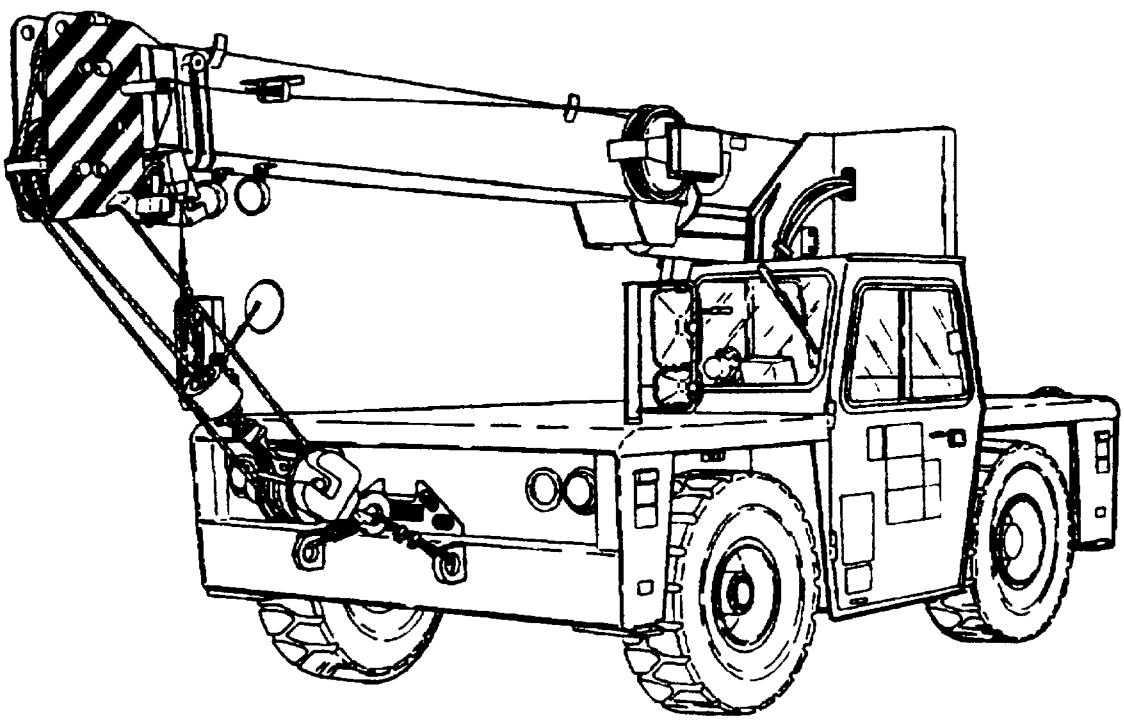
TECHNICAL MANUAL

Unit, Direct Support
and
General Support Maintenance Manual
for
WAREHOUSE CRANE
10,000 LB. CAPACITY, M469
WHEELED, DIESEL POWERED
NSN 3950-01-412-5345
(Grove Model AP 308T)



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HEADQUARTERS, DEPARTMENT OF THE ARMY
June 1997

Technical Manual

No. 10-3950-672-24-2

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 15June 1997

Unit, Direct Support and General Support Maintenance Manual for WAREHOUSE CRANE 10,000 LB. CAPACITY, M469 WHEELED, DIESEL POWERED NSN 3950-01-412-5345 (Grove Model AP 308T)

REPORTING OF ERRORS

You can improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms) or DA Form 2028-2 located in the back of this manual direct to: Commander, US Army Tank-automotive and Armaments Command, ATTN: AMSTA-IM-OPIT, Warren MI 48397-5000. A reply will be furnished to you. You may also provide DA Form 2028-2 information to TACOM via datafax or email. TACOM's datafax number for AMSTA-IM-OPIT is: (810) 574-6323 and email address is: tacomtech-pubs@cc.tacom.army.mil

This manual is an authentication of the manufacturer's commercial literature and does not conform with the format and content specified in AR 25-30, Military Publications. This technical manual does, however, contain valuable information that is essential to the operation and maintenance of the equipment.

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HOW TO USE THIS MANUAL

This manual is designed to help you operate and maintain the equipment. All task descriptions will take you step-by-step through the procedure. Don't take shortcuts. Before you begin any task, you should read through the complete procedure, make sure you know what needs to be done, then go back and follow the steps as written.

Pay particular attention to WARNINGS and CAUTIONS, as they contain information that will prevent injury to personnel or damage to equipment.

Use the alphabetical index at the back of the manual to find a topic not listed in the table of contents.

CHAPTER 4

ENGINE MAINTENANCE

INTRODUCTION

Generic Symbols

The following group of 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.

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

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.

Definition of Terms

The following is a list of guidelines for each procedure in the " Repair Sections" of the Troubleshooting and Repair Manual. The procedure will be given first; followed by a definition of the step or steps involved.

Check - Examine a component or system for damage, excessive wear, accuracy, safety, or performance.

Inspect - Examine a component or dimension to make sure it meets the required specifications.

Test - Check or compare the performance of a component or system to established specifications.

Adjust - Complete the necessary steps to set or adjust the component, assemblies, or system in the required setting or position.

Visually Inspect - Look for any obvious damage or problem.

Remove - Take off a component or assembly.

Clean - Remove dirt, grease or other contamination.

Disassemble - Take the component or assembly apart.

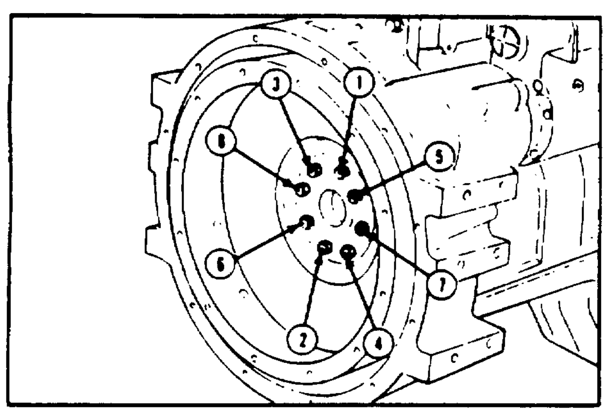
Repair - Restore a component or assembly to a serviceable condition within the established specifications.

> **Note: Only the easiest and simplest repairs will be made to a component or assembly. If a component or assembly must be rebuilt; it must be replaced with a new or Cummins Diesel ReCon®, Inc. replacement or be rebuilt at a Cummins authorized repair location.**

Replace - Install a new, properly rebuilt, or Cummins Diesel ReCon®, Inc. component or assembly in place of one which is removed.

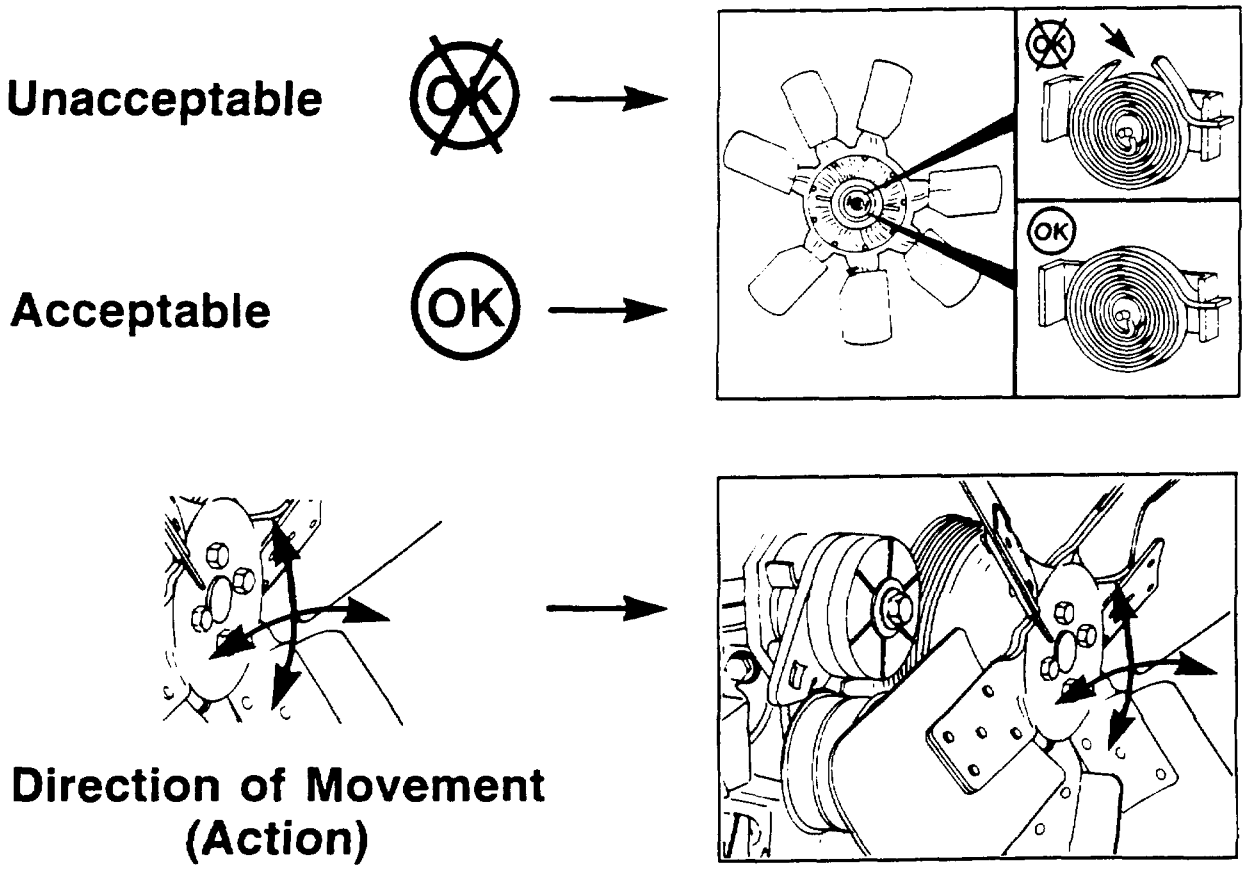
Install - Place a component or assembly in the correct position.

Star Pattern Torque Sequence -



Illustrations

The illustrations used in the Diagnosis Sections of this manual are intended to give an example of a problem, show what to look for and where to look for the problem. Most of the illustrations are generic and might 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 unacceptable condition.



The illustrations used in the Replacement Sections are intended to show replacement procedures when the engine is installed in a chassis. The illustration may differ from your application, but the procedure given will be the same.

General Safety Instructions
Important Safety Notice

Read and understand all safety precautions and warnings before performing repairs.

This symbol appears in the manual when a potential safety hazard exists that can cause personal injury or death. These hazards are not always apparent to a trained mechanic.

It is not possible for Cummins Engine Co., Inc. to anticipate every possible circumstance that can involve a potential hazard.

Warning: 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

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.

Be 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 such as rings, watches, etc., when working.

Disconnect the battery and discharge any capacitors before beginning any repair work. Disconnect the air starter 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 lift 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 avoid personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lbs] or more. Be sure all chains, hooks, slings, etc., are in good condition and are of the correct capacity. Be 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.

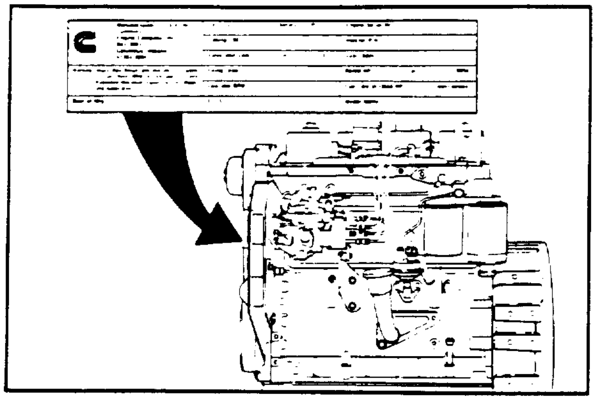
Always use tools that are in good condition. Be sure you understand how to use them before performing any service work. Use **ONLY** genuine Cummins or Cummins Recon® replacement parts.

Always use the same fastener part number (or equivalent) when replacing fasteners. Do not use a fastener of less quality if replacements are necessary.

CHAPTER 5

MAINTENANCE PROCEDURES

Section 1. General Engine Maintenance



Engine Dataplate

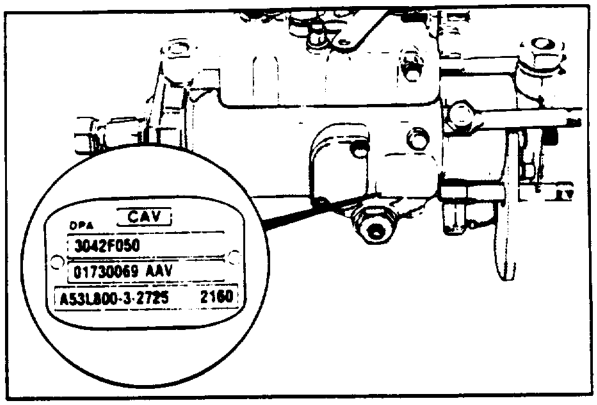
The engine dataplate shows specific information about your engine. The engine serial number (1) and Control Parts List (CPL) (2) provide information for ordering parts and service needs.

Manufactured in U.S.A. for: Cummins Engine Company, Inc. Box 3005 Columbus, Indiana 47202-3005	Cert. I.D. 239 C.I.D./L. 3.9 Series B CPL 0591	Engine Serial No. 44005065
	Timing-TDC Letter G	Injector P/N. 3903383
	Valve lash cold .010 in. Int. .020 in. Exh.	Cust. Spec.
Warning: Injury May Result and Warranty Is Voided If Fuel Rate RPM or Altitudes Exceed Published Maximum Values for This Model and Application.	Firing Order 1342	Rated HP 76 at 2500 RPM
	Low Idle RPM 750	Fuel rate at rated HP 52 mm³/stroke
Date of Mfg. 4/27/83	E.C.S.	Model Name 4B-3.9

The model name provides the following engine data:

4 B T A 3.9

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



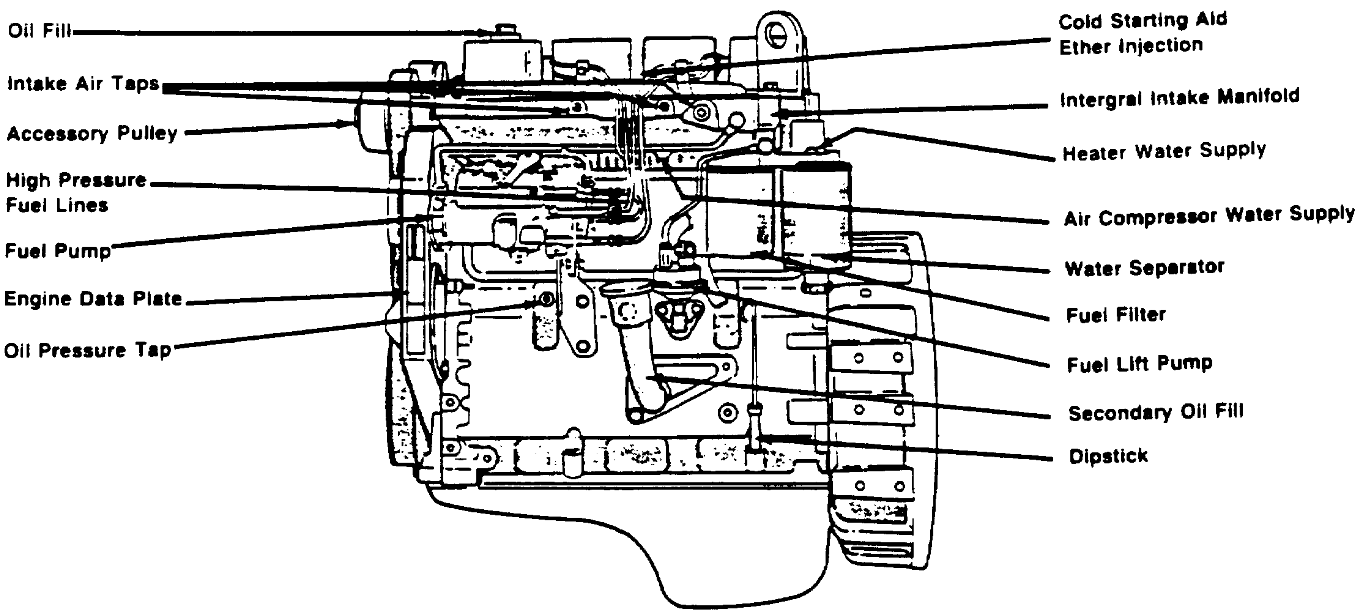
Fuel Pump Dataplate (Nameplate)

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

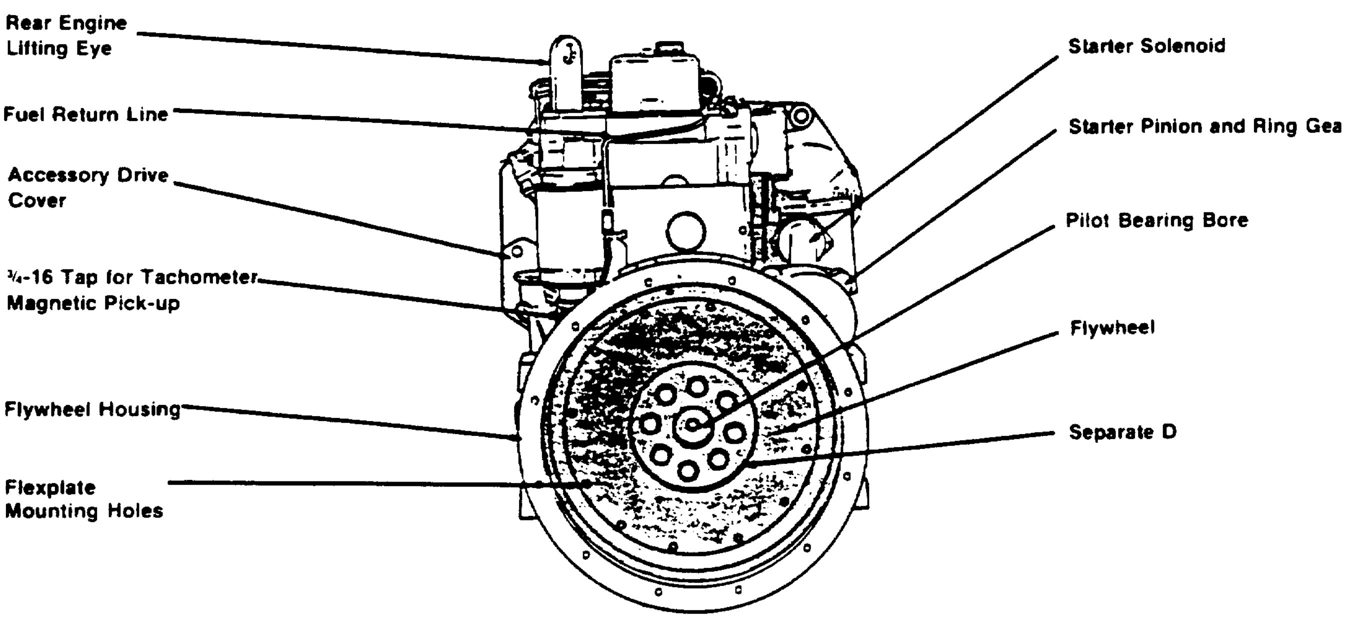
External Engine Components

The pictures which follow 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.

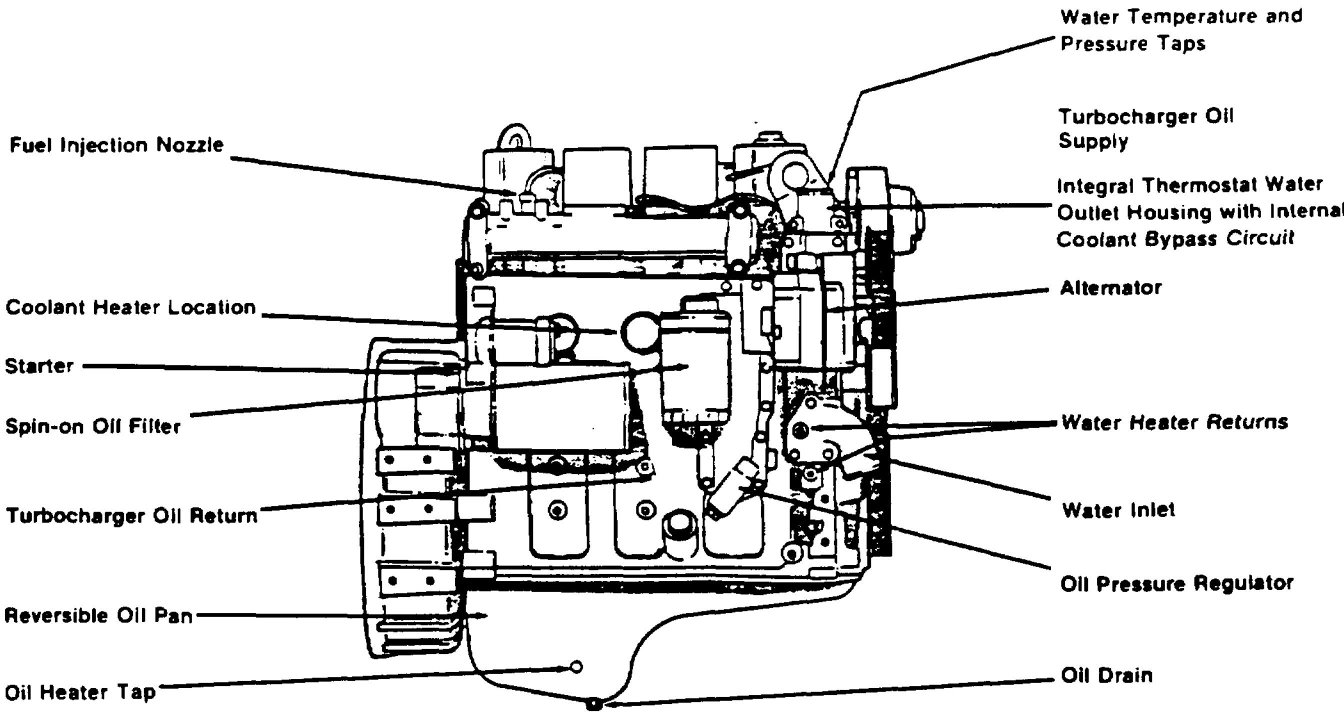
Note: The pictures are only a reference to show a typical engine.



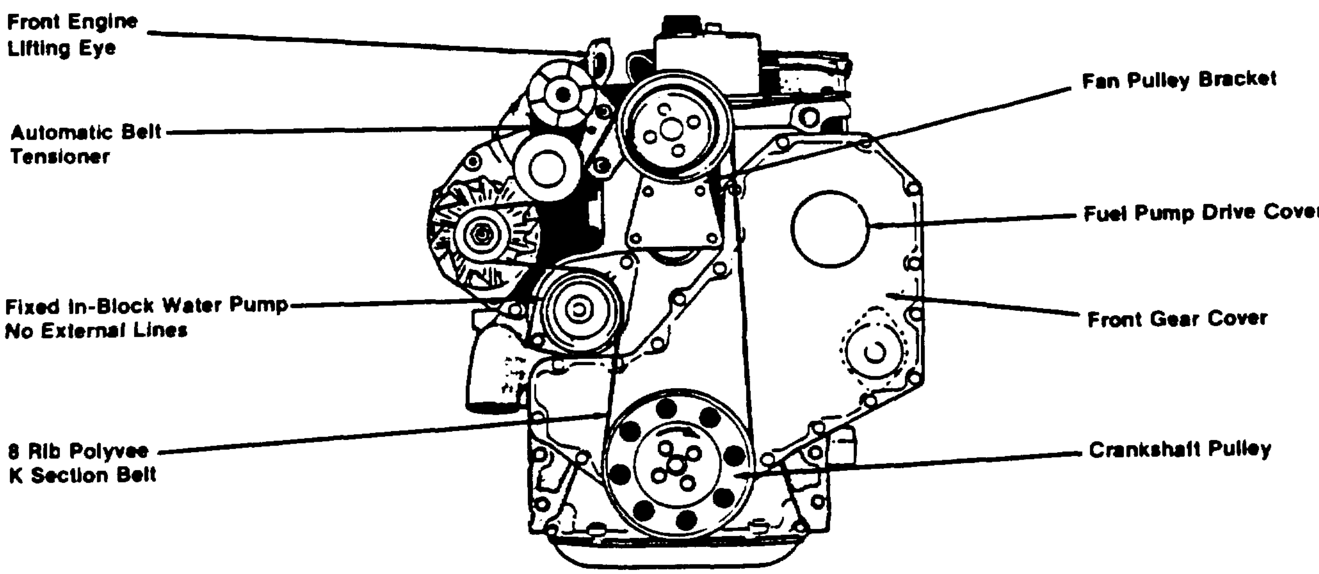
Fuel Pump Side View



Rear View



Side View



Front View

Engine Specifications

General Engine Data

Bore mm [in.]	102 [4.02]
Stroke -mm [in.]	120 [4.72]
Displacement litre [in.^{3}]	3.9 [239]
Engine Weight (Dry) Less Flywheel and Electric's-kg [lbs]	308 [680]
Firing Order	1.3.4.2
Valve Clearances	
-Intake - mm [in.]	25 [.010]
-Exhaust - mm [in.]	51 [.020]
Compression Ratio	18.5: 1
Rotation, viewed from the Front of -the Engine	Clockwise
Aspiration	
-Naturally Aspirated	X

Lubrication System

Oil Pressure at Idle (Minimum Allowable) kPa [PSI]	69 [10]
Oil Pressure at Rated (Minimum Allowable) kPa [PSI]	207 [30]
Regulating Valve Opening Pressure kPa [PSI]	414 [60]
Differential Pressure to Open the Bypass Valve kPa [PSI]	138 (20]
Oil Capacity of Pan (High/Low) Litre [U.S. Qts.]	9.5 [10] 8.5 [9]

Cooling System

Coolant Capacity (Engine Only) Litre [U.S. Qts.]	7[7.4]	
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]	

Intake Air, Exhaust and Fuel System

Maximum Allowable Intake Restriction at Rated Speed and Load with Dirty Air Filter Element mm H20 [in. H20]...............	508 [20]
Maximum Allowable Exhaust Restriction at Rated Speed and Load mm Hg [in. Hg]	-- 76.2 [3]--
Maximum Allowable Restriction to Pump With Dirty Filter mm Hg [in. Hg]	--- 95 [3.75]---
Maximum Allowable Return Line Restriction................... mm Hg [in. Hg]	---518 [20.4)--

Electrical System

Minimum Recommended Battery Capacity With Light Accessories* .... -12 V Starter	625CCA
With Heavy Accessories*. -12 V Starter.......................	800CCA
	--- --
Maximum Allowable Resistance of Starting Circuit With - 12 V Starter Ohms	--0012 ---

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

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

Section 2. Troubleshooting Logic

Troubleshooting Logic

Engine Diagrams

A schematic of each of the major engine systems is provided at the beginning of the Section of the manual devoted to troubleshooting and repairing that particular system.

The diagrams depict flow through the various engine systems. The information and configuration of the components illustrated in the drawings are of a general nature. Some items for specific applications and installations may be different.

Each Section also contains a discussion regarding diagnosing malfunctions for that specific system.

A knowledge of the systems can help you troubleshoot and repair the engine.

Problem Isolation and Correction

The following Troubleshooting Logic is designed to help you organize your study of a problem and to plan a procedure to correct it. The series of fault/logic charts given do not provide all the answers, but they should stimulate a train of thought that will lead you to the source of the trouble.

Be sure to consider any maintenance or repair action that could have caused the problem.

If the engine surges or runs rough initially after not being used for 2 months or more, do not assume that the engine has a malfunction. Varnish can form on the internal parts of the injection pump and the oil film can drain from the piston rings. Operate the engine for at least 5 minutes before troubleshooting.

The basic procedure is as follows:

- Study the problem thoroughly.
- Relate the symptoms to your knowledge of the engine components and systems.
- Double-check before beginning the disassembly.
- Solve the problem by deduction starting with the easiest things.
- Determine the cause of the problem and make a thorough repair.
- After making corrections, operate the engine in normal conditions to verify the cause of the problem was corrected.

Troubleshooting Logic

Engine Will Not Crank Or Cranks Slowly

Cause	Correction
Starting Motor Operating But Not Cranking the Engine	Remove the Starting Motor and Check for Broken Teeth on the Flywheel or Broken Starting Motor Spring.
OK ↓	
Crankshaft Rotation Restricted	Bar the Engine to Check for Rotational Resistance.
OK ↓	
Starting Circuit Connections Loose or Corroded	Clean and Tighten Connections.
OK ↓	
Battery Charge Low	Check Battery Voltage.
OK ↓	
No Voltage to Starter Solenoid	Check Voltage to Solenoid.
OK ↓	
Solenoid or Starting Motor Malfunction	Replace Starting Motor.

Engine Cranks But Will Not Start No Smoke From Exhaust

Cause	Correction
No Fuel in Supply Tank	Check/Replenish Fuel Supply
OK	
Electrical or Manual Fuel Shutdown Not Open	Check for Loose Wires and Verify that the Valve is Functioning. Check to be sure Manual Shut Off Lever is in the Run Position.
OK	
Air Intake or Exhaust Plugged	Visually Check; Remove the Obstruction.
OK	
Fuel Filter Plugged With Water or Other Contamination	Drain Fuel/Water Separator or Replace Fuel Filter.
OK	
Injection Pump Not Getting Fuel or Fuel is Aerated	Check Fuel Flow/Bleed Fuel System.
OK	
Worn or Malfunctioning Injection Pump	Visually Check Fuel Delivery with an Externally Connected Injector to One of the Pump Outlets. Replace the pump if fuel is not being delivered.
OK	

(Continued)

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

Cause	Correction
Internal Pump Timing Incorrect	Verify/Time the Pump.
OK ↓	
Camshaft Out of Time	Check/Correct Gear Train Timing Alignment.

Engine Hard To Start Or Will Not Start Smoke From Exhaust

Cause	Correction
Incorrect Starting Procedure	The Fuel Control Lever on the Lucas CAV Pump Must be Moved to One-Half Travel. The Fuel Shut Off Control Must Be in the Run Position. Refer to O&M Manual.
OK ↓	
Cranking Speed Too Slow	Verify that the Driven Units are not Engaged
	Check the Battery, Starting Motor, and Look for Loose or Corroded Wiring Connections.
	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.
OK ↓	
Insufficient Intake Air	Inspect or Replace Filter and Check for Obstructions to the Air Supply Tube.
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.
OK ↓	

(Continued)

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

Cause	Correction
Contaminated Fuel	Verify by Operating the Engine with Clean Fuel from a Temporary Tank. Drain and Flush Fuel Supply Tanks.
OK	
Worn or Malfunctioning Injection Pump	Visually Check Fuel Delivery With an Externally Connected Injector to one of the Pump Outlets. Replace the Pump if Fuel is Not Being Delivered.
OK	
Injection Pump Out of Time	Check/Time the Pump.
OK	
Valves Incorrectly Adjusted	Adjust Valves.
OK	
One or More Injectors Worn or Malfunctioning	Check/Replace Injectors.
OK	
Engine Compression Low	Perform a Compression Check to Identify the Problem.

Engine Starts But Will Not Keep Running

Cause	Correction
Engine Starting Under Load	Disengage Driven Units
Idle Speed Too Low for Accessories	Adjust the Idle Speed.
Intake Air or Exhaust System Restricted	Visually Check for Exhaust Restriction and Inspect the Air Intake.
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.
Fuel Waxing Due to Extremely Cold Weather	Verify by Inspecting the Fuel Filter. Clean the System and Use Climatized Fuel or Fuel Heaters.
Contaminated Fuel	Verify by Operating the Engine With Clean Fuel from a Temporary Supply Tank. Drain and Flush the Fuel Supply Tank.
Restricted Fuel Drain Manifold or Return Line (Lucas CAV Only)	Check/Correct the Restriction.

OK

Surging (Speed Change)

Cause	Correction
If the Condition Occurs at Idle, the Idle Speed is Set Too Low for Accessories	Adjust the Idle.
OK ↓	
High Pressure Fuel Leak	Inspect/Correct Leaks in the High Pressure Lines, Fittings, Injector Sealing Washers or Delivery Valves.
OK ↓	
One or More Injectors Worn or Malfunctioning	Check/Replace the Injectors.
OK ↓	
Malfunctioning Delivery Valve	Replace Delivery Valves.
OK ↓	
Malfunctioning Injection Pump	Replace the Pump.

Rough Idle (Irregularly Firing Or Engine Shaking)

Cause	Correction
Cold Engine	Refer to Troubleshooting Logic for Engine Running Too Cold.
OK ↓	
Idle Speed Too Low for the Accessories	Check/Adjust Low Idle Screw.
OK ↓	
Engine Mounts Over-Tightened, Damaged or Loose	Verify Condition of Mounts. Refer to Volume 1.
OK ↓	
High Pressure Fuel Leak	Inspect/Correct Leaks in the High Pressure Lines, Fittings Injection Sealing Washers or Delivery Valve Seals.
OK ↓	
Air in the Fuel System	Bleed the Fuel System and Correct the Source of the Air.
OK ↓	
Sticking Needle Valve in an Injector	Replace the Injector.
OK ↓	
Malfunctioning Delivery Valve	Replace Delivery Valves.
OK ↓	

(Continued)

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

Cause	Correction
Valves Not Sealing	Adjust Valves.
OK ↓	
One or More Cylinders Losing Compression	Perform a Compression Check and Repair as Required.

Engine Runs Rough Or Misfiring

Cause	Correction
Fuel Injection Lines Leaking	Inspect/Correct Leaks in the High Pressure Lines, Fittings Injector Sealing Washers, or Delivery Valves.
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.
OK	
Contaminated Fuel	Verify by Operating the Engine with Clean Fuel from a Temporary Tank.
OK	
Incorrect Valve Adjustment	Check for a Bent Push Rod and Adjust Valves.
OK	
Injection Pump Timing Incorrect	Check/Time Pump.
OK	
One or More Cylinders Has Low Compression	Perform a Compression Check to Isolate the Cause of Low Compression (Piston Rings, Head Gasket or Valves).
OK	

(Continued)

Engine Runs Rough Or Misfiring (Continued)

Cause	Correction
Malfunctioning Injectors	Replace Injectors.
OK	
Defective Injection Pump (Delivery Valves)	Replace Injection Pump.
OK	
Camshaft Out of Time	Check/Correct Gear Train Timing Alignment.
OK	
Damaged Camshaft or Tappets	Inspect Camshaft.

Engine RPM Will Not Reach Rated Speed

Cause	Correction
Engine Overloaded	Verify High Idle Speed Without Load. Investigate Operation to be Sure Correct Gear is Being Used.
OK	
Malfunctioning Tachometer	Verify Engine Speed with Hand Tachometer - Correct as Required
OK	
Throttle Linkage Worn or Incorrectly Adjusted	Adjust Linkage for Stop-to-Stop Fuel Control Lever Travel.
OK	
High Speed Stop Screw Incorrectly Adjusted	Check/Set High Speed Stop Screw.
OK	
Partially Engaged Mechanical Shutdown Lever	Check/Place Shutdown Lever in Run Position.
OK	
Inadequate Fuel Supply	Check the Flow Through and Filter to Locate the Source of the Restriction.
OK	

(Continued)

Engine RPM Will Not Reach Rated Speed (Continued)

Cause	Correction
If the Condition is Intermittant, Restricted Manifold Drain Line (Lucas CAV DPA Only)	Check/Remove Restriction.
OK	
Malfunctioning Injection Pump	Replace Pump.

Low Power

Cause	Correction
If the Condition is Slow Throttle Response, Leaking Air Fuel Control Tube or Malfunction Control in the Pump (Automotive Only)	Tighten the Fittings. Replace the pump if the Controls are Not Functioning.
OK	
Fuel Control Lever Not Moving to Full Speed	Check/Correct for Stop-to-Stop Travel.
OK	
Mechanical/Shutdown Lever Partially Engaged	Check/Replace Shutdown Lever in Run Position.
OK	
High Oil Level	Check/Correct Oil Level
OK	
Engine Overloaded	Check for Added Loading from Malfunctioning Accessories or Driven Units, Brakes Dragging and Other Changes in Vehicle Loading
OK	
Incorrect External Injection Pump Timing	Verify Pump Timing Marks are Aligned.
OK	

(Continued)

Low Power (Continued)

Cause	Correction
Inadequate, or High or Low Temperature Intake Air	Inspect/Replace Air Cleaner Element. Look for Other Restrictions.
OK ↓	
High Pressure Fuel Leak	Inspect/Correct Leaks in the High Pressure Lines, Fittings Injector Sealing Washers or Delivery Valve Seals.
OK ↓	
Inadequate Fuel Supply	Check the Flow Through the Filter to Locate the Source of the Restriction.
OK ↓	
High Fuel Temperature	Verify that Fuel Heater is Off During Warm Weather. Check for a Restricted Fuel Drain Manifold (Robert Bosch VE).
OK ↓	
If Low Power is Intermittant, Restricted Fuel Drain Manifold (Lucas CAV Only)	Check/Correct Restriction.
OK ↓	
Poor Quality Fuel	Verify by Operating From a Temporary Tank With Good Fuel
OK ↓	

(Continued)

Low Power (Continued)

Cause	Correction
Exhaust Leak at the Manifold	Check/Correct Leaks in the Manifold Gasket. Look for a cracked Manifold.
OK ↓	
Valve Clearances Incorrect	Check/Adjust Valves.
OK ↓	
Injection Pump Internal Malfunctioning	Check/Time Pump.
OK ↓	
Low Engine Compression	Perform Compression Check to Identify Malfunction. Correct as Required.
OK ↓	
Worn or Malfunctioning Injectors	Check Injectors.
OK ↓	

(Continued)

Low Power (Continued)

Cause	Correction
Malfunctioning Injection Pump	Replace Injection Pump.
OK ↓	
Excessive Exhaust Restriction	Check/Correct Exhaust System.

Excessive Exhaust Smoke

Cause	Correction
Engine Running Too Cold (White Smoke)	Refer to Troubleshooting Logic for Coolant Temperature Below Normal
OK	
Inadequate Intake Air	Inspect/Change Air Cleaner. Look for Other Restrictions.
OK	
Exhaust leak at the Manifold	Check/Correct Leaks in the Manifold Gasket. Look for a Cracked Manifold.
OK	
More than One Sealing Washer Under an Injector	Remove Extra Washer.
OK	
Malfunctioning Injectors	Replace Injectors.
OK	
Malfunctioning or Overfueled Injection Pump	Replace Injection Pump.
OK	
Piston Rings Not Sealing (Blue Smoke)	Perform a Compression Check. Correct as Required.

Coolant Temperature Above Normal

Cause	Correction
Low Coolant Level	Check/Replenish Coolant.
OK	Locate and Correct the Source of the Coolant Leak. Refer to Troubleshooting Logic for Coolant Loss.
Incorrect/Malfunctioning Pressure Cap	Replace Cap with the Correct Rating for the System.
OK	
High Lube Oil Level	Check/Drain Oil to Correct Level.
OK	
Loose Drive Belt on Water Pump/Fan	Check/Correct Belt Tension.
OK	
Inadequate Air Flow to the Radiator	Check/Repair Fan Shroud, Shutters, Fan Sensors, and Fan Clutch as Required. Refer to Volume 1.
OK	
Radiator Fins Plugged	Blow Debris from Fins
OK	
Collapsed Radiator Hose	Check/Replace Hose.
OK	

(Continued)

Coolant Temperature Above Normal (Continued)

Cause	Correction
Malfunctioning Temperature Sensor/Gage	Verify that the Gage and Temperature Sensor are Accurate.
OK	
Malfunctioning, Incorrect or No Thermostat	Check/Replace the Thermostat.
OK	
Air in the Cooling System	*Make Sure the Fill Rate is not Being* Exceeded and the Correct Vented Thermostat is Installed.
	If Aeration Continued, Check for a Compression Leak Through the Head Gasket.
OK	
Malfunctioning Water Pump	Check/Replace the Water Pump.
OK	
Incorrect Injection Pump Timing	Check/Time the Injection Pump.
OK	
Incorrect External Injection PumpTiming	Verify Pump Timing Marks are Aligned.
OK	
Overfueled Injection Pump	Replace the Injection Pump.
OK	

(Continued)

Coolant Temperature Above Normal (Continued)

Cause	Correction
Plugged Cooling Passages in Radiator, Head, Head Gasket or Block	Flush the System and Fill with Clean Coolant.
OK ↓	
Engine Overloaded	Verify that the Engine Load Rating is Not Being Exceeded.

Coolant Temperature Below Normal

Cause	Correction
Too Much Air Flow Across the Radiator	Check/Repair Shutters, Fan Clutch, Viscous Fan as Required. Refer to Volume 1.
OK	
Incorrect Thermostat, Broken Thermostat Jiggle Pin or Contamination in Thermostat	Check/Replace Thermostat.
OK	
Temperature Sensor or Gage Malfunctioning	Verify that the Gage and Sensor are Accurate.
OK	
Coolant Not Flowing by Temperature Sensor	Check/Clean Coolant Passages.

Coolant Loss

Cause	Correction
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 or Gasket Leaks.
OK	
Overheating or Leaking Compression Gases 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.
OK	

(Continued)

Coolant Loss (Continued)

Cause	Correction
Lube Oil Cooler Leak	Check/Replace the Oil Cooler. Look for Coolant in the Oil.
OK ↓	
Head Gasket Leak	Check/Replace the Head Gasket.
OK ↓	
Cracked or Porous Head	Check/Replace the Head.
OK ↓	
Leak in Cylinder Block Coolant Passages	Check/Replace the Cylinder Block.

Lubricating Oil Pressure Low

Cause	Correction
Low Oil Level	Check/Replenish Oil.
OK	Check for a Severe External Oil Leak that Could Reduce the Pressure.
Oil Viscosity Thin; Diluted or Wrong Specification	Verify the Correct Oil is Being Used. Check for Oil Dilution. Refer to Troubleshooting Logic for Contaminated Lube Oil.
OK	
Malfunctioning Pressure Switch/Gage	Verify the Pressure Switch is Functioning Correctly.
OK	
Relief Valve Stuck Open	Check/Replace Valve.
OK	
Plugged Oil Filter	Change Oil Filter; Review Change Interval.
OK	
If Cooler was Replaced, Shipping Plugs Left in Cooler	Check/Remove Shipping Plugs.
OK	

(Continued)

Lubricating Oil Pressure Low (Continued)

Cause	Correction
Loose or Missing Cup Plugs	Check/Replace Cup Plugs.
OK ↓	
Suction Tube Loose or Seal Leaking	Check/Replace Seal.
OK ↓	
Worn Lube Pump	Check/Replace Lube Pump.
OK ↓	
Loose Main Bearing Cap	Check/Install New Bearings (s) and Tighten Cap
OK ↓	
Worn Bearings	Inspect/Replace Bearings; also Check/Replace Piston Cooling Nozzles.

Lubricating Oil Pressure Too High

Cause	Correction
Malfunctioning Pressure Switch/Gage	Verify the Pressure Switch is Functioning Correctly.
OK ↓	
Engine Running Too Cold	Refer to Troubleshooting Logic for Coolant Temperature Below Normal
OK ↓	
Oil Viscosity Too Thick	Make Sure the Correct Oil is Being Used. Refer to O&M Manual.
OK ↓	
Relief Valve Stuck Closed	Check/Replace Valve.
OK ↓	
If Replaced, Six Cylinder Lube Pump, Installed in Four Cylinder	Verify that the Correct Pump is Installed.

Lube Oil Loss

Cause	Correction
External Leaks	Visually Inspect for Oil Leaks.
OK	
Crankcase Being Overfilled	Verify that the Dipstick is Correctly Marked
OK	
Incorrect Oil (Specification or Viscosity)	Make Sure the Correct Oil is Being Used.
OK	Look for Reduced Viscosity from Dilution with Fuel.
	Review/Reduce the Oil Change Intervals.
Oil Cooler Leak	Check for Oil in the Coolant.
OK	

(Continued)

Lube Oil Loss (Continued)

Cause	Correction
High Blowby Forcing Oil Out the Breather	Check the Breather Tube Area for Signs of Oil Loss. Measure the Blowby and Perform the Required Repairs.
OK	
Worn Valve Seals	Inspect/Replace the Valve Seals.
OK	
Piston Rings Not Sealing - Oil Being Consumed by the Engine	Perform a Compression Check. Repair as Required.

Contaminated Coolant

Cause	Correction
Rusty Coolant, 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.
OK	
If Equipped, Leaking Transmission Oil Cooler	Check/Replace Radiator. Refer to Volume 1.
OK	
Oil Leaks from Oil Cooler, Head Gasket, Head and Cylinder Block	Refer to Troubleshooting Logic for Lube Oil Loss.

Contaminated Lube Oil

Cause	Correction
Coolant in the Oil, Internal Engine Component Leaks	Refer to Troubleshooting Logic for Coolant Loss
OK	
Excessive Oil Sludge	Review Oil and Filter Change Intervals
OK	Make Sure the Correct Oil is Being Used
Fuel in the Oil, Engine Operating Too Cold	Review the Operation for Excessive Idling Resulting in the Engine Running Below Normal Temperature.
OK	
Fuel Pump Seal Leaking	Replace the Pump.
OK	
Injector Needle Valves Not Sealing	Locate and Replace Malfunctioning Injector.

Fuel Or Oil Leaking From Exhaust Manifold

Cause	Correction
Intake Air Restriction	Check/Replace Filter Element.
OK ↓	Review Operation for Excessive Idling.
Injector Needle Valve Stuck Open	Locate and Replace Malfunctioning Injector.

Compression Knocks

Cause	Correction
Air in the Fuel System	Bleed the Fuel System.
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 ↓	
Incorrect Injection Pump Timing	Check/Time Injection Pump.
OK ↓	
Malfunctioning Injectors	Replace Injectors.

Excessive Fuel Consumption

Cause	Correction
Additional Loading from Malfunctioning Accessories	Check/Repair Accessories and Vehicle Components. Refer to Volume 1.
OK	
Operator Technique	Review Operation for Correct Gear Shifts, Deceleration, and Idling
OK	
Poor Quality Fuel	Make Sure Quality No. 2 Fuel is Being Used.
OK	
Inadequate Intake Air or Exhaust Restriction	Refer to Troubleshooting Logic for Excessive Exhaust Smoke
OK	
Fuel Pump TIming	Check/Time the Pump.
OK	
Worn or Malfunctioning Injectors	Check/Replace Injectors.
OK	
Valves Not Seating	Check/Adjust Valves.
OK	
Malfunctioning Power Functions	Check/Repair Power Functions.

Engine Will Not Shut Off

Cause		Correction
Fuel Shutoff Valve Inoperative	- - -	Stop the Engine Mechanically with Lever on the Fuel Pump. Check/Replace Sealing Washer, Piston and Spring.
OK ↓		
Engine Running on Fumes Drawn into the Air Intake	- - -	Check the Air Intake Ducts for the Source of the Fumes

Excessive Vibration

Cause	Correction
Engine Not Running Smoothly	Refer to Troubleshooting Logic for Rough Running or Misfiring.
OK ↓	
Loose or Broken Engine Mounts	Check/Replace Engine Mounts. Refer to Volume 1.
OK ↓	
Damaged Fan or Malfunctioning Accessories	Check/Replace the Vibrating Component. Refer to Volume 1.
OK ↓	
Malfunctioning Fan Hub	Inspect/Replace the Fan Hub.
OK ↓	
Worn or Damaged Alternator Bearing	Check/Replace the Alternator.
OK ↓	
Flywheel Housing Misaligned	Check/Correct Flywheel Alignment.
OK ↓	

(Continued)

Excessive Vibration (Continued)

Cause	Correction
Loose or Broken Power Component	Inspect the Crankshaft and Rods for Damage that Cause and Unbalance.
OK	
Worn or Unbalanced Drive Line Components	Check/Repair Refer to Volume 1.

Excessive Engine Noises

Cause	Correction
Drive Belt Squeal, Insufficient Tension or Abnormally High Loading	Check the Tensioner and Inspect the Drive Belt. Make Sure Water Pump, Tensioner Pulley, Fan Hub and Alternator Turn Freely.
OK	
Intake Air or Exhaust Leaks	Refer to Troubleshooting Logic for Excessive Exhaust Smoke
OK	
Excessive Valve Lash	Adjust valves. Make sure the Push rods are Not Bent or the Rocker Levers are Not Severely Worn.
OK	
Gear Train Noise	Visually Inspect and Measure Gear Backlash. Replace Gears as Required.
OK	
Power Function Knock	Check/Replace Rod and Main Bearings.

Alternator Not Charging Or Insufficient Charging

Cause	Correction
Loose or Corroded Battery Connections	Clean/Tighten Battery Connections.
OK ↓	
Alternator Belt Slipping	Check/Replace Belt Tensioner.
OK ↓	
Alternator Pulley Loose on Shaft	Tighten Pulley.
OK ↓	
Malfunctioning Alternator	Replace Alternator.

Section 3. Coolant System

Coolant System

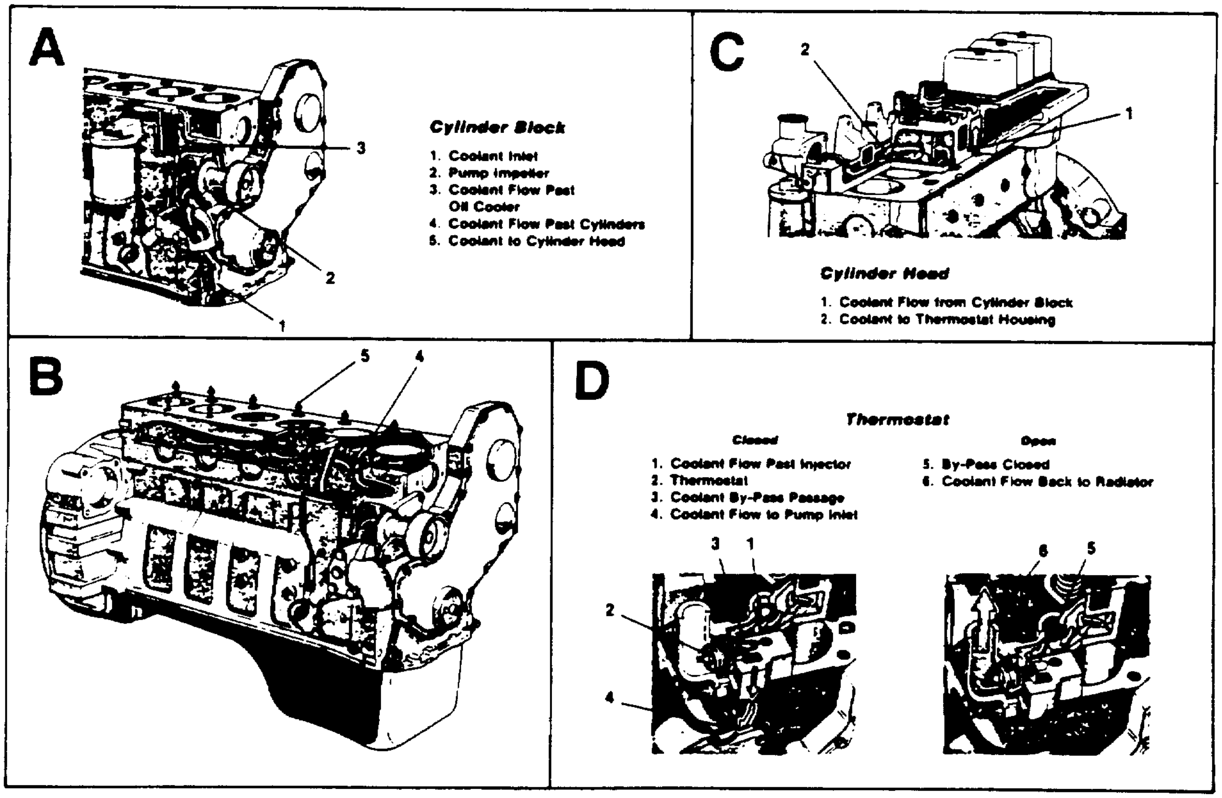
Coolant System Components and Flow

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 nozzle. 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 via 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.



Cooling System
Specifications

Coolant Capacity (Engine
Only)- Litre [U.S. Qts.].. 7 [7.4]

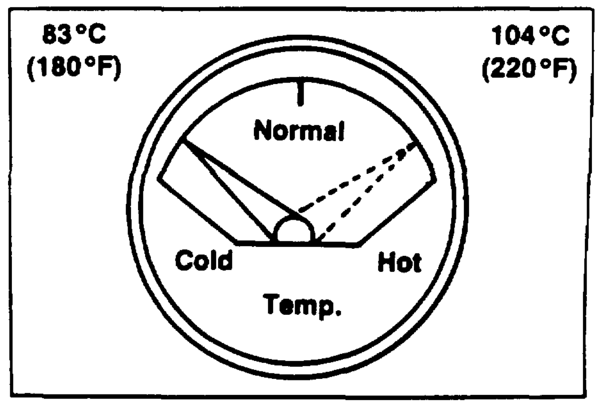
Standard Modulating
Thermostat - Range -
° C [° F] .... -------------------Start 80 [180] -----------------Fully Open 95 [203]----------------------------

Pressure Cap (kPa [PSI])
104° C 1220° F] Systems .... 103 [15]

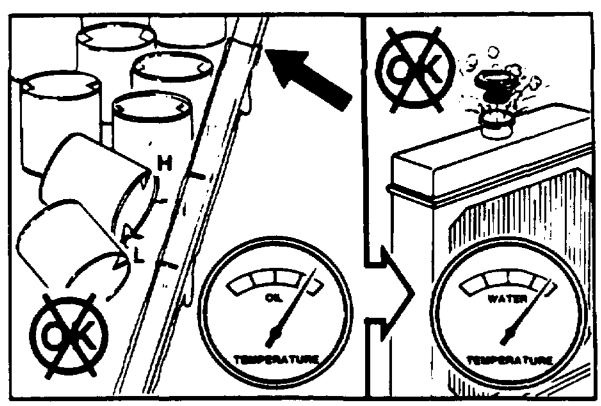
Pressure Cap (kPa [PSI])
99°C [210° F] Systems .... 48 [7]

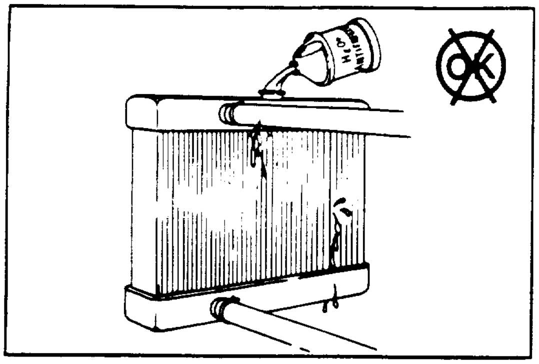
Coolant System Malfunctions Diagnosis

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.



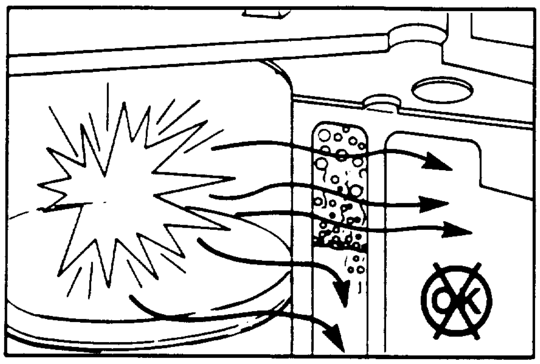
Overfilling with oil raises the oil temperature which is transferred to the coolant system at the oil cooler.





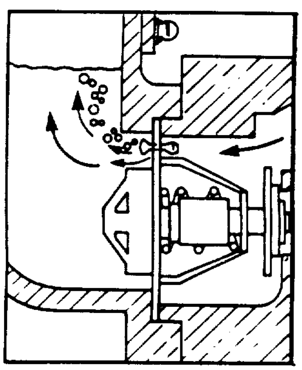
The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

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



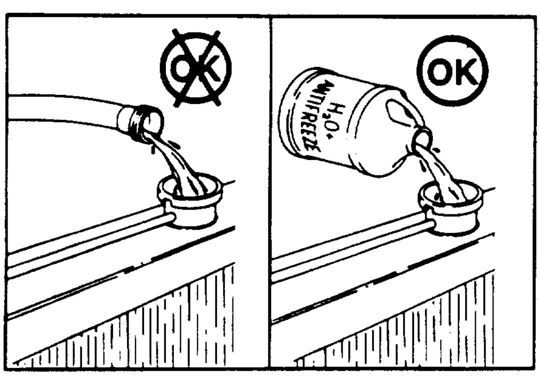
Caution: The engine coolant passages must be completely filled with coolant.

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" opening and the notched vent hole to the top radiator hose and out the fill opening.

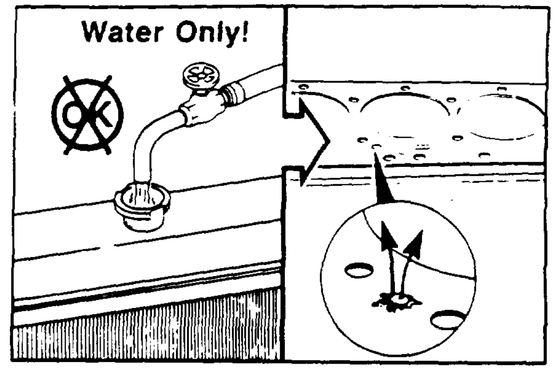
Note: Adequate venting is provided for a fill rate of 30 liters/minute [8 U.S. Gallon/minute].



Caution: Never use only water for engine coolant. In tropical climates where antifreeze availability may be limited, use a corrosion inhibitor (Cummins Liquid DCA) to protect the engine cooling system.

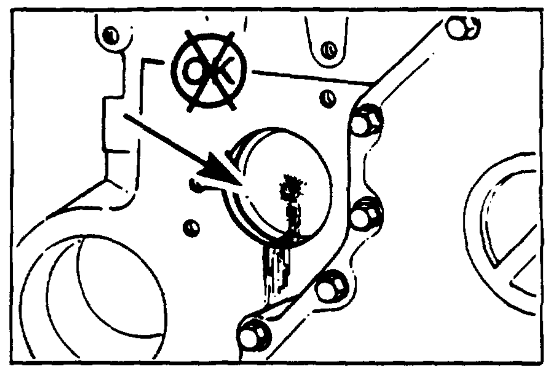
A mixture of 50% ethylene-glycol base antifreeze is required for operation of the engine in temperature environments above -37° C [-34° F]. A mixture of 40% water and 60% antifreeze is recommended for temperatures below -37° C [-34° F].

Caution: The small holes in the head gasket are especially susceptible to plugging.



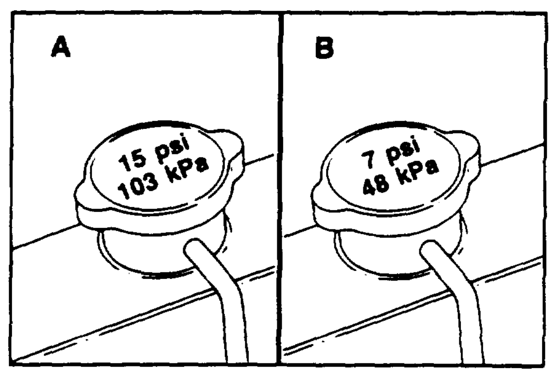
Water will cause rust formation reducing the flow in the smaller coolant passages.

Caution: 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.



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.

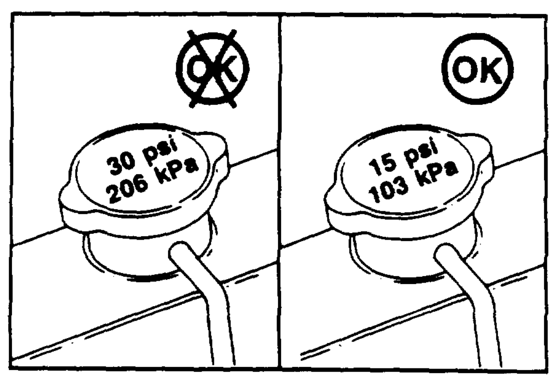
Note: A sudden loss of coolant from a heavily loaded engine can result in severe damage to the pistons and cylinder bore.



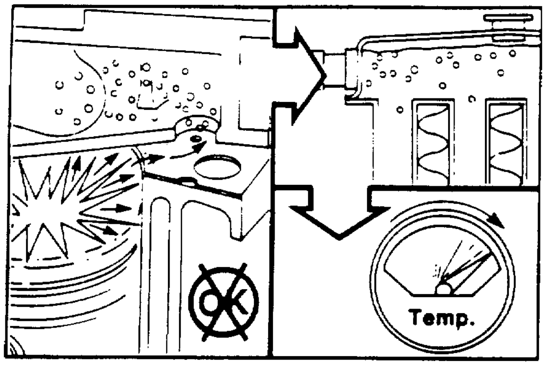
Pressure Caps The system is designed to use a pressure cap to prevent boiling of the coolant.

Different caps are specified for the two recommended systems:

System	Cap
A - 104°C [220° F]	103kPa [15 PSI]
B - 99°C [210°F]	48kPa [7 PSI]

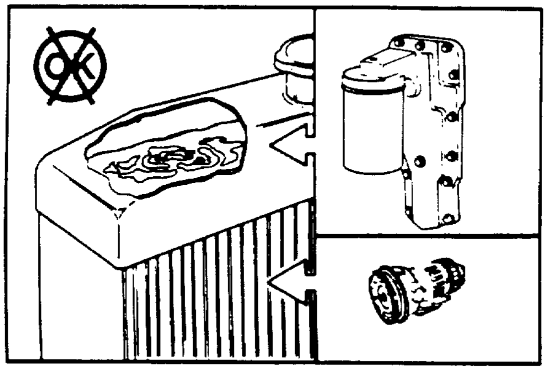


An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



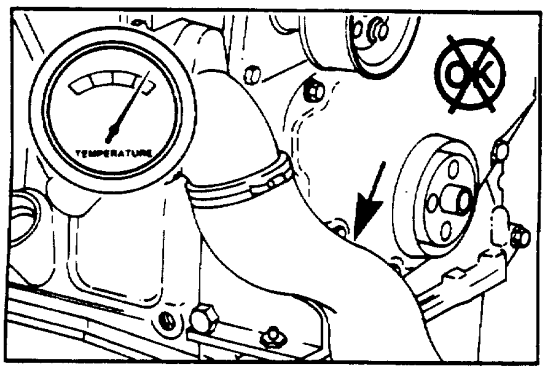
Air in the coolant can result in loss from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system causing the cap to open.

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



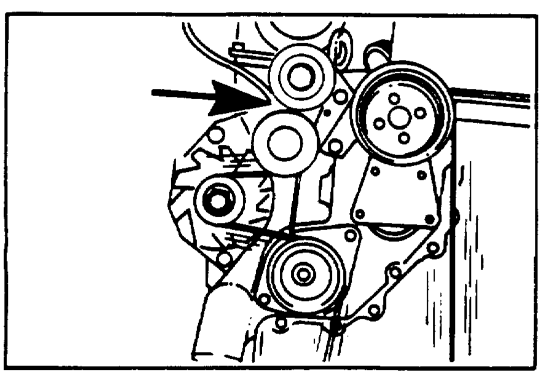
The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: head gasket, oil cooler, etc. (refer to the Lubricating System).

Note: Transmission fluid can also leak into the coolant through bottom tank oil coolers.



Water (Coolant) Pump

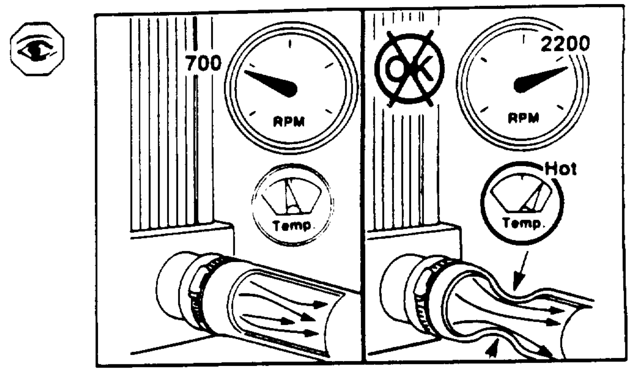
The water pump pulls coolant from the bottom of the radiator and pumps it through the engine back to the top of the radiator for cooling. Reduced or interrupted flow will result In the engine. running hot.



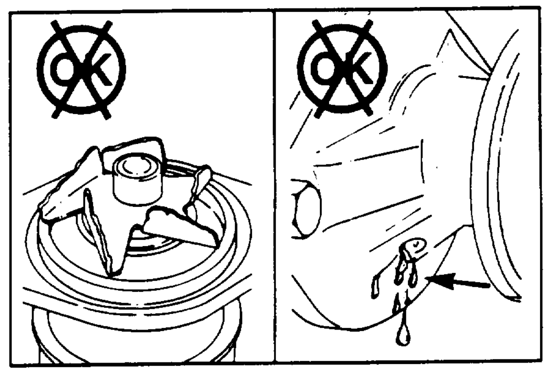
The pump is belt driven from the crankshaft pulley. An automatic belt tensioner is used to prevent the belt from slipping on the pump pulley. A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed reducing the amount of coolant flow.

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.

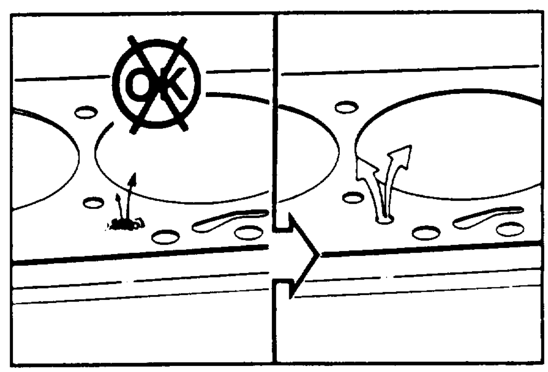
Note: Be sure the engine is warm, a minimum of 95°C [203° F], so the thermostat is open.



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.

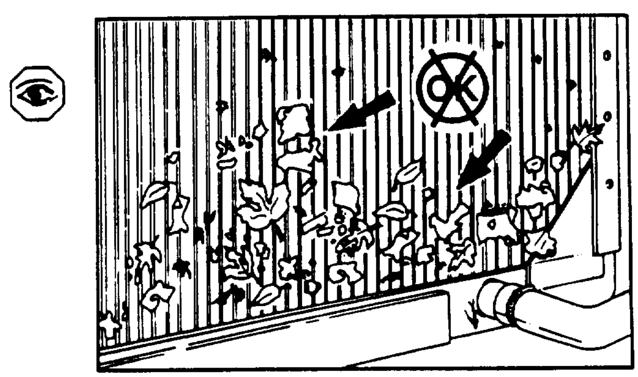


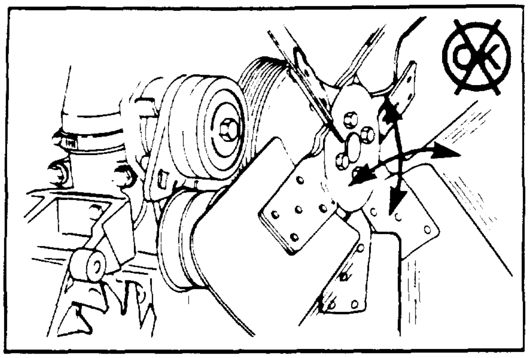
As stated in the coolant discussion, an obstruction in the passages can interrupt flow.



Radiator, Fans and Shutters

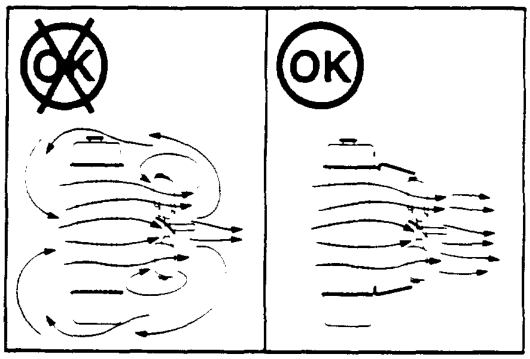
Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (paper, straw, lint, dust, etc.) can obstruct the fins and stop the flow of air which will reduce the cooling effect of the radiator.





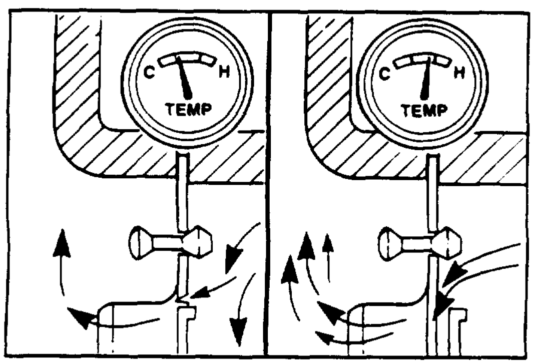
If the fan is belt driven, a slipping belt will result in a slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem.

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



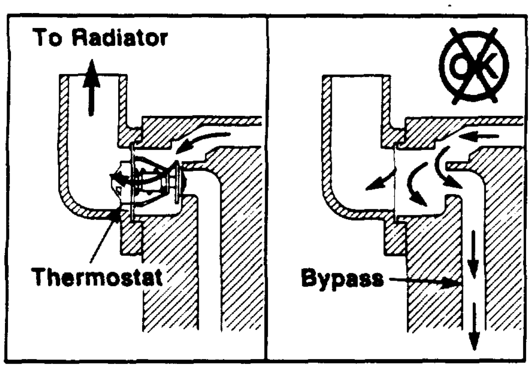
An incorrect fan shroud or obstructions can reduce air flow and cause the engine to run hot.

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



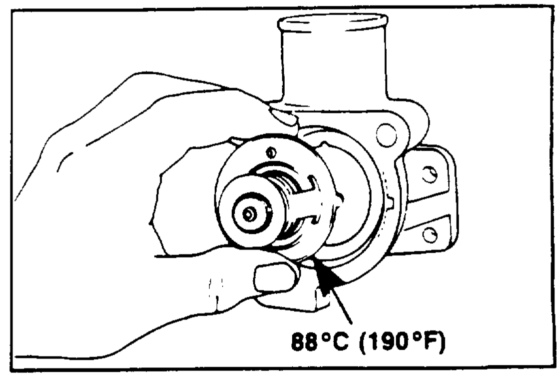
Thermostat

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.

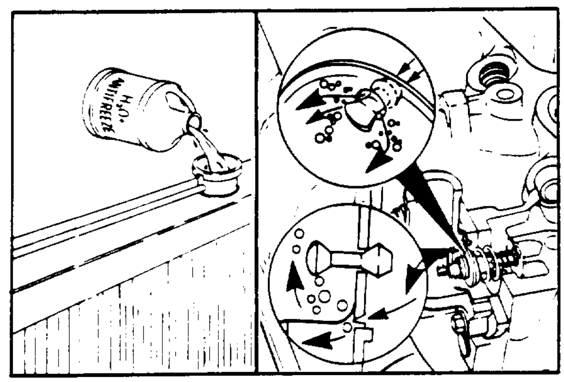


Caution: Never operate the engine without a thermostat. Without a thermostat the path of least resistance for the coolant is through the bypass to the pump inlet. This will cause the engine to overheat.

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

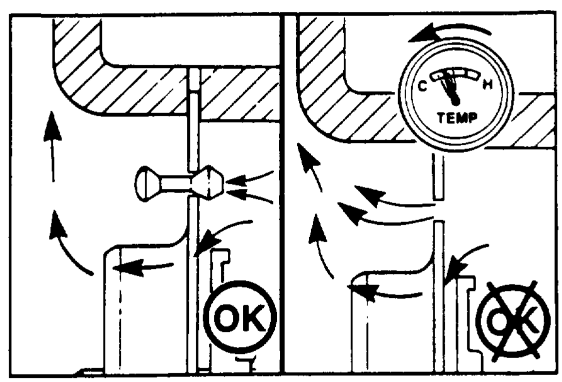


As described in the coolant discussion, a jiggle pin fitted to an opening in the thermostat flange is used to vent air during filling of the coolant system.

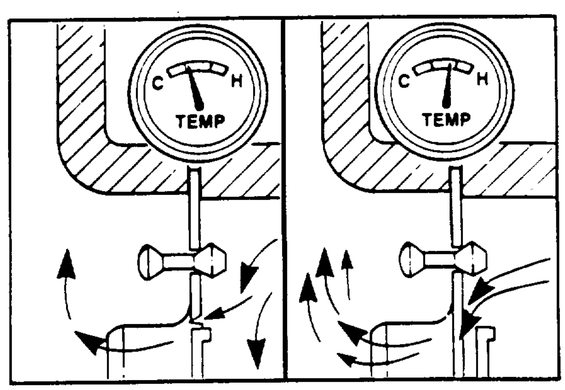


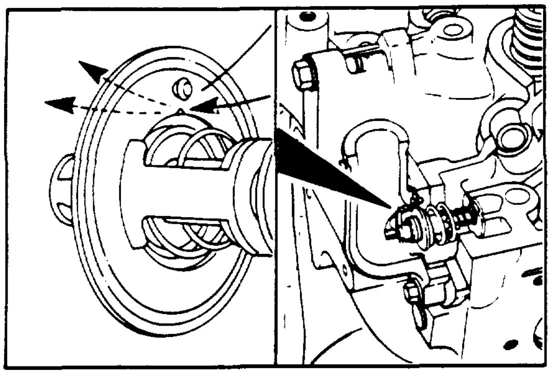
After the engine is vented and filled, the jiggle pin acts as a check valve to block the flow of coolant through the opening during engine operation.

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

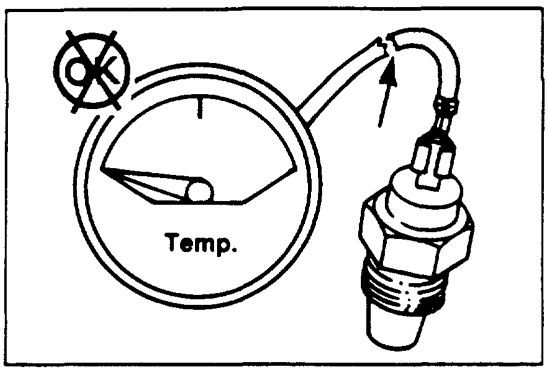


With the jiggle pin sealing the opening, most of the flow to the radiator is controlled by the thermostat in response to the engine coolant temperature.



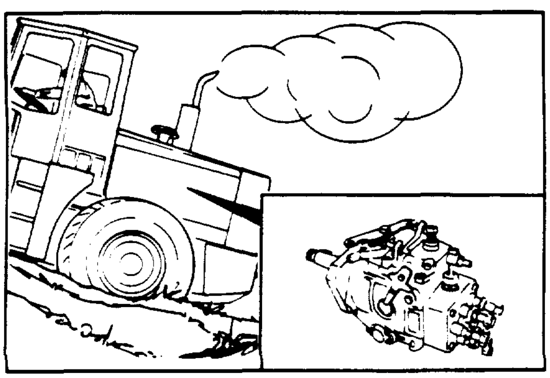


A small amount of continuous flow through the vent notch reduces the frequency of the closing or surging of the thermostat.

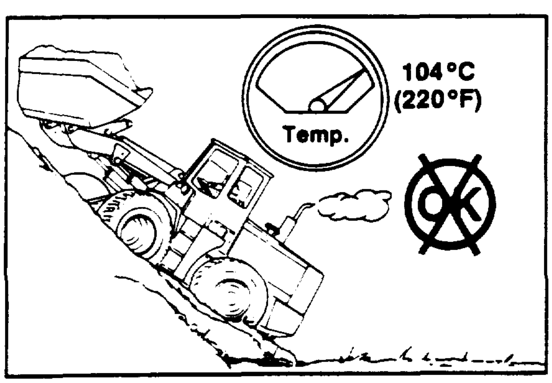


Gauges, Overfueling and Loading

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



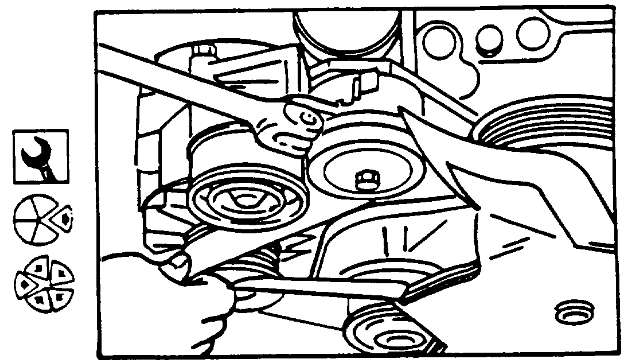
Caution: Overfueling can cause the engine to overheat. Make sure that the fuel pump is calibrated correctly.



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

Cooling System Replacement Procedures

Drive Belt - Replacement



1/2 inch Square Drive

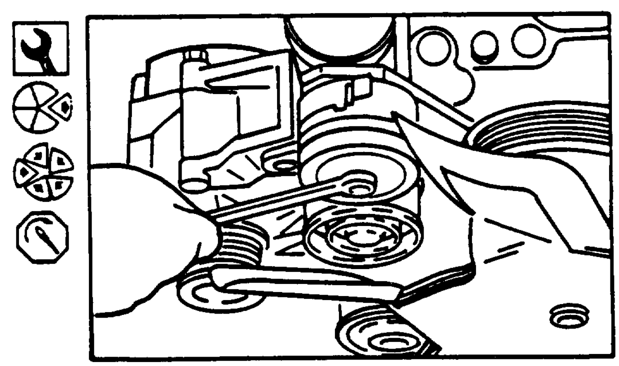
Lift the tensioner to remove and install the drive belt.

Belt Tensioner - Replacement

Preparatory Step:

• Remove the drive belt

15mm



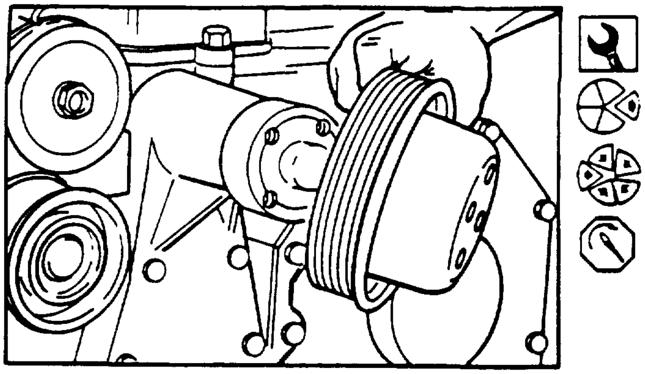
Remove the capscrew and replace the tensioner.

Torque Value: 43 N•m 132 ft-lbs]

Fan Pulley Replacement

Preparatory Step:

• Remove the drive belt.



13mm

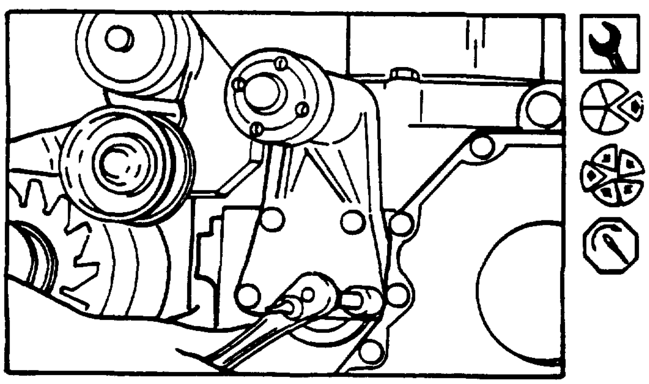
Remove the four capscrews, fan and spacer. Replace the fan pulley.

Torque Value: 24N•m [18 ft4bs]

Fan Hub - Replacement

Preparatory Steps:

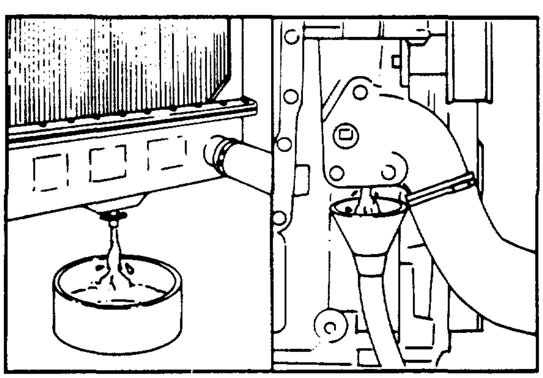
- Remove the drive belt.
- Remove the fan pulley.



10mm

Remove the four capscrews and replace the fan hub.

Torque Value: 24N•m [18 ft4bs]



Coolant - Draining

The coolant is 50% mixture of water and ethylene-glycol base antifreeze; use an 8 gal. (30.3 L) capacity container.

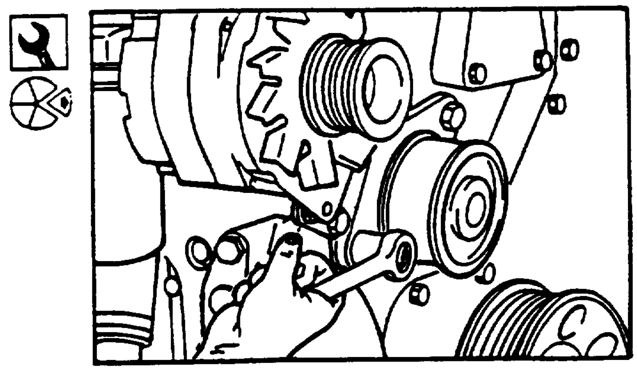
Water Pump - Replacement

Preparatory Steps:

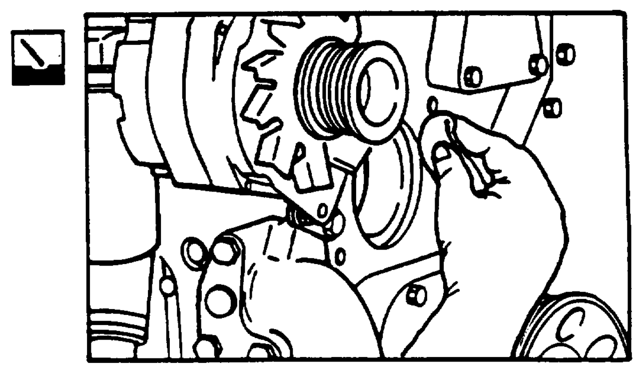
- Drain the coolant.
- Remove the drive belt.

1
3mm

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



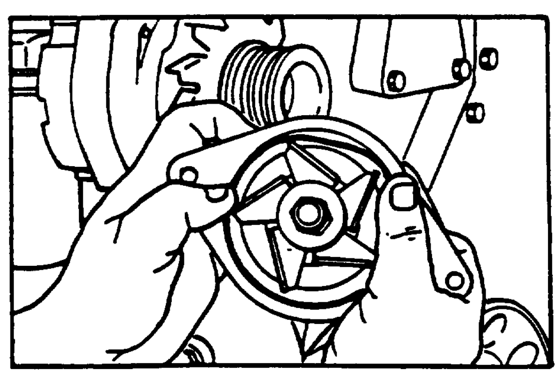
Clean the sealing surface on the cylinder block.

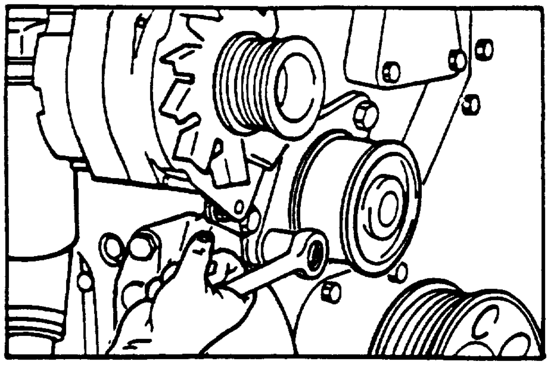


Inspect impeller blades for wear or corrosion.

Inspect pump for free rotation. Check weep hole for evidence that seal has been leaking.

Install the new o-ring into the pump groove.






13mm

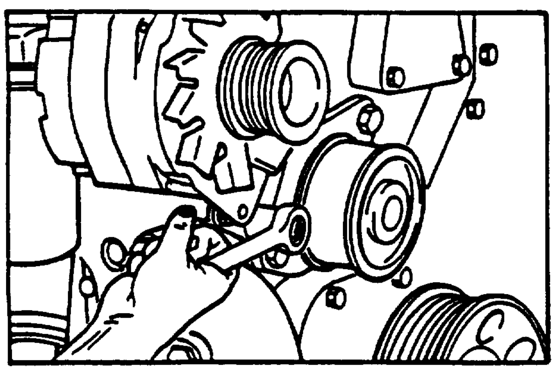
Install the water pump.

Torque Value: 24 N•m [18 ft-lbs]

Thermostat - Replacement

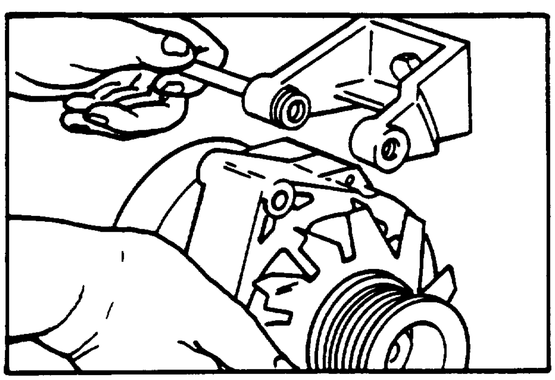
Preparatory Steps:

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




13mm

Note: Loosen the alternator link capscrew and complete the following steps.

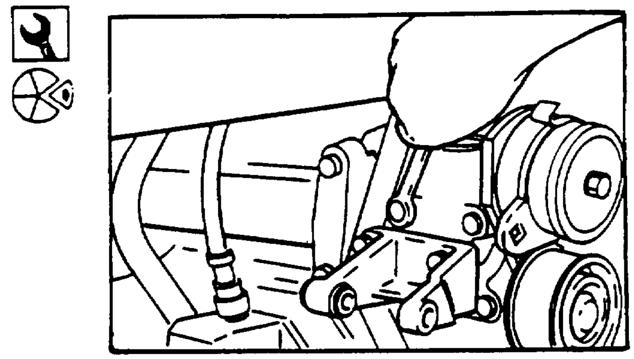



16mm

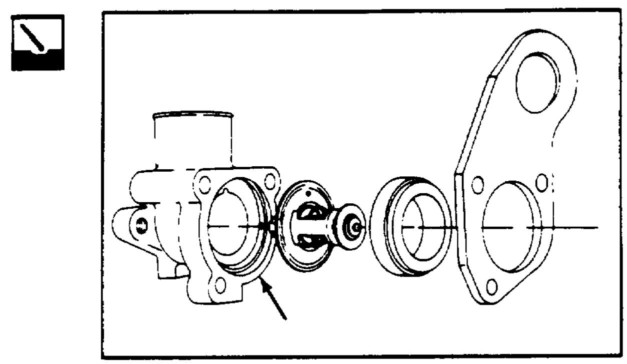
Remove the alternator mounting capscrew and lower the alternator.

10 mm

Remove the thermostat housing, lifting bracket and thermostat.



Clean the mating surfaces.

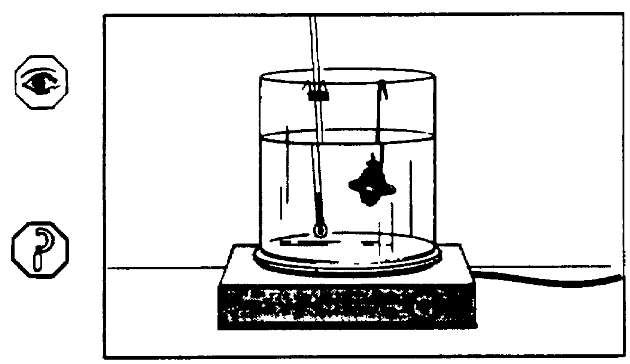


Thermostat - Inspection

Verify the thermostat is the new style pressure balanced thermostat. Do not reuse old style thermostats. Older style thermostats use a tang to orient the thermostat jiggle pins in the proper location. The newer style thermostat does not have a locator tang.

Visually inspect the thermostat for obvious damage such as obstructions caused by debris, broken springs, or stuck or missing vent pins.

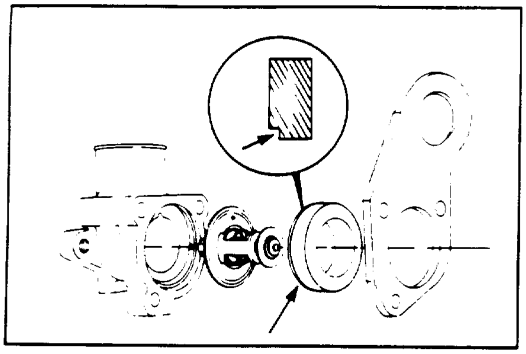
The thermostat can be checked for correct operation.



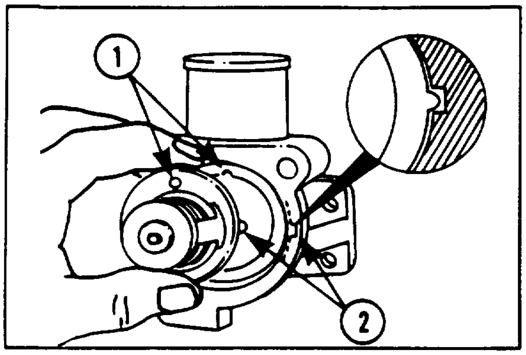
Requirements

Start to open at 83° C [181 °F].

Fully open at 95°C [203°F].



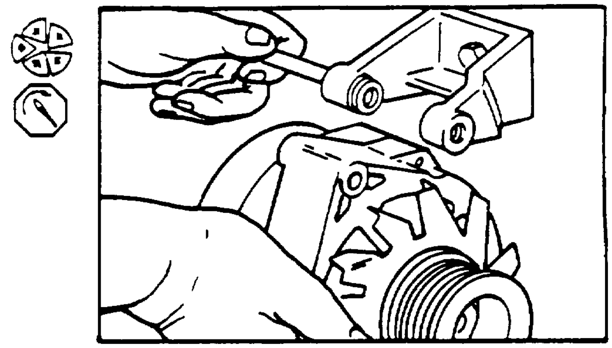
Position the rubber seal as shown for reassembly.



Note: Make sure the "jiggle" pin (1) is in the notch and the tang (2) is in the slot in the housing.

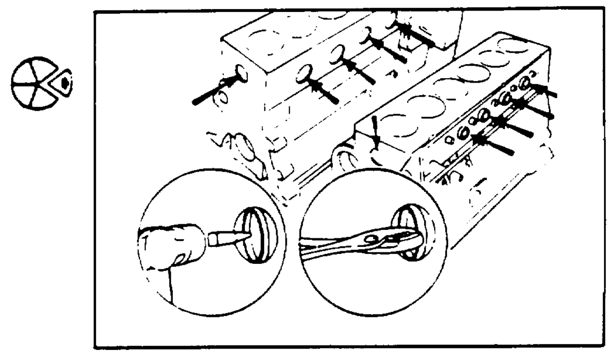
Assemble the removed parts in the reverse order of removal.

Torque Value: (Alternator Link) 43 N•m [32 ft-lbs]
(Alternator Mounting) 43 N•m [32 ft-lbs]
(Thermostat Mounting) 24 N•m ([18 ft-lb]

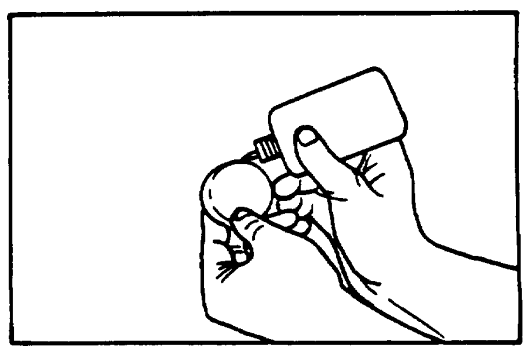


Cup Plugs Replacement

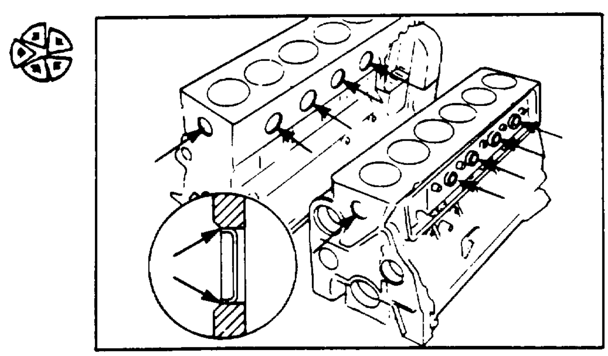
Remove the cup plugs from the coolant passages as shown.



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



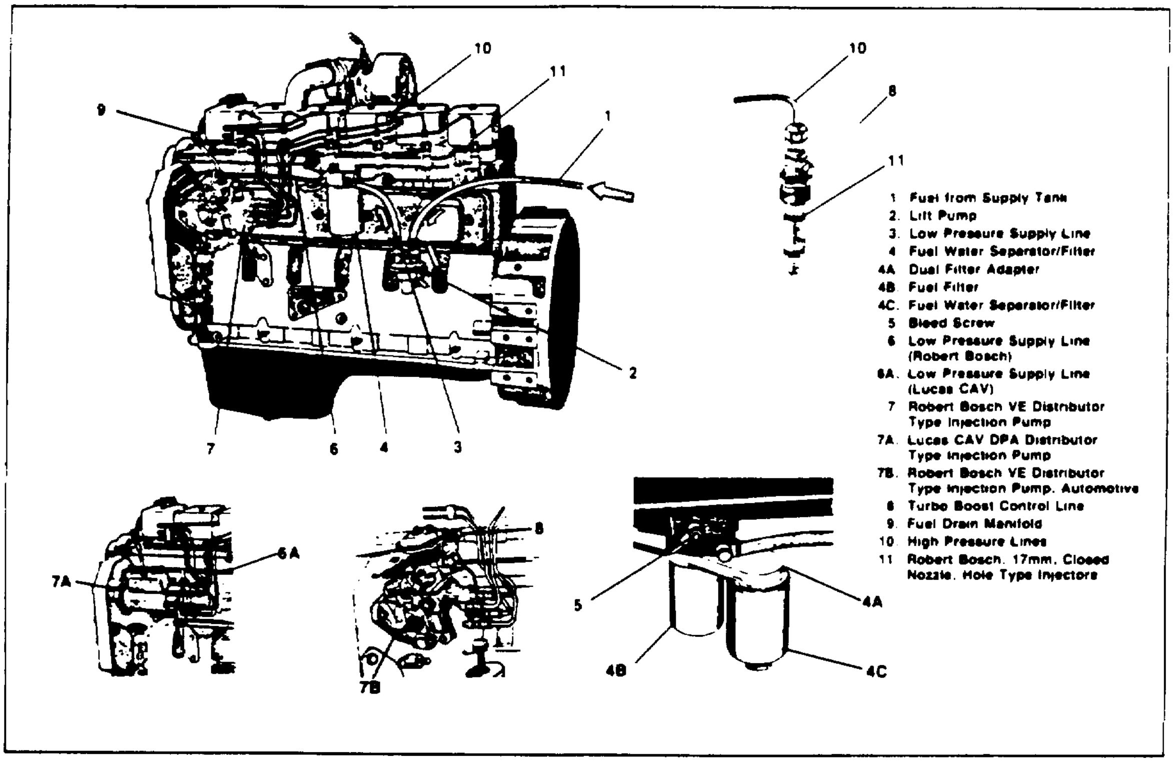
Drive the plugs in until the outer edge is flush with the counter sink in the block.



Section 4. Fuel System

Fuel System Components And Flow

The following illustration identifies the components of the fuel system.



Most of the engines will be equipped with a cam-actuated lift pump. Fuel flow begins as the lift pump pulls fuel from the supply tank. The 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 engines use distributor-type fuel pumps supplied by Lucas CAV.

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.

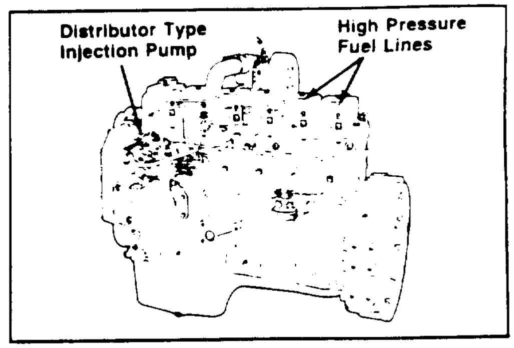
Any leakage past the needle valve enters the fuel drain manifold. The fuel drain manifold routes controlled venting from the distributor injection pump and leakage from the injectors back into the fuel tank.

Fuel System Specification

Maximum Allowable Restriction to Pump With Dirty Filter - mm Hg [in. Hg]	-------------------------	95 [3.75]	-------------------------
Maximum Allowable Return Line Line Restriction - mm Hg [in. Hg]	-------------------------	127 [5.0]	-------------------------
Maximum Allowable Pressure Drop Across Fuel Filter - kPa [psi]	-------------------------	21 [3]	-------------------------

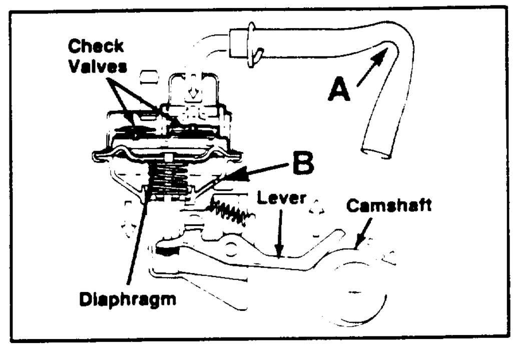
Fuel System Malfunction Diagnosis

The function of the fuel system is to inject clean, atomized fuel into the engine cylinders at a precise time near the end of the compression stroke of each piston. The components of the system contribute to the delivery of fuel to the cylinders.



Lift Pump

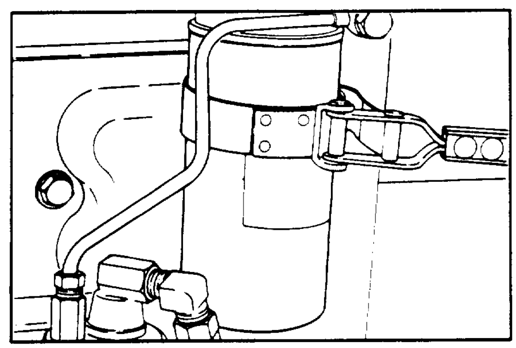
Note: A malfunctioning lift pump can cause low power from the engine.



The lift 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 152mm (6 inches) Hg.

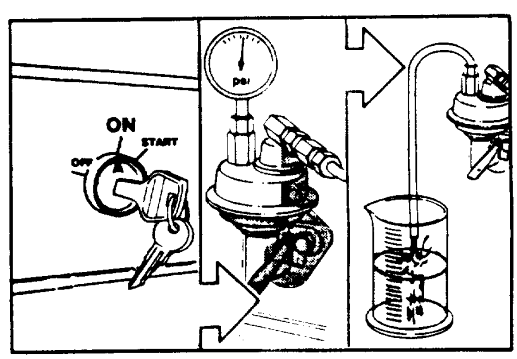
Caution: If the diaphragm ruptures, fuel will drain from the weep hole (B) in the housing.



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 lift 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 lift pump.

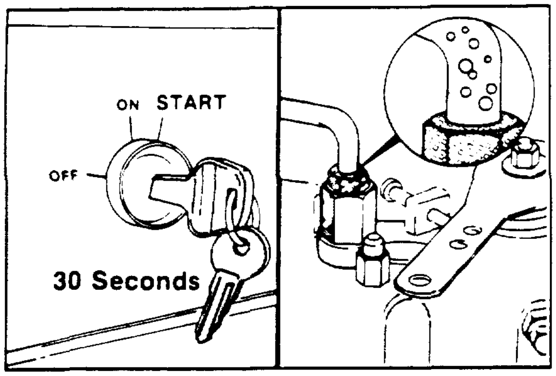


The output of the pump can be measured:

• Volume (within 30 seconds):

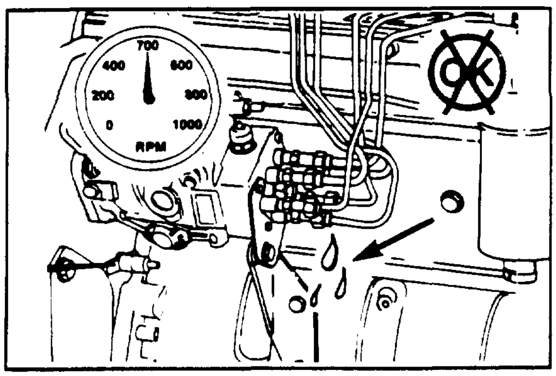
0.75 [0.70 U.S. qt.]

• Pressure: 21 to 35 kPa [3 to 5 psi]

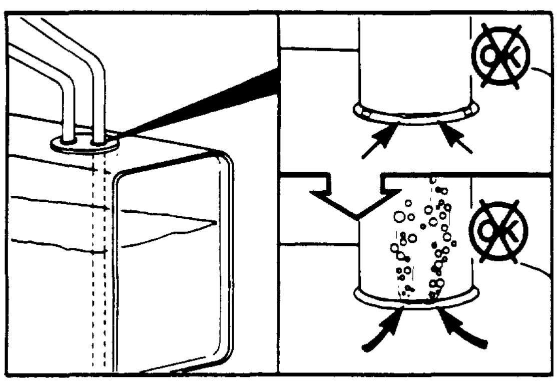


Air In the Fuel System

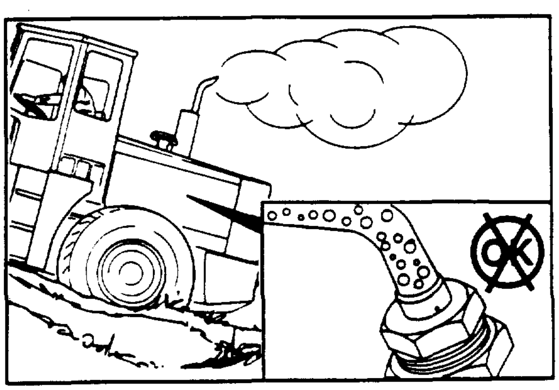
A replacement of supply lines, fuel filters, injection pump, high pressure lines and injectors will let air enter the fuel system. Follow the specified procedure to bleed the air from the system.



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



The most usual place for air to enter the fuel system is between the inlet of the lift pump and the suction tube in the tank. Fuel tanks that have the 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.

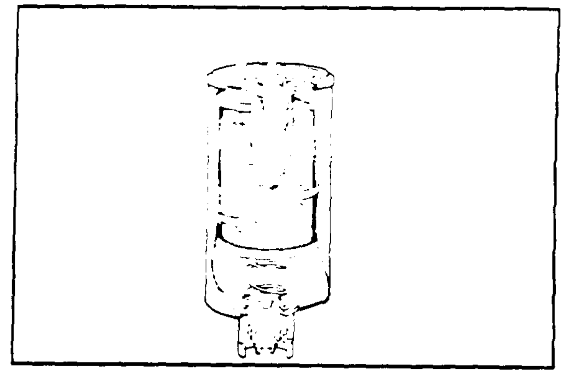


Air in the system will make the engine: hard to start, run rough, misfire, produce low power, and can cause excessive smoke and a fuel knock.

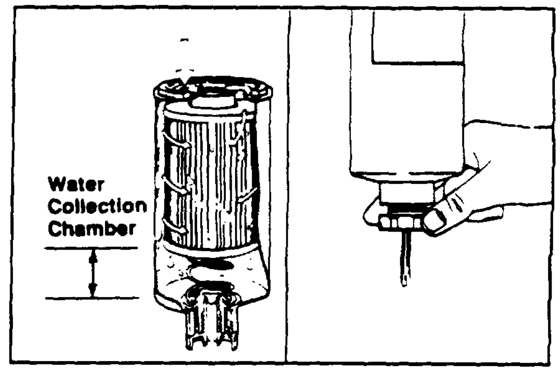
Fuel Water Separator/Filter Unit

Caution: Be sure to use the correct element.

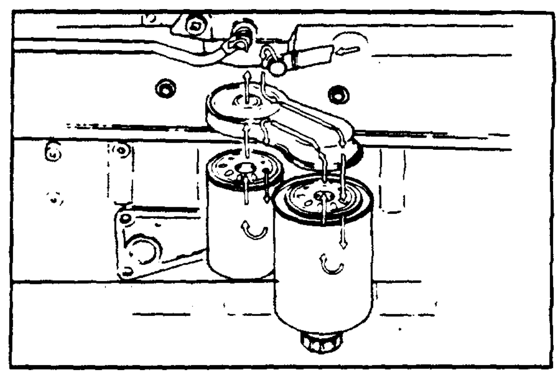
Filtration and separation of water from the fuel is important for trouble-free operation and long life of the fuel system. Some of the clearances between the pump parts are very close. For this reason the parts can easily be damaged by rust formation and contaminants.



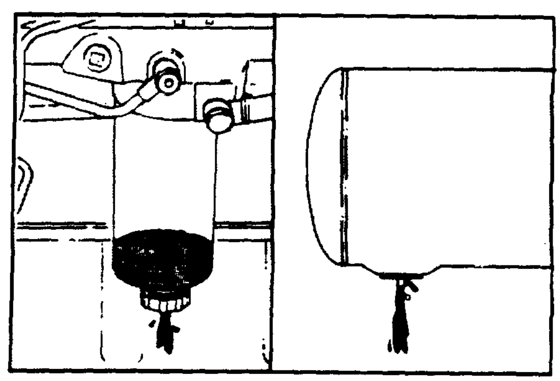
The element has a valve which can be opened regularly to drain the collected water.

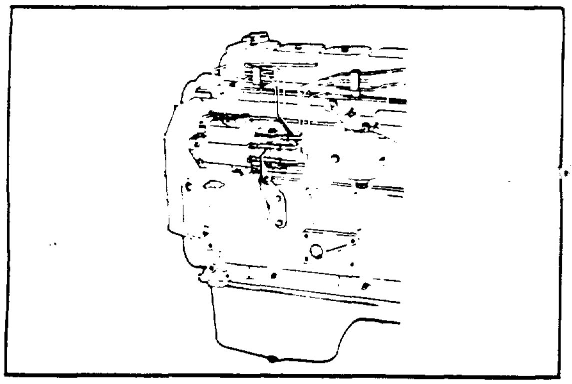


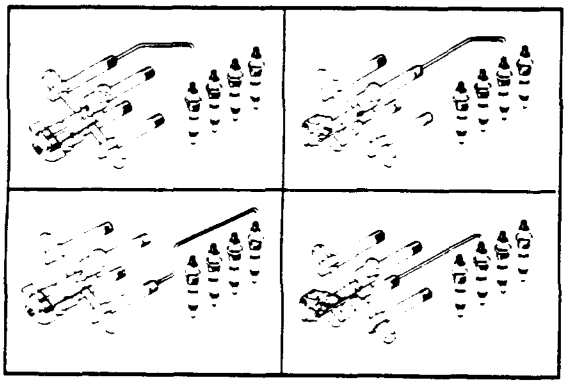
A dual water separator/filter adaptor option provides additional filtering capacity. It is used in severe environments, where there is great exposure of the fuel to water, rust particles, dust and other contaminants. The fuel flows through the adapter to a larger combination fuel water separator filter, 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.







Injection Pump

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 pumps to develop and distribute the high pressure required for injection.

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 pump is injecting fuel from one outlet, it will deliver from all outlets.

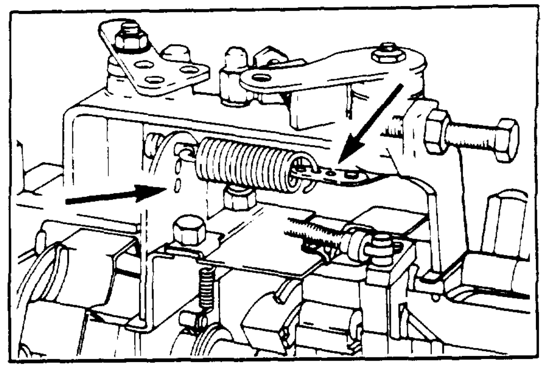
Governor Malfunctions

Balance between the flyweight governor 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.

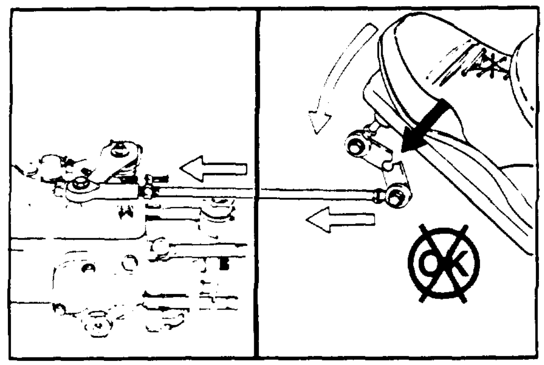
The Lucas CAV DPA pump uses a coded spring connection to change the governor setting. Incorrect connection of the governor spring can affect performance.

Adjustments and rating changes are described in this section.



Fuel Control Lever Travel and Adjustment

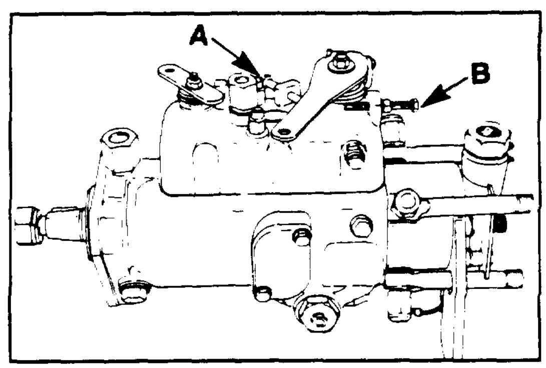
The amount of fuel injected and subsequently the speed and power from the engine is controlled by the fuel control lever. Restricted travel of the lever can cause low power. Always check for full travel of the lever when diagnosing a low power complaint.



Lucas CA V DPA 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.

A - Idle screw

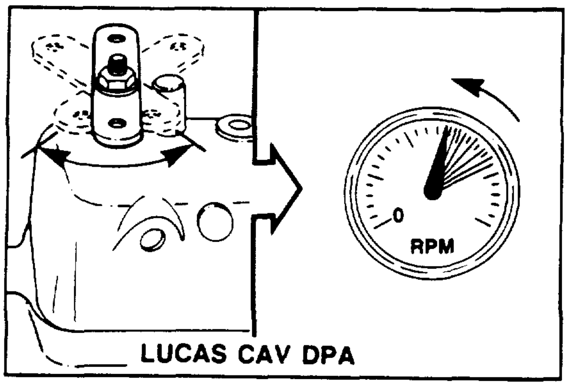
B - High Idle Screw



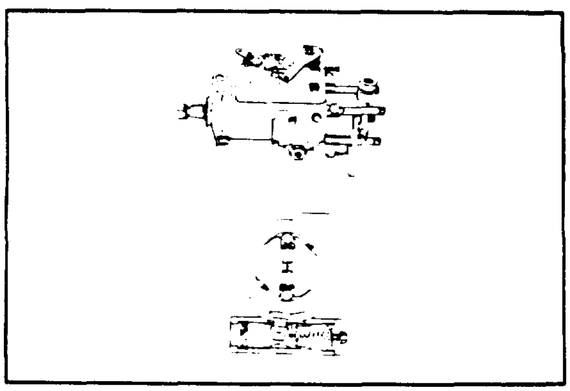
Manual Shut Down Levers

Both 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 shutdown 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.



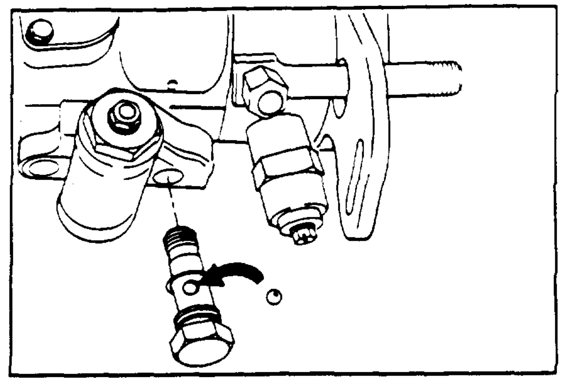
Advance Timing Mechanism

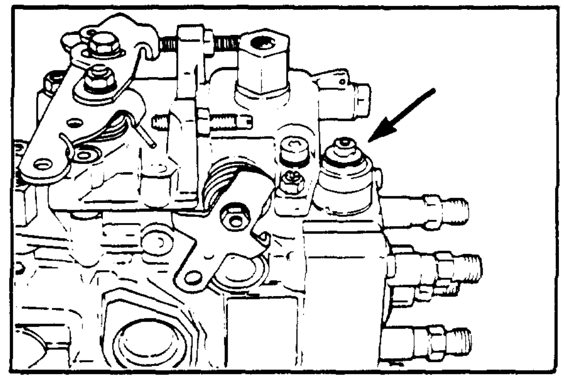
Regulated pressure produced by a vane supply in both injection pumps is used to advance the timing as the engine speed increases. A return spring is used to retard the timing as the engine speed is reduced. If a spring should break, the timing will go to the advance position resulting in torque loss, 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 advance timing mechanism uses a check ball in the circuit which, if omitted during assembly, will result in no timing advance. If the pump has been replaced or the mechanism has been removed to fix a leak, the problem can be that the check ball is missing.

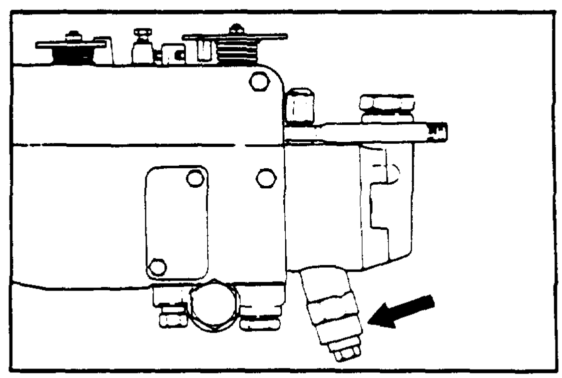
Replacement of the spring and repair of the advance timing mechanism must be performed by an authorized injection pump service center.





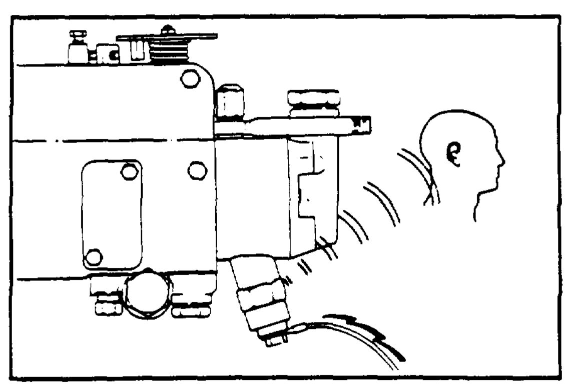
Electrical Shut Off Valves

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

The valves are designed to be closed when there is no electrical power to the solenoid.

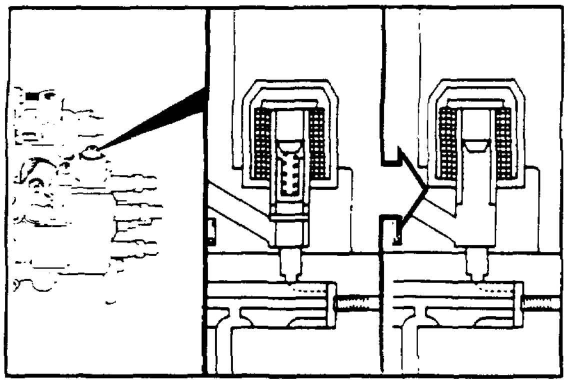


When the valve on the Lucas CAV pump opens, a "click" can be heard.

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

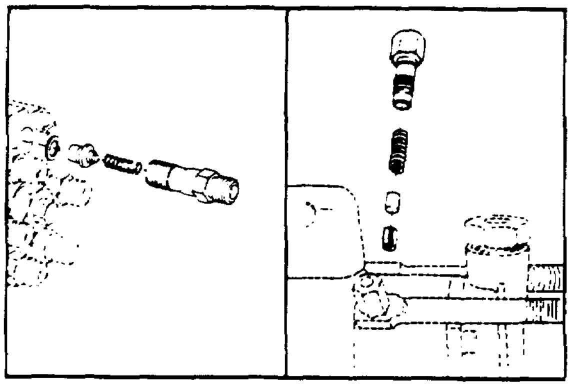
CAV Solenoid Values

Volts	**Resistance Ohms**	**Volts to Energize (Minimum)**
12	9@ 22 ° C (71.6° F)	9



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 can be diagnosed by removing the plunger and spring, then reinstall the solenoid.



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.

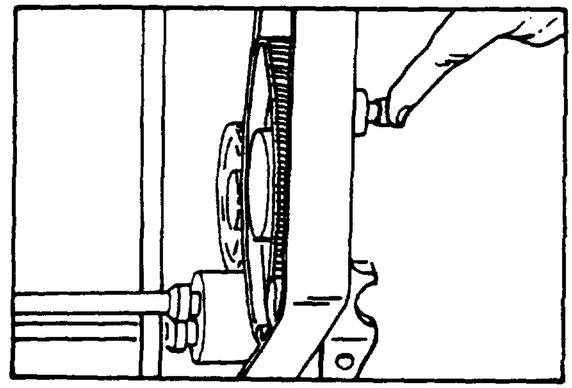
Injection Pump Timing

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

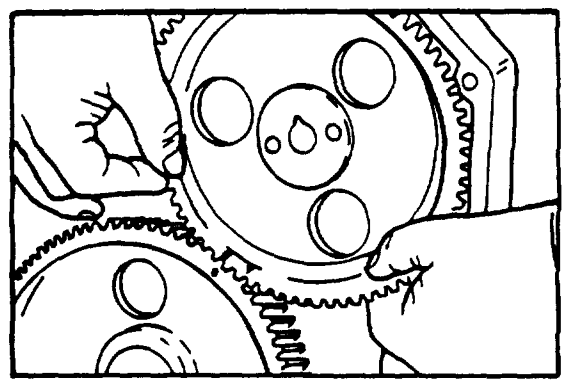
Engine pump timing begins with the timing of the injection pump drive gear to the camshaft gear.

The first step is the location of TDC for Cylinder Number 1.



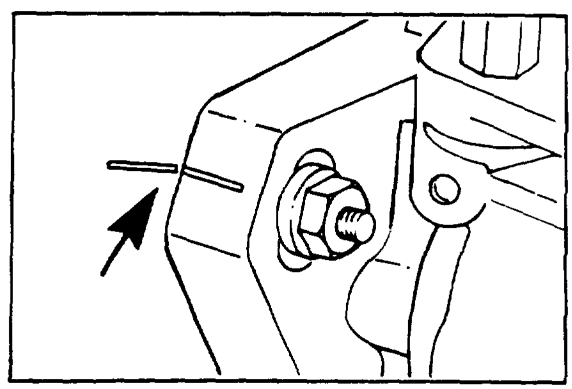
Then, depending on the engine configuration, a letter on the gear is aligned with the mark on the camshaft gear.

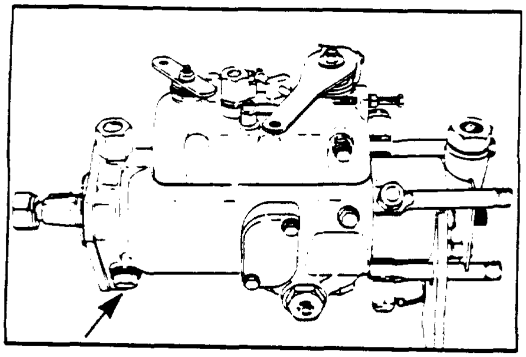
Letter	Engine
A	4B3.9, 4BT3.9 (Lucas CAV DPA Pump)



To verify that the injection pump is timed correctly, first check the alignment marks on the pump flange and gear housing.

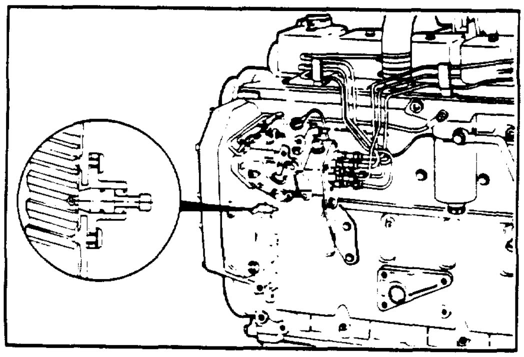
Note: 1 mm of rotation past the timing mark will advance or retard (depending on direction of rotation) the pump timing by 1 degree.



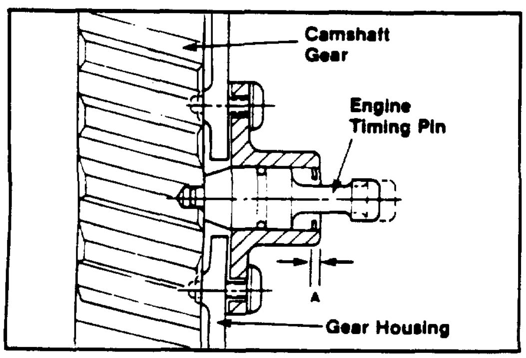


Both pumps have a provision for locking the pump shaft at a position corresponding to top-dead-center for Cylinder Number 1. New and reconditioned pumps should be received with the shafts locked in this position.

Note: The illustration shows pumps for the 4 cylinder and has the keys aligned with the number 1 delivery valve.

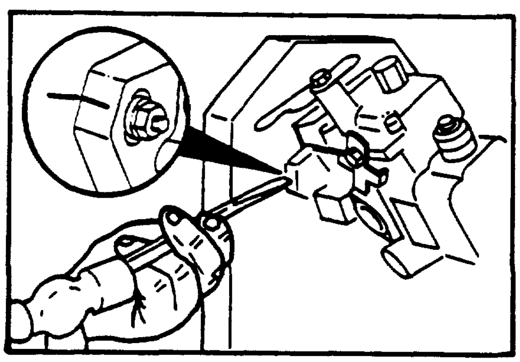


The engine is equipped with an engine timing pin to locate TDC for Cylinder Number 1.



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 Number 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

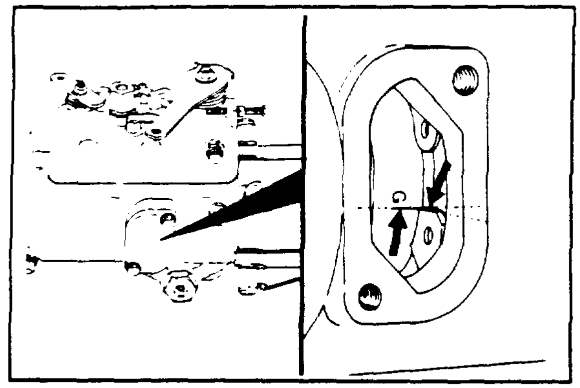


Caution: The flange of a replacement pump must be marked to align with the mark on the gear housing after installation.

During production, after the locked pump is fitted to the engine with Cylinder Number 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.

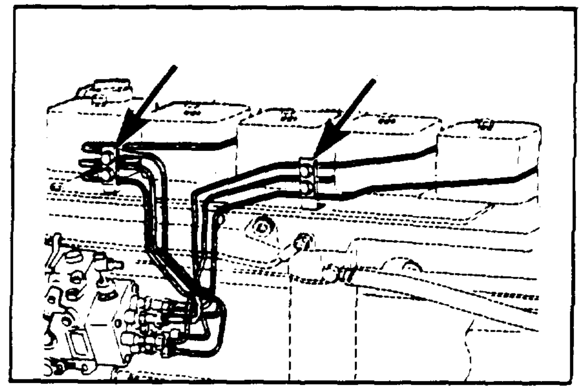
Correct timing of the Lucas CAV DPA pump can be verified by removing the inspection plate.



Note: Special equipment in an authorized shop is required to precisely time the Lucas CAV DPA pump. However, for trouble-shooting and in an emergency, visual alignment of the timing mark is close enough for the engine to run.

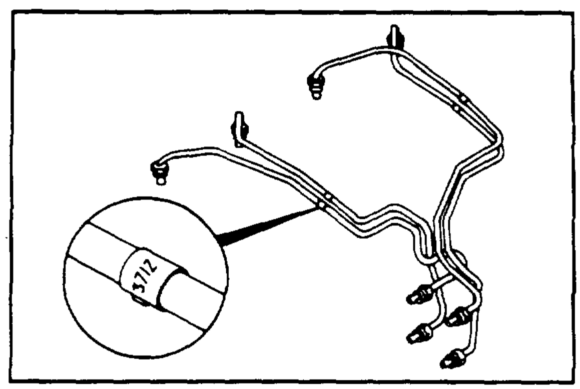
Both of these check are described in the injection pump replacement discussion. Installation of the timing pin housing is described in the Base Engine Components Section.

High Pressure Fuel Lines



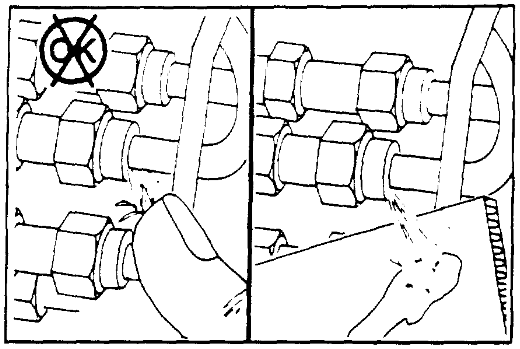
Caution: The high pressure lines must be clamped securely and routed so they do not contact each other or any other component.

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.



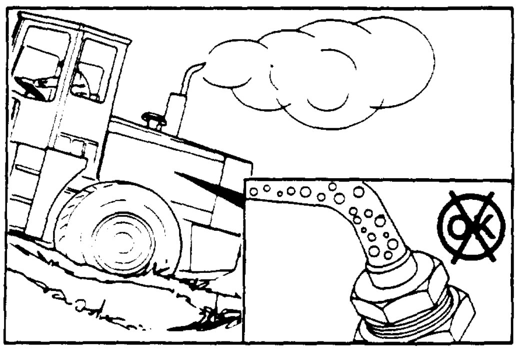
Caution: Do not weld or substitute lines; use only the specified part number for the engine.

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.

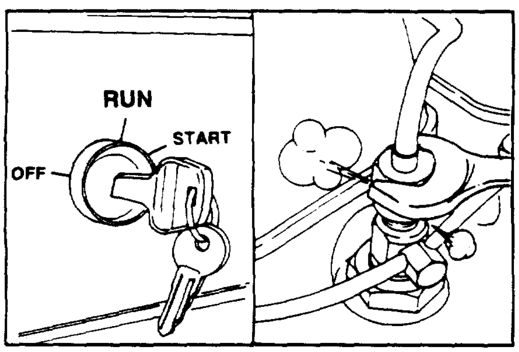


Warning: The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious bodily harm.

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.

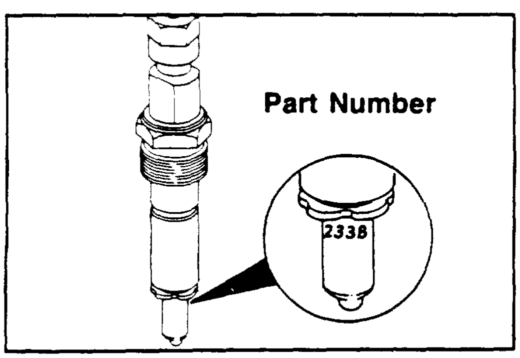


It is normal to have entrapped air in the fuel lines after replacing the pump or the lines. Air in the lines will cause the engine to run rough or produce a fuel knock.



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.

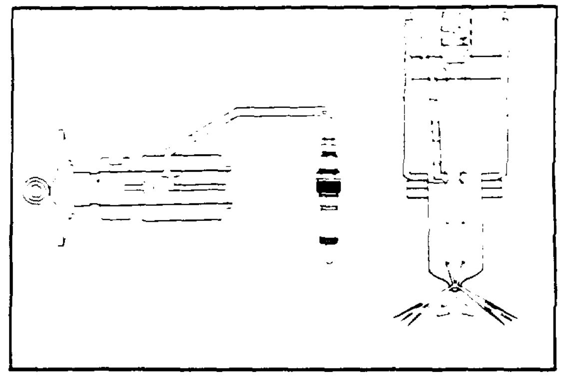


Injectors

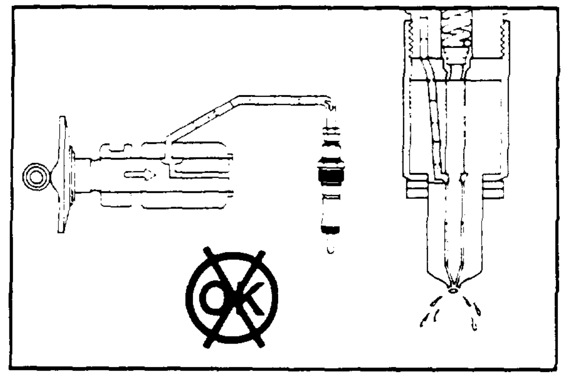
Caution: Use only injectors with number 2338 marked on the side as shown in illustration.

All engines use Robert Bosch, 7mm closed nozzles, hole-type injectors. 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.

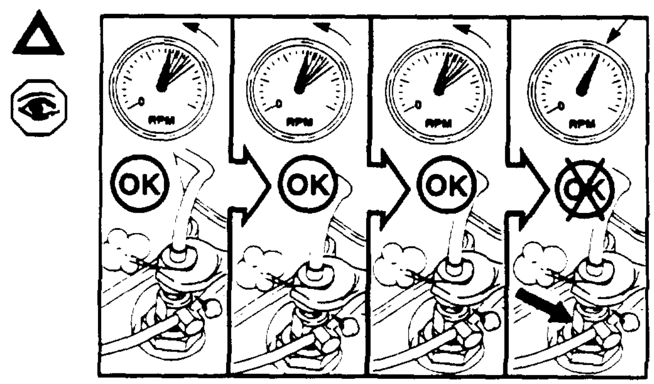


Caution: Be sure to tighten the fuel line nut before proceeding to the next injector.

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.

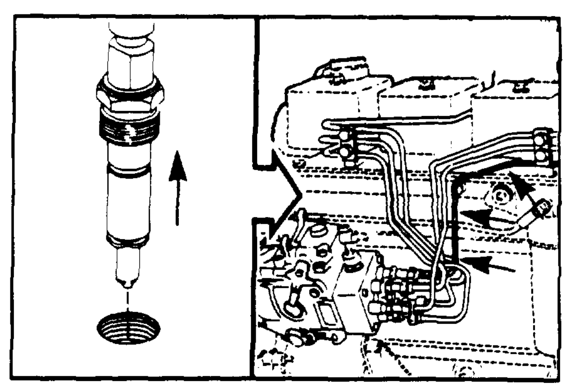
Note: A drop in engine speed indicates the injector was delivering fuel to the cylinder.

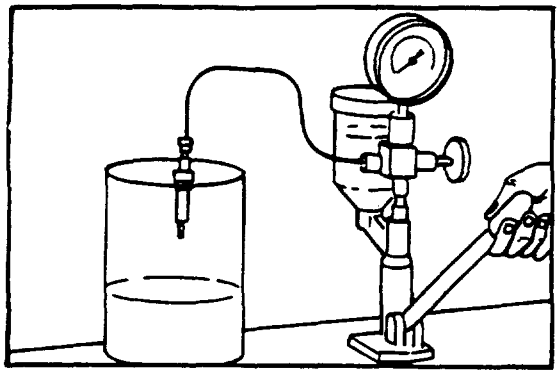
Check each cylinder until the malfunctioning injector is found.



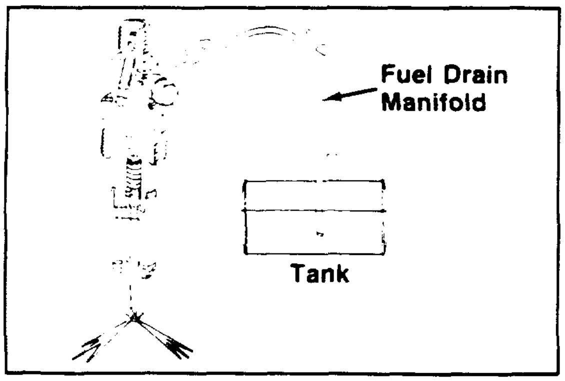
Remove the malfunctioning injector to test or replace it.

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.



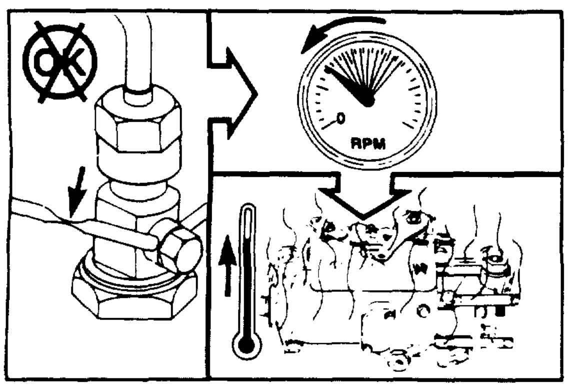


Carbon build up in the orifices in the nozzle will also cause low power from the engine. Remove and check the spray pattern or replace the injectors.



Fuel Drain Manifold

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 injection pump metering controls and the operation of the injectors. Restricting the fuel drain manifold raises the case pressure of the 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.

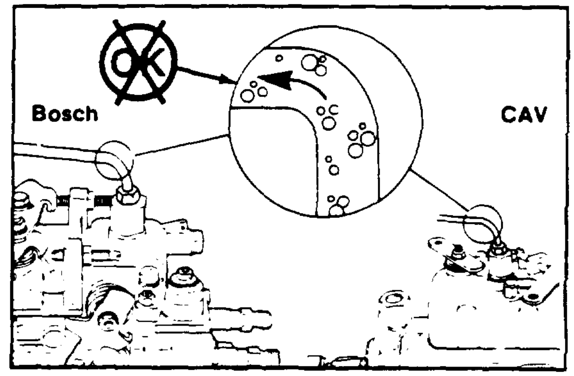
Note: Restriction can cause the fuel temperature to rise reducing power from the engine.

Fuel System Replacement Procedures

A certain amount of air will be entrapped in the system during replacement of any of the system components. After replacement of a component, bleed the system according to the following procedure.

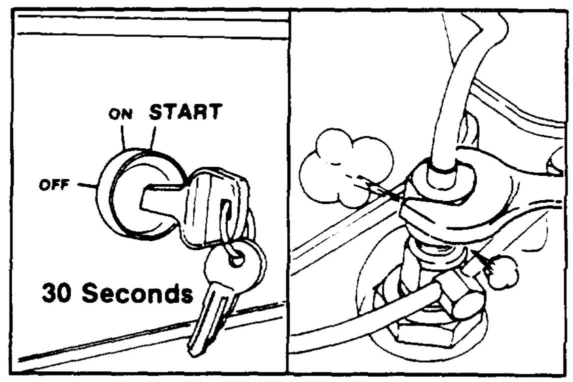
Fuel System - Bleeding

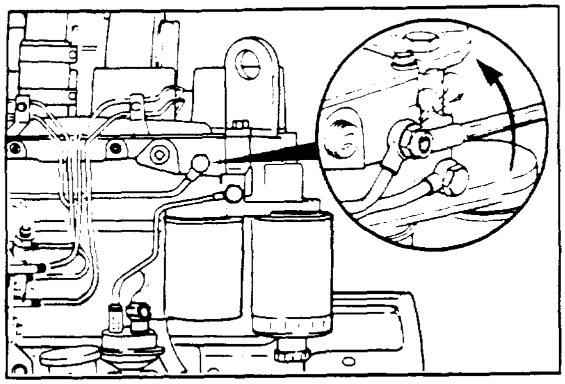
Controlled venting is provided at the injection pump through the fuel drain manifold. Small amounts of air introduced by changing the filters or injection pump supply line will be vented automatically, if the fuel filter is changed in accordance with the instructions.



However, manual bleeding will be required if:

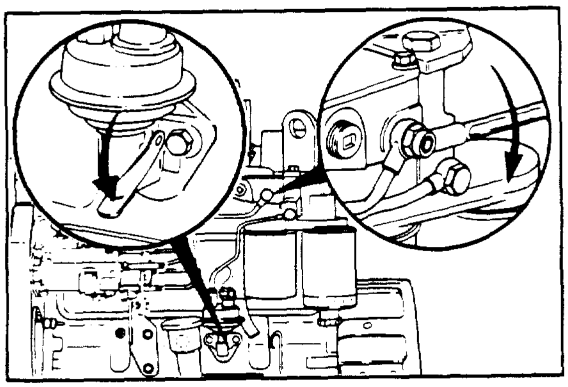
- The fuel filter is not filled prior to installation.
- Injection pump is replaced.
- High pressure fuel line connections are loosened or lines replaced.
- Initial engine start up or start up after an extended period of no engine operation.





Low Pressure Lines and Fuel Filter - Venting 10mm

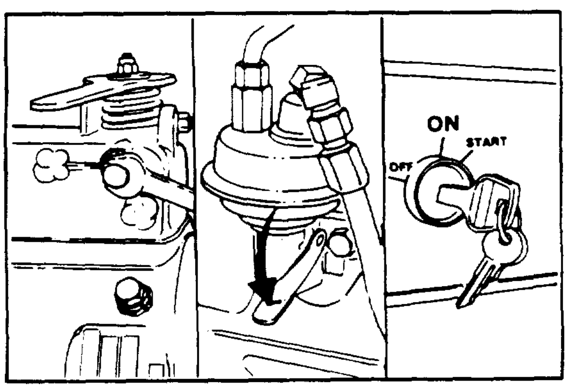
Open the bleed screw.



Operate the hand lever until the fuel flowing from the fitting is free of air.

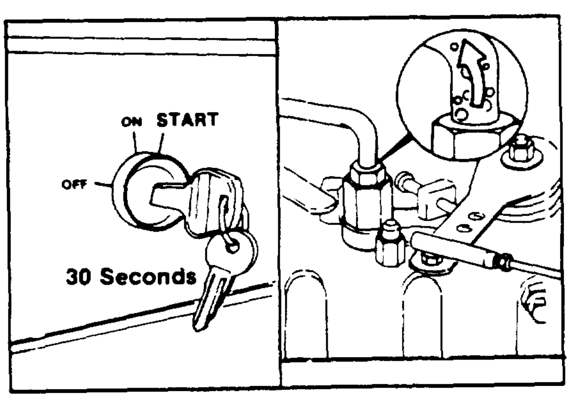
Tighten the bleed screw.

Torque Value: 8 N•m [6 ft-lb]



Injection Pumps - Venting 8mm

Air/Fuel can be pumped from this location on the Lucas CAV pump with the hand lever on the lift pump, if the fuel solenoid valve is energized.



Warning: 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.

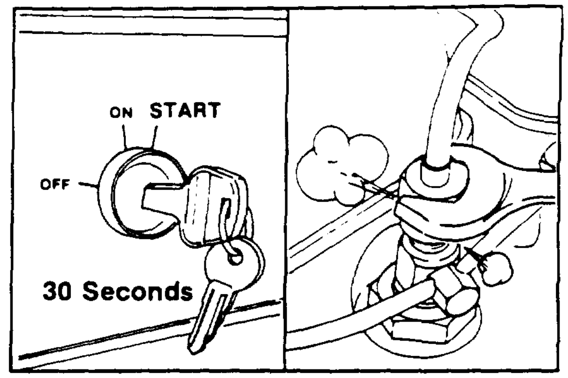
Caution: When using the starting motor to vent the system, do not engage it for more than 30 seconds at a time: Wait two (2) minutes between engagements.

Air can also be vented through the fuel drain manifold line by operating the starting motor.

High Pressure Lines - Venting 17mm

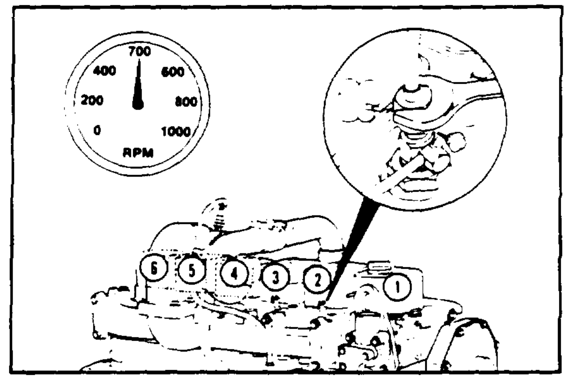
Warning: The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious bodily harm.

Loosen the fittings at the injector, and crank the engine to allow entrapped air to bleed from the line. Tighten the fittings.



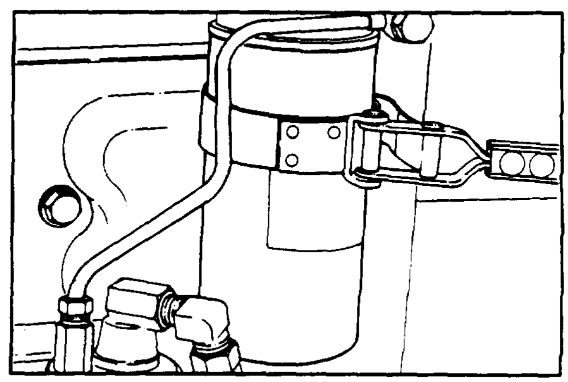
Warning: Do not bleed a hot engine as this could cause fuel to spill onto a hot exhaust manifold creating a danger of fire.

Start the engine and vent one line at a time until the engine runs smoothly.



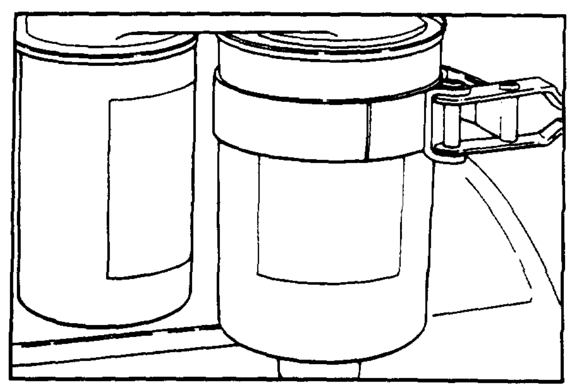
Fuel Filter - Replacement
80 to 95mm, Filter Wrench

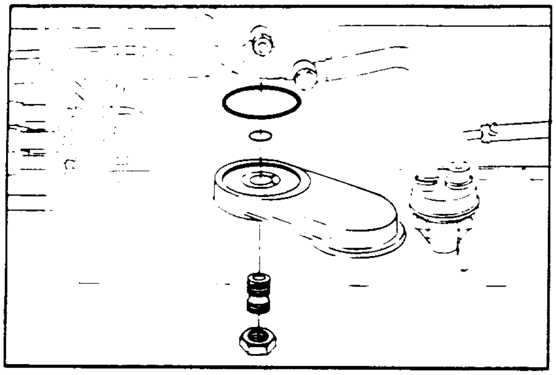
Remove the combination water separator/fuel filter.

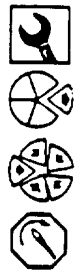


80 to 95mm, Filter Wrench

If used, remove the two filters from the dual filter adaptor.



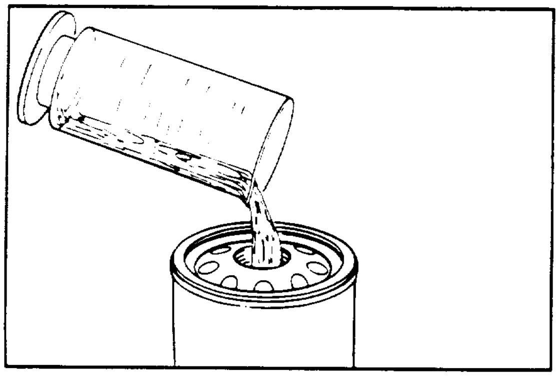




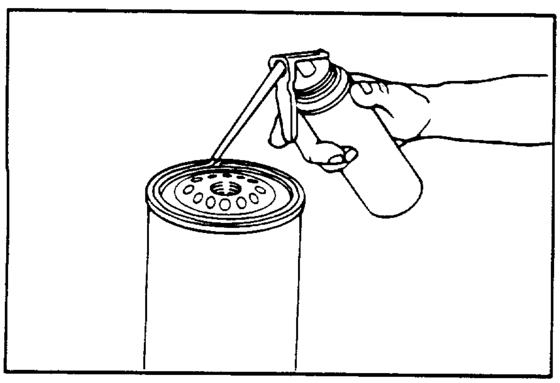
24mm, Flat Blade Screwdriver

If a leak is found, remove the dual filter adapter and replace the o-rings.

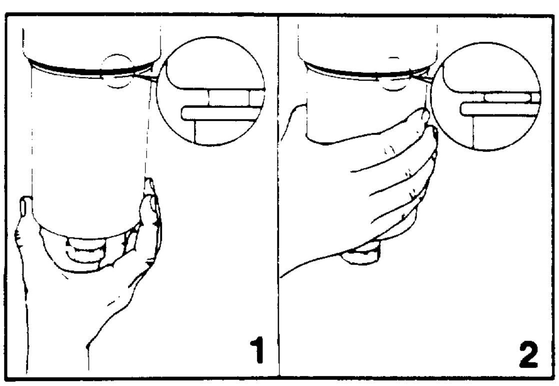
Torque Value: 32 N•m [24 ft4bs]



Fill the new filter(s) with clean fuel.



Lubricate the seal with clean oil.

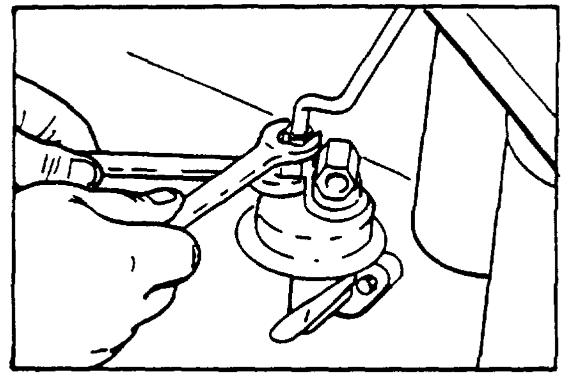


Install the filter(s) and tighten it ½ turn after its seal contacts the filter head.

Low Pressure Fuel Line - Replacement 14mm and 17mm

Remove the line from the lift pump and filter head.
Clean fuel lines with approved solvent. Then blow dry with clean low pressure air.

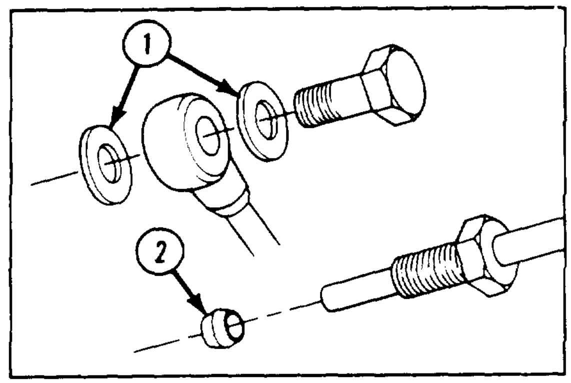
Inspect fuel lines for cracks and worn seals.
Inspect and replace any damaged seals.



NOTE
Coat seals in clean engine oil to aid in installation.

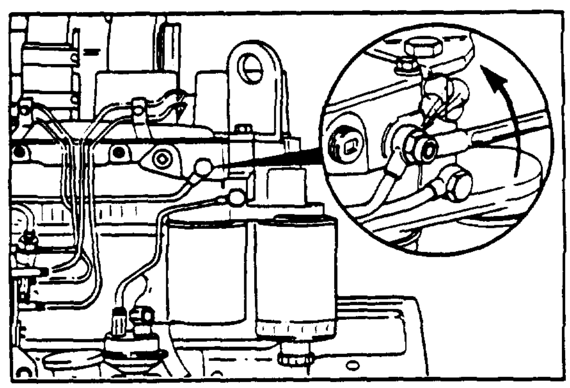
Caution: When replacing fuel lines, replace banjo fitting sealing washers (1) and ferrules (2) each time they are removed.

Install the line and tighten the fittings securely.



10mm

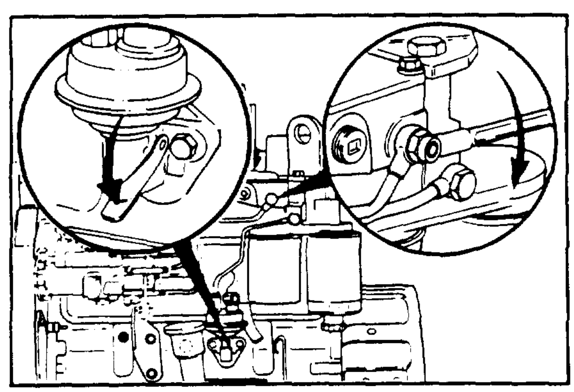
Bleed the line by opening the banjo bleed screw.

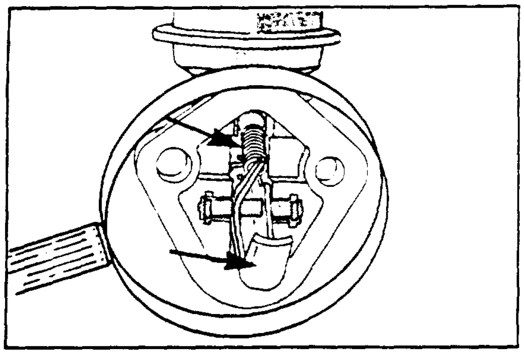


10mm

Operate the hand lever until the fuel flowing from the fitting is free of air.

Tighten the bleed screw.



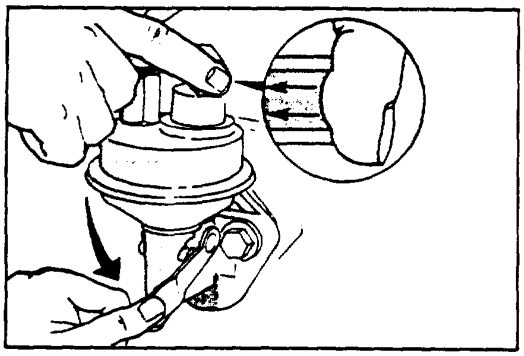


Lift Pump - Replacement

Preparatory Step:
- Disconnect the low pressure fuel lines

10mm

Remove the lift pump and complete the following steps. Inspect the camshaft lever and the return spring for excessive wear.

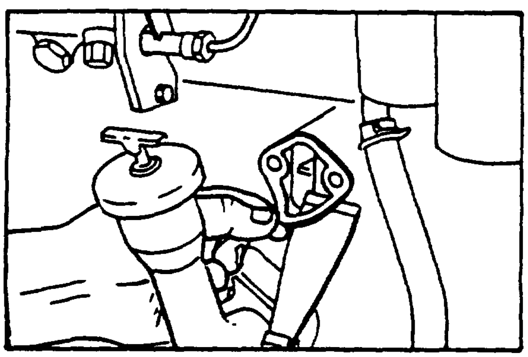


To inspect the lift pump, pour clean diesel fuel or engine oil into the inlet connection and perform the following test:

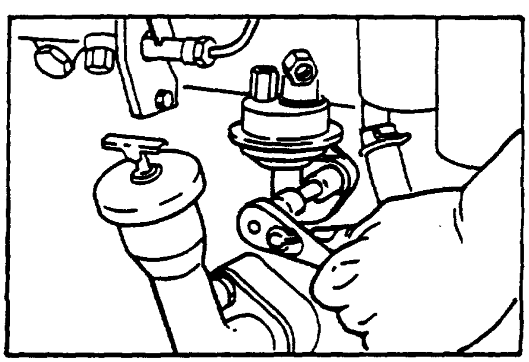
Inspect the diaphragm by blocking the fuel inlet line with your finger and operating the priming lever.

A good pump will have suction that will not bleed down until the finger is removed from the inlet.

On standard lift pumps, parts replacement is not practical; the pump is serviced as an assembly. An optional lift pump is available which can be cleaned and repaired with a minor repair kit.



Clean the mounting surface on the cylinder block.



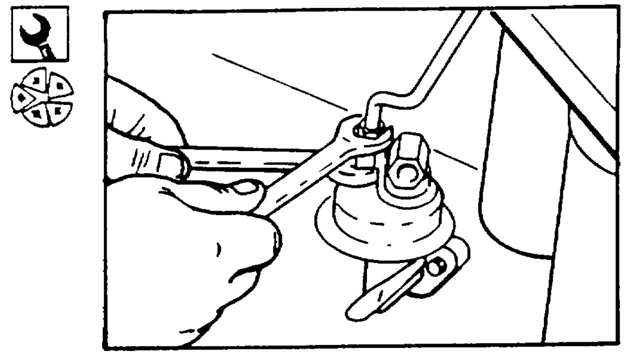
10mm

Install the lift pump with a new gasket.

Torque Value: 24 N•m [18 ft-lbs]

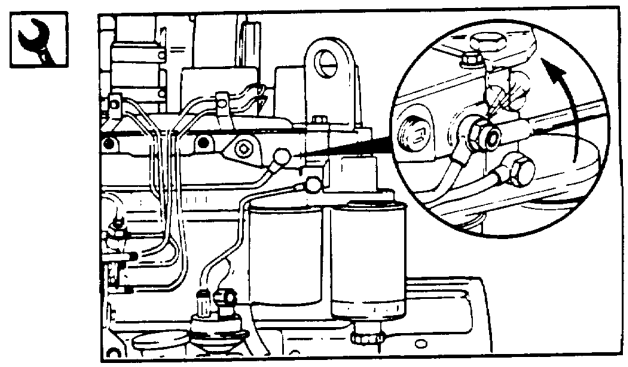
14mm and 17mm

Install the low pressure fuel lines.



10mm

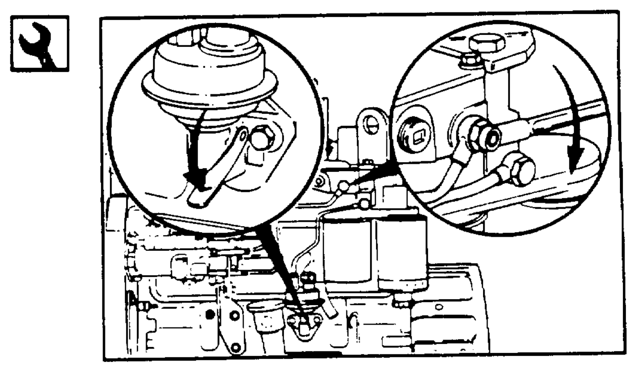
Open the banjo bleed screw to bleed the low pressure line.



10mm

Operate the hand lever until the fuel flowing from the fitting is free of air.

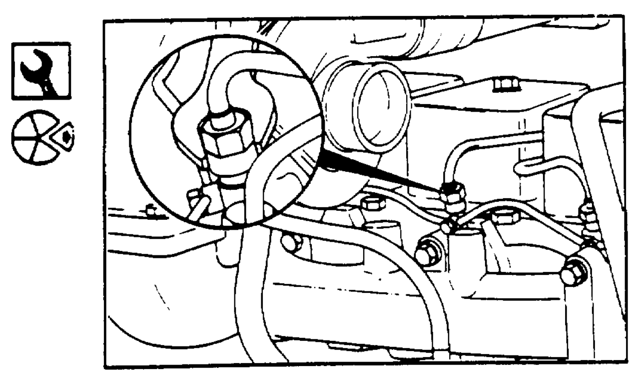
Tighten the bleed screw.

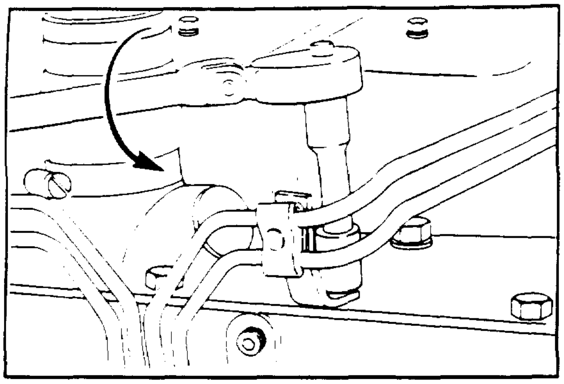


High Pressure Lines - Replacement

17mm

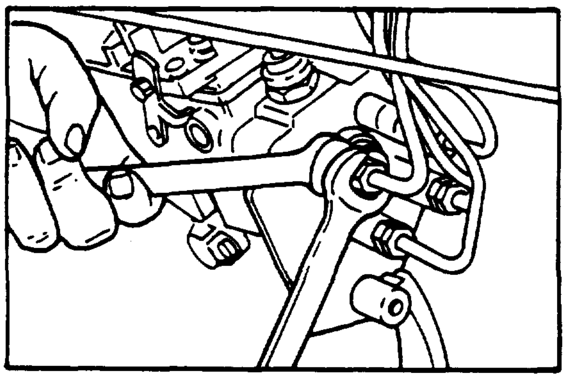
Disconnect the high pressure lines from the injectors and complete the following steps.





10mm

Remove the line clamp capscrews from the intake cover.



14mm and 17mm

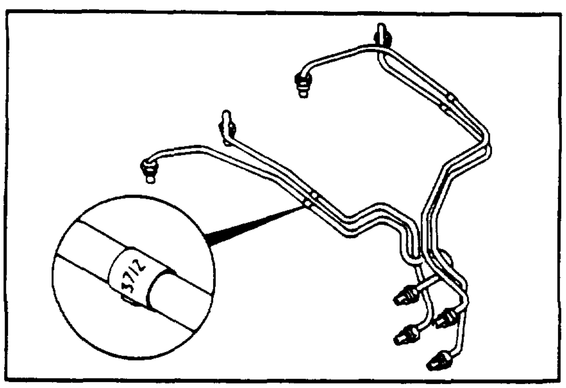
Remove the lines from the injection pump.

Note: Use two wrenches to prevent the delivery valve holder from turning.

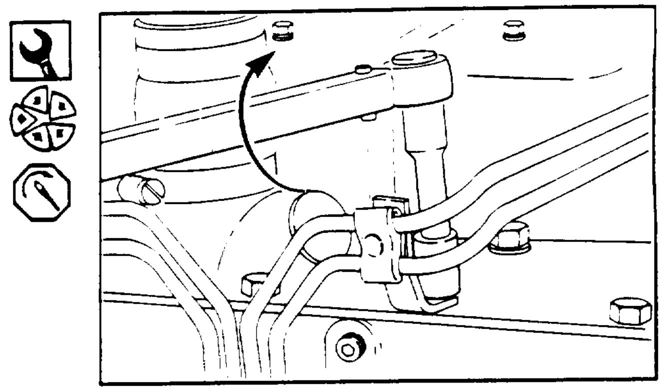
Visually inspect for cracks at both ends of the fuel lines.

Caution: The high pressure lines must be damped securely and routed so they do not contact each other or any other component. Inspect for areas of contact that have worn the material thin.

Inspect the vibration isolators (clamps). Make sure all the vibration isolators are positioned and tightened properly. Missing or improperly installed isolators will almost certainly result in fuel line failure.



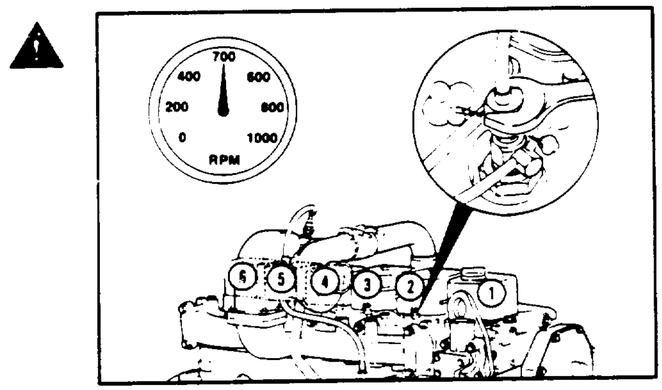
Caution: Do not weld or substitute lines; use only the specified part number for the engine.



10mm

Assemble the lines in the reverse order of removal.

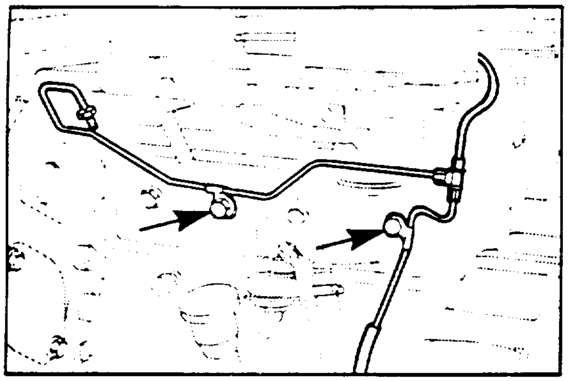
Torque Value: 24 N•m [18 ft-lbs]



Warning: Do not bleed a hot engine as this could cause fuel to spill onto a hot exhaust manifold creating a danger of fire.

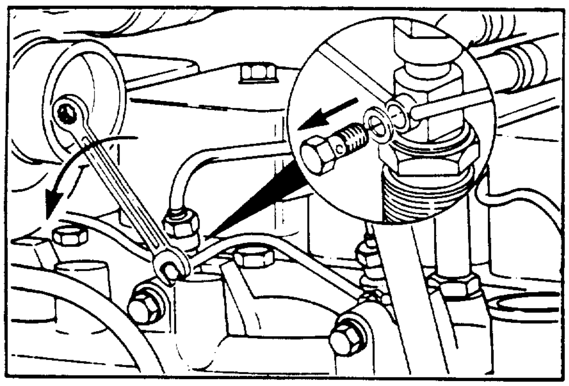
Start the engine and vent one line at a time until the engine runs smoothly.

Fuel Drain Manifold - Replacement



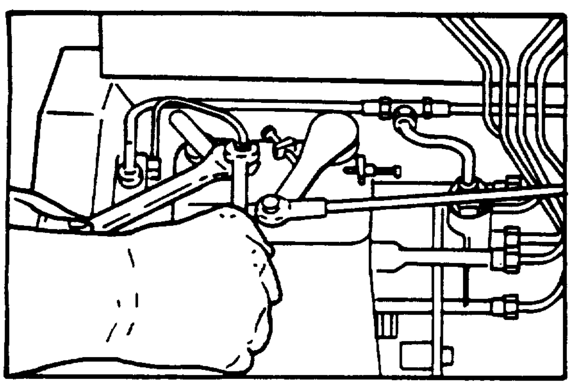
10mm

Remove the capscrews from the hold-down clamps and complete the following steps.



10mm

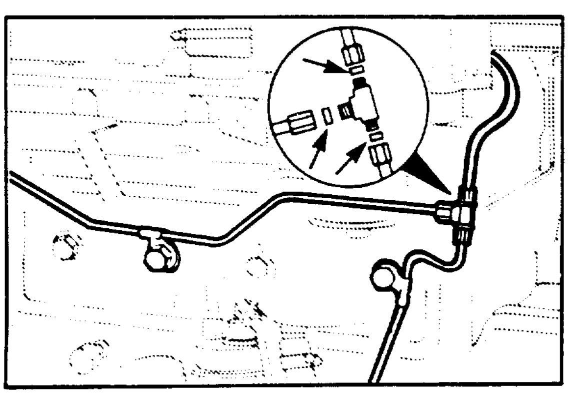
Remove the banjo fitting screws and washers.



10mm

Disconnect the drain line fittings.
Inspect drain line for cracks and other damage.
Inspect rubber sealing surfaces for leak paths.
Replace any rubber seals that are damaged.

NOTE
Lubricate seals with clean engine oil to aid in installation.

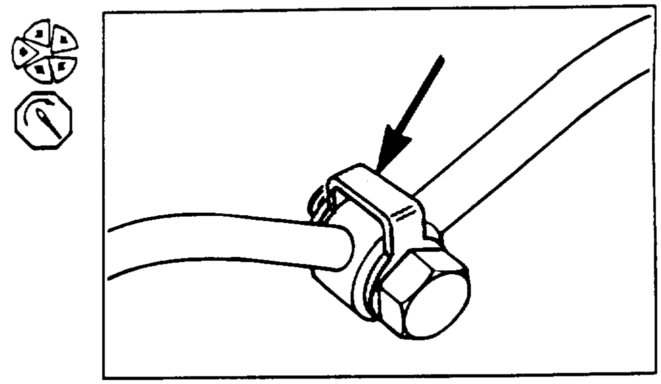


Assemble the drain line and fuel drain manifold in the reverse order of disassembly.

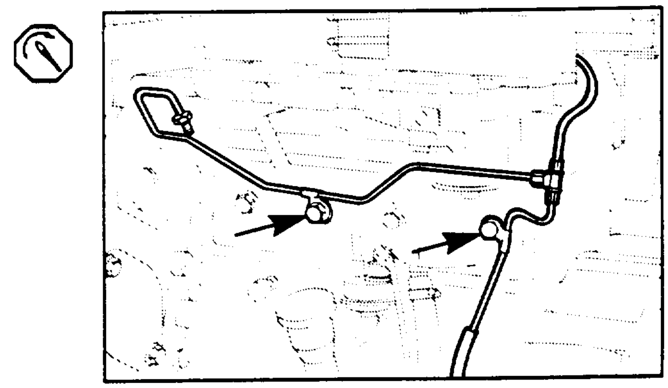
Note: Use new seals for the fittings.

The installation torque for the banjo fitting screw is 9 N•m [6.5 ft-lbs].

Note: Use new sealing washers for the fuel drain manifold.



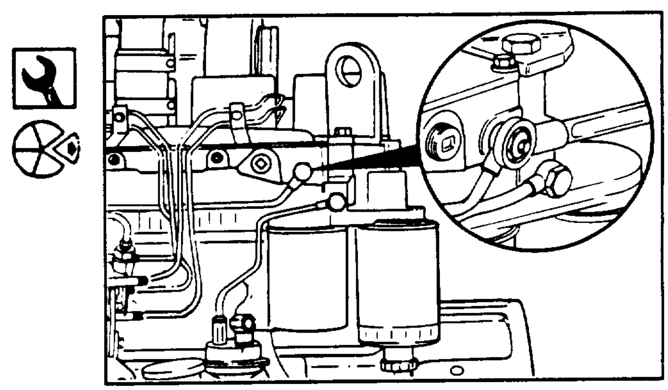
The installation torque for the clamp capscrews is 24 N•m [18 ft-lbs].

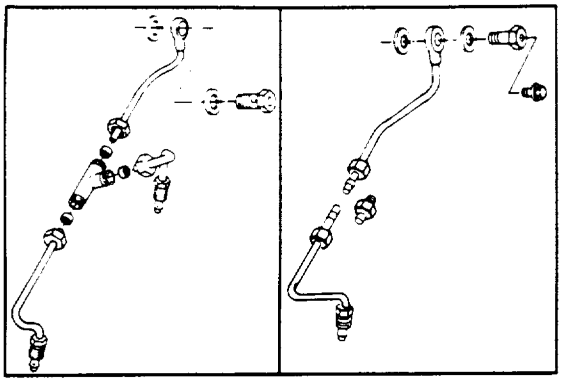


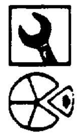
Injection Pump Supply Line - Replacement

17mm

Remove the bleed screw banjo fitting and complete the following steps.



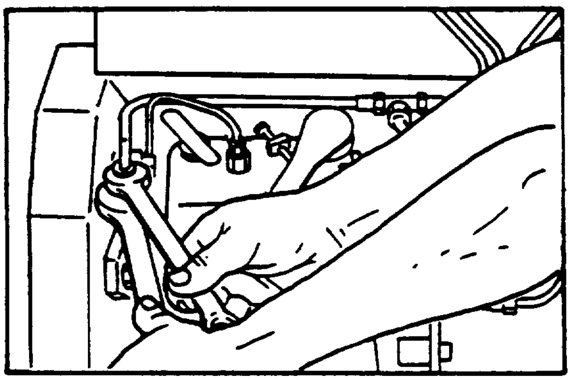




14mm, 16mm, 19mm and 24mm

Remove the supply line assembly from the two Lucas CAV pump fittings.

Note: Replace the seals in the fittings if the line is disassembled.

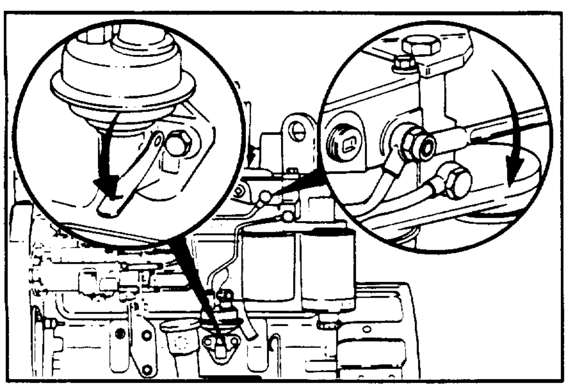


17mm

Install the supply line in the reverse order of removal. Tighten line securely to pump fittings.

Banjo Screw Torque Value:

32 N•m [27 ft-lbs]



Operate the hand lever 10-20 strokes to fill the supply line.

Injector - Replacement

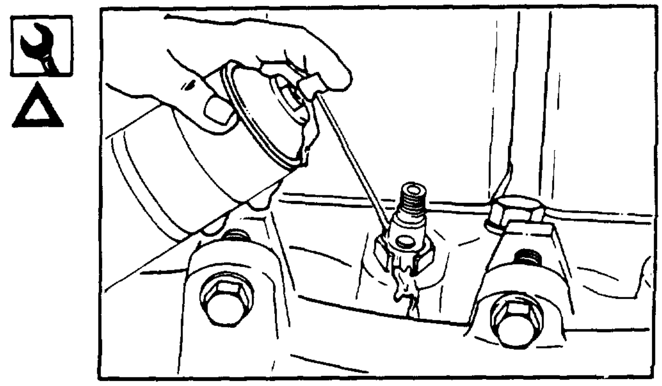
Preparatory Steps:

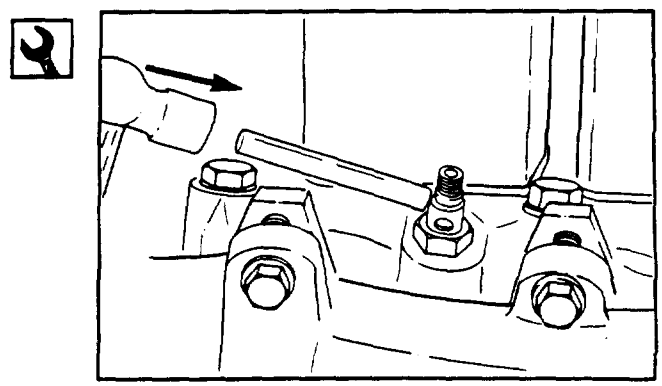
- Disconnect the high pressure fuel supply lines
- Disconnect the fuel drain manifold
- Clean around the injectors

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.

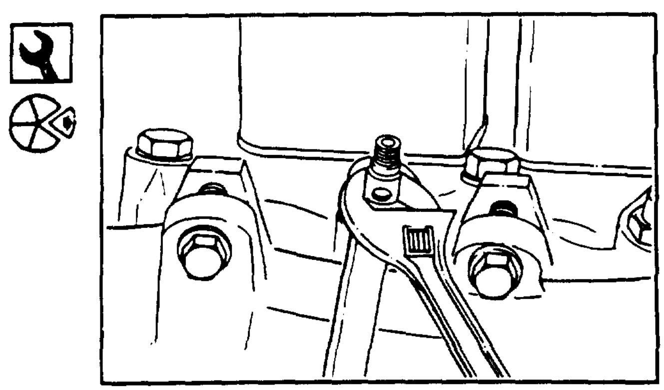
Soak the hold down nut with a rust penetrating solvent for a minimum of 3 minutes.





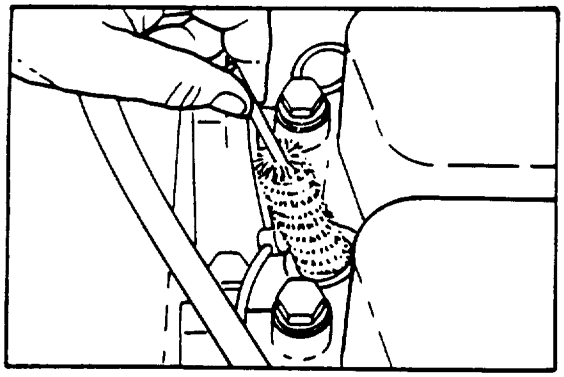
Brass Drift Pin, Hammer

Hit the injector body with the drift pin to loosen any rust.



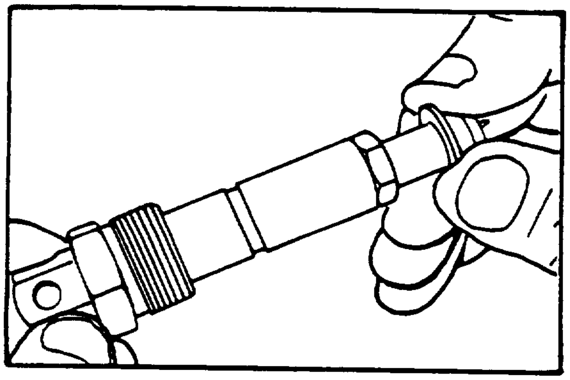
24mm Box Wrench, Adjustable Wrench

Hold the injector body with an adjustable wrench while you loosen the hold down nut with a 24mm box wrench.



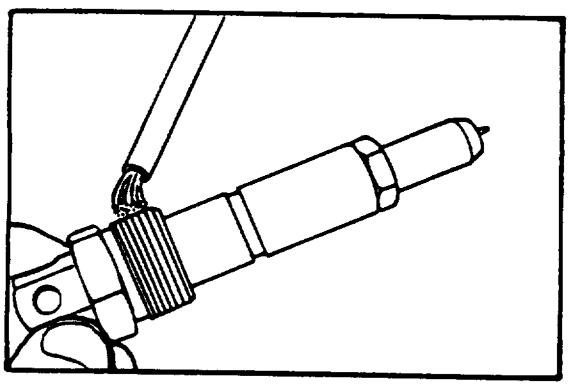
Injector Bore Brush

Clean the injector nozzle bore.

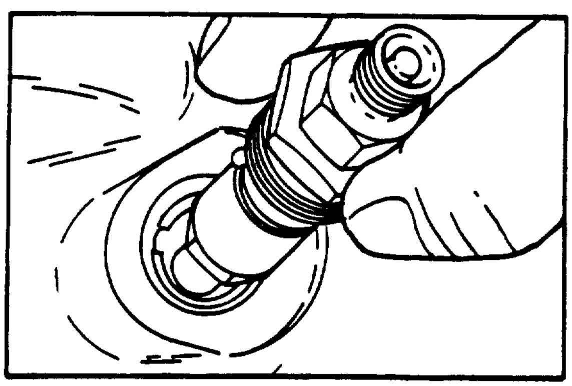


Assemble the injector and new copper sealing washer.

Use Only One Copper Washer.



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.



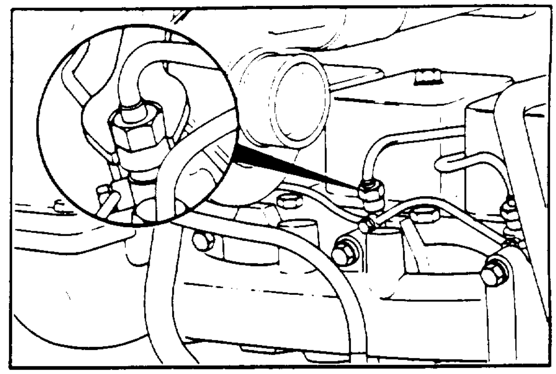
24mm Deep Well Socket

Caution: Align the injector's protrusion with the notch in the bore.

Torque Value: 60 N•m [44 ft-lbs]

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.

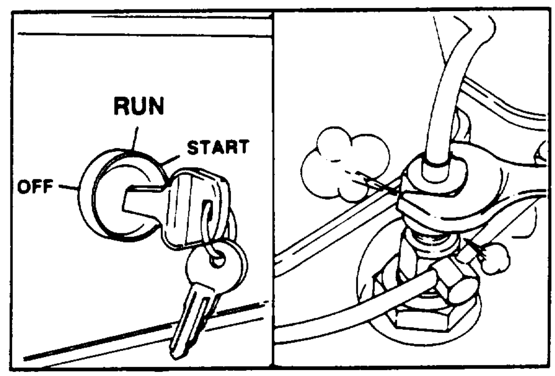
Assemble the fuel drain manifold and high pressure lines. Leave the high pressure fittings loose at the injectors.



17mm

Warning: It is necessary to put the engine in the a run position: Because the engine may start, be sure to follow all the safety precautions. Use the normal engine starting procedure.

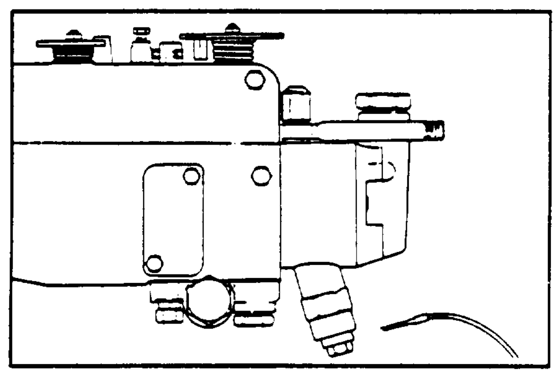
Crank the engine to allow entrapped air to bleed from the lines. Tighten the fittings.



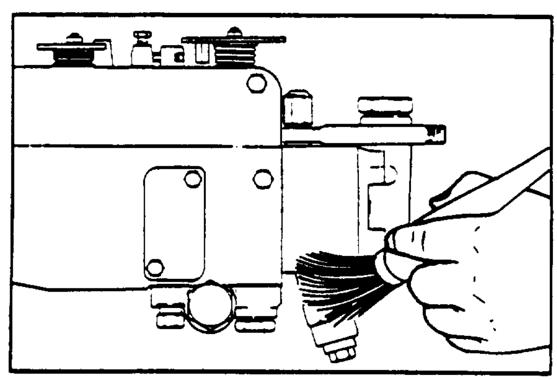
Electric Fuel Shut Off Valve - Replacement

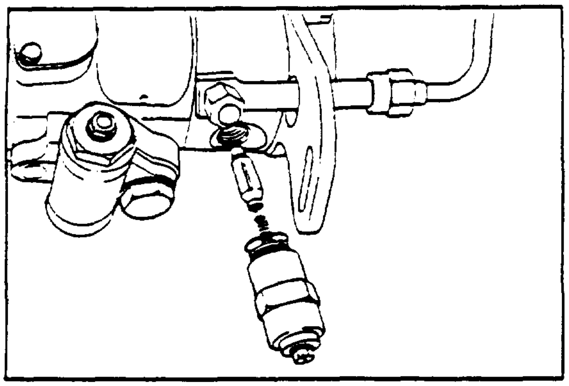
8mm

Remove the electrical wire and complete the following steps.



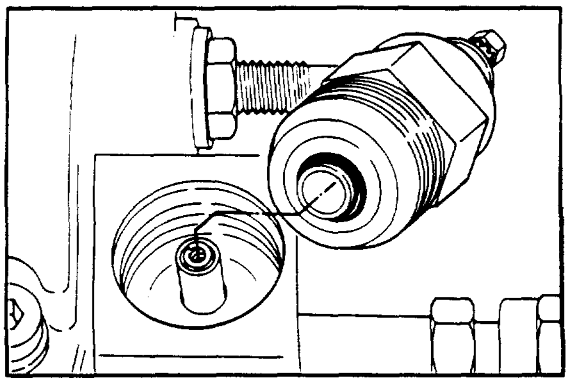
Clean around the valve.



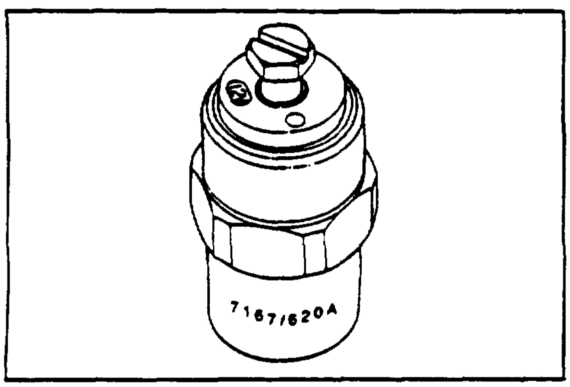


22mm

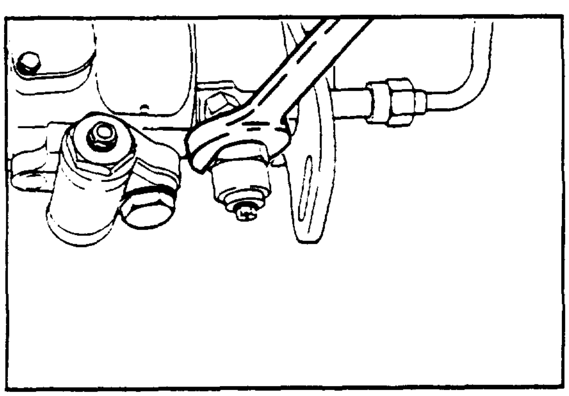
Remove the valve.



Caution: When removing the valve. be careful not to drop the plunger and spring.



"Package" the solenoid, o-ring, spring and plunger.



22mm
Tighten the solenoid securely.

Connect the electric wire.

Torque Value: 1 5 N•m [130 in-lbs]

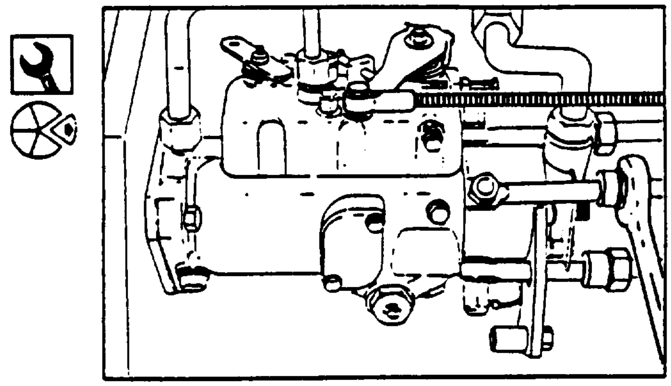
Lucas CAV DPA Back Leakage Valve and Sealing Washer - Replacement

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.

Caution: The installation torque is very critical. Overtightening 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.

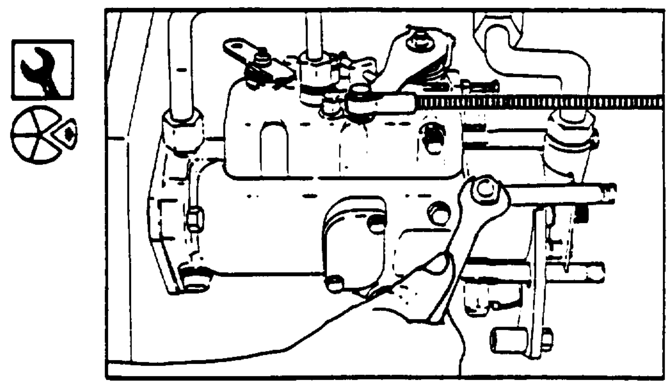
17mm

Disconnect the high pressure line.

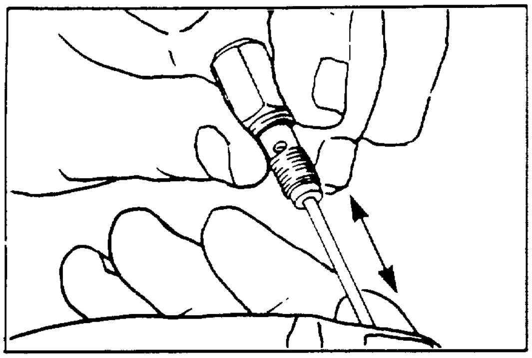


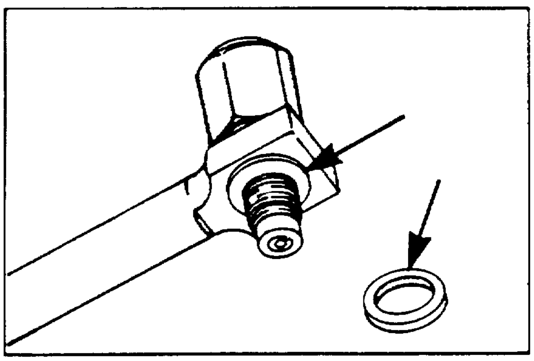
16mm

Remove the valve.

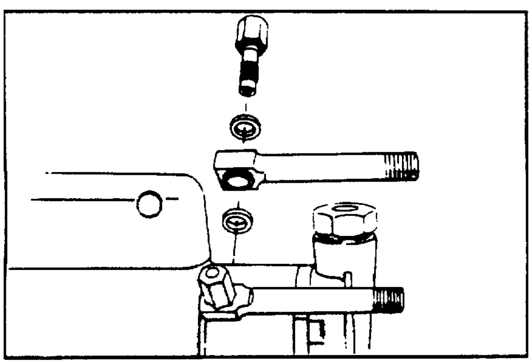


Inspect the valve to be sure it is not stuck.





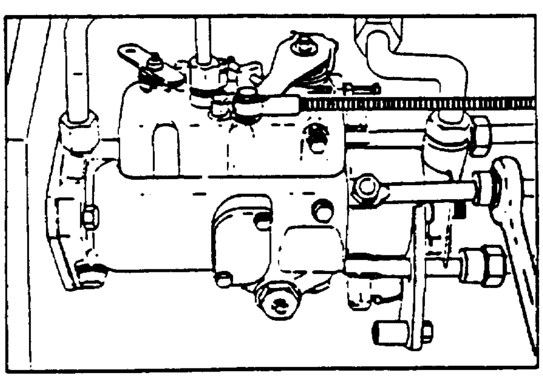
Inspect the sealing surfaces for possible leak paths.



16mm

Assemble the back leakage valve and new washers.

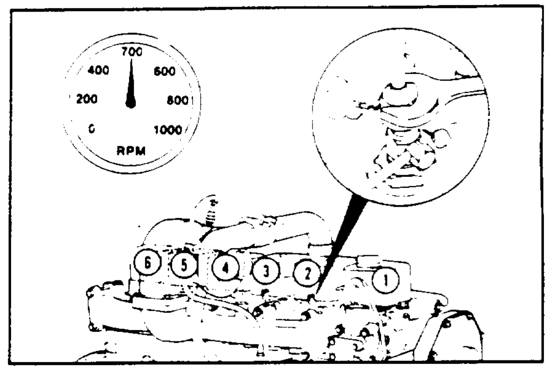
Tighten the valve to 30 N•m [23 ft-lbs].



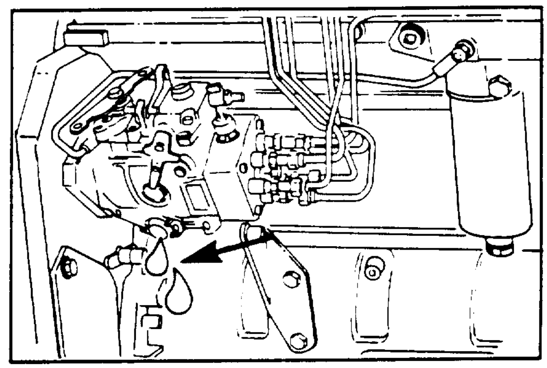
17mm

Connect the high pressure line.

Start the engine and vent one line at a time until the engine runs smoothly.



External Pump Leaks - Repair



Caution: 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. This bulletin can be obtained by calling 1-800-343-7357 or by writing Cummins @ Cummins Engine Co., Publishing Services, CMC 40924, P.O. Box -3005, Columbus, IN 47202-3005

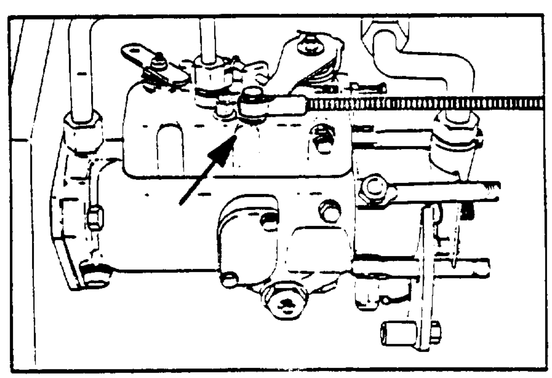
Replacing the Fuel Pump

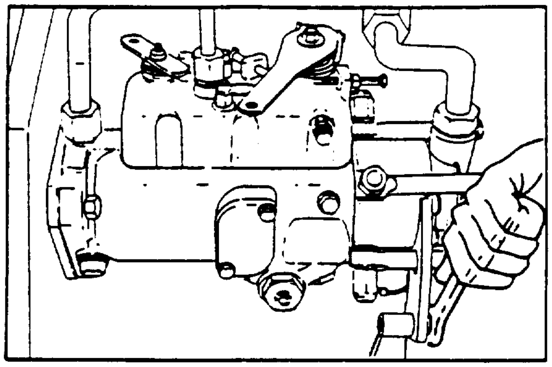
Preparatory Steps:

- 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

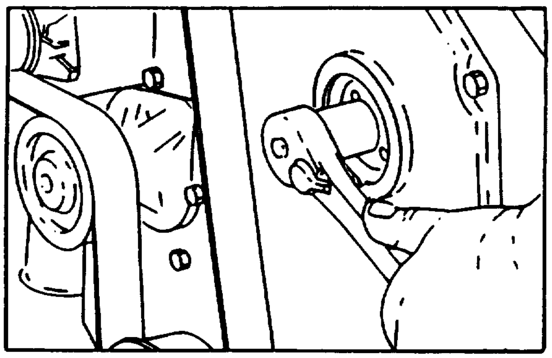
Disconnect all control linkage.





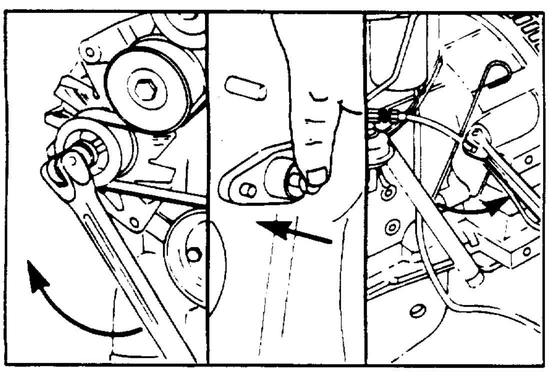
13mm

Remove the pump support bracket.



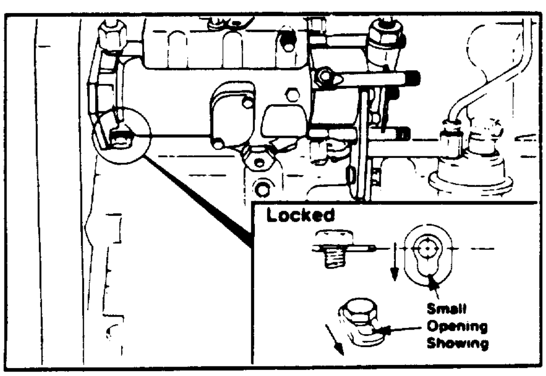
22mm

Remove the access cap and gear retaining nut and washer.



Caution: Be sure to disengage the pin after locating TDC.

Locate TDC for Cylinder Number 1 by barring engine slowly while pushing in on TDC pin.



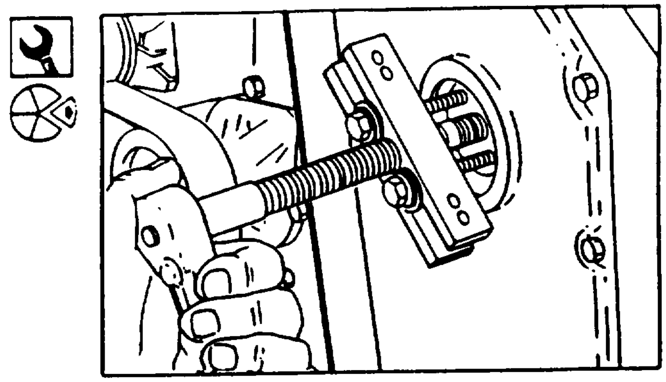
9/16 inch

Loosen the CAV injection pump lockscrew and position the special washer, then tighten the lockscrew against the pump drive shaft.

Torque Value: 7 N•m [5 ft-lbs]

75mm T-Bar

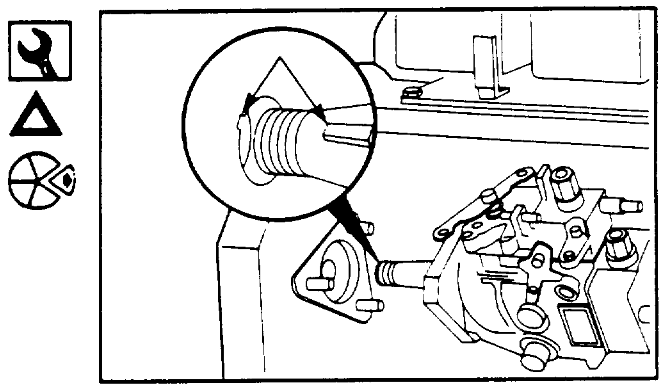
Pull the pump drive gear loose from the drive shaft.



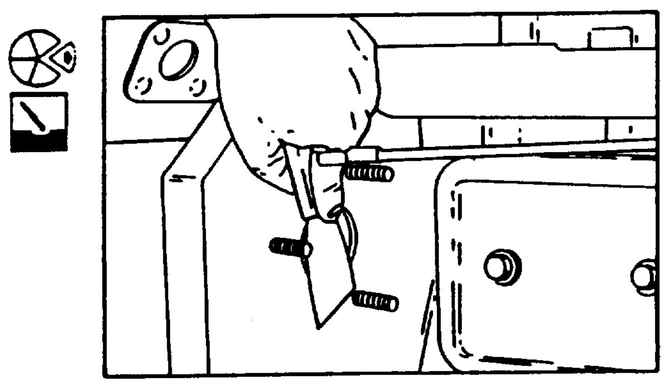
13mm

Caution: Do not drop drive gear key when removing the pump.

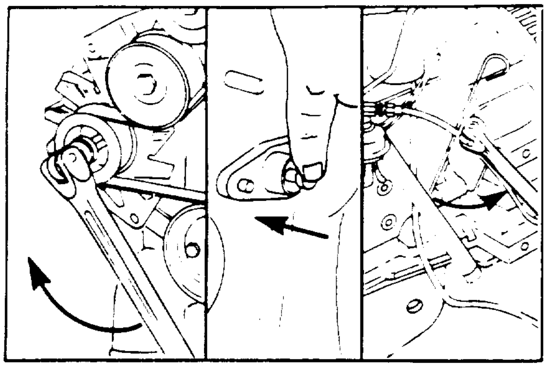
Remove the 3 mounting nuts and take off the injection pump.



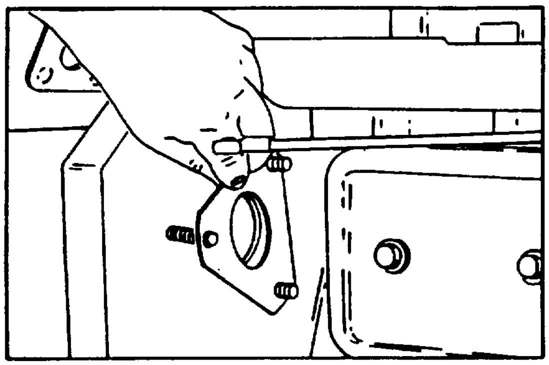
Remove the gasket and clean the surface.



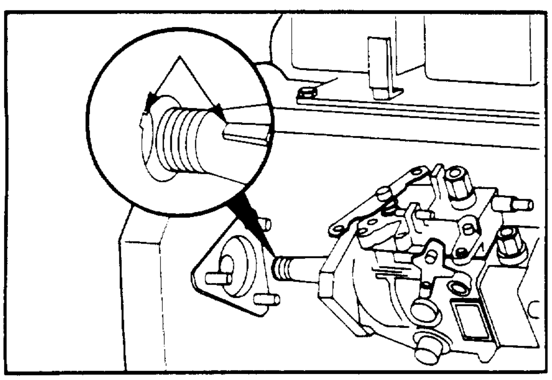
Installing the Pump



Verify Cylinder Number 1 is at TDC by barring engine slowly while pushing in on TDC pin.

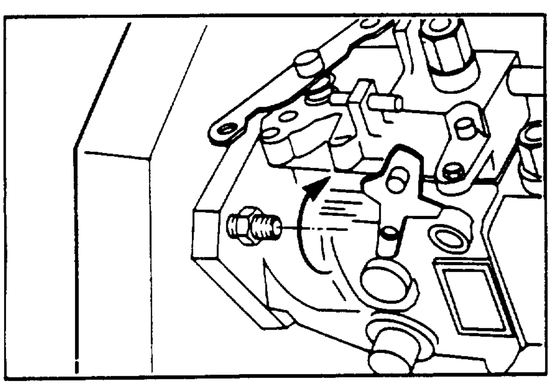


Install a new gasket.



Note: The shaft of a new or reconditioned pump is locked so the key aligns with the drive gear keyway when Cylinder Number 1 is at TDC on the compression stroke.

Install the pump. Make sure the key does not fall into the gear housing.



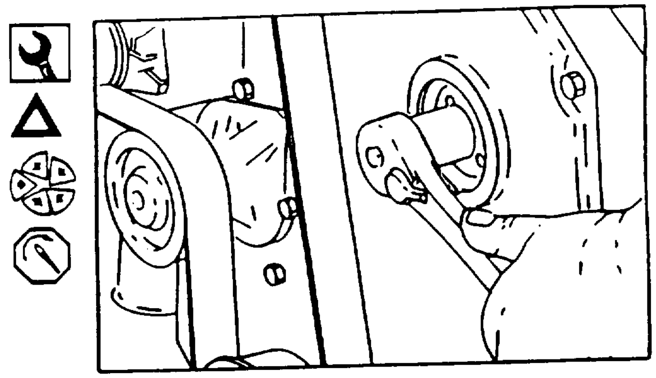
Use your hands to tighten the three mounting nuts. The pump must be free to move in the slots.

22mm

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.

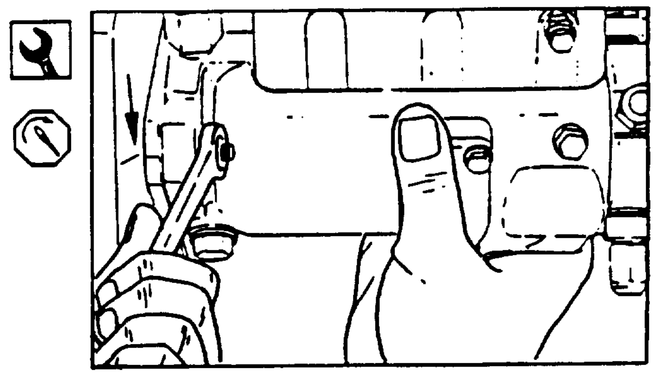
Torque Valve: 15 to 20 N•m [11 to 15 ft-lbs]



13mm

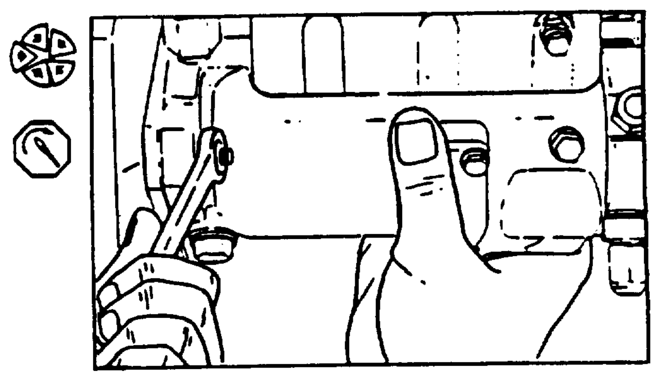
If installing the original pump, rotate the pump to align the scribe marks.

Torque Value: 24 N•m [18 ft-lbs]

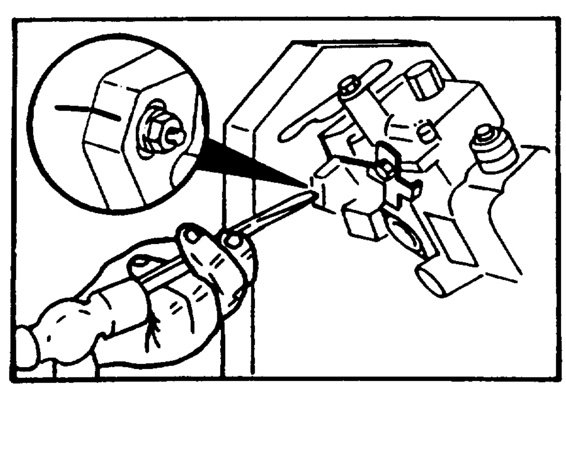


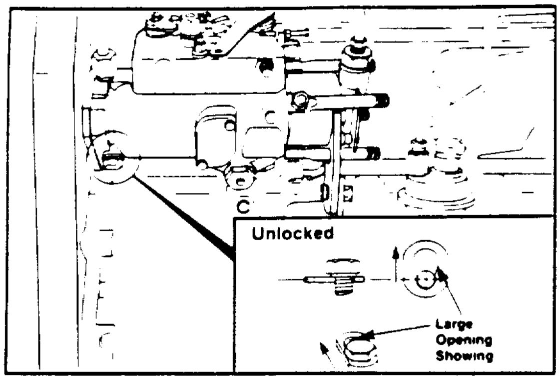
If installing a new or rebuilt pump without scribe marks, take up gear lash by rotating the pump against the direction of drive rotation. Tighten the flange mounting nuts.

Torque Value: 24 N•m [18 ft-lbs]



Permanently mark the injection pump flange to match the mark on the gear housing.

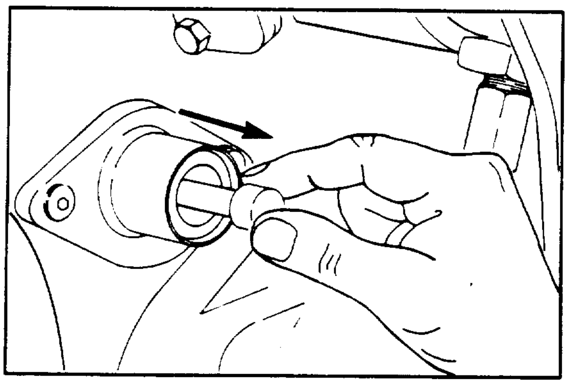




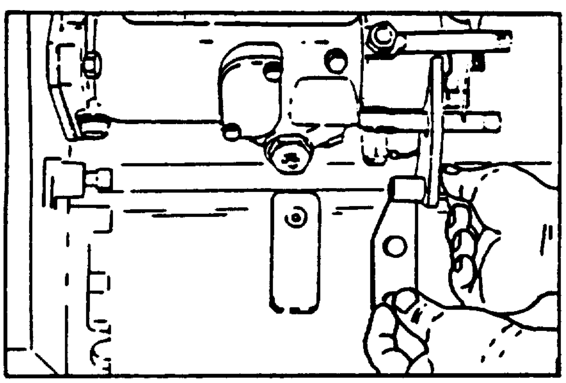
9/16 inch

Loosen the CAV pump lockscrew and position the special washer behind the lockscrew head.

Torque Value: 20 N•m [15 ft-lbs]



Caution: Disengage the timing pin, before rotating the crankshaft.

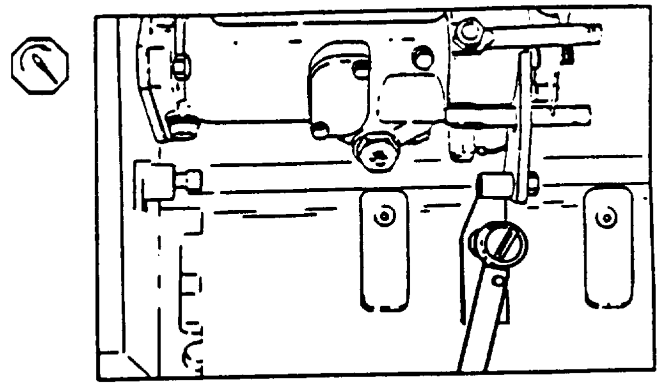


10mm

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.

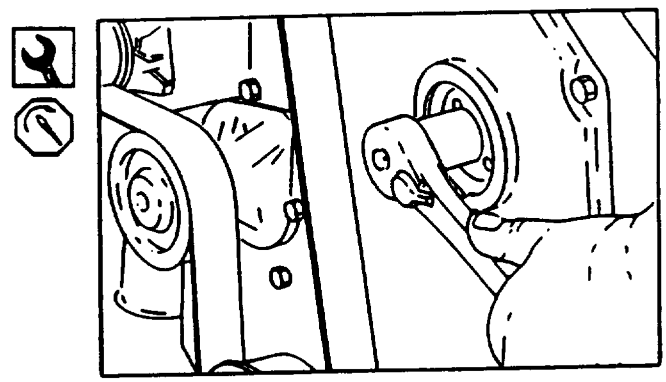
Torque Value: 24 N•m [18 ft-lbs]



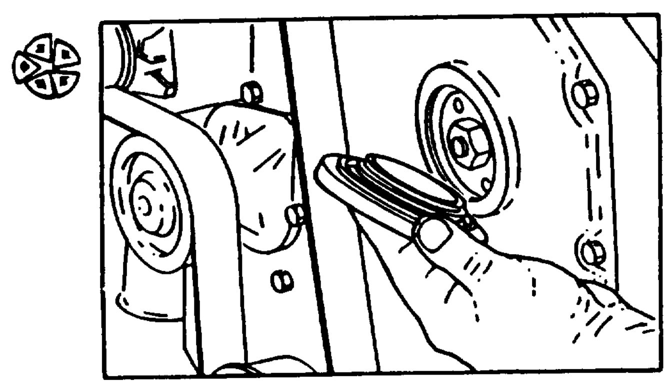
22mm

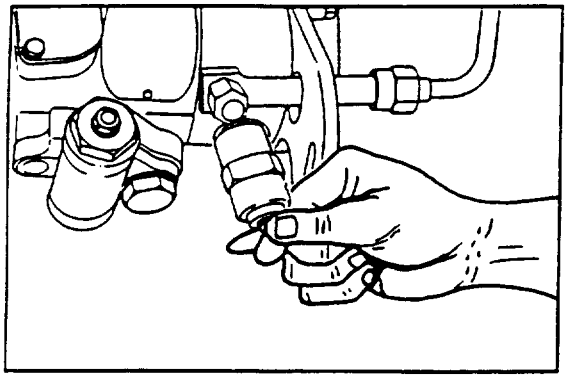
Tighten the pump retaining nut.

Torque Value: 65 N•m 48ft-lbs]



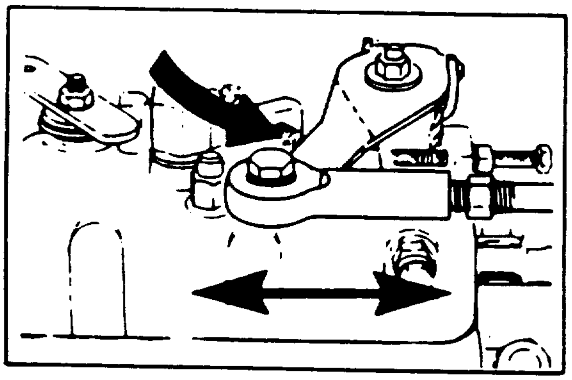
Install the access cap.



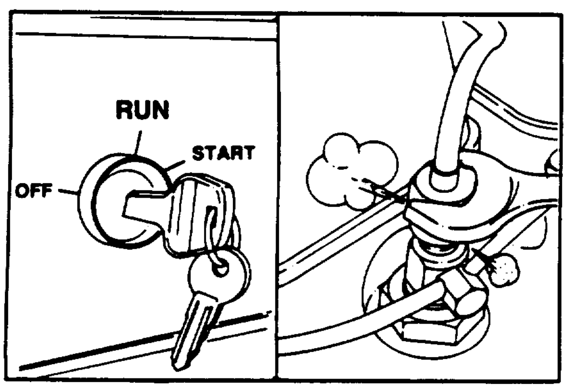


8mm

Install all fuel lines and the electrical wire to the fuel shut off valve.

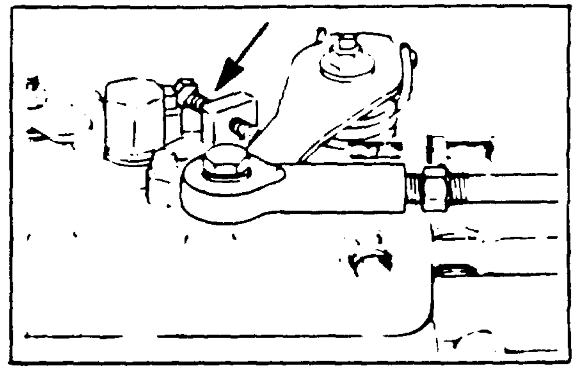


When connecting the cable/rod to the control lever, adjust the length so the lever has stop-to-stop movement.



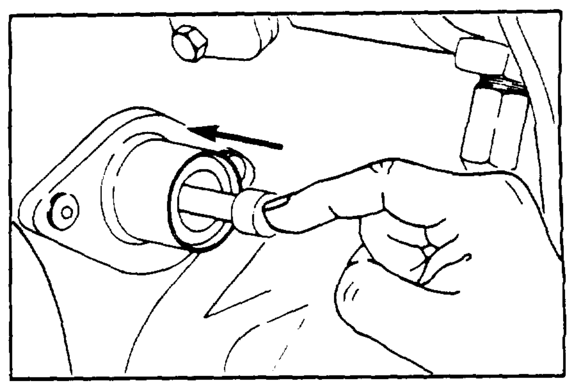
Bleed all air from the fuel system.

If necessary, adjust the idle speed.



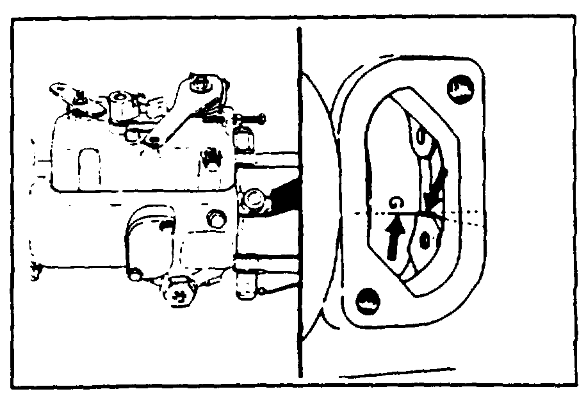
__Injection Pump Timing Check__

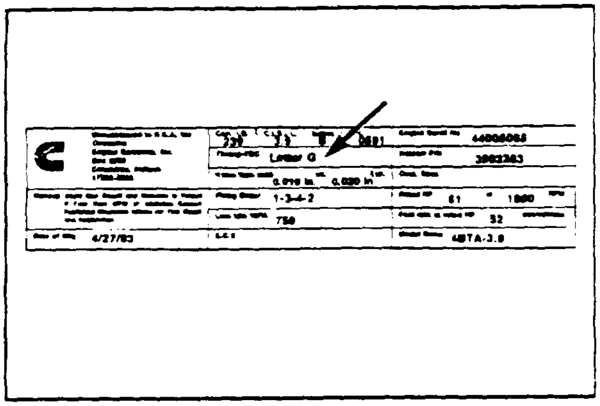
Rotate the engine to TDC.



Correct timing of the Lucas CAV DPA pump can be verified by removing the inspection plate. Clean all dirt and foreign material from around the timing window cover on the injection pump.

NOTE: Special equipment in an authorized shop is required to precisely time the Lucas CAV DPA pump. However, for troubleshooting and in an emergency, visual alignment of the timing mark is close enough for the engine to run.





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.

Injection Pump Rerating

Refer to the Injection Pumps Shop Manual, Bulletin 3666037-03 for additional information. This bulletin can be obtained by calling 1-800-343-7357 or by writing Cummins @ Cummins Engine Co., Publishing Services, CMC 40924, P.O. Box 3005, Columbus, IN 47202-3005.

Section 5. Air System

Air System
Air System Flow

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 damage the cylinders very quickly.

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

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

Intake Air, Exhaust and Fuel System **<u>4B3.9</u>**

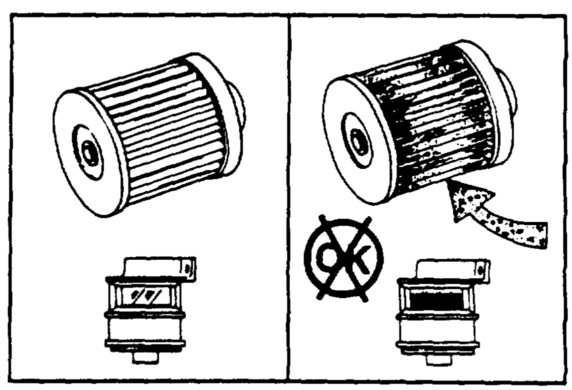
Intake Restriction at Rated Speed and Load with Dirty Air Filter Element - mm H_20 [in. H_20]..................... 508 [20]

Exhaust Restriction at Rated Speed and Load - mm Hg [in. Hg].........76.2 [3 in.]

Diagnosing Air System Malfunctions

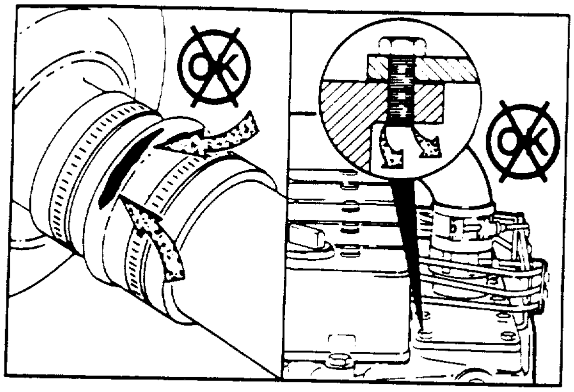
Air Flow Restriction Results in Excess Smoke and Low Power

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.



NOTE

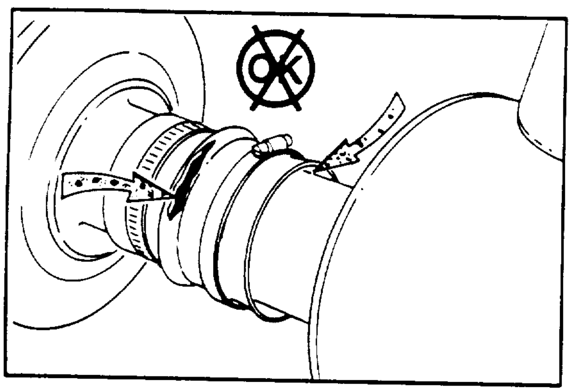
Air restriction is indicated by an air restriction indicator mounted in the air intake tubing on the output side of the air cleaner assembly.



Damage From Non-Filtered Air

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

Air System Replacement Procedures

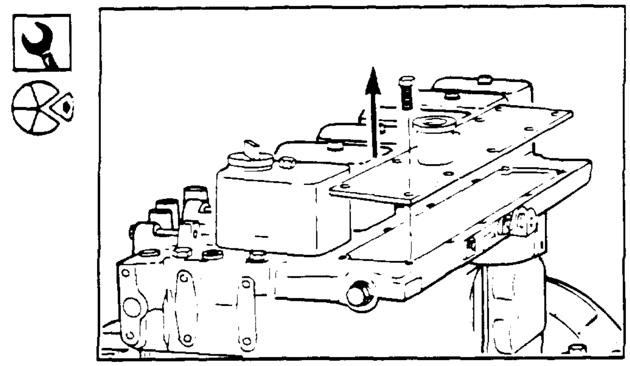
Intake Manifold Cover and Gasket - Replacement

Preparatory Steps:

- Remove the high pressure fuel lines.
- Disconnect the cold starting aid.
- Remove the air crossover tube.

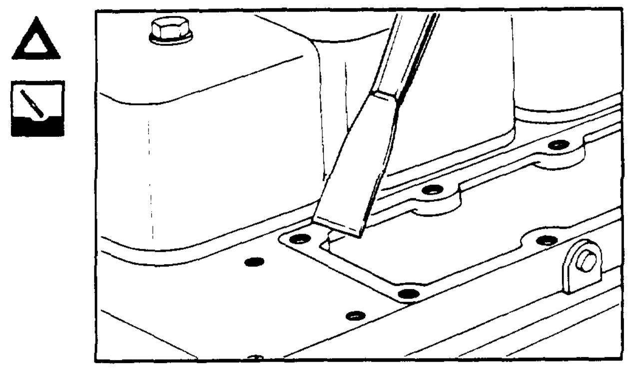
10 mm

Remove the manifold cover and complete the following steps.

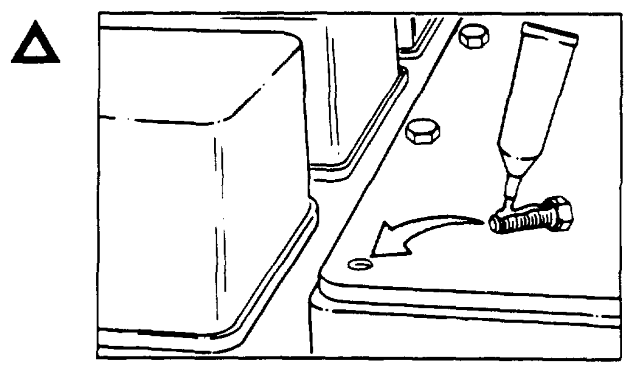


Caution: Keep the gasket material and any other material out of the air intake.

Clean the sealing surface.



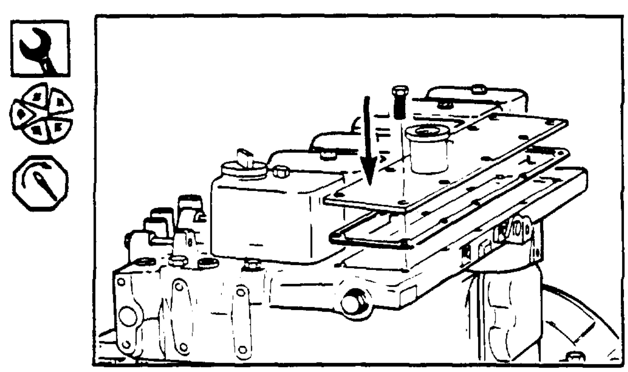
Caution: Some of the capscrew holes are drilled through and must be sealed. Apply liquid teflon sealant to the capscrews.



10mm

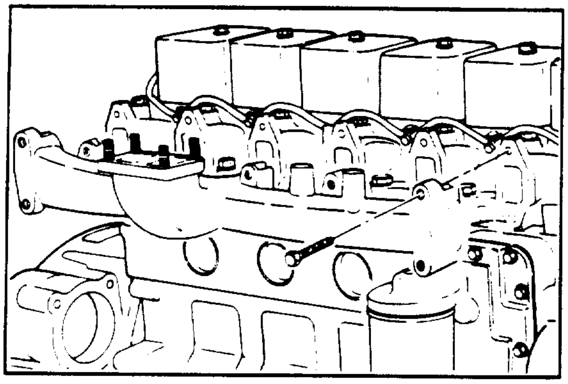
Install the gasket and cover.

Torque Value: 24 N•m [18 ft-lbs]



Exhaust Manifold and/or Gasket - Replacement
Preparatory Steps:

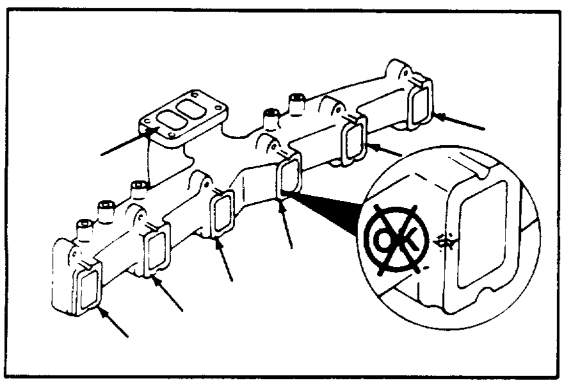
- Remove the air crossover tube.
- Disconnect the air intake and exhaust piping.




13mm

Remove the manifold and gasket.

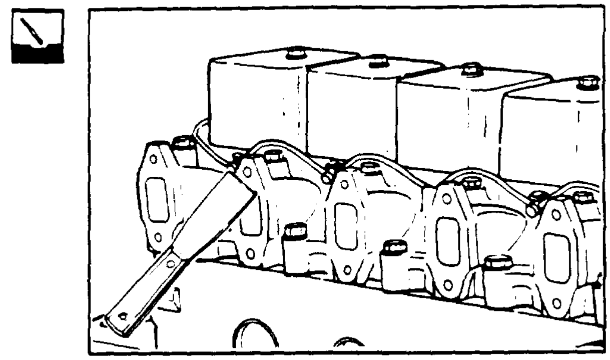
Exhaust Manifold Inspection




Inspect the Exhaust Manifold for cracks, burn-out, or damaged threads.

Place straight edge across the exhaust ports. The maximum allowable clearance between the manifold and straight edge is 0.10 mm [0.004 inch].

Clean the sealing surfaces.

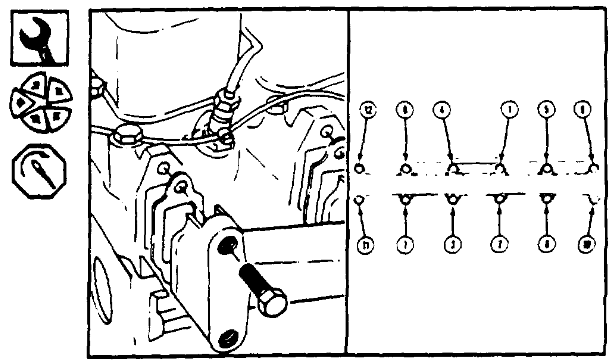


13mm

Install the manifold and gaskets.

Torque Value: 43 N•m [32 ft-lbs]

Follow the sequence shown in the illustration.



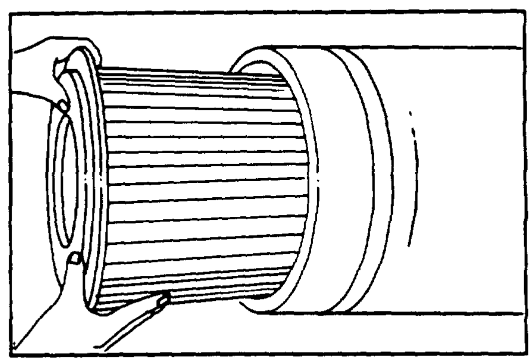
Intake Air Restriction

Replace the air cleaner element when the restriction reaches the maximum limit at rated engine RPM.

Naturally Aspirated

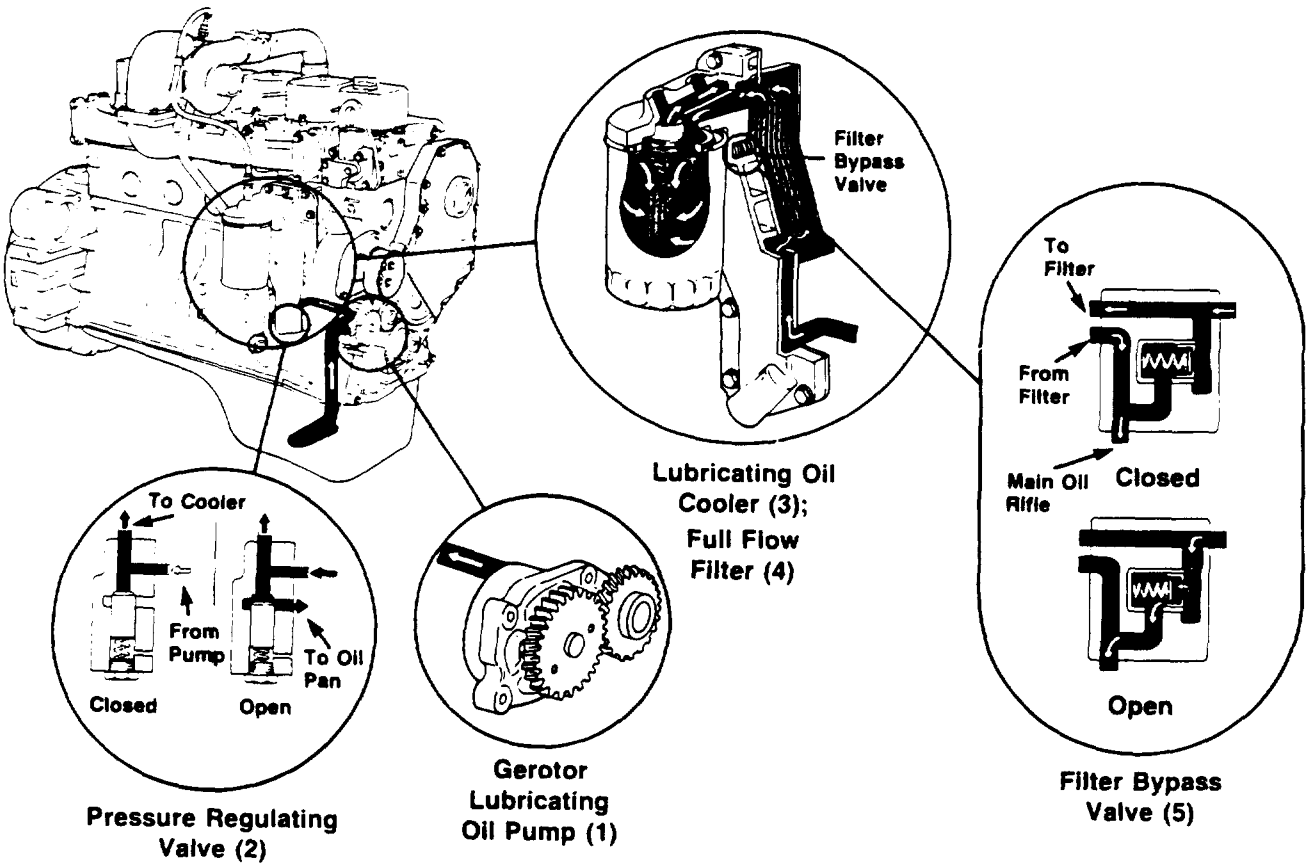
508mm H_2O
[20 in. H_2O]

Refer to the Operator's Manual TM 10-3950-672-10 for a description of the air restriction indicator which indicated air intake restriction as the air cleaner element clogs.



Section 6. Lubricating System

Lubricating System
Lubricating System Flow



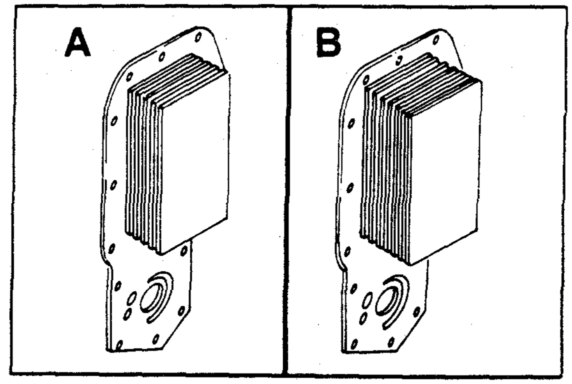
Lubricating Oil Pump

The engine use gerotor type oil pumps (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 pump capacity. Consequently, the pumps are not interchangeable.

Pressure Regulating Valve

The pressure regulating valve (2) is designed to keep the oil pressure from exceeding 414 kPa [60 PSI]. When the oil pressure from the pump is greater than 414 kPa [60 PSI], the valve opens uncovering the dump port so part of the oil is routed to the oil pan. The minimum and maximum oil pressure limits is the same for the four cylinder and the six cylinder engine. Because of manufacturing tolerances of the components and the oil passages, the oil pressure can differ as much as 69 kPa [10 PSI] between engines.

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 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.

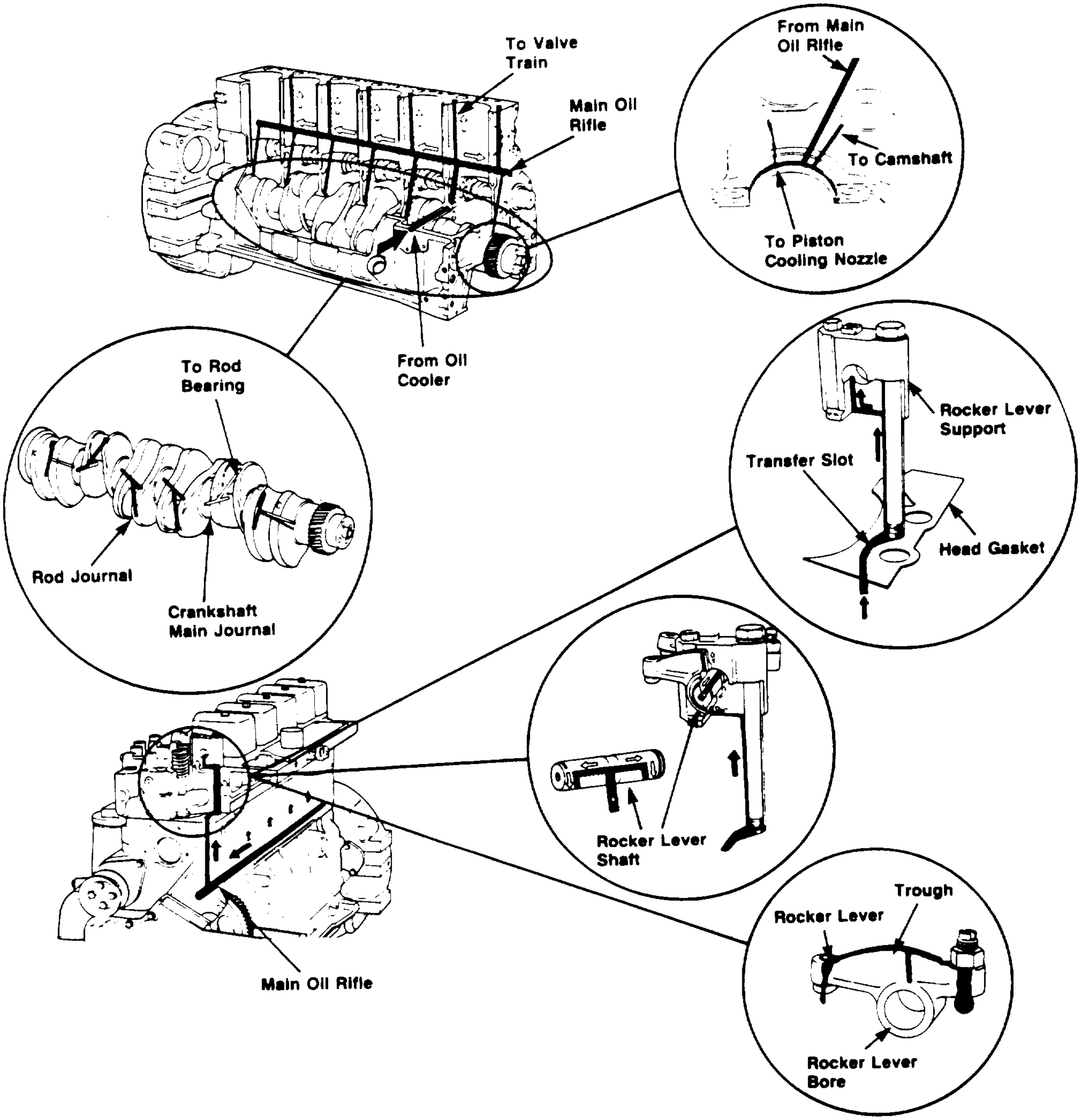
Oil Filters

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: Never use a filter for a six-cylinder engine on a four cylinder engine in order to extend the oil change interval.

Oil Filter Bypass Valve

The oil cooler cover contains a bypass valve (5) that will let the 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 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 oil pressure gauge.


To Valve Train
Main Oil Rifle
From Main Oil Rifle
To Camshaft
To Piston Cooling Nozzle
From Oil Cooler
To Rod Bearing
Rod Journal
Crankshaft Main Journal
Rocker Lever Support
Transfer Slot
Head Gasket
Rocker Lever Shaft
Trough
Rocker Lever
Rocker Lever Bore
Main Oil Rifle

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.

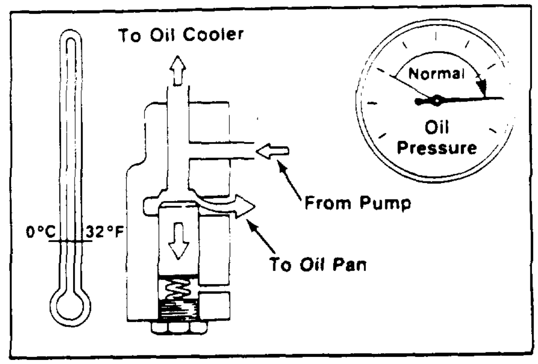
The number one main bearing saddle does not contain a piston cooling nozzle. **Cylinder Number One** receives the lubricating and cooling spray from the nozzle located in the **Number Two Bearing Saddle. Cylinder Number Two** receives the spray from the **Number Three Bearing Saddle,** etc.

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.

Lubrication System Specifications

(Minimum Allowable) kPa [PSI]	69 [10]
(Minimum Allowable) kPa [PSI]	207 [30]
Pressure kPa [PSI].........	414 [60]
Open the Filter Bypass Valve - kPa [PSI]	138 [20]
(High/Low) - Litre [U.S. Qts.]..............................	9.5 [10] 8.5 [9]

Diagnosing Lubricating System Malfunctions

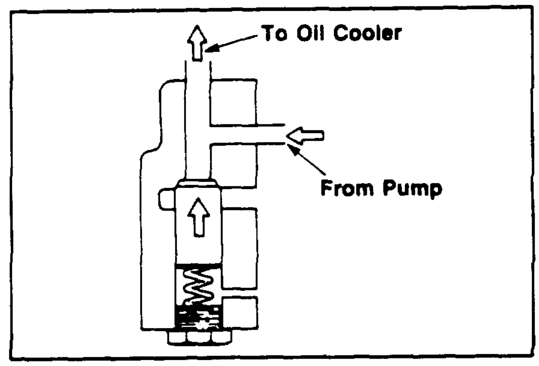


Be sure to check items related to oil pressure, such as: gauges, high and low oil level, excessive oil contamination, oil viscosity, etc.

High Oil Pressure

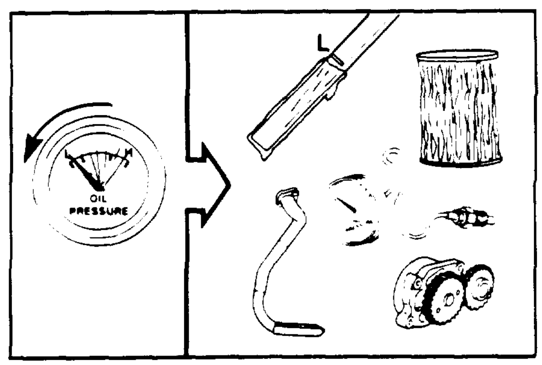
High oil pressure usually occurs after the engine is first started in cold weather. The lubrication system does not have a cold start relief valve. The pressure regulating valve components are machined to a size that will relieve the excessive pressure created by cold engine oil.

Oil Pressure Regulating Valve



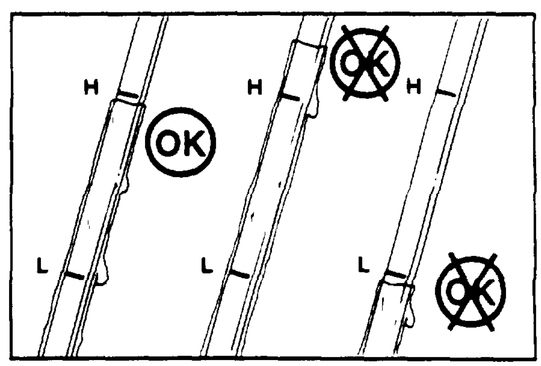
The engine will have high oil pressure if the regulator sticks in the closed position. Check the regulator for freedom of movement.

Low Oil Pressure



Low 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.

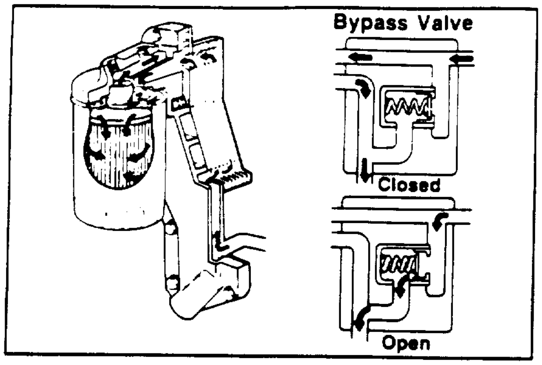
Oil Level



Low oil level can cause low oil pressure.

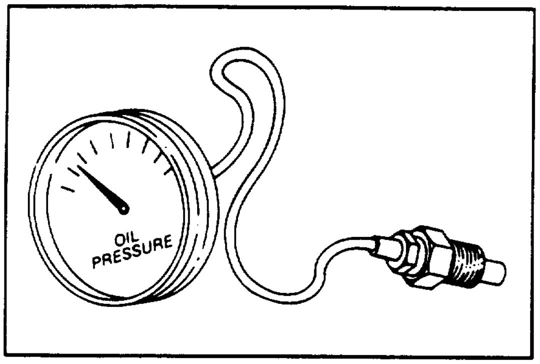
Caution

Never operate the engine with the oil level below the low (L) mark.



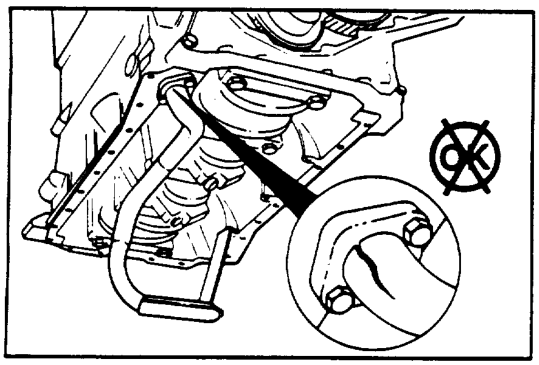
Oil Filter

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.



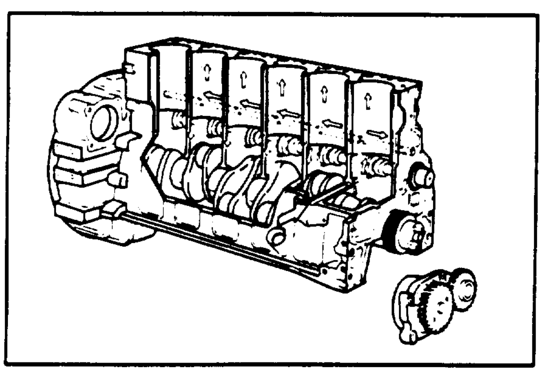
Oil Gauge

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



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.

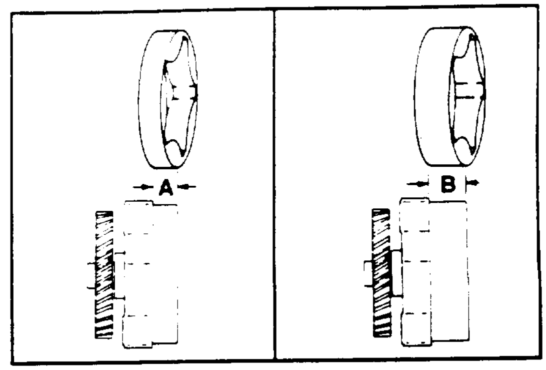


Bearings and Oil Pump

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 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.



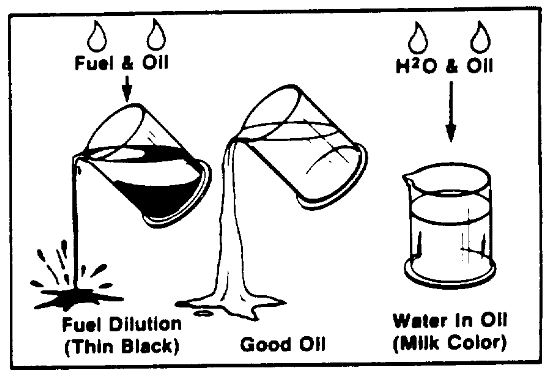
A - Four Cylinder
- 12.947mm [0.516 inch]

B - Six Cylinder
- 17.947mm [0.715 inch]

Oil Dilution

Caution

Diluted oil can cause severe engine damage.



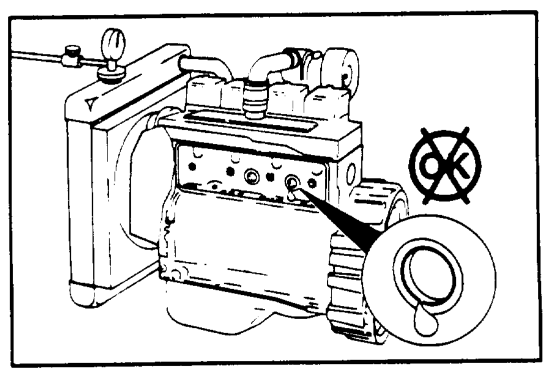
Check the condition of the oil.
- Thin, black oil is an indication of fuel in the oil.
- Milky discoloration is an indication of coolant in the oil.

Coolant in the oil can be caused by:
- Cup plugs leaking.
- Damaged cylinder head gasket.
- Oil cooler element leaking.

Coolant Diluted Oil

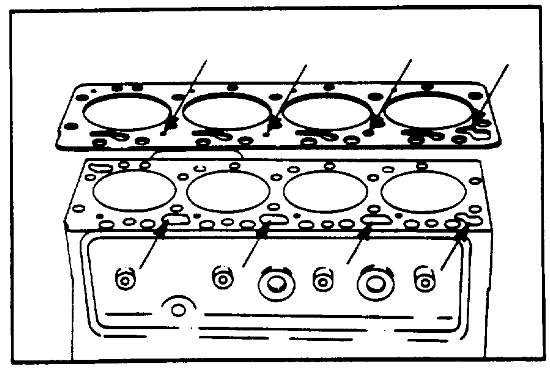
Coolant leaking from the cup plugs in the cylinder block water jacket will dilute the oil.

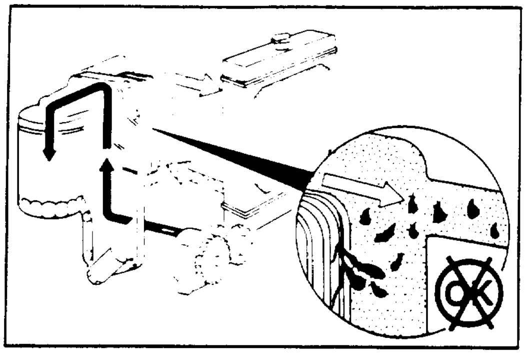
To check for leaks, remove the tappet cover and pressurize the cooling system.



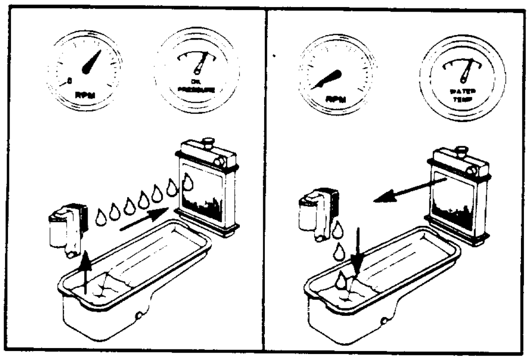
Coolant in the oil can also be caused by a damaged cylinder head gasket.

Pressurize the cooling system to check for leaks. It may be necessary to remove the oil pan to locate internal leaks.



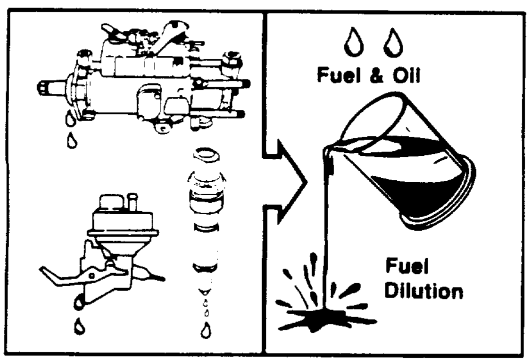


Since the oil cooler design does not require gaskets or seals to maintain the separation of oil and coolant, the element itself must leak to allow mixing of the fluids (refer to page 6-21).



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



<u>Fuel Diluted Oil</u>

Fuel dilution is limited to four sources:

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

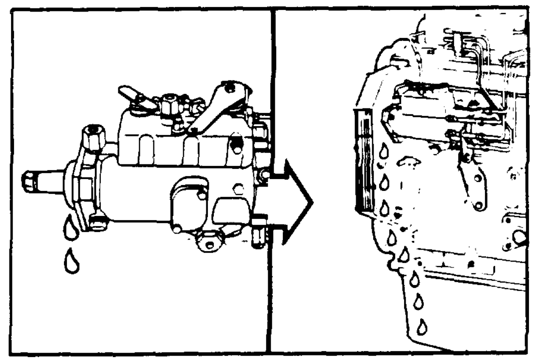
Use the following logic to determine the source of the oil dilution with fuel:

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 Lift Pump For Seal Leakage
⇓
Replace the Fuel Pump

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

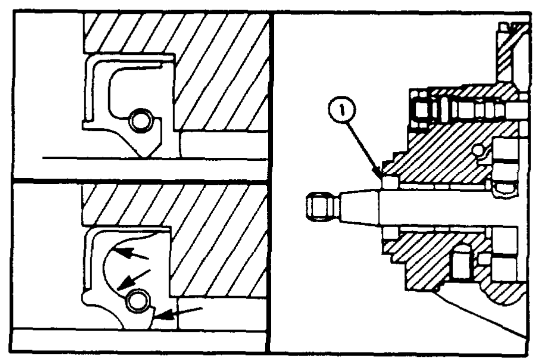


The seal is designed to provide increased sealing as the pump case pressure increases. Pressure forces the lip (1) tighter around the shaft.

A worn seal is more apt to leak during start up and shut down when case pressure is low.

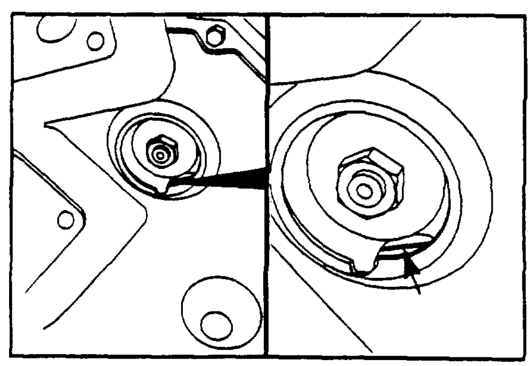
Caution

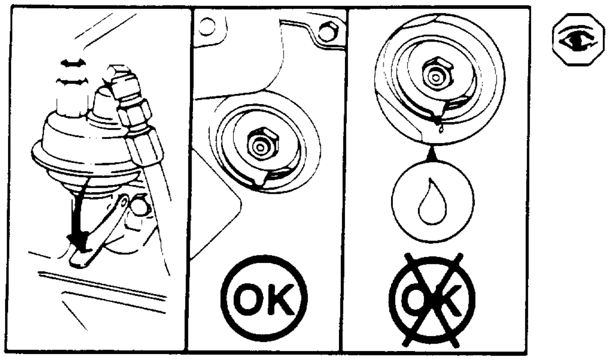
A worn seal can not be detected by pressurizing the pump.



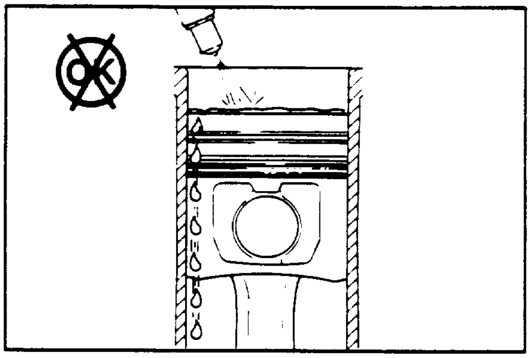
Remove the access cover and rotate the engine so one of the holes in the fuel pump gear exposes the back gear housing.

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



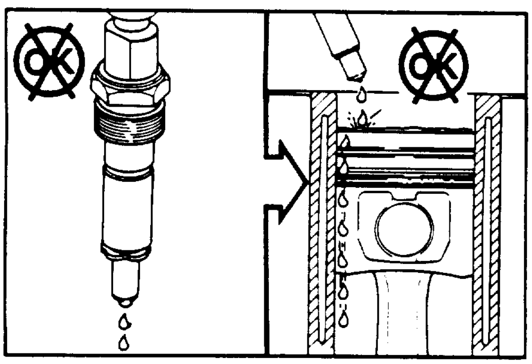


Use a small mirror to check for leaks while pumping the priming lever on the lift pump. If a leak is found, replace the injection pump. The seal can be replaced by an authorized Service Center.



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

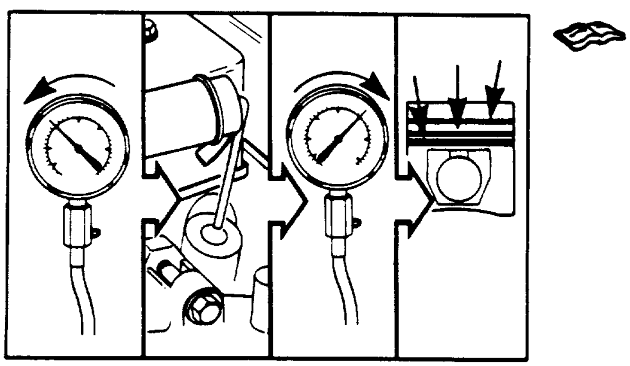
This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.



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.

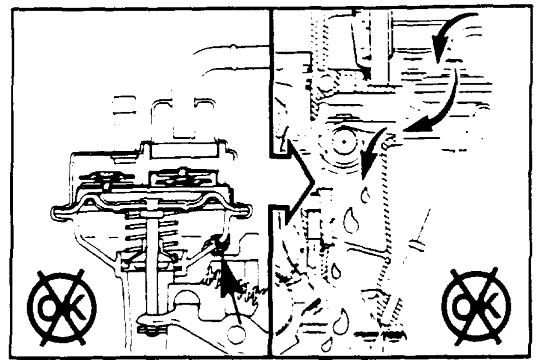
Remove and replace leaking injectors (refer to Shop Manual, 3810206 for test and repair instructions).



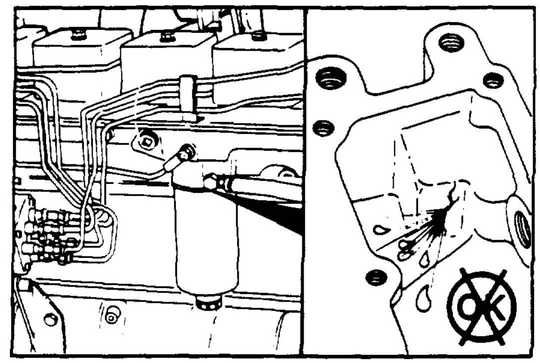
Perform a compression check to verify piston ring sealing (refer to the Base Engine Components Section).

There is a remote possibility for fuel to drain into the oil from the lift pump.

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

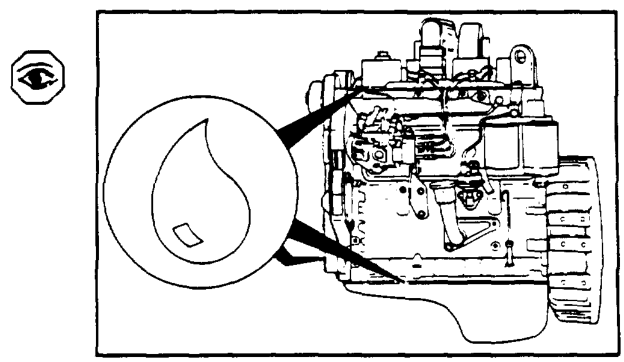


Another remote possibility, is a crack or porosity in the head casting could allow fuel to leak to the air intake and on to the cylinders.



Oil Leaks

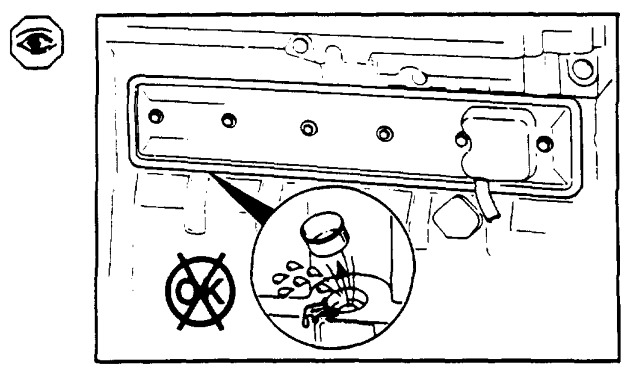
Various gaskets, seals and plugs are used to contain the oil. Most leaks can be identified during routine inspection of the engine and vehicle.

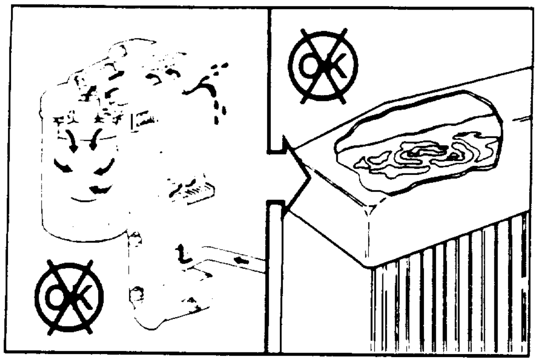


A blown cup plug can allow a relative large quantity of oil to escape resulting in a sudden drop in the oil pressure.

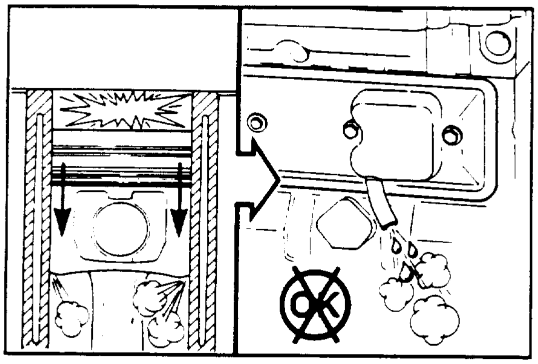
When checking for such a leak, be sure to check the plug behind the tappet cover as well as those that may be obscured by chassis parts.

Oil blowing out the breather of a four-cylinder engine is a good sign of a blown plug.





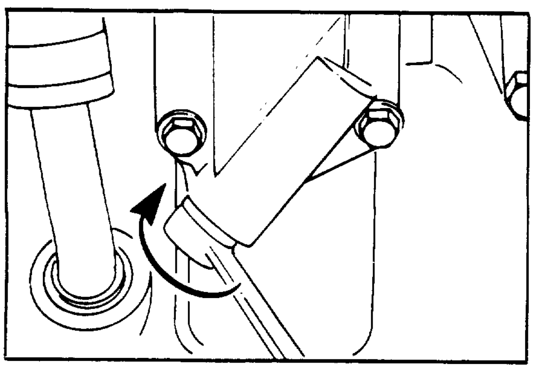
If the oil cooler element ruptures, the oil pressure will force oil into the coolant system. Oil in the coolant should be visible when the radiator cap is removed.



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

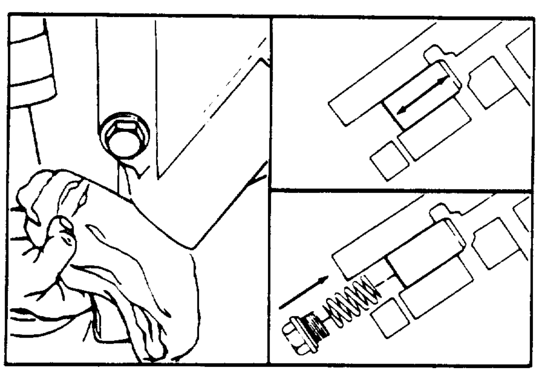
Lubricating System Replacement Procedures

Oil Pressure Regulator Valve and/or Spring - Replacement



19mm

Remove the plug and valve.



Clean and inspect the plunger, bore and seat before assembly.

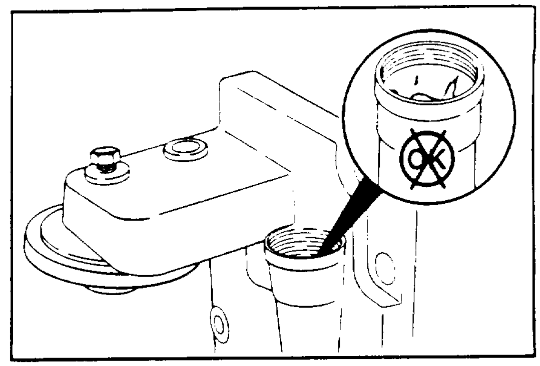
Note

The plunger must move freely in the valve bore.

Assemble the valve in the reverse order of disassembly.

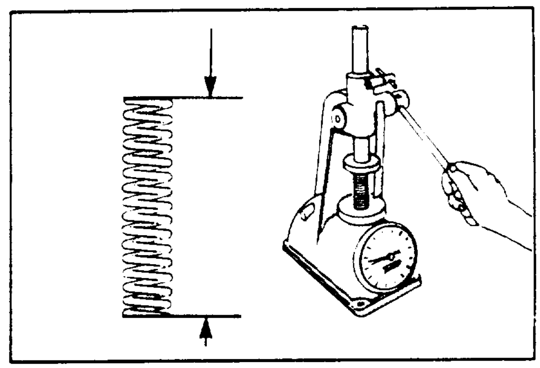
Torque Value: 80 N•m [60 ft-lbs]

Pressure Regulator Valve - Inspection



Inspect the plunger bore for nicks or scratches.

The plunger must move freely in the bore.



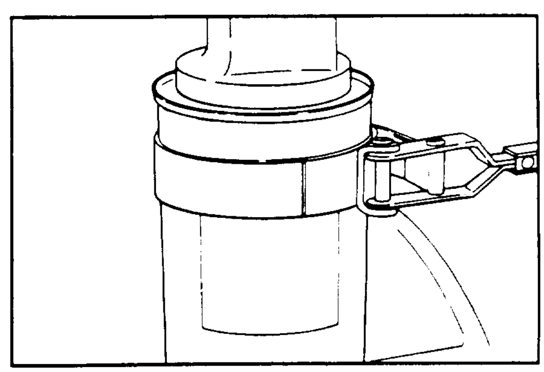
Check or replace the spring.

Limit
Valve Open (Min.) Height: 39.98 mm [1.574 inches] Load: 91 N [20.5 lbs]
Assembled (Min.) Height: 44.98 mm (1.77 inches] Load: 60 N [13.5 lbs]

Oil Cooler Element and/or Gasket - Replacement

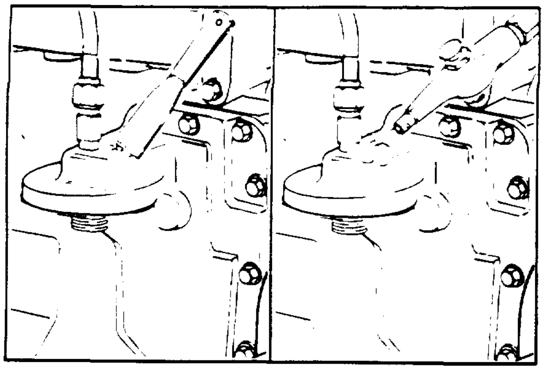
Preparatory Step:

- Drain the coolant.

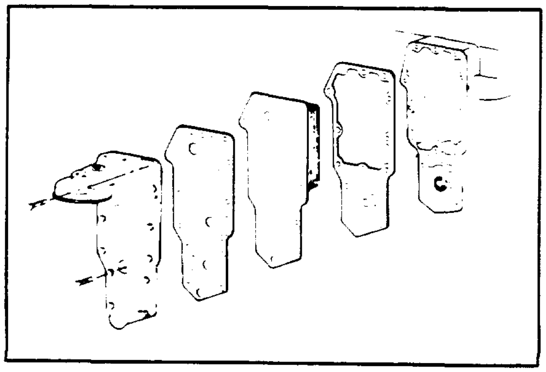


90-95mm

Remove the oil filter.

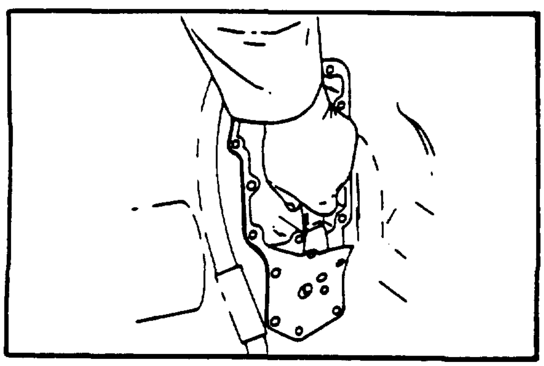


Clean around the oil cooler cover.

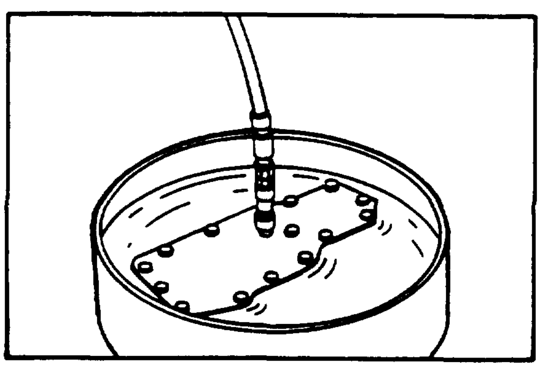


10mm

Remove the oil cooler cover, gaskets and cooler element.



Clean the sealing surfaces.



Apply 483 kPa [70 PSI] air pressure to the element to check for leaks.

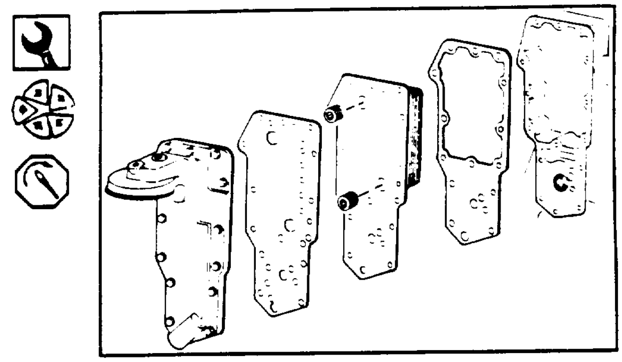
10mm

Assemble the oil cooler gaskets, element and cover.

Torque Value: 24 N•m [18 ft-lbs]

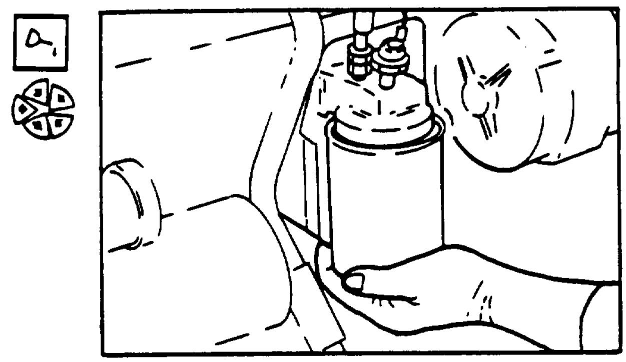
Note

Be sure to remove the shipping plugs from the element.



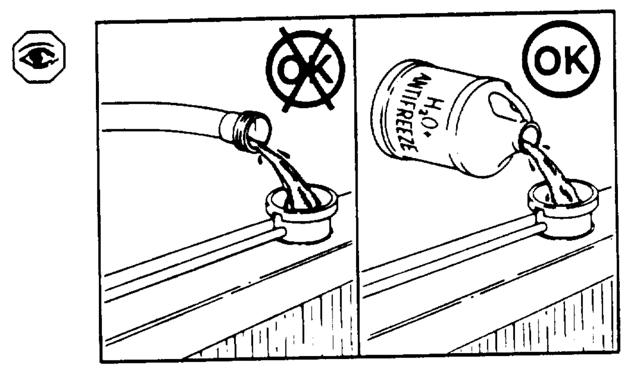
Fill the filter with clean lubricating oil and apply a light coat of oil to the sealing gasket.

Install the oil filter.



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

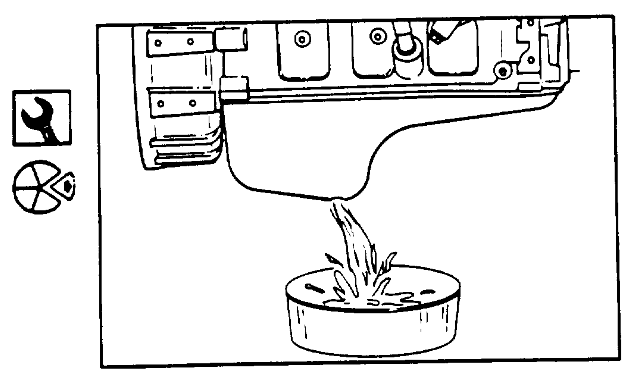
Stop the engine and check the coolant and oil level.

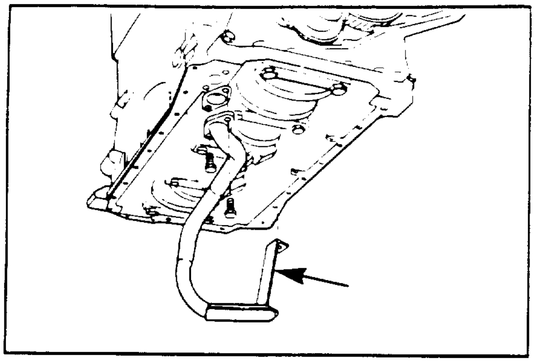


Oil Pan, Suction Tube and/or Gaskets - Replacement

17mm and 10mm

Drain the oil and remove the pan and gasket.





13mm

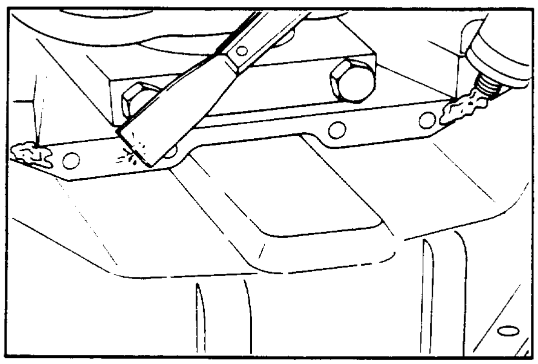
Caution
Be sure to connect the support bracket.

If required, remove the suction tube and gasket.

Clean the sealing surfaces.

Install the suction tube and gasket.

Torque Value: 24 N•m [18 ft-lbs]

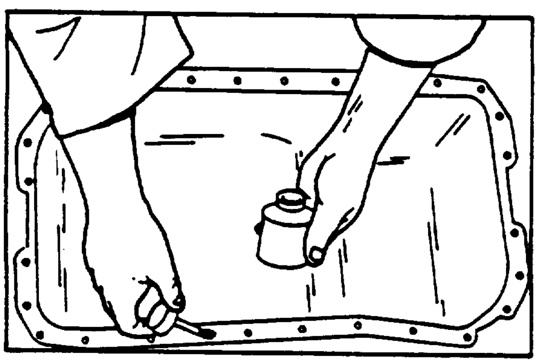


Caution
Be sure to fill the joints between the pan rail, gear housing and rear cover. Use Three Bond 1207C.

Clean the pan sealing surfaces.

Inspect oil pan for cracks and damaged threads.

Inspect oil suction tube and brace for cracks. Replace if damaged.

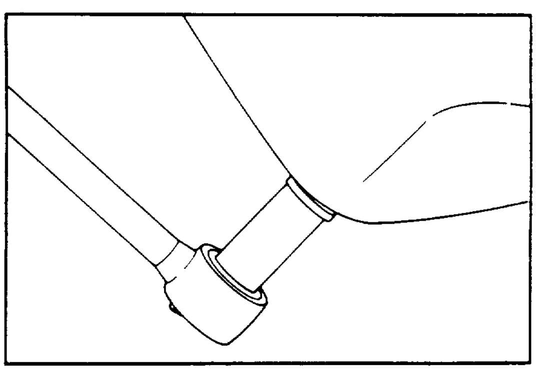


10mm and 17mm

Apply " K&W Copper Coat" sealant to both sides of the gasket.

Install the pan and gasket.

Torque Value: 24 N•m [18 ft-lbs]

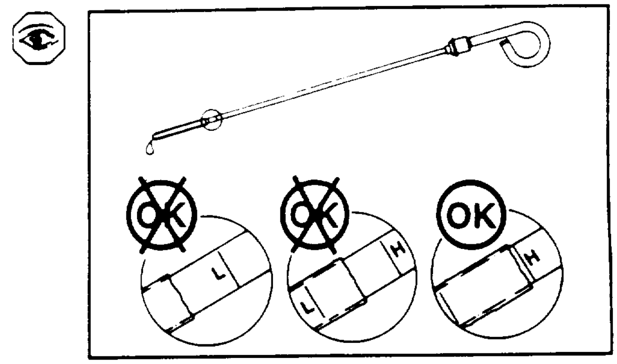


Install the drain plug.

Torque Value: 80 N•m [60 ft-lbs]

Fill the engine with oil. Run the engine and check for leaks.

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



Oil Pump Replacement

Preparatory Step:

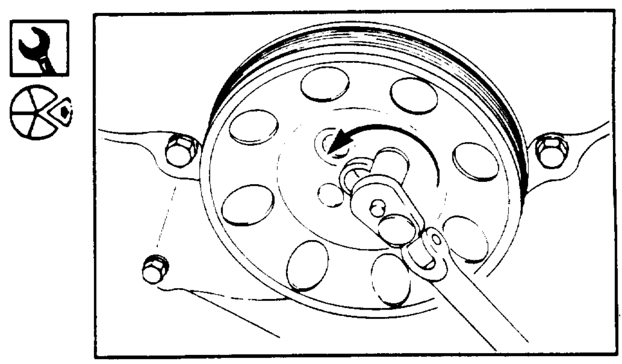
- Remove the drive belt.

Note

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

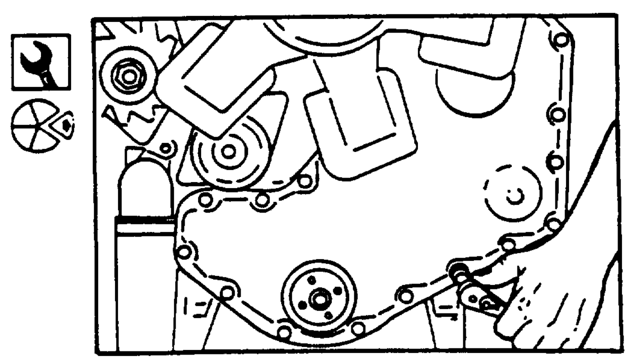
15mm

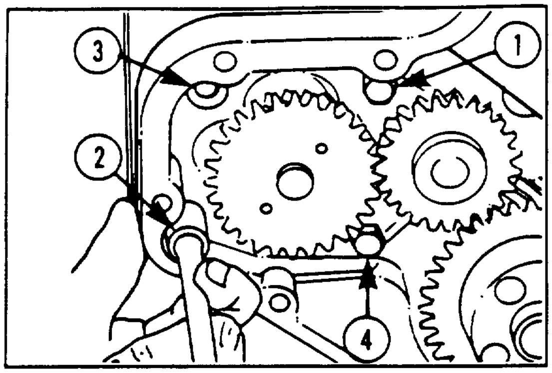
Remove the crankshaft pulley.



10mm

Remove the front cover.



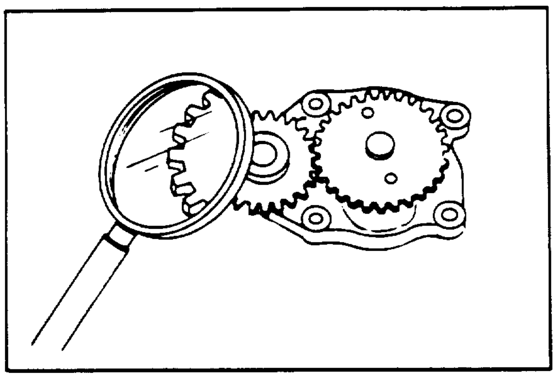


Remove the Lubricating Oil Pump

13mm

Remove the four mounting capscrews.

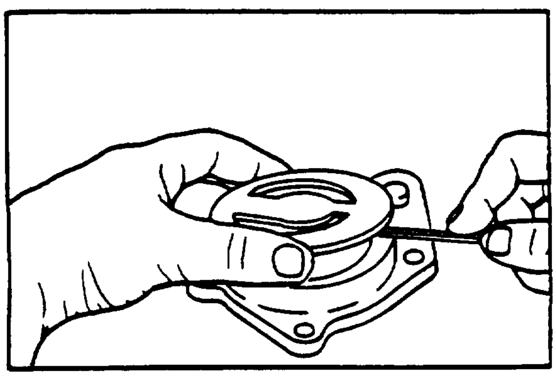
Remove the pump from the bore in the cylinder block.



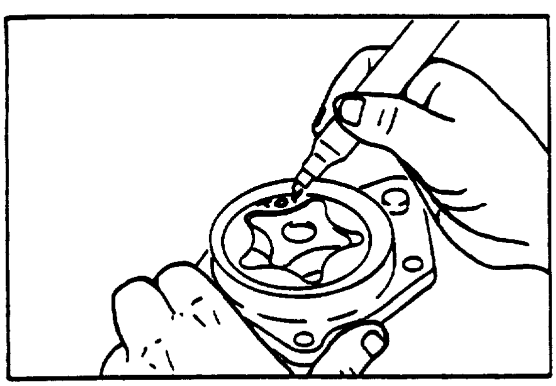
Clean and Inspect

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

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



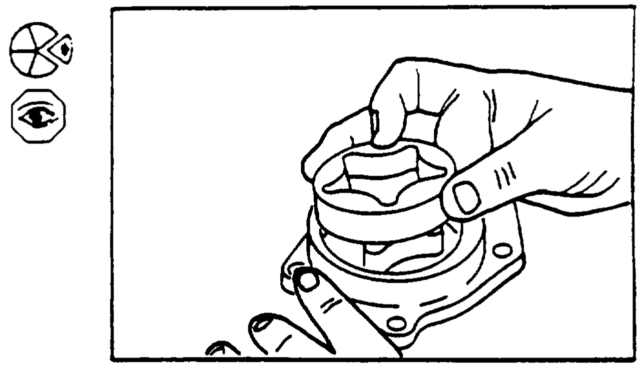
Remove the back plate.



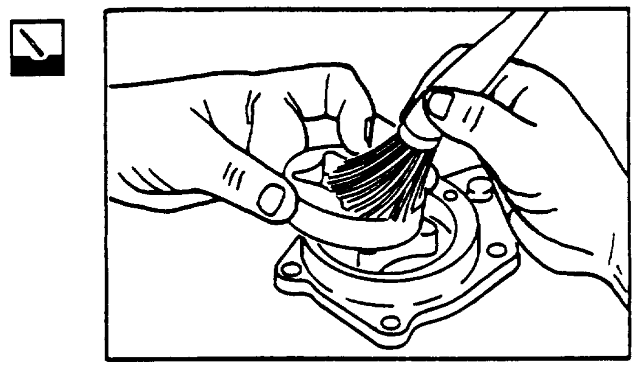
Mark "TOP" on the gerotor planetary.

Remove the gerotor planetary.

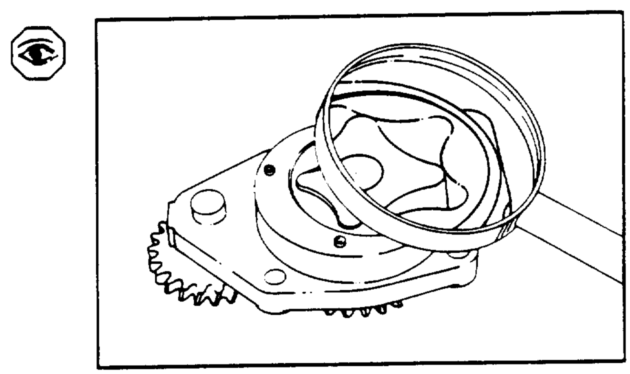
Inspect for excessive wear or damage.



Clean all parts in solvent and dry with compressed air.



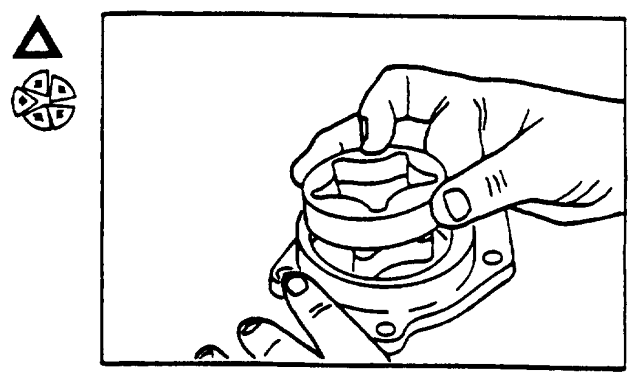
Inspect the pump housing and gerotor drive for damage and excessive wear.

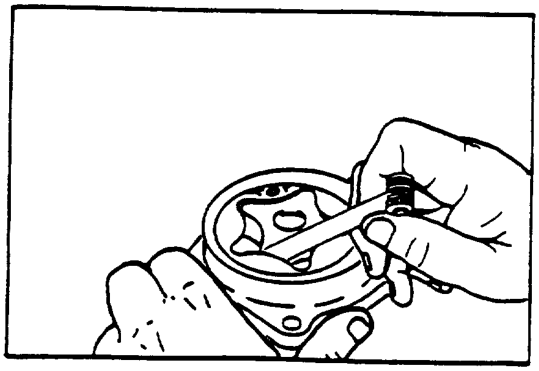


Caution

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

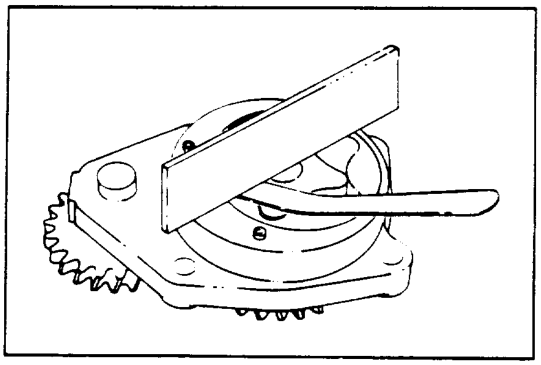
Install the gerotor planetary.





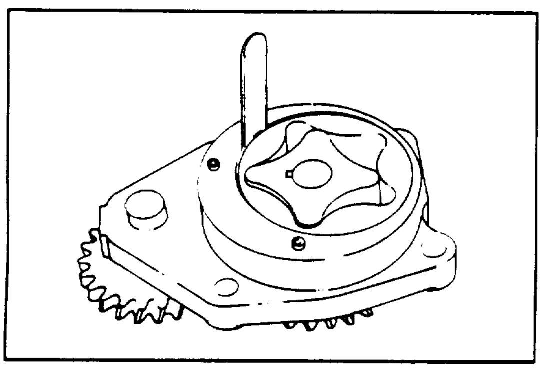
Measure the tip clearance.

Limit
Maximum Clearance: 0.1778mm [0.007 inch]



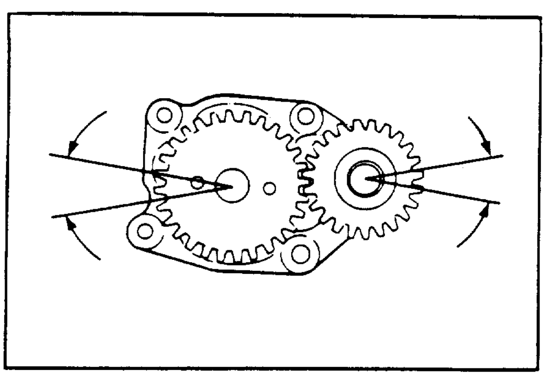
Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Limit
Maximum Clearance: 0.127mm [0.005 inch]



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

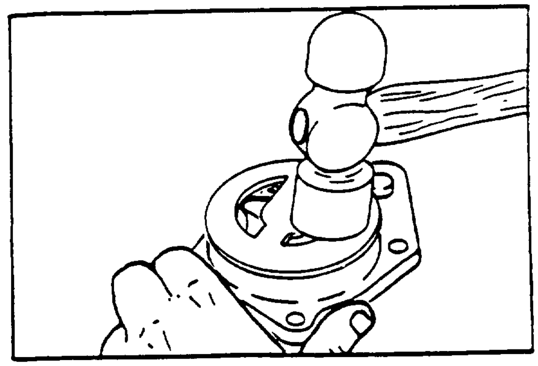
Limit
Maximum Clearance: 0.381mm [0.015 inch]



Measure the gears backlash.

Limits (Used Pump)
0.05 to 0.38mm [0.003 to 0.15 inch]

Install the back plate.

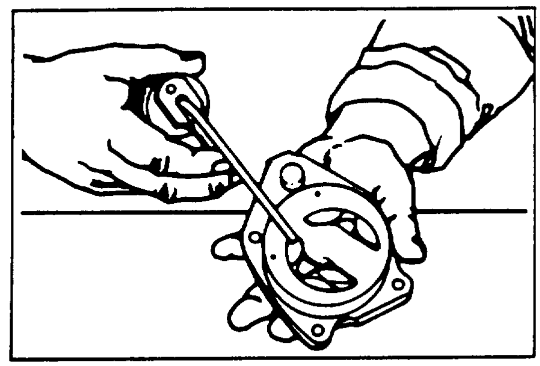


Installing the Lubricating Oil Pump

Lubricate the pump with. clean engine oil.

Note

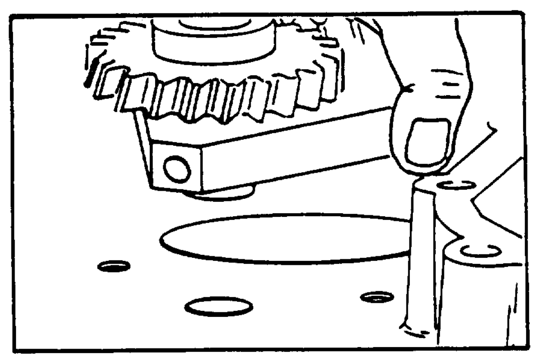
Filling the pump with oil during installation will help to prime the pump at engine start up.



Caution

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

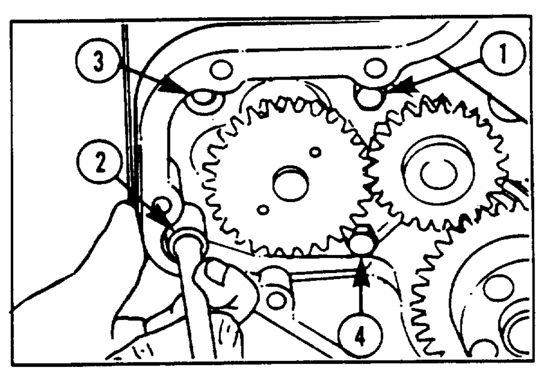
Install the pump.

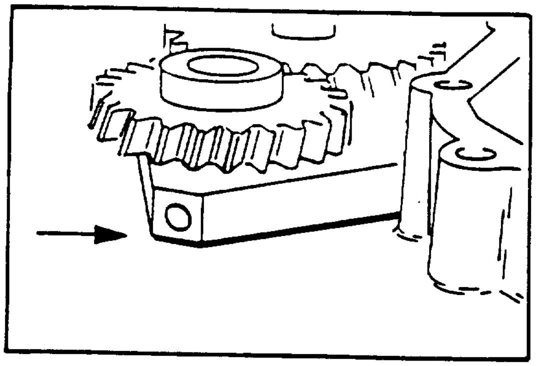


13mm

Tighten in the sequence shown.

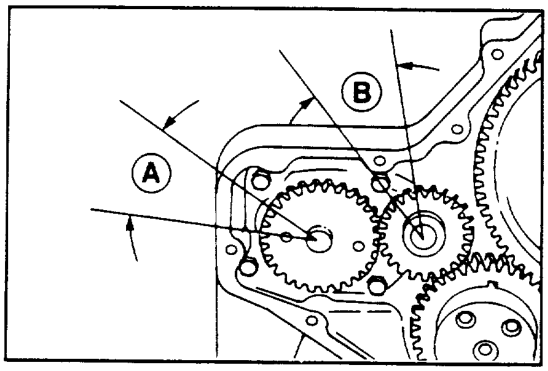
Torque Value: 24 N•m   [18 ft-lbs]





Note

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



Note

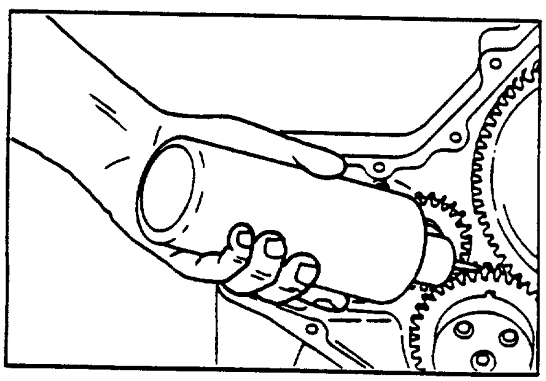
Be sure the gear backlash is correct if installing a new pump.

Measure gear backlash.

Backlash Limits	
A	B
.08 to .254mm [.003 to .010 inch]	.08 to .254mm [.003 to .010 inch]

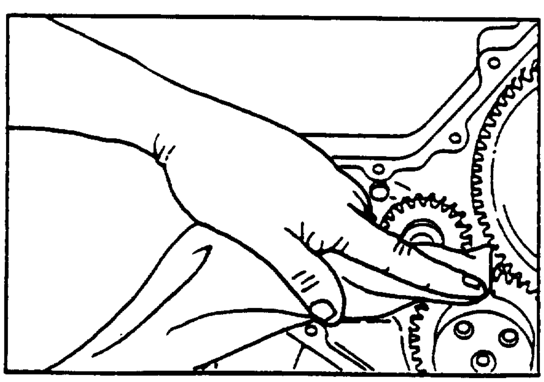
Note

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

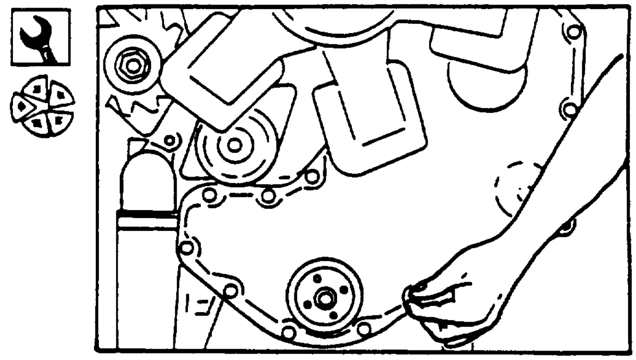
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Thoroughly clean the front seal area of the crankshaft.

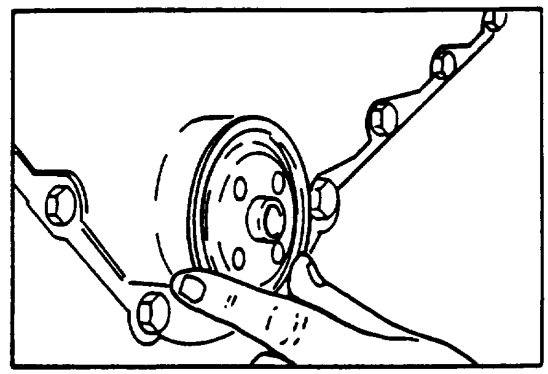
10mm

Install the front cover and gasket.

Note
Install the capscrews but do not tighten at this time.



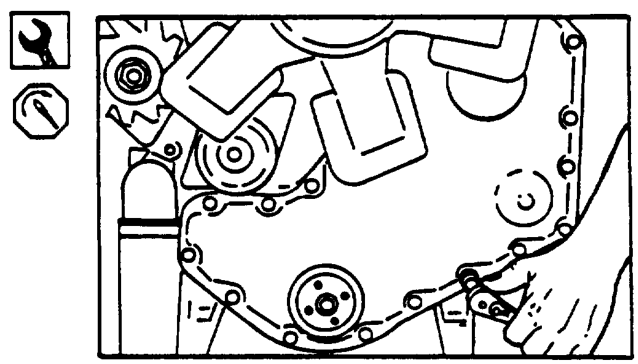
Use the alignment/installation tool from the seal kit to align the cover to the crankshaft.



10mm

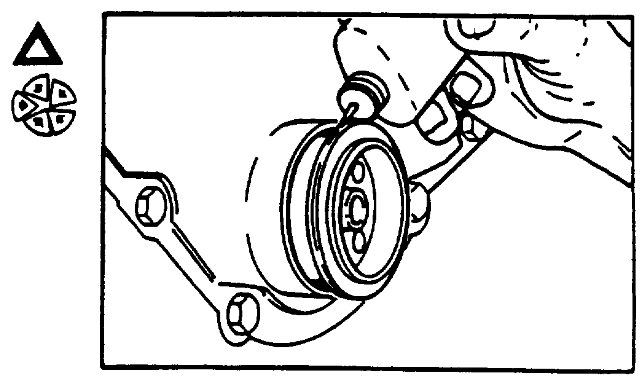
Torque Value: 24 N•m [18 ft-lbs]

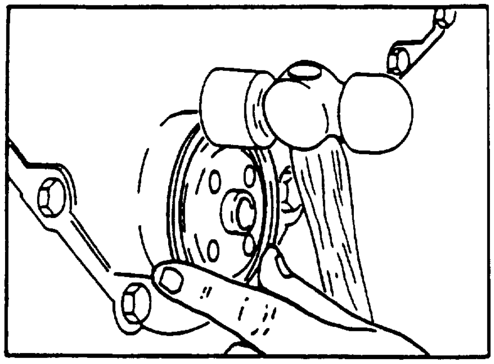
Remove the alignment/installation tool.



Caution
Always use a seal pilot when you install a seal.

Apply a bead of Loctite 277 to the outside diameter of the seal. Install the pilot from the seal kit onto the crankshaft. Install the seal onto the pilot and start into the front cover. Remove the pilot.

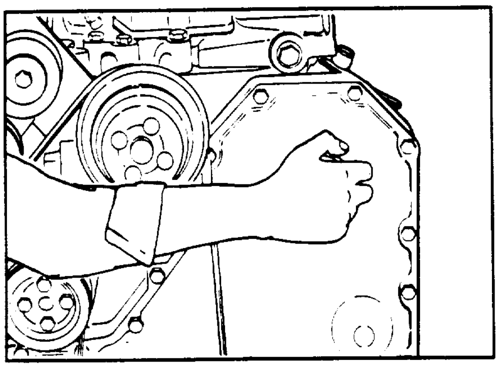




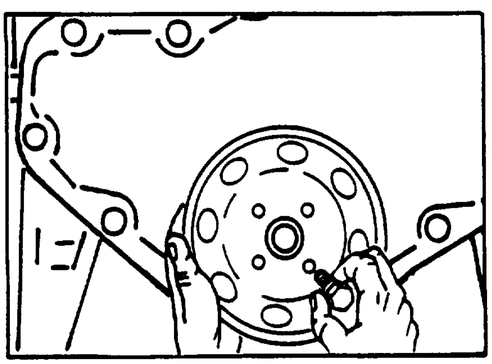
Note

To prevent damage to the seal carrier, hit the alignment/installation tool alternately at the 12, 3, 6 and 9 o'clock positions.

Use the alignment/installation tool and a plastic hammer to install the seal to the correct depth.

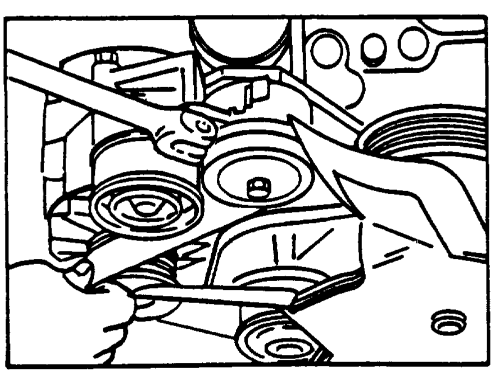


Install the front cover access cap and seal.



15mm

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

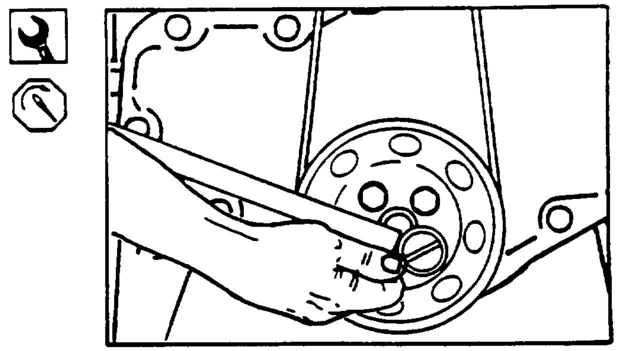


1/2 inch Square Drive

Raise the belt tensioner to install the belt.

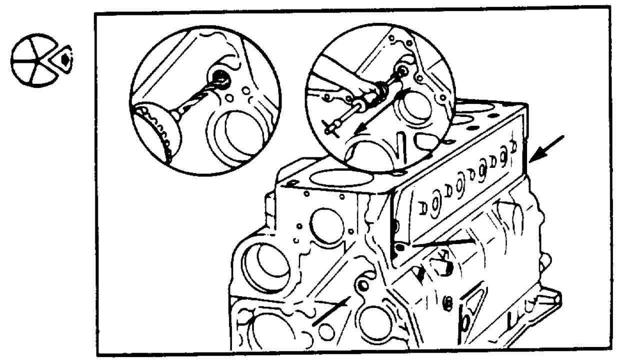
15mm

Torque Value: 125 Nrm [92 ft-lbs]



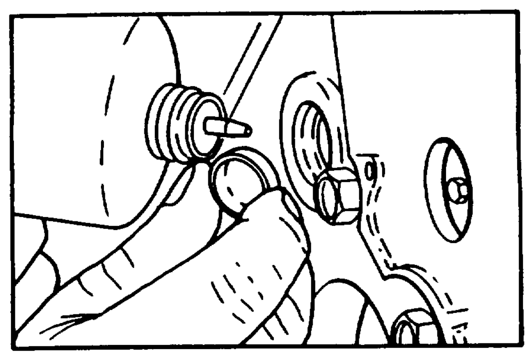
Cup Plugs Replacement

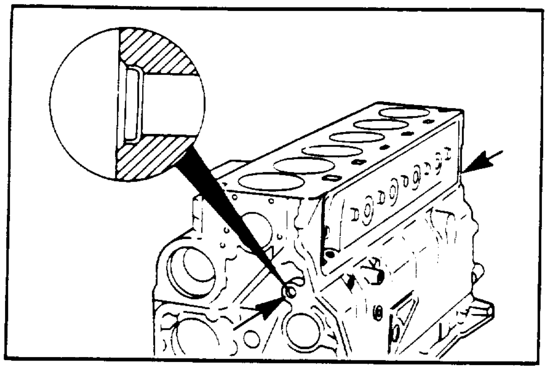
Remove the cup plugs from the oil passages.



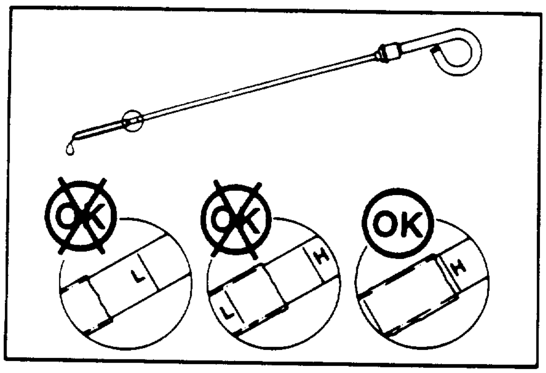
To Install the Cup Plugs

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





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



Fill the engine with oil. Run the engine and check for leaks.

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

Section 7. Electrical System

Electrical System

Electrical System Description/Operation

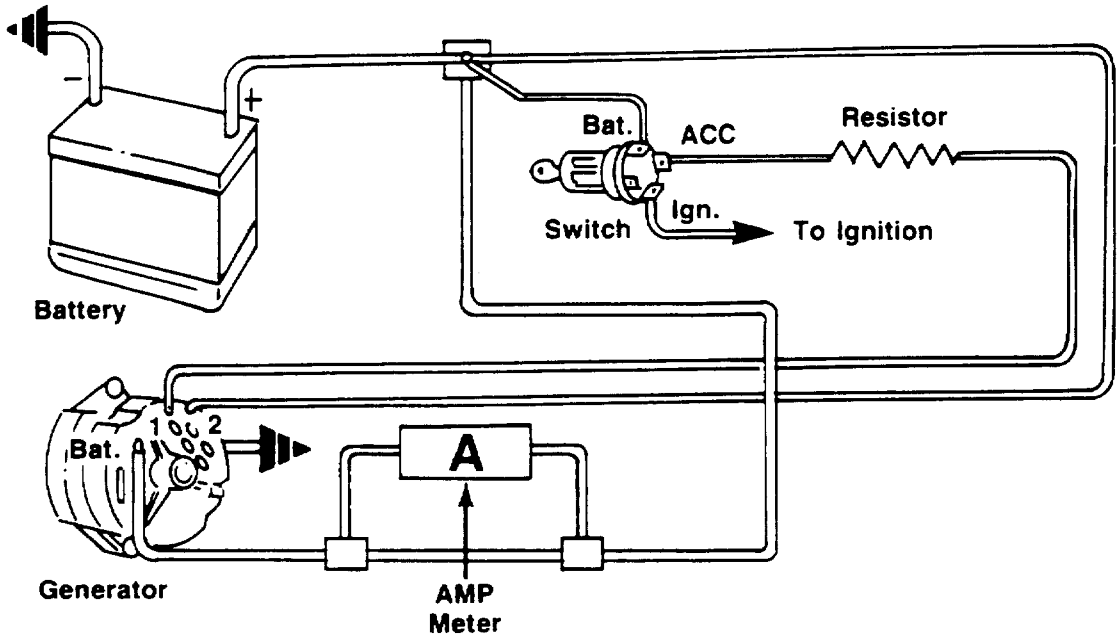
The electrical system basically consists of the starting motor and the alternator.

The injection pump uses an electrical fuel shutoff valve. The function of the valve was discussed in the fuel system section.

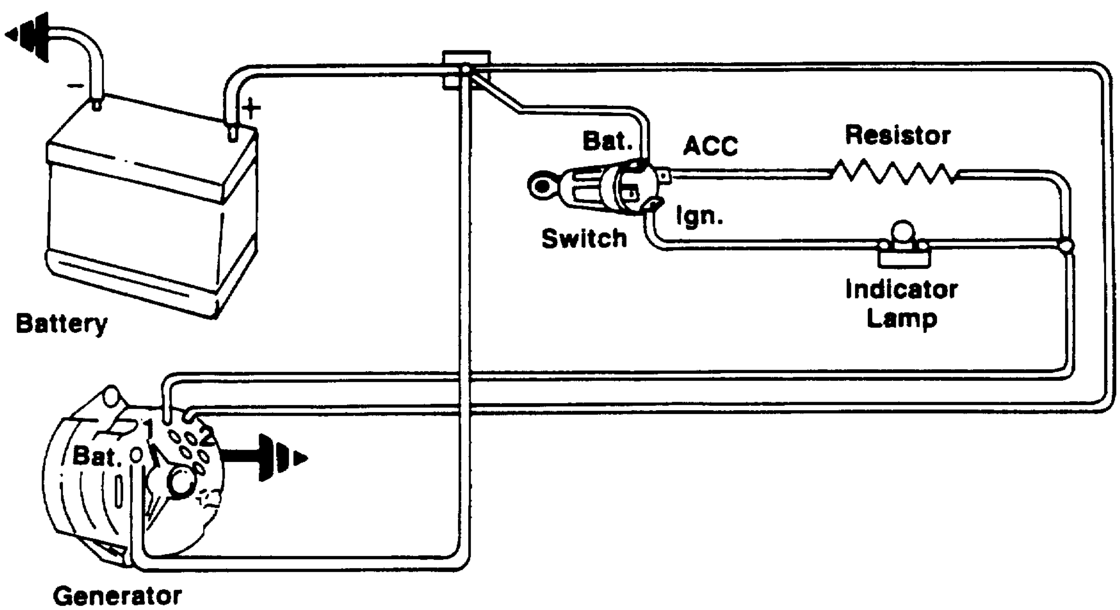
The engine should have temperature and oil pressure sensors connected to indicators or wired for automatic shutdown.

The engine may also be fitted with a block heater or an oil pan heater.

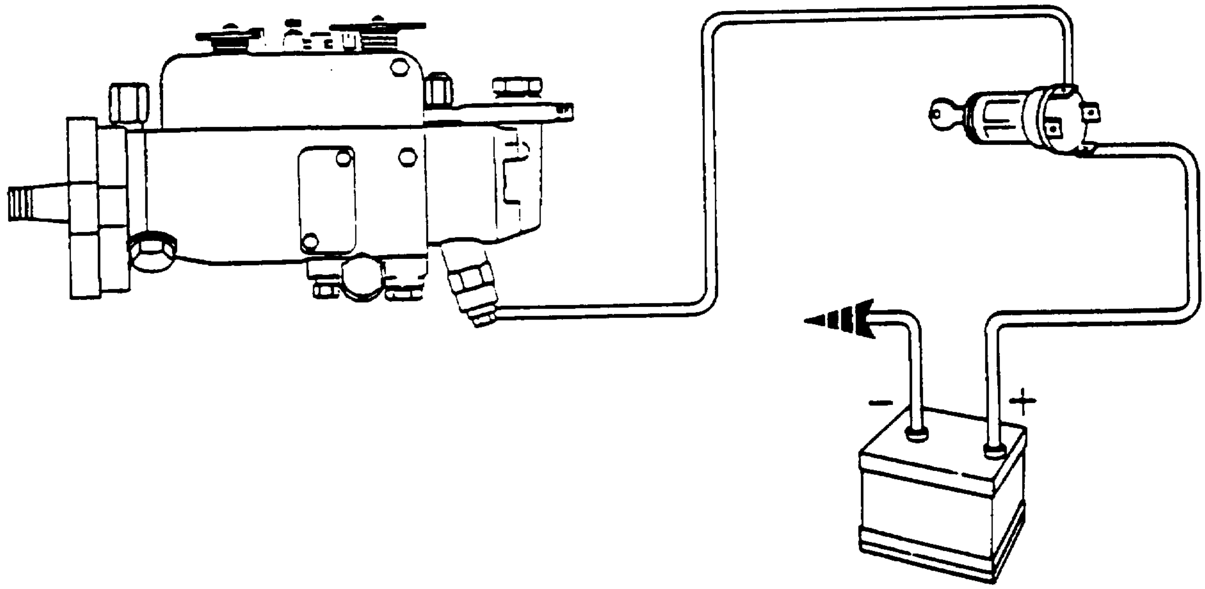
Prestolite Model 8AR2201L Alternator



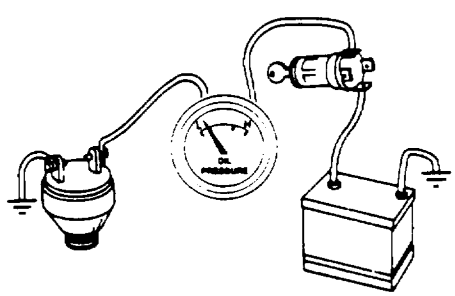
Typical External Circuit

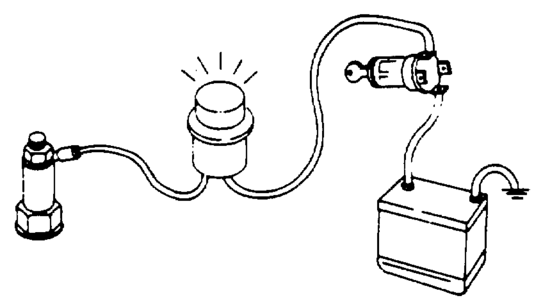


Injection Pump Fuel Shutoff Valve



Oil Pressure Switch and Temperature Sensors





Electrical System 4B39

Minimum Recommended Battery

Capacity - With Light

Accessories*

- 12 V Starter 625CCA

With Heavy Accessories**

- 12 V Starter 800CCA

Maximum Allowable Resistance of Starting Circuit

- With 12 V Starter - Ohms .... -- .0012 --

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

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

Starter

Nippondenso - 12 VDC.................... --- 2.5 Kw --

Nippondenso P/N 028000-0540

Nut Size:

Battery Connection 3/8x16 inch

Switch Connection 8-32 inch

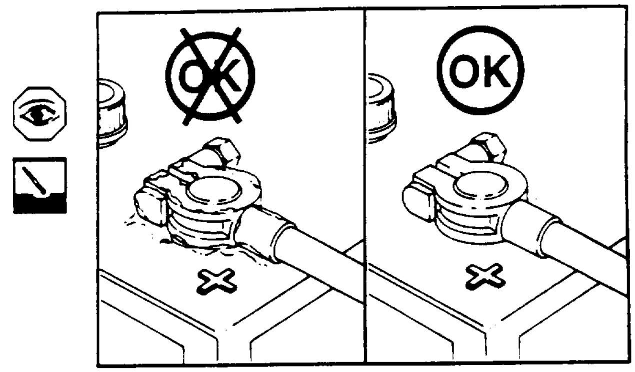
Alternator

Prestolite Model 8AR2201L, 65 ampere

Diagnosing Electrical Malfunctions

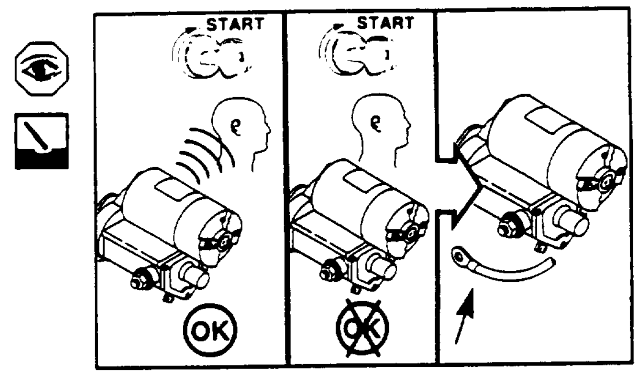
Starting Motor

Before you troubleshoot the starting motor, make sure the battery terminals are not loose or corroded.



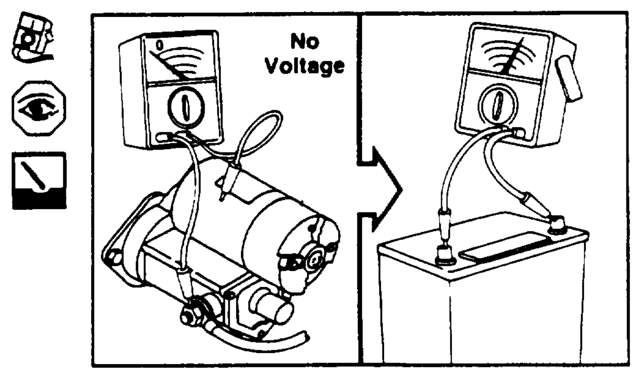
Engine Does Not Crank

If the solenoid does not make an audible sound, check for loose wiring connections.



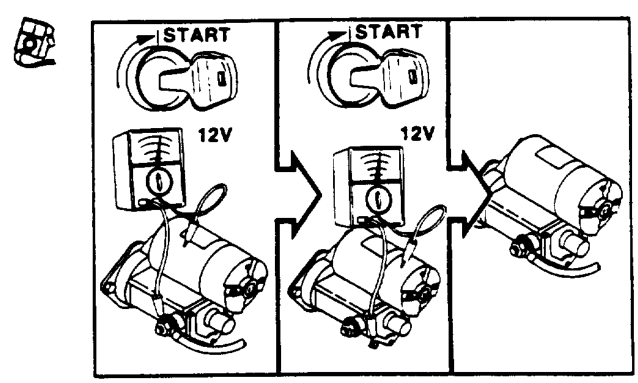
Check the voltage at the solenoid battery post.

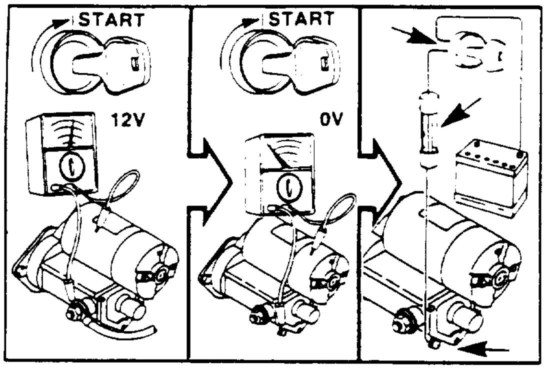
- No voltage check the condition of the battery. Check the connections at the battery, engine and solenoid.



- 12 volts at the solenoid battery post check the voltage at the S (switch) terminal on the solenoid. The ignition switch must be in the start position.

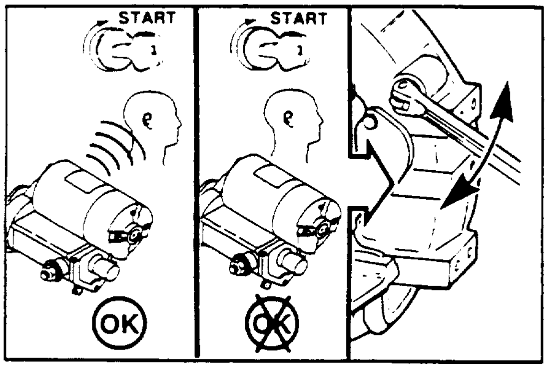
The solenoid is at fault if the check indicates 12 volts at the S terminal.



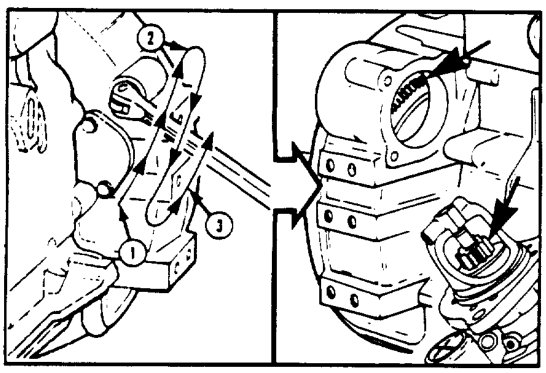


If no voltage is indicated at the S terminal. check:

- Fuses
- Voltage to the ignition switch
- And, voltage to neutral safety switch and engine safety shutoff system.



If the solenoid does make an audible sound, turn the switch off and attempt to bar the engine in both directions.



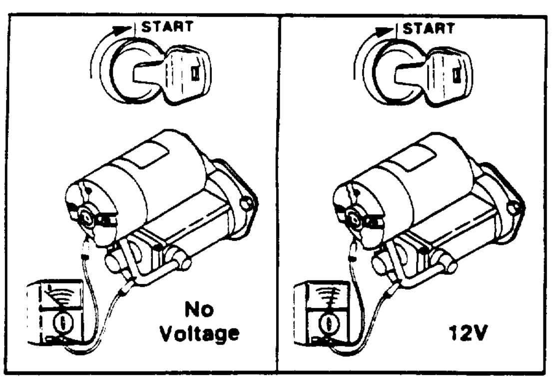
Bar the engine as follows:

1. Direction of engine rotation.

2. Direction opposite engine rotations.

3. Direction of engine rotation.

If the engine will bar at Step 3, attempt to start the engine. If the starter cranks the engine, check the starter pinion gear and flywheel ring gear for damage.



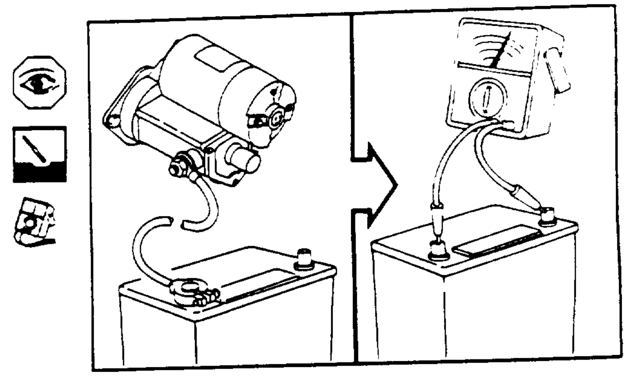
If the engine bars and the starting motor does not crank, check the voltage between the solenoid and starting motor. The ignition switch must be in the start position.

No Voltage: Starter is at fault
Normal Voltage: The solenoid is at fault

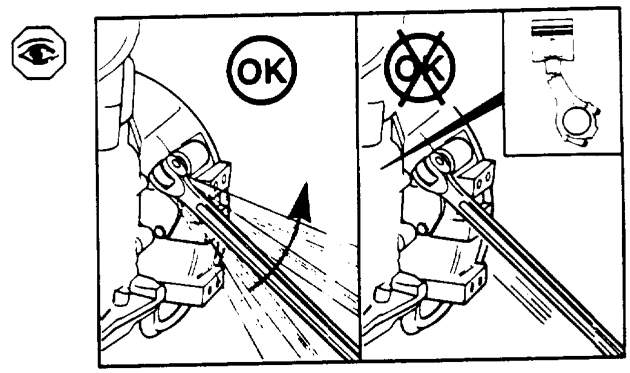
Engine Cranking Speed Too Slow

Make sure the wiring connections are clean, tight and not damaged.

Check the battery voltage.

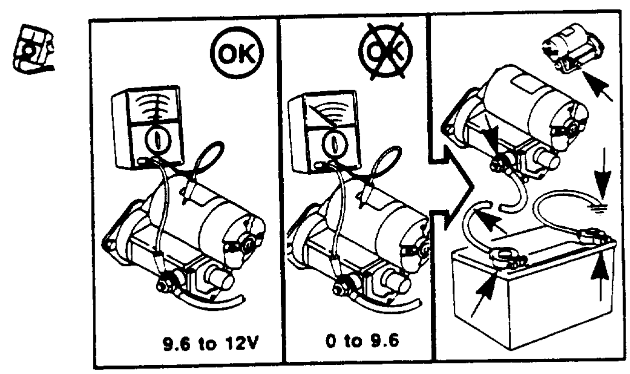


If the engine was not rotated to check the starting motor, bar the engine in the direction of engine rotation to make sure the engine is free and does not have an internal malfunction.

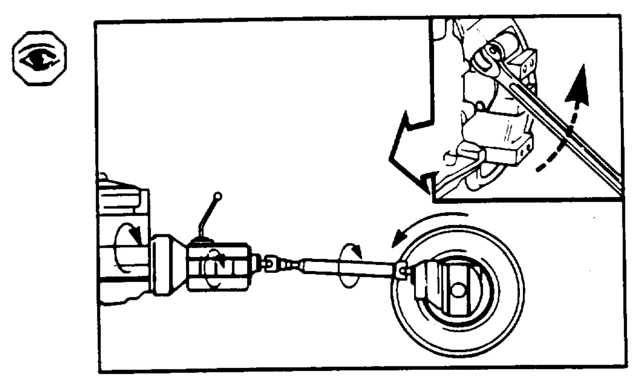


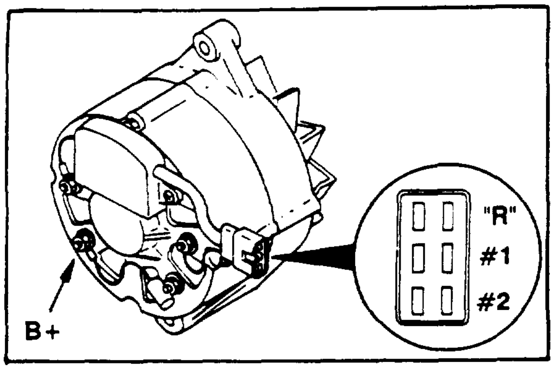
If the engine is free, check the voltage at the starter during cranking. If the voltage drops more than 2.4 volts, check that all connections are tight.

If the cables are correct and the voltage drop exceeds the limit, replace the starter.



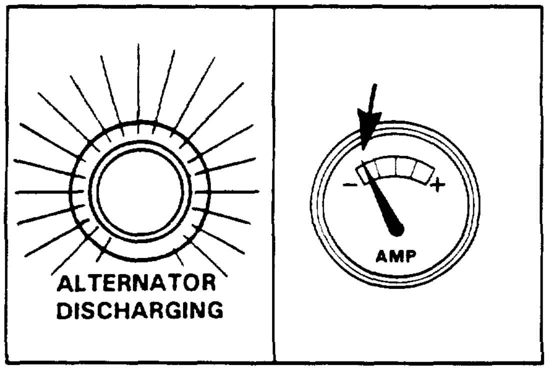
If the engine requires more than a normal effort to bar, check for excessive load from the driven units and accessories.



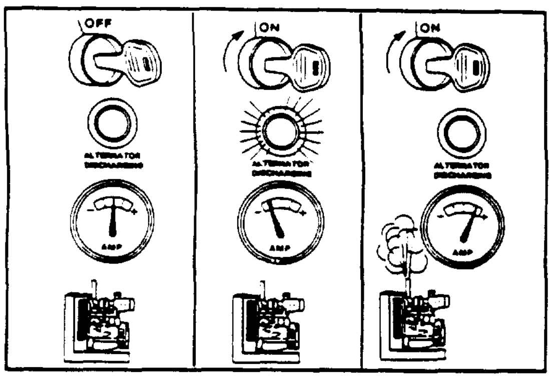


Alternator

The terminals on the alternator are shown in this illustration. The "R" terminal provides voltage to operate the hourmeter.



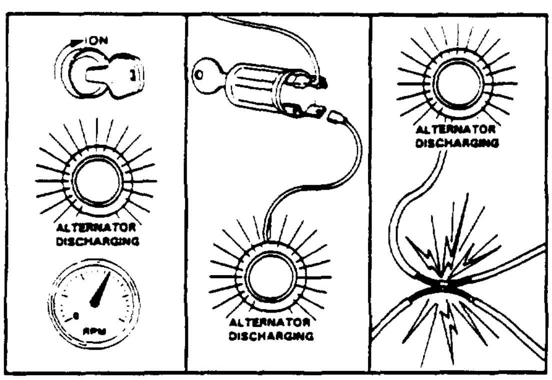
The ALTERNATOR DISCHARGING indicator and the BATTERY ammeter indicate trouble with the charging system.



Normal Indicator Lamp Operation

Check the indicator lamp for normal operation as shown below.

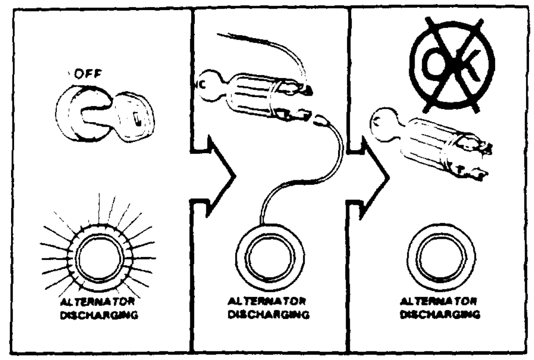
Engine	Switch	Lamp	Ammeter
Stopped	Off	Off	o
Stopped	On	On	-
Running	On	Off	+



Switch Off, Lamp On, Engine Stopped

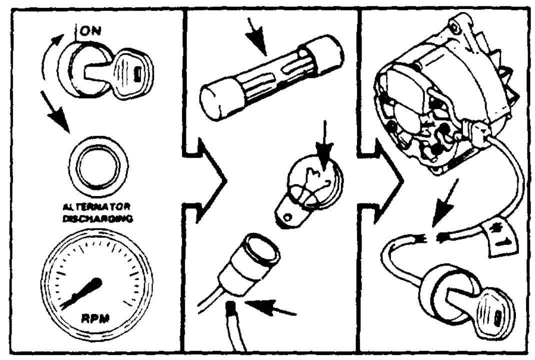
Disconnect the lamp lead at the ignition switch. If the lamp stays on, there is a short to a positive wire on the ignition side of the lamp.

If the lamp goes out, there is a short in the switch.



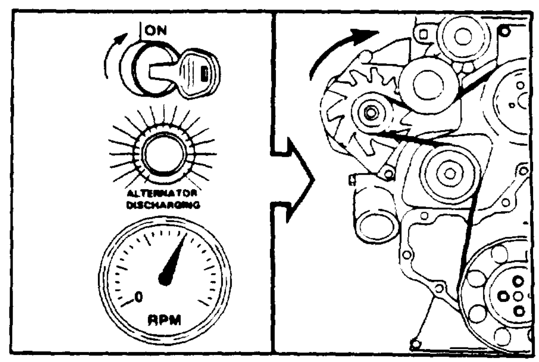
Switch On, Lamp Off, Engine Stopped

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 lead circuit between alternator and ignition switch.

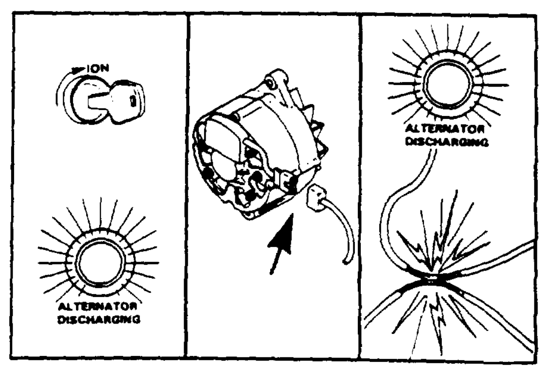


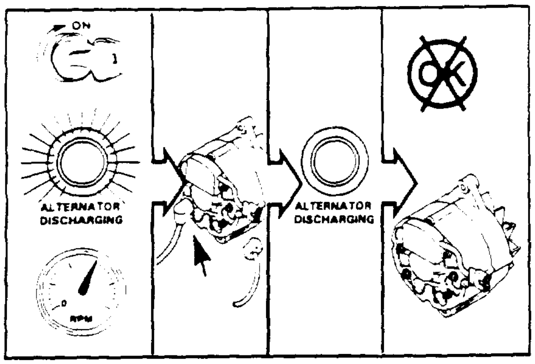
Switch On, Lamp On, Engine Running

Check the drive belt and alternator pulley to be sure the alternator is rotating.

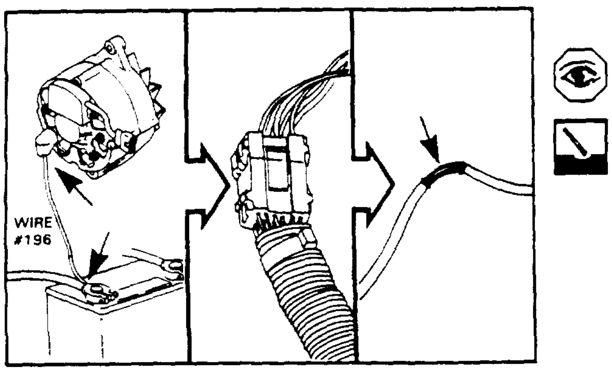


Disconnect the lead to Terminals No. 1 and No. 2. If the lamp stays on, there is a short to ground on the alternator side of the lamp.





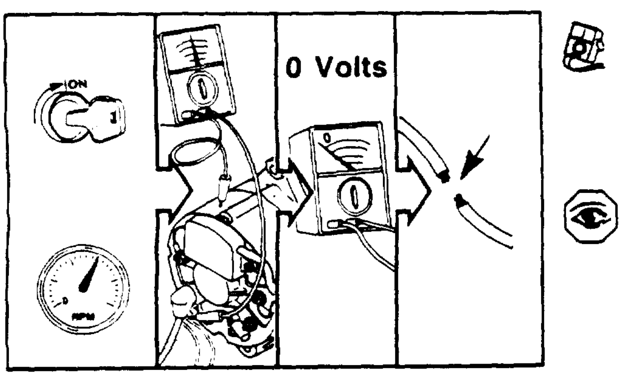
If the lamp goes out, replace the alternator.



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:

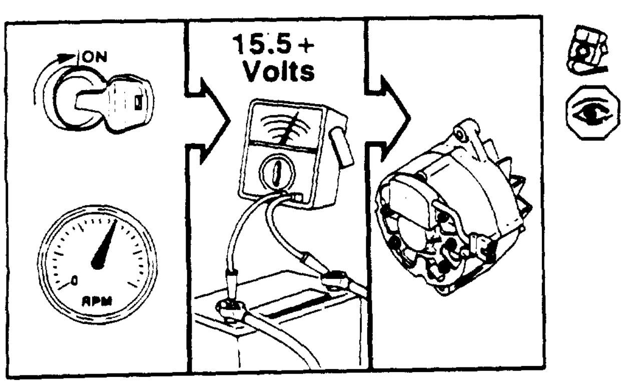
A. Alternator B + terminal to ground

B. Alternator No. 1 terminal to ground

C. Alternator No. 2 terminal to ground

A zero reading indicates an open between the voltmeter connection 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.

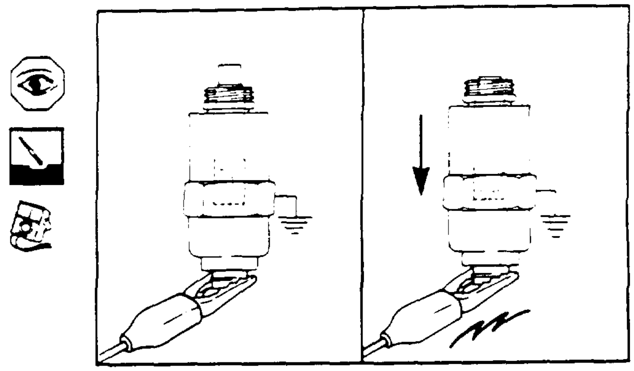
If voltage is 15.5 or more, remove the alternator for repair.

Fuel Shutoff Valve - Check

Note

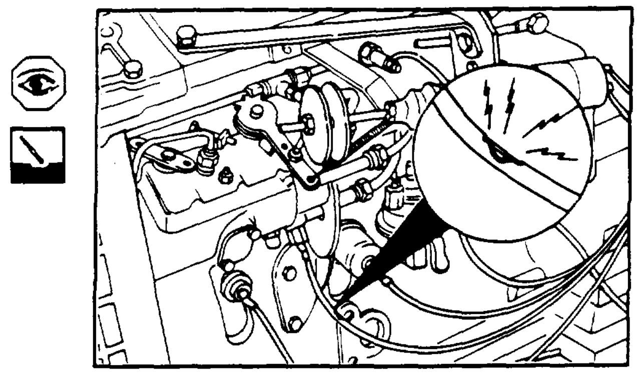
Check all connections for loose or corroded connections and for broken wires.

Remove the valve. Ground the valve and connect 12 volts DC to the terminal and observe plunger movement.



Oil Pressure Switch and Temperature Sensor

When diagnosing problems with either the pressure switch or the temperature sensor, check for loose or corroded connections and for broken wires.



Oil Pressure Switch - Check

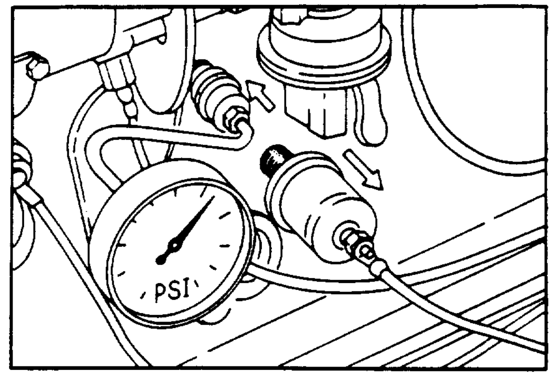
Remove the pressure switch, install a gage, start the engine and measure oil pressure. Minimum oil pressure:

Idle (675 to 725 RPM) .... 69 kPa [10 PSI]

Full Speed......................... 207 kPa [30 PSI]

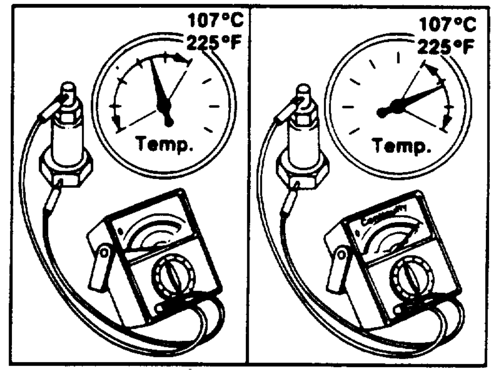
Note

The Pressure switch is set to actuate when oil pressure drops to 34 kPa [5 psi].



Temperature Sensor - Check

Check for continuity. The sensor will have continuity only when coolant temperature is above 107° C [225° F]



Engine Electrical System Replacement Procedures

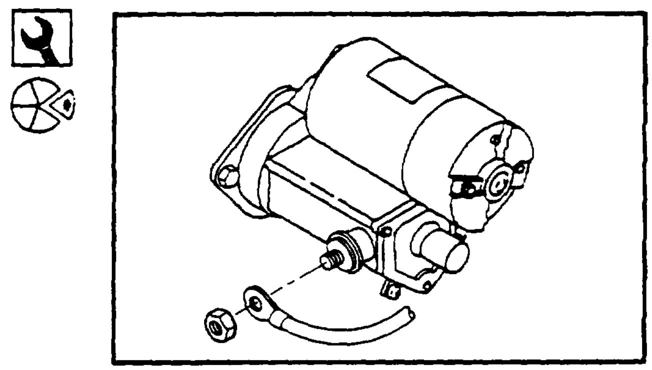
Starting Motor Replacement

Preparatory Steps:

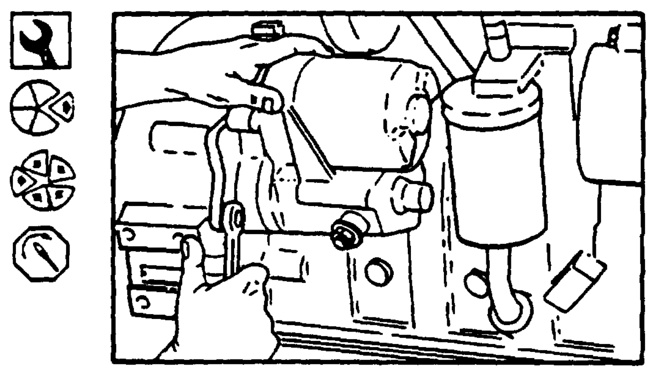
- Disconnect the ground cable from the battery terminal.

- Identify each electrical wire with a tag indicating location.

17mm
Remove the battery cable from the solenoid.



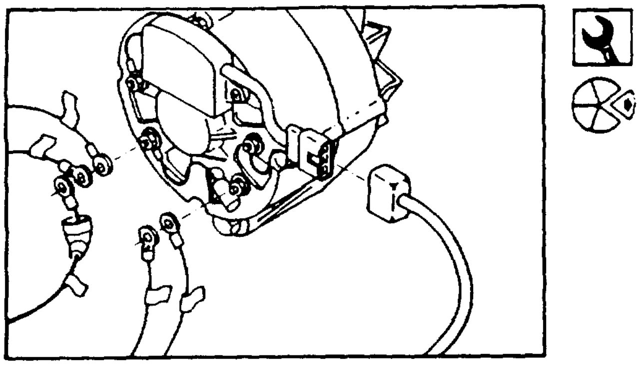
10mm
Remove the starting motor.
Install the starting motor in the reverse order of removal.
Torque Value: 43 N•m [32 ft-lbs]



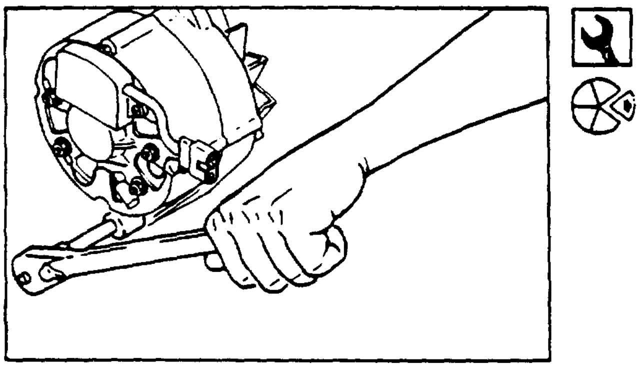
Alternator - Replacement
Preparatory Steps:

- Disconnect the ground cable from the battery terminal.

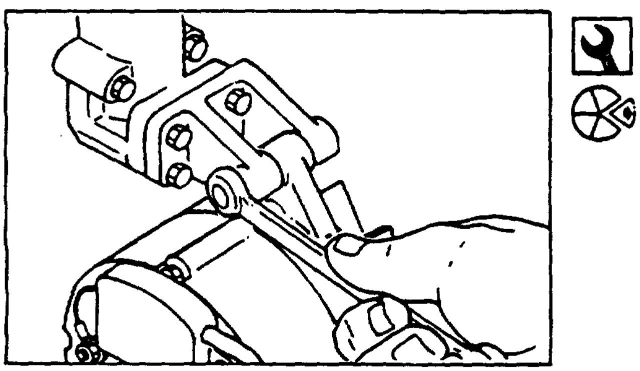
- Remove the drive belt from the alternator pulley.



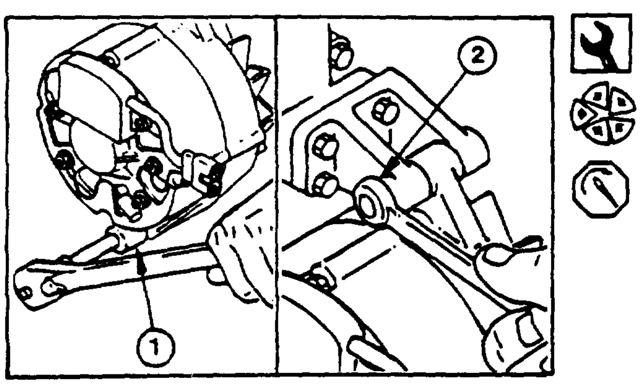
7/16 inch
Remove and tag all wires and complete the following _ steps.



13mm
Remove the alternator link capscrew.



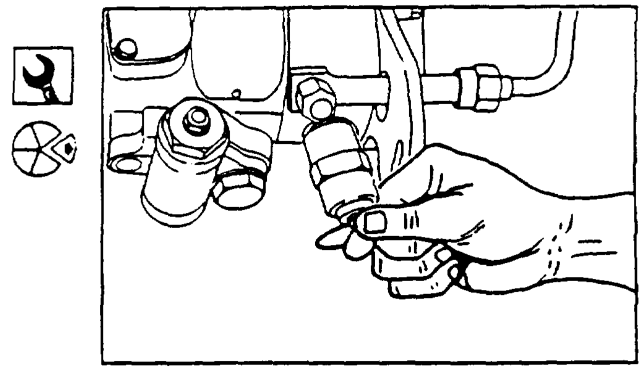
16mm
Remove the alternator mounting capscrew.



13mm, 16mm
Install the alternator by tightening the 13mm capscrews before the 16mm capscrew. Reconnect all wires.

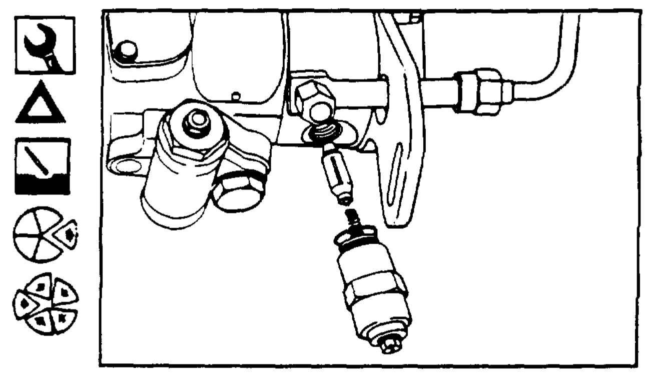
Torque Value: (13mm) 24 N•m [18 ft-lbs]
(16mm) 43 N•m [32 ft-lbs]

Electric Fuel Shut Off Valve - Replacement
8mm
Remove the electrical wire(s) and complete the following steps.

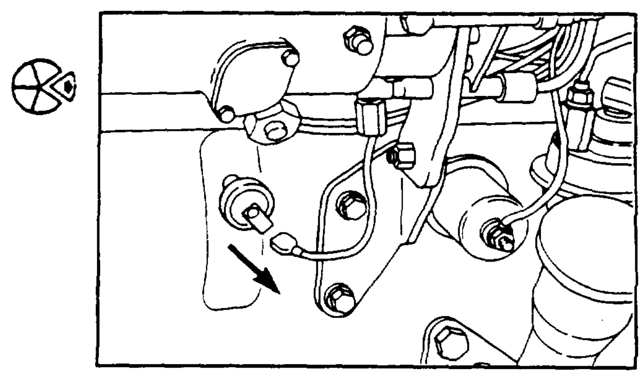


24mm
Caution: When removing the valve, be careful not to drop the piston and spring.
Clean around the valve.

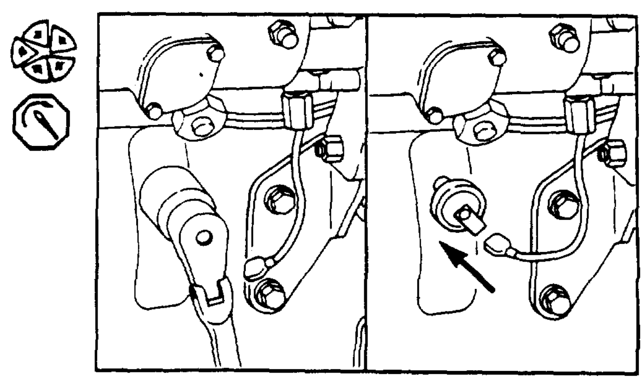
Replace the valve and connect the electrical wire.



Oil Pressure Switch - Replacement
Disconnect the wire from the sending unit.
Note: The sending units illustrated may differ from those installed by the equipment manufacturer.

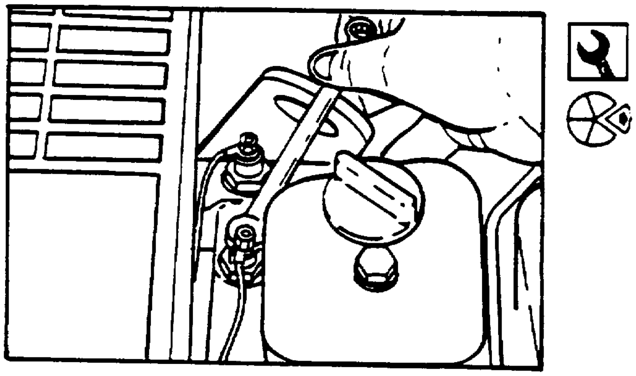


Reconnect the wire to the sending unit.
Torque Value:
(Installed into Cast Iron)
16 N•m [12 ft-lbs]
(Installed into Aluminum)
10 N•m [7 ft-lbs]

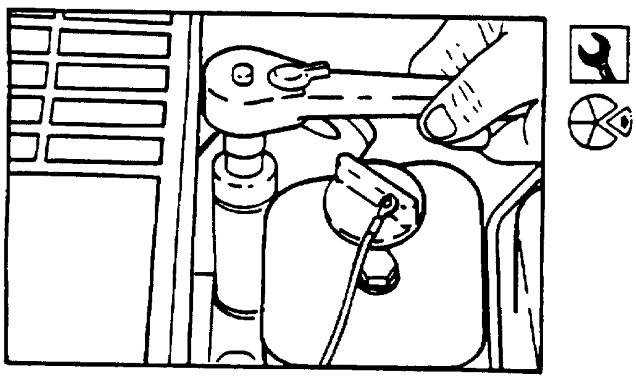


Temperature Sensor Replacement
Preparatory Step:

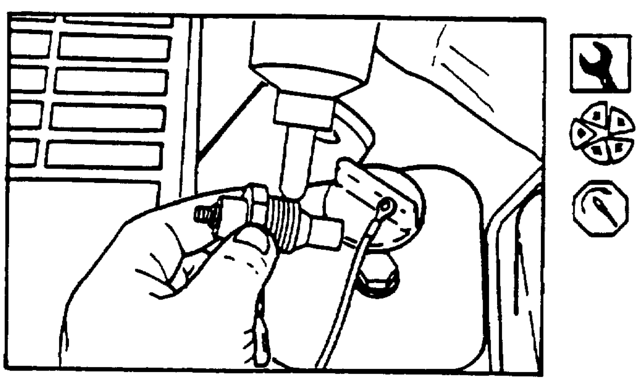
- Drain coolant



3/8 inch or Screwdriver
Disconnect the temperature sensor wiring.



7/8 inch
Remove the temperature sensor.



7/8 inch
Apply liquid teflon sealant to the threads when installing the temperature sensor.
Reconnect the wiring.
Torque Value:
50 N•m [37 ft-lbs]

Section 8. Base Engine Components

Section 8. Base Engine Components - continued

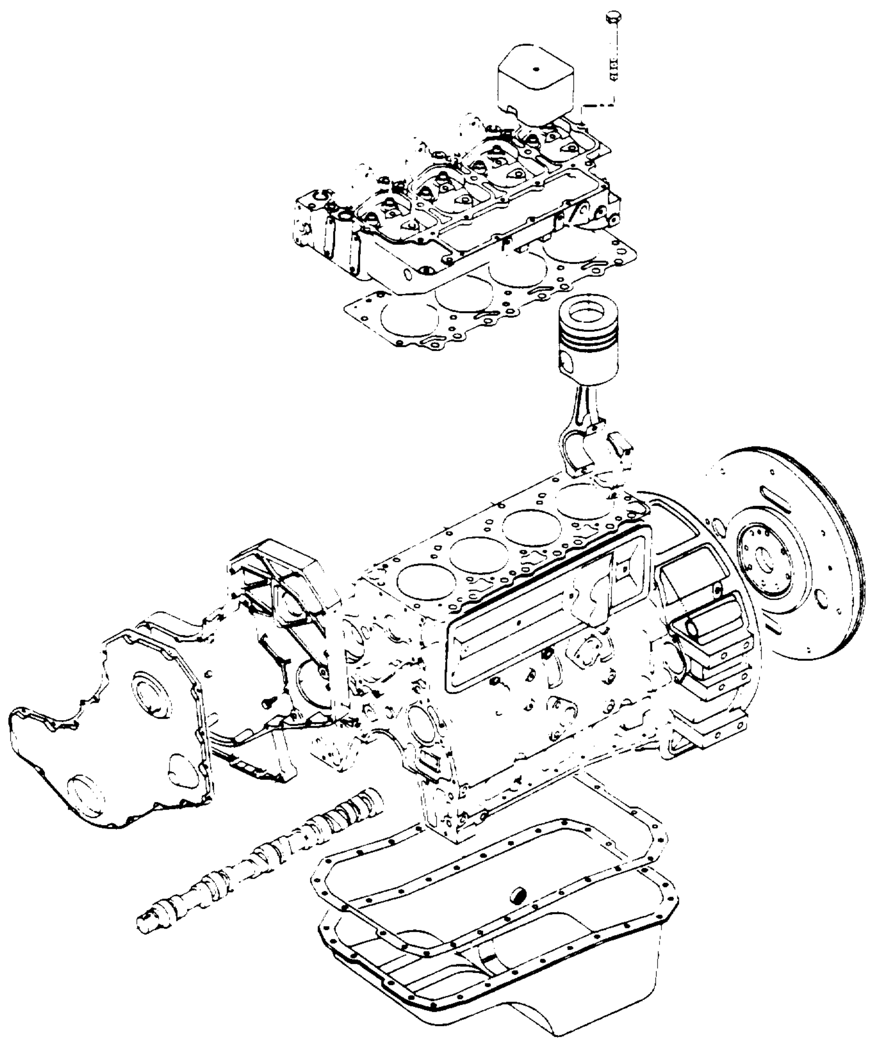
Operation and Description

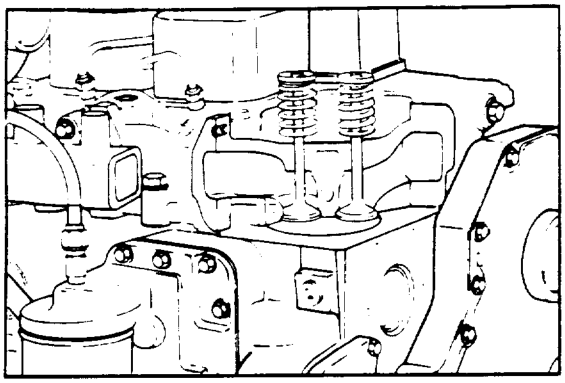
This section of the manual defines the base engine components, describes the operation of those components, provides guidelines for diagnosing malfunctions and gives procedures for component replacement and in-chassis overhaul.

Definition

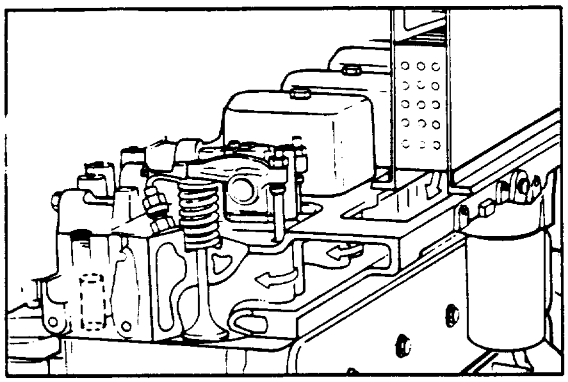
For the purpose of this manual, Base Engine Components are defined as mechanical functions not included in the other major engine systems. The components include:

- Valve Train and Cylinder Head
- Front Gear Housing and Gear Train
- Camshaft, Tappets and Push Rods
- Piston and Connecting Rod Assemblies
- Crankshaft and Main Bearings
- Cylinder Block

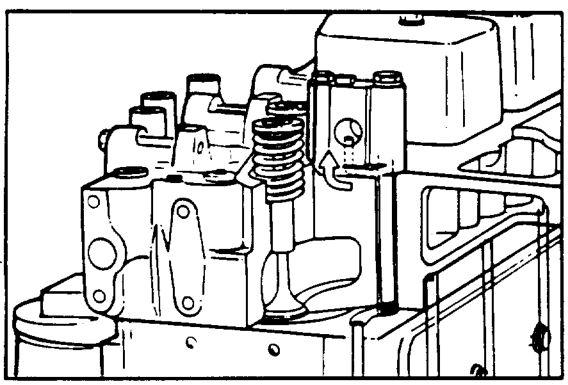




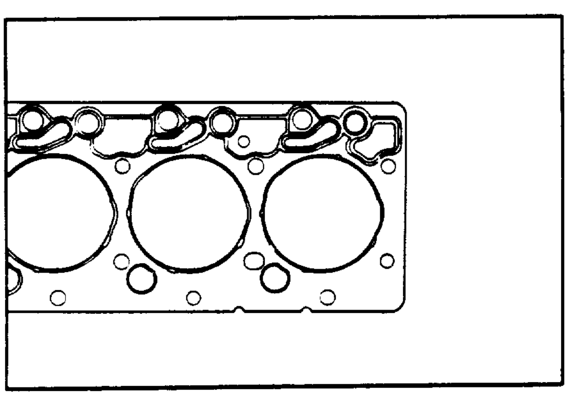
Cylinder Head and Valve Train
The cylinder head is a one piece, crossflow design with two valves per cylinder. The head has integrally cast valve guides and hardened valve seat surfaces which can be repaired in a machine shop using the appropriate service parts.



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.

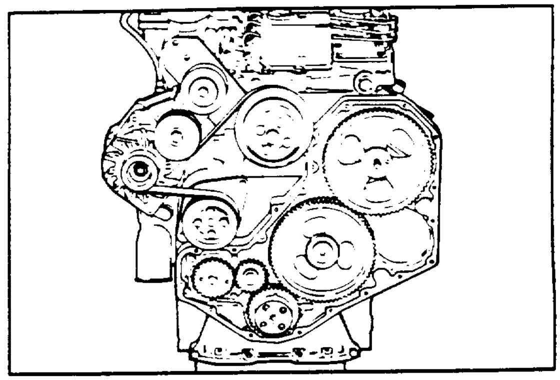


Separate pedestals for each cylinder are used to support and route oil to the rocker levers.

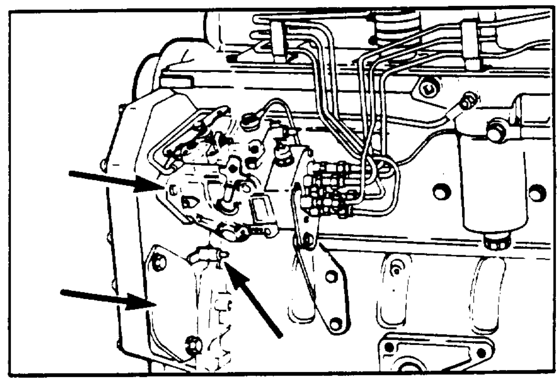


The cylinder head gasket is a laminated design with print-o-seal on both sides around the water holes. A fire ring in the gasket seals the cylinder bores. As discussed in the Cooling System, the gasket also provides orifices to control coolant flow.

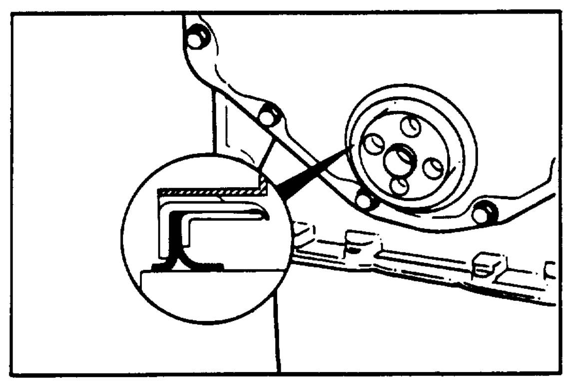
Front Gear Housing and Gear Train
The gear train consists of the crankshaft gear, lube pump gear idler and drive gear, the camshaft gear, the fuel pump gear and the accessory drive gear, if used.



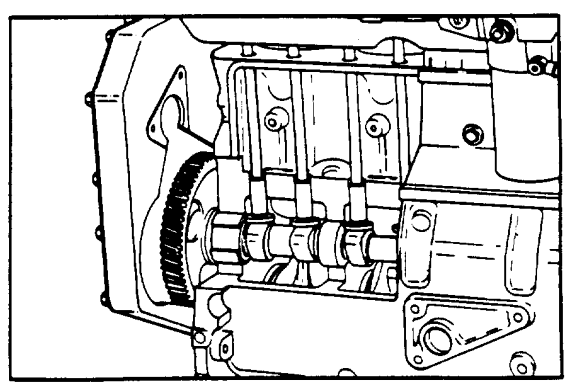
The gear housing provides a support for the injection pump, the timing pin and the accessory drive gear, if used.

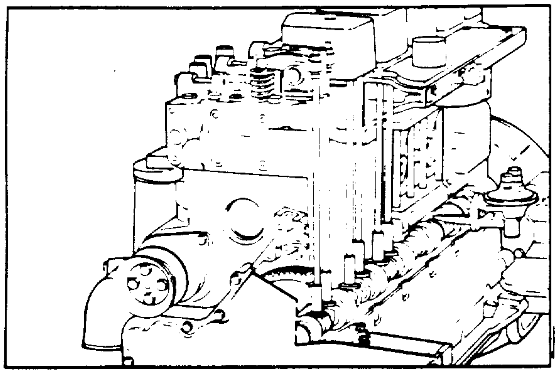


Front Crankshaft Seal
The front crankshaft seal is mounted in the front gear cover. A double lipped Teflon seal is used. The sealing surface on the crankshaft must be clean and free of oil during assembly.

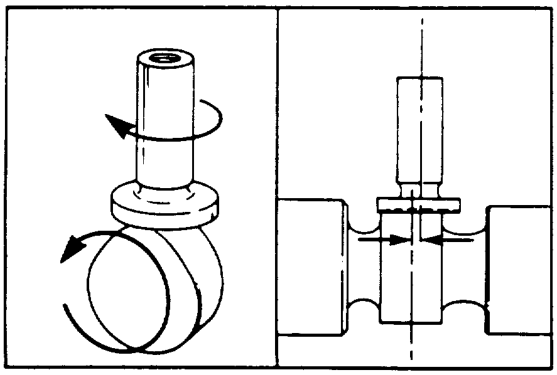


Camshaft, Tappets and Push Rods
The camshaft is gear driven from the crankshaft. A replaceable bushing is used for the front journal to carry the side loading from the accessory drive. The remainder of the journals operate in cast iron bores in the cylinder block; however, these bores can be repaired in a machine shop by installing service bushings.

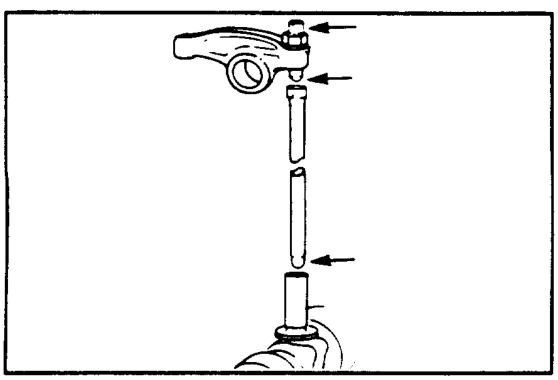




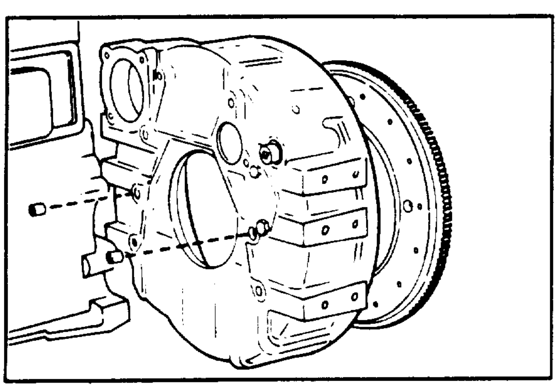
The camshaft has lobes to operate the intake and exhaust valves and a special lobe to drive the lift pump. The valve lobes contact " mushroom" shaped valve tappets which operate the push rods. The operating arm of the lift pump rides directly on the special lobe on the camshaft. The profile of the cam lobes is the same for all B Series engines.



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.



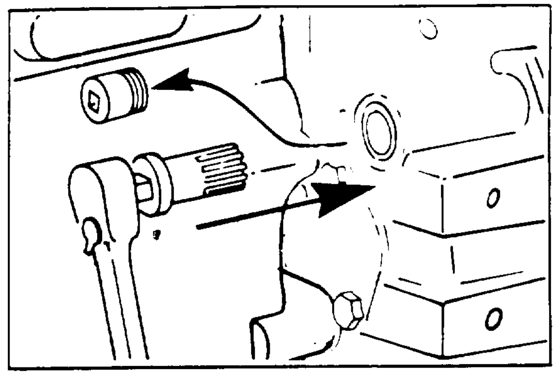
The ball end of the push rod fits into a ball socket in the tappet. The other end of the push rod is fitted with a socket into which the ball end of the rocker lever adjusting screw operates.



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 0.20mm [0.008 in.) TIR.

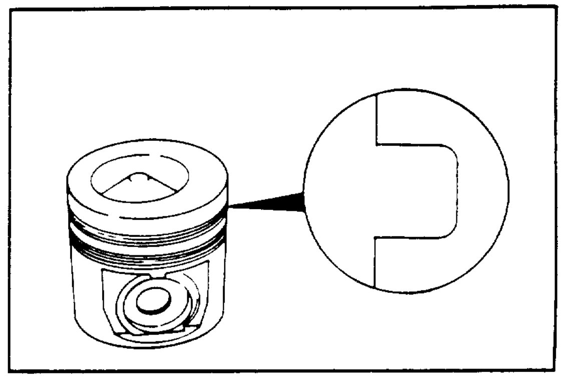
Note: Service housings are drilled. Re-dowelling is not required.

Some housings are machined for the use of an optional engine barring device.

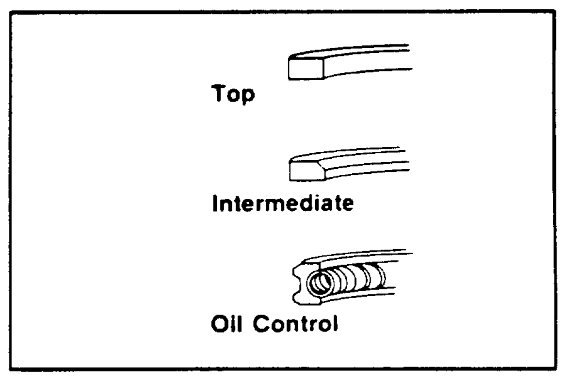


Piston and Rod Assemblies

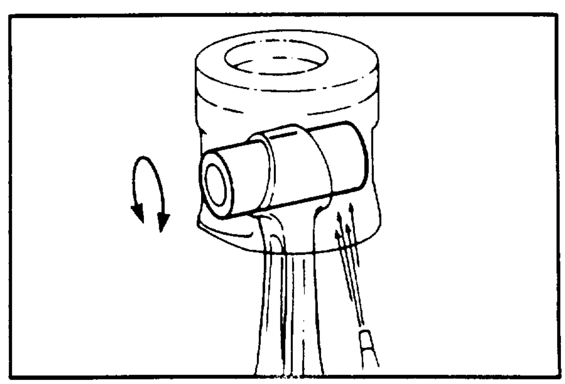
Piston features include: high swirl combustion bowl cast aluminum body and three ring grooves. Always check the part number to be sure that the correct configuration is used during piston replacement.

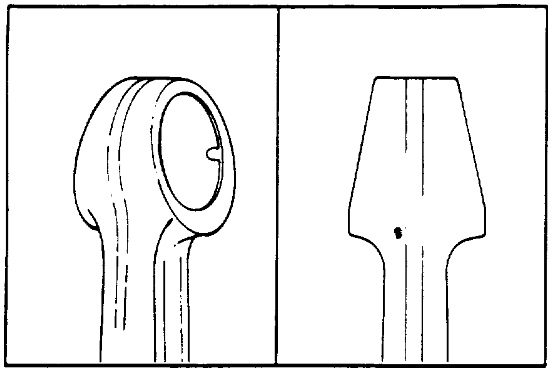


The piston ring sets are also different. While both sets consist of three rings, the top ring of the turbocharged/aftercooled set has a keystone profile which operates in a ni-resist insert cast into the piston. The naturally aspirated top ring is square cut and operates in a groove machined into the aluminum piston.

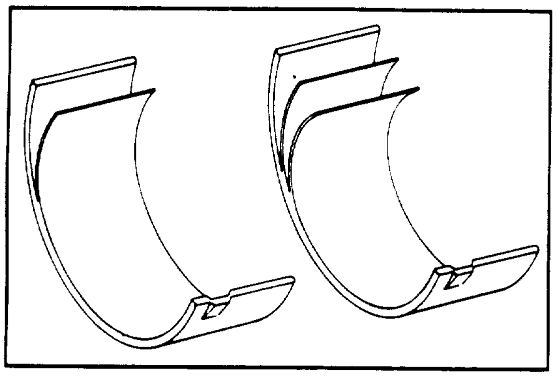


A free floating, hollow piston pin is used to attach the piston to the connecting rod. Lubrication of the pin and journal is accomplished by residual spray from piston cooling.

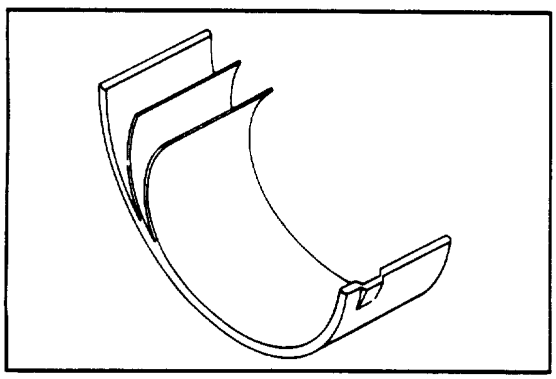




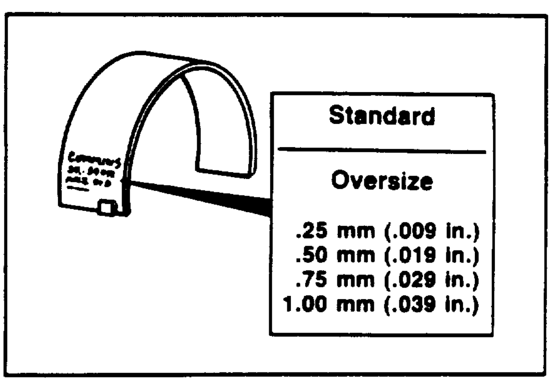
The piston pin end of the connecting rod is angle cut to provide additional bearing surface. The rod end is fitted with a bronze bushing.



In production, steel backed aluminum rod bearings are used for naturally aspirated engines. Steel backed trimetal bearings are used in production for the additional loading resulting from turbocharging and aftercooling.

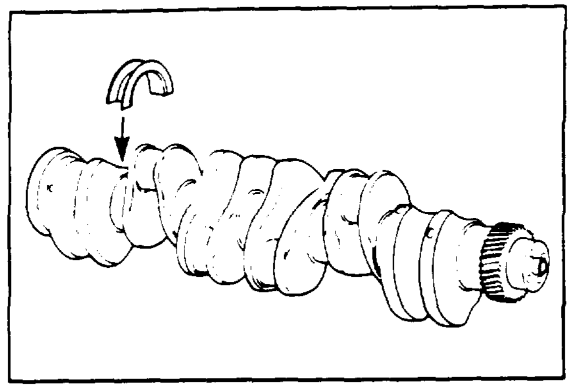


To prevent incorrect use of the two bearings at time of repair, only steel back tri-metal bearings are available for service.

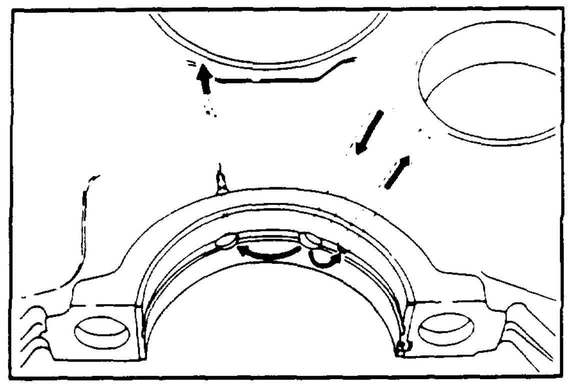


Oversize service rod bearings are available for use with re-ground crankshafts.

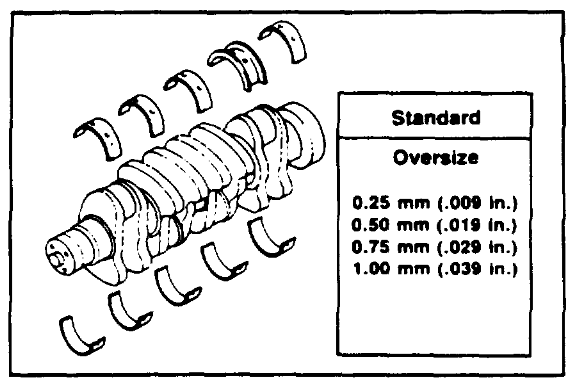
Crankshaft and Main Bearings



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.



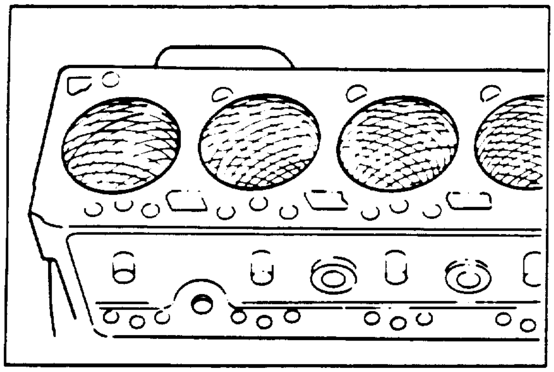
The upper bearings have three holes in them. The middle hole receives oil from the main oil rifle. One of the adjacent holes is aligned with drilling to the camshaft journal and serves as an orifice for lubrication flow to the journal. The other adjacent hole supplies oil for piston cooling. The hole does not align perfectly with the cooling nozzle. The hole is off-set to keep it away from the highly loaded bearing area.



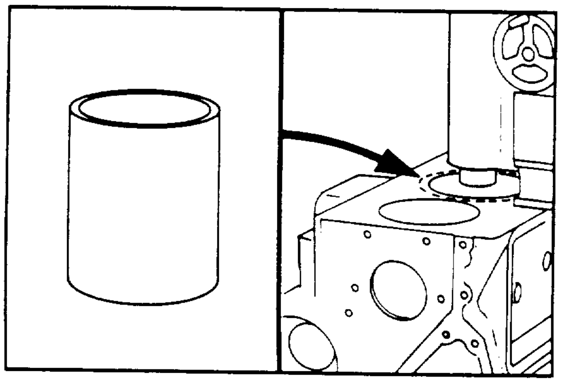
Note: Oversize service main bearings are available for reground crankshafts.

Cylinder Block

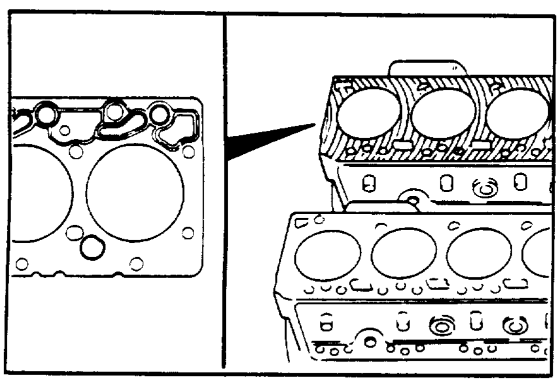
We have discussed the cylinder block relative to cooling and lubrication in those respective systems. We have also discussed the interfaces of some of the above power functions with the block. This discussion will cover the remaining interfaces including the cylinder bores.



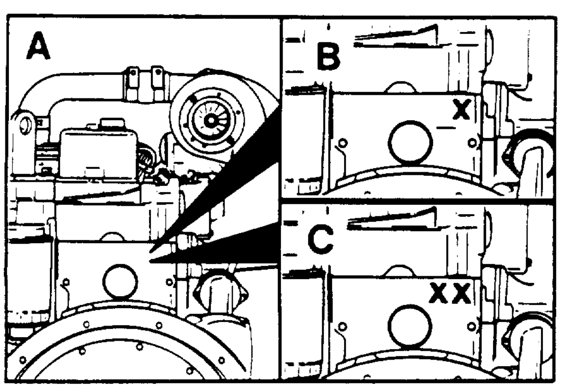
The cylinder bores are machined directly into the block during production. The size and condition of the bore is critical to engine performance and life. During repair, be sure to inspect the bore carefully. It will also be necessary to deglaze the cylinder walls before reassembly. A 30 degree crosshatch 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.



Note: The head surface of the block is also critical to sealing the bores. Inspect the surface carefully during repair before assembly. The head deck can be resurfaced in a machine shop and a thicker surface head gasket installed to keep the piston-to-head clearance the same.

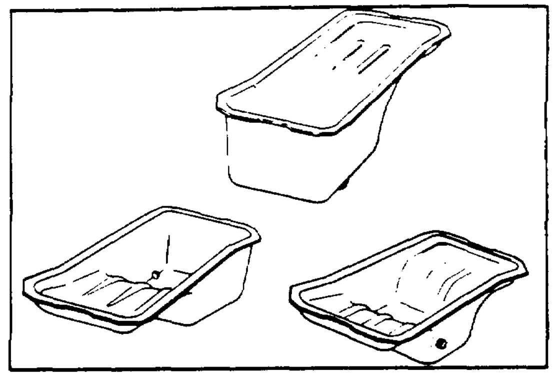


After machining, the block is identified as follows:

Machining	Mark
A - Standard	None
B - 0.15mm [0.006 inch]	X
C - 0.35mm [0.014 inch]	XX

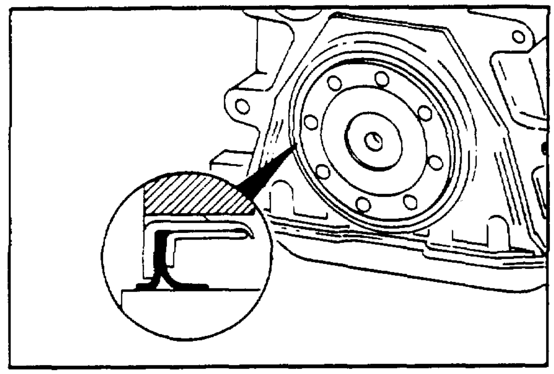
Oil Pan

A front sump, rear sump or center sump pan options may be used depending on the application. The mounting of the oil pick up tube will vary with the pan used.



Rear Crankshaft Seal

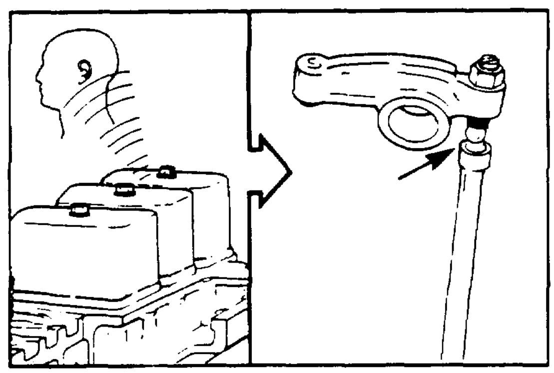
The rear crankshaft seal is mounted in a housing that bolts to the rear of the block. Double lipped Teflon seals are used. The sealing surface on the crankshaft must be clean and free of oil during installation of the seal.



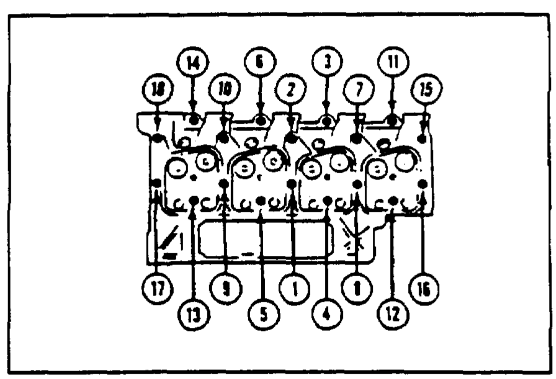
Diagnosing Base Engine Component Malfunctions

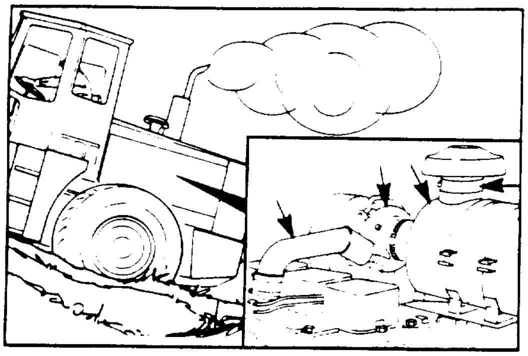
Valve Train and Head Assembly

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.



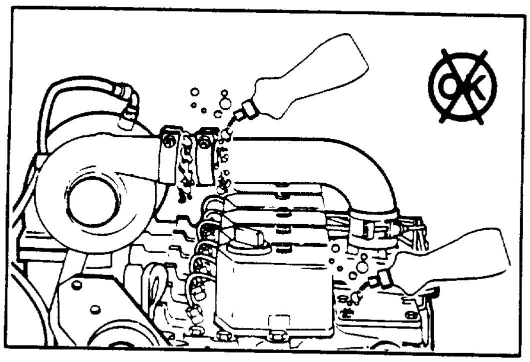
Caution: If the one of the individual support pedestals is removed during inspection or repair, all head bolts must be retightened according to the head bolt torque sequence.



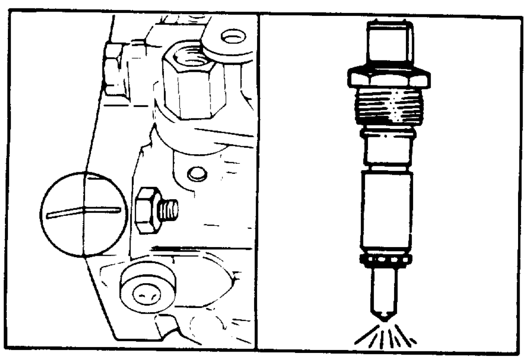


Air and Fuel Systems Check

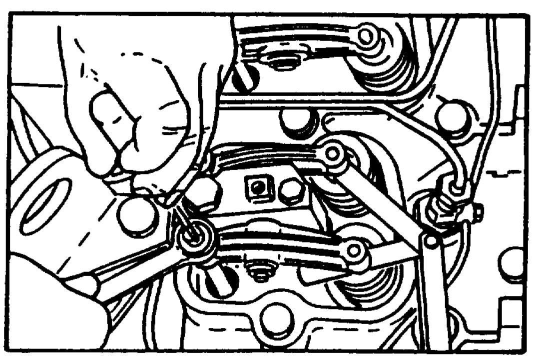
When diagnosing a low power problem first troubleshoot the air and fuel systems to make sure the engine is receiving adequate intake air and fuel.



Check the intake air system for leaks. Make sure a sealant is used on the through-hole capscrews which secure manifold cover to the head.



Check the fuel system for correct timing and fuel delivery.

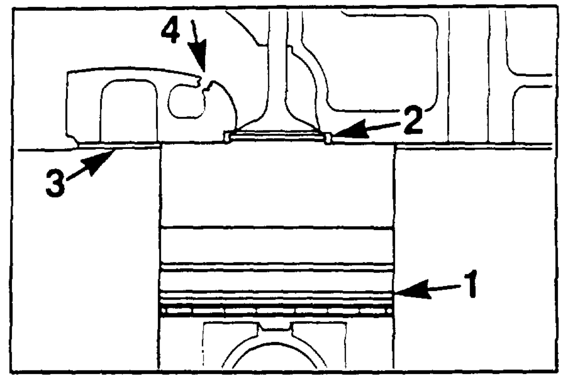


Valve Adjustment Check

Verify that the valves are adjusted correctly (refer to page 5-197).

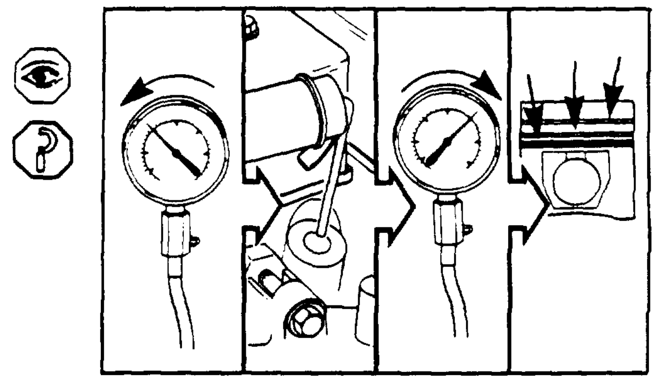
Compression Check
If the air and fuel system are functioning correctly, perform a compression check to determine whether the problem is:

- Piston ring sealing
- Valve sealing
- Head gasket sealing or a crack in the cylinder head



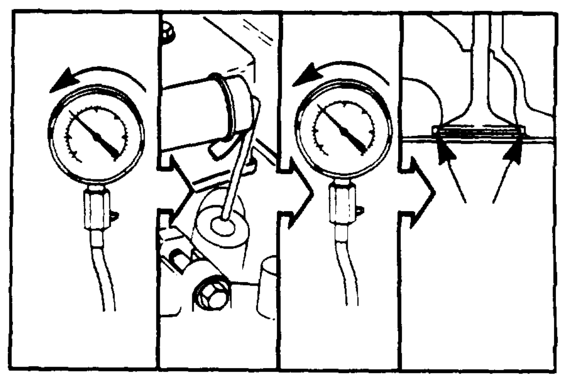
Piston Ring Sealing
If the compression is low but can be increased significantly by squirting oil into the cylinder, the cause of low compression is inadequate sealing between the rings and the cylinder walls.

Normal compression is 2413 kPa (350 PSI] at 250 RPM cranking speed. A 1007 kPa [100 PSI] difference between cylinders indicates a compression seal problem.

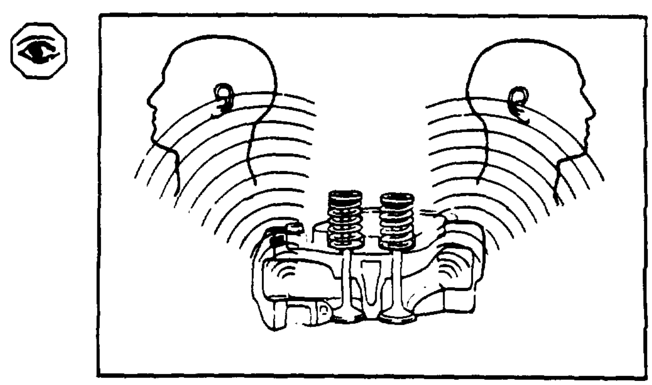


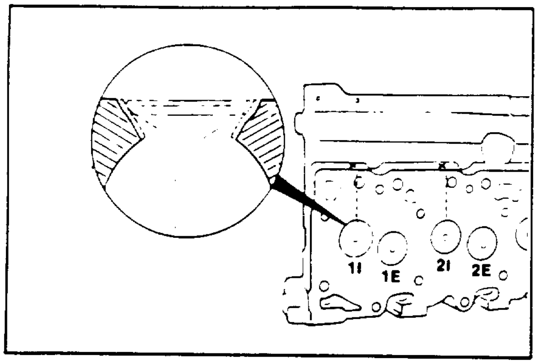
Valve Sealing

f 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.

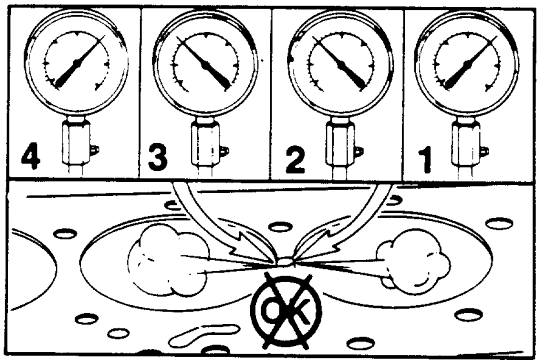


Valve leakage is often audible from the intake and exhaust manifold.



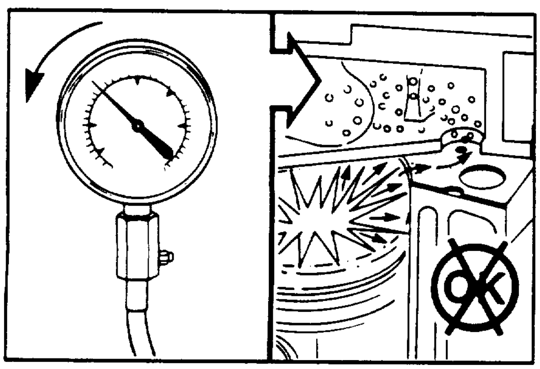


The parent valve seats can be re-ground to a depth of 0.010 in. (0.254 mm). Re-ground seats are identified with a mark on the cylinder head. Service valve seats must be installed in previously ground seats (refer to page 5-252).

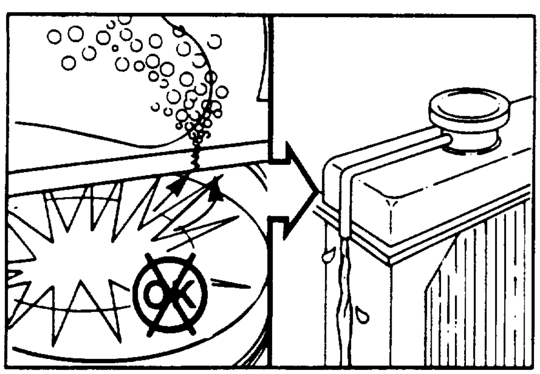


Head Gasket Sealing

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.

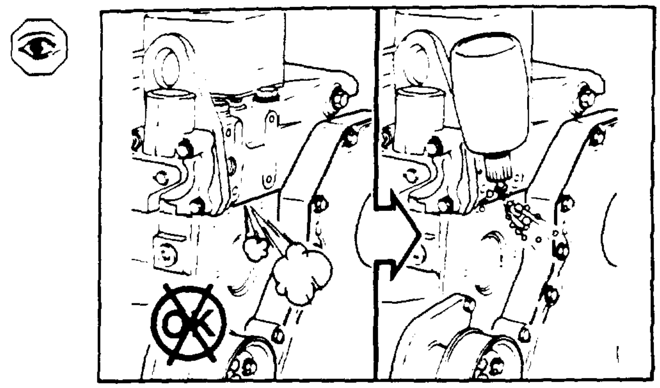


Low compression on a single cylinder can be caused by an external leak or a leak to a coolant passage.



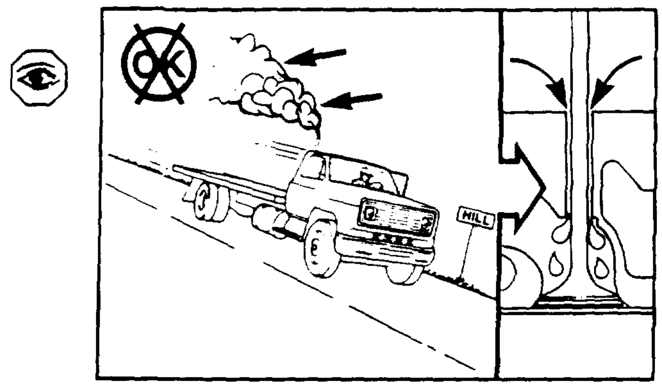
A compression leak to the coolant will normally be detected by loss of coolant as the coolant is blown from the cylinder system.

External head gasket leaks can be detected visually. Liquid soap can be used to locate external leaks.

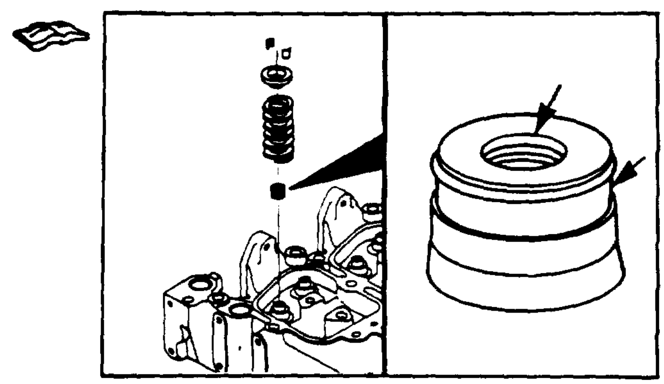


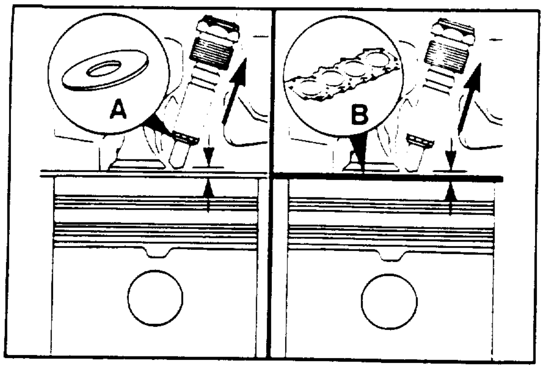
Valve Seal Wear

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 seals.



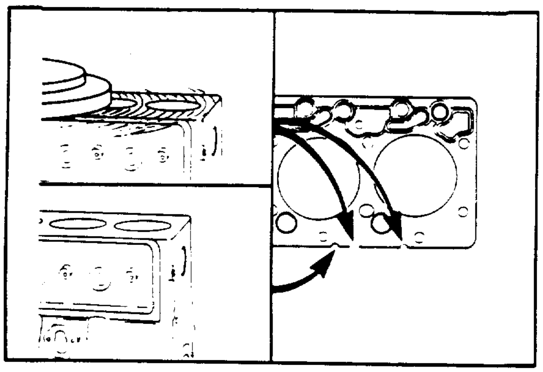
Hardening of the material and wear or damage to the sealing surfaces will cause the seal to leak (refer to page 5-255 for replacement instructions).



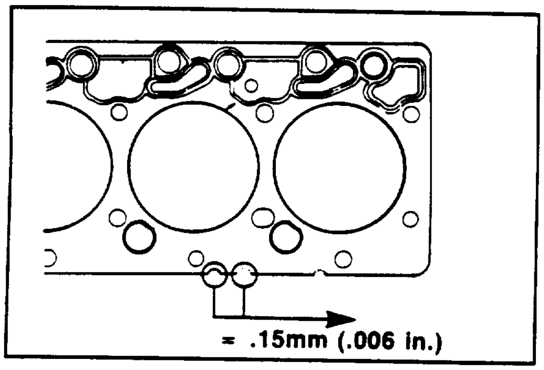


Injector Protrusion

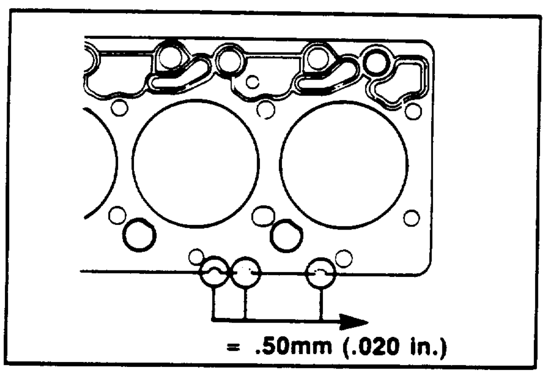
Injector protrusion can affect power from the engine. In addition to a single sealing washer (A) on the injector, the thickness (B) of the head gasket controls injector protrusion.



Oversized service head gaskets are used when the head surface on the block has been refaced. The head gasket is marked to indicate the thickness. One notch means the gasket is standard for use with blocks that have not been refaced.



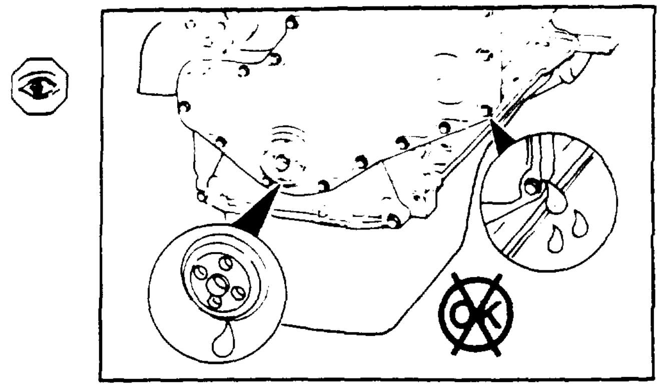
Two notches identify that the gasket is for use with blocks that have been refaced 0.15mm [0.006 in.]. The block should be marked with one X to indicate the surface has been refaced 0.15mm [0.006 in.].



Three notches indicate the gasket is for use with a block that has been refaced 0.50mm [0.20 in.]. Two XX's identify a block has been refaced 0.O5Omm [0.020 in.].

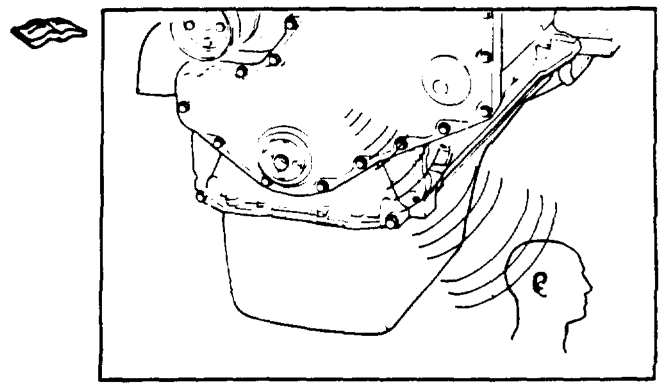
Front Gear Housing and Gear Train

Troubleshooting the front gear housing and gear train consists of checking for leaks at the gaskets (front cover, timing pin assembly and injection pump) and the front crankshaft oil seal, inspecting the gears and measuring backlash when required.

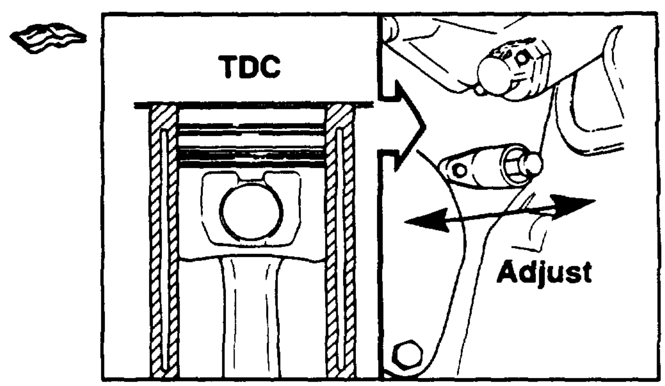


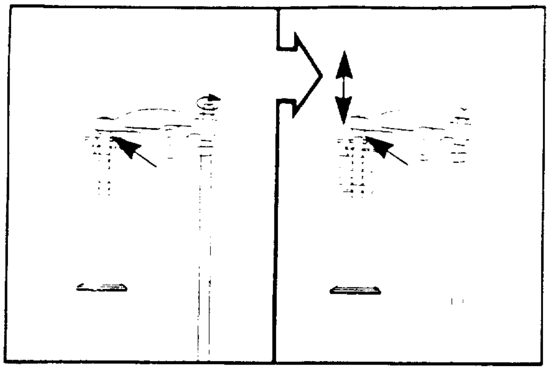
Gear noise emitted from the cover can indicate worn gear teeth (refer to page 8-43).

Note: Excessive backlash can affect engine timing and engine performance.



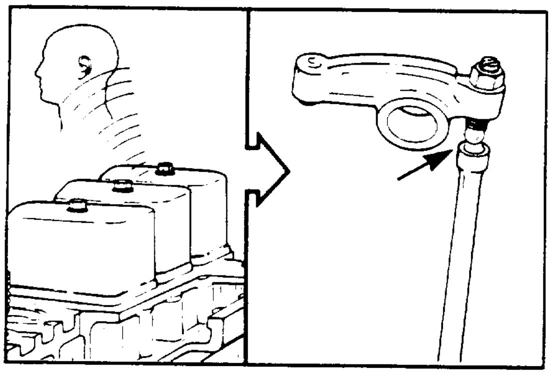
As previously discussed in the fuel system, replacement of the gear housing or the timing pin assembly necessitates a realignment of the pin assembly on the housing to correspond to TDC for Cylinder Number 1 (refer to page 5-211 for replacement instructions).



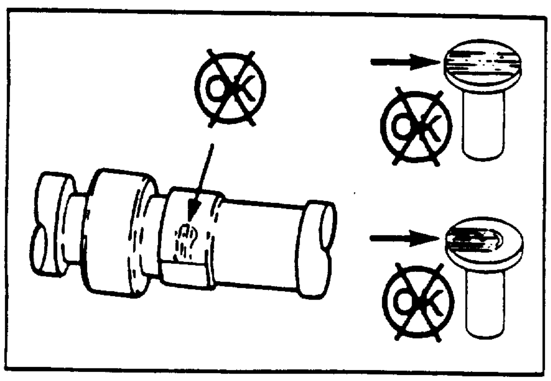


Rocker Lever, Valve Stem, Push Rod, Tappet, and Camshaft

Excessive valve lash can indicate a worn valve stem or rocker lever.

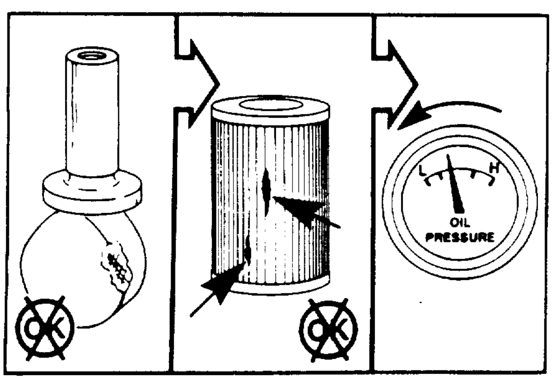


Loose rocker levers and the need to re-set the valve clearance frequently, can also indicate cam lobe or tappet wear. If an inspection of the levers, valve stems and push rods does not show wear, then tappet and/or cam lobe wear can be suspected.



Caution: Anytime a new camshaft is installed, new tappets must also be installed.

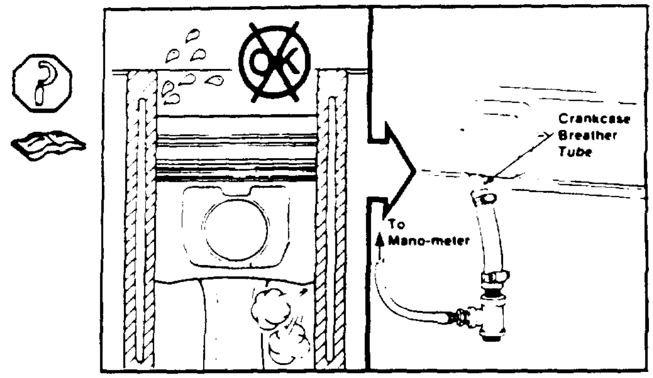
The camshaft lobes can be visually inspected after removing the pan. Similarly, the face of the tappet can be inspected after removing the push rods and lifting the tappet.



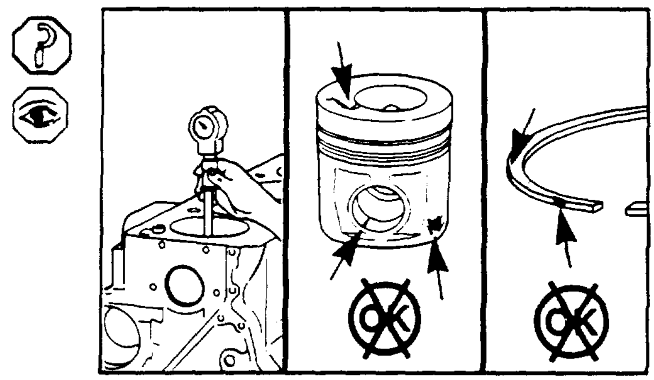
A severely damaged camshaft journal(s) can generate metal chips which will be found in the pan and filter. As the clearance in the journal(s) increases, a small decrease in oil pressure may be detected.

There are a number of power related problems including excessive oil consumption, smoke, blow-by, and poor performance that can be caused by inadequate sealing between the piston rings and the cylinder walls.

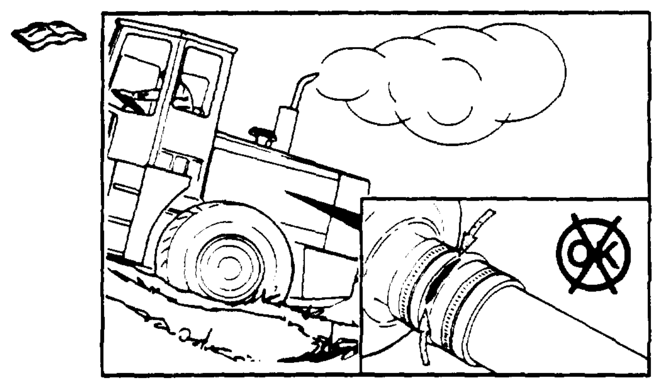
A blowby measurement can help detect the problem.



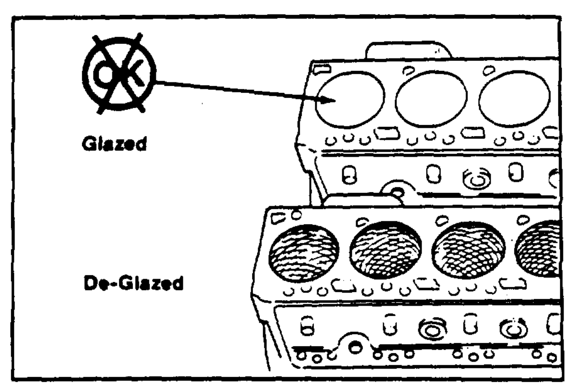
Verification of the damaged or worn component requires visual/dimensional inspection of rings, pistons and cylinder bore.

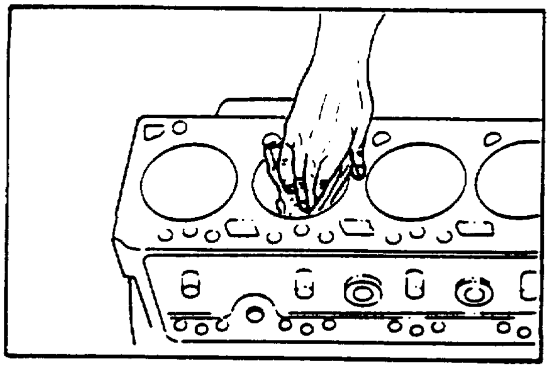


Piston wear can be the result of wear over a long period of time or due to poor air intake system maintenance over a short period of time. If necessary, troubleshoot the air intake system.

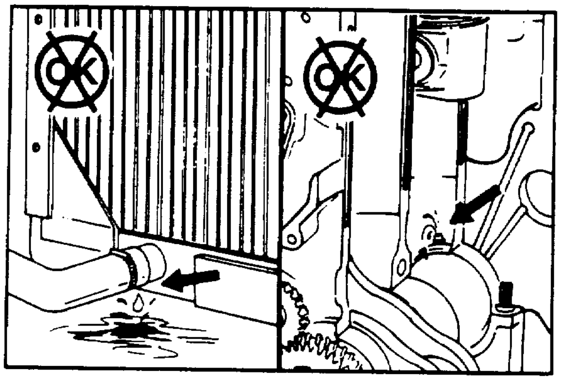


During repair it is essential that the cylinder wall be deglazed so that new rings will seat against the cylinder wall. Failure of the rings to seat can result in high blow-by and excessive oil consumption.

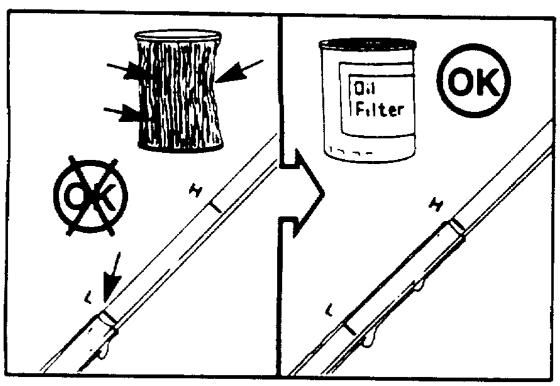




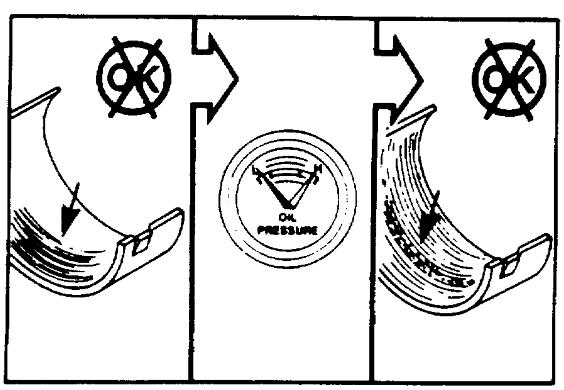
However, it is also critical that the cylinder walls be thoroughly cleaned after the de-glazing. Grit left in the cylinder wall will cause rapid wear out of the new rings leading to the previously discussed power problems.



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 can also lead to piston seizure.

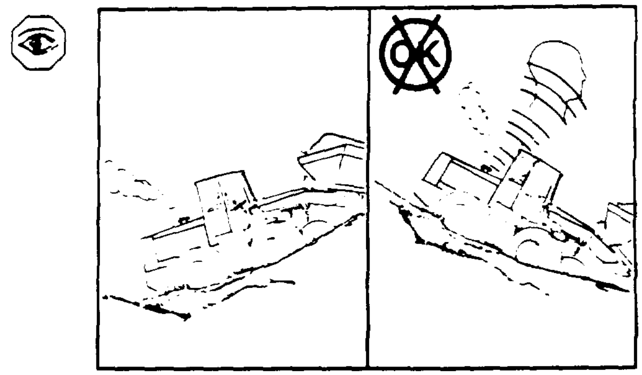


Improper maintenance of the lubrication system is the primary cause of reduced main bearing life.



Normally, worn bearings can be detected by reduced oil pressure. But if this wear goes undetected, the excessive clearance will cause the rod to strike the crankshaft causing a distinct knocking sound.

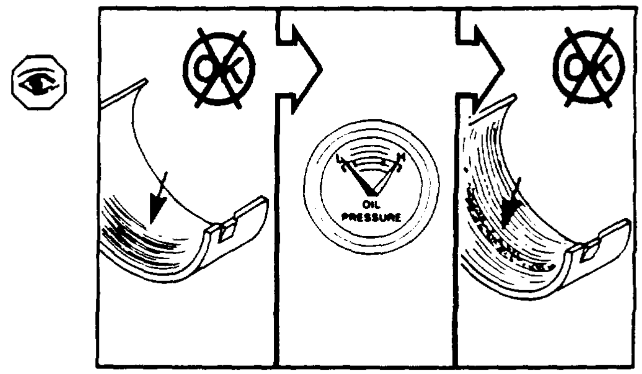
A rod knock occurs when the engine is not loaded. Verify by first applying load and then unloading and listening for the knock.



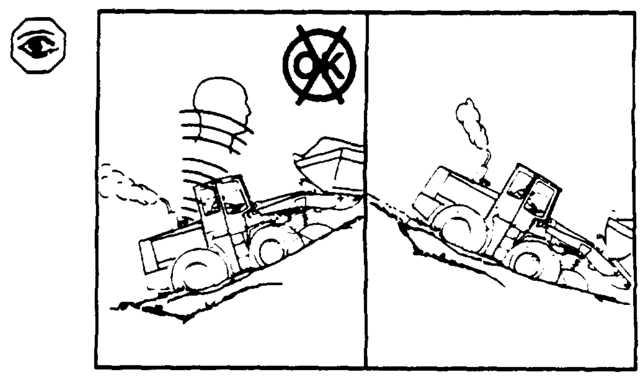
Crankshaft and Main Bearings

Improper maintenance of the lubrication system is also the primary cause of reduced main bearing life.

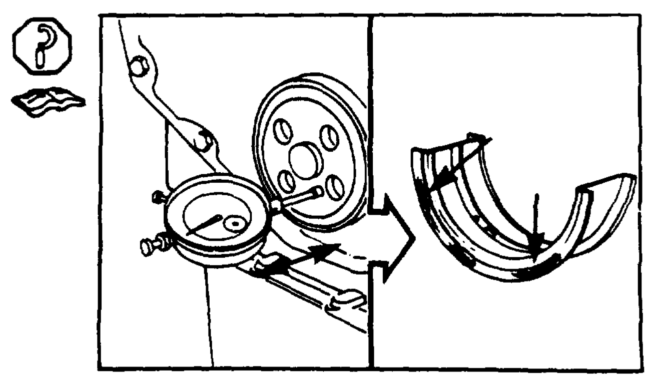
A malfunction of the crankshaft/main bearing will usually be detected by reduced oil pressure. As with rod bearings, continued operation with low oil pressure will lead to a rapid deterioration of the bearings and eventually will produce a knocking sound.

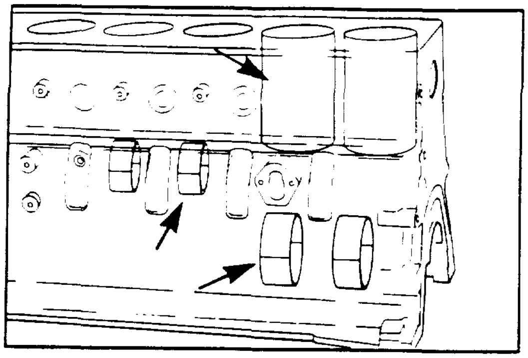


A main bearing will be heard when the engine is loaded.



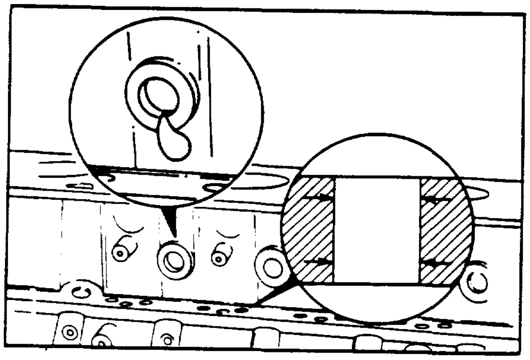
A damaged or worn thrust bearing flange of the upper main bearing shell can be detected by measuring the end play of the crankshaft (refer to page 5-231).



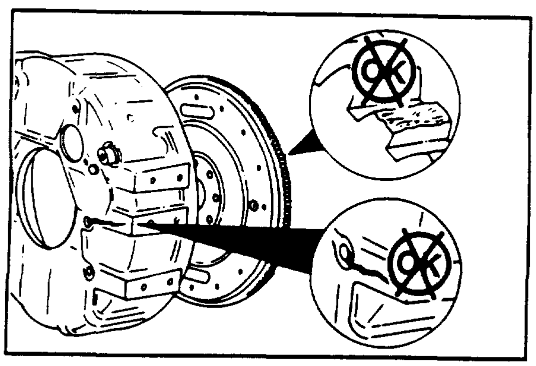


Cylinder Block

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.

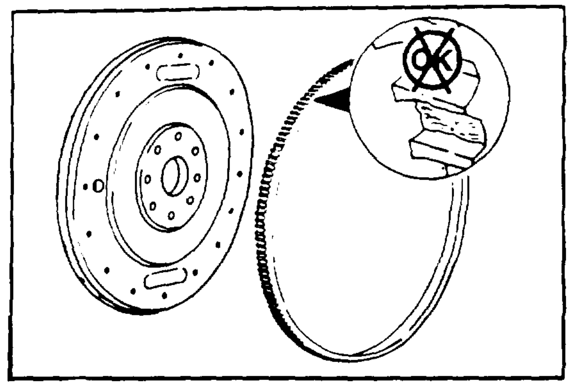


Malfunctions of the block such as leaks, tappet bore wear, etc. require a visual or dimensional inspection to isolate the problem.



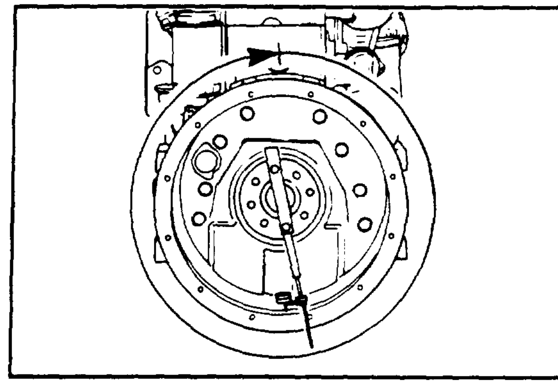
Flywheel Housing and Flywheel Diagnostics of the flywheel housing and flywheel is normally limited to a visual inspection of the parts for damage or wear.

Occasional failure of a starter to engage can be caused by damaged teeth on the ring gear. Service ring gears are available for repairing flywheels (refer to page 5-215).



When troubleshooting a transmission vibration problem, it may be necessary to measure the concentricity of flywheel housing-to-crankshaft.

Note: The following procedure is for use with an indicator whose needle rotates clockwise as the top is depressed.

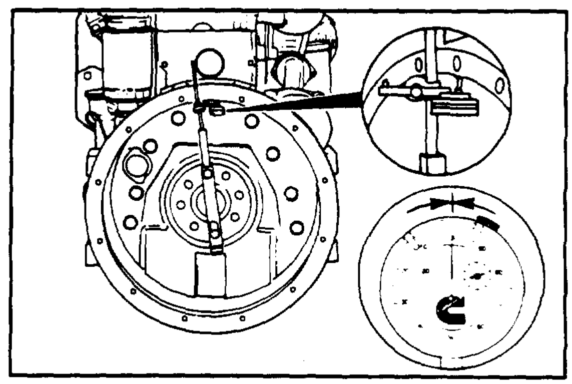


Flywheel Housing Concentricity Check

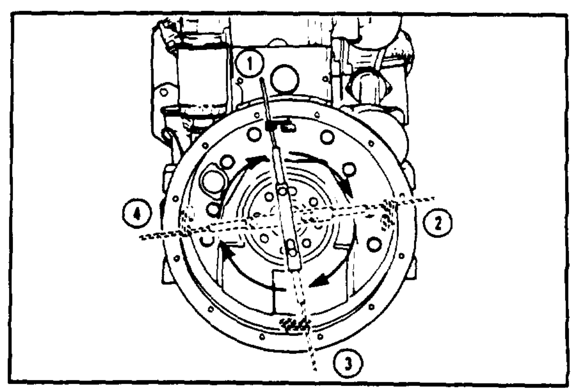
Attach a dial indicator to the crankshaft as illustrated.

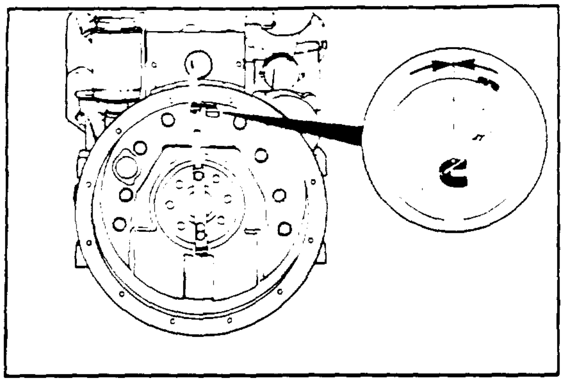
Note: The extension bar for the indicator must be rigid for an accurate reading. It must not sag

Position the indicator at the 12 o'clock position. Adjust the dial until the needle points to zero.

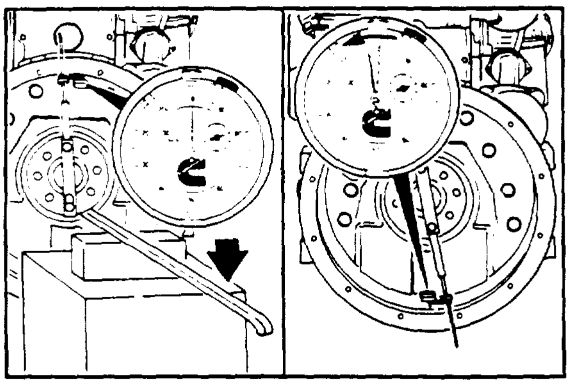


Slowly rotate the crankshaft. Record the readings obtained at the 3 o'clock, 6 o'clock and 9 o'clock position.





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.



Caution: Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not use the flywheel housing as a fulcrum.

Determine the adjustment for main bearing clearance by raising the rear of the crankshaft to its upper limit. Use a floor mounted support with a padded pry bar to raise the crankshaft.

Record the indicator reading.

Calculate the bearing clearance adjustment by subtracting one-half of the reading obtained in the previous step from the reading obtained at the 6 o'clock position.

Example:

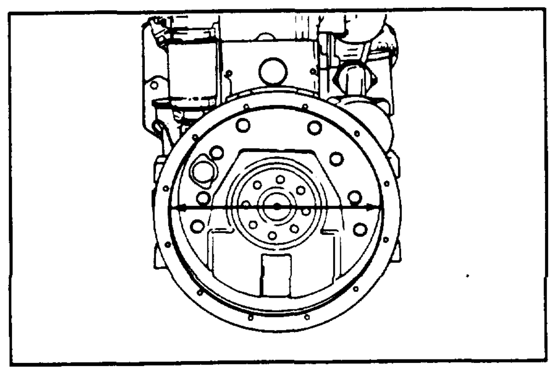
Total bearing clearance - +0.08mm [0.003 in]
One-half bearing clearance +0.04mm [0.0016 in]
6 o'clock position reading = +0.20mm [0.008 in]
+0.20mm [0.008 in]
<u>+0.04mm [0.0016 in]</u>
+0.16mm [0.0064 in] (Adjusted 6 o'clock reading)

Determine the Total Indicator Reading (TIR). The following is intended to give examples of TIR calculations with a mix of positive (+) and negative (-) readings.

	mm	in
12 o'clock	0.00	0.000
6 o'clock (adjusted)	+0.16	+0.0064
Total Vertical Reading =	+0.16	+0.0064
3 o'clock	+0.08	+0.003
9 o'clock	-0.08	- 0.003
Total Horizontal Reading =	0.00	0.000
	+0.16	+0.0064
TIR =	0.16	0.064

12 o'clock	0.00	0.000
6 o'clock	+0.16	+0.0064
Total Vertical Reading =	+0.16	+0.0064
3 o'clock	+0.08	+0.003
9 o'clock	-0.05	- 0.002
Total Horizontal Reading =	+0.03	+0.001
	+0.16	+0.0064
TIR =	0.19	0.0074

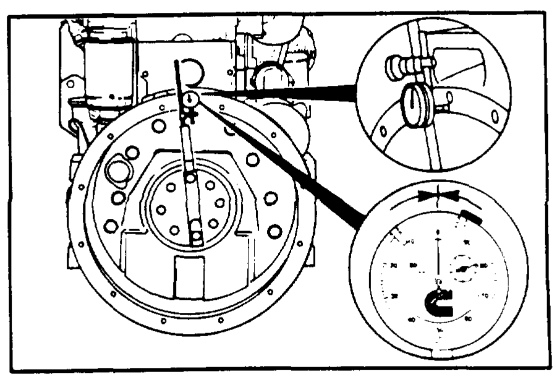
The maximum allowable Total Indicator Reading (TIR) is determined by the diameter of the housing bore. If out of specifications replace the housing.



SAE No.	Bore Diameter mm	in	TIR Max mm	n
2	447.68 to 447.80	17.625 to 17.630	0.20	0.008
3	409.58 to 409.70	16.125 to 16.130	0.20	0.008

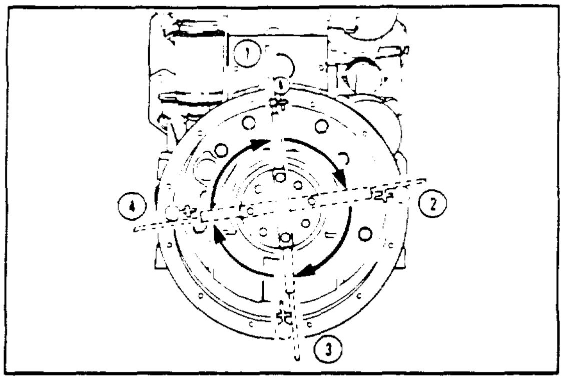
Flywheel Housing Face Alignment Check

Caution: The dial indicator tip must not enter the capscrew holes or the gauge will be damaged.



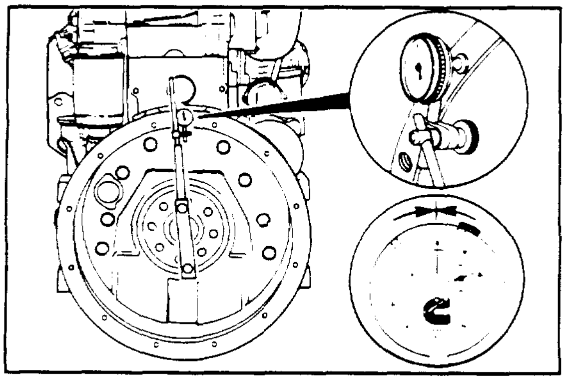
Install a dial indicator as illustrated.

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.

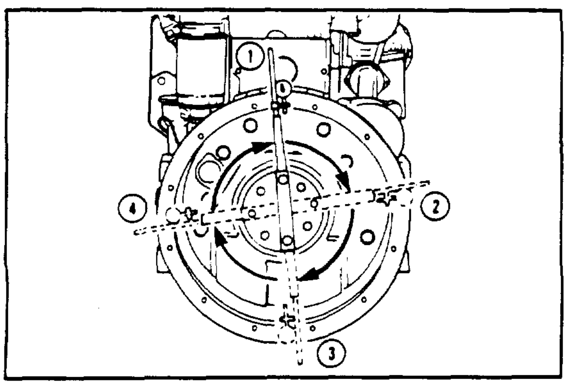


Slowly rotate the crankshaft. Record the readings at the 3 o'clock, 6 o'clock and 9 o'clock positions.

Note: The crankshaft must be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.

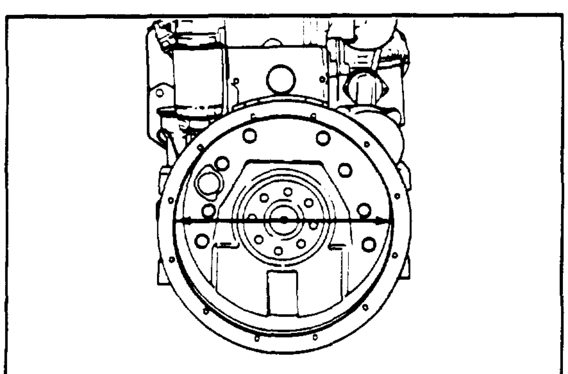


Continue to rotate the crankshaft until the indicator is at the 12 o'clock position. Check the indicator to make sure the needle points to zero. If it does not, the readings will be incorrect.



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

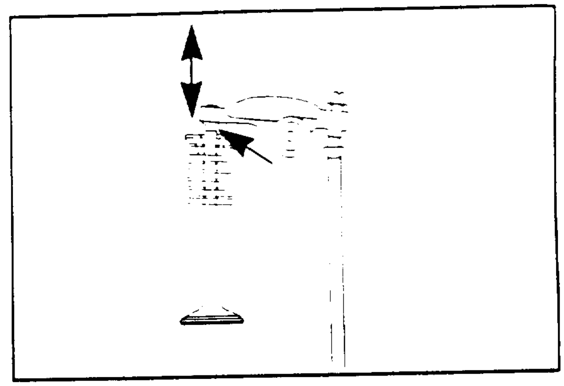


The maximum TIR is determined by the diameter of the housing bore. Replace the housing If out of specifications.

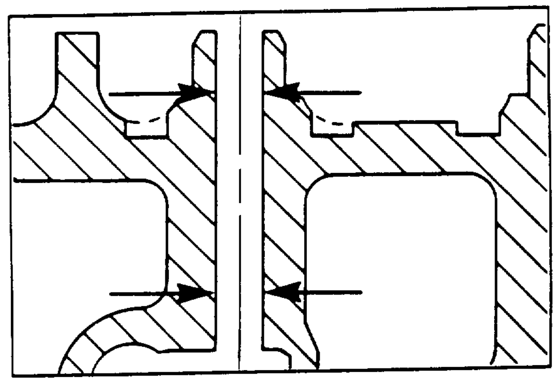
SAE No.	Bore Diameter mm	Bore Diameter in	TIR Max mm	TIR Max in
2	447.68 to 447.80	17.625 to 17.630	0.20	0.008

Base Engine Components Specifications

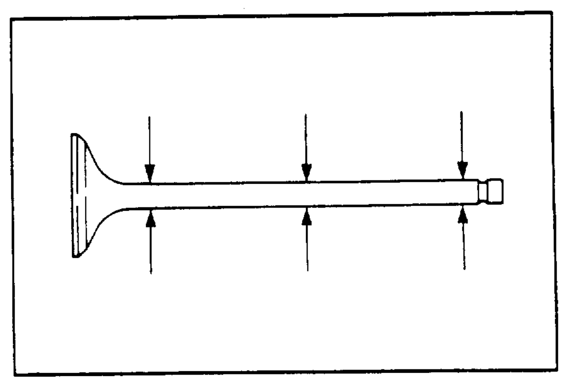
Valve Train
Valve Clearance
- Intake 0.25mm [0.010 in]
- Exhaust 0.51mm [0.020 in]



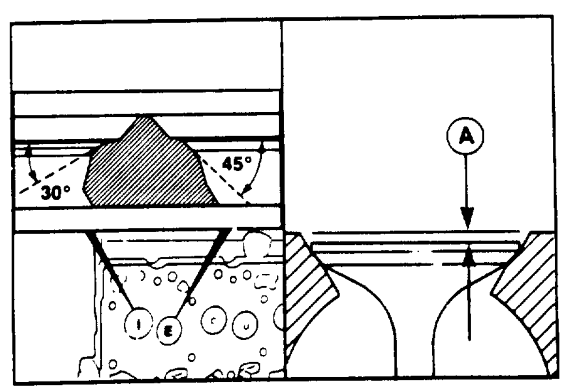
- Valve Guide Diameter (Maximum)
  8.019 (0.3157)

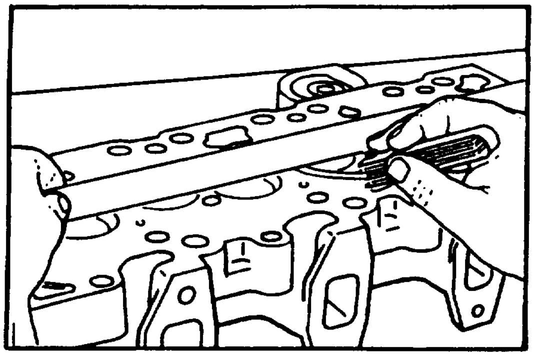


- Valve Stem Diameter (Minimum)
  7.960 (0.3134)



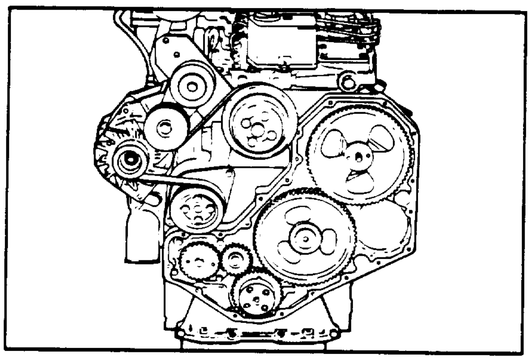
- Valve Seat Angle
  Intake 30 degrees
  Exhaust 45 degrees
- Valve Depth (Installed)
  0.89 to 1.42mm [0.035 to 0.056 in]
  0.99 to 1.52 (0.039 0.060)



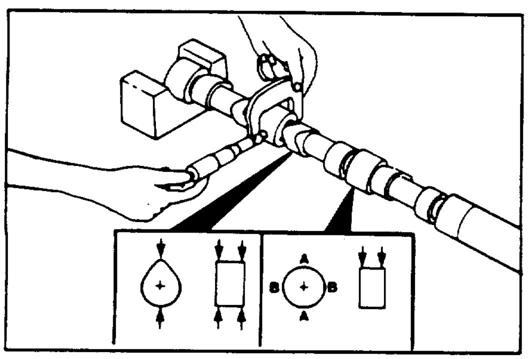


• Cylinder Head Flatness
Total
Maximum Overall
0.30 [0.012]

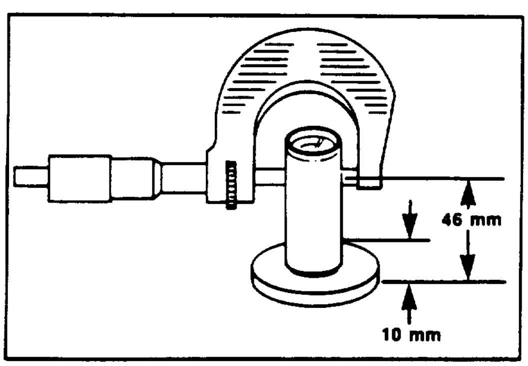
Incremental
Maximum variation within any 50.0 [2.0 in.] diameter area
0.01 [0.0004]



Gear Train
• Gear Backlash (all gears)
0.08 to 0.33mm [0.003 to 0.013 in]



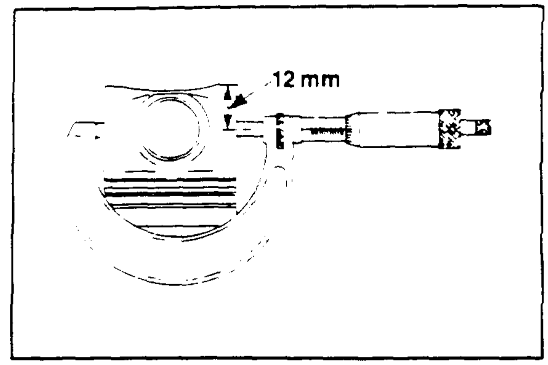
Camshaft
• Journal Diameter (Minimum)
53.962mm [2.1245 in]
• Valve Lobes (Min. Dia. at Peak of Lobe)
Intake 47.040mm [1.852 in]
Exhaust 46.770mm [1.841 in]
• Lift Pump Lobe (Min. Dia. at Peak of Lobe)
35.5mm [1.398 in]



Tappets
• Stem Diameter (Minimum at 10mm and 46mm height)
15.925mm [0.627 in]

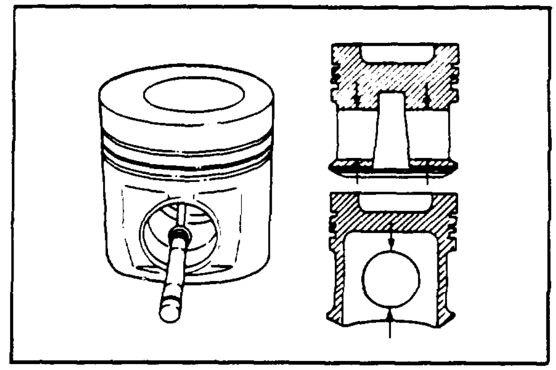
Pistons

- Skirt Diameter (Minimum)
  - Nominal
    - 101.880mm [4.011 in]
  - Worn Limit
    - 101.823mm [4.0088 in]

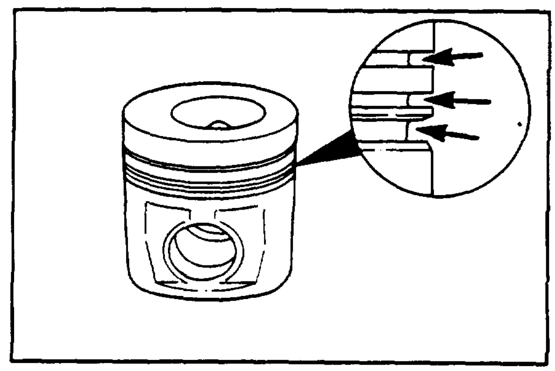


- Pin Bore Diameter (Maximum)
  - 40.025mm 11.5758 in]

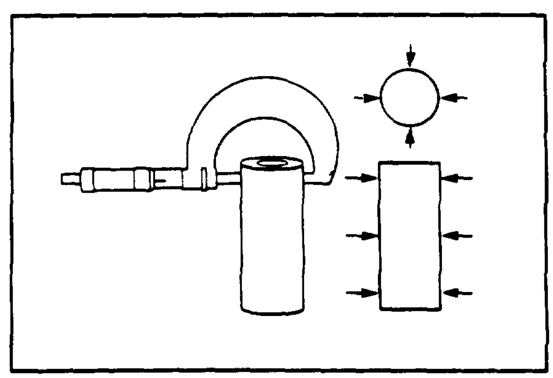
Note: Measure the diameter on a vertical axis only.

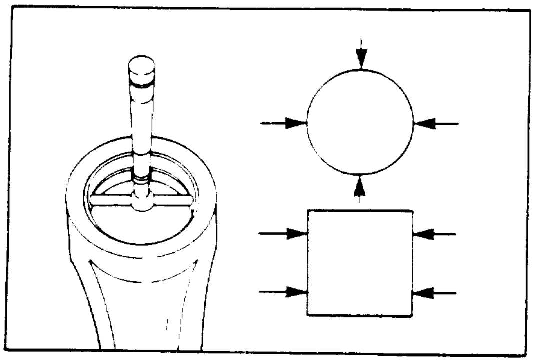


- Ring Groove (Maximum)
  - Top Groove
    - Use Keystone Gauge
  - Intermediate Groove
    - 0.150mm [0.006 in]
  - Oil Control Groove
    - 0.130mm [0.005 in]



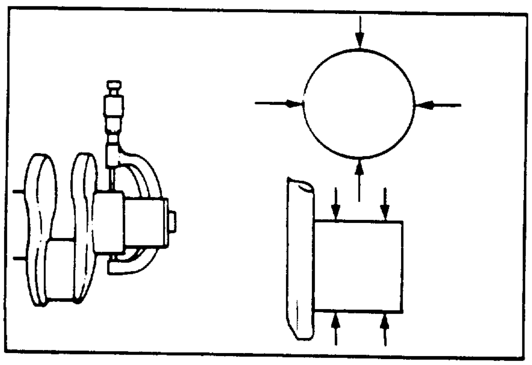
- Piston Pin Diameter (Minimum)
  - 39.990mm [1.5744 in]





Connecting Rod

- Pin Bore Diameter (Maximum)
  40.053mm [1.5769 in]

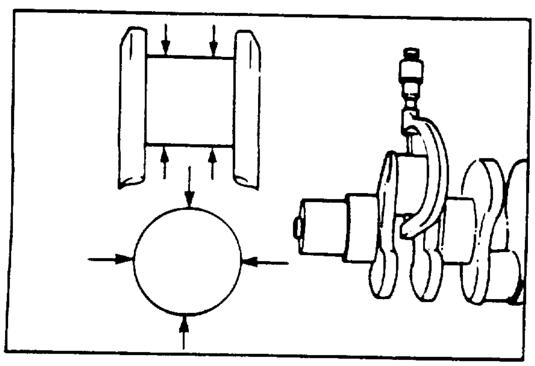


Crankshaft

- Main Bearing Journal Diameter

	Minimum
Standard	82.962mm [3.2662 in]
Machined 0.25mm	82.712mm [3.2564 in]
Machined 0.50,mm	82.462mm [3.2465 in]
Machined 0.75mm	82.212mm [3.2367 in]
Machined 1.00mm	81.962mm [3.2269 in]

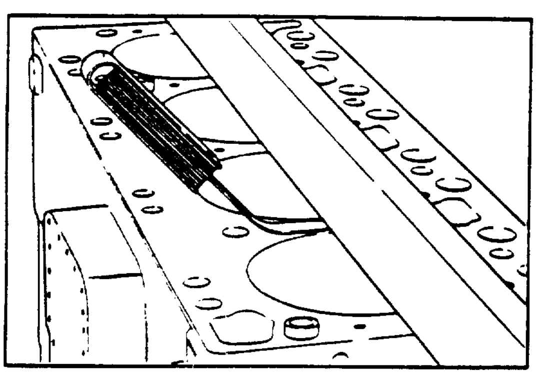
- Journal Out of Round (Maximum)
  0.050mm [0.002 in]
- Journal Taper (Maximum)
  0.013mm [0.0005 in]



- Connecting Rod Journal

	Minimum
Standard	68.962mm [2.7150 in]
Machined 0.25mm	68.712mm [2.7052 in]
Machined 0.50mm	68.462mm [2.6954 in]
Machined 0.75mm	68.212mm [2.6855 in]
Machined 1.00mm	67.962mm [2.6757 in]

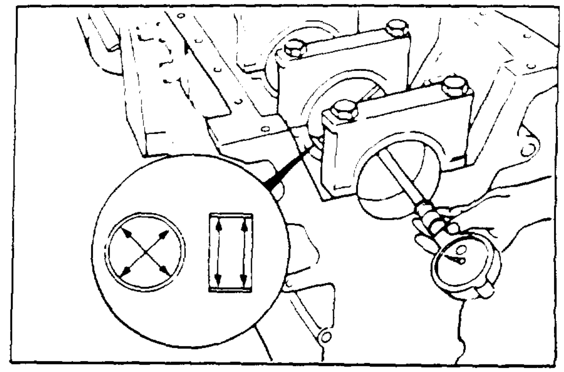
- Journal Out of Round (Maximum)
  0.050mm [0.002 in]
- Journal Taper (Maximum)
  0.013mm [0.0005 in]



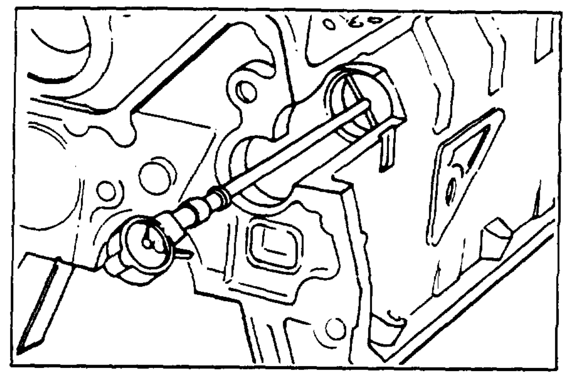
Cylinder Block

- Top Surface Flatness (Maximum Overall Variation)
  0.075mm [0.003 in]
  (Maximum Variation within any 50.Omm [2.0 in] diameter area) 0.01mm [0.0004 in]

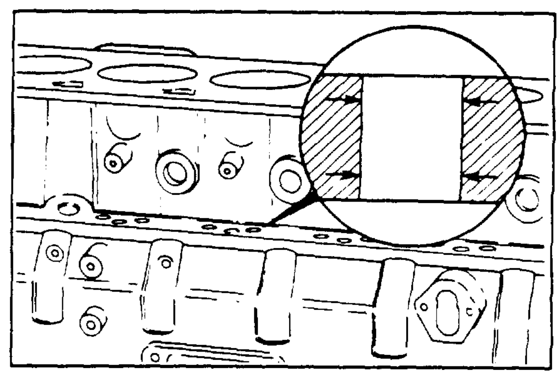
- Main Bearing Bore Diameter (Maximum)
  83.106mm [3.272 in] (with bearing installed)



- Camshaft Bore Diameter (Maximum)
  57.258 [2.2543] (without bushing) No. 1 only
  54.133 [2.1312] No. 1 with bushing
  54.139 [2.1316] No. 2 through No. 7

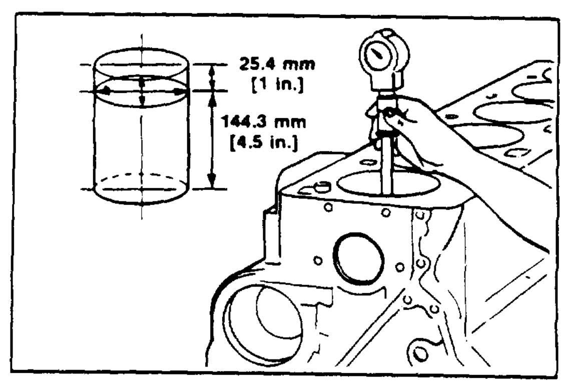


- Tappet Bore Diameter (Maximum)
  16.055mm [0.632 in



Cylinder Bore

- Cylinder Bore Diameter
  Maximum
  102.116mm [4.0203 in]
- Out of Round (Maximum)
  0.04mm [0.0016 in]
- Taper (Maximum)
  0.076mm [0.003 in]

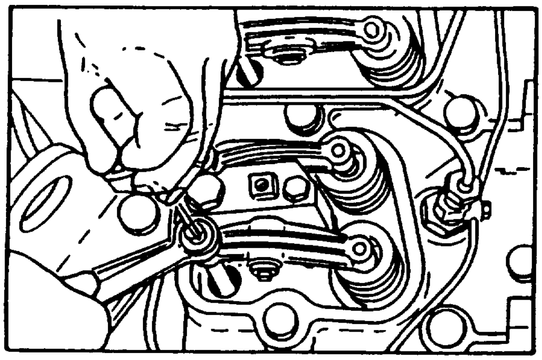


Base Engine Components Replacement Procedures

Rocker Levers and Push Rods - Replacement

Preparatory Step:

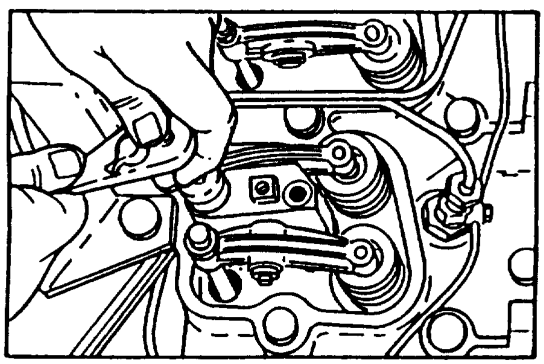
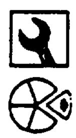
- Remove the valve covers.




Removal

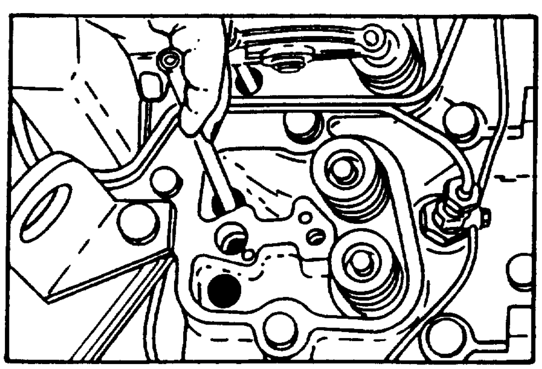
9/16 inch

Loosen the adjusting screw locknuts. Loosen the adjusting screws until they stop.

13mm, 18mm

Remove the 8mm and 12mm capscrews from the rocker lever pedestals. Remove the pedestals and rocker lever assemblies.

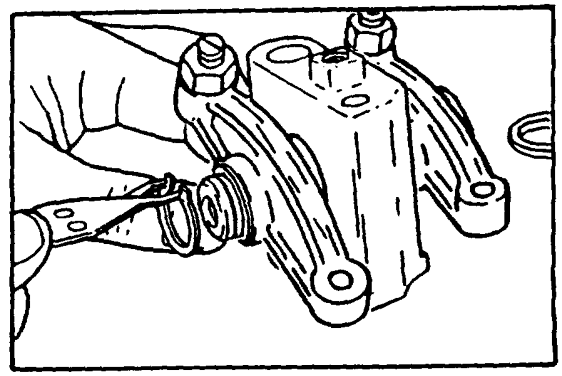



Remove the push rods.

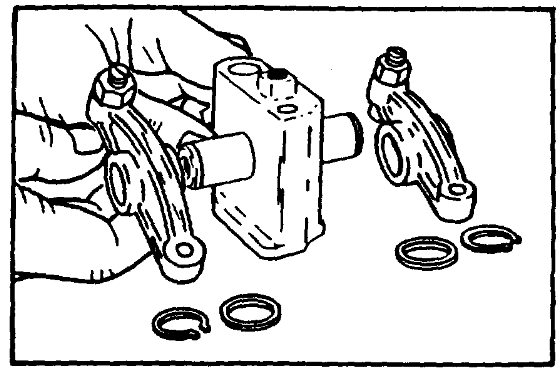
Rocker Levers - Disassembly

If the rocker lever and push rods are to be inspected for reuse, follow these steps.

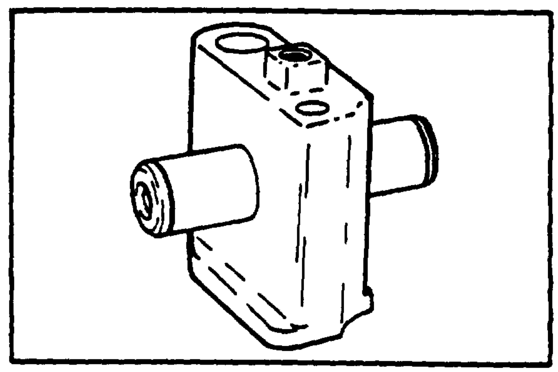
Remove the retaining rings and thrust washers.



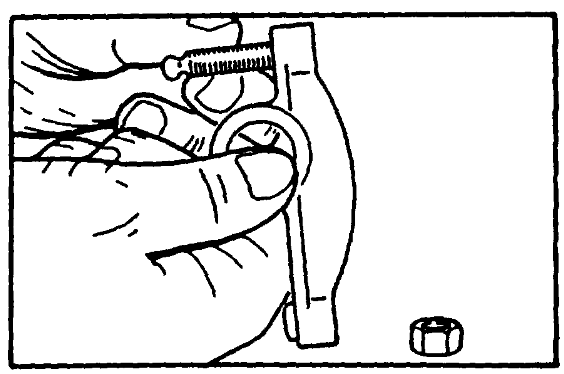
Remove the rocker levers.

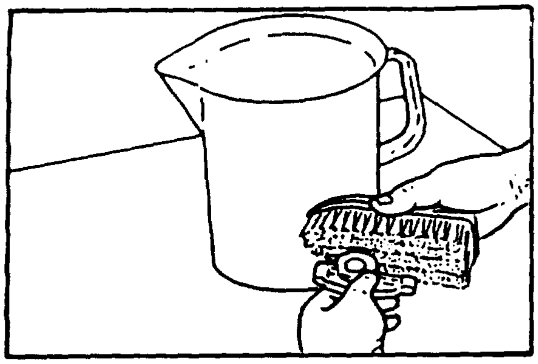


Caution: Do not disassemble the rocker lever shaft and pedestal. The pedestal and shaft must be replaced as an assembly.

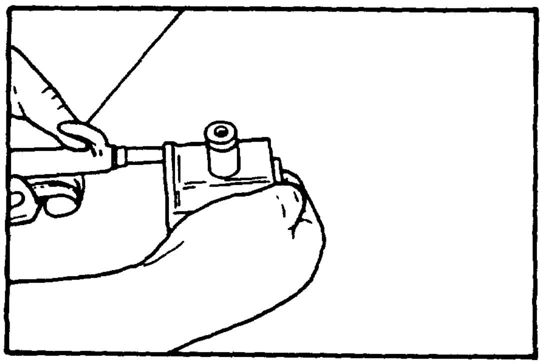


Remove the lock nut and adjusting screw.



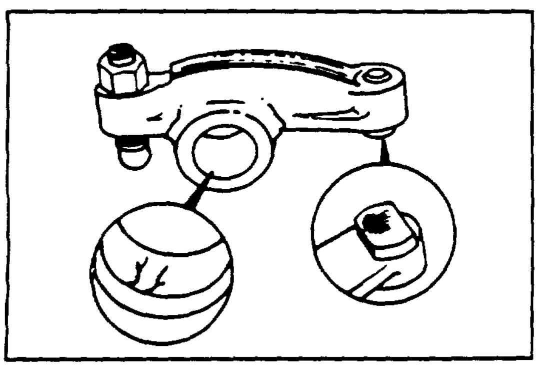


Clean all parts in a strong solution of laundry detergent in hot water.

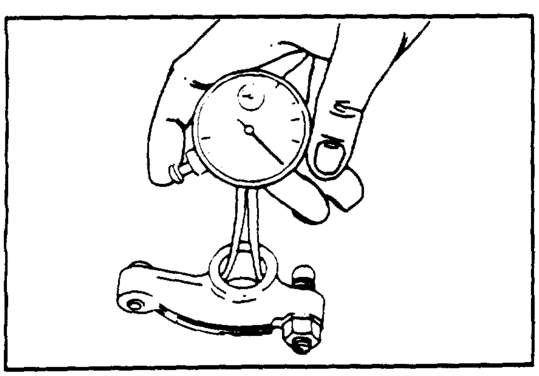


Use compressed air to dry the parts after rinsing in clean hot water.

Note: The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.



Inspect for cracks and excessive wear in the bore and the contact surface for the valve stem.

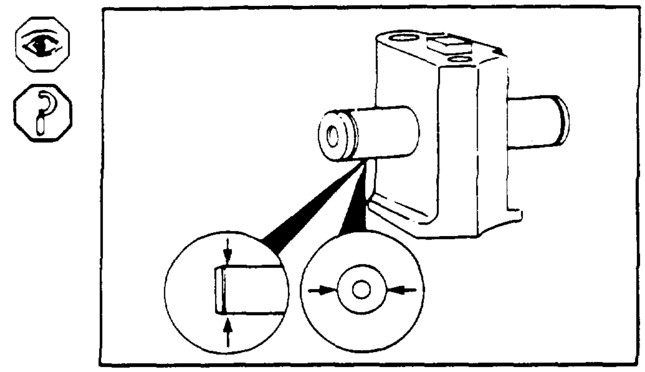


Measure the rocker lever bore.

	Limits
Diameter (Maximum)	19.05mm (0.75 inch]

Inspect the pedestal and shaft.

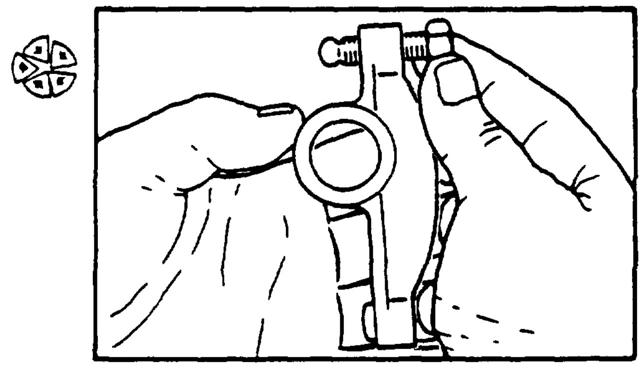
Measure the shaft diameter.



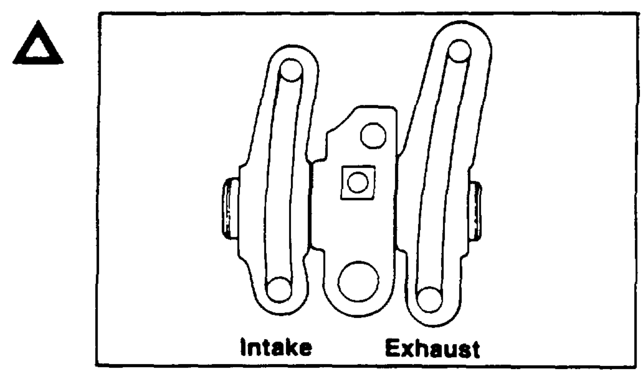
	Limits
Minimum Diameter	18.94mm [0.746 inch]

Rocker Levers Assembly

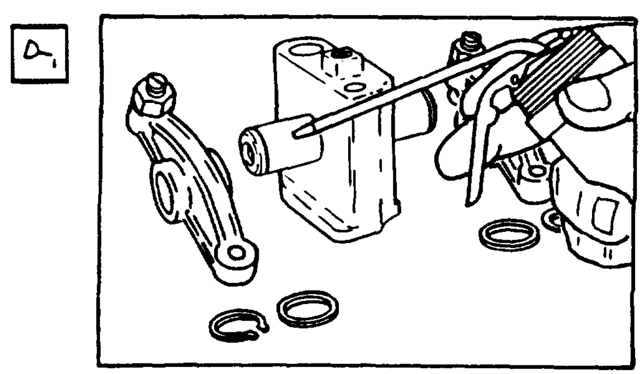
Install the adjusting screw and lock nut.

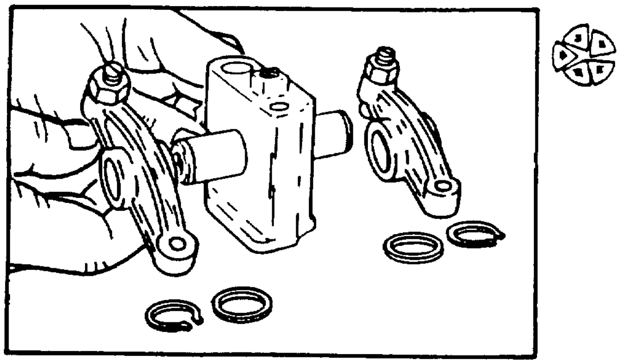


Caution: Be sure to assemble the intake and exhaust rocker levers in the correct location.

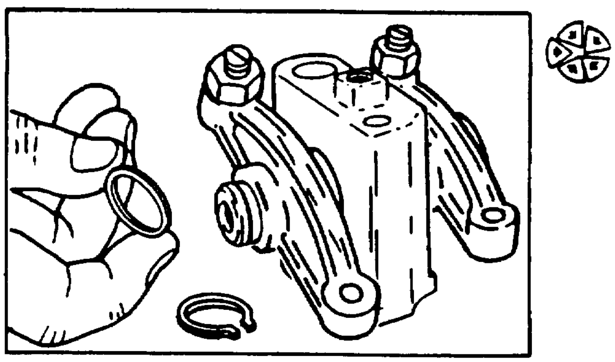


Lubricate the shaft with engine oil.

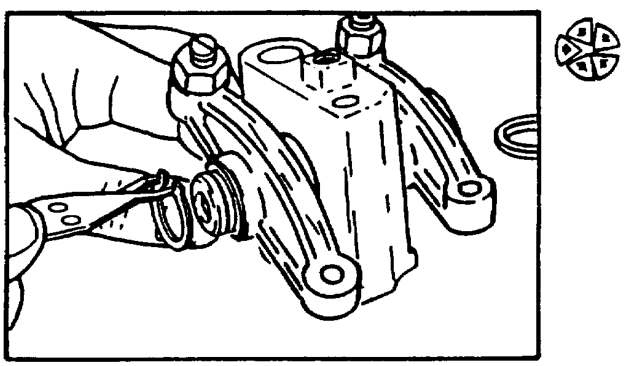




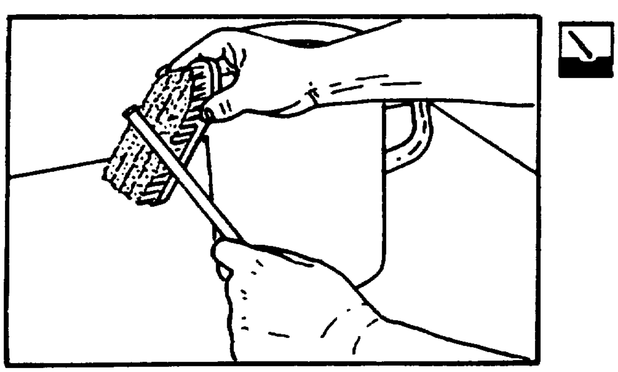
Position the levers on the rocker shaft.



Install the thrust washers.

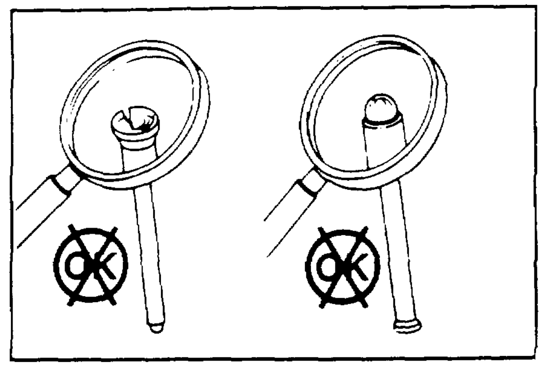


Install the snap rings.

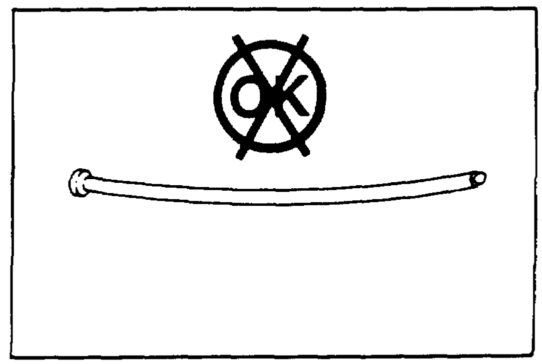


Clean the push rods in hot soapy water.

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.

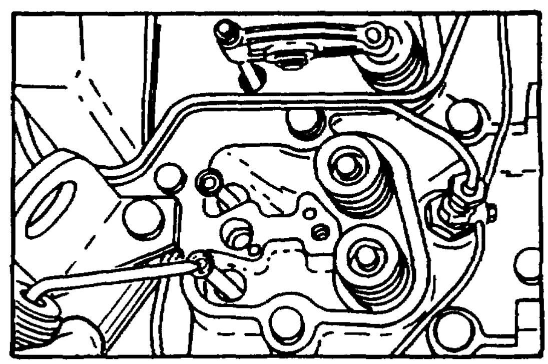


Check the push rods for roundness and straightness.

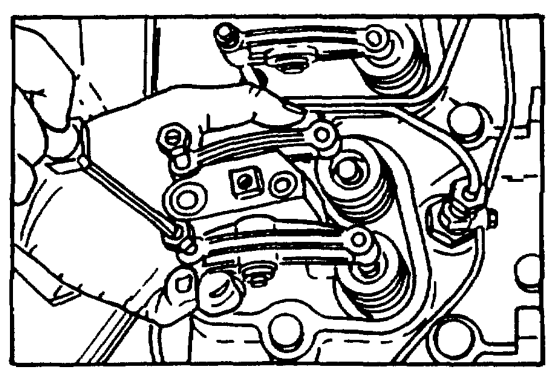


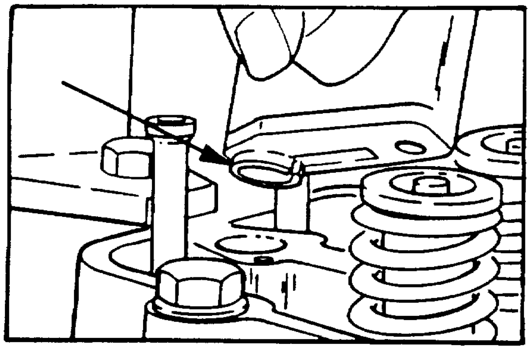
Install the push rods into the sockets of the valve tappets.

Lubricate the push rod sockets with dean engine oil.



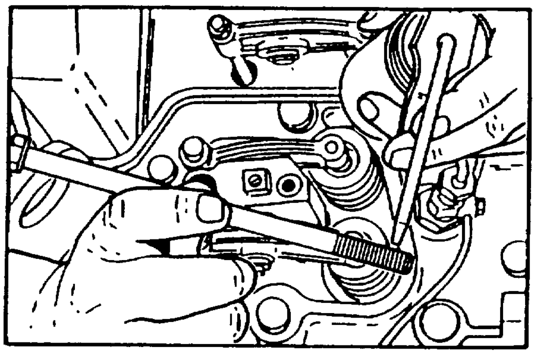
Caution: Make sure the rocker lever adjusting screws are completely backed out.





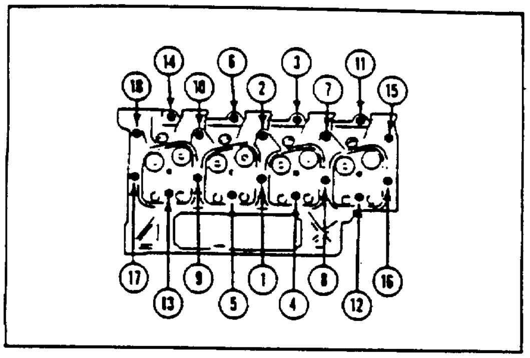
Rocker Lever Assembly Installation

Caution: Make sure the dowel rings in the pedestals are installed into the dowel bores.



Use clean engine oil to lubricate the threads and under the heads of the 8mm and 12mm capscrews.

Install the capscrews into the pedestals.

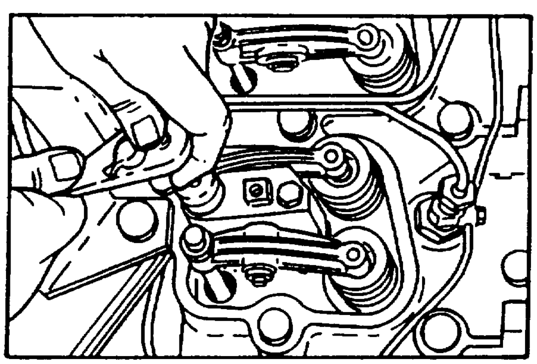


18mm

Use the sequence shown to tighten ALL of the 12mm cylinder head capscrews.

Torque Value:

Step 1 - 40 N•m [29 ft-lbs]
Step 2 - 85 N•m [62 ft-lbs]
Step 3 - 126 N•m [92 ft-lbs]



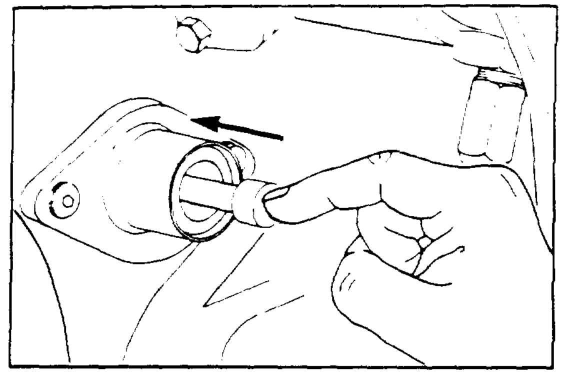
13mm

Tighten the 8mm pedestal capscrews.

Torque Value: 24 N•m [18 ft-lbs]

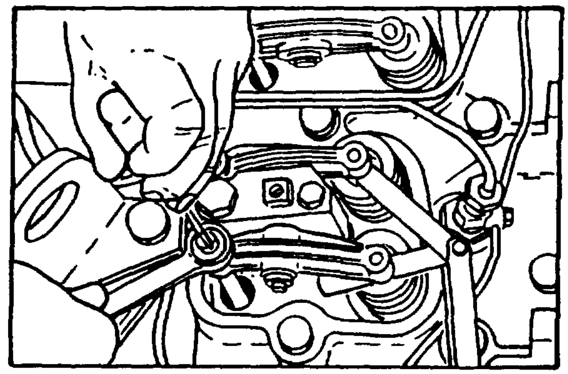
Caution: Be sure to disengage the pin after locating top dead center.

Use the timing pin to locate Top Dead Center for Cylinder Number 1.



Valve Clearance Adjustment

Caution: Adjust the valves when the engine is cold - below 60°C [140° F].



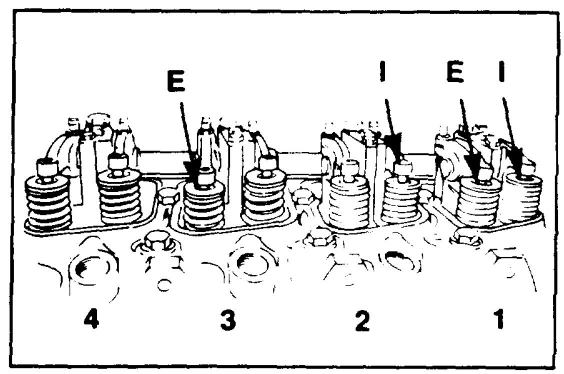
Four-Cylinder Engine

Step A

9/16 inch

Adjust the clearance for the valves shown in the illustration.

(I = Intake; E = Exhaust)
Intake: 0.254mm [0.010 inch]
Exhaust: 0.508mm [0.020 inch]



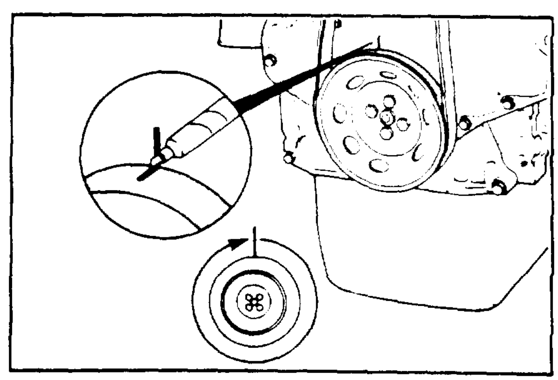
Tighten the locknut and check the clearance.

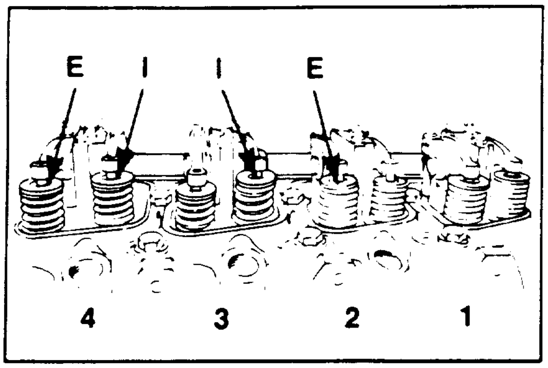
Note: The clearance is correct when some friction is felt when the feeler gauge is moved between the valve stem and the rocker lever.

Caution: Be sure the timing pin is disengaged before rotating the crankshaft.

Mark the pulley and rotate the crankshaft 360 degrees.

Torque Value: 24 N•m [18 ft-lbs]



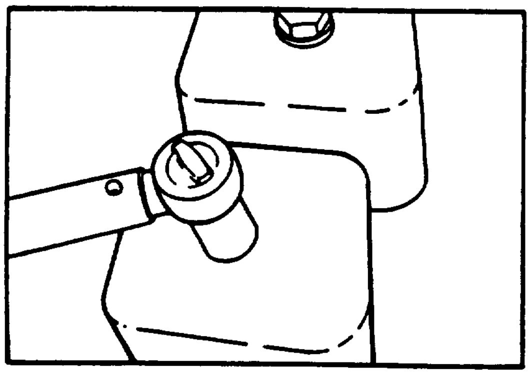


Step B

Adjust the clearance for the valves shown in the illustration.

Intake: 0.254mm [0.010 inch]
Exhaust: 0.508mm [0.020 inch]

Torque Value: 24 N•m [18 ft-lbs]



15mm

Install the valve covers.

Torque Value: 24 N•m [18 ft-lbs]

Camshaft and Tappet - Replacement

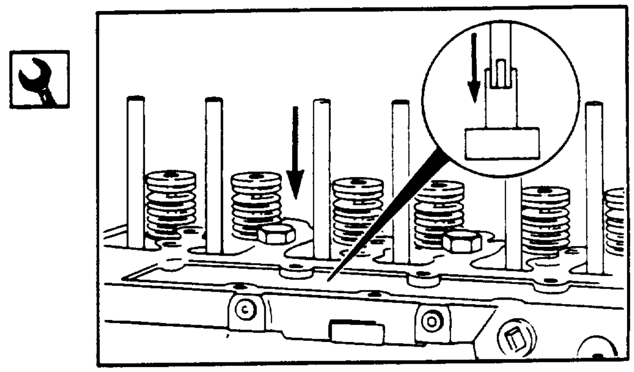
Preparatory Steps:

- Remove the valve covers
- Remove the push rods
- Remove the drive belt
- Remove the crankshaft pulley
- Remove the gear cover
- Remove the lift pump

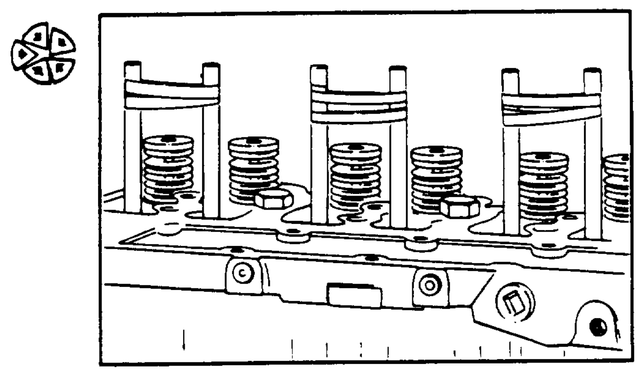
Camshaft Removal

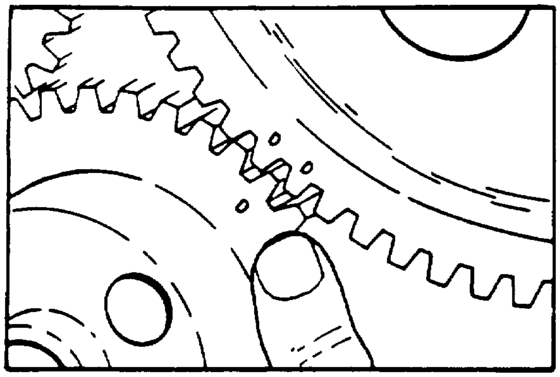
3822513, Plastic Hammer

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.

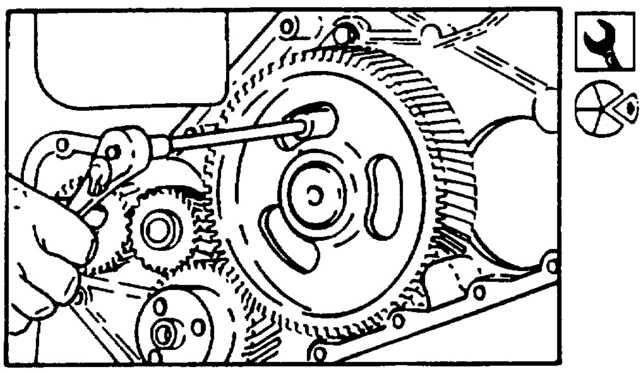


Pull the tappets up and wrap a rubber band around the top of the dowel rods. This will prevent the tappets from dropping down.



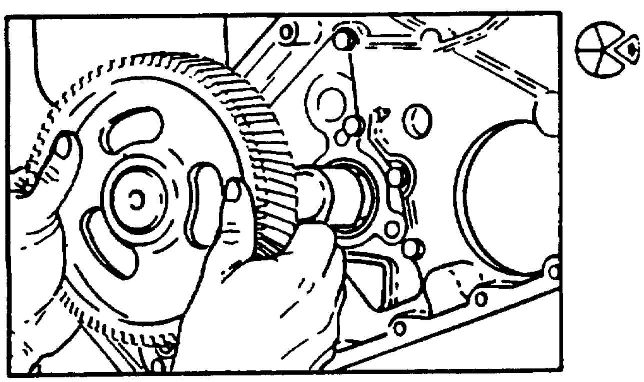


Rotate the engine to align the crankshaft to camshaft timing marks.

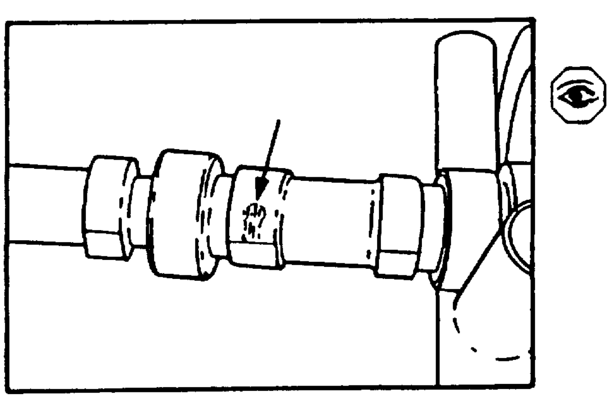


13mm

Remove the capscrews from the thrust plate.



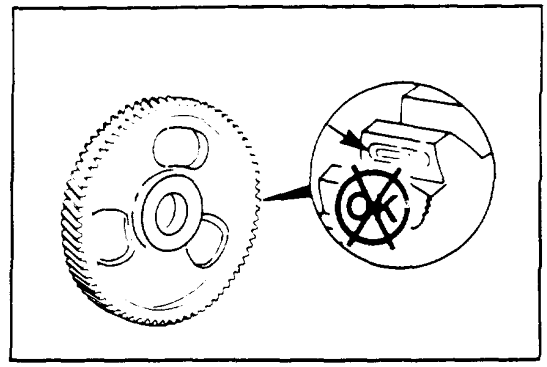
Remove the camshaft and thrust plate.



Camshaft Inspection

Inspect the lift pump lobe, valve lobes and bearing journals for wear, cracking, pitting and other damage.

Inspect the gear teeth for wear and damage. Look for cracks at the root of the teeth.

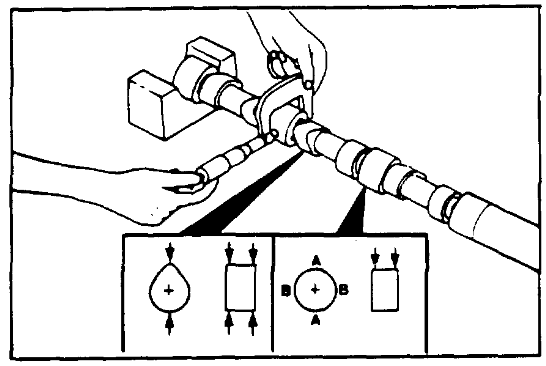


Measure the bearing journals and valve lobes.

Limits

Journal

Minimum Diameter: 53.962mm (2.1245 inches]
Valve Lobes: (Minimum Diameter at Peak of Lobe)
Intake Minimum Height: 47.040mm (1.852 inches]
Exhaust Minimum Height: 46.770mm [1.841 inches]
Lift Pump Lobe Diameter Minimum: 35.5mm [1.398 inches]

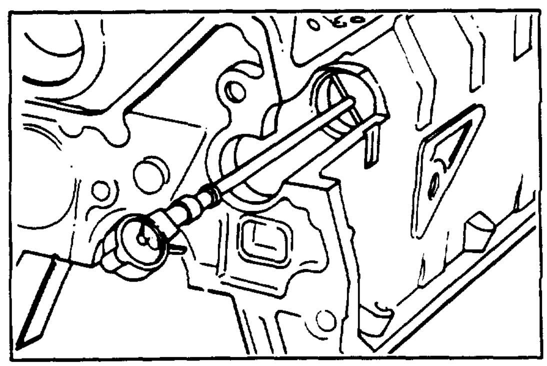


Camshaft Bushing inspection

Caution: If the bushing is worn beyond the limit, install a new service bushing.

Inspect the camshaft bore for damage or excessive wear.

The limit for the bushing in the No. 1 bore is the same as for the other bores without bushings.

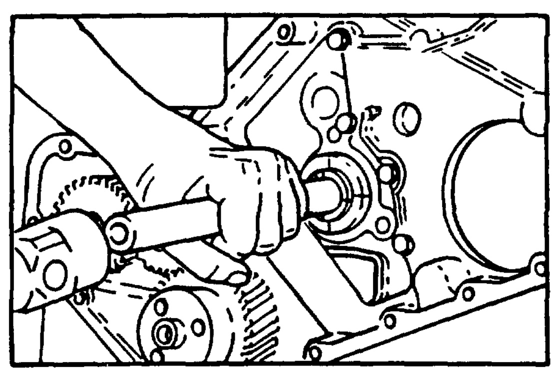


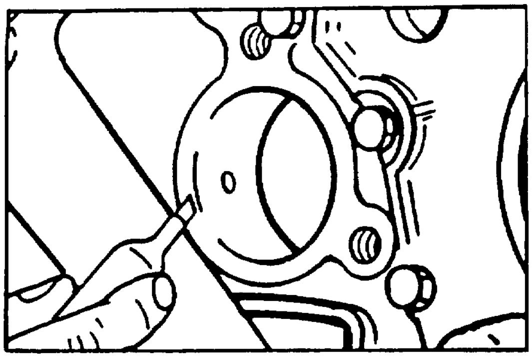
Limit

Inside Diameter: 54.133mm [2.1312 inches]

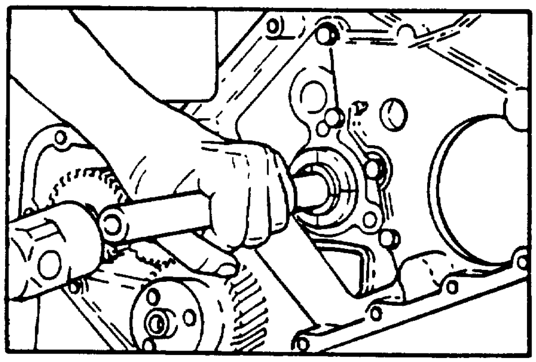
Note: If the bores without a bushing are worn beyond the limit, the engine must be removed for machining and installation of service bushings or replacement of the cylinder block.

Remove the bushing from the Number 1 bore.

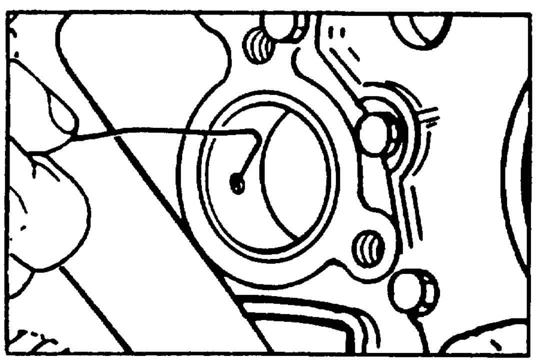




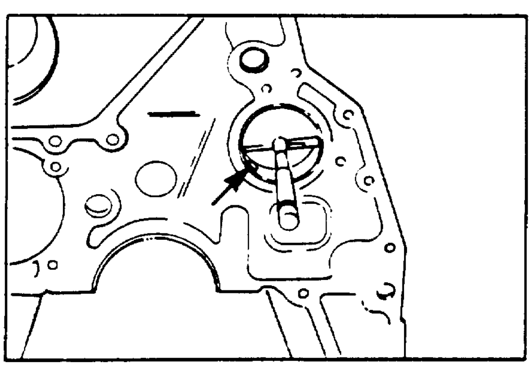
Note: Mark the cylinder block so you can align the oil hole in the cylinder block with the oil hole in the bushing.



Install the bushing so that it is even with the front face of the cylinder block.



Caution: the oil hole must be aligned.

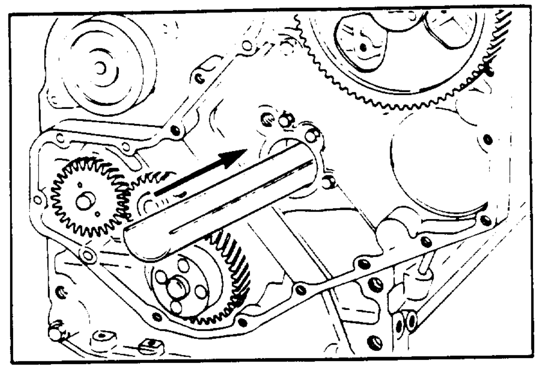


Measure the installed bushing.

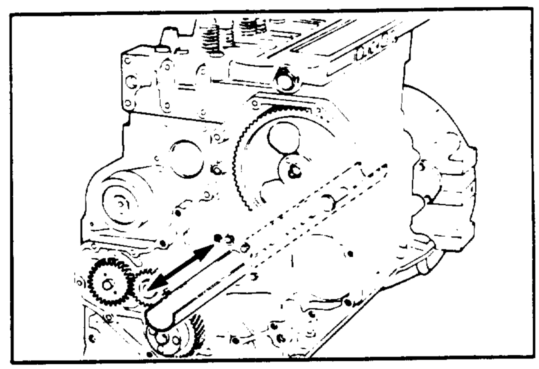
Limits
Inside Diameter: 54.146mm [2.1315 inches]

Tappet Removal

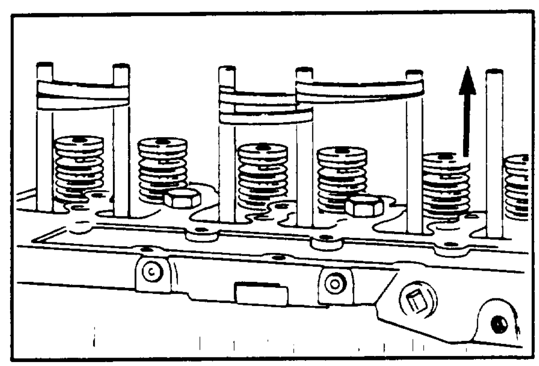
Insert the trough to the full length of the cam bore.



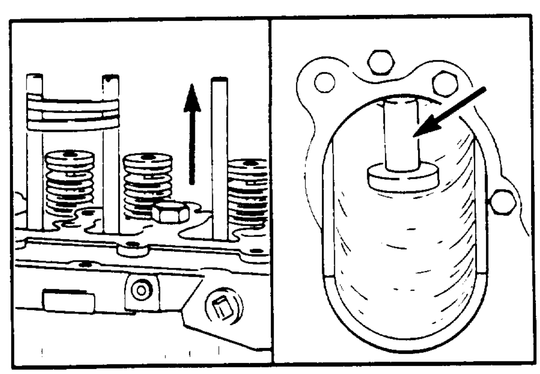
Make sure the trough is positioned so it will catch the tappet when the wooden dowel is removed.

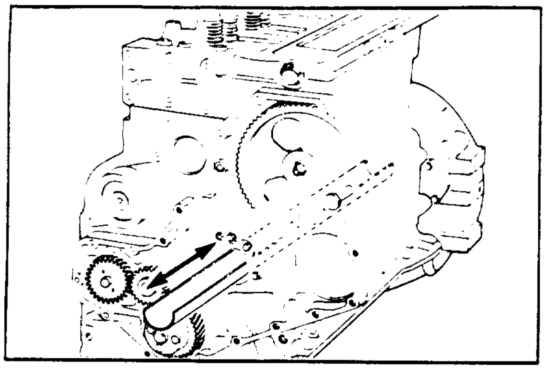


Only remove one tappet at a time. Remove the rubber band from the two companion tappets, securing the tappet not to be removed with the rubber band.



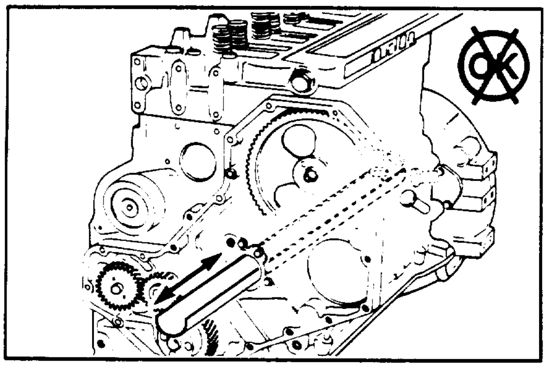
Pull the wooden dowel from the tappet bore allowing the tappet to fall into the plastic trough.



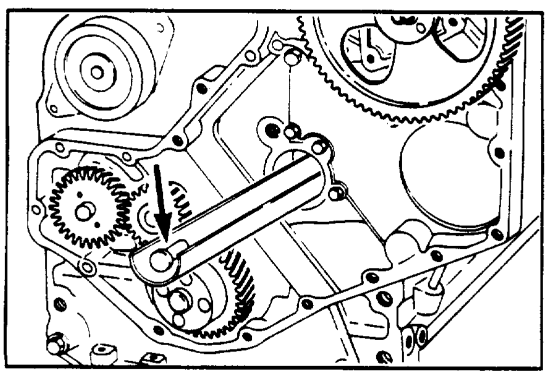


Flashlight

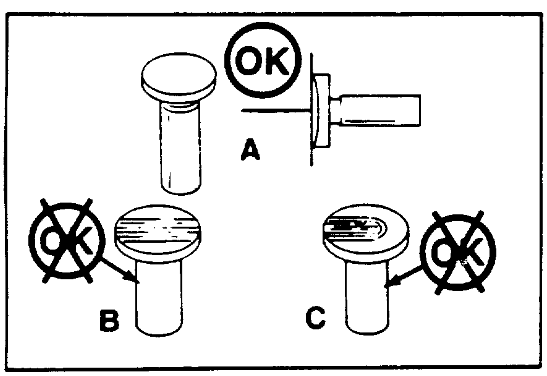
When the tappet is dropped into the bottom trough, due to the roundness of the trough most of the time, they will fall over. However, if they do not, gently shake the trough just enough to allow the tappet to fall over before removing.



NOTE: Take special care when removing the Number 4 cylinder tappets to avoid knocking or shaking the tappets over the tape barrier 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.

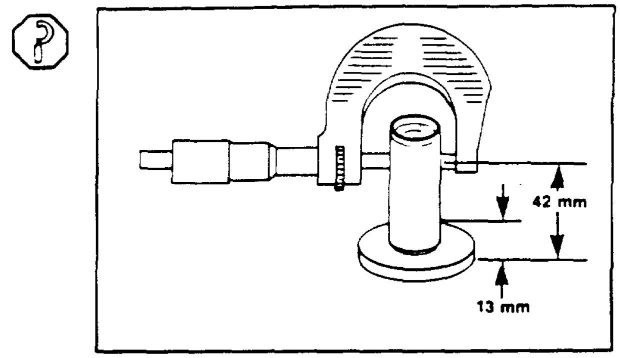


Tappet Inspection

Inspect the socket, stem and face for excessive wear, cracks and other damage.

Limits	
(A)	- Normal wear
(B) and (C)	- Abnormal wear - **Do not reuse**

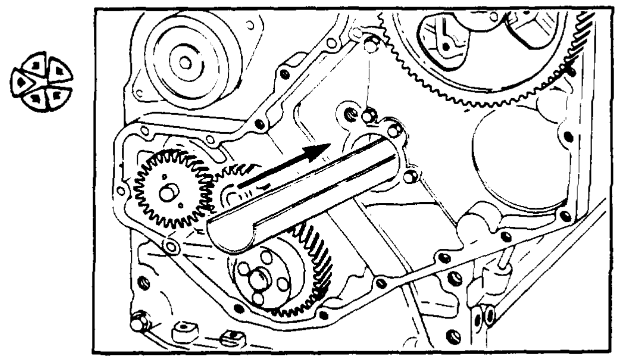
Tappet stem specifications



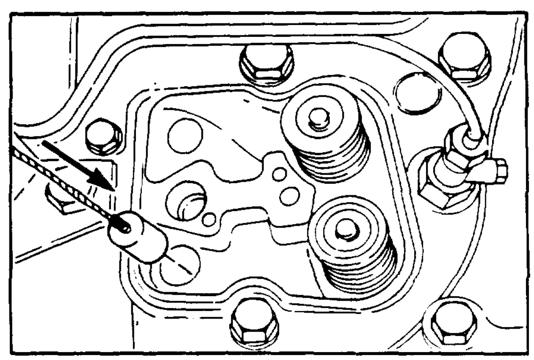
	Limits
Minimum Diameter: 15.925mm [0.627 inches]	

Tappet Installation

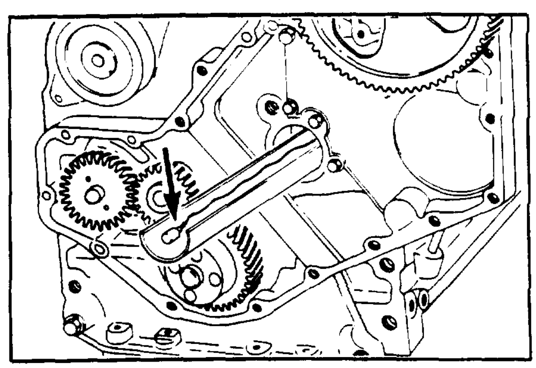
Insert the plastic trough the full length of the cam bore.

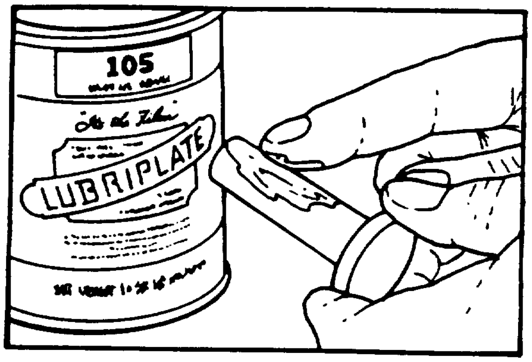


Feed the installation tool down the tappet bore and into the plastic trough.

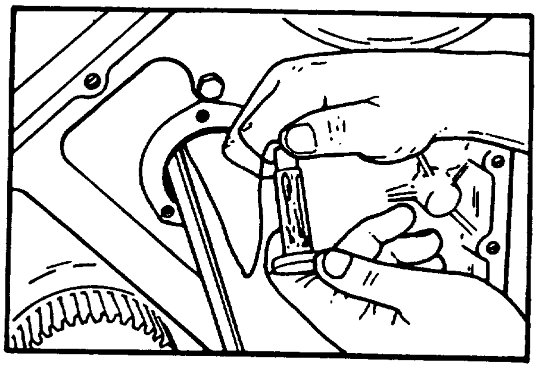


Feed the installation tool through the cam bores by carefully pulling the plastic trough/installation tool out the front. The barrier at the rear of the trough will pull the tool out most of the time.



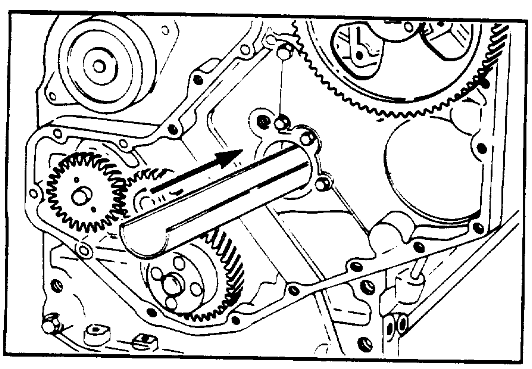


Lubricate the tappets with Lubriplate™ 105.

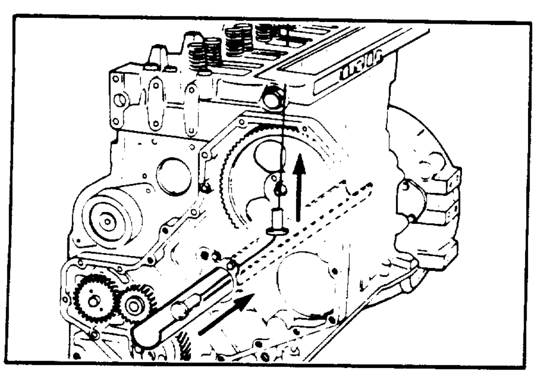


Insert the installation tool into the tappet.

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.

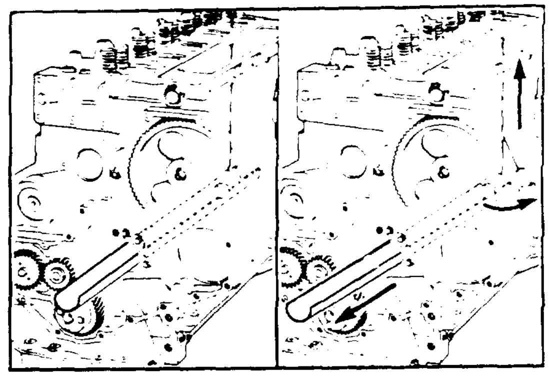


Slide the trough back into the cam bore.

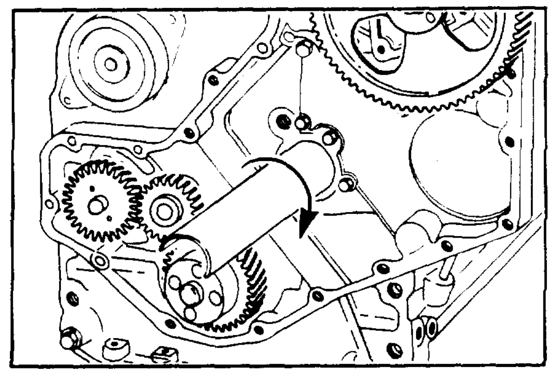


Pull the tool/tappet through the cam bore and up into the tappet bore.

If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore (due to the webbing of the block), pull the trough out enough to allow the tappet to drop down and align itself, then pull the tappet up into the bore.



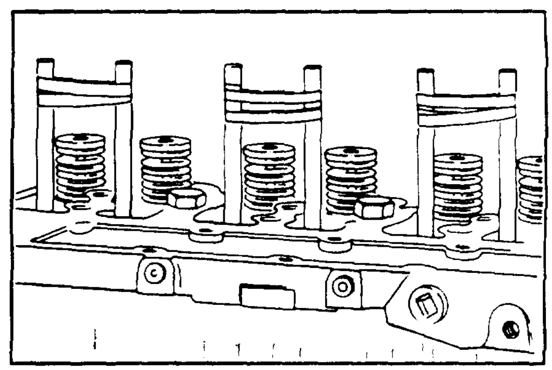
After the tappet has been pulled up into position, slide the trough back into the cam bore and rotate it 1/2 turn. This will position the round side of the trough up, which will hold the tappet in place.



Remove the installation tool from the tappet.

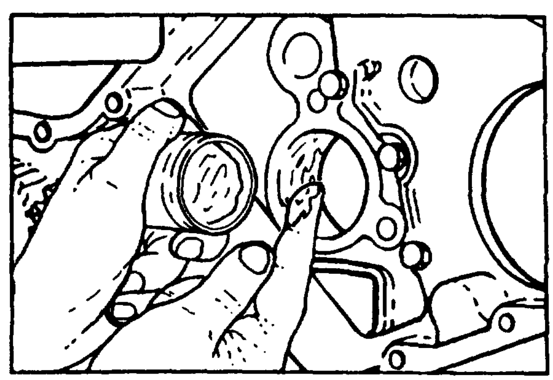
Install a wooden dowel into the top of the tappet. Wrap rubber bands around the wooden dowels to secure the tappets.

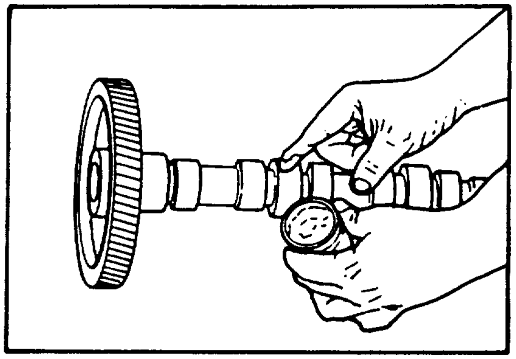
Repeat this process until all tappets have been installed.



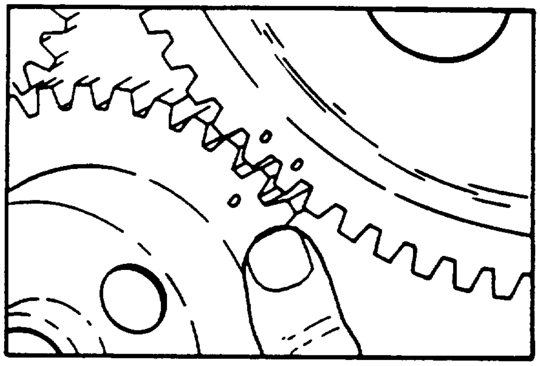
Camshaft Installation

Apply a coat of Lubriplate 105 to the camshaft bores.

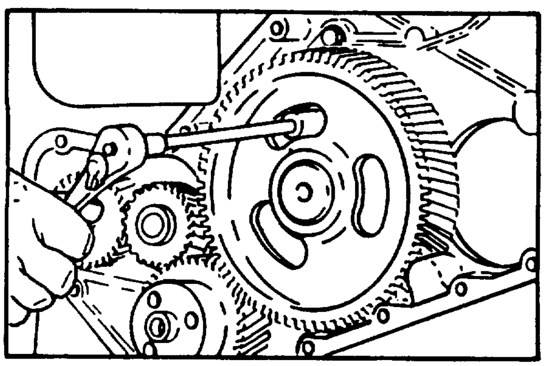




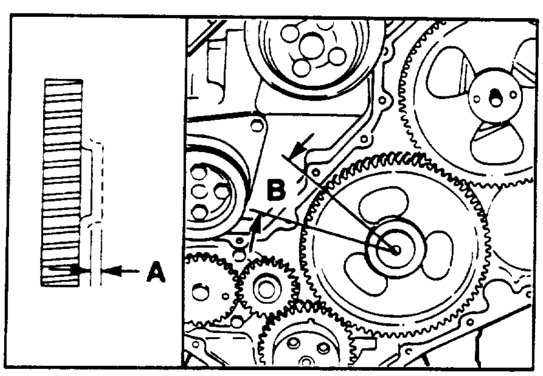
Lubricate the camshaft lobes, journals and thrust washer with Lubriplate^{TM} 105.



Install the camshaft/thrust washer. Align the timing marks as illustrated.



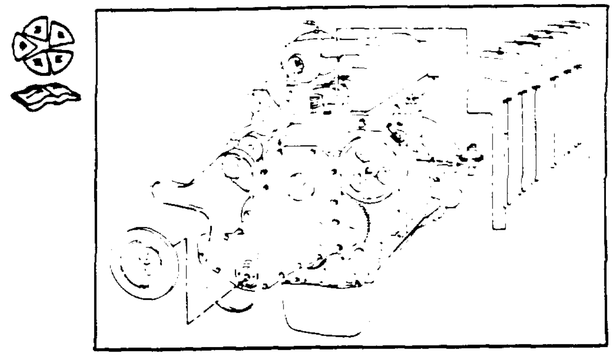
Install the thrust washer capscrews and tighten to 24 N•m [18 ft lbs].



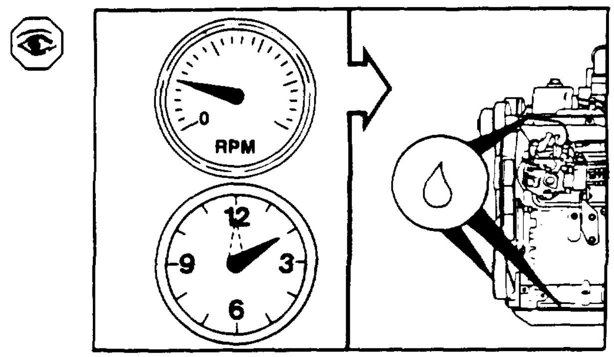
Verify the camshaft has proper back lash and end play.
A = 0.152 to 0.254mm [0.006 to 0.010 inch]
B = 0.12 to 0.33mm [0.005 to 0.013 inch]

Complete the installation of the removed parts.

- Gear cover
- Vibration damper
- Rocker levers and valve cover
- Lift pump

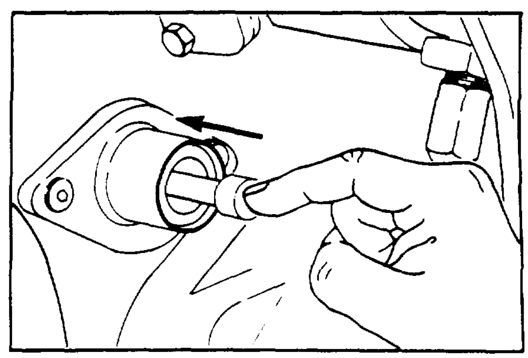


- Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.



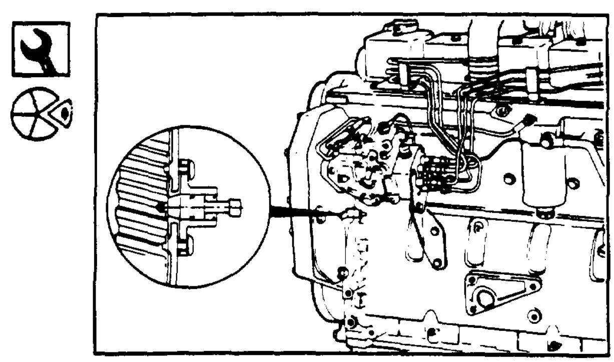
Timing Pin Assembly or Gasket - Replacement

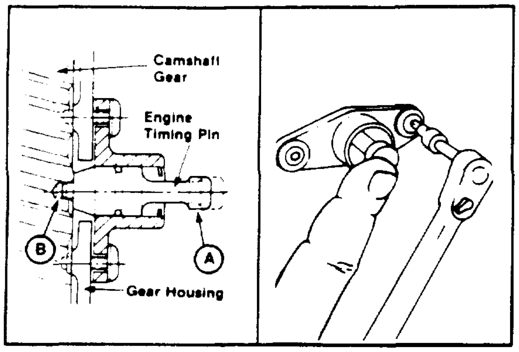
Locate TDC for Cylinder No. 1.



T-25 Torx

Remove the timing pin assembly and gasket.





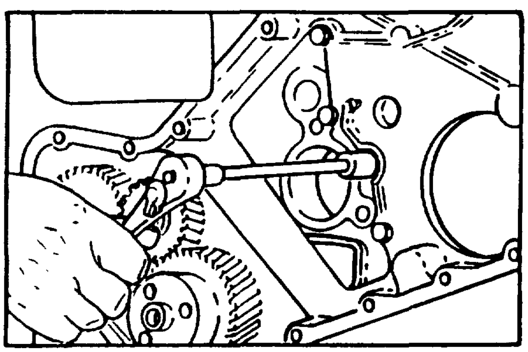
Install a new gasket and, if required, new timing pin assembly. Hold the pin (A) in the hole (B) in the camshaft gear to align the housing.

Torque Value: 5 N•m [4 ft-lbs]

Gear Housing or Gasket - Replacement

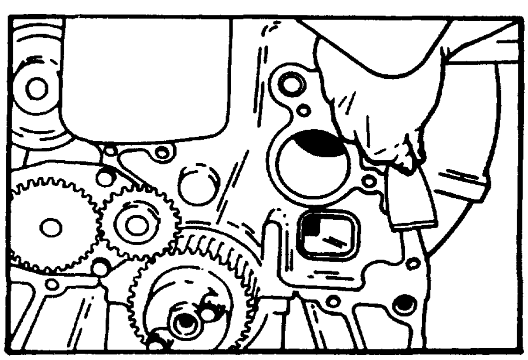
Preparatory Step:

- Remove the camshaft.
- Remove the gear driven accessory drive if the engine is so equipped.



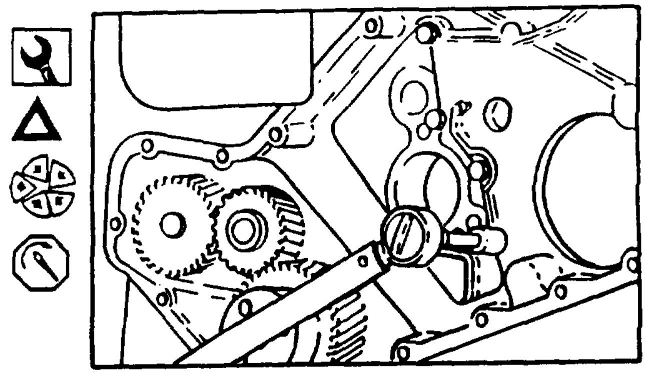
10 mm

Remove the gear housing and gasket.



Clean the gasket material from the cylinder block.

10mm

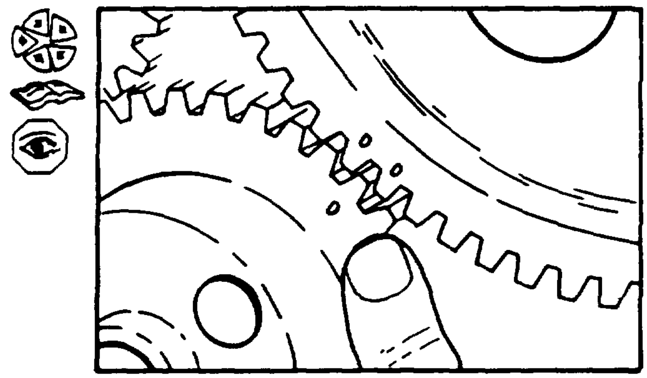


Caution: If a new housing or other than the original housing is installed, the timing pin assembly must be accurately located.

Install a new gasket and gear housing.

Torque Value: 24 N•m [18 ft-lbs]

Install the camshaft.

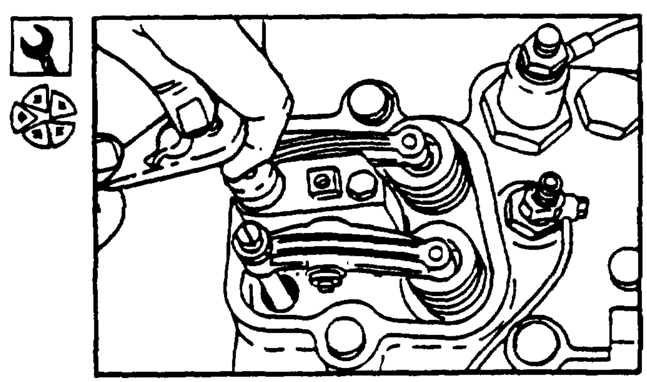


Note: Make sure the alignment marks on the camshaft and camshaft gears are aligned.

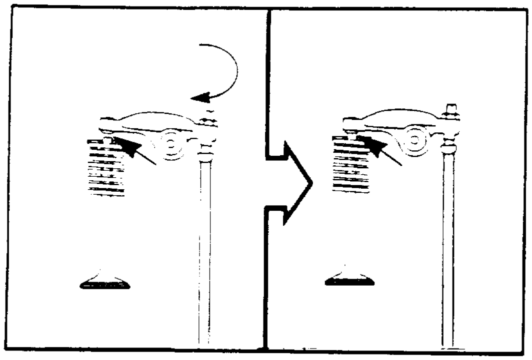
Timing Pin - Installation

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.

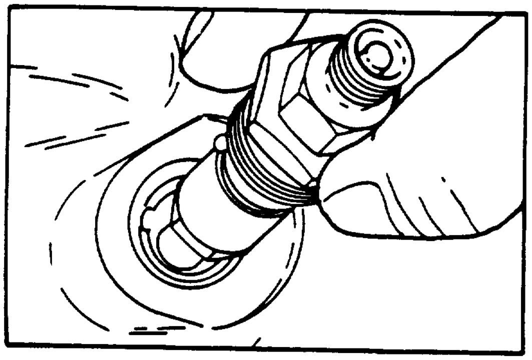
18mm, 13mm



Install the rocker levers and the exhaust push rod for Cylinder Number 1.

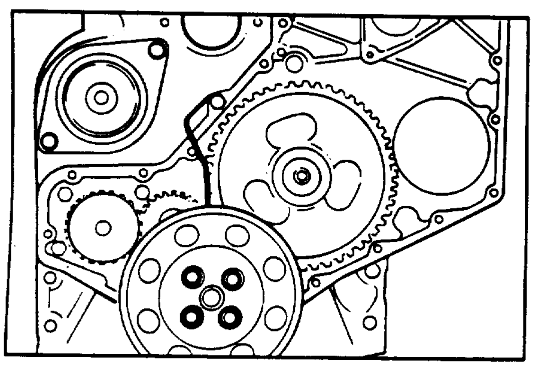


Adjust the exhaust rocker lever to have zero (0) valve clearance.



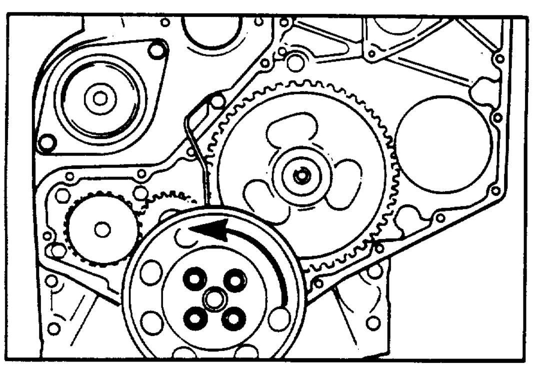
Remove the injector nozzles from all of the cylinders.

Note: This step is important to vent the cylinders so the crankshaft can be rotated smoothly to locate TDC for Cylinder Number 1.



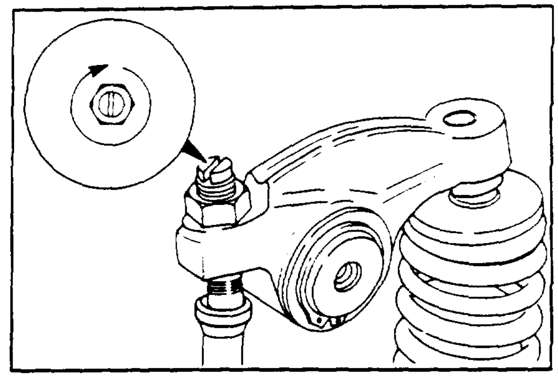
18mm

Temporarily install the crankshaft pulley. Fabricate and install a wire pointer as shown.



Rotate the crankshaft one-quarter rotation in the direction opposite engine rotation.

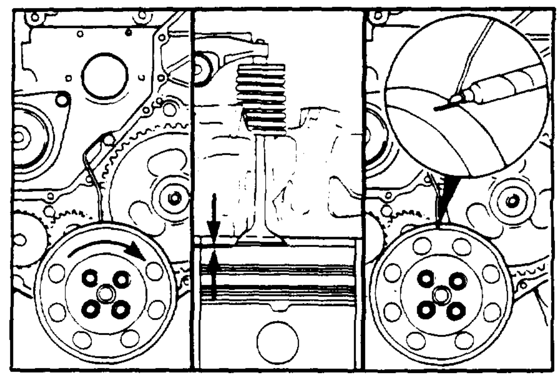
Tighten the adjusting screw for the exhaust valve two complete turns of the screw.



Caution: Use extreme care that the piston does not push against the exhaust valve with so much force that it bends the push rod.

Rotate the crankshaft slowly in the direction of engine rotation until the piston touches the exhaust valve.

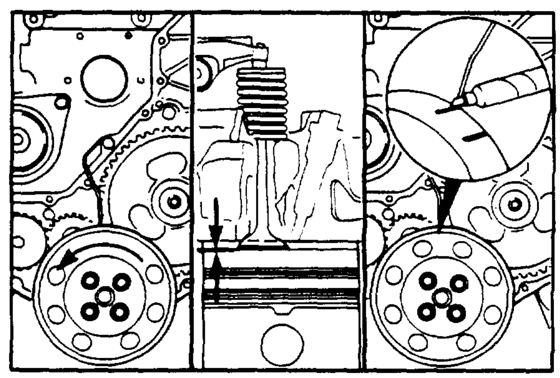
Mark the crankshaft pulley.



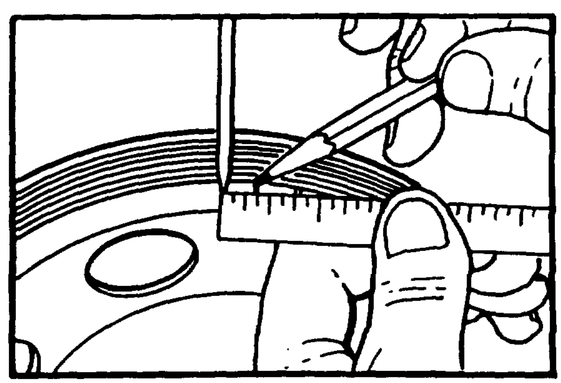
Caution: Make sure that the piston touches the valve with approximately the same amount of force as in the previous step.

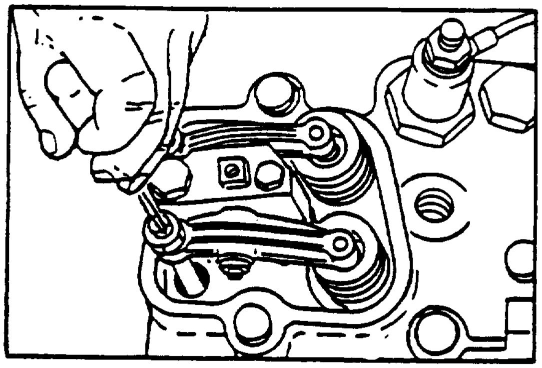
Rotate the crankshaft in the opposite direction until the piston touches the valve.

Mark the crankshaft pulley.

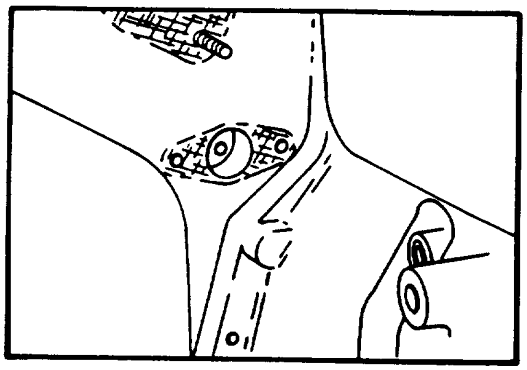


Measure the distance and mark the pulley at one-half the distance between the two marks. This mark is the TDC mark.

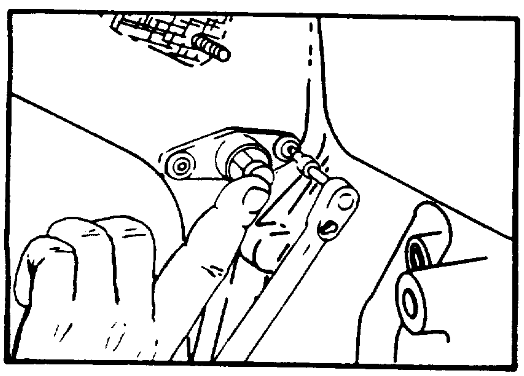




Completely loosen the exhaust valve adjusting screw.



Rotate the crankshaft in the direction of engine rotation until the pointer is aligned with the TDC mark. Look through the back side of the gear housing for the timing pin hole in the camshaft gear. If the hole is not visible, the crankshaft must be rotated one revolution.



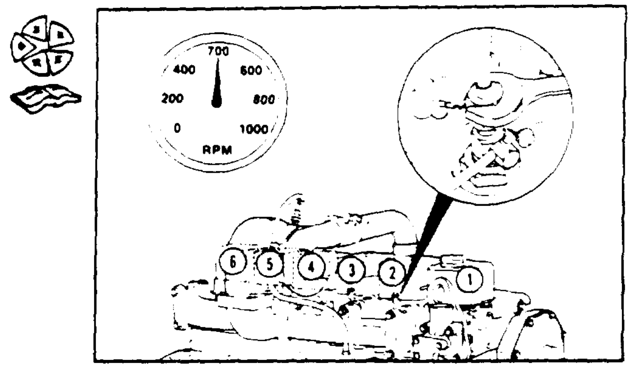
T-25 Torkscrew

Apply a coat of Lactate 59241 to the threads of the torkscrews. Hold the timing pin in the hole to align the housing.

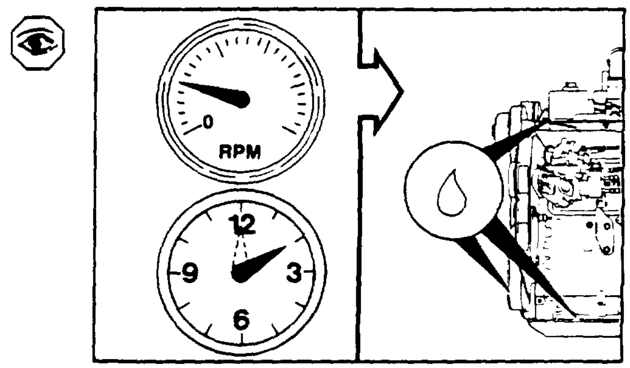
Torque Value: 5 N•m [4 ft-lbs]

Complete the procedure for camshaft installation

Install the injectors and bleed the fuel system.



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



Flywheel Ring Gear and Rear Seal - Replacement

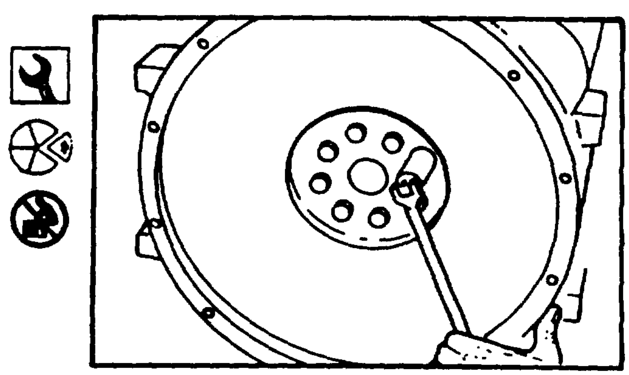
Preparatory Step:

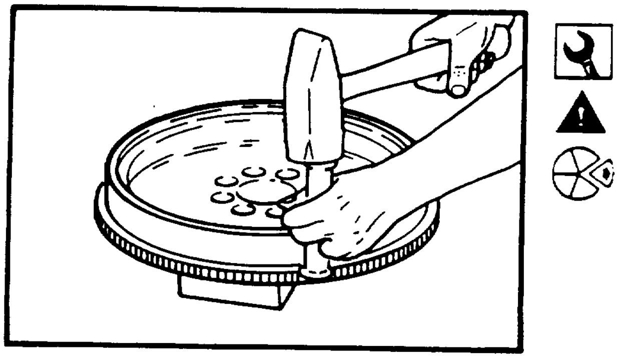
- Remove the transmission

Ring Gear - Replacement

19mm

Remove the flywheel.

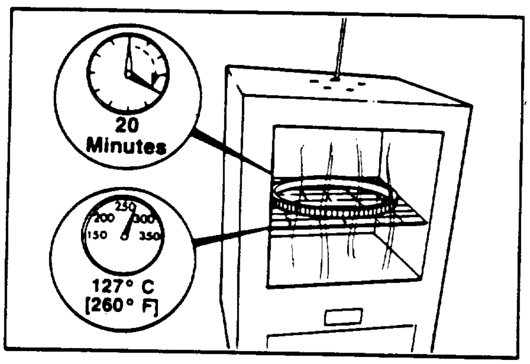




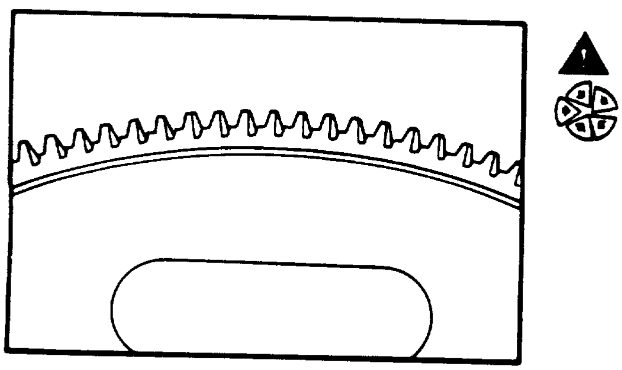
Brass Drift Pin

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.

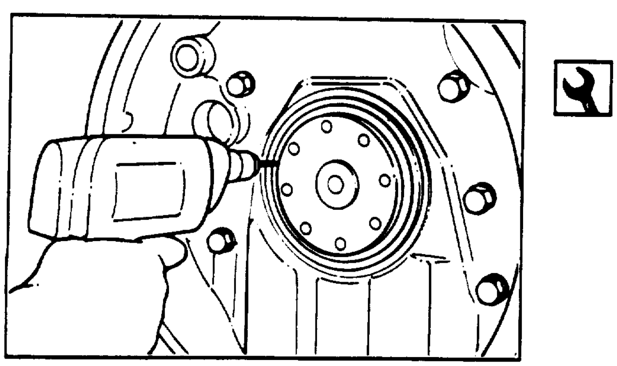


Heat the new ring gear for 20 minutes in an oven preheated to 127° C [260° F].



Warning: Wear protective gloves when you install the heated gear.

Install the gear. The gear must be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

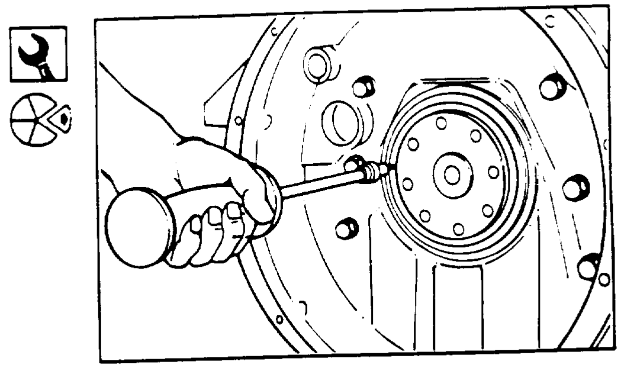


Rear Seal - Replacement

1/8 inch Drill

Drill two holes 180 degrees apart into the seal carrier.

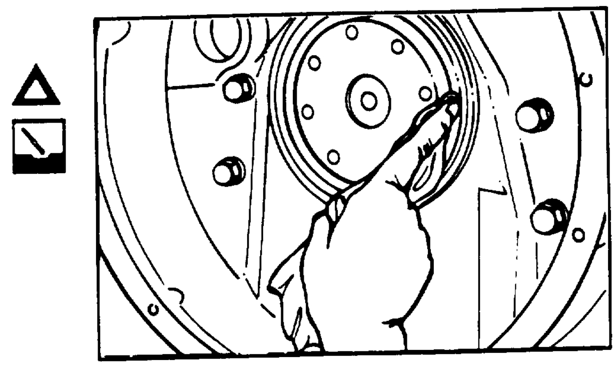
No. 10 Sheet Metal Screw, Slide Hammer Dent Puller
Remove the rear seal.



Rear Seal - Installation

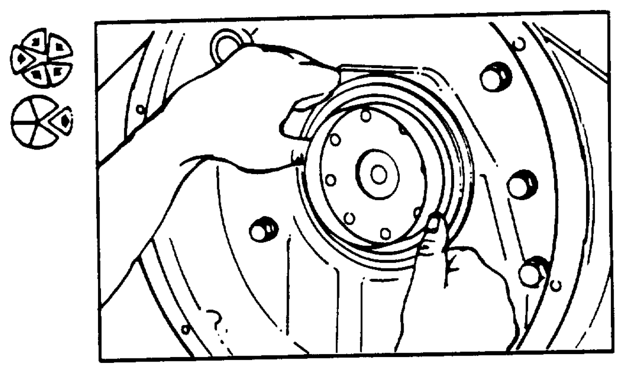
Caution: The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Clean and dry the rear crankshaft sealing surface.



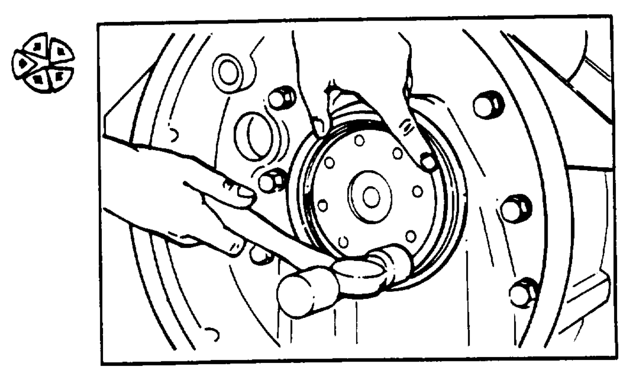
Install the seal pilot, provided in the replacement kit, onto the crankshaft. Push the seal onto the pilot and crankshaft.

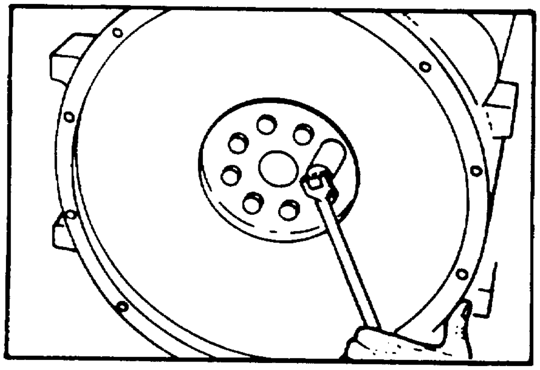
Remove the seal pilot.



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 tool stops against the housing.

Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier.

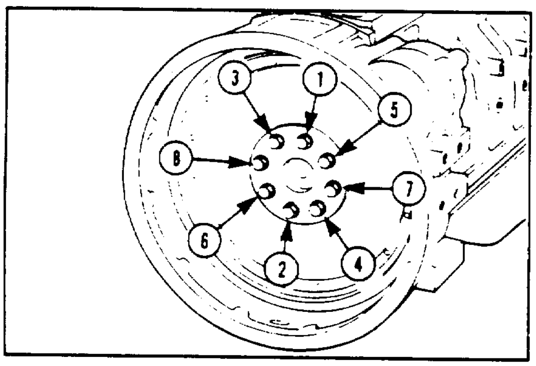




Flywheel - Installation

Caution: Never use the timing pin to hold the crankshaft.

Use two capscrews in the front of the crankshaft, or similar device, to hold the crankshaft when the flywheel capscrews are being tightened.



19mm Socket, Torque Wrench

Tighten the capscrews in the sequence shown.

Torque Value: 137 N•m [101 ft-lbs]

In-Chassis Overhaul

The remaining procedures in this manual are organized for an in-chassis overhaul. An in-chassis overhaul includes:

- Replacing piston rings
- Replacing connecting rod bearings
- Replacing crankshaft main bearings
- Grinding valves
- Testing injectors

This manual gives the procedures to replace the piston rings, rod bearings, main bearings, and grinding the valves. The procedures to test the injectors are given in the Shop Manual, Bulletin Number 3810206.

Segments of the procedures can also be used to replace individual components when required.

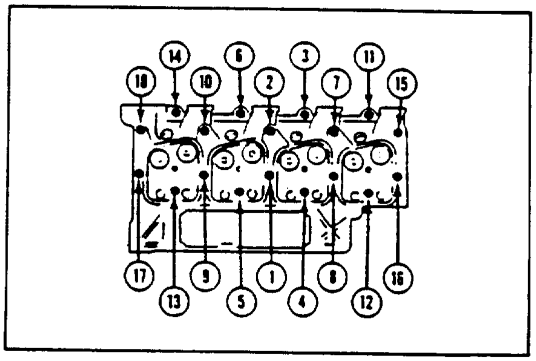
The condition of the cylinder block and crankshaft is the limiting criteria for in-chassis overhaul. If there is reason to believe that either are severely damaged, the engine should be removed for major overhaul.

Prior to deciding on an in-chassis overhaul, inspect the air intake for evidence of ingestion of particles that could have severely damaged the cylinder walls. Check the oil and oil filter to be sure the lube system is not thoroughly contaminated with metal. Also check for rust in the coolant which can indicate build up in the passages in the cylinder block and require the block to be removed for cleaning. Also consider the condition of other components, particularly those that are more difficult to replace in-chassis; e.g. the camshaft rear seal, etc. The combination of in-chassis overhaul and time to repair those components may exceed the time required to remove the engine and perform an out of chassis overhaul.

The in-chassis overhaul procedures include prescribed checks of the hardware to determine if continued in-chassis work is practical. If the conditional limits are not met, the engine should be removed for completion of the overhaul.

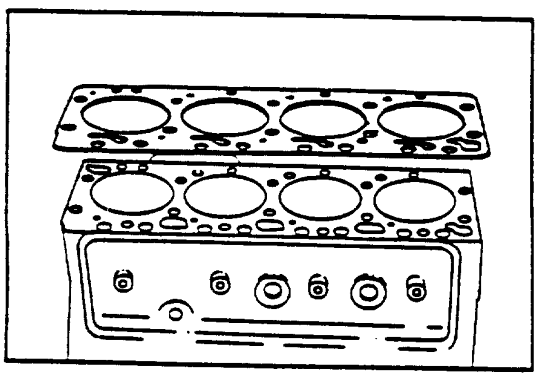
Cylinder Head Removal

- Drain the coolant and oil
- Disconnect the radiator and heater
- Remove the exhaust manifold
- Remove the fuel lines and injector nozzles
- Remove the valve covers
- Remove the rocker levers and push rods
- Remove the fuel filter



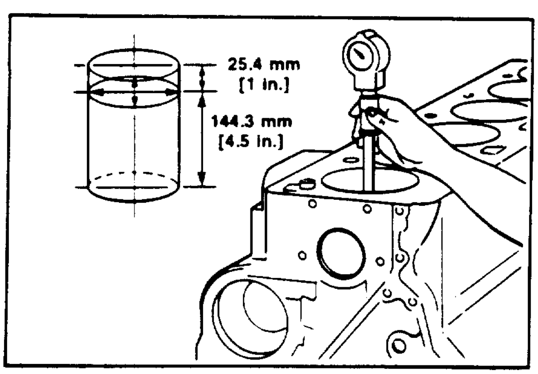
18mm

Remove the cylinder head capscrews in the sequence shown.



Remove the cylinder head and gasket from the block.

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.



Inspect the cylinder bores for damage or excessive wear. Rotate the crankshaft so the piston is at BDC for the bores being inspected.

Measure the cylinder bores.

Limits

Max. Diameter: 102.116mm [4.0203 inches]
Out-of-Roundness: .038mm [.0015 inch]
Taper: .076mm [.003 inch]

Refer to page 8-30 for the limits of the oversize cylinder bores.

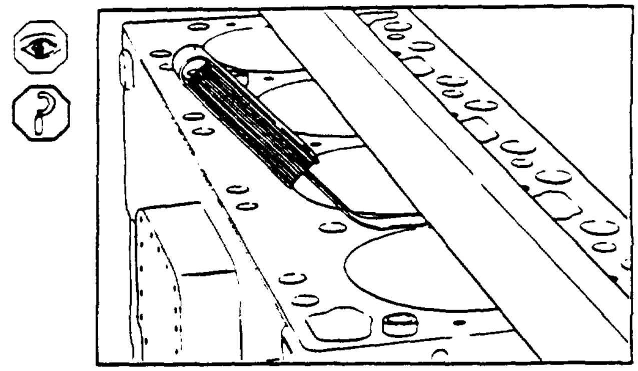
Note: Do not proceed with in-chassis overhaul if the bores are damaged or worn beyond the above limits.

Check the top surface for damage caused by the cylinder head gasket leaking between cylinders.

Check the top surface for flatness between each cylinder.

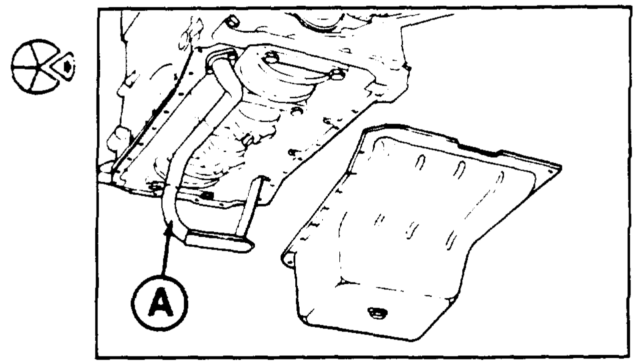
Limits
Variance: .050mm [.002 inch]

Note: Do not proceed with the in-chassis overhaul if the cylinder block head surface is damaged or not flat.

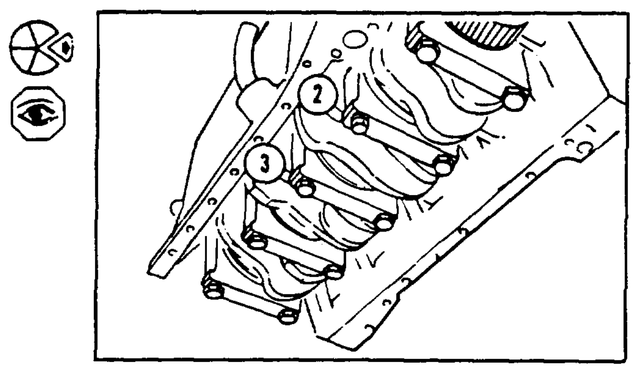


Main Bearing Preliminary Inspection

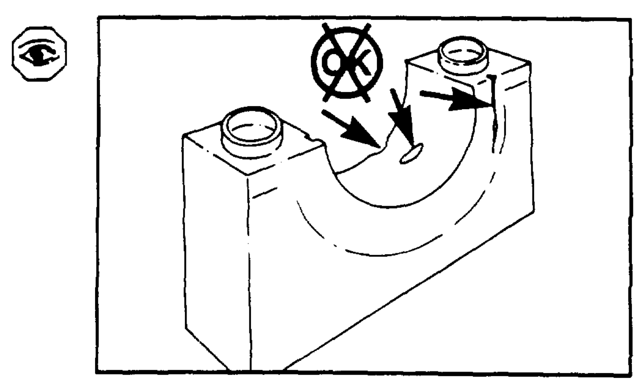
Remove the pan and suction tube (A).

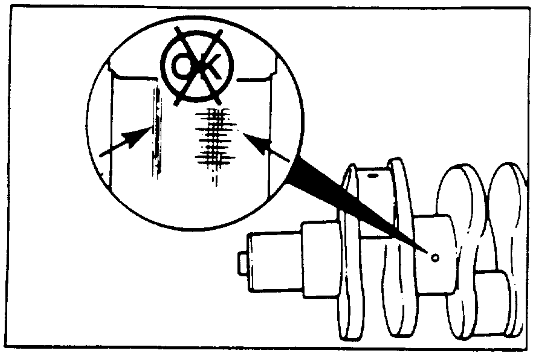


Perform a visual inspection of the main bearings and crankshaft journals. Remove the No. 2 and 3 caps and check the journals for signs of overheating, deep scratches or other damage. If there is no damage, there is no need to pull the other caps at this time.



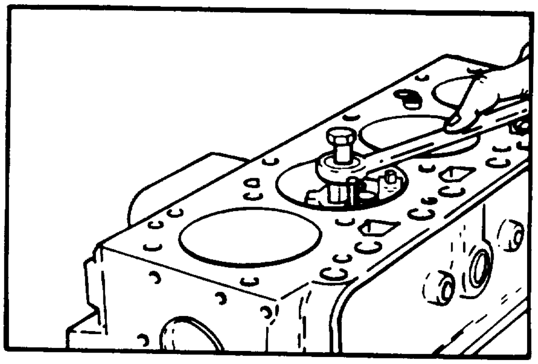
Inspect the main bearing caps for dents, cracks, or other damage.





Inspect the journals for deep scratches, indications of overheating and other damage.

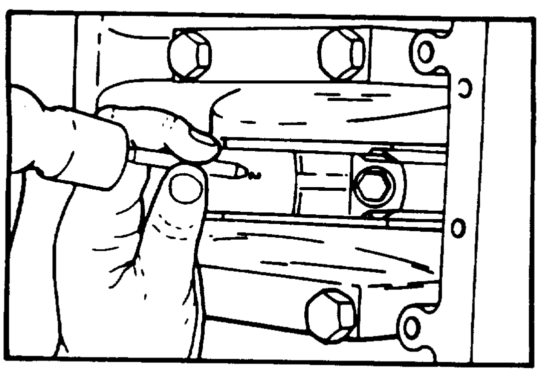
Note: If the journals or main caps are damaged, the engine will need to be removed to complete the overhaul.



Piston and Rod Removal

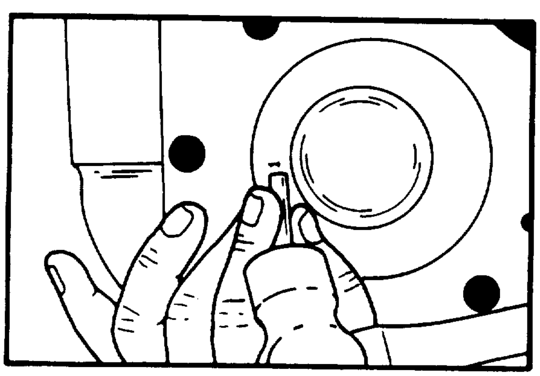
Caution: Make sure the ridge reamer does not make a deep cut into the bore. Do not remove more metal than is necessary to remove the ridge.

If the cylinder bores have edges, use a ridge reamer to cut the ridge from the top of the cylinder bore.



Hammer, Steel Number Stamps

Mark the cylinder number onto each connecting rod cap.

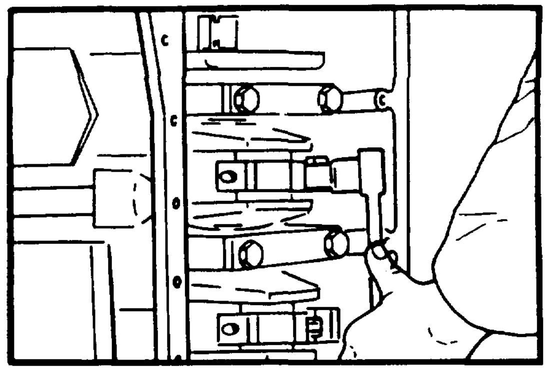


Hammer, Steel Number Stamps

Mark the cylinder number onto the top of each piston.

12mm

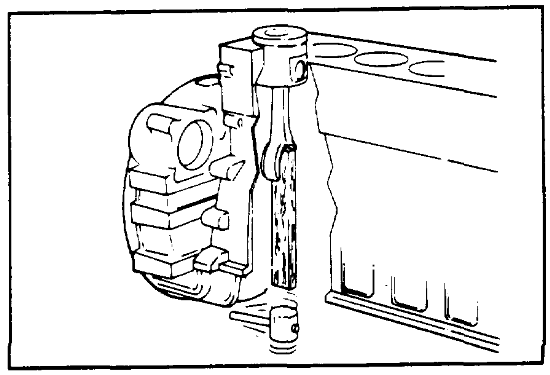
Remove the capscrews, connecting rod cap and bearings.



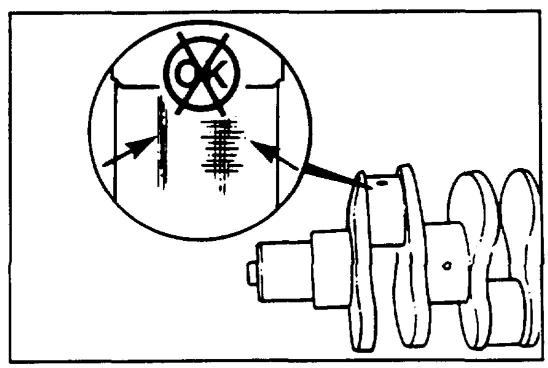
Caution: Use care so that the cylinder bore or connecting rod are not damaged.

Use a hammer handle or similar object to push the piston and connecting rod through the cylinder bore.

Put the assemblies in a rack for disassembly later.



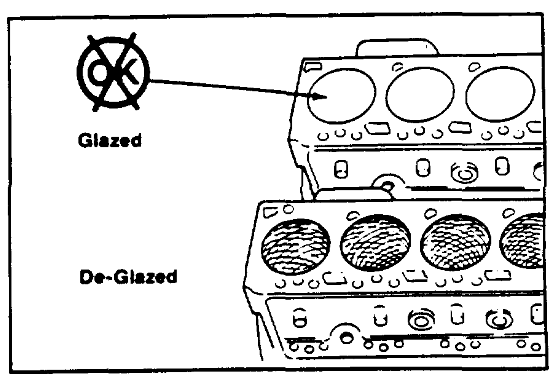
Inspect the rod journals for deep scratches, indications of overheating and other damage.

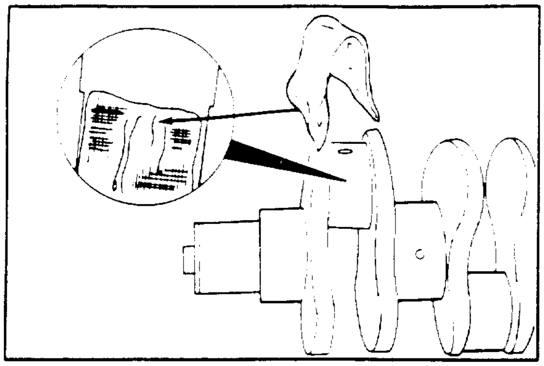


Cylinder Bores - De-Glaze

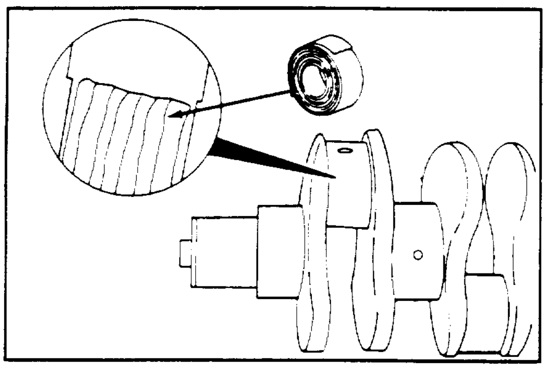
Note: New piston rings may not seat in glazed cylinder bores.

De-glazing gives the bore the correct surface finish required to seat the rings. The size of the bore is not changed by proper deglazing.

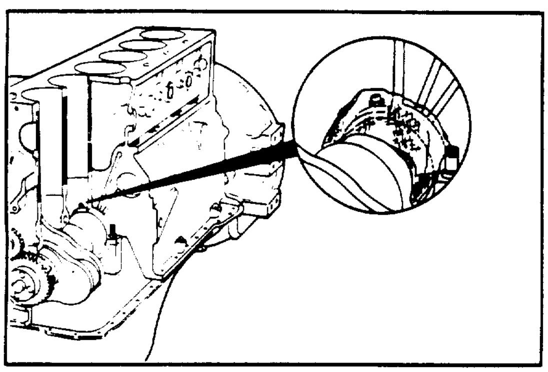




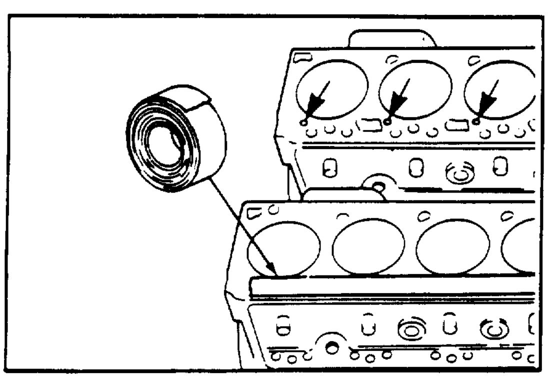
Wrap the journals with clean cloth.



Cover the cloth with waterproof tape.

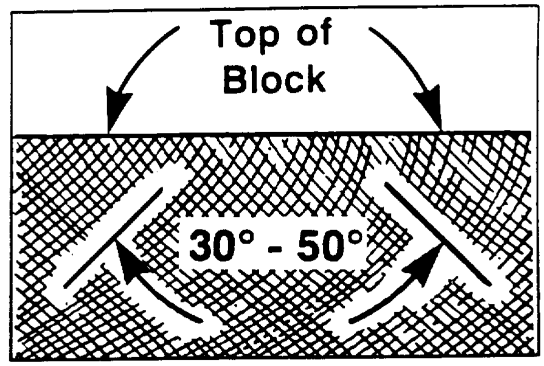


Place a clean shop towel around the top main bearing saddle to deflect water and residue from the piston cooling nozzles.

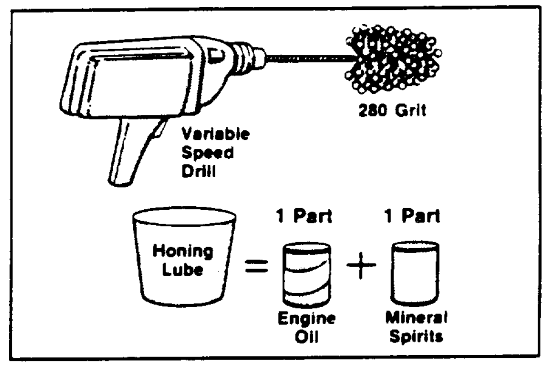


Also cover the lube holes in the top of the block with waterproof tape.

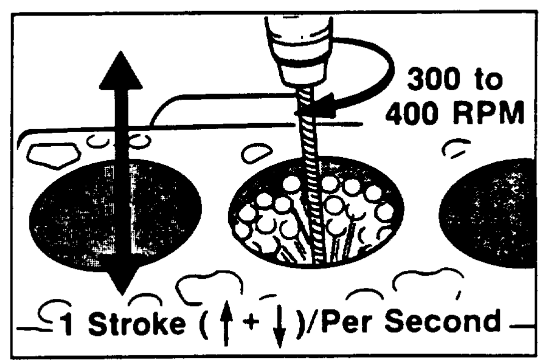
A correctly de-glazed surface will have a crosshatched appearance with the lines at 15 to 25 degree angles with the top of the cylinder block, 30 to 50 degree included angles on crosshatch.



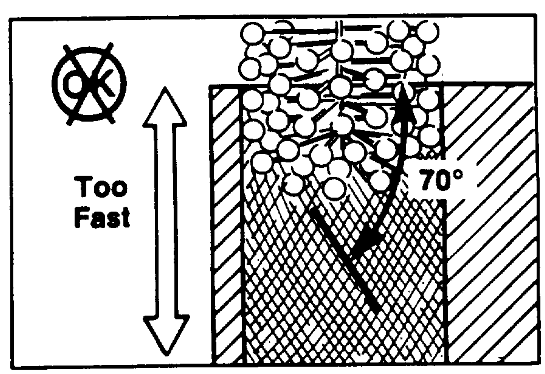
Use a drill, a fine grit Flexi-Hone and a mixture of equal parts of mineral spirits and SAE 30W engine oil to deglaze the bores.

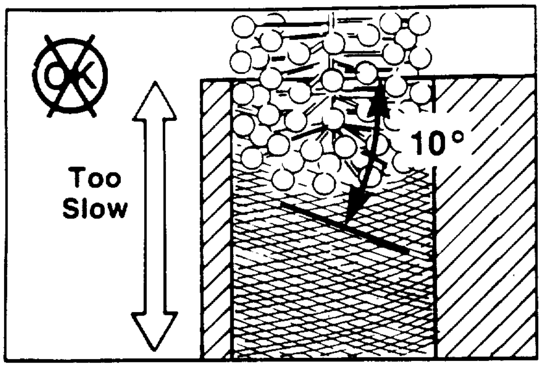


The crosshatch angle is a function of drill speed and how fast the hone is moved vertically.

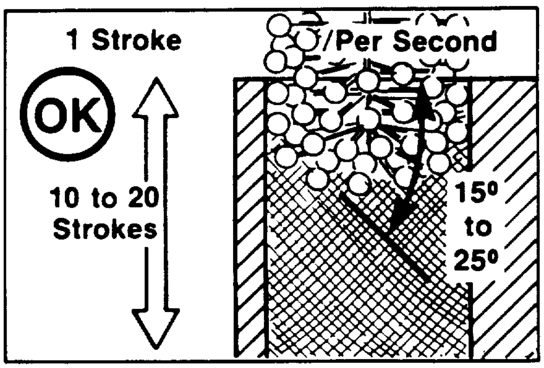


This illustration shows the result of the drill speed too slow or the vertical stroke is too fast.



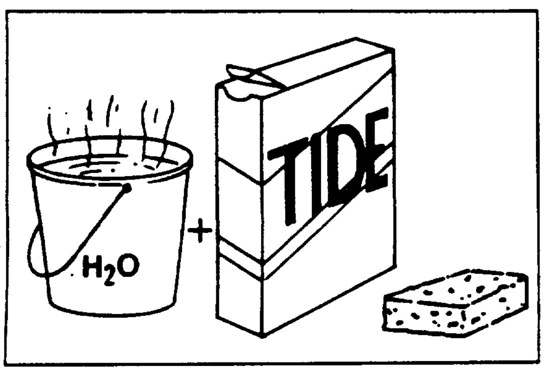


This illustration shows the result of the drill speed too fast or the vertical stroke is too slow.



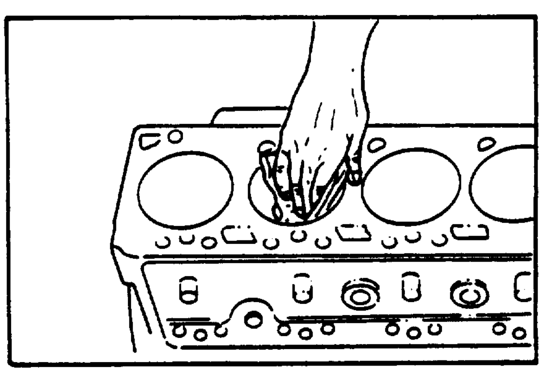
Note: Vertical strokes must be smooth continuous passes along the full length of the bore.

Inspect the bore after 10 strokes.



Use a strong solution of hot water and laundry detergent to clean the bores.

Since a relatively large volume of water will be used to rinse the bores, position the vehicle over or close to a floor drain.

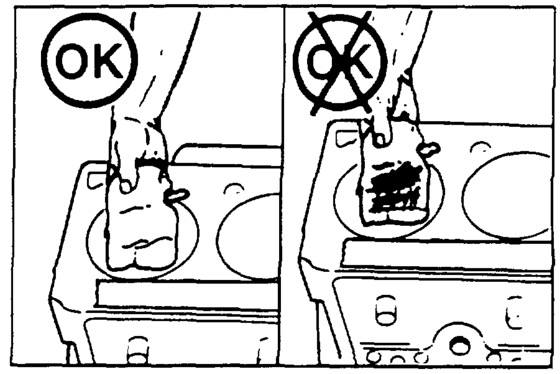


Caution: Clean the cylinder bores immediately after deglazing.

Rinse the bores until the detergent is removed and blow the block dry with shop air.

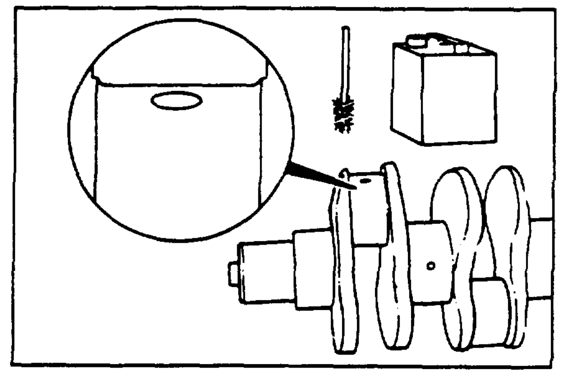
Caution: Be sure to remove the tape covering the lube holes after the cleaning process is complete.

Check the 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 bores with solvent and blow the block dry with shop air.



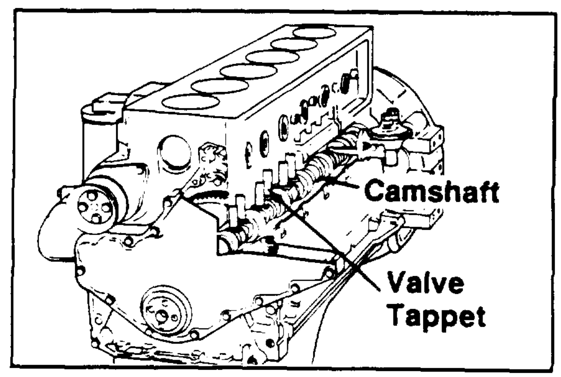
Caution: Be sure to remove the covering from the piston cooling nozzles.

Remove the protective tape and cloth, and clean the crankshaft journals.



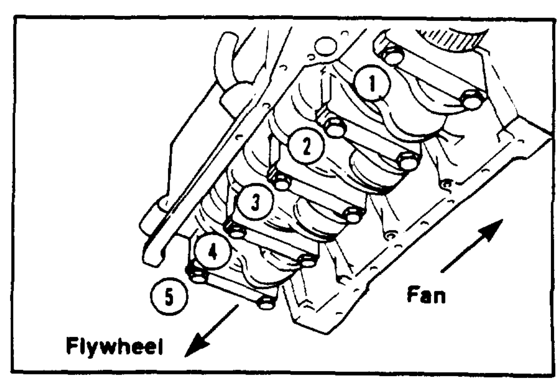
Use solvent and a brush to clean any residue that may have splashed on the camshaft.

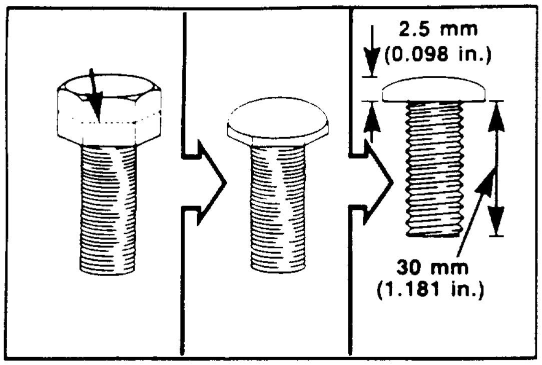
Note: Inspect the camshaft lobes and tappet faces for signs of wear or damage. (Refer to page 5-200 for camshaft information.)



Main Bearing Replacement

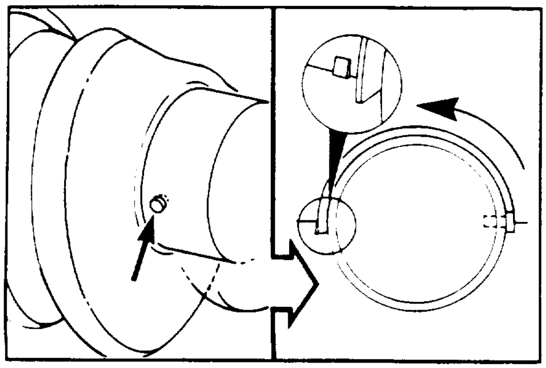
Remove all main bearing caps except the No. 1 and 5 cap for 4 cylinder engine, No. 1 and 7 cap for 6 cylinder engine. The 4 cylinder engine is depicted in the illustration.





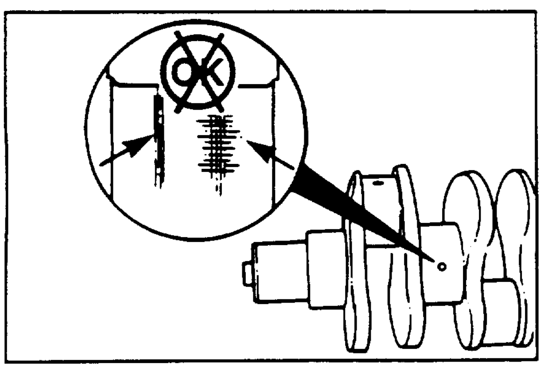
Use a pin to roll out the upper bearings from between the crankshaft and cylinder block.

To make a pin, grind a 6mm capscrew to the dimensions shown.

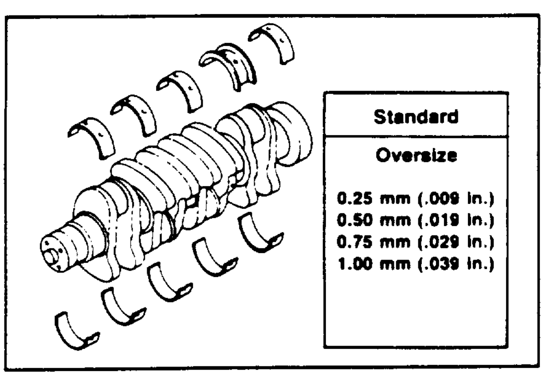


Install the pin into the oil hole in the crankshaft. Rotate the crankshaft so the pin pushes against the end of the bearing opposite the tang. Remove the bearing.

Follow this procedure to remove the other bearings.



Inspect all caps and main bearing crankshaft journals.

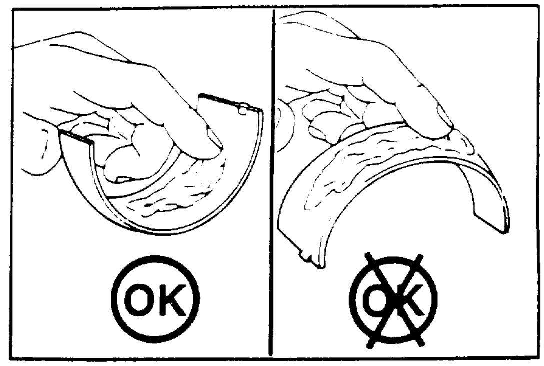


Determine the size of the bearing removed and obtain the same size for installation.

Refer to page 5-188 for the dimensions of the standard and undersize main bearing journals.

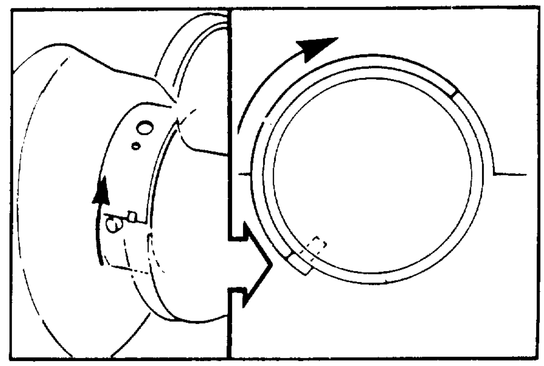
Caution: Do not lubricate the side that is against the cylinder block.

Apply a coat of Lubriplate 105 to the new upper bearings.

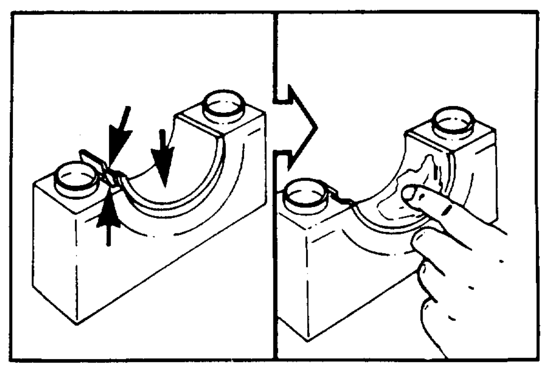


Use the pin to push the bearing shell into position. Use the pin to push against the end of the bearing with the tang. Push the bearing in slowly being sure it is aligned with the block. Make sure the tang on the bearing sets into the notch.

Note: Make sure the tang on the bearing sets into the notch in the bearing saddle.



Install the lower bearings into the caps. Apply a coat of Lubriplate 105 to the bearings.



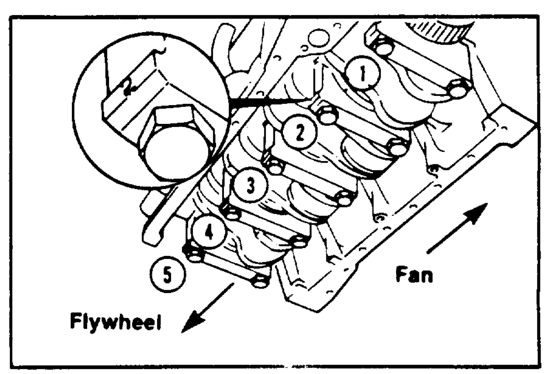
23mm

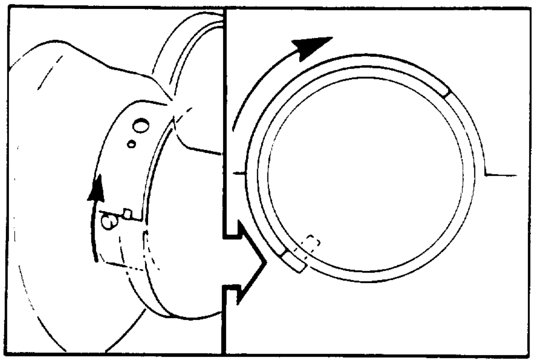
Caution: Make sure the caps are correctly installed with the number towards the oil cooler side of the engine.

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

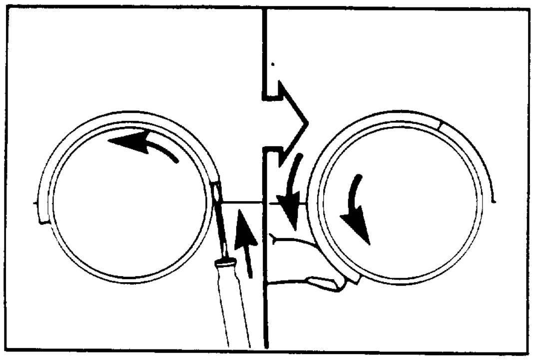
Tighten the capscrews to 50 N•m [37 ft-lbs].

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





Use the same procedure to remove and install rear main cap, No. 5 or No. 7.

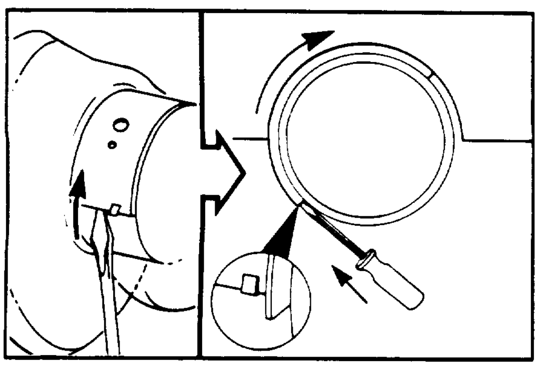


Flat Blade Screwdriver

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

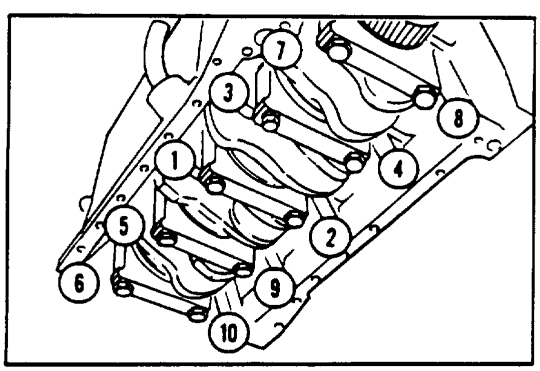
Note: The front main, No. 1, does not have a hole in the journal so the pin can not be used to replace the bearing.

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



Lubricate and install the bearing.

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



23mm

Caution: The crankshaft must rotate freely.

Tighten the capscrews evenly and in sequence.

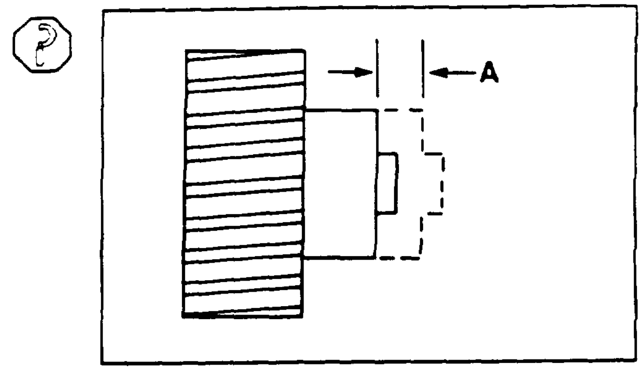
Step	Torque Value
1	60 N•m [44 ft-lbs]
2	119 N•m [88 ft-lbs]
3	176 N•m [129 ft-lbs]

Check the bearing installations and the size of the bearings if the crankshaft does not rotate freely.

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

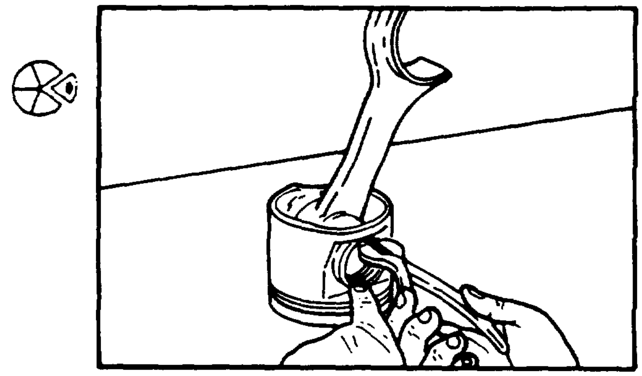
Measure the crankshaft end play.

Dim. (A) End Play Limits	
Min	Max
0.13mm [0.005 in)	0.25mm [0.010 in]



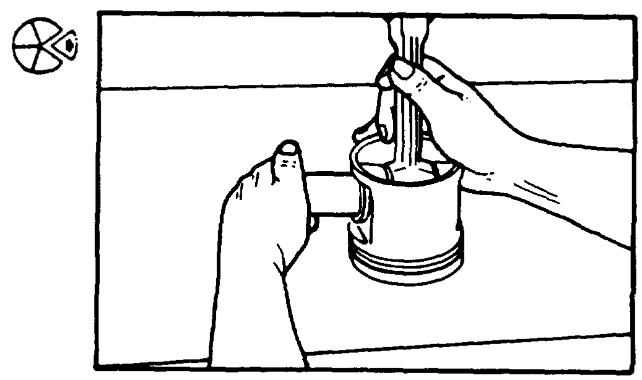
Piston and Rod - Disassembly

Remove the retaining rings.

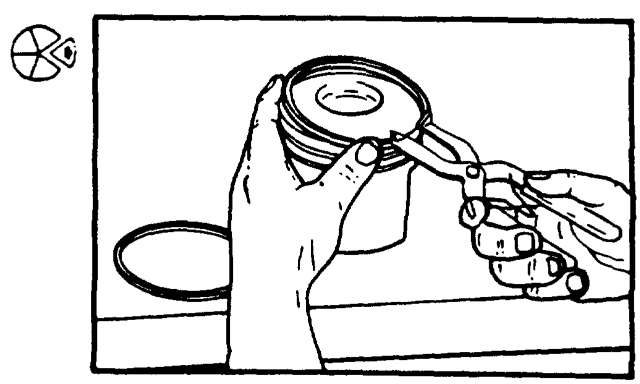


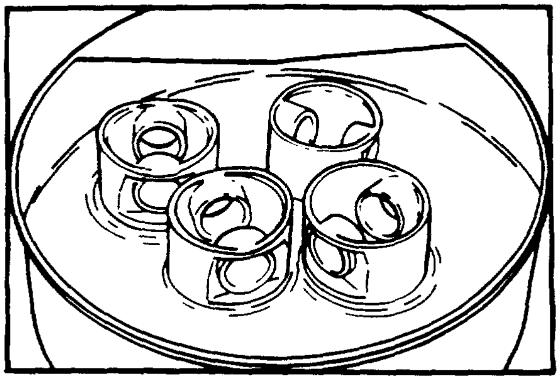
Remove the piston pin.

Note: Heating the piston is not required.



Remove the piston rings.



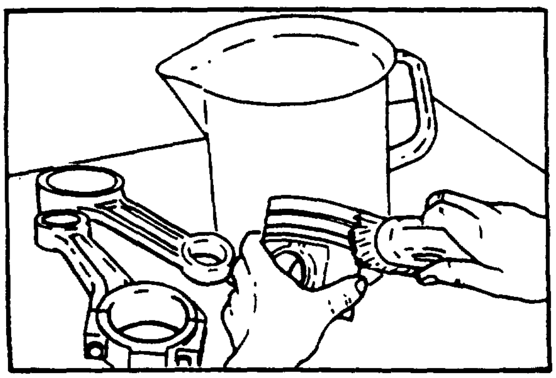


Piston, Pin and Connecting Rod - Clean

Caution: Do not use bead blast to clean the pistons.

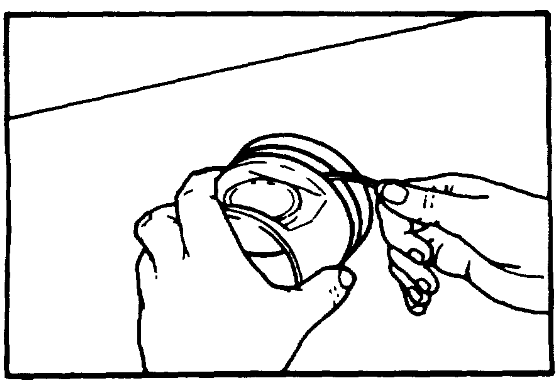
Soak the pistons in cold parts cleaner.

Soaking the pistons overnight will usually loosen the carbon deposits.



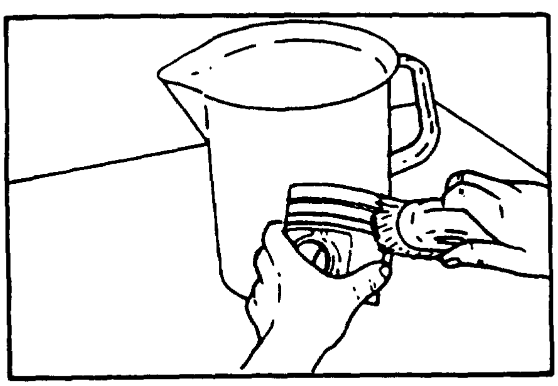
Caution: Do not clean the pistons and rods in an acid tank.

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.

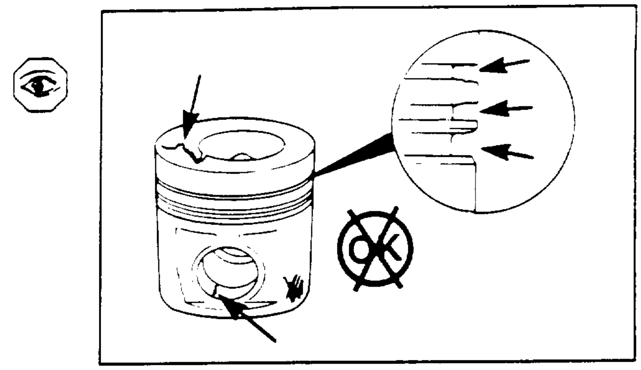


Wash the pistons again in a detergent solution or solvent.

Rinse the pistons. Use compressed air to dry.

Piston, Pin and Rod - Inspection

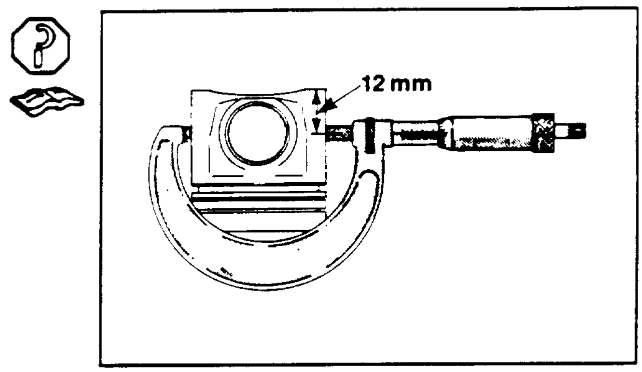
Inspect the piston for damage and excessive wear. Check the top, ring grooves, skirt and pin bore.



Measure the piston skirt diameter as illustrated.

Minimum Diameter
101.823mm [4.0088 in]

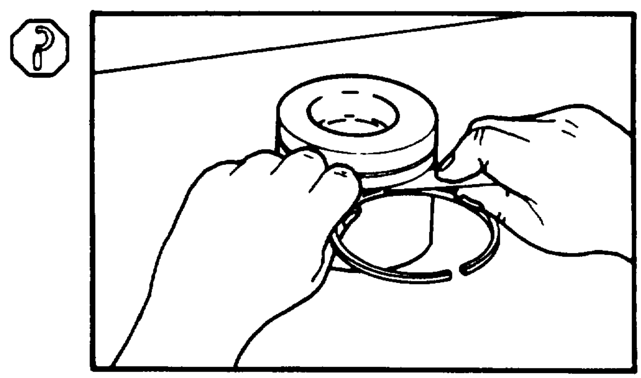
Refer to page 5-187 for the limits of the oversize pistons.



Use a new piston ring to measure the clearance in the ring groove.

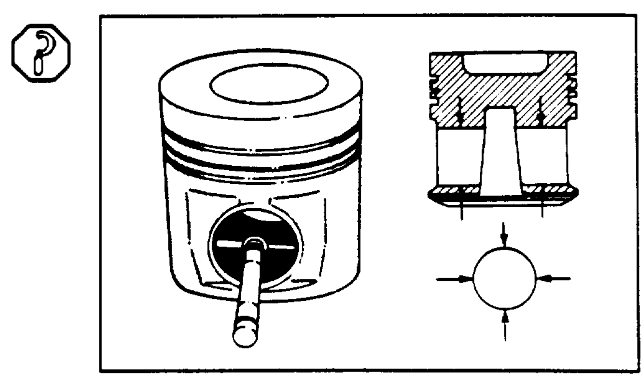
Limits
Maximum Clearance

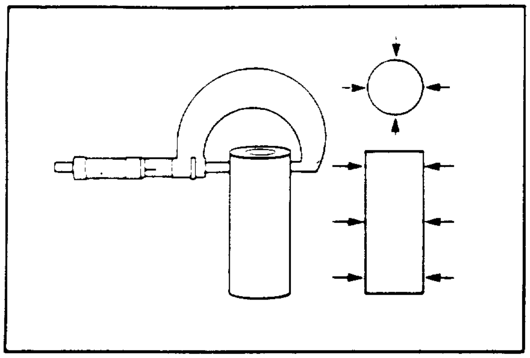
Top
(Naturally Aspirated): 0.150mm [0.006 inch]
Intermediate: 0.150mm [0.006 inch]
Oil Control: 0.130mm [0.005 inch]



Measure the pin bore.

Maximum Diameter
40.025mm [1.5758 in]

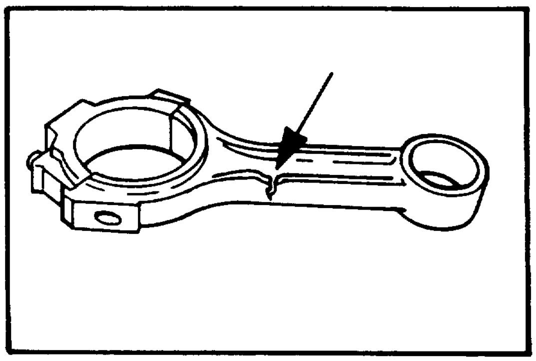




Inspect the piston pin for nicks, gouges and excessive wear.

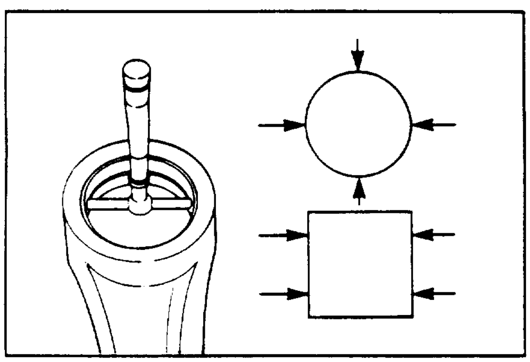
Measure the pin diameter.

Minimum Diameter
39.990mm [1.5744 in]



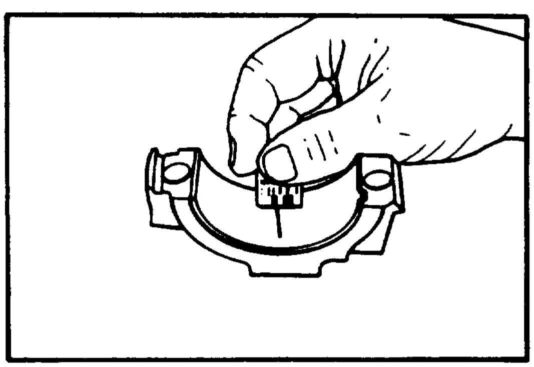
Caution: The I-beam section cannot have dents or other damage. Damage to this part can cause stress risers which will progress to breakage.

Inspect the rod for damage and wear.



Measure the pin bore.

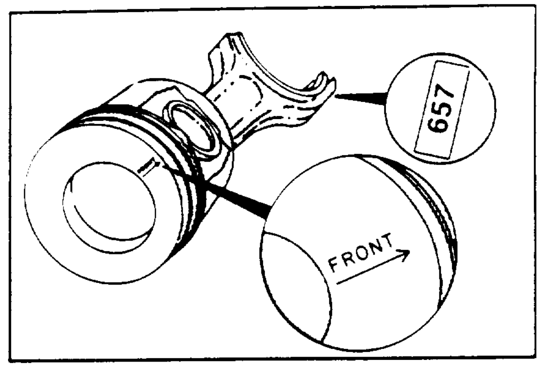
Maximum Diameter
40.053mm [1.5769)



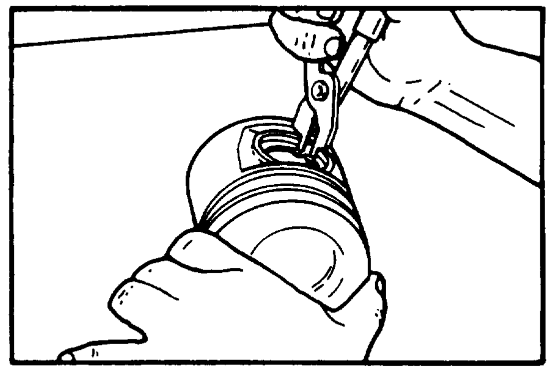
Bearing clearance can also be determined with Plastigage during engine assembly.

Piston to Connecting Rod Installation

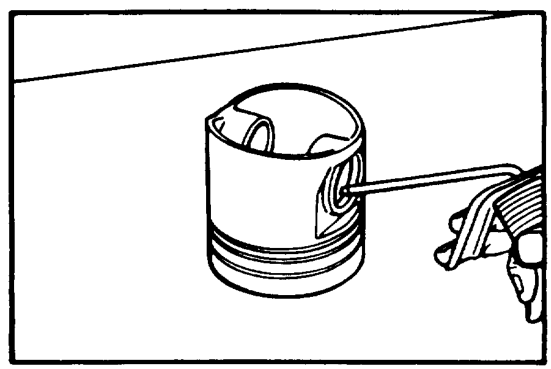
Caution: Be sure 'Front' marking on piston and the numbers on the rod and cap are oriented as illustrated.



Install the retaining ring into the pin groove on the " Front" side of the piston.

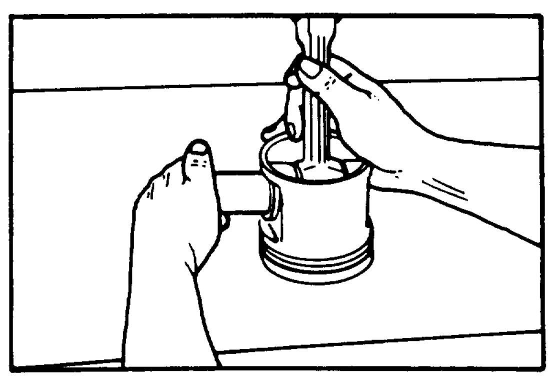


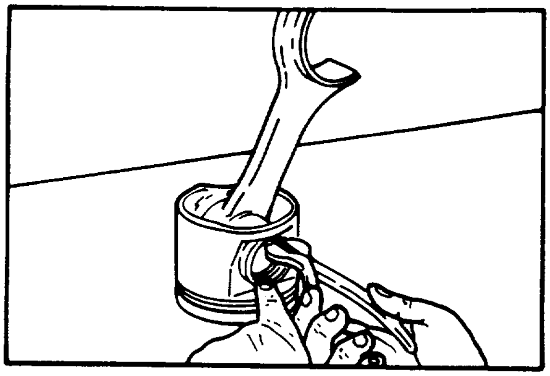
Lubricate the pin and pin bores with engine oil.



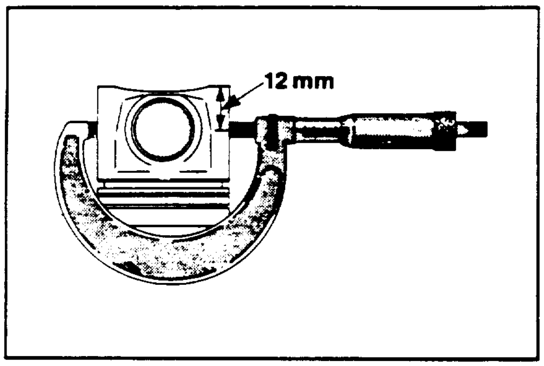
Install the pin.

Note: Pistons do not require heating to install the pin, however, the piston does need to be at room temperature or above.

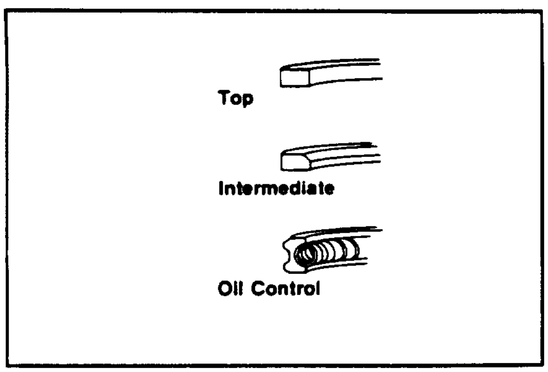




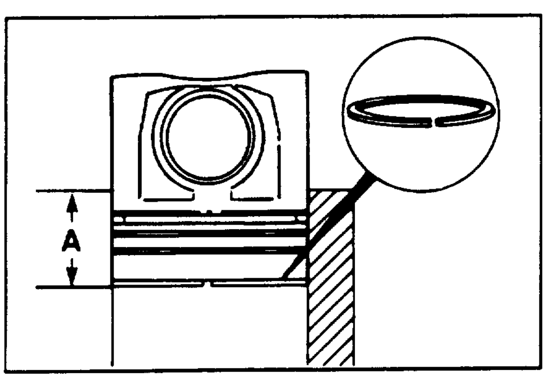
Install the second retaining ring.



Determine the piston diameter and obtain the appropriate ring set.



Piston Ring Gap Check



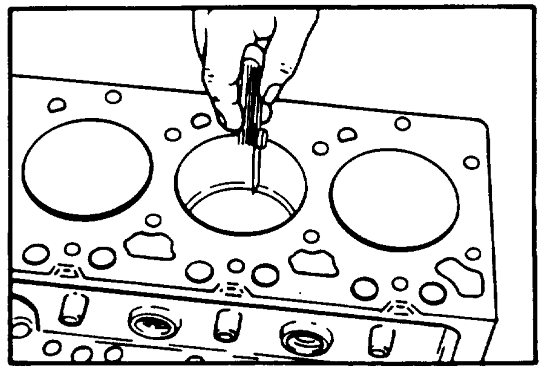
Position each ring in the cylinder and use a piston to square it with the bore.

A 89mm [3.5 inches]

Use a feeler gauge to measure the gap.

Limits

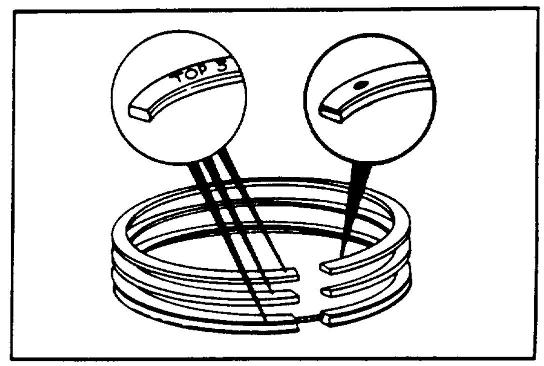
Ring	Minimum	Maximum
Top (N. Aspirated):		
	0.25mm [0.0100 in.]	0.55mm [0.0215in]
Intermediate:		
	0.25mm [0.0100 in.]	0.55mm [0.0215 in.]
Oil Control:		
	0.25mm [0.0100 in.]	0.55mm [0.0215 in.]



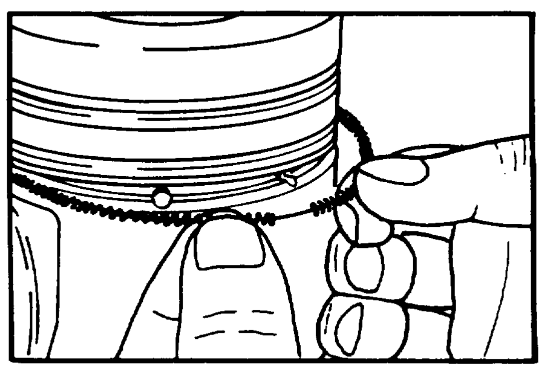
Piston Rings Installation

Note: The top surface of all of the rings are identified:

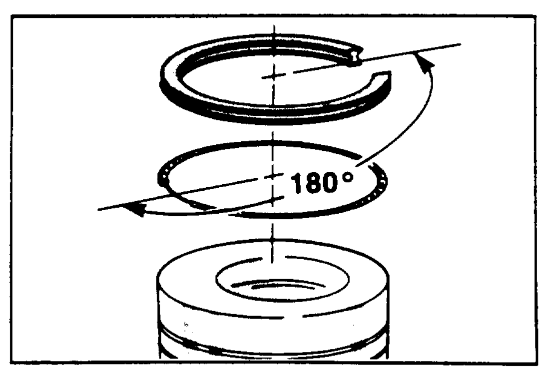
Assemble with the word "Top" or the supplier mark up.

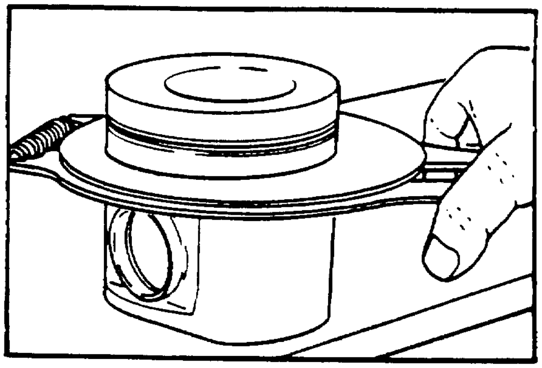


Position the oil ring expander in the oil control ring groove.

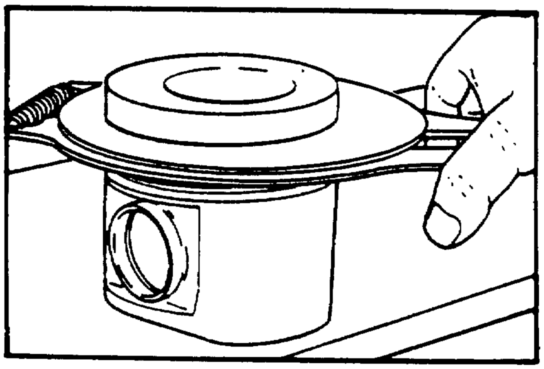


Install the oil control ring with the end gap opposite the ends on the expander.



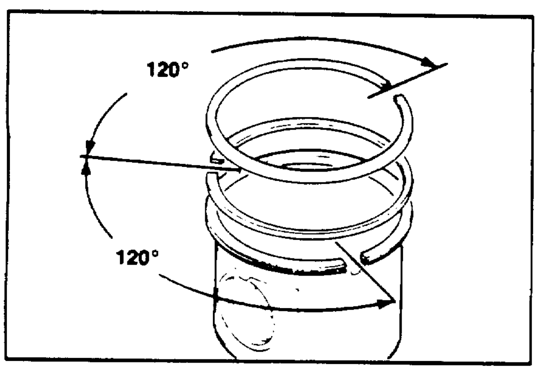


Install the intermediate ring.

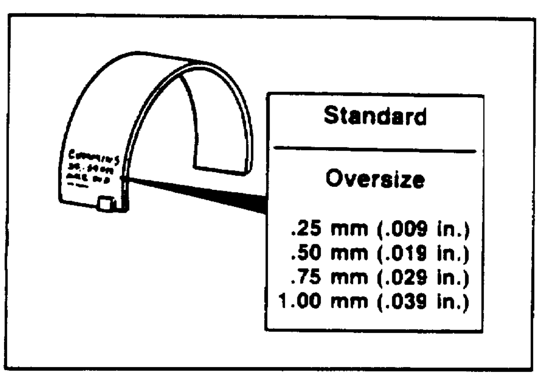


Caution: The top ring for a turbocharged engine is not the same as the top ring for a naturally aspirated engine.

Install the top ring.

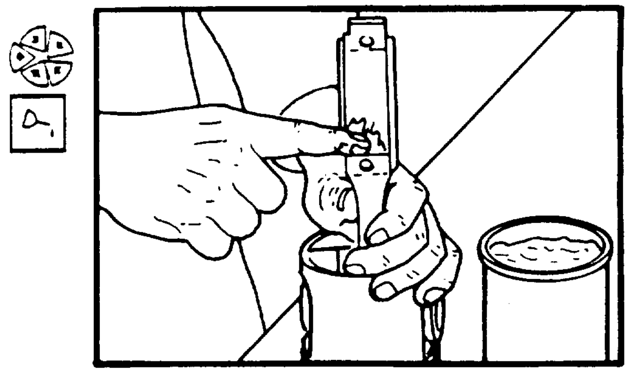


Position the rings.

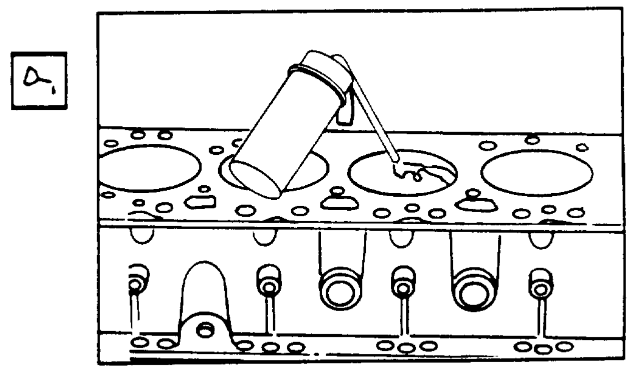


Determine the size of the removed rod bearing and obtain a set of the same size.

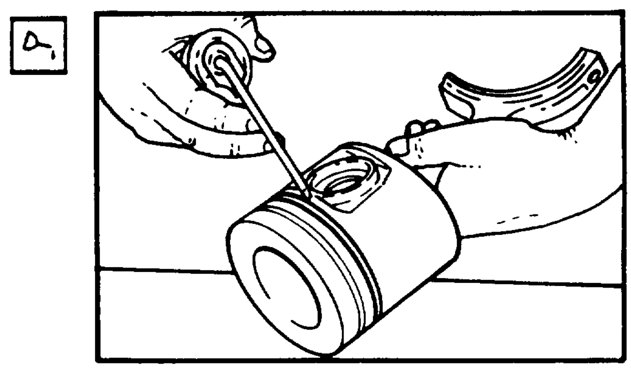
Install the new bearings in the rods and caps and lubricate them with a light coat of Lubriplate 105.



Piston and Rod Assembly Installation Lubricate the cylinder bore with clean engine oil.



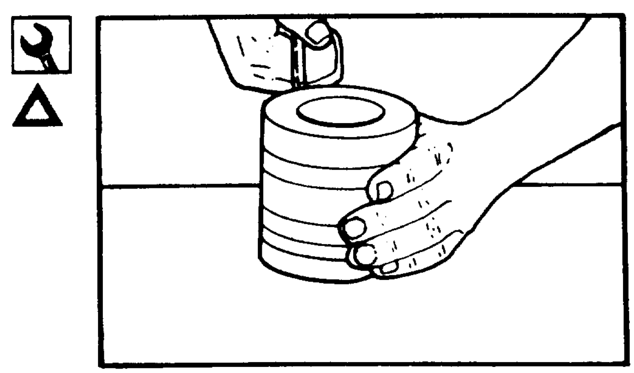
Generously lubricate the rings and piston skirts with clean engine oil.

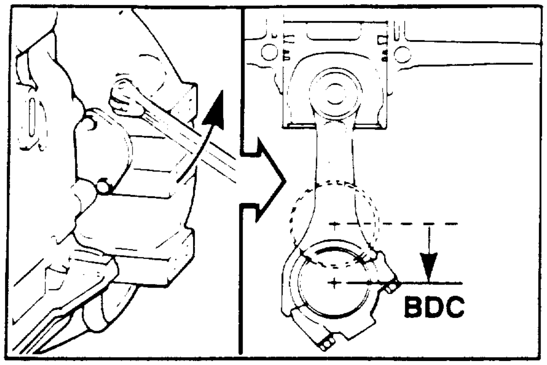


75 to 125mm Ring Compressor

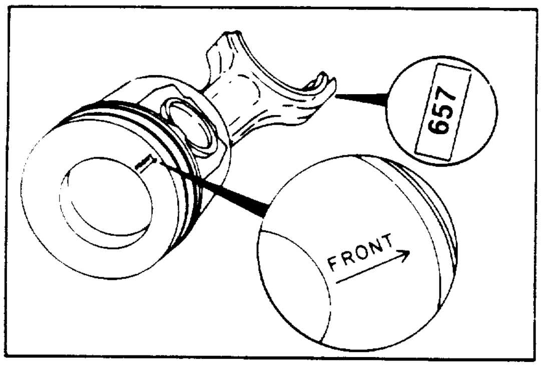
Caution: If using a strap-type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.

Compress the rings.

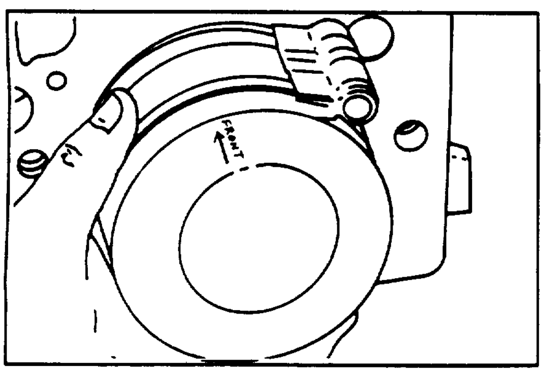




Bar the crankshaft so the rod journal for the piston to be installed is at Bottom Dead Center (BDC).

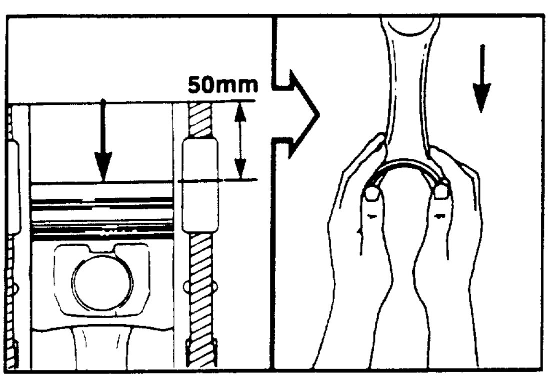


Caution: Be sure 'Front' marking on piston and the numbers on the rod and cap are oriented as illustrated.



Caution: Use care when you install the piston and connecting rod so the cylinder bore is not damaged.

Position the piston and rod assembly into cylinder bore with the word " Front" on piston towards the front of the cylinder block.

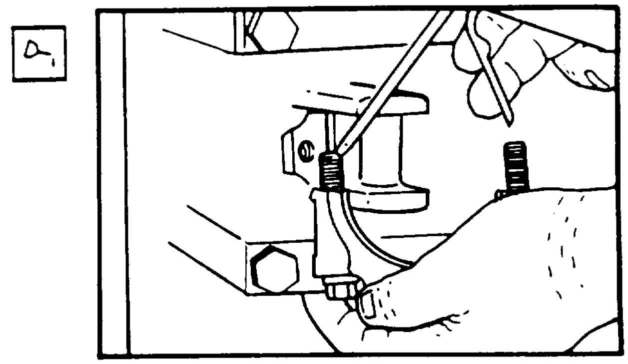


Push the piston into the bore until the top of the piston is approximately 50mm [2 inches] below the top of the bore.

Then, pull the connecting rod onto the crankshaft journal.

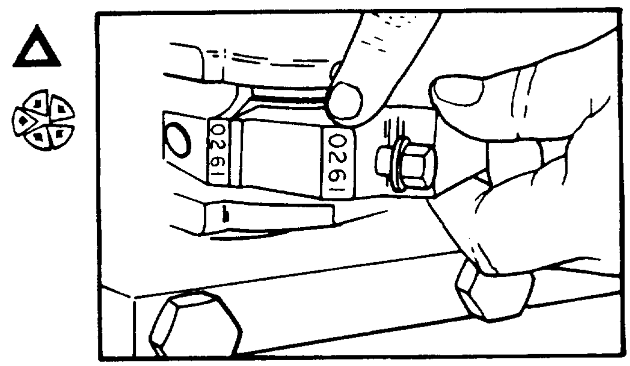
Note: The following series of illustrations show the engine in a vertical position. This is for clarity of illustration only.

Use clean engine oil to lubricate the threads and under the heads of the connecting rod capscrews.



Caution: The four digit number stamped on the rod and cap at the parting line must match and be installed towards the oil cooler side of the engine.

Install the rod cap and capscrews to the connecting rod.

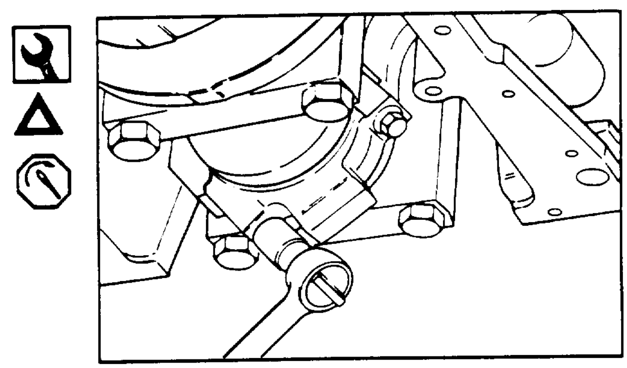


12mm Socket. Torque Wrench

Caution: Tighten the connecting rod and capscrews evenly.

Torque Value:

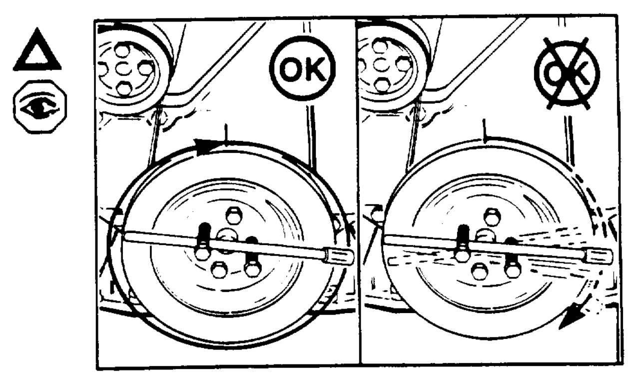
Step 1 - 35 Nom [26 ft4bs]
Step 2 - 70 Nom [70 ft-lbs]
Step 3 - 100 Nom [73 ft4bs]

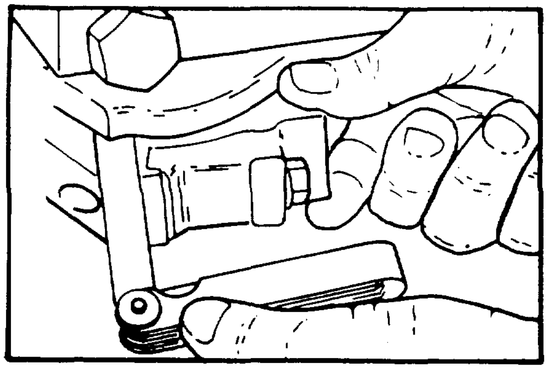


Caution: The crankshaft must rotate freely.

Check for freedom of rotation as the caps are installed.

If the crankshaft does not rotate freely, check the installation of the rod bearings and the bearing size.



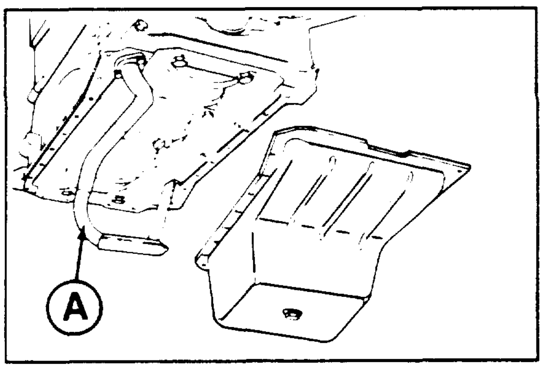


Caution: Do not measure the clearance between the cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

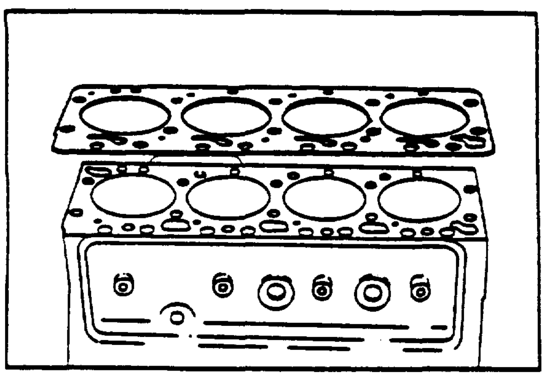
Side Clearance Limits

Min	Max
0.10mm [0.004 in]	0.30mm [0.012 in]



Install the suction tube and oil pan.

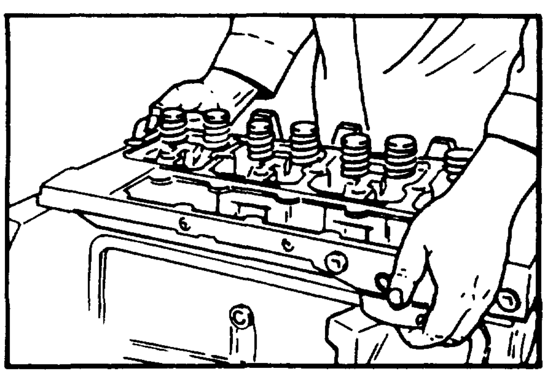
Cylinder Head and Gasket Installation



Caution: Make sure the gasket is correctly aligned with the holes in the cylinder block.

The cylinder block and head must be clean and dry.

Position the gasket onto the dowels.

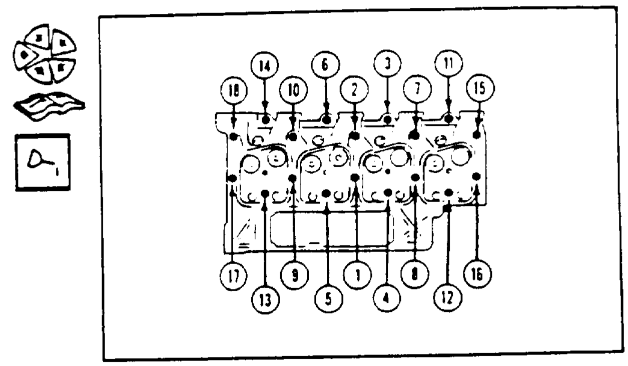


Carefully, put the cylinder head onto the gasket and cylinder block.

Note: Make sure the cylinder head is installed onto the dowels in the cylinder block.

install the push rods and rocker levers (refer to page 5-190).

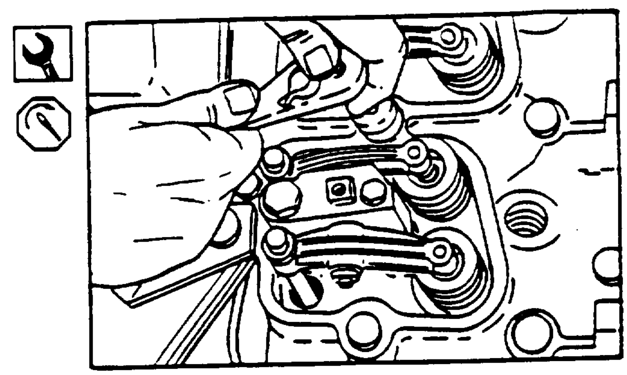
Lubricate the cylinder head capscrews. Use the illustrated torque sequence.



18mm

Torque Value:

Step 1 -	40 Nom [29 ft-lbs]
Step 2 -	85 Nom [62 ft-lbs]
Step 3 -	126 Nom [92 ft-lbs]

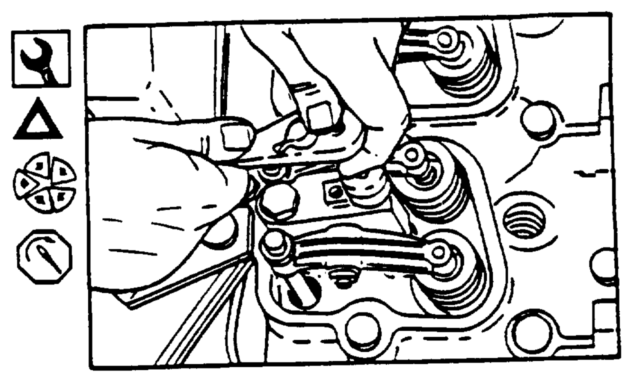


13mm

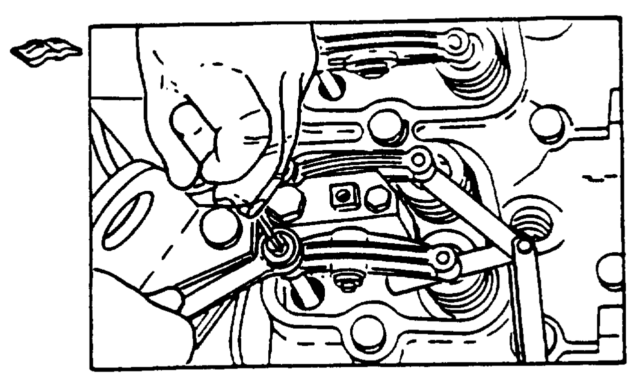
Caution: Be sure to lubricate the push rod sockets with dean engine oil.

Install the rocker lever pedestal capscrews.

Torque Value: 24 Nom [18 ft-lbs]



Adjust the valve clearance.



Install the parts previously removed:

- Valve covers
- Injector nozzles
- Fuel lines
- Fuel filters
- Exhaust manifold

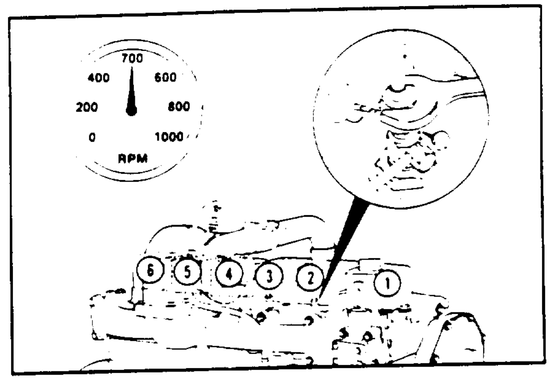
Observe the Following Check List During Final Assembly

	OK
• Correct injectors for the engine rating used and only one copper sealing washer installed?..................	______
• Sealant applied to the capscrews that attach the intake manifold cover or aftercooler?..........................	______
• Engine filled with oil; oil filter filled with oil prior to installation so the engine has an immediate supply of oil?	______
• Fuel filter(s) filled with fuel and the injection pump primed using the lever on the lift pump?.................	______

Caution: It is extremely important that all air is vented prior to operating the engine

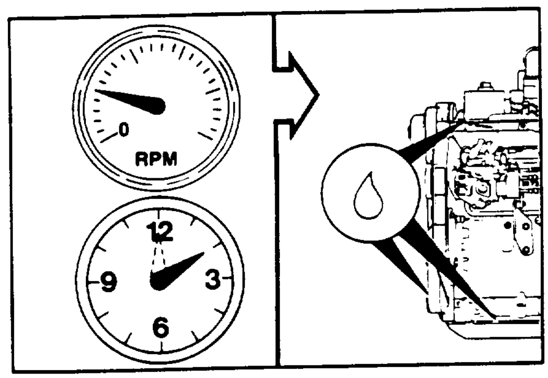
Caution: Stop the engine immediately if any unusual sounds are heard.

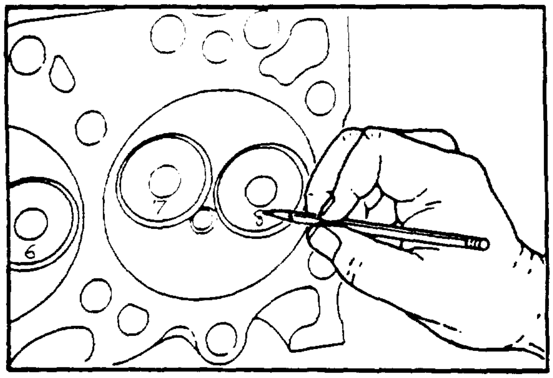
Start the engine. If necessary, bleed the high pressure lines at the injectors until the engine runs smoothly.



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

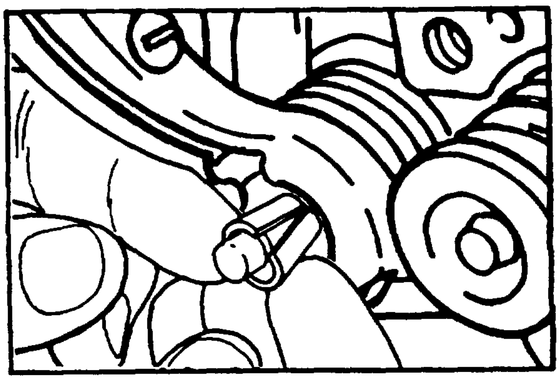
Check the coolant and oil level.



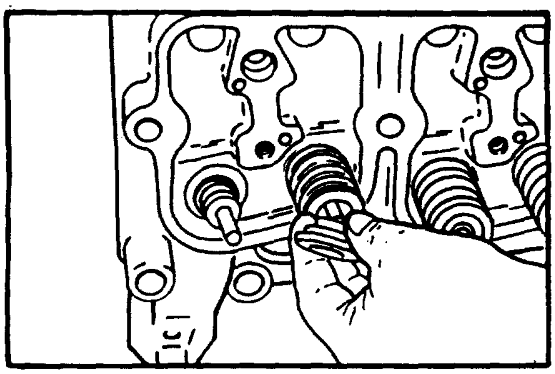


Cylinder Head Disassembly

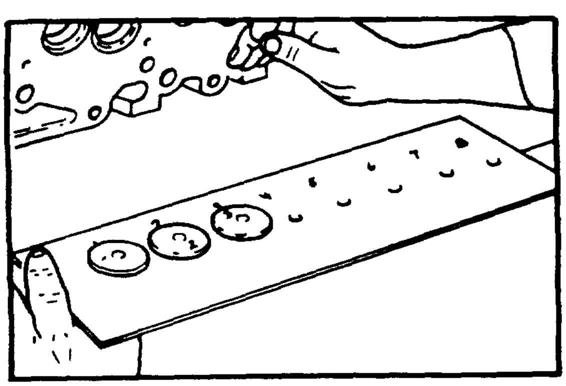
Mark the valves to identify their position.



Compress the valve spring and remove the valve stem collets. Use a magnet to remove the collets.



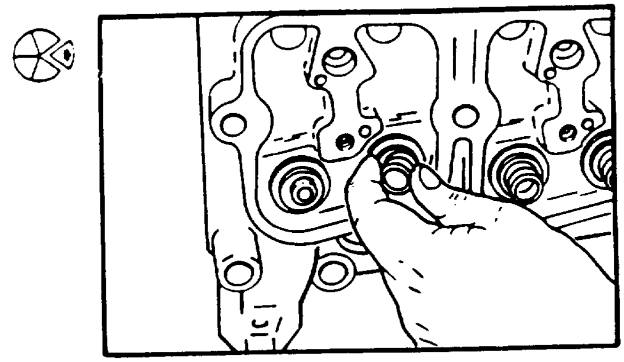
Release valve spring and remove the retainer and spring.



Caution: Keep the valves in a labeled rack.

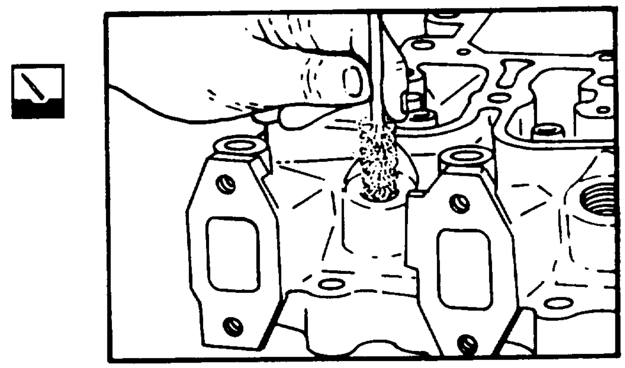
Remove the remaining collets, retainers, springs and valves.

Remove the valve stem seals.

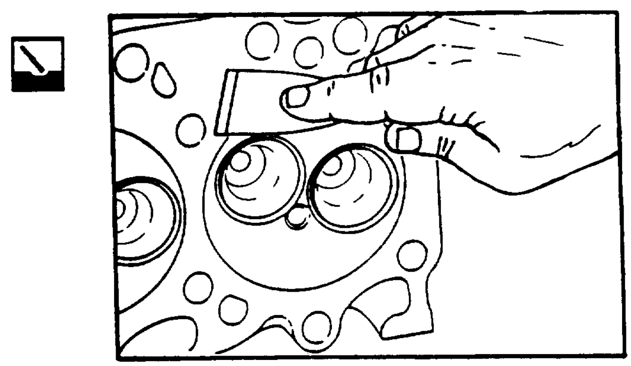


Cylinder Head Clean and Inspect

Clean the carbon from the injector nozzle seat with a nylon brush.

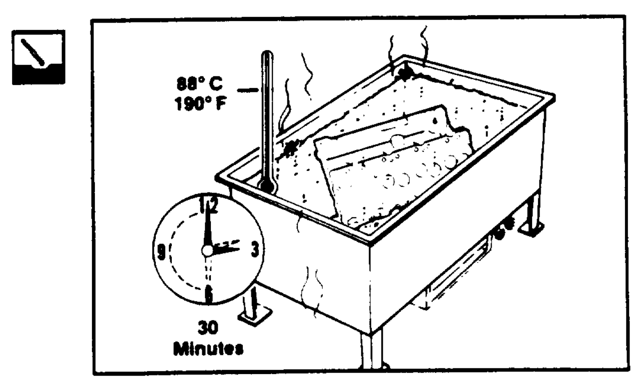


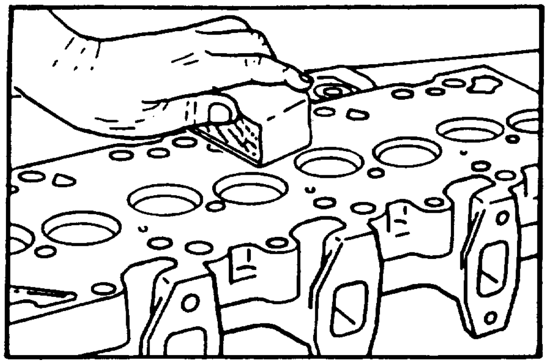
Scrape the gasket material from all gasket surfaces.



Wash the cylinder head in hot soapy water solution.

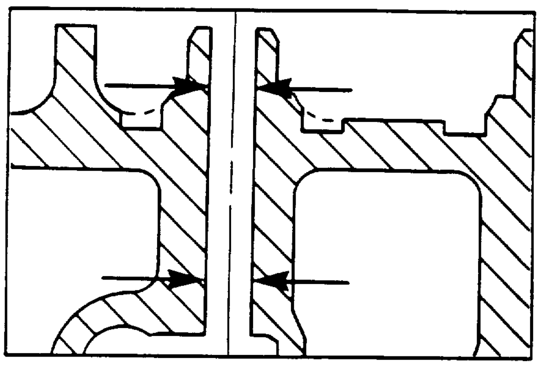
After rinsing, use compressed air to dry the cylinder head.





Polish the gasket surfaces with 400 grit paper.

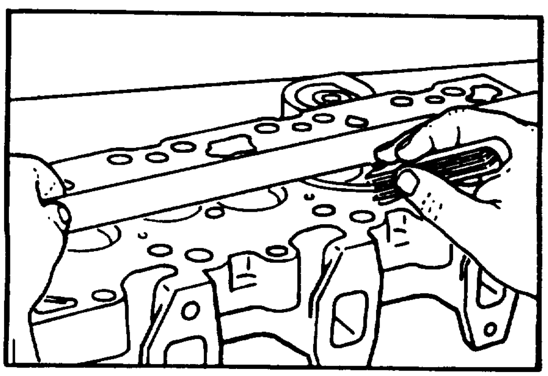
Use an orbital sander or sanding block to keep a flat surface.



Inspect the valve guides for scuffing or scoring.

Measure the valve guide bore.

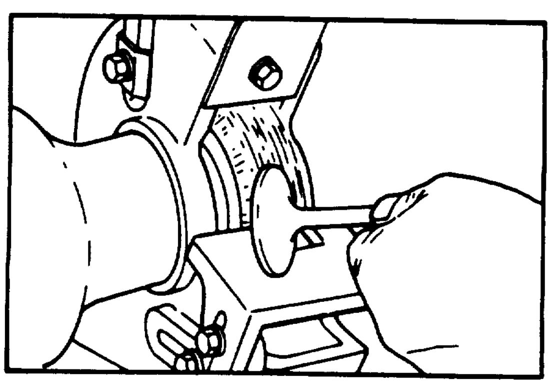
Maximum Diameter
8.019mm [0.3157 in]



Inspect the head surface for nicks, erosion, or any other damage.

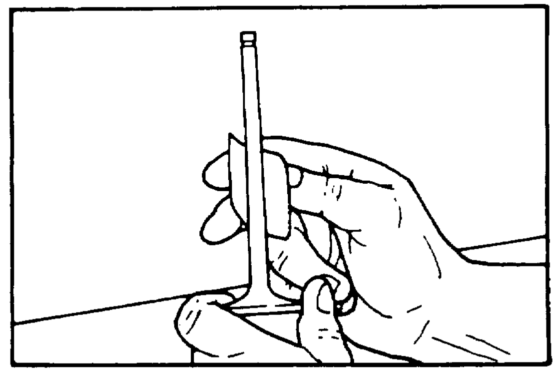
Check for head distortion as illustrated.

Maximum Variation (within any 50.Omm [2.0in] dia. area)
0.01 mm [0.0004 in]

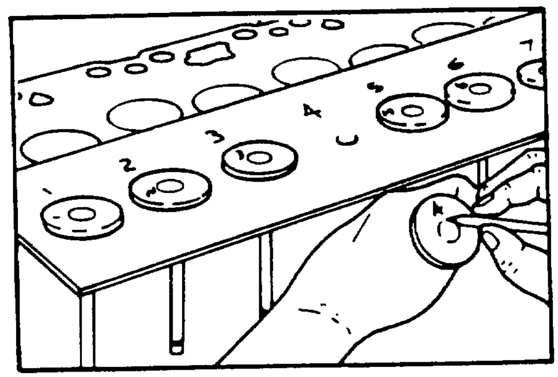


Clean the valve heads with a soft wire wheel.

Polish the valve stem with crocus cloth.



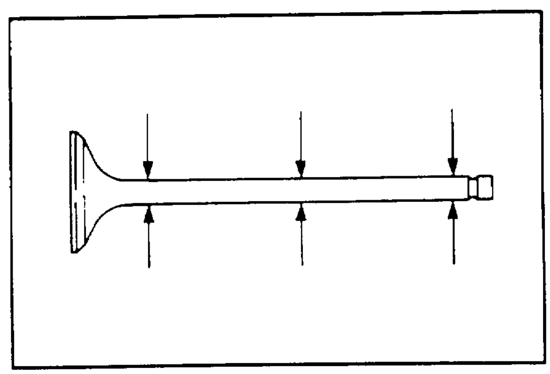
Mark the valves again for location in the cylinder head.



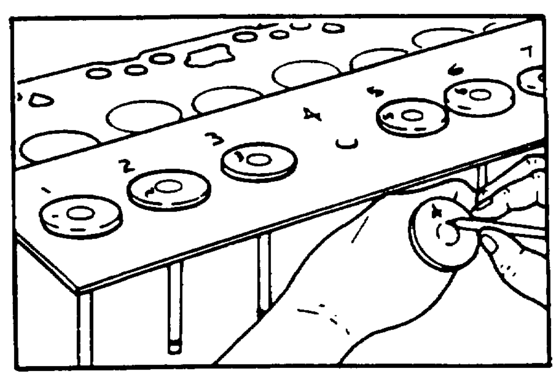
Inspect for abnormal wear on the heads and stems.

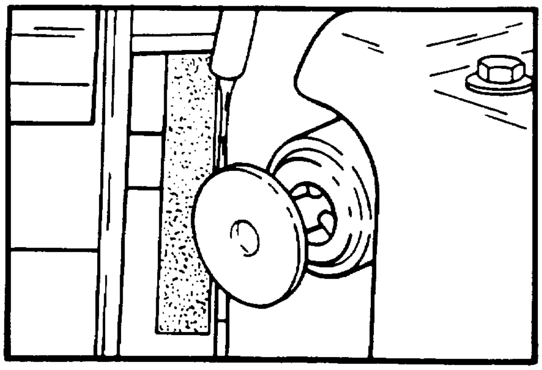
Measure the valve stem diameter.

Maximum Diameter
7.960mm [0.3134 in]



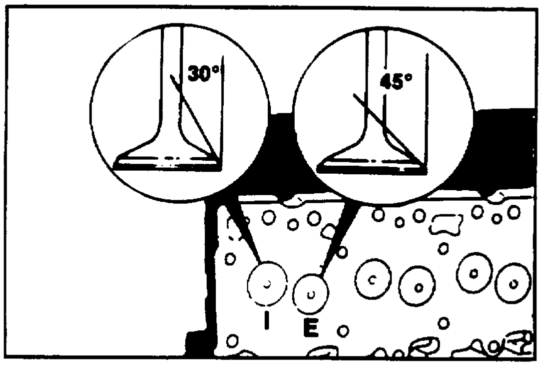
If new valves are required, mark them for location in the cylinder head.





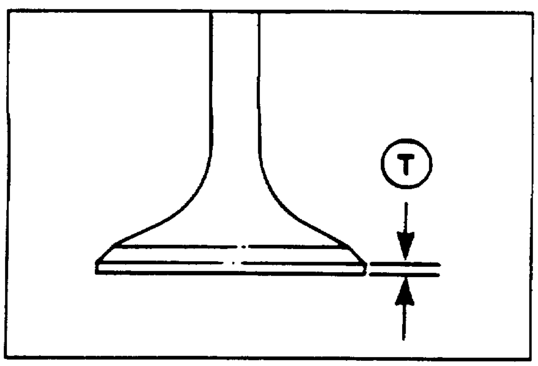
Valves Grind

Re-face all reused valves. Check/replace bent valves.



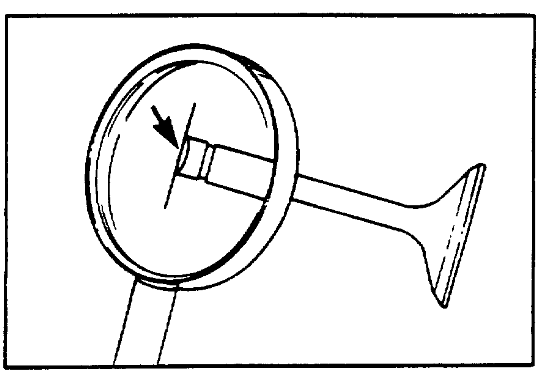
Seat Angle

Intake:	30 Degrees
Exhaust:	45 Degrees



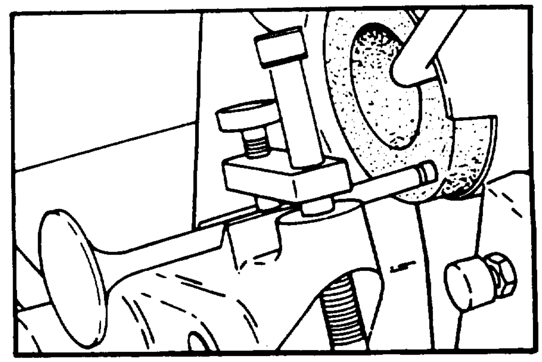
Measure rim thickness.

Minimum Thickness (T)
0.79mm [0.031 inch]



Check the valve stem tip for flatness.

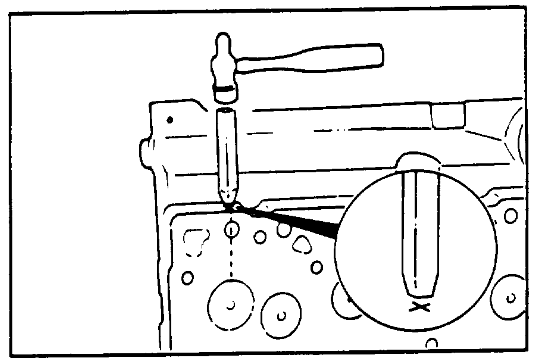
If required, re-surface the valve stem tip.



Valve Seats Grind

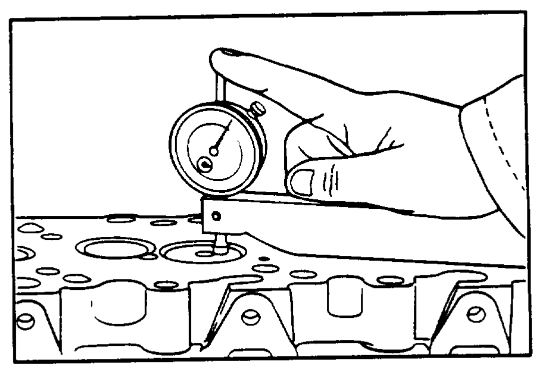
Note: The illustrated marks indicate valve seats have been ground previously.

Previously re-ground seats can be replaced with service seats.



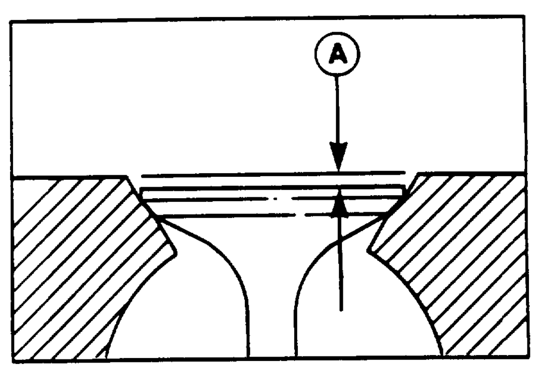
Calculating the Grinding

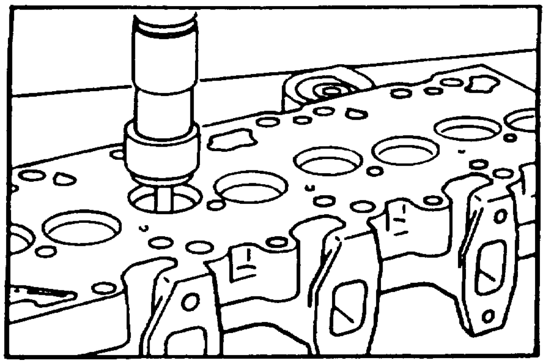
Depth Install the valves in their designated location and measure valve depth.



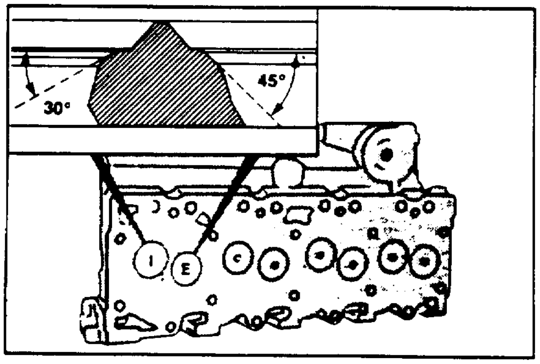
Note: The valve depth is the distance from the valve face to the head deck.

Record the depth of each valve as (A).

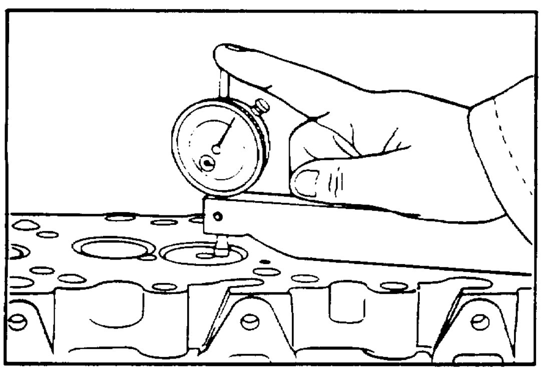




Grind the valve seats to remove scores, scratches and burns.

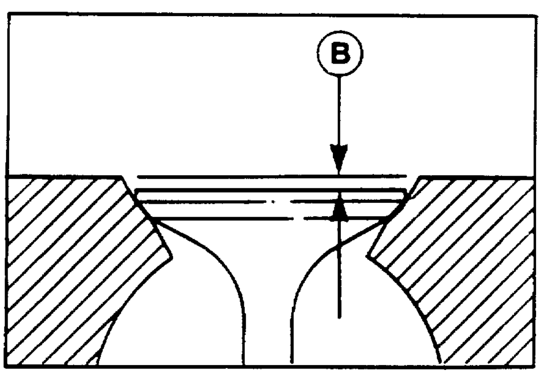


Seat Angle	
Intake:	30 Degrees
Exhaust:	45 Degrees



Install the valves in their respective bores and measure depth again.

Note: Make sure the seats are clean before you measure the depth.

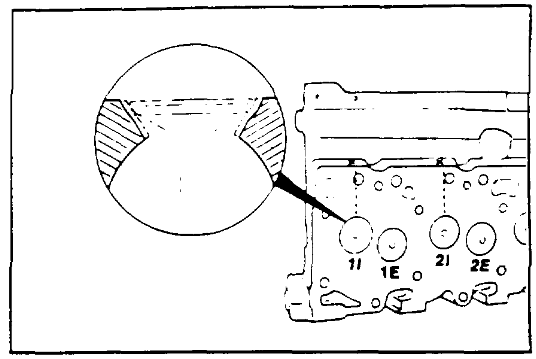


Record the depth of each valve as (B).

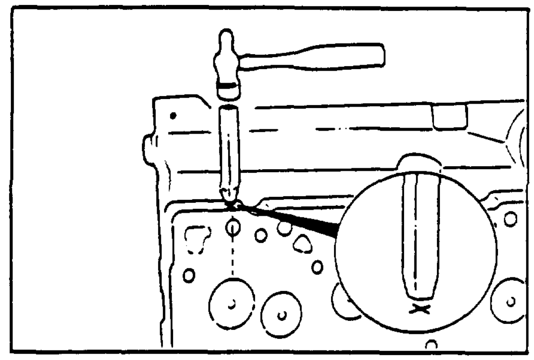
Calculate grinding depth (GD) as follows:

GD = (B) - (A)

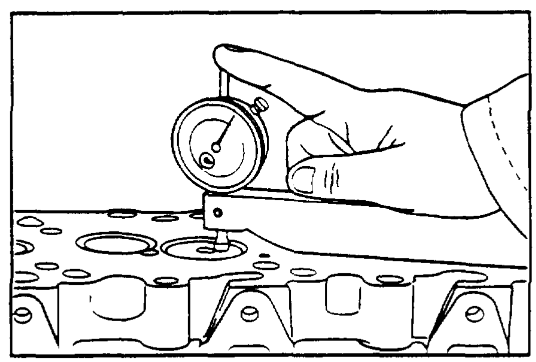
Dimension (GD)
0.254mm [0.010 inch]



Note: Identify re-ground valve seats.

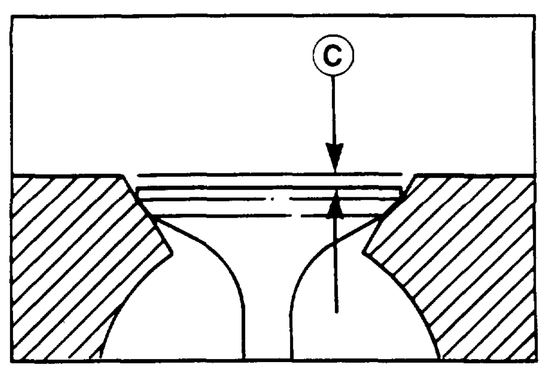


Install the valves in their designated location and measure the depth.



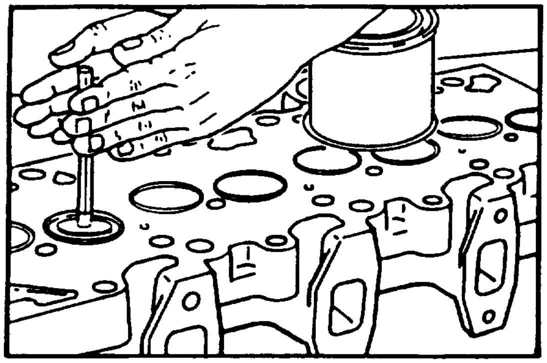
Caution: Replace the valve if the depth is over the limit.

Check valve depth (C).

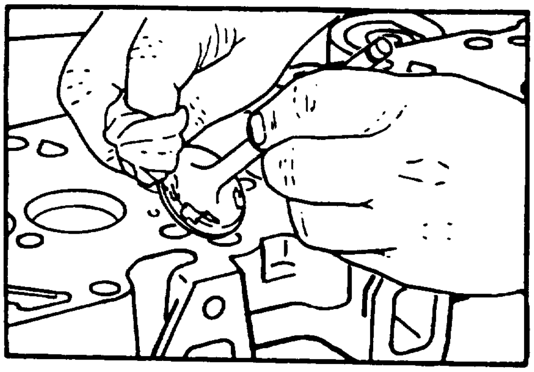


Valve Depth

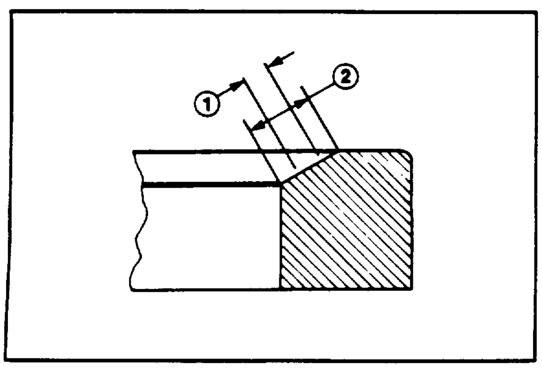
Min	Max
0.99mm [0.0389 in]	1.52mm [0.0598 in]



Apply a light coat of valve lapping compound to each valve and lap each valve to its companion seat.

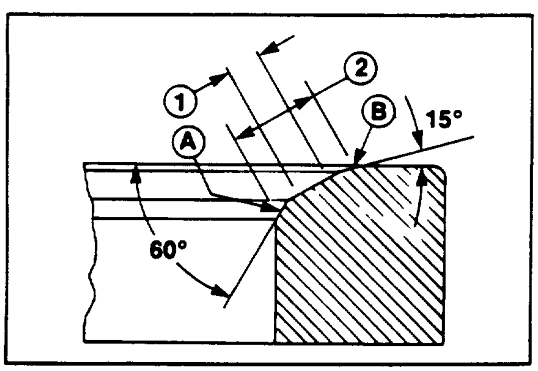


Remove the valves and clean lapping compound from the valves and seats.



Measure the valve seat width indicated by the lapped surface.

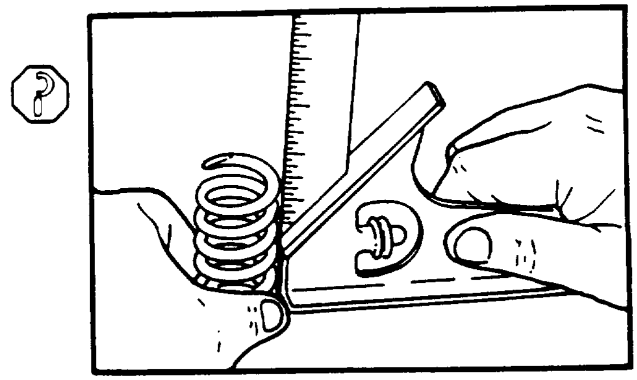
Valve Seat Width Limit
Minimum 1: 1.5mm [0.060 inch]
Maximum 2: 2.0mm [0.080 inch]



If required. grind area (A) with a 60 degree stone and (B) with a 15 degree stone to center the seat on the valve face. Maintain the valve seat width limits.

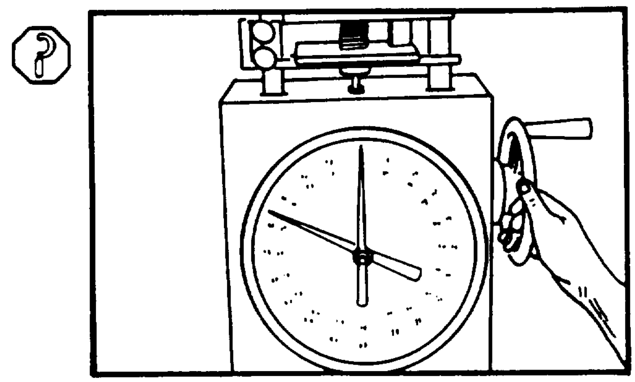
Minimum 1: 1.5mm [0.060 inch]
Maximum 2: 2.0mm [0.090 inch]

Valve Springs Inspection
Measure the valve spring.



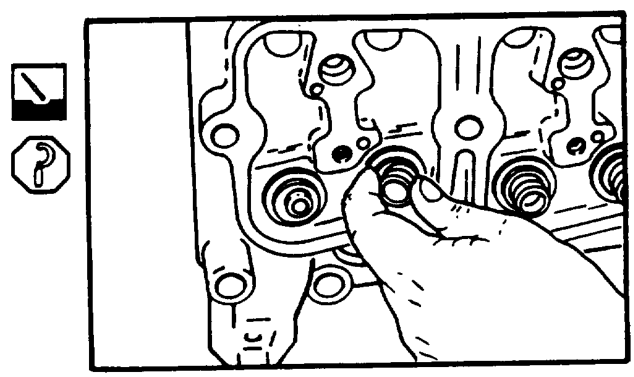
Limits
Approx. Free Length (L): 55.63mm [2.190 in.]
Maximum Inclination: 1.Omm [0.039 in.]

Check the valve spring tension.



A minimum load of 289.32 N. [65.0 72.2 lb] is required to compress the spring to a height of 49.25mm [1.94 inches].

Cylinder Head Assembly

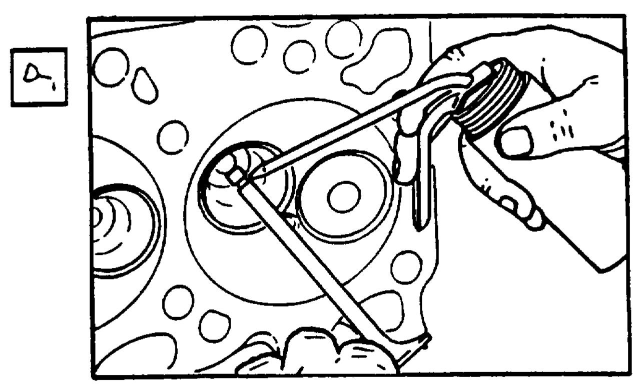


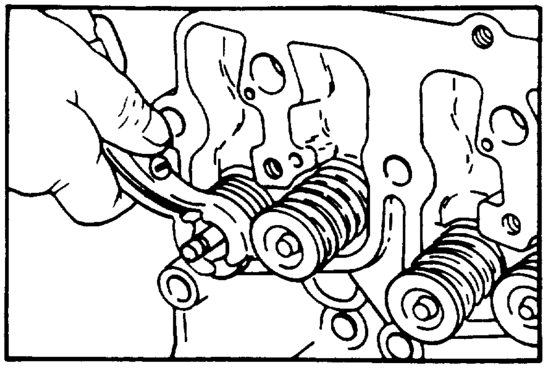
Note: Clean all cylinder head components before assembling.

Install the valve stem seals.

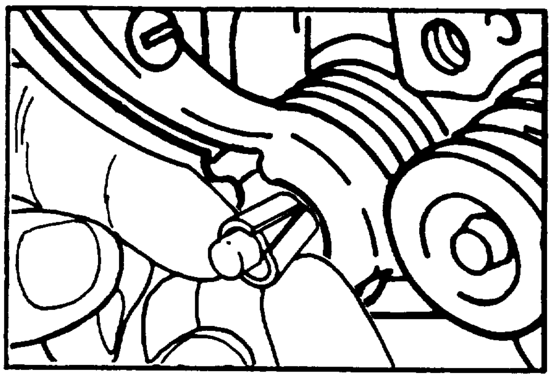
Note: The intake and exhaust seals are the same.

Lubricate the stems with SAE 90W engine oil before installing the valves.

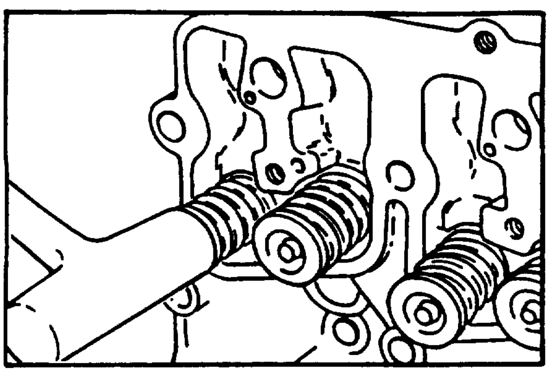




Compress the valve spring after assembling the spring and retainer.



Install new valve collets and release the spring tension.



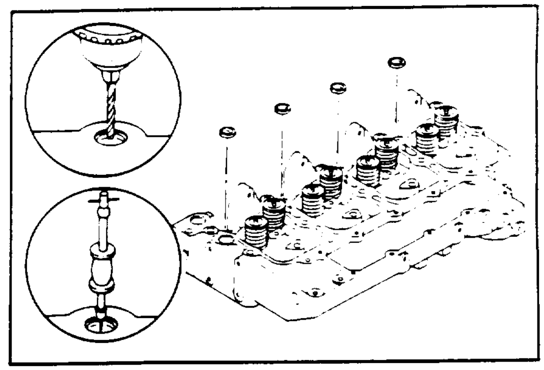
Warning: Wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

After assembly, hit the valve stems with a plastic hammer to make sure that the collets are seated.

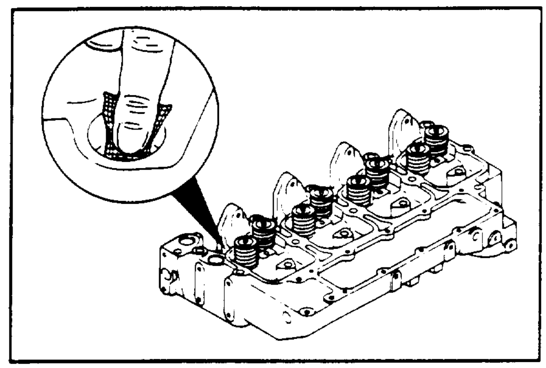
Cup Plug Replacement

Drill Motor, 3 mm [1/8 inch] drill bit, slide hammer, #10 metal screw.

Remove the cup plugs from the cylinder head.



400 grit sandpaper, Diesel Fuel
Thoroughly clean the cup plug holes.

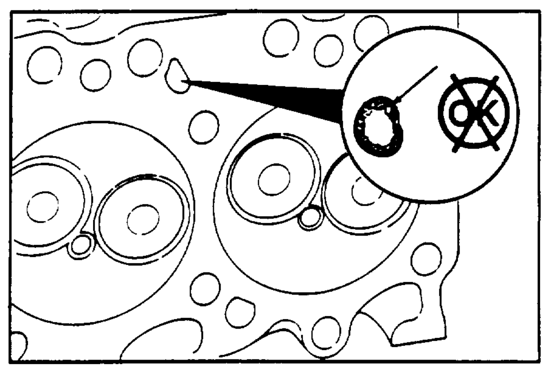


Caution: Use protective clothing to prevent personal injury.

Inspect for build-up of deposits in the coolant passages which can cause engine overheating.

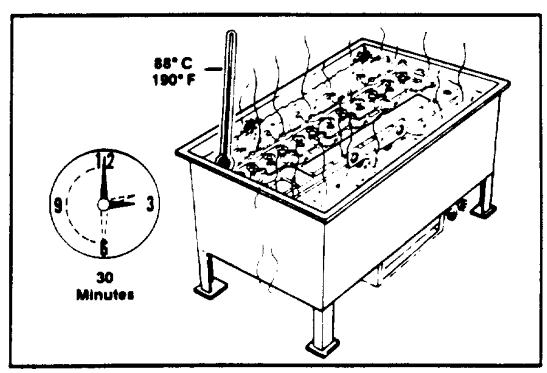
Be sure the coolant passages are clean.

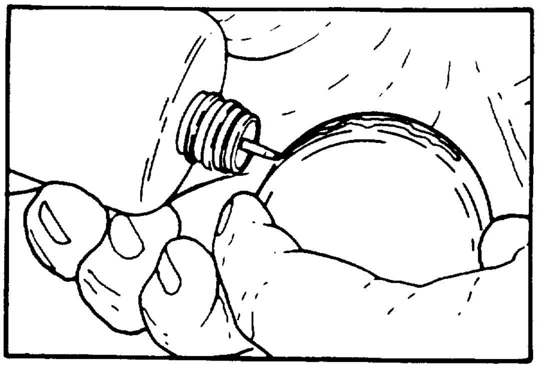
Excessive deposits may be cleaned in an acid tank, but the cylinder head must be disassembled first.



Caution: Use protective clothing to prevent personal injury.

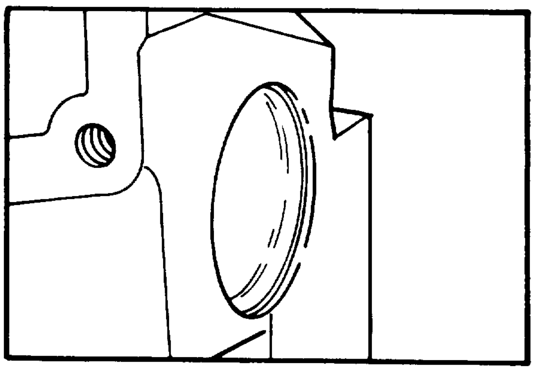
The cylinder head may be cleaned in a hot tank using a soap and water solution.





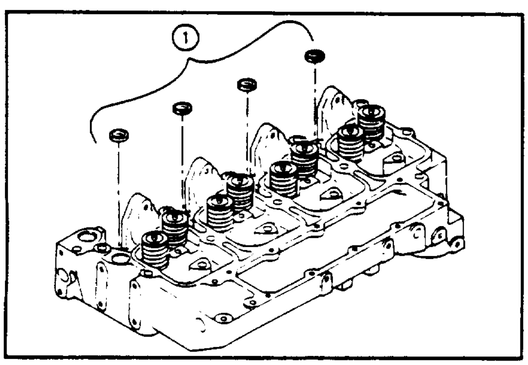
NOTE: The cup plugs and cup plug holes must be dean and free of oil before installing the cup plugs.

Apply a bead of Loctite -277 around the outside diameter of all cup plugs before installing.



Cup Plug Driver Part No. 3900965

Drive all cup plugs in until the outer edge is flush with the counter sink.



Cup Plug Locations (As Required)

Section 9. Engine Disassembly and Assembly

Engine Disassembly

Disassemble the engine (removed from vehicle) in the following order.

a. Remove starter, refer to Chapter 5, Section 7.

b. Drain oil, refer to Chapter 5, Section 6.

c. Remove lifting bracket.

d. Remove drive belt, refer to Chapter 5, Section 3.

e. Remove fan pulley, refer to Chapter 5, Section 3.

f. Remove belt tensioner, refer to Chapter 5, Section 3.

g. Remove fan hub, refer to Chapter 5, Section 3.

h. Remove alternator, refer to Chapter 5, Section 7.

i. Remove thermostat and housing, refer to Chapter 5, Section 3.

j. Remove exhaust manifold, refer to Chapter 5, Section 5.

k. Remove high pressure fuel lines, refer to Chapter 5, Section 4.

I. Remove fuel drain manifold, refer to Chapter 5, Section 4.

m. Remove low pressure fuel lines, refer to Chapter 5, Section 4.

n. Remove dipstick.

o. Remove intake manifold, refer to Chapter 5, Section 5.

p. Remove rocker covers, refer to Chapter 5, Section 8.

q. Remove fuel injectors, refer to Chapter 5, Section 4.

r. Remove rocker levers, refer to Chapter 5, Section 8.

s. Remove push rods, refer to Chapter 5, Section 8.

t. Remove cylinder head, refer to Chapter 5, Section 8.

u. Remove front cover, refer to Chapter 5, Section 8.

v. Remove water pump, refer to Chapter 5, Section 3.

w. Remove flywheel, refer to Chapter 5, Section 8.

Engine Disassembly continued

x. Remove flywheel housing, refer to Chapter 5, Section 8.

y. Remove fuel injection pump, refer to Chapter 5, Section 4.

z. Remove fuel injection pump drive gear, refer to Chapter 5, Section 8.

aa. Remove fuel lift pump, refer to Chapter 5, Section 4.

bb. Remove tappet cover, refer to Chapter 5, Section 8.

cc. Remove oil fill, refer to Chapter 5, Section 6.

dd. Remove oil cooler, refer to Chapter 5, Section 6.

ee. Remove water inlet connection, refer to Chapter 5, Section 3.

ff. Remove oil pan, refer to Chapter 5, Section 6.

gg. Remove suction tube, refer to Chapter 5, Section 6.

hh. Remove rear seal housing, refer to Chapter 5, Section 8.

ii. Remove camshaft, refer to Chapter 5, Section 8.

jj. Remove valve tappets, refer to Chapter 5, Section 8.

kk. Remove lube oil pump, refer to Chapter 5, Section 6.

ll. Remove timing pin, refer to Chapter 5, Section 8.

mm. Remove gear housing, refer to Chapter 5, Section 8.

nn. Remove pistons and rods, refer to Chapter 5, Section 8.

oo. Remove crankshaft, refer to Chapter 5, Section 8.

Engine Assembly

Assembly the engine (removed from vehicle) in the following order.

a. Install valve tappets, refer to Chapter 5, Section 8.

b. Install crankshaft, refer to Chapter 5, Section 8.

c. Install pistons and rods, refer to Chapter 5, Section 8.

d. Install gear housing, refer to Chapter 5, Section 8.

e. Install lube oil pump, refer to Chapter 5, Section 6.

f. Install camshaft, refer to Chapter 5, Section 8.

g. Install timing pin, refer to Chapter 5, Section 8.

h. Install rear seal housing, refer to Chapter 5, Section 8.

i. Install suction tube, refer to Chapter 5, Section 6.

j. Install oil pan, refer to Chapter 5, Section 6.

k. Install oil cooler, refer to Chapter 5, Section 6.

l. Install oil fill, refer to Chapter 5, Section 6.

m. Install fuel lift pump, refer to Chapter 5, Section 4.

n. Install tappet cover, refer to Chapter 5, Section 8.

o. Install fuel injection pump, refer to Chapter 5, Section 4.

p. Install flywheel housing, refer to Chapter 5, Section 8.

q. Install flywheel, refer to Chapter 5, Section 8.

r. Install water pump, refer to Chapter 5, Section 3.

s. Install front cover, refer to Chapter 5, Section 8.

t. Install cylinder head, refer to Chapter 5, Section 8.

u. Install push rods, refer to Chapter 5, Section 8.

v. Install rocker levers, refer to Chapter 5, Section 8.

w. Adjust valve clearances, refer to Chapter 5, Section 8.

Engine Assembly - continued

x. Install fuel injectors, refer to Chapter 5, Section 4.

y. Install rocker covers, refer to Chapter 5, Section 8.

z. Install intake manifold, refer to Chapter 5, Section 5.

aa. Install fuel supply line, refer to Chapter 5, Section 4.

bb. Install injection pump supply line, refer to Chapter 5, Section 4.

cc. Install fuel drain manifold, refer to Chapter 5, Section 4.

dd. Install fuel injection pump vent line, refer to Chapter 5, Section 5.

ee. Install high pressure fuel lines, refer to Chapter 5, Section 4.

ff. Install fuel filter head, refer to Chapter 5, Section 4.

gg. Install exhaust manifold, refer to Chapter 5, Section 5.

hh. Install thermostat, refer to Chapter 5, Section 3.

ii. Install fan hub, refer to Chapter 5, Section 3.

jj. Install belt tensioner, refer to Chapter 5, Section 3.

kk. Install water inlet connection, refer to Chapter 5, Section 3.

ll. Install alternator, refer to Chapter 5, Section 7.

mm. Install drive belt, refer to Chapter 5, Section 3.

nn. Install oil filter, refer to Chapter 5, Section 6.

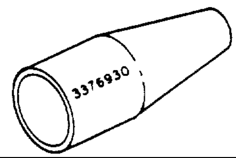
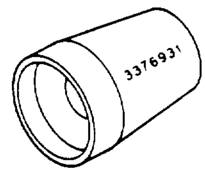
oo. Install starter, refer to Chapter 5, Section 7.

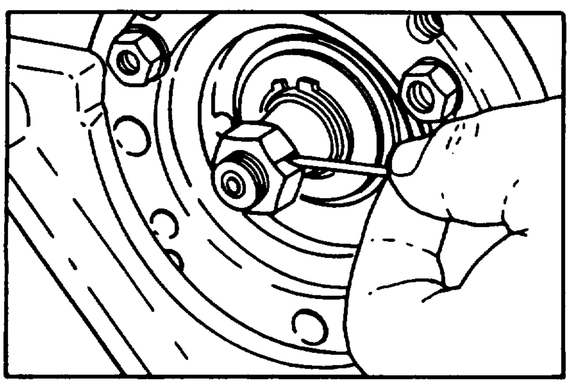
Section 10. Fuel Injector Pump

Subject........Page

Injection Pump - Service Tools

The following special tools are recommended for repairing the fuel injection pump. Use of the tool is shown on the appropriate procedure.

Tool No.	Tool Description	Tool Illustration
3376930	Protective Sleeve Used to replace the o-ring on the shut down solenoid for the Lucas CAV fuel pump.	
3376931	Protective Sleeve Used to replace the o-ring on the pressure end cap of the timing advance mechanism on the Lucas CAV pump.	



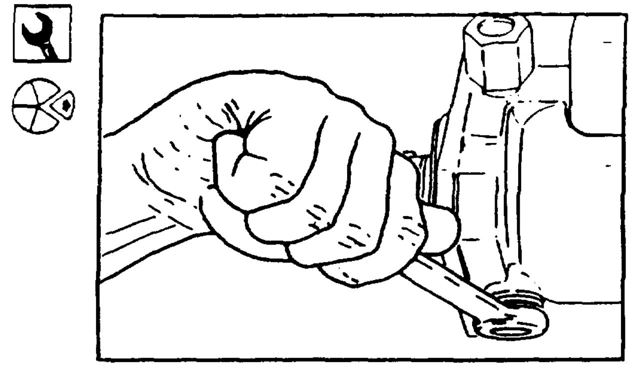
Injection Pump Repairs Lucas CAV DPA

Locking Screw/O-Ring Replacement

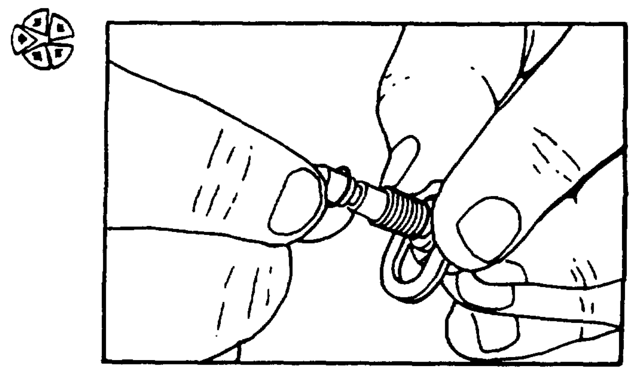
Precisely mark the shaft position before removing the locking screw.

15 mm

Remove the locking screw and washer.



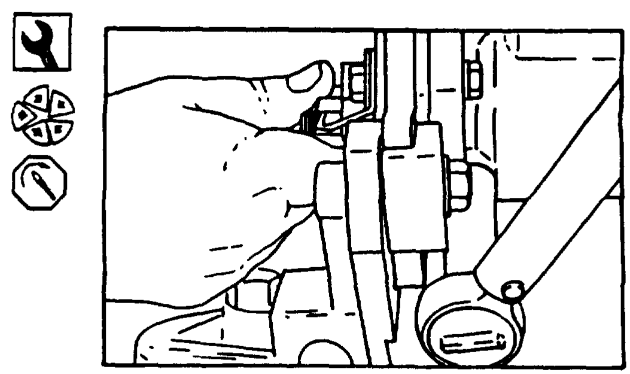
Install a new o-ring. Replace special washer, if required.



15 mm

Verify the shaft is still aligned and install the locking screw assembly.

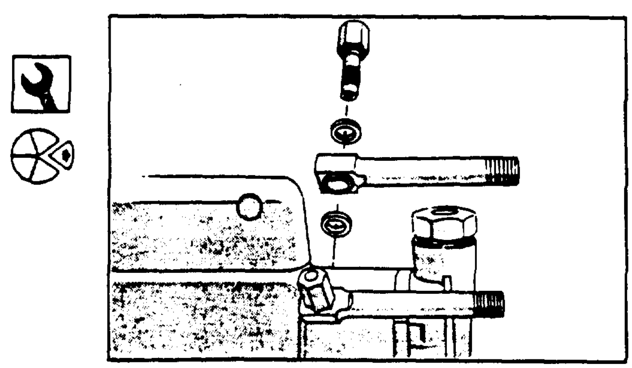
Torque Value: 30 Nom [22 ft4b]

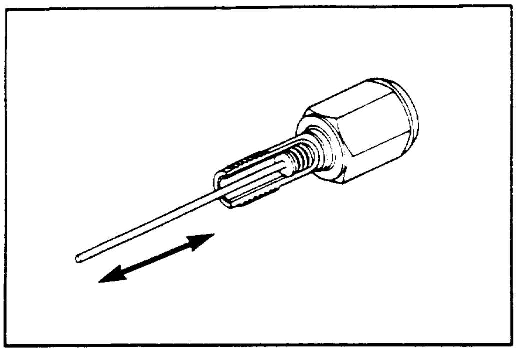


Back Leakage Valve Replacement/ Inspection

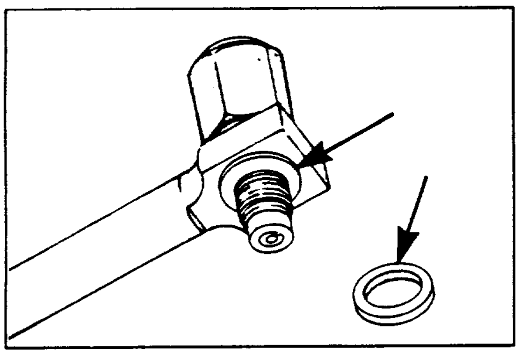
16 mm

Remove the back leakage valve and sealing washer.

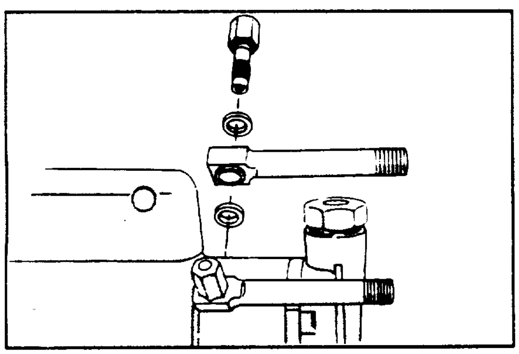




Inspect the valve to be sure it is not stuck.



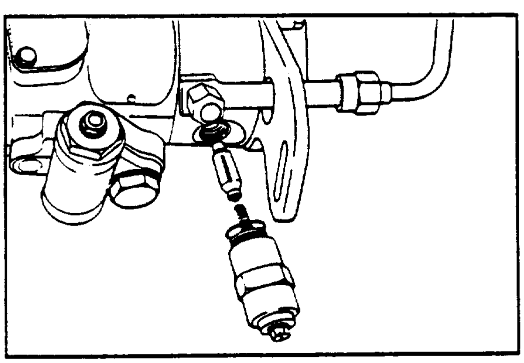
Inspect the sealing surfaces for possible leak paths.



16 mm

Assemble the back leakage valve and new washers.

Torque Value: 31 Nom [23 ft4b]



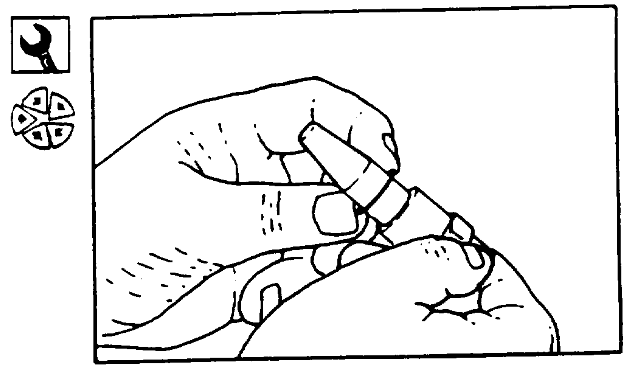
Shutdown Solenoid Replacement

24 mm

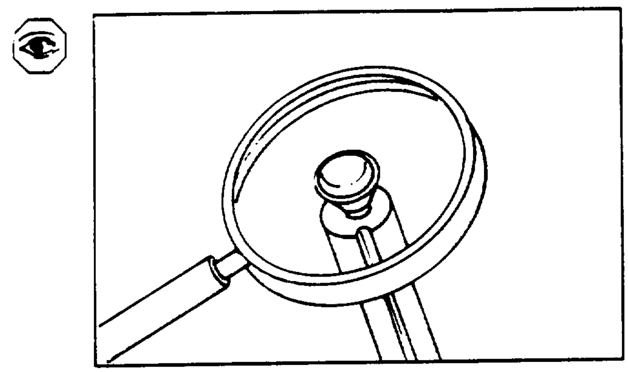
Remove the solenoid, o-ring, spring and plunger.

14.7 mm Protective Sleeve Part No. 3376930

Replace the o-ring. Use the protective sleeve to prevent cutting the o-ring.



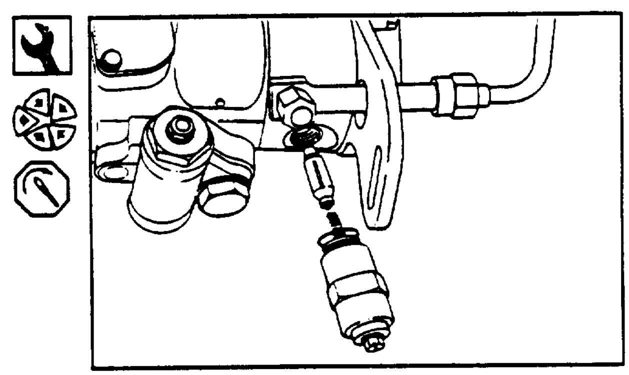
Inspect the plunger tip. If the tip is damaged or deformed, replace the solenoid assembly.



22 mm

Install the plunger, spring, solenoid and o-ring.

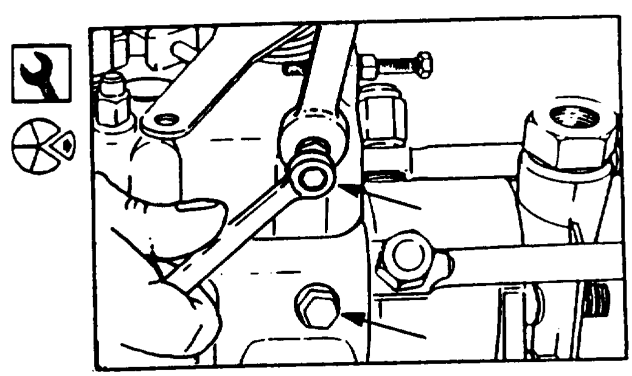
Torque Value: 15 Nom [11 ft4b]

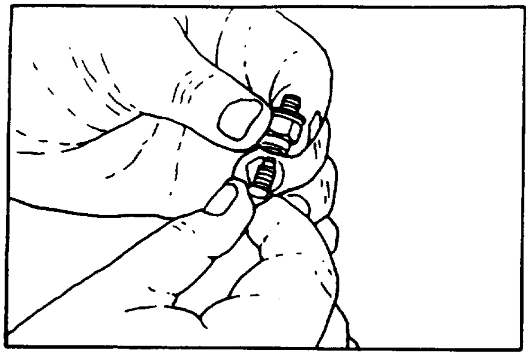


Bleed Screws/Sealing Washers Replacement

8 mm, 11 mm

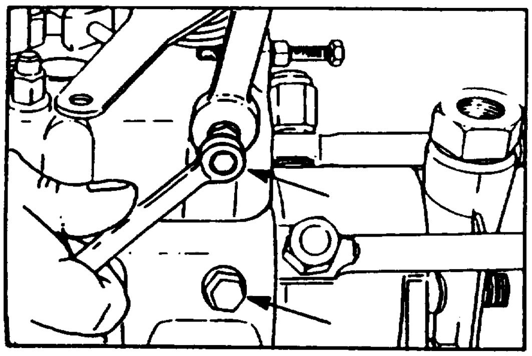
Remove the screw, fitting and washer.






Inspect the threads and sealing surfaces.

If the fitting or bleed screw is damaged, replace the damaged components.

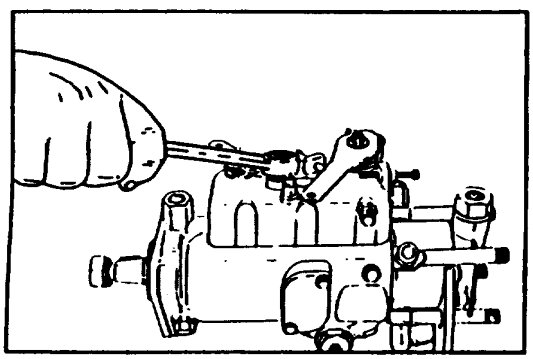



8 mm, 11 mm

Install the bleed screw, fitting and new sealing washer.

Torque Value: (Fitting) 7.3 Nom [65 in-lb]

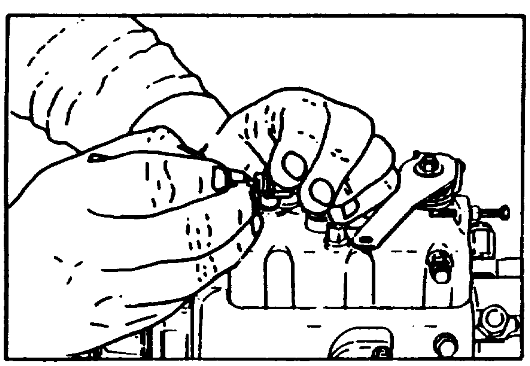
Torque Value: (Bleed Screw) 4.5 Nom [40 in-lb]




Vent Fitting/Sealing Washer Inspection/ Replacement

16 mm

Remove the fitting and washer.

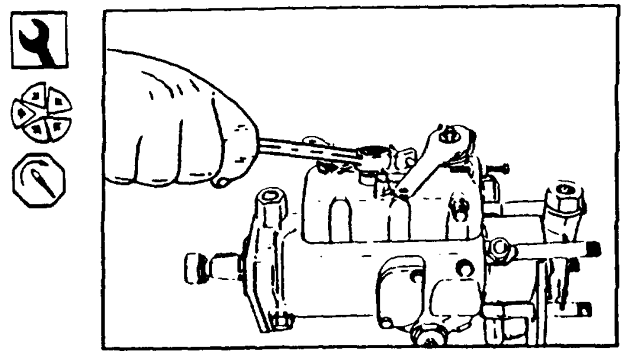



Inspect the sealing surfaces and verify that the orifice is open.

16 mm

Install a new washer and vent fitting.

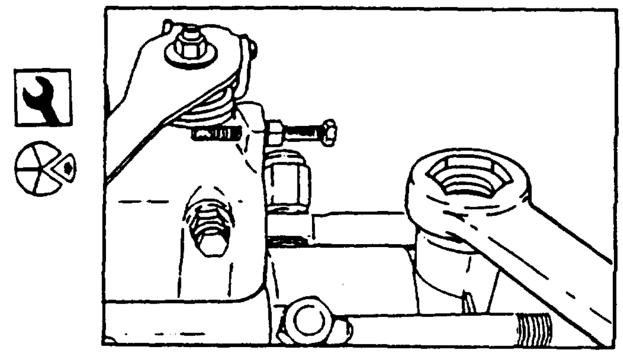
Torque Value: 20.6 Nom [15 ft-b]



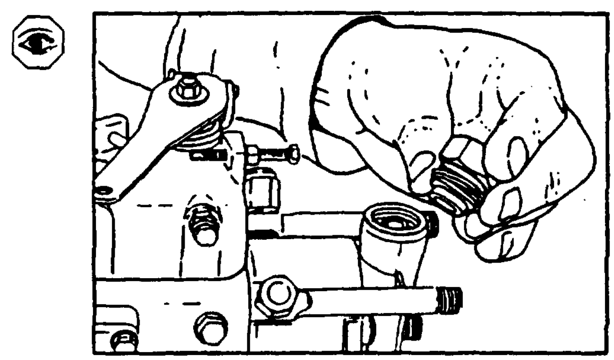
Fuel Inlet Fitting/Sealing Washer Replacement

24 mm

Remove the fitting and washer.



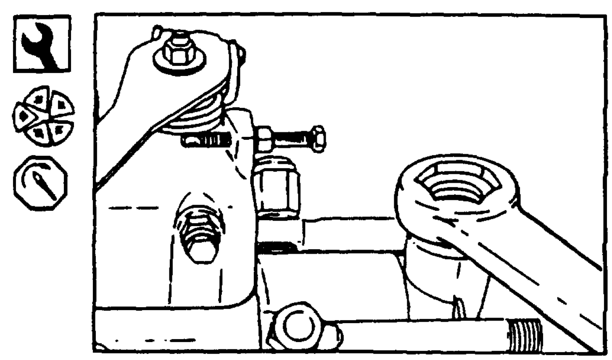
Inspect the surface for a leak path.



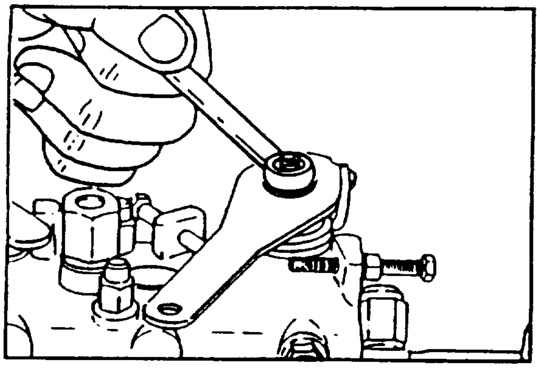
24 mm

Install a new washer and fitting.

Torque Value: 51 Nom [38 ft-b]

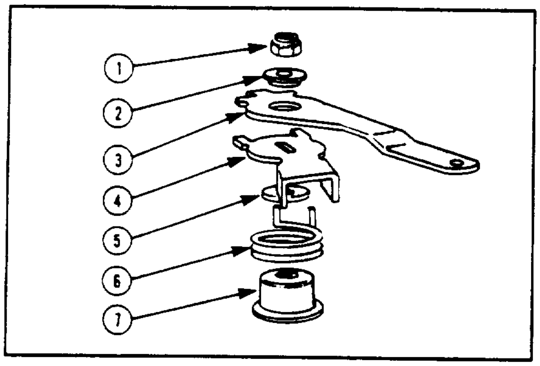


Control Lever Replacement



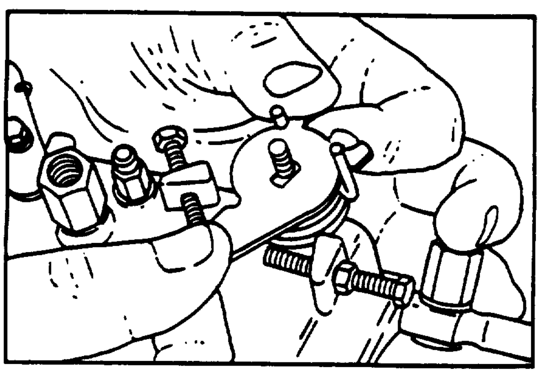
8 mm

Remove the locknut.



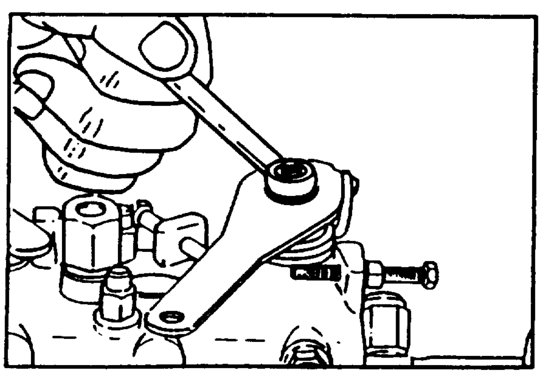
Inspect the lever components:

1. Locknut
2. Bushing
3. Throttle Lever
4. Stop Arm
5. Washer
6. Torsion Spring
7. Spring Guide



Assemble the spring guide, torsion spring, washer and stop arm.

The stop arm must slide over flats of the shaft.



8 mm

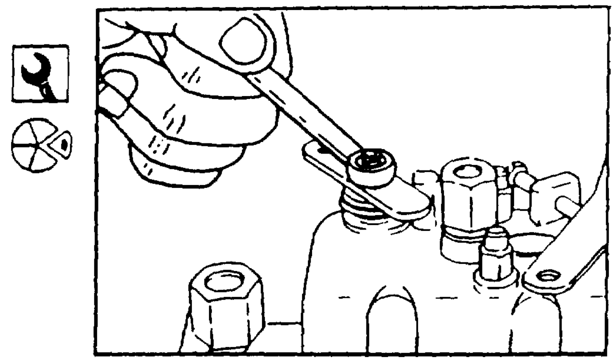
Install the lever, bushing and locknut.

Torque Value: 3.4 Nom [30 in-lb]

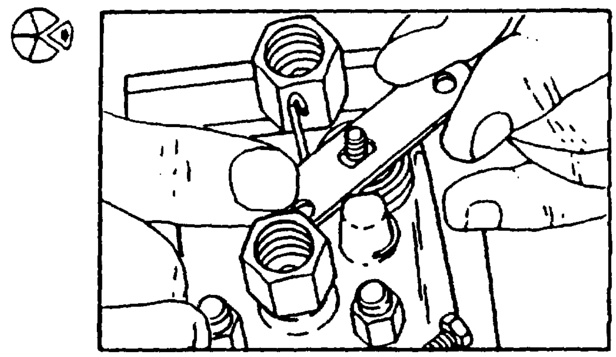
Shutdown Lever/Spring Replacement

8 mm

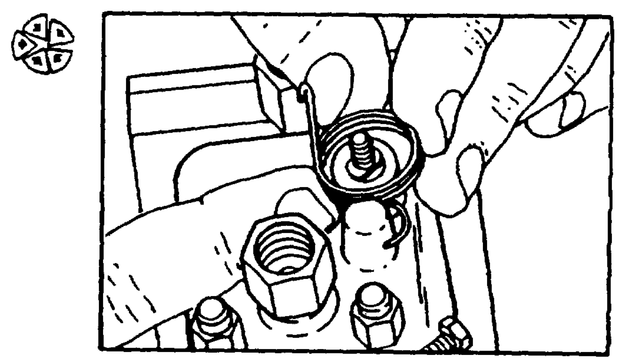
Remove the locknut and washer.



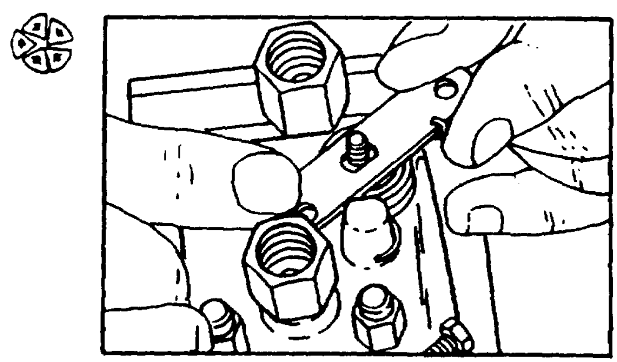
Lift off the lever while allowing the return spring to unwind.

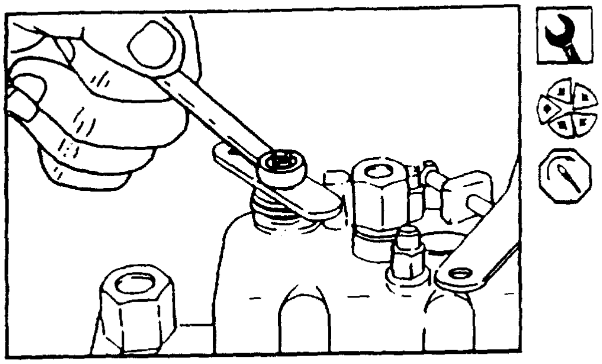


Position the return spring with one end of spring contacting the boss on the governor cover.



Hook the free end around the shut-off lever and rotate the lever in a clockwise direction until it engages with the flats on the shut-off shaft.

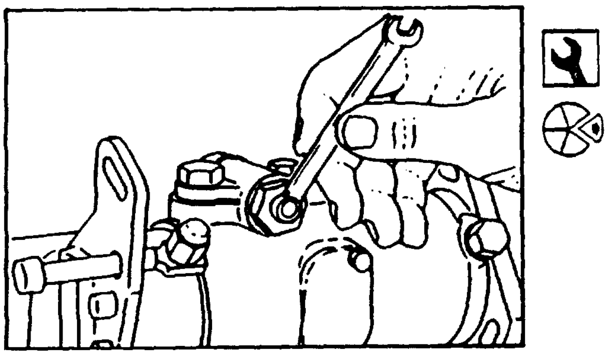




8 mm

Install the nut with a new lock washer.

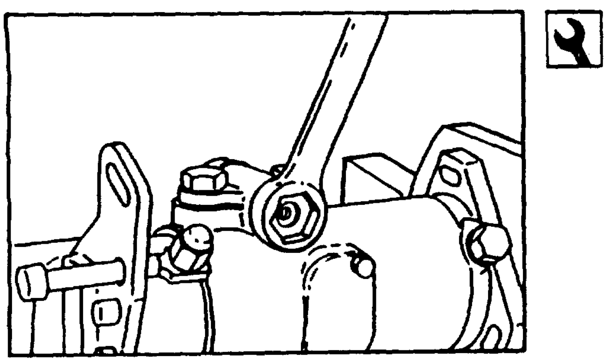
Torque Value: 3.4 Nom [30 in-lb]



Automatic Timing Advance Disassembly

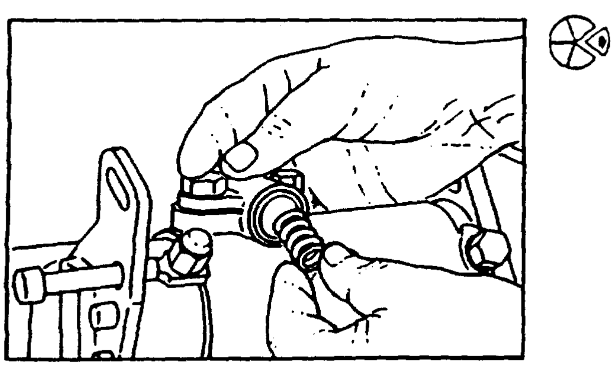
8 mm

Remove the small plug and washer.



24 mm

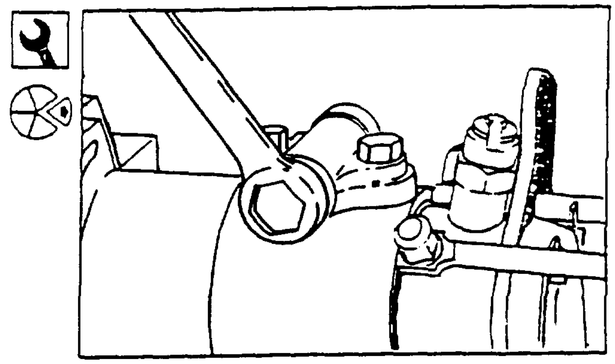
The spring cap is under spring tension; remove the cap slowly.



Remove the shims and springs.

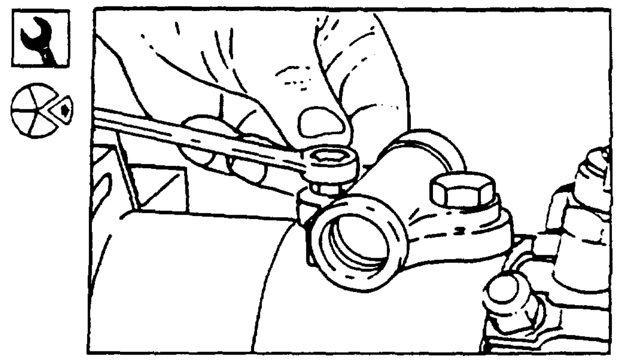
24 mm

Remove the pressure end plug and o-ring.



13 mm

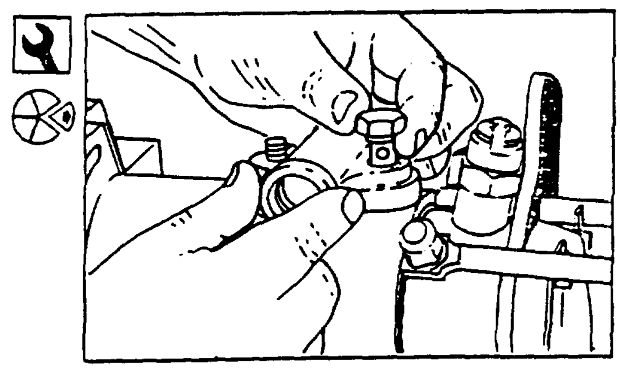
Remove the cap nut and sealing washer.



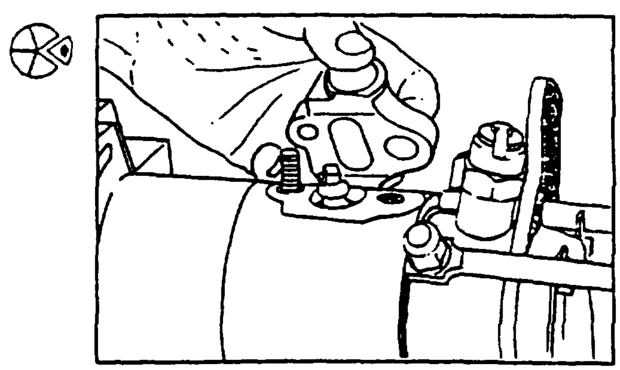
19 mm

Remove the head/locating fitting assembly.

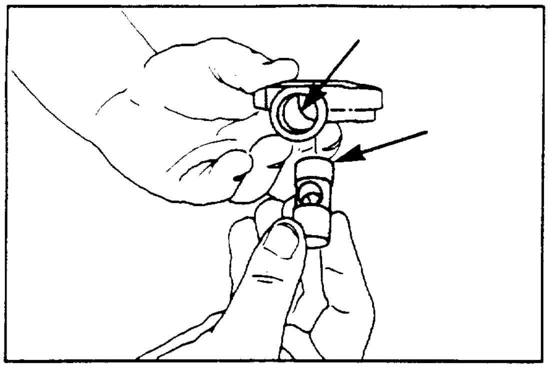
Do not lose the check ball.



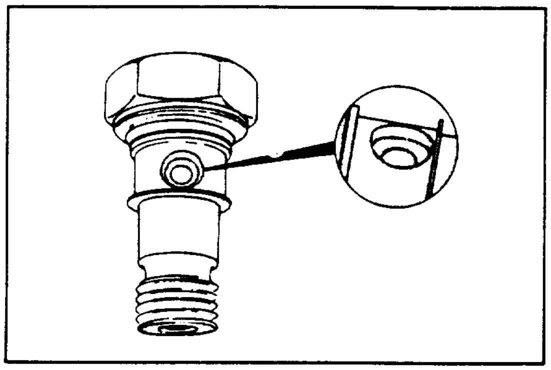
Remove the housing and slide the advance piston from the bore.



Timing Advance Components Inspection

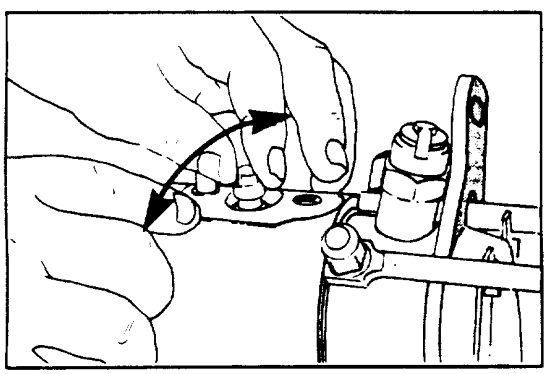


Inspect the advance piston and housing for scoring.



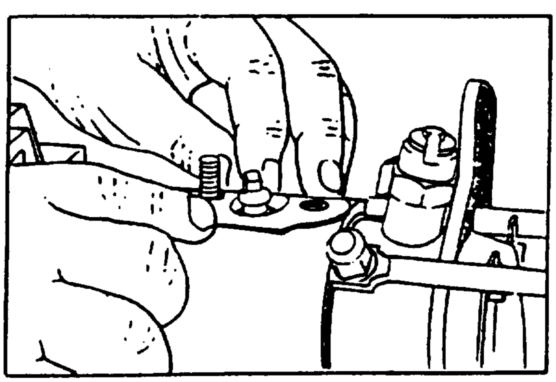
Inspect the check ball and seat for erosion. Make sure the ball can move freely on the seat.

Be sure the orifice in the side of the seat in the head locating fitting is open.



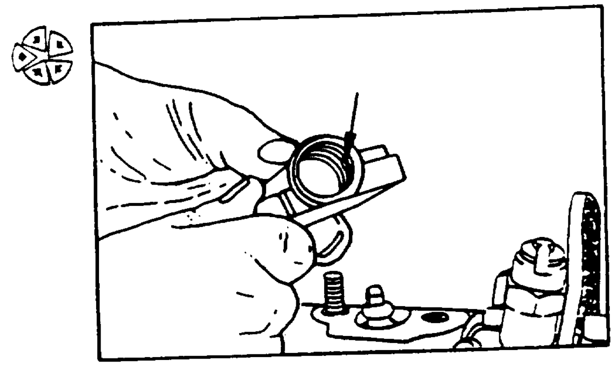
Check that the cam ring is free to move in the fuel pump.

Timing Advance Assembly

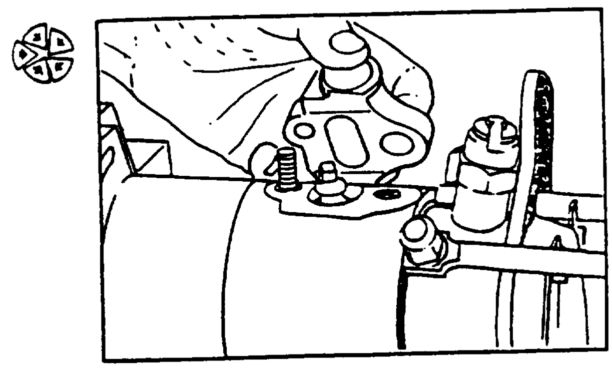


Position a new gasket on the injection pump housing.

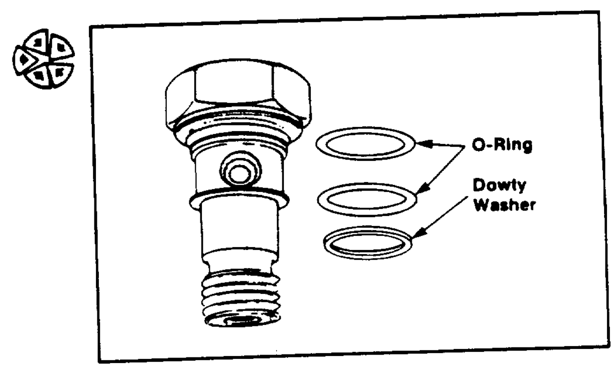
Insert the advance piston into the housing with the blank end toward the oil feed hole in the bore.



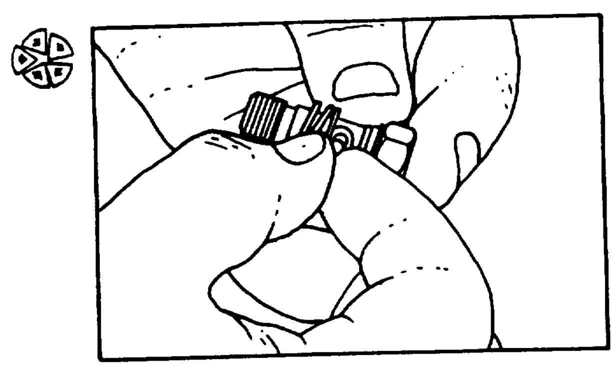
Position the advance housing over the stud in the injection pump with the cam advance screw positioned into the center bore in the piston.

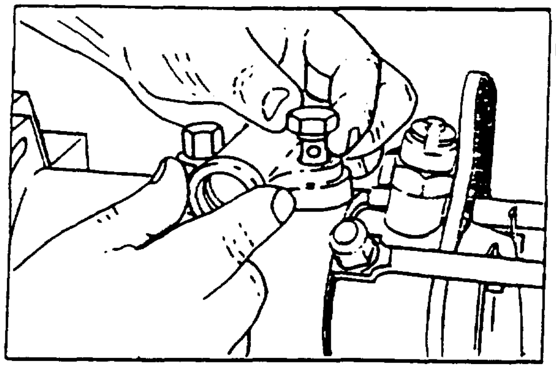


Install new o-rings on the head locating fitting.

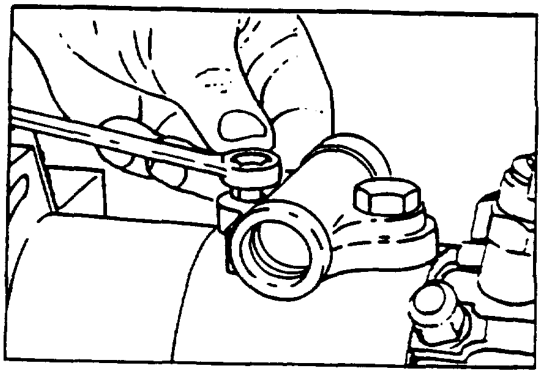


Position the check ball in the head/locating fitting.





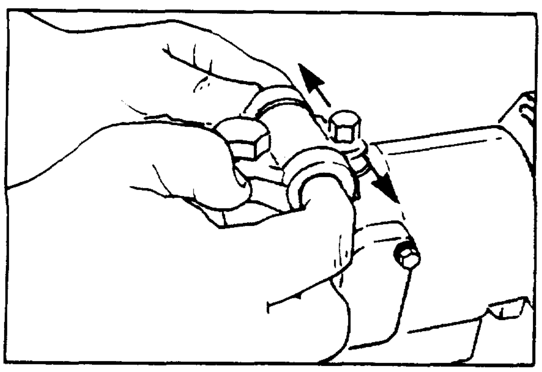
Position head/locating fitting through the advance housing and hand tighten.



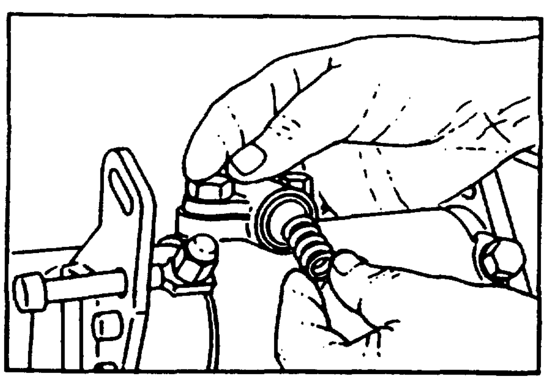
13 mm, 19 mm

Install cap nut and a new washer. Tighten the cap nut and head locating fitting progressively and evenly.

Torque Value		
(Cap Nut)	30 N•m	[22 ft-lb]
(Locating Fitting)	40 N•m	[29 ft-lb]

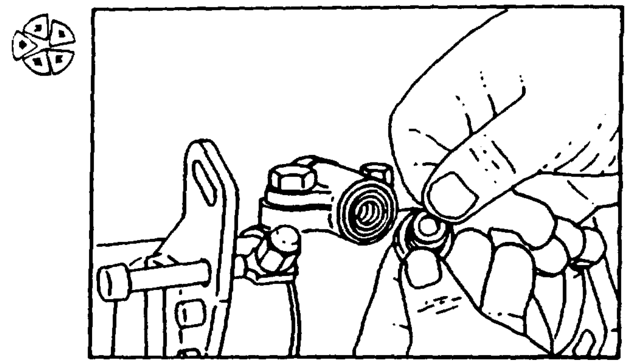


Verify that the piston moves freely in the bore.



Install the springs and shims into the pocket end of the advance piston.

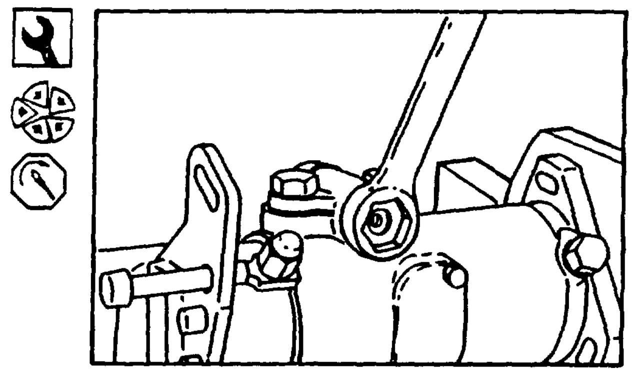
Install a new o-ring on the spring cap and place the shims in the pocket.



24 mm

Install and tighten the spring cap on the advance housing.

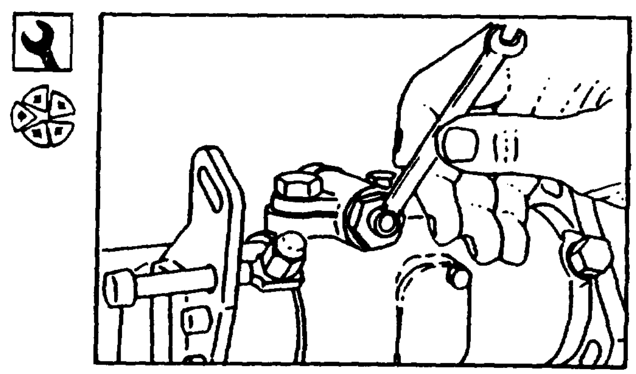
Torque Value: 24 N•m [17.5 ft-b]



8 mm

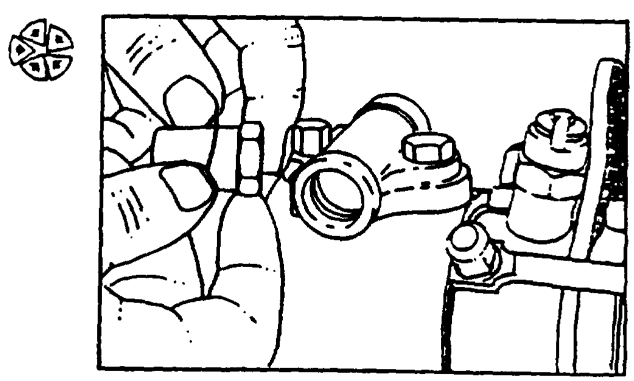
Use a new washer and install the spring cap plug.

Torque Value: 2.3 N•n [20 in-lb]



21 mm Protective Sleeve Part No. 3376931

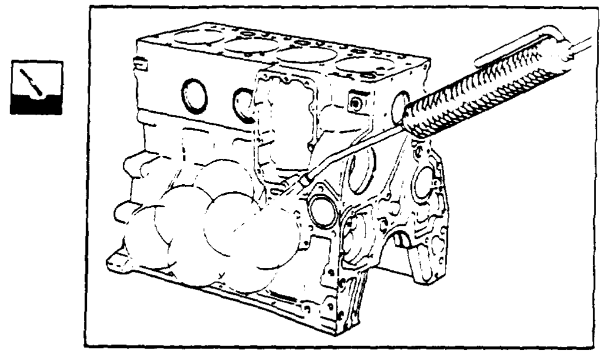
Install a new o-ring on the pressure end cap. Use the protective sleeve to avoid damaging the o-ring.



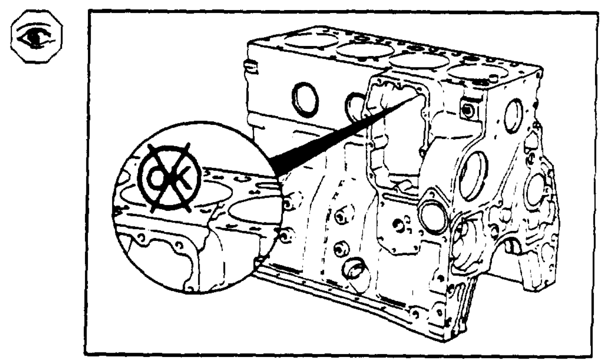
Section 11. Cylinder Block Disassembly and Assembly

Cylinder Block - Precheck Before Disassembly

Thoroughly clean the cylinder block with steam.



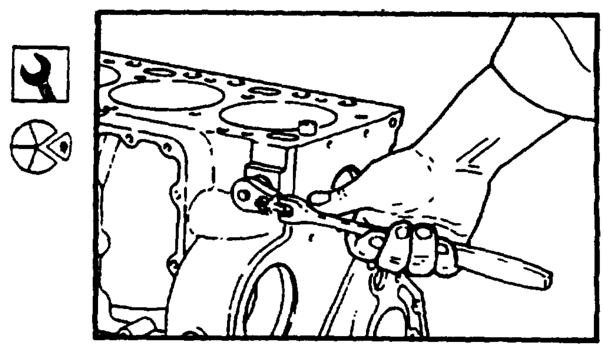
Visually inspect the cylinder block for damage that would prohibit reuse.



Cylinder Block - Disassembly

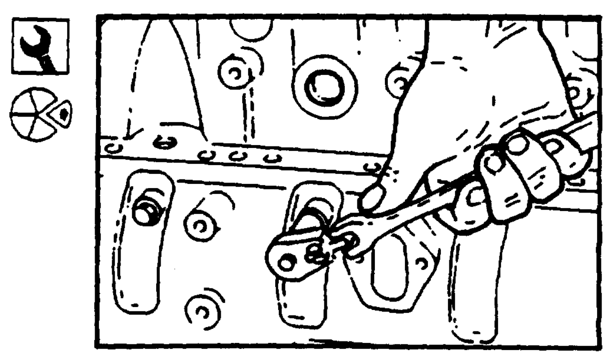
3/8 Inch Square Drive

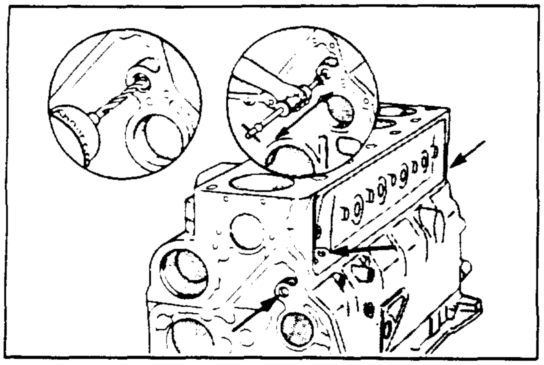
Remove the pipe plug from the water passage.



7/16 Inch

Remove the pipe plugs from the oil passages.

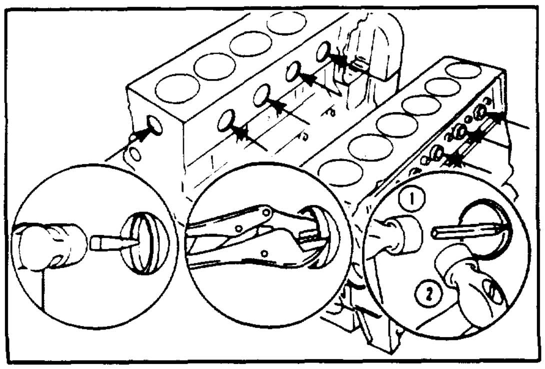




Drill Motor, 3mm [1/8 inch] drill bit, Slide Hammer, No. 10 Sheet Metal screw.

Drill a 3mm [1/8 inch] hole and use a slide hammer equipped with a No. 10 sheet metal screw to remove expansion plugs.

Remove the expansion plugs from the oil passages.

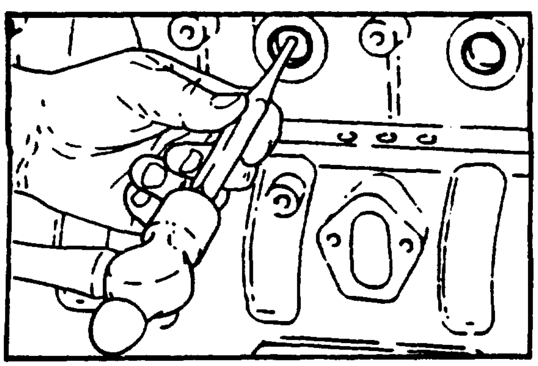


Punch, Visegrips®

Remove the large expansion plugs (58.06 mm [2.29 in.]) from the coolant passages.

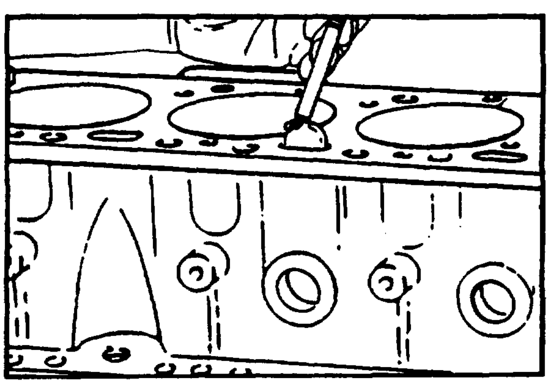
Care should be taken not to drive the expansion plug out and into the water jacket, especially the plug on the end of the block.

Service Tip: If it becomes apparent the cup plug is not going to pivot in the bore, use a center punch to catch the edge of the cup plug and pry against the block to pivot the plug out.



Hammer, Punch

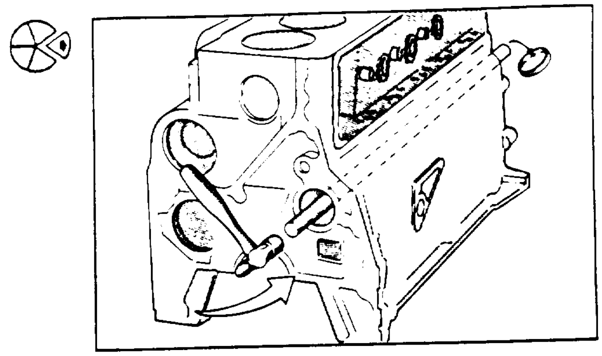
Remove the small expansion plugs (25.07 mm [1 in.]) by driving the plugs into the water jacket.



Mechanical Fingers

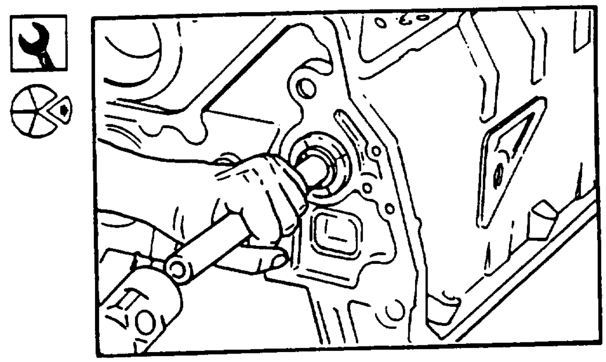
Retrieve the plugs through the water passages in the top of the block.

Remove the expansion plug from the camshaft bore.



Universal Bushing Installation Tool

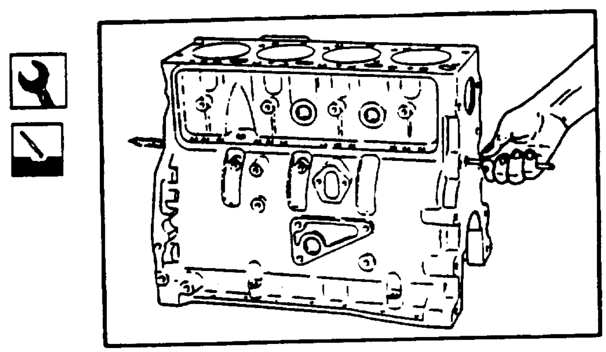
Remove the camshaft bushing.



Cylinder Block - Cleaning

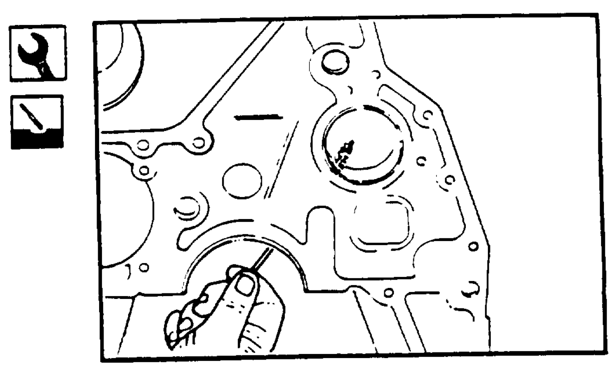
Cleaning Brush Kit, 3823614

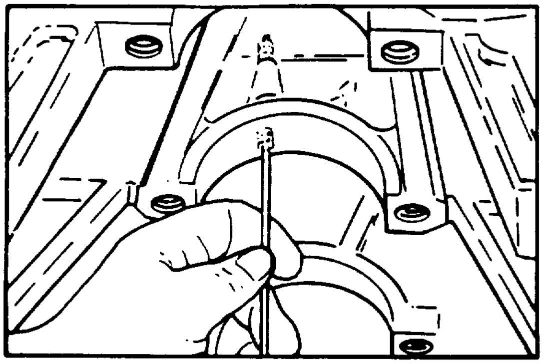
Use clean solvent and a brush to clean the main oil drilling.



Cleaning Brush Kit, 3823614

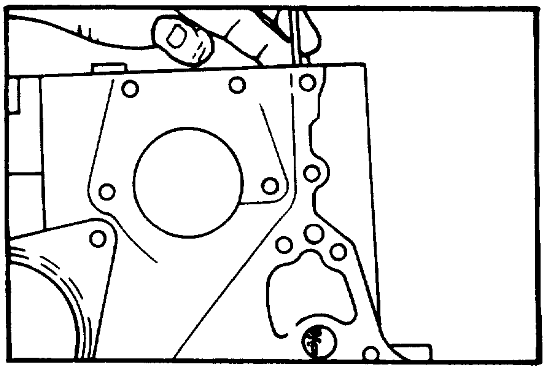
Use clean solvent and a brush to clean the main bearing to cam bore oil drilling.





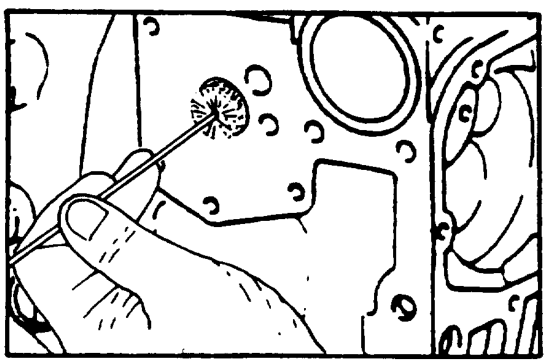
Cleaning Brush Kit, 3823614

Use clean solvent and a brush to clean the piston cooling nozzle bores.



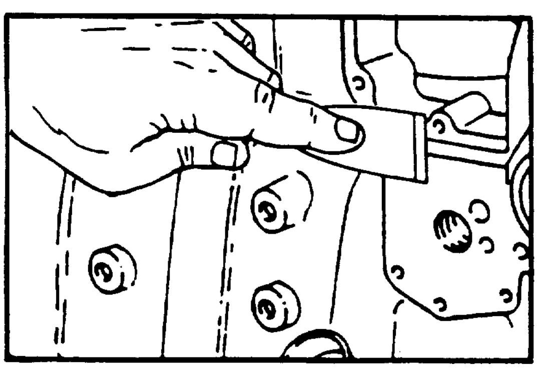
Cleaning Brush Kit, 3823614

Use clean solvent and a brush to clean the main oil rifle to overhead oil drilling.



Cleaning Brush Kit, 3823614

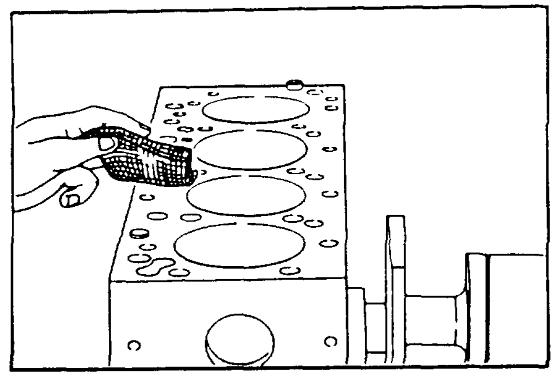
Use clean solvent and a brush to clean the oil cooler oil passages.



Gasket Scraper

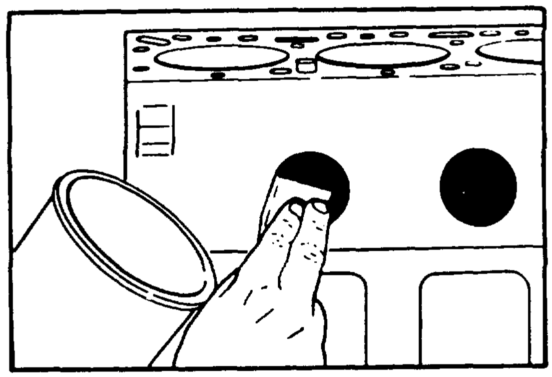
Thoroughly clean all gasket sealing surfaces.

Clean the combustion deck with a Scotch-Brite® cleaning pad or equivalent and diesel fuel or solvent.



Brush, 400 Grit Sandpaper, Diesel Fuel

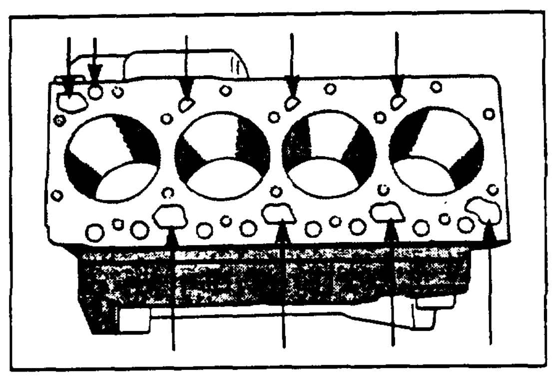
Thoroughly clean all cup plug holes.



Caution: Excessive deposits may be cleaned in an acid tank, but the cam bushings must first be removed.

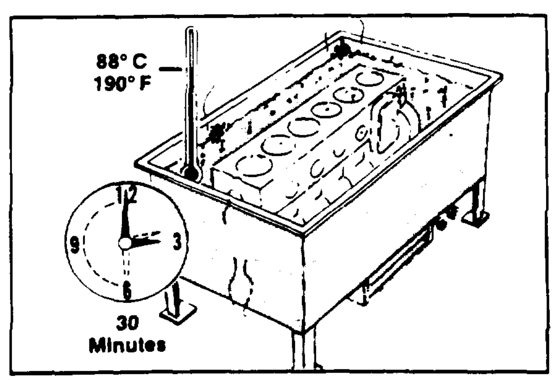
Build-up of deposits in the coolant passages can cause engine overheating.

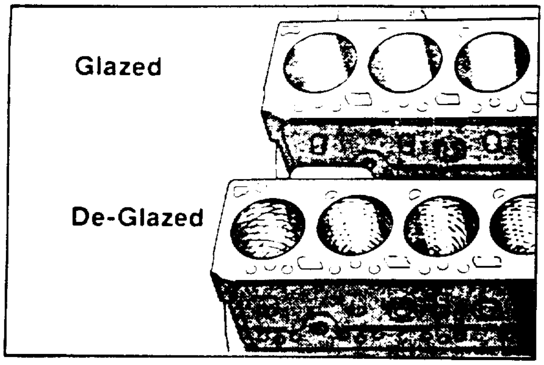
Be sure the coolant passages are clean.



Warning: Use protective measures to prevent personal injury.

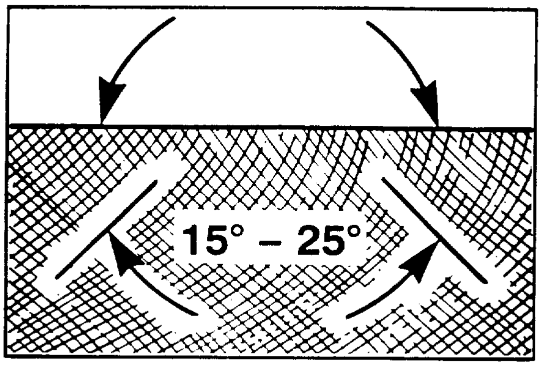
The block may be cleaned in a hot tank using a soap and water solution without removing the cam bushing.



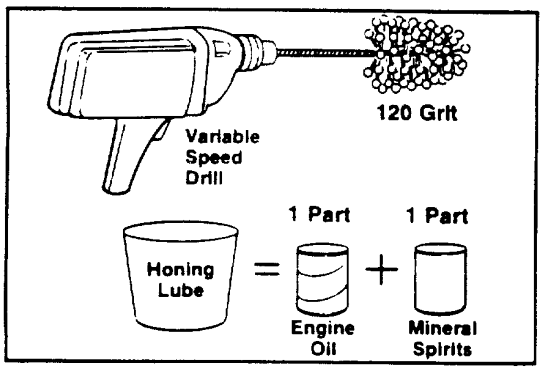


Caution: New piston rings may not seat in glazed cylinder bores.

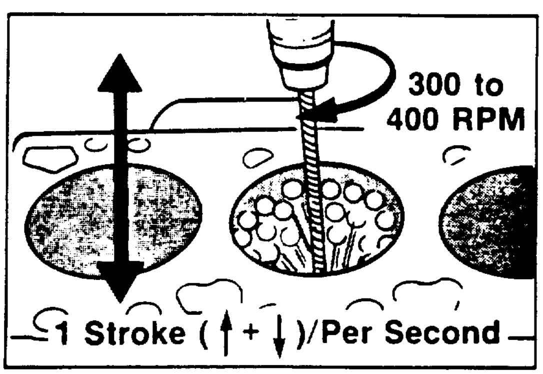
De-glazing makes the bore "rough" to help seat the rings. The size of the bore is not changed by proper de-glazing.



A correctly de-glazed surface will have a crosshatched appearance with the lines at 15 to 25 degree angles with the top of the cylinder block.

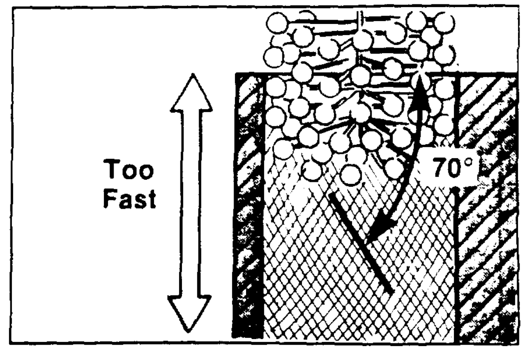


Use a drill, a medium grit Flexi-Hone and a mixture of equal parts of diesel fuel and SAE 30W engine oil to de-glaze the bores.

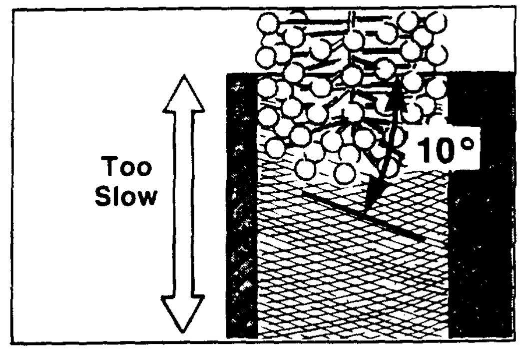


The crosshatch angle is a function of drill speed and how fast the hone is moved vertically.

The drill speed is too slow or the vertical stroke is **too fast.**

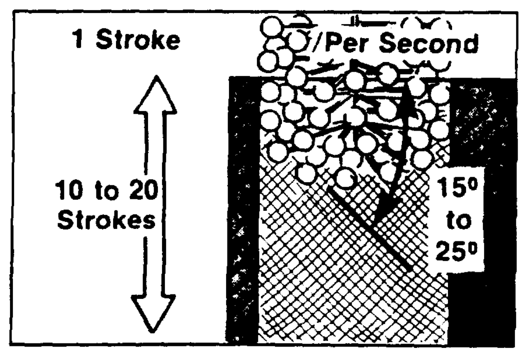


The drill speed is too fast or the vertical stroke is **too slow.**



Caution: Vertical strokes must be smooth continuous passes along the full length of the bore.

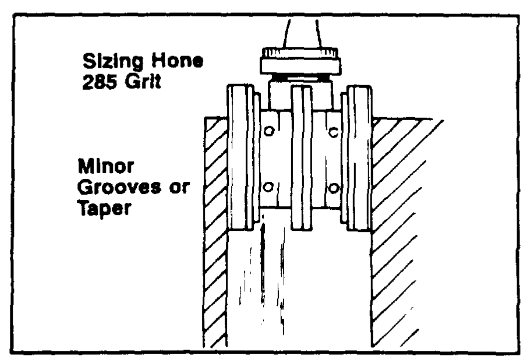
Inspect the bore after 10 strokes.

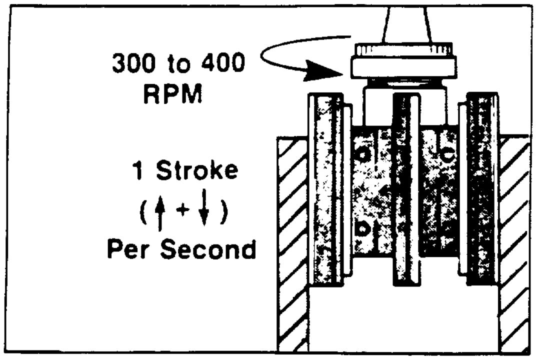


Caution: Be extremely careful not to hone the bore out of specification.

A sizing hone can be used to remove minor grooves or to correct minor out of taper.

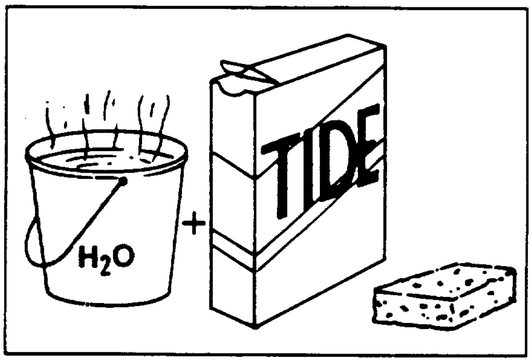
Taper: 0.076mm [0.003 in].





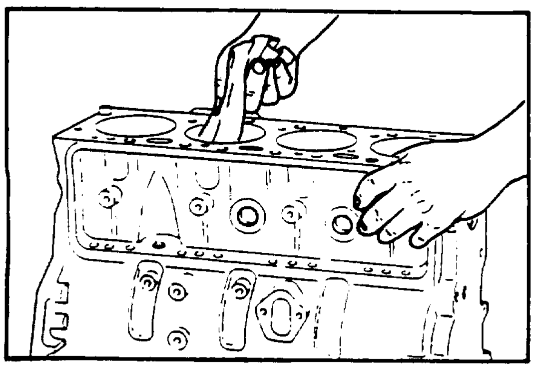
Operate the sizing hone similar to the Flexi-Hone.

Inspect the bore after 10 strokes.

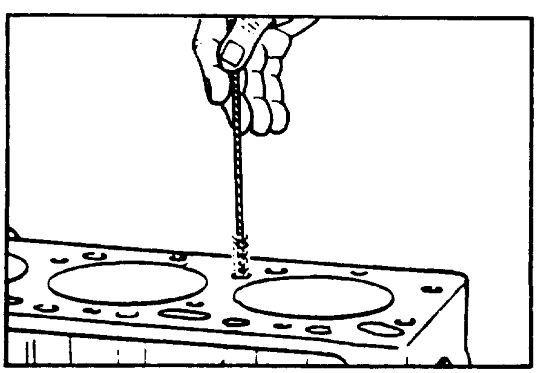


Immediately clean the cylinder bores with a strong solution of laundry detergent and hot water.

After rinsing, use compressed air to dry the block.



Check the bore cleanliness by wiping with a white, lint free, lightly oiled cloth. If grit residue is still present, re-clean.

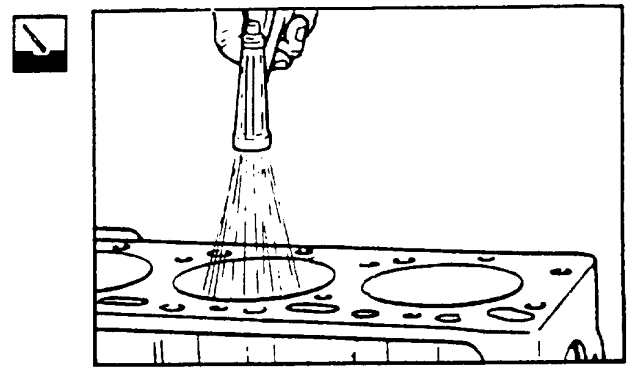


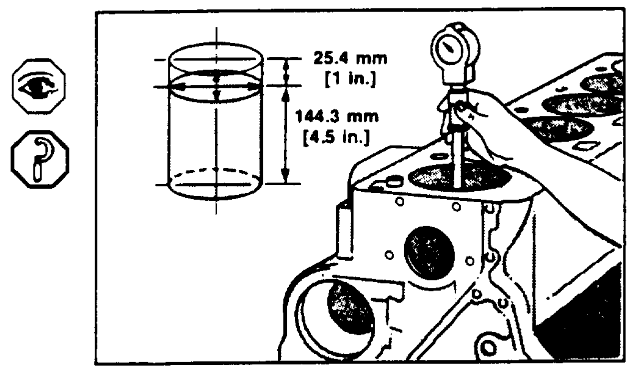
Cleaning Brush Kit, 3823614

Wash the block in solvent.

Use a brush to clean all oil passages.

After rinsing with clean solvent, use compressed air to dry the block.





Cylinder Block - Inspection

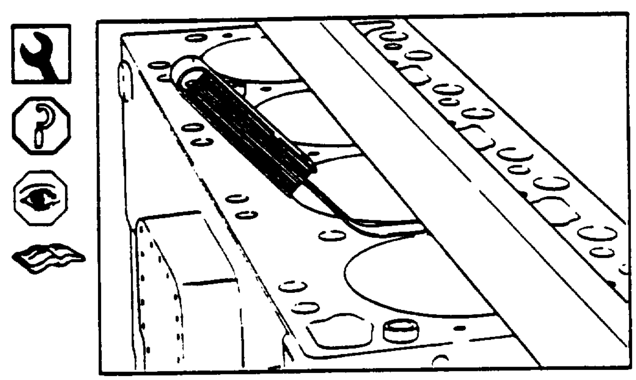
Inspect the cylinder bores for damage or excessive wear.

Measure the cylinder bores.

	Diameter	
mm		in
102.000	MIN	[4.0157]
102.116	MAX	[4.0203]

Out-of-Roundness: .038mm [.0015 in]
Taper: 0.76mm [.003 in]

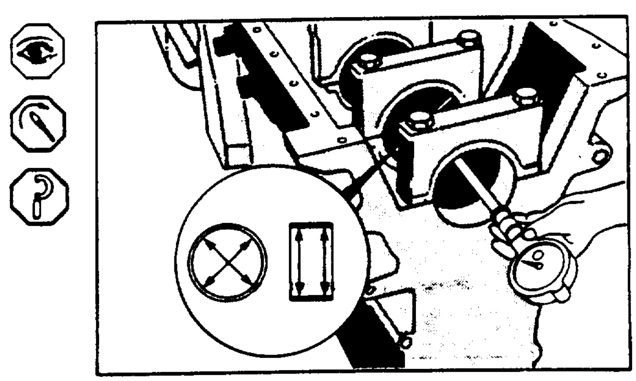
Oversize pistons and rings (0.5mm and 1.Omm over- size) are available for re-bored cylinder blocks.



Straight Edge and Feeler Gauge

Use a straight edge and feeler gauge to measure the overall flatness of the block. The overall flatness, end to end and side to side, must not exceed 0.75 mm [0.003 in].

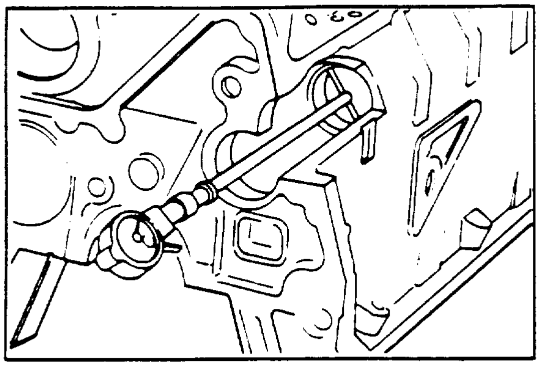
Visually inspect the combustion deck for any localized dips or imperfections. If present, the block deck must be reground.



Inspect the main bearing bores for damage or abnormal wear.

Install the main bearings and measure main bearing bore diameter with main bolts tightened to 176 N•m [130 ft-lb]. Record for later reference.

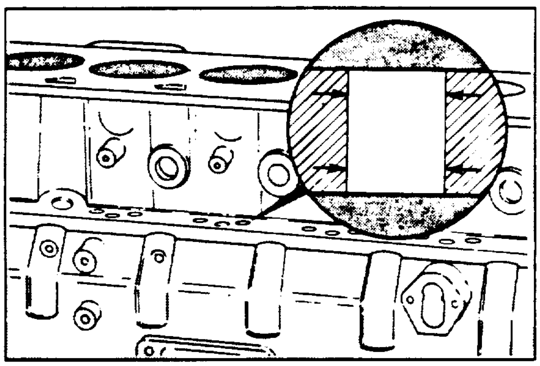
	Diameter	
mm		in
83.106	MAX	[2.2720]



Inspect the camshaft bores for scoring or excessive wear.
Measure the diameter of camshaft bores No. 2 through No. 5.

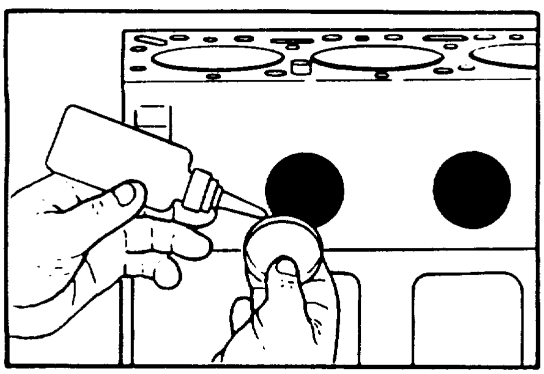
Diameter No. 2-5		
mm		**in**
54.164	MAX	[2.1324]

Service bushings are available and must be used if wear exceeds above dimensions.



Inspect the tappet bores for scoring or excessive wear.

Diameter		
mm		**in**
16.000	MIN	[0.630]
16.055	MAX	[0.632]



Cylinder Block Assembly
Expansion and Pipe Plug - Installation

All expansion plug bores in the block are machined to a standard english dimension (i.e., 11/16 in, 1-1/4 in, etc.).

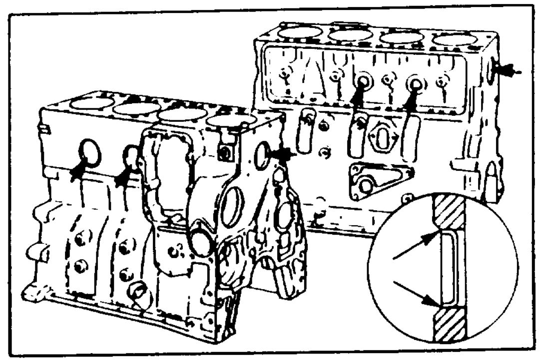
To achieve the correct press fit of the expansion plug in the bore, the expansion plug must be larger than the bore diameter and the expansion plug driver must be smaller than the bore diameter. Therefore, expansion plugs and their drivers are not made to a standard english dimension.

The plug drivers are called out by the dimension of the bore they are to be used on (i.e., a 1 in driver for 1" bore). The expansion plugs are called out by Cummins part number (a dimension is also listed for reference).

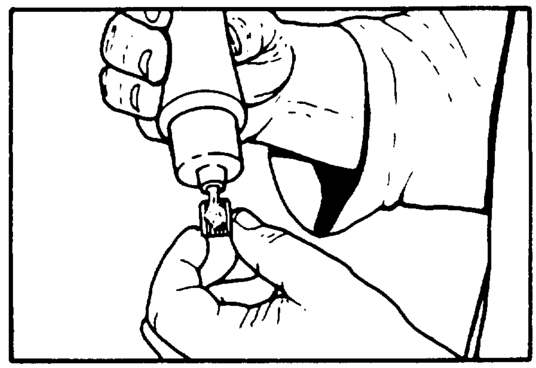
Apply a bead of Loctite™ 277 around the outside diameter of all expansion plugs before installing.

Drive all expansion plugs in until the outer edge is flush with the counter sink in the block

Refer to Page 5-290 for camshaft expansion plug installation.

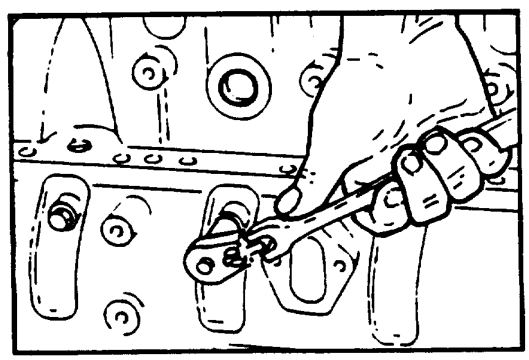


Apply a bead of liquid teflon sealant to pipe plugs.



Pipe Plug Torque Values

Size in Inches	**Torque (Onto Case Iron)**
1/8	8 N•m [6 ft-lb]
1/2	24 N•m [18 ft lb]

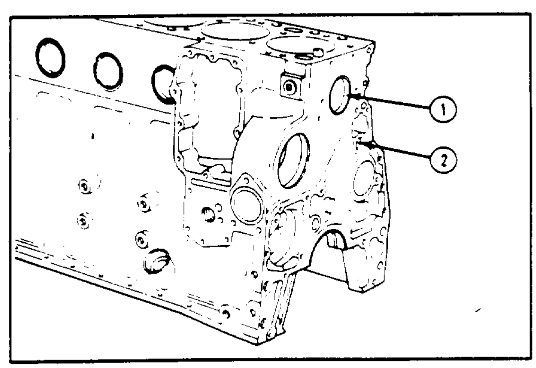


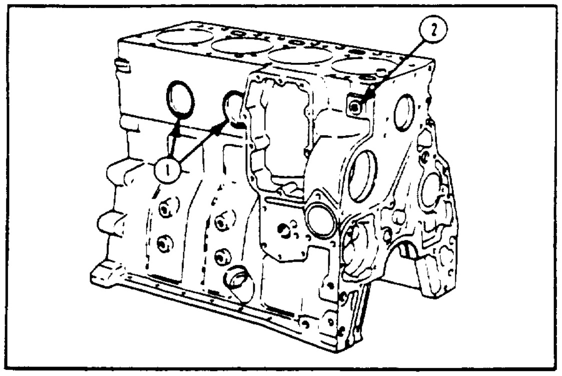
Driver Part No. 3823524 (Coolant Passages), Part No. 3823520 (Oil Rifle)

Expansion plug locations. Front of block.

1. Expansion Plug Part No. 3900965 (58.06 mm)

2. Expansion Plug Part No. 3900956 (17.73 mm)



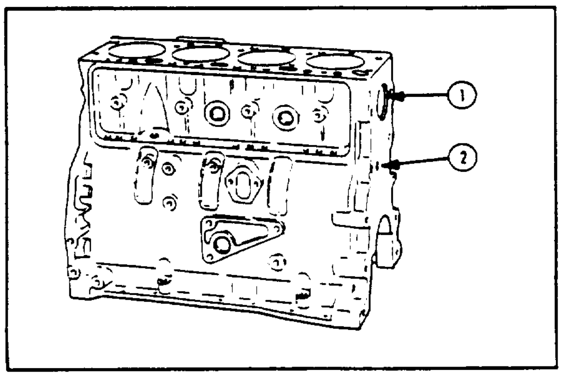


Driver Part No. 3823524 (Coolant Passages)

Pipe plug and cup plug locations. Right side of block.

1. Expansion Plug Part No. 3900965 (58.06 mm)

2. Pipe Plug, 0.50 in (1/2 in)

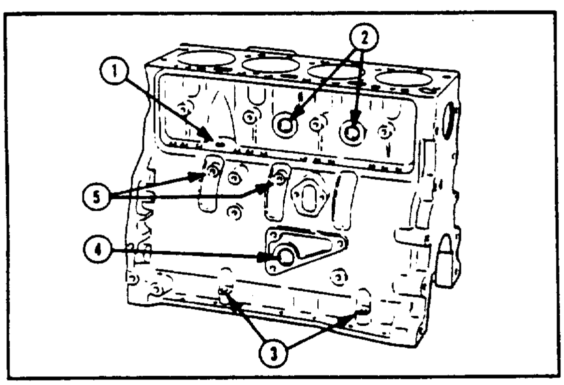


Driver Part No. 3823524 (Coolant Passages), Part No. 3823520 (Oil Rifle)

Expansion plug locations. Rear of block.

1. Expansion Plug Part No. 3900956 (17.73 mm)

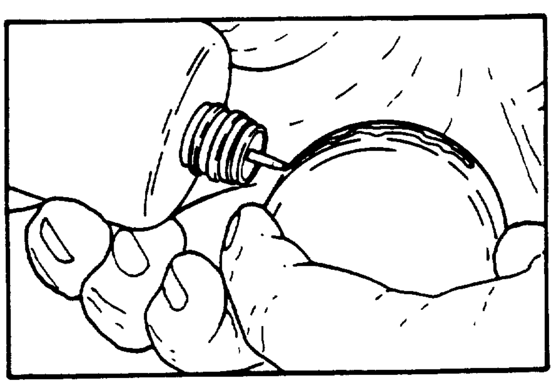
2. Expansion Plug Part No. 3900965 (58.06 mm)



Driver Part No. 3823520 (Oil Rifle), Part No. 3376816 (Crankcase), Part No. 3376817 (Alternate Oil Fill), Part No. 3822372 (Alternate Dipstick Holes)

Pipe plug and expansion plug locations. Left side of block.

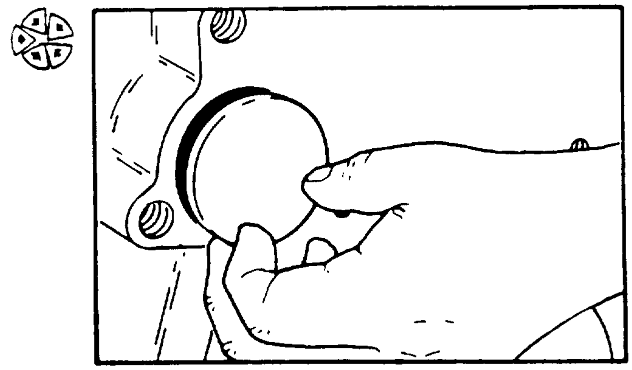
1. Expansion Plug Part No. 3900956 (17.73 mm)
2. Expansion Plug Part No. 3914035 (25.75 mm)
3. Expansion Plug Part No. 3900955 (9.80 mm)
4. Expansion Plug Part No. 3900958 (32.03 mm)
5. Pipe Plug, 0.1250 in (1/8) NPTF Hex Head



Camshaft Expansion Plug - Installation

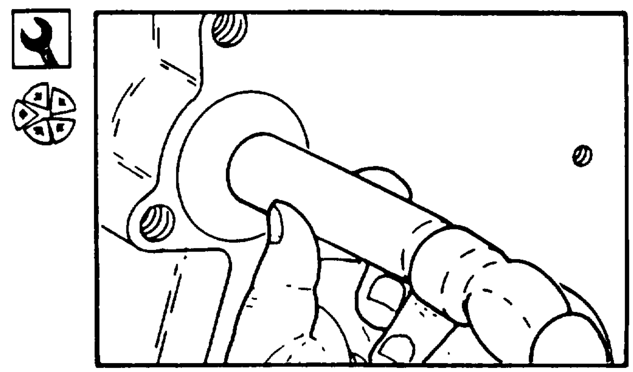
Apply a bead of Loctite ™ 277 around the outside diameter of the camshaft expansion plug.

Position the plug with the convex side out.

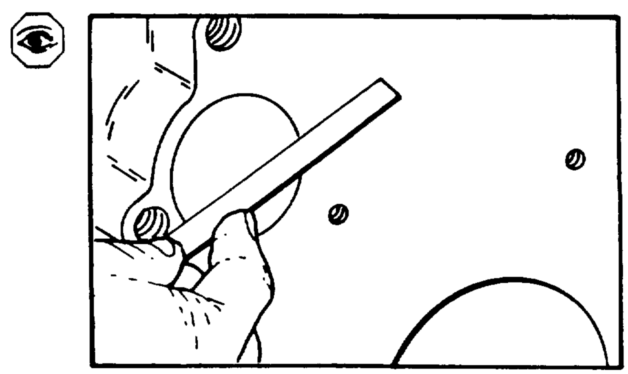


Large Drift, Hammer

Expand the plug with a large drift and a hammer.

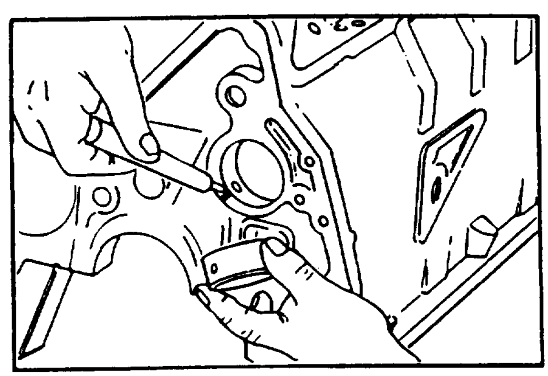


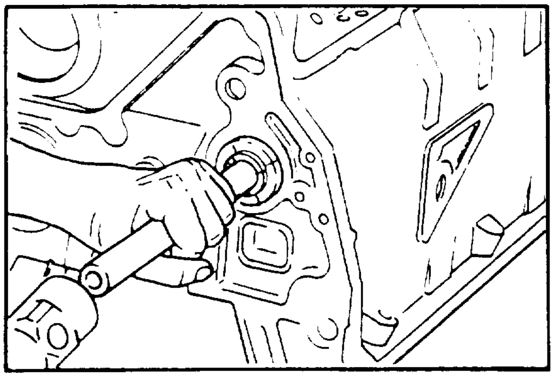
Expand the plug until the convex side is flush with the block.



Camshaft Bushing - Installation

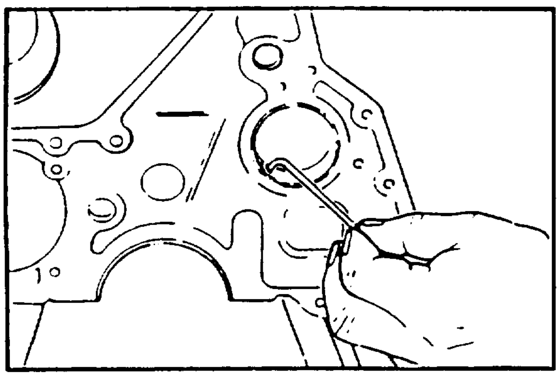
Mark the camshaft bushing and block to align the oil hole.





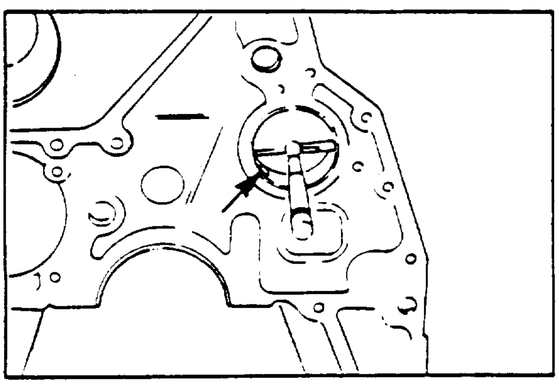
Universal Bushing Installation Tool

Install the camshaft bushing flush with the block.



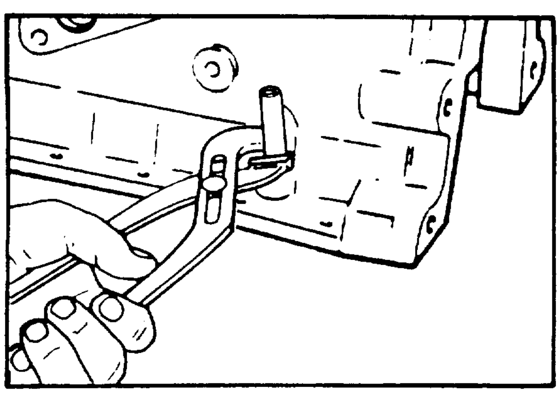
Be sure the oil hole is aligned.

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



Measure the installed camshaft bushing.

Camshaft Bushing Bore		
mm		**in**
54.107	MIN	2.1302
54.146	MAX	2.1317

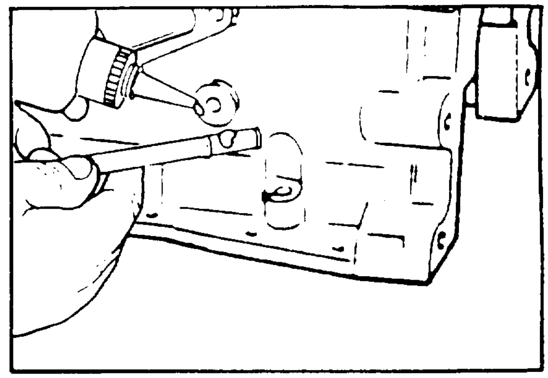


Dipstick Tube - Replacement

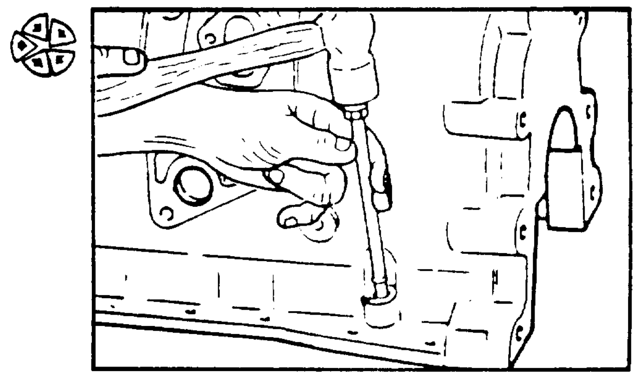
Pliers

If the dipstick tube is loose or damaged, remove it from the cylinder block.

Apply sealant, Part No. 3375068, to the new dipstick tube.

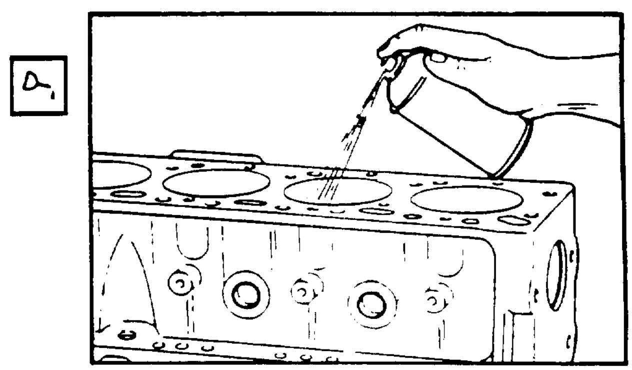


Use a hex head capscrew to drive the tube into the block.



Cylinder Block - Storing

If the block is not to be used immediately, lubricate all surfaces to prevent rusting.

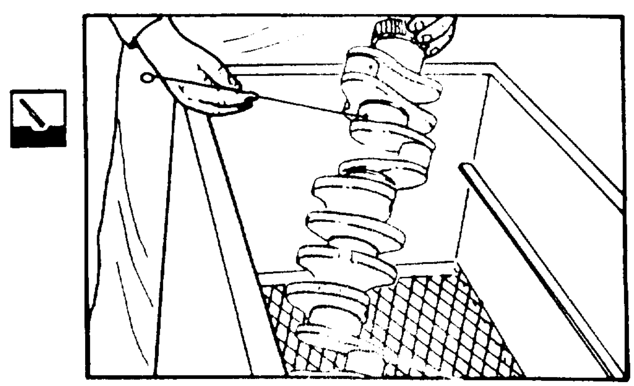


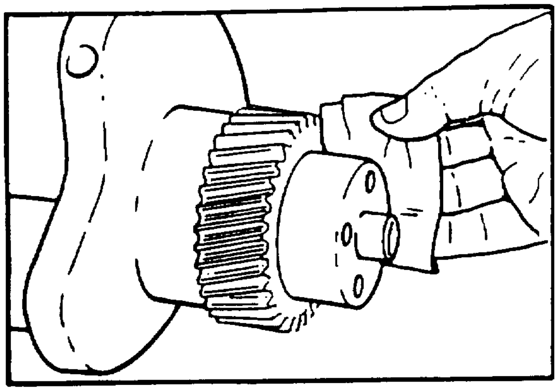
Crankshaft - Cleaning

Cleaning Brush Kit PIN 3823614

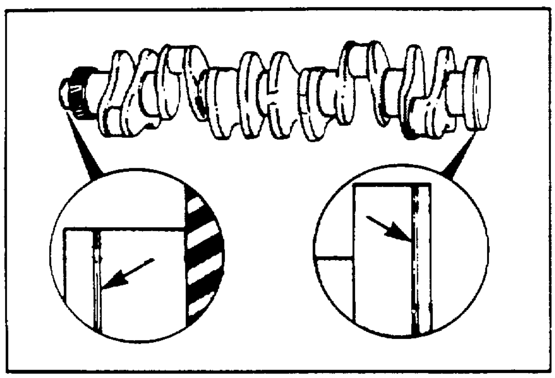
Clean the crankshaft oil drillings with a brush.

Rinse in clean solvent and use compressed air to dry.





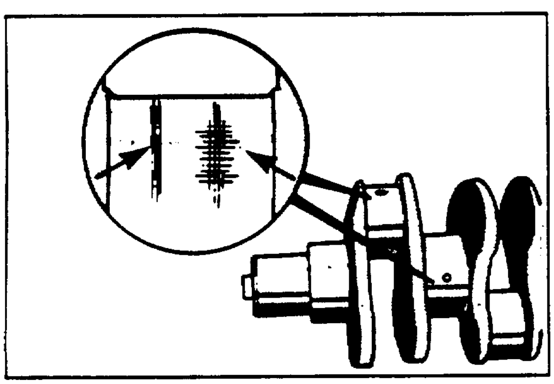
Clean the oil seal wear surfaces with diesel fuel and crocus cloth.



Crankshaft - Inspection

Inspect the crankshaft seals wear surfaces for scratches or grooving.

If shaft is grooved, install a wear sleeve.



Inspect the rod and main journals for deep scoring, over-heating, etc.

Determining Main Bearing Clearance

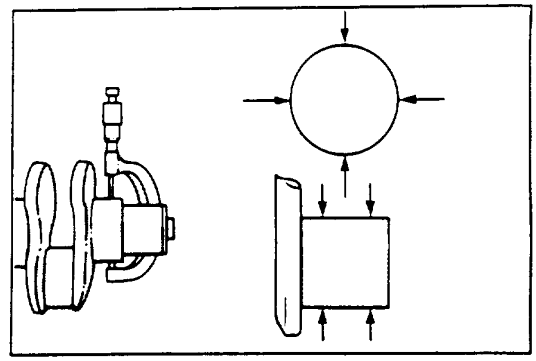
Measure the main journal diameters and determine main bearing clearance.

Main Bearing Journal Diameter		
mm		in
82.962	MIN	3.2662
83.013	MAX	3.2682

Out-of-Roundness: 0.050mm [0.002 in]
Taper: 0.013mm [0.0005 in]

Bearing Clearance = Main Bore Diameter with bearing installed minus (-) Crankshaft Main Journal Diameter.

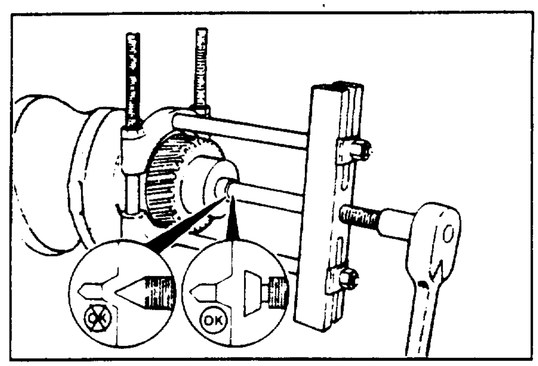
Maximum Bearing Clearance: 0.119mm [0.0047 in]



Crankshaft Gear - Replacement

Remove the crankshaft gear.

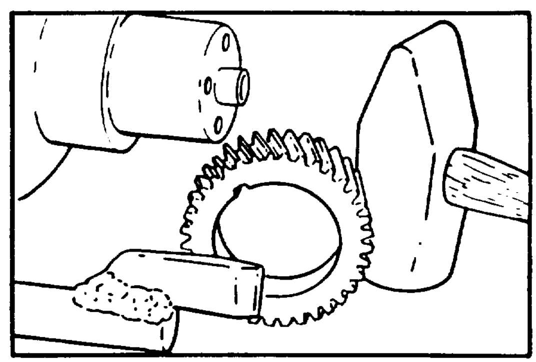
Use a heavy duty puller.



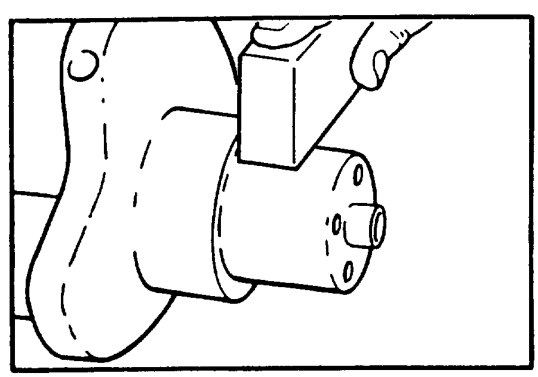
2 lb Steel Hammer, Gear Splitter Part No. 3823585

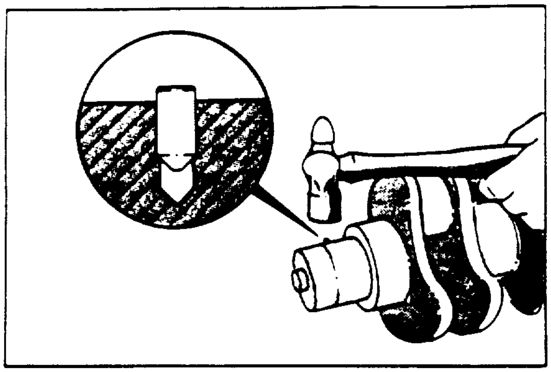
An optional tool is available to split the crankgear off of the crankshaft.

Service Tip: Always use a large steel hammer when splitting the crankshaft gear. Lead hammers absorb the shock required to break the gear.

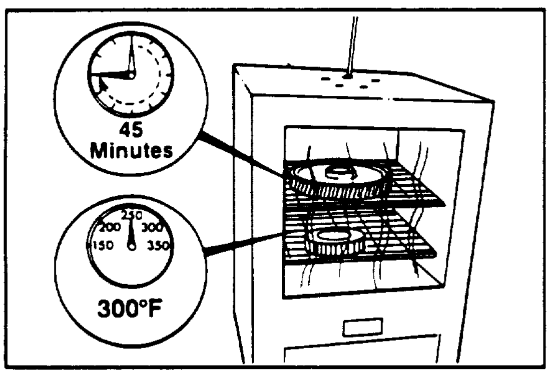


Remove all burrs and make sure the gear surface on the end of the crankshaft is smooth.



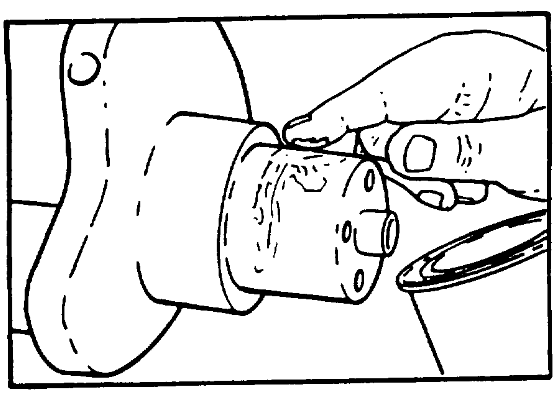


If previously removed, install the alignment pin until it bottoms.

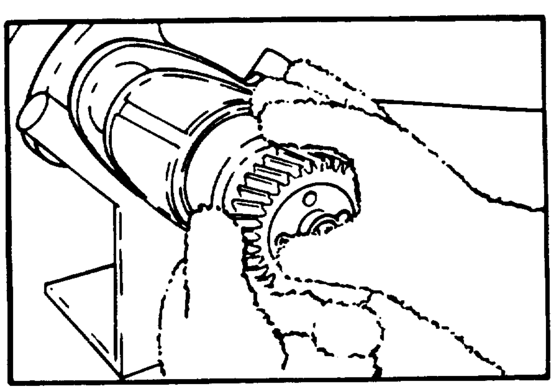


Caution: The gear will be permanently distorted if over-heated. The oven temperature should never exceed 177° C [350° F].

Heat the crankshaft gear in a preheated oven for 45 minutes at 148° C [300° F].



Apply a thin coating of lubricant to the nose of the crankshaft.

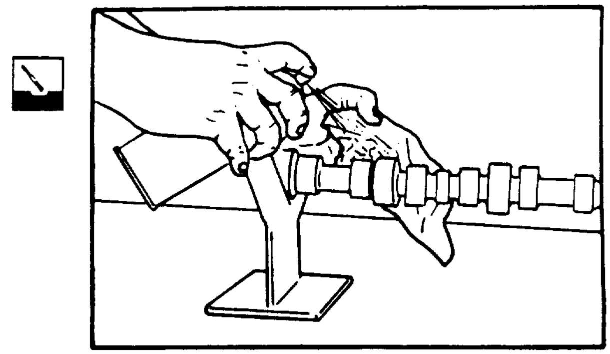


Warning: Wear protective gloves to prevent personal injury.

Install the hot gear up to the crankshaft shoulder with the timing mark out.

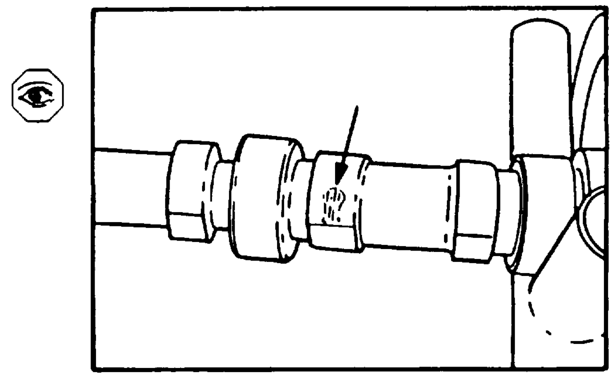
Camshaft - Cleaning

Wash the camshaft and gear with solvent and a lint free cloth.

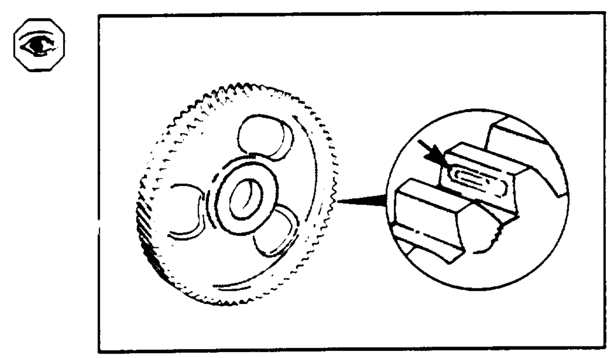


Camshaft and Gear - Inspection

Inspect the lift pump lobe, valve lobes and bearing journals for cracking, pitting or scoring.

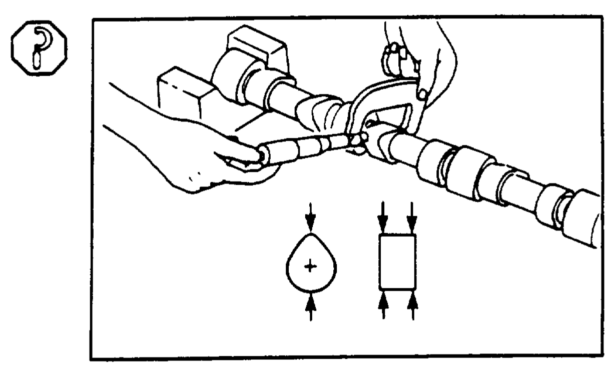


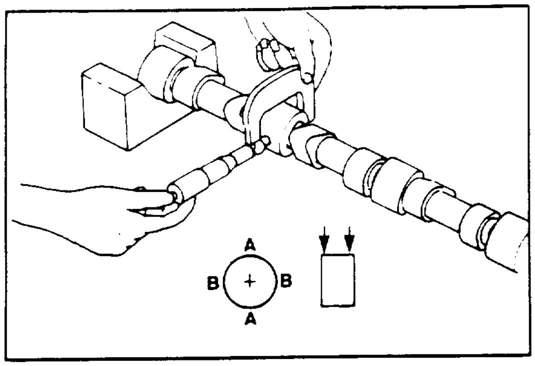
Inspect the gear teeth for pitting; look for cracks at the root of the teeth.



Measure the life pump and valve lobes.

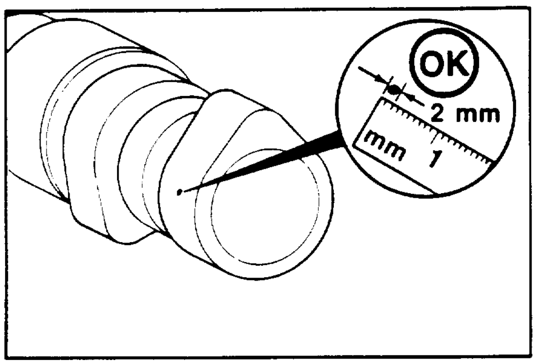
	Diameter at Peak of Lobe		
	mm		in
Intake	47.040	MIN	1.852
	47.492	MAX	1.870
Exhaust	46.770	MIN	1.841
	47.222	MAX	1.859
Lift Pump	35.50	MIN	1.398
	36.26	MAX	1.428





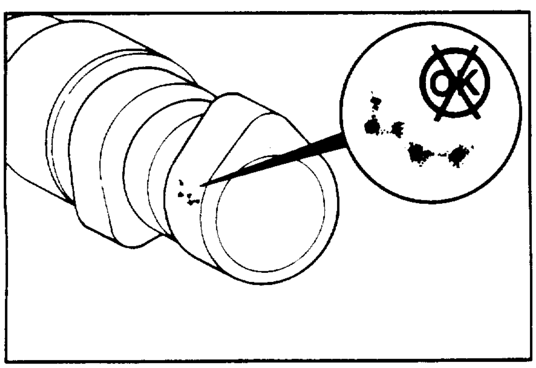
Measure the bearing journals.

Journal Diameter		
mm		in
53.962	MIN	2.1245
54.013	MAX	2.1265

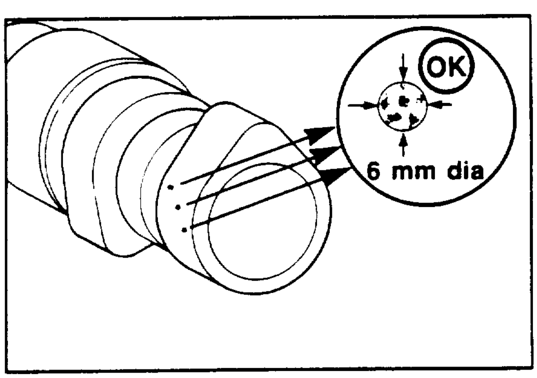


Pitting Reuse Criteria

A single pit should not be greater than the area of a 2 mm [.079 in] diameter circle.

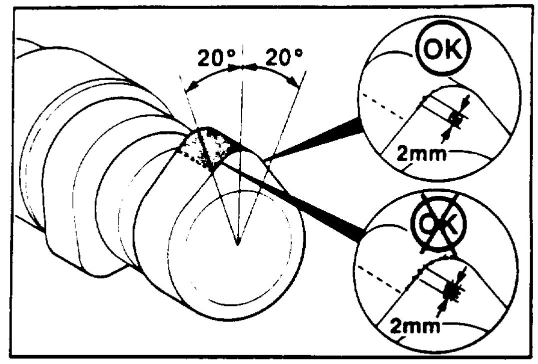


Interconnection of pits is not allowable and is treated as one pit.



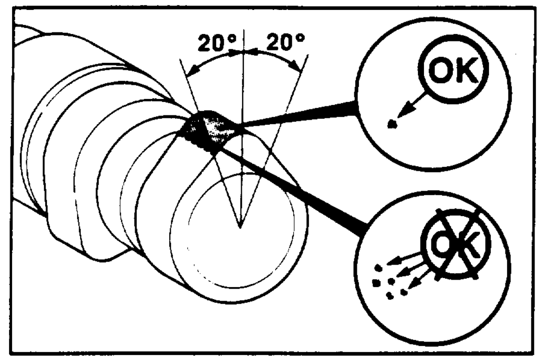
The total pits, when added together, should not exceed a circle of 6 mm [0.236 in].

Only one pit is allowed within + or - 20 degrees of the nose of the cam lobe.

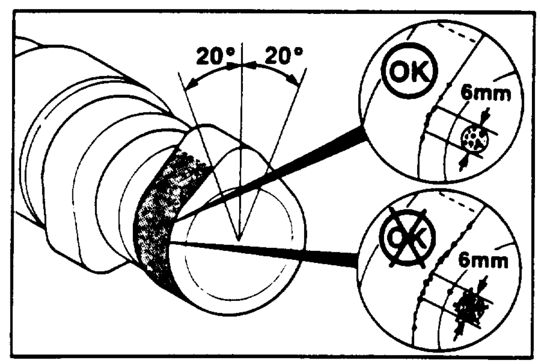


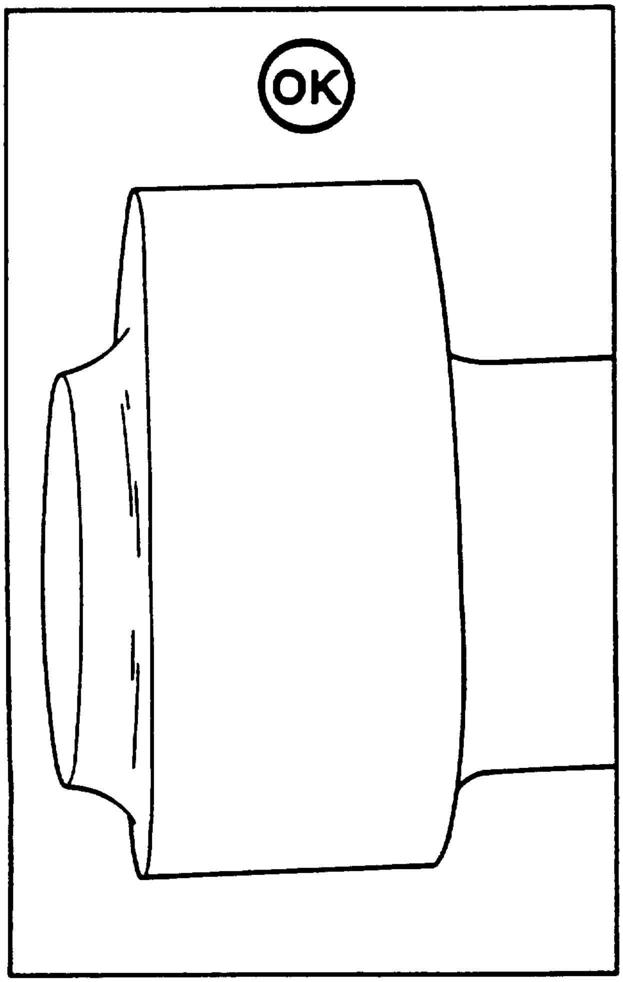
Edge Deterioration (Breakdown) Criteria

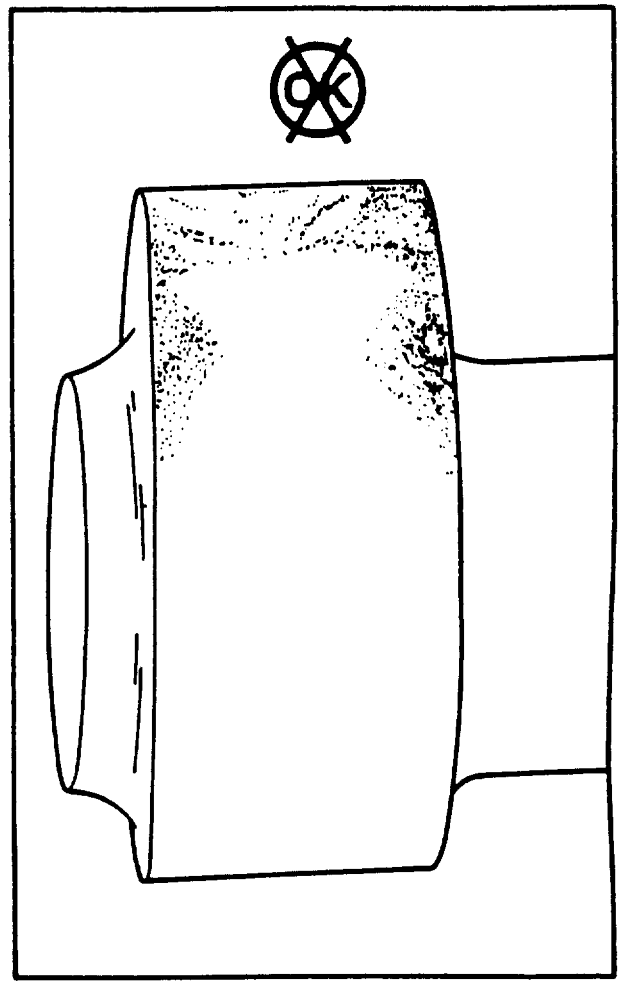
The area of edge deterioration should not be greater than the equivalent area of a 2 mm [0.079 in] circle within + or - 20 degrees of the nose of the cam lobe.



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.




OK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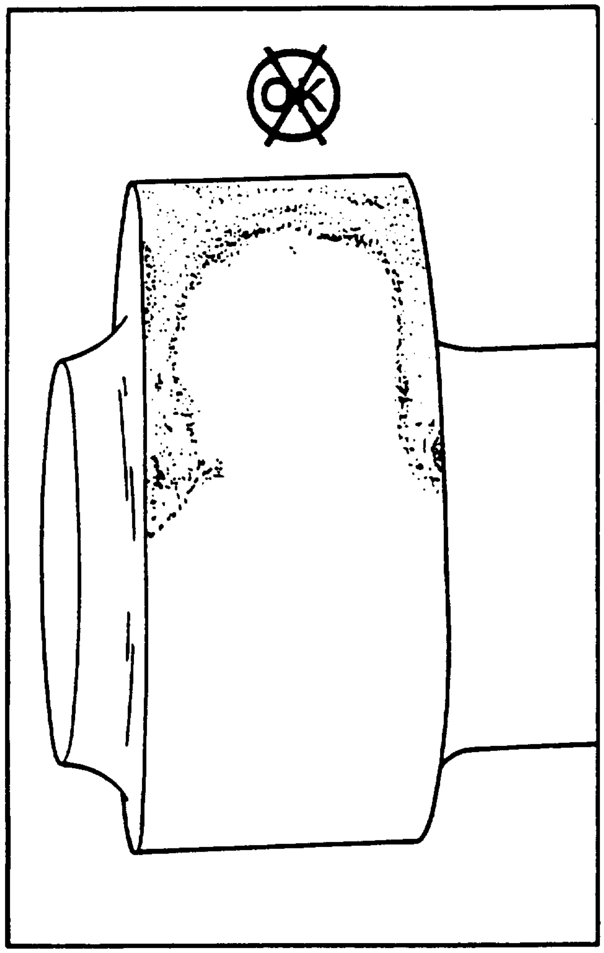
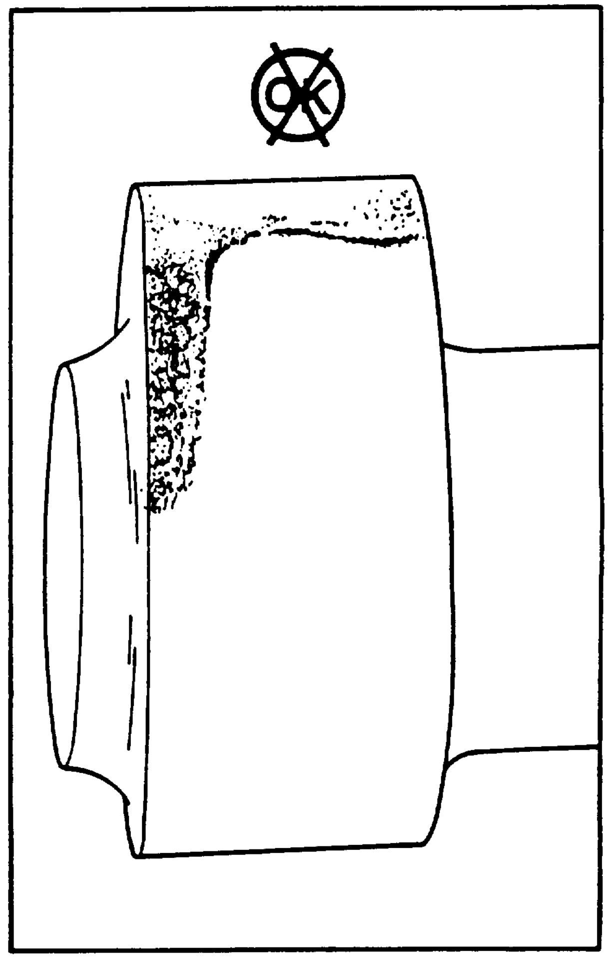
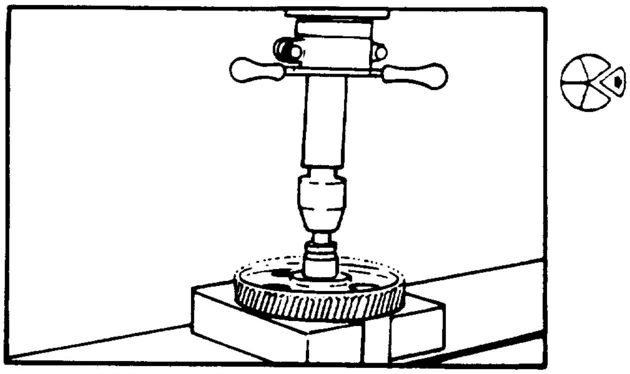
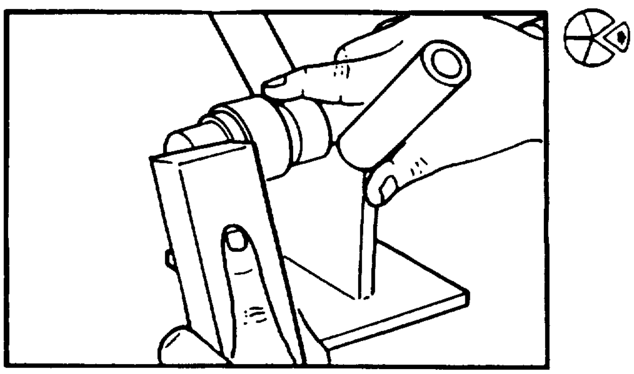

OK


OK

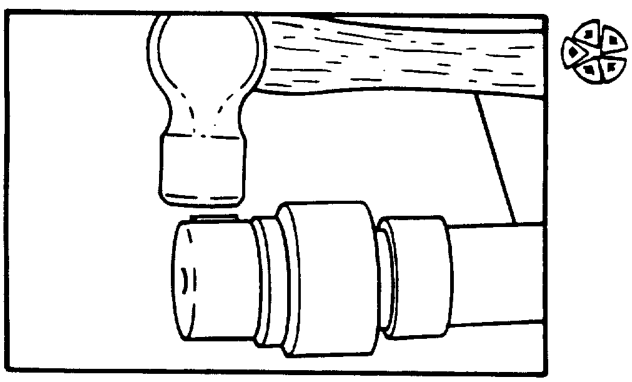
Camshaft Gear - Replacement



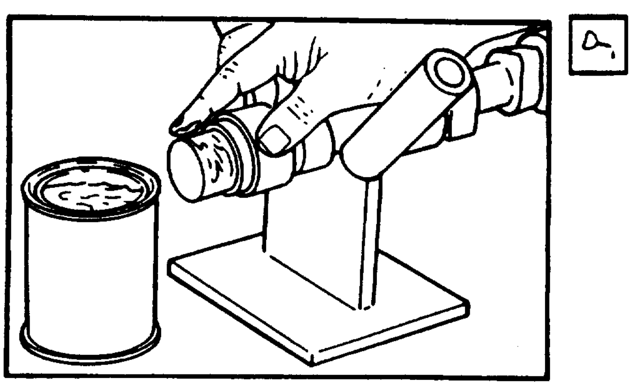
Remove the gear.



Remove all burrs and smooth any rough surfaces caused by removing the gear.



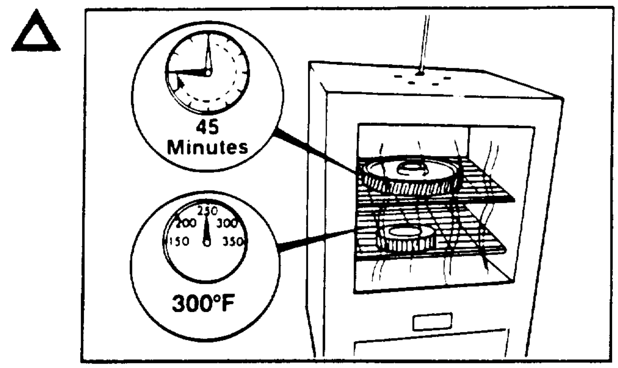
Install the key.



Lubricate the camshaft surface with Lubriplate 105.

Caution: The gear will be permanently distorted if over-heated. The oven temperature should never exceed 177° C [350° F].

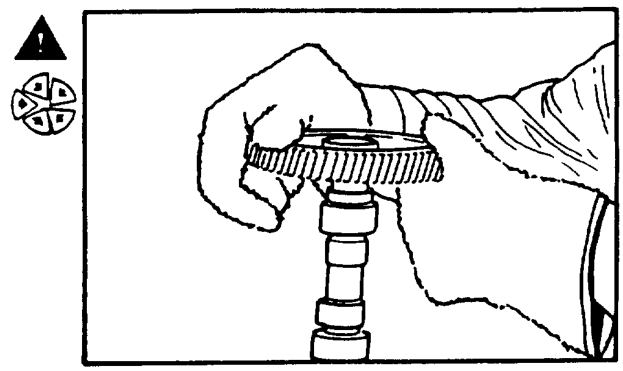
Heat the camshaft gear in a preheated oven at 149° C [300° F] for 45 minutes.



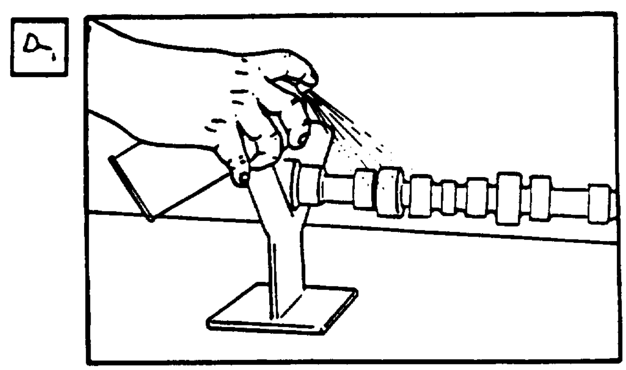
Wear protective gloves to prevent personal injury.

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

Be sure the gear is seated against the camshaft shoulder.

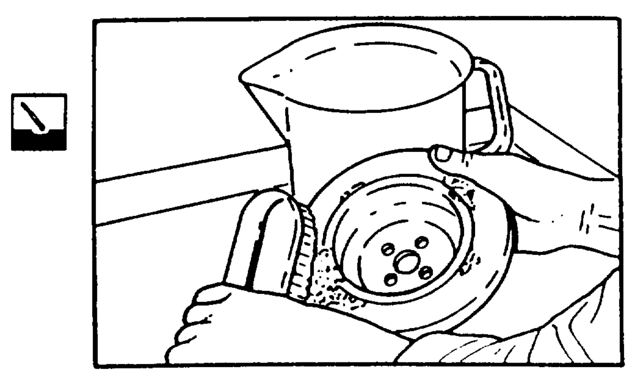


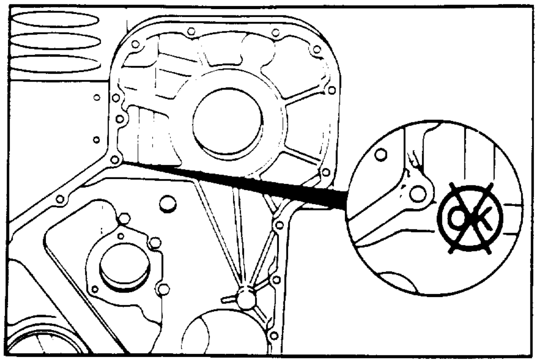
If the camshaft is not to be used immediately, lubricate the lobes and journals to prevent rusting.



Vibration Damper - Cleaning and Inspection

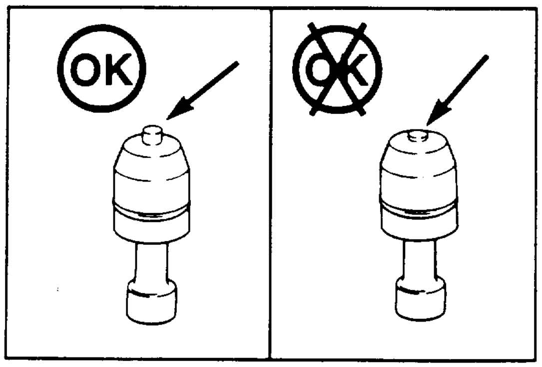
Clean the damper with hot soapy water and a brush. After rinsing with clean water, use compressed air to dry.



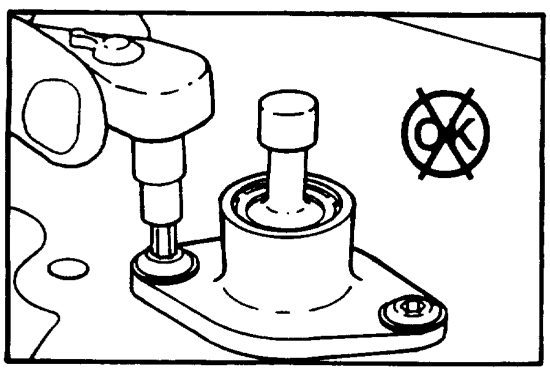


Gear Housing and Timing Pin Assembly - Inspection

Visually inspect the gear housing for cracks or damaged sealing surfaces.

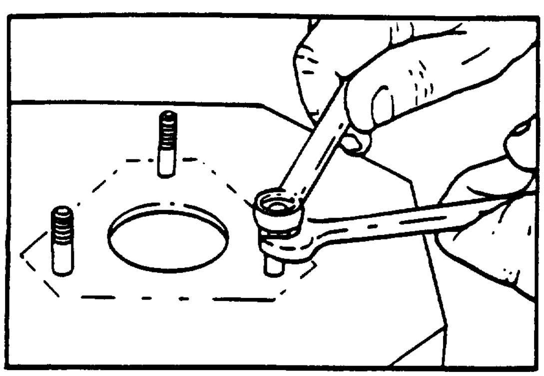


Inspect the timing pin housing and pin for damage.



Gear Housing - Disassembly

Do not remove the timing pin housing unless it is damaged or leaking, or the gear housing is being replaced. Refer to Page 5-210 for replacement procedures.



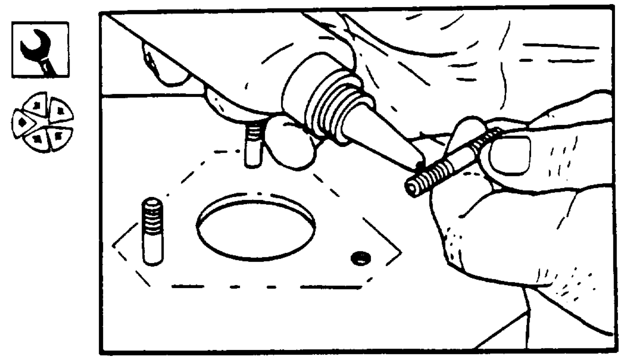
Fuel Pump Stud - Replacement

13 mm

To install or remove fuel pump studs, use two nuts jam locked onto the stud.

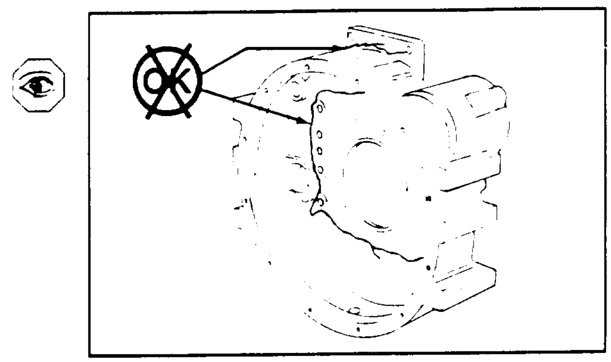
13 mm

If the fuel pump studs are damaged or being installed in a new housing, coat the threads with Loctite™ 601 and use two jam locked nuts to install and remove.

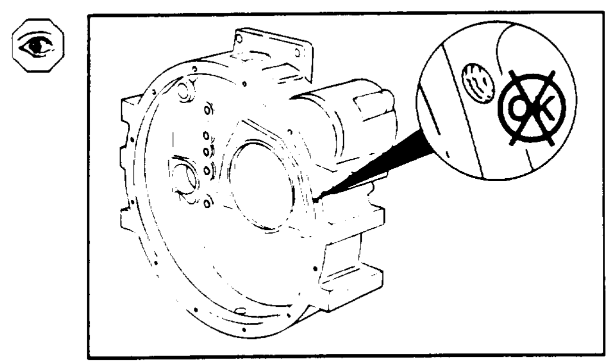


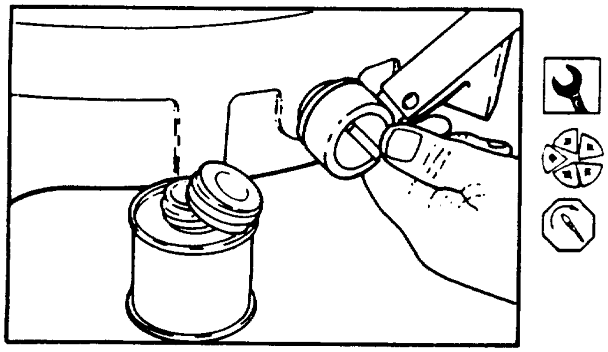
Flywheel Housing Inspection

Inspect the flywheel housing for cracks, especially in the bolt pattern area.



Inspect for damaged threads commonly caused by cross threaded capscrews or installing an incorrect capscrew. Heli-coils are available to repair damaged threads.



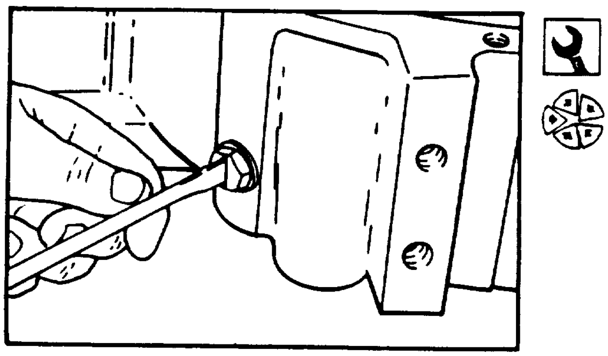


Flywheel Housing Assembly

3/8" square drive

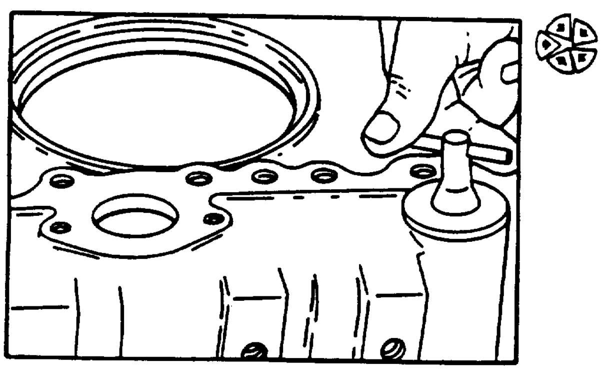
Coat the drain plug with KW Copper Coats ™ and install.

Tighten to 47 N•m [42 ft-lbs]



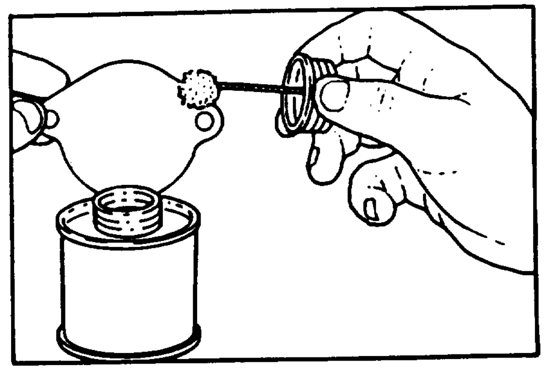
Screwdriver

Install the plastic plug in the tach probe hole.



Install the expanding plug in the barring tool hole.

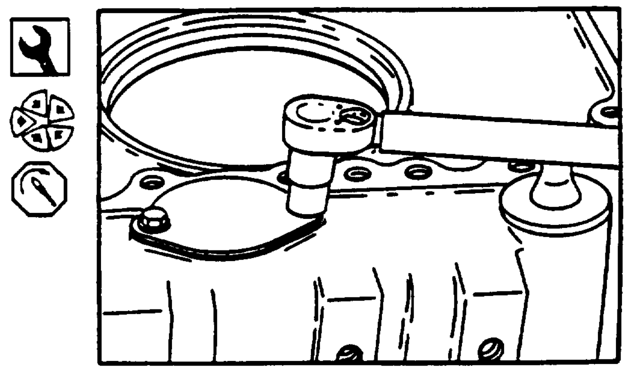
Coat both sides of the inspection plate gasket with KW Copper Coat™.



13 mm

Install the inspection plate.

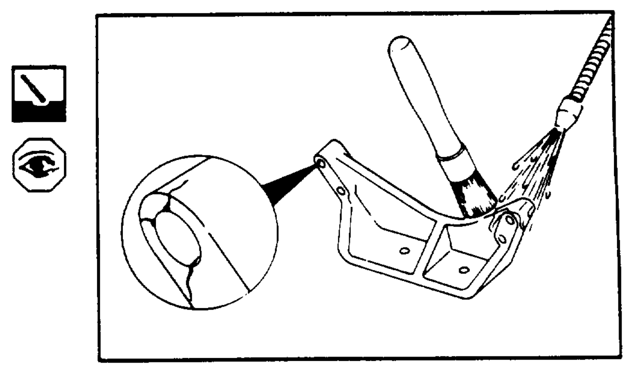
Tighten to 24 N•m [18 ft-lbs].



Front Support - Cleaning and Inspection

Use solvent. Clean the part.

Check the part for cracks or damage.



Section 12. Engine Replacement and Testing

Engine Replacement and Testing

Engine Replacement

If the engine cannot be repaired in chassis, use the following guidelines for removal and installation of the engine.

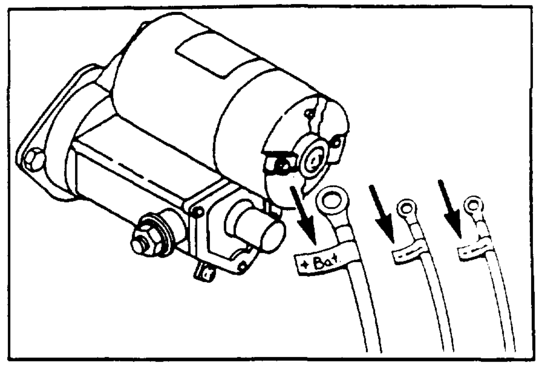
△ **Caution: Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.**

Engine Removal

Preparatory Steps:

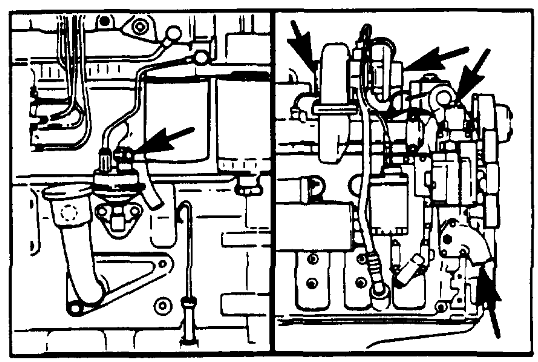
- Disconnect the air intake and exhaust pipes.
- Disconnect the throttle linkage from the control lever.
- Do not remove the control lever from the injection pump.
- Disconnect all engine driven accessories.
- Disconnect the drive units from the flywheel.
- Drain the coolant.
- Drain the lubricating oil.
- Remove the chassis parts as necessary to lift the engine from the equipment.

Disconnect all electrical connections. Put tags on the connections to identify their locations.

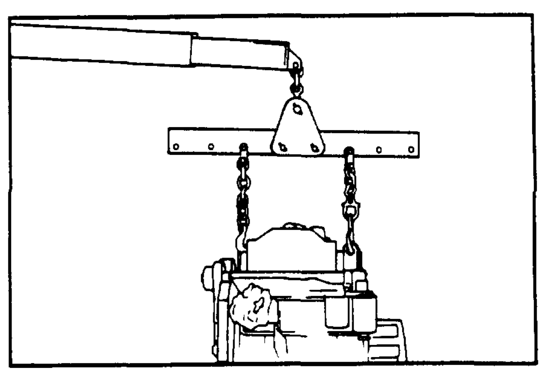


Disconnect all lines including fuel lines to the lift pump and fuel return. Use tags to identify the lines.

Put a cover or tape over all engine openings.



Use the lifting eyes to lift the engine. Apply tension to the hoist to hold the engine while you disconnect the engine mounts from the chassis.



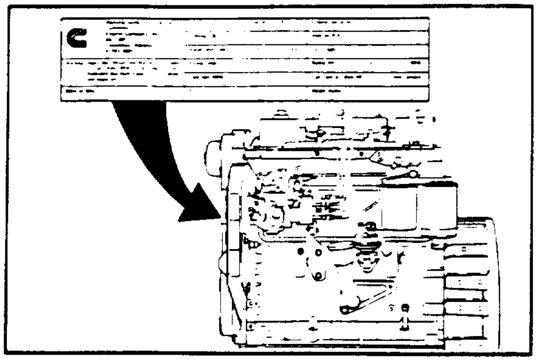
Lift the engine from the equipment.

Dry Engine Weight:

4BTA3.9	329 Kg	[725 lb]
6BT5.9	399 Kg	[880 lb]

Note: Remove all accessories and brackets not previously removed to use with the replacement engine.

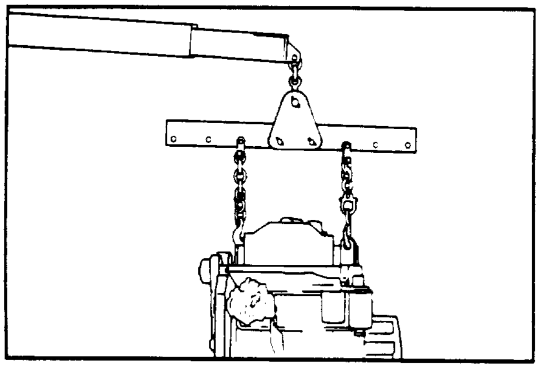
Engine Installation



Caution: Do not exceed the torque value for the engine supports.

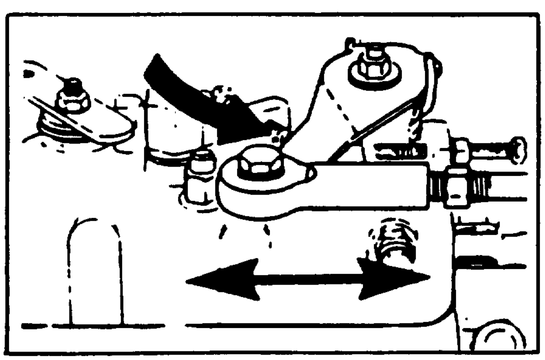
Check the data plate to verify that the replacement engine is the same model and rating as the engine that was removed.

Note: Install all accessories and brackets that had been removed from the previous engine.
Torque Value: 77 N•n [57 ft-lbs]



Use the lifting eyes to lift the engine. Keep tension on the hoist while you align the engine in the chassis and tighten the engine mounts.

Connect the engine and chassis parts in the reverse order of removal.



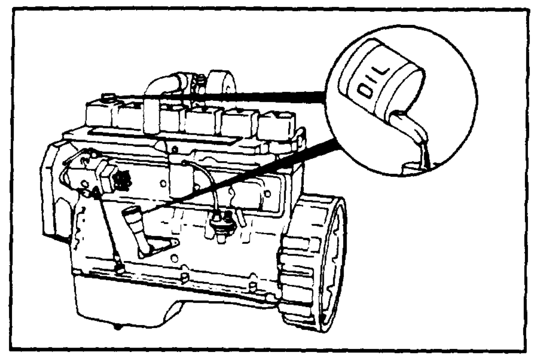
When connecting the cable/rod to the control lever, adjust the length so the lever has stop-to-stop movement.

Note: Make sure the air intake and exhaust pipe connec tions are tight and free of leaks

Fill the engine with the required amount of lubricating oil.

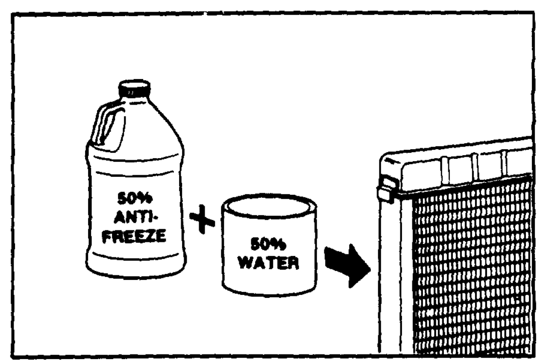
<u>Four Cylinder</u>
9.5L
[10 U.S. Qt]

Note: Check the oil level after the engine has run for 2 to 3 minutes. Oil held in the oil filter and oil passages will cause the oil level in the oil pan to lower.

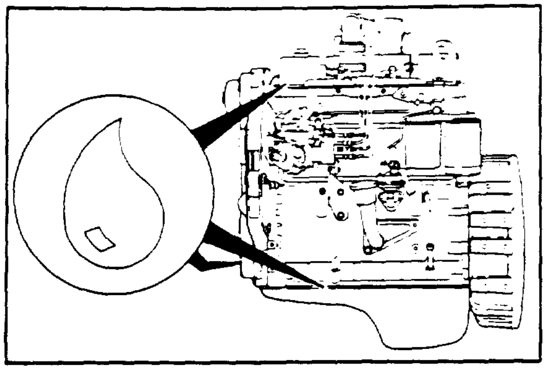


Fill the cooling system with a mixture of 50% water and 50% ethylene-glycol base antifreeze.

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



Engine Only Coolant Capacity
Litres
[U.S. Quarts]
<u>4B</u>
7
[7.4]



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

Engine Testing

Verify engine performance by performing an in-chassis check.

Operating Conditions for Run-In and Test

Measurement	Limit(s)
Coolant Temperature	88° C [190° F] Maximum
Lubricating Oil Temperature	121° C [250° F] Maximum
Lubricating Oil Pressure	241 kPa [35 psi] Minimum
Air Inlet Temperature	38° C [100° F] Maximum
Air Inlet Restriction	25.4cm [10 in.] H_2O Maximum
Boost Pressure	50.8cm [20 in.] Hg Minimum
	66cm 126 in.] Hg Maximum
Exhaust Temperature	700° C [1290° F] Maximum

Smoke	
Bosch Smoke Meter	2.5 Units Maximum
Celesco Smoke Meter	4% Opacity Maximum

Blowby Limits

The following table gives the values of blow-by that should be seen on the B Series engines. These blow-by values have been calculated on amount of displacement of the engine, volumetric efficiency, and cylinder pressure.

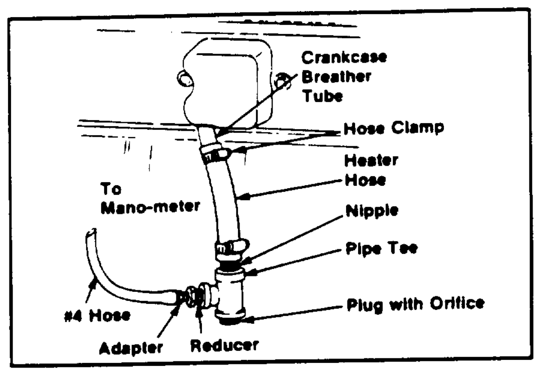
Engine Model	Speed RPM	New Limit (Litres/Minute)	Worn Limit (Litres/Minute)
4B	2200	18	36
4B	2500	20	40
4B	2800	23	46

Note: The blow-by values are for 100 percent load at the given speed. The B Series engines are measured using a 5.613 mm [0.221 in] diameter orifice.

Blowby Measurement

Blowby is generally recorded in Liters/Minute, but a water manometer may be used to measure blowby from the breather tube after fabricating the following adaptation:

1. Plug the end of the straight portion of a pipe tee.
2. Drill a 5.613 mm [0.221 in] orifice in the plug.
3. Connect the open straight portion of the pipe tee to the breather tube.
4. Connect a water manometer to the 90 degree outlet.
5. Use the Blowby Conversion Chart to convert the manometer reading to litres/minute.



Blowby Conversion Chart (5.613 mm [0.221 in] Orifice)

Inches of Water	Litres/Minute	Inches of Water	Litres/Minute
1	27	19	121
2	40	20	124
3	49	21	128
4	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 Run-In and Test in the Chassis

B Series Engine Rating Chart

Engine Model	Rating Hp/RPM	Torque ft-lb/RPM	Torque ft-lb/RPM
4B3.9	52/1500	182/1500	- -
	61/1800	177/1800	- -
	64/2200	153/2200	165/1200
	69/2100	172/2100	184/1200
	71/2200	169/2200	184/1200
	73/2300	167/2300	184/1200
	76/2500	160/2500	184/1200

Engine Run-In and Test in the Chassis

Perform the run-in and test as follows:

1. Make sure that the fuel solenoid is in the "OFF" position or disconnected.
2. Crank the engine to establish oil pressure on the gauge.

△ **Caution: Do not engage the starter for more than 30 seconds at a time, wait two (2) minutes between engagements.**

3. Reconnect the fuel solenoid if disconnected and move to the "RUN" position.

   Note: Bleeding of the fuel system may be required to start the engine.
4. Start the engine and run at 1000-1200 RPM for 30 minutes. Observe the oil pressure and water temperature. If oil pressure drops below 103 kPa [15 psi], stop the engine and troubleshoot the lubrication system. If water temperature exceeds 88^o C [190^o F], stop the engine and allow to cool, then repeat step 4. If overheating continued, troubleshoot the cooling system.
5. After completing Step 4, stop the engine and inspect for leaks.
6. Restart the engine and test drive the vehicle at approximately 1/3 throttle in "Drive" or "High" gear. Periodically, open the throttle and accelerate to governed RPM and decelerate rapidly. Repeat this procedure at least 10 times.

   For industrial engines, lightly load the engine with driven accessory and accelerate as above.

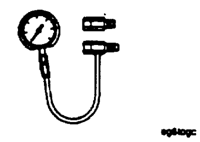
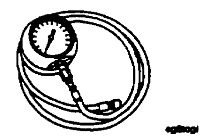
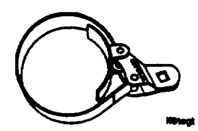
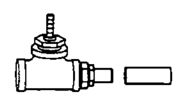
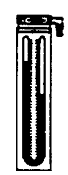
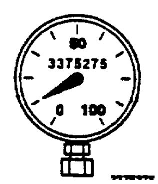
The engine should be operated normally, but not at continuous high speeds and loads for the first 500 miles or 20 hours. Occasional quick acceleration followed by quick deceleration during this period is beneficial to engine break in.

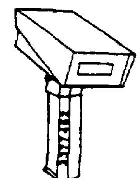
Change the oil and filters after 500 miles or 20 hours of operation. Follow oil specification recommended in the Operator's Manual.

Section 13. Engine Testing

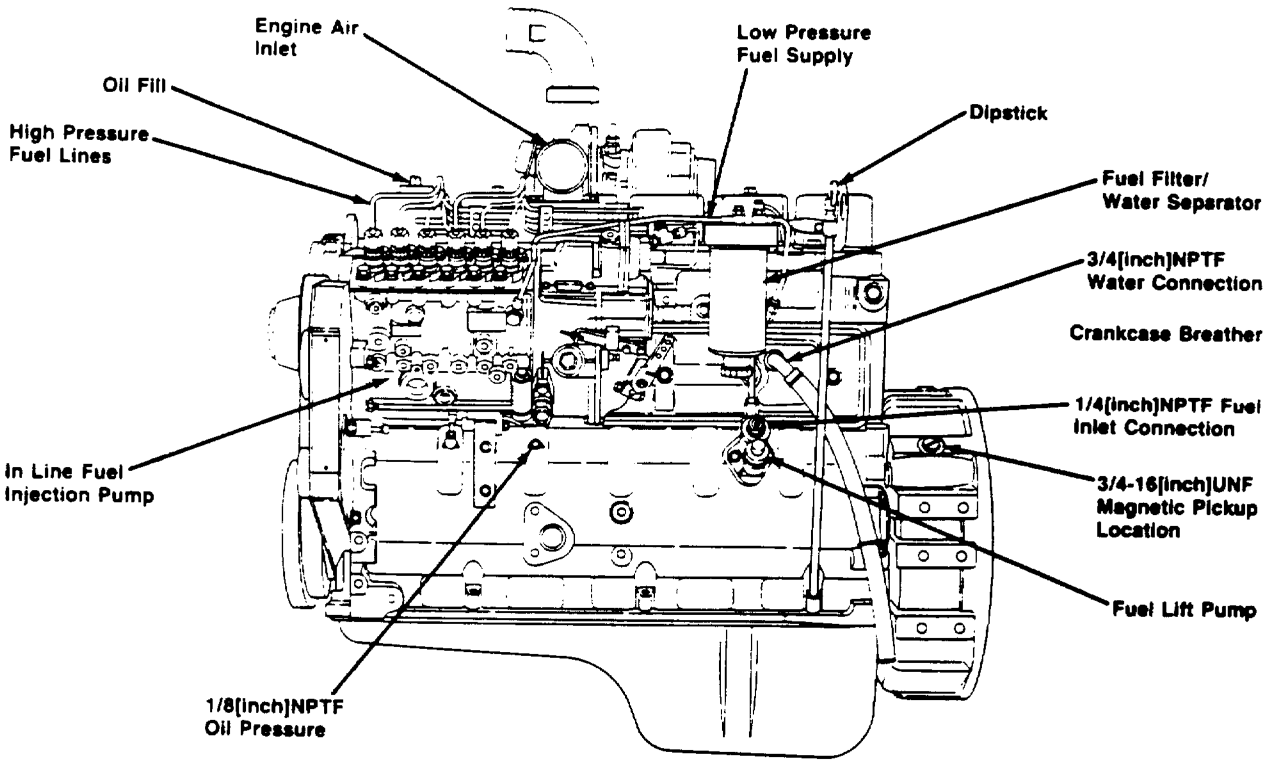
Engine Testing - Service Tools

The following special tools are recommended for testing the engine. Use of the tool is shown on the appropriate procedure.

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-424-12, are used to perform the test.	
ST-1 273	**Pressure Gauge** Use to measure the engine intake manifold pressure.	
3375049	**Oil Filter Wrench** Use to remove or tighten spin-on lubricating oil or fuel filters.	
3822476	**Blowby Checking Tool** Use to check engine crankcase blowby.	
ST-11 1-3	**Water Manometer** Used with the blowby check tool to measure engine crankcase pressure.	
3375275	**Pressure Gauge (0-160 psi)** Used to measure lubricating oil pressure.	

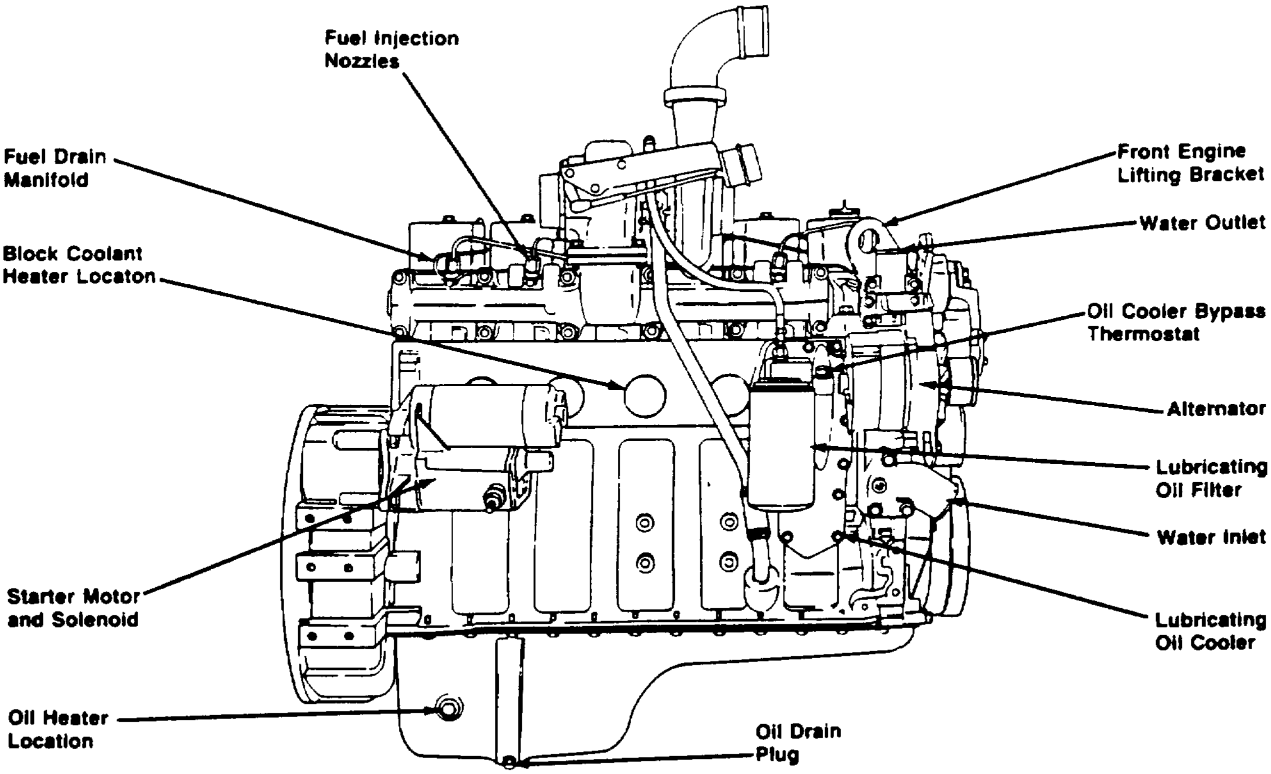
Tool No.	Tool Description	Tool Illustration
3377462	**Digital Optical Tachometer** Used to measure engine speed (RPM).	

Engine Testing - Engine Side Views



Fuel Pump Side

Engine Testing - Engine Side Views



Exhaust Side

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 specifications 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)

- Industrial.................... 76 mm Hg [3.0 in. Hg]
- EPA Certified.................... 11 4 mm Hg [4.5 in. Hg]

Blowby** (at Given Speed, 100% Load)

	New (L/Min)	**Worn (L/Min)**
4B @ 2200	18	36
4B @ 2500	20	40
4B @ 2800	23	46

** 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.

Oil Pressure

- Low Idle (minimum allowable)....................69 kPa [10 psi]
- Rated Speed (minimum allowable) ....207 kPa [30 psi]

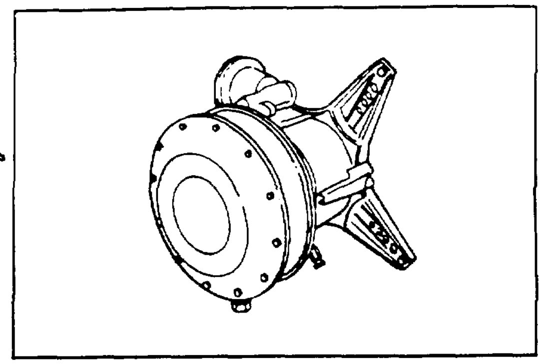
Fuel Filter Restriction (Maximum)

- Dirty Filter.................... 89 mm Hg [3.5 in. Hg]

Fuel Return Restriction (Maximum)....................35 kPa [5 psi]

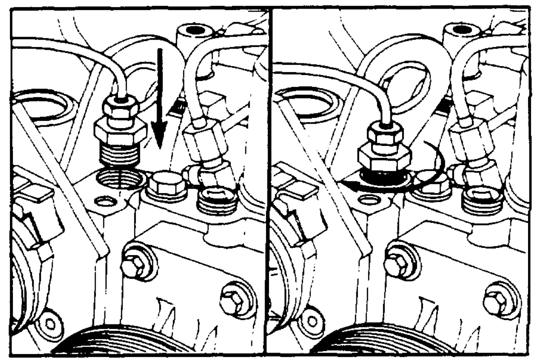
*** Due to variations in ratings of different engine models, refer to the specific engine data sheet for the particular engine model being tested.**

Engine Dynamometer Test - Installation of the Engine (14-01)

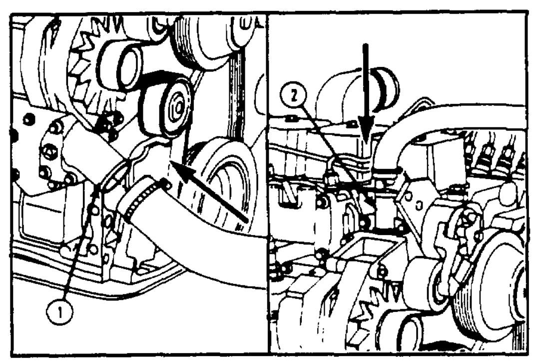


Use engine lifting fixture, Part No. ST-125, to install the engine to the test stand. Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

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 match the restrictions of the dynamometer.



Install the coolant temperature sensor.
Minimum Gauge Capacity: 107°C [225° F]

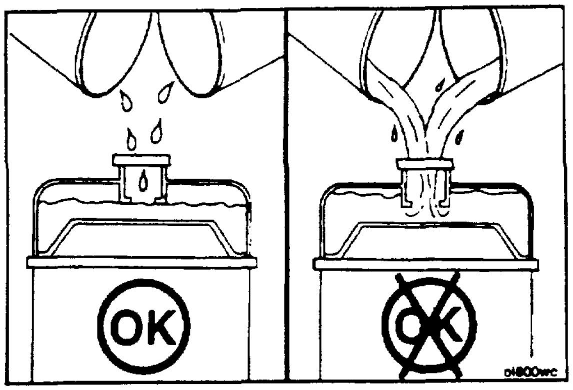


Connect the coolant supply to the water inlet connection (1).

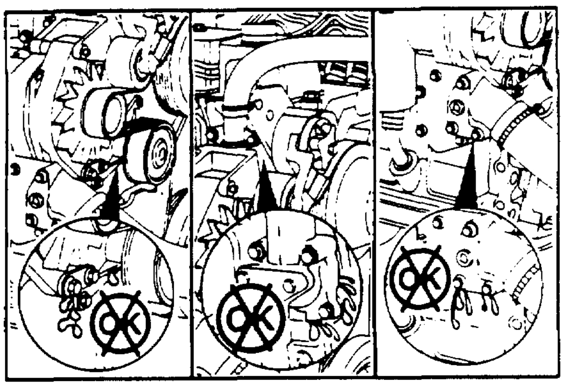
Connect the coolant return to the water outlet connection (2).

Install the drain plugs, close all the water drain cocks, and make sure all the clamps and fittings are tight.

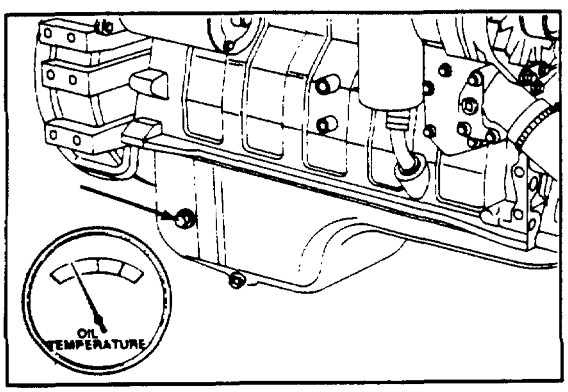
Connect the vent tube to the vent connection on the thermostat housing.



Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank.



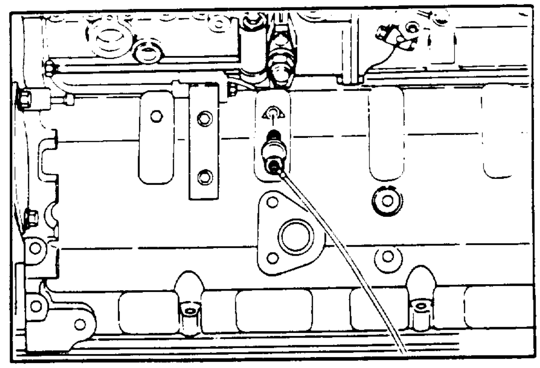
Inspect the engine for coolant leaks at connections, fittings, plates, and plugs. Repair as necessary.



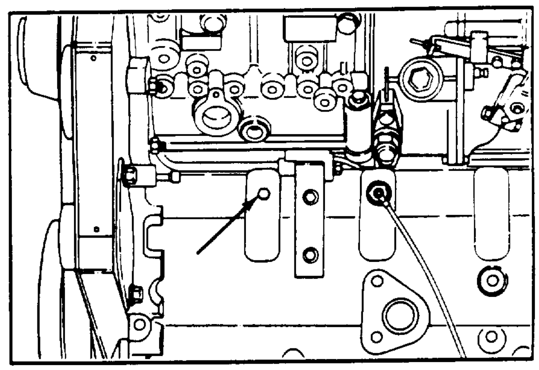
Attach the lubricating oil temperature sensor in one of the locations on the side of the engine as shown.

Minimum Gauge Capacity: 150° C [300° F]

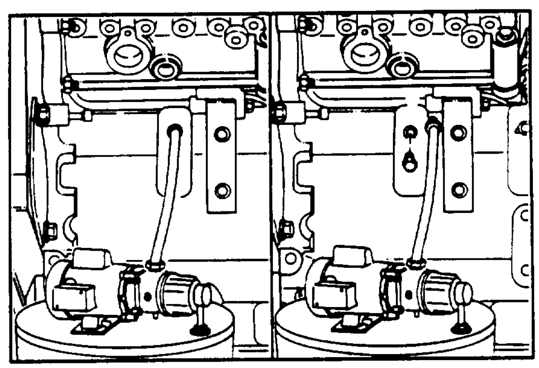
Attach the lubricating oil pressure sensor to the main oil rifle drilling in the cylinder block.
Minimum Gauge Capacity: 1034 kPa [150 psi]



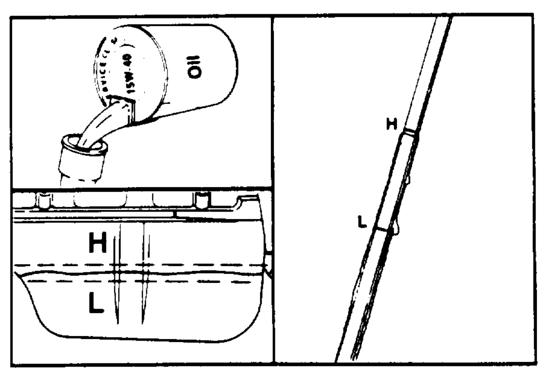
Caution: The lubricating oil system must be primed before operating the engine after it has been rebuilt to avoid Internal damage. Do not prime the system from the bypass filter head If an external pressure pump is used. Damage to the bypass filter will result.
To prime the system using external pressure, connect the supply to the tapped hole in the main oil rifle.

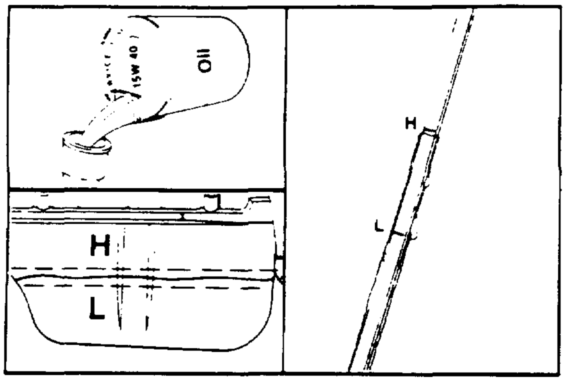


Use a pump capable of supplying 210 kPa (30 psi] continuous pressure. Connect the pump to the port on the main oil rifle as shown.
Use clean 15W-40 oil to prime the system until the oil pressure registers on the gauge.
Remove the oil supply tube, and install the plug.

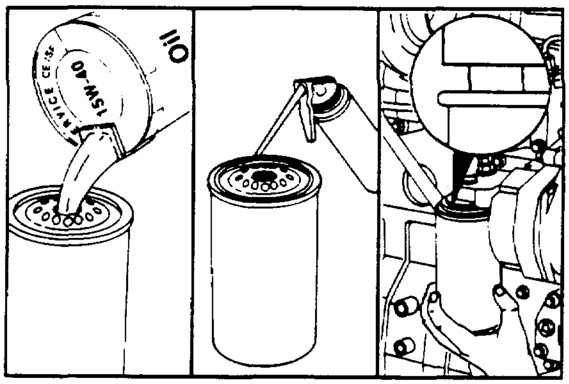


Make sure the lubricating oil has had time to drain to the pan, and fill the engine to the high mark as measured on the dipstick.

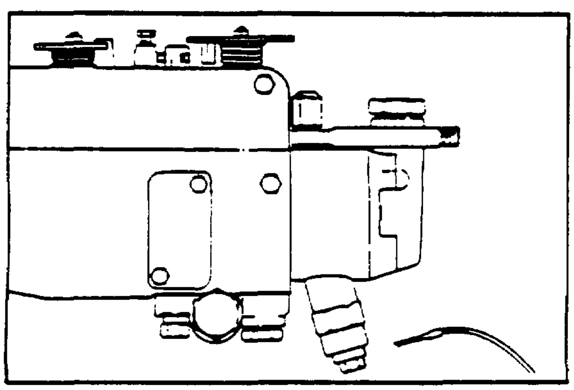




If an external pressure pump is **not** available, prime the lubricating system according to the following procedure.
Fill the engine with oil to the high level mark on the dipstick.



Fill the lubricating oil filters with clean 15W-40 oil.
Screw the filters onto the filter head fitting until the gasket contacts the filter head surface.
Use oil filter wrench, Part No. 3375049, to tighten the filters an additional 3/4 to 1 turn.



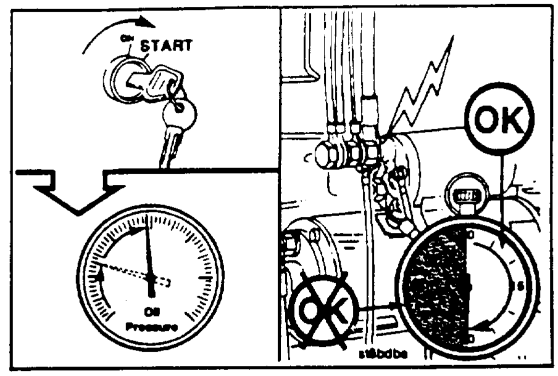
To make sure the lubricating oil pump is providing adequate oil to the engine, first disconnect any wires leading to the fuel pump solenoid.

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 oil pressure gauge indicates system pressure.

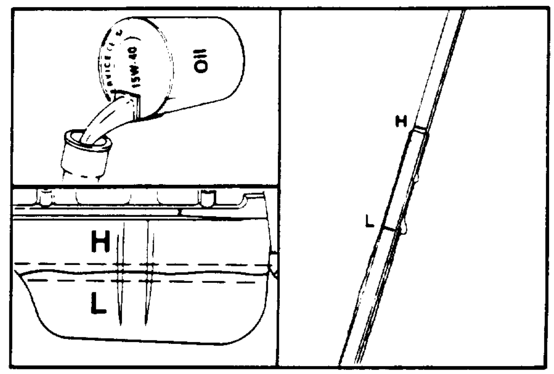
NOTE: Allow 2 minutes between the 30-second cranking periods so the starting motor can cool.

NOTE: If pressure is not indicated, find and correct the problem before continuing.



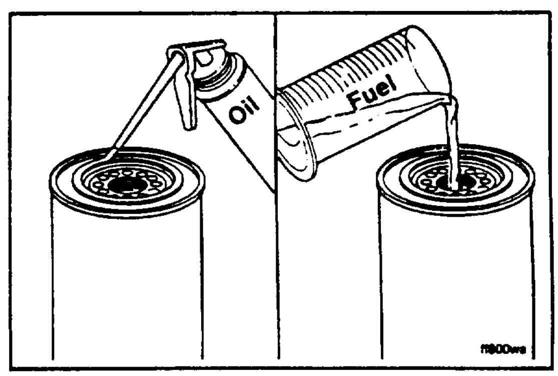
Allow the lubricating oil to drain into the oil pan, and measure the oil level with the dipstick.

Add oil as necessary to bring the level to the high level mark.



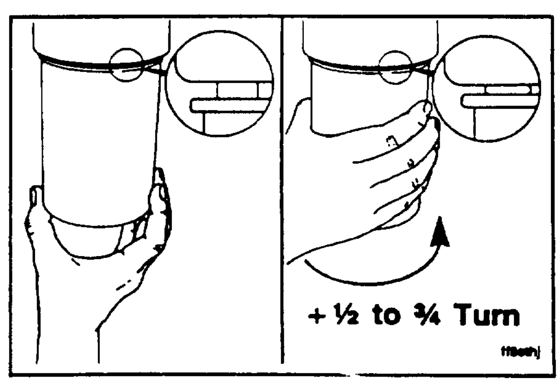
Lubricate the gasket on the fuel filter with clean 15W-40 oil.

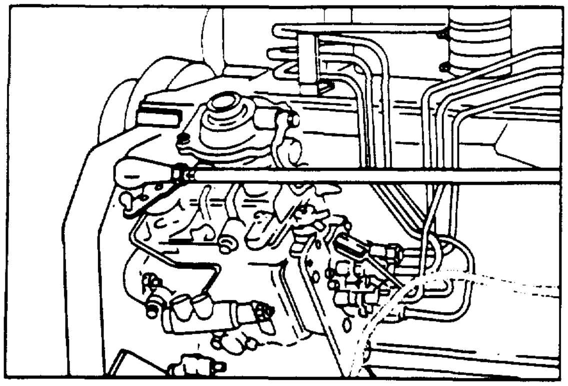
Fill the fuel filter with clean fuel.



Screw the fuel filter onto the filter head until the gasket contacts the filter head surface.

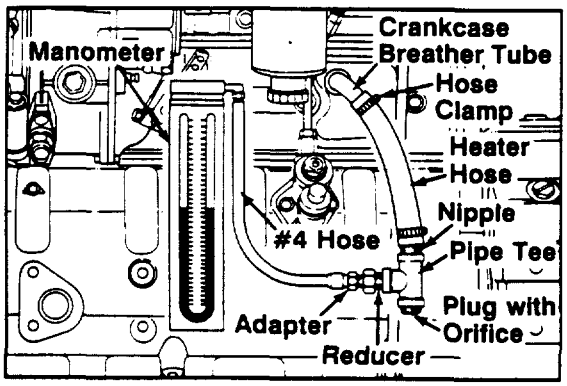
Tighten the filter an additional 1/2 to 3/4 turn.





Make sure the voltage supply matches that of the fuel pump solenoid before connecting the electrical wires to it.

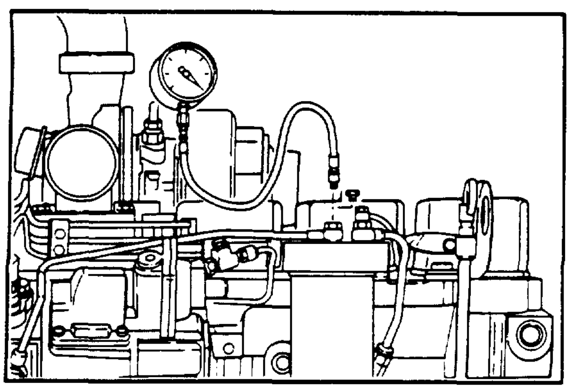
Attach the throttle control rod onto the fuel pump throttle lever.



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_20 150 in. H_20]



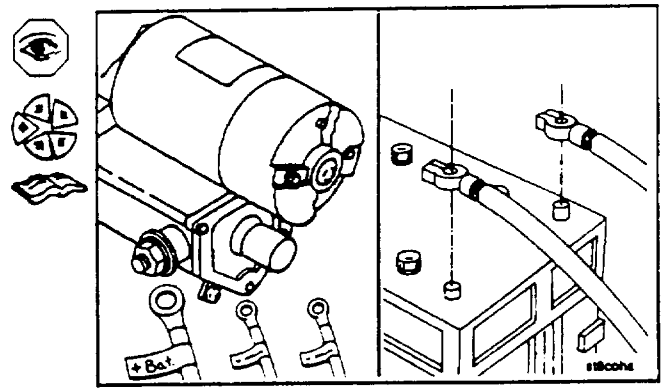
To measure fuel filter restriction, connect vacuum gauge, Part No. ST-434, to the lift pump inlet line.

Minimum Gauge Capacity: 760 mm Hg [30 in. Hg]

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.

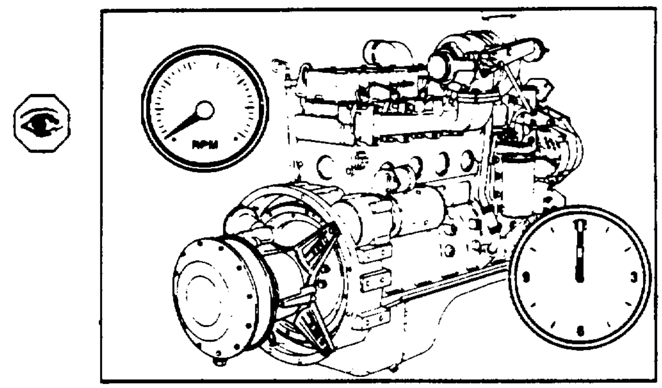
NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.



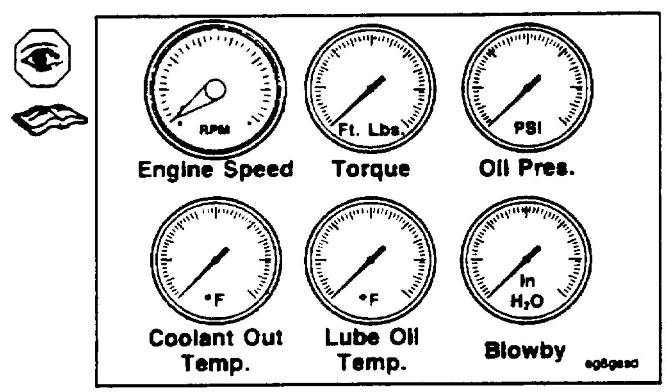
Engine Dynamometer Test Engine Run-In (14-02)

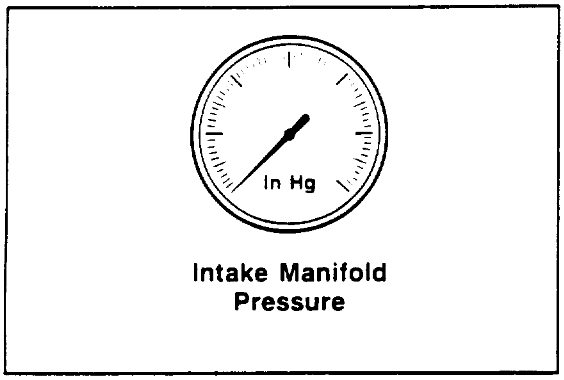
The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used at each phase **except** engine idle periods, if so desired.

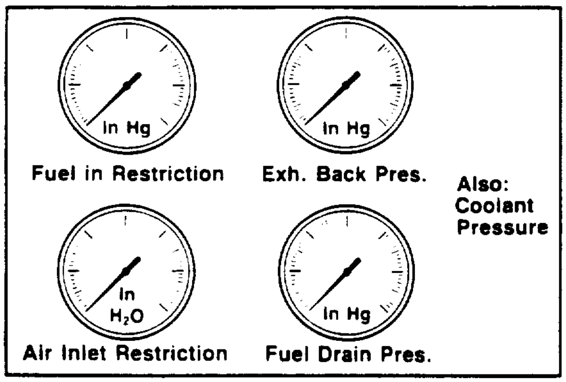


Measurements from these indicators and gauges must be observed closely during all phases of the engine run-in period. Refer to page 5-320 for specifications and acceptable readings.

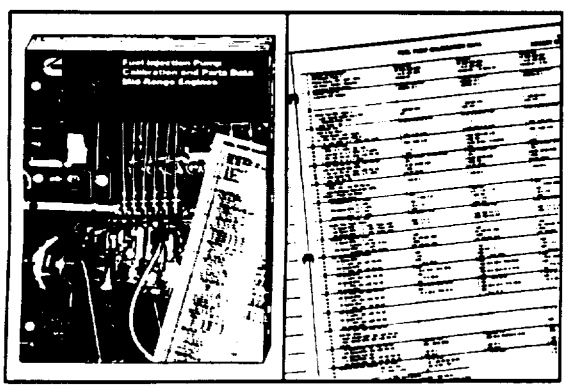




To correctly evaluate the engine performance, this additional measurement **must** be observed during engine run-in phases.



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.



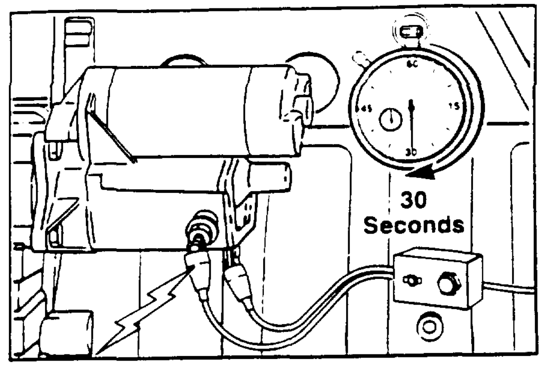
Engine performance specifications and fuel system calibration values are listed in the following publications:

1. Fuel Injection Pump Calibration and Parts Data, Bulletin No. 3810449.
2. Engine Data Sheets

NOTE: Fuel pump calibration changes must be performed by an ADS shop.

Caution: Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

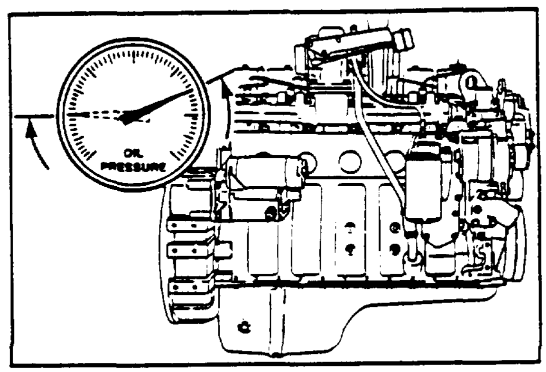
Crank the engine and observe the oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before cranking the engine again.



Caution: If the lubricating oil pressure is not within specifications, shut off the engine immediately. Either excessively low or excessively high oil pressure will cause engine damage.

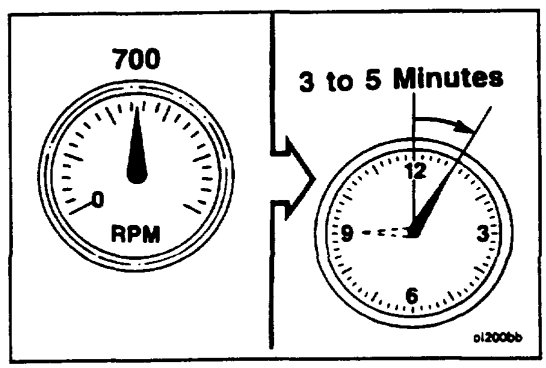
Engine oil pressure must be between 69 kPa and 310 kPa [10 psi and 45 psi] at 700 RPM.

Correct the problem if the oil pressure is not within specifications.



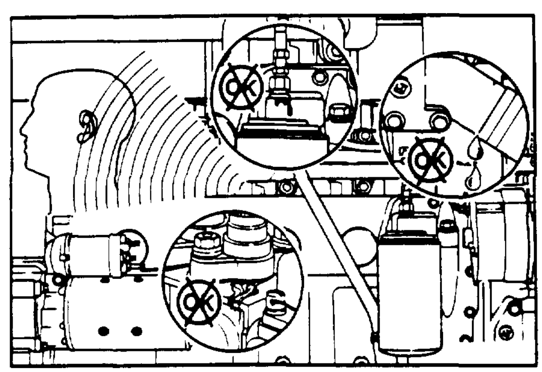
Caution: Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

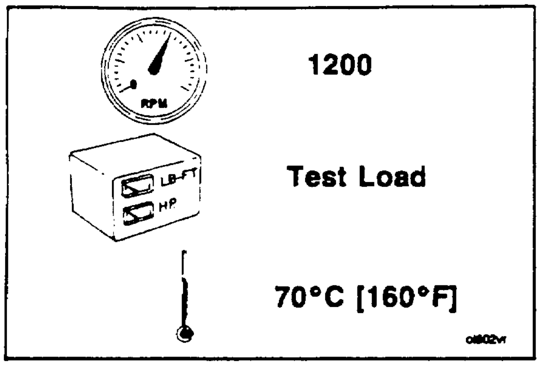
Operate the engine at approximately 700 RPM for 3 to 5 minutes.



Listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

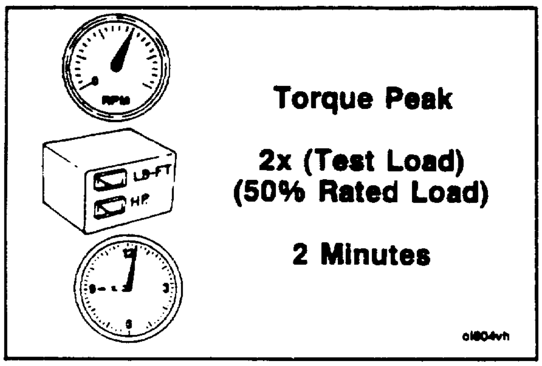
NOTE: Repair all leaks or component problems before continuing the engine run-in.





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.

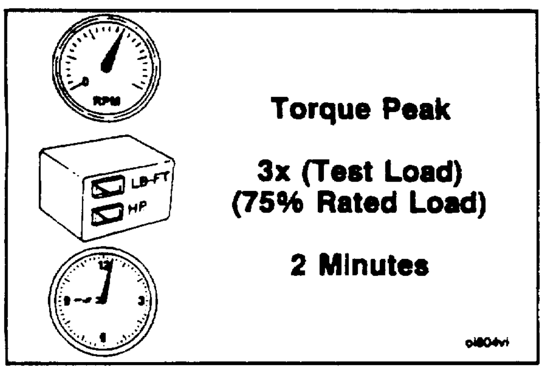
NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.



Open the throttle to the speed at which peak torque occurs, and adjust the dynamometer load to 50 percent of rated load. Operate the engine at this speed and load level for 2 minutes.

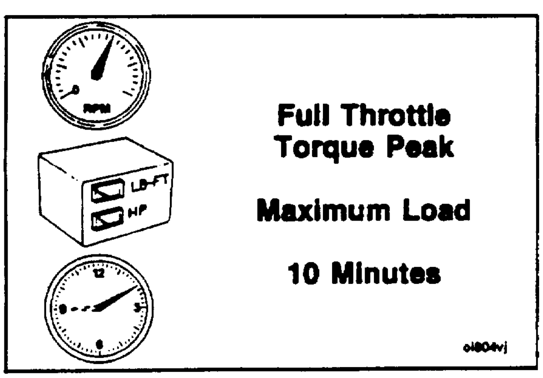
Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable and within specifications.



With the engine speed remaining at torque peak RPM, increase the dynamometer load to 75 percent of rated load. Operate the engine at this speed and load level for 2 minutes. Check all gauges and record the data.

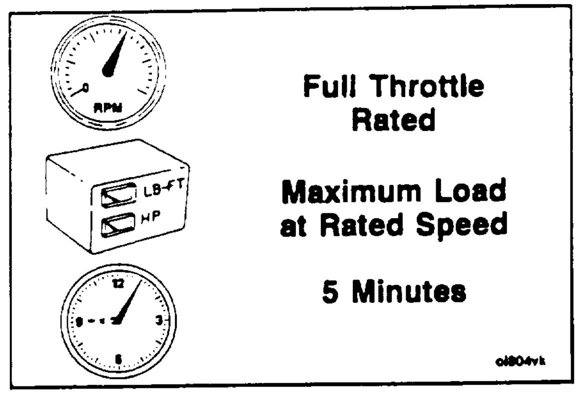
NOTE: Do **not** proceed to the next step until blowby is stable and within specifications.



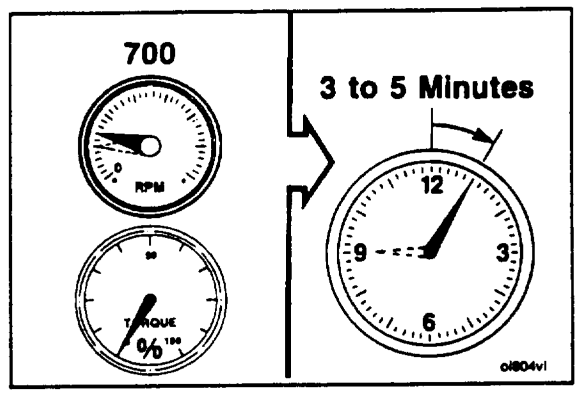
Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak RPM. Operate the engine at this speed and load level for 10 minutes or until the blowby becomes stable and within specifications.

Check all gauges and record the data.

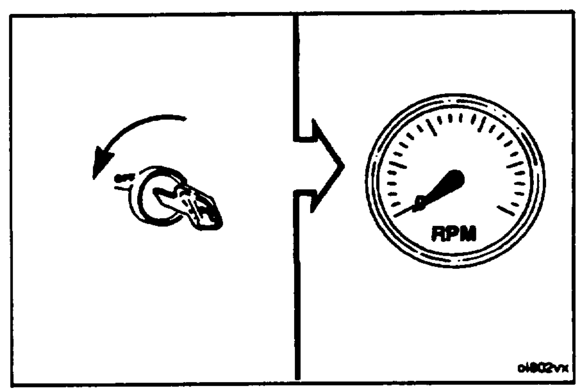
Reduce the dynamometer load until the engine speed increases to the engine's rated RPM.
Operate the engine at rated RPM for 5 minutes.
Check all gauges and record the data.

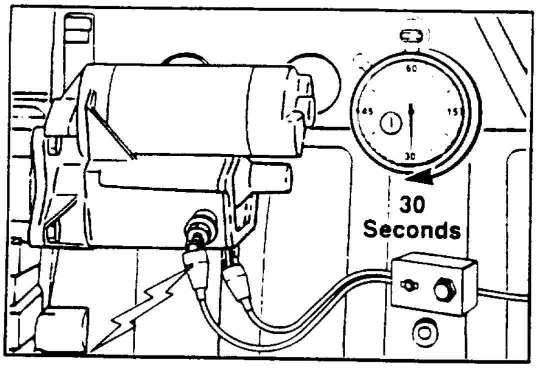


Caution: Shutting off the engine Immediately after operating at full load will damage the turbocharger and Internal components. Always allow the engine to cool before shutting it off.
Remove the dynamometer load completely, and operate the engine at 700 RPM for 3 to 5 minutes. This period will allow the engine components to cool.



Shut off the engine.

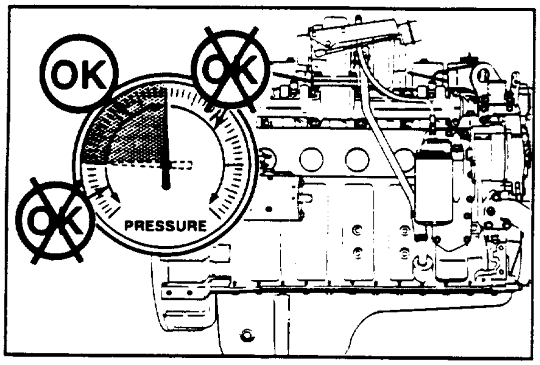




Engine Dynamometer Test Performance Checking

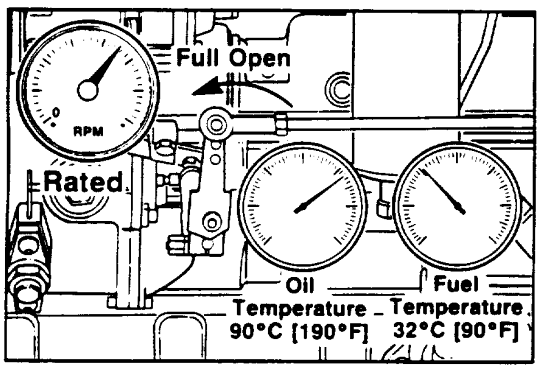
Caution: Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

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. Either excessively low or excessively high oil pressure will cause engine damage. Correct the problem If oil pressure is not within specifications.

Engine oil pressure must be between 69 kPa and 310 kPa [10 psi and 45 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.

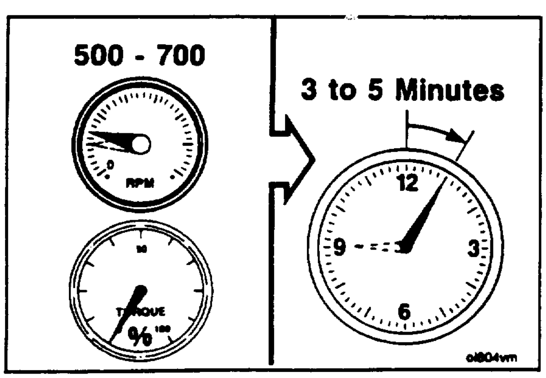
Check all the gauges, and record the readings.

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^{o} C [190^{o} F]

Fuel Temperature: MAX 32^{o} C [90^{o} F]

Check all gauges and record the data.

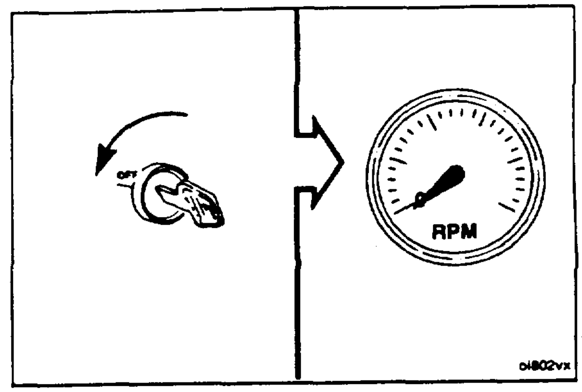


Caution: Do not shut off the engine immediately after it has been loaded. it must be allowed to sufficiently cool.

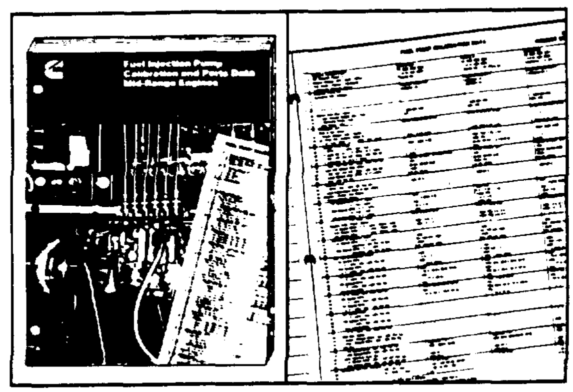
Remove the dynamometer load completely, and operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

NOTE: Idle periods longer than 5 minutes are to be avoided.

Shut off the engine after the cool-down period.



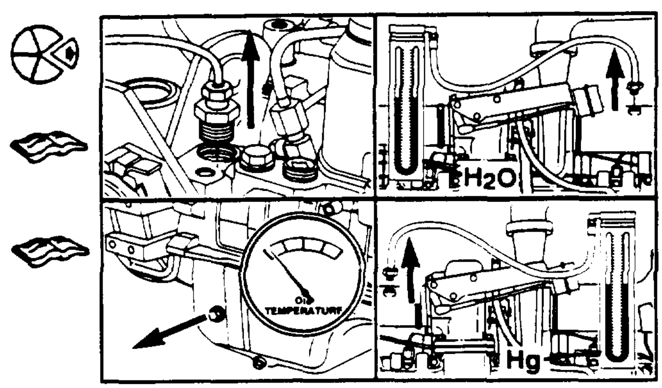
If power specifications are not met, remove the fuel pump and have the pump checked against the calibration specification sheet.

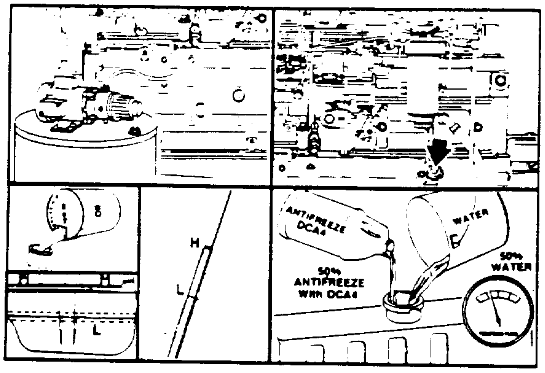


Remove all test instrumentation. Remove the engine from the dynamometer.

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 5-318 and 5-319.

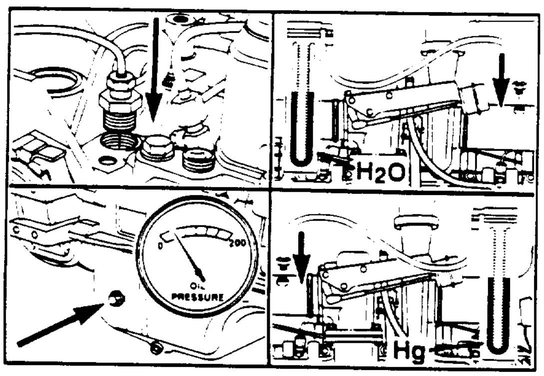
Prepare the engine for Engine Painting (5-337) or Engine Storage (5-338) or (5-341).





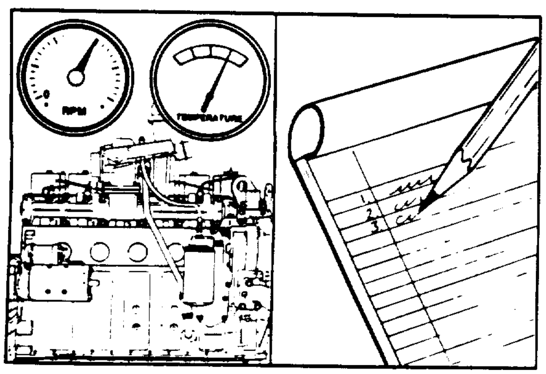
General Engine Test Procedures (Chassis Dynamometer) (14-05)

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 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 (14-01) 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.



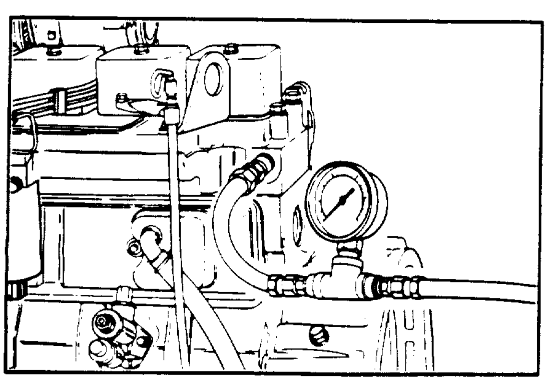
The number of instruments and gauges required to perform a chassis dynamometer test will vary according to the type and the capability of the test equipment used.

Refer to pages 5-318 and 5-319 for the correct system pressure and temperature gage connecting locations.



To correctly monitor an engine's performance, record the following parameters:

- 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)



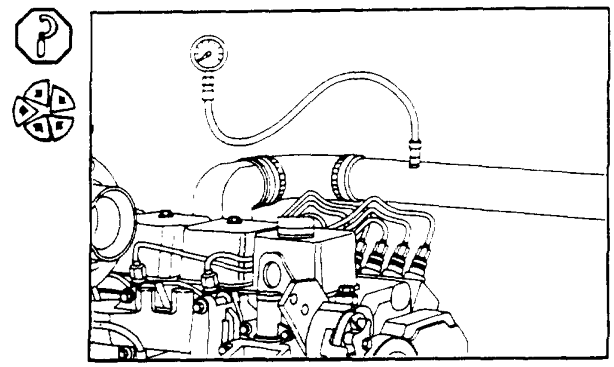
* See the following for the Service Tools required and the installation locations on the engine.

Measure the coolant pressure at the cylinder head, rear fuel pump side.

Minimum Gauge Capacity: 415 kPa [60 psi]

Measure the intake manifold pressure. Install a pressure gauge, Part No. ST-1273, in the location shown.

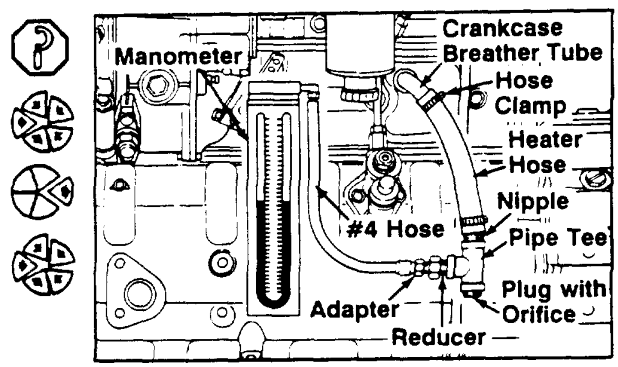
Minimum Gauge Capacity: 1905 mm Hg [75 in. Hg]



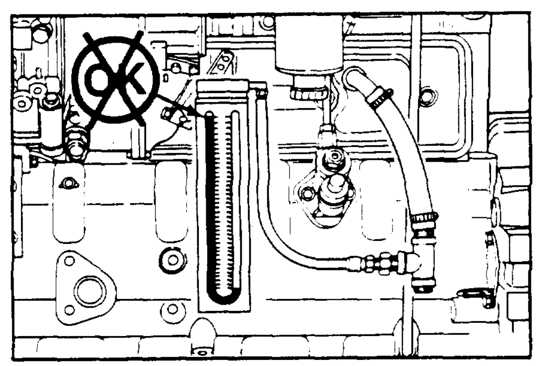
Measure the blowby by installing blowby checking tool in the crankcase breather vent. Connect the blowby tool to a water manometer.

NOTE: Excessive blowby indicates an engine internal components malfunction, allowing combustion gases to enter the crankcase.

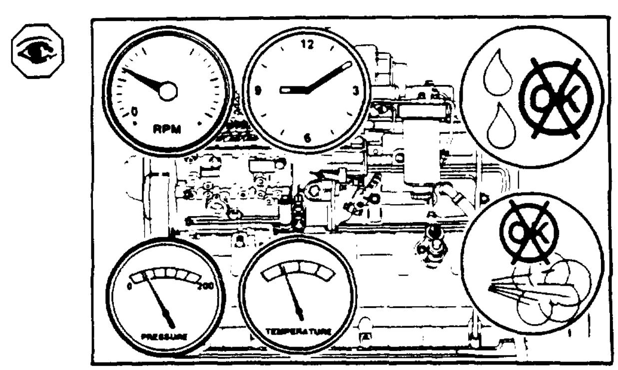
Minimum Gauge Capacity: 1270 mm H_20 [50 in. H_20]

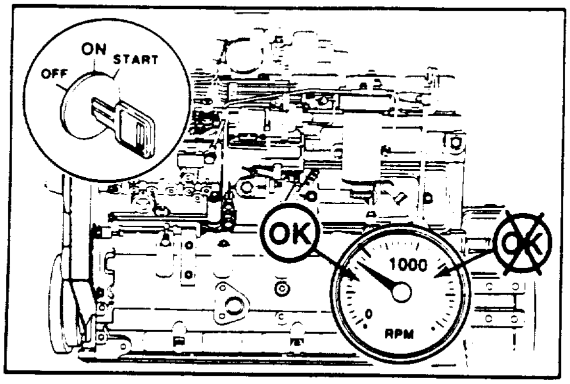


NOTE: If a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in step, return to the previous step and continue the run-in. If blowby does **not** reach an acceptable level, discontinue the run-in and determine the cause.

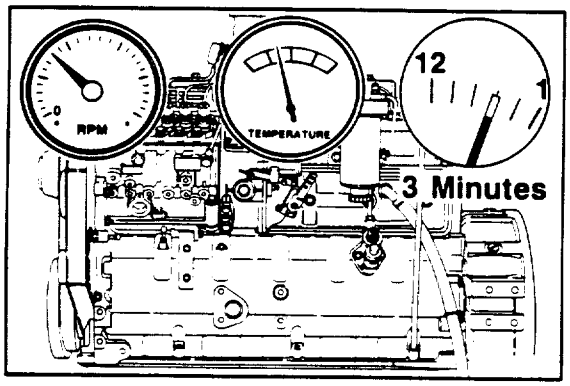


NOTE: Avoid long idle periods. Operate the engine at low idle only long enough (3 to 5 minutes) to check for correct oil pressure and any fuel, oil, water, or air leaks.

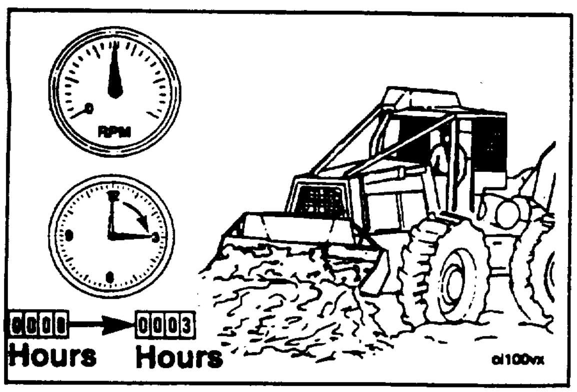




Caution: Do not allow the engine speed to exceed 1,000 RPM before run-in. The internal components can be damaged.



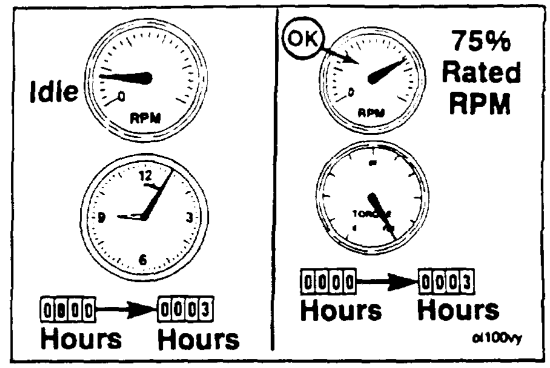
Caution: Do not shut off the engine Immediately after the last stop of the run-in is completed. Allow the engine to cool by operating at low idle for a minimum of 3 minutes to avoid Internal component damage.



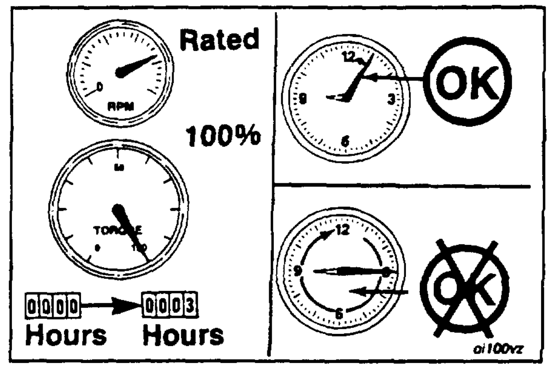
Engine Run-In Procedure "In Chassis" (Off-Highway Vehicles)

Caution: Refer to General Engine Test Procedures (Chassis Dynamometer) (1 4-05) 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.



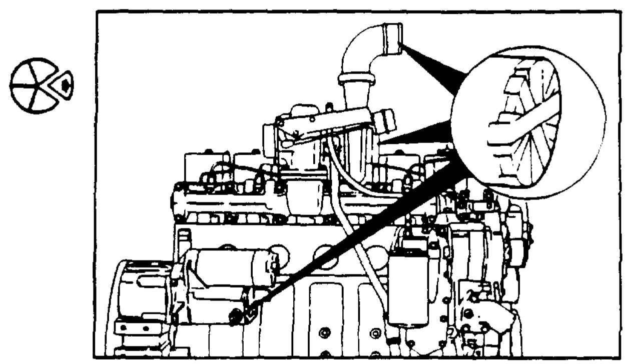
3. Do **not** operate the engine at rated speed (RPM) and full load for more than 5 minutes at any one time.



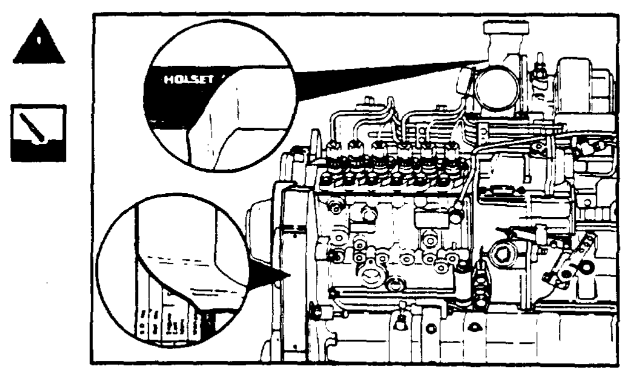
Engine Painting (14-08)

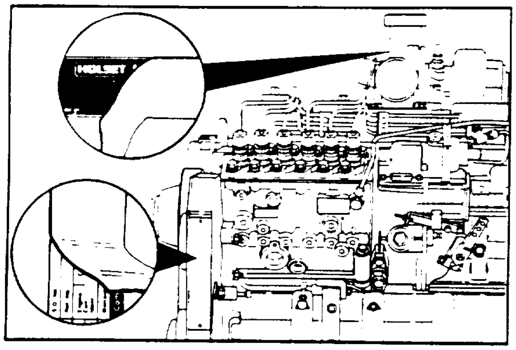
Remove all belts from the engine.
Cover the following parts of the engine:

- Exhaust and intake openings
- Electrical components
- Fuel inlet and drain connections
- Any exposed fittings, threads, and electrical wire terminals



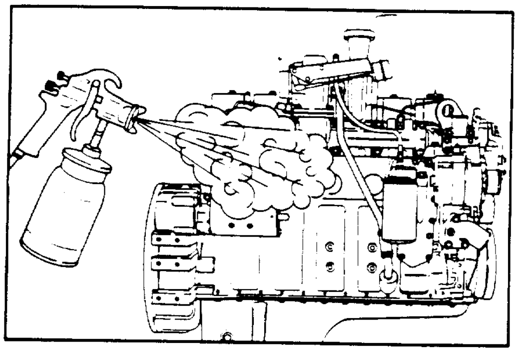
Warning: When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam can cause serious personal injury.
Use steam to clean the engine, and dry with compressed air.
NOTE: Make sure all engine surfaces are dean and dry before painting the engine.



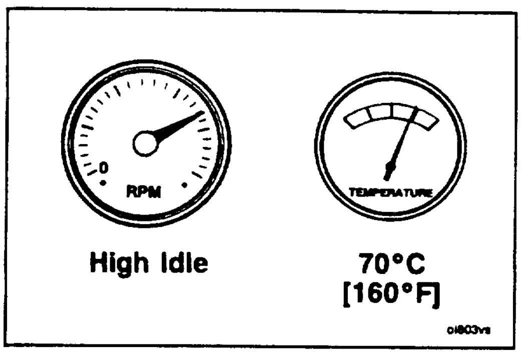


Protect the following components from the paint:

- All dataplates
- Valve and injector set marks.
- Exhaust manifold
- Flywheel
- Flywheel housing transmission mounting surface



Paint the engine.

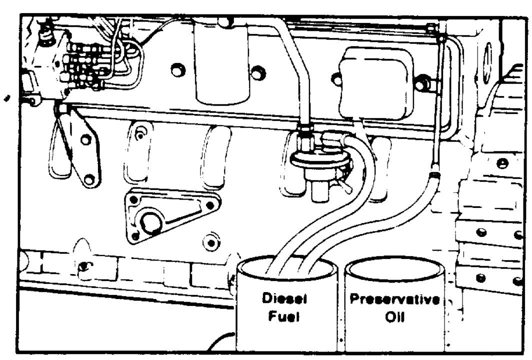


Engine Storage Short Term (14-09)

NOTE: This procedure describes the correct method of preparing an engine for short-term (1 to 6 months) storage.

Operate the engine at high idle until the coolant temperature reaches 70° C [160° F].

Shut off the engine.

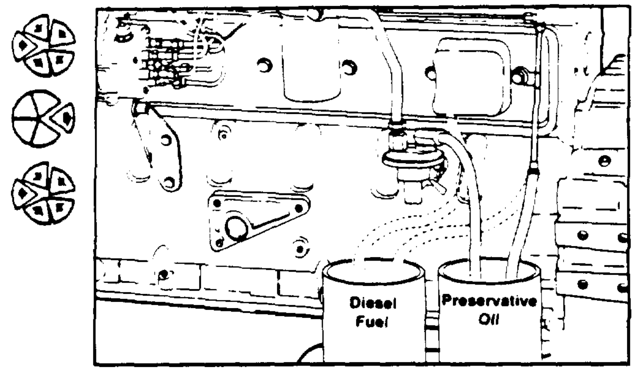


Remove the fuel tube to the engine fuel filter and the injector return tube.

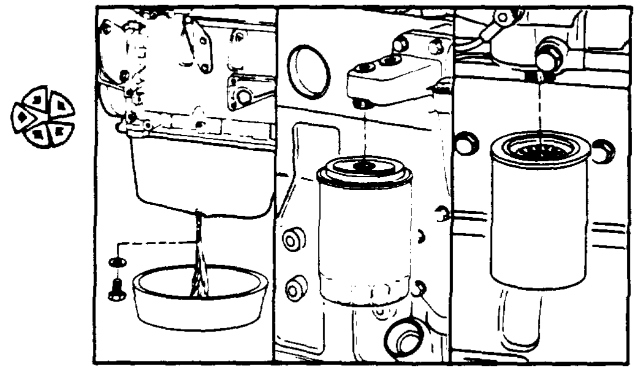
NOTE: Fuel system preservative oil must meet Federal Specification VV-L-800C. (Example: Daubert Chemical NoxRust No. 518.)

Fill two containers, one with diesel fuel and the other with the preservative oil. Put both fuel tubes into the container of diesel fuel.

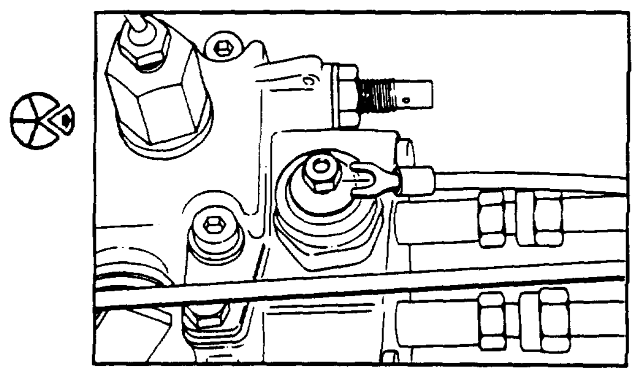
Start the engine. When it is operating smoothly, put the fuel supply tube into the container of preservative oil.
Remove the injector return tube from the diesel fuel container. When preservative oil flows from the tube, shut off the engine.
Install the fuel supply tube to the fuel filter, and put a cap on all other fuel tubes.



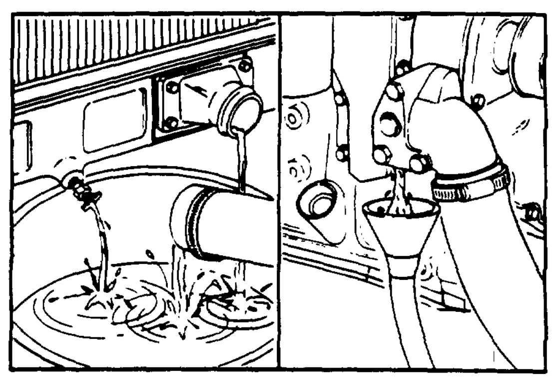
Drain the lubricating oil pan, the oil filters, and the fuel filter.
Install the drain plug into the oil pan, and install the filter cans. Tighten according to specifications.

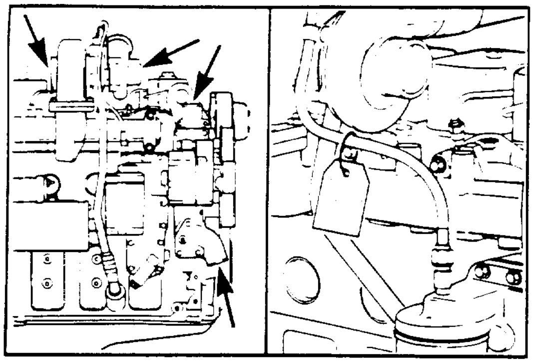


Disconnect the electrical wires from the fuel pump solenoid.

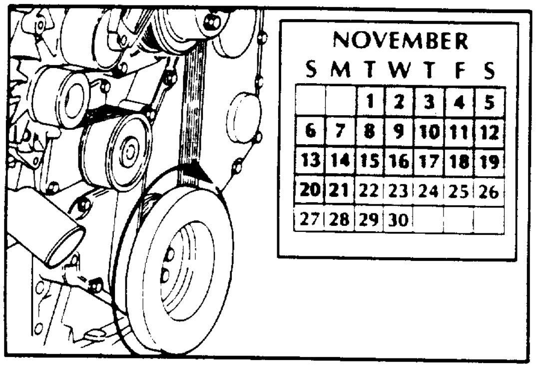


Drain the coolant passages and jackets.
NOTE: It is **not** necessary to drain the coolant if it is a permanent-type antifreeze with a rust inhibitor. Do **not** drain the coolant if the engine is installed in a vehicle.

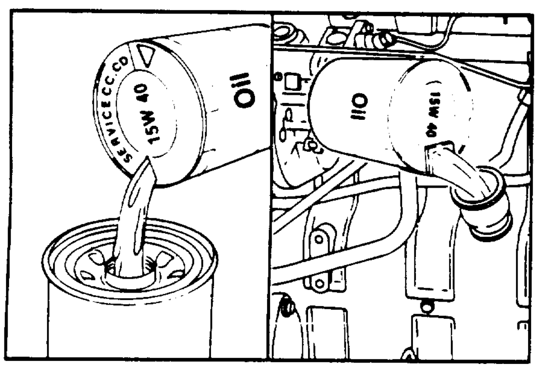




Look the engine over closely, and cover all openings with tape to prevent dirt and moisture from entering.
Install a warning tag which alerts others of no oil in the engine and that it must not be started.

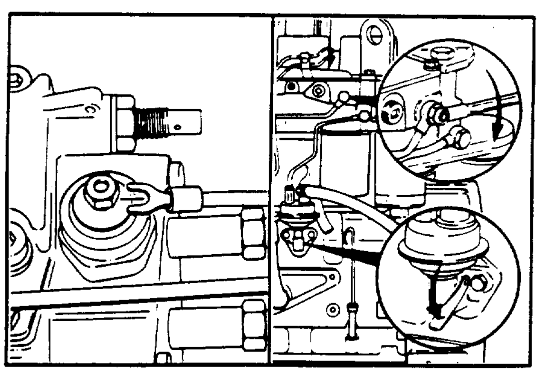


Store the engine in a dry area of even temperature.
Rotate the crankshaft two to three revolutions every 3 to 4 weeks use the barring gear, Part No. 3904682 to rotate the crankshaft.



Removing the Engine from Short-Term storage

Remove the tape from all openings, and remove the warning tag.
Refill the oil filters with clean 15W-40 oil, and prime the lubrication system. Refer to Engine Dynamometer Test Engine Run-in (14-02).
Use clean diesel fuel to flush the preservative oil from the fuel system, and fill the fuel filter again.

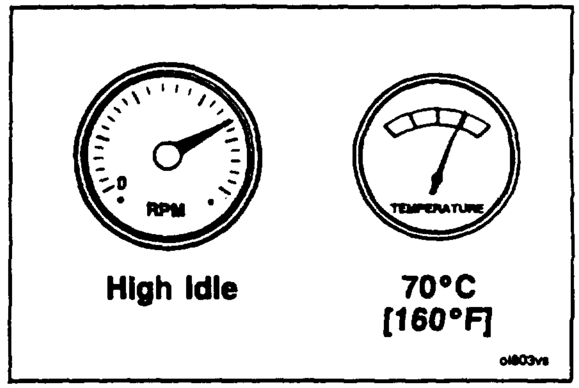


Connect the electrical wiring to the fuel pump solenoid.
Prime and vent the fuel system.

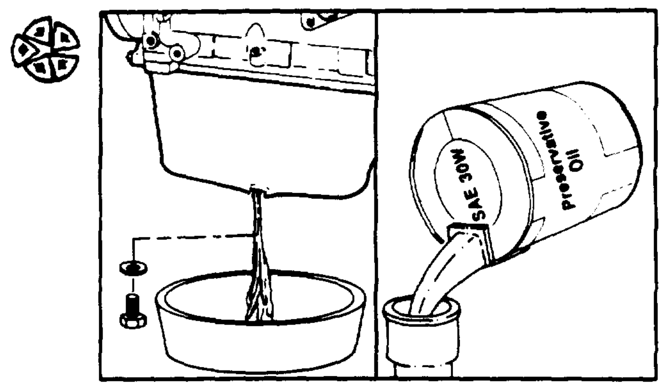
Engine Storage - Long Term (14-10)

This procedure describes the correct method of preparing an engine for long-term (6 to 24 months) storage.
NOTE: If the engine has been stored for 24 months, the cooling system **must** be flushed with a solvent. Repeat the flushing procedure a second time.

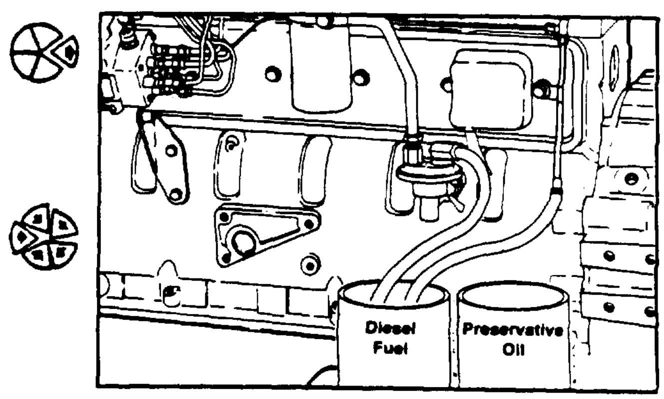
Operate the engine at the high idle throttle position until the coolant temperature is 70° C [160° F].
Shut off the engine.

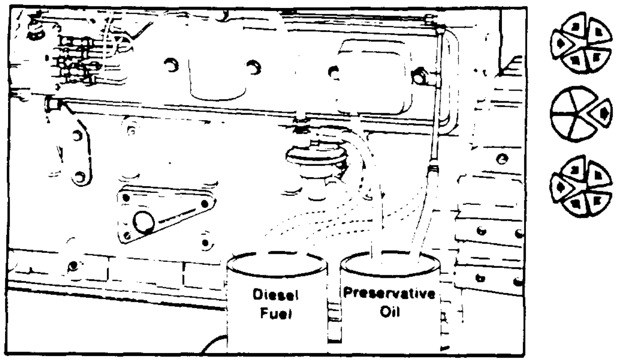


Drain the lubricating oil pan. Install the drain plug, and fill the oil pan to the high level mark on the dipstick with preservative oil.
NOTE: Lubricating system preservative oil must meet Military Specification MIL-L-21260 Type PE30-1 SAE 30. (Example: Shell 66202.)

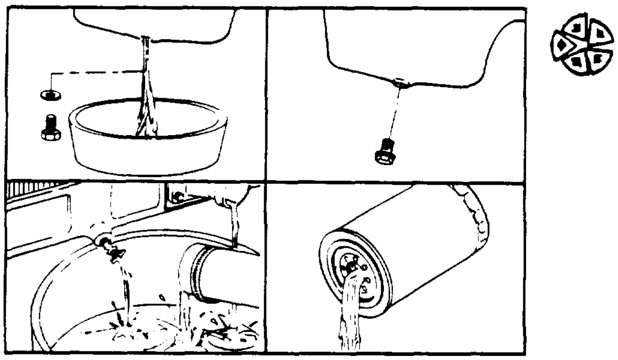


Disconnect the fuel supply tube at the fuel filter and the injector return tube at a convenient place.
NOTE: Fuel system preservative oil **must** meet Federal Specification VV-L-800C. (Example: Daubert Chemical NoxRust No. 518.)
Fill two containers, one with diesel fuel and the other with preservative oil. Put both fuel tubes into the container of diesel fuel.

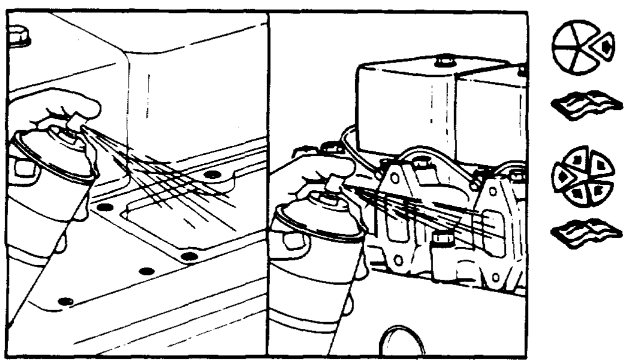




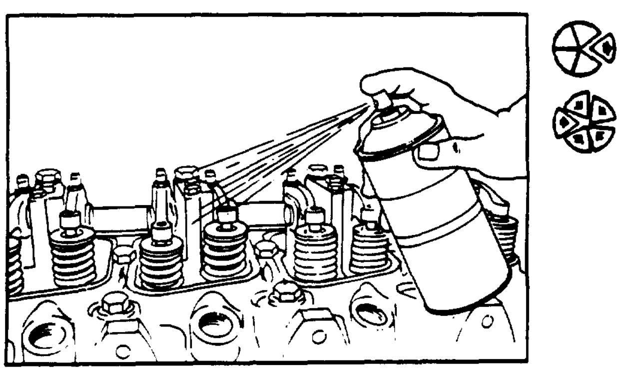
Start the engine and, when operating smoothly, put the fuel supply tube into the container of preservative oil.
Remove the injector return tube from the diesel fuel container. When the preservative oil flows from the tube, shut off the engine.
Connect the fuel supply tube to the fuel filter, and put a cap on the ends of all the other fuel tubes.



Drain the preservative oil from the lubricating oil pan and the oil filters. Install the drain plug.
Drain and flush the cooling system, using a water-soluble rust inhibitor.



Remove the exhaust manifold.
Refer to Engine Disassembly
Spray preservative oil into the intake and the exhaust ports of the cylinder head and into the aftercooler housing and the exhaust manifold.
Install the aftercooler assembly and the exhaust manifold. Refer to Engine Assembly.



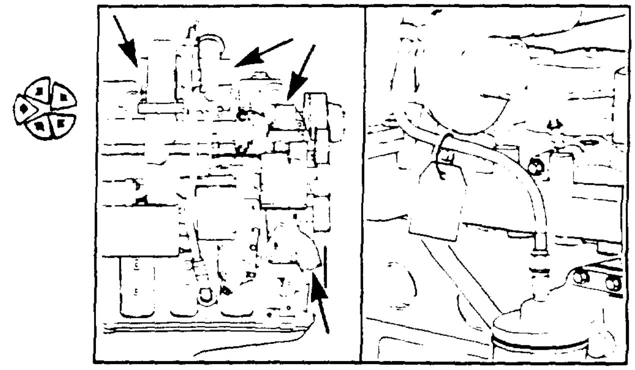
Remove the rocker housing covers, and spray the rocker levers, valve springs, valve stems, valve guides, and the push rods with preservative oil. Install the rocker housing cover.
Spray preservative oil into the intake port of the air compressor and on all exposed metal surfaces that are not painted.
NOTE: Use a preservative compound that meets Military Specification MIL-C-16137C Type P-2 Grade 1 or 2.

Cover all openings with heavy paper and tape to prevent entrance of dirt and moisture.

Put a warning tag on the engine which contains the following information:

- Date the engine was prepared for storage.
- Crankshaft must not be rotated.
- Coolant has been drained.
- Engine must not be operated.

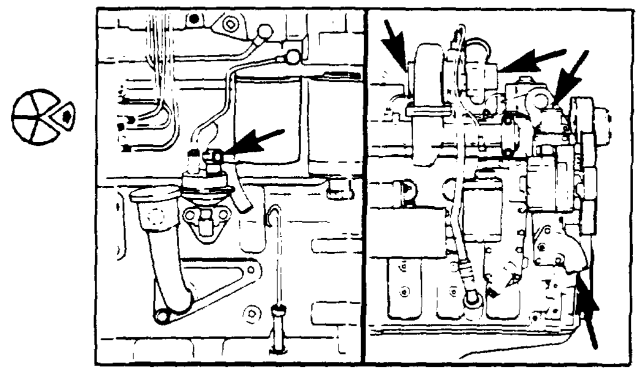
Store the engine in a dry area of even temperature.



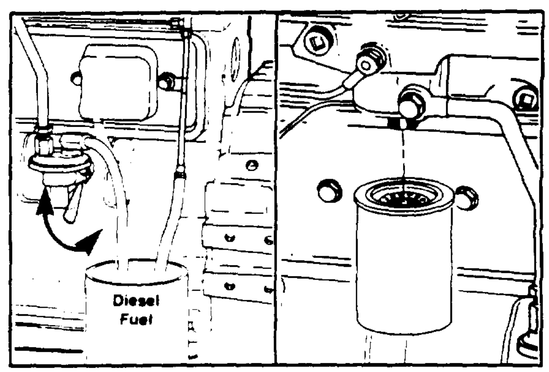
Removing the Engine from Long-Term Storage

Remove the paper and the tape from all openings.

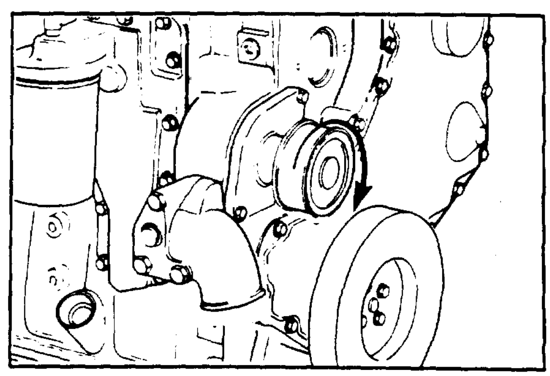
Remove the warning tag.

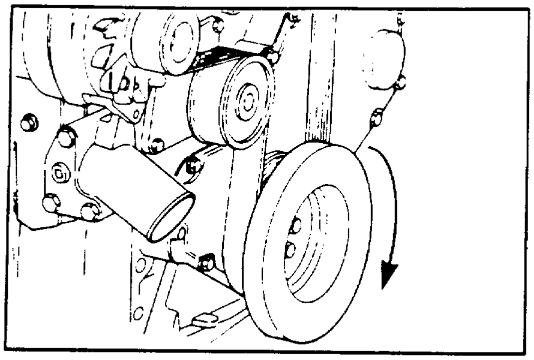


Flush the fuel system with clean diesel fuel to remove preservative oil.

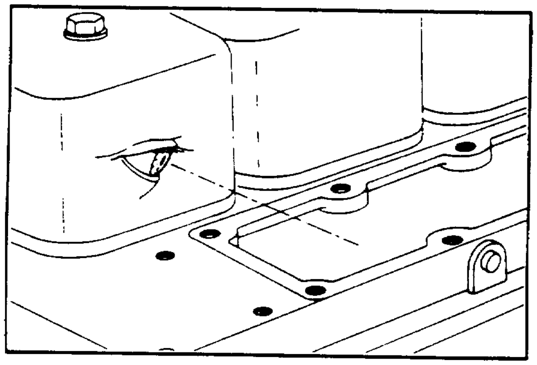


Rotate the water pump to make sure it hasn't rusted in place.

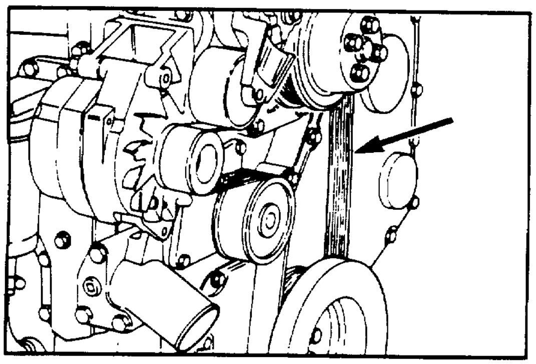




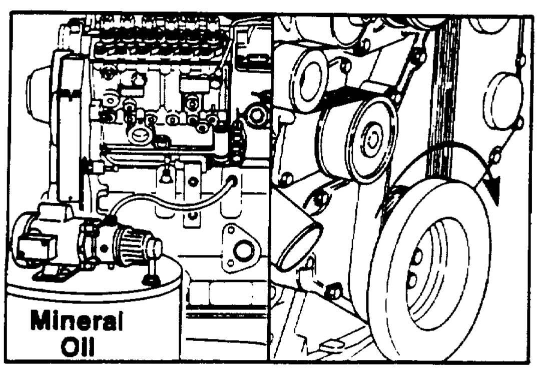
Rotate the crankshaft two complete revolutions to make sure the piston rings are free and no foreign objects are in the engine.



Remove the intake manifold cover or aftercooler and visually inspect the lower valve stem area for presence of rust. An accumulation of rust requires disassembly and rebuild of the cylinder head.

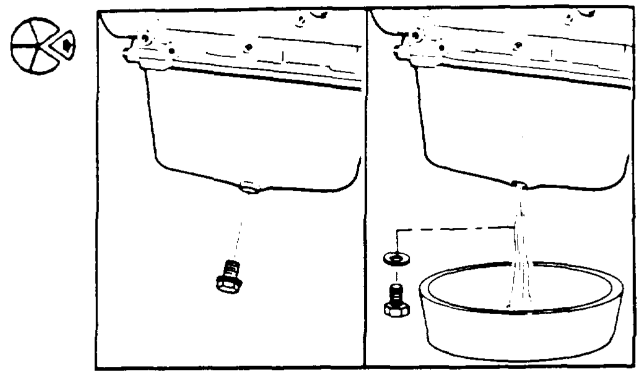


Install the drive belt or belts.

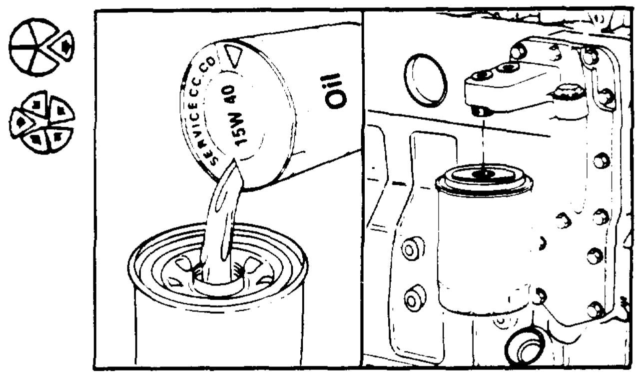


Remove a plug from the main oil rifle drilling and flush the preservative oil from the engine by pumping 4 liters of light mineral oil into the oil rifle. Rotate the crankshaft three or four revolutions as the engine is flushed. Install the plug.

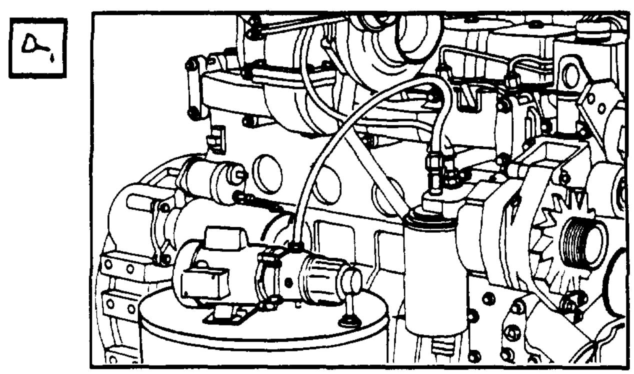
Remove the oil drain plug and allow the mineral oil to drain from the engine.



Remove the lubricating oil filter. Install a new filter according to the manufacturer's specifications.

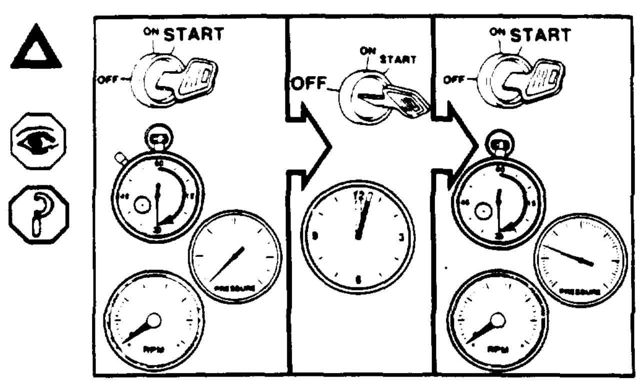


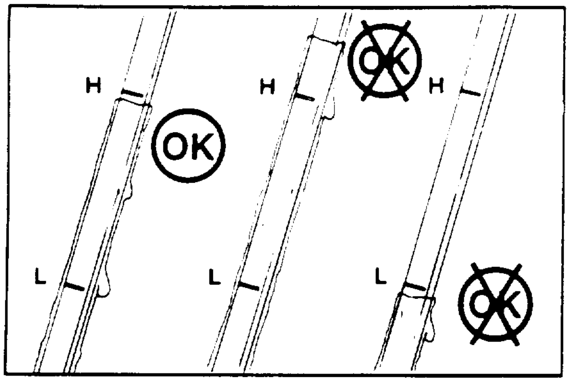
Pressure fill the engine with 15W40 lubricating oil through the 1.8 inch pipe tap on the side of the oil filter housing directly below the turbocharger oil supply connection. Use 207 kPa (30 psi) to pressure fill the system with a minimum of 3.6 L (1 U.S. gal).



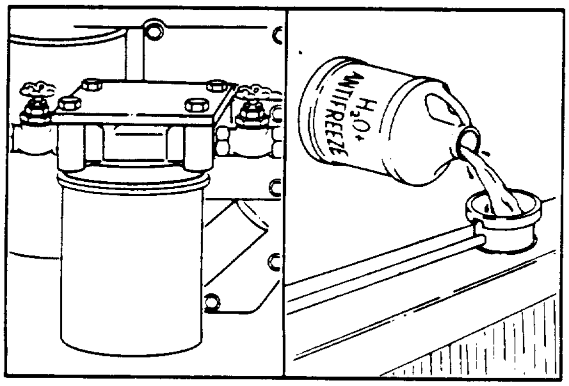
Caution: Make sure the engine does not start when you crank the engine by disconnecting the fuel solenoid or positioning the shut down lever in the stop position.

Use the starter to crank the engine for a maximum of 30 seconds, with two minute intervals, until oil pressure registers on the lubricating oil gauge.

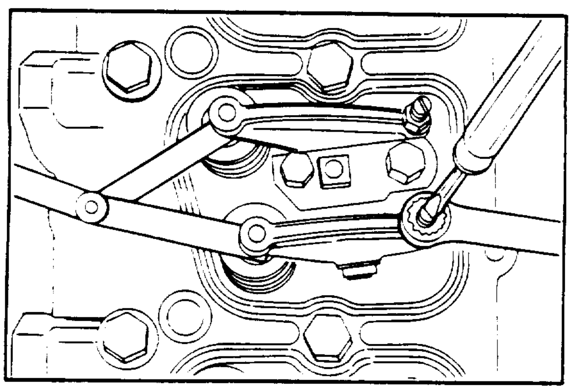




Fill the oil pan to the high mark on the dipstick.



Install a new coolant filter if so equipped. Fill the cooling system with a mixture of 50% water and 50% ethyleneglycol type antifreeze.



Adjust the valve clearance according to the procedure in the applicable service manual.

Tighten all capscrews, plugs and fittings as necessary.

Section 14. Specifications

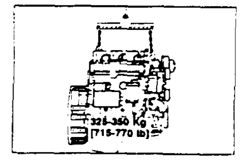
Tools Required to Repair the B Series Engine

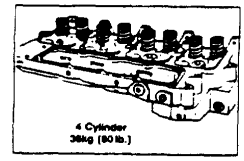
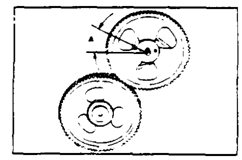
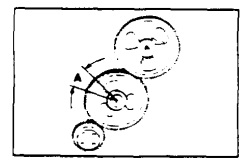
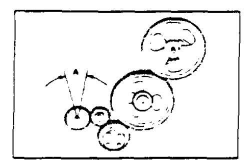
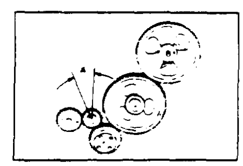
Sockets	Wrenches	Other
12rnm	8mm	Allen Wrench (8mm)
13mm	10mm	Breaker Bar (1/2 in. Square Drive)
14mm	13mm	Flat Screwdriver
15mm	14mm (open end)	Ratchet (3/8 in. Square Drive)
17mm	15mm (open end)	Ratchet (1/2 in. Square Drive)
22mm	17mm	Filter Wrenches (75-80mm and 90-95mm)
24mm (deep well)	19mm	Drill Motor (1/4 inch)
	22mm	Drill Bit (3mm)
	24mm	Slide Hammer
		Flat Chisel
		Tear Puller (75mm)
		Sheet Metal Screw (#10)
		Torque Wrench
		Pliers
		Injector Bore Cleaning Brush (Part No. 3822509)
		Tappet Removal/Installation Tool (Part No. 3822513)

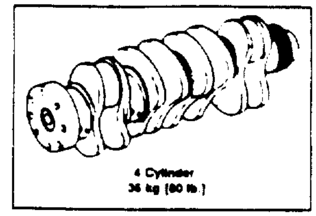
Part or Assembly	Ref. Point	mm		in	

Engine Disassembly - Group 0 Specifications

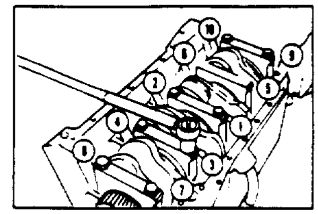
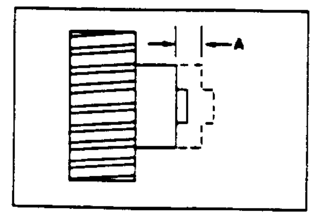
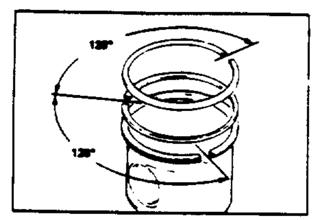
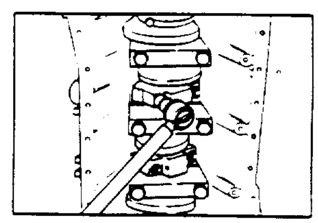
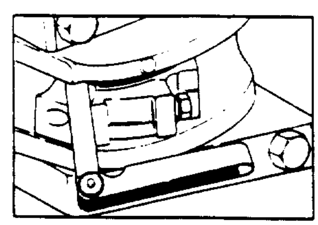
Engine Weight
4B Wet Weight 325-350 Kg [715-770 lb]

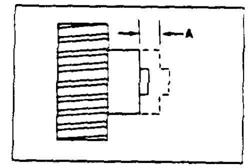
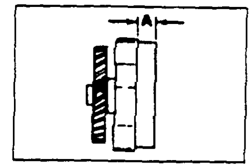
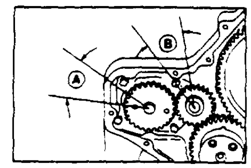
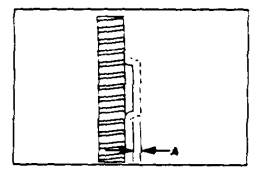
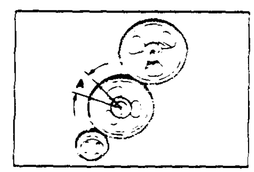


Part or Assembly	Ref. Point	mm		in	
Cylinder Head Weight.	4 cylinder	36 Kg		[80 lb]	
Injection Pump drive gear backlash limits	A	0.076 0.330	MIN MAX	[0.003] [0.013]	
Camshaft gear backlash limits.	A	0.076 0.330	MIN MAX	[0.003] [0.013]	
Lube pump gear backlash limits.	A	0.076 0.330	MIN MAX	[0.003] [0.013]	
Lube pump idler gear backlash limit.	A	0.076 0.330	MIN MAX	[0.003] [0.013]	

Part or Assembly	Ref. Point	mm		in	
Crankshaft Weight	4 Cylinder	36 Kg		[80 lb] [123 lb]	

Engine Assembly - Group 0 Specifications

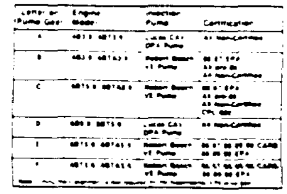
Part or Assembly	Ref. Point	mm		in	
Main bearing capscrew torque value and sequence.	1 2 3	60 N•m 119 N•m 176 N•m		[44 ft-lb] [88 ft-lb] [129 ft-lb]	
Crankshaft end play.	A	0.127 0.355	MIN MAX	[0.005] [0.014]	
Piston ring position					
Connecting Rod torque value.	1 2 3	35 N•m 70 N•m 100 N•m		[26 ft-lb] [51 ft-lb] [73 ft-lb]	
Connecting Rod side clearance limits.		0.100 0.300	MIN MAX	[0.004] [0.012]	

Part or Assembly	Ref. Point	mm		in	
Crankshaft end play		0.13 0.25	MIN MAX	[0.005] [0.010]	
Lube pump gerotor size.	A = Four cylinder gerotor size 12.947mm [0.516 inch]				
Lube pump gears backlash limits.	A&B	0.08 0.33	MIN MAX	[0.003] [0.013]	
Camshaft end play limits	A	0.12 0.34	MIN MAX	[0.005] [0.013]	
Camshaft gear backlash limits	A	0.08 0.45	MIN MAX	[0.003] [0.018]	

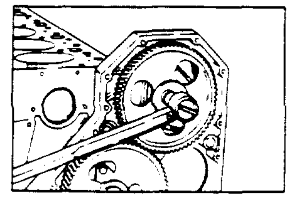
Part or Assembly	Ref. Point	mm		in

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 No3379133-20) must be used to determine whether or not the engine is certified, and if so, what year and regulating agency (EPA ro CARB)

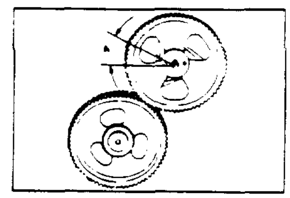
Given this information, use the table to determine which letter on the fuel injection pump drive gear is aligned with the camshaft gear.



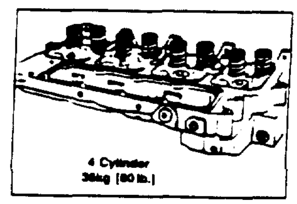
Part or Assembly	Ref. Point	mm		in
Injection pump drive gear torque values	Bosch & CAV 65 N•m			[48 ft-lb]



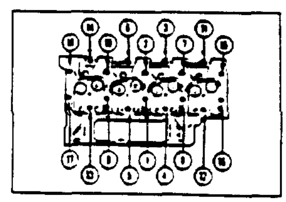
Part or Assembly	Ref. Point	mm		in
Injection pump drive gear backlash limits	A	0.08	MIN	[0.003]
		0.045	MAX	[0.018]



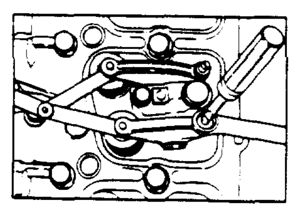
Part or Assembly	Ref. Point	mm		in
Cylinder Head Weight	4 Cylinder	36 Kg		[80 lb]



Part or Assembly	Ref. Point	mm		in
Cylinder Head Torque value and sequence	1	40 N•m		[29 ft-lb]
	2	85 N•m		[62 ft-lb]
	3	126 N•m		[93 ft-lb]

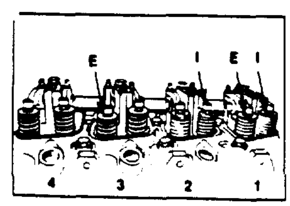


Part or Assembly	Ref. Point	mm		in
Valve stem to rocker lever clearances				
Intake		0.25mm		[0.010]
Exhaust		0.51mm		[0.020]



Valve adjustment procedure
Perform step A of the valve set procedure with Cylinder Number 1 at TDC compression stroke (timing pin will engage).

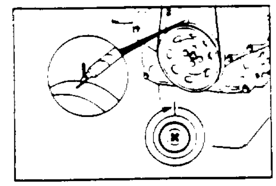
Step A - Four Cylinder



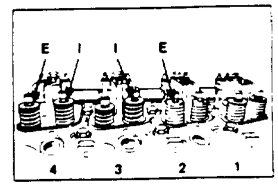
Part or Assembly	Ref. Point	mm	in

Perform Step B of the valve set procedure with Cylinder Number 1 at TDC plus 360 degrees (timing pin will not engage).

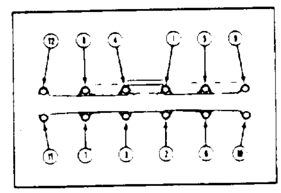
Mark the crankshaft and front cover. Rotate the crankshaft one full turn.



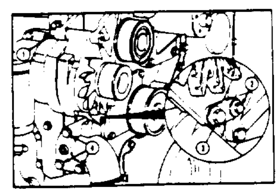
Step B - Four Cylinder



Exhaust Manifold torque value and sequence		43 N•m	[32 ft-lb]



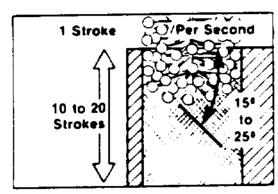
Alternator assembly torque sequence

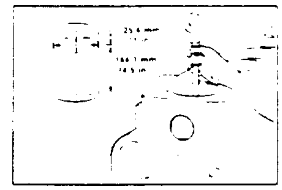
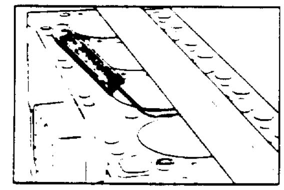
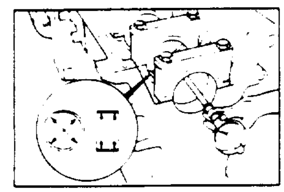
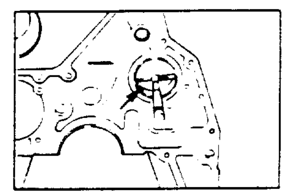
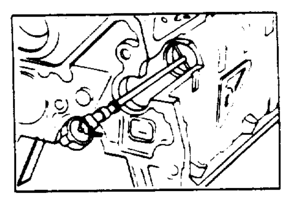
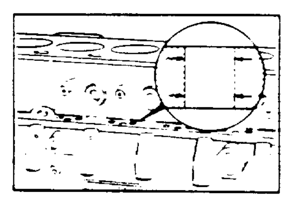


Cylinder Block - Group 1 Specifications

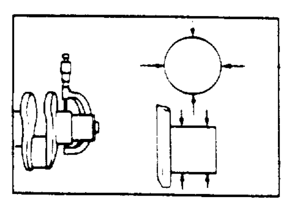
Cylinder Block

De-glaze the cylinder bore with a medium (120) grit flex-hone. The crosshatch should be at 15 to 25 degrees with the top of the cylinder block.

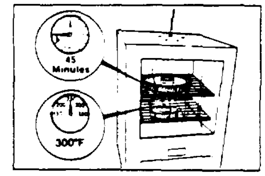


Part or Assembly	Ref. Point	mm		in	
Cylinder bore diameter		102.000	MIN	[4.0157]	
		102.116	MAX	[4.0203]	
Out-of-Roundness		0.035	MAX	[0.0015]	
Taper		0.76	MAX	[0.003]	
Overall Flatness		0.75	MAX	[0.003]	
Main bearing bore diameter with bolts tightened to 176 N·m [130 ft-lb]		83.106	MAX	[2.2720]	
Camshaft bore diameter with bushing installed.		54.107	MIN	[2.1302]	
		54.146	MAX	[2.1317]	
Camshaft bore diameter for all journals except no. 1.		54.164	MAX	[2.1324]	
Tappet bore diameter.		16.000	MIN	[0.630]	
		16.055	MAX	[0.632]	

Crankshaft

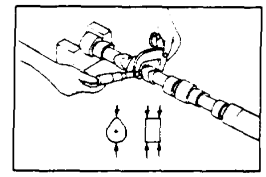
Crankshaft main bearing journal diameter		82.962	MIN	[3.2662]	
		83.013	MAX	[3.2682]	
Out of roundness		0.050	MAX	[0.002]	
Taper		0.013	MAX	[0.0005]	
Bearing clearance		0.119	MAX	[0.0047]	

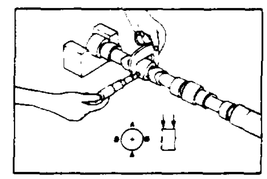
Heat the crankshaft gear at 148° C [300° F] for 45 minutes. The gear will be permanently distorted if temperature exceeds 177° C [350° F].



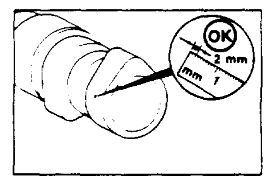
Camshaft

Part or Assembly	Ref. Point	mm		in
Camshaft diameter at peak of the lobe.	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
Camshaft bearing journal diameter.		53.962	MIN	2.1245
		54.013	MAX	2.1265

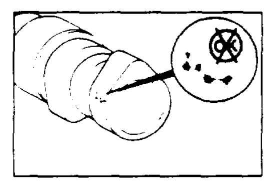




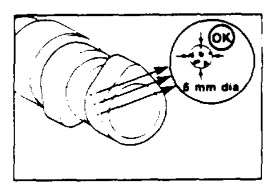
Pitting Reuse Criteria
A single pit should not be greater than the area of a 2 mm [.079 in] diameter circle.



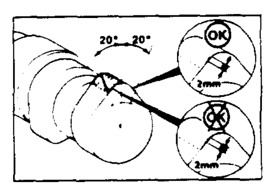
Interconnection of pits is not allowable and is treated as one pit.



The total pits, when added together, should not exceed a circle of 6 mm [0.236 in].

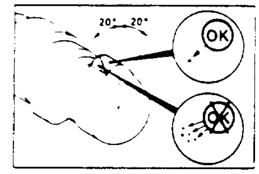


Only one pit is allowed within + or - 20 degrees of the nose of the cam lobe.

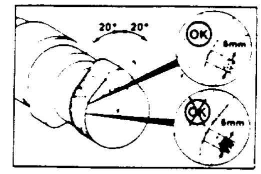


Part or Assembly	Ref. Point	mm		in

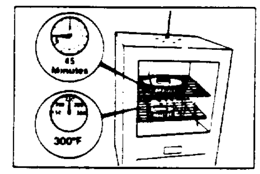
Edge Deterioration (Breakdown) Criteria
The area of edge deterioration should not be greater than the equivalent area of a 2 mm [0.079 in] circle within + or - 20 degrees of the nose of the cam lobe.



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.

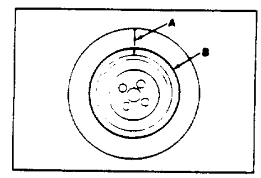


Heat the camshaft gear at 148° C [300° F) for 45 minutes. The gear will be permanently distorted if temperature exceeds 177° C [350° F].



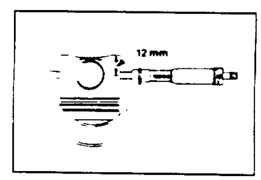
Vibration Damper

Part or Assembly	Ref. Point	mm		in
Index line out of alignment.	A	1.59	MAX	[1/16
Missing rubber member chunks	B	3.18	MAX	[1/8]

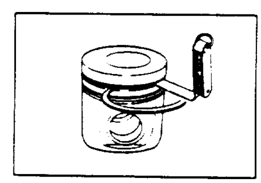


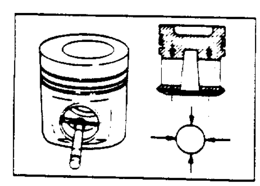
Piston

Part or Assembly	Ref. Point	mm		in
Measure the piston skirt diameter as illustrated.		101.823	MIN	[4.0088]
		101.887	MAX	[4.0107]



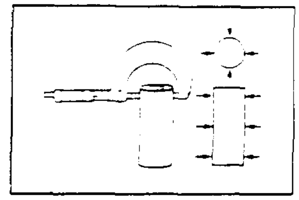
Part or Assembly	Ref. Point	mm		in
Use a new piston ring to measure the clearance in the ring groove.				
	Top	0.075	MIN	[0.003]'
		0.150	MAX	[0.0059]
	Intermediate	0.075	MIN	[0.003]
		0.150	MAX	[0.0059]
	Oil Control	0.040	MIN	[0.0016]
		0.130	MAX	[0.0051]
Pin bore diameter		40.006	MIN	[1.5750]
		40.025	MAX	[1.5758]





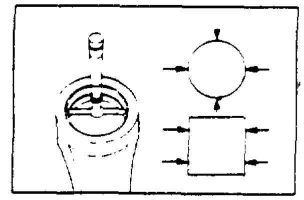
Part or Assembly	Ref. Point	mm		in

Piston Pin



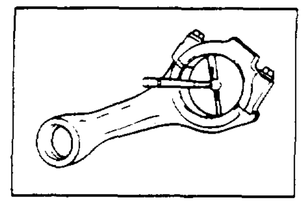
Piston pin diameter		39.990 40.003	MIN MAX	[1.5744] [1.5749]

Connecting Rod



Pin bore diameter (with bushing installed).		40.053 40.092	MIN MAX	[1.5769] [1.5784]

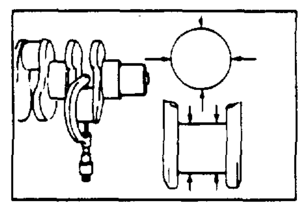
Rod Bearing Clearance - Checking



Measure the crankshaft bore with the bearings installed and the capscrews tightened to 99 N•m [73 ft4b].

Record the smallest diameter.

Measure and record the mean diameter of rod journal on the crankshaft.	68.962 69.013	MIN MAX	[2.7150] [2.7170]

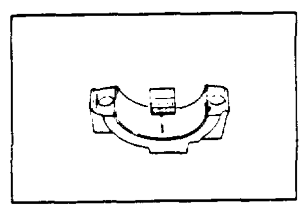


Out-of-Roundness: 0.050mm [0.002 in]
Taper: 0.013mm [.0005 in]

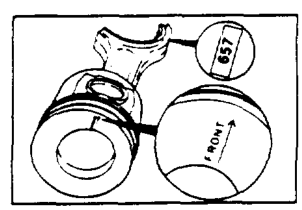
Bearing clearance - Rod Inside Diameter Minus Crankshaft Journal Diameter.

Clearance: 0.114mm [0.0045 in]

Bearing clearance can also be determined with plastigage during engine assembly.

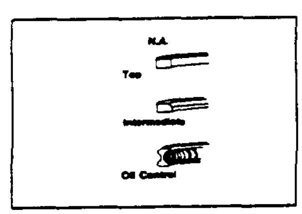


Piston and Connecting Rod - Assembly



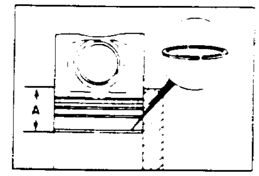
Caution: Be sure "front" marking on piston and the numbers on the rod and cap are oriented as illustrated.

Piston Ring Gap - Checking

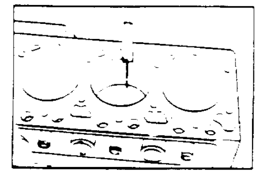


Caution: The top ring for a turbocharged engine is not the same as the top ring for a naturally aspirated engine.

Part or Assembly	Ref. Point	mm		in
Position each ring in the cylinder and use a piston to square it with the bore.	A - 89mm [3.5 in]			

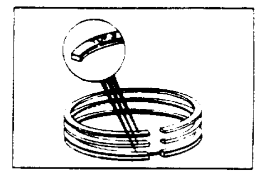


Part or Assembly	Ref. Point	mm		in
Use a feeler gauge to measure the gap.				
	Top	0.25	MIN	[0.0100]
	(N. Aspirated)	0.55	MAX	[0.0215]
	Intermediate	0.25	MIN	[0.0100]
		0.55	MAX	[0.0215]
	Oil Control	0.25	MIN	[0.0100]
		0.55	MAX	[0.0215]

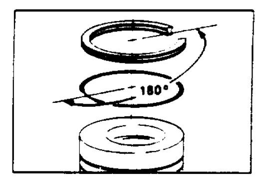


Piston Rings - Installation

The top surface of all of the rings are identified: Assemble the word "top" up.



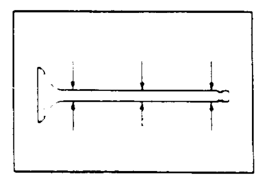
Install the oil control ring with the end gap 180' from the ends of the expander.



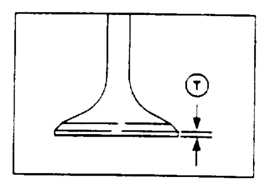
Cylinder Head - Group 2 Specifications

Valve Inspection

Part or Assembly	Ref. Point	mm		in
Valve stem diameter.		7.94	MIN	0.3126
		7.98	MAX	0.3142

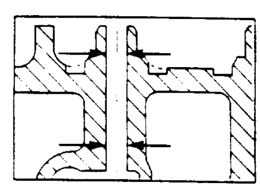


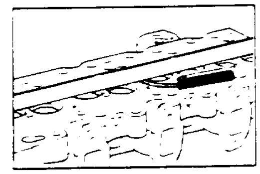
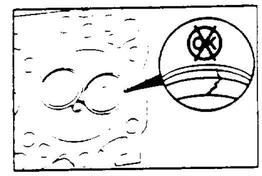
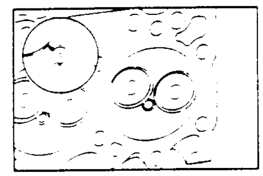
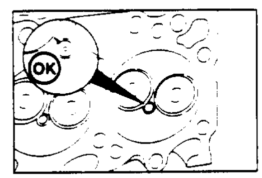
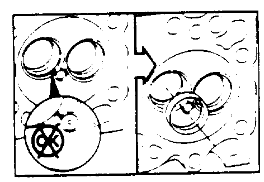
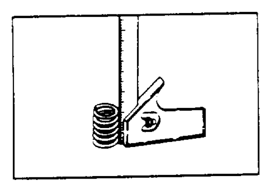
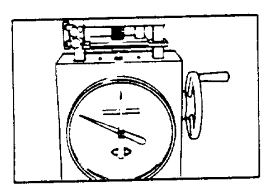
Part or Assembly	Ref. Point	mm		in
Rim thickness Limit	T	0.79	MIN	[0.031]



Valve Guide

Part or Assembly	Ref. Point	mm		in
Valve guide bore diameter.		8.019	MIN	0.3157
		8.090	MAX	0.3185

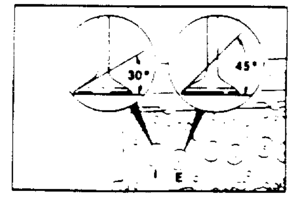


Part or Assembly	Ref. Point	mm		in	
Cylinder Head Deck Flatness					
Overall Flatness, end to end and side to side		0.75	MAX	[0.003]	
Valve Seats					
Grinding cleanup		0.254	MAX	[0.010]	
Cylinder Head Cracks - Reuse Guidelines					
These guidelines apply only to cracks extending from the injector bore 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 head is reusable.					
If the crack extends into or through the valve seat, the head must be repaired by installing a valve seat insert per the Alternative Repair Manual, Bulletin No. 3810234.					
Valve Springs					
Valve spring measurements. Approx. Free Length 55.63 mm [2.190 in.]	Inclination:	1.0	MAX	[0.039]	
A load of 289.13 - 321.16 N. [65.0 - 72.2 lb] is required to compress the spring to a height of 49.25 mm [1.94 inches].					

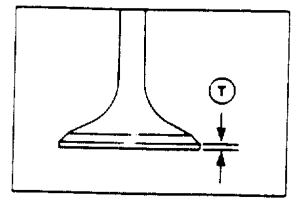
Part or Assembly	Ref. Point	mm		in

Valve Grinding

Grinding angle		Intake: 30 degrees Exhaust: 45 degrees		



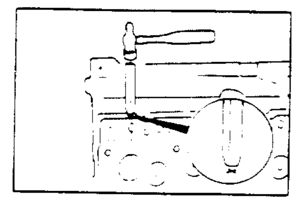
Rim thickness	T	0.79	MIN	0.031]



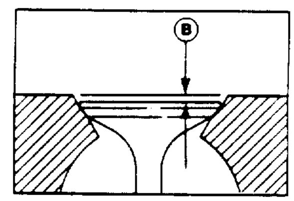
Valve Seat Grinding

The illustrated marks indicate valve seats have been ground previously. Additional grinding will result in grinding past the induction hardened area.

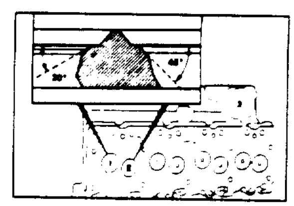
Replace previously re-ground seats will with service seats. Refer to the Alternative Repair Manual, Bulletin No. 3810234.



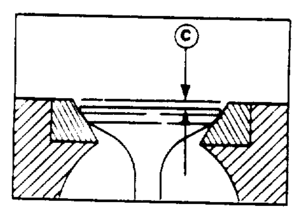
Seat grinding depth	B	0.254	MAX	[0.010]



Seat grinding angle		Intake: 30 Degrees Exhaust: 45 Degrees		

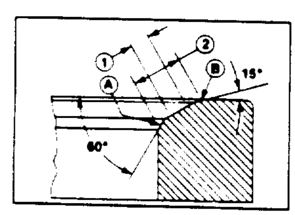


Valve depth	C	0.99 1.52	MIN MAX	[0.039] [0.060]



Valve seat width limit

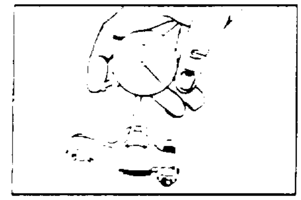
Grind area (A) with a 60 degree stone and (B) with a 15 degree stone to center the seat on the valve face and obtain the valve seat width limits.	1 2	1.5 2.0	MIN MAX	[0.060] [0.080]



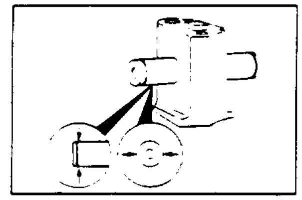
Part or Assembly	Ref. Point	mm		in

Rocker Levers and Pedestals - Group 3 Specifications

Rocker lever bore diameter.		19.000	MIN	[0.7480]
		19.051	MAX	[0.7500]

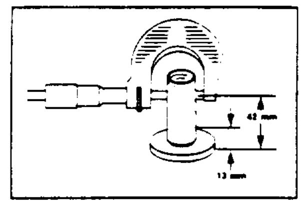


Pedestal shaft diameter.		18.938	MIN	[0.7456]
		18.975	MAX	[0.7470]



Tappet and Push Rods - Group 4 Specifications

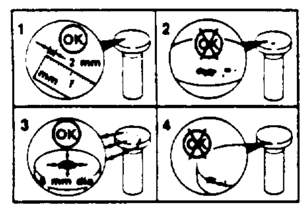
Valve Tappet stem diameter.		15.936	MIN	[0.627]
		15.977	MAX	[0.629]



Pit marks on the tappet face are acceptable.

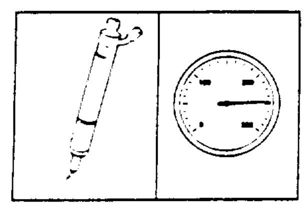
The following criteria defines the size of the pits allowed.

1. A single pit can not 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 inch] 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.

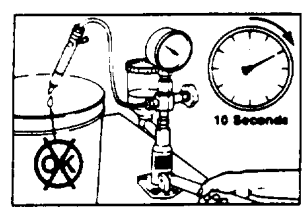


Injectors - Group 6 Specifications

Injector opening pressure
a. Open valve
b. Operate lever at one stroke per second
c. Read pressure indicated when spray begin

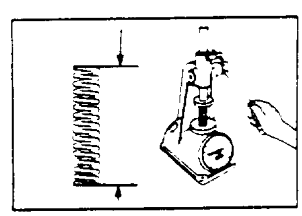


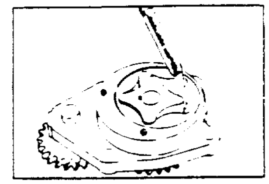
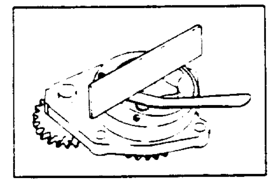
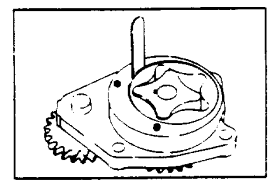
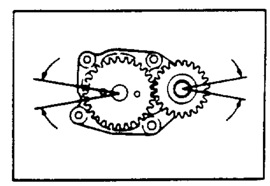
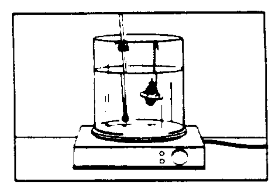
Leakage Test:
a. Open valve
b. Operate lever to hold pressure 20 bar [290 psi] below opening pressure
c. No drops should fall from the tip within 10 seconds



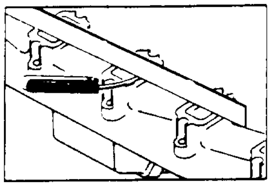
Lubrication - Group 7 Specifications

Pressure regulator valve spring valves.		Valve Open (Min.) Height: 39.98 mm [1.574 inches] Load: 91 N [20.5 lbs] Assembled (Min.) Height: 44.98 mm [1.77 inches] Load: 60 N [13.5 lbs]		

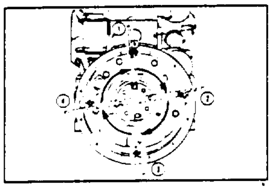


Part or Assembly	Ref. Point	mm		in	
Oil pump tip clearance		0.1778	MAX	[0.007]	
Port plate clearance		0.127	MAX	[0.005]	
Body bore clearance		0.381	MAX	[0.015]	
Gear backlash Limits for a used pump.		0.05 0.45	MIN MAX	[0.003] [0.018]	
Cooling System - Group 8 Specifications Thermostat requirements.		Start to open 83° C [181° F] Fully open 95° C [203° F]			

Part or Assembly	Ref. Point	mm		in
Exhaust System - Group 11 Specifications				
Exhaust manifold flatness.		0.10	MAX	[0.004]

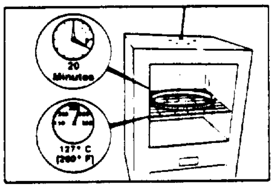


Part or Assembly	Ref. Point	mm		in
Mounting Adaptations - Group 16 Specifications				
Flywheel Housing Runout		0.20	MAX	[0.008]



Ring Gear Replacement

Heat the new ring gear for 20 minutes in an oven preheated to 127° C [2600 Fl.



Capscrew Markings and Torque Values - Metric

Metric capscrews are identified by the grade number stamped on the head of the capscrew or on the surface of metric nuts. The higher the number, the greater the strength of the capscrew.

Commercial Steel Class

			
Thread Diameter mm	Torque N•m [ft-lb]	Torque N•m [ft4b]	Torque N•m [ft-lb]
5	6 [5]	8 [6]	8 [6]
6	9 [7]	14 [10]	15 [11]
8	24 [18]	34 [25]	38 [28]
10	43 [32]	64 [47]	77 [57]
12	77 [57]	112 [83]	137 [101]
14	127 [94]	180 [133]	216 [159]
16	195 [144	266 [196]	319 [235)

Notes:
1. Do not use these values when the torque values are specified in another section of the manual.
2. These values are based on clean, dry threads. Reduce the value by 10% when a lubricant is used. Reduce the value by 20% if new plated capscrews are used.

Torque Specification
The B series engine uses parts that are of metric dimensions.

Always use caution to be sure that capscrews from the engine are put back in their proper locations.

When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Incorrect capscrews can result in engine damage.

Metric Capscrew Nomenclature

M8 X 1.25 - 25

25 — Length in millimeters

1.25 — Distance between threads in millimeters

M8 — Major thread diameter in millimeters

Pipe: Plugs, Fittings, and Adapters

• When installing directional fittings, tees or elbows, first tighten it to the appropriate torque value and then continue to turn it in the tightening direction until it is aligned. Do not turn it in the loosening direction, and do not turn it more than one revolution past the specified torque value.

• Apply liquid Teflon to all pipe fittings and plugs.

Torque For Pipe Plugs

Pipe Plug Size	Torque (Into Aluminum Or Cast Iron)	
	N•m	[Ft-lb]
1/16"	6	[4]
1/8"	8	[6]
1/4"	12	[9]
3/8"	15	[11]
1/2"	24	[18]
3/4"	36	[27]
1"	45	[33]

Engine Component Torque Value

Socket Or Wrench Size MM (Inch)			Torque ± N•m	(Ft-lb)	
12	Air Fuel Control Banjo Screw (In Pump)		12 ± 2	(9)	
(1/2)	Air Fuel Control Fitting (In Head)		8 ± 1	(6)	
(15/16)	Alternator Pulley		80 ± 8	(59)	
16	Alternator Mounting Bolt 15 SI		43 ± 4	(32)	
18	Alternator Mounting Bolt and Nut 20-27 SI		77 ± 7	(57)	
13	Alternator Support (Upper)		24 ± 3	(18)	
23	Balancer Mounting	Step 1	50	(36)	
	(Alternately Tighten	Step 2	80	(58)	
	in Three Steps)	Step 3	175	(129)	
Allen 8mm	Balancer Idler Gear		43 ± 4	(32)	
Allen 8mm	Belt Tensioner Flat Bracket		24 ± 3	(18)	
15	Belt Tensioner Mounting		43 ± 4	(32)	
13	Cam Thrust Plate		24 2 3	(18)	
12	Connecting Rod	Step 1	35	(26)	
	(Alternately Tighten	Step 2	70	(51)	
	in three Steps)	Step 3	100	(73)	
15	Crankshaft Damper & Pulley		125 ± 6	(92)	
18	Cylinder Head Mounting	Step 1	40	(29)	
		Step2	85	(62)	
		Step 3	126	(93)	
13	Exhaust Manifold		43 ± 4	(32)	
10	Fan Bracket Mounting		24	3	(18)
13	Fan Pulley		24	3	(18)
19	Flywheel		137	7	(101)
15	Flywheel Housing		60 ± 6	(45)	
13	Flywheel Housing Cover		24 ± 3		(18)
(1/2)	Flywheel Housing Plug		36 ± 3	(25)	
--	Front Cover Cap		Hand Tighten		
18	Front Engine Support Mounting		77 ± 7	(57)	
(1 1/8)	Front Engine Support (Barrel)		350 ± 20	(257)	
17	Fuel Banjo Screw (In Fuel Pump)		32 ± 3	(27)	
17	Fuel Banjo Screw (In Head)		24 ± 3	(18)	
10	Fuel Banjo Screw (in Injector)		8 ± 1	(6)	
10	Fuel Vent Screw on Banjo)		8 ± 1	(6)	
80-95	Fuel Filter		3/4 Turn After Contact		

Engine Component Torque Value

Socket Or Wrench Size MM (Inch)			Torque ± N•m	(Ft-lb)
14	Fuel Low Pressure Supply		32 ± 3	(27)
24	Fuel Filter Adapter Nut		32 ± 3	(24)
17	Fuel Line Fitting (High Press)		24 ± 3	(18)
22	Fuel Pump Drive Gear (With Pump Unlocked)		65 ± 6	(48)
(9/16)	Fuel Pump Lock (CAV)		7 ± 1	(5)
	Fuel Pump Unlock (CAV)		20 ± 3	(15)
13	Fuel Pump Mounting Nut		24 ± 3	(18)
10	Fuel Pump Support Bracket		24 ± 3	(18)
10	Gear Cover		24 ± 3	(18)
10	Gear Housing-to-Block		24 ± 3	(18)
24	Injector Retaining Nut		60 ± 5	(44)
10	Intake Manifold Cover		24 ± 3	(18)
(5/8)	Intake Heater Plug		125 ± 10	(90)
10	Lift Pump Mounting/Cover Plate		24 ± 3	(18)
18	Lifting Bracket (Rear)		77 ± 7	(57)
23	Main Bearing Cap	Step 1	60	(44)
		Step2	119	(88)
		Step 3	176	(129)
15	Oil Fill Tube Mounting		43 ± 4	(32)
75-85	Oil Filter		3/4 Turn After Contact	
10	Oil Cooler Assembly		24 ± 3	(18)
17	Oil Pan Drain Plug		80 ± 3	(60)
17	Oil Pan Heater Plug		80 ± 3	(60)
10	Oil Pan Mounting		24 ± 3	(18)
19	Oil Pressure Regulator Plug		80 ± 12	(60)
13	Oil Pump Mounting		24 ± 3	(18)
13	Oil Suction Tube (Flange)		24 ± 3	(18)
10	Oil Suction Tube Brace		24 ± 3	(18)
15	PTO Adapter		77 ± 7	(57)
13	PTO Adapter Cover Plate (A Drive)		43 ± 4	(32)
15	PTO Adapter Cover Plate (B Drive)		77 ± 7	(57)
(3/4)	PTO Gear Nut A Drive		100 ± 10	(74)
(15/16)	PTO Gear Nut B Drive		134 ± 13	(100)
8	Rear Seal Mounting		9 ± 1	(7)
13	Rocker Support		24 ± 3	(18)
(9/16)	Rocker Lever Nut		24 ± 3	(18)
10	Starter Mounting		43 ± 4	(32)
10	Tach Drive Retainer		3 ± 1	(2)

Engine Component Torque Value

Socket Or Wrench Size MM (Inch)		Torque ± N•m	(Ft-lb)
10	Tappet Cover/Fuel Drain Line Supports	24 ± 3	(18)
(7/16)	Tee Bolt Type Clamp	8 ± 1	(6)
10	Thermostat Housing	24 ± 3	(18)
T-25 Torx	Timing Pin Flange Mounting	5 ± 1	(4)
	Water Hose Clamps	4 ± 5	(4)
13	Water Inlet Connection	43 ± 4	(32)
(3/8)	Water Inlet Plugs	24 ± 3	(18)
13	Water Pump Mounting	24 ± 3	(18)
15	Valve Cover	24 ± 3	(18)
--	Valve Cover Oil Fill	Hand Tighten	

B Series Sealants

Use the sealants listed below or sealants containing equivalent properties.

Part	Sealing Method
Pipe Plugs	Precoated blue teflon.
Gaskets	
Oil Pan	Apply Three Bond 1 207-C to the four "T" joints and smear into the joints with finger until full.
Gear Cover	No sealant required.
Tappet Cover	Self-adhesive tappet cover side. K&W Copper Coat #1504 - block side.
All Other Gaskets	K&W Copper Coat #1504- both sides.
Cup Plugs	Loctite 277 or 11,264.
O-Rings	No sealant required.
Rear Camshaft Expansion Plug	Loctite 277.
Intake Cover Capscrews	Precoated or Loctite 59,241 liquid teflon.
Fuel Pump Studs	Loctite 601.
Dipstick Tube in Block	Loctite 277 or 11,264 or precoated.
Wet Flywheel Housing to Block	Permatex 2-C.
Front Seal in Gear Cover	Loctite 277 or 11,264.
Rear Seal in Rear Cover	No sealant required.
Timing Pin Housing C/S	Loctite 59,241 liquid teflon or precoated.

B Series Lubricants

Use the lubricants listed below or lubricants containing equivalent properties.

Part	Lubricant Reauired
Rod Bearings	Lubriplate 105
Main Bearings	Lubriplate 105
Cam Lobes and Journals	Lubriplate 105
Tappets	Lubriplate 1 05
Pistons	15W40 Engine Oil
Piston Rings	15W40 Engine Oil
Piston Pin	15W40 Engine Oil
Rocker Assemblies	15W40 Engine Oil
Push Tubes	15W40 Engine Oil + Lubriplate 105 in Cup
Capscrews (under head and on threads)	15W40 Engine Oil
Main Capscrews	15W40 Engine Oil
Balancer Mounting Capscrews	15W40 Engine Oil
Cylinder Head Capscrews	15W40 Engine Oil
Connecting Rod Capscrews	15W40 Engine Oil
Flywheel Mounting Capscrews	15W40 Engine Oil
Damper Mounting Capscrews	15W40 Engine Oil
All Other Capscrews	Preservative oil or 1 5W40 Engine Oil
Valve Stems	90W or 140W Oil
Front and Rear Seals to Crankshaft	Dry - use no Lubricants
Rear Seal in Seal Housing	Soapy water to install seal in housing
Lube Oil Pressure Regulator	15W40 Engine Oil

ALPHABETICAL INDEX

ALPHABETICAL INDEX - continued

ALPHABETICAL INDEX - continued

ALPHABETICAL INDEX - continued

ALPHABETICAL INDEX - continued

ALPHABETICAL INDEX - continued

ALPHABETICAL INDEX - continued

ALPHABETICAL INDEX - continued

By Order of the Secretary of the Army:

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