SB4106E01

Service Manual

A2300 Diesel Engine
D15S-5, D18S-5, D20SC-5
G15S-5, G18S-5, G20SC-5
GC15S-5, GC18S-5, GC20SC-5

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the “Safety” section of the Service or Technical Manual. Additional safety precautions are listed in the “Safety” section of the owner/operation/maintenance publication.
Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards.
If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.

⚠ WARNING

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.
Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

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Introduction

About the Manual

The procedures in this manual were developed for an in-chassis environment. The information has been grouped by the main engine systems. The Table of Contents defines the systems. The index at the beginning of each section subdivides the instructions for the various components of the system. Wrench sizes and special tools are identified in the procedures as needed.

How to Use the Manual

The organization of this manual is based on the troubleshooting logic presented in Section 2. To fix a problem, find the logic chart for the particular symptom. Follow the steps specified until the problem is corrected.

The left column of the charts indicates a probable cause. The right column provides a brief description of the corrective action with a reference to the repair procedure or diagnostic discussion when appropriate.

The logic charts reflect three basic considerations:

1. Assumes the engine has provided satisfactory service prior to the problem.
2. Performing the easiest things first.
3. Most logical cause in descending order.

If the problem occurs with a new engine or after repair of the engine, the diagnostics discussion for each major system will provide guidance for sorting out the cause of the problem.

Generic Symbols

The following group of symbols has 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.

Causion – 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 23kg [50lb] 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.

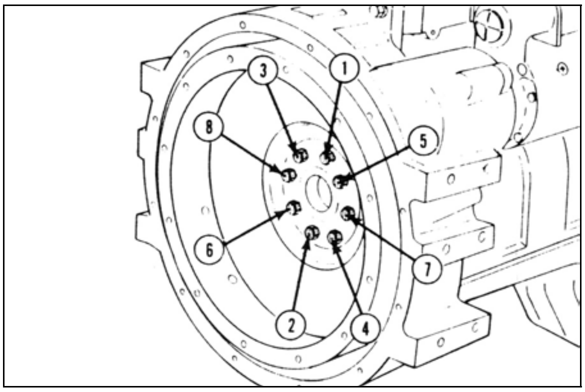
TIGHTEN to a specific torque

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 o the step or steps involved.

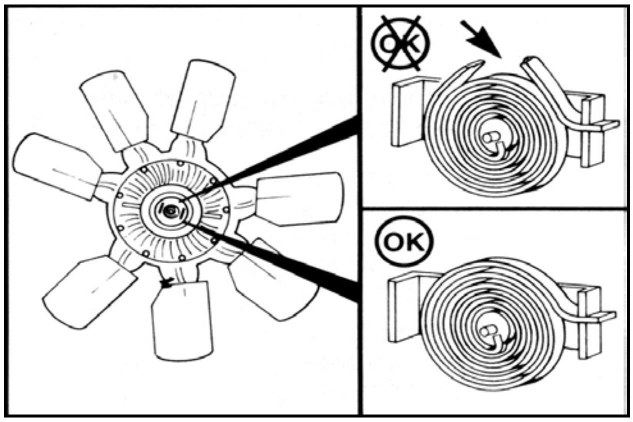
Check	Examine a component or system for damage, excessive wear, accuracy, safety, or performance.
Inspect	Examine a component or dimension to make sure it meets the required specifications.
Test	Check or compare the performance of a component or system to established specifications.
Adjust	Complete the 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	

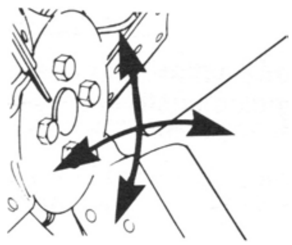
Illustrations

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.

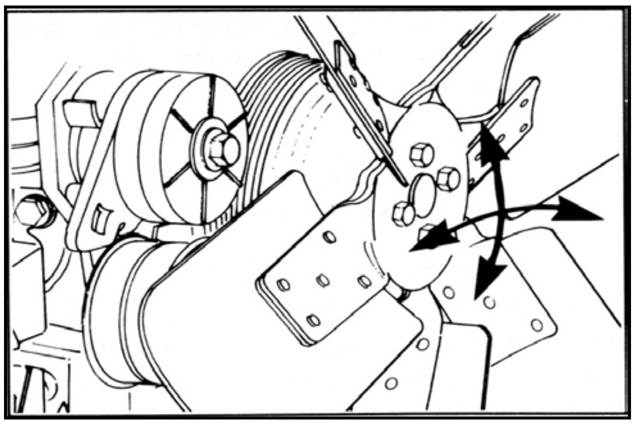
Unacceptable

Acceptable





Direction of Movement (Action)

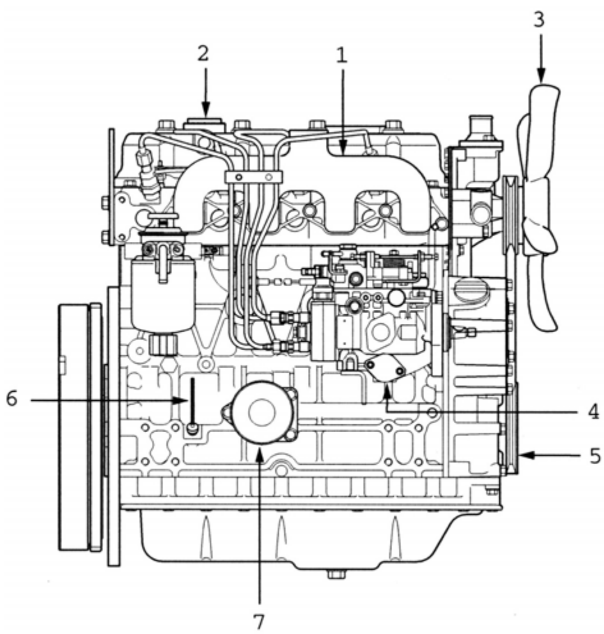


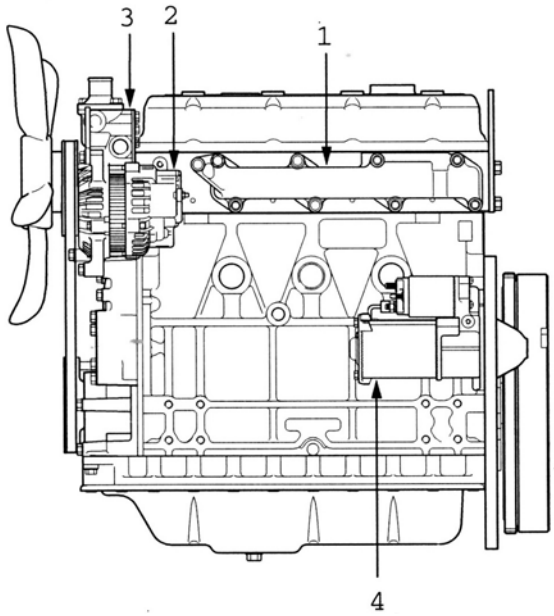
The illustrations used in the Replacement Sections are intended to show replacement procedures when the engine is installed in a chassis. The illustration may differ from your application, but the procedure given will be the same.

General Engine Information

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.



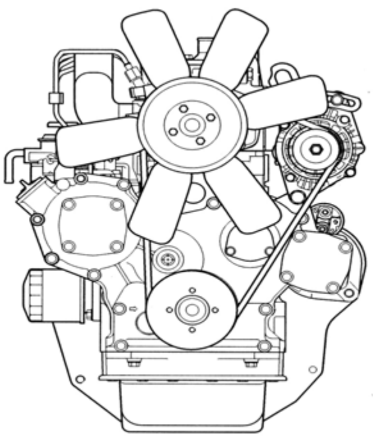


Exhaust Side [Naturally Aspirated]

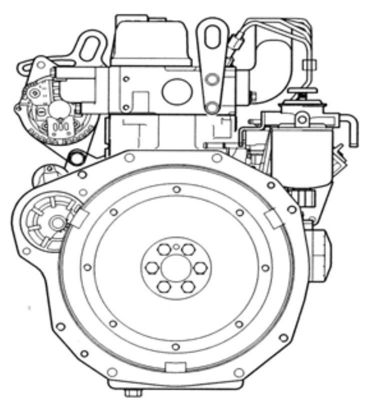
1. Exhaust Manifold
2. Oil Fill Cap
3. Fan
4. Fuel Injection Pump
5. Crankshaft Pulley
6. Dip Stick
7. Oil Filter

Intake Side [Naturally Aspirated]

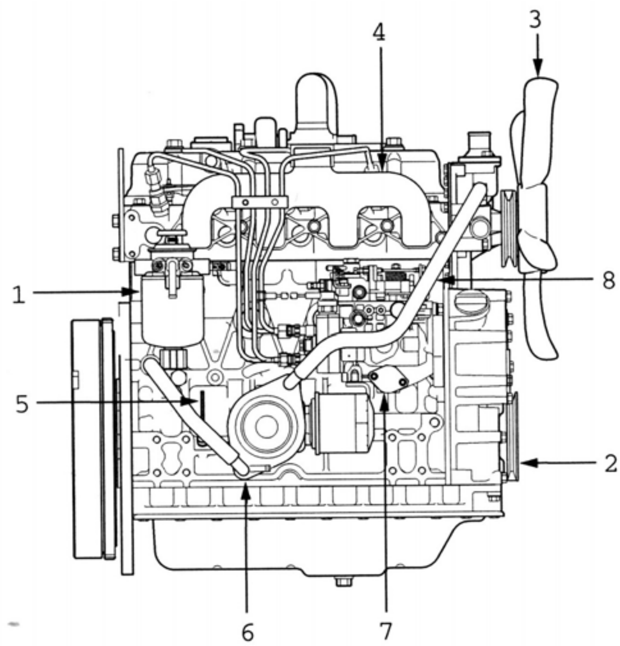
1. Intake Manifold
2. Alternator
3. Thermostat housing
4. Starting Motor

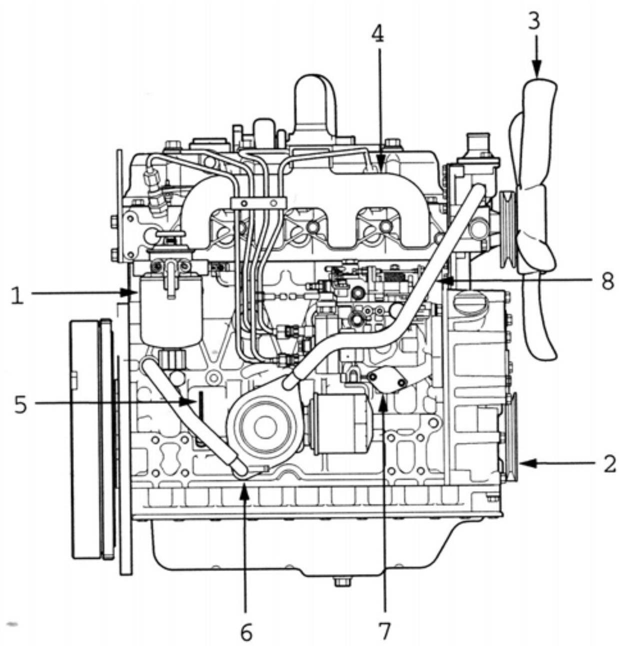


Front View
(Naturally Aspirated)



Rear View
(Naturally Aspirated)



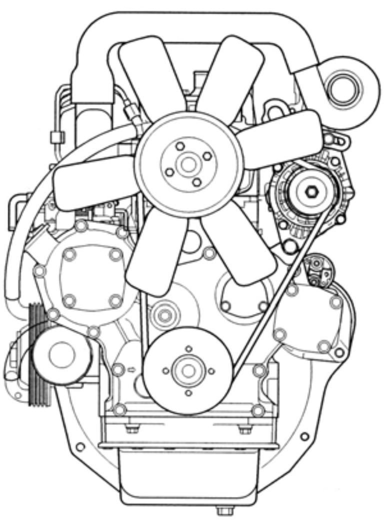


Exhaust Side [Turbocharged]

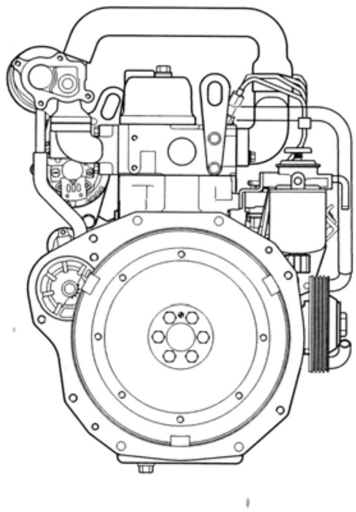
1. Fuel Filter
2. Crankshaft Pulley
3. Cooling Fan
4. Exhaust Manifold
5. Dipstick
6. Oil Cooler
7. Fuel Injection Pump
8. Turbocharger Oil Drain Tube

Intake Side [Turbocharged]

1. Turbocharger
2. Alternator
3. Thermostat Housing
4. Intake Manifold
5. Starting Motor
6. Turbocharger Oil Tube
7. Oil Fill Cup
8. Air Crossover Tube



Front View
(Turbocharged)



Rear View
(Turbocharged)

Engine Specifications

Engine Model		A2300
General Engine Data		Naturally Aspirated
Engine Weight(Dry) Less Flywheel and Electronics		169 kg [373 lb]
Compression Ratio		21:1
Bore [mm/inch]		88 [3.46]
Stroke [mm/inch]		94 [3.7]
Displacement [ℓ/in3]		2.29 [139]
Firing Order		1-3-4-2
Valve Clearance	Intake Exhaust	0.3 mm [0.012 in] 0.3 mm [0.012 in]
Rotation Viewed from the Front of the Engine		Clockwise

Lubrication System		Naturally Aspirated
Regulating Valve Opening Pressure		290 – 390kPa [42-56 psi]
Lubricating Oil Capacity [ℓ/gal]	Total System Standard Oil Pan Only	7.0 [1.85] 6.5 [1.72]
Lubricating Oil Pressure at Idle(Max. Allowable)		69 kPa [10 psi]
Lubricating Oil Pressure at Rated(Min. Allowable)		245 kPa [35 psi]
Oil Filter Differential Pressure to Open Bypass Valve		98 kPa [14 psi]
Number of liters [qt] from Low to High		2.0 ℓ [0.53 gal]
Lubrication System		Forced Lubrication with Pump

Cooling System		Naturally Aspirated
Coolant Capacity (Engine Only) [ℓ/gal]		3.0 [0.7]
Standard Modulating Thermostat Range [℃/F]	Start Pulley Open	71 [160] 8 [185]
Cooling System		Forced Lubrication with Pump

Air Induction System	Naturally Aspirated
Maximum Allowable Intake Restriction at Rated Speed and Load with Dirty Filter Element	6.23 kPa [635 mmAq]

Exhaust System	Naturally Aspirated
Maximum Allowable Exhaust Restriction at Rated Speed and Load with Dirty Filter Element	5.88 kPa [600 mmAq]

Fuel System	Naturally Aspirated
Injection Pressure	150 kPa [22 psi]
Starting System	Electric starting with Starter Motor (12 V –2.0 kW)

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.
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

Page	List of Symptoms
52	Alternator Not Charging or Insufficient Charging
36	Coolant Loss
32	Coolant Temperature Above Normal
35	Coolant Temperature Below Normal
46	Compression Knocks
43	Contaminated Coolant
44	Contaminated Lube Oil
15	Engine Cranks But Will Not Start – No Smoke From Exhaust
16	Engine Hard to Start Or Will Not Start – Smoke From Exhaust
24	Engine RPM Will Not Reach Rated Speed
22	Engine Runs Rough or Misfiring
18	Engine Starts But Will Not Keep Running
14	Engine Will Not Crank Or Cranks Slowly
48	Engine Will Not Shut Off
51	Excessive Engine Noises
30	Excessive Engine Smoke
47	Excessive Fuel Consumption
49	Excessive Vibration
45	Fuel or Oil Leaking From Exhaust Manifold
26	Low Power
41	Lube Oil Loss
38	Lubricating Oil Pressure Low
40	Lubricating Oil Pressure Too High
20	Rough Idle (Irregularly Firing Or Engine Shaking)
19	Surging (Engine Speed Change)

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. Refer to Page 138
OK ↓	
Crankshaft Rotation Restricted	Bar the Engine to Check for Rotational Resistance. Refer to Page 138
OK ↓	
Starting Circuit Connections Loose Or Corroded	Clean and Tighten Connections. Refer to Page 137
OK ↓	
Battery Charge Low	Check Battery Voltage. Refer to Page 137
OK ↓	
No Voltage to Starter Solenoid	Check Voltage to Solenoid. Refer to Page 137
OK ↓	
Solenoid or Starting Motor Malfunction	Replace Starting Motor. Refer to Page 144

Engine Cranks But 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. Refer to Page 74
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. Refer to Page 71, 83
OK ↓	
Injection Pump Not Getting Fuel or Fuel is Aerated	Check Fuel Flow/Bleed Fuel System. Refer to Page 83
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. Refer to Page 94
OK ↓	
Internal Pump Timing Incorrect	Verify/Time the Pump. Refer to Page 77
OK ↓	
Camshaft Out of Time	Check/Correct Gear Train Timing Alignment. Refer to Page 77, 185

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

Cause	Correction
Incorrect Starting Procedure	The Fuel Control Lever on the Bosch VE 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. Refer to Page 137
	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. Refer to Page 98, 112
OK ↓	
Air in the Fuel System or the Fuel Supply is Inadequate	Check the Flow through the Filter and Bleed the System. Locate and Correct the Air Source. Refer to Page 83
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. Refer to 94
OK ↓	
Injection Pump Out of Time	Check/Time the Pump. Refer to Page 77, 96
OK ↓	
Valves Incorrectly Adjusted	Adjust Valves. Refer to Page 179
OK ↓	
One or More Injectors Worn or Malfunctioning	Check/Replace Injectors. Refer to Page 88
OK ↓	
Engine Compression Low	Perform a Compression Check to Identify the Problem. Refer to Page 158

Engine Starts But Will Not Keep Running

Cause	Correction
Engine Starting Under Load	Disengage Driven Units.
OK ↓	
Idle Speed Too Low For Accessories	Adjust the Idle Speed. Refer to Page 73
OK ↓	
Intake Air or Exhaust System Restricted	Visually Check for Exhaust Restriction and Inspect the Air Intake. Refer to Page 99, 101
OK ↓	
Air in the Fuel System or the Fuel Supply is Inadequate	Check the Flow Through the Filter and Bleed the System. Locate and Correct the Air Source. Refer to Page 83
OK ↓	
Fuel Waxing Due to Extremely Cold Weather	Verify by Inspecting the Fuel Filter. Clean the System and Use Climatized Fuel or Fuel Heaters.
OK ↓	
Contaminated Fuel	Verify by Operating the Engine With Clean Fuel from a Temporary Supply Tank. Drain and Flush the Fuel Supply Tank.
OK ↓	
Restricted Fuel Drain Manifold or Return Line	Check/Correct the Restriction. Refer to Page 81

Surging (Speed Change)

Cause	Correction
If the Condition Occurs at Idle, the Idle Speed is Set Too Low for Accessories	Adjust the Idle. Refer to Page 73
OK ↓	
High Pressure Fuel Leak	Inspect/Correct Leaks in the Pressure Lines. Fittings, Injector Sealing Washers or Delivery valves. Refer to Page 78
OK ↓	
One or More Injectors Worn or Malfunctioning	Check/Replace the Injectors. Refer to Page 88
OK ↓	
Malfunctioning Delivery Valve	Replace Delivery Valves. Refer to Page 84
OK ↓	
Malfunctioning Injection Pump	Replace the Pump. Refer to Page 94

Rough Idle (Irregularly Firing Or Engine Shaking)

Cause	Correction
Cold Engine	Refer to Troubleshooting Logic for Engine Running Too Cold. Refer to 35
OK ↓	
Idle Speed Too Low for the Accessories	Check/Adjust Low Idle Screw. Refer to Page 73
OK ↓	
Engine Mounts Over-Tightened, Damaged or Loose	Verify Condition of Mounts. Refer to Equip. Manufactures Service Instructions.
OK ↓	
High Pressure Fuel Leak	Inspect/Correct Leaks in the High Pressure Lines, Fittings Injection Sealing Washers or Delivery Valve Seals. Refer to Page 78
OK ↓	
Air in the Fuel System	Bleed the Fuel System and Correct the Source of the Air. Refer to Page 83
OK ↓	
Sticking Needle Valve in an Injector	Replace the Injector. Refer to Page 88
OK ↓	
Malfunctioning Delivery Valve	Replace Delivery Valves. Refer to Page 92
OK ↓	

(Continued)

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

Cause	Correction
Valves Not Sealing	Adjust Valves. Refer to Page 179
OK ↓	
One or More Cylinders Losing Compression	Perform a Compression Check and Repair as Required. Refer to Page 160

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 Valve. Refer to Page 78
OK ↓	
Air in the Fuel or the Fuel Supply is Inadequate	Check the Flow Through the Filter and Bleed the System. Locate and Correct the Air Source. Refer to Page 83
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. Refer to Page 179
OK ↓	
Injection Pump Timing Incorrect	Check/Time Pump. Refer to Page 77
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). Refer to Page 158
OK ↓	

(Continued)

Engine Runs Rough Or Misfiring (Continued)

Cause	Correction
Malfunctioning Injectors	Replace Injectors. Refer to Page 88
OK ↓	
Defective Injection Pump (Delivery Valves)	Replace Injection Pump. Refer to Page 94
OK ↓	
Camshaft Out of Time	Check/Correct Gear Train Timing Alignment. Refer to Page 185
OK ↓	
Damaged Camshaft or Tappets	Inspect Camshaft. Refer to Page 182

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.
Malfunctioning Tachometer	Verify Engine Speed with Hand Tachometer - Correct as Required.
Throttle Linkage Worn or Incorrectly Adjusted	Adjust Linkage for Stop-to-Stop Fuel Control Lever Travel. Refer to Page 73, 225
If the Problem Occurs After Replacing the Fuel Control Lever or Pump, Incorrectly Indexed Lever (Robert Bosch VE Only)	Check/Correct Fuel Control Lever Indexing. Refer to Page 74
High Speed Stop Screw Incorrectly Adjusted	Check/Set High Speed Stop Screw. Refer to Page 74, 225
Partially Engaged Mechanical Shutdown Lever	Check/Place Shutdown Lever in Run Position. Refer to Page 74, 225
Inadequate Fuel Supply	Check the Flow Through and Filter to Locate the Source of the Restriction. Refer to Page 68

OK (after each cause)

(Continued)

Engine RPM will Not Reach Rated Speed (Continued)

Cause	Correction
If the Condition is Intermittent, Restricted Manifold Drain Line	Check/Remove Restriction. Refer to Page 81
OK ↓	
Malfunctioning Injection Pump	Replace Pump. Refer to Page 94

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. Refer to Page 87
OK ↓	
Fuel Control Lever Not Moving to Full Speed.	Check/Correct for Stop-to-Stop Travel. Refer to Page 73, 225
OK ↓	
Mechanical/Shutdown Lever Partially Engaged	Check/Replace Shutdown Lever in Run Position. Refer to Page 74, 225
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. Refer to Page 77, 96
OK ↓	

(Continued)

Low Power (Continued)

Cause	Correction
Inadequate, or High or Low Temperature Intake Air	Inspect/Replace Air Cleaner Element. Look for Other Restrictions. Refer to Page 112
	If the vehicle is equipped with a Valve to Switch the Intake Source from Under the Hood to Outside, Position the Valve for the Season.
	Coolant Passage in the After Cooler Plugged.
OK ↓	
High Pressure Fuel Leak	Inspect/Correct Leaks in the High Pressure Lines, Fittings Injector Sealing Washers or Delivery Valve Seals. Refer to Page 78
OK ↓	
Inadequate Fuel Supply	Check the Flow Through the Filter to Locate the Source of the Restriction. Refer to Page 68
OK ↓	
High Fuel Temperature	Check for a Restricted Fuel Drain Manifold (Robert Bosch VE)
OK ↓	
If Low Power is Intermittent, Restricted Fuel Drain Manifold	Check/Correct Restriction. Refer to Page 81
OK ↓	
Poor Quality Fuel	Verify by Operating From a Temporary Tank With Good Fuel.
OK ↓	

(Continued)

Low Power (Continued)

Cause	Correction
Air Leak Between the Turbocharger and the Intake Manifold.	Check/Correct Leaks in the Air Crossover Tube, Hoses, or Through Holes in the Manifold Cover. Refer to Page 100, 101
OK ↓	
Exhaust Leak at the Manifold or Turbocharger	Check/Correct Leaks in the Manifold or Turbocharger Gaskets. Look for a cracked Manifold. Refer to Page 101
OK ↓	
Malfunctioning Turbocharger	Inspect/Replace Turbocharger. Refer to Page 101, 105, 109
OK ↓	
Valve Clearances Incorrect	Check/Adjust Valves. Refer to Page 179
OK ↓	
Injection Pump Internal Malfunctioning	Check/Time Pump. Refer to Page 77
OK ↓	
Low Engine Compression	Perform Compression Check to Identify Malfunction. Correct as Required. Refer to Page 158
OK ↓	
Worn or Malfunctioning Injectors	Check Injectors. Refer to Page 79
OK ↓	

(Continued)

Low Power (Continued)

Cause	Correction
Malfunctioning Injection Pump	Replace Injection Pump. Refer to Page 94
OK ↓	
Excessive Exhaust Restriction	Check/Correct Exhaust System. Refer to Page 101

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. Refer to Page 112
OK ↓	
Air Leak Between the Turbocharger and the Intake Manifold	Check/Correct Leaks in the Air Crossover Tube, Hoses, or Through Holes in the Manifold Cover. Refer to Page 100, 101
OK ↓	
Exhaust leak at the Manifold or Turbocharger	Check/Correct Leaks in the Manifold or Turbocharger Gaskets. Look for a Cracked Manifold. Refer to Page 100, 101
OK ↓	
Malfunctioning Turbocharger	Inspect/Replace Turbocharger. Refer to Page 101
OK ↓	
More than One Sealing Washer Under an Injector	Remove Extra Washer. Refer to Page 89
OK ↓	
Malfunctioning Injectors	Replace Injectors. Refer to Page 88
OK ↓	

(Continued)

Excessive Exhaust Smoke (Continued)

Cause	Correction
Malfunctioning or Over fueled Injection Pump	Replace Injection Pump. Refer to Page 94
OK ↓	
Piston Rings Not Sealing (Blue Smoke)	Perform a Compression Check. Correct as Required. Refer to Page 158

Coolant Temperature Above Normal

Cause	Correction
Low Coolant Level	Check/Replenish Coolant. Refer to Pages 54
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. Refer to Page 55
OK ↓	
High Lube Oil Level	Check/Drain Oil to Correct Level. Refer to Page 116
OK ↓	
Loose Drive Belt on Water Pump/Fan	Check/Correct Belt Tension. Refer to Page 57, 62
OK ↓	
Inadequate Air Flow to the Radiator	Check/Repair Fan Shroud, Shutters, Fan Sensors, and Fan Clutch as Required. Refer to the Equipment Manufacturer's Procedures.
OK ↓	
Radiator Fins Plugged	Blow Debris from Fins.
OK ↓	
Collapsed Radiator Hose	Check/Replace Hose. Refer to Page 58
OK ↓	

(Continued)

Coolant Temperature Above Normal (Continued)

Cause	Correction
Malfunctioning Temperature Sensor/Gage	Verify that the Gage and Temperature Sensor are Accurate. Refer to Pages 55
OK ↓	
Malfunctioning, Incorrect or No Thermostat	Check/Replace the Thermostat. Refer to Page 60, 65
OK ↓	
Air in the Cooling System	Make Sure the Fill Rate is not Being Exceeded and the Correct Vented Thermostat is Installed. Refer to Page 55
OK ↓	If Aeration Continued, Check for a Compression Leak Through the Head Gasket. Refer to Page 116
Malfunctioning Water Pump	Check/Replace the Water Pump. Refer to Page 58, 64
OK ↓	
Incorrect Injection Pump Timing	Check/Time the Injection Pump. Refer to Page 77
OK ↓	
Incorrect External Injection Pump Timing	Verify Pump Timing Marks are Aligned. Refer to Page 77, 83
OK ↓	
Over fueled Injection Pump	Replace the Injection Pump. Refer to Page 94
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. Refer to Page 55
OK ↓	
Engine Overloaded	Verify that the Engine Load Rating is Not being Exceeded. Refer to Page 60, 65

Coolant Temperature Below Normal

Cause	Correction
Too Much Air Flow Across the Radiator	Check/Repair Shutters, Fan Clutch, Viscous Fan as Required. Refer to the Equip. Manufacturer's Procedure.
OK ↓	
Incorrect Thermostat, Broken Thermostat Jiggle Pin or Contamination in Thermostat	Check/Replace Thermostats. Refer to Page 60, 65
OK ↓	
Temperature Sensor or Gage Malfunctioning	Verify that the Gage and Sensor are Accurate. Refer to Page 61
OK ↓	
Coolant Not Flowing by Temperature Sensor	Check/Clean Coolant Passages. Refer to Page 55

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 Flood. Refer to Page 57, 62
OK ↓	
If Equipped with a Water Cooled Air Compressor, Leaking Head or Head Gasket	Look for Coolant in the Oil. Check/Replace Head or Gasket. Refer to the Equipment Manufacturer's Procedures.
OK ↓	

(Continued)

Coolant Loss (Continued)

Cause	Correction
If the Engine is Aftercooled, After Cooler Leak	Check/Replace the Aftercooler. Look for Coolant in the Intake Manifold and in the Oil. Refer to Page 119
OK ↓	
Lube Oil Cooler Leak	Check/Replace the Oil Cooler. Look for Coolant in the Oil. Refer to Page 119
OK ↓	
Head Gasket Leak	Check/Replace the Head Gasket. Refer to Page 118
OK ↓	
Cracked or Porous Head	Check/Replace the Head. Refer to Page 157
OK ↓	
Leak in Cylinder Block Coolant Passages	Check/Replace the Cylinder Block. Refer to Page 55, 56.

Lubricating Oil Pressure Low

Cause	Correction
Low Oil Level	Check/Replenish Oil. Refer to Page 116
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. Refer to Page 44.
OK ↓	
Malfunctioning Pressure Switch/Gage	Verify the Pressure Switch is Functioning Correctly. Refer to Page 143
OK ↓	
Relief Valve Stuck Open	Check/Replace Valve. Refer to Page 116
OK ↓	
Plugged Oil Filter	Change Oil Filter; Review Change Interval. Refer to Page 117
OK ↓	

(Continued)

Lubricating Oil Pressure Low (Continued)

Cause	Correction
Loose or Missing Cup Plugs	Check/Replace Cup Plugs. Refer to Page 123, 132
OK ↓	
Suction Tube Loose or Seal Leaking	Check/Replace Seal. Refer to Page 117
OK ↓	
Worn Lube Pump	Check/Replace Lube Pump. Refer to Page 118, 128
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. Refer to Page 154, 165

Lubricating Oil Pressure Too High

Cause	Correction
Malfunctioning Pressure Switch/Gage	Verify the Pressure Switch is Functioning Correctly. Refer to Page 143
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. Refer to Page 116

Lube Oil Loss

Cause	Correction
External Leaks	Visually Inspect for Oil Leaks. Refer to Pages 55.
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.
	Look for Reduced Viscosity from Dilution with Fuel. Refer to Page 116
	Review/Reduce the Oil Change Intervals.
OK ↓	
Oil Cooler Leak	Check for Oil in the Coolant.
OK ↓	
If Equipped, Air Compressor Pumping Oil	Check/Replace Air Compressor. Refer to Page 94
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. Refer to Page 124
OK ↓	
Turbocharger Leaking Oil to the Air Intake	Inspect the Air Crossover Tube for Evidence of Oil Transfer. Refer to Page 124
OK ↓	
Worn Valve Seals	Inspect/Replace the Valve Seals. Refer to Page 160
OK ↓	
Piston Rings Not Sealing – Oil Being Consumed by the Engine	Perform a Compression Check. Repair as Required. Refer to Page 116

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. Refer to Page 55.
OK ↓	Review the Coolant Change Interval.
If Equipped, Leaking Transmission Oil Cooler	Check/Replace Oil Cooler. Refer to Equipment Manufacturer's Procedures.
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. Refer to Page 94, 120
OK ↓	
Injector Needle Valves Not Sealing	Locate and Replace malfunctioning Injector. Refer to Page 88.

Fuel Or Oil Leaking From Exhaust Manifold

Cause	Correction
Intake Air Restriction	Check/Replace Filter Element. Refer to Page 105
OK ↓	Review Operation for Excessive Idling.
Injector Needle Valve Stuck Open	Locate and Replace Malfunctioning Injector
OK ↓	
Obstructed Turbocharger Drain Line	Check/Clean Line. Refer to Page 102
OK ↓	
Turbocharger Seals Leaking Oil	Check/Replace Turbocharger. Refer to Page 102

Compression Knocks

Cause	Correction
Air in the Fuel System	Bleed the Fuel System. Refer to Page 83.
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. Refer to Page 61.
OK ↓	
Incorrect Injection Pump Timing	Check/Time Injection Pump. Refer to Page 68, 96
OK ↓	
Malfunctioning Injectors	Replace Injectors. Refer to Page 88.

Excessive Fuel Consumption

Cause		Correction
Additional Loading form Malfunctioning Accessories		Check/Repair Accessories and Vehicle Components. Refer to the Equipment Manufacturer's Procedures.
OK ↓		
Operator Technique		Review Operation for Correct Gear Shifts, Deceleration, and Idling.
OK ↓		
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. Refer to Page 77, 96
OK ↓		
Worn or Malfunctioning Injectors		Check/Replace Injectors. Refer to Page 88.
OK ↓		
Valves Not Seating		Check/Adjust Valves. Refer to Page 179
OK ↓		
Malfunctioning Power Functions		Check/Repair Power Functions. Refer to Page 148
OK ↓		

(Continued)

Excessive Fuel Consumption (Continued)

Cause	Correction
Fuel Shutoff Valve Inoperative	Stop the Engine Mechanically with Lever on the Fuel Pump. Check/Replace Sealing Washer, Piston and Spring. Refer to Page 75
OK ↓	
Engine Running on Fumes Drawn into the Air Intake	Check the Air Intake Ducts for 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 the Equipment Manufacturer's Service Instructions.
OK ↓	
Damaged Fan or Malfunctioning Accessories	Check/Replace the Vibrating Component. Refer to the Equipment Manufacturer's Service Instructions.
OK ↓	
Malfunctioning Vibration Damper (Six-Cylinder Only)	Inspect/Replace the Vibration Damper. Refer to Page 164
OK ↓	
Malfunctioning Fan Hub	Inspect/Replace the Fan Hub. Refer to Page 59, 63
OK ↓	
Worn or Damaged Alternator Bearing	Check/Place the Alternator. Refer to Page 144
OK ↓	
Flywheel Housing Misaligned	Check/Correct Flywheel Alignment. Refer to Page 167
OK ↓	

(Continued)

Excessive Vibration (Continued)

Cause	Correction
Loose or Broken Power Component	Inspect the Crankshaft and Rods for Damage That Cause and Unbalance. Refer to Page 199
OK ↓	
Worn or Unbalanced Drive Line Component	Check/Repair According to the Equipment's Manufacturer's Procedures.

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 ↓	Check the Tension of Accessory Drive Belts. Refer to the Equipment Manufacturer's Procedures. Make Sure the Accessories Turn Freely.
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. Refer to Page 162
OK ↓	
Turbocharger Noise	Check Turbocharger Impeller and Turbine Wheel for Housing Contact. Refer to Page 101
OK ↓	
Gear Train Noise	Visually Inspect and Measure Gear Backlash. Replace Gears as Required. Refer to Page 161
OK ↓	
Power Function Knock	Check/Replace Rod and Main Bearings. Refer to Page 165

Alternator Not Charging Or Insufficient Charging

Cause	Correction
Loose or Corroded Battery Connections	Clean/Tighten Battery Connections. Refer to Page 137
OK ↓	
Alternator Belt Slipping	Check/Replace Belt Tensioner. Refer to Page 62
OK ↓	
Alternator Pulley Loose on Shaft	Tighten Pulley.
OK ↓	
Malfunctioning Alternator	Replace Alternator. Refer to Page 144

Coolant System

Coolant System Component and Flow

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

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.

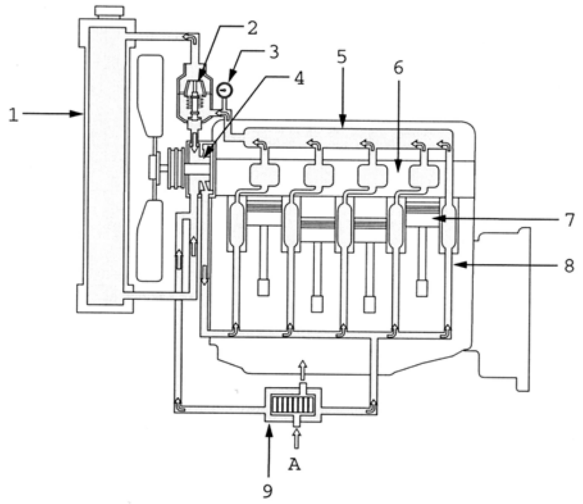
The Coolant then circulates around each cylinder and crosses the block to the fuel pump side fot the engine.

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

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.

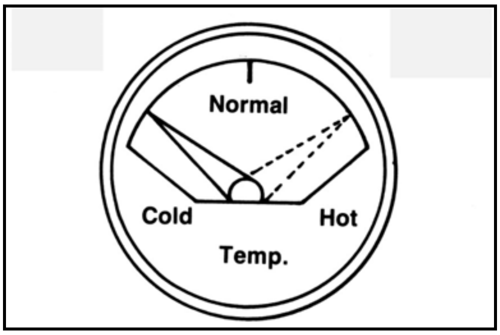
When Operating temperature is reached, the thermostat open, blocking the bypass passage to the water pump and opening the outlet to the radiator.

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

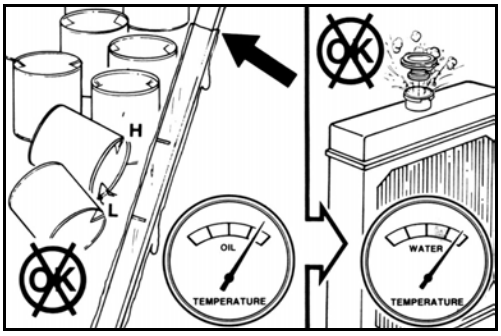


1. Radiator. 2. Thermostat. 3. Water Temperature Gauge. 4. Water Pump. 5. Water Manifold. 6. Cylinder Head
7. Piston. 8. Cylinder Block. 9. Oil Cooler (Optional).
A. From Oil Pump (Oil)

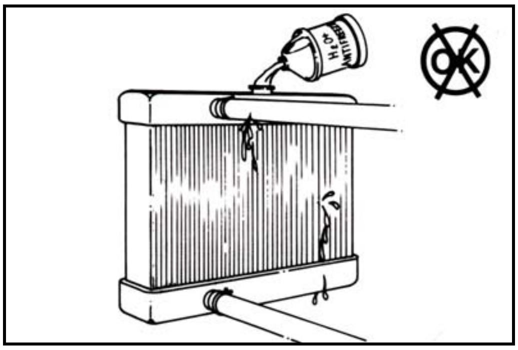
Cooling System Specifications	A2300
Coolant Capacity (Engine Only) - Liter [U.S. Qts.]..	3.0 [3.2]
Standard Modulating Thermostat – Range – °C [°F]	71 [160] to 85 [185]



Coolant System Malfunctions - Diagnosis –
The function of the coolant system is to maintain a specified operating temperature of 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 over heating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil.

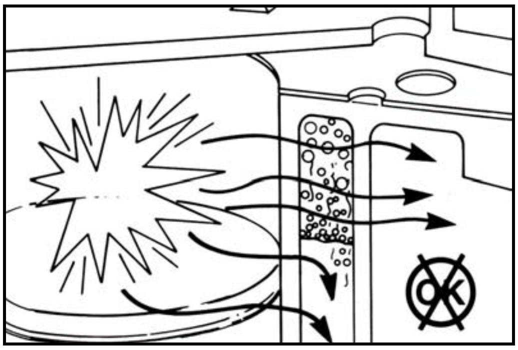


Overfilling with oil raises the oil temperature which is transferred to the coolant system at the oil cooler.



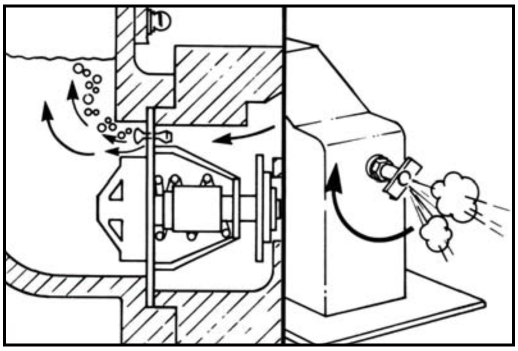
The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

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

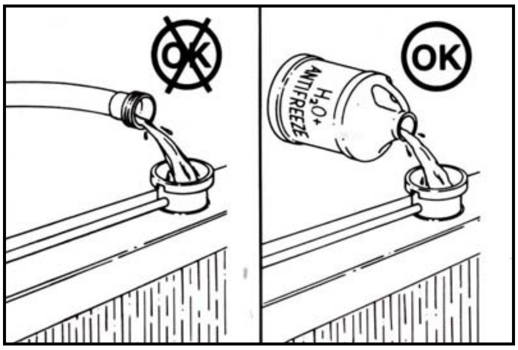


Caution : The engine coolant passages must be completely filled with coolant.

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.

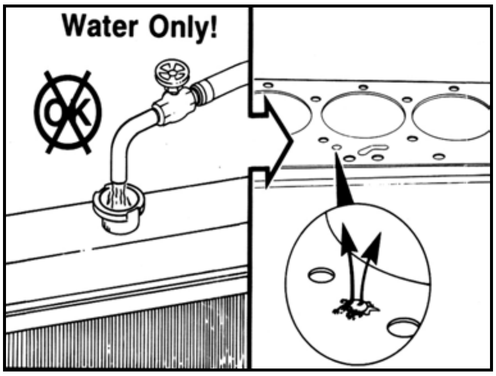


During filling, air must be vented from the engine coolant passages. The air vents through the “jiggle pin” opening and the notched vent hole to the top radiator hose and out the fill opening. Additional venting is provided for engines equipped with an after cooler. Open the petcock during filling.



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.

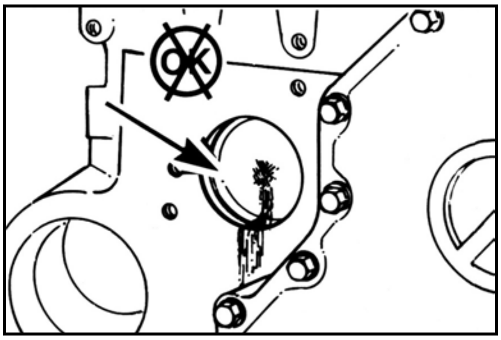
A mixture of 50% ethylene-glycol base antifreeze is required for operation of the engine in temperature environments above
-37°C [-34°F]. A mixture of 40% water and 60% antifreeze is recommended for temperatures below -37 °C [-34°F].



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

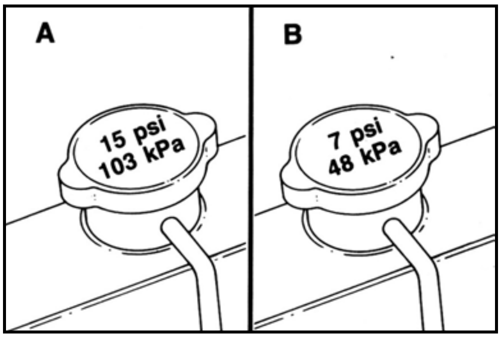
Water will cause rust formation reducing the flow in the smaller coolant passages.

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.

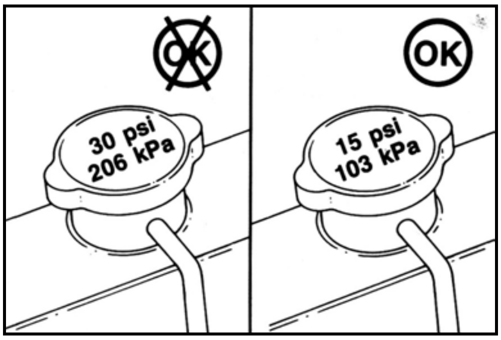


Pressure Caps

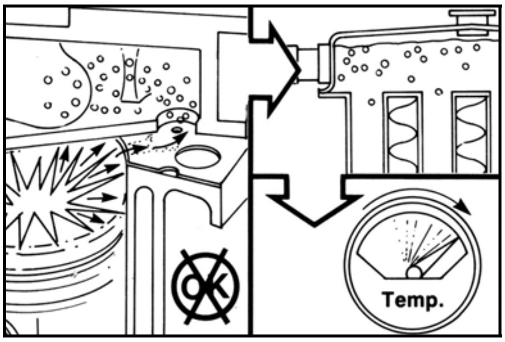
The system is designed to use a pressure cap to prevent boiling of the coolant.
Different caps are specified for the two recommended

systems:

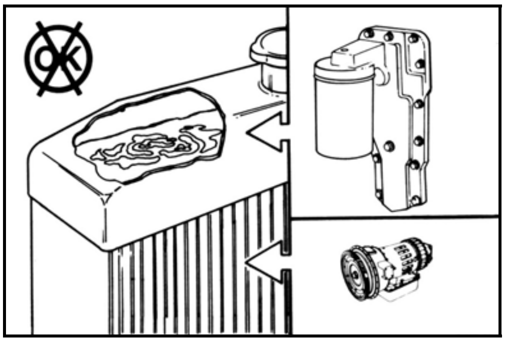
	System	Cap
A -	104 °C [220°F]	103kPa [15 PSI]
B -	99 °C [210°F]	48kPa [7 PSI]



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

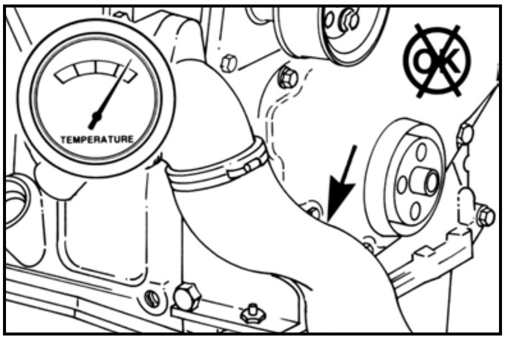


Air in the coolant can result in loss from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system causing the cap to open.
Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gasses to the coolant system.



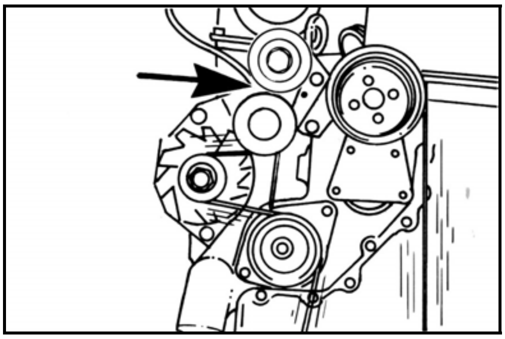
The operating pressure of the coolant system and the lubricating system can result in mixing go the fluids if there is leak between the systems: head gasket, oil cooler, etc. (refer to the Lubricating System).

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

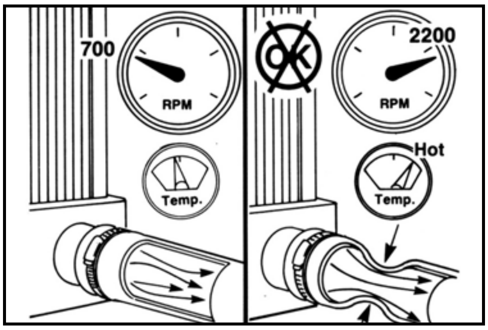


Water (Coolant) Pump

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.

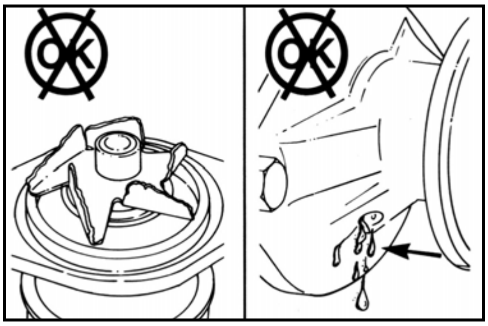


The pump is belt driven from the crankshaft pulley.
An belt tensioner is used to prevent the belt from slipping on the pump pulley.
A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed reducing the amount of coolant flow.

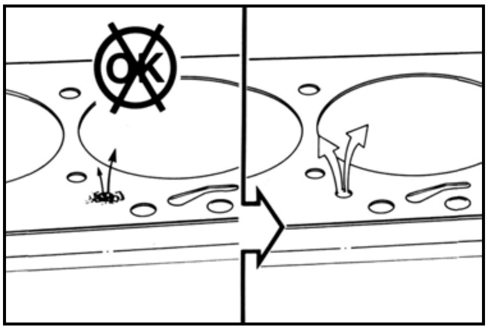


The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually not collapse while the engine is running at low speed. Check the hose while the engine is running at rated speed.

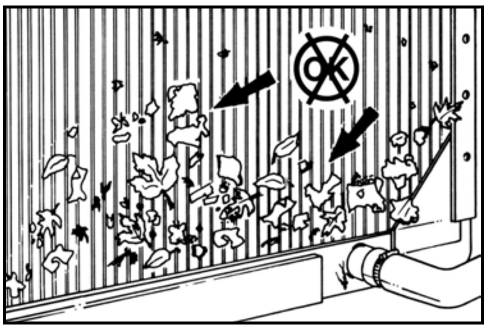
Note : Be sure the engine is warm, a minimum of 85°C[185°F], so the thermostat is open.



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.

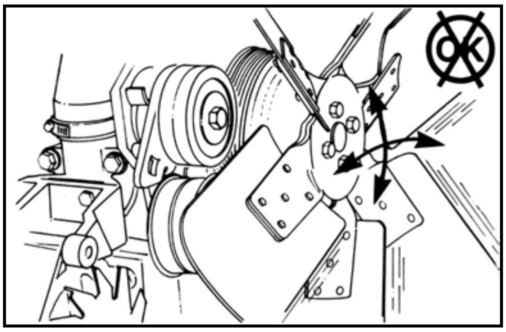


As stated in the coolant discussion, an obstruction in the passages can interrupt flow.



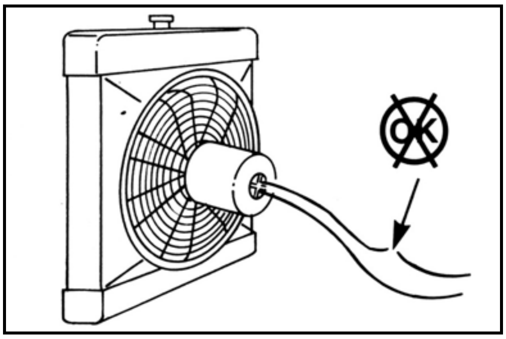
Radiator, Fans and Shutters

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.



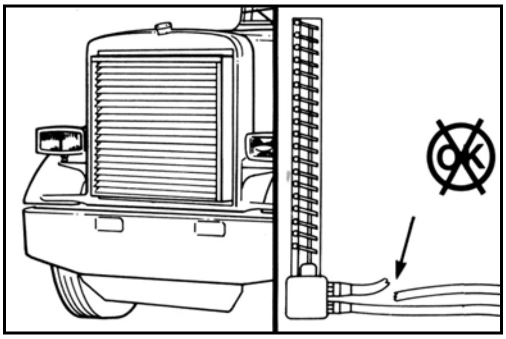
If the fan is belt driven, a slipping belt will result in a slower fan speed and reduced cooling. A malfunctioning belt tensioner can be the problem.

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



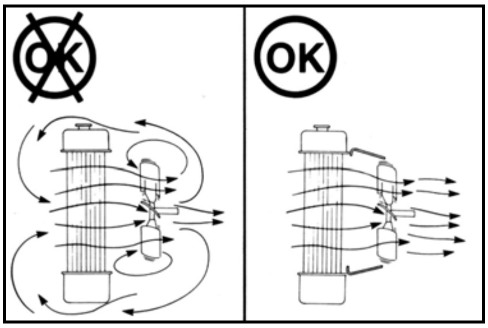
Interruption of the circuit to an electrically driven fan can result in insufficient airflow and cause the engine to run hot.

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



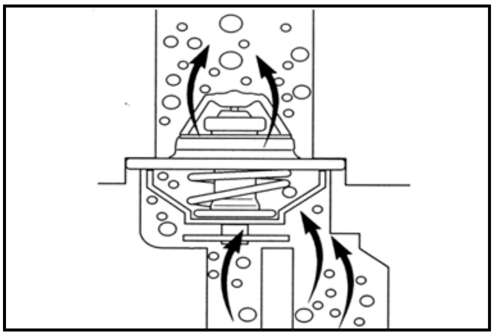
Shutters are designed to control air flow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much air flow and the engine running cold.

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



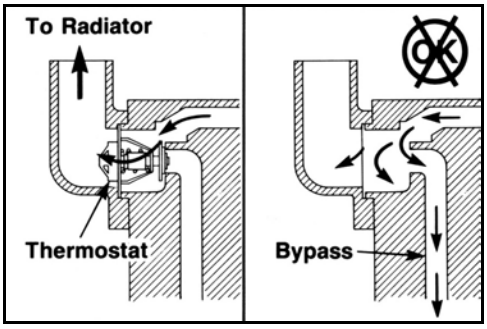
An incorrect fan shroud or obstructions can reduce airflow and cause the engine to run hot.

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



Thermostat

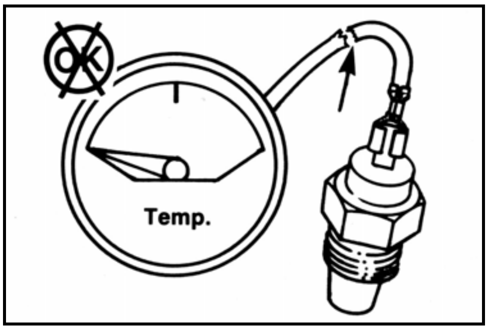
The thermostat controls the coolant temperature. When the coolant temperature is below the operating range, coolant is bypassed back to the inlet of the water pump.
When the coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, forcing coolant to flow to the radiator.



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.

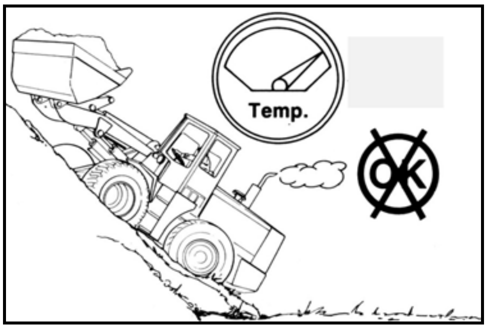
An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



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.

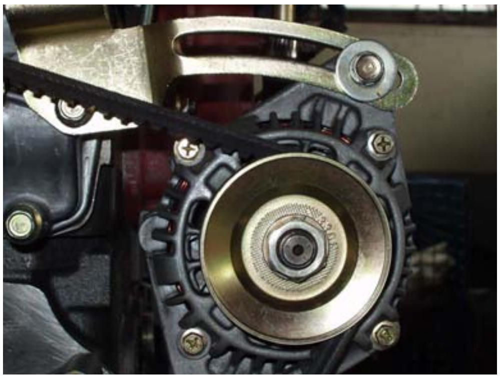
Cooling System Replacement Procedures

Drive Belt – Replacement
12mm
Lift the tensioner to remove and install the drive belt.

Belt Tensioner – Replacement

Preparatory Step:

- Remove the drive belt

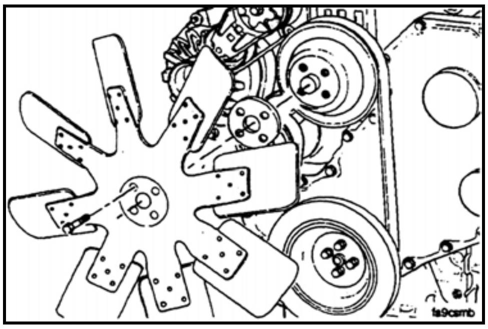


12mm
Remove the capscrew and replace the tensioner.
Torque Valve: 25.5 Nm [19ft-lbs]

Fan Pulley – Replacement

Preparatory Step:

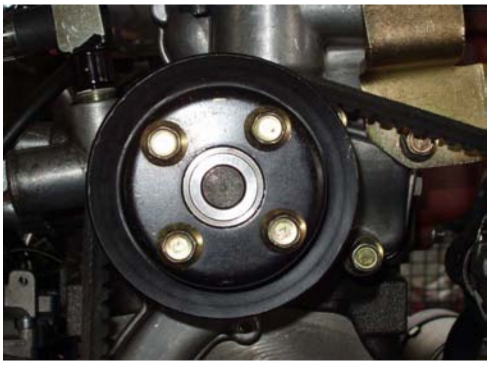
- Remove the drive belt.



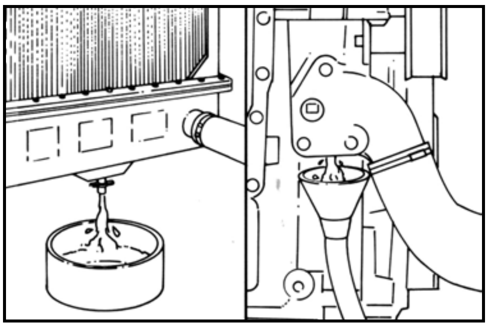
12mm
Remove the four capscrews, fan and spacer.
Replace the fan pulley.
Torque Valve: 25.5 Nm [19ft-lbs]

Fan Hub – Replacement

Preparatory Steps:
- Remove the drive belt.
- Remove the fan pulley.



12mm
Remove the four capscrews and replace the fan hub.
Torque Valve: 25.5 Nm [19ft-lbs]



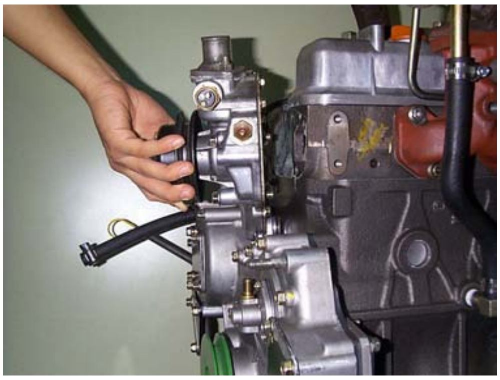
Coolant – Draining

The coolant is 50% mixture of water and ethylene-glycol base antifreeze; a 20 liter (4 U.S. gallons) drain pan will contain the coolant in most applications.

Water Pump – Replacement

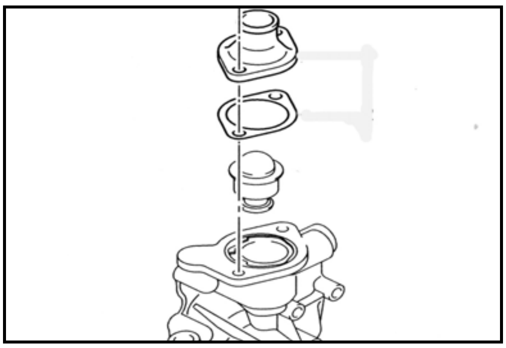
Preparatory Steps:

- Drain the coolant.
- Remove the drive belt.

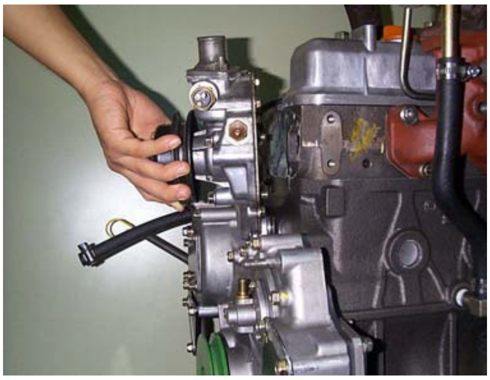


12mm
Remove the four capscrews and water pump, and complete the following steps.

Clean the sealing surface on the cylinder block.



Install the new gasket.



12mm
Install the water pump.
Torque Valve: 25.5 Nm [19ft-lbs]

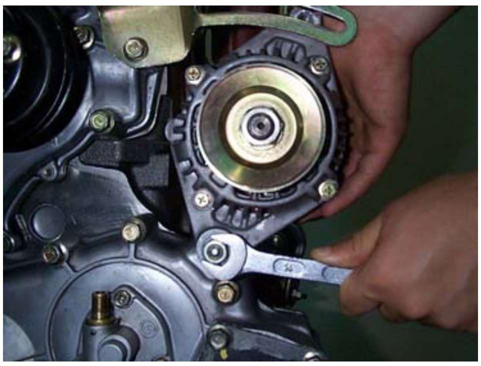
Thermostat - Replacement

Preparatory Steps:

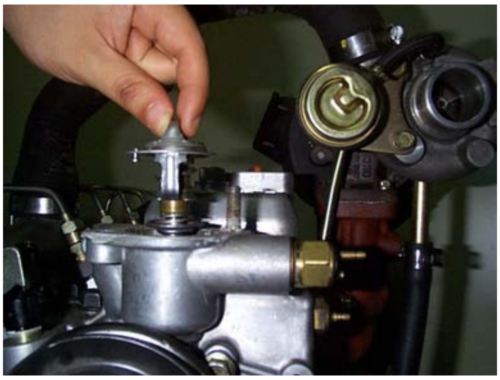
- Drain the coolant.
- Remove the drive belt.
- Disconnect negative battery cable.
- Disconnect the upper radiator hose.

12mm

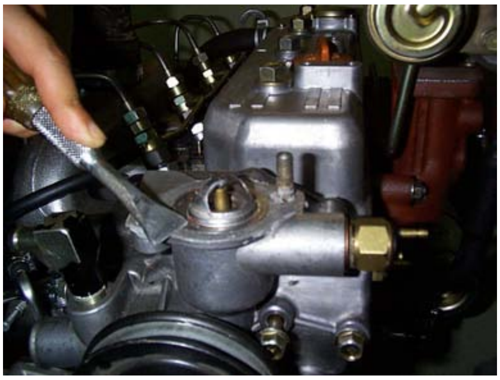
Note : Loosen the alternator link capscrew and complete the following steps.



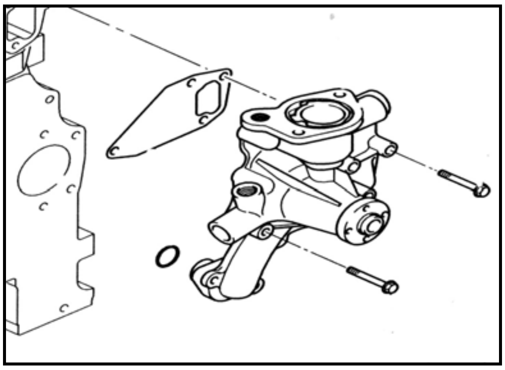
14mm
Remove the alternator mounting capscrew and lower the alternator.



12mm
Remove the thermostat housing, lifting bracket and thermostat.



Clean the mating surfaces.



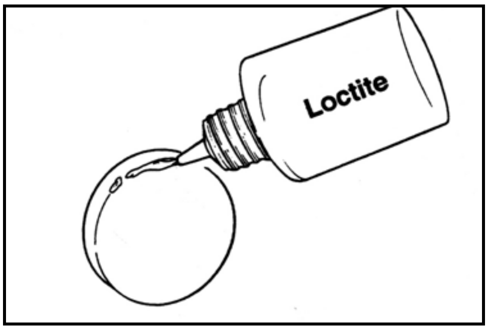
Position the rubber seal as shown for reassembly.

Assemble the removed parts in the reverse order of removal.

Torque Valve:
(Alternator Link) 25.5 Nm [19 ft-lbs]
(Alternator Mounting) 49Nm [37 ft-lbs]
(Thermostat Mounting) 25.5 Nm [19 ft-lbs]

Cup Plugs – Replacement

Remove the cup plugs from the coolant passages as shown.



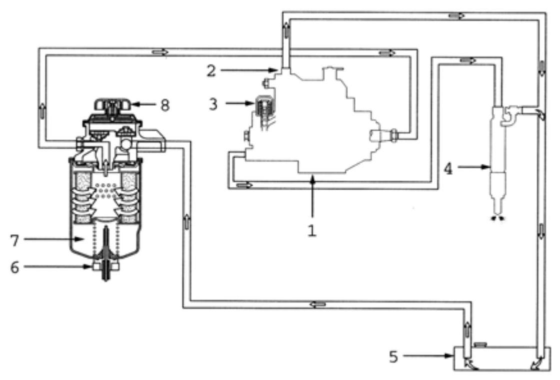
Apply a bead of Loctite 277 to the coolant passage cup plugs.

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

Fuel System

Fuel System Component and Flow

The following illustration identifies the components of the fuel system.



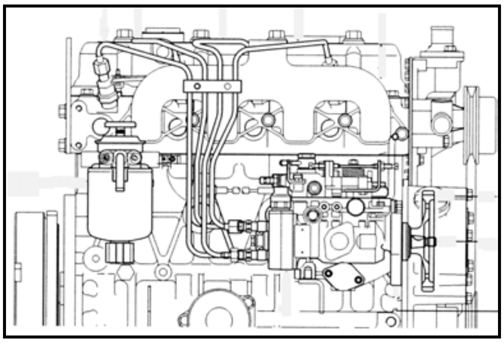
1. Fuel Injection Pump. 2. Overflow Valve. 3. Fuel Shut-Off Solenoid. 4. Fuel Injection Nozzle. 5. Fuel Tank. 6. Water in Fuel Sensor (WIF). 7. Fuel Filter. 8. Hand Priming Pump

Most of the engines will be quipped 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 (21-35kPa, [3-5psi]) to the fuel filter head, through the filter and then to the distributor injection pump.

The engines use distributor-type fuel pumps supplied by Robert Bosch.

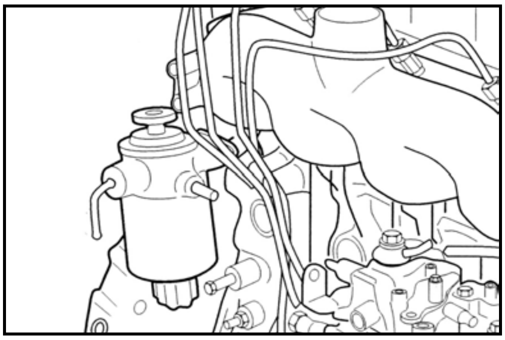
The distributor pump builds the high injection pressures required for combustion, and routes the fuel through individual high-pressure fuel lines to each injector.

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.



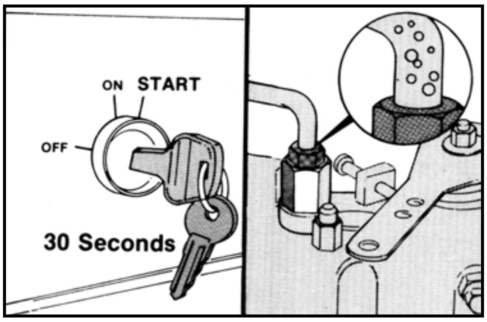
Fuel System Malfunction – Diagnosis

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.



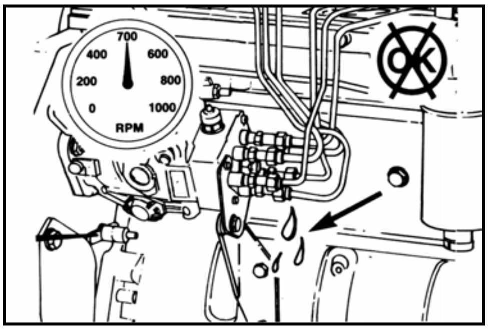
Normal pressure drop across the filter is 21 kPa [3 psi], maximum.
The pressure drop will increase as the filter removes contamination form the fuel. Therefore, a worn lit pump will have reduced capacity to force fuel through a dirty filter. This can cause low engine power.

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

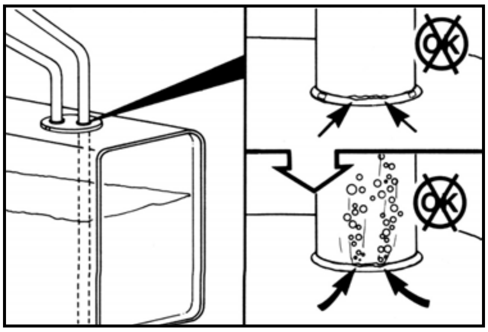


Air In the Fuel System

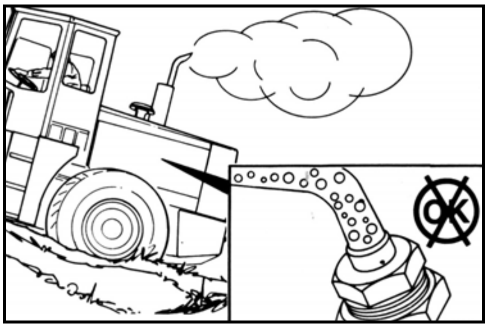
A replacement of supply lines, fuel filters, injection pump, high pressure lines and injectors will let air enter the fuel system. Follow the specified procedure to bleed the air from the system.



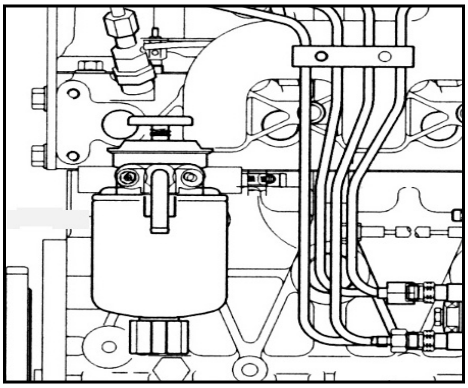
Since the lift pump provides a positive pressure through the fuel filter and supply line to the injection pump, loose connections or defective seals will show as a fuel leak.



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: hart to start, run rough, misfire, produce low power, and can cause excessive smoke and a fuel knock.

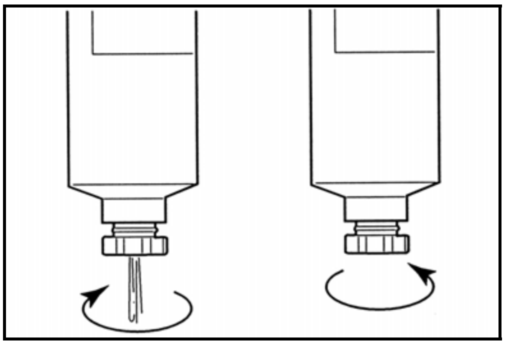


Fuel Water Separator/Filter Unit

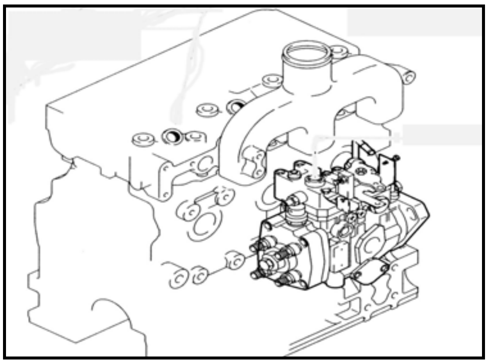
Caution : Be sure to use the correct element.

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.



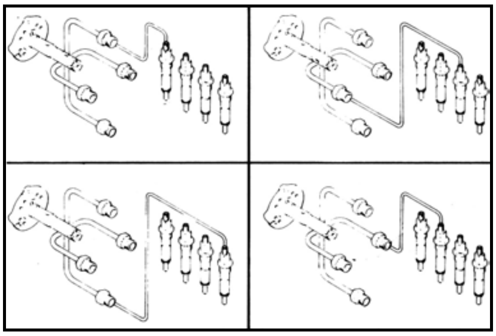
Regular maintenance, including draining moisture from the fuel water separator/filter and supply tanks, is essential to keep water out of the fuel.



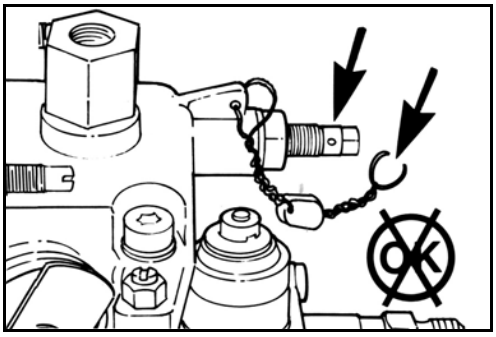
Injection Pump

The injection pumps are rotary distributor pumps. These pumps perform the four basic functions of:

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

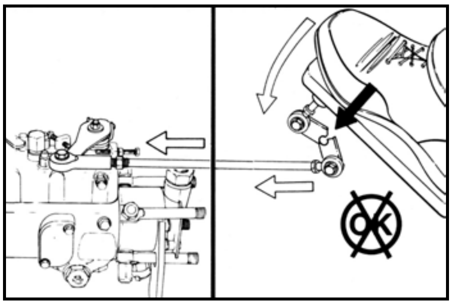


A single plunger or rotor is used by the pumps to develop and distribute the high pressure required for injection.
A four-cylinder, Robert Bosch VE pump plunger is shown in this illustration.



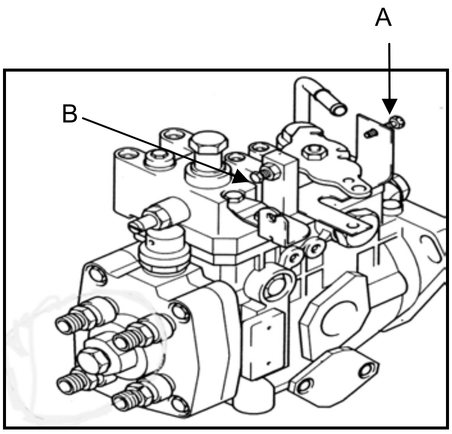
Governor Malfunctions

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. If the seals are broken on the external Robert Bosch VE adjustment screw, the fuel rate may be out of adjustment.



Fuel Control Lever Travel and Adjustment

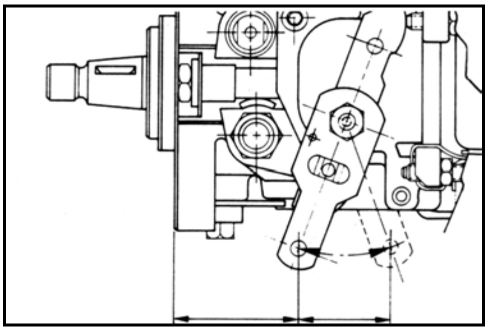
The amount of fuel injected and subsequently the speed and power from the engine is controlled by the fuel control lever. Restricted travel of the lever can cause low power. Always check for full travel of the lever when diagnosing a low power complaint.



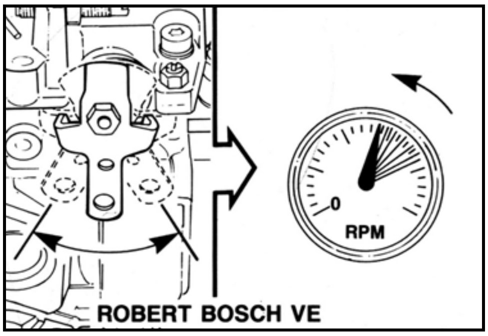
VE Pump Adjustment Screws

A – Idle Screw
B – High Idle Screw

The high speed adjustment screw on both pumps provides the stop for full speed. The high speed adjusting screws are sealed. Adjustment of this screw must be performed only be an authorized pump service center, and then resealed.
The high speed adjusting screw can be used to derate engines. The procedure is provided in this section.



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

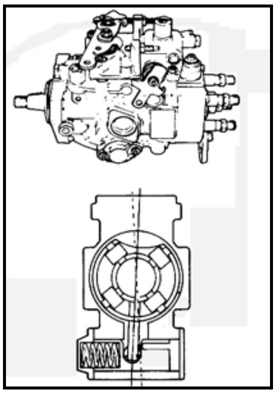


Manual Shut Down Levers

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.

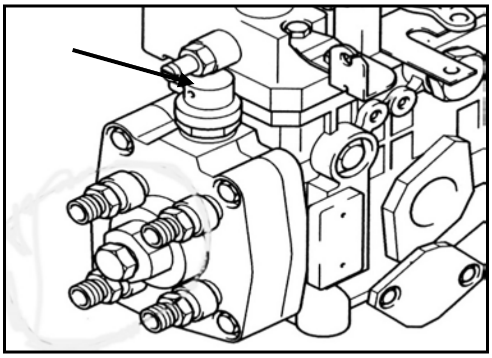
Note : Partial actuation of the mechanical shutdown levers will affect fuel flow and engine power.

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.



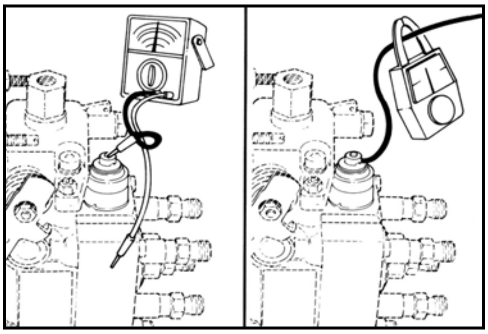
Advance Timing Mechanism

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.



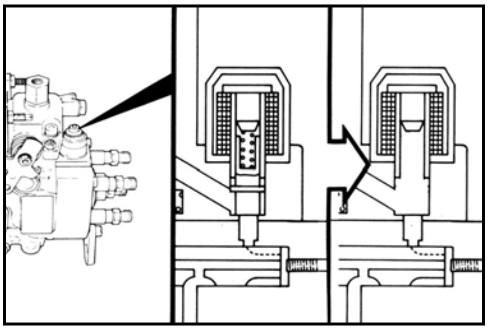
Electrical Shut Off Valves

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



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

Robert Bosch Shut Down Values	Resistance Ohms	Peak Amperes
12 Volt	7.4 + 0.5	2

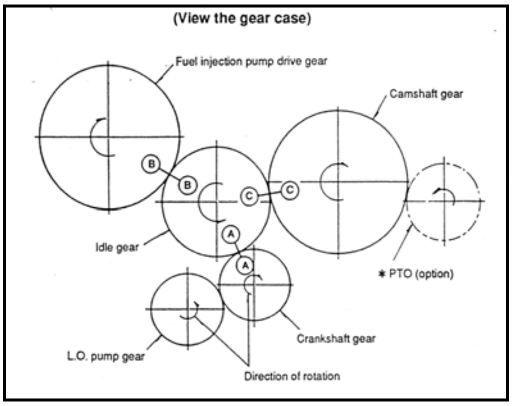


Caution : Do not connect the electrical wire to the solenoid when the plunger has been removed. Without the plunger the valve can be damaged.

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

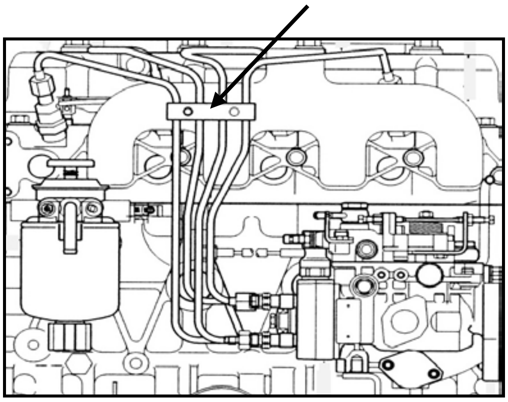
Injection Pump Timing

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 emission
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.

After installing each gear, make sure that aligning marks A, B and C of the idle gear are aligned with those of the fuel injection pump drive gear, cam shaft gear and crank shaft gear.



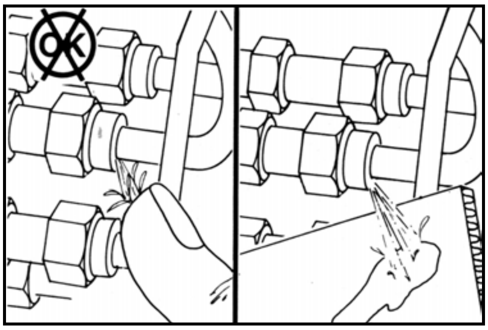
High Pressure Fuel Line

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.

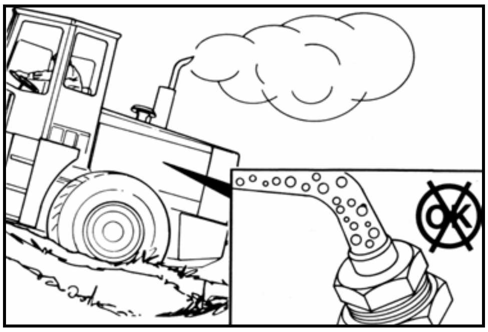
Caution : Do not weld or substitute lines; use only the specified part number for the engine.

The length, internal size and rigidity of the lines is critical to smooth engine operation.

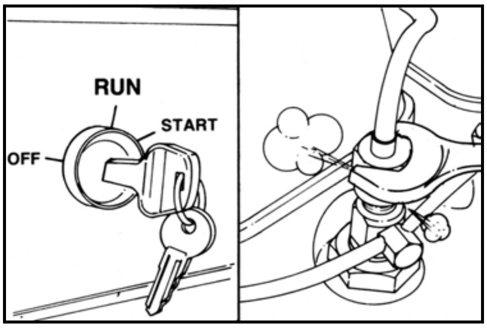


Warning : The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious bodily harm.

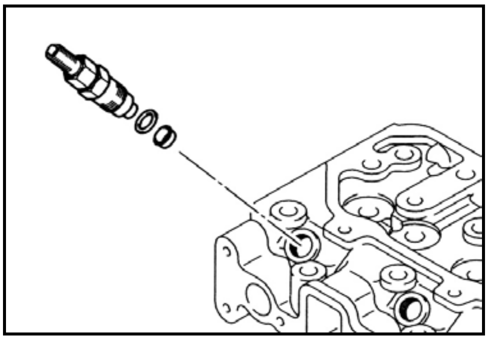
Use cardboard to check for cracks and leaks. With the engine running, move the cardboard over the fuel lines and look for fuel spray on the cardboard. Fuel leaks can cause poor engine performance.



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.

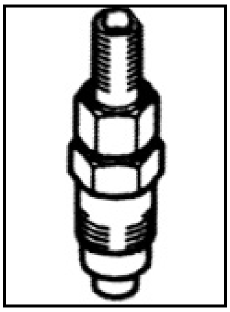


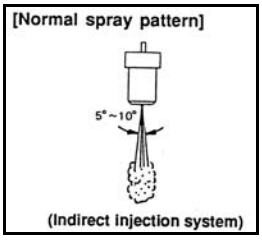
Bleed the air from the high pressure line at the fitting that connects the injector. Bleed one line at a time until the engine runs smooth.
If the air cannot be removed, check the pump and supply line for suction leaks.



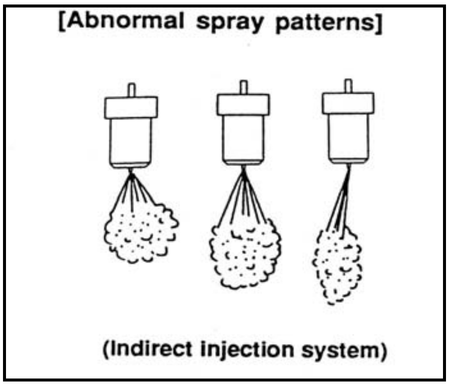
Injectors

Caution: Use only the specified injector for the engine.

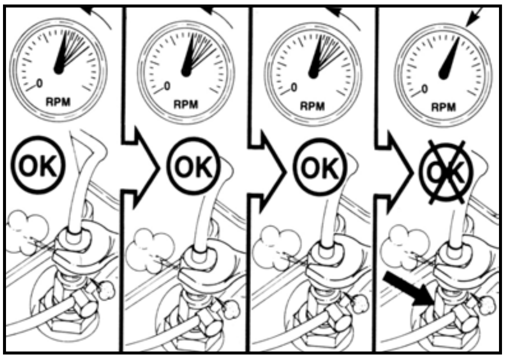




During the injection cycle, high pressure from the injection pump rises to the operating (pop) pressure which causes the needle valve in the injector to lift. Fuel is then injected into the cylinder. A shimmed spring is used to force the needle valve closed as the injection pressure drops belowe the 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.

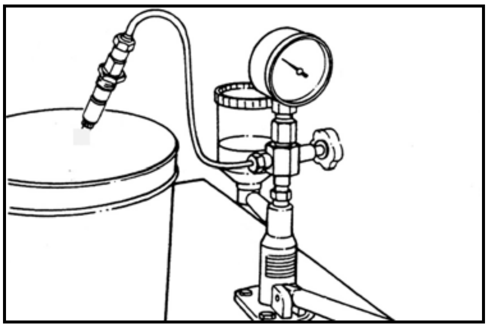


Caution : Be sure to tighten the fuel line nut before proceeding to the next injector.

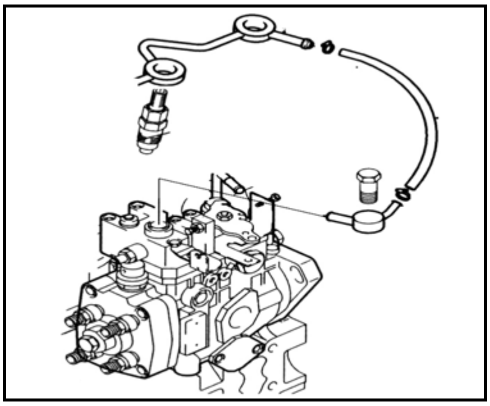
To find which cylinder is misfiring, operate the engine and loosen the fuel line nut at one injector and listen for a change in engine speed.

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 continuous 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.

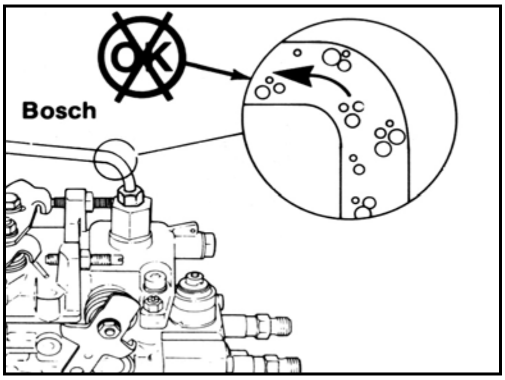


Fuel Drain Manifold

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.

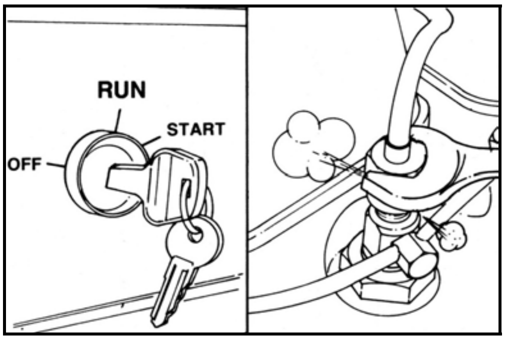
Fuel System Replacement Procedure

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.

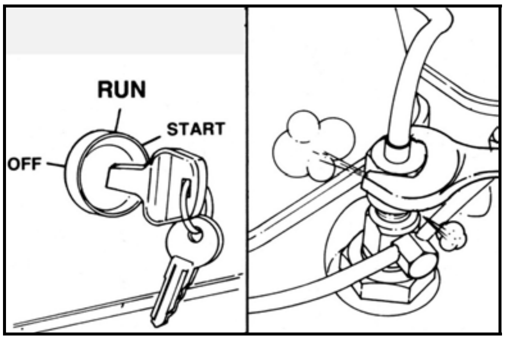


Fuel System – Bleeding

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.



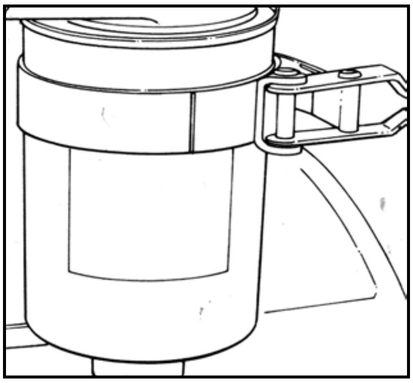
High Pressure Lines – Venting

17mm

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

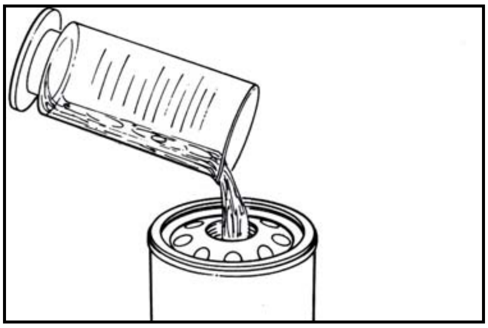
Loosen the fittings at the injector, and crank the engine to allow entrapped air to bleed from the line. Tighten the fittings.

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

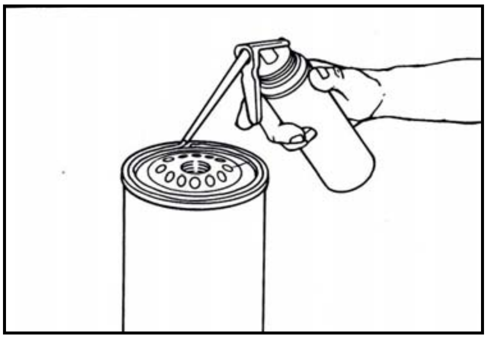


Fuel Filter – Replacement

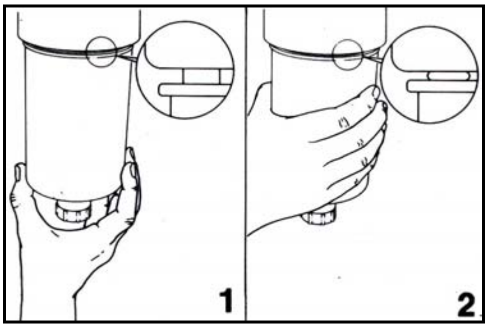
80 to 95 mm, Filter Wrench
Remove the combination water separator/fuel filter.



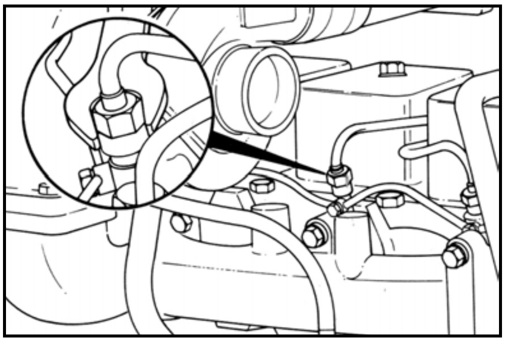
Fill the new filter(s) with clean fuel.



Lubricate the seal with clean oil.



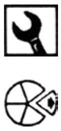
Install the filter(s) and tighten it 1/2 turn after its seal contacts the filter head.



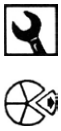
High Pressure Lines – Replacement

17mm

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



10mm
Remove the line clamp capscrew 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.

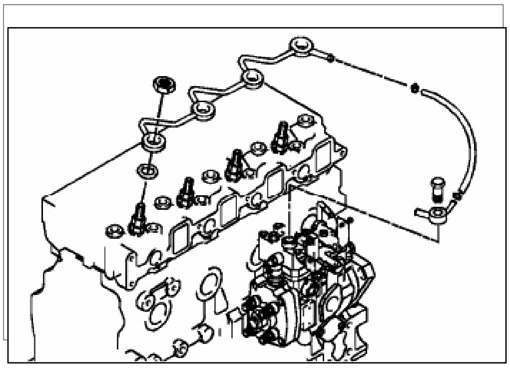
10mm
Assemble the lines in the reverse order of removal.
Torque Value: 11Nm [8 ft-lbs]

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

17mm
Remove the high pressure fuel line.



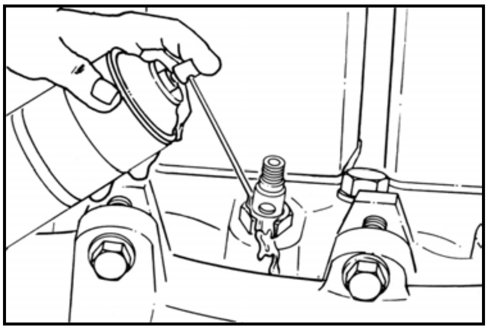
17mm
Remove the head cap nuts.

17mm
Assemble the high pressure fuel line and fuel drain manifold in the reverse order of disassembly.
Torque Value: 49Nm [37 ft-lbs]

Injector – Replacement

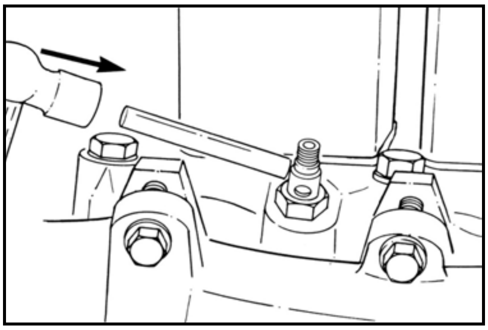
Preparatory Steps:

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



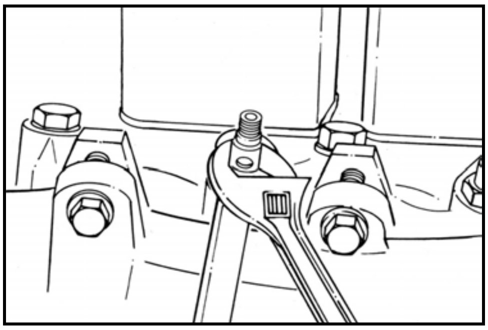
Rust Penetrating Solvent

Caution : When rust has formed on the hold down nut, the injector can turn in the bore when the nut is loosed. This will cause severe damage to the head by the injector locating ball cutting a groove in the bore.



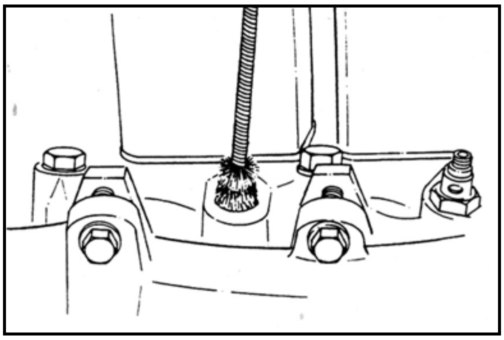
Brass Drift Pin, Hammer

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



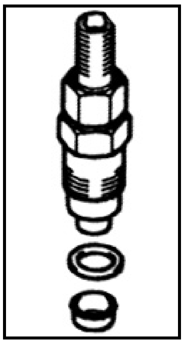
22mm Box Wrench, Adjustable Wrench

Hold the injector body with an adjustable wrench while you loosen the hold won nut with a 22mm box wrench.



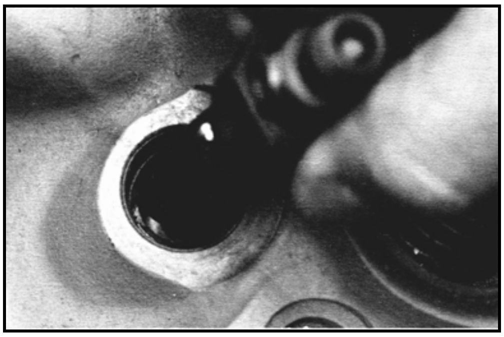
Injector Bore Brush

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.

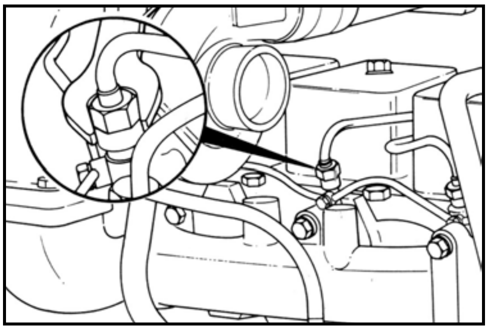


22mm Deep Well Socket

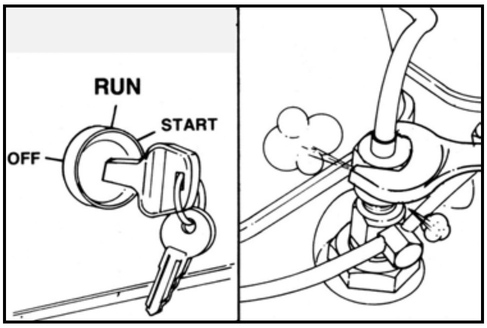
Caution : Align the injector's protrusion with the notch in the bore.

Torque Value: 73 Nm [55 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.



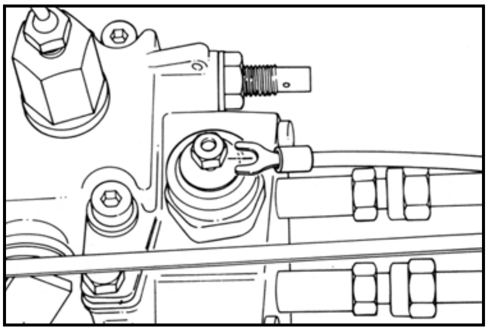
Assemble the fuel drain manifold and high pressure lines.
Leave the high pressure fittings loose at the injectors.



17mm

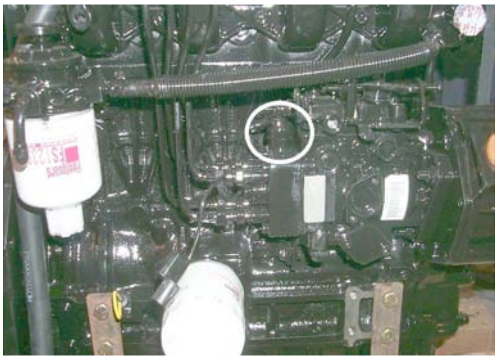
Warning : It is necessary to put the engine in the "run" position: Because the engine may start, be sure to follow all the safety precautions. Use the normal engine starting procedure.

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



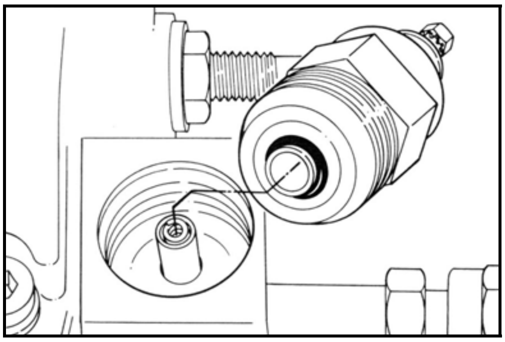
Electrical Fuel Shut Off Valve – Replacement

8mm
Remove the electrical wire and complete the following steps.
Clean around the valve.

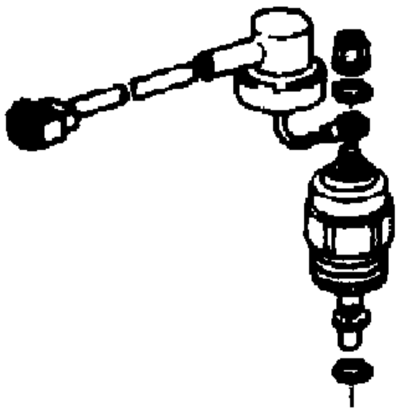


24mm
Remove the valve.

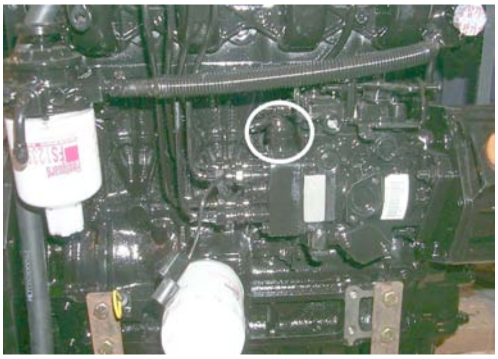
Note : The Bosch VE valve is shown.



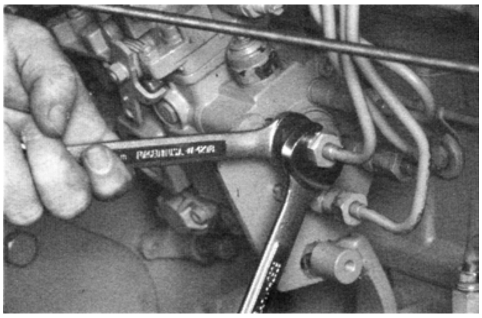
Caution : When removing the valve, be careful not to drop the plunger and spring.



“Package” the solenoid, o-ring, spring and plunger.

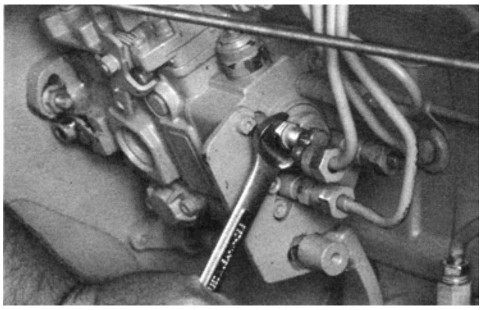


24mm
Tighten the solenoid securely.
Connect the electric wire.
Torque Value: 20 Nm [15 ft-lbs]

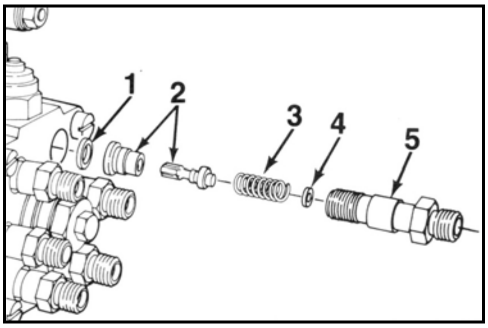


Delivery Valve Holder and Sealing Washer (Bosch VE) – Replacement

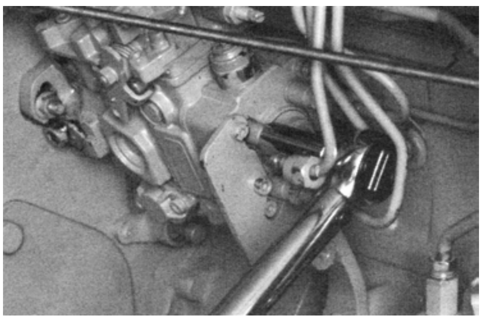
14mm and 17mm
Disconnect the high pressure line.



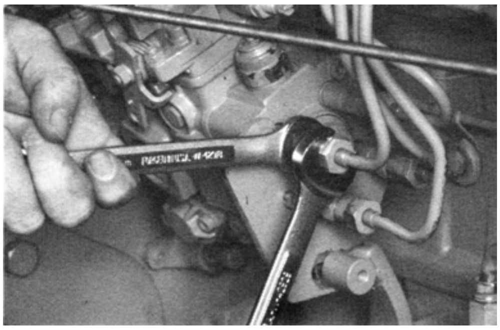
14mm
Remove the delivery valve holder and sealing washer.



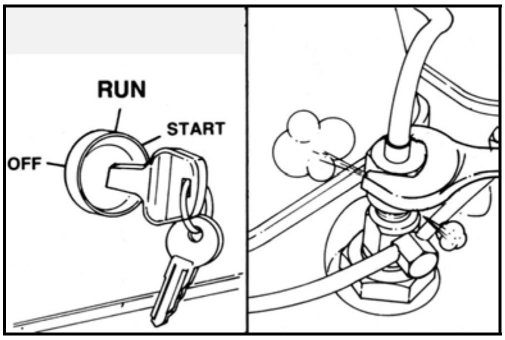
Insert the sealing washer(1) and the delivery valve(2) in the pump. Insert the ship(4) and spring(3) in the holder(5).
Fit the spring(3) over the valve(2) and turn the holder(5) into the pump.



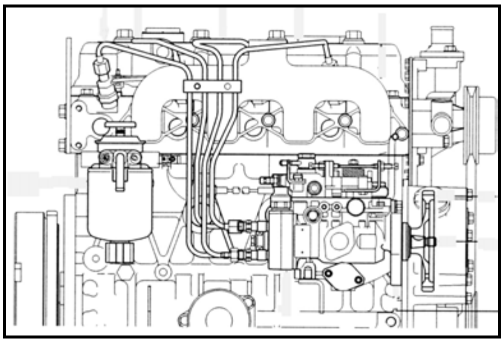
14mm
Tighten the holder to 49 Nm [37 ft-lbs].



14mm and 17mm
Connect the high pressure lines.

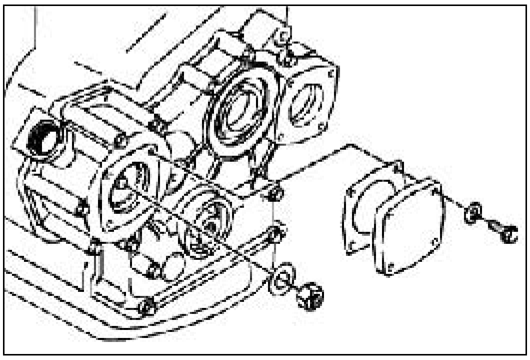


17mm
Start the engine and vent one line at a time until the engine runs smoothly.



External Pump Leaks

Check for excessive flow in the injection pump and fuel line due to leakage

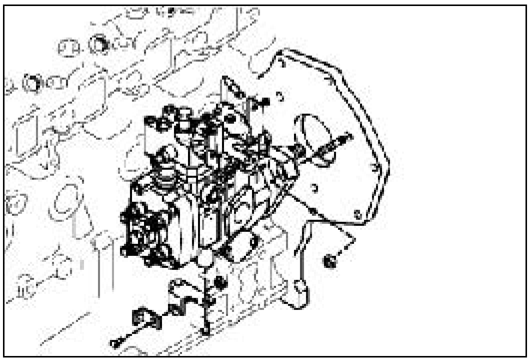


Removal (Injection Pump)

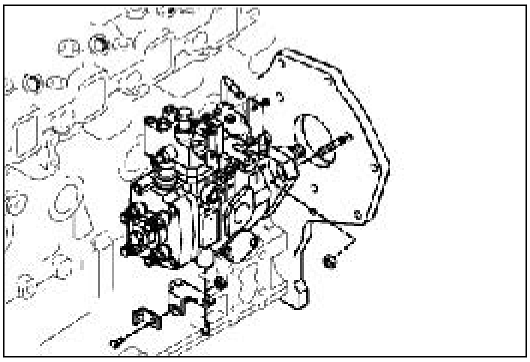
Caution : Do not drop the nut and washer inside gear housing or engine damage can occur.

12mm
Remove the retaining nuts on the fuel injection pump mounting on the rear of the gear housing.
Remove the access cover and gasket from the front of the gear housing.
Rotate the engine to line up the “B” mark on the fuel pump gear to the “B” mark on the idler gear. This can take a number of crankshaft revolutions to accomplish

17mm.
Remove the nut from the fuel injection pump shaft inside the housing.
Remove the fuel injection pump support bracket and mounting capscrews.
Remove the gear with a gear puller.
If the gear housing is in place, use the arms of the puller to push against the inside front of the housing and force the pump shaft rearward out of the gear.



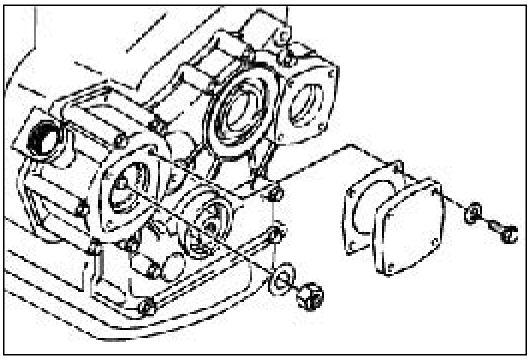
12mm
Remove the fuel injection pump.



Installation (Injection Pump)

The pump shaft is keyed to the gear, and the gear has timing mark “B” for alignment to the idler gear mark “B”.
In order to make sure that the fuel pump key is aligned properly to the gear keyway; rotate the engine opposite engine rotation (counterclockwise) several degrees to put the keyway in the gear approximately at 9:00 o'clock position. The “B” mark on the fuel pump gear will be on the top edge of the viewing hole.
Make sure the o-ring seal is installed.
The key on the pump shaft must be approximately in the 9:00 o'clock position looking at the shaft end.
Hold the fuel pump drive gear to the back of the housing to prevent disengagement of gear teeth.

12mm
Align the shaft key to the gear keyway and install the fuel injection pump on the rear of the gear housing.



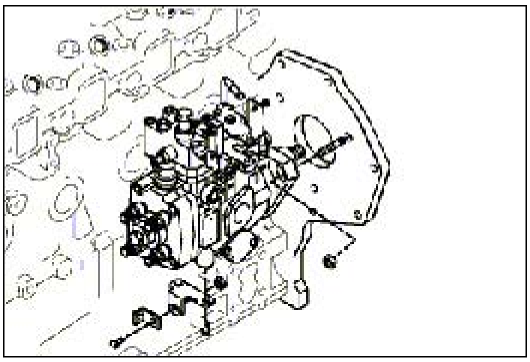
Hand-tighten the retaining nuts on the mounting studs.

17mm
Install the gear, washer, and nut on the fuel injection pump shaft. Tighten the nut.
Torque Value : 88 n.m [65 ft-lb]

Rotate the engine in the direction of engine rotation. Check the “B” timing marks again for proper alignment.

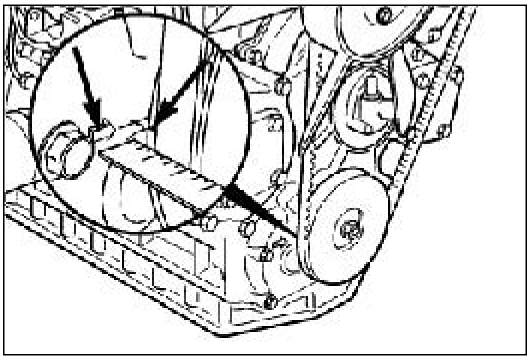
12mm
Install the access cover. Tighten the cover capscrews.
Torque Value : 26 n.m [19 ft-lb]

Refer to Procedure 1 for fuel injection pump timing.



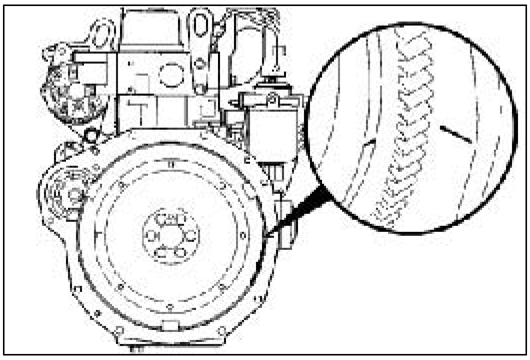
Tighten the retaining nuts on the fuel injection pump mounting studs on the rear of the gear housing.
Torque Value : 26 n.m [19 ft-lb]

Tighten the supporting bracket on the bottom of the fuel injection pump.
Torque Value : 26 n.m [19 ft-lb]

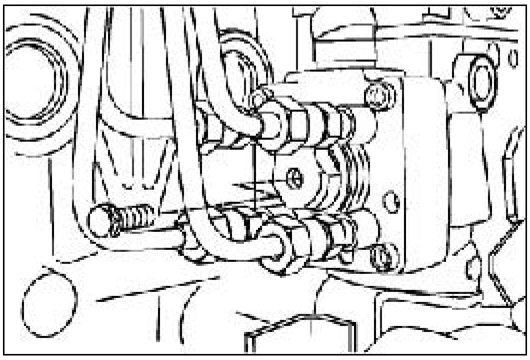


Timing

Dial Indicator Method
Find number 1 or top dead center (TDC) on compression for the number 1 cylinder by barring the engine until the hashmarks on the crank pulley line up with the indicator mark on the gear cover. This can be confirmed by removing the front cover access plate and ensuring that the idler gear and fuel pump gear timing marks are aligned.
A straight edge can be used to aid lining up the gear cover pointer and number 1 or top dead center (TDC) mark.

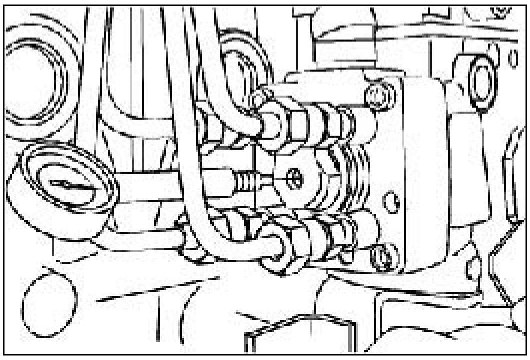


The flywheel also contains number 1 or top dead center (TDC) marks. The starter plate or flywheel contains the alignment mark. The mark is located at the 3 o'clock position as viewed from the rear of the engine. The flywheel can be used instead of the crank pulley if accessible.

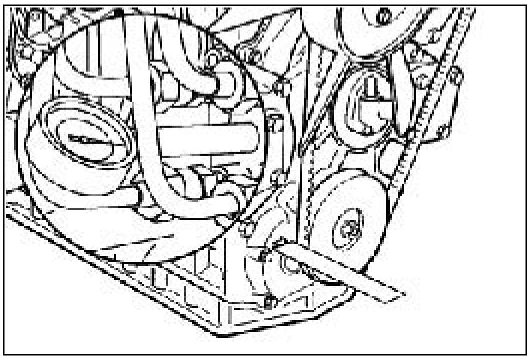


12mm

Remove the access plug from the distributor head on the fuel pump.

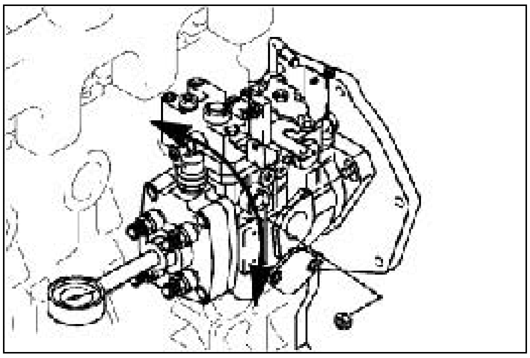


Thread the timing tool assembly into the access plug hole and finger tighten.



Bar the crankshaft in the direction opposite engine rotation until the indicator needle stops moving. Adjust the indicator face to read zero.

Rotate the crankshaft in direction of engine rotation back to the mark on the crank pulley. This is the number 1 or top dead center (TDC) mark.
If accessible, the flywheel and starter plate can be used to locate this position more easily.

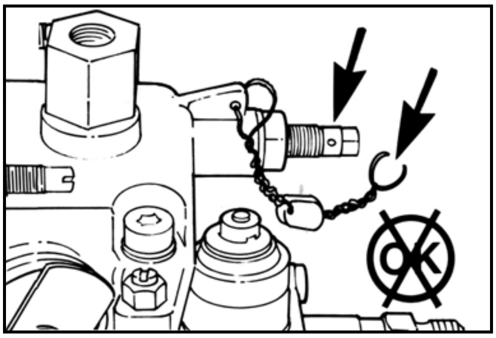


At this point the dial indicator should read 1 mm [0.04 in] of lift.

If the dial indicator does not read 1 mm [0.04 in], loosen the fuel pump mounting bolts and rotate the pump till the correct plunger lift value is attained

12mm

Tighten the fuel pump mounting capscrews.
Torque Value : 29 n.m [21 ft-lb]



Re-rating

The pump governor performance and setting can affect engine power. Special equipment and qualified personnel are required to verify governor performance. The fuel rate change is not allowed

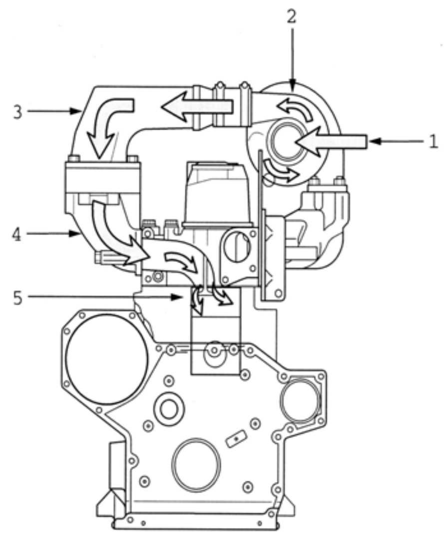
Injection pump re-rating must be discuss with Cummins dealer.

Air System

Air System Flow

The engines are available in naturally aspirated, turbocharged.
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 damaged 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.



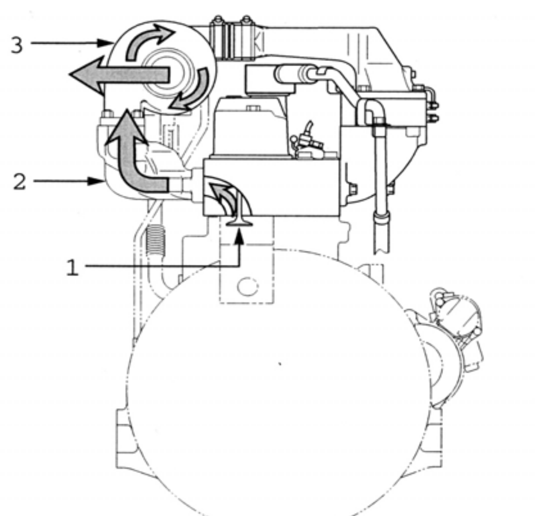
Air Intake System

1. Filtered air. 2. Turbocharger. 3. Air crossover tube
4. Intake manifold. 5. Intake valve port

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.

On turbocharged engines the flow is from the filter to the turbocharger, and then through the crossover tube to the manifold. From the intake manifold, air is forced into the cylinder and used for combustion. The exhaust gases flows through the turbocharger to rotate the turbine and impeller, thereby utilizing exhaust energy to force more air into the cylinders.

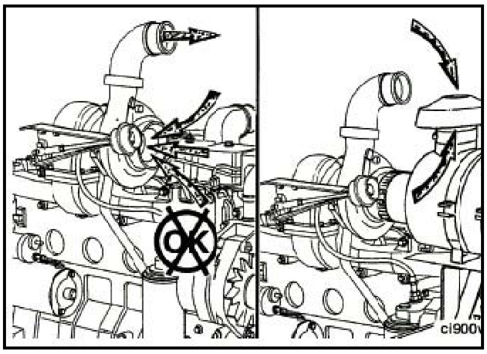
The additional air provided by the turbocharger allows more fuel to be injected to increase the power output from the engine. Thus, the power-to-weight ration for the engine is increased significantly with the addition of the turbocharger.



Exhaust System

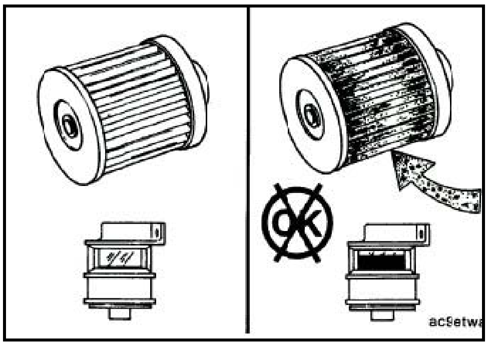
1. Exhaust valve port. 2. Exhaust manifold
3. Turbocharger turbine

Intake Air, Exhaust and Fuel System	A2300
Intake Restriction at Rated Speed and Load with Dirty Air Filter Element – kPa [mmAq]	6.23 [635]
Exhaust Restriction at Rated Speed and Load – kPa [mmAq]	7.65 [780]



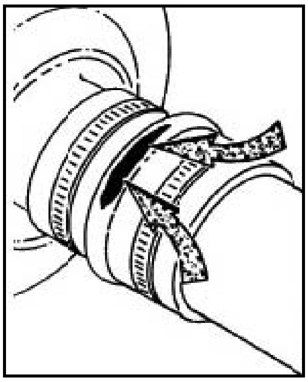
Diagnosing Air System Malfunctions

The correct amount of clean air to the cylinders is required for good performance. As discussed earlier in System Air Flow, ingested dust and dirt will manage the engine cylinders. Dust and dirt can also damage the valve stems and guides. Larger debris can damaged the blades of the turbocharger.



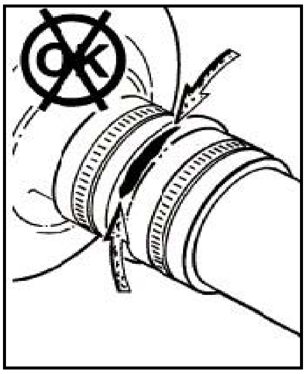
Air Flow Restriction Results in Excess Smoke and Low Power

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.
Measurement of air intake restriction is described in this Section.

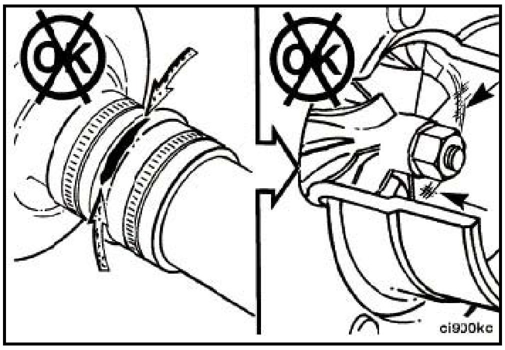


Damage From Non-Filtered Air

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 all dust and dir to be ingested into naturally aspirated engines.



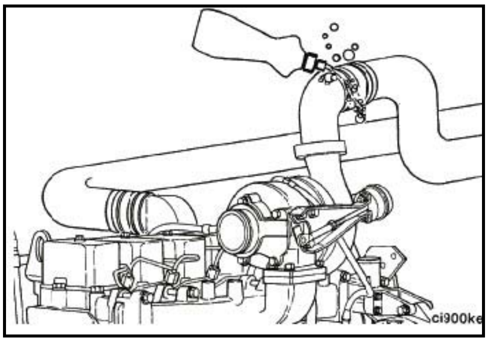
Loose connections or cracks in the suction side of the intake pipe on turbocharged engines can allow debris to be ingested into the turbocharger compressor and forced into the engine.



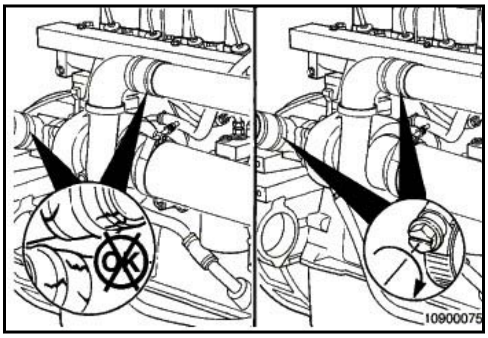
Debris drawn into the air suction side can damage the compressor blades causing and imbalance resulting in a bearing failure.
To verify a bearing failure or damaged compressor, remove the intake and exhaust piping and check for contact. The rotor assembly must rotate freely. Measurement of axial and radial clearance is described in this Section.

Pressure Side Air Leaks (Turbocharged Engines)

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

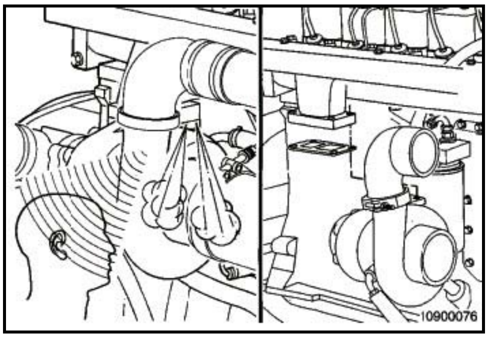


In addition to the visual inspection for cracks and loose fittings, liquid soap can be applied to the crossover tube, connections and the manifold cover sealing surfaces to find the leaks.
The leaks will create bubbles that are easier to detect.
Measurement of manifold pressure is described in this Section.

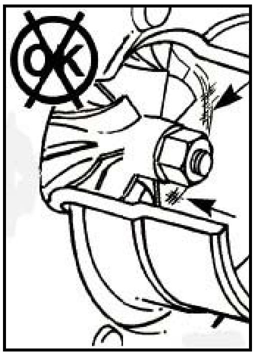


Exhaust Leaks (Turbocharged Engines)

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

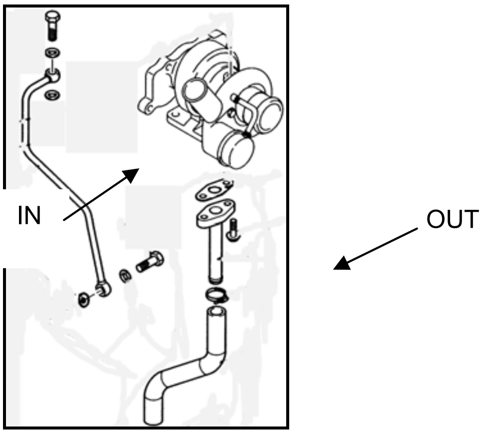


Exhaust leaks can usually be detected audibly or visually by a discoloration caused by the escaping hot gases.
Don’t overlook exhaust restrictions as a cause of low power. If the exhaust gasses can not flow freely, the turbocharger will not operate efficiently.



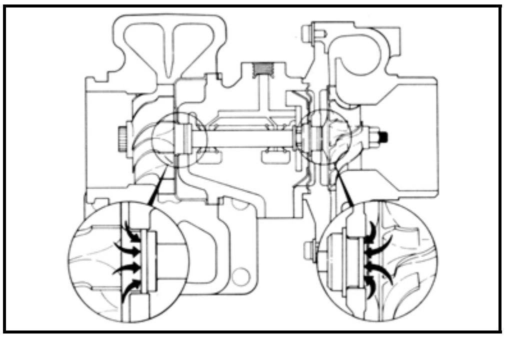
Malfunctioning Turbocharger

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

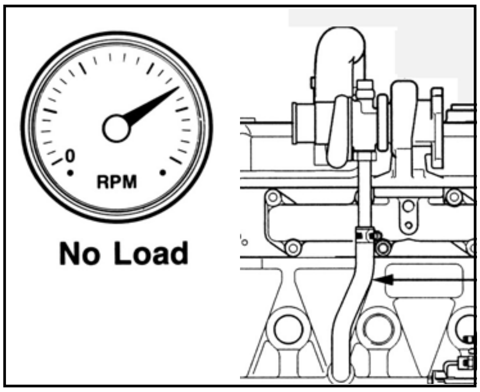


Oil Consumption and Leaks

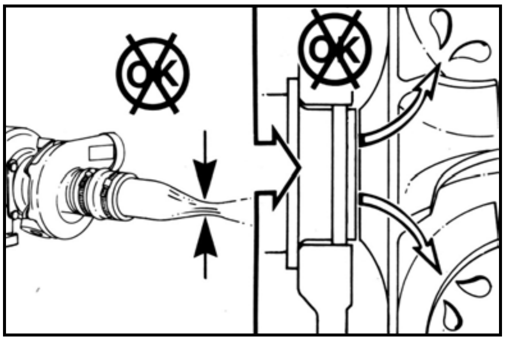
Engine lubricating oil is used to lubricate the bearings and provide some cooling for the turbocharger.
The oil is supplied to the turbocharger through the supply line is at engine operating pressure.
A return line connected to the bottom of the turbocharger routes the oil back to the engine oil pan.



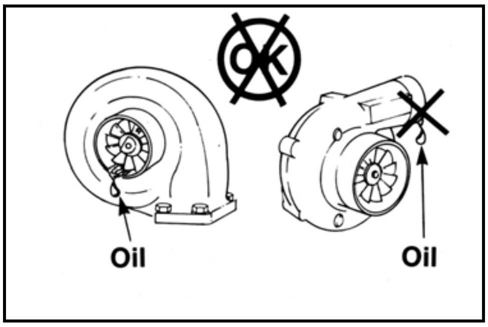
Seals are used on each end of the rotor assembly. The primary function of the seals is to prevent exhaust gases and compressed air from entering the turbocharger housing. Oil leakage from the seals is rare, but it can occur.



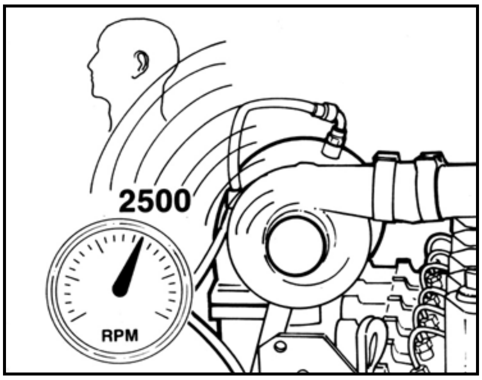
A restricted or damaged oil return line will cause the turbocharger housing to be pressurized causing oil to migrate by the seals.



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

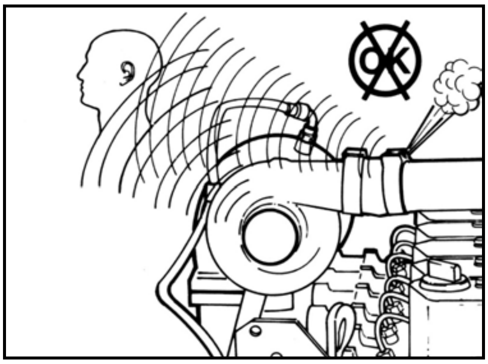


To verify oil leakage past the seals, remove the exhaust pipe and crossover tube and look for oil in the turbine casing and the crossover tube. Locate and correct the restriction as previously discussed.

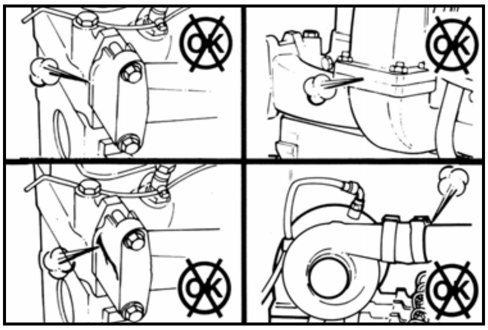


Turbocharger Noise

It is normal for the turbocharger to emit a “whine” sound that varies in intensity depending on engine speed and load. The sound is caused by the very high rotational speed of the rotor assembly. Consequently, the sound will be more audible at full speed.
Note: If possible, operate the engine at full speed to verify the noise level.

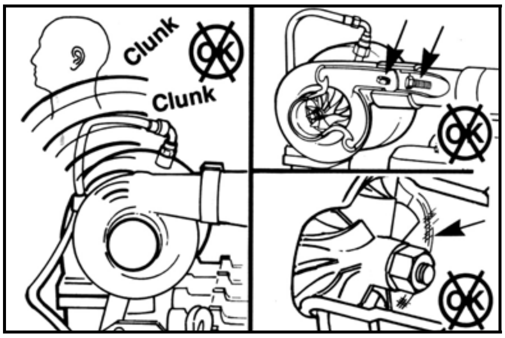


Leaks in the air system, both intake and exhaust components, can produce additional noises.
Check the air intake and crossover tube leaks.

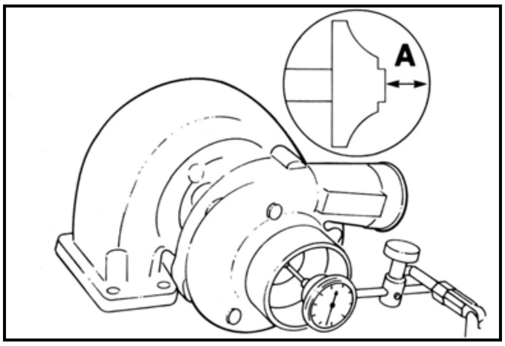


Note : Before removing a turbocharger, make sure that the noise complaint is not caused by leaks in the air system components.

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



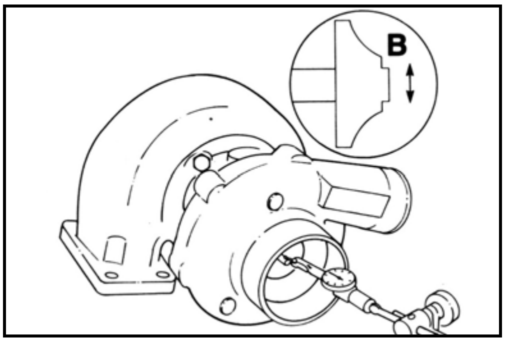
Lower pitch sounds or rattles at slower engine speeds can indicate debris in the system or the rotor assembly is touching the housings.



Rotor Assembly Clearance – Measure

Measure the shaft end play.

mm	End Play (a)	Inch
0.03	MIN	0.001
0.06	MAX	0.0024

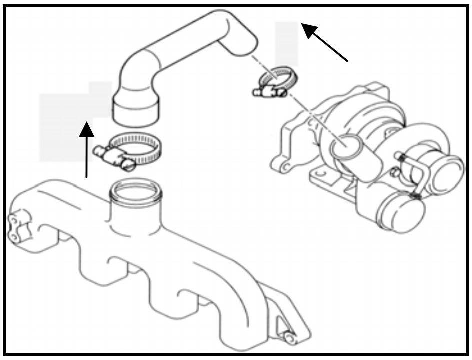


Measure radial clearance of the shaft.

mm	Radial Clearance (B)	Inch
0.08	MIN	0.003
0.13	MAX	0.005

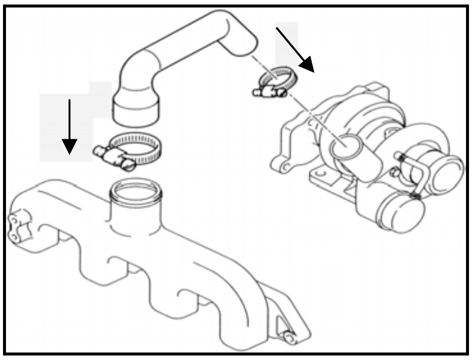
The turbocharger should be removed for replacement or rebuild if the clearances are beyond these limits.

Air System Replacement Procedures



Air Crossover Tube – Replacement

7mm
Loosen the hose clamps and position the hose so the crossover tube can be remove.



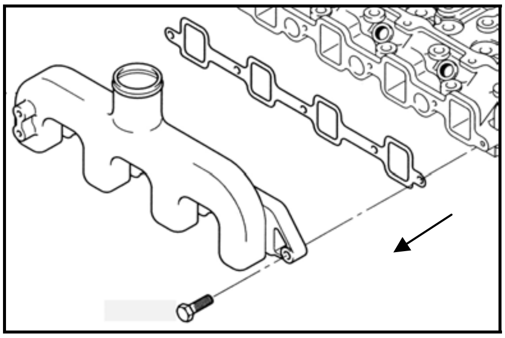
Use a new gasket and new hoses and clamps as required to install the air crossover tube.
Torque Value:

- **Hose Clamps: 39 Nm** [29 ft-lbs]

Intake Manifold Cover and Gasket – Replacement

Preparatory Steps:

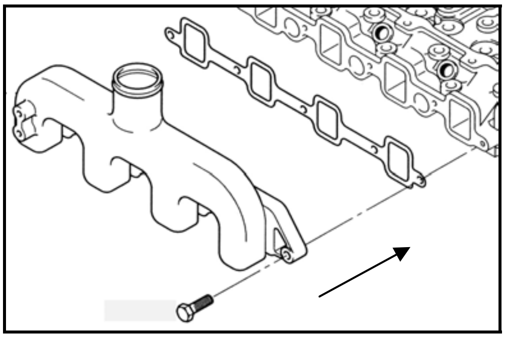
- Remove the high pressure fuel lines.
- Disconnect the cold starting aid.
- Remove the air crossover tube.



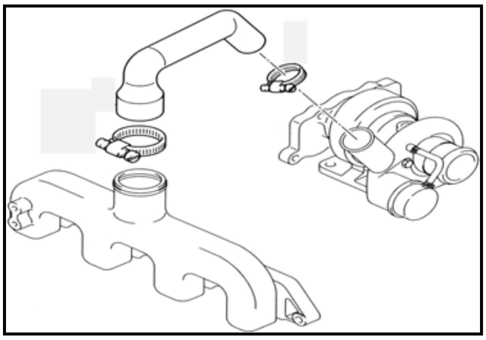
12mm
Remove the manifold cover and complete the following steps.

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

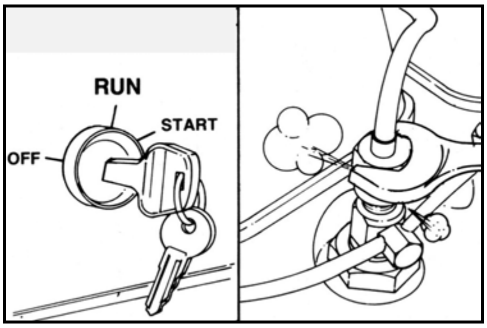
Clean the sealing surface.



12mm
Install the gasket and cover.
Torque Value : 25.5Nm [19 ft-lbs]



Assemble the intake piping and connect the cold starting aid.

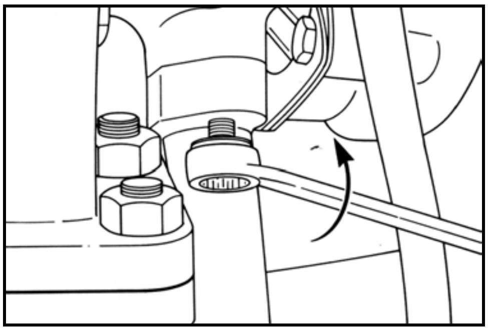


Install and bleed the high pressure fuel lines.

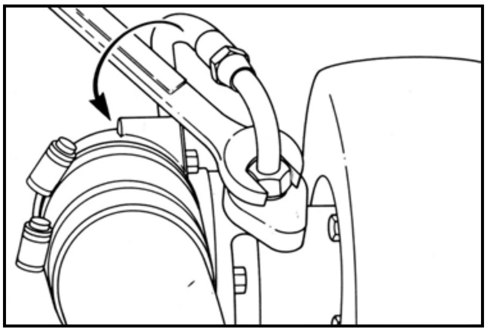
Turbocharger – Replacement

Preparatory Steps:

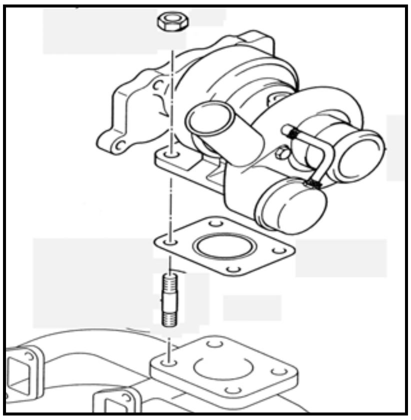
- Remove the air crossover tube.
- Disconnect the intake and exhaust piping.



10mm
Remove the oil drain tube capscrews and complete the following steps.

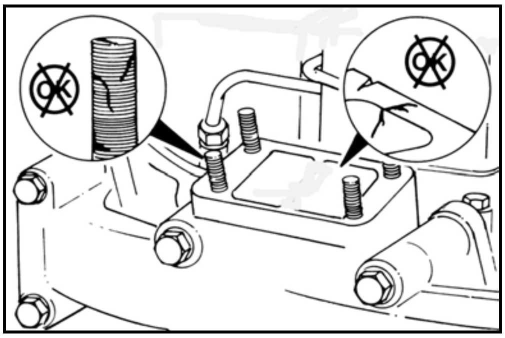


14mm
Remove the oil supply line.



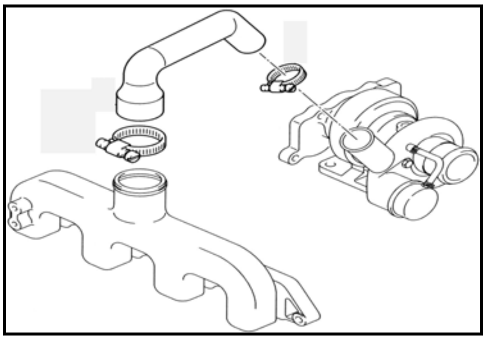
12mm
Remove the turbocharger.

Caution : If the turbocharger is not to be installed immediately, cover the opening to prevent material from falling into the manifold.

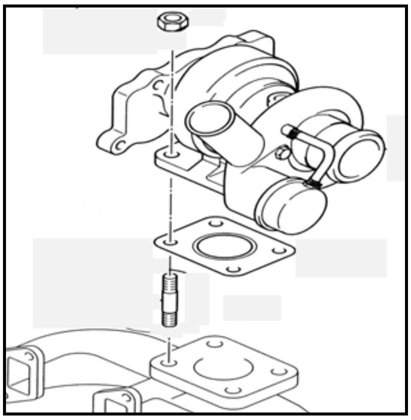


Clean and inspect the sealing surface.

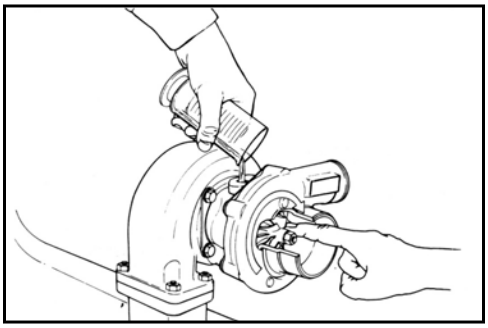
Install a new gasket and apply antiseize compound to the mounting studs.



7mm
Install the turbocharger and connect the air crossover tube.
Torque Value : 39Nm [29 ft-lbs]



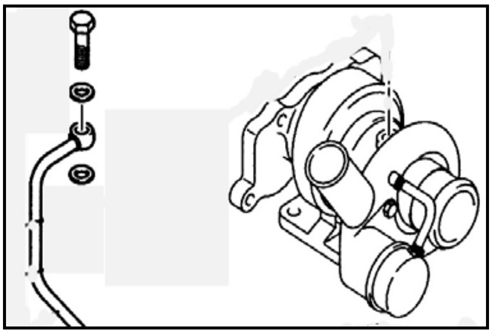
12mm
Use a new gasket and connect drain line.
Torque Value : 25.5Nm [19 ft-lbs]



Caution : New turbochargers must be prelubricated before start up.

Pour 30 to 40cc of oil into supply fitting.

Note : Rotate the turbine wheel to allow oil to enter the turbocharger.

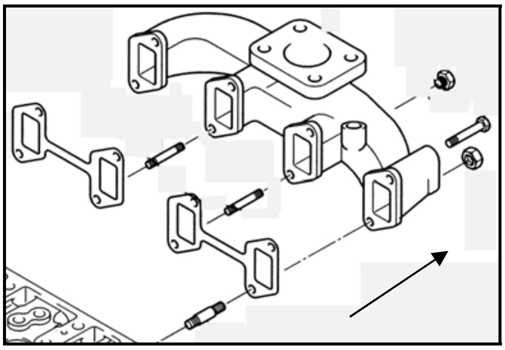


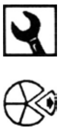
14mm
Install the oil supply line.
After installing the air intake and exhaust piping, operate the engine to check for leaks.

Exhaust Manifold and/or Gasket - Replacement

Preparatory Steps:

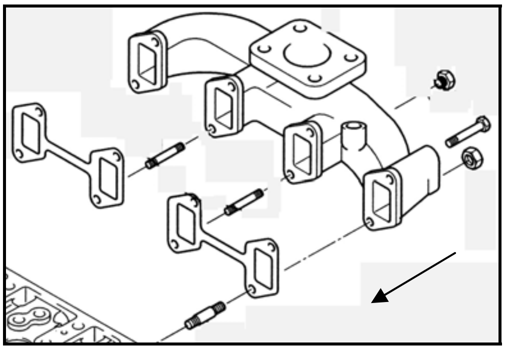
- Remove the air crossover tube.
- Disconnect the air intake and exhaust piping.
- Remove the turbocharger and gasket.





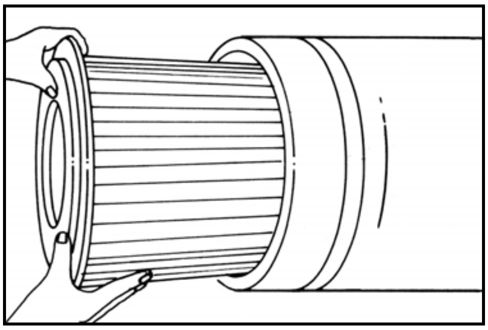
12mm
Remove the manifold and gasket.

Clean the sealing surface.



12mm
Install the manifold and gaskets.
Torque Value : 25.5Nm [19 ft-lbs]
Follow the sequence shown in the illustration.

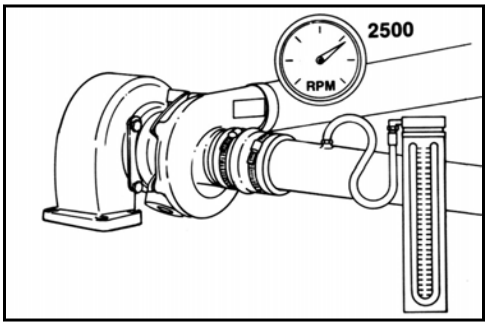
Install the turbocharger, air crossover tube, oil drain tube, oil supply line, and the exhaust and intake piping. Operate the engine to check for leaks.



Intake Air Restriction

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

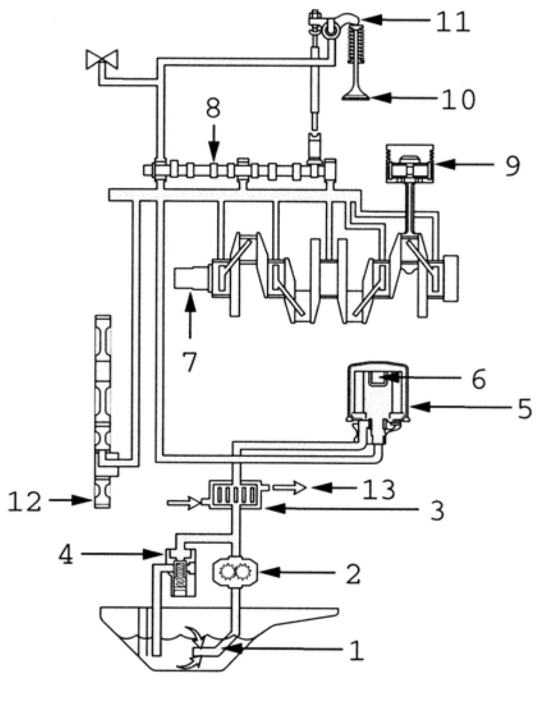
Naturally Aspirated	Turbocharged
6.23 kPa [635 mmAq]	6.23 kPa [635 mmAq]



Measure the restriction just before the turbocharger. Measure just before the intake manifold for naturally aspirated engines.

Lubricating System

Lubricating System Flow



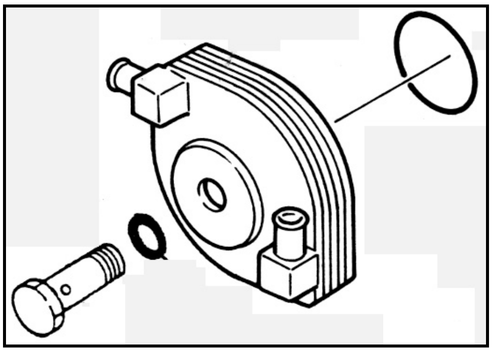
1. Oil strainer. 2. Oil pump. 3. Oil cooler (Option).
4. Regulator valve. 5. Oil filter. 6. Safety valve.
7. Crankshaft. 8. Camshaft. 9. Piston.
10. Intake and exhaust valve. 11. Rocker arm
12. Timing gear. 13. Cooling water. 14. Turbocharger

Lubricating Oil Pump

The engine use trochoid type oil pumps (1). The machined cavity in the block is the same for all engines.

Pressure Regulating Valve

The pressure regulating valve (2) is designed to keep the oil pressure from exceeding 343 kPa [50 PSI]. When the oil pressure from the pump is greater than 343 kPa [50 PSI, the valve opens uncovering the dump port so part of the oil is routed to the oil pan. Because of manufacturing tolerances of the components and the oil passages, the oil pressure can differ as much as 50 kPa [7.2 PSI] between engines.



Oil Coolers

The engines use full flow, plate type oil coolers. 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 use of incorrect components can cause high or low oil temperature, varnish and sludge build up.

Oil Filters

After the oil is cooled, it flows through the full flow oil filter.

Oil Filter Bypass Valve

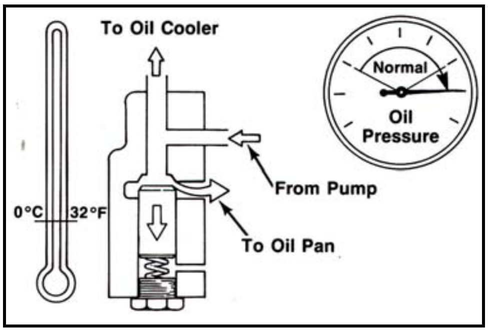
The oil cooler cover contains a safety valve that will let the oil flow bypass a plugged filter. The valve is designed to open when the pressure drop across the filter is more than 138 kPa [20 PSI], as with a plugged filter, and lets the oil continue on through the engine. When a filter becomes plugged, an oil pressure decrease of 50 kPa [7.2 PSI] or less from the normal operating pressure can be observed on the vehicle oil pressure gauge.

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 bearing. 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 form the nozzles also provides lubrication for the piston pins.

The number five 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 One Bearing Saddle. Cylinder Number Two receives the spray form the Number Two 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 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 roads and tappets.

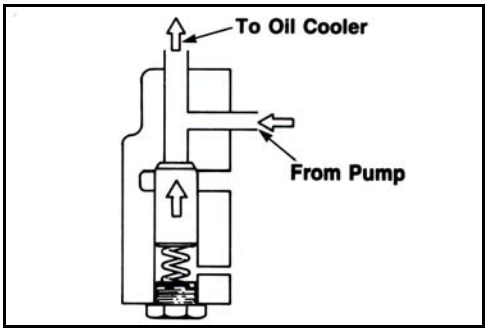


Diagnosing Lubricating System Malfunctions

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

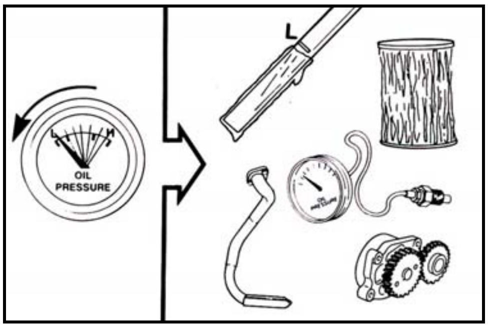
High Oil Pressure

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.



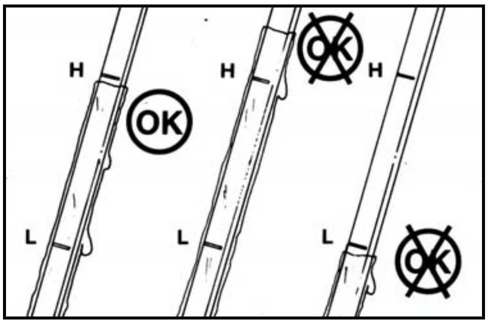
Oil Pressure Regulating Valve

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



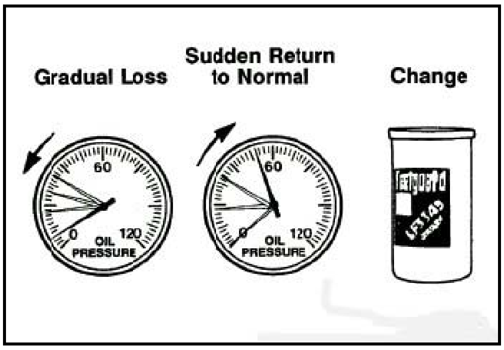
Low Oil Pressure

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.



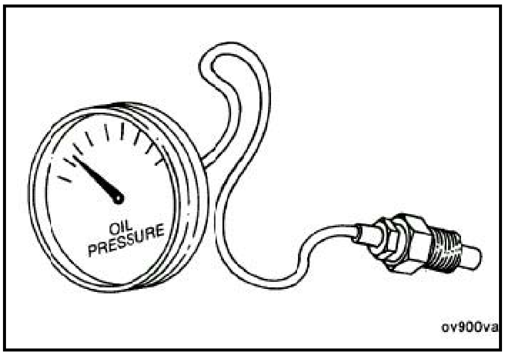
Oil Level

Low oil level can cause low oil pressure.
Caution: Never operate the engine with the oil level below the low (L) mark.



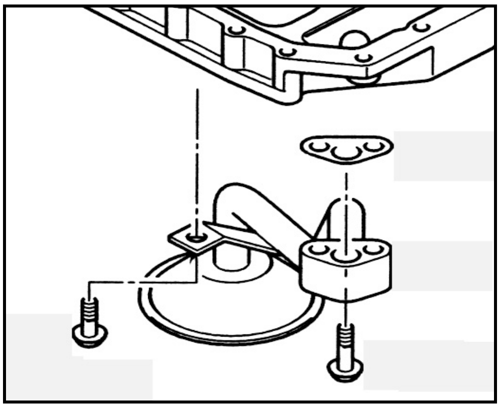
Oil Filter

A plugged filter will cause a gradual loss of pressure by approximately 69 kPa [10 PSI]. The pressure will return to normal when the filter bypass valve opens.



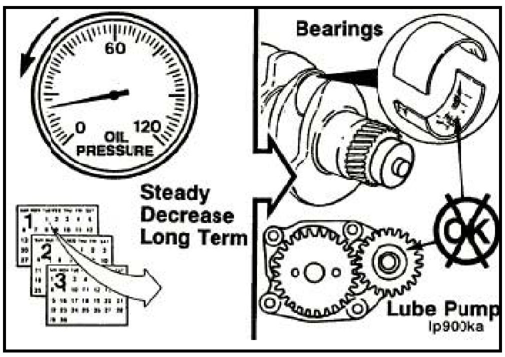
Oil Gauge

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



Oil Suction Tube

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

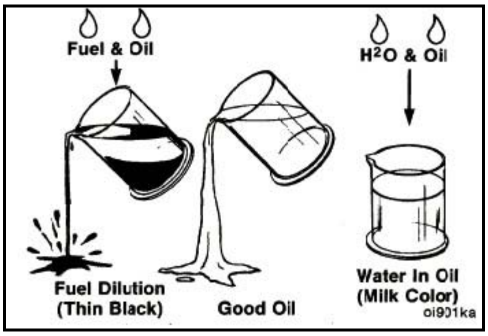


Bearings and Oil Pump

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

If low or high pressure occurs after changing the pump, verify that the correct pump was used.



Oil Dilution

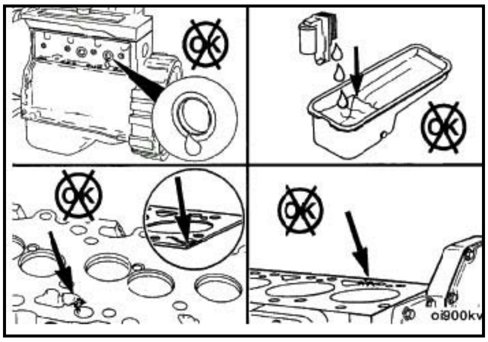
Caution: Diluted oil can cause severe engine damage.

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.

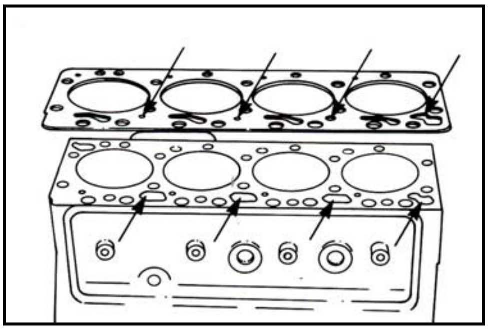
Coolant in the oil can be caused by

- Cup plugs leaking.
- Damaged cylinder head gasket.
- Oil cooler element leaking.

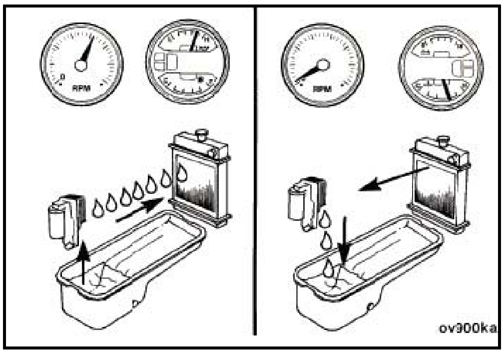


Coolant Diluted Oil

Coolant leaking from the oil 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.



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.

Fuel Diluted Oil

Fuel dilution is limited to four sources:

1. Injection pump shaft seal
2. Fuel leaking by the rings
3. 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 -

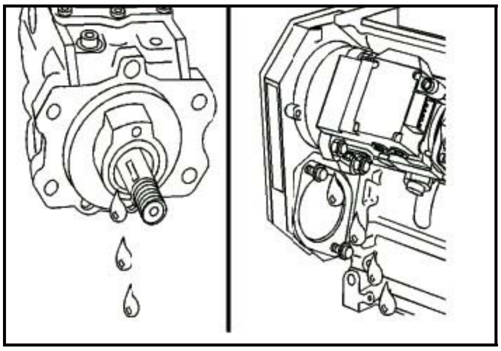
↓

Check/Replace the Injectors

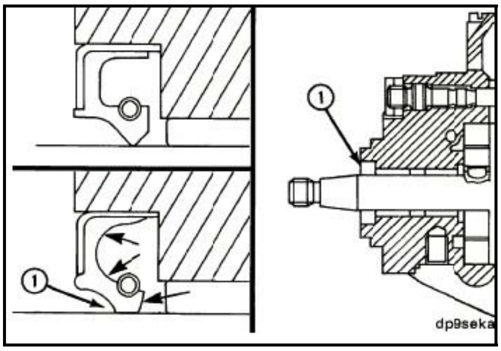
Power Low – Increased Black Smoke

↓

Verify the Rings are Sealing by Performing a Compression Check

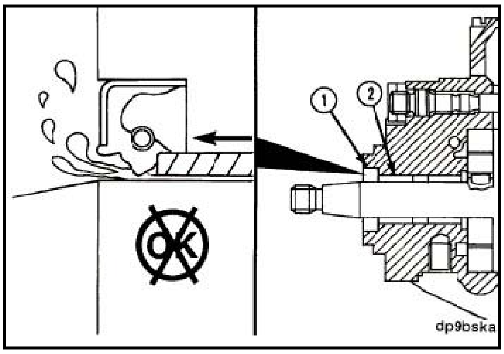


A worn or damaged injection pump shaft seal will allow fuel to leak into the gear housing and then into the oil pan.

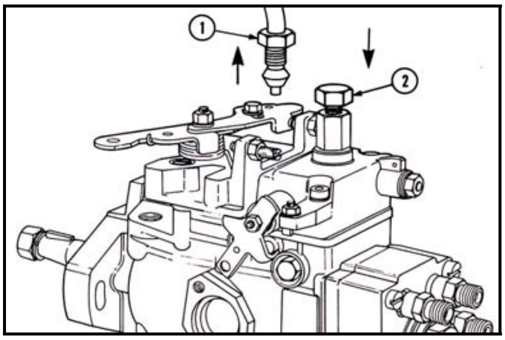


The seal is designed to provide increased sealing as the pump case pressure increases. Pressure forces the lip (1) tighter around the shaft.
A worn seal is more apt to leak during start up and shut down when case pressure is low.

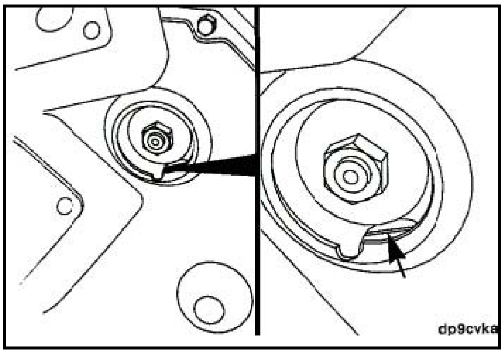
Caution : A worn seal can not be detected pressurizing the pump.



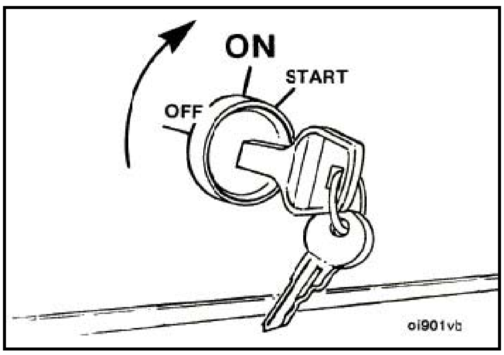
The bushing (2) in the Bosch VE pump can causes a seal leak. If the bushing is loose in the housing it will move toward the seal raising the lip (1) and providing a leak path for fuel.



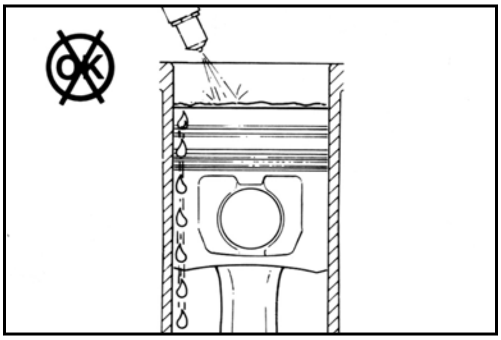
To check for such a leak remove the fuel drain manifold connection (1) at the pump and install a plug (2).



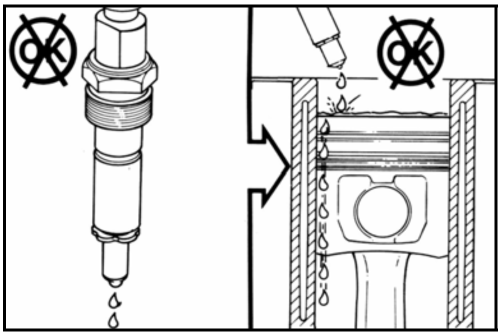
Remove the access cover and rotate the engine so one of the holes in the fuel pump gear exposes the back gear housing.



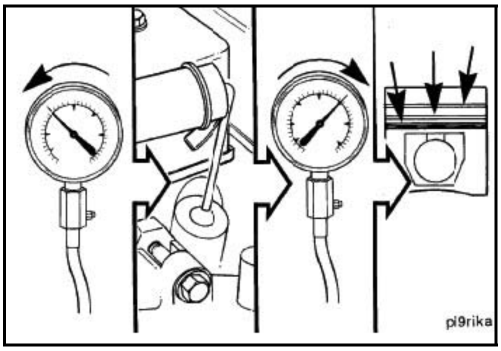
Activate the fuel shut down valve by turning the switch to the ON position.



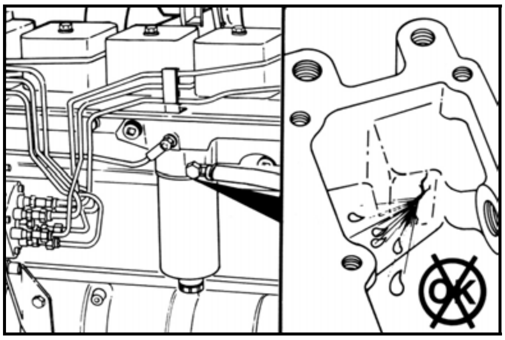
Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.
This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.



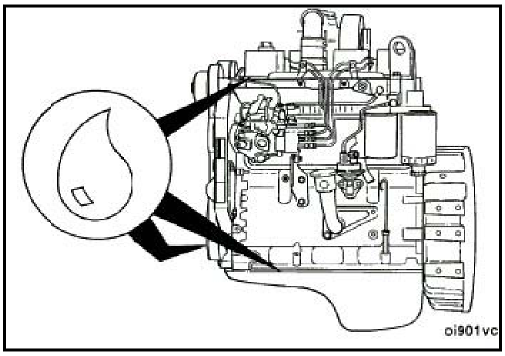
An increase in white exhaust smoke during the first start of the day is a symptom that an injector is leaking.
An injector leak will also cause the engine to run rough and have low power.
Remove and replace leaking injectors



Perform a compression check to verify piston ring sealing

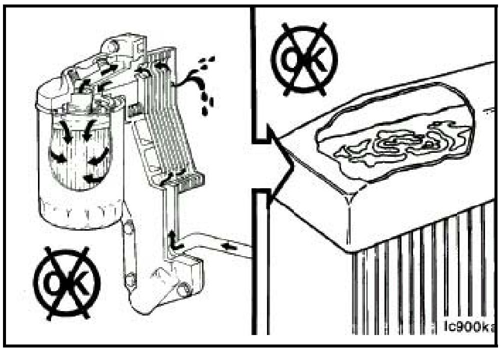


Another remote possibility is a crack or porosity in the head casting could allow fuel to leak to the air intake and on to the cylinders.

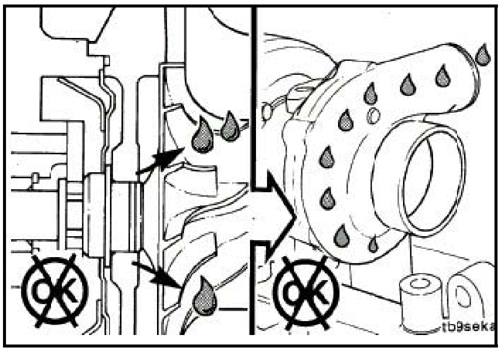


Oil Leaks

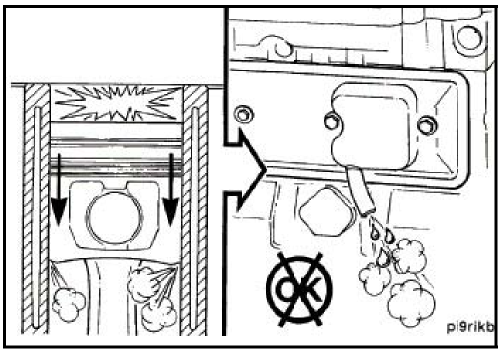
Various gaskets, seals and plugs are used to contain the oil. Most leaks can be identified during routine inspection of the engine and vehicle.



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.

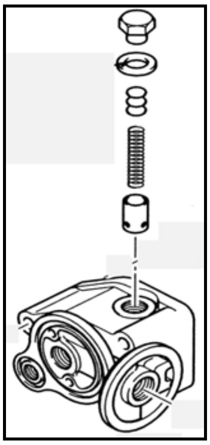


Worn or damaged seal sin the turbocharger can also allow oil to leak into the air crossover pipe and be burned in the engine.
The condition can be verified by removing the air crossover tube and looking for oil.



Inadequate sealing of the piston rings will result in oil being blown out the breather tube and/or consumed by the engine

Lubricating System Replacement Procedures



Oil Pressure Regulator Valve and/or Spring Replacement

24mm
Remove the plug and valve.

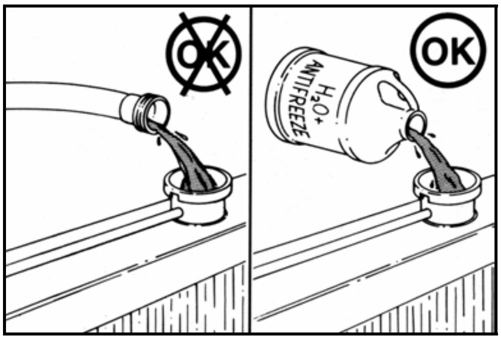
Clean and inspect the plunger, bore and seat before assembly.

Note : The plunger must move freely in the valve bore.

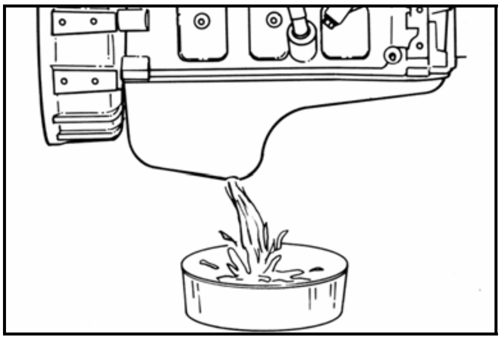
Assemble the vale in the reverse order of disassembly.
Torque Value : 69Nm [51 ft-lbs]

Oil Cooler Element and/or Gasket – Replacement

Preparatory Step : Drain the coolant.

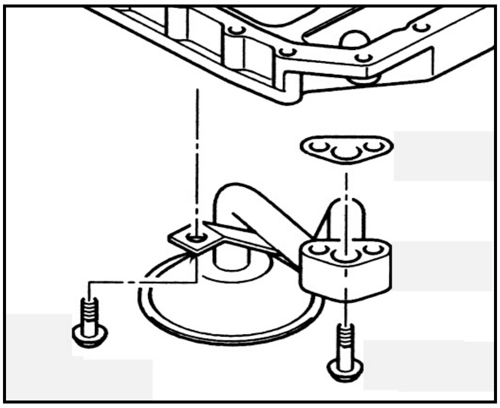


Fill the coolant system and operate the engine to check for leaks.
Stop the engine and check the coolant and oil level.



Oil Pan, Suction Tube and/or Gaskets – Replacement

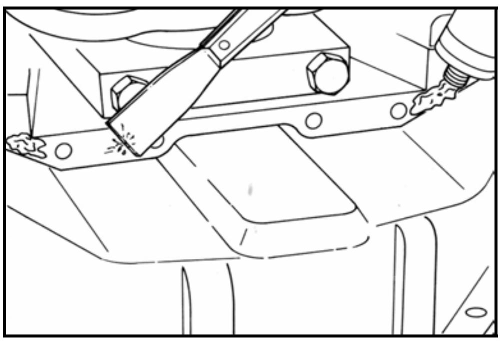
17mm
Drain the oil and remove the pan and gasket.



12mm

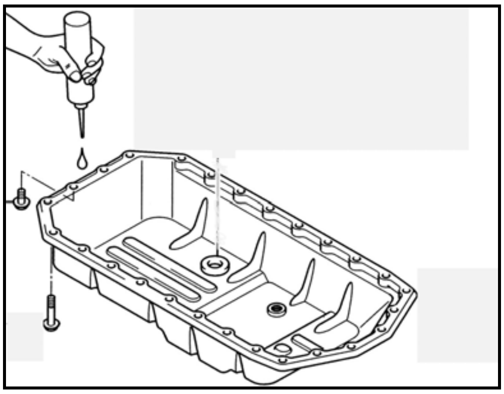
Caution : Be sure to connect the support bracket.

If required, remove the suction tube and gasket.
Clean the sealing surfaces.
Install the suction tube and gasket.
Torque Value: 25.5Nm [19 ft-lbs]

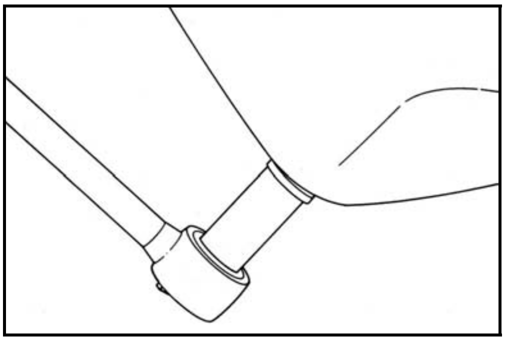


Caution : Be sure to fill the joints between the pan rail, gear housing and rear cover. Use Three Bond 1207-C.

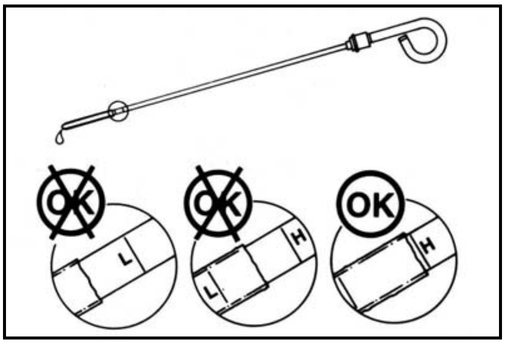
Clean the pan sealing surfaces.



12mm
Install the pan and gasket.
Torque Value: 25.5Nm [19 ft-lbs]



17mm
Install the drain plug.
Torque Value: 78 Nm [59 ft-lbs]



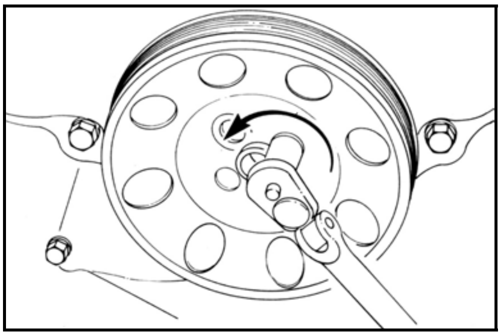
Fill the engine with oil. Run the engine and check for leaks.
Stop the engine and check the oil level with the dipstick.

Oil Pump – Replacement

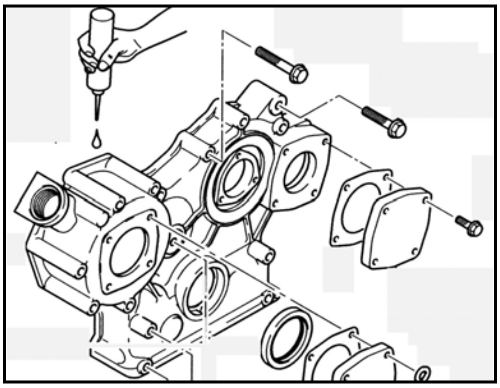
Preparatory Step:

- Remove the drive belt.

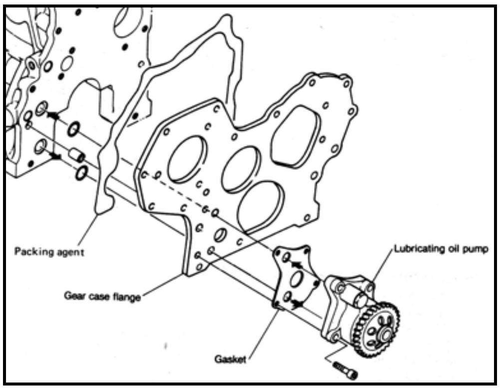
Note : Removal is easier if the crankshaft pulley is loosened before removing the belt.



19mm
Remove the crankshaft pulley.

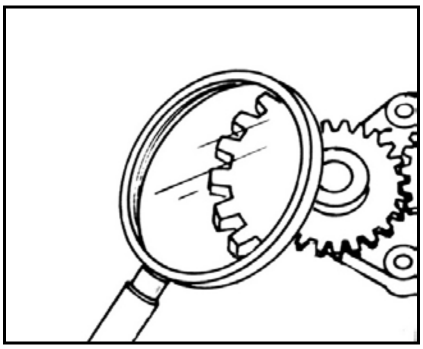


12mm
Remove the front cover.

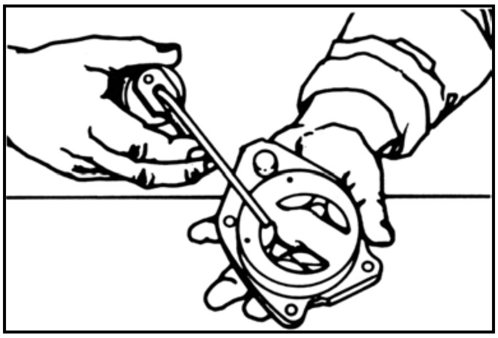


Remove the Lubricating Oil Pump

5mm Hex Lench
Remove the four mounting capscrews.
Remove the pump from the bore in the cylinder block.



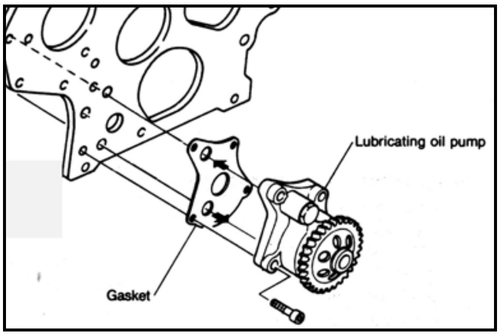
Clean and Inspect
If the pump is to be inspected for reuse, follow these steps.
Visually inspect the lube pump gears for chips, cracks, or excessive wear.



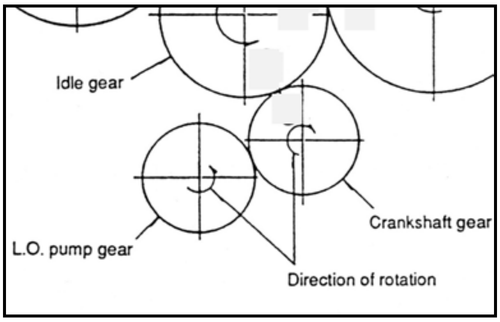
Installing the Lubricating Oil Pump

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.



12mm
Install a new gasket.
Tighten in the sequence shown.
Torque Value : 25.5Nm [19 ft-lbs]



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

Measure gear backlash.

Backlash Limits

A
0.11 to 0.19mm [0.0043 to 0.0075 inch

Note : If the adjusting 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.

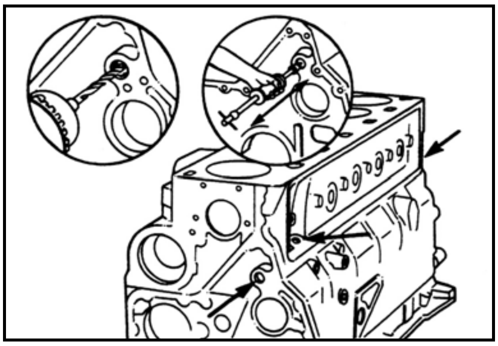
12mm
Install the front cover and gasket.

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

Torque Value : 25.5 Nm [19 ft-lb]

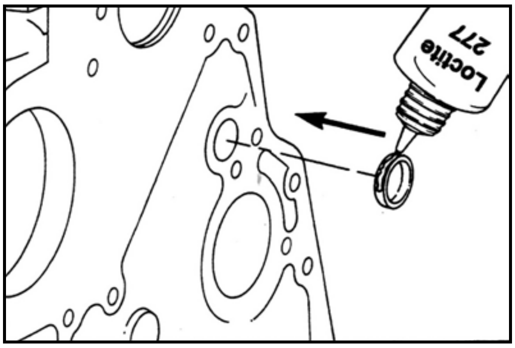
19mm
Install the crankshaft pulley

19mm
Torque Value : 113Nm [98 ft-lbs]



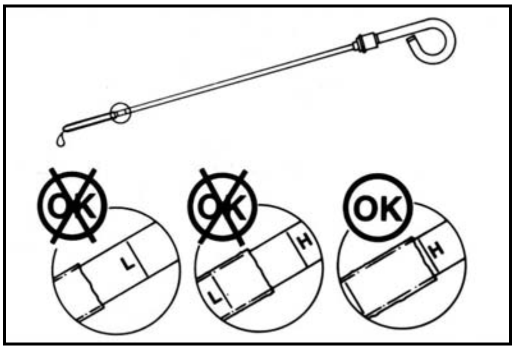
Cup Plugs – Replacement

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.



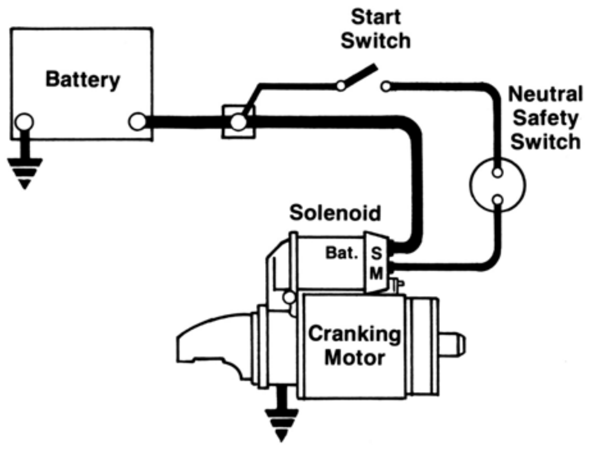
Fill the engine with oil. Run the engine and check for leaks.
Stop the engine and check the oil level with the dipstick.

Electrical System

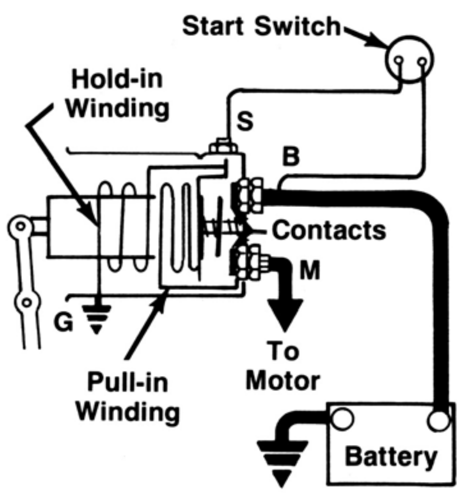
Electrical System Description/Operation

The electrical system basically consists of the starting motor and the alternator.
The injection pump uses an electrical fuel shut off 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.

Densko Poongsung 12V 2.0kw Starting Motor

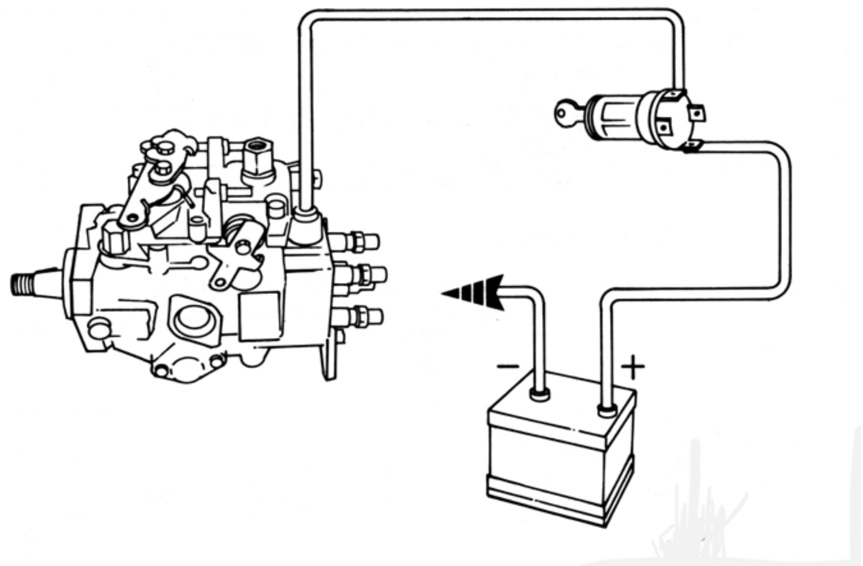


Basic Wiring Circuit

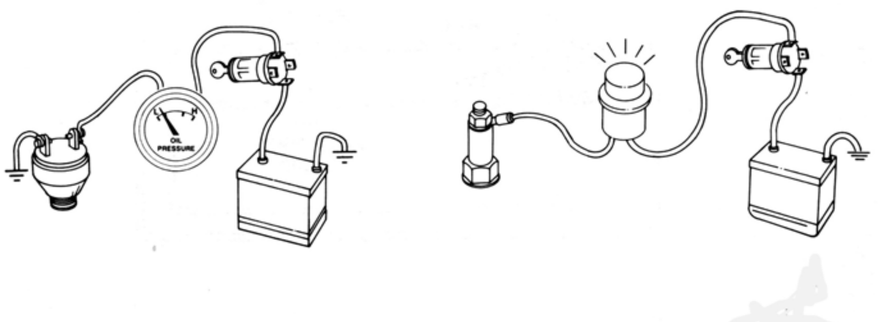


Basic Solenoid Circuit

Injection Pump Fuel Shut Off Valve

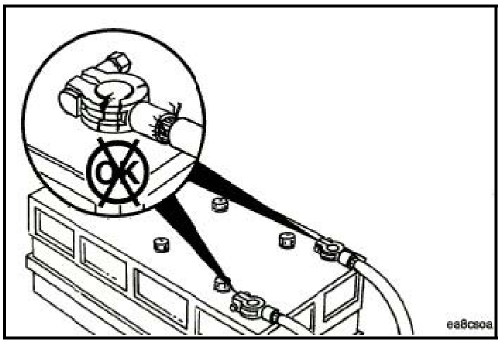


Oil Pressure Switch and Temperature Sensors



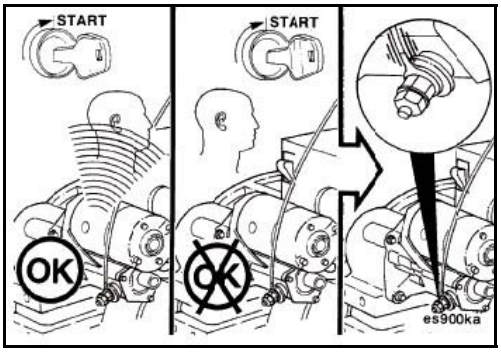
Electrical System Spec.

- Minimum Recommended Battery : 12 V –75A
- Starter Motor: 12V – 2.0kW
- Alternator: 12V – 45A

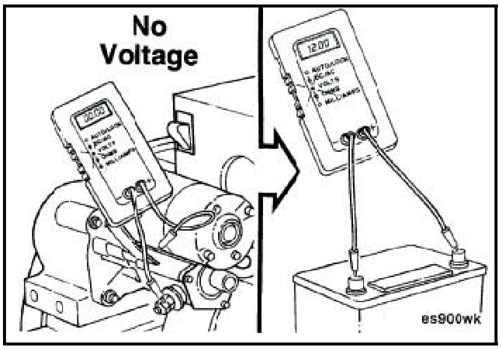


Diagnosing Electrical Malfunctions Starting Motor

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

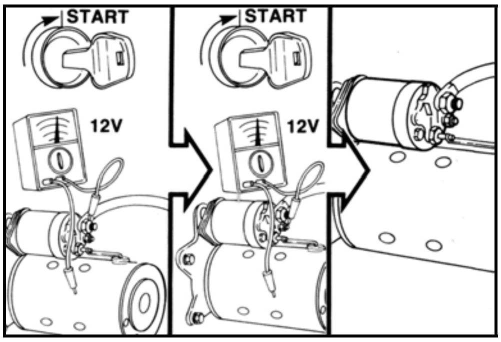


Engine Does Not Crank
If the solenoid does not make an audible sound, check for loose wiring connections.



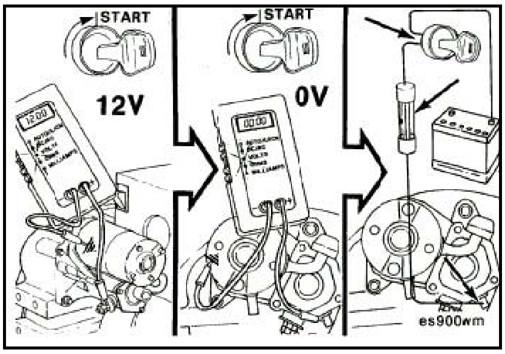
Check the voltage at the solenoid battery post.

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

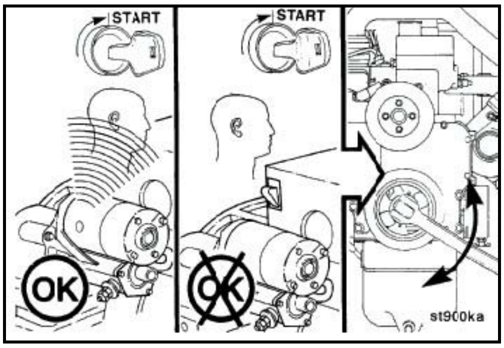


- 12 volts at the solenoid battery post – check the voltage at the S (switch) terminal on the solenoid. The ignition switch must be in the start position.

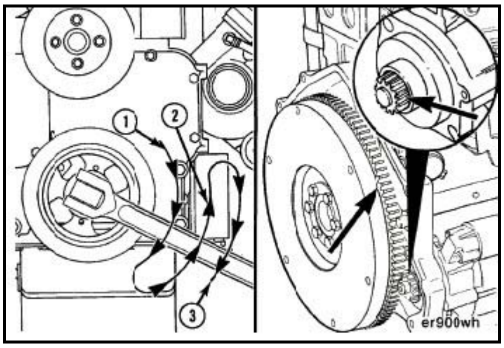
The solenoid is at fault if the check indicates 12 volts at the S terminal.



- If no voltage is indicated at the S terminal, check:
- Fuses
- Voltages to the ignition switch
- And, if the vehicle is so equipped, voltage to clutch switch, neutral safety switch and engine safety shutoff system.



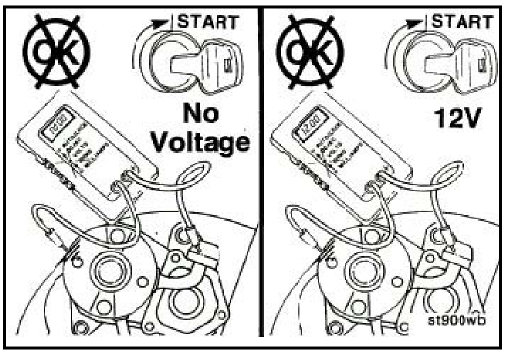
If the solenoid does make an audible sound, turn the switch off and attempt to bar the engine in both directions.



Bar the engine as follows:

1. Direction of engine rotation.
2. Direction of 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.



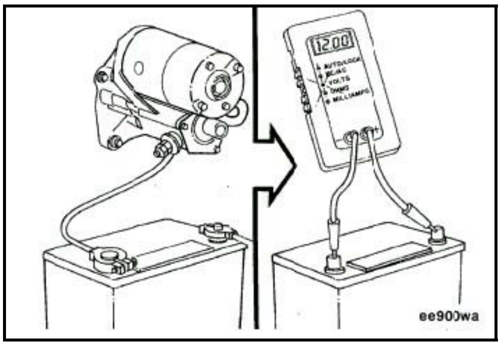
If the engine bars and the starting motor does not crank, check the voltage between the solenoid and starting motor. The ignition switch must be in the start position.

No Voltage: Starter is at fault

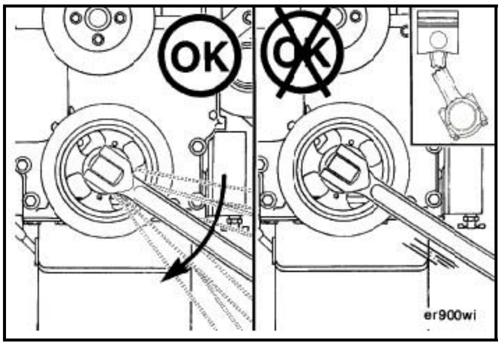
Normal Voltage: The solenoid is at fault.

When troubleshooting a 24 volt system, the value is 24 volts.

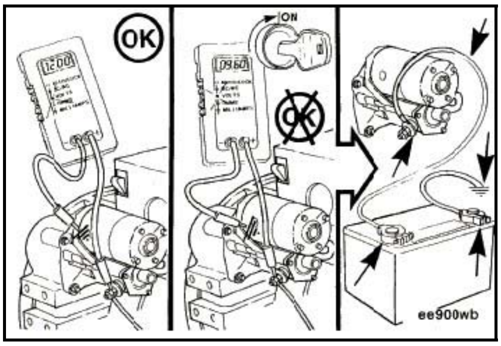
Engine Cranking Speed Too Slow



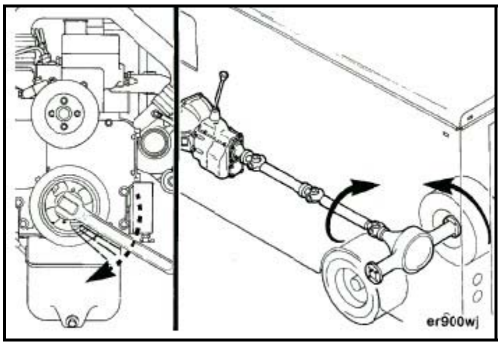
Make sure the wiring connections are clean, tight and not damaged.
Check the battery voltages.



If the engine was not rotated to check the starting motor (page 7-8), bar the engine in the direction of engine rotation to make sure the engine is free and does not have an internal malfunction.



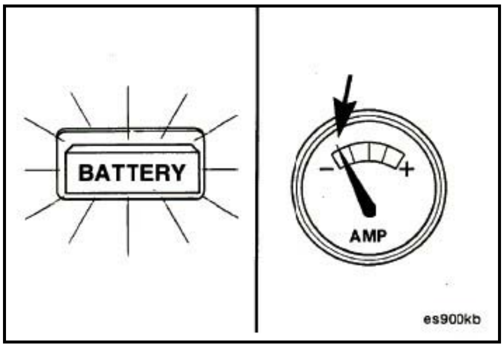
If the engine is free, check the voltage at the starter during cranking. If the voltage drops more than 2.4 volts, check that all connections are tight. The limit for 24 volt systems is 4.8 volts.
If the cable correct and the voltage drop exceeds the limit, replace the starter.



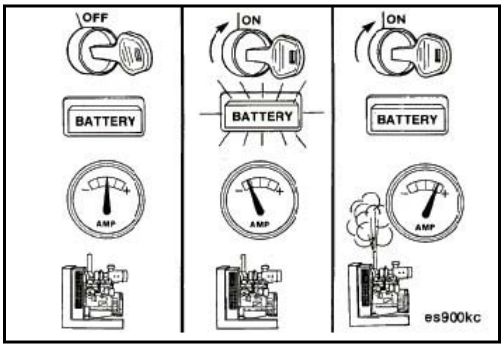
If the engine requires more than a normal effort to bar, check for excessive load from the driven units and accessories.

Alternator

The terminals on the alternator are shown in this illustration. The “R” terminal provides one-half system voltage and is used to operate accessories such as the tachometer on generator sets.

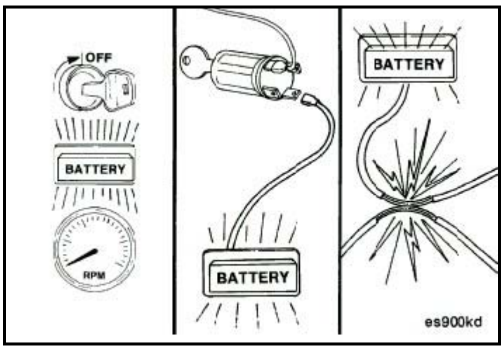


Trouble with the charging system may be indicated by the indicator lamp or ammeter.

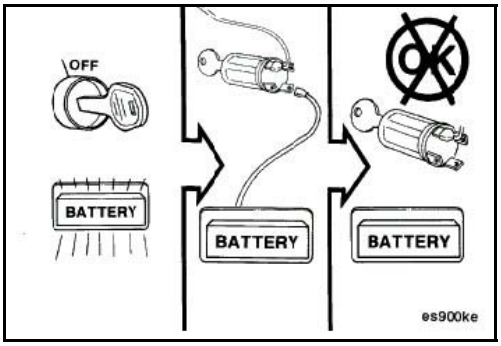


Abnormal Indicator Lamp Operation
Check the indicator lamp for normal operation as shown below.

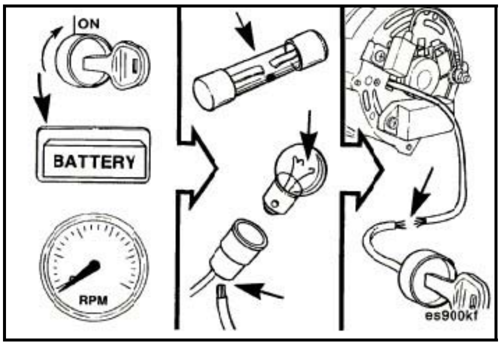
Engine	Switch	Lamp	Ammeter
Stopped	Off	Off	0
Stopped	On	On	-
Running	On	On	+



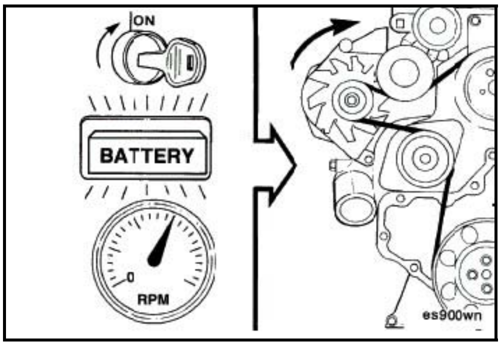
Switch Off, Lamp On, Engine Stopped
Disconnect the lamp lead at the ignition switch. If the lamp stays on, there is a short to a positive wire on the ignition side of the lamp.



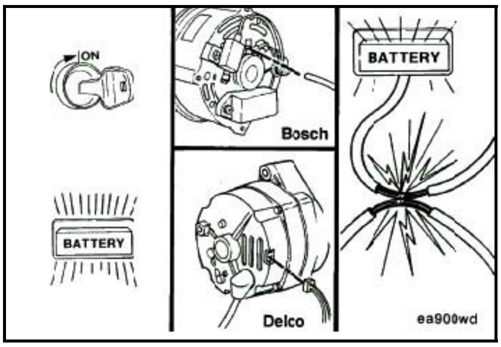
If the lamp goes out, there is a short in the switch.



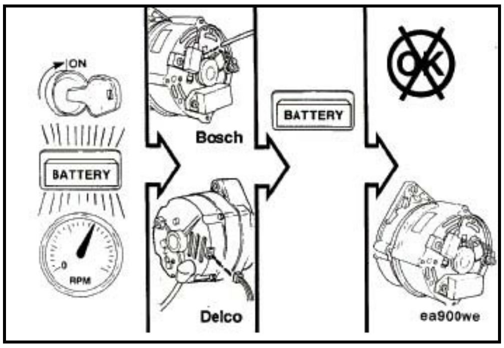
Switch On, Lamp Off, Engine Stopped
The condition can be caused by an open in the circuit. To determine where an open exists. Check for a blown fuse, a burned out bulb, defective bulb socket, or an open in No. 1 lead circuit between alternator and ignition switch.



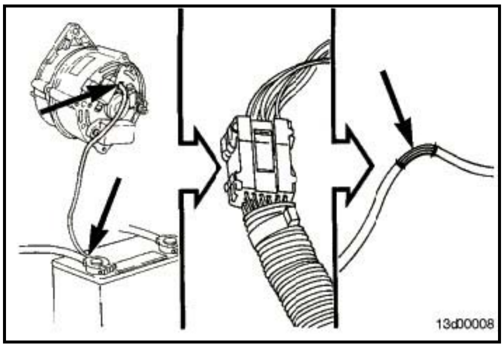
Switch On, Lamp On, Engine Running
Check the drive belt and alternator pulley to be sure the alternator is rotating.



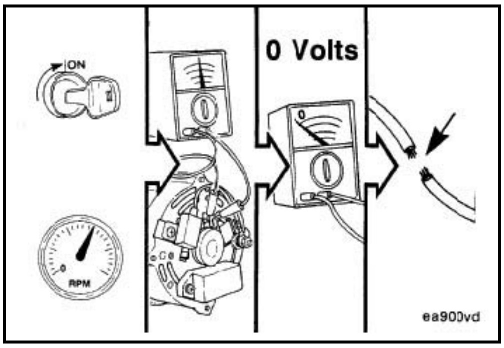
Disconnect the lead to Terminals No. 1 and No. 2. If the lamp stays on, there is a short to ground on the alternator side of the lamp.



If the lamp goes out, replace the alternator.



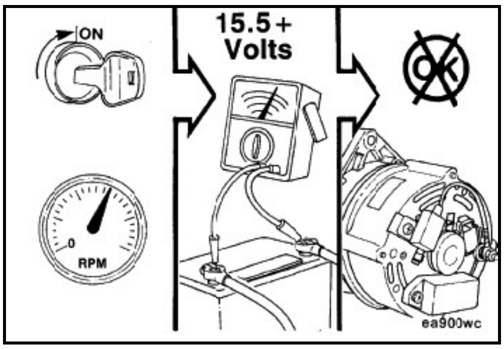
Abnormal Charging System Operation
Check the battery and all wiring connections.
Inspect the wiring for defects.
Check all connections for tightness and cleanliness, including the slip connectors at the alternator and firewall, and connections at the battery.



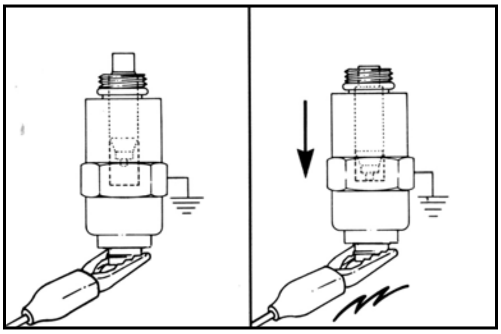
With ignition switch on and all wiring harness leads connected, connect a voltmeter from:

A. Alternator “BAT” 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.



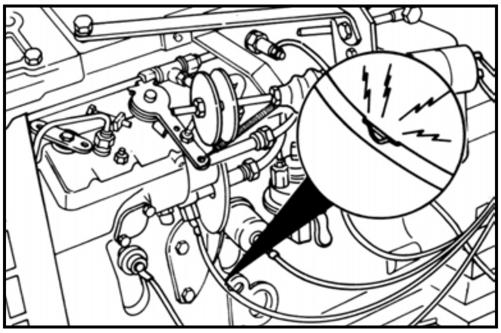
With all accessories turned off, connect a voltmeter across the battery.
Operate engine at moderate speed.
If voltage is 15.5 or more, remove the alternator for repair. The limit for 24 volt system is 25 volts.



Fuel Shutoff Valve – Check

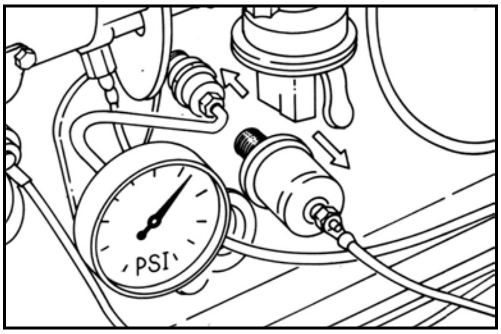
Note : Check all connections for loose or corroded connections for broken wires.

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



Oil Pressure Switch and Temperature Sensor

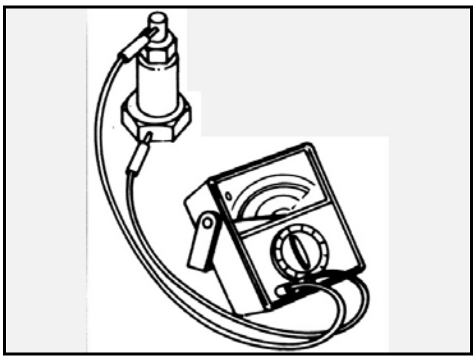
When diagnosing problems with either the pressure switch or the temperature sensor, check for loose or corroded connections and for broken wires.



Oil Pressure Switch - Check
Remove the pressure switch, install a gauge, start the engine and measure oil pressure. Minimum oil pressure:

Idle	147 kPa [21PSI]
Full Speed	294 kPa [42 PSI]

Note : The pressure switch is set to actuate when oil pressure drops to 98 kPa [14 PSI].



Temperature Sensor – Check
Check for continuity.
Voltage : DC 12 V

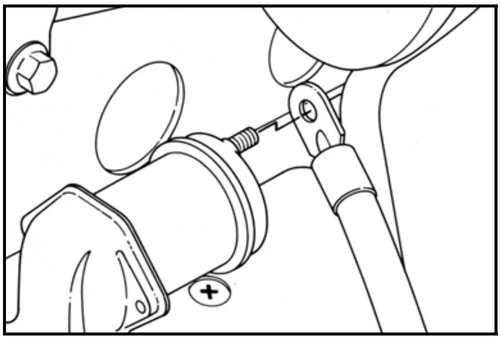
Temperature	54.4 ℃	110 ℃
Resistance	560~716Ω	72.1~81.8Ω

Engine Electrical System Replacement Procedures

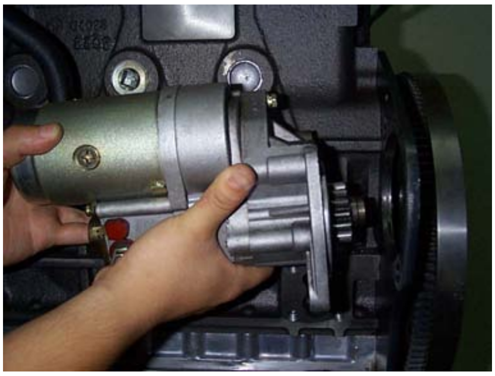
Starting Motor - Replacement

Preparatory Steps:

- Disconnect the ground cable from the battery terminal.
- Identify each electrical wire with a tag indicating location.



12mm
Remove the battery cable from the solenoid.

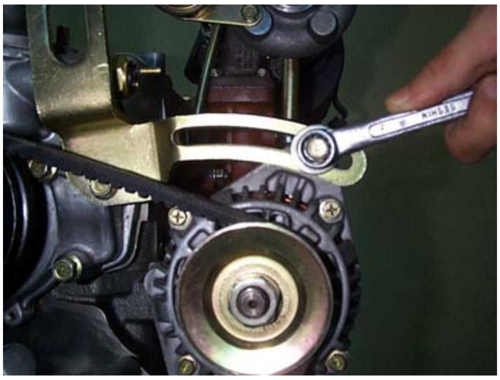


17mm
Remove the starting motor.
Install the starting motor in the reverse order of removal.
Torque Value : 78Nm [59 ft-lbs]

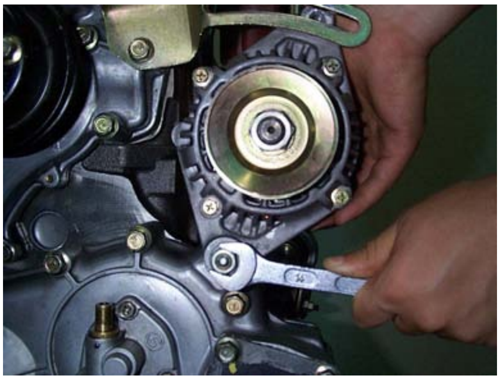
Alternator - Replacement

Preparatory Steps:

- Disconnect the ground cable from the battery terminal.
- Remove the drive belt from the alternator pulley.



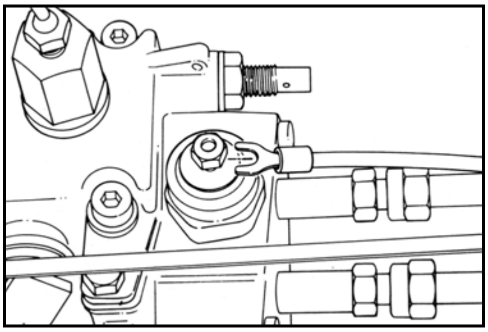
12mm
Remove the alternator bolts.



14mm
Remove the alternator mounting nuts.

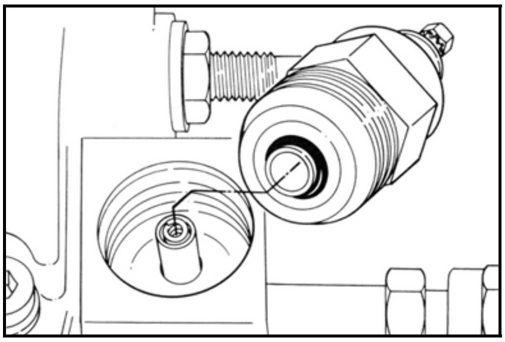
12mm, 14mm
Install the alternator by tightening the 12mm bolts before the 14mm bolts. Reconnect all wires.

Torque Value : (12mm) 25.5Nm [19 ft-lbs]
(14mm) 49Nm [37 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.

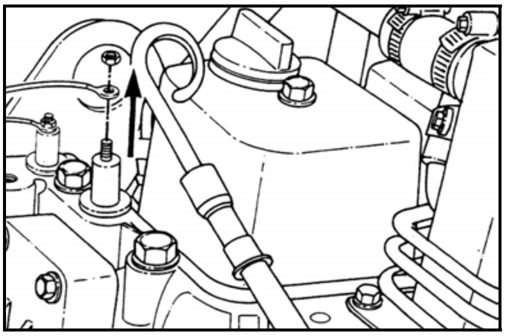
Note : The sending units illustrated may differ from those installed by the equipment manufacturer.

Reconnect the wire to the sending unit.

Torque Value :
(Installed into Cast Iron)
16Nm [12 ft-lbs]

Temperature Sensor – Replacement

Preparatory Step:
Drain coolant



Disconnect the temperature sensor wiring.

17mm
Remove the temperature sensor.

17mm
Apply liquid Teflon sealant to the threads when installing the temperature sensor.
Reconnect the wiring.

Torque Value:
(Installed into Aluminum)
39Nm [29 ft-lbs]

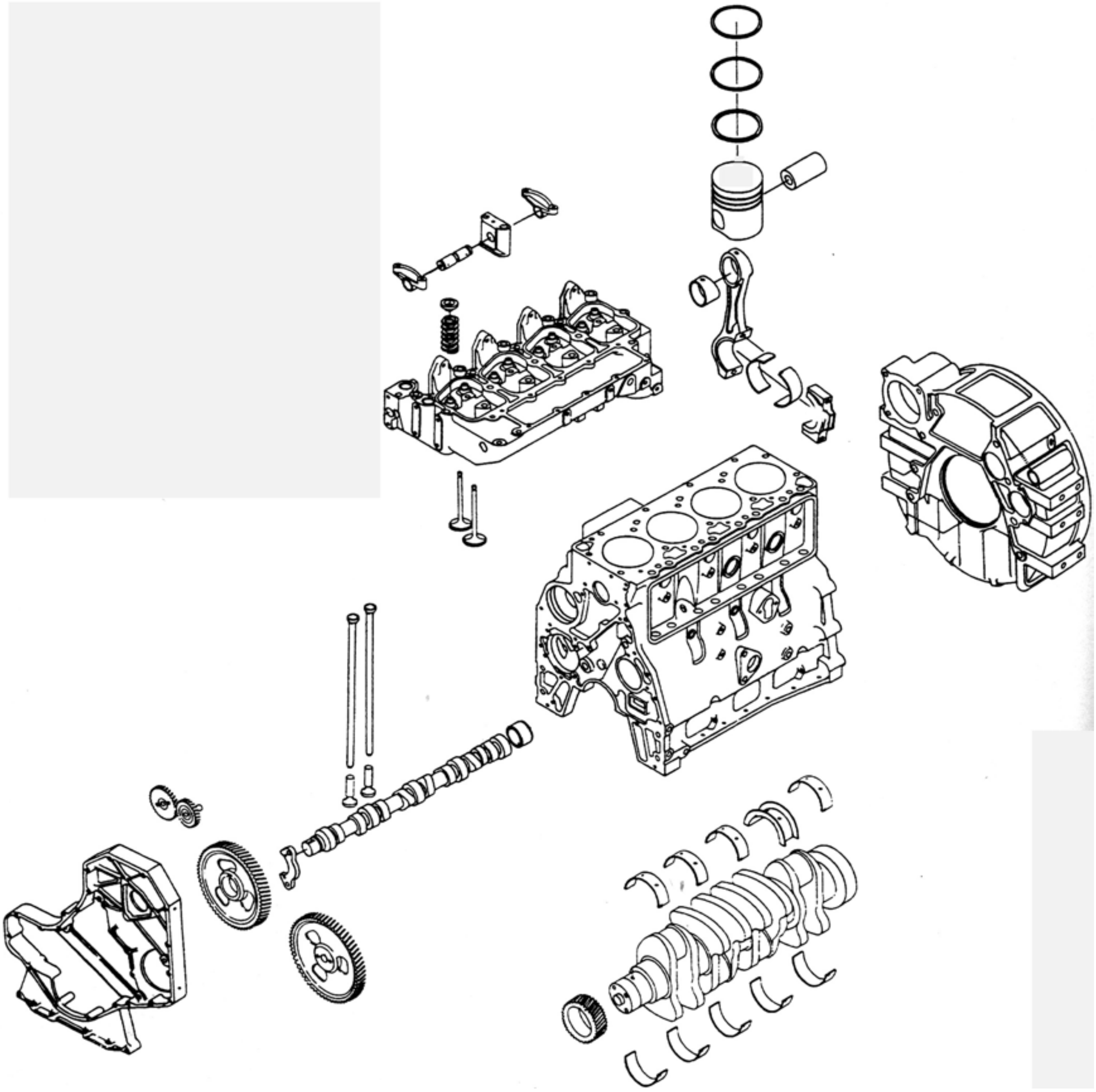
Base Engine Components

Operation and Description

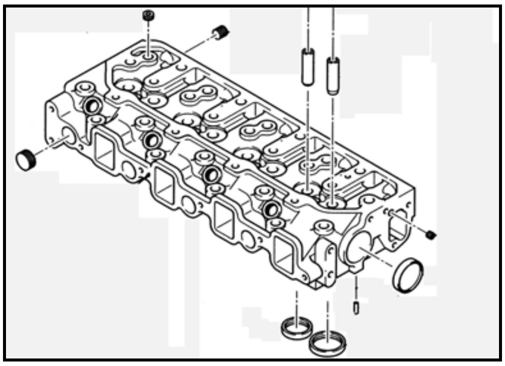
This section of the manual defines the base engine components, describes the operation of those components, provides guidelines for diagnosing malfunctions and gives procedures for component replacement and in-chassis overhaul.

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:

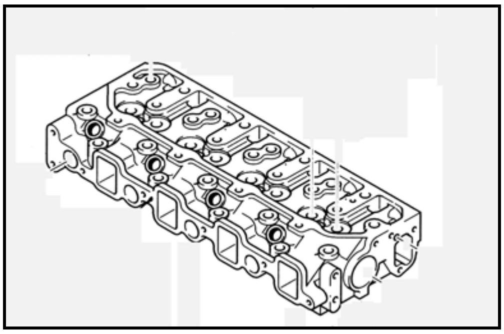
- Valve Train and Cylinder Gear Head
- Front Gear Housing and Gear Train
- Camshaft, Tappets and Push Rods
- Piston and Connecting Rod Assemblies
- Crankshaft and Main Bearings
- Cylinder Block



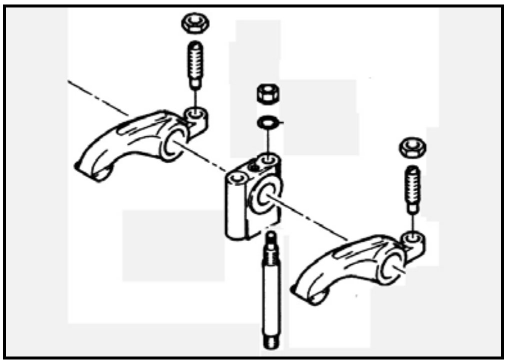
Cylinder Head and Valve Train



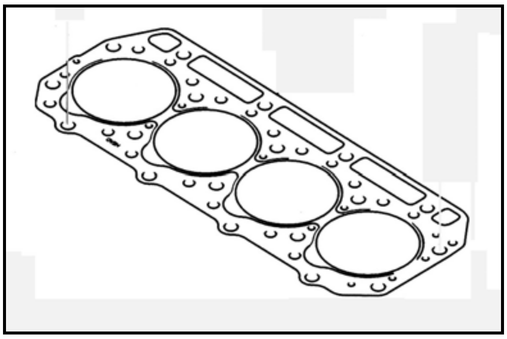
The cylinder head is a one piece, crossflow design with two valves per cylinder.
The head has integrally steel alloy valve guides and hardened valve seat surfaces which can be repaired in a machine shop using the appropriate service parts.



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.



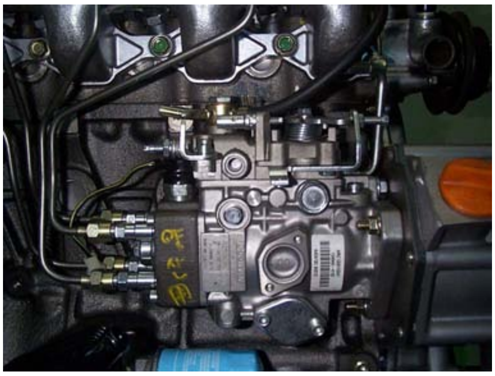
Separate pedestals for each cylinder are used to support and route oil to the rocker levers.



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

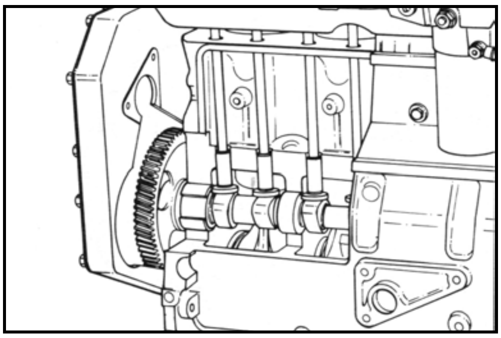
The gear train consists of the crankshaft gear, lube pump gear idler, the camshaft gear, the fuel pump gear and the accessory drive gear, if used.



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

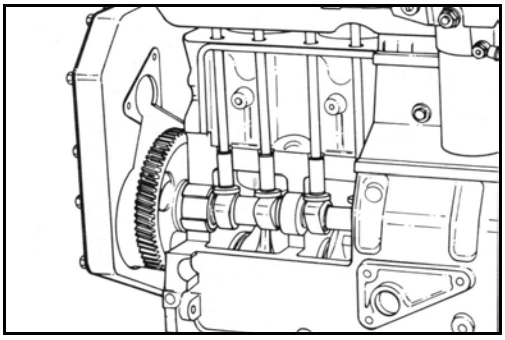
Front Crankshaft Seal

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

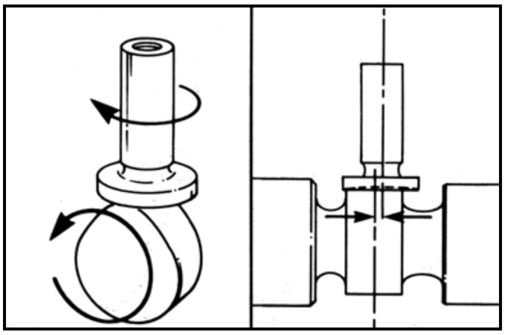


Camshaft, Tappets and Push Rods

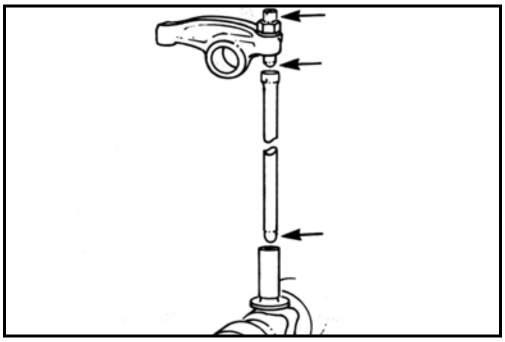
The camshaft is gear driven from the crankshaft.
A replaceable bushing is used for the front journal to carry the side loading from the accessory drive.
The remainder of the journals operate in cast iron bores in the cylinder block.



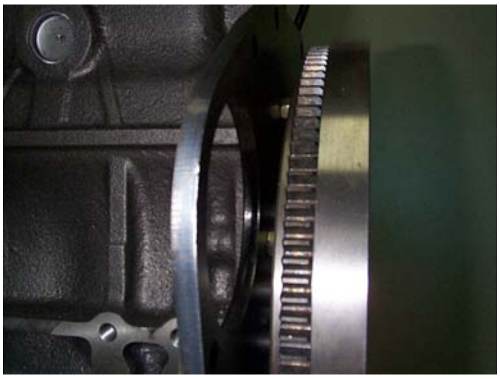
The camshaft has lobes to operate the intake and exhaust valves.
The valve lobes contact “mushroom” shaped valve tappets which operate the push rods.
The profile of the cam lobes is the same for all A series engines.



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.

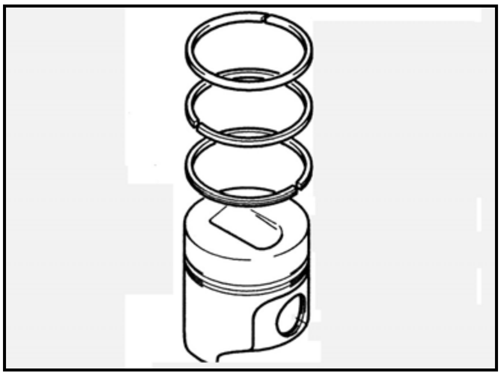


The ball end of the push rod fits into a ball socket in the tappet.
The other end of the push rod is fitted with a socket into which the ball end of the rocker lever adjusting screw operates.



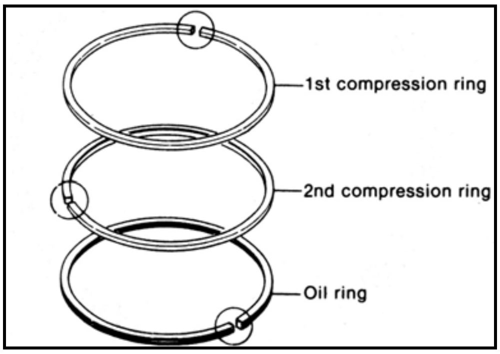
Flywheel Housing and Flywheel

Several Optional flywheel housing and flywheels are used depending on the application.

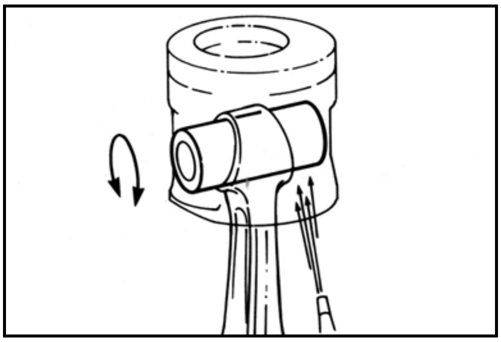


Piston and Rod Assemblies

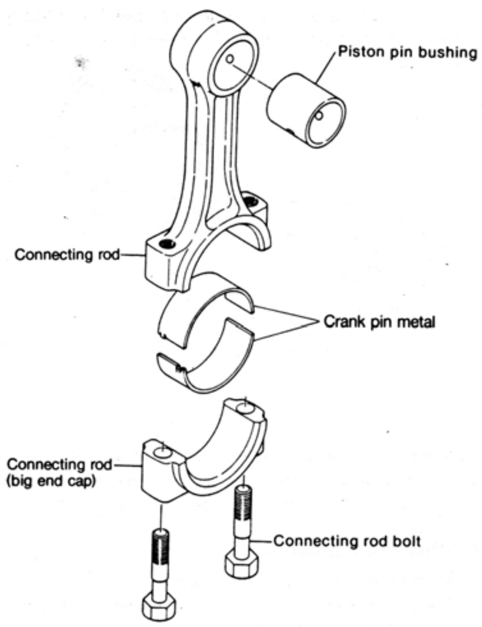
Piston features include : high swirl combustion bowl cast aluminum body and 3 ring grooves.
Always check the part number to be sure the correct configuration is used during piston replacement.



The piston ring sets are also different. While both sets consist of three rings; two compression rings and one oil ring.

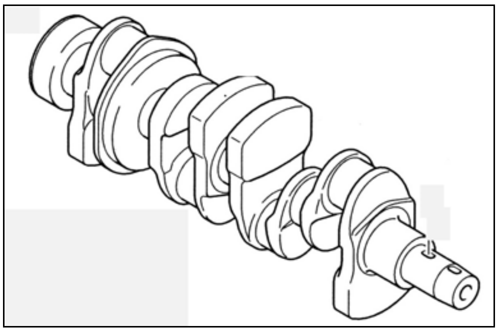


A free floating, hollow piston pin is used to attach the piston to the connecting rod.
Lubrication of the pin and journal is accomplished by residual spray from piston cooling.



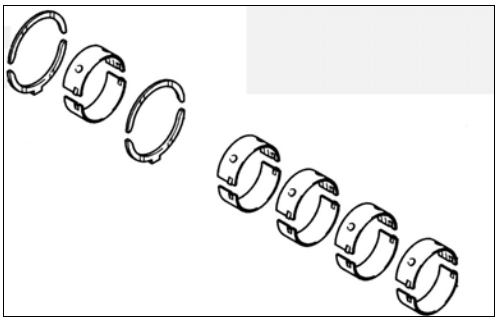
The connecting rod is made of high-strength gorged carbon-steel.
The large end with the special aluminum-ally metal can be separated into two and the small end has a copper alloy coil bushing.

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 a main bearing.
The lower bearing shells are all the same.
All of the upper bearing shells are all the same.
The two thrust bearings control the end thrust of the crankshaft.

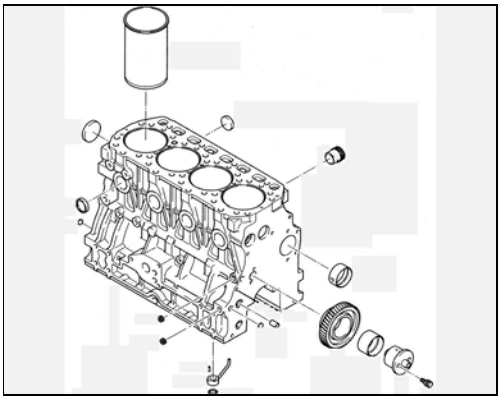


The upper bearings have two holes in them. The one side hole receives oil from the main oil rifle.
One of the adjacent holes is aligned with drilling to the camshaft journal and serves as an orifice for lubrication flow to the journal and is used for piston cooling.
The hole does not align perfectly 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

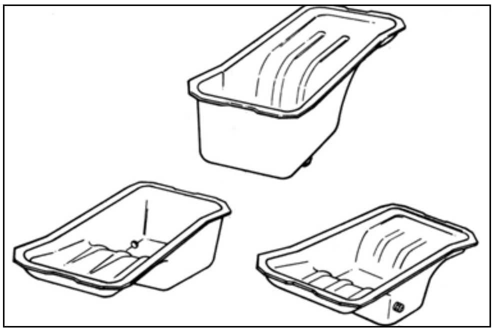
We have discussed the cylinder block relative to cooling and lubrication in those respective systems. We have also discussed the interfaces of some of the above power functions with the block. This discussion will cover the remaining interfaces including the cylinder bores.



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.

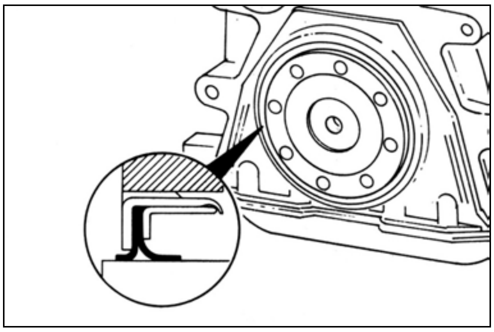
Cylinder liner can be replaced into cylinder block. Both cylinder and liner have size mark on.
The block and liner marks are identified as follows:

	Mark
Cylinder block	L M S
Cylinder Liner	L M S



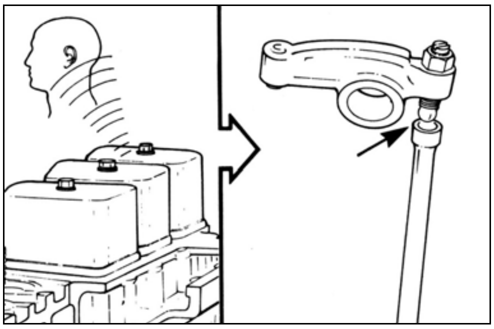
Oil Pan

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

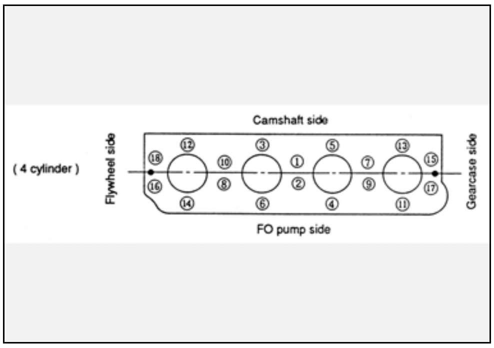
The rear crankshaft seal is mounted in a housing that bolts to the rear of the block.
Double lipped Telflon seals are used. The sealing surface on the crankshaft must be cleaned and free of oil during installation of the seal.



Diagnosing Base Engine Component Malfunctions

Valve Train and Head Assembly

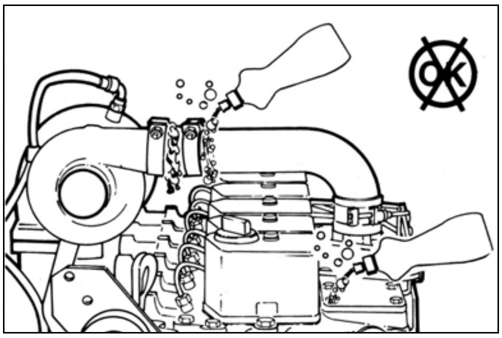
The sound emitted from the overhead can indicate a valve train problem. Loose rocker levers will chatter. A squeaking noise can mean lack of lubrication for adjusting screw and the push rod socket.



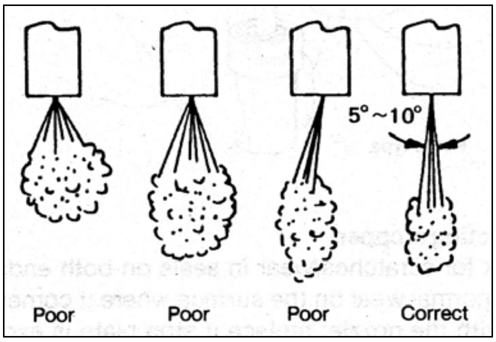
Caution : If the end of the individual support pedestals is removed during inspection or repair, all head bolts must be retightened according to the head bolt torque sequence.

Air and Fuel System – Check

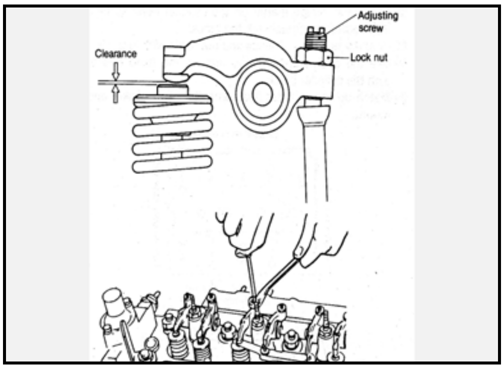
When diagnosing a low power problem first troubleshoot the air and fuel systems to make sure the engine is receiving adequate intake air and fuel.



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

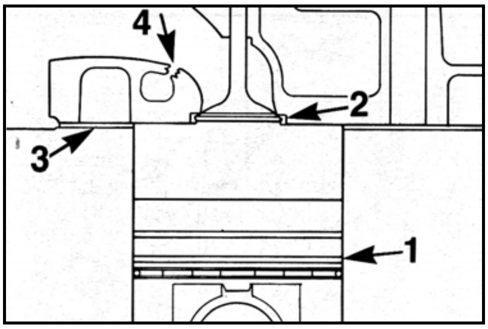


Check the fuel system for correct timing and fuel delivery.



Valve Adjustment – Check

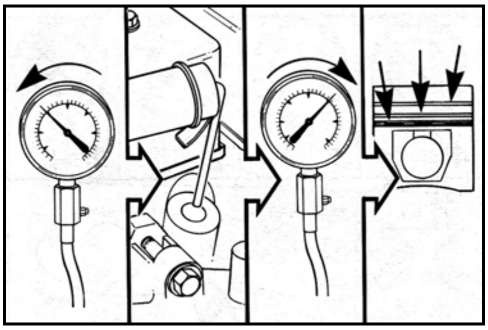
Verify that the valves are adjusted correctly.



Compression Check

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

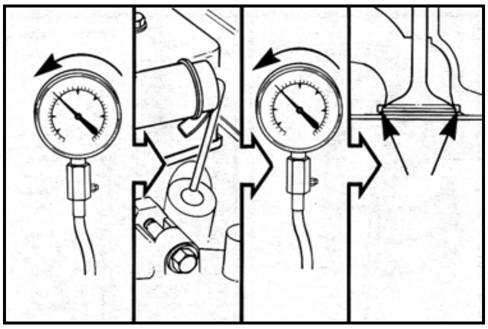
- Piston ring sealing
- Valve sealing
- Head gasket sealing or a crack in the cylinder head



Piston Ring Seal

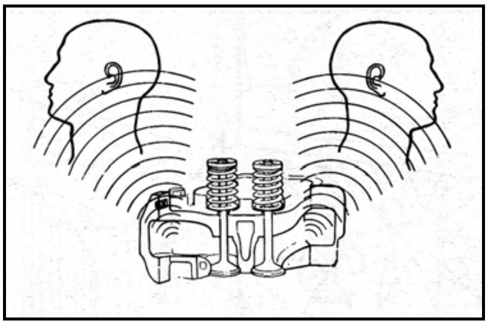
If the compression is low but can be increased significantly by squirting oil into the cylinder, the cause of low compression is inadequate sealing between the rings and the cylinder walls.

Normal compression is 3430 kPa [497 PSI] at 250 RPM cranking speed. A 26 kPa [383 PSI] difference between cylinders indicates a compression seal problem.

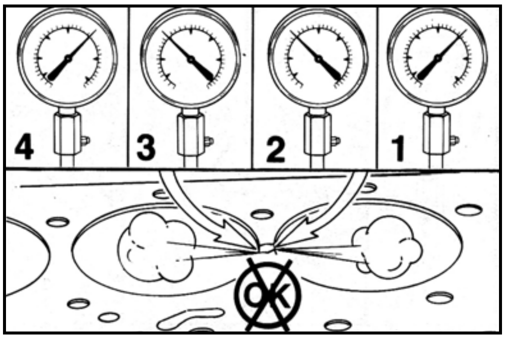


Valve Sealing

If the compression is low on one or more non-adjacent cylinders and the pressure cannot be increased by oiling the rings, poor valve sealing is to be suspected.

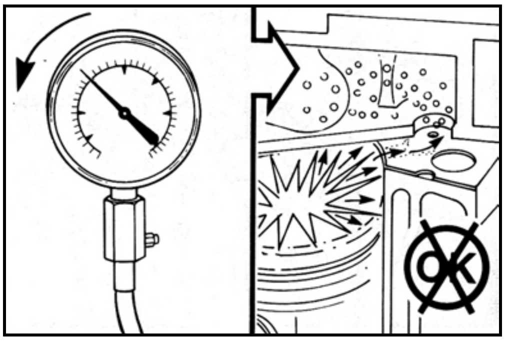


Valve leakage is often audible from the intake and exhaust manifold.

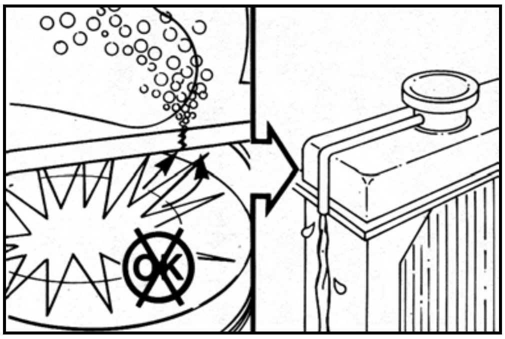


Head Gasket Sealing

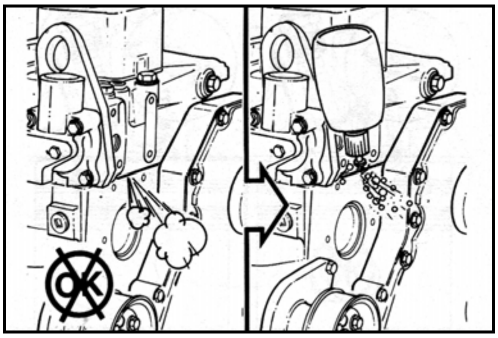
If the compression was found low on adjacent cylinders and the pressure cannot be increased by oiling the rings, the head gasket is probably leaking between the cylinders.



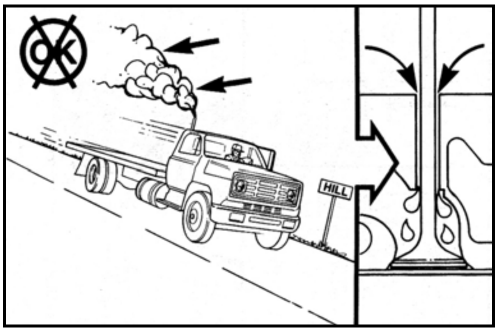
Low compression on a single cylinder can be caused by an external leak or a leak to a coolant passage.



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

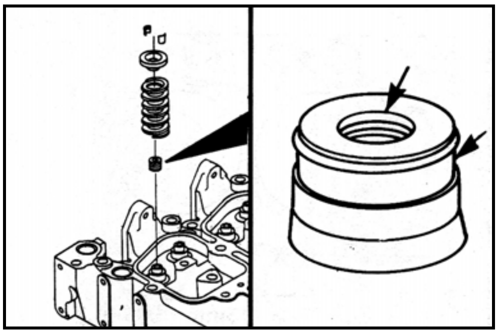


External head gasket leaks can be detected visually. Liquid soap can be used to locate external leaks.

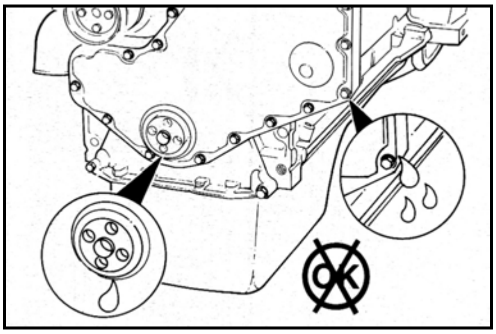


Valve Seal – Wear

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.

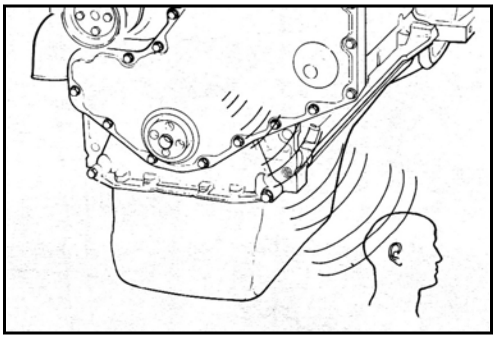


Hardening of the material and wear or damage to the sealing surface will cause the seal to leak (refer to page 219 for replacement instructions).



Front Gear Housing and Gear Train

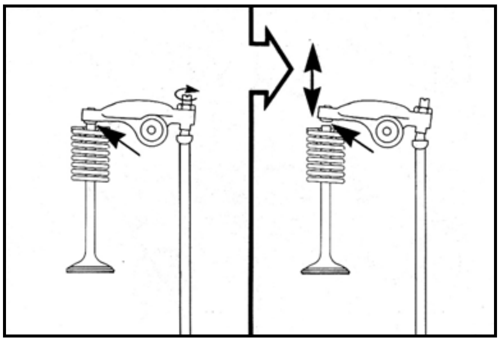
Troubleshooting the front gear housing and gear train consists of checking for leaks at the gaskets (front cover, and injection pump) and the front crankshaft oil seal, inspecting the gears and measuring backlash when required.



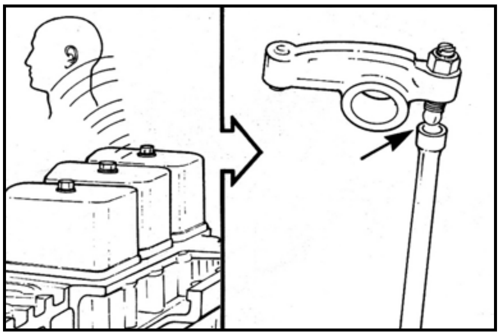
Gear noise emitted from the cover can indicate worn gear teeth.

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

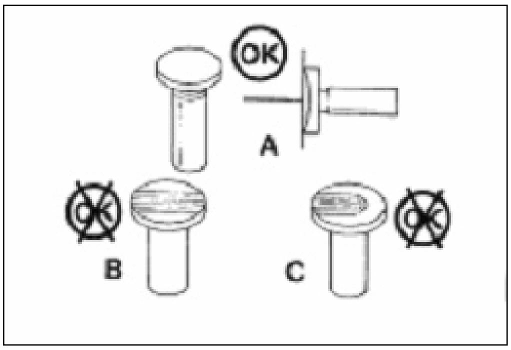
Rocker Lever, Valve Stem, Push Rod, Tappet, and Camshaft



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

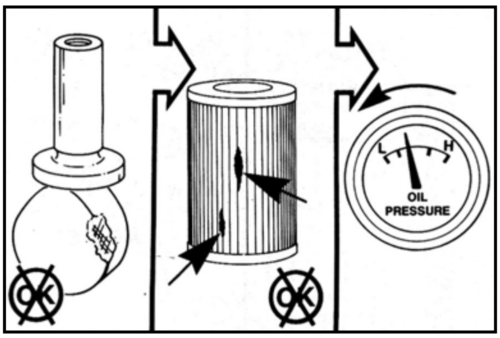


Loose rocker levers and the need to re-set the valve clearance frequently, can also indicate cam lobe or tappet wear. If an inspection of the levers, valve stems and push rods does not show wear, then tappet and/or cam lobe wear can be suspected.

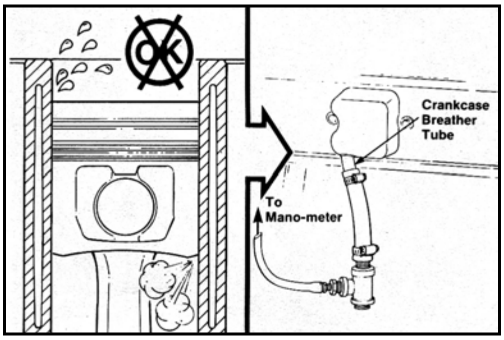


Caution : Anytime a new camshaft is installed, new tappets must also be installed.

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.

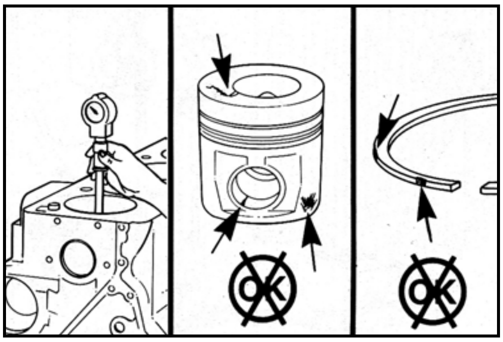


A several damaged camshaft journal (s) can generate metal chips which will be found in the pan and filter. As the clearance in the journal (s) increases, a small decrease in oil pressure may be detected.

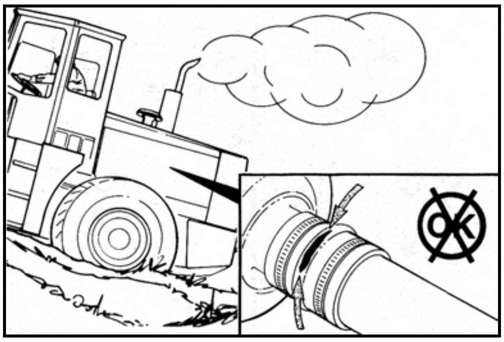


Piston and Rod Assembly

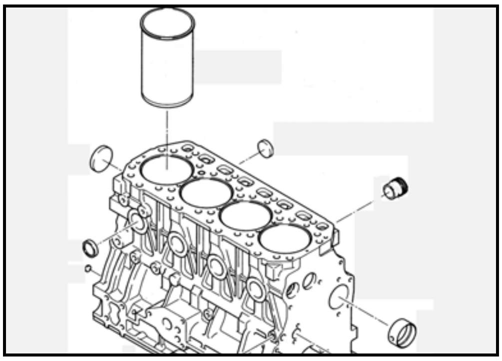
There are a number of power relate problems including excessive oil consumption, smoke, blow-by and poor performance that can be caused by inadequate sealing between the piston rings and the cylinder walls.
A blow-by measurement can help detect the problem.



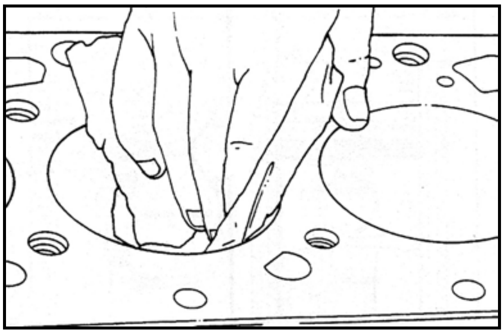
Verification of the damaged or worn component requires visual/dimensional inspection of rings, pistons and cylinder bore.



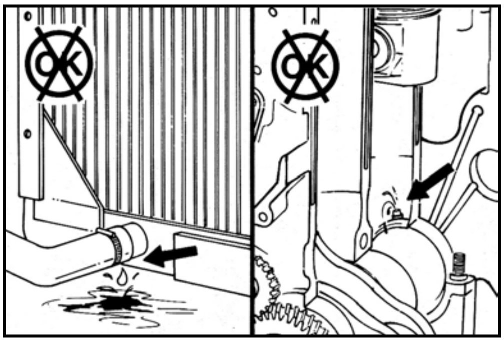
The cause of piston ring wear can range from wear over a long period of service to a dust-out in a short period of time because of poor maintenance of the air intake system.
Refer to Section 5 for troubleshooting the Air System.



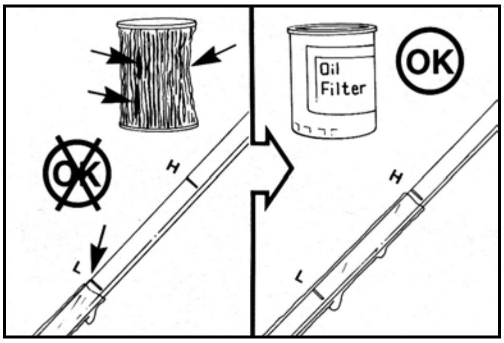
During repair it is essential that the cylinder wall be deglazed so that new rings will seat against the cylinder wall.
The marks on cylinder block and cylinder liner must be matched.
The different marks are matched, excessive blow by gas and excessive oil consumption occur.



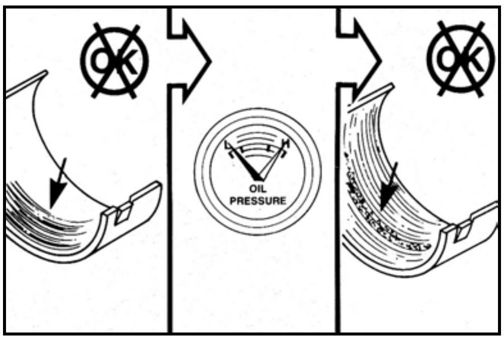
However, it is also critical that the cylinder liner walls be thoroughly cleaned.
Grit left in the cylinder wall will cause rapid wear out of the new rings leading to the previously discussed power problems.



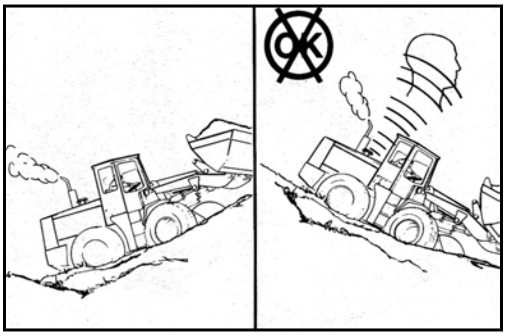
Overheating of the engine from a loss of coolant will cause the cylinder to overheat resulting in seizure of the piston.
Loss of piston cooling can also lead to piston seizure.



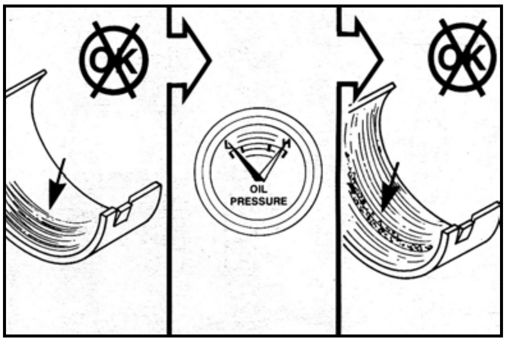
Improper maintenance of the lubrication system is the primary cause of reduced main bearing life.



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.

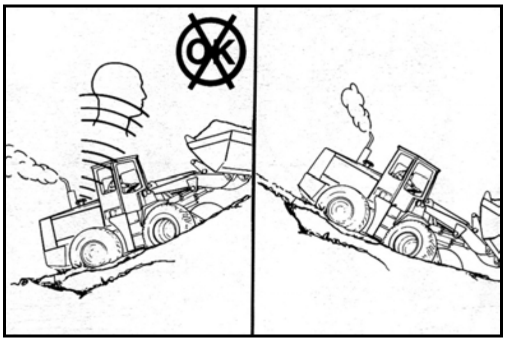


A rod knock occurs when the engine is not loaded. Verify by first applying load and then unloading and listening for the knock.

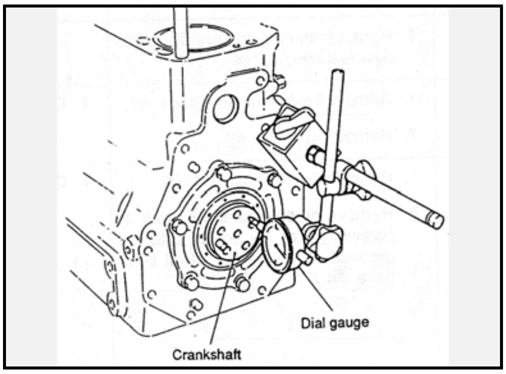


Crankshaft and Main Bearings

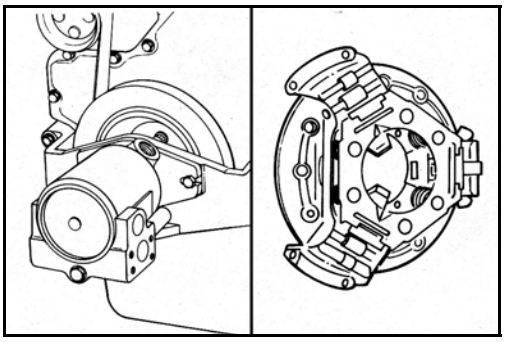
Improper maintenance of the lubrication system is also the primary cause of reduced main bearing life.
A malfunction of the crankshaft/main bearing will usually be detected by reduced oil pressure. As with rod bearings, continued operation with low oil pressure will lead to a rapid deterioration of the bearings and eventually will produce a knocking sound.



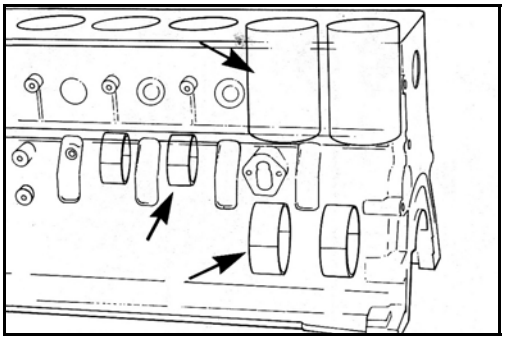
A main bearing will be heard when the engine is loaded.



A damaged or worn thrust bearing flange of the upper main bearing shell can be detected by measuring the end play of the crankshaft .



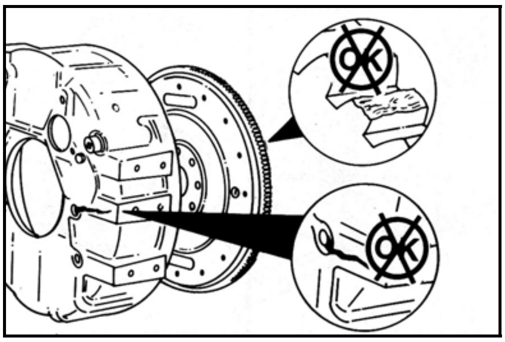
Failure of driven units at the front or rear of the engine which increase the end loading can damage the thrust bearing.



Cylinder Block

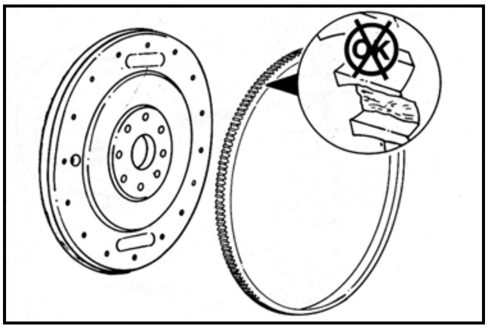
Diagnosis of cylinder block malfunctions relative to cooling and lubrication has been discussed in those respective systems.
The potential problems with cylinder, the camshaft bore and the crankshaft main journals have also been discussed in this Section.

Malfunctions of the block such as leaks.
Require a visual or dimensional inspection to isolate the problem.

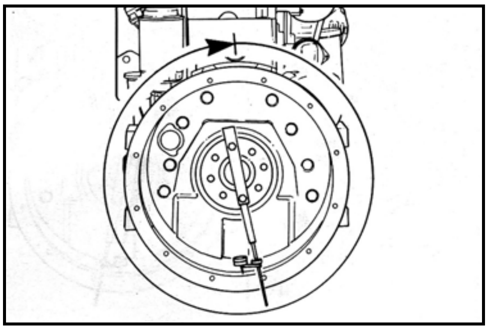


Flywheel Housing and Flywheel

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



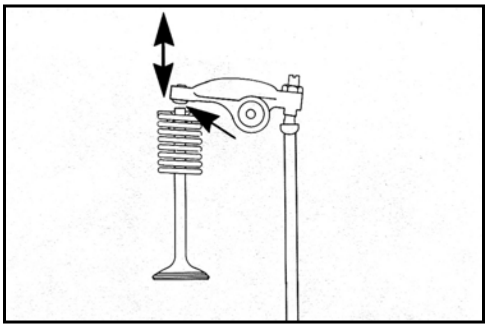
Occasional failure of a starter to engage can be caused by damaged teeth on the ring gear.
Service ring gears are available for repairing flywheels.



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

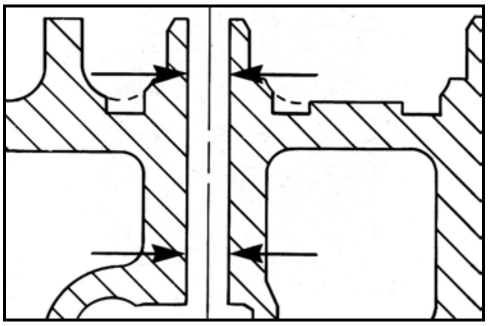
Note : The following procedure is for use with an indicator whose needle rotates clockwise as the top is depressed.

Base Engine Components Specifications

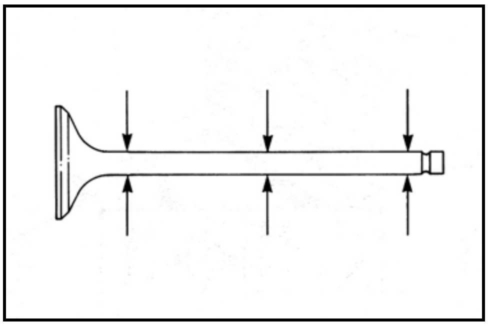


Valve Train

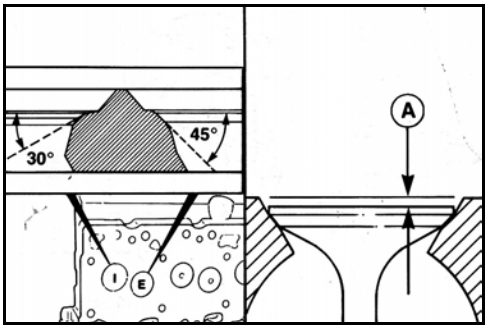
Valve Clearance
- - Intake 0.3mm [0.012 in]
- - Exhaust 0.3mm [0.012 in]



- Valve Guide Diameter
  8.025 mm [0.316 in] MAX
  8.010 mm [0.3153 in] MIN

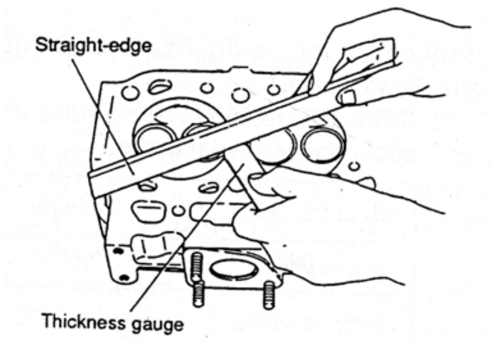


- Valve Stem Diameter
  7.97 mm [0.3138 in] MAX
  7.96 mm [0.3134 in] MIN

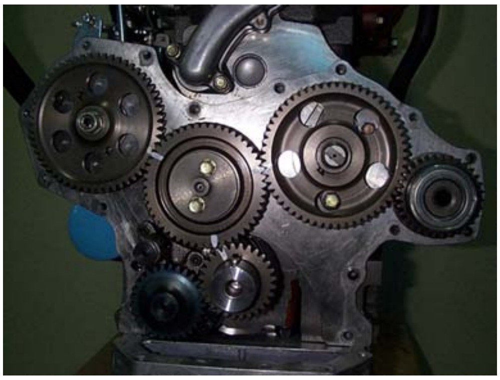


- Valve Seat Angle
  Intake 30 degrees
  Exhaust 45 degrees

- Valve Depth (Installed)
  0.6 to 0.8 mm [0.0236 to 0.0315 in]
  Wear Limit: 1.0 mm [0.0394 in]

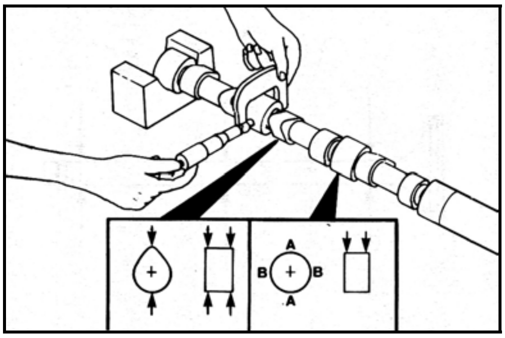


- Cylinder Head Flatness
  Total
  Maximum Overall
  0.15 mm [0.006 in]



Gear Train

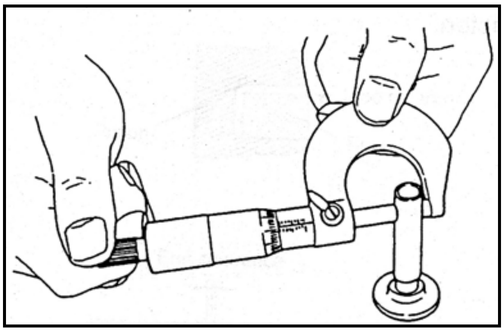
- Gear Backlash
  Crankshaft, Injection pump drive, camshaft:
  0.07 to 0.15mm [0,0027 to 0.006 in]
  Oil pump:
  0.11 to 0.119mm [0,0043 to 0.0075 in]



Camshaft

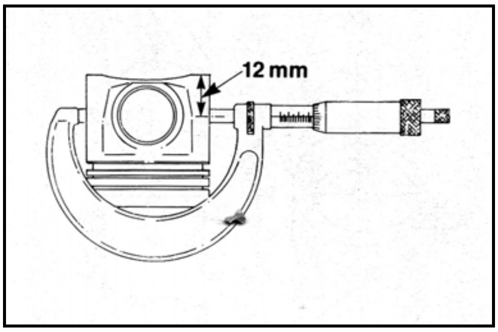
- Journal Diameter
  44.964 to 44.95 mm [1.7702 to 1.7697 in]
  Worn Limit: 44.89 mm [1.767 in]

- Valve Lobes
  Standard: 37. 935 to 38.065 mm
  [1.4935 to 1.4986 in]
  Worn Limit: 37.83 mm [1.4893 in]



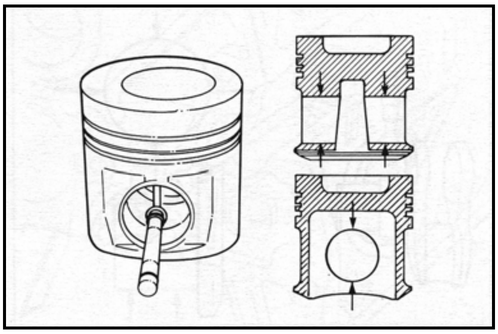
Tappets

- Stem Diameter
  Standard: 14.238 to 14.210 mm
  [0.5606 to 0.5598 in]
  Worn Limit: 14.18 mm [0.5583 in]



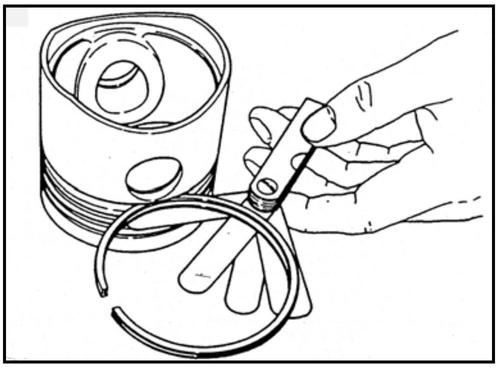
Pistons

- Skirt Diameter (Minimum)
  Nominal
  87.95 to 87.97 mm
  [3.463 to 3.4634 in]
  Worn Limit
  87.90 mm [3.46 in]

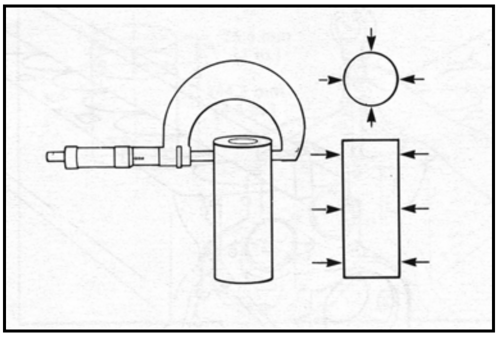


- Pin Bore Diameter (Maximum)
  30.008 mm [1.181 in]
  Worn Limit: 30.02 mm [1.1819 in]

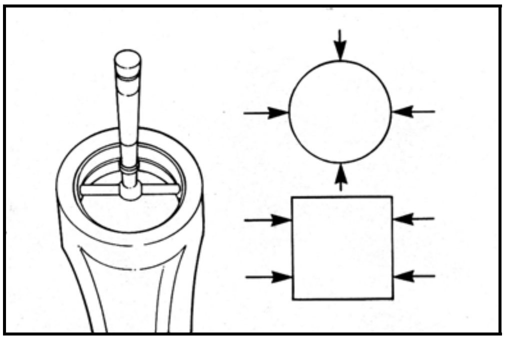
Note : Measure the diameter on a vertical axis only.



- Ring Groove (Minimum)
  Top Groove
  2.006 mm [0.079 in]
  Oil Control Groove
  3.002 mm [0.118 in]

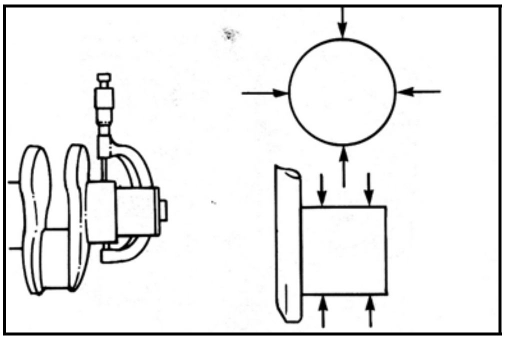


- Piston Pin Diameter (Minimum)
  30 mm [1.181 in]
  Worn Limit: 29.9 mm [1.177 in]



Connecting Rod

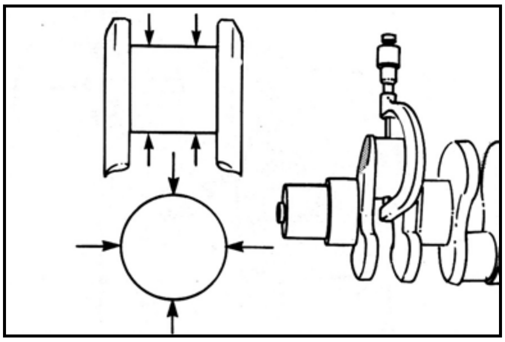
- Pin Bore Diameter
  MAX: 30.038 mm [1.1823 in]
  Worn Limit: 30.1 mm [1.185 in]

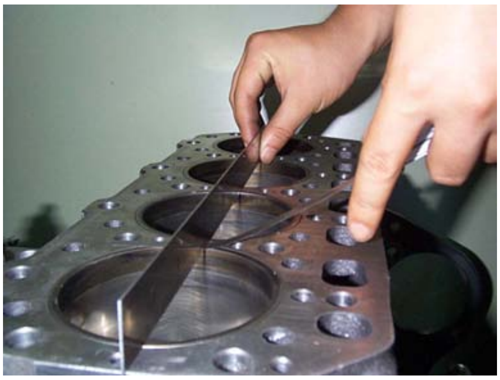


Crankshaft

- Main Bearing Journal Diameter
  Standard: 53.964 to 53.95 mm
  [2.2146 to 2.1240 in]
  Worn Limit: 53.91 mm [2.122 in]

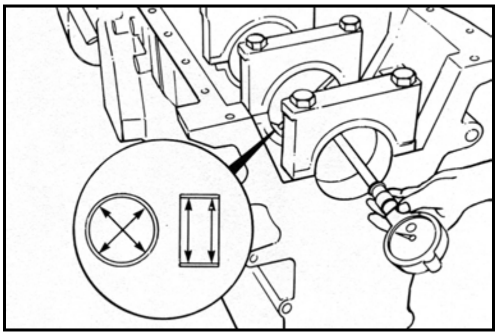
- Connecting Rod Journal
  Standard: 49.964 to 49.95 mm
  [1.967 to 1.966 in]
  Worn Limit: 49.91 mm [1.965 in]



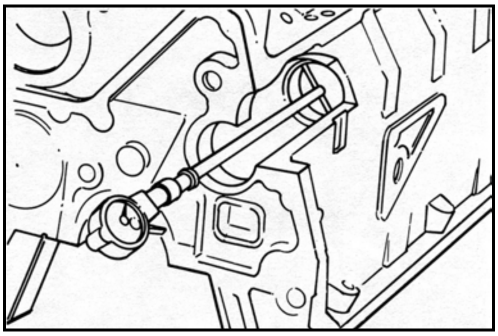


Cylinder Block

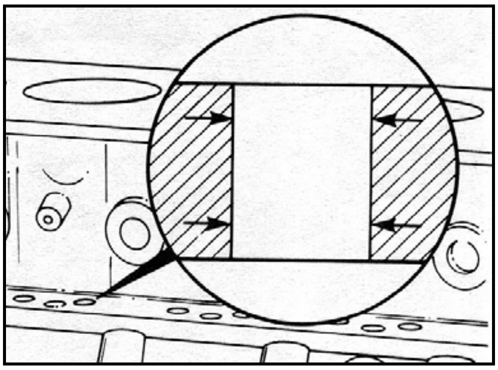
- Top Surface Flatness
  (Maximum Overall Variation
  Standard: 0.03 mm [0.00118 in]
  Worn Limit: 0.15 mm [0.0059 in]



- Main Bearing Bore Diameter
  Standard: 50.0 to 50.045 mm
  [1.9685 to 1.97 in]



- Camshaft Bore Diameter (Maximum)
  Standard: 45.03 to 45.06 mm
  [1.773 to 1.774 in]



- Tappet Bore Diameter
  Standard: 14.26 to 14.28 mm
  [0.561 to 0.562 in]

Cylinder Bore

- Cylinder Bore Diameter
  Standard: 88.0 to 88.02 mm
  [3.464 to 3.465 in]

- Out of Round
  0.34mm [0.0012 in]

Base Engine Components Replacement Procedures

Rocker Lever and Push Rods – Replacement

Preparatory Step:
17mm

- Remove the valve covers.

Removal
12mm
Loosen the adjusting screw locknuts. Loosen the adjusting screws until they stop.

19mm
Remove the 19mm nuts from the rocker lever pedestals. Remove the pedestals. Remove the pedestals and rocker lever assemblies.

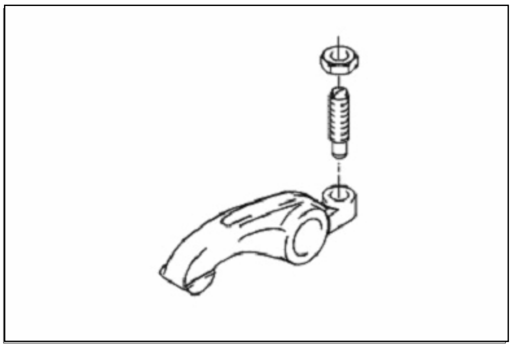
Remove the push rods.

Rocker Levers – Disassembly

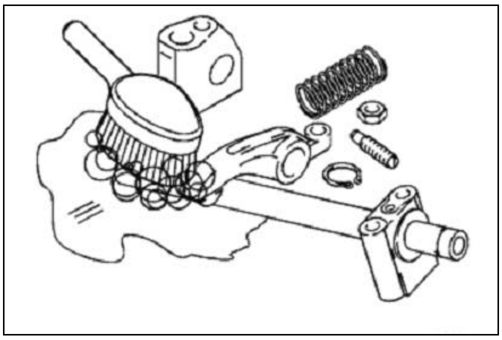
If the rocker lever and push rods are to be inspected for reuse, follow these steps.
Remove the retaining rings and thrust washers.

Remove the rocker levers.

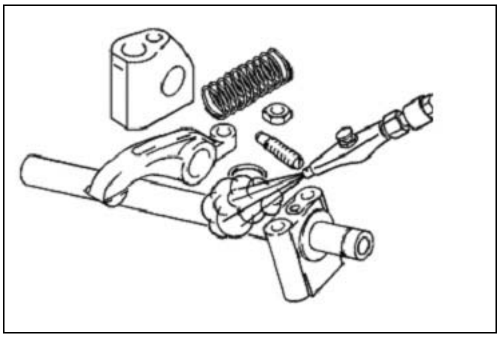
Caution : Do not disassemble the rocker lever shaft and pedestal. The pedestal and shaft must be replaced as an assembly.



Remove the lock nut and adjusting screw.

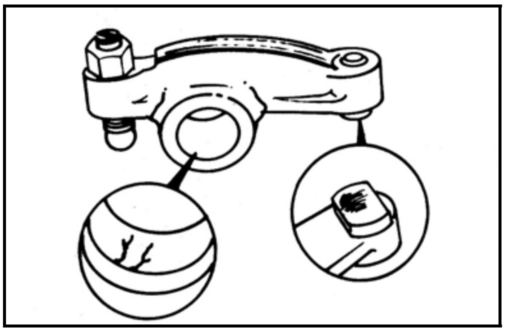


Clean all parts in a strong solution of laundry detergent in hot water.

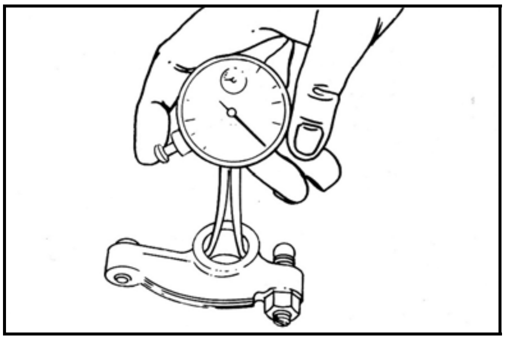


Use compressed air to dry the parts after rinsing in clean hot water.

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.

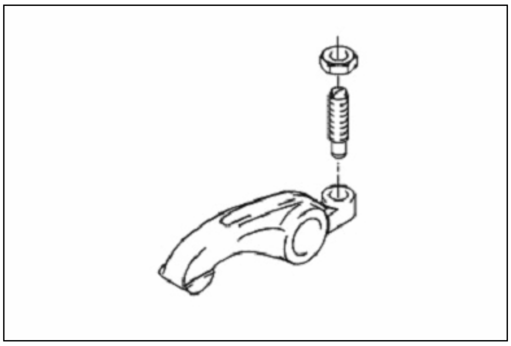
Standard: 19.0 to 19.021 mm [0.748 to 0.749 in]

Worn Limit: 19.09 mm [0.751 in]

Inspect the pedestal and shaft.
Measure the shaft diameter.

Standard: 19.0 to 19.021 mm [0.748 to 0.749 in]

Worn Limit: 19.09 mm [0.751 in]



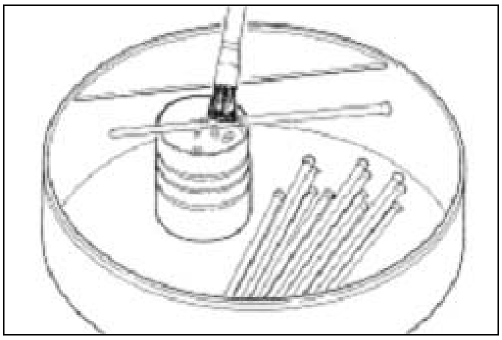
Rocker Levers – Assembly

Install the adjusting screw and lock nut.

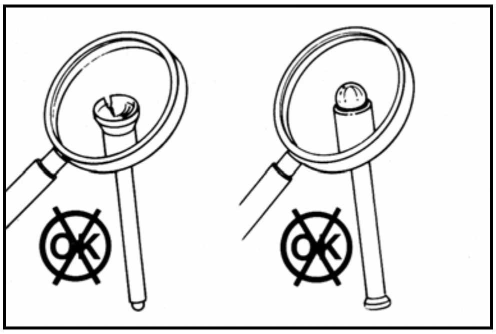
Lubricate the shaft with engine oil.

Position the levers on the rocker shaft.

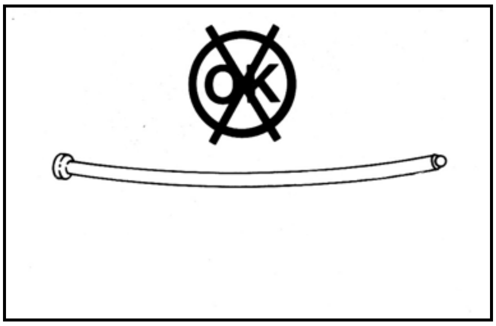
Install the snap rings.



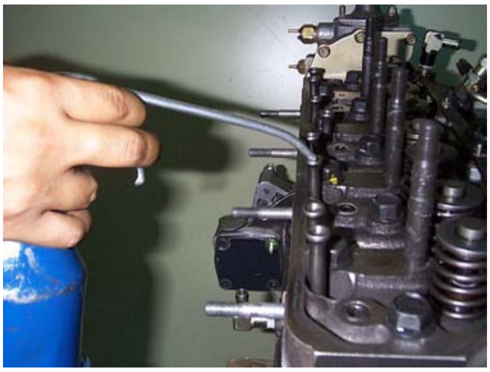
Clean the push rods in hot soapy water.



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 clean engine oil.

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

Rocker Lever Assembly – Installation

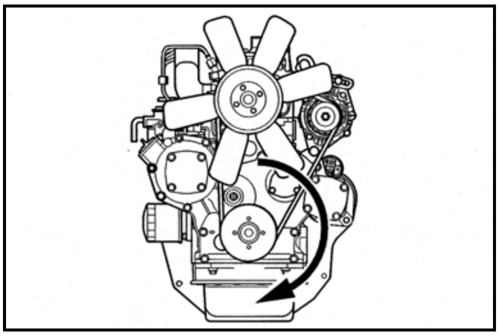
Use clean engine oil to lubricate the threads and under the heads of the 19mm nuts.
Install the nuts into the pedestals.

Valve Clearance – Adjustment

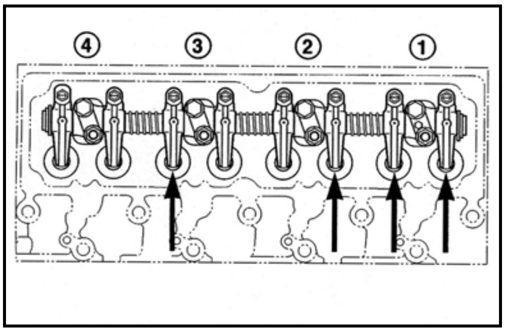
Caution : Adjust the valves when the engine is cold – below 60℃ [140°F].

Four-Cylinder Engine

Step A
12mm
Adjust the clearance for the valves shown in the illustration.
Clearance: 0.3 mm [0.012 in]
Tighten the locknut and check the clearance.

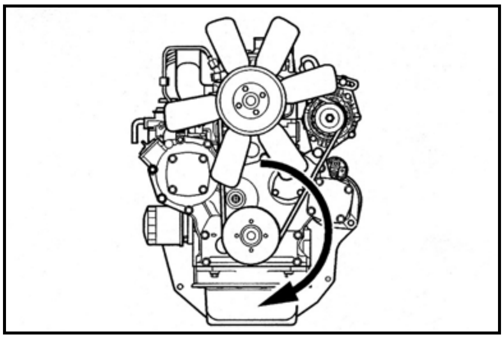


Note : Adjust intake and exhaust clearances in the following firing order by rotating the crankshaft 180 degrees in the normal direction:
(1->2->3->4)



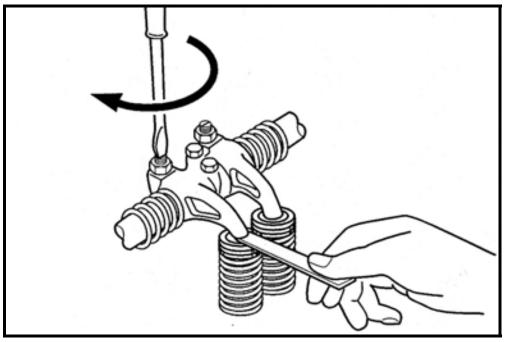
Adjust the valve clearances for intake valves No. 1 and No. 2.

Adjust the valve clearances for exhaust valves No. 1 and No. 3.



Rotate the crankshaft in the normal direction one revolution.
Adjust the valve clearances for intake valves No. 3 and No. 4.

Adjust the valve clearances for exhaust valves No. 2 and No. 4.



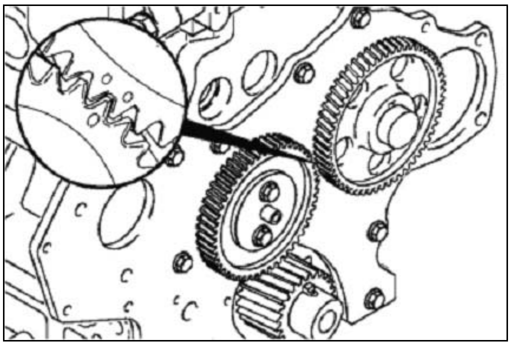
Tighten the locknut to secure the adjustment screw.

Locknut Torque Value		
N.m		Ft-lb
23	MIN	17
29	MAX	21

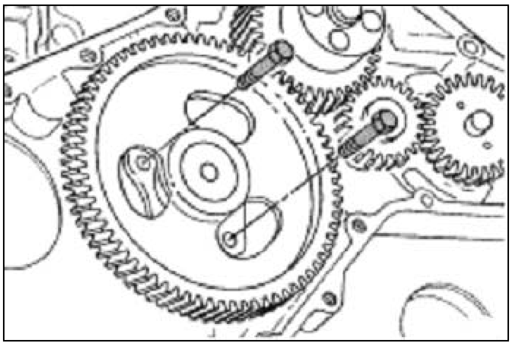
Camshaft and Tappet – Replacement

Preparatory Steps:

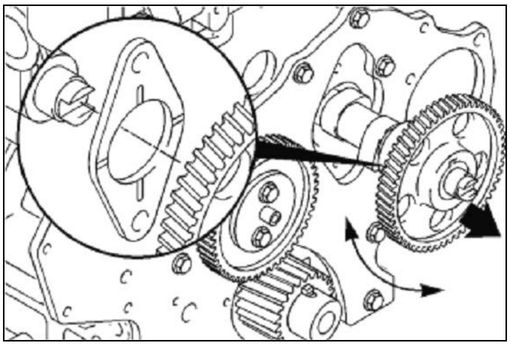
- Remove the valve covers
- Remove the push rods
- Remove the drive belt
- Remove the crankshaft pulley
- Remove the gear cover
- Remove the oil pan
- Remove the oil pan flange



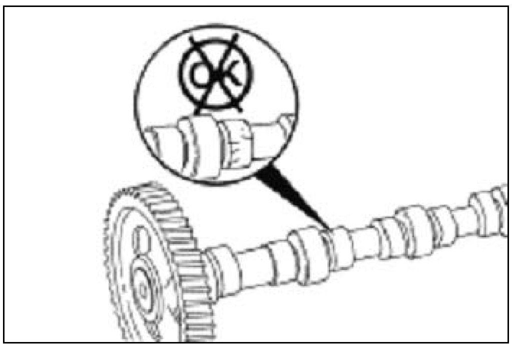
Rotate the engine to align the crankshaft to camshaft timing marks.



12mm
Remove the capscrews from the thrust plate.

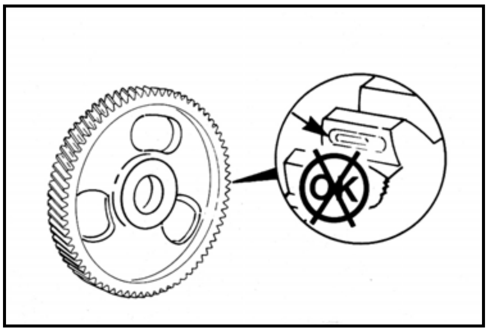


Remove the camshaft and thrust plate.

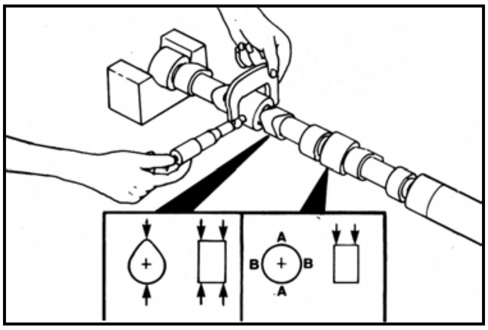


Camshaft Inspection

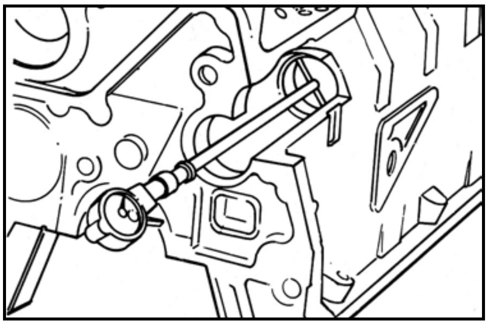
Inspect the lift pump lobe, valve lobes and bearing journals for wear, cracking, pitting and other damage.



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



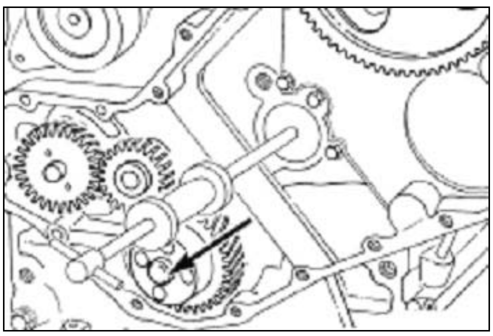
Measure the bearing journals and valve lobes.
Journal Diameter:
Standard: 44.964 to 44.95 mm [1.7702 to 1.7697 in]
Worn Limit: 44.89 mm [1.767 in]



Camshaft Bushing Inspection

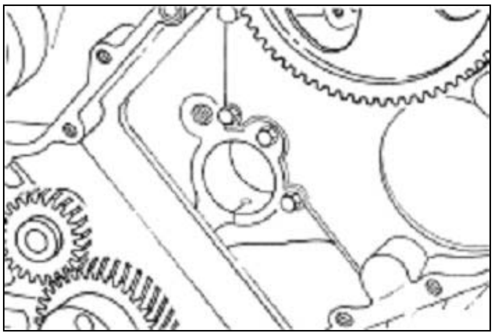
Caution : If the bushing is worn beyond the limit, install a new service bushing.

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.
Standard: 37.935 to 38.065 mm [1.4935 to 1.4986 in]
Worn Limit: 37.83 mm [1.4893 in]



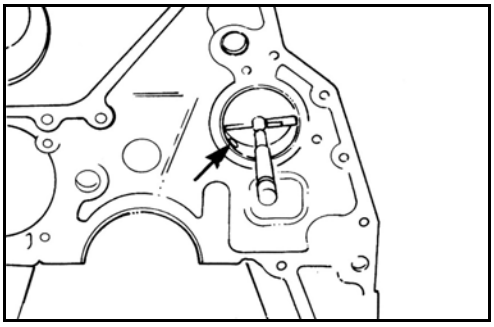
Note : If the bores without a bushing are worn beyond the limit, the engine must be removed for machining and installation of service bushings or replacement of the cylinder block.

Remove the bushing from the Number 1 bore.

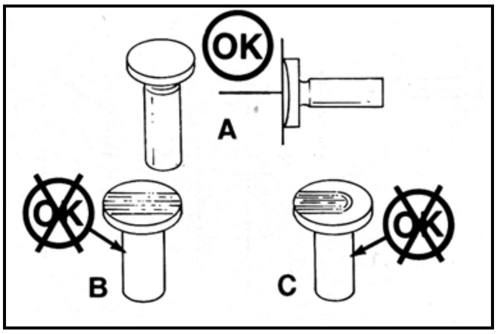


Note : Mark the cylinder block so you can align the oil hole in the cylinder block with the oil hole in the bushing.

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



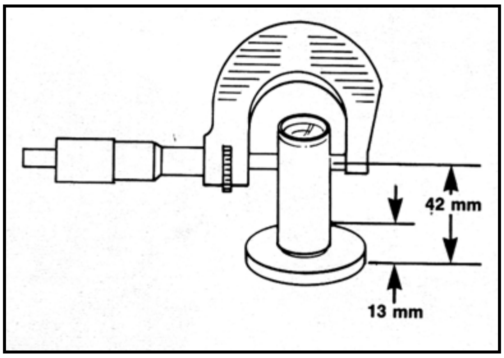
Measure the installed bushing.
Inside Diameter:
Standard: 45.03 to 45.06 mm [1.773 to 1.774 in]



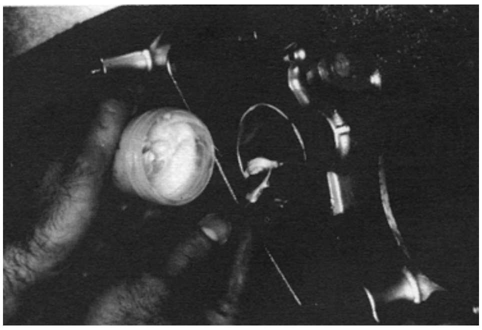
Tappet Inspection

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

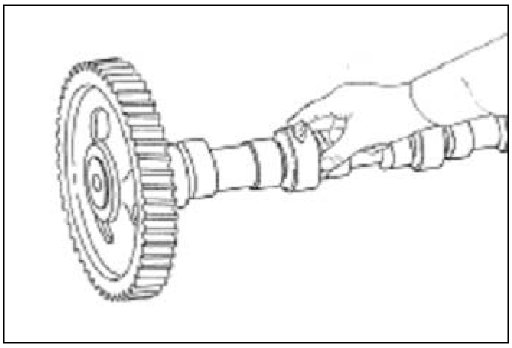
Limit	
(A)	- Normal wear
(B) and (C)	- Abnormal wear – Do not reuse



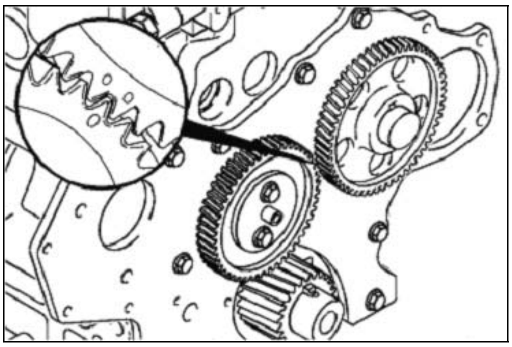
Tappet stem specifications
Inside Diameter:
Standard: 1.4228 to 14.243 mm [0.5601 to 0.5607 in]



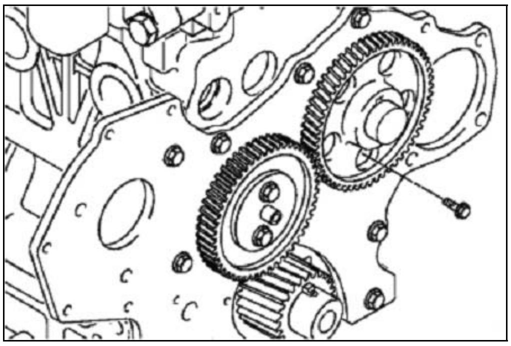
Camshaft Installation
Apply a coat of Lubriplate 105 to the camshaft bores.



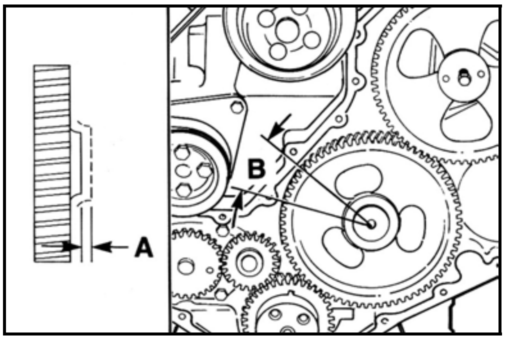
Lubricate the camshaft lobes, journals and thrust washer with Lubriplate 105.



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

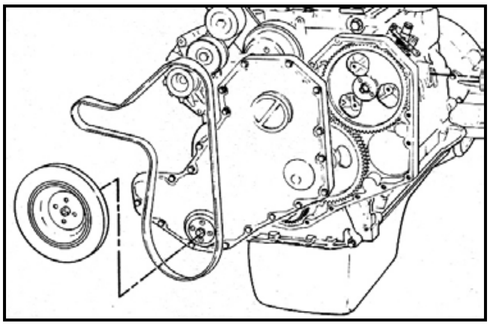


Install the thrust washer capscrews and tighten to 25.5Nm [19 ft-lbs].



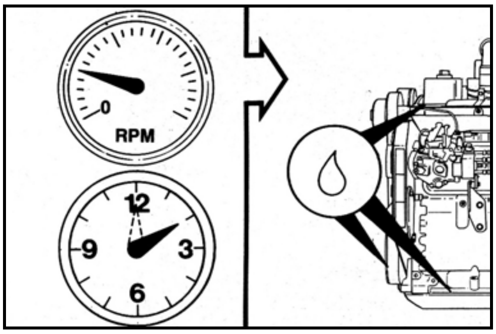
Verify the camshaft has proper back lash and end play.

A = 0.07 to 0.15 mm [0.0027 to 0.0059 in]
B = 0.05 to 0.25 mm [0.002 to 0.0098 inch]



Complete the installation of the removed parts.

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

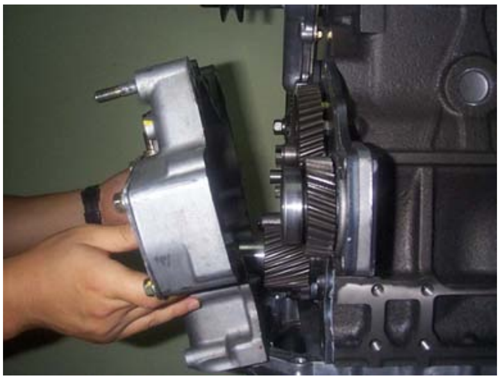


Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.

Gear Housing or Gasket – Replacement

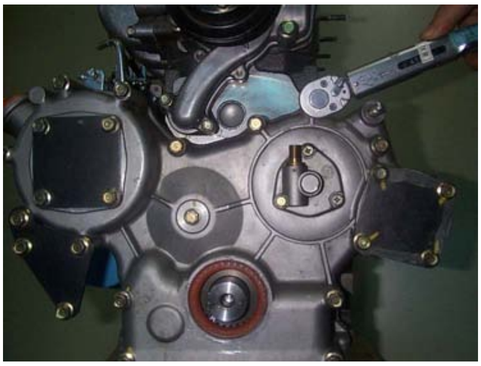
Preparatory Step:

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



12mm
Remove the gear housing and gasket.

Clean the gasket material from the cylinder block.



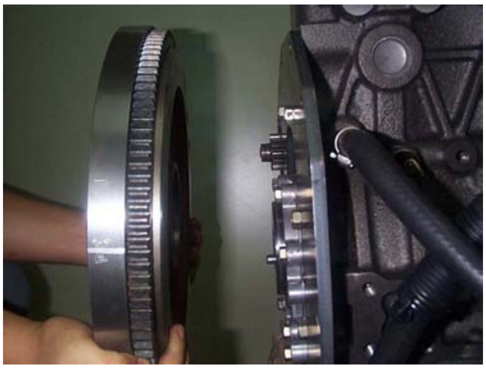
12mm
Caution : If a new housing or other than the original housing is installed, the timing pin assembly must be accurately located.

Install a new gasket and gear housing.
Torque Value: 25.5Nm [19 ft-lbs]

Flywheel Ring Gear and Rear Seal – Replacement

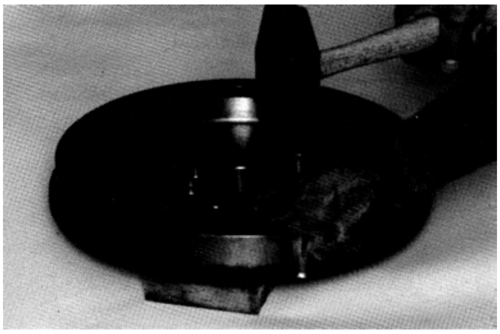
Preparatory Step:

- Remove the transmission



Ring Gear – Replacement

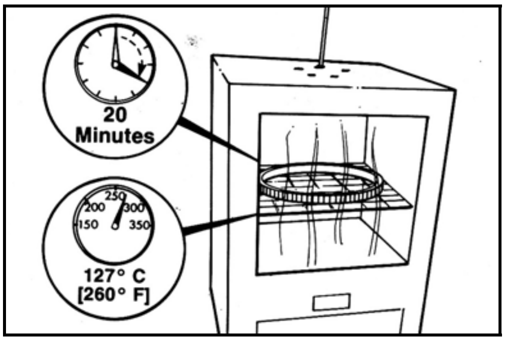
19mm
Remove the Flywheel.



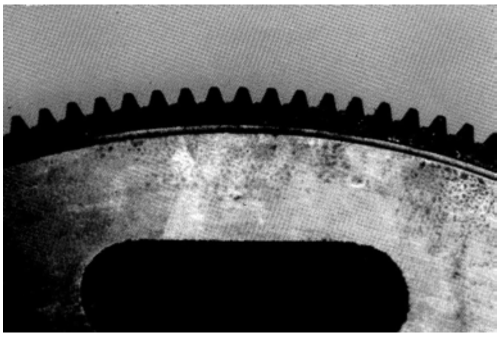
Brass Drift Pin

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℃ [260°F].



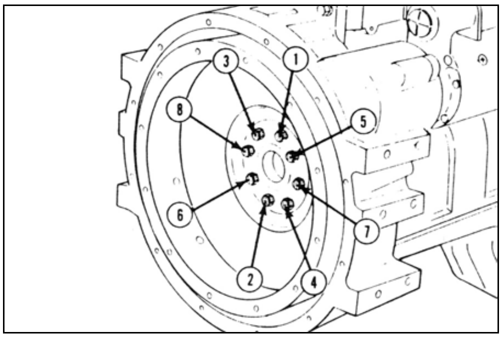
Warning : Wear protective glove when you install the heated gear.

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

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.



17mm Socket, Torque Wrench

Tighten the capscrews in the sequence shown.
Torque Value: 85Nm [64 ft-lbs]

In-Chassis Overhaul

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

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

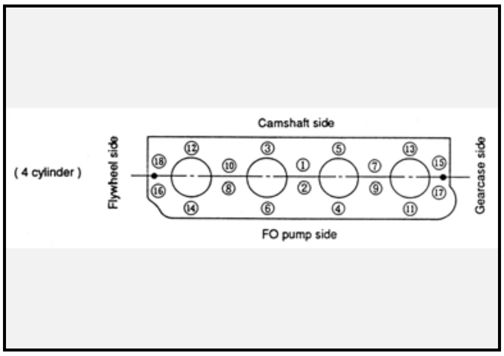
This manual gives the procedures to replace the piston rings, rod bearing, main bearings and grinding the valves. The procedure to test the injectors and rebuild the turbocharger are given in the Shop Manual, Bulletin Number 3810206. Refer to pages 5-3 through 5-9 for inspecting the turbocharger. Segments 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 is 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 sea, 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

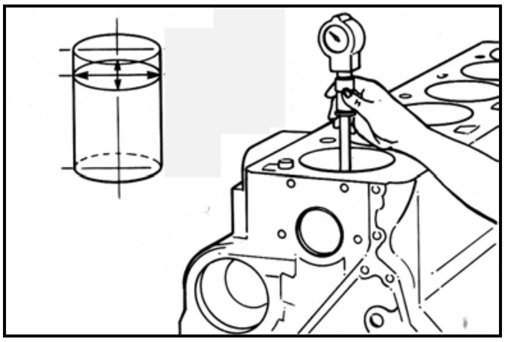
- Drain the coolant and oil
- Disconnect the radiator and heater hoses
- Remove the turbocharger and air crossover, if the engine is so equipped
- Remove the exhaust manifold
- Remove the fuel lines and injector nozzles
- Remove the valve covers
- Remove the rocker levers and push rods
- Remove the fuel filter



17 mm
Remove the cylinder head bolts in the sequence shown.

Remove the cylinder head and gasket from the cylinder 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.



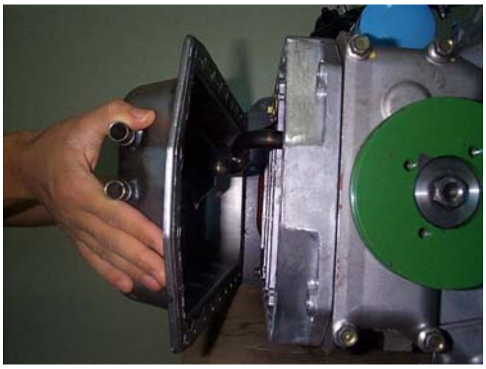
Inspect the cylinder bores for damage or excessive wear. Rotate the crankshaft so the piston is at BDC for the bores being inspected.
Measure the cylinder bores.
Limits
Diameter: Standard: 88.0 to 88.02
[3.464 to 3.465 in]
Out-of-Roundness: 0.03mm [0.0012 inch]
Refer to page 8-31 for the limits of the 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.

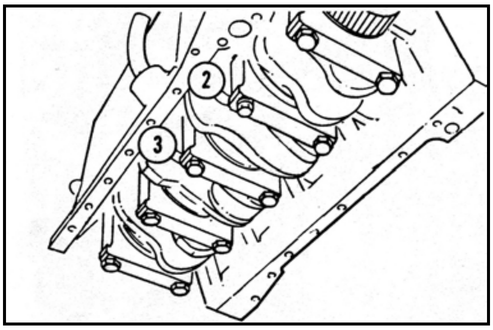
Limits
Variance: Standard: 0.03 mm [0.0012 in]
Worn Limit: 0.15 mm [0.006 in]

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

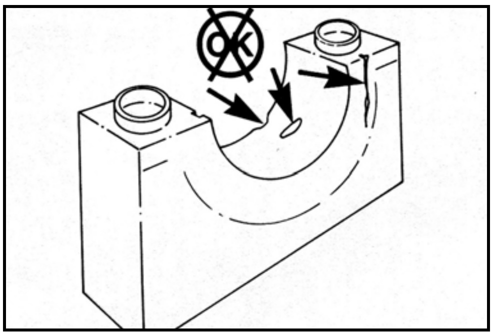


Main bearing Preliminary inspection

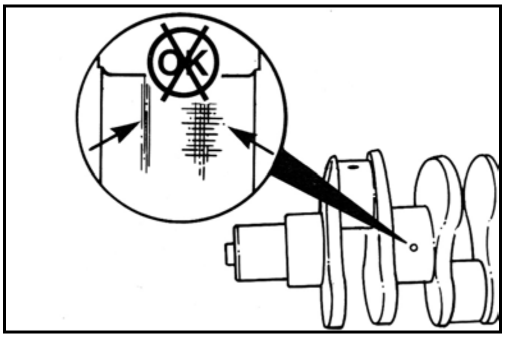
Remove the pan and suction tube.



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.

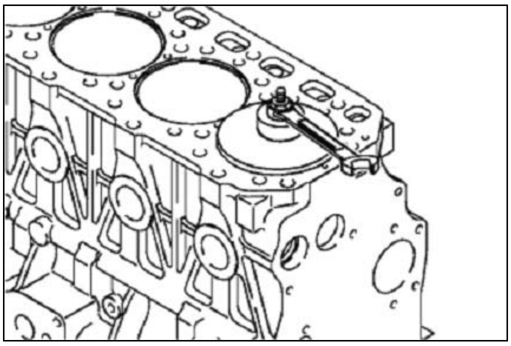


Inspect the main bearing caps for dents, cracks, or other damage.



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

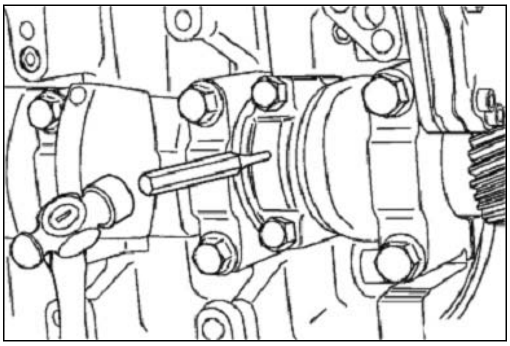
Note : If the journals or main caps are damaged, the engine will need to be removed to complete the overhaul.



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.

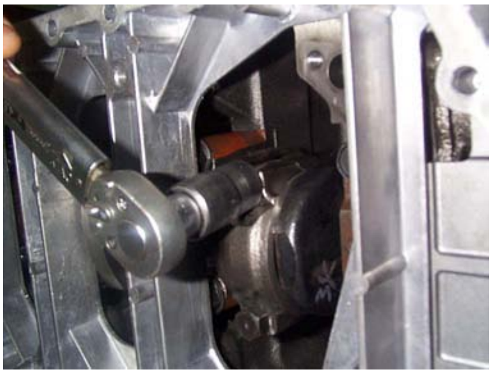


Hammer, Steel Number Stamps

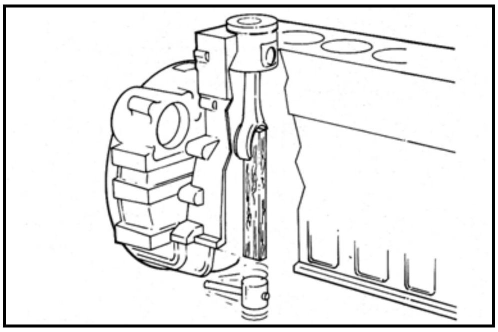
Mark the cylinder number onto each connecting rod cap.

Hammer, Steel Number Stamps

Mark the cylinder number onto the top of each piston.

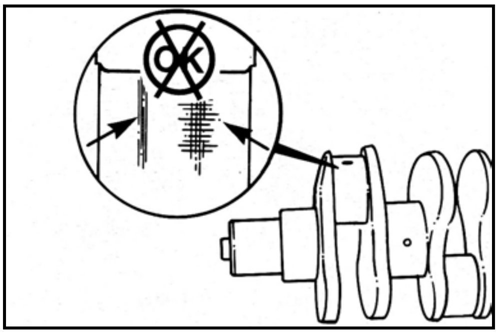


14mm
Remove the capscrews, connecting rod cap and bearings.

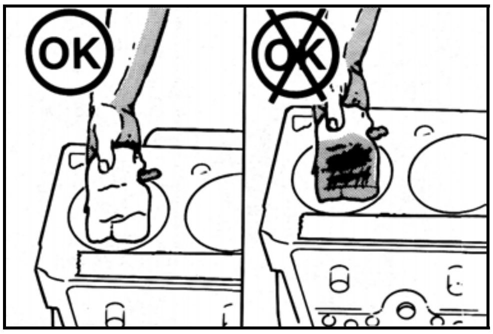


Caution : Use care so that the cylinder bore or connecting rod is not damaged.

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.

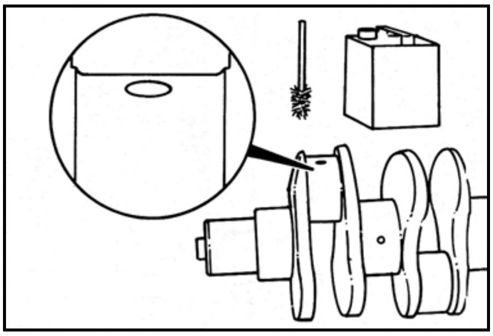


Inspect the rod journals for deep scratches, indications of overheating and other damage.



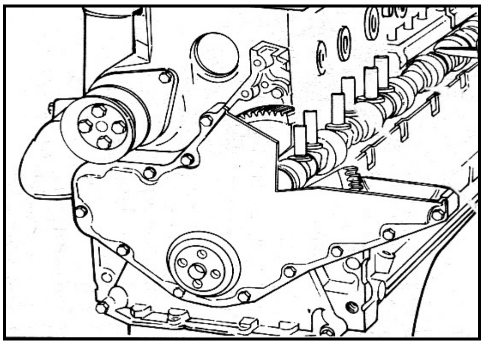
Caution : Be sure to remove the tape covering the lube holes after the cleaning process is complete.

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.



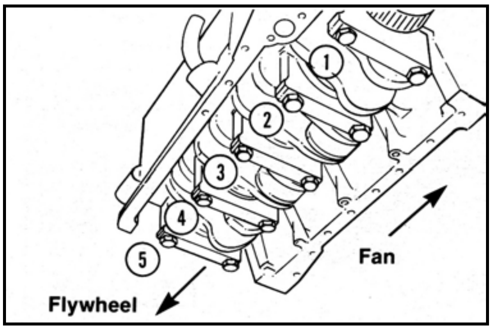
Caution : Be sure to remove the covering from the piston cooling nozzles.

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



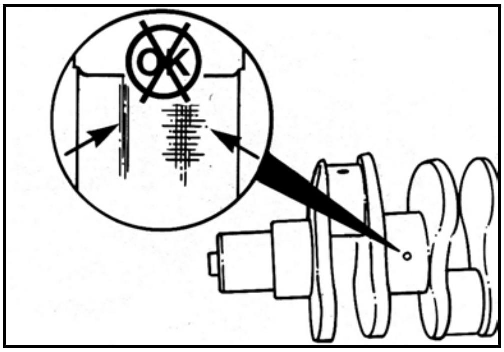
Use solvent and a brush to clean any residue that may have splashed on the camshaft.

Note : Inspect the camshaft lobes and tappet faces for signs of wear or damage.

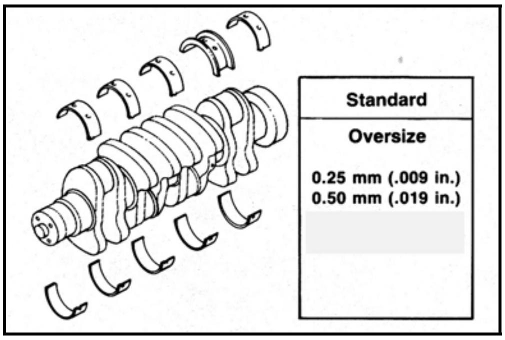


Main Bearing Replacement

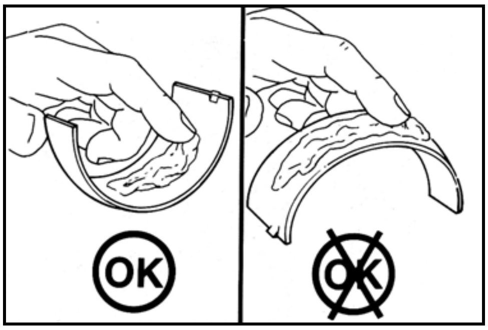
Remove all main bearing caps except the No.1 and 5 cap for 4 cylinder engine. The 4 cylinder engine is depicted in the illustration.



Inspect all caps and main bearing crankshaft journals. (refer to page 171)

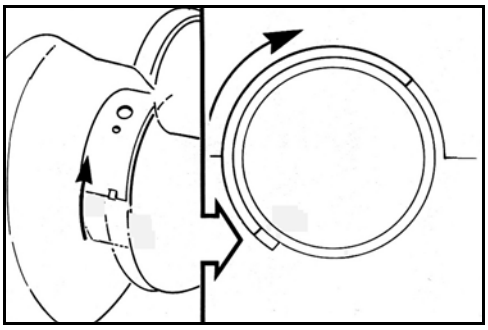


Determine the size of the bearing removed and obtain the same size for installation.
Refer to page 171 for the dimensions of the standard and undersize main bearing journals.



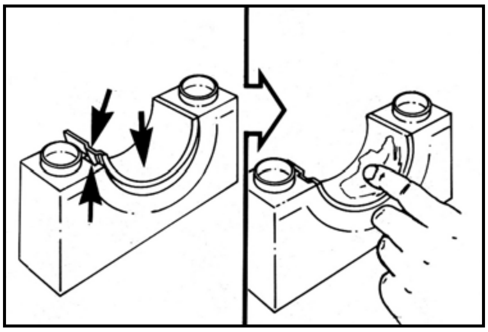
Caution : Do not lubricate the side that is against the cylinder block.

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

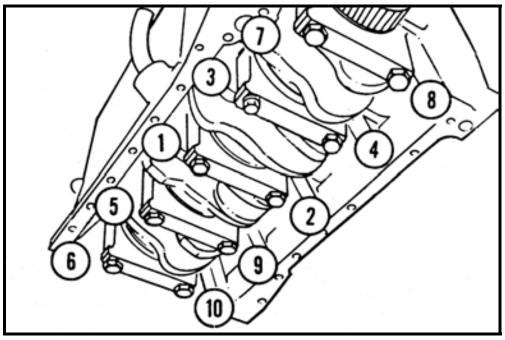


Use the pin to push the bearing shell into position. Use the pin to push against the end of the bearing with the tang. Push the bearing in slowly being sure it is aligned with the block. Make sure the tang on the bearing sets into the notch.

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 Lubricate 105 to the bearings.



19mm

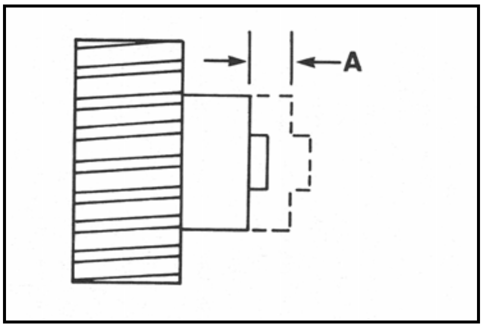
Caution : The crankshaft must rotate freely.

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 evenly and in sequence.

Step	Torque Value
1	39Nm [50 ft-lbs]
2	69Nm [52 ft-lbs]
3	98Nm [74 ft-lbs]

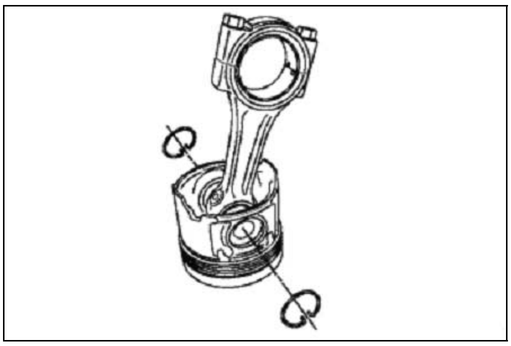
Check the bearing installations and the size of the bearings if the crankshaft does not rotate freely.



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

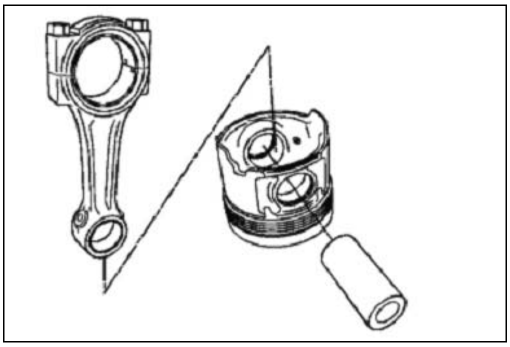
Measure the crankshaft end play
Dim. (A) End Play Limits

Min	Max
0.09mm [0.0035 in]	0.271mm [0.0107 in]



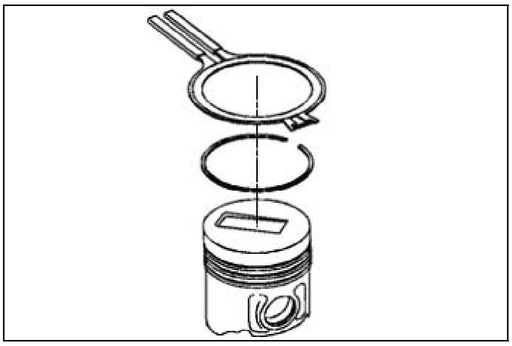
Piston and Rod – Disassembly

Remove the retaining rings.

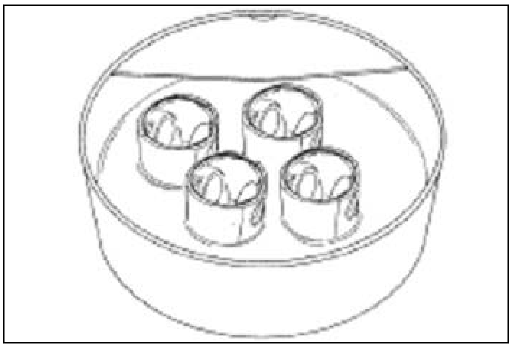


Remove the piston pin.

Note : Heating the piston is not required.



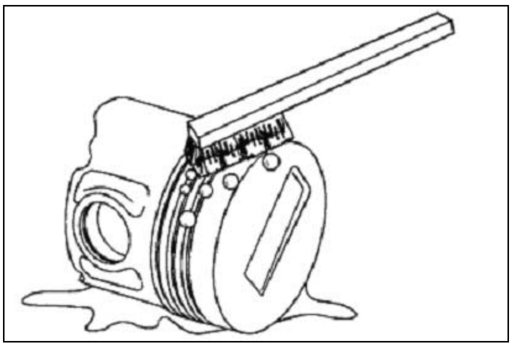
Remove the piston rings.



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.



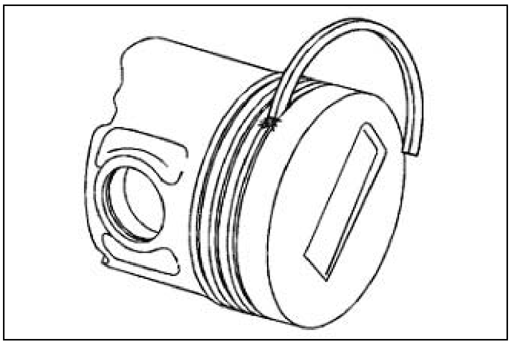
Caution : Do not clean the pistons and rods in an acid tank.

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.

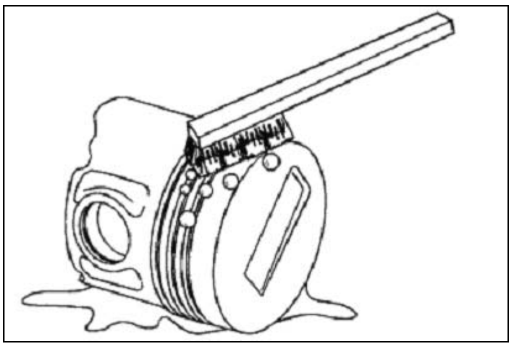
Clean the remaining deposits from the ring grooves with the square end of a broken ring.

Wash the pistons again in a detergent solution or solvent. Rinse the pistons. Use compressed air to dry.



Piston, Pin and Rod – Inspection

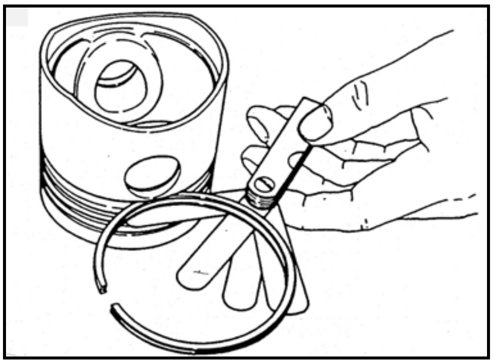
Inspect the piston for damage and excessive wear. Check the top, ring grooves, skirt and pin bore.



Measure the piston skirt diameter as illustrated.

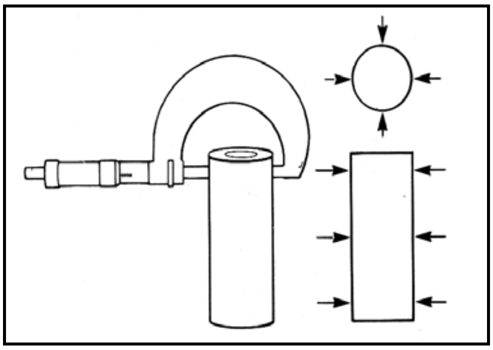
Standard: 87.95 to 87.97 mm
[3.463 to 3.4634 in]

Worn Limit: 87.9 mm [3.46 in]



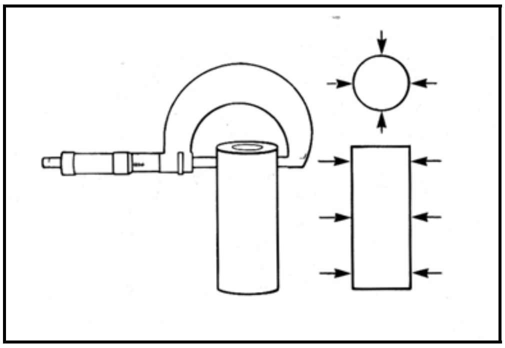
Use a new piston ring to measure the clearance in the ring groove.

Limits
Minimum Clearance
Top groove: 2.006 mm [0.079 in]
Oil Control: 3.002mm [0.1102 in]



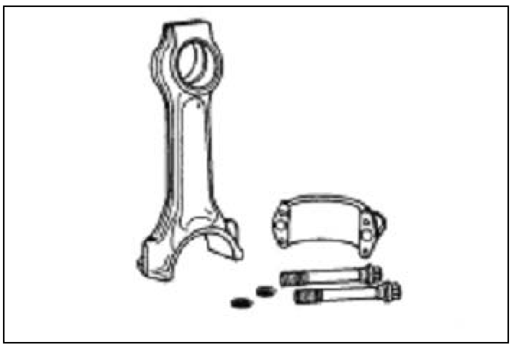
Measure the pin bore

Diameter
30.008 mm [1.1814 in]
Worn Limit: 29.9 mm [1.177 in]



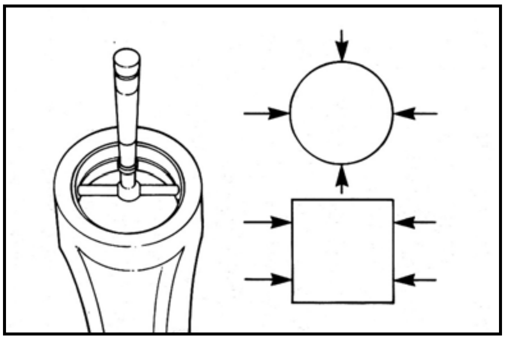
Inspect the piston pin for nicks, gouges and excessive wear.
Measure the pin diameter.

Diameter
30.0 mm [1.181 in]



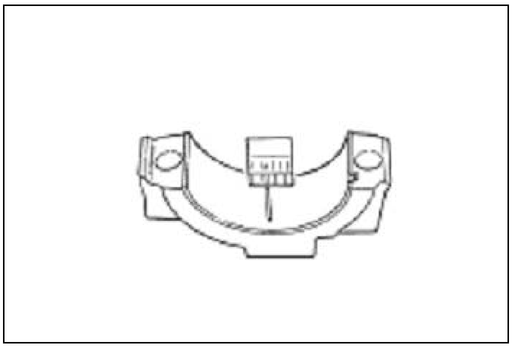
Caution : The I-beam section cannot have dents or other damage. Damage to this part can cause stress risers which will progress to breakage.

Inspect the rod for damage and wear.



Measure the pin bore.

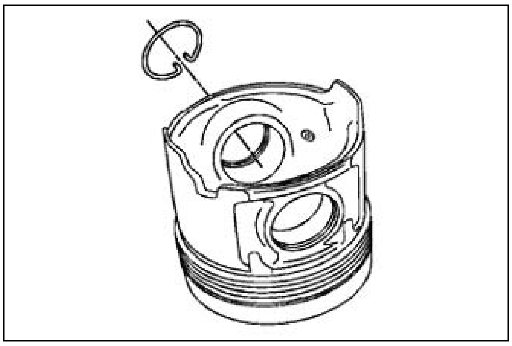
Maximum Diameter
30.038 mm [1.1826 in]
Worn Limit: 30.1 mm [1.185 in]



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.



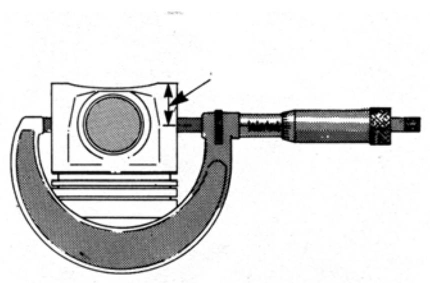
Install the retaining ring into the pin groove on the “Front” side of the piston.

Lubricate the pin and pin bores with engine oil.

Install the pin.

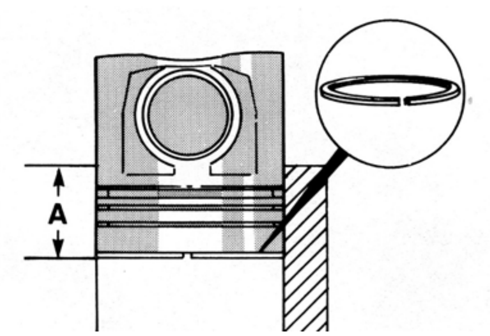
Note : Pistons do not require heating to install the pin, however, the piston does need to be at room temperature or above.

Install the second retaining ring.

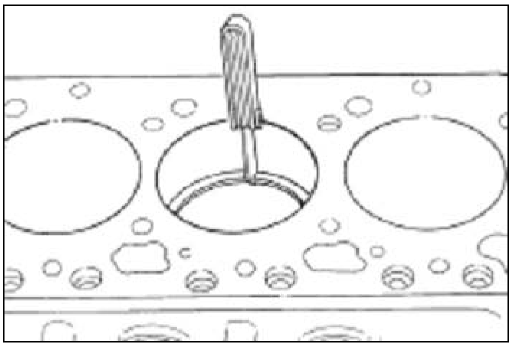


Determine the piston diameter and obtain the appropriate ring set.

Piston Ring Gap – Check

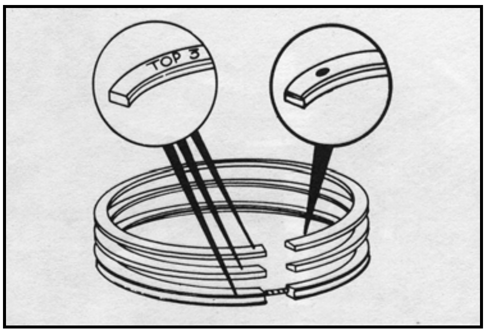


Position each ring in the cylinder and use a position to square it with the bore.
A= 20 mm [0.0787 in]



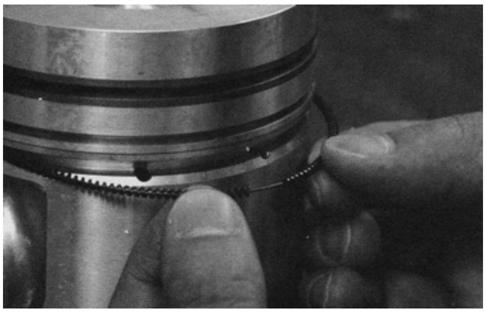
Use a feeler gauge to measure the gap.

Ring	Limits Minimum	Maximum
Top:	0.20 mm [0.0079 in.]	0.35 mm [0.0138 in.]
Intermediate:	0.25mm [0.0100 in.]	0.70 mm [0.0276 in.]
Oil Control:	0.20 mm [0.0079 in.]	0.40mm [0.0157 in.]

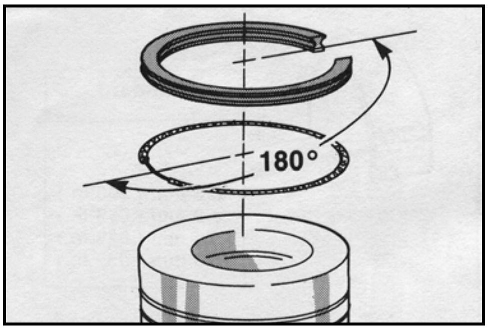


Piston Rings – Installation

Note : The top surface of all of the rings are identified: Assemble with the word "Top" or the supplier mark up.



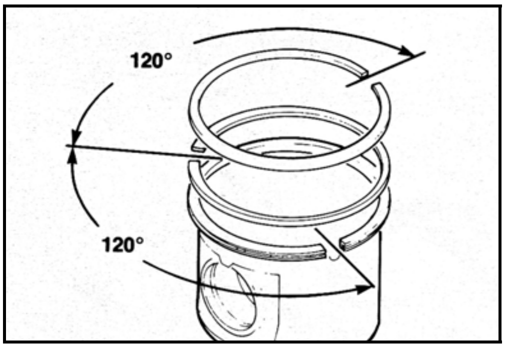
Position the oil ring expander in the oil control ring groove.



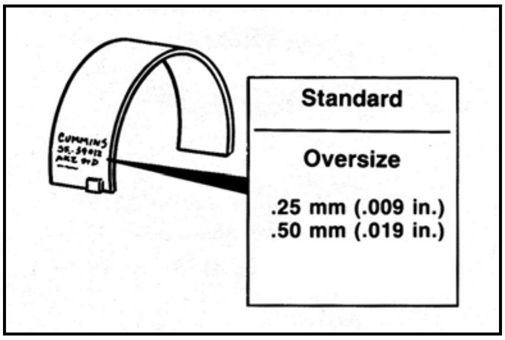
Install the oil control ring with the end gap opposite the ends on the expander.

Install the intermediate ring.

Install the top ring.

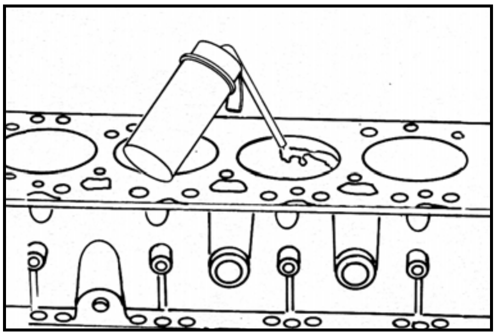


Position the rings.



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

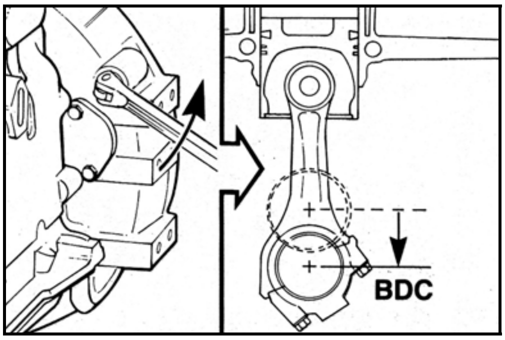
Lubricate the cylinder bore with clean engine oil.

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

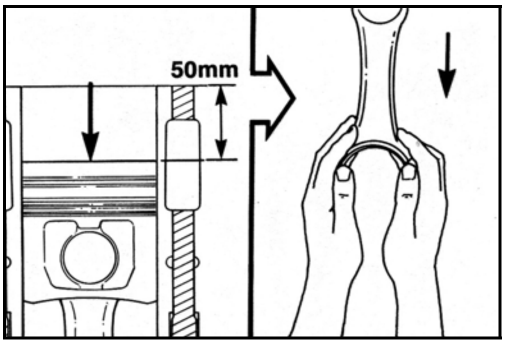
75 to 125mm Ring Compressor

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

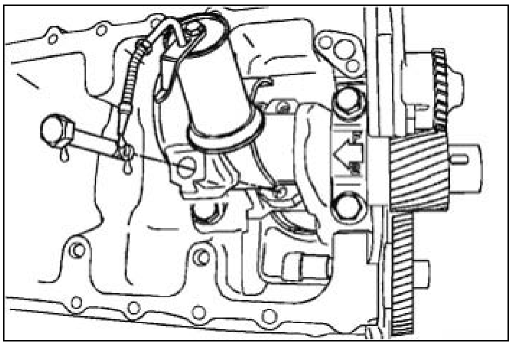
Compress the rings.



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

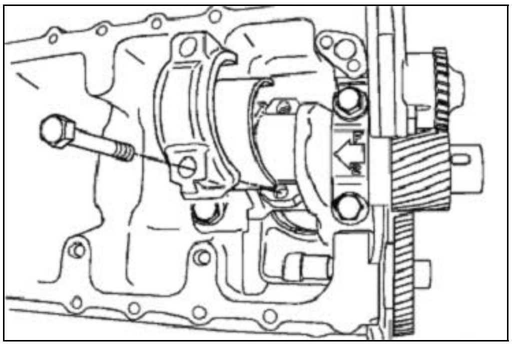


Push the piston into the bore until the top of the piston is approximately 50mm [2 inches] below the top of the bore.
Then, pull the connecting rod onto the crankshaft journal.



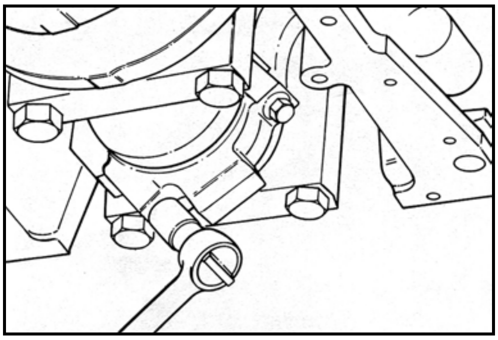
Note : The following series of illustrations show the engine in a vertical position. This is for clarity of illustration only.

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.

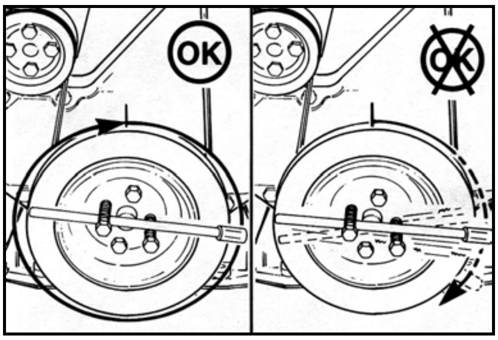
Install the rod cap and capscrews to the connecting rod.



12mm Socket, Torque Wrench

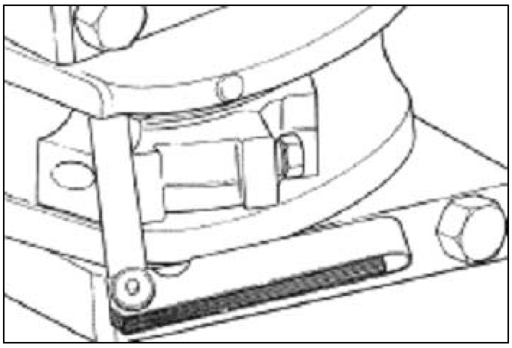
Caution : Tighten the connecting rod and capscrews evenly.

Torque Value:
Step 1 – 20 Nm [15 ft-lbs]
Step 2 – 34 Nm [26 ft-lbs]
Step 3 – 49 Nm [37 ft-lbs]



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.

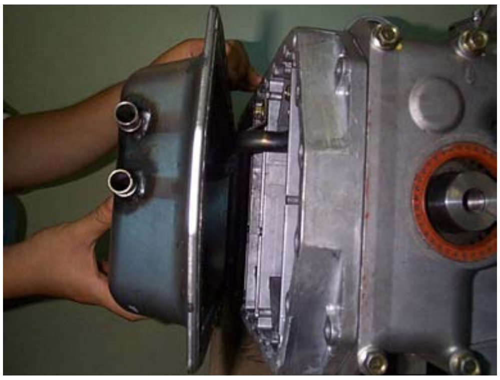


Caution : Do not measure clearance between the cap and crankshaft.

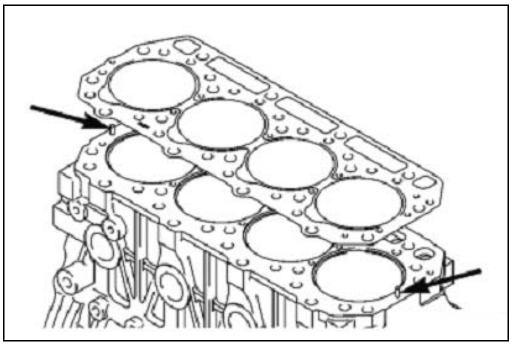
Measure the side clearance between the connecting rod and crankshaft.

Side Clearance Limits

Min	Max
0.15 mm	0.35 mm
[0.006 in]	[0.0138 in]



Install the suction tube and oil pan (refer to page 6-19).



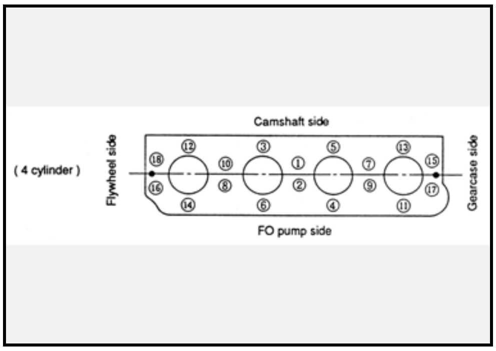
Cylinder Head and Gasket – Installation

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 179).
Lubricate the cylinder head capscrews. Use the illustrated torque sequence.

17mm

Torque Value:
Step 1 – 29 Nm [22 ft-lbs]
Step 2 – 59 Nm [44 ft-lbs]
Step 3 – 93 Nm [70 ft-lbs]

19mm

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

Install the rocker lever pedestal capscrews.
Torque Value: 59 Nm [44 ft-lbs]

Adjust the valve clearance (refer to page 179).

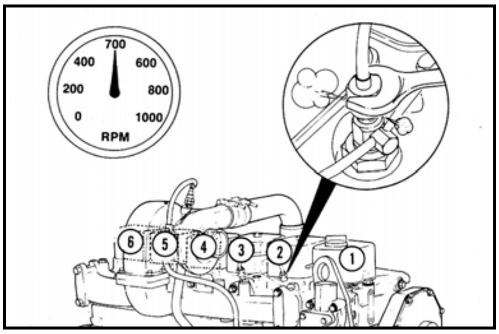
Install the parts previously removed:

- Valve covers
- Injector nozzles
- Fuel lines
- Fuel filters
- Exhaust manifold
- Torbocharger, air crossover and aftercooler, if the engine is so equipped.

Observe the Following Check List During Final Assembly

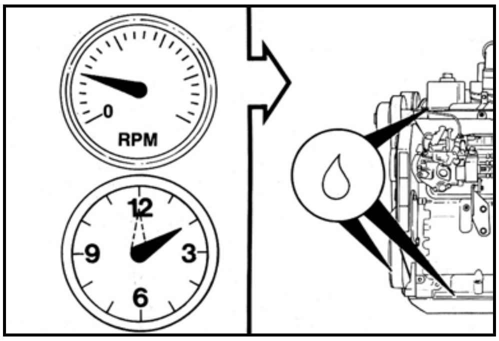
	OK
• Correct injectors for the engine rating used and only one copper sealing washer installed?	________
• Sealant applied to the capscrews that attach the intake manifold cover or aftercooler?	________
• Turbocharger pre-lubed?	________
• Engine filled with oil; oil filter filled with oil prior to installation 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?	________
• Aftercooler vent opened during coolant fill?	________

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.

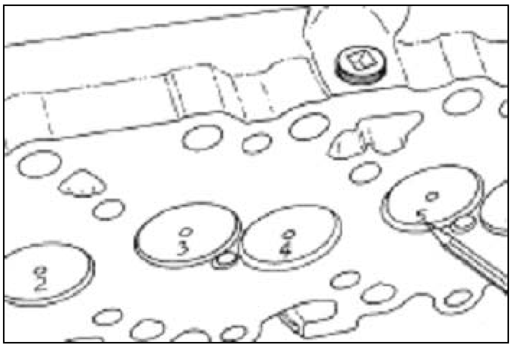
Start the engine. If necessary, bleed the high pressure lines at the injectors until the engine runs smoothly.



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

Refer to page 226 through ? for test and performance requirements.

Cylinder Head – Disassembly



The following disassembly and assembly procedures are provided for inspection purposes only.
Refer to the Shop Manual, Bulletin No. 3810206, for complete rebuild instructions.
Mark the valve 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.

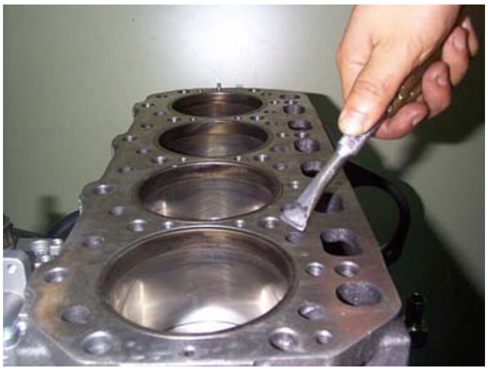
Caution : Keep the valves in a labeled rack.

Remove the remaining collets, retainers, springs and valves.

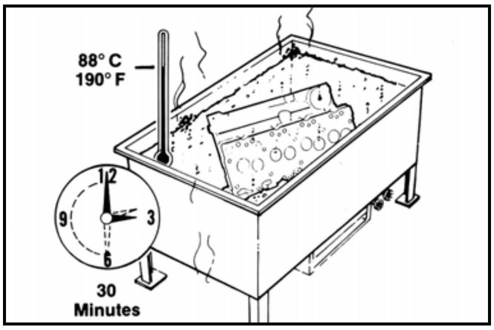
Remove the valve stem seals.

Cylinder Head – Clean and Inspect

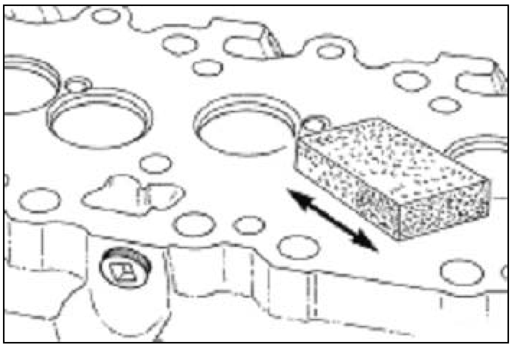
Clean the carbon from the injector nozzle seat with a nylon brush.



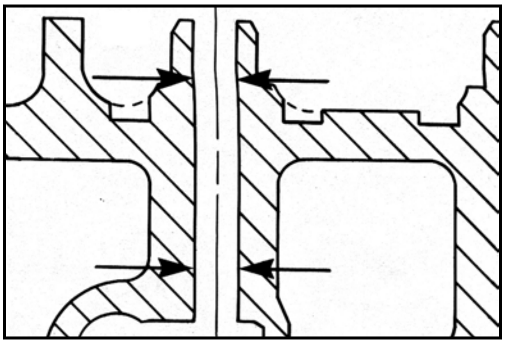
Scrap the gasket material from all gasket surfaces.



Wash the cylinder head in hot soapy water solution. After rinsing, use compressed air to dry the cylinder head.



Polish the gasket surface with 400 grit paper.
Use an orbital sander or sanding block to keep a flat surface.



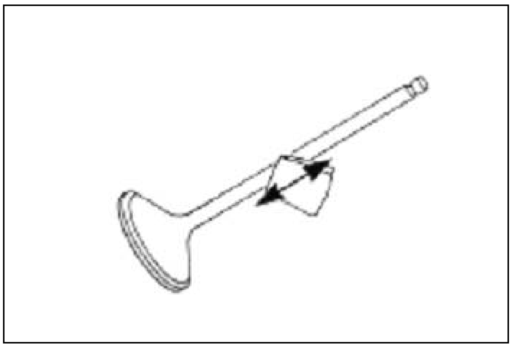
Inspect the valve guides for scuffing or scoring.
Measure the valve guide bore.

Maximum Diameter
8.025 mm [0.3160 in]
Worn Limit: 8.1 mm [0.319 in]

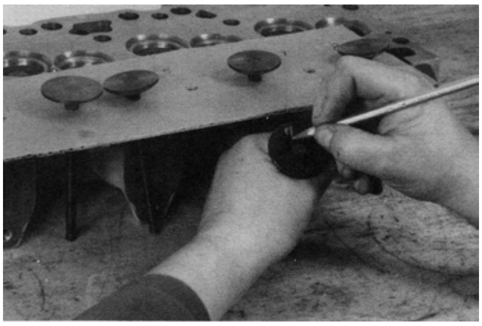
Inspect the head surface for nicks, erosion, or any other damage.
Check for head distortion as illustrated.

Standard: 0.03 mm [0.0012 in]
Worn Limit: 0.15 mm [0.0059 in]

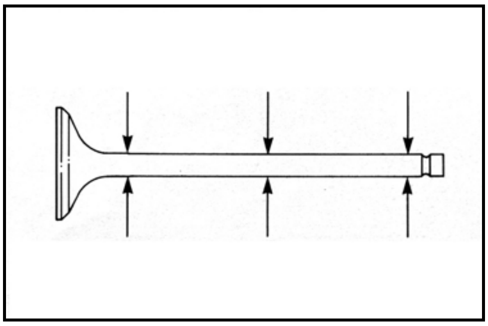
Refer to the Salvage Manual if head distortion exceeds limits.



Polish the valve stem with crocus cloth.



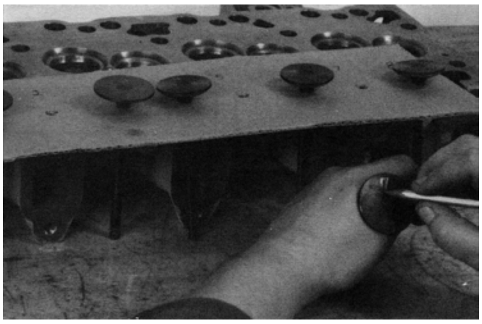
Mark the valves again for location in the cylinder head.



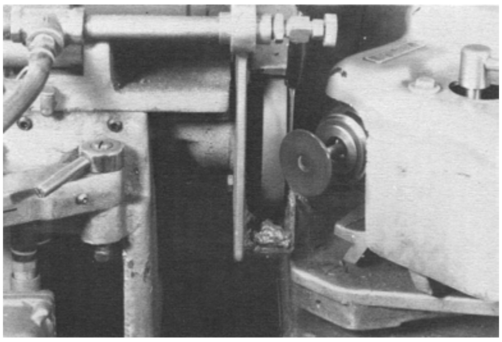
Inspect for abnormal wear on the heads and stems.
Measure the valve stem diameter.

Maximum Diameter

7.960mm [0.3134 in]

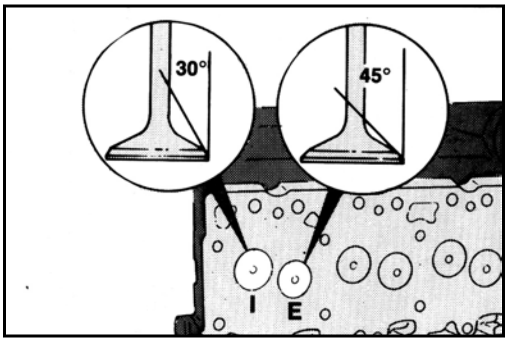


If new valves are required, mark them for location in the cylinder head.



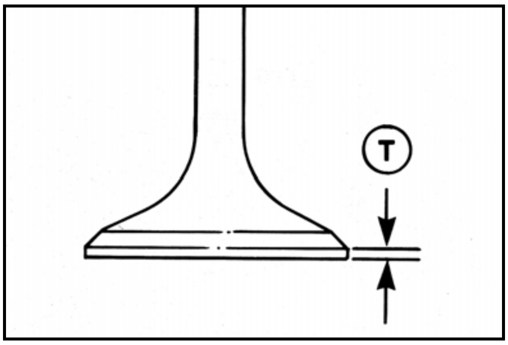
Valves – Grind

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



Seat Angle

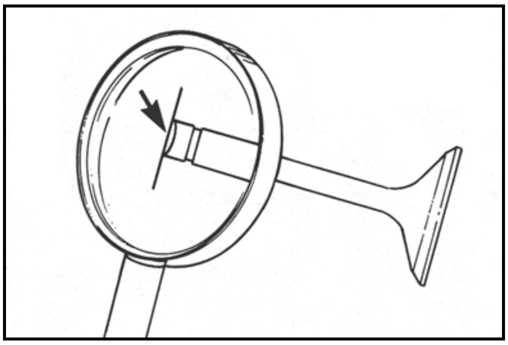
Intake: 30 Degrees
Exhaust: 45 Degrees



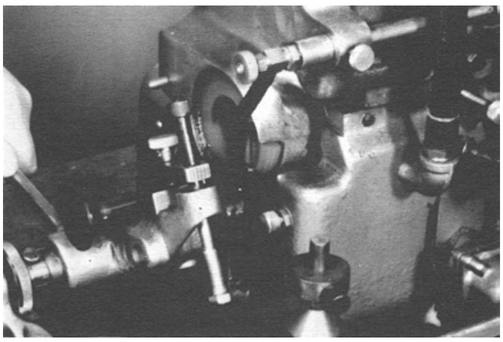
Measure rim thickness.

Minimum Thickness (T)

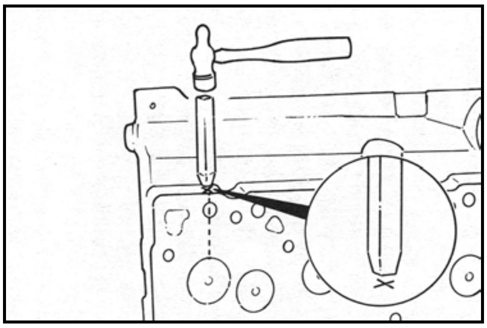
Standard: 1.2 mm [0.047 in]
Worn Limit: 0.5 mm [0.0197 in]



Check the valve stem tip for flatness.



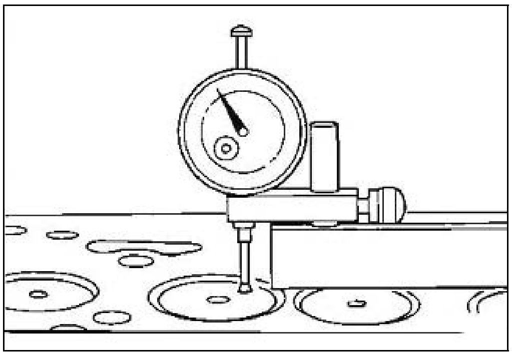
If required, re-surface the valve stem tip.



Valve Seats – Grind

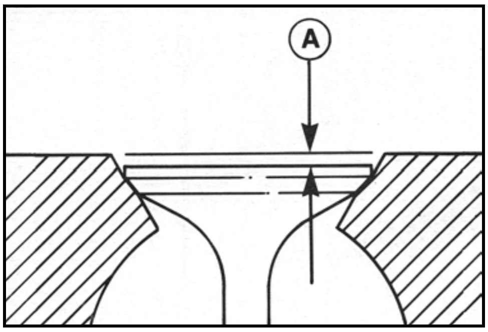
Note: The illustrated marks indicate valve seat have been ground previously.

Previously re-ground seat can be replace with service seats.



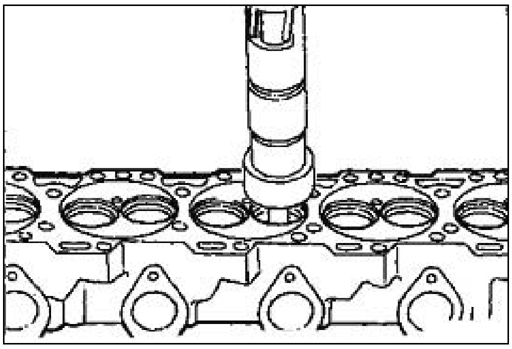
Calculating the Grinding Depth

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

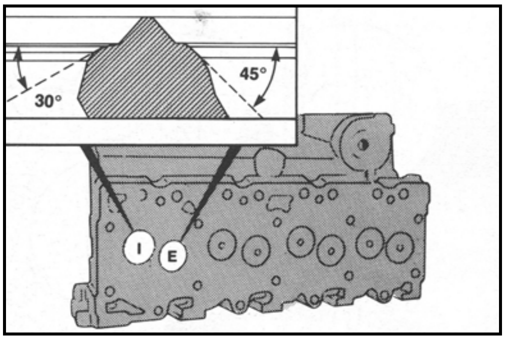


Note : The valve depth is the distance from the valve face to the head deck.

Record the depth of each valve as (A).

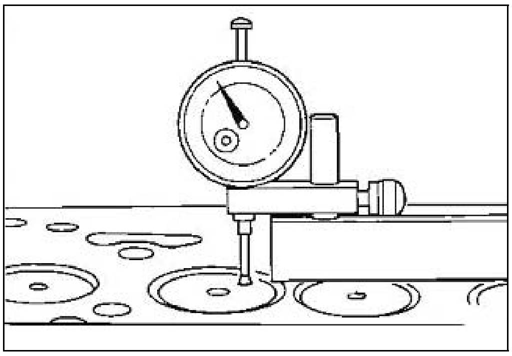


Grind the valve seat to remove scores, scratches and burns.



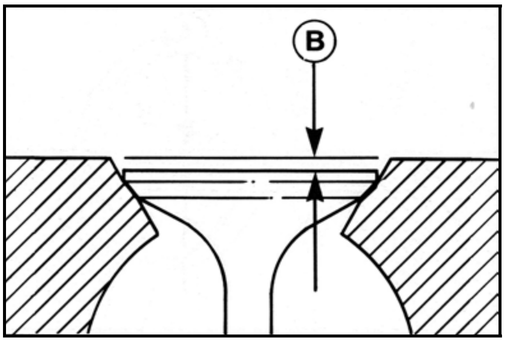
Seat Angle

Intake: 30 Degrees
Exhaust: 45 Degrees

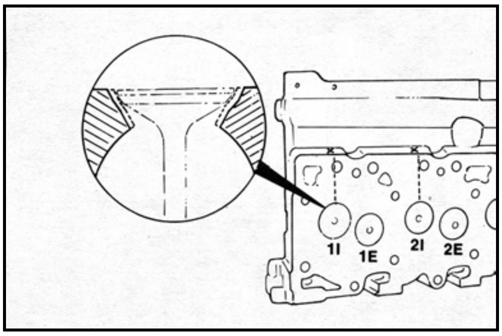


Install the valves in their respective bores and measure depth again.

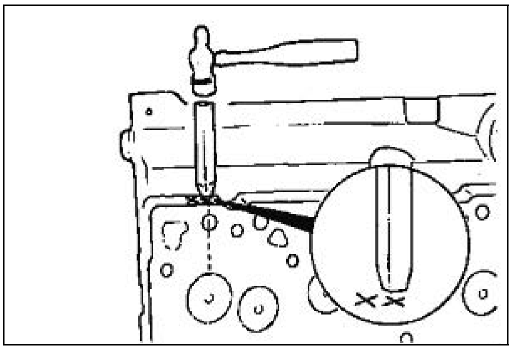
Note : Make sure the seats are clean before you measure the depth.



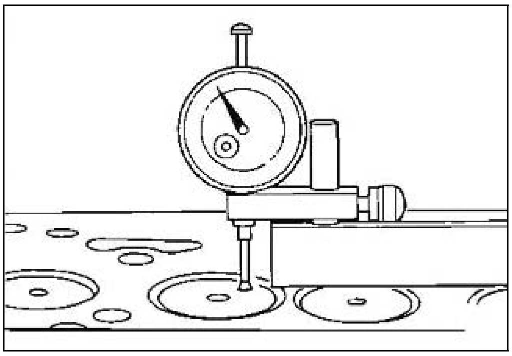
Record the depth of each valve as (B).
Calculate grinding depth (GD) as follows:
GD= (B) – (A)



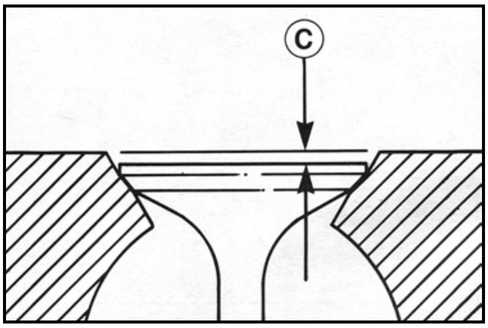
Dimension (GD)
0.20 mm [0.008 in]



Note : Identify re-ground valve seats.



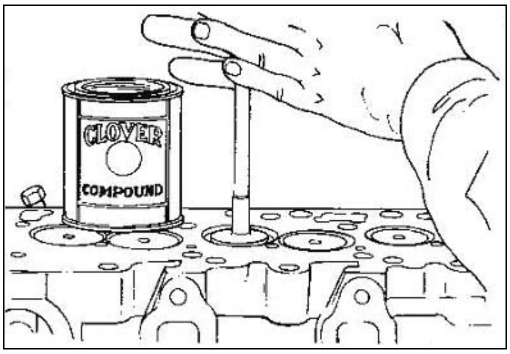
Install the valves in their designated location and measure the depth.



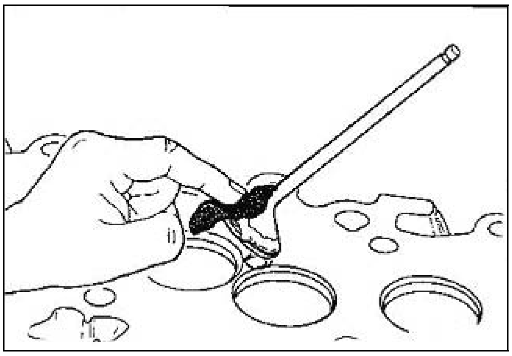
Caution: Replace the valve if the depth is over the limit.
Check valve depth (C).

Valve Depth

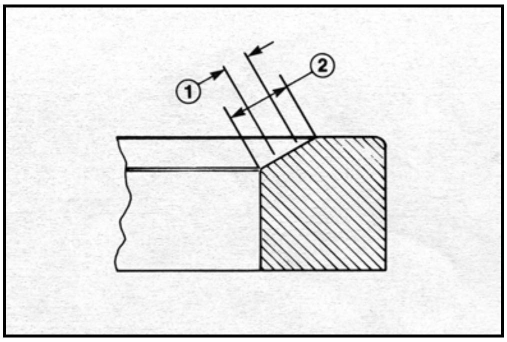
Standard: 0.69 to 0.70 mm [0.0271 to 0.0279 in]
Worn Limit: 1.0 mm [0.0394 in]



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



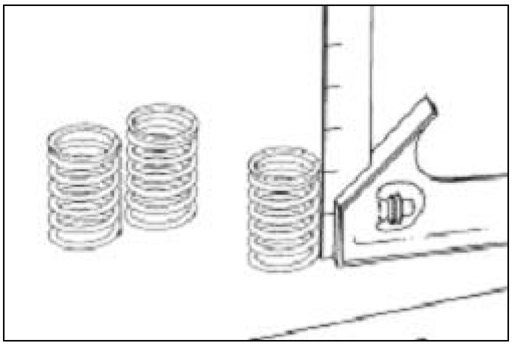
Remove the valves and clean lapping compound from the valves and seats.



Measure the valve seat width indicated by the lapped surface.

Valve Seat Width Limit

Intake:
Standard: 1.73 mm [0.0681 in]
Worn Limit: 2.23 mm [0.088 in]
Exhaust:
Standard: 2.12 mm [0.083 in]
Worn Limit: 2.62 mm [0.103 in]

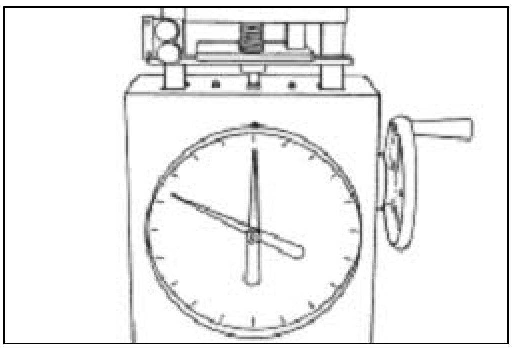


Valve Springs – Inspection

Measure the valve spring.

Limits

Approx. Free Length (L): 46.1 mm [1.815 in.]



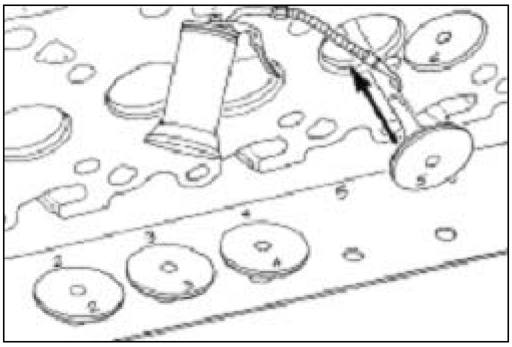
Check the valve spring tension.
A minimum load of 299.5 N. [67 lb] is required to compress the spring to a height of 29.85mm [1.175 in].

Cylinder Head – Assembly

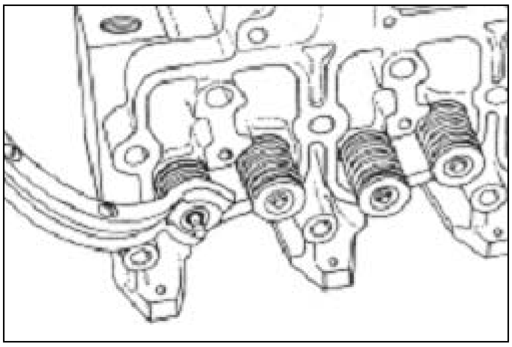
Note : Clean all cylinder head components before assembling.

Install the valve stem seals.

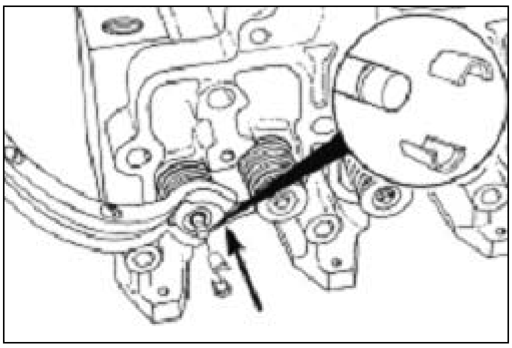
Note : The intake and exhaust seals are the same.



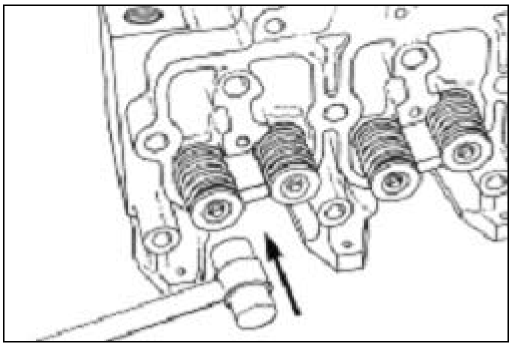
Lubricate the stems with SAE 90W engine oil before installing the valves.



Compress the valve spring after assembling the spring and retainer.



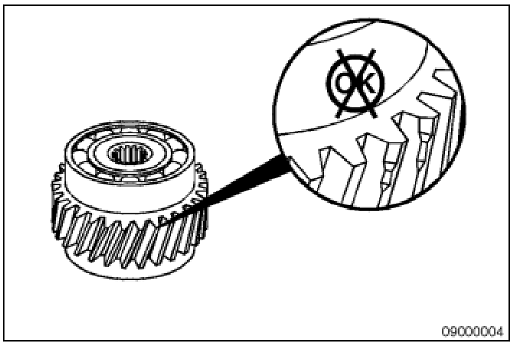
Install new valve collets and release the spring tension.



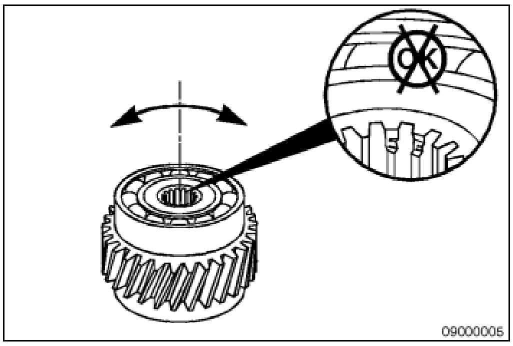
Warning : Wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

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

Hydraulic Pump Drive Gear and Shaft - Inspect for Reuse (Just for D15S/18S/20SC-2)

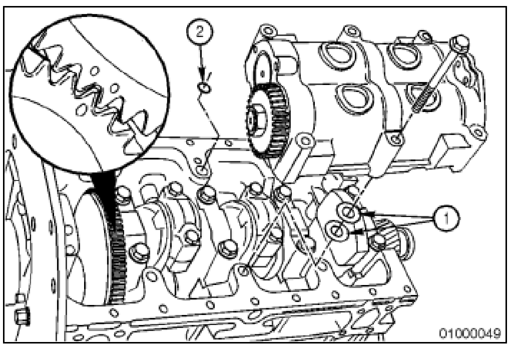


Inspect the hydraulic pump gear for damaged, broken, or excessively worn teeth.



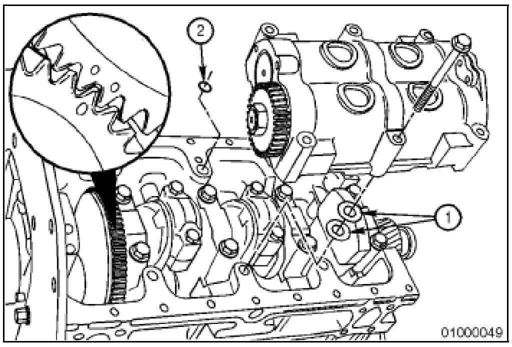
Rotate the gear, and inspect for rough spots in the bearing.
Inspect the bearing bore and shaft spline for excessive wear.

Balancer - Remove



Check the gear backlash before removing balancer.
Refer to Section 1.
Remove the mounting capscrews.
Remove the balancer and shim or shim plate (1).
Remove the o-ring (2) in the oil passage.

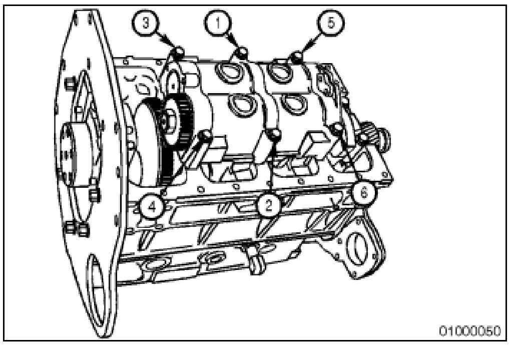
Balancer - Install



Align the timing marks on the crankshaft drive gear and the balancer driven gear.

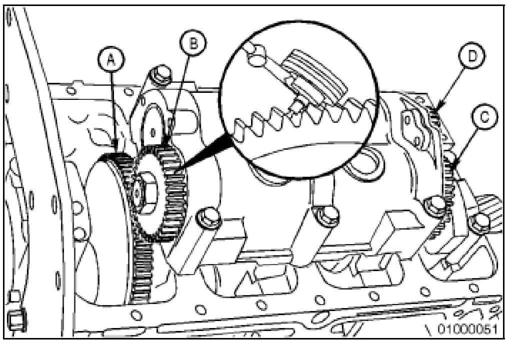
Install the shim or shim plate (1), balancer, and lightly lubricate the capscrews with clean 15W-40 engine oil.

Make sure that the oil supply passage is open and the o-ring (2) is installed..



Tighten the capscrews in a criss-cross pattern. Rotate the engine to make sure of free movement of components.

Torque Value:	28 n.m	[21 ft-lb]



Note : Prevent movement of the adjoining gear when checking backlash or the reading will be the total of both gears.

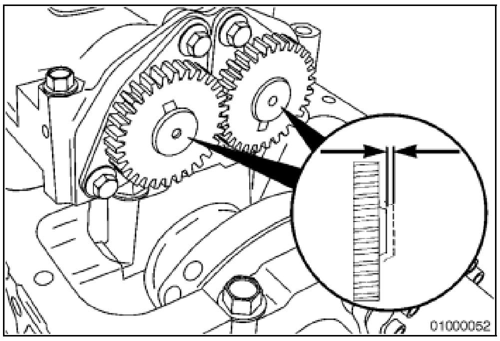
Measure the balancer gear backlash.

Balancer Gear Backlash

	mm		in
Crankshaft Drive Gear (A)-to-Balancer Drive Gear (B)	0.06	MIN	0.0024
	0.14	MAX	0.0055
Balancer Drive Gear (C)-to-Balancer Driven Gear (D)	0.06	MIN	0.0024
	0.14	MAX	0.0055

.

Measure the balancer end play.



Balancer Shaft End Play

mm		in
0.05	MIN	0.002
0.25	MAX	0.0098

Engine Replacement and Testing

Engine Replacement

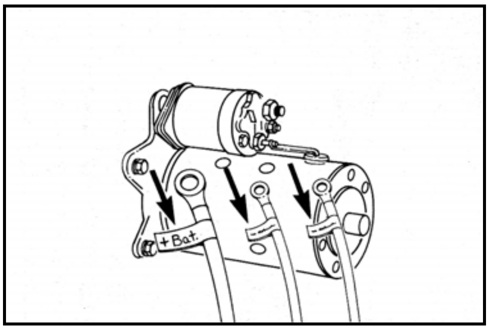
If the engine cannot be repaired in chassis, use the following guidelines for removal and installation of the engine.

Caution : Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.

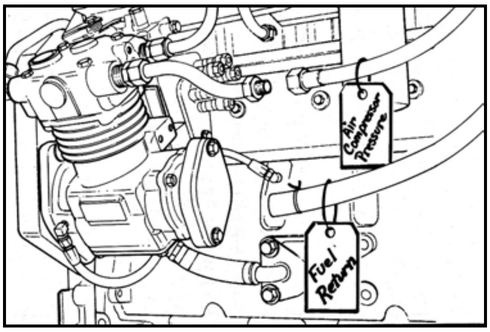
Engine Removal

Preparatory Steps:

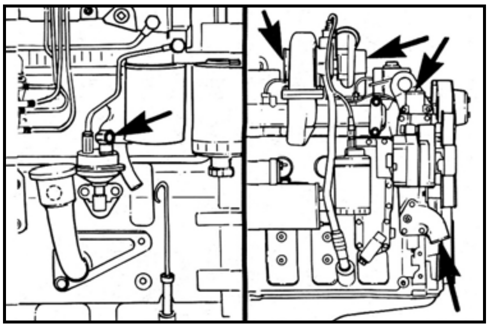
- Disconnect the air intake and exhaust pipes.
- Disconnect the throttle linkage from the control lever.
- Do not remove the control lever from the injection pump.
- Disconnect all engine driven accessories.
- Disconnect the drive units from the flywheel.
- Drain the coolant.
- Drain the lubricating oil.
- Remove the chassis parts as necessary to lift the engine from the equipment



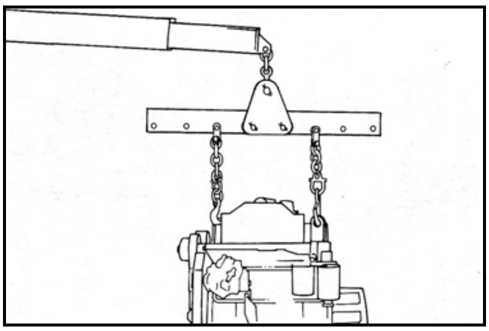
Disconnect all electrical connections. Put tags on the connections to identify their locations.



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: 169 kg

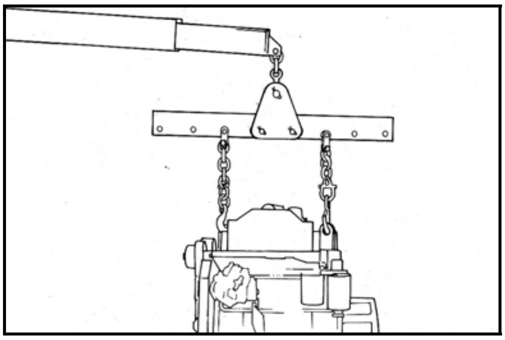
Note : Remove all accessories and brackets not previously removed to use with the replacement engine.

Engine Installation

Caution : Do not exceed the torque value for the engine supports.

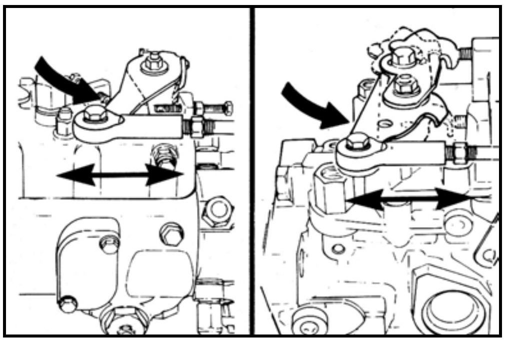
Check the data plate to verify that the replacement engine is the same model and rating as the engine that was removed.

Note : Install all accessories and brackets that had been removed form the previous engine.

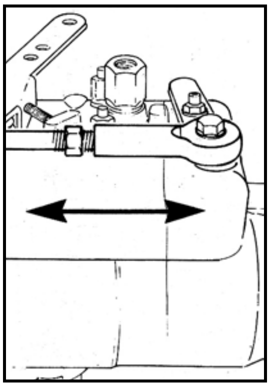


Use the lifting eyes to lift the engine. Keep tension on the hoist while you align the engine in the chassis and tighten the engine mounts.

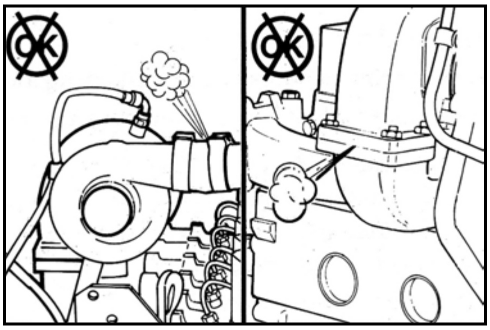
Connect the engine and chassis parts in the reverse order of removal.



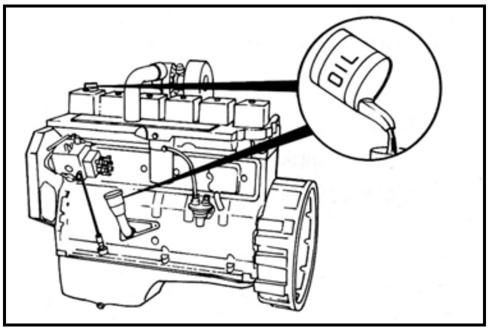
When connecting the cable/rod to the control lever, adjust the length so the lever has stop-to-stop movement.



Adjust the length of the cable/rod to the mechanical shut down lever so there is stop-to-stop movement.

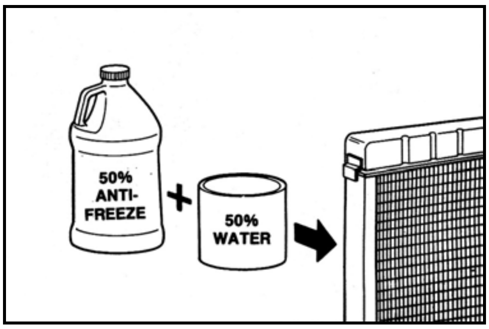


Note : Make sure the air intake and exhaust pipe connections are tight and free of leaks.



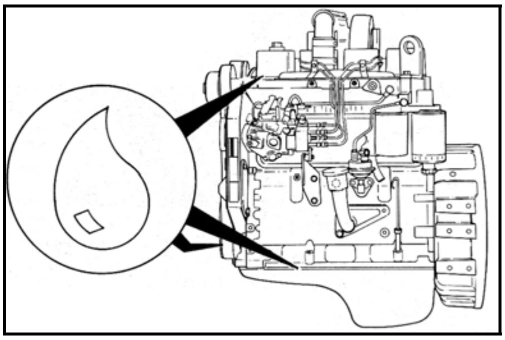
Fill the engine with the required amount of lubricating oil.
6.5 Liters [1.85 gal]

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 manufacture's specifications for radiator capacity.

Engine Only Coolant Capacity
3.0 Liters [0.7 gal]



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	100℃ [212°F] Maximum
Lubricating Oil Temperature	120℃ [248°F] Maximum
Lubricating Oil Pressure	294 kPa [42.6 PSI] Minimum
Air Inlet Temperature	25℃ [77°F] Maximum
Air Inlet Restriction	250 mmHg Maximum
Boost Pressure	66cm [26 in.] Hg Minimum
Exhaust Temperature	630℃ [1166°F] Maximum
Smoke	
Bosch Smoke Meter	2.5 Units Maximum
Celsco Smoke Meter	4% Opacity Maximum

Specifications

General Engine

General Engine Data	
- A2000, and A2300	Naturally Aspirated
Engine Weight (Dry) Less Flywheel and Electronics	
- A2000 and A2300	203 kg [448 lbs]
Compression Ratio	21:1
Bore	
- A2000	84 mm [3.31 in]
- A2300	88 mm [3.46 in]
Stroke	
- A2000, and A2300	94 mm [3.7 in]
Displacement	
- A2000	2.08 liters [127 C.I.D.]
- A2300	2.29 liters [139 C.I.D.]
Firing Order	
- A2000, and A2300	1-3-4-2
Valve Clearance	
- Intake	0.3 mm [0.012 in]
- Exhaust	0.3 mm [0.012 in]
Engine Rotation (Viewed From the Front of the Engine)	Clockwise

Fuel System

Maximum Fuel Inlet Restriction to Injection Pump (Clean FIlter)	76.3 mm-Hg [3 in-Hg]
Maximum Fuel Drain Restriction	381 mm-Hg [15 in-Hg]
Maximum Fuel Inlet Temperature	65°C [149°F]
Minimum Engine Cranking Speed	180 rpm

Lubricating Oil System

Regulating Valve Opening Pressure	290 - 390 kPa [42 - 56 psi]
Lubricating Oil Capacity (Total System*)	
- A2000, and A2300	7 liters [7.5 qt]
Lubricating Oil Capacity (Standard Oil Pan Only*)	
- A2000, and A2300	6.5 liters [7.0 qt]
Lubricating Oil Pressure at Idle (Minimum Allowable)	69 kPa [10 psi]
Lubricating Oil Pressure at Rated (Minimum Allowable)	168 kPa [24 psi]
* Some applications use different oil pan capacities. Contact your local Cummins Distributor if you have questions.	

Cooling System

Coolant Capacity (Engine Only)	
- A2000, and A2300	3 liters [3.2 qt]
Standard Modulating Thermostat - Range	71 - 85°C [160 - 185°F]
Maximum Allowable Operating Temperature	100°C [212°F]
Minimum Recommended Operating Temperature	71°C [160°F]
Minimum Recommended Pressure Cap	48 kPa [7 psi]

Air Intake System

Maximum Intake Air Restriction	
- Dirty Filter	635 mm-H2O [25 in-H2O]
- Clean Filter	254 mm-H2O [10 in-H2O]
Minimum Dirt Holding Capacity	25 g/cfm

Exhaust System

Maximum Allowable Exhaust Restriction	
- A2000, and A2300	75 mm-Hg [3 in-Hg]

Electrical System

Recommended Battery Capacity	
- A2000, and A2300	
- 12 Volt Battery with Light Accessories	500 Cold Cranking Amps
- 12 Volt Battery with Heavy Accessories	650 Cold Cranking Amps
- 24 Volt Battery with Light Accessories	250 Cold Cranking Amps
- 24 Volt Battery with Heavy Accessories	325 Cold Cranking Amps
Maximum 12 Volt Starting System Resistance	0.001 ohm
Maximum 24 Volt Starting System Resistance	0.002 ohm
Minimum Cranking Speed	180 rpm

Drive Belt Tension

Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240

Note : This chart does not apply to automatic belt tensioners.
* A belt is considered used if it has been in service for ten minutes or longer.
* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

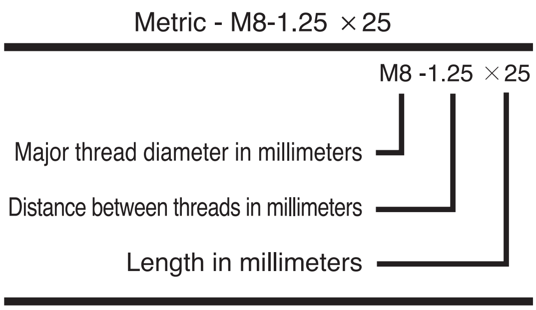
Capscrew Markings and Torque Values

General information

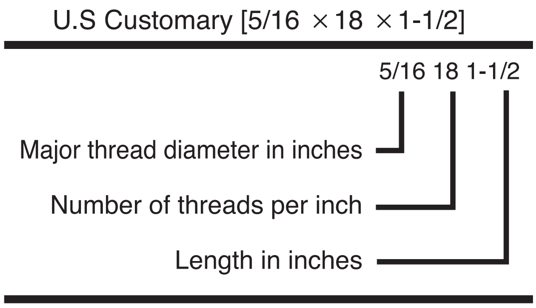
Caution : When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:



17800016

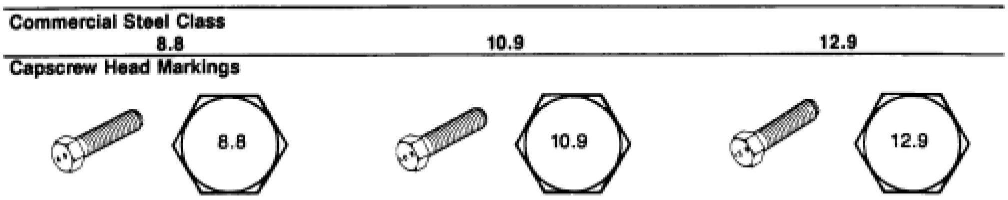


17800017

NOTES:

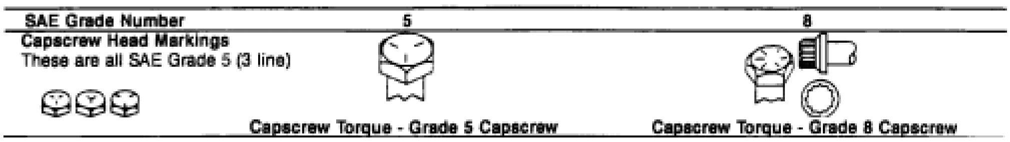
1. Always use the torque values listed in the following tables when specific torque values are not available.
2. Do not use the torque values in place of those specified in other sections of this manual.
3. The torque values in the table are based on the use of lubricated threads.
4. When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values – Metric



Body Size	Torque				Torque				Torque			
Diameter	**Cast Iron**		**Aluminum**		**Cast Iron**		**Aluminum**		**Cast Iron**		**Aluminum**	
mm	**N•m**	**ft-lb**	**N•m**	**ft-lb**	**N•m**	**ft-lb**	**N•m**	**ft-lb**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
6	9	5	7	4	13	10	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7
8	23	17	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	—	—	550	400	—	—	—	—	—	—

Capscrew Markings and Torque Values – U.S Customary



Capscrew Body Size	Cast Iron		Aluminum		Cast Iron		Aluminum	
	N•m	**ft-lb**	**N•m**	**ft-lb**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/4 - 20	9	7	8	6	15	11	8	6
1/4 - 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
5/16 - 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
3/8 - 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
7/16 - 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
1/2 - 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
9/16 - 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
5/8 - 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
3/4 - 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
7/8 - 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
1 - 14	800	590	650	480	1200	890	650	480

Fraction, Decimal, Millimeter Conversions

Fraction	inch	Mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	37880	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	37749	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	37941	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	37684	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	37810	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

Newton-Meter to Foot-Pound Conversions

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	9 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
11	97 in-lb	90	66	190	140
12	106 in-lb	95	70	195	144
14	124 in-lb	100	74	200	148
15	133 in-lb	105	77	205	151
16	142 in-lb	110	81	210	155
18	159 in-lb	115	85	215	159
20	15 ft-lb	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184

Note : To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.

Pipe Plug Torque Values

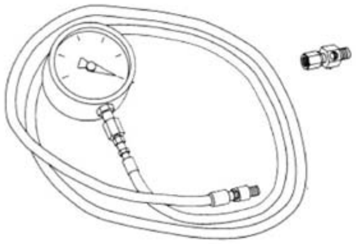
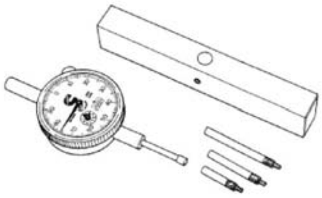
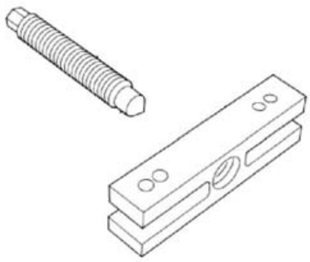
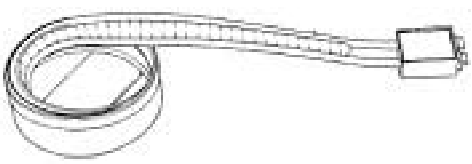
Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	**in**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

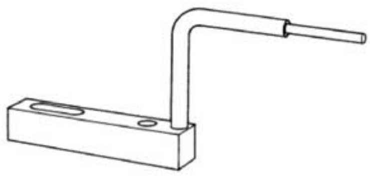
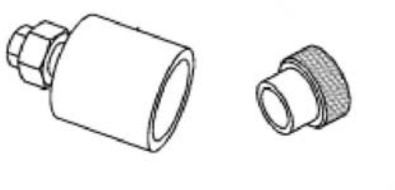
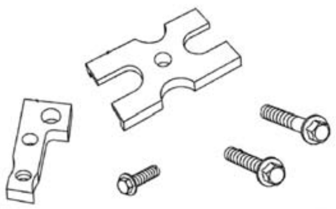
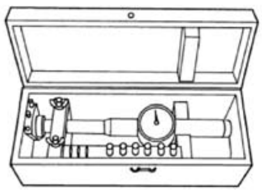
Weights and Measures – Conversion Factors

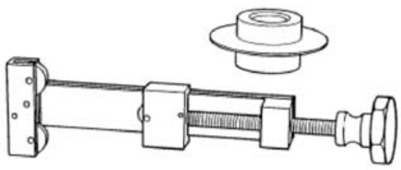
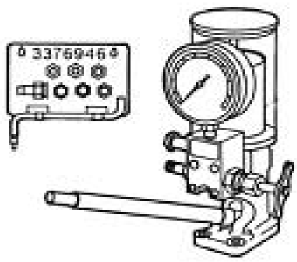
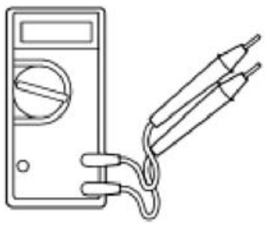
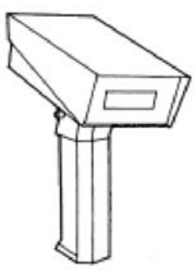
Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbreviation		
Area	sq. inch	in2	sq. millimeters	mm2	645.16	0.001550
			sq. centimeters	cm2	6.452	0.155
	sq. foot	ft2	sq. meter	m2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H2O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H2O	millimeters of water	mm H2O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333

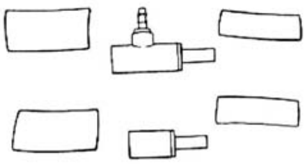
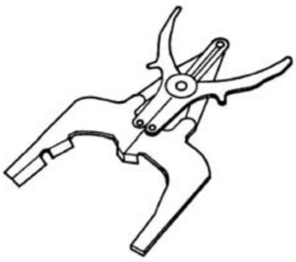
Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in3	liter	l	0.01639	61.02545
	cubic inch	in3	cubic centimeter	cm3	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

SPECIAL TOOLS

Style	Tool No.	Tool name
	ST 434	Vacuum Gauge
	ST 537	Dial Depth Gauge
	ST 647	Standard Puller
	ST 1111-3	Manometer
	ST 1273	Pressure Gauge

Style	Tool No.	Tool name
	ST 1325	Dial guage attachment
	3162745	Injector/Connector Removal tool
	3163292	Valve spring compressor
	3375072	Dial bore gauge, kit
	3375432	Crack Detection Kit

Style	Tool No.	Tool name
	3376579	Tube(Filter) Cutter
	3376946	Injector nozzle tester
	3377161	Digital multimeter
	3377259	Fuel Pump Timing tool
	3377462	Digital optical tachometer

Style	Tool No.	Tool name
	3822476	Blow By tool, use with ST1111-3
	3822666	Digital Thermometer
	3823137	Pistion ring expander