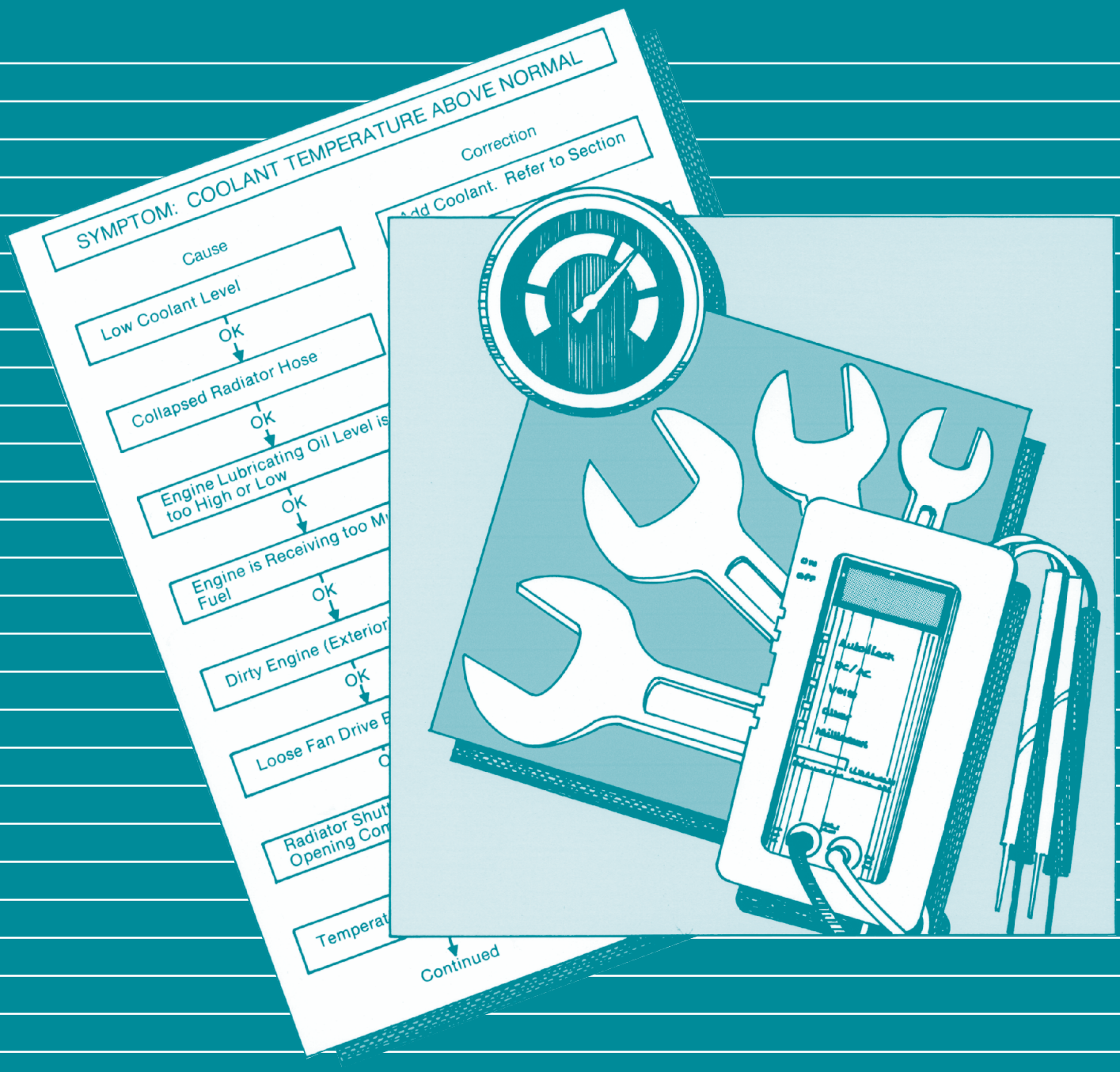
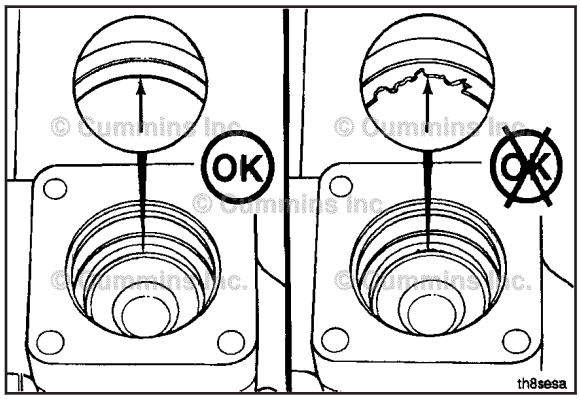
Troubleshooting and Repair Manual
C Series Engines

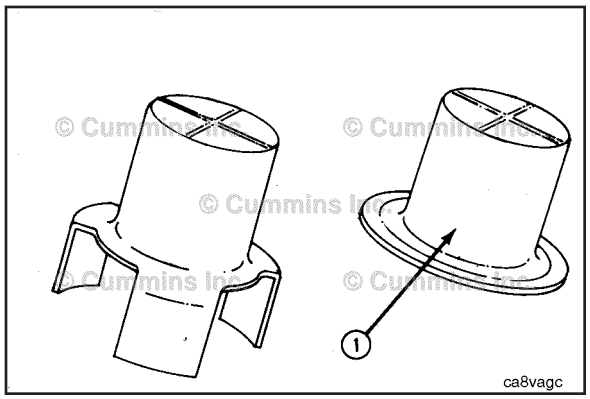




Illustrations

General Information

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



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

Acronyms and Abbreviations

General Information

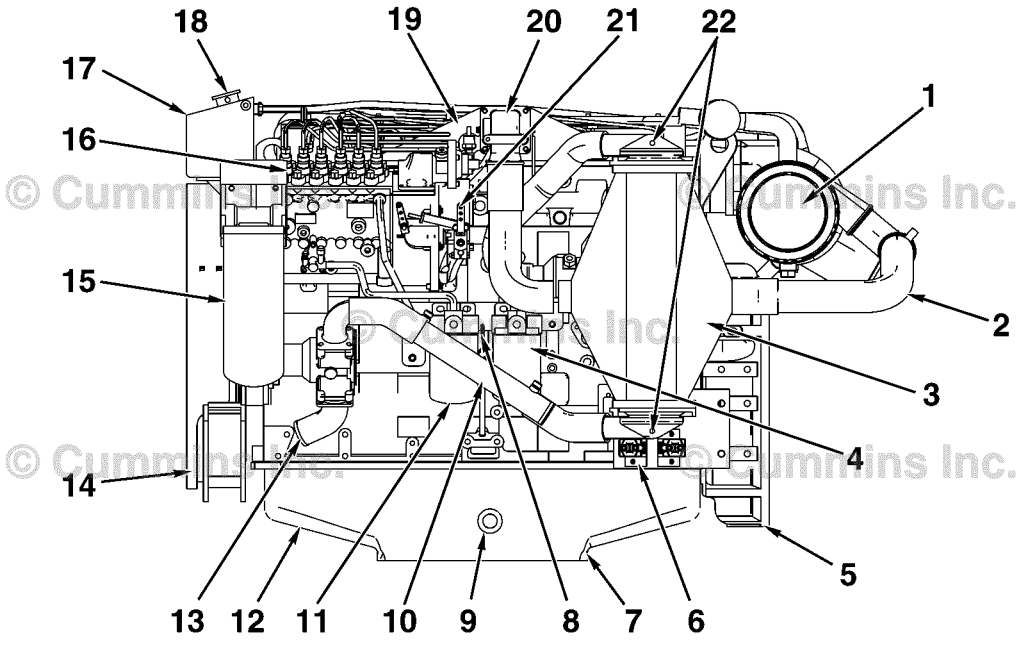
The following list contains some of the acronyms and abbreviations used in this manual.

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
ATDC	After Top Dead Center
BTU	British Thermal Unit
BTDC	Before Top Dead Center
°C	Celsius
CAN	Controller Area Network
CO	Carbon Monoxide
CCA	Cold Cranking Amperes
CARB	California Air Resources Board
C.I.B.	Customer Interface Box
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CPL	Control Parts List
cSt	Centistokes
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECM	Engine Control Module
EFC	Electronic Fuel Control
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
°F	Fahrenheit
ft-lb	Foot-Pound Force
FMI	Failure Mode Indentifier
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H_2O	Water
inHg	Inches of Mercury
in H_20	Inches of Water
ICM	Ignition Control Module
IEC	International Electrotechnical Commission
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquid Natural Gas
LPG	Liquified Petroleum Gas
LTA	Low Temperature Aftercooling
MCRS	Modular Common Rail System
MIL	Malfunction Indicator Lamp
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter

Engine Diagrams

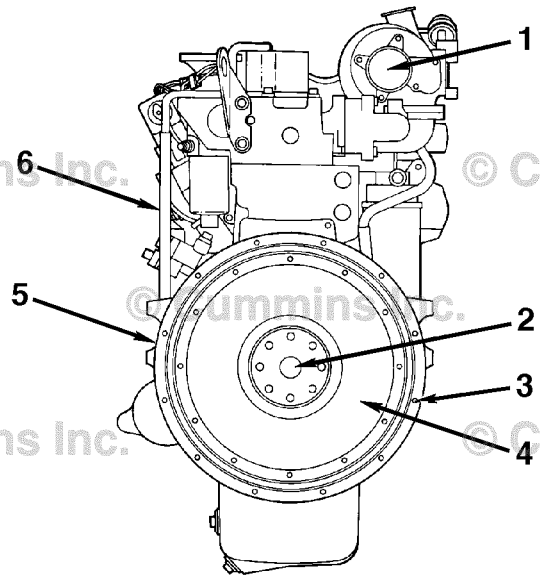
Engine Views

Marine Applications



Port View, C 8.3, Six-Cylinder Sea Water Aftercooled 450C

1 Air cleaner
2 Inlet air crossover tube
3 Aftercooler (sea water-type)
4 Water (coolant) filter
5 Flywheel housing
6 Air heater control solenoids
7 Engine oil drain, rear
8 Dipstick (engine oil) port-side standard
9 Oil pan heater location (if equipped)
10 Fuel cooler
11 Fuel filter (standard)
12 Oil pan
13 Sea water pump inlet (rotatable)
14 Belt guard
15 Remote mounted oil filter (optional)
16 Fuel pump
17 Expansion tank
18 Coolant fill
19 Stop lever
20 Air heater
21 Throttle lever
22 Zinc plugs (aftercooler).



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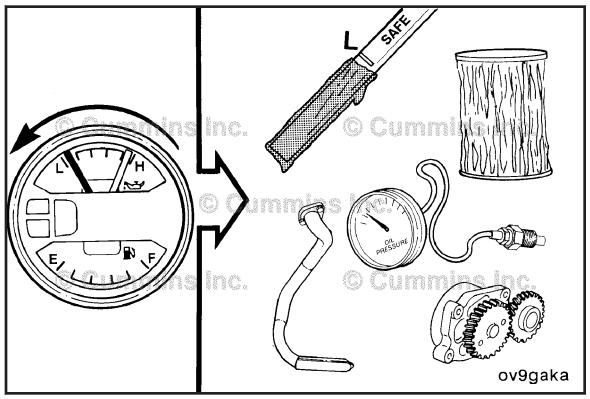
Rear View - C8.3 - Automotive

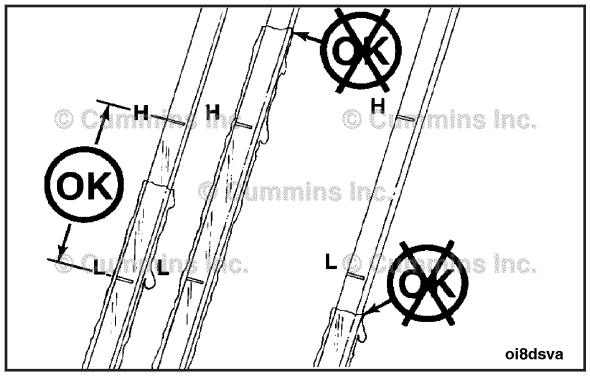
1 Turbocharger exhaust outlet
2 Pilot bearing bore
3 Transmission mounting holes
4 Flywheel
5 Flywheel housing
6 Crankcase breather vent tube.

Technology	Name	Suffix
Exhaust Gas Recirculation	Not used	None
	Pneumatic	P
	Electric	E
Diesel Particulate Filter (DPF)	Not used	None
	Full Flow DPF	F
	Partial Flow DPF	F2
Diesel Oxidation Catalyst	Not used	None
	DOC	C
3-Way Oxidation Catalytic Converter	Not used	None
	3-Way Catalyst	J
Selective Catalytic Reduction System	Not used	None
	Air Driven	S
	Airless	A
Nox Sensor	Not used	None
	Nox Sensor	N
Modular Common Rail System	Used only on QSK19, 38, 50 , 60 HHP Engines	MCRS
Integrated Dosing Control Unit	Not Used	None
	Integrated	I



Low Oil Pressure

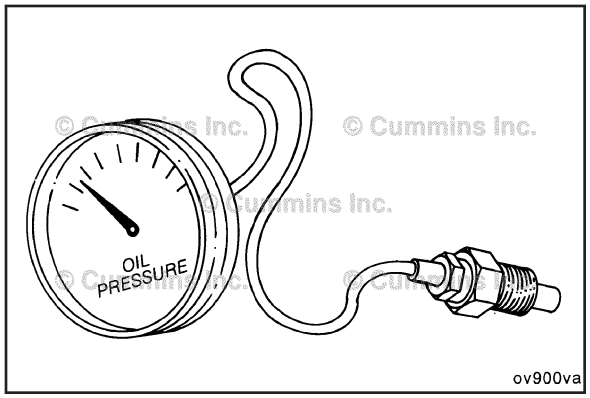
Low oil pressure can be caused by several lubrication system-related malfunctions. To begin the investinvestigation, determine the engine operating conditions when the low pressure was first observed.



Oil Level

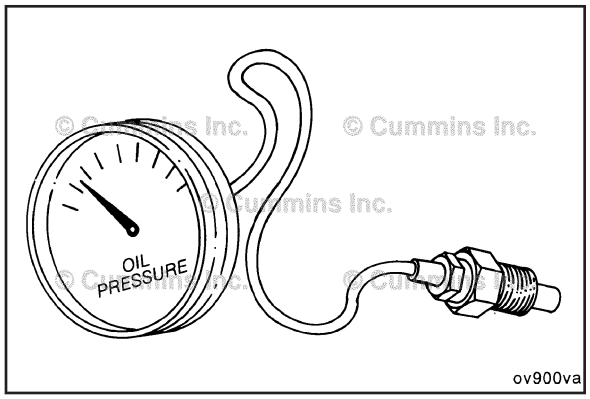
An improper lubricating oil level can cause low lubricating oil pressure.

△CAUTION△
Never operate the engine with the oil level below the low (L) mark or above the high (H) mark.



Oil Filter

A plugged filter will cause a gradual loss of oil pressure by approximately 69 kPa [10 psi]. This will cause the bypass valve to open, allowing unfiltered oil to flow to internal engine components. The oil pressure will remain low until a new filter is installed.



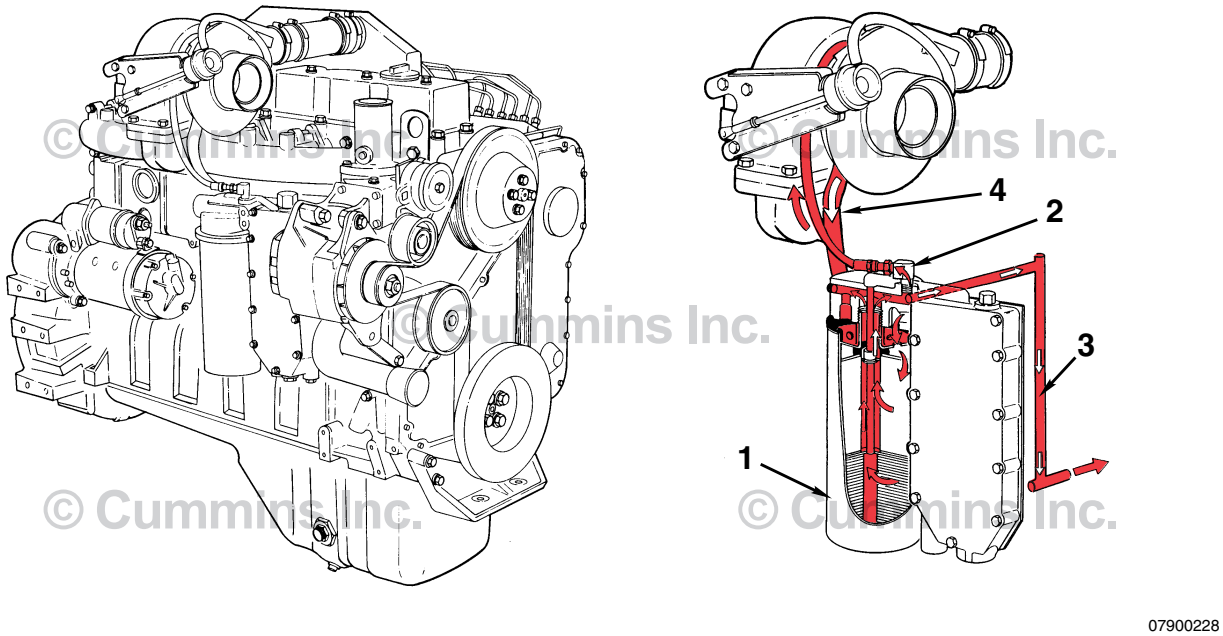
Oil Pressure Gauge - Inspection

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

Flow Diagram, Lubricating Oil System (200-002)

Engine Views

All Applications



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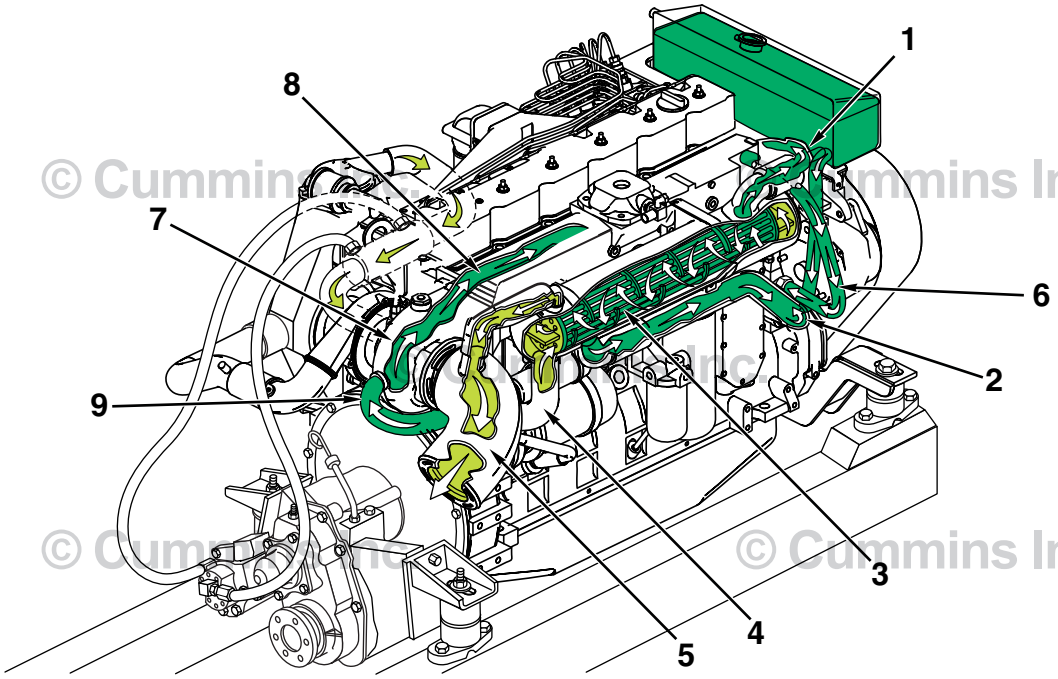
1 Oil filter
2 Turbocharger oil supply line
3 Flow to main oil rifle
4 Turbocharger oil drain line.

Flow Diagram, Cooling System (200-003)

Engine Views

Industrial and Marine



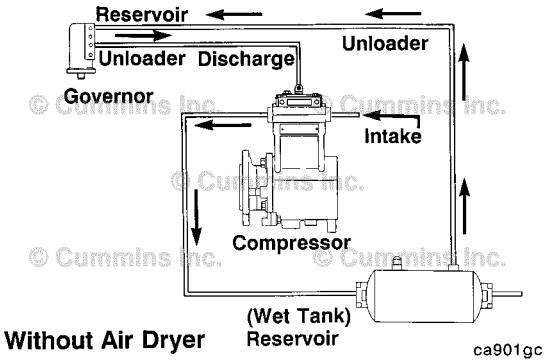
Sea Water Aftercooled

1. From thermostat (coolant outlet)
2. To water pump (coolant inlet)
3. Heat exchanger
4. Sea water from pump
5. Sea water outlet (in exhaust)
6. Coolant from exhaust manifold to block
7. Turbocharger exhaust housing
8. Exhaust manifold
9. Coolant from block.

Compressed Air System - Overview (012-999)

General Information

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



The Holset® QE296 single-cylinder air compressor is an engine-driven, piston-type compressor that supplies compressed air to operate air-activated devices. The compressor runs continuously but has loaded and unloaded operating modes. The operating mode is controlled by a pressure-activated governor and the compressor unloading assembly.

The QE296 air compressor used on C Series engines uses an (E-type) unloader. The economy (E-type) unloader system was designed to reduce pumping losses and engine boost pressure losses through the compressor intake valve while operating in unloading mode.

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

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

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

⚠CAUTION⚠

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

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

Other brands of air compressors can be used on C Series engines. Troubleshooting procedures are very similar for these air compressors compared to the Holset® QE296. Refer to the specific air compressor manufacturer's manual for detailed repair information and torque specifications.

The Holset® heavy-duty (HD) air compressors was designed for the C Series engine. Applications include industrial markets, such as transit buses, refuse trucks, on-off highway construction vehicles, and other.

The Holset® heavy-duty model air compressor is a continuous pump version of the QE model already released for the C Series engines. The air compressor crank housing and head are the same; however, the Holset® heavy-duty model does **not** have an integral unloader. Unloading is controlled at the air dryer by way of an internal or external air governor. A discharge line unloader is required for installations **without** air dryers.

The advantage of this air compressor is that the downstream plumbing is simplified because of the elimination of the unloader valve. Standard valves have been replaced with Reed valves to enable the air compressor to run continuously without valve endurance issues.

During unloaded operations, the air compressor's discharge air is continuously vented to the atmosphere through the air dryer's purge port.

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Driveability - General Information

Driveability is a term that in general describes vehicle performance on the road. Driveability problems for an engine can be caused by several different factors. Some of the factors are engine-related and some are **not**.

Before troubleshooting, it is important to determine the exact complaint and whether the engine has a real driveability problem or if it simply does **not** meet driver expectations. The Driveability-Low-Power Customer Complaint Form is a valuable list of questions that **must** be used to assist the service technician in determining what type of driveability problem the vehicle is experiencing. Complete the checklist before troubleshooting the problem. The form can be found at the end of this section. If an engine is performing to factory specifications but does **not** meet the customer's expectations, explain to the customer that nothing is wrong with the vehicle and why.

The troubleshooting symptom charts have been set up to divide driveability problems into two different symptoms: Engine Power Output Low and Engine Acceleration or Response Poor.

Low power is a term that is used in the field to describe many different performance problems. However, in this manual low power is defined as the inability of the engine to produce the power necessary to move the vehicle at a speed that can be reasonably expected under the given conditions of load, grade, wind, and so on. Low power is usually caused by the lack of fuel flow that can be caused by any of the following factors:

- Lack of full travel of the throttle pedal
- Failed boost sensor
- Excessive fuel inlet, intake, exhaust, or drainline restriction
- Loose fuel pump suction lines.

Low power is **not** the inability of the vehicle to accelerate satisfactorily from a stop or the bottom of a grade. Refer to the Engine Power Output Low troubleshooting symptom tree in Section TS for the proper procedures to locate and correct a low-power problem. The chart starts off with basic items that can cause lower power.

Poor acceleration or response is described in this manual as the inability of the vehicle to accelerate satisfactorily from a stop or from the bottom of a grade. It can also be the lag in acceleration during an attempt to pass or overtake another vehicle at conditions less than rated speed and load. Poor acceleration or response is difficult to troubleshoot since it can be caused by factors such as:

- Engine- or pump-related factors
- Driver technique
- Improper gear shifting
- Improper engine application
- Worn clutch or clutch linkage.

Engine-related poor acceleration or response can be caused by several different factors such as:

- Failed boost sensor
- Excessive drainline restriction
- Throttle deadband.

Refer to the Engine Acceleration or Response Poor troubleshooting symptom tree in Section TS for the proper procedures to locate and correct a poor acceleration or response complaint. For additional information, see Troubleshooting Driveability Complaints, Bulletin Number 3387245.

Engine Noise Diagnostic Procedures - General Information

NOTE: When diagnosing engine noise problems, make sure that noises caused by accessories, such as the air compressor and power take-off, are **not** mistaken for engine noises. Remove the accessory drive belts to eliminate noise caused by these units. Noise will also travel to other metal parts **not** related to the problem. The use of a stethoscope can help locate an engine noise.

Engine noises heard at the crankshaft speed, engine rpm, are noises related to the crankshaft, rods, pistons, and piston pins. Noises heard at the camshaft speed, one-half of the engine rpm, are related to the valve train. A handheld digital tachometer can help determine if the noise is related to components operating at the crankshaft or camshaft speed.

Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously)

This is symptom tree t008

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121 and the OEM service manual.

OK
Go To Next Step

STEP 2 Air compressor intake or exhaust valve leaks air	Inspect the air compressor intake and exhaust valve assemblies. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

OK
Go To Next Step

STEP 3 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause		Correction
STEP 18 Fuel injection pump is malfunctioning	.....	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.

OK
Go To Next Step

STEP 19 Plugged cooling passages in the cylinder head, head gasket, or cylinder block	.....	Pressure-test the cooling system. Refer to Procedure 008-018.

OK
Go To Next Step

STEP 20 Cooling system has insufficient capacity	.....	Refer to the OEM service manual.

Engine Acceleration or Response Poor

This is symptom tree t033

Cause	Correction
STEP 27 Injectors are **not** correct	Remove the injectors and compare the part numbers to the Control Parts List (CPL), Bulletin 3379133 or 4021327. Replace the injectors if necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 28 Injector is malfunctioning	Inspect the injectors. Replace the injectors as necessary. Refer to Procedure 006-026.
OK Go To Next Step	
STEP 29 Fuel supply line restriction between the fuel pump and the injectors	Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions. Refer to Procedure 006-024.
OK Go To Next Step	
STEP 30 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.
OK Go To Next Step	
STEP 31 Fuel injection pump is malfunctioning	Remove and test the fuel injection pump. Replace the pump if necessary. Refer to Procedure 005-012.
OK Go To Next Step	
STEP 32 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-013.

Engine Noise Excessive — Connecting Rod

This is symptom tree t049

Cause	Correction
STEP 1 Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 and Procedure 007-025.
OK Go To Next Step	
STEP 2 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer toProcedure 007-025.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Refer to Cummins Lubricating Oil Reccomendations, Bulletin 3810240 and the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 4 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.
OK Go To Next Step	
STEP 5 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 6 Connecting rod capscrews are loose or **not** tightened correctly	Check the torque on the connecting rod capscrews. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 7 Connecting rod bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings	Inspect the connecting rod bearings. Refer to Procedure 001-005.

Engine Runs Rough or Misfires

This is symptom tree t062

Cause	Correction
STEP 1 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 2 Fuel leak	Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to Procedure 006-024.
OK Go To Next Step	
STEP 3 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 4 Air in the fuel system	Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.
OK Go To Next Step	
STEP 5 Fuel contaminated	Verify by operating the engine with clean fuel from a temporary tank.
OK Go To Next Step	
STEP 6 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	
STEP 7 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 8 Fuel injection pump timing is **not** correct	Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.
OK Go To Next Step	
STEP 9 Valves are **not** sealing correctly	Check and adjust the valves. Refer to Procedure 003-004.
OK Go To Next Step	

Engine Will Not Reach Rated Speed (RPM)

This is symptom tree t080

Cause	Correction
STEP 8 Poor fuel quality or wrong fuel grade	Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuel for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 9 Fuel filter or fuel inlet restriction	Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.
OK Go To Next Step	
STEP 10 Fuel pump return overflow valve is malfunctioning	Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.
OK Go To Next Step	
STEP 11 Manifold drain line restricted (Lucas CAV DPA **only**)	Check and remove restriction. Refer to Procedure 006-021.
OK Go To Next Step	
STEP 12 Fuel transfer pump malfunctioning	Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.
OK Go To Next Step	
STEP 13 Drivetrain or propeller is damaged or is **not** correctly matched to the engine	Check for the correct gearing, drivetrain components, or propeller. Refer to the manufacturer's specification.
OK Go To Next Step	
STEP 14 Turbocharger wastegate is malfunctioning (if equipped)	Check the wastegate for correct operation. Refer to Procedure 010-050.
OK Go To Next Step	
STEP 15 Fuel injection pump is malfunctioning	Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.
OK Go To Next Step	

Intake Manifold Air Heater System Malfunctioning

This is symptom tree t097-25

Cause	Correction
STEP 1 Batteries have failed	Check the condition of the batteries, replace if necessary. Refer to Procedure 013-007.
OK Go To Next Step	
STEP 2 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK Go To Next Step	
STEP 3 Fuse(s) malfunctioning	Replace the battery circuit fuse(s). Refer to Procedure 010-122.
OK Go To Next Step	
STEP 4 Low voltage	Check wire gauge, check batteries. Refer to the Marine Recreational High Output Propulsion Units B and C Series Installation Directions, Bulletin 3884649 and Procedure 010-122.
OK Go To Next Step	
STEP 5 Intake manifold heater wiring harness malfunctioning	Check the wiring harness. Refer to Procedure 010-122.
OK Go To Next Step	
STEP 6 Solenoid valve is malfunctioning	Check for voltage at the solenoid valve. Procedure 010-126
OK Go To Next Step	
STEP 7 Intake air temperature sensor is malfunctioning	Check the intake air temperature sensor. Refer to Procedure 010-123.
OK Go To Next Step	
STEP 8 Intake air heater element malfunctioning	Check and replace if necessary. Refer to Procedure 010-124.
OK Go To Next Step	
STEP 9 Engine speed sensor or circuit is malfunctioning	Check the engine speed sensor for correct adjustment and for debris on the sensor. Check the engine speed sensor circuit. Refer to Procedure 010-127.
OK Go To Next Step	

Lubricating or Transmission Oil in the Coolant

This is symptom tree t108

Cause		Correction
STEP 1 Bulk coolant supply is contaminated	.....	Check the bulk coolant supply. Drain the coolant and replace with noncontaminated coolant. Replace the coolant filters. Refer to Procedure 007-025.

OK
Go To Next Step

STEP 2 Lubricating oil cooler is malfunctioning	.....	Check the oil cooler. Refer to Procedure 007-003.

OK
Go To Next Step

STEP 3 Torque converter cooler or hydraulic oil cooler is malfunctioning	.....	Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.

OK
Go To Next Step

STEP 4 Air compressor cylinder head is cracked or porous, or has a leaking gasket	.....	Inspect the air compressor cylinder head and gasket. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

OK
Go To Next Step

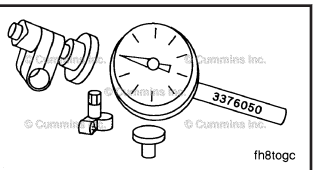
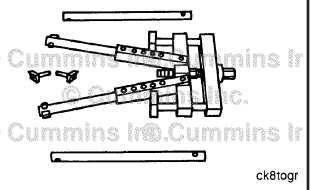
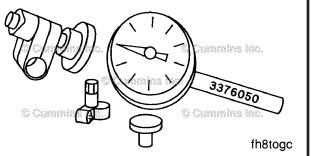
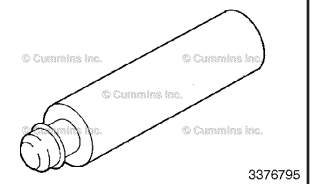
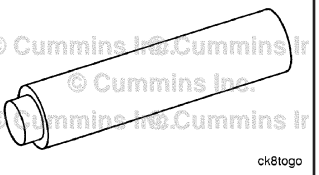
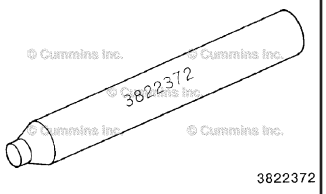
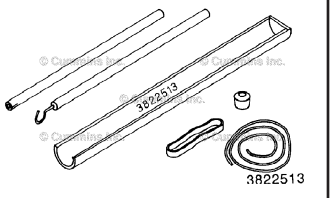
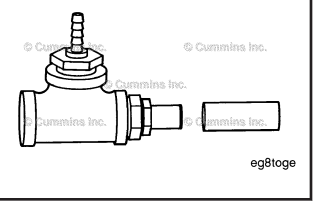
STEP 5 Cylinder head gasket is leaking	.....	Check the cylinder head gasket. Refer to Procedure 002-004.

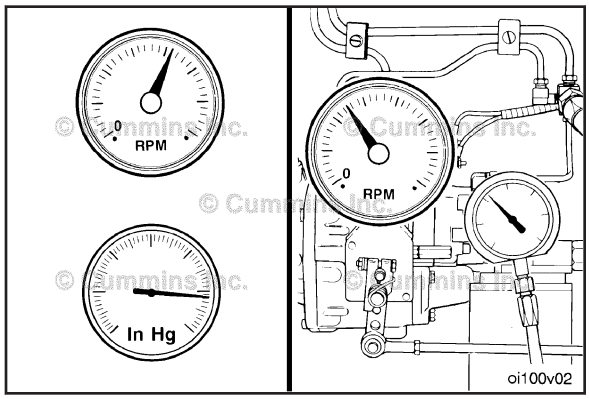
OK
Go To Next Step

STEP 6 Cylinder head is cracked or porous	.....	Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.

OK
Go To Next Step

STEP 7 Cylinder block is cracked or porous	.....	Inspect the cylinder block. Refer to Procedure 001-026.

Tool No.	Tool Description	Tool Illustration
ST-1325	**Dial Gauge Attachment** Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.	
3376015	**Cylinder Liner Puller** Removes cylinder liners from the cylinder block. Require two, Part No. 3376649 puller arm extension feet.	
3376050	**Dial Indicator and Sleeve Assembly** Used to measure flywheel and flywheel housing runout.	
3376795	**Expansion Plug Driver Handle** Used with all expansion plug drivers larger than 0.375-inch diameter.	
3376816	**Expansion Plug Driver** Install 1-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No.3376795.	
3822372	**Expansion Plug Driver** Install 0.375-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No. 3376795.	
3822513	**Tappet Removal Tool Kit** Used to remove and install valve tappets.	
3822566	**Blowby Check Tool** Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.	



Operate the engine at 1000 to 1200 rpm for 8 to 10 minutes to check for correct engine operation, unusual noises, and coolant, fuel, or lubricating oil leaks.

Repair all leaks and component problems as needed. Refer to the appropriate sections.

Refer to the following procedures for the Engine Run-in and Testing Procedures.

014-002
014-003
014-004

Engine Storage - Long Term (000-005)

General Information

⚠WARNING⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠CAUTION⚠

After 24 months in storage, the engine cooling system must be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Repeat flushing procedure a second time before being put back into service.

This procedure describes the proper method for the long-term (more than 6 months) storage of an engine that is currently in running condition. This procedure applies to this engine either remaining in chassis - or being removed out of chassis upon completion of the steps below.

Prepare the Engine for Long Term Storage

⚠CAUTION⚠

DO NOT use fuel system preservative oil on Natural Gas or Propane Engines.

- Operate the engine at high idle until the coolant temperature is 70°C [158°F].
- Turn the engine off.
- Drain the oil.
- Install the drain plugs.
- Fill the engine oil pan sump to the high mark using Tectyl™ 910 or equivalent engine preservative oil. This will provide long term engine rust protection. The oil **must** meet military specification MIL-PRF-21260, Type P-10, Grade 2, SAE 30.

Internal Preservation of the Fuel System with Mechanically and Electronically Actuated Injectors.

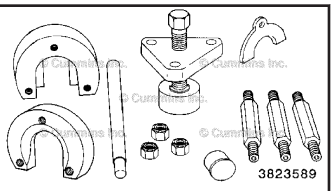
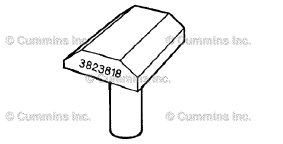
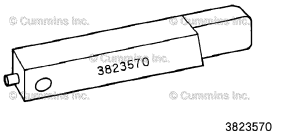
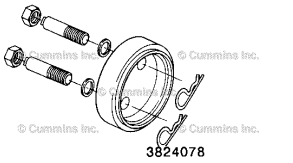
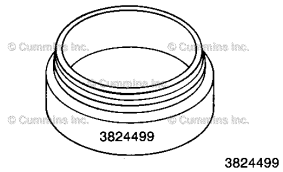
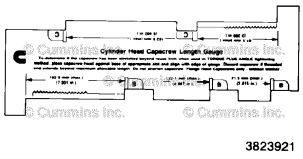
⚠CAUTION⚠

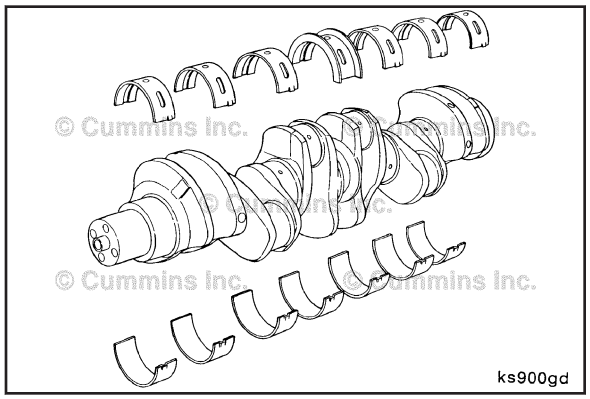
DO NOT use diesel fuel containing bio components for internal preservation of fuel system for engine storage. Fuel properties degradation may cause damages and lead to premature failure of fuel system components.

- Disconnect the fuel lines to the engine fuel filter and the injector return line.
- Use Diesel Pump and Injector calibration fluid that meets ISO 4113 standard, SAE J967d standard and Bosch VS 15665-OL standard.

NOTE: Using calibration fluid allows storage for up to 12 months. After 12 months the engine fuel system **must** be drained and flushed again with fresh calibration fluid. Repeat after each 12-month period.

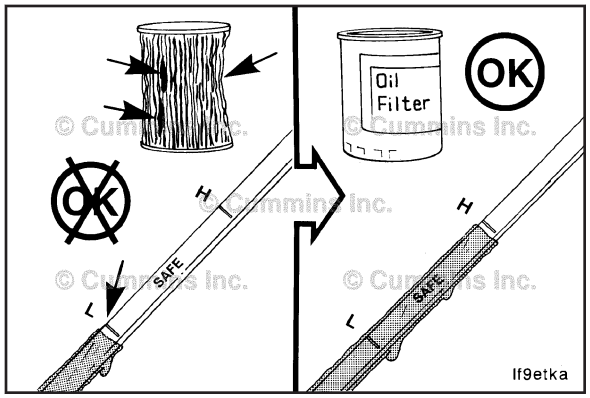
Alternatively you can use the diesel fuel with 0 percent bio components content for Internal Preservation of the Fuel System.

Tool No.	Tool Description	Tool Illustration
3823589	**Camshaft Gear Installation/Removal Tool** Used to remove and install the camshaft gear from the camshaft with the camshaft installed.	
3823818	**Main Bearing Rollout Tool** Used to remove and install main bearings with the crankshaft installed.	
3823567	**Cutter Plate** Used with Part Number 3823558, cylinder liner counterbore tool.	
3823570	**Cutter Bit** Used with Part Number 3826567, cutter plate, to machine the cylinder liner counterbore ledge.	
3824078	**Wear Sleeve Installation Tool** Used to install the rear crankshaft lubricating oil seal wear sleeve.	
3824499	**Lubricating Oil Seal Installation Tool** Used to install the front lubricating oil seal in the front cover to a specified depth.	
3823921	**Capscrew Length Gauge** Used to measure capscrew free length.	
3375068	**Cup Plug Sealant** Used when installing pipe plugs and cup plugs to prevent leaks.	

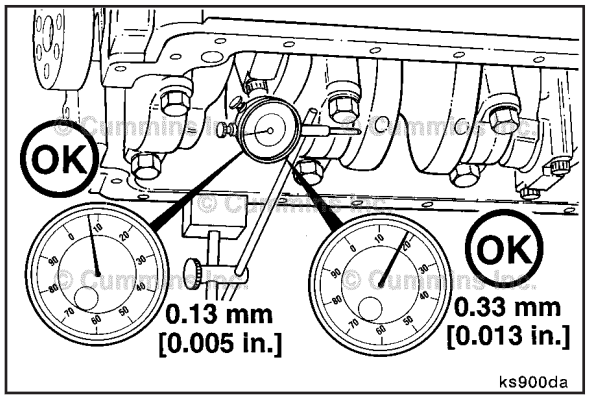


NOTE: Oversize service main bearings are available for reground crankshafts.

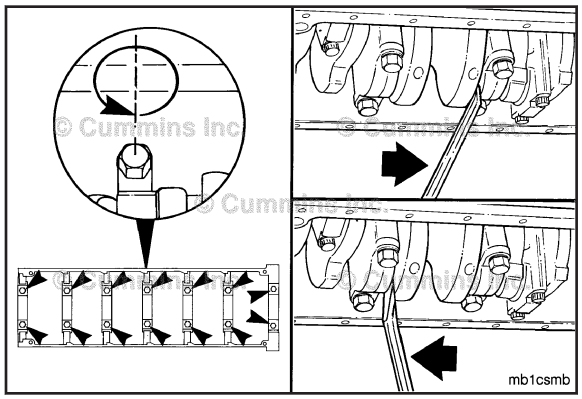
Main Bearing Sizes	
Standard	
Oversize	- 0.25 mm (0.009 in)
	- 0.50 mm (0.019 in)
	- 0.75 mm (0.029 in)
	- 1.00 mm (0.039 in)



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

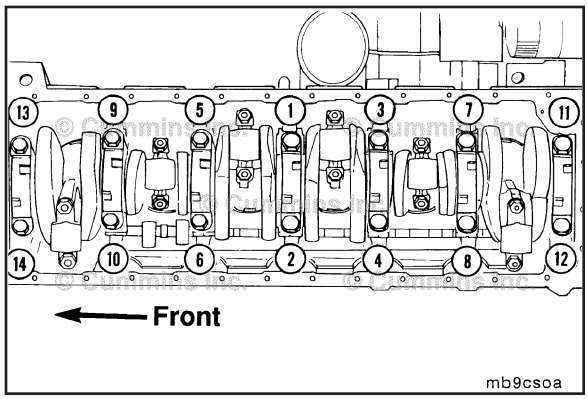


Increased end loading of the engine and its driven units at the front or rear of the engine can cause damage to the thrust bearings.



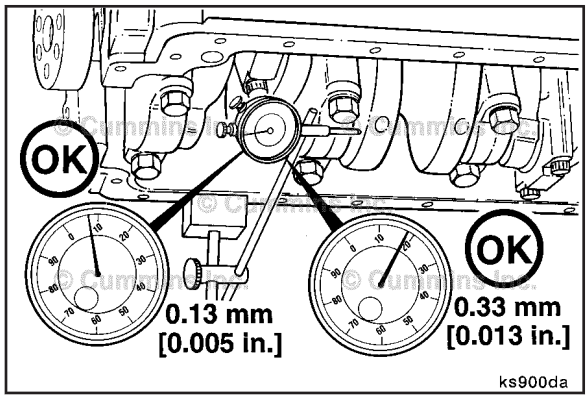
If the end clearance is less than 0.127 mm [0.005 in], do the following:

- Loosen the main bearing capscrews one turn.
- Push the crankshaft toward the front and then toward the rear of the cylinder block.



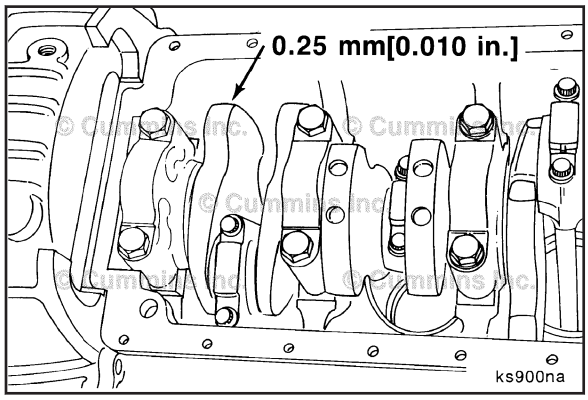
Tighten the main bearing capscrews in the sequence shown.

Torque Value: Step1 50 N•m [37 ft-lb]
Step2 95 N•m [70 ft-lb]
Step3 60° turn.



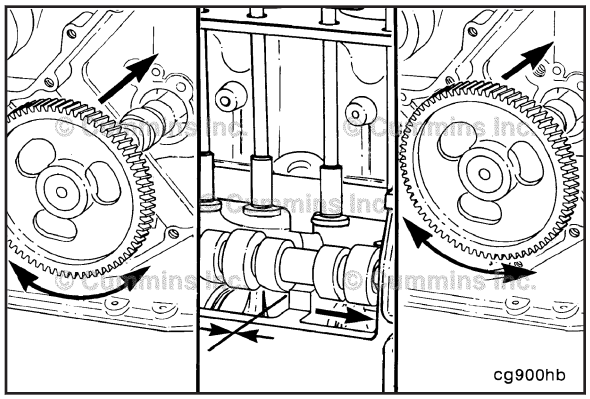
Measure the crankshaft end clearance.

Crankshaft End Clearance		
mm		**in**
0.127	MIN	0.005
0.330	MAX	0.013

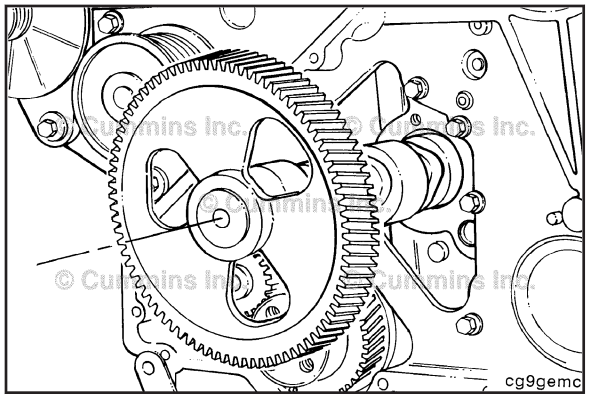


NOTE: Crankshafts that have been reground on the thrust bearing surfaces are marked for oversize thrust bearings on the rear crankshaft counterweight. If the crankshaft counterweight is marked, check the thrust bearing part number to make sure the correct bearing size is used.

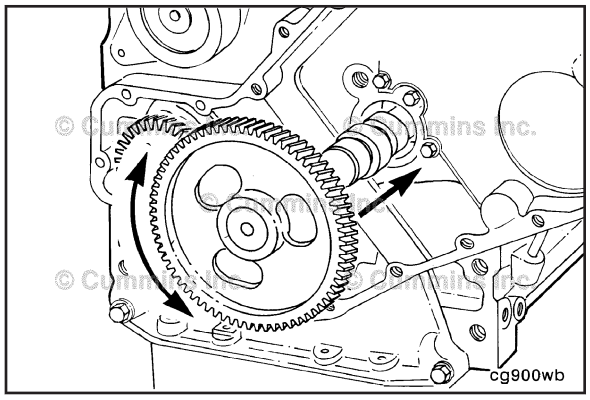
Example: 0.010 = 0.25 mm [0.010 in]



Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft installtion to continue.

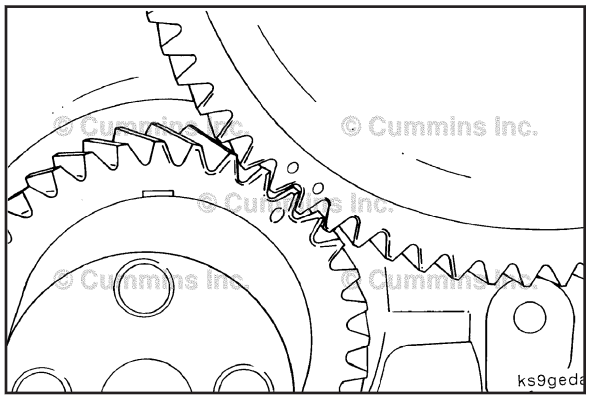


Position the camshaft and gear assembly into the cylinder block up to the last journal.

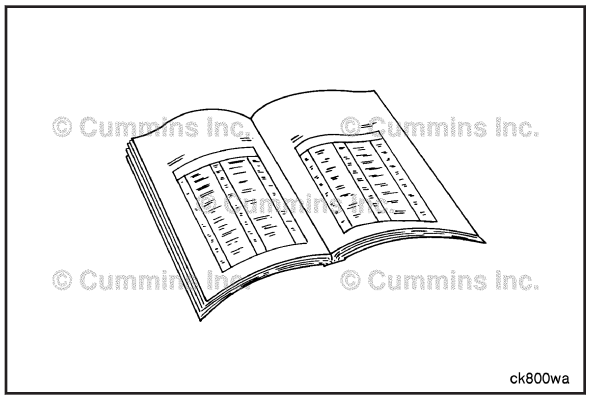


△CAUTION△
Do not try to force the camshaft into the camshaft bore, damage to the camshaft bushing can result.

Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft will rotate freely.



Align the timing marks on the camshaft with the timing marks on the crankshaft.



Connecting Rod (001-014)

Preparatory Steps

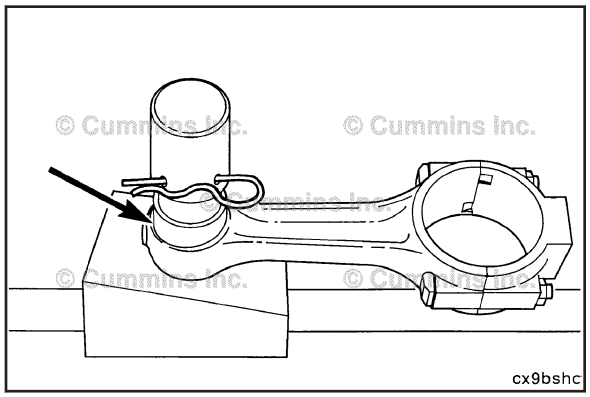
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

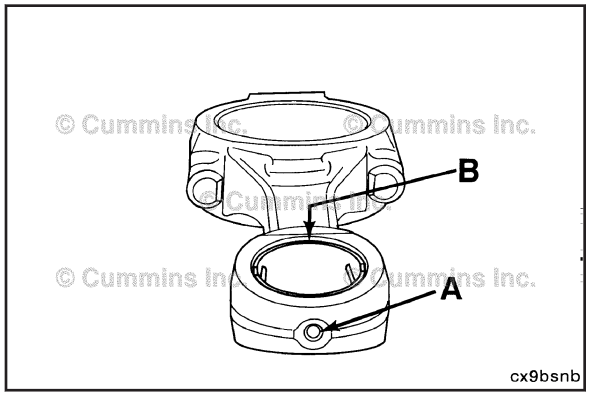
- Close the fuel supply valve. Refer to the OEM instructions.
- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Drain the coolant. Refer to Procedure 008-018 (Cooling System) in Section 8.
- Remove the cylinder head. Refer to Procedure 002-004 (Cylinder Head) in Section 2.
- Drain the lubricating oil. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 (Lubricating Oil Pan) in Section 7.
- Remove lubricating oil suction tube. Refer to Procedure 007-035 (Lubricating Oil Suction Tube (Block-Mounted)) in Section 7.
- Remove and disassemble the piston and connecting rod assemblies. Refer to Procedure 001-054 (Piston and Connecting Rod Assembly) in Section 1.



Press the bushing into the connecting rod by applying force on the top of the cup.

Use either an arbor or hydraulic press.

Push through in a continuous motion until the driver ring makes contact with the connecting rod.



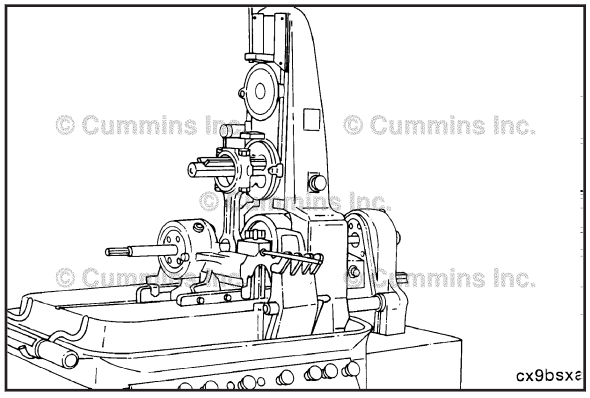
Check the alignment of the oil holes.

A 3 mm [0.118 in] diameter rod **must** move freely through the connecting rod and the bushing oil holes (A).

Check for clearance between the connecting rod bushing and the connecting rod.

Use a 0.025 mm [0.001 in] feeler gauge to make sure the bushing is properly seated.

The 0.025 mm [0.001 in] feeler gauge **must not** enter between the bushing and the connecting rod (B).

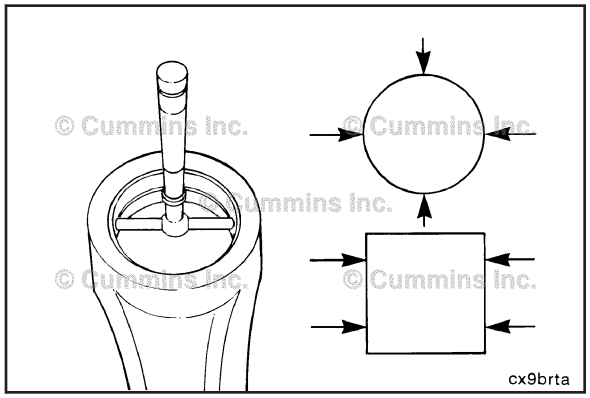


Machine

The inside diameter of new connecting rod bushings **must** be machined with a rod boring machine, such as Part Number 3823601 (Sunnen PM-300®) or Part Number 3375144 (Tobin Arp®).

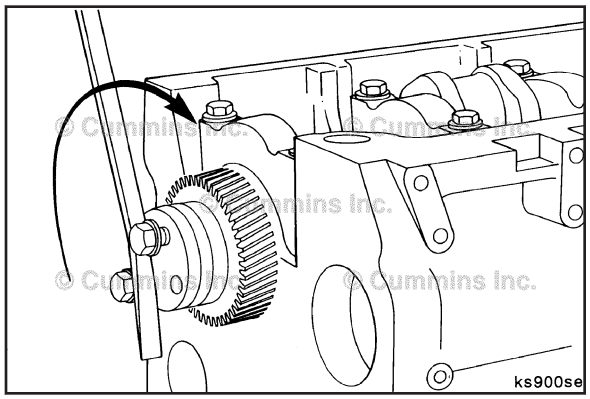
When properly adjusted, a Sunnen PM-300®, or equivalent, connecting rod boring machine is capable of maintaining all the critical dimensions.

Do **not** use a ”floating rod" type honing machine.



After machining the connecting rod bushings, it will be necessary to check all critical dimensions.

See the instructions within this procedure.



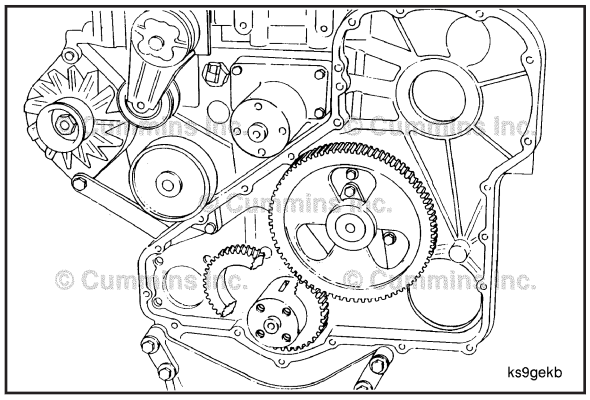
NOTE: The crankshaft **must** rotate freely after the main bearings have been installed.

Inspect the main bearing installations and the size of the main bearings if the crankshaft will **not** rotate freely.

Crankshaft Gear, Front (Crankshaft Installed) (001-018)

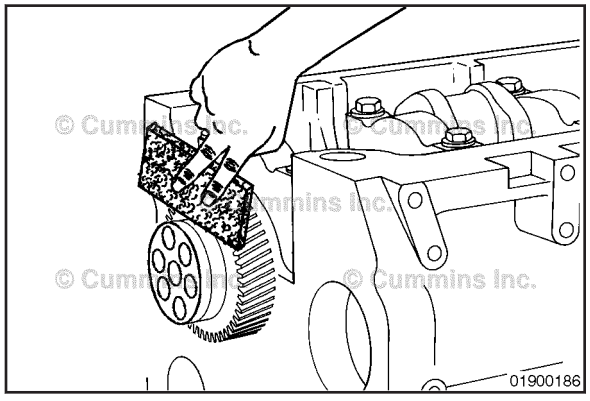
General Information

The front crankshaft gear has an interference fit with the crankshaft. If the gear is damaged, the crankshaft will also be damaged. If it is necessary to replace the front crankshaft gear, the crankshaft **must** be replaced. Refer to Procedure 001-016 in the Troubleshooting and Repair Manual, C8.3G, C Gas Plus, and L Gas Plus Engines, Bulletin 3666206 or Procedure 001-016 in the Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003.

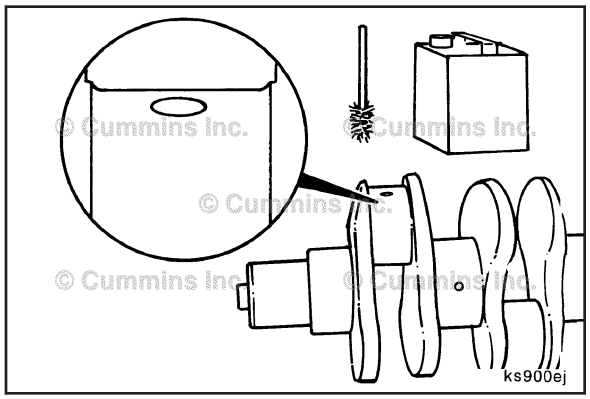


Inspect for Reuse

Inspect the crankshaft gear for cracks and broken or chipped teeth.



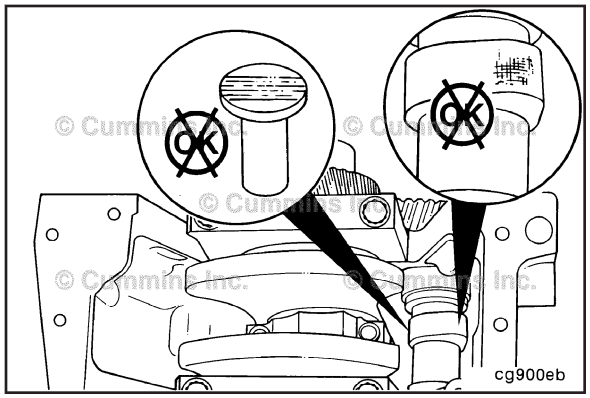
Remove any burrs with Scotch-Brite™ 7448 abrasive pad, Part Number 3823258.



NOTE: Remove the covering from the piston cooling nozzles.

Remove the protective tape and cloth from the crankshaft journals.

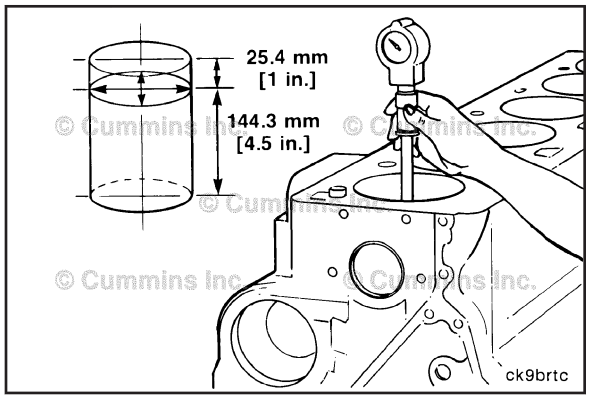
Clean the crankshaft journals.



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

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

NOTE: Inspect the camshaft lobes and tappet faces for signs of wear or damage. Refer to Procedure 001-008.



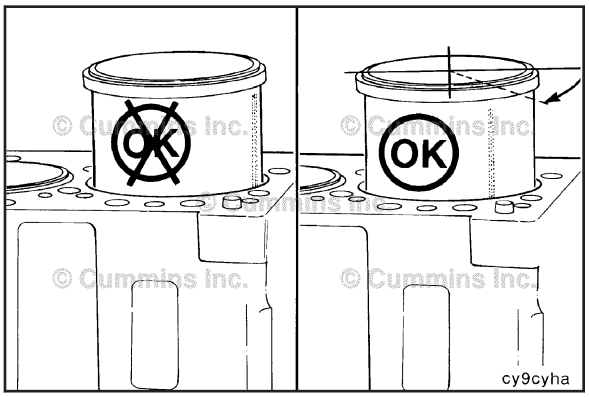
Inspect for Reuse

Measure the cylinder bore diameter at 25.4 mm [1 in] and 170.7 mm [5.5 in] from the top of the cylinder block.

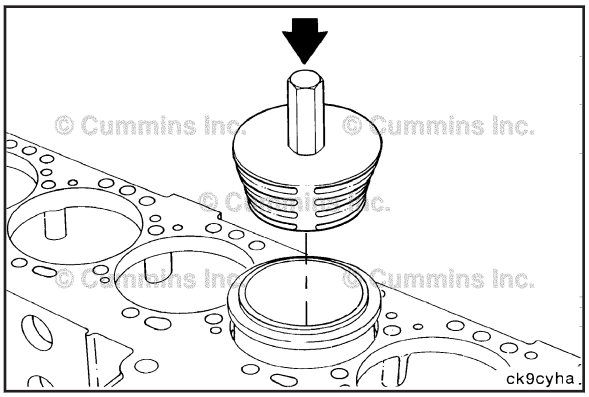
Cylinder Bore Dimensions

	mm		in
Bore Inner Diameter	114.00	MIN	4.488
	114.04	MAX	4.990
Bore Out of Round	0.08	MAX	0.003
Bore Taper	0.02	MAX	0.001

NOTE: Do **not** proceed with in chassis overhaul if the cylinder bores are worn beyond specifications.

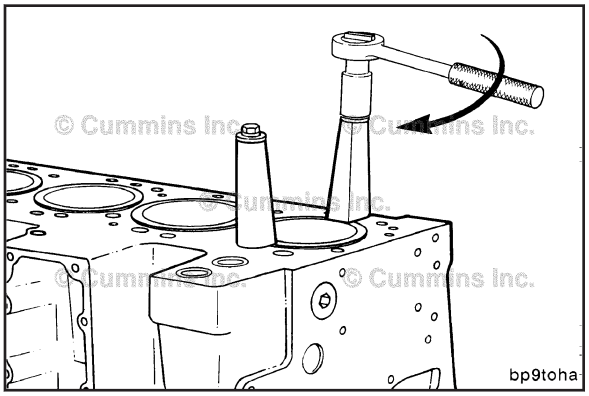


NOTE: When reusing liners, install them in the same cylinder from where they were removed, and rotate the liner 45 degrees (1/8 of a turn) from their original position. When correctly installed, any liner pitting can be positioned as illustrated so the pitted surface is rotated away from the location where pitting occurs.



Install the cylinder liners into the bore of the cylinder block, use cylinder liner driver, Part Number ST-1229, and a leather mallet.

NOTE: If the liner does **not** rest on the cylinder block counterbore seat, remove the liner. Inspect the counterbore seat and liner for nicks, burrs, or dirt. Install the liner again.

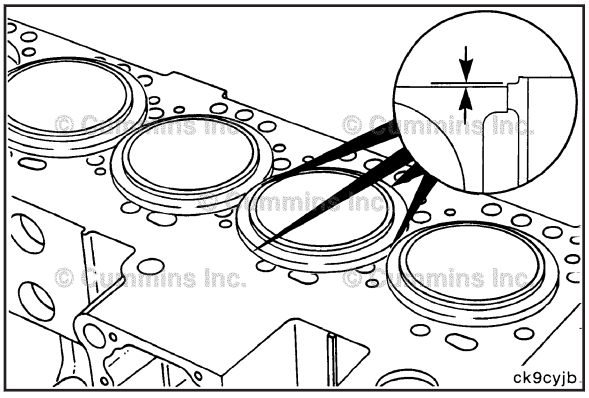


Use two cylinder head capscrews and position the two liner clamps, Part Number 3822503, as illustrated.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

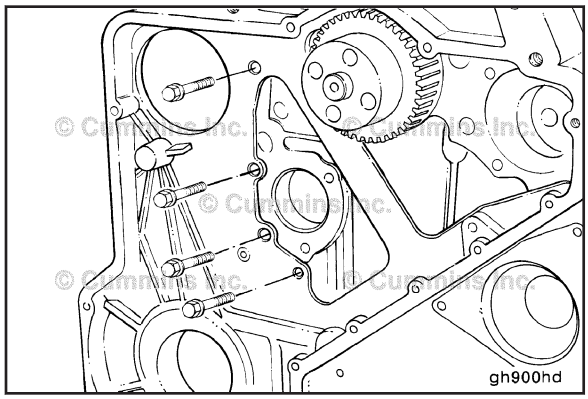
Remove the clamps and repeat this procedure until all liners have been clamped and released.



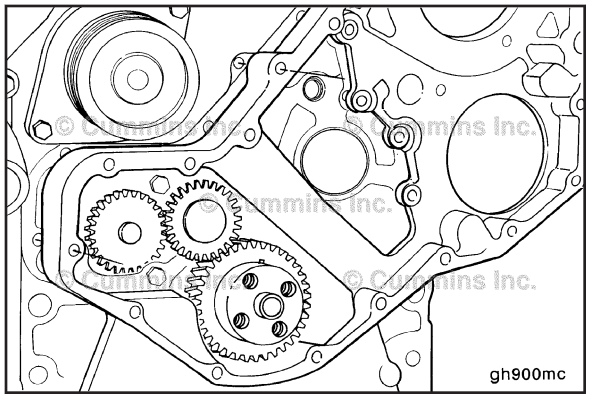
Liner protrusion is the distance the liner protrudes above the block face.

Measure the liner protrusion with the liner protrusion gauge, Part Number 3823495, at four points 90 degrees apart.

Cylinder Liner Protrusion		
mm		**in**
0.025	MIN	0.001
0.122	MAX	0.005

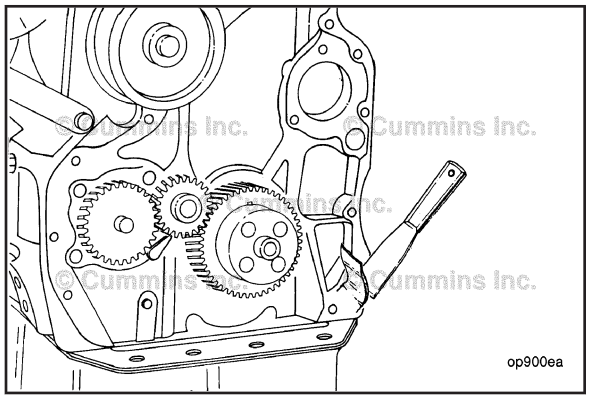


Remove the front gear housing capscrews.



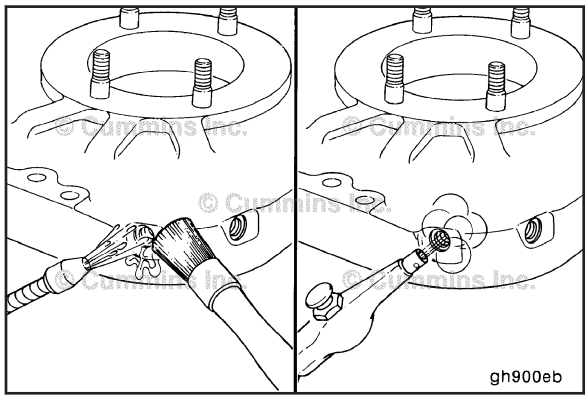
Remove the front gear housing.

•



Clean

Clean the gasket material from the cylinder block.

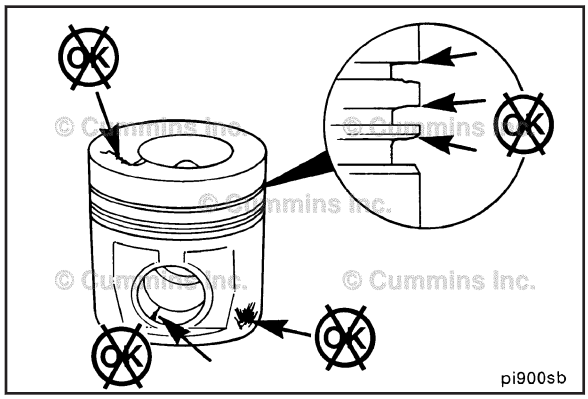


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use solvent and a nylon bristle brush to clean the oil drillings.

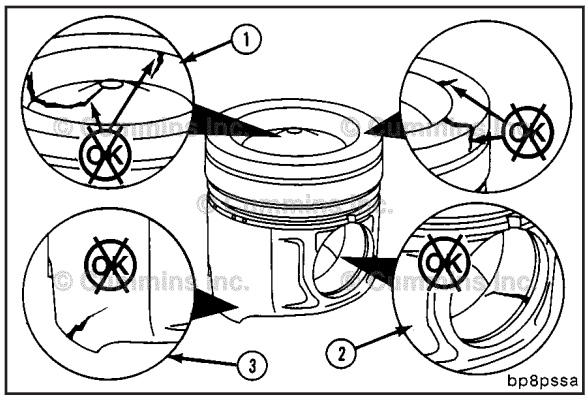
Dry the front gear housing with compressed air.



NOTE: Dimensional inspection of the piston is required **only** when the cause of the lack of sealing is **not** apparent.

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

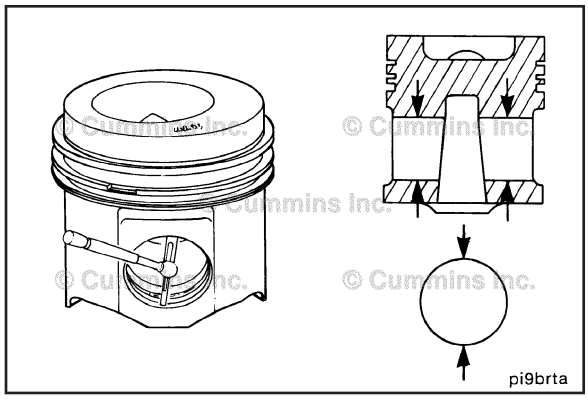
Inspect the piston for rolled edges on the ring lands. If the ring lands are rolled in, this indicates ring beat-in and can cause loss of sealing.



Inspect the piston bowl (1), pin bore (2), and skirt (3) for cracks or damage.

NOTE: Do **not** use pistons with cracks.

NOTE: If severe piston damage has occurred, check the turbocharger and other exhaust components for damage from debris.

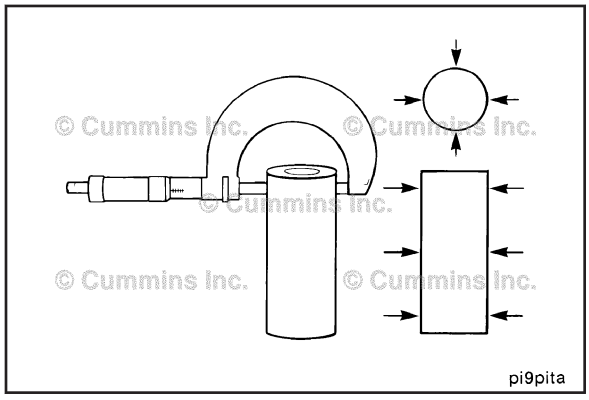


Measure the piston bore when the piston temperature is at 20°C [68°F].

Piston Pin Bore Inside Diameter		
mm		**in**
45.01	MIN	1.772
45.03	MAX	1.773

NOTE: Add 0.013 mm [0.0005 in] to the piston pin bore inside diameter per 5°C [10°F] temperature rise up to 32°C [90°F].

The piston pin bore **must** be checked closer to the outside diameter of the piston since the piston pin bore is tapered.

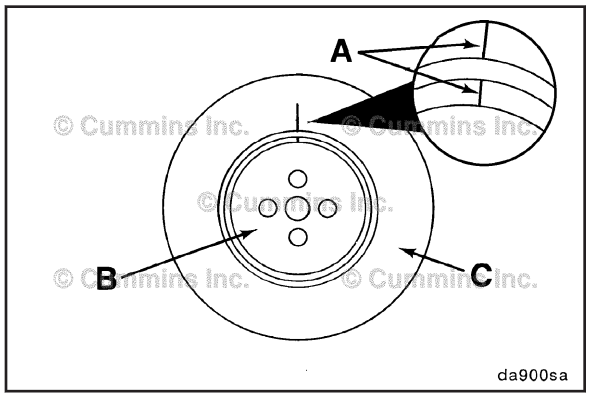


Inspect the piston pin for scratches, grooves, or other damage.

Measure the piston pin outside diameter.

Piston Pin Diameter		
mm		**in**
44.99	MIN	1.771
45.00	MAX	1.772

NOTE: Discard the piston pin if it is more than 0.03 mm [0.001 in] out of round.

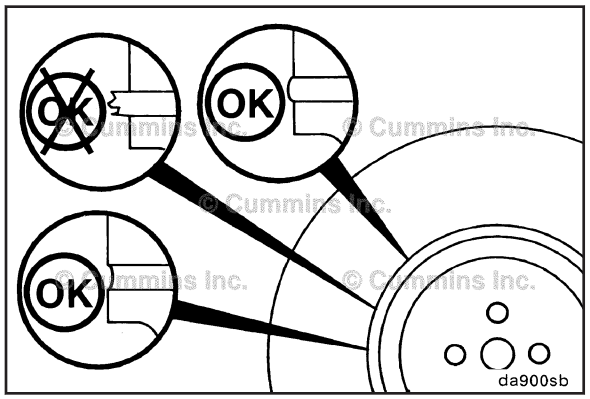


Check the index lines (A) on the damper hub (B) and the inertia member (C).

If the lines are more than 1.59 mm [1/16 in] out of alignment, replace the damper.

Inspect the vibration damper hub for cracks.

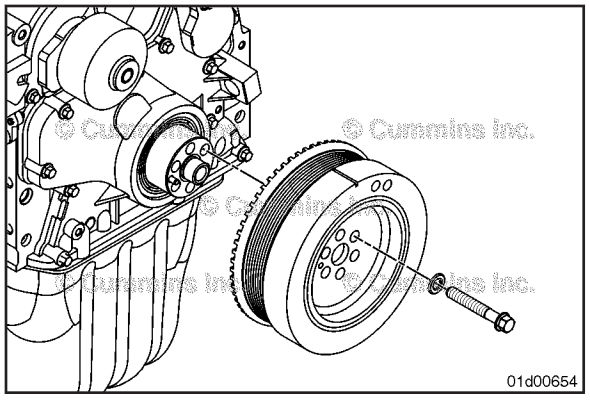
Replace the damper if the hub is cracked.



Inspect the rubber member for deterioration.

If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8in] below the metal surface, replace the vibration damper.

NOTE: Check for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



Install

NOTE: Align the crankshaft speed indicator ring and vibration damper with the index pin located on the nose of the crankshaft.

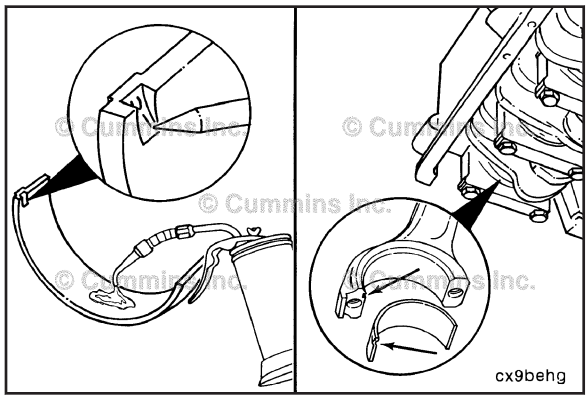
Lubricate the capscrews with clean engine oil.

Install the vibration damper and crankshaft speed indicator ring.

Tighten the six vibration damper capscrews in a criss-cross pattern.

Torque Value:

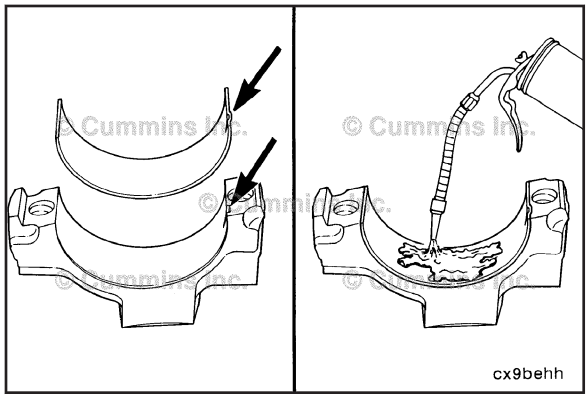
Step 1	50 N•m	[37 ft-lb]
Step 2	Rotate 90 degrees	



NOTE: The connecting rod bearings **must** be installed in the original connecting rod and cap.

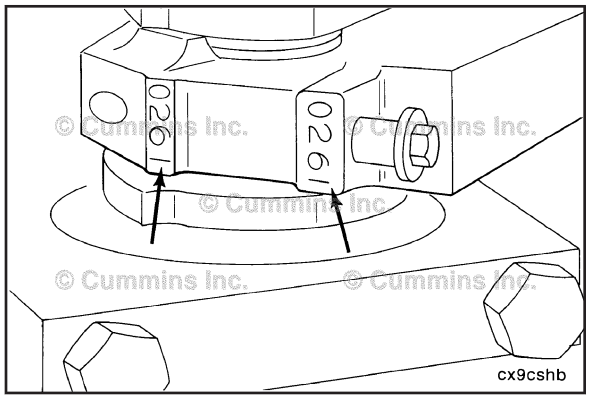
Install the upper bearing shell in the connecting rod with the tang of the bearing in the slot of the connecting rod.

Use clean lubricating oil to coat the inside of the connecting rod bearing shell.



Install the bearing shell in the connecting rod cap with the tang of the bearing in the slot of the cap.

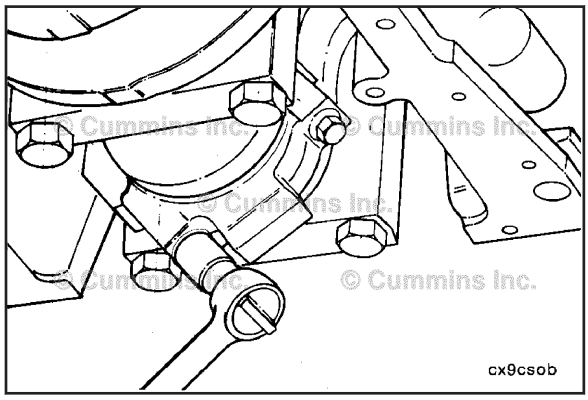
Use clean lubricating oil to coat the inside diameter of the connecting rod bearing shell.



The four-digit number stamped on the connecting rod and cap at the parting line **must** match and be installed on the same side in all cylinders.

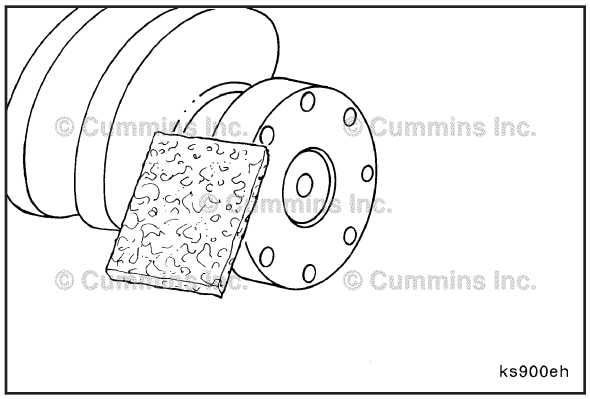
Install the connecting rod cap and capscrews to the connecting rod.

NOTE: The word FRONT on the piston will now be toward the front of the block. The combustion bowl in the piston will be on the fuel pump side of the engine.



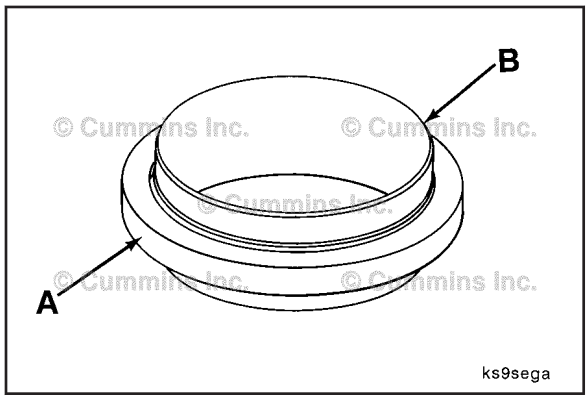
Tighten the two connecting rod capscrews.

Torque Value: 40 N•m [30 ft-lb]

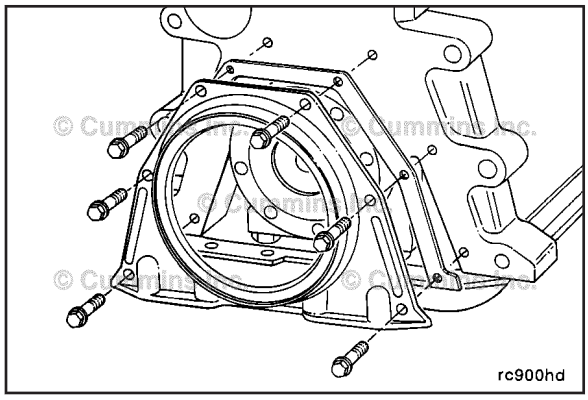


Install

Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the oil seal and the crankshaft clean and dry to secure proper oil sealing.



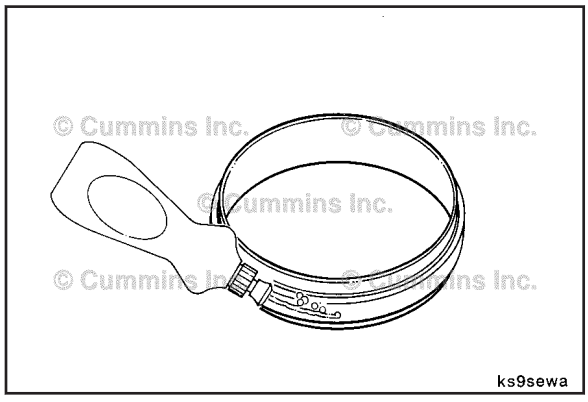
The combination crankshaft oil seal (A) wear sleeve (B) replacement kit for service usage is installed on the crankshaft as an assembly. The crankshaft rear oil seal **must not** be removed from the crankshaft rear seal wear sleeve.



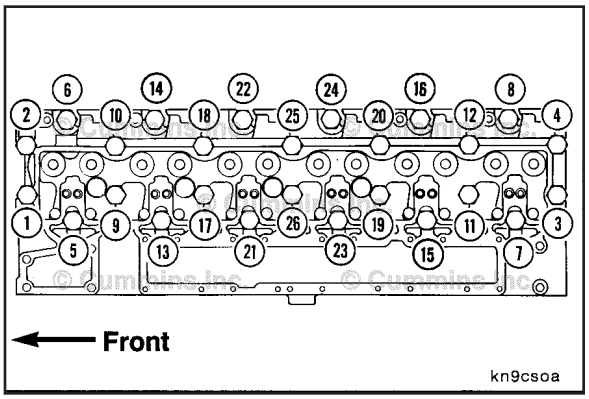
Install the rear cover and gasket.

Install the rear cover capscrews. Do **not** tighten. If the oil pan is installed, loosen the oil pan capscrews to allow clearance for rear cover and gasket clearance.

The seal installation is being used to align the rear cover properly. Do **not** push or force the cover in any direction to prevent irregular seal lip position after seal installation.

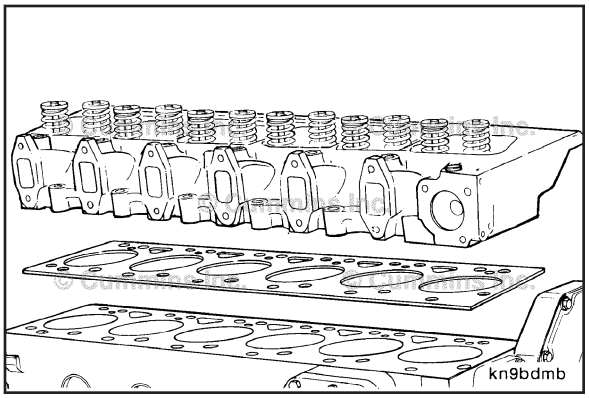


The oil seal for a wet flywheel housing requires soap on the outside of the seal case. Nothing is required on the outside of the seal case for dry housings.



Remove

Remove the cylinder head capscrews in the sequence shown.

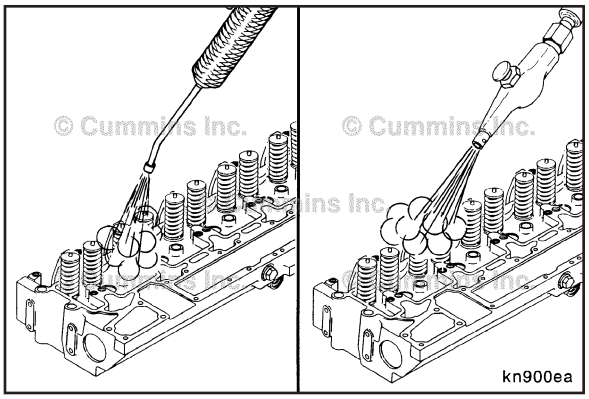


⚠WARNING⚠
The component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

△CAUTION△
Do not lay the cylinder head on the combustion deck. This can damage the combustion deck.

Use a hoist or hydraulic arm to remove the cylinder head. Make sure the head is removed in a direct upward motion.

Remove the cylinder head gasket from the cylinder block.



Clean and Inspect for Reuse

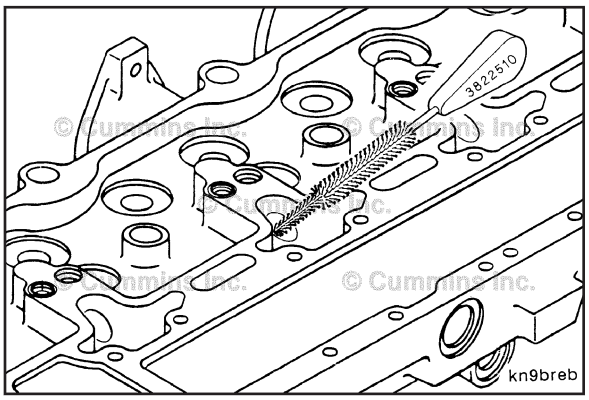
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Steam-clean the cylinder head.

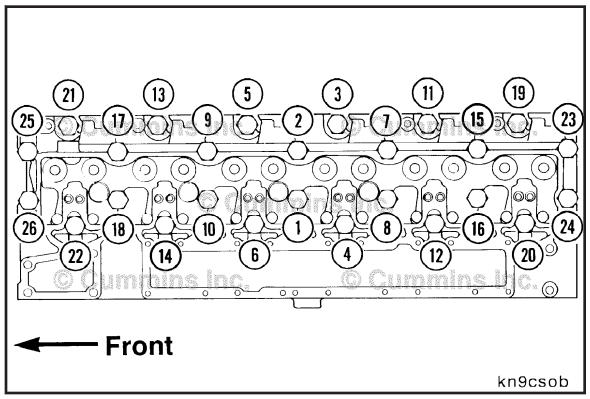
NOTE: Make sure to blow out all the capscrew holes.

Dry the cylinder head with compressed air.



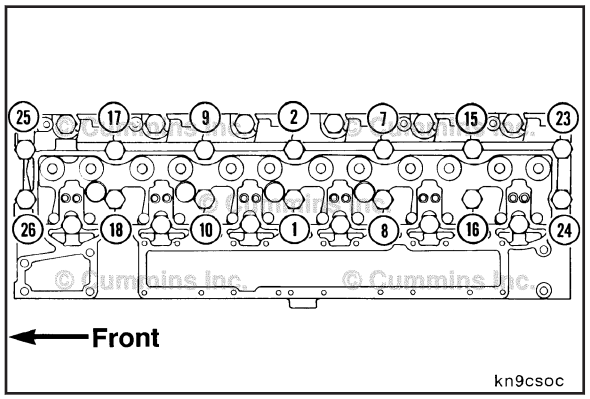
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Clean the injector bores with an Cummins® injector bore brush, Part Number 3822510, and solvent.



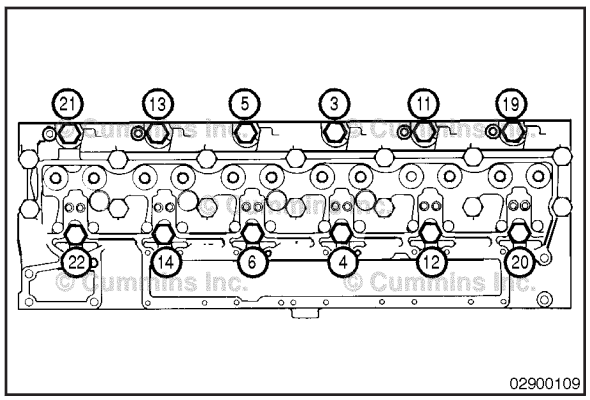
1. Follow the numbered sequence and tighten all 26 capscrews.

Torque Value: 70 N•m [52 ft-lb]



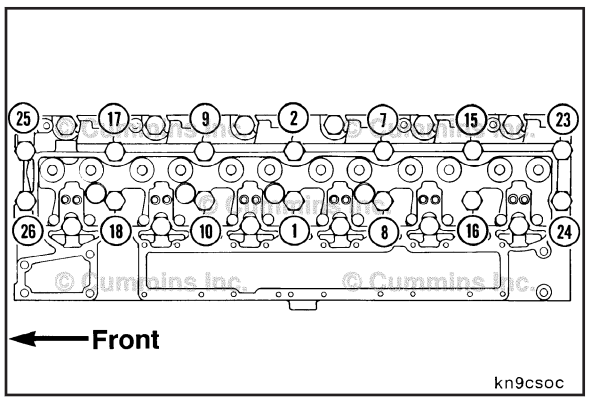
2. Follow the numbered sequence and tighten **only** the 14 long capscrews. (Number 1, 2, 7, 8, 9, 10, 15, 16, 17, 18, 23, 24, 25, and 26.)

Torque Value: 145 N•m [107 ft-lb]



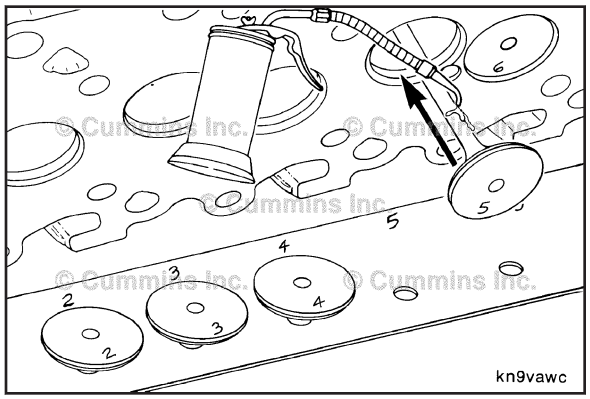
3. Retighten the short capscrews: Number 3, 4, 5, 6, 11, 12, 13, 14, 19, 20, 21, and 22 because of cylinder head relaxation and to obtain proper cylinder head torque requirements.

Torque Value: 70 N•m [52 ft-lb]



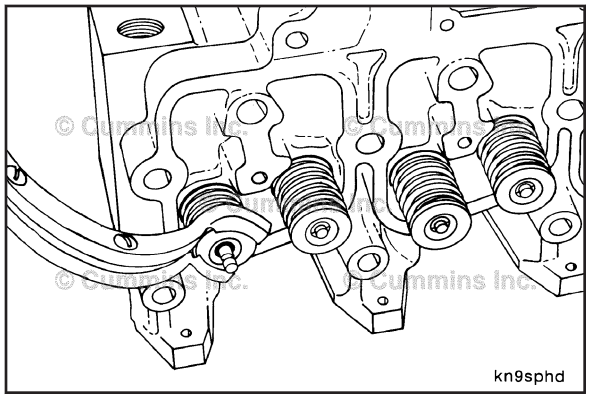
4. Follow the numbered sequence and retighten **only** the 14 long capscrews. (Number 1, 2, 7, 8, 9, 10, 15, 16, 17, 18, 23, 24, 25, and 26.)

Torque Value: 145 N•m [107 ft-lb]



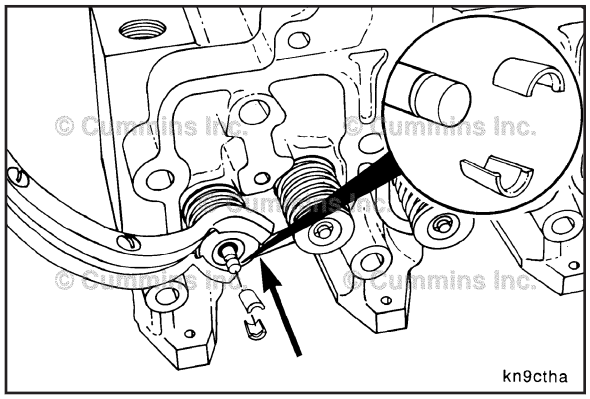
Lubricate the valve stems with clean SAE 90W oil.

Install the valves in their original locations.

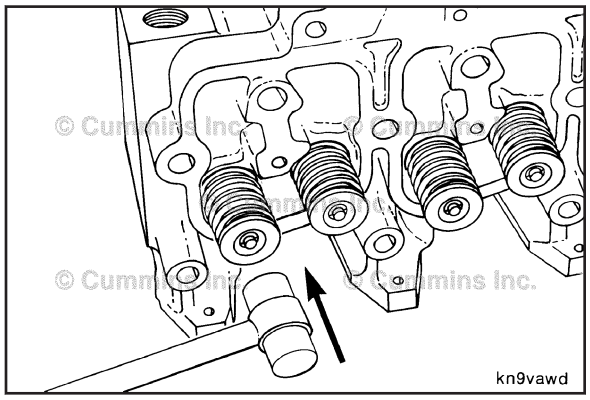


Assemble the valve spring and retainer.

Install and compress the valve spring retainer assembly, using valve spring compressor, Part No. 3375962.

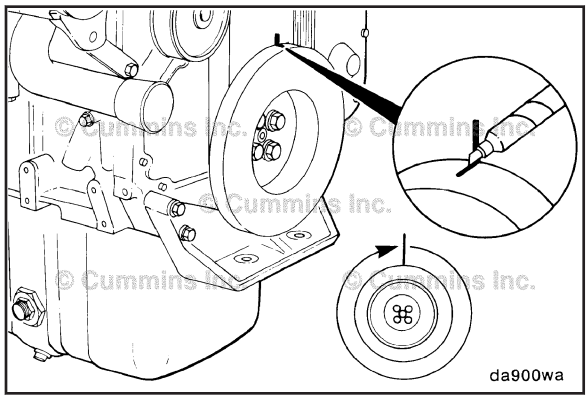


Install the valve collets and release the valve spring compressor tension.



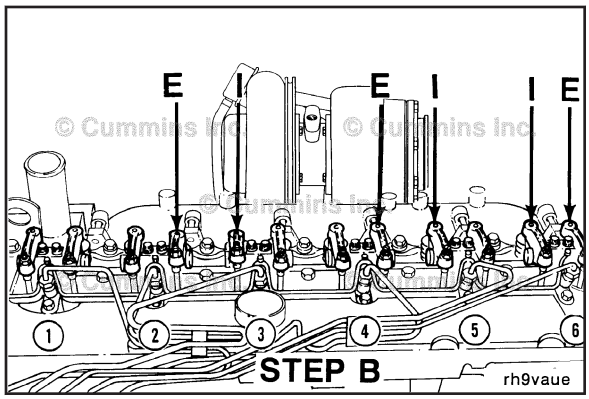
⚠WARNING⚠
To avoid personal injury wear eye protection when installing valve collets. If the collets are not correctly installed, they can fly out when the stems are hit with the hammer.

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



⚠CAUTION⚠
Be sure the engine timing pin is disengaged to prevent damage to the engine timing pin.

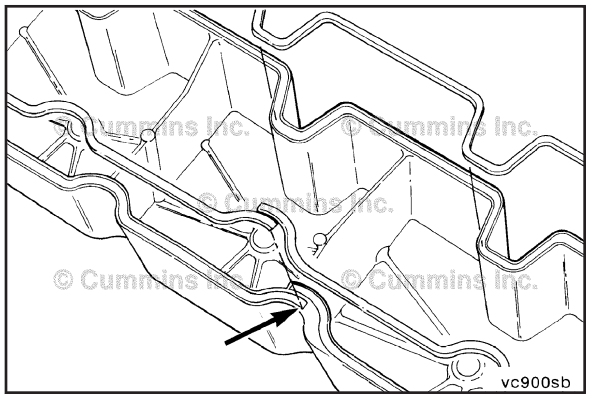
Mark vibration damper and rotate the crankshaft 360 degrees.



Set the valves indicated for STEP B.

After tightening the rocker lever locknut, check the valve clearance to make sure the valve clearance has **not** changed.

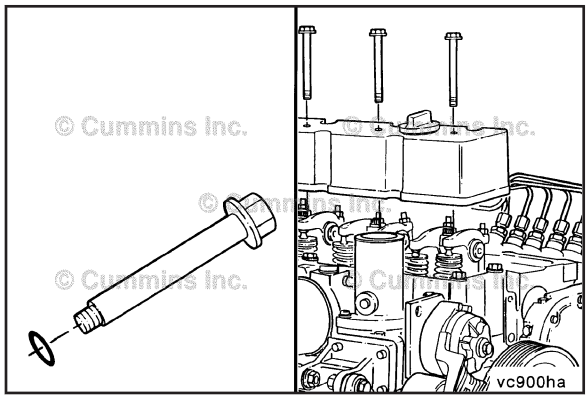
Torque Value: 24 N•m [212 in-lb]



NOTE: If the seal is **not** damaged, it can be used again. If the seal is damaged, install a new seal.

Install the rubber seal into the groove in the valve cover. Start the installation at the overlap area shown in the illustration. Do **not** stretch the rubber seal.

If the seal has more overlap than shown in the illustration, trim the length to provide the correct overlap.

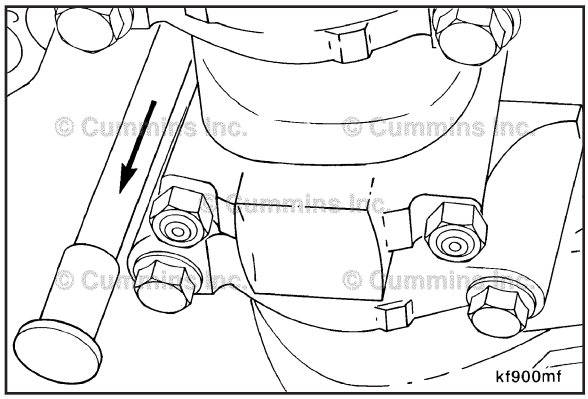


Install new sealing o-rings on the capscrews.

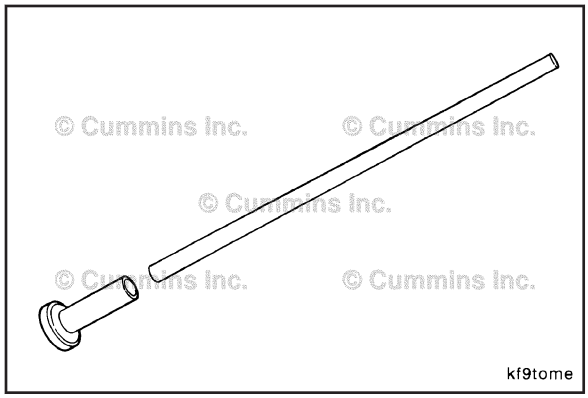
Install the valve cover and wastegate sensing tube.

Torque Value: 24 N•m [212 in-lb]

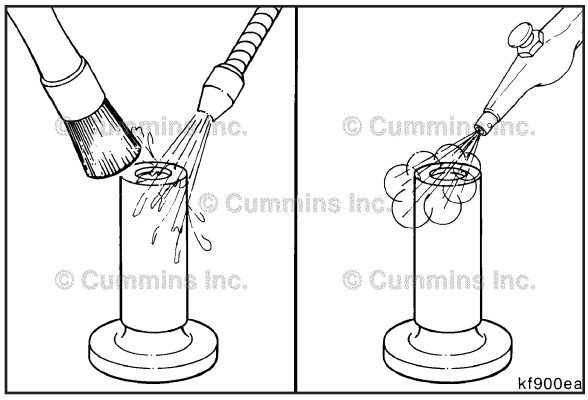
Notes



Remove the accessible tappets and dowels.



Remove the tappets from the wooden dowels.



Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

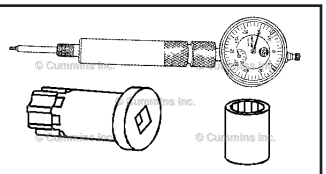
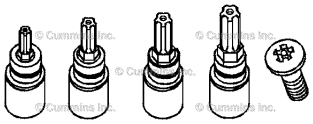
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

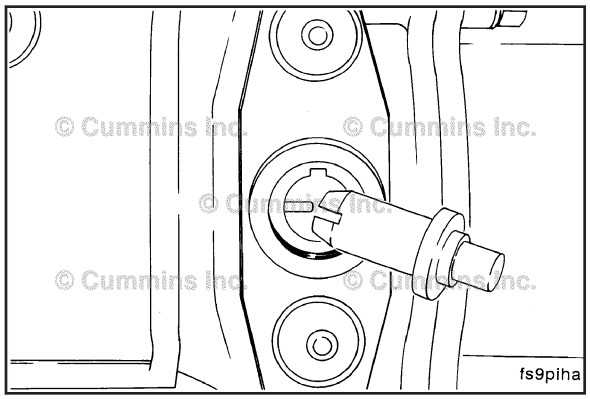
Clean the tappets with solvent.

Dry the tappets with compressed air.

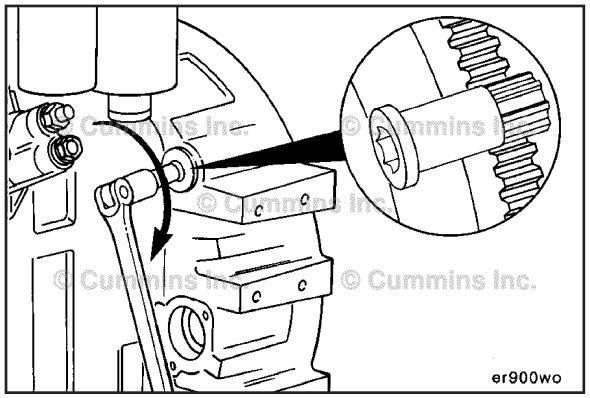
⚠CAUTION⚠
Anytime a new camshaft is installed, new tappets and push rods must also be installed.

⚠CAUTION⚠
If a tappet is replaced, the corresponding push rods must also be replaced. Failure to do this can cause major engine damage.

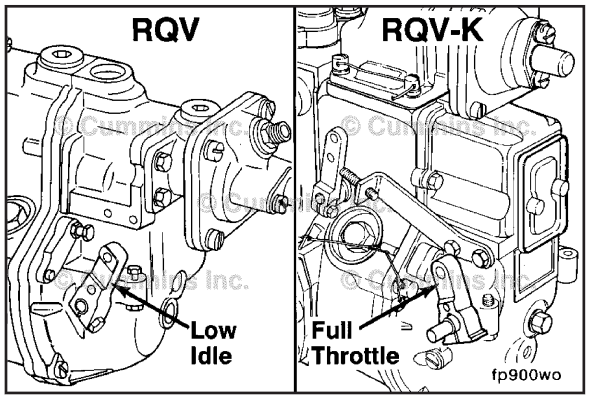
Tool No.	Tool Description	Tool Illustration
3824563	**Lift Plunger Timing Tool** Used to time the lift plunger.	 3824563
3399870	**Tamper Screw, Removal Tool** Used to remove the tamper screws.	 3399870



Before continuing, make certain that the fuel injection pump timing pin is disengaged.



Rotate the crankshaft **counterclockwise**, as viewed from the front of the engine, to approximately 40 degrees before top dead center.



Adjust

Governor

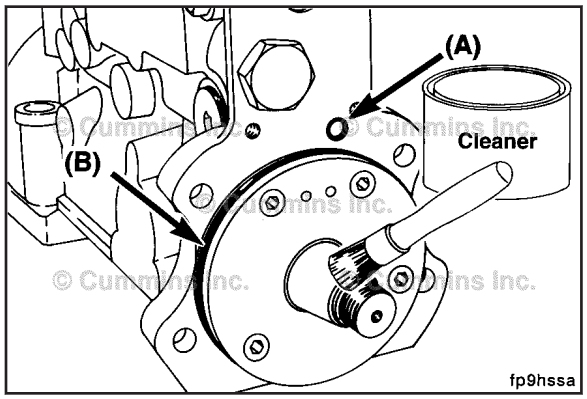
⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arching equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

NOTE: The governor lever **must** be positioned before pressuring the fuel injection pump.

The RQV governor throttle lever **must** be in the low-idle lever position.

Automotive engines with a RQV-K governor throttle lever **must** be in the high-idle throttle position.

Industrial engines with a RQV-K governor throttle lever **must** be in the low-idle throttle position.



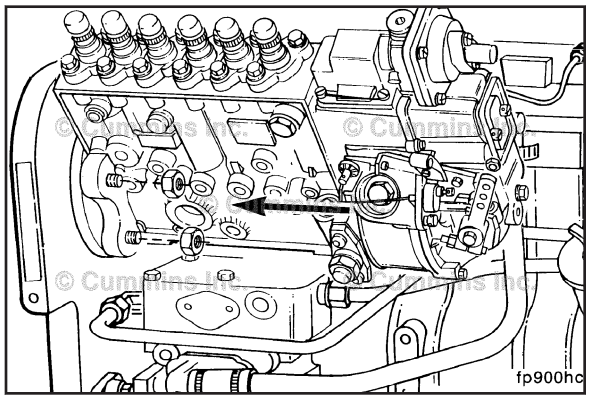
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Make certain that the o-ring seals for the fill orifice and pilot are correctly installed and are **not** damaged.

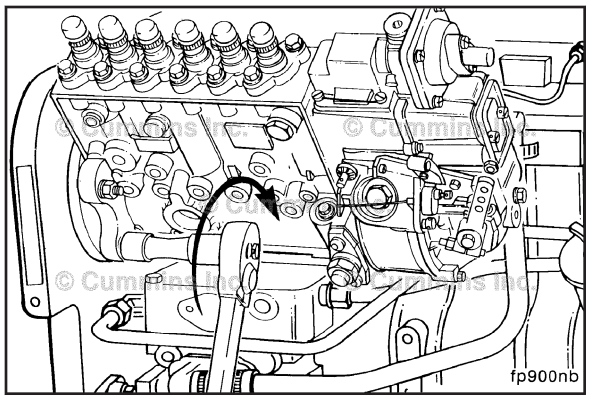
Lubricate the mounting flange with clean lubricating engine oil.

Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with QD Contact Cleaner, Part Number 3824510, by spraying into the gap between the shaft and the gear.

Dry the surface with compressed air.



Slide the fuel injection pump shaft through the drive gear, and position the fuel injection pump flange onto the mounting studs.



△CAUTION△
Do not pull the injection pump into the gear housing with the mounting nuts. Damage to the gear housing and fuel pump can result.

Install the fuel injection pump mounting nuts.

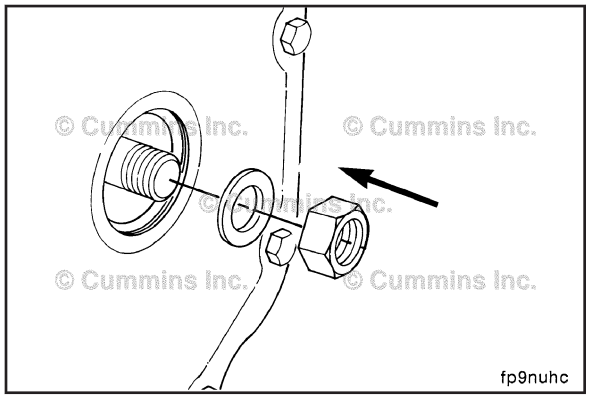
Install the support bracket, if equipped.

Torque Value:
Mounting nuts

Step 1	44 N•m	[32 ft-lb]

Torque Value:
Support bracket nuts

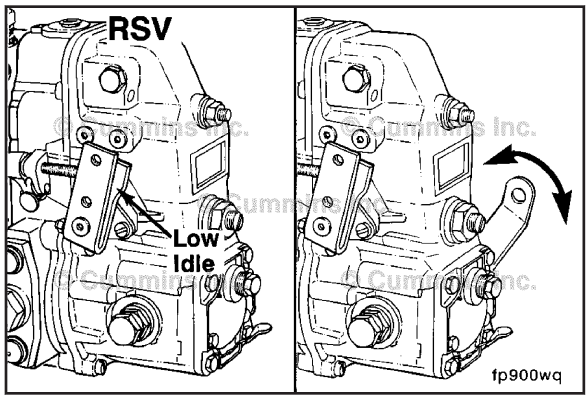
Step 1	32 N•m	[24 ft-lb]



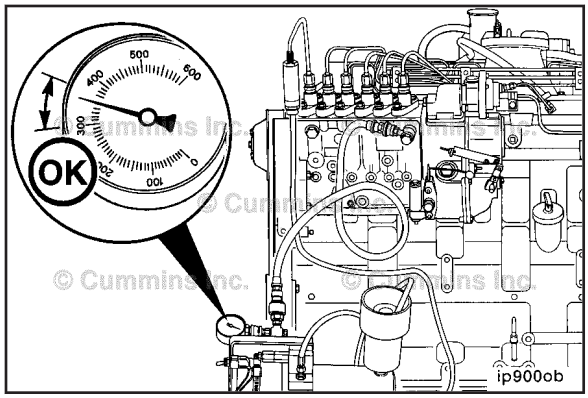
NOTE: To prevent damage to the timing pins, do **not** exceed the torque value given. This is **not** the final torque value for the retaining nut.

Install and tighten the fuel injection pump retaining nut and washer.

Torque Value: 12 N•m [106 in-lb]



The RSV governor throttle lever **must** be in the low-idle position and the shutdown lever needs to be wired or locked in the ½-travel position.



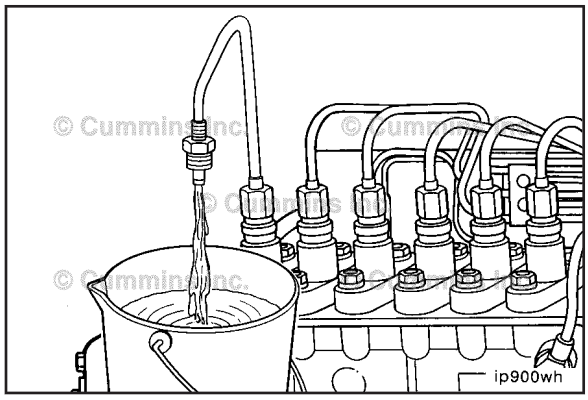
Turn on the spill timing cart pump.

Check the fuel pressure.

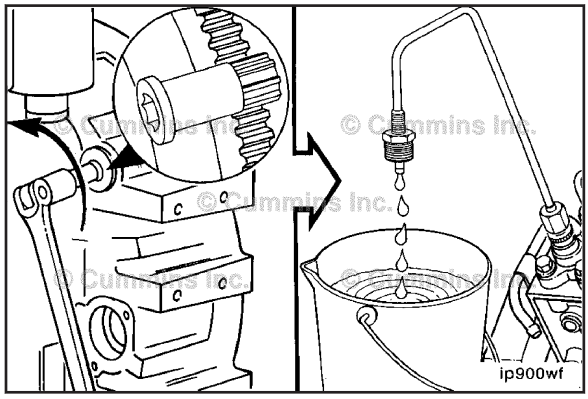
Fuel Spill Timing Cart - Fuel Pressure

kPa		psi
2068	MIN	300
2551	MAX	370

NOTE: The shutdown lever **must** be held in the required position before turning the spill cart pump on.

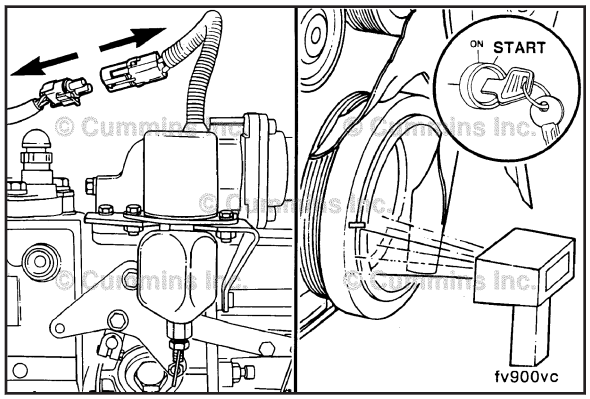


Fuel **must** be flowing out of the tube attached to the fuel injection pump. If the fuel is **not** flowing, recheck the procedures carefully.



Slowly rotate the crankshaft **clockwise**, as viewed from the front of the engine, until fuel flow from cylinder No. 1 begins.

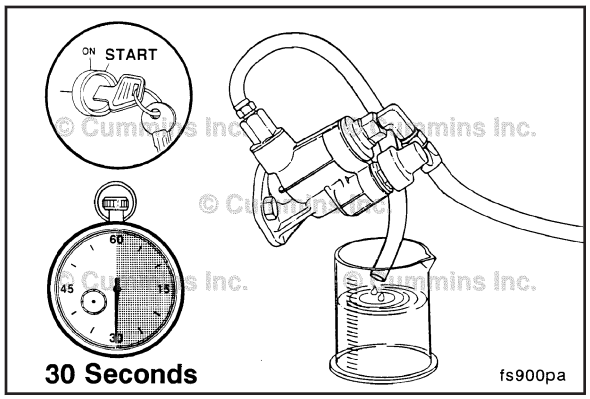
The plunger No. 1 element is now approaching port closure. Continue to rotate the crankshaft slowly until the flow is reduced to a drip. At the point that the steady stream of flow changes from a solid flow to a drip, **stop**. This is the static timing position of the fuel injection pump.



Disconnect the fuel shutdown solenoid wire.

Measure the engine cranking speed with a handheld tachometer, Part Number 3377462.

The minimum cranking speed is 120 rpm.

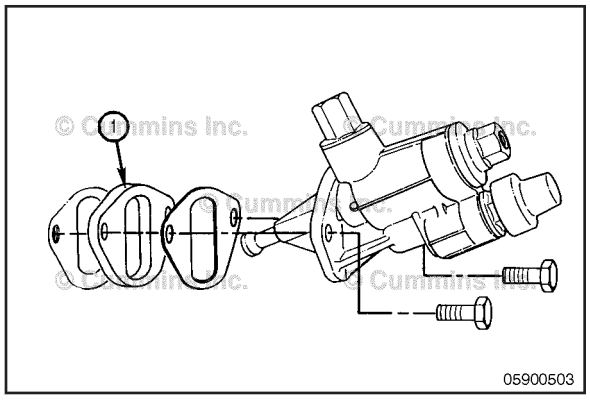


⚠CAUTION⚠
Leave the shutdown solenoid disconnected for the following check:

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

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

The minimum flow volume is 150 mL [5 oz].



Install

⚠CAUTION⚠
Alternately tighten the mounting capscrews. As the capscrews are tightened, the fuel lift pump plunger is pushed into the pump. Failure to tighten the capscrews in an even manner can result in the plunger being bent or broken, causing sticking and failure.

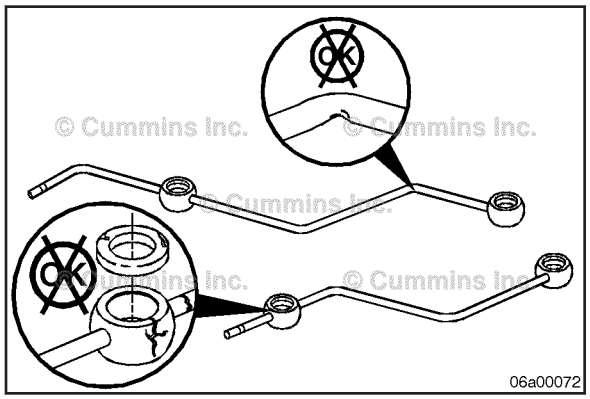
Piston Style

Install the pump.

Torque Value: 24 N•m [18 ft-lb]

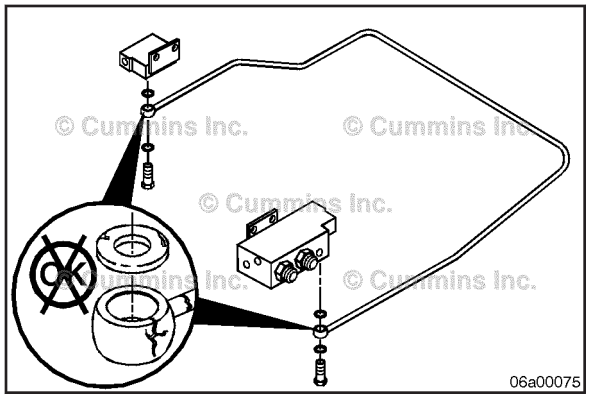
The 5-mm [0.20-in] spacer (1), Part Number 3914284, **must** be installed along with a gasket, Part Number 3931348, on each side of the spacer.

NOTE: For some applications, a bracket used for supporting other options will replace the 5-mm spacer.



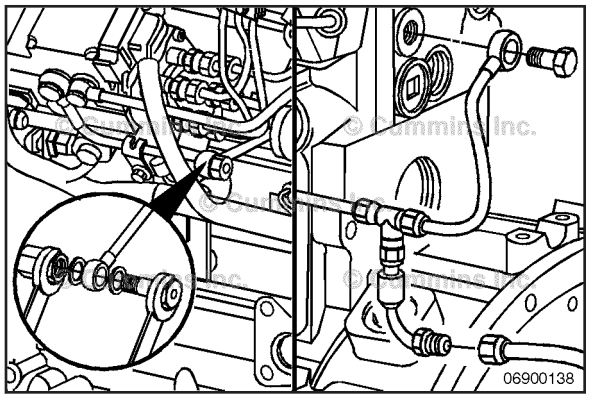
Inspect the rubber seals. Replace any damaged seals and any seals that are hard or brittle.

Service Tip: Lubricate the seals with clean engine oil to facilitate the installation.



Inspect the rubber seals. Replace any damaged seals and any seals that are hard or brittle.

Service Tip: Lubricate the seals with clean engine oil to facilitate the installation.

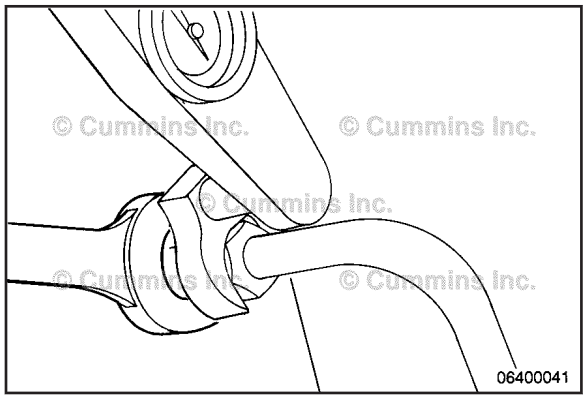


Install

Engine-to-Fuel Tank

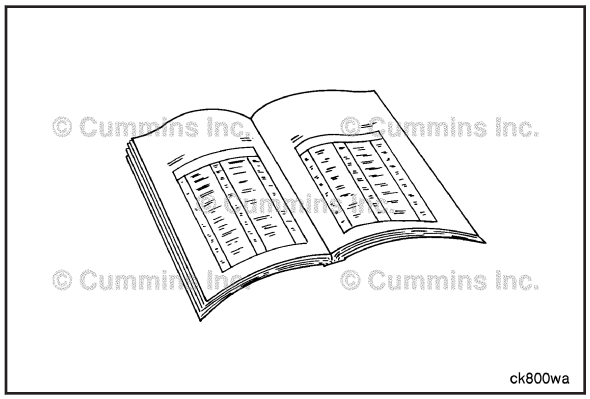
Install and tighten the drain hose at the main fuel connection block.

Torque Value: 23 N•m [204 in-lb]



Fuel Drain Line

If the fuel drain line has been removed, install and tighten the line. Refer to Procedure 006-024.

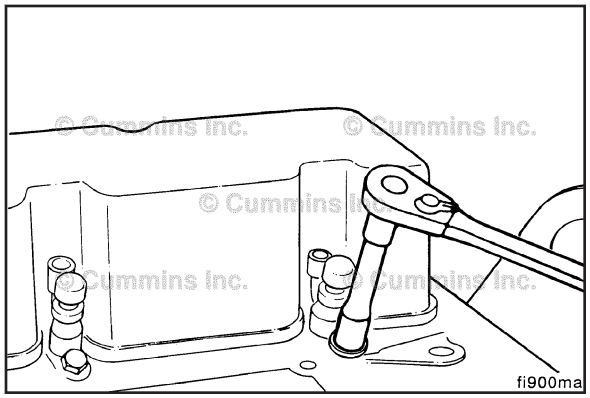


Preparatory Steps

Thoroughly clean around the injectors.

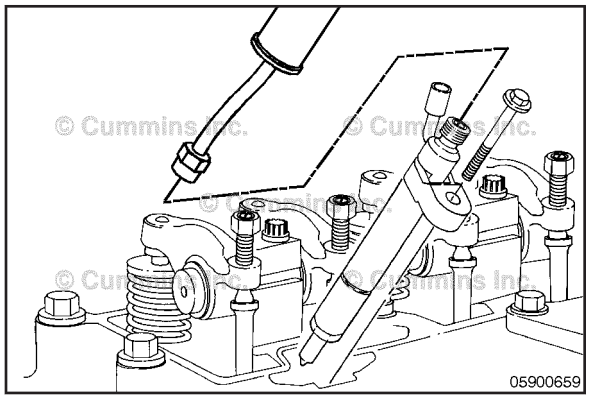
Disconnect the high-pressure injector supply lines; refer to Procedure 006-051.

Disconnect the fuel drain manifold; refer to Procedure 006-021.



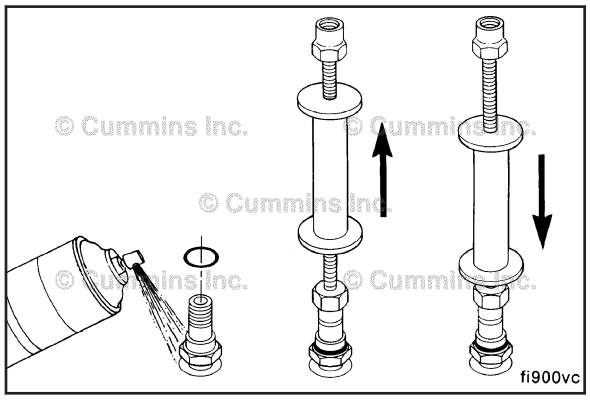
Remove

Remove the injector hold-down clamp.



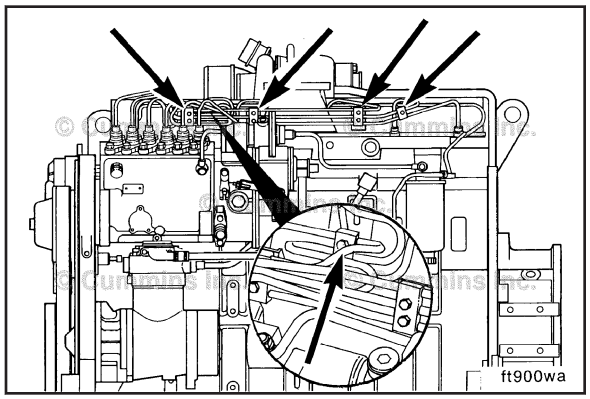
Use injector puller, Part Number 3823276 or 3164706, to remove the injectors.

Remove the injectors.



To remove some injectors, it will probably be necessary to:

- Tap the injector with the injector puller
- Work the injector up and down.

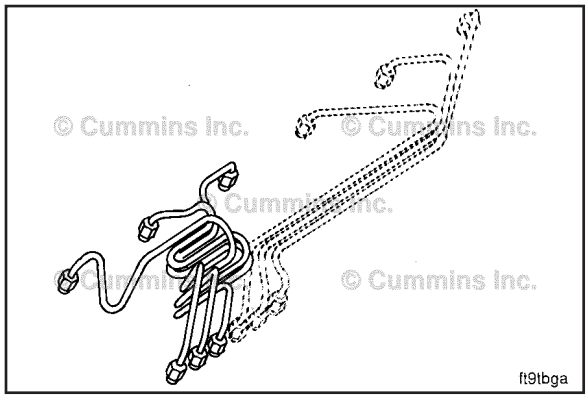


Injector Supply Lines (High Pressure) (006-051)

General Information

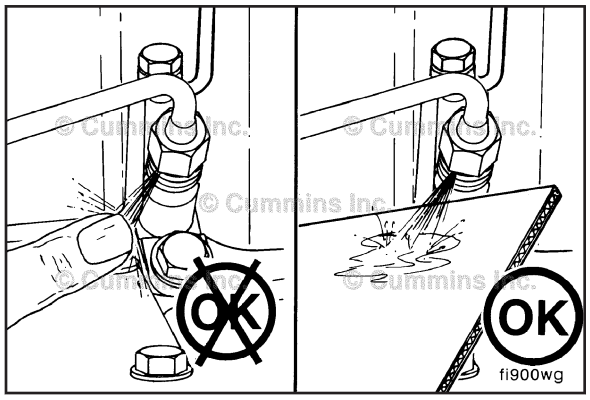
⚠CAUTION⚠
The high-pressure fuel lines will be damaged, unless they are clamped securely and routed so they do not contact each other or any other components.

The high-pressure fuel lines are designed and manufactured to deliver fuel at injection pressure to the injectors. The high-pressure pulses will cause the lines to expand and contract during the injection cycle.



The length, internal size, and rigidity of the high-pressure fuel lines is critical to smooth engine operation. An attached metal tag is used to identify each line with a part number.

NOTE: Do **not** weld or substitute line. Use **only** the specified part number for the engine.

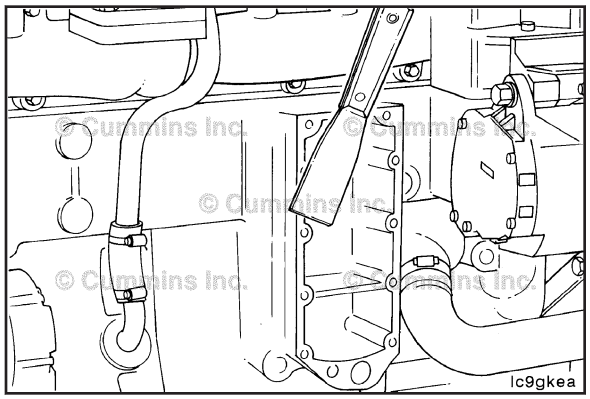


⚠WARNING⚠
The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious personal injury. Wear gloves and protective clothing.

Use cardboard to check for cracks and leaks in the high-pressure fuel lines. 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.

Preparatory Steps

Clean all debris from around the fuel lines.



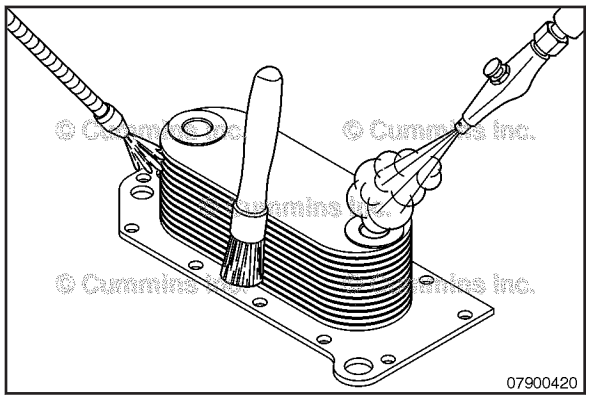
Clean and Inspect for Reuse

⚠WARNING⚠
When using solvent, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

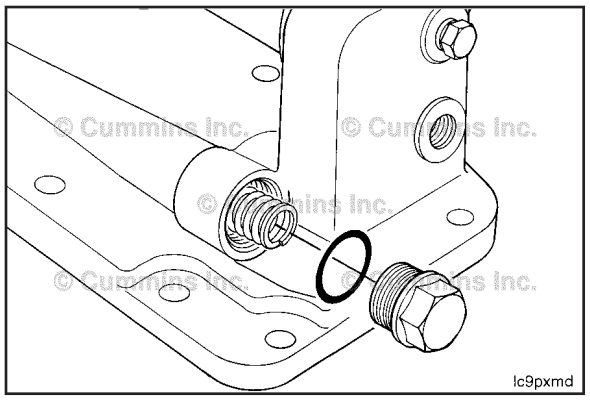
△CAUTION△
Use a solvent that will not harm copper to clean the oil cooler elements.

Clean the sealing surfaces of the cylinder block and the oil cooler cover.

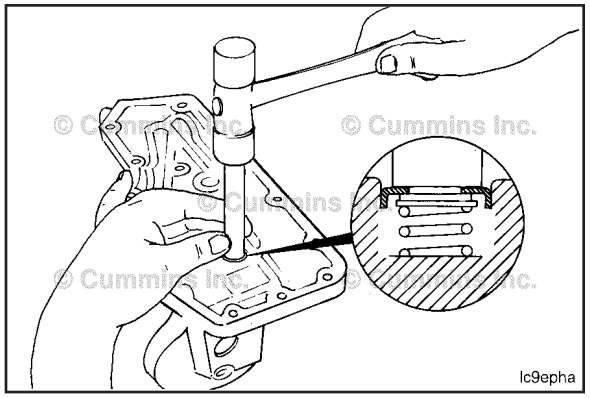
NOTE: Replace the lubricating oil cooler if any debris is found or if the engine has had a debris-generating failure.



△CAUTION△
Do not reuse an oil cooler core after a debris related engine malfunction since there is no practical method for cleaning the cooler core. Metal particles which can circulate through the lubricating oil system can remain in the cooler core and cause engine damage.

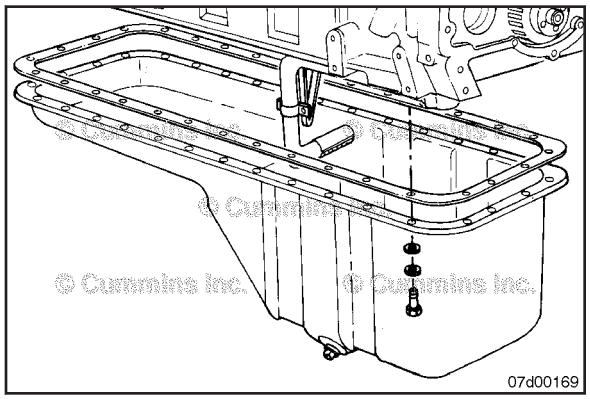


If any debris is suspected to have gone through the engine, or if troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary. Refer to Procedure 007-029 in Section 7.



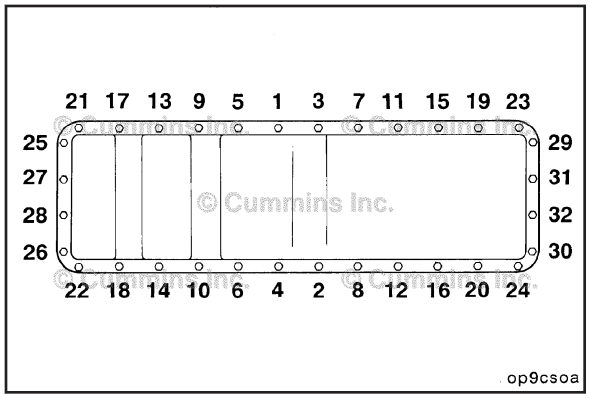
If any debris is suspected to have gone through the engine, inspect the oil filter bypass valve located in the lubricating cooler cover. Make sure the valve is fully seated and opens and closes freely. Replace if necessary.

The bypass valve requires a 345 kPa [50 psi] pressure differential to open.



Install the gasket and lubricating oil pan.

Install the oil pan corner braces, if equipped.

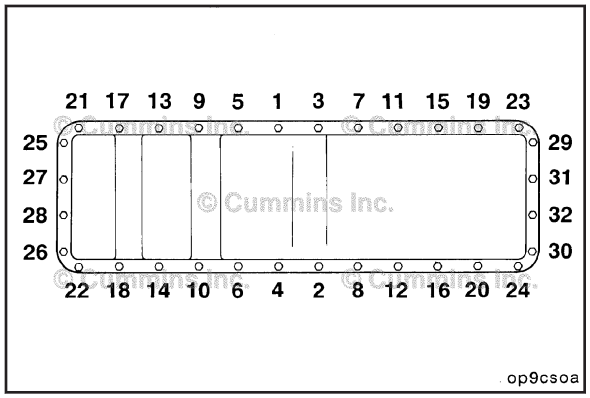


Assemble the washers and capscrews to secure the lubricating oil pan, as illustrated.

Remove the guide pins and install the capscrews.

Tighten all capscrews in the sequence shown in the accompanying chart.

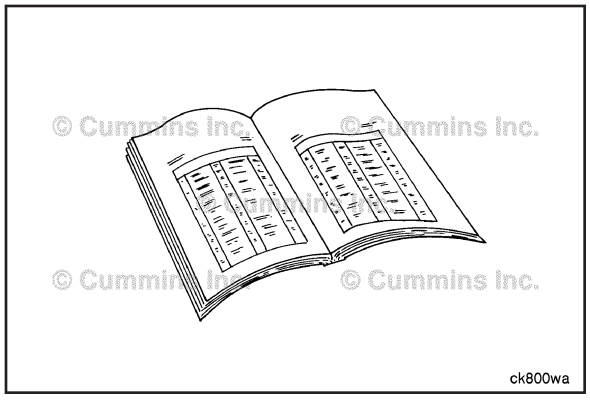
Torque Value: 24 N•m [212 in-lb]



Hand tighten all the capscrews, to secure the oil pan to the engine, before tightening the capscrews.

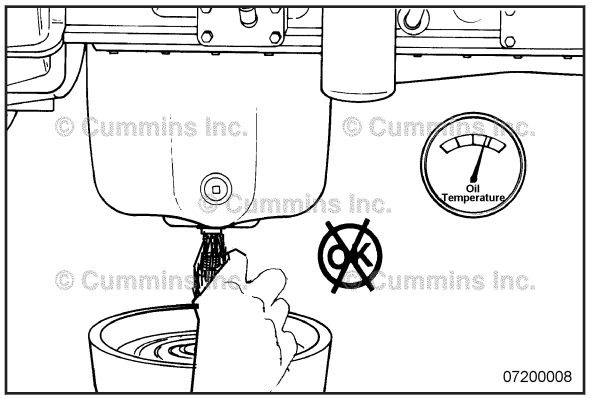
Tight all the capscrews in the sequence shown in the illustration.

Torque Value: 23 N•m [204 in-lb]



Finishing Steps

- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.



Lubricating Oil System (007-037)

Drain

⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

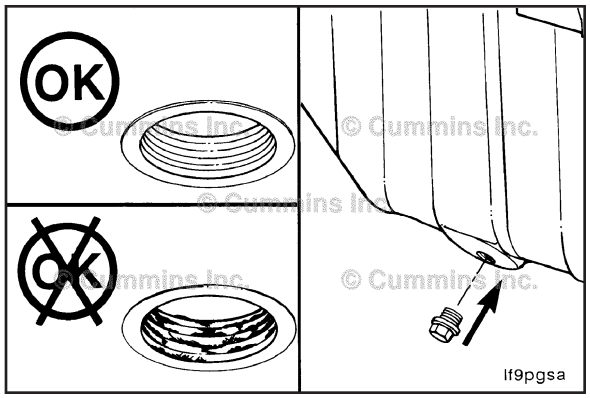
Operate the engine until the coolant temperature reaches 60°C [140°F].

Shut the engine off.

Remove the oil drain plug.

Drain the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.

Use a container with a capacity of at least 23.6 liters [25 qt] of lubricating oil.



Fill

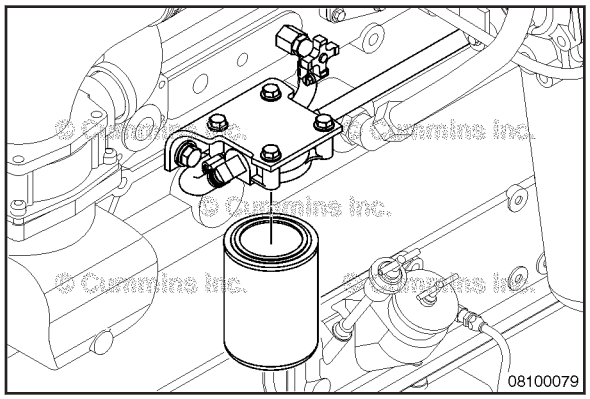
Clean and check the lubricating oil drain plug threads and sealing surface.

Install the lubricating oil pan drain plug.

Torque Value		
	N•m	[ft-lb]
Steel Oil Pan	80	59
Cast Aluminum Oil Pan	60	45

Use a high-quality 15W-40 multiviscosity oil, such as Cummins Premium Blue, or equivalent, in Cummins engines.

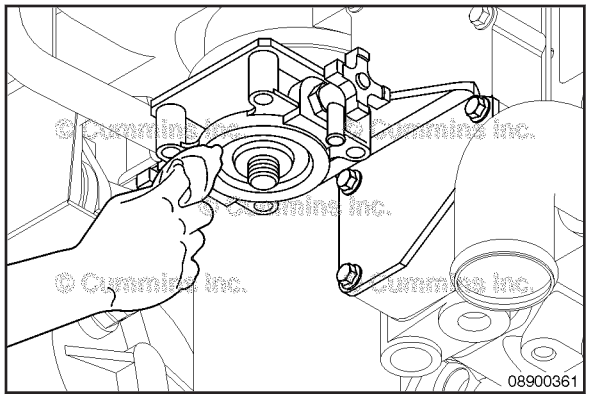
Choose the correct oil for your application and climate as outlined in the Operation and Maintenance Manual, or Cummins Engine Oil Recommendations, Bulletin 3810340.



⚠WARNING⚠
A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

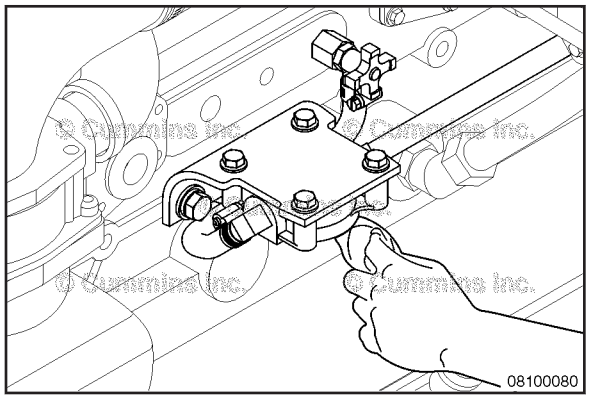
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove and discard the coolant filter.

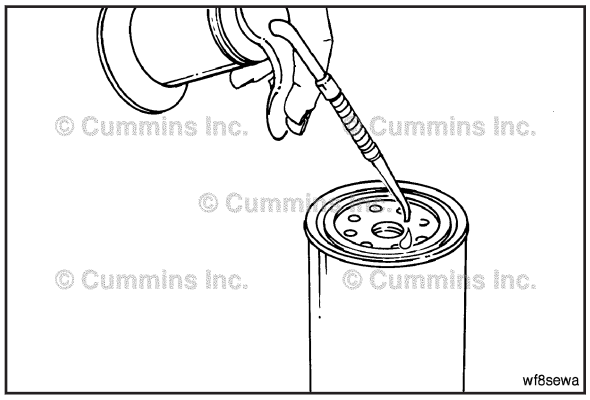


Clean

Clean the gasket surface.



Clean the gasket surface.



Install

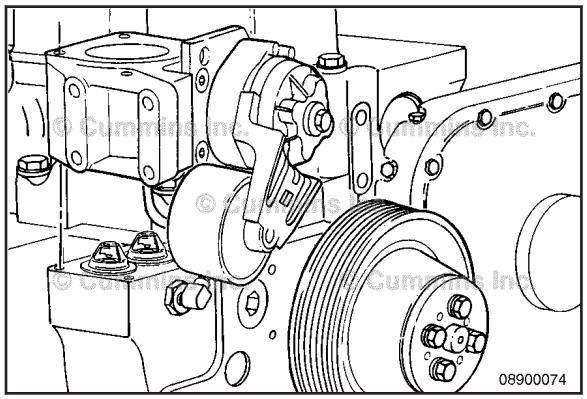
△CAUTION△
Do not allow oil to get into the filter. Oil will damage the DCA.

△CAUTION△
Mechanical overtightening can distort the threads or damage the filter head.

Apply a thin film of lubricating oil to the gasket sealing surface before installing the new coolant filter.

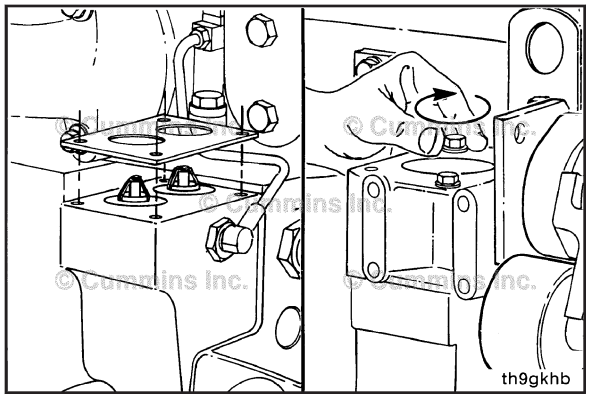
Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the coolant filter an additional ½ to ¾ of a turn, or as specified by the filter manufacturer.



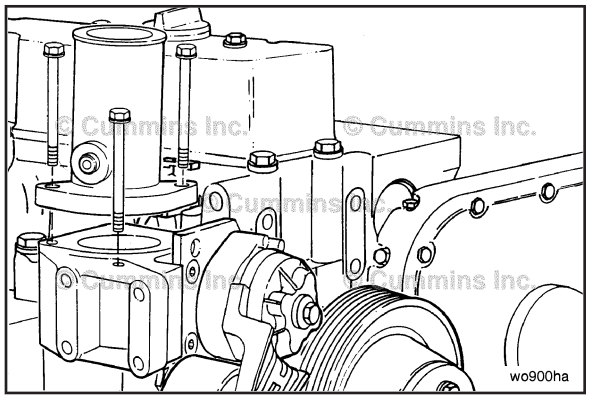
Position the thermostat housing and belt tensioner over the thermostats and gasket.

NOTE: If an external bypass system is used, the thermostat housing support (between the thermostat housing and cylinder block) **must** be installed.



Make sure the gasket is aligned with the capscrew holes.

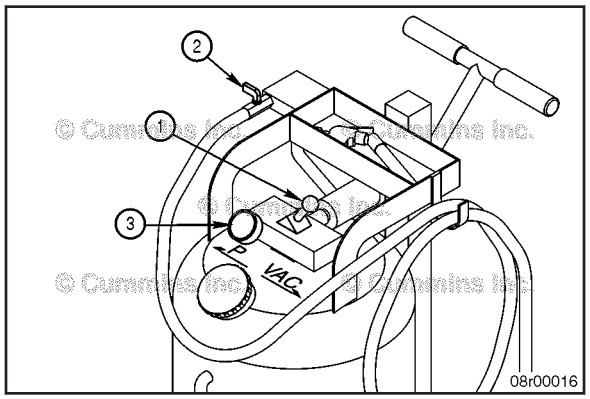
Install the capscrews and finger-tighten.



Install the water outlet connection.

Tighten all capscrews.

Torque Value: 24 N•m [212 in-lb]



Place the coolant dam over the coolant fill neck in the radiator or overflow tank.

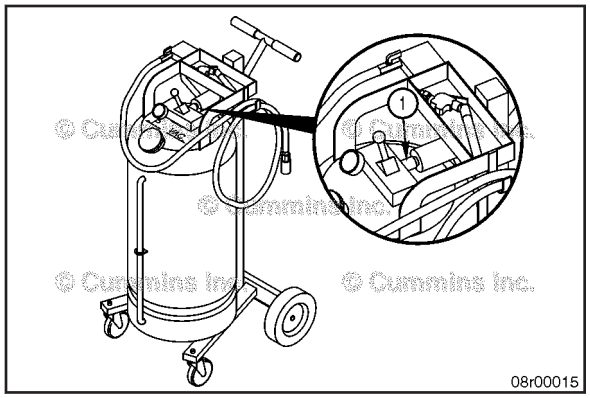
The size of the fill neck will differ between OEMs. Choose the appropriate sized coolant dam rubber adapters.

Switch the coolant replacement tool control lever (1) to “VAC” and leave the service hose valve (2) closed. This will create a vacuum in the tank to evacuate coolant from the cooling system package.

Monitor the gauge (3) and build a vacuum of approximately 508 mm-Hg [20 in-Hg] in the coolant replacement tool tank.

Slowly open the service hose valve (2) by turning it **clockwise** until it is completely open approximately ¼ turn.

Once the cooling system is put into a vacuum, any air trapped in the cooling system will be evacuated through the top of the system. This is noticed as air bubbles through the overflow tank or top of the radiator.

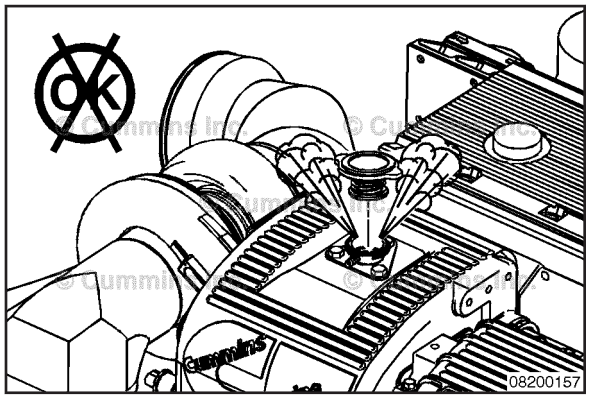


When air bubbles are no longer being drawn to the top of the cooling system move the control lever to the middle position. Remove the vacuum on the coolant replacement tool tank by opening the pressure relief valve located on the control block of the coolant replacement tool (1).

Remove the coolant dam from the radiator fill neck or overflow tank.

Disconnect the coolant replacement tool from the regulated shop air supply.

Install the radiator cap.



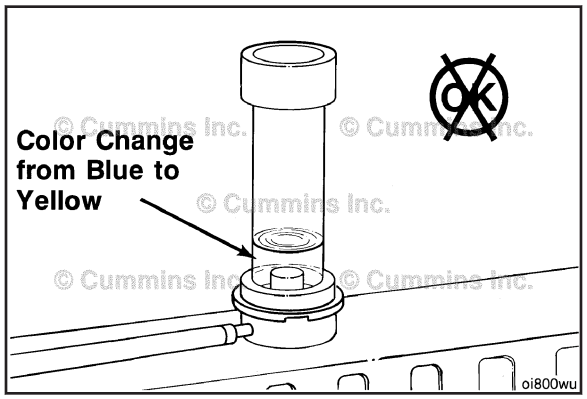
Drain

Marine Applications

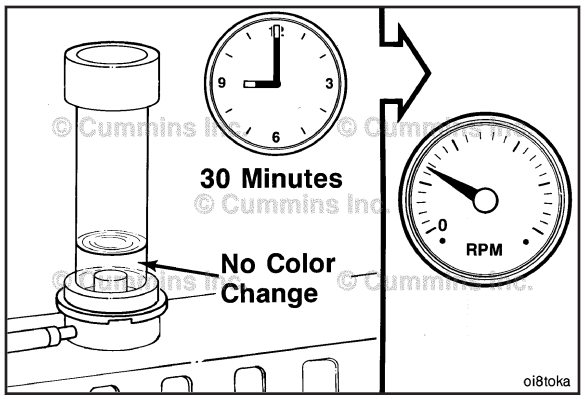
⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

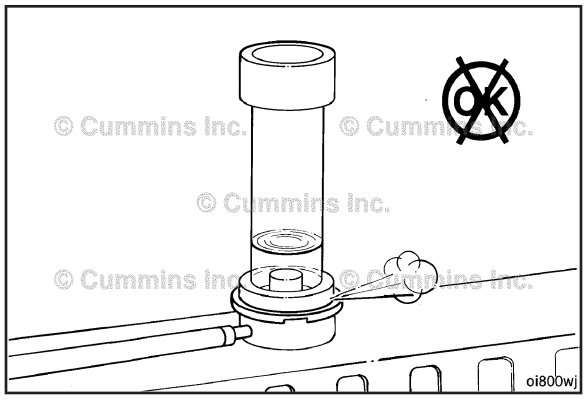
- Avoid excessive contact, and wash thoroughly after contact.
- Keep out of reach of children.



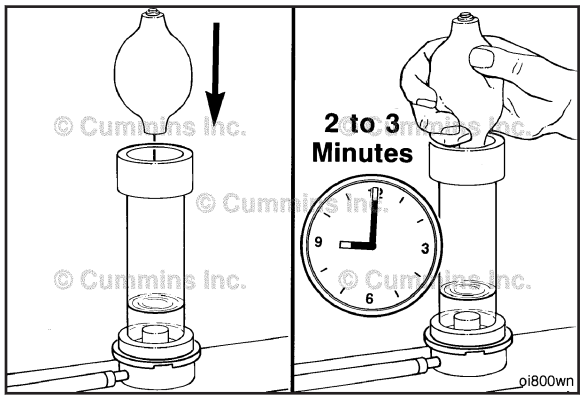
If the color of the test fluid changes from blue to yellow or green anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow.



If the color of the test fluid does **not** change from blue to yellow or green during the 30-minute test period, return the engine to low idle.



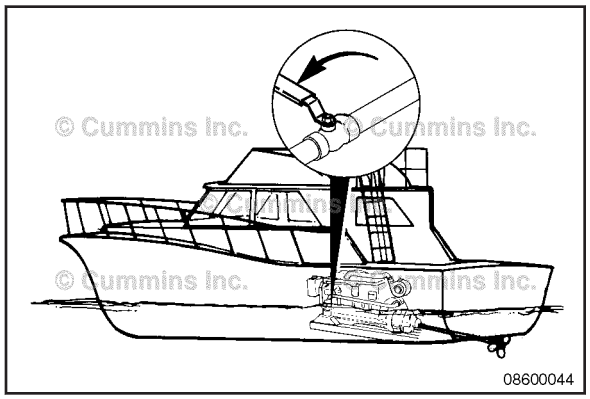
Check the test instrument to make sure it is firmly sealed in the radiator fill neck.



Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system.

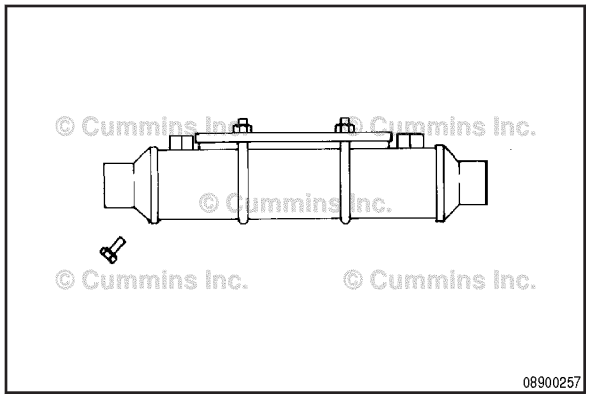
If the color of the test fluid changes from blue to yellow or green, combustion gases are entering the cooling system and further investigation is required to determine the source of the combustion leak.



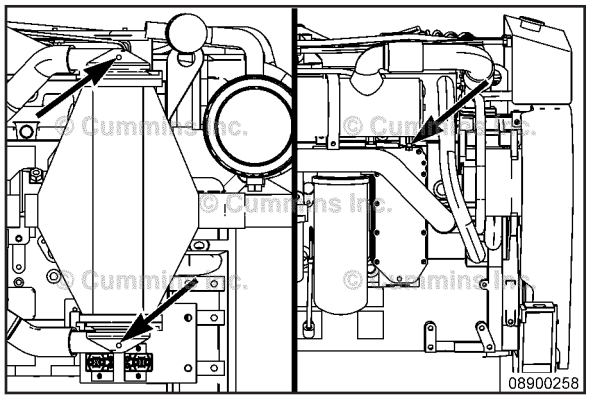
Heat Exchanger (008-053)

Flush

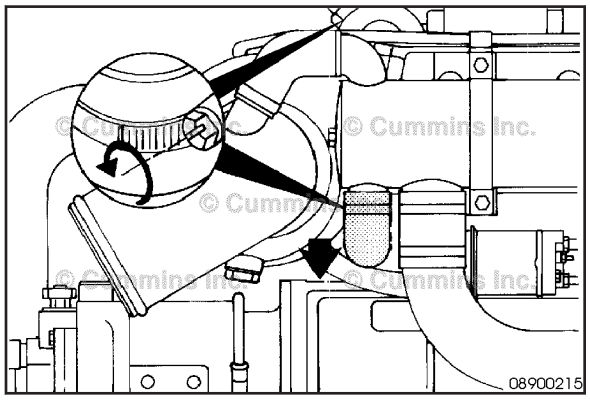
Shut off the sea water valve on the vessel hull.



To flush the marine gear oil cooler, refer to Procedure 008-041 (Marine Gear Oil Cooler) in Section 5.



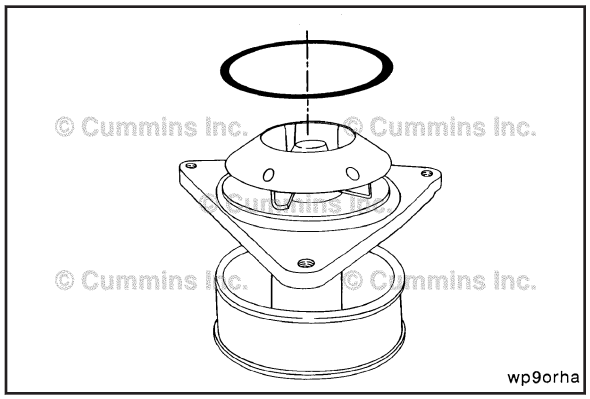
Remove the zinc plugs from the aftercooler and heat exchanger.



Typical hose connections are shown.

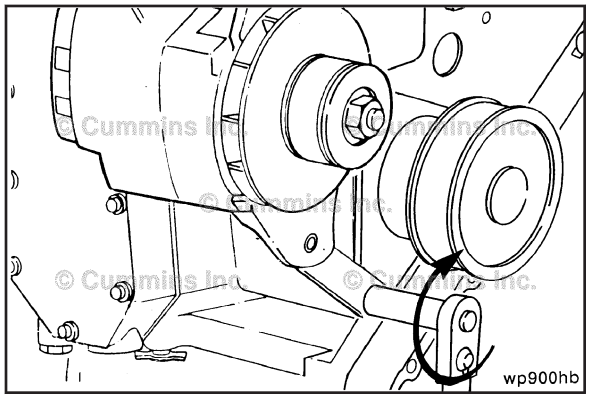
Refer to 100-002 (Engine Diagrams) in Section E.

Disconnect the sea water inlet and outlet connection from the heat exchanger.



Install

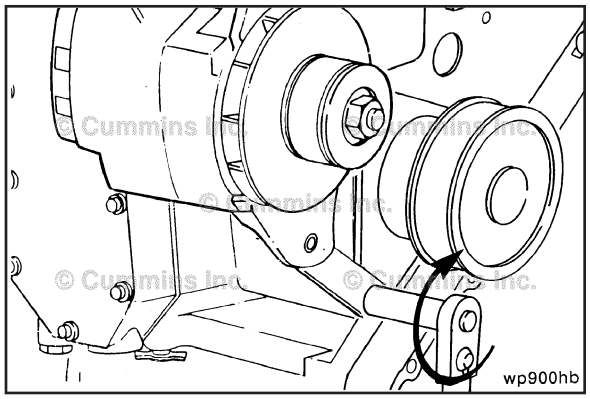
Install a new o-ring into the groove in the water pump.



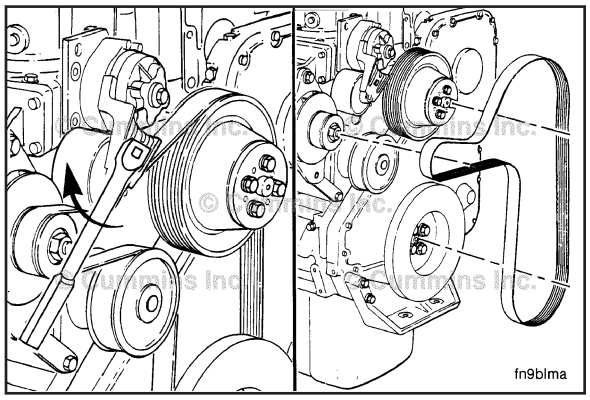
Install the water pump and water pump mounting capscrews.

Tighten the water pump mounting capscrews.

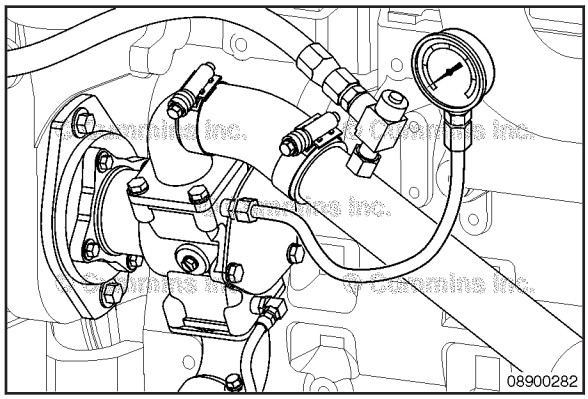
Torque Value: 24 N•m [212 in-lb]



Install and tighten the alternator link; refer to Procedure 013-001.

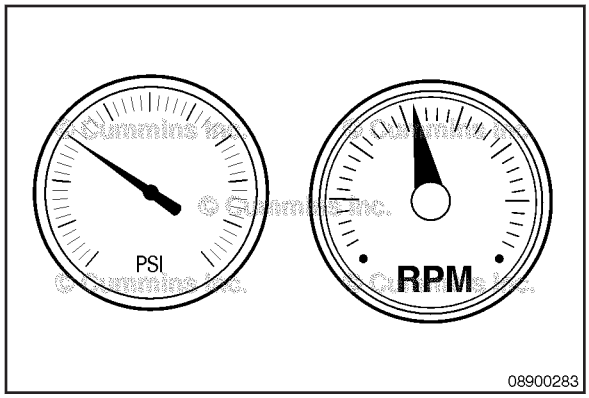


Install the drive belt; refer to Procedure 008-002.



Pressure Test

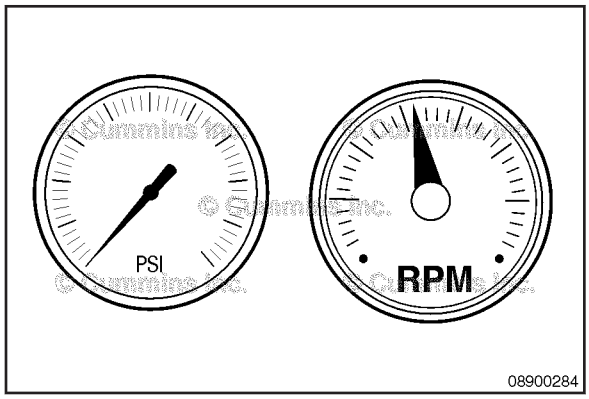
Attach a pressure gauge to the outlet side of the sea water pump to check pump outlet pressure.



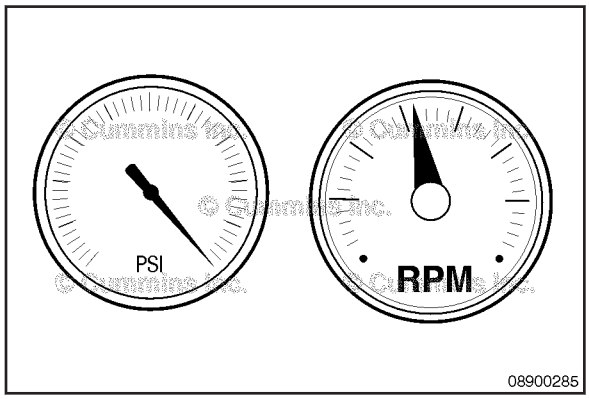
Start the engine and record the sea water outlet pressure from low idle to rated speed at 500 rpm increments. This test can be conducted while the vessel is at dock and **not** in gear or underway.

Refer to Procedure 018-018 for Marine engine specifications.

If the sea water pump outlet pressure is within specifications, refer to the Temperature Differential Test in this procedure.

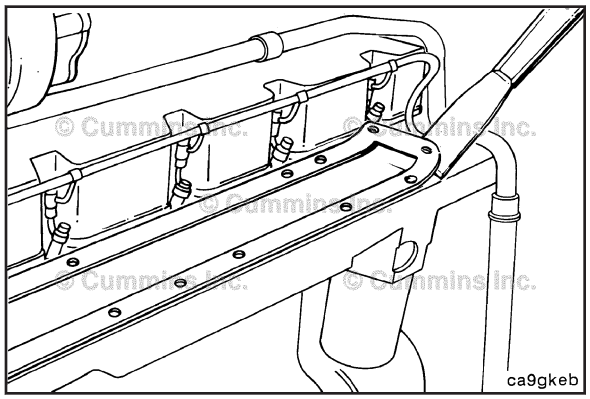


If sea water pressure is **not** present, check the pump for damage. Refer to Procedure 008-057.



If the sea water pump outlet pressure is above the maximum specification test the individual sea water system components for excessive pressure drop as described in the Pressure Differential Test step.

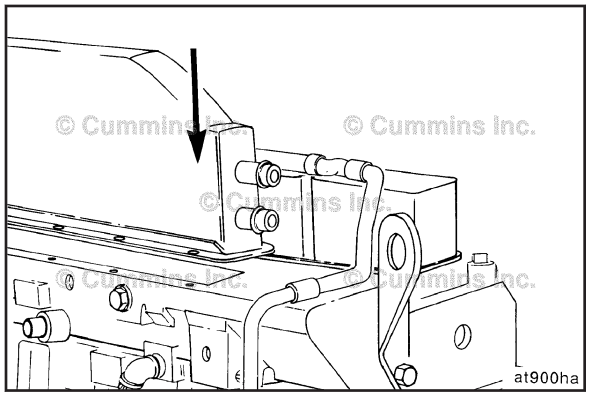
Refer to Procedure 018-018 for Marine engine specifications.



Clean

Clean the aftercooler housing sealing surfaces.

Keep the gasket material and all other materials out of the intake manifold.



Install

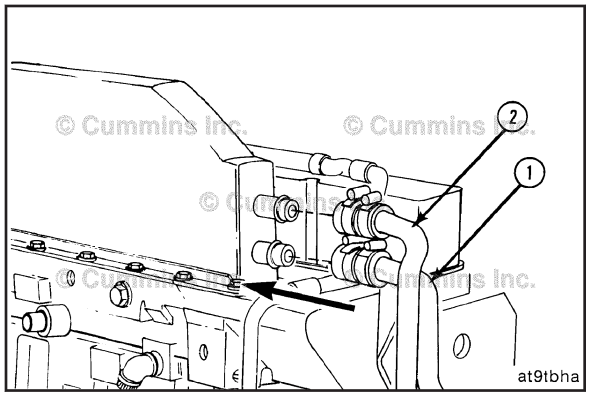
Use silicone sealant, Part Number 3823494, on both sides of the aftercooler housing gasket.

Install the aftercooler housing and new gasket.

NOTE: For aftercoolers with a form-in-place gasket, apply a 4-mm bead of sealant to the cylinder head.

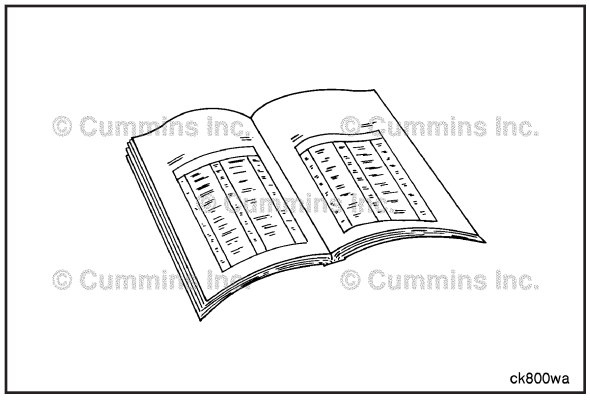
Install and tighten the aftercooler housing mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]



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

Torque Value: 5 N•m [44 in-lb]



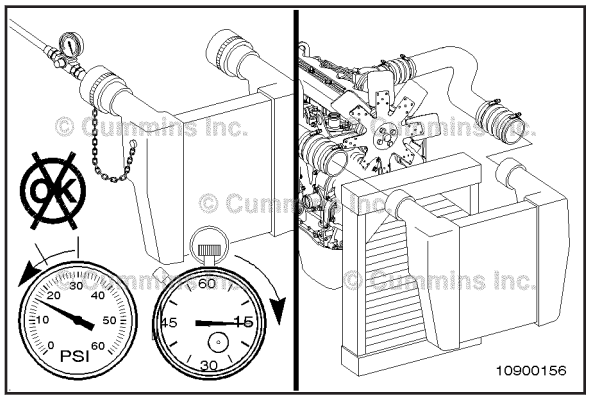
Finishing Steps

⚠CAUTION⚠
During filling, air must be vented from the engine coolant passages. Open the engine vent petcock. Make sure to open the petcock on the aftercooler for aftercooled engines. The system must be filled slowly to prevent air locks. Wait two to three minutes to allow air to be vented; then add coolant to bring the level to the bottom of the radiator filler neck.

Connect the cold starting aid, if used. Refer to the OEM service manual.

Install the air crossover tube. Refer to Procedure 010-019.

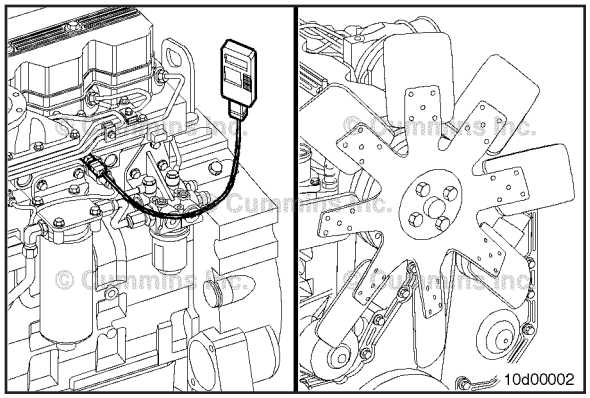
Fill the cooling system. Refer to Procedure 008-018.



If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge-air cooler **must** be replaced.

Refer to the OEM service manual for replacement instructions.

NOTE: Charge-air coolers are **not** designed to be 100-percent leak free. If the pressure drop is less than 48 kPa [7 psi] in 15 seconds, then the charge-air cooler does **not** need to be replaced.

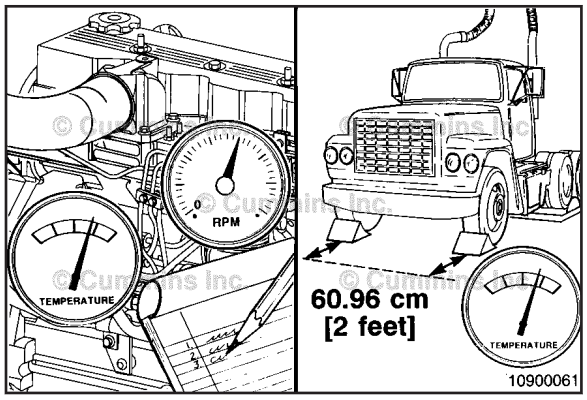


Temperature Differential Test

Install a temperature gauge in the intake manifold.

Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper across the temperature switch or supplying shop air to the fan. Refer to the OEM service manual for the lockup procedure.

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

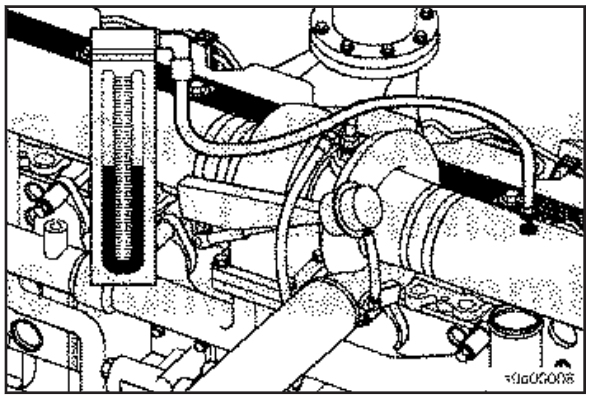


Operate the engine at rated rpm and load. Record the intake manifold temperature.

Measure the ambient temperature at least 2 feet in front of the vehicle.

The maximum temperature differential **must not** be greater than 25°C [77°F].

If the temperature differential is greater than 25°C [77°F], check the charge-air cooler for dirt and debris on the fins, and clean as necessary. If the problem still exists, check the cooler for internal contamination or plugging.



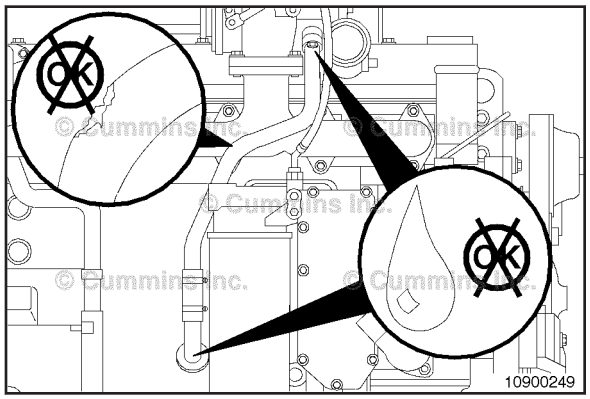
Air Intake Restriction (010-031)

Measure

NOTE: For naturally aspirated engines, measure the intake restriction just before the intake manifold.

Install a vacuum gauge or water manometer, Part Number ST-1111-3, in the intake air piping.

The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.

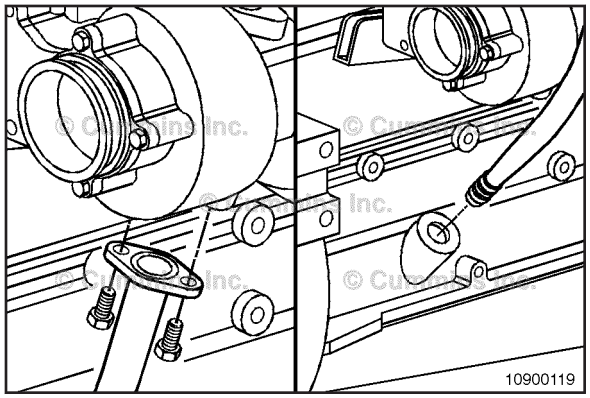


Turbocharger Oil Drain Line (010-045)

Initial Check

Inspect the turbocharger oil drain line for oil leaks or damage.

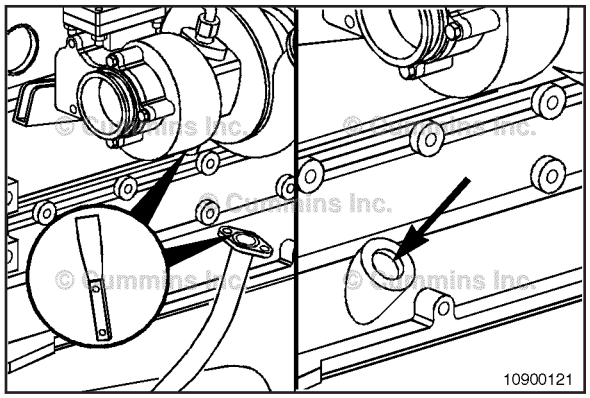
Repair as necessary.



Remove

Remove the capscrews from the oil drain tube.

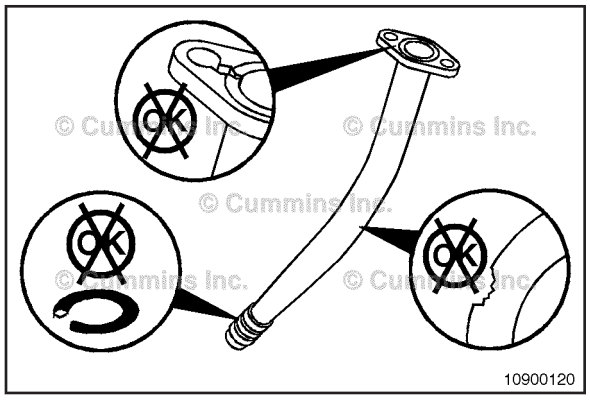
Pull the drain line out of the drain line boss.



Clean and Inspect for Reuse

Clean the gasket sealing surfaces.

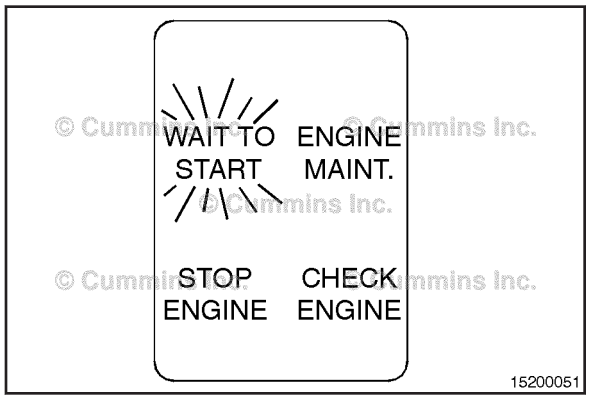
Clean the o-ring seating bore and make sure it is free of dirt and debris.



Inspect the line for cracks, wear, and damage.

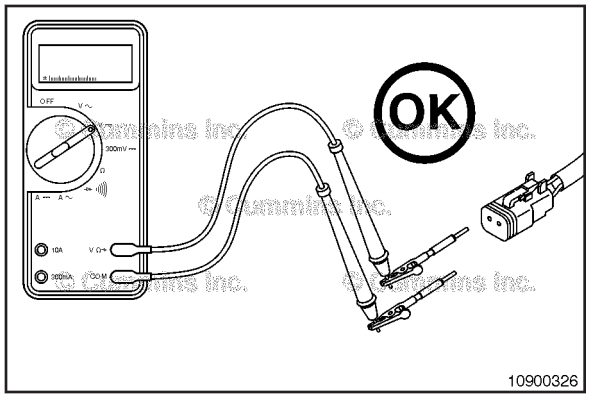
Inspect the o-ring for fretting and cracking. Replace if necessary.

Check the rubber section of the drain line for deterioration.



Check the voltage to the heater control module.

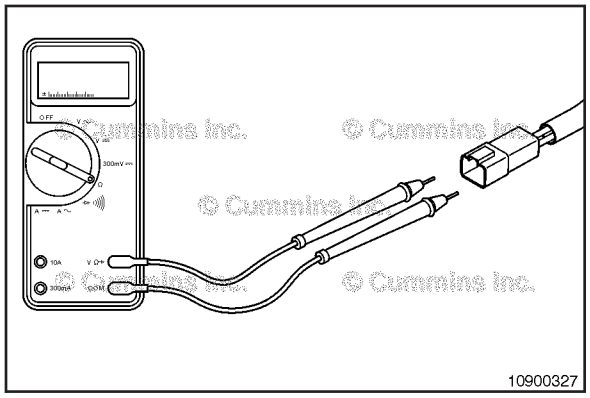
The WAIT TO START lamp, if equipped, will stay on if there is no voltage to the heater control module.



If there is no WAIT TO START lamp, check the voltage at the resistor in the supply wire from the fuse to the heater control module.

If no voltage is present, repair the wiring harness.

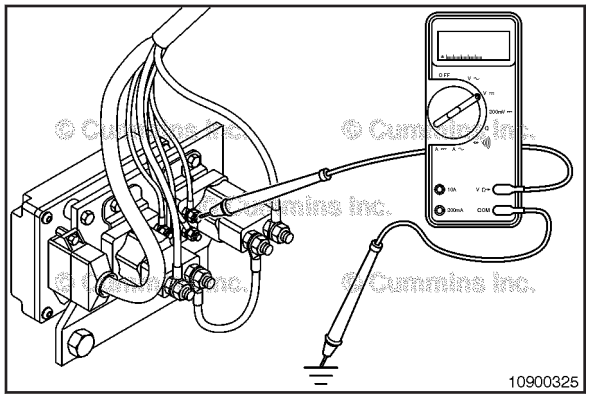
Refer to the wiring diagram.



If voltage is present, check the resistor with an ohmmeter.

Replace the resistor if necessary.

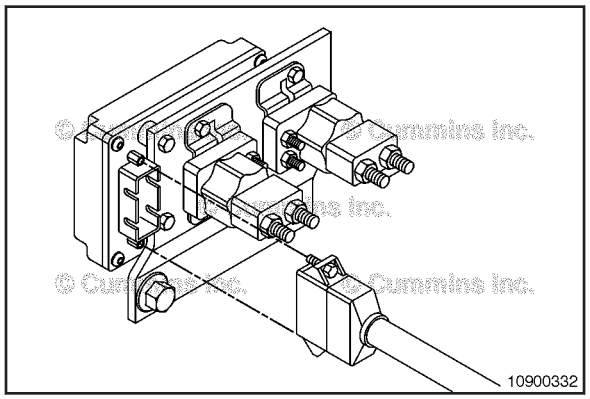
Resistance: 15.8k ohms at 12-VDC



Check the voltage at both positive leads at the connection to the heater control module.

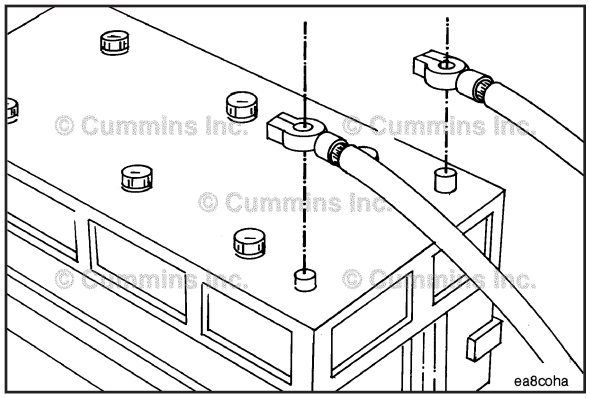
If voltage is **not** present, repair the wiring harness.

If voltage is present, replace the heater control module.

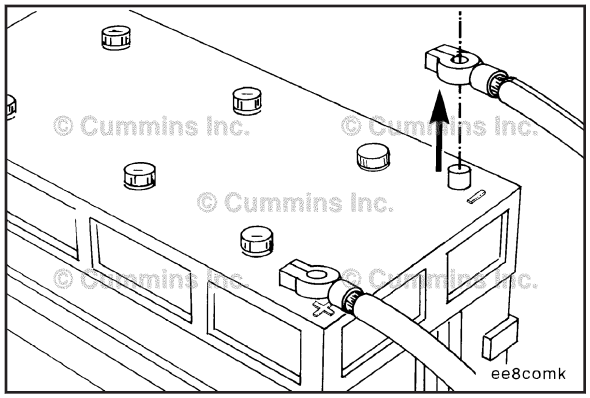


Install the heater control module plug.

Torque the hold down screws hand tight.



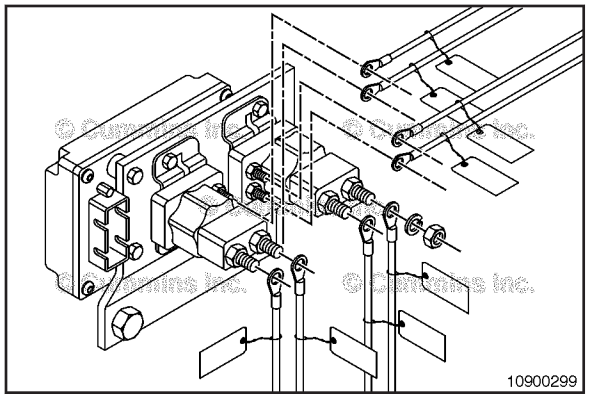
Connect the ground cable to the battery terminals.



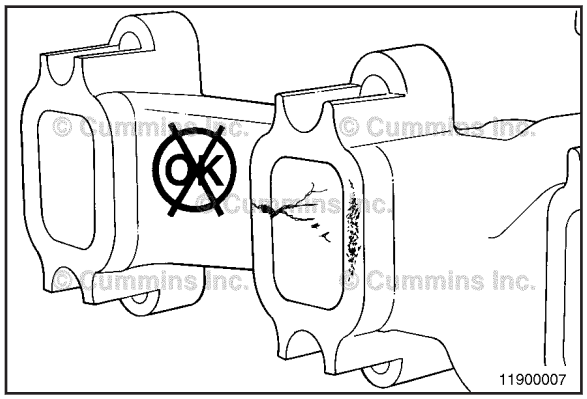
Intake Manifold Air Heater Solenoid Switch (010-126)

Resistance Check

Disconnect the ground cable from the battery terminal.

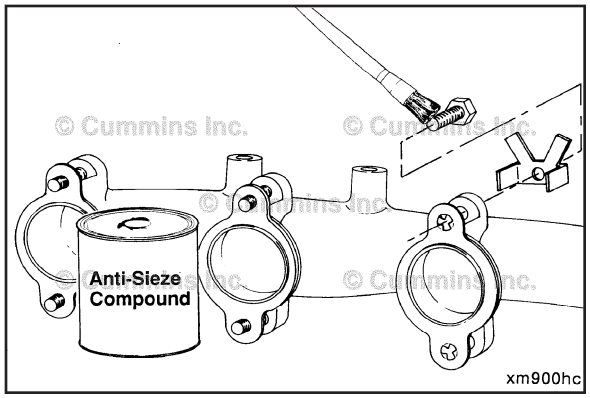


Label and remove the leads on the air heater solenoid(s) to be tested.



Inspect for Reuse

Inspect the exhaust manifold for cracks, burnout, or damaged threads in the bosses.

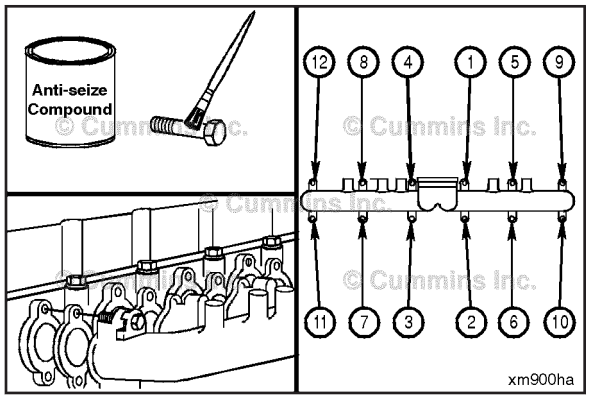


Install

Assemble the exhaust manifold capscrews, lock plates, and new gaskets onto the exhaust manifold.

Apply a thin coat of anti-seize compound, Part Number 3824879, to the capscrew threads.

NOTE: The exhaust manifold gaskets are nondirectional.

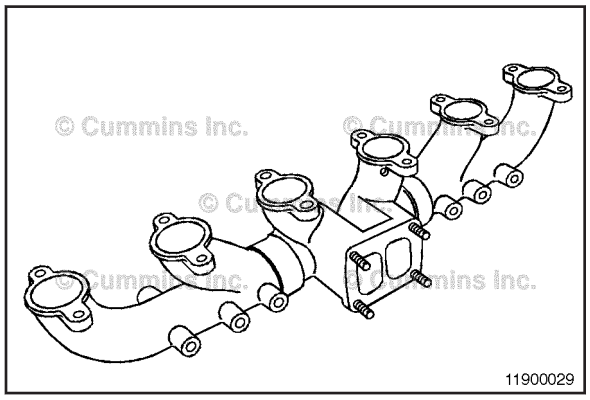


Install the exhaust manifold, new gaskets, and lock plates.

Torque Value: 43 N•m [32 ft-lb]

Follow the tightening sequence shown in the illustration.

Apply anti-seize compound to the exhaust manifold bolts upon assembly.

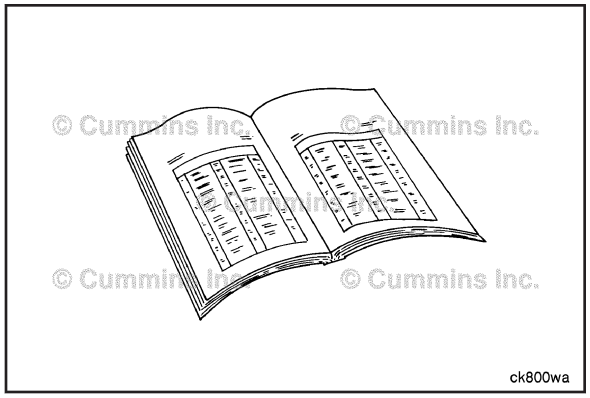


Three-Piece Manifold

If required, the end sections can be oiled, allowing the center section to slide.

NOTE: The manifolds are oxide-coated and can leak slightly on start-up. It will seal within the first few hours of use.

NOTE: Leaks in systems that hold pressure for 5 to 10 minutes may be hard to find.



Preparatory Steps

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

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

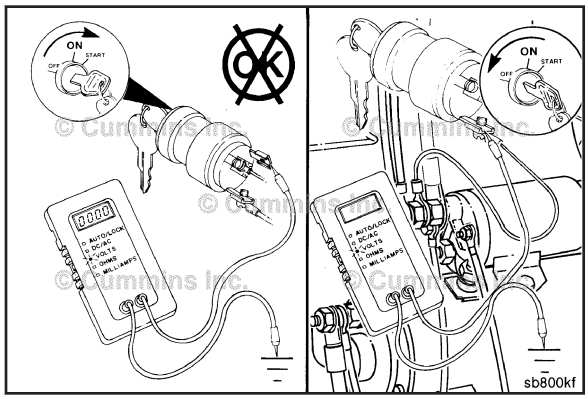
⚠WARNING⚠
When using a steam cleaner, wearsafety glasses or a face shield, as wellas protective clothing. Hot steam cancause serious personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

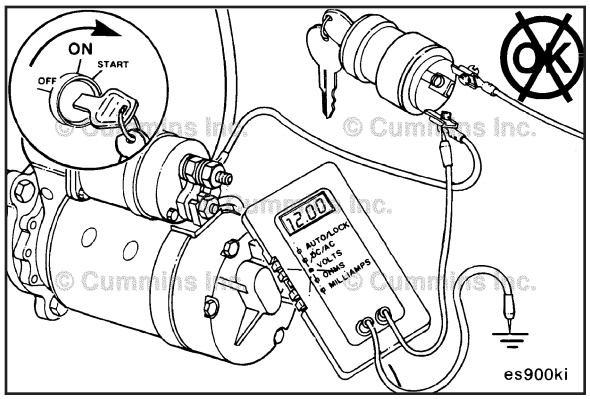
- Disconnect the batteries. Refer to the OEM service manual.
- Steam clean the air compressor. Refer to Procedure 000-009 in Section 0.
- Drain the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Refer to the OEM service manual or remove the hydraulic pump, if equipped. Refer to Procedure 009-016 in Section 9.
- Remove any attachments on the rear of the air compressor. Refer to the OEM service manual.
- Remove the coolant lines from the air compressor. Refer to Procedure 012-004 in Section 12.
- Remove the air connections from the air compressor.
- Remove the air inlet and air outlet connections from the air compressor.
- Remove the air compressor oil supply line. Refer to Procedure 012-110 in Section 12.

Notes



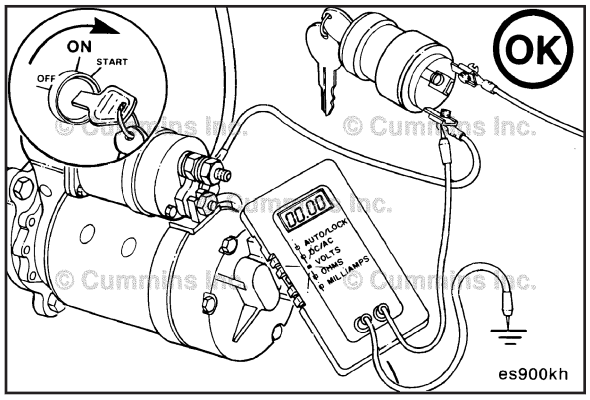
If there is no voltage:

- Turn the starting motor switch to the OFF position.
- Connect the multimeter positive lead to the starting motor switch terminal having a wire connecting the starting motor switch to the starting motor solenoid B terminal.

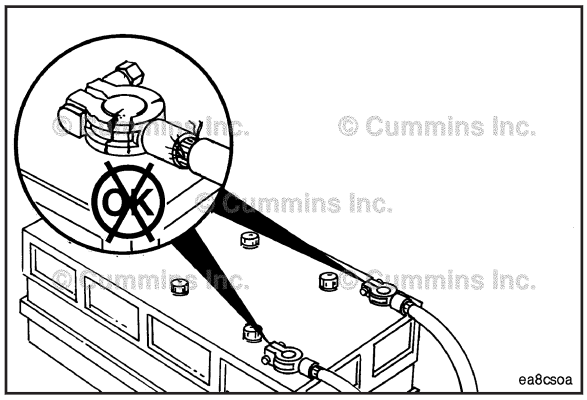


Turn the starter switch to the START position. If the multimeter indicates system voltage at the starting motor switch input terminal, the starting motor switch is **not** the cause of the complaint.

Inspect the wiring from the starting motor switch to the starting motor solenoid B terminal and from the starting motor solenoid to the battery from damaged or broken wires.



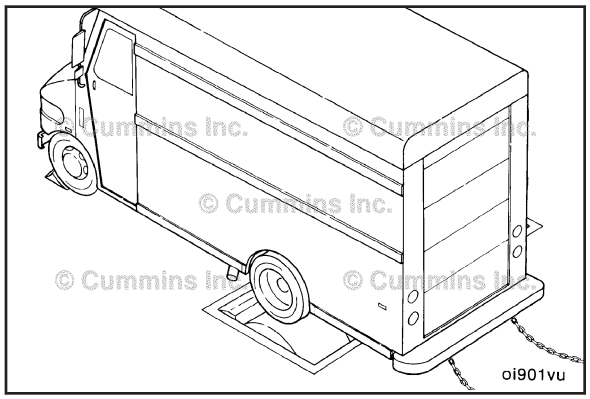
If the multimeter indicates no voltage, the switch is defective and **must** be replaced.



Starter Solenoid (013-019)

Initial Check

Before troubleshooting the starting motor, make sure the battery terminals are **not** loose or corroded.



Engine Testing (Chassis Dynamometer) (014-002)

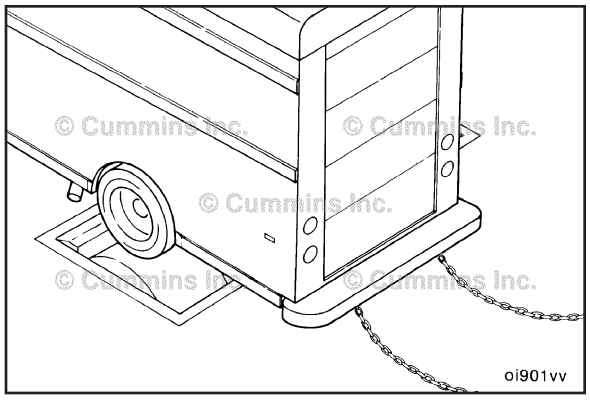
Setup

The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

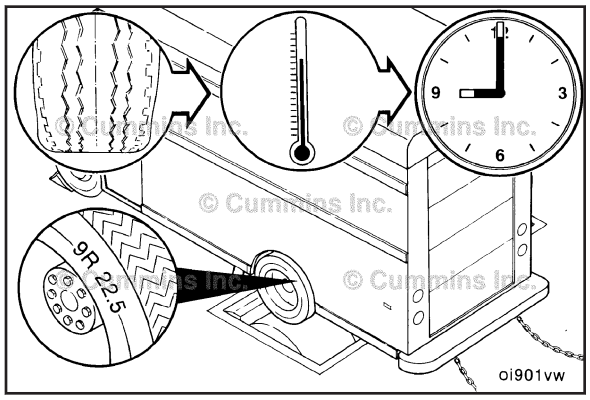
NOTE: Because of driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

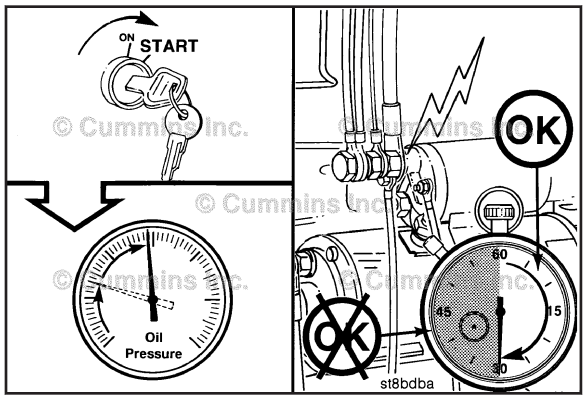
NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.



⚠WARNING⚠
Follow all of the vehicle manufacturer's safety precautions before installing or operating a vehicle on a chassis dynamometer. Failure to do so can cause damage to the vehicle and/or harm personnel.

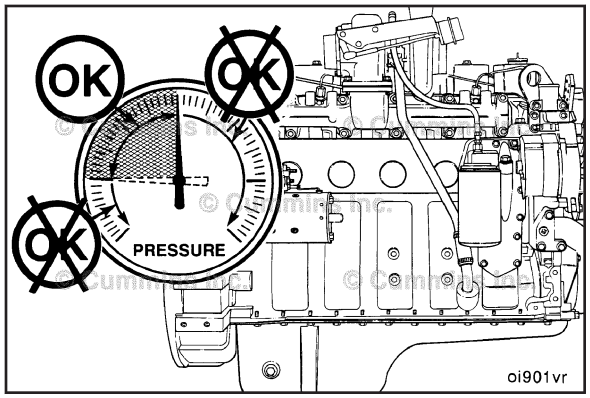


⚠CAUTION⚠
Low-profile tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

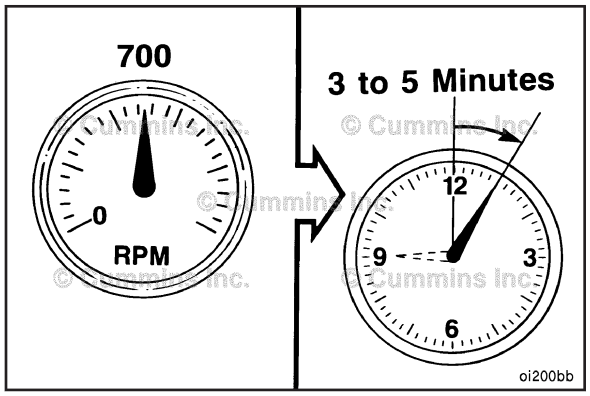
Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before ranking the engine again.



⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

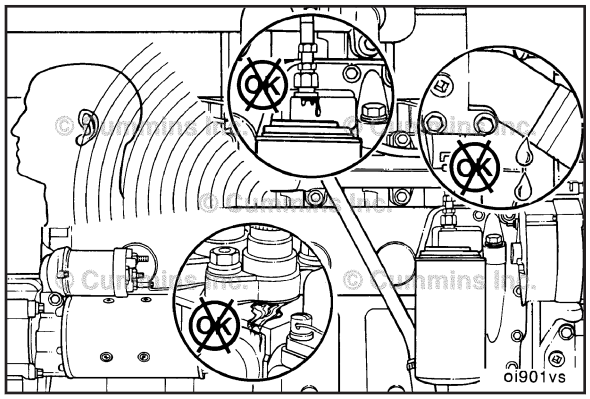
Engine lubricating oil pressure **must** be at least 70 kPa [10 psi] at 700 rpm.

Correct the problem if the lubricating oil pressure is **not** within specifications.



⚠CAUTION⚠
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

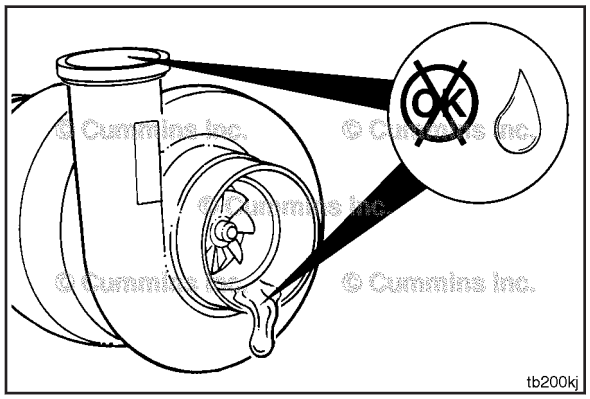
Operate the engine at approximately 700 rpm for 3 to 5 minutes.



Listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

Repair all leaks or component problems before continuing the engine run-in.

MidRange Blowby Specifications Chart				
	Blowby Specification For New or Rebuild - mm [in] H_2O		Blowby Specification For Troubleshooting - mm [in] H_2O	
Engine Model	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice
A1400 and A1700 (Naturally Aspirated)	25.4 [1]		25.4 [1]	
A2000 and A2300 (Naturally Aspirated)	25.4 [1]		38.1 [1.5]	
A2000 and A2300 (Turbocharged)	38.1 [1.5]		50.8 [2]	
ISF2.8	147.3 [5.8]		711.2 [28]	
ISF3.8		71.1 [2.8]		254 [10]
B3.3 Tier 1, 2		50.8 [2]		101.6 [4]
B3.3, QSB3.3 Tier 3		101.6 [4]		152.04 [6]
B3.3, QSB3.3 Tier 4 Interim (Less than 74 HP)		50.8 [2]		101.6 [4]
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Naturally Aspirated) (Less than 250 hp)	25.4 [1]		76.2 [3]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Less than 250 hp)	101.6 [4]		431.8 [17]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Greater than 250 hp)		25.4 [1]		127 [5]
B5.9 (Naturally Aspirated)	50.8 [2]			
B5.9, and QSB5.9-30, (Less than 250 hp)	228 .6 [9]		863.6 [34]	
B5.9, and QSB5.9-30, (Greater than 250 hp)		50.8 [2]		228.6 [9]
ISB, ISB^{e}, QSB^{e}, ISD^{e}, QSB5.9-44, ISB6.7, and QSB6.7		101.6 [4]		254 [10]
C8.3		101.6 [4]		254 [10]
ISC, ISC^{e}, QSC8.3, ISL, ISL^{e}, and QSL9		203.2 [8]		304.8 [12]
B Gas International, B Gas Plus, B LPG Plus, B5.9G, B5.9 LPG	228.6 [9]		889 [35]	
C8.3G, C Gas Plus, ISL G, L Gas Plus		203 [8]		457 [18]
ISB4.5 CM2350 B104	152.4		330.2	



Determine the turbocharger blowby pressure contribution by determining the difference in the blowby pressure measurement with the turbocharger drain isolated, valve (A) open, and turbocharger drain **not** isolated, valve (A) closed.

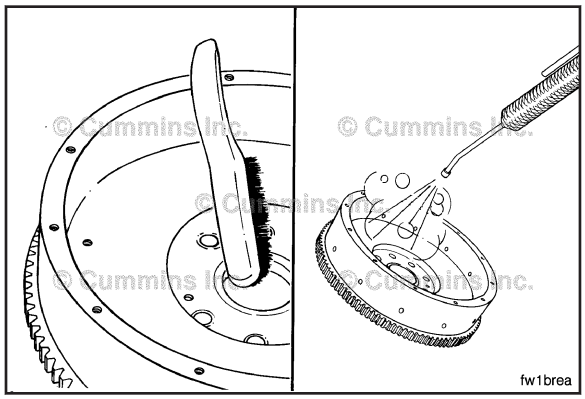
Blowby Pressure Differential	
Turbocharger Blowby Contribution	Maximum: 30 percent

If the turbocharger blowby contribution is out of specification, inspect the compressor and turbine areas of the turbocharger for signs of an oil leak. Replace the turbocharger, if necessary.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-033 in Section 10 (single turbocharger). Refer to Procedure 010-034 in Section 10 (dual turbocharger). Refer to Procedure 010-035 in Section 10 (dual turbocharger).
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and (dual turbocharger applications) ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178 for single turbocharger applications. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-033 in Section 10.

Piston or piston rings are worn or damaged.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 001-043 in Section 1.Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 001-043 in Section 1.



Clean

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

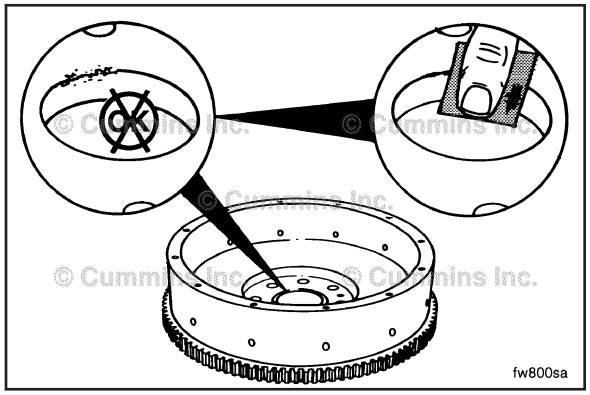
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use a wire brush to clean the crankshaft pilot bore.

Use steam or solvent to clean the flywheel.

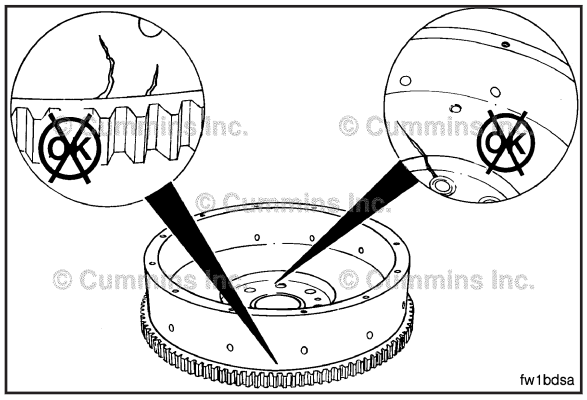
Dry with compressed air.



Inspect for Reuse

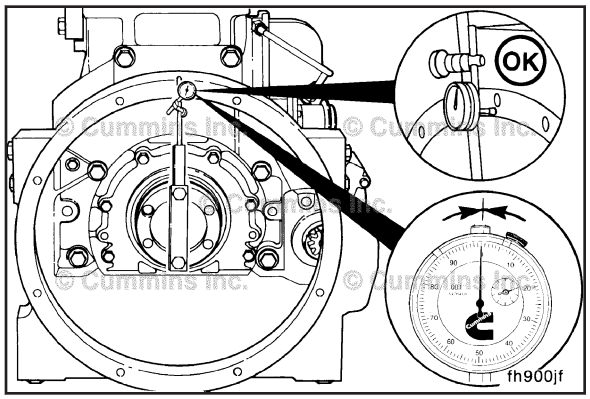
Inspect for nicks or burrs.

Use Scotch-Brite™ 7448, or equivalent, to remove small nicks and burrs.



⚠WARNING⚠
Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.

Use the crack detection kit, Part Number 3375432, to check for cracks in the flywheel. Follow the instructions provided with the kit.



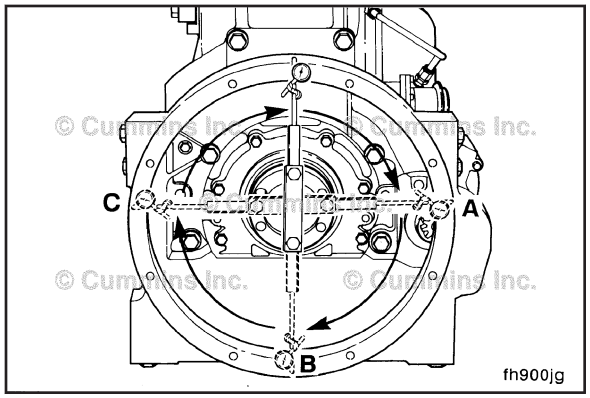
CAUTION

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

Face Alignment

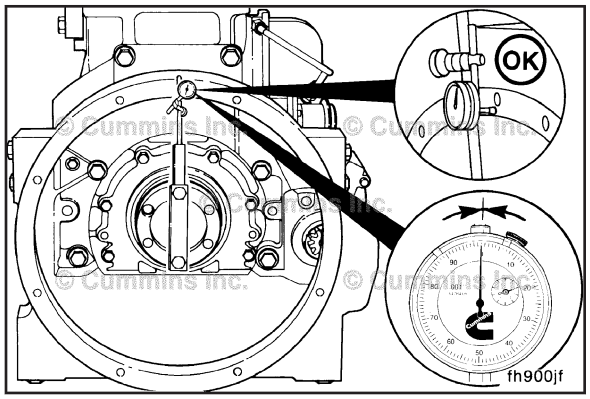
Install the dial indicator gauge, Part No. 3376050, as illustrated.

NOTE: The extension bar for the indicator **must** be rigid for an accurate reading. It **must not** sag. Position the indicator at the twelve-o'clock position. Adjust the dial until the needle points to zero.

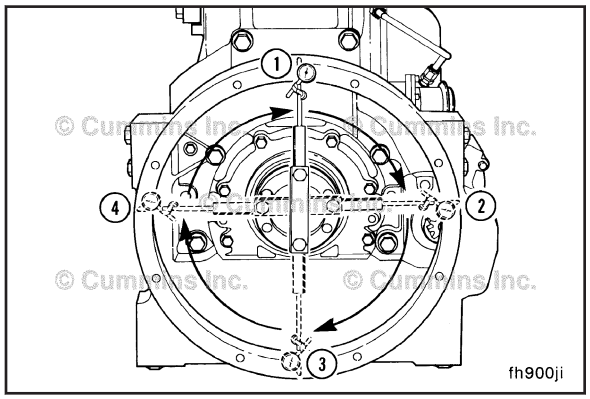


Slowly rotate the crankshaft. Record the readings at the three-o'clock, six-o'clock, and nine-o'clock positions.

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

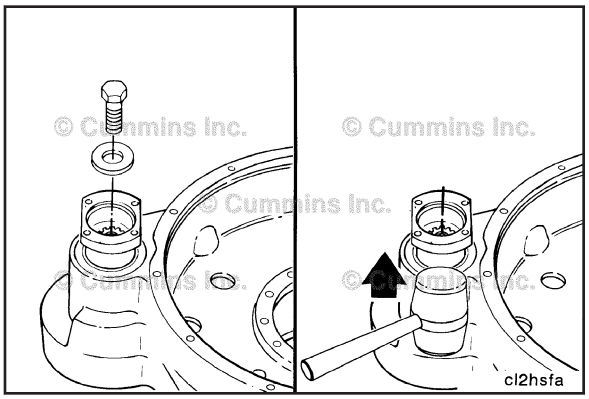


Continue to rotate the crankshaft until the indicator is at the twelve-o'clock position. Check the indicator to make sure the needle points to zero. If it does **not**, the readings will be incorrect.



Determine the total indicator reading (TIR).

Example:	**mm**	**in**
12 o'clock	0.00	0.000
3 o'clock	+0.08	+0.003
6 o'clock	-0.05	-0.002
9 o'clock	+0.08	+0.003
Equals TIR	0.13	0.005

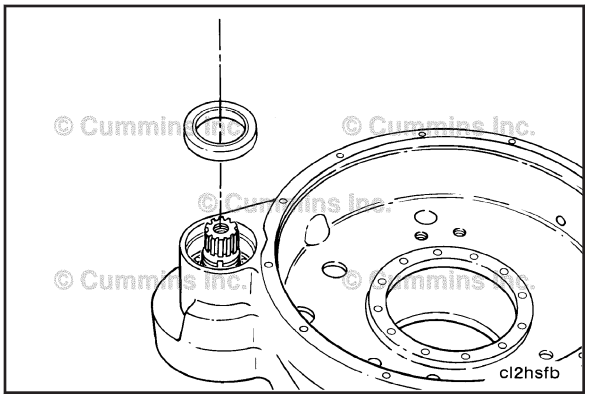


Disassemble

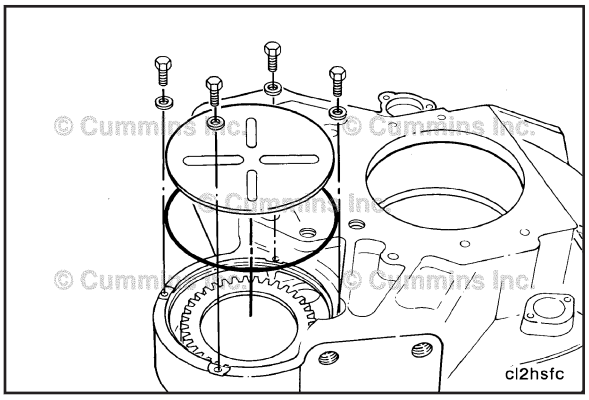
NOTE: Use gear locking tool, Part Number 3823891, to prevent the output shaft from turning when removing the retainer capscrew.

Remove the capscrew and washer that secures the output flange to the output shaft.

Use a rawhide hammer to remove the output flange and flat washer from the output shaft.



Use a dent puller to remove the seal. Do **not** damage the surface of the housing or seal bore.

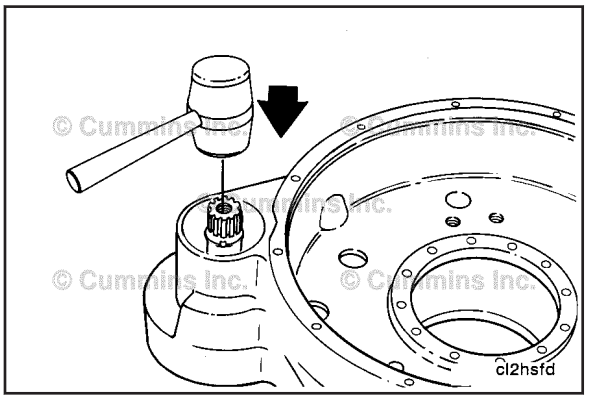


NOTE: When the housing is turned over, the bearing will fall out. Do **not** allow the bearing to be damaged.

Turn the housing over so the four cover plate capscres are accessible. Be careful **not** to damage the output shaft.

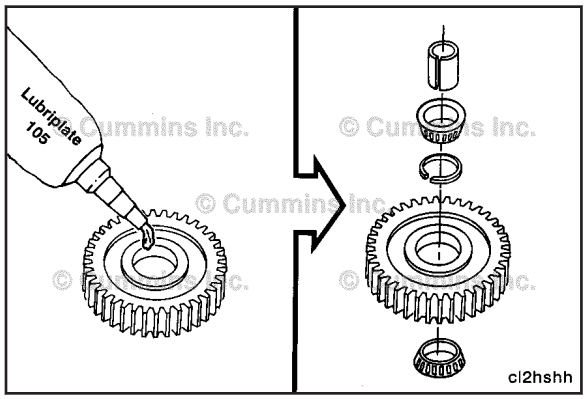
Remove the capscrews and ribbed cover plate from the output gear housing.

Remove and discard the square cut o-ring seal.



NOTE: Save the original shims for rebuild purposes. They will be used to set the proper end clearance on the output shaft and bearing assembly.

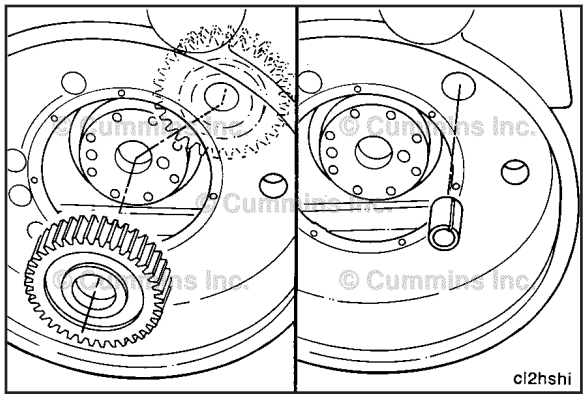
Turn the housing over and use a rawhide hammer to hit the end of the output shaft to remove the poutput shaft subassembly from the REPTO housing.



NOTE: The outer bearing races of new replacement gears are already pressed into the gear.

Apply a thin film of Lubriplate™ 105 or equivalent on the outer races and the bearings.

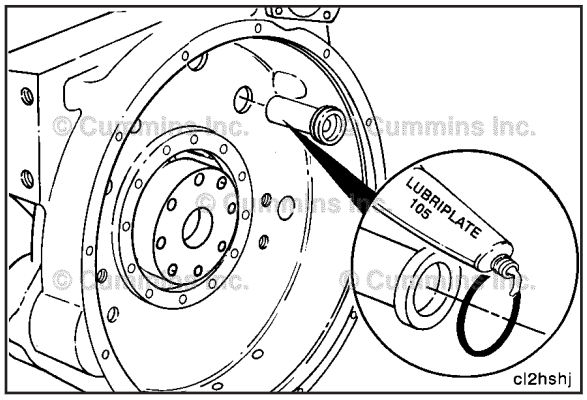
Install the bearing and spacer into the idler gear. Use a plastic sleeve to hold the bearing assembly together when installing the idler gear assembly.



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

Install the idler gear assembly into the flywheel housing.

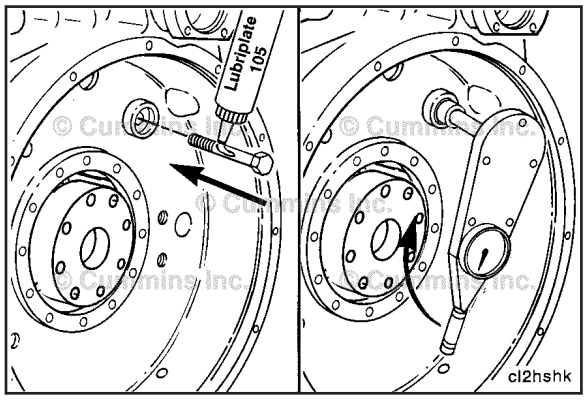
Hold the idler gear and bearing in place and remove the plastic sleeve.



Use clean Lubriplate™ 105 to lubricate the idle shaft o-ring and install the o-ring into the shaft.

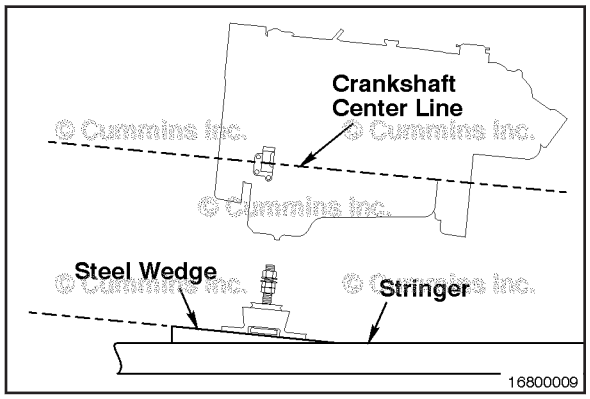
Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.

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

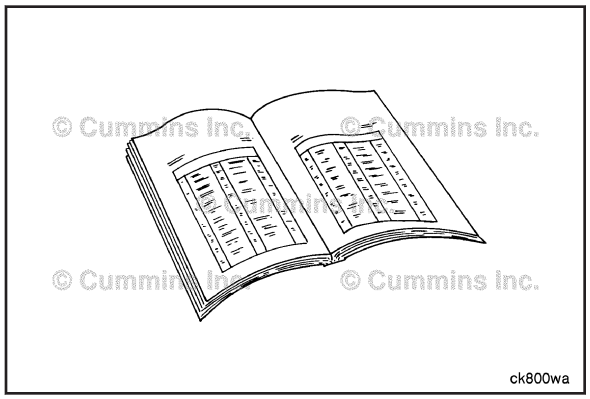


Apply Lubriplate™ 105 under the head of the idler shaft capscrew. Insert the capscrew through the idler shaft. Tighten the installation capscrew with a torque wrench.

NOTE: The toque needed to draw the idler shaft in place **must not** exceed 88 N•m [65 ft-lb]. If installation torque exceeds this amount, it is an indication of misalignment between the bore and the shaft. Remove the idler shaft and install it again.



If the isolator is out of alignment, the mounting will need to be adjusted. Wedges can be used to shim the base to achieve proper alignment. Shims **must** be made of a solid material that will **not** compress under the weight of the engine.



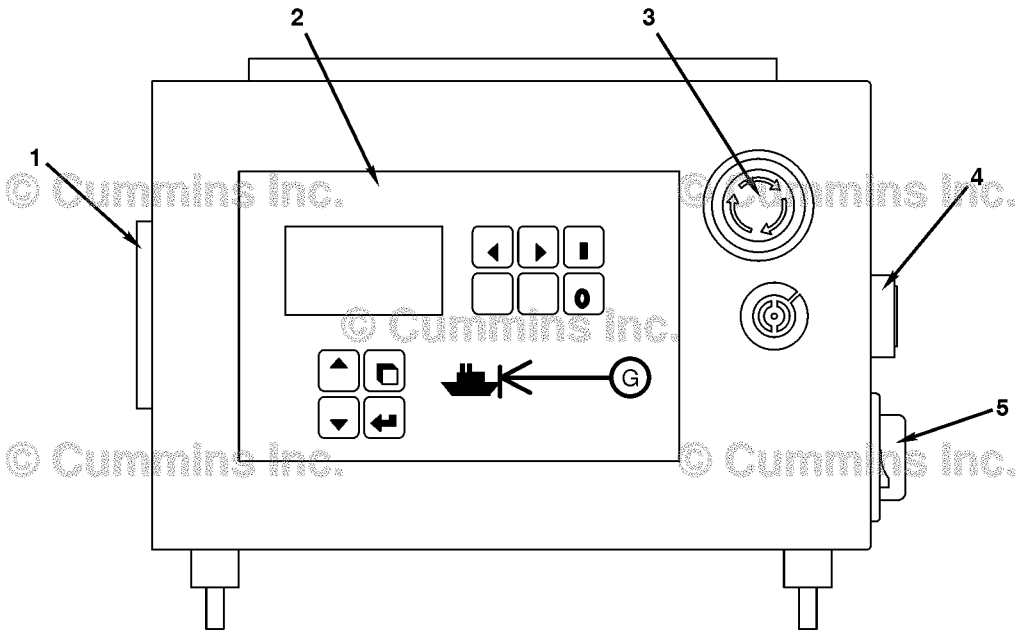
Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the propeller shaft. Disengage the flange. Refer to Procedure 016-025 in Section 16.

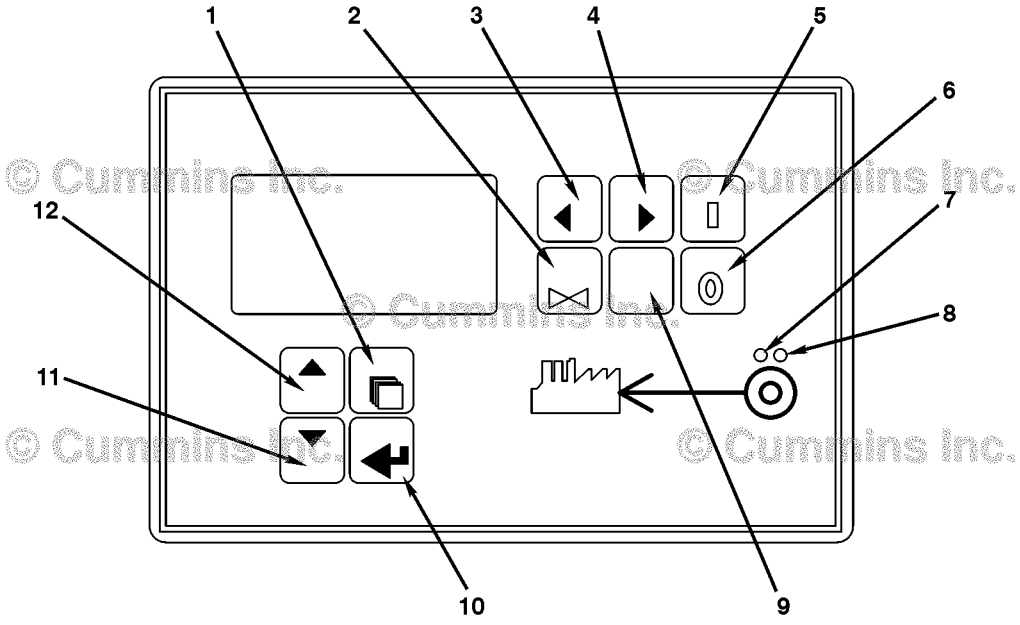
Notes



21900004

1. Engine harness connector
2. Control panel
3. Emergency stop button
4. Alarm horn
5. Cabinet power switch.

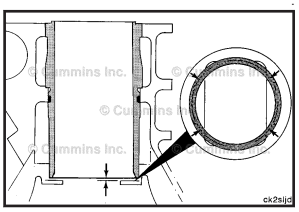
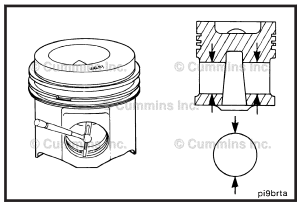
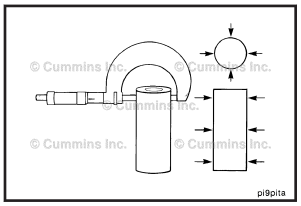
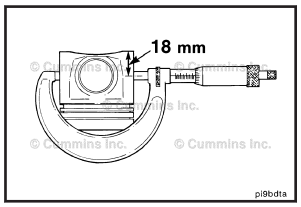
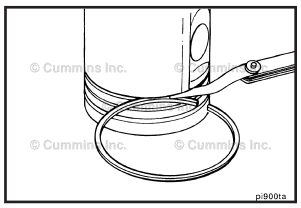
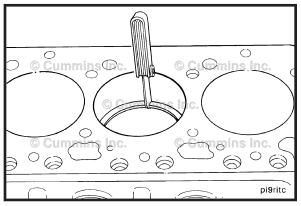
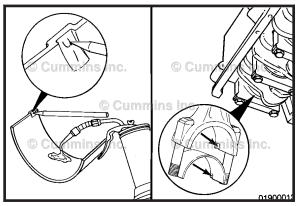
Un-Classed Base Panel Digital Display - The un-classed base panel is a comprehensive controller for single engine sets. The un-classed base panel is equipped with a graphic display showing icons, symbols and bar-graphs for intuitive operation. The un-classed base panel automatically starts and stops the engine on external signal from the un-classed remote panel or by pressing push buttons on the base panel itself. The un-classed base panel automatically checks engine conditions and protects against out-of-limit operation.



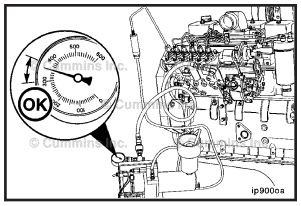
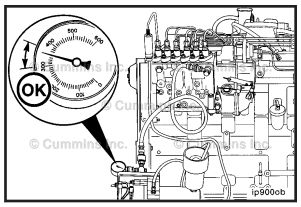
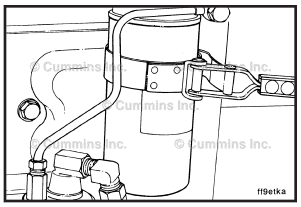
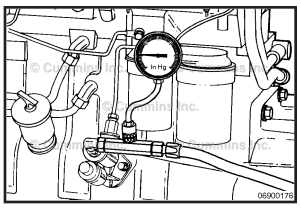
21900005

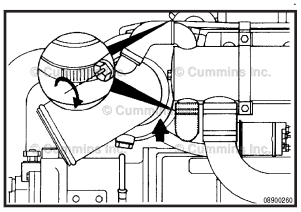
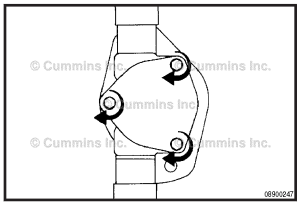
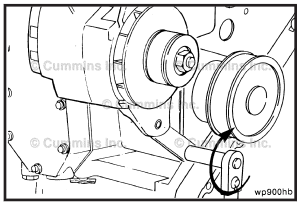
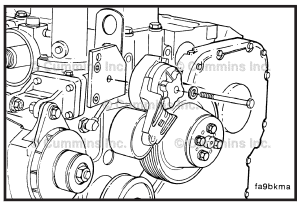
Un-Classed Base Panel Digital Display

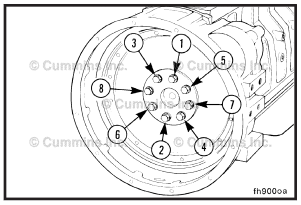
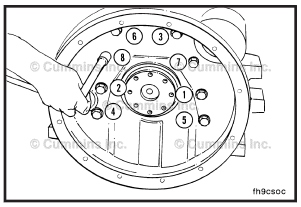
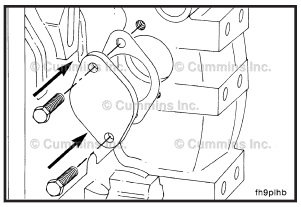
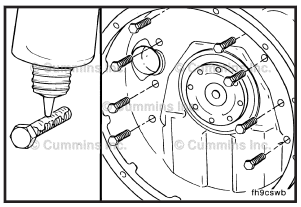
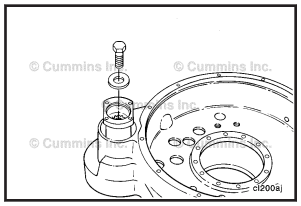
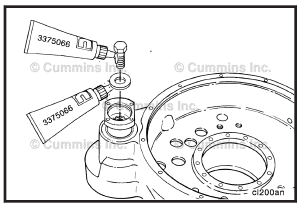
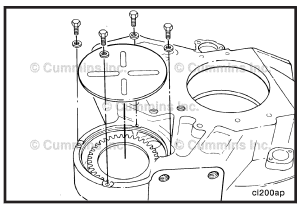
Notes

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder-Liner-to-Block Clearance		0.23 mm	MIN	0.009 in	
Piston (001-043)					
Piston Pin Bore Inside Diameter		45.01 mm 45.03 mm	MIN MAX	1.772 in 1.773 in	
Piston Pin Diameter		44.99 mm 45.00 mm	MIN MAX	1.771 in 1.772 in	
Piston Skirt Diameter		113.81 mm 113.88 mm	MIN MAX	4.481 in 4.484 in	
Piston Rings (001-047)					
Piston Ring Side Clearance (Rectangular Grooves)					
Intermediate Ring		0.07 0.15	MIN MAX	0.003 0.006	
Oil Control Ring		0.02 0.13	MIN MAX	0.001 0.005	
Ring Gap					
Top		0.40 0.70	MIN MAX	0.016 0.028	
Intermediate		0.25 0.55	MIN MAX	0.010 0.022	
Oil Control		0.25 0.55	MIN MAX	0.010 0.022	
Piston and Connecting Rod Assembly (001-054)					
Engines built after 1/1/1994		0.584 0.635	MIN MAX	0.023 0.025	

Fuel System - Group 05 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Injection Pumps, In-Line (005-012)					
Fuel Spill Timing Cart - Fuel Pressure		2068 kPa 2551 kPa	MIN MAX	300 psi 370 psi	
Fuel Injection Pump, In-Line, Spill Port Timing (005-013)					
Fuel Spill Timing Cart - Fuel Pressure		2068 kPa 2551 kPa	MIN MAX	300 psi 370 psi	
Fuel Lift Pump (005-045)					
Pressure Drop Across Filter					
Piston Lift Pump		34	MAX	5	
Fuel Lift Pump Inlet Restriction		27 kPa	MAX	8 in Hg	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Heat Exchanger (008-053)				
Seawater Inlet And Outlet Connections		5 N•m	[44 in-lb]	
Sea Water Pump (008-057)		24 N•m	[212 in-lb]	
Water Pump (008-062)				
Water Pump Mounting Capscrews		24 N•m	[212 in-lb]	
Belt Tensioner, Automatic (Water Pump) (008-080)				
Belt Tensioner Mounting Capscrew		43 N•m	[32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Mounting Adaptations - Group 16 - Torque Values				
Flywheel (016-005)				
Flywheel Capscrew Torque		137 N•m	[101 ft-lb]	
Flywheel Housing (016-006)				
Flywheel Housing Capscrew Torque		77 N•m	[57 ft-lb]	
Flywheel Housing Access Plate Capscrew		24 N•m	[18 ft-lb]	
		77 N•m	[57 ft-lb]	
Flywheel Housing, REPTO (016-007)				
Output Shaft Capscrew		205 N•m	[150 ft-lb]	
Output Flange Capscrew		205 N•m	[150 ft-lb]	
Cover Mounting Capscrews		18 N•m	[14 ft-lb]	

Compressed Air System

Specifications

Holset® SS296 A/C Model

Compressor Swept Volume at 1250 RPM.....6.2 liters per second [13.20 CFM]
Piston Displacement.....296 cc [18.06 C.I.D.]
Bore.....92.08 mm [3.625 in]
Stroke.....44.45 mm [1.750 in]
Speed.....1.135 times greater than Engine Speed
Cooling.....Engine Coolant
Lubrication.....Engine Lubricating Oil

Plumbing Line Sizes

- Coolant Inlet and Outlet (Pipe Fitting) .....3/8 in NPTF
- Air Inlet (Inside Diameter).....19 mm [0.750 in]
- Air Outlet (Minimum Inside Diameter).....1/2 in NPTF 12.7 mm [0.50 in]

Height, Overall (Approximate).....23.5 mm [9.25 in]
Width, Overall (Approximate).....14.6 cm [5.75 in]
Length, Overall (Approximate).....26.7 cm [10.5 in]
Weight (Approximate).....18 kg [40.0 lb]