
Maximum Allowable Intake Restriction at Rated Speed and Load with Dirty Air Filter Element - mm H_2O [in. H_2O]	635 [25]	635 [25]
Exhaust System		
Maximum Allowable Exhaust Restriction at Rated Speed and Load - mm Hg [in. Hg]	76.2 [3] 152.4 [6] with catalyst	76.2 [3] 152.4 [6] with catalyst
Fuel System		
(Distributor Type Fuel Injection Pumps)		
Maximum Inlet Restriction to the Fuel Transfer Pump Must Not Exceed - mm Hg [in Hg]	100 [4]	100 [4]
Maximum Allowable Return Line Restriction - mm Hg [in Hg]	518 [20.4]	518 [20.4]
Maximum Allowable Pressure Drop Across Fuel Filter - kPa [psi]	35 [5]	35 [5]
Maximum Inlet Pressure to the Injection Pump Must Not Exceed - kPa [psi]	70 [10]	70 [10]
(In-Line Type Fuel Injection Pumps)		
Maximum Inlet Restristion to the Fuel Transfer Pump Must Not Exceed - mm [in Hg]	100 [4]	100 [4]
Fuel Transfer Pump Minimum Output Pressure - kPa [psi] @ Rated RPM	172 [25]	172 [25]
Fuel Filter Restriction (Maximum Pressure Drop Across Filters) - kPa [psi]	35 [5]	35 [5]
Fuel Pump Gallery Pressure - kPa [psi] Minimum @ Rated RPM	140 [20]	140 [20]
Fuel Return Maximum Restriction - mm Hg [in Hg]	518 [20.4]	518 [20.4]
Electrical System		
Minimum Recommended Battery Capacity		
With Light Accessories*		
- 12 V Starter	625CCA	800CCA
- 24 V Starter	400CCA	475CCA
With Heavy Accessories**		
- 12 V Starter	800CCA	950CCA
- 24 V Starter	400CCA	475CCA
Maximum Allowable Resistance of Starting Circuit		
- With 12 V Starter - Ohms	0.0012	0.0012
- With 24 V Starter - Ohms	0.0020	0.0020

*Typical light accessories include (alternator, small steering pump, and disengaged clutch)

**Typical heavy accessories include (hydraulic pump and torque converter)

Non-Automotive Engine Specifications

General Engine Data	4B3.9	4BT3.9	4BTA3.9	6B5.9	6BT5.9	6BTA5.9
Bore - mm [in.]	102 [4.02]					
Stroke - mm [in.]	120 [4.72]					
Displacement - litre [in.^{3}]	3.9 [239]			5.88 [359]		
Engine Weight (Dry) Less Flywheel and Electrics-kg [lbs]	308 [680]	320 [705]	329 [725]	388 [855]	399 [880]	411 [905]
Firing Order	1.3.4.2			1.5.3.6.2.4		
Valve Clearances						
-Intake- mm [in.]	.25 [.010]					
-Exhaust- mm [in.]	.51 [.020]					
Compression Ratio	18.5:1	17.5:1	16.5:1	18.5:1	17.5:1	16.5:1
Rotation, viewed from the Front of the Engine	Clockwise					
Aspiration						
-Naturally Aspirated	X			X		
-Turbocharged		X	X		X	X
-Aftercooled			X			X
Lubrication System						
Lubricating Oil Pressure at Idle - (Minimum Allowable) kPa [PSI]	69 [10]					
Lubricating Oil Pressure at Rated - (Minimum Allowable) kPa [PSI]	207 [30]					
Regulating Valve Opening Pressure kPa [PSI]	449 [65]					
Differential Pressure to Open the Bypass Valve - kPa [PSI]	138 [20]					
Lubricating Oil Capacity						
Standard Pan Only - Liter [U.S. Quarts]	9.5 [10]	9.5 [10]	9.5 [10]	14.2 [15]	14.2 [15]	14.2 [15]
Total System - Liter [U.S. Quarts]	10.9 [11.5]	11 [11.6]	11 [11.6]	16.3 [17.2]	16.4 [17.3]	16.4 [17.3]
Number of Liters [U.S. Quarts] from Low to High	0.9 [1]	0.9 [1]	0.9 [1]	1.9 [2]	1.9 [2]	1.9 [2]
Cooling System						
Coolant Capacity (Engine Only) - Litre - [U.S. Qts.]	7 [7.4]	7 [7.4]	9.7 [10.3]	10.5 [11.1]	10.5 [11.1]	14.5 [15.3]
Standard Modulating Thermostat - Range - °C [°F]	Start 83 [180]			Fully Open 95 [203]		
Pressure Cap (kPa [PSI])						
104°C [220°F] Systems	103 [15]					
99°C [210°F] Systems	48 [7]					

Air Induction System

	4B3.9	4BT3.9	4BTA3.9	6B5.9	6BT5.9	6BTA5.9
Maximum Allowable Intake Restriction at Rated Speed and Load with Dirty Air Filter Element - mm H_2O [in. H_2O]	508 [20]	635 [25]	635 [25]	508 [20]	635 [25]	635 [25]

Exhaust System

Maximum Allowable Exhaust Restriction at Rated Speed and Load - mm Hg [in. Hg]	76.2 [3.0]

Fuel System

(Distributor Type Fuel Injection Pumps)

Maximum Allowable Restriction to the Fuel Transfer Pump Must Not Exceed - mm Hg [in Hg]	100 [4]
Maximum Allowable Return Line Restriction - mm Hg [in Hg]	518 [20.4]
Maximum Allowable Pressure Drop Across Fuel Filter - kPa [psi]	35 [5]
Maximum Inlet Pressure to the Injection Pump Must Not Exceed - kPa [psi]	70 [10]

(In-Line Type Fuel Injection Pumps)

Maximum Inlet Restriction to the Fuel Transfer Pump Must Not Exceed - mm [in Hg]	100 [4]
Fuel Transfer Pump Minimum Output Pressure - kPa [psi] @ Rated RPM	172 [25]
Fuel Filter Restriction (Maximum Pressure Drop Across Filters) - kPa [psi]	35 [5]
Fuel Pump Gallery Pressure - kPa [psi] Minimum @ Rated RPM	140 [20]
Fuel Return Maximum Restriction - mm Hg [in Hg]	518 [20.4]

Electrical System

Minimum Recommended Battery Capacity

	4B3.9	4BT3.9	4BTA3.9	6B5.9	6BT5.9	6BTA5.9
With Light Accessories*						
- 12 V Starter	625CCA	625CCA	625CCA	800CCA	800CCA	800CCA
- 24 V Starter	312CCA	400CCA	400CCA	475CCA	475CCA	475CCA
With Heavy Accessories**						
- 12 V Starter	800CCA	800CCA	800CCA	950CCA	950CCA	950CCA
- 24 V Starter	400CCA	400CCA	400CCA	475CCA	475CCA	475CCA

Maximum Allowable Resistance of Starting Circuit

- With 12 V Starter - Ohms	0.0012
- With 24 V Starter - Ohms	0.0020

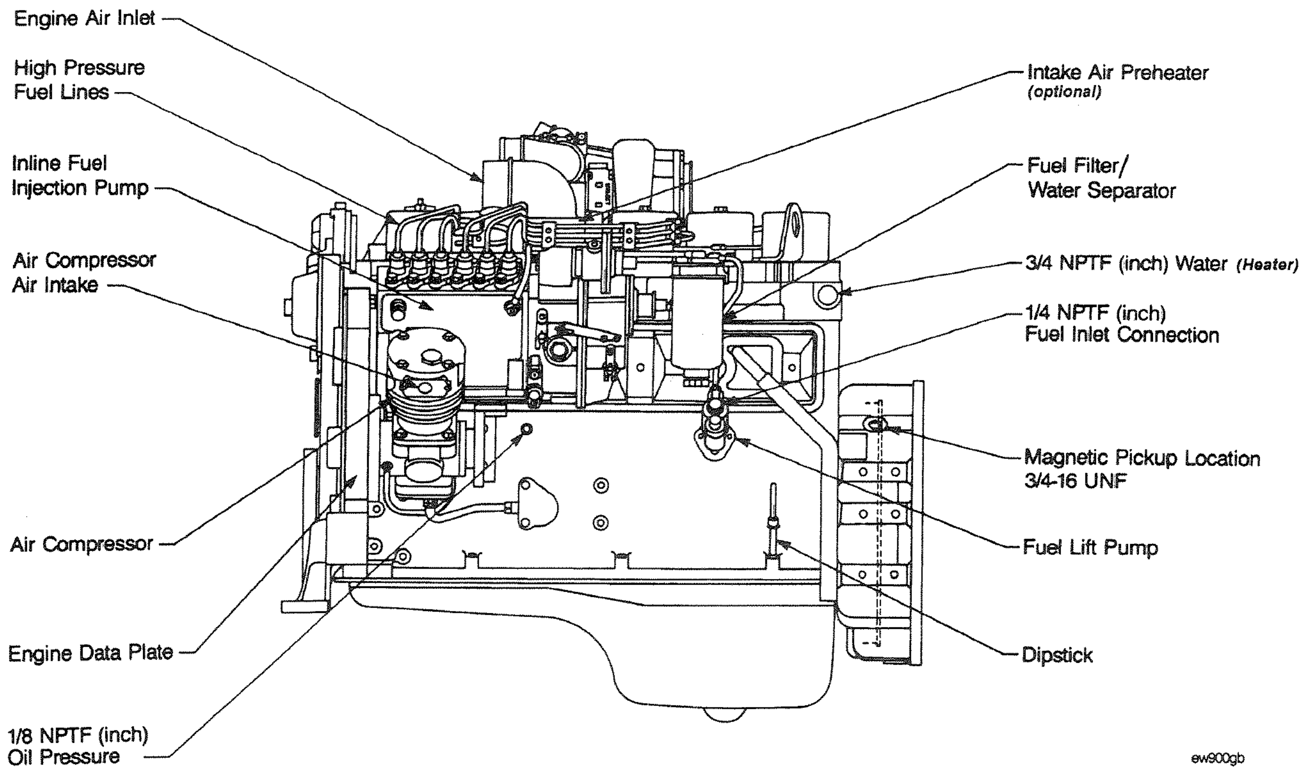
*Typical light accessories include (alternator, small steering pump, and disengaged clutch)

**Typical heavy accessories include (hydraulic pump and torque converter)

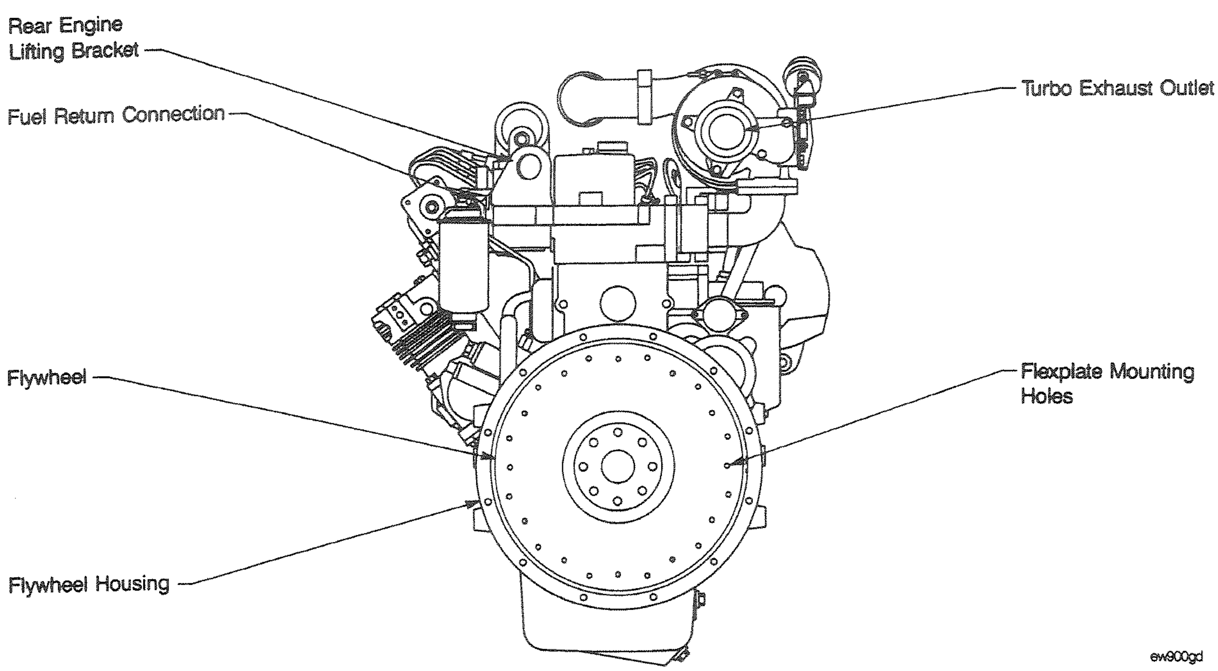
Engine Diagrams

The following 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.

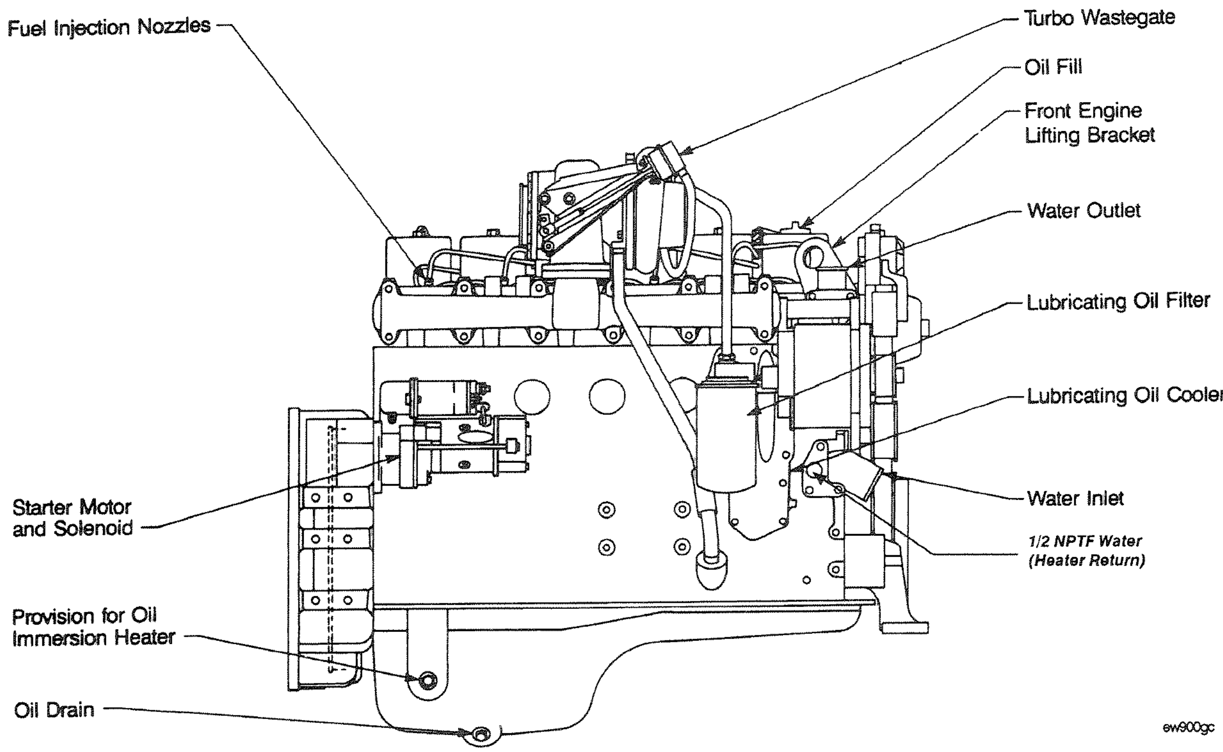
NOTE: The illustrations are only a reference to show a typical engine.



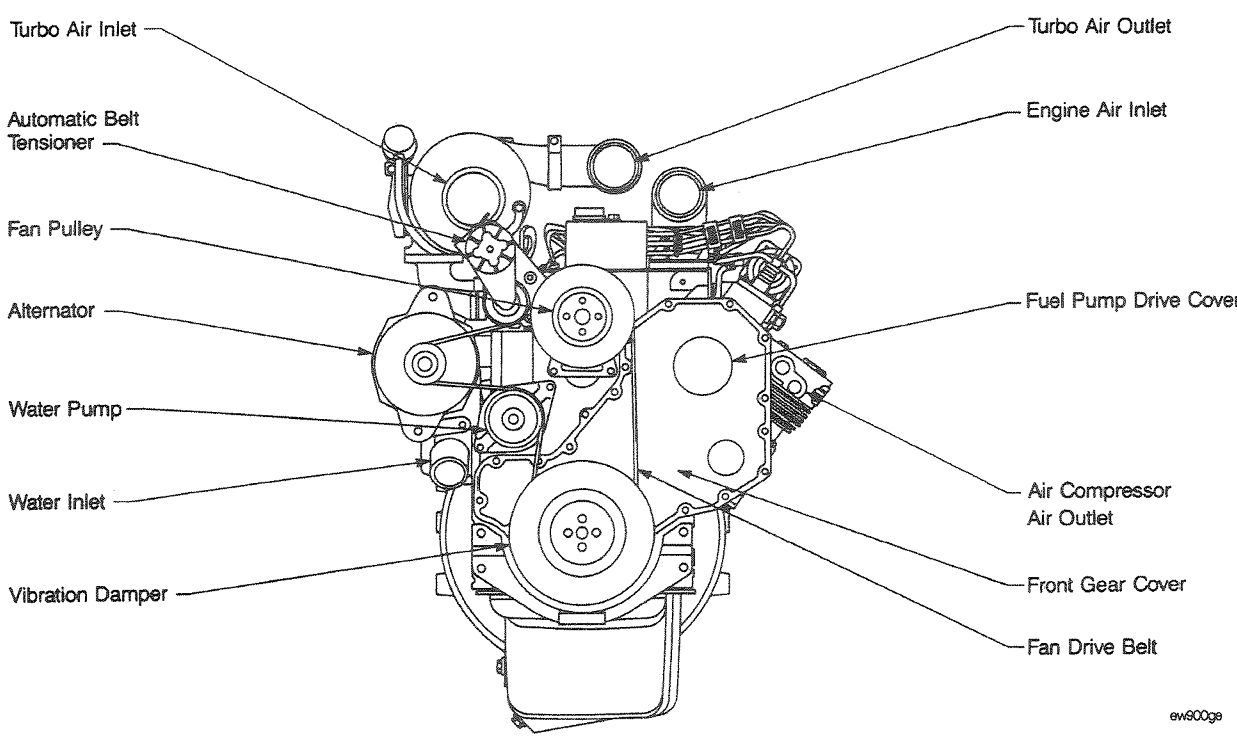
Fuel Pump Side View



Rear View



Turbocharger Side View



Front View

NOTES

Section T - Troubleshooting Logic

Section Contents

Page

Section T - Troubleshooting

Procedures and Techniques

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

The Troubleshooting Symptoms Charts beginning on Page T-4 are organized so that a problem can be located and corrected by doing the easiest and most logical things first. Complete all steps in the sequence shown from top to bottom.

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

Follow these basic troubleshooting steps:

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

Troubleshooting Symptoms Charts

Use the charts given on the following pages of this section to help you to diagnose and repair a problem with your engine. Read each row of blocks from top to bottom. Follow the arrows through the chart to identify the corrective action.

Engine Will Not Crank Or Cranks Slowly

Cause	Corrections
Starting Motor Operating But Not Cranking the Engine	Remove the starting motor and check for broken teeth on the ring gear or broken starting motor spring. Refer to Procedure 6-10.
OK ↓	
Starting Circuit Connections Loose or Corroded	Clean and tighten connections.
OK ↓	
Battery Charge Low	Check battery voltage. Refer to Procedure 6-01.
OK ↓	
No Voltage to Starter Solenoid	Check voltage to solenoid. Refer to Procedure 6-03.
OK ↓	
Crankshaft Rotation Restricted	Bar the engine to check for rotational resistance.
OK ↓	
Solenoid or Starting Motor Malfunction	Replace starting motor. Refer to Procedure 6-10.

Engine Cranks But Will Not Start - No Smoke From Exhaust

Cause	Corrections
No Fuel in Supply Tank	Check/replenish fuel supply
OK	
Electrical or Manual Fuel Shutoff Not Open	Check for loose wires and verify that the valve is functioning. Check to be sure manual shutoff lever is in the run position. Refer to Procedures 5-05 or 5-11.
OK	
Improper Starting Procedure	Verify proper starting procedure. Refer to the Operation and Maintenance Manual.
OK	
Fuel Filter Plugged With Water or Other Contamination	Drain fuel/water separator or replace fuel filter. Refer to Procedure 5-04.
OK	
Inspect Fuel Transfer Pump Operation	Refer to Procedure 5-02.
OK	
Fuel Injection Pump Not Getting Fuel or Fuel is Aerated	Check fuel flow/bleed fuel system. Refer to Procedures 5-03 and 5-15.
OK	
Check Fuel Inlet Restriction	Maximum inlet restriction to fuel transfer pump must not exceed 100 mm Hg [4 in. Hg].
OK	
Air Intake or Exhaust System Plugged	Visually check; remove the obstruction. Check exhaust system for obstruction.
OK	

(Continued)

Engine Cranks But Will Not Start - No Smoke From Exhaust (Continued)

Cause	Corrections
Fuel Drain Back	Verify that the fuel return line is plumbed to the bottom of the fuel tank.
OK ↓	
Malfunctioning Fuel Return Overflow Valve (Inline fuel pump only)	Check/replace return overflow valve. Refer to Procedure 5-27.
OK ↓	
Worn or Malfunctioning Fuel Injection Pump	Visually check fuel delivery with an externally connected injector to one of the pump outlets. Remove the fuel injection pump. Have calibration checked.
OK ↓	
Injection Pump Timing Incorrect	Verify/time the pump. Refer to Procedures 5-36.
OK ↓	
Engine Camshaft Out of Time	Check/correct gear train timing alignment. Refer to Procedure 7-19.

Engine Hard To Start Or Will Not Start - Smoke From Exhaust

Cause	Corrections
Starting Procedure Incorrect	Refer to the Operation and Maintenance Manual.
OK ↓	
Cranking Speed Too Slow (Minimum Cranking Speed = 150 RPM)	Verify that the driven units are not engaged
	Check the battery, starting motor, and look for loose or corroded wiring connections. Refer to Procedure 6-02.
	Bar the engine to check for internal rotational resistance.
OK ↓	
Cold Starting Aids Not Working or Are Needed	Verify the aids are operating. Refer to O&M manual for recommendations.
OK ↓	
Intake Air Insufficient	Inspect or replace filter and check for obstructions to the air supply tube.
OK ↓	
Air in the Fuel System or the Fuel Supply Inadequate	Check the flow through the filter and bleed the system. Locate and correct the air source. Refer to Procedures 5-03 and 5-15.
OK ↓	
Fuel is Contaminated or Diesel Fuel Grade No. 1 Used Above 0°C [32°F]	Verify by operating the engine with clean fuel from a temporary tank of No. 2 diesel fuel. Refer to the "Fuel Recommendations/ Specifications" in the Operation and Maintenance Manual, Bulletin No. 3810205-10.
OK ↓	

(Continued)

Engine Hard To Start Or Will Not Start - Smoke From Exhaust (Continued)

Cause	Corrections
Fuel Drain Back	Verify fuel return line is plumbed to bottom of fuel tank.
OK ↓	
Inspect Fuel Transfer Pump Operation	Refer to Procedure 5-02.
OK ↓	
Malfunctioning Fuel Return Overflow Valve	Check/replace return overflow valve. Refer to Procedure 5-27.
OK ↓	
Check Fuel Inlet Restriction	Maximum inlet restriction to fuel transfer pump must not exceed 100 mm Hg [4 in. Hg].
OK ↓	
Fuel Injection Pump Out of Time	Check top dead center (TDC). Refer to Procedure 7-21. Check/adjust injection pump timing. Refer to Procedure 5-36. Check/time the fuel injectin pump using the spill port timing if equipment is available. Refer to Procedure 5-36.
OK ↓	
Valves Incorrectly Adjusted	Adjust valves. Refer to Procedure 7-04.
OK ↓	
One or More Injectors Worn or Malfunctioning	Check/replace injectors. Refer to Procedures 5-13 and 5-40.
OK ↓	

(Continued)

Engine Hard To Start Or Will Not Start - Smoke From Exhaust (Continued)

Cause	Corrections
Engine Compression Low	Perform a compression check to identify the problem. Refer to Procedure 7-01.
OK ↓	
Fuel Injection Pump Malfunctioning/ Delivery Valves Malfunctioning	Remove fuel injection pump. Have calibration checked.

Engine Starts But Will Not Keep Running

Cause	Corrections
Low Fuel Level	Check/fill fuel tank.
OK ↓ Engine Starting Under Load	Disengage driven units
OK ↓ Idle Speed Too Low for Accessories	Adjust the idle speed. Refer to Procedures 5-38 and 5-39.
OK ↓ Intake Air or Exhaust System Restricted	Visually check for exhaust restriction and inspect the air intake. Refer to page 3-11 and 3-23.
OK ↓ Air in the Fuel System or the Fuel Supply is Inadequate	Check the flow through the filter and bleed the system. Locate and correct the air source. Refer to Procedures 5-03 and 5-15.
OK ↓ Fuel Waxing Due to Extremely Cold Weather	Verify by inspecting the fuel filter. Clean the system and use climatized fuel or fuel heaters.
OK ↓ Fuel Contaminated	Verify by operating the engine with clean fuel from a temporary supply tank. Drain and flush the fuel supply tank.
OK ↓ Plugged Fuel Filter	Check/replace filter. Refer to Procedures 5-04 and 5-16.
OK ↓ Fuel Drain Manifold or Return Line Restricted (Lucas CAV Only)	Check/correct the restriction. Refer to Procedure 5-14.

Engine Surging (Speed Change)

Cause	Corrections
Fuel Level Low	Check/fill fuel tank.
OK ↓	
If the Condition Occurs at Idle, the Idle Speed Set Too Low for Accessories	Adjust the idle. Refer to Procedures 5-38 and 5-39.
OK ↓	
Throttle Linkage Misadjusted or Damaged	Adjust or repair linkage. Refer to Procedures 5-05 and 5-10.
OK ↓	
High Pressure Fuel Leak	Inspect/correct leaks in the high pressure lines, fittings, injector sealing washers or delivery valves. Refer to Procedure 5-12.
OK ↓	
Aerated Fuel	Bleed the fuel system and correct source of the leak. Refer to Procedures 5-03 and 5-15.
OK ↓	
One or More Injectors Worn or Malfunctioning	Check/replace the injectors. Refer to Procedures 5-13 and 5-40.
OK ↓	
Fuel Injection Pump Malfunctioning/ Delivery Valves Malfunctioning	Remove fuel injection pump. Have calibration checked.

Engine Idle Rough (Irregularly Firing Or Engine Shaking)

Cause	Corrections
Engine is Cold	Allow engine to warm to operating temperature if engine will not reach operating temperature. Refer to Troubleshooting Logic for Coolant Temperature Below Normal.
OK ↓	
Idle Speed Too Low for the Accessories	Check/adjust low idle screw. Refer to Procedures 5-38 and 5-39.
OK ↓	
Engine Mounts Over-Tightened, Damaged or Loose	Verify condition of mounts. Refer to equipment manufacture's service instructions.
OK ↓	
High Pressure Fuel Leak	Inspect/correct leaks in the high pressure lines, fittings injection sealing washers or delivery valve seals. Refer to Procedures 5-12 and 5-33.
OK ↓	
Air in the Fuel System	Bleed the fuel system and correct the source of the air. Refer to Procedures 5-03 and 5-15.
OK ↓	
Fuel Return Overflow Valve Malfunctioning	Check/replace fuel return overflow valve. Refer to Procedure 5-27.
OK ↓	
Fuel Transfer Pump Malfunctioning	Check/replace fuel transfer pump. Refer to Procedure 5-02.
OK ↓	
Fuel Supply Restricted	Clean pre-filters and screens and check fuel line for restriction. Replace fuel filter. Refer to Procedure 5-04.
OK ↓	

(Continued)

Engine Idle Rough (Irregularly Firing Or Engine Shaking) (Continued)

Cause	Corrections
Injector Needle Valve Sticking	Check/replace the injector. Refer to Procedure 5-40.
OK ↓	
Fuel Injection Pump or Delivery Valve Malfunctioning	Remove fuel injection pump. Have calibration checked.
OK ↓	
Valves Not Sealing	Adjust valves. Refer to Procedure 7-04.
OK ↓	
Compression in One or More Cylinders Low	Perform a compression check and repair as required. Refer to Procedure 7-01.

Engine Runs Rough Or Misfiring

Cause	Corrections
Condition Only Occurs at Idle	Refer to the troubleshooting logic - Rough Idle.
OK ↓	
Engine is Cold	Allow engine to warm to operating temperature.
OK ↓	
Fuel Injection Lines Leaking	Inspect/correct leaks in the high pressure lines, fittings injector sealing washers, or delivery valves. Refer to Procedures 5-12.
OK ↓	
Air in the Fuel or the Fuel Supply is Inadequate	Check the flow through the filter and bleed the system. Locate and correct the air source. Refer to Procedures 5-03 and 5-15.
OK ↓	
Malfunctioning Fuel Return Overflow Valve	Check/replace return overflow valve. Refer to Procedure 5-27.
OK ↓	
Fuel Transfer Pump Malfunctioning	Check/replace fuel transfer pump. Refer to Procedure 5-02.
OK ↓	
Fuel Supply Restricted	Clean pre-filters and screens and check fuel line for restriction. Replace fuel filter. Refer to Procedure 5-04.
OK ↓	
Fuel Contaminated	Verify by operating the engine with clean fuel from a temporary tank.
OK ↓	

(Continued)

Engine Runs Rough Or Misfiring (Continued)

Cause	Corrections
Valve Adjustment Incorrect	Check for a bent push rod and adjust valves. Refer to Procedures 7-03 and 7-04.
OK ↓	
Injection Pump Timing Incorrectly Adjusted	Check top dead center (TDC). Refer to Procedure 7-21. Check/adjust injection pump timing. Refer to Procedure 5-36. Check/time the fuel injection pump using the spill port timing if equipment is available. Refer to Procedure 5-36.
OK ↓	
Compression in One or More Cylinders Low	Perform a compression check and repair as required. Refer to Procedure 7-01.
OK ↓	
Injectors Malfunctioning	Check/replace injectors. Refer to Procedures 5-13 and 5-40.
OK ↓	
Injection Pump (Delivery Valves) Defective	Remove fuel injection pump. Have calibration checked.
OK ↓	
Camshaft Out of Time	Check/correct gear train timing alignment. Refer to Procedure 5-36.
OK ↓	
Camshaft or Tappets Damaged	Inspect camshaft and tappets. Refer to Procedure 7-19.

Engine RPM Will Not Reach Rated Speed

Cause	Corrections
Tachometer Malfunctioning	Verify engine speed with hand tachometer. Correct as required.
OK ↓	
Engine Overloaded	Verify high idle speed without load. Investigate operation to be sure correct gear is being used.
OK ↓	
Throttle Linkage Worn or Incorrectly Adjusted	Adjust linkage for stop-to-stop fuel control lever travel. Refer to Procedures 5-05 and 5-10.
OK ↓	
Mechanical Shutoff Lever Partially Engaged	Check/place shutoff lever in run position. Refer to Procedures 5-05 and 5-11.
OK ↓	
Fuel Quality Poor or Diesel Fuel Grade No. 1 Used Above 0°C [32°F]	Verify by operating the engine from a temporary tank of No. 2 diesel fuel. Refer to the "Fuel Recommendations/Specifications" in the B Series Operation and Maintenance Manual, Bulletin No. 3810205-10.
OK ↓	
Fuel Supply Inadequate	Check the flow through the filter to locate the source of the restriction. Refer to Procedures 5-01 and 5-02.
OK ↓	
Fuel Return Overflow Valve Malfunctioning	Check/replace fuel return overflow valve.
OK ↓	
Fuel Transfer Pump Malfunctioning	Check/replace fuel transfer pump. Refer to Procedure 5-04.
OK ↓	

(Continued)

Engine RPM Will Not Reach Rated Speed (Continued)

Cause	Corrections
Air-Fuel Control Leak/Obstructions	Check/repair leak. Check/clean AFC tubing and fittings for obstruction.
OK ↓	
If the Condition is Intermittant, Manifold Drain Line Restricted (Lucas CAV DPA Only)	Check/remove restriction. Refer to Procedure 5-14.
OK ↓	
Turbocharger Wastegate Actuator Diaphragm Ruptured	Repair turbocharger.
OK ↓	
Fuel Injection Pump Malfunctioning	Remove fuel injection pump. Have calibration checked.

Engine Power Output Low

Cause	Corrections
Engine Overloaded	Check for added loading from malfunctioning accessories or driven units, brakes dragging and other changes in vehicle loading.
OK	
Fuel Control Lever Misadjusted	Check/correct for stop-to-stop travel. Refer to Procedures 5-05 and 5-10.
OK	
Mechanical/Shutoff Lever Partially Engaged	Check/replace shutoff lever in run position. Refer to procedures 5-05, 5-11, and 5-31.
OK	
Fuel Quality Poor or Diesel Fuel Grade No. 1 Used Above 0°C [32°F]	Verify by operating the engine from a temporary tank of No. 2 diesel fuel. Refer to the "Fuel Recommendations/Specifications" in the B Series Operation and Maintenance Manual, Bulletin No. 3810205-10.
OK	
If the Condition is Slow Throttle Response, Air Fuel Tube Leaking, Wastegate Diaphram Ruptured, Wastegate Plumbing Damaged	Tighten the fittings, repair plumbing or repair wastegate diaphram.
OK	
AFC Plumbing Obstructed	Check the AFC line and fitting between the intake manifold and fuel injection pump.
OK	
High Pressure Fuel Leak	Inspect/correct leaks in the high pressure lines, fittings injector sealing washers or delivery valve seals.
OK	
Fuel Supply Inadequate	Check the flow through the filter to locate the source of the restriction. Refer to Procedures 5-01 and 5-02.
OK	
Air in the Fuel System	Bleed the fuel system and check for suction leaks. Refer to Procedures 5-03 and 5-15.
OK	

(Continued)

Engine Power Output Low(Continued)

Cause	Corrections
Fuel Transfer Pump Malfunctioning	Check/replace fuel transfer pump. Refer to Procedures 5-01, 5-02, 5-22 and 5-21.
OK ↓	
Malfunctioning Fuel Return Overflow Valve	Check/replace return overflow valve. Refer to Procedure 5-27.
OK ↓	
Oil Level Incorrect	Check/correct oil level.
OK ↓	
Intake Air Inadequate or Overheated	Inspect/replace air cleaner element. Look for other restrictions. Refer to page 3-11.
	If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position the valve for the season.
	Coolant passages plugged in the aftercooler.
	Check charge air cooler for internal restriction. Replace restricted cooler.
	Check/clean debris from front of charge air cooler.
OK ↓	

(Continued)

Engine Power Output Low (Continued)

Cause	Corrections
Air Leak Between the Turbocharger and the Intake Manifold	Check/correct leaks in the air crossover tube, charge air cooler connections, hoses, or through holes in the manifold cover. Refer to Procedure 3-08.
OK ↓	
Exhaust Restriction	Check/correct exhaust system. Check catalyst for restriction. Refer to Page 3-23.
OK ↓	
Fuel Temperature High. Greater Than 71°C [160°F]	Verify that fuel heater is off during warm weather. Check for a restricted fuel drain line.
OK ↓	
Exhaust Leak at the Manifold or Turbocharger	Check/correct leaks in the manifold or turbocharger gaskets. Look for a cracked manifold.
OK ↓	
Extra Injector Sealing Washer Installed Under Injector.	Remove extra injector sealing washer.
OK ↓	
Injectors Worn or Malfunctioning	Check injectors.
OK ↓	

(Continued)

Engine Power Output Low (Continued)

Cause	Corrections
Turbocharger Malfunctioning	Check for the specified boost pressure. Refer to turbocharger boost pressure specifications, Section 3.
OK	Inspect/replace turbocharger. Refer to Procedures 7-05, 3-01, and 3-13.
Valve Clearances Incorrect	Check/adjust valves. Refer to Procedure 7-04.
OK	
Fuel Injection Pump Timing Incorrect	Check/time fuel injection pump. Refer to Procedures 5-36.
OK	
Fuel Injection Pump Malfunctioning	Remove fuel injection pump. Have calibration checked.
OK	
Engine Compression Low	Perform compression check to identify malfunction. Correct as required.

Exhaust Black Smoke Excessive

Cause	Corrections
Engine Being Lugged Down	Use lower gear.
OK	
Intake Air Restricted	Inspect/change air cleaner. Look for other restrictions. Refer to page 3-11.
OK	
Exhaust Restriction	Check exhaust restriction. Refer to page 3-23.
OK	
Air Leak Between the Turbocharger and the Intake Manifold	Check/correct leaks in the air crossover tube, hoses, or through holes in the manifold cover. Refer to Procedures 3-10 and 3-11.
OK	
Charge Air Cooler Malfunction	Check for plugged charge air cooler, internal charge air restriction, or leaking charge air cooler.
OK	
Exhaust leak at the Manifold orTurbocharger	Check/correct leaks in the manifold or turbocharger gaskets. Look for a cracked manifold.
OK	
Turbocharger Wastegate Malfunctioning	Repair or replace wastegate. Refer to Procedure 3-02.
OK	
Turbocharger Malfunctioning	Inspect/replace turbocharger. Refer to Procedure 3-13.
OK	

(Continued)

Exhaust Smoke Black Excessive (Continued)

Cause	Corrections
Injector Installed With More Than One Sealing Washer	Remove extra washer. Refer to Procedure 5-40.
OK ↓	
7 mm Injector Installed With a 9 mm Sealing Washer	Remove the injector and install the proper sealing washer. Refer to Procedure 5-40.
OK ↓	
Injectors Malfunctioning	Replace injectors. Refer to Procedure 5-40.
OK ↓	
Fuel Injection Pump Malfunctioning or Overfueled	Remove fuel injection pump. Have calibration checked.
OK ↓	
Piston Rings Not Sealing (Blue Smoke)	Perform a compression check. Correct as required. Refer to Procedure 7-01.
OK ↓	
Fuel Injection Pump Timing Incorrect	Check/time fuel injection pump. Refer to procedure 7-20 and 5-36.

Exhaust White Smoke Excessive

Cause	Corrections
Improper Starting Procedure	Verify proper starting procedure. Refer to the starting procedure in the Operation and Maintenance Manual.
OK ↓	
Coolant Temperature Too Low	Refer to Troubleshooting Logic Chart for "Coolant Temperature Below Normal".
OK ↓	
Intake Air Temperature Too Low	Refer to vehicle operation manual for shutter operation.
OK ↓	
Fuel Quality Poor	Verify by operating engine from a temporary tank with good quality fuel. Clean and flush the fuel supply tanks. Use a diesel fuel with cetane value of 42-50.
OK ↓	
Injection Pump Timing Incorrectly Adjusted	Check top dead center (TDC). Refer to Procedure 7-21. Check/adjust injection pump timing. Refer to Procedure 5-36. Check/time the fuel injection pump using the spill port timing if equipment is available. Refer to Procedure 5-36.
OK ↓	
Troubleshoot the KSB (Bosch VE Pump Only)	Refer to Procedure 5-07, 5-08 and 5-09.
OK ↓	
Injector installed with more than one sealing washer	Remove extra washer. Refer to Procedure 5-40.
OK ↓	
Injectors Malfunctioning	Check/replace injectors. Refer to Procedures 5-13 and 5-40.
OK ↓	

(Continued)

Exhaust White Smoke Excessive (Continued)

Cause	Corrections
Coolant Leaking Into Combustion Chamber	Refer to Troubleshooting Logic for Coolant Loss.
OK ↓	
Fuel Injection Pump Malfunctioning/ Delivery Valves Malfunctioning	Remove fuel injection pump. Have calibration checked.

Coolant Temperature Above Normal - Gradual Overheat

Cause	Corrections
Coolant Level Low	Check/replenish coolant. Refer to Procedure 1-06.
OK	Locate and correct the source of the coolant leak. Refer to troubleshooting logic for Coolant Loss.
Charge/Radiator Air Cooler Fins Plugged (Automotive Only)	Blow debris from fins.
OK	
Air Flow to the Radiator Inadequate or Restricted	Check/repair fan shroud, shutters, fan sensors, and fan clutch as required. Refer to the equipment manufacturer's procedures.
OK	
Water Pump or Fan Drive Belts Loose	Check/correct belt tension.
OK	
Radiator Hose Collapsed, Restricted or Leaking	Check/replace hose.
OK	
Lubricating Oil Level High	Check/drain oil to correct level.
OK	
Cooling Fan Shroud Damaged or Missing	Inspect shroud, repair/replace or install.
OK	

(Continued)

Coolant Temperature Above Normal - Gradual Overheat (Continued)

Cause	Corrections
Pressure Cap Incorrect or Malfunctioning	Replace cap with the correct rating for the system. Refer to Procedure 1-01.
OK ↓	
Overconcentration of Anti-Freeze	Remove part of the coolant from cooling system and replace with water.
OK ↓	
Temperature Sensor or Gage Malfunctioning	Verify that the gauge and temperature sensor are accurate. Refer to Procedure 1-01.
OK ↓	
Thermostat Malfunctioning, Incorrect or Missing	Check/replace the thermostat. Refer to Procedure 1-08.
OK ↓	
Radiator Shutters Are Not Opening Completely or Cold Weather Radiator Cover Closed	Inspect the shutters, repair or replace if necessary. Open radiator cover.
OK ↓	
Air or Combustion Gases in the Cooling System	Make sure the fill rate is not being exceeded and the correct vented thermostat is installed. Refer to Procedure 1-01.
	If aeration continued, check for a compression leak through the head gasket. Refer to Procedure 7-01.
OK ↓	

(Continued)

Coolant Temperature Above Normal - Gradual Overheat (Continued)

Cause	Corrections
Water Pump Malfunctioning	Check/replace the water pump. Refer to Procedure 1-07.
OK ↓	
Cooling Passages in Radiator, Head, Head Gasket or Block Plugged	Flush the system and fill with clean coolant.
OK ↓	
Vehicle Cooling System Design	Contact vehicle manufacturer for confirmation of correct fan, radiator, and other cooling system components.
OK ↓	
Fuel Injection Pump Timing Incorrect	Verify fuel injection pump timing marks are aligned. Refer to Procedure 5-36.
OK ↓	
Fuel Injection Pump Overfueled	Remove fuel injection pump. Have calibration checked.

Coolant Temperature Above Normal - Sudden Overheat

Cause	Corrections
Coolant Level Low	Add coolant. Refer to Procedure 1-06.
Temperature Sensor or Gauge Malfunctioning	Verify that the gauge and temperature sensor are accurate. Refer to Procedure 1-01.
Fan Drive Belt Loose	Check belt tension.
Radiator Hose Collapsed, Restricted, or Leaking	Inspect hoses.
Radiator Cap Incorrect or Malfunctioning. Cap Rated Pressure Too Low	Check the radiator pressure cap. Refer to Procedure 1-01.
Thermostat Incorrect or Malfunctioning	Check thermostat. Refer to Procedure 1-01.
Radiator Shutters Are Not Opening Completely or Cold Weather Radiator Cover Closed. Shutterstat Setting Wrong.	Inspect the shutters. Repair or replace if necessary. Open radiator cover. Check shutterstat setting. Refer to Procedure 1-01.
Air or Combustion Gases in the Cooling System	Check for air or combustion gases in the cooling system. Refer to Procedure 7-01.

OK

(Continued)

Coolant Temperature Above Normal - Sudden Overheat (Continued)

Cause	Corrections
Vent Line From Engine and/or Radiator Plugged or Incorrectly Routed	Check routing and operation of vent line.
OK ↓	
Water Pump Malfunctioning	Check water pump operation. Replace the water pump. Refer to Procedures 1-09 and 1-07.
OK ↓	
Leak Between the Top Tank and the Auxiliary Tank	Check for coolant leakage between radiator auxiliary tank and radiator top tank.

Coolant Temperature Below Normal

Cause	Corrections
Air Flow Across the Radiator Excessive	Check/repair shutters, fan clutch, viscous fan as required. Refer to the equipment manufacturer's procedures.
OK ↓	
Thermostat Broken, Damaged, Contaminated or Not Sealing	Check/replace Thermostat. Refer to Procedures 1-01 and 1-08.
OK ↓	
Temperature Sensor or Gauge Malfunctioning	Verify that the gauge and sensor are accurate. Refer to Procedure 1-01.
OK ↓	
Coolant Not Flowing by Temperature Sensor	Check/clean coolant passages.

Coolant Loss

Cause	Corrections
Radiator or Cab Heater Leaking	Visually inspect the radiator heater, hoses and connections to locate the leak.
OK	
	If oil is present in the coolant, check for a transmission or lube oil cooler leak
External Engine Leak	Visually inspect the engine and components for seal, gasket, or drain cock leaks.
OK	
Overheating or Compression Gases Leaking Resulting in Loss Through the Radiator Overflow	Review the operation for overheating and low power. Refer to troubleshooting logic for Coolant Temperature Above Normal.
OK	
If Equipped, Transmission Cooler Leak	Check for mixing of coolant and transmission fluid. Refer to Procedure 2-03.
OK	
If Equipped with a Water Cooled Air Compressor, Head or Head Gasket Leaking	Look for coolant in the oil. Check/ replace head or gasket. Refer to the equipment manufacturer's procedures.
OK	
If the Engine is Coolant Aftercooled, Aftercooler Leak	Check/replace the aftercooler. Look for coolant in the intake manifold and in the oil.
OK	
Lubricating Oil Cooler Leak	Check/replace the oil cooler. Look for coolant in the oil. Refer to Procedure 2-05.
OK	

(Continued)

Coolant Loss (Continued)

Cause	Corrections
Cylinder Head Gasket Leak	Check/replace the head gasket. Refer to Procedure 7-07.
OK ↓	
Cylinder Head Cracked or Porous	Check/replace the head. Refer to Procedure 7-07.
OK ↓	
Cylinder Block Coolant Passages Leaking	Check/replace the cylinder block.

Lubricating Oil Pressure Low

Cause	Corrections
Lubricating Oil Level Low	Check/replenish lubricating oil. Refer to page 2-08.
OK	Check for a severe external oil leak that could reduce the pressure.
Lubricating Oil Viscosity Thin; Diluted or Does Not Meet Specification	Verify the correct oil is being used. Check for oil dilution. Refer to troubleshooting logic for Contaminated Lubricating Oil.
OK	
Engine Temperature High (Above 95°C [203°F])	Refer to troubleshooting logic for Coolant Temperature Above Normal.
OK	
Pressure Switch or Gauge Malfunctioning	Verify the pressure switch is functioning correctly.
OK	
Pressure Regulator Valve Stuck Open	Check/replace valve. Refer to Procedure 2-04.
OK	
Lubricating Oil Filter Plugged	Change lubricating oil filter; review change interval.
OK	
Lubricating Oil Cooler Plugged	Replace lubricating oil cooler. Refer to Procedure 2-05.
OK	

(Continued)

Lubricating Oil Pressure Low (Continued)

Cause	Corrections
If Lubricating Oil Cooler was Replaced, Shipping Plugs Left in Cooler	Check/remove shipping plugs.
OK	
If Replaced, Four Cylinder Lubricating Oil Pump Installed in a Six Cylinder Engine	Verify that the correct lubricating oil pump is installed. Refer to Procedure 2-07.
OK	
If Replaced, a Pre-1991 Lubricating Oil Pump Installed in a 1991 or Later Engine.	Verify that the correct lubricating oil pump is installed. Refer to Procedure 2-07.
OK	
Cylinder Block or Cylinder Head Plugs Loose or Missing	Check/replace expansion plugs. Refer to Procedure 2-08.
OK	
Suction Tube Loose or Broken Seal Leaking	Check/replace seal. Refer to Procedure 2-06.
OK	
Lubricating Oil Pump Worn	Check/replace lubricating oil pump. Refer to Procedure 2-07.
OK	
Main Bearing Cap Loose	Check/install new bearings and tighten cap. Refer to Procedure 7-13.
OK	
Bearings Worn	Inspect/replace bearings; also check/replace piston cooling nozzles. Refer to Procedure 7-13.

Lubricating Oil Pressure High

Cause	Corrections
Pressure Switch or Gauge Malfunctioning	Verify the pressure switch is functioning correctly.
OK ↓	
Engine Running Too Cold	Refer to troubleshooting logic for Coolant Temperature Below Normal
OK ↓	
Lubricating Oil Viscosity Too Thick	Make sure the correct lubricating oil is being used. Refer to O&M manual.
OK ↓	
Pressure Regulator Valve Stuck Closed	Check/replace valve. Refer to Procedure 2-04.
OK ↓	
If Replaced, Six Cylinder Lubricating Oil Pump, Installed in Four Cylinder	Verify that the correct lubricating oil pump is installed. Refer to Procedure 2-07.

Lubricating Oil Consumption Excessive

Cause	Corrections
External Leaks	Visually inspect for lubricating oil leaks.
OK ↓	
Crankcase Being Overfilled (Dipstick Calibrated Incorrectly)	Verify that the dipstick is correctly marked.
OK ↓	
Incorrect Lubricating Oil (Specification or Viscosity)	Make sure the correct lubricating oil is being used.
OK ↓	Look for reduced viscosity from dilution with fuel. Fuel dilution in lubricating oil can originate from fuel injection pump driveshaft seal or fuel transfer pump.
	Review/reduce the lubricating oil change intervals.
High Blowby Forcing Lubricating Oil Out the Breather	Check the breather tube area for signs of lubricating oil loss. Measure the blowby and perform the required repairs. Refer to Procedure 8-05.
OK ↓	
Lubricating Oil Cooler Leak	Check for lubricating oil in the coolant. Refer to Procedure 2-03.
OK ↓	
If Equipped, Air Compressor Pumping Lubricating Oil	Check/replace air compressor. Refer to Procedure 4-06.
OK ↓	

(Continued)

Lubricating Oil Consumption Excessive (Continued)

Cause	Corrections
Turbocharger Leaking Lubricating Oil to the Air Intake or Exhaust	Inspect the air crossover tube for evidence of lubricating oil transfer.
OK ↓	
Valve Seals Worn	Inspect/replace the valve seals. Refer to Procedure 7-01.
OK ↓	
Piston Rings Not Sealing - Lubricating Oil Being Consumed by the Engine	Perform a compression check. Repair as required. Refer to Procedure 7-01.

Coolant Contaminated

Cause	Corrections
Coolant Rusty, Operation Without Correct Mixture of Antifreeze and Water	Drain and flush the cooling system. Fill with correct mixture of antifreeze and water.
	Review the coolant change interval. Refer to the Operation and Maintenance Manual.
OK ↓	
If Equipped, Transmission Lubricating Oil Cooler Leaking	Check/replace lubricating oil cooler. Refer to equipment manufacturer's procedures.
OK ↓	
Lubricating Oil Leaks from Lubricating Oil Cooler, Head Gasket, Head and Cylinder Block	Refer to troubleshooting logic for Lubricating Oil Loss.

Lubricating Oil Contaminated

Cause	Corrections
Coolant in the Lubricating Oil, Internal Engine Component Leaks	Refer to troubleshooting logic for Coolant Loss.
OK	
Lubricating Oil Sludge Excessive	Review lubricating oil and filter change intervals
	Make sure the correct lubricating oil is being used
OK	
Fuel in the Lubricating Oil, Engine Operating Too Cold	Review the operation for excessive idling resulting in the engine running below normal temperature.
OK	
Fuel Transfer Pump Seal Leaking	Repair or replace fuel transfer pump. Refer to Procedures 5-03 and 5-21.
OK	
Fuel Injection Pump Seal Leaking (Rotary)	Remove the fuel injection pump and have repaired. Refer to Procedure 5-35.
OK	
Internal Plunger Seal Leaking (In-Line)	Remove the fuel injection pump and have repaired. Refer to Procedure 5-37.
OK	
Injector Needle Valves Not Sealing	Locate and replace malfunctioning injector. Refer to Procedures 5-13 and 5-40.

Fuel Or Oil Leaking From Exhaust Manifold

Cause	Corrections
Operating for Extended Periods Under Light or no Load Conditions	Review operating procedure with operator.
OK	
Intake Air Restriction	Review operation for excessive idling.
OK	Check/replace filter element. Refer to Procedures 5-05 and 5-16.
Injector Needle Valve Stuck Open	Locate and replace malfunctioning injector. Refer to Procedures 5-13 and 5-40.
OK	
Turbocharger Lubricating Oil Drain Line Obstructed	Check/clean line.
OK	
Turbocharger Seals Leaking Oil	Check/replace turbocharger. Refer to Procedure 3-13.
OK	
Blowby Excessive	Check for excessive blowby. Refer to Procedure 8-05.
OK	
Fuel Injection Pump Timing Incorrect	Check/time the injection pump. Refer to Procedure 5-36.

Compression Knocks

Cause	Corrections
If Equipped, Malfunctioning Ether Starting Aid	Repair or replace ether starting aids.
OK ↓	
Air in the Fuel System	Bleed the fuel system. Refer to Procedures 5-03 and 5-15.
OK ↓	
Poor Quality Fuel	Verify by operating from a temporary tank with good fuel; clean and flush the fuel supply tanks.
OK ↓	
Engine Overloaded	Verify that engine load rating is not being exceeded.
OK ↓	
Fuel Injection Pump Timing Incorrect	Check/time fuel injection pump. Refer to Procedure 5-36.
OK ↓	
Injectors Malfunctioning	Replace injectors. Refer to Procedures 5-13 and 5-40.
OK ↓	
Coolant Operating Temperature Incorrect	Refer to troubleshooting logic for Low Coolant Temperature.

Fuel Consumption Excessive

Cause	Corrections
Additional Loading from Malfunctioning Accessories	Check/repair accessories and vehicle components. Refer to the equipment manufacturer's procedures.
OK ↓	
Operator Technique	Review operation for correct gear shifts, deceleration, and idling
OK ↓	
Fuel Leaks	Check for external leaks and engine lubricating oil dilution.
OK ↓	For fuel dilution, check for internal leaks at the fuel transfer pump and injection pump.
Poor Quality Fuel or No. 1 Fuel Used	Make sure quality No. 2 fuel is being used.
OK ↓	
Intake Air or Exhaust Restriction	Refer to troubleshooting logic for Excessive Exhaust Smoke
OK ↓	
Injectors Worn or Malfunctioning	Check/replace injectors. Refer to Procedures 5-13 and 5-40.
OK ↓	

(Continued)

Fuel Consumption Excessive (Continued)

Cause	Corrections
Fuel Injection Pump Timing Incorrect	Check/time the fuel injection pump. Refer to Procedure 5-36.
OK ↓	
Fuel Injection Pump Settings Incorrect	Check for broken adjustment seals on the fuel injection pump. If the seals are broken, remove and recalibrate fuel injection pump. Refer to Procedures 5-35 and 5-37.
OK ↓	
Valves Not Seating	Check/adjust valves. Refer to Procedure 7-04.
OK ↓	
Power Functions Malfunctioning	Check/repair power functions.

Engine Will Not Shut Off

Cause	Corrections
Fuel Shutoff Valve Inoperative	Stop the engine mechanically with lever on the fuel pump. Check for correct solenoid operation. Refer to Procedures 5-05, 5-11 and 5-31.
OK ↓	
Fuel Injection Pump Malfunctioning	Remove the fuel injection pump and have checked/repaired. Refer to Procedures 5-35 and 5-37.
OK ↓	
Engine Running on Fumes Drawn into the Air Intake	Check the air intake ducts for the source of the fumes.

Engine Vibration Excessive

Cause	Corrections
Engine Not Running Smoothly	Refer to troubleshooting logic for Rough Running or Misfiring.
OK	
Engine Low Idle Speed Too Low	Adjust engine low idle speed. Refer to Procedures 5-38 and 5-39.
OK	
Fan Damaged or Accessories Malfunctioning	Check/replace the vibrating component. Refer to equipment manufacturer's service instructions.
OK	
Fan Hub Malfunctioning	Inspect/Replace the fan hub. Refer to Procedure 1-05.
OK	
Alternator Bearing Worn or Damaged	Check/replace the alternator. Refer to Procedure 6-11.
OK	
Vibration Damper Malfunctioning (Six-Cylinder Only)	Inspect/replace the vibration damper. Refer to Procedure 7-15.
OK	
Engine Counter Balancer Not Timed Correctly (4 Cylinder Only)	Time counter balancer. Refer to Shop Manual 3810206.
OK	
Flywheel Housing Misaligned	Check/correct flywheel alignment. Refer to Procedure 7-24.
OK	

(Continued)

Engine Vibration Excessive (Continued)

Cause	Corrections
Power Components Loose or Broken	Inspect the crankshaft and rods for damage that cause and unbalance. Refer to Procedure 7-11.
OK ↓	
Engine Mounts Loose or Broken	Check/replace engine mounts. Refer to the equipment manufacturer's service instructions.
OK ↓	
Drive Line Components Worn or Unbalanced	Check/repair according to the equipment manufacturer's procedures.

Engine Noises Excessive

Cause	Corrections
Drive Belt Squeal, Insufficient Tension or Abnormally High Loading	Check the tensioner and inspect the drive belt for deterioration. Make sure water pump, tensioner pulley, fan hub and alternator turn freely.
	Check for paint/oil or other material on pulleys.
	Check the tension of accessory drive belts. Refer to the equipment manufacturer's procedures. Make sure the accessories turn freely.
OK	
Intake Air or Exhaust Leaks	Refer to troubleshooting logic for Excessive Exhaust Smoke
OK	
Valve Lash Excessive	Adjust valves. Make sure the push rods are not bent or the rocker levers are not severely worn. Refer to Procedure 7-04.
OK	
Turbocharger Noise	Check turbocharger impeller and turbine wheel for housing contact. Refer to Procedure 3-01.
OK	
Gear Train Noise	Visually inspect and measure gear backlash. Replace gears as required. Refer to page 7-05.
OK	
Power Function Knock	Check/replace rod and main bearings. Refer to Procedures 7-11 and 7-13.

Alternator Not Charging Or Insufficient Charging

Cause	Corrections
Battery Connections Loose or Corroded	Check/tighten battery connections. Refer to Procedure 6-02.
OK ↓	
Battery Condition	Load test the battery. If battery charge is low, charge the battery and load test again. If the battery fails the load test, replace the battery.
OK ↓	
Alternator Belt Slipping	Check/replace belt tensioner. Refer to Procedure 1-03.
OK ↓	
Alternator Pulley Loose on Shaft	Repair/tighten pulley.
OK ↓	
Wires at Alternator Loose or Broken	Repair wiring.
OK ↓	
Alternator Malfunctioning	Refer to the vehicle manufacturer's instructions for troubleshsooting the alternator and charging circuit.
	Replace alternator. Refer to Procedure 6-11.

Section 1 - Cooling System

Section Contents

Coolant System Components and Flow

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

A. Coolant is drawn from the radiator by the integrally mounted water pump. The output from the water pump empties into the oil cooler cavity of the cylinder block.

B. The coolant then circulates around each cylinder and crosses the block to the fuel pump side of the engine.

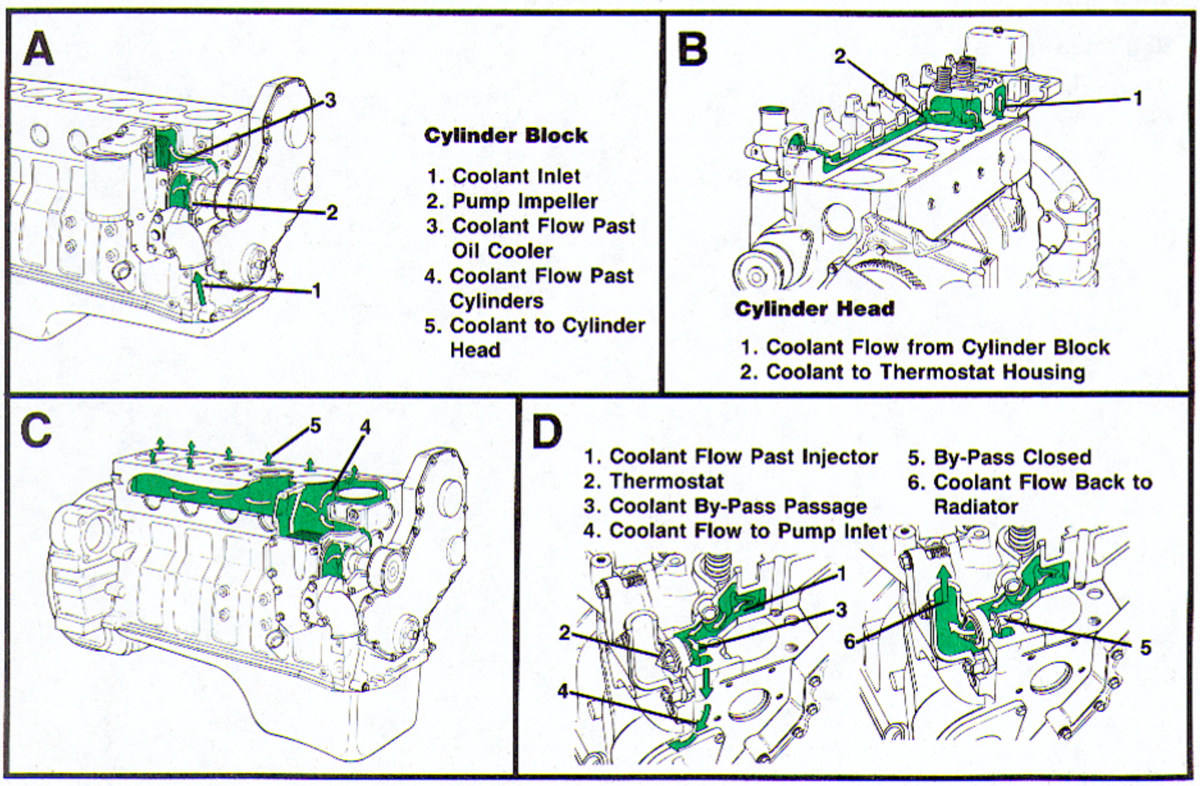
C. Coolant then flows up into the cylinder head, crosses over the valve bridges and down the exhaust manifold side of the engine to the integral thermostat housing.

D. As the coolant flows across the head toward the thermostat housing, it provides cooling for the injector. When the engine is below operating temperature, the thermostat is closed, and the coolant flow bypasses the radiator and goes to the water pump inlet through internal drillings in the block and cylinder head.

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

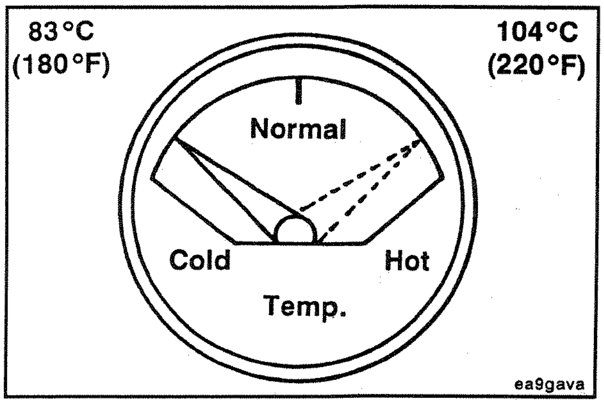
⚠ **Caution: Never operate the engine without a thermostat. Without a thermostat, the coolant will not flow to the radiator and the engine will overheat.**

Coolant System



Cooling System Specifications

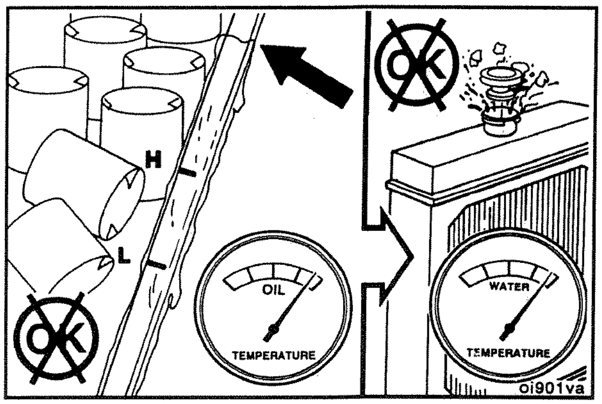
Cooling System Specifications	B3.9, 4B3.9	4BT3.9	4BTA3.9	6B5.9, 6BT5.9, B5.9	6BTA5.9
Coolant Capacity (Engine Only)- Litre [U.S. Qts.]..	7 [7.4]	7 [7.4]	9.7 [10.3]	10.5 [11.1]	14.5 [15.3]
Standard Modulating Thermostat - Range - °C [°F]........................	-------------------	Start 83 [181]	-------------------	Fully Open 95 [203]	-------------------
Pressure Cap (kPa [PSI]) 104°C [220°F] Systems......................	103 [15]	103[15]	103 [15]	103 [15]	103 [15]
Pressure Cap (kPa [PSI]) 99°C [210°F] Systems......................	48 [7]	48 [7]	48 [7]	48 [7]	48 [7]



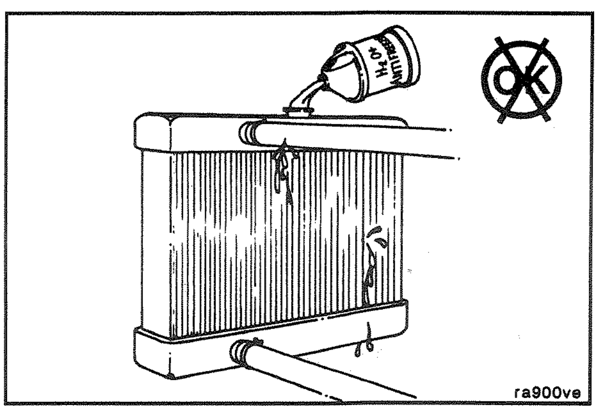
Coolant System Malfunctions (1-01)

Diagnosis

The function of the coolant system is to maintain a specified operating temperature for the engine. Some of the heat generated by the engine is absorbed by the coolant flowing through the passages in the cylinder block and head. Then, heat is removed from the coolant as it flows through the radiator. When you troubleshoot overheating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil.

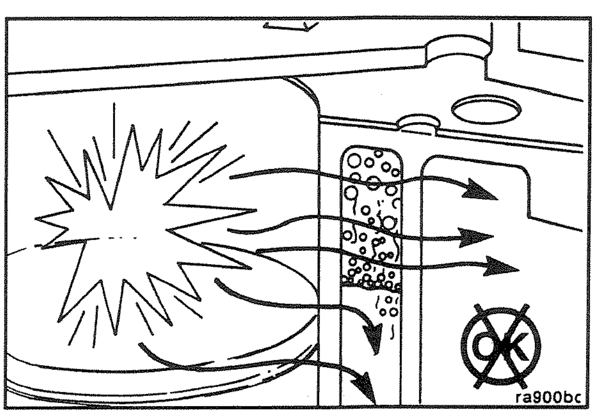


Overfilling with oil raises the oil temperature which is transferred to the coolant system at the oil cooler.



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

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

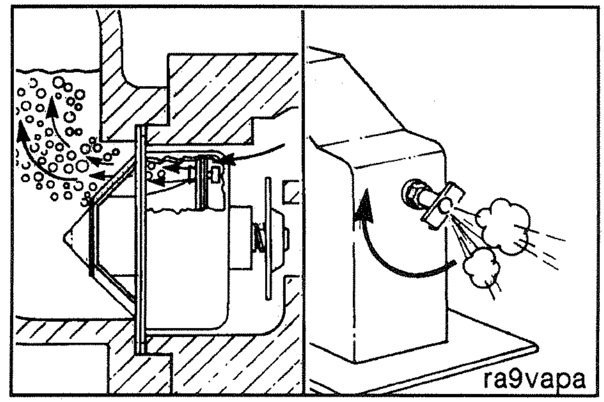


Caution: The engine coolant passages must be completely filled with coolant.

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

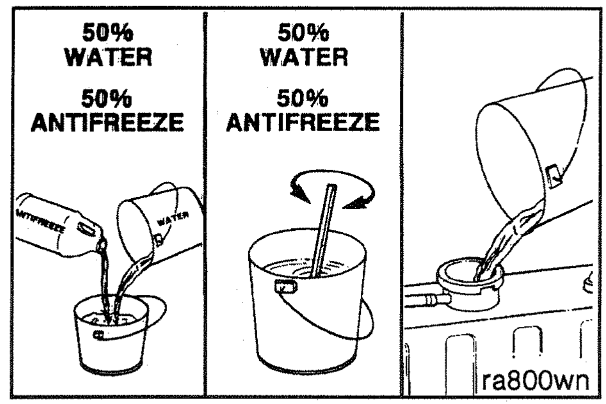
During filling, air must be vented from the engine coolant passages. The air vents through the "jiggle pin" openings to the top radiator hose and out the fill opening. Additional venting is provided for engines equipped with an aftercooler. Open the petcock during filling.

NOTE: Adequate venting is provided for a fill rate of 14 liters/minute [3.5 U.S. Gallon/minute].



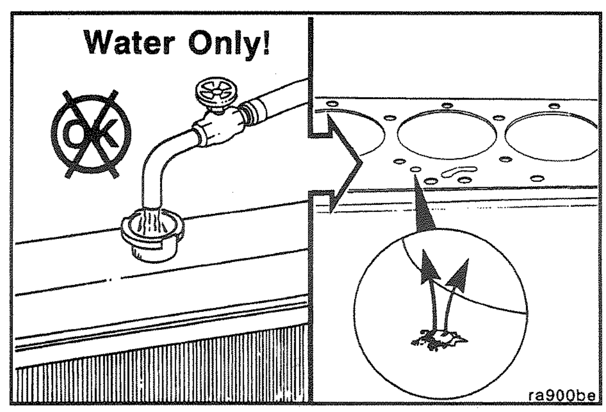
NOTE: A 50 percent mixture of antifreeze and water **must** be premixed before filling the system. The ability of antifreeze to remove heat from the engine is not as good as water, so pouring antifreeze into the engine first could contribute to an over heated condition before the liquids are completely mixed.

A mixture of 50% ethylene-glycol base antifreeze is required for operation of the engine in temperature environments above -37°C [-34°F]. A mixture of 40% water and 60% antifreeze is recommended for temperatures below -37°C [-34°F]. Never use more than 60% antifreeze.



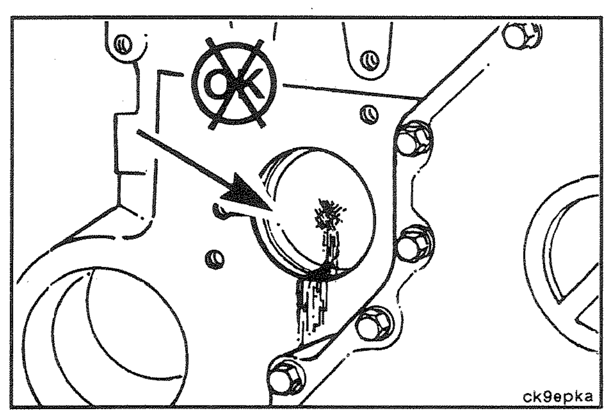
Caution: Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant. The small holes in the head gasket are especially susceptible to plugging. These holes are orifices and their size is critical. Do not enlarge the size of the orifices. To do so will disturb the coolant flow and will not solve an overheating problem.

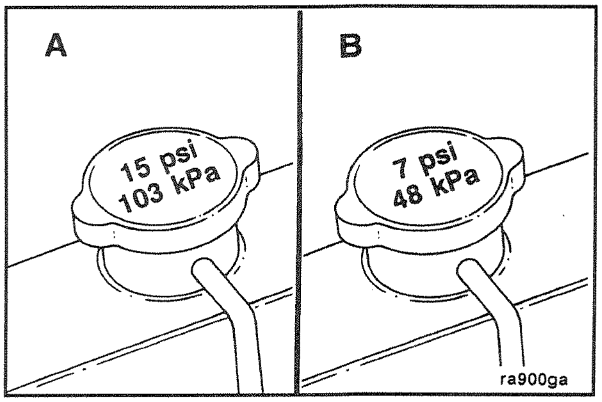
Water will cause rust formation reducing the flow in the smaller coolant passages.



Also, water used as a coolant for even a relatively short period can result in the cup plugs rusting through allowing the coolant to leak.

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



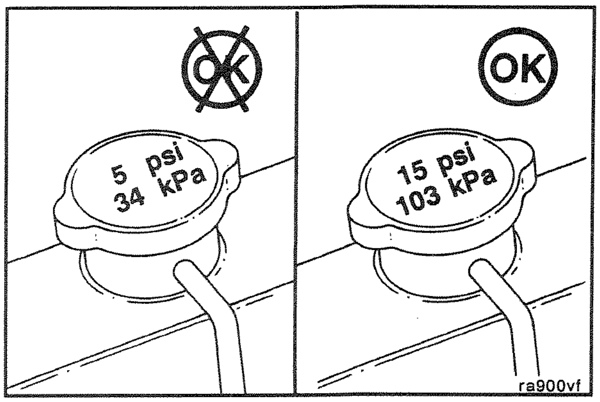


Pressure Caps

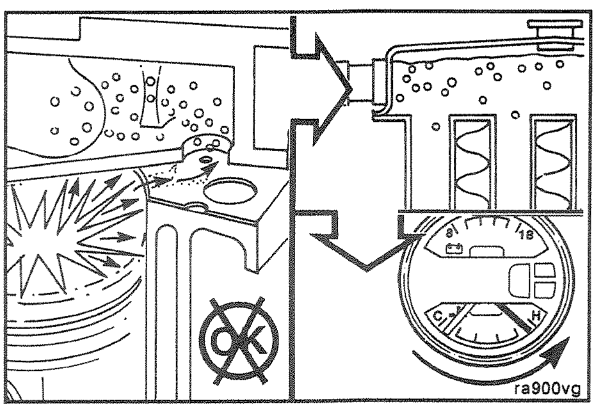
The system is designed to use a pressure cap to prevent boiling of the coolant.

Different caps are specified for the two recommended systems:

	System	Cap
A (Normal Duty)	104°C [220°F]	103kPa [15 PSI]
B (Light Duty)	99°C [210°F]	48kPa [7 PSI]

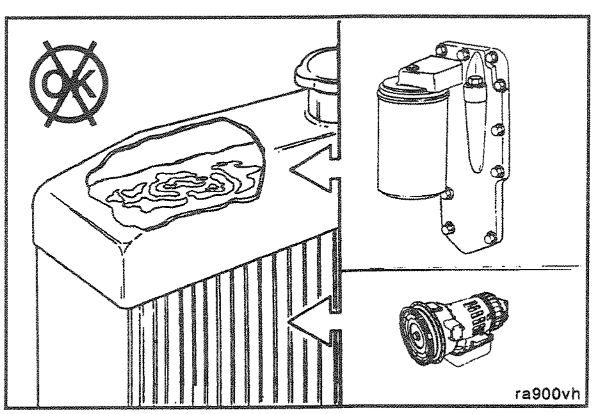


An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gasses to the coolant system.

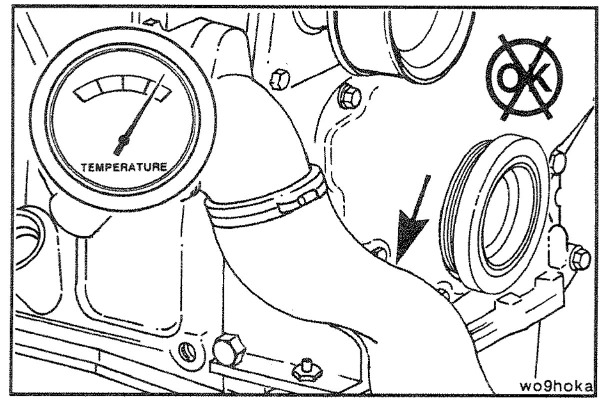


The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: head gasket, oil cooler, etc. (refer to the Lubricating System).

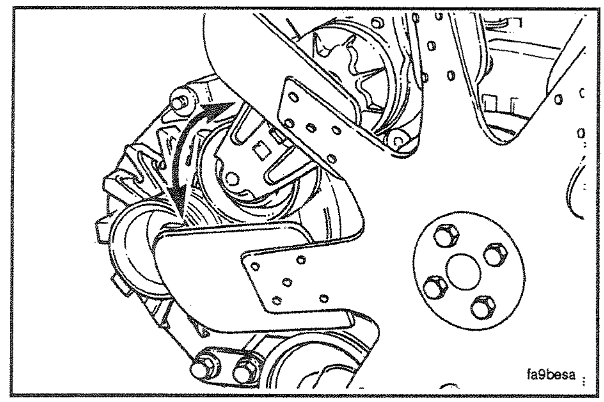
NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers.

Water (Coolant) Pump

The water pump pulls coolant from the bottom of the radiator and pumps it through the engine back to the top of the radiator for cooling. Reduced or interrupted flow will result in the engine running hot.

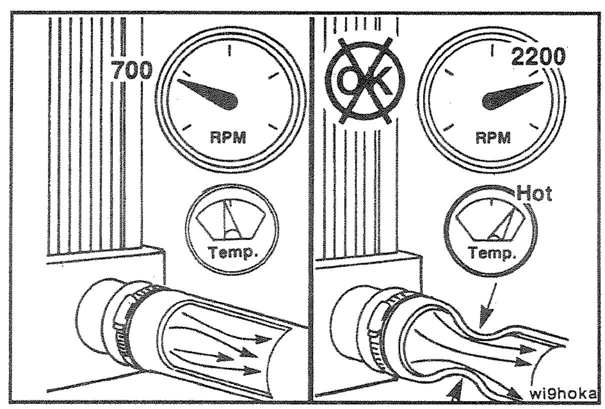


The pump is belt driven from the crankshaft pulley. An automatic belt tensioner is used to prevent the belt from slipping on the pump pulley. A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed reducing the amount of coolant flow.

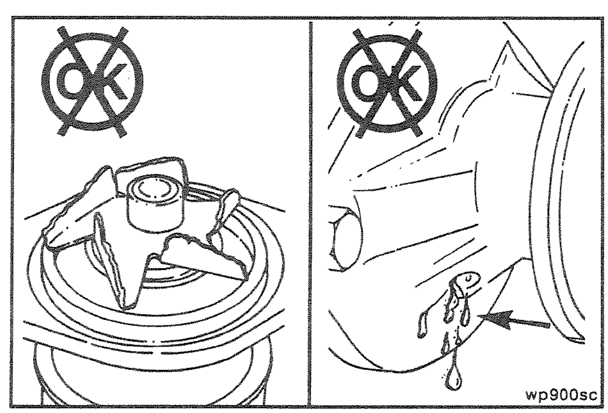


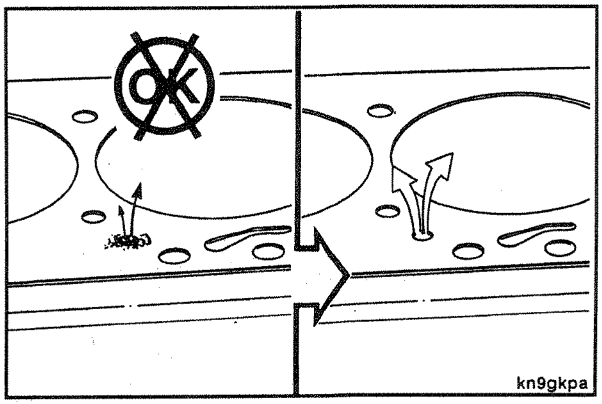
The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually not collapse while the engine is running at low speed. Check the hose while the engine is running at rated speed.

NOTE: Be sure the engine is warm, a minimum of 95°C [203°F], so the thermostat is open.

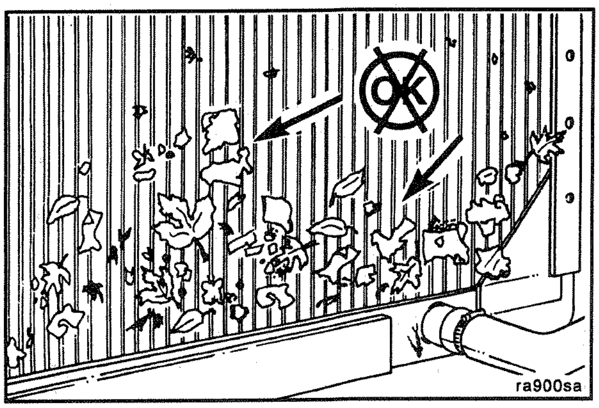


A worn or malfunctioning water pump will not produce the flow required to prevent the engine from running hot. However, be sure to check the other possibilities indicated in the Troubleshooting Logic before checking the flow or replacing the pump.



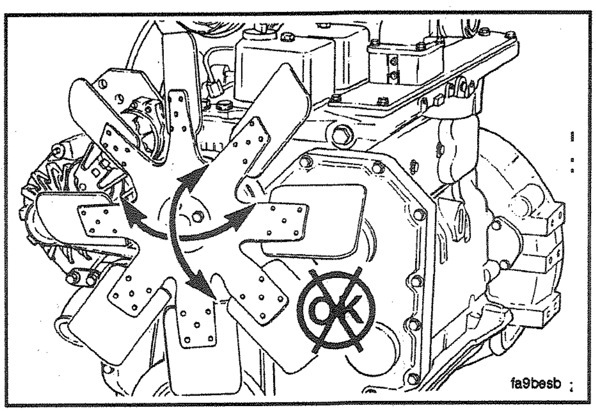


As stated in the coolant discussion, an obstruction in the passages can interrupt flow.



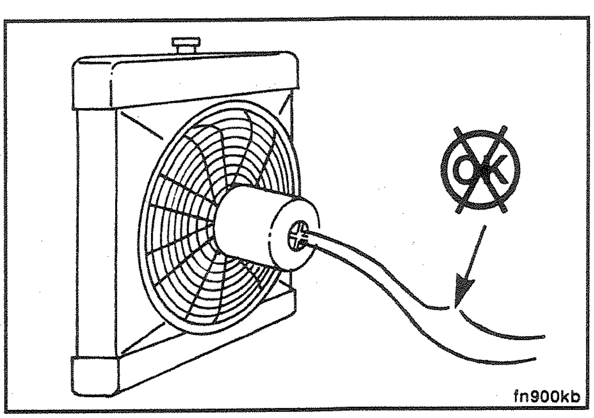
Radiator, Fans and Shutters

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (paper, straw, lint, dust, etc.) can obstruct the fins and stop the flow of air which will reduce the cooling effect of the radiator.



If the fan is belt driven, a slipping belt will result in a slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem.

NOTE: Check the bearings in the fan hub and other pulleys to make sure they are not causing excessive belt vibration and slippage.

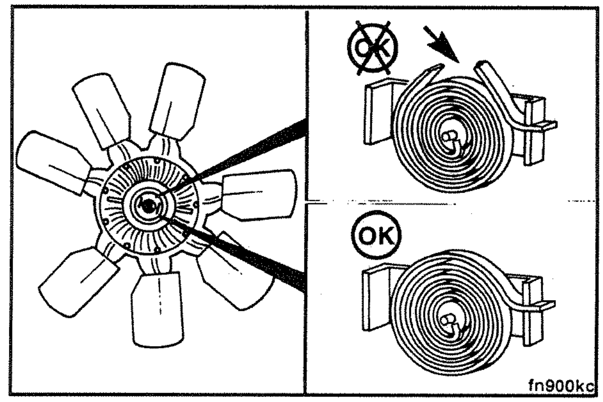


Interruption of the circuit to an electrically driven fan can result in insufficient air flow and cause the engine to run hot.

NOTE: Make sure that the temperature sensor is functioning correctly.

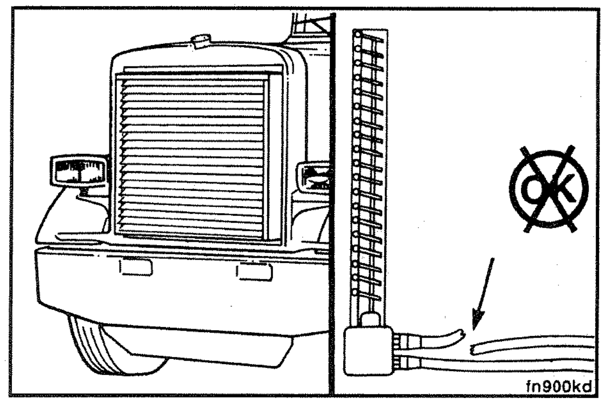
Some applications use thermatic fans. These fans operate only as needed to keep the coolant at the correct temperature. If the fan does not operate when the coolant temperature increases, the engine will run hot. If the fan does not shut off when coolant temperature decreases, the engine will run cold.

NOTE: Make sure that the coolant temperature sensor is functioning correctly.

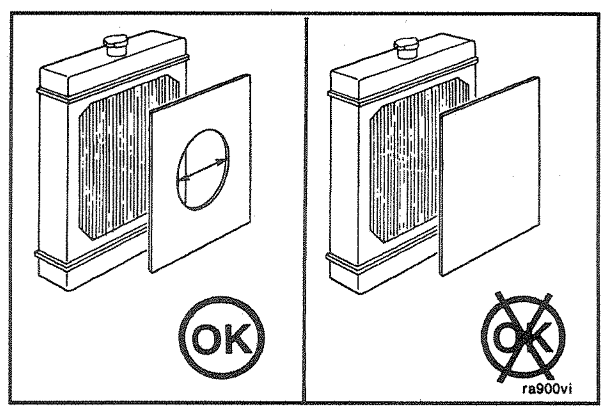


Shutters are designed to control air flow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much air flow and the engine running cold.

NOTE: Make sure that the air temperature sensor is functioning correctly. Check the air operated shutter controls. Check for air leaks.

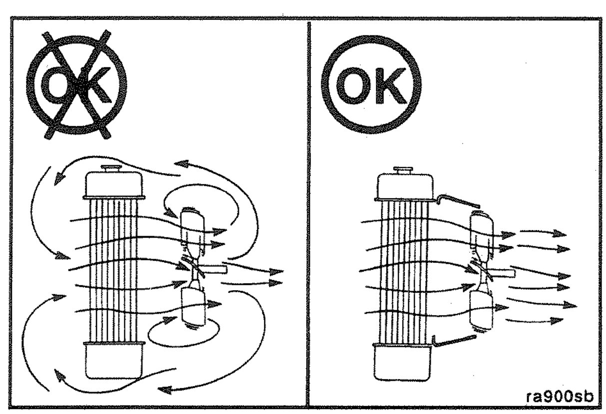


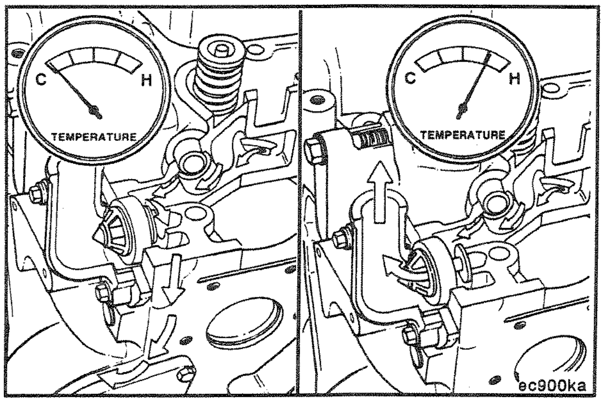
Winterfronts can be used on a charge air cooled engine, but must be designed to partially cover the frontal area of the cooling system. A minimum of 120 square inches of charge air cooled frontal area must be left open to air flow.



An incorrect fan shroud or obstructions can reduce air flow and cause the engine to run hot.

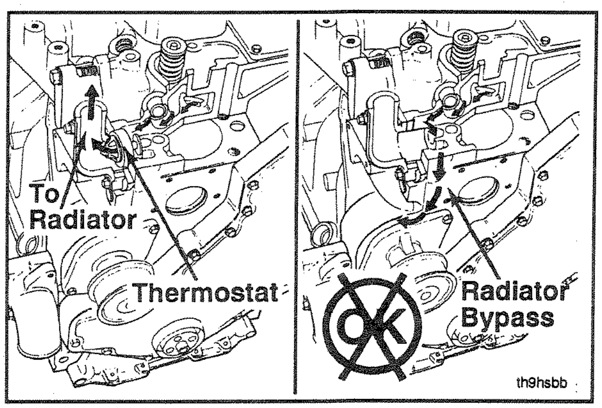
NOTE: Check to be sure air is not recirculating. Check for missing baffles.



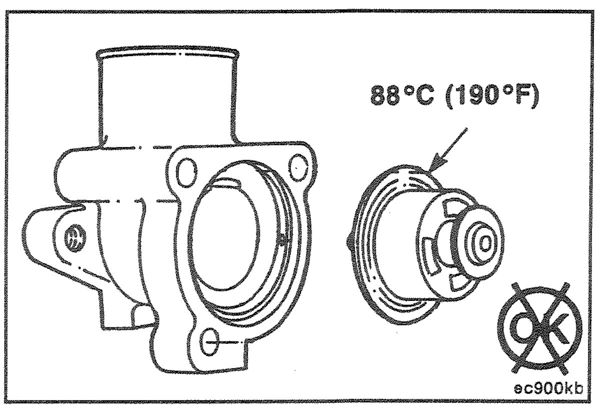


Thermostat

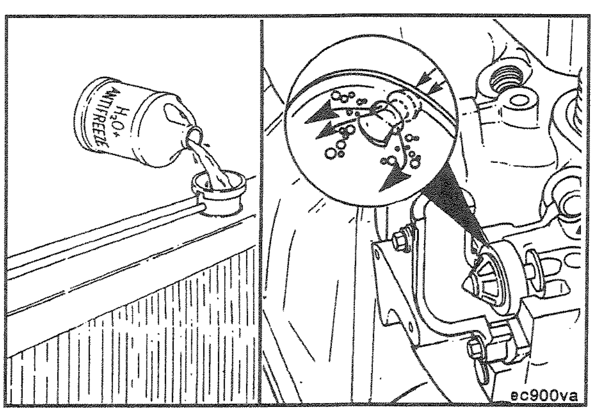
The thermostat controls the coolant temperature. When the coolant temperature is below the operating range, coolant is bypassed back to the inlet of the water pump. When the coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, forcing coolant to flow to the radiator.



Caution: Never operate the engine without a thermostat. Without a thermostat the path of least resistance for the coolant is through the bypass to the pump inlet. This will cause the engine to overheat.



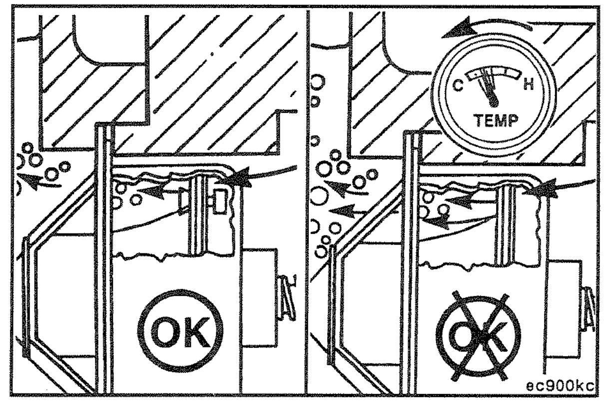
An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



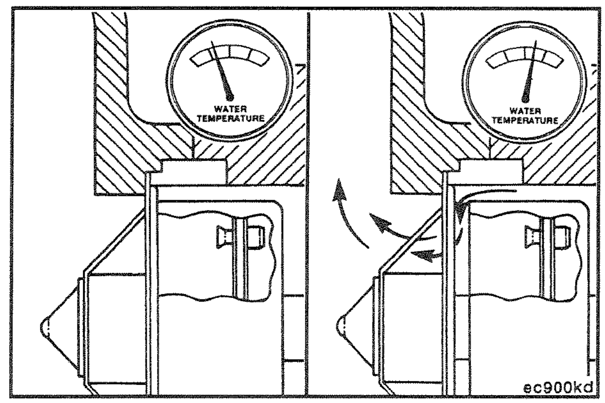
As described in the coolant discussion, jiggle pins vent air during filling of the coolant system.

After the engine is vented and filled, the jiggle pins act as check valves to block the flow of coolant through the opening during engine operation.

NOTE: A missing jiggle pin can cause the engine to run cold.

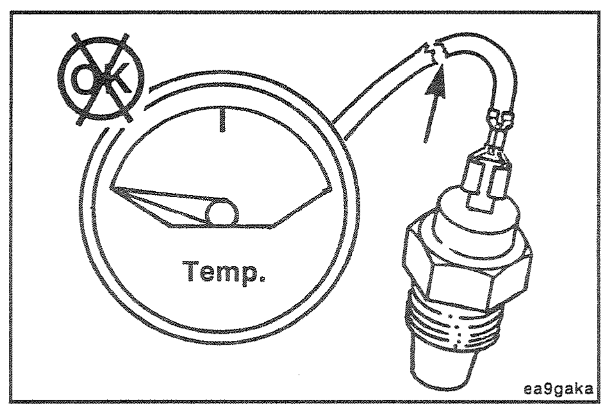


With the jiggle pins sealing the openings, the flow to the radiator is controlled by the thermostat opening in response to the engine coolant temperature.

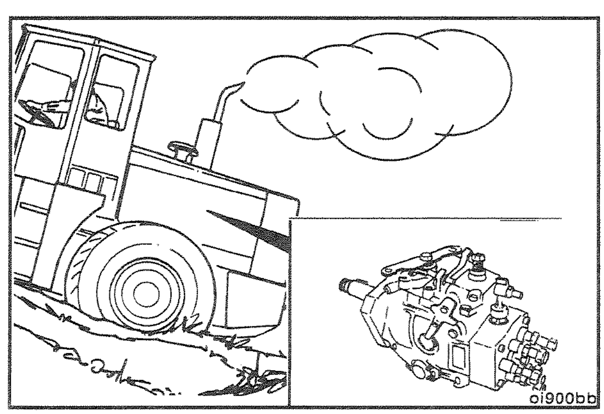


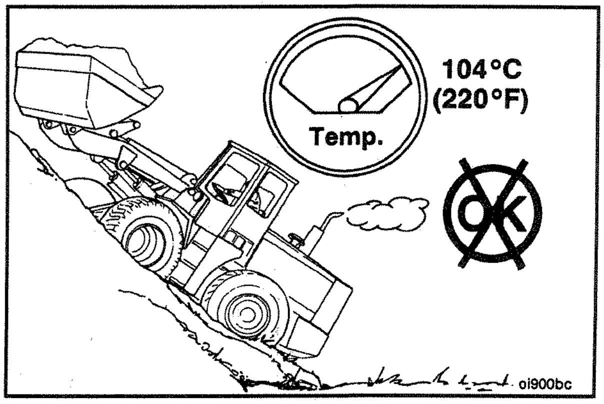
Gauges, Overfueling and Loading

Gauges and sensors are used in the system to measure the coolant temperature. These can malfunction and provide an incorrect temperature indication.

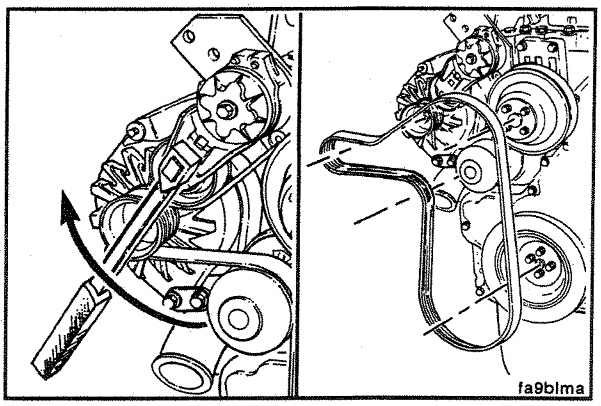


Caution: Overfueling can cause the engine to overheat. Make sure that the fuel pump is calibrated correctly.





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



Drive Belt - Replacement (1-02)

3/8 inch Square Drive

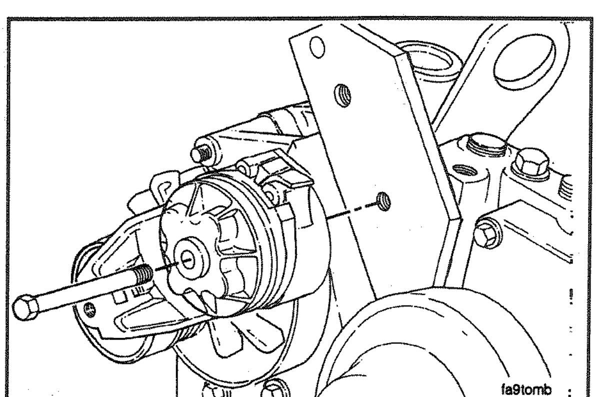
Lift the tensioner to remove and install the drive belt.

NOTE: The belt tensioner is spring loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Belt Tensioner - Replacement (1-03)

Preparatory Step:

- Remove the drive belt



15 mm

Remove the capscrew and replace the tensioner.

Torque Value: 43 N•m [32 ft-lb]

Fan Pulley - Replacement (1-04)

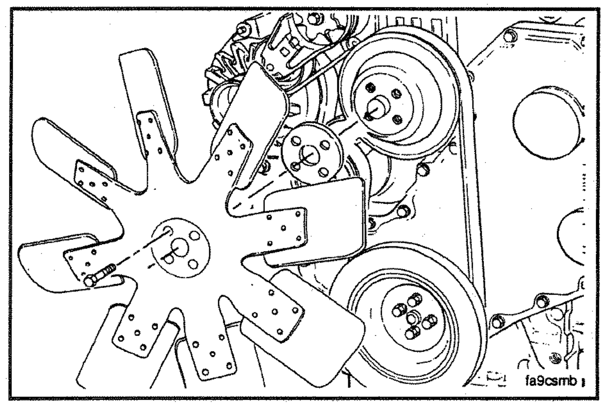
Preparatory Step:

- Remove the drive belt.

13 mm

Remove the four capscrews, fan and spacer. Replace the fan pulley.

Torque Value: 24 N•m [18 ft-lb]



Fan Hub - Replacement (1-05)

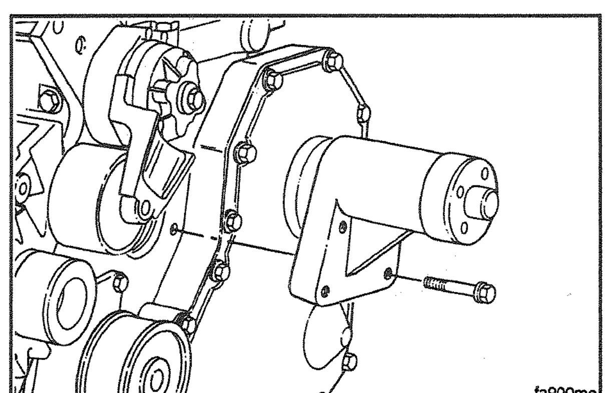
Preparatory Steps:

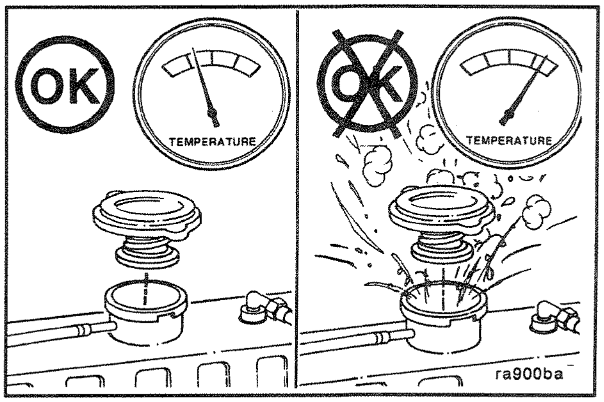
- Remove the drive belt.
- Remove the fan pulley.

10 mm

Remove the four capscrews and replace the fan hub.

Torque Value: 24 N•m [18 ft-lb]

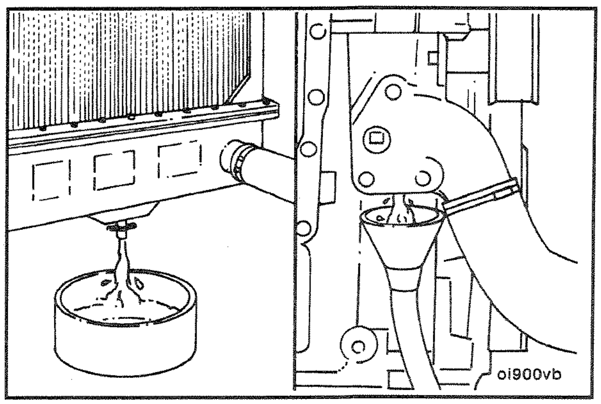




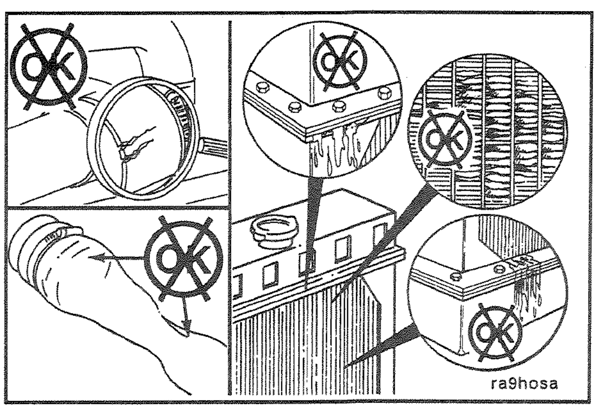
Coolant (1-06)

Draining

Warning: Wait until the temperature is below 50°C [122°F] before removing the coolant system pressure cap. Failure to do so can cause personal injury from heated coolant spray.



Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet. A drain pan with a capacity of 20 liters [4 U.S. gallons] will be adequate in most applications.

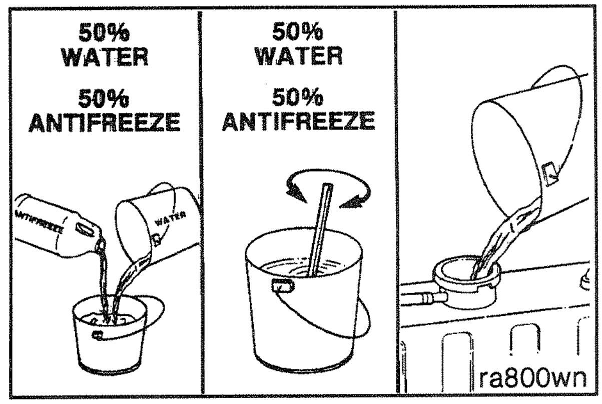


Check for damaged hoses and loose or damaged hose clamps. Replace as required. Check the radiator for leaks, damage and build up of dirt. Clean and repair as required.

Filling

Caution: Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

NOTE: A 50 percent mixture of antifreeze and water **must** be premixed before filling the system. The ability of anti-freeze to remove heat from the engine is not as good as water, so pouring antifreeze into the engine first could contribute to an over heated condition before the liquids are completely mixed.



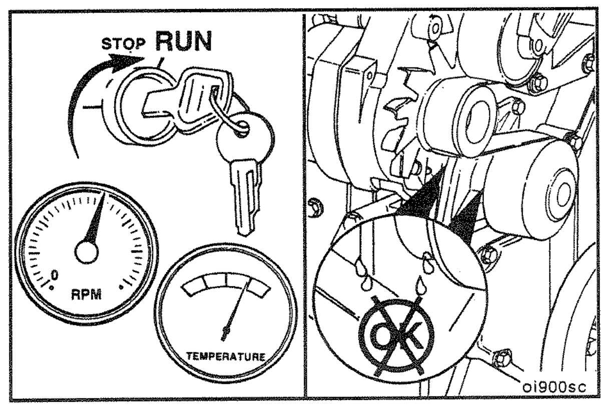
Close all drain valves and fill the system. Use a mixture of 50 percent water and 50 percent ethlene glycol anti-freeze to provide freeze protection to -36°C [-34°F].

Coolant Capacity (Engine Only)		Litre [U.S. Quarts]	
B3.9 4B3.9 4BT3.9	**4BTA3.9**	**B5.9 6B5.9 6BT5.9**	**6BTA5.9**
7.0 [7.4]	9.7 [10.3]	10.5 [11.1]	14.5 [15.3]

Install the pressure cap. Operate the engine until it reaches a temperature of 80°C [180°F], and check for coolant leaks.

Check the coolant level again to make sure the system is full of coolant.

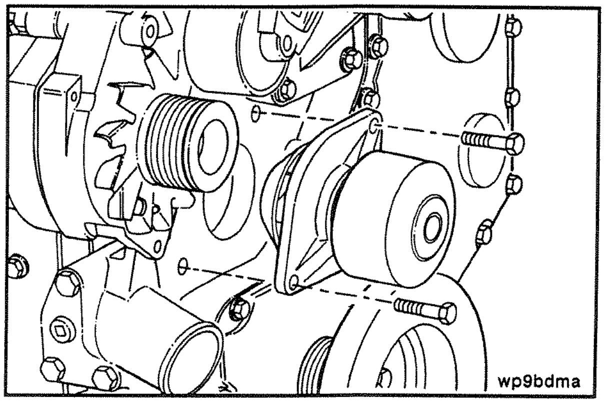
Warning: Before removing the pressure cap, wait until the coolant temperature is below 50°C [120°F]. Failure to do so can cause personal injury from heated coolant spray.



Water Pump - Replacement (1-07)

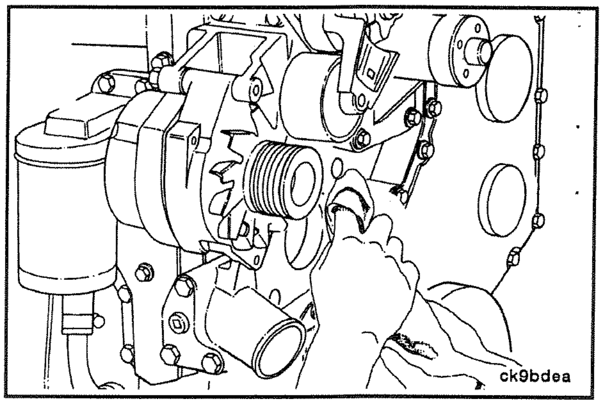
Preparatory Steps:

- Drain the coolant.
- Remove the drive belt.

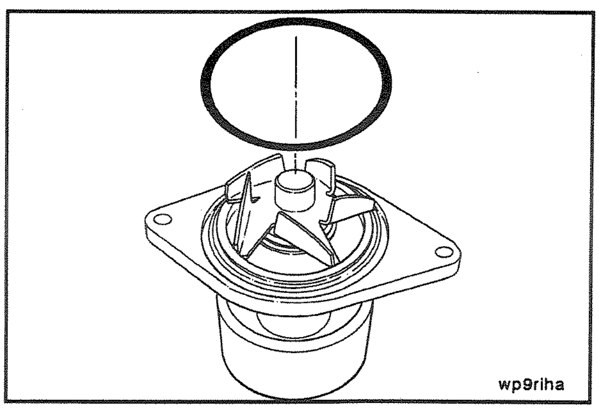


13 mm

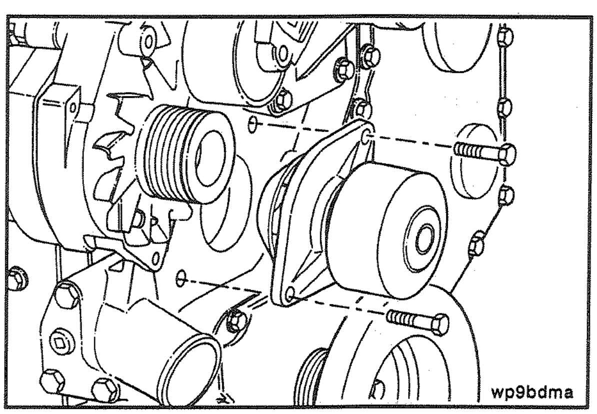
Remove the two capscrews and water pump, and complete the following steps.



Clean the sealing surface on the cylinder block.



Install the new sealing ring into the pump groove.



13 mm

Install the water pump.

Torque Value: 24 N•m [18 ft-lb]

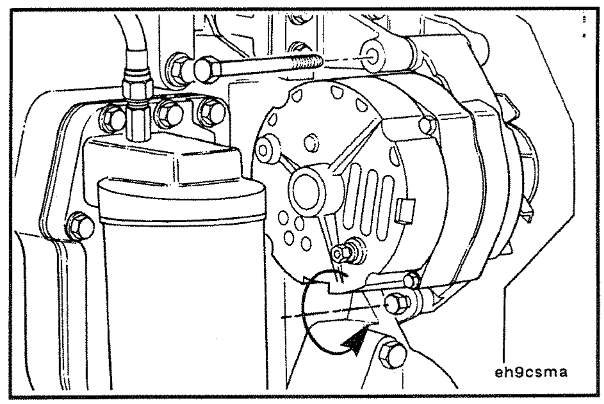
Thermostat - Replacement (1-08)

Preparatory Steps:

- Drain the coolant.
- Remove the drive belt.
- Disconnect negative battery cable.
- Disconnect the upper radiator hose.

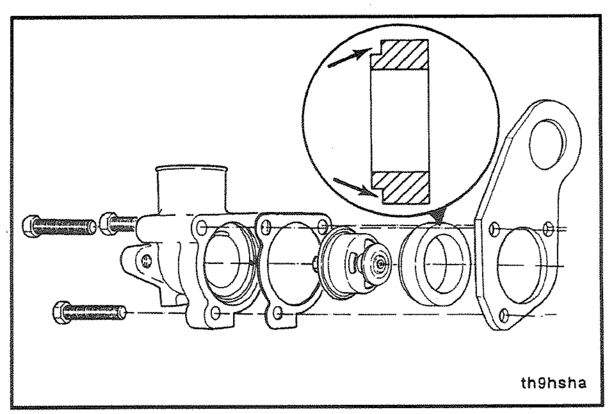
13 mm, 16 mm

Remove the alternator mounting capscrew, loosen the alternator link capscrew and lower the alternator.

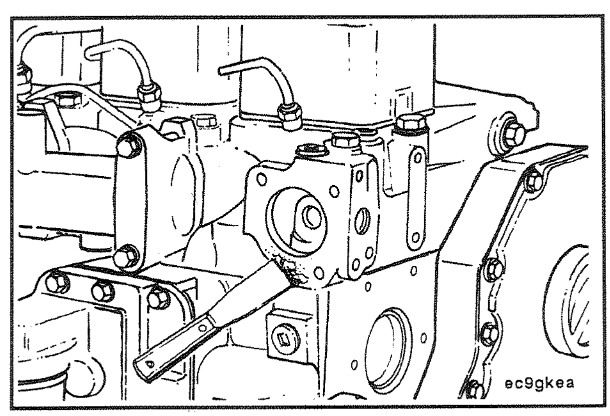


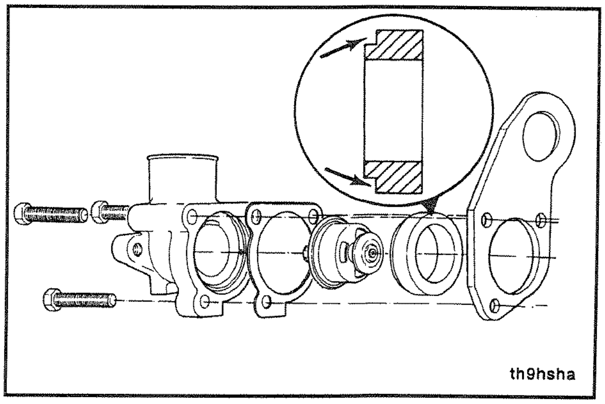
10 mm

Remove the thermostat housing, lifting bracket, thermostat and thermostat seal.

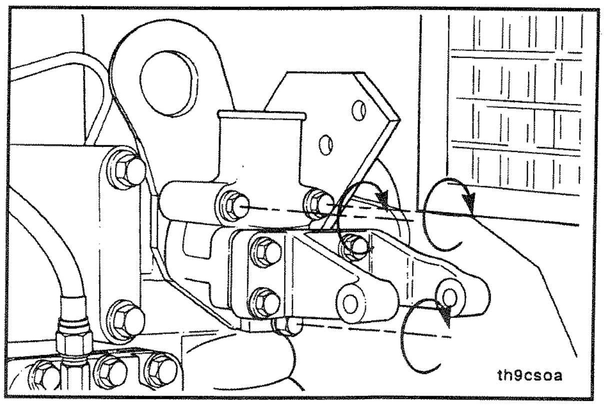


Clean the mating surfaces.





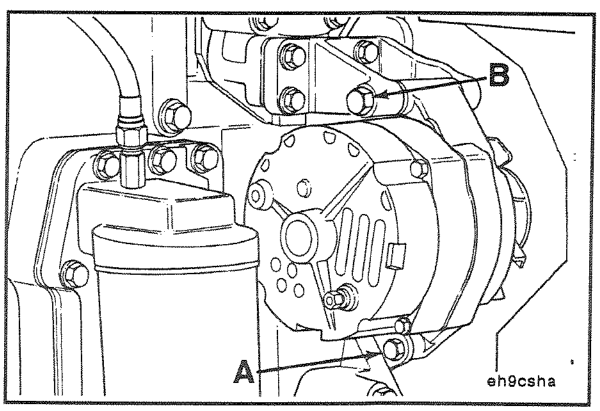
Position the rubber seal as shown for reassembly.



10 mm

Assemble the removed parts in the reverse order of removal.

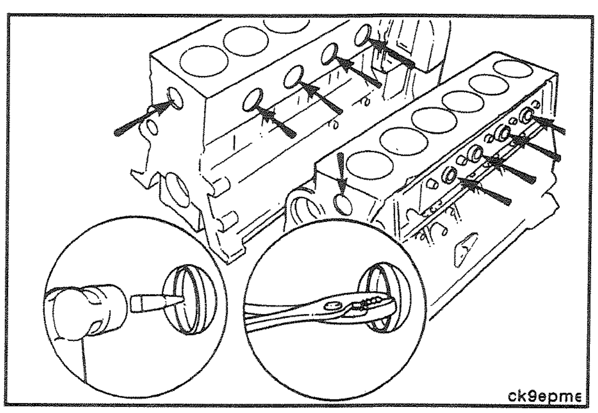
Torque Value: 24 N•m [18 ft-lb]



13 mm, 16 mm

Install the alternator.

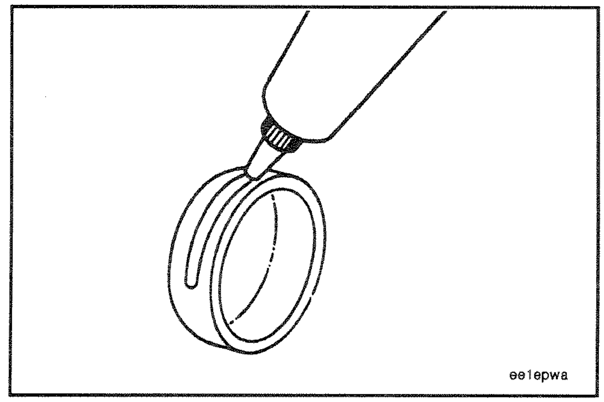
Torque Value: (A) 24 N•m [18 ft-lb]
(B) 43 N•m [32 ft-lb]



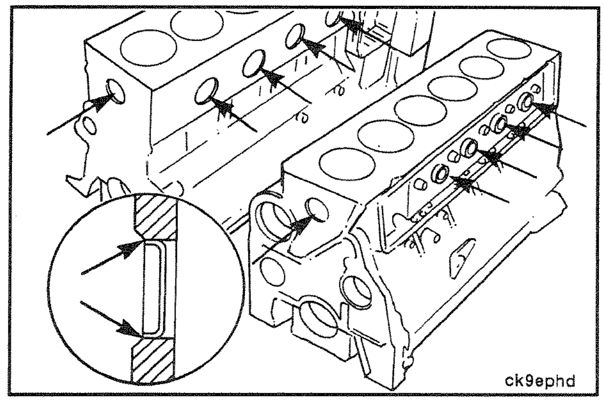
Expansion Plugs - Replacement (1-09)

Remove the expansion plugs from the coolant passages as shown.

Apply a bead of Loctite 277 to the coolant passage expansion plugs.



Drive the expansion plug in until the outer edge is flush with the counter sink in the block.



NOTES

Lubricating Oil System - Section 02

Section Contents

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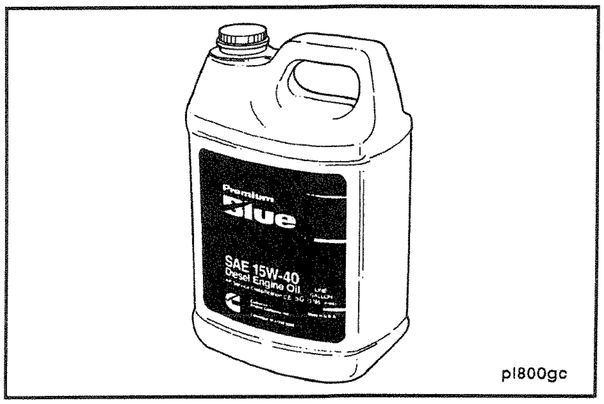
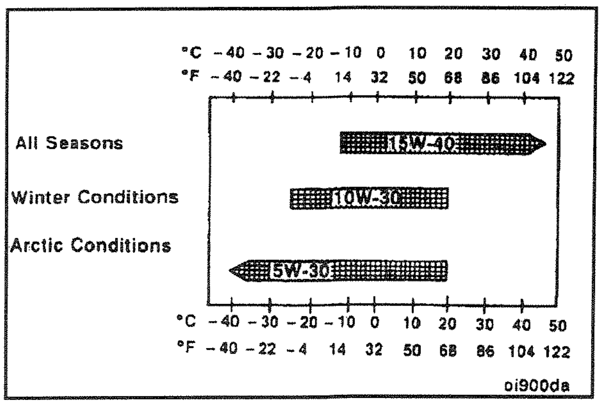
General Information - Lubrication System



pl800gc

Cummins Engine Company, Inc. recommends the use of a high quality SAE 15W-40 heavy duty engine oil (such as Cummins Premium Blue) which meets the American Petroleum Institute (API) performance classification CE/SG.

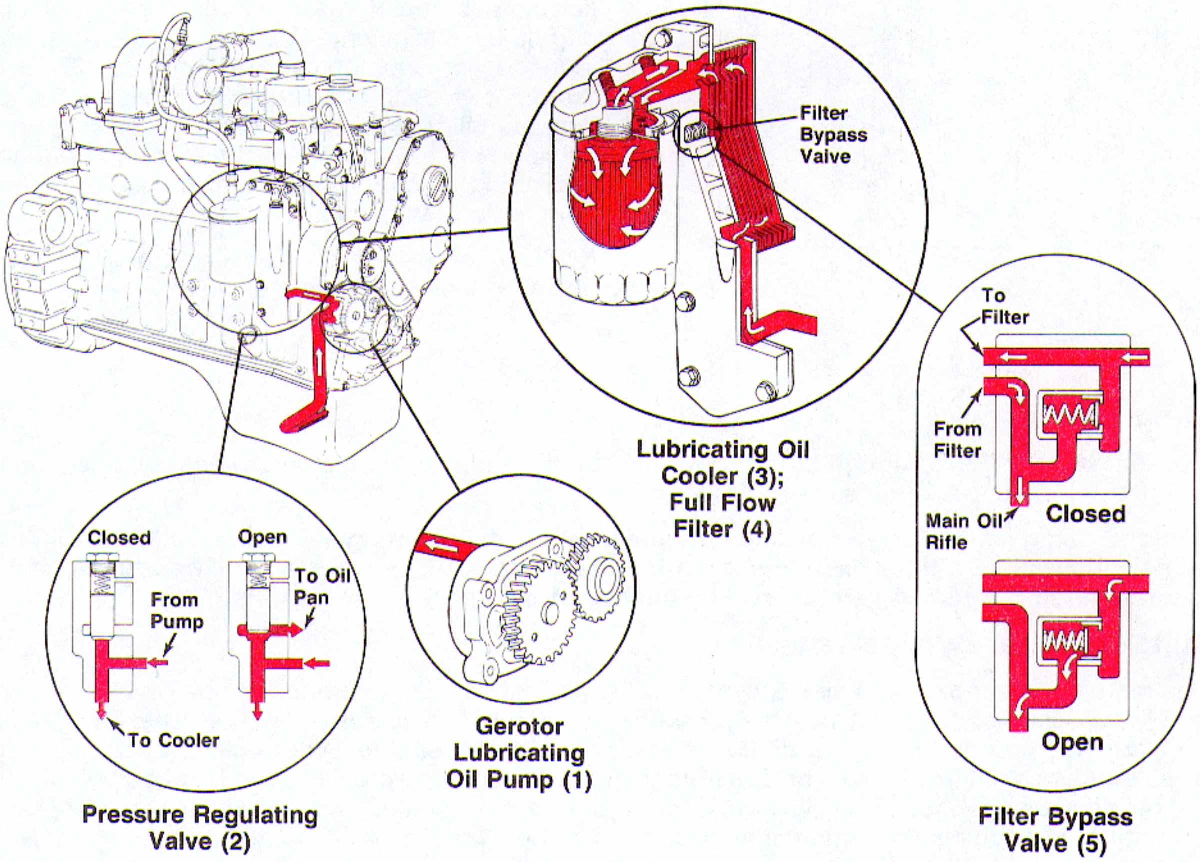
NOTE: CC/CD or CD/SF engine oils can be used in areas where CE oil is not yet available, but the lubricating oil change interval must be reduced to one-half the interval given in the maintenance schedule.



oi900da

Caution: Limited use of lubricating oils, such as 10W-30, can aid in starting the engine and providing sufficient lubricating oil flow at ambient temperatures below -5°C [23°F]. However, the continuous use of low viscosity lubricating oils can decrease engine life. Refer to the accompanying chart.

Flow Diagrams - Lubricating System

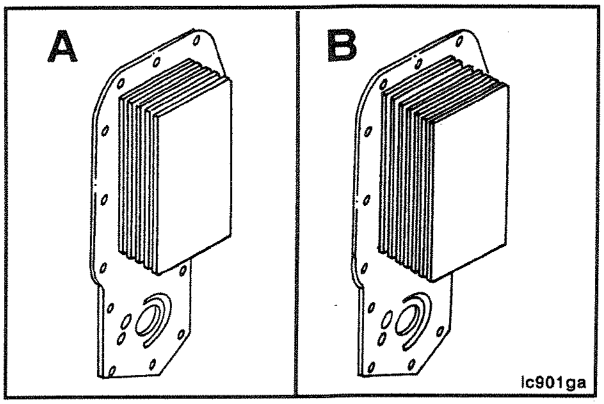


Lubricating Oil Pump

The engine uses a gerotor type lubricating oil pump (1). The machined cavity in the block is the same for all engines. A wider gerotor is used in the six cylinder engine to increase the lubricating pump capacity. Consequently, the 4 cylinder and 6 cylinder lubricating pumps are not interchangeable.

Pressure Regulating Valve

The pressure regulating valve (2) is designed to keep the lubricating oil pressure from exceeding 449 kPa [65 psi]. When the lubricating oil pressure from the pump is greater than 499 kPa [65 psi], the valve opens uncovering the dump port so part of the lubricating oil is routed to the oil pan. The minimum lubricating oil pressure limit is the same for the four cylinder and the six cylinder engine. Because of manufacturing tolerances of the components and the oil passages, the lubricating oil pressure can differ as much as 69 kPa [10 psi] between engines.



Lubricating Oil Coolers

The engines use full flow, plate type oil coolers (3). The oil flows through a cast passage in the cooler cover and through the element where it is cooled by engine coolant flowing past the plates of the element. The four cylinder engine uses an element with five plates (A), the six cylinder uses an element with seven plates (B). Because of the differences in plate restriction and oil pump capacities, the oil cooler components are not interchangeable between the four cylinder and six cylinder engines. The use of incorrect components can cause high or low oil temperature, varnish and sludge build up.

NOTE: Prior to 10/21/86 six cylinder engines were assembled with 9 plate oil cooler elements.

Lubricating Oil Filters

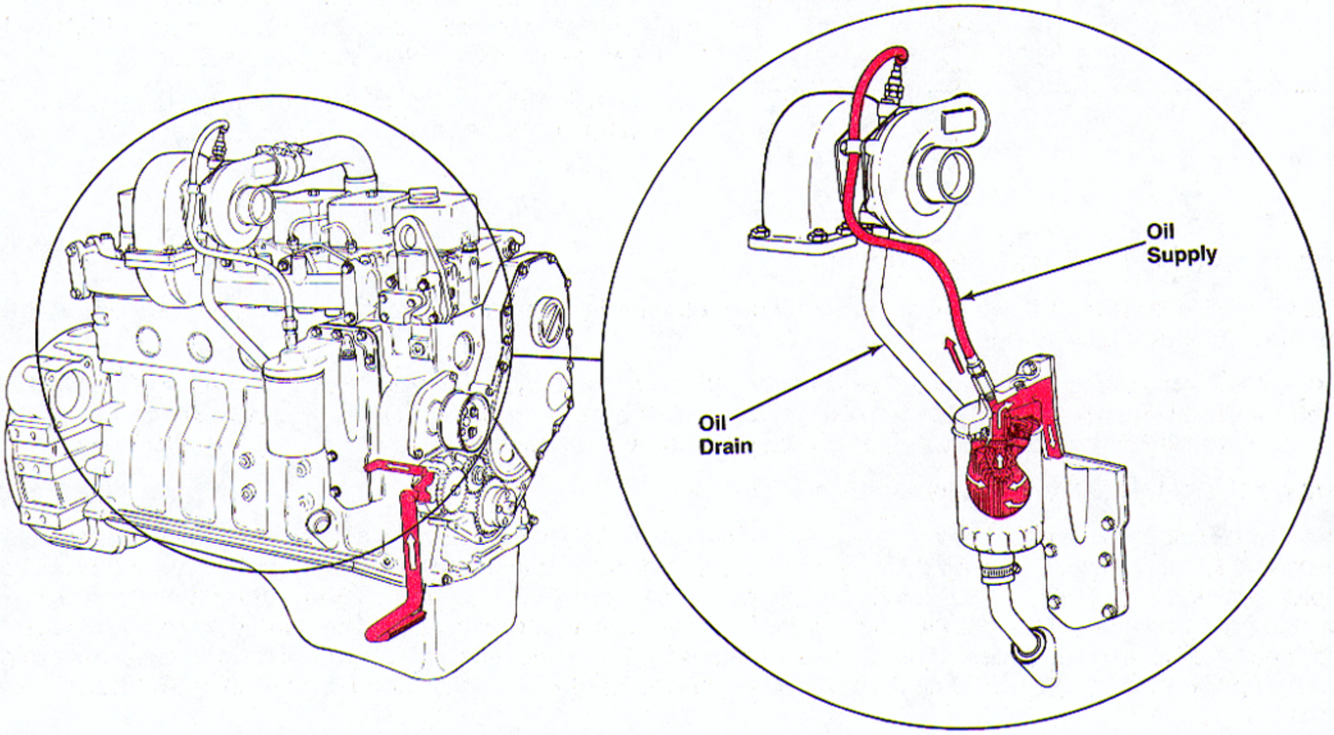
After the oil is cooled, it flows through the full flow oil filter (4). The filter for the six cylinder engine is longer than the filter for the four cylinder engine.

Caution: Using a filter for a six cylinder engine on a four cylinder engine does not allow extended change interval. Never use a filter for a four cylinder engine on a six cylinder engine because of the reduced material holding capability and increased chance of plugging.

Lubricating Oil Filter Bypass Valve

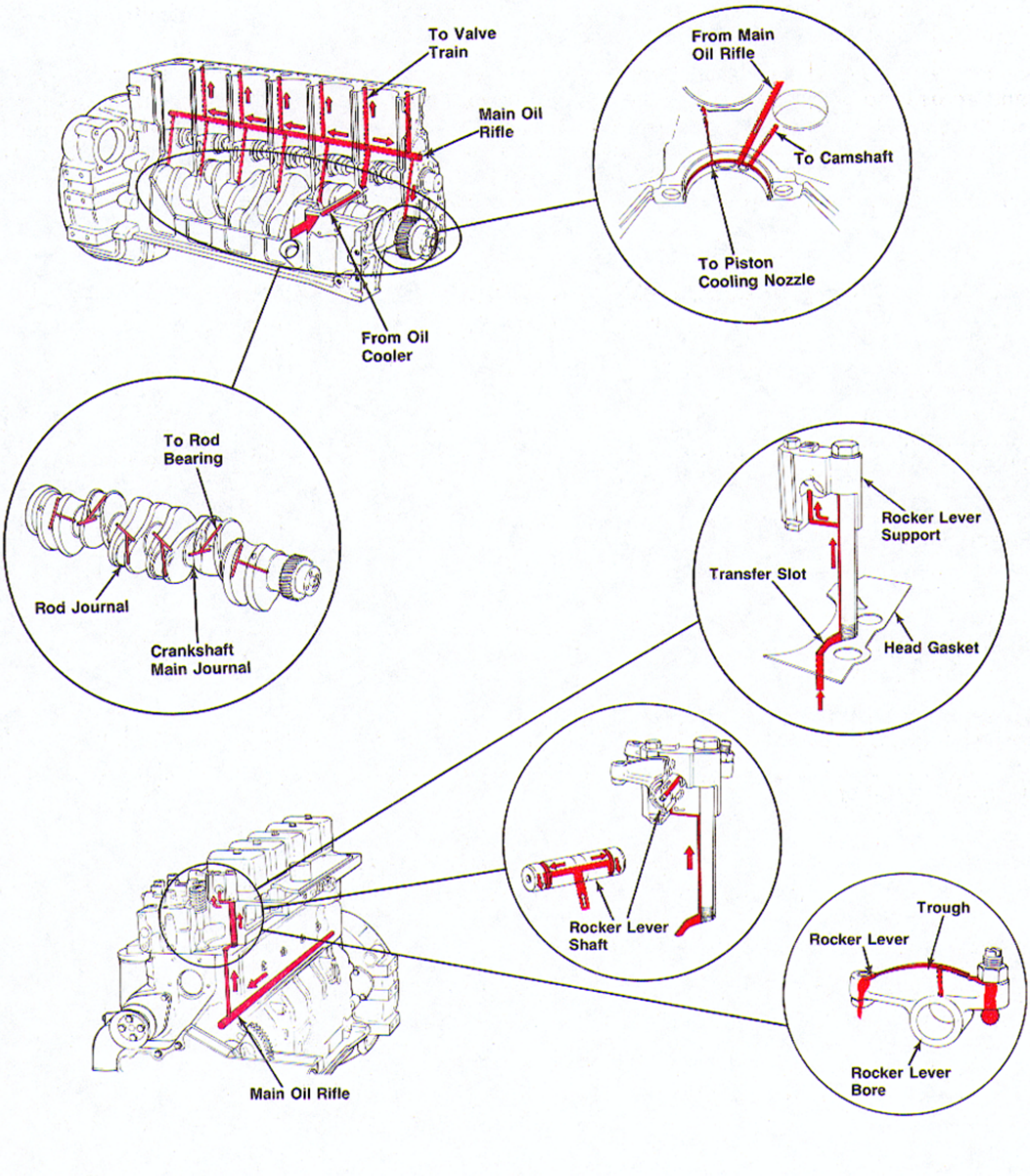
The lubricating oil cooler cover contains a bypass valve (5) that will let the lubricating oil flow bypass a plugged filter. The valve is designed to open when the pressure drop across the filter is more than 138 kPa [20 psi], as with a plugged filter, and lets the lubricating oil continue on through the engine. When a filter becomes plugged, an oil pressure decrease of 60 kPa [10 psi] or less from the normal operating pressure can be observed on the vehicle lubricating oil pressure gauge. This allows unfiltered oil into the engine. This condition should be avoided by changing the filter at each oil drain interval as described in the Operation and Maintenance Manual, Bulletin No. 3810205-10.

Lubrication for the Turbocharger



The turbocharger receives filtered, cooled and pressurized lubricating oil through a supply line from the filter head. A drain line connected to the bottom of the turbocharger housing returns the lubricating oil to the lubricating oil pan through a fitting in the cylinder block.

Lubrication for the Power Components



The main bearings and the valve train are lubricated by pressurized oil directly from the main oil rifle. The other power components, connecting rods, pistons, and camshaft receive pressurized oil indirectly from the main oil rifle.

The drillings in the crankshaft supply oil to the connecting rod bearings. The oil is supplied to the camshaft journals through drillings in the main bearing saddle. Smaller drillings in the main bearing saddle supply oil to the piston cooling nozzles. The spray from the nozzles also provides lubrication for the piston pins.

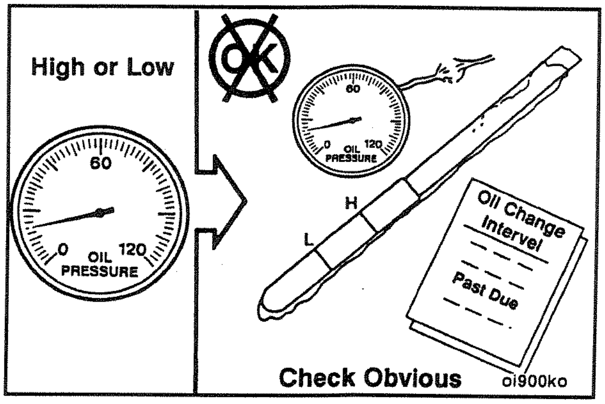
The number one main bearing saddle does not contain a piston cooling nozzle. Cylinder Number One receives the lubricating and cooling spray from the nozzle located in the Number Two Bearing Saddle. Cylinder Number Two receives the spray from the Number Three Bearing Saddle, etc.

Lubrication for the valve train is supplied through separate drillings in the cylinder block. The oil flows through the drillings and across the oil transfer slot in the cylinder head gasket. From the transfer slot, the oil flows around the outside diameter at the cylinder head capscrew, across a slot in the bottom of the rocker lever support, and up a vertical drilling in the support. From these drillings, oil flows through drillings in the rocker lever shaft to lubricate the rocker levers. Oil flows through a drilling in the rocker levers to fill a channel cast into the top of the levers. The oil from the channel lubricates the valve stems, push rods and tappets.

Specifications - Lubricating Oil System (*At Normal Operating Temperature)

Lubrication System Specifications	4B3.9	B3.9, 4BT3.9	4BTA3.9	6B5.9	B5.9, 6BT5.9	6BTA5.9
Lubricating Oil Pressure at Idle (Minimum) kPa [psi]	69 [10]	69 [10]	69 [10]	69 [10]	69 [10]	69 [10]
Lubricating Oil Pressure at Rated Speed (Minimum) kPa [psi]	207 [30]	207 [30]	207 [30]	207 [30]	207 [30]	207 [30]
Pressure Regulator Valve Opening Pressure - kPa [psi]	449 [65]	449 [65]	449 [65]	449 [65]	449 [65]	449 [65]
Filter Bypass Valve Opening Pressure - kPa [psi]	138 [20]	138 [20]	138 [20]	138 [20]	138 [20]	138 [20]
Lubricating Oil Pan Capacity (Standard Sump) (High/Low) - Litre [U.S. Qts.]	9.5 [10] 8.5 [9]	9.5 [10] 8.5 [9]	9.5 [10] 8.5 [9]	14.2 [15] 12.4 [13]	14.2 [15] 12.4 [13]	14.2 [15] 12.4 [13]
Total System	10.9 [11.5]	11 [11.6]	11 [11.6]	16.3 [17.2]	16.4 [17.3]	16.4 [17.3]

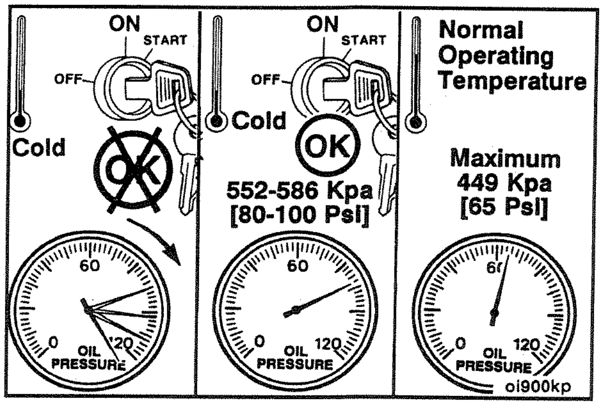
* Normal operating oil temperature is typically 110°C [230°F] measured in the oil pan.



Diagnosing Lubricating System Malfunctions (2-01)

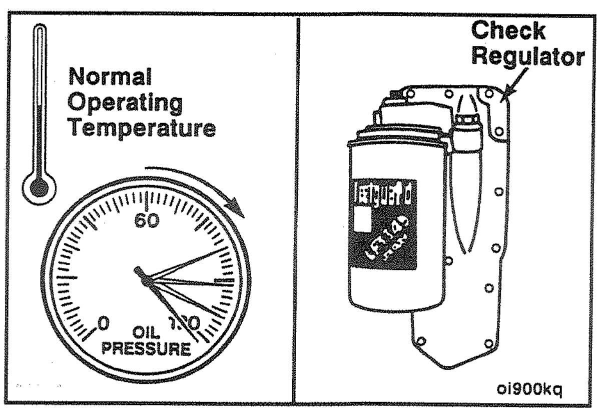
General Information

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



High Lubricating Oil Pressure (2-02)

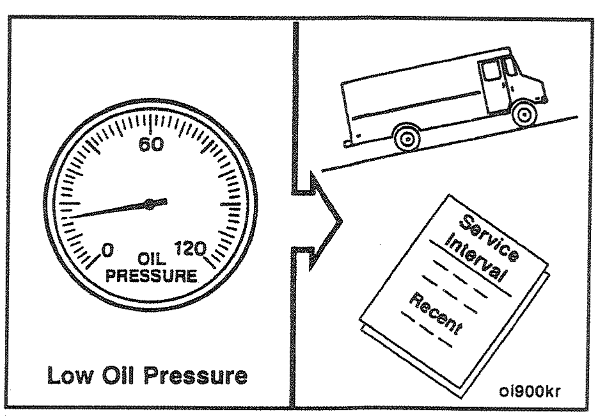
High oil pressure usually occurs after the engine is first started in cold weather. Cold start oil pressure typically will be approximately 552-689 kPa [80-100 psi]. If the pressure regulator plunger is operating properly the oil pressure should drop back to approximately of 449 kPa [65 psi] when normal operating temperature is reached.



Lubricating Oil Pressure Regulating Valve

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

Refer to the Oil Pressure Regulator Valve/Spring Replacement procedure on page 2-17.

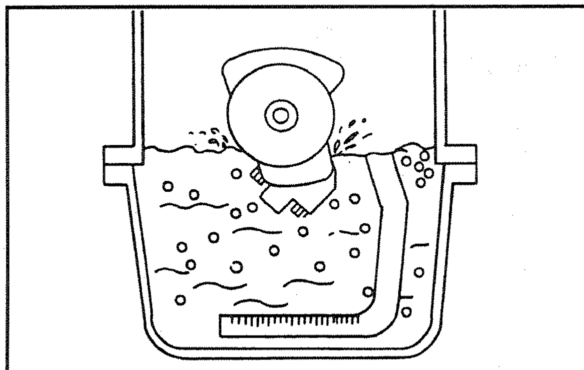


Low Lubricating Oil Pressure (2-03)

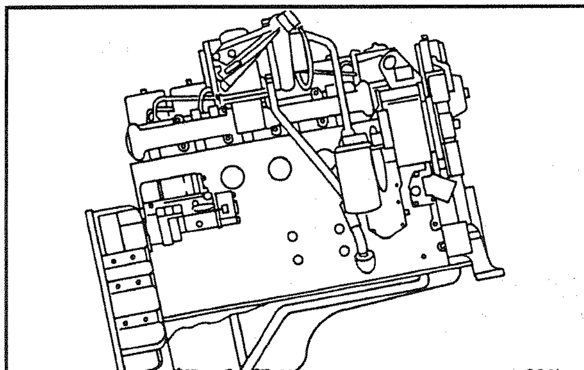
Low lubricating oil pressure (or no oil pressure) can be caused by several lubrication system related malfunctions. To begin the investigation, determine the engine operating conditions when the low pressure was first observed; i.e. following a service interval, at idle only, while operating on a steep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

Lubricating Oil Level

High oil level can cause low oil pressure. If the oil level is high enough for the connecting rods to dip into during operation, the oil can become aerated resulting in low oil pressure.

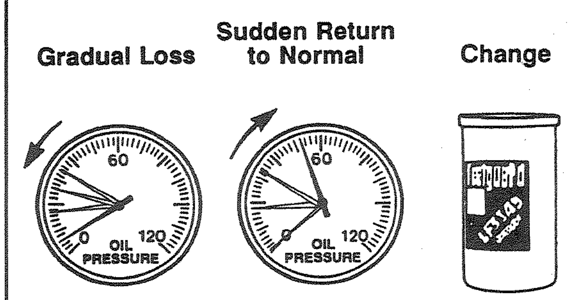

oi900ks

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


ew900kt

Lubricating Oil Filter

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



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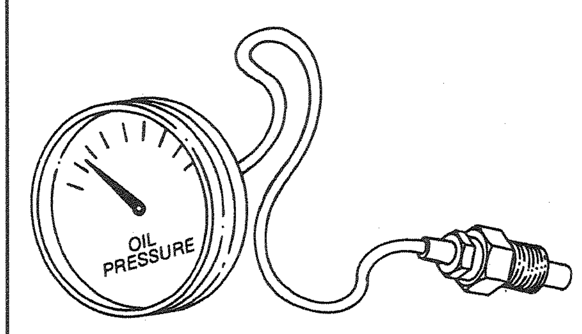
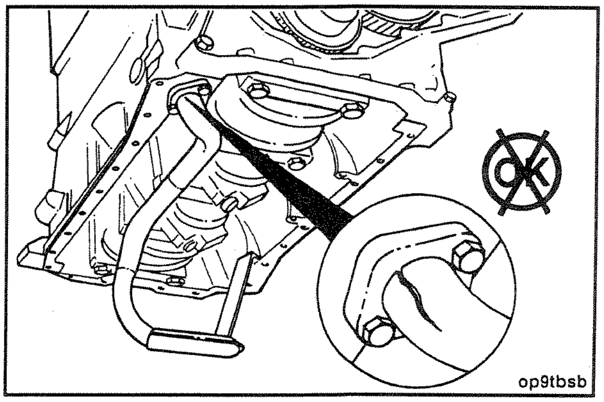
Lubricating Oil Gauge

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

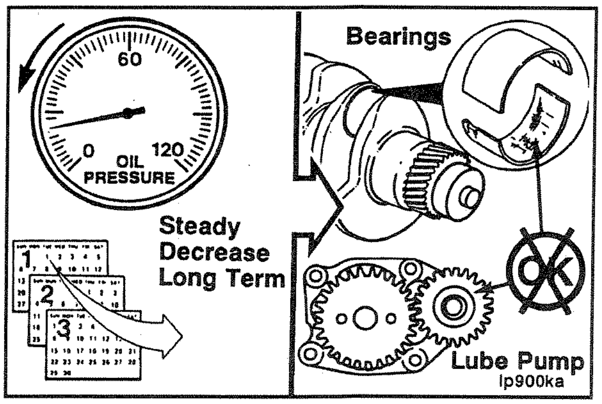


ov900va



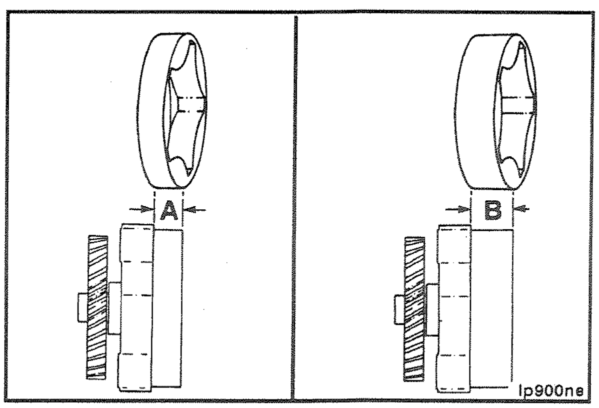
Lubricating Oil Suction Tube

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



Bearings and Lubricating Oil Pump

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



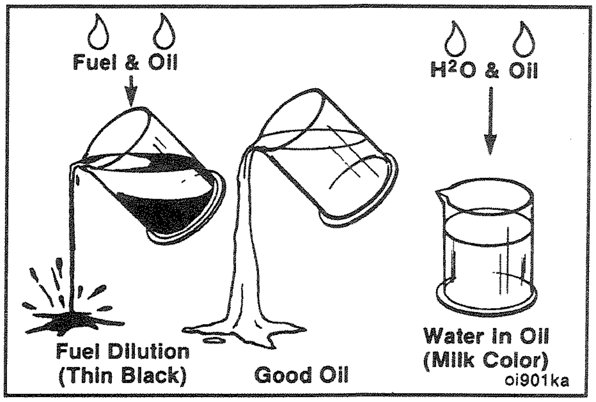
Incorrect Lubricating Oil Pump

The capacity of the six cylinder oil pump is greater than the four cylinder. If low or high pressure occurs after changing the pump, verify that the correct pump was used. Refer to oil pump replacement, page 2-24.

A - Four Cylinder
- 12.947 mm [0.516 inch]

B - Six Cylinder
- 17.947 mm [0.715 inch]

NOTE: Earlier model B-Series engines used lower capacity pumps. Check to be sure the correct model pump is used.



Lubricating Oil Dilution

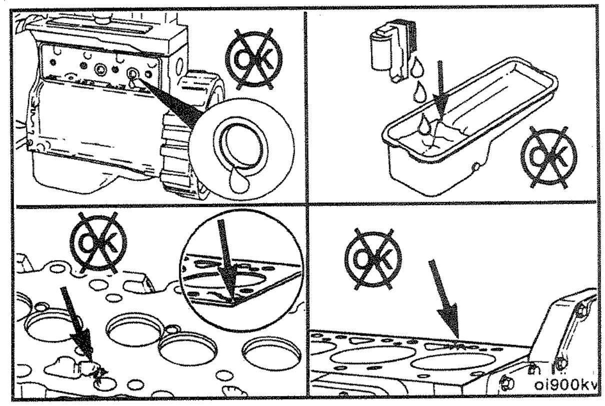
Caution: Diluted oil can cause severe engine damage.

Check the condition of the lubricating oil.

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

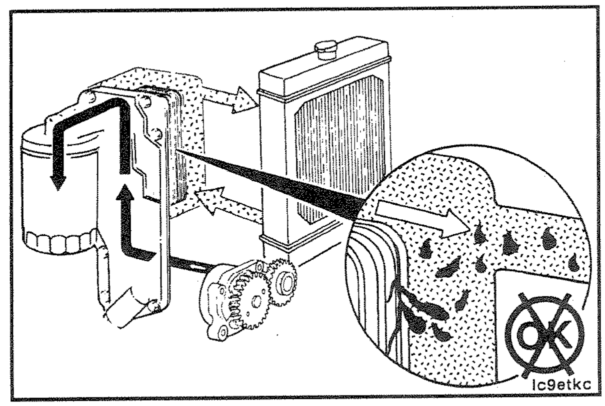
Coolant in the oil can be caused by:

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



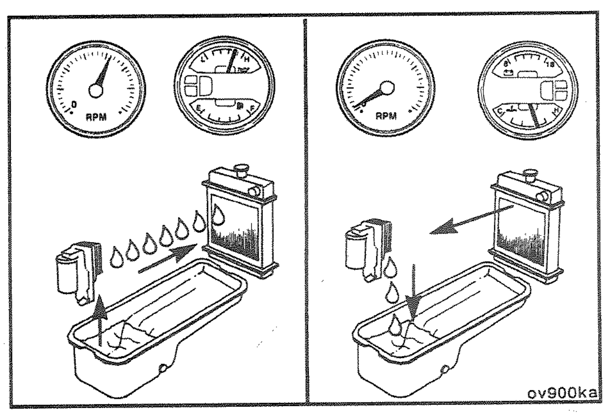
Coolant Diluted Lubricating Oil

Since the lubricating oil cooler design does not require gaskets or seals to maintain the separation of oil and coolant, the element itself must leak to allow mixing of the fluids (refer to page 2-18 for the replacement and oil cooler testing procedures).



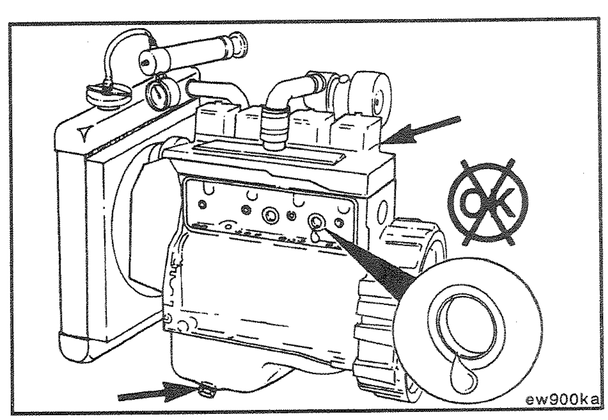
During operation, the lubricating oil pressure will be higher than coolant pressure. A leak in the lubricating oil cooler will show as lubricating oil in the coolant.

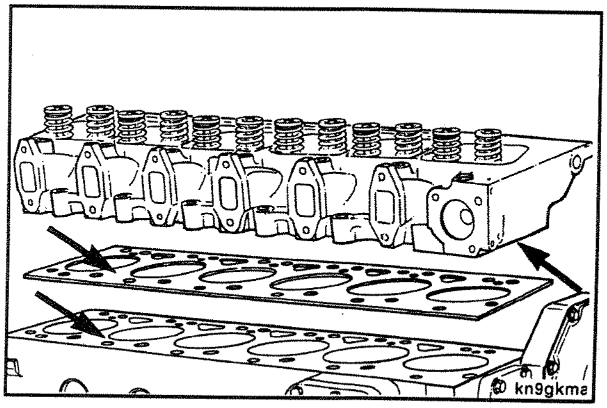
However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the lubricating oil.



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

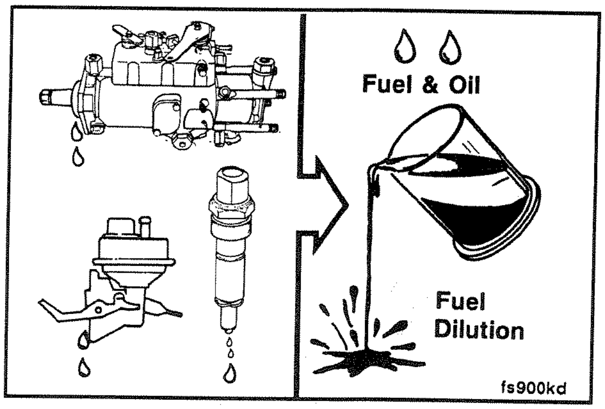
- Valve covers (leaks indicate cracked head)
- Lubricating oil drain plug (leaks indicate defective lubricating oil cooler, head gasket, cracked head or block)
- Tappet cover (expansion plug leak)





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

Remove the cylinder head and gasket and inspect for cracks or damage.



Fuel Diluted Lubricating Oil

Fuel dilution is limited to five sources:

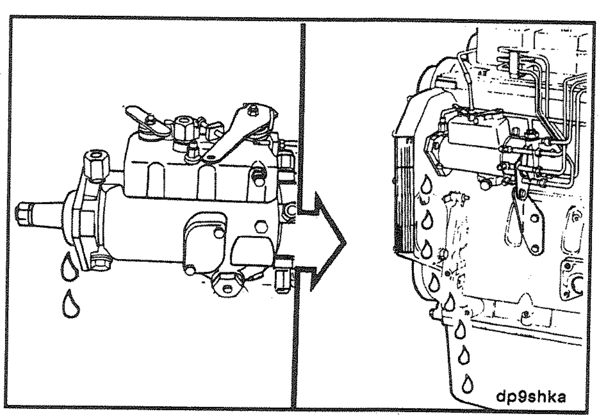
1. Injection pump shaft seal
2. Fuel leaking by the rings
3. Fuel Transfer pump
4. A crack in the cylinder head from the fuel filter location to the air intake
5. Injector leakage

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

Power Low - Increased White Smoke During Start Up -
↓
Check/Replace the Injectors

Power Low - Increased Black Smoke
↓
Verify the Rings are Sealing by Performing a Compression Check

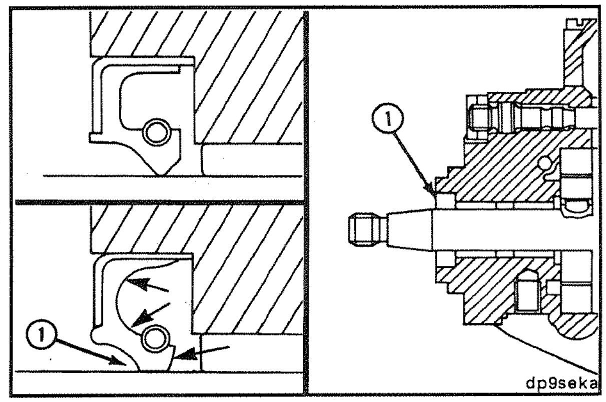
Power Normal
↓
Check fuel transfer Pump For Seal Leakage
↓
Replace the Fuel Pump Seal



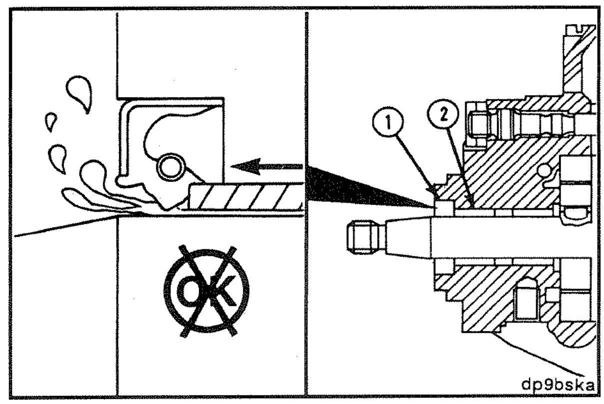
A worn or damaged fuel injection pump shaft seal will allow fuel to leak into the gear housing and then into the lubricating oil pan.

The seal is designed to provide increased sealing as the pump case pressure increases. Pressure forces the lip (1) tighter around the shaft.

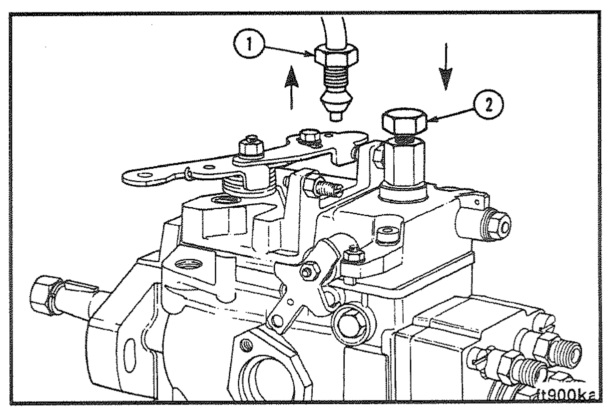
A worn seal is more apt to leak during start up and shut down when case pressure is low. A worn seal cannot **easily** be detected by pressurizing the pump.



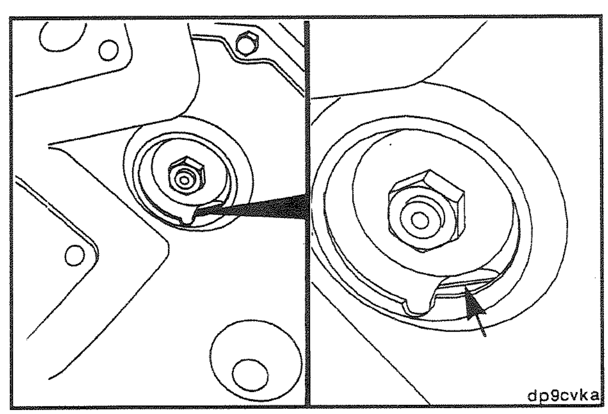
The bushing (2) in the **Bosch VE** fuel injection pump can cause a seal leak. If the bushing is loose in the housing it will move toward the seal raising the lip (1) and providing a leak path for fuel.

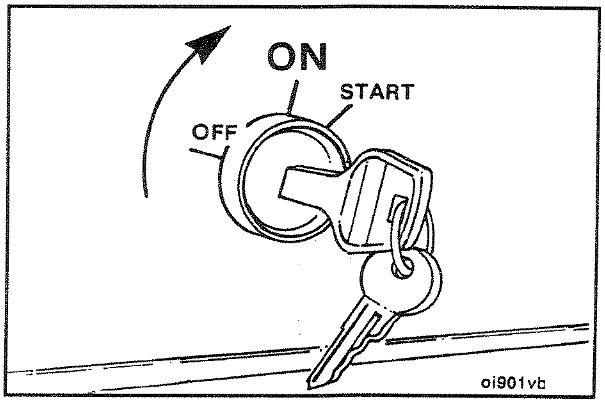


To check for such a leak, or a damaged seal (**Bosch VE only**), remove the fuel drain manifold connection (1) at the pump and install a plug (2).

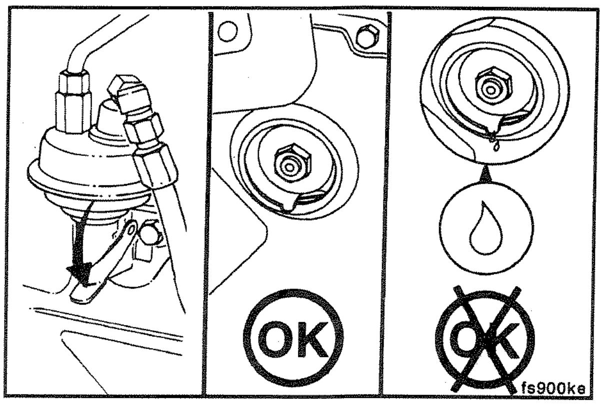


Remove the access cover and rotate the engine so one of the holes in the fuel injection pump gear exposes the back gear housing.

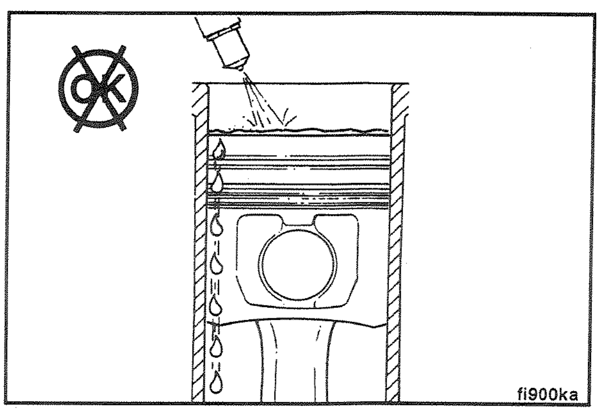




Activate the fuel shut down valve by turning the switch to the ON position.

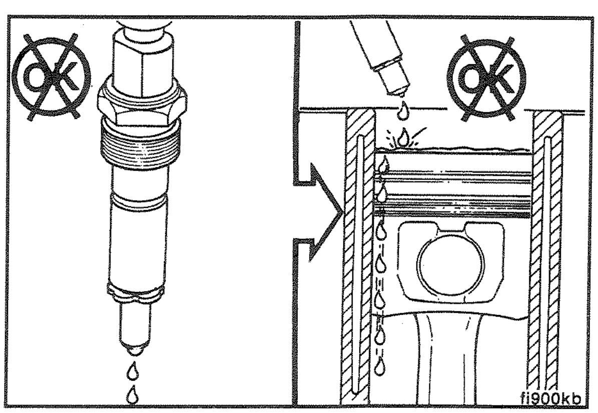


Use a small mirror to check for leaks while pumping the priming lever on the lift pump. If a leak is found, replace the injection pump. The seal can be replaced by an authorized Service Center.



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

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

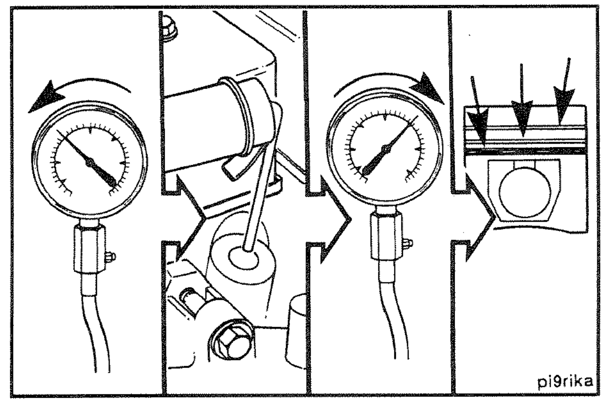


An **increase** in white exhaust smoke during the first start of the day is a symptom that an injector is leaking.

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

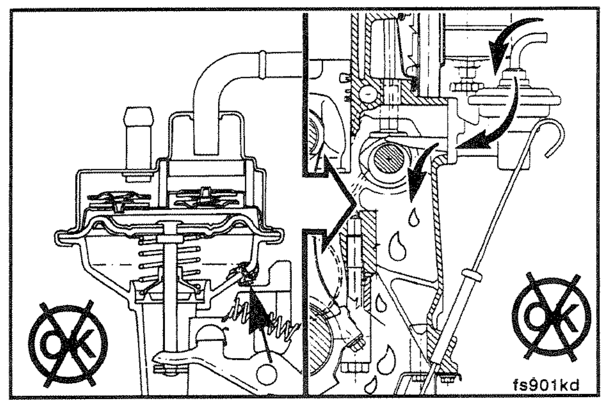
Remove and repair or replace leaking injectors (refer to Shop Manual, 3810206, for test and repair instructions).

Perform a compression check to verify piston ring sealing (refer to the Base Engine Components Section).

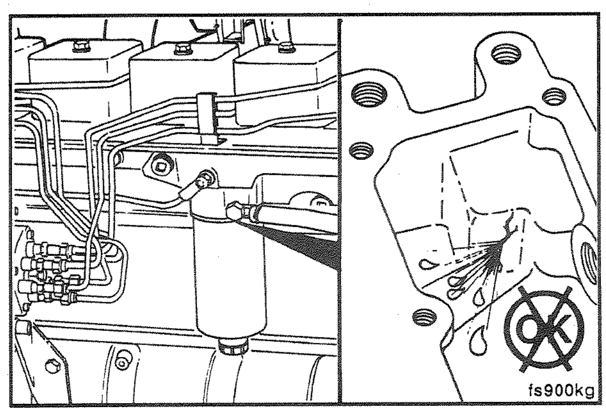


There is a remote possibility for fuel to drain into the oil from the diaphram type fuel transfer pump.

For this to happen, the diaphragm in the pump would have to break and the drain hole would have to be plugged.

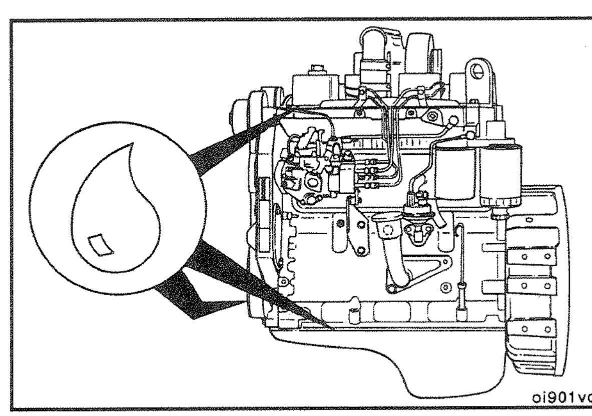


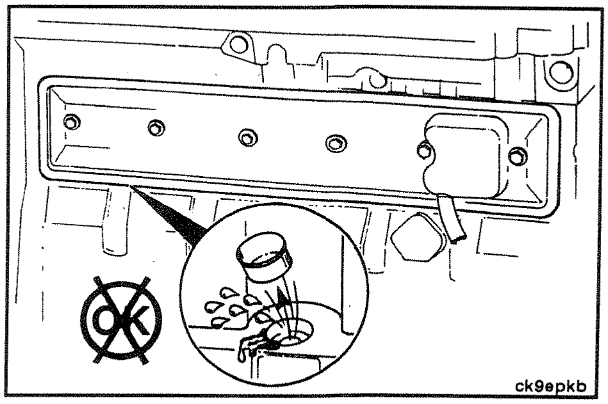
Another remote possibility, is a crack or porosity in the head casting could allow fuel to leak to the air intake and on to the cylinders.



Lubricating Oil Leaks (2-04)

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

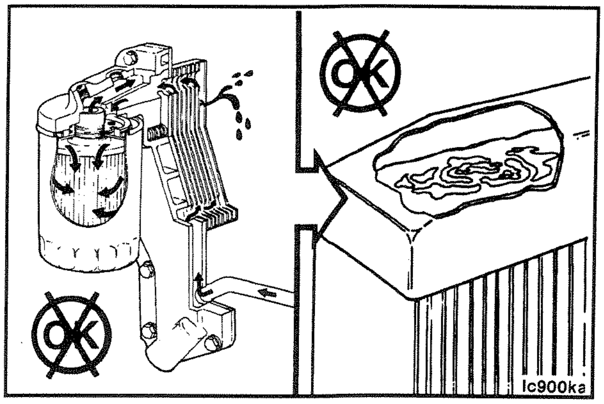




A blown expansion plug can allow a relatively large quantity of lubricating oil to escape resulting in a sudden drop in the lubricating oil pressure.

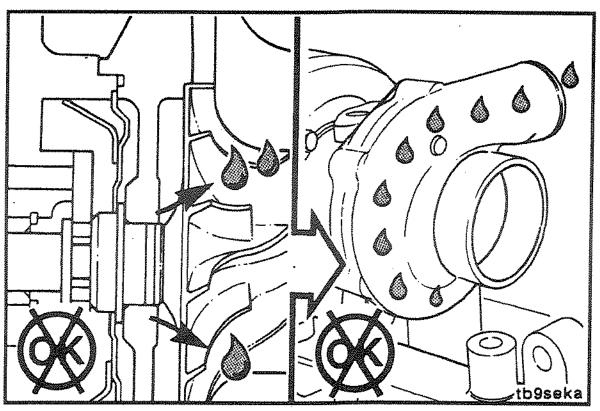
When checking for such a leak, be sure to check the expansion plug behind the tappet cover as well as those that may be obscured by chassis parts.

Lubricating oil blowing out the breather is a good sign of a blown expansion plug. This is usually more obvious on a four cylinder engine.



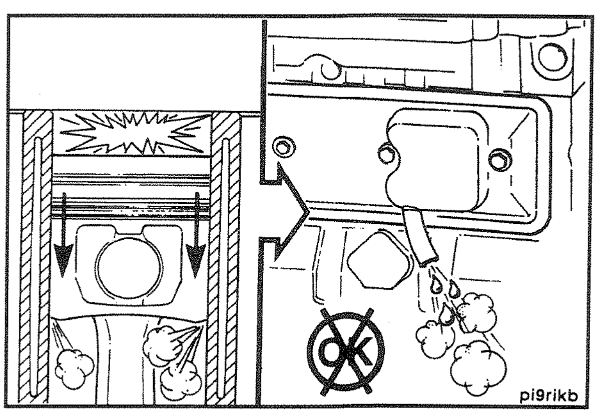
If the lubricating oil cooler element ruptures, the lubricating oil pressure will force lubricating oil into the coolant system. Lubricating oil in the coolant should be visible when the radiator cap is removed.

Refer to page 2-18 for lubricating oil cooler element replacement and testing.



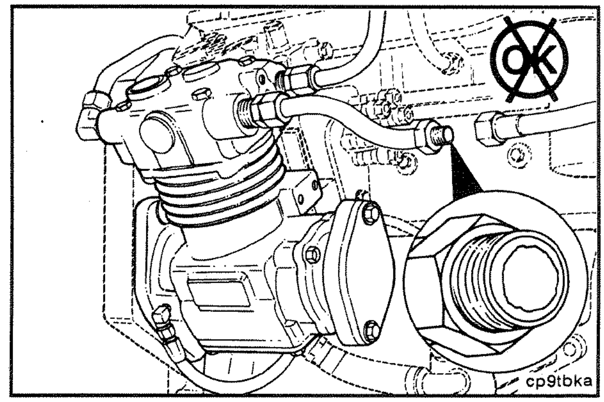
Worn or damaged seals in the turbocharger can also allow lubricating oil to leak into the air crossover pipe and be burned in the engine.

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



Inadequate sealing of the piston rings will result in lubricating oil being blown out the breather tube and/or consumed by the engine (refer to the Base Engine Components Section for measuring blow-by).

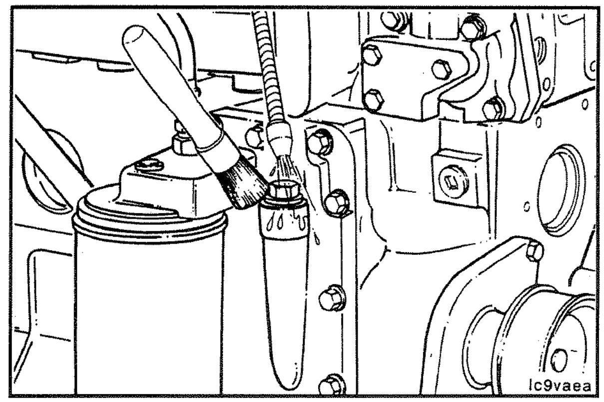
Lubricating oil can also be lost through a worn or malfunctioning air compressor. Look for carbon build up in the air line from the compressor to the air tank. Also, a failed air compressor head or head gasket can allow oil to leak into the coolant or coolant to leak into the oil during hot shutdown.



Lubricating Oil Pressure Regulator Valve/ Spring - Replacement (2-04)

Disassembly

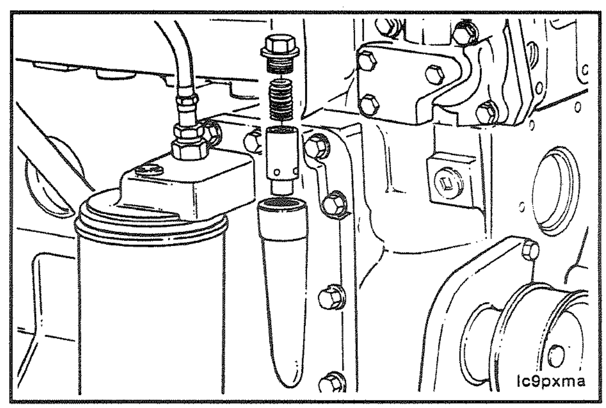
Thoroughly clean the area around the pressure regulator plug to prevent debris from falling into the plunger bore when the plug is removed.



19 mm

Remove the threaded plug, spring and plunger.

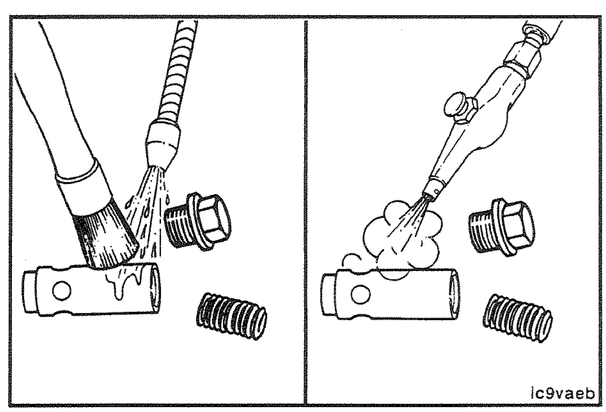
Service Tip: The plunger normally can be removed by inserting one finger into the plunger bore until snug and pulling up. If the plunger cannot be removed in this manner, the plunger is probably stuck and will require removal of the housing for plunger removal and cleaning.

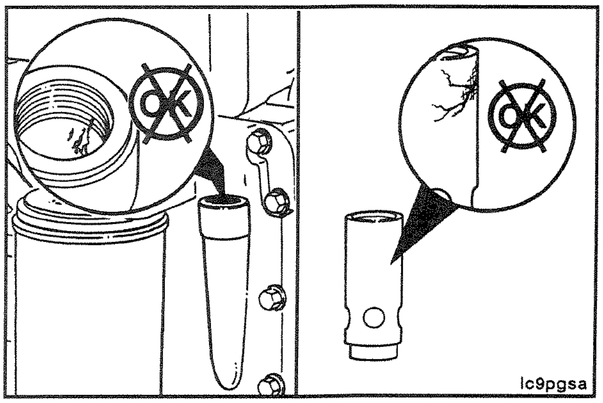


Cleaning and Inspection

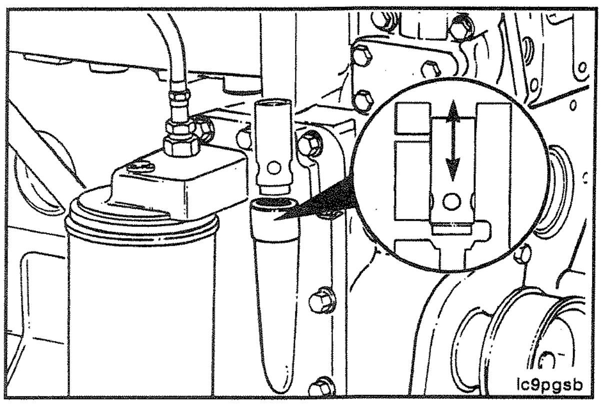
Thoroughly clean all components with clean solvent. Blow dry with compressed air.

NOTE: If the plunger bore requires cleaning, remove the housing so as not to flush debris into the engine.

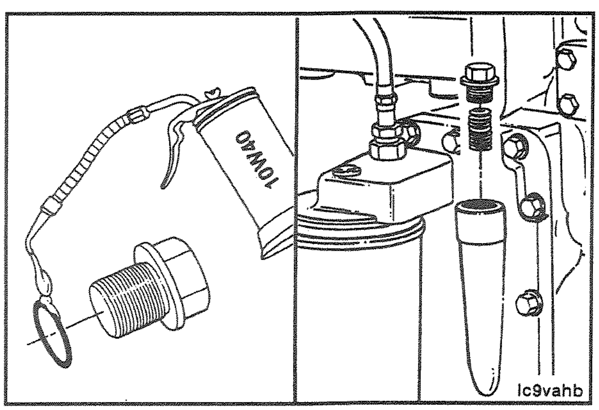




Inspect the plunger and plunger bore. Polished areas on the plunger and bore are acceptable.



Verify the plunger moves freely in the bore.



Assembly

19 mm

Install a new sealing o-ring on the threaded plug and lubricate with clean engine oil. Install the pressure regulator assembly.

Torque Value: 80 N•m [60 ft-lb]

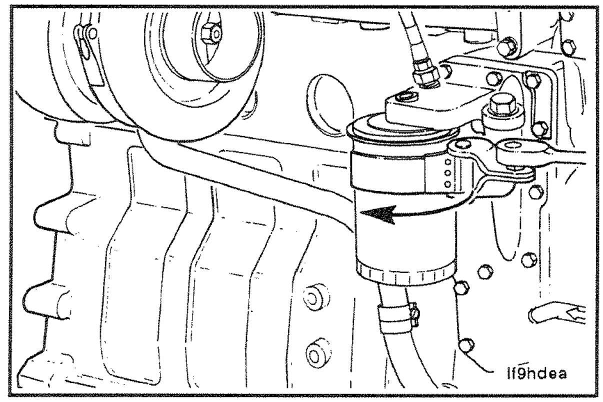
Lubricating Oil Cooler Element and/or Gasket - Replacement (2-05)

Preparatory Step:

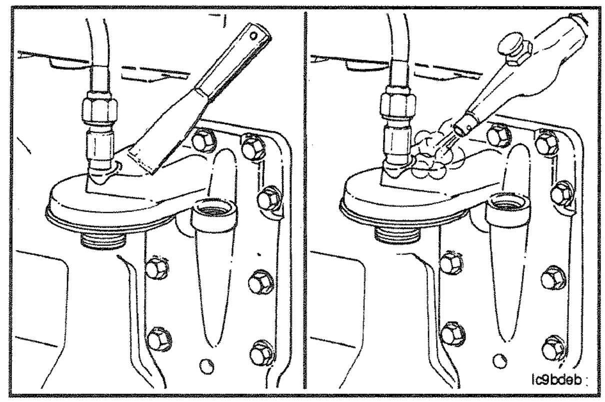
- Drain the coolant.

90-95 mm

Remove the lubricating oil filter.

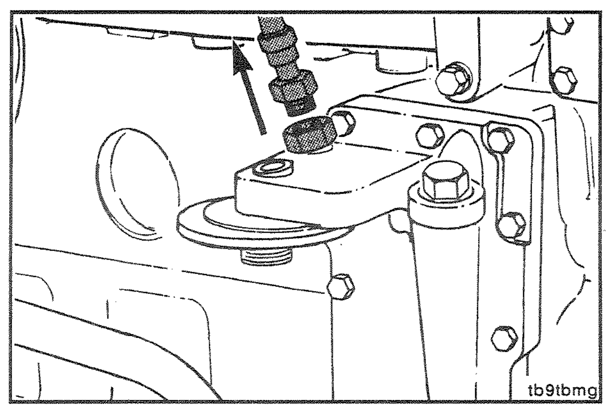


Clean around the lubricating oil cooler cover.



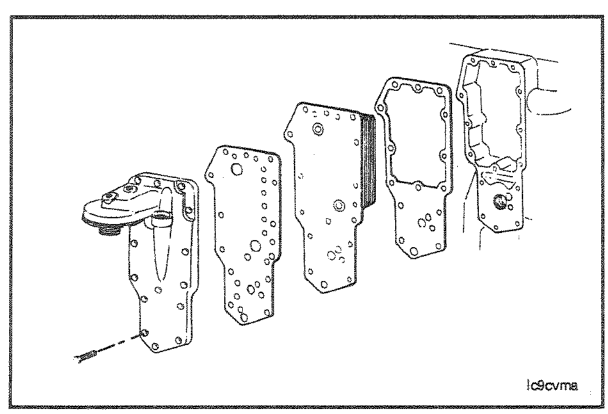
16 mm, 19 mm

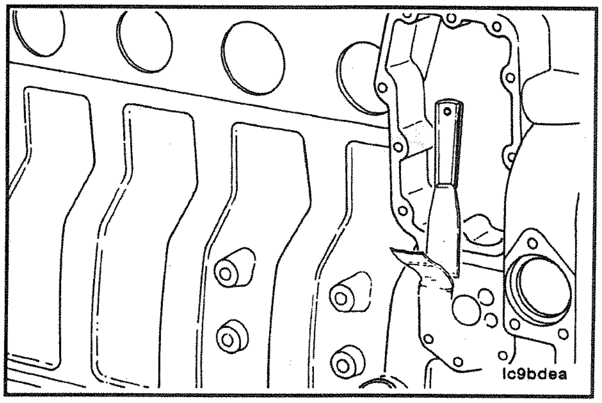
Disconnect the turbocharger supply line.



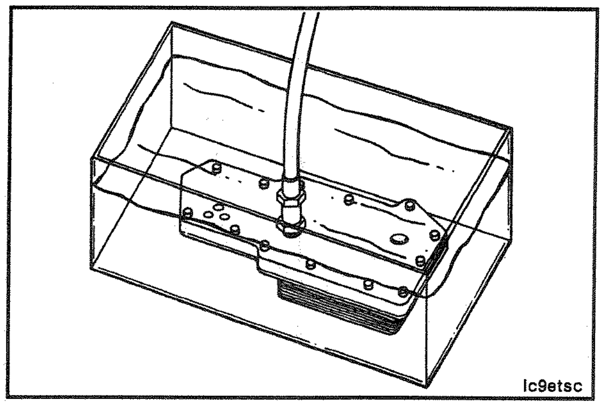
10 mm

Remove the lubricating oil cooler cover, gaskets and cooler element.





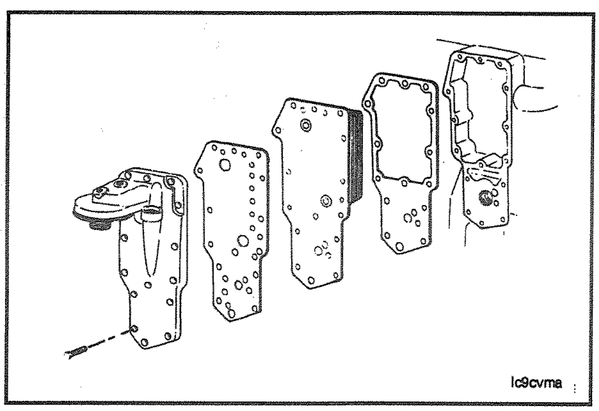
Clean the sealing surfaces.



Leak Test Kit 3823876

Pressure test the element to check for leaks. If leaks are detected, replace the element.

Air Pressure Test		
518 kPa	MAX	[75 psi]
449 kPa	MIN	[65 psi]

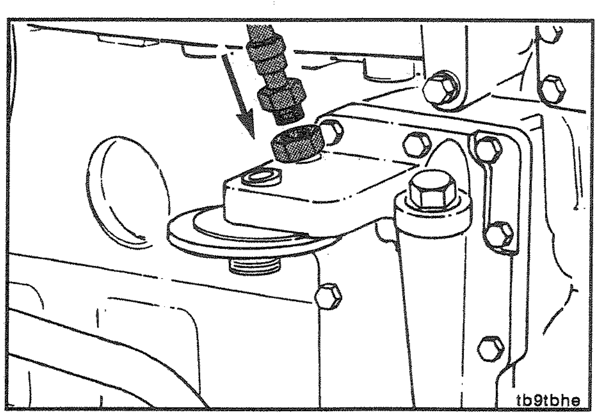


10 mm

Assemble the lubricating oil cooler gaskets, element and cover.

Torque Value: 24 N•m [18 ft-lb]

NOTE: Be sure to remove the shipping plugs from the element.



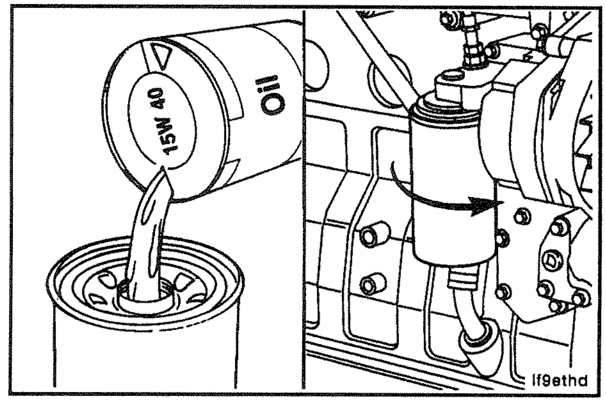
16 mm, 19 mm

Connect the turbocharger lubricating oil supply line.

Part No. 3823494

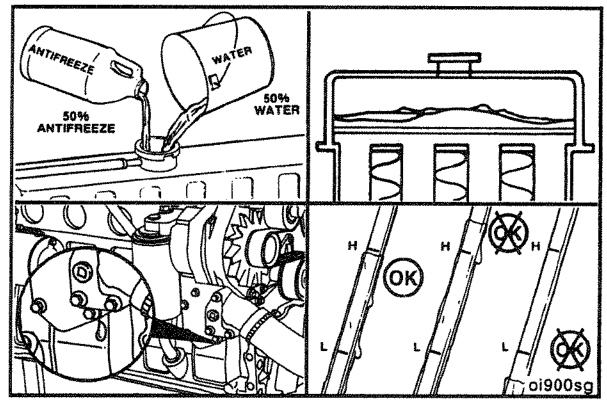
Fill the filter with clean lubricating oil and apply a light coat of oil to the sealing gasket.

Install the lubricating oil filter.



Fill the coolant system and operate the engine to check for leaks.

Stop the engine and check the coolant and lubricating oil level.

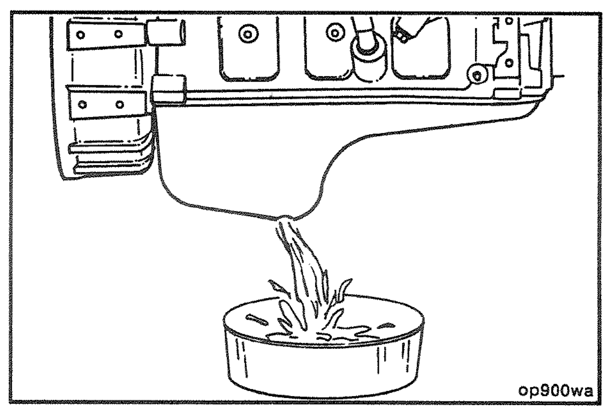


Lubricating Oil Pan, Suction Tube and/or Gaskets - Replacement (2-06)

17 mm

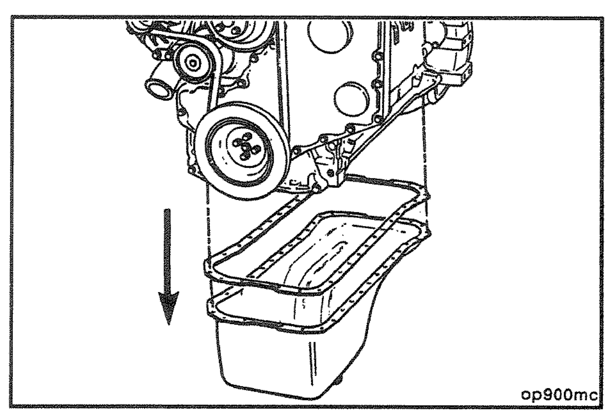
Drain the lubricating oil.

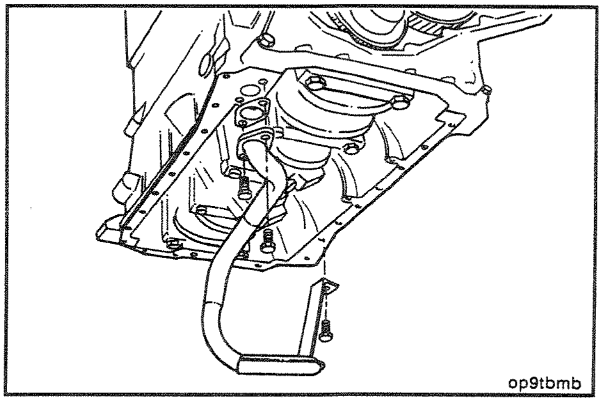
NOTE: Use a container that can hold at least 20 litres [15 U.S. qts.] of lubricating oil.



10 mm

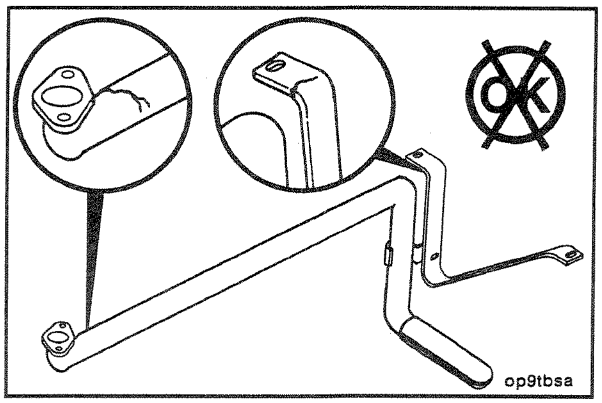
Remove the lubricating oil pan.



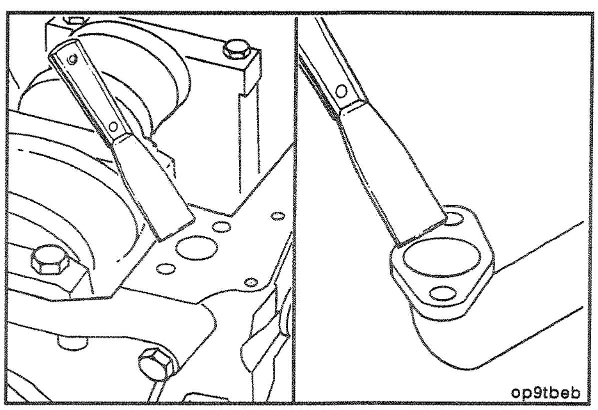


10 mm

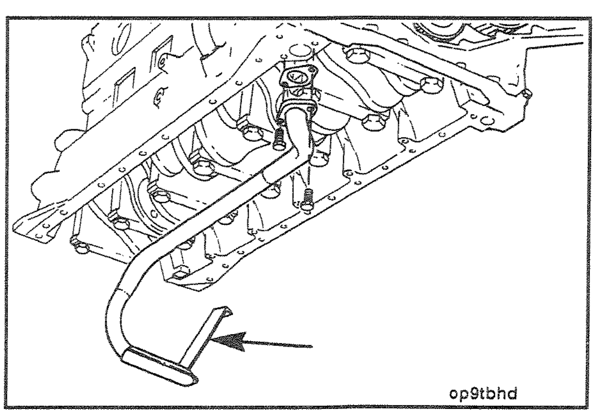
Remove the lubricating oil suction tube.



Inspect the suction tube for cracks.



Clean the gasket surfaces.

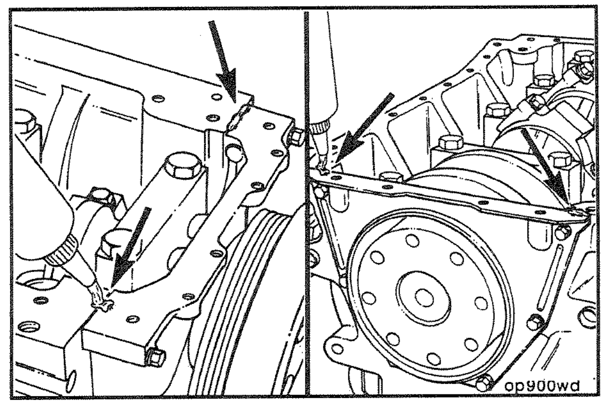


10 mm

Install the lubricating oil suction tube and new gasket.

Torque Value: 24 N•m [18 ft-lb]

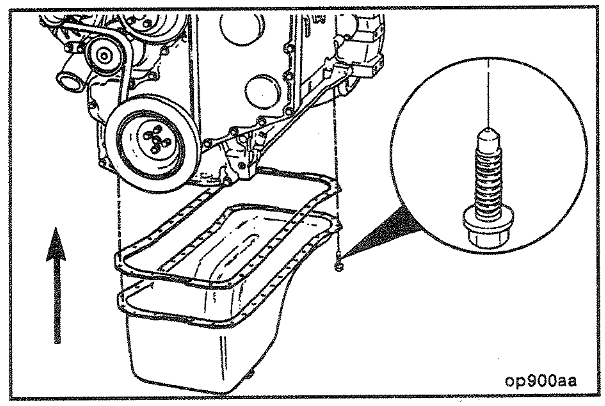
Use Three Bond 1207-C® to fill the joints between the lubricating oil pan rail, gear housing, and rear seal housing.



10 mm

Install the lubricating oil pan and gasket.

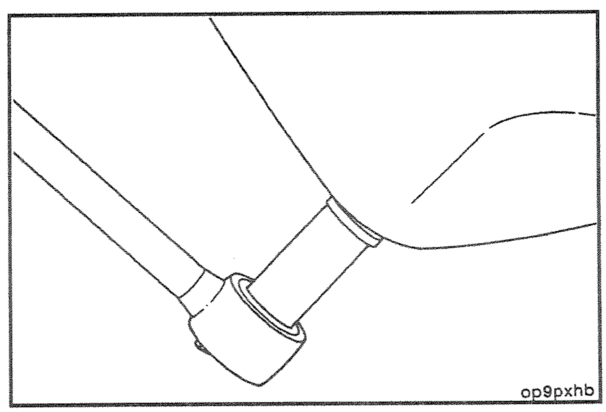
Torque Value: 24 N•m [18 ft-lb]



17 mm

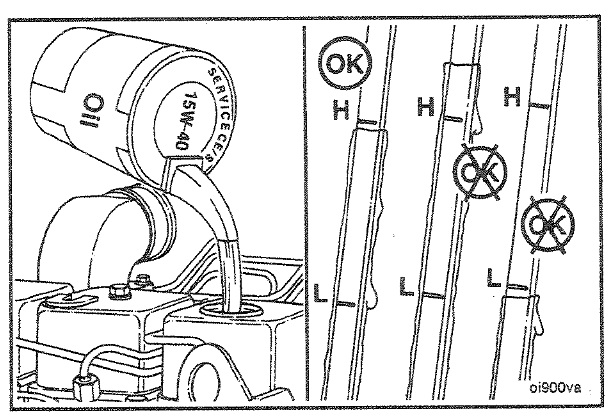
Install the lubricating oil pan drain plug.

Torque Value: 80 N•m [60 ft-lb]



Fill the engine with lubricating oil. Operate the engine and check for leaks.

Stop the engine and check the lubricating oil level with the dipstick.

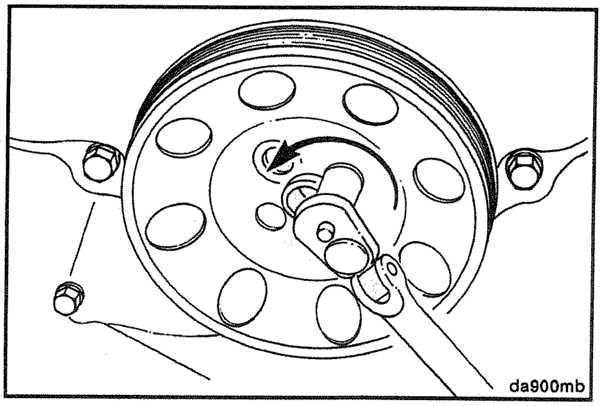


Lubricating Oil Pump - Replacement (2-07)

Preparatory Step:

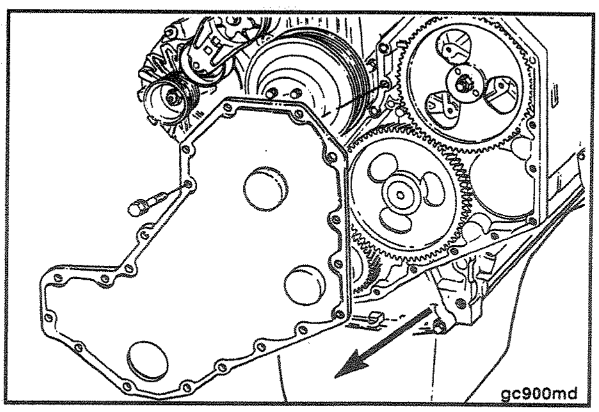
- Remove the drive belt.

NOTE: Removal is easier if the crankshaft pulley is loosened before removing the belt.



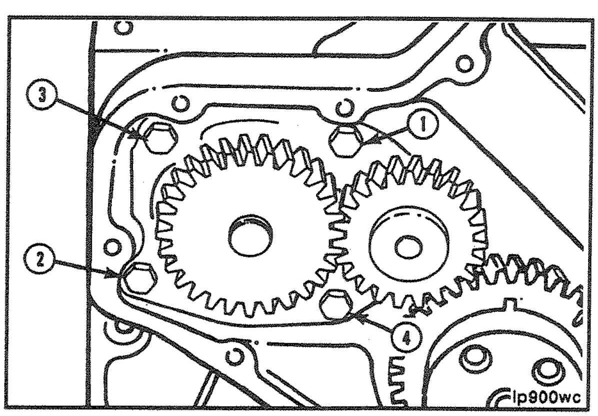
15 mm

Remove the crankshaft pulley.



10 mm

Remove the front cover.



Lubricating Oil Pump - Removal

13 mm

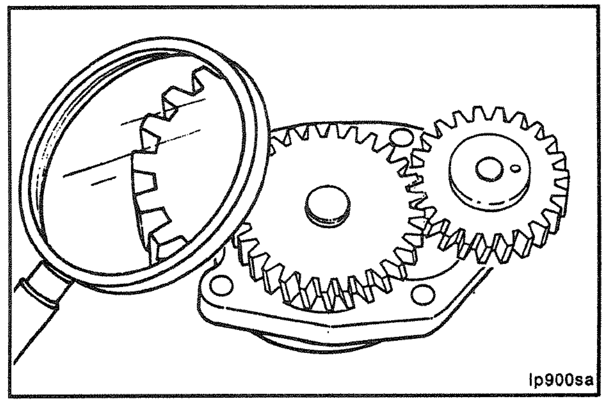
Remove the four mounting capscrews.

Remove the pump from the bore in the cylinder block.

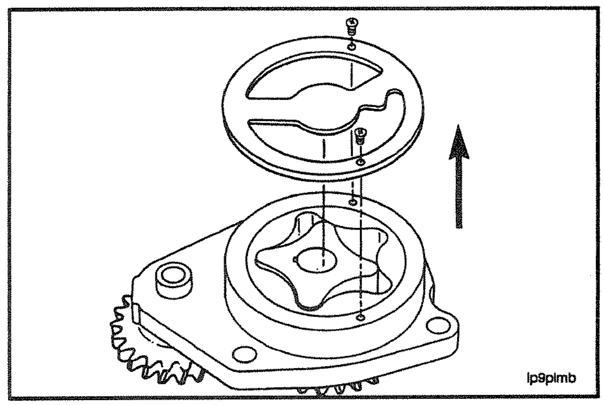
Clean and Inspect

If the lubricating oil pump is to be inspected for reuse, follow these steps.

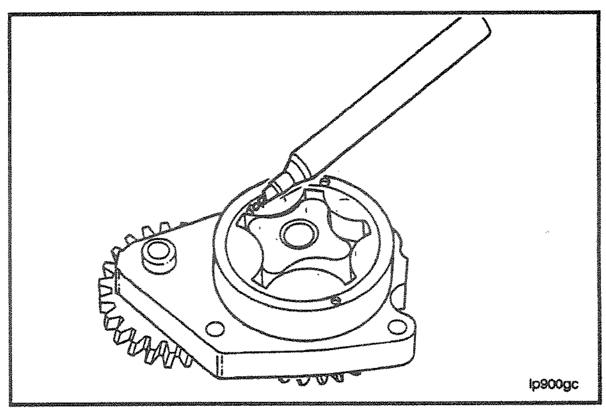
Visually inspect the llubricating oil pump gears for chips, cracks, or excessive wear.



Remove the back plate.

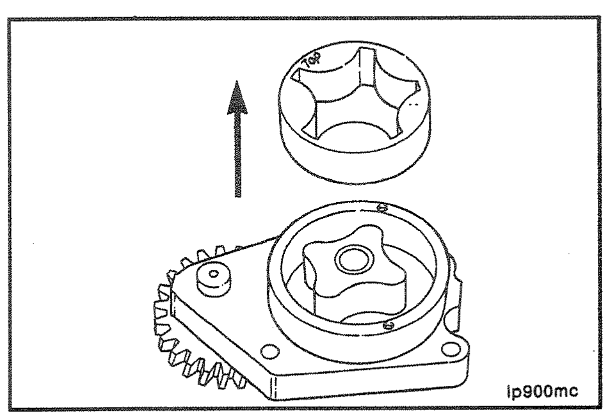


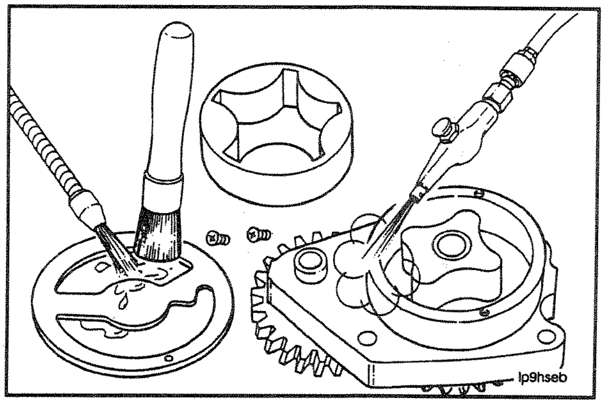
Mark "TOP" on the gerotor planetary.



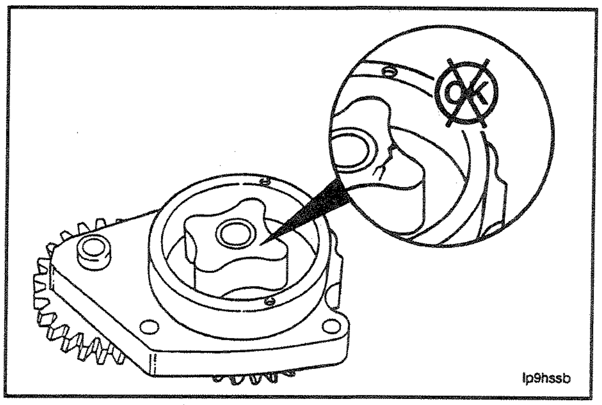
Remove the gerotor planetary.

Inspect for excessive wear or damage.

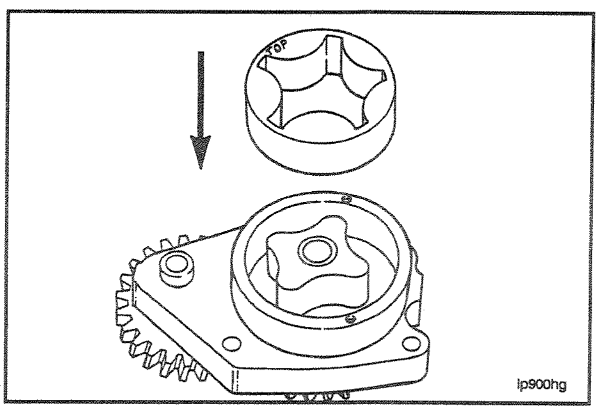




Clean all parts in solvent and dry with compressed air.

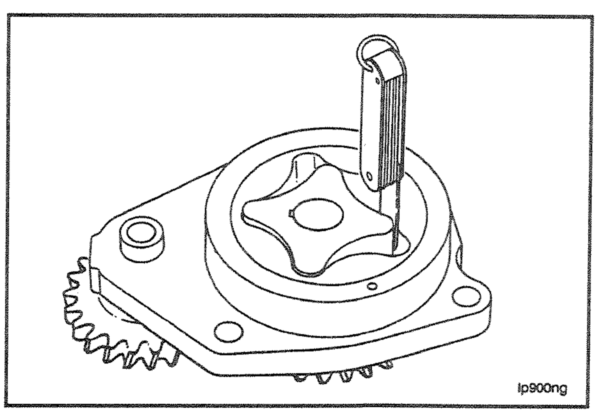


Inspect the lubricating oil pump housing and gerotor drive for damage and excessive wear.



Caution: Be sure the gerotor planetary is installed in the original position.

Install the gerotor planetary.

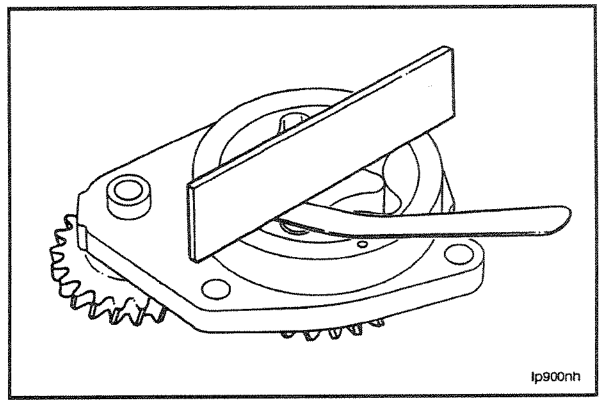


Measure the tip clearance.

Limit
Maximum Clearance: 0.1778 mm [0.007 in]

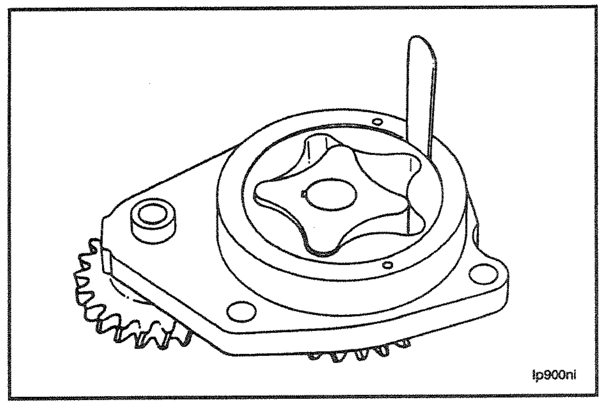
Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Limit
Maximum Clearance: 0.127 mm [0.005 in]



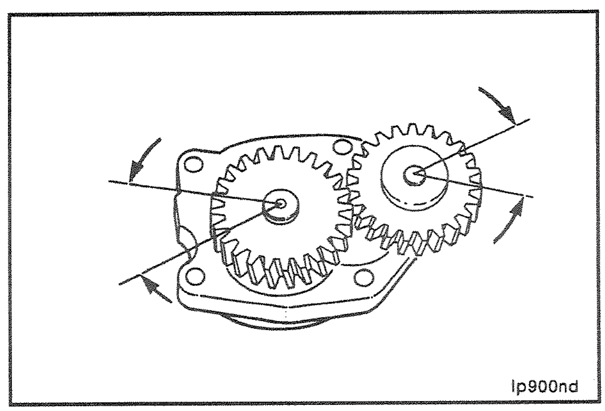
Measure the clearance of the gerotor planetary to the body bore.

Limit
Maximum Clearance: 0.381 mm [0.015 in]

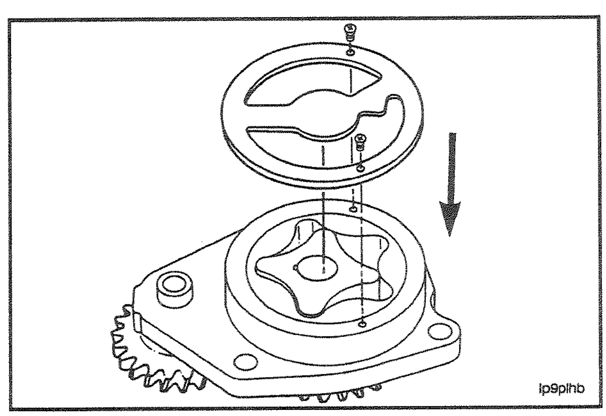


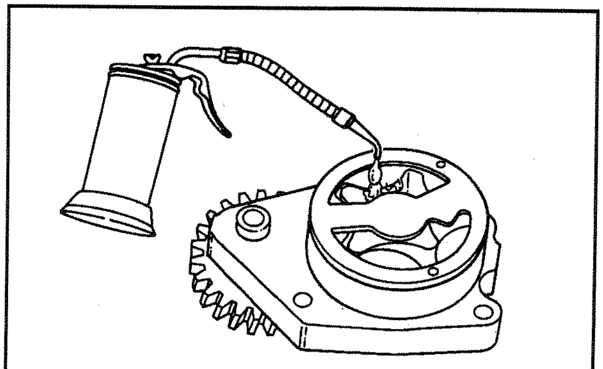
Measure the gears backlash.

Limits (Used Pump)		
.076 mm	MIN	[.003 in]
.330 mm	MAX	[.013 in]



Install the back plate.

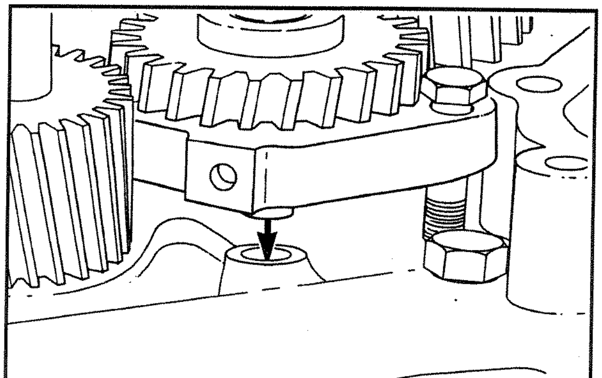



lp9hswa

Lubricating Oil Pump - Installation

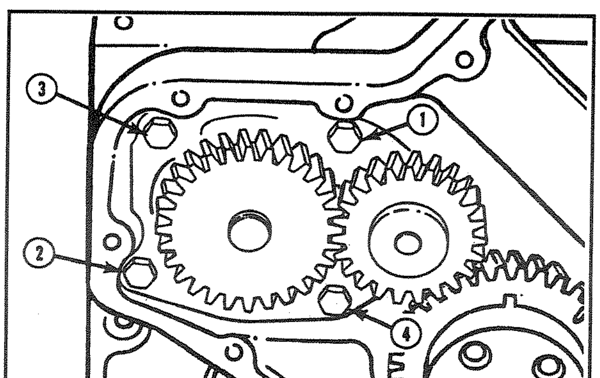
Caution: Failure to fill the pump with oil during installation can result in a slow prime at initial engine start up, resulting in severe engine damage.

Lubricate the lubricating oil pump with clean engine oil.


lp900hf

Caution: Make sure the idler gear pin is installed in the locating bore in the cylinder block.

Install the lubricating oil pump.

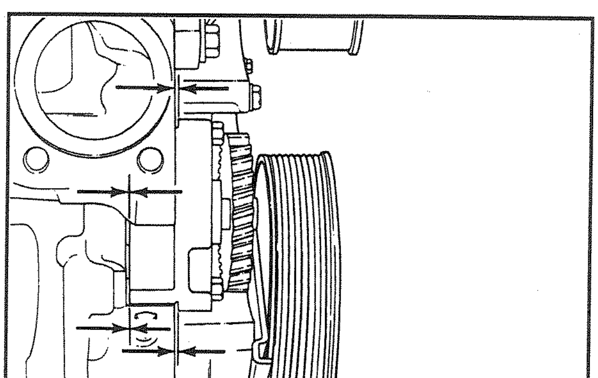


lp900wc

13 mm

Tighten in the sequence shown.

Torque Value: 24 N•m [18 ft-lb]


lp900wd

NOTE: The back plate on the pump seats against the bottom of the bore in the cylinder block. When the lubricating oil pump is correctly installed, the flange on the lubricating oil pump will not touch the cylinder block.

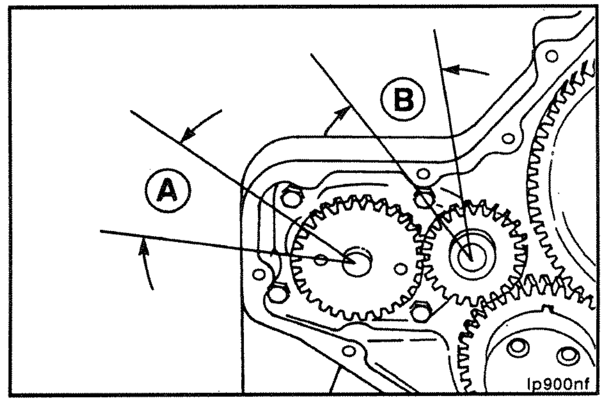
NOTE: Be sure the gear backlash is correct if installing a new lubricating oil pump.

Measure gear backlash.

Backlash Limits

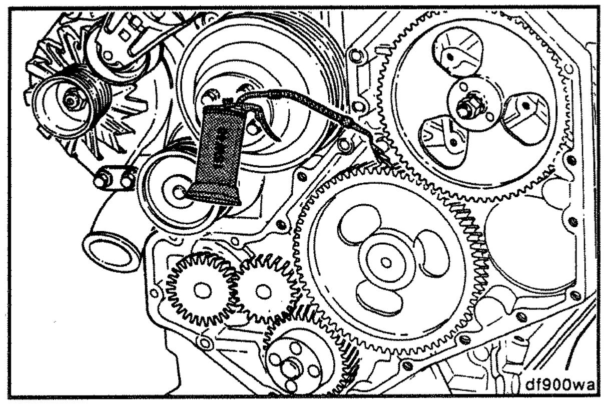
A	B
.076 to .330 mm [.003 to .013 in]	.076 to .330 mm [.003 to .013 in]

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



Gear Cover - Installation

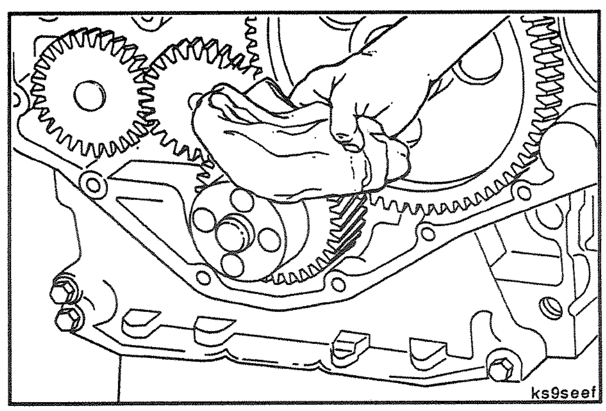
Lubricate the front gear train with clean engine oil.



Caution: The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Thoroughly clean the front seal area of the crankshaft.

NOTE: Always replace the front seal when removing and installing the gear cover.

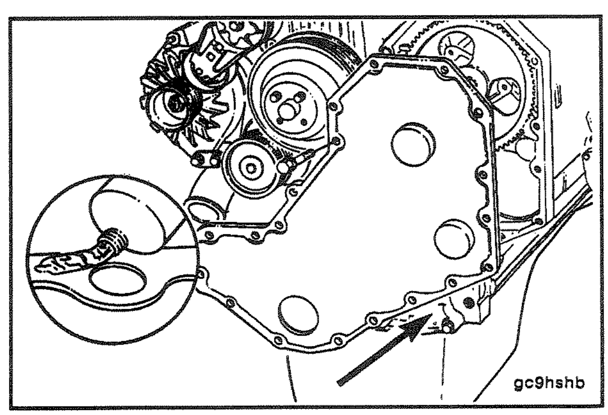


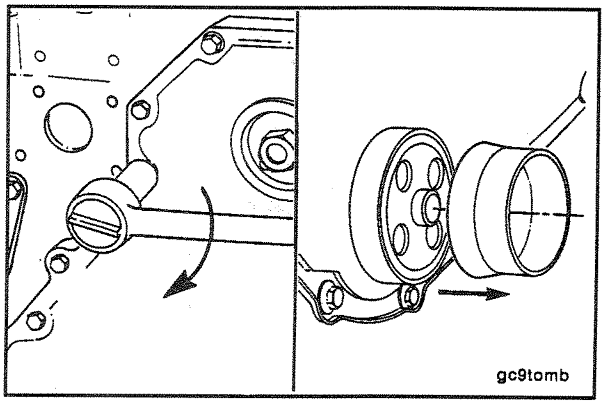
10 mm

Apply a thin bead of Three Bond™ to the front cover side of the gasket only.

NOTE: Do not remove the plastic seal pilot tool from the lubricating oil seal at this time. Use the plastic seal pilot tool to guide the seal on the crankshaft.

Install the gasket and front cover on the engine.

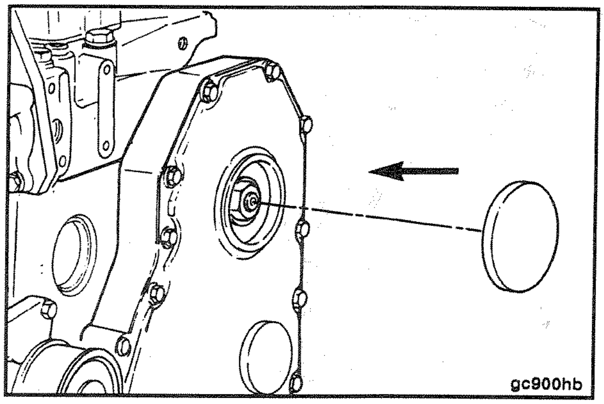




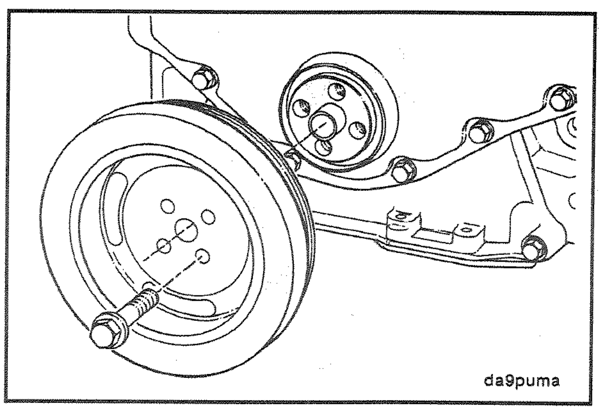
Tighten the front cover mounting capscrews.

Remove the plastic pilot tool from the crankshaft.

Torque Value: 24 N•m [18 ft-lb]

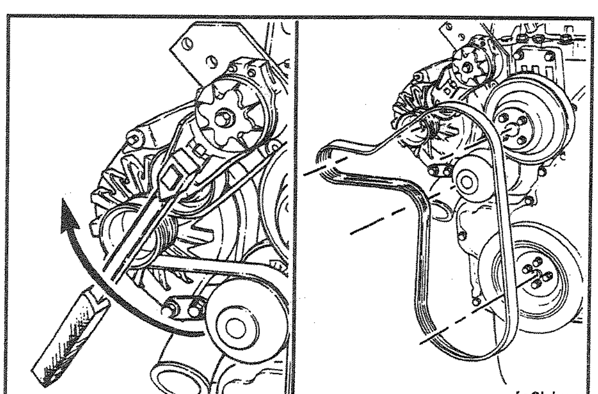


Install the front cover access cap and seal.



15 mm

Install the crankshaft pulley or vibration damper. Do not tighten the capscrews to the correct torque value at this time.



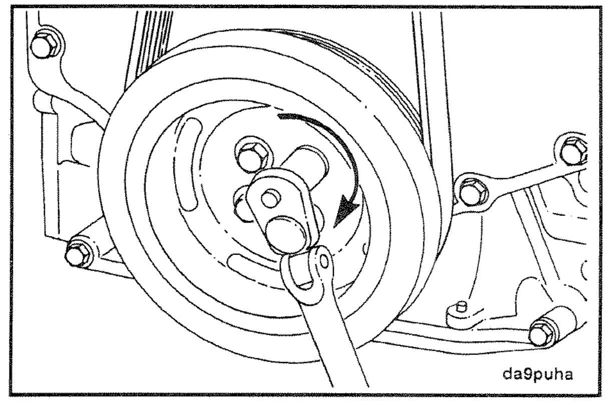
1/2 inch Square Drive

Raise the belt tensioner to install the belt.

15 mm

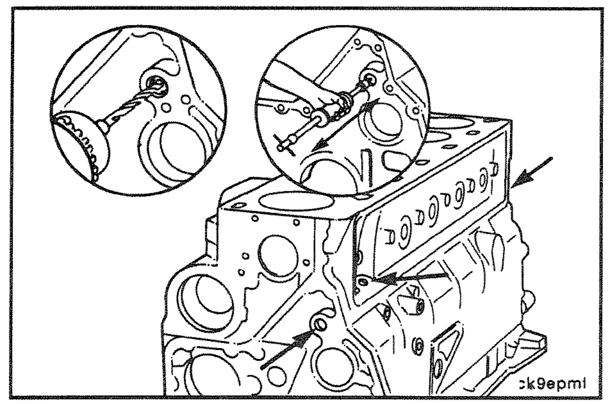
Tighten the crankshaft pulley.

Torque Value: 125 N•m [92 ft-lb]



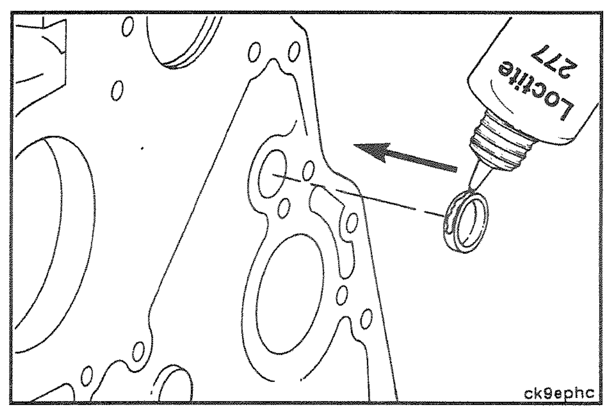
Expansion Plug - Replacement (2-08)

Remove the expansion plugs from the oil passages.

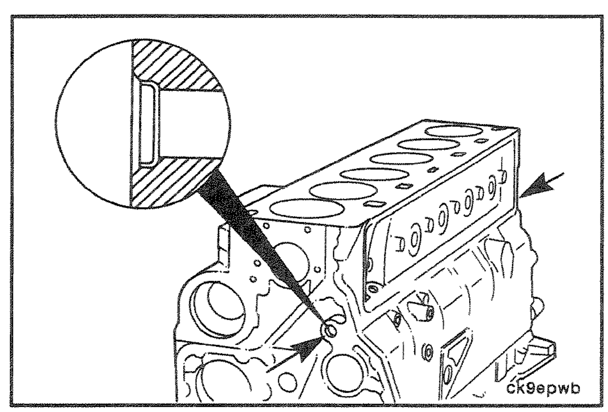


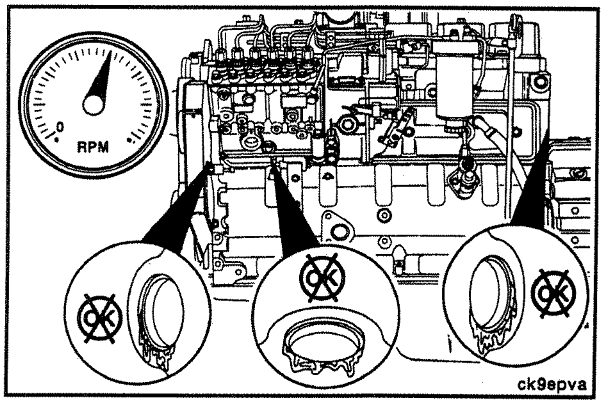
To Install the Expansion Plugs

Apply a bead of Loctite 277 around the outside diameter of the lubricating oil passage expansion plugs.



Drive the expansion plugs in until they bottom in the bore.





Fill the engine with lubricating oil. Operate the engine and check for leaks.

Stop the engine and check the lubricating oil level with the dipstick.

Section 3 - Combustion Air System

Section Contents

Combustion Air System Flow - General Information

The engine was designed as a turbocharged engine, but a naturally aspirated version of the B engine is available for industrial applications.

Air is pulled into the engine from an air filter. Clean air is very important to the life of the engine. Ingested dust and dirt can very quickly damage the cylinders.

Make sure that an excellent quality air cleaner is used and that it is periodically replaced according to the manufacturer's recommendations.

Intake air for the naturally aspirated engine flows from the air cleaner to the intake manifold. From the intake manifold, the air is pulled into the cylinders and used for combustion. After combustion it is forced out of the cylinders and through the exhaust manifold.

On the turbocharged engines the intake air is drawn through the air cleaner into the compressor side of the turbocharger and then through the crossover tube and into the intake manifold. From the intake manifold the air is forced into the cylinders and used for combustion. Energy from the exhaust gases is utilized by flowing the exhaust through the exhaust side of the turbocharger to drive the turbine wheel. The turbine wheel and shaft drives the compressor wheel which forces more air into the cylinders for combustion. The additional air provided by the turbocharger allows more fuel to be injected to increase the power output from the engine.

On turbocharged-aftercooled engines, intake air from the turbocharger flows through the cooling fins of the aftercooler before entering the intake manifold. The cooled air becomes more dense and contains more oxygen which allows more fuel to be injected further increasing the power output from the engine.

The 1991 to 1994 automotive engines use a chassis-mounted charge air cooler instead of an engine mounted aftercooler to provide cooler charge air to the engine to improve engine performance and reduce emissions. This system also uses large diameter piping to transfer the air from the engine turbocharger to the charge air cooler, then returns the air from the charge air cooler to the engine intake manifold.

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

Some turbocharged engines use a wastegated turbocharger to limit the maximum boost pressure that the turbo can develop. Wastegate operation is controlled by an actuator that senses compressor pressure and balances it against a preset spring load. The wastegate valve is located in the turbine inlet passage. When open, it diverts a portion of the exhaust gas away from the turbine wheel, thereby controlling the shaft speed and boost.

⚠ **Caution: The turbocharger is a performance part and must not be tampered with. The wastegate bracket is an integral part of the turbocharger. Tampering with the Wastegate Components can reduce durability by increasing cylinder pressure and thermal loading due to incorrect inlet and exhaust manifold pressure. Poor fuel economy and failure to meet regulatory emissions laws may result. Increasing the turbocharger boost will not increase engine power.**

The turbine and compressor wheels and shaft are supported by two rotating bearings in the bearing housing. Passages within the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearing. The oil is used to lubricate and cool the rotating components to provide for smooth operation. The oil then drains from the bearing housing to the engine sump through the oil drain line. A restricted or damaged oil drain line can cause the turbocharger bearing housing to be pressurized causing oil to leak past the seals.

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

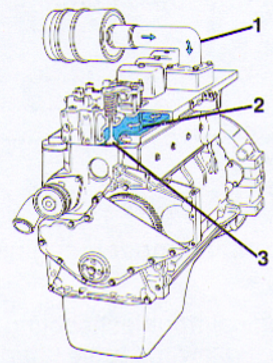
⚠ **Caution: A catalyst is installed on all EPA and CARB approved automotive applications. Lubricating oil blending is not permitted. It will plug up and eventually damage the catalyst. High sulfur fuels must not be used with the catalyst. No welding or modifications of the catalyst are permited without permission of catalyst manufacturer.**

Air System Flow - Diagrams

Air System - Intake Air

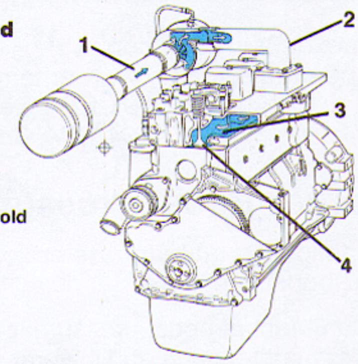
Naturally Aspirated

Intake System
1. Intake Air Inlet
2. Intake Manifold
3. Intake Valve



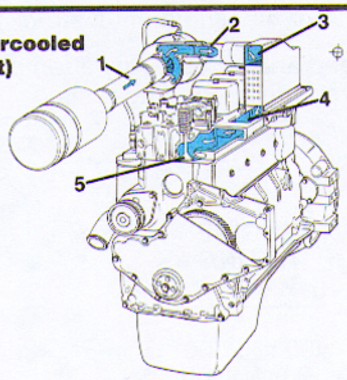
Turbocharged

Intake System
1. Intake Air Inlet to Turbocharger
2. Air to Intake Manifold
3. Intake Manifold
4. Intake Valve



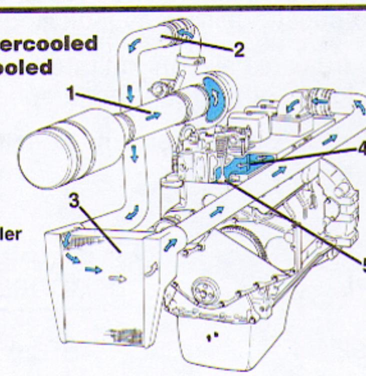
Turbocharged-Aftercooled (Waterjacket)

Intake System
1. Intake Air Inlet to Turbocharger
2. Turbocharger Air to Aftercooler
3. Aftercooler
4. Intake Manifold
5. Intake Vavle



Turbocharged-Aftercooled Charge Air-Cooled

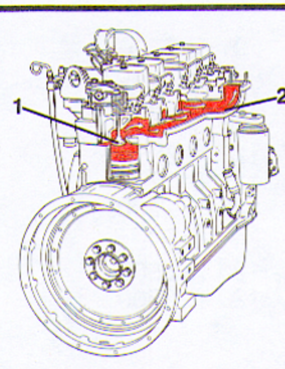
Intake System
1. Intake Air Inlet to Turbocharger
2. Turbocharger Air to Charge Air Cooler
3. Charge Air Cooler
4. Intake Manifold
5. Intake Valve



Air System - Exhaust Air

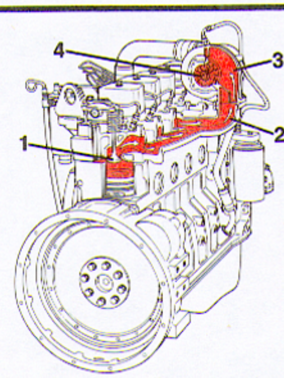
Naturally Aspirated

Exhaust System
1. Exhaust Valve
2. Exhaust Manifold

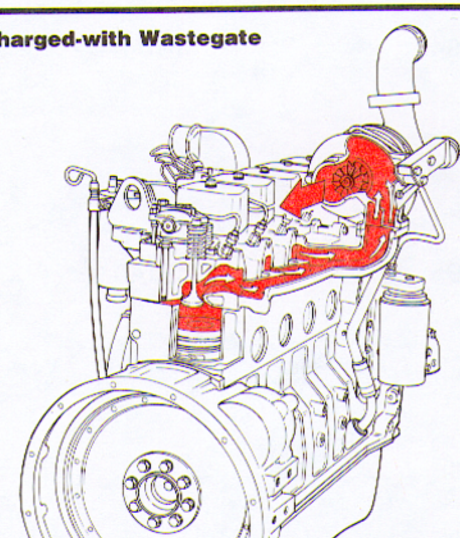


Turbocharged

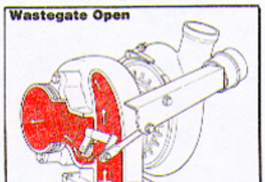
Exhaust System
1. Exhaust Valve
2. Exhaust Manifold
3. Turbocharger Inlet
4. Turbocharger Exhaust Outlet



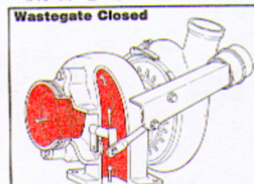
Turbocharged-with Wastegate



Wastegate Open



Wastegate Closed



Intake Air and Exhaust System Specifications

- Maximum allowable intake restriction (compressor inlet) (with dirty air filter element)
  - Non turbo .... 20 in/H_2O (50.8 cm/H_2O)
  - Turbo .... 25 in/H_2O (63.5 cm/H_2O)
- Maximum exhaust restriction at rated speed and load
  - Non automotive .... 3 in/Hg (76.2 mm/Hg)
  - 91 EPA Cert .... 4.5 in/Hg (114.3 mm/Hg)
  - 94 EPA Cert. with oxidation catalyst .... 6 in/Hg (152.6 mm/Hg)

Turbocharger Boost Pressure Specificlations

Refer to the following table for the critical parts list (CPL), engine model, engine rating and corresponding rated turbocharger boost pressure.

NOTE: Measurement of boost pressure is not a short cut to logical troubleshsooting. Low power can be caused by the fuel used, filter maintenance and several engine components. Follow the logic charts for "Engine Power Output Low" and measure boost pressure as indicated. Refer to page 3-13 for measurement instructions.

These pressures are valid only at rated conditions (rated speed and power). Any attempt to use the values at engine speeds and loads other than those specified will result in an incorrect diagnosis.

Table 1. B Series Boost Pressure Specifications

CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
0592	4BT3.9	100 @ 2500	22 to 28
		96 @ 2300	19 to 25
		94 @ 2200	18 to 24
		93 @ 2200	18 to 24
		92 @ 2100	16 to 22
		80 @ 2200	14 to 20
		71 @ 2200	12 to 18
		70 @ 2100	11 to 17
0594	4BTA3.9	91 @ 2200	17 to 23
		95 @ 2200	18 to 24
		107 @ 2100	21 to 27
		109 @ 2200	23 to 29
		112 @ 2300	24 to 30
		116 @ 2500	27 to 35
		125 @ 2200	27 to 33
0595	4BTA3.9	120 @ 2500	32 to 40
		120 @ 2800	34 to 42

CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
0597	6BT5.9	88 @ 2000	10 to 16
		89 @ 2000	10 to 16
		99 @ 2200	13 to 19
		100 @ 2200	14 to 20
		120 @ 2100	18 to 24
		122 @ 2200	18 to 24
		124 @ 2400	20 to 26
		124 @ 2500	21 to 27
		126 @ 2100	19 to 25
		130 @ 2100	21 to 27
		130 @ 2500	23 to 29
		135 @ 2200	22 to 28
		137 @ 2000	18 to 24
		140 @ 2200	24 to 30
		142 @ 2100	24 to 30
		143 @ 2200	25 to 31
		145 @ 2200	25 to 31
		148 @ 2300	27 to 33
		152 @ 2500	28 to 36
0598	6BT5.9	160 @ 2500	28 to 36
		160 @ 2800	31 to 39
0599	6BTA5.9	141 @ 2200	27 to 35
		152 @ 2500	33 to 41
		157 @ 2200	33 to 41
		160 @ 2200	34 to 42
		167 @ 2000	35 to 43
		169 @ 2100	36 to 44
		174 @ 2200	39 to 47
		176 @ 2300	40 to 48
		177 @ 2400	30 to 38
		177 @ 2500	41 to 49
0600	6BTA5.9	180 @ 2500	39 to 47
0646	4BT3.9	82 @ 1800	11 to 17
		71 @ 1500	9 to 15
0692	6BT5.9	160 @ 2500	30 to 38
		160 @ 2600	31 to 39
0696	4BT3.9	102 @ 1800	19 to 25
		87 @ 1500	15 to 21
0697	6BT5.9	113 @ 1500	15 to 21
		134 @ 1800	21 to 27
0698	6BT5.9	143 @ 1500	25 to 31
		166 @ 1800	32 to 40
0710	4BT3.9	75 @ 2200	13 to 19
		100 @ 2500	22 to 28
0711	4BT3.9	71 @ 1500	9 to 15
		82 @ 1800	11 to 17

CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
0712	6BT5.9	88 @ 2000	10 to 16
		99 @ 2200	13 to 19
		100 @ 2200	13 to 19
		120 @ 2100	18 to 24
		122 @ 2200	18 to 24
		124 @ 2400	20 to 26
		130 @ 2100	20 to 26
		130 @ 2500	23 to 29
		135 @ 2200	22 to 28
0713	6BT5.9	113 @ 1500	15 to 21
		134 @ 1800	21 to 27
0715	6BTA5.9	143 @ 2100	26 to 32
0716	6BT5.9	156 @ 2500	45 to 53
0727	4BT3.9	105 @ 2500	46 to 54
0728	6BT5.9	128 @ 2800	19 to 25
		130 @ 2650	19 to 25
0729	6BT5.9	134 @ 2200	23 to 29
0730	4BT3.9	70 @ 2100	10 to 16
		75 @ 2200	13 to 19
		77 @ 2200	13 to 19
		79 @ 2350	14 to 20
		80 @ 2200	14 to 20
		84 @ 2200	15 to 21
		85 @ 2500	17 to 23
		90 @ 2000	16 to 22
		91 @ 2200	17 to 23
		92 @ 2100	16 to 22
		93 @ 2200	18 to 24
		96 @ 2300	19 to 25
		100 @ 2500	22 to 28
0741	4BT3.9-M	130 @ 2500	18 to 24
		150 @ 2800	25 to 31
0742	6BT-M	180 @ 2500	39 to 47
		210 @ 2600	47 to 55
0761	6BT5.9	160 @ 2800	29 to 37
0762	4BT3.9	105 @ 2500	28 to 36
		105 @ 2800	31 to 39
0763	4BT3.9	67 @ 2200	10 to 16
		71 @ 2200	10 to 16
0766	6BT5.9	160 @ 2500	28 to 36
		160 @ 2800	31 to 39
0767	4BT3.9	105 @ 2500	24 to 31
		105 @ 2800	27 to 33

CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
0792	6BT5.9	115 @ 1500	16 to 22
		135 @ 1800	22 to 28
0793	4BT3.9	74 @ 1500	10 to 16
		86 @ 1800	12 to 18
0804	6BT5.9	145 @ 2600	39 to 47
		160 @ 2500	44 to 52
0807	6BT5.9	99 @ 2200	13 to 19
0826	4BT3.9	87 @ 1500	15 to 21
		102 @ 1800	19 to 25
0834	6BTA5.9	180 @ 2500	32 to 40
0856	6BTA5.9	180 @ 2500	46 to 54
0857	4BT3.9	120 @ 2500	40 to 48
0858	4BT3.9	105 @ 2500	35 to 43
0912	6BTA5.9	190 @ 2600	34 to 42
		192 @ 2800	37 to 45
0937	4BT3.9	74 @ 1500	10 to 16
		86 @ 1800	12 to 18
0938	6BT5.9	88 @ 2000	10 to 16
		100 @ 2200	14 to 20
		110 @ 2000	15 to 21
		113 @ 2100	16 to 22
		121 @ 2200	18 to 24
		124 @ 2400	21 to 27
		124 @ 2500	21 to 27
		125 @ 2200	20 to 26
		126 @ 2100	19 to 25
		130 @ 2100	21 to 27
		130 @ 2500	23 to 29
		134 @ 2100	22 to 28
		137 @ 2000	18 to 24
		140 @ 2200	24 to 30
		142 @ 2100	24 to 30
		145 @ 2200	25 to 31
		148 @ 2300	27 to 33
		152 @ 2500	28 to 36
0940	6BTA5.9	190 @ 2500	42 to 50
0943	6BT5.9	120 @ 2100	18 to 24
0947	6BT5.9	145 @ 2600	24 to 30
		160 @ 2500	29 to 37
		160 @ 2600	31 to 39
		130 @ 2500	20 to 26
0948	6BT5.9	145 @ 2600	24 to 30

CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
0949	6BT5.9	88 @ 2000	10 to 16
		121 @ 2200	14 to 20
		124 @ 2400	21 to 27
		126 @ 2100	19 to 25
		130 @ 2500	23 to 29
		140 @ 2200	24 to 30
		142 @ 2100	24 to 30
		145 @ 2200	25 to 31
		148 @ 2300	27 to 33
		152 @ 2500	28 to 36
0950	6BT5.9	120 @ 2100	18 to 24
0953	6BTA5.9	220 @ 2500	23 to 29
		250 @ 2600	44 to 52
0961	6BT5.9	115 @ 1500	16 to 22
		135 @ 1800	22 to 28
0962	6BT5.9	143 @ 1500	25 to 31
		166 @ 1800	32 to 40
0970	6BTA-M2	300 @ 2800	46 to 54
0971	4BT3.9	96 @ 2200	19 to 25
		100 @ 2500	22 to 28
0983	6BTA5.9	157 @ 2500	35 to 43
		177 @ 2500	38 to 46
*0986	B3.9-120	120 at 2500	27 to 35
*0987	B5.9-230	230 at 2500	39 to 48
0998	6BTA5.9	200 @ 2500	45 to 53
1160	6BT5.9	160 @ 2500	29 to 37
1165	6BTA5.9	227 @ 1760	37 to 45
		255 @ 2100	46 to 54
1168	6BT5.9	148 @ 2300	25 to 31
		152 @ 2500	27 to 35
12101	4BT3.9	80 @ 2500	19 to 25
1202	4BT3.9	74 @ 2500	18 to 24
1207	6BT	145 @ 2600	23 to 29
1209	6BTA5.9	176 @ 2300	30 to 36
1247	6BTA5.9	220 @ 2500	30 to 36
		250 @ 2600	39 to 47
1266	6BT5.9	142 @ 2500	27 to 35

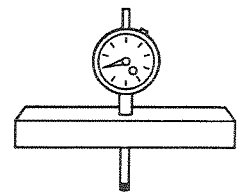
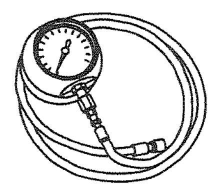
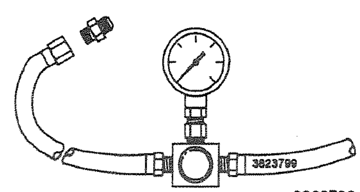
CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
1247	6BTA5.9	220 @ 2500 250 @ 2600	23 to 29 44 to 52
*1260	B3.9-105	105 @ 2500	20 to 28
*1261	B5.9-190	190 @ 2500	37 to 45
1268	4BT3.9	105 @ 2500 105 @ 2800	28 to 36 31 to 39
1288	6BT	152 @ 2500	28 to 36
1322	6BT-M1	250 @ 2600	42 to 50
*1351	B5.9-160	160 @ 2500	31 to 39
1419	6BT	250 @ 2200	38 to 46
*1422	B5.9-210	210 @ 2500	38 to 46
1518	6BT-G2	143 @ 1500 166 @ 1800	20 to 26 25 to 33
1519	6BT-G1 6BT-G2	115 @ 1500 135 @ 1800	12 to 18 20 to 26
1520	4BT-G2	102 @ 1800 87 @ 1500	18 to 26 15 to 21
1521	4BT-G1	74 @ 1500 86 @ 1800	3.4 to 9.4 5.8 to 12
1523	6BT-G2	143 @ 1500 166 @ 1800	16 to 22 25 to 33
1524	6BT-G1	115 @ 1500 135 @ 1800	13 to 19 20 to 26
1525	4BT-G2	102 @ 1800 74 @ 1500	11 to 17 6 to 12
1526	4BT-G1	68 to 1500 86 to 1800	6 to 12 12 to 18
1527	6BTA	175 @ 2500	38 to 46
**1549	6BTA5.9	160 @ 2500	30 to 38
**1550	6BTA5.9	175 @ 2500	30 to 38
**1551	6BTA5.9	190 @ 2300	44 to 52
**1552	6BTA5.9	210 @ 2300 210 @ 2500	45 to 53 45 to 53

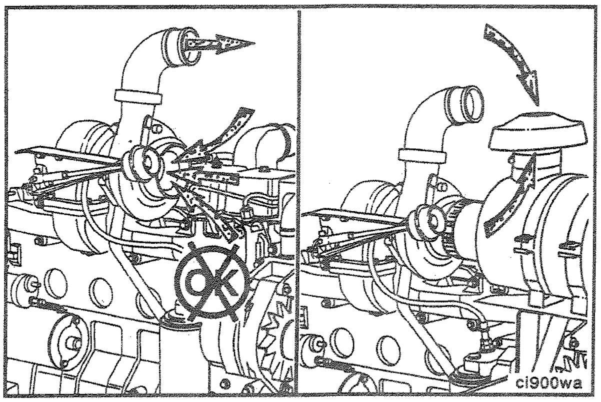
CPL	ENGINE MODEL	ENGINE RATING (HP @ RPM)	RATED BOOST PRESSURE (in. Hg)
**1553	6BTA5.9	230 @ 2300	47 to 57
1570	6BT-M1	220 @ 2500	36 to 44
1577	6BTA	210 @ 2500	35 to 43
*1579	6BTA	160 @ 2500	31 to 39
1613	6BTA-M2	250 @ 2600	36 to 44

* Designates 1991, ** designates 1994 charge air cooled ratings. Boost readings measured at the turbocharger compressor outlet may be 4-6 in Hg higher than the values shown in the following table due to a normal pressure drop through the charge air cooler. Be sure charge air cooler related components are not the cause of a low pressure reading.

Combustion Air System - Service Tools

The following special tools are recommended to perform procedures in Section 3. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

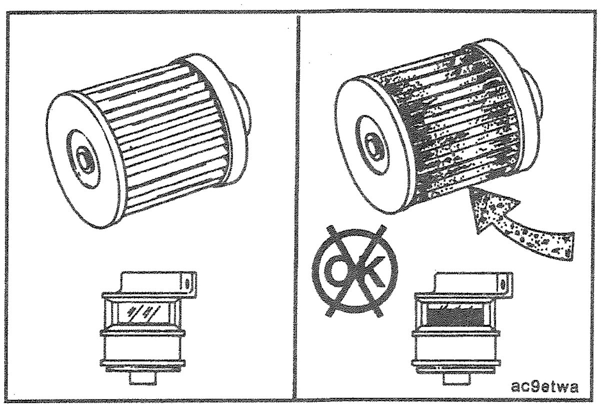
Tool No.	Tool Description	Tool Illustration
ST-537	**Dial Depth Gauge** Measure turbocharger axial motion.	 tb8togf
ST-1273	**Pressure Gauge (0-75 in. Hg.)** Used to measure the intake manifold pressure and exhaust back pressure.	 eg8togi
3823799	**Turbocharger Wastegate Pressure Setting Kit** Used to set wastegate pressure.	 3823799



Diagnosing Air System Malfunctions

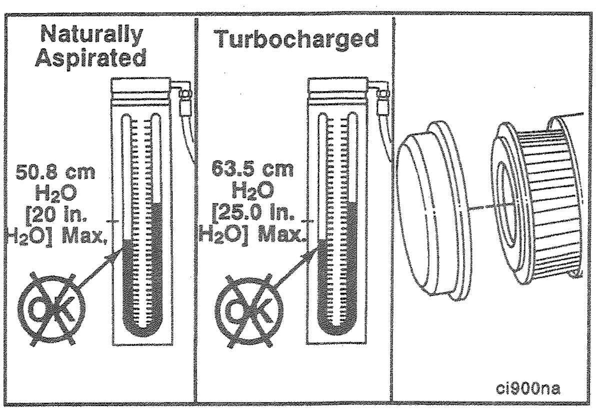
Clean Air

The correct amount of clean air to the cylinders is required for good performance. As discussed earlier in Air Flow System, ingested dust and dirt will damage the engine cylinders. Dust and dirt can also damage the valve stems and guides as well as wear down the turbo compressor vanes affecting efficiency. Larger debris can damage the blades of the turbocharger.



Air flow restriction results in excessive smoke and low power.

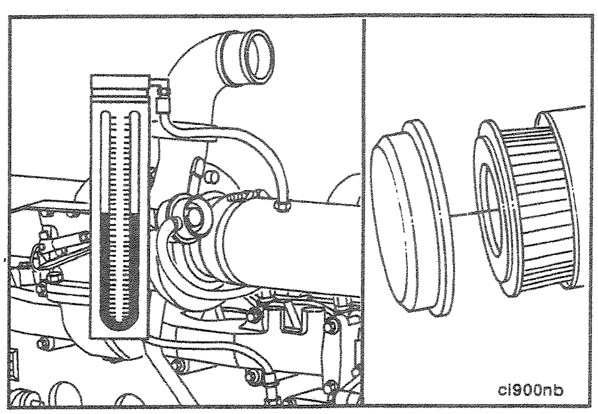
Restriction increases as the filter removes contaminants from the intake air. Restricted air flow changes the air-to-fuel ratio, reducing power and increasing smoke from the engine. Verify that the air cleaner is being maintained correctly.



Intake Air Restriction - Checking

Replace the air cleaner element when the restriction reaches the maximum limit at rated engine power and speed.

Naturally Aspirated	Turbocharged
50.8 cm H_20	63.5 cm H_20
[20 in. H_20]	[25 in. H_20]

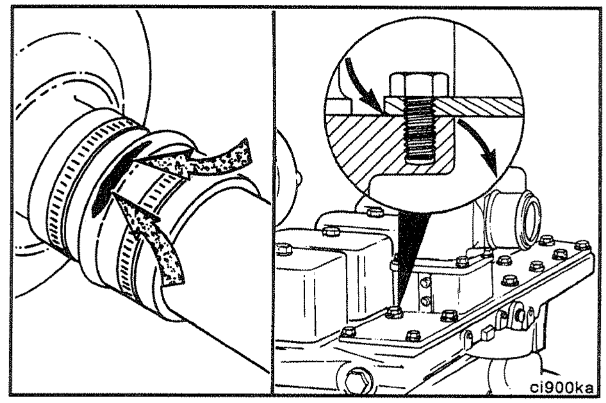


For turbocharged engines, measure the restriction just before the turbocharger. Measure just before the intake manifold for naturally aspirated engines.

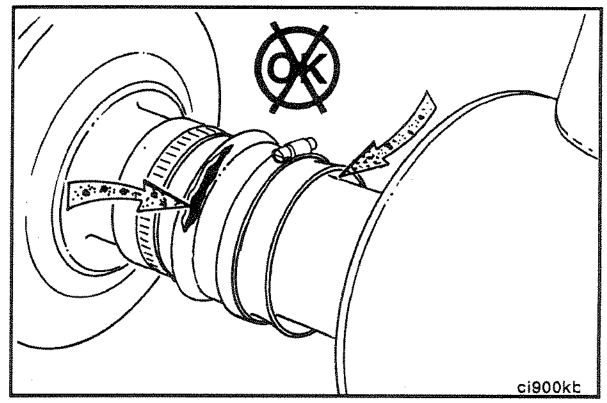
Damage From Non-filtered Air

Loose connections or cracks in the suction side of the intake pipe and after the air filter can allow debris to be ingested by the engine causing rapid wear in the cylinders.

Leaks at the intake manifold, unsealed bolt holes or manifold cover gasket can also allow dust and dirt to be ingested into naturally aspirated engines.

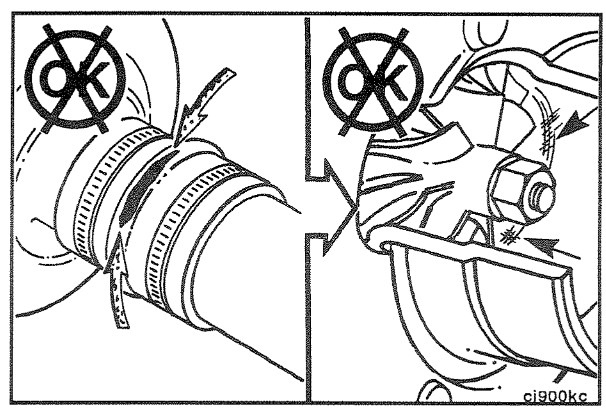


Loose connections or cracks in the suction side of the intake pipe and after the air filter on turbocharged engines can allow debris to be ingested into the turbocharger compressor and forced into the engine.



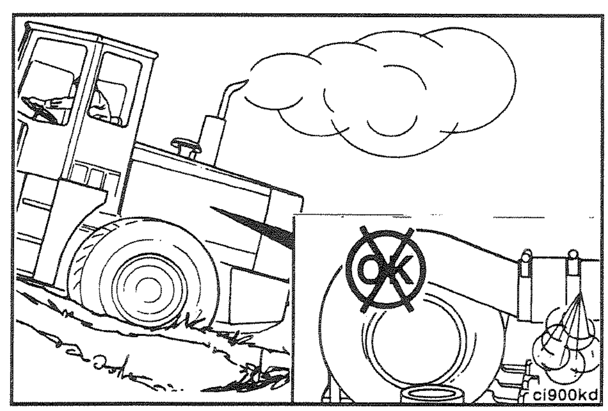
Debris drawn into the air suction side can damage the compressor blades causing an imbalance resulting in bearing failure.

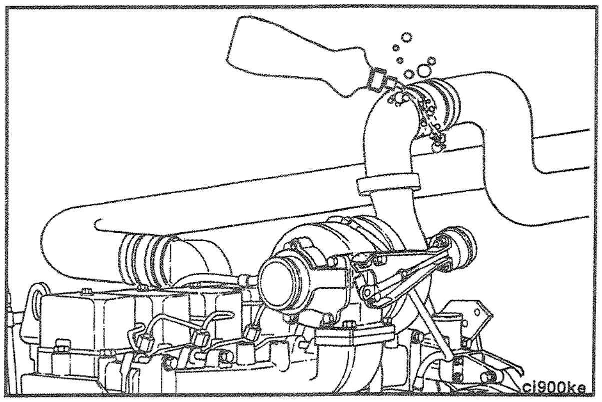
To verify a bearing failure or damaged compressor, remove the intake and exhaust piping and check for contact. The rotor assembly must rotate freely and should not be damaged. Measurement of axial and radial clearance is described in this Section.



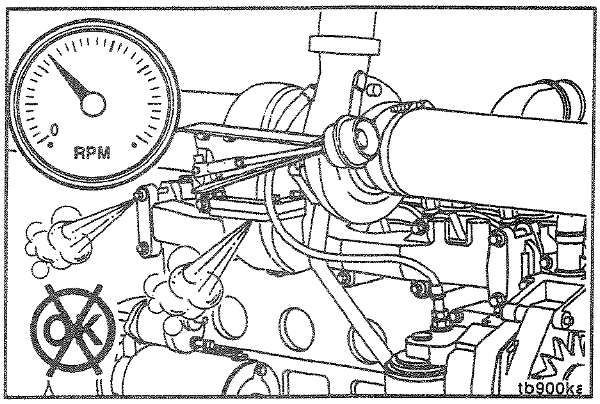
Turbocharged Engines - Air Leaks, Pressure Side

Excess smoke and low power from a turbocharged engine can be caused by pressurized air leaking from loose connections or cracks in the crossover tube or intake manifold. This can also cause a noise problem.



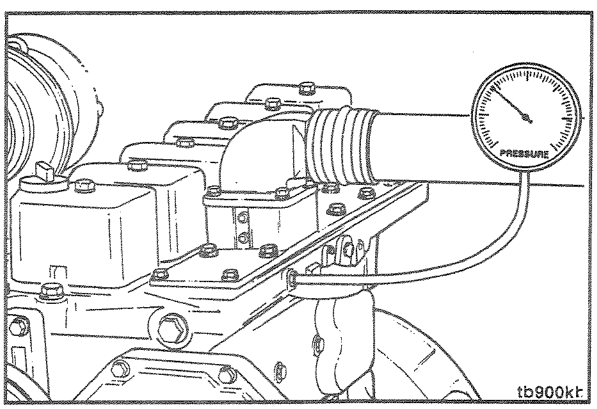


In addition to the visual inspection for cracks and loose fittings, liquid soap can be applied to the charge air cooler, connections and the manifold cover sealing surfaces to find the leaks. The leaks will create bubbles that are easier to detect. Measurement of manifold pressure is described in this Section.



Turbocharged Engines - Exhaust Leaks

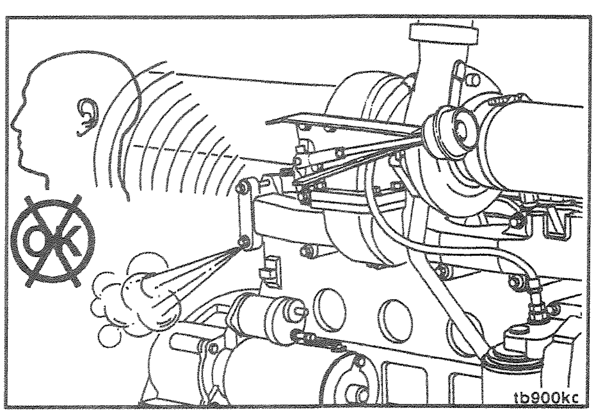
Inspect for exhaust leaks at the exhaust manifold and turbocharger, gasket leaks, or exhaust pipe, muffler or catalyst restrictions. Leaks or restrictions will cause the turbine and impeller to operate at a lower speed and reduce the amount of air being forced into the cylinders. Again, the symptom will be excess smoke, low manifold pressure and low power.



Turbocharger Boost Pressure - Measurement

Measure the boost pressure at the intake manifold by using one of the tapped or plugged intake access holes shown in the illustration. Refer to the specifications in this section.

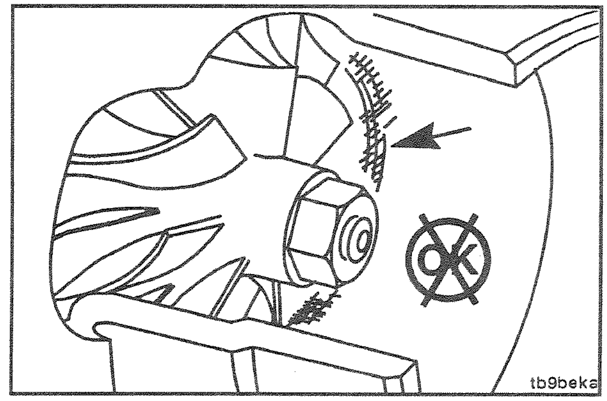
NOTE: If the engine has charge air cooling, testing must be done to ensure that the charge air cooler system is not leaking or restricting the turbo boost pressure - refer to Procedure (3-08) for charge air cooler testing.



Exhaust leaks can usually be detected audibly or visually by a discoloration caused by the escaping hot gases.

Don't overlook exhaust restriction as a cause of low power. If the exhaust gasses can not flow freely, the turbocharger will not operate efficiently.

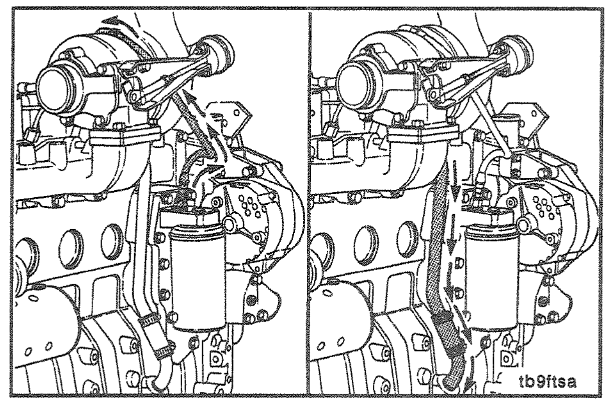
Malfunctioning Turbocharger



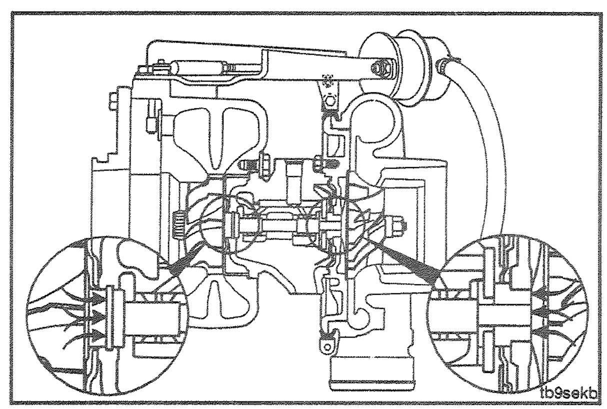
Failure of the internal components of the turbocharger can reduce its effectiveness and also cause excessive smoke and low power. A bearing failure can produce friction which will slow the speed of the rotor assembly. Failed bearings can also allow the blades of the rotor assembly to rub the housings,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

Malfunctioning turbocharger wastegate failure or miscalibration of the turbocharger wastegate can result in excessively high or low boost pressures. Low boost pressures can cause excessive smoke and low power. High boost pressures can cause major engine damage.

Lubricating Oil Consumption and Leaks



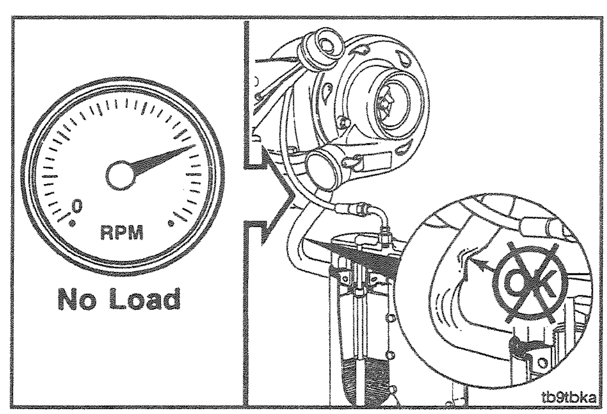
Engine lubricating oil is used to lubricate the bearings and provide some cooling for the turbocharger. The lubricating oil supplied to the turbocharger through the supply line is at engine operating pressure. A return line connected to the bottom of the turbocharger routes the lubricating oil back to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



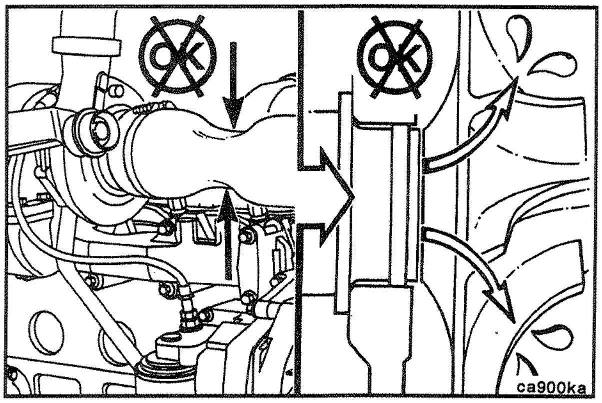
Seal rings are used on each end of the rotor assembly. The primary function of the seals is to prevent exhaust gases and compressed air from entering the turbocharger housing. Lubricating oil leakage from the seals is rare, but it can occur.

NOTE: Excessive crankcase pressure will not allow the oil to drain from the turbocharger. This will load the bearing housing and allow lubricating oil to leak past the compressor seals and into the engine.

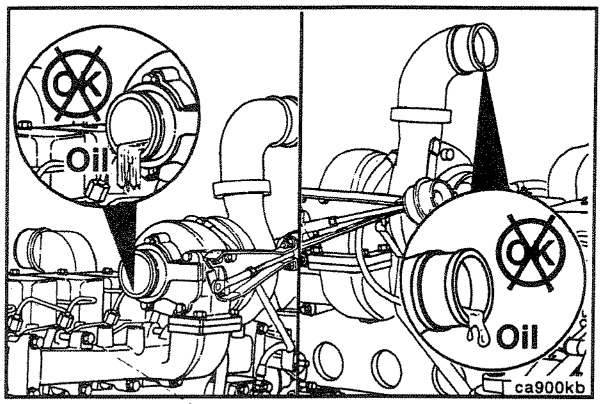
If turbine seal leakage into the exhaust occurs on engines with a catalyst, check the exhaust restriction during the repair.



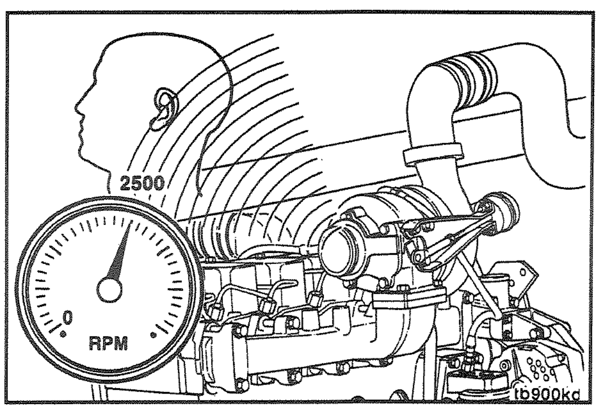
A restricted or damaged lubricating oil return line will cause the turbocharger housing to be pressurized causing lubricating oil to migrate past the seals.



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



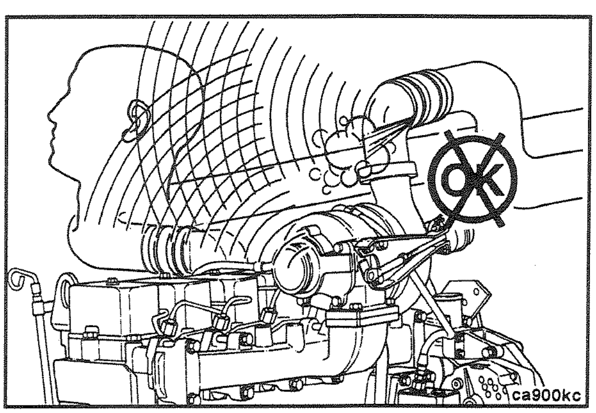
To verify lubricating oil leakage past the seals, remove the exhaust pipe and crossover tube and look for lubricating oil in the turbine casing and the crossover tube. Locate and correct the restriction as previously discussed.



Turbocharger Noise

It is normal for the turbocharger to emit a "whine" sound that varies in intensity depending on engine speed and load. The sound is caused by the very high rotational speed of the rotor assembly. Consequently, the sound will be more audible at full speed.

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

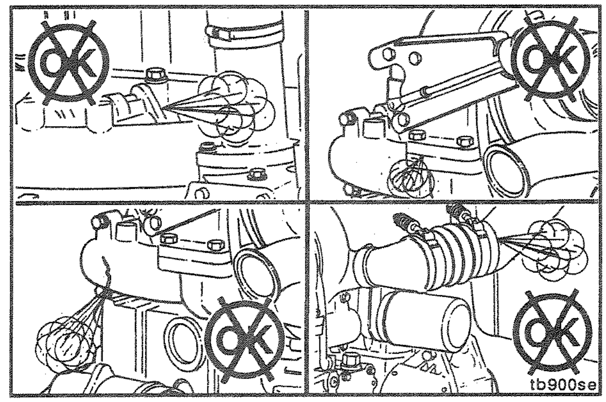


Leaks in the air system intake and/or exhaust components can produce additional noises.

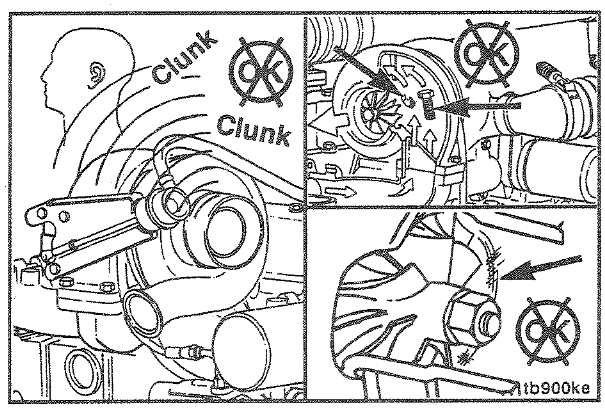
Pressurize the intake system and check for air intake and crossover tube leaks.

Before removing the turbocharger, make sure that the noise complaint is not caused by leaks in the air system components.

Look for loose turbocharger mounting, exhaust manifold gasket leaks, and cracks in the exhaust manifold.



Lower pitch sounds or rattles at slower engine speeds can indicate debris in the system or the rotor assembly is touching the housings.

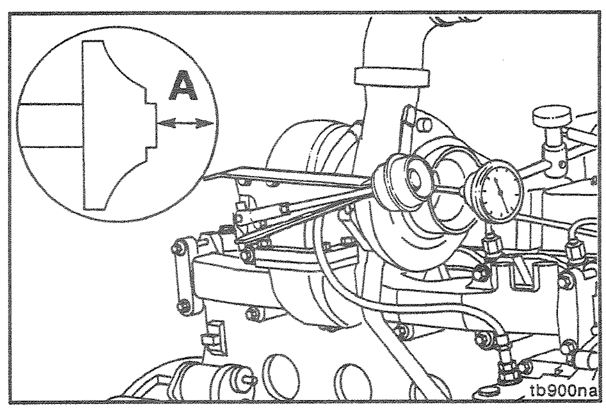


Turbocharger - Testing (3-01)

Rotor Assembly Clearance - Measurement

Measure the shaft end play.

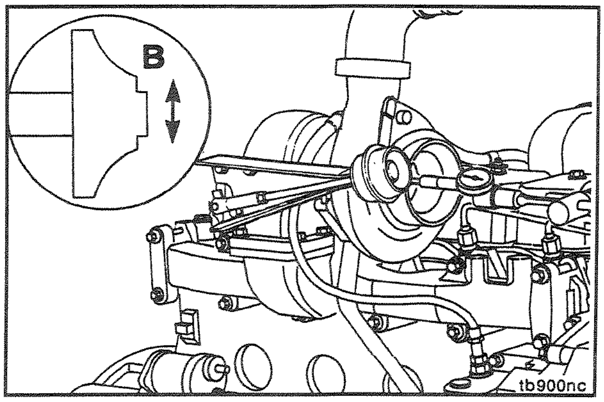
Service tool Part No. ST-537.



End Play (A)		
mm		in
* 0.10	MIN	[0.004]
0.16	MAX	[0.006]
** 0.03	MIN	[0.001]
0.08	MAX	[0.003]

* For turbochargers with a serial number **before** 840638.

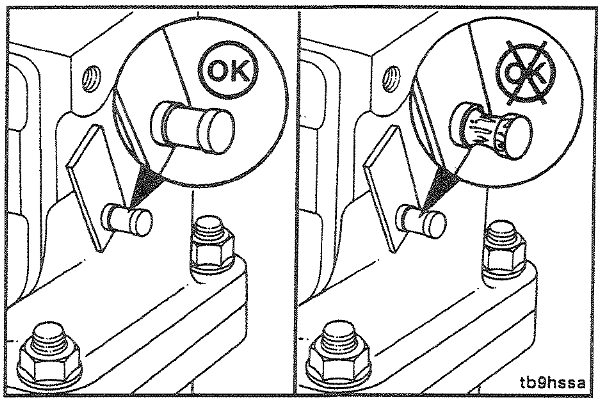
** For turbochargers with a serial number 840638 and **after**.



Measure radial clearance of the shaft.

Radial Clearance (B)		
mm		in
.30	MIN	[.012]
0.46	MAX	[0.018]

The turbocharger must be removed for replacement or rebuild if the clearances are beyond these limits. Refer to the Turbocharger Shop Manual, Bulletin No. 3810321, for rebuild procedures.



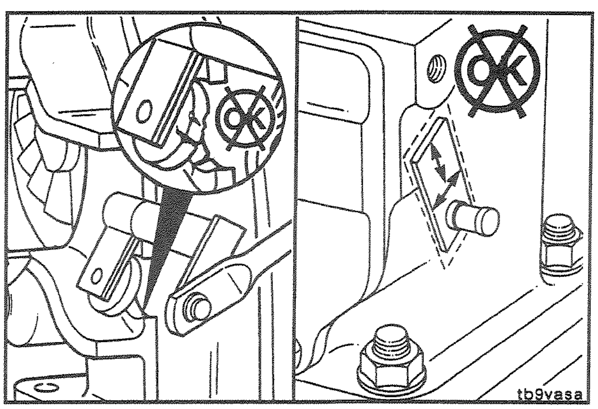
Turbocharger Wastegate Valve Assembly (3-02)

Checking

Inspect the lever pin.

Replace the turbine housing assembly if worn excessively.

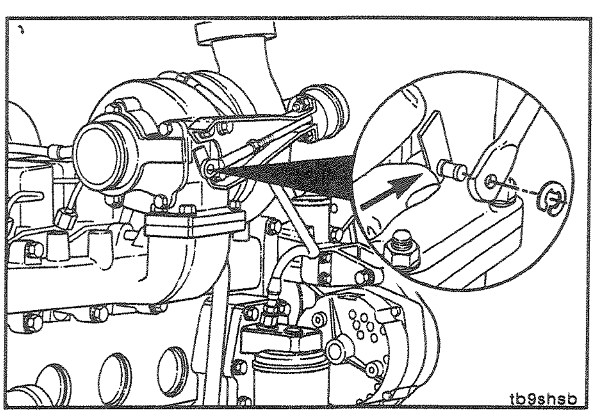
Refer to the Turbocharger Shop Manual, Bulletin No. 3810321.



Inspect the valve and valve seat for cracks or erosion.

Replace the turbine housing assembly if worn excessively.

Refer to the Turbocharger Shop Manual, Bulletin No. 3810321.



Actuate the lever by hand to be sure that the shaft rotates freely and is not seized.

Check for excessive movement between the shaft and bushing.

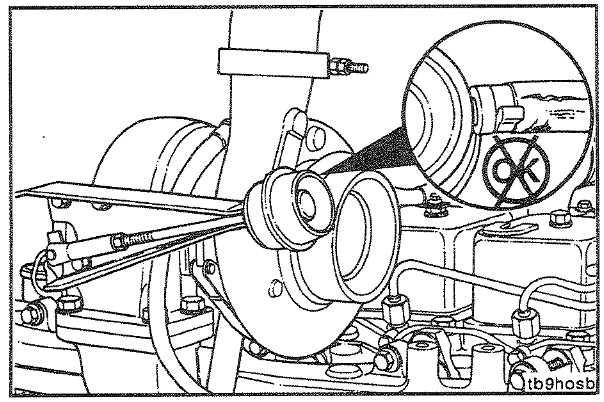
Replace the turbine housing if the shaft and bushing are damaged or seized.

Refer to the Turbocharger Shop Manual, Bulletin No. 3810321.

Turbocharger Wastegate Capsule (3-03)

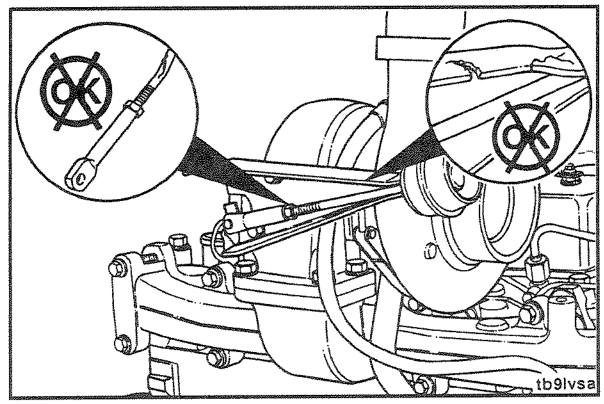
Checking

Visually inspect the wastegate actuator hose for cracks or holes. Replace the hose if damaged.



Visually inspect the wastegate mounting bracket, actuator rod, and lever for damage. A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

If the wastegate mounting bracket, actuator rod, or lever is bent, it must be replaced. Refer to Procedure 3-05.



Turbocharger Wastegate Functional (3-04)

Checking

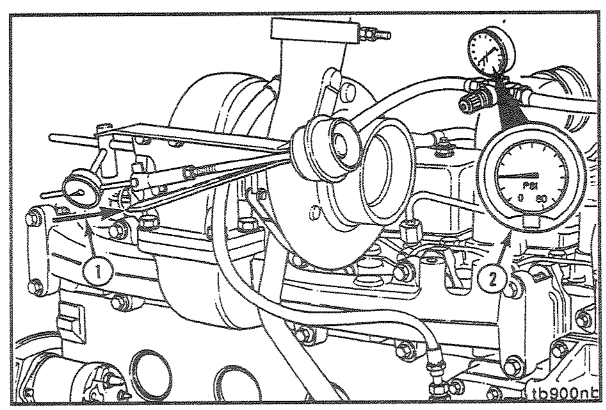
Attach a dial indicator (1) as shown, so that its shaft is in line with the wastegate actuator rod. Set the indicator to zero, with no air pressure applied to the wastegate capsule.

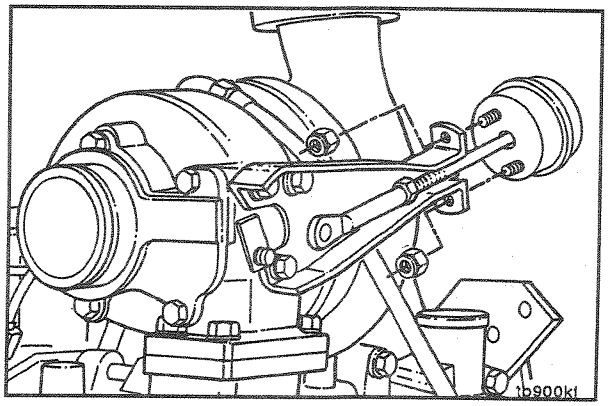
Connect clean regulated air pressure and a pressure gauge to the capsule (2). Apply 200 kPa [29 psi] to make sure the wastegate is functioning properly.

The rod should move approximately 5 mm [0.200 in] without any sticking or air leakage.

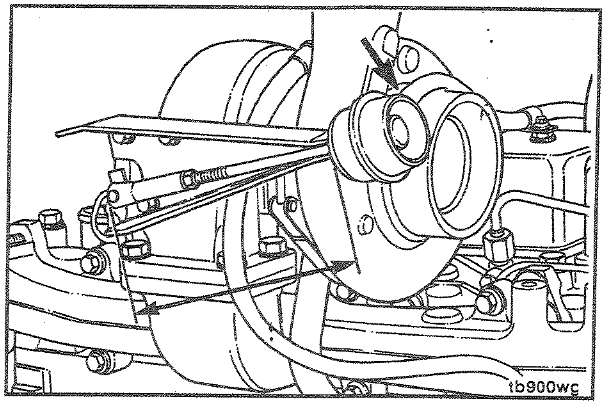
NOTE: No air should be heard to leak through a functional wastegate capsule.

NOTE: A small amount of travel when air pressure is first applied is normal, the tolerance is being removed from the system.





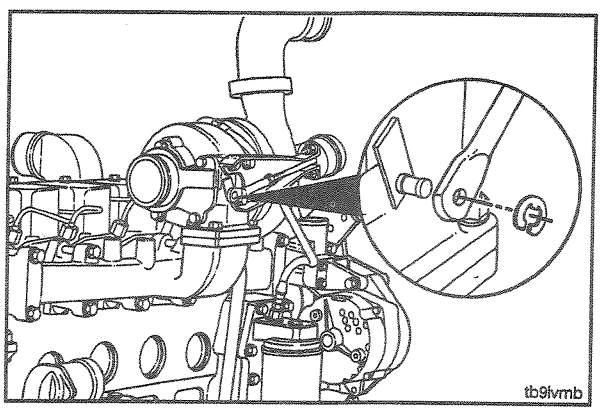
Replace the actuator if no movement of the actuator rod and lever is detected. Refer to Procedure 3-05.



Turbocharger Wastegate Actuator Boost Capsule (3-05)

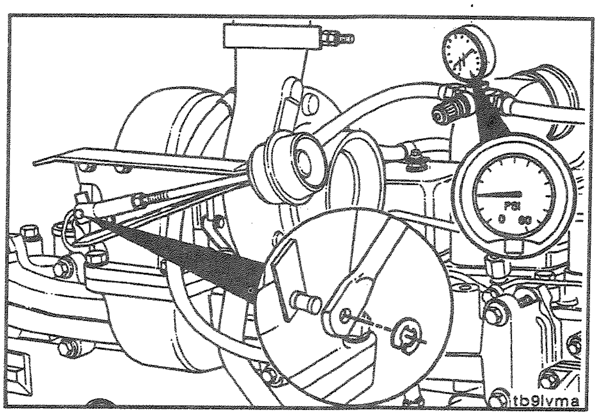
Replacement

NOTE: Prior to removal, note position length of the control rod from the boost capsule housing and orientation of the boost capsule hose connector in relation to the mounting bracket.



Air regulator with pressure gauge

Remove the retaining clip from the control lever.



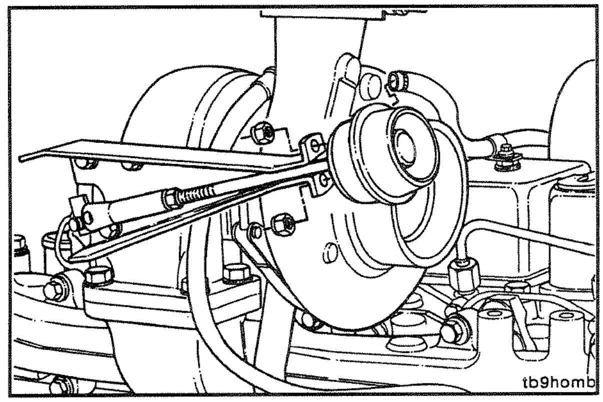
Disconnect the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by applying regulated air pressure to the boost capsule in a sufficient amount to activate control rod movement.

Disconnect the control rod from the turbocharger wastegate lever pin.

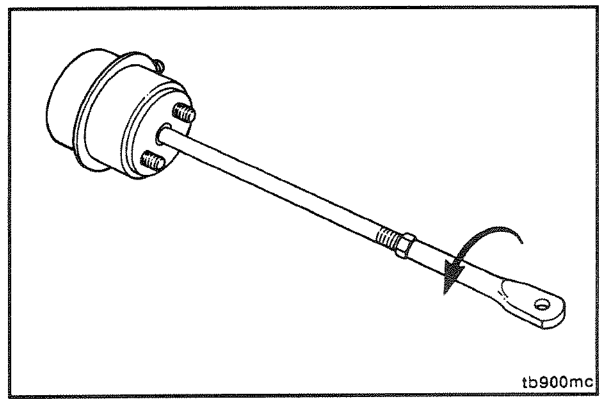
Caution: Be careful not to bend the control lever.

NOTE: If the boost capsule diaphragm material is ruptured and will not hold air pressure other than by hand, manually pull the control rod outward in order to overcome boost capsule spring tension for removal of the control rod from the turbochager wastegate lever pin.

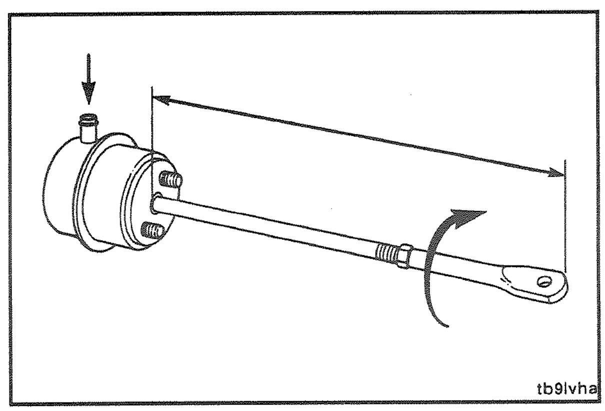
Loosen the boost capsule mounting capscrews, disconnect the air supply hose and remove assembly from the mounting bracket.



Remove the adjusting link end from the boost capsule actuator.

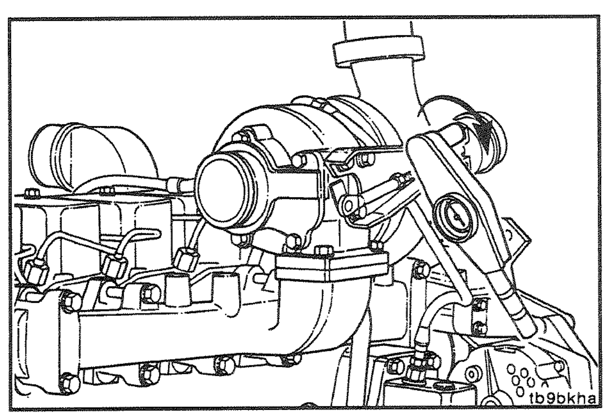


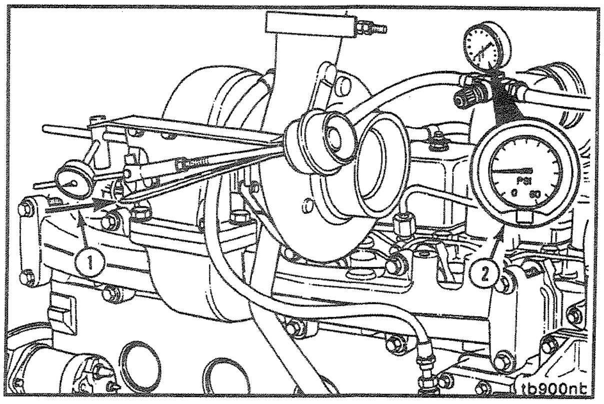
Install the adjusting link end onto the new replacement boost capsule actuator assembly into approximately the same position as originally removed.



Fit the new boost capsule actuator assembly to the actuator mounting bracket and install the mounting capscrews.

Torque Value: 4.5 N•m [40 in-lb]





Turbocharger Wastegate Actuator (3-06)

Calibration

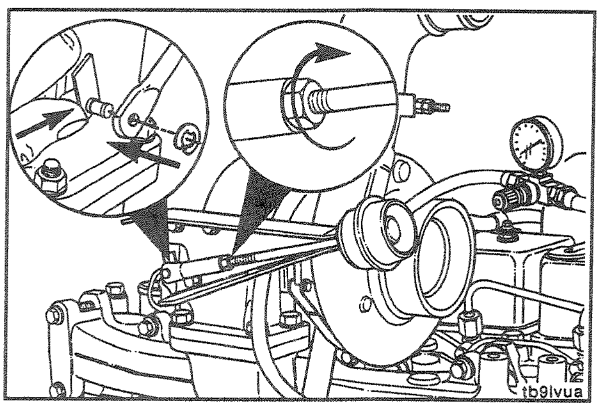
NOTE: The wastegate is set accurately from the factory. Adjustment is not necessary unless the capsule is removed.

Connect clean regulated air pressure to the boost capsule (2).

Regulate the air pressure to the wastegate capsule per the following table.

Model Year	Rating (HP)	Application	Pressure (kPa)	Pressure (psi)
91	190-230	Automotive	153	22.2
94	160-175	Automotive	133	19.3
94	190-230	Automotive	198	28.7
94	All	Industrial	191	27.7

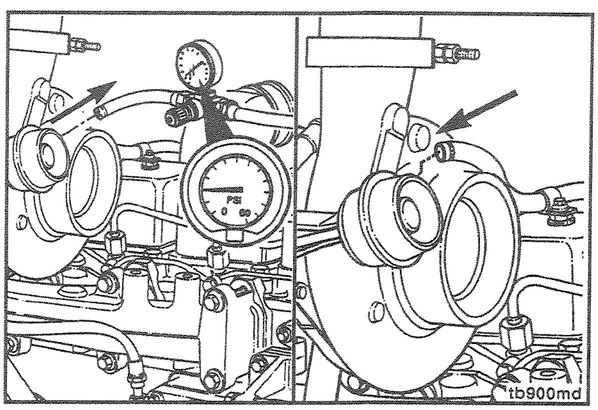
Measure actuator travel (1). Specified wastegate measurement is 0.33 to 1.3 mm [0.013 to 0.050 inch].



Caution: Do not pull or push or force alignment of the clevis pin.

Adjust the wastegate if necessary to achieve specified travel.

- Pull the wastegate lever to the foremost closed position (lever toward boost capsule).
- Adjust the length of the clevis end of the control rod to where the clevis pin hole aligns to the wastegate lever.
- Install the adjusting link and retaining clip.
- After adjustment is completed, tighten actuator rod jam nuts.



Disconnect regulated air pressure line from the boost capsule.

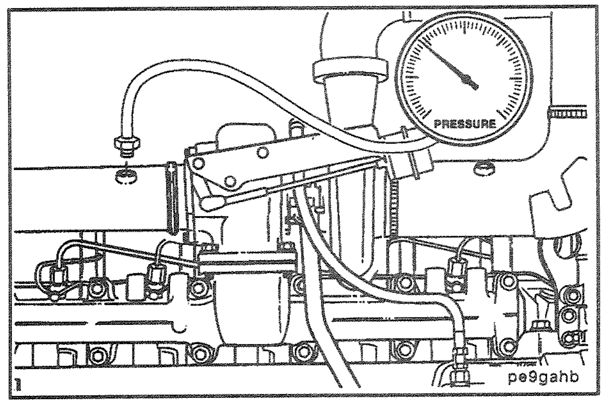
Connect the turbo boost line to the boost capsule and secure hose clamp.

If possible, a more accurate method of wastegate adjustment is to check the manifold pressure at rated RPM per turbocharger boost pressure specifications on pages 3-4 to 3-11 of this section.

EXHAUST RESTRICTION - MEASUREMENT (3-07)

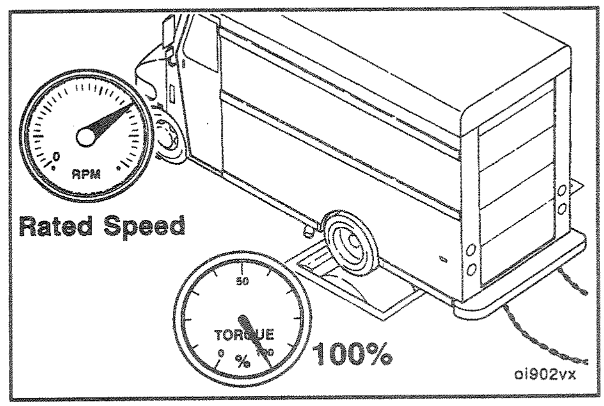
Install pressure gauge, Part no. ST-1273 to the pressure tap in the exhaust head pipe or at the inlet to the catalyst/ muffler assembly.

Operate the engine at rated speed and load. Record the exhaust restriction.



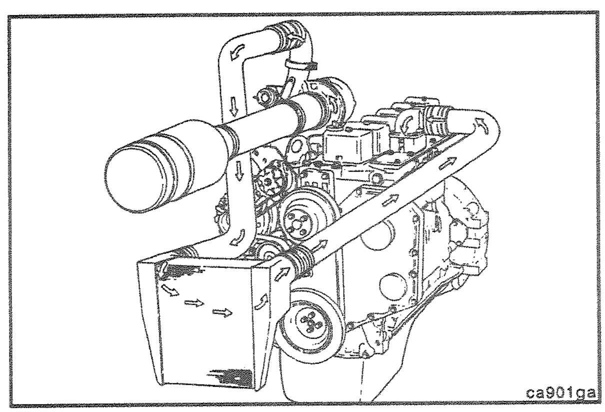
If restriction exceeds specification, inspect the oxidation catalyst and/or muffler and replace per vehicle manufacturers instructions.

Industrial .... 76 mm Hg [3 in Hg]
91 EPA certification .... 114 mm Hg [4.5 in Hg]
94 EPA Certification with
oxidation catalyst .... 152 mm Hg [6 in Hg]



Charge Air Cooler - Troubleshooting (3-08)

NOTE: The long term integrity of the charge air cooler system is the responsibility of the vehicle and component manufacturers; however, the following symptoms can be checked by any Cummins Authorized Repair Location:



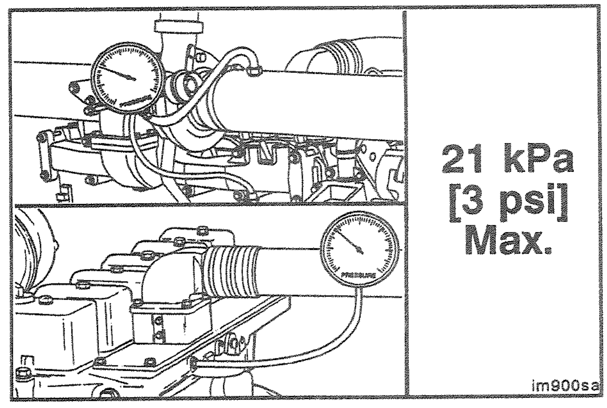
Intake Manifold Pressure - Check

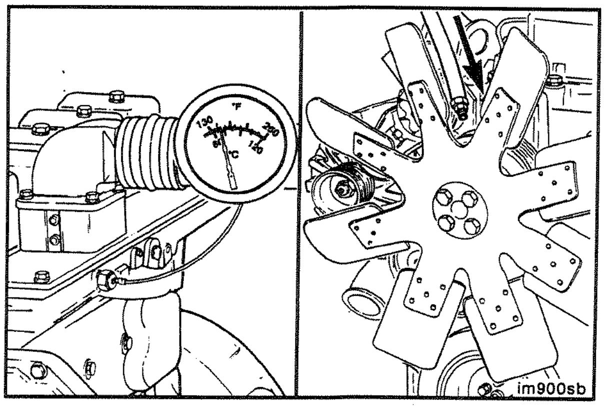
Install pressure gauge, Part No. ST-1273, to the fitting in the turbocharger outlet.

Install another pressure gauge, Part No. ST-1273, in the intake manifold.

Operate the engine at rated RPM and load. Record the readings on the two gauges.

If the differential pressure is greater than 21 kPa [3 psi], check the charge air cooler for plugging. Clean or replace if necessary. Refer to Procedure 3-09.



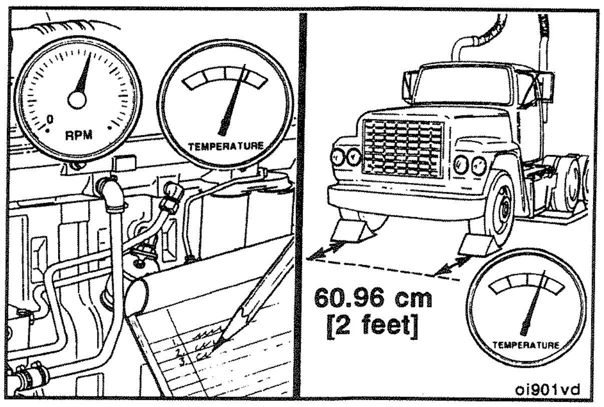


Intake Manifold Temperature - Check

Install a temperature gauge in the intake manifold.

Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper across the temperature switch or supplying shop air to the fan. Refer to the fan drive manufacturer for lock-up procedure.

NOTE: Some trucks have a manual switch that will lock on the fan.

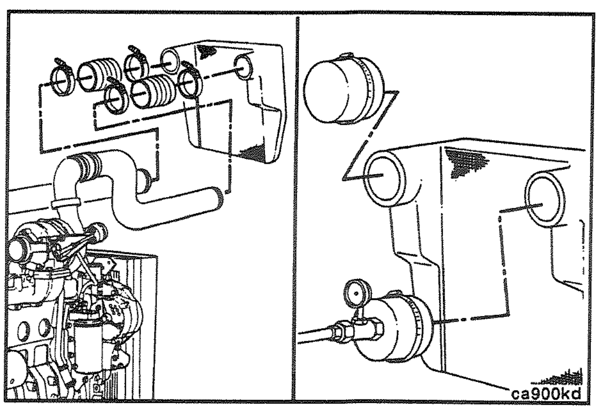


Operate the engine at rated RPM and load. Record the intake manifold temperature.

Measure the ambient temperature at least two feet in front of the vehicle.

The maximum temperature differential **must not** be greater than 25°C [45°F].

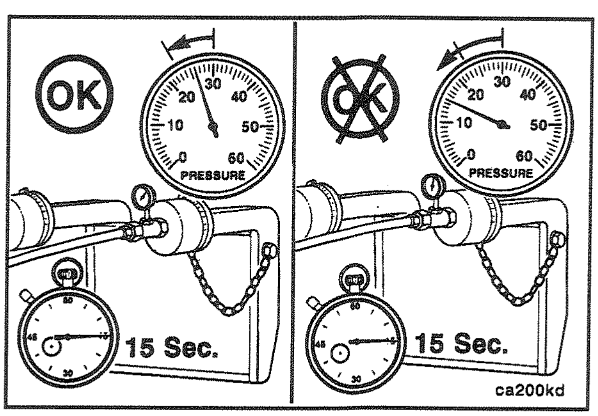
If the temperature differential is greater than 25°C [45°F], check the charge air cooler for dirt and debris on the fins, and clean as necessary. If the problem still exists, check the cooler for internal contamination or plugging.



To check the charge air cooler for cracked tubes or header, remove the inlet and outlet hoses from the cooler.

Remove the charge air cooler.

Install a cap over the outlet side of the cooler. Install a pressure gauge and a shop air supply line to the inlet side of the cooler.



Apply 207 kPa [30 psi] of air pressure to the cooler. If the pressure drop is 48 kPa [7 psi] or less in 15 seconds, the cooler is okay.

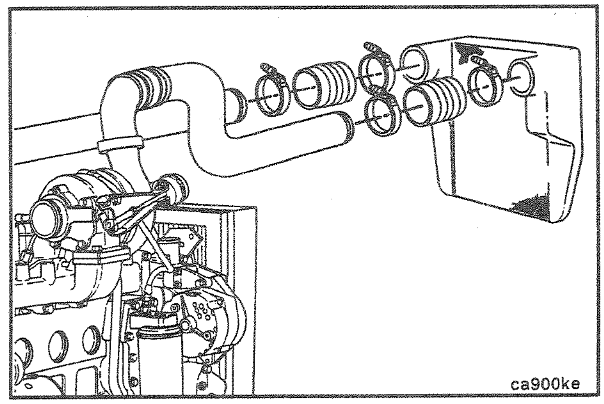
If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge air cooler **must** be repaired or replaced. Refer to the CAC manufacturer for repair instructions.

NOTE: A leak tank can be used to locate the air leak.

Charge Air Cooler - Cleaning and Inspection (3-09)

If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the CAC, the CAC must be cleaned.

Remove the CAC from the vehicle. Refer to the vehicle manufacturer's instructions.

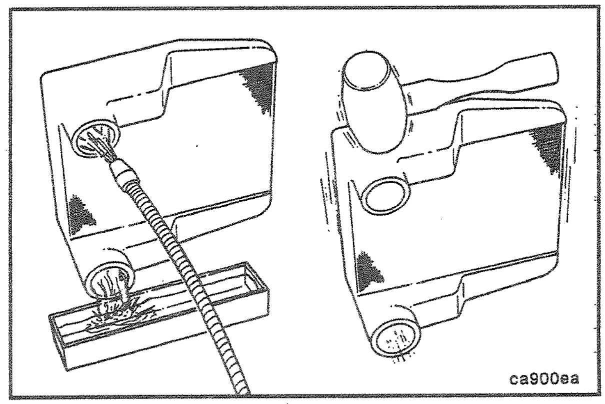


Flush the CAC internally with solvent in the opposite direction of normal air flow. Shake the CAC and lightly tap on the end tanks with a rubber mallet to dislodge trapped debris. Continue flushing until all debris or oil is removed.

Use a flashlight and mirror to visually inspect the CAC for internal debris.

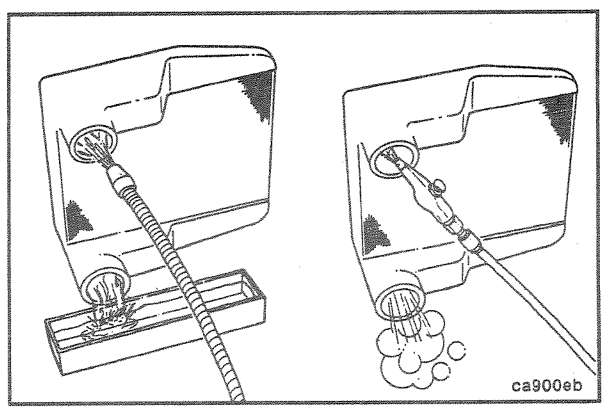
Caution: If internal debris cannot be removed, scrap the CAC.

Caution: Do not use caustic cleaners to clean the CAC. Damage to the CAC will result.



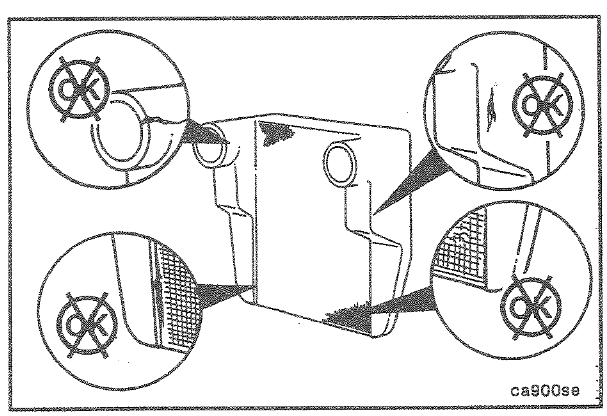
After the CAC has been thoroughly cleaned of all oil and debris with solvent, wash the CAC internally with hot soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

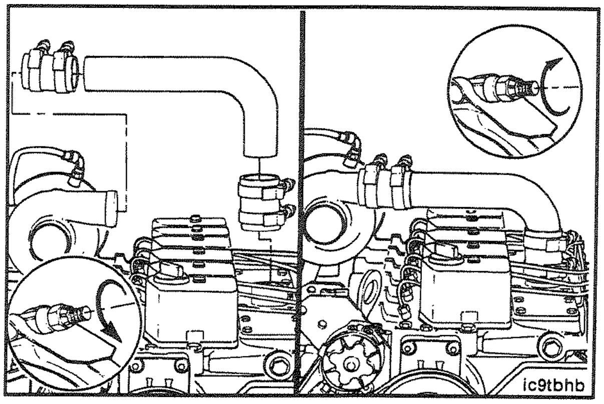
Blow compressed air into the CAC in the opposite direction of normal air flow until the CAC is dry interanlly.



Visually inspect the CAC for cracks, holes or damage.

Inspect the tubes, fins and welds for tears, breaks or other damage. If any damage causes the CAC to fail the air leak check mentioned earlier in this publication, the CAC must be replaced. Install the CAC on the vehicle. Refer to the vehicle manufacturer for instructions.





Air Crossover Tube (3-10)

Replacement

Removal and Installation

8 mm or Screwdriver

Loosen the hose clamps and position the hose so the crossover tube can be removed.

Use new hose and clamps as required to install the cross-over tube.

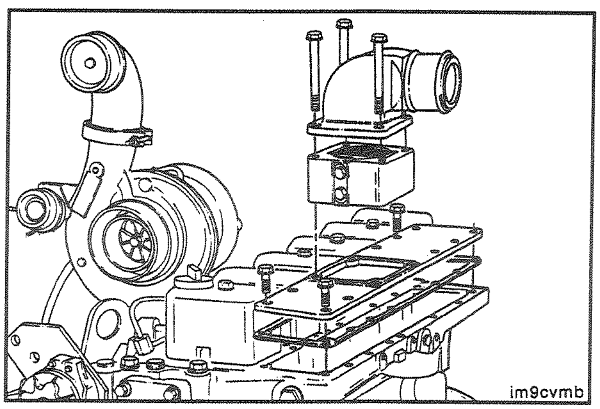
Torque Value: 8 N•m [72 in-lb]

Intake Manifold Cover and Gasket (3-11)

Replacement

Preparatory Steps:

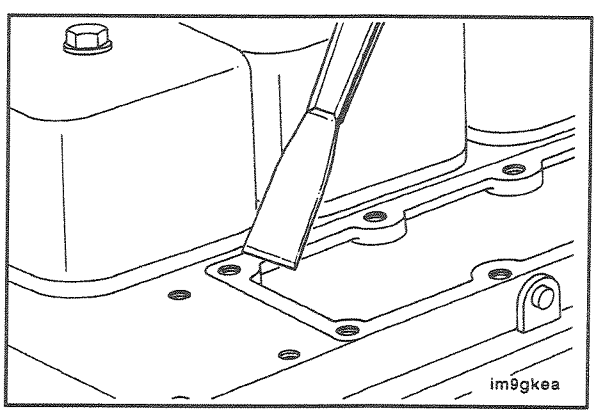
- Disconnect the cold starting aid, if used.
- Remove the air crossover tube, if used.
- Disconnect the charged air cooler hose, if used.
- Remove the high pressure fuel lines.



Removal

10 mm

Remove the manifold cover, gasket, and grid heater if equipped.



Cleaning

Clean the sealing surface.

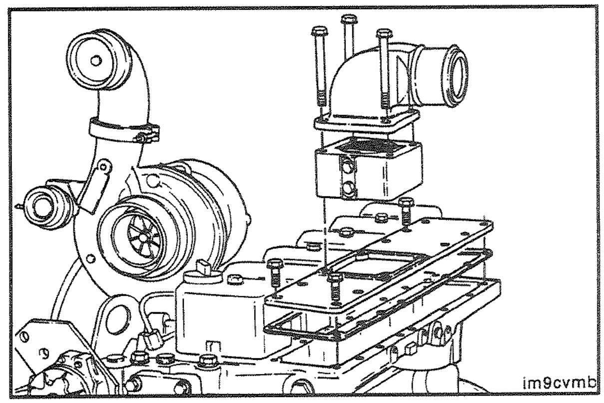
NOTE: Keep the gasket material and any other material out of the air intake.

Installation

10 mm

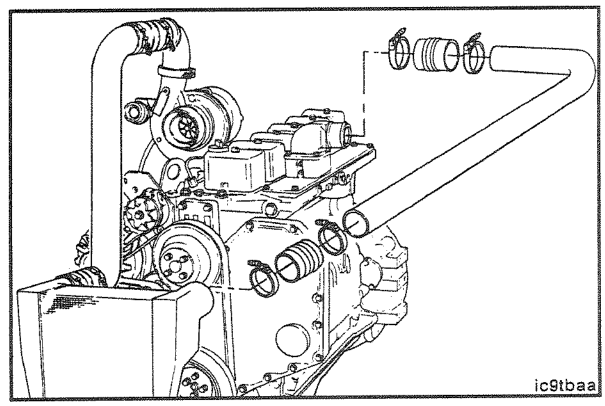
Install the cover and a new gasket.

Torque Value: 24 N•m [18 ft-lb]



Assemble the intake piping and connect the cold starting aid if used.

Torque clamps to 8 N•m [75 in-lb].



Aftercooler and Gasket (3-12)

Replacement

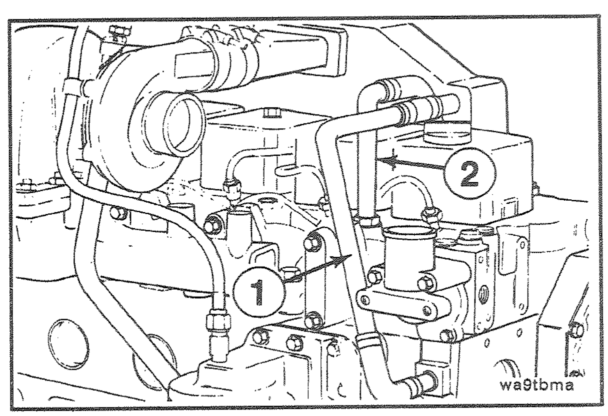
Preparatory Steps:

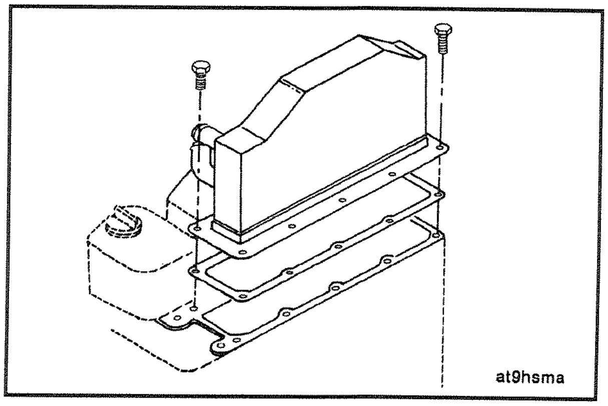
- Disconnect the cold starting aid, if used.
- Remove the air crossover tube.
- Drain 2 litres [2.1 U.S. quarts] of coolant.

Removal

8 mm

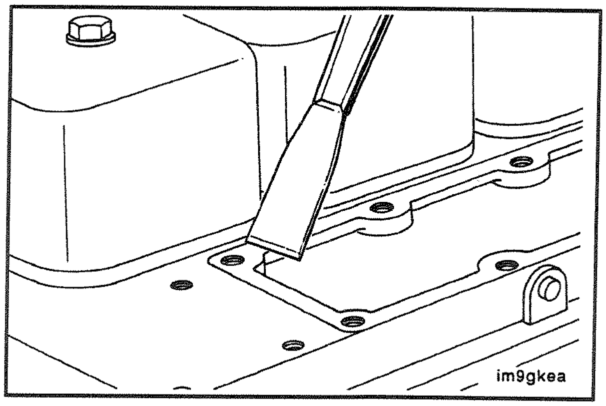
Remove the coolant supply tube (1) and the coolant return tube (2).





10 mm

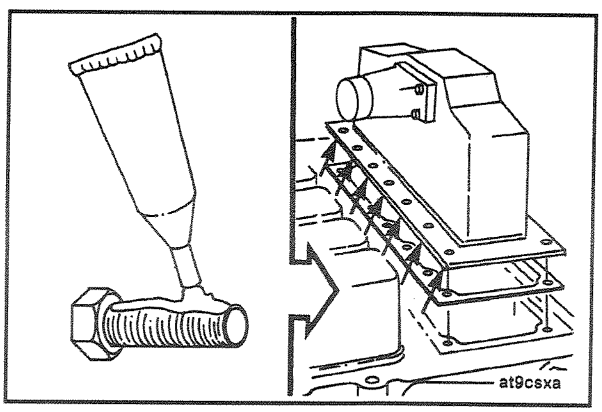
Remove the aftercooler housing and gasket.



Cleaning

Clean the sealing surface.

NOTE: Keep the gasket material and any other material out of the air intake.



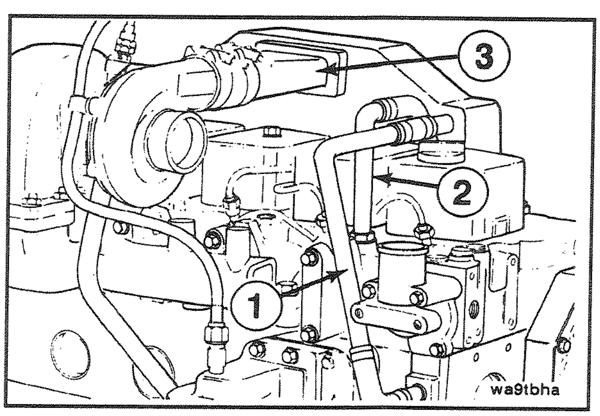
Installation

10 mm

NOTE: The holes shown in the illustration are drilled through. Apply liquid teflon sealant to the capscrews.

Install the aftercooler housing and a new gasket.

Torque Value: 24 N•m [18 ft-lb]



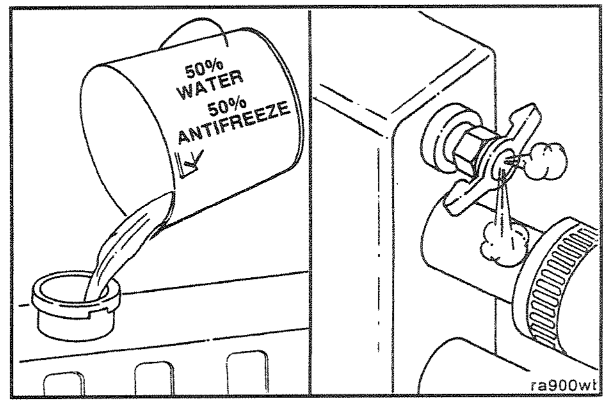
8 mm

Install the coolant supply tube (1) and coolant return tube (2). Install the air crossover tube (3).

Torque Value: 8 N•m [75 in-lb]

Caution: Be sure to vent the engine and aftercooler to prevent entrapment of air as the system is filled.

Fill the coolant system with a premixture of 50 percent water and 50 percent ethylene-glycol type antifreeze.



Turbocharger (3-13)

Replacement

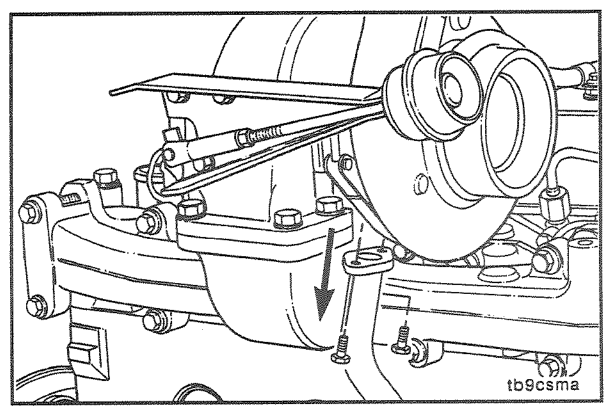
Preparatory Steps:

- Remove the air crossover tube, if used.
- Disconnect the charge air cooler hose.
- Disconnect the boost capsule actuator hose.
- Disconnect the intake and exhaust piping.

Removal

10 mm

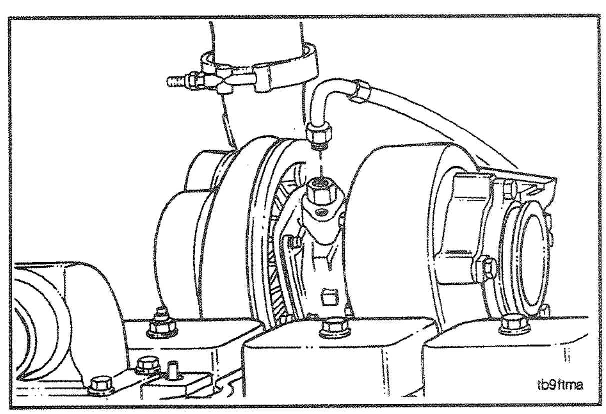
Remove the capscrews from the oil drain tube.

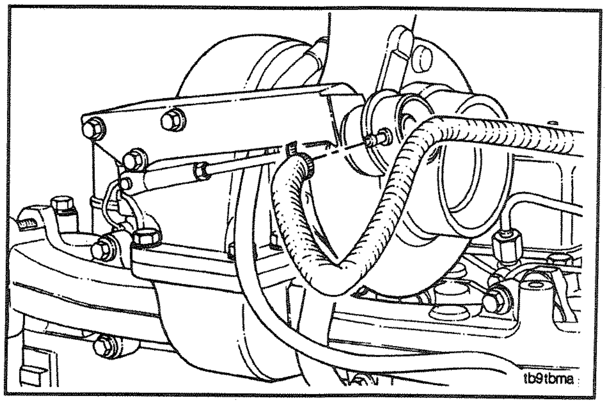


16 mm

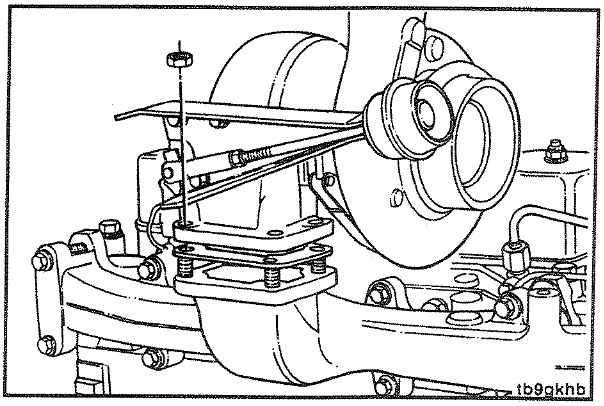
Disconnect the oil supply line.

NOTE: Engines built after June 1993 may use a copper washer in both ends of the turbocharger lubricating oil supply line. The washer should be replaced whenever the line is removed.



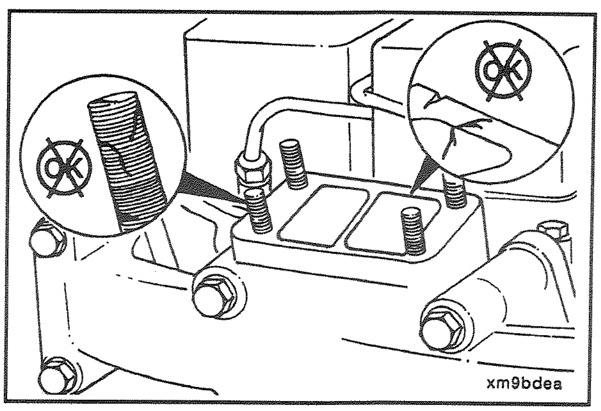


Remove the intake manifold pressure supply line from the boost capsule.



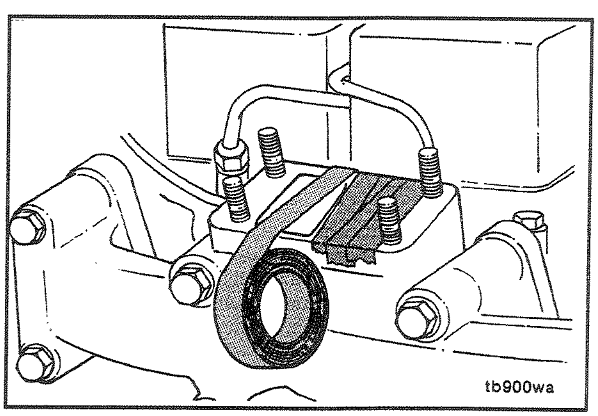
15 mm and 7/16-inch

Remove the exhaust clamp, turbocharger, and gasket.



Cleaning and Inspection

Clean the sealing surfaces. Inspect the sealing surface and mounting studs for damage.



NOTE: If the turbocharger is **not** to be immediately replaced, cover the opening to prevent any material from falling into the manifold.

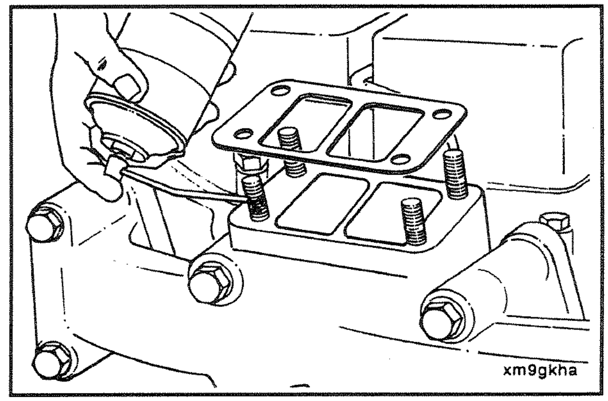
Inspect turbocharger wastegate linkage, valve shaft, module, and pressure signal line.

Check or calibrate wastegate.

Refer to Turbocharger Shop Manual, Bulletin No. 3810321, for calibration procedures.

Installation

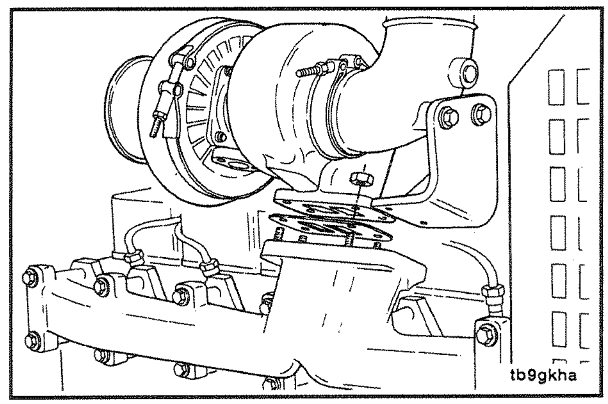
Install a new gasket and apply anti-seize compound to the mounting studs.



15 mm

Install the turbocharger.

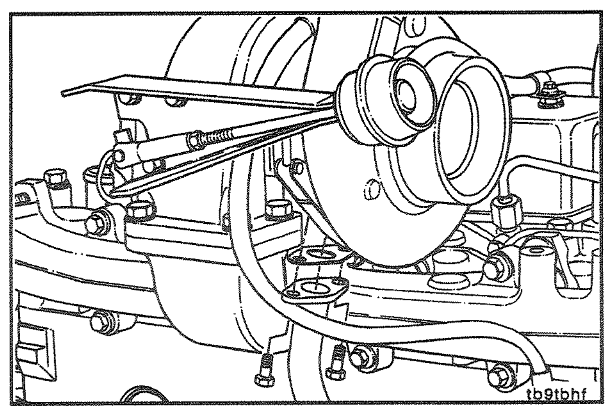
Torque Value: 45 N•m [33 ft-lb]



10 mm and 7/16-inch

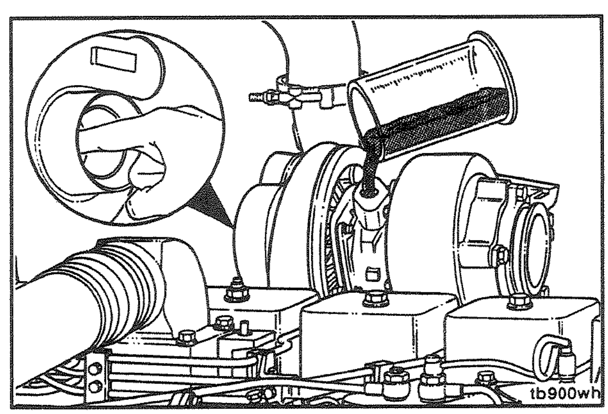
Use a new gasket and connect the oil drain tube.

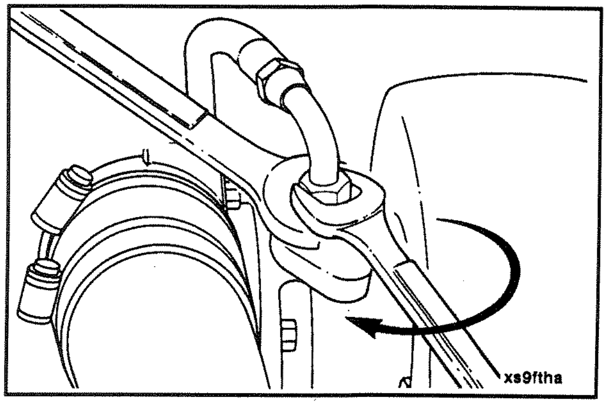
Torque Value: 24 N•m [18 ft-lb]



NOTE: New turbochargers **must** be prelubricated before start-up.

Pour 50 to 60 cc [2 to 3 ounces] of clean engine oil into the oil supply fitting. Rotate the turbine wheel to allow the oil to enter the bearing housing.

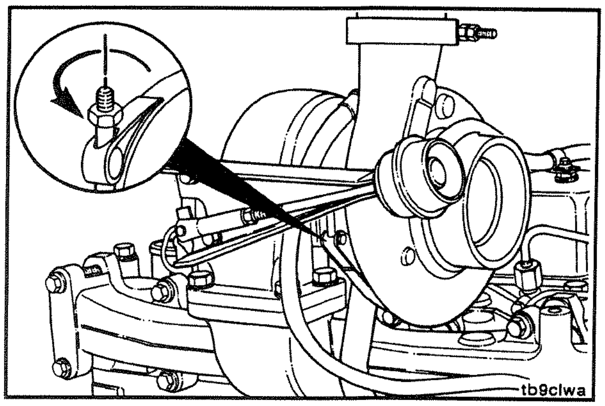




16 mm

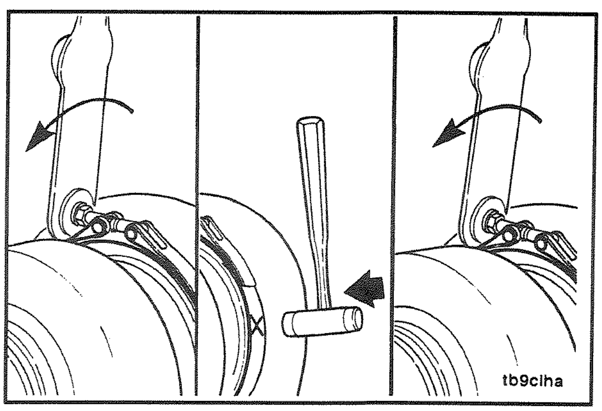
Connect the oil supply line.

Torque Value: 35 N•m [26 ft-lb]



7/16 inch

If required, loosen the compressor housing V-band clamp and position the housing to align with the turbocharger air outlet tube.

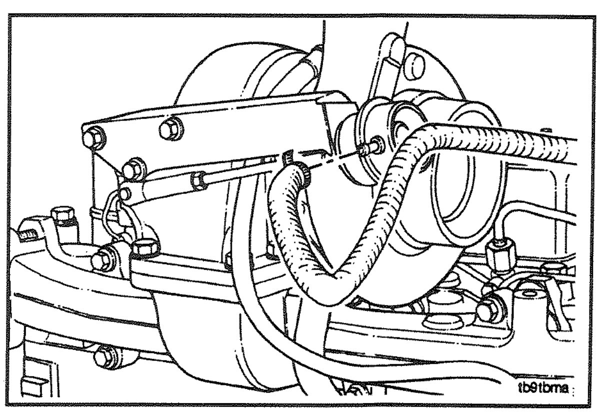


7/16 inch, Plastic Hammer

Tighten the band clamp. Tap around the clamp with a plastic hammer and tighten again.

Torque Value: 8.5 N•m [75 in-lb]

NOTE: Effective Oct. 1, 1990 all Holset Turbochargers use silver plated nuts with the v-band clamp. The silver plated nuts require a **lower** torque than the stainless steel nut to provide the same v-band clamp load.

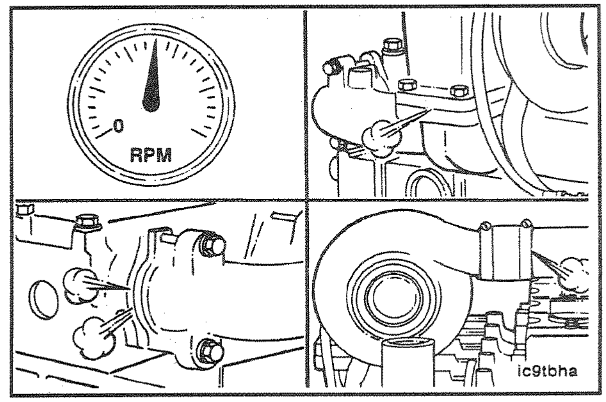


Install the boost control capsule actuator hose.

Install the air inlet and exhaust piping.

Operate the engine and check for leaks.

Torque Value: 8 N•m [72 in-lb]



Exhaust Manifold and Gaskets (3-14)

Replacement

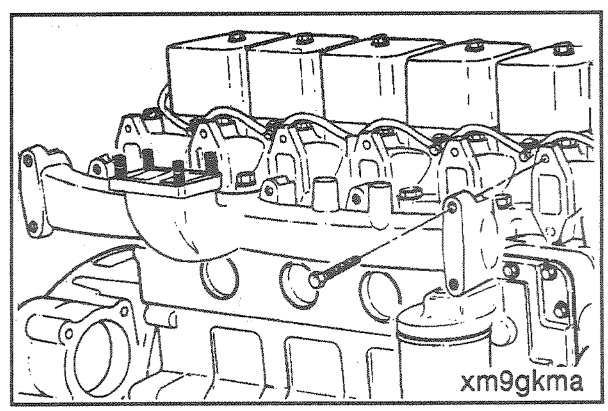
Preparatory Steps:

- Remove the air crossover tube, if used.
- Disconnect the charge air cooler hose (automotive engines only).
- Disconnect the air intake and exhaust piping.
- Remove the turbocharger, if used.

Removal

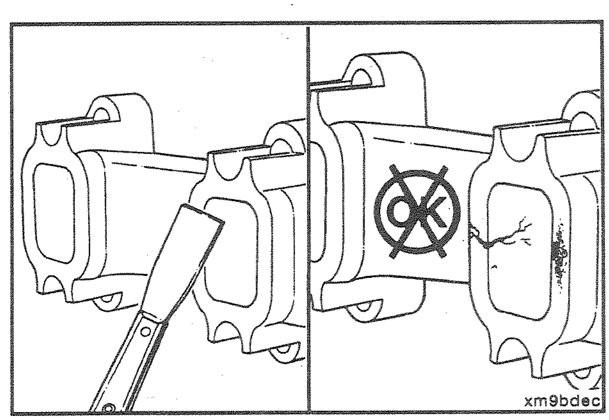
15 mm

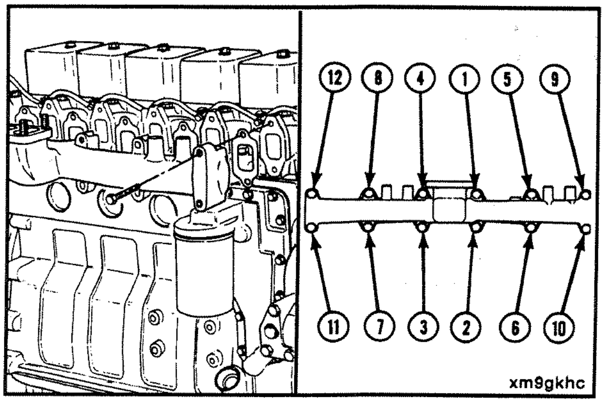
Remove the exhaust manifold and gaskets.



Cleaning and Inspection

Clean the sealing surfaces and inspect the exhaust manifold for cracks, burn-out, or damaged threads..





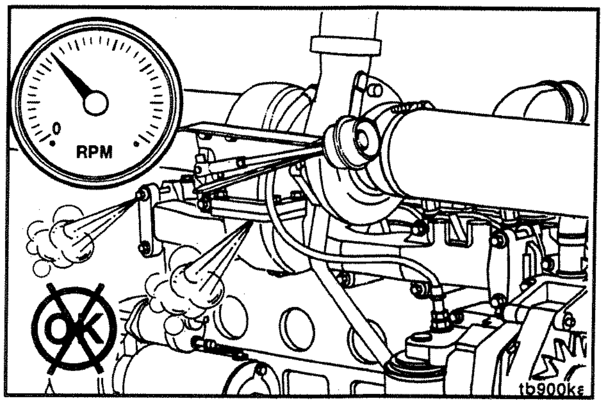
Installation

15 mm

Install the exhaust manifold and new gaskets.

Torque Value: 43 N•m [32 ft-lb]

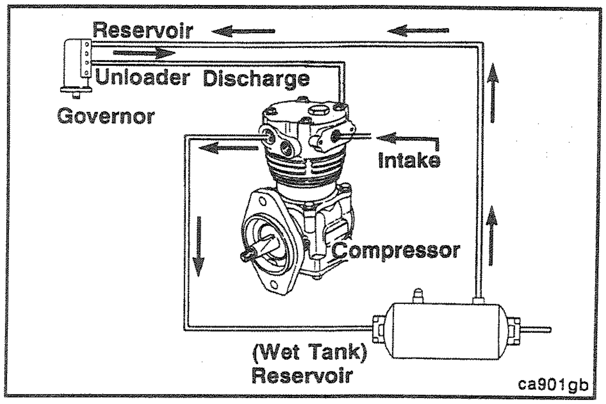
Follow the tightening sequence shown in the illustration.



Install the parts previously removed. Operate the engine and check for leaks.

Section 4 - Compressed Air System

Section Contents



Compressed Air System - General Information

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

The Holset SS191B air compressor is an engine-driven, piston-type compressor which supplies compressed air to operate air activated devices. The compressor operates continuously but has a "loaded" and "unloaded" operating mode. The operating mode is controlled by a pressure activated governor and the compressor unloading assembly. When the air system reaches a predetermined pressure, the governor applies an air signal to the air compressor unloader assembly causing the unloader valve to hold the compressor intake valve open and compressed air stops flowing into the air system. As the air in the air system is used, the pressure drops. At a predetermined pressure the governor exhausts the air signal to the compressor unloader assembly allowing the compressor to again pump compressed air into the air system.

This air compressor is available in an air cooled or water cooled version, the only difference being changes to the cylinder head to incorporate a water passage.

This air compressor is also available with or without a power steering pump housing.

Other brands of compressors may be used on the B series engine. Troubleshooting procedures are very similar for these air compressors compared to the Holset SS191B. Refer to the specific air compressor manufacturer's manual for detailed repair information including torque values.

NOTE: The cylinder head and unloader components of the Holset SS191B air compressor can be serviced without removal of the air compressor on many engine applications. This troubleshooting manual will cover servicing of the air compressor unloader components while the compressor is still on the engine. All other servicing of the air compressor internal components should be done after the compressor has been removed from the engine. Reference the SS191B Shop Manual, Bulletin No. 3810433, for detailed disassembly and assembly information of the air compressor.

The Holset SS296 single cylinder air compressor is an engine-driven piston-type compressor which supplies compressed air to operate air activated devices. The compressor runs continuously but has a loaded and unloaded operating mode. The operating mode is controlled by a pressure-activated governor and the compressor unloading assembly.

The SS296 air compressor used on B series engines uses an (E-type) unloader. The Economy (E-type) unloader system was designed to reduce pumping losses and engine boost pressure losses through the compressor intake valve while operating in unloaded mode.

When the air system reaches a predetermined pressure, the governor applies an air signal to the air compressor unloader assembly causing the unloader cap to seal off incoming air at the intake valve, and compressed air stops flowing into the air system.

NOTE: System pressure **must** be maintained on the outlet side of the discharge valve to keep the discharge valve closed.

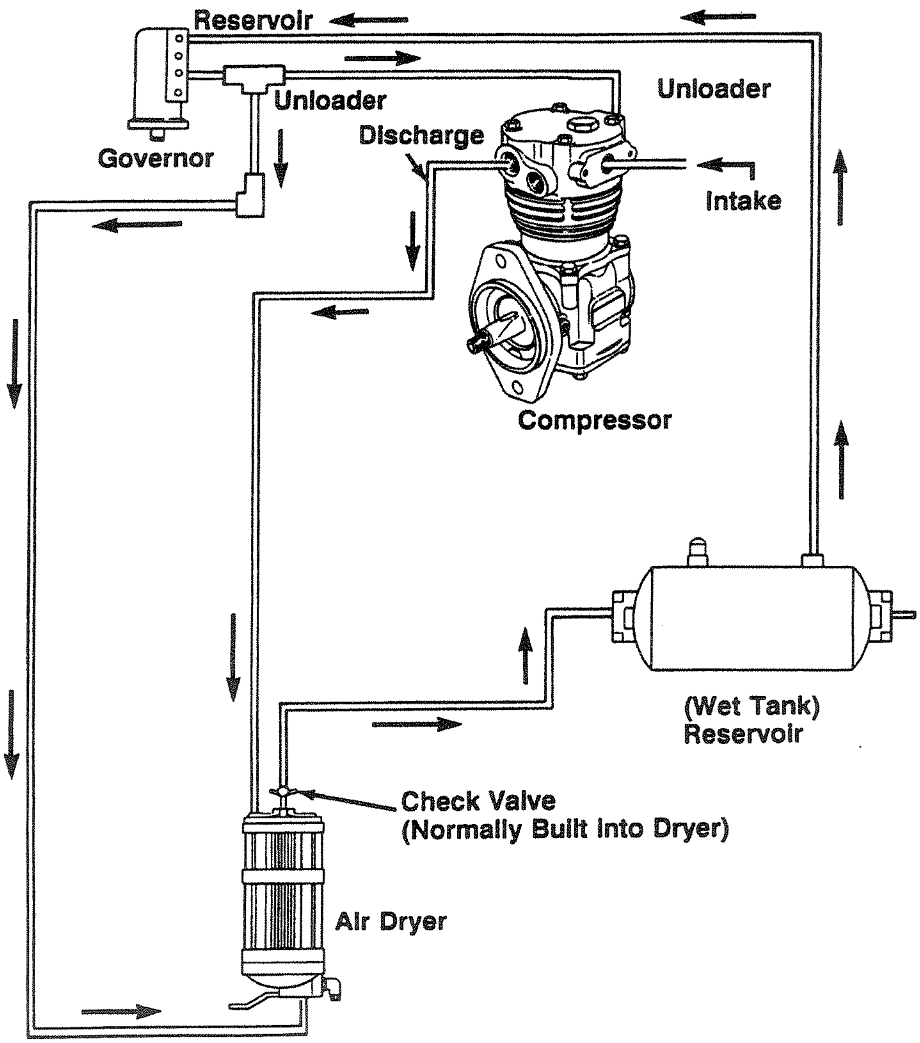
As the air in the air system is used, the pressure drops. At a predetermined pressure the governor exhausts the air signal to the compressor unloader assembly allowing the compressor to again pump compressed air into the air system.

Caution: Vehicles equipped with air dryers vented to atmosphere during unloaded compressor operation, using the Holset (E-type) air compressor, require the installation of an Econ valve to prevent excessive oil consumption.

If the air system pressure is **not** maintained on the discharge valve during unloaded operation, air will be pumped out of the compressor cylinder causing a low pressure (vacuum) condition to form in the cylinder. With the intake valve sealed off by the unloader cap, and the exhaust valve being a one-way pressure actuated valve, no air will be allowed to enter the cylinder. When the compressor cylinder pressure falls below crankcase pressure, oil will be drawn past the piston rings and pumped into the air system.

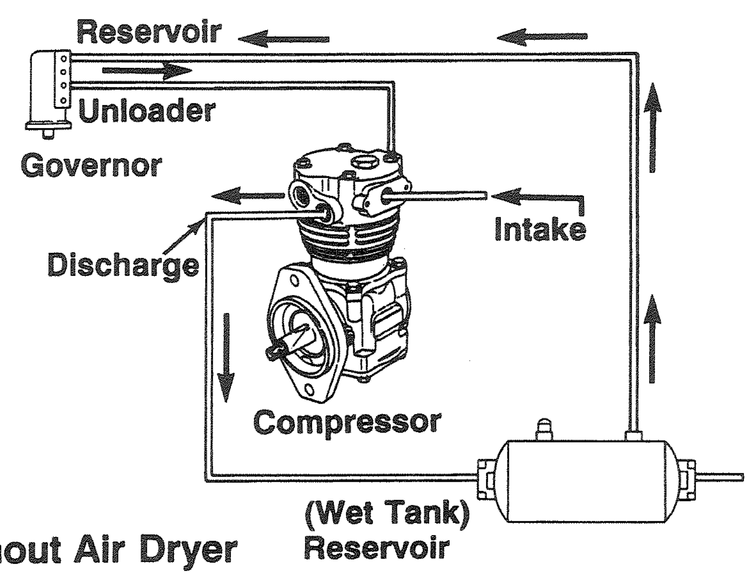
Other brands of compressors may be used on B series engines. Troubleshooting procedures are very similar for these air compressors compared to the Holset SS296. Refer to the specific air compressor manufacturers manual for detailed repair information and torque specifications.

Flow Diagrams - Compressed Air System



With Air Dryer

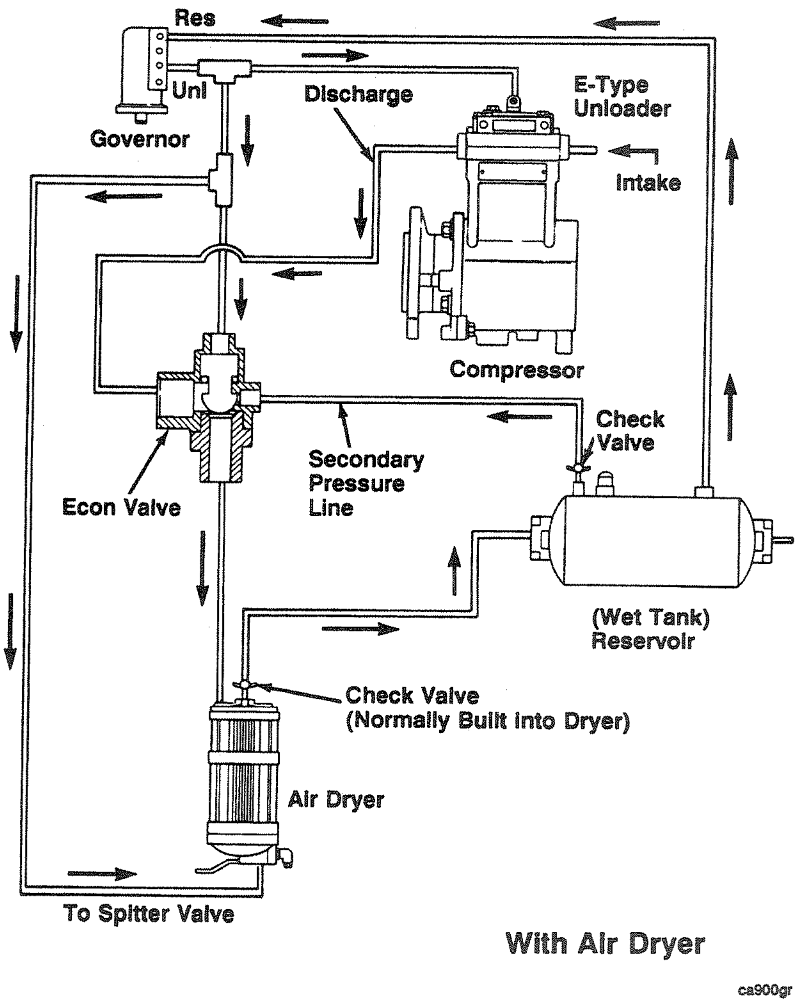
ca900ge



Without Air Dryer

ca900gq

Flow Diagrams - Compressed Air System (Continued)



Holset SS296BE E-Type System With Air Dryer

Specifications - Compressor Air System

Holset SS191B Single Cylinder Air Compressor

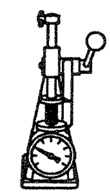
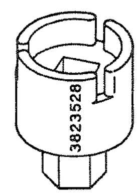
Compressor Swept Volume @ 1250 RPM	8.5 cfm
Piston Displacement	191.5 cc [11.69 C.I.D.]
Bore	80 mm [3.15 in.]
Stroke	38.1 mm [1.50 in.]
Speed	.98 Times Engine Speed
Cooling	Engine Coolant or Air Cooled
Lubrication	Engine Lubricating Oil
Plumbing Line Sizes	
Coolant Inlet and Outlet (Pipe Fitting)	[1/2 in NPTF]
Air Inlet (Inside Diameter)	[1/2 in]
Air Outlet (Minimum Inside Diameter)	[1/2 in.]
Height, Overall (Approximate)	269 mm (11 in.)
Width, Overall (Approximate)	125 mm [5 in.]
Length, Overall (Approximate)	186 mm [7.32 in]
Weight (Approximate)	13.6 kg [30 lb]

Holset SS296 Single Cylinder Air Compressor

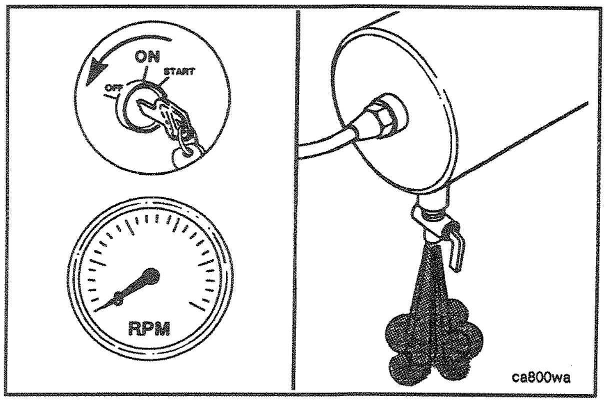
Compressor Swept Volume @ 1250 RPM	6.2 L per sec. [13.20 CFM]
Piston Displacement	296 cc [18.06 C.I.D.]
Bore	92.08 mm [3.625 in.]
Stroke	44.45 mm [1.750 in.]
Speed	1.135 times greater than Engine Speed
Cooling	Engine Coolant
Lubrication	Engine Lubricating Oil
Plumbing Line Sizes	
Coolant Inlet and Outlet (Pipe Fitting)	3/8 in NPTF
Air Inlet (Inside Diameter)	19 mm [0.750 in]
Air Outlet (Minimum Inside Diameter)	1/2″ NPTF 12.7 mm [0.50 in.]
Height, Overall (Approximate)	23.5 mm [9.25 in.]
Width, Overall (Approximate)	14.6 cm [5.75 in.]
Length, Overall (Approximate)	26.7 cm [10.5 in]
Weight (Approximate)	20 kg [44.0 lb]

Compressed Air System - Service Tools

The following special tools are recommended to perform procedures in Section 4. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

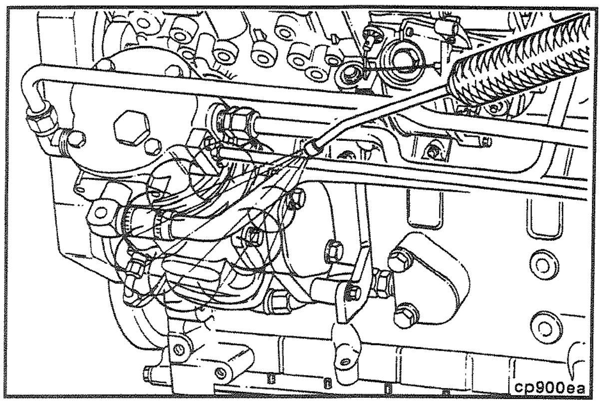
Tool No.	Tool Description	Tool Illustration
3375182	**Valve Spring Tester** Use to check spring tension.	
3823528	**Air Compressor Seat Socket** Use to remove the exhaust valve seat and the inlet valve cage.	

Carbon Buildup, Air Compressor - Check (4-01)



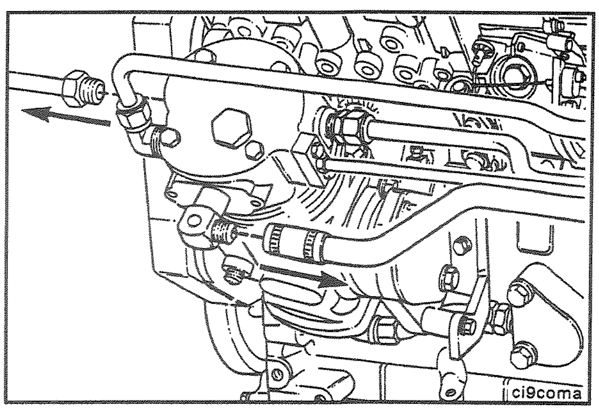
Shut off the engine.

Open the draincock on the wet tank to release compressed air from the system.

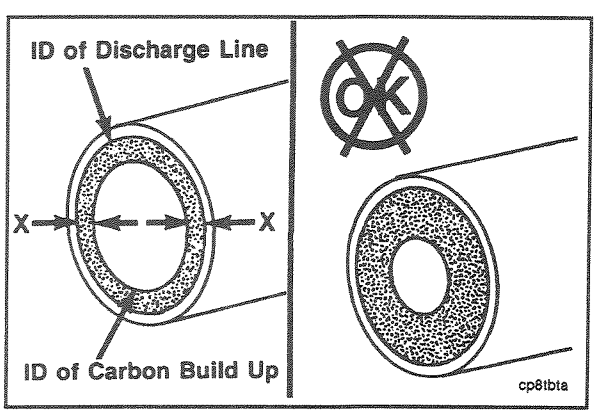


Use steam to clean the compressor.

Use compressed air to dry.



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



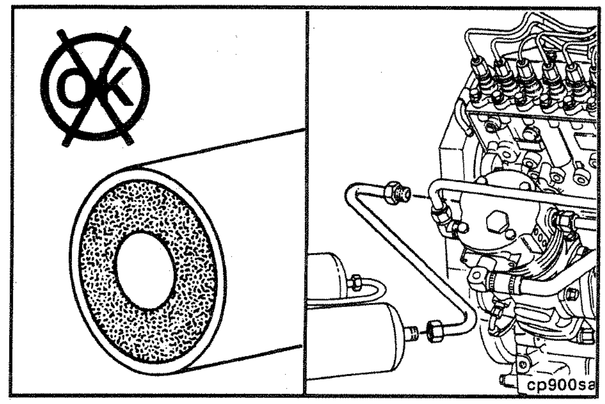
Measure the total carbon deposit thickness inside the air discharge line as shown.

NOTE: The carbon deposit thickness must not exceed 1.6 mm [1/16 inch].

Warning: The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

NOTE: If the total carbon deposit thickness exceeds specification:

* Remove and clean or replace the air discharge line. Refer to manufacturer's material specifications.
* Remove and inspect unloader components and cylinder head.



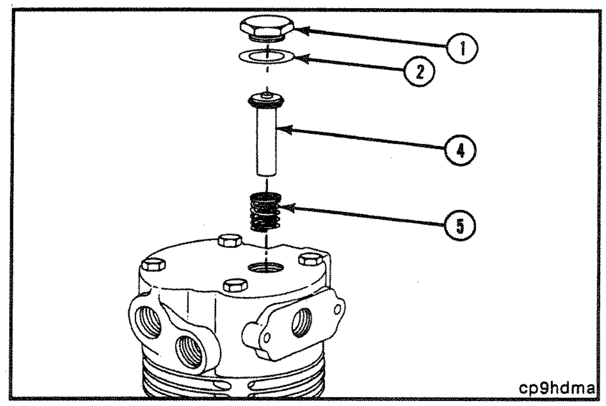
Unloader and Cylinder Head Disassembly (4-02)

1-1/4 inch

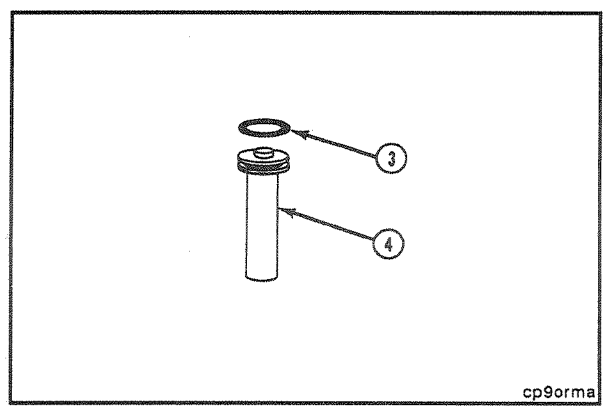
Remove the following parts:

- Unloader cover (1)
- Copper washer (2)
- Unloader pin (4)
- Spring (5)

Discard the copper washer.



Remove and discard the o-ring (3).



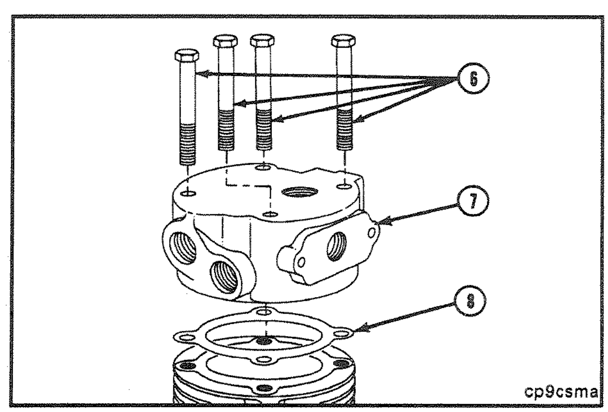
9/16 inch

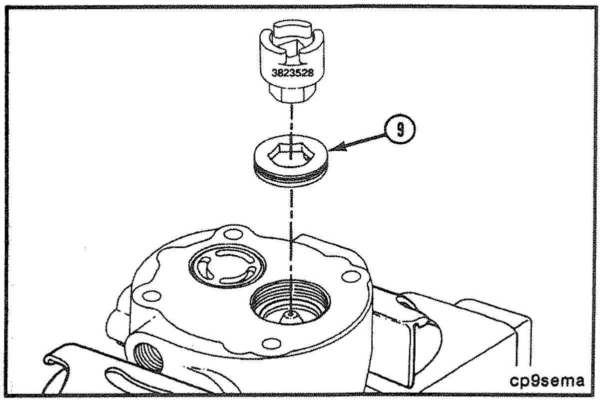
Remove the four cylinder head capscrews (6).

Remove the cylinder head (7).

Remove and discard the cylinder head gasket (8).

Service Tip: Scribe a mark to show proper head orientation before removing the head.

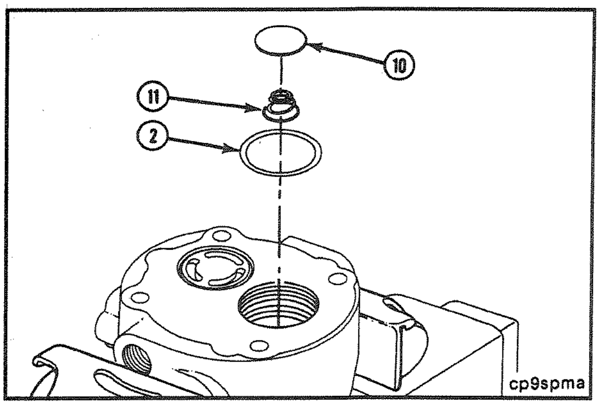




Part No. 3823528, Air Compressor Seat Socket or 3/4 inch Allen Wrench.

Install the head with the bottom side up in a soft jawed vise.

Remove the exhaust valve seat (9).

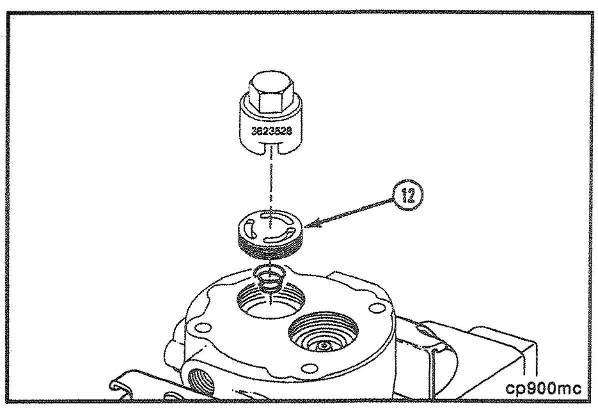


Remove the following parts:

- Exhaust valve disc (10)
- Spring (11)
- Copper washer (2)

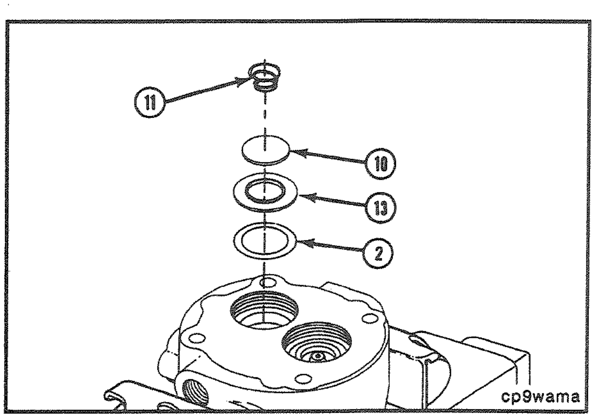
Discard the copper washer.

NOTE: The exhaust valve stop is pressed in place and **must not** be removed.



Part No. 3823528, Air Compressor Seat Socket

Remove the inlet valve cage (12).



Remove the following parts:

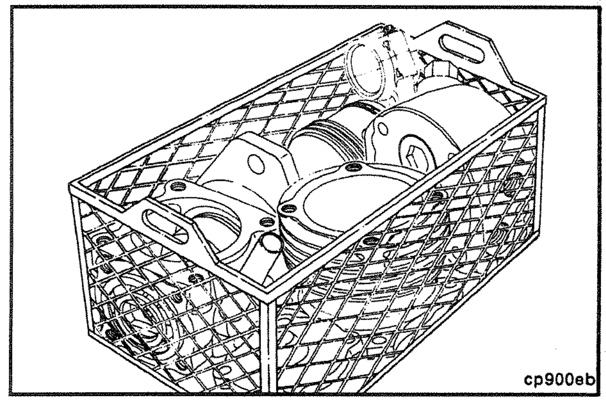
- Spring (11)
- Inlet valve disc (10)
- Inlet valve seat (13)
- Copper washer (2)

Discard the copper washer

Cleaning

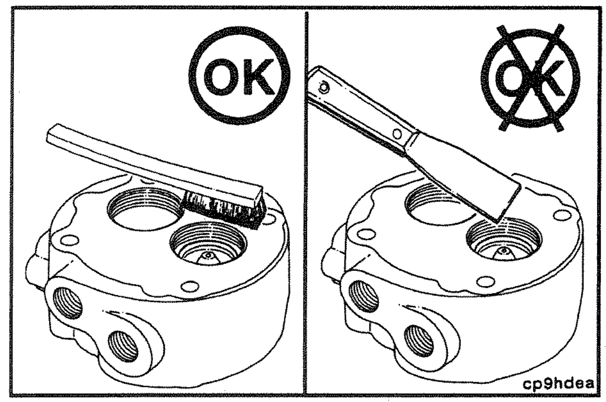
Warning: When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing.

Soak the parts in a kerosene emulsion based cleaner designed to remove carbon. The cleaner **must** have a pH of 9.5 or less to avoid turning aluminum parts black. The cleaner manufacturer or supplier can be contacted about solution concentration, temperature and soak time.



Caution: Do not use a scraper to remove carbon and scale. This can damage sealing surfaces.

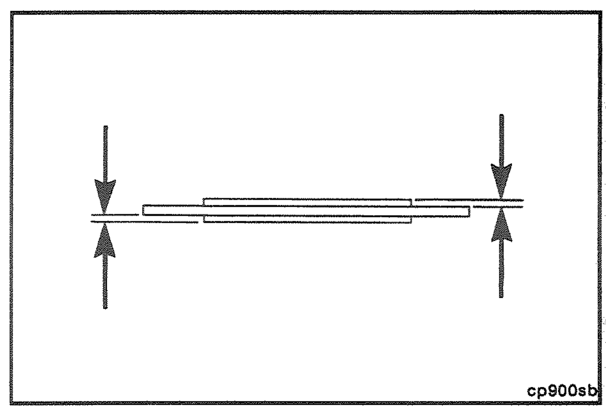
Use a stiff non-metalic bristle brush to scrub the parts.



Cleaning

Valve Discs

Inspect and replace if cracked, pitted or grooved in excess of 0.13 mm [0.005 in].

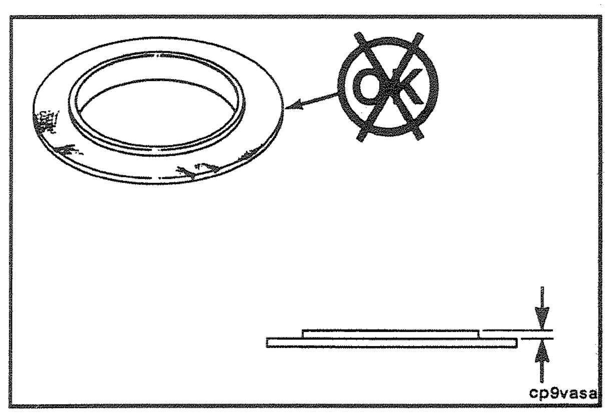


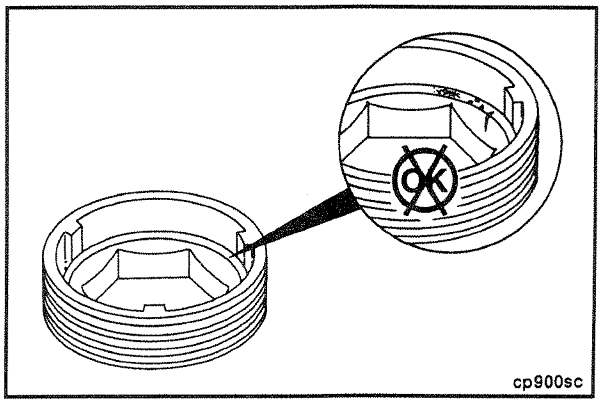
Inlet Valve Seat

Measure the distance from the valve seating surface to the surface that contacts the valve cage.

Intake Valve Seat		
mm		in
0.597	MIN	0.0235
0.673	MAX	0.0265

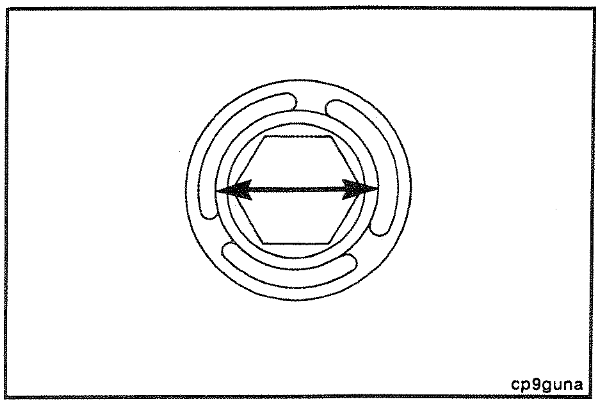
Replace the intake valve seat if **not** within limits or if cracked or damaged.





Exhaust Valve Seat

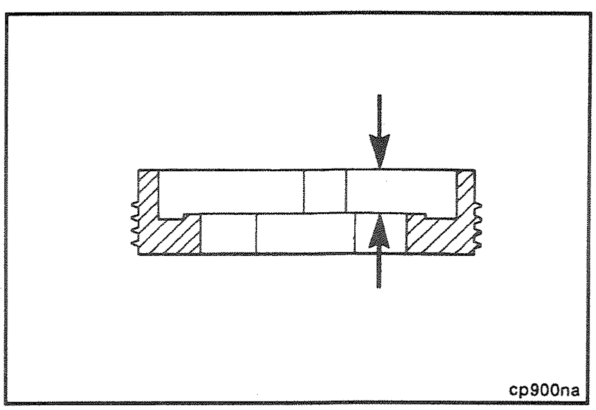
Inspect the seat for damage and wear.



Measure the valve guide diameter.

Valve Guide Diameter		
mm		in
25.53	MIN	1.005
25.65	MAX	1.010

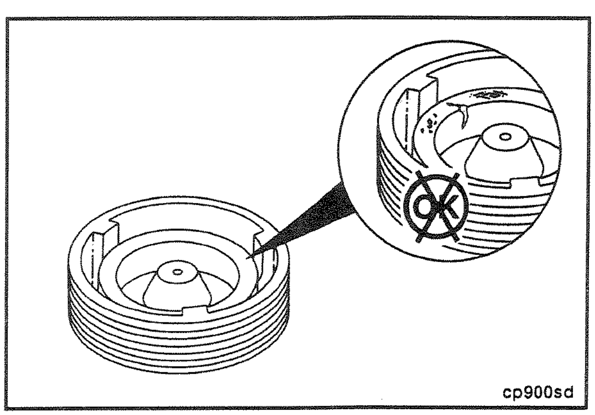
Replace the exhaust valve seat if **not** within limits.



Measure the distance from the top of the valve seat to the valve seating surface.

Seat Height		
mm		in
4.01	MIN	0.158
4.11	MAX	0.162

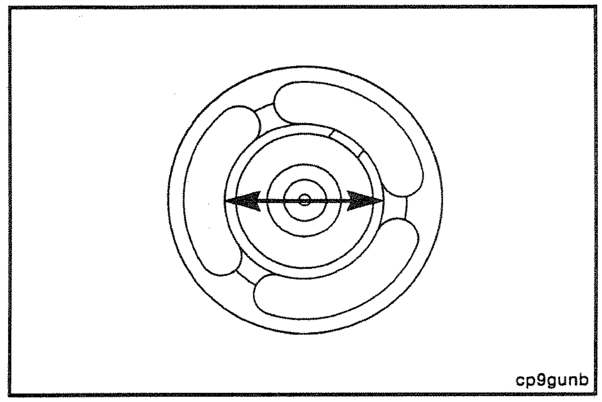
Replace the exhaust valve seat if **not** within limits.



Inlet Valve Cage

Inspect the inlet valve cage for damage and wear.

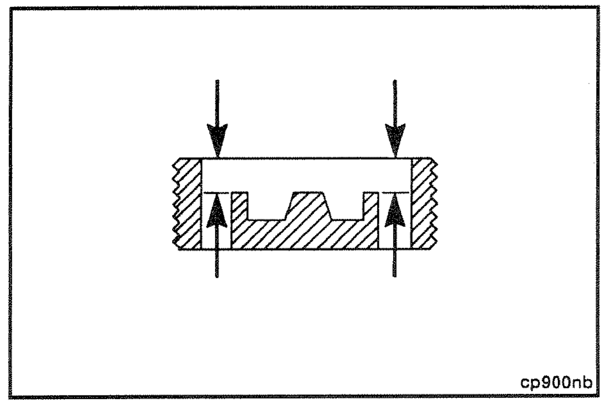
Measure the valve guide diameter.



Valve Guide Diameter		
mm		**in**
25.53	MIN	1.005
25.65	MAX	1.010

Replace the inlet valve cage if **not** within limits.

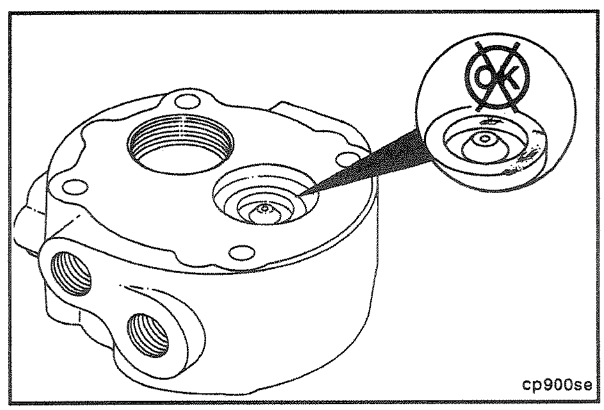
Measure top of cage to valve stop.



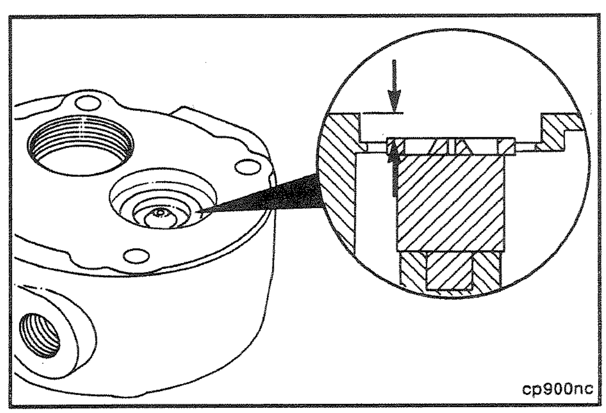
Stop Depth		
mm		**in**
3.63	MIN	0.143
3.78	MAX	0.149

Exhaust Valve Stop

Inspect the exhaust valve stop. Replace the cylinder head assembly if the stop is loose or damaged.

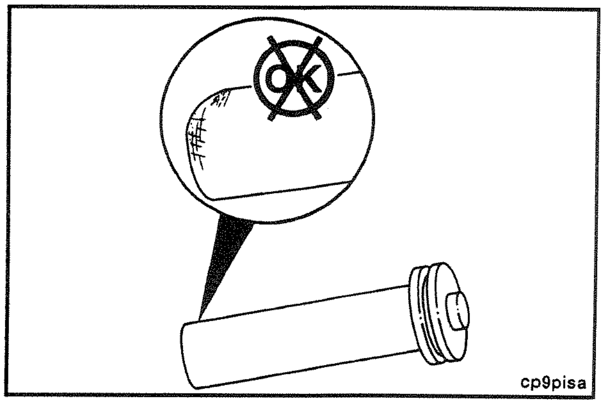


Measure the distance from the valve end of the stop to the face of the cylinder head.



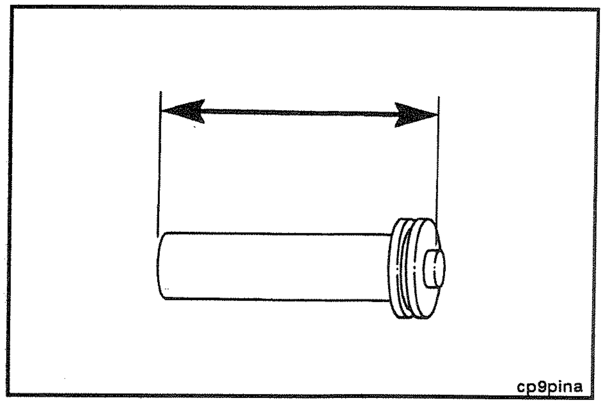
Stop Height		
mm		**in**
4.42	MIN	0.175
4.70	MAX	0.185

Replace the cylinder head if **not** within limits.



Unloader Pin

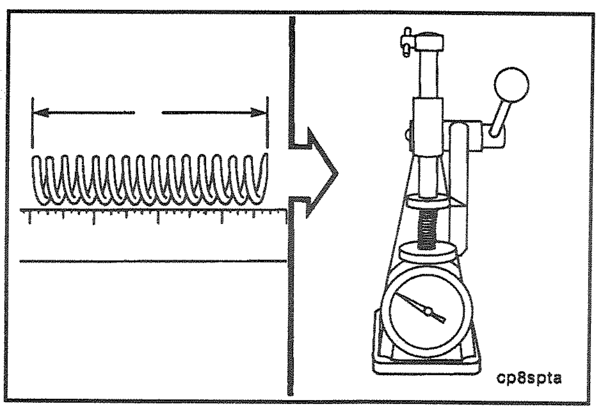
Inspect for scoring or pitting.



Measure the length of the pin.

Pin Length		
mm		in
40.51	MIN	1.595
40.72	MAX	1.603

Replace the pin if **not** within limits.



Valve Springs

Use valve spring tester, Part No. 3375182, to check the springs.

Replace if **not** within limits in Table 1, shown below.

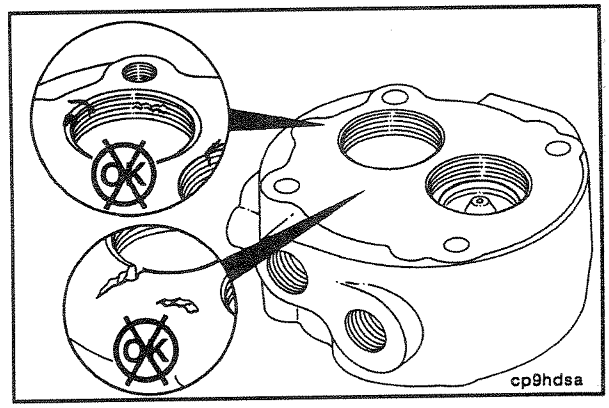
NOTE: Cummins Engine Company, Inc. recommends that new springs be installed during rebuild.

Table 1: Spring Data

	Load Required to Compress Spring to Length		
	Length mm [in]	**Minimum Kg [lb]**	**Maximum Kg [lb]**
Inlet Valve	5.08 [0.20]	0.272 [0.60]	0.340 [0.75]
Unloader	10.0330 [0.395]	1.53 [3.38]	1.90 [4.18]
Exhaust Valve	5.08 [0.20]	0.272 [0.60]	0.340 [0.75]

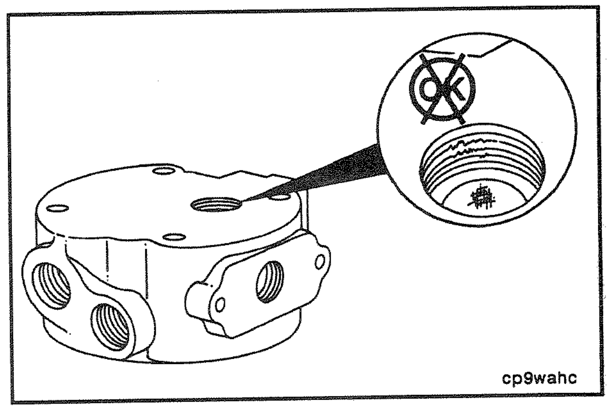
Cylinder Head

Inspect and replace if cracks, nicks, gouges or damaged threads are found.



Inspect the unloader seal bore for scoring or pitting.

Replace the cylinder head if damaged.



Assembly

Turn the cylinder head bottom side up and install it in a soft jawed vise.

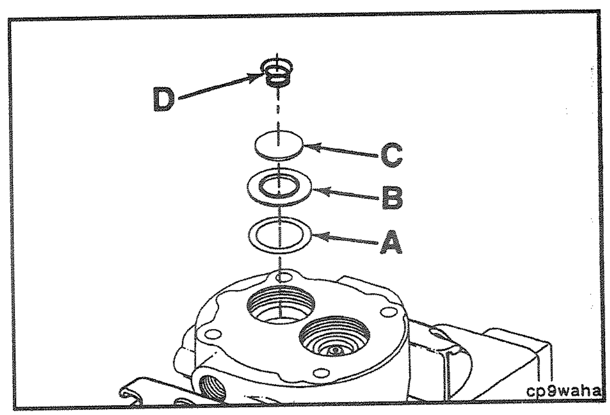
Install the following parts.

a. New washer

b. Inlet valve seat

c. Inlet valve

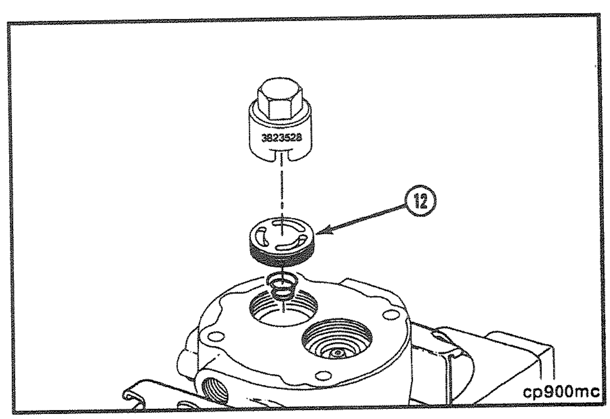
d. Inlet valve spring

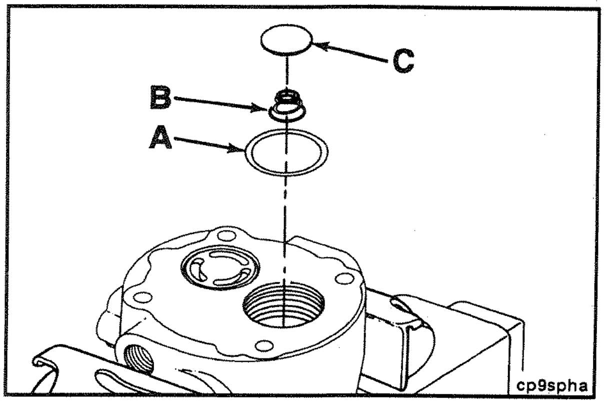


Air Compressor Seat Socket, Part No. 3823528 and Torque Wrench

Tighten the cage.

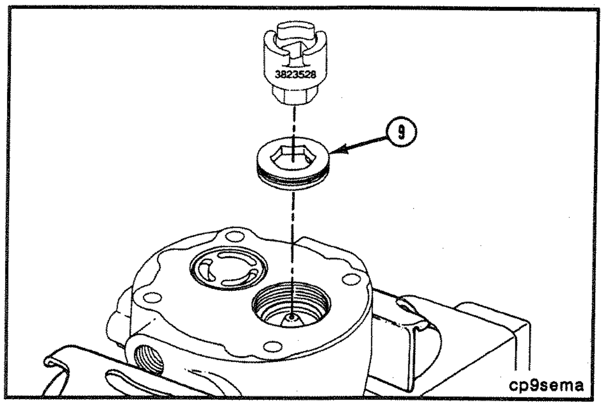
Torque Value: 108 N•m [80 ft-lb]





Install the following parts:

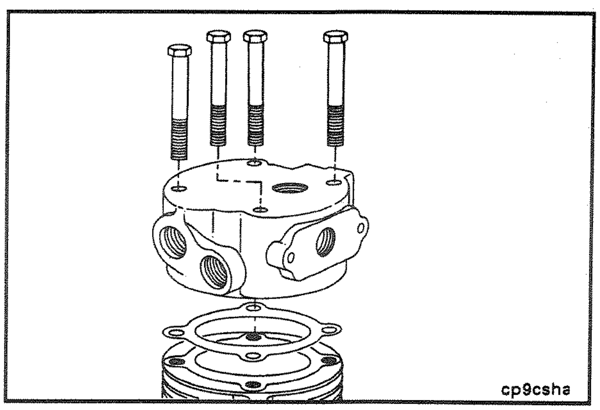
a. New washer
b. Exhaust valve spring
c. Exhaust valve disc



3/4 inch Allen Wrench or Air Compressor Seat Socket, Part No. 3823528, and Torque Wrench

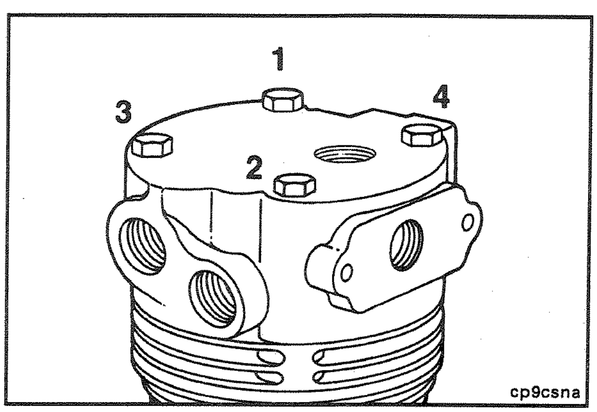
Tighten the seat.

Torque Value: 108 N•m [80 ft-lb]



Install a new gasket and the cylinder head to the cylinder block, aligning the scribe marks.

Install the four capscrews.



9/16 inch and Torque Wrench

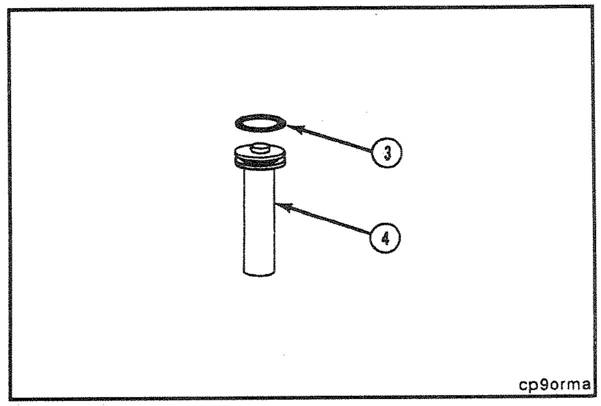
Tighten the capscrews.

Torque Value: 30 N•m [22 ft-lb]

Tighten the capscrews again, in the sequence shown.

Torque Value: 41 N•m [30 ft-lb]

Install a new o-ring on the unloader pin.



1-1/4 inch and Torque Wrench

Install the following parts:

a. Spring

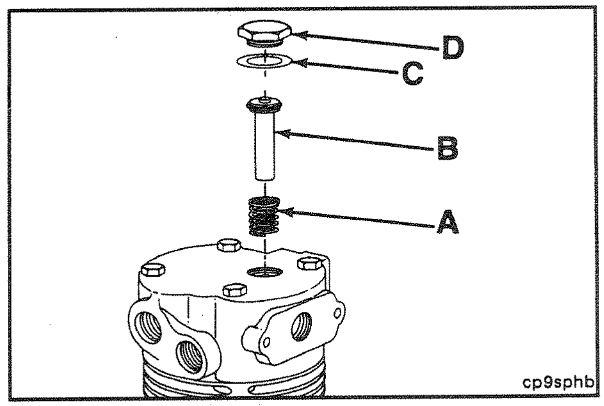
b. Unloader pin

c. New washer

d. Unloader cover

Tighten the cover.

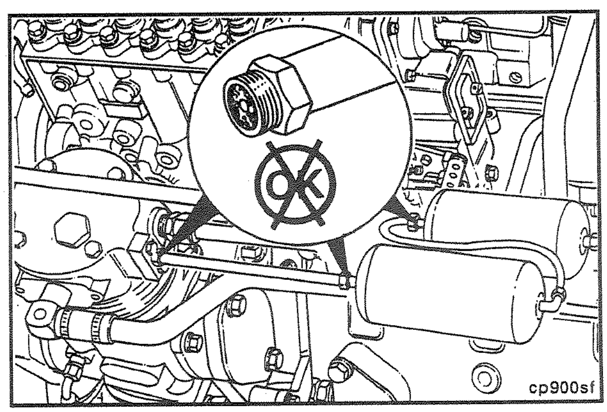
Torque Value: 41 N•m [30 ft-lb]



Warning: The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

Continue to check for carbon buildup in the air discharge line connections up to the first or wet tank.

Clean or replace any lines and fittings with carbon deposits greater than 1.6 mm [0.06 (1/6 inch]. Refer to the manufacturer's specifications for cleaning or replacement instructions.



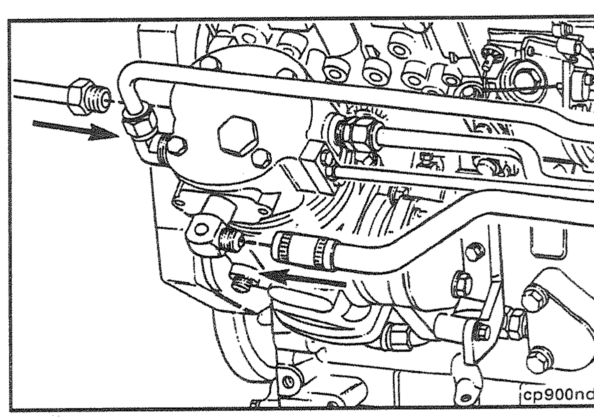
Install and tighten the air inlet and outlet connections.

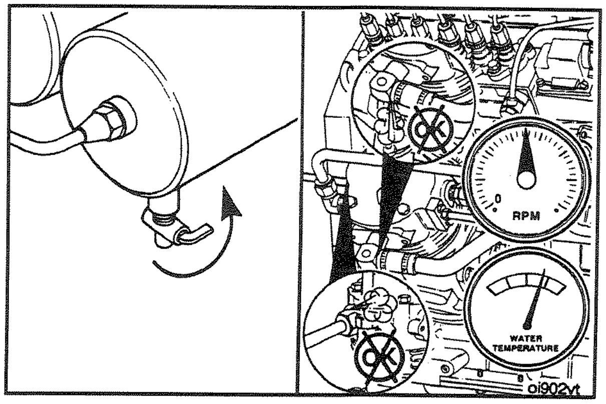
Torque Value:

Inlet	5 N•m [48 in-lb]
*Outlet	24 N•m [18 ft-lb]

*1/2 NPT fitting in head

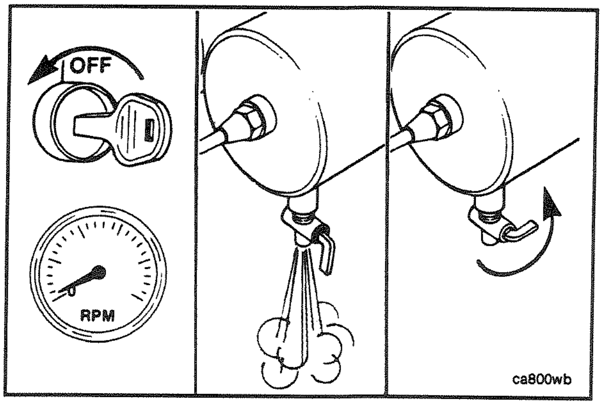
NOTE: Torque of discharge line dependent upon line size and type. Consult vehicle manufacturer for correct torque value.





Close the wet tank draincock.

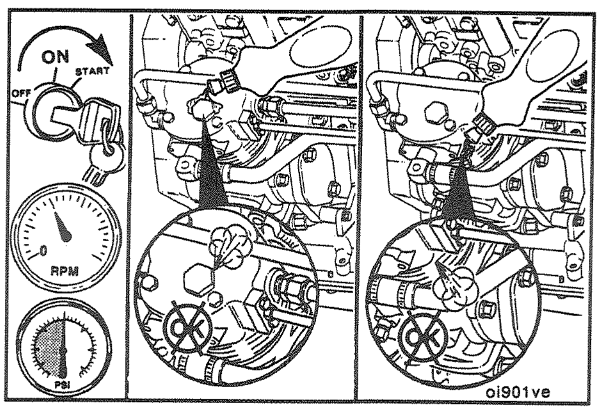
Operate the engine and check for air leaks.



Gasket Leaks, Air Compressor, Check (4-03)

Shut off the engine.

Open the drain cock on the wet tank to release air from the system. Close the draincock after the pressure is released.

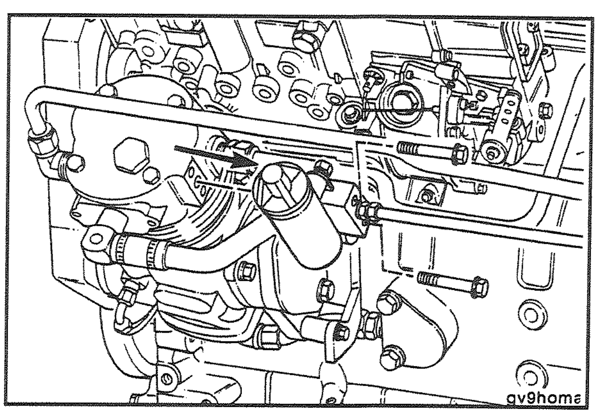


Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks in the following areas:

- Unloader cover gasket
- Unloader pin o-ring
- Air compressor head gasket

If air leaks are found, refer to Procedure 4-02 for repair of these components.



Air Governor and Compressor Unloader Valve - Check (4-04)

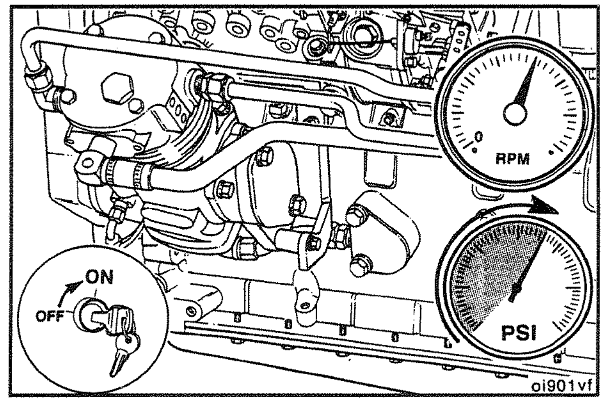
Air Compressor Will Not Pump

Remove the air governor hose from the air compressor unloader body.

If the air governor is mounted directly on the air compressor, then remove the air governor from the compressor.

Warning: During this test, do not exceed maximum vehicle air system pressure or 1035 kPa [150 psi] whichever is lower. Refer to the manufacturer's specifications.

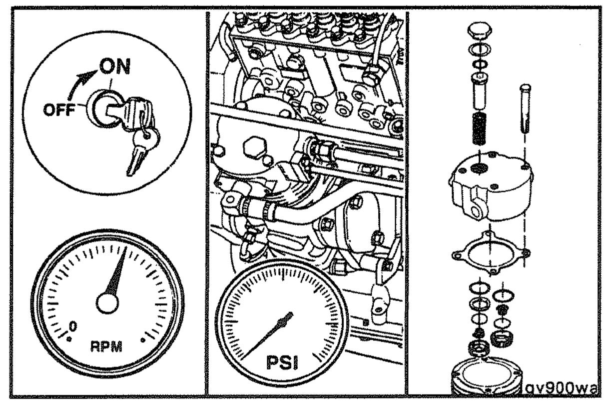
Operate the engine to activate the air compressor.



If the air compressor does not pump, then the fault is in the air compressor.

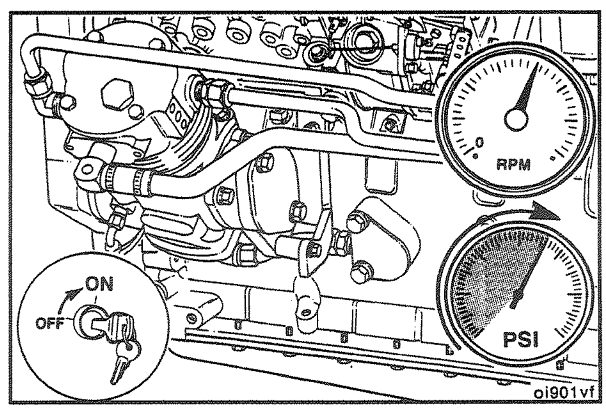
Remove and inspect the cylinder head and unloader components. Refer to Procedure 4-02. If no problems are found during disassembly or inspection of the cylinder head or unloader components, then the compressor should be removed and disassembled to determine the cause of the problem.

Refer to Procedure 4-09 and Shop Manual, Bulletin No. 3810433.

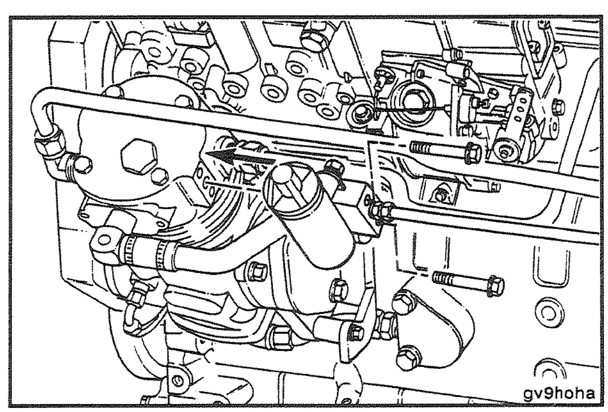


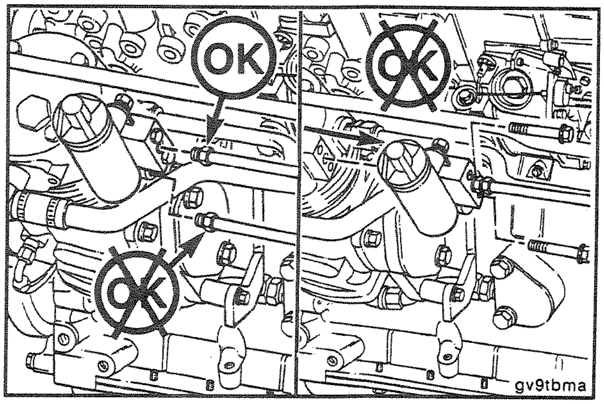
Warning: During this test, do not exceed maximum vehicle air system pressure or 1035 kPa [150 psi] whichever is lower. Refer to the manufacturer's specifications.

Operate the engine and check air compressor operation with the air governor removed.



Install the air governor line to the unloader body and tighten.



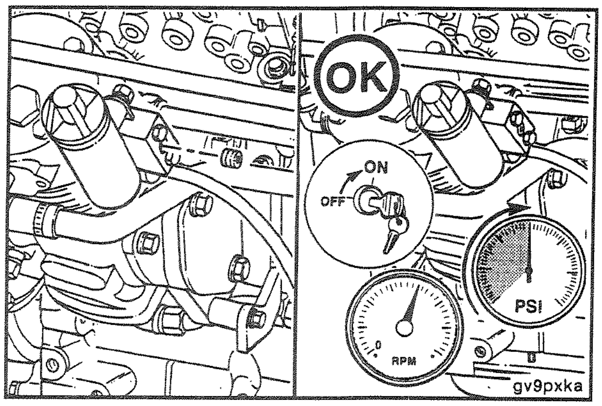


Air Governor - Check (4-05)

Air Compressor Pumps Continuously

Remove the accessory air lines from the air governor unloader port.

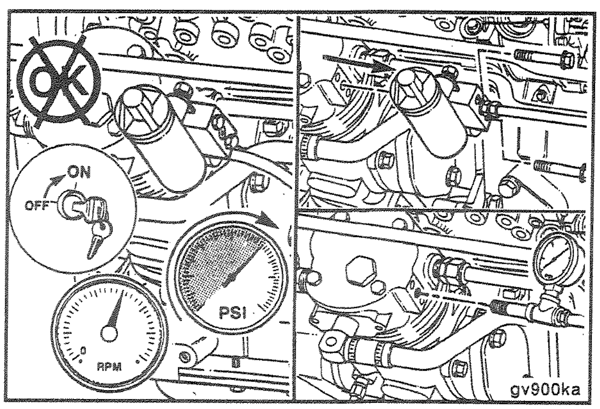
NOTE: Do not disconnect the line from the air compressor unloader valve. Do not disconnect the reservoir air line from the air governor. If the governor is mounted on the compressor, do not remove the governor from the compressor.



Install pipe plugs in the air governor unloader ports where accessory air lines were removed.

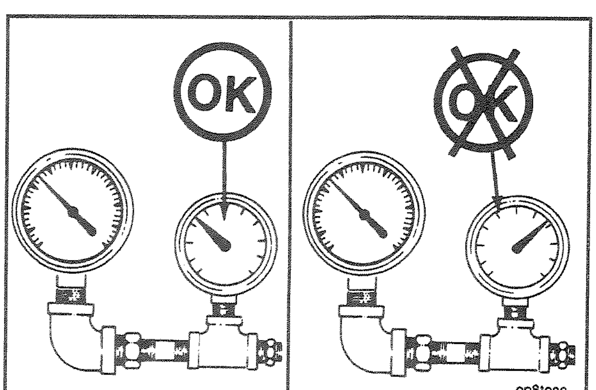
Operate the engine to activate the air compressor.

If the air compressor stops pumping (air pressure stops rising) at the governed air pressure, there is a leak in an accessory or an accessory air line. Refer to the equipment manufacturer's instructions for troubleshooting and repair.



If the air compressor does not stop pumping (air pressure continues to rise) at the governed air pressure, connect a regulated shop air pressure line to the the air compressor unloader valve port.

NOTE: If the governor is mounted on the air compressor, then the governor will have to be removed.

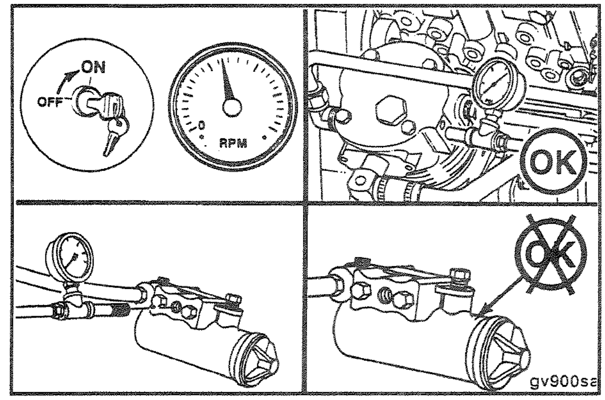


NOTE: Be sure the air pressure gauge is accurate and the supply lines and fittings are in good condition before performing any air pressure checks.

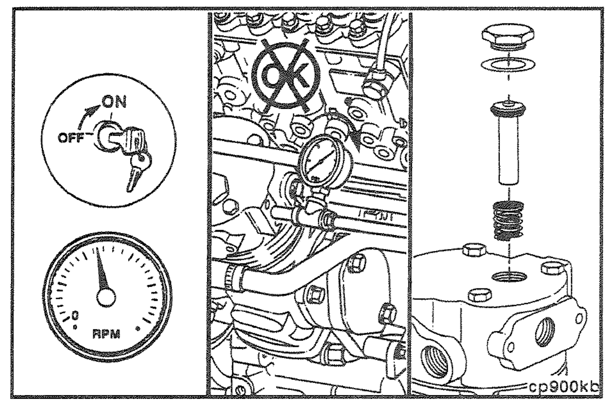
Use a master gauge of known accuracy to check the air pressure gauge.

Apply 690 kPa [100 psi] air pressure to the unloader port.

If the air compressor stops pumping (air pressure stops rising), the air governor is malfunctioning and must be repaired or replaced. Refer to the manufacturer's instructions.



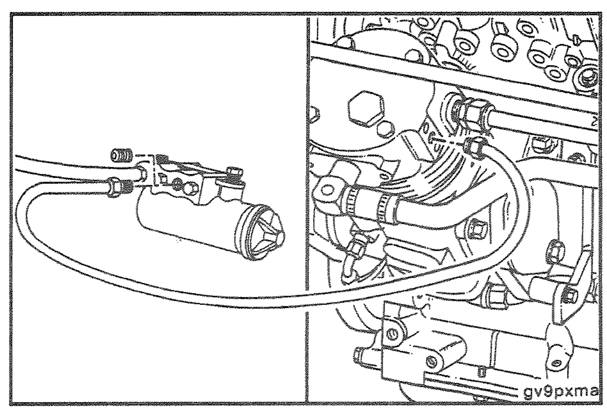
If the air compressor continues to pump (air pressure continues to rise), the unloader valve is malfunctioning and must be repaired or replaced. Refer to Procedure 4-02.



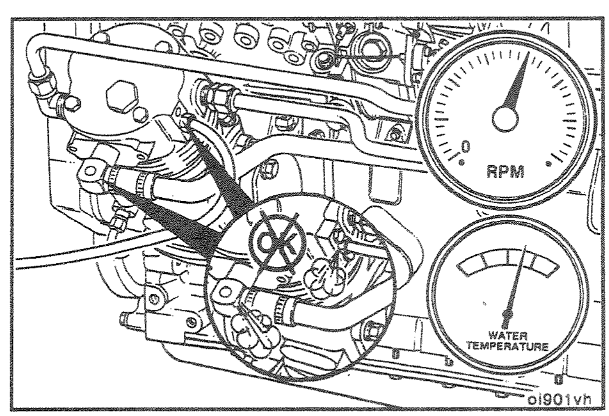
Remove the pipe plugs from the unloader ports used for accessory air lines.

Install and tighten the accessory air lines.

Connect the line to the unloader valve.



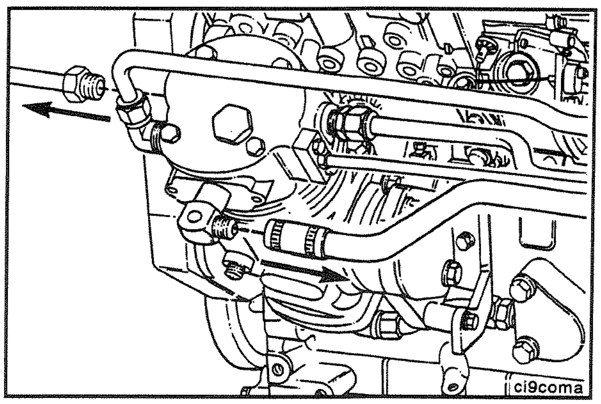
Operate the engine and check for air leaks.



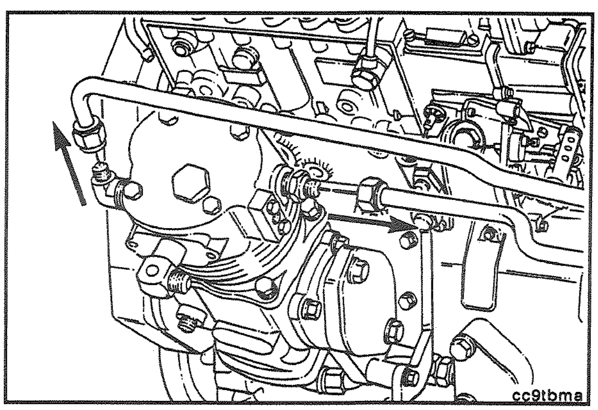
Air Compressor - Removal (4-06)

Preparatory Steps:

- Steam clean the air compressor and dry with compressed air.
- Drain the engine coolant if the air compressor has a liquid cooled cylinder head. If compressor is air cooled, then the engine coolant need not be drained.
- Open the drain cock on the wet tank to release air from the system. Close the draincock after the pressure is released.

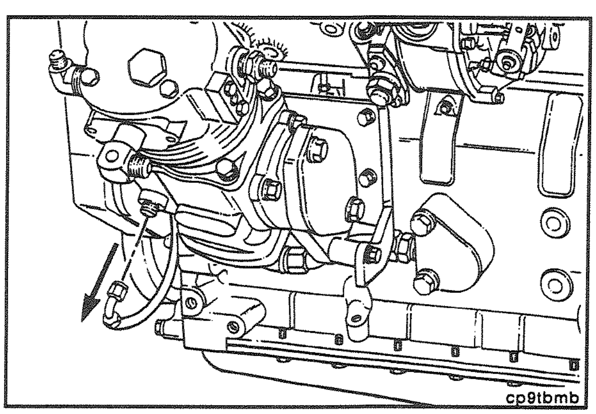


Remove the air connections from the air compressor.



15/16 in, 7/8 in

Remove the coolant lines from the air compressor (does not apply to air cooled compressors).

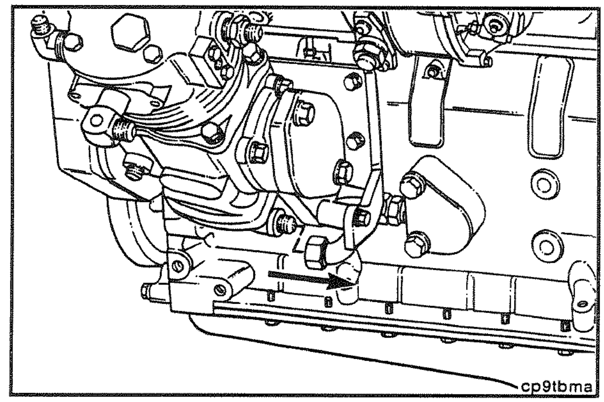


9/16 inch

Remove the oil supply line.

15/16 in

Remove the oil return line from the bottom of the air compressor.

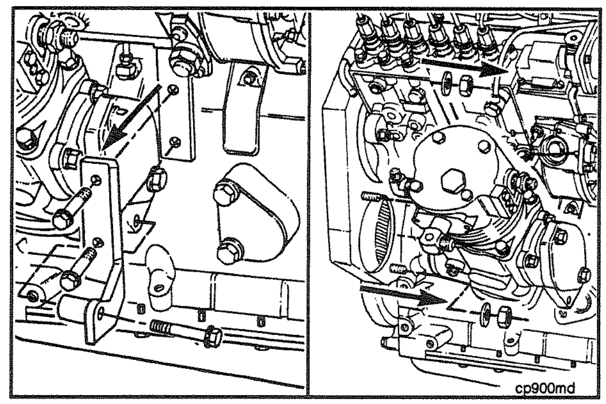


18 mm, 14 mm, 10 mm

Remove the air compressor support bracket and capscrews.

Remove the air compressor mounting nuts.

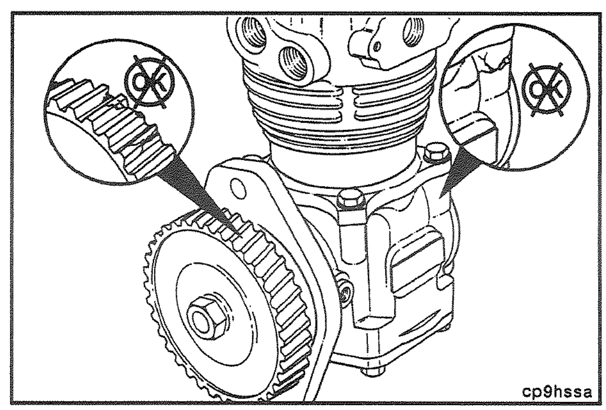
Remove the air compressor.



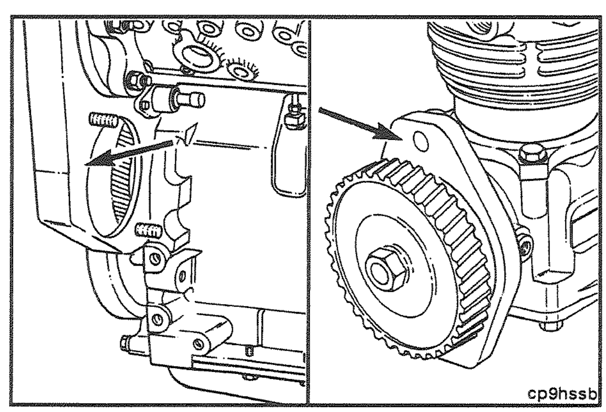
Inspection

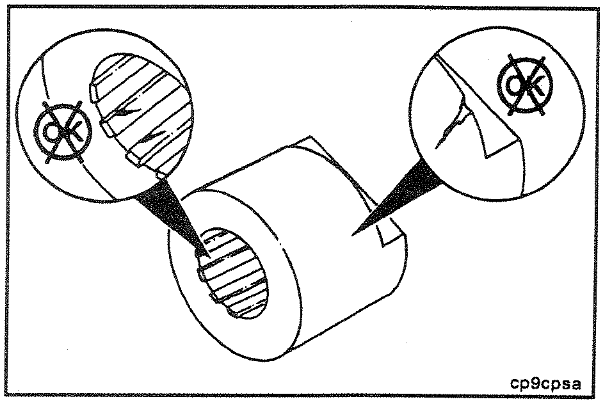
Visually inspect the compressor housing for cracks or damage.

Visually inspect the drive gear for cracks or damaged.



Be sure the gasket surfaces of the gear housing and air compressor are clean and **not** damaged.

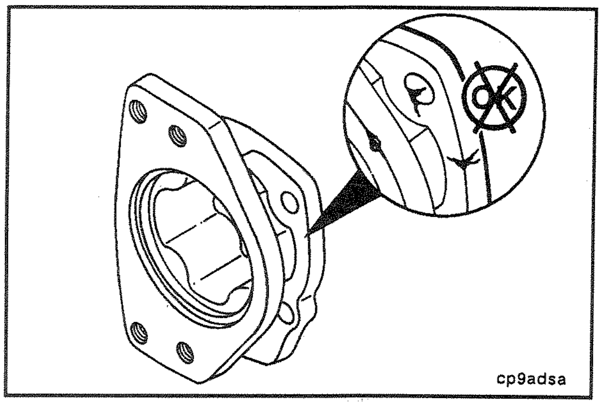




Power Steering Coupling (if Applicable)

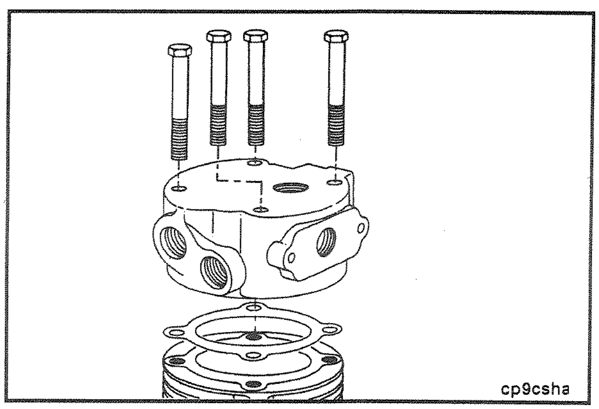
Inspect the coupling for wear or cracks.

Replace the coupling if damaged.



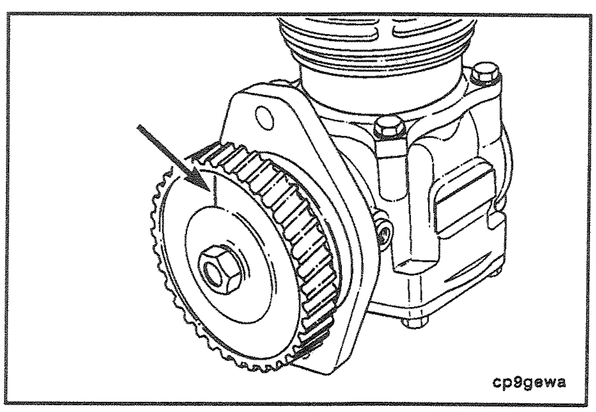
Power Steering Adapter

Inspect and replace the adapter if any damage is found.



Air Compressor Timing (For Single Cylinder Air Compressor only)

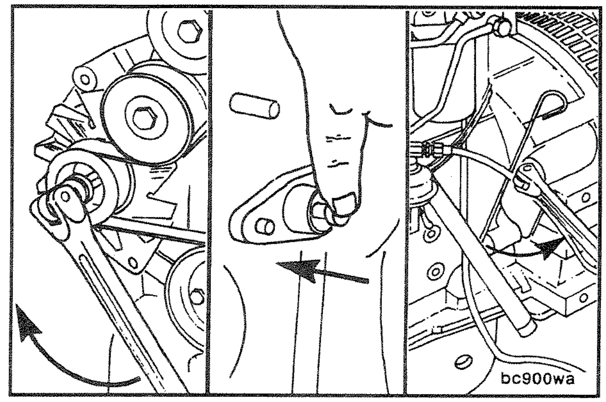
Locate TDC on the compressor crankshaft by removing the unloader valve or head, (refer to the (respective) air compressor manual.) TDC does not have to be exact. The system is tolerant of some misalignment.



Use ink or dychem to mark the air compressor gear face at TDC (12:00 o'clock position when viewed from the front.)

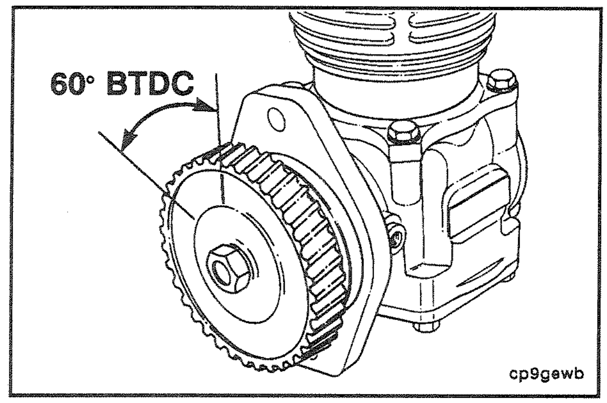
Be sure to disengage the timing pin after locating TDC.

Locate TDC for cylinder No. 1 by barring the crankshaft slowly while pushing on the Timing pin.



Rotate the compressor TDC mark to 60 degrees, or 6 teeth on a 36 tooth gear, before TDC. This is approximately 10:00 o'clock when viewed from the front of the air compressor.

NOTE: Holset air compressors Series SS, QE220, 296 and 338 will have a radial line etched on the gear representing TDC.



Installation

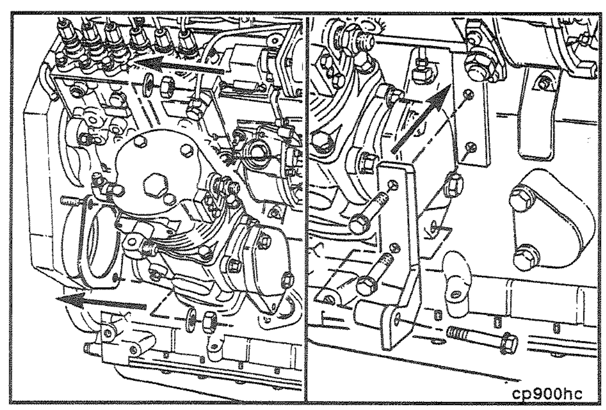
18 mm, 14 mm, 10 mm

Use a new gasket. Install the air compressor to the gear housing.

Install the air compressor support bracket.

Torque Values: Mounting Nuts 77 N•m [57 ft-lb]
Support Capscrews 24 N•m [18 ft-lb]

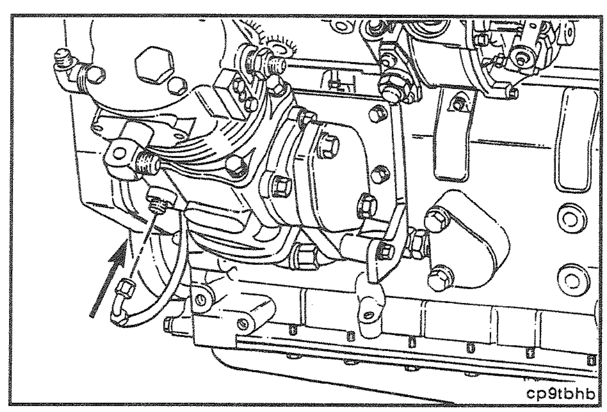
NOTE: No timing of gears is necessary.

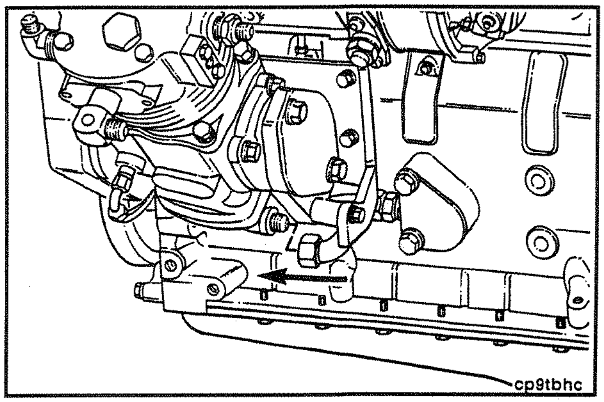


9/16 inch

Install the oil supply line.

Torque Value: 15 N•m [12 ft-lb]

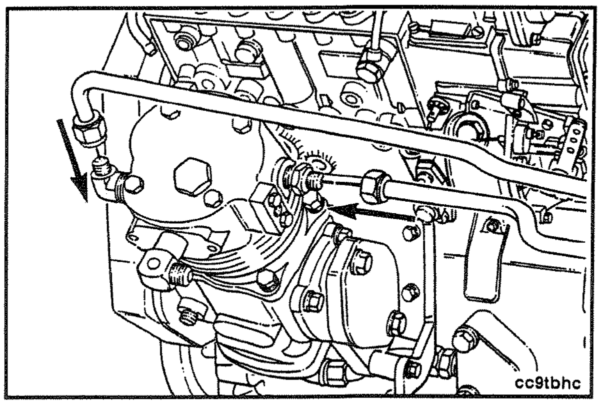




15 mm

Install the oil drain to the bottom of the compressor.

Torque Value: 24 N•m [18 ft-lb]

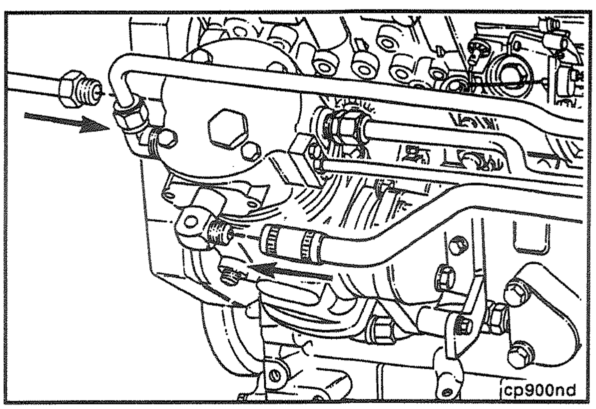


15/16 in, 7/8 in

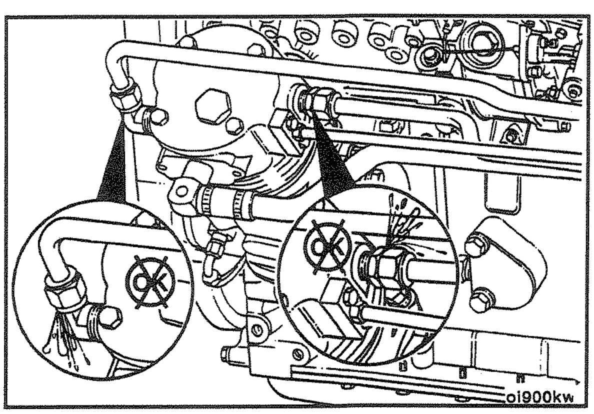
Caution: If rubber grommets are used on the coolant or air lines, be sure they are installed carefully to prevent cuts or tears to the grommets which will cause leaks.

Install the coolant lines.

Torque Value: 24 N•m [18 ft-lb]



Install the air lines.

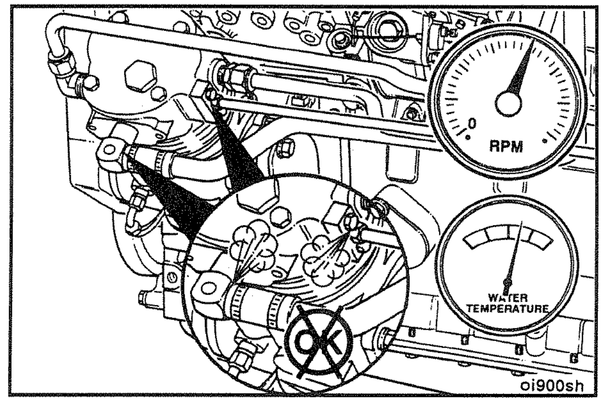


Fill the engine cooling system (liquid cooled air compressor).

Operate the engine and check for leaks.

Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks.



NOTES

Section 5 - Fuel Systems

Section Contents

General Information - Fuel Systems

Fuel System Components and Flow - Distributor Type Fuel Injection Pump

Most of the engines will be equipped with a cam actuated fuel transfer pump. Two types of fuel transfer pumps are available for rotary type fuel injection pumps.: a) A diaphragm style fuel transfer pump and 2) a piston style fuel transfer pump. The piston style fuel transfer pump is offered as an option, and may be disassembled, cleaned and reassembled, using a fuel transfer pump rebuild kit. Fuel flow begins as the fuel transfer pump pulls fuel from the supply tank though a mandatory prefilter. The fuel transfer pump supplies low pressure fuel (21-35 kPa [3-5 psi]) to the fuel filter head, through the filter and then to the distributor injection pump.

The distributor pump builds the high injection pressures required for combustion, and routes the fuel through individual high-pressure fuel lines to each injector.

When the high-pressure fuel reaches the injector, the pressure lifts the needle valve against the spring tension to let the fuel enter the combustion chamber.

Any leakage past the needle valve enters the fuel drain manifold. The fuel drain manifold routes controlled venting from the distributor injection pump and leakage from the injectors back into the fuel tank.

Fuel System Components and Flow - In-Line Fuel Injection Pump

A cam-actuated piston style fuel fuel transfer pump provides positive fuel pressure to the fuel injection pump. Fuel flow begins as the fuel transfer pump pulls fuel from the supply tank. The system should have a pre-filter or screen to remove larger contaminants from the fuel before reaching the fuel transfer pump. The fuel transfer pump supplies low pressure fuel through the fuel filter head and filter to the fuel injection pump at 172 kPa [25 psi].

The Bosch P7100 fuel injection pump is used on higher rated automotive 91 B Series engines and all 94 B Series automotive engines. The Nippondenso EP-9 is used on the higher horsepower marine B Series engine.

The fuel injection pump builds the high injection pressures required for combustion and routes the fuel through high pressure fuel lines to each injector.

All B Series engines use closed-nozzle, hole-type injectors. When the high-pressure fuel reaches the injector, the pressure lifts the needle valve against the spring tension to allow fuel to enter the combustion chamber.

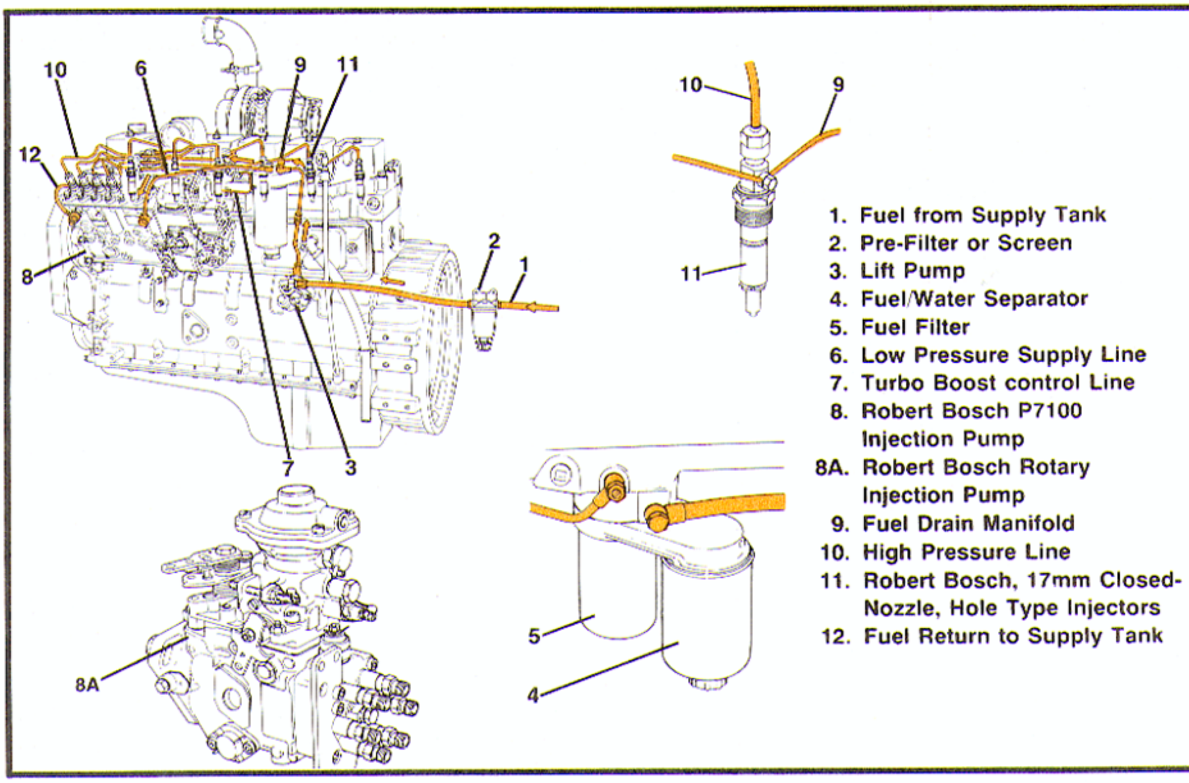
Any leakage past the needle valve enters the fuel drain manifold.

On engines equipped with the P7100 fuel injection pump, the manifold routes leakage from the injectors to the inlet side of the fuel filter. On engines equipped with the Nippondenso EP-9 fuel injection pump, the manifold routes leakage from the injectors to the supply tank.

Fuel System Components and Flow

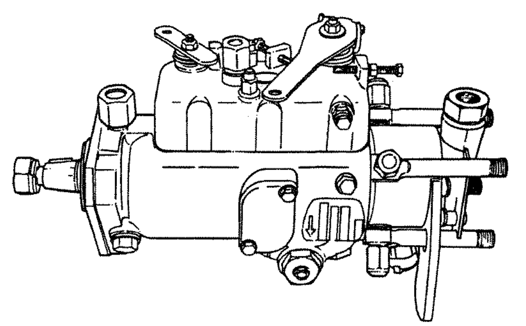
The following illustration identifies the components of the fuel system.

Fuel System



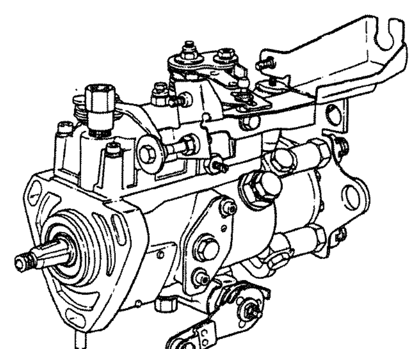
Fuel System Identification

Beginning in 1991, the B Series engine will use six different fuel injection pumps depending on the horsepower rating and application.


fp901gp

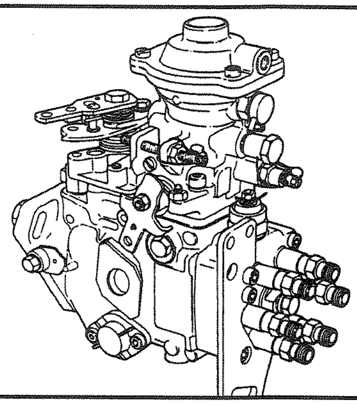
The Lucas CAV DPA distributor type fuel injection pump.

- Marine
- Industrial


fp901gq

The Lucas CAV DPS distributor type fuel injection pump.

- European automotive ratings.

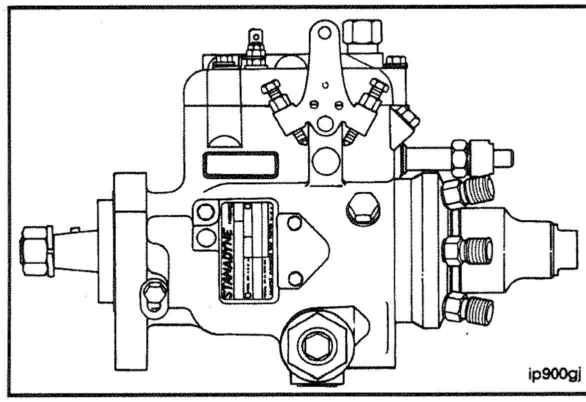

fp901gr

The Bosch VE distributor type fuel injection pump.

- Industrial
- 1991 low horsepower automotive ratings

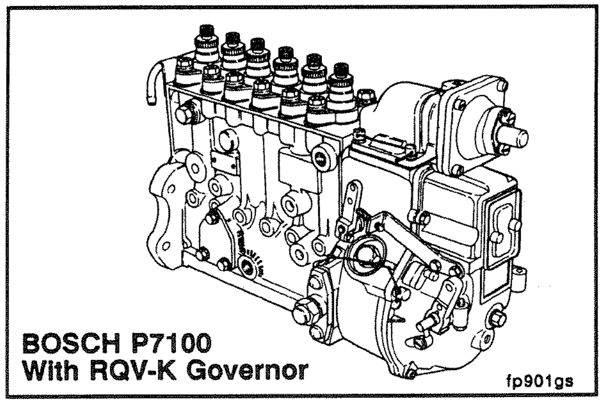
The Stanadyne DB4 distributor type fuel injection pump.

- Gensets



The Bosch P7100 in-line fuel injection pump.

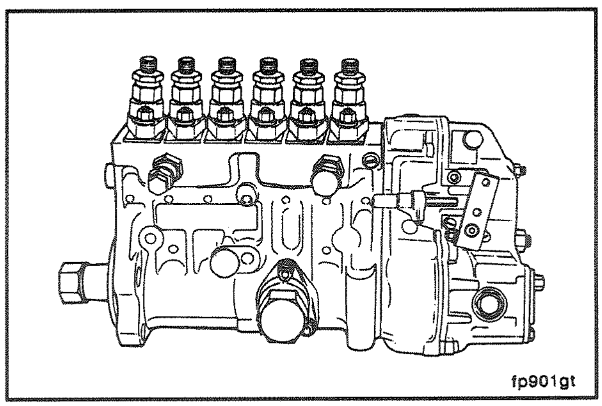
- 1991 high horsepower automotive ratings
- 1994 automotive, all 6B ratings



BOSCH P7100
With RQV-K Governor

The Nippondenso EP-9 in-line fuel injection pump with the RSV governor.

- higher horsepower marine rating



Fuel System Specifications

Distributor Type Fuel Injection Pumps

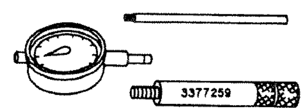
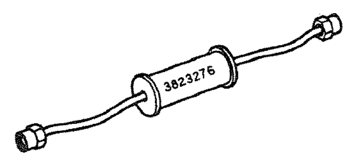
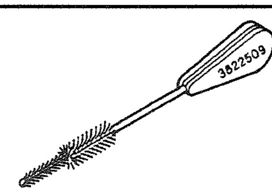
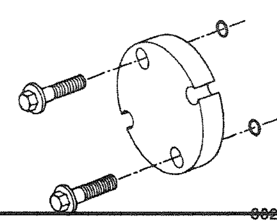
	4B3.9	4BT3.9	4BTA3.9	6B5.9	6BT5.9	6BTA5.9
Maximum Inlet Restriction to the Fuel Transfer Pump Must Not Exceed - mm Hg [in Hg]	100 [4]					
Maximum Allowable Return Line Restriction - mm Hg [in Hg]	518 [20.4]					
Maximum Allowable Pressure Drop Across Fuel Filter - kPa [psi]	35 [5]					
Maximum Inlet Pressure to the Injection Pump Must Not Exceed - kPa [psi]	70 [10]					

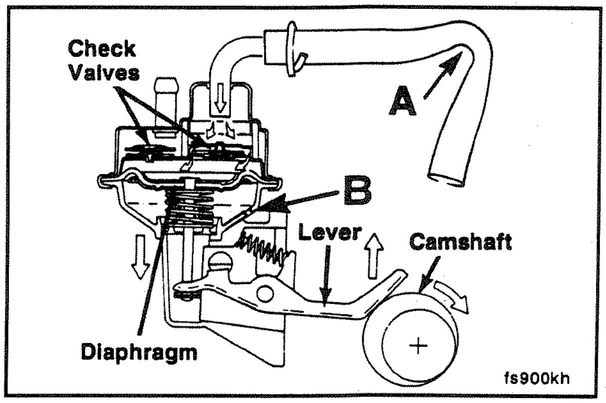
In-Line Type Fuel Injection Pumps

Maximum Inlet Restriction to the Fuel Transfer Pump Must Not Exceed mm Hg [in Hg]	100 [4]
Fuel Lift Pump Maximum Output Pressure - kPa [psi] @ Rated RPM	172 [25]
Fuel Filter Restriction (Maximum Pressure Drop Across Filters) - kPa [psi]	35 [5]
Fuel Pump Gallery Pressure - kPa [psi] Minimum @ Rated RPM	140 [20]
Fuel Return Maximum Restriction - mm Hg [in Hg]	518 [20.4]

Fuel System - Service Tools

The following special tools are recommended to perform procedures in Section 5. 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
3377259	**Bosch Timing Tool (VE)**	 3377259
3823276	**Injector Puller** Used to pull the injector.	
3822509	**Injector Bore Brush** Used to clean the injector bore.	 3822509
3824469	**Fuel Pump Gear Puller** Used to pull the fuel pump gear.	 3824469



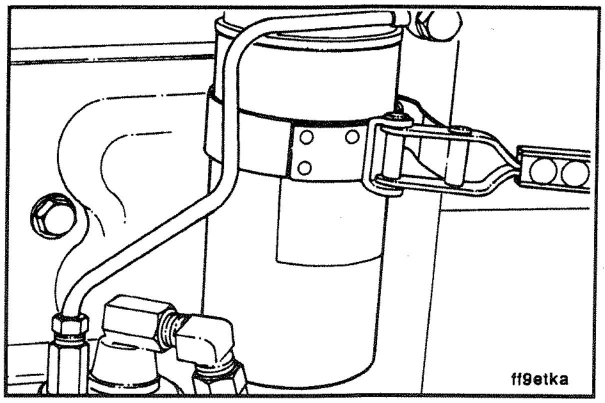
Fuel Transfer Pump (Diaphragm Style) Diagnosing Malfunctions (5-01)

A malfunctioning fuel transfer pump can cause low power from the engine. The diaphragm style pump cannot be cleaned and rebuilt.

The transfer pump is mechanically driven by a lobe on the camshaft. Wear on the lever or a damaged lobe can reduce the pumping action.

(A) - Do not operate the fuel system with a suction restriction of more than 100 mm [4 in Hg].

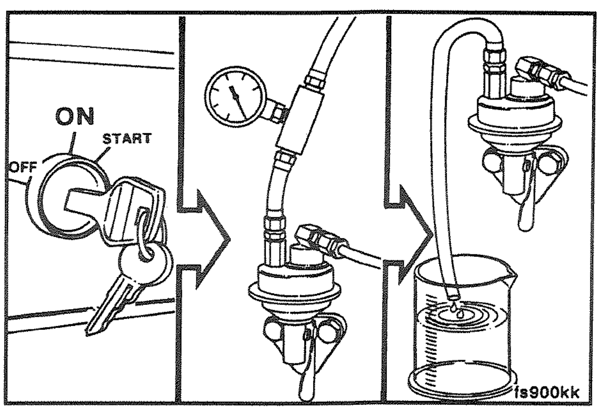
If the diaphragm ruptures, fuel will drain from the weep hole (B) in the housing.



Normal pressure drop across the filter is 21 kPa [3 psi], maximum.

The pressure drop will increase as the filter removes contamination from the fuel. Therefore, a worn transfer pump will have reduced capacity to force fuel through a dirty filter. This can cause low engine power.

NOTE: Frequent filter replacement to get full power from the engine can indicate a worn transfer pump.

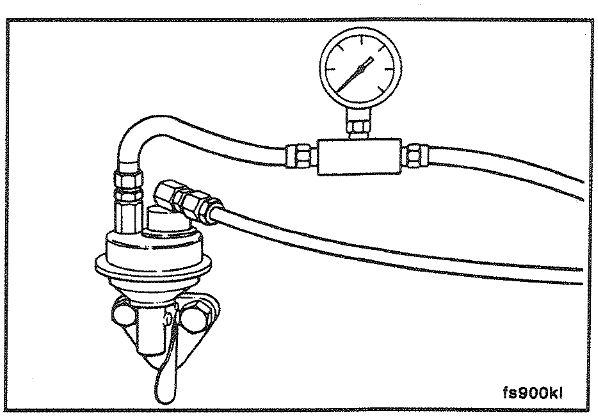


Fuel Transfer Pump - Testing (5-02)

The output of the fuel transfer pump can be checked two ways.

Test 1: Measure the output pressure using an in-line pressure gauge.

Test 2: Measure the flow volume.



Test 1: Output Pressure Test (Diaphragm Style)

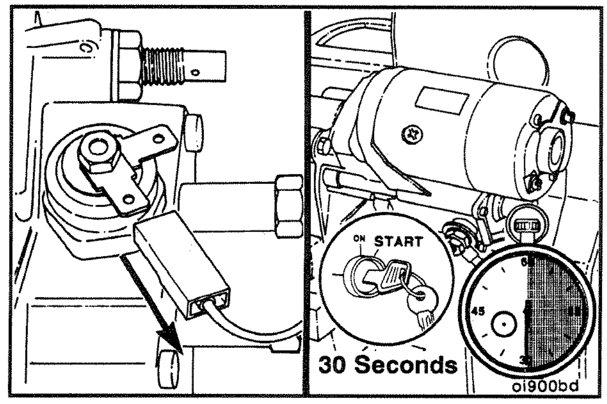
Start the engine and measure the output pressure of the fuel transfer pump using an in-line pressure gauge.

Minimum Pressure
21 kPa [3 psi]

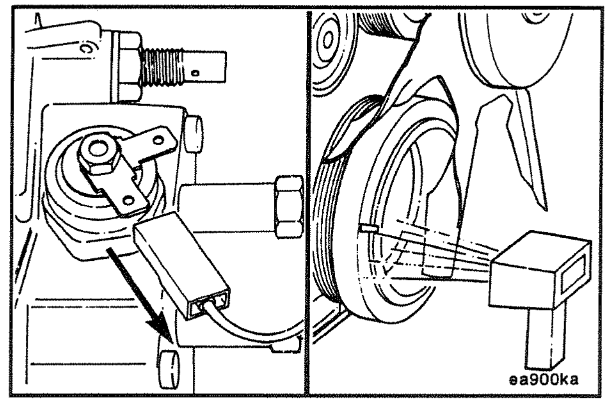
Test 2: Flow Volume Test (Diaphragm Style)

Caution: To prevent the engine from starting, disconnect the fuel shutdown wiring. Residual fuel in the injection pump may cause the engine to start.

Caution: Do not crank the starter for more than 30 seconds at a time. Doing so may result in starter damage.



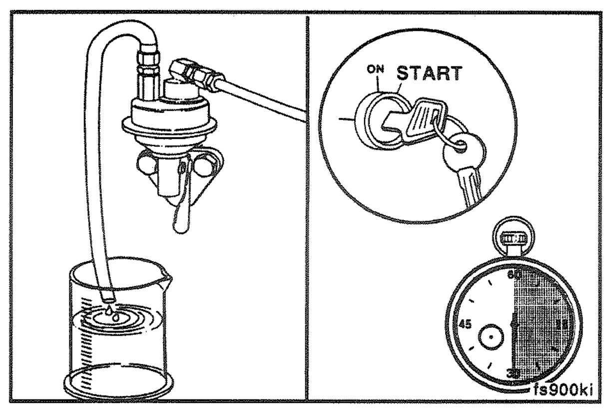
Disconnect the fuel shutdown solenoid wire and measure the engine cranking speed with a hand held tachometer (Part No. 3377462).



Caution: Leave the shutdown solenoid disconnected for the following check.

Disconnect the output pressure line from the fuel transfer pump and run it into a container.

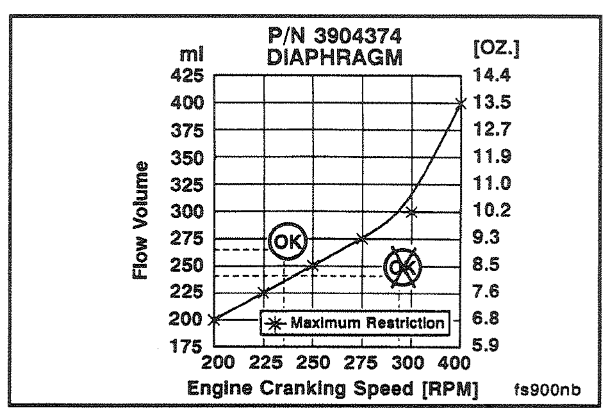
Measure the fuel transfer pump flow volume, while cranking the engine with the starter for 30 seconds.



Use the chart in the illustration to find the correct flow volume specification for the diaphragm fuel transfer pump.

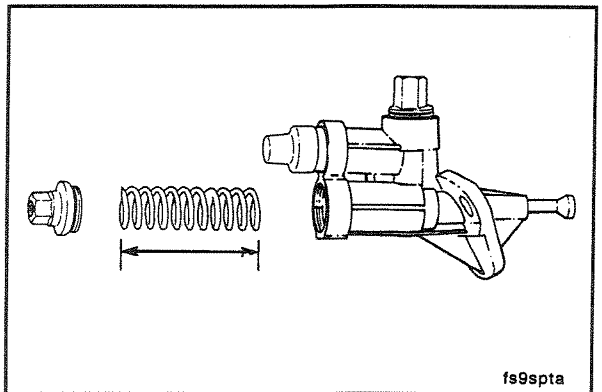
- Draw a straight vertical line above the measured cranking RPM.
- Draw a straight horizontal line from the measured flow volume to the engine cranking RPM vertical line to find the intersection point.
- Any intersection point above the required flow line indicates an acceptable flow.
- Any intersection point below the required flow line indicates unacceptable flow and a defective pump or too much line restriction.

Example 1 Good Pump	Engine cranking speed Flow volume	230 RPM 260 M1 [8.8 oz]
Example 2 Bad Pump	Engine cranking speed Flow volume	290 RPM 240 M1 [8.1 oz]



Fuel Transfer Pump (Piston Style) - Diagnosing Malfunctions

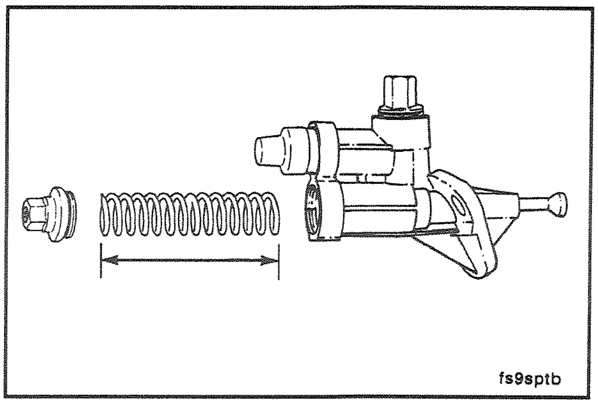
The B series engine uses three different piston style fuel transfer pumps. All three deliver different flow volumes.


fs9spta

Piston style fuel transfer pump, Part No. 3918076, is offered as an option on B series engines equipped with distributor type fuel injection pumps.

NOTE: Part No. 3918076 and 3918000 are identical in appearance. The pumping spring free length can be measured to identify the fuel transfer pump.

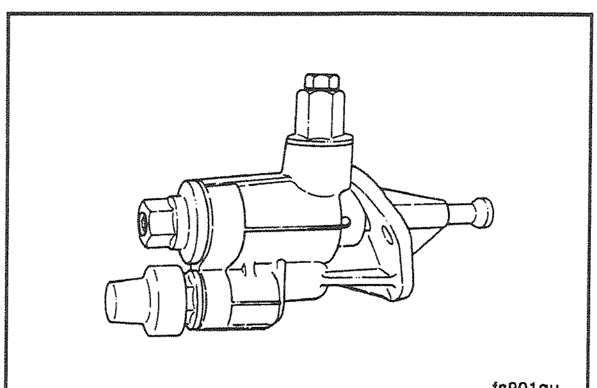
Fuel transfer pump 3918076 spring free length 53.5 mm [2 7/64 in].


fs9sptb

Piston style fuel transfer pump, Part No. 3918000, comes standard on the 300 HP marine B series engine.

NOTE: Part No. 3918076 and 3918000 are identical in appearance. The pumping spring free length can be measured to identify the fuel transfer pump.

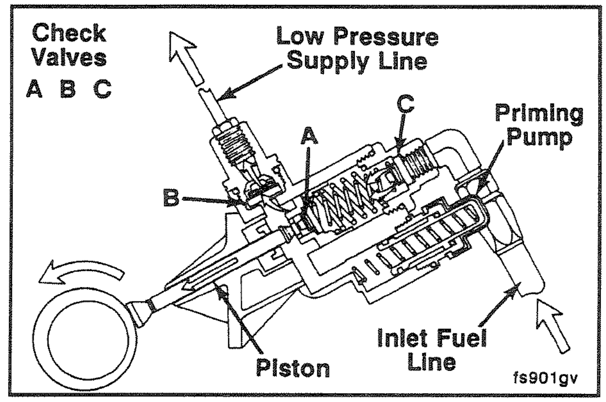
Fuel transfer pump 3918000 spring free length 58 mm [2 9/32 in].


fs901gu

Piston style fuel transfer pump, Part No. 3921550 comes standard on the 91 B series engines equipped with the Bosch P7100 in-line fuel injection pumps.

Piston style fuel transfer pump, Part No. 3925709, comes standard on the 94 B series engines equipped with the Bosch P7100 in-line fuel injection pumps.

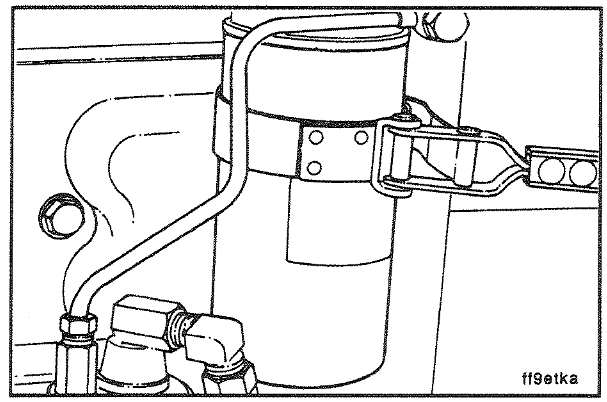
The piston style fuel transfer pump is mechanically driven by a plunger running against a special lobe on the camshaft. The fuel transfer pump contains a pumping piston and check valves to control the flow of fuel, and bleed back during engine shutdown.



Normal pressure drop across the fuel filter is 35 kPa [5 psi], maximum.

The pressure drop will increase as the fuel filter removes contamination from the fuel. Therefore, a worn fuel transfer pump will have reduced capacity to force fuel through a dirty fuel filter. This can cause low engine power.

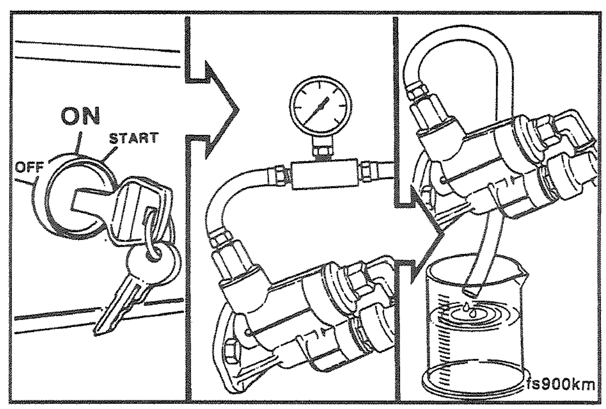
NOTE: Frequent fuel filter replacement to get full power from the engine can indicate a worn transfer pump.



The output of the piston style fuel transfer pump can be checked two ways.

Test 1: Measure the output pressure using an in-line pressure gauge.

Test 2: Measure the flow volume.

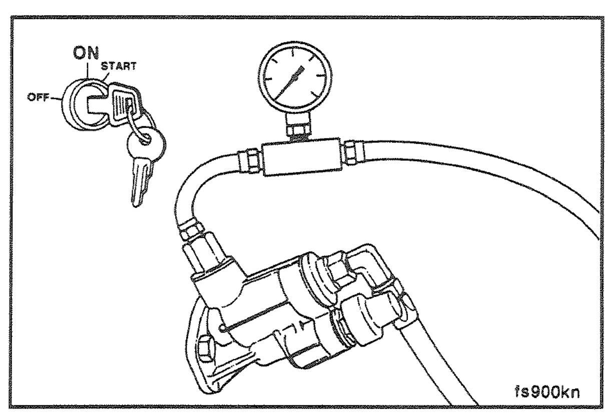


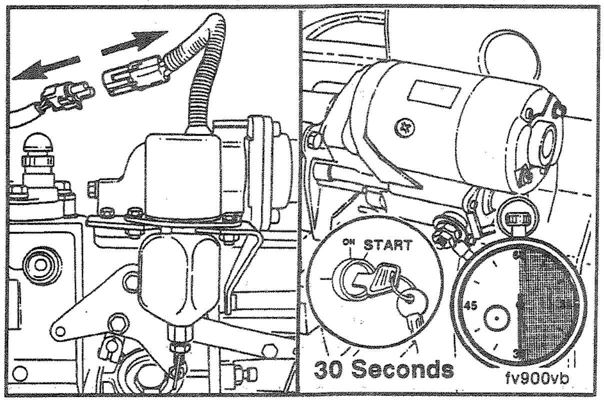
Test 1: Output Pressure Test (Piston Style)

Operate the engine and measure the output pressure of the fuel transfer pump using an in-line pressure gauge.

Minimum Pressure @ Rated Speed

172 kPa [25 psi]

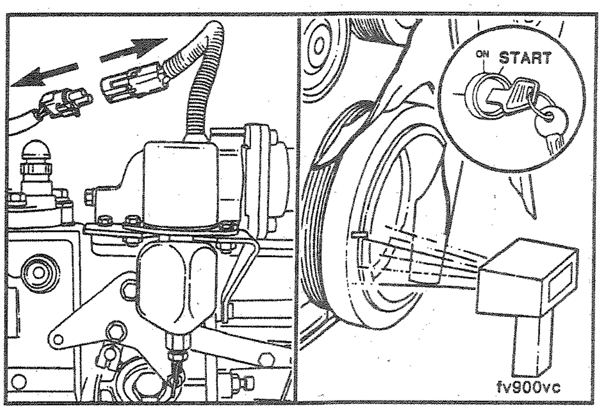




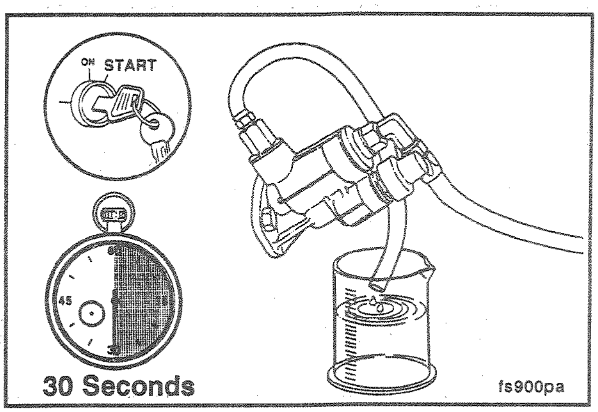
Test 2: Flow Volume Test (Piston Style)

Caution: To prevent the engine from starting, disconnect the fuel shutdown wiring. Residual fuel in the fuel injection pump may cause the engine to start.

Caution: Do not crank the starter for more than 30 seconds at a time. Doing so may result in starter damage. Also, high voltage during cranking may damage the shutdown solenoid.



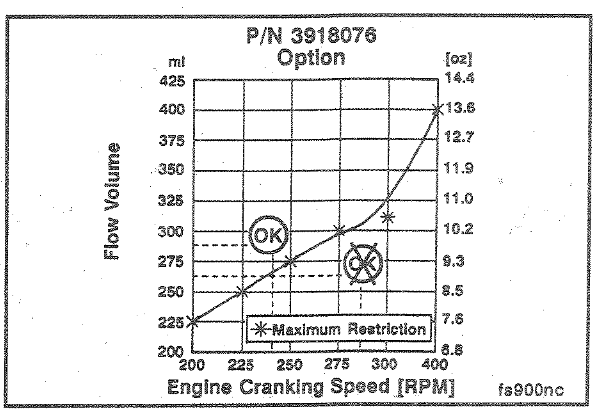
Disconnect the fuel shutdown solenoid wire and measure the engine cranking speed with a hand held tachometer, (Part No. 3377462).



Caution: Leave the shutdown solenoid disconnected for the following check.

Disconnect the output pressure line from the transfer pump and run it into a container.

Crank the engine for 30 seconds and measure the fuel transfer pump flow volume.



Use the chart in the illustration to find the correct flow volume specification for P/N 3918076 fuel transfer pump.

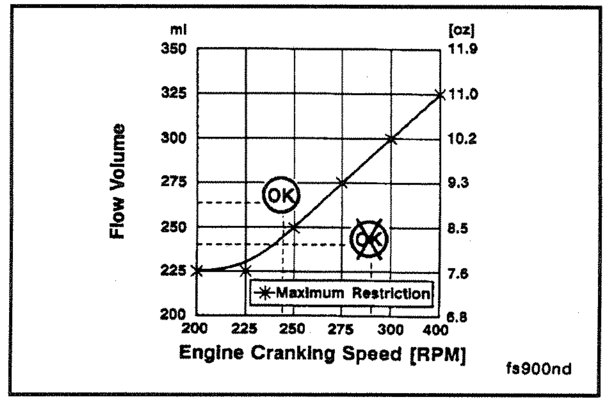
- Draw a straight vertical line above the measured cranking RPM.
- Draw a straight horizontal line from the measured flow volume to the engine cranking RPM vertical line to find the intersection point.
- Any intersection point above the required flow line indicates an acceptable flow.
- Any intersection point below the required flow line indicates unacceptable flow and a defective pump or too much line restriction.

Example 1	Engine cranking speed	240 RPM
Good Pump	Flow volume	280 M1 [9.5 oz]
Example 2	Engine cranking speed	280 RPM
Bad Pump	Flow volume	260 M1 [8.8 oz]

Use the chart in the illustration to find the correct flow volume specification for P/N 3918000 fuel transfer pump, used on the 300 HP B series marine engine.

- Draw a straight vertical line above the measured cranking RPM.
- Draw a straight horizontal line from the measured flow volume to the engine cranking RPM vertical line to find the intersection point.
- Any intersection point above the required flow line indicates an acceptable flow.
- Any intersection point below the required flow line indicates unacceptable flow and a defective pump or too much line restriction.

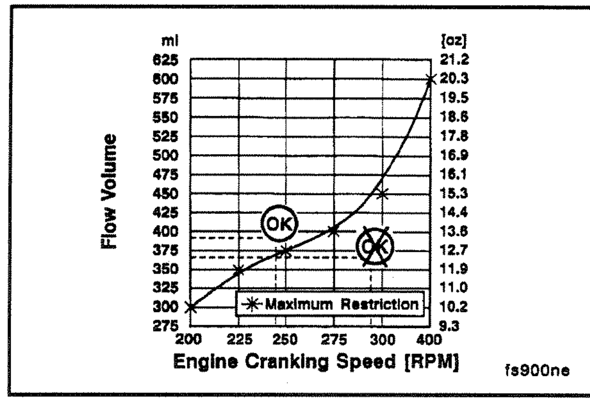
Example 1	Engine cranking speed	240 RPM
Good Pump	Flow volume	260 M1 [8.8 oz]
Example 2	Engine cranking speed	280 RPM
Bad Pump	Flow volume	235 M1 [7.9 oz]



Use the chart in the illustration to find the correct flow volume specification for P/N 3917334 fuel transfer pump, used with the Bosch P7100 in-line injection pump.

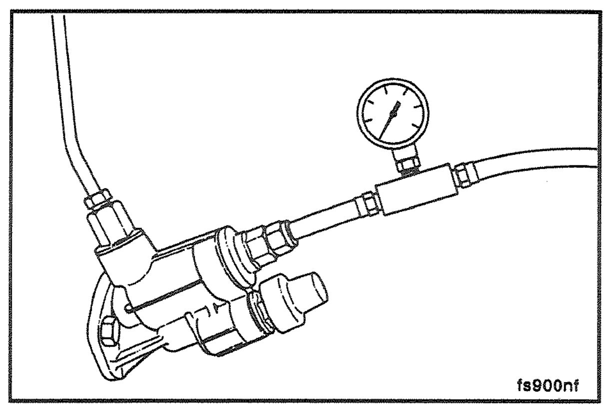
- Draw a straight vertical line above the measured cranking RPM.
- Draw a straight horizontal line from the measured flow volume to the engine cranking RPM vertical line to find the intersection point.
- Any intersection point above the required flow line indicates an acceptable flow.
- Any intersection point below the required flow line indicates unacceptable flow and a defective pump or too much line restriction.

Example 1	Engine cranking speed	240 RPM
Good Pump	Flow volume	390 M1 [13.2 oz]
Example 2	Engine cranking speed	290 RPM
Bad Pump	Flow volume	360 M1 [12.2 oz]

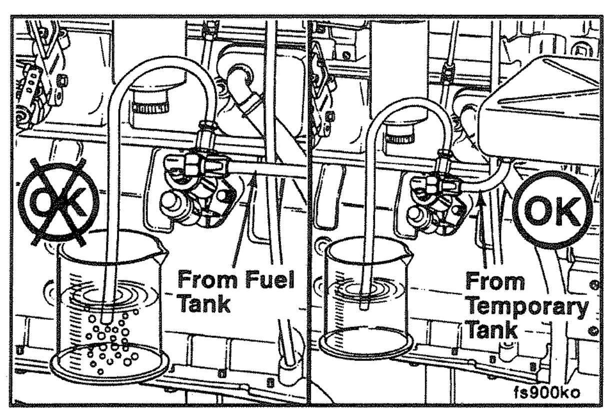


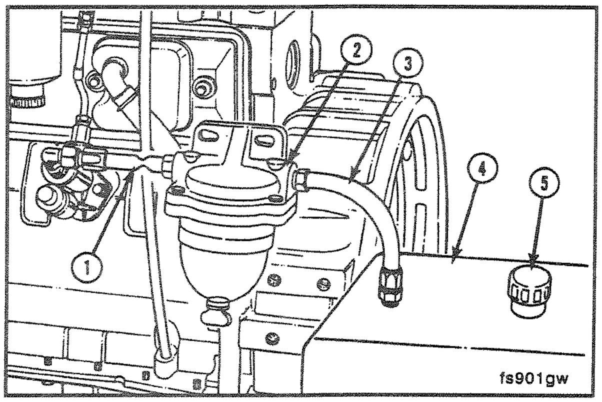
If the flow volume measured falls below the line in the respective chart above, check inlet restriction before disassembling and cleaning the fuel transfer pump.

Inlet restriction must not exceed 100 mm Hg [4 in Hg].



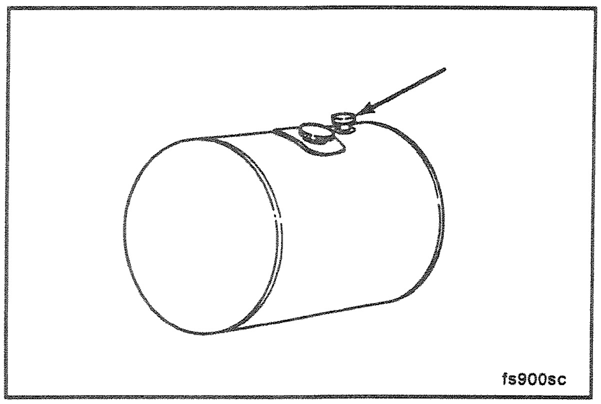
If the fuel is aerated or the volume is low, isolate the fuel transfer pump by connecting the fuel transfer pump inlet to a temporary supply and perform the same check as above.



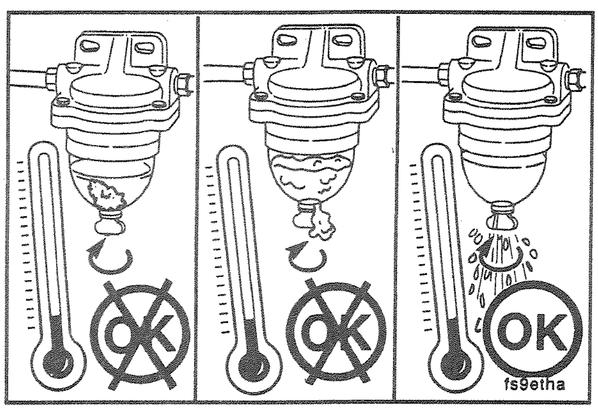


If the fuel transfer pump delivers the required volume of fuel from a temporary supply, check for restrictions or suction leaks in the fuel circuit to the fuel transfer pump:

1. Supply line
2. Pre-filter
3. Supply line
4. Supply tank
5. Tank vent

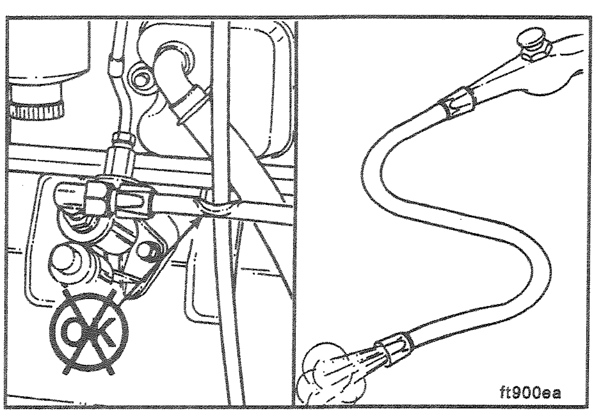


Look for a plugged supply tank vent first.



Replace or clean the pre-filter.

In cold weather look for gelled fuel blocking the pre-filter.

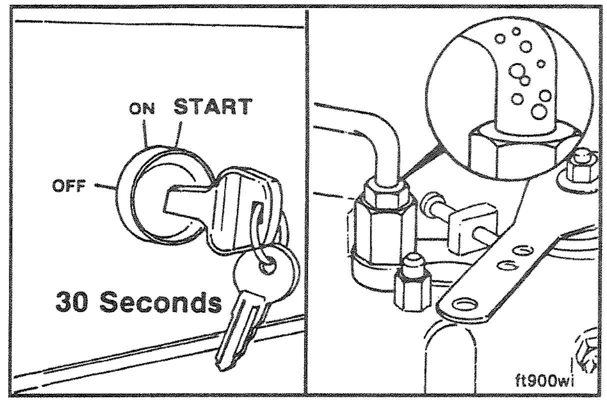


Look for kinks that can restrict the fuel supply lines.

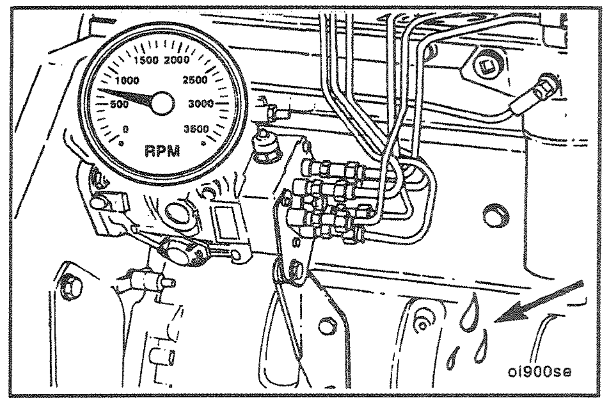
Remove and blow out the fuel supply lines.

Air In The Fuel System (5-03)

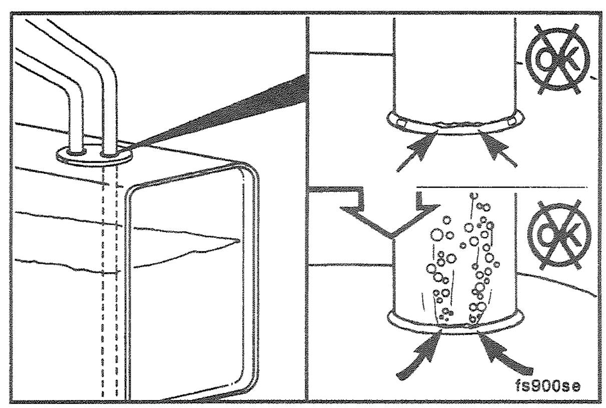
A replacement of fuel supply lines, fuel filters, fuel injection pump, high pressure fuel lines and injectors will let air enter the fuel system. Follow the specified procedure to bleed the air from the system.



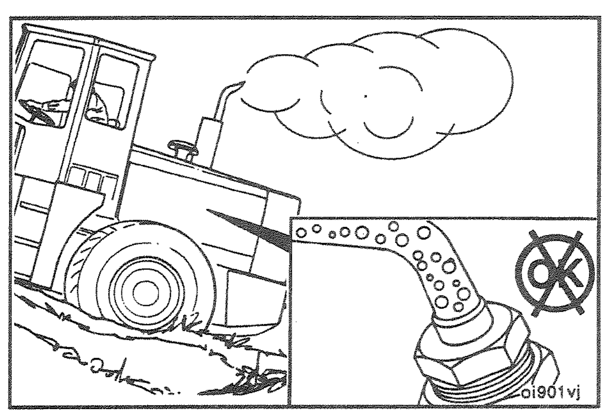
Since the fuel transfer pump provides a positive pressure through the fuel filter and fuel supply line to the fuel injection pump, loose connections or defective seals will show as a fuel leak.

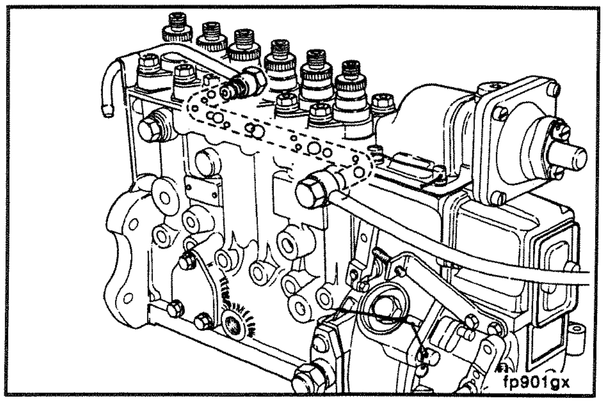


The most common place for air to enter the fuel system is between the inlet of the fuel transfer pump and the suction tube in the fuel tank. Fuel tanks that have the fuel outlet fitting at the top will have a suction tube that extends down in the tank. Cracks or pin holes in the weld that joins the tube to the fitting can let air enter the fuel system.



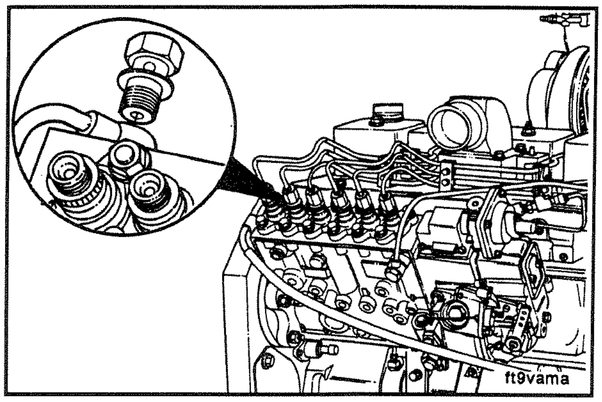
Air in the fuel system will make the engine: hard to start, run rough, misfire, produce low power, and can cause excessive smoke and a fuel knock.



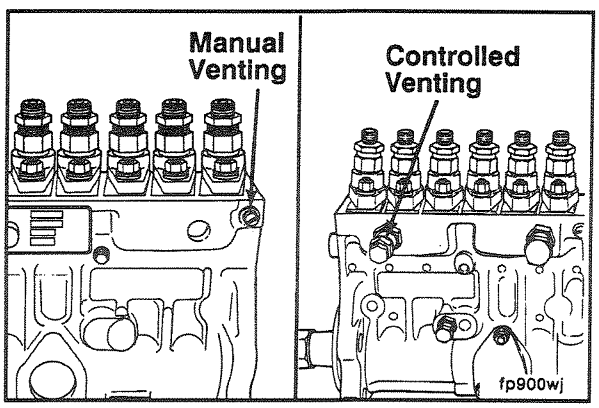


The pressure relief valve arrangement on the Bosch P7100 fuel injection pump in the supply side of the fuel circuit creates a self-bleeding system for air introduced during replacement of the supply side components.

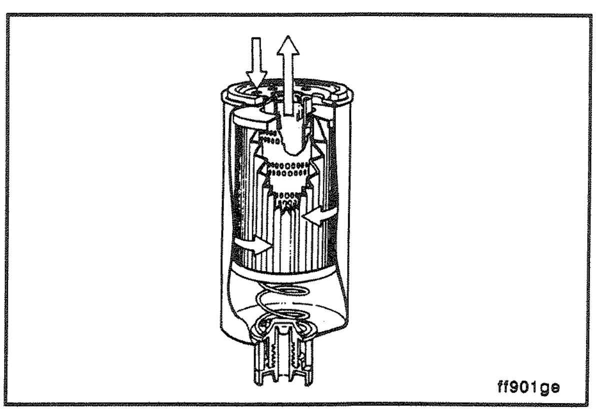
Small amounts of air can be bled from the pump by operating the hand primer on the fuel transfer pump or by cranking the engine.



The Bosch P7100 fuel injection pump has a jump-over tube to route return fuel and entrapped air from the pressure relief valve directly to the supply tank.



The Nippondenso EP-9 in-line fuel injection pumps will require additional venting prior to initial start-up, pump replacement, or if the engine has been allowed to run out of fuel.

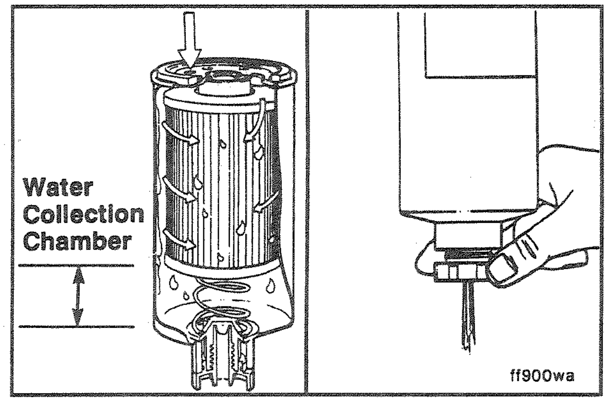


Fuel Water Separator/Filter Unit (5-04)

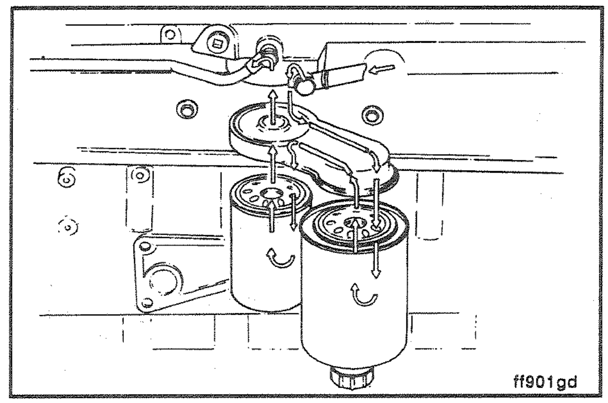
Filtration and separation of water from the fuel is important for trouble-free operation and long life of the fuel system. Some of the clearances between the fuel injection pump parts are very close. For this reason, the parts can easily be damaged by rust formation and contaminants.

Be sure to use the correct element.

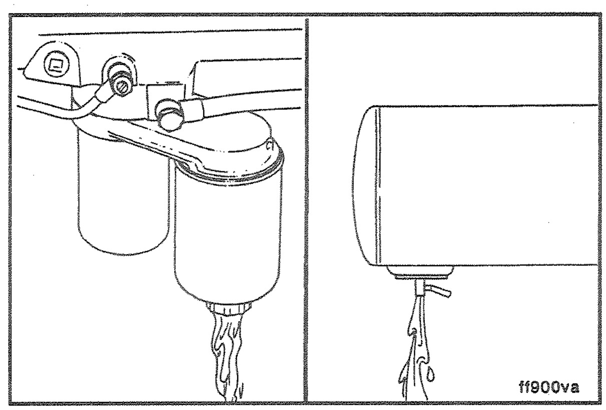
The element has a valve which can be opened regularly to drain the collected water.



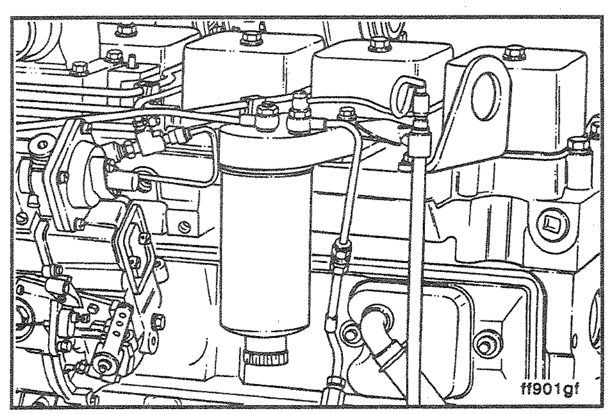
A dual water separator/filter adapter provides additional filtering capacity. The fuel flows through the adapter to a larger combination fuel water separator filter, and back to the fuel filter for final filtering.

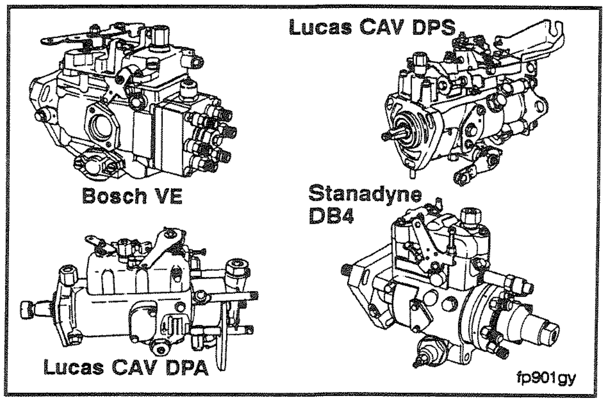


Regular maintenance, including draining moisture from the fuel water separator/filter and supply tanks, is essential to keep water out of the fuel.



1991 model and newer automotive B series engines that are equipped with the Bosch P7100 in-line fuel injection pump have the fuel filter mounted at the rear of the intake manifold, as shown.

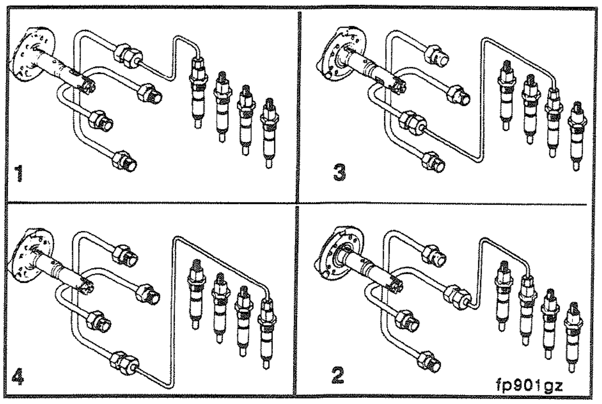




Fuel Injection Pump (Distributor Type) - Troubleshooting (5-05)

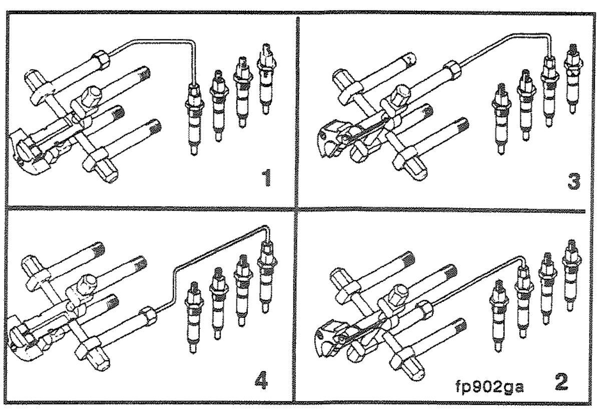
The fuel injection pumps, Bosch VE, Lucas CAV DPA, Stanadyne DB4, and Lucas CAV DPS, are rotary distributor pumps. These pumps perform the four basic functions of:

1. Producing the high fuel pressure required for injection.
2. Metering the exact amount of fuel for each injection cycle.
3. Distributing the high pressure, metered fuel to each cylinder at the precise time.
4. Varying the timing relative to engine speed.



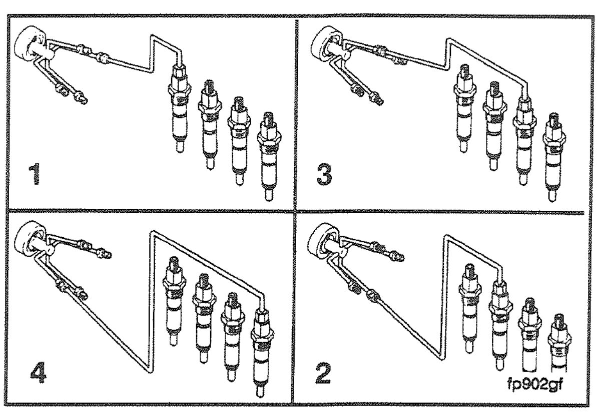
A single plunger or rotor is used by the fuel injection pumps to develop and distribute the high pressure required for injection.

A four-cylinder Robert Bosch VE fuel injection pump plunger is shown in this illustration.



A four-cylinder Lucas CAV DPA rotor is shown in this illustration.

A worn or damaged rotor or plunger can affect the pressure and amount of fuel injected, thus reducing the power from the engine. Generally, if the fuel injection pump is injecting fuel from one outlet, it will deliver from all outlets.



A single rotor with two plungers is used by the Stanadyne DB4 fuel injection pump to develop and distribute the high pressure required for fuel injection.

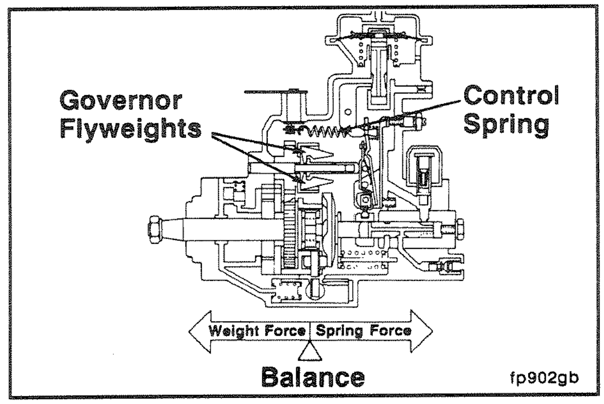
A four-cylinder DB4 rotor is shown in this illustration.

A worn or damaged rotor or plunger can affect the pressure and amount of fuel injected, thus reducing the power from the engine. Generally, if the pump is injecting fuel from one outlet, it will deliver from all outlets.

Governor Malfunctions

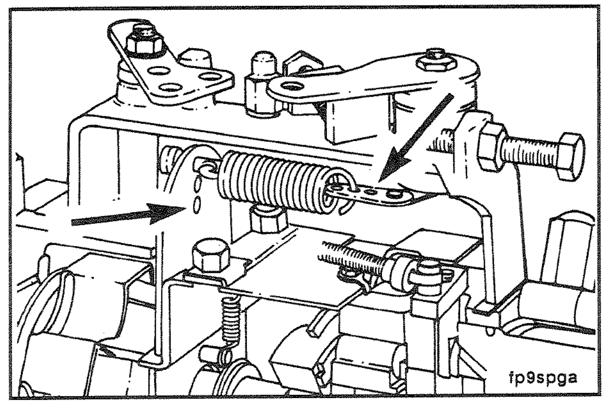
Balance between the governor flyweights and control lever position controls the metering of the amount of fuel to be injected.

The fuel injection pump governor performance and setting can affect engine power. Special equipment and qualified personnel are required to verify governor performance. If the seals are broken on the external Robert Bosch VE adjustment screw, the fuel rate may be out of adjustment.



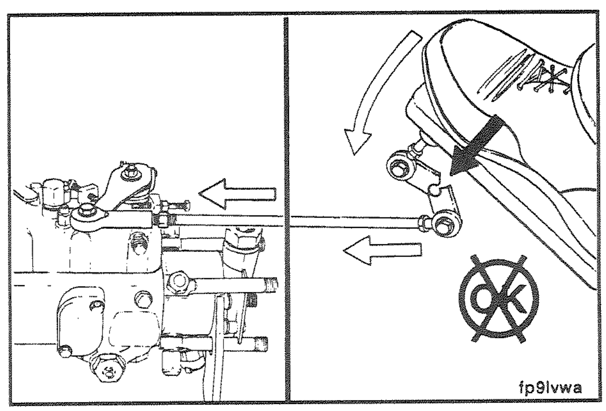
The Lucas CAV DPA/DPS fuel injection pump uses a coded spring connection to change the governor setting. Incorrect connection of the governor spring can affect performance.

Adjustments and rating changes are described in this section.



Fuel Control Lever Travel and Adjustment

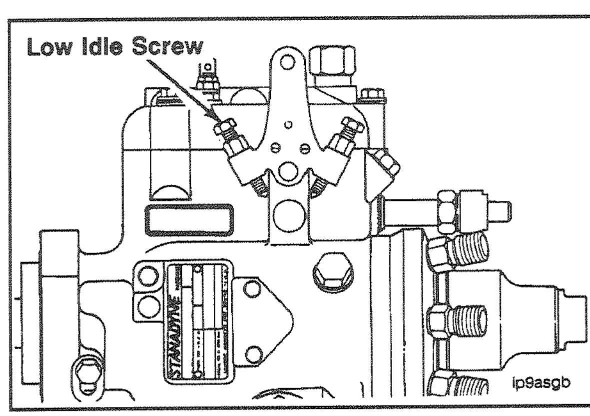
The amount of fuel injected and subsequently the speed and power from the engine is controlled by the fuel control lever. Restricted travel of the lever can cause low power. Always check for full travel of the lever when diagnosing a low power complaint.

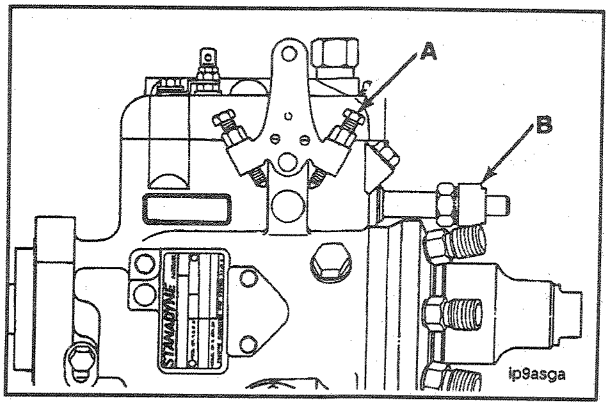


Stanadyne DB4 Fuel Injection Pump Adjustment Screw

The low idle adjustment screw on the DB4 fuel injection pump is mounted on the control lever assembly. The adjustment screw can be used to increase the idle speed to compensate for accessory loading. The low idle adjustment screw must be adjusted by an authorized service dealer and resealed.

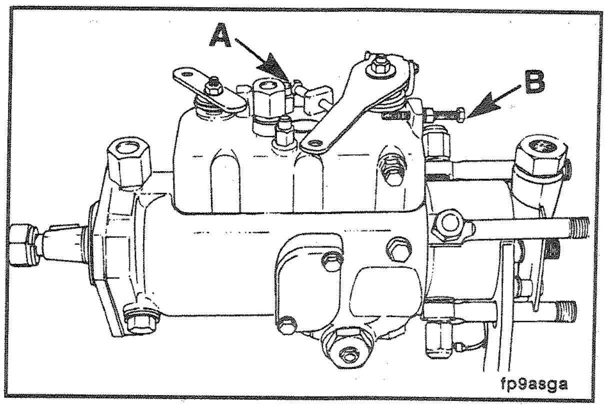
NOTE: Never turn the idle adjusting screw out (reduce idle speed) on the speed drop governor equipped fuel injection pump; this can result in disengagement of the throttle lever from the guide bushing.





The high idle adjustment screw (A) is sealed. The adjustment screw on the DB4 fuel injection pump is mounted on the control level assembly. The high idle adjustment screw must be adjusted by an authorized service dealer.

The speed droop adjustment screw (B) is located above the delivery head. The fuel pump governor sensitivity can be adjusted to increase or decrease governor regulation.

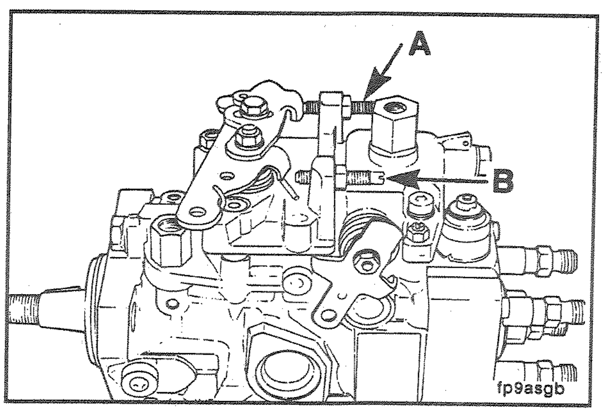


Lucas CAV DPA/DPS Fuel Injection Pump Adjustment Screws

The idle adjustment screw provides a stop for the lever at low speed. The adjustment screw can be used to increase idle speed for accessory loading or, if required, to lower the idle speed. The high idle screw is sealed and must be adjusted by an authorized repair shop, and then resealed.

A - Idle screw

B - High idle screw



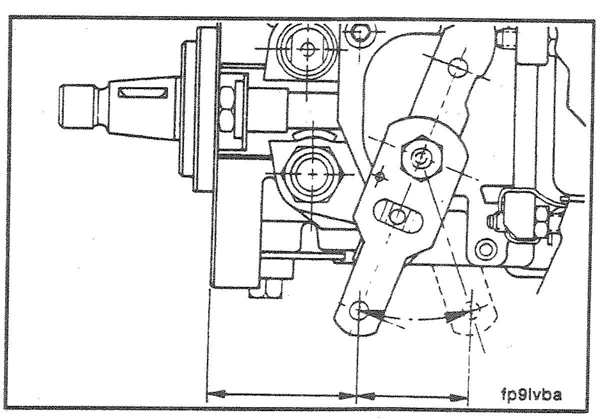
Robert Bosch VE Fuel Injection Pump Adjustment Screws

A - Idle Screw

B - High Idle Screw

The high speed adjustment screw on both fuel injection pumps provides the stop for full speed. The high speed adjusting screws are sealed. Adjustment of this screw must be performed only by an authorized fuel injection pump service center, and then resealed.

The high speed adjusting screw can be used to derate engines.

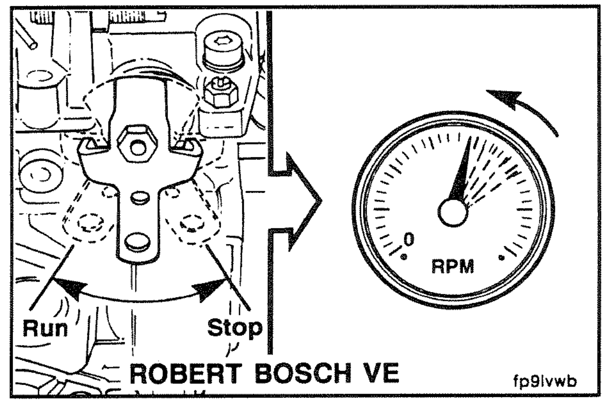


Caution: The fuel control lever on the Robert Bosch VE fuel injection pump is indexed to the shaft during pump calibration. If the lever has been removed and reinstalled incorrectly, engine speed and power will be affected.

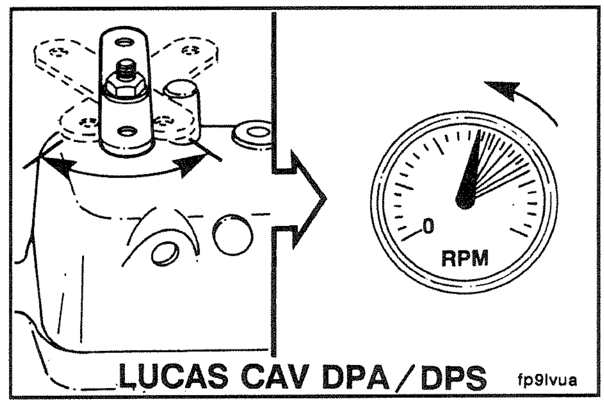
Manual Shut Down Levers

Both fuel injection pumps are equipped with mechanical shut down levers. These levers are spring-loaded in the run position. Not all applications will use these manual shut down controls and there will be no cable or rod connected to the lever.

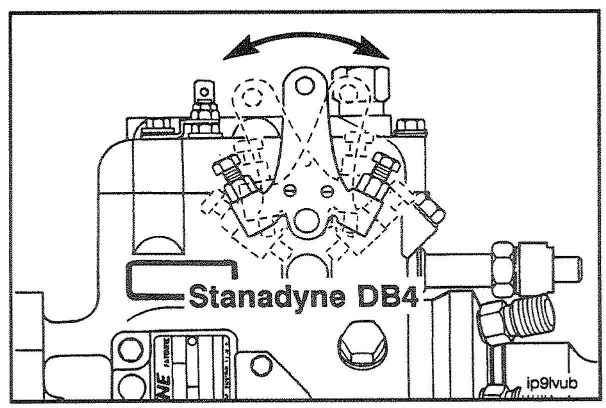
NOTE: Partial actuation of the mechanical shut down levers will affect fuel flow and engine power.



Low power or the inability to stop the engine with the manual shut down control can be corrected by adjusting the cable/rod length to permit stop-to-stop lever travel.



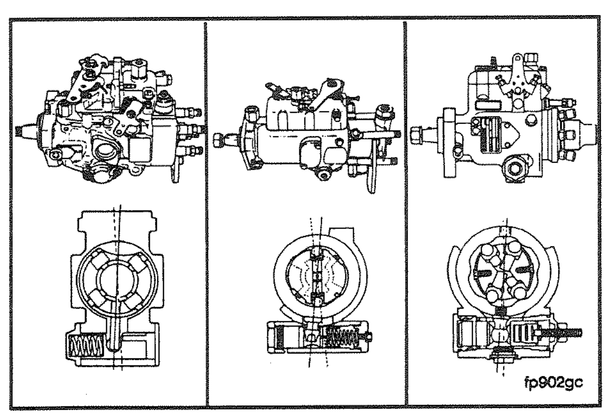
Low power or the inability to stop the engine with the manual shut down control can be corrected by adjusting the cable or rod length to permit stop-to-stop lever travel.

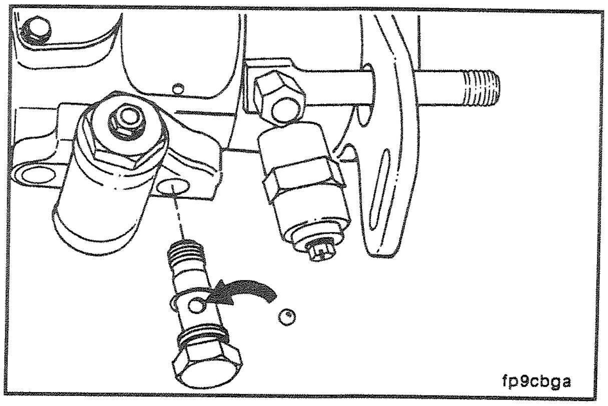


Advance Timing Mechanism

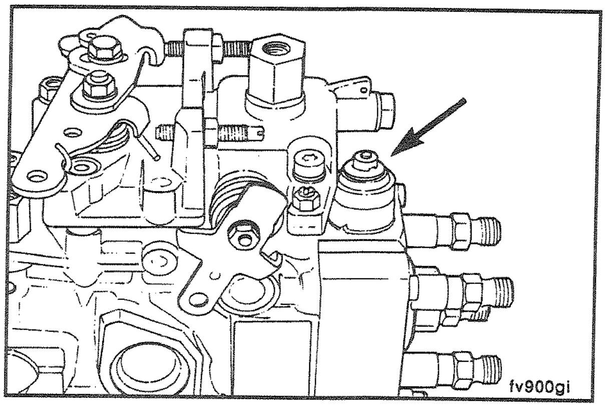
Regulated pressure produced by a vane supply pump in both fuel injection pumps is used to advance the timing as the engine speed increases. A return spring is used to retard the timing as the engine speed is reduced. If a spring should break, the timing will go to the advance position resulting in torque loss, a fuel knock and possible engine overheating.

Retarded (late) timing will result in torque loss, high fuel consumption and white to black smoke.





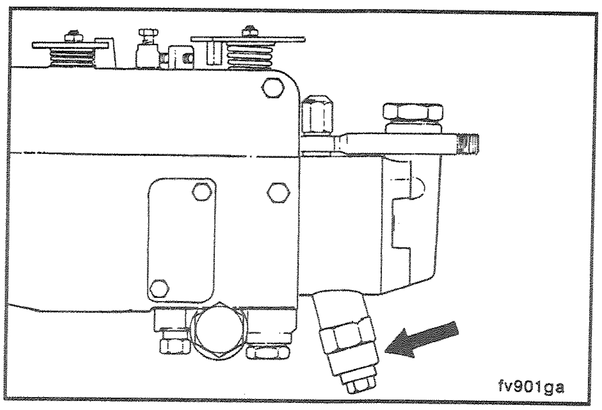
The Lucas CAV DPA/DPS advance timing mechanism uses a check ball in the circuit which, if omitted during assembly, will result in no timing advance. If the fuel injection pump has been replaced or the mechanism has been removed to fix a leak, the problem can be that the check ball is missing.



Electrical Shut Off Valves

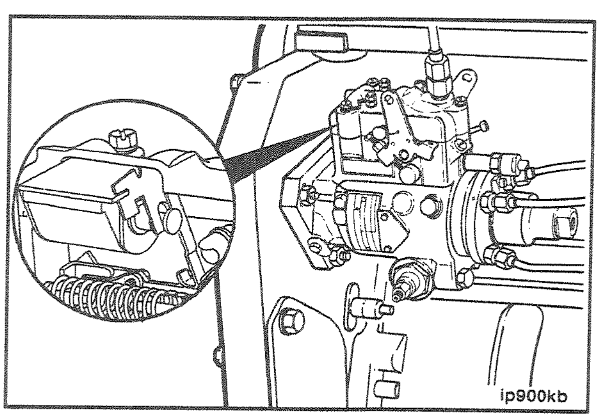
The fuel injection pumps are equipped with electrical shut off valves. These solenoid-operated valves block the supply of fuel to the high pressure pumping and distribution components.

The Robert Bosch VE shut off valve is located at the top, rear of the pump.



The Lucas CAV DPA/DPS shut off valve is located at the bottom rear of the pump.

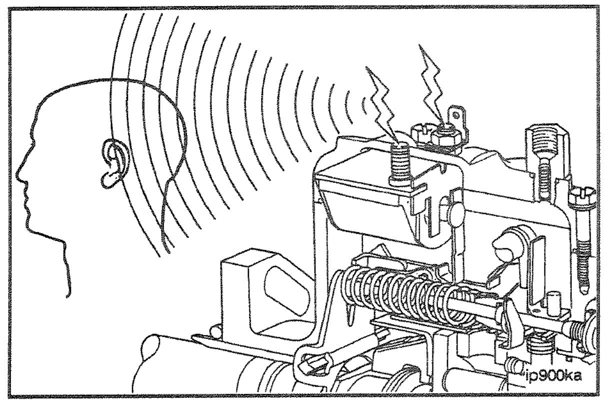
Both 12 and 24 volt activate-to-run and activate-to-stop solenoids are available.



The Stanadyne DB4 shut down solenoid is located under the governor cover.

Both 12 volt and 24 volt energize-to-run and energize-to-stop solenoids are available.

Test the shutdown solenoid on the Stanadyne DB4 fuel injection pump by applyng an electrical current to the terminals and listening for an audible "click". If a solid "click" is heard, the solenoid is operating freely.



Caution: Do not check energize-to-run solenoid operation with governor cover removed from the fuel injection pump.

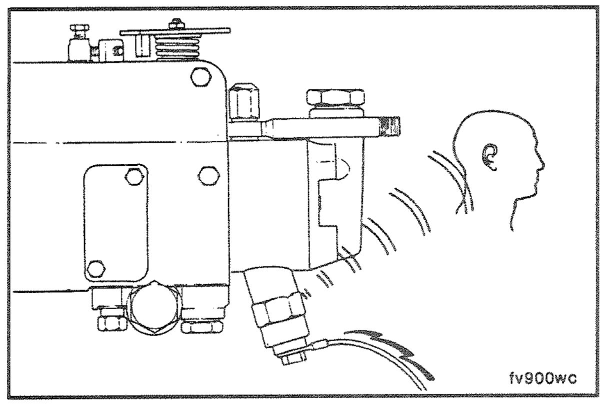
Use the following values to check energize-to-run solenoids with an ohmmeter:

Stanadyne DB4 Solenoid

Volts	Volts to Energize (Minimum)
12	8.8
24	17.6

When the valve on the Lucas CAV DPA/DPS pump opens, a "click" can be heard.

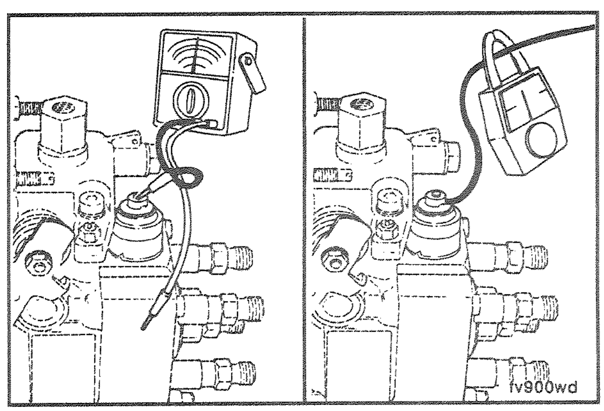
Use the following values to check the solenoid with an ohmmeter.



CAV Solenoid Values

Volts	Resistance Ohms	Volts to Energize (Minimum)
12	9 @ 22°C [71.6°F]	9
24	36 @ 22°C [71.6°F]	18

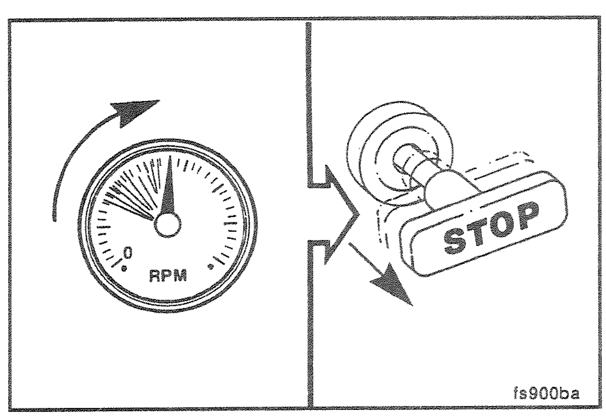
The Robert Bosch valve does not make a very audible sound when actuated, but it can be checked with an ohmmeter for the following values:

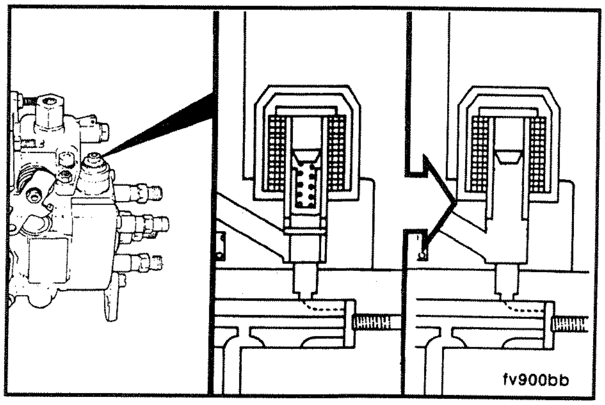


Robert Bosch Shut Down Values	Resistance Ohms	Peak Amperes
12 Volt	7.4 + 0.5	2
24 Volt	29.5 + 2.5	1

Caution: Do not connect the electrical wire to the solenoid when the plunger has been removed. Without the plunger, the valve can be damaged.

Malfunctioning valves and electrical wiring to the valve can be diagnosed by removing the plunger and spring, then reinstall the solenoid.

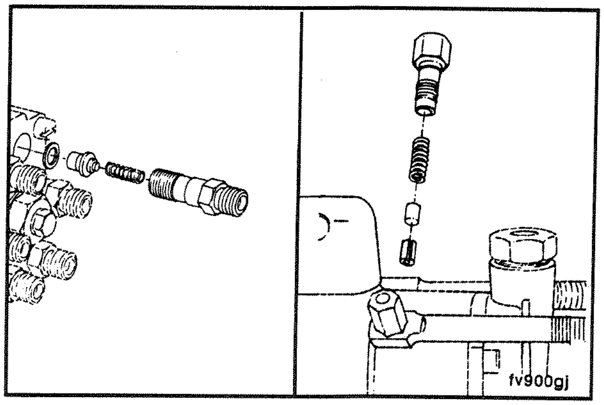




Caution: Use the mechanical shut down lever to stop the engine.

If the engine will start without the valve, the valve or the wiring to the valve is malfunctioning.

This method of removing the plunger to start the engine can be used if necessary to move the equipment to a service location.



Delivery Valves (Back Leakage Valves On Lucas CAV Pumps)

There is a valve for each discharge tube. The purpose of the valve is to control the residual pressure in the high pressure line. A malfunctioning valve will cause an imbalance of the residual pressure resulting in rough engine operation or surging.

Stanadyne DB4 (Generator Application) (5-06)

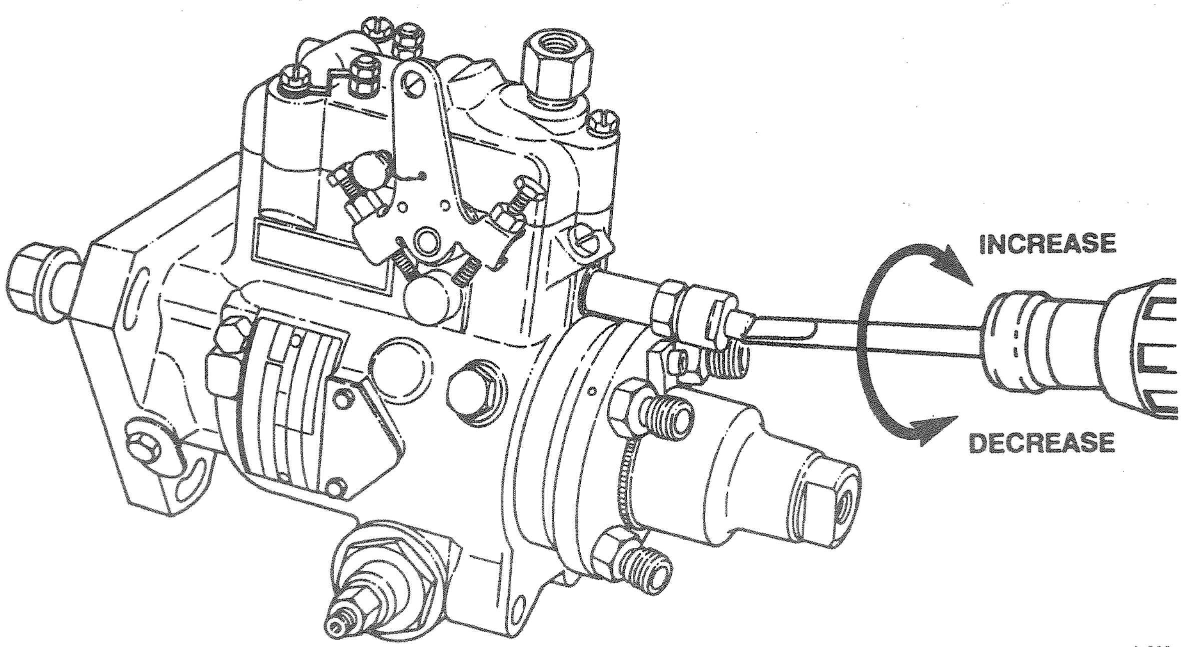
Speed Droop Governor - Adjustment

Governor regulation of 3 percent to 5 percent can be attained with the speed droop governor. Precise control of governor regulation is done by decreasing or increasing the effective length of the governor control spring, this also decreases or increases the spring control spring rate. The governor control spring is threaded into an adjusting cap assembly and is referred to as the control rod assembly. By turning the adjusting cap in the clockwise direction, as viewed from the fuel transfer pump end, the control rod spring shortens and becomes less sensitive, thereby increasing governor regulation. Turning the adjusting cap in the counter-clockwise direction increases the control rod spring length and sensitivity which will decrease governor regulation.

The external speed droop adjustment screw, located at the rear of the fuel injection pump housing, controls the governor sensitivity. The droop screw adjustment varies the governor regulation by changing the effective spring rate. This adjustment will affect both full load and no load frequency settings and may require that the high speed stop screw be reset.

Speed droop adjustments must be made while the engine is operating. After each adjustment of the droop screw, the engine must be shut down briefly in order to allow the governor spring to unload and the adjusting mechanism to seek its final position in the spring. Turning the screw in shortens the control spring, making it less sensitive and increases speed droop. Turning the adjusting screw out has the opposite effect. Speed droop is the fuel injection pump's ability to respond to changing engine loads.

Adjust the governor as follows:



Speed Droop Adjustment

1. Operate the engine until normal operating temperature is obtained (195°F).

   Note: If serious surging occurs during the warm-up period, turn the speed droop adjusting screw clockwise until the surging stops.

2. When the engine reaches operating temperature, position the throttle to attain rated speed and apply 100 percent load. Adjust the throttle position as necessary to obtain 100 percent performance.

3. Remove the load and check for the specified no-load or, in the case of a generator set, note the frequency. If the no-load speed is incorrect, loosen the locking cap and adjust the speed droop adjusting screw (clockwise for increased droop, counter-clockwise for less droop). If surging occurs when the load is removed, turn the adjusting cap clockwise to eliminate the surge. Tighten the locking cap to secure the adjusting screw.

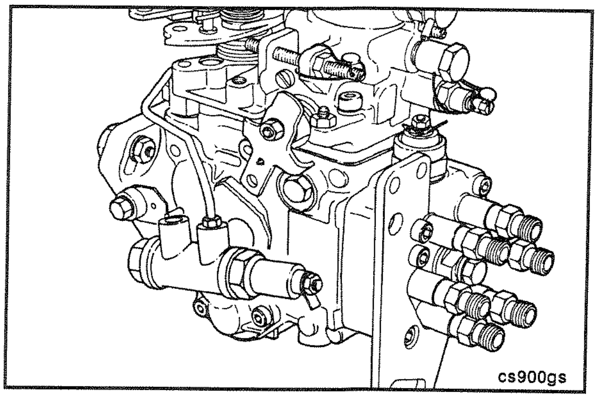
   Note: When the speed droop adjustments are made, it is necessary to adjust the throttle position.

4. Check the 100 percent load and no-load performance again and make adjustments as necessary.

Cold Start Timing Advance System (KSB) - Wax Motor Style (5-07)

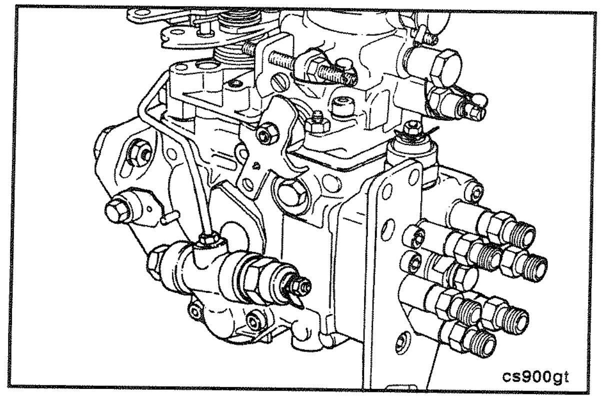
The wax motor style KSB is used on pre-1991 B series automotive engine ratings using the Bosch VE fuel pump.

NOTE: The electrical solenoid style KSB is used on 1991 model and newer B series atuomotive engine ratings using the Bosch VE fuel injection pump. See Procedure (5-08), Cold Start Timing Advance System (KSB) - Electrical Solenoid Style, for additional information.



Wax Motor Style KSB

Note: Temperature switch is located in coolant jacket.



Electrical Solenoid Style KSB

Note: Temperature switch is located in intake manifold.

Need For KSB on 1988 VE Pumps

1988 emission requirements prompted the need for a cold start timing advance system (KSB) to minimize white smoke.

After the engine starts, the wax motor style KSB fully advances the ignition timing at low idle until the engine warms up. The KSB is not functional after the engine reaches 160°F coolant temperature.

VE Pump Timing Advance Principles (Without KSB)

Pump housing pressure acts on an internal timing piston (1), Figure 1, to partially advance the injection timing at idle, and fully advance the timing when the engine RPM reaches approximately 60% of rated speed. As pump pressure increases, timing advances.

The pump housing pressure is controlled by the pressure regulator valve (2) (a spring loaded slider valve). The valve is shown in the open and closed position.

When housing pressure is low, the spring (3) forces the slider (4) into the closed position. This permits the housing pressure to increase by preventing fuel draining through the return passage (5).

As housing pressure increases, it forces the slider (4) to compress the spring (3). This action opens the return passage (5) and relieves the housing pressure.

A relief port (6), located on the spring side of the slider valve, allows fuel that seeps past the slider (4) to drain. Relief port drainage is necessary to avoid a hydraulic lock of the slider valve, which would render the pressure regulator valve (2) inoperable. In fact, it is this characteristic that is used in conjunction with the KSB to advance the timing during cold engine operation.

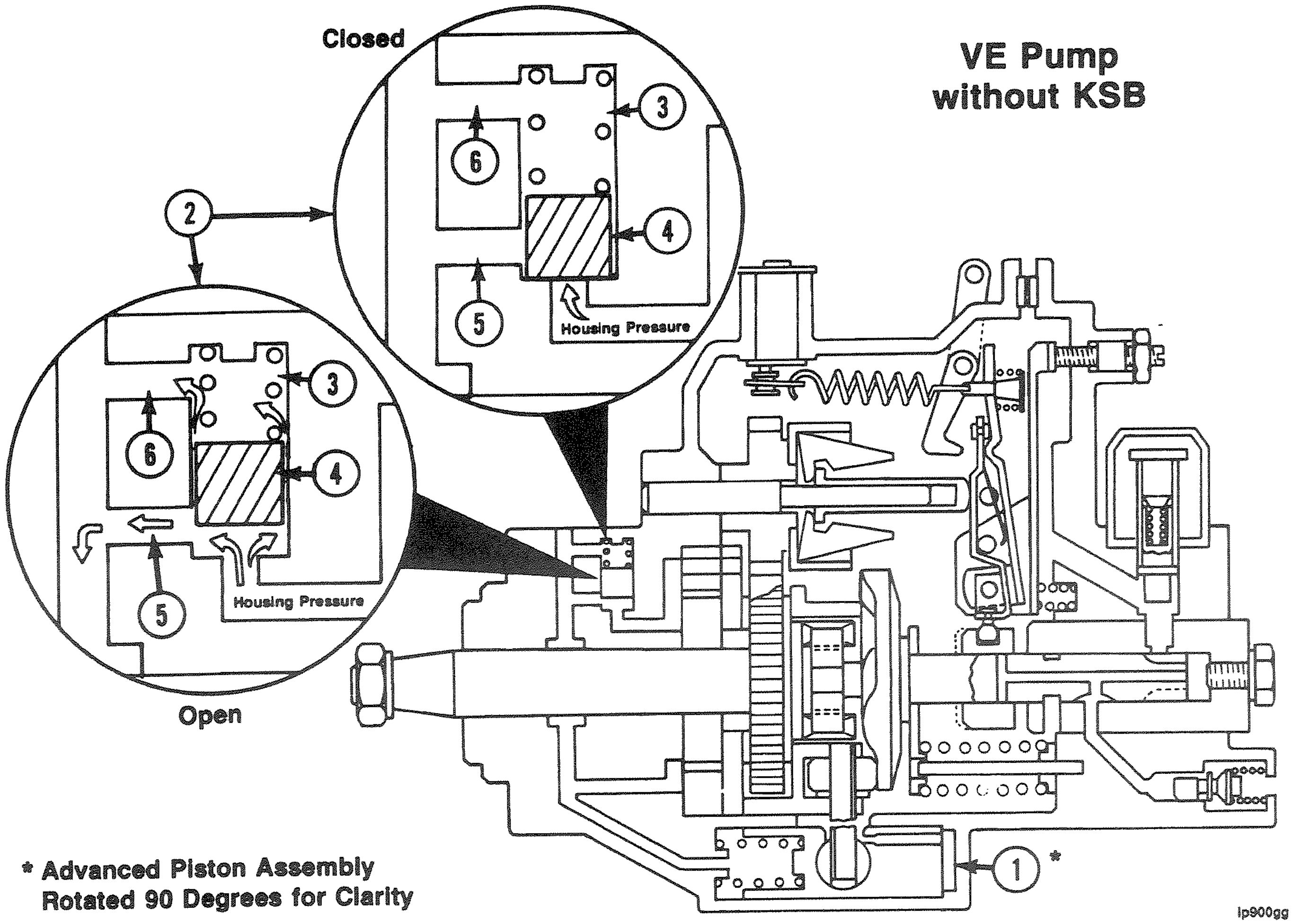


Figure 1, VE pump timing, regulated by opening and closing the pressure regulator valve.

VE Pump Timing Advance Principles (With Wax Motor KSB Installed)

The KSB introduces a new fuel line (1), Figure 2, which routes fuel from the relief port (2) of the pressure regulator valve (3) to a pressure holeing valve (4), bypassing the normal return passage (6), Figure 1.

The pressure holding valve (4), Figure 2, is closed when the engine is cold. When the engine starts, the pressure regulating valve (3) attempts to regulate fuel pressure as before (without KSB) but the fuel from the relief port (2) now meets a 'dead end' at the closed pressure holding valve (4). This action hydraulically locks (closes) the pressure regulator slider valve (4), Figure 1.

Housing pressure (5), Figure 2, is not regulated because the pressure regulator valve (3) is inoperable and so the pressure continues to increase. This action fully advances the timing. The timing remains fully advanced until the pressure holding valve (4) is opened.

The pressure holding valve (4), Figure 3, is opened by the expansion of an internal wax pellet (6). When the wax pellet expands, it causes the pin (7) to extend and open the pressure holding valve (4). The wax pellet is expanded by a resistance heating element. This element is wired to the shut down solenoid valve (8) and receives current when a thermal switch (9) in the engine block is closed. This switch actuates at 160°F.

Fuel from the relief port of the pressure regulating valve now has a drain path (10) through the pressure holding valve (4) (which is now open) to an alternate drain. The pressure regulator valve resumes normal operation and the injection timing is regulated accordingly.

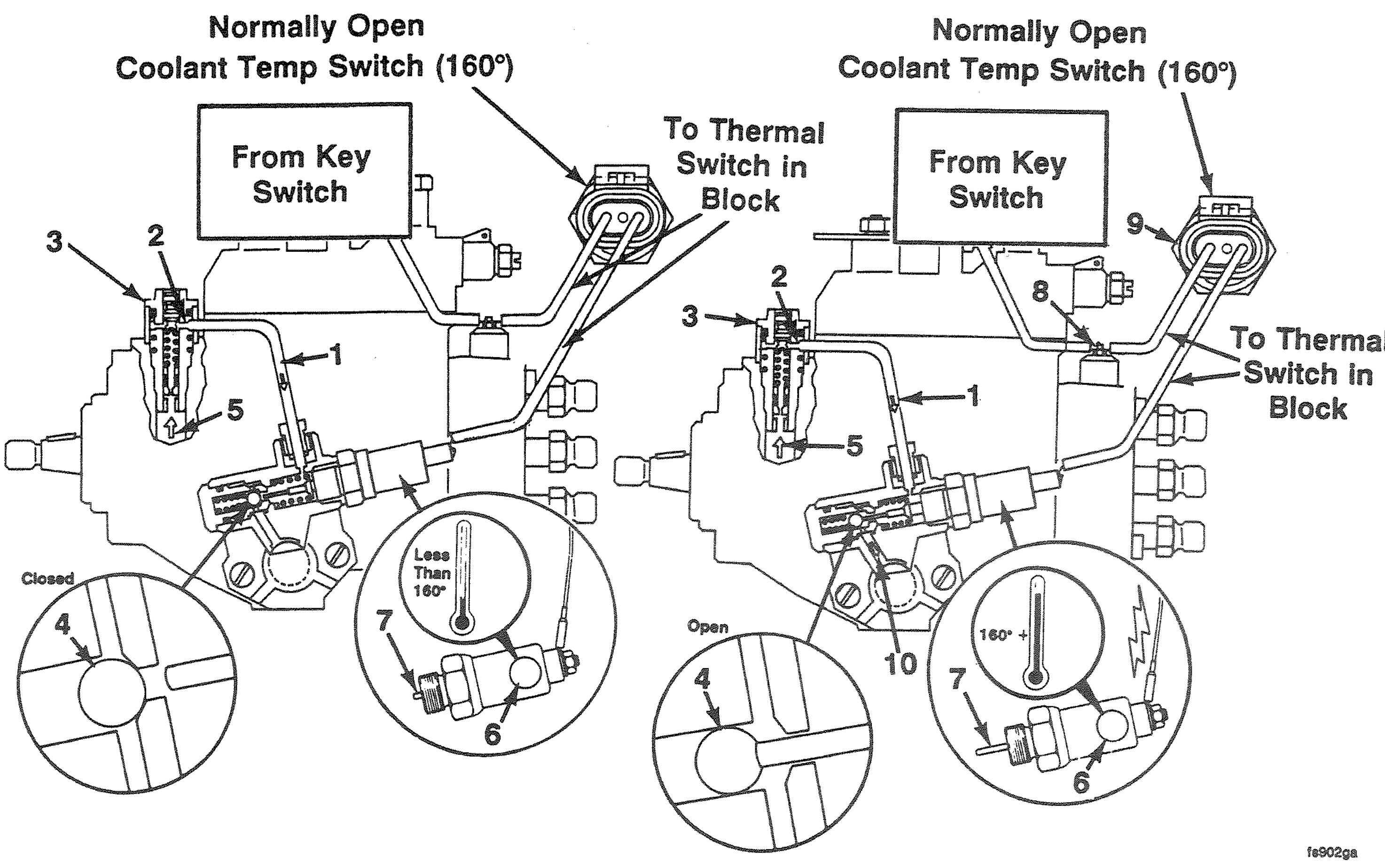


Figure 2, Cold engine operation (pressure holding valve closes, no pressure regulation, advanced timing).

Figure 3, Warm engine operation (pressure holding valve open, pressure regulator valve regulates pressure, normal timing).

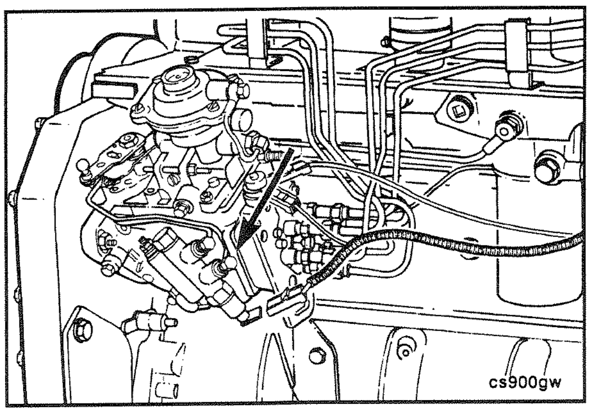
KSB Hardware Definition

There are currently two versions of pump mounted wax motor style KSBs released in the Cummins system and one remote mounted version. The remote mounted option is necessary in applications where the pump mounted KSB causes interference (i.e. with the air compressor, etc.).

Pump Mounted KSBs

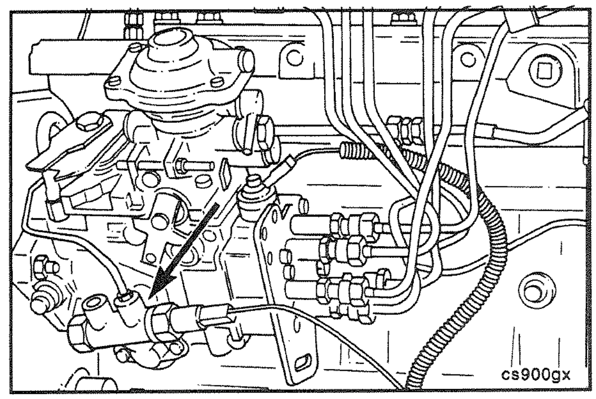
The early pump mounted KSB is a different design using two control lines. The two line version was superseded in mid-1988 with a one control line version which is the current design used for both production and service.

There is no remote mount hardware available for the two control line KSB so they cannot be remote mounted.

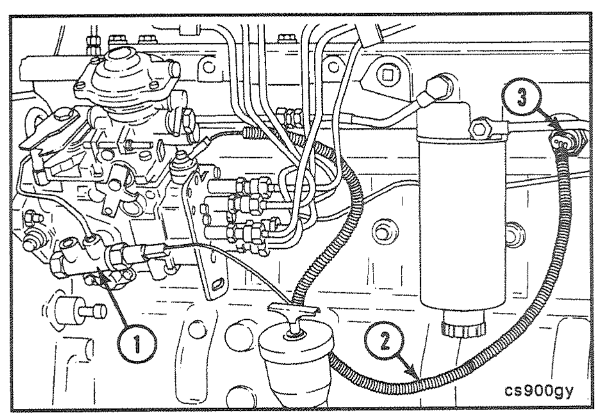


Two Control Line KSB

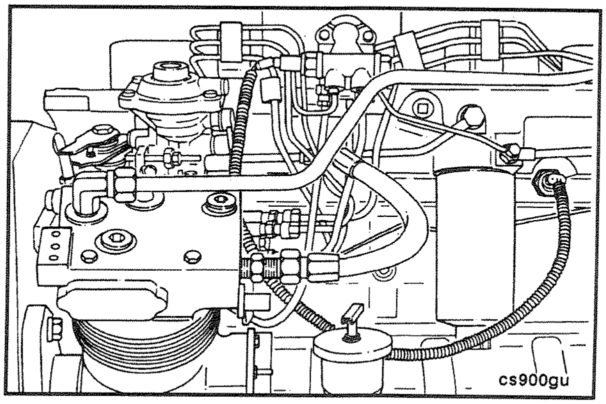
1. KSB (one control line).
2. Wiring Harness
   Part Number 3918364 (4B)
   Part Number 3918431 (6B).
3. 160°F Temperature Switch
   Part Number 3915945



One Control Line KSB

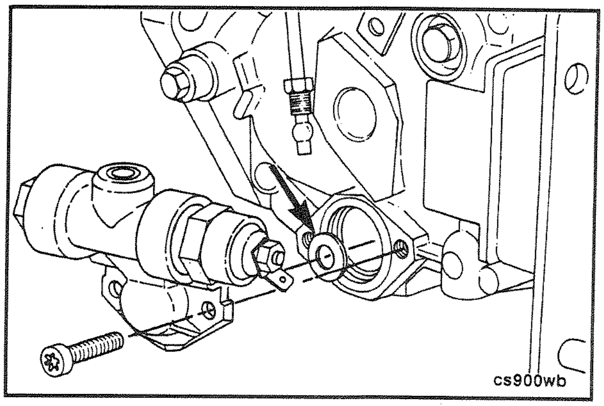


Pump Mounted Wax Motor Style KSB

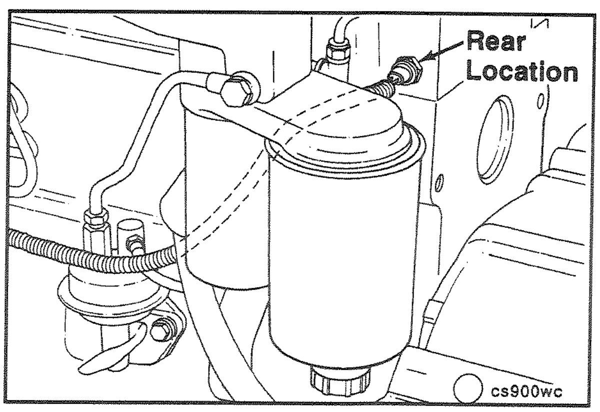


Remote Mounted KSB

The remote mounted KSB is used on B series automotive engines which have an air compressor.



Caution: Most pumps will have a shim between the KSB and the timing piston. This shim must be reassembled between the cover plate and the timing piston. If this shim sticks to the KSB and is installed with the remote mounting hardware, it will block the regulating valve drain path and damage the pump. This damage is usually evidenced by a fuel leak.

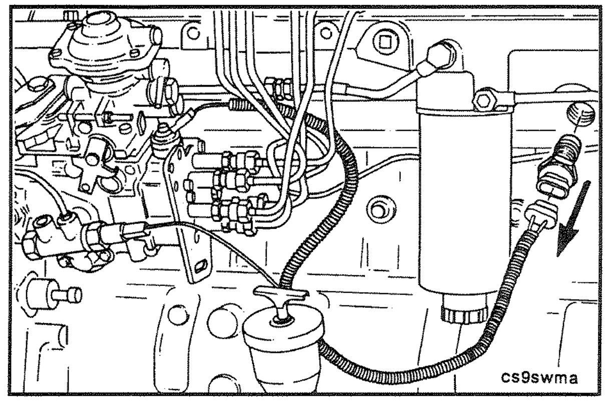


The four cylinder engine using remote mounting requires the temperature switch to be installed in the cylinder head as illustrated.

Troubleshooting The Wax Motor Style KSB

27 mm

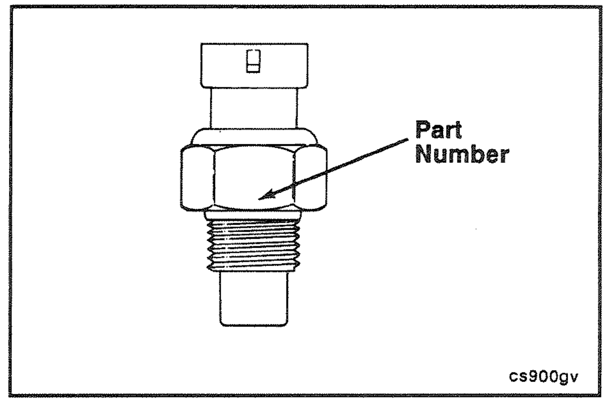
Remove the temperature switch.


cs9swma

Caution: The switches are not interchangeable. White smoke will be present if the wrong temperature switch is used.

Notes:

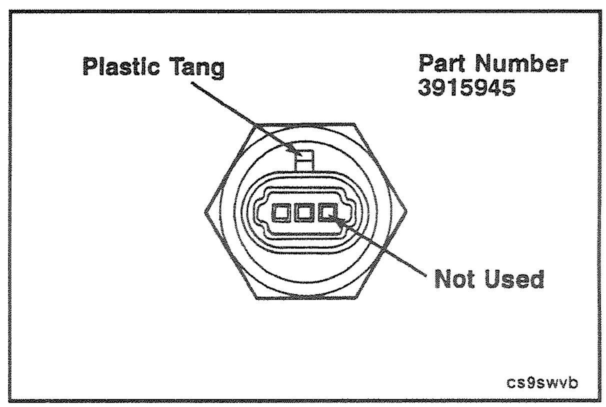
1) The wax motor KSB (used on pre-91 engines) uses a 160°F [71°C] normally open coolant temperature switch, Part No. 3915945.
2) The electrical solenoid style KSB (used on 91 models and newer) uses a 90°F [32°C] normally closed intake manifold temperature switch, Part No. 3921642.



cs900gv

The operation of the temperature switch for the wax motor style KSB can be checked by connecting a volt ohmmeter to the switch, placing the switch in water, and then heating the water to 160°F [71°C].

Connect the VOM to the two pins on the left when viewed with the plastic tang on top.

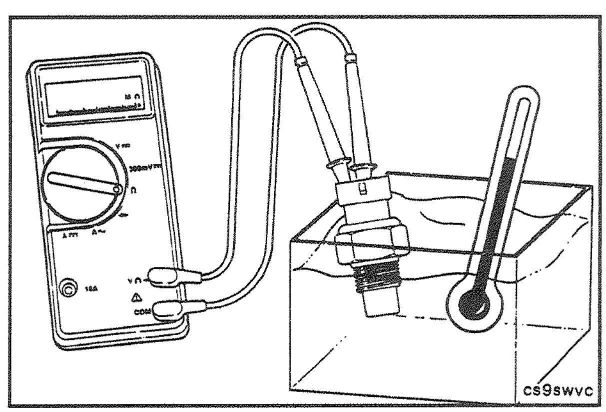


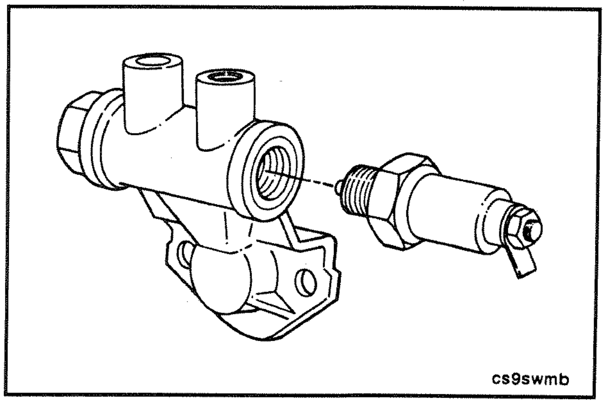
cs9swvb

Check the water temperature with a thermometer.

The VOM should indicate an open circuit below 160°F [71°C], and a closed circuit above 160°F [71°C].

Replace the switch if necessary.

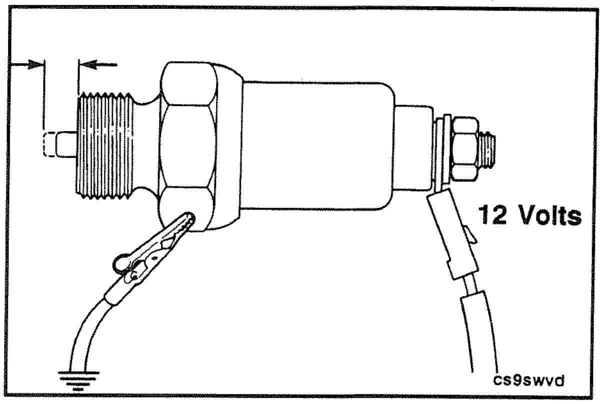

cs9swvc



KSB Wax Motor Element

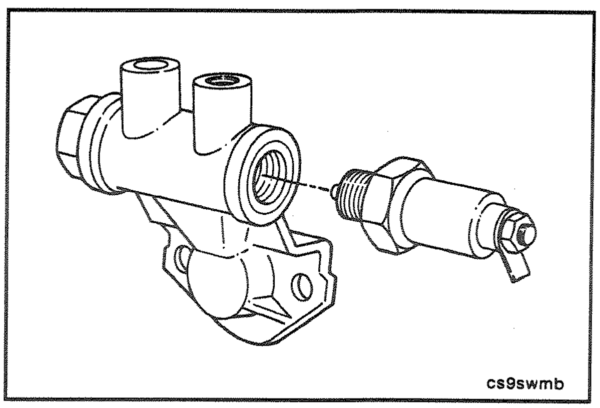
22 mm

Loosen and remove the KSB electrical element from the KSB housing.



Apply 12 volts to the electrical terminal and a ground strap to the hexagonal portion of the element. Observe for extensional movement of the plunger. If the plunger does not move after approximately one minute, check to make sure the element has been correctly connected to ground. If all connections are correct and the plunger does not move, the element is defective and must be replaced.

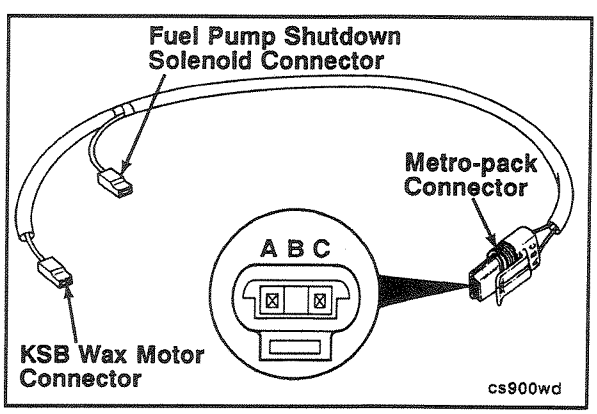
NOTE: The amount of plunger movement will vary depending upon the ambient temperature.



22 mm

Install the original element or a replacement into the KSB housing.

Torque Value: 22 N•m [16 ft-lb]



KSB Wiring Harness - Inspection (5-08)

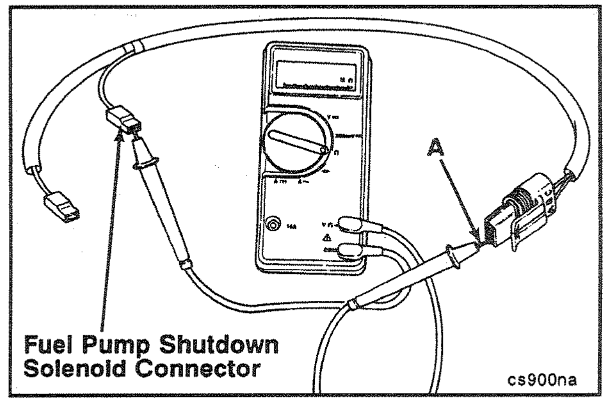
The wiring harness used on the wax motor style KSB can be inspected using a volt/ohm meter.

NOTE: Pin 'C' of the metro-pack connector is blank on the wax motor style KSB wiring harness.

Use a volt/ohm meter to perform a continuity check between port 'A' of the metro-pack connector and the female spade connector at the fuel pump shut down solenoid connector.

Repair the wire if there is an open circuit.

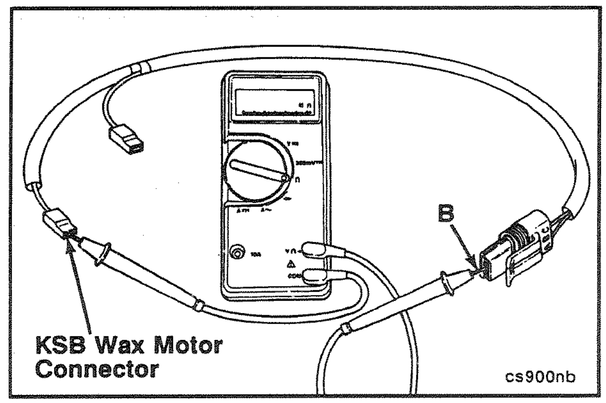
Ohms Resistance - Less than 10.



Use a volt/ohm meter to perform a continuity check between Port 'B' of the metro-pack connector and the female spade connector at the KSB wax motor connector.

Repair the wire if there is an open circuit.

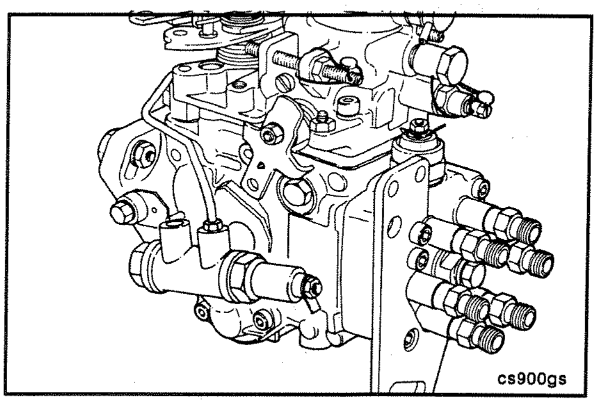
Ohms Resistance - Less than 10.



Cold Start Timing Advance System (KSB) - Electrical Solenoid Style (5-09)

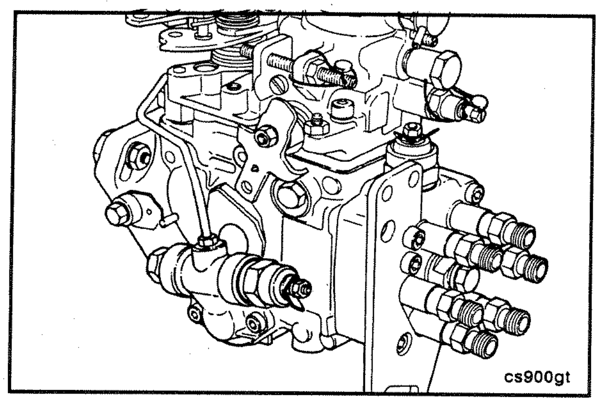
The electrical solenoid style KSB is used on 1991 model and newer B series automotive engine ratings using the Bosch VE fuel pump.

Note: The wax motor style KSB is used on pre-1991 B series automotive engine ratings using the Bosch VE fuel pump. See Section (5-07), Cold Start Timing Advance System (KSB) - Wax Motor Style, for additional information.



Wax Motor Style KSB

Note: Temperature switch is located in coolant jacket.



Electrical Solenoid Style KSB

Note: Temperature switch is located in intake manifold.

VE Pump Timing Advance Principles (Without KSB)

Pump housing pressure acts on an internal timing piston (1), Figure 1, to partially advance the injection timing at idle, and fully advance the timing when the engine RPM reaches approximately 60% of rated speed. As pump pressure increases, timing advances.

The pump housing pressure is controlled by the pressure regulator valve (2) (a spring loaded slider valve). The valve is shown in the open and closed position.

When housing pressure is low, the spring (3) forces the slider (4) into the closed position. This permits the housing pressure to increase by preventing fuel drainage through the return passage (5).

As housing pressure increases, it forces the slider (4) to compress the spring (3). This action opens the return passage (5) and relieves the housing pressure.

A relief port (6) located on the spring side of the slider valve, allows fuel that seeps past the slider (4) to drain. Relief port drainage is necessary to avoid a hydraulic lock of the slider valve, which would render the pressure regulator valve (2) inoperable. In fact, it is this characteristic that is used in conjunction with the KSB to advance the timing during cold engine operation.

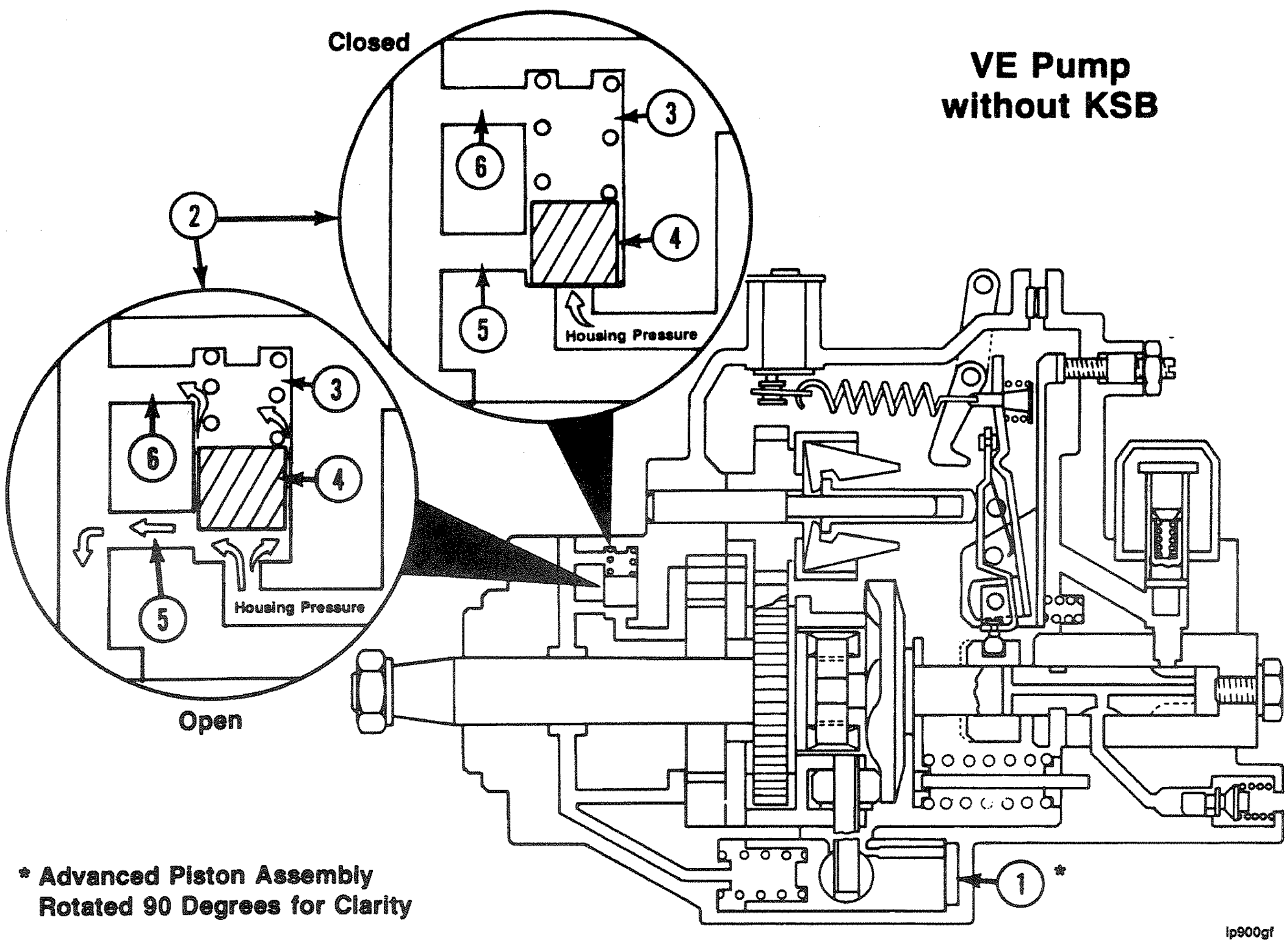


Figure 1, VE pump timing, regulated by opening and closing the pressure regulator valve.

VE Pump Timing Advance Principles (With Electrical Solenoid KSB Installed)

The KSB introduces a new fuel line (1), Figure 2, which routes fuel from the relief port (2) of the pressure regulator valve (3) to the plunger end (6), Figure 3, of the electrical solenoid, bypassing the normal return passage (6), Figure 1.

With the key switch on, current flows from the key switch line to the 90°F normally closed intake manifold switch to the 12V electrical KSB solenoid (see Figure 2). When the engine starts, the pressure regulating valve (3) attempts to regulate fuel pressure as before (without KSB) but the fuel from the relief port (2) now meets a 'dead end' at the plunger of the KSB solenoid (6), Figure 3. With the key switch on, the plunger moves outward and closes off the flow path of the fuel (8), Figure 3. This action hydraulically locks (closes) the pressure regulator slider valve (4), Figure 1.

Housing pressure (5), Figure 2, is not regulated because the pressure regulator valve (3) is inoperable and so the pressure continues to increase. This action fully advances the timing. The timing remains fully advanced until the plunger (6), Figure 3, is opened and fuel is allowed to drain through fuel drain flow path (8), Figure 3.

When the intake manifold temperature reaches 90°F, the 90°F normally closed IMT switch opens and voltage is no longer applied to the KSB solenoid (10). With no voltage applied to the KSB solenoid (13), fuel pressure overcomes the plunger force and pushes the plunger back to open the fuel drain flow path (8).

Fuel from the relief port of the pressure regulating valve now has a drain path (8), Figure 4, past the KSB solenoid plunger (6), Figure 4 (which is now open) to the drain. The pressure regulator valve resumes normal operation and the injection timing is regulated accordingly.

The electrical solenoid style KSB is also equipped with a pressure relief valve (7), Figure 3. If the engine is taken to high idle with the KSB solenoid plunger in the closed position (6), Figure 3, housing pressure can increase enough to rupture the fuel pump housing. The pressure relief valve (7), Figure 3, will pop off its seat before this occurs, however. At a pressure of 4 bar (60 psi), the pressure relief valve (7), Figure 3, opens and allows fuel to drain through an alternate flow path (9), Figure 3.

VE Pump Timing Advance Principles (With Electrical Solenoid KSB Installed)

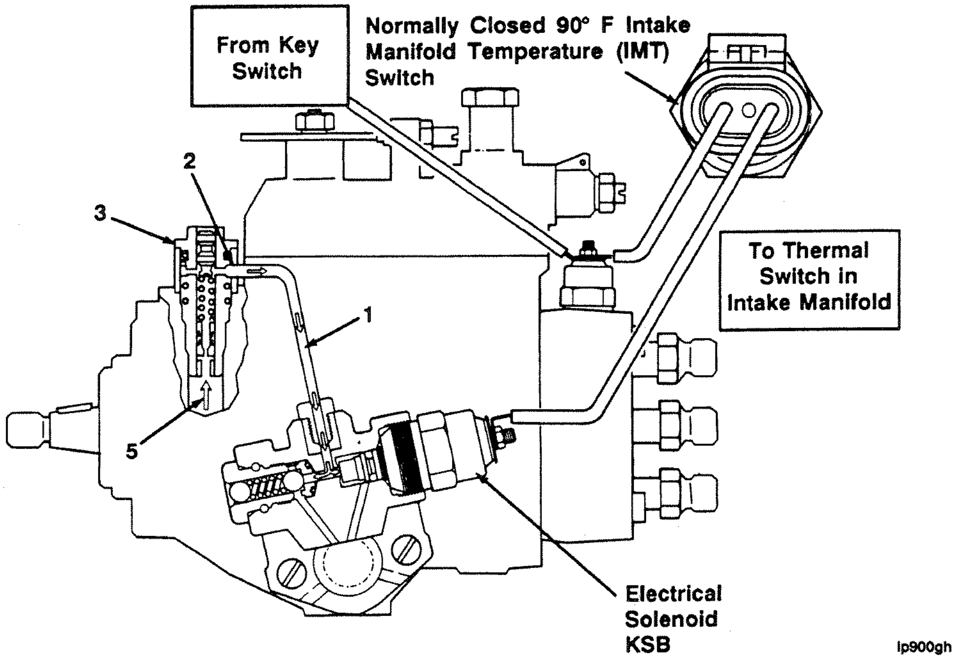


Figure 2: Bosch VE Fuel Pump With Electrical Solenoid KSB

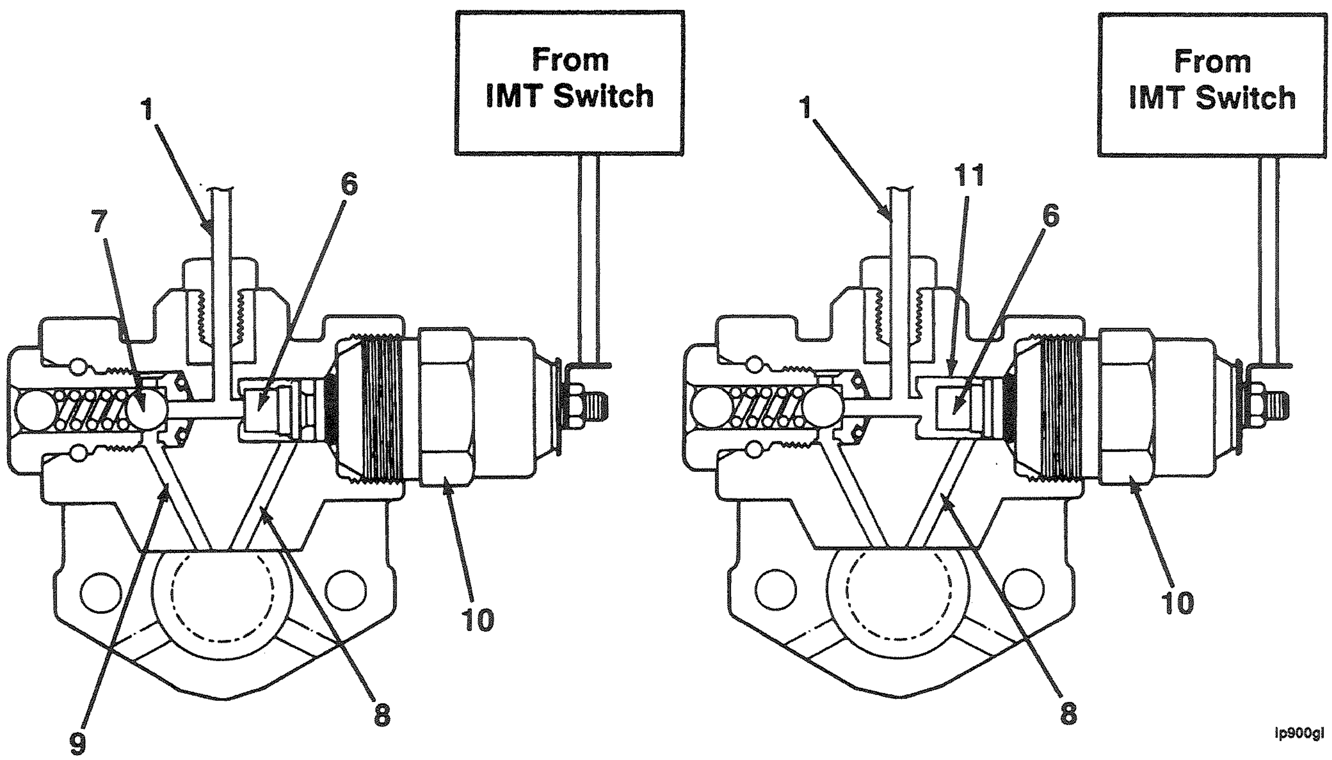
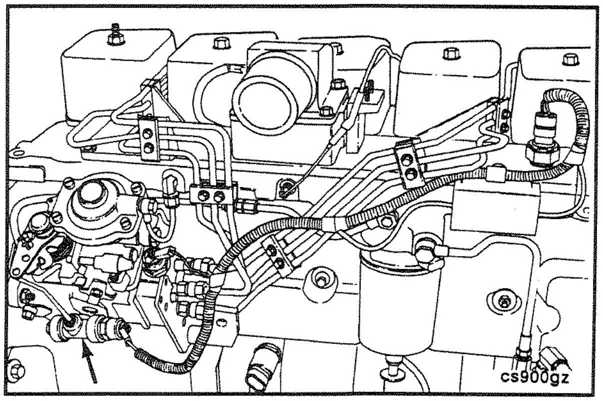


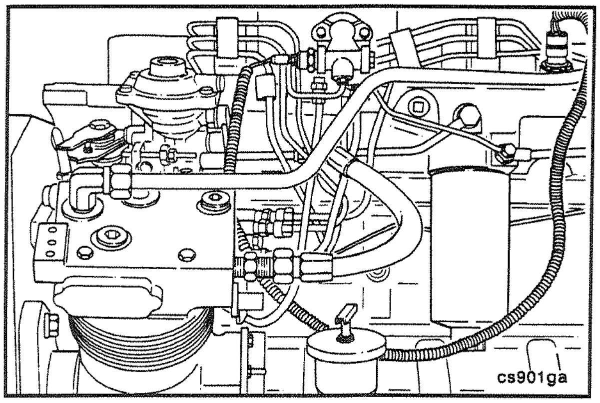
Figure 3: Cold Engine Operation (Less Than 90°F IMT), Advanced Timing

Figure 4: Warm Engine Operation (More Than 90°F IMT), Retarded Timing



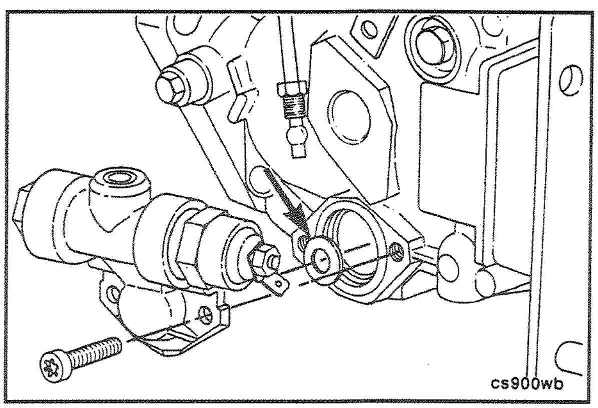
Two types of electrical solenoid style KSB valves are available.

The first type is the pump mounted KSB, as shown.

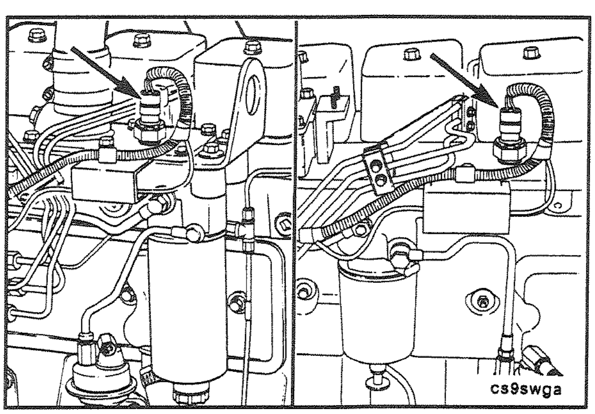


The second type is the remote mounted KSB, as shown.

The remote mounted KSB is used on B series automotive engines which have an air compressor.



Caution: Most pumps will have a shim between the KSB and the timing piston. This shim must be reassembled between the cover plate and the timing piston. If this shim sticks to the KSB and is installed with the remote mounting hardware, it will block the regulating valve drain path and damage the pump. This damage is usually evidenced by a fuel leak.

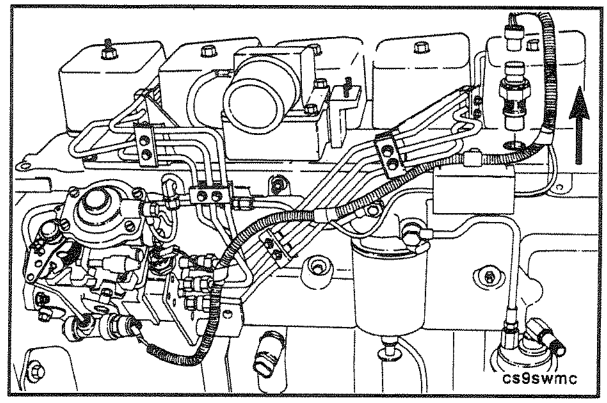


Both the 4 and 6 cylinder have the temperature switch mounted in the intake manifold as shown.

Troubleshsooting the Electrical Solenoid Style KSB

27 mm

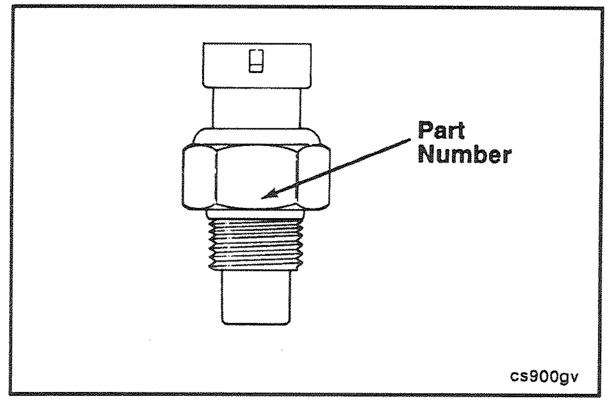
Remove the temperature switch from the intake manifold.



Caution: The switches are not interchangeable. White smoke will be present if the wrong temperature switch is used.

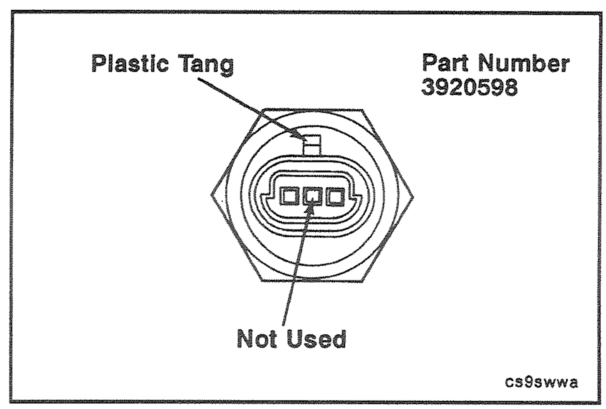
Check the part number to be sure the correct temperature switch is used.

NOTE: The electrical solenoid style KSB (used on 91 models and newer) uses a 90°F [32°C] normally closed intake manifold temperature switch, Part No. 3921642.



Although the electrical solenoid style KSB uses an intake manifold temperature switch, the operation of the switch can be checked by connecting a volt/ohm meter to the switch, placing the switch in ice water, and then heating the water to 90°F [32°C].

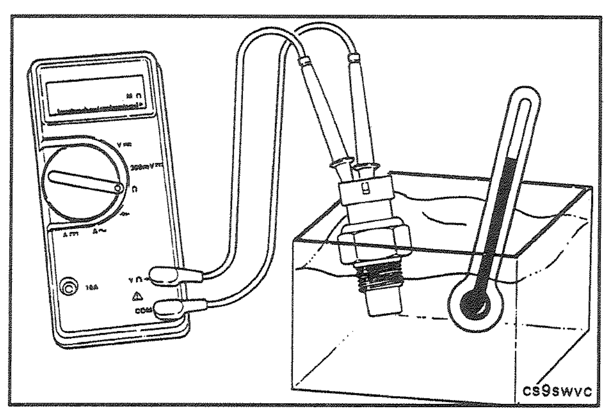
Connect the VOM to the two outside pins of the temperature switch.



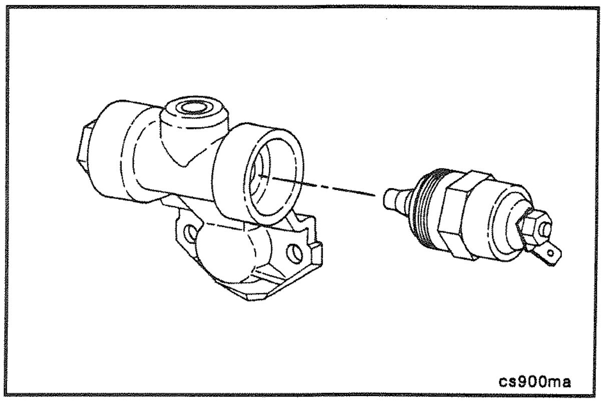
Check the water temperature with a thermometer.

The VOM should indicate a closed circuit below 90°F [32°C] and an open circuit above 90°F [32°C].

Replace the switch if necessary.

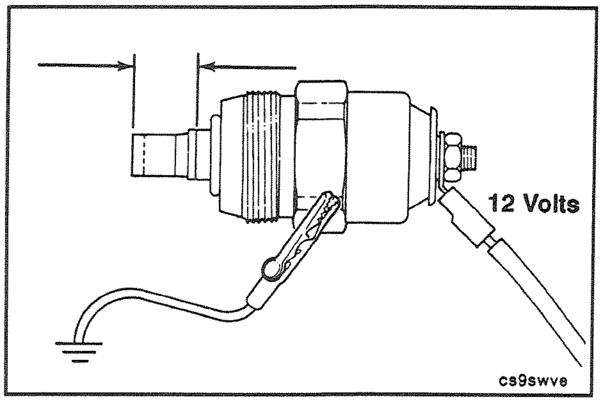


KSB Electrical Solenoid - Inspection



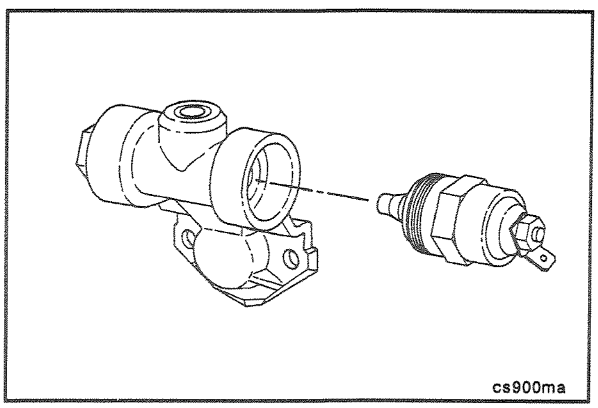
24 mm

Remove the KSB electrical solenoid from the KSB housing.



Apply 12 volts to the electrical terminal and ground the hexagonal portion of the element. The magnetic coil of the solenoid must push the plunger outward.

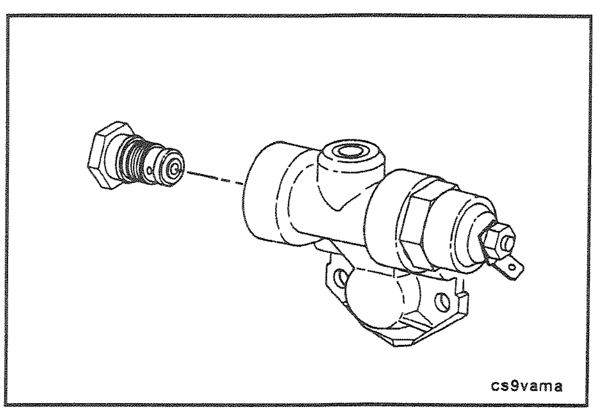
If the plunger does not push outward when voltage is applied, the solenoid is defective and must be replaced.



24 mm

Install the original solenoid or a replacement into the KSB housing.

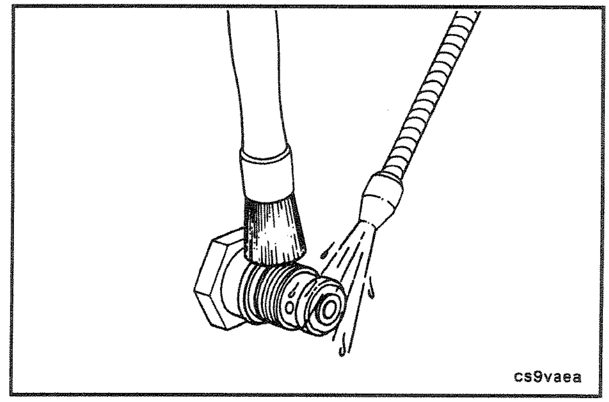
Torque Value: 22 N•m [16 ft-lb]



17 mm

Remove the pressure relief valve.

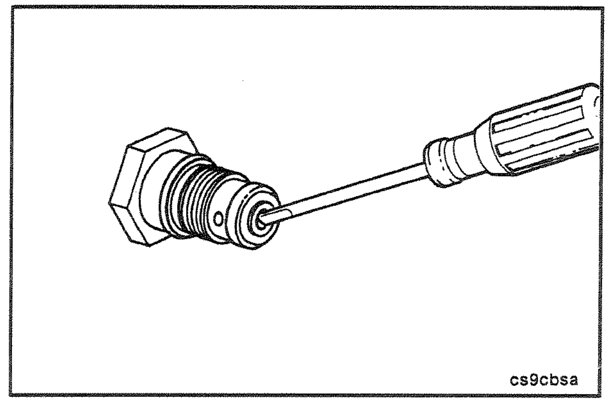
Thoroughly flush the pressure relief valve with cleaning solution.



Use a very small screwdriver to be sure the check ball is not sticking.

NOTE: A sticking or malfunctioning pressure relief valve will result in either white smoke or a ruptured fuel pump housing.

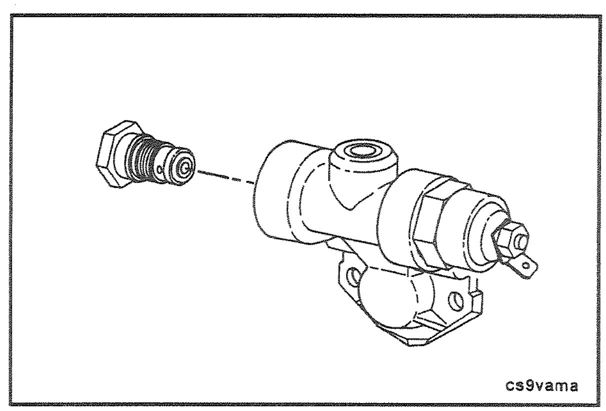
Replace the pressure relief valve assembly if necessary.



17 mm

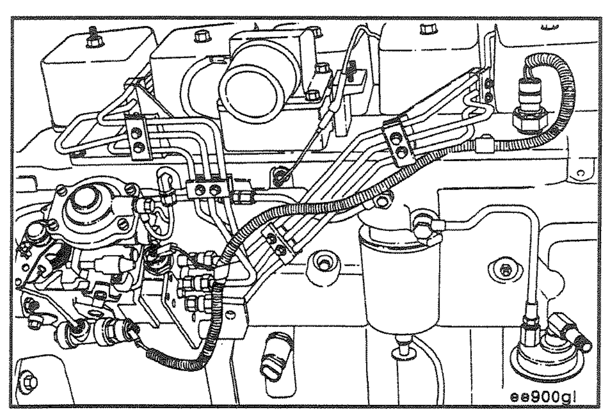
Install the original pressure relief valve or a replacement into the KSB housing.

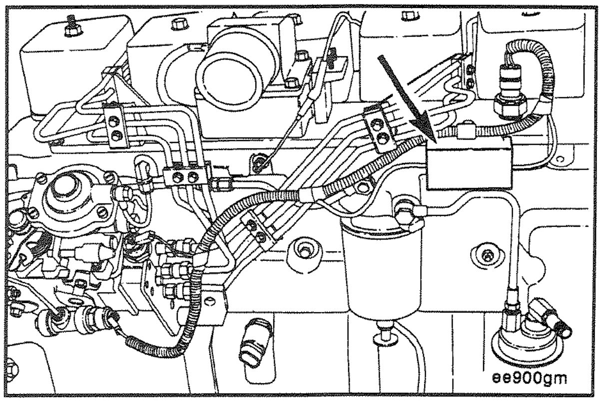
Torque Value: 13 N•m [10 ft-lb]



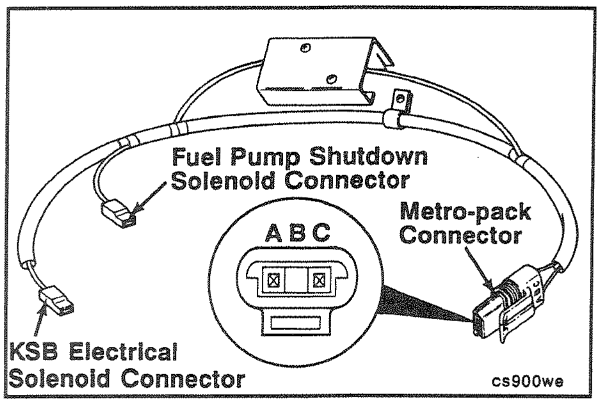
KSB Wiring Harness - Inspection

Engines with CPL 1579 do not have a resistor in the harness.



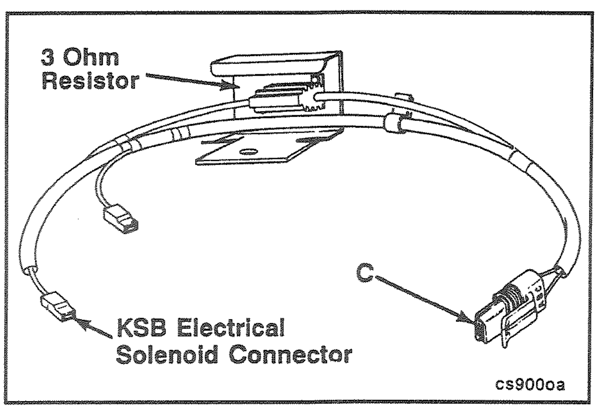


Engines with CPL 1351 **must be wired with** the resistor in the harness.



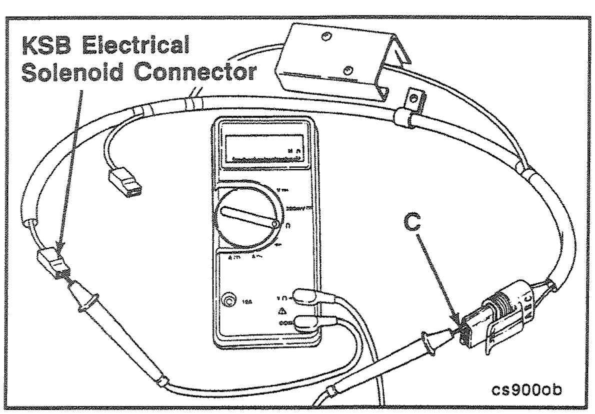
The wiring harness used on the electric solenoid style KSB can be inspected using a volt/ohm meter.

NOTE: Pin 'B' of the metro-pack connector is blank on the electric solenoid style KSB wiring harness.



The electric solenoid style KSB wiring harness contains a 3 ohm resistor in the wire leading from Port 'C' of the metro-pack connector to the KSB electrical solenoid connector.

The 3 ohm resistor is mounted to a bracket which is used as a 'heat sink' to absorb heat that is generated by the resistor.



Use a volt/ohm meter to perform a continuity check between Port 'C' of the metro-pack connector and the KSB electrical solenoid connector.

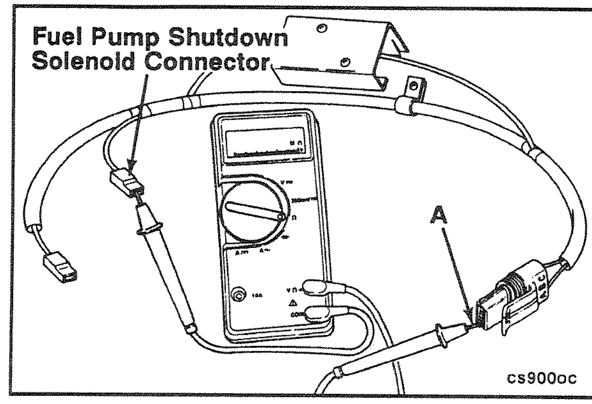
Repair the wire if there is an open circuit.

(Spec = Less than 10 ohms).

Use a volt/ohm meter to perform a continuity check between Port 'A' of the metro-pack connector and the fuel pump shut down solenoid connector.

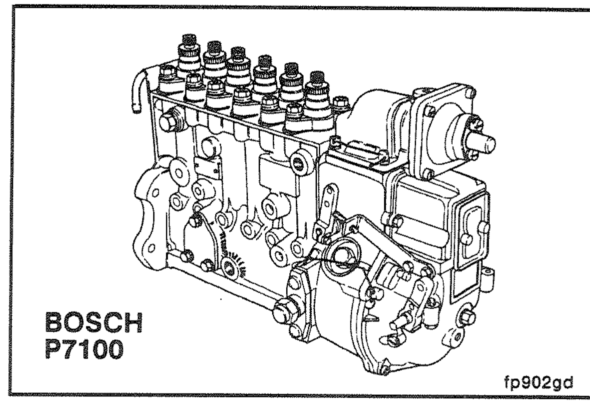
Repair the wire if there is an open circuit.

(Spec = Less than 10 ohms).



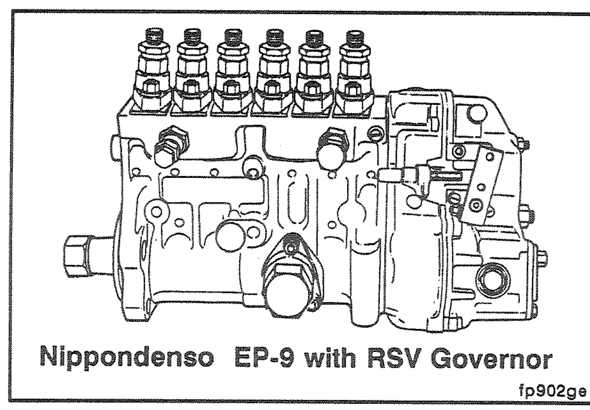
Fuel Injection Pump (In-Line Type) - Troubleshooting (5-10)

Beginning in 1991, the B series engine used the Bosch P7100 in-line fuel injection pump on higher horsepower automotive ratings. In 1994 all automotive 6B series engines will use the Bosch P-7100 in-line fuel injection pump.



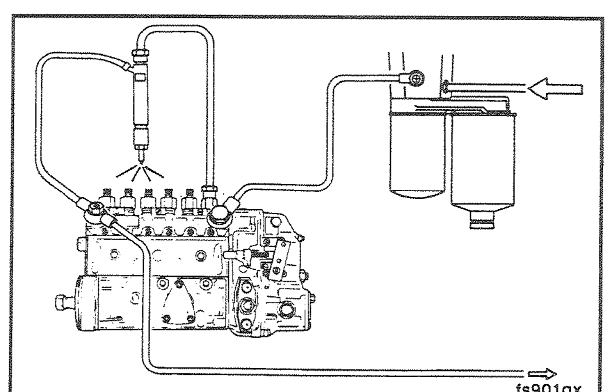
The B series engine also uses the Nippondenso EP-9 with RSV governor on 250 and 300 horsepower marine rating.

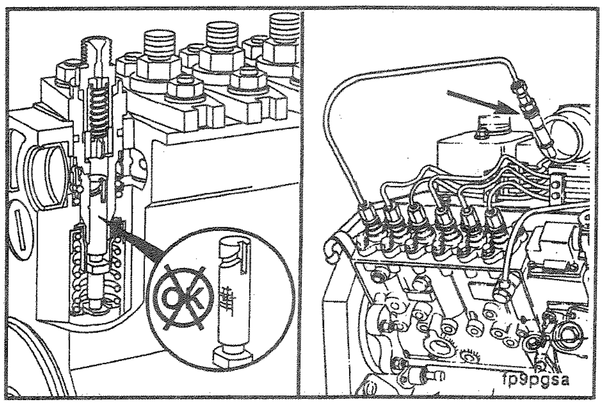
Refer to the B Series Marine Operation and Maintenance Manual, Bulletin No. 3810466, for additional information.



The fuel injection pump performs the three basic functions of:

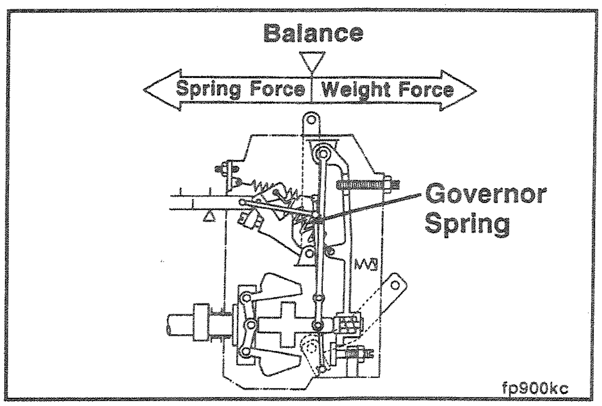
1) Producing the high fuel pressure required for injection.
2) Metering the exact amount of fuel for each injection cycle.
3) Delivering the high pressure metered fuel to each cylinder at the precise time.





Individual plungers are used in the pumps to develop and distribute the high pressure required for injection.

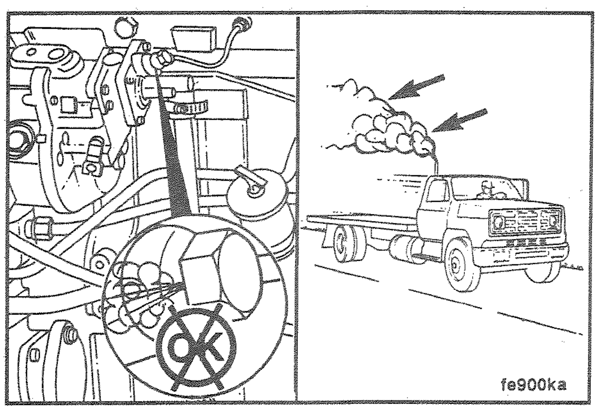
A worn or damaged plunger in the pump will affect only one cylinder.



Governor Malfunctions

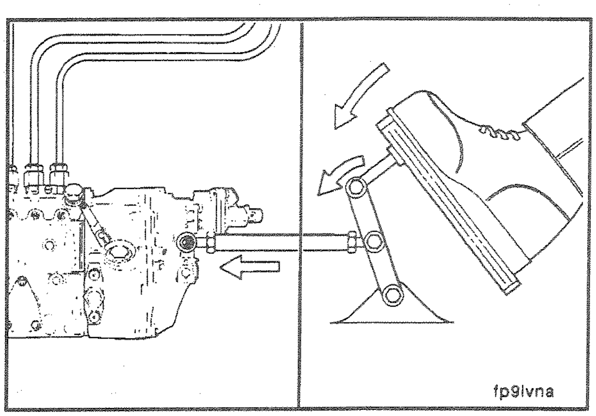
Balance between the governor flyweights and control lever position controls the metering of the amount of fuel to be injected.

The pump governor performance and setting can affect engine power. Special equipment and qualified personnel are required to verify governor performance. If the seals are broken on the external adjustment screw, the fuel rate may be out of adjustment.



Air Fuel Control (AFC) Malfunctions

The RQVK governors are equipped with an air fuel control (AFC) device to help control emissions. The AFC regulates the fuel to air mixture by sensing manifold pressure. A malfunction of the AFC can cause low power or excessive exhaust smoke under load. Leaks at the fittings or a restriction in the tube from the intake manifold to the AFC can also cause low power.



Fuel Control Lever Travel and Adjustment

The amount of fuel injected and subsequently the speed and power from the engine is controlled by the fuel control lever. Restricted travel of the lever can cause low power. Always check for full travel of the lever when diagnosing a low power complaint.

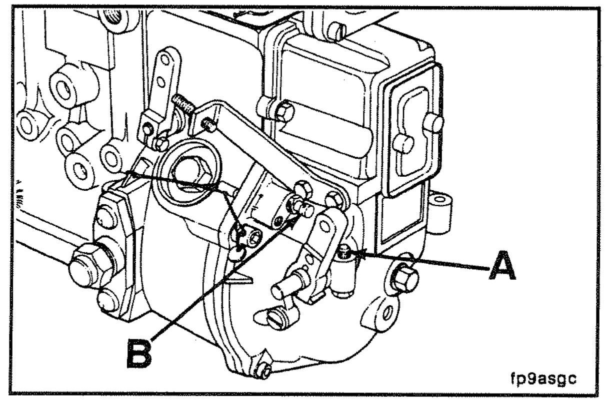
Fuel Injection Pump Idle Adjustment Screws

The idle adjustment screw provides a stop for the lever at low speed. The adjustment screw can be used to increase idle speed for accessory loading or, if required, to lower the idle speed.

The high speed screw is set at the factory and can only be adjusted at a certified fuel pump shop.

A - Idle Screw

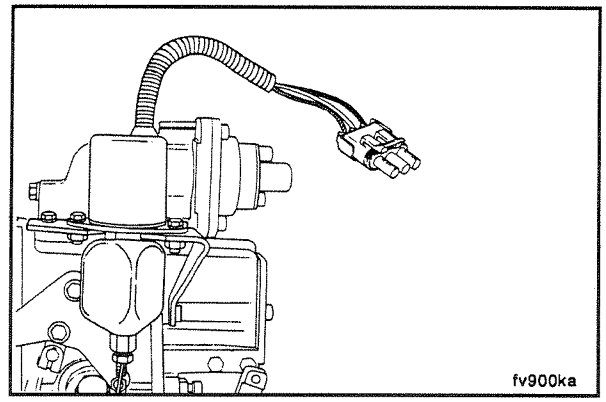
B - High Idle Screw



Shut Down Solenoid (In-Line Type Injection Pump) - Troubleshooting (5-11)

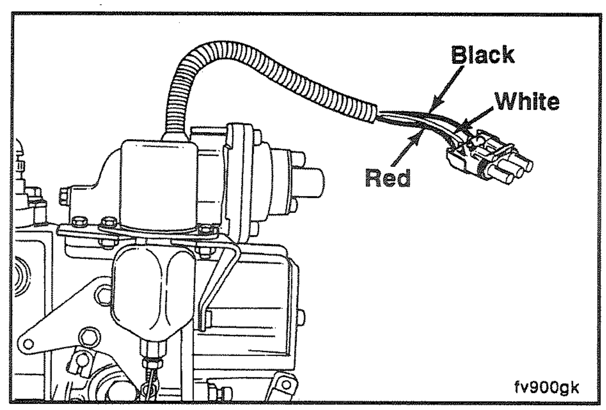
Engines using the Bosch P7100 fuel injection pump with the RQVK governor are equipped with the synchro-start fuel shut off solenoid to actuate the shut off lever. Both 12 volt and 24 volt external fuel shut off solenoids are available.

NOTE: Refer to Procedure (5-31), Fuel Shut Off Solenoid Adjustment/Replacement - Bosch P7100, for instructions to replace and adjust the synchro-start solenoid.



The synchro-start has a weatherpack connector with 3 wires in it.

Color	Description	Weatherpack Port
Black	Ground	'C'
White	Pull In	'B'
Red	Hold In	'A'



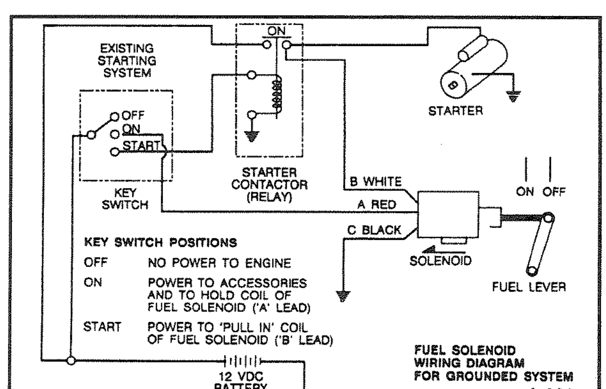
Wiring Guidelines:

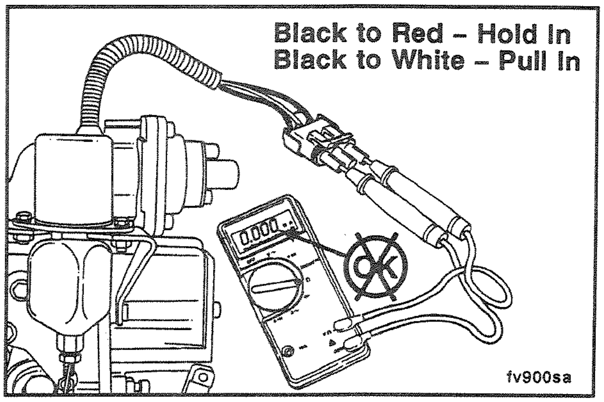
Refer to the chart below to find the correct gauge size and length of continuous wire for the white (pull-in) wire, which connects to the solenoid wiring.

	Length of Wire		
	0-4.5 ft	0-7.0 ft	0-11 ft
Gauge	14	12	10

NOTE: 14 gauge wire is required for the red (hold-in) wire, which connects to the "Run" terminal on the ignition switch.

NOTE: The black (ground) wire must be the same size as the white (pull-in) wire.

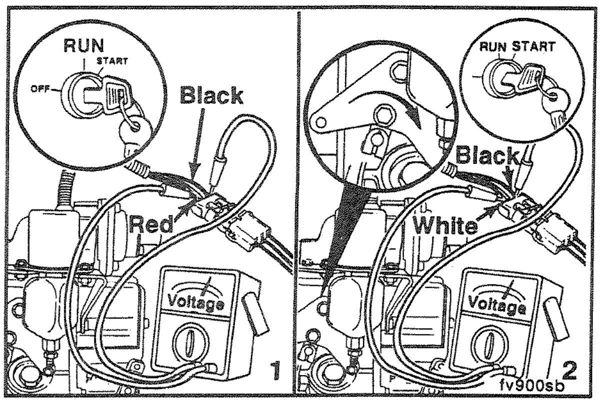




Solenoid Resistance Check

The synchro-start solenoid can be checked using a volt-ohmmeter. Disconnect the wiring harness and check the solenoid resistance.

Solenoid Voltage	Resistance Min Ohms Pull-in	Hold-in
12	0.22	11.1
24	0.82	41.3



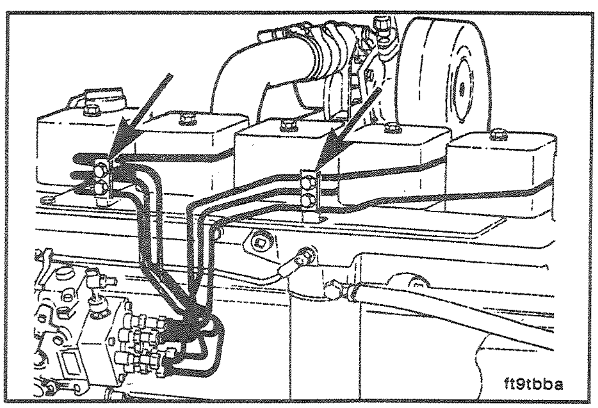
Solenoid Voltage Check

If the synchro-start solenoid checks good, the problem is with the wiring circuit to the solenoid.

To preform the solenoid voltage check, connect the wiring harness and apply voltage to the solenoid with the ignition key as follows:

1. With the key in the run position check the voltage hold-in.
2. With the shut down lever held in the shut down position move the key to the start position and check the pull-in voltage.

Battery Voltage	Min Voltage Pull-in	Hold-in
12	6.5	4.0
24	13.0	8.0

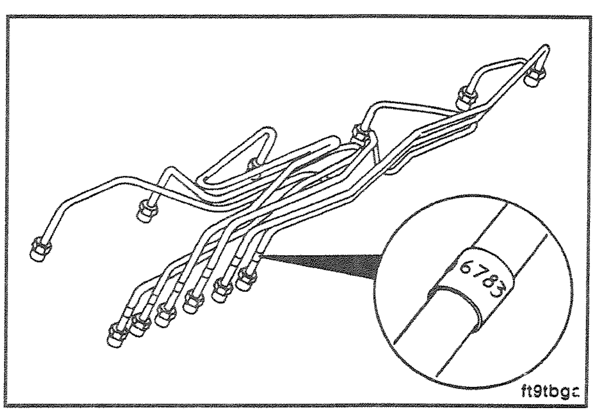


High Pressure Fuel Lines (5-12)

Caution: The high pressure lines must be clamped securely and routed so they do not contact each other or any other components.

The high pressure fuel lines are designed and manufactured to deliver fuel at injection pressure to the injectors. The high pressure pulses will cause the lines to expand and contract during the injection cycle.

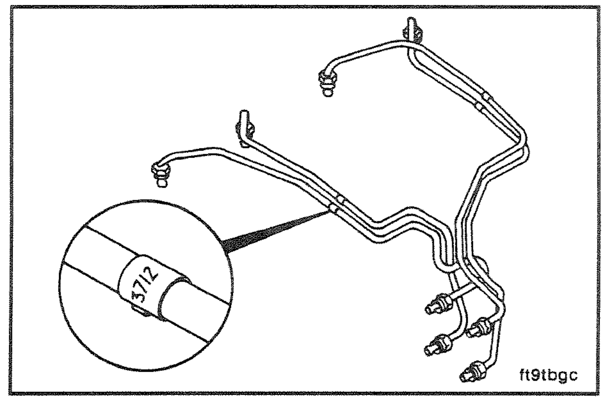
Shown here are the high pressure fuel lines for distributor type injection pump.



Shown here are the high pressure fuel lines for the Bosch P7100 in-line injection pump.

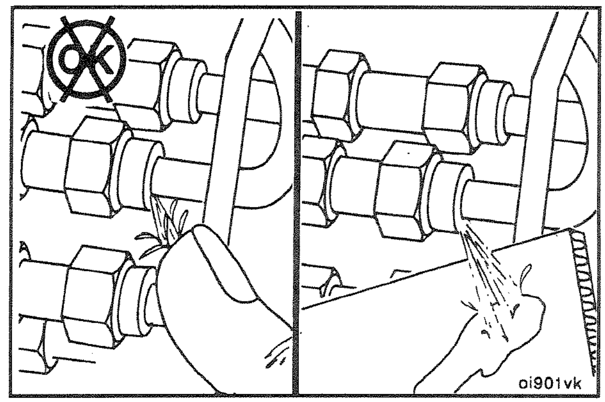
Do not weld or substitute lines; use only the specified part number for the engine.

The length, internal size and rigidity of the lines is critical to smooth engine operation. An attached metal tag is used to identify each line with a part number.

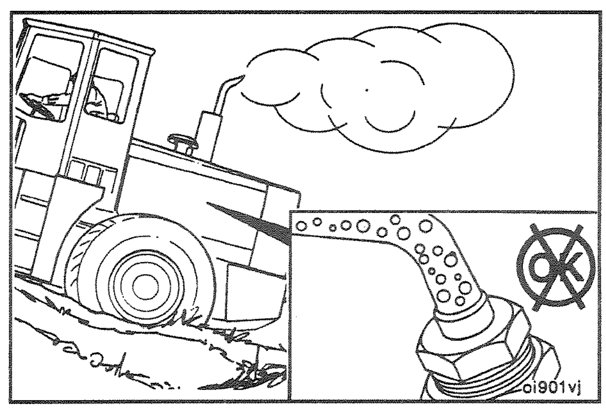


Caution: The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious bodily harm.

Use cardboard to check for cracks and leaks. With the engine running, move the cardboard over the fuel lines and look for fuel spray on the cardboard. Fuel leaks can cause poor engine performance.

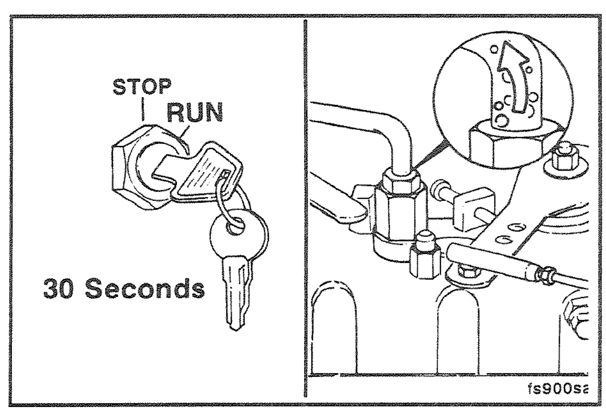


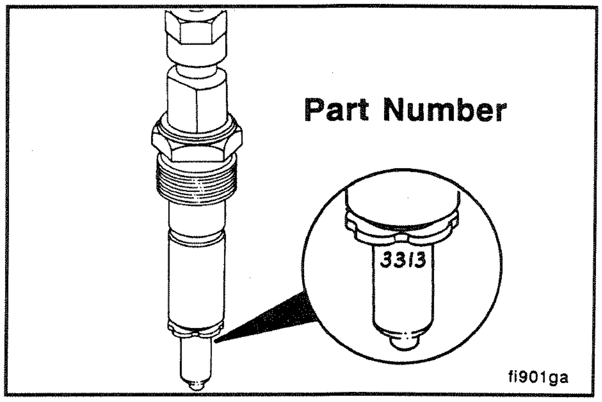
It is normal to have entrapped air in the fuel lines after replacing the pump or the lines. Air in the lines will cause the engine to run rough or produce a fuel knock.



Bleed the air from the high pressure line at the fitting that connects the injector. Bleed one line at a time until the engine runs smooth.

If the air cannot be removed, check the pump and supply line for suction leaks.

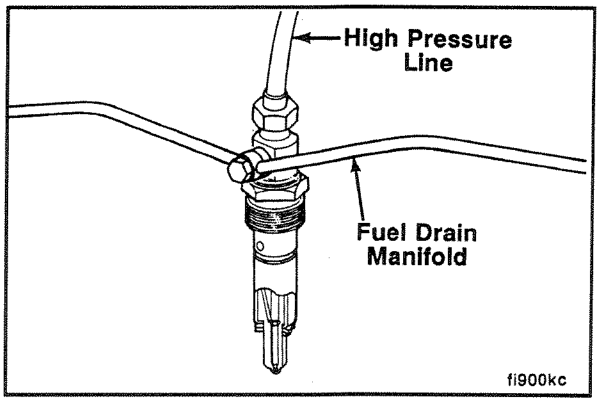




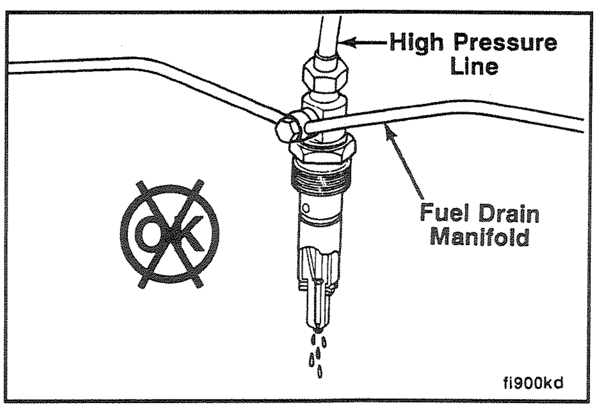
Injectors (5-13)

Caution: Use only the specified injector for the engine.

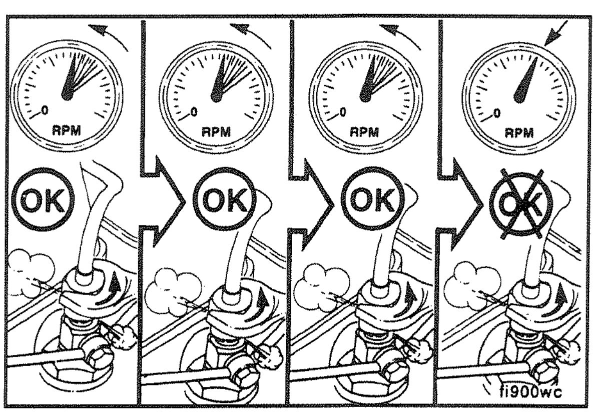
All engines use closed nozzle, hole-type injectors. However, the injectors can have different part numbers for different engine ratings. The last four digits of the Cummins part number are used to identify the injectors.



During the injection cycle, high pressure from the injection pump rises to the operating (pop) pressure which causes the needle valve in the injector to lift. Fuel is then injected into the cylinder. A shimmed spring is used to force the needle valve closed as the injection pressure drops below the pop pressure to seal off the nozzle after injection.



Failure of the needle valve to lift and close at the correct time or needle valve stuck open can cause the engine to misfire and produce low power. Fuel leaking from the open nozzle can cause a fuel knock, poor performance, smoke, poor fuel economy and rough running.



To find which cylinder is misfiring, operate the engine and loosen the fuel line nut at one injector and listen for a change in engine speed.

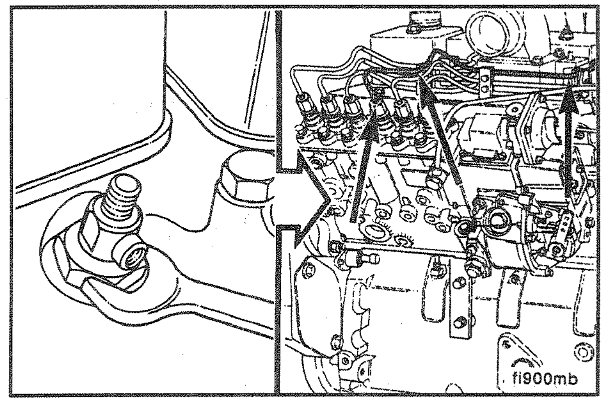
A drop in engine speed indicates the injector was delivering fuel to the cylinder.

Check each cylinder until the malfunctioning injector is found.

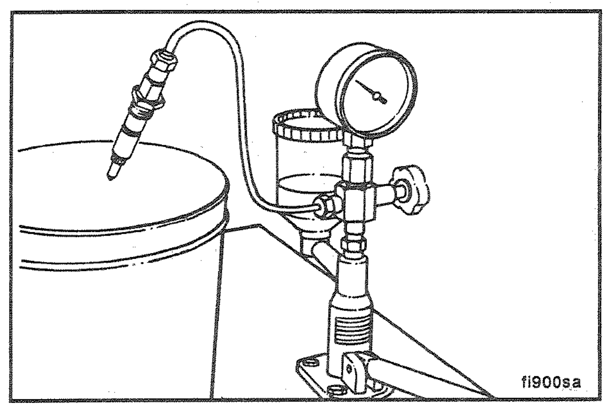
Be sure to tighten the fuel line nut before proceeding to the next injector.

Remove the malfunctioning injector to test or replace it.

If the engine continues to misfire after replacing the injector, check for leaks in the high pressure line. Also check for a defective delivery valve that lets the fuel drain back into the injection pump.

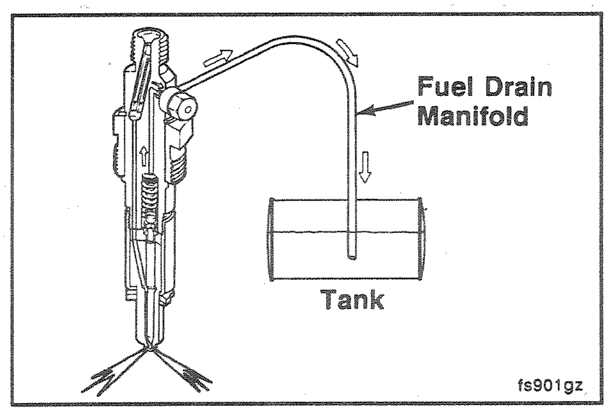


Carbon build up in the orifices in the nozzle will also cause low power from the engine. Remove and check the spray pattern or replace the injectors.



Fuel Drain Manifold (5-14)

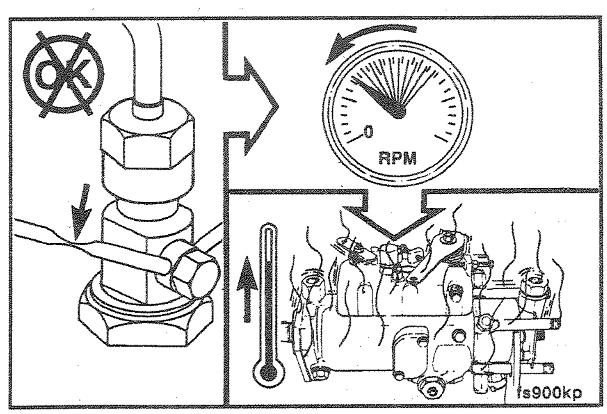
The fuel system is designed to use fuel to cool and lubricate the injection pump and injectors. Fuel is continually vented from the injection pump and a small amount of fuel leaks by the injector needle valve during injection. This fuel is returned to the supply tank by the fuel drain manifold.

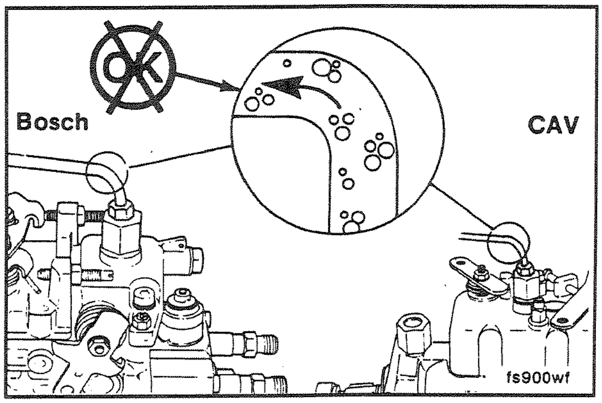


Restriction of the fuel drain manifold can affect the Lucas CAV DPA/DPS fuel injection pump metering controls and the operation of the injectors. Restricting the fuel drain manifold raises the case pressure of the fuel injection pump which can prevent injection.

If the engine will restart after a waiting period following an unexplained shut down, look for a restriction of the manifold drain line.

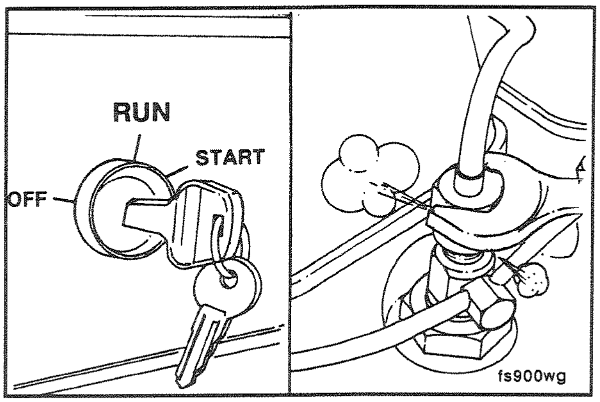
NOTE: Restriction can cause the fuel temperature to rise reducing power from the engine.





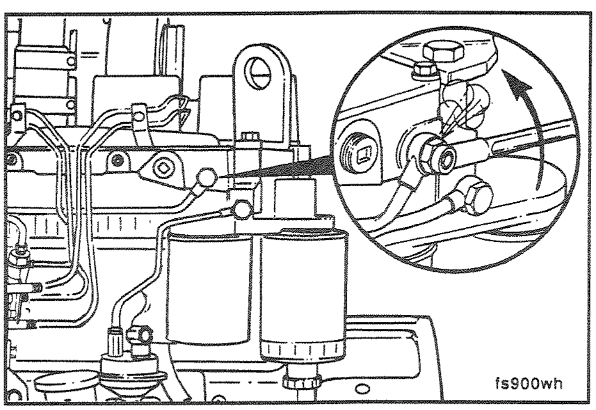
Venting the Fuel Systems (5-15)

Controlled venting is provided at the injection pump through the fuel drain manifold. Small amounts of air introduced by changing the filters or injection pump supply line will be vented automatically if the fuel filter is changed in accordance with the instructions.



However, manual bleeding will be required if:

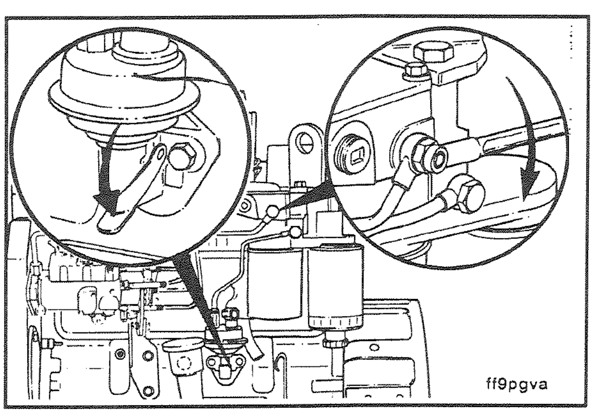
- The fuel filter is not filled prior to installation.
- Fuel injection pump is replaced.
- High pressure fuel line connections are loosened or lines replaced.
- Initial engine start up or start up after an extended period of no engine operation.



Low Pressure Lines and Fuel Filter - Venting

10 mm

Open the bleed screw.

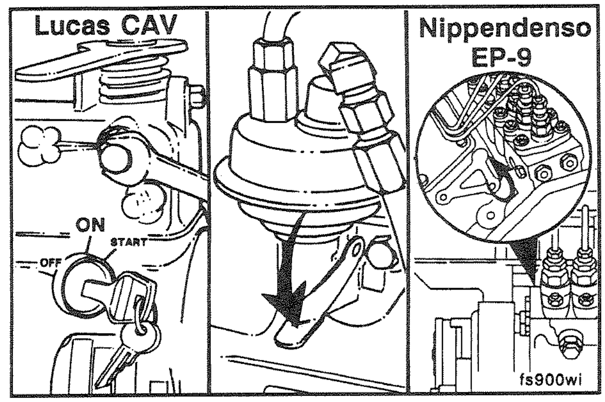


Operate the hand lever until the fuel flowing from the fitting is free of air.

Tighten the bleed screw.

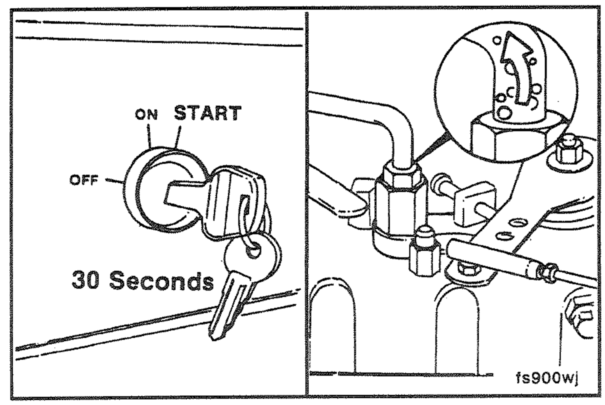
Torque Value: 9 N•m [7 ft-lb]

Injection Pumps - Venting



Air/fuel can be vented from the illustrated vent locations on the Nippondenso EP-9 and the Lucas CAV fuel injection pumps. The Lucas CAV fuel injection pump requires the fuel solenoid valve be energized before venting.

Loosen the vent screw and operate the priming lever on the fuel transfer pump until fuel injection pump is primed. Tighten the vent screw.

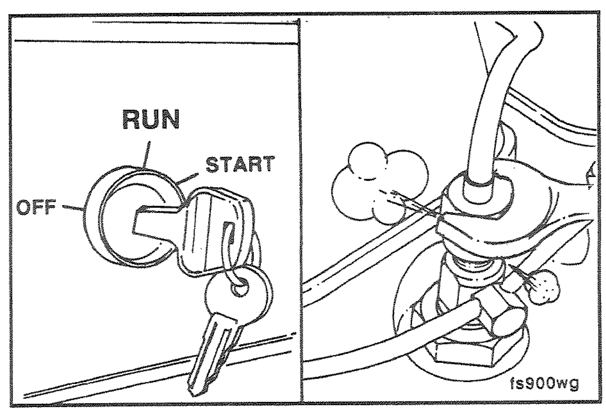


Caution: It is necessary to put the engine in the "run" position: Because the engine may start, be sure to follow all the safety precautions. Use the normal engine starting procedure.

Caution: When using the starting motor to vent the system, do not engage it for more than 30 seconds at a time: Wait two (2) minutes between engagements.

Air can also be vented through the fuel drain manifold line by operating the starting motor.

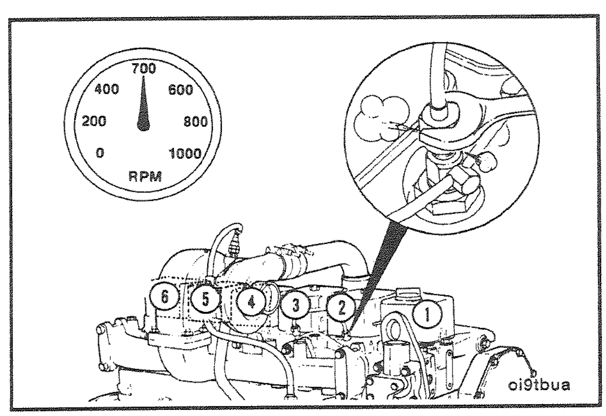
High Pressure Fuel Lines - Venting



17 mm, 19 mm

Caution: The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious bodily harm.

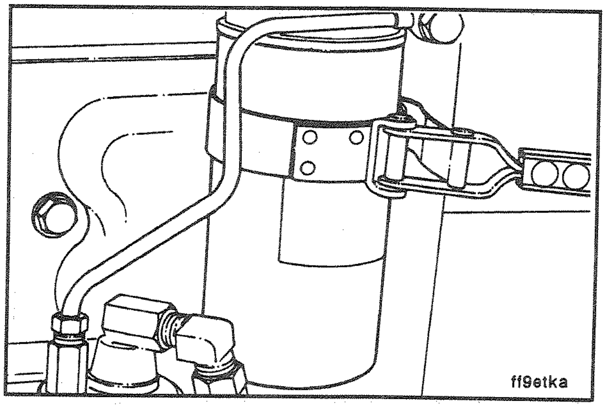
Loosen the fittings at the injector, and crank the engine to allow entrapped air to bleed from the line. Tighten the fittings.



Caution: Do not bleed a hot engine as this could cause fuel to spill onto a hot exhaust manifold creating a danger of fire.

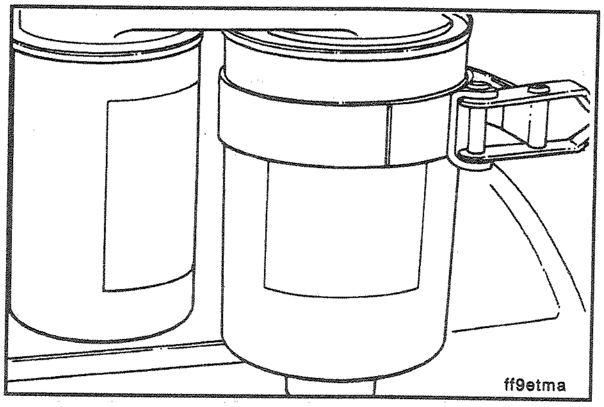
Operate the engine and vent one line at a time until the engine runs smoothly.

Fuel Filter - Replacement (5-16)



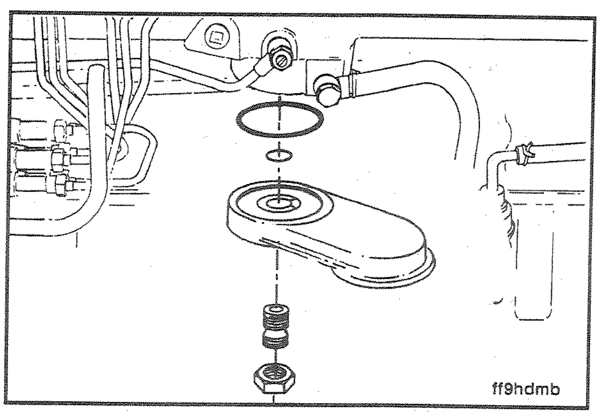
80 to 95 mm, Filter Wrench

Remove the combination water separator/fuel filter.



80 to 95 mm, Filter Wrench

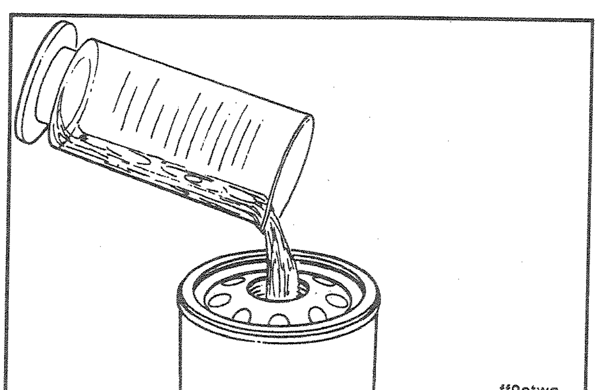
If used, remove the two filters from the dual filter adaptor.



24 mm, Flat Blade Screwdriver

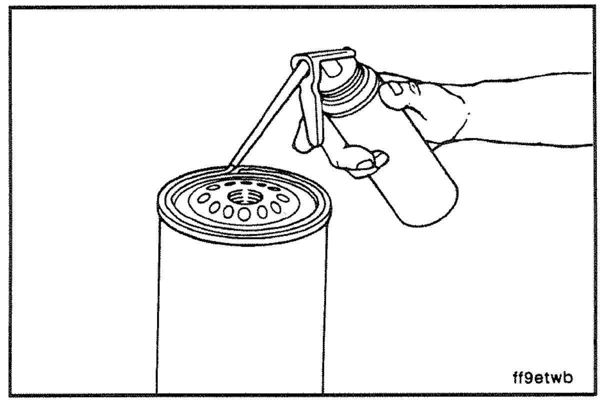
If a leak is found, remove the dual filter adapter and replace the o-rings.

Torque Value: 32 N•m [24 ft-lb]



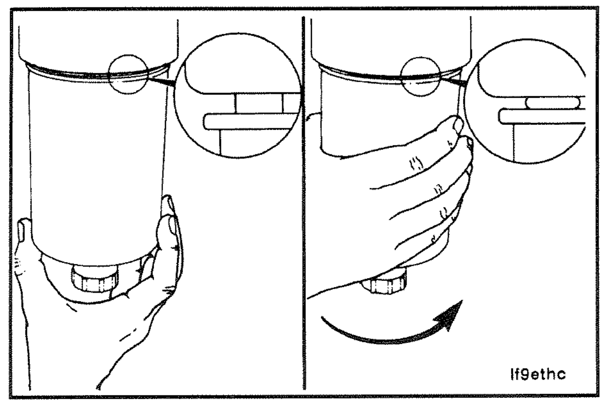
Fill the new filter(s) with clean fuel.

Lubricate the seal with clean lubricating oil.

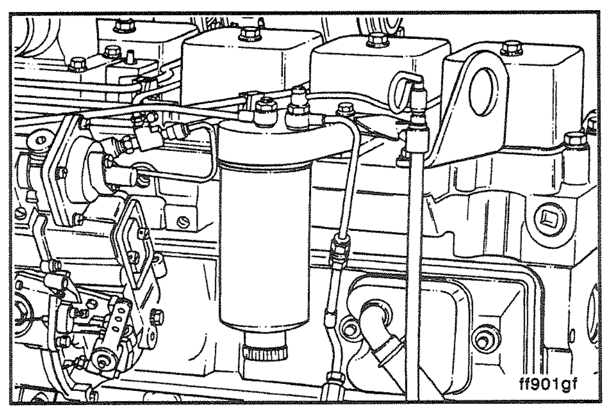


Caution: Mechanical tightening may distort the threads, damage the filter element seal or filter can.

Install the filter as specified by the filter manufacturer.



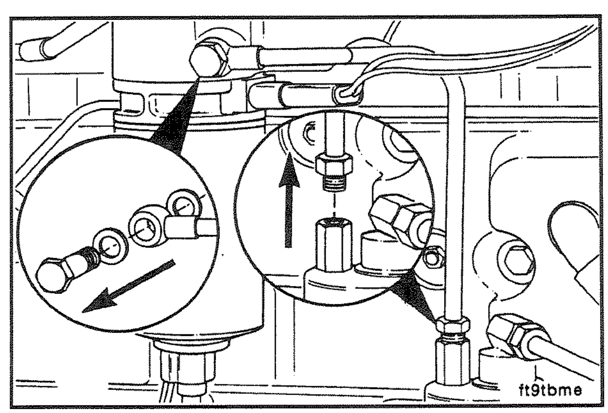
91 model and newer automotive B series engines that are equipped with the Bosch P7100 in-line fuel injection pump have the fuel filter mounted at the rear of the intake manifold as shown.

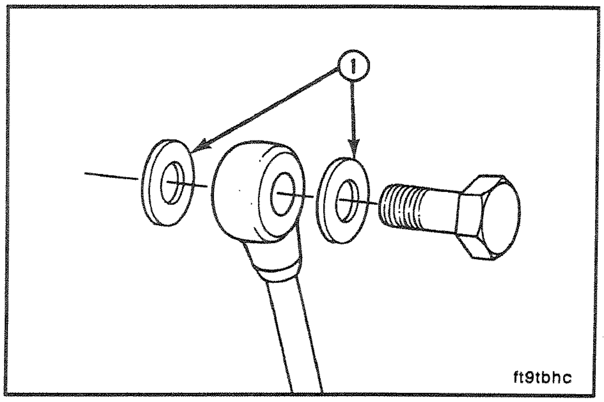


Low Pressure Fuel Line Replacement - Distributor Pumps (5-17)

14 mm and 17 mm

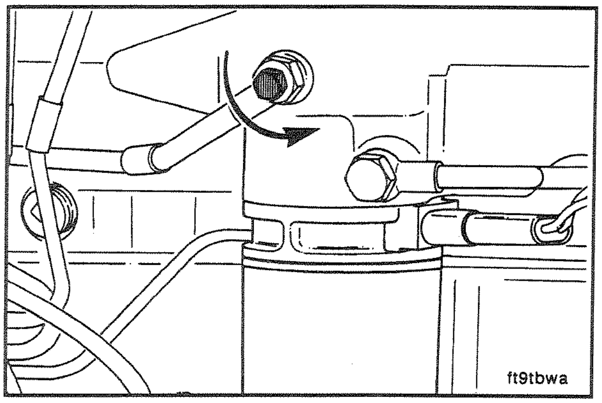
Remove the line from the fuel transfer pump and fuel filter head.





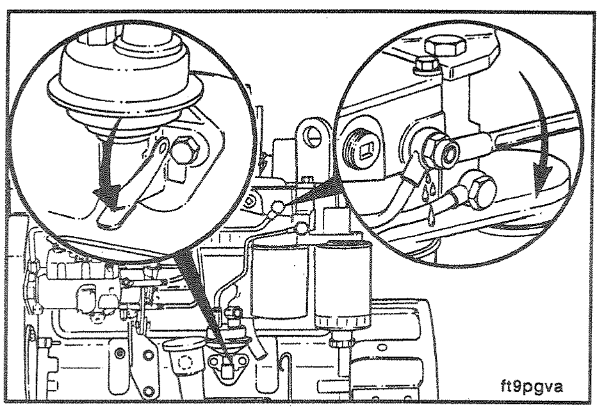
When replacing fuel lines, replace banjo fitting sealing washers (1) each time they are removed.

Install the fuel line and tighten the fittings securely.



10 mm

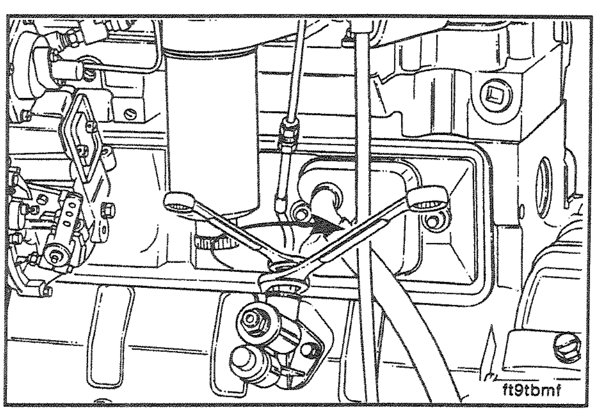
Bleed the fuel line by opening the banjo bleed screw.



10 mm

Operate the hand lever until the fuel flowing from the fitting is free of air.

Tighten the bleed screw.



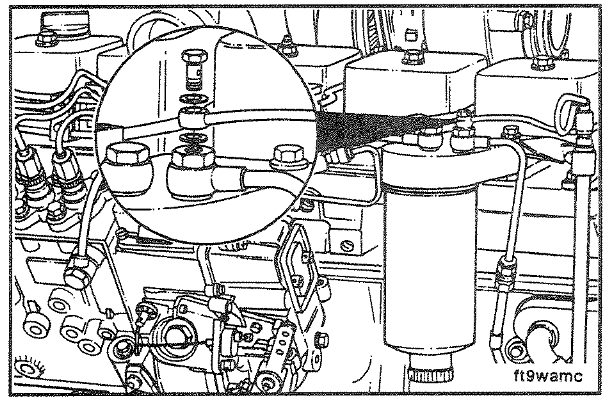
Low Pressure Fuel Line Replacement - Bosch P7100 Fuel Injection Pump (5-18)

14 mm, 20 mm

Remove the fuel line from the piston style fuel transfer pump.

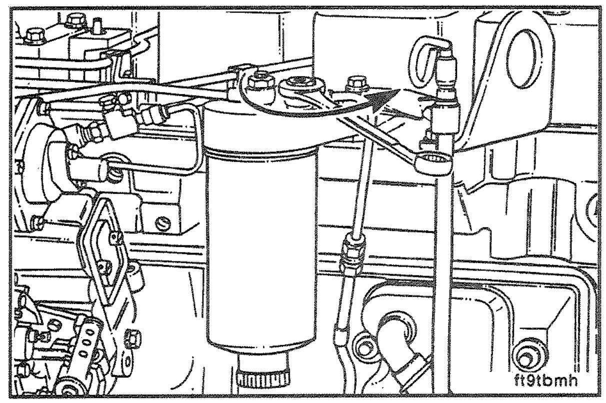
12 mm

Remove the fuel drain manifold line at the filter head.



17 mm

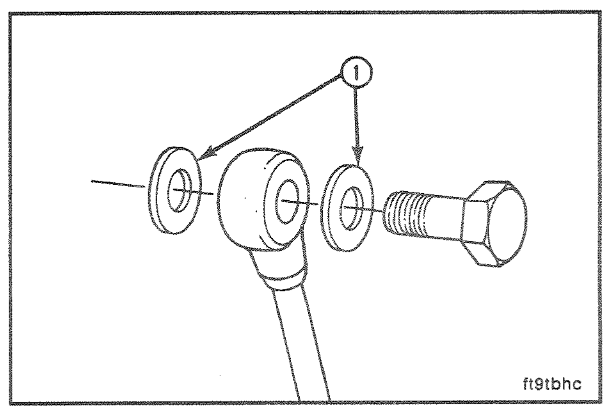
Remove the fuel line from the filter head.



17 mm, 12 mm, 14 mm, 20 mm

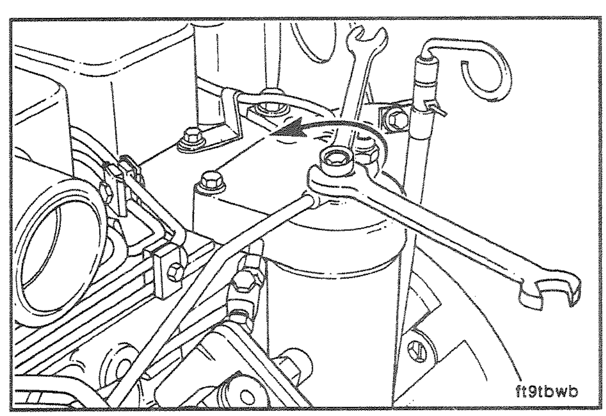
When replacing fuel lines, replace banjo sealing washers (1) each time they are removed.

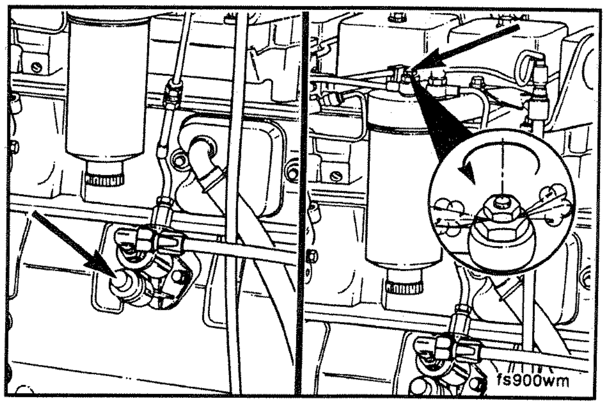
Install the fuel line in the reverse order of removal.



10 mm, 17 mm

Bleed the fuel line by opening the banjo bleed screw.

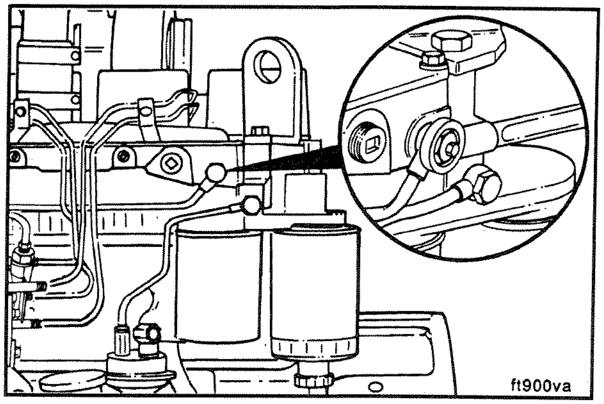




10 mm, 17 mm

Operate the priming button on the fuel transfer pump until the fuel flowing from the fitting is free of air.

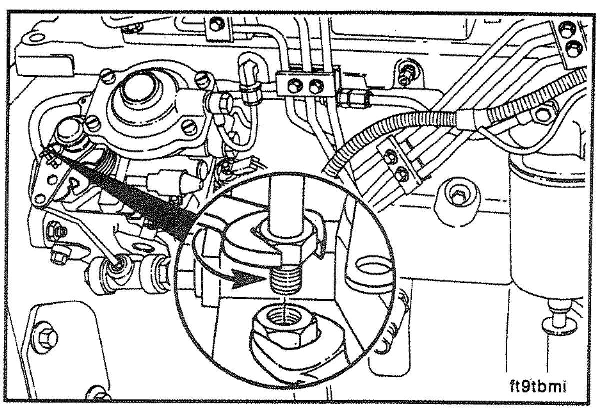
Tighten the bleed screw.



Fuel Injection Pump Supply Line Replacement - Distributor Type Pumps (5-19)

17 mm

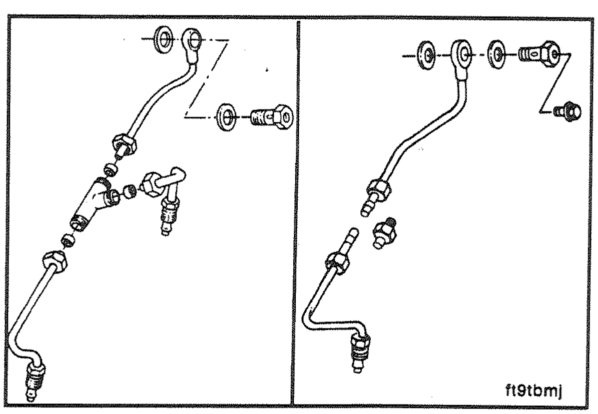
Remove the bleed screw banjo fitting and complete the following steps.



14 mm and 17 mm

Remove the fuel line from the Bosch fuel injection pump fitting.

NOTE: To prevent loosening the fuel injection pump inlet fitting, use two wrenches when removing the fuel supply line.



14 mm, 16 mm, 19 mm and 24 mm

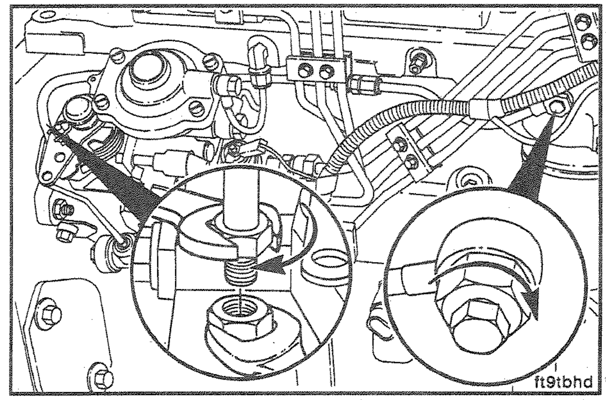
Remove the fuel supply line assembly from the two Lucas CAV fuel injection pump fittings.

NOTE: Replace the seals in the fittings if the line is disassembled.

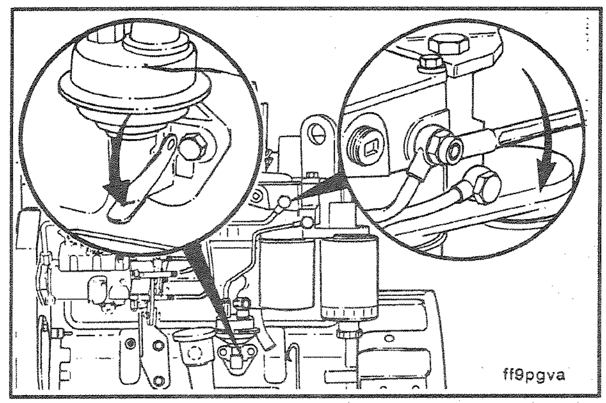
17 mm

Install the fuel supply line in the reverse order of removal. Tighten the fuel line securely to the fuel injection pump fittings.

Banjo Screw Torque Value: 32 N•m [24 ft-lb]



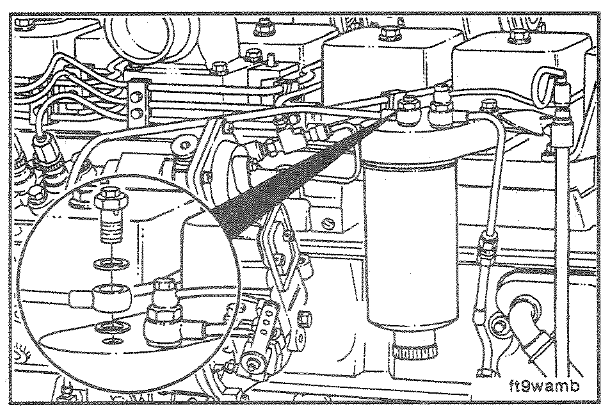
Operate the hand lever 10-20 strokes to fill the fuel supply line.



Fuel Injection Pump Supply Line Replacement - Bosch P7100 Pump (5-20)

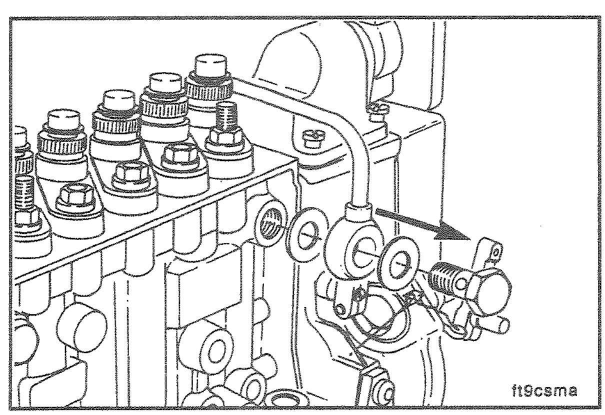
17 mm

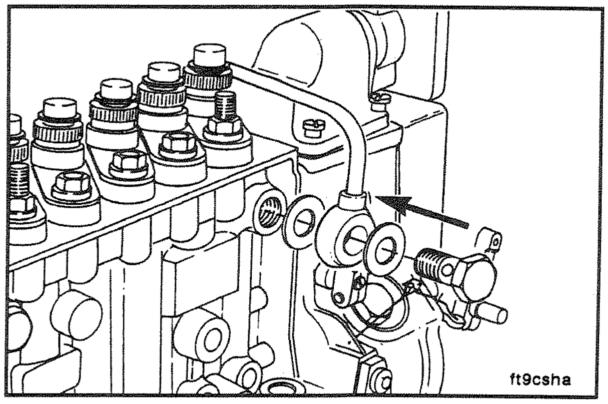
Remove the banjo capscrew and sealing washers at the filter head.



19 mm

Remove the banjo capscrew and copper sealing washer at the fuel injection pump inlet.





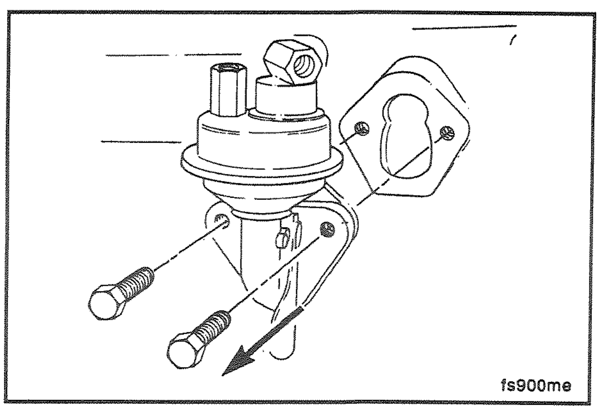
17 mm, 19 mm

Install in the reverse order of removal.

Fuel Transfer Pump Replacement - Diaphragm Style (5-21)

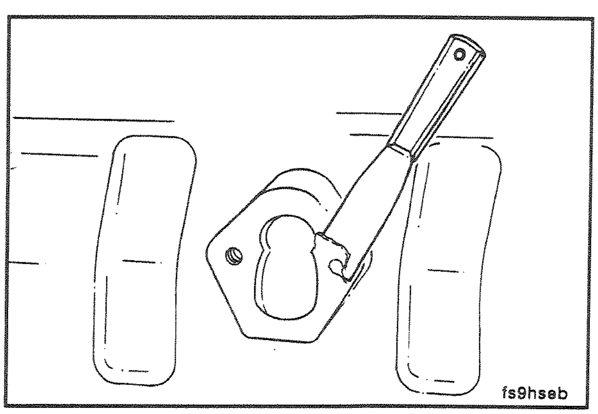
Preparatory Step:

- Disconnect the low pressure fuel lines.



10 mm

Remove the fuel transfer pump and complete the following steps.

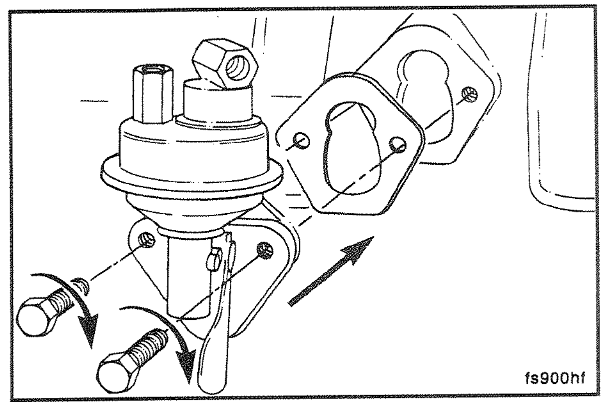


Clean the mounting surface on the cylinder block.

10 mm

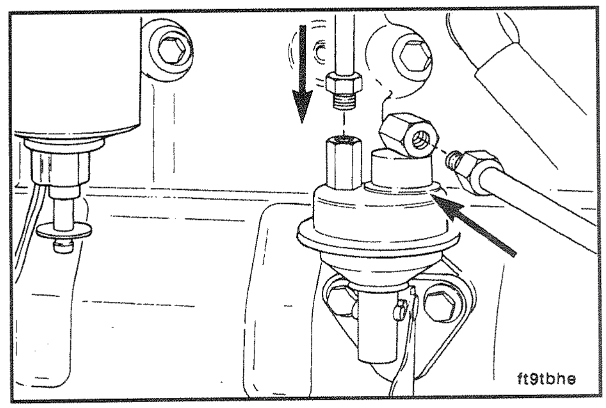
Install the fuel transfer pump with a new gasket.

Torque Value: 24 N•m [18 ft-lb]



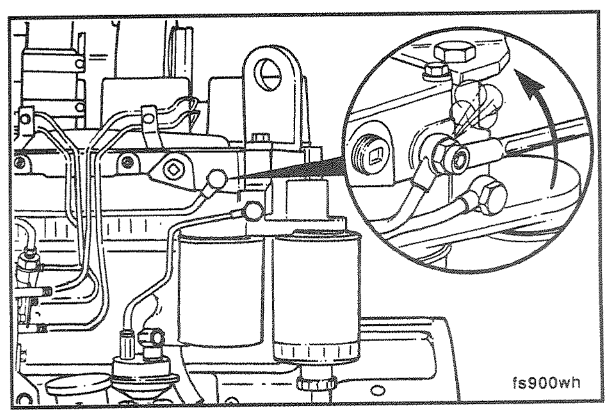
14 mm and 17 mm

Install the low pressure fuel lines.



10 mm

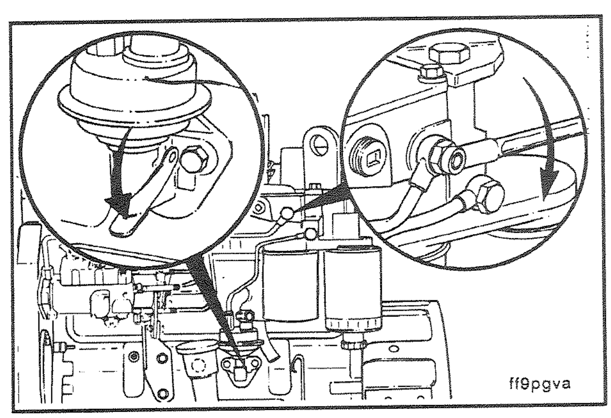
Open the banjo bleed screw to bleed the low pressure fuel line.



10 mm

Operate the hand lever until the fuel flowing from the fitting is free of air.

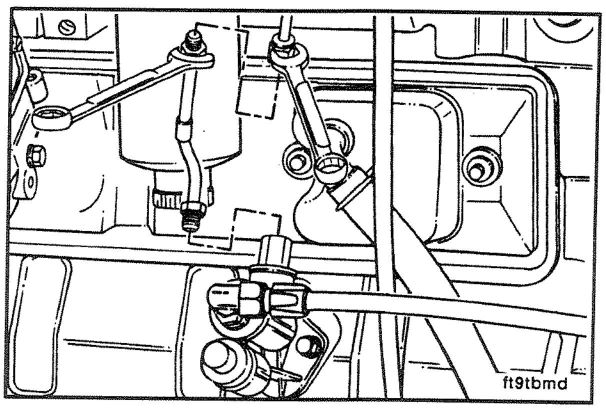
Tighten the bleed screw.



Fuel Transfer Pump Replacement/ Rebuild - Piston Style (5-22)

Preparatory Step:

- Clean debris from the fuel line fittings and the fuel transfer pump.

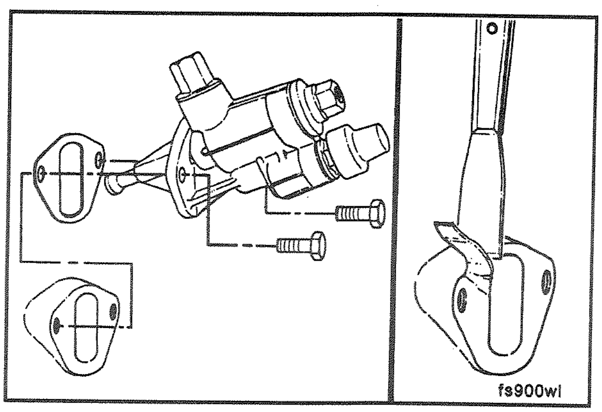


Removal

14 mm, 17 mm, 20 mm Wrench

Disconnect the fuel line from the fuel transfer pump and fuel filter head.

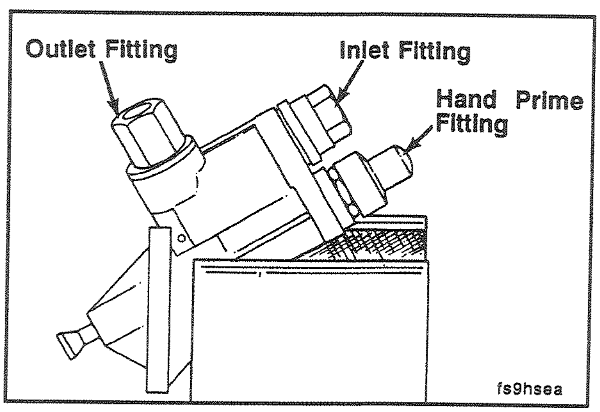
Use two wrenches to disconnect the fuel line from the fuel transfer pump.



10 mm Wrench

Remove the fuel transfer pump.

Clean the mounting surfaces on the cylinder block.



20 mm, 26 mm Wrench

Caution: The hand-prime fitting and inlet fitting are spring loaded. Sudden removal of these two fittings can cause personal injury.

Secure the fuel transfer pump in a vise, taking care not to damage the pump housing.

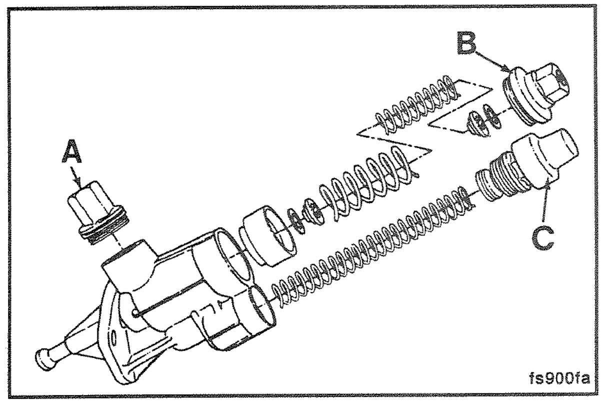
Remove the rubber boot from the hand-prime fitting.

Remove the three illustrated fittings.

Remove all internal components of the fuel transfer pump.

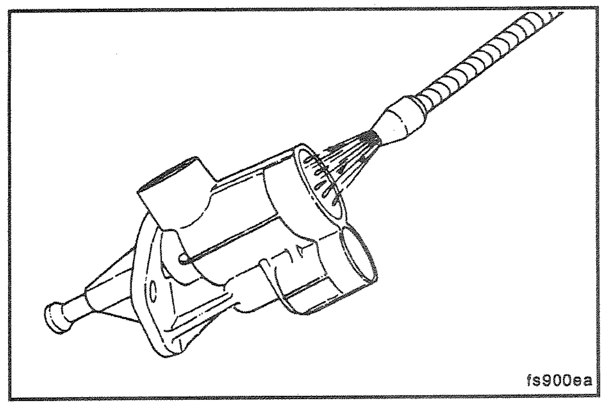
NOTE: Make sure the check valve gaskets are removed from the inlet fitting.

(A) Outlet Fitting(B) Inlet Fitting
(B) Inlet Fitting
(C) Hand Primer Fitting



Cleaning

Thoroughly flush the fuel transfer pump with a cleaning solution to remove any debris.



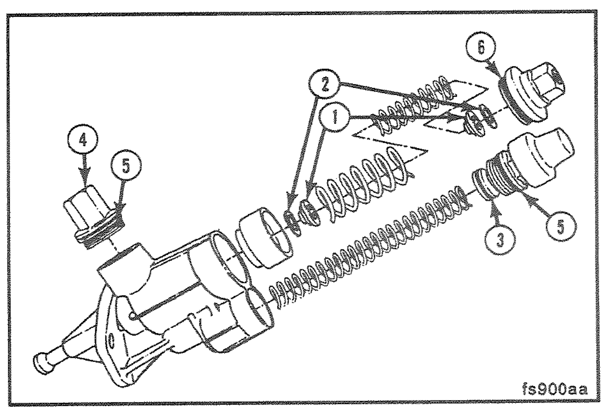
Assembly

20 mm, 26 mm Wrench

Assemble the fuel transfer pump with the new components supplied in the rebuild kit.

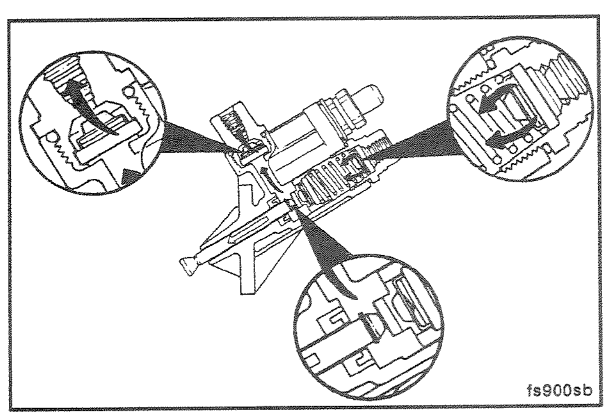
1. Check valves
2. Check valve gaskets
3. O-ring seal
4. Outlet fitting/check valve
5. *O-ring seal (25 mm)
6. *O-ring seal (30 mm) or (25 mm)

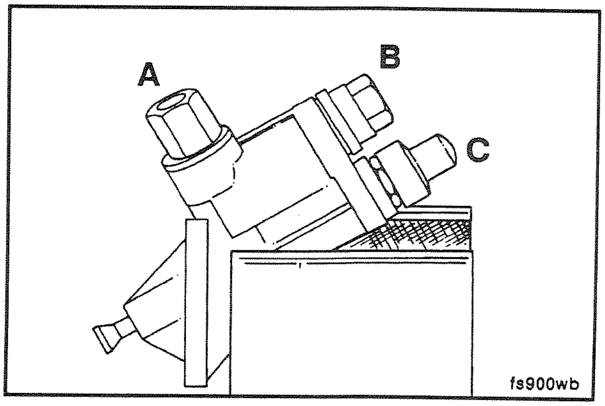
* O-ring required is determined by the size of the inlet fitting. Discard unused o-ring.



NOTE: Extreme caution must be used to make sure the check valves are installed to open in the direction of the fuel flow.

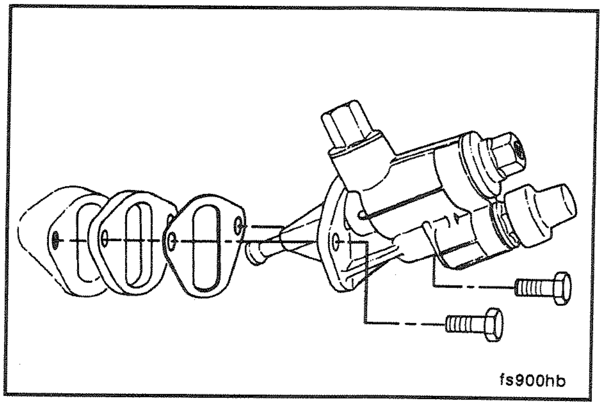
Improper installation of the check valves will result in low power from the engine.





Place the fuel transfer pump in a vise and torque the fittings to the following values:

(A) Outlet Fitting	30 N•m [22 ft-lb]
(B) Hand-Prime Fitting	30 N•m [22 ft-lb]
(C) Inlet Fitting	30 N•m [22 ft-lb]



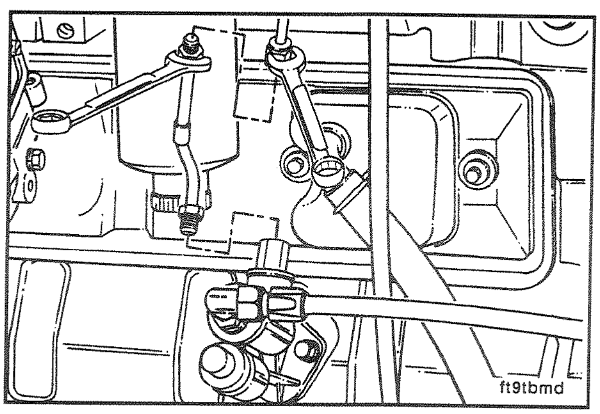
Installation

10 mm

Caution: Alternately tighten the mounting capscrews. As the capscrews are tightened the fuel transfer pump plunger is pushed into the pump. Failure to tighten the capscrews in an even manner can result in the plunger being bent or broken.

Install the pump.

Torque Value: 24 N•m [18 ft-lb]

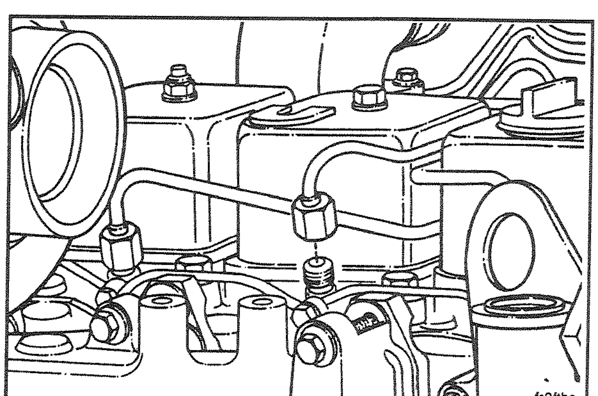


14 mm, 17 mm, 20 mm Wrench

Install the fuel line to the fuel transfer pump and fuel filter head. Use two wrenches to tighten the connection to the pump.

Torque Value: 24 N•m [18 ft-lb]

Refer to Procedure 5-15 for venting the low pressure fuel lines.



High Pressure Fuel Line Replacement - Distributor Type Pumps (5-23)

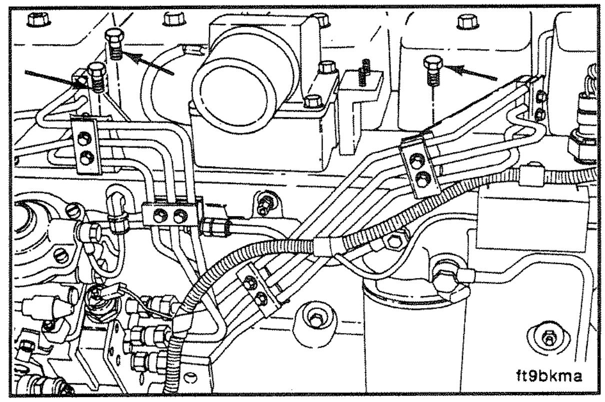
17 mm

Disconnect the high pressure fuel lines from the injectors and complete the following steps.

NOTE: Thoroughly clean area around fuel lines before removal.

10 mm

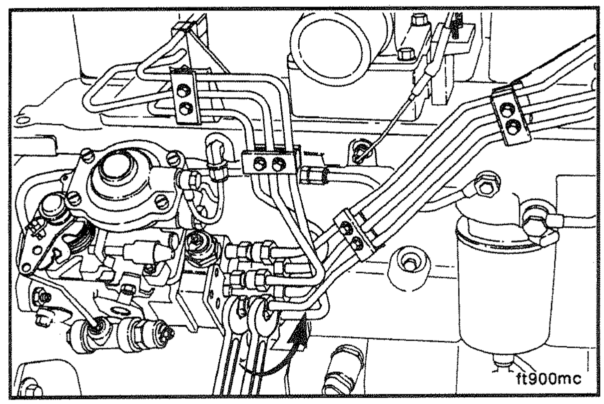
Remove the fuel line clamp capscrews from the intake cover.



14 mm and 17 mm

Remove the fuel lines from the fuel injection pump.

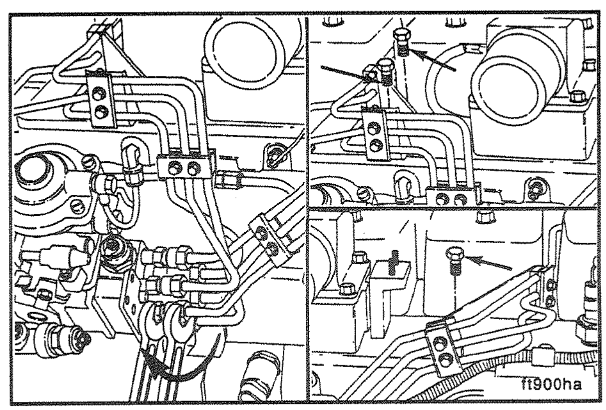
NOTE: Use two wrenches to prevent the delivery valve holder from turning.



10 mm

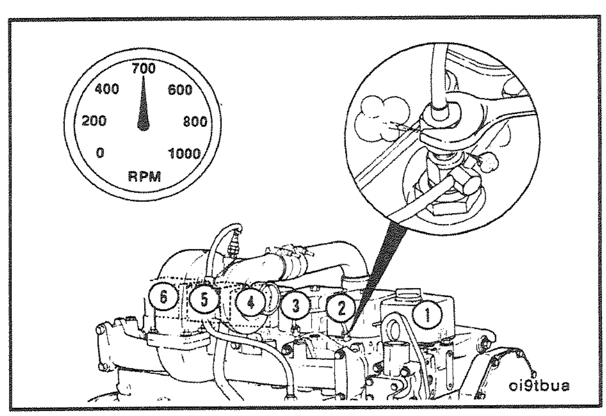
Assemble the fuel lines in the reverse order of removal.

Torque Value: 30 N•m [22 ft-lb]



Warning: Do not bleed a hot engine as this could cause fuel to spill onto a hot exhaust manifold creating a danger of fire.

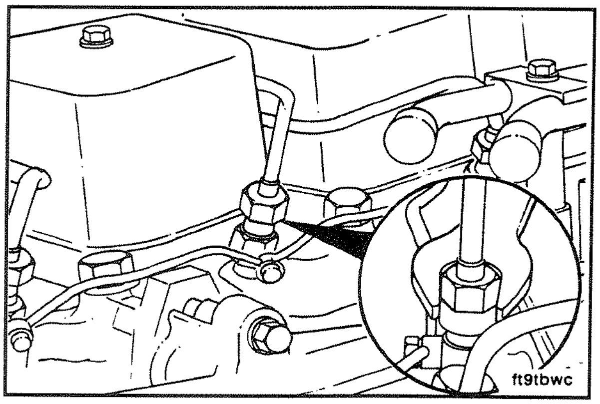
Operate the engine and vent one line at a time until the engine runs smoothly.



High Pressure Fuel Line Replacement - Bosch P7100 Pump (5-24)

Preparatory Steps:

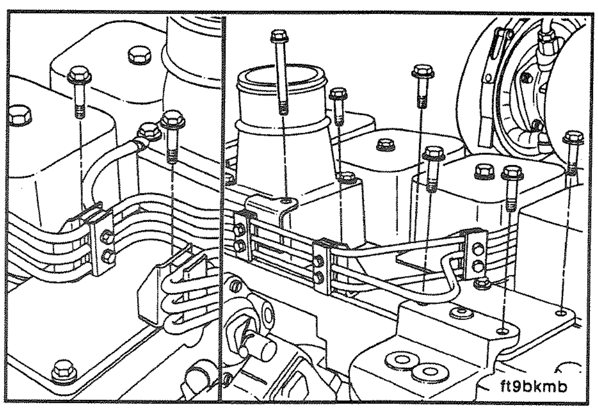
- Clean debris.



19 mm

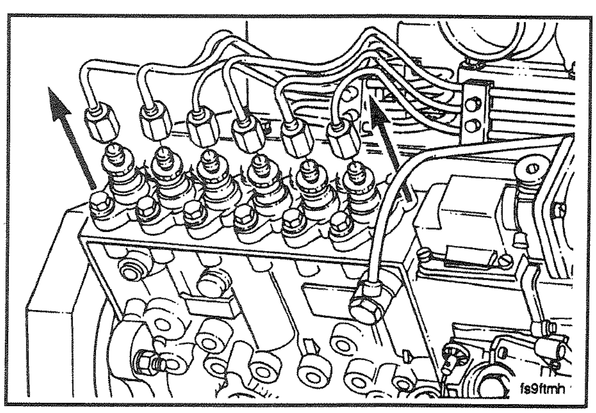
NOTE: If individual fuel lines are to be replaced, remove the support clamp from the set of fuel lines containing the line to be replaced.

Disconnect the fuel line(s) from the injectors.



10 mm

Remove the fuel line clamp capscrews from the intake cover.



19 mm

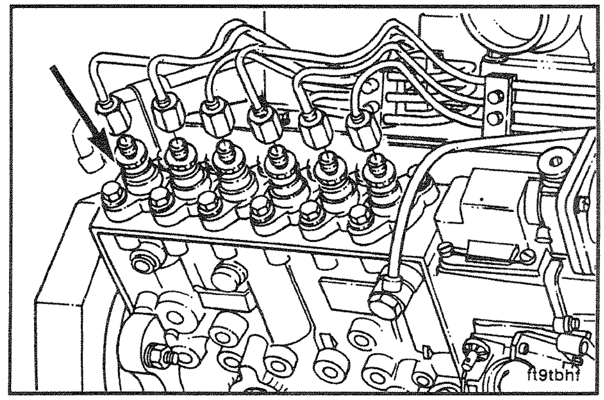
Disconnect the fuel line(s) from the fuel injection pump.

If removed, reinstall the support clamp in the original position and make sure the lines do not contact each other or another component.

Loosen the vibration isolator capscrews so the fuel lines can be easily moved.

NOTE: To prevent breakage to the fuel lines, they **must** be connected to the injector and fuel injection pump in a "free state" without forcing the connecting nuts. Since the fuel lines are properly sized for specific application, bending should **not** be necessary.

Install the fuel lines in the reverse order of removal.



Torque Value:

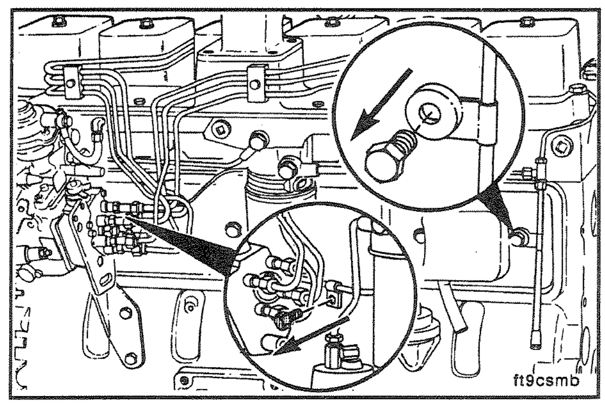
(Line Fittings)	30 N•m	[22 ft-lb]
(Support Clamp)	6 N•m	[4 ft-lb]
(Support Bracket)	24 N•m	[18 ft-lb]

NOTE: The inside holes of the intake manifold are drilled through and require liquid teflon sealant.

Fuel Drain Manifold Replacement - Distributor Type Pumps (5-25)

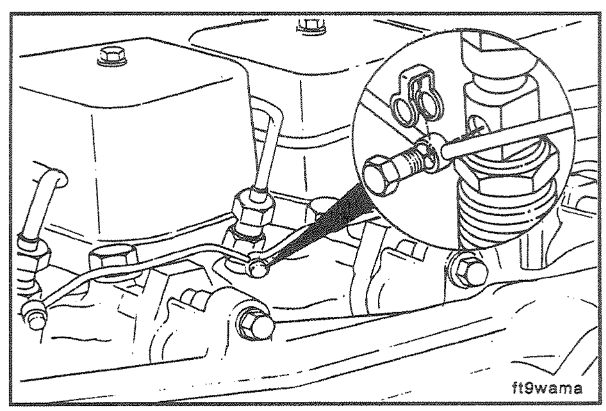
10 mm

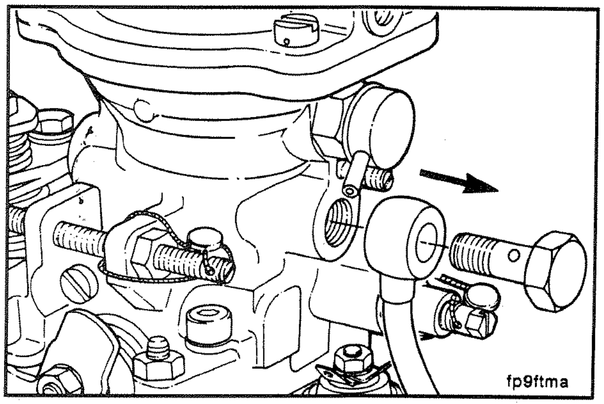
Remove the capscrews from the hold-down clamps and complete the following steps.



10 mm

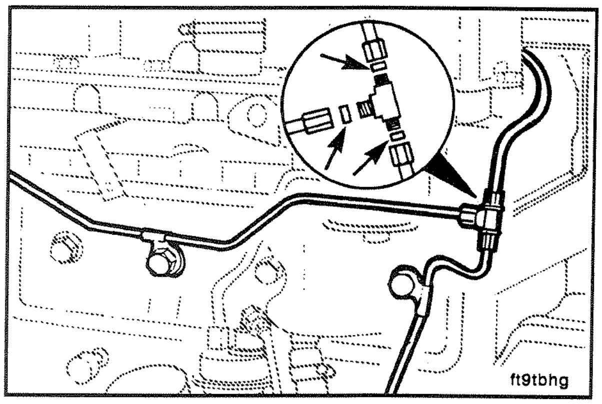
Remove the banjo fitting screws and washers.





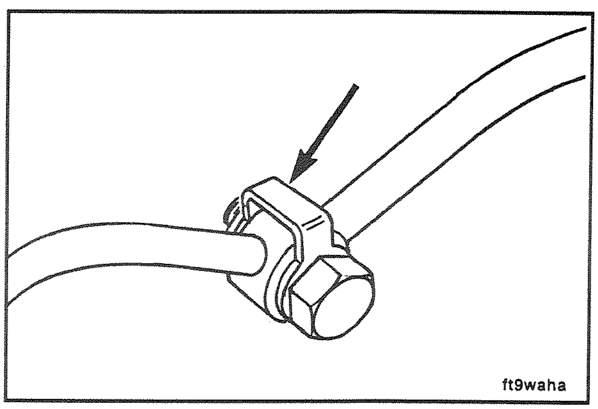
17 mm

Disconnect the fuel drain line fittings.



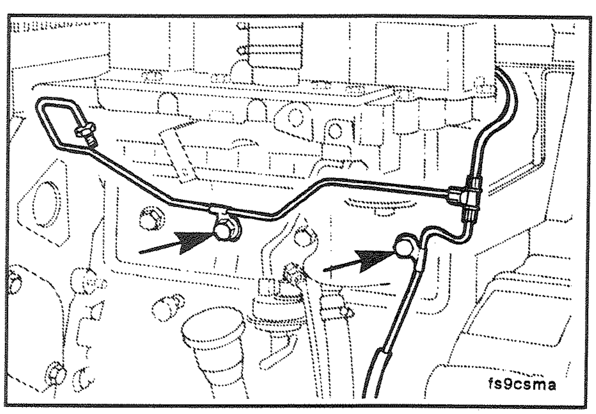
Assemble the fuel drain line and fuel drain manifold in the reverse order of disassembly.

NOTE: Use new seals for the fittings.



The installation torque for the banjo fitting screw is 9 N•m [7 ft-lb].

NOTE: Use new sealing washers for the fuel drain manifold.

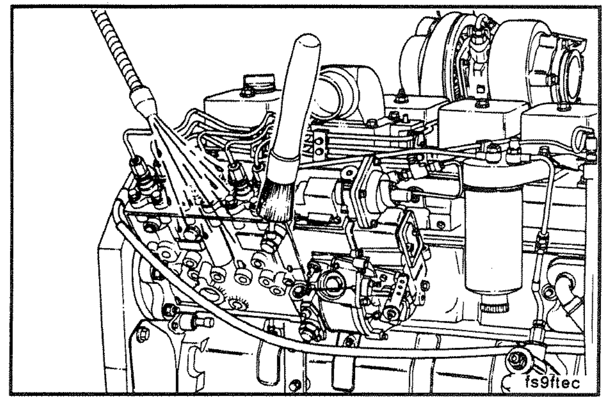


The installation torque for the clamp capscrews is 24 N•m [18 ft-lb].

Fuel Drain Manifold Replacement - Bosch P7100 (5-26)

Preparatory Steps:

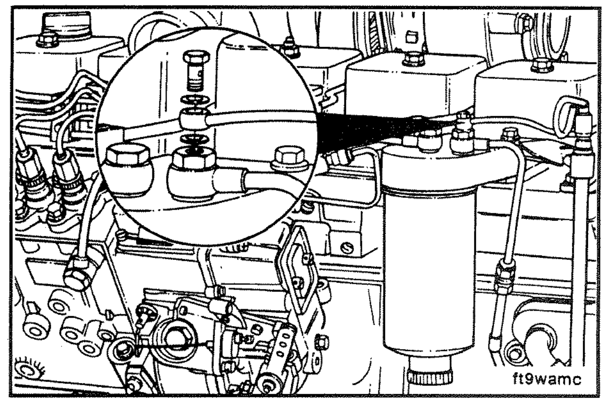
- Clean debris.



10 mm, 12 mm

Remove the banjo capscrews and copper sealing washers at the fuel filter head.

Remove the fuel line support bracket capscrew from the intake manifold.



10 mm

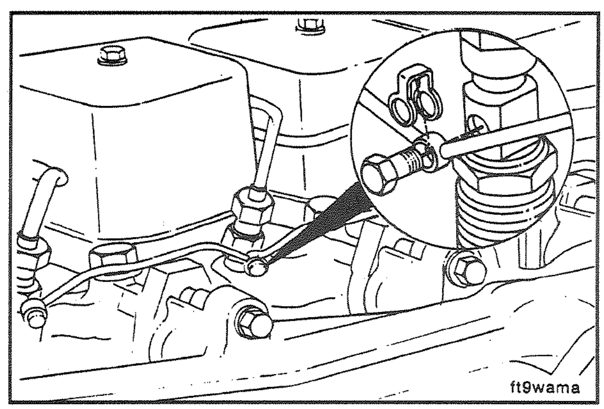
Remove the banjo capscrews and copper sealing washers from the injectors.

Install the fuel drain manifold in the reverse order of removal.

Torque Value:

- Injector Banjo 9 N•m [7ft-lb]
- Fuel Filter Head 13 N•m [10 ft-lb]

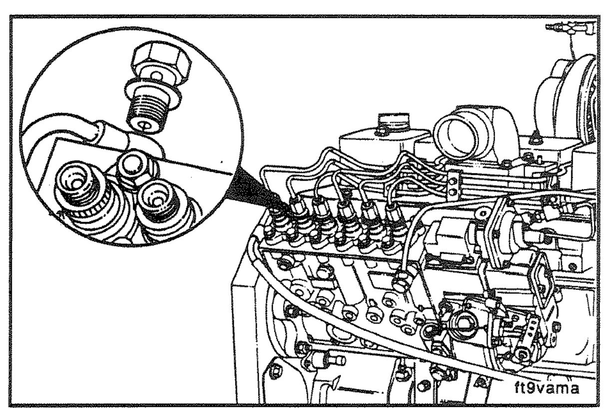
NOTE: The fuel line support bracket capscrew in the intake manifold requires liquid teflon sealant.

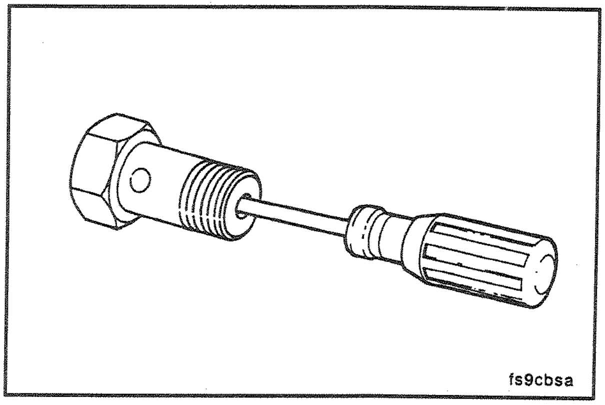


Pressure Relief Valve Replacement - Bosch P7100 (5-27)

19 mm

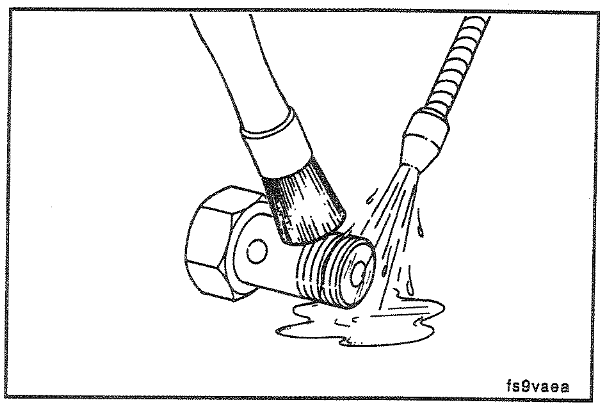
Remove the pressure relief valve and copper sealing washer.



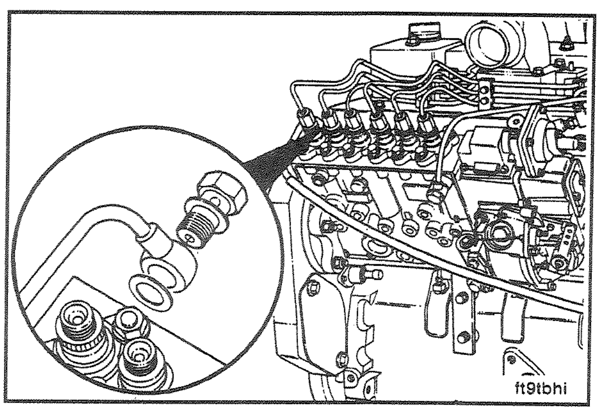

fs9cbsa

Use a small screwdriver to check that the check ball is not sticking in the high pressure relief valve assembly.

Caution: A sticky check ball will result in engine low power.

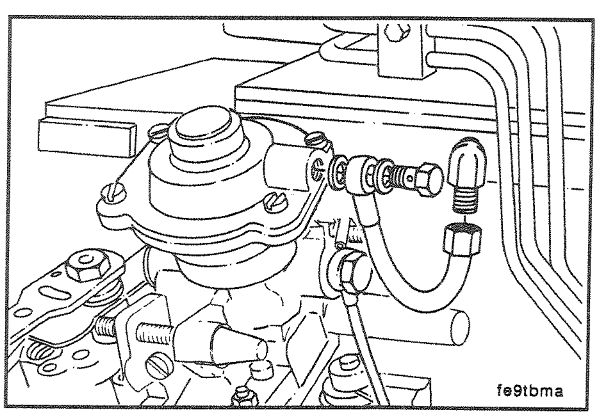

fs9vaea

Thoroughly flush the high pressure relief valve with cleaning solution.


ft9tbhi

10 mm, 19 mm

Install the high pressure relief valve assembly in the reverse order of removal.


fe9tbma

Air Fuel Control Tube Replacement - Bosch VE Pump (5-28)

12 mm, 1/2 inch

Remove the fuel tube from the manifold fitting and from the pump.

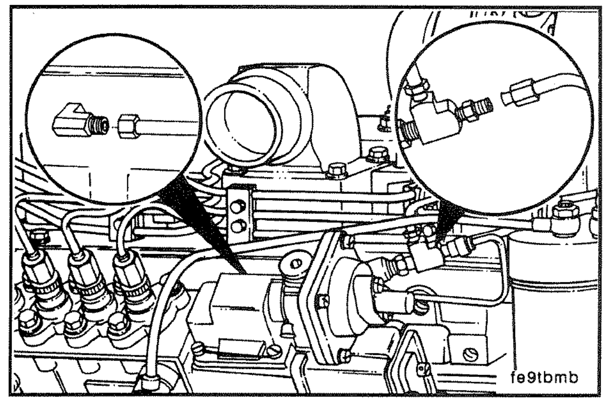
NOTE: Use new sealing washers when installing the tube.

Assemble in the reverse order of removal.

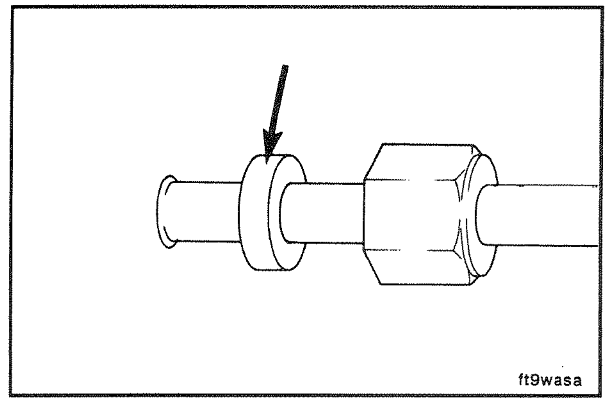
Air Fuel Control Tube Replacement - Bosch P7100 Pump (5-29)

13 mm

Remove the AFC tube.

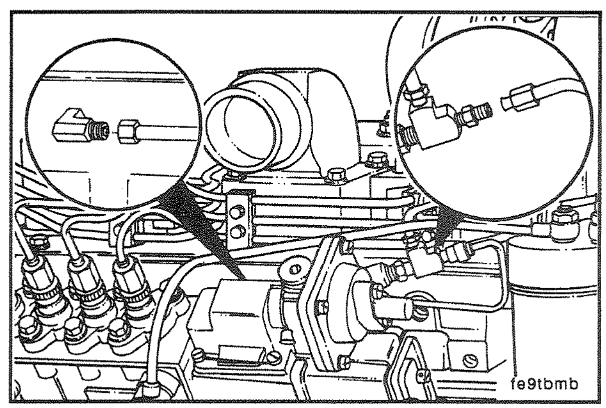


Inspect the rubber sealing washers and replace as necessary.



Install the AFC tube in the reverse order of removal.

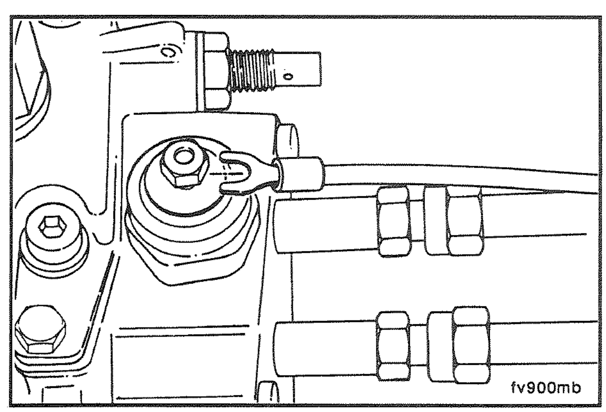
Torque Value: 24 N•m [18 ft-lb]

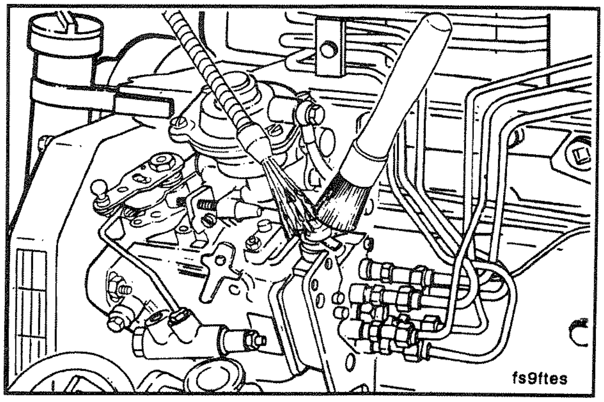


Fuel Shut Off Valve Replacement - Bosch VE (5-30)

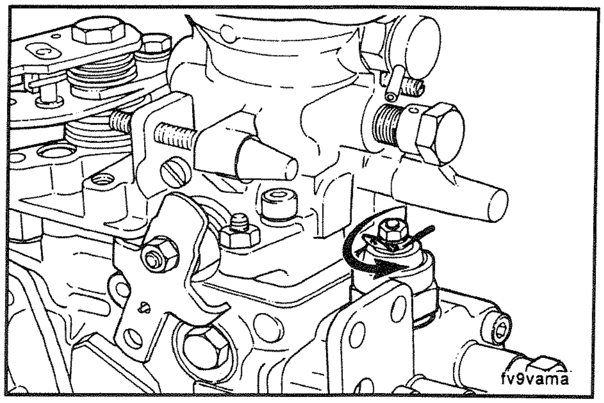
8 mm

Remove the electrical wire and complete the following steps.





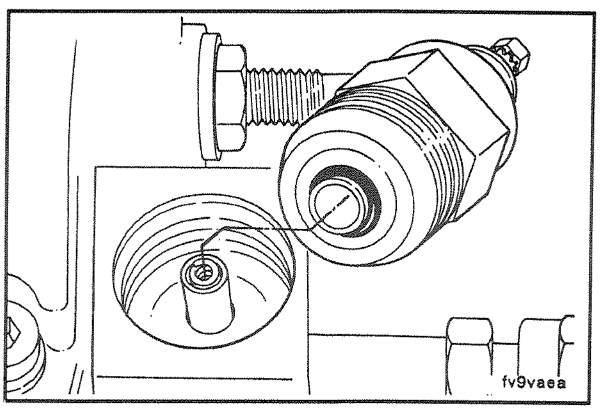
Clean around the valve.



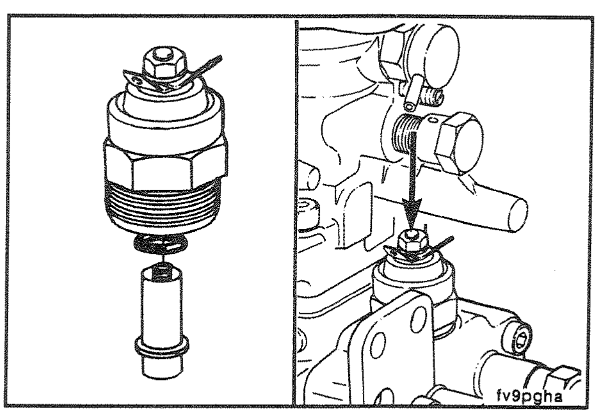
24 mm

Remove the valve.

NOTE: The Bosch VE valve is shown. The valve for Lucas CAV is located at the bottom of the pump.



Caution: When removing the valve, be careful not to drop the plunger and spring.



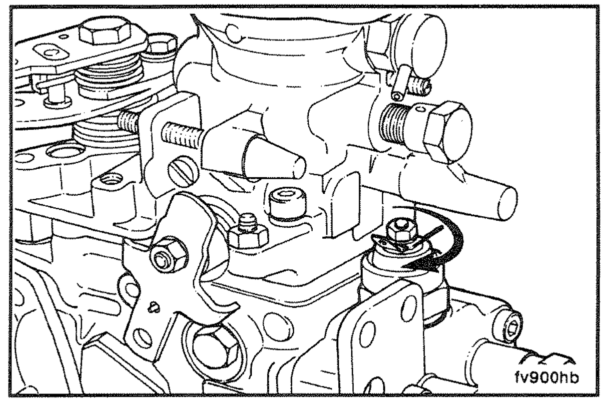
"Package" the solenoid, o-ring, spring and plunger.

24 mm

Tighten the solenoid securely.

Connect the electric wire.

Torque Value: 43 N•m [32 ft-lb]



Fuel Shut Off Solenoid Adjustment/ Replacement - Bosch P7100 (5-31)

Preparatory Steps:

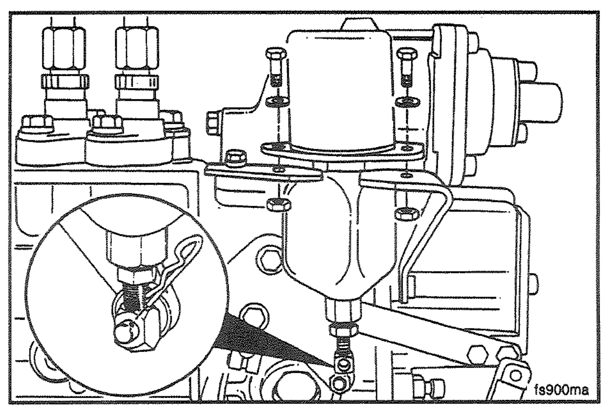
- Label and disconnect the wiring.

10 mm

Remove the two hold-down capscrews and clip pin.

Remove and replace the fuel shut off solenoid.

Torque Value: 9 N•m [7 ft-lb]



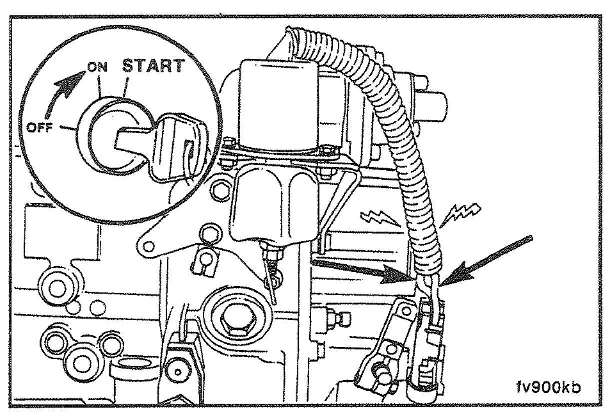
Adjustment

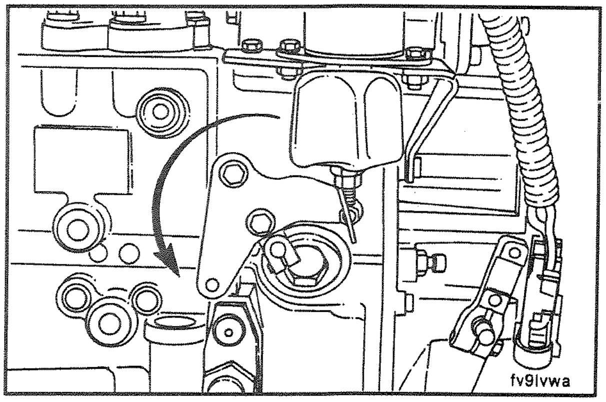
Refer to Procedure (5-11), Shut Down Solenoid (In-Line Type Injection Pump) - Troubleshooting, for troubleshooting the solenoid.

Turn the key to the "on" position. This will energize the red (hold) wire and black (common) wire.

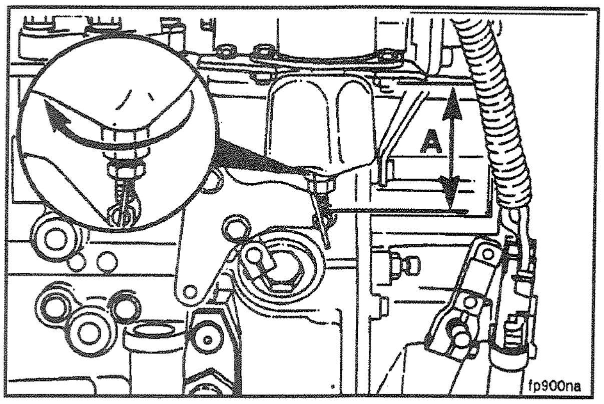
This is the low current hold-in coil and must be energized continuously during this adjustment.

NOTE: Do not turn the key to the "run" position at this time. This will energize the white (pull-in) wire.





Move the shutoff lever by hand to the full run position.



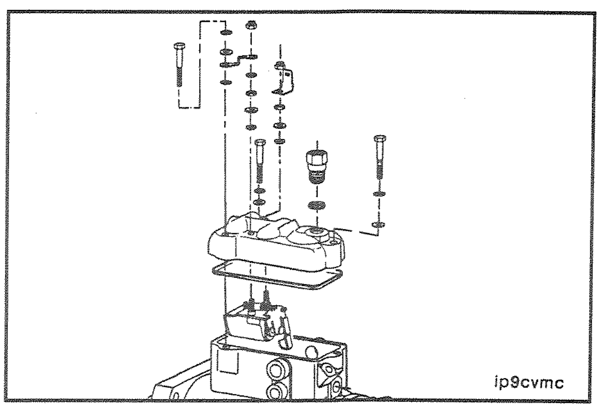
10 mm, 16 mm

Check the plunger travel.

A = 66.9 mm [2.64 in] maximum

NOTE: Dimension A is measured from the bottom of the mounting bracket to the top of the pivot pin.

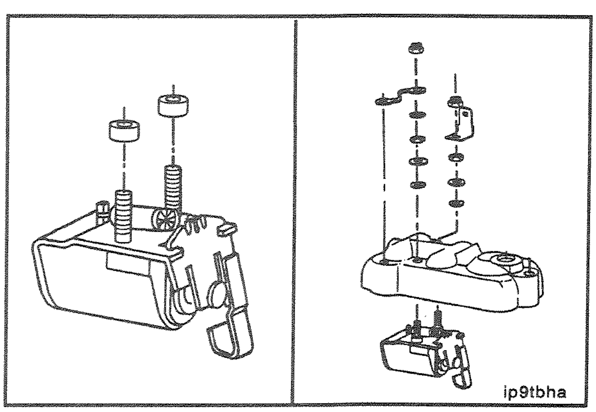
Adjust the solenoid linkage as necessary so that the plunger is magnetically held in now with the shutoff lever in the absolute full run position. Turn the large hex on the end of the plunger to make adjustments.



Fuel Shut Off Valve Replacement Stanadyne DB4 (5-32)

Removal

- Remove the electrical wiring.
- Remove the fuel drain line.
- Remove the throttle/shutoff linkage.
- Remove the fuel injection pump top cover.
- Disassemble the fuel injection pump top cover.



5/16 Inch

Install new insulating tubes onto the terminals on the terminal studs of the new solenoid.

Install the valve into the cover.

Torque Value: 14 N•m [12 in-lb]

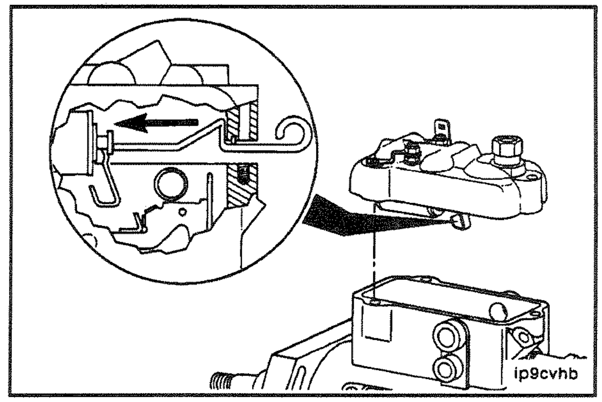
Installation

5/16 Inch

Install the cover and gasket onto the fuel injection pump.

With the tool installed as shown, place the cover in position on the pump housing. Twist the tool to release it and slide it out from between the cover and the housing.

NOTE: Extreme care must be taken in assembling the cover to a fuel injection pump to make sure the shutoff arm is in proper contact with the linkage hook tab.

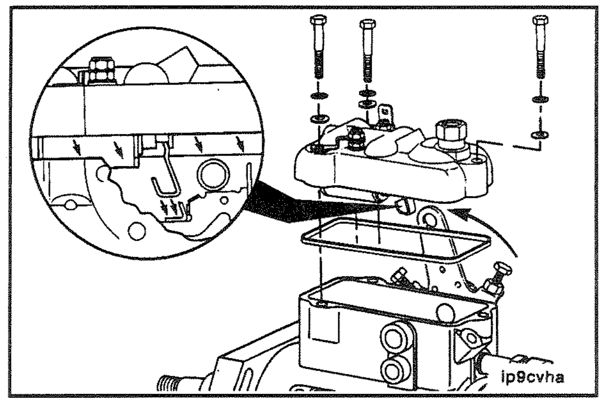


In the event that the service tool is not available, the governor cover should be installed as follows:

Move the shut off lever to the stop position.

Install the cover to pump at a downward angle from the drive shaft end of the fuel injection pump, then slide the cover horizontally into position.

Torque Value: 4.6 N•m [41 in-lb[

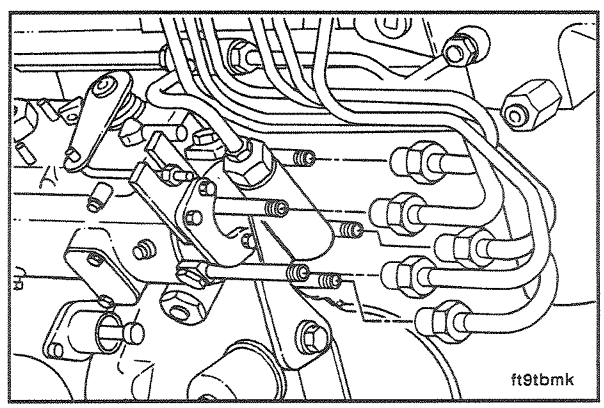


Back Leakage Valve and Sealing Washer (Lucas CAV DPA) - Replacement (5-33)

17 mm

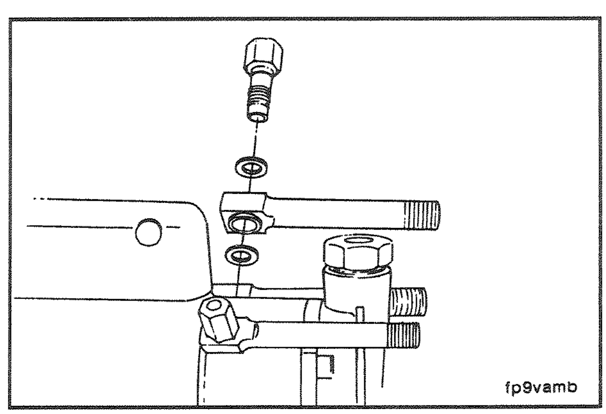
Disconnect the high pressure line.

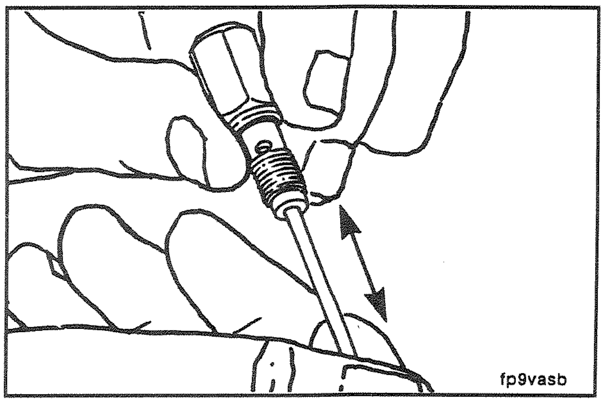
NOTE: Because the valves are installed 90 degrees to the pump axis, the pump may need to be removed to change the valves close to the cylinder block.



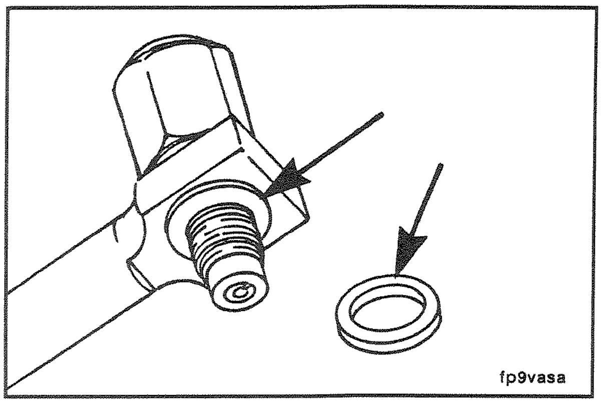
16 mm

Remove the valve.

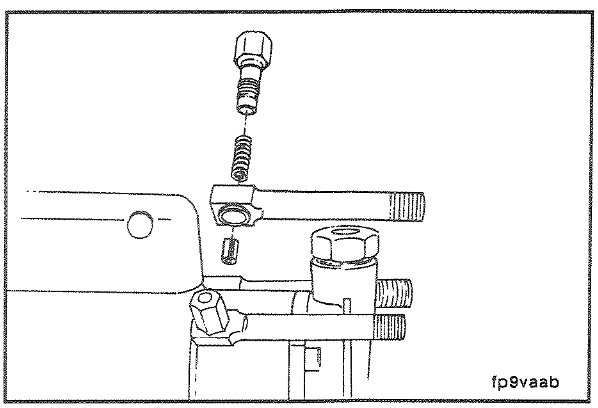




Inspect the valve to be sure it is not stuck.



Inspect the sealing surfaces for possible leak paths.

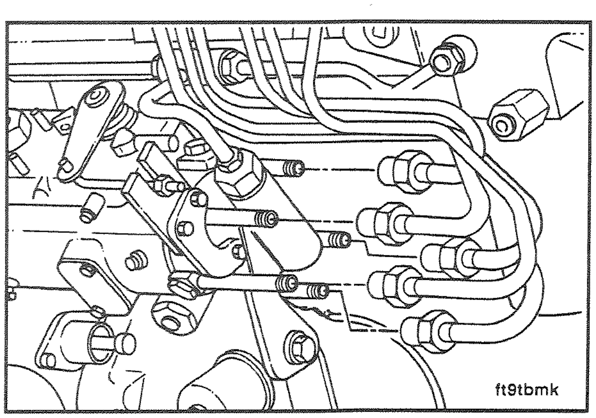


16 mm

Caution: The installation torque is very critical. Over-tightening can distort the bore in the pump hydraulic head causing the rotor to seize in the bore. Never tighten the valve with the engine running.

Assemble the back leakage valve and new washers.

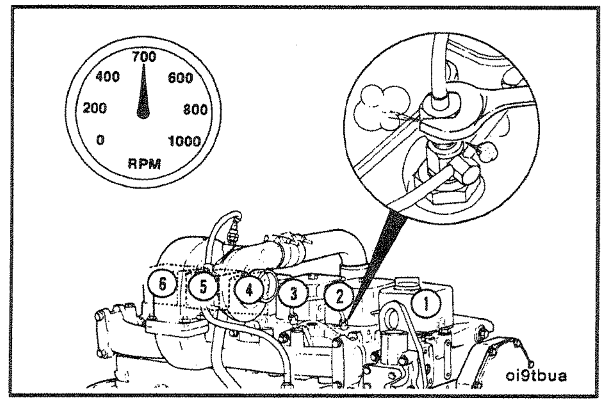
Tighten the valve to 30 N•m [23 ft-lb].



17 mm

Connect the high pressure line.

Start the engine and vent one line at a time until the engine runs smoothly.

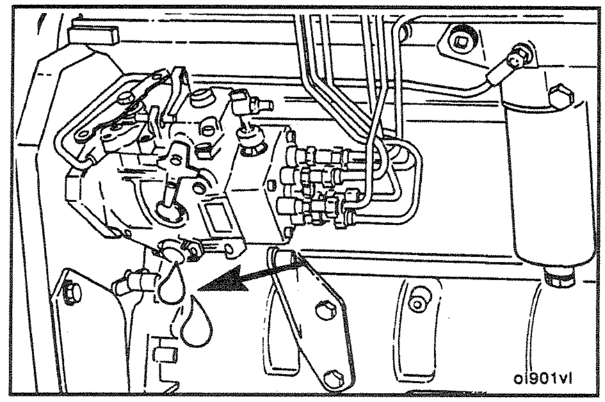


External Pump Leaks (Distributor Type Pumps) - Repair (5-34)

Make sure that the surrounding area is clean before removing the leaking part.

NOTE: Accessible sealing washers and gaskets can be replaced without removing the pump.

Refer to the Shop Manual, Bulletin 3810206 for additional information.

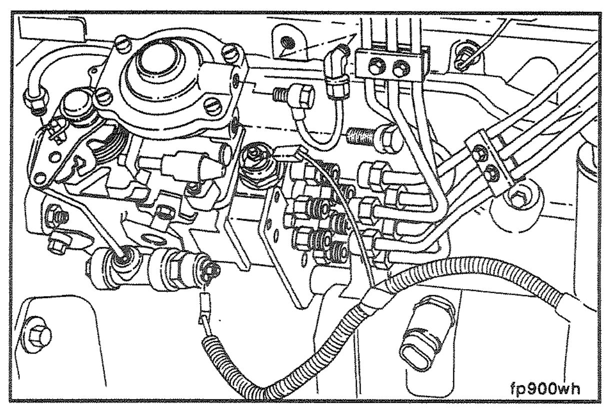


Fuel Injection Pump Replacement (Distributor Type Pumps) (5-35)

Bosch VE, Lucas CAV DPA, and Stanadyne DB4

Preparatory Steps:

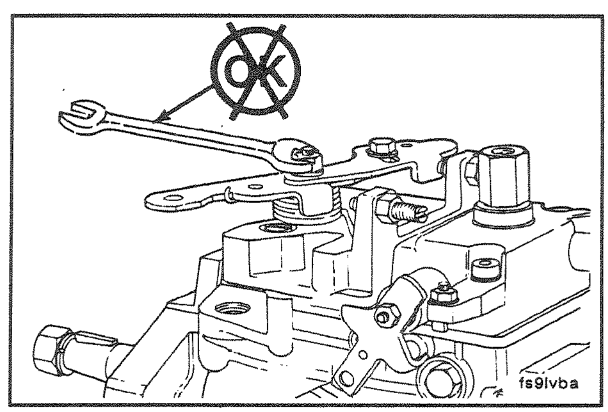
- Disconnect the fuel drain manifold.
- Remove the injection pump supply line.
- Remove the high pressure lines.
- Disconnect the electrical wire to the fuel shut off valve.
- Remove the fuel air control tube, if used.

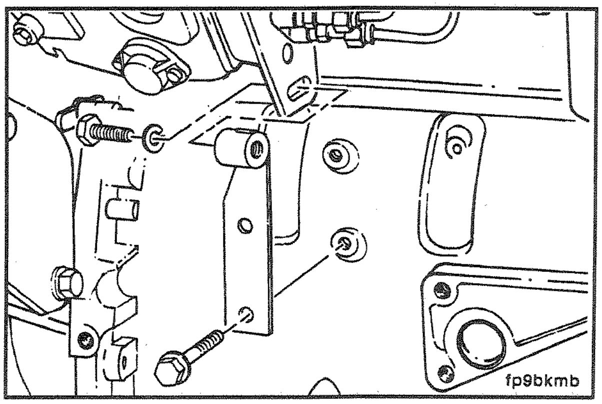


Removing the Pump

Caution: Do not remove the control lever. The Bosch VE lever is indexed to the shaft during pump calibration.

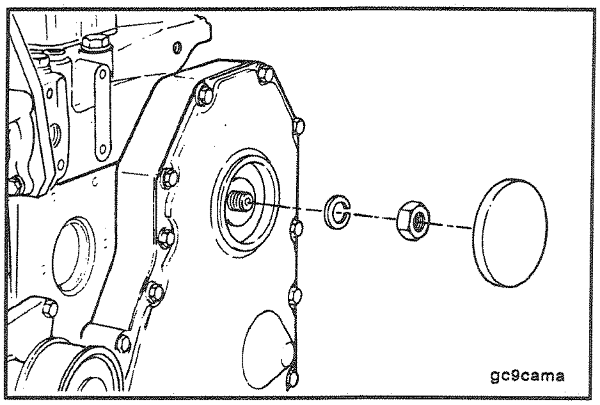
Disconnect all control linkage.





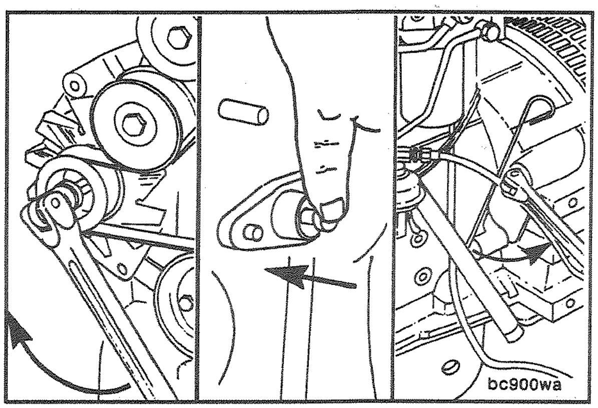
13 mm

Remove the pump support bracket.



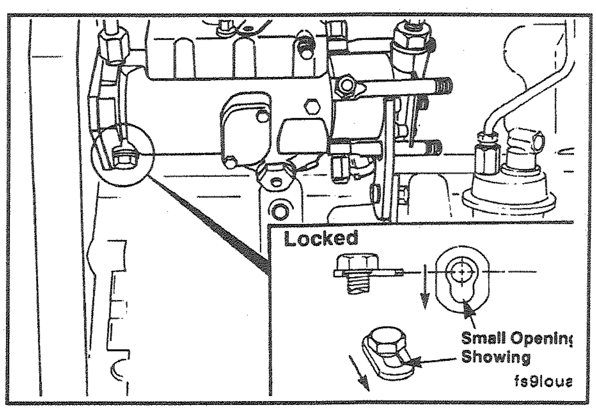
22 mm

Remove the access cap and gear retaining nut and washer.



Be sure to disengage the pin after locating TDC.

Locate TDC for Cylinder No. 1 by barring engine slowly while pushing in on TDC pin.



9/16 inch

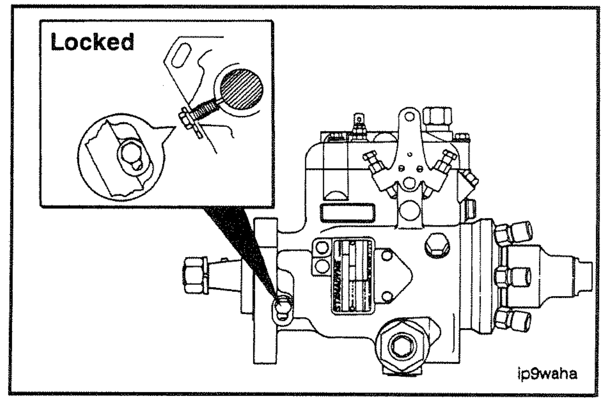
Loosen the CAV fuel injection pump lock screw and position the special washer, then tighten the lock screw against the pump drive shaft.

Torque Value: 7 N•m [5 ft-lb]

3/8 Inch

Loosen the Stanadyne DB4 fuel injection pump lock screw and position the special washer. Tighten the lock screw until contact is made with the fuel injection pump drive shaft.

Torque Value: 12 N•m [9 ft-lb]

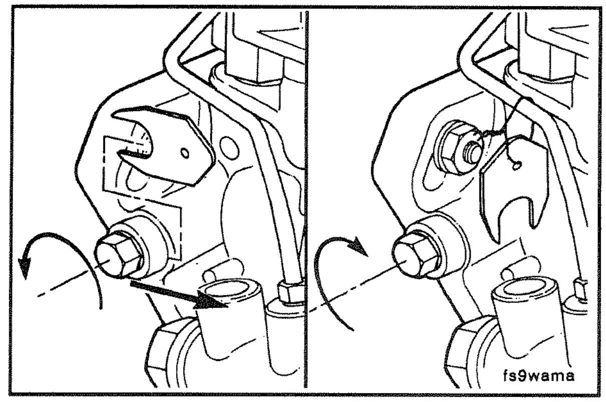


8 mm Allen Wrench or 10 mm Hex

The special washer on the Bosch injection pump must be removed so the lock screw can be tightened against the drive shaft.

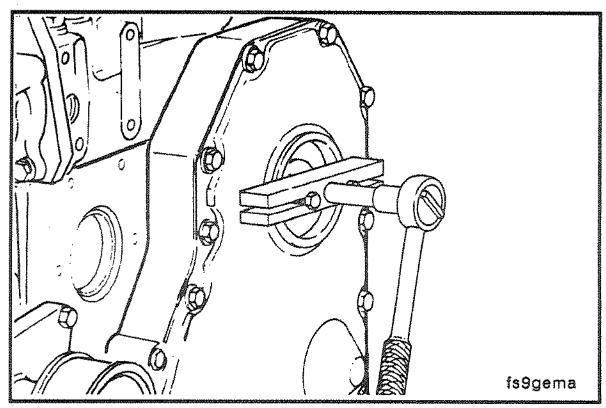
Torque Value: 30 N•m [22 ft-lb]

NOTE: Wire the washer to the pump.



75 mm T-Bar

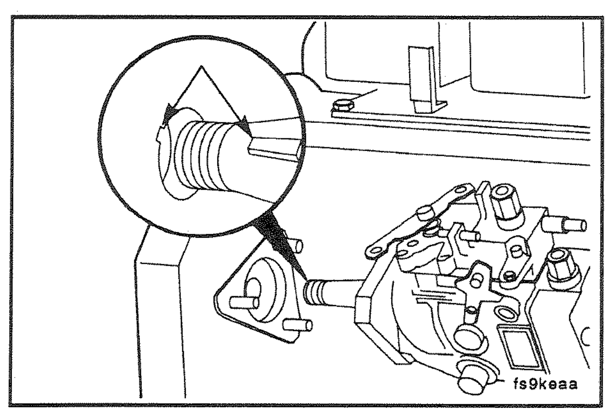
Pull the fuel injection pump drive gear loose from the pump drive shaft.

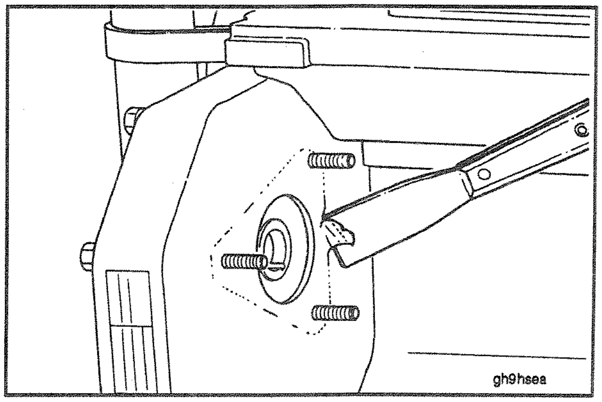


13 mm

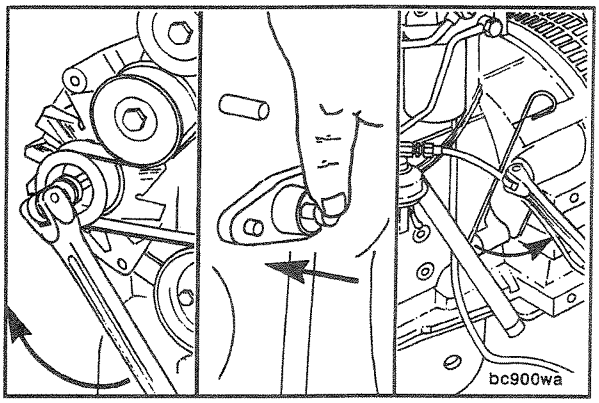
Do not drop drive gear key when removing the pump.

Remove the 3 mounting nuts and take off the fuel injection pump.



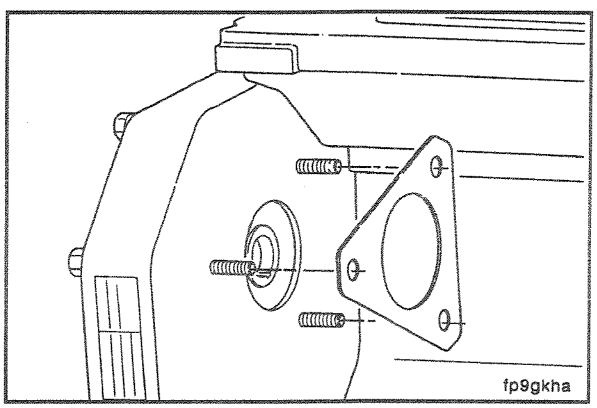


Remove the gasket and clean the surface.

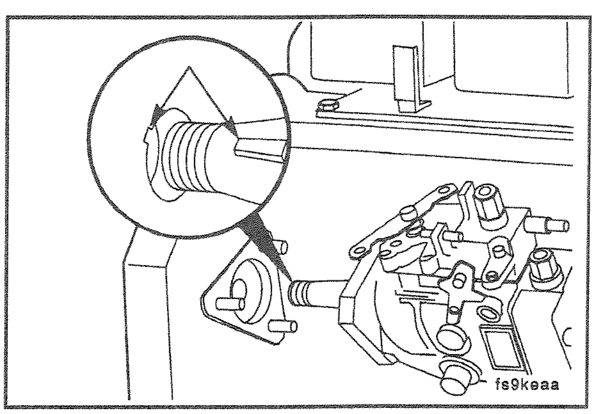


Installing the Pump

Verify Cylinder No. 1 is at TDC by barring engine slowly while pushing in on TDC pin.



Install a new gasket.

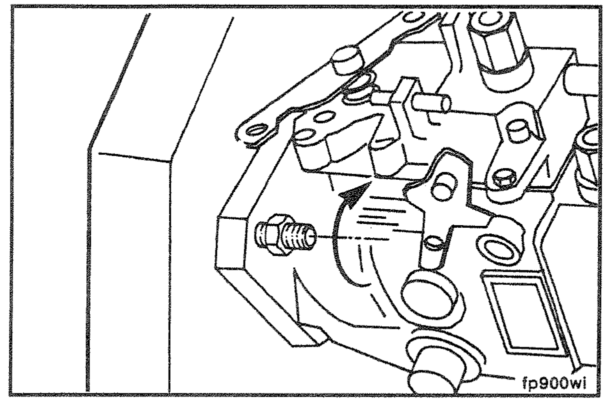


Caution: The drive shaft must be clean and free of all oil before installation. Failure to ensure the drive shaft is free of oil can result in the drive gear slipping on the shaft.

NOTE: The shaft of a new or reconditioned pump is locked so the key aligns with the drive gear keyway when Cylinder No. 1 is at TDC on the compression stroke.

Install the pump. Make sure the key does not fall into the gear housing.

Use your hands to tighten the three mounting nuts. The pump must be free to move in the slots.

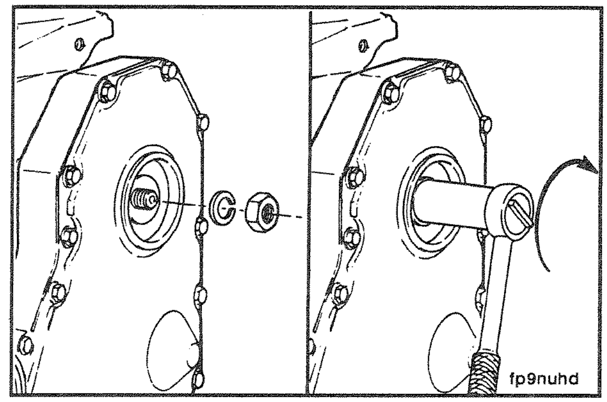


22 mm

Caution: Do not overtighten. This is not the final torque.

Install the pump drive shaft nut and spring washer. The pump will rotate slightly because of gear helix and clearance. This is acceptable providing the pump is free to move on the flange slots and the crankshaft does not move.

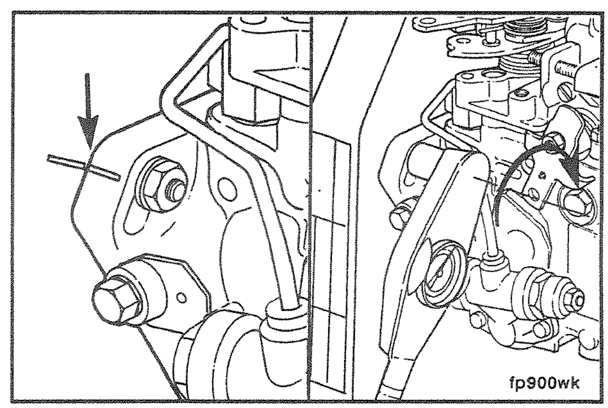
Torque Value: 15 to 20 N•m [11 to 15 ft-lb]



13 mm

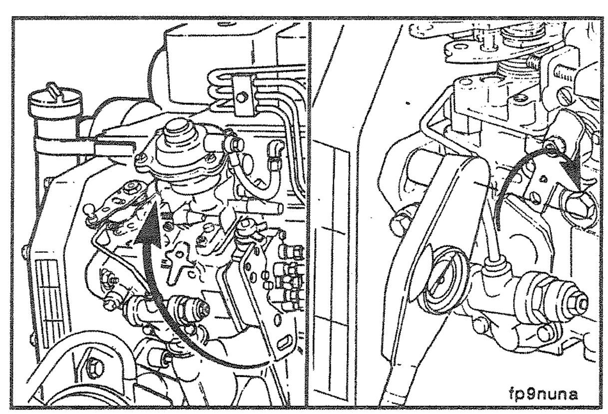
If installing the original pump, rotate the pump to align the scribe marks.

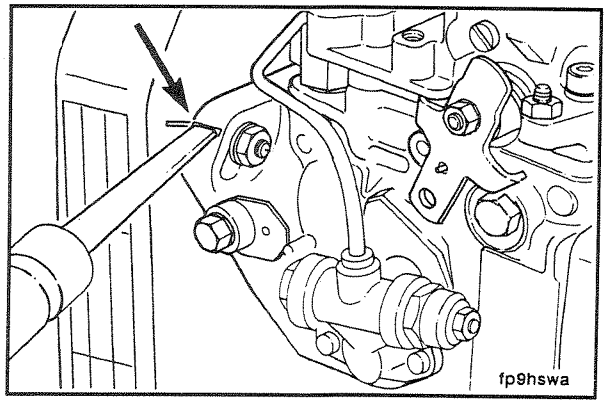
Torque Value: 24 N•m [18 ft-lb]



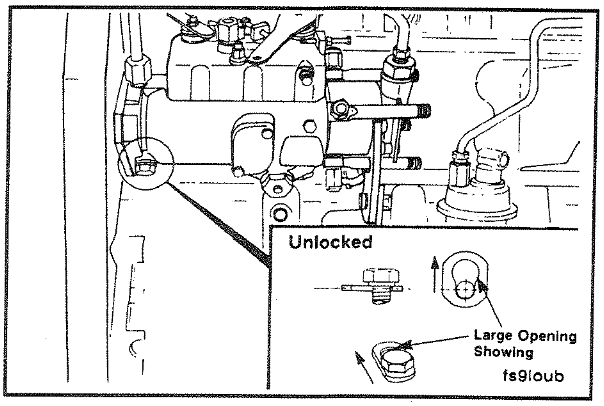
If installing a new or rebuilt pump without scribe marks, take up gear lash by rotating the pump against the direction of drive rotation. Tighten the flange mounting nuts.

Torque Value: 24 N•m [18 ft-lb]





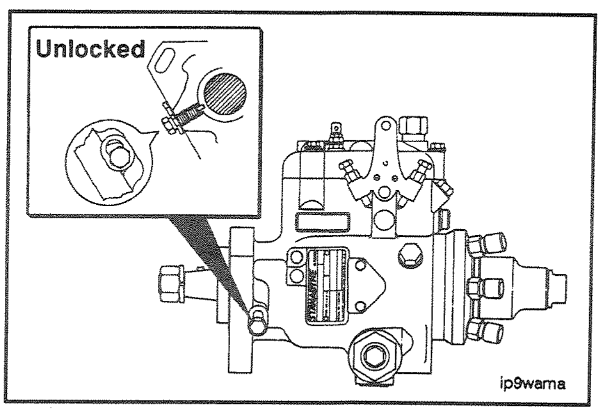
Permanently mark the injection pump flange to match the mark on the gear housing.



9/16 inch

Loosen the CAV pump lockscrew and position the special washer behind the lockscrew head.

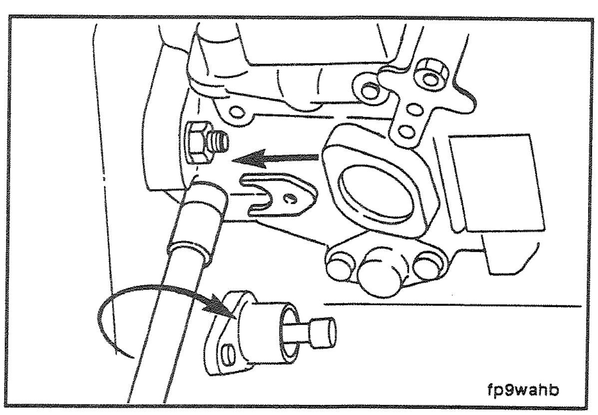
Torque Value: 20 N•m [15 ft-lb]



3/8 Inch

Loosen the Stanadyne DB4 fuel injection pump lock screw and position the special washer behind the lock screw head.

Tighten the lock screw.

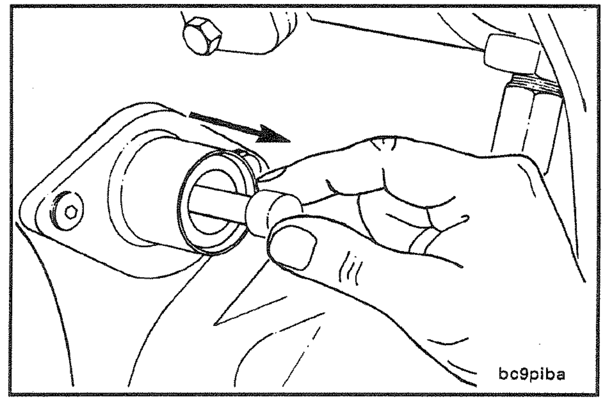


8 mm Allen or 10 mm Hex

On the Bosch pump, the special washer is wired to the pump and must be installed under the lockscrew.

Torque Value: 13 N•m [10 ft-lb]

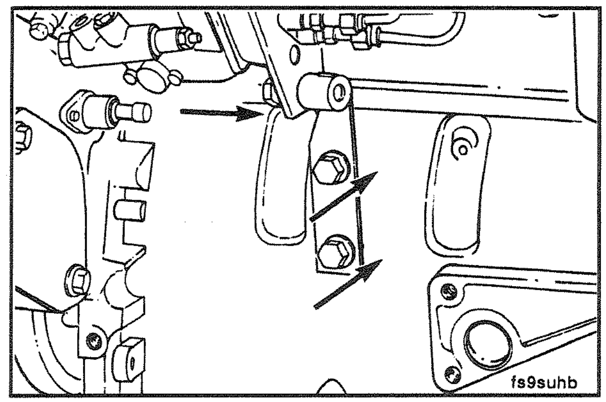
Disengage the timing pin before rotating the crankshaft.



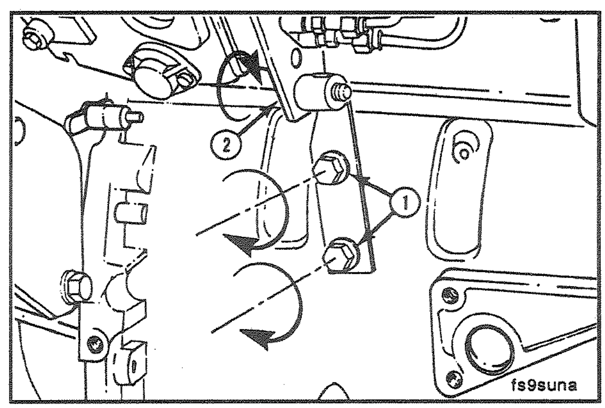
10 mm

Install the injection pump support bracket. Finger tighten all capscrews before final tightening.

NOTE: Tighten the bracket to block mounting capscrew before tightening the bracket to injection pump capscrews.



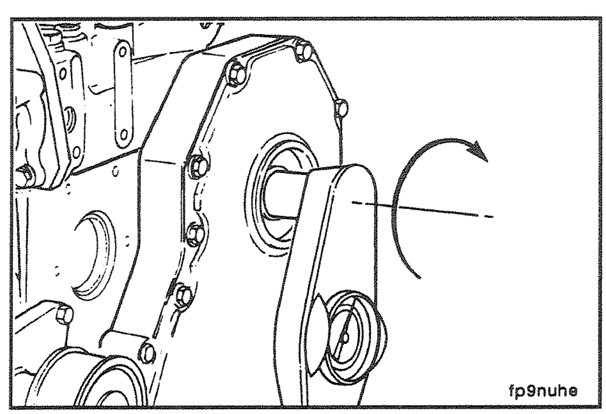
Torque Value: 24 N•m [18 ft-lb]

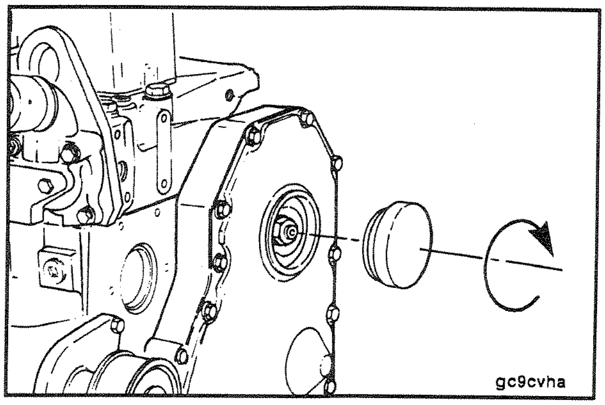


22 mm

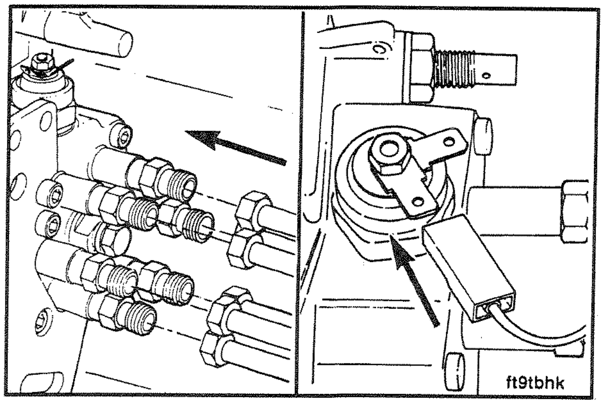
Tighten the pump retaining nut.

Torque Value: Bosch 65 N•m [48 ft-lb]
Stanadyne 65 N•m [48 ft-lb]



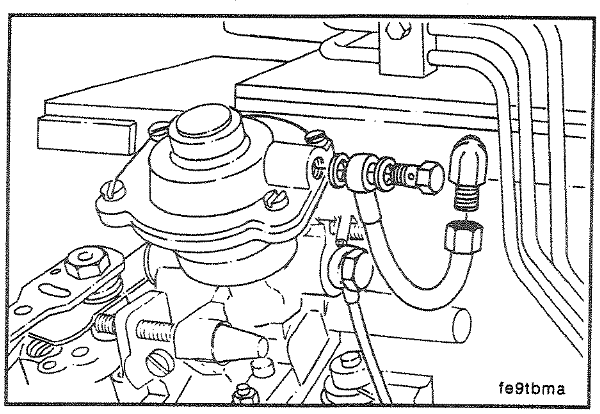


Install the access cap.



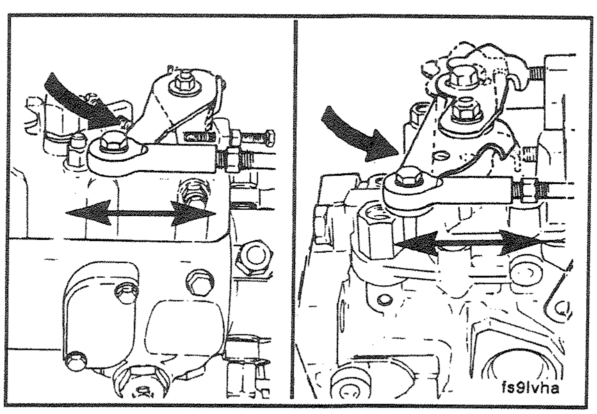
8 mm

Install all fuel lines and the electrical wire to the fuel shut off valve.



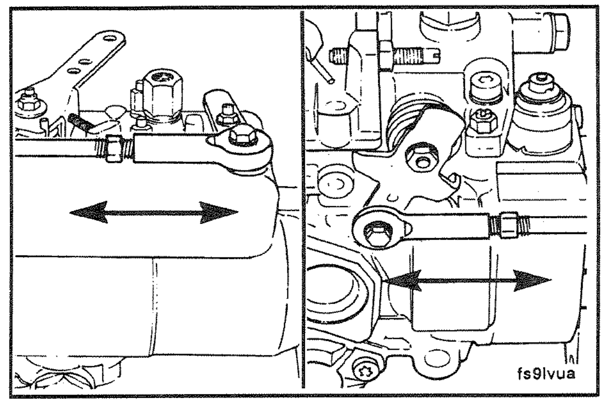
12 mm and 1/2 inch

If required, install the air fuel control tube.



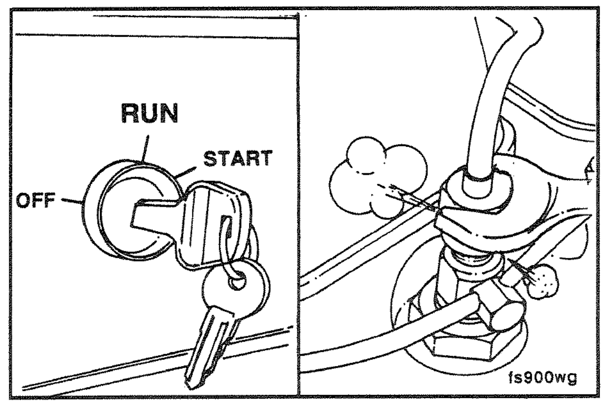
When connecting the cable/rod to the control lever, adjust the length so the lever has stop-to-stop movement.

Adjust the length of the cable or rod to the mechanical shut down lever so there is stop-to-stop movement.

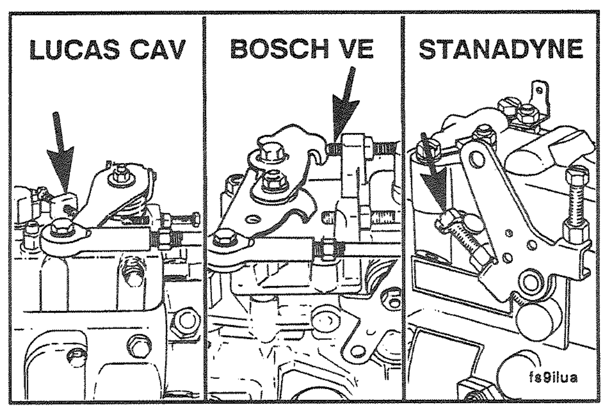


Bleed all air from the fuel system.

Refer to Procedure (5-15).



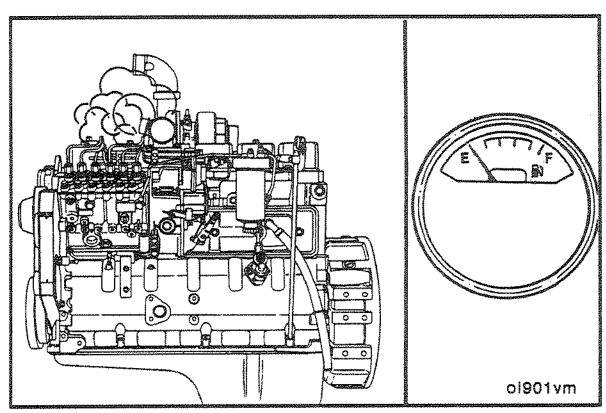
If necessary, adjust the idle speed.

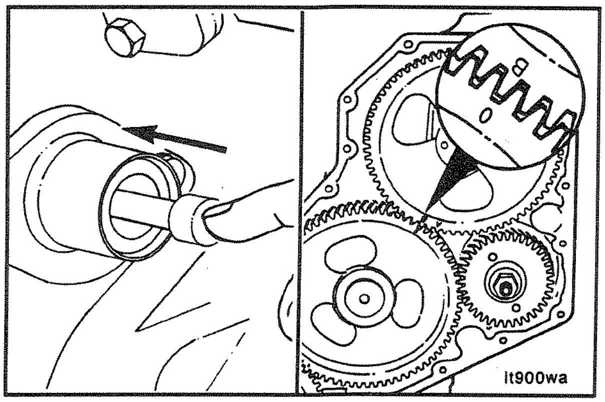


Fuel Injection Pump Timing (5-36)

Pump-to-engine timing is extremely critical. Pump timing that is off by only a few crankshaft degrees will cause:

1. Poor performance - starting and power.
2. Excessive smoke and emissions.
3. Poor fuel economy.





Engine pump timing begins with the timing of the fuel injection pump drive gear to the camshaft gear.

The first step is the location of TDC of the compression stroke for Cylinder No. 1.

Then, depending on the engine configuration, a letter on the gear may need to be aligned with the mark on the camshaft gear.

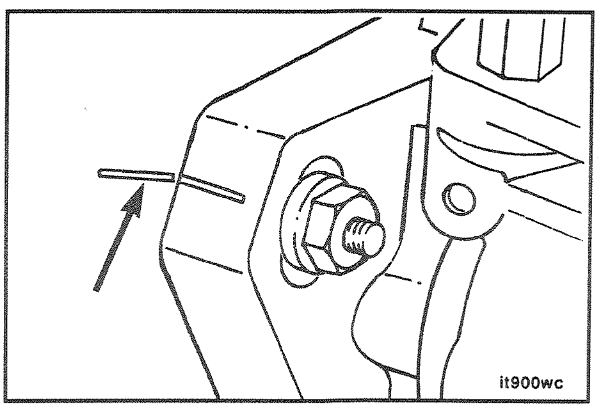
Letter on Pump Gear	Engine Model	Injection Pump	Certification
A	4B3.9, 4BT3.9	Stanadyne	Non-Certified
A	4B3.9, 4BT3.9, 4BTA3.9	Lucas CAV DPA Pump	All Non-Certified
B	4B3.9, 4BTA3.9	Robert Bosch VE Pump	86.87 EPA All pre-86 All Non-Certified
C	6BT5.9, 6BTA5.9	Rober Bosch VE Pump	86.87 EPA All pre-86 All Non-Certified CPL 600
D	6B5.9, 6BT5.9	Stanadyne	Non-Certified
D	6B5.9, 6BT5.9, 6BTA5.9	Lucas CAV DPA Pump	All Non-Certified
E	6BT5.9, 6BTA5.9	Rober Bosch VE Pump	86,87,88,89,90,91,92 CARB 88,89,90,91,92 EPA
F	4BT3.9, 4BTA3.9	Rober Bosch VE Pump	86,87,88,89,90,91,92 CARB 88,89,90,91,92 EPA
G	6BTA5.9	Lucas CAV DPA	All Fire Pump CPL 1165
H	Not Used at This Time		

It900ga

This table must be used to make sure of proper fuel injection pump-to-engine timing. The critical parts list (CPL) number from the engine data plate and the Control Parts List Manual, Bulletin No. 3379133-20, must be used to determine whether or not the engine is certified, and if so, what year and regulating agency (EPA or CARB).

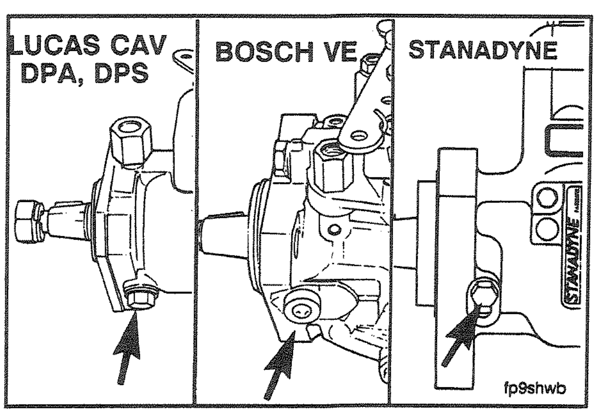
Given this information, use the following table to determine which letter on the fuel injection pump drive gear is aligned with the camshaft gear.

NOTE: Timing mark alignment is not required for the Nippondenso EP-9 or Bosch P7100 drive gear.



To verify that the fuel injection pump is timed correctly, first check the alignment marks on the pump flange and gear housing.

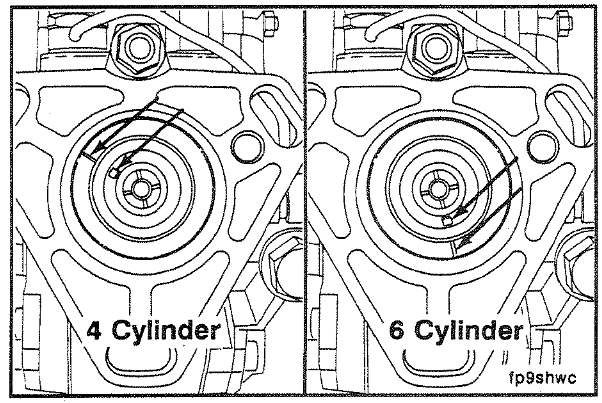
NOTE: 1 mm of rotation past the timing mark will advance or retard (depending on direction of rotation) the pump timing by 1 degree.



The Lucas CAV DPA, DPS, Stanadyne DB4, and the Bosch VE fuel injection pumps all have a provision for locking the pump shaft at a position corresponding to top-dead-center for Cylinder No. 1. New and reconditioned fuel injection pumps should be received with the shafts located in this position.

At the point of injection the key way of the shaft will align with the delivery valve receiving the injection, and the illustrated hash mark on the seal housing.

NOTE: The illustrated mark is for reference only and should not be used for setting the fuel injection pump timing.

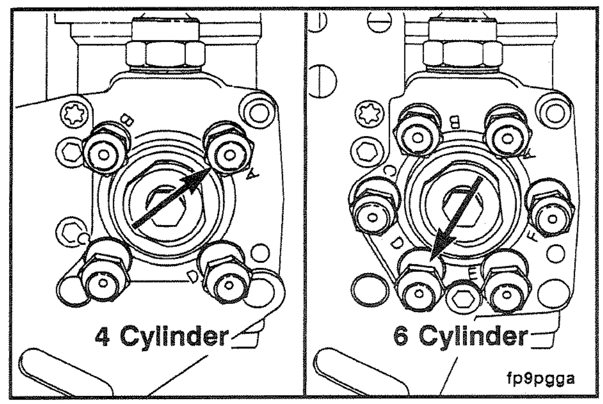


The number one cylinder delivery valve is marked as illustrated.

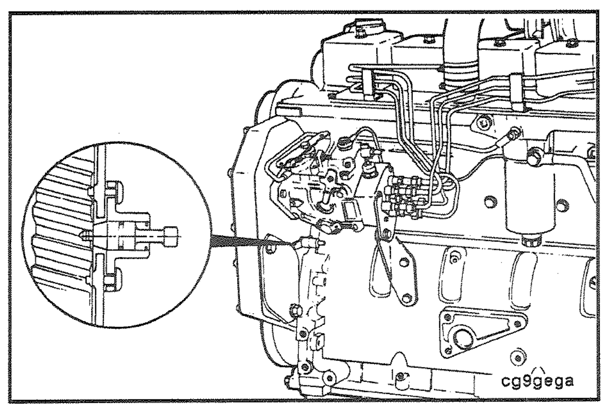
4 cylinder = A
6 cylinder = D

Firing Order

4 Cylinder	6 Cylinder
A = 1	D = 1
B = 3	E = 5
C = 4	F = 3
D = 2	A = 6
	B = 2
	C = 4



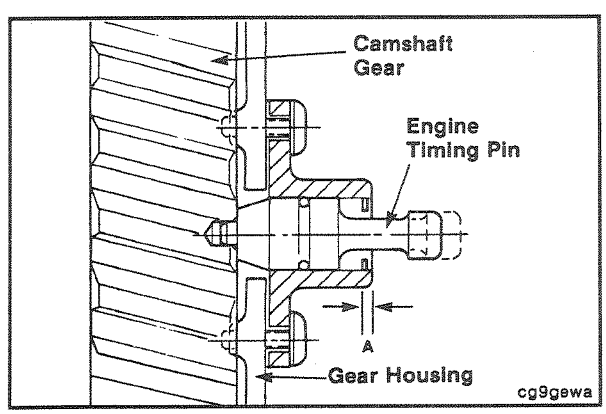
The engine is equipped with an engine timing pin to locate TDC for Cylinder No. 1.

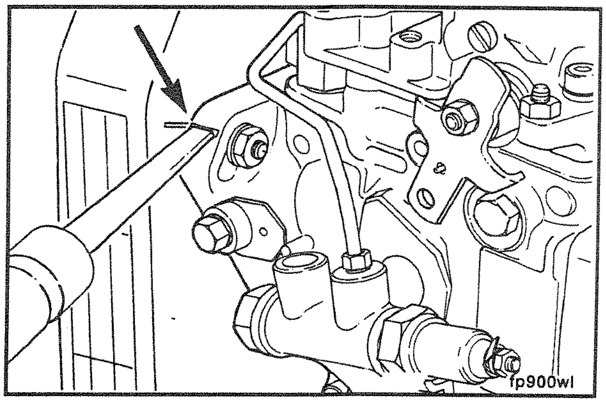


Caution: If the timing pin is incorrectly located on the gear housing, the timing procedure will not ensure that the pump is timed correctly.

After precisely locating TDC for Cylinder No. 1, the factory positions the timing pin assembly to the gear housing using the timing pin and the hole in the camshaft gear. If the gear housing or timing pin assembly are removed, the same precision is required to relocate it. Refer to Procedure (7-20).

If the timing pin assembly is incorrectly located, reposition the timing pin. Refer to Procedure (7-20).

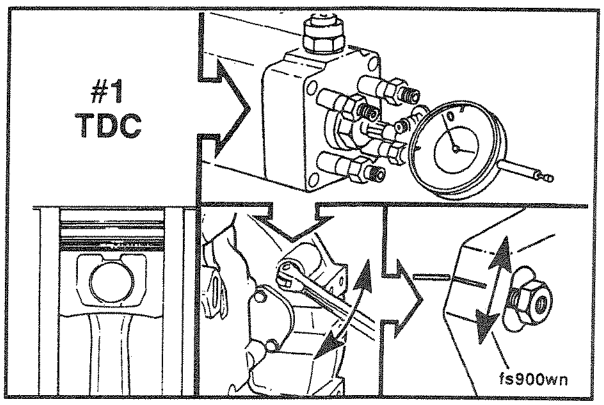




The flange of a replacement pump must be marked to align with the mark on the gear housing after installation.

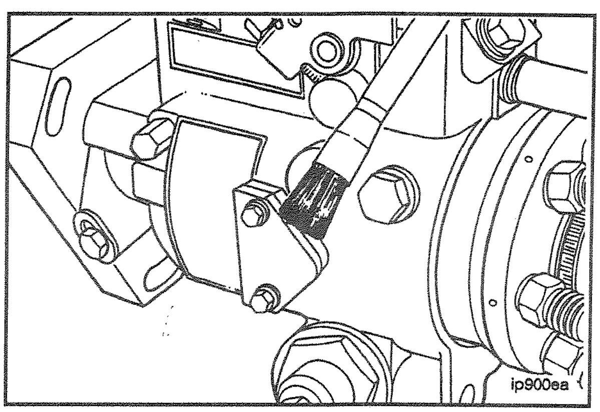
During production, after the locked pump is fitted to the engine with Cylinder No. 1 at TDC, a mark is stamped on the gear housing and the pump flange. Thereafter, when these marks are aligned, the pump is correctly timed to the engine.

NOTE: The marks on the gear housing and the pump flange are unique to each engine.



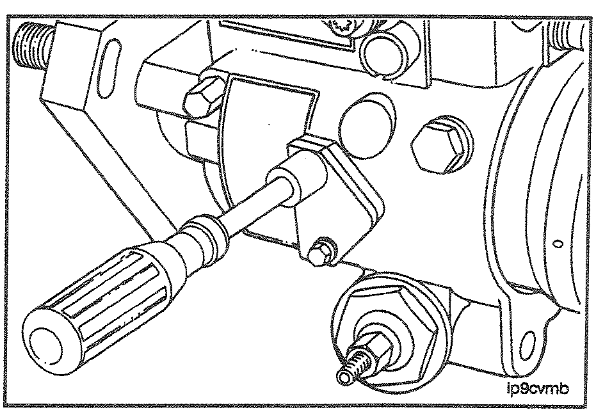
A special indicator can be used to measure the position of the Robert Bosch VE fuel injection pump plunger to check pump timing.

Refer to Timing Check - (Bosch VE Pump) - Procedure (5-36).



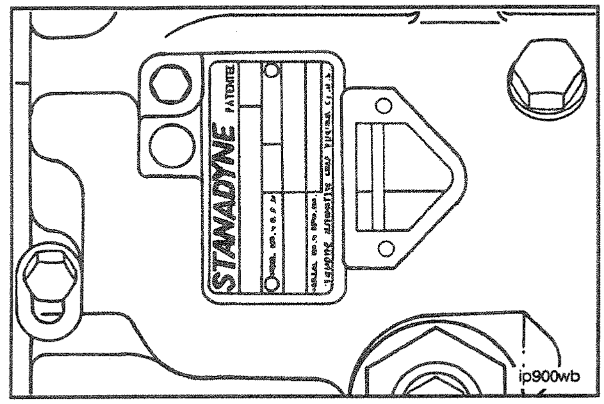
Stanadyne DB4 Fuel Injection Pump Timing

Clean all debris from around the fuel injection pump timing window cover.



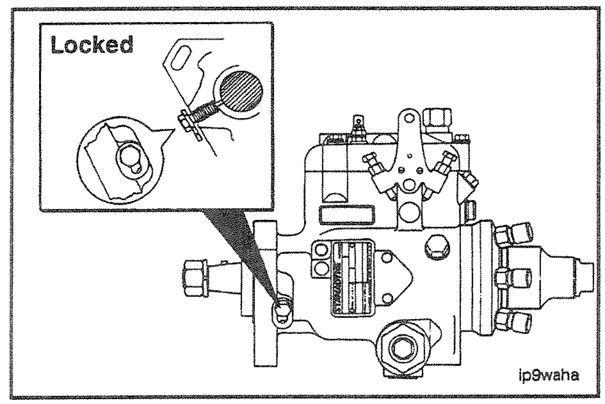
Remove the fuel injection pump timing cover.

Rotate the fuel injection pump drive shaft in the direction of pump rotation to align the timing line on the weight retainer hub with the line on the cam ring.

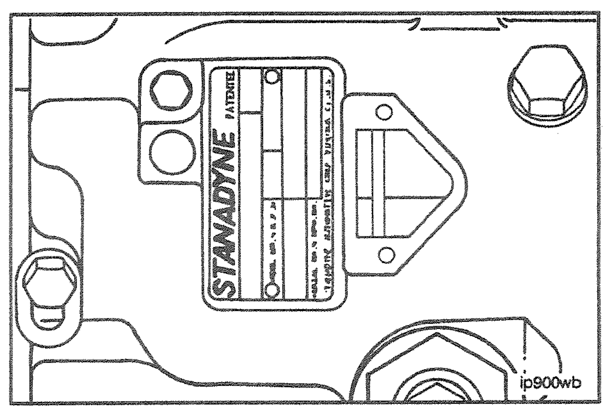


Position the fuel injection drive shaft locking key plate in the locked position. Turn the locking screw in until contact is made with the drive shaft.

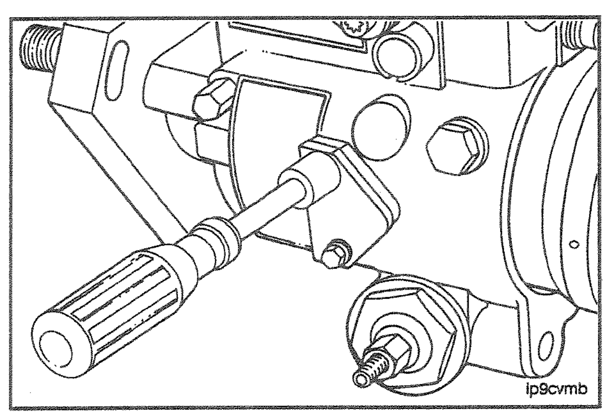
Torque Value: 11.9 N•m [105 in-lb]

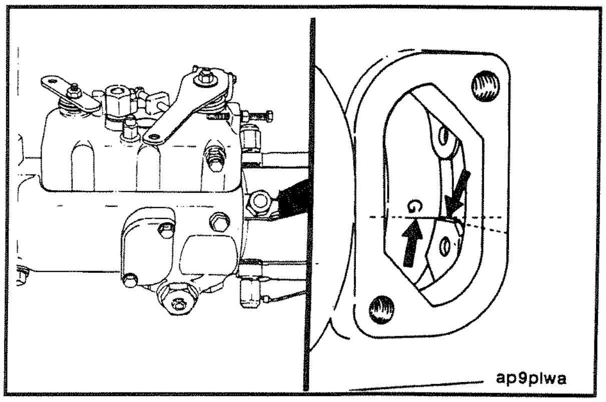


Verify the timing marks are aligned after lock timed.



Install the fuel injection pump timing cover.



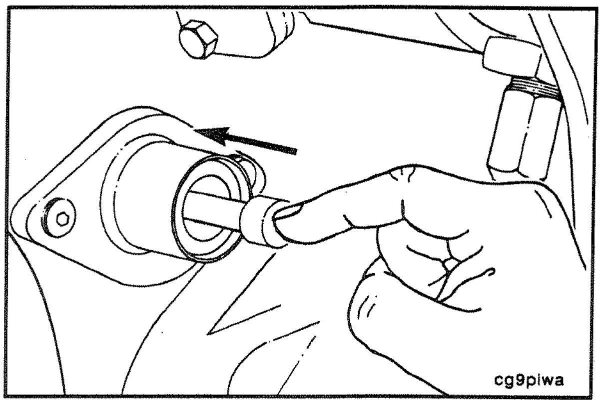


CAV DPA/DPS Fuel Injection Pump Timing

Correct timing of the Lucas CAV DPA/DPS fuel injection pump can be verified by removing the inspection plate.

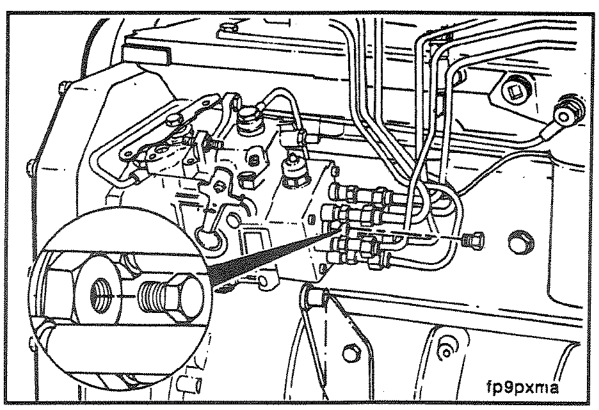
NOTE: Special equipment in an authorized shop is required to precisely time the Lucas CAV DPA fuel injection pump. However, for troubleshooting and in an emergency, visual alignment of the timing mark is close enough for the engine to run.

Both of these checks are described in the fuel injection pump replacement discussion. Installation of the timing pin housing is described in the Base Engine Components Section.



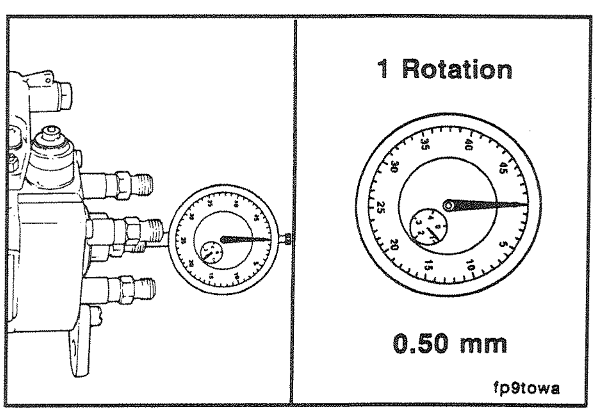
Timing Check - (Bosch VE Pump)

Rotate the crankshaft to TDC.



12 mm

Remove the plug from the end of the pump.



3377259 Timing Indicator

Caution: Do not bend the fuel lines.

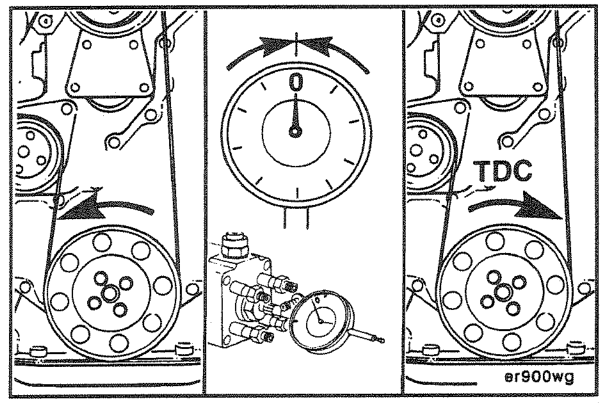
Install the timing indicator. Be sure to allow adequate travel for the indicator.

In order to install the timing indicator, it may be necessary to disconnect one or more of the fuel lines from the fuel pump.

NOTE: The indicator is marked in increments of 0.01 mm. One revolution of the indicator needle is equal to 0.50 mm.

Bar the crankshaft in the direction opposite engine rotation until the indicator needle stops moving. Adjust the indicator face to read zero.

Rotate the crankshaft back to TDC and count the number of revolutions of the indicator needle. The reading shown when the engine timing pin engages is the amount of plunger lift the pump has at that point.



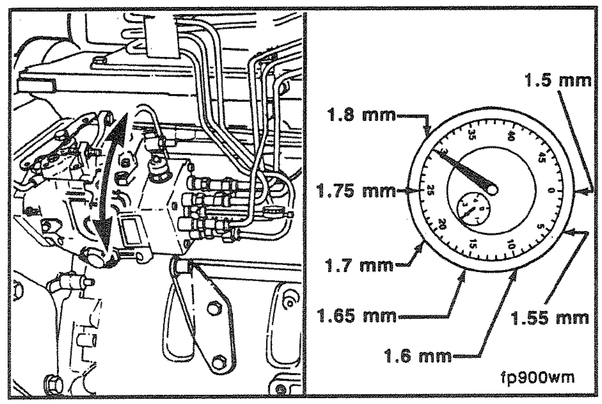
er900wg

13 mm

Rotate the pump on the mounting studs until the indicator reads the correct value for plunger lift. This illustration gives an example of the indicator readings for the various plunger lift values.

Tighten the flange mounting nuts.

Torque Value: 24 N•m [18 ft-lb]

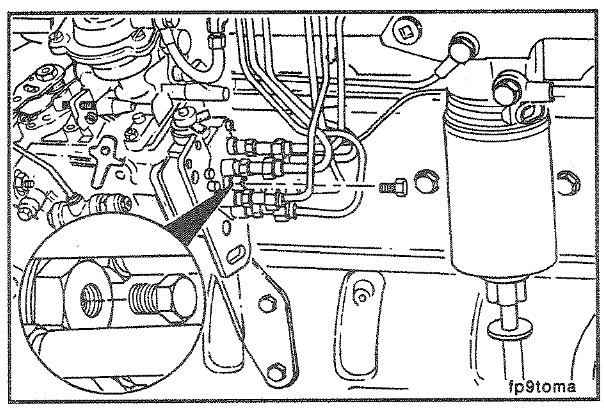


fp900wm

12 mm

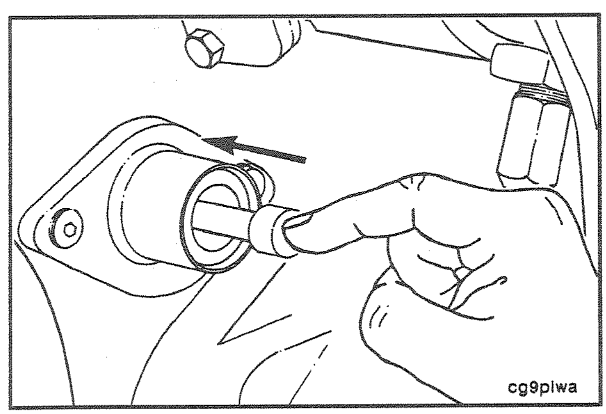
Remove the timing indicator. Install the plug.

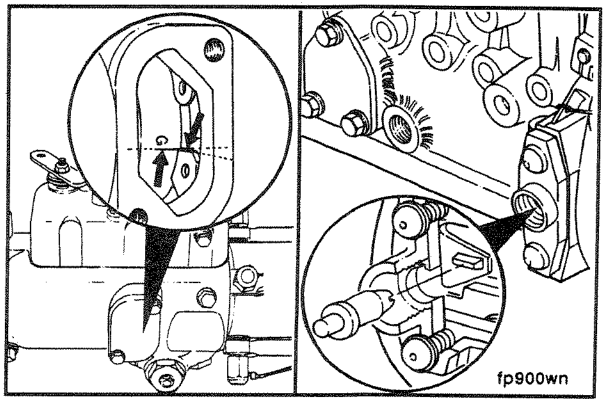
Torque Value: 10 N•m [7.5 ft-lb]


fp9toma

Pump Timing Check - Lucas CAV DPA, Stanadyne DB4, Nippendenso EP-9, and Bosch P-7100

Rotate the engine to TDC.


cg9plwa

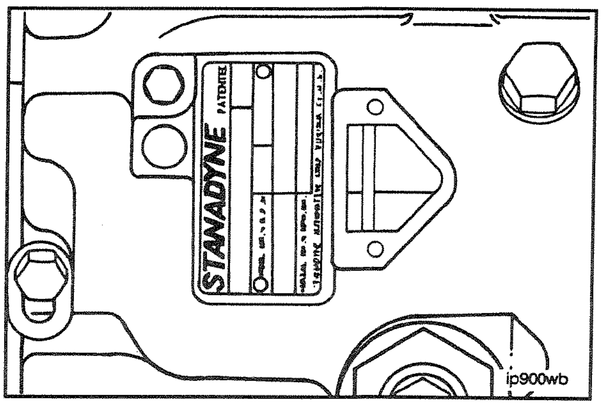


Correct timing of the Lucas CAV DPA and Stanadyne DB4 fuel injection pump can be verified by removing the timing window cover plate.

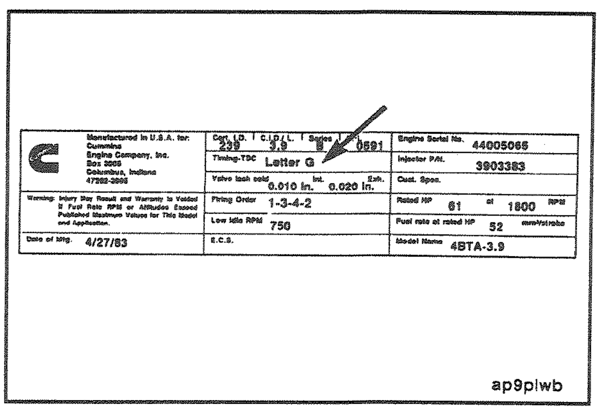
The Nippendenso EP-9 and Bosch P-7100 fuel injection pumps are checked by removing the timing pin access plug and verifying the slot in the pin will fit over the timing tooth in the fuel injection pump.

NOTE: Special equipment in an authorized shop is required to precisely time the Lucas CAV DPA fuel injection pump. However, for troubleshooting and in an emergency, visual alignment of the timing mark is close enough for the engine to run.

To correct the timing on the Bosch P-7100 and Nippendenso EP-9 refer to the replacement procedure for the respective pump.



Two injection pump timing marks are used on the Stanadyne DB4 for timing injection of fuel into the No. 1 cylinder. One mark is located on the governor weight retainer hub. The other is located on the internal cam ring. These two marks **must** be aligned at No. 1 cylinder Top Dead Center.

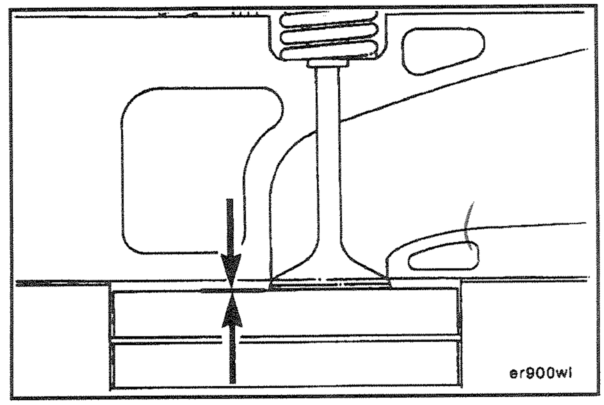


On the Lucas CAV DPA the correct timing letter can be located on the engine data plate as shown.

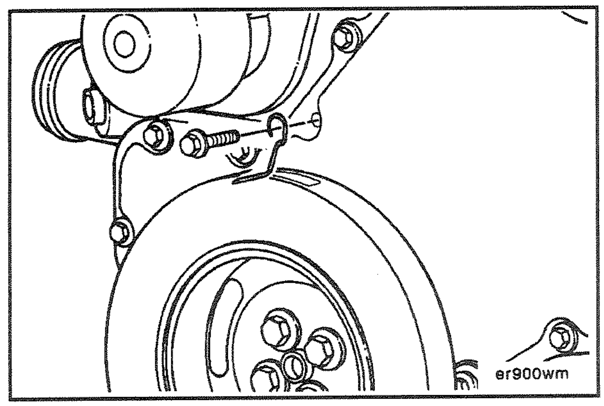
The letter G indicated refers to the correct timing letter alignment as shown in the previous frame.

In-line Fuel Injection Pump Spill-Port Timing

Use the No. 1 intake valve to make sure the engine is at top dead center (TDC) on the compression stroke for cylinder No. 1. Refer to page 7-141.



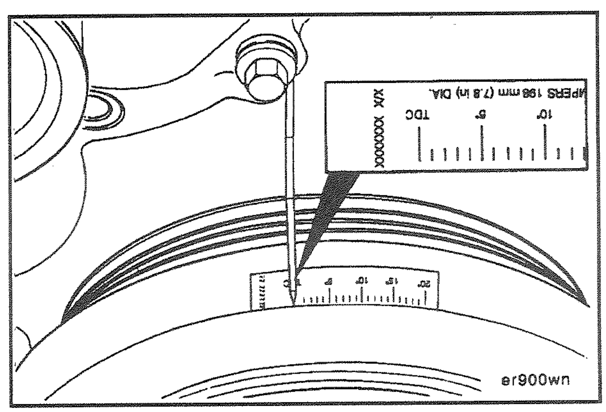
Fabricate a timing mark pointer for the front of the engine. This can be done by forming a piece of wire that can be tightened under one of the gear cover capscrews. Sharpen the wire at the vibration damper end so that it comes to a point for better accuracy.



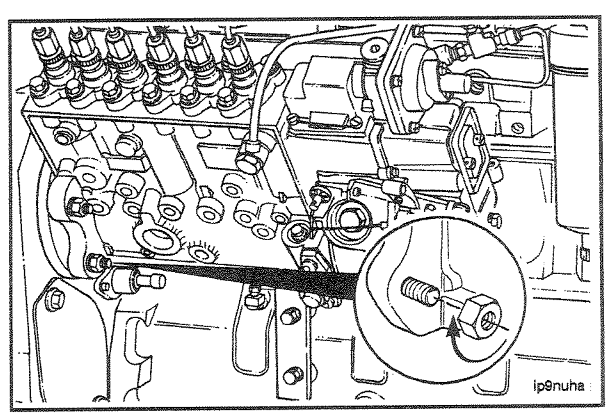
Attach a degree wheel or degree tape to the front of the vibration damper.

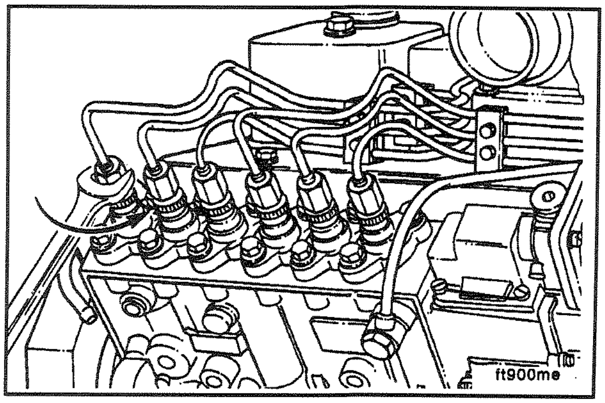
Line the "TDC" mark up with the pointer.

The degree wheel/tape should measure to an accuracy of at least one degree.



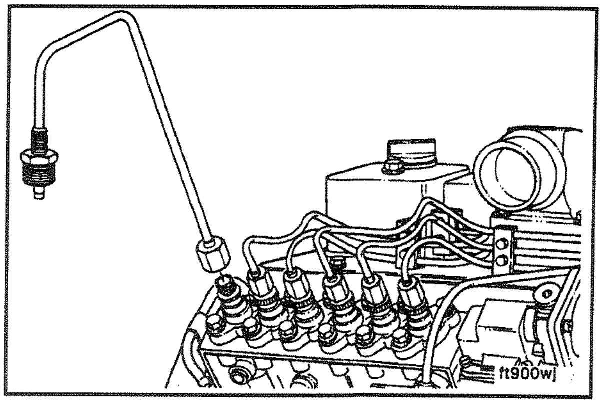
Install the fuel injection pump per the procedures for a new fuel injection pump installation. If the fuel injection pump is already installed, continue the procedures.





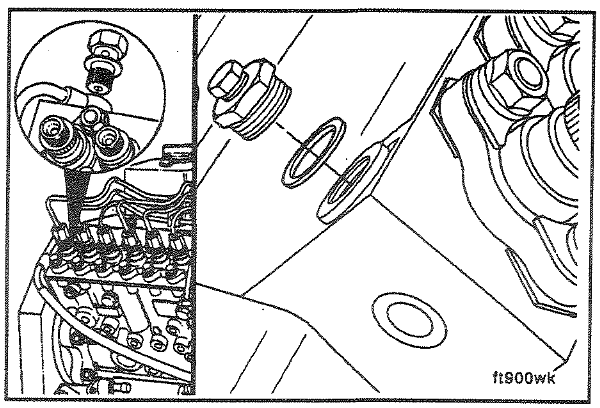
Remove the No. 1 high pressure fuel line from the fuel injection pump.

NOTE: Lines 2 through 6 must not be removed or loosened.



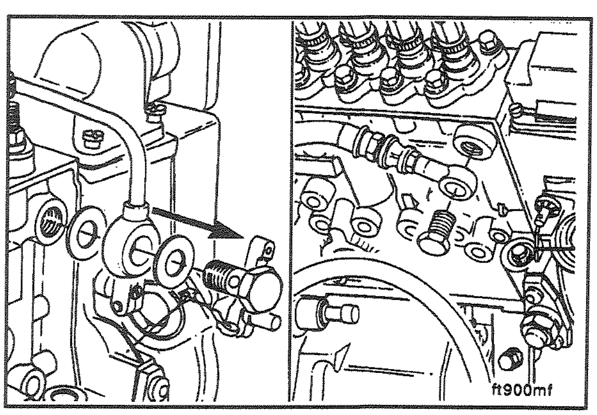
Caution: When attaching the fabricated tube, do not bend the No. 1 high pressure fuel line. This could cause the inside of the fuel line to flake and cause injector failure.

A short length of high pressure line that is compatible with the fuel lines used on the engine should be bent in a "U" shape and installed onto the delivery valve holder of the fuel injection pump. The line is used to observe when the fuel is or is not flowing through the delivery valve holder assembly. Place a container under the tube to catch the fuel or drain the fuel back into the spill port pump.



Remove the overflow valve from the fuel injection pump. Install a 14 mm threaded plug and sealing washer into the fuel return port of the fuel injection pump.

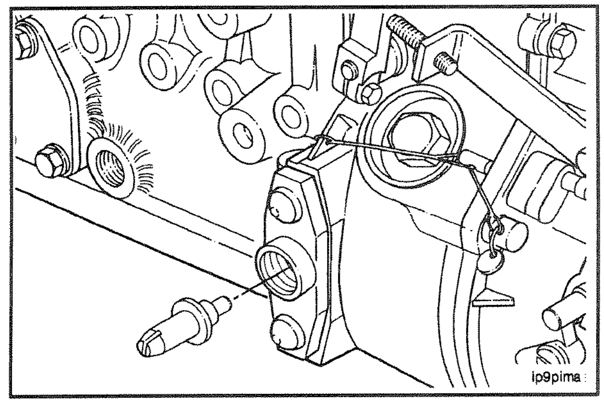
NOTE: The fuel return port is located on the inboard front side of the fuel injection pump for automotive in-line application and on the outboard front side for most of the industrial applications.



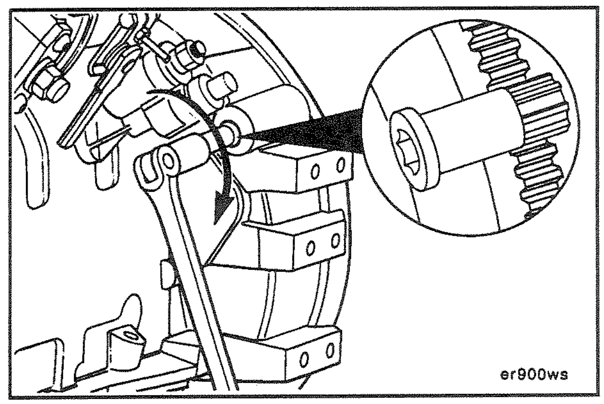
Remove the supply line from the fuel filter head to the fuel injection pump.

Attach the high pressure outlet hose from the spill port to the fuel injection pump supply port.

Before continuing, make sure the fuel injection pump lock-timing pin is disengaged.



Rotate the crankshaft counterclockwise, as viewed from the front of the engine, to approximately 40 degrees before TDC.

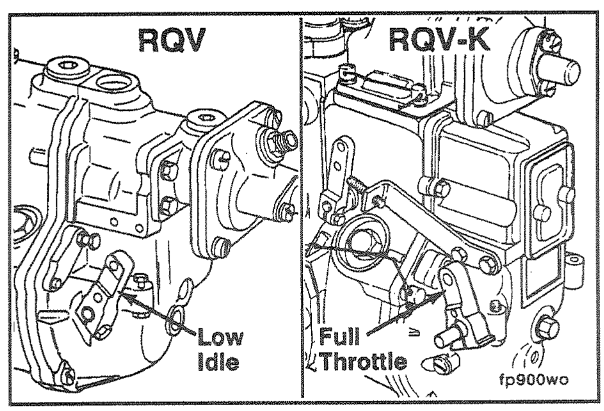


Governor Lever Positioning

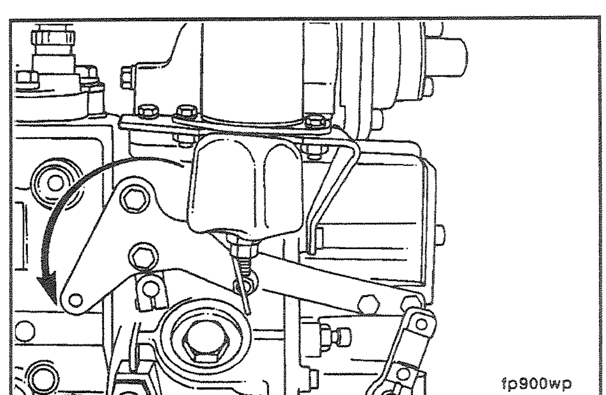
Caution: The governor lever must be positioned before pressurizing the fuel injection pump.

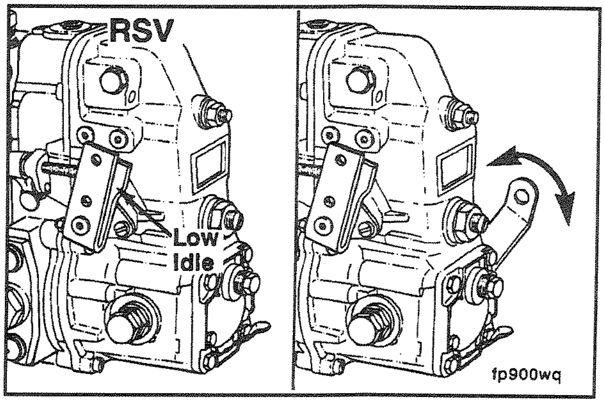
The RQV governor throttle lever must be in the low idle lever position.

The RQV-K governor throttle lever must be in the high idle throttle position.

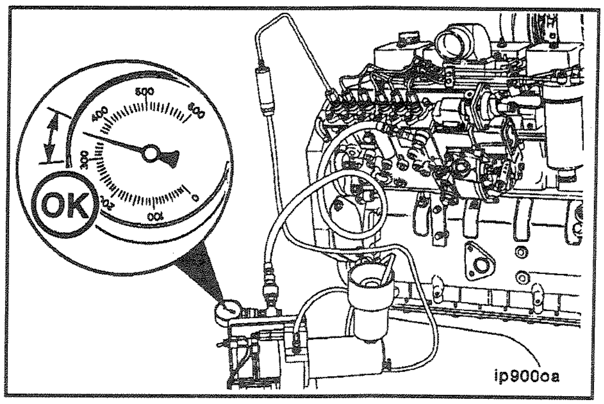


Both the RQV and RQV-K governor require the shut down lever to be in the full run position.





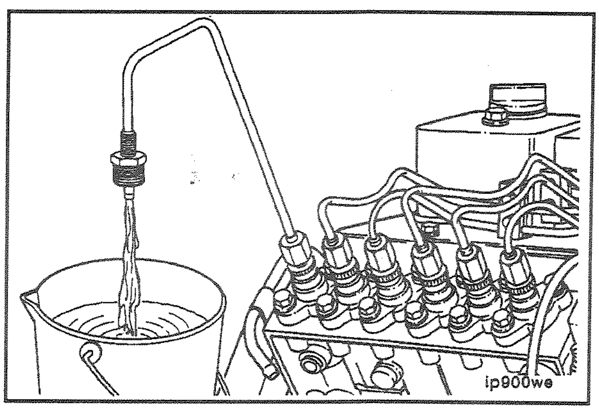
The RVS governor throttle lever must be in the low idle position and the shutdown lever needs to be wired or locked in a suitable fashion to hold the shutdown lever in the 1/2 travel position.



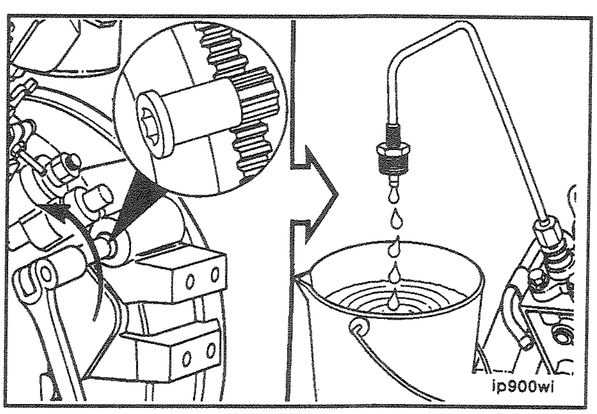
Turn on the spill timing cart pump.

Check the fuel pressure.

The pressure must be between 300 psi and 370 psi.



The fuel should be flowing out of the tube attached to the No. 1 cylinder of the fuel injection pump. If the fuel is not flowing, recheck the procedures carefully.

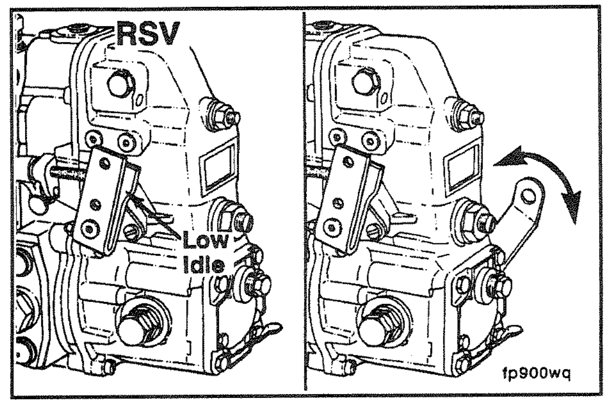


Slowly rotate the crankshaft in the clockwise direction, as viewed from the front of the engine, until the fuel flow from the No. 1 cylinder begins.

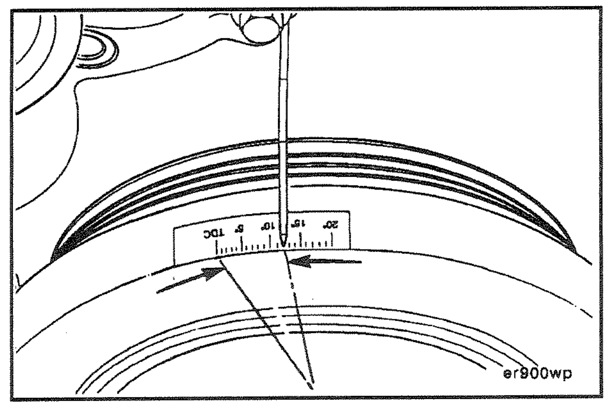
The No. 1 plunger element is now approaching ''port closure''. Continue to rotate the crankshaft slowly until the flow is reduced to a fast drip (more than one drip per second.) At the point where the steady stream of flow changes from a solid flow to a fast drip, stop. This is the static timing position of the fuel injection pump.

If the flow does not slow down to a drip, check the governor position. Also make sure that the engine is before TDC on the compression stroke.

Turn off the spill port pump.

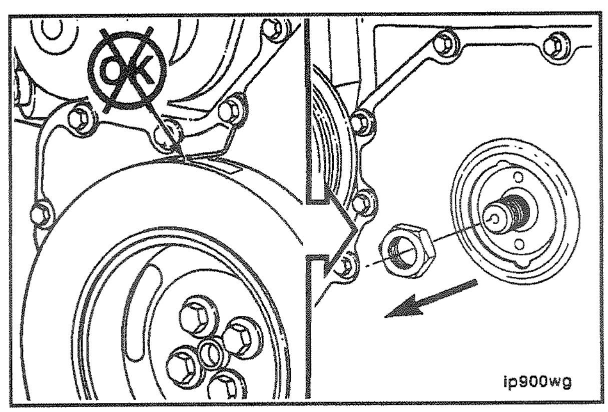


Check the degree wheel on the vibration damper to see what engine degree the timing pointer is indicating. This is spill port static timing. Compare this number to the timing specification for your particular application.

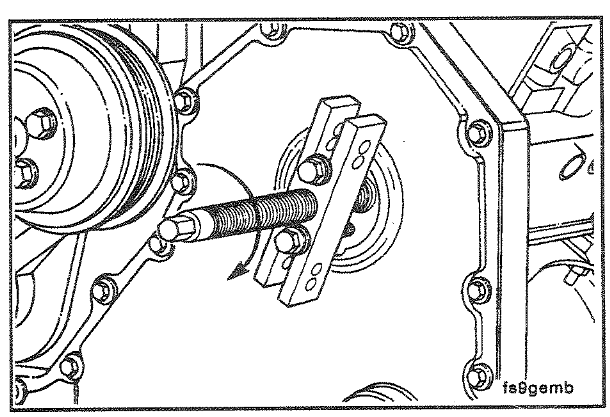


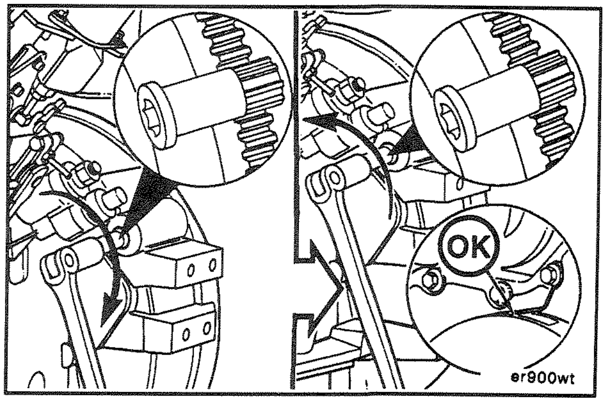
If the fuel injection pump static timing, as measured by the above method, does not agree with the specifications you have been given, remove the large nut that fastens the fuel injection pump camshaft to the fuel pump drive gear. If the crankshaft has rotated, turn on the spill port pump and rotate the crankshaft to find port closure.

Turn off the spill port pump.

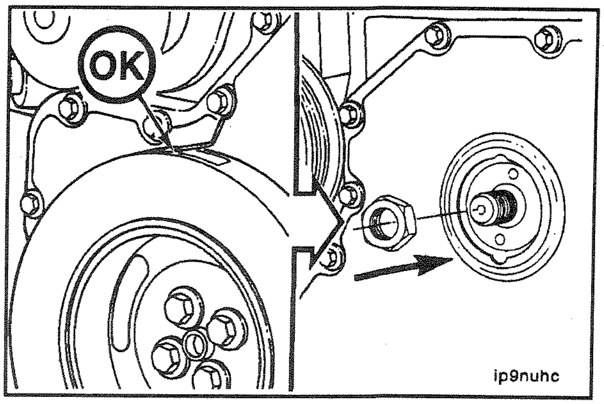


Use a gear puller tool, pull the fuel injection pump drive gear from the fuel injection pump camshaft taper.





Slowly rotate the crankshaft counterclockwise about 40 degrees past the desired static timing specification. Slowly rotate the crankshaft in the clockwise direction until the timing pointer is indicating the desired static timing.

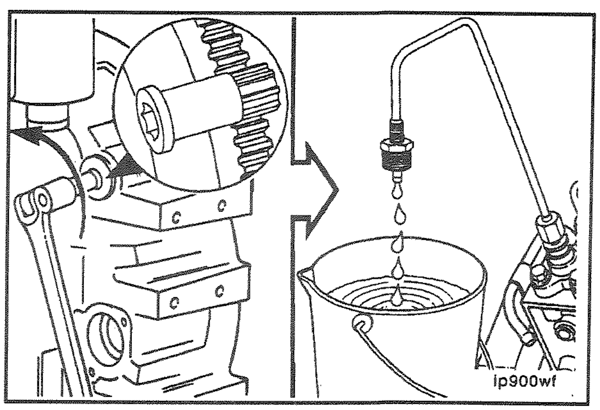


Tighten the fuel injection pump drive nut.

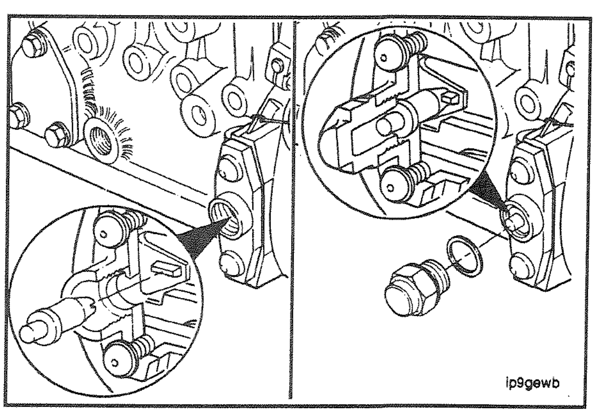
Make sure the static timing has not changed after the fuel injection drive nut is torqued to the required specification.

Torque Value:

PES6A Fuel Injection Pump	92 N•m [68 ft-lb]
PES6MW Fuel Injection Pump	104 N•m [77 ft-lb]
PES6P Fuel Injection Pump	165 N•m [122 ft-lb]



Repeat this procedure as needed until the timing is found to be in agreement with the specification.



The fuel injection pump lock timing pin should fit over the injecting pump pointer when the engine is at TDC or on the compression stroke for the No. 1 cylinder. If it does not, the fuel injection pump should be adjusted by an authorized fuel injection pump shop or the fuel injection pump was installed incorrectly.

Fuel Injection Pump Replacement (In-line) (5-37)

Bosch P7100

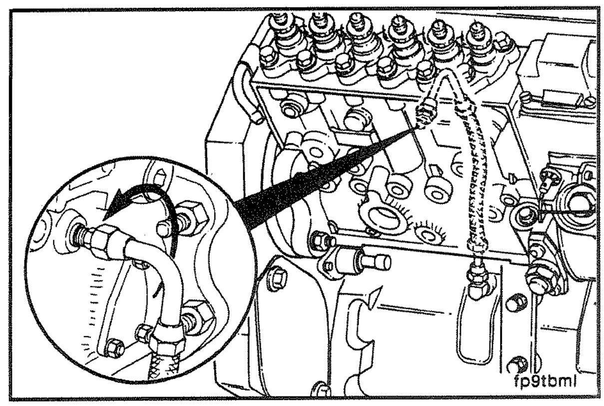
Preparatory Steps:

- Clean debris.
- Disconnect all fuel lines to the pump.
- Remove control linkage.
- Disconnect AFC tube.
- Disconnect waste-gate turbo control line.

Removal

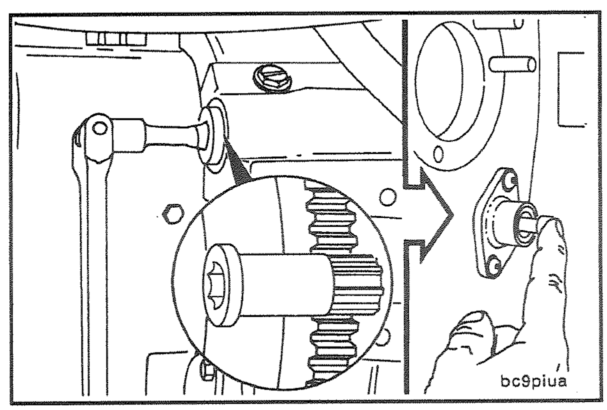
9/16

Disconnect the external oil feed line at the inboard side of the fuel injection pump and the main oil rifle.



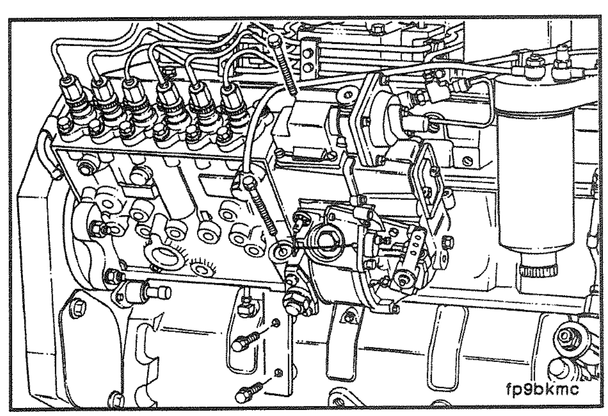
Locate TDC for Cylinder No. 1. Push the TDC pin into the hole in the camshaft gear while slowly barring the engine.

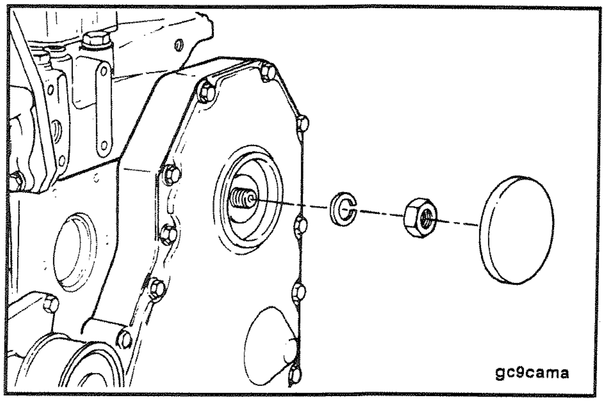
NOTE: Be sure to disengage the timing pin after locating TDC.



10 mm

Remove the fuel injection pump mounting bracket.

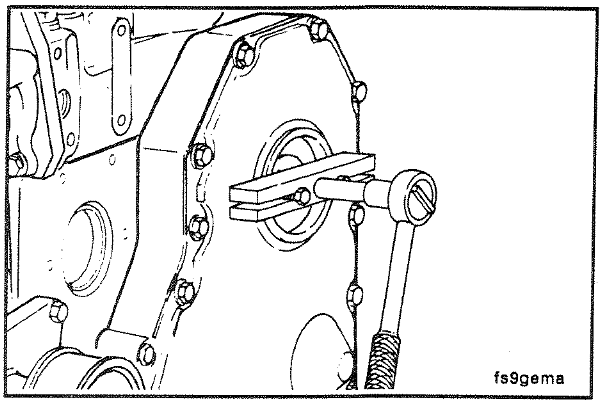




30 mm

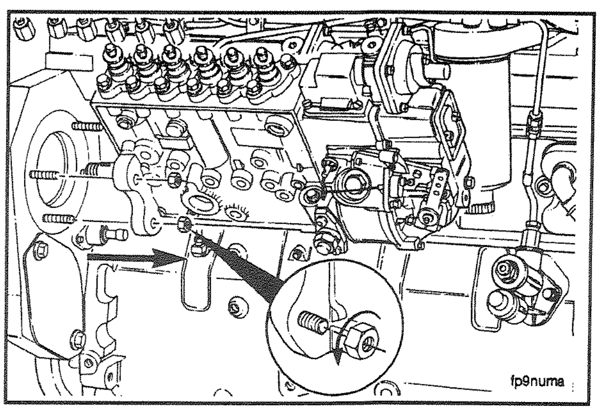
Remove the gear cover access cap.

Remove the nut and washer from the fuel injection pump shaft.



T-Bar Puller

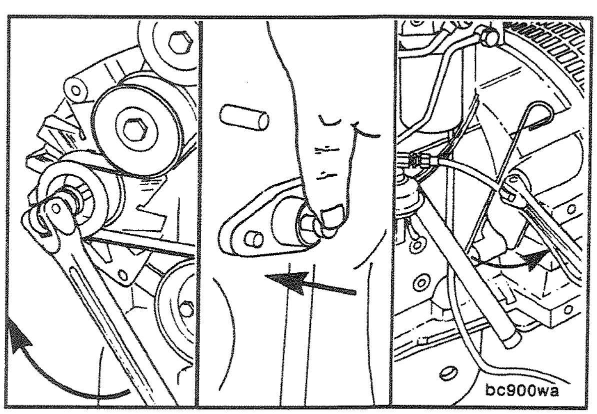
Pull the fuel injection pump drive gear loose from the shaft.



15 mm

Remove the four mounting nuts.

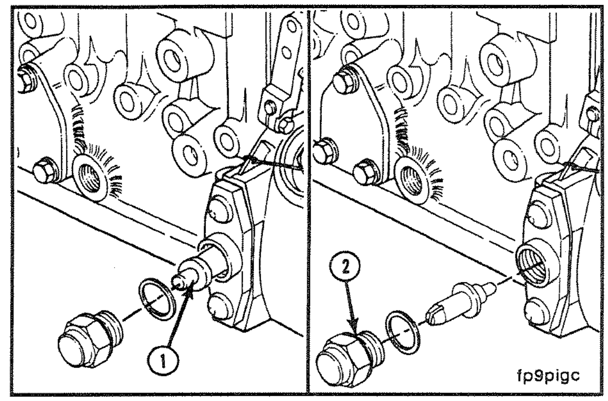
Remove the fuel injection pump.



Installation

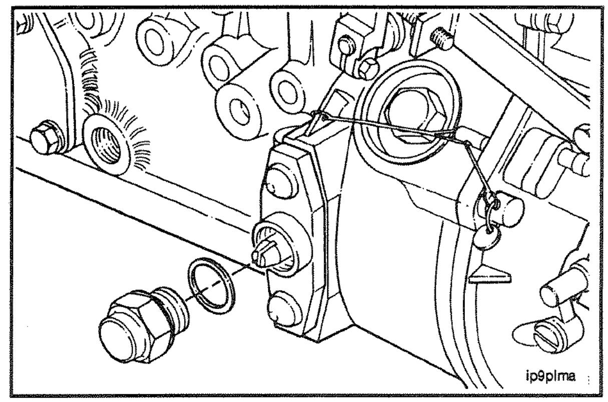
Make sure the engine has Cylinder No. 1 at TDC.

The fuel injection pump also has a timing pin (1), located in the governor housing, to position the pump shaft to correspond with TDC for Cylinder No. 1. The pin is to be reversed and stored in the housing (2) after the pump is installed.

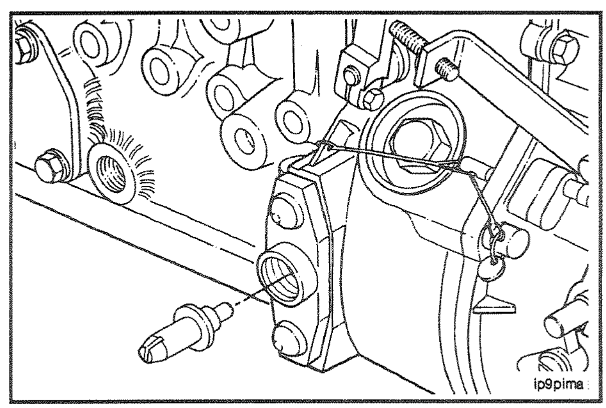


24 mm

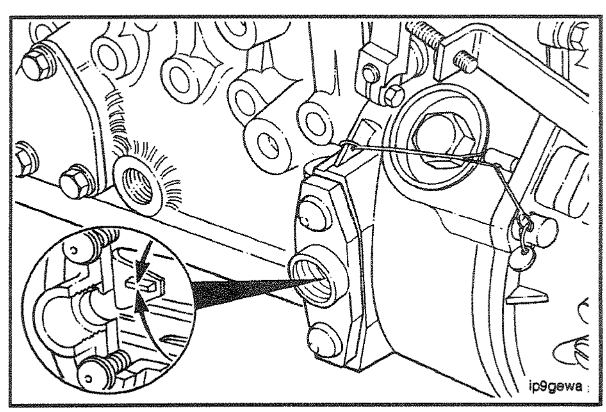
Remove the access plug.

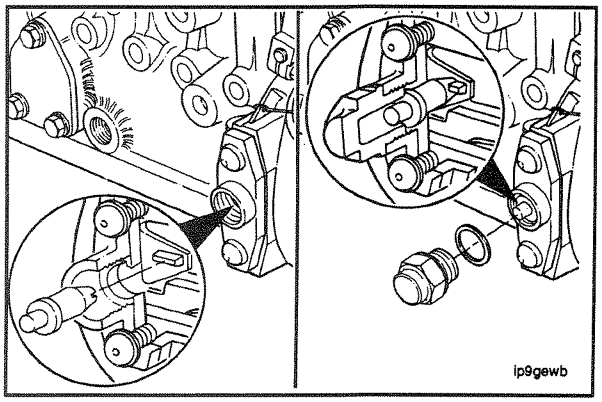


Remove the timing pin.



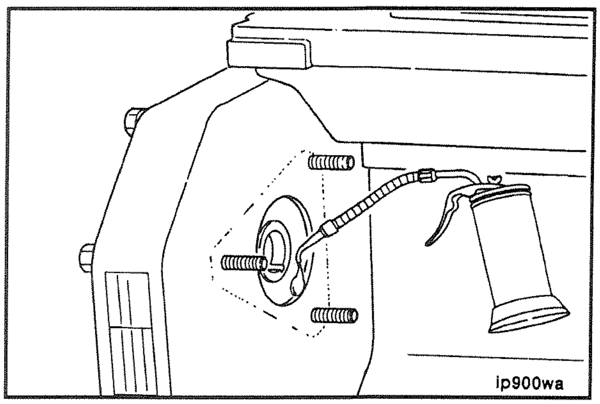
If the timing tooth is not aligned with the timing pin hole, rotate the fuel injection pump shaft until the timing tooth aligns.



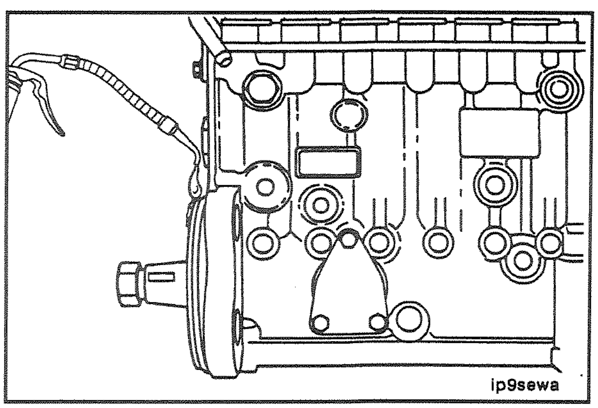


Reverse the position of the timing pin so the slot of the timing pin will fit over the timing tooth in the pump.

Install and secure the timing pin with the access plug.



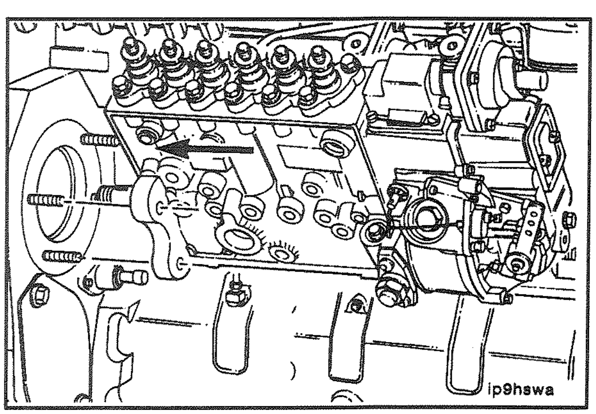
Use a 50/50 mixture of clean engine oil and STP or equivalent to lubricate the gear cover housing to ensure the fuel injection pump will slide into the gear cover housing easily.



Also lubricate the mounting flange of the fuel injection pump.

NOTE: The P7100 fuel injection pump driveshaft has a provision for a Woodruff key, however, it is not required. Timing mark alignment is not required for the P7100 drive gear.

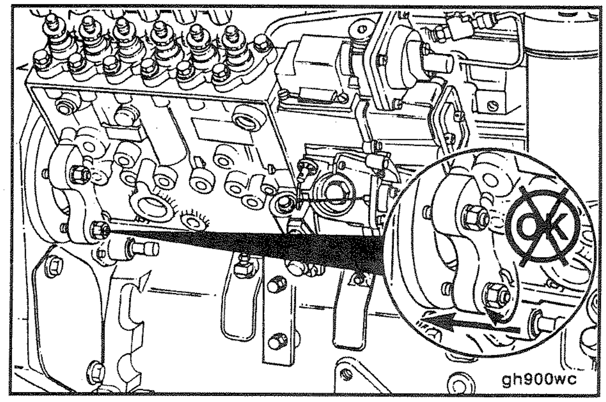
Caution: The fuel injection pump drive gear inside diameter and the shaft outside diameter must be clean and dry before installing the gear.



Slide the pump shaft through the drive gear and position the pump flange onto the mounting studs.

Push the pump forward until the mounting flange and o-ring are properly fitted into the gear housing bore.

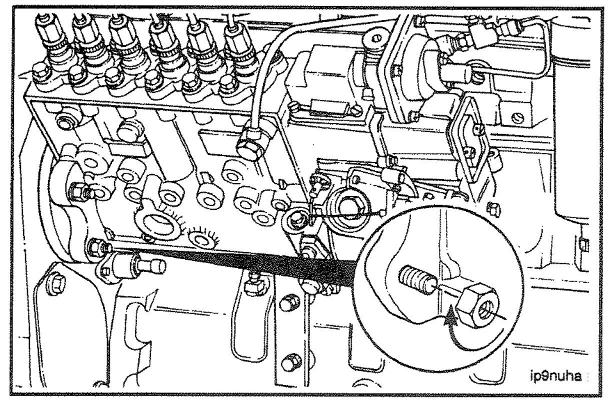
Do not attempt to pull the pump flange into the gear housing with the mounting nuts as damage to housing will occur.



15 mm

Install the mounting nuts.

Torque Value: 43 N•m [32 ft-lb]

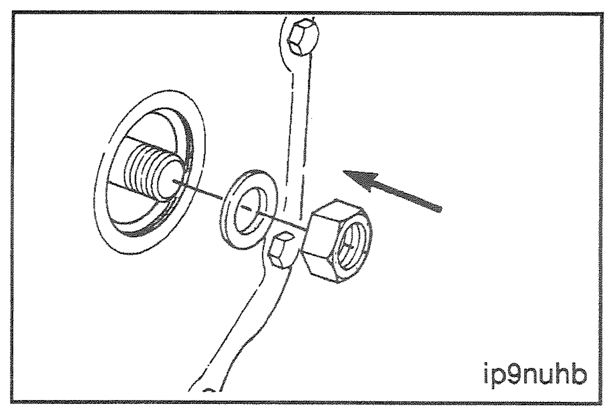


30 mm

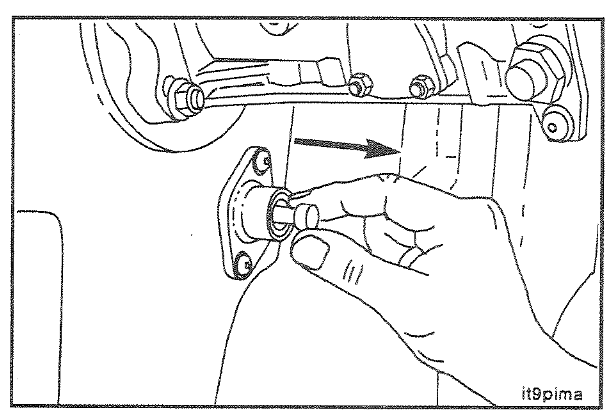
Install the retaining nut and washer.

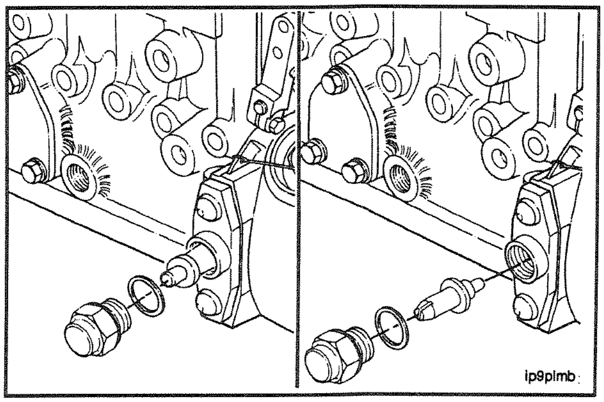
Torque Value: 10 to 15 N•m [7 to 11 ft-lb]

To prevent damage to the timing pins, do not exceed the torque value given. This is not the final torque value for the retaining nut.



Disengage the engine timing pin.

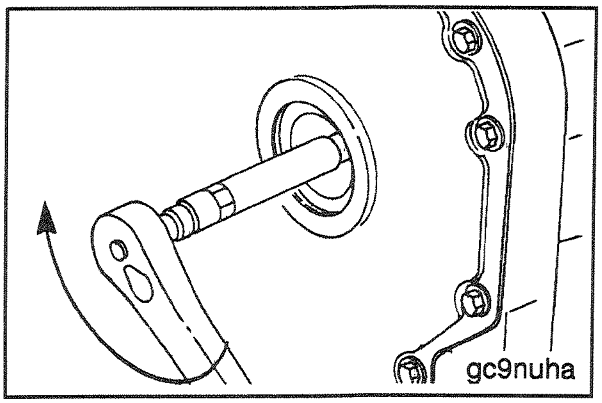




24 mm

Remove the fuel injection pump timing pin plug, Reverse the position of the timing pin and install the timing pin, plug, and sealing washer.

Torque Value: 15 N•m [11 ft-lb]

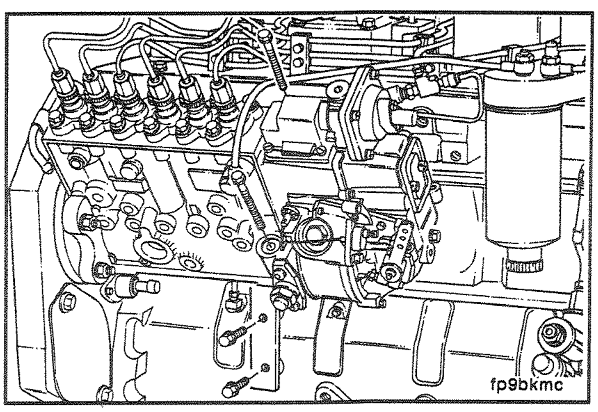


30 mm

Tighten the fuel injection pump drive nut.

Torque Value: 165 N•m [122 ft-lb]

Install the gear cover access cap hand tight.

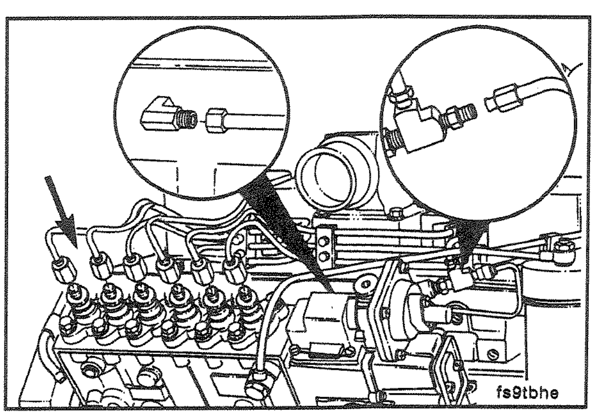


10 mm

Install the fuel injection pump mounting bracket capscrews.

Tighten all capscrews by hand to ensure proper alignment.

Torque Value: 24 N•m [18 ft-lb]



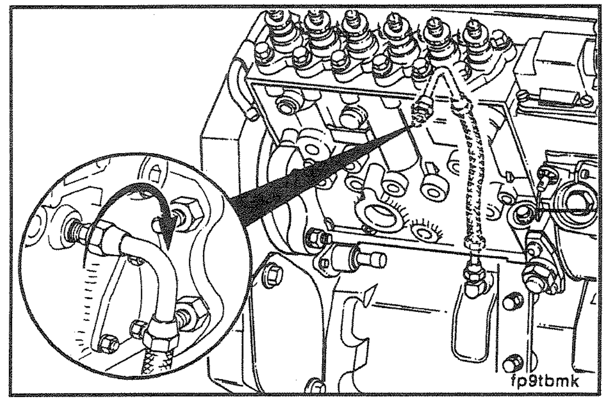
Install the fuel lines, AFC line, control linkage and turbocharger wastegate line.

Torque Values:

High Pressure Fuel Lines	30 N•m [22 ft-lb]
Low Pressure Fuel Supply Fitting	15 N•m [11 ft-lb]

9/16 in

Install the external oil feed line at the inboard side of the fuel injection pump and the main oil rifle.

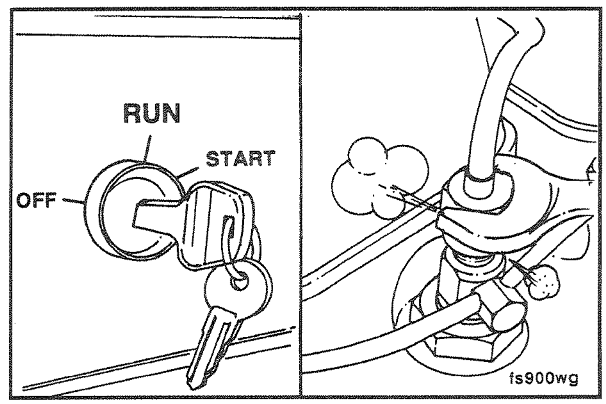


19 mm

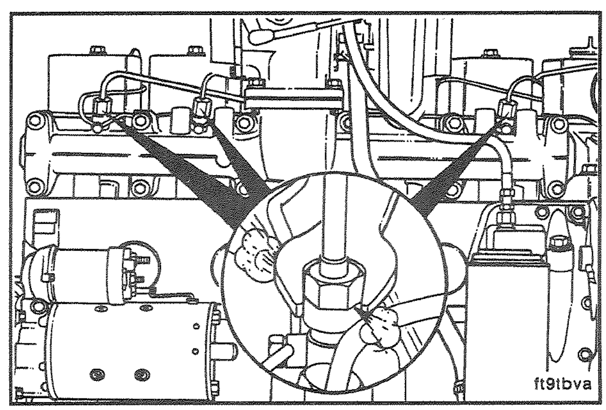
Caution: The pressure of the fuel in the high pressure line is sufficient to penetrate the skin and cause serious bodily harm.

Vent the high pressure fuel lines. Loosen the fitting at the number 1 injector. Place the fuel control in the run position. Crank the engine so air can bleed from the fuel lines. Then, tighten the fitting.

Torque Value: 30 N•m [22 ft-lb]

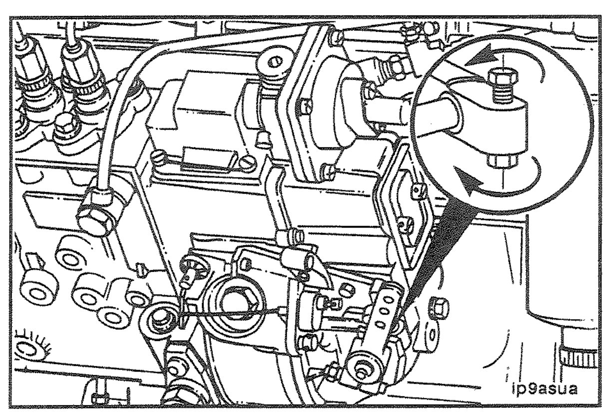


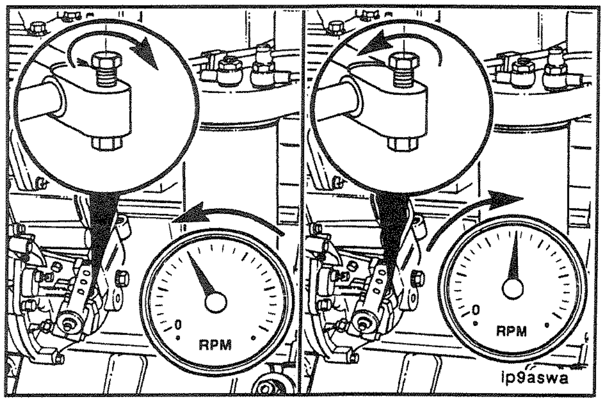
Vent each high pressure line separately until the engine runs smoothly.



Idle Speed Adjustment - Bosch P7100 (5-38)

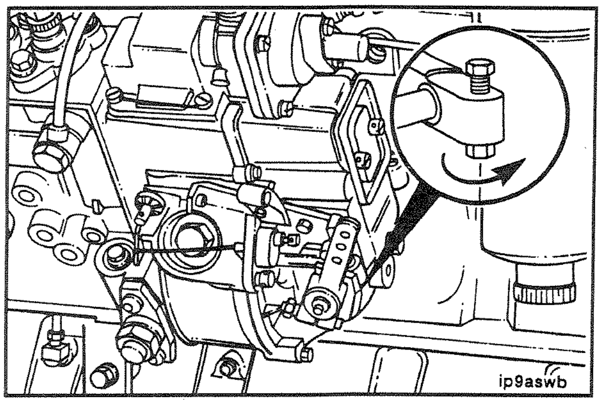
Idle speed adjustment on the Bosch P7100 can be made by loosening the idle screw locknut (1) and turning the idle screw (2) to achieve the desired idle speed.



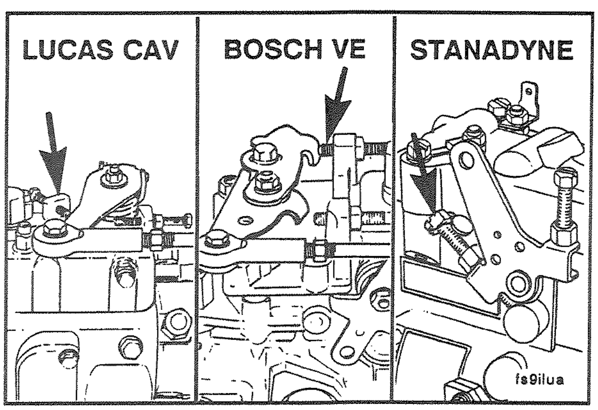


Turn the screw down (clockwise viewed from top) to decrease idle sped.

Turn the screw up (counterclockwise viewed from top) to increase idle speed.



After the desired idle speed is obtained, tighten the locknut.

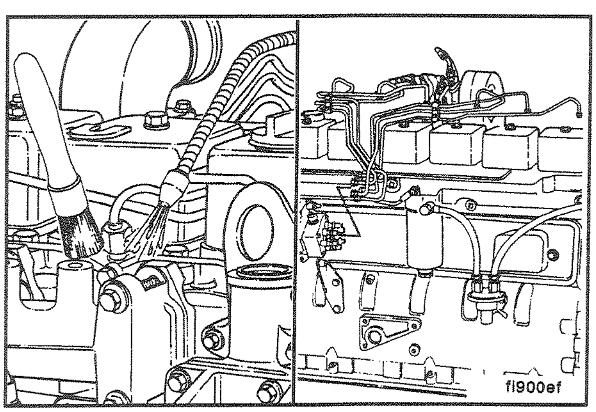


Idle Speed Adjustment - Distributor Pumps (5-39)

10 mm

Loosen the adjusting screw locknut and adjust the idle as required.

Caution: Do not reduce idle spped from factory setting on the Stanadyne DB4 fuel injection pump. Internal damage may result.



Injector - Replacement (5-40)

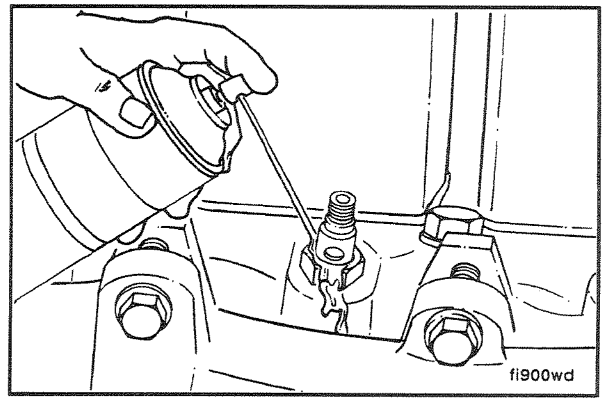
Preparatory Steps:

- Clean around the injectors.
- Disconnect the high pressure fuel supply lines.
- Disconnect the fuel drain manifold.

Rust Penetrating Solvent

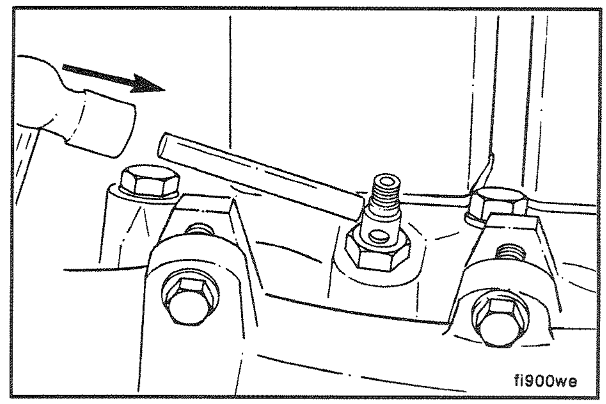
Caution: When rust has formed on the hold down nut, the injector can turn in the bore when the nut is loosened. This will cause severe damage to the head by the injector locating ball cutting a groove in the bore.

Soak the hold down nut with a rust penetrating solvent for a minimum of 3 minutes.



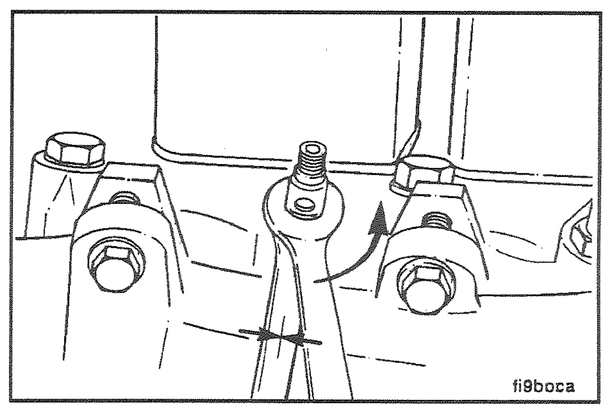
Brass Drift Pin, Hammer

Hit the injector body with the drift pin to loosen any rust.



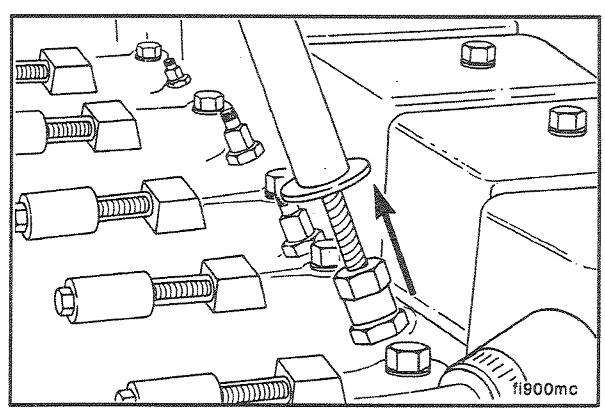
24 mm Box Wrench, Adjustable Wrench

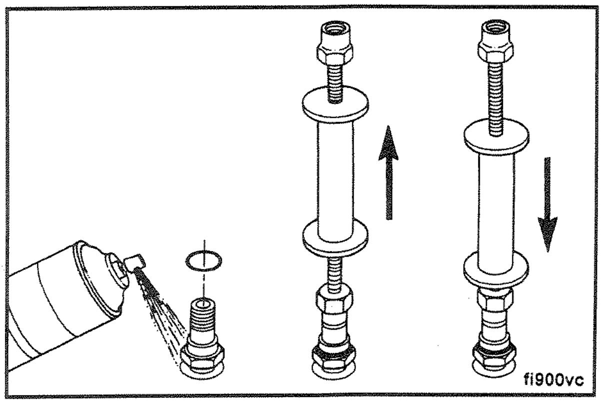
Hold the injector body with an adjustable wrench while you loosen the hold down nut with a 24 mm box wrench.



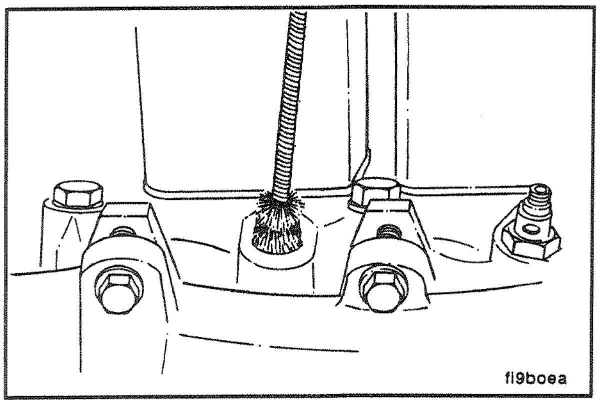
Injector Puller 3823276

Remove the injectors. An injector puller is available for difficult to remove injectors.



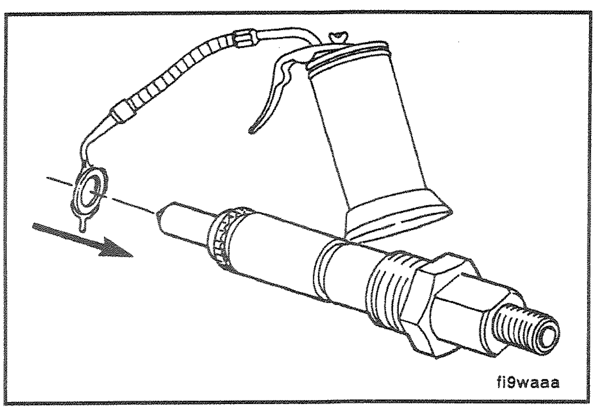


It may be necessary to tap the injector with the injector puller to work the injector up and down in order to remove it.



Injector Bore Brush 3822509

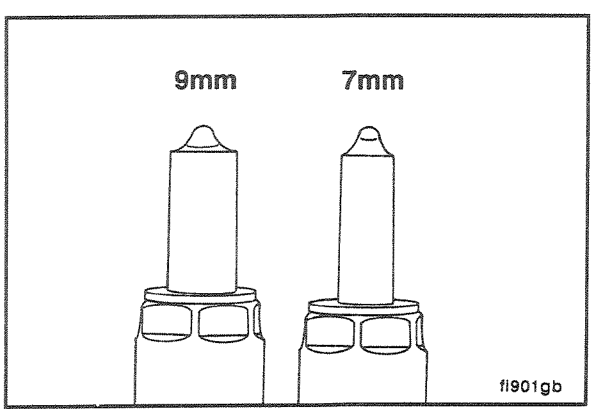
Clean the injector nozzle bore.



Assemble the injector and new copper sealing washer.

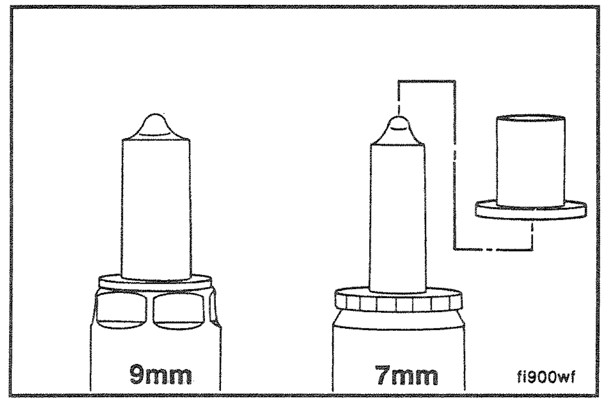
Use only one copper washer.

Service Tip: A light coat of clean 15W40 engine oil between the washer and injector can help to keep the washer from falling during installation.

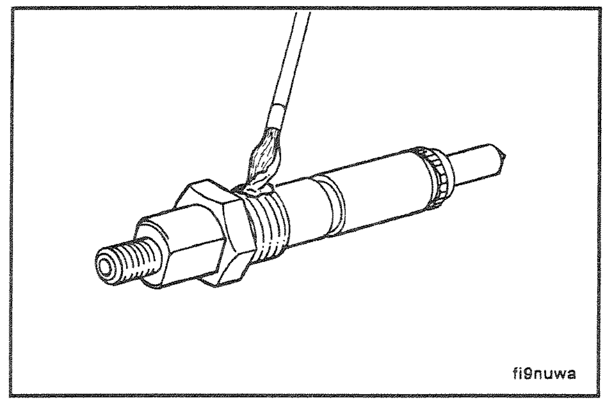


Warning: Early model injectors (pre 1991) have a 9 mm injector tip which cannot be used in engines built in 1991 or later as these engines use a 7 mm injector tip.

7 mm injectors can be used in early model (9 mm) injector holes providing the special adapter sleeve is installed onto the 7 mm injector tip.



Apply a coat of anti-seize compound to the threads of the injector hold down nut and between the top of the nut and injector body.

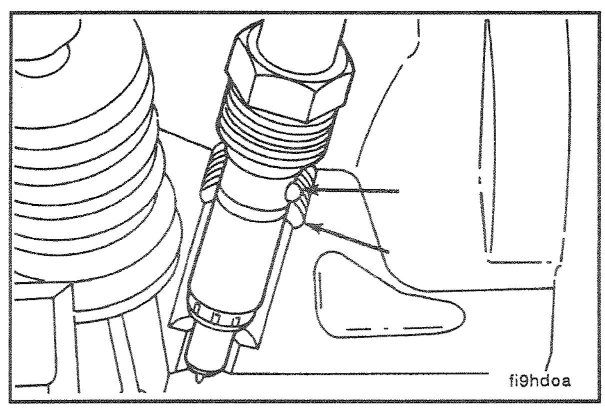


24 mm Deep Well Socket

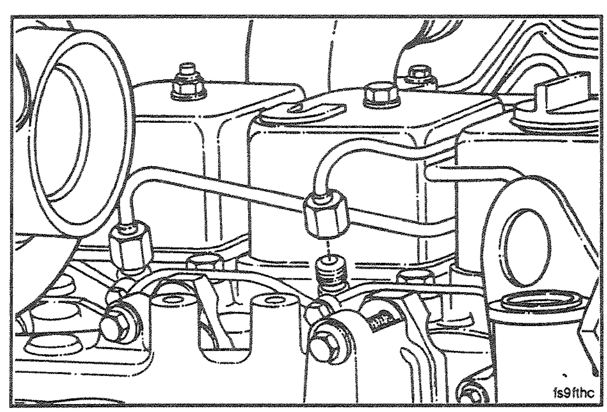
Caution: Align the injector's protrusion with the notch in the bore.

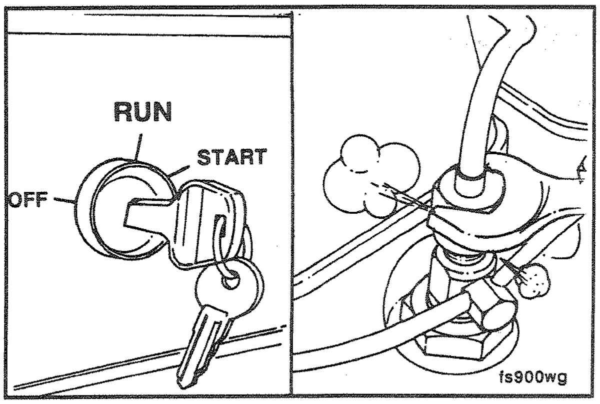
Torque Value: 60 N•m [44ft-lb]

NOTE: The current Bosch injector has an o-ring located above the hold down nut. After tightening the injector be sure to push the o-ring into the groove.



Assemble the fuel drain manifold and high pressure lines. Leave the high pressure fittings loose at the injectors.





17 mm, 19 mm

Caution: It is necessary to put the engine in the "run" position. Because the engine may start, be sure to follow all the safety precautions. Use the normal engine starting procedure.

Crank the engine to allow entrapped air to bleed from the lines. Tighten the fittings.

Electrical System - Section 06

Section Contents

General Information - Electrical System

The electrical system basically consists of the starting motor and the alternator.

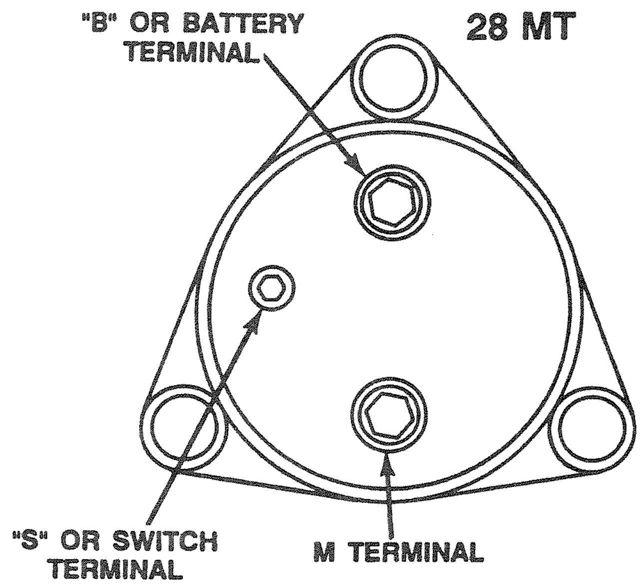
The rotary injection pump uses an electrical fuel shut off valve. The in line injection pump use an electrically activated solenoid shut down system. The function of the valve is discussed in the fuel system section.

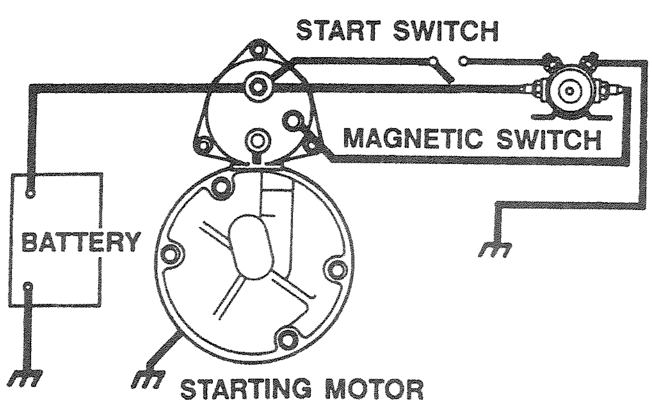
The engine should have temperature and oil pressure sensors connected to indicators or wired for automatic shutdown. The engine may also be fitted with a block heater, an oil pan heater, or an intake manifold air heater.

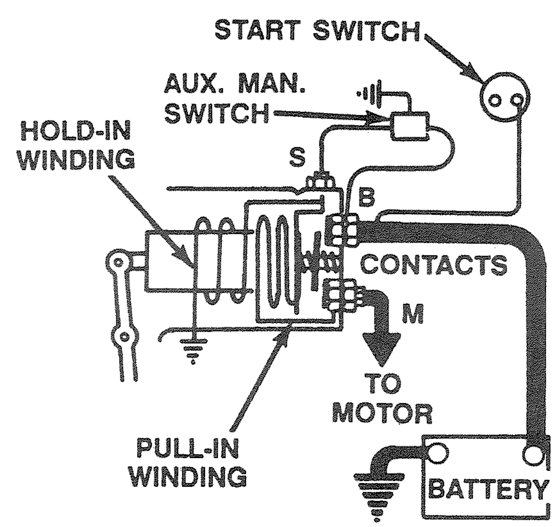
NOTE: When troubleshooting a Cummins B Series generator set, refer to the Operation and Maintenance Manual Bulletin No. 3810208.

Flow Diagrams - Electrical System

Delco Remy Model 27MT/28MT Starting Motor



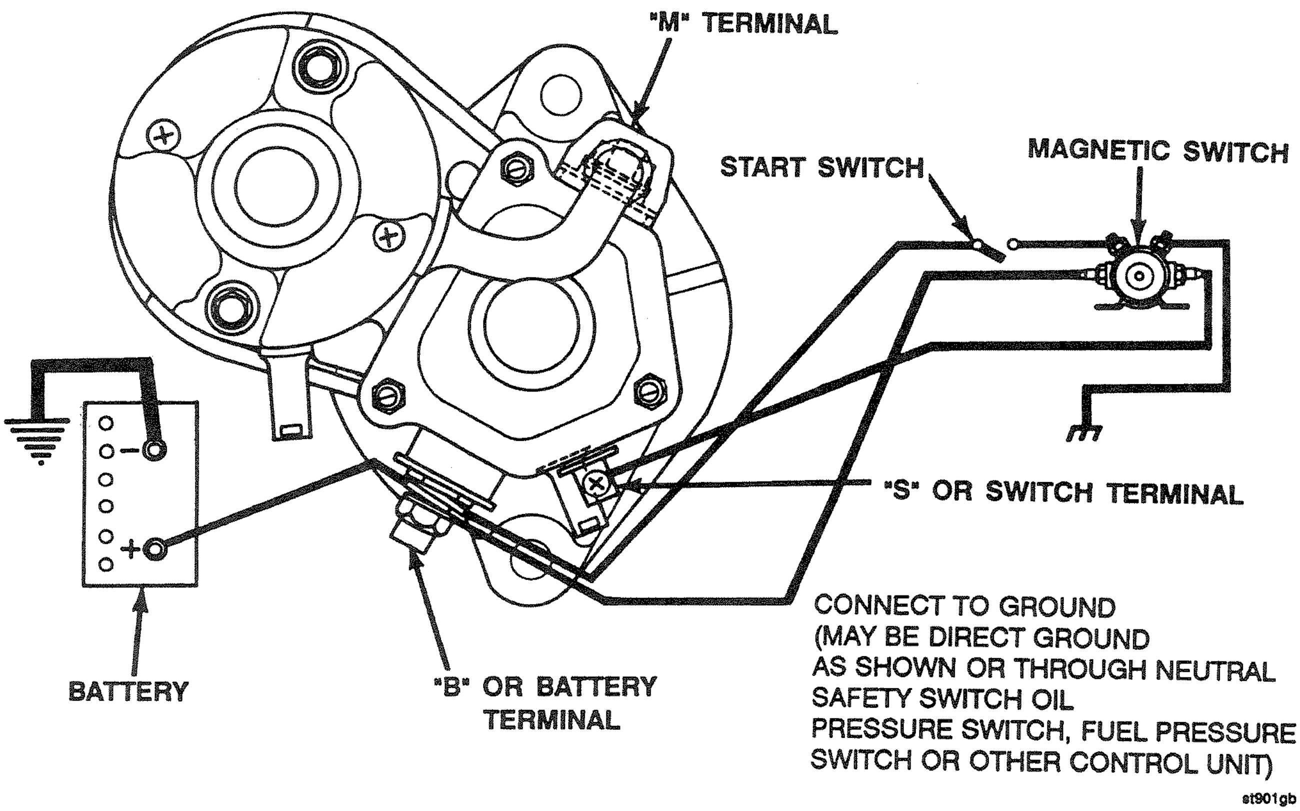




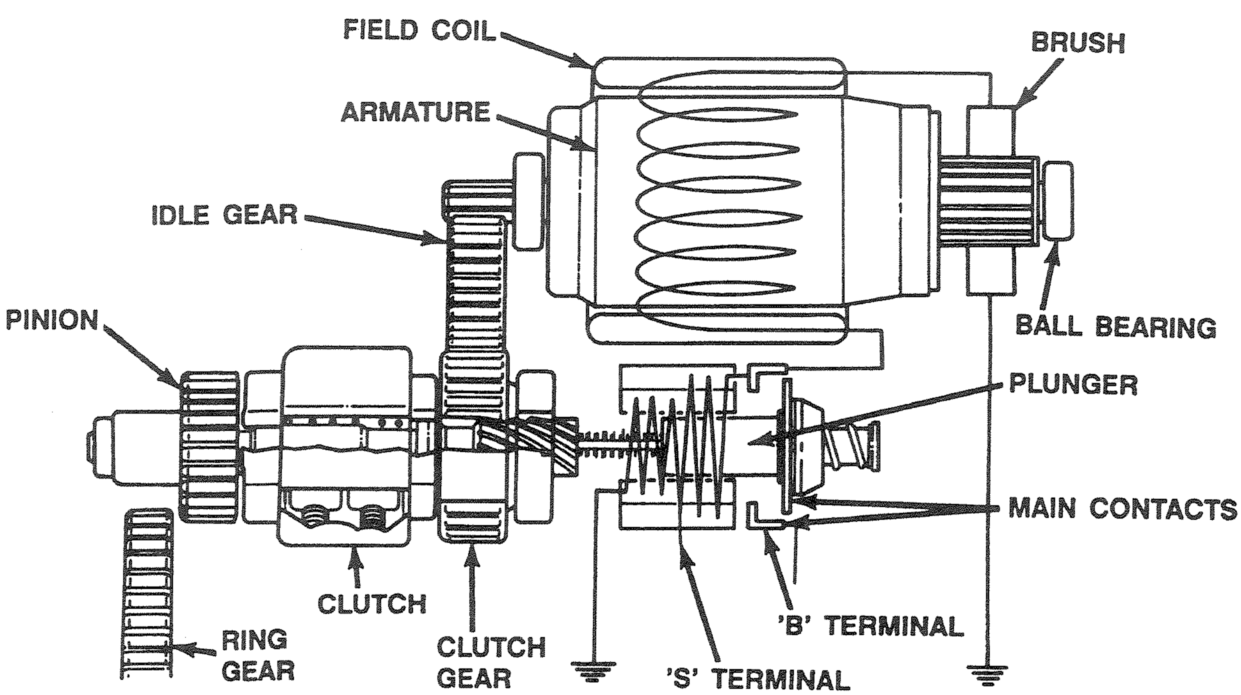
CONNECT TO GROUND
(MAY BE DIRECT GROUND
AS SHOWN OR THROUGH NEUTRAL
SAFETY SWITCH OIL
PRESSURE SWITCH, FUEL PRESSURE
SWITCH OR OTHER CONTROL UNIT)

st901ga

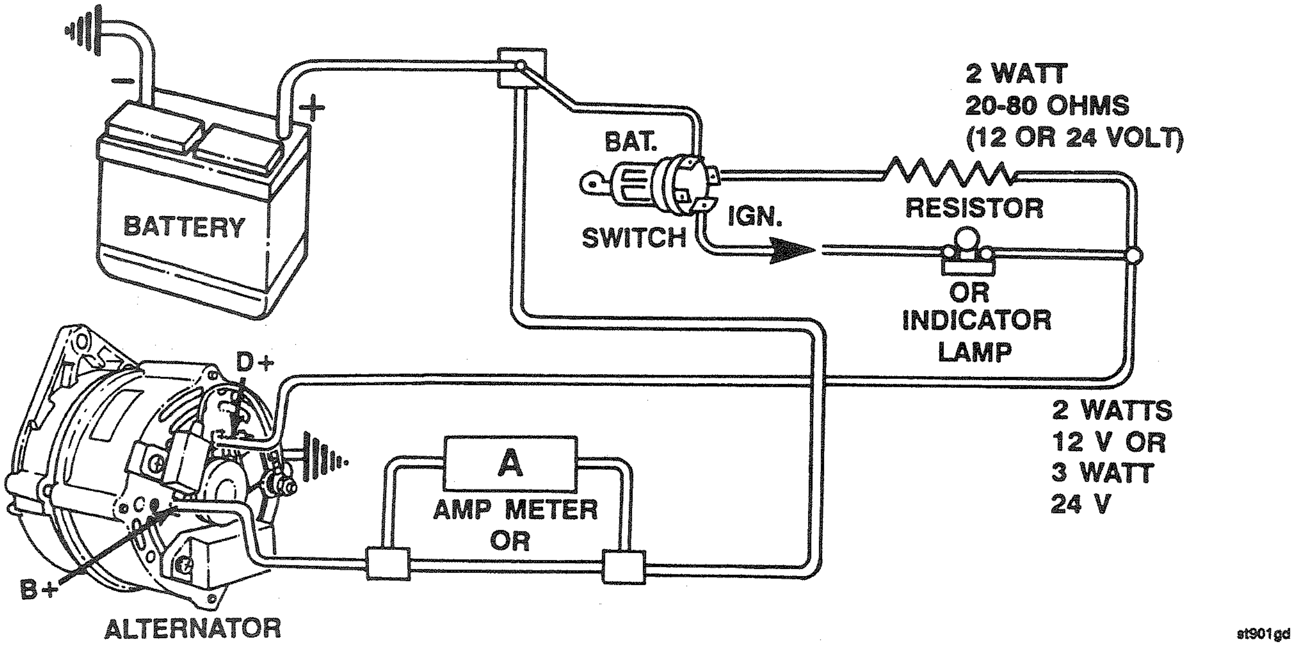
Nippondenso "R" type starting motor



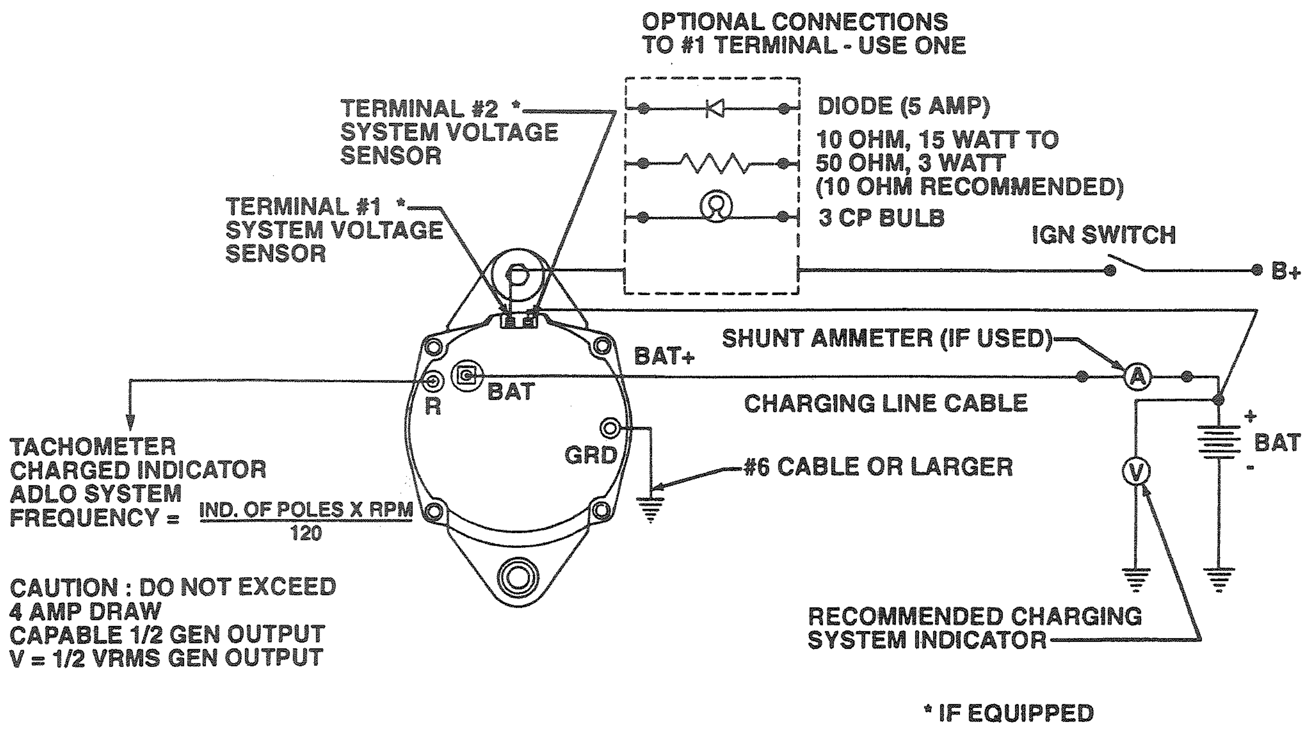
Basic Wiring Circuit (with auxillary magnetic switch)



Typical Bosch K1 charging system circuit



Typical Delco charging system circuit



Specifications - Electrical System

Battery Capacity

	4B3.9	4BT3.9	4BTA3.9	6B5.9
Minimum Recommended Battery Capacity - With Light Accessories*				
- 12 V Starter	625CCA	625CCA	625CCA	800CCA
- 24 V Starter	312CCA	312CCA	312CCA	400CCA
With Heavy Accessories**				
- 12 V Starter	800CCA	800CCA	800CCA	950CCa
- 24 V Starter	400CCA	400CCA	400CCA	475CA

* Typical light accessories include alternator, small steering pump, and disengaged clutch.
** Typical heavy accessories include hydraulic pump and torque converter.

Starting Circuit Resistance

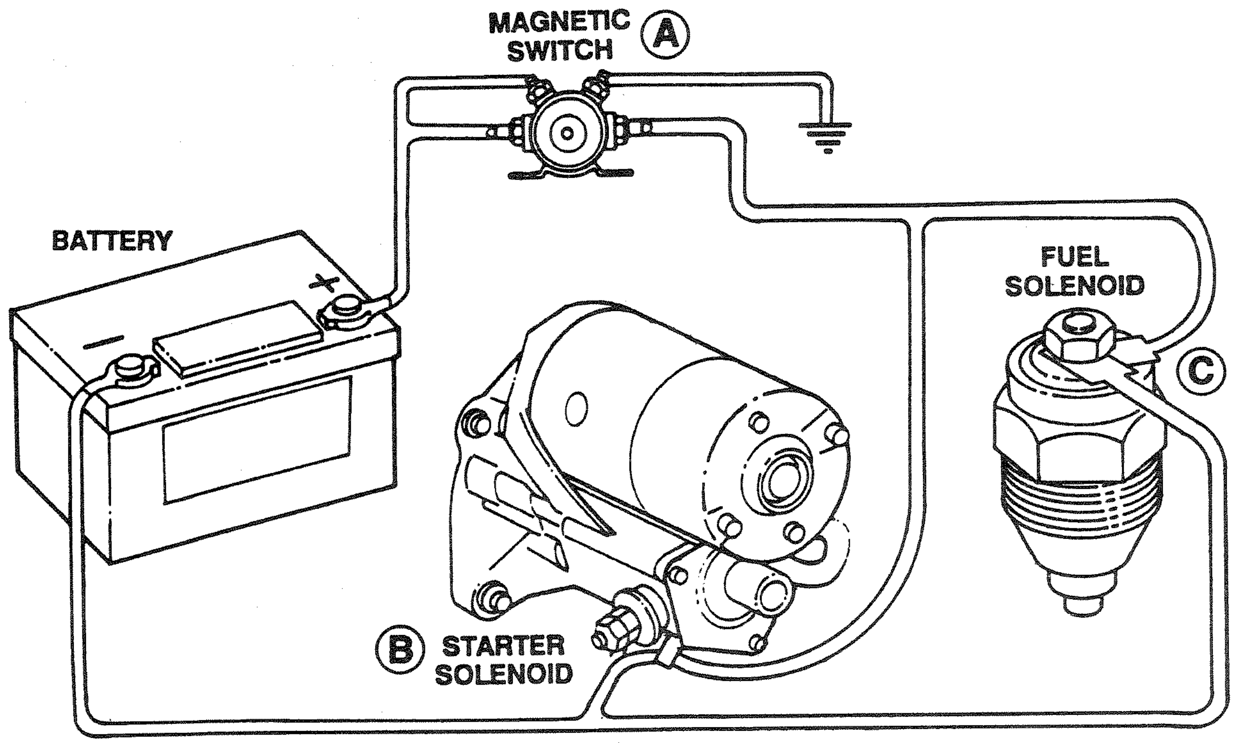
Maximum Allowable Resistance of Starting Circuit		
- With 12 V Starter - Ohms	Medium duty .0012	Heavy duty .00075
- With 24 V Starter - Ohms	Medium duty .004	Heavy duty .0020

Battery Cable specifications

Cable Size	Nominal Resistance In Ohms		Maximum Total Length (sum of both cables)			
			12V		24V	
Gauge	Per Meter	Per Foot	Meter	Feet	Meter	Feet
4	0.000984	0.00030	NR*	NR*	2.03	6.7
2	0.000615	0.000188	1.63	5.3	3.26	10.6
1	0.000492	0.000150	2.03	6.7	4.06	13.4
0	0.000386	0.000118	2.59	8.5	5.18	17.0
00	0.000292	0.000090	3.43	11.3	6.86	22.6
000	0.000232	0.000071	4.32	14.2	8.64	28.4

* Not recommended

Wiring Size Recommendations - Starter and Fuel Solenoid



RECOMMENDED WIRE GAUGE:

Values in table are AWG. size for 12/24 volt systems.

Wire length in circuit:	BAT to A.	A. to B.	A. to C.
3 ft.	10/14	12/14	14/16
4 ft.	10/12	10/14	14/16
5 ft.	8/10	10/12	14/16
9 ft.	6/8	8/10	12/14
18 ft.	4/6	6/8	8/10

Wire length in circuit means total length in each individual circuit, e.g: BAT. to A. = One circuit.

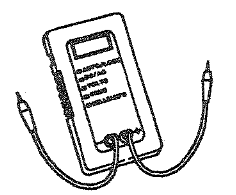
For example, in a 12 volt circuit:

BAT. to A. = 5 ft; gauge required = 8g.
A. to B. = 5 ft; gauge required = 10g.
A. to C. = 9 ft; gauge required = 12g.

If the system is double pole wiring, (no frame ground), then the Fuel & Starter solenoid circuit lengths would include the return cable run to the battery negative.

Electrical System - Service Tools

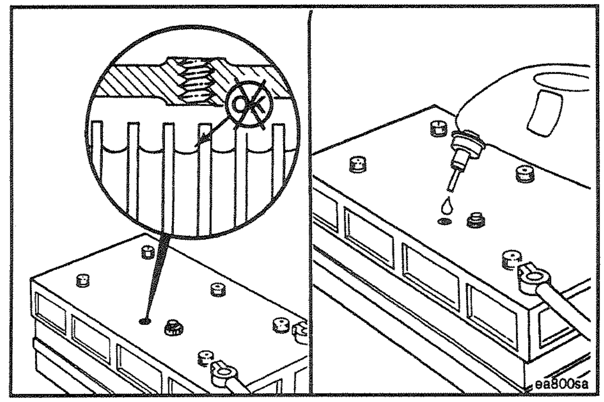
The following special tools are recommended to perform procedures in Section 6. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3376898	**Digital Multimeter** Use to measure voltage (volts) and resistance (ohms) in a circuit.	 3376898

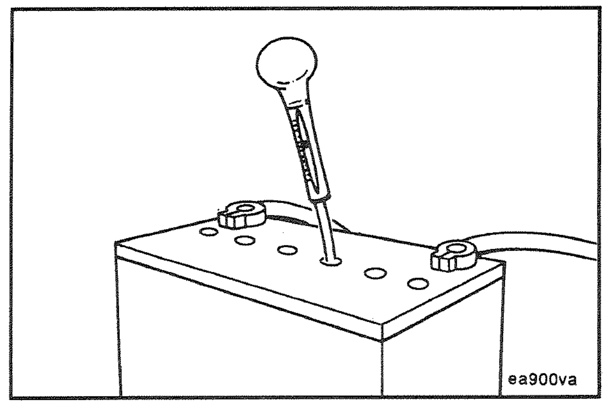
Battery Checking (6-01)

Fill each battery cell with distilled water. Refer to the manufacturer's specifications.

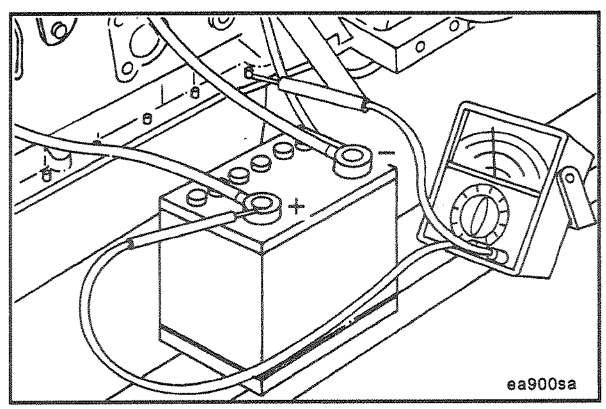
NOTE: Maintenance-free batteries are sealed and do not require the addition of water.



If conventional batteries are used (now maintenance free), check the specific gravity of the battery electrolyte in each cell.



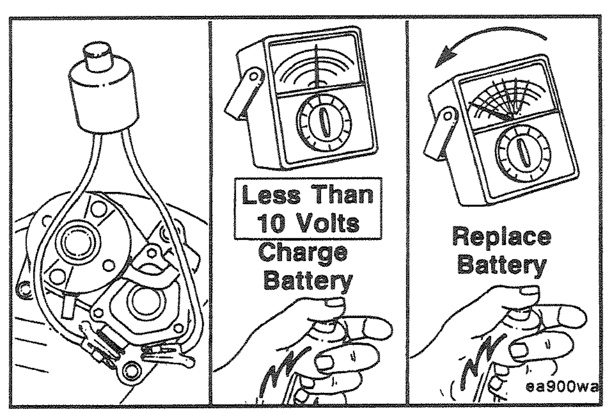
All batteries, including maintenance free, can be checked by measuring the voltage between the positive battery cable and the engine block (ground). Note the voltage.

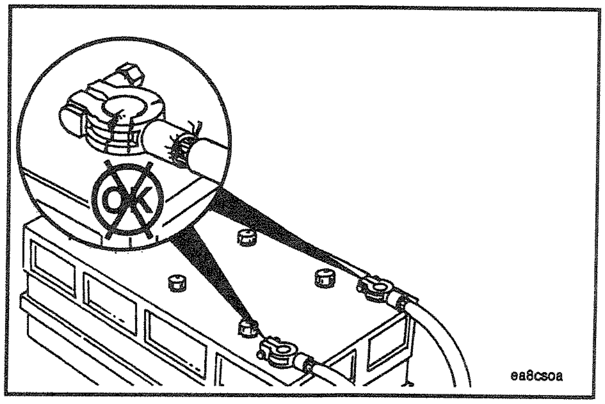


Using a remote start connection, attempt to engage the starter while observing the voltage.

If the voltage reads less than 10 volts DC, charge the battery.

If the voltage drops rapidly more than 2 volts DC, replace the battery.

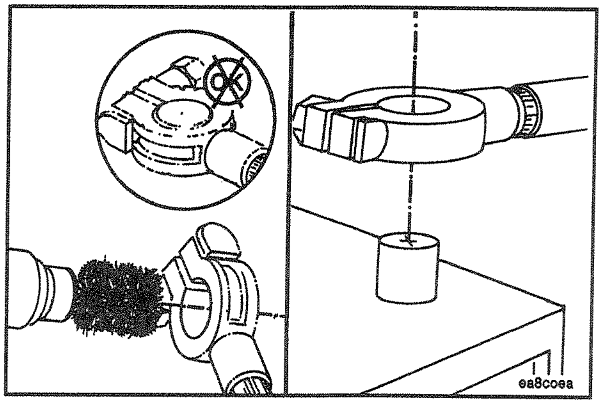




Battery Terminal Connections - Checking (6-02)

Visually inspect the battery terminals for loose, broken, or corroded connections.

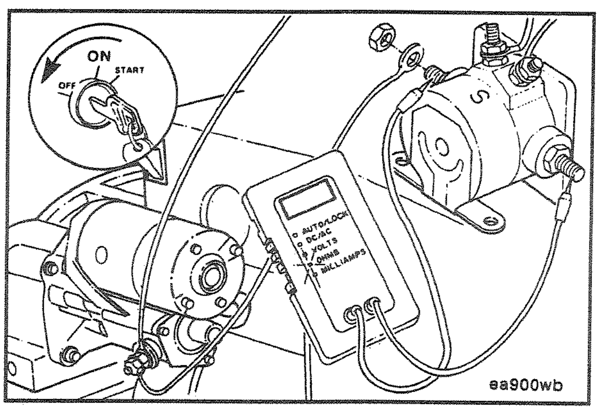
Repair or replace broken cables or terminals.



If the connections are corroded, remove the cables and use a battery brush to clean the cable and battery terminals.

Install and tighten the battery cables.

Use grease to coat the battery terminals to prevent corrosion.



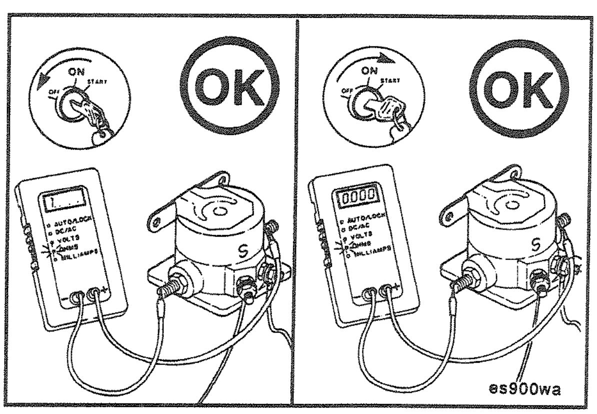
Starting Circuit - Checking (6-03)

Magnetic Switch - Checking

Caution: Be sure the starting motor switch is in the "OFF" position to prevent electrical shock and personal injury.

Remove the cable connecting the magnetic switch to the starting motor solenoid from the magnetic switch terminal.

Connect the leads of Part No. 3376898 Digital Multimeter or equivalent to the two large switch terminals.



Set the multimeter to measure resistance (OHMS).

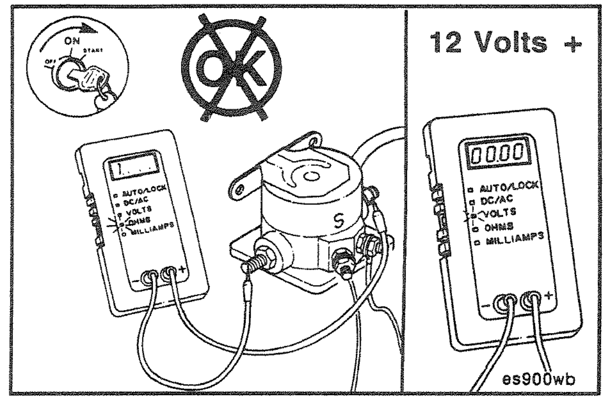
With the starting motor switch in the "OFF" position, the multimeter must indicate resistance at infinity.

Turn the starting motor switch to the "START" position.

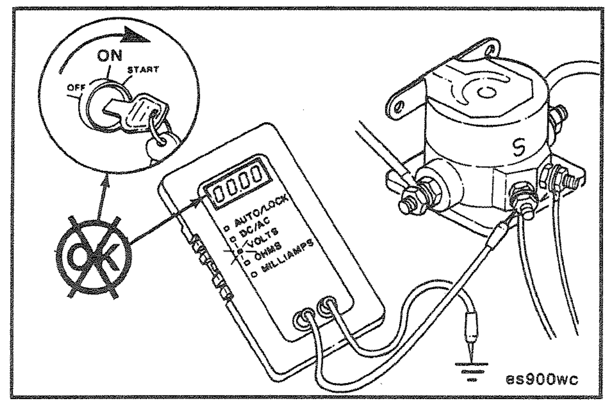
The multimeter must indicate zero ("0") or very little resistance.

If the multimeter indicates resistance at infinity with the starting motor switch in the "START" position:

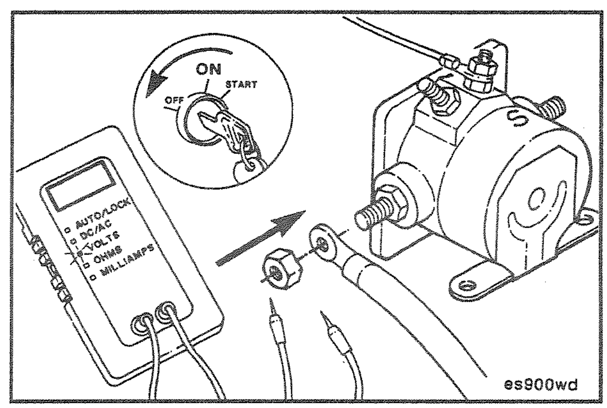
- Turn the starting motor switch to the "OFF" position.
- Set the multimeter scale to read DC voltage.



- Connect one multimeter lead to the magnetic switch terminal marked "S" and the other lead to the ground.
- Turn the starting motor switch to the "START" position.
- If the multimeter indicates no voltage, the magnetic switch is not the cause of the complaint. Refer to "Starting Motor Switch - Check" in this Procedure.



- Turn the starting motor switch to the "OFF" position.
- Remove the multimeter leads and connect the magnetic switch to the starting motor solenoid wire.

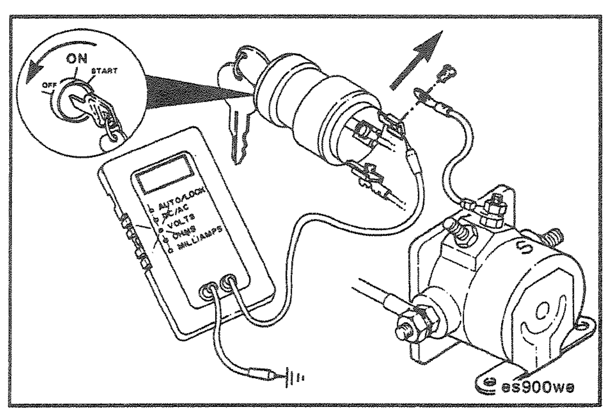


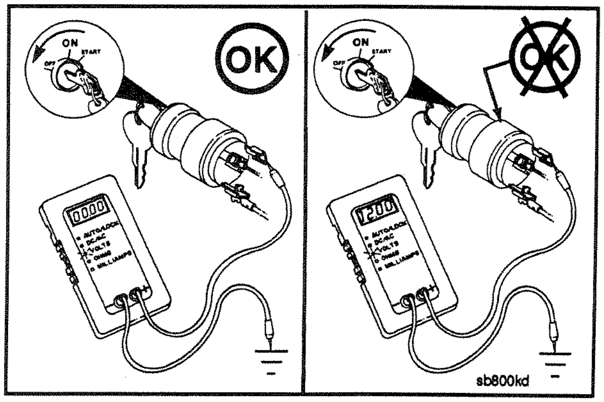
Starting Motor Switch - Checking

Caution: Be sure the starting motor switch is in the "OFF" position to prevent electrical shock and personal injury.

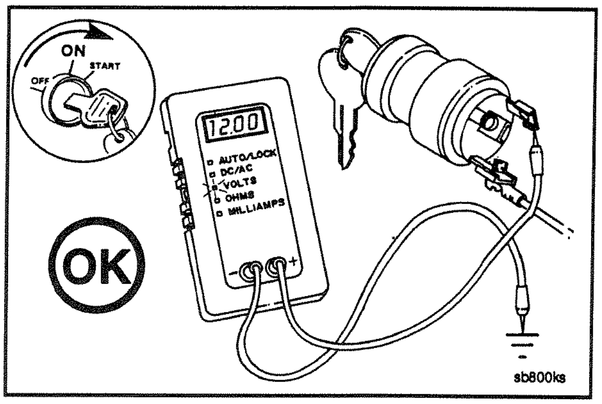
Remove the wire connecting the starting motor switch to the magnetic switch (marked "S" or "Start") from the starting motor switch terminal.

Connect the positive lead of Part No. 3376898 Digital Multimeter or equivalent to the starting motor switch terminal and the negative lead to a chassis or engine ground location.



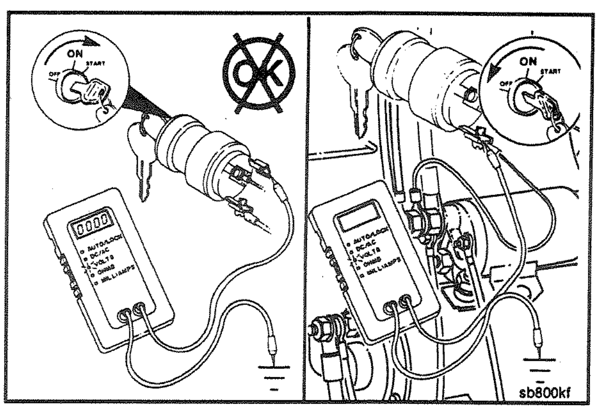


NOTE: With the starting motor switch in the "OFF" position, there must not be voltage at the starting motor switch terminal. If the meter indicates voltage, the starting motor switch is malfunctioning and must be replaced.



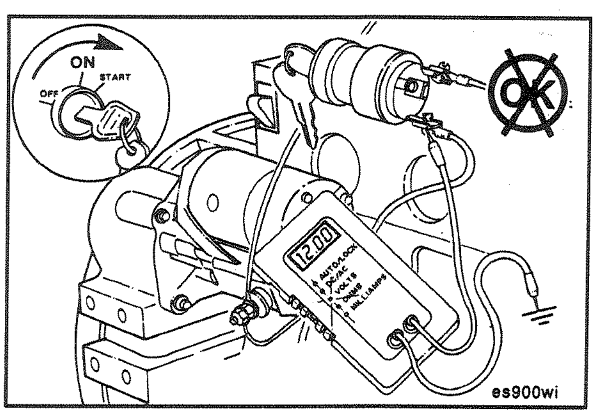
Turn the starting motor switch to the "START" position.

The multimeter must indicate system voltage.



If there is not voltage:

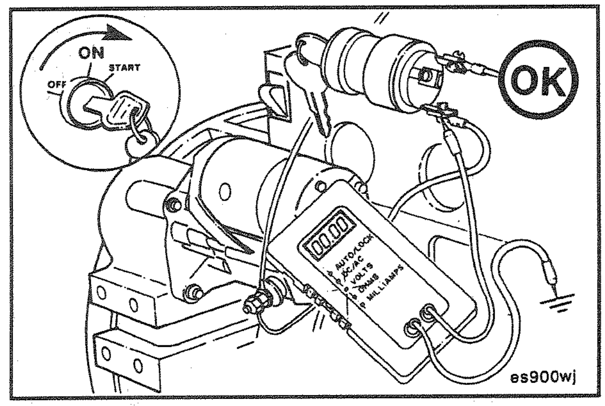
- Turn the starting motor switch to the "OFF" position.
- Connect the multimeter positive lead to the starting motor switch terminal having a wire connecting the starting motor switch to the starting motor solenoid "B" terminal.



If the meter indicates system voltage at the starting motor switch input terminal, the starting motor switch is defective and must be replaced.

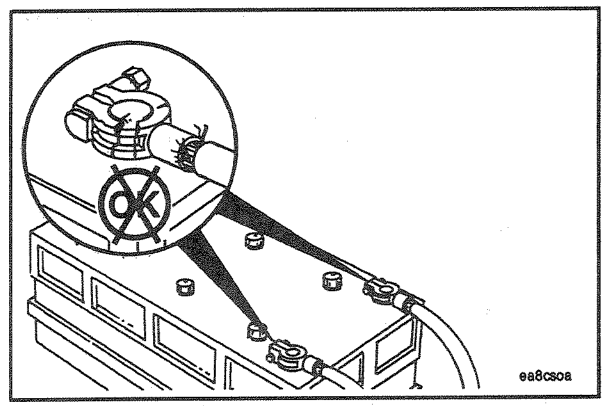
If the meter indicates no voltage, the switch is not the cause of the complaint.

Check the wiring from the starting switch to the starting motor solenoid "B" terminal and from the starting motor solenoid to the battery for broken or damaged wires.



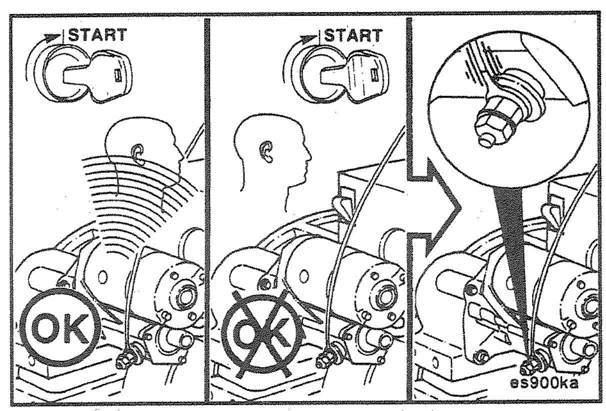
Starting Motor Solenoid and Starting Motor - Checking

Before troubleshooting the starting motor, make sure the battery terminals are not loose or corroded.



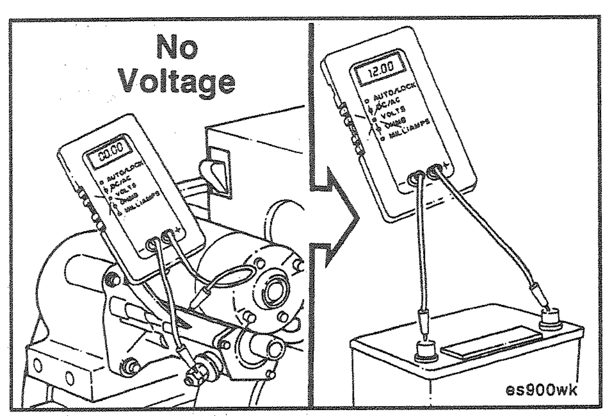
Starting Motor Solenoid

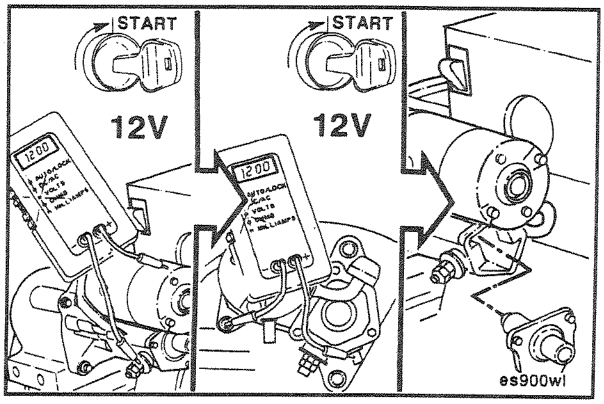
If the starting motor solenoid does not make an audible sound, check for loose wiring connections.



Use a Digital Multimeter such as Part No. 3377161 to set the voltage scale.

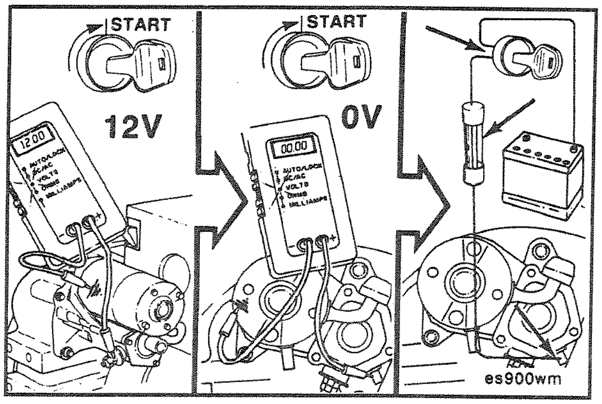
Check for system voltage at the starting motor solenoid battery terminal.





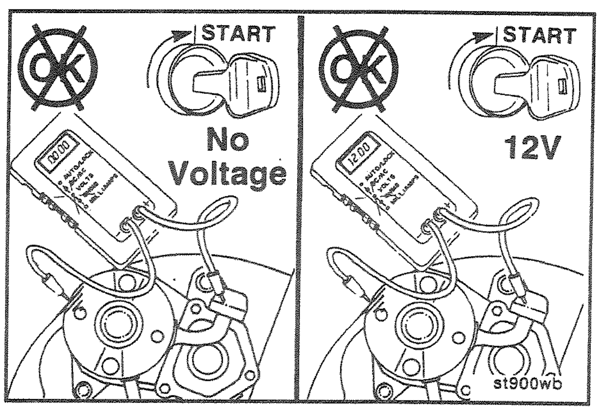
If the multimeter indicates system voltage at the starting motor battery terminal, check the voltage at the starting motor solenoid "S" terminal, which the starting switch is energized.

If the multimeter indicates system voltage at "S" terminal, but the starter does not engage, the starting motor solenoid is malfunctioning and the starter must be replaced.



If the multimeter does not indicate system voltage at the "S" terminal, check:

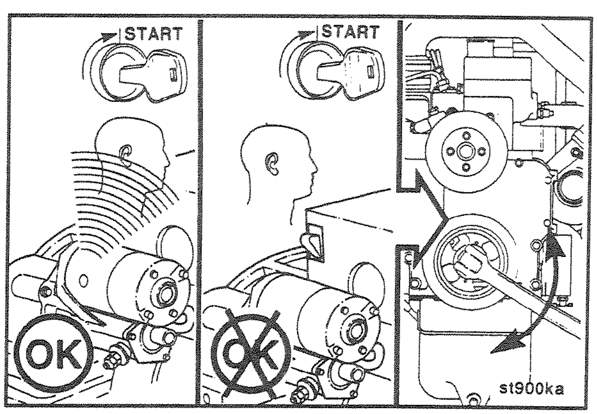
- Fuses
- Voltage to the ignition switch and magnetic switch. Refer to "Starting Motor Switch and Magnetic Switch - Checking" in this section.
- Application safety shutoff systems.



Starting Motor

Check for system voltage at the "M" terminal of the starting motor, while the starter switch is energized.

- System Voltage: Starting motor is malfunctioning or not adequately grounded and must be repaired or replaced.
- No Voltage: Starting Motor solenoid is malfunctioning and must be replaced.

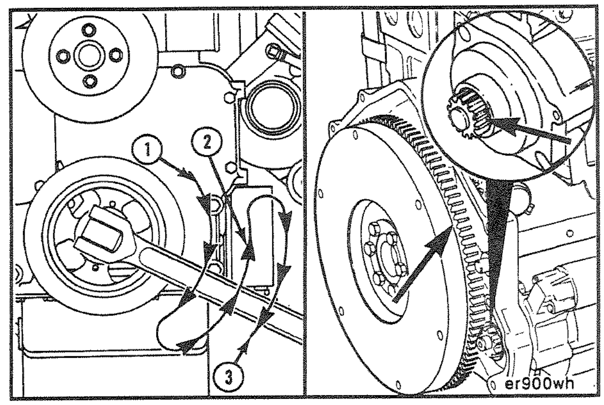


If the starting motor solenoid makes an audible sound, turn the switch off and attempt to bar the crankshaft in both directions.

Bar the crankshaft as follows:

1. Direction of engine rotation.
2. Direction opposite engine rotation.
3. Direction of engine rotation.

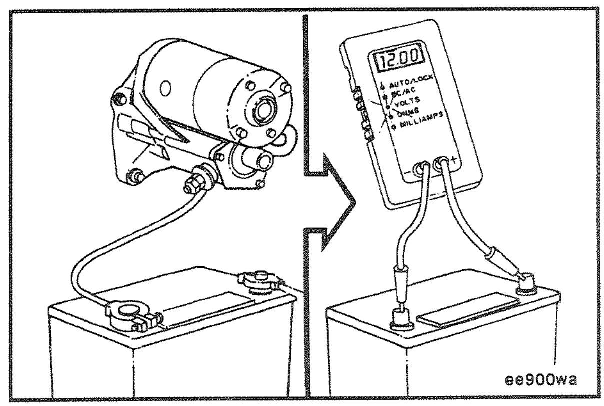
If the crankshaft will bar at step No. 3, attempt to start the engine. If the starting motor cranks the engine, check the starting motor pinion gear and flywheel ring gear for damage.



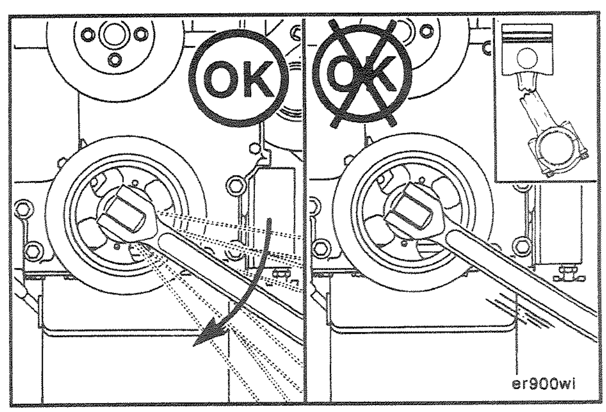
Engine Cranking Speed Too Slow

Make sure the wiring connections are clean, tight and not damaged.

Check the battery voltage. Refer to "Batteries - Checking".

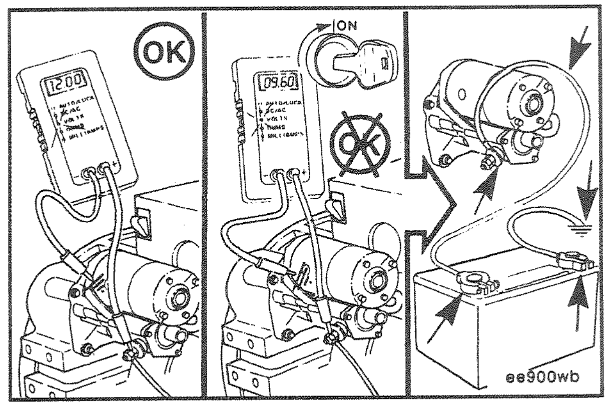


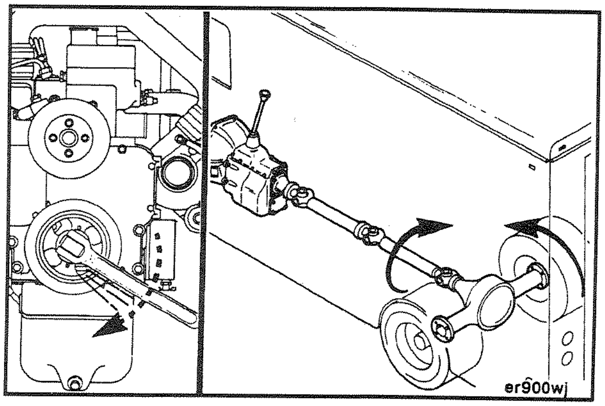
If the crankshaft was not rotated to check the starting motor, bar the crankshaft in the direction of engine rotation to make sure the engine is free and does not have an internal malfunction.



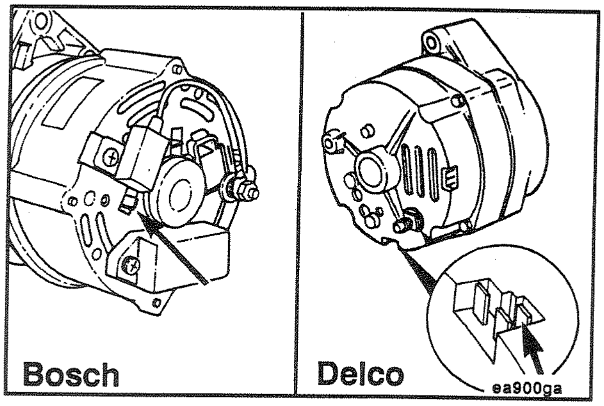
If the engine is free, check the voltage at the starting motor during cranking. If the voltage drops more than 2.4 volts on a 12 volt system, check that all connections are tight. The limit for 24-volt systems is 4.8 volts.

If the cables are correct and the voltage drop exceeds the limit, replace the starting motor.



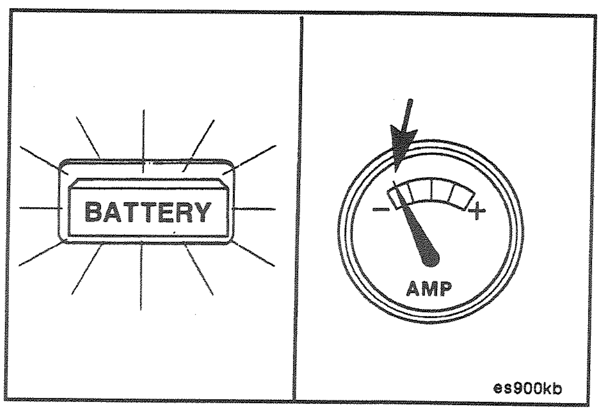


If the crankshaft requires more than a normal effort to bar, check for excessive load from the driven units and accessories.

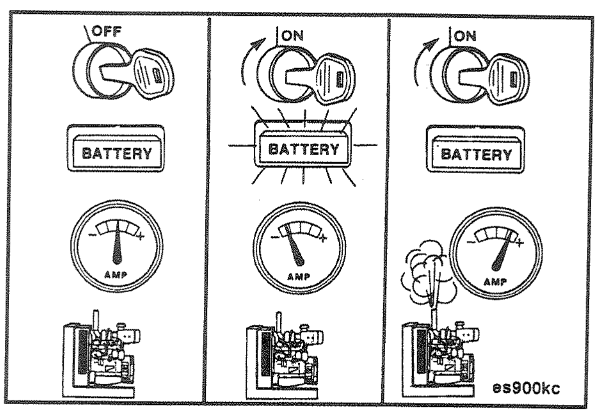


Alternator - Checking (6-04)

The terminals on the alternator are shown in this illustration. The "R" (Delco) and "W" (Bosch) terminal provide one-half system voltage and is used to operate accessories such as the tachometer on generator sets.



Trouble with the charging system may be indicated by the indicator lamp or ammeter.



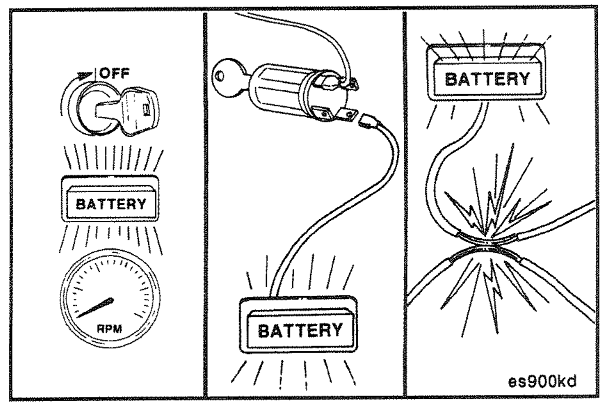
Abnormal Indicator Lamp Operation

Check the indicator lamp for normal operation as shown below.

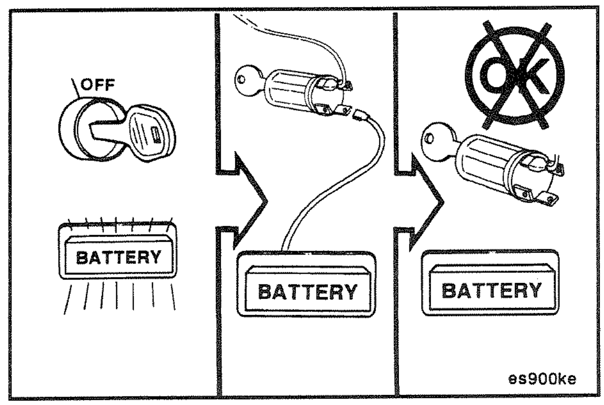
Engine	Switch	Lamp	Ammeter
Stopped	Off	Off	o
Stopped	On	On	-
Running	On	On	+

Switch Off, Lamp On, Engine Stopped

Disconnect the lamp lead at the ignition switch. If the lamp stays on, there is a short to a positive wire on the ignition side of the lamp.

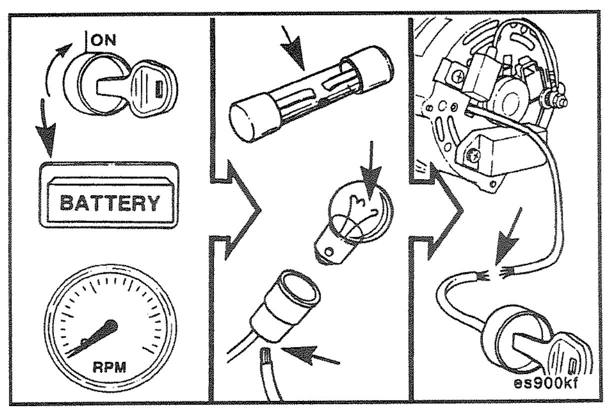


If the lamp goes out, there is a short in the switch.



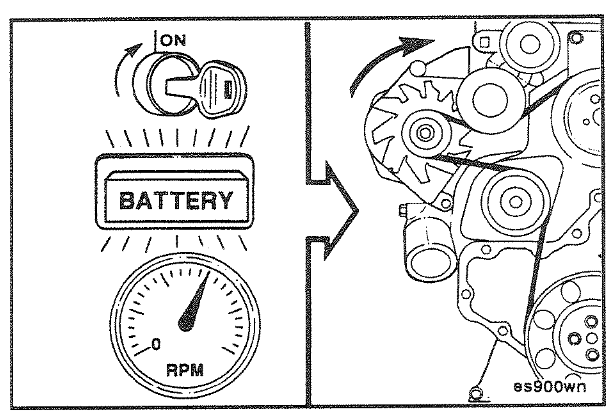
Switch On, Lamp Off, Engine Stopped

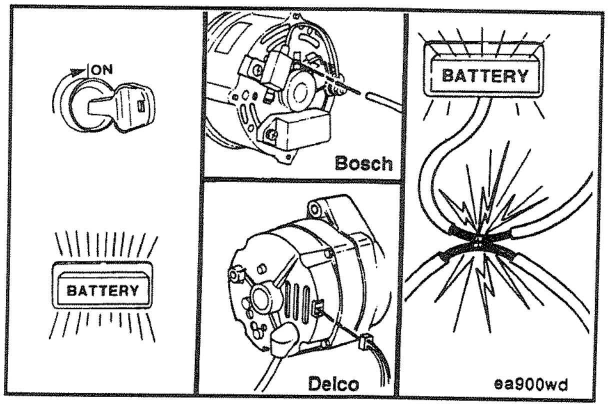
This condition can be caused by an open in the circuit. To determine where an open exists. Check for a blown fuse, a burned out bulb, defective bulb socket, or an open in No. 1 or "D+" lead circuit between alternator and ignition switch.



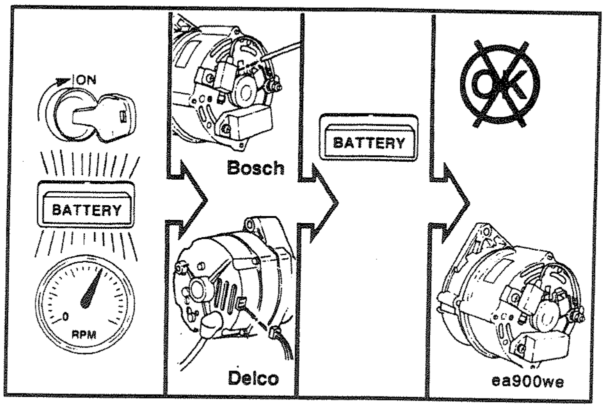
Switch On, Lamp On, Engine Running

Check the drive belt and alternator pulley to be sure the alternator is rotating.

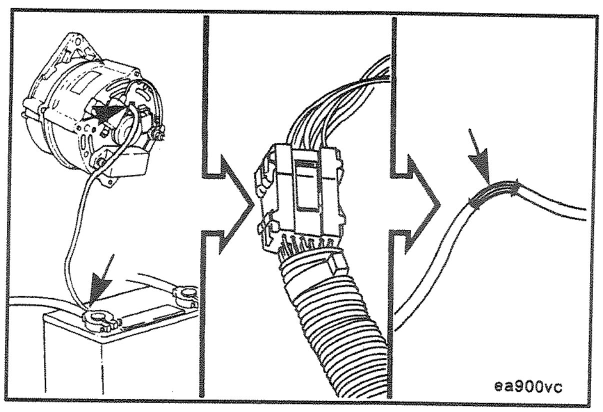




Disconnect the lead to Terminals No. 1 and No. 2 (Delco) or D+ (Bosch K1). If the lamp stays on, there is a short to ground on the alternator side of the lamp.



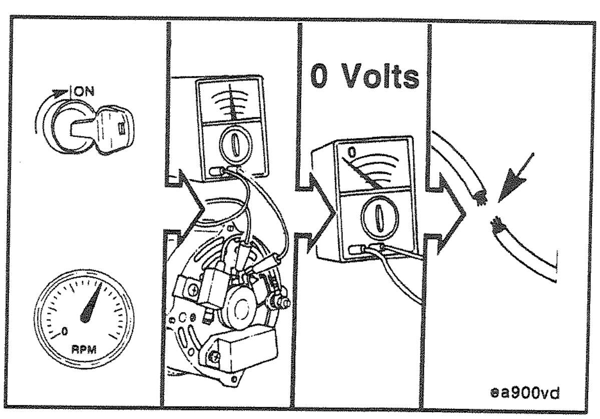
If the lamp goes out, replace the alternator.



Abnormal Charging System Operation

Check the battery and all wiring connections.

Inspect the wiring for defects. Check all connections for tightness and cleanliness, including the slip connectors at the alternator and firewall, and connections at the battery.



With ignition switch on and all wiring harness leads connected, connect a voltmeter from:

A. Alternator "BAT" (Delco 15SI)"B+" (Bosch K1) terminal to ground.

B. Alternator No. 1 (Delco 15SI) to ground.

C. Alternator No. 2 (Delco 15SI) to ground.

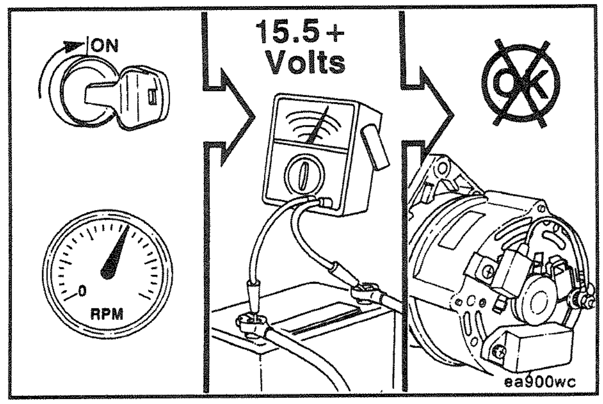
D. Alternator D+ (Bosch K1) to ground.

A zero reading indicates an open between the Alternator connections and the battery.

Locate and repair the open circuit.

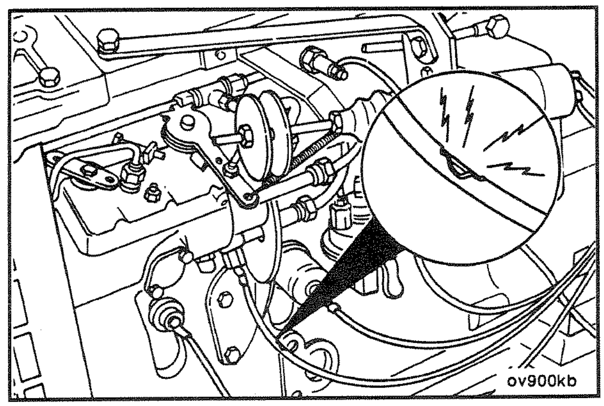
With all accessories turned off, connect a voltmeter across the battery. Operate engine at moderate speed.

If voltage is 15.5 or more on a 12 volt system, remove the alternator for repair. The limit for 24 volt systems is 28 volts.



Lubricating Oil Pressure Switch and Temperature Sensor - Checking (6-05)

When diagnosing problems with either the pressure switch or the temperature sensor, check for loose or corroded connections and for broken wires.



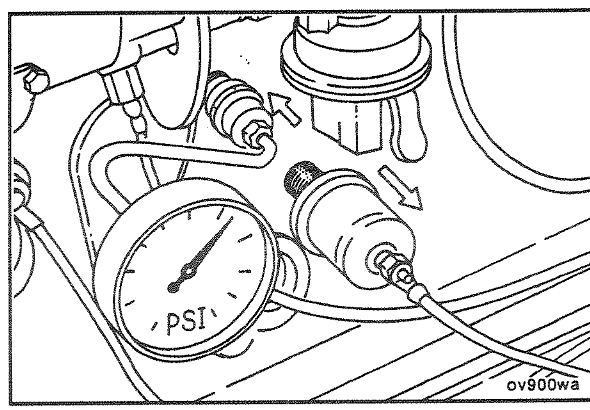
Lubricating Oil Pressure Switch - Check (6-06)

Remove the lubricating oil pressure switch, install a gage, start the engine and measure the lubricating oil pressure. Minimum lubricating oil pressure:

Low Idle (675 to 725 RPM) .... 69 kPa [10 PSI]

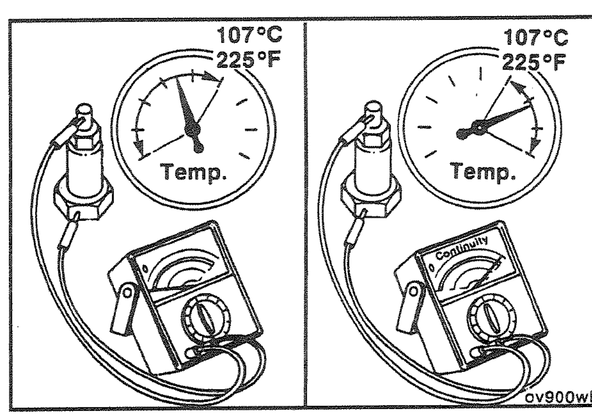
High Idle .... 207 kPa [30 PSI]

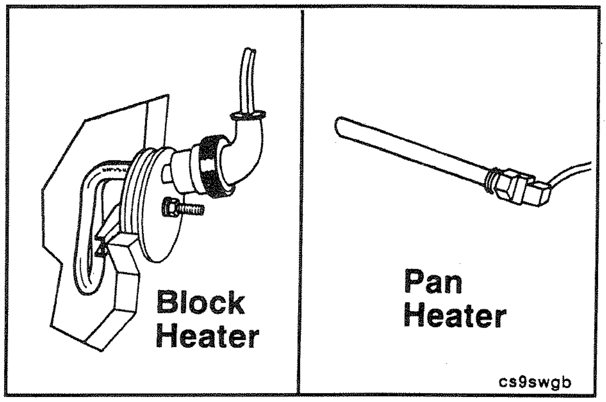
NOTE: The Pressure switch is set to actuate when oil pressure drops to 55 kPa [8 PSI].



Temperature Sensor - Check (6-07)

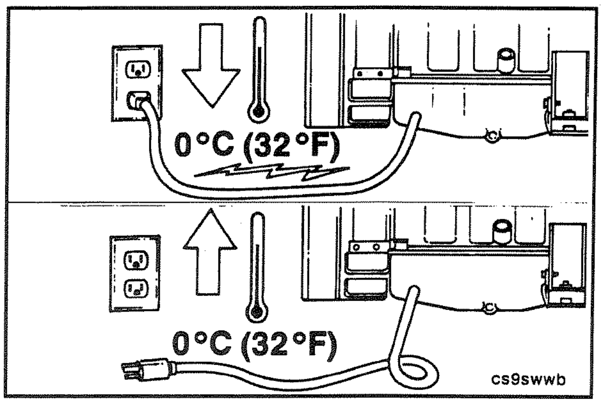
Check for continuity. The sensor will have continuity only when coolant temperature is above 107°C [225°F].





Coolant or Pan Heater - Check (6-08)

When operating, the engine block or oil pan heater should make an audible sound and the adjacent parts should be warm to the touch.



Some heaters will operate continuously when plugged into the correct voltage electrical socket. Operate them only when the ambient temperature is below 0°C [32°F].

White Smoke - Check

White smoke indicates unburned fuel during cold engine operation.

The intake manifold heater system is not directly connected to the fuel system but it monitors the temperature of the air to the engine. The thermistor sends varying resistance values to the Electronic Control Module or equivalent. The ECM in turn controls the "Wait to Start" light and the heater solenoids.

The intake manifold heater elements operate in both the preheat and postheat modes.

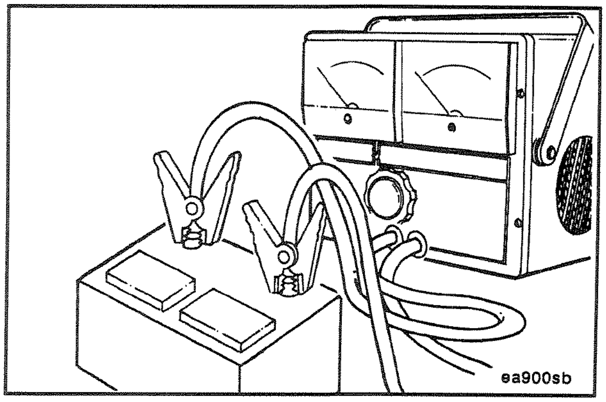
- In preheat, the ignition switch is on but the engine has not been started.
- In postheat, the engine is running.

The proper operation of the intake manifold heater system and starting procedures will preclude excessive engine starter motor use and minimize white exhaust smoke when the engine is first started.

Normal Operation of the Intake Manifold Heater System

Engine Intake Manifold Temperature	Preheater Cycle Time Ignition Key "ON" Before Crank Cycle	Post Heater Cycle Occurs Ignition Key "ON" After Crank Cycle
Above 15°C [59°F]	0-Seconds	No
-9°C to 15°C [15°F to 59°F]	*10-Seconds	Yes
-18°C to -9°C [0°F to 15°F]	15-Seconds	Yes
-26°C to 18°C [-15°F to 0°F]	17-Seconds	Yes
Below -26°C [15°F]	20-Seconds	Yes

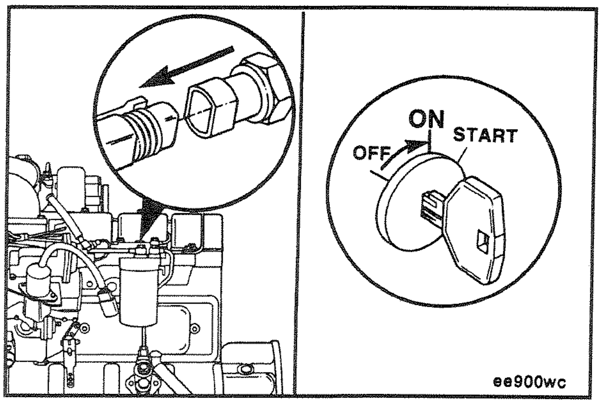
* Heater Control Modules/Electronic Control Modules with serial numbers below 0080000A will not have a Preheat Cycle during this cycle.



Intake Manifold Heater - Check (6-09)

Check the battery voltage.

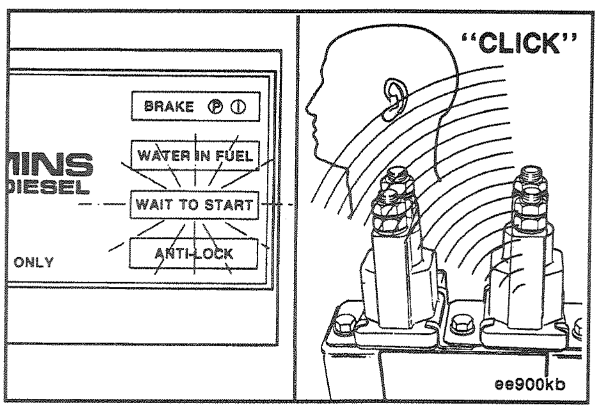
Minimum: 6.5 Volts



Check the thermistor.

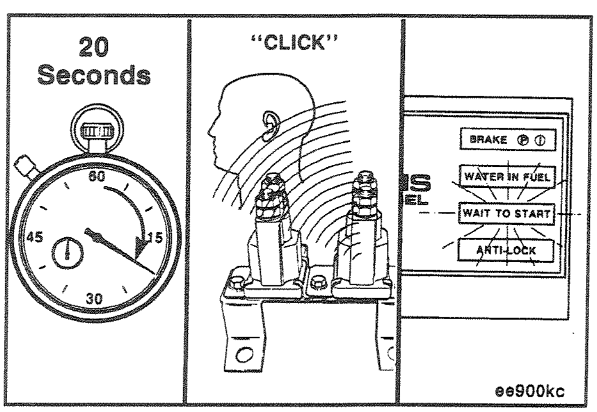
Disconnect the thermistor.

Turn the ignition switch to the "ON" position.



NOTE: The "Wait to Start" light should come on.

The solenoids should click on.



Wait 20 seconds.

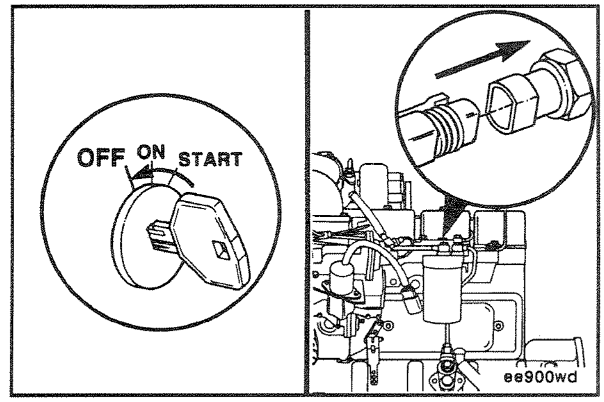
The solenoids should click off.

The "Wait to Start" light should begin flashing.

NOTE: The "Wait to Start" light will flash indicating an open circuit in the thermistor wiring. Disconnecting the thermistor simulates this condition.

Turn the ignition switch to the "OFF" position.

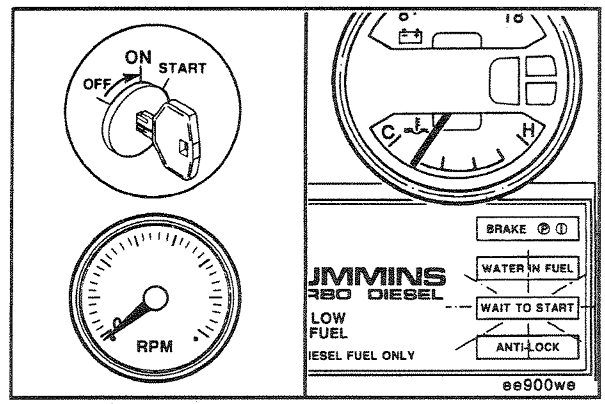
Connect the thermistor wire harness.



Preheat Cycle - Check

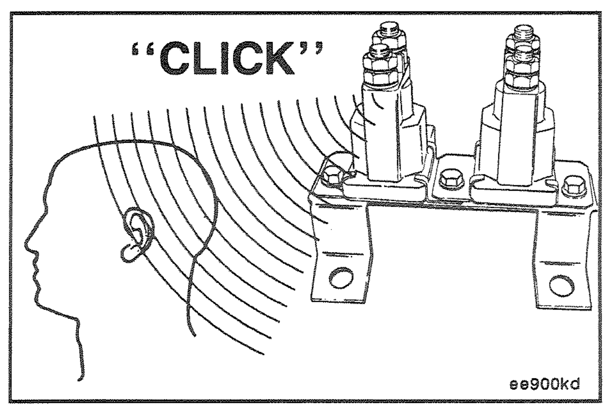
Turn the ignition switch to the "ON" position.

Do not start the engine.



The solenoids (2) should click on.

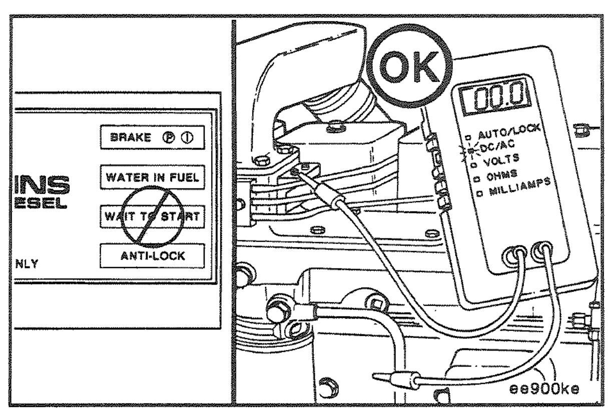
NOTE: If the engine has been running, the temperature is probably above 15°C [59°F].

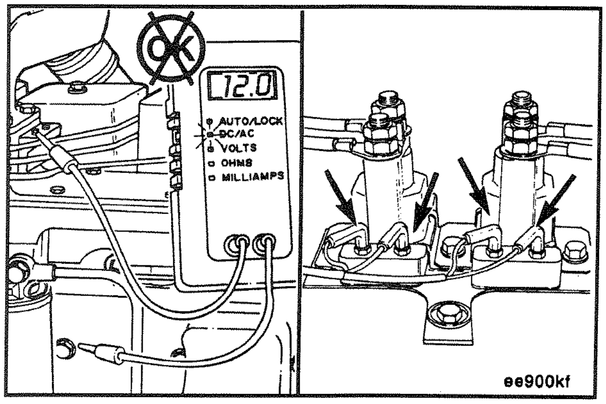


After the preheat period, the "Wait to Start" light will go off and not flash.

Set the multimeter scale to read DC-voltage.

Connect the multimeter lead to the intake manifold heater terminals. Check each terminal individually.



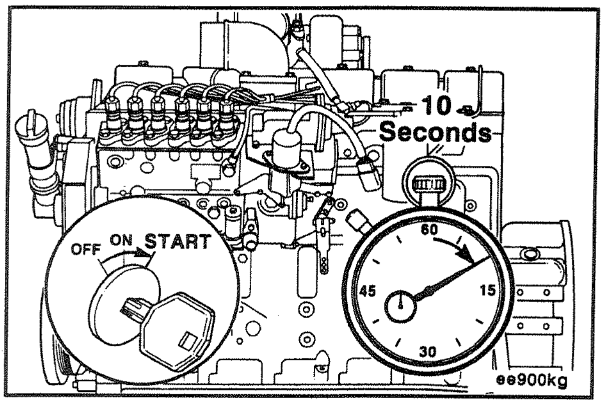


ee900kf

If voltage is present, check the pull-in coil of the solenoids.

Check for voltage at the pull-in coil of solenoid.

1. If voltage at pull-in coil, replace electronic control module.
2. If no voltage present at pull-in, replace solenoid.

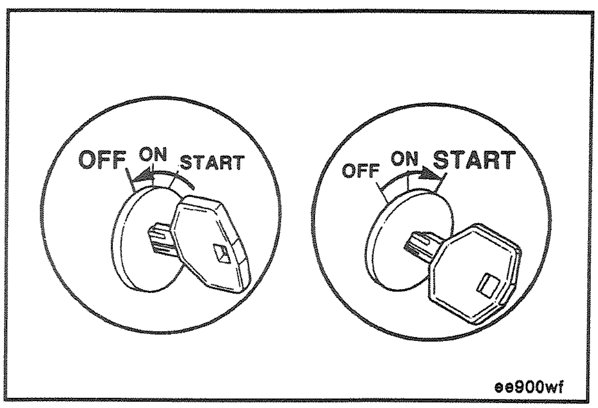


ee900kg

Start the engine.

Do **not** hold the ignition switch in the start position longer than 10 seconds.

If the engine does not start, turn the ignition switch to the "OFF" position.



ee900wf

Return the ignition switch to the "ON" position then begin the normal starting cycle again.

Engine Electrical System Replacement Procedures (6-10)

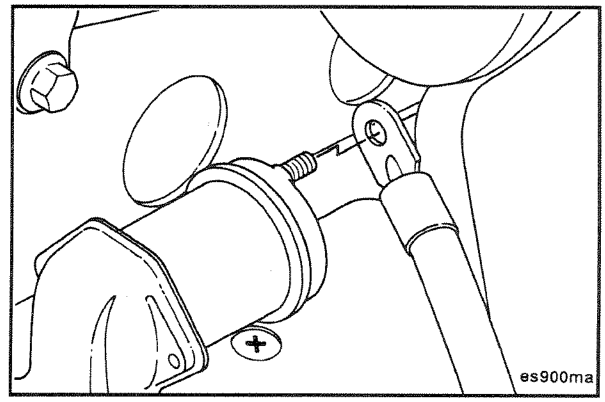
Starting Motor - Replacement

Preparatory Steps:

- Disconnect the ground cable from the battery terminal.
- Identify each electrical wire with a tag indicating location.

17 mm

Remove the battery cable from the solenoid.

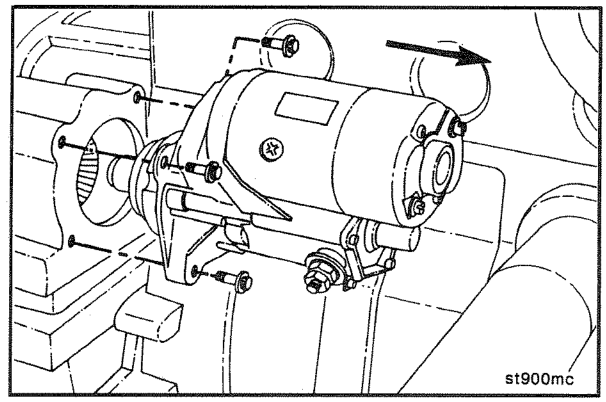


10 mm

Remove the starting motor.

Install the starting motor in the reverse order of removal.

Torque Value: 43 N•m [32 ft-lb]



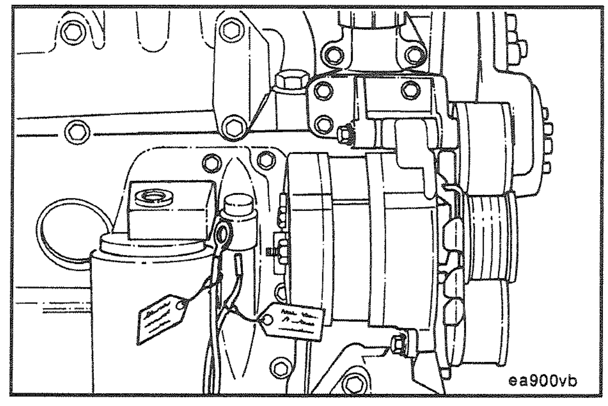
Alternator - Replacement (6-11)

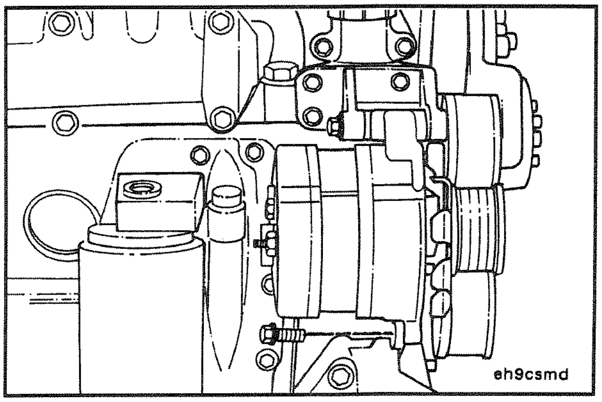
Preparatory Steps:

- Disconnect the ground cable from the battery terminal.
- Remove the drive belt from the alternator pulley.

11 mm

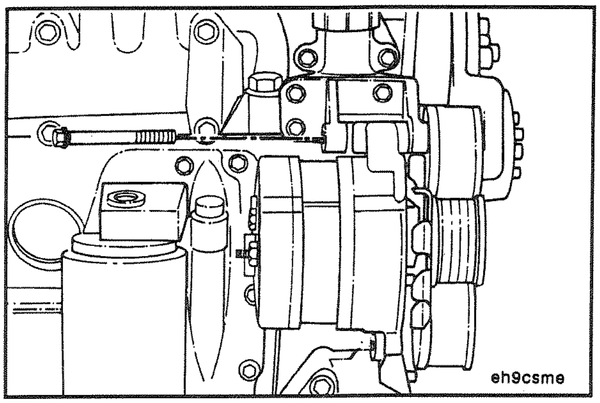
Remove and tag all wires and complete the following steps.





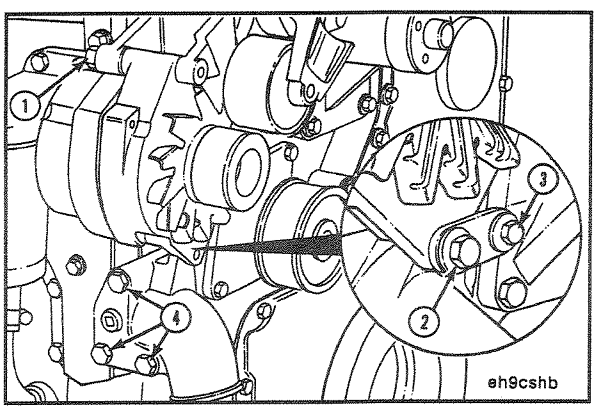
13 mm

Remove the alternator link capscrew.



16 mm

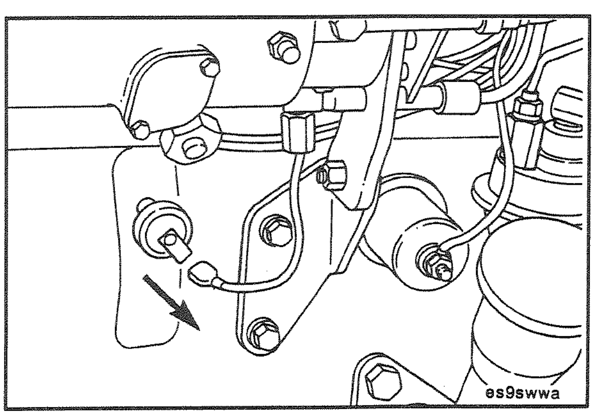
Remove the alternator mounting capscrew.



To assemble the alternator, the alternator mounting components must be loosened and tightened in the following sequence.

1. Alternator-to-alternator bracket capscrew.
2. Lower brace-to-alternator capscrew.
3. Alternator-to-water inlet capscrew.
4. Water inlet-to-block capscrews.

NOTE: Wrench size and torque value is determined by the make and model of alternator. Refer to the Engine Component Torque Values.



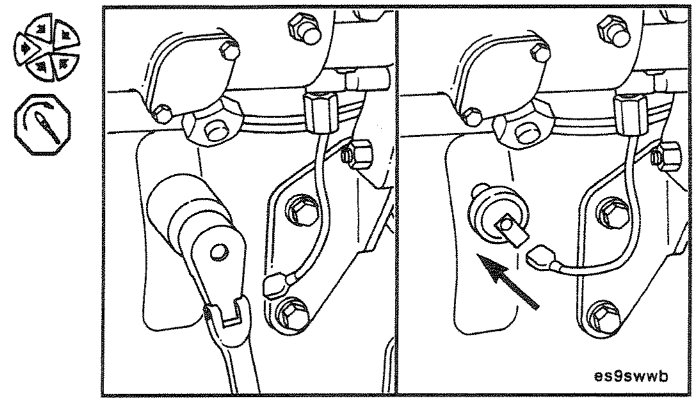
Lubricating Oil Pressure Switch - Replacement (6-12)

Disconnect the wire from the sending unit.

NOTE: The sending units illustrated may differ from those installed by the equipment manufacturer.

Reconnect the wire to the sending unit.

Torque Value:
(Installed into Cast Iron)
16 N•m [12 ft-lb]
(Installed into Aluminum)
10 N•m [7 ft-lb]



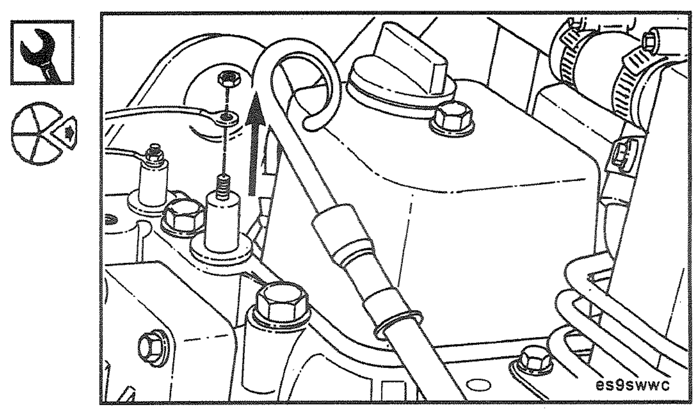
Temperature Sensor - Replacement (6-13)

Preparatory Step:

- Drain coolant

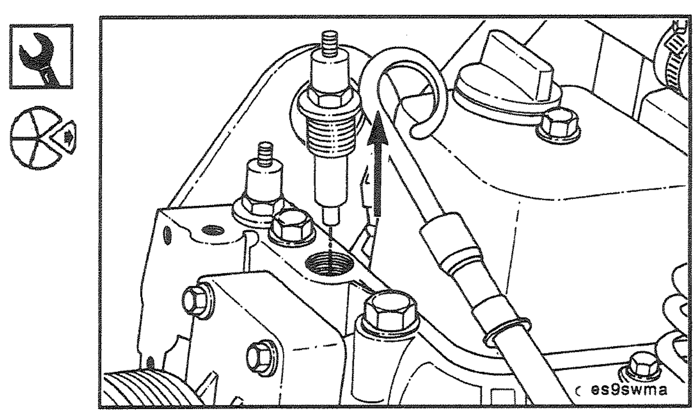
10 mm or Screwdriver

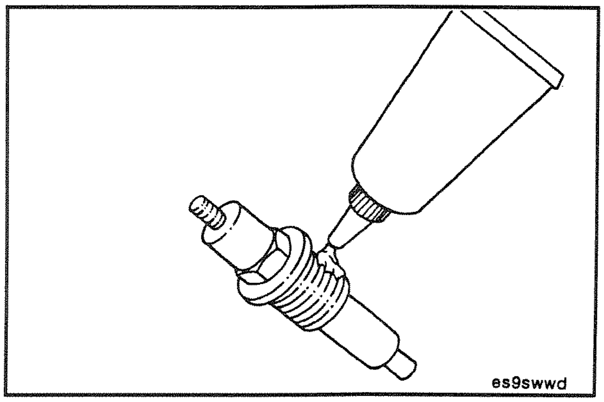
Disconnect the temperature sensor wiring.



22 mm

Remove the temperature sensor.



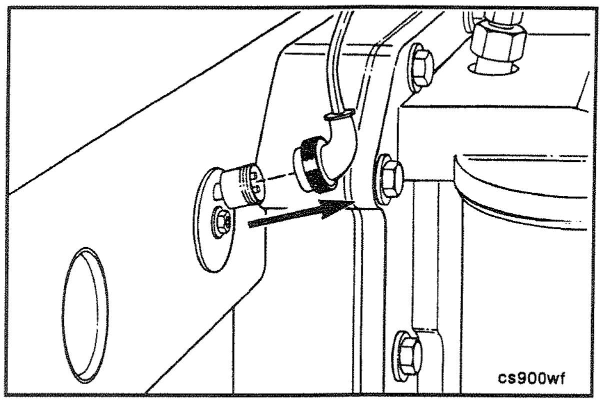


22 mm

Apply liquid teflon sealant to the threads when installing the temperature sensor.

Reconnect the wiring.

Torque Value:
(Installed into Cast Iron)
50 N•m [37 ft-lb]
(Installed into Aluminum)
30 N•m [22 ft-lb]

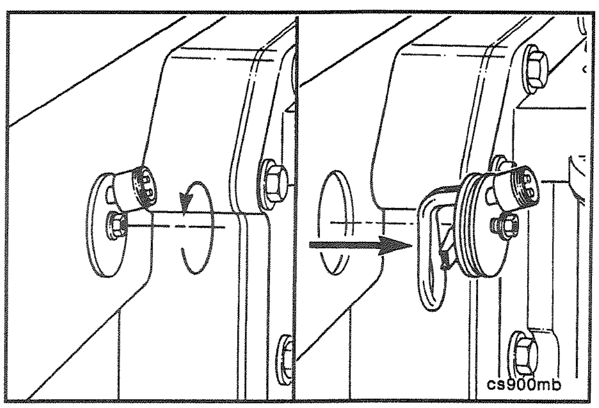


Block Water Heater Replacement (6-14)

Preparatory Step:

- Drain at least 19 litres [5 U.S. gallons] of coolant.

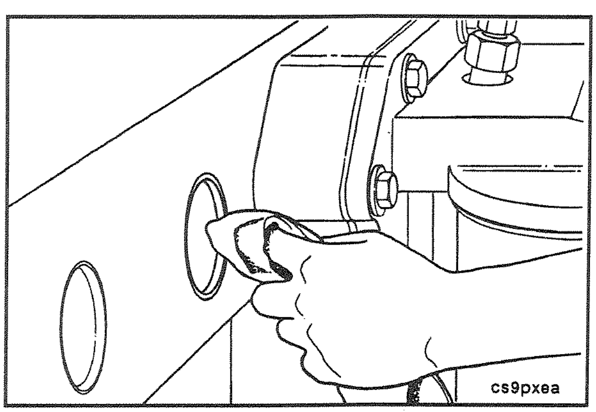
Disconnect the block heater electrical cord.



10 mm

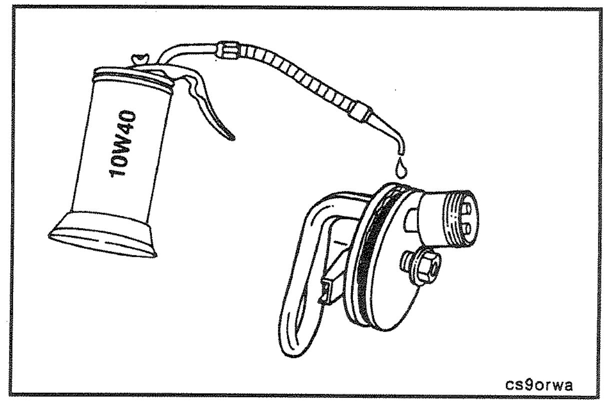
Loosen the block heater retaining nut.

Remove the block heater from the block.

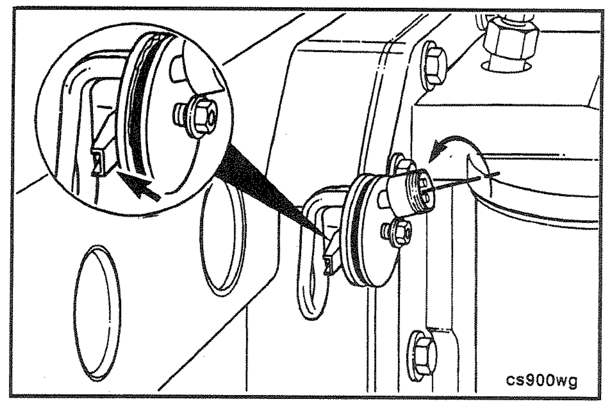


Clean the core plug hole thoroughly. Make sure there are not burrs or sharp edges that might cut the o-ring.

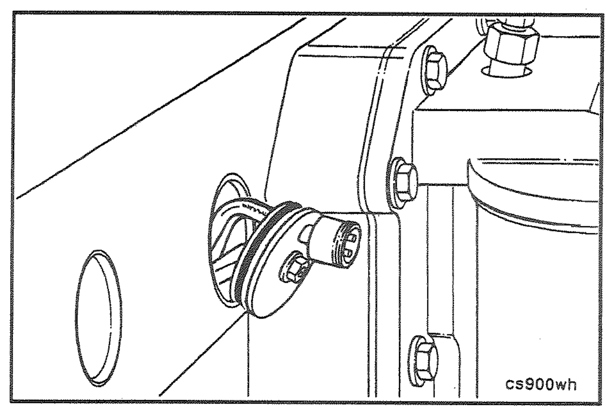
Lubricate the new heater o-ring with clean engine oil.



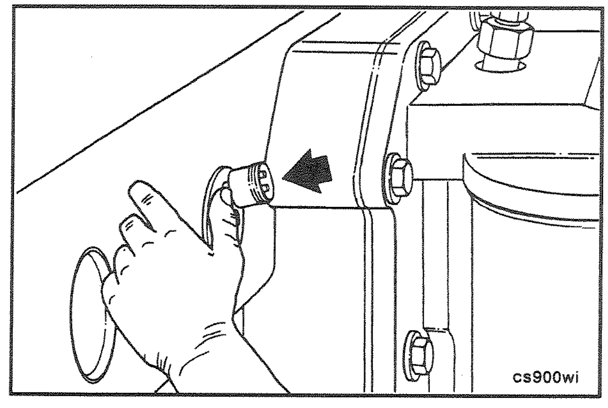
The locking channel (T-Bar) should be threaded out to the end of the bolt. If so equipped, do not remove the retaining wire used to position the channel (T-Bar).

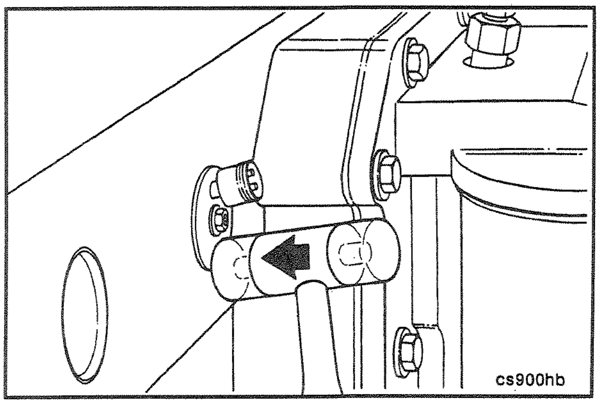


Hook the element and one leg of the channel (T-Bar) into the hole as illustrated.



Hook the other leg of the channel in the hole and push the heater into the hole as far as possible by hand.

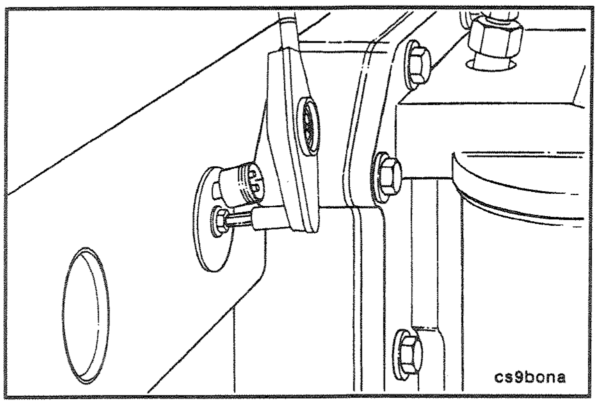




Plastic Hammer

Caution: Do not pull the heater into location with the locking bolt as the channel (T-Bar) can bend or cause the threads to strip.

If necessary, use a plastic hammer to tap the heater in until the shoulder contacts the block.



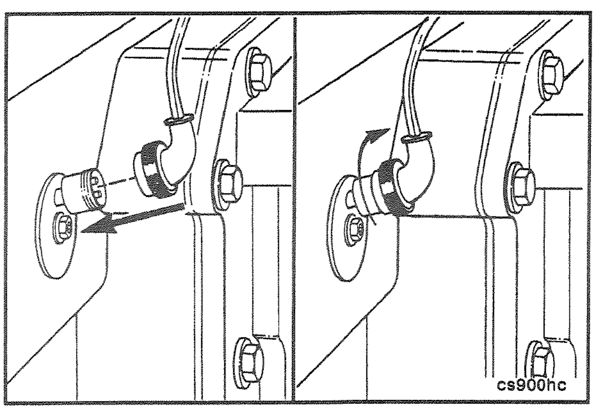
10 mm Socket, Inch lb. Torque Wrench

Tighten the locking bolt to:

Minimum: 1.3 N•m [12 in-lb]

Maximum: 2.8 N•m [25 in-lb]

Do not over-tighten.



Insert the power cord into the socket being careful to align the pins with the sockets of the power cord. Tighten the retaining nut by hand.

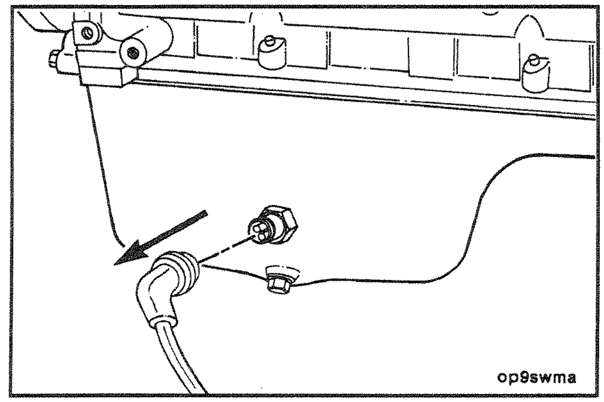
Do not apply power until the cooling system is filled, and run long enough for the thermostats to open and ensure all air has escaped.

Oil Pan Heater Replacement (6-15)

Preparatory Step:

- Drain the engine oil.

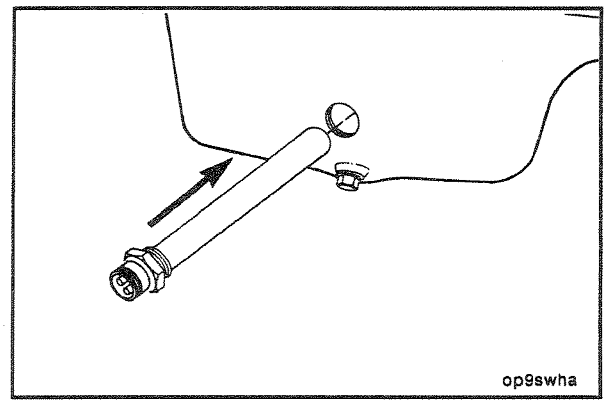
Disconnect the oil heater electrical cord. Remove the heater element.

Ratchet, 1 inch Deep Well Socket, Torque Wrench

Replace the heater element. Refill the engine to the correct oil level.

Torque Value: 120 N•m [88 ft-lb]

NOTES

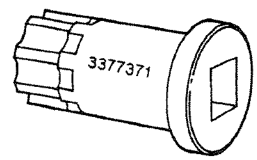
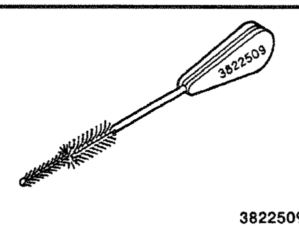
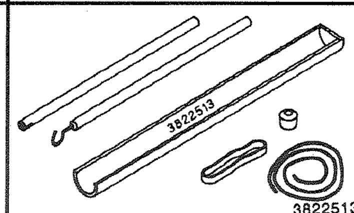
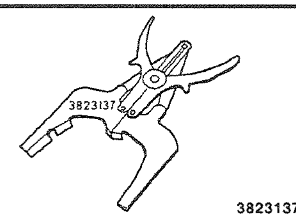
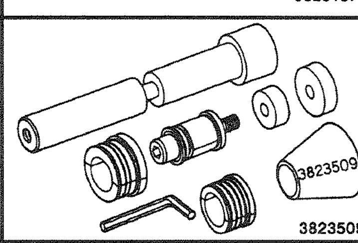
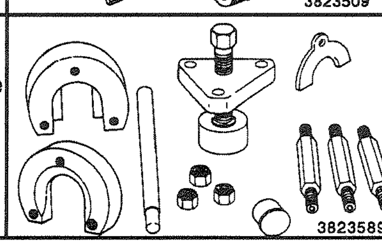
Section 7 - Base Engine Components System

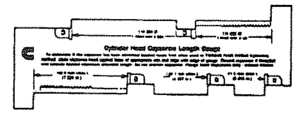
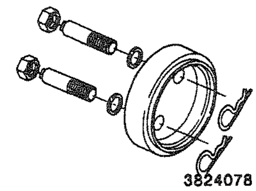
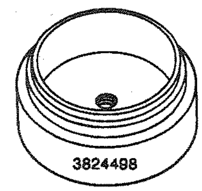
Section Contents

Page

Base Engine Components - Service Tools

The following special tools are recommended to perform procedures in Section 7. 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
3377371	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	
3822509	**Injector Bore Brush** Used to clean carbon from injector bores.	
3822513	**Tappet Removal Tool Kit** Used to remove and install valve tappets.	
3823137	**Piston Ring Expander** Used to install piston rings onto pistons without damaging or distorting the rings.	
3823509	**Camshaft Bushing Tool** Used to remove camshaft bushings.	
3823589	**Camshaft Gear Installation/Removal Tool** Used to install/remove the camshaft gear without removing the camshaft from the engine.	

Tool No.	Tool Description	Tool Illustration
3823921	**Capscrew Length Gauge** Used to measure capscrew free length.	 3823921
3824078	**Wear Sleeve Installation Tool** Used to install the rear crankshaft lubricating oil seal wear sleeve.	 3824078
3824498	**Oil Seal Installation Tool** Used to install the front crankshaft lubricating oil seal in the front cover to a specified depth.	 3824498

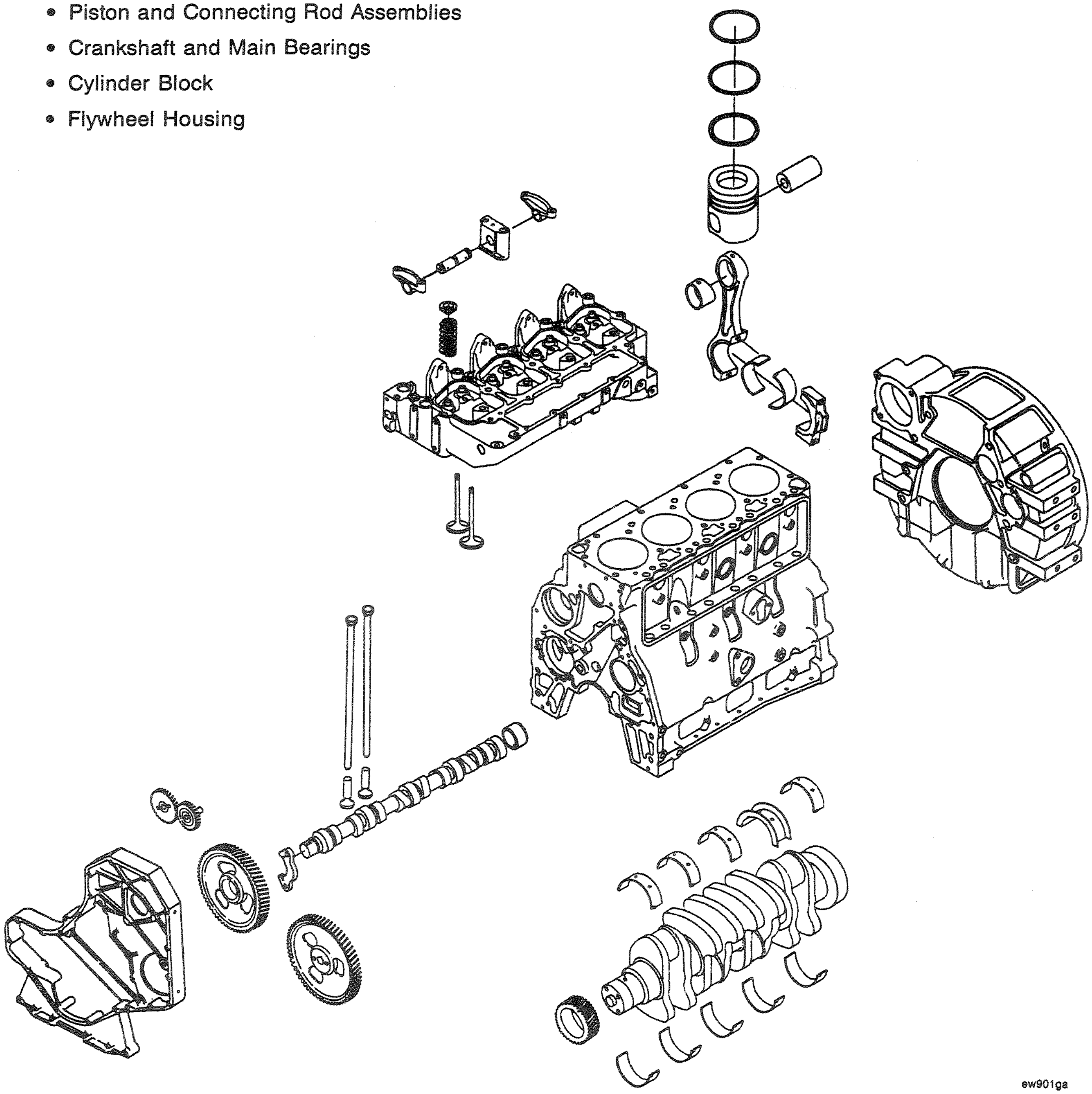
Base Engine Components - General Information

This section of the manual defines the base engine components, describes the operation of those components, provides guidelines for diagnosing malfunctions and gives procedures for component replacement and in-chassis overhaul.

Definition

For the purpose of this manual, Base Engine Components are defined as mechanical functions not included in the other major engine systems. The components include:

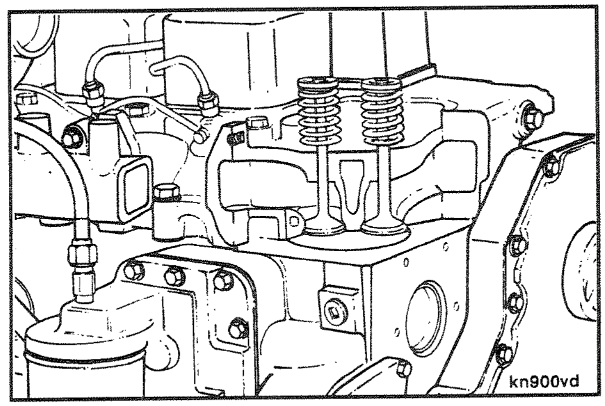
- Cylinder Head and Valve Train
- Front Gear Housing and Gear Train
- Camshaft, Tappets and Push Rods
- Piston and Connecting Rod Assemblies
- Crankshaft and Main Bearings
- Cylinder Block
- Flywheel Housing



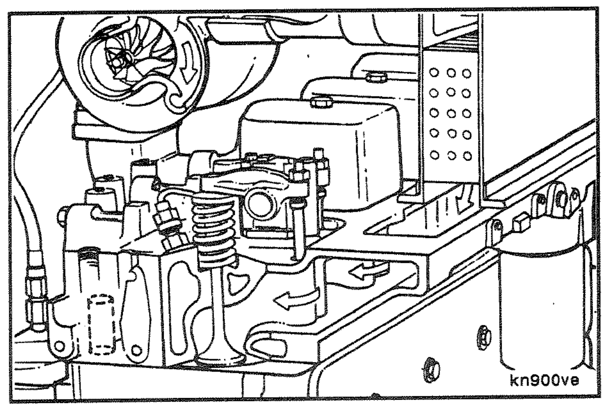
Operation and Description

Cylinder Head and Valve Train

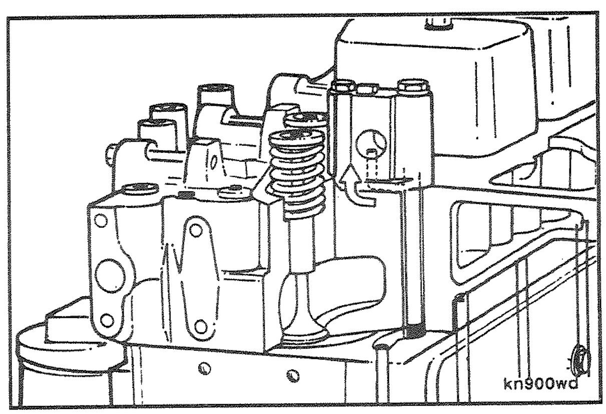
The cylinder head is a one piece, cross flow design with two valves per cylinder. The head has integrally cast valve guides and hardened valve seat surfaces which can be repaired in a machine shop using the appropriate service parts.



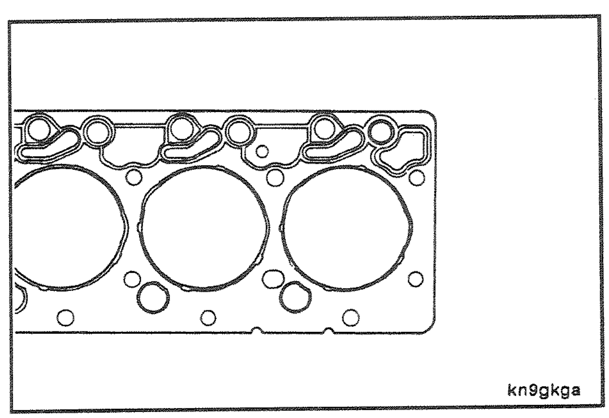
The cylinder head has a cast intake manifold, fuel filter head, thermostat housing and an internal water bypass. The injectors are mounted in the head for direct injection into the cylinders. Fuel filter head is remote for engines with inline fuel injection pump.



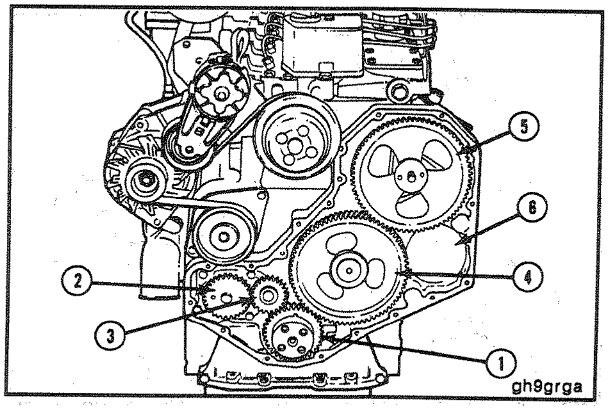
Separate pedestals for each cylinder are used to support and route oil to the rocker levers.



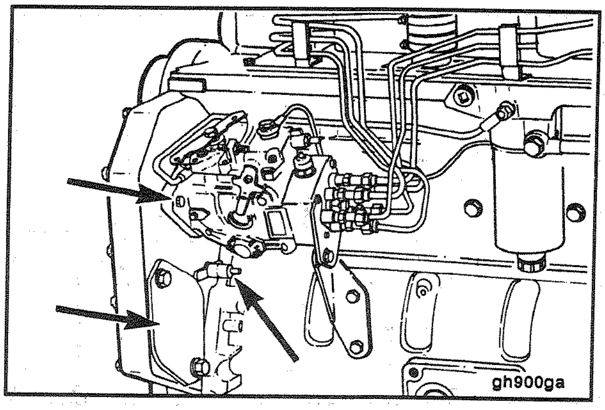
The cylinder head gasket is a laminated design with print-o-seal on both sides around the water holes. An emboss-ment in the gasket seals the cylinder bores. As discussed in the Cooling System, the gasket also provides orifices to control coolant flow.



Front Gear Housing and Gear Train

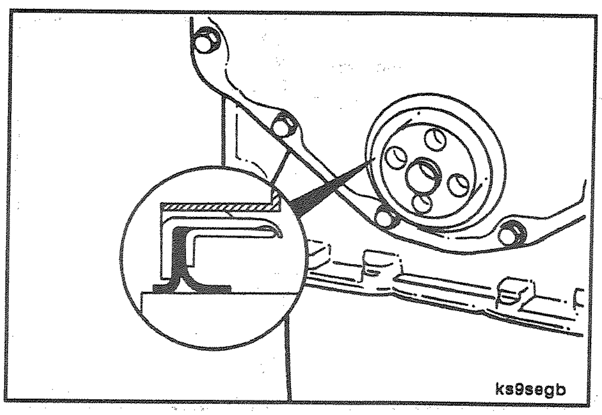


The gear train consists of the crankshaft gear (1), lubricating oil pump gear (2), idler gear (3), the camshaft gear (4), the fuel injection pump gear (5) and the accessory drive gear (6), if used.



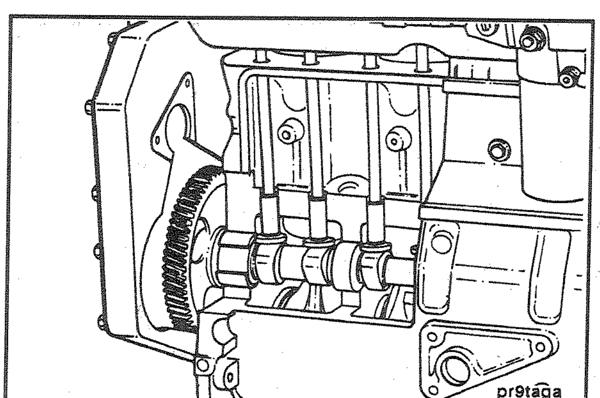
The gear housing provides a support for the fuel injection pump, the timing pin and the accessory drive gear, if used.

Front Crankshaft Seal



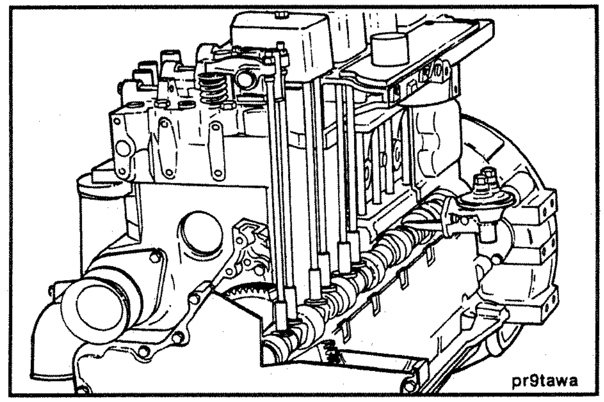
The front crankshaft seal is mounted in the front gear cover. A double lipped Teflon seal is used. The sealing surface on the crankshaft must be clean and free of lubricating oil during assembly.

Camshaft, Tappets and Push Rods

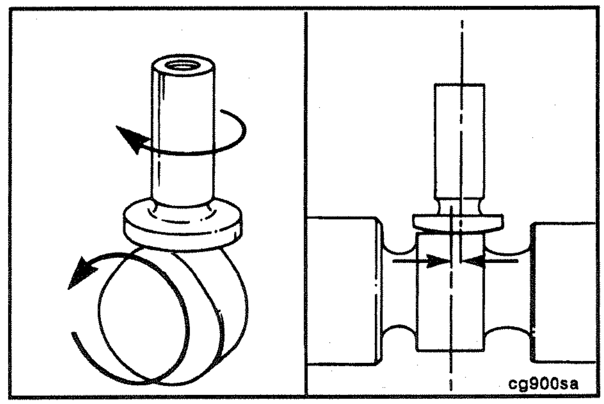


The camshaft is gear driven from the crankshaft. A replaceable bushing is used for the front journal to carry the side loading from the accessory drive. The remainder of the journals operate in cast iron bores in the cylinder block; however, these bores can be repaired in a machine shop by installing service bushings.

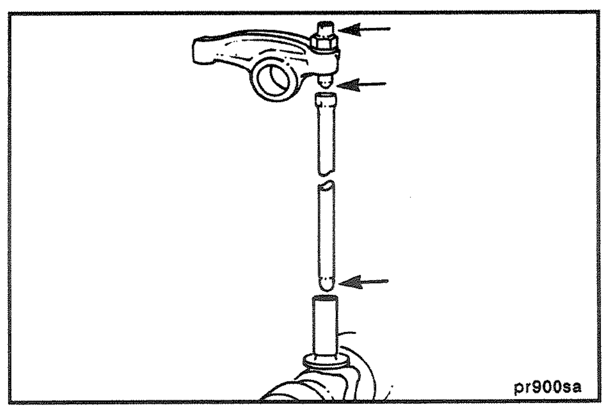
The camshaft has lobes to operate the intake and exhaust valves and a special lobe to drive the fuel transfer pump. The valve lobes contact "mushroom" shaped valve tappets which operate the push rods. The operating arm of the fuel transfer pump rides directly on the special lobe on the camshaft. The profile of the camshaft lobes is the same for all B Series engines except 1994 automotive engines which use a new early intake valve opening intake lobe.



The tappets are mushroom shaped. The convex shape of the surface which contacts the camshaft lobe causes the tappet to rotate as it lifts the push rod.



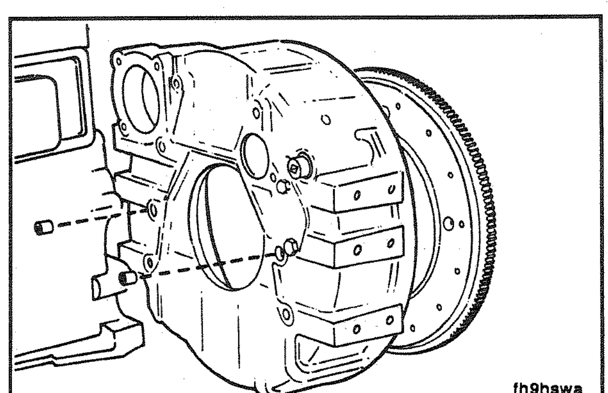
The ball end of the push rod fits into a ball socket in the tappet. The other end of the push rod is fitted with a socket into which the ball end of the rocker lever adjusting screw operates.

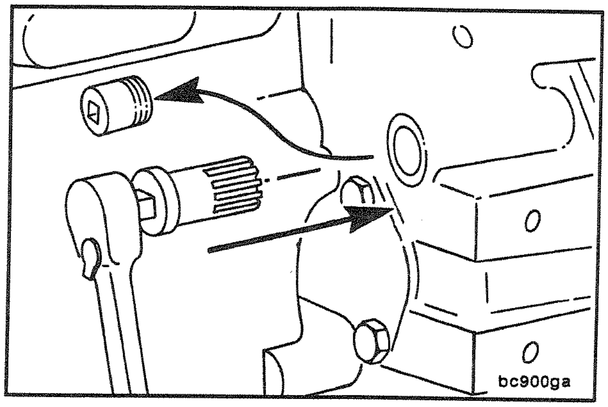


Flywheel Housing and Flywheel

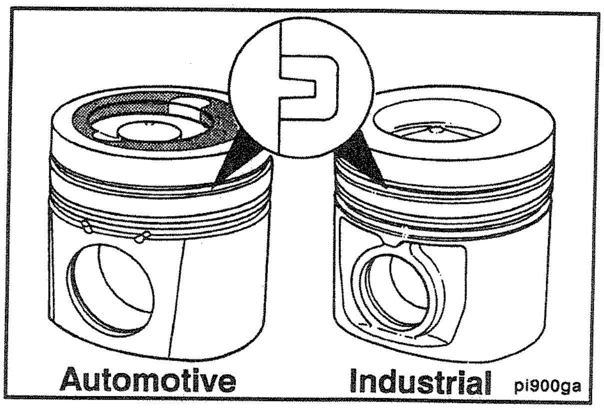
Several optional flywheel housing and flywheels are used depending on the application. Ring dowels are used to locate the housing within 0.20 mm [0.008 in] TIR.

NOTE: Service housings are drilled, Re-dowelling is not required.





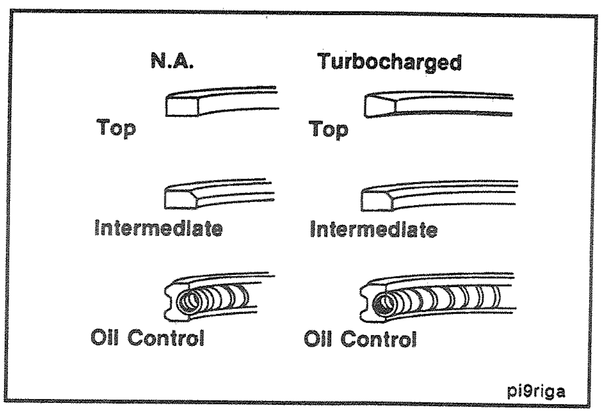
Some flywheel housings are machined for the use of an optional engine barring device.



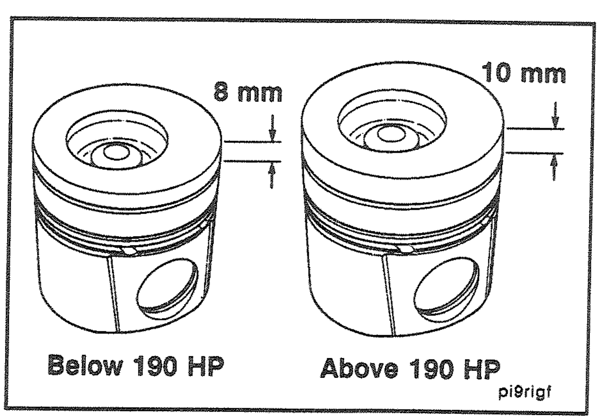
Piston and Connecting Rod Assemblies

Piston features include: high swirl combustion bowl cast aluminum body and 3 ring grooves. The piston for turbocharged, turbocharged/aftercooled engines includes a ni-resist insert with a keystone profile for the top piston ring. Always check the part number to be sure the correct configuration is used during piston replacement.

In addition to the ni-resist insert, automotive turbocharged engines also feature pistons with a hard-anodized combustion surface.

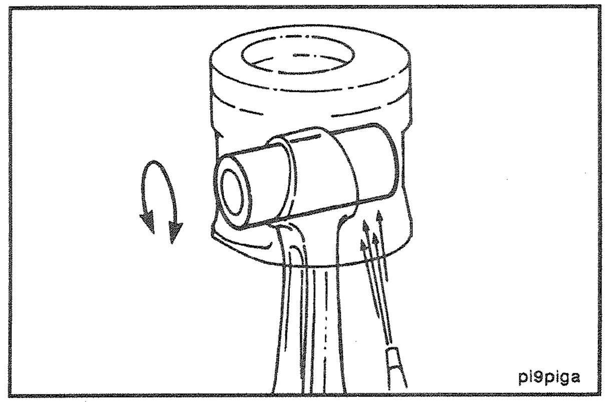


The piston ring sets are also different. While both sets consist of three rings, the top ring of the turbocharged/aftercooled set has a keystone profile which operates in a ni-resist insert cast into the piston. The naturally aspirated top ring is square cut and operates in a groove machined into the aluminum piston.

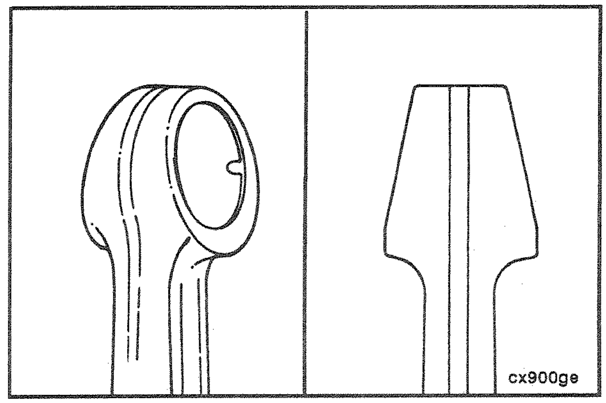


The 1994 automotive pistons utilize different top ring locations. The 160 hp to 175 hp ratings use 8 mm crown to ring land pistons and 190 hp, 210 hp and 230 hp use 10 mm. The 1994 industrial pistons continue with the 14 mm ring position.

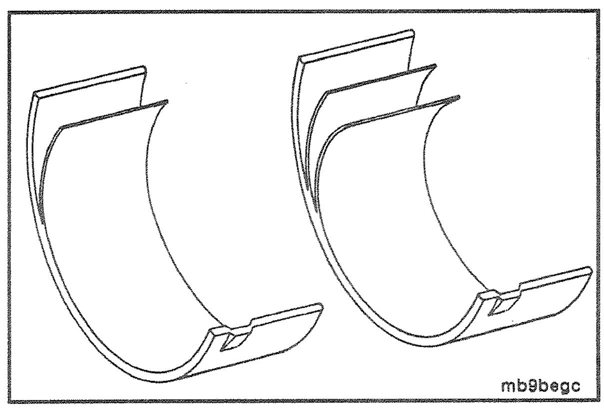
A free floating, hollow piston pin is used to attach the piston to the connecting rod. Lubrication of the pin and journal is accomplished by residual spray from piston cooling.



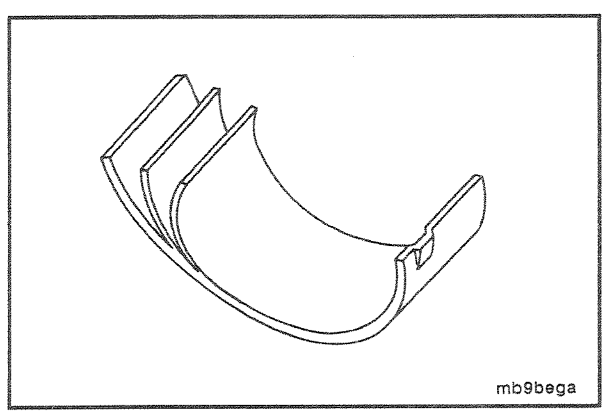
The piston pin end of the connecting rod is angle cut to provide additional bearing surface. The connecting rod end is fitted with a bronze bushing.

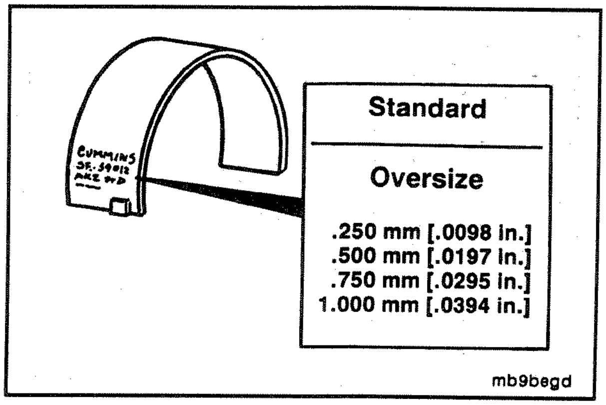


In production, steel backed aluminum connecting rod bearings are used for naturally aspirated engines. Steel backed tri-metal bearings are used in production for the additional loading resulting from turbocharging and aftercooling.

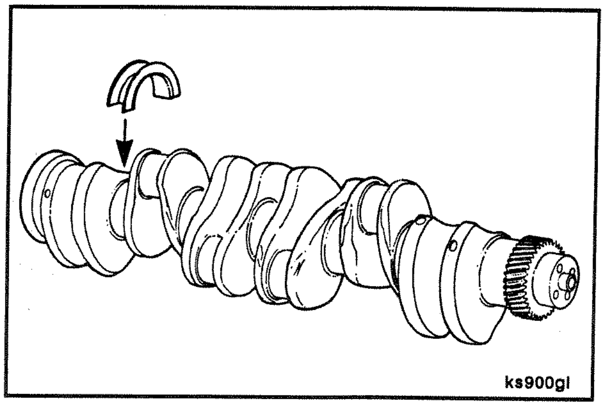


To prevent incorrect use of the two bearings at time of repair, only steel back tri-metal bearings are available for service.



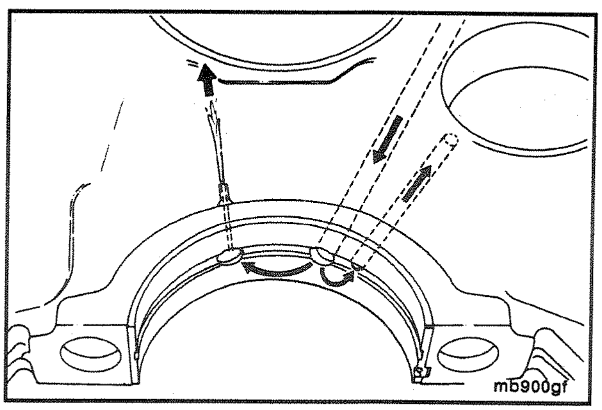


Oversize service connecting rod bearings are available for use with re-ground crankshafts.

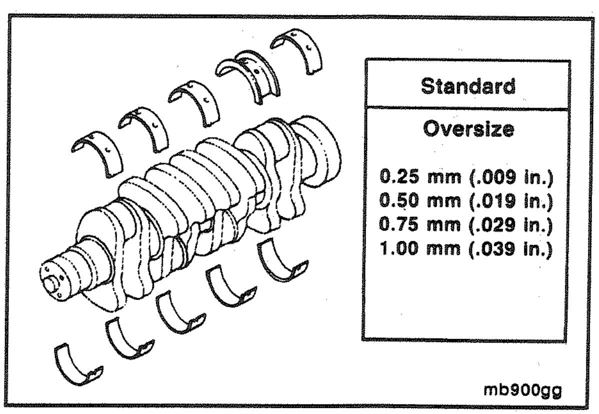


Crankshaft and Main Bearings

The crankshaft is a balanced, forged steel unit. Four cylinder engines have 5 main bearings. Six cylinder engines have 7 main bearings. The lower bearing shells are all the same. All of the upper bearing shells are also the same with the exception of the journal adjacent to the rear one. The next to the last journal is fitted with a flanged upper bearing shell. The flanges control the end thrust of the crankshaft.



The upper bearings have three holes in them. The middle hole receives lubricating oil from the main oil rifle. One of the adjacent holes is aligned with a drilling to the camshaft journal and serves as an orifice for lubrication flow to the journal. The other adjacent hole supplies lubricating oil for piston cooling. The hole does not align perfectly with the cooling nozzle. The hole is off-set to keep it away from the highly loaded bearing area.

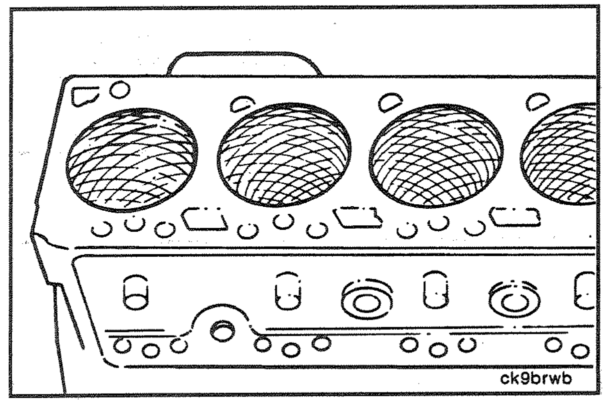


NOTE: Oversize service main bearings are available for re-ground crankshafts.

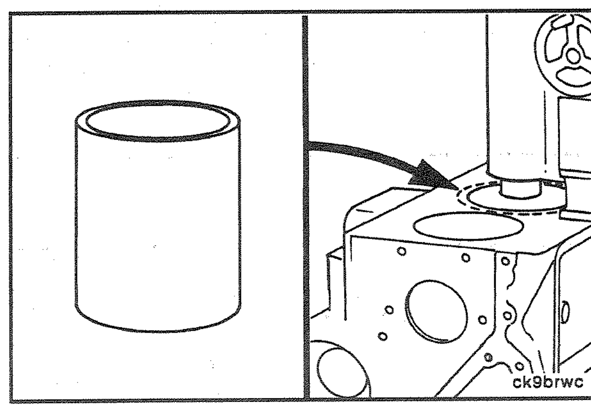
Cylinder Block

We have discussed the cylinder block relative to cooling and lubrication in those respective systems. We have also discussed the interfaces of some of the above power functions with the block. This discussion will cover the remaining interfaces including the cylinder bores.

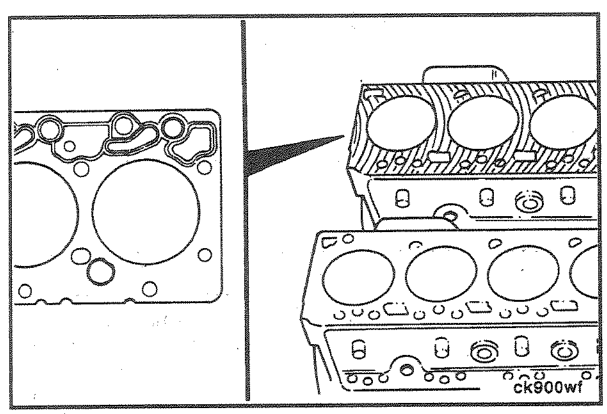
The cylinder bores are machined directly into the cylinder block during production. The size and condition of the cylinder bore is critical to engine performance and life. During repair, be sure to inspect the cylinder bore carefully. It will also be necessary to deglaze the cylinder walls before reassembly. A 30 degree crosshatch pattern is needed to seat the new piston rings.

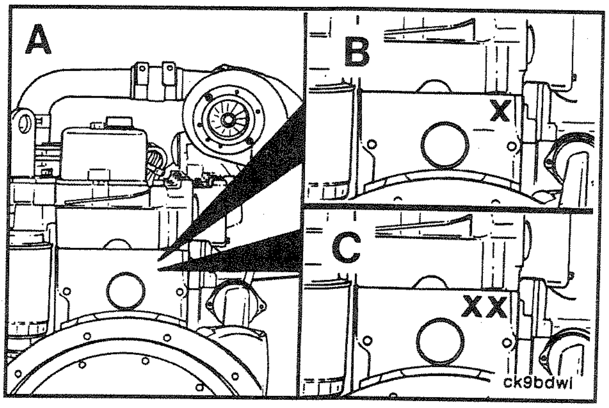


The cylinder bores can be rebored in a machine shop and fitted with an oversize service piston. The cylinder bore may also be bored to accept a service liner and standard pistons. Refer to the B Series Alternative Repair Manual, Bulletin No. 3810234 for rebore procedures.



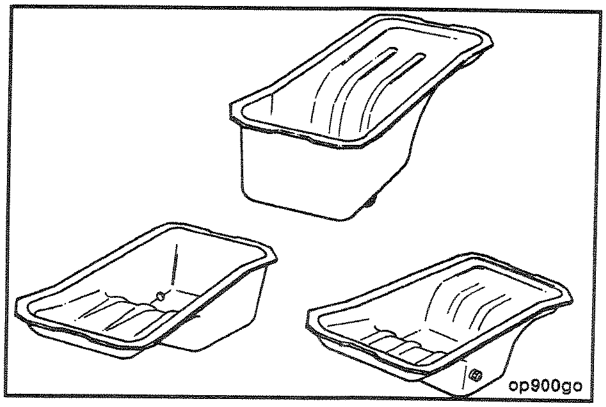
NOTE: The head surface of the block is also critical to sealing the cylinder bores. Inspect the surface carefully during repair before assembly. The cylinder head deck can be resurfaced in a machine shop and a thicker surface cylinder head gasket installed to keep the piston-to-head clearance the same.





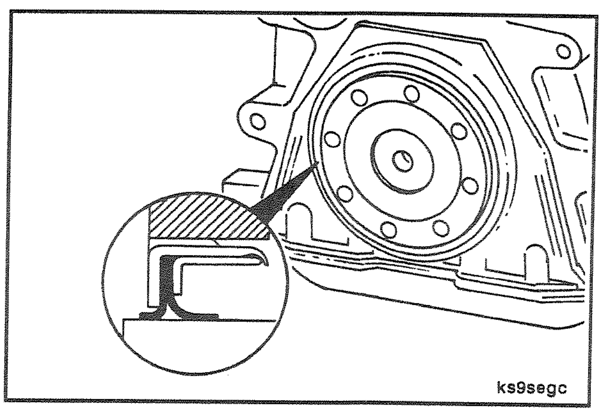
After machining, the cylinder block is identified as follows:

Machining	Mark
A - Standard	None
B - .25 mm (.010 in) machined for first oversized gasket	X
C - .25 mm (.010 in) machined [.50 mm (.020 in.) total] for second oversized gasket	XX



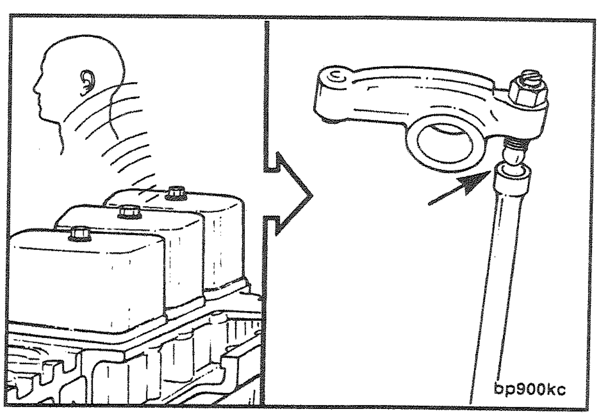
Lubricating Oil Pan

A front sump, rear sump or center sump lubricating oil pan option may be used depending on the application. The mounting of the lubricating oil pick up tube will vary with the lubricating oil pan used.



Rear Crankshaft Seal

The rear crankshaft seal is mounted in a housing that bolts to the rear of the cylinder block. Double lipped Teflon seals are used. The sealing surface on the crankshaft **must be clean and free of lubricating oil** during installation of the seal.

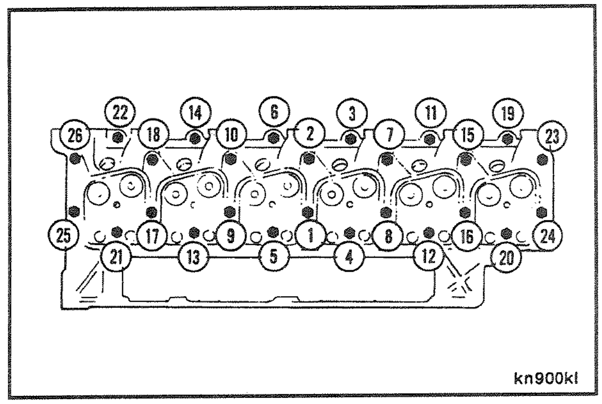


Diagnosing Base Engine Component Malfunctions (7-01)

Valve Train and Head Assembly

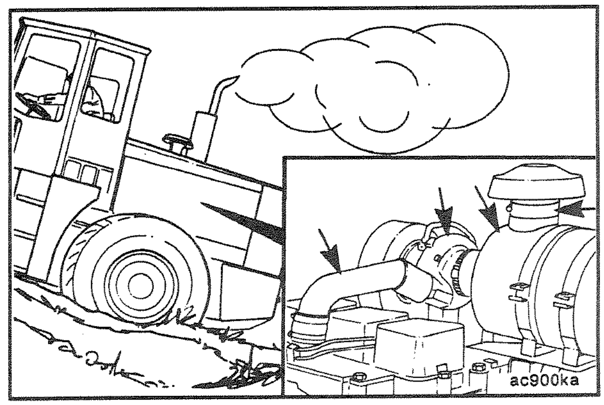
The sound emitted from the overhead can indicate a valve train problem. Loose rocker levers will clatter. A squeaking noise can mean lack of lubrication for adjusting screw and the push rod socket.

Caution: If one of the individual support pedestals is removed during inspection or repair, all head bolts must be retightened according to the head bolt torque sequence. Refer to Procedure (7-07).



Air and Fuel Systems - Check

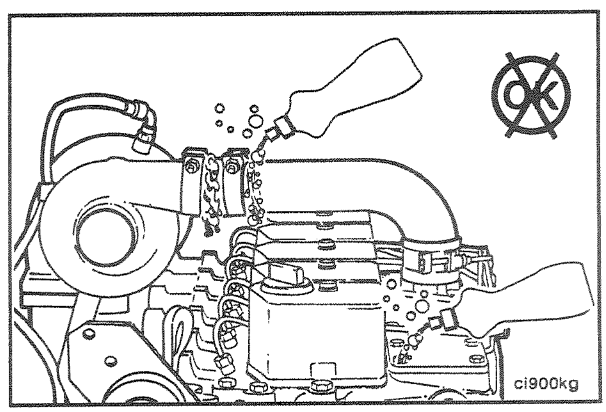
When diagnosing a low power problem, first troubleshoot the air and fuel systems to make sure the engine is receiving adequate intake air and fuel.



Check the intake air system for leaks. Make sure a sealant is used on the through-hole capscrews which secure the manifold cover to the head.

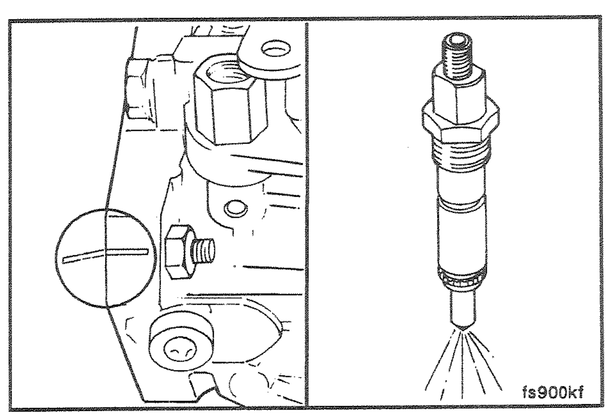
Verify the turbocharger is operating correctly.

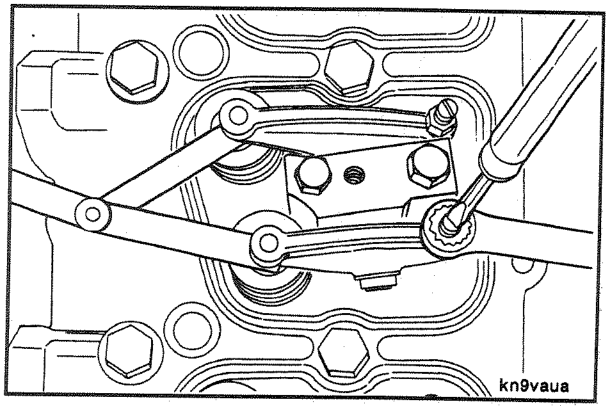
Refer to Section 3 for additional air system checks.



Check the fuel system for correct timing and fuel delivery.

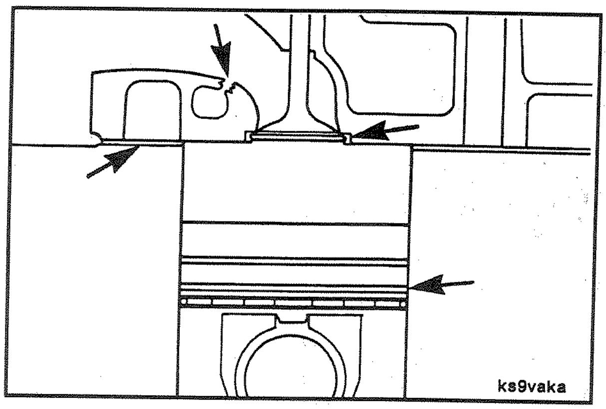
Refer to Section 5 for fuel system malfunction diagnosis.





Valve Adjustment - Check

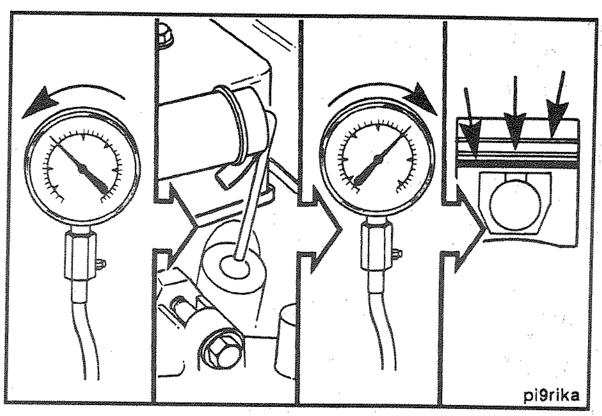
Verify that the valves are adjusted correctly. Refer to Procedure (7-04).



Compression Check

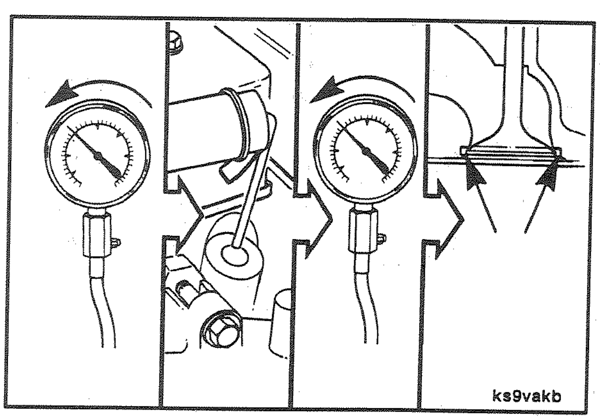
If the air and fuel system are functioning correctly, perform a compression check to determine whether the problem is:

- Piston ring sealing
- Valve sealing
- Cylinder head gasket sealing or a crack in the cylinder head



Piston Ring Sealing

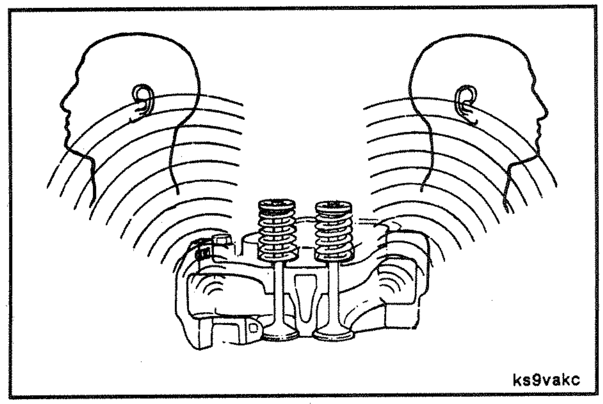
If the compression is low but can be increased significantly by squirting lubricating oil into the cylinder, the cause of low compression is inadequate sealing between the piston rings and the cylinder walls.



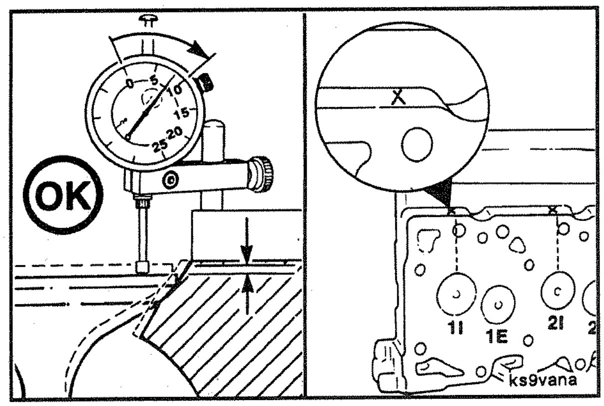
Valve Sealing

If the compression is low on one or more non-adjacent cylinders and the pressure cannot be increased by oiling the rings, poor valve sealing is to be suspected.

Valve leakage is often audible from the intake and/or exhaust manifold.

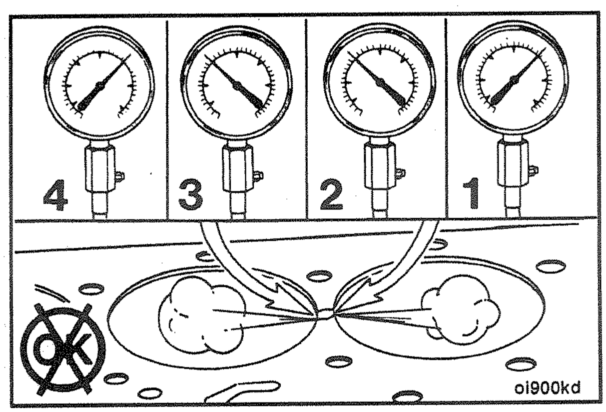


The parent valve seats can be re-ground to a depth of .254 mm [.010 inch]. Re-ground seats are identified with a mark on the cylinder head. Service valve seats must be installed in previously ground valve seats.

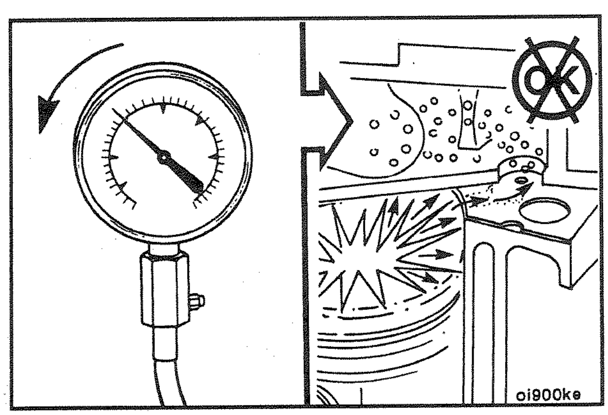


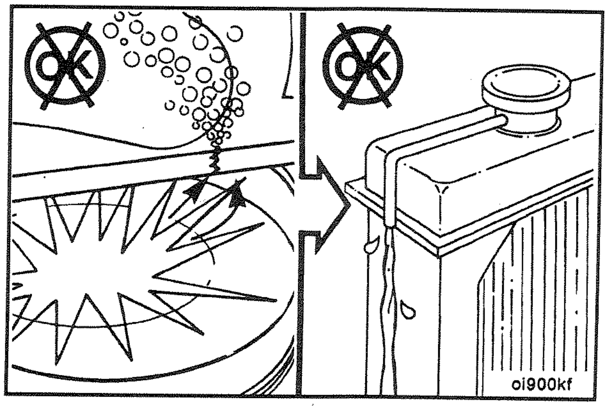
Head Gasket Sealing

If the compression was found low on adjacent cylinders and the pressure cannot be increased by oiling the rings, the head gasket is probably leaking between the cylinders.

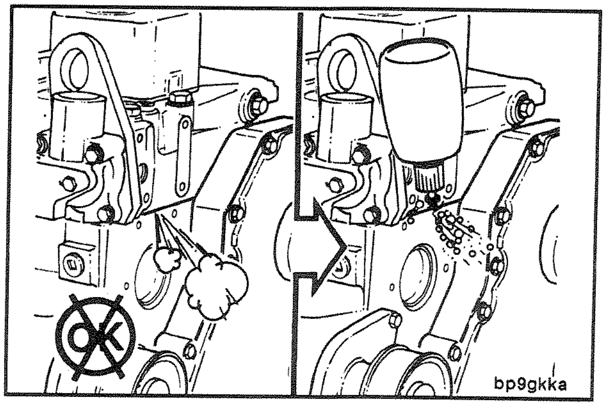


Low compression on a single cylinder can be caused by an external leak or a leak to a coolant passage.

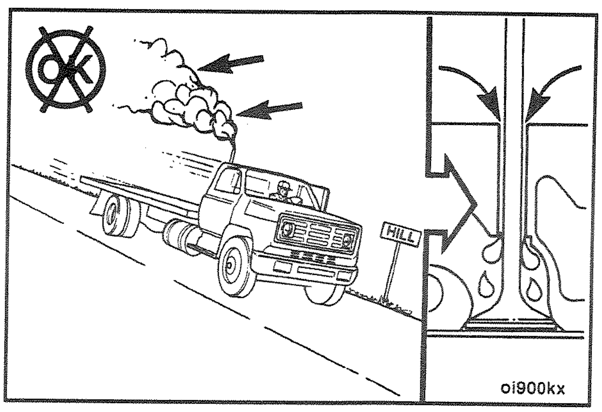




A compression leak to the coolant will normally be detected by loss of coolant as the coolant is blown from the cooling system.

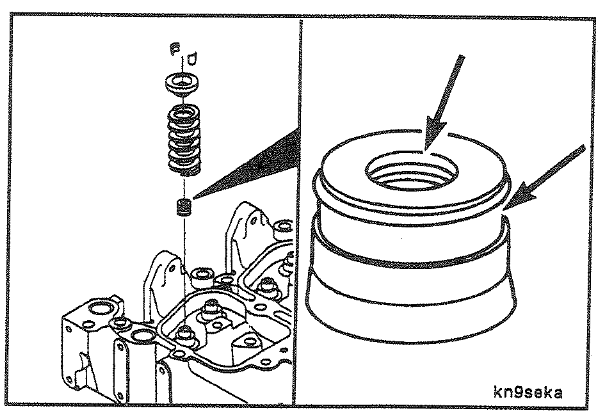


External cylinder head gasket leaks can be detected visually. Liquid soap can be used to locate external leaks.



Valve Seal - Wear

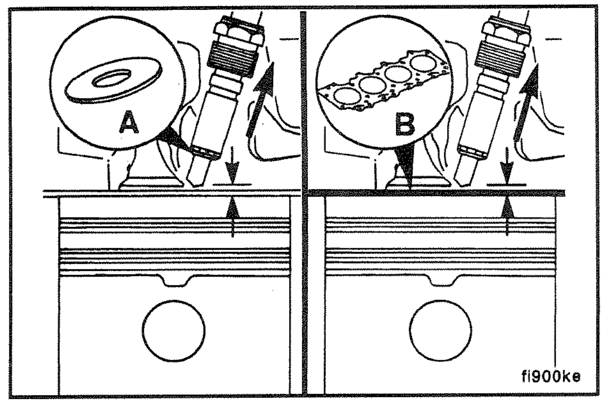
Worn valve seals are typically detected by excessive smoke at idle or when the engine is unloaded when the vehicle is going down hill. Verify the condition by removing the valve spring and inspecting the valve seals.



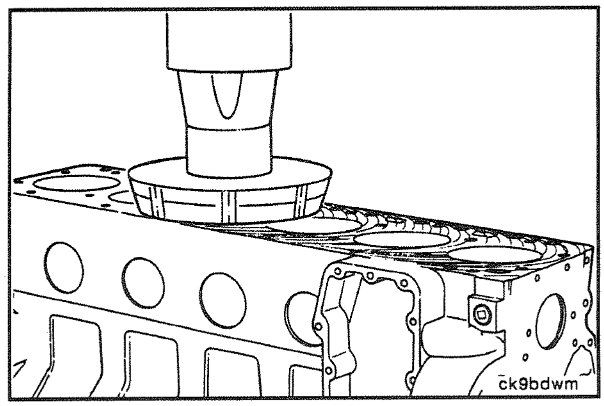
Hardening of the material and wear or damage to the sealing surfaces will cause the valve seal to leak.

Injector Protrusion

Injector protrusion can affect power from the engine. In addition to a single sealing washer (A) on the injector, the thickness (B) of the head gasket controls injector protrusion.

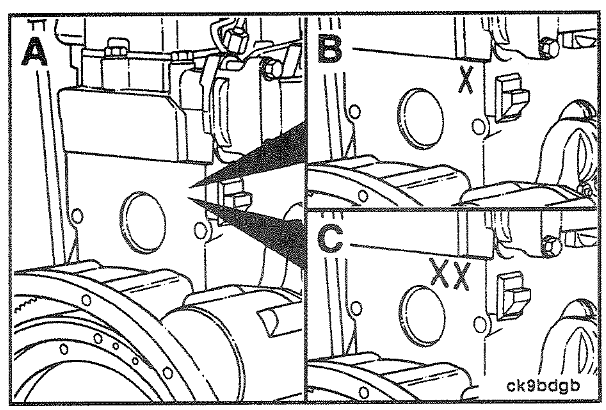


Thicker service head gaskets are used when the head surface on the block has been refaced.

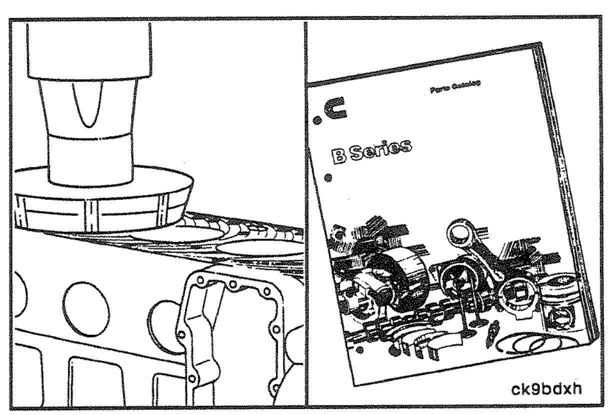


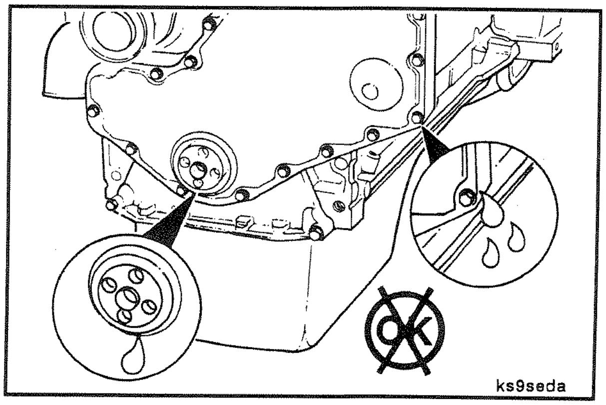
After machining, the block is identified as follows:

Machining	Mark
A - Standard	None
B - .25 mm [.010 in] machined for first oversized gasket	X
C - .25 mm [.010 in] machined (.50 mm [.020 in] total) for second oversized gasket	XX



After determining the amount of machining that has been performed, refer to the parts catalog for the proper oversized head gasket.

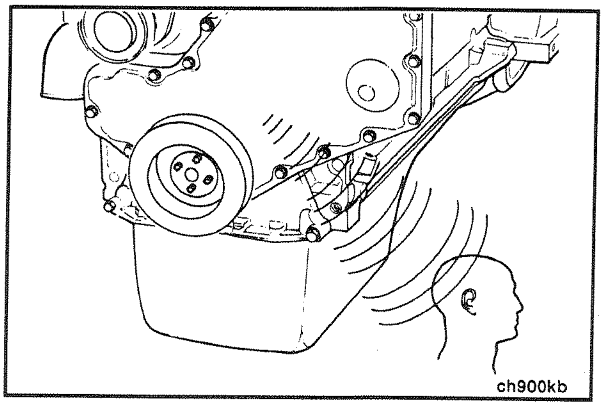




Front Gear Housing and Gear Train

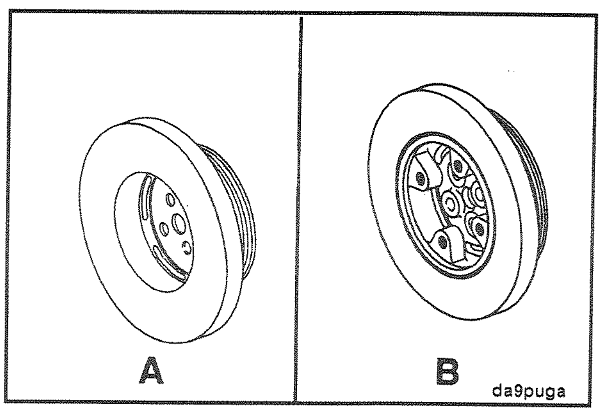
Troubleshooting the front gear housing and gear train consists of checking for leaks at the gaskets (front cover, timing pin assembly and fuel injection pump) and the front crankshaft lubricating oil seal, inspecting the gears and measuring backlash when required.

Refer to Procedure 7-16 to replace the front crankshaft oil seal.



Gear noise emitted from the cover can indicate worn gear teeth.

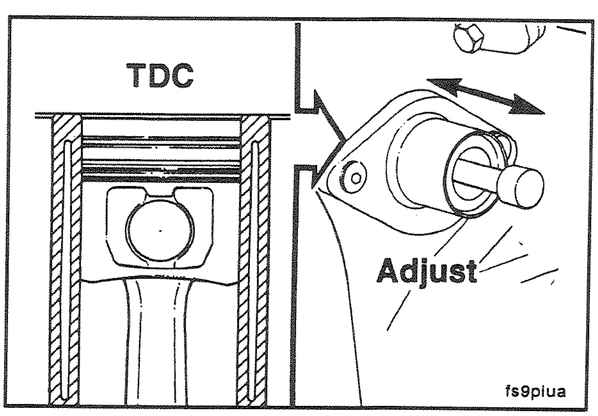
NOTE: Excessive backlash can affect engine timing and engine performance.



Vibration Damper

NOTE: There are two different design vibration dampers used:

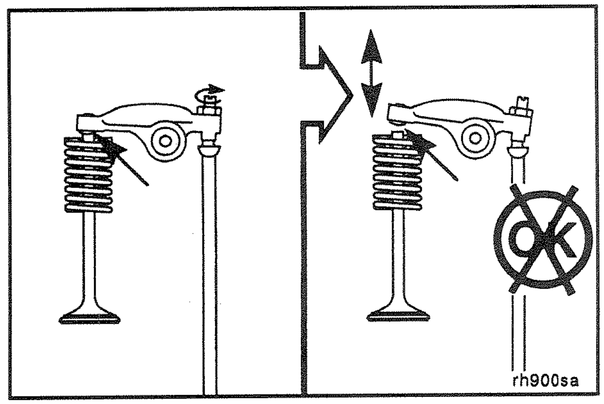
- Viscous damper (A) for certain marine engines and some automotive applications
- Rubber element damper (B) for all other applications



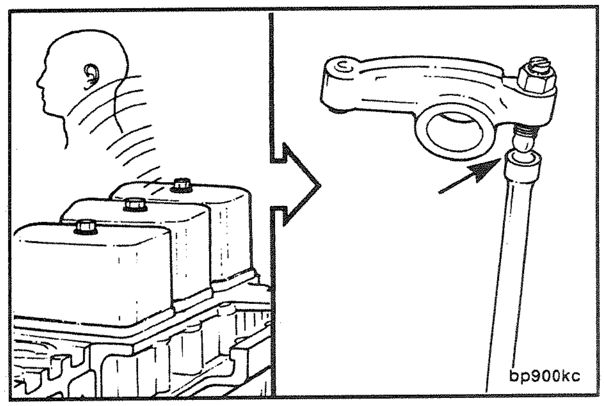
As previously discussed in the fuel system, replacement of the gear housing or the timing pin assembly necessitates a realignment of the pin assembly on the housing to correspond to TDC for Cylinder Number 1. Refer to Procedure 7-20 for replacement instructions.

Rocker Lever, Valve Stem, Push Rod, Tappet, and Camshaft

Excessive valve lash can indicate a worn valve stem or rocker lever.

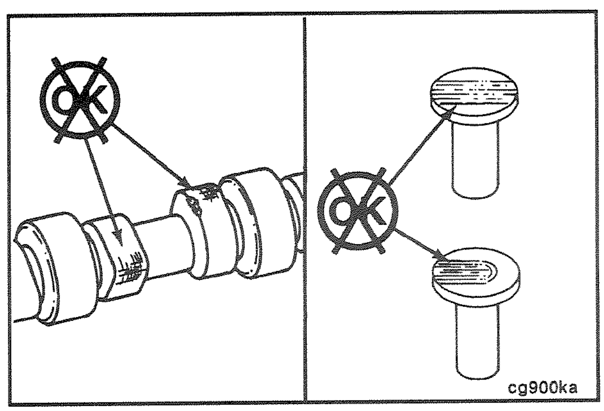

rh900sa

Loose rocker levers and the need to re-set the valve clearance frequently, can also indicate camshaft lobe or tappet wear. If an inspection of the levers, valve stems and push rods does **not** show wear, then tappet and/or camshaft lobe wear can be suspected.

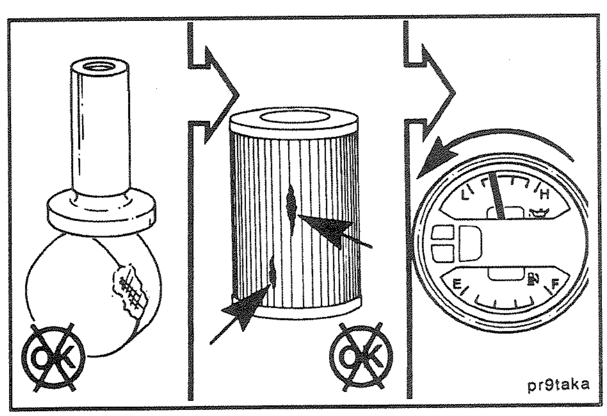

bp900kc

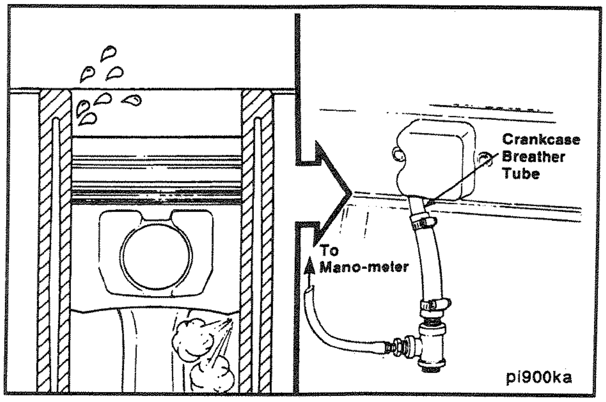
Caution: Anytime a new camshaft is installed, new tappets must also be installed.

The camshaft lobes can be visually inspected after removing the lubricating oil pan. Similarly, the face of the tappet can be inspected after removing the push rods and lifting the tappet.


cg900ka

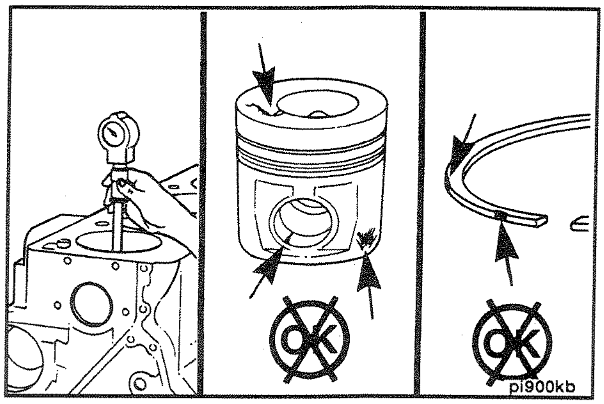
A severely damaged camshaft journal(s) can generate metal chips which will be found in the lubricating oil pan and lubricating oil filter. As the clearance between the bushing(s) and journal(s) increases, a small decrease in lubricating oil pressure may be detected.


pr9taka

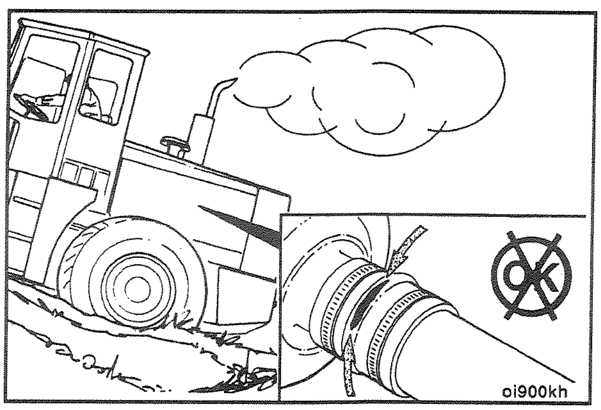


Piston and Connecting Rod Assembly

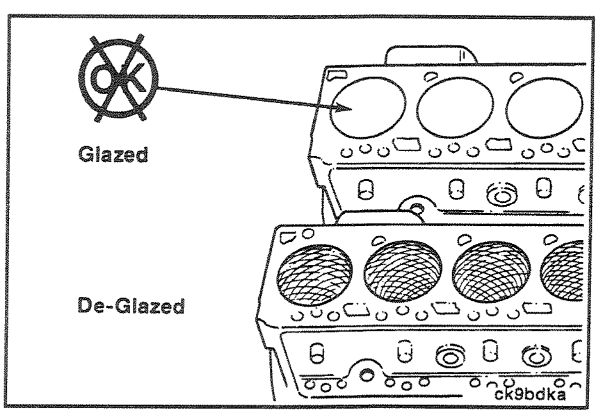
There are a number of power related problems including excessive lubricating oil consumption, smoke, blowby and poor performance that can be caused by inadequate sealing between the piston rings and the cylinder walls. A blowby measurement can help detect the problem.



Verification of the damaged or worn component requires visual/dimensional inspection of rings, pistons and cylinder bore.

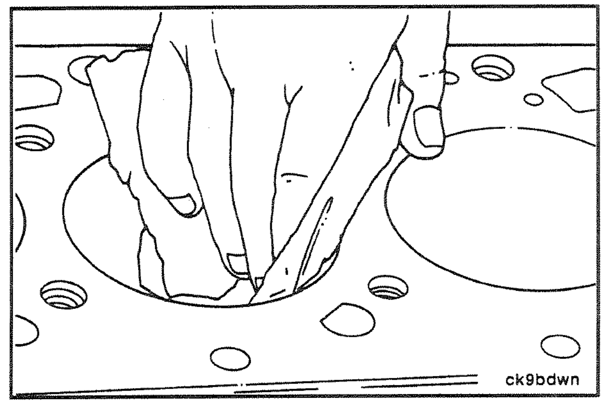


The cause of piston ring wear can range from wear over a long period of service to a dust-out in a short period of time because of poor maintenance of the air intake system. Refer to Section 3 for troubleshooting the Air System.

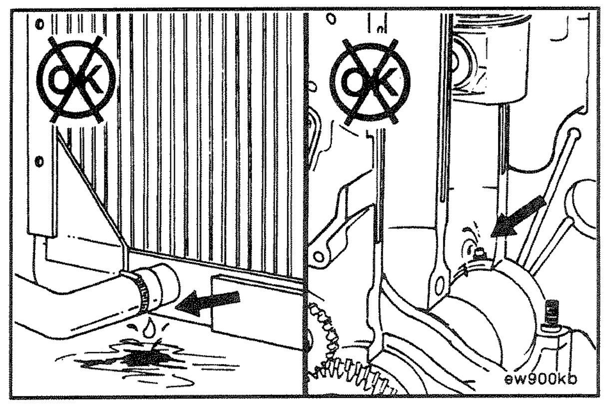


During repair it is essential that the cylinder wall be deglazed so that new rings will seat against the cylinder wall. Failure of the rings to seat can result in high blowby and excessive oil consumption.

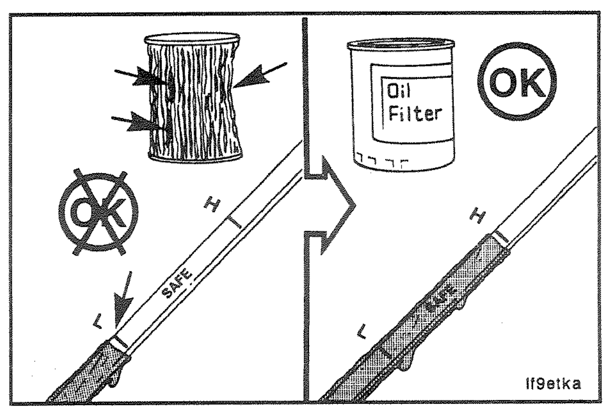
However, it is also critical that the cylinder walls be thoroughly cleaned after the de-glazing. Grit left in the cylinder wall will cause rapid wear out of the new rings leading to the previously discussed power problems.



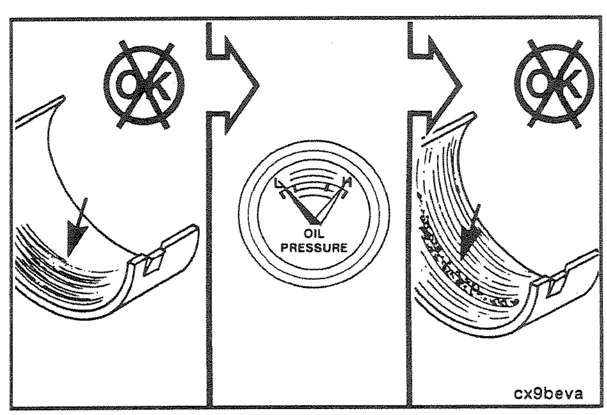
Overheating of the engine from a loss of coolant will cause the cylinder to overheat resulting in seizure of the piston. Loss of piston cooling lubricating oil can also lead to piston seizure.

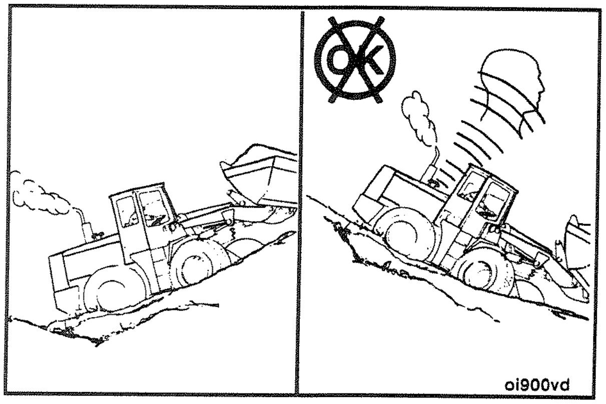


Improper maintenance of the lubrication system is the primary cause of reduced main bearing life.



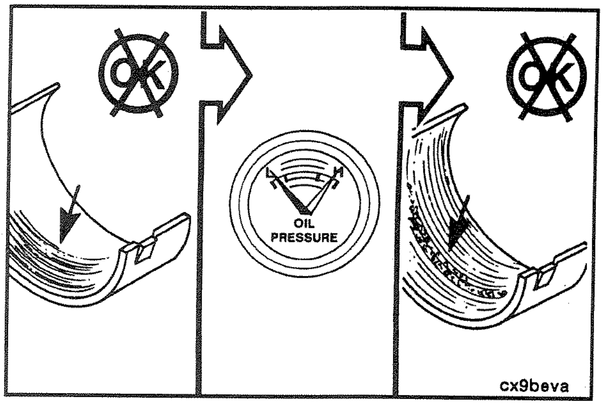
Normally, worn bearings can be detected by reduced oil pressure. But if this wear goes undetected, the excessive clearance will cause the connecting rod to strike the crankshaft causing a distinct knocking sound.





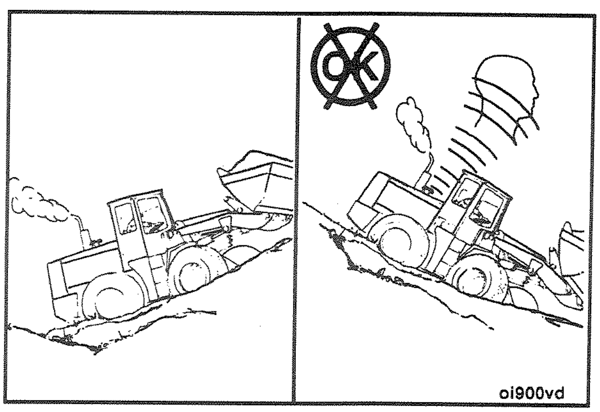
A connecting rod knock occurs when the engine is not loaded. Verify by first applying load and then unloading and listening for the knock.

Crankshaft and Main Bearings

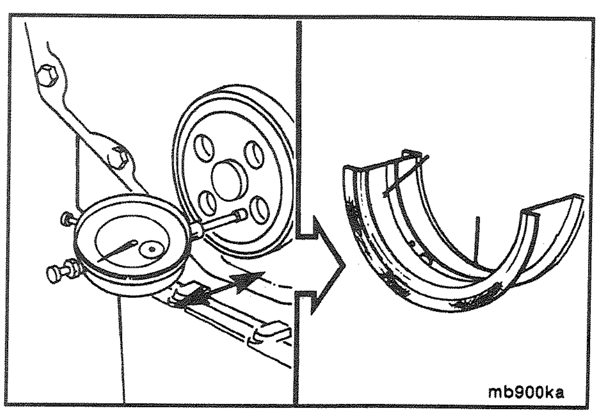


Improper maintenance of the lubrication system is also the primary cause of reduced main bearing life.

A malfunction of the crankshaft/main bearing will usually be detected by reduced lubricating oil pressure. As with rod bearings, continued operation with low lubricating oil pressure will lead to a rapid deterioration of the bearings and eventually will produce a knocking sound.



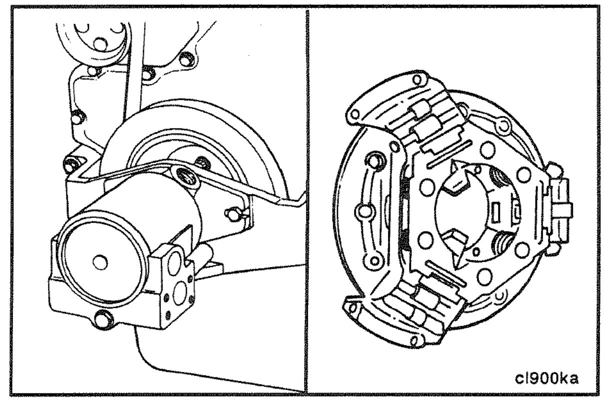
A main bearing will be heard when the engine is loaded.



A damaged, worn or missing thrust bearing flange of the upper main bearing shell can be detected by measuring the end play of the crankshaft.

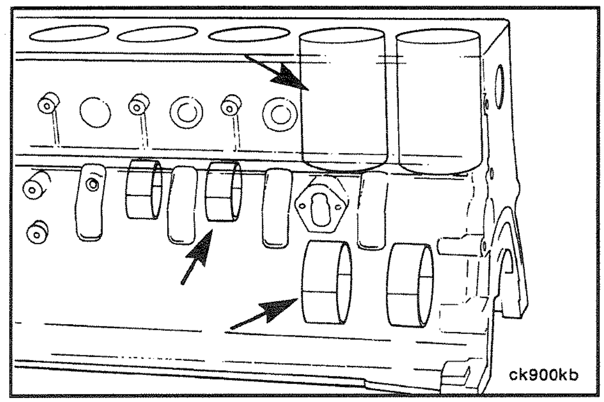
Dimension (A) End Play Limits	
MIN	MAX
0.127 mm [0.005 in]	0.431 mm [0.017 in]

Failures of driven units at the front or rear of the engine which increase the end loading can damage the thrust bearing.

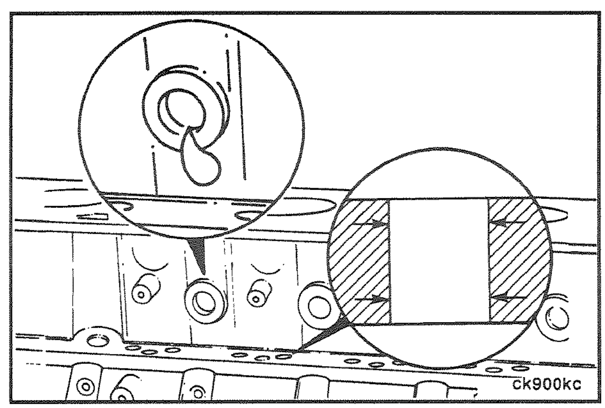


Cylinder Block

Diagnosis of cylinder block malfunctions relative to cooling and lubrication have been discussed in those respective systems. The potential problems with cylinder, the camshaft bore and the crankshaft main journals has also been discussed in this section.

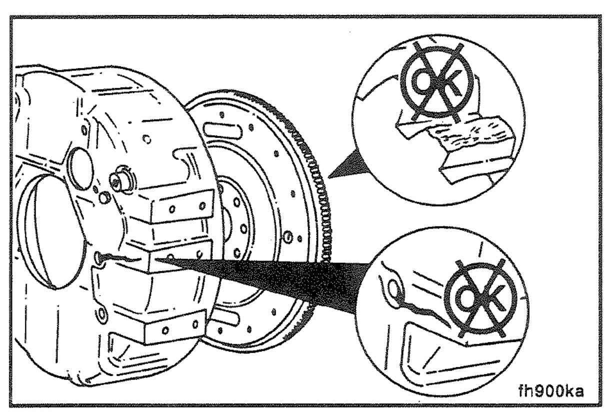


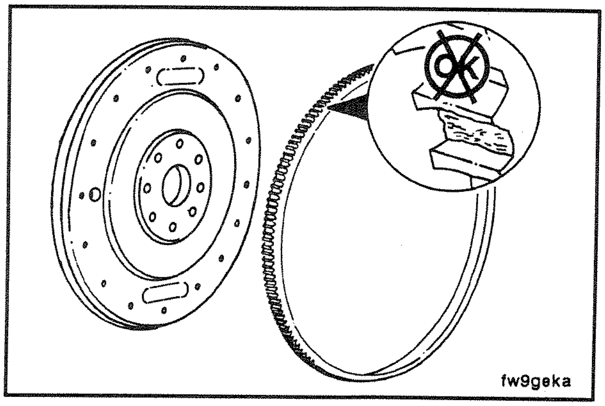
Malfunctions of the cylinder block such as leaks, tappet bore wear, etc. require a visual or dimensional inspection to isolate the problem.



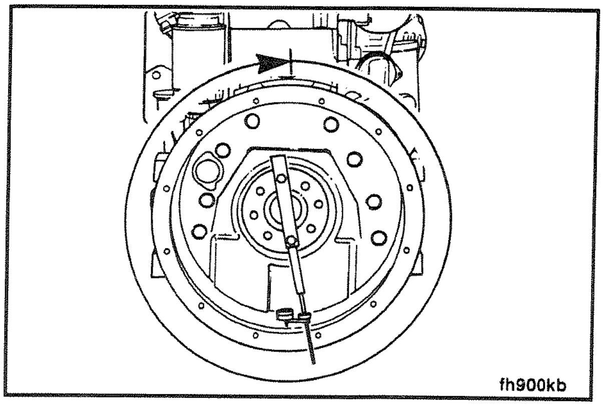
Flywheel Housing and Flywheel

Diagnostics of the flywheel housing and flywheel is normally limited to a visual inspection of the parts for damage or wear.



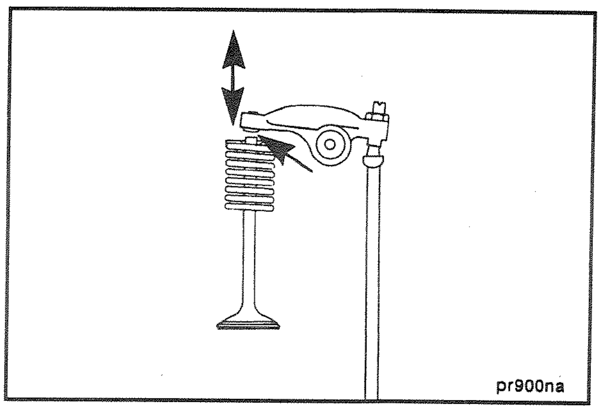


Occasional failure of a starting motor to engage can be caused by damaged teeth on the ring gear. Service ring gears are available for repairing flywheels (refer to procedure 7-23).



When troubleshooting a transmission vibration problem, it may be necessary to measure the concentricity of flywheel housing-to-crankshaft and flywheel housing face alignment

Refer to Procedures 7-24.

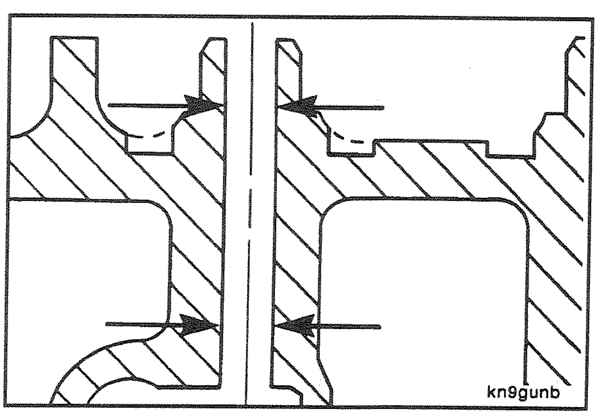


Base Engine Components Specifications (7-02)

Valve Train

Valve Clearance

- Intake 0.25 mm [0.010 in]
- Exhaust 0.51 mm [0.020 in]

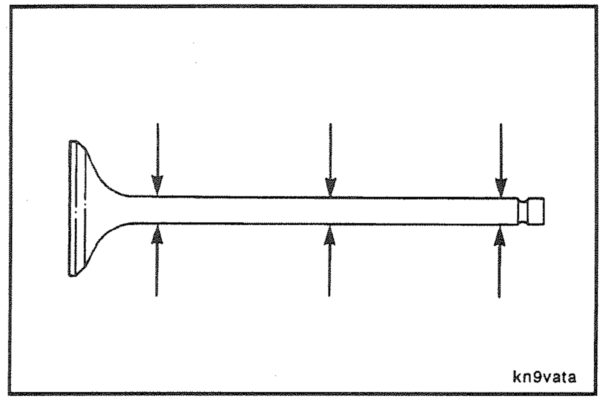


- Valve Guide Diameter (Maximum)

  8.090 mm [0.3185 in] Max
  8.019 mm [0.3157 in] Min

* Valve Stem Diameter (Minimum)

  7.94 mm [0.3126 in] Min
  7.98 mm [0.3142 in] Max

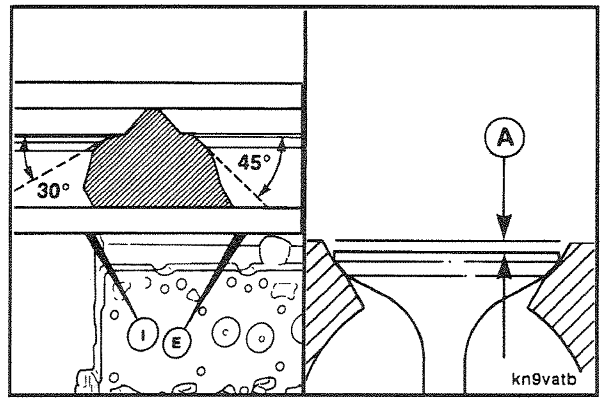


* Valve Seat Angle

Intake	30 degrees
Exhaust	45 degrees

* Valve Depth (Installed)

  0.99 to 1.52 mm [0.039 to 0.060 in]



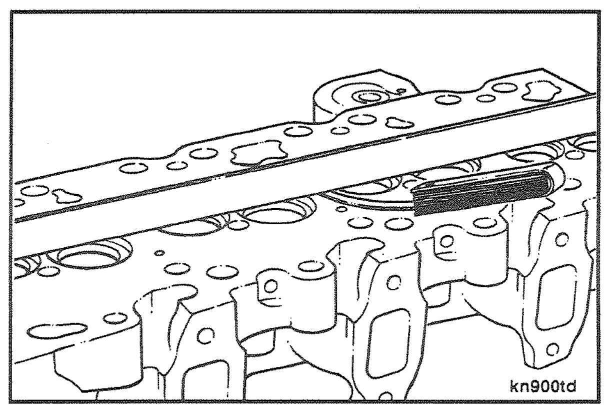
* Cylinder Head Flatness

Use a straight edge and feeler gauge to measure the overall flatness of the cylinder head deck.

The overall flatness must not exceed:
Side to Side ---------------------------------- .076 mm [.003 in]
End to End - 4B ---------------------------- .203 mm [.008 in]
6B ---------------------------- .305 mm [.012 in]

Visually inspect for any localized dips or imperfections. If present, the cylinder head deck must be ground.

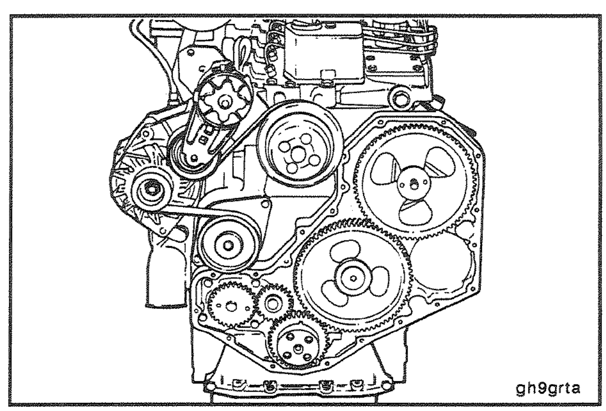
Refer to the Alternative Repair Manual, Bulletin No. 3810234, for regrind/milling procedures and limits.

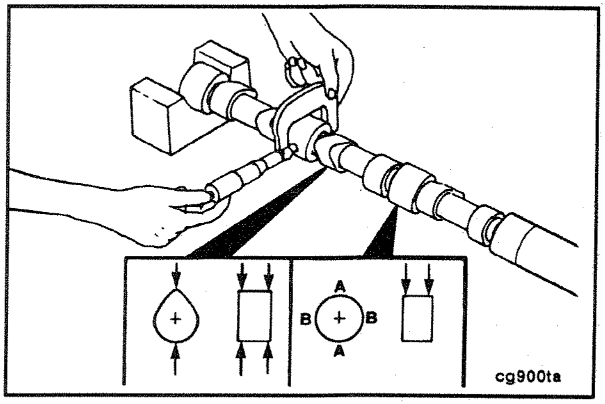


Gear Train

* Gear Backlash (all gears)

  0.08 to 0.33 mm [0.003 to 0.013 in]





Camshaft

- Journal Diameter (Minimum)

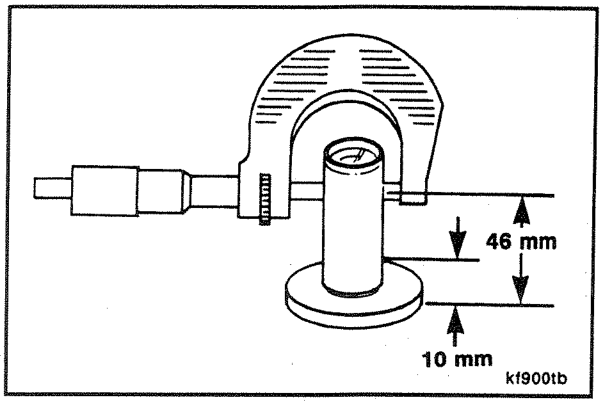
  53.962 mm [2.1245 in]

- Valve Lobes (Min. Dia. at Peak of Lobe)

Intake	47.040 mm [1.852 in]
Exhaust	46.770 mm [1.841 in]

- Lift Pump Lobe (Min. Dia. at Peak of Lobe)

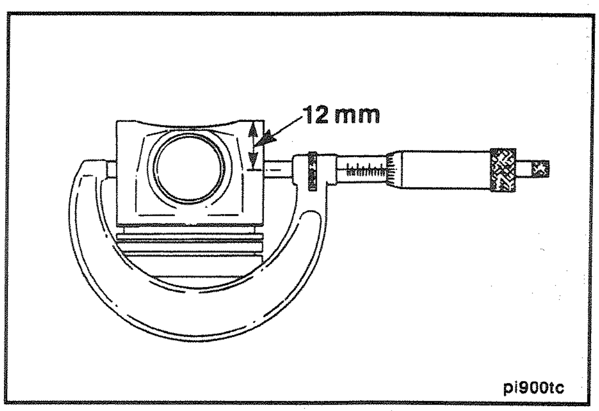
  35.5 mm [1.398 in]



Tappets

- Stem Diameter (Minimum at 28 mm height)

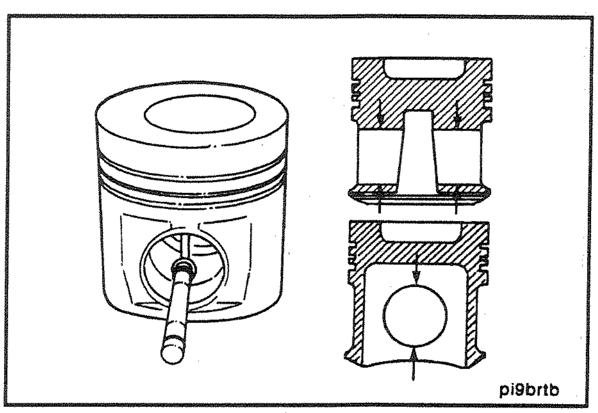
  15.925 mm [0.627 in]



Pistons

- Skirt Diameter

  101.823 mm MIN [4.0088 in]
  101.887 mm MAX [4.0107 in]



- Pin Bore Diameter

  40.006 mm MIN [1.5750 in]
  40.025 mm MAX [1.5758 in]

NOTE: Measure the diameter on a vertical axis only.

- Ring Groove (Maximum)

  Top Groove

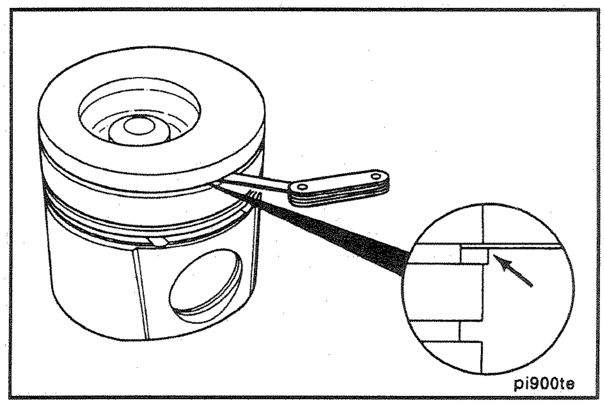
  Use Keystone Gauge

  Intermediate Groove (Ring Side Clearance)

  0.150 mm [0.006 in]

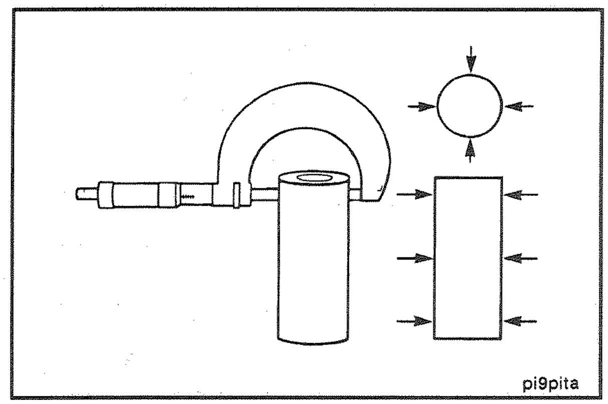
  Oil Control Groove (Ring Side Clearance)

  0.130 mm [0.005 in]



- Piston Pin Diameter (Minimum)

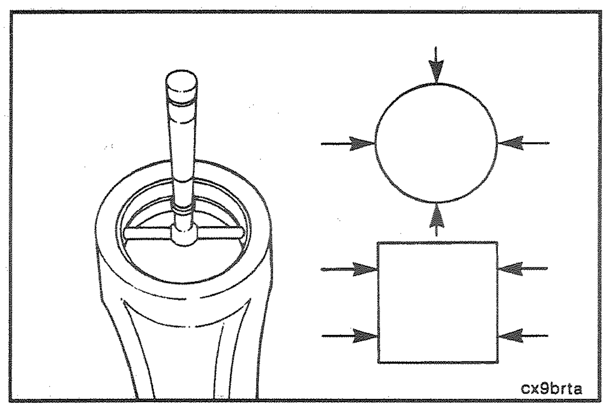
  39.990 mm [1.5744 in]



Connecting Rod

- Pin Bore Diameter (Maximum) - Bushing Installed

  40.019 MIN 1.5755
  40.042 MAX 1.5765



Crankshaft

- Connecting Rod Journal

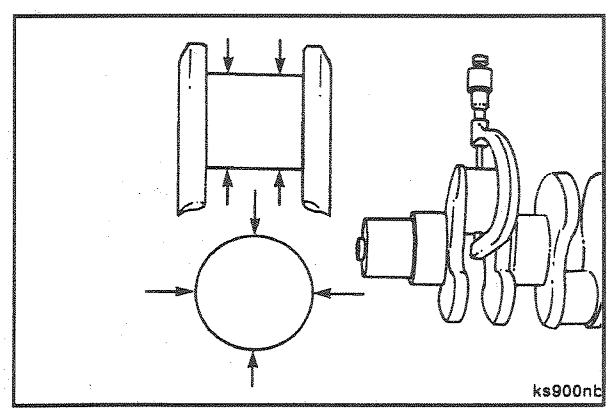
	Minimum
Standard	68.962 mm [2.7150 in]
Machined 0.25 mm	68.712 mm [2.7052 in]
Machined 0.50 mm	68.462 mm [2.6954 in]
Machined 0.75 mm	68.212 mm [2.6855 in]
Machined 1.00 mm	67.962 mm [2.6757 in]

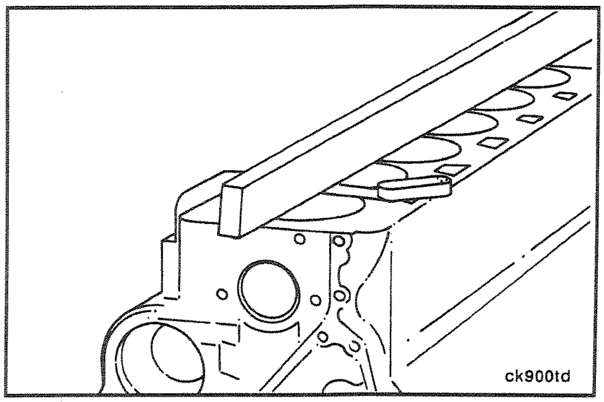
- Journal Out of Round (Maximum)

  0.050 mm [0.002 in]

- Journal Taper (Maximum)

  0.013 mm [0.005 in]



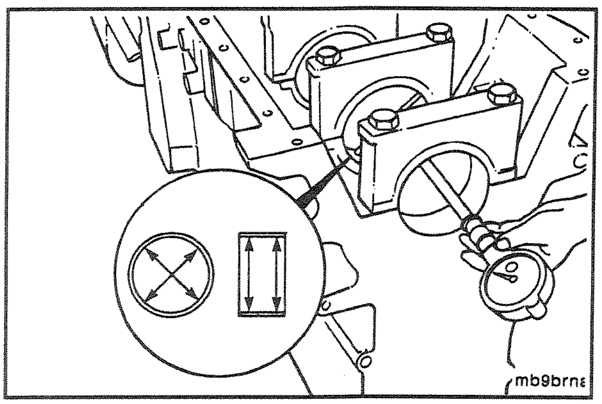


Cylinder Block

Use a straight edge and feeler gauge to measure the overall flatness of the cylinder block. The overall flatness, must not exceed .076 mm [0.003 in] end-to-end, and .051 mm [.002 in] side-to-side.

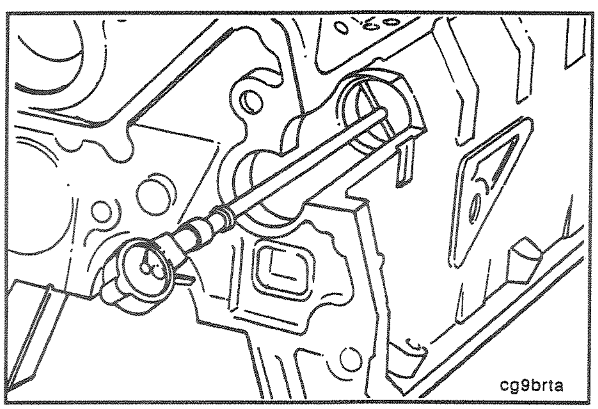
Visually inspect for any localized dips or imperfections. If present, the cylinder block head deck must be reground.

Refer to the Alternative Repair Manual, Bulletin No. 3810234, for regrind/milling procedures and limits.



Main Bearing Bore Diameter (Maximum)

83.106 mm [3.272 in] (with bearing installed)

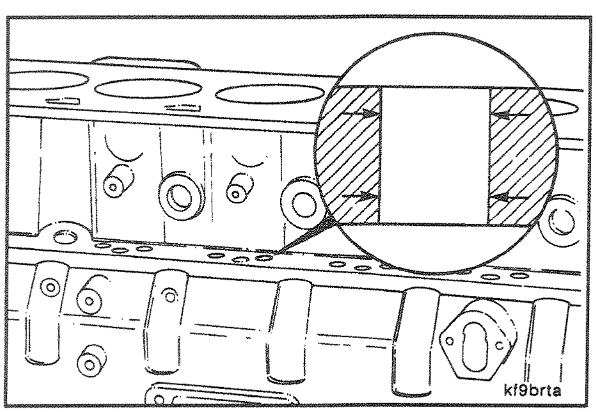


Camshaft Bore Diameter (Maximum)

57.258 mm [2.2543 in] (without bushing) No. 1 only

54.146 mm [2.1317 in] No. 1 with bushing

54.164 mm [2.1324 in] No. 2 through No. 7



Tappet Bore Diameter (Maximum)

16.055 mm [0.632 in]

Cylinder Bore

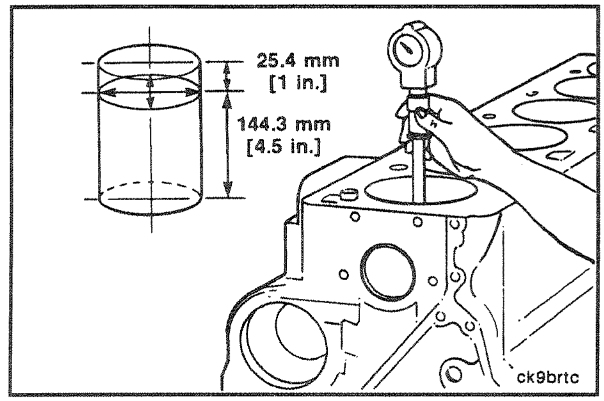
- Cylinder Bore Diameter

  Maximum

  102.116 mm [4.0203 in]
- Out of Round (Maximum)

  .035 mm [0.0014 in]
- Taper (Maximum)

  0.076 mm [0.003 in]

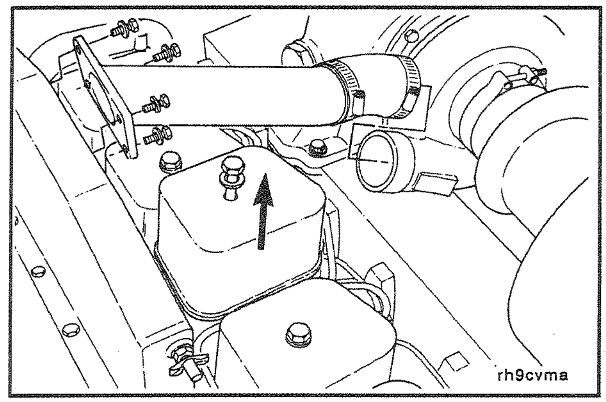


Rocker Levers and Push Rods - Replacement (7-03)

Removal

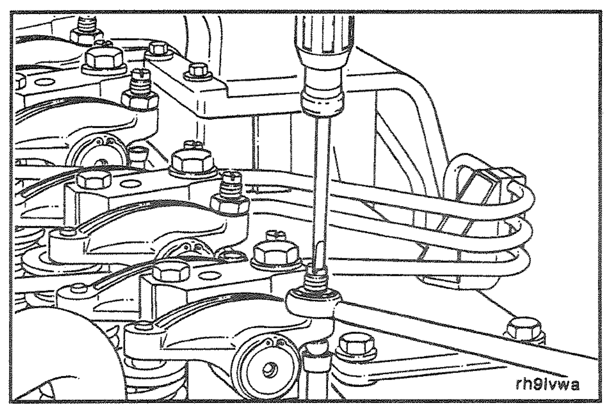
15 mm

Remove the valve covers.



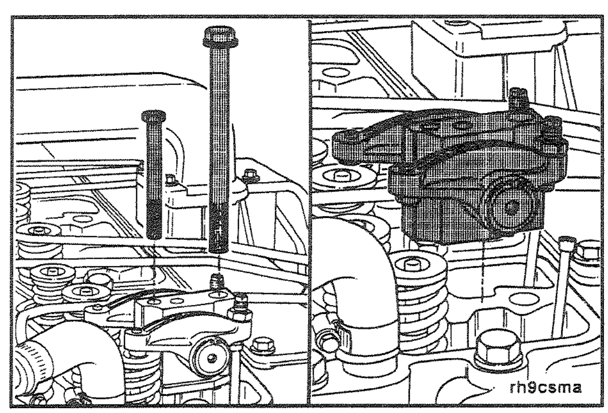
14 mm

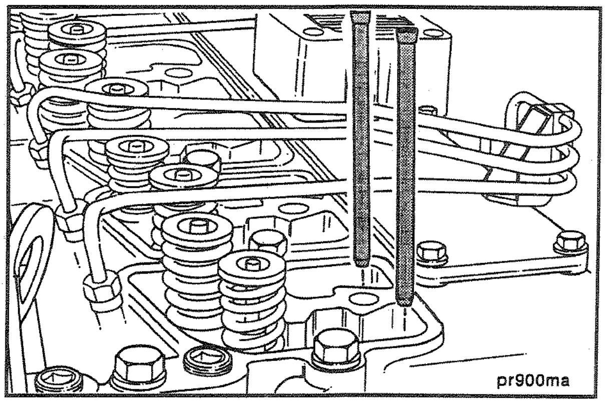
Loosen the adjusting screw locknuts. Loosen the adjusting screws until they stop.



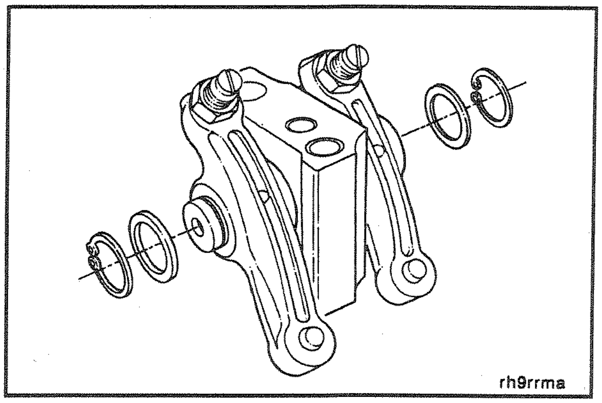
13 mm, 18 mm

Remove the capscrews from the rocker lever pedestals. Remove the pedestals and rocker lever assemblies.





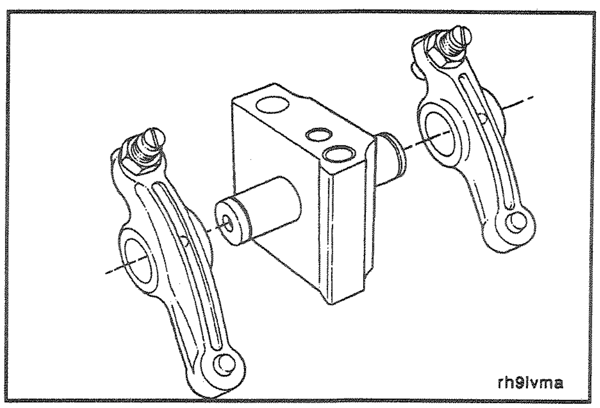
Remove the push rods.



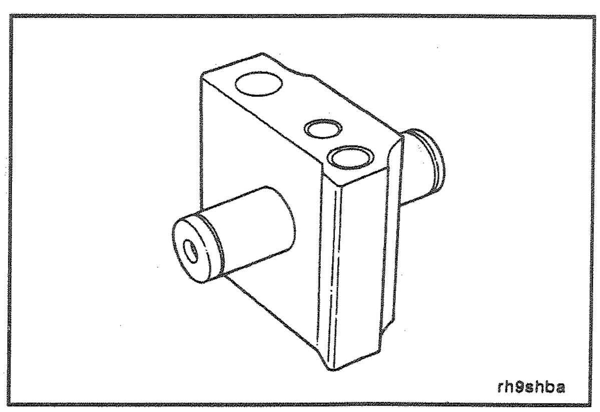
Rocker Levers - Disassembly

If the rocker lever and push rods are to be inspected for reuse, follow these steps.

Remove the retaining rings and thrust washers.

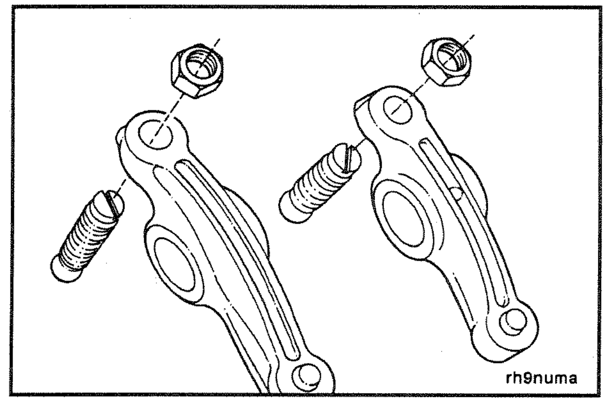


Remove the rocker levers.



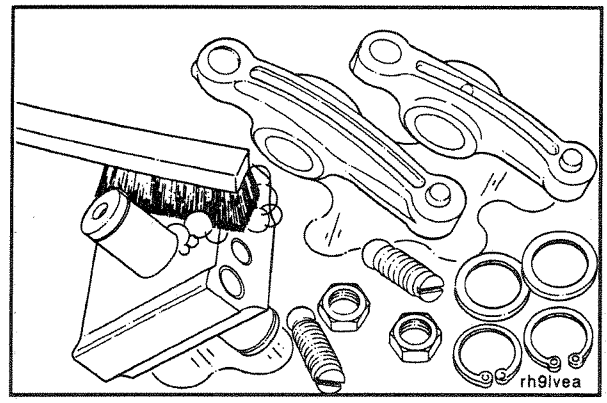
Caution: Do not disassemble the rocker lever shaft and pedestal. The pedestal and shaft must be replaced as an assembly.

Remove the lock nut and adjusting screw.



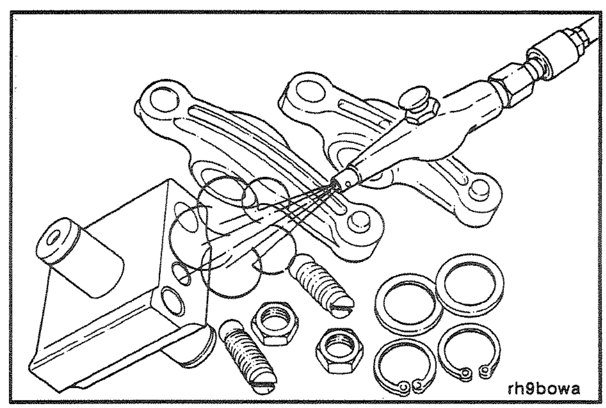
Rocker Levers - Cleaning

Clean all parts in a strong solution of laundry detergent in hot water.



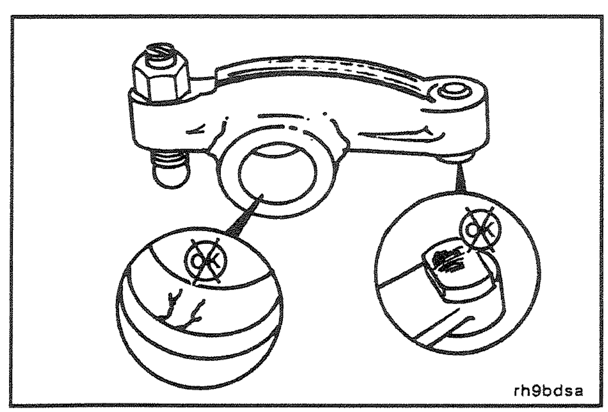
Use compressed air to dry the parts after rinsing in clean hot water.

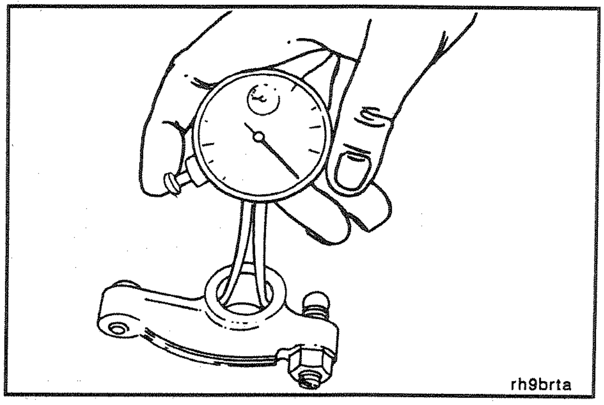
NOTE: The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.



Rocker Levers - Inspection

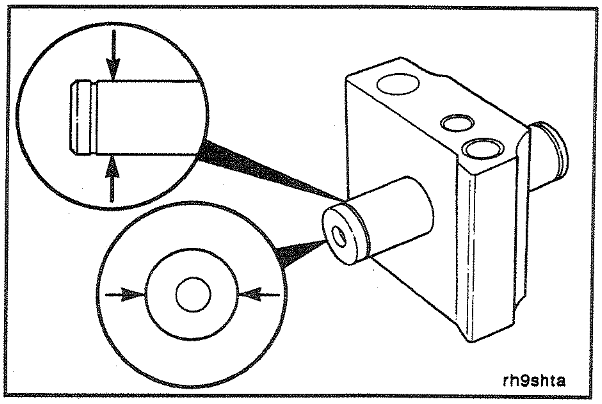
Inspect for cracks and excessive wear in the bore and the contact surface for the valve stem.





Measure the rocker lever bore.

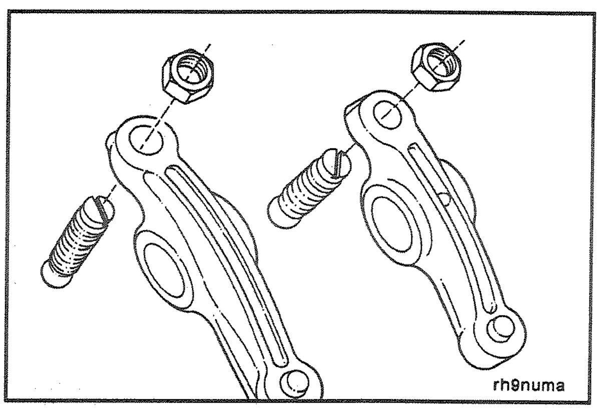
Limits	
Diameter (Maximum):	19.05 mm [0.75 in]



Inspect the pedestal and shaft.

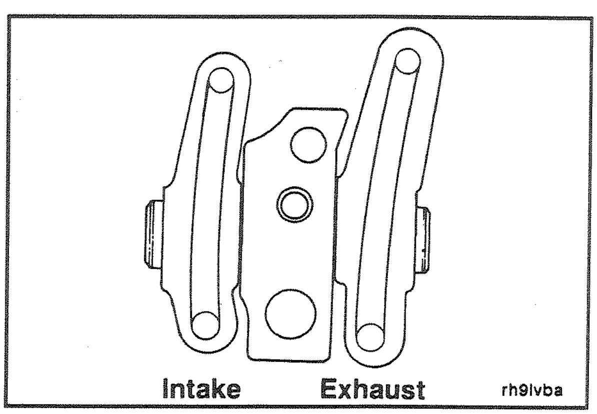
Measure the shaft diameter.

Limits	
Minimum Diameter:	18.94 mm [0.746 in]



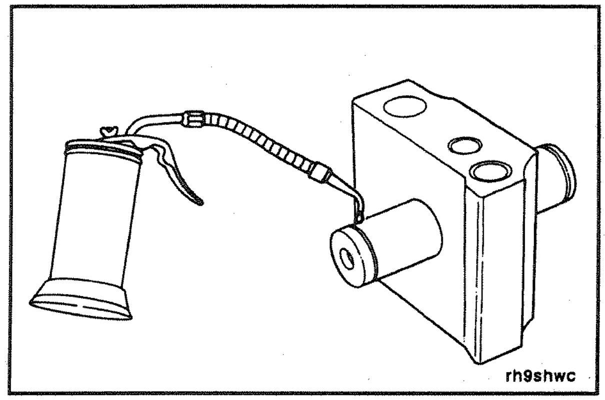
Rocker Levers - Assembly

Install the adjusting screw and lock nut.

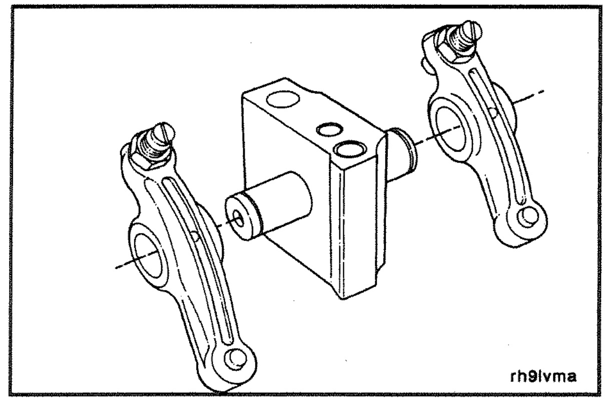


Caution: Be sure to assemble the intake and exhaust rocker levers in the correct location.

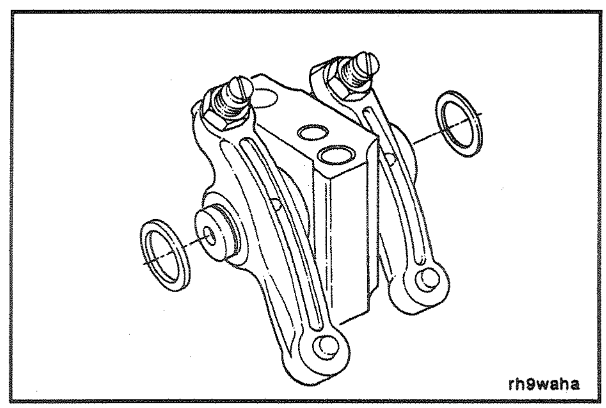
Lubricate the shaft with engine lubricating oil.



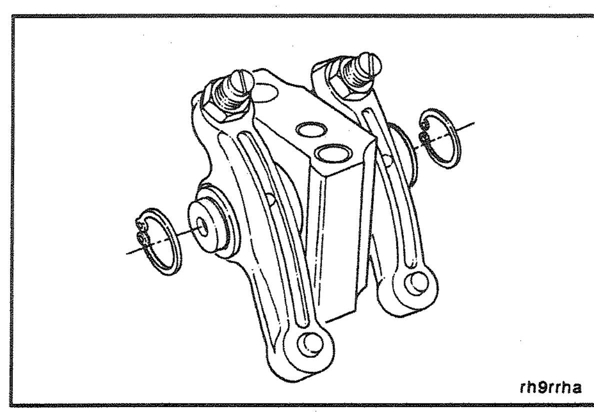
Position the levers on the rocker shaft.

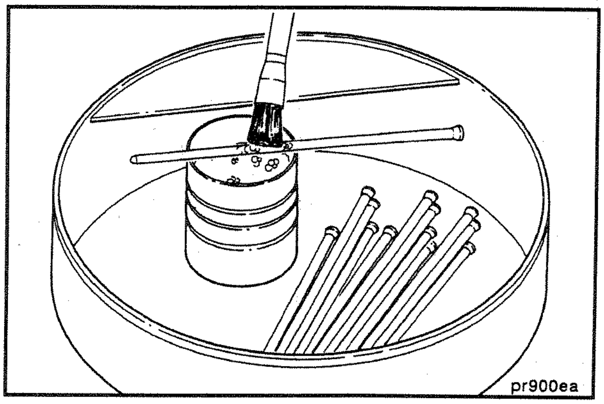


Install the thrust washers.



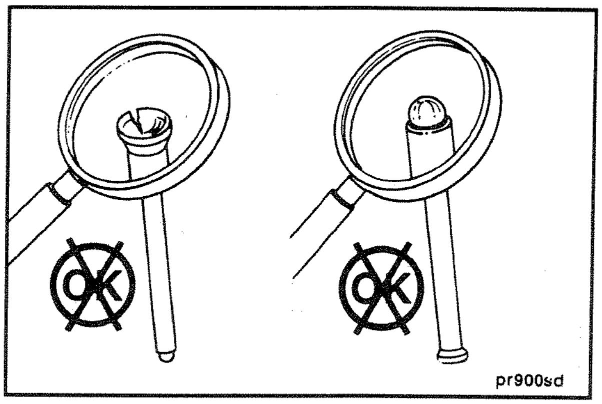
Install the snap rings.





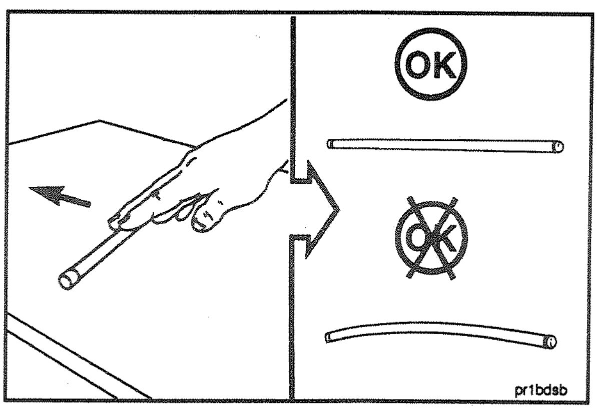
Push Rods - Cleaning

Clean the push rods in hot soapy water.

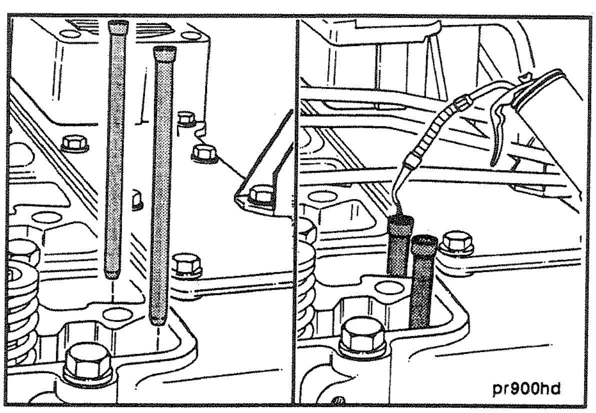


Push Rods - Inspection

Inspect the push rod ball and socket for signs of scoring. Check for cracks where the ball and the socket are pressed into the tube.



Check the push rods for roundness and straightness.

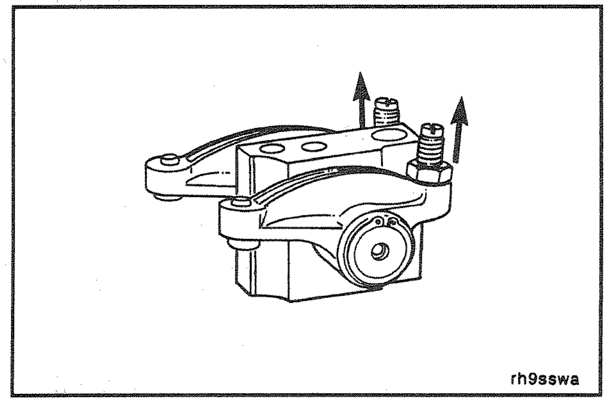


Push Rod - Installation

Install the push rods into the sockets of the valve tappets.

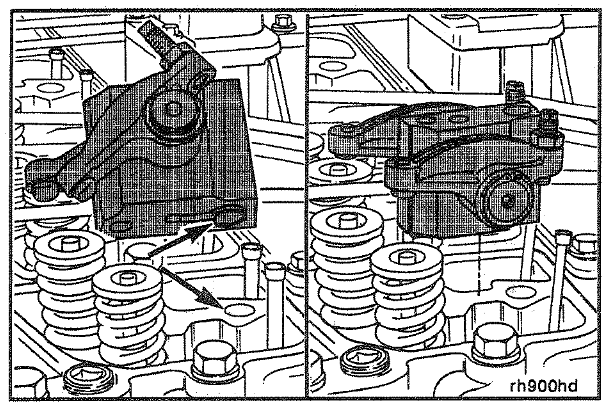
Lubricate the push rod sockets with clean engine oil.

Make sure the rocker lever adjusting screws are completely backed out.



Rocker Lever Assembly - Installation

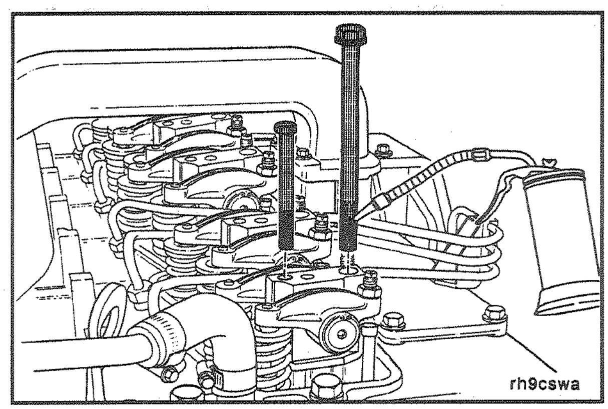
Make sure the dowel rings in the pedestals are installed into the dowel bores.



Inspect all cylinder head capscrews for proper length using Service Tool Part No. 3823921.

Use clean engine oil to lubricate the threads and under the heads of the capscrews.

Install the capscrews into the pedestals.

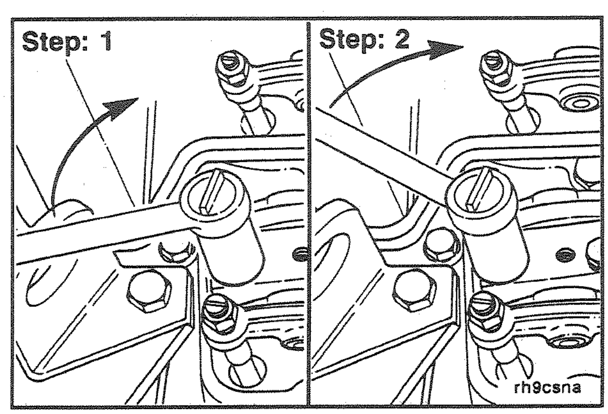


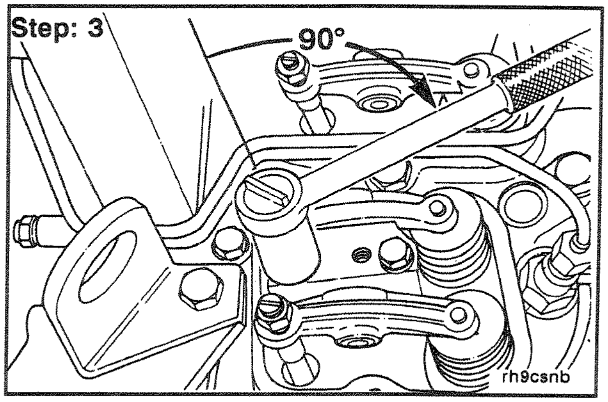
18 mm

Step 1: All

Tighten the cylinder head capscrews to 90 N•m [66 ft-lb].

Step 2: (Long cylinder head capscrews only) Tighten the cylinder head capscrews to 120 N•m [90 ft-lb].

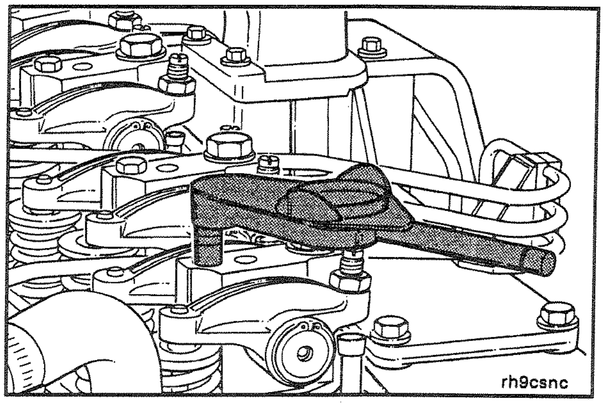




18 mm

STEP 3:

After the long cylinder head capscrews have been tightened to 120 N•m [90 ft-lb], rotate all capscrews an additional 90°.

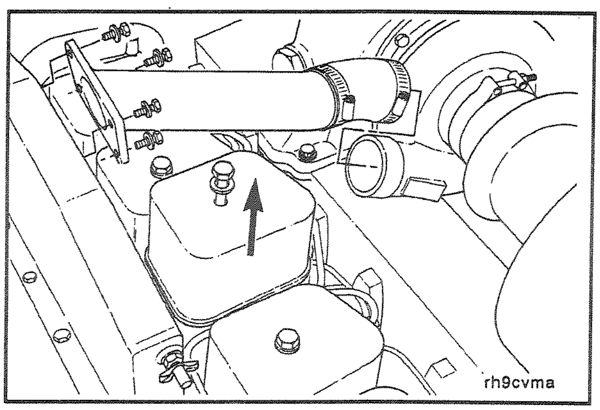


13 mm

Tighten the 8 mm pedestal capscrews.

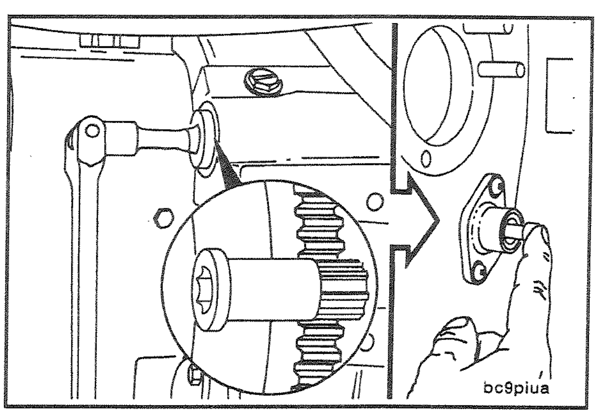
Torque Value: 24 N•m [18 ft-lb]

Valves - Adjustment (7-04)



15 mm

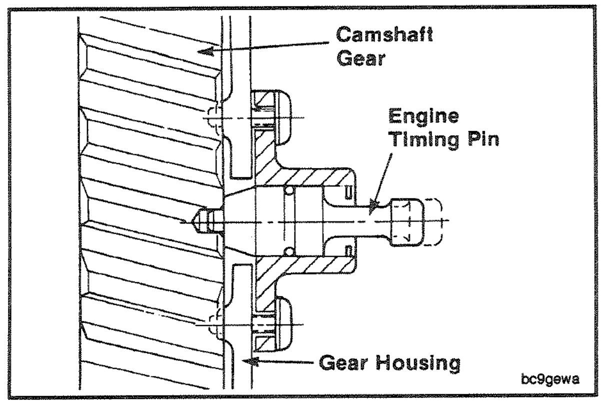
Remove the valve cover.



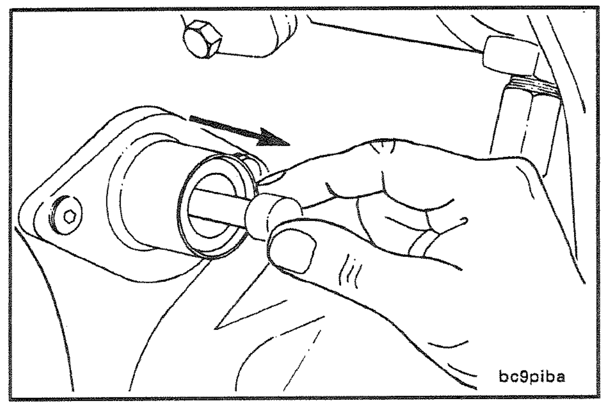
1/2 Inch Drive, 3377371 Engine Barring Gear

Locate Top Dead Center (TDC) for Cylinder Number 1 by barring the crankshaft slowly while pressing on the engine timing pin.

When the timing pin engages in the hole in the camshaft gear, Cylinder Number 1 is at TDC on the compression stroke.



NOTE: To prevent damage to the engine or timing pin, be sure to disengage the timing pin after locating TDC.



Feeler Gauge

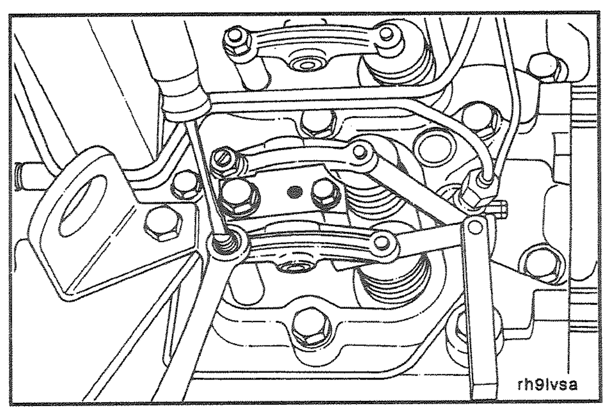
Intake Clearance: 0.254 mm [0.010 in].

Exhaust Clearance: 0.508 mm [0.020 in].

Check/set valves with engine cold - **below** 60°C [140°F].

NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the valve stem and the rocker lever.

NOTE: Caution must be used when setting the exhaust valve lash on marine cylinder heads with rotators. The top of the valve stem is slightly recessed below the top of the valve rotator.



Four Cylinder Engine Adjustment

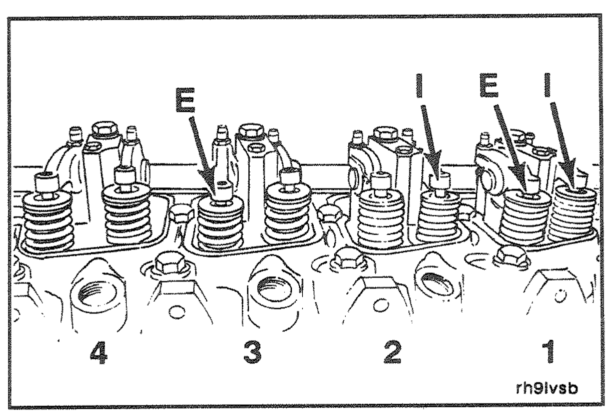
14 mm, Flat Blade Screwdriver

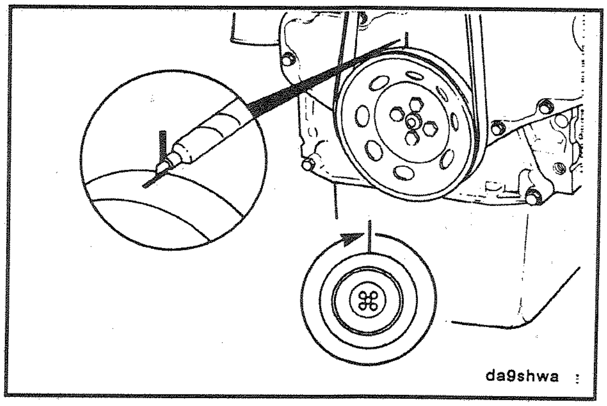
Locate Top Dead Center (TDC) for Cylinder Number 1.

Check/adjust the valves as indicated in the illustration (I = Intake, E = Exhaust).

Tighten the locknut and measure the valve lash again.

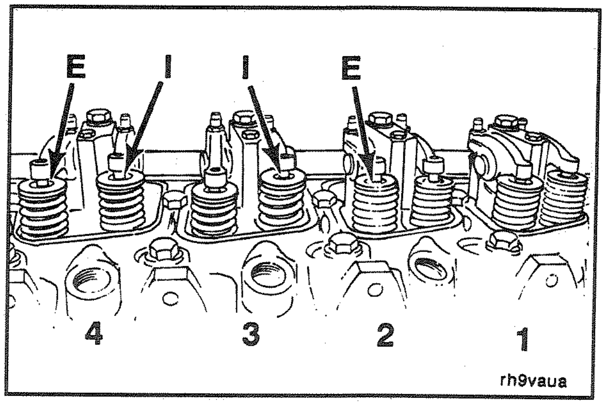
Torque Value: 24 N•m [18 ft-lb]





Mark the vibration damper and rotate the crankshaft 360 degrees.

Caution: To prevent engine or pin damage, be sure timing is disengaged.

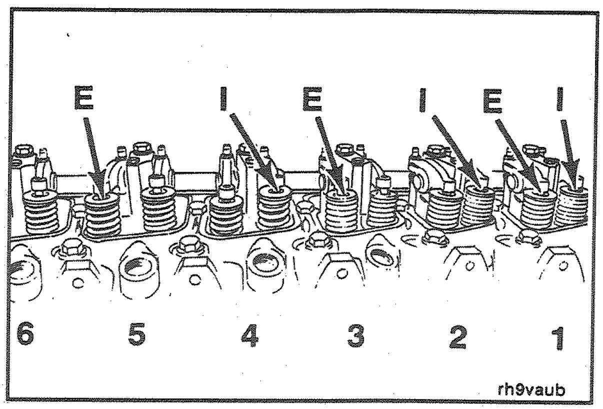


14 mm, Flat Blade Screwdriver

Adjust the valves as indicated in the illustration.

Tighten the locknut and measure the valve lash again.

Torque Value: 24 N•m [18 ft-lb]



Six-Cylinder Engine Adjustment

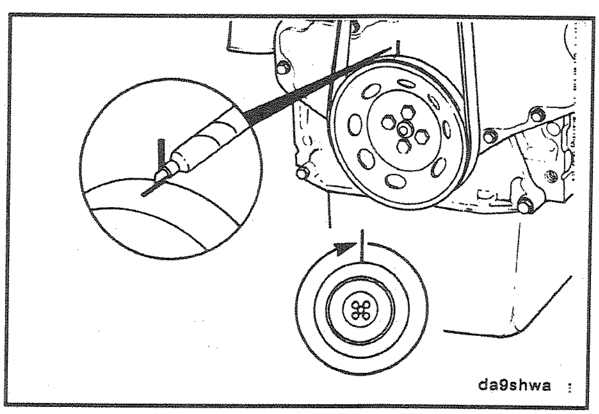
14 mm, Flat Blade Screwdriver

Locate Top Dead Center (TDC) for Cylinder Number 1.

Check/adjust the valves as indicated in the illustration (I = Intake, E = Exhaust).

Tighten the locknut and measure the valve lash again.

Torque Value: 24 N•m [18 ft-lb]



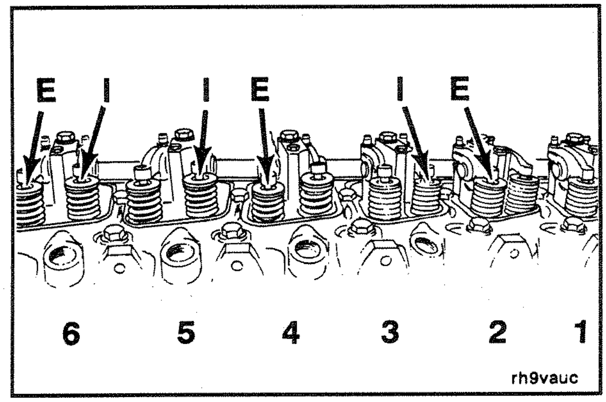
Mark the pulley and rotate the crankshaft 360 degrees.

Caution: To prevent engine or pin damage, be sure timing pin is disengaged.

Adjust the valves as indicated in the illustration.

Tighten the lock nut and measure the valve lash again.

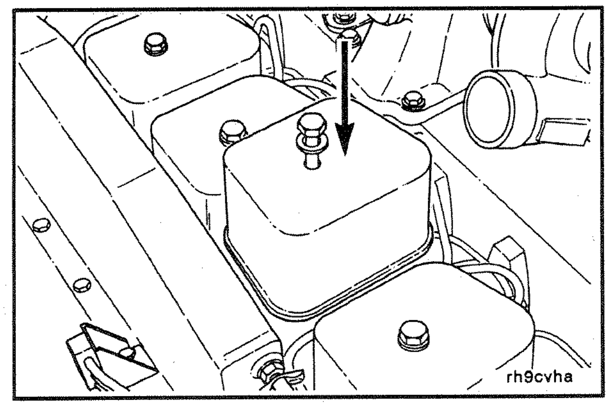
Torque Value: 24 N•m [18 ft-lb]



15 mm

Install the valve covers and tighten capscrews.

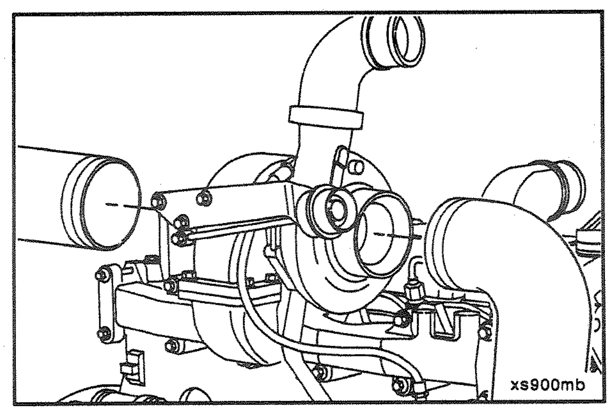
Torque Value: 24 N•m [18 ft-lb]



Turbocharger - Replacement (7-05)

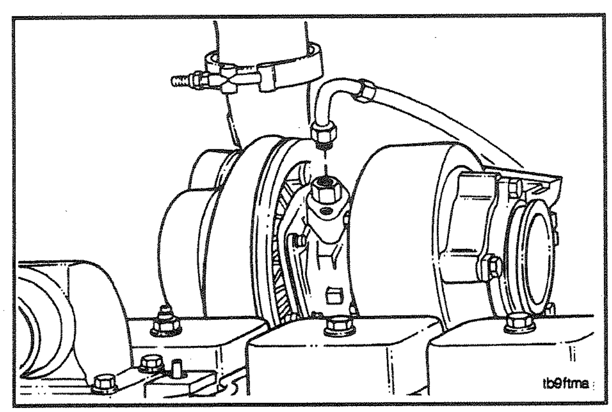
Removal

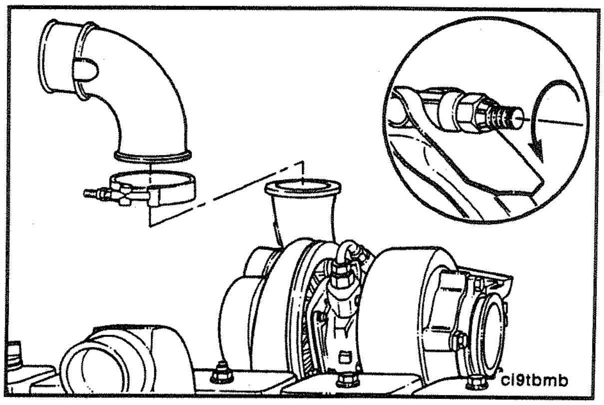
Remove the exhaust and intake air piping.



16 mm and 19 mm

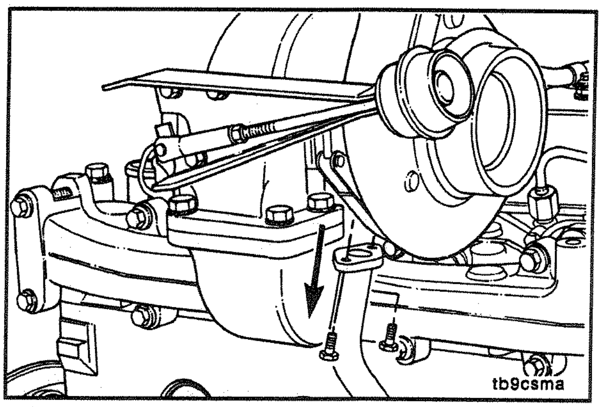
Remove the turbocharger lubricating oil supply line from the turbocharger and oil filter head.





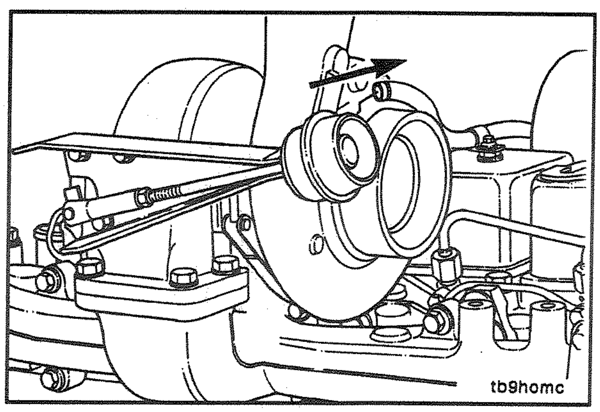
Screwdriver or 7/16 in

Remove the air crossover tube or charge air cooler piping from the turbocharger.



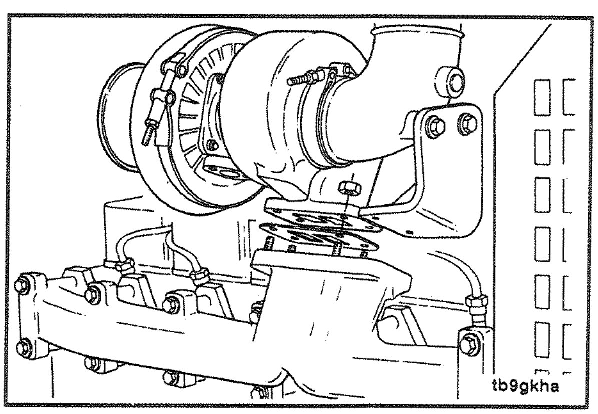
10 mm

Disconnect the lubricating oil drain tube from the bottom of the turbocharger.



Screwdriver

Disconnect the hose from the turbocharger wastegate.



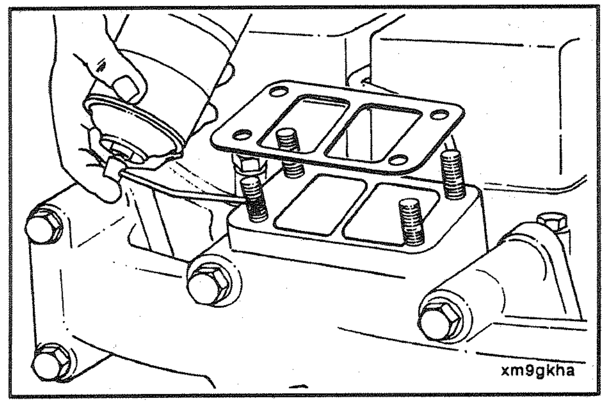
15 mm

Remove the turbocharger mounting nuts, turbocharger and gasket.

NOTE: Inspection of the turbocharger is described in Component Section 3.

Installation

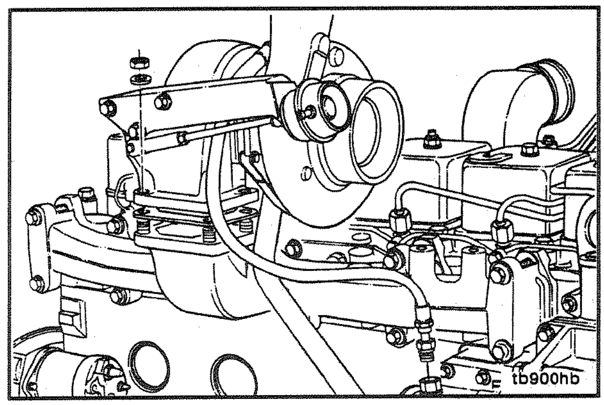
Install the turbocharger gasket and apply anti-seize compound to the mounting studs.



15 mm

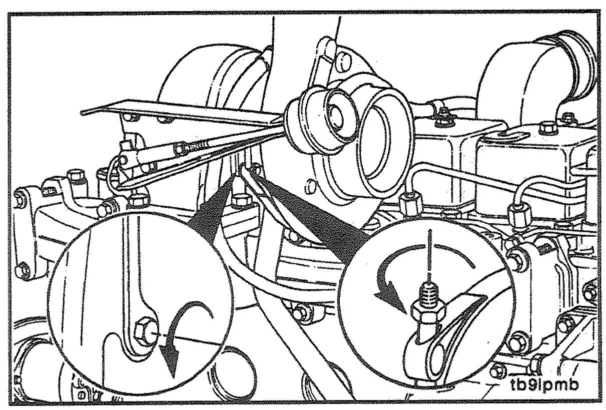
Install the turbocharger.

Torque Value: 45 N•m [33 ft-lb]



13 mm, 7/16 inch

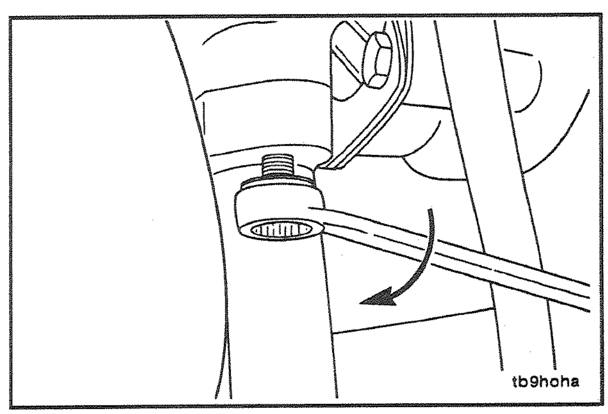
If required, loosen the turbine housing capscrews and the compressor housing clamp to position the bearing housing for installation of the turbocharger drain tube.

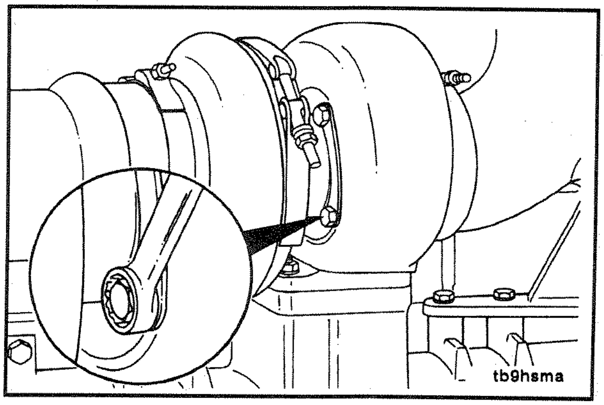


10 mm

Install the turbocharger lubricating oil drain tube and gasket.

Torque Value: 24 N•m [18 ft-lb]

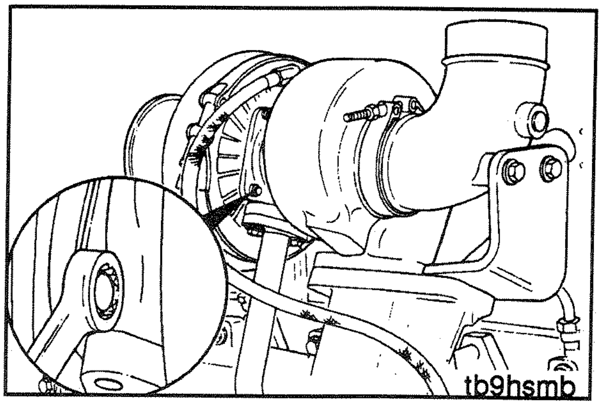




13 mm

If loosened, tighten the turbocharger turbine housing capscrews.

Torque Value: 20 N•m [15 ft-lb]

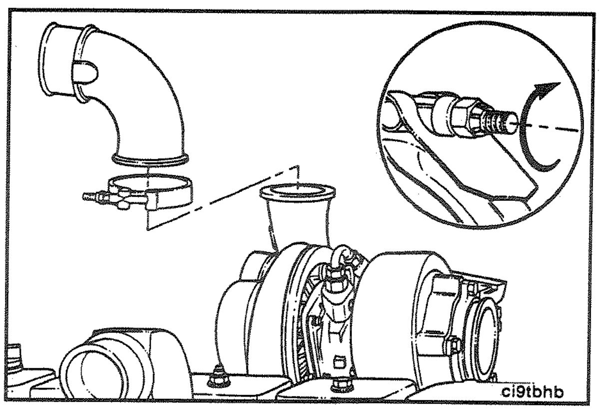


7/16 inch

If required, loosen the compressor housing clamp and position the housing to align with the air crossover tube.

Tighten the clamp.

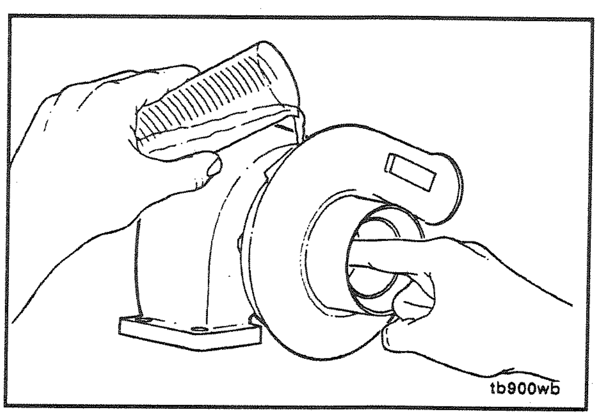
Torque Value: 8 N•m [72 in-lb]



Screwdriver or 7/16 inch

Install the air crossover tube or charge air piping. Tighten the clamps.

Torque Value: 8 N•m [72 in-lb]



Caution: The turbocharger must be prelubricated.

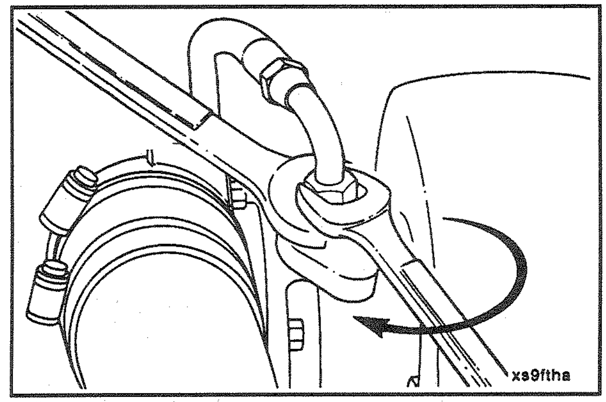
Pour 50 to 60 cc [2 to 3 oz.] of clean engine lubricating oil into the oil inlet fitting on top of the turbocharger while spinning the turbocharger impeller to distribute the lubricating oil in the bearing.

16 mm and 19 mm

Install the lubricating oil supply line.

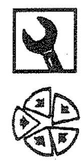
Tighten the fittings securely.

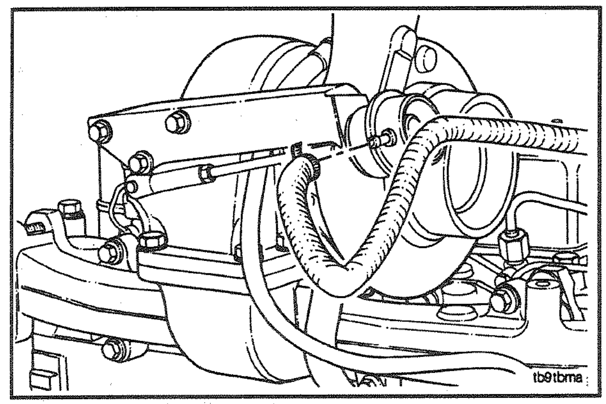
Torque Value: 35 N•m [26 ft-lb]



Screwdriver

Connect the hose to the turbochager wastegate.





Exhaust Manifold - Replacement (7-06)

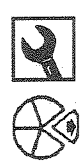
Removal

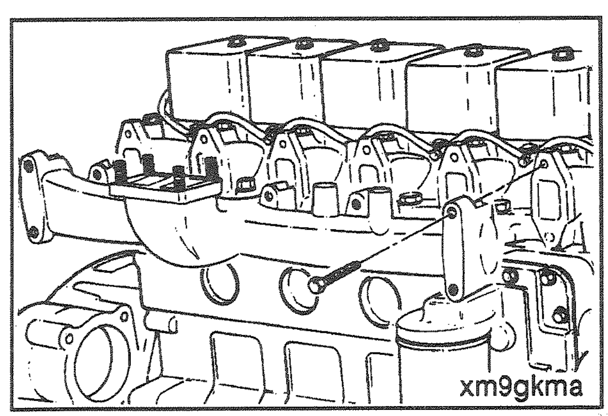
Preparatory Steps:

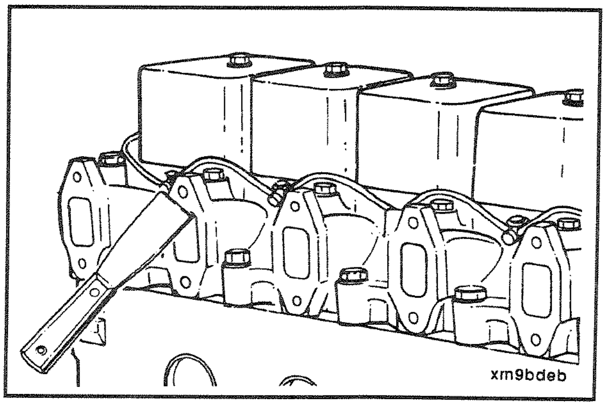
- Remove the turbocharger. Refer to Procedure (7-05).

13 mm

Remove the mounting capscrews, exhaust manifold and gaskets.

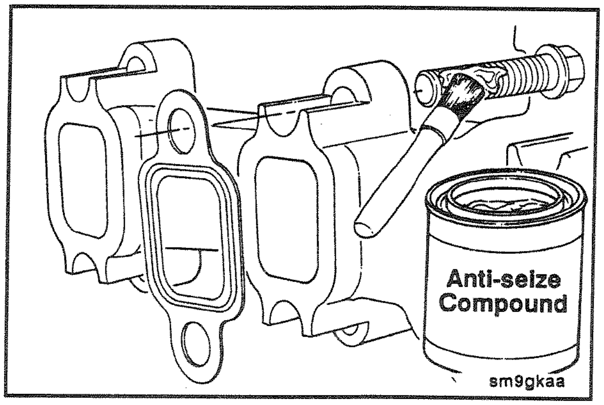






Cleaning

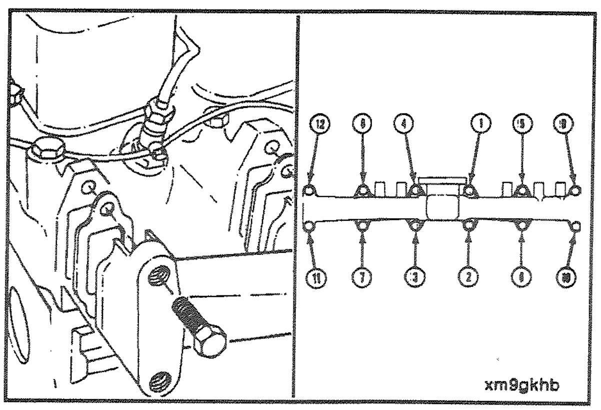
Clean the gasket sealing surfaces.



Installation

"Package" the exhaust manifold capscrews and gaskets on the manifold. Apply anti-seize compound to the capscrews.

The bead on the exhaust manifold gasket can be installed in either direction.

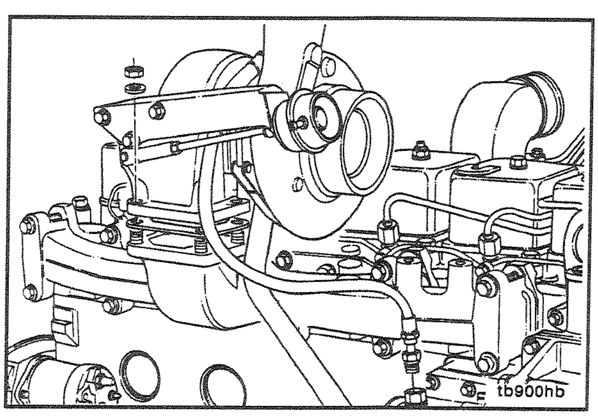


13 mm

Install the exhaust manifold and gaskets.

Torque Value: 43 N•m [32 ft-lb]

Follow the sequence shown.



Install the turbocharger. Refer to Procedure (7-05).

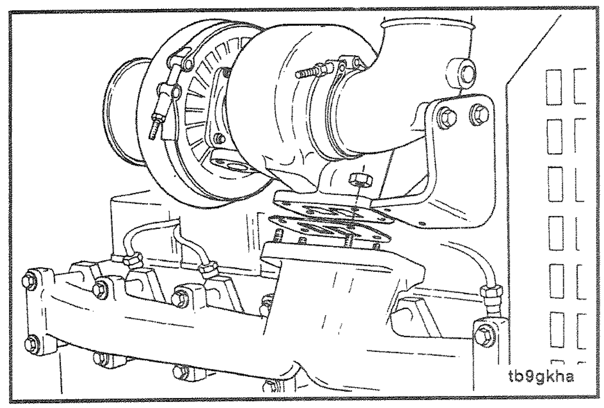
Cylinder Head - Replacement (7-07)

Removal

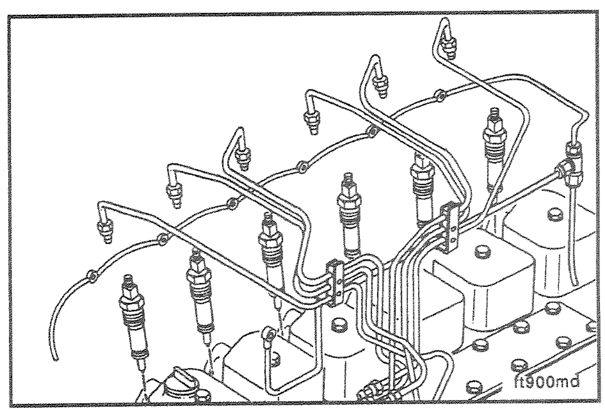
Preparatory Step:

- Drain the coolant.
- Remove all water and heater hoses.

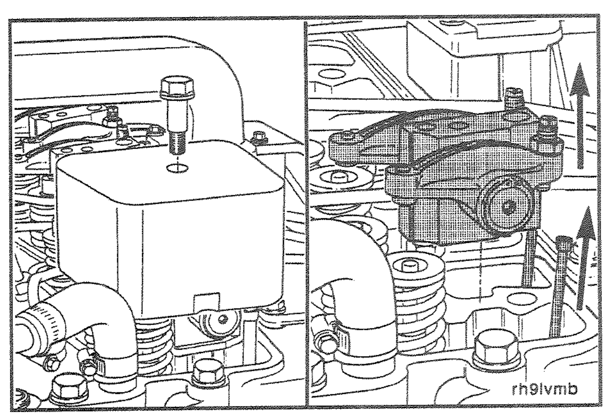
Remove the turbocharger and exhaust manifold. Refer to Procedures (7-05) and (7-06).

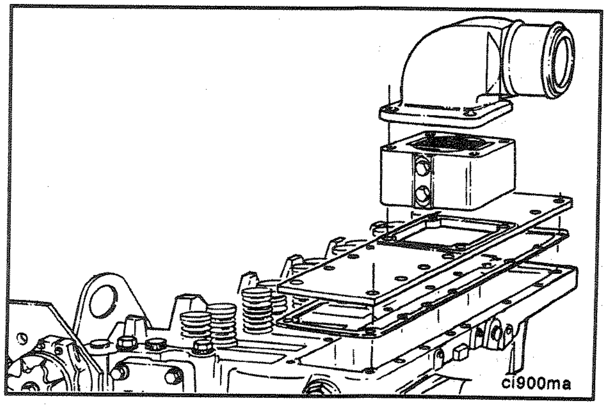


Remove the injectors and fuel lines.



Remove the rocker levers and push tubes. Refer to Procedure (7-03).

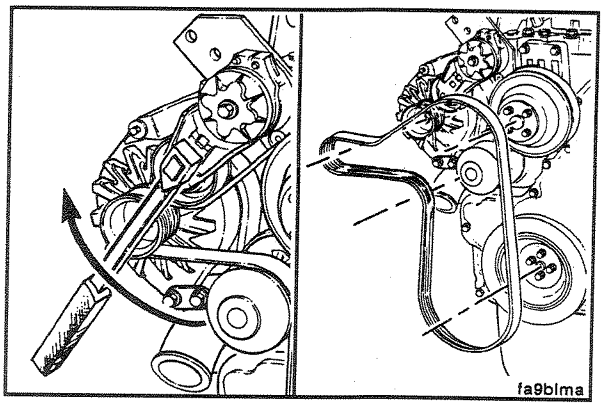




10 mm

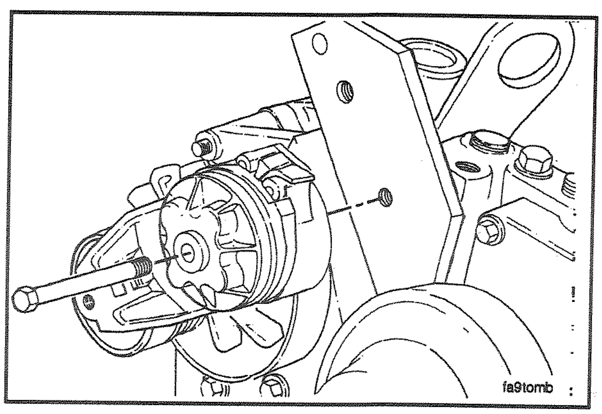
Remove the intake manifold cover and intake heater (if equipped).

Note the manifold cover orientation for proper direction during installation.



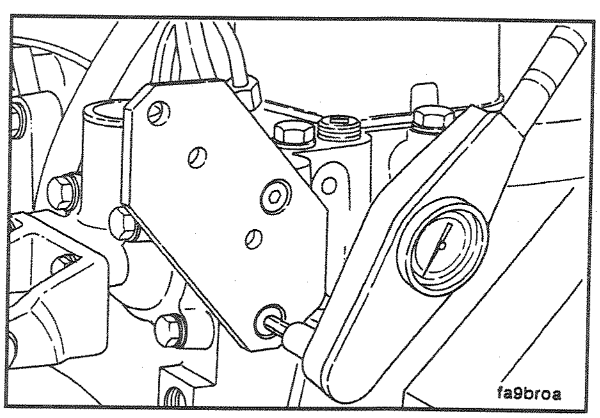
3/8 Inch Square Drive

Remove the drive belt.



13 mm

Remove the belt tensioner.



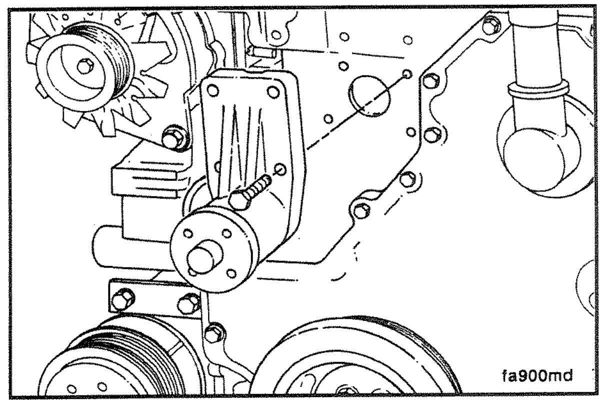
5 mm Allen

Remove the belt tensioner bracket.

10 mm

Remove the fan hub assembly.

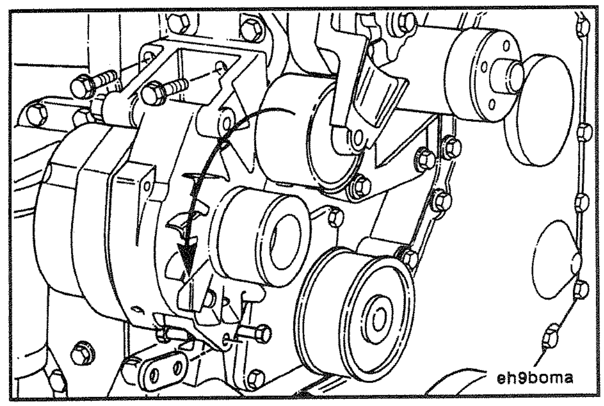
NOTE: Omit this step if the fan bracket is not attached to the cylinder head.



10 mm

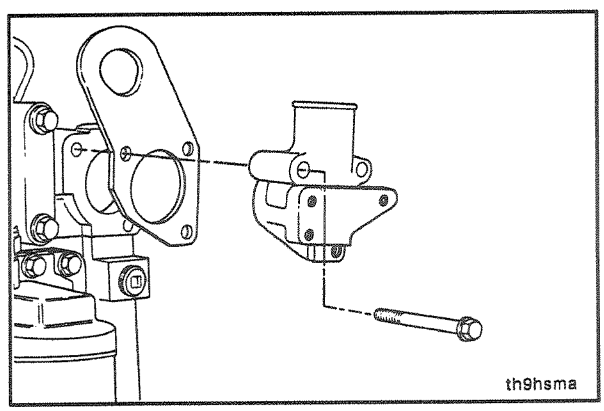
Loosen the alternator link, mounting bolt and water inlet connection capscrews.

Remove the alternator bracket mounting capscrews and pivot the alternator away from the engine.



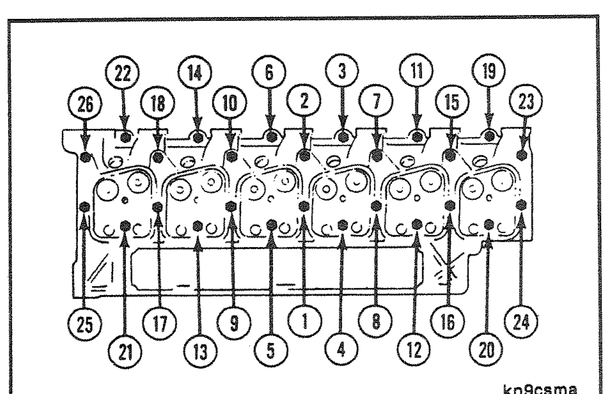
10 mm

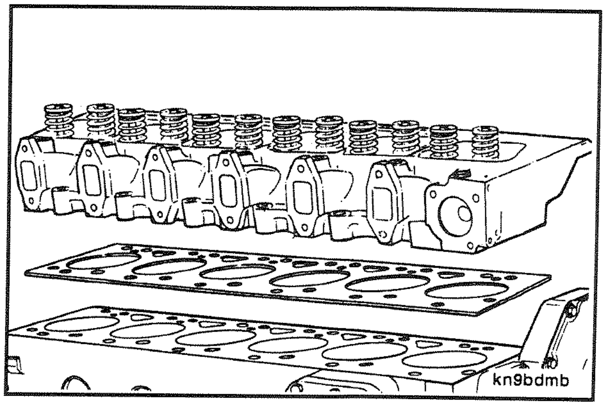
Remove the thermostat housing assembly.



18 mm

Remove the cylinder head capscrews in the sequence shown.



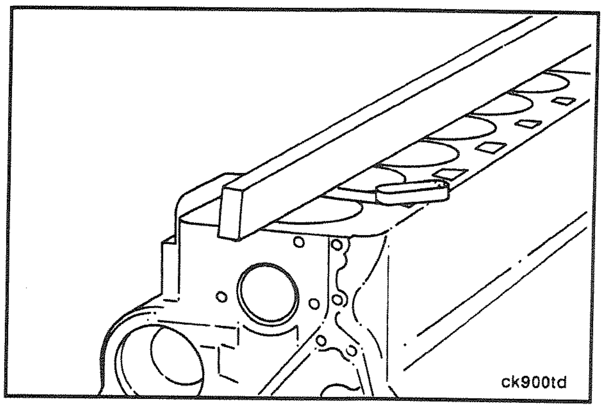


Remove the cylinder head and gasket from the cylinder block.

Cylinder Head Weight:

4 Cylinder - 36 Kg [80 lb]
6 Cylinder - 51.3 Kg [114 lb]

NOTE: Inspect the coolant passages. A large build up of rust and lime will require removal of the cylinder block for cleaning in a hot tank.

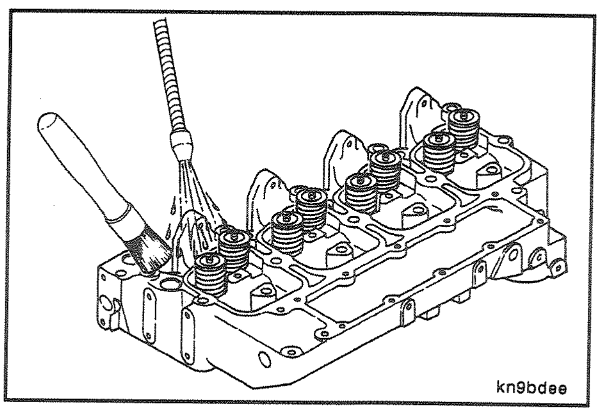


Straight Edge and Feeler Gauge

Use a straight edge and feeler gauge to measure the overall flatness of the cylinder block. The overall flatness, end to end and side to side, must not exceed 0.075 mm [0.003 in].

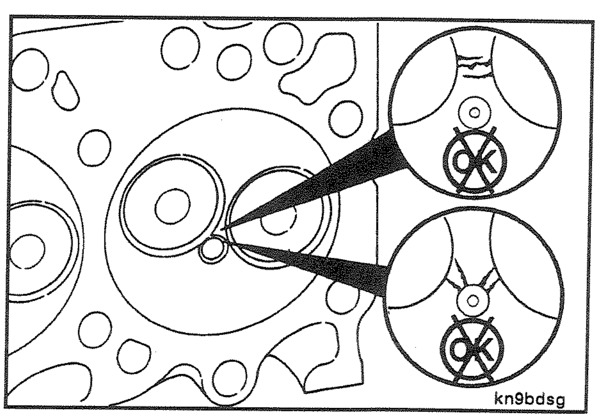
Visually inspect the combustion deck for any localized dips or imperfections. If present, the cylinder block head deck must be ground.

Refer to the Alternate Repair Manual for regrind/milling procedures and limits.



Cylinder Head - Precheck Before Disassembly

Clean the cylinder head with solvent.

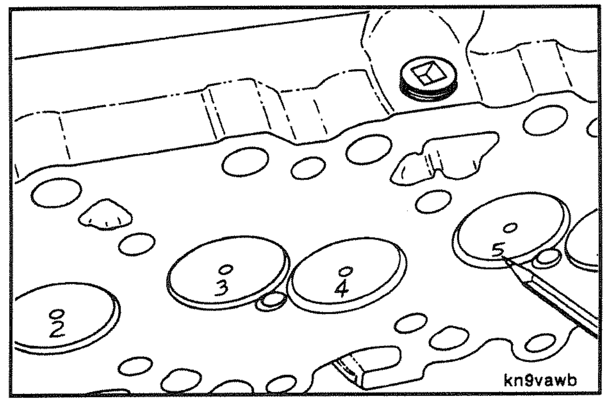


Visually inspect the cylinder head for obvious damage that would prohibit reuse. Check for cracks and damage to the deck surface that would result in loss of sealing.

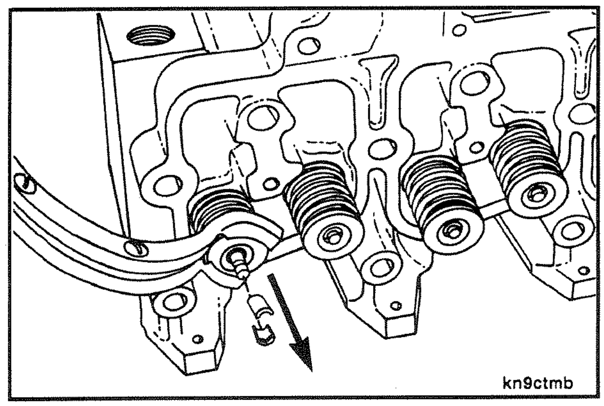
Cylinder Head - Disassembly

The following disassembly and assembly procedures are provided for inspection purposes only. Refer to the Shop Manual, Bulletin No. 3810206, for complete rebuild instructions.

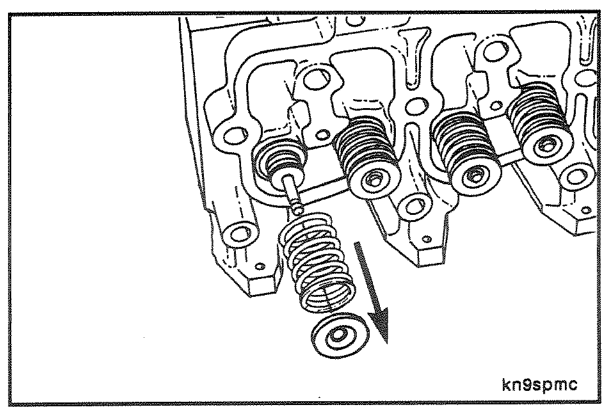
Mark the valves to identify their location.



Compress the valve spring and remove the valve stem collets. Remove the collets.

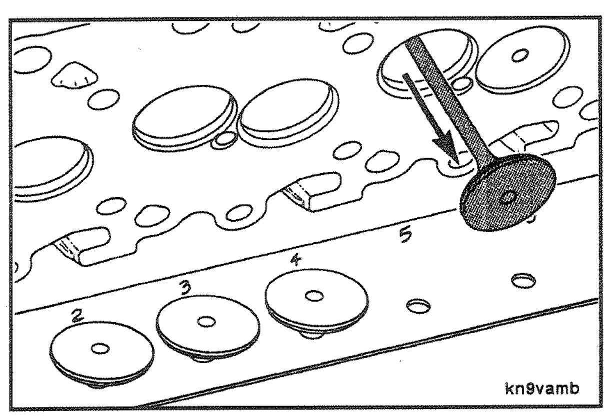


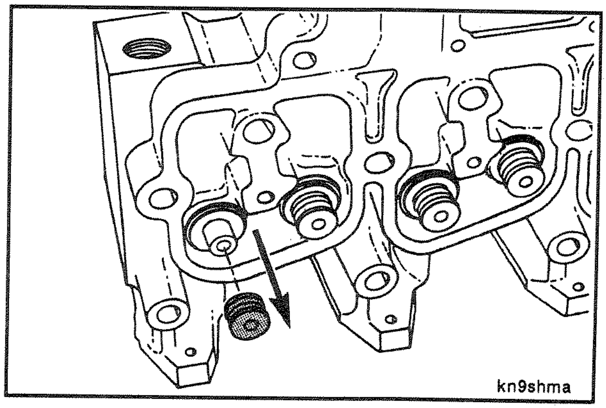
Release valve spring and remove the retainer spring.



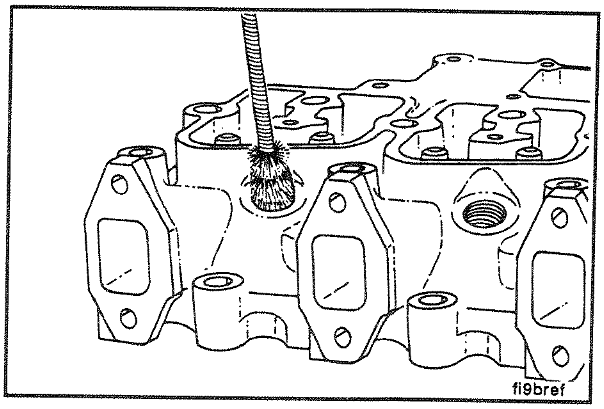
Remove the remaining collets, retainers, springs and valves.

Keep the valves in a labeled rack for a correct match with companion seats while making measurements.





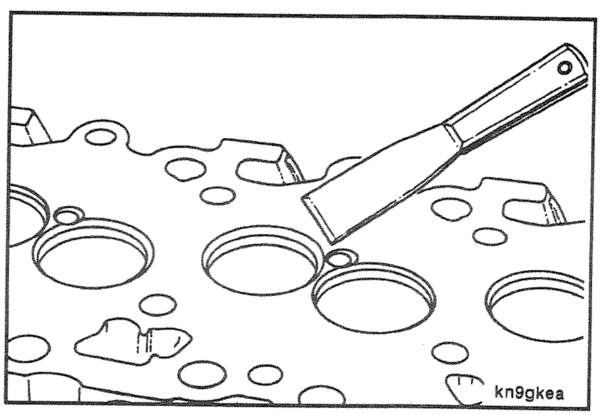
Remove the valve stem seals.



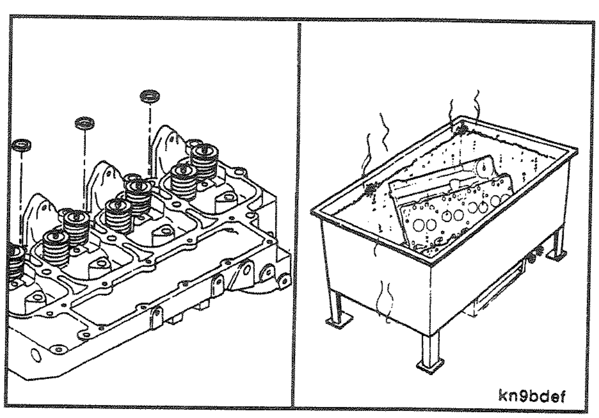
Cylinder Head - Cleaning

Injector Bore Brush 3822509

Clean the carbon from the injector nozzle seat.

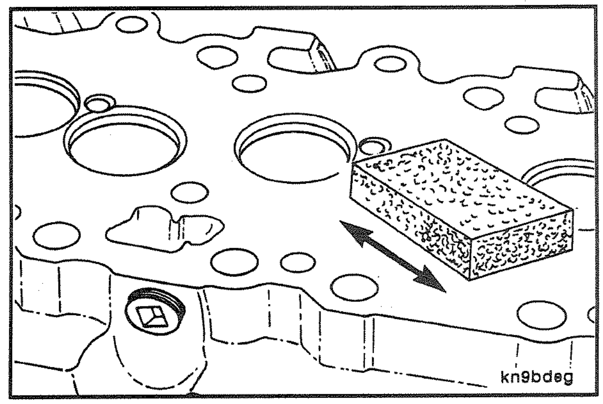


Scrape the gasket material from all gasket surfaces.



Clean the build-up of deposits from the coolant passages. Excessive deposits may be cleaned in an acid tank but the expansion plugs must first be removed.

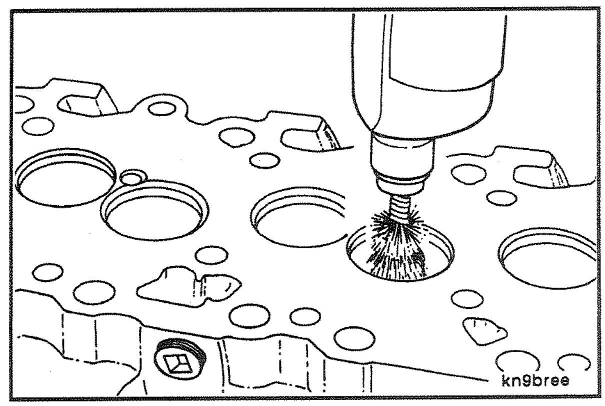
Clean the cylinder head combustion deck with a Scotch-Brite® pad or an equivalent cleaning pad and diesel fuel or solvent.



Warning: Wear protective eye covering.

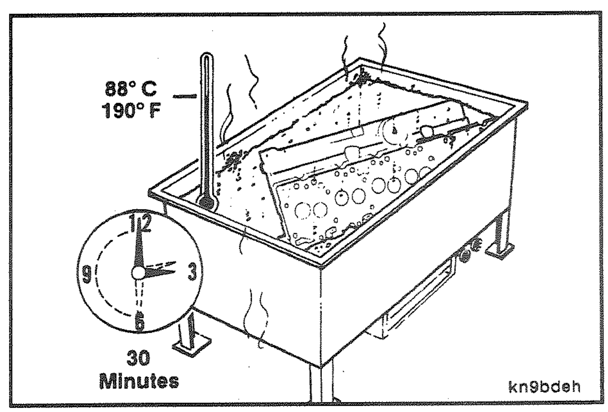
Clean carbon deposits from the valve pockets with a high quality steel wire wheel installed in a drill or a die grinder.

NOTE: An inferior quality wire wheel will loose steel bristles during operation, thus causing additional contamination.



Wash the cylinder head in hot soapy water solution.

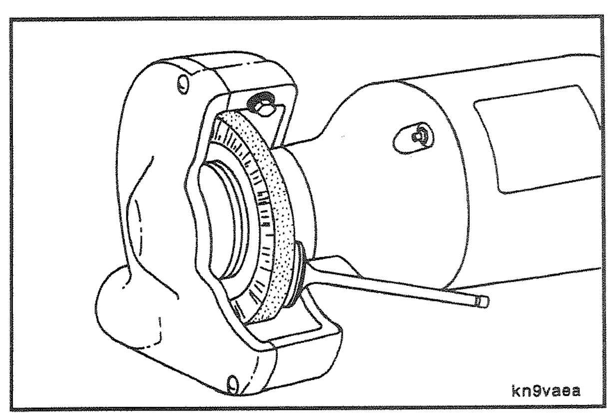
After rinsing, use compressed air to dry the cylinder head.

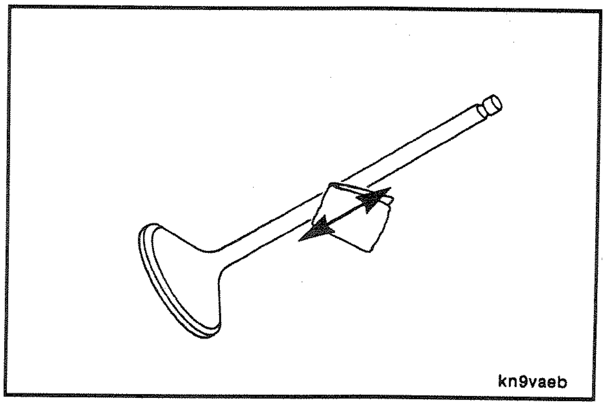


Warning: Wear protective eye covering.

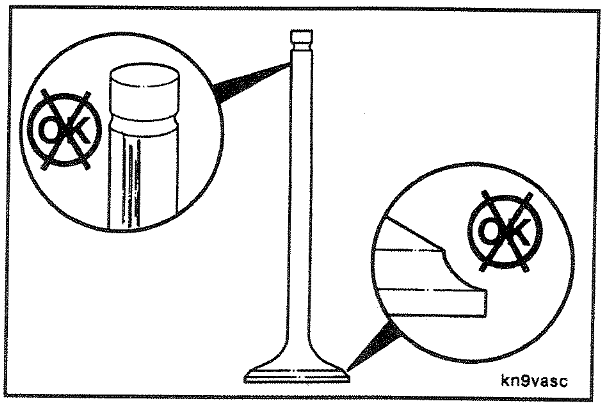
Clean the valve heads with a soft wire wheel.

Keep the valves in a labeled rack to prevent mixing prior to making measurements.



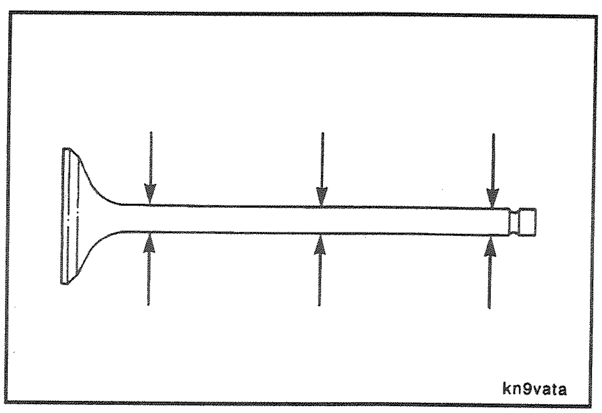


Polish the valve stem with a Scotch-Brite® pad or equivalent cleaning pad and diesel fuel or solvent.



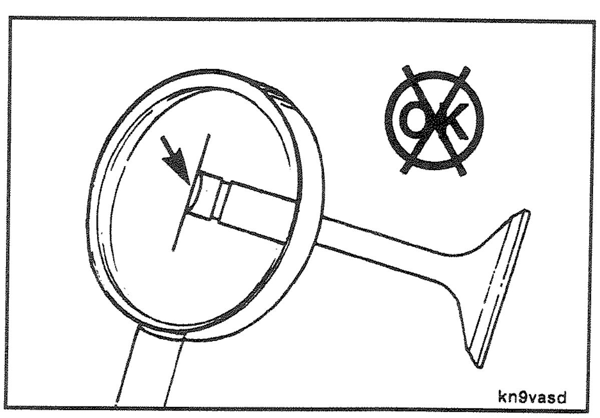
Valve - Inspection

Inspect for abnormal wear on the heads and stems.



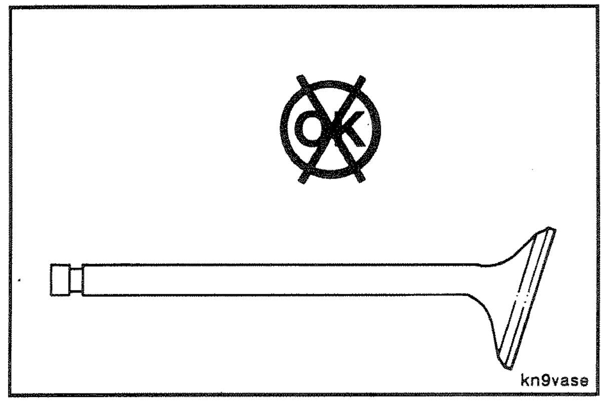
Measure the valve stem diameter.

Valve Stem Diameter		
mm		in
7.94	MIN	0.3126
7.98	MAX	0.3142



Check the valve stem tip for flatness.

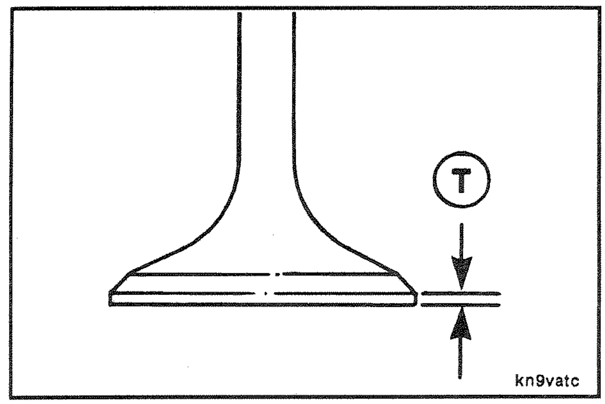
Visually inspect for bent valves.



Measure the rim thickness to determine if there is enough stock to grind the valve.

Limits	
Minimum (T):	0.79 mm [0.031 in]

If the valves are determined to be suitable for resurfacing, refer to the B Series Shop Manual, Bulletin No. 3810206.



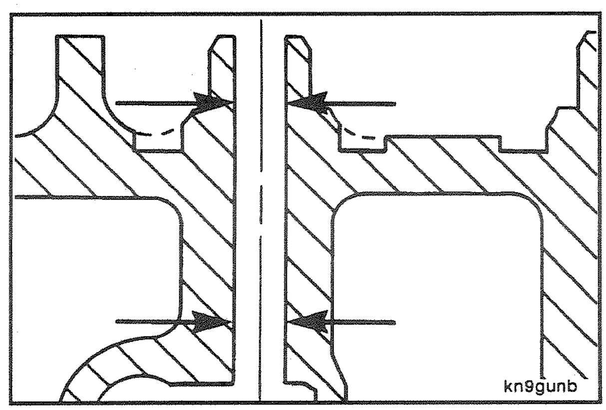
Valve Guide Inspection

Inspect the valve guides for scuffing or scoring.

Measure the valve guide bore.

Valve Guide Bore Diameter		
mm		in
8.019	MIN	0.3157
8.090	MAX	0.3185

If the inspection reveals damaged valve guides, refer to the Alternative Repair Manual, Bulletin No. 3810234.

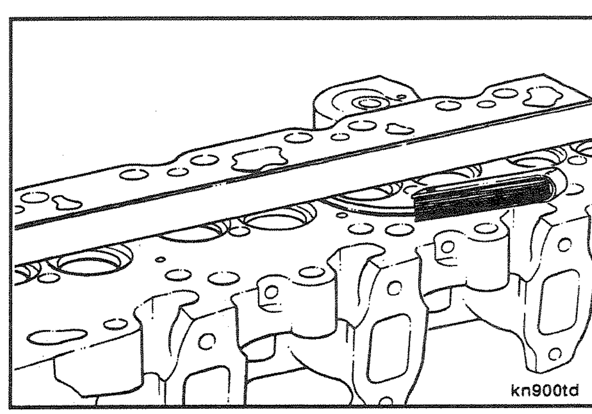


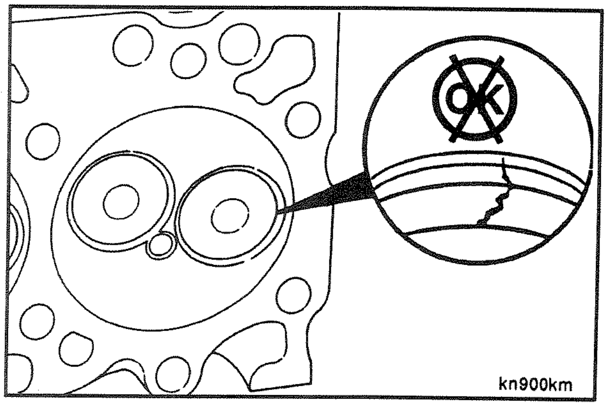
Cylinder Head Deck Inspection

Use a straight edge and feeler gauge to measure the overall flatness of the cylinder head deck. The overall flatness, side to side, must not exceed 0.075 mm [0.003 in]. The overall flatness, end to end, must not exceed .203 mm (.008 inch) for the 4B and .305 mm (.012 inch) for the 6B.

Visually inspect for any localized dips or imperfections. If present, the cylinder head deck must be ground.

Refer to the Alternative Repair Manual, Bulletin No. 3810234 for regrind/milling procedures and limits.

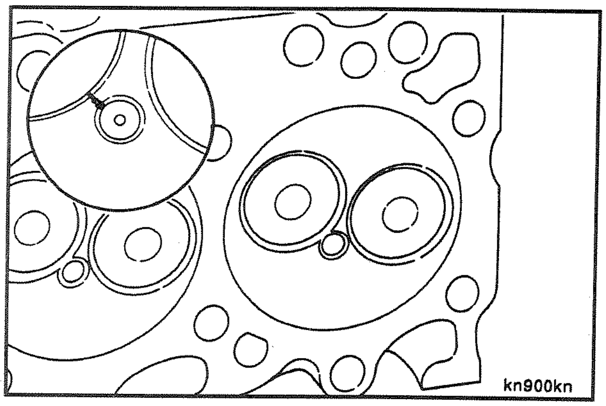




Valve Seat Inspection

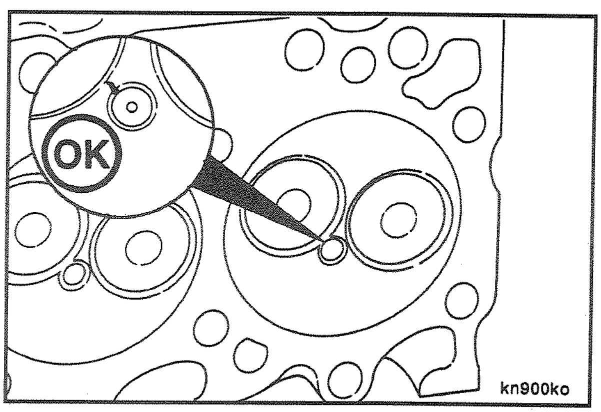
Inspect the valve seats for cracks or burned spots.

Refer to the following reuse guidelines for any cracks discovered. Service valve seats are available for seats with burned spots that will require more than 0.254 mm [0.010 in] grinding to clean up. Refer to the Alternative Repair Manual, Bulletin No. 3810234, for valve seat installation procedures.



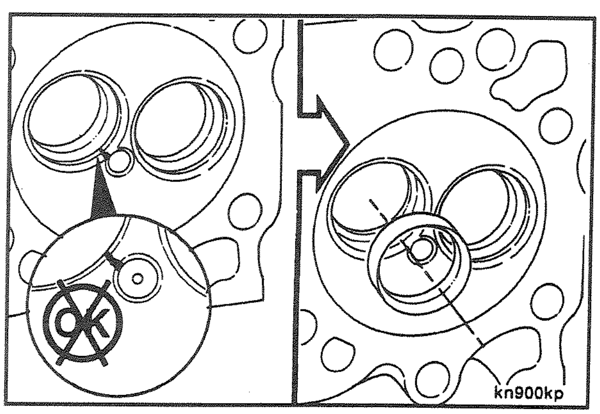
Cylinder Head Cracks - Reuse Guidelines

These guidelines apply **only** to cracks extending from the injector bore to the **intake** valve seats. Replace cylinder heads which exhibit valve bridge cracks in any other location.



The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

If the crack does not extend into the valve seat, the cylinder head is reusable.

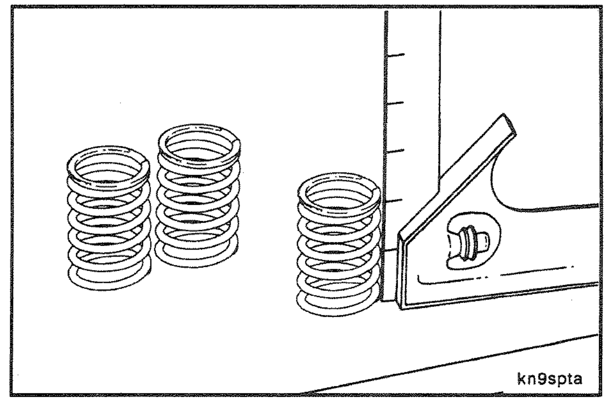


If the crack extends into or through the valve seat, the cylinder head must be repaired by installing a valve seat insert per the Alternative Repair Manual, Bulletin No. 3810234.

Valve Spring Inspection

Inspect the valve springs.

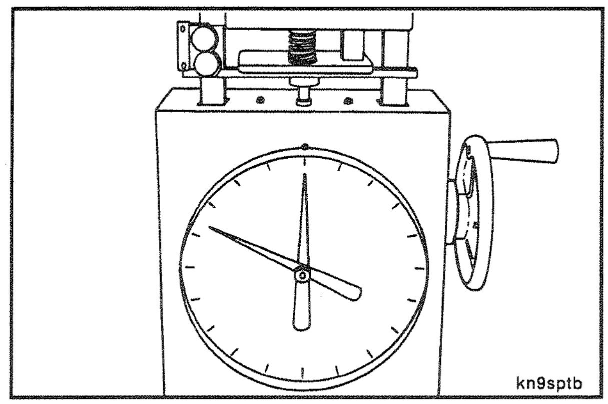
Measure the valve spring.



Limits

Approx. Free Length (L):	(1991)	55.63 mm [2.190 in]
Maximum Inclination:		1.0 mm [0.039 in]
Approx. Free Length (L):	(1994)	60.00 mm [2.362 in]
Maximum Inclination:		1.00 mm [0.039 in]

A load of 289.13 to 321.16 N. [65.0 to 72.2 lb] (1991) and 359 to 397 N. [80.7 to 89.2 lb] (1994) is required to compress the spring to a height of 49.25 mm [1.94 in].

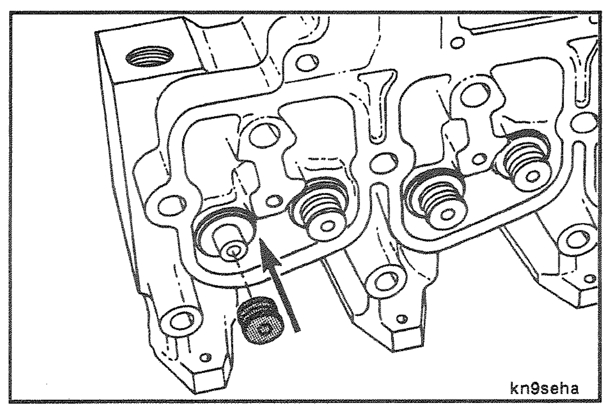


Cylinder Head - Assembly

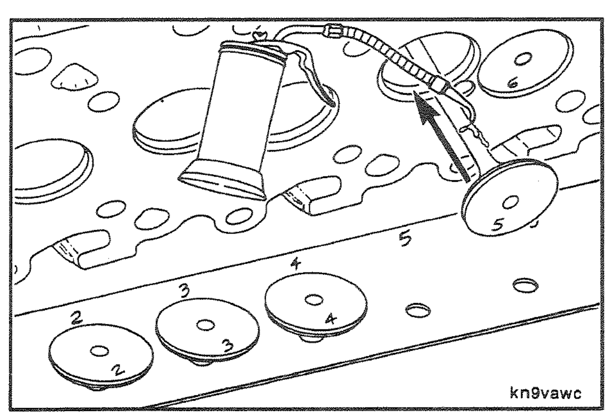
NOTE: Clean all cylinder head components before assembling.

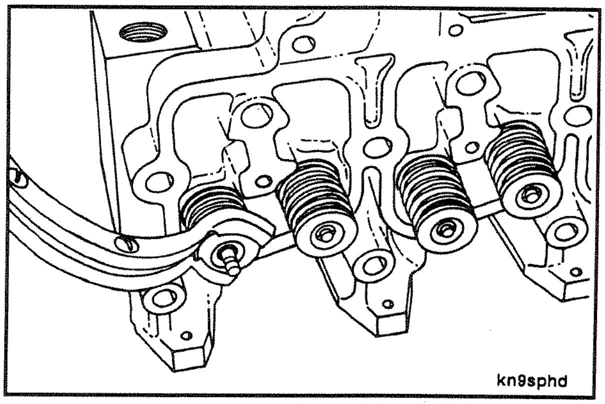
Install the valve stem seals.

The intake and exhaust seals are the same.



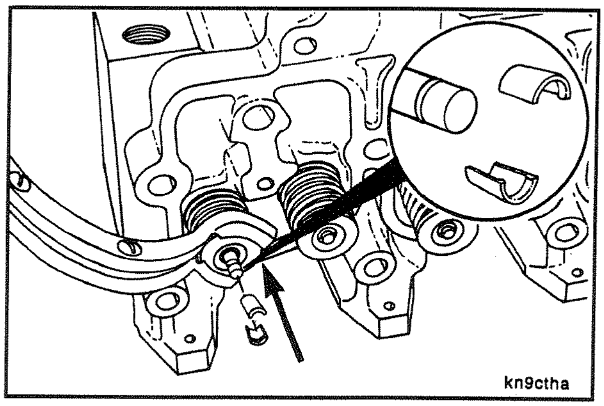
Lubricate the stems with SAE 90W engine oil before installing the valves.



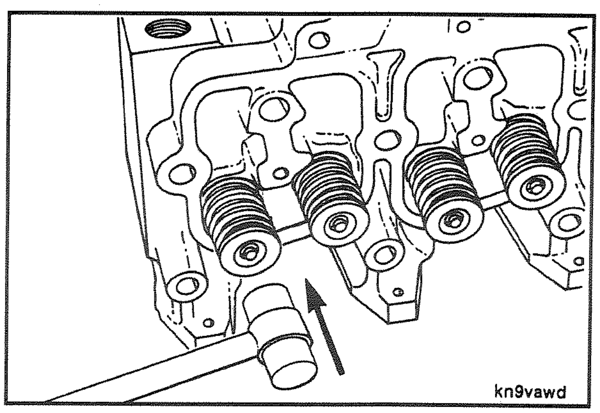


Valve Spring Compressor

Compress the valve spring after assembling the spring and retainer.



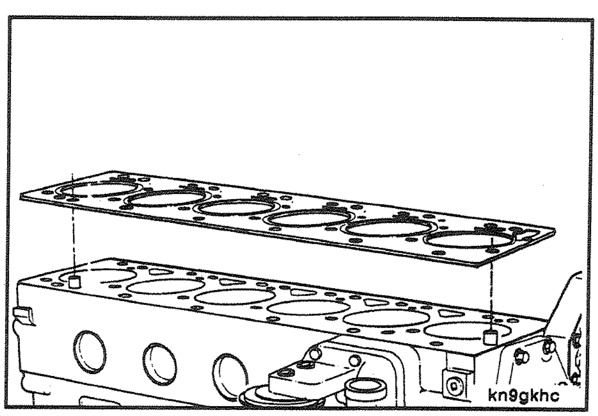
Install new valve collets and release the spring tension.



Plastic Hammer

Caution: Wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

After assembly, hit the valve stems with a plastic hammer to make sure that the collets are seated.



Cylinder Head - Installation

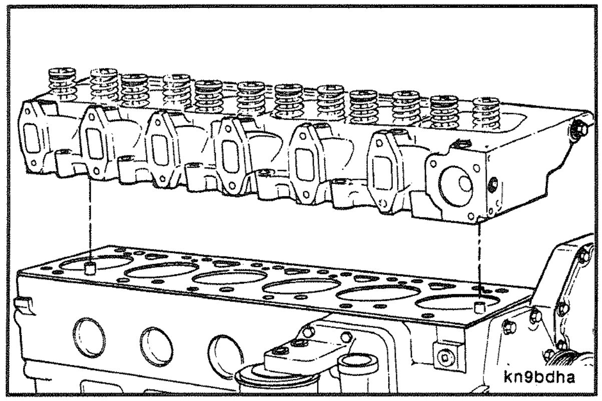
Caution: Be sure the gasket is correctly aligned with holes in the cylinder block.

Position the cylinder head gasket over the dowels.

Carefully put the cylinder head on the cylinder block and seat it onto the dowels.

Cylinder Head Weight:

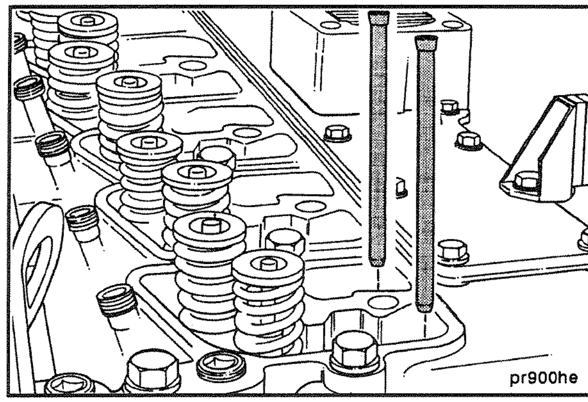
4 Cylinder - 36 Kg [80 lb]
6 Cylinder - 51.3 Kg [114 lb]



kn9bdha

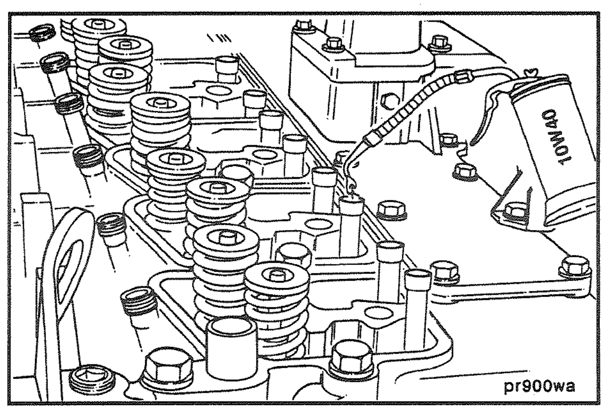
Push Rods - Installation

Position the push rods into the valve tappets.



pr900he

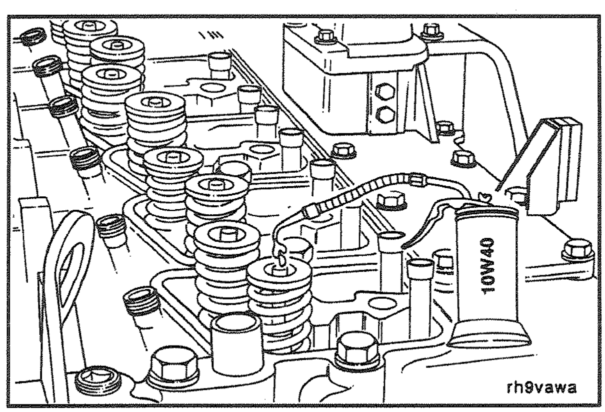
Lubricate the push rod sockets with engine lubricating oil.



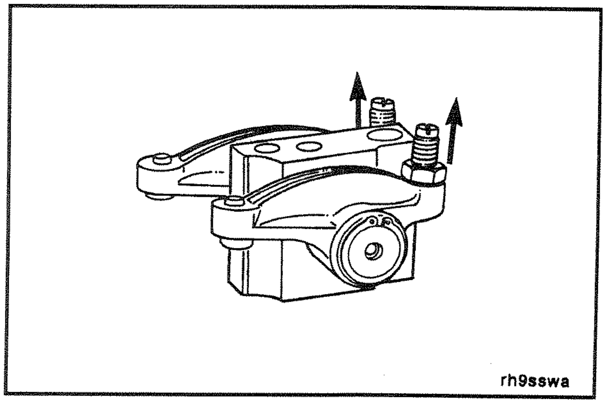
pr900wa

Rocker Levers - Installation

Lubricate the valve stems with engine lubricating oil.

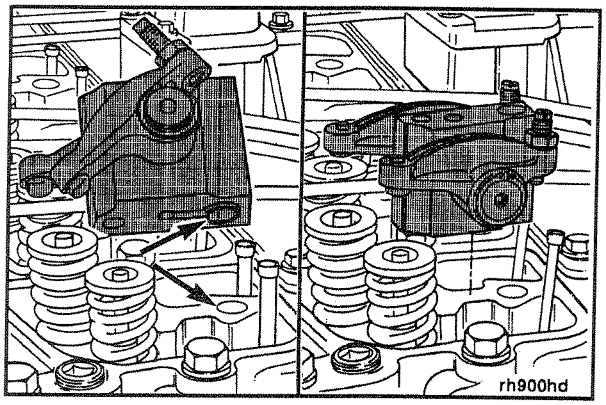


rh9vawa


rh9sswa

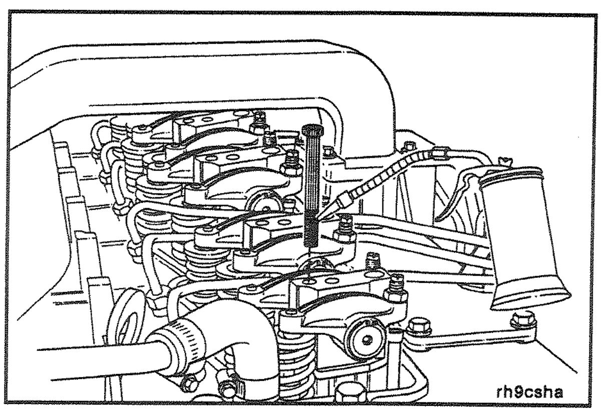
14 mm, Flat Blade Screwdriver

Completely loosen the rocker lever adjusting screws.


rh900hd

NOTE: The rocker lever pedestals are aligned with dowels.

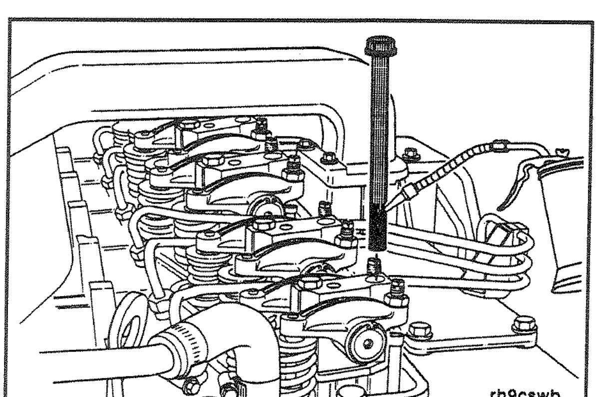
Install the pedestals.


rh9csha

Inspect all cylinder head capscrews for proper length using Service Tool Part No. 3823921.

Lubricate the 8 mm pedestal capscrew threads and under the capscrew heads with engine lubricating oil.

Install the capscrews finger tight.

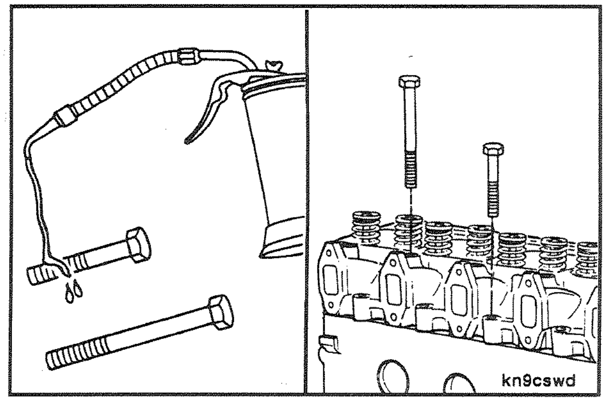

rh9cswb

Lubricate the 12 mm pedestal/head capscrew bolt threads and under the capscrew heads with engine lubricating oil.

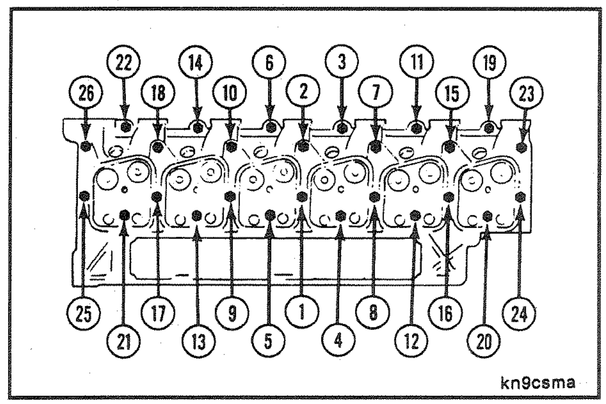
Install the capscrews finger tight.

Lubricate the threads and under the heads on the remaining head capscrews with engine lubricating oil.

Install the capscrews finger tight.

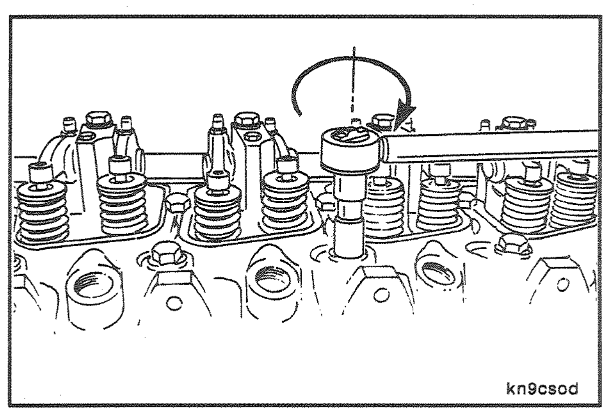


Use the illustrated sequence to tighten the cylinder head capscrews.



18 mm

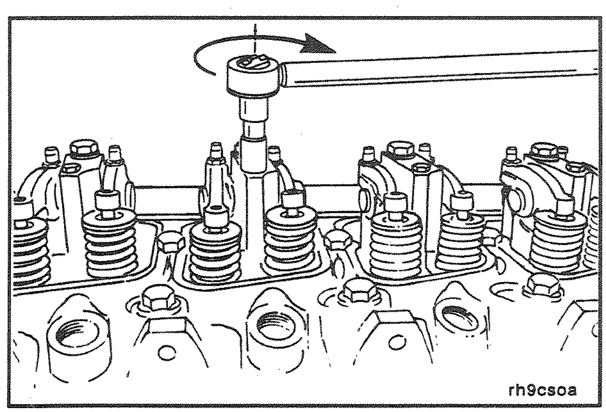
Step	Torque Value
1 TIGHTEN ALL CAPSCREWS	90 N•m [66 ft-lb]
2 Recheck to	90 N•m [66 ft-lb]
3 Long Capscrews Only	120 N•m [89 ft-lb]
4 Recheck Long Capscrews	120 N•m [89 ft-lb]
5 Advance All	90 degrees

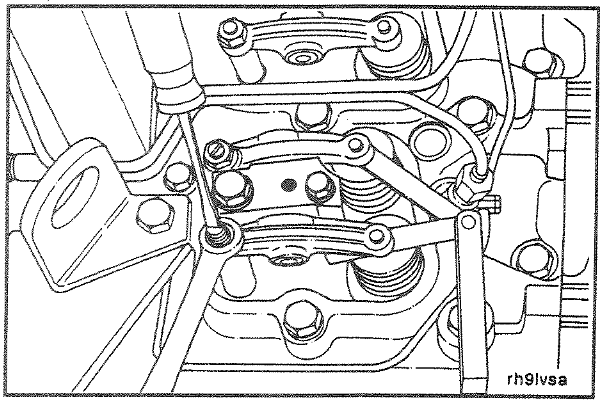


13 mm

Tighten the 8 mm pedestal capscrews.

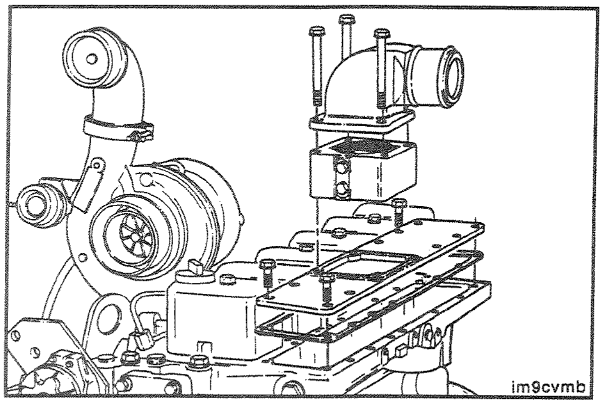
Torque Value: 24 N•m [18 ft-lb]





Valve Clearance - Adjustment

Adjust the valve clearance. Refer to Procedure (7-04).

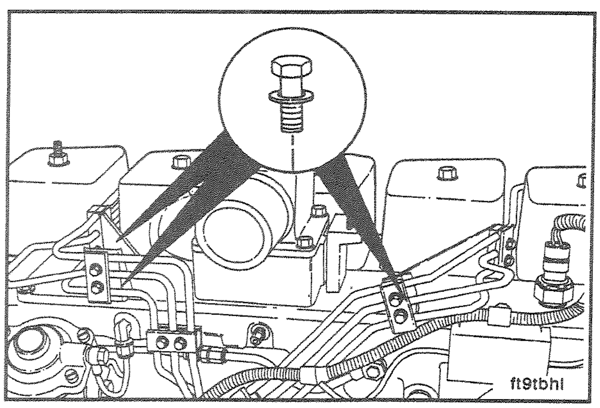


10 mm

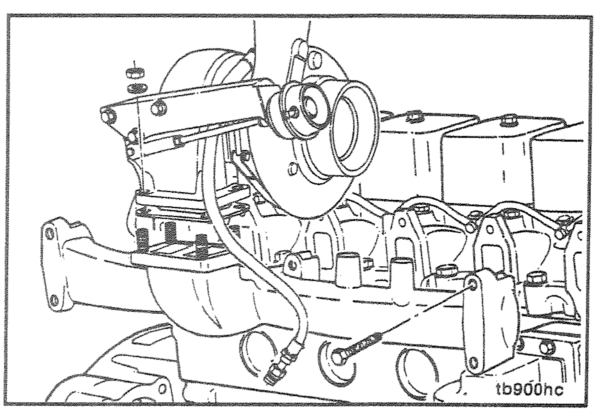
Install the manifold cover plate, fuel filter head, and intake heater.

Use the illustrated capscrews to secure the cover plate. The remaining holes are used to secure fuel line brackets.

Torque Value: 24 N•m [18 ft-lb]



Install the injectors and fuel lines.



Install the exhaust manifold and turbocharger. Refer to Procedures (7-05) and (7-06).

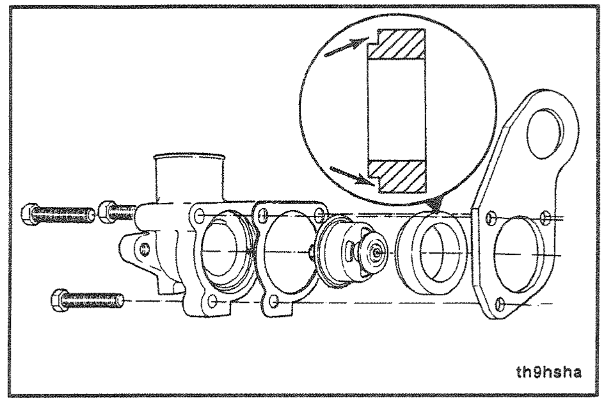
Thermostat - Installation

Position the thermostat as shown in the illustration.

"Package" the lifting bracket and thermostat gasket to the thermostat and thermostat housing.

Make sure the gasket is aligned with the capscrew holes. Install the capscrews and use your fingers to tighten.

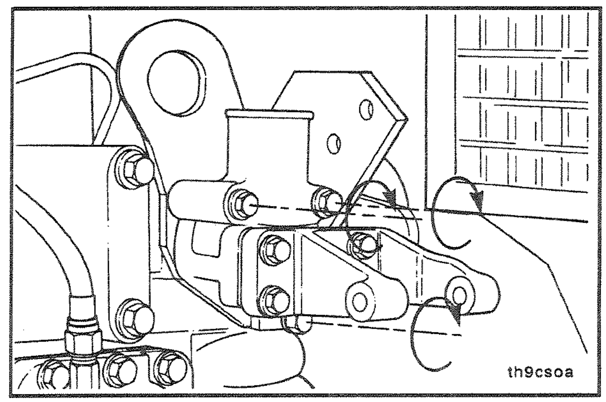
The notched end of the rubber thermostat seal points away from the cylinder head.



10 mm

Install the "package".

Torque Value: 24 N•m [18 ft-lb]

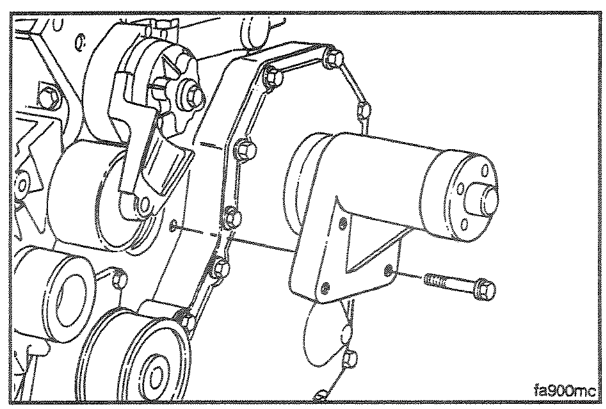


Fan Hub - Installation

10 mm

Install the fan hub.

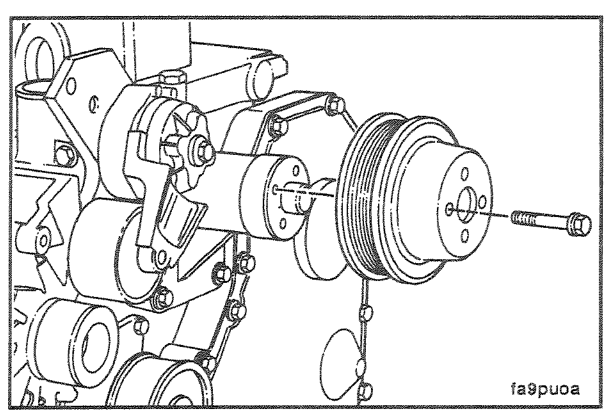
Torque Value: 24 N•m [18 ft-lb]

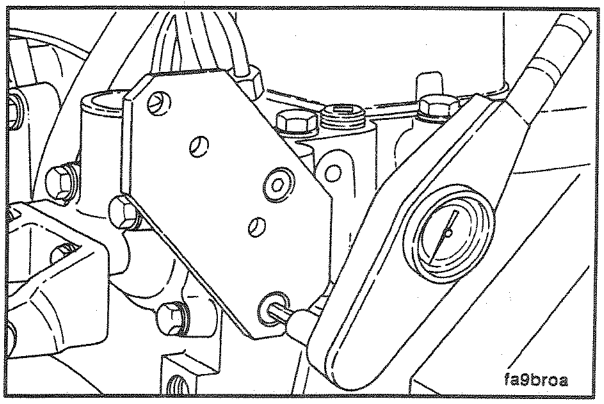


10 mm or 13 mm

Install the fan hub pulley.

Torque Value	
8 mm Capscrew	24 N•m [18 ft-lb]
10 mm Capscrew	43 N•m [32 ft-lb]





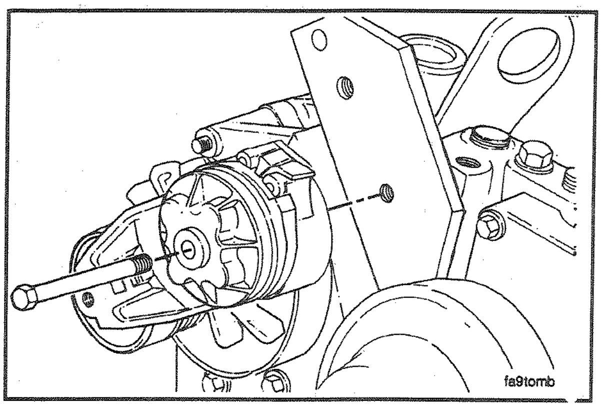
Belt Tensioner - Installation

5 mm Allen

Install the tensioner bracket to the cylinder head.

Tighten the socket head screws.

Torque Value: 24 N•m [18 ft-lb]

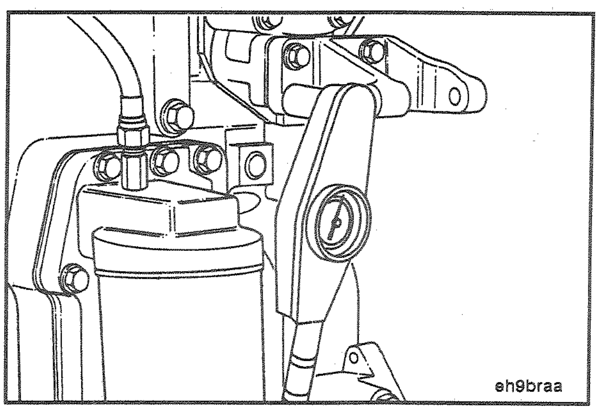


13 mm

Position the belt tensioner on the bracket and secure it with the capscrew.

Torque Value: 43 N•m [32 ft-lb]

NOTE: Some tensioners can be bolted to two different locations on the bracket. Install into the location dictated by your requirement.

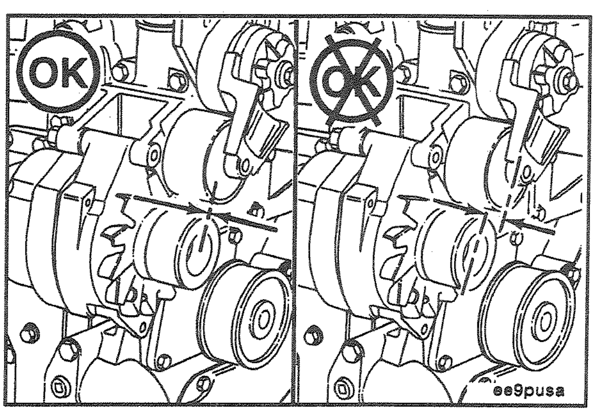


Alternator - Installation

10 mm

Assemble the alternator bracket to the thermostat housing.

Torque Value: 24 N•m [18 ft-lb]

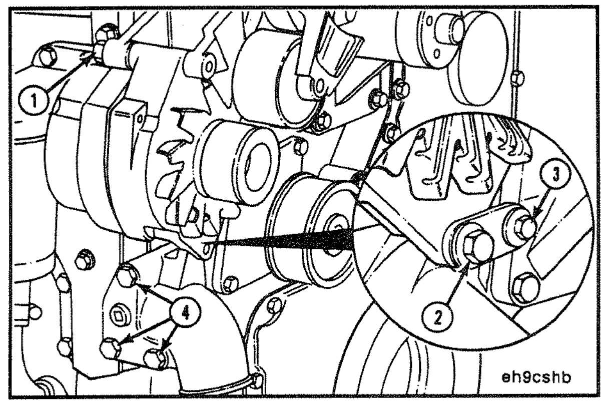


Check the alternator pulley visually or with a straight edge to make sure it is aligned with the other pulleys and is parallel to the front face of the block.

Tighten all capscrews in the following sequence:

1. Alternator-to-alternator bracket capscrew.
2. Lower brace-to-alternator capscrew.
3. Alternator-to-water inlet capscrew.
4. Water inlet-to-block capscrews.

NOTE: Wrench size and torque value is determined by the make and model of alternator. Refer to the Engine Component Torque Values.



Drive Belt - Installation

3/8 Inch Square Drive

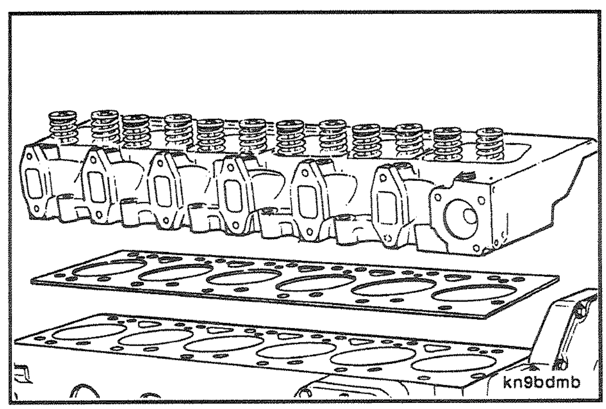
Lift the tensioner and install the belt.

Service Tip: If difficulty is experienced installing the drive belt (the belt seems too short), position the belt over the grooved pulleys first and then while holding the tensioner up, slide the belt over the water pump pulley.

Piston and Rings - Replacement (7-08)

Preparatory Steps:

- Drain the coolant.
- Remove the cylinder head. Refer to Procedure (7-07).

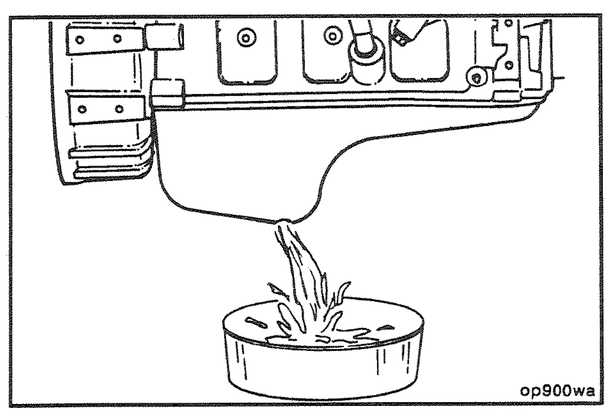


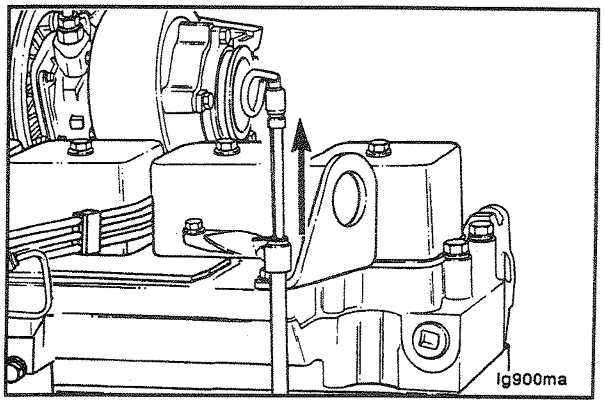
17 mm

Drain the lubricating oil.

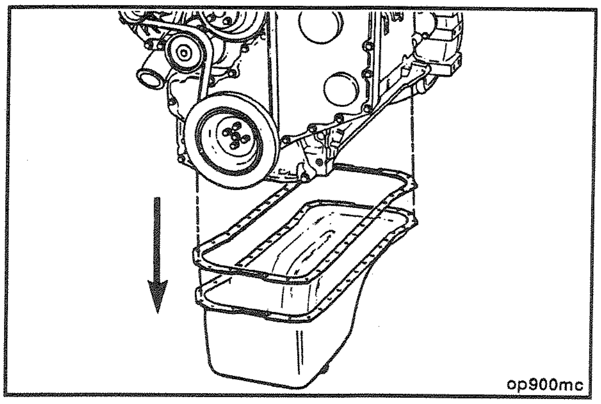
After lubricating oil is drained, install the drain plug and a new sealing washer.

Torque Value: 80 N•m [60 ft-lb]



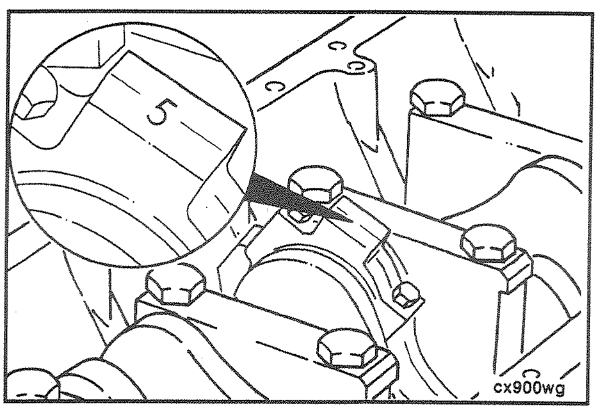


Remove the dipstick bayonet.



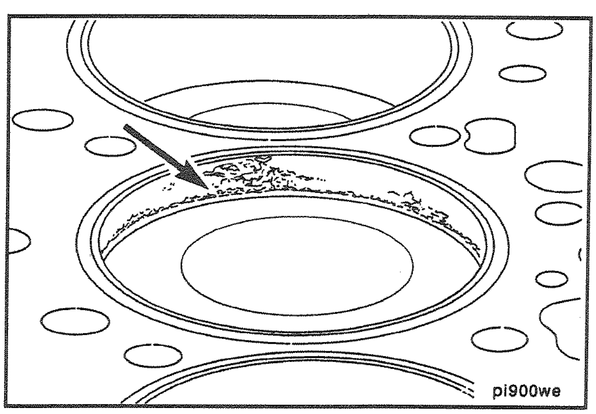
10 mm

Remove the lubricating oil pan.



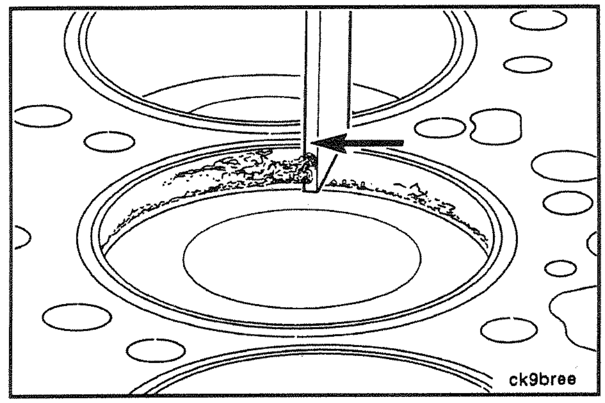
Piston and Connecting Rod Assemblies - Removal

Mark each connecting rod cap according to cylinder.

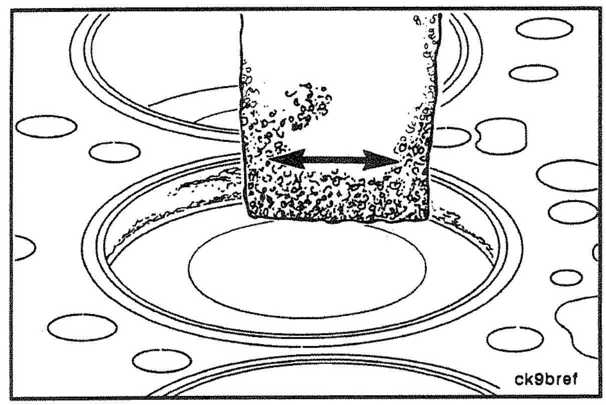


Rotate the crankshaft until the pistons are below the carbon deposits which are found above the ring travel area.

Use a scraper or a blunt edged instrument to loosen the carbon deposits. Do not damage the cylinder with the scraper.



Remove the remaining carbon with a Scotch-Brite® cleaning pad or equivalent.

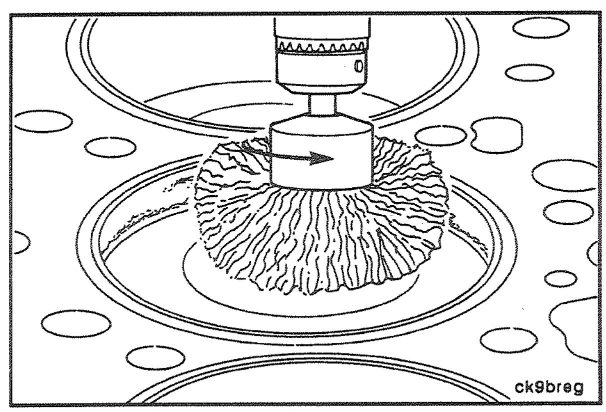


Warning: To prevent serious eye damage wear eye protection during this operation.

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

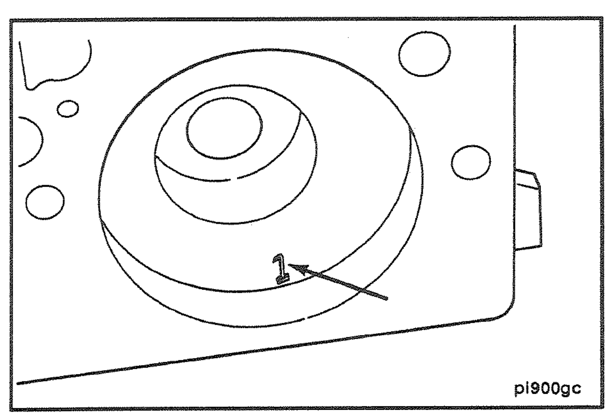
NOTE: An inferior quality wire wheel will lose steel bristles during operation, thus causing additional contamination.

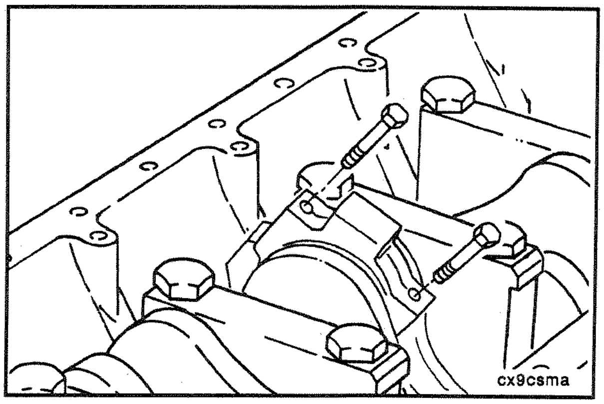
Do not use the steel wire wheel in the piston travel area. Operate the wheel in a circular motion to remove the deposits.



Mark each piston according to the cylinder.

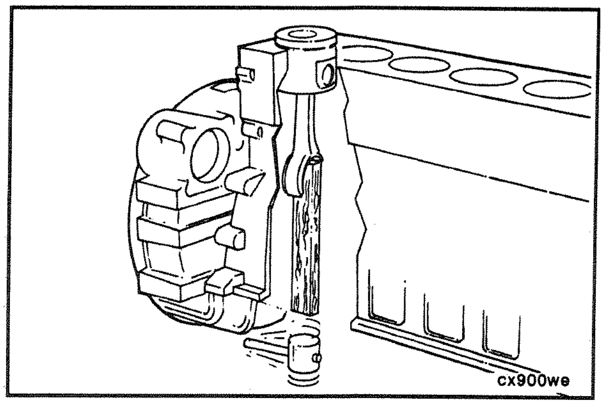
NOTE: On pistons with anodized coatings, do not stamp on the anodized coating or on the outer rim.



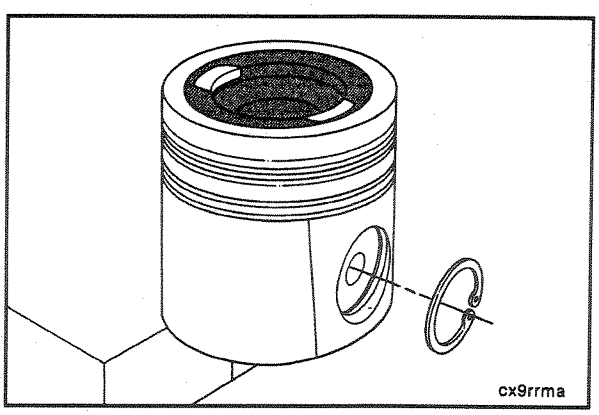


12 mm

Remove the capscrews, connecting rod cap and connecting rod bearings.

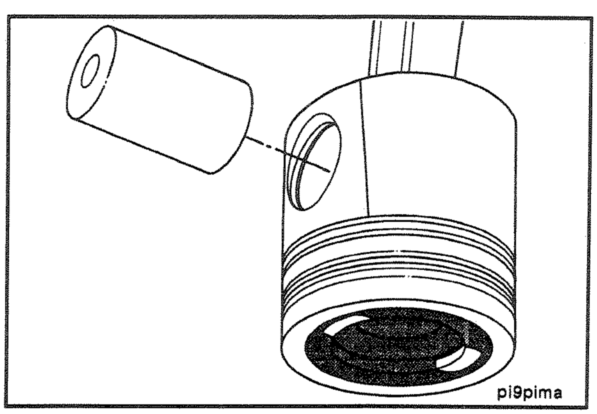


Push the connecting rod and piston assembly out of cylinder bore. Care must be taken not to mutilate the connecting rod or bearing.



Piston and Connecting Rod - Disassembly

Remove the retaining rings.

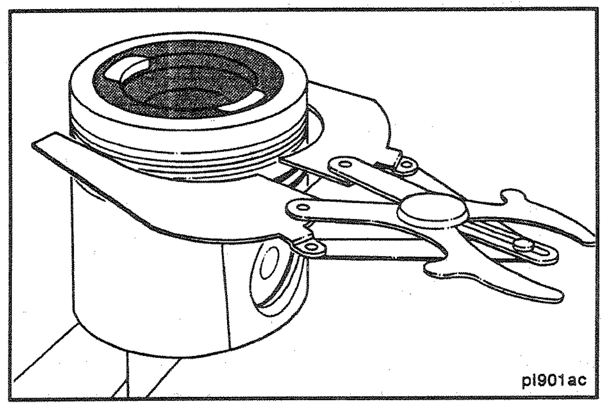


Remove the piston pin.

Heating the piston is not required.

Piston Ring Expander Part No. 3823137

Remove the piston rings.

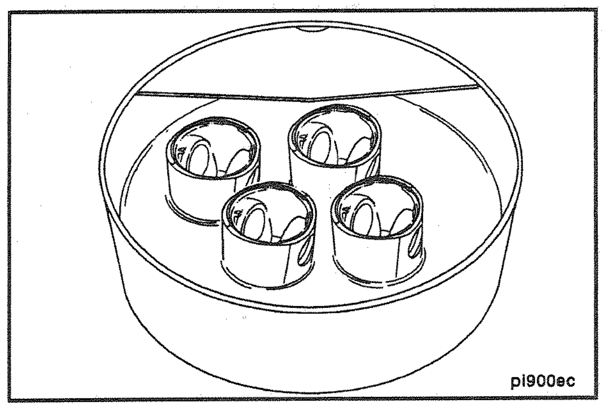


Piston, Pin and Connecting Rod - Cleaning

Caution: Do not use the bead blast method to clean the piston. The piston will be damaged by blast material embedded in the aluminum.

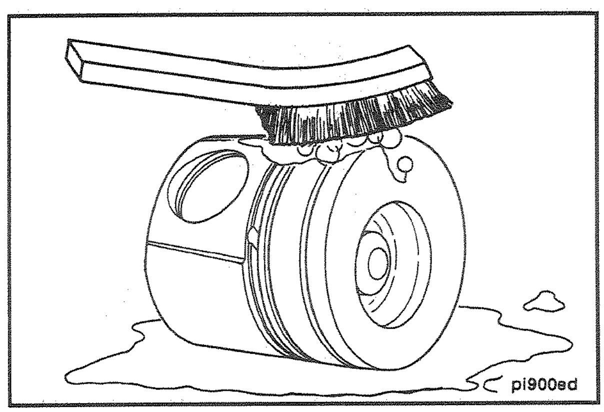
Soak the pistons in cold parts cleaner.

Soaking the pistons overnight will usually loosen the carbon deposits.



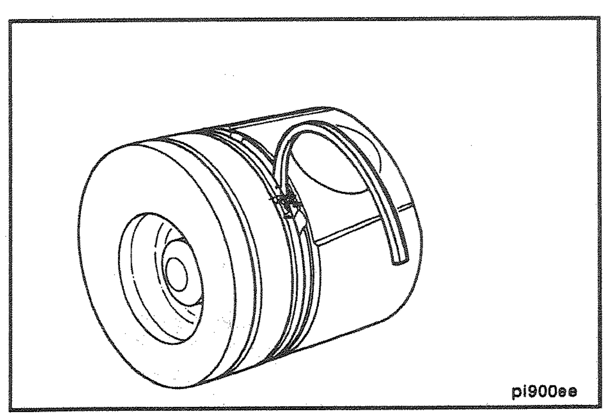
Caution: Do not clean the pistons and rods in an acid tank.

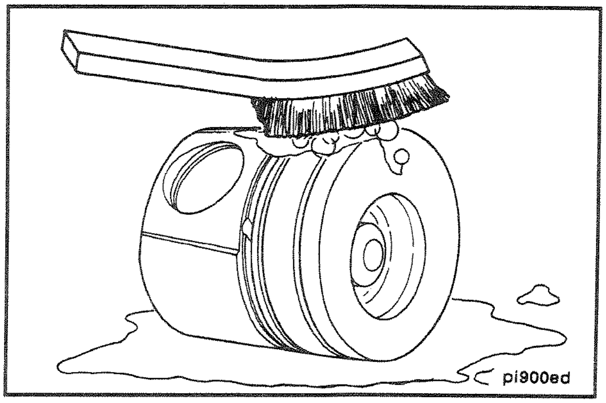
Wash the pistons and rods in a strong solution of laundry detergent in hot water.



Caution: Do not use a ring groove cleaner and be sure not to scratch the ring sealing surface in the piston groove.

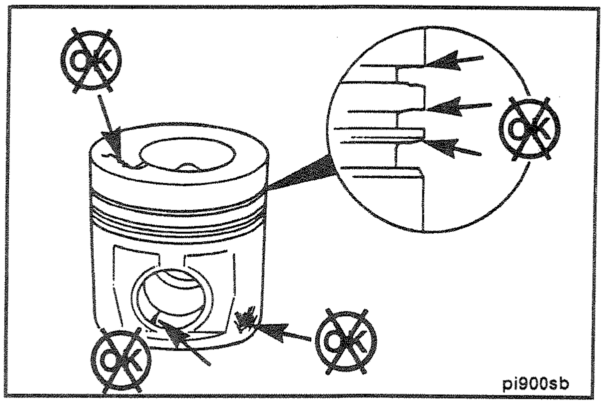
Clean the remaining deposits from the ring grooves with the square end of a broken ring.





Wash the pistons again in a detergent solution or solvent.

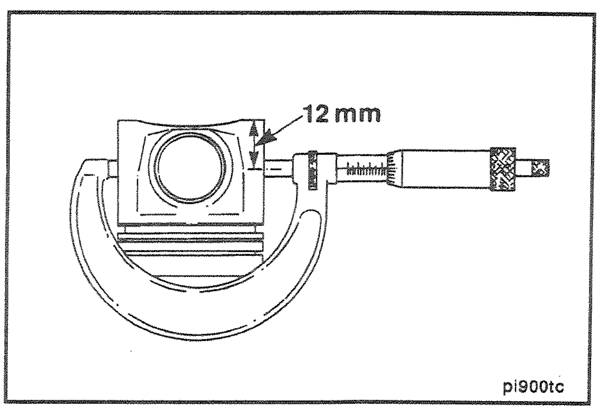
After rinsing, use compressed air to dry.



Piston Inspection (7-09)

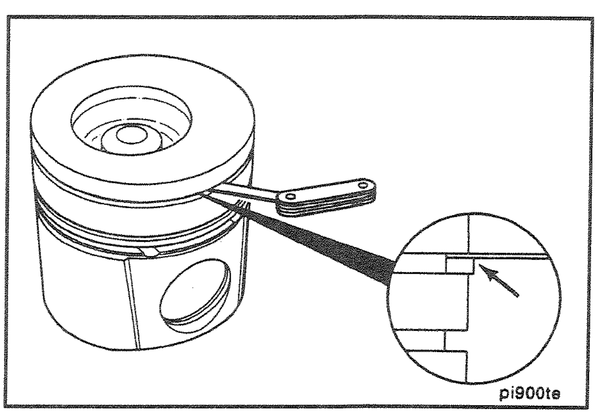
Inspect the piston for damage and excessive wear. Check the top, ring, grooves, skirt and pin bore.

NOTE: If severe piston damage has occurred, check the turbocharger and other exhaust components for damage from debris.



Measure the piston skirt diameter as illustrated.

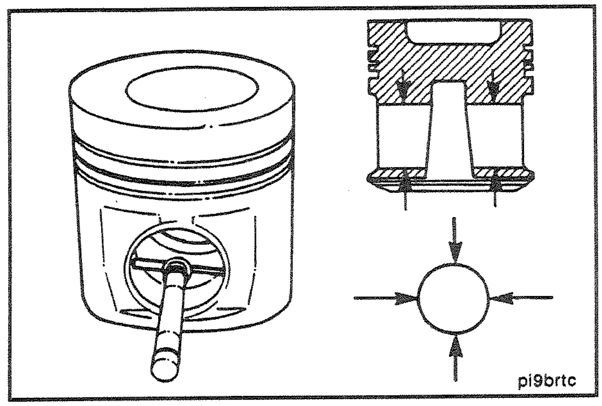
mm	Diameter	in
101.823	MIN	[4.0088]
101.887	MAX	[4.0107]



Use a new piston ring to measure the clearance in the ring groove.

Ring Clearance	mm		in
Top			
• (Turbocharged)	No Check Needed		
• (Naturally Aspirated)	0.075	MIN	[0.003]
	0.150	MAX	[0.0059]
Intermediate	0.075	MIN	[0.003]
	0.150	MAX	[0.0059]
Oil Control	0.040	MIN	[0.0016]
	0.130	MAX	[0.0051]

Measure the pin bore.

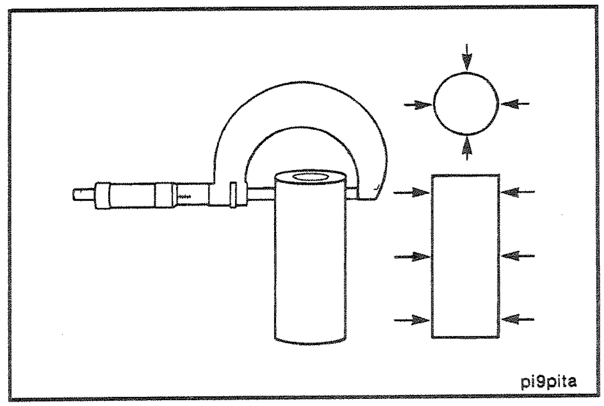


Diameter		
mm		in
40.006	MIN	[1.5750]
40.025	MAX	[1.5758]

Piston Pin - Inspection (7-10)

Inspect the piston pin for nicks, gouges and excessive wear.

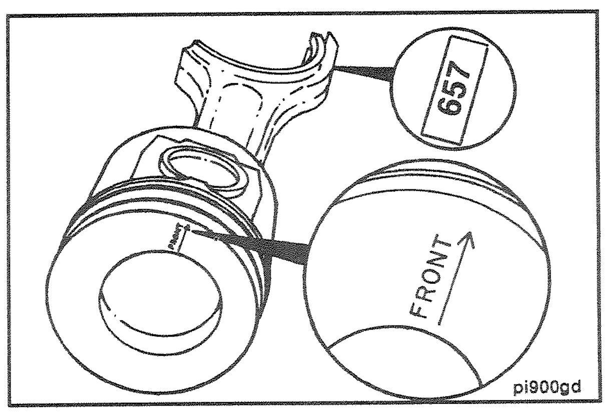
Measure the pin diameter.



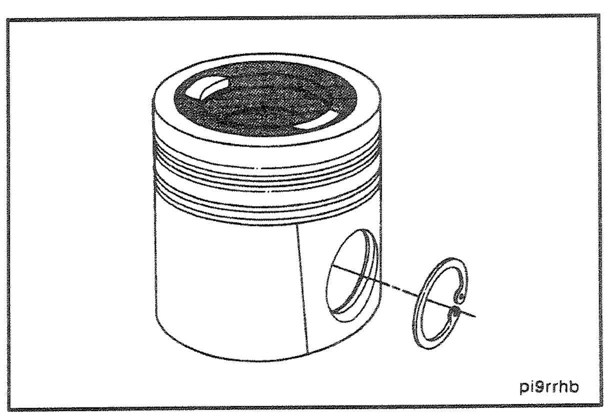
Diameter		
mm		in
39.990	MIN	[1.5744]
40.003	MAX	[1.5749]

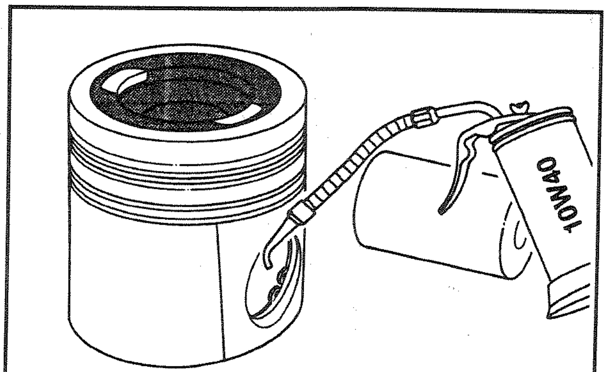
Piston and Connecting Rod - Assembly

Be sure "**front**" marking on piston and the numbers on the connecting rod and cap are oriented as illustrated.



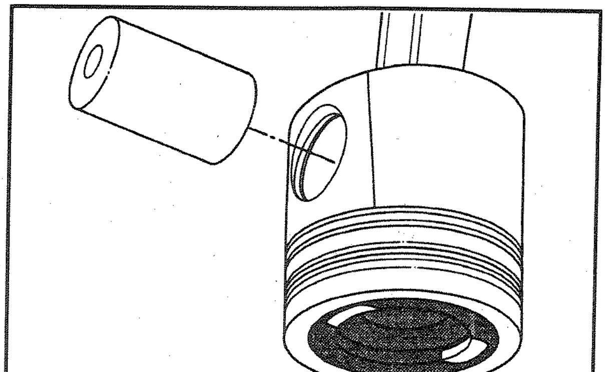
Install the retaining ring in the pin groove on the "front" side of the piston.





pi9piwa

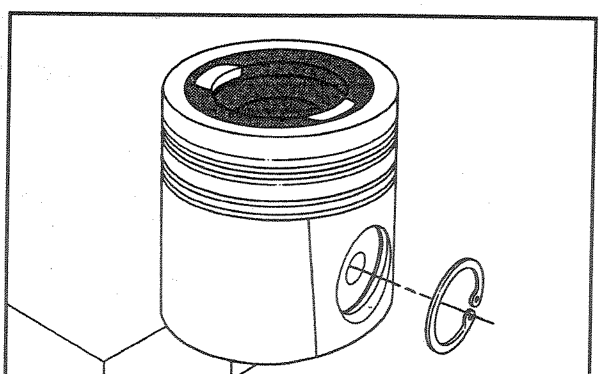
Lubricate the pin and pin bores with engine lubricating oil.



pi9pima

Install the pin.

Pistons do not require heating to install the pin, however, the pistons do need to be at room temperature or above.



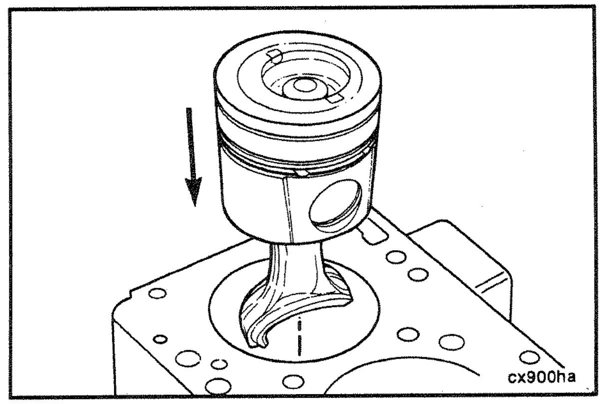
cx9rrma

Install the second retaining ring.

Piston Grading For '94 Automotive Applications Only

When rebuilding an engine with the original cylinder block, crankshaft, and pistons, make sure the pistons are installed in the original cylinder. If replacing the piston(s), make sure the replacement piston(s) are the same grade as the original piston. If a new cylinder block or crankshaft is used, the piston grading procedure Must be performed to determine the proper piston grade for each cylinder.

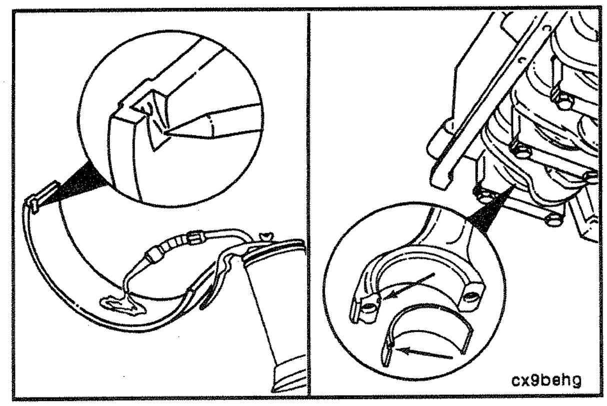
Install the connecting rod/piston assembly into the No. 1 cylinder without the rings installed.



NOTE: The connecting rod bearing shells must be installed in the original connecting rod and cap.

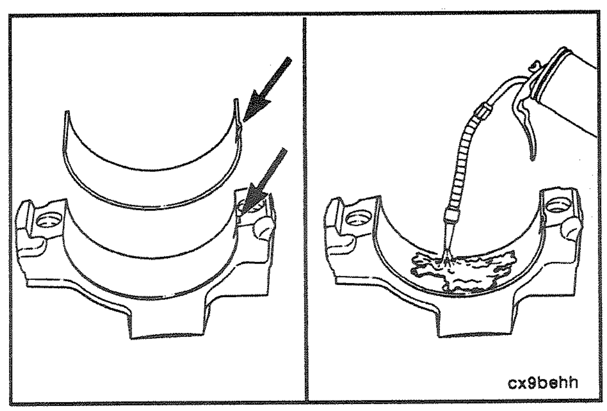
Install the upper bearing shell in the connecting rod with the tang of the bearing in the slot of the connecting rod.

Use clean lubricating oil to coat the inside diameter of the connecting rod bearing shell.



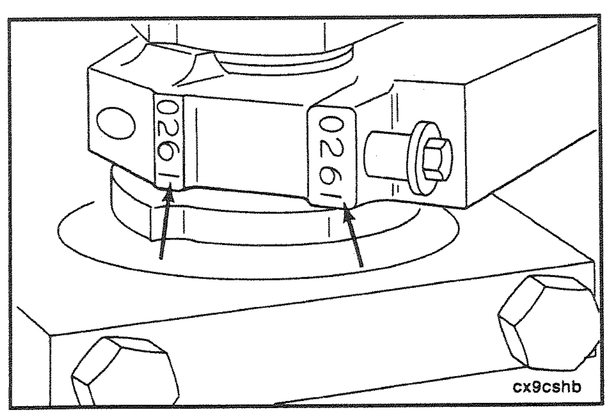
Install the bearing shell in the connecting rod cap with the tang of the bearing in the slot to the cap.

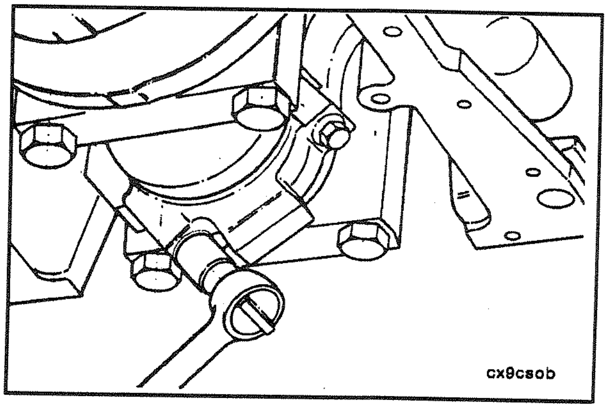
Use clean lubricating oil to coat the inside diameter of the bearing shell.



The four digit number stamped on the connecting rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

Install the connecting rod cap and capscrews to the connecting rod.

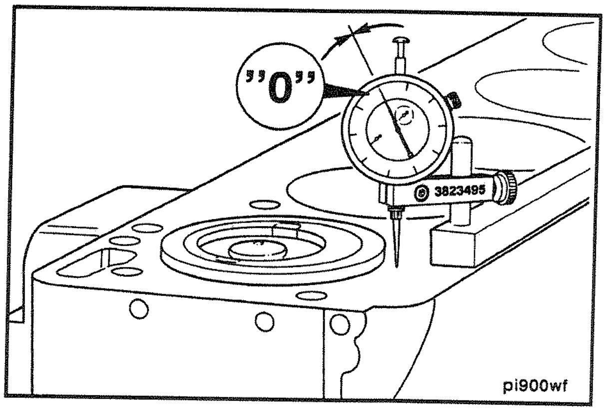




12 mm, Torque Wrench

Tighten the two capscrews.

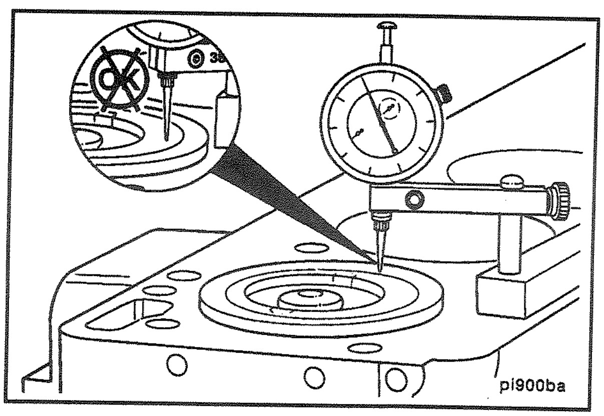
Torque Value: 35 N•m [26 ft-lb]



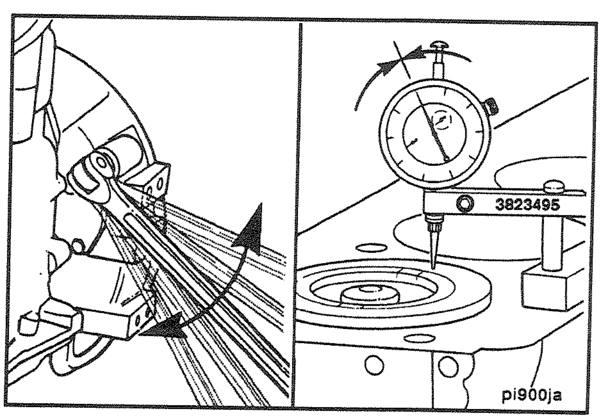
3823495 dial indicator

Use a fine grit home to remove any burrs from the cylinder block head deck.

Zero "0" the dial indicator to the cylinder block head deck.



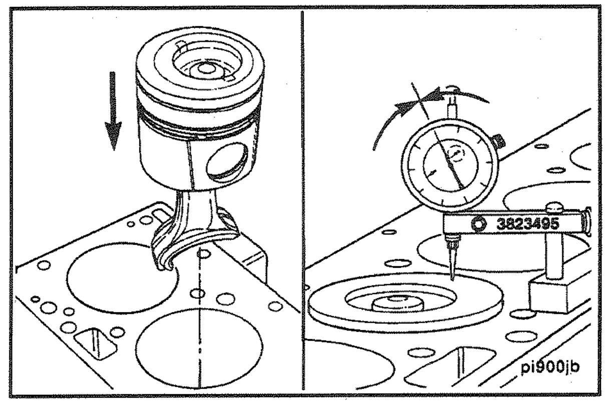
Move the dial indicator over the piston directly over the piston pin to eliminate any side-to-side movement. Do not place the indicate tip on the anodized area.



Rotate the crankshaft to top dead center (TDC). Rotate the crankshaft clockwise and counterclockwise to find the highest dial indicator reading.

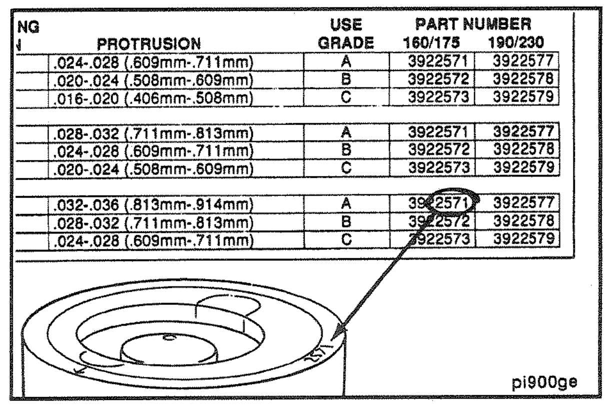
Record the reading.

Remove the piston/connecting rod assembly from the No. 1 cylinder and install the assembly into the No. 2 cylinder. Repeat the procedure for every cylinder using the same piston/connecting rod assembly.



Determine the grade of the piston being used by referring to the chart.

Four digits on top of piston are the last four digits of the part number.



NG	PROTRUSION	USE GRADE	PART NUMBER 160/175	190/230
	.024-.028 (.609mm-.711mm)	A	3922571	3922577
	.020-.024 (.508mm-.609mm)	B	3922572	3922578
	.016-.020 (.406mm-.508mm)	C	3922573	3922579
	.028-.032 (.711mm-.813mm)	A	3922571	3922577
	.024-.028 (.609mm-.711mm)	B	3922572	3922578
	.020-.024 (.508mm-.609mm)	C	3922573	3922579
	.032-.036 (.813mm-.914mm)	A	3922571	3922577
	.028-.032 (.711mm-.813mm)	B	3922572	3922578
	.024-.028 (.609mm-.711mm)	C	3922573	3922579

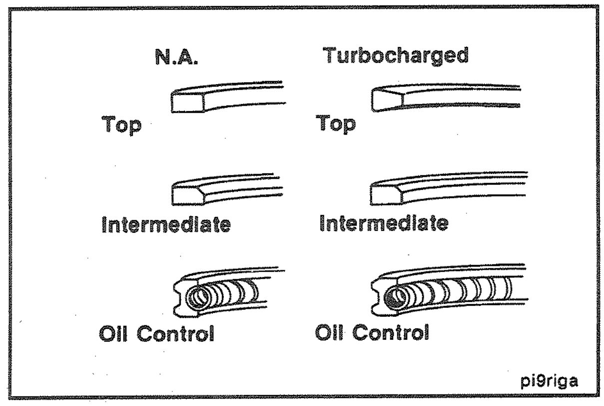
PISTON PROTRUSION

MEASURING PISTON	PROTRUSION	USE GRADE	PART NUMBER 160/175	PART NUMBER 190/230
A	.024-.028 (.609mm-.711mm)	A	3922571	3922577
A	.020-.024 (.508mm-.609mm)	B	3922572	3922578
A	.016-.020 (.406mm-.508mm)	C	3922573	3922579
B	.028-.032 (.711mm-.813mm)	A	3922571	3922577
B	.024-.028 (.609mm-.711mm)	B	3922572	3922578
B	.020-.024 (.508mm-.609mm)	C	3922573	3922579
C	.032-.036 (.813mm-.914mm)	A	3922571	3922577
C	.028-.032 (.711mm-.813mm)	B	3922572	3922578
C	.024-.028 (.609mm-.711mm)	C	3922573	3922579

The specification for Piston Protrusion is 0.024 to 0.028 inch.

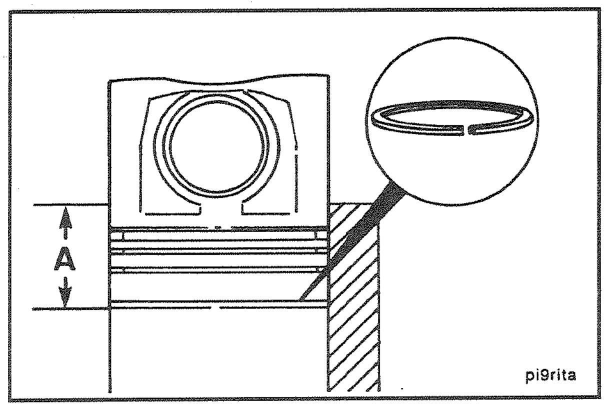
Piston Ring Gap - Checking

The top ring for a turbocharged engine is not the same as the top ring for a naturally aspirated engine.



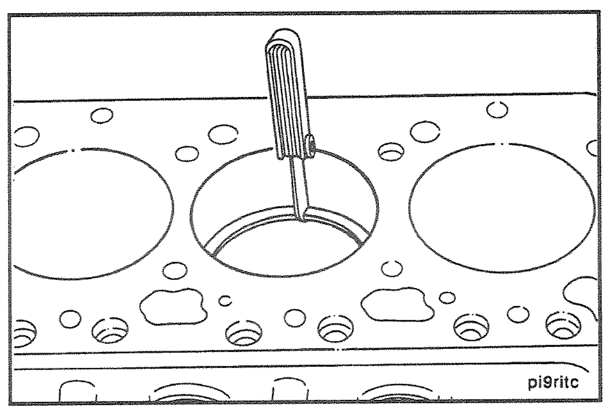
Position each ring in the cylinder and use a piston to square it with the bore.

A = 89 mm [3.5 in].



Use a feeler gauge to measure the gap.

	Ring Gap		
	mm		in
Top	0.40	MIN	[0.0160]
(Turbocharged)	0.70	MAX	[0.0275]
Top	0.25	MIN	[0.0100]
(N. Aspirated)	0.55	MAX	[0.0215]
Intermediate	0.25	MIN	[0.0100]
	0.55	MAX	[0.0215]
Oil Control	0.25	MIN	[0.0100]
	0.55	MAX	[0.0215]

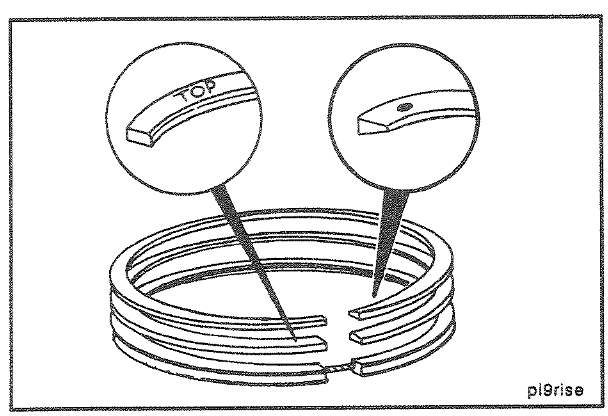


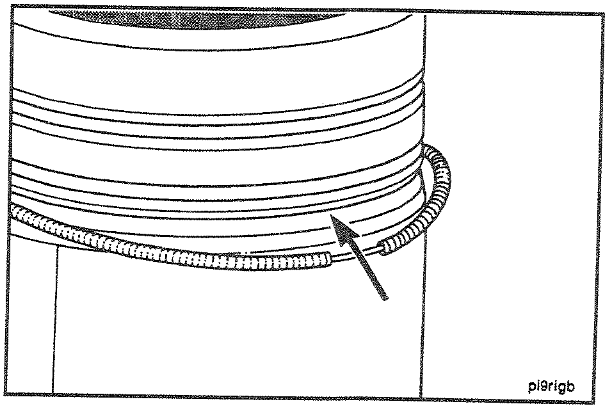
Piston Rings - Installation

Caution: If a ring expander tool is being used, be careful not to over expand the ring.

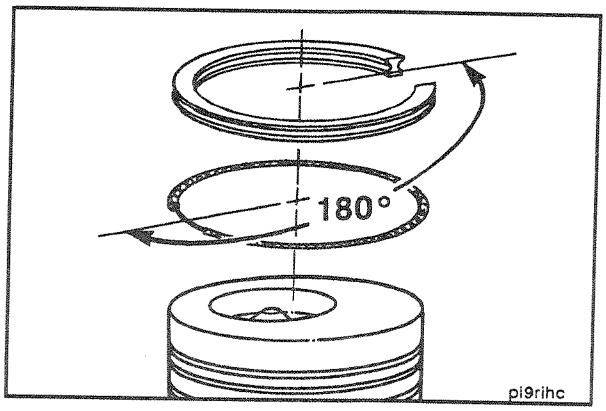
The top surface of the top and intermediate rings are identified as illustrated.

The oil control ring can be assembled with either side up.

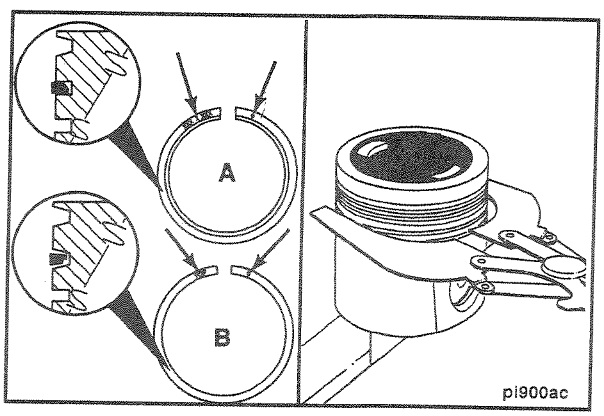




Position the oil ring expander in the control ring groove.

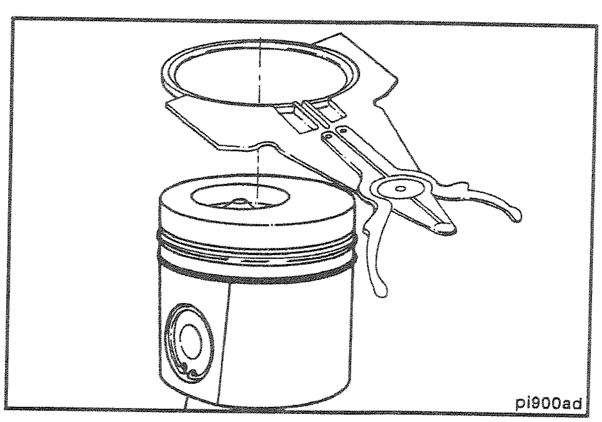


Install the oil control ring with the end gap 180° from the ends of the expander.



Piston Ring Expander, Part No. 3823137

Install the intermediate ring.



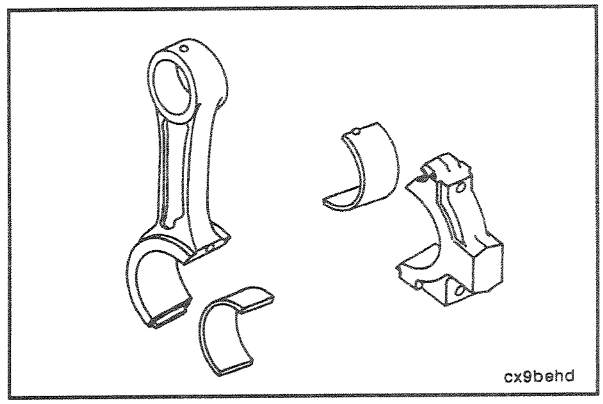
Piston Ring Expander, Part No. 3823137

The top ring for a turbocharged engine is not the same as the top ring for a naturally aspirated engine.

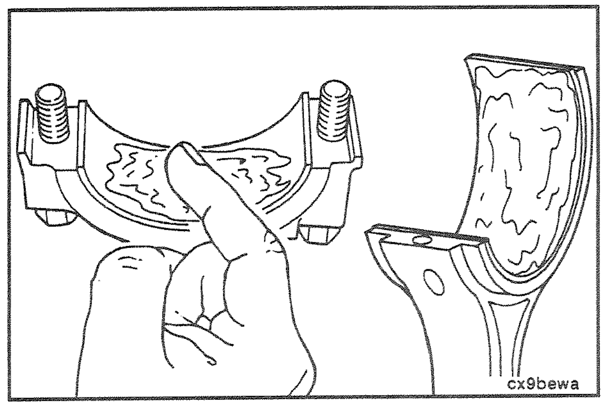
Install the top ring.

Piston and Connecting Rod Assemblies - Installation

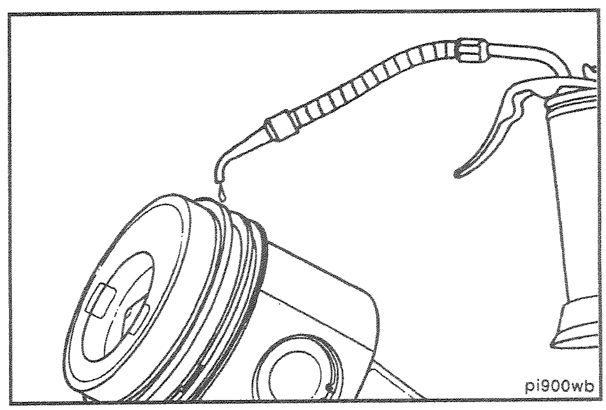
Install the bearing shells into both the connecting rod and the connecting rod cap. Make sure the tank on the bearing shells is in the slot of the connecting rod cap and connecting rod.



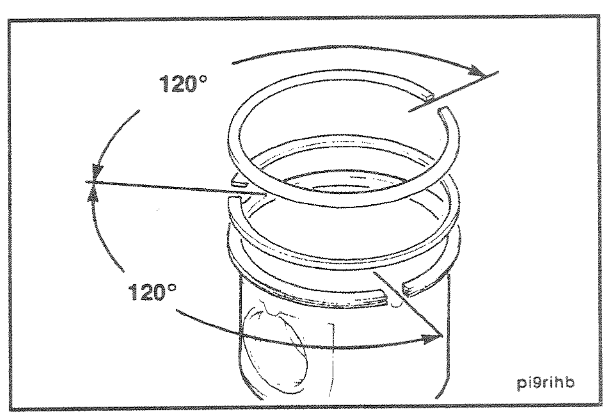
Lubricate the connecting rod bearings with a light film of Lubriplate 105®.

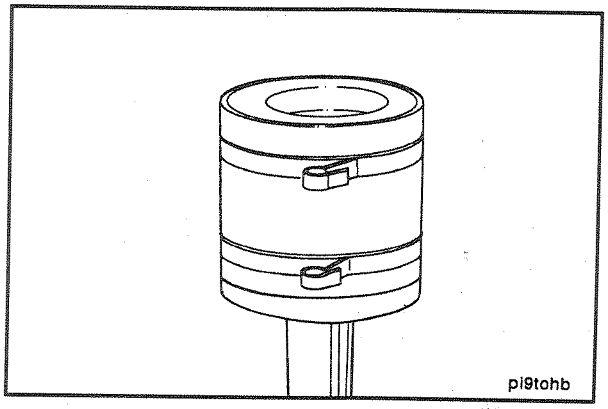


Lubricate the rings and piston skirts with clean engine lubricating oil.



Position the rings.

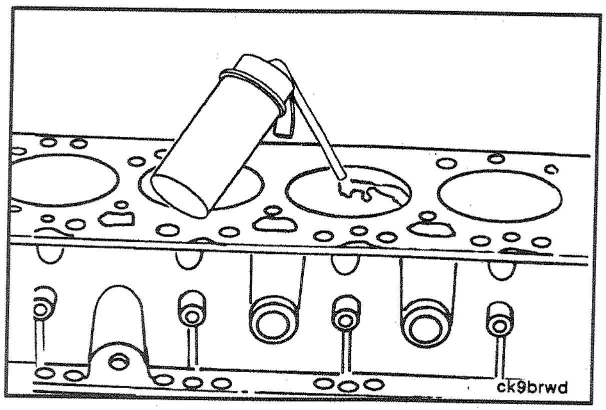




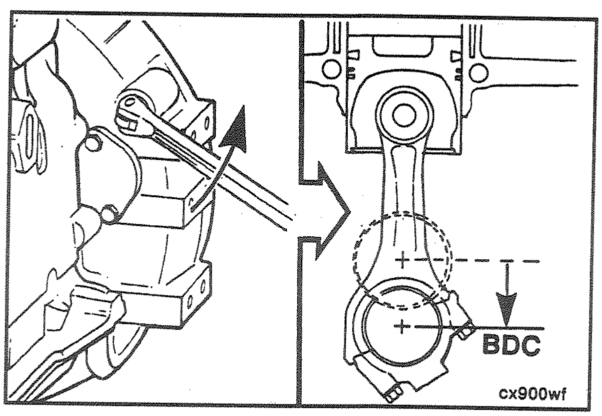
75-125 mm [3-5 in]

Caution: If using a strap type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.

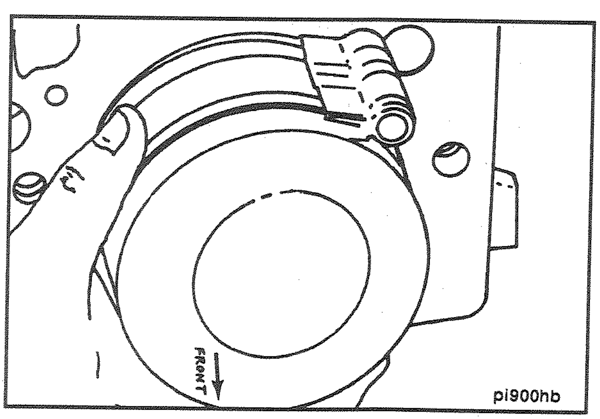
Compress the rings.



Lubricate the cylinder bore with clean engine lubricating oil.



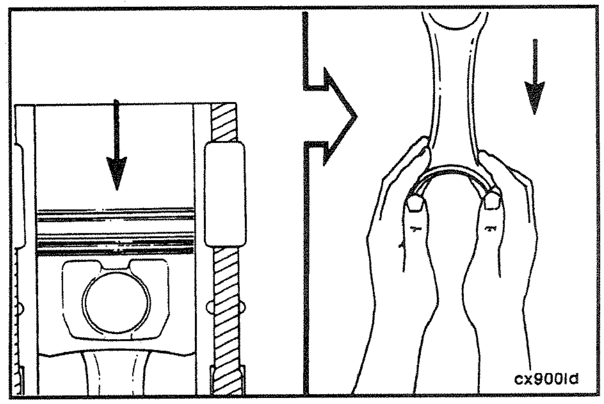
Position the connecting rod journal for the piston to be installed to bottom dead center (BDC).



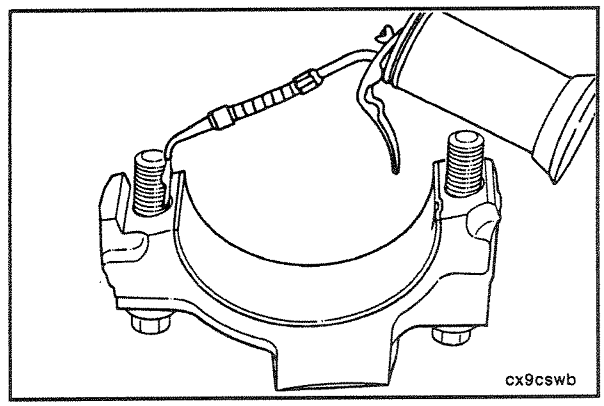
Take care not to damage the cylinder wall when inserting the connecting rod.

Position the piston and connecting rod assembly into cylinder bore with the word "front" on piston towards the front of the cylinder block.

Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

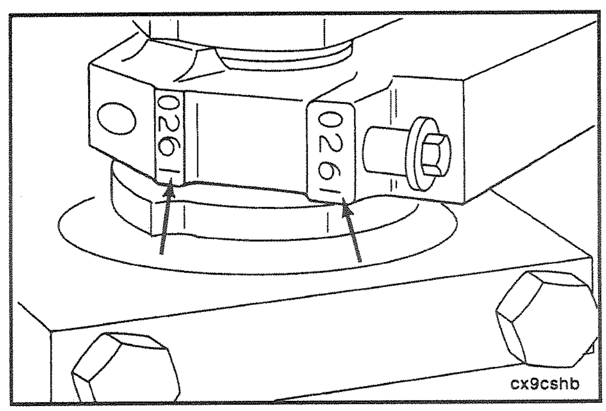


Lubricate the threads and underside of the connecting rod capscrew heads with engine lubricating oil.



Caution: The four digit number stamped on the rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

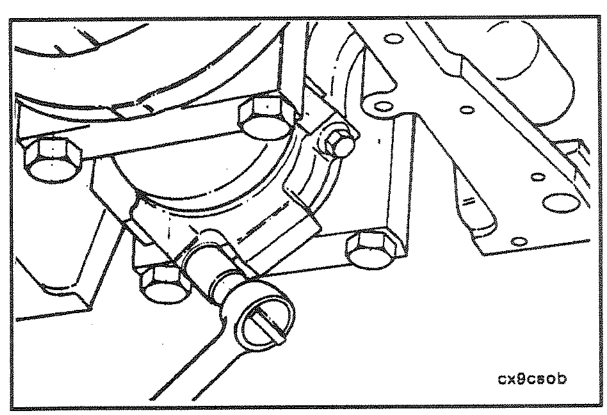
Install the connecting rod cap and capscrews to the connecting rod.

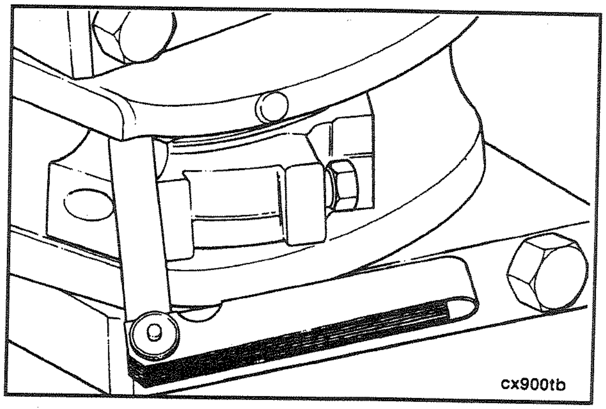


12 mm, Torque Wrench

Alternately, tighten the two capscrews.

Step	Torque Value
1	35 N•m [26 ft-lb]
2	70 N•m [51 ft-lb]
3	100 N•m [73 ft-lb]



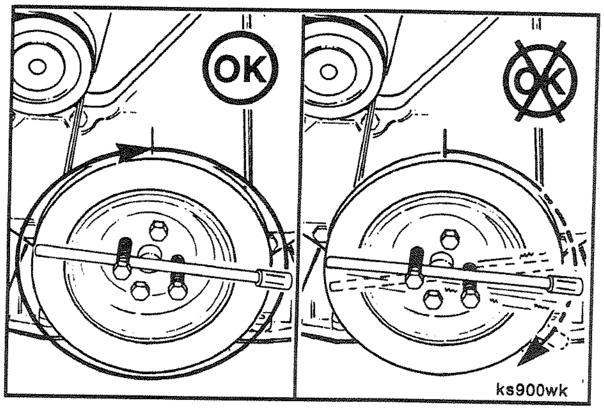


Measure the side clearance between the **connecting rod** and **crankshaft**.

Do not measure the clearance between the rod cap and crankshaft.

Side Clearance Limits

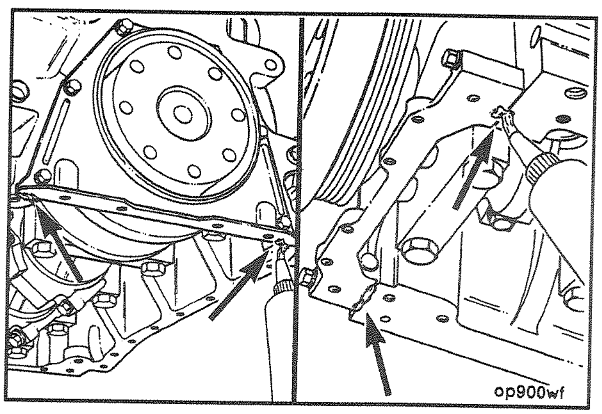
0.10 to 0.33 mm [0.004 to 0.013 inch]



Caution: The crankshaft must rotate freely.

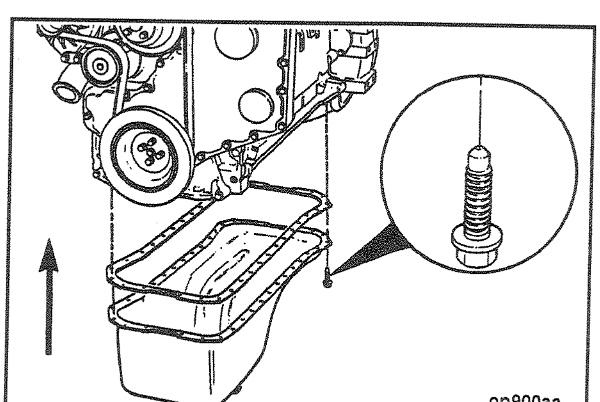
Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does not rotate freely, check the installation of the connecting rod bearings and the bearing size.

NOTE: If the connecting rod is not properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.



Oil Pan Sealing Surfaces - Sealants

Use Cummins Sealant, Part No. 3823494, to fill the joints between the lubricating oil pan rail, gear housing and rear cover.



Assemble the lubricating oil pan and capscrews as illustrated.

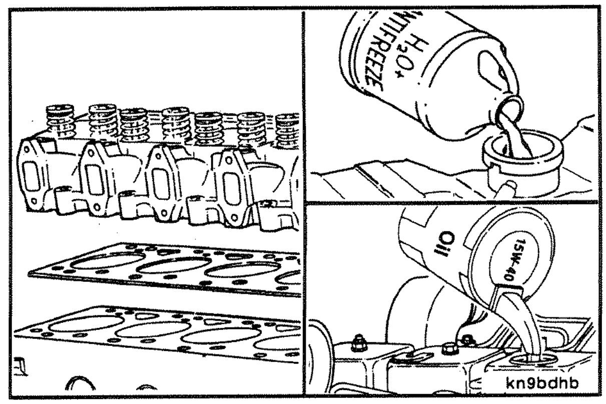
Torque Value: 24 N•m [18 ft-lb]

10 mm

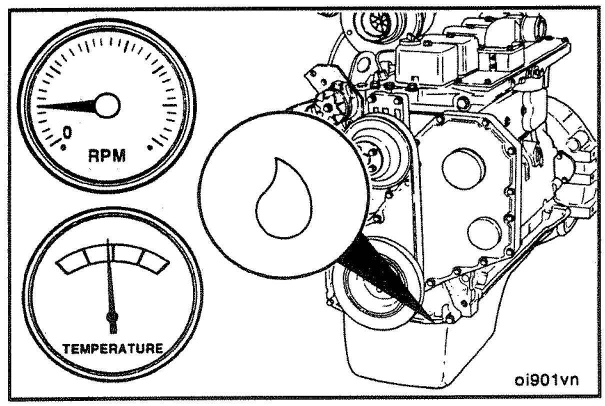
Install the cylinder head. Refer to Procedure (7-44).

Fill the cooling system.

Fill the engine with lubricating oil.



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

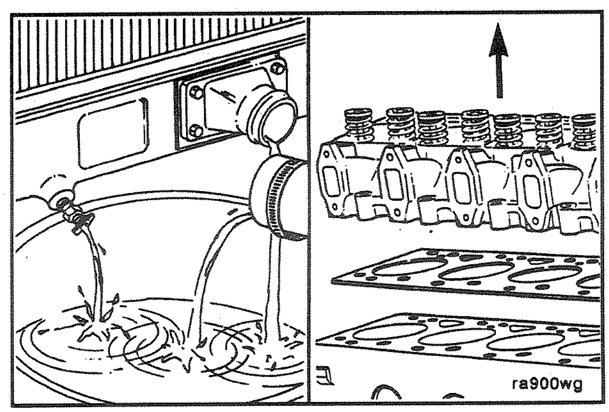


Connecting Rods - Replacement (7-11)

Removal

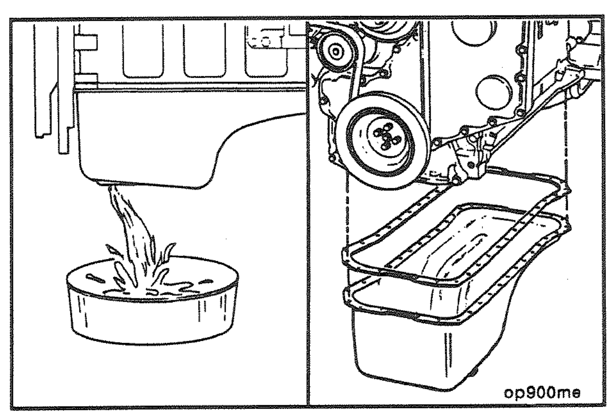
Drain the coolant.

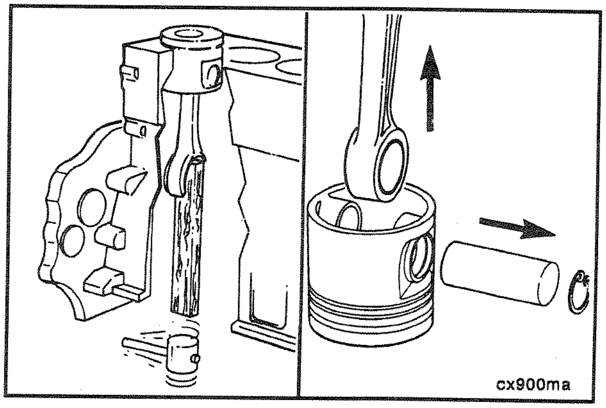
Remove the cylinder head. Refer to Procedure (7-07).



Drain the lubricating oil.

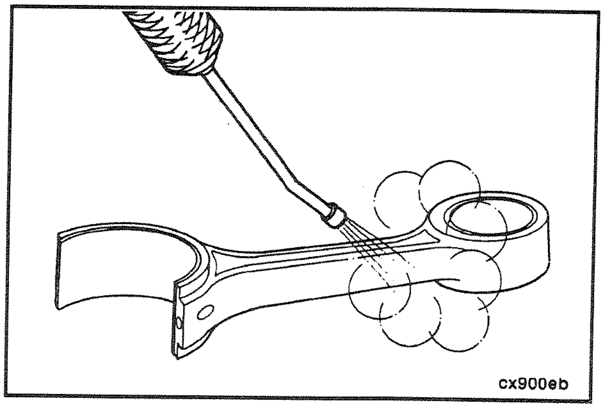
Remove the lubricating oil pan.





Remove the piston and connecting rod assemblies from the engine. Refer to Procedure (7-10).

Remove the pistons from the connecting rods. Refer to Procedure (7-10).

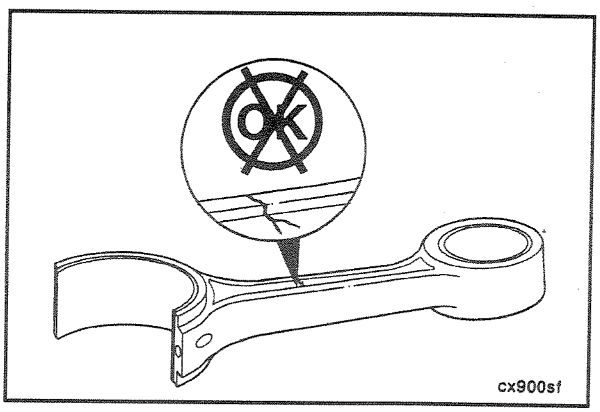


Cleaning and Inspection

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

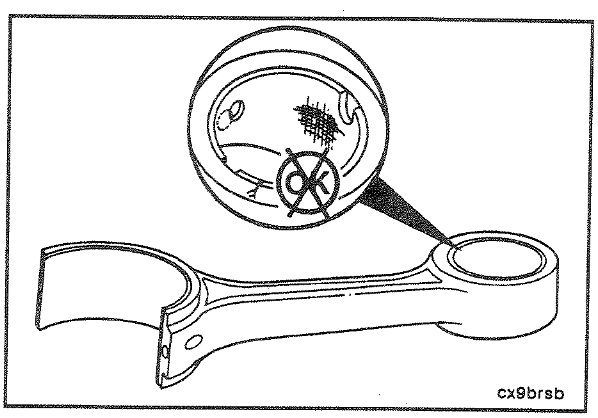
Use a nylon bristle brush to clean the oil drillings.

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



Inspect the connecting rods and connecting rod caps for damage.

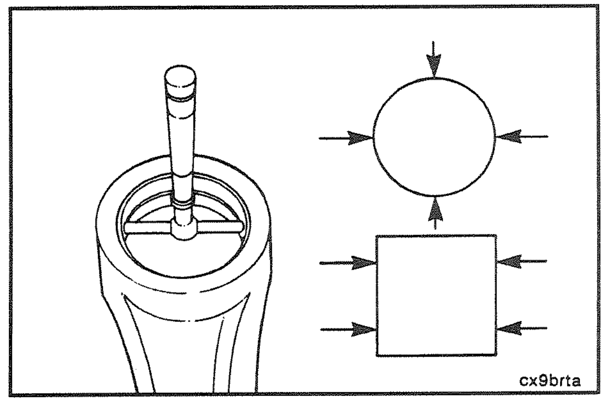
Replace the connecting rod if the ''I-beam'' is nicked or damaged.



Visually inspect the piston pin bore for damage or mis-alignment of the oil passage and bushing.

Measure the connecting rod piston pin bushing I.D.

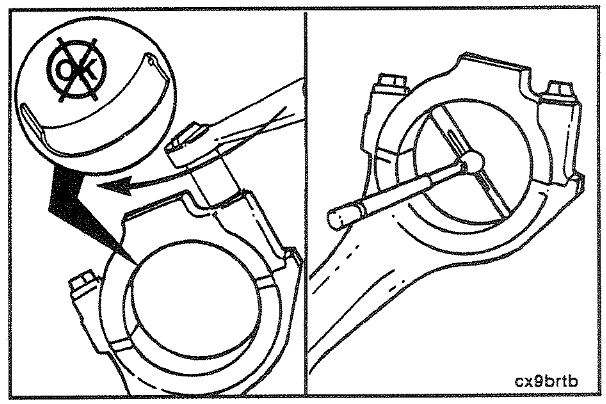
Piston Pin Bushing Diameter		
mm		in
40.019	MIN	1.5755
40.042	MAX	1.5765



Measure the connecting rod crank bore with the bearing shells removed and the capscrews torqued to 100 N•m [73 ft-lb].

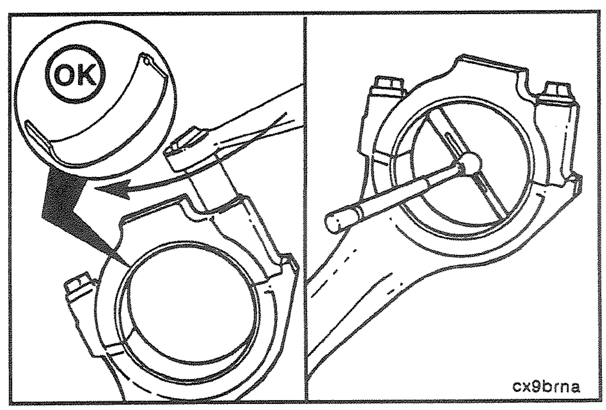
Connecting Rod Diameter (Bearings Removed)		
mm		in
72.987	MIN	2.8735
73.013	MAX	2.8745

If the crank bore measurements are not within specifications, replace the rod assembly.



Measure the connecting rod crankshaft bore inside diameter with the bearings installed (capscrews torqued to 100 N•m [73 ft-lb].

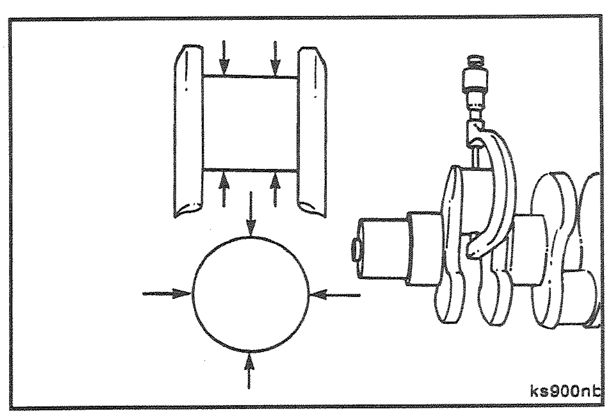
Connecting Rod Diameter (Bearings Installed)		
Standard	69.051-69.103 mm	[2.7185-2.7205 in]
.25 mm O/S	68.801-68.853 mm	[2.7087-2.7107 in]
.50 mm O/S	68.551-68.603 mm	[2.6989-2.7009 in]
.75 mm O/S	68.301-68.353 mm	[2.6890-2.6910 in]
1.00 mm O/S	68.051-68.103 mm	[2.6812-2.6832 in]

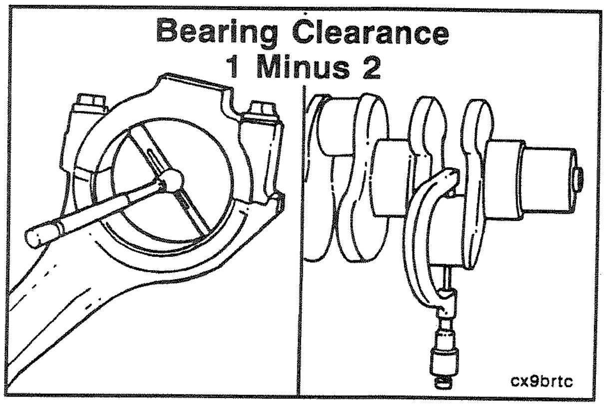


Measure the diameter of the rod journal on the crankshaft.

Crankshaft Rod Journal Diameter		
Standard	68.962-69.012 mm	[2.7150-2.7170 in]
.25 mm U/S	68.712-68.762 mm	[2.7052-2.7072 in]
.50 mm U/S	68.462-68.512 mm	[2.6953-2.6973 in]
.75 mm U/S	68.212-68.262 mm	[2.6855-2.6875 in]
1.00 mm U/S	67.962-69.012 mm	[2.6757-2.6777 in]

NOTE: If crankshaft rod journals are not within the given specifications, the crankshaft must be removed and reground. Refer to Bulletin No. 3810234.

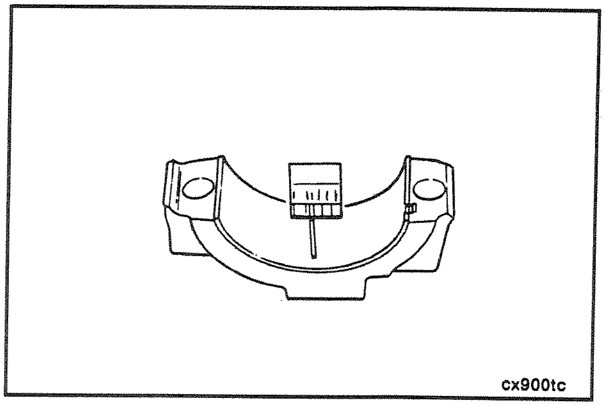




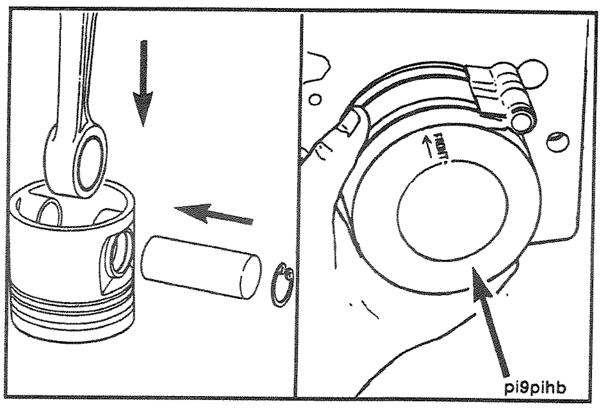
Bearing clearance = rod inside diameter (with bearing) minus crankshaft journal diameter.

Bearing Clearance

mm		in
.038	MIN	.0015
.116	MAX	.0045



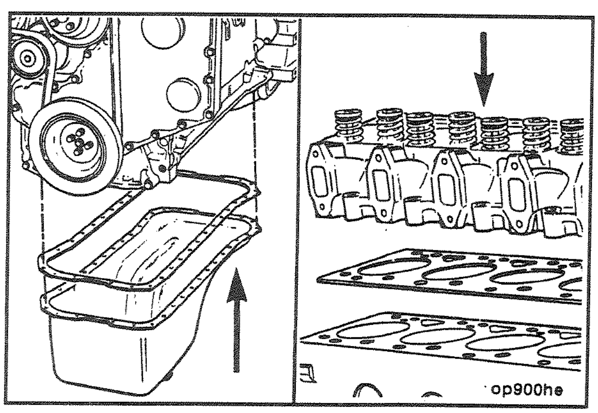
Bearing clearance can also be determined with plasti-gauge during engine assembly.



Installation

Install the pistons on the connecting rods. Refer to Procedure (7-10).

Install the pistons and connecting rod assemblies.

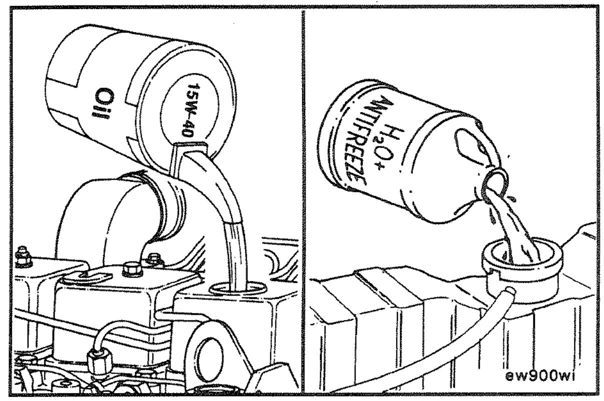


Install lubricating oil pan.

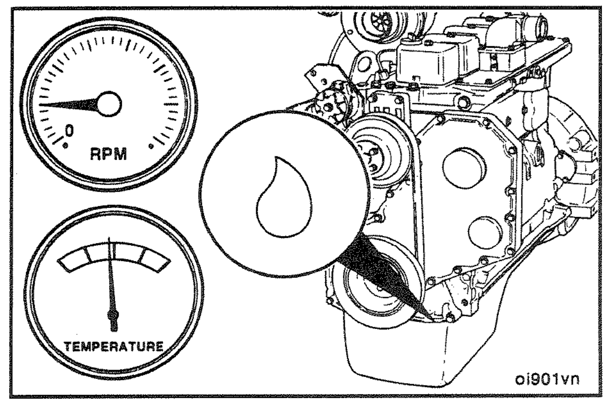
Install the cylinder head. Refer to Procedure (7-07).

Fill the lubricating oil pan.

Fill the cooling system.



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

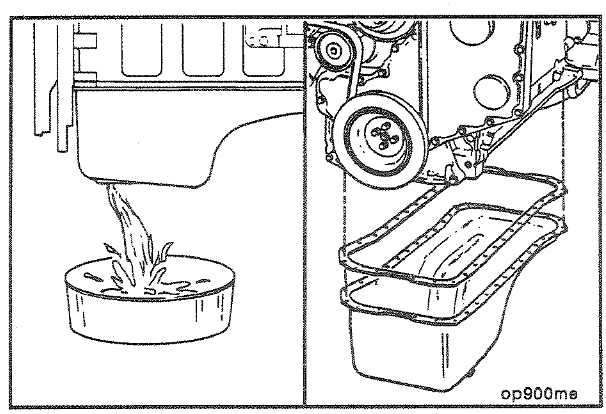


Connecting Rod Bearing - Replacement (7-12)

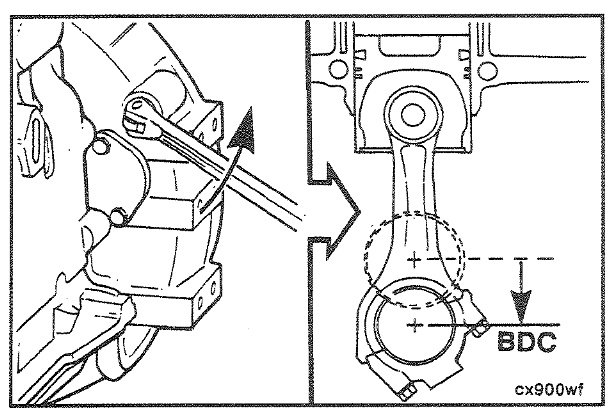
Removal

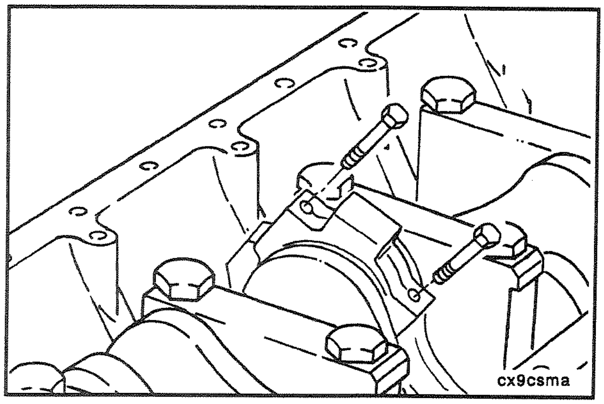
Drain the lubricating oil.

Remove the lubricating oil pan.



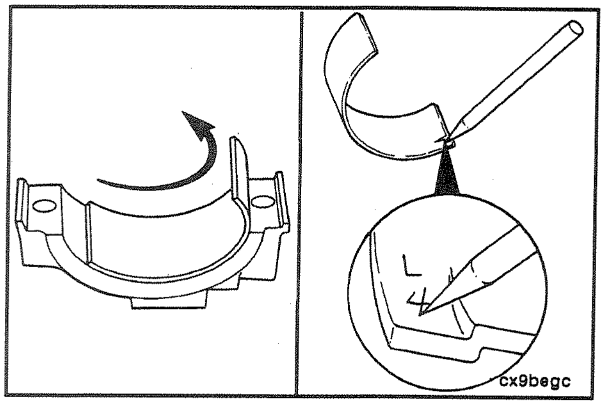
Rotate the crankshaft to position two of the connecting rods at "BDC" (Bottom Dead Center).



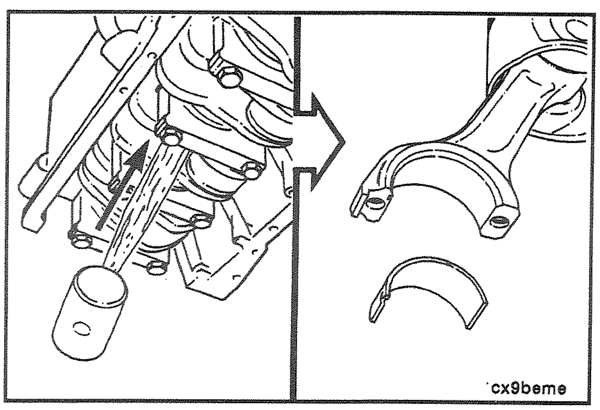


12 mm

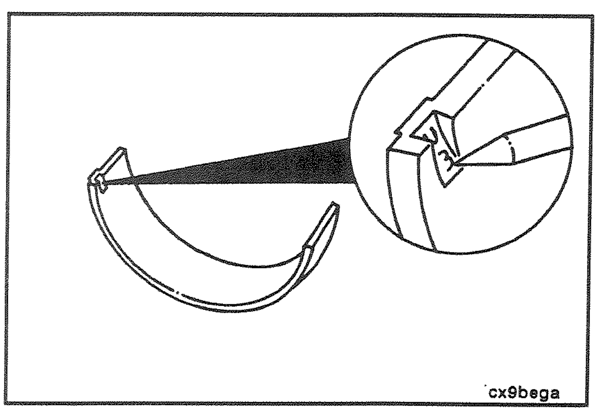
Remove the connecting rod capscrews and connecting rod caps.



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



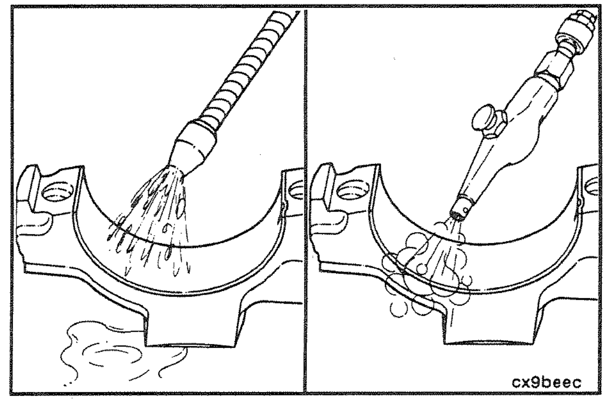
Push the connecting rod away from the crankshaft to allow the upper bearing shell to be removed.



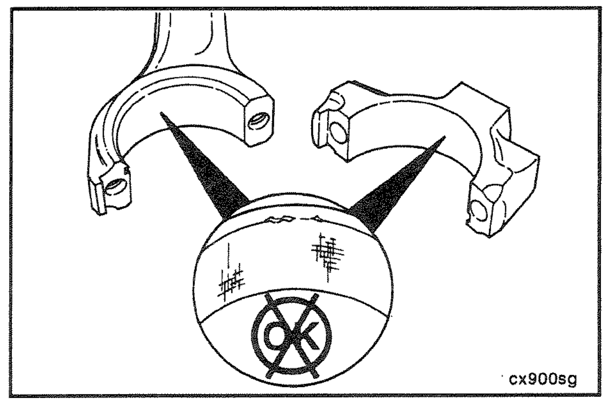
Remove the upper bearing shell and mark it with the letter "U" (upper) and the cylinder number it was removed from.

Cleaning and Inspection

Wash the bearing and connecting rod caps. Dry with compressed air.



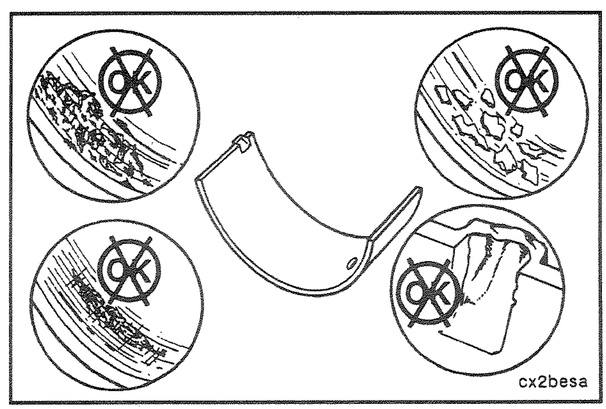
Visually inspect the connecting rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, or fretting.



Visually inspect the bearings for damage.

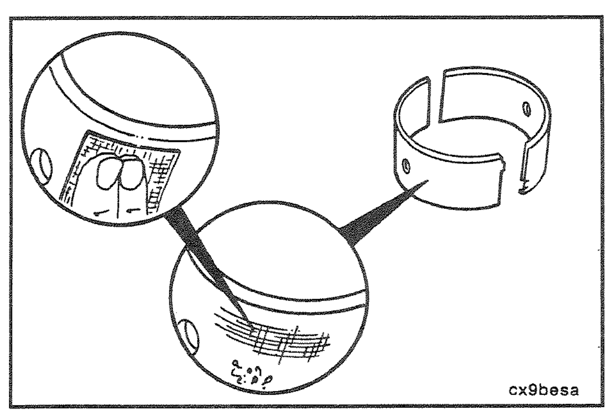
Replace any bearings with the following damage:

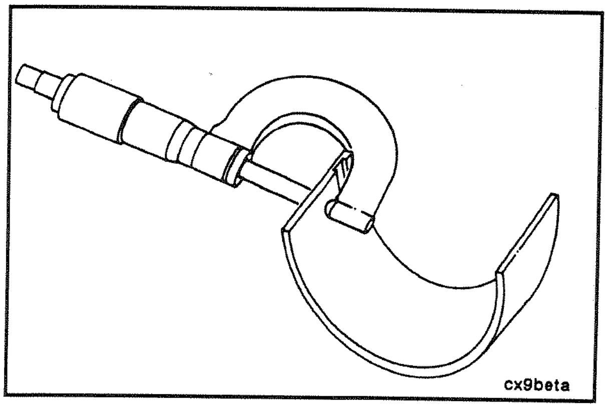
Pitting
Flaking
Corrosion
Lock tang damage
Scratches



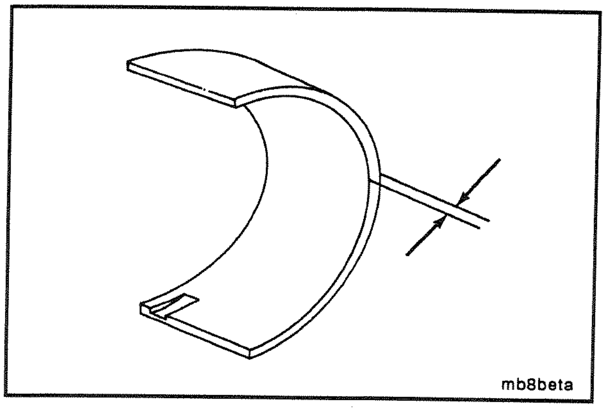
Visually inspect the bearing shell seating surface for nicks or burrs.

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

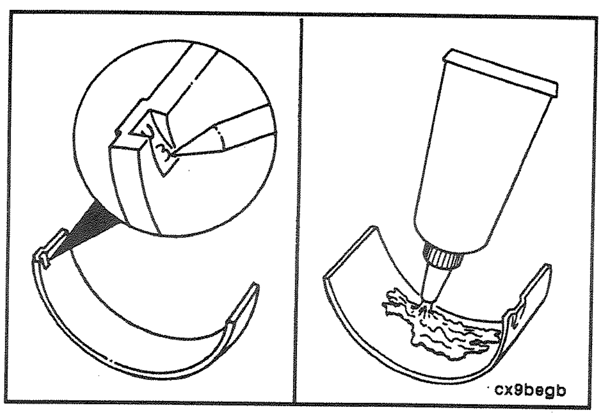




Use an outside diameter ball tipped micrometer to measure the connecting rod bearing thickness.



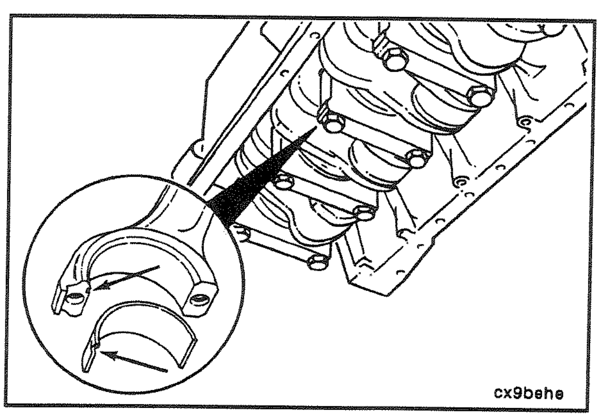
Connecting Rod Bearing Dimensions		
Standard	1.955-1.968 mm	[.0770-.0775 in]
.25 mm O/S	2.080-2.093 mm	[.0819-.0824 in]
.50 mm O/S	2.205-2.218 mm	[.0868-.0873 in]
.75 mm O/S	2.330-2.343 mm	[.0917-.0922 in]
1.00 mm O/S	2.455-2.468 mm	[.0967-.0972 in]



Installation

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

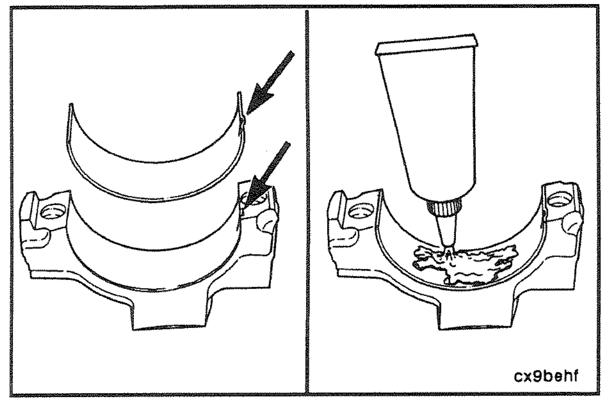
Use Lubriplate 105® or equivalent to coat the inside diameter of the bearing shell.



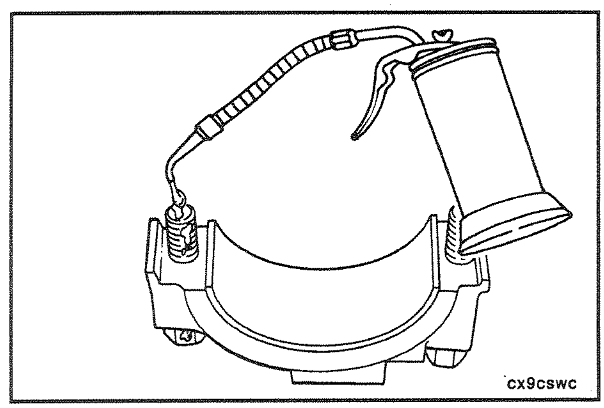
Install the upper bearing shell in the connecting rod with the tang of the bearing in the slot of the connecting rod.

Install the bearing shell in the connecting rod cap with the tang of the bearing in the slot of the connecting rod cap.

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

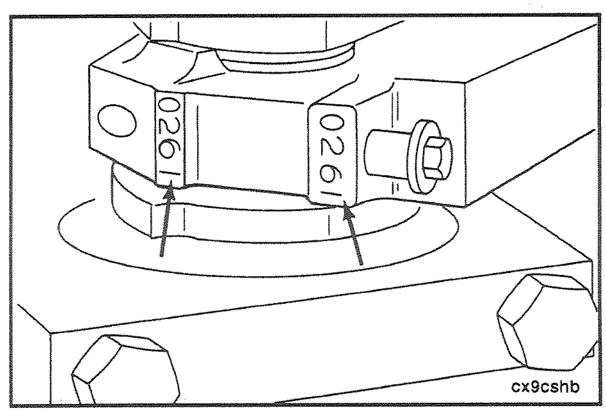


Use clean 15W-40 oil to lubricate the threads and underside of the connecting rod capscrew head.



The four digit number stamped on the connecting rod and connecting rod cap at the parting line must match and be installed on the lubricating oil cooler side of the engine.

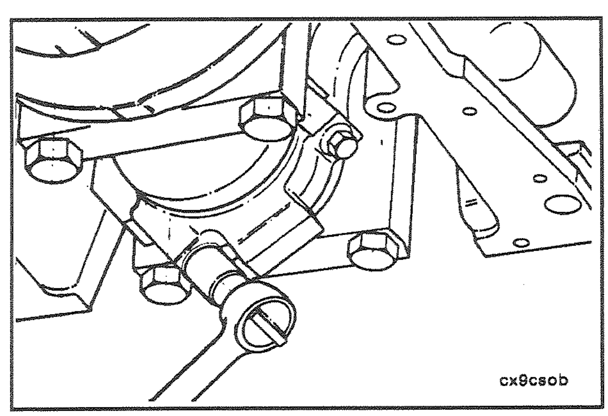
Install the connecting rod cap and capscrews to the connecting rod.

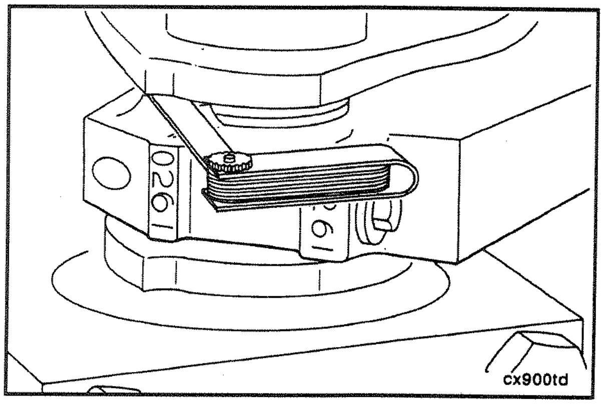


12 mm, Torque Wrench

Alternately tighten the two capscrews.

Step	Torque Value
1	35 N•m [26 ft-lb]
2	70 N•m [51 ft-lb]
3	100 N•m [73 ft-lb]

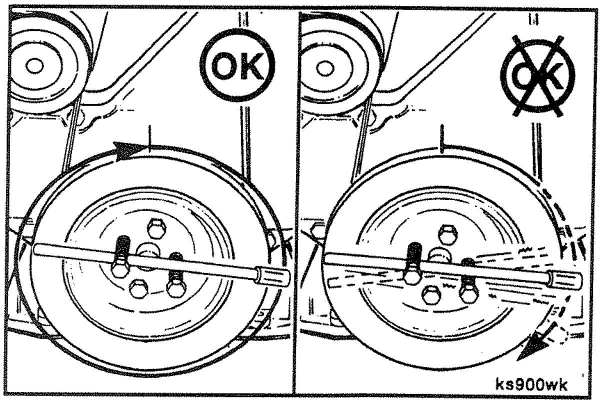




Measure the side clearance between the connecting rod and crankshaft.

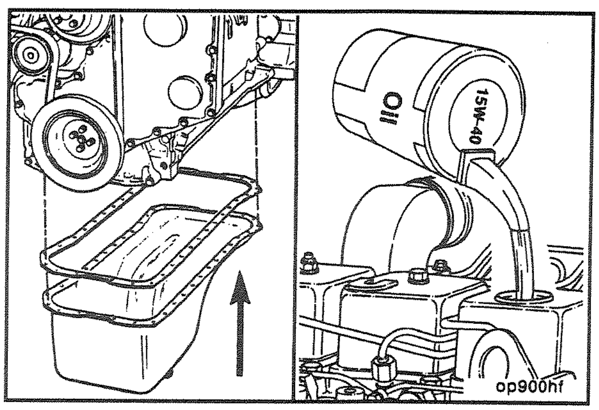
Do not measure the clearance between the **connecting rod cap** and crankshaft.

Side Clearance Limits	
0.10 to 0.33 mm	[.004 to .013 in]



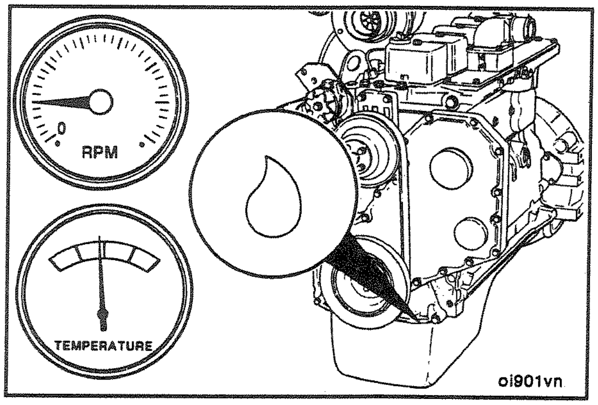
The crankshaft must rotate freely.

Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does not rotate freely, check the installation of the connecting rod bearings and bearing size.



Install the lubricating oil pan.

Fill the lubricating oil pan.



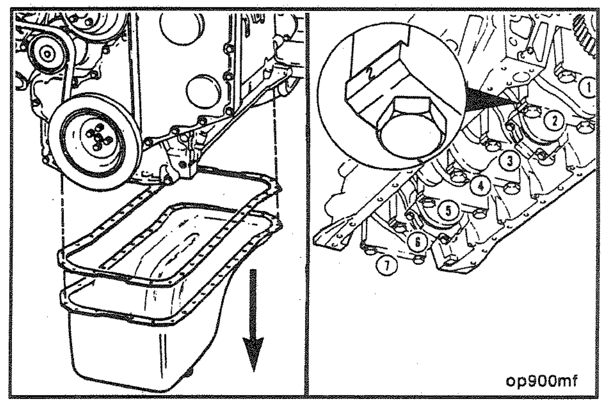
Operate the engine to normal operating temperature and check for leaks.

Main Bearing - Replacement (7-13)

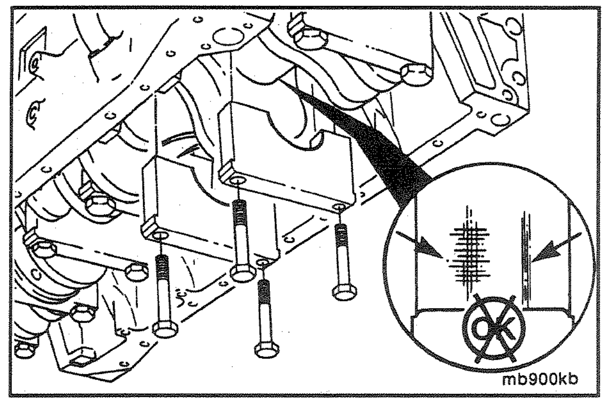
Main Bearing Preliminary Inspection

Drain the lubricating oil and remove the lubricating oil pan.

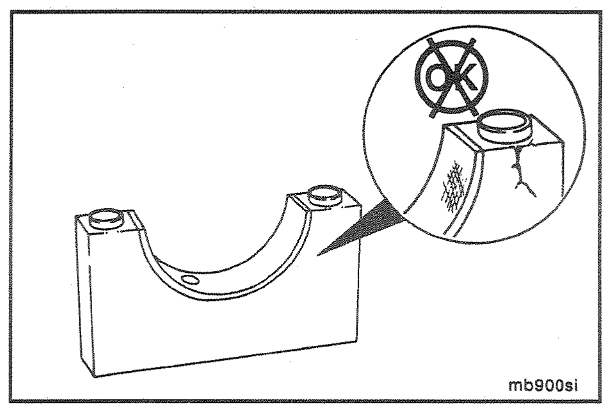
NOTE: Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap.



Perform a visual inspection of the main bearings and crankshaft journals. Remove the No. 2 and 3 caps and check the crankshaft journals for signs of overheat, deep scratches or other damage. If there is no damage, there is no need to pull the other main bearing caps at this time.

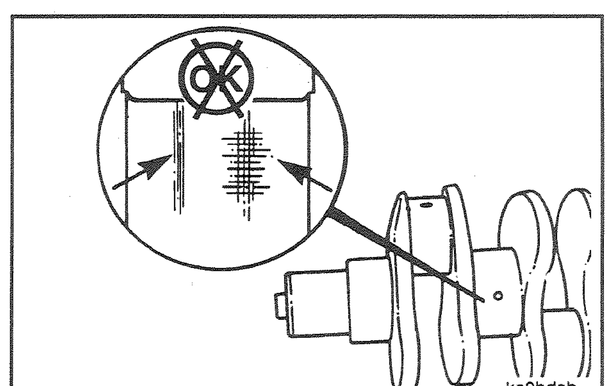


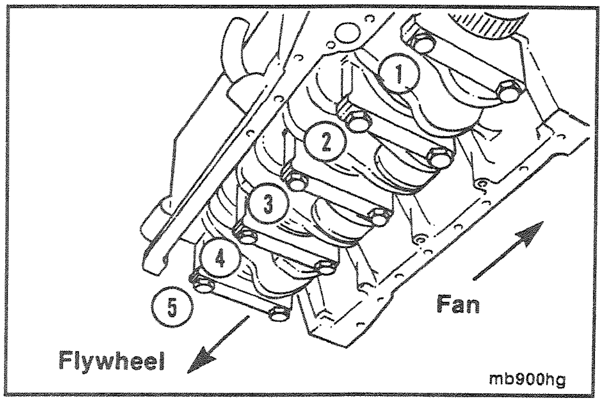
Inspect the main bearing caps for dents, cracks, or other damage.



Inspect the crankshaft journals for deep scratches, indications of overheating and other damage.

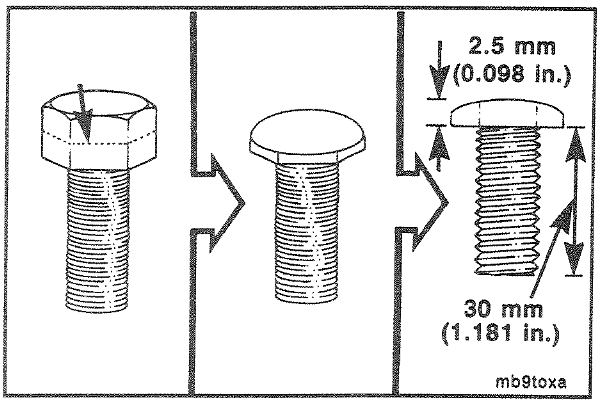
NOTE: If the crankshaft journals or main caps are damaged, the engine will need to be removed to complete the overhaul.





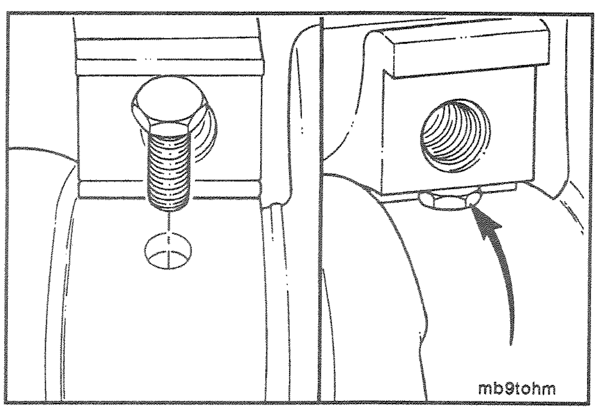
Main Bearing Replacement

Remove all main bearing caps except the No. 1 and 7 main bearing cap for 6 cylinder engine. The 4 cylinder engine is depicted in the illustration.



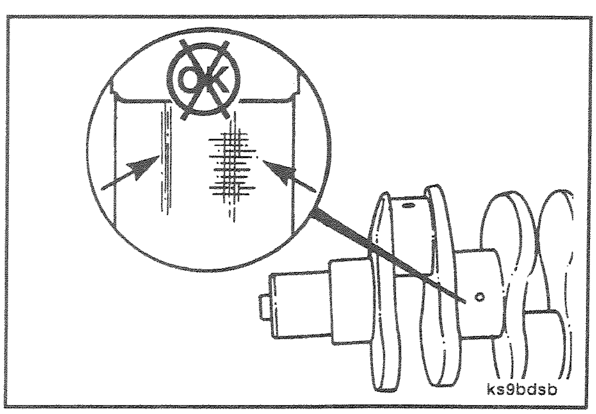
Use a pin to roll out the upper bearings from between the crankshaft and cylinder block.

To make a pin, grind a 6 mm capscrew to the dimensions shown.



Install the pin into the lubricating oil hole in the crankshaft. Rotate the crankshaft so the pin pushes against the end of the main bearing opposite the tank. Remove the main bearing.

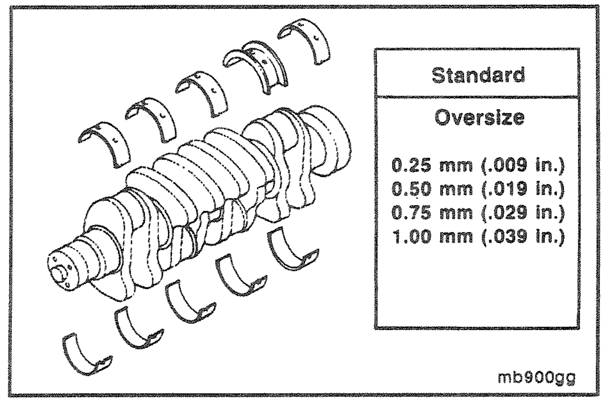
Follow this procedure to remove the other main bearings.



Inspect all main bearing caps and main bearing crankshaft journals.

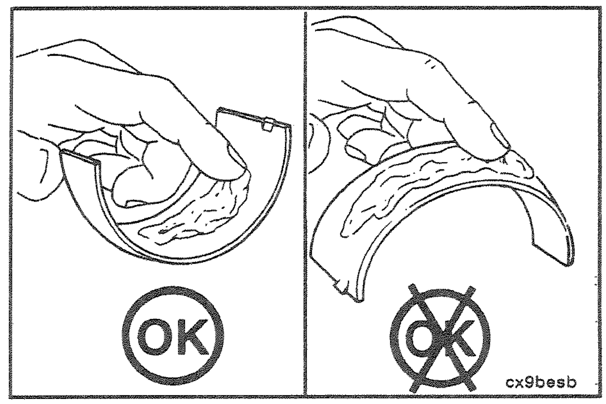
Determine the size of the main bearing removed and obtain the same size for installation.

Refer to Base Engine Component Specifications for the dimensions of the standard and undersize main bearing journals.

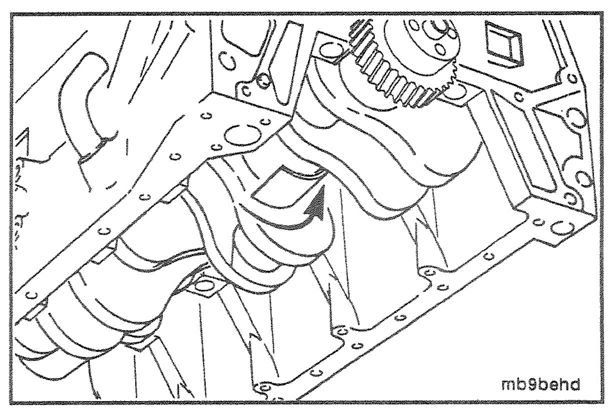


Caution: Do not lubricate the side that is against the cylinder block.

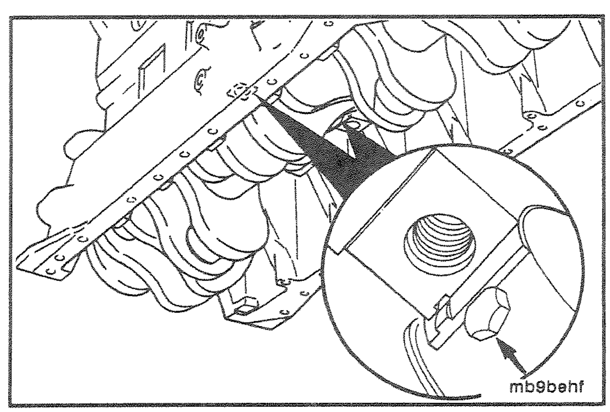
Apply a coat of Lubriplate 105® to the new upper main bearings.

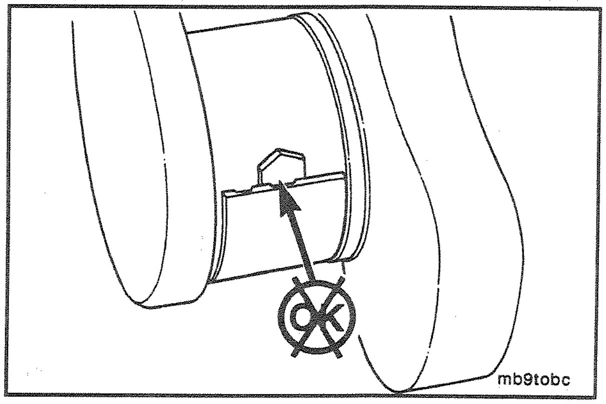


Position the new main bearing on the crankshaft and install as far as possible by hand.

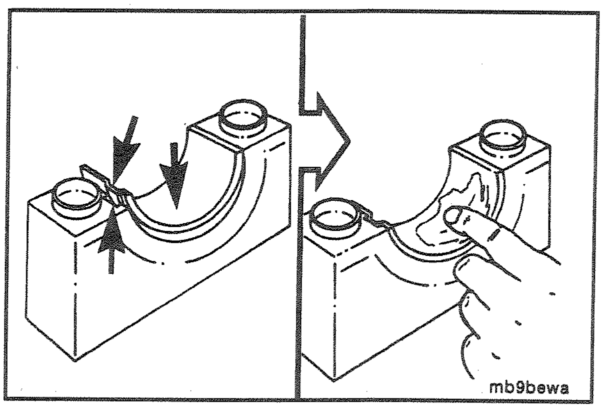


Using the pin, finish pushing the main bearing in slowly being sure it is aligned with the cylinder block. Make sure the tang on the main bearing sets into the notch.

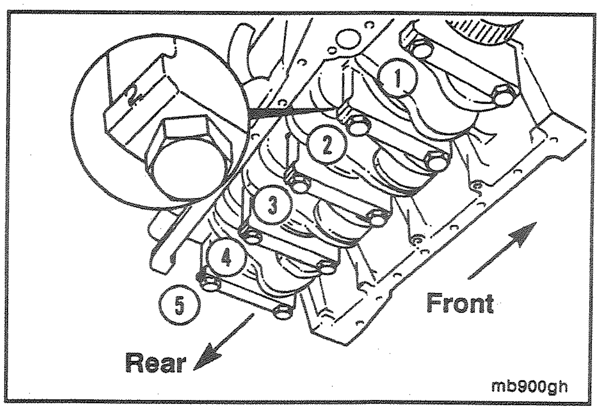




Caution: Make sure the pin does not slide under the bearing.



Install the lower main bearings into the main bearing caps. Apply a coat of Lubriplate 105® to the main bearings.



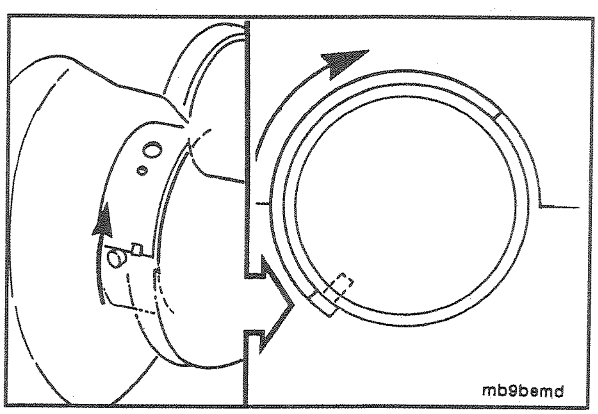
23 mm

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

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

Tighten the capscrews to 50 N•m [37 ft-lb].

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



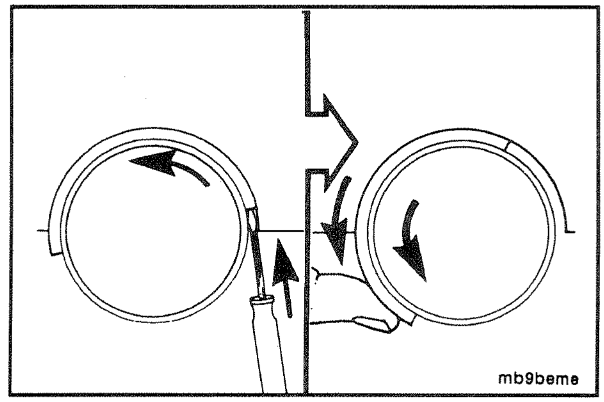
Use the same procedure to remove and install rear main bearing cap, No. 5 or No. 7.

Flat Blade Screwdriver

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

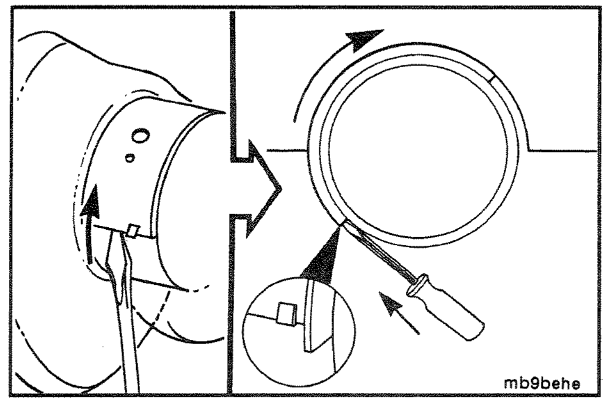
NOTE: The front main, No. 1, does not have a hole in the journal so the pin cannot be used to replace the bearing.

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



Lubricate and install the main bearing.

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



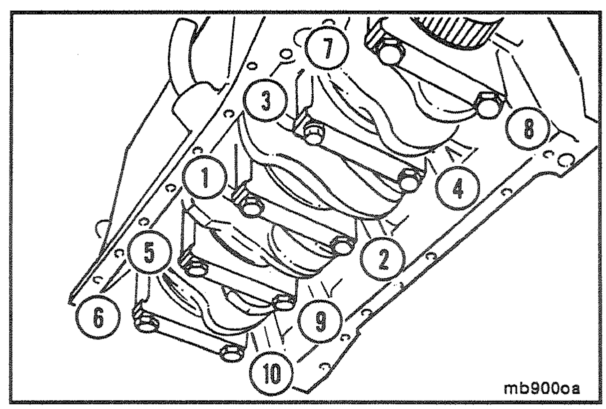
23 mm

Caution: The crankshaft must rotate freely.

Tighten the capscrews evenly and in sequence.

Step	Torque Value
1	60 N•m [44 ft-lb]
2	119 N•m [88 ft-lb]
3	176 N•m [129 ft-lb]

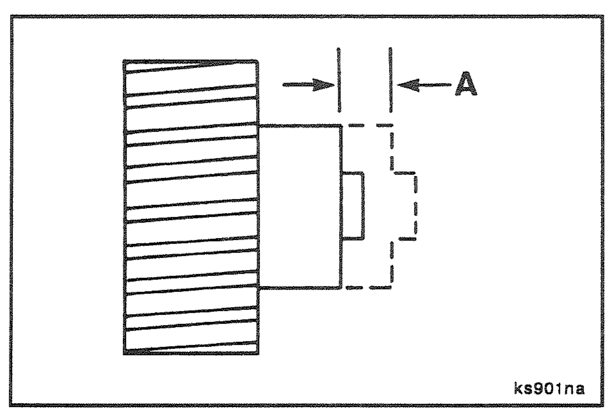
Check the main bearing installation and the size of the main bearings if the crankshaft does not rotate freely.

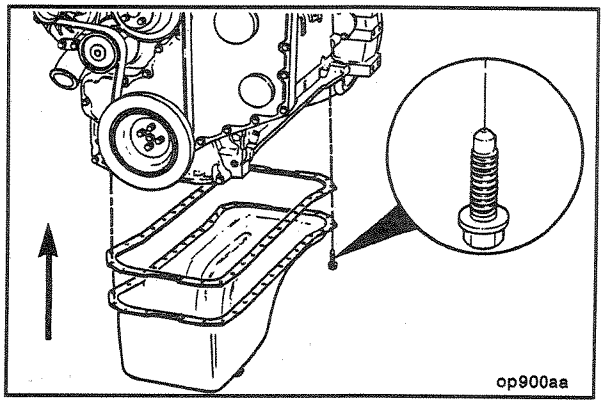


NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play.

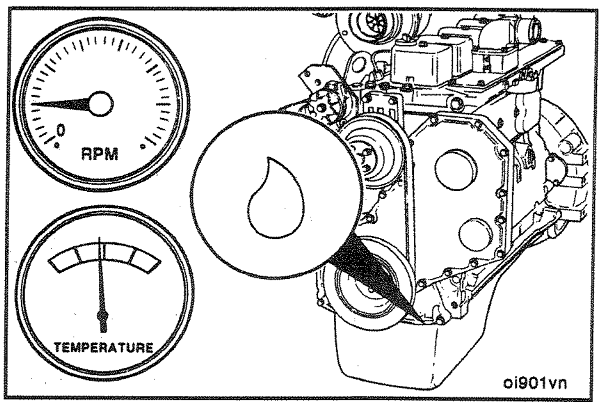
Dim. (A) End Play Limits	
MIN	**MAX**
0.102 mm [0.004 in]	0.432 mm [0.017 in]



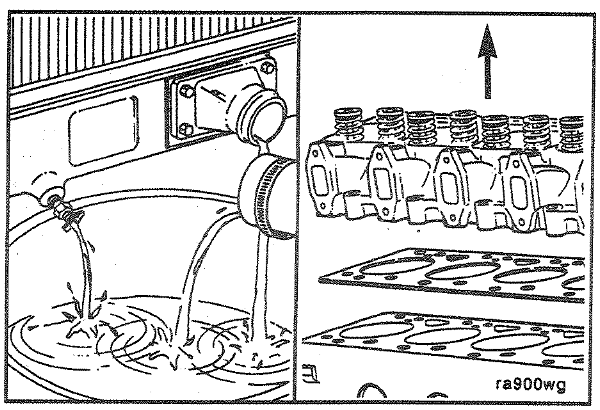


10 mm

Install the lubricating oil pan.



Fill the system with lubricating oil. Operate the engine at idle for 5 to 10 minutes. Check for loose parts and leaks.

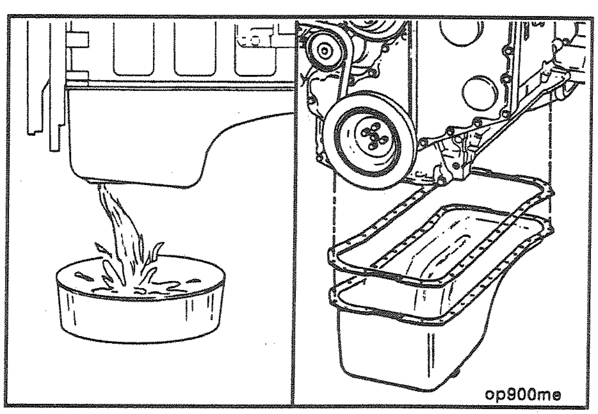


Cylinder Bore Deglaze (7-14)

Disassembly

Drain the coolant.

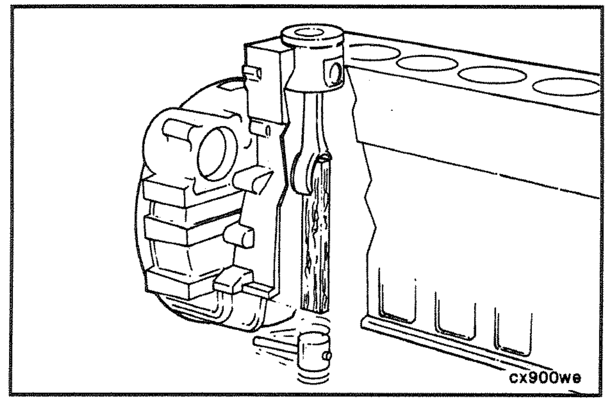
Remove the cylinder head. Refer to Procedure (7-07).



Drain the lubricating oil.

Remove the lubricating oil pan.

Remove the piston and connecting rod assemblies. Refer to Procedure (7-10).



Inspection

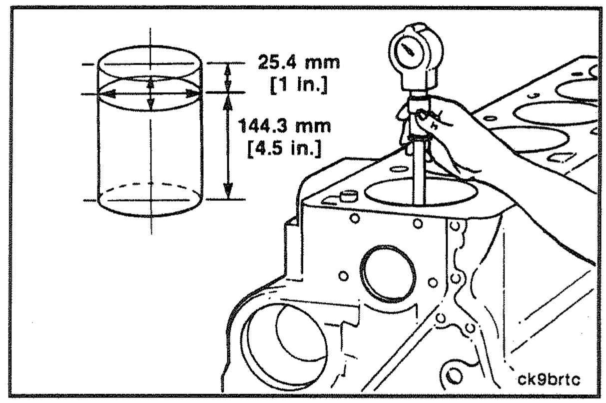
Measure the cylinder bore diameter at 25.4 mm [1 in] and 170.7 mm [5.5 in] from the top of the cylinder block.

Bore I.D. Max - 102.116 mm [4.0203 in]

Bore out of round - .035 mm [.0015 in]

Bore taper - .076 mm [.003 in]

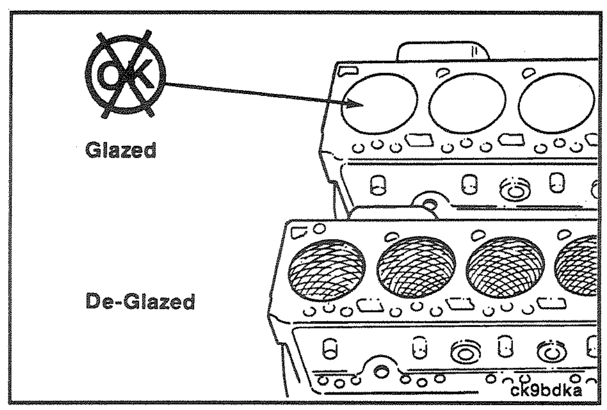
NOTE: Do not proceed with in-chassis overhaul if the cylinder bores are worn beyond specifications.



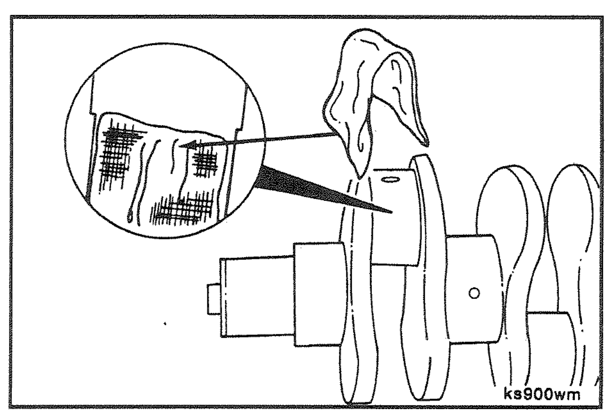
Deglazing

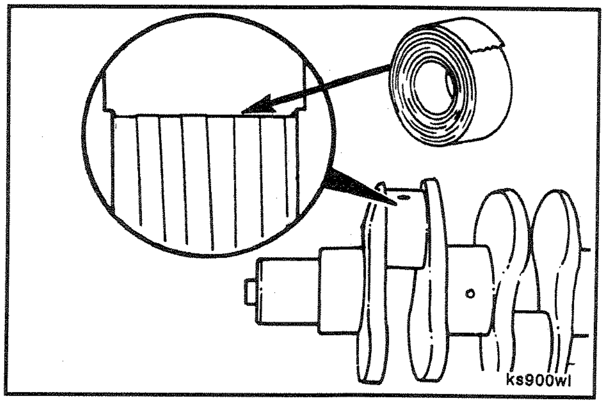
Deglazing gives the cylinder bore the correct surface finish required to seat the rings.

NOTE: New piston rings may not seat in glazed cylinder bores.

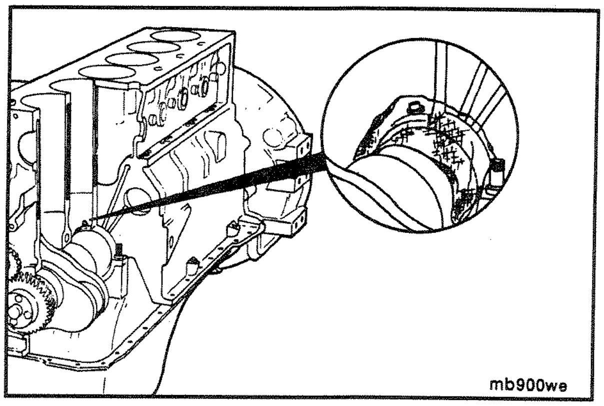


Wrap the connecting rod journals with a clean cloth.

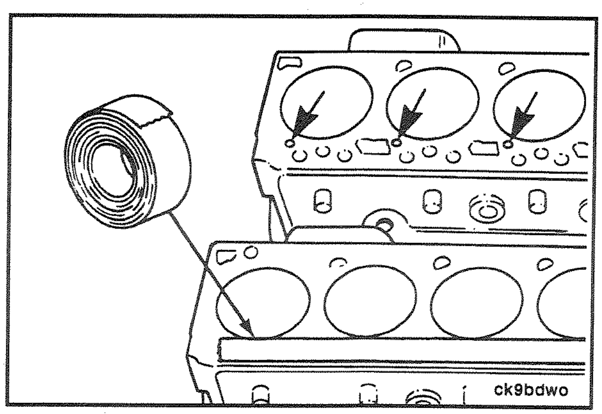




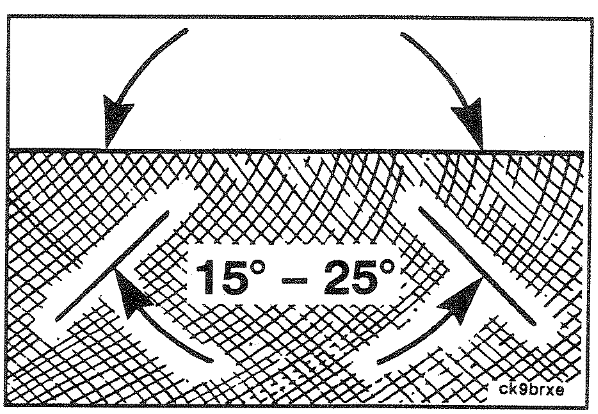
Cover the cloth with waterproof tape.



Place a clean shop towel around the top main bearing saddle to deflect water and residue from the piston cooling nozzles.

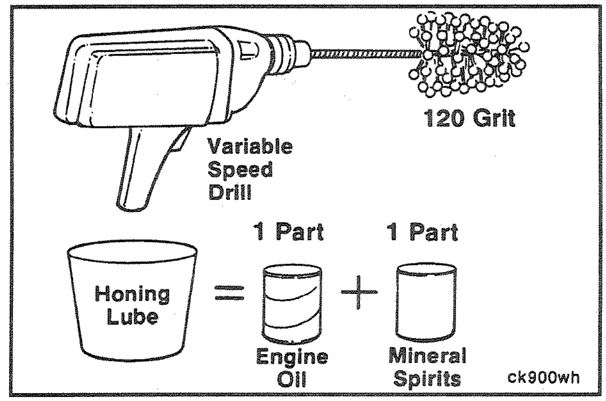


Also cover the lubricating holes and tappet holes in the top of the cylinder block with waterproof tape.

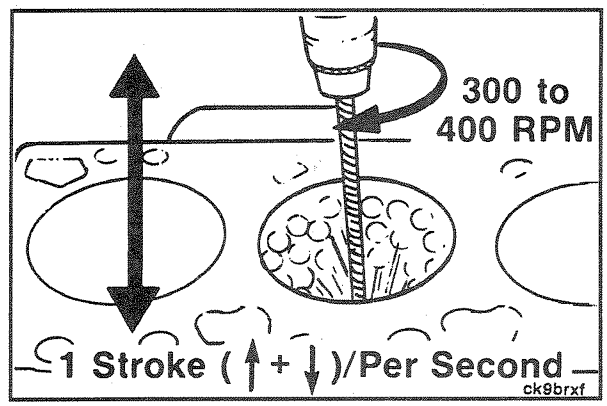


A correctly deglazed surface will have a crosshatched appearance with the lines at 15 to 25 degree angles with the top of the cylinder block.

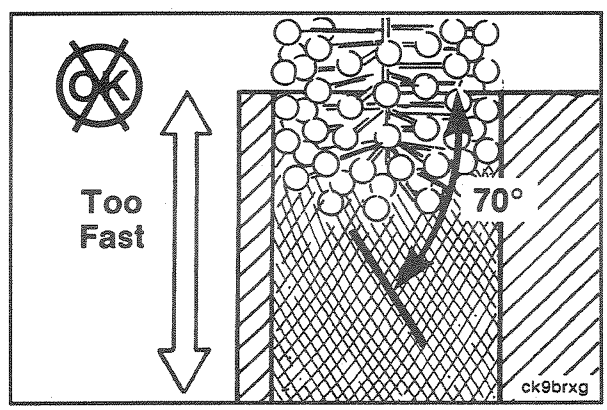
Use a drill, a fine grit flex-hone and a mixture of equal parts of mineral spirits and SAE 30W engine lubricating oil to deglaze the cylinder bores.



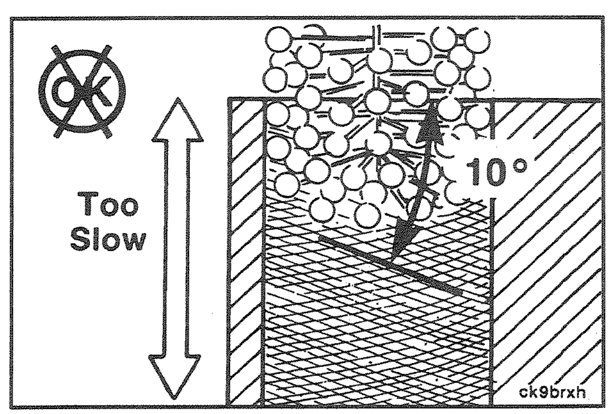
The crosshatch angle is a function of drill speed and how fast the hone is moved vertically.

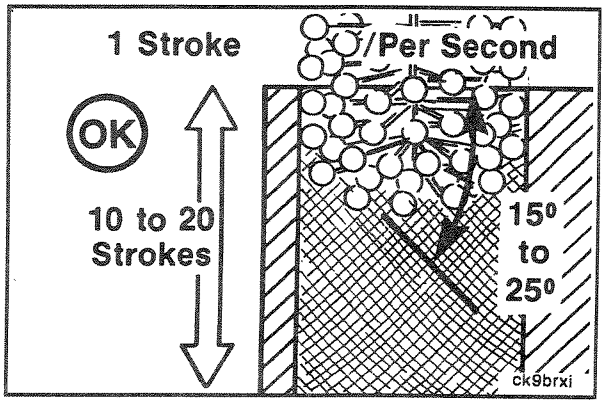


This illustration shows the result of the drill speed too slow or the vertical stroke too fast.



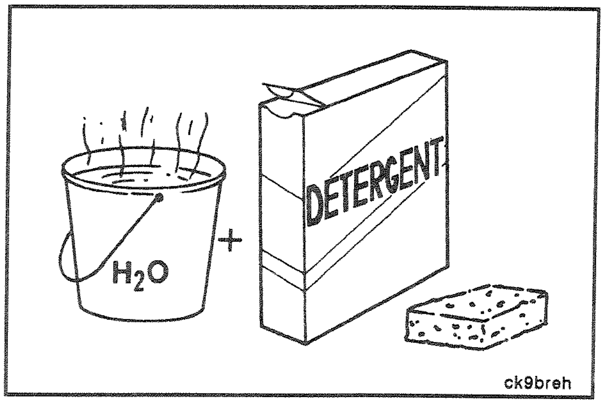
This illustration shows the result of the drill speed too fast or the vertical stroke too slow.





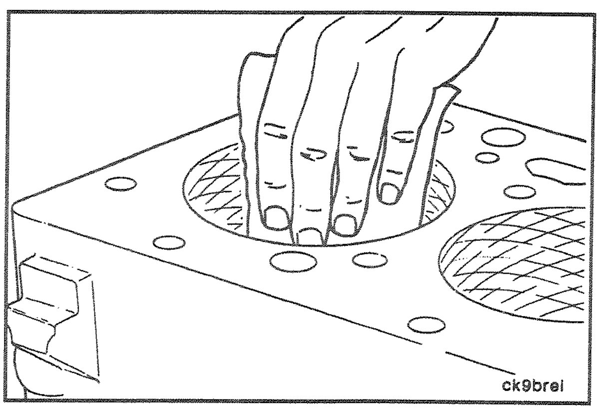
NOTE: Vertical strokes must be smooth continuous passes along the full length of the cylinder bore.

Inspect the cylinder bore after 10 strokes.



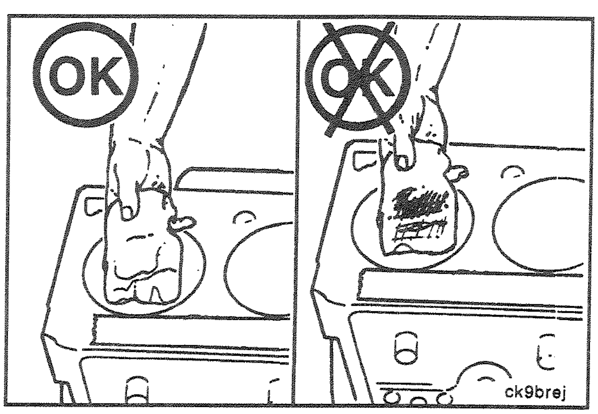
Cleaning

Use a strong solution of hot water and laundry detergent to clean the cylinder bores.



Caution: Clean the cylinder bores immediately after deglazing.

Rinse the cylinder bores until the detergent is removed. Dry the cylinder block with compressed air.

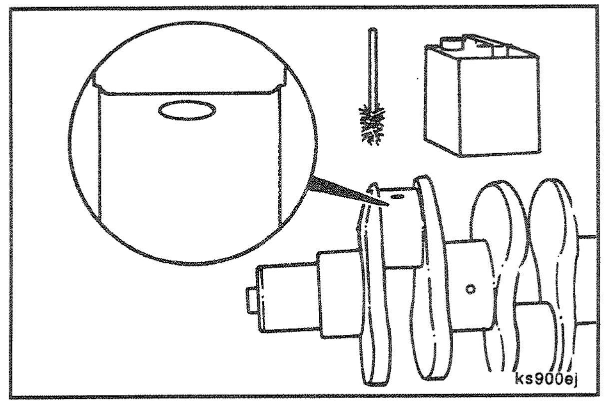


Be sure to remove the tape covering the tappet and lubricating oil holes after the cleaning process is complete.

Check the cylinder bore cleanliness by wiping with a white, lint free, lightly oiled cloth. If grit residue is still present, repeat the cleaning process until all residue is removed. Wash the cylinder bores with solvent. Dry the cylinder block with compressed air.

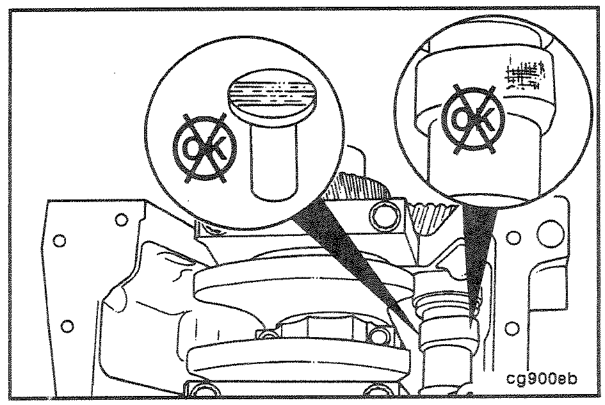
Be sure to remove the covering from the piston cooling nozzles.

Remove the protective tape and cloth, and clean the crankshaft journals.



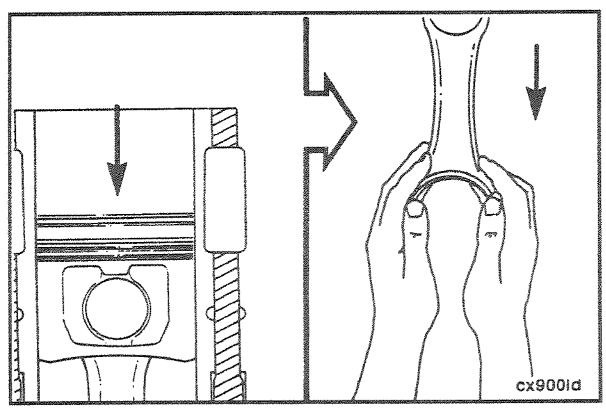
Use a solvent and a brush to clean any residue that may have splashed on the camshaft.

NOTE: Inspect the camshaft lobes and tappet faces for signs of wear or damage. Refer to Procedure (7-19).



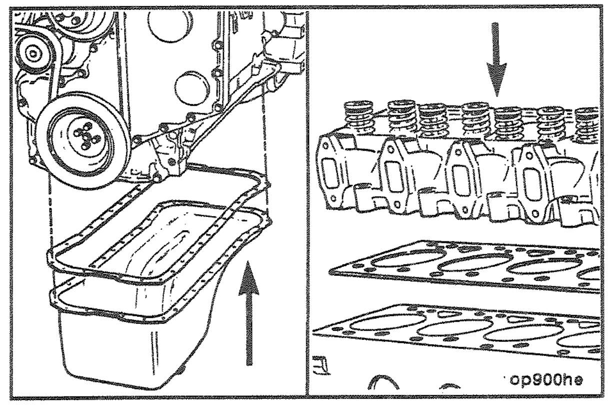
Assembly

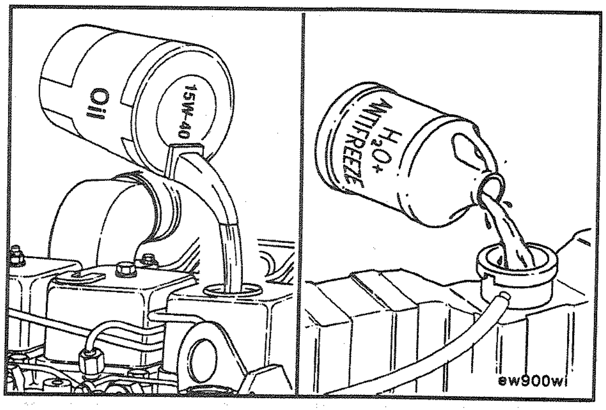
Install the piston and connecting rod assemblies. Refer to Procedure (7-10).



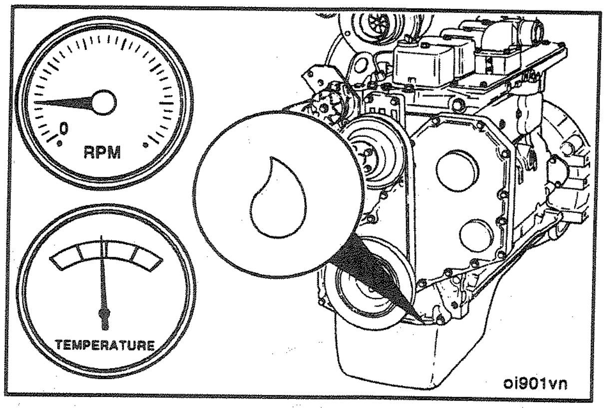
Install the lubricating oil pan.

Install the cylinder head. Refer to Procedure (7-07).

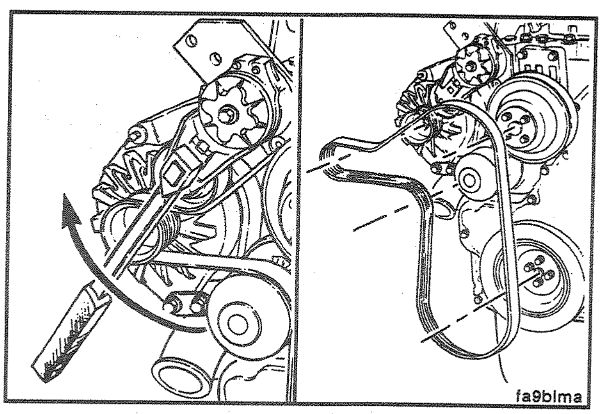




Fill the lubricating oil pan. Fill the engine with coolant.



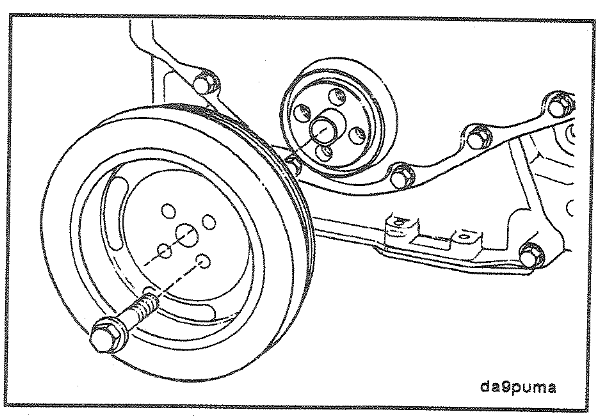
Operate the engine to normal operating temperature and check for leaks.



Vibration Damper/Crank Pulley - Replacement (7-15)

Removal

Remove the drive belt.



15 mm

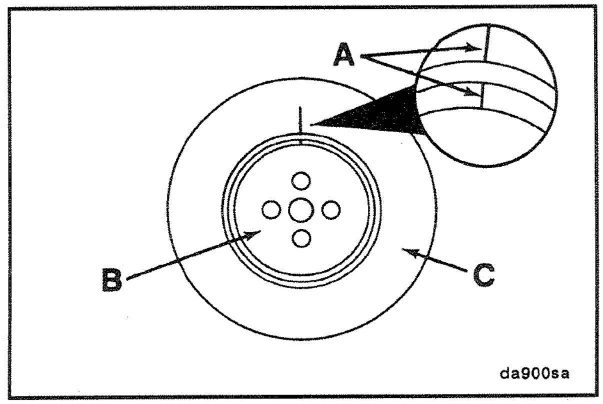
Remove crankshaft pulley/vibration damper.

(On six cylinder engines, a vibration damper is integral to the crankshaft pulley.)

Rubber Element Vibration Damper - Inspection (In-Chassis)

Check the index lines (A) on the damper hub (B) and the inertia member (C). If the lines are more than 1.59 mm [1/16 inch] out of alignment, replace the damper.

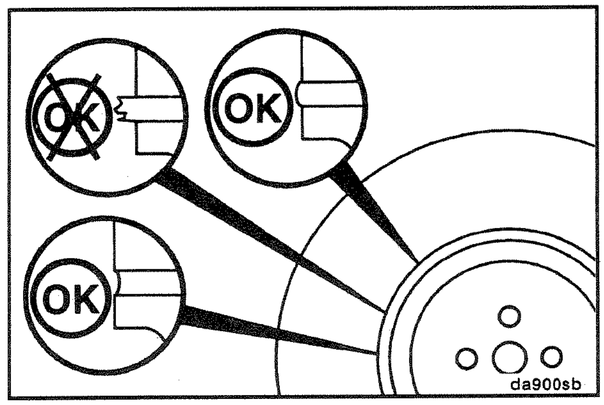
Inspect the vibration damper hub (B) for cracks. Replace the damper if the hub is cracked.



Installation

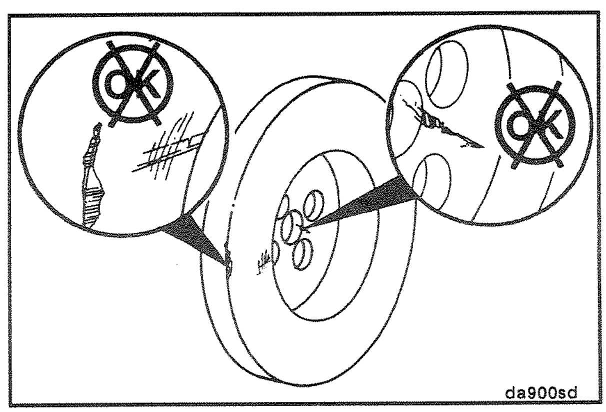
Inspect the rubber member for deterioration. If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8 inch] below the metal surface, replace the damper.

NOTE: Also look for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



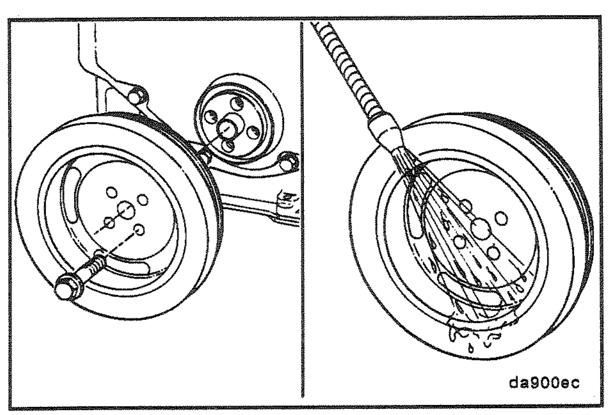
Viscous Vibration Damper - Inspection

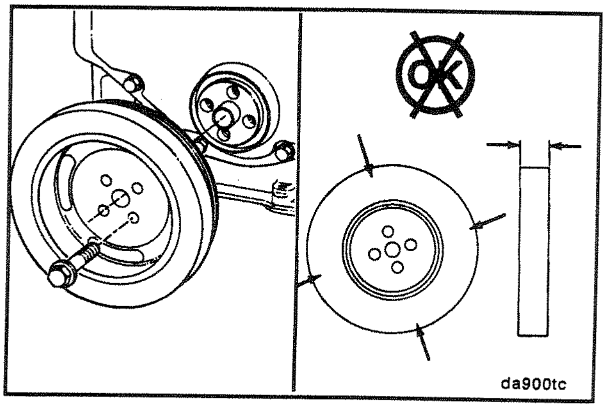
Check the mounting web for cracks. Check the housing for dents or raised surfaces. Replace the damper if any of these defects are identified. Refer to replacement procedure in this section.



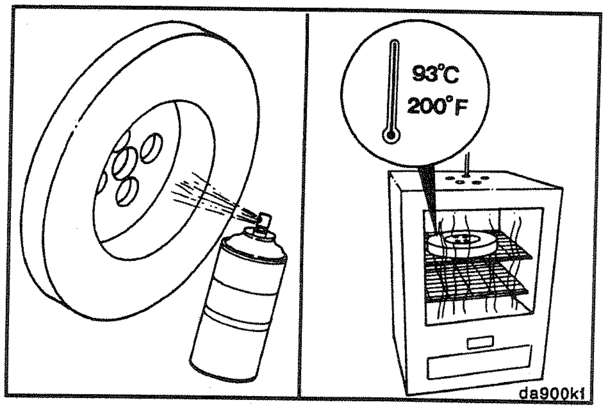
Remove the viscous vibration damper. Refer to replacement procedure in this section.

Clean the damper with a solvent cleaner.

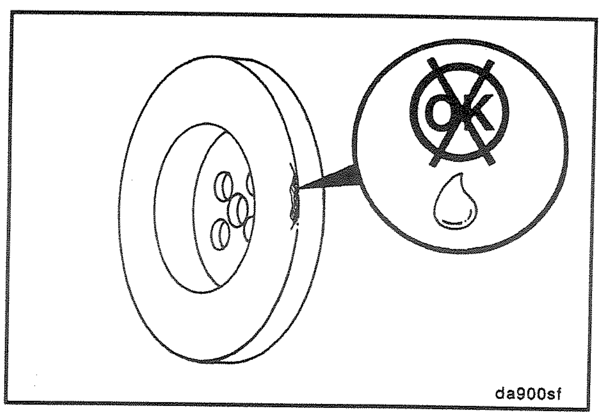




The viscous damper is filled with a silicone fluid. After many hours of use, the silicone fluid may become thicker and expand. To determine if the damper thickness is correct, remove the paint from the damper in four locations on either side of the damper. Measure and record the thickness of the damper in four places. Measure the thickness 3.175 mm [0.125 inch] from the out side of the damper. Replace the damper if its thickness varies by more than 0.25 mm [0.010 inch].



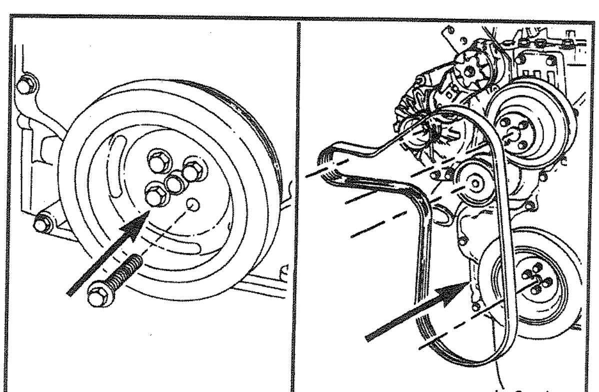
Spray the damper with spot check developer, Type SKD-NF or its equivalent. Heat the damper in an oven (rolled lip side down) at 93°C [200°F] for 2 hours.



Caution: Wear protective gloves to prevent personal injury when handling parts that have been heated.

Remove the damper from the oven and check for fluid leakage. If there is leakage, replace the damper.

Refer to replacement procedure in this section.



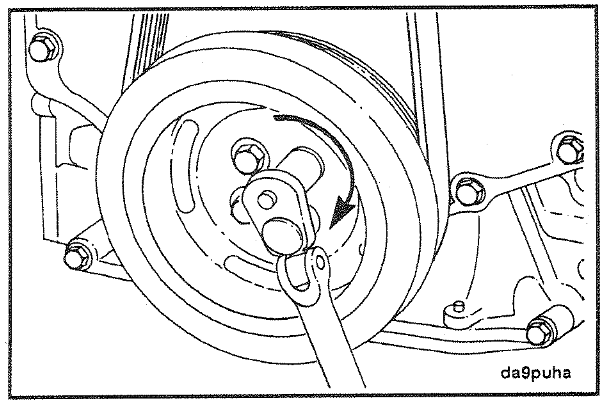
15 mm

Install the crankshaft pulley/vibration damper. Do not tighten the capscrews to the correct torque value at this time.

Install the drive belt.

Tighten crankshaft pulley/vibration damper capscrews.

Torque Value: 125 N•m [92 ft-lb]

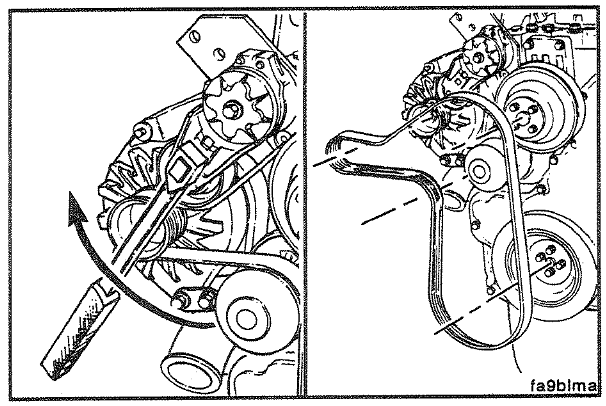


Front Seal - Replacement (7-16)

Removal

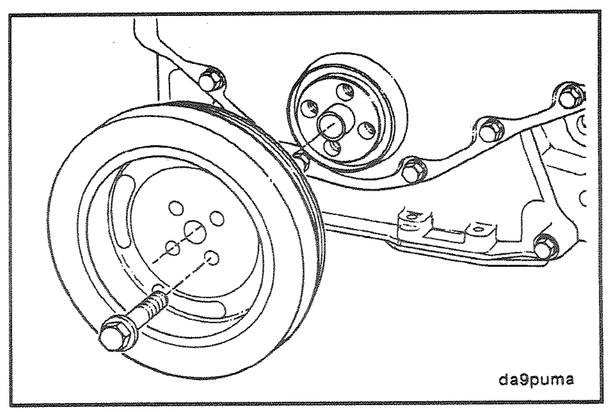
Remove the drive belt.

NOTE: Removal is easier if the crankshaft pulley is loosened before removing the belt.

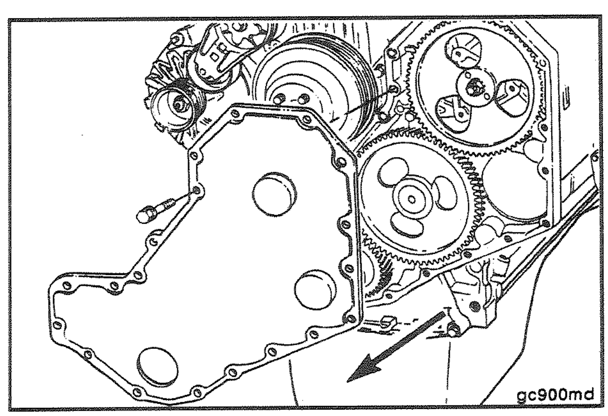


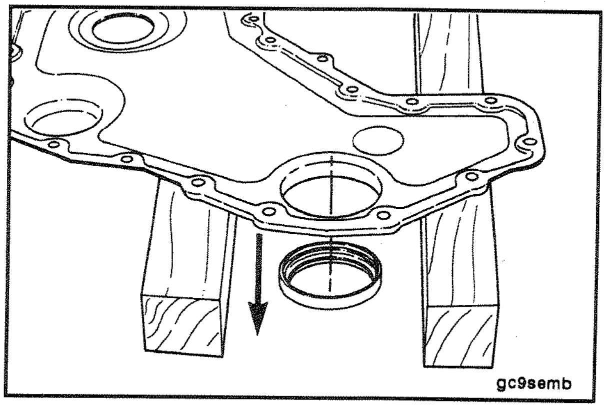
15 mm

Remove the crankshaft pulley.

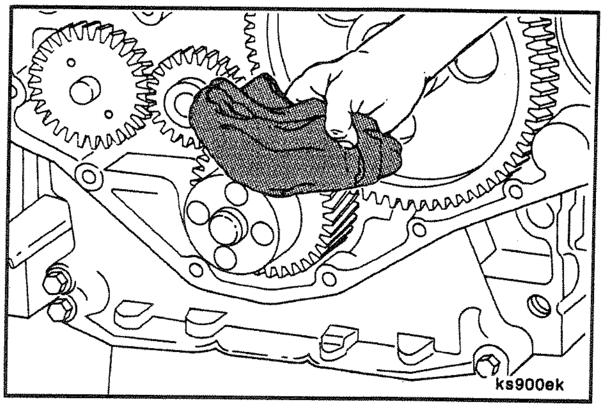


Remove the front cover. Refer to Procedure (7-18).



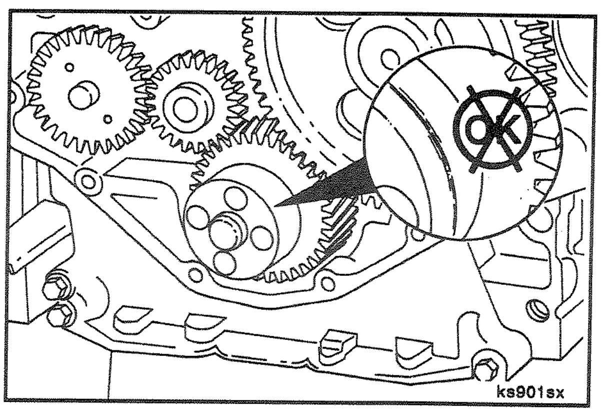


Remove the oil seal from the gear cover. Drive the oil seal from the back side of the cover toward the front side of the cover, while supporting the gear cover.



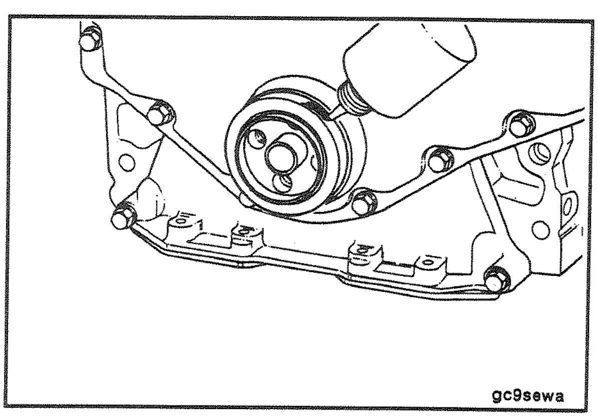
Cleaning and Inspection

Clean the gear cover seal bore and the crankshaft surface free of all oil and seal residue.



Inspect the crankshaft for excessive wear.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available.



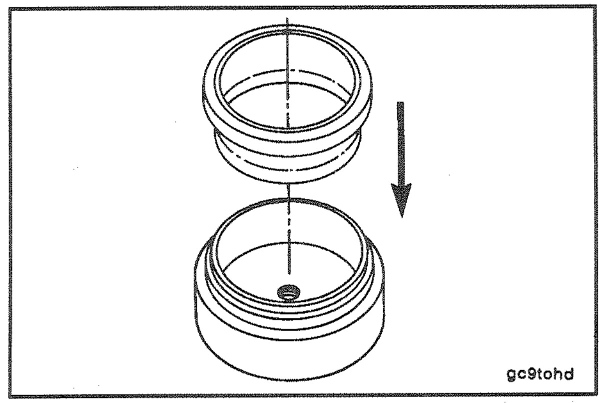
Installation

Apply a bead of Loctite 277 or equivalent to the outside diameter of the seal.

3824498 Installation Tool

Leave the plastic pilot installation tool in the lubricating oil seal.

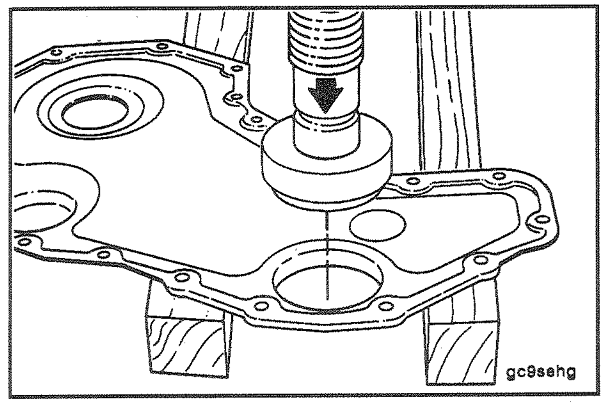
Position the seal on the service tool, Part No. 3824499, with the lubricating oil seal dust lip facing outward.



NOTE: Properly support the front cover lubricating oil seal flange to prevent damage to the lubricating oil seal and front cover.

Press the lubricating oil seal into the front cover from the back side of the cover toward the front side of the cover.

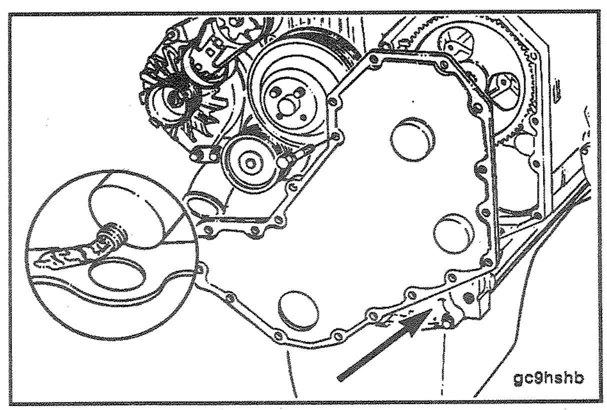
Press the lubricating oil seal until the service tool bottoms against the front cover.



Apply a thin bead of Three Bond™ to the cover side of the front cover gasket only.

NOTE: Do not remove the plastic seal pilot tool from the lubricating oil seal at this time. Use the plastic seal pilot tool to guide the seal on the crankshaft.

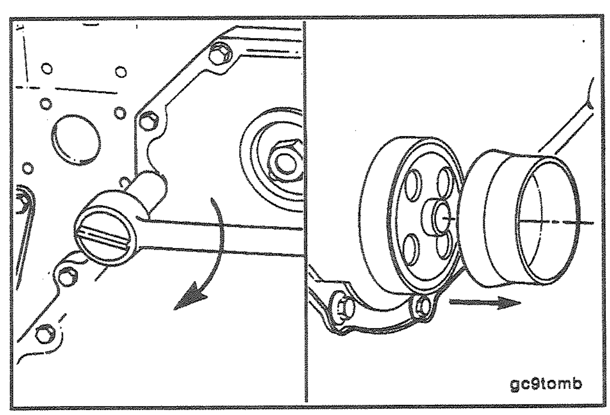
Install the gasket and front cover on the engine.

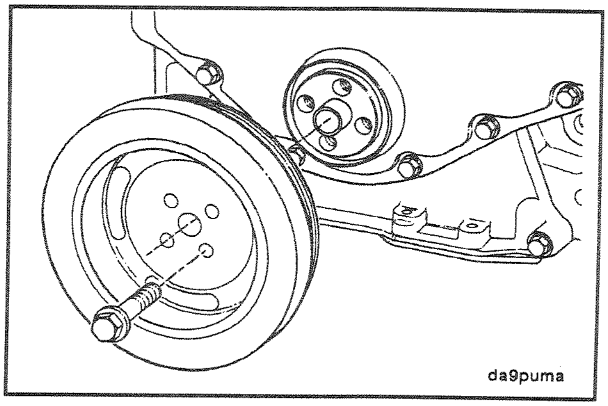


Tighten the front cover mounting capscrews.

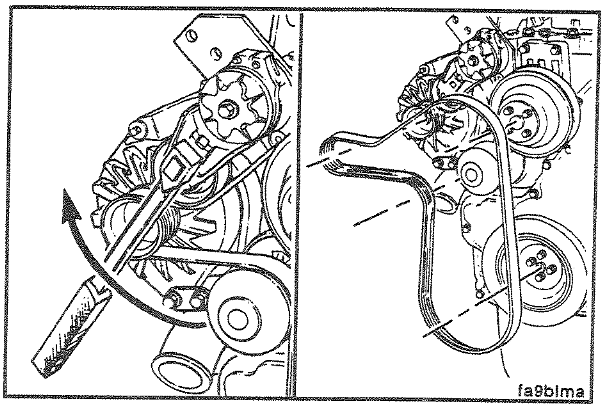
Remove the plastic pilot tool from the crankshaft.

Torque Value: 24 N•m [18 ft-lb]

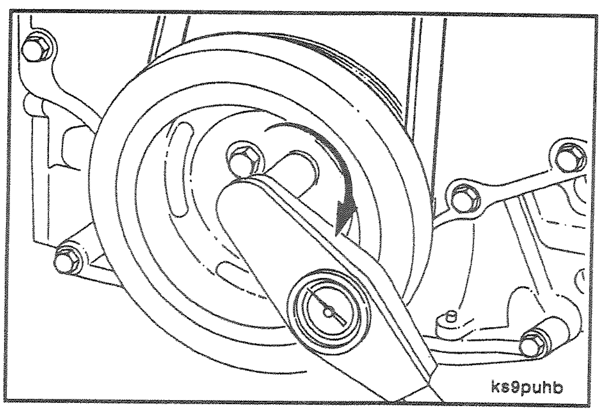




Install the crankshaft pulley. Do not tighten the capscrews to the correct torque value at this time.

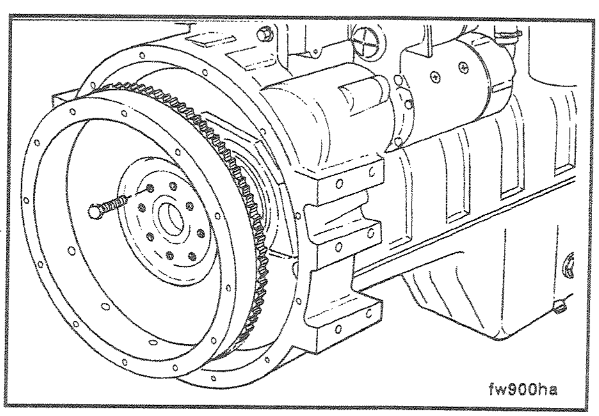


Install the drive belt.



Tighten the crankshaft pulley capscrews.

Torque Value: 125 N•m [92 ft-lb]



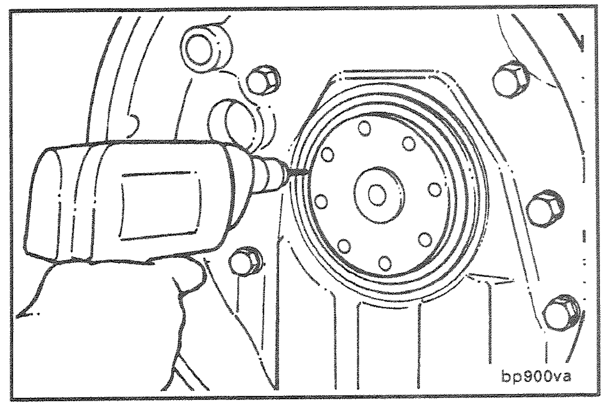
Rear Seal - Replacement (7-17)

Preparatory Step:

- Remove the transmission.
- Remove the flywheel.

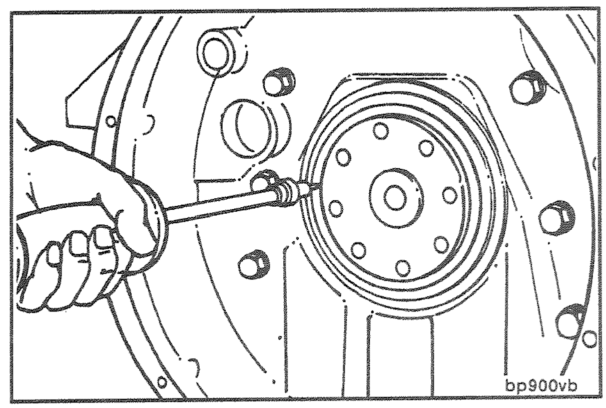
1/8 inch Drill

Drill two holes 180 degrees apart into the seal carrier.



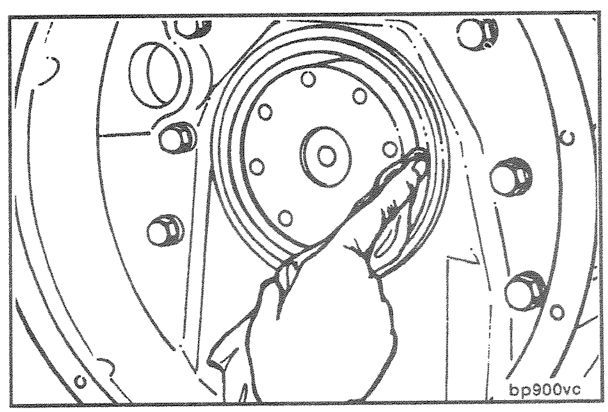
No. 10 Sheet Metal Screw, Slide Hammer Dent Puller

Remove the rear seal.



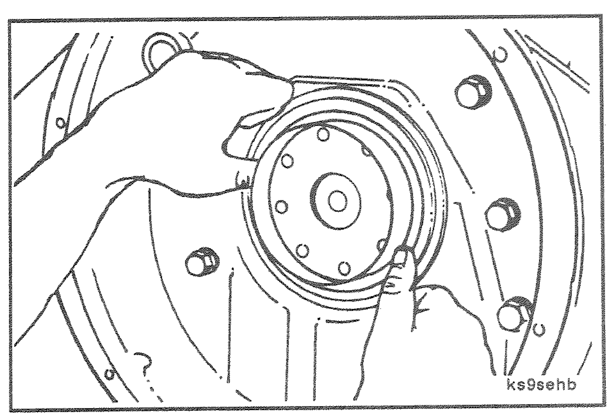
Caution: The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

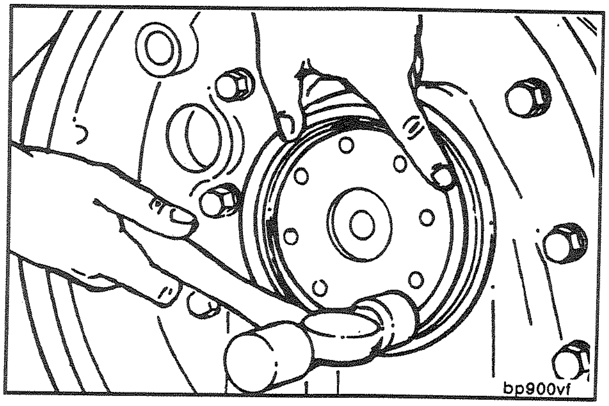
Clean and dry the rear crankshaft sealing surface.



Install the seal pilot, provided in the replacement kit, onto the crankshaft. Push the seal onto the pilot and crankshaft.

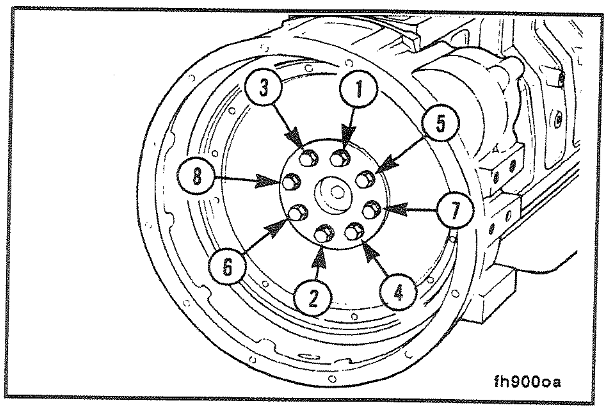
Remove the seal pilot.





Use the alignment tool to install the seal to the correct depth in the housing. Use a hammer to drive the seal into the housing until the alignment tools tops against the housing.

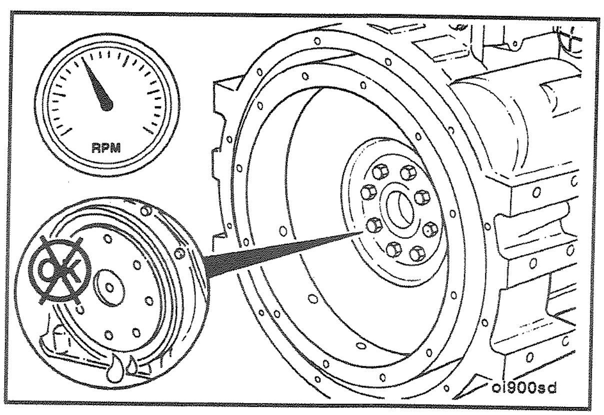
Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier.



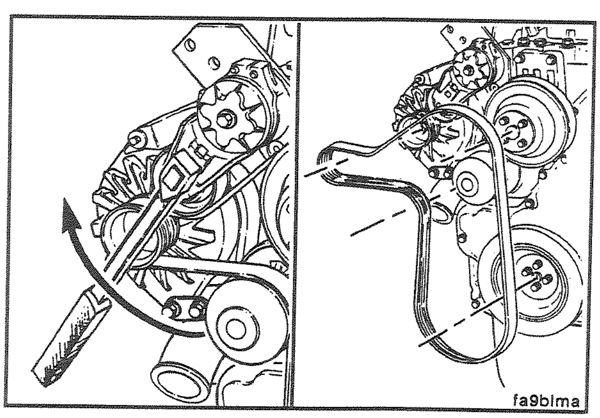
19 mm

Install the flywheel. Tighten the capscrews in sequence as shown in the illustration.

Torque Value: 137 N•m [101 ft-lb]



Install the clutch, transmission and starter. Operate the engine and check for leaks.



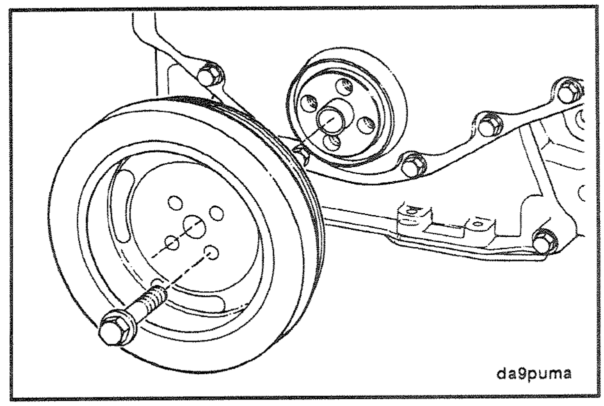
Gear Cover - Replacement (7-18)

Removal

Remove the drive belt.

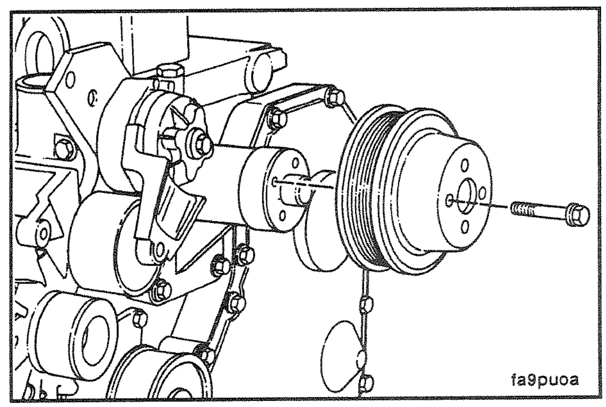
15 mm

Remove the crankshaft pulley.



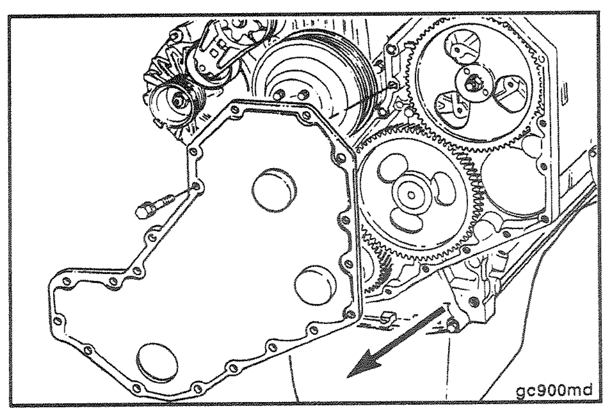
10 mm

If required remove the fan hub pulley.



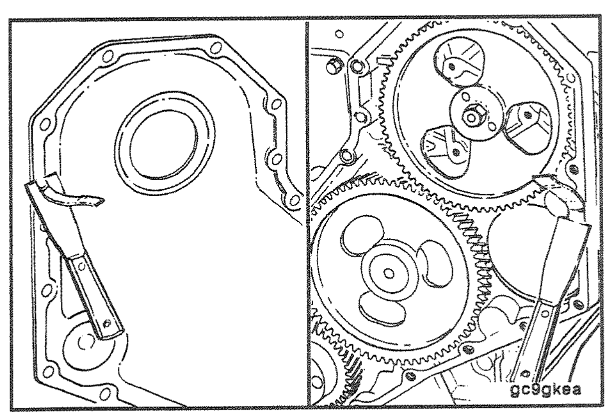
10 mm

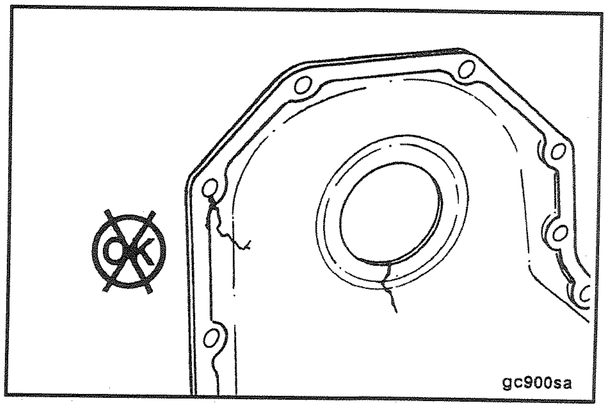
Remove the front gear cover.



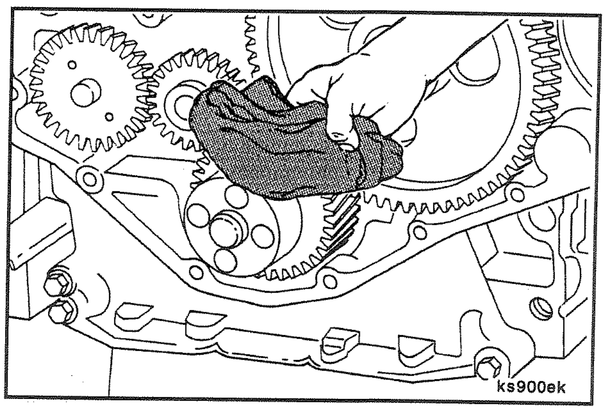
Cleaning and Inspection

Clean the gear cover and gear housing gasket surface.



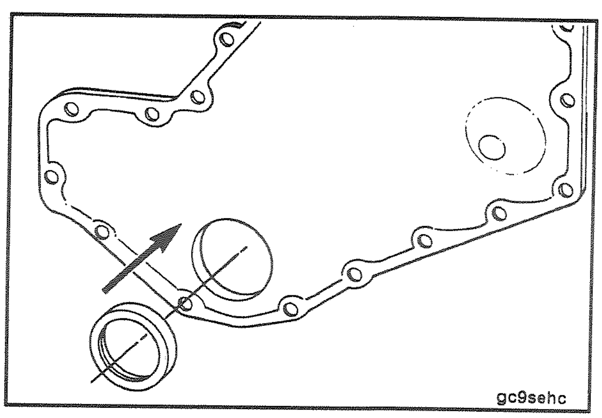


Inspect the gear cover for cracks or damage.

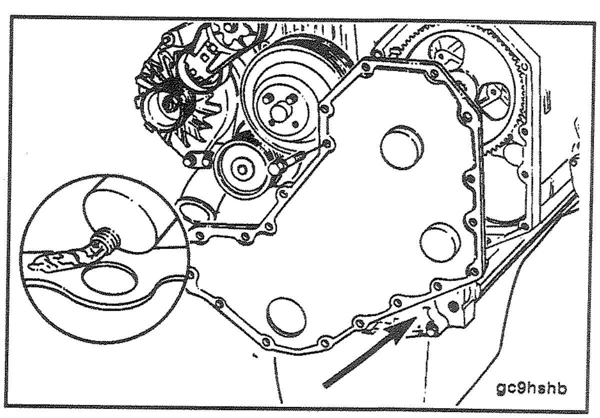


Caution: The crankshaft must be clean, dry and oil free before installing the gear cover. Failure to properly clean the sealing surface will result in an oil leak.

Installation



Install a new seal in the gear cover. Refer to Procedure (7-16).



Apply a thin bead of Three-Bond™ to the cover side of the front cover gasket only.

NOTE: Do not remove the plastic seal pilot tool from the lubricating oil seal at this time. Use the plastic seal pilot tool to guide the seal on the crankshaft.

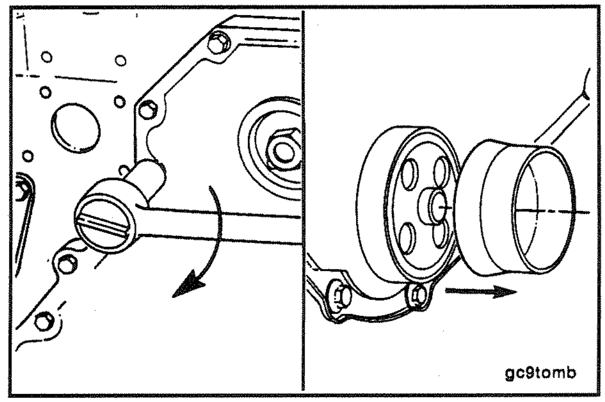
Install the gasket and front cover on the engine.

10 mm

Tighten front cover capscrews.

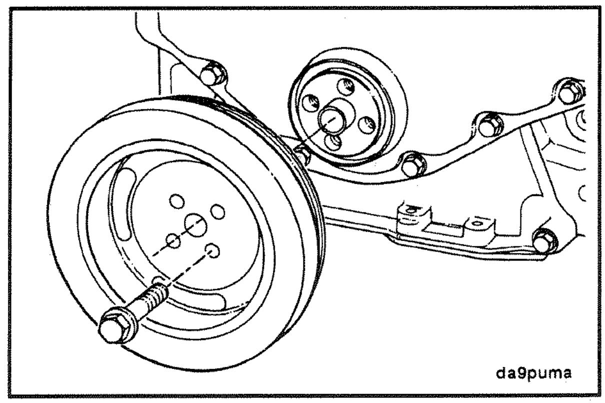
Remove the plastic pilot tool from the crankshaft.

Torque Value: 24 N•m [18 ft-lb]

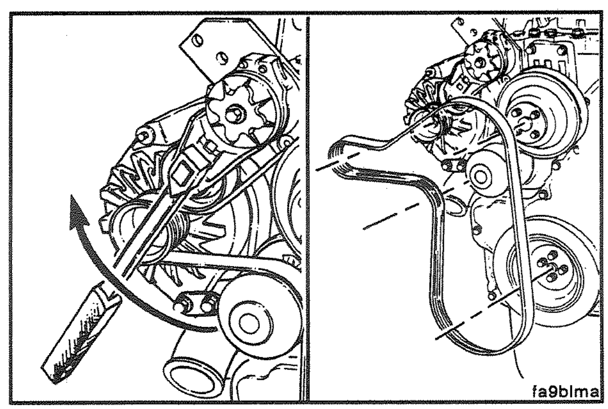


15 mm

Install the crankshaft pulley. Do not tighten the capscrews to the correct torque value at this time.

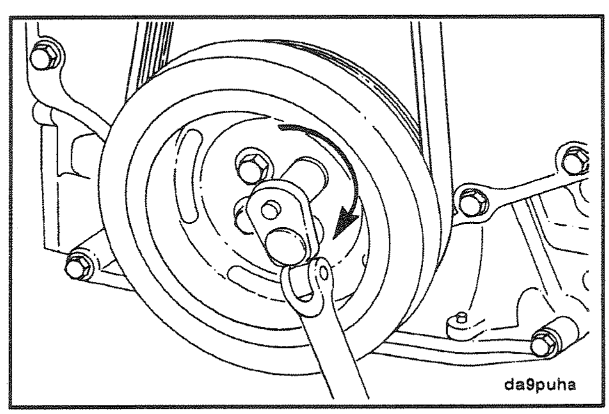


Install the drive belt.



Tighten crankshaft pulley capscrews.

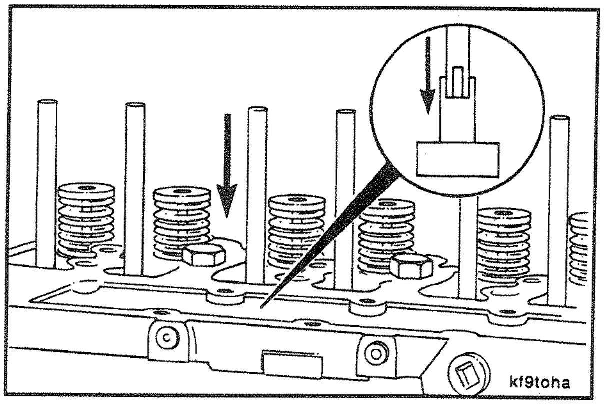
Torque Value: 125 N•m [92 ft-lb]



Camshaft and Tappet - Replacement (7-19)

Preparatory Steps:

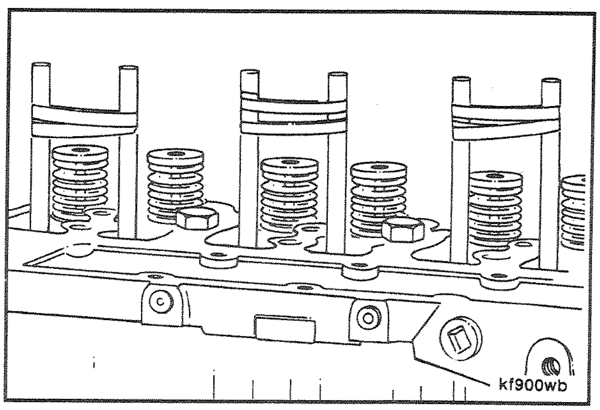
- Remove the valve covers.
- Remove the push rods.
- Remove the drive belt.
- Remove the crankshaft pulley.
- Remove the gear cover.
- Remove the fuel transfer pump.



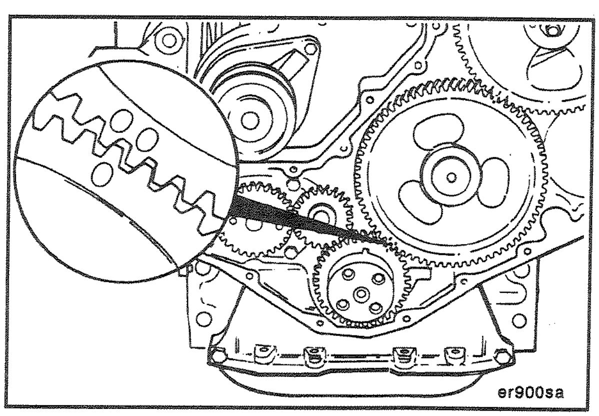
Camshaft Removal

Tappet Changing Tool, Part No. 3822513

Insert the dowels through the push tube holes and into the top of each tappet securely. When properly installed, the dowels can be used to pull the tappets up and should not be able to be pulled out without considerable effort.



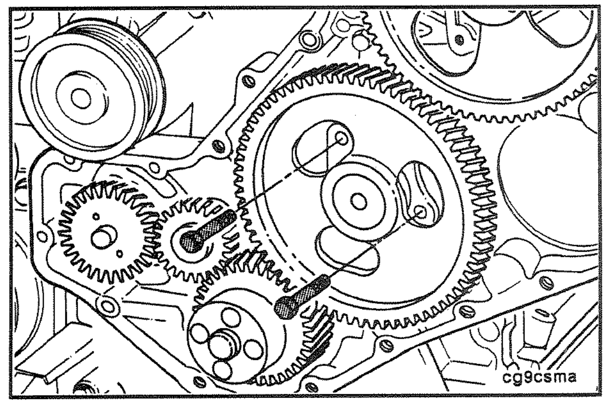
Pull the tappets up and wrap a rubber band around the top of the dowel rods. This will prevent the tappets from dropping down.



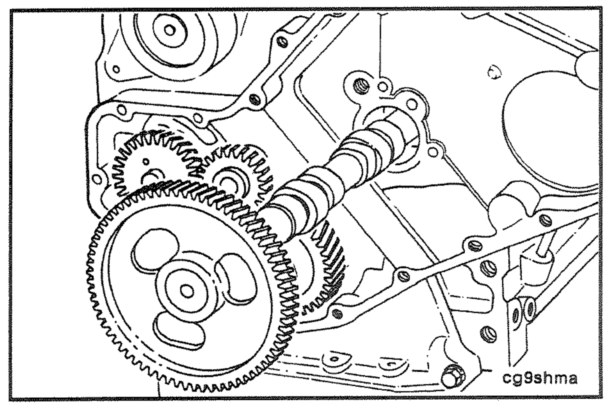
Rotate the crankshaft to align the crankshaft to camshaft timing marks.

13 mm

Remove the capscrews from the thrust plate.

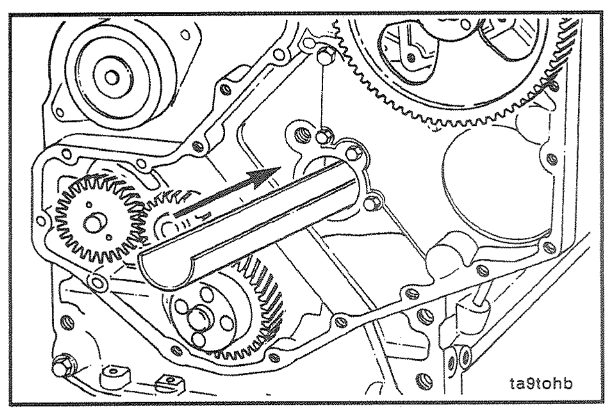


Remove the camshaft and thrust plate.

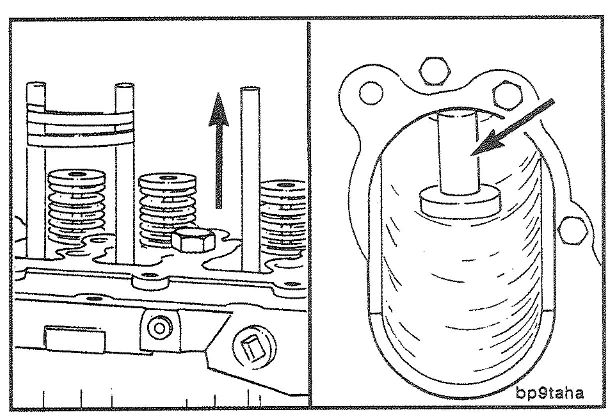


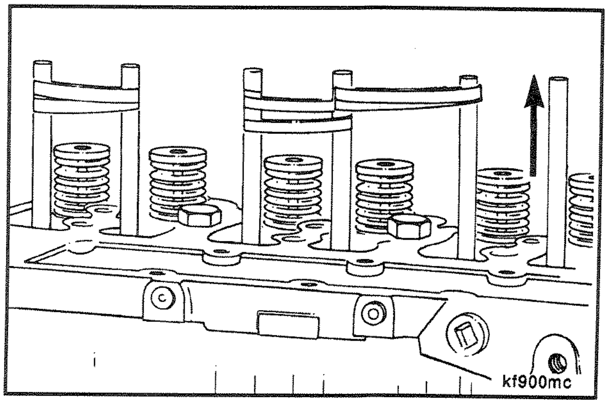
Tappet Removal

Insert the trough to the full length of the cam bore.

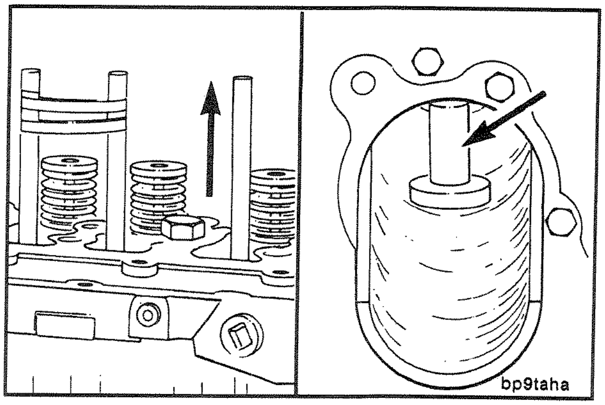


Make sure the trough is positioned so it will catch the tappet when the wooden dowel is removed.

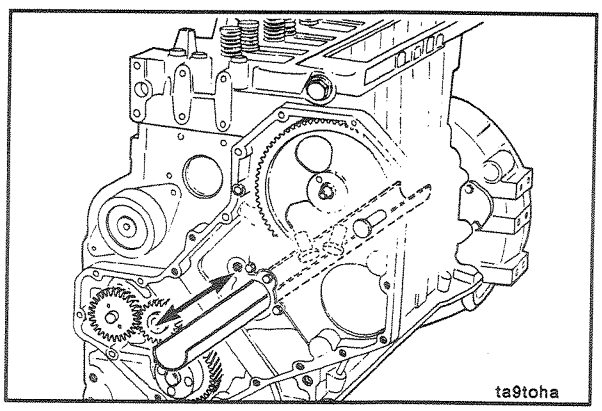




Only remove one tappet at a time. Remove the rubber band from the two companion tappets, securing the tappet not to be removed with the rubber band.

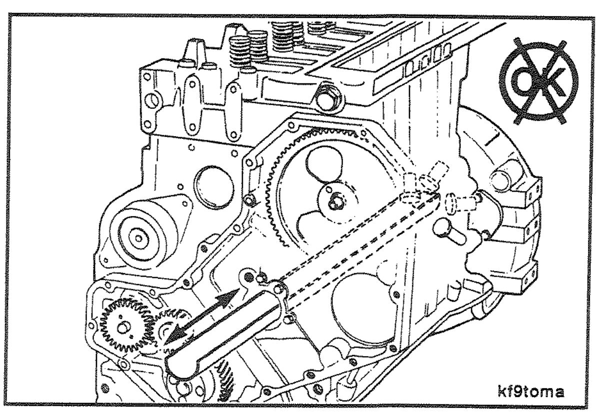


Pull the wooden dowel from the tappet bore allowing the tappet to fall into the plastic trough.



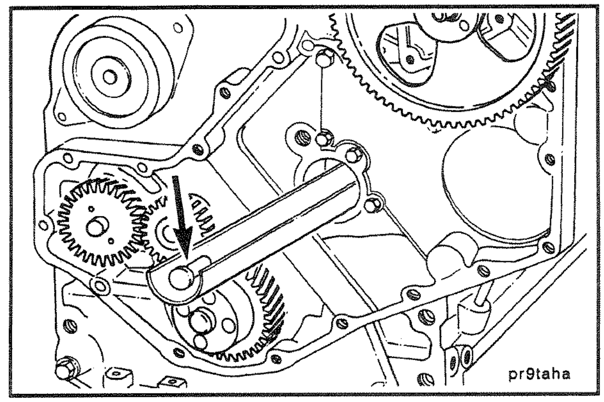
Flashlight

When the tappet is dropped into the trough, most of the time it will fall over. However, if it doesn't, gently shake the trough just enough to allow the tappet to fall over before removing.



NOTE: Special care should be taken, when removing the Number 6 Cylinder tappets, not to knock or shake the tappet over the end of the trough.

Carefully pull the trough and tappet from the cam bore and remove the tappet. Repeat the process until all tappets are removed.

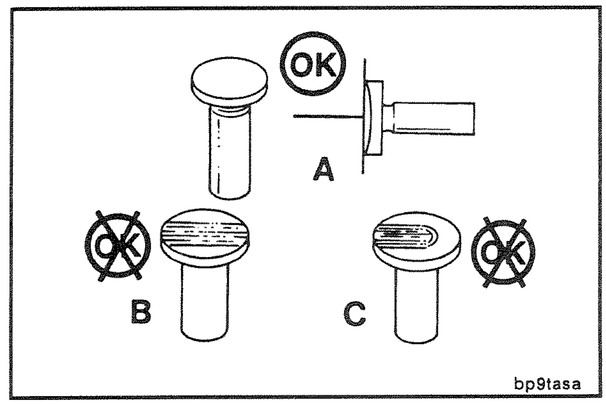


Tappets - Inspection

Inspect the socket, stem and face for excessive wear, cracks and other damage.

Visual Limits

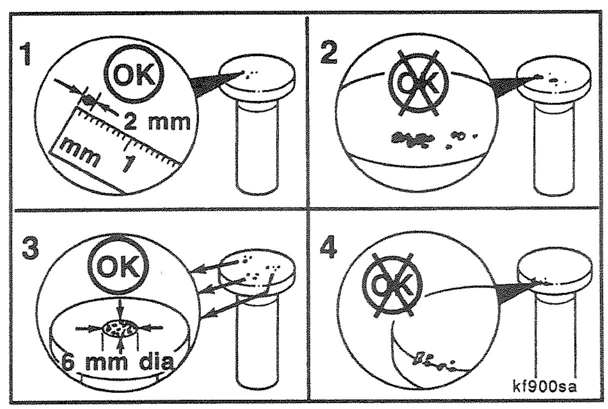
(A) - Normal Contact (exaggerated)
(B) and (C) - Irregular Contact: Do not reuse.



Pit marks on the tappet face are acceptable.

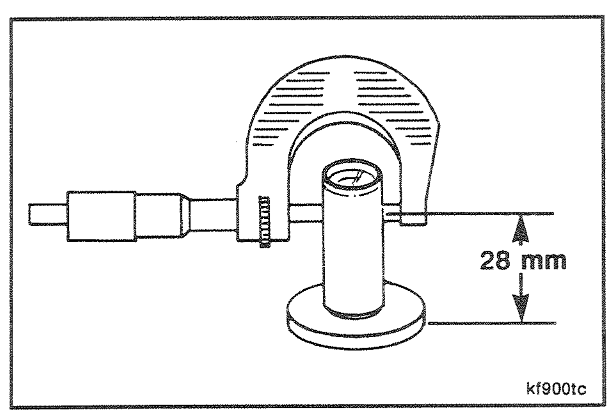
The following criteria defines the size of the pits allowed.

1. A single pit cannot be greater than 2 mm [0.078 in].
2. Interconnection of pits is not allowed.
3. Total pits when added together should not exceed 6 mm [0.236 in] diameter or a total of 4 percent of the tappet face.
4. No pitting is allowable on the edges of the wear face of the tappet.

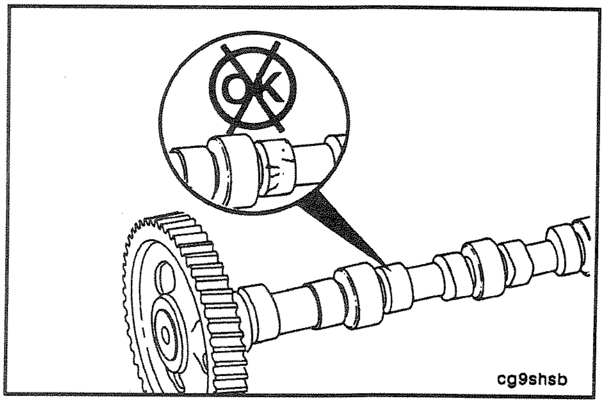


Measure the valve tappet stem.

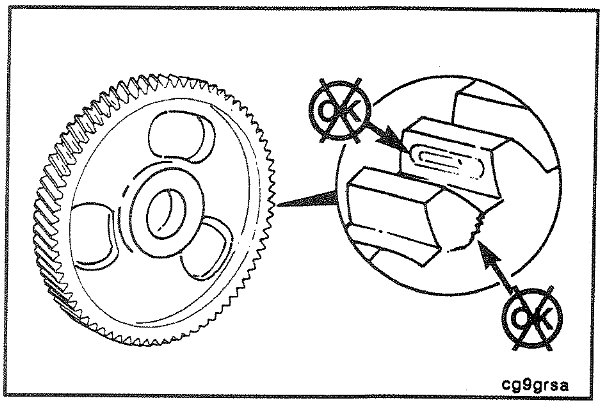
Diameter		
mm		in
15.936	MIN	[0.627]
15.977	MAX	[0.629]



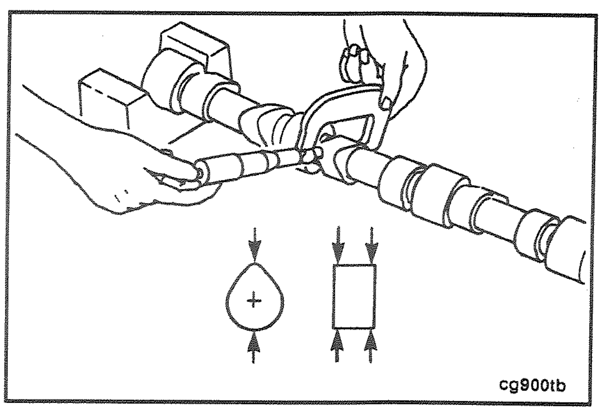
Camshaft and Gear - Inspection



Inspect the fuel transfer pump lobe, valve lobes and bearing journals for cracking, pitting or scoring.

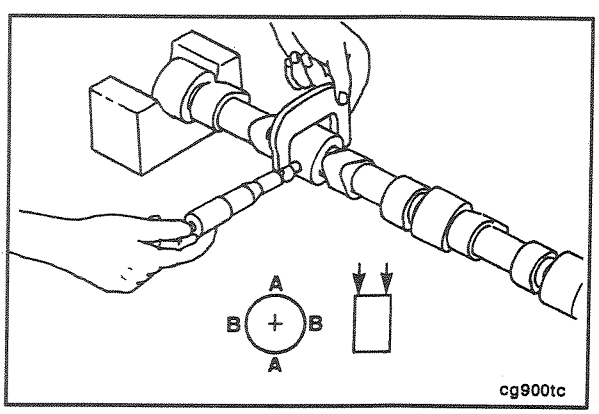


Inspect the camshaft gear teeth for pitting; look for cracks at the root of the teeth.



Measure the fuel transfer pump and valve lobes.

Diameter at Peak of Lobe	mm		in
Intake	47.040	MIN	1.852
	47.492	MAX	1.870
Exhaust	46.770	MIN	1.841
	47.222	MAX	1.859
Lift Pump	35.50	MIN	1.398
	36.26	MAX	1.428

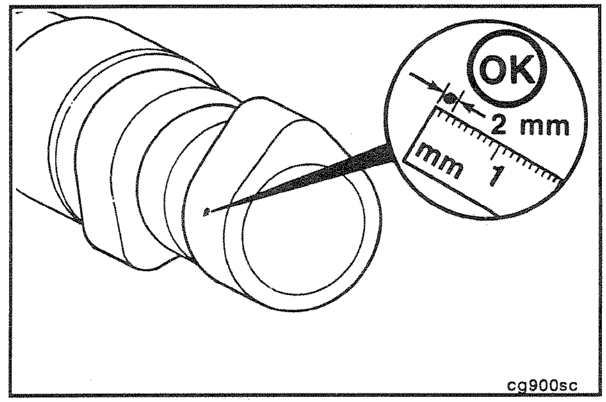


Measure the bearing journals.

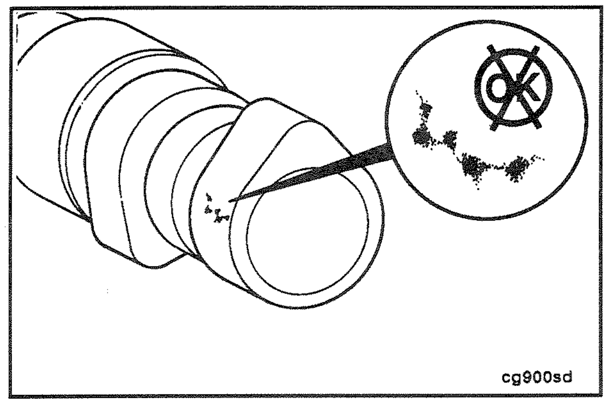
Journal Diameter mm		in
53.962	MIN	2.1245
54.013	MAX	2.1265

Pitting Reuse Criteria

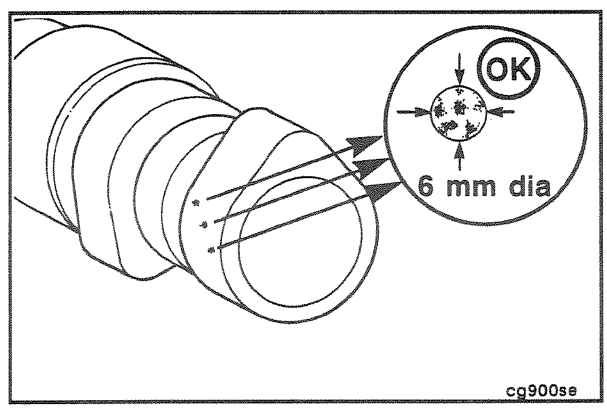
A single pit should not be greater than the area of a 2 mm [.079 in] diameter circle.



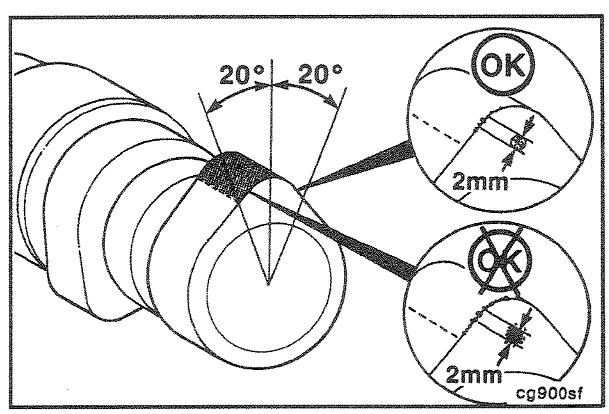
Interconnection of pits is not allowable and is treated as one pit.

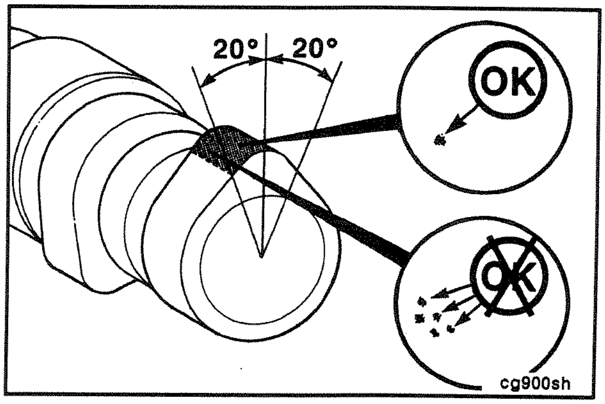


The total pits, when added together, should not exceed a circle of 6 mm [0.236 in].



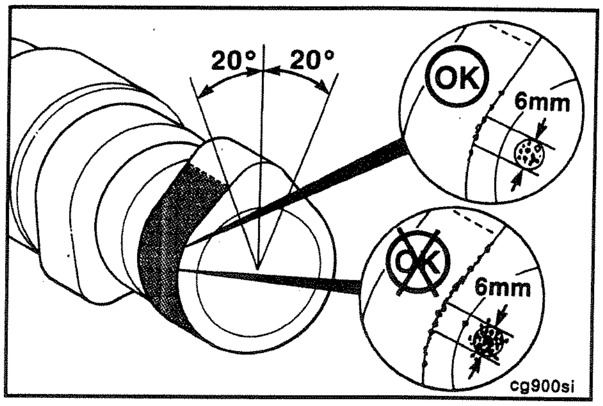
Only one pit is allowed within + or -20 degrees of the nose of the cam lobe.





Edge Deterioration (Breakdown) Criteria

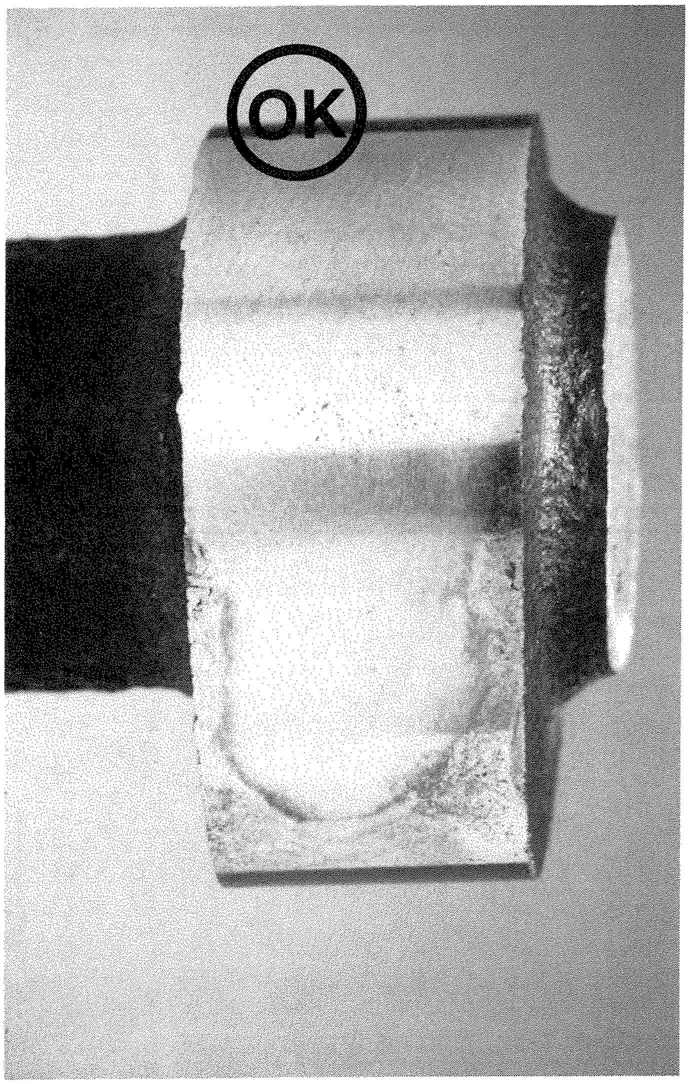
The area of edge deterioration should not be greater than the equivalent area of a 2 mm [0.079 in] circle within + or -20 degrees of the nose of the cam lobe.

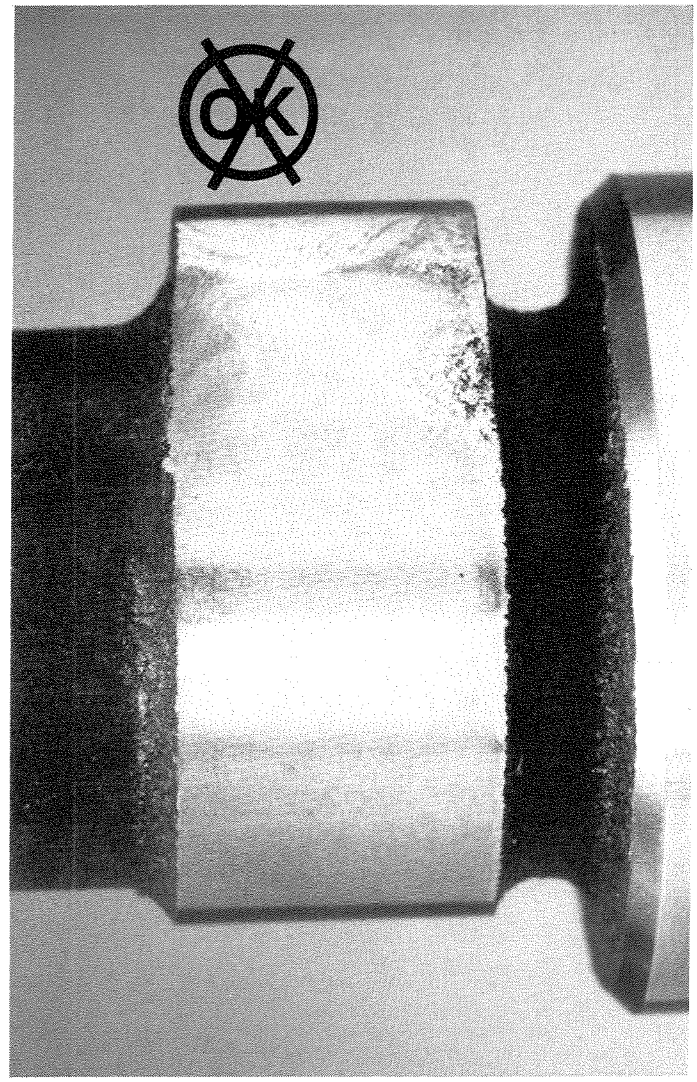


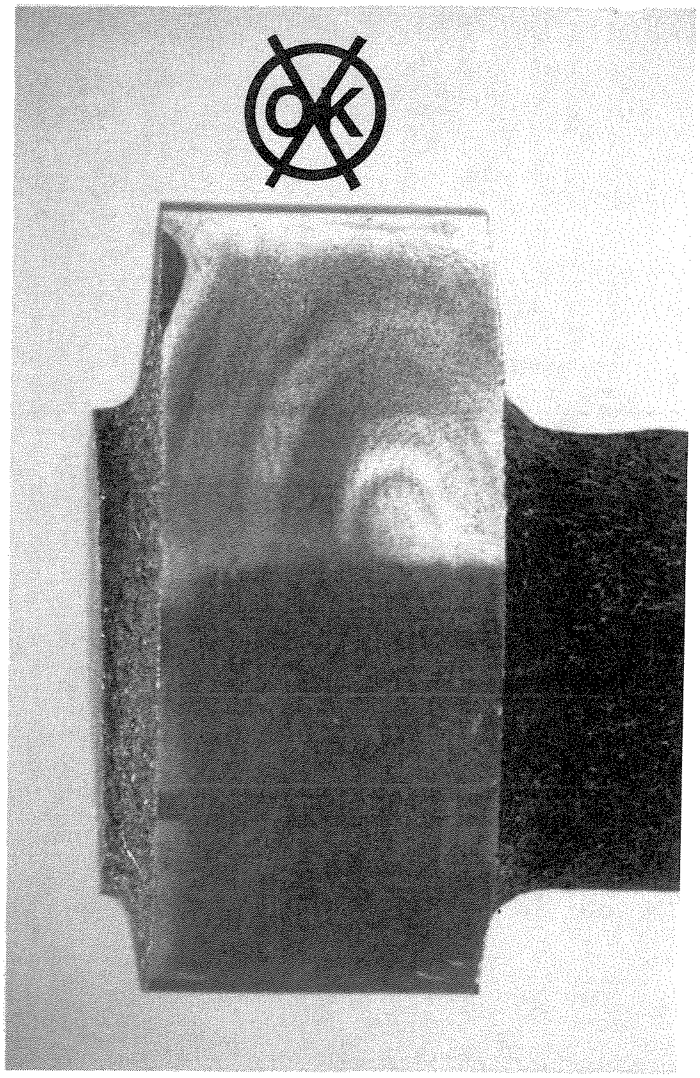
Outside of the + or -20 degrees of the nose of the cam lobe, the areas of edge deterioration should not be greater than the equivalent area of a 6 mm [0.236 in] circle.

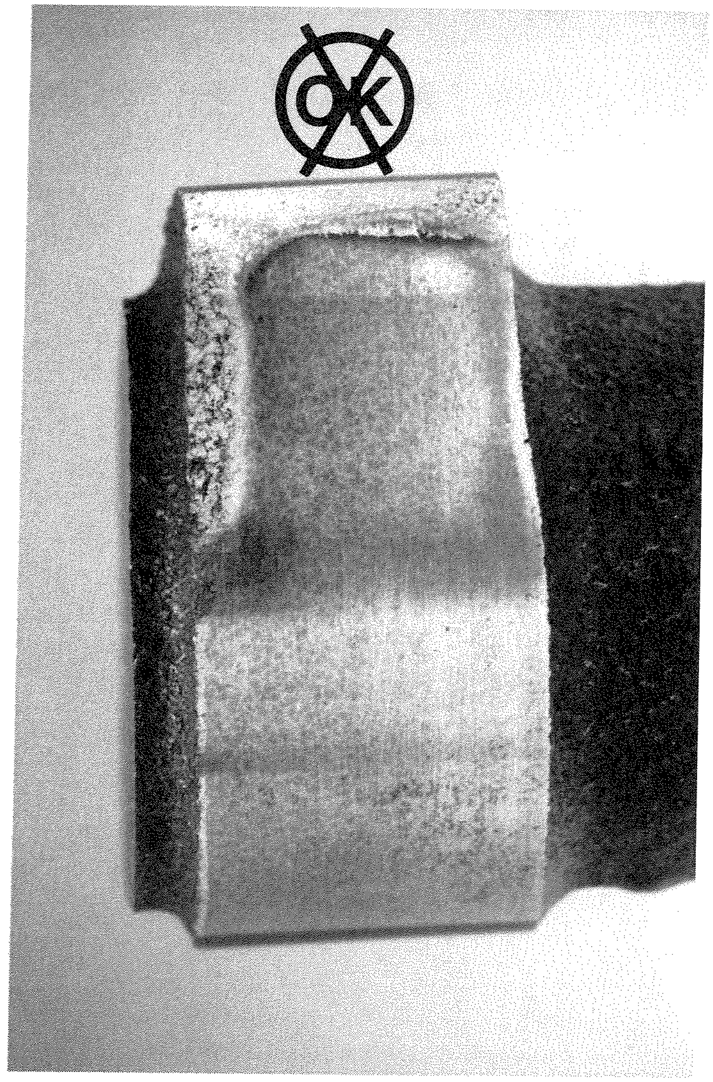
The first of the following illustration shows normal grain pattern and a casting flaw within the nose area. Both of these conditions are acceptable for reuse.

The following three illustrations show wear patterns that are not acceptable for reuse.



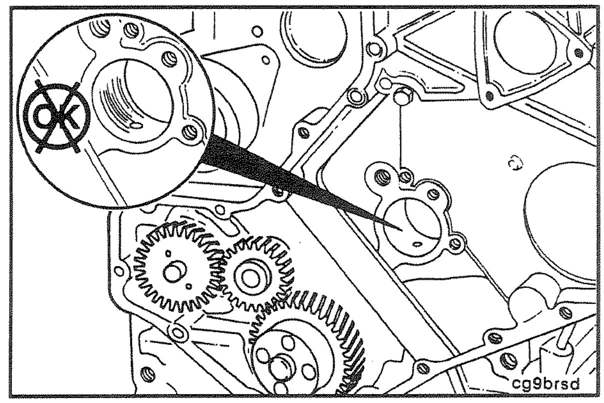






Camshaft Bore - Inspection

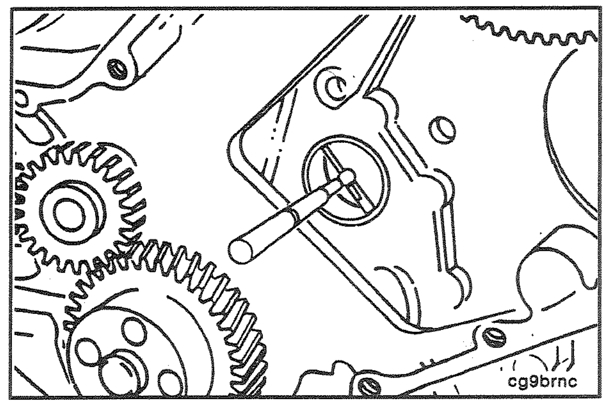
Inspect the camshaft bore for obvious damage and excessive wear.



Measure the camshaft bore.

	Inside Diameter		
No. 1 bushing	54.146 mm	MAX	[2.1317 in]
All Except No. 1	54.164 mm	MAX	[2.1324 in]

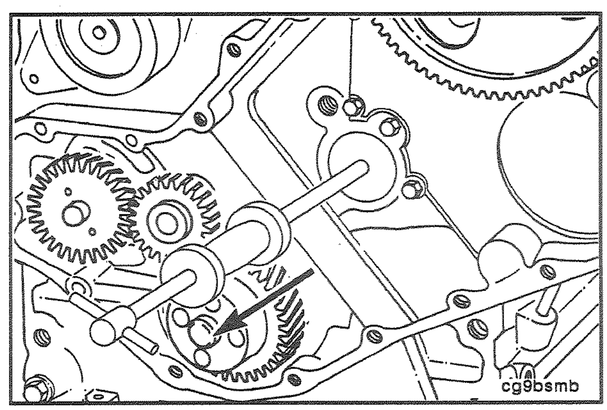
NOTE: If the bores without a bushing are worn beyond the limit, the engine must be removed for machining and installation of service bushings or replacement of the cylinder block.



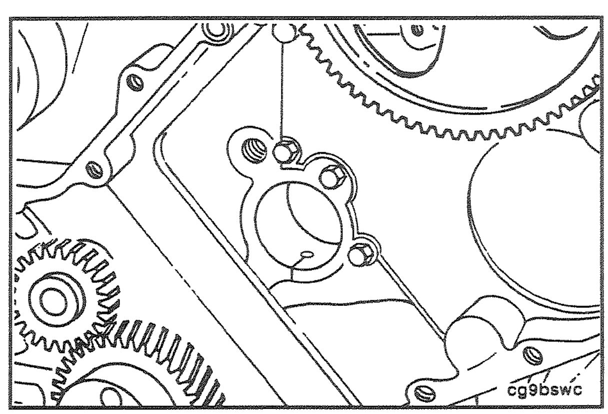
Camshaft Bushing - Replacement

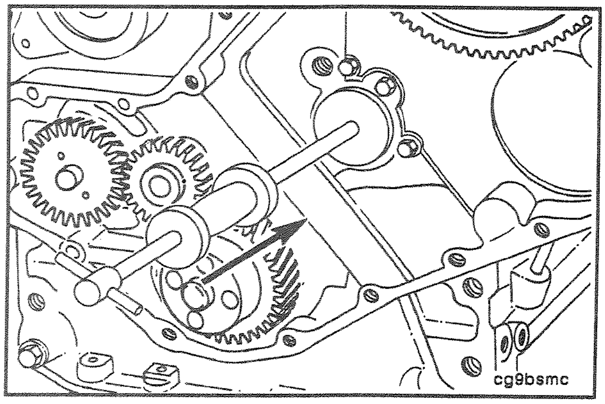
Camshaft Bushing Tool, Part No. 3823509

Remove the camshaft bushing from the No. 1 bore.



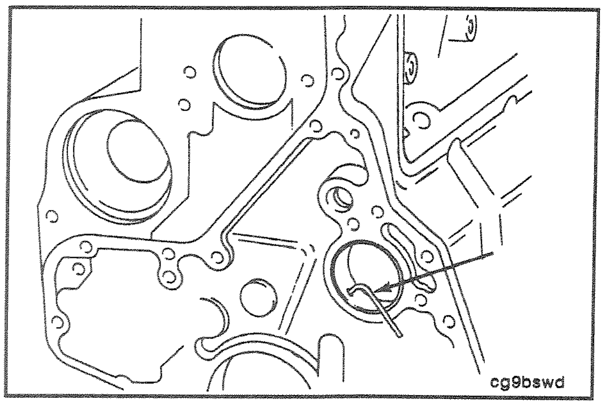
Mark the camshaft bushing and cylinder block so you can align the lubricating oil hole in the cylinder block with the lubricating oil hole in the bushing.





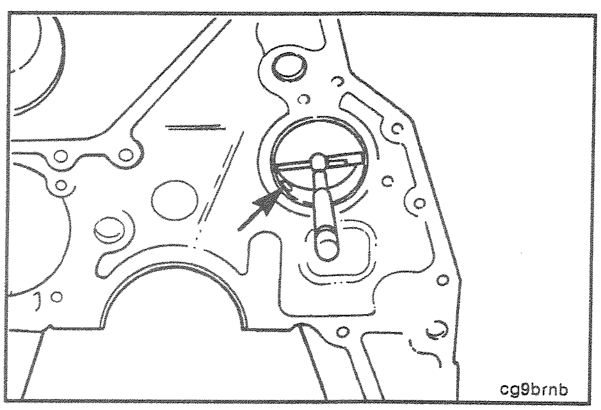
Cam Bushing Tool, Part No. 3823509

Install the camshaft bushing so that it is even with the front face of the cylinder block.



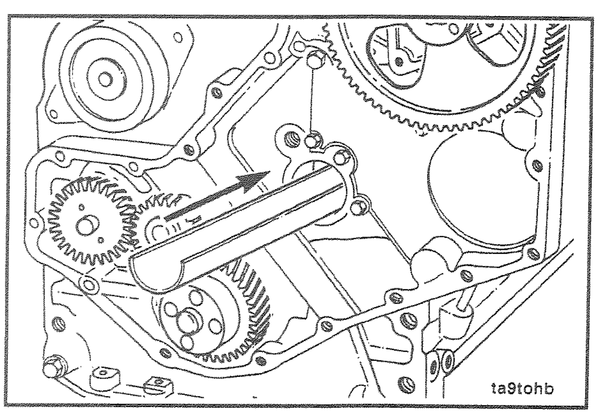
Be sure the lubricating oil hole is aligned.

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



Measure the installed camshaft bushing.

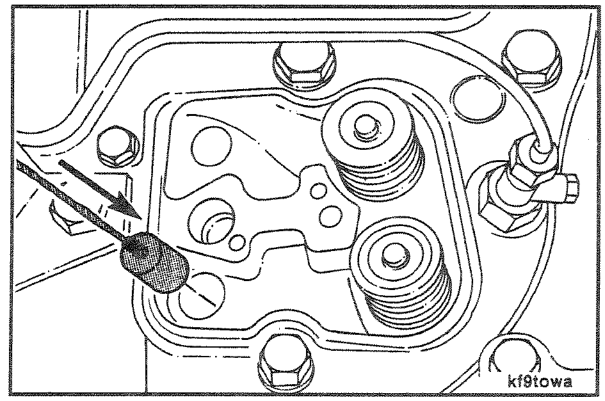
Camshaft Bushing Bore		
mm		in
54.107	MIN	2.1302
54.146	MAX	2.1317



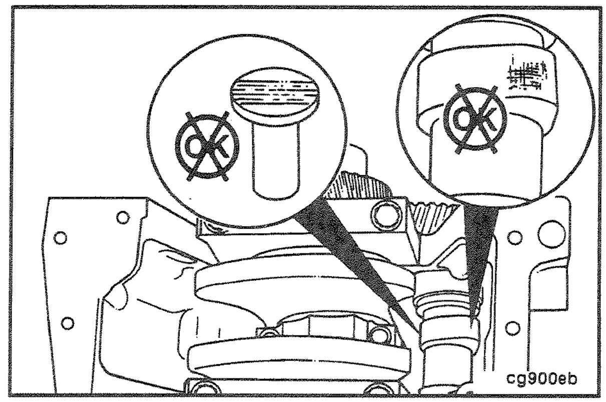
Tappet Installation

Insert the plastic trough the full length of the cam bore.

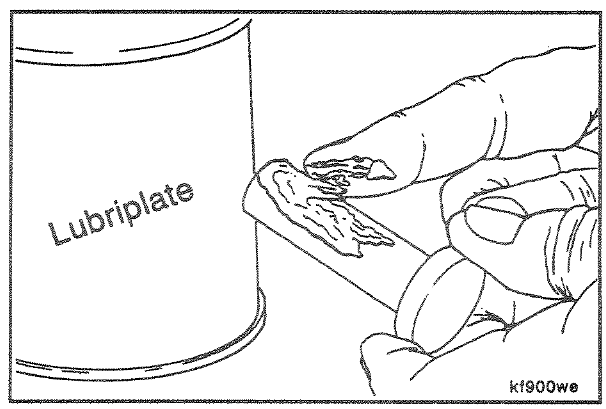
Lower the tappet installation tool down the push tube hole, through the tappet bore, and into the trough.



Feed the installation tool through the cam bores by carefully pulling the plastic trough/installation tool out the front. The barrier at the rear of the trough will pull the tool out most of the time.

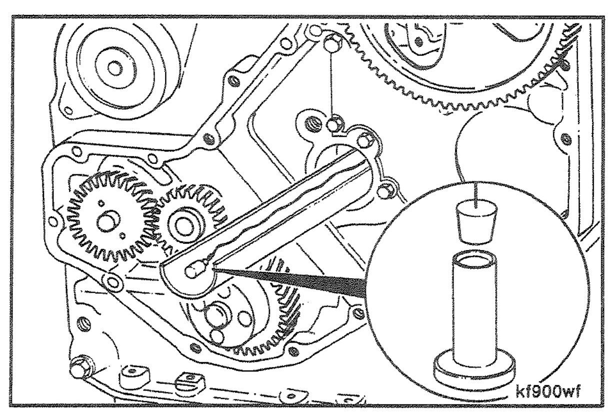


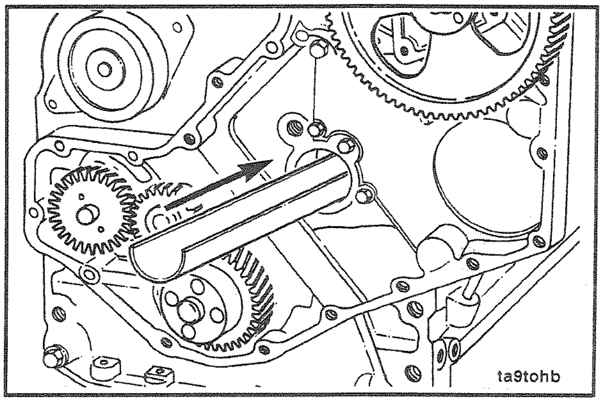
Lubricate the tappets with Lubriplate™ 105.



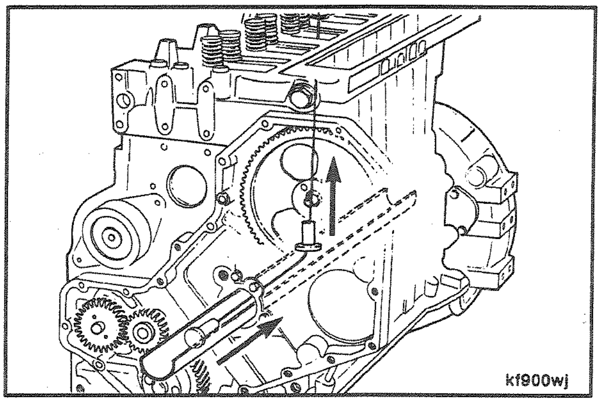
Insert the installation tool into the tappet.

NOTE: To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times before installing the tappets.

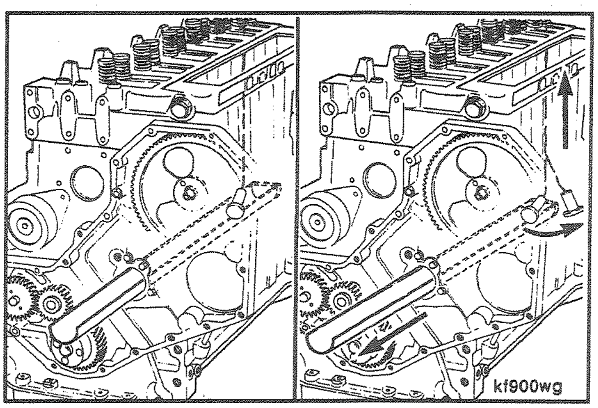




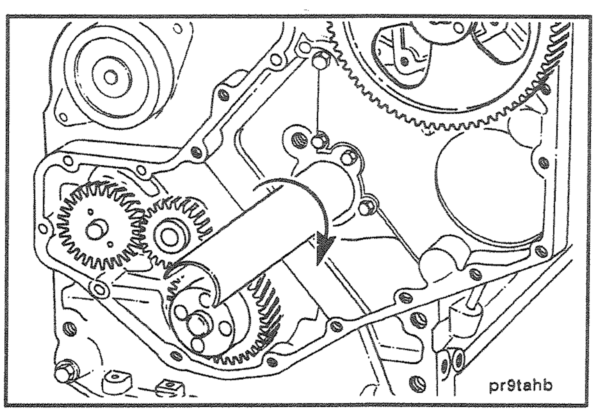
Slide the trough into the cam bore.



Pull the tool/tappet through the cam bore and up into the tappet bore.

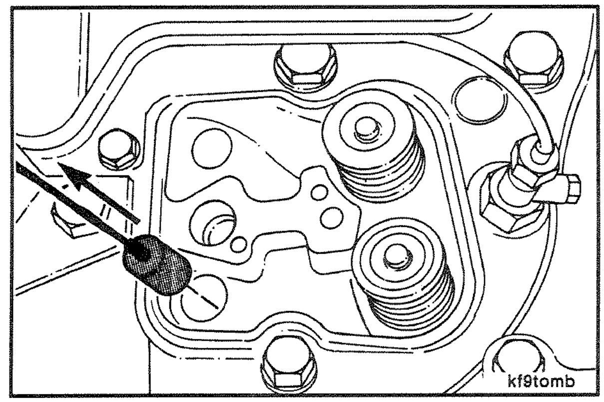


If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore, pull the trough out enough to allow the tappet to drop down and align itself, then pull the tappet up into the bore.



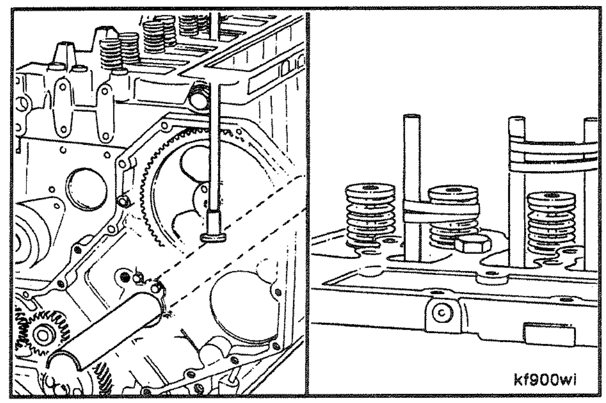
After the tappet has been pulled up into position, slide the trough back into the cam bore and rotate it 1/2 turn. This will position the round side of the trough up, which will hold the tappet in place.

Remove the installation tool from the tappet.



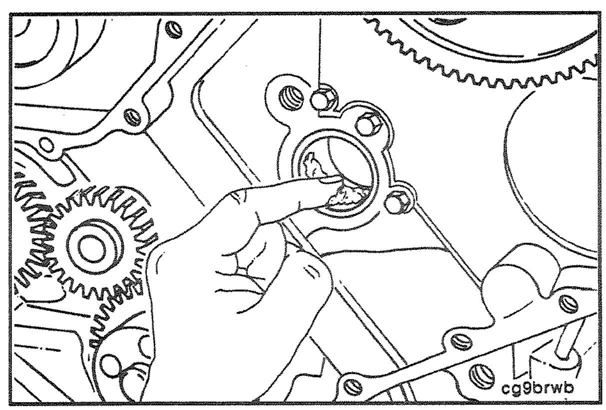
Install a wooden dowel into the top of the tappet. Wrap rubber bands around the wooden dowels to secure the tappets.

Repeat this process until all tappets have been installed.

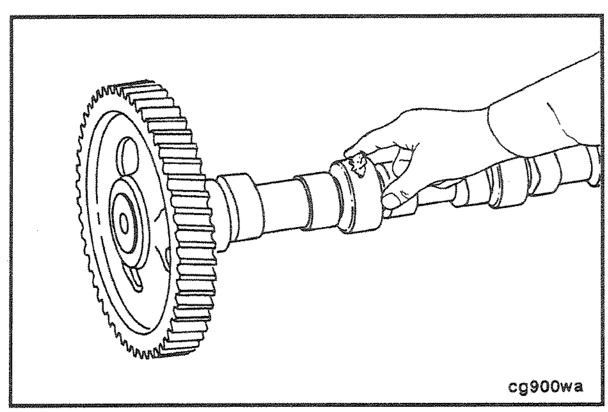


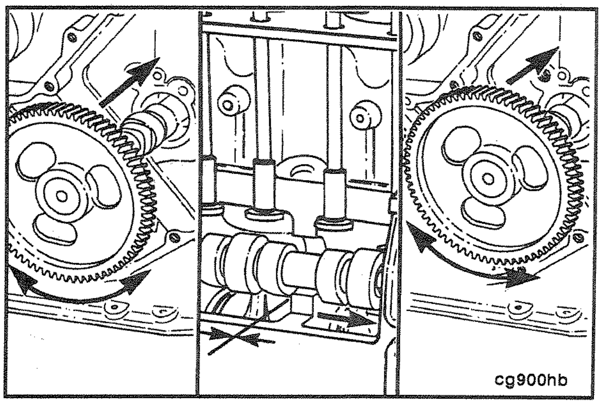
Camshaft Installation

Apply a coat of Lubriplate 105 to the front camshaft bore.

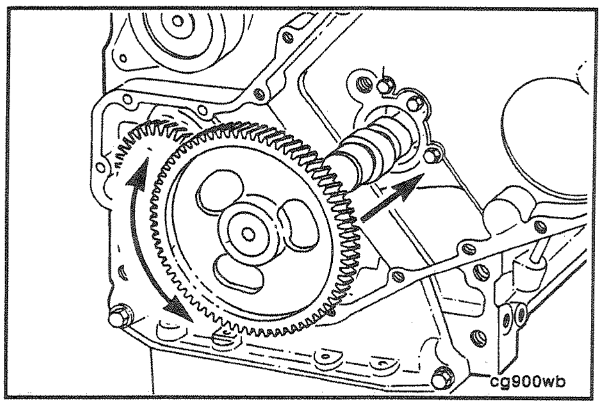


Lubricate the camshaft lobes, journals and thrust washer with Lubriplate™ 105.



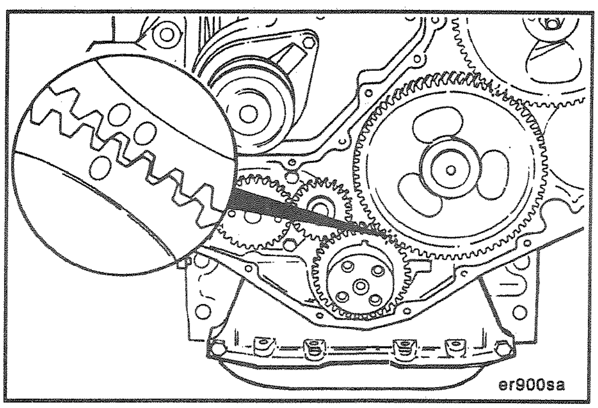


Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the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

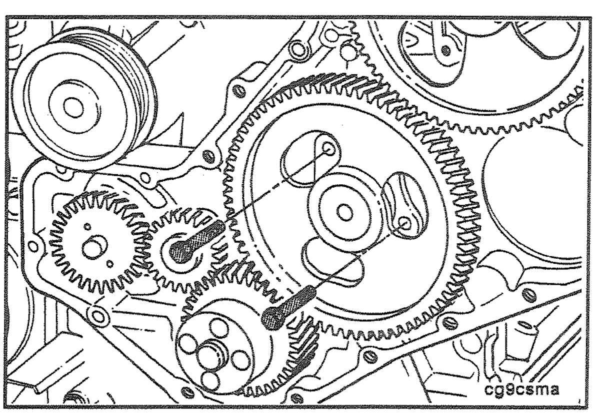


Caution: Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

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



Install the thrust washer, Align the timing marks as illustrated and finish installing the camshaft.

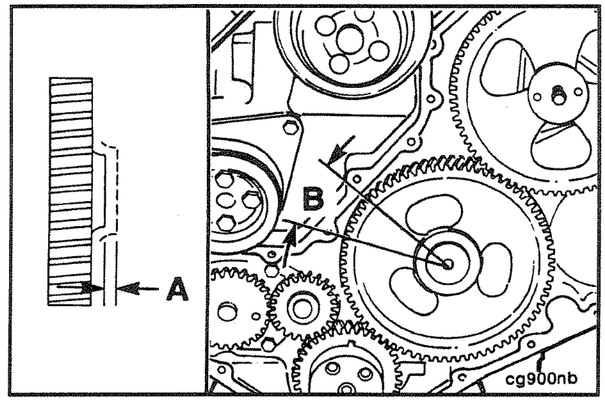


Install the thrust washer capscrews and tighten to 24 N•m [18 ft-lb].

Verify the camshaft has proper backlash and end play.

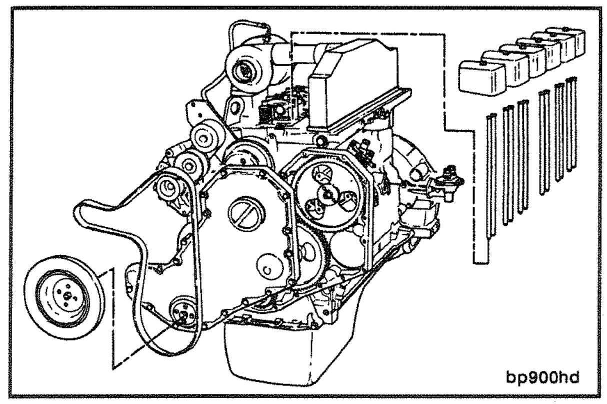
A = 0.12 to 0.47 mm [0.005 to 0.018 inch]

B = 0.76 to 0.330 mm [0.003 to 0.013 inch]

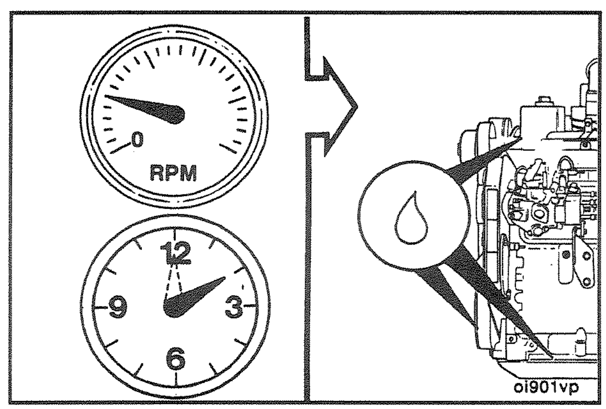


Complete the installation of the removed parts.

- Gear cover. Refer to Procedure (7-18).
- Vibration damper. Refer to Procedure (7-15).
- Rocker levers and valve cover. Refer to Procedure (7-03).
- Fuel transfer pump. Refer to Procedure (5-21).



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



Camshaft Gear - Replacement (7-20)

A camshaft gear removal/installation tool, Part No. 3823589 is available for replacing the camshaft gear in restricted areas where the camshaft can not be removed from the engine. Follow the directions included with the tool.

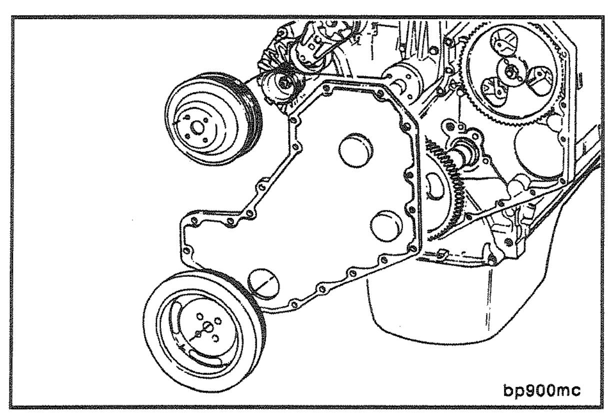
Removal

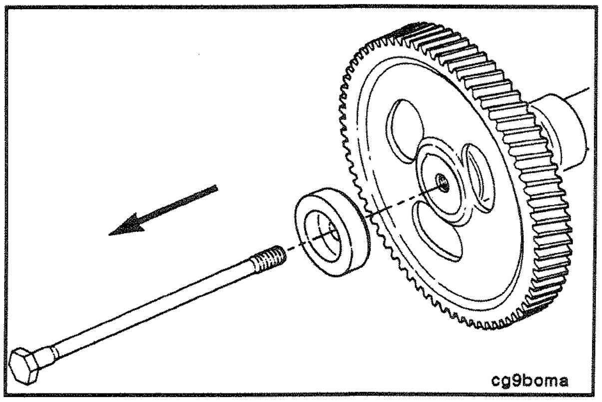
Remove the fan pulley.

Remove the crankshaft pulley. Refer to Procedure (7-15).

Remove the gear cover. Refer to Procedure (7-18).

Remove the camshaft. Refer to Procedure (7-19).

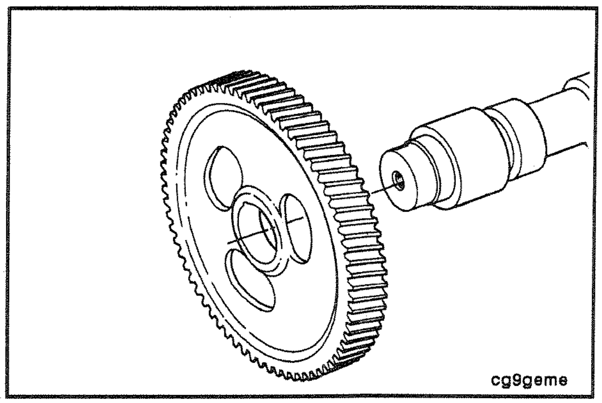




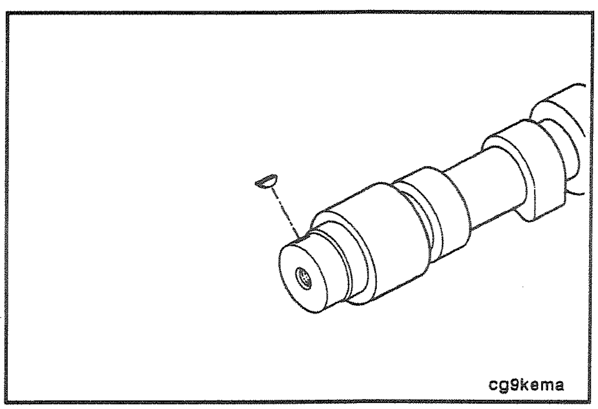
18 mm

On bolted camshafts, remove the camshaft bolt and washer.

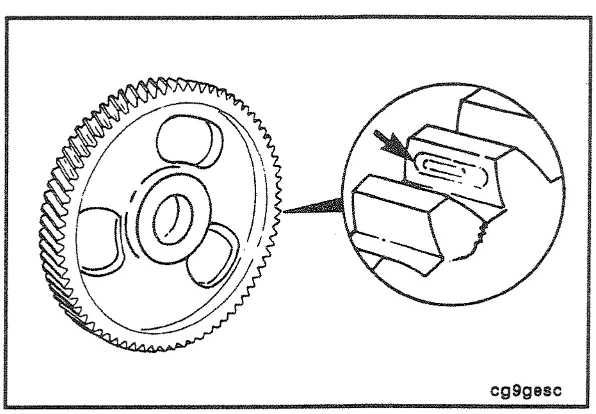
Bolted camshafts are only used on 1991 engines equipped with an inline pump.



Remove the gear.



Remove the camshaft key.



Cleaning and Inspection

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

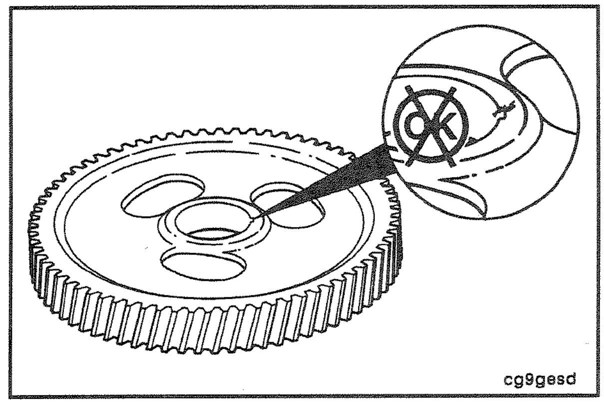
Inspect the camshaft bore for fretting or burrs.

NOTE: If the fretting, burrs or raised material cannot be removed with Scotch-Brite® 7448 or equivalent, replace the camshaft gear.

Inspect the camshaft gear keyway for burrs.

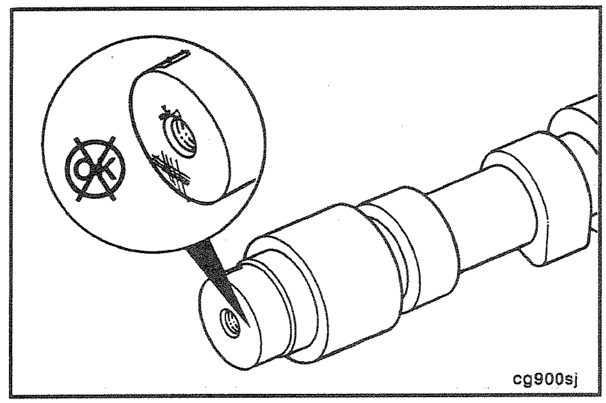
Remove burrs with Scotch-Brite® 7448, or equivalent.

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



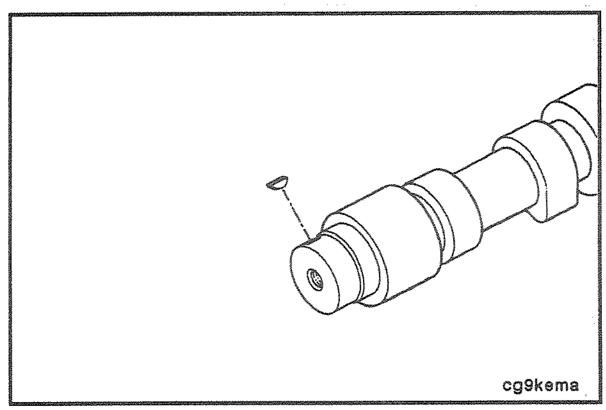
Visually inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs cannot be removed with Scotch-Brite® 7448, or equivalent, replace the camshaft.

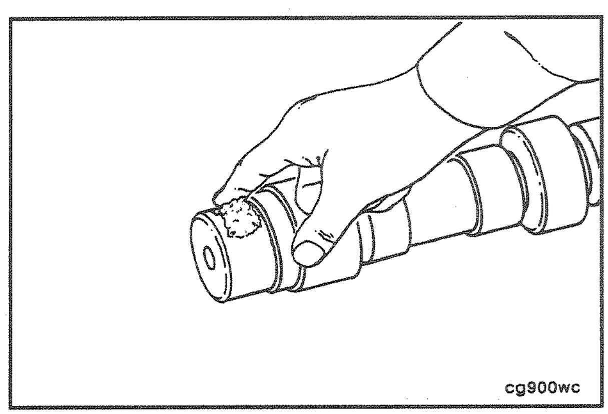


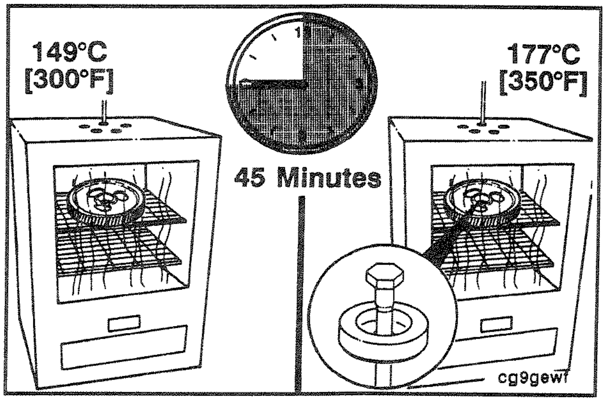
Installing the Camshaft Gear

Install the key.



Lubricate the camshaft surface with Lubriplate 105 or equivalent.

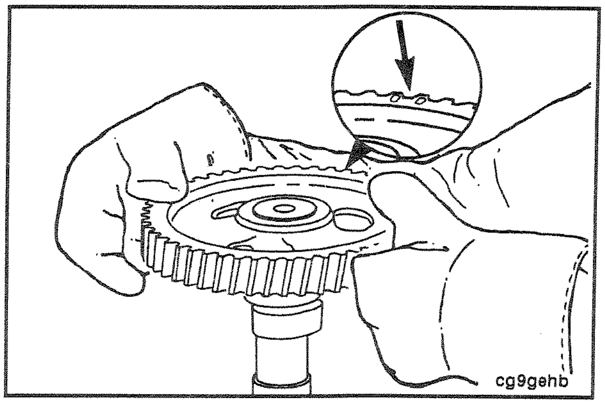




Caution: The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 177°C [350°F].

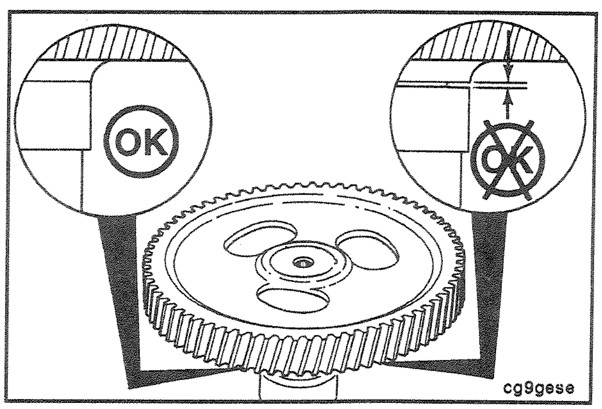
Heat the camshaft gear for **non bolted** 91' camshafts in an oven at 149°C [300°F] for 45 minutes.

Heat the camshaft gear for **bolted** 91' camshafts (steel gear) and all 94' automotive to 177°C [350°F].



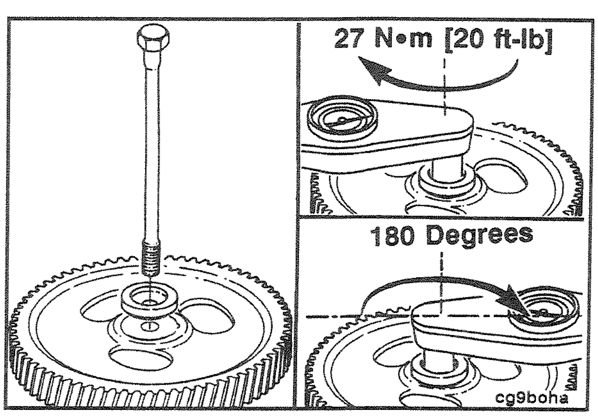
Wear protective gloves to handle the hot gear.

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



Be sure the gear is seated against camshaft shoulder.

Using a .001 inch feeler gauge, check to see if the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. If the feeler gauge can be inserted, the camshaft gear is not properly seated.



Bolted Camshafts (1991 engines equipped with an inline pump)

18 mm

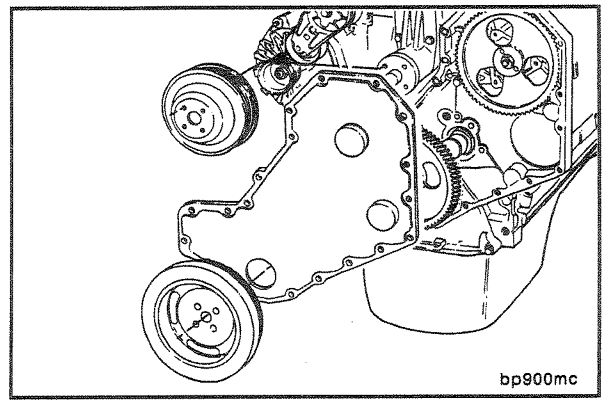
Install camshaft bolt and washer. Torque the capscrew to 27 N•m [20 ft-lb], then rotate the capscrew an additional 180 degrees.

Install camshaft. Refer to Procedure (7-96).

Install gear cover.

Install crank pulley.

Install fan pulley.

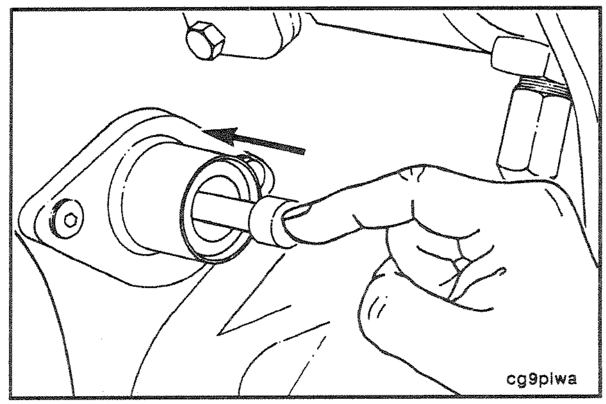


Timing Pin Assembly - Replacement (7-20)

1/2 inch Drive, 3377371, Engine Barring Gear

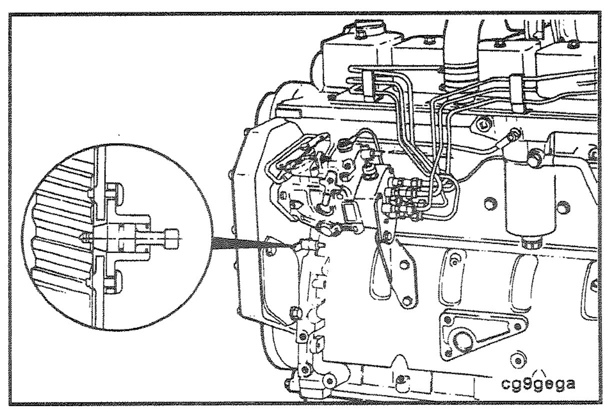
Locate Top Dead Center (TDC) for Cylinder Number 1 by barring crankshaft slowly while pressing on the engine timing pin.

Service Tip: If the timing pin has been damaged and cannot be used to locate TDC, refer to Procedure 7-21.



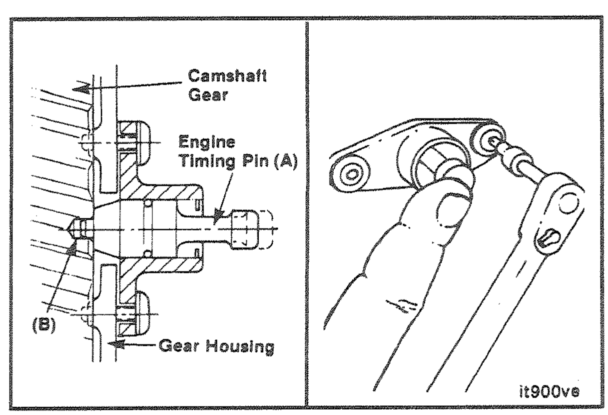
T-25 Torx

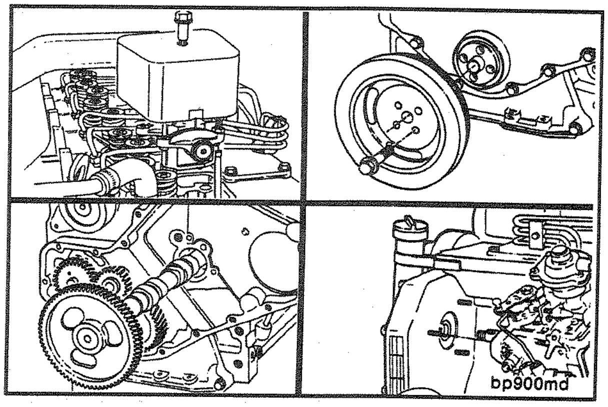
Remove the timing pin assembly and seal.



Install a new seal and, if required, new timing pin assembly. Hold the pin (A) in the hole (B) in the camshaft gear to align the housing.

Torque Value: 5 N•m [4 ft-lb]



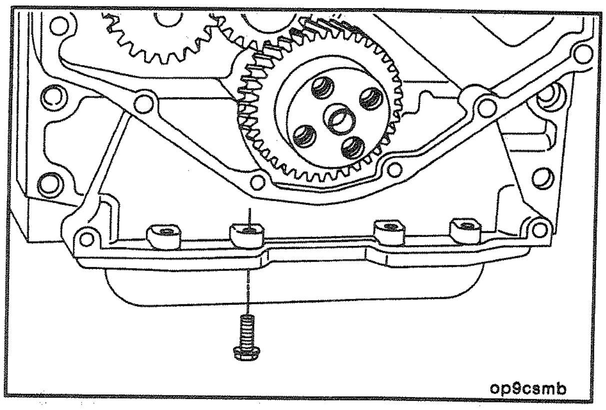


Gear Housing or Gasket - Replacement (7-21)

Removal

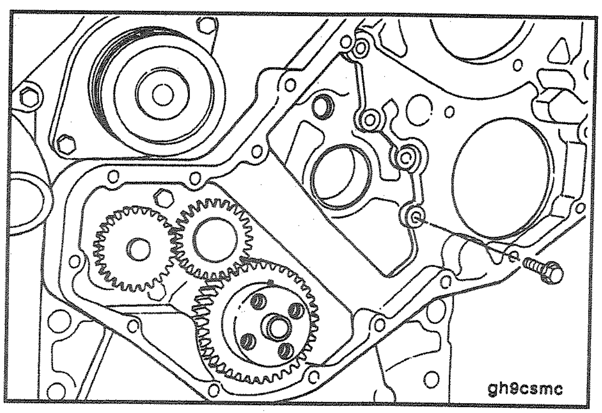
Preparatory Steps:

- Remove the valve cover rocker levers and push rods.
- Remove the vibration damper. Refer to Procedure (7-15).
- Remove the camshaft. Refer to Procedure (7-19).
- Remove the fuel pump. Refer to Procedures (5-35) or (5-37).



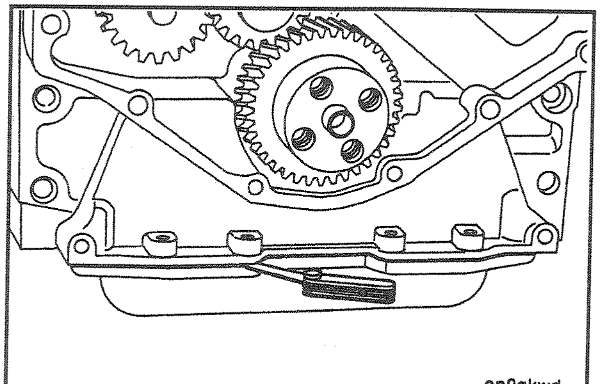
10 mm

Remove the six front oil pan capscrews.



10 mm

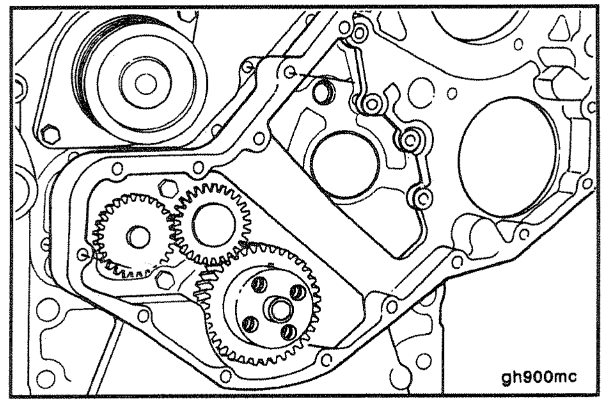
Remove the gear housing capscrews.



Using a feeler gauge, attempt to separate the lubricating oil pan gasket from the gear housing.

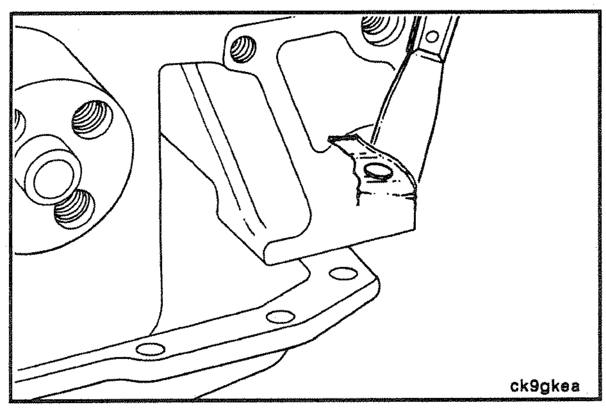
Plastic Hammer

Remove the gear housing.

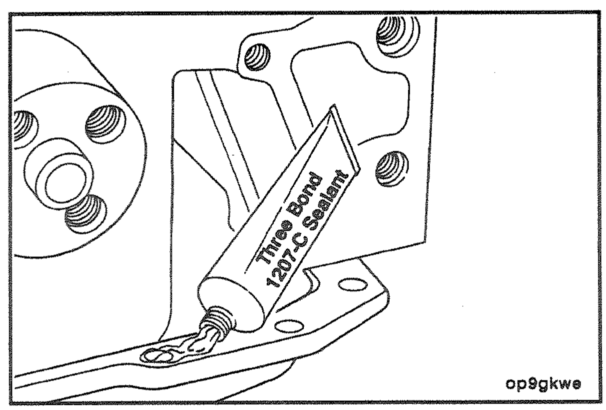


Cleaning and Inspection

Clean the gasket material from the cylinder block.

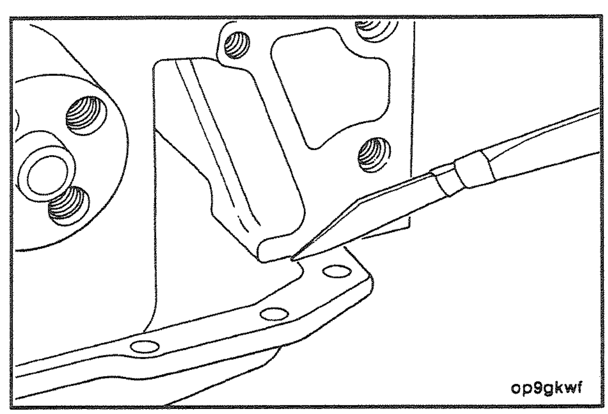


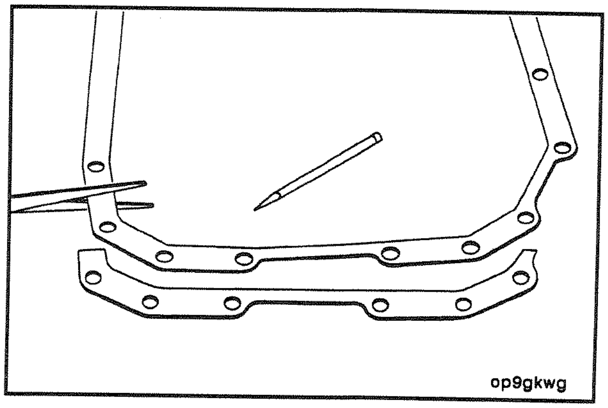
Inspect the lubricatin oil pan gasket. If it is not torn, coat with Three Bond 1207-C® sealant.



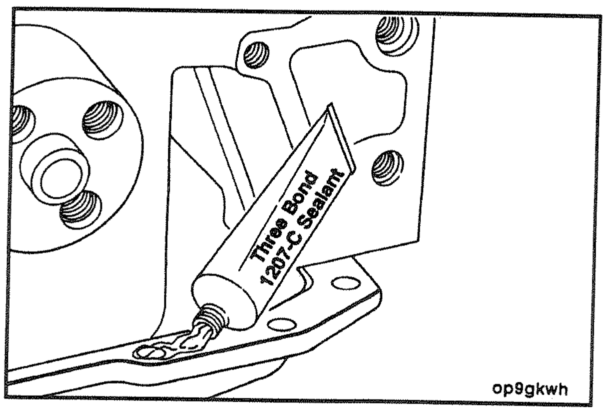
Pan Gasket - Repair

If the gasket is torn, it may be repaired. Cut the torn gasket off even with the front of the cylinder block.

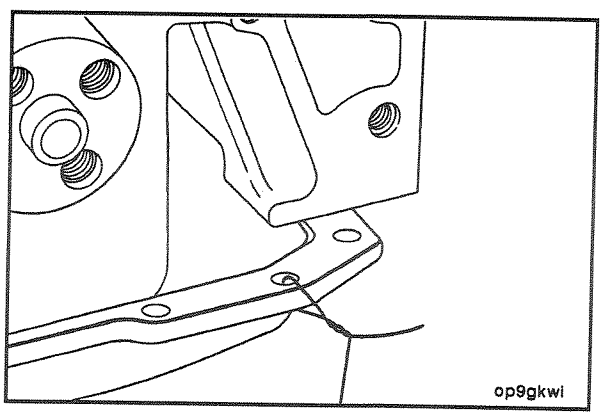




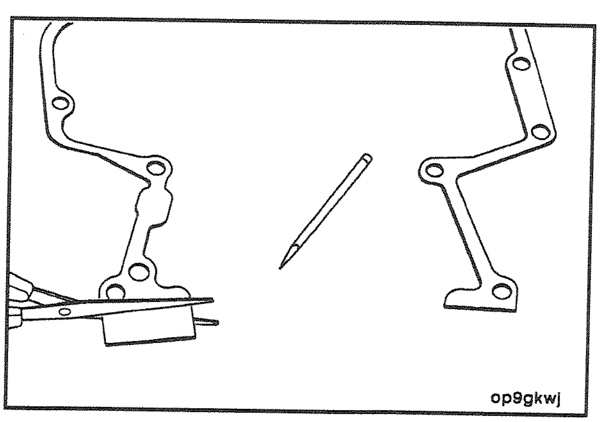
Using the old gasket as a pattern, cut the front section of a new gasket to the same size.



Clean the sealing surfaces and coat the new gasket on both sides with Three Bond 1207-C® sealant.



Use common thread or a very fine wire to hold the new gasket splice in position as illustrated.

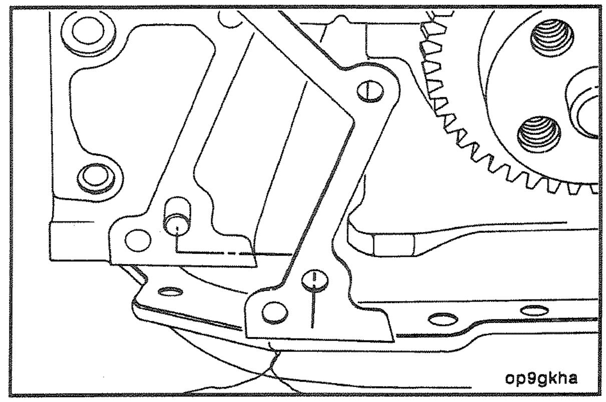


Installation

Mark and trim 1.59 mm [1/16 inch] off of the new gear housing gasket.

NOTE: When properly trimmed, the gear housing gasket should be even with the lubricating oil pan gasket when installed.

Position the gasket on the alignment dowels.

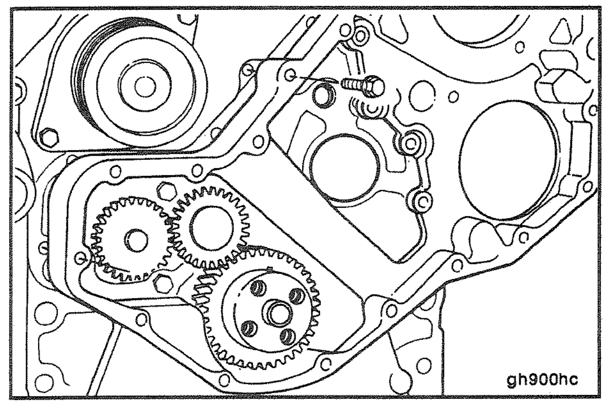


10 mm

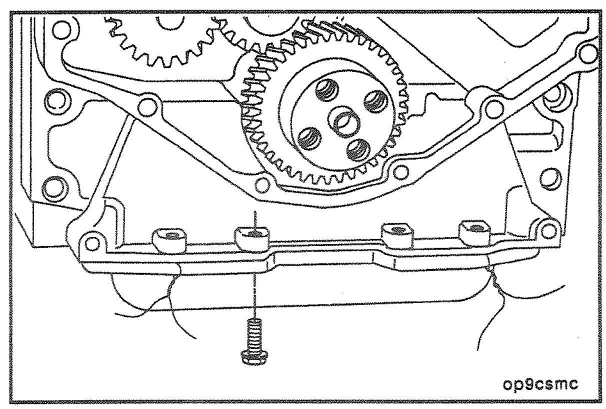
Carefully install the gear housing, making sure both gaskets are in place.

Torque Value: 24 N•m [18 ft-lb]

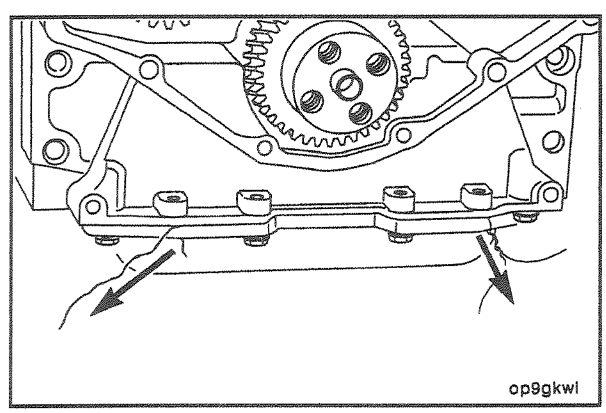
Caution: If a new housing or other than the original housing is installed, the timing pin assembly must be accurately located. Refer to procedure (7-20).

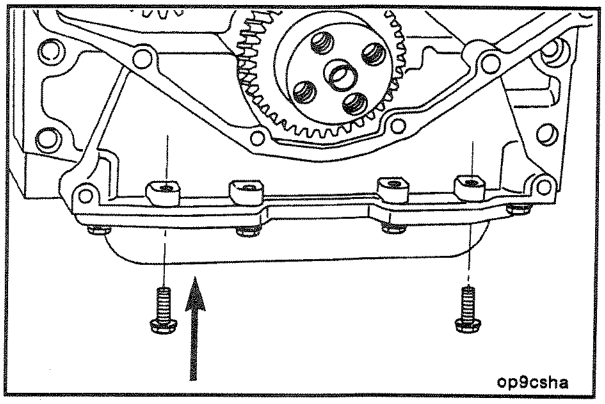


Start the oil pan capscrews in the holes not being used to tie the gasket in place.



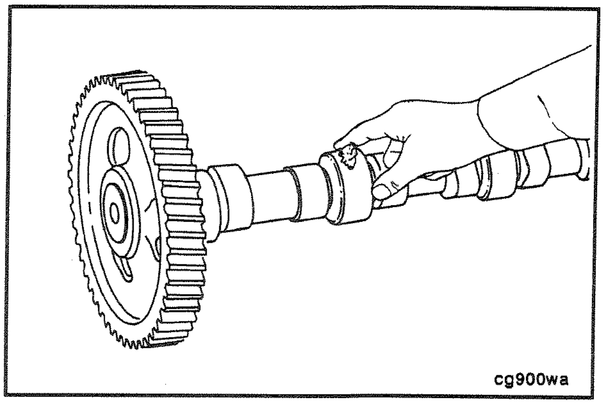
Remove the thread or wire holding the gasket in place.



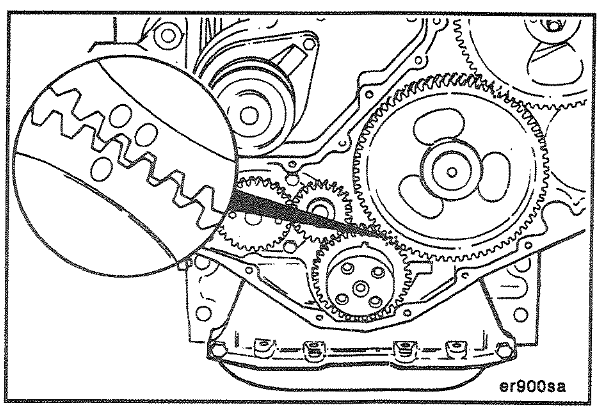


10 mm

Install the remaining two capscrews and tighten the capscrews to 24 N•m [18 ft-lb].



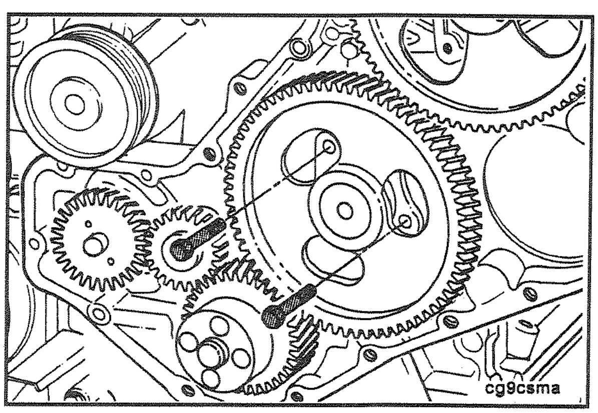
Lubricate the camshaft and thrust washer with Lubriplate™ 105.



Install the camshaft/thrust washer.

Make sure the alignment marks on the camshaft and camshaft gears are aligned.

Refer to the camshaft installation procedure procedure (7-19) if additional information is needed.



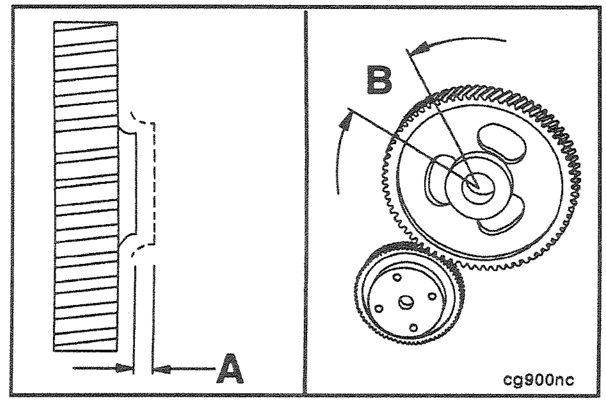
Install the thrust washer capscrews.

Torque Value: 24 N•m [18 ft-lb]

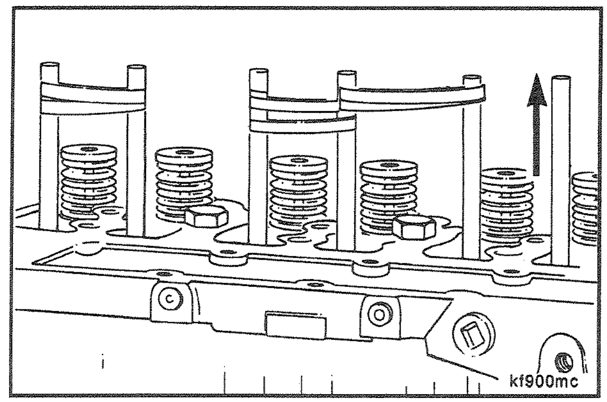
Verify the camshaft has proper backlash and end play.

A = 0.12 to 0.47 mm [0.005 to 0.018 in]

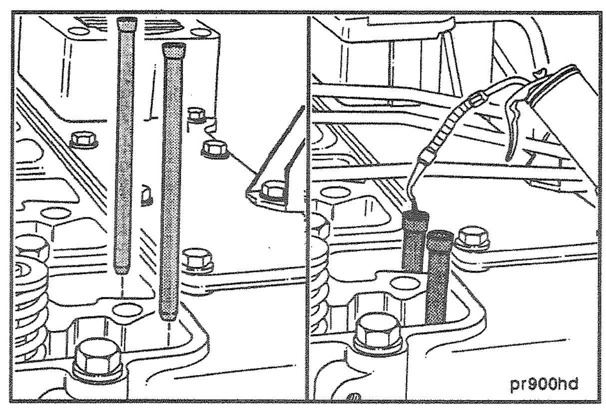
B = 0.076 to 0.330 mm [0.003 to 0.013 in]



Remove the wooden dowels from the tappets.



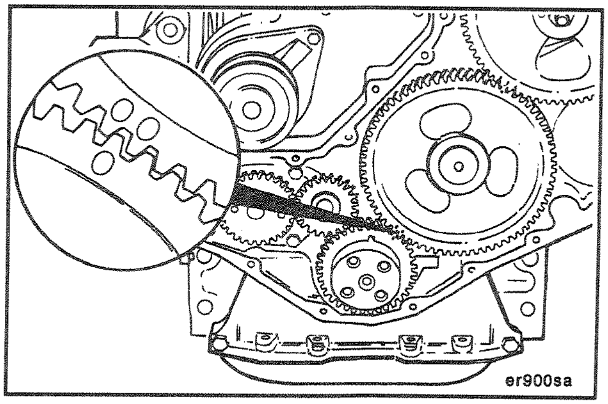
Install and lubricate the push tubes.



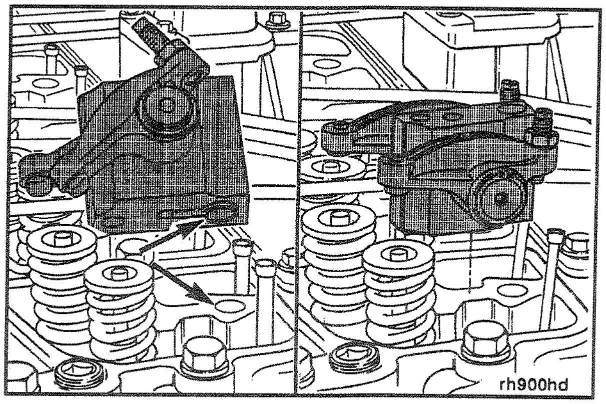
Relocating the Timing Pin

NOTE: Omit this step if the removed gear housing was installed; proceed to page 7-143 and complete the installation of the rocker levers.

The location of the timing pin assembly on the gear housing is critical for correct engine adjustments. Follow this procedure to install the assembly so that it corresponds to Top Dead Center (TDC), for Cylinder Number 1.



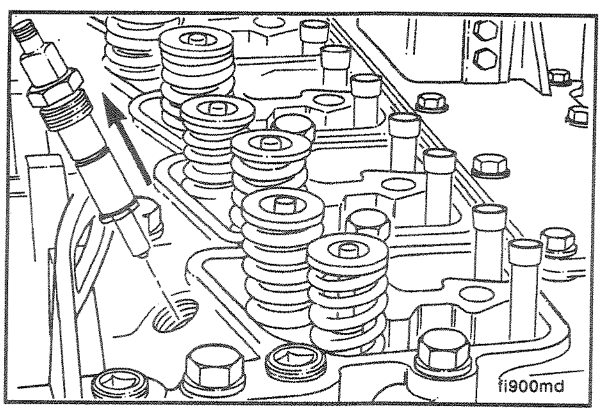
Verify that the No. 1 cylinder is at or near TDC on the compression stroke by rotating the crankshaft until the engine timing pin engages in the cam gear hole or the hole is visible through the gear housing. Disengage the timing pin.



10 mm

Install the rocker lever, pedestal assembly for Cylinder Number 1.

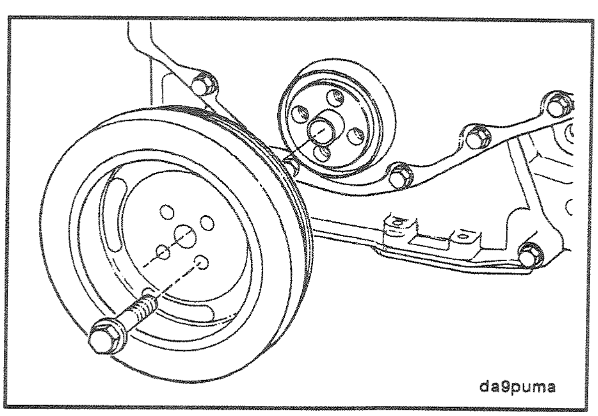
Refer to Procedure (7-03).



10 mm

Remove the injector nozzles from all of the cylinders.

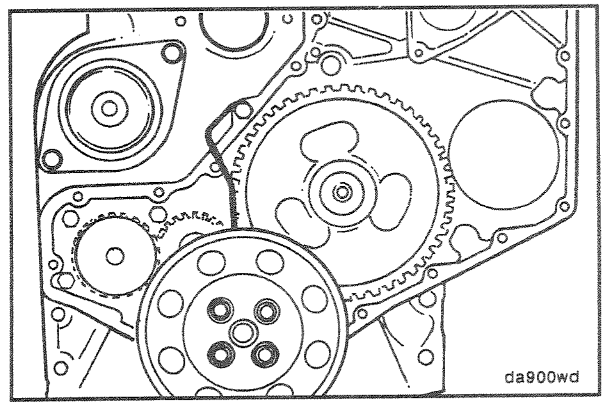
This step is important to vent the cylinders so the crankshaft can be rotated smoothly to locate TDC for Cylinder Number 1.



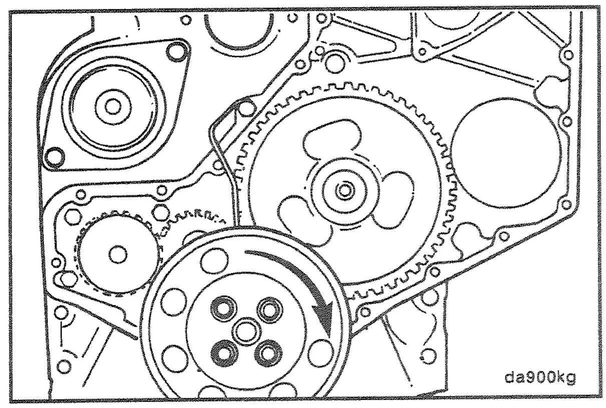
18 mm

Temporarily install the crankshaft damper or crankshaft pulley.

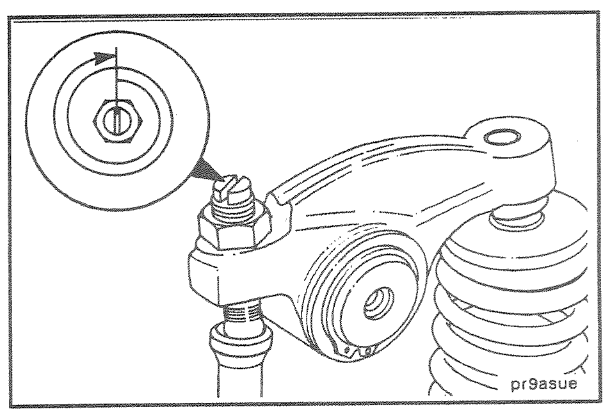
Fabricate and install a wire pointer for the front of the engine. This can be done by forming a piece of wire that can be tightened under one of the gear housing capscrews. The wire should extend from the gear cover to a place on the crankshaft vibration damper that is easily seen.



Rotate the crankshaft one-quarter revolution in the direction of normal engine rotation.



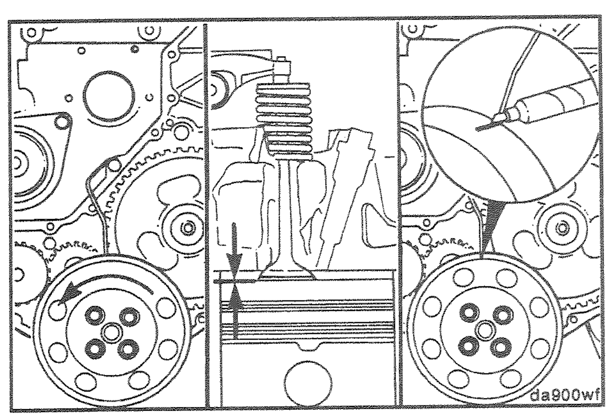
Tighten the adjusting screw for the No. 1 intake valve to zero (0) lash plus 5 turns.

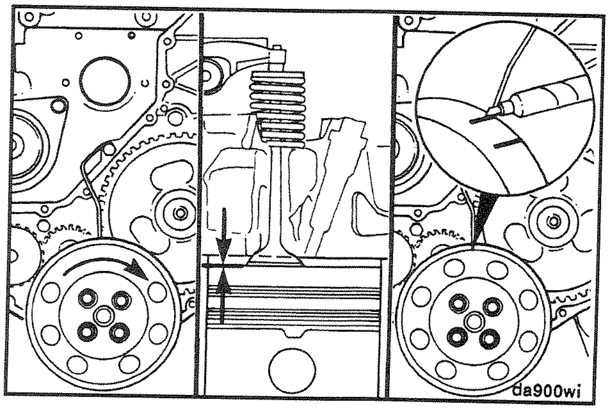


Caution: Use extreme care when rotating the crankshaft. Use of too much force could damage the valve or push rod.

Rotate the crankshaft slowly in the opposite direction of normal engine rotation until the piston touches the intake valve.

Mark the vibration damper at the wire pointer.

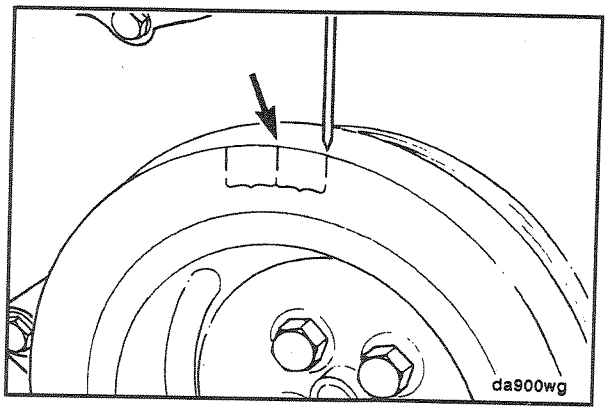




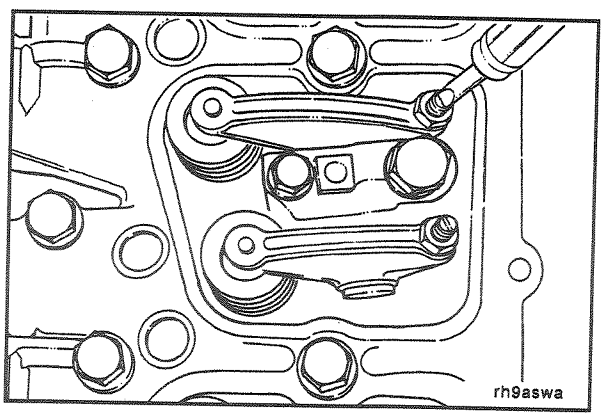
Caution: Make sure that the piston touches the intake valve with approximately the same amount of force as in the previous step.

Rotate the crankshaft in the direction or normal engine roation until the piston touches the intake valve.

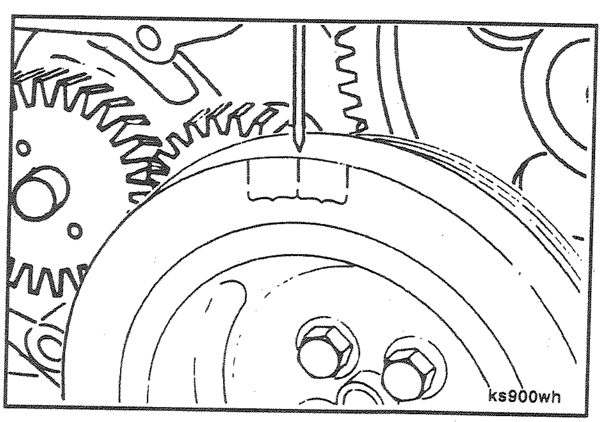
Mark the vibration damper at the wire pointer.



Measure the distance and mark the vibration damper at one-half the distance between the two marks. This mark is the TDC mark.

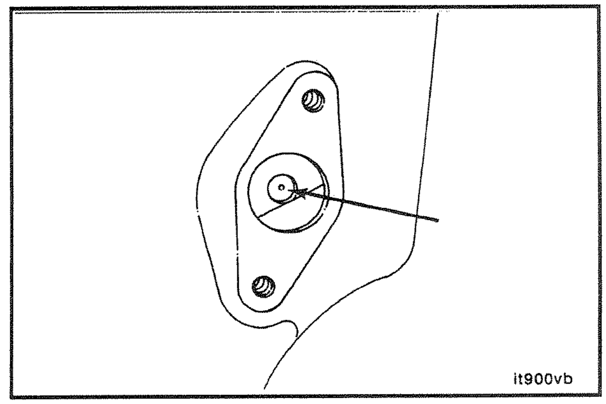


Caution: Completely loosen the intake valve adjusting screw. Failure to do so will result in damage to the intake valve or push rod when the crankshaft is rotated.

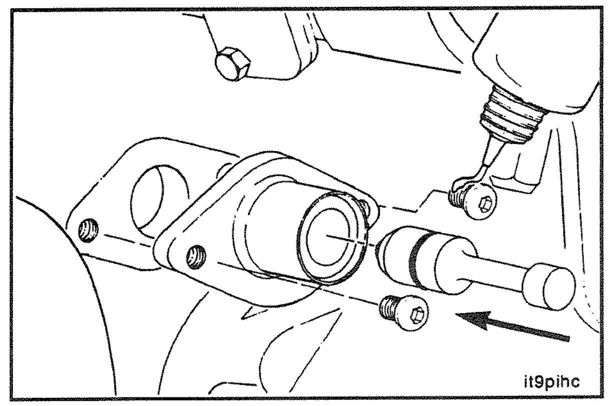


Rotate the crankshaft in the direction of normal engine rotation until the pointer is aligned with the TDC mark, then rotate the crankshaft one additional revolution.

The timing pin hole in the cam gear should be visible or felt through the back side of the gear housing. If not, the crankshaft must be rotated one revolution in the direction of engine rotation.



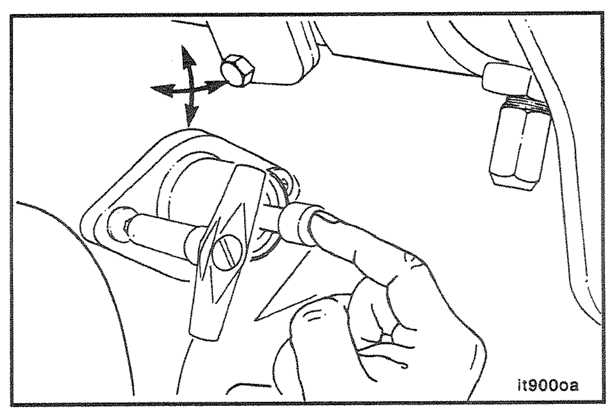
Apply a coat of Loctite™ 59241 to the threads of the torx screws and install the timing pin assembly and new o-ring.



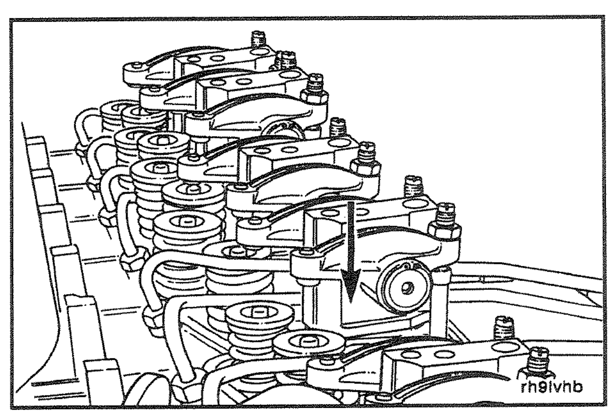
T-25 Torx

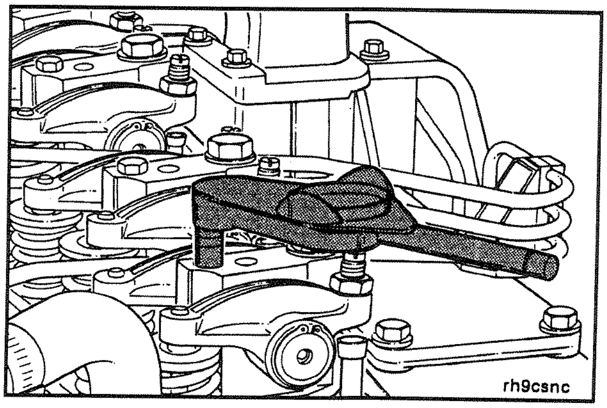
Hold the timing pin in the hole to align the housing.

Torque Value: 5 N•m [4 ft-lb]



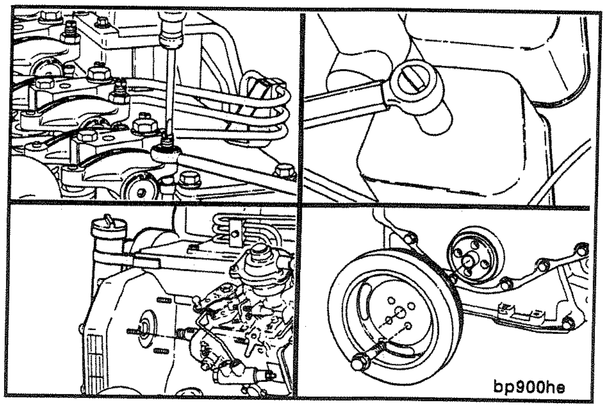
Install the remaining rocker lever pedestal assemblies.





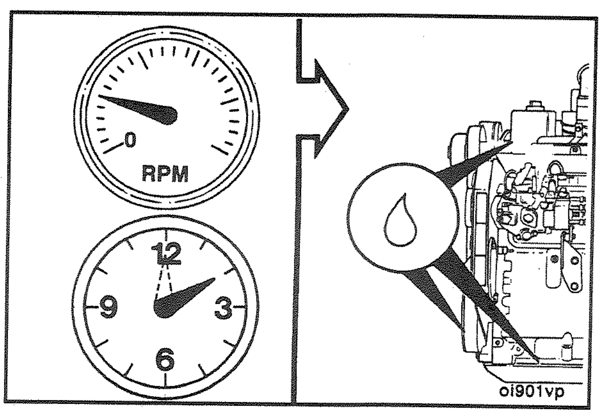
10 mm

Tighten the rocker lever pedestal mounting capscrews. Refer to Procedure (7-03).



Complete the installation of the removed components.

- Adjust the valves. Refer to Procedure (7-03).
- Injectors. Refer to Procedure (5-13).
- Fuel injection pump. Refer to Procedures (5-35) or (5-37).
- Gear cover. Refer to Procedure (7-18).
- Vibration damper. Refer to Procedure (7-15).



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

Crankshaft Gear - Replacement (7-22)

The crankshaft gear cannot be removed in-chassis. To remove crankshaft gear, refer to B Series Engine Shop Manual, Bulletin No. 3810206.

Flywheel/Ring Gear - Replacement (7-23)

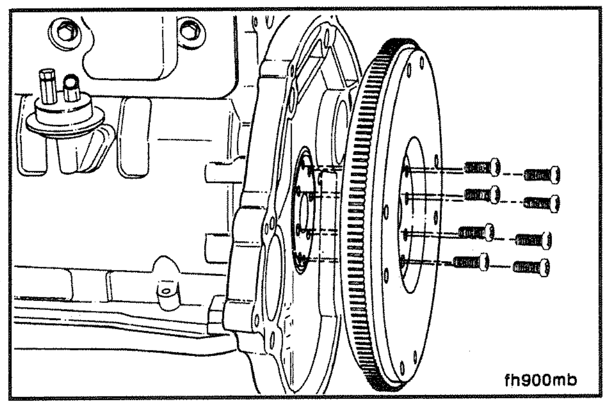
Preparatory Step:

- Remove the transmission.

Ring Gear - Replacement

18 mm

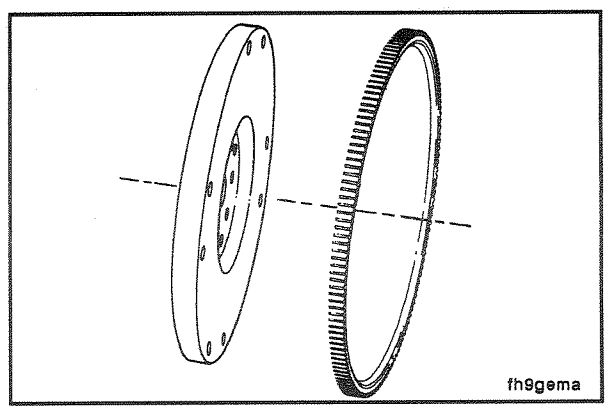
Remove the flywheel.



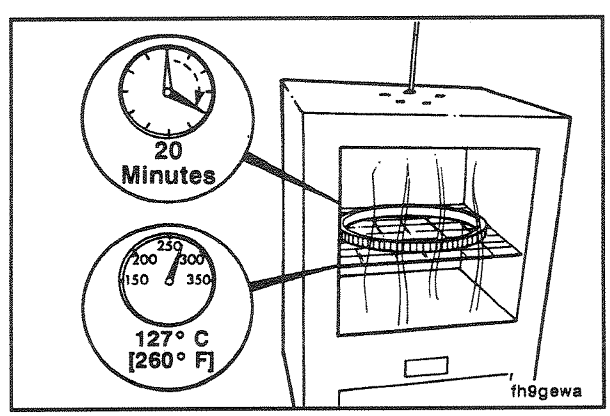
Brass Drift Pin

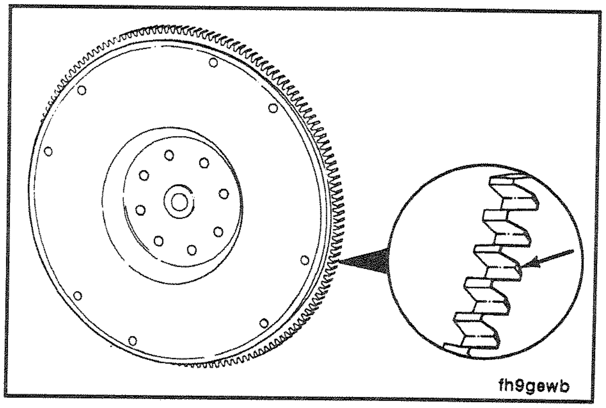
Warning: Wear eye protection when you drive the gear from the flywheel. Do not use a steel drift pin.

Use the drift pin to drive the ring gear from the flywheel.



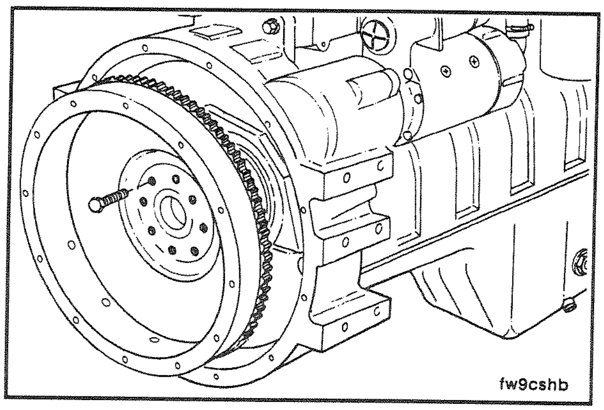
Heat the new ring gear for 20 minutes in an oven pre-heated to 127°C [260°F].





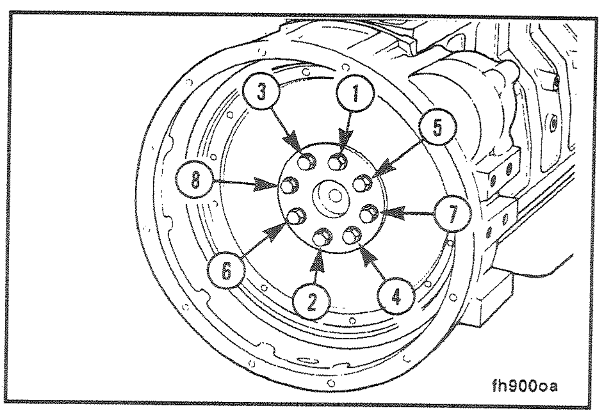
Warning: Wear protective gloves when you install the heated gear.

Install the ring gear. The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.



Flywheel - Installation

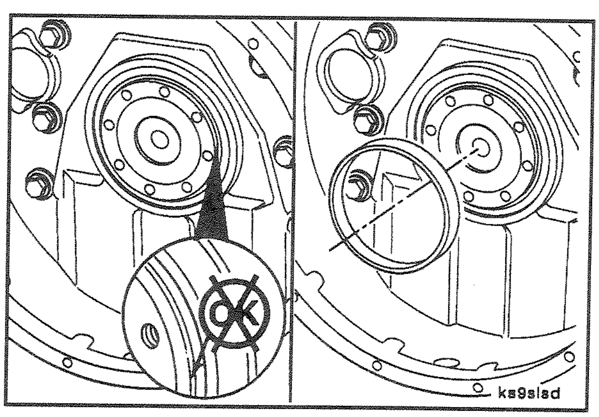
Use two capscrews in the front of the crankshaft, or similar device, to hold the crankshaft when the flywheel capscrews are being tightened.



18 mm Torque Wrench

Tighten the capscrews in the sequence shown.

Torque Value: 137 N•m [101 ft-lb]

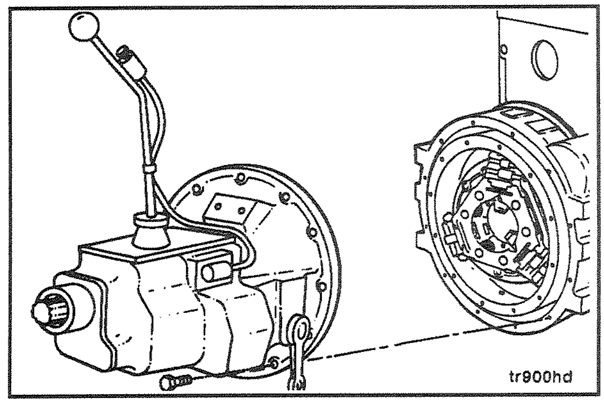


Wear Sleeve, Rear Crankshaft Seal - Replacement (7-24)

Removal

If the crankshaft seal has worn a groove in the crankshaft flange, a wear sleeve **must** be installed to prevent oil leakage.

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

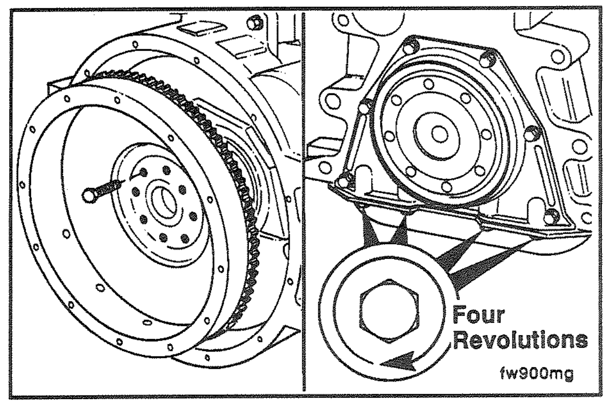


19 mm

Remove the clutch and flywheel, if equipped. Refer to Procedure 7-25.

Remove the flywheel housing. Refer to Procedure 7-25.

Loosen the oil pan mounting capscrews four revolutions.

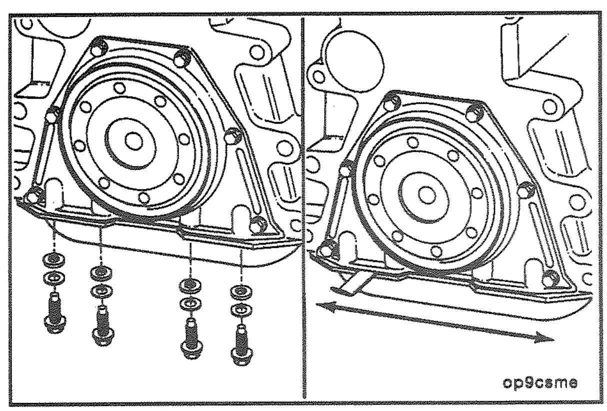


10 mm

Remove the four oil pan mounting capscrews which secure the oil pan to the rear cover.

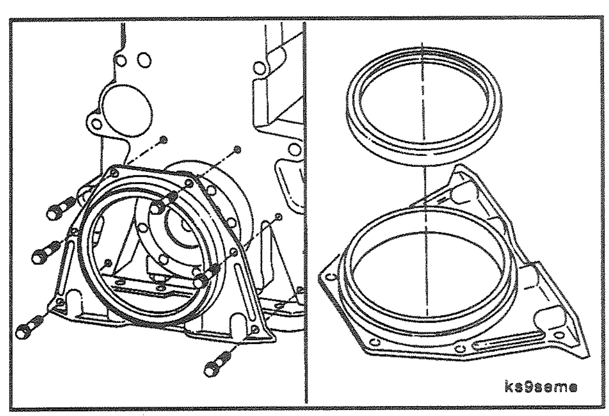
Caution: Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket. If the gasket is damaged, the oil pan must be removed and the gasket replaced. Refer to Procedure 2-06.

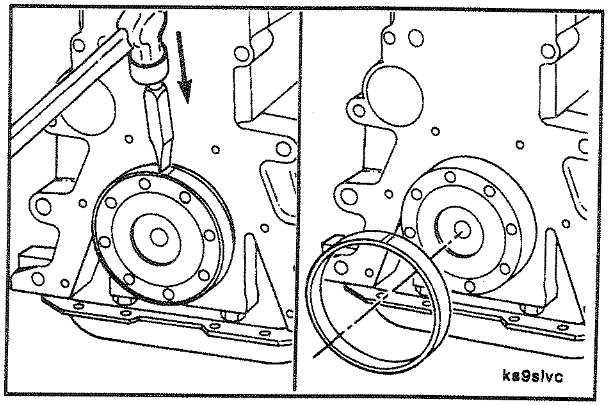
Insert a feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to release the gasket from the rear cover.



Remove the capscrews from the rear cover, and remove the cover from the crankshaft flange.

Remove the seal from the rear cover.





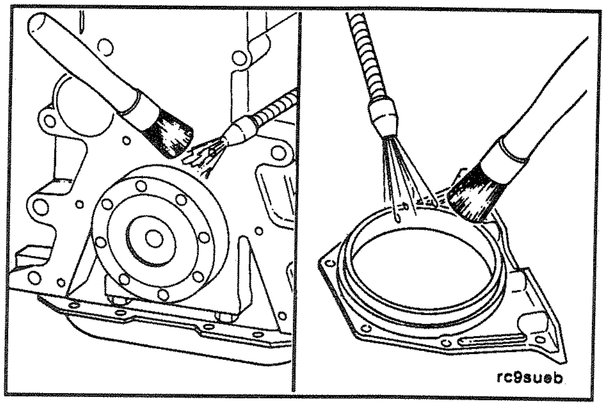
Hammer, Chisel

If the crankshaft currently has a wear sleeve, it **must** be removed before installing a new one.

Caution: Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

Use a dull chisel that is only as wide as the wear sleeve.

Make one or two soft blows with a hammer to make chisel marks across the wear sleeve. This will expand the wear sleeve allowing the sleeve to be removed.

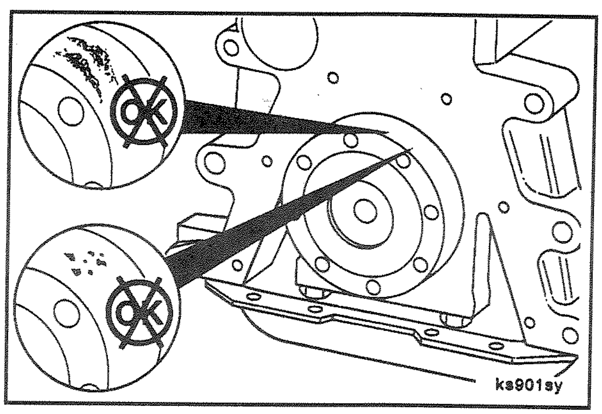


Cleaning and Inspection

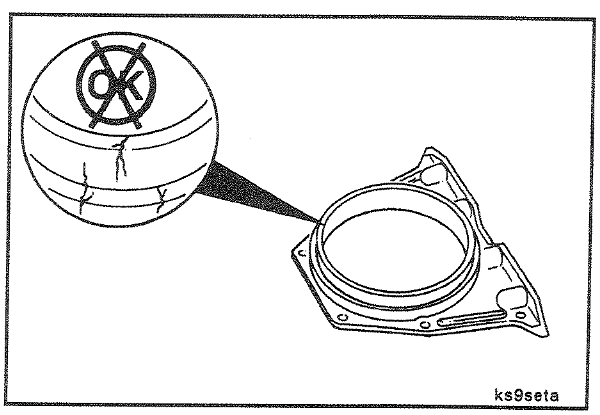
Clean the gasket surface of the cylinder block and rear cover.

Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth to clean the crankshaft flange.



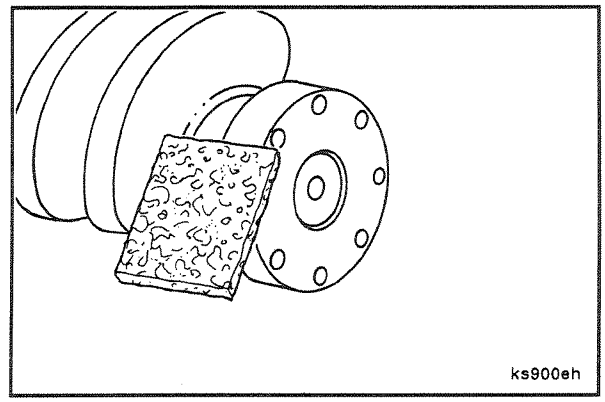
Inspect the crankshaft flange for dirt or nicks.



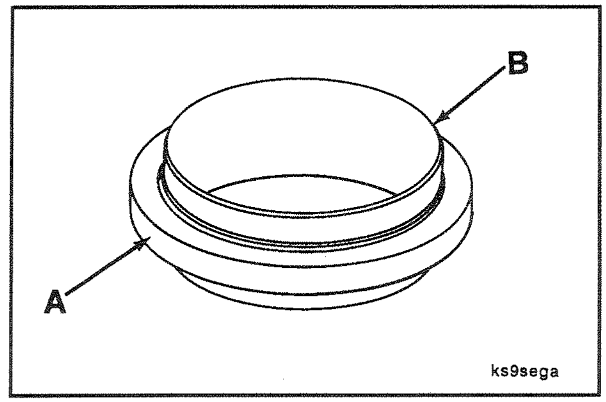
Inspect the rear cover for cracks or other damage.

Installation

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



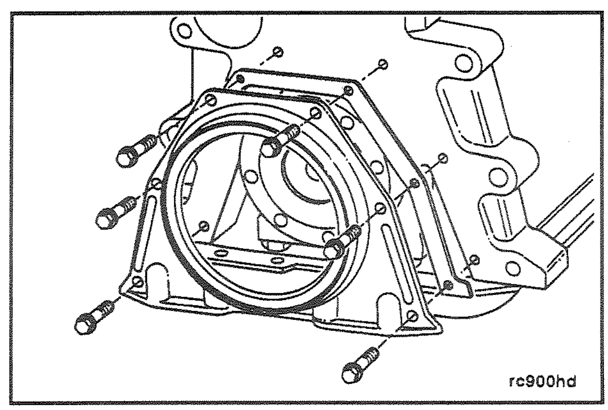
NOTE: The combination crankshaft oil seal (A)/wear sleeve (B) replacement kit for service usage is installed on the crankshaft as an assembly. The crankshaft rear oil seal should not be removed from the crankshaft rear seal wear sleeve.



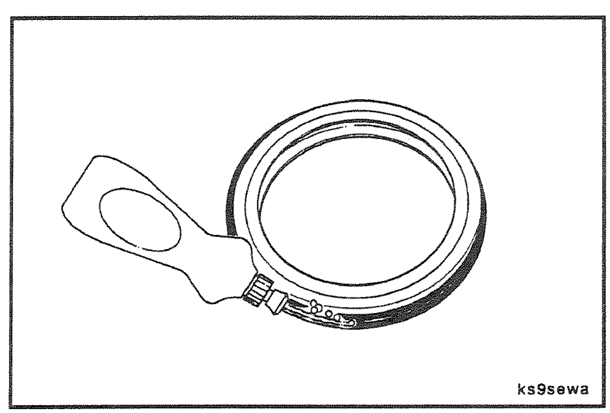
Install the rear cover and gasket.

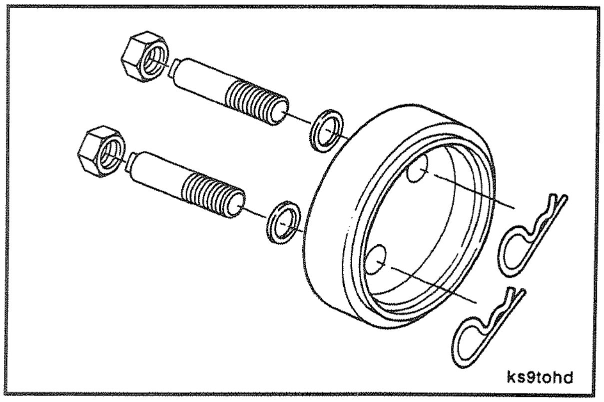
NOTE: Install the rear cover capscrews. Do not tighten. If the oil pan is installed, loosen the oil pan capscrews to allow clearance for rear cover and gasket clearance.

NOTE: The seal installation is being used to properly align the rear cover. Do not push or force the cover in any direction to prevent irregular seal lip position after seal installation.



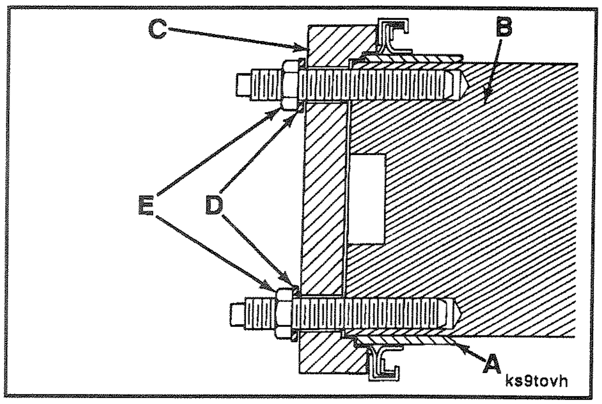
NOTE: The oil seal for a wet flywheel housing requires soap on the outside diameter of the seal case. Nothing is required on the outside diameter of the seal case for dry housings.





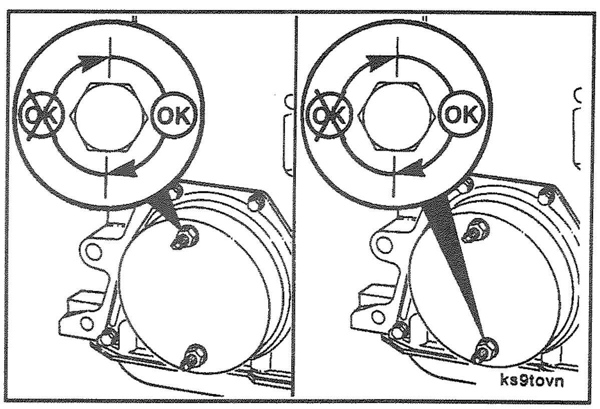
Use a service tool, Part No. 3824078, to install oil seal/ wear sleeve assembly. Install two (2) threaded studs into the crankshaft capscrew holes.

Apply a small amount of clean 15W-40 engine oil to the crankshaft, threaded studs, and inside diameter of the crankshaft rear seal/wear sleeve installation tool.



Position the chamfered end of the wear sleeve (A) onto the end of the crankshaft (B). Position the counterbore end of installation tool (C) over threaded studs and align with wear sleeve, perpendicular to the end of the crankshaft. Install the washers (D) and nuts (E) onto the threaded studs.

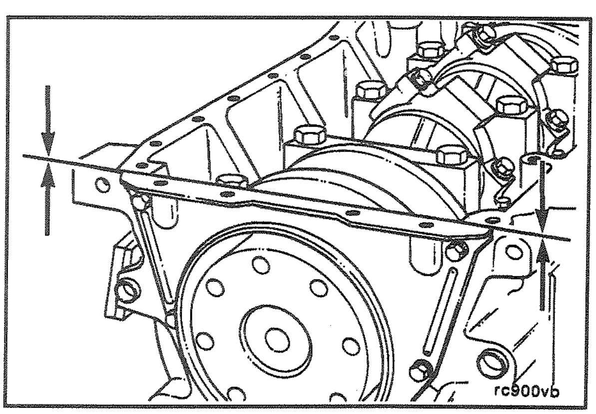
Alternately tighten the nuts until the installation tool contacts the end of the crankshaft.



NOTE: Do not exceed 1/2 revolution of each nut to prevent wear sleeve binding and irregular stretch.

Torque Value: 20 N•m [15 ft-lb]

Remove the installation tool and threaded studs.

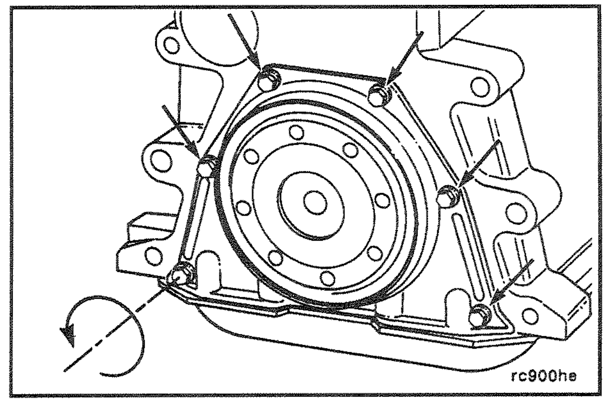


10 mm

Align the rear cover even with both sides of the oil pan rail on the cylinder block.

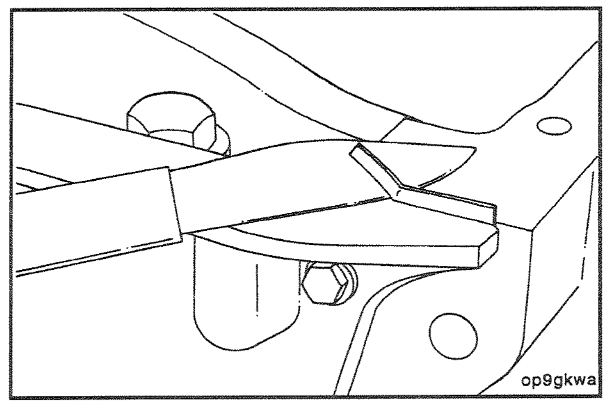
Tighten the rear cover capscrews.

Torque Value: 9 N•m [80 in-lb]



Trim the gaskets even with the oil pan mounting surface.

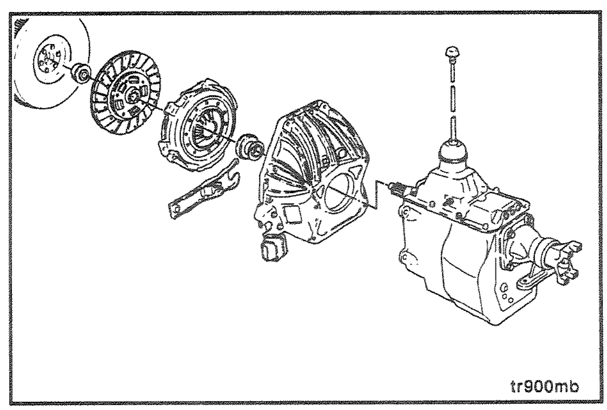
Make sure the gasket trim does **not** enter the engine.



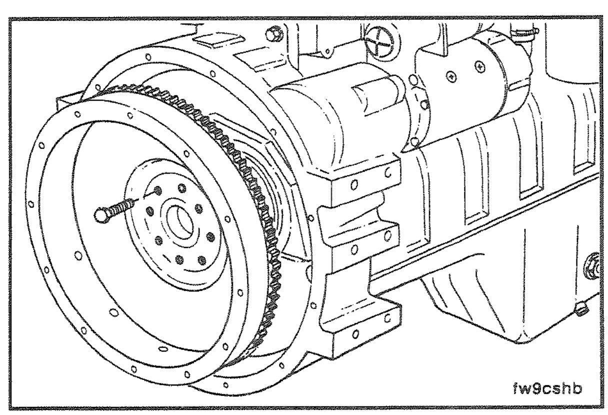
Flywheel Housing - Replacement (7-25)

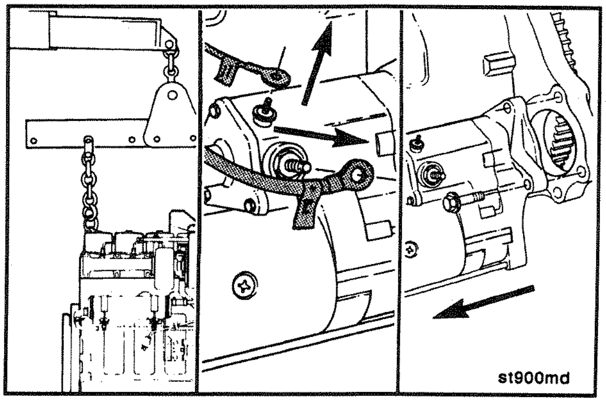
Removal

Remove the transmission, clutch and all related components (if equipped). Refer to the manufacturer's instructions.



Remove the flywheel/ring gear assembly. Refer to Procedure (7-23).

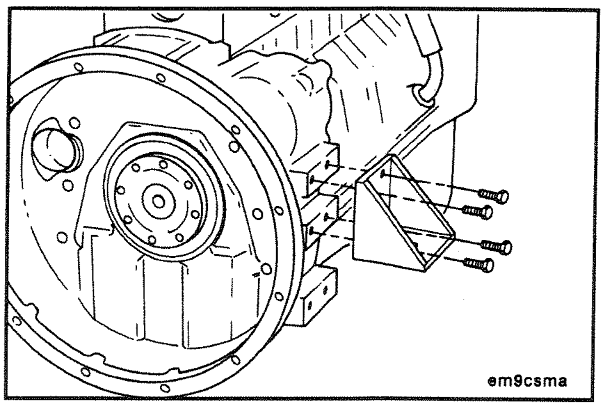




Adequately support the engine to prevent damage.

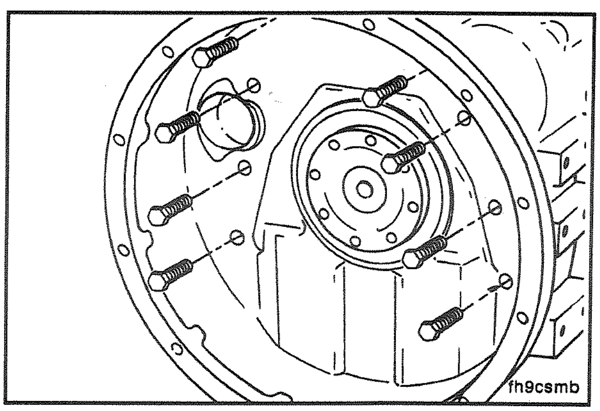
Disconnect the battery cables.

Remove the starting motor.



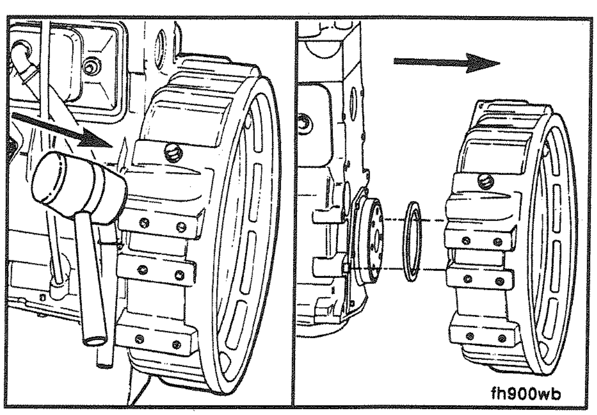
15 mm

Remove the capscrews and both rear engine mounts.



Remove the mounting capscrews.

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



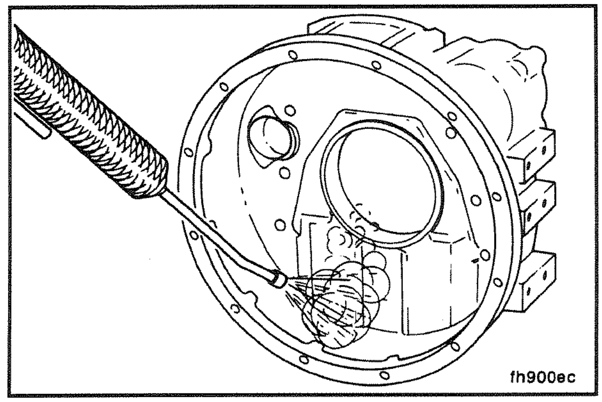
Use a rubber hammer to loosen the flywheel housing.

Remove the flywheel housing and rectangular seal.

Cleaning and Inspection

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

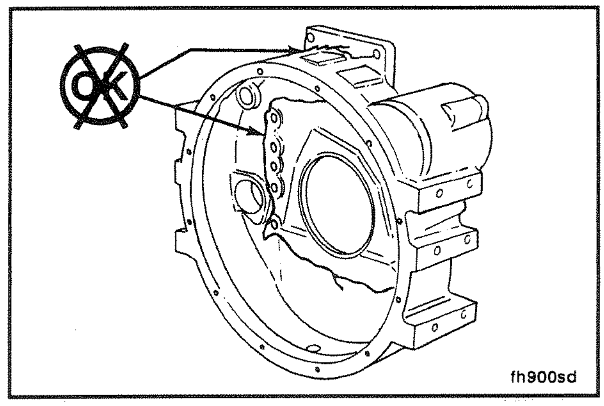
Use steam or solvent to clean the flywheel housing. Dry with compressed air.



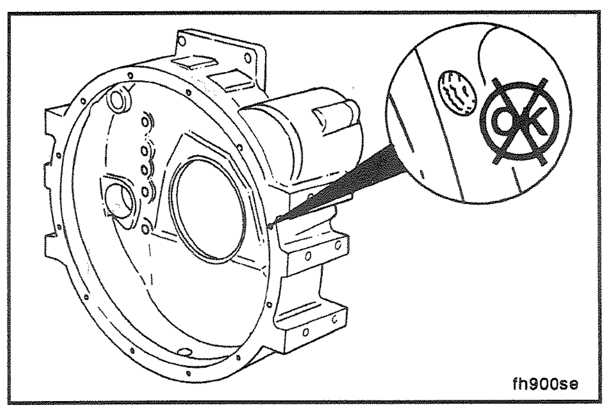
Inspect the flywheel housing for cracks, especially in the bolt pattern area.

Visually inspect all surfaces for nicks, burrs, or cracks.

Use fine crocus cloth to remove small nicks and burrs.

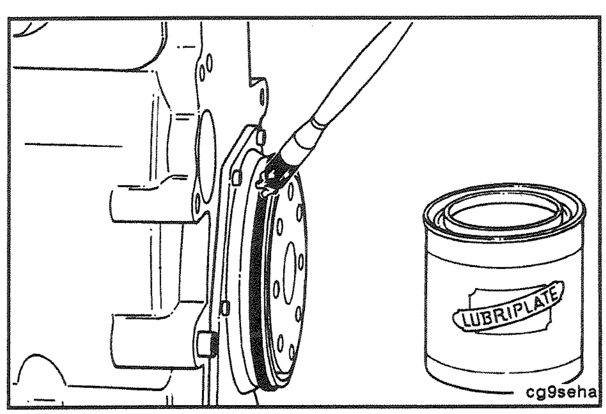


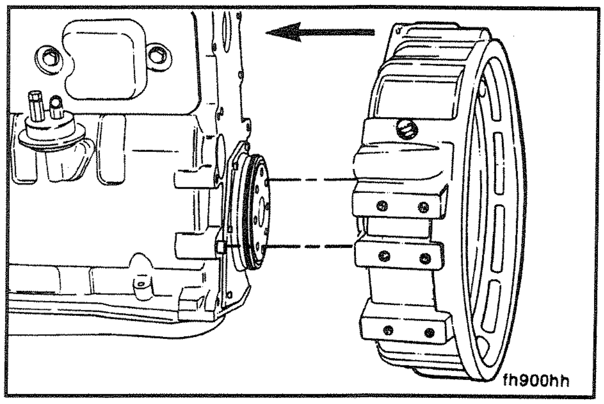
Inspect for damaged threads commonly caused by cross theaded capscrews or installing an incorrect capscrew. Heli-coils are available to repair damaged threads.



Installation (Dry Clutch Application)

Install rectangular seal and lubricate with Lubriplate® 105.

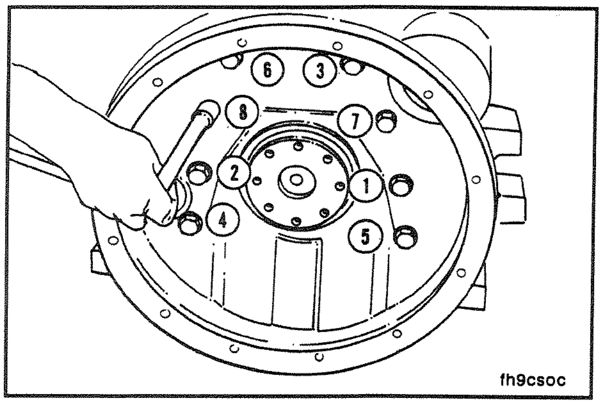




Visually inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Install the flywheel housing over the two ring dowels.

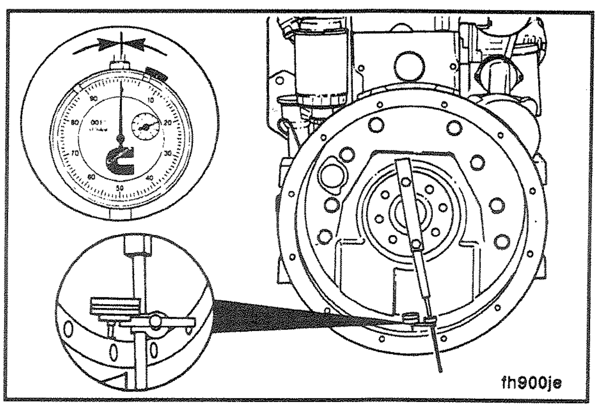
NOTE: Be sure the sealing ring is not damaged during installation.



15 mm

Tighten the flywheel housing capscrews in sequence shown.

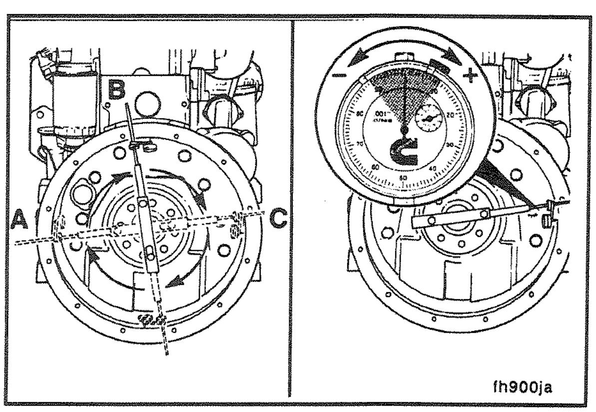
Torque Value: 77 N•m [57ft-lb] cast iron housing
60 N•m [44 ft-lb] aluminum housing



Flywheel Housing Bore Alignment - Check

Attach a dial indicator to the crankshaft. The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid so it does not sag. If the bar sags or the indicator slips, the readings obtained will not be accurate.

Position the indicator in the 6 o'clock position and zero the gauge.



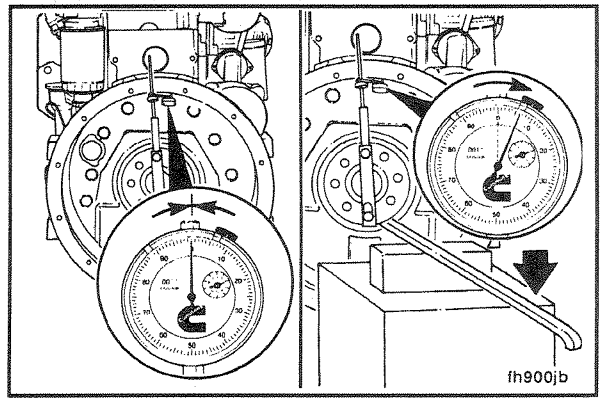
Slowly rotate the crankshaft. Record the readings obtained at the 9 o'clock, 12 o'clock, and 3 o'clock positions as [a], [b], and [c] in the concentricity work sheet. Recheck zero at the 6 o'clock position.

The values for [a], [b], and [c] could be positive or negative. Refer to the accompanying figure to determine the correct sign when recording these values.

Rotate the crankshaft until the dial indicator is at the 12 o'clock position and zero the gauge.

Caution: do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings.

Using a pry bar, raise the rear of the crankshaft to its upper limit. Record the value as [d] in the concentricity work sheet. This is the vertical bearing clearance adjustment and will always be positive.



fh900jb

Using the concentricity work sheet, determine the values for the 'total vertical' and 'total horizontal' values.

The 'total horizontal' is equal to the 9 o'clock reading, [a], minus the 3 o'clock reading, [c].

The 'total vertical' is equal to the 12 o'clock reading, [b], plus the bearing clearance, [d].

Example:

6 o'clock = ref = 0
9 o'clock = [a] = 0.004"
12 o'clock = [b] = 0.003"
3 o'clock = [c] = -0.002

Concentricity Worksheet

9 o'clock	a = 0.004
3 o'clock	c = -0.002
Total Horizontal	a – c = .006
12 o'clock	b = .003
Bearing Clearance	d = .002
Total Vertical	b + d = .005

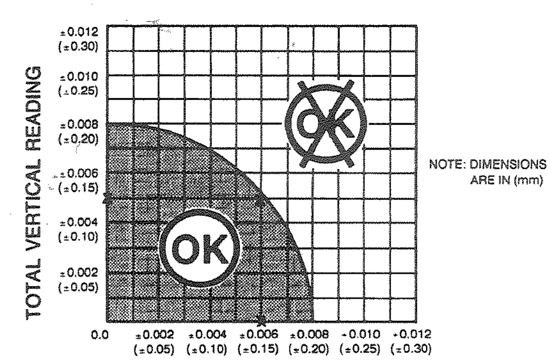
oi900vf

Using the work sheet and the numbers from the example, the 'total horizontal' value = 0.006" and the 'total vertical' value = 0.005".

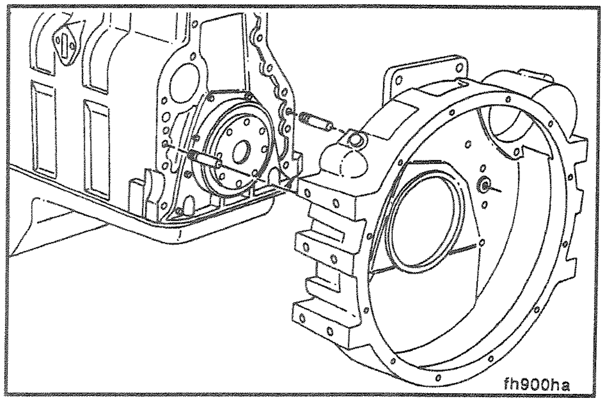
Mark the 'total horizontal' value on the horizontal side of the chart and the 'total vertical' on the vertical side of the chart.

Using a straight edge, find the intersection point of the 'total horizontal' and 'total vertical' values. The intersection point must fall within the shaded area for the flywheel housing concentricity to be with specification.

Using the 'total horizontal' and 'total vertical' values from the previous example, the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.



oi900vg



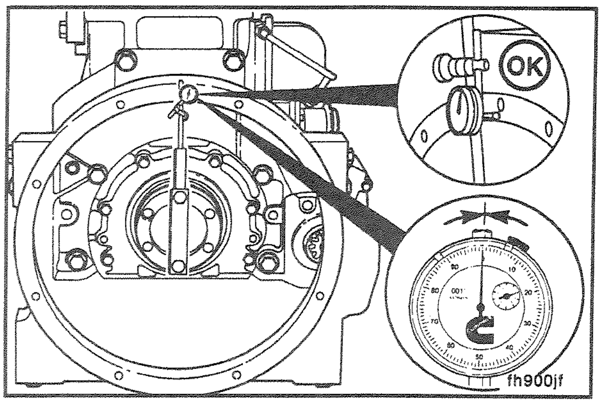
If the intersection point falls outside the shaded area, the ring dowels must be removed and the housing repositioned.

NOTE: The ring dowels are not required to maintain concentricity of the housing; the clamping force of the capscrews holds the housing in pace.

After the ring dowels are discarded, install the flywheel housing on the engine.

To position the housing, tighten the capscrews enough to hold the flywheel housing in place, but loose enough to enable small movement when struck lightly with a mallet.

Recheck the concentricity. When concentricity is within specification, torque the capscrews to the specified value.

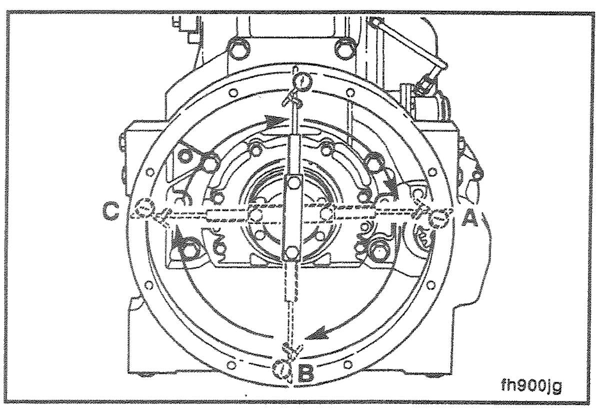


Flywheel Housing Face Alignment - Check

Caution: The dial indicator tip must not enter the capscrew holes or the gauge will be damaged.

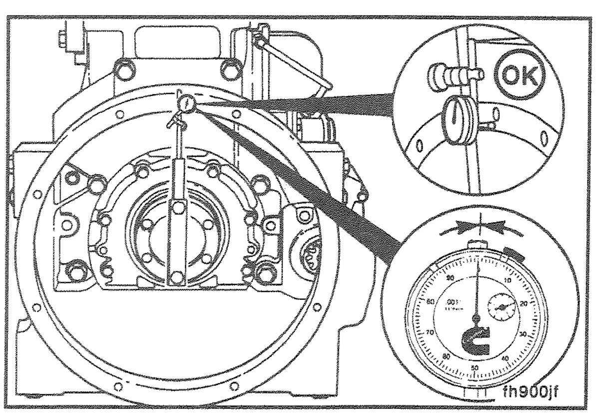
Install a dial indicator as illustrated.

NOTE: The extension bar for the indicator must be rigid for an accurate reading. It must not sag. Position the indicator at the 12 o'clock position. Adjust the dial until the needle points to zero.



Slowly rotate the crankshaft. Record the readings at the 3 o'clock, 6 o'clock and 9 o'clock positions.

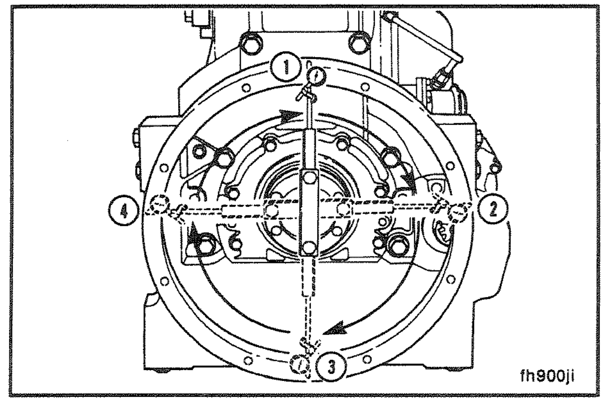
NOTE: The crankshaft must be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.



Continue to rotate the crankshaft until the indicator is at the 12 o'clock position. Check the indicator to make sure the needle points to zero. If it does not, the readings will be incorrect.

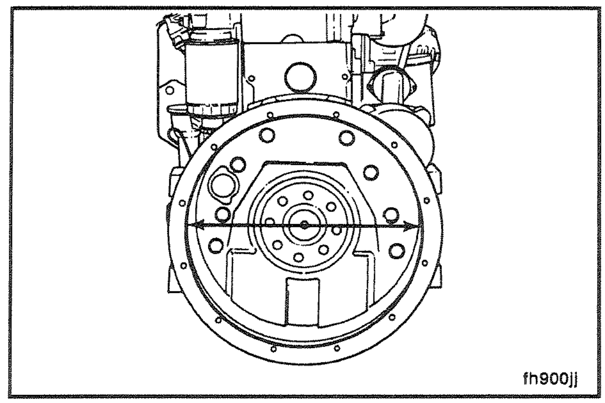
Determine the Total Indicator Reading (TIR).

Example:	mm	in
12 o'clock	0.00	0.000
3 o'clock	+0.08	+0.003
6 o'clock	- 0.05	- 0.002
9 o'clock	+0.08	+0.003
Equals TIR	0.13	0.005



The maximum allowable Total Indicator Reading (TIR) is determined by the diameter of the housing bore. If out of specifications, replace the housing.

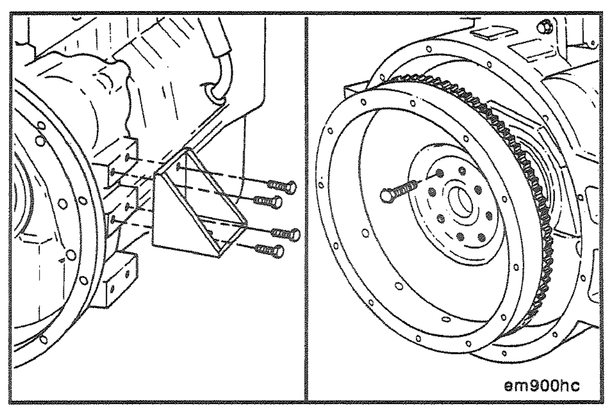
SAE	Bore Diameter		TIR Max	
No.	mm	in	mm	in
2	447.68 to 447.80	17.625 to 17.30	0.20	0.008
3	409.58 to 409.70	16.125 to 16.130	0.20	0.008



Install both rear engine mounts.

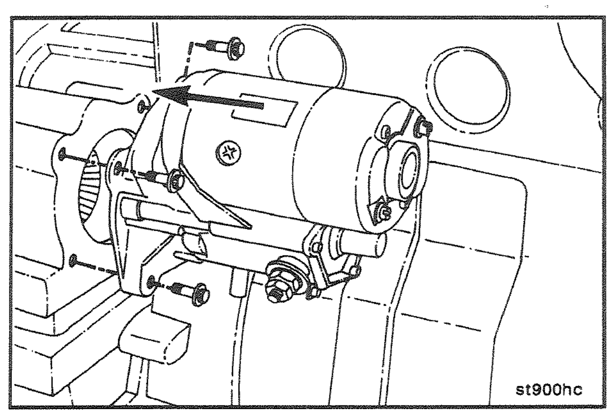
Install the flywheel and clutch (if equipped). Refer to the manufacturer's instructions.

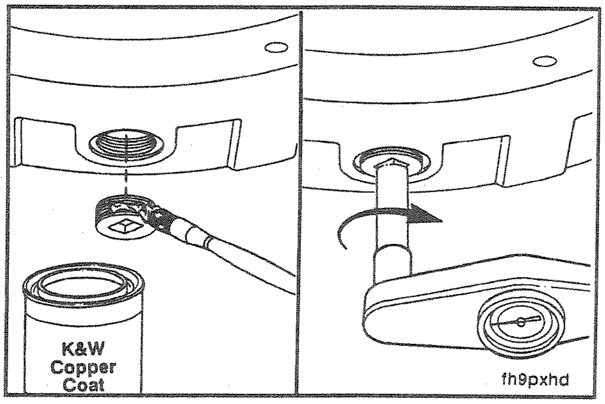
Install the transmission and related components. Refer to the manufacturer's instructions.



Install the starting motor.

Connect the battery cables.





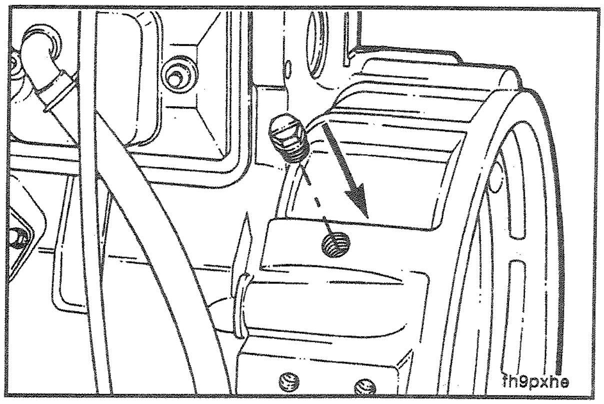
Installation (Wet Clutch Application)

Perform all the steps in the procedure for dry clutch installation in addition to the following:

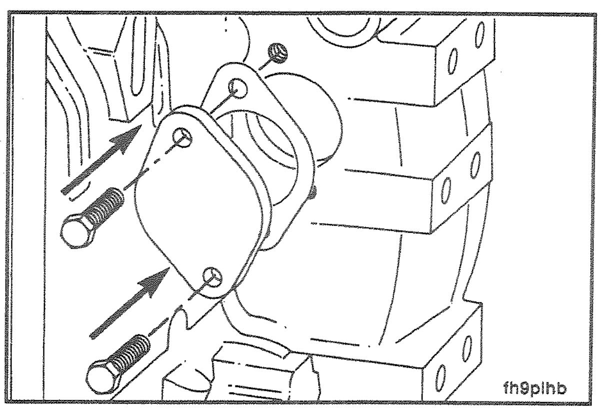
Coat the flywheel housing drain plug with pipe sealant and install in the hole in the bottom of the flywheel housing.

Tighten the plug.

Refer to the pipe plug torque values in Section 10 for different plug sizes.



Install the plastic plug in the tachometer drive access hole.

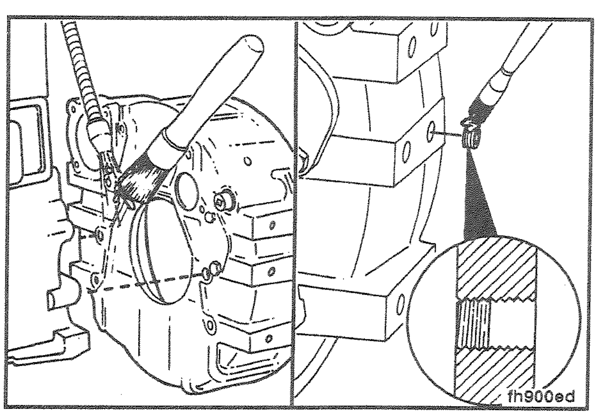


13 mm

Install the access plate and new gasket.

Install the capscrews and tighten.

Torque Value: 24 N•m [18 ft-lb]



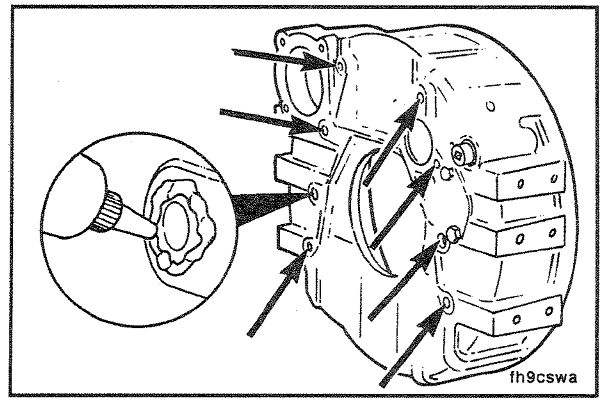
Thoroughly clean the flywheel housing and cylinder block mating surfaces. These surfaces must be clean and free of oil or debris.

NOTE: The capscrew holes on the mounging pads are drilled through. Coat set screws with Loctite™ 277 and install into holes.

Set Screw Installation Depth

mm		in
0.00	MIN	0.000
3.00	MAX	0.118

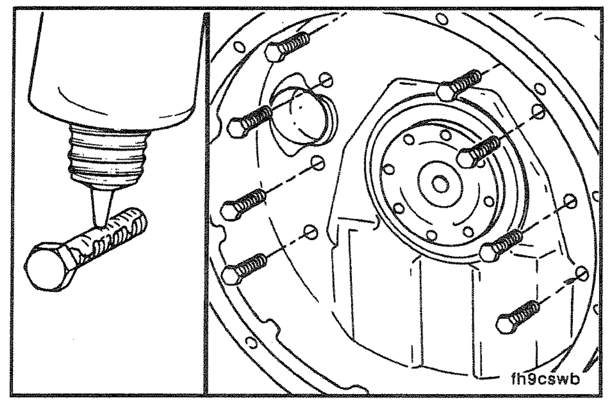
Apply a continuous bead of three bond around all capscrew holes on the mounting surface of the flywheel housing.



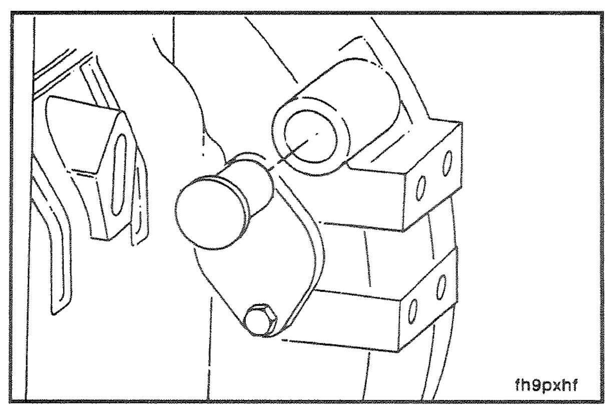
Coat the threads of the mounting capscrews with Loctite™ 277.

Install and tighten the capscrews.

Torque Value: 60 N•m [45 ft-lb]



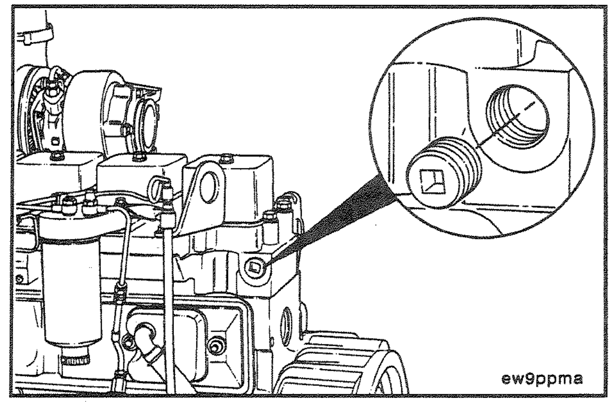
Install the plug into the barring gear hole.



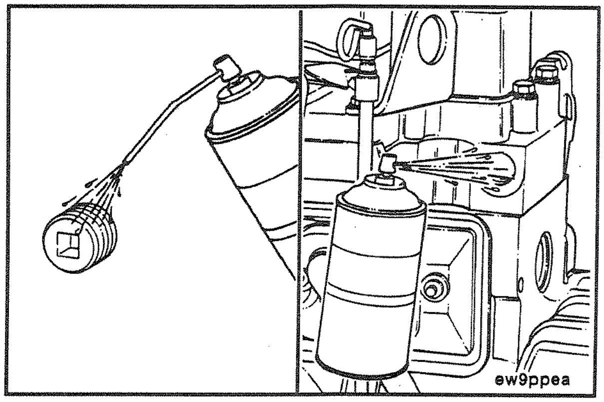
Pipe Plug - Replace (7-26)

Removal

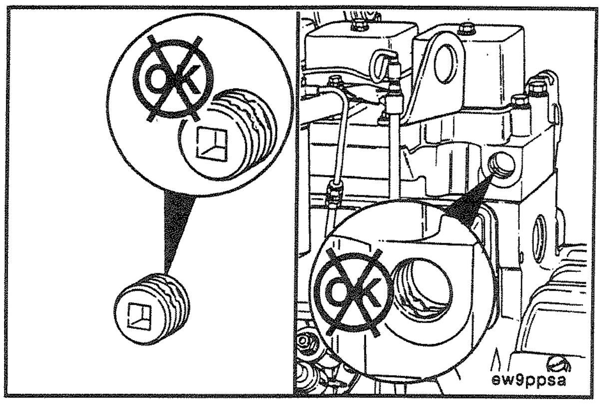
Remove the pipe plug.



Cleaning and Inspection



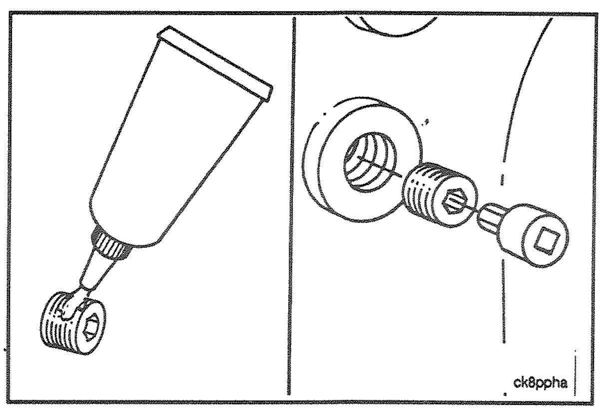
Use spray cleaner, Part No. 3375433, or equivalent to clean the threads of the pipe plugs and threaded bores.



Visually inspect the threads of the pipe plugs for mutilation or damage.

Visually inspect the threaded bores for damage.

Installation



Apply a film of pipe plug sealant, Part No. 3375066, or equivalent, to the threads.

Install and tighten the pipe plugs.

Refer to the following chart for torque values.

Pipe Plug Torque Values

Size			Torque		Torque	
Thread	Actual Thread O.D.		In Aluminum Components		In Cast Iron or Steel Components	
in.	mm	[in]	N•m	[ft-lbs]	N•m	[ft-lbs]
1/16	8.1	[0.32]	5	[45 in-lb]	15	[10]
1/8	10.4	[0.41]	15	[10]	20	[15]
1/4	13.7	[0.54]	20	[15]	25	[20]
3/8	17.3	[0.68]	25	[20]	35	[25]
1/2	21.6	[0.85]	35	[25]	55	[40]
3/4	26.7	[1.05]	45	[35]	75	[55]
1	33.5	[1.32]	60	[45]	95	[70]
1¼	42.2	[1.66]	75	[55]	115	[85]
1½	48.3	[1.90]	85	[65]	135	[100]

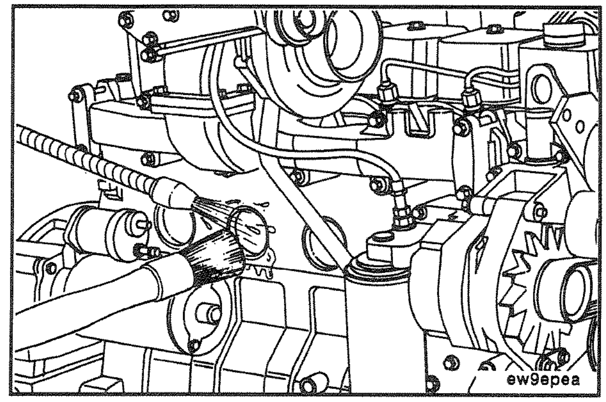
ck8ppoa

Tighten pipe plugs to the appropriate torque values.

Expansion Plug Replacement (7-27)

Removal

Clean the area near the expansion plug of all debris.

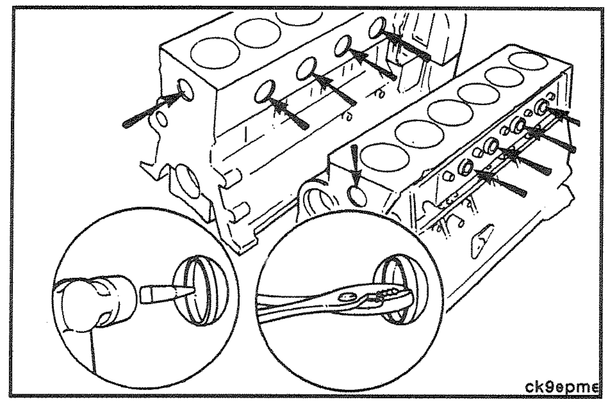


Punch, Visegrips

Remove the large expansion plugs (58.06 mm [2.29 in.]) from the coolant passages.

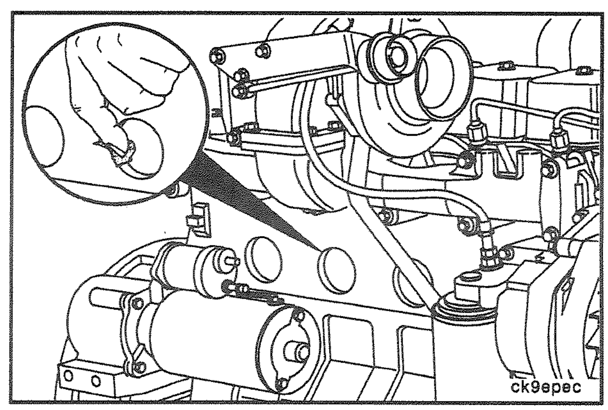
Care should be taken not to drive the expansion plug out and into the water jacket, especially the plug on the end of the cylinder block.

Service Tip: If it becomes apparent the expansion plug is not going to pivot in the bore, use a center punch to catch the edge of the expansion plug and pry against the cylinder block to pivot the expansion plug out.

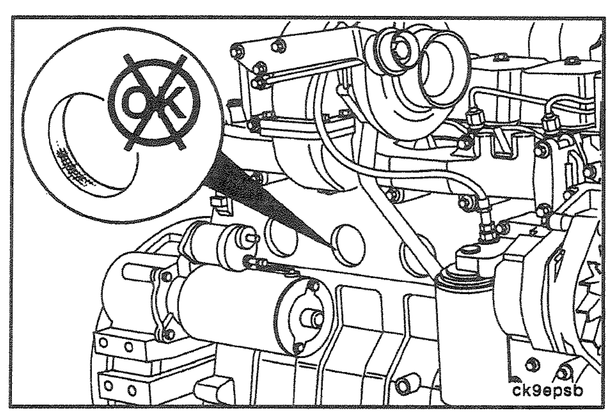


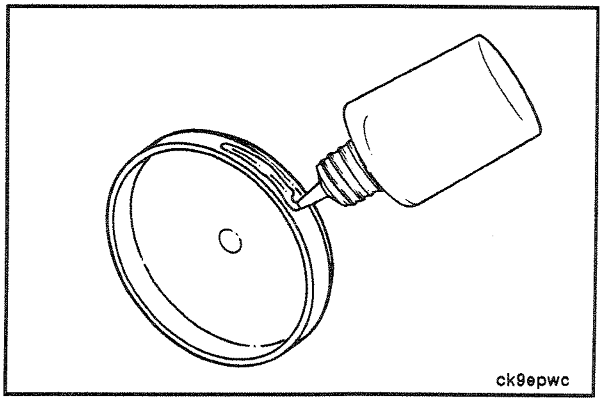
Cleaning

Thoroughly clean the expansion plug hole using scotch-brite or equivalent. Use spray cleaner 3375433 or equivilant to final clean the bore.



Visually inspect the cup plug bores for damage.

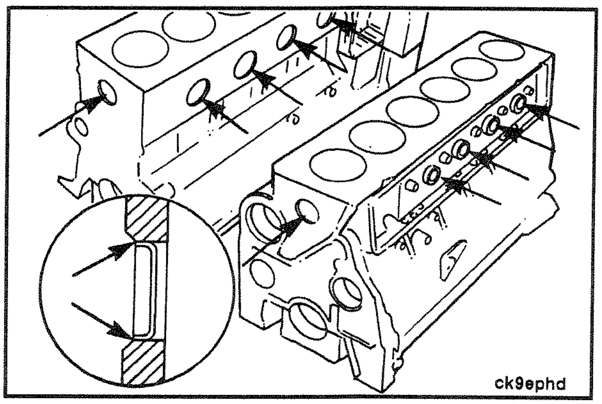




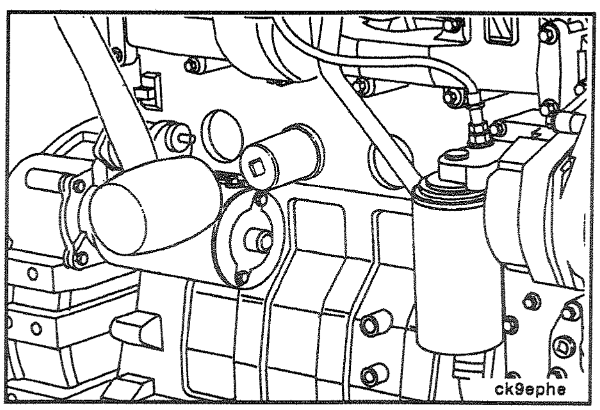
Installation

Caution: Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine.

Apply a 2 mm [1/16 inch] bead of expansion plug lock 'N seal, Part No. 3375068, or equivalent to the outside diameter of the expansion plug and the inside diameter of the expansion plug installation bore.



Using an appropriate deep socket as a driver, install the expansion plug.



The expansion plug must be installed with the edge of the expansion plug 0.5 to 1.0 mm [0.020 to 0.040 in] deeper than the entrance chamber of the bore.

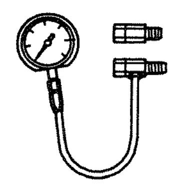
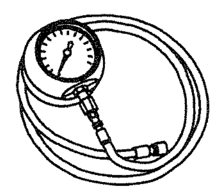
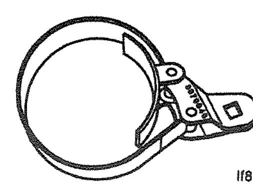
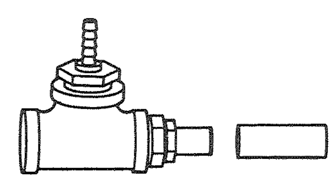
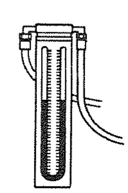
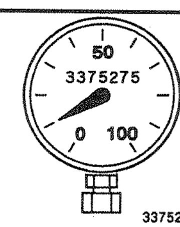
NOTE: Do not install the expansion plug too deep. If the expansion plug is not installed straight and flat, it must be replaced with a new expansion plug.

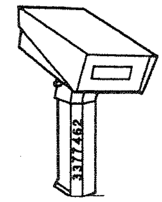
Section 8 - Engine Testing

Section Contents

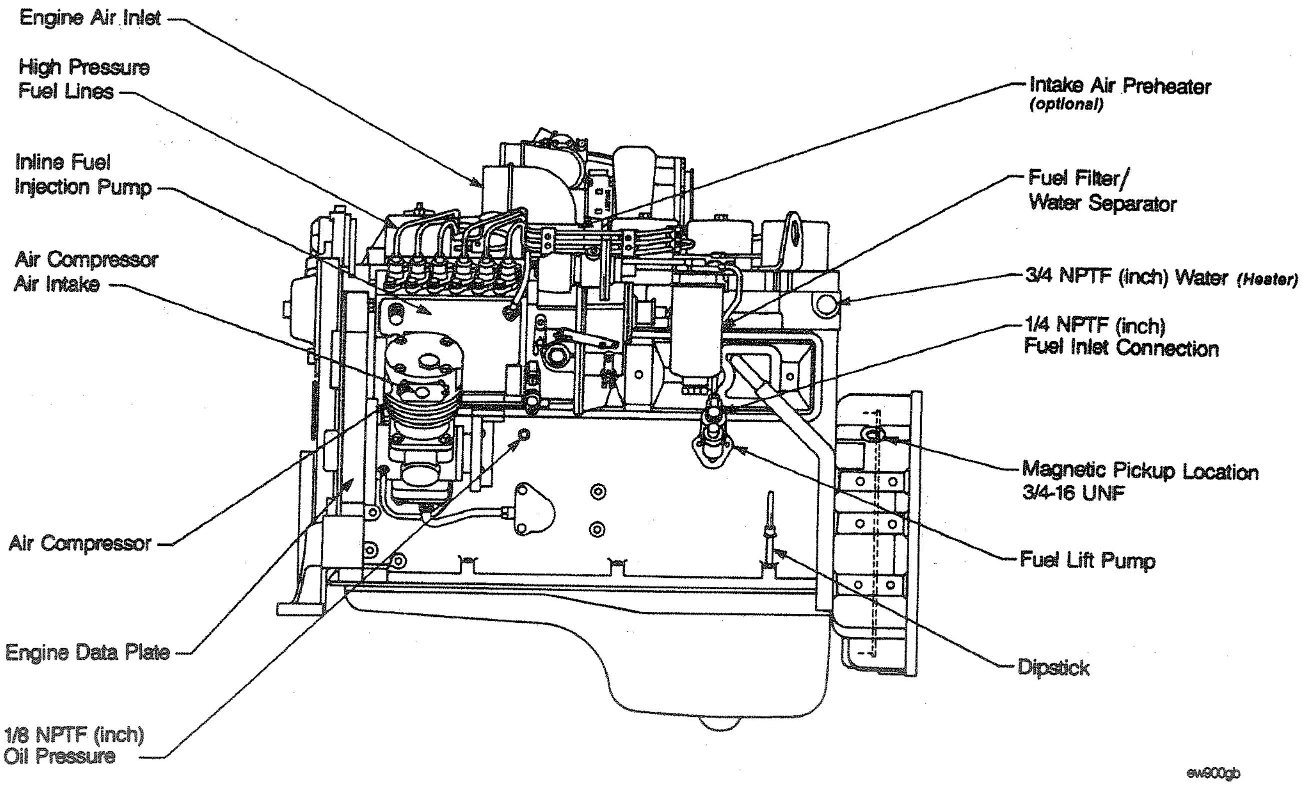
Engine Testing - Service Tools

The following special tools are recommended to perform procedures in section 8. The use of these tools is shown in the appropriate procedure. These tools can be purchased from your local Cummins Authorized Repair Location.

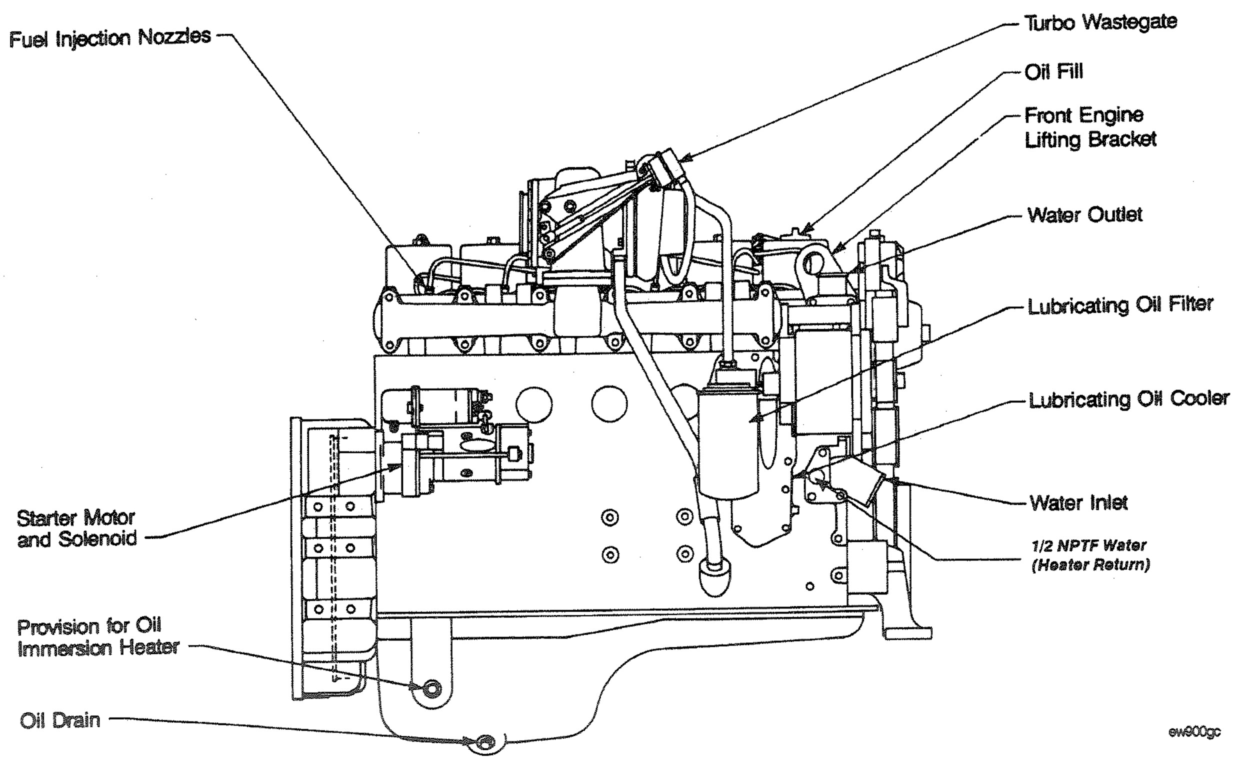
Tool No.	Tool Description	Tool Illustration
ST-434	**Vacuum Gauge** Check the fuel filter restriction during the engine performance test. Hose Adapter, Part No. ST-434-2, and vacuum gauge, Part No. ST-434-12, are used to perform the test.	 eg8togc
ST-1273	**Pressure Gauge** Use to measure the engine intake manifold pressure and exhaust restriction.	 eg8togi
3375049	**Oil Filter Wrench** Use to remove or tighten spin-on lubricating oil or fuel filters.	 lf8togb
3822476	**Blowby Checking Tool** Use to check engine crankcase blowby	 eg8toge
ST-1111-3	**Manometer** Used with the blowby check tool to measure engine crankcase pressure.	 eg100ja
3375275	**Pressure Gauge (0-160 psi)** Used to measure lubricating oil pressure	 3375275

Tool No.	Tool Description	Tool Illustration
3377462	**Digital Optical Tachometer** Used to measure engine speed (RPM).	 3377462

Engine Testing - Engine Side Views



Engine Testing - Engine Side Views



Engine Testing - General Information

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

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

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

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

General* Engine Test Specifications

Maintain the following limits during a chassis dynamometer test:

Intake Restriction (Maximum)

- Clean Filter (light duty) .... 254 mm H_20 [10 in H_20]
  (medium duty) .... 305 mm H_20 [12 in. H_20]
  (heavy duty) .... 381 mm H_20 [15 in. H_20]
- Dirty Filter (light duty) .... 635 mm [25 in]
  (medium duty) .... 635 mm [25 in]
  (heavy duty) .... 635 mm [25 in]

Exhaust Back Pressure (maximum) Non Automotive .... 76 mm Hg [3.0 in Hg]

Exhaust Back Pressure (maximum) Automotive With Catalyst .... 152 mm Hg [6.0 in. Hg]

Exhaust Back Pressure (maximum) Automotive Without Catalyst .... 114 mm Hg [4.5 in. Hg]

Oil Pressure

- Low Idle (minimum allowable) .... 69 kPa [10 psi]
- Rated Speed (minimum allowable) .... 207 kPa [30 psi]

Fuel Inlet Restriction (maximum) .... 100 mm Hg [4 in Hg]

Fuel Return Restriction (maximum) .... 518 mm Hg [20.4 in Hg]

* Due to variations in ratings of different engine models, refer to the specific engine data sheet for the particular engine model being tested.

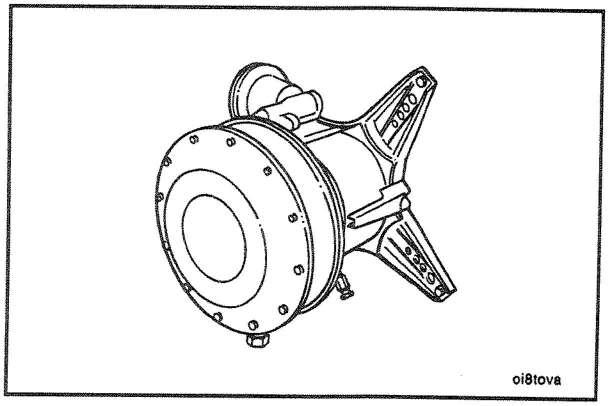
Blowby** (at Given Speed, 100% Load)

	New (L/Min)	Worn (L/Min)
4B @ 2200	18	36
4B @ 2500	20	40
4B @ 2800	23	46
4BT @ 2200	45	90
4BT @ 2500	51	102
4BT @ 2800	57	114
6B @ 2200	26	52
6B @ 2500	30	60
6B @ 2800	34	68
6BT @ 2200	63	126
6BT @ 2500	76	152
6BT @ 2800	85	170

Blowby checking tool, Part No. 3822476, has a special 5.613 mm [0.221 in.] orifice that **must be used to get an accurate reading.

Blowby Conversion Chart (5.613 mm [0.221 in] Orifice)

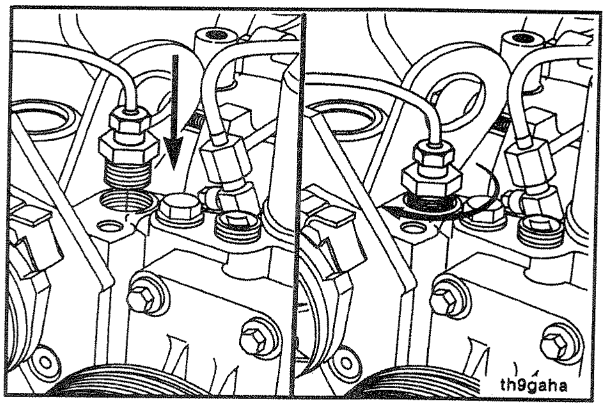
Inches of Water	Liters/Minute	Inches of Water	Liters/Minute
1	27	19	121
2	40	20	124
3	58	22	131
5	64	23	135
6	71	24	137
7	76	25	140
8	81	26	144
9	86	27	147
10	90	28	150
11	94	29	154
12	98	30	157
13	102	31	160
14	105	32	163
15	109	33	166
16	112	34	169
17	115	35	172
18	118		



Engine Dynamometer Test - Installation of the Engine (8-01)

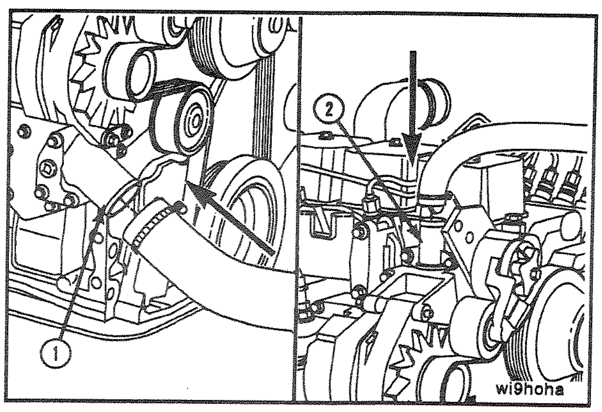
Use engine lifting fixture, Part No. ST-125, to install the engine to the test stand. Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

NOTE: Make sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engine rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.



Install the coolant temperature sensor.

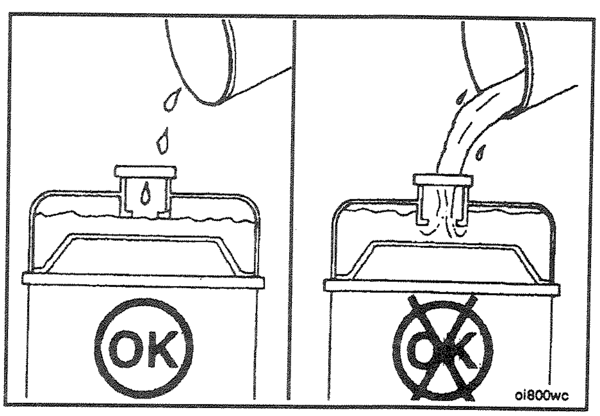
Minimum Gauge Capacity: 107° C [225° F]



Connect the coolant supply to the water inlet connection (1).

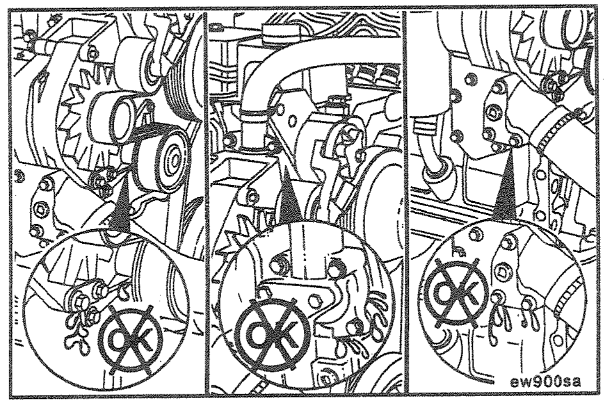
Connect the coolant return to the water outlet connection (2).

Install the drain plugs, close all the water drain cocks, and make sure all the clamps and fittings are tight.



Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank.

Inspect the engine for coolant leaks at connections, fittings, plates, and plugs. Repair as necessary.

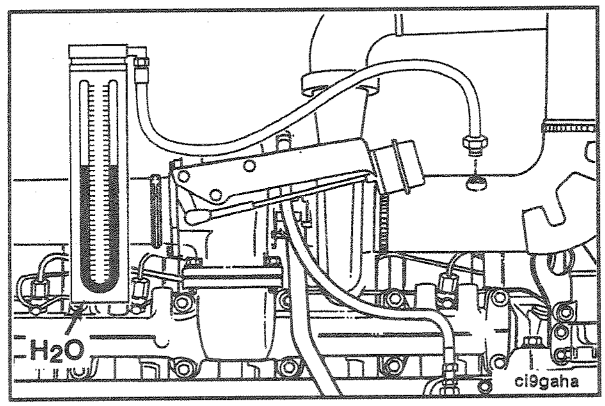


Connect a water manometer to the turbocharger air inlet pipe to test air restriction.

NOTE: The manometer connection **must** be installed at a 90 degree angle to the air flow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: A vacuum gauge can be used in place of the water manometer.

Minimum Gauge Capacity: 760 mm H_20 [30 in. H_20]

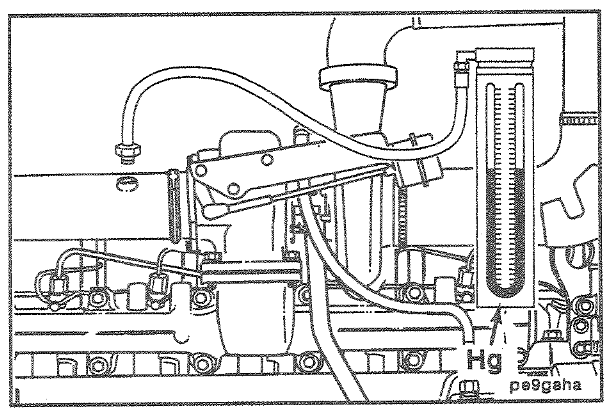


Connect a mercury manometer to a straight section of the exhaust piping near the turbocharger outlet to check exhaust restriction.

NOTE: A pressure gauge can be used in place of the mercury manometer.

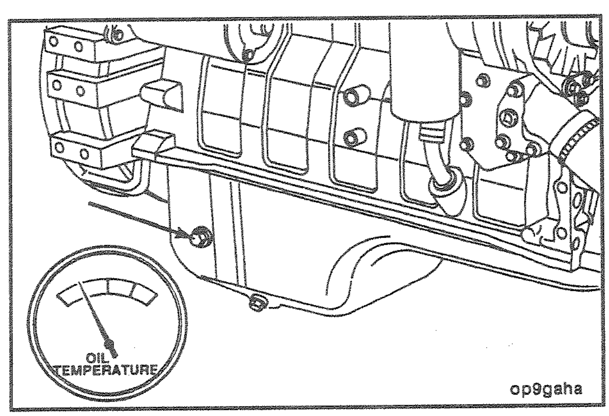
NOTE: For automotive applications a taped hole is provided on the inlet side of the catalyst for checking exhaust restrictions.

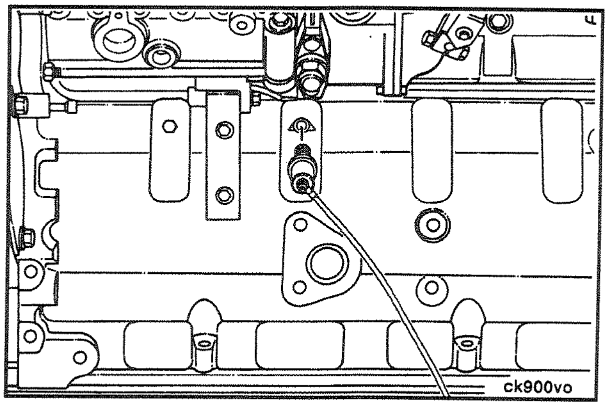
Minimum Gauge Capacity: 254 mm Hg. [10 in. Hg.]



Attach the lubricating oil temperature sensor in the location shown.

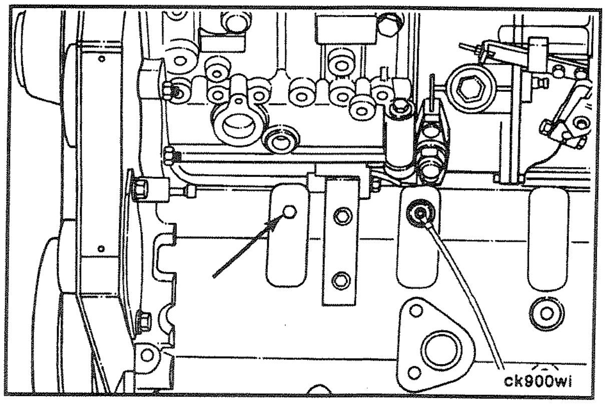
Minimum Gauge Capacity:150° C [300° F]





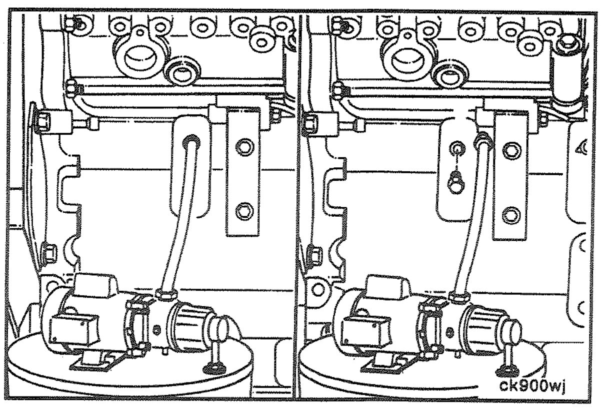
Attach the lubricating oil pressure sensor to the main oil rifle drilling in the cylinder block.

Minimum Gauge Capacity: 1034 kPa [150 psi]



Caution: The lubricating oil system must be primed before operating the engine after if has been rebuilt to avoid internal damage.

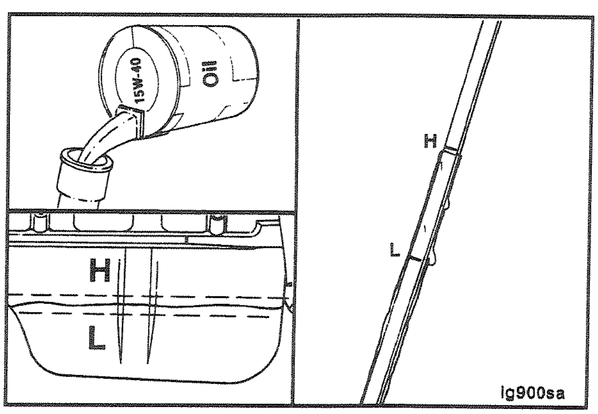
To prime the system using external pressure, connect the supply to a tapped hole in the main lubricating oil rifle.



Use a pump capable of supplying 210 kPa [30 psi] continuous pressure. Connect the pump to the port on the main lubricating oil rifle as shown.

Use clean 15W-40 lubricating oil to prime the system until the oil pressure registers on the gauge.

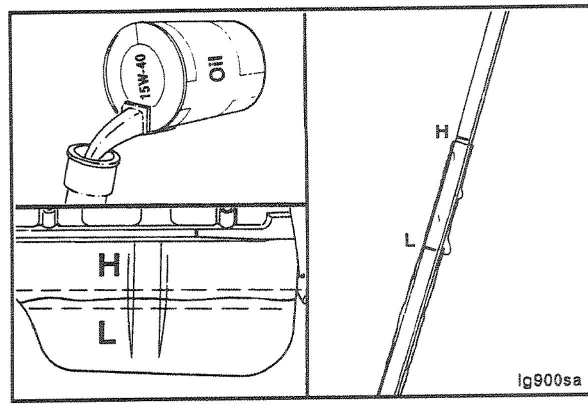
Remove the lubricating oil supply tube, and install the plug.



Make sure the lubricating oil has had time to drain to the lubricating oil pan, and fill the engine to the high mark as measured on the dipstick.

If an external pressure pump is **not** available, prime the lubricating system according to the following procedure.

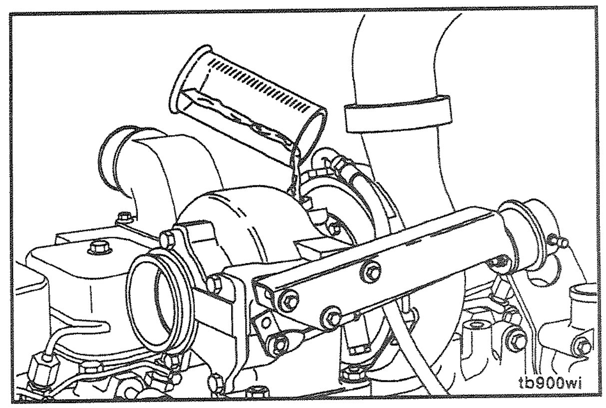
Fill the engine with lubricating oil to the high level mark on the dipstick.



Disconnect the turbocharger lubricating oil supply tube.

Pour 50 cc to 60 cc [2.0 fl. oz. to 3.0 fl. oz.] of clean 15W-40 lubricating oil into the turbocharger lubricating oil supply hole.

Connect the lubricating oil supply tube to the turbocharger.

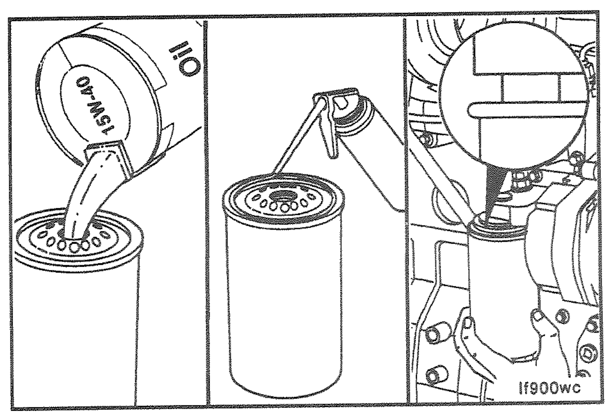


Caution: Mechanical over-tightening can distort the threads or damage the filter element seal.

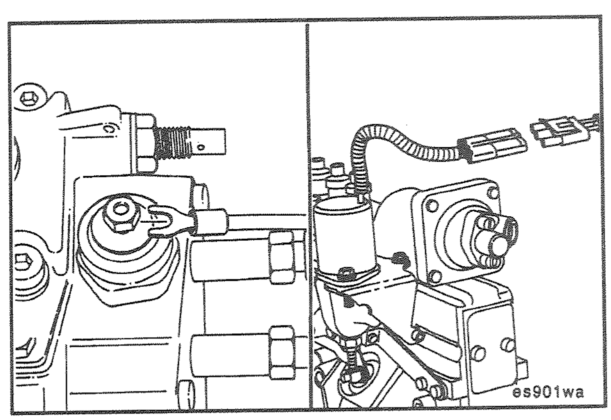
Fill the lubricating oil filters with clean 15W-40 lubricating oil.

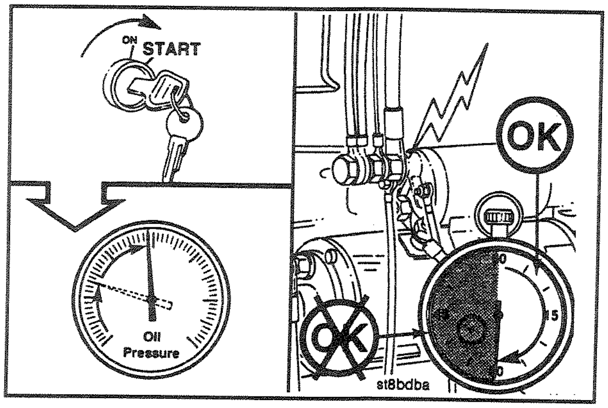
Screw the filters onto the filter head fitting until the gasket contacts the filter head surface.

Tighten the filter as specified by the manufacturer.



To make sure the lubricating oil pump is providing adequate lubricating oil to the engine, first disconnect any wires leading to the fuel injection pump solenoid.



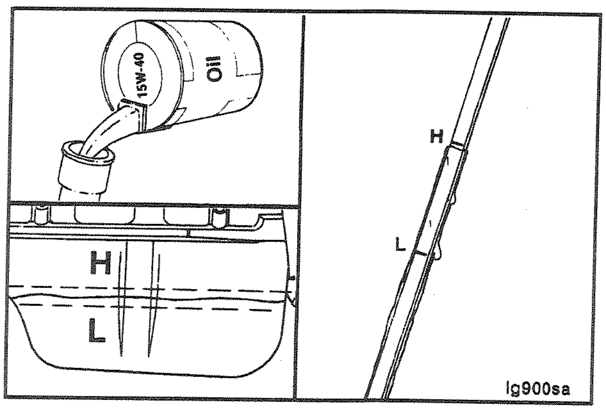


Caution: Do not crank the starting motor for periods longer than 30 seconds. Excessive heat will damage the starting motor.

Crank the engine until the lubricating oil pressure gauge indicates system pressure.

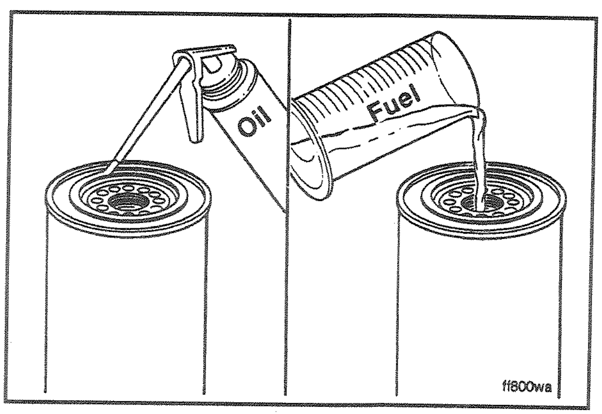
NOTE: Allow 2 minutes between the 30-second cranking periods so the starting motor can cool.

NOTE: If pressure is **not** indicated, find and correct the problem before continuing.



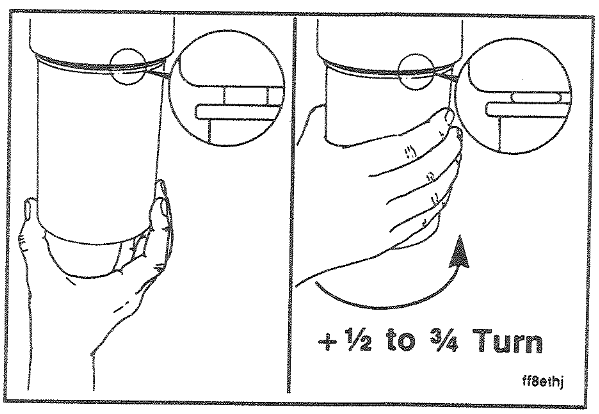
Allow the lubricating oil to drain into the lubricating oil pan, and measure the lubricating oil level with the dipstick.

Add lubricating oil as necessary to bring the level to the high level mark.



Lubricate the gasket on the fuel filter with clean 15W-40 lubricating oil.

Fill the fuel filter with clean fuel.

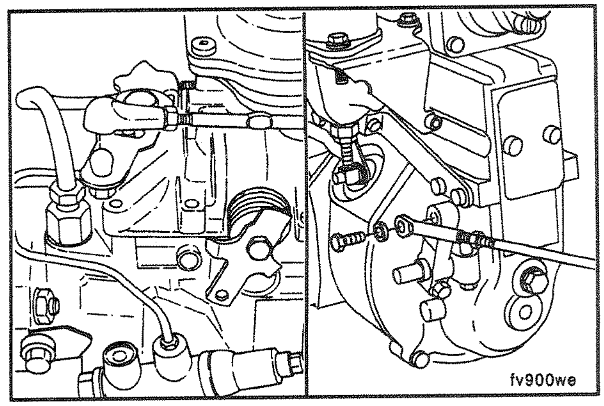


Screw the fuel filter onto the filter head until the gasket contacts the filter head surface.

Tighten the filter an additional 1/2 to 3/4 turn.

Make sure the voltage supply matches that of the fuel pump solenoid before connecting the electrical wires to it.

Attach the throttle control rod onto the fuel injection pump throttle lever.


fv900we

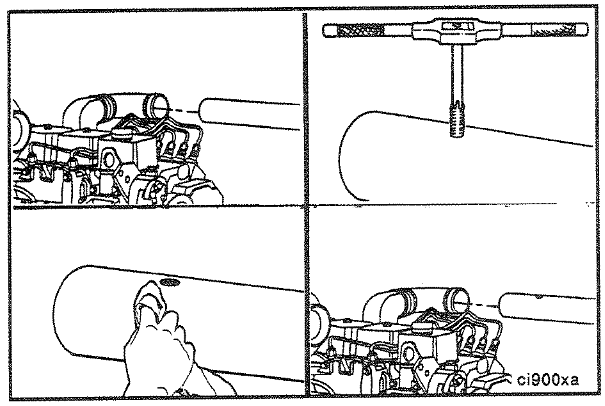
If the air crossover tube does not have a pipe plug and tapped hole, perform the following procedure.

Remove the air crossover tube from the engine.

Drill and tap a 1/8 inch pipe thread hole in the crossover tube in the location shown.

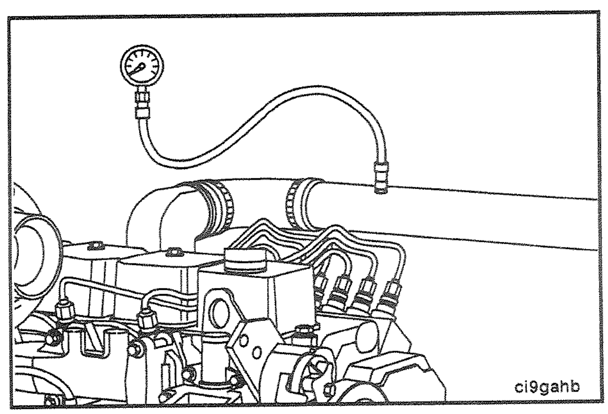
Clean all metal shavings from the air crossover tube.

Install the crossover tube.


ci900xa

To determine the amount of turbocharger boost, remove the pipe plug in the air crossover tube; and install the intake manifold pressure sensor or pressure gauge, Part No. ST-1273.

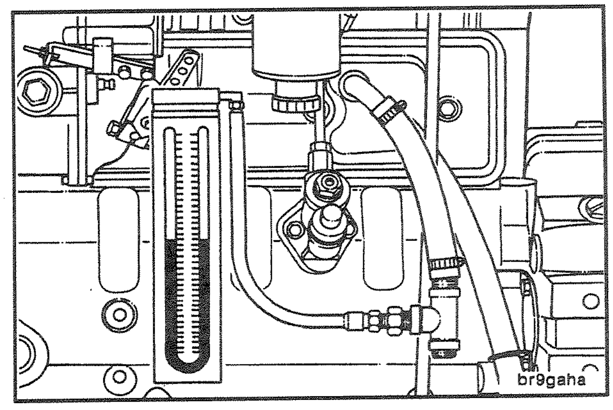
Minimum Gauge Capacity: 1905 mm Hg [75 in. Hg]

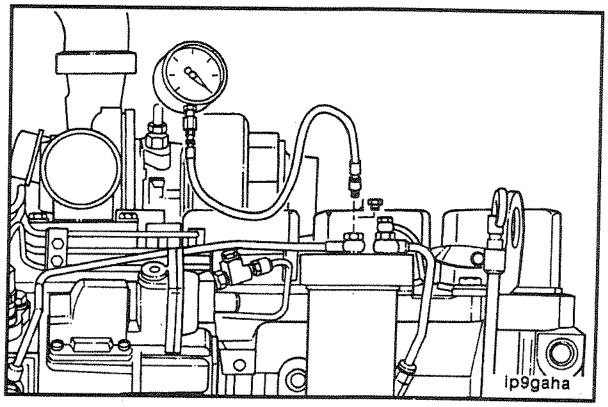

ci9gahb

For accurate engine crankcase blowby measurement, insert a blowby checking tool in the crankcase breather vent.

Connect a water manometer to the blowby tool. A pressure gauge can be used in place of the manometer.

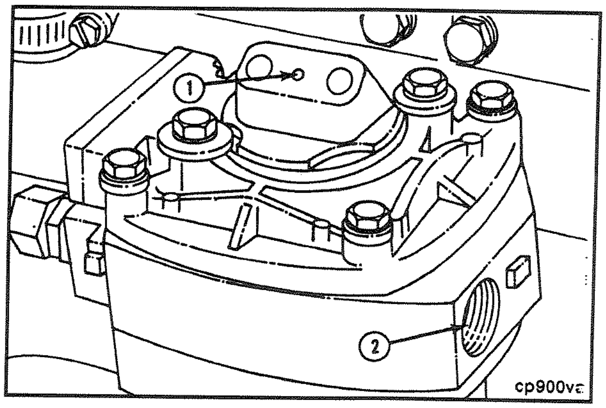
Minimum Gauge Capacity: 1270 mm H_2O [50 in. H_2O]


br9gaha



To measure fuel filter restriction, connect vacuum gauge, Part No. ST-434, to the injection pump inlet line.

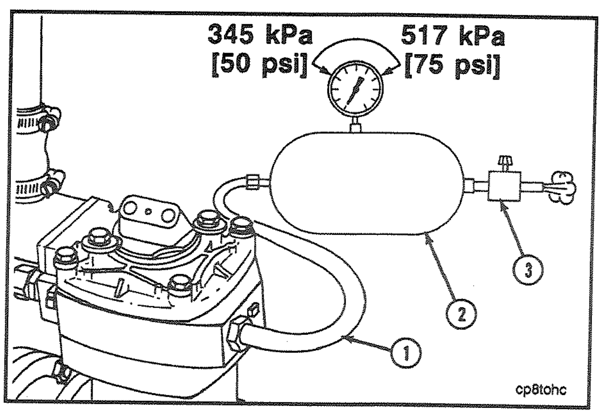
Minimum Gauge Capacity: 760 mm Hg [30 in. Hg]



To be able to unload the compressor, connect a source of compressed air to the unloader (1). This air line **must** contain a valve between the source and the unloader.

NOTE: All air compressors manufactured by Cummins Engine Company, Inc. **must** be **loaded** during engine run-in. All air compressors **must** be **unloaded** during the engine performance check.

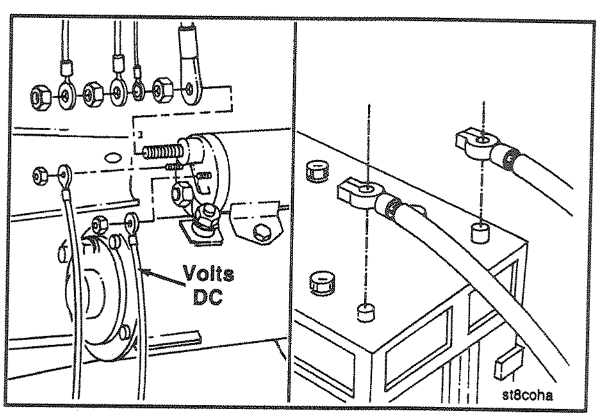
NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).



To provide a load on the air compressor, connect an air tank (2) to the compressor outlet, use steel tubing or a high temperature hose (1).

Install an air regulator (3) that can maintain tank air pressure of 345 kPa to 517 kPa [50 psi to 75 psi] at both the minimum and the maximum engine RPM.

Hose Temperature (Minimum): 260° C [500° F]



Inspect the voltage rating on the starting motor before installing the electrical wiring.

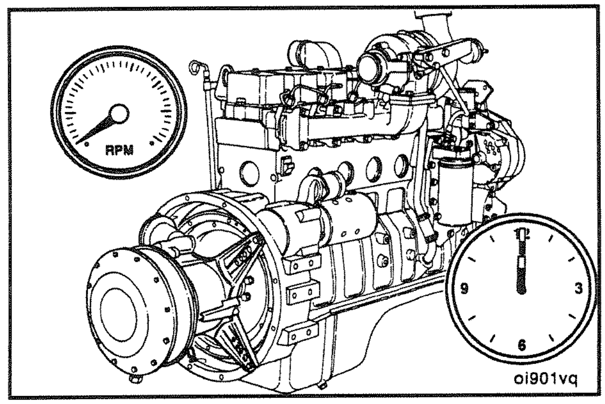
Attach electrical wires to the starting motor and the batteries, if used.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

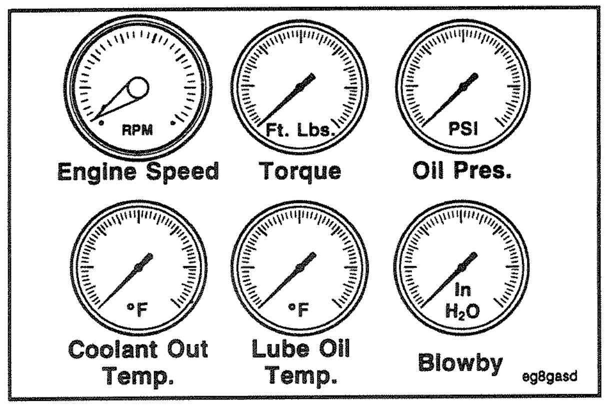
Engine Dynamometer Test - Engine Run-In (8-02)

The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

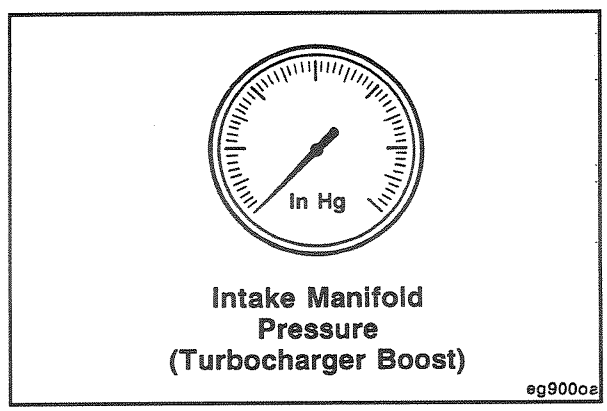
NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used, if desired, at each phase **except** engine idle periods.



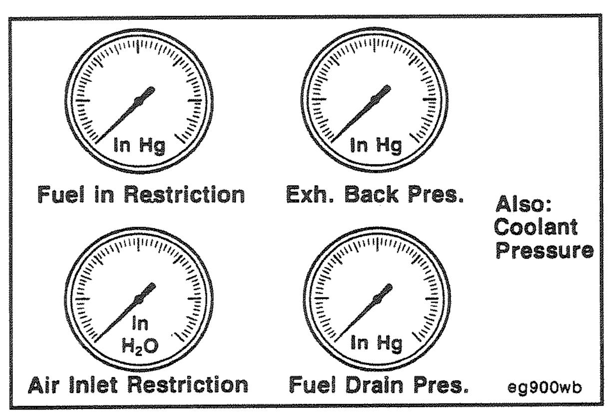
Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period. Refer to page 8-6 for specifications and acceptable readings.

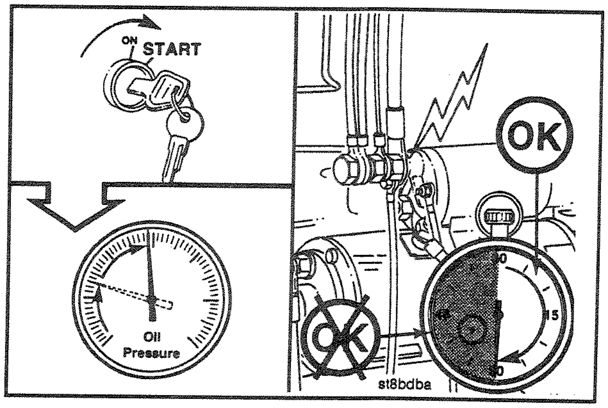


To correctly evaluate the engine performance, this additional measurement **must** be observed during engine run-in phases.



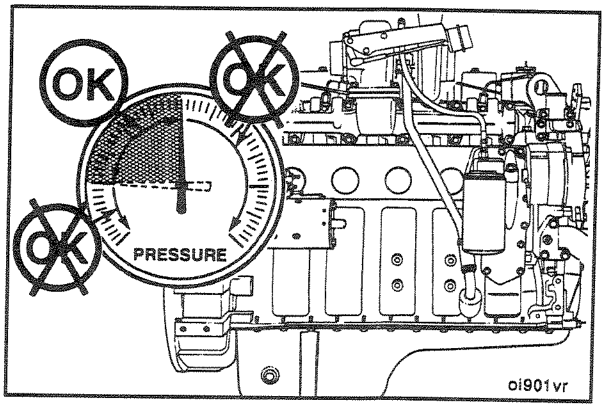
It is good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for under-performance.





Caution: Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

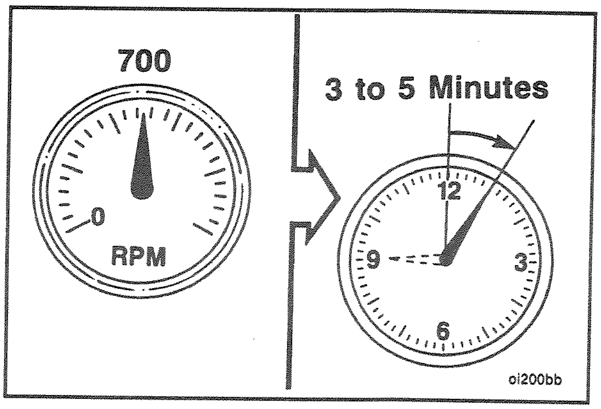
Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before ranking the engine again.



Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at 700 RPM.

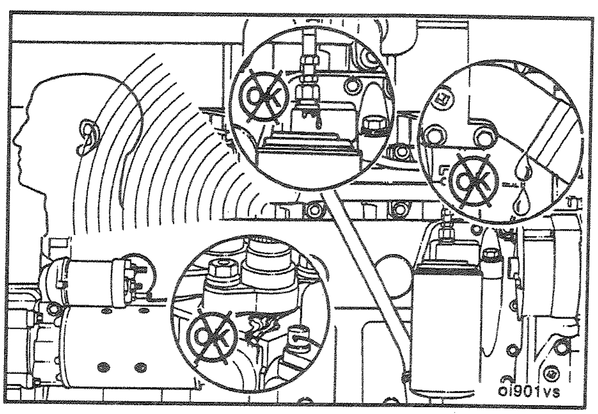
Caution: If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

Correct the problem if the lubricating oil pressure is **not** within specifications.



Caution: Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

Operate the engine at approximately 700 RPM for 3 to 5 minutes.



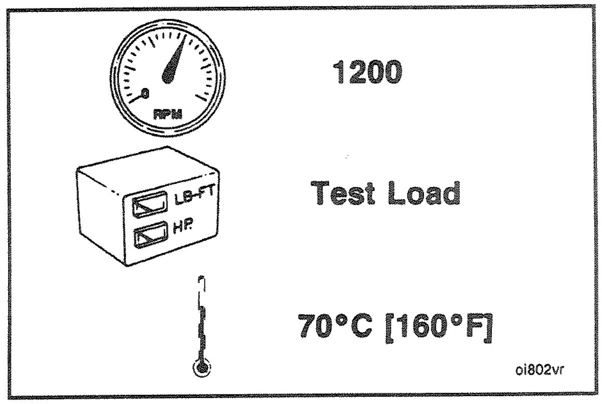
Listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

NOTE: Repair all leaks or component problems before continuing the engine run-in.

Move the throttle to obtain 1,200 RPM engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70° C [160° F]. Check all gauges and record the data.

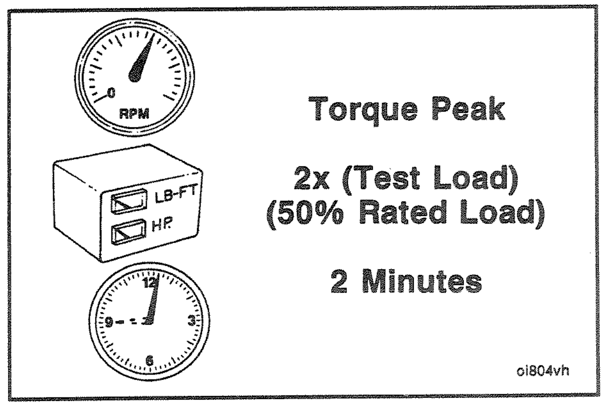
NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.



Open the throttle to the speed at which peak torque occurs, and adjust the dynamometer load to 50 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

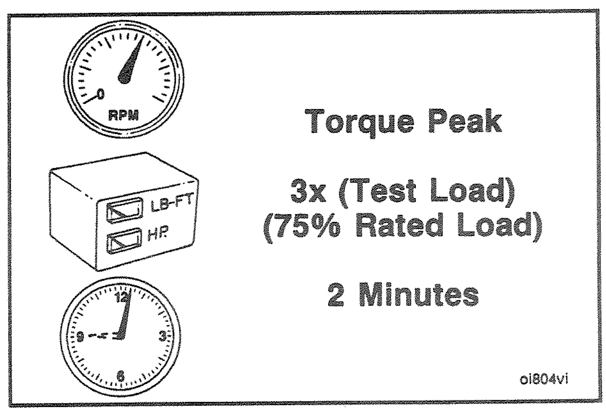
Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



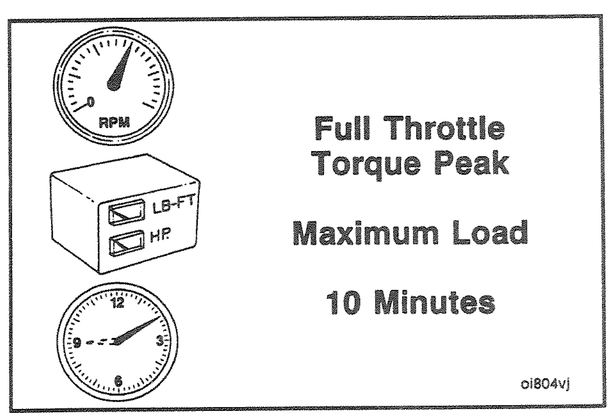
With the engine speed remaining at torque peak RPM, increase the dynamometer load to 75 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes. Check all gauges and record the data.

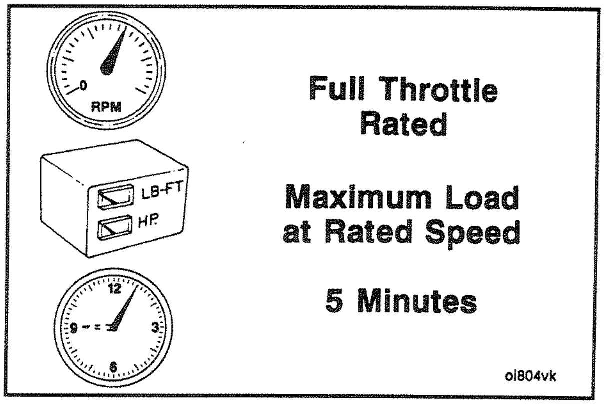
NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak RPM. Operate the engine at this speed and load level for 10 minutes or until the blowby becomes stable within specifications.

Check all gauges and record the data.

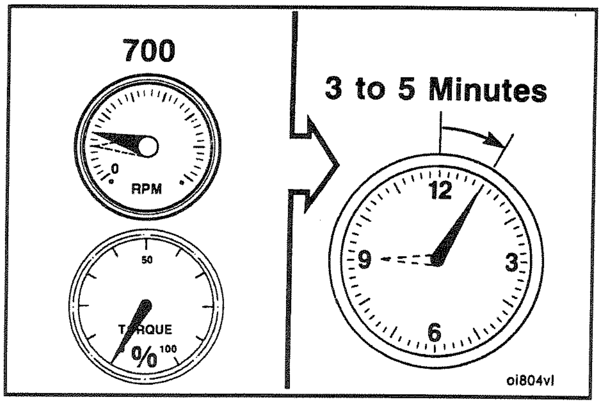




Reduce the dynamometer load until the engine speed increases to the engine's rated RPM.

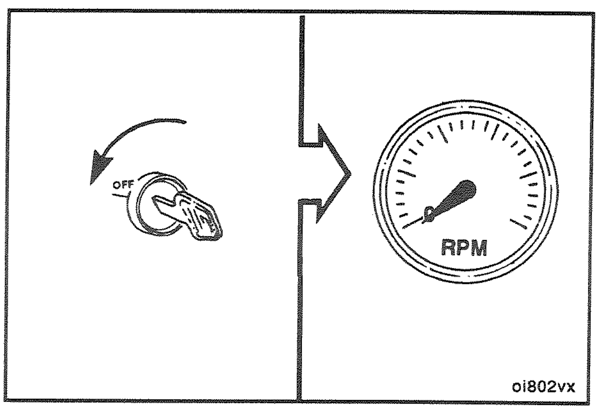
Operate the engine at rated RPM for 5 minutes.

Check all gauges and record the data.

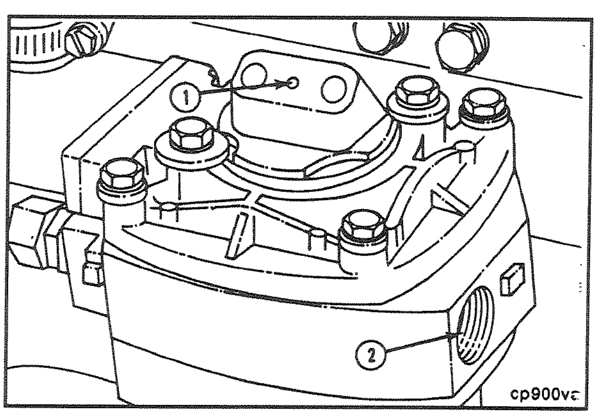


Caution: Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

Remove the dynamometer load completely, and operate the engine at 700 RPM for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.



Shut off the engine.



Engine Dynamometer Test - Performance Checking (8-03)

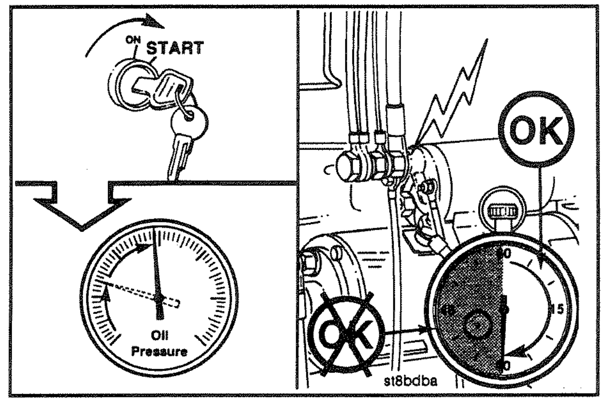
Make sure the air compressor will be unloaded during the performance check.

Apply regulated air pressure of 655 kPa [95 psi] to the air compressor unloader (1).

NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).

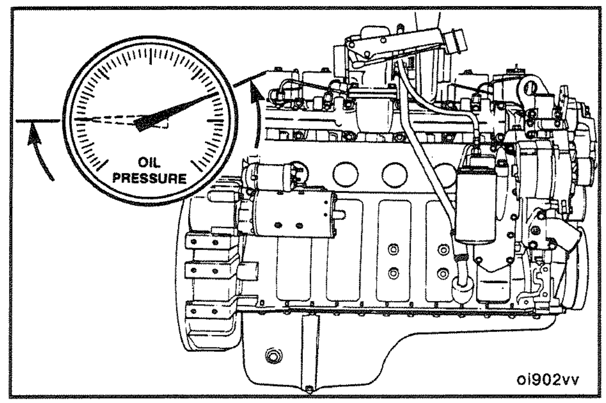
Caution: Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

Crank the engine and observe the oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before cranking the engine again.



Caution: If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage. Correct the problem if lubricating oil pressure is not within specifications.

Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at approximately 700 RPM.



Make sure the engine is at operating temperature.

Move the throttle lever to the "FULL OPEN" position. Adjust the dynamometer load until the engine maintains the rated RPM.

Allow the readings to stabilize. Read the horsepower.

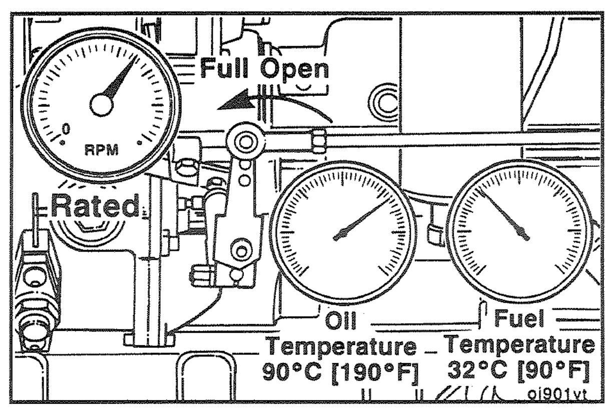
Check all the gauges, and record the readings.

NOTE: The horsepower reading will **not** be accurate if the lubricating oil temperature and fuel temperature are **not** within specifications.

Lubricating Oil Temperature: MIN 90° C [190° F]

Fuel Temperature: MAX 32° C [90° F]

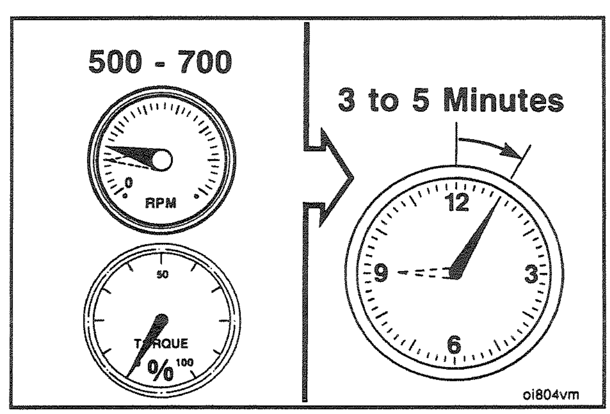
Check all gauges and record the data.

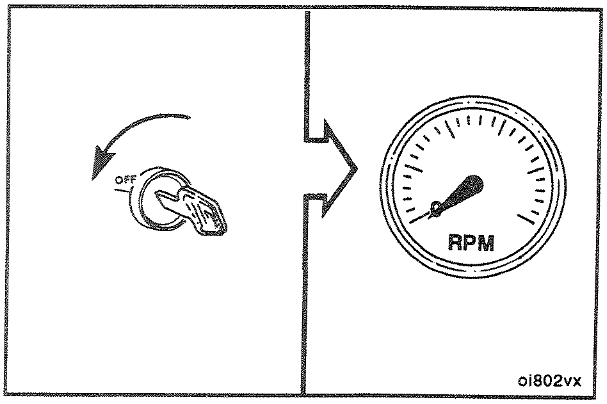


Caution: Do not shut off the engine immediately after it has been loaded. It must be allowed to sufficiently cool.

Remove the dynamometer load completely, and operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

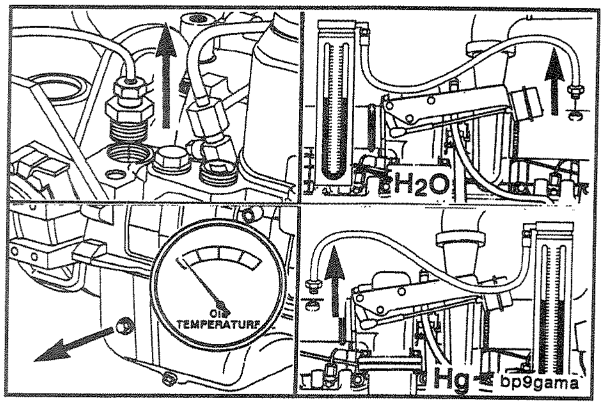
NOTE: Idle periods longer than 5 minutes are to be avoided.





oi802vx

Shut off the engine after the cool-down period.

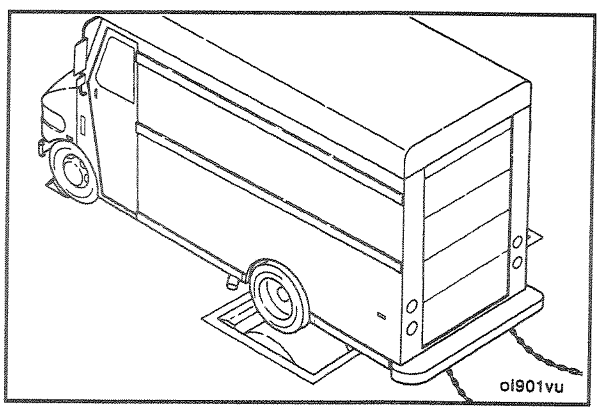


bp9gama

Remove all test instrumentation. Remove the engine from the dynamometer.

NOTE: If the engine is to be stored temporarily and does **not** have permanent-type antifreeze, it is necessary to drain all coolant. Drain locations are identified on the engine side views, pages 8-4 and 8-5.

Prepare the engine for Engine Painting (8-08)



ol901vu

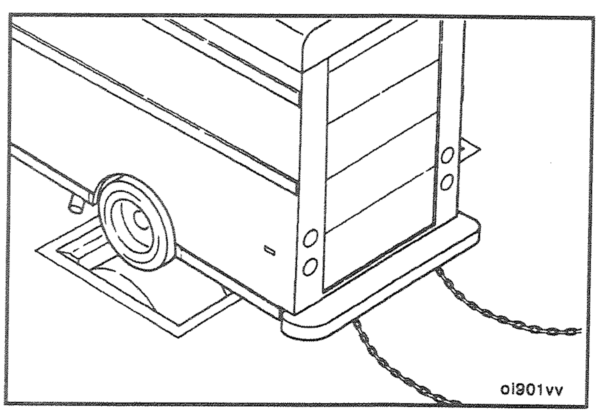
Chassis Dynamometer - Operation (8-04)

The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

NOTE: Due to driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

- 20 percent for single axle vehicles
- 25 percent for tandem axle vehicles

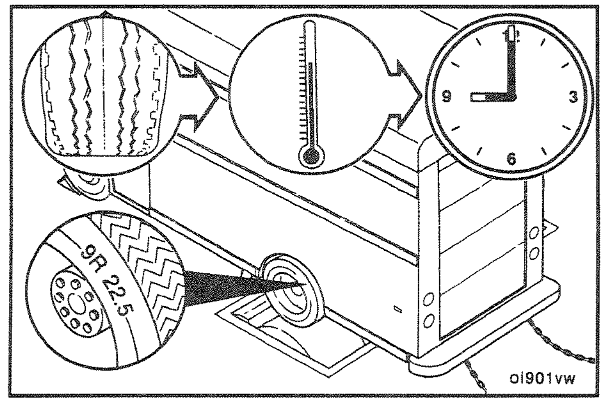
NOTE: These percentages are used for engine run-in only and are **not** to be used as absolute figures.



ol901vv

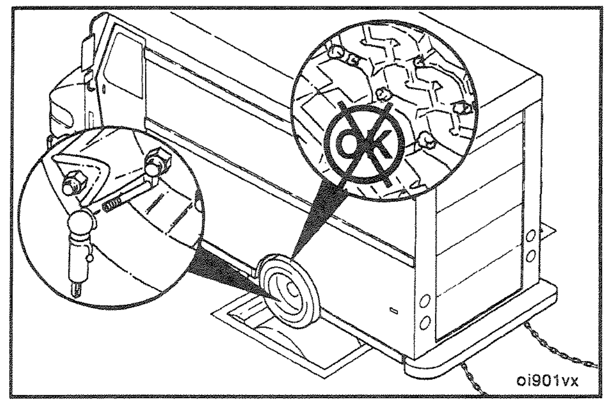
Caution: Follow all the vehicle manufacturer's safety precautions before installing or operating a vehicle on a chassis dynamometer.

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.

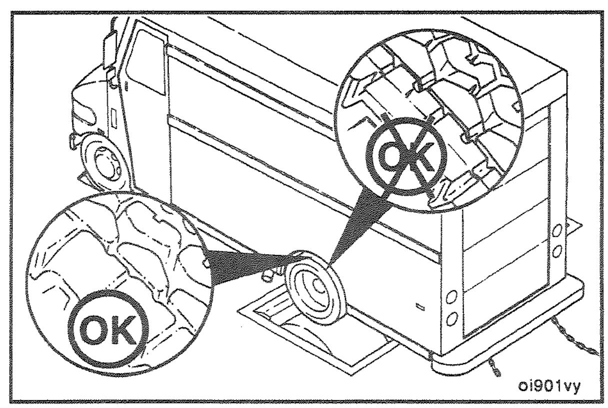


Follow the general safety precautions listed below while operating the chassis dynamometer:

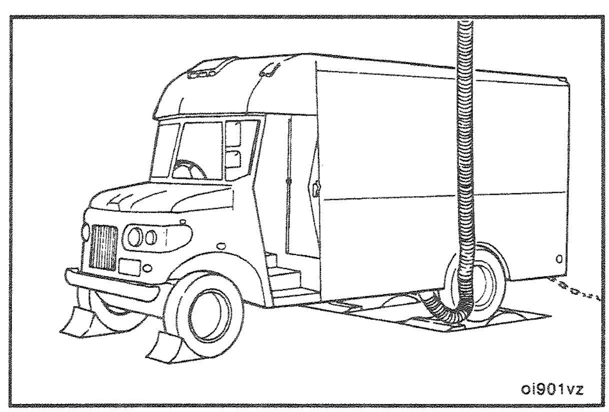
- Use tires that have more than 160 kilometers [100 miles] on them. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.

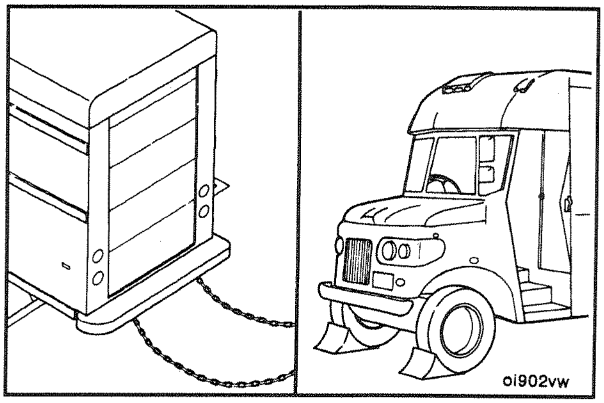


- Make sure the tires are inflated to the manufacturer's specifications.
- Remove all rocks or other material from the tread of all tires that will be rotating on the dynamometer rollers.



- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.

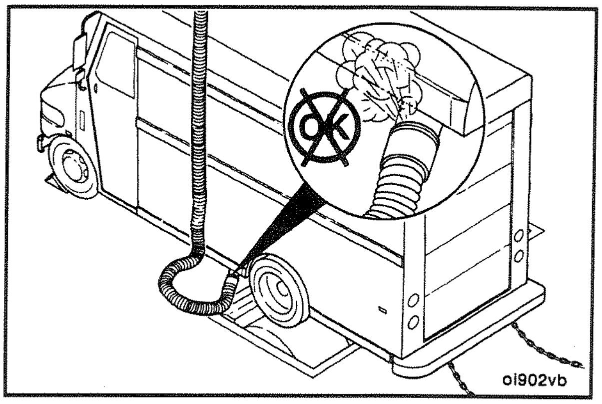




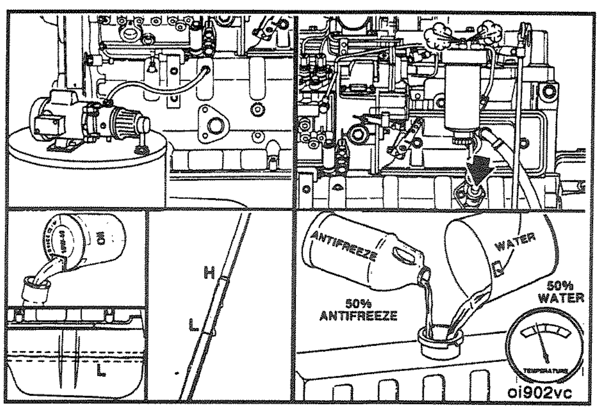
- Carefully position the vehicle on the rollers.

Caution: To prevent damage to the chassis dynamometer, there must be some slack in the tension of the tie-down chains.

- Attach the tie-down chains to the rear of the vehicle, and put wheel chocks in front of the front wheels.

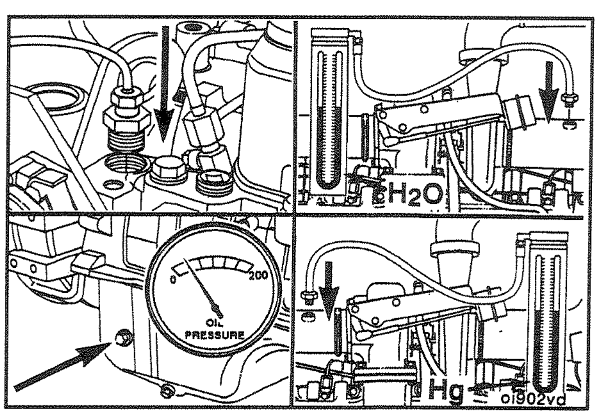


- Adjust the vehicle and dynamometer room exhaust system to make sure all exhaust gases are removed from the room.
- Refer to the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.



General Engine Test Procedures - (Chassis Dynamometer) (8-05)

The following procedure assumes that the lubricating oil and fuel systems were correctly primed, the dipstick calibrated, and the engine filled to the correct levels with lubricating oil and coolant during installation of the engine into the chassis. If these systems were **not** serviced during installation of the engine, refer to Engine Dynamometer Test - Installation of the Engine (8-01) for instructions on priming the lubricating oil and the fuel systems and calibrating the dipstick. Refer to the latest B Series Operation and Maintenance Manual, Bulletin No. 3810205, for instructions on filling the lubricating oil and the cooling systems.

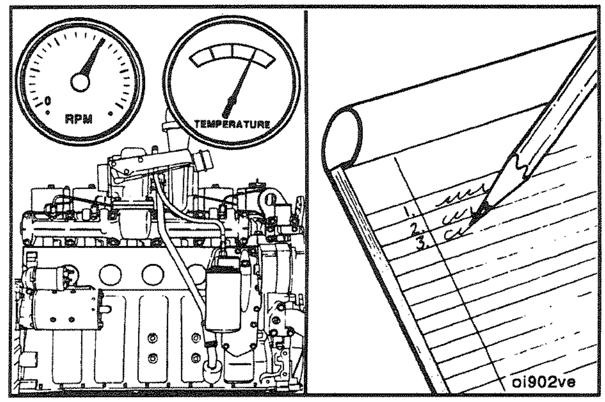


The number of instruments and gauges required to perform a chassis dynamometer test will vary according to the type and the capability of the test equipment used.

Refer to pages 8-4 and 8-5 for the correct system pressure and temperature gauge connecting locations.

To correctly monitor an engine's performance, record the following parameters:

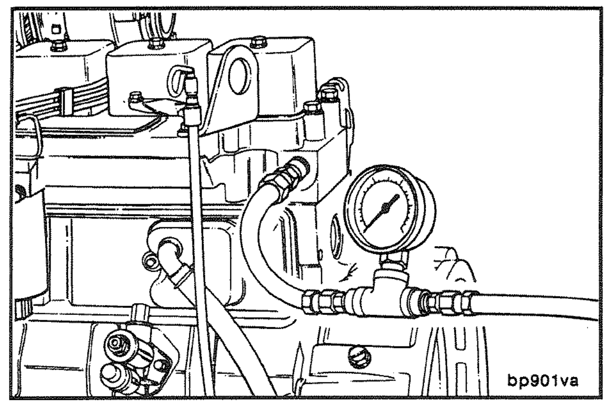
- Exhaust Back Pressure
- Lubricating oil pressure (vehicle instrument panel)
- Coolant temperature (vehicle instrument panel)
- Coolant pressure*
- Intake manifold pressure*
- Inlet air restriction*
- Blowby*
- Engine speed (RPM) (vehicle instrument panel)
- Wheel horsepower (WHP) (dynamometer controls)



*See the following for the Service Tools required and the installation locations on the engine.

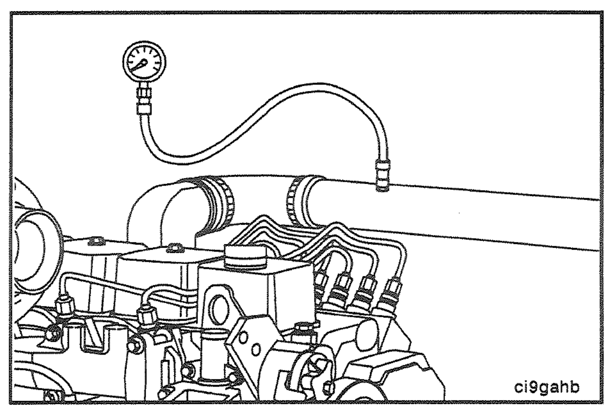
Measure the coolant pressure at the cylinder head, rear fuel pump side.

Minimum Gauge Capacity: 415 kPa [60 psi]



Measure the intake manifold pressure (turbocharger boost). Install a pressure gauge, Part No. ST-1273, in the location shown.

Minimum Gauge Capacity: 1905 mm Hg [75 in. Hg]

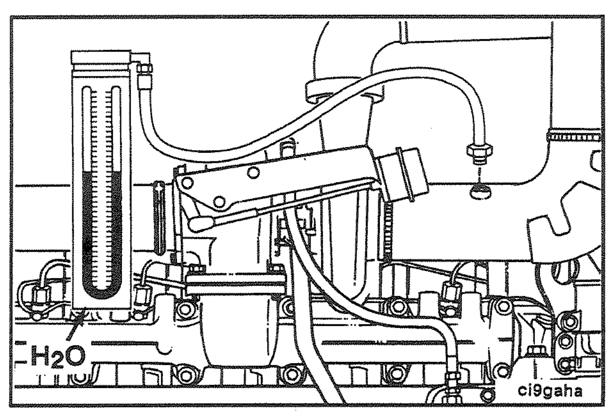


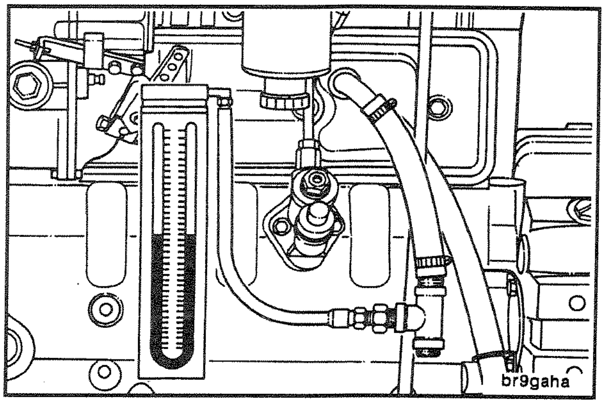
Connect a water manometer to the turbocharger air inlet pipe to test air restriction.

NOTE: The manometer connection **must** be installed at a 90 degree angle to the air flow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: A vacuum gauge can be used in place of the water manometer.

Minimum Gauge Capacity: 760 mm H_20 [30 in. H_2O]

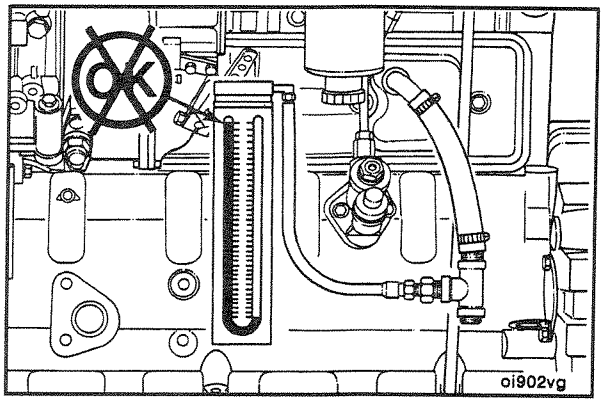




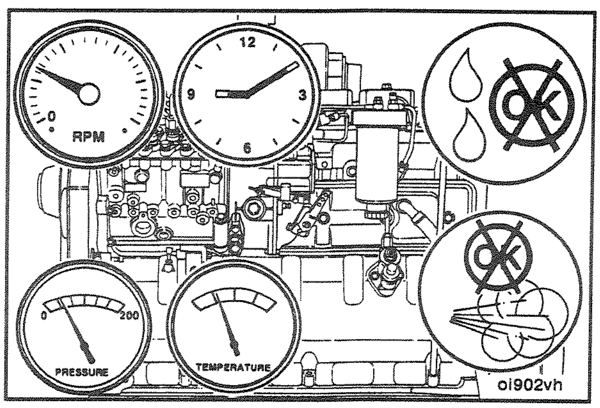
Measure the blowby by installing blowby checking tool in the crankcase breather vent. Connect the blowby tool to a water manometer.

NOTE: Excessive blowby indicates a turbocharger malfunction or an engine internal components malfunction, allowing combustion gases to enter the crankcase.

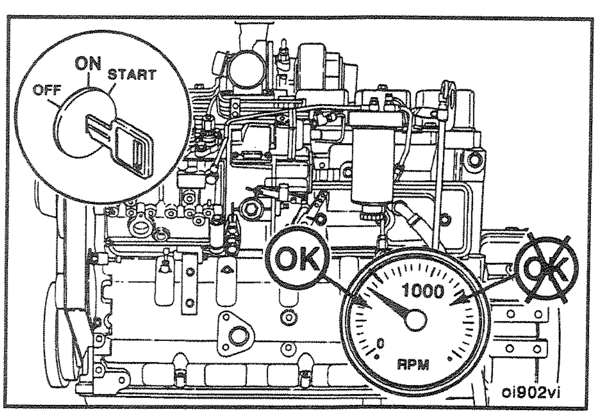
Minimum Gauge Capacity: 1270 mm H_2O [50 in. H_2O]



NOTE: If a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in step, return to the previous step and continue the run-in. If blowby does **not** reach an acceptable level, discontinue the run-in and determine the cause.

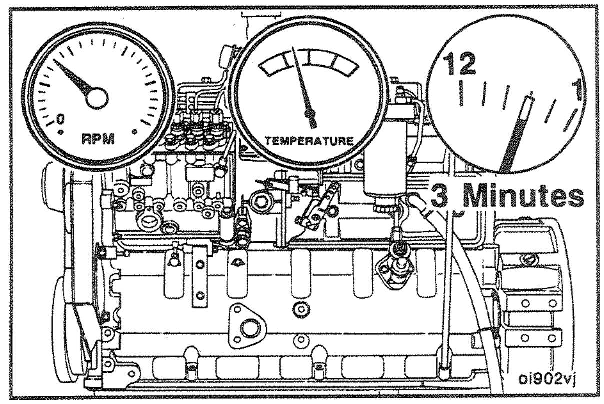


NOTE: Avoid long idle periods. Operate the engine at low idle only long enough (3 to 5 minutes) to check for correct lubricating oil pressure and any fuel, lubricating oil, water, or air leaks.



Caution: Do not allow the engine speed to exceed 1,000 RPM before run-in. The internal components can be damaged.

Caution: Do not shut off the engine immediately after the last step of the run-in is completed. Allow the engine to cool by operating at low idle for a minimum of 3 minutes to avoid internal component damage.

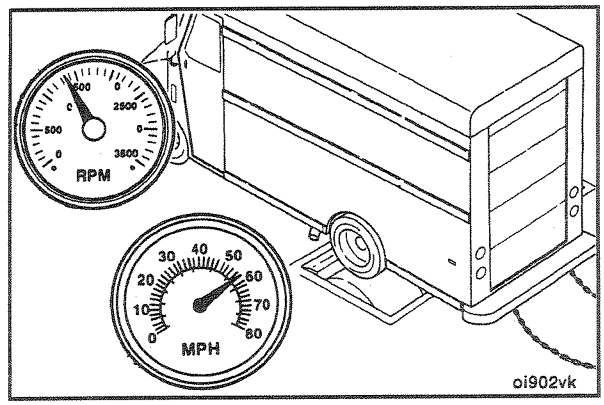


Engine Run-In Procedure - (Chassis Dynamometer) (8-06)

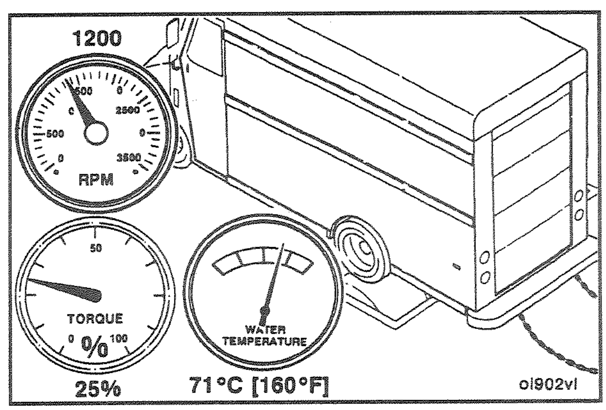
Caution: Refer to General Engine Test Procedures - (Chassis Dynamometer) (8-05) before operating the engine to avoid internal component damage.

NOTE: Refer to Chassis Dynamometer Operation on page 8-20 for general operating procedures and safety precautions.

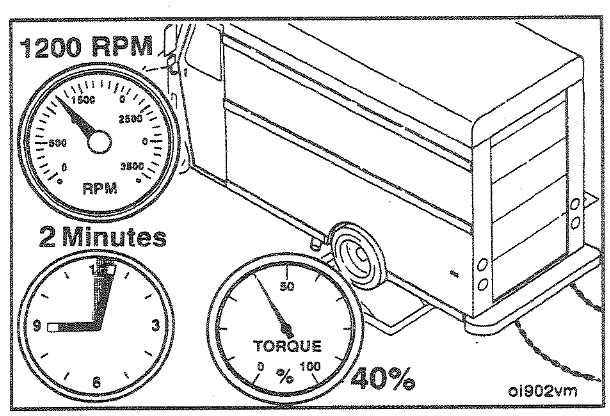
NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 km/h [55 to 60 mph].

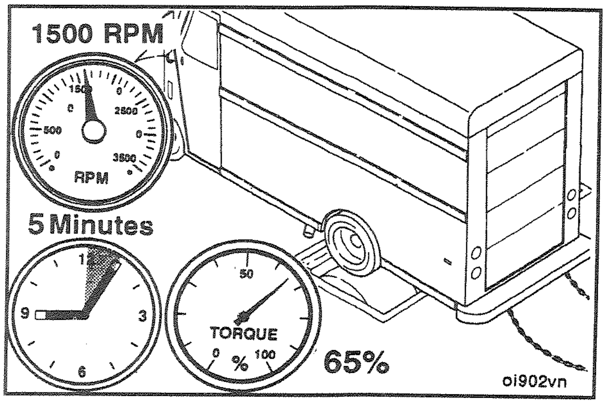


Operate the engine at 1,200 RPM and 25 percent of torque peak load until the water temperature reaches 70° C [160° F].

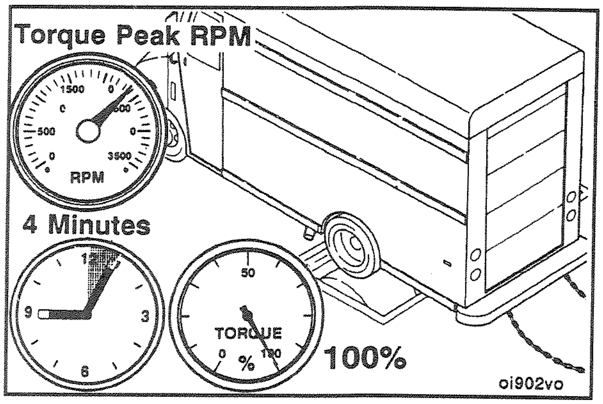


Operate the engine at 1,200 RPM and 40 percent of torque peak load for 2 minutes. Check the gauges, and record the readings.



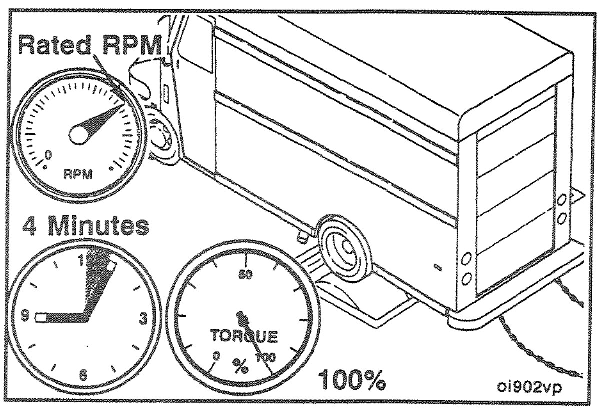


Operate the engine at 1,600 RPM and 65 percent of torque peak load for 5 minutes. Check the gauges, and record the readings.



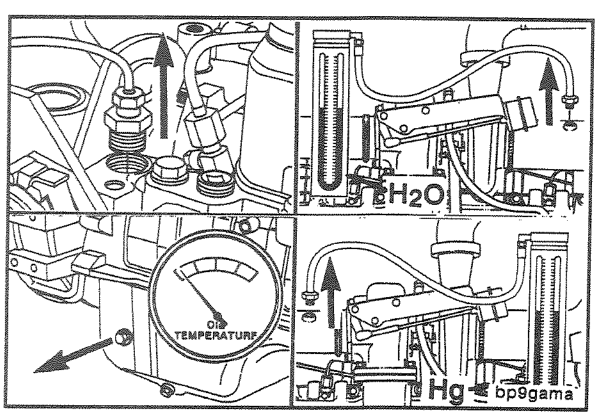
Operate the engine at torque peak RPM and full load for 4 minutes. Check the gauges, and record the readings.

NOTE: Refer to the engine data sheet for the torque peak RPM of the engine model being tested.



Operate the engine at rated speed (RPM) and full load for 4 minutes. Check the gauges, and record the readings. Compare the readings to those published on the appropriate engine data sheet.

Caution: Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating it at low idle for a minimum of 3 minutes to avoid internal component damage.



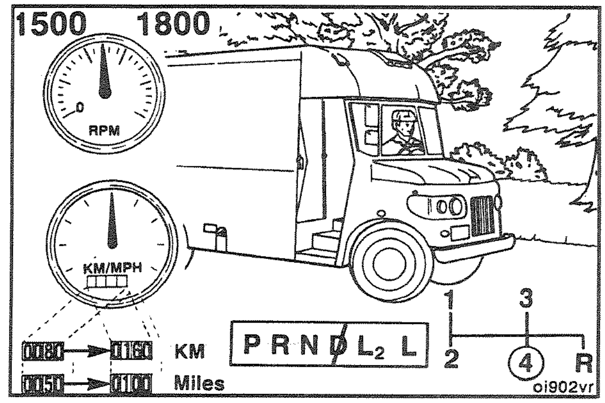
Make sure all instrumentation is removed before removing the vehicle from the dynamometer.

Engine Run-In Procedure "In Chassis" - (On- and Off-Highway Vehicles) (8-07)

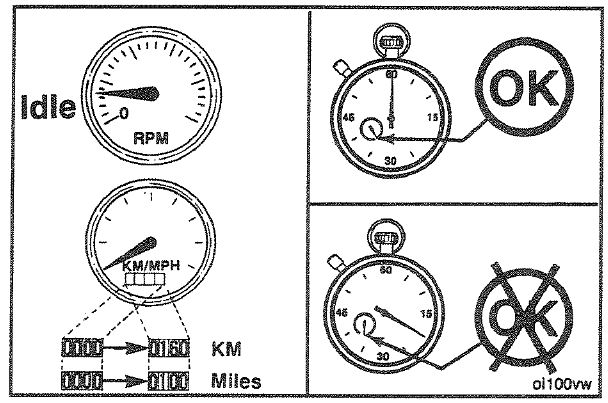
On-Highway

Caution: Refer to General Engine Test Procedures - (Chassis Dynamometer) (8-05) before operating the engine to avoid internal component damage.

Operate the engine at 1,500 to 1,800 RPM in high gear for the first 80 to 160 kilometers [50 to 100 miles] after rebuild.



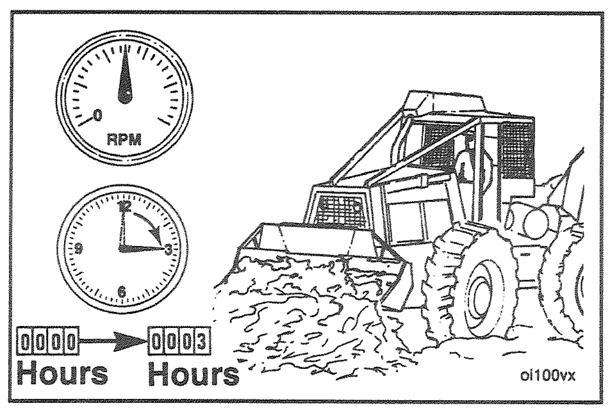
NOTE: Do **not** idle the engine for more than 5 minutes at any one time during the first 160 kilometers [100 miles] of operation.



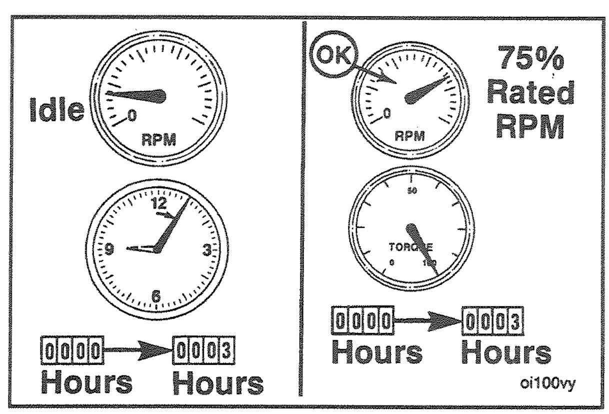
Off-Highway

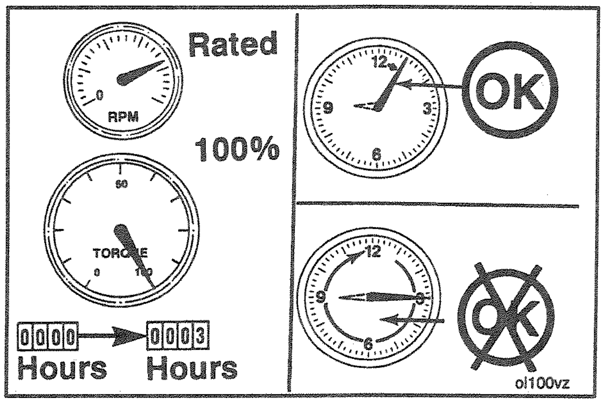
Caution: Refer to General Engine Test Procedures - (Chassis Dynamometer) (8-05) before operating the engine to avoid internal component damage.

Operate the engine as follows during the first 3 hours after rebuild:

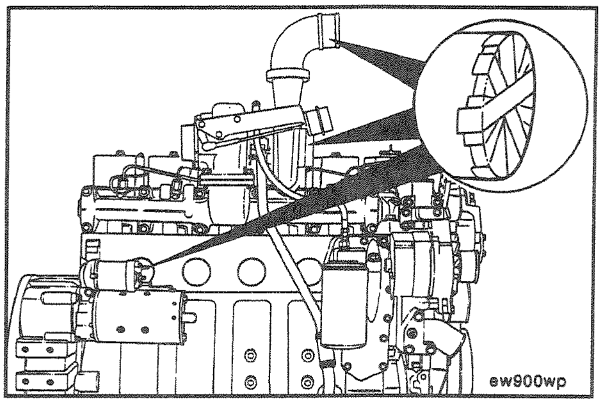


1. Do **not** idle the engine for more than 5 minutes at any one time.
2. Operate the engine at 75 percent throttle while loaded.





3. Do **not** operate the engine at rated speed (RPM) and full load for more than 5 minutes at any one time.

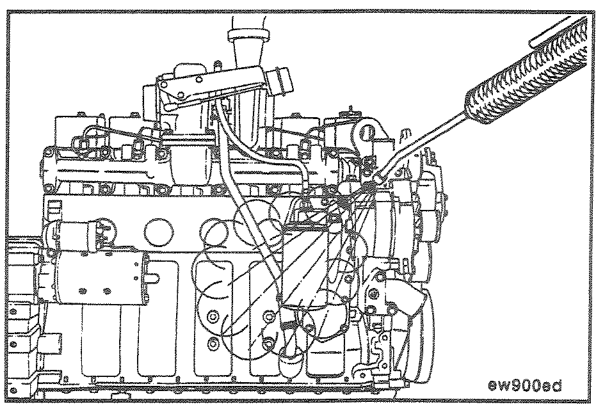


Engine - Painting (8-08)

Remove all belts from the engine.

Cover the following parts of the engine:

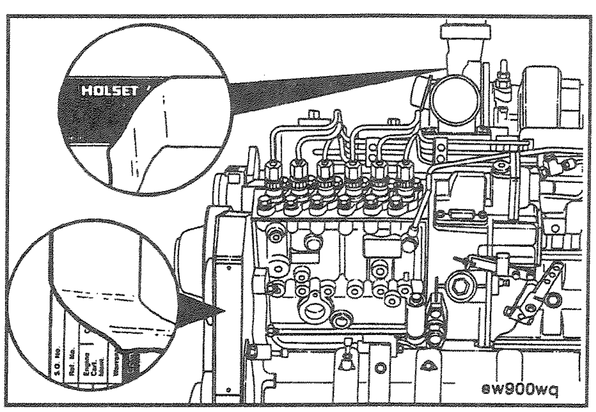
- All pulley belt surfaces
- Exhaust and intake openings
- Electrical components
- Fuel inlet and drain connections
- Any exposed fittings, threads, and electrical wire terminals



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

Use steam to clean the engine, and dry with compressed air.

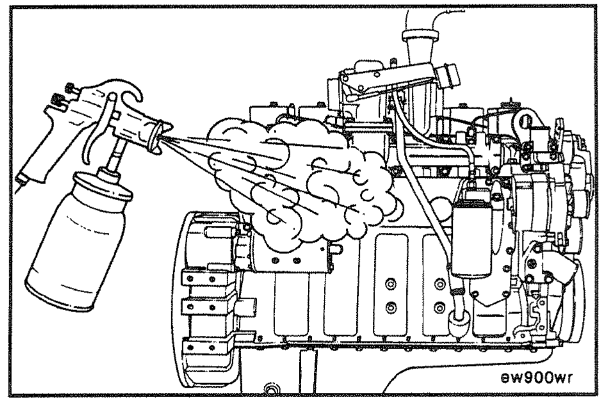
NOTE: Make sure all engine surfaces are clean and dry before painting the engine.



Protect the following components from the paint:

- All dataplates
- Valve and injector set marks.
- Exhaust manifold
- Turbocharger turbine housing
- Flywheel
- Flywheel housing transmission mounting surface

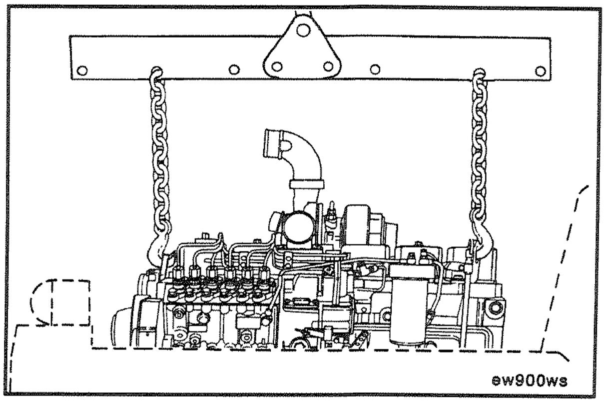
Paint the engine.



NOTES

Section 9 - Engine Removal and Installation

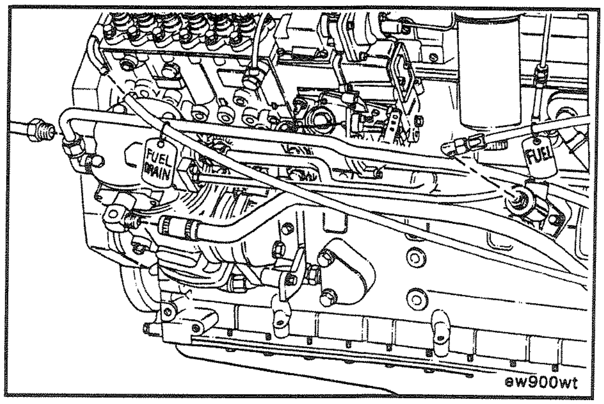
Section Contents



General Information

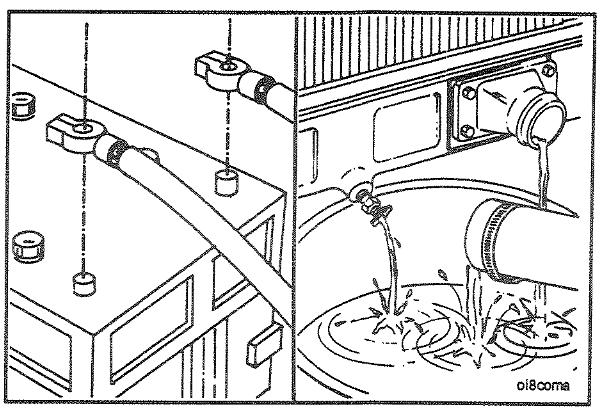
The procedures required to replace an engine will vary with different engine models, the type of equipment, optional equipment, and the shop facilities. Use the following procedures as a guide:

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



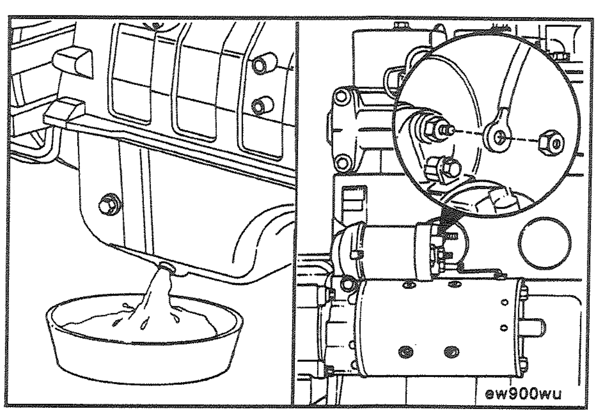
Engine - Removal (9-01)

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



Disconnect the battery cables.

Drain the engine coolant.

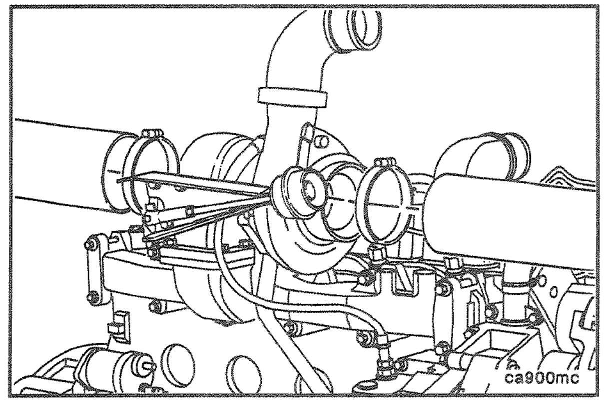


Drain the lubricating oil.

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

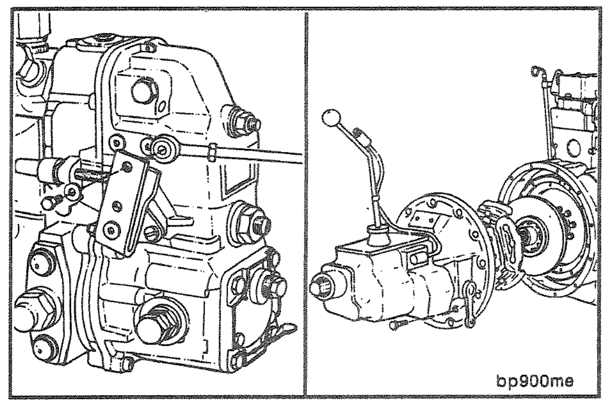
Disconnect the intake and exhaust pipes.

Disconnect all chassis mounted engine driven accessories.

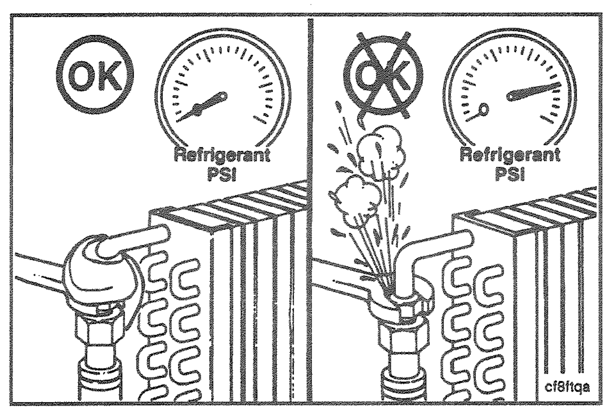


Disconnect the throttle linkage from the fuel injection pump control lever.

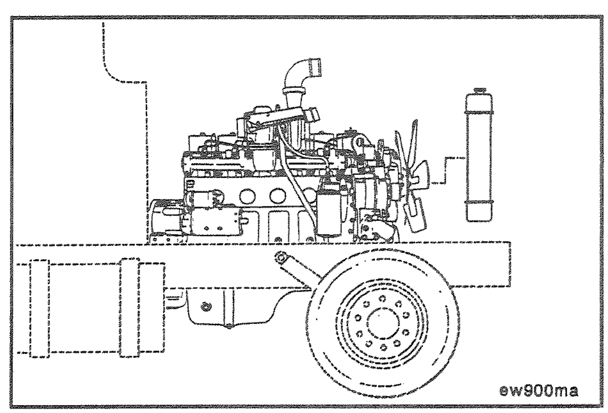
Disconnect the drive units from the flywheel.

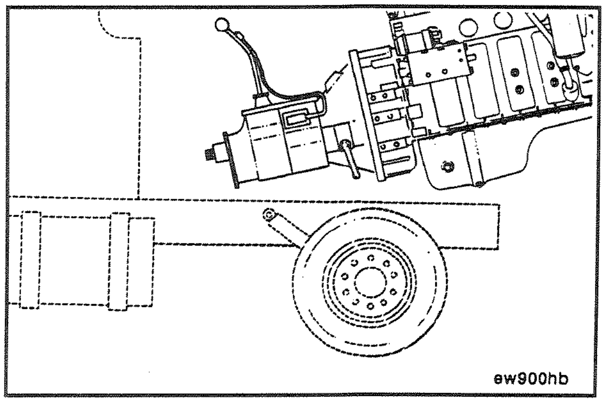


Warning: If a liquid refrigerant system (air conditioning) is used, wear eye and face protection and wrap a cloth around the fittings before removal. Liquid refrigerant can cause serious eye and skin injury.



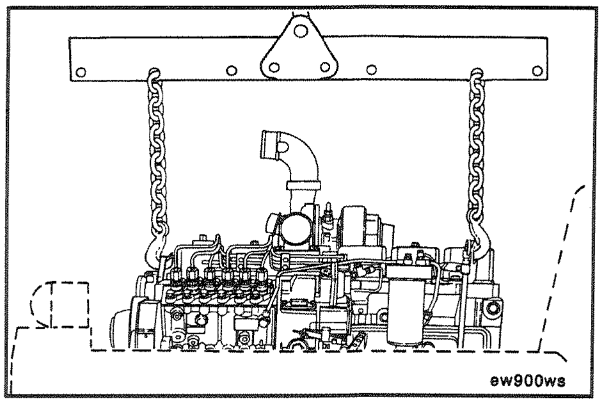
Remove all chassis components necessary to remove the engine from the equipment.





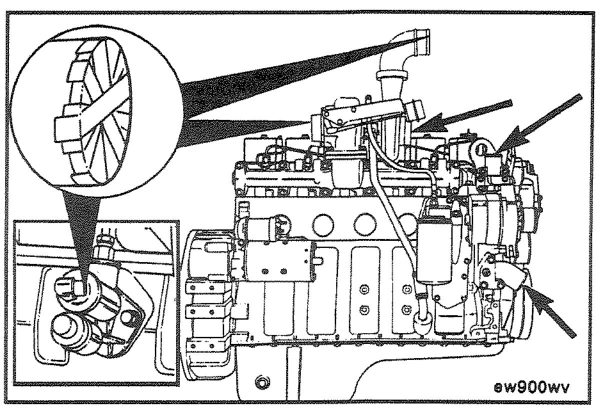
NOTE: On applications where the rear engine mounts are attached to the transmission, it may be necessary to remove the engine and transmission as an assembly.

Warning: The engine lifting equipment must be designed to safely lift the engine and transmission as an assembly. The dry weight of the standard 6BTA5.9 without accessories is 411 kg [905 lb]. Refer to the equipment manufacturer's specifications for the transmission weight.



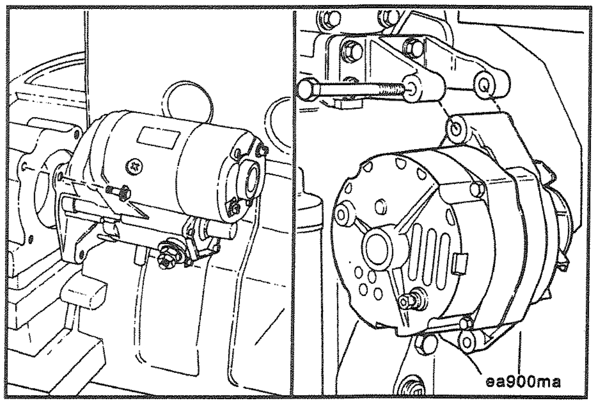
Use a properly rated hoist and engine lifting fixture, attached to the engine mounted lifting brackets to remove the engine.

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



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

Place the engine on suitable engine support stands.



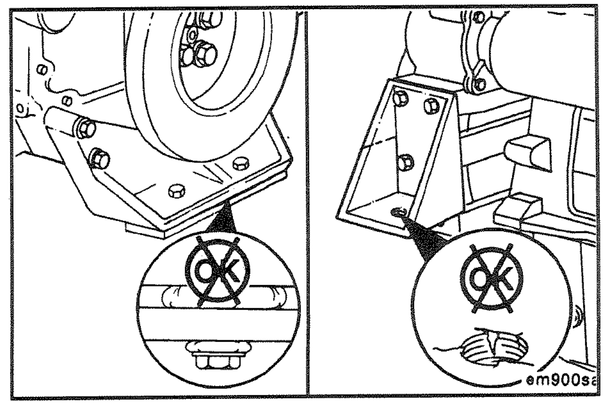
Remove all remaining accessories and brackets to use with the replacement engine.

Engine Mount - Inspection (9-02)

Inspect all rubber-cushioned mounts for cracks or damage.

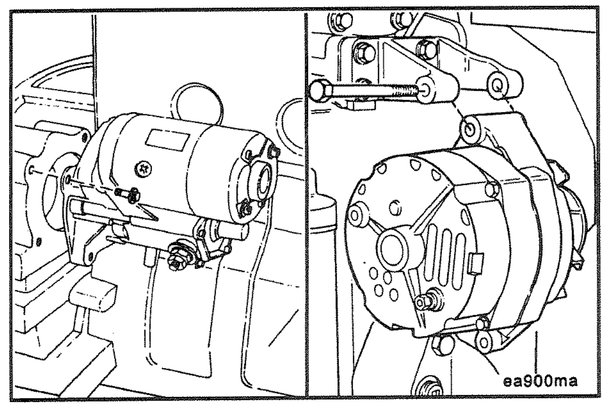
Inspect all mounting brackets for cracks or damaged bolt holes.

NOTE: Damaged engine mounts and brackets can cause engine misalignment, drive line components damage, and result in vibration complaints.



Engine - Installation (9-03)

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



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

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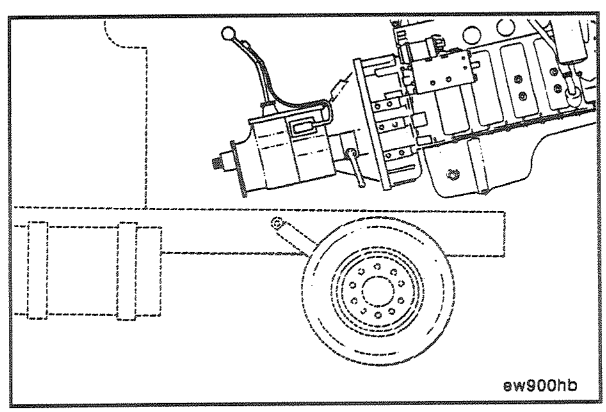
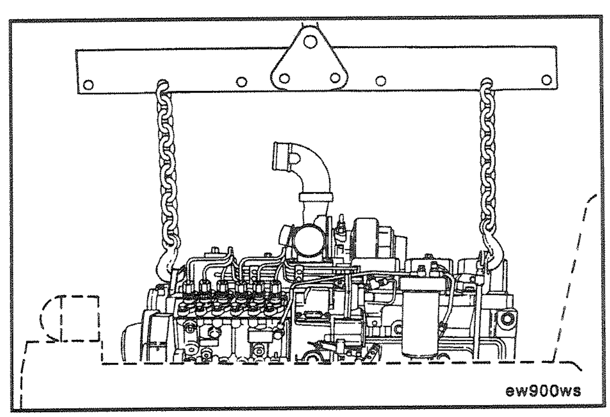
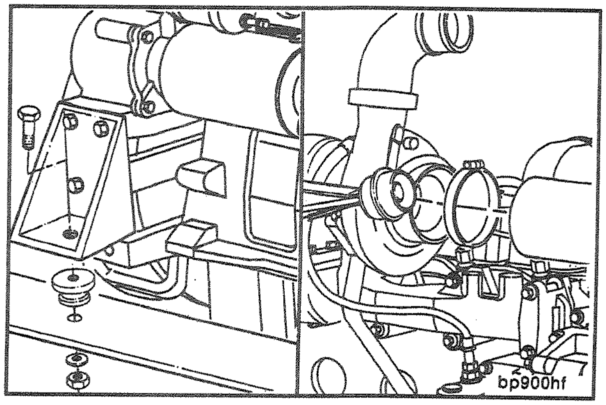


Use a properly rated hoist and engine lifting bracket, attached to the engine mounted lifting brackets to install the engine.

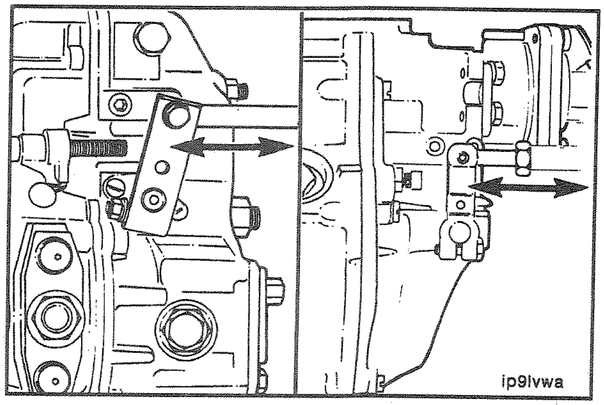




Align the engine in the chassis and tighten the engine mounting capscrews. Refer to the equipment manufacturer's torque specifications.

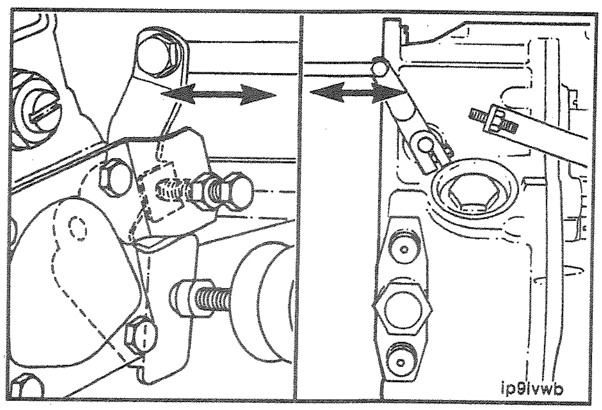
Connect all engine and chassis mounted accessories that were removed.

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

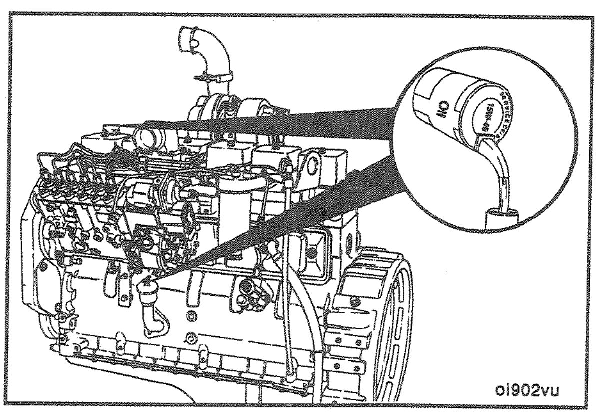


Throttle Control Lever Connection

When connecting the cable/rod to the control lever, adjust the length so the lever has stop-to-stop movement.



Adjust the length of the cable/rod to the mechanical shut down lever so there is stop-to-stop movement.



Fill the engine with clean 15W-40 lubricating oil.

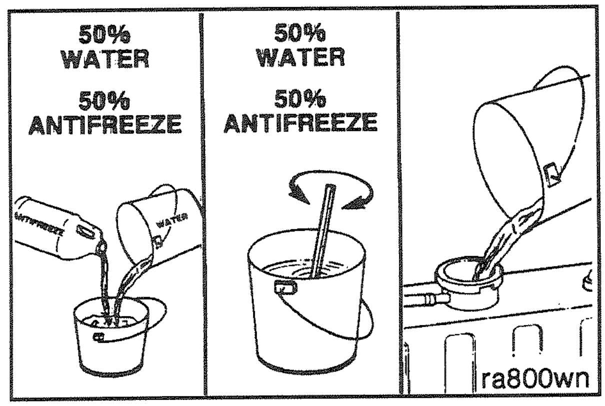
NOTE: The total oil system capacity, including lubricating oil filters is:

	Liters	U.S. Qt.
4 Cylinder	11.0	11.6
6 Cylinder	16.4	17.3
Optional 6 Cylinder	12.6	13.3
Optional 6 Cylinder (Ford)	18.9	20.0

Fill the cooling system with a premixture of 50 percent water, 50 percent ethylene glycol base antifreeze and DCA4 corrosion protection. Refer to Procedure 1-06.

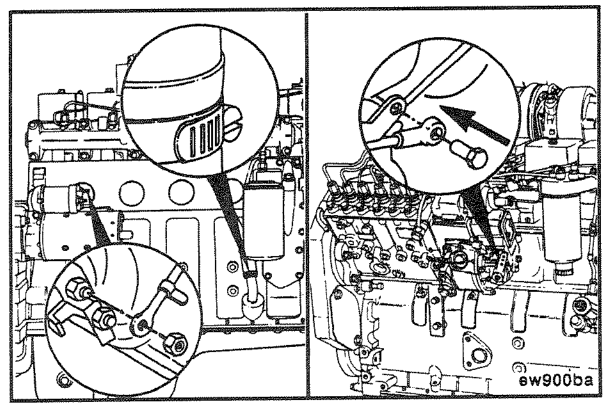
NOTE: The total coolant capacity (engine only) is:

	Liters	U.S. Qt.
4 Cylinder	7	7.4
4 Cylinder (Water Aftercooled)	9.7	10.3
6 Cylinder	10.5	11.1
6 Cylinder (Water Aftercooled)	14.5	15.3

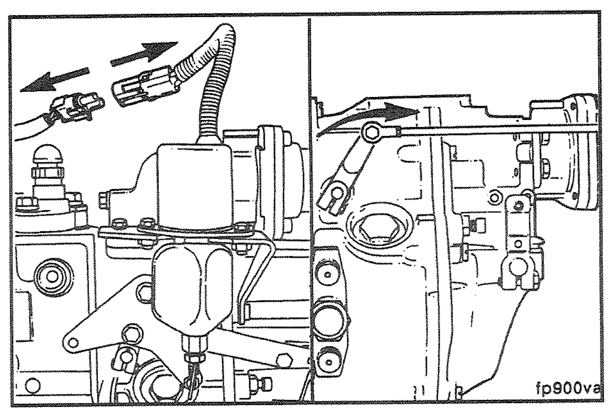


Caution: Installation of the radiator cap at this point is critical to proper purging of air trapped in the cooling system. Improper purging of air from the cooling system will result in engine damage from overheating.

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

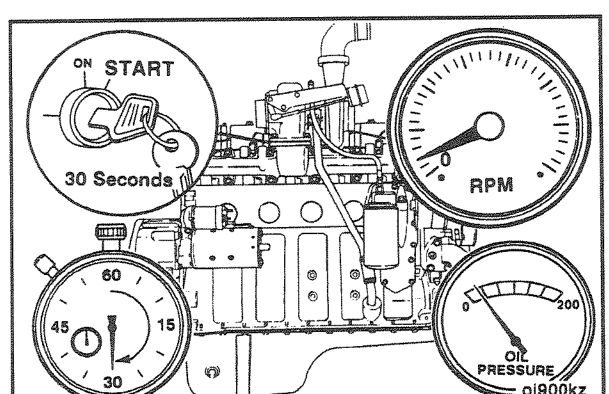


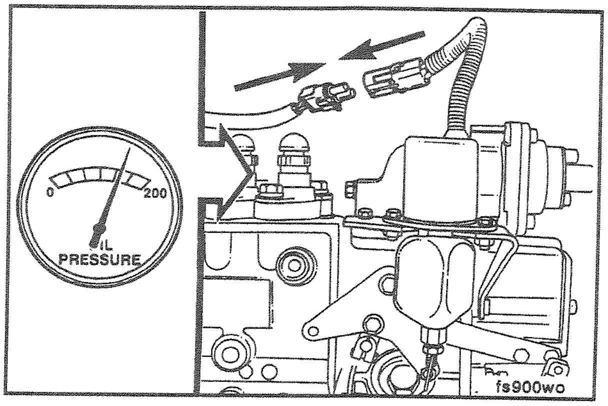
Make sure the fuel is shut off by removing the wire from the fuel solenoid or the mechanical fuel shutoff is in the "OFF" position. This is necessary to prevent the engine from starting during the lubricating oil rifle pressure charging operation.



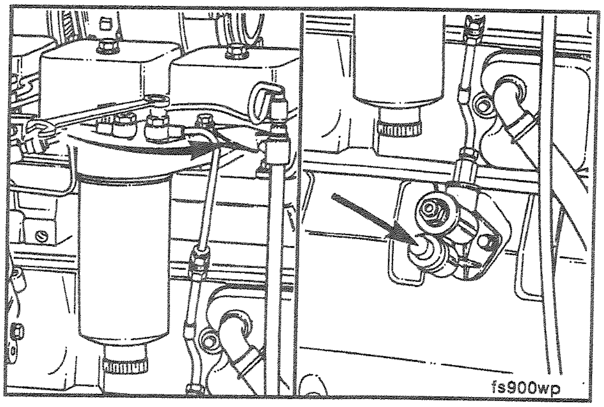
Caution: Do not engage the starting motor for more than 30 seconds. Wait 2 minutes between starter engagements to cool the starting motor.

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





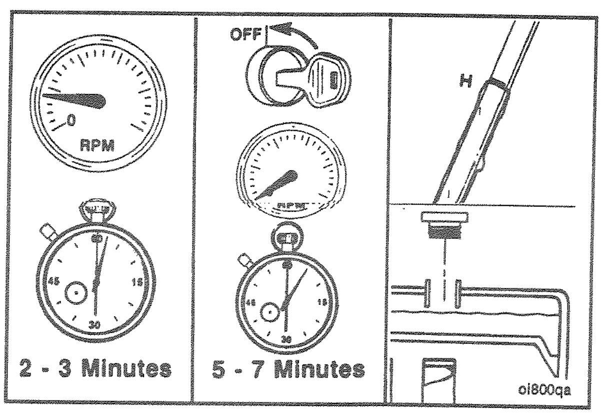
After pressure is observed, connect the wire to the fuel solenoid.



Prime the low pressure fuel system by opening the bleed screw.

Operate the plunger on the fuel transfer pump until the fuel flowing from the fitting is free of air.

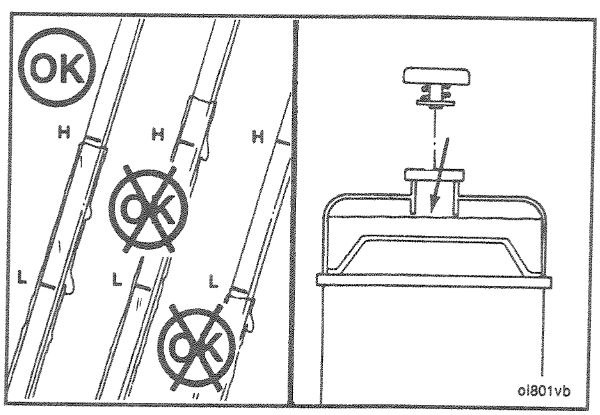
Tighten the bleed screw.



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

Warning: Do not remove the radiator cap from a hot engine. Hot steam can cause serious personal injury. The engine coolant temperature must be below 50°C [122°F].

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

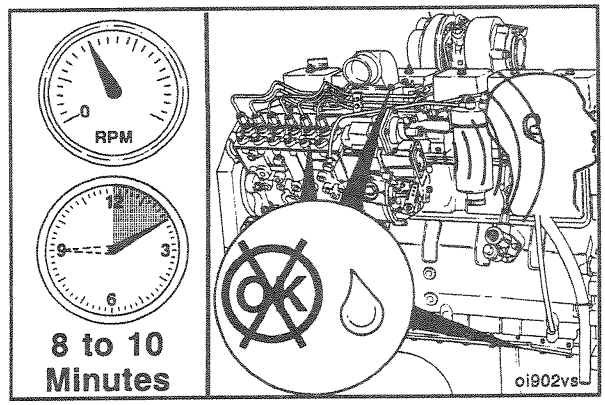


Fill the engine to the correct lubricating oil and coolant levels if necessary.

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

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

Refer to Section 8 for the Engine Run-In and Test Procedures.



NOTES

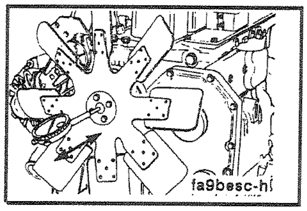
Section V - Engine Component Specifications

Section Contents

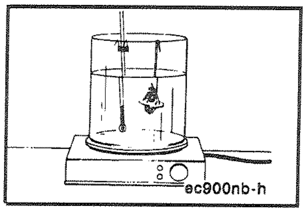
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

Component Specifications and Torque Values

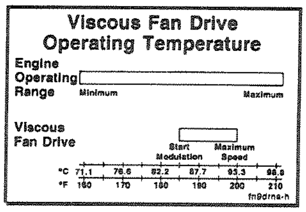
Cooling System Specifications



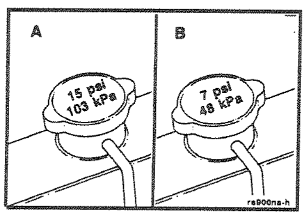
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fan Hub Shaft End Clearance		0.15 mm	MAX	0.006 in



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Thermostat Operating Temperature				
Initial Opening Temperature		80°C	MIN	176°F
		83°C	MAX	182°F
Fully Open Temperature		95°C	MAX	203°F
Maximum Opening Distance		6.6 mm	MAX	0.260 in

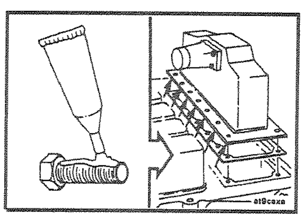


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Viscous Fan Drive Operating Temperature	---			
Start Modulation		85°C		185°F
Maximum Speed		93°C		200°F

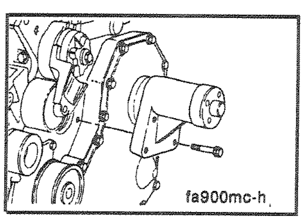


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Radiator Cap Pressure Test				
A - 104°C [220°F]		103 kPa	MIN	15 psi
B - 99°C [210°F]		48 kPa	MIN	7 psi

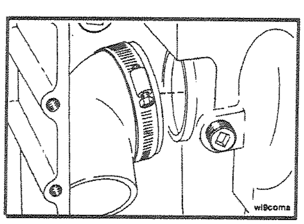
Cooling System Torque Values



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Aftercooler Mounting		24 N•m		18 ft-lb

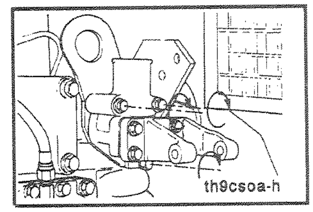


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fan Hub Pulley Mounting Capscrews		24 N•m		18 ft-lb

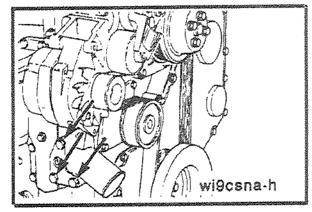


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Hose Clamps		5 N•m		40 in-lb

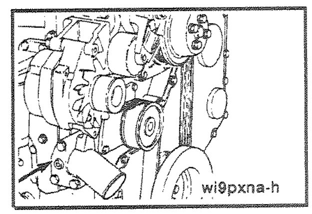
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Thermostat Housing Mounting Capscrews		24 N•m		18 ft-lb



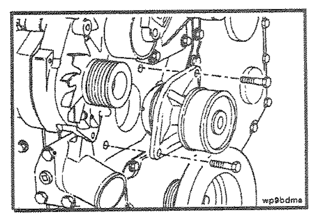
Coolant Inlet Connection		43 N•m		32 ft-lb



Water Inlet Plugs		24 N•m		18 ft-lb

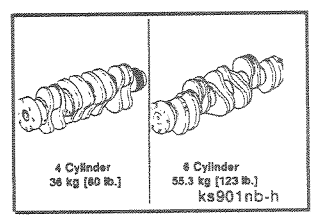


Water Pump Mounting Capscrews		24 N•m		18 ft-lb

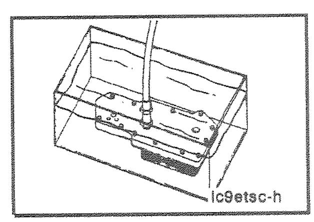


Lubricating Oil System Specifications

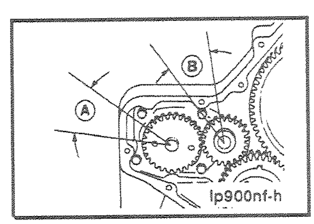
Crankshaft Weight				
4 Cylinder		36 Kg		80 lb
6 Cylinder		55 Kg		123 lb



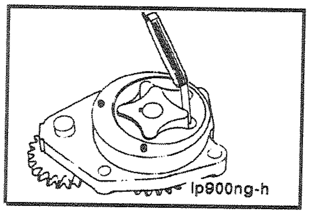
Oil Cooler Pressure Test				
Pressurize the cooler		483 kPa		70 psi
Check for leaks by submerging in water				



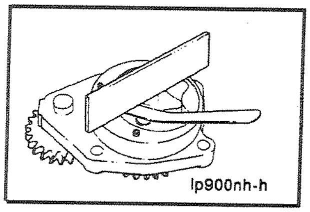
Oil Pump Gear	A			
Backlash Limits		0.076 mm	MIN	0.003 in
		0.330 mm	MAX	0.013 in
Oil Pump Idler Gear	B			
Backlash Limits		0.076 mm	MIN	0.003 in
		0.330 mm	MAX	0.013 in



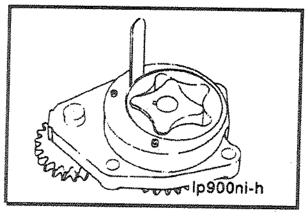
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



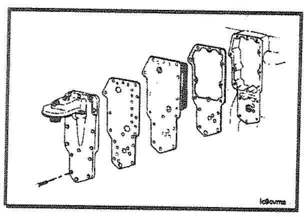
Oil Pump Tip Clearance		0.025 mm	MIN	0.001 in
		0.178 mm	MAX	0.007 in



Oil Pump Port Plate Clearance		0.127 mm	MAX	0.005 in

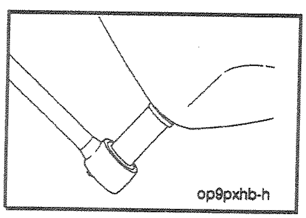


Oil Pump Body Bore Clearance		0.127 mm	MIN	0.005 in
		0.381 mm	MAX	0.015 in

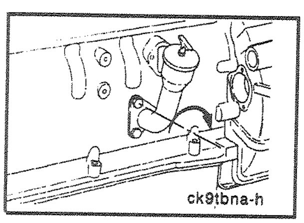


Lubricating Oil System Torque Values

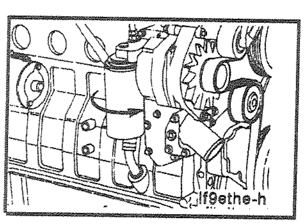
Oil Cooler Assembly		24 N•m		18 ft-lb



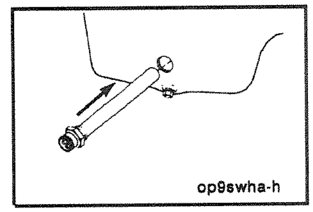
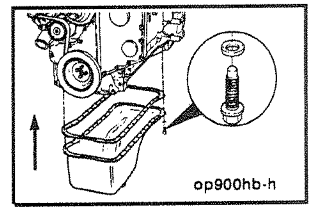
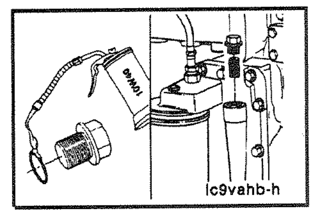
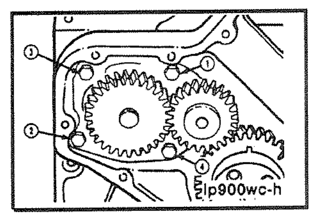
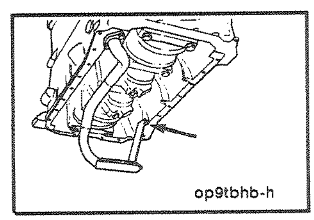
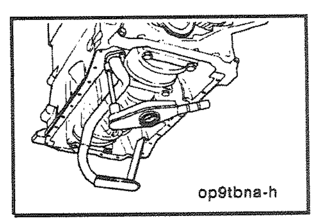
Oil Drain Plug		80 N•m		60 ft-lb



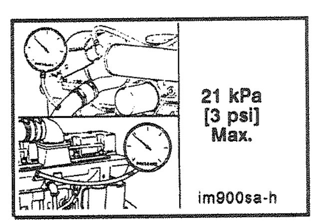
Oil Fill Tube Mounting		43 N•m		32 ft-lb

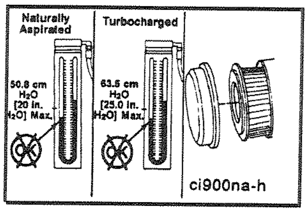


Oil Filter		3/4 turn after contact		

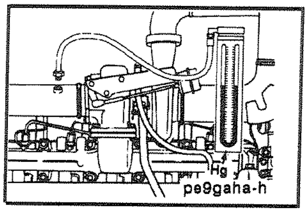
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Oil Pan Heater Plug		80 N•m		60 ft-lb	 op9swha-h
Oil Pan Mounting Capscrews		24 N•m		18 ft-lb	 op900hb-h
Oil Pressure Regulator Plug		80 N•m		60 ft-lb	 lc9vahb-h
Oil Pump Mounting Capscrews		24 N•m		18 ft-lb	 lp900wc-h
Oil Pump Suction Tube Brace 10 mm Wrench		24 N•m		18 ft-lb	 op9tbhb-h
Oil Pump Suction Tube Flange 13 mm Wrench		24 N•m		18 ft-lb	 op9tbna-h

Combustion Air System Specifications

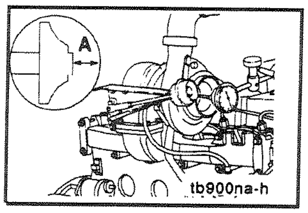
Charge Air Cooler Differential Pressure Across Cooler		21 kPa	MAX	3 psi	 21 kPa [3 psi] Max. im900sa-h



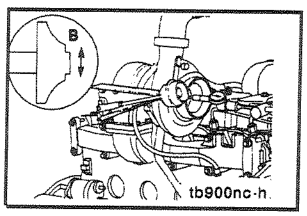
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Intake Air Restriction		65.5 cm H_2O	MAX	25.0 in H_2O



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Exhaust Gas Restriction				
Non Automotive		76.2 mm/Hg	MAX	3 in Hg
91 EPA Cert		114.3 mm/Hg	MAX	4.5 in/Hg
94 EPA Cert. with oxidation catalyst		152.6 mm/Hg	MAX	6 in/Hg

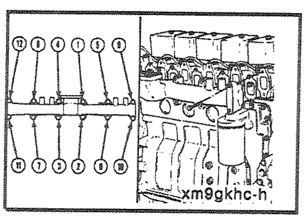


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Turbocharger Axial Clearance				
Holset	A	0.030 mm	MIN	0.012 in
		0.46 mm	MAX	0.018 in
With Engine Serial Numbers Before 840638		0.10 mm	MIN	0.004 in
		0.16 mm	MAX	0.006 in
With Engine Serial Numbers After/Including 840638		0.03 mm	MIN	0.001 in
		0.08 mm	MAX	0.003 in

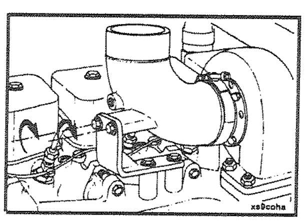


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Turbocharger Radial Clearance - Side to Side	B	0.03 mm	MIN	0.001 in
		0.08 mm	MAX	0.003 in

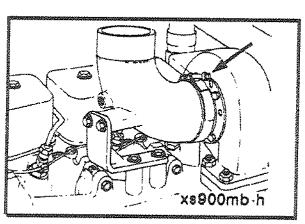
Combustion Air System Torque Values



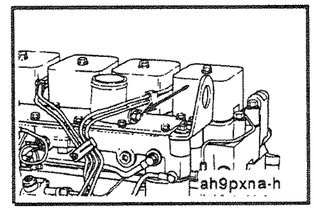
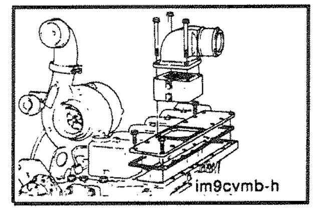
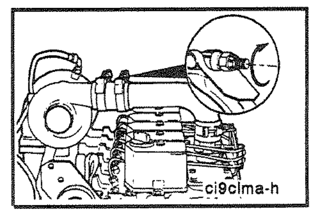
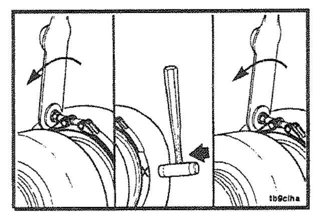
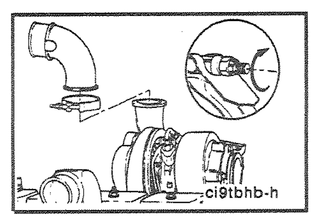
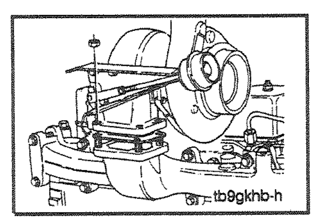
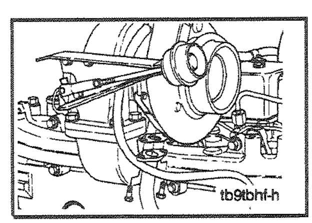
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Exhaust Manifold Torque Value and Sequence		43 N•m		32 ft-lb

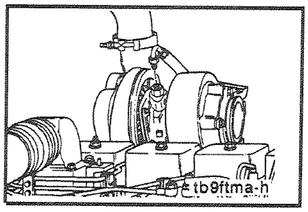
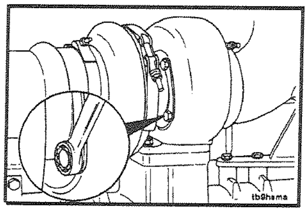


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Exhaust Outlet Pipe Bracket		43 N•m		32 ft-lb

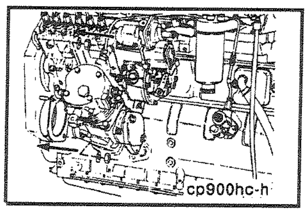
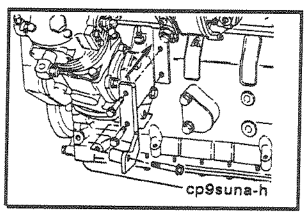
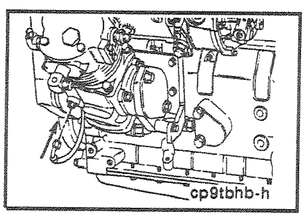
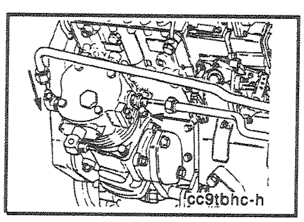


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Exhaust Outlet Pipe, V-Band		8 N•m		72 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Intake Heater Plug		125 N•m	92 ft-lb	
Intake Manifold Cover		24 N•m	18 ft-lb	
Turbocharger Air Crossover Hose Clamps		8 N•m	72 in-lb	
Turbocharger Compressor Housing Clamp		8 N•m	72 in-lb	
Turbocharger Discharge Elbow		8 N•m	75 in-lb	
Turbocharger Mounting Nut and Stud		45 N•m	33 ft-lb	
Turbocharger Oil Drain Mounting		24 N•m	18 ft-lb	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Turbocharger Oil Supply		35 N•m	26 ft-lb
	Turbocharger Turbine Housing Capscrews		20 N•m	15 ft-lb

Compressed Air System Torque Values

	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Air Compressor Mounting Nuts		77 N•m	57 ft-lb
	Air Compressor Support Capscrews		24 N•m	18 ft-lb
	Air Compressor Oil Supply Line		15 N•m	12 ft-lb
	Air Compressor Coolant Lines		24 N•m	18 ft-lb

Letter on Pump Gear	Engine Model	Injection Pump	Certification
A	4B3.9, 4BT3.9	Stanadyne	Non-Certified
A	4B3.9, 4BT3.9, 4BTA3.9	Lucas CAV DPA Pump	All Non-Certified
B	4B3.9, 4BTA3.9	Robert Bosch VE Pump	86,87 EPA All pre-88 All Non-Certified
C	6BT5.9, 6BTA5.9	Robert Bosch VE Pump	86,87 EPA All pre-88 All Non-Certified CPL [illegible]
D	6B5.9, 6BT5.9	Stanadyne	Non-Certified
D	6B5.9, 6BT5.9, 6BTA5.9	Lucas CAV DPA Pump	All Non-Certified
E	6BT5.9, 6BTA5.9	Robert Bosch VE Pump	86,87,88,89,90 CARB 88,89,90 EPA
F	4BT3.9, 4BTA3.9	Robert Bosch VE Pump	86,87,88,89,90 CARB 88,89,90 EPA
G	6BTA5.9	Lucas CAV DPA	All Fire Pump CPL 1198
H	Not Used at This Time		

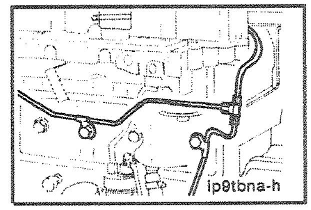
lt900ga

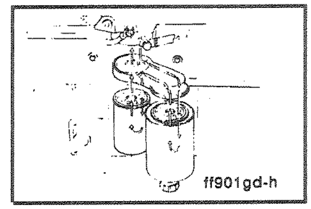
Fuel System Specifications

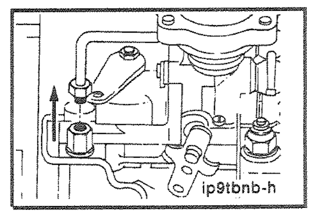
This table **must** be used to make sure of proper fuel injection pump-to-engine timing. The critical parts list (CPL) number from the engine data plate and the Control Parts List Manual, Bulletin No. 3379133-20, **must** be used to determine whether or **not** the engine is certified, and if so, what year and regulating agency (EPA or CARB).

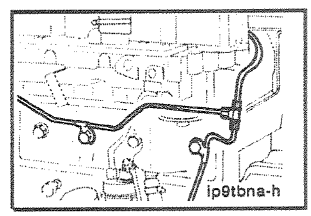
Given this information, use the table to determine which letter on the fuel injection pump drive gear is aligned with the camshaft gear.

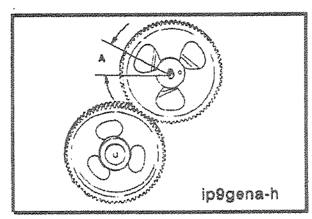
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fuel Drain Line Restriction		70 kPa	MAX	10 psi
Fuel Filter Restriction Pressure Drop Across Filter		35 kPa	MAX	5 psi
Fuel Injection Pump Fuel Inlet Pressure (Rotary Pump)		70 kPa	MAX	10 psi
Fuel Injection Pump Fuel Return Line Restriction		518 mm Hg	MAX	20.4 in Hg
Fuel Injection Pump Drive Gear Backlash Limits	A	0.076 mm 0.330 mm	MIN MAX	0.003 in 0.013 in
Fuel Transfer Pump Inlet Restriction 6B, 6BT, 6BTA		100 mm Hg	MAX	4 in Hg
Fuel Transfer Pump Outlet Pressure at High Idle Rotary Pump In-Line Pump		70 kPa 193 kPa	MAX MAX	10 psi 28 psi

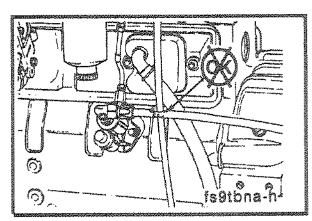


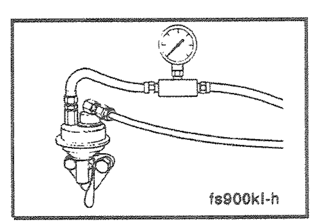




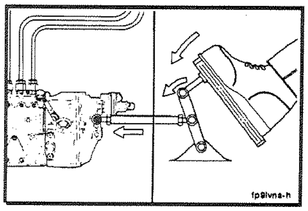






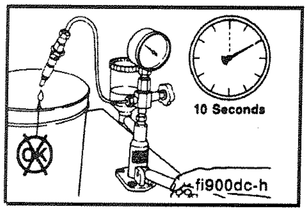


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



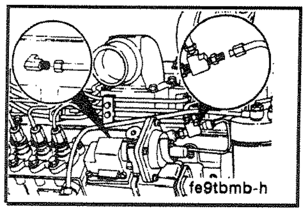
Injection Pump Throttle Lever
Breakover

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Breakover		3.18 mm	MIN	0.125 in
		6.35 mm	MAX	0.250 in



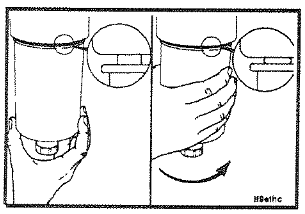
Leakage Test:

a. Open valve
b. Operate lever to hold pressure 20 bar [290 psi] below opening pressure
c. No drops are to fall from the tip within 10 seconds

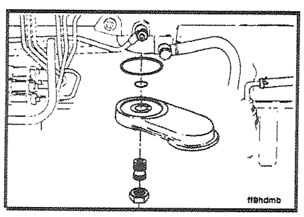


Fuel System Torque Values

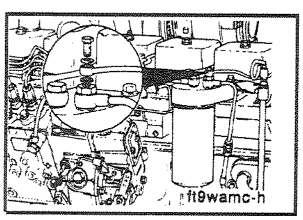
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
AFC Air Fuel Control Fitting		24 N•m		18 ft-lb



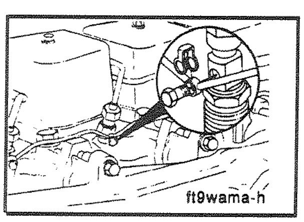
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fuel Filter		8 N•m (1/2 turn after contact)		6 ft-lb



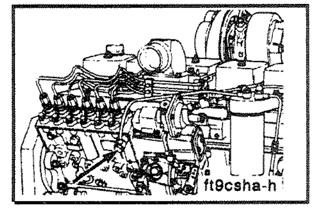
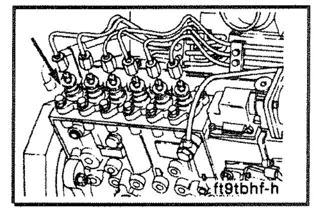
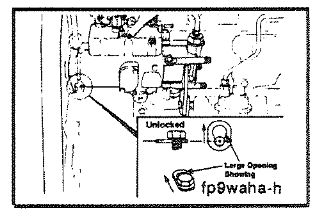
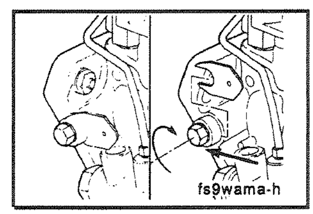
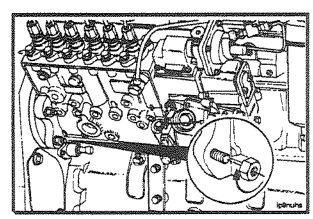
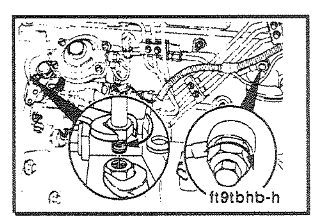
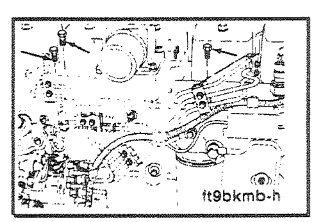
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fuel Filter Adapter Nut		32 N•m		24 ft-lb



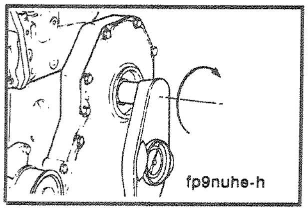
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fuel Filter Banjo Screw (In Head)		24 N•m		18 ft-lb



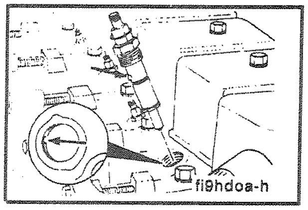
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Fuel Drain Banjo Screw (In Injector)		8 N•m		72 in-lb

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Fuel Banjo Screw (In Pump)		32 N•m	24 ft-lb	
High Pressure Fuel Line Fittings		30 N•m	22 ft-lb	
Fuel Injection Pump Lock (CAV)		7 N•m	60 in-lb	
Fuel Injection Pump Unlock (CAV)		20 N•m	15 ft-lb	
Fuel Injection Pump Lock (Bosch Rotary)		30 N•m	22 ft-lb	
Fuel Injection Pump Unlock (Bosch Rotary)		13 N•m	10 ft-lb	
Fuel Injection Pump Mounting Nuts				
Bosch		24 N•m	18 ft-lb	
Nippendenso		43 N•m	32 ft-lb	
Lucas, CAV		30 N•m	22 ft-lb	
Fuel Injection Pump Fuel Supply		32 N•m	24 ft-lb	
High Pressure Fuel Support		6 N•m	48 in-lb	

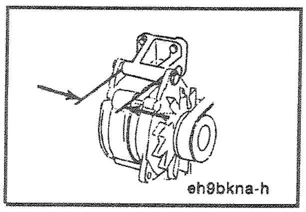
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Injection Pump Drive Gear Nut				
Bosch, CAV (Rotary) and Stanadyne		65 N•m		48 ft-lb
Nippondenso		123 N•m		92 ft-lb
Bosch In-Line		165 N•m		122 ft-lb

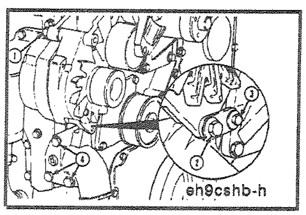


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Injector Retaining Nut		60 N•m		44 ft-lb



Electrical System Specifications

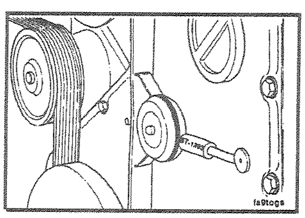
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Alternator Mounting Bracket Dimension				
Delco 10/15SI		55.72 mm		2 3/16 in
Motorola 100 Amp		81 mm		3 3/16 in
Delco 20/27SI		98 mm		3 7/8 in
Lucas		78 mm		3 in



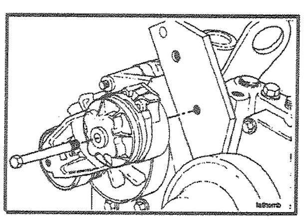
Electrical System Torque Values

Alternator Assembly Torque Sequence

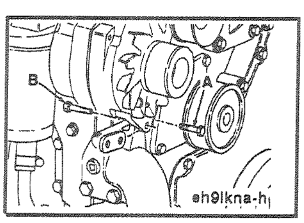
1. Alternator-to-alternator bracket capscrew.
2. Lower brace-to-alternator capscrew.
3. Alternator-to-water inlet capscrew.
4. Water inlet-to-block capscrews.



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Alternator Belt				
New Belt Tension		360 N	MIN	80 lbf
Used Belt Tension		490 N	MAX	100 lbf

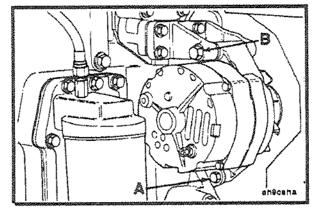


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Belt Tensioner Capscrew		43 N•m		32 ft-lb

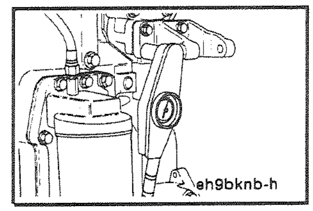


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Alternator Link				
8 mm Capscrew	A	24 N•m		18 ft-lb
10 mm Capscrew	B	43 N•m		32 ft-lb

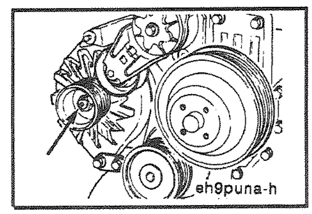
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Alternator Mounting Bolt	B		
10 to 15SI		43 N•m	32 ft-lb
20SI, 27SI, 29SI		80 N•m	59 ft-lb



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Alternator Bracket Mounting Capscrews 8 mm		24 N•m	18 ft-lb



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Alternator Pulley		80 N•m	59 ft-lb



Batteries

Specific Gravity at 27°C [80°F]	State of Charge
1.260 to 1280	100 percent
1.230 to 1250	75 percent
1.200 to 1220	50 percent
1.170 to 1190	25 percent
1.110 to 1130	Discharged

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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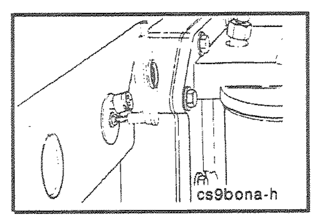
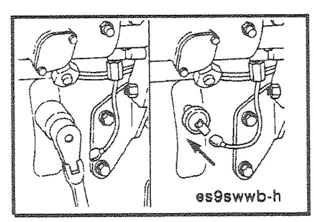
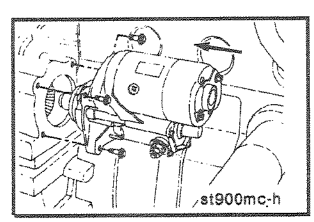
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Coolant Heater		12 N•m	108 in-lb



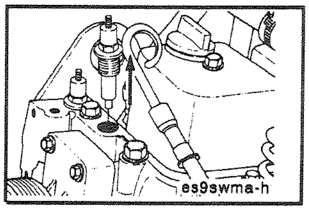
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Oil Pressure Switch			
Installation - Cast Iron		16 N•m	12 ft-lb
Installation - Aluminum		10 N•m	84 in-lb



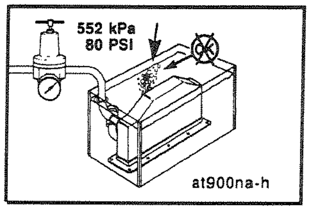
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Starting Motor Mounting Capscrews		43 N•m	32 ft-lb



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

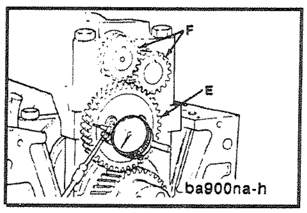


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Temperature Sensor				
Installation - Cast Iron		50 N•m		37 ft-lb
Installation - Aluminum		30 N•m		22 ft-lb

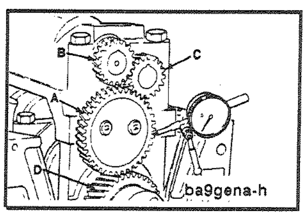


Base Engine Specifications

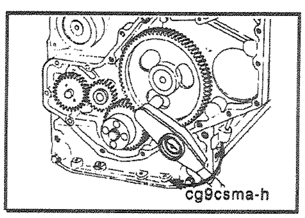
Aftercooler - Inspection
Inspect the housing and core for damage.
Check the core for leaks:
- Plug the bottom inlet tube
- Pressurize the core to 483 kPa [70 psi] and submerge in a container of water.



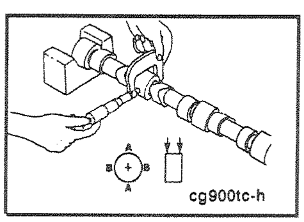
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Balancer End Play Limits	D	0.130 mm	MIN	0.005 in
		0.630 mm	MAX	0.025 in
	E	0.075 mm	MIN	0.003 in
		0.175 mm	MAX	0.007 in



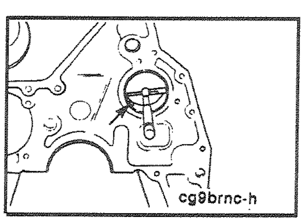
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Balancer Idler Gear Backlash	A to D	0.088 mm	MIN	0.003 in
		0.420 mm	MAX	0.017 in
	B to C	0.153 mm	MIN	0.006 in
		0.355 mm	MAX	0.014 in
	A to C	0.088 mm	MIN	0.003 in
		0.420 mm	MAX	0.017 in



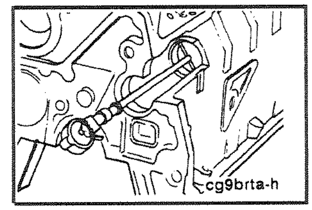
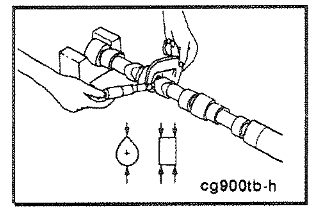
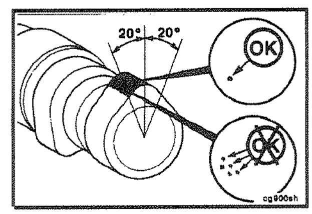
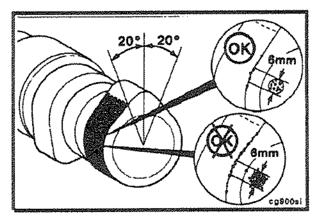
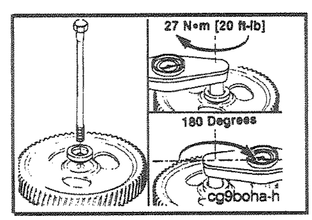
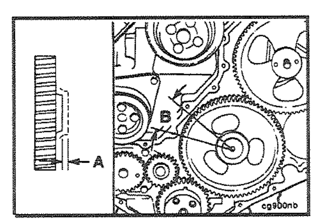
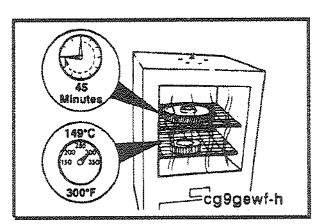
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Cam Thrust Plate		24 N•m		18 ft-lb

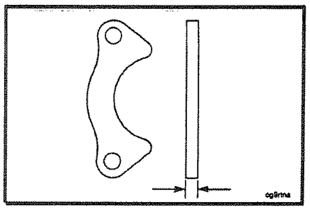
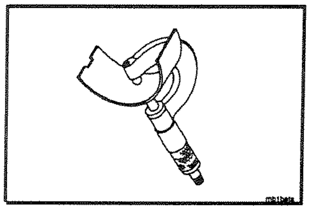
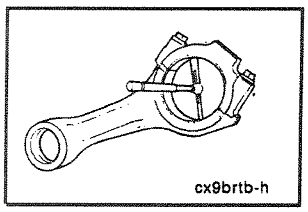
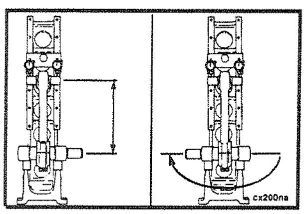
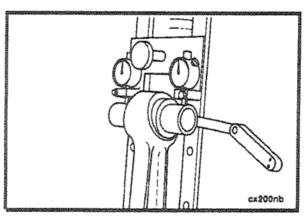
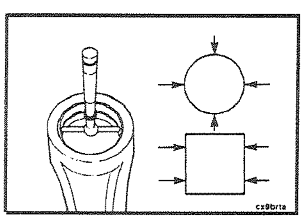
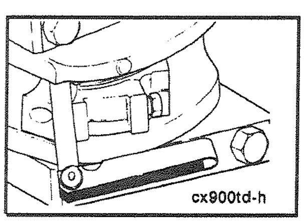


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Camshaft Bearing Journal Diameter		53.962 mm	MIN	2.1245 in
		54.013 mm	MAX	2.1265 in

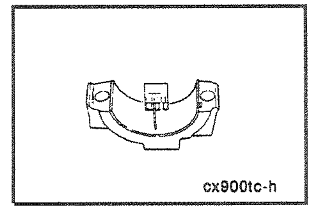


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Camshaft Bore Diameter - Cylinder No. 1				
With Bushing Installed		54.107 mm	MIN	2.1302 in
		54.146 mm	MAX	2.1317 in

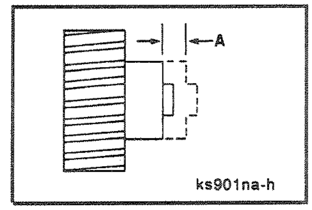
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Camshaft Bore Diameter All Journals Except Cylinder No. 1		54.164 mm	MAX	2.1324 in	
Camshaft Diameter at Peak of Lobe Intake		47.040 mm 47.492 mm	MIN MAX	1.852 in 1.870 in	
Exhaust		46.770 mm 47.222 mm	MIN MAX	1.841 in 1.859 in	
Lift Pump		35.50 mm 36.26 mm	MIN MAX	1.398 in 1.428 in	
Camshaft Deterioration Gear Edge (+ or -20 degrees nose of cam lobe)		2 mm	MAX	0.079 in	
Outside nose (+ or -20 degrees edge deterioration)		6 mm	MAX	0.236 in	
Camshaft Capscrew Torque	Step 1 Step 2	27 N•m +180°		20 ft-lb	
Camshaft End Play	A	0.12 mm 0.47 mm	MIN MAX	0.005 in 0.018 in	
Camshaft Gear Backlash Limits	B	0.076 mm 0.330 mm	MIN MAX	0.003 in 0.013 in	
Camshaft Gear Temperature (45 minutes)		148°C	MAX	300°F	

	Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
	**Camshaft Thrust Plate Thickness**		9.340 mm 9.580 mm	MIN MAX	0.368 in 0.377 in
	**Connecting Rod Bearing Thickness (Standard)**		1.955 mm 1.968 mm	MIN MAX	0.0769 in 0.0775 in
	**Connecting Rod Crankshaft Bore I.D.** (Without Bearings)		72.987 73.013	MIN MAX	2.8735 in 2.8745 in
	**Connecting Rod Length (Center to Center)**		191.975 mm 192.025 mm	MIN MAX	7.5581 in 7.5600 in
	Connecting Rod Alignment • With Bushing		0.150 mm	MAX	0.006 in
	**Connecting Rod Twist** • With Bushing		0.150 mm	MAX	0.006 in
	**Connecting Rod Pin Bore Diameter I.D.** (with bushing installed)		40.019 mm 40.042 mm	MIN MAX	1.5755 in 1.5764 in
	**Connecting Rod Side Clearance Limits**		0.100 mm 0.330 mm	MIN MAX	0.004 in 0.013 in

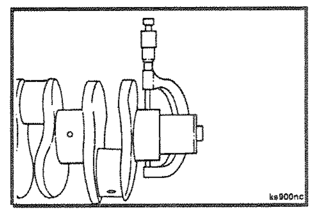
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft Bearing Clearance				
With plastigauge during engine assembly				
Clearance		0.114 mm	MAX	0.0045 in



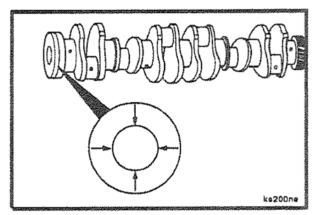
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft End Clearance	A	0.102 mm	MIN	0.004 in
		0.432 mm	MAX	0.017 in



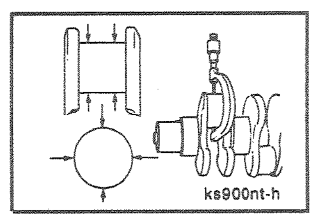
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft Main Bearing Journal O.D. Diameter		82.962 mm	MIN	3.2662 in
		83.013 mm	MAX	3.2682 in
Out of roundness		0.050 mm	MAX	0.002 in
Taper		0.013 mm	MAX	0.0005 in
Bearing clearance		0.119 mm	MAX	0.0047 in



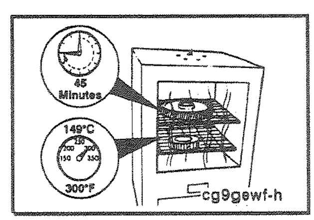
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft Rear Oil Seal Flange O.D.		129.975 mm	MIN	5.1171 in
		130.025 mm	MAX	5.1191 in



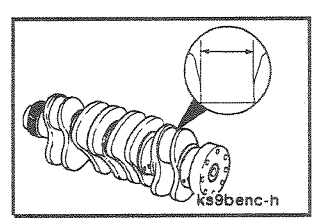
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft Rod Journal Mean Diameter		68.962 mm	MIN	2.7150 in
		69.013 mm	MAX	2.7170 in
Out of Roundness		0.050 mm	MAX	0.002 in
Taper		0.013 mm	MAX	0.0005 in
Clearance		0.114 mm	MAX	0.0045 in



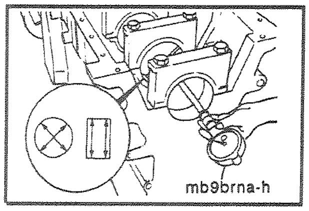
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft Gear Temperature (45 minutes)		148°C	MAX	300°F



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Crankshaft Thrust Bearing Width (Standard)		37.305 mm	MIN	1.4687 in
		37.355 mm	MAX	1.4707 in

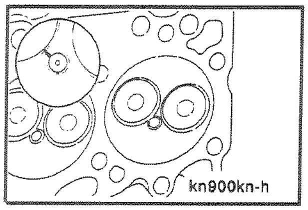


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

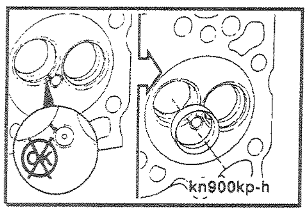


Main Bearing Bore Diameter (Bearings Installed)
Measure the crankshaft bore with the bearings installed and the capscrews tightened.
Record the smallest diameter.

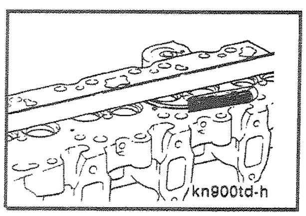
Capscrew torque		176 N•m		130 ft-lb
Smallest diameter		83.106 mm		3.272 in



Cylinder Head Cracks - Reuse Guidelines
These guidelines apply only to cracks extending from the injector bore to the intake valve seats. Replace cylinder heads which exhibit valve bridge cracks in any other location.

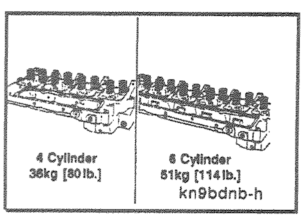


If the crack extends into or through the valve seat, the head **must** be repaired by installing a valve seat inset per the Alternative Repair Manual, Bulletin No. 3810234.



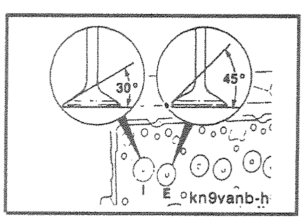
Cylinder Head Flatness

End to End				
4 cylinder		0.203 mm	MAX	0.008 in
6 cylinder		0.305 mm	MAX	0.012 in
Side to Side				
4 cylinder and 6 cylinder		0.076 mm	MAX	0.003 in



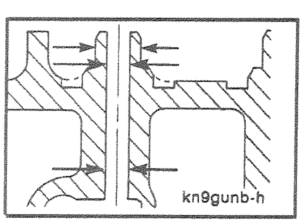
Cylinder Head Weight

4 Cylinder		36 Kg		80 lb
6 Cylinder		51 Kg		114 lb



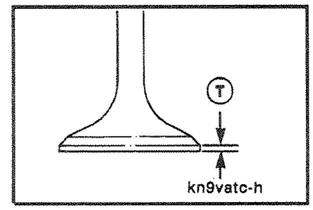
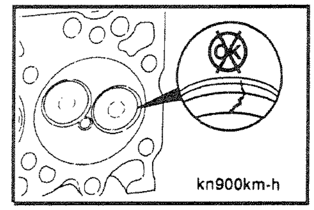
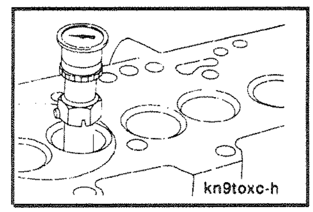
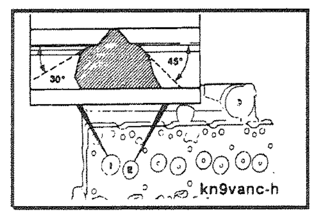
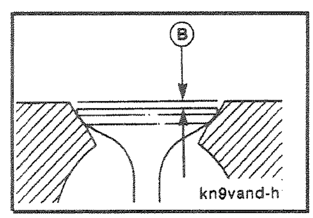
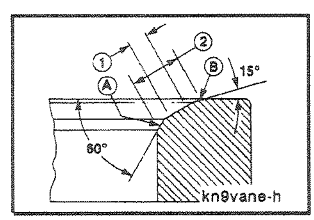
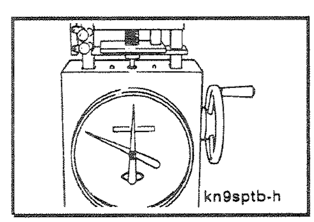
Valve Grinding Angle

Intake: 30 degrees
Exhaust: 45 degrees

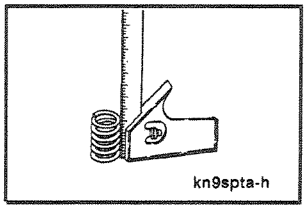


Valve Guide Bore Diameter

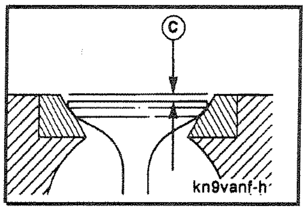
		8.019 mm	MIN	0.3157 in
		8.090 mm	MAX	0.3185 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Valve Head Rim Thickness	T	0.79 mm	MIN	0.031 in	
Valve Seats Grinding Cleanup Depth		0.254 mm	MAX	0.010 in	
Valve Seat-to-Valve Guide Concentricity 360 Degrees		0.05 mm	MAX	0.002 in	
Valve Seat Grinding Angle		Intake: 30 Degrees Exhaust: 45 Degrees			
Valve Seat Grinding Depth Seat Grinding Depth is the Difference in Dimension "B" Before and After Grinding	B	0.254 mm	MAX	0.010 in	
Valve Seat Grinding Width Grind Area (A) with a 60 degree stone, (B) with a 15 degree stone	1 2	1.5 mm 2.0 mm	MIN MAX	0.060 in 0.080 in	
Valve Spring Compression Height 49.25 mm [1.94 in]		289.13 N 321.16 N	MIN MAX	65.0 lbf 72.2 lbf	

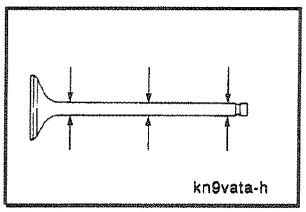
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



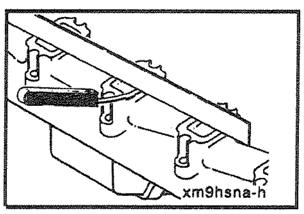
Valve Spring Measurement				
Free Length		55.63 mm	MIN	2.190 in
Inclination:		1.0 mm	MAX	0.039 in



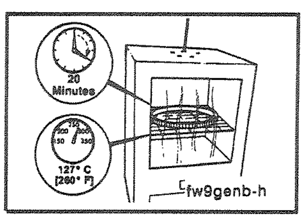
Valve Depth	C	0.99 mm	MIN	0.039 in
		1.52 mm	MAX	0.060 in



Valve Inspection				
Valve Stem Diameter		7.94 mm	MIN	0.313 in
		7.98 mm	MAX	0.314 in

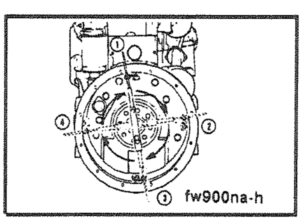


Exhaust Manifold Flatness		0.10 mm	MAX	0.004 in

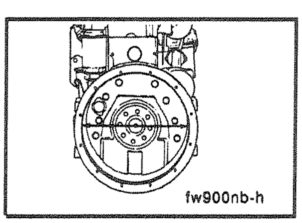


Ring Gear Replacement

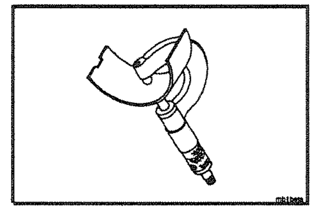
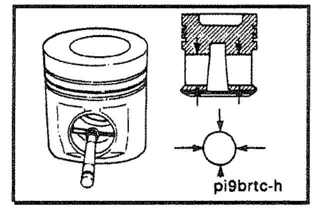
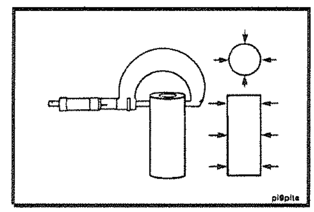
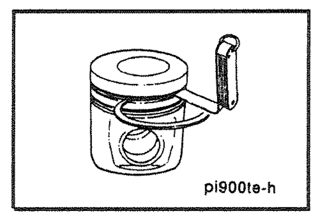
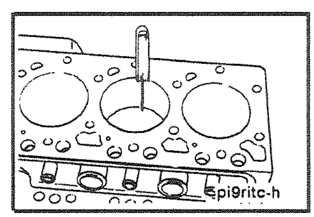
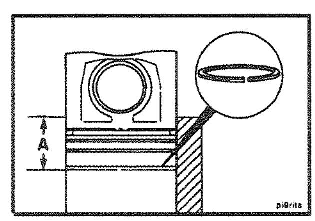
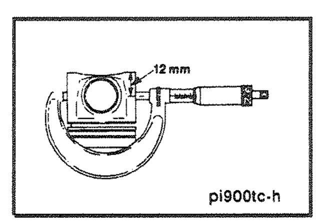
Heat the new ring gear for 20 minutes in an oven preheated to 127°C [260°F].



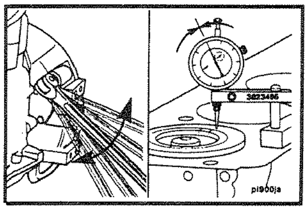
Flywheel Bore Alignment T.I.R.	SAE No.			
	1	0.020 mm	MAX	0.008 in
	2	0.020 mm	MAX	0.008 in
	3	0.020 mm	MAX	0.008 in



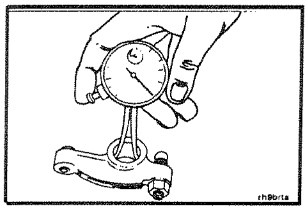
Flywheel Bore Runout T.I.R.		0.127 mm	MAX	0.005 in

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Main Bearing Thickness (Standard)		2.456 mm	MIN	0.0967 in	
		2.464 mm	MAX	0.0970 in	
Piston Pin Bore Diameter		40.006 mm	MIN	1.5750 in	
		40.025 mm	MAX	1.5758 in	
Piston Pin Diameter		39.990 mm	MIN	1.5744 in	
		40.003 mm	MAX	1.5749 in	
Piston Ring Clearance (In Ring Groove)					
Top (Turbocharged)		No Check Needed			
(Naturally Aspirated)		0.075 mm	MIN	0.003 in	
		0.150 mm	MAX	0.0059 in	
Intermediate		0.075 mm	MIN	0.003 in	
		0.150 mm	MAX	0.0059 in	
Oil Control		0.040 mm	MIN	0.0016 in	
		0.130 mm	MAX	0.0051 in	
Piston Ring Gap (Feeler Gauge)					
Top (Turbocharged)		0.40 mm	MIN	0.016 in	
		0.70 mm	MAX	0.028 in	
Top (Naturally Aspirated)		0.25 mm	MIN	0.010 in	
		0.55 mm	MAX	0.022 in	
Intermediate		0.25 mm	MIN	0.010 in	
		0.55 mm	MAX	0.022 in	
Oil Control		0.25 mm	MIN	0.010 in	
		0.55 mm	MAX	0.022 in	
Piston Ring Position	A	89 mm		3.5 in	
Piston Skirt O.D. Diameter		101.823 mm	MIN	4.0088 in	
		101.887 mm	MAX	4.0107 in	

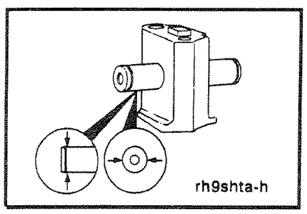
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.



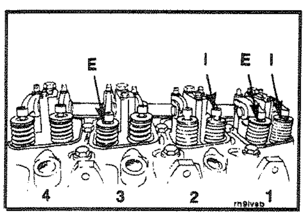
Piston Protrusion		0.609 mm	MIN	0.024 in
		0.711 mm	MAX	0.028 in



Rocker Lever Bore Diameter		19.000 mm	MIN	0.7480 in
		19.051 mm	MAX	0.7500 in

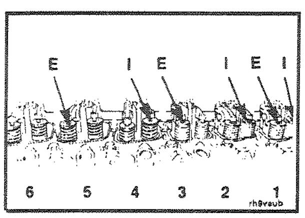


Rocker Lever Pedestal Shaft Diameter		18.938 mm	MIN	0.7456 in
		18.975 mm	MAX	0.7470 in

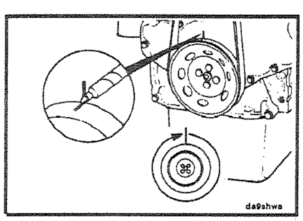


Valve Adjustment Procedure
With Cylinder No. 1 at TDC compression stroke (timing pin will engage)

Step A - Four Cylinder

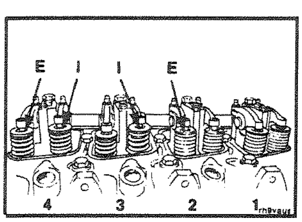


Step A - Six Cylinder



Perform **Step B** of the valve set procedure with Cylinder No. 1 at TDC plus 360 degrees (timing pin will **not** engage).

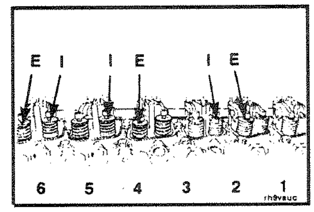
Mark the crankshaft and front cover. Rotate the crankshaft one full turn.



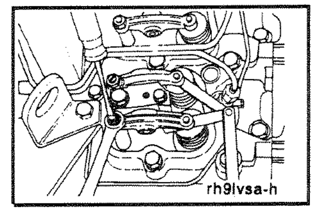
Step B - Four Cylinder

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.

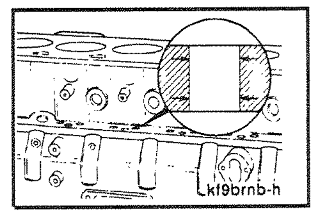
Step B - Six Cylinder



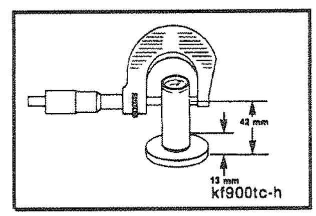
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Valve Stem to Rocker Lever Clearance				
Intake		0.25 mm		0.010 in
Exhaust		0.51 mm		0.020 in



Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Valve Tappet Bore Diameter		16.000 mm	MIN	0.630 in
		16.055 mm	MAX	0.632 in

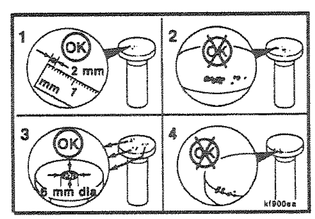


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Valve Tappet Stem Diameter		15.94 mm	MIN	0.627 in
		15.98 mm	MAX	0.629 in

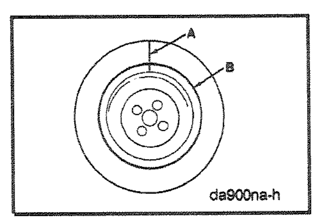


Valve Tappet Reuse Guidelines
Pit marks on the tappet face are acceptable.
The following criteria defines the size of the pits allowed.

1. A single pit cannot be greater than 2 mm [0.078 in].
2. Interconnection of pits is not allowed.
3. Total pits when added together are not to exceed 6 mm [0.236 in] diameter or a total of 4 percent of the tappet face.
4. No pitting is allowable on the edges of the wear face of the tappet.

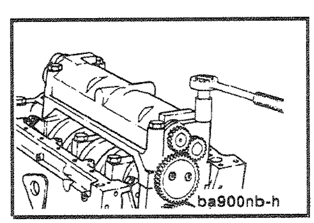


Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Vibration Damper				
Index line out of alignment	A	1.59 mm	MAX	1/16 in
Missing rubber member chucks	B	3.18 mm	MAX	1/8 in

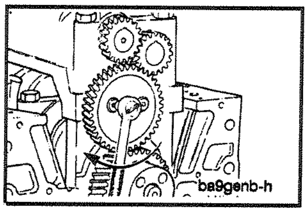


Base Engine Torque Values

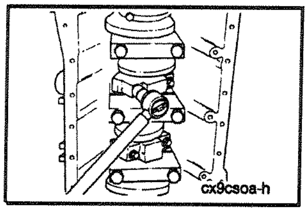
Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.
Balancer				
Torque Value and Sequence	1	50 N•m		36 ft-lb
	2	80 N•m		58 ft-lb
	3	175 N•m		129 ft-lb



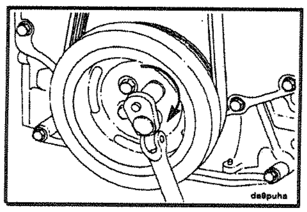
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.



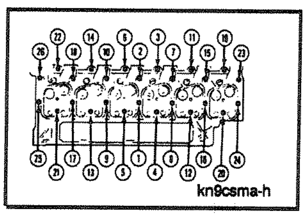
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Balancer Idler Gear		43 N•m	32 ft-lb



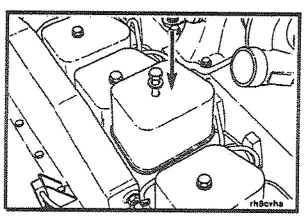
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Connecting Rod	Step 1	35 N•m	26 ft-lb
	Step 2	70 N•m	52 ft-lb
	Step 3	100 N•m	74 ft-lb



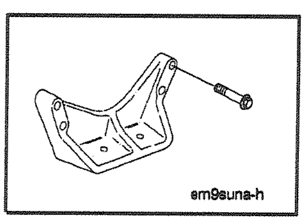
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Crankshaft Damper and Pulley		125 N•m	92 ft-lb



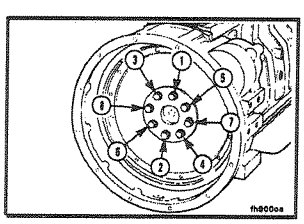
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Cylinder Head Mounting Capscrews	Step 1	90 N•m (All capscrews)	66 ft-lb
	Step 2 Recheck to	90 N•m (All capscrews)	66 ft-lb
	Step 3	120 N•m (Long capscrews only)	90 ft-lb
	Step 4 Recheck to	120 N•m (Long capscrews only)	90 ft-lb
	Step 5	+90 degrees (All capscrews)	



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Valve Cover		24 N•m	18 ft-lb

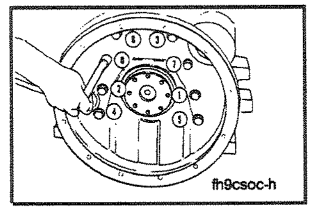


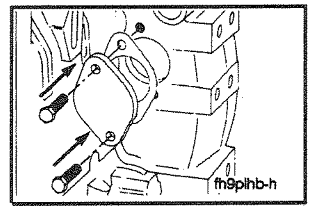
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Front Engine Support Mounting		77 N•m	57 ft-lb

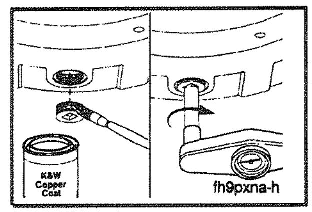


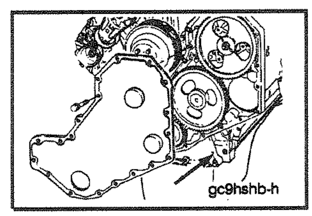
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Flywheel		137 N•m	101 ft-lb

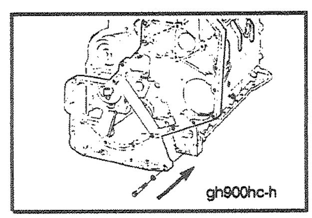
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
Flywheel Housing			
Aluminum		60 N•m	44 ft-lb
Cast Iron		77 N•m	57 ft-lb
Flywheel Housing Cover		24 N•m	18 ft-lb
Flywheel Housing Plug		36 N•m	27 ft-lb
Gear Cover		24 N•m	18 ft-lb
Gear Housing		24 N•m	18 ft-lb
Lifting Bracket (Rear)		77 N•m	57 ft-lb
Main Bearing Capscrew			
Torque and Sequence	Step 1	60 N•m	44 ft-lb
	Step 2	119 N•m	88 ft-lb
	Step 3	176 N•m	129 ft-lb

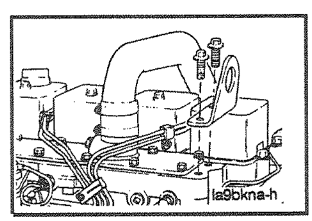


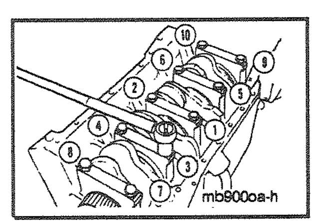


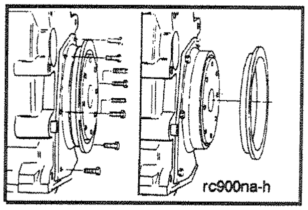
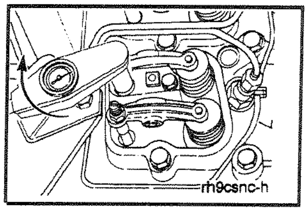










	Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
	Rear Seal Cover Mounting		9 N•m	48 in-lb
	Rocker Support Capscrews		24 N•m	18 ft-lb

Drive Belt Tension

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
.380 in.	3822524		620	140	270 to 490	60 to 110
.440 in.	3822524		620	140	270 to 490	60 to 110
1/2 in.	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in.	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in.	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in.	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240

* A belt is considered used if it has been in service for ten minutes or longer.
* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

FRACTION, DECIMAL, MILLIMETER CONVERSIONS

8 THS.	16 THS.	32 NDS.	64 THS.	INCHES	MM	8 THS.	16 THS.	32 NDS.	64 THS.	INCHES	MM
			1	0.0156	0.397				33	0.5156	13.097
		1		0.0313	0.794			17		0.5313	13.494
			3	0.0469	1.191				35	0.5469	13.891
	1			0.0625	1.588		9			0.5625	14.288
			5	0.0781	1.984				37	0.5781	14.684
		3		0.0938	2.381			19		0.5938	15.081
			7	0.1094	2.778				39	0.6094	15.478
1				0.1250	3.175	5				0.6250	15.875
			9	0.1406	3.572				41	0.6406	16.272
		5		0.1563	3.969			21		0.6563	16.669
			11	0.1719	4.366				43	0.6719	17.066
	3			0.1875	4.763		11			0.6875	17.463
			13	0.2031	5.159				45	0.7031	17.859
		7		0.2188	5.556			23		0.7188	18.256
			15	0.2344	5.953				47	0.7344	18.653
1/4				0.2500	6.350	3/4				0.7500	19.050
			17	0.2656	6.747				49	0.7656	19.447
		9		0.2813	7.144			25		0.7813	19.844
			19	0.2969	7.541				51	0.7969	20.241
	5			0.3125	7.938		13			0.8125	20.638
			21	0.3281	8.334				53	0.8281	21.034
		11		0.3438	8.731			27		0.8438	21.431
			23	0.3594	9.128				55	0.8594	21.828
3				0.3750	9.525	7				0.8750	22.225
			25	0.3906	9.922				57	0.8906	22.622
		13		0.4063	10.319			29		0.9063	23.019
			27	0.4219	10.716				59	0.9219	23.416
	7			0.4375	11.113		15			0.9375	23.813
			29	0.4531	11.509				61	0.9531	24.209
		15		0.4688	11.906			31		0.9688	24.606
			31	0.4844	12.303				63	0.9844	25.003
1/2				0.5000	12.700	1 IN.				1.0000	25.400

CONVERSION FACTOR: 1 INCH = 25.4MM

Weight and Measures - Conversion Factors

QUANTITY	U.S. CUSTOMARY		METRIC		FROM U.S. CUSTOMARY TO METRIC MULTIPLY BY	FROM METRIC TO U.S. CUSTOMARY MULTIPLY BY
	Unit Name	Abbr.	Unit Name	Abbr.		
Area	sq. inch	in^2	sq. millimeters	mm^2	645.16	0.001550
			sq. centimeters	cm^2	6.452	0.155
	sq. foot	ft^2	sq. meter	m^2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kw-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.3527	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kw	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H_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

Newton-Meter to Foot-Pound Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	8.850756 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
1	0.737562 ft-lb	90	66	190	140
12	9	95	70	195	144
14	10	100	74	200	148
15	11	105	77	205	151
16	12	110	81	210	155
18	13	115	85	215	159
20	15	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184

NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.

Capscrew Markings and Torque Values

Caution: When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:

Metric - M8-1.25 X 25

M8	1.25	25
Major Thread Diameter in Millimeters	Distance Between Threads in Millimeters	Length in Millimeters

U.S. Customary [5/16 X 18 X 1-1/2]

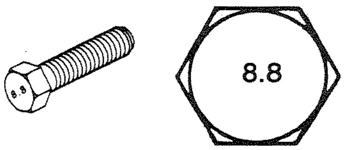
5/16	18	1-1/2
Major Thread Diameter in Inches	Number Threads per Inch	Length in Inches

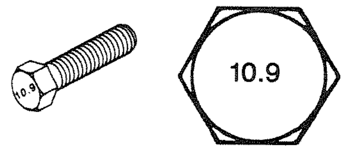
NOTES:

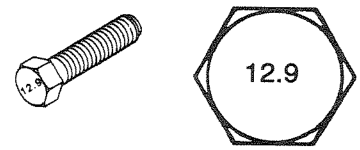
1. **Always** use the torque values listed in the following tables when specific torque values are **not** available.
2. Do **not** use the torque values in place of those specified in other sections of this manual.
3. The torque values in the table are based on the use of lubricated threads.
4. When the ft-lb value is less than 10, give consideration to converting the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values - Metric

Commercial Steel Class	8.8	10.9	12.9
Capscrew Head Markings			





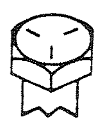


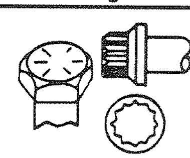
Body Size	Torque (8.8)				Torque (10.9)				Torque (12.9)			
Diam.	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
6	9	5	7	4	12	9	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7
8	25	18	18	14	33	25	18	14	40	29	18	14
10	45	33	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 Body Size	Capscrew Torque - Grade 5 Capscrew				Capscrew Torque - Grade 8 Capscrew			
	Cast Iron		Aluminum		Cast Iron		Aluminum	
	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1/4 - 20	9	7	8	6	15	11	8	6
- 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

Tap-Drill Chart - U.S. Customary & Metric

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

Tap Size		Drill Size
60%	75%	
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill Size
60%	75%	
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill Size
60%	75%	
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
		Z
M12x1.75	M12x1.5	10.50mm
	1/2-13	27/64
M12x1.5	M12x1.25	10.75mm
M12x1.25		11.00mm
1/2-13		7/16
1/4-18NPT		
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size		Drill Size
60%	75%	
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
	3/4-10	41/64
	M18x1.5	16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1″-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1″-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1″-12	29/32
M25x2		23.25mm
1″x12	1″-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1″-14		15/16

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

Section C - 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 may be contacted directly for any specifications **not** covered in this manual.

Air Compressors

Bendix Heavy Vehicles Systems
Div. of Allied Automotive
901 Cleveland Street
Elyria, OH 44036
Telephone: (216) 329-9000

Midland-Grau
Heavy Duty Systems
Heavy Duty Group Headquarters
10930 N. Pomona Avenue
Kansas City, MO 64153
Telephone: (816) 891-2470

Air Cylinders

Bendix Ltd.
Douglas Road
Kingswood
Bristol
England
Telephone: 0272-671881

Catching Engineering
2101 Roberts Drive
Broadview, IL 60153
Telephone: (312) 344-2334

Air Heaters

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone: (509) 534-6171

Air Starting Motors

Ingersoll Rand
Chorley New Road
Horwich
Bolton
Lancashire
England
BL6 6JN
Telephone: 0204-65544

Ingersoll-Rand Engine
Starting Systems
888 Industrial Drive
Elmhurst, IL 60126
Telephone: (312) 530-3800

StartMaster
Air Starting Systems
A Division of Sycon Corporation
P. O. Box 491
Marion, OH 43302
Telephone: (614) 382-5771

Alternators

Robert Bosch Ltd.
P.O. Box 98
Broadwater Park
North Orbital Road
Denham
Uxbridge
Middlesex UD9 5HG
England
Telephone: 0895-833633

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 0744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 0908-66001

C. E. Niehoff
2021 Lee Street
Evanston, IL 60202
Telephone: (708) 866-6030

Delco-Remy
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-7838

Leece-Neville Corp.
1374 E. 51st St.
Cleveland, OH 44013
Telephone: (216) 431-0740

Auxiliary Brakes

The Jacobs Manufacturing Company
Vehicle Equipment Division
22 East Dudley Town Road
Bloomfield, CT 06002
Telephone: (203) 243-1441

Belts

Dayco Rubber U.K.
Sheffield Street
Stockport
Cheshire
SK4 1RV
England
Telephone: 061-432-5163

T.B.A. Ind. Products
P.O. Box 77
Wigan
Lancashire
WN2 4XQ
England
Telephone: 0942-59221

Dayco Corp.
Belt Technical Center
P.O. Box 3258
Springfield, MO 65804
Telephone: (417) 881-7440

Gates Rubber Company
5610 Crawfordsville Road
Suite 2002
Speedway, IN 46224
Telephone: (317) 248-0386

Goodyear Tire and
Rubber Company
49 South Franklin Road
Indianapolis, IN 46219
Telephone: (317) 898-4170

Catalyst

Donaldson Company, Inc.
1400 West 94th Street
P.O. Box 1299
Minneapolis, MN 55440
Telephone: (612) 887-3131

Nelson Industries, Inc.
Exhaust and Filtration Systems
Highway 51 West, P.O. Box 428
Stoughton, WI 53589
Telephone: (608) 873-4373

Walker Manufacturing
3901 Willis Road
P.O. Box 157
Grass Lake, MI 49240
Telephone: (517) 522-5500

Clutches

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belguim
Telephone: 067-224941

Twin Disc Clutch Co.
Racine, WI 53403
Telephone: (414) 634-1981

Coolant Heaters

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Drive Plates

Detroit Diesel Allison
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206
Telephone: (317) 244-1511

Electric Starting Motors

Butec Electrics
Cleveland Road
Leyland
PR5 1XB
England
Telephone: 0744-21663

C.A.V. Electrical Equipment
P.O. Box 36
Warple Way
London
W3 7SS
England
Telephone: 01-743-3111

A.C. Delco Components Group
Civic Offices
Central Milton Keynes
MK9 3EL
England
Telephone: 0908-66001

Delco-Remy
P.O. Box 2439
Anderson, IN 46018
Telephone: (317) 646-7838

Leece-Neville Corp.
1374 E. 51st Street
Cleveland, OH 44013
Telephone: (216) 431-0740

Nippondenso Sales, Inc.
24777 Denso Drive
P.O. Box 5133
Southfield, MI 48086-5133
Telephone: (313) 350-7500

Nippondenso of Los Angeles, Inc.
3900 Via Oro Avenue
Long Beach, CA 90810
Telephone: (310) 834-6352

Engine Protection Controls

Teddington Industrial
Equipment
Windmill Road
Sunburn on Thames
Middlesex
TW16 7HF
England
Telephone: 09327-85500

The Nason Company
10388 Enterprise Drive
Davisburg, MI 48019
Telephone: (313) 625-5381

Fan Clutches

Holset Engineering Co. Ltd.
P.O. Box 9
Turnbridge
Huddersfield
England
Telephone: 0484-22244

Horton Industries, Inc.
P.O. Box 9455
Minneapolis, MN 55440
Telephone: (612) 378-6410

Rockford Division
Borg-Warner Corporation
1200 Windsor Road
P.O. Box 7007
Rockford, IL 61125-7007
Telephone: (815) 633-7460

Transportation Components Group
Facet Enterprises, Inc.
Elmira, NY 14903
Telephone: (607) 737-8212

Fans

Truflo Ltd.
Westwood Road
Birmingham
B6 7JF
England
Telephone: 021-557-4101

Hayes-Albion
1999 Wildwood Avenue
Jackson, MI 49202
Telephone: (517) 782-9421

Engineering Cooling Systems
201 W. Carmel Drive
Carmel, IN 46032
Telephone: (317) 846-3438

Brookside
McCordsville, IN 46055
Telephone: (317) 335-2014

Aerovent
8777 Purdue Rd.
Indianapolis, IN 46268
Telephone: (317) 872-0030

Kysor
1100 Wright Street
Cadillac, MI 49601
Telephone: (616) 775-4681

Schwitzer
1125 Brookside Avenue
P.O. Box 80-B
Indianapolis, IN 46206
Telephone: (317) 269-3100

Filters

Fleetguard International Corp.
Cavalry Hill Industrial Park
Weedon
Northampton NN7 4TD
England
Telephone: 0327-41313

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Flexplates

Corrugated Packing and
Sheet Metal
Hamsterley
Newcastle Upon Tyne
Telephone: 0207-560-505

Detroit Diesel Allison
Division of General Motors
Corporation
P.O. Box 894
Indianapolis, IN 46206
Telephone: (317) 244-1511

Detroit Diesel Allison
Division of General Motors
36501 Van Born Road
Romulus, MI 48174
Telephone: (313) 595-5711

Midwest Mfg. Co.
30161 Southfield Road
Southfield, MI 48076
Telephone: (313) 642-5355

Wohlert Corporation
708 East Grand River Avenue
Lansing, MI 48906
Telephone: (517) 485-3750

Fuel Warmers

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Gauges

A.I.S.
Dyffon Industrial Estate
Ystrad Mynach
Hengoed
Mid Glamorgan
CF8 7XD
England
Telephone: 0443-812791

Grasslin U.K. Ltd.
Vale Rise
Tonbridge
Kent
TN9 1TB
England
Telephone: 0732-359888

Icknield Instruments Ltd.
Jubilee Road
Letchworth
Herts
England
Telephone: 04626-5551

Superb Tool and Gauge Co.
21 Princip Street
Birmingham
B4 61E
England
Telephone: 021-359-4876

Kabi Electrical and Plastics
Cranborne Road
Potters Bar
Herts
EN6 3JP
England
Telephone: 0707-53444

Datcon Instrument Co.
P.O. Box 128
East Petersburg, PA 17520
Telephone: (717) 569-5713

Rochester Gauge of Texas
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Dallas, TX 75229
Telephone: (214) 241-2161

Governors

Woodward Governors Ltd.
P.O. Box 15
663/664 Ajax Avenue
Slough
Bucks
SL1 4DD
England
Telephone: 0753-26835

Woodward Governor Co.
1000 E. Drake Road
Fort Collins, CO 80522
Telephone: (303) 482-5811

Barber Colman Co.
1300 Rock Street
Rockford, IL 61101
Telephone: (815) 877-0241

United Technologies
Diesel Systems
1000 Jorie Blvd.
Oak Brook, IL 60521
Telephone: (312) 325-2020

Hydraulic and Power Steering Pumps

Hobourn Eaton Ltd.
Priory Road
Strood
Rochester
Kent
ME2 2BD
Telephone: 0634-71773

Honeywell Control Systems Ltd.
Honeywell House
Charles Square
Bracknell
Berks RG12 1EB
Telephone: 0344-424555

Sundstrand Hydratec Ltd.
Cheney Manor Trading Estate
Swindon
Wiltshire
SN2 2PZ
England
Telephone: 0793-30101

Sperry Vickers
1401 Crooks Road
Troy, MI 48084
Telephone: (313) 280-3000

Z.F.
P.O. Box 1340
Grafvonsoden Strasse
5-9 D7070
Schwaebisch Gmuend
West Germany
Telephone: 7070-7171-31510

Oil Heaters

Fleetguard, Inc.
P.O. Box 6001
Cookeville, TN 38502
Telephone: (615) 526-9551

Kim Hotstart Co.
West 917 Broadway
Spokane, WA 99210
Telephone: (509) 534-6171

Torque Converters

Twin Disc International S.A.
Chaussee de Namur
Nivelles
Belgium
Telephone: 067-224941

Twin Disc Clutch Co.
Racine, WI 53403
Telephone: (414) 634-1981

Rockford Division
Borg-Warner Corporation
1200 Windsor Road
P.O. Box 7007
Rockford, IL 61125-7007
Telephone: (815) 633-7460

Modine
1500 DeKoven Avenue
Racine, WI 53401
Telephone: (414) 636-1640

Section L - Service Literature

Section Contents

Additional Service Literature

The following publications can be purchased by filling in and mailing the Service Literature Order Form:

Bulletin No.	Title Of Publication
3810207	Troubleshooting and Repair Manual
3810206	B Series Engine Shop Manual
3810234	B Series Alternative Repair
3810326	4B Series Standard Repair Times
3810350	6B Series Standard Repair Times

Service Literature Ordering Location

Region	Ordering Location
United States and Canada	Cummins Distributors or Contact 1-800-DIESELS (1-800-343-7357)
U.K., Europe, Mid-East, Africa, and Eastern European Countries	Cummins Engine Co., Ltd. Royal Oak Way South Daventry Northants, NN11 5NU, England
South and Central America (excluding Brazil and Mexico)	Cummins Americas, Inc. 16085 N.W. 52nd Avenue Hialeah, FL 33104
Brazil and Mexico	Cummins Engine Co., Inc. International Parts Order Dept., MC 40931 Box 3005 Columbus, IN 47202-3005
Far East (excluding Australia and New Zealand)	Cummins Diesel Sales Corp. Literature Center 8 Tanjong Penjuru Jurong Industrial Estate Singapore
Australia and New Zealand	Cummins Diesel Australia Maroondah Highway, P.O.B. 139 Ringwood 3134 Victoria, Australia

Obtain current price information from your local Cummins Distributor or (for U.S.A. and Canada) by calling Cummins Toll Free Number 1-800-DIESELS (1-800-343-7357).

Mail the Literature Order Form along with your ship-to address to your nearest Cummins distributor.

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Country: ____________

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Cummins is pleased to announce the availability of a parts catalog compiled specifically for you. Unlike the generic versions of parts catalogs that support general high volume parts content; Cummins Customized catalogs contains only the new factory parts that were used to build your engine.

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This new catalog was designed to provide you with the exact information you need to order parts for your engine. This will be valuable for customers that do not have easy access to the Cummins Electronic Parts Catalog or the Cummins Parts Microfilm System.

Additional Features of the Customized Catalog include:

- Engine Configuration Data
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- Separate Option and Parts Indexes
- Service Kits (when applicable)
- ReCon Part Numbers (when applicable)

ORDERING THE CUSTOMIZED PARTS CATALOG

Customers can call Gannett Marketing Services at 1-800-646-5609 and order by credit card. Ask for bulletin 3672139 the Customized Parts Catalog. North American customers can mail in the attached postage pre-paid order card.

ATTENTION: INTERNATIONAL CUSTOMERS (outside U.S.A.) insert the completed Customized Catalog order form in an envelope and mail to the address printed on the order form. Or, use the E-mail address **catalog@gdms.com** to place an order for a Customized Parts Catalog.

Contact GDMS for the current price; Freight will be an additional expense.

This information is required to provide a Customized Parts Catalog:

- Name
- Street Address
- Company Name (optional)
- Telephone no.
- Credit Card No.
- Cummins Engine Serial Number (located on the engine dataplate)

Unfortunately not all Cummins Engines can be supported by this parts catalog. Engines older than 1984 or newer than 3 months may not have the necessary parts information to compile a catalog. We will contact you if this occurs and explain why we are unable to fill your order.

Customized Parts Catalogs are produced specifically for a single customer. This means they are not returnable for a refund. If we make an error and your catalog is not useable, we will correct that error by sending you a new catalog.

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5					
6					
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For problems with literature orders, contact 1-800-DIESELS (1-800-343-7357) (for U.S.A. and Canada).

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5					
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City ____________________ State __________ Zip __________

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Telephone ____________________

Credit Card Number ____________________ Expires __________

Signature ____

Engine Serial Number ____

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

Registered Office
Cummins Engine Company, Ltd.
46-50 Coombe Road
New Malden,
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England
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