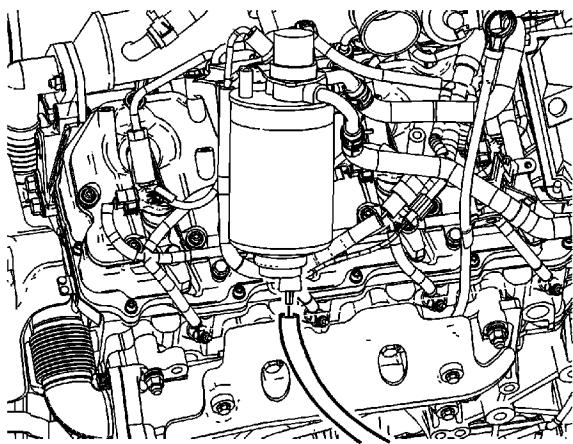
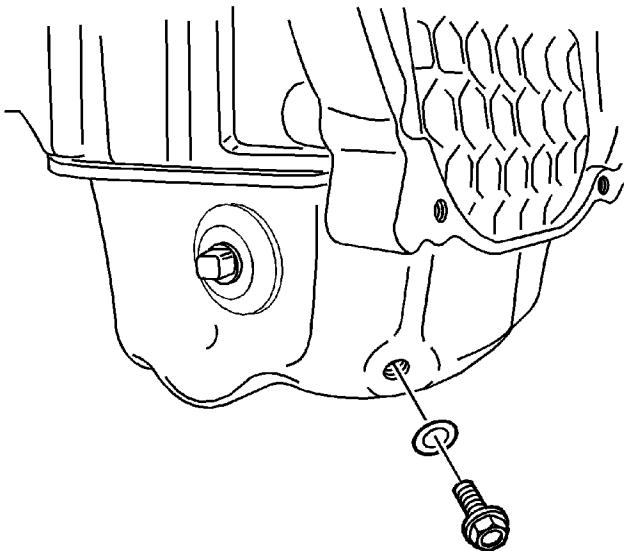


Draining Fluids and Oil Filter Removal

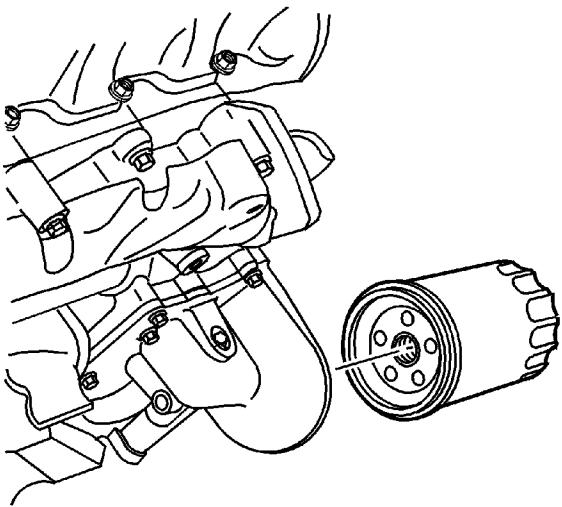


1. Drain the fuel from the fuel filter.
 - 1.1. Attach drain tube to fuel filter drain tap.
 - 1.2. Place open end of drain tube into a suitable container.
 - 1.3. Open fuel filter drain, and allow fuel to drain.
 - 1.4. Close fuel filter drain.
 - 1.5. Remove drain tube.
 - 1.6. Properly dispose of used fuel.

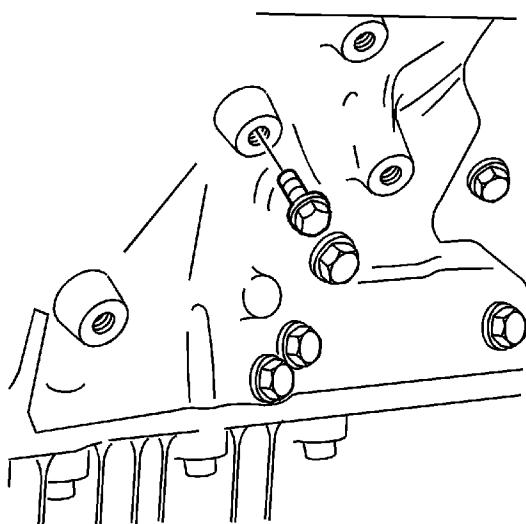




2. Remove the oil drain plug and gasket, and allow engine oil to drain.
3. Discard the oil drain plug gasket.

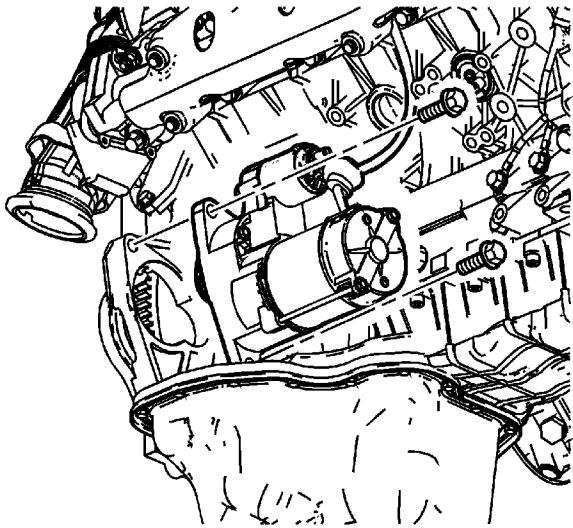


4. Remove the oil filter.



5. Remove the engine block coolant plugs, and allow coolant to drain.

Starter Removal

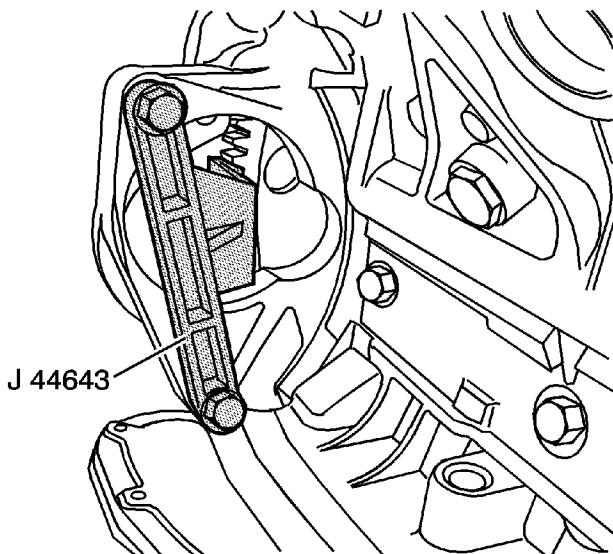


1. Remove the starter motor bolts.
2. Remove the starter motor assembly.

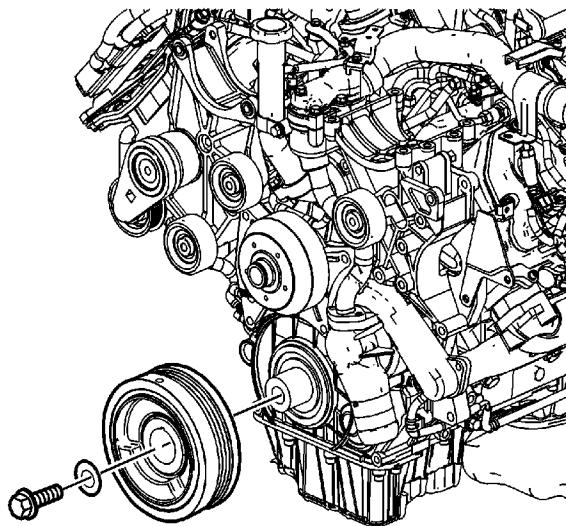
Crankshaft Balancer Removal

Tools Required

[J 44643](#) Flywheel Hold Tool



1. Install [J 44643](#) to lock the flywheel.



2. Remove the crankshaft balancer bolt.
3. Remove the crankshaft balancer.

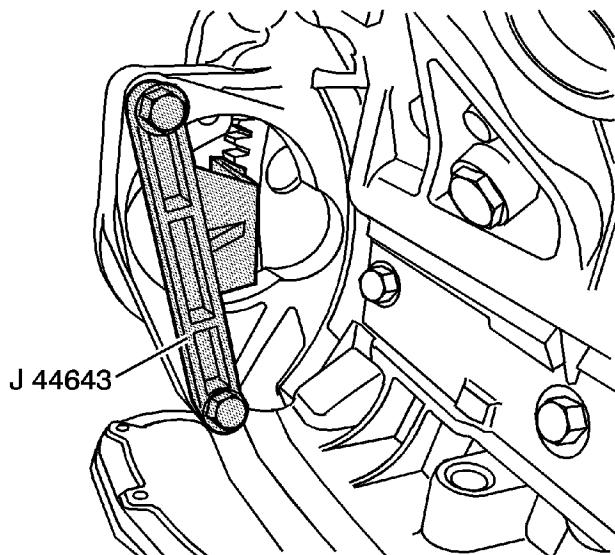
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Engine Flywheel Removal (Manual Transmission)

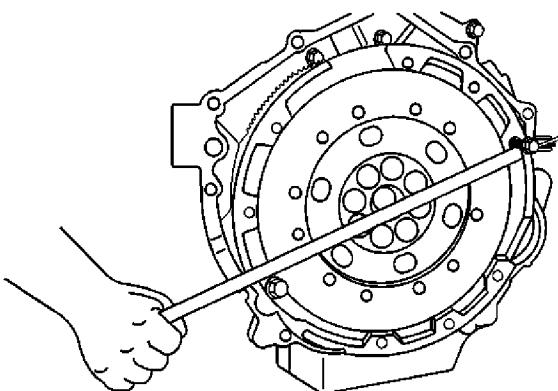
Special Tools

J 44643 Flywheel Hold Tool

For equivalent regional tools, refer to [Special Tools](#).



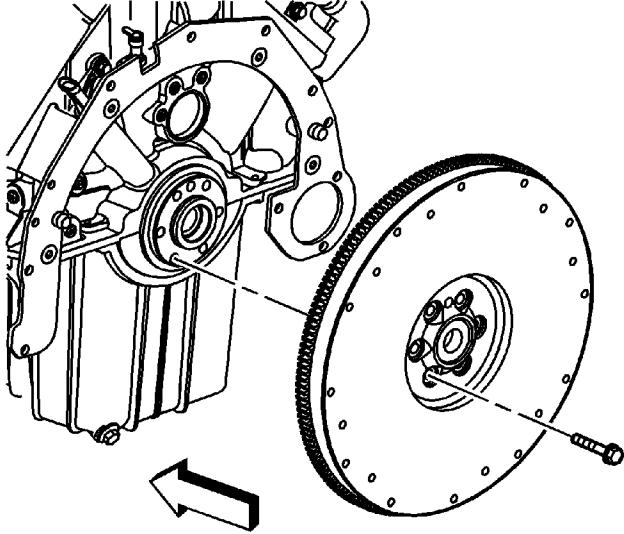
1. Install the *J 44643* tool to the starter opening in order to hold the flywheel.



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Note: Do not use the clutch pressure plate bolts. Use a bolt of the correct thread and a length that protrudes enough to use a pry bar.

2. Install two bolts into the clutch pressure plate mounting holes 180 degrees apart.
3. Using a long pry bar, turn the secondary ring of the dual mass flywheel clockwise until the flywheel mounting bolts can be accessed. It may require to turn the secondary ring past the bolt holes in order to compensate the spring tension.



4. Remove the flywheel mounting bolts and discard.
5. Remove the J44643 tool .

Warning: When removing, handling or installing this component wear protective gloves. The sharp edges on the component may be very sharp and may cause injury.

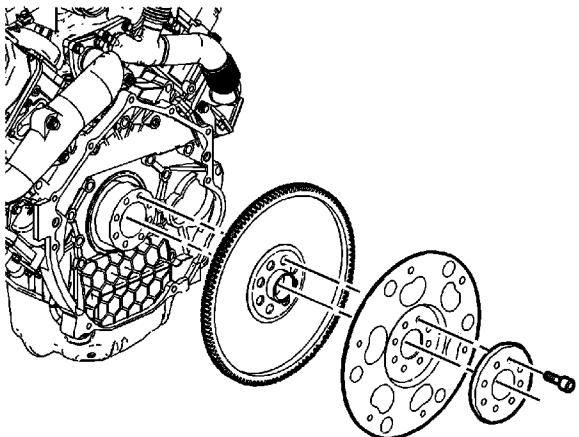
6. Remove the flywheel.

Engine Flywheel Removal (Automatic Transmission)

Special Tools

J44643 Flywheel Hold Tool

For equivalent regional tools, refer to [Special Tools](#).

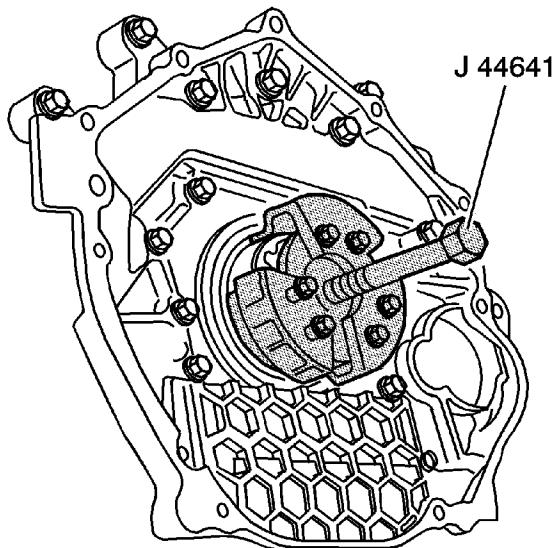


1. Remove the flywheel mounting bolts and discard.
2. Remove the flywheel washer.
3. Remove the *J44643* tool .
4. Remove the flywheel assembly.

Crankshaft Rear Oil Seal Removal

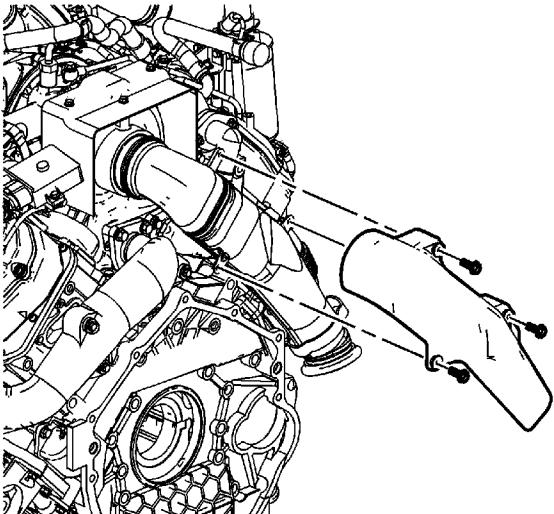
Tools Required

[J 44641](#) Crankshaft Rear Oil Seal Remover

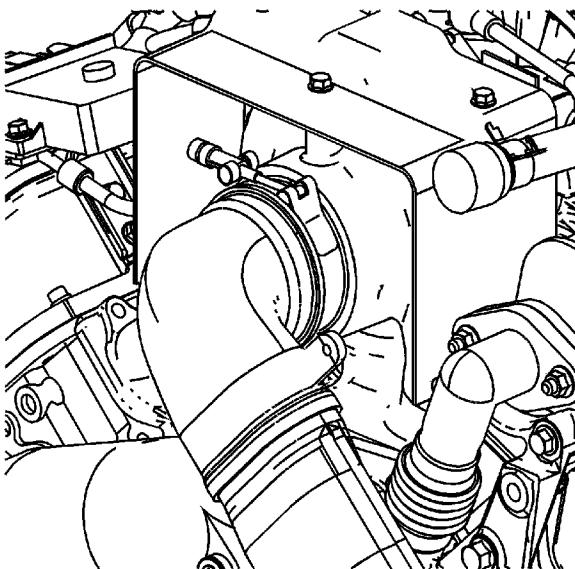


1. Install the button of [J 44641](#) into the crankshaft.
2. Press the jaws of [J 44641](#) into the felt portion of the seal far enough to engage the inner lip of the seal.
3. While holding the jaws of [J 44641](#) tightly to the seal's inner sleeve, tighten the jaw bolts.
4. Remove the crankshaft rear oil seal using the [J 44641](#).

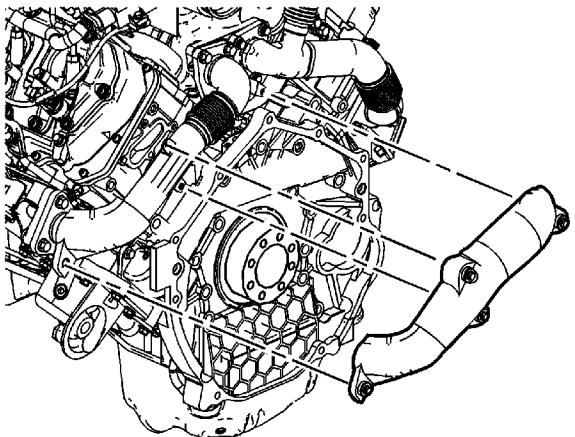
Exhaust Outlet Removal



1. Remove the exhaust outlet heat shield bolts.
2. Remove the exhaust outlet heat shield.
3. Remove the exhaust outlet to right exhaust pipe bracket bolt.

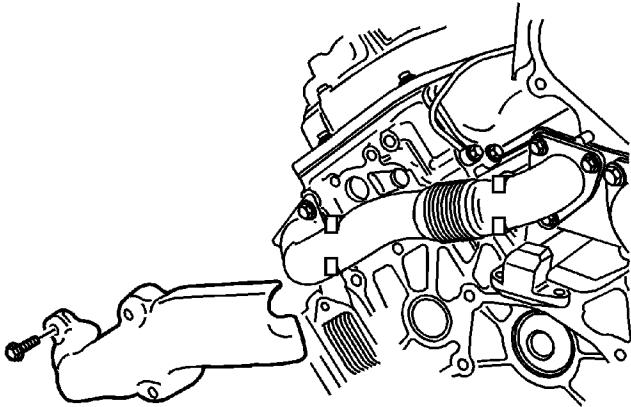


4. Loosen the exhaust outlet holding clamp.

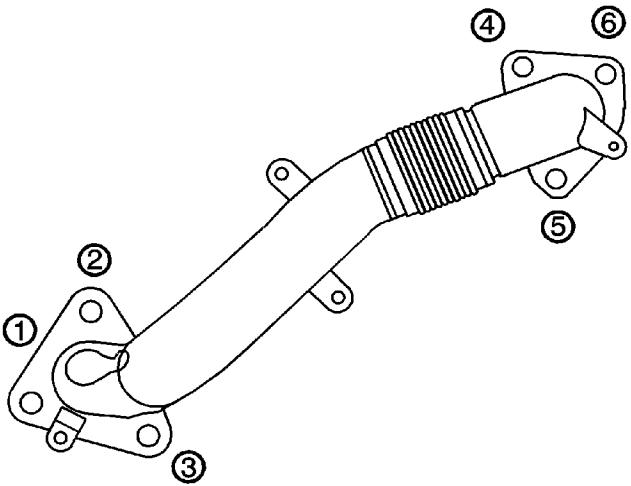


5. Remove the exhaust outlet.

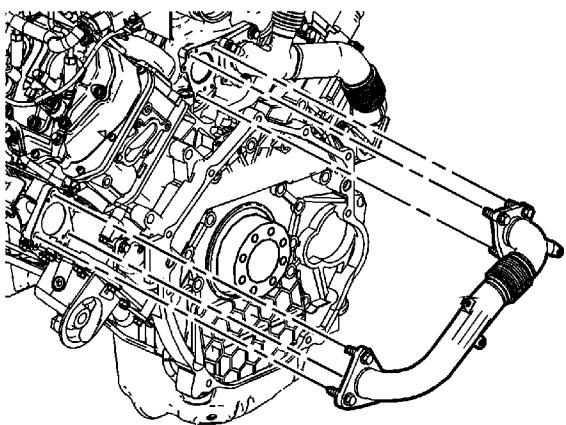
Exhaust Pipe Removal - Left Side



1. Remove the left exhaust pipe heat shield bolts.
2. Remove the left exhaust pipe heat shield.

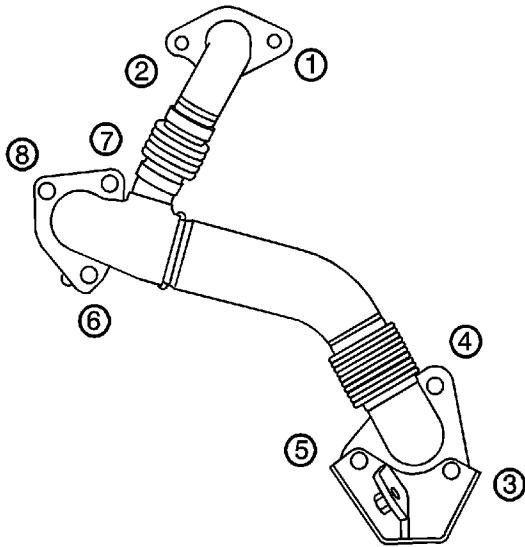


3. Remove the exhaust pipe bolts in the proper sequence.

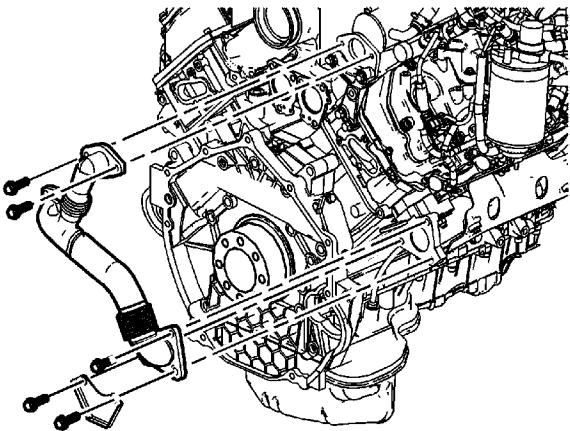


4. Remove the exhaust pipe and gaskets.

Exhaust Pipe Removal - Right Side



1. Remove the exhaust pipe bolts in the proper sequence.

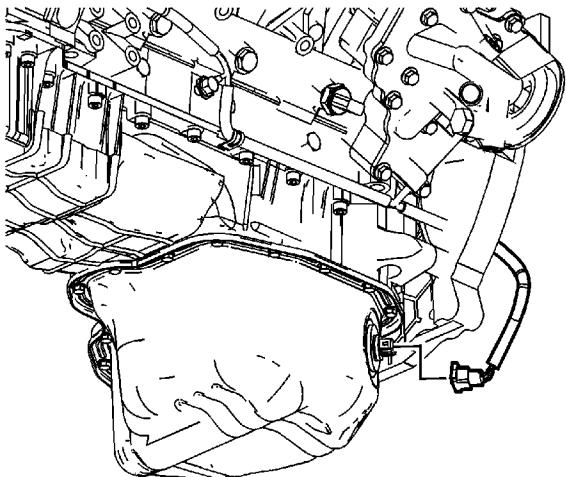


2. Remove the exhaust pipe, exhaust outlet bracket and gaskets.

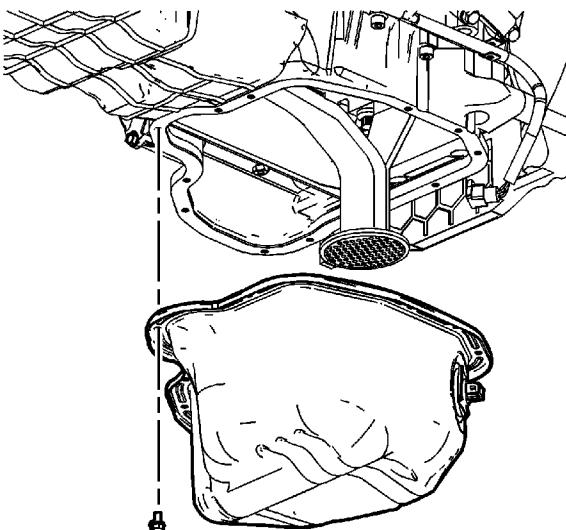
Lower Oil Pan Removal

Tools Required

[J 37228](#) Seal Cutter



1. Disconnect the oil level sensor.



2. Remove the lower oil pan bolts.

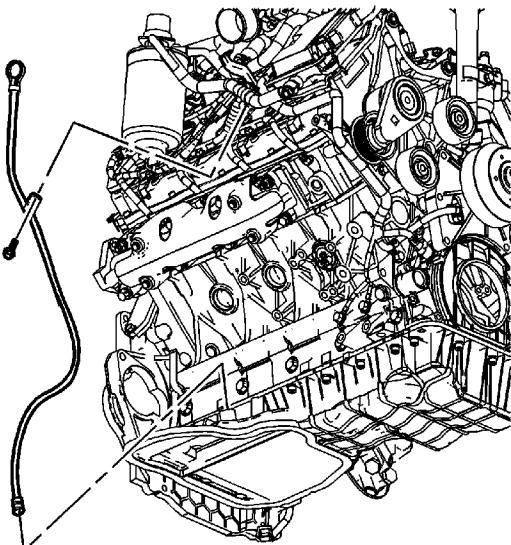
Important: Do not damage the sealing surfaces when separating the lower oil pan from the upper oil pan.

3. Separate the lower oil pan from the upper oil pan using [J 37228](#) .
4. Remove the lower oil pan.

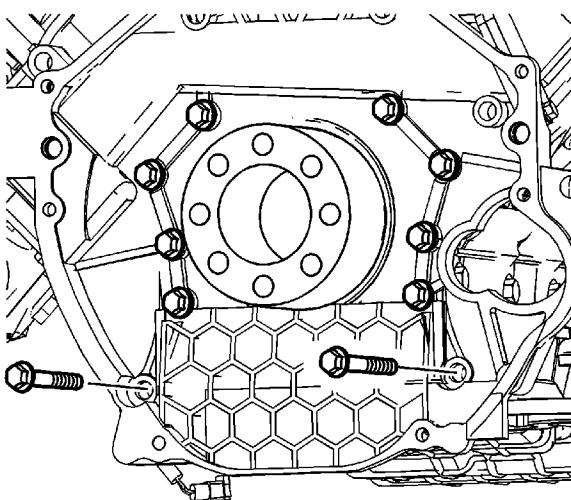
Upper Oil Pan Removal

Tools Required

[J 37228](#) Seal Cutter

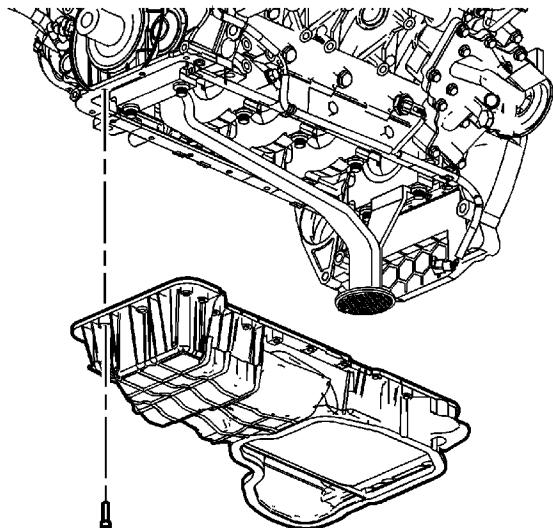


1. Remove the oil level indicator tube bracket bolt.
2. Remove the oil level indicator tube.



3. Remove the two oil pan to flywheel housing bolts.

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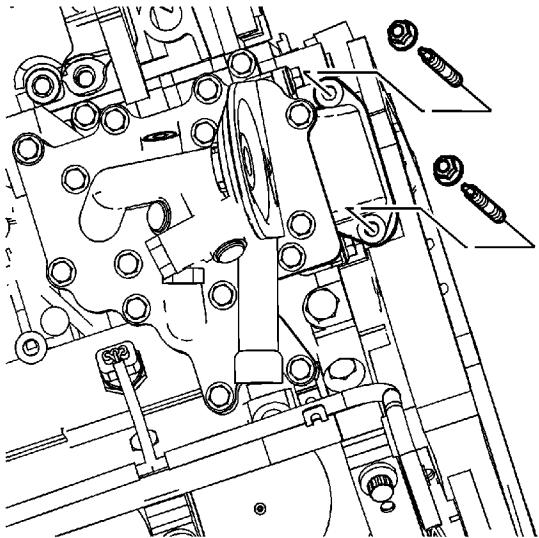


4. Remove the 24 upper oil pan bolts using a long bit 6 mm hex driver.
5. Separate the upper oil pan from the engine block using [J 37228](#).
6. Remove the upper oil pan.

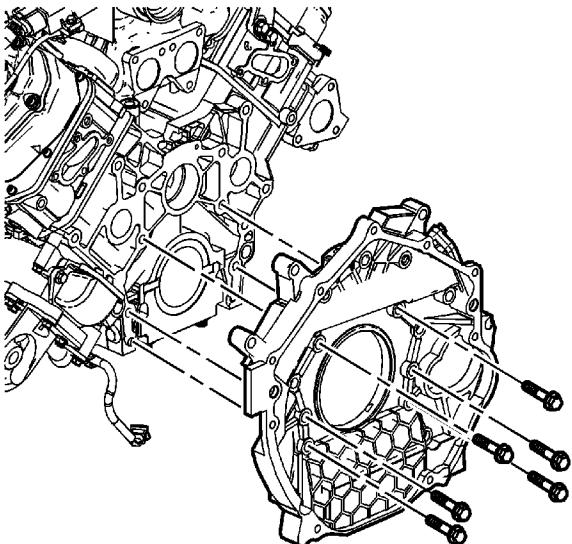
Engine Flywheel Housing Removal

Tools Required

[J 37228 Seal Cutter](#)



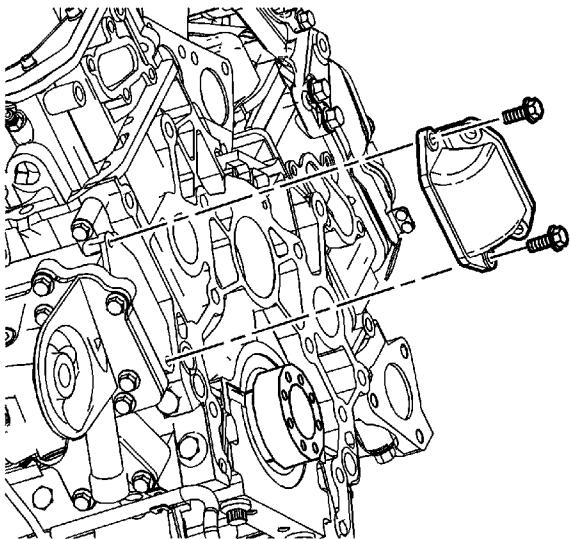
1. Remove the turbocharger oil return pipe nuts from the top of the flywheel housing.
2. Remove the turbocharger oil return pipe studs.



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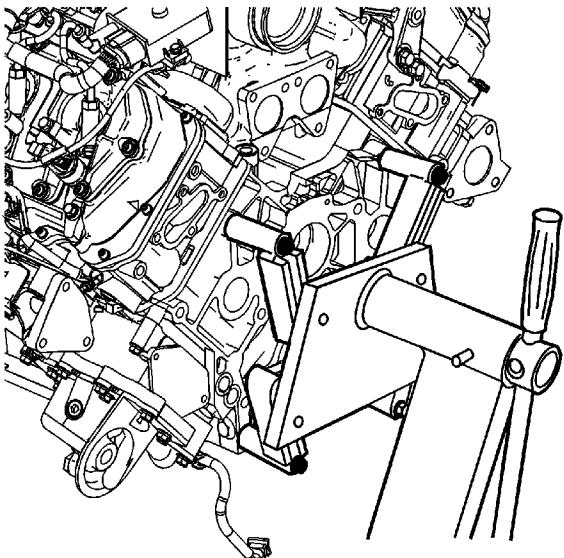
Important: The upper oil pan must be removed before removing the flywheel housing.

3. Remove the flywheel housing bolts.
4. Separate the flywheel housing from the cylinder block using [J 37228](#).
5. Remove the flywheel housing.



6. Remove the turbocharger oil return pipe gasket from the flywheel housing.
7. Remove the oil cooler adapter bolts.
8. Remove the oil cooler adapter with gaskets.

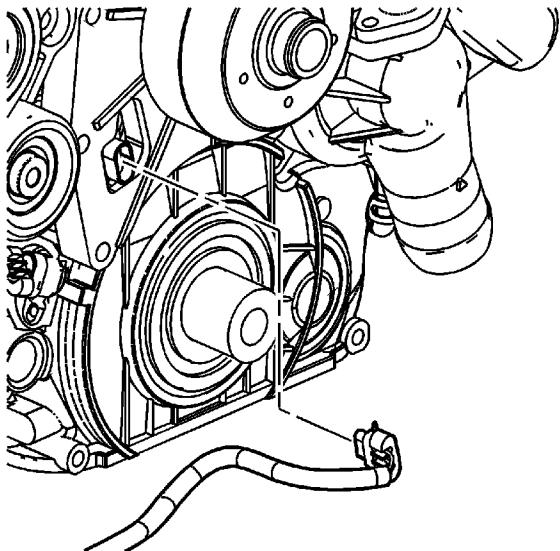
Engine Mounting to Stand



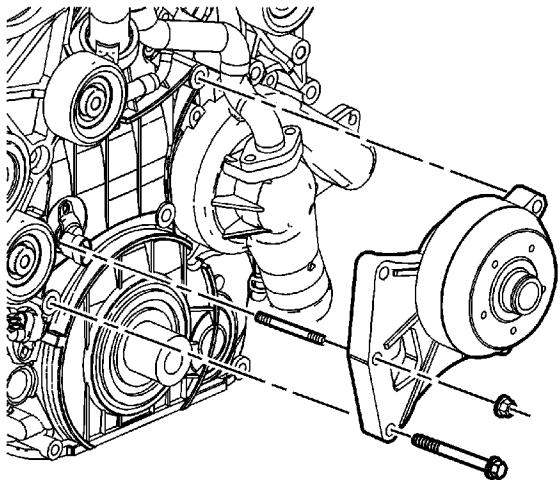
Warning: Do not mount the engine to a engine stand by the flywheel housing. The aluminum flywheel housing is not designed to support the weight of the engine when mounted to a typical rear-mount engine stand. Mounting the engine stand to the aluminum flywheel housing may result in engine damage and serious personal injury.

After the flywheel housing has been removed, mount the engine block to a suitable engine stand.

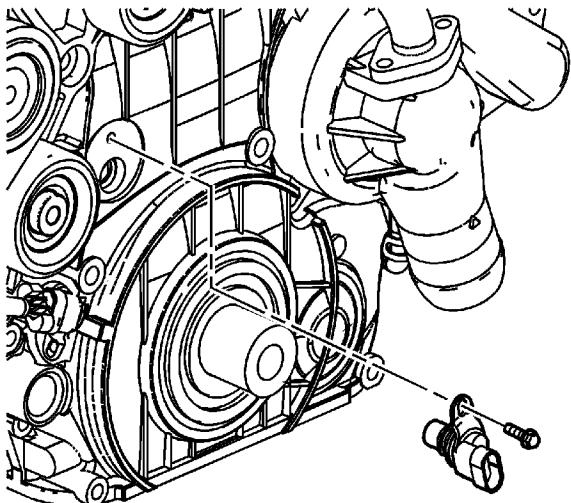
Cooling Fan Pulley Removal



1. Disconnect the camshaft position sensor connector.

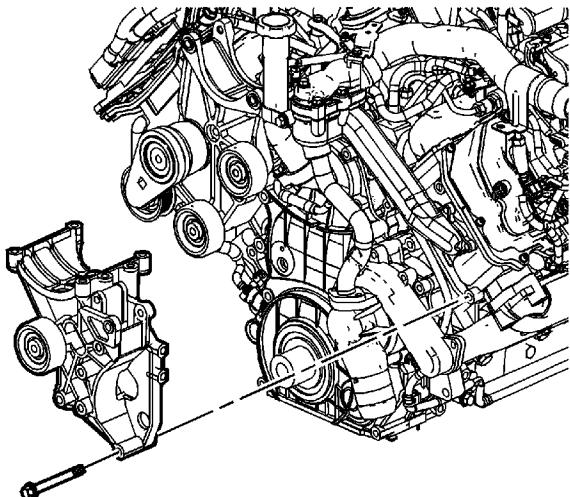


2. Remove the cooling fan pulley bolts and nuts.
3. Remove the cooling fan pulley.



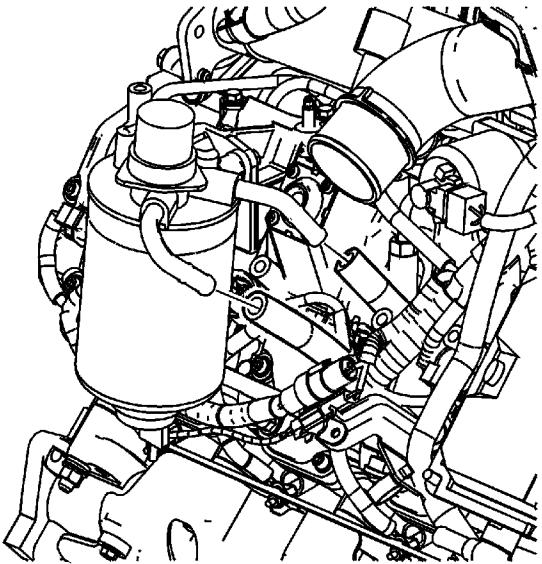
4. Remove the camshaft position sensor retaining bolt.
5. Remove the camshaft position sensor.

Power Steering Pump Mounting Bracket Removal

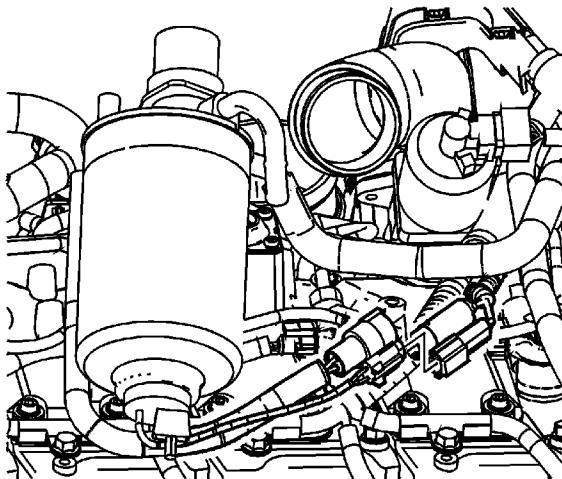


1. Remove the power steering pump mounting bracket bolts.
2. Remove the power steering pump mounting bracket.

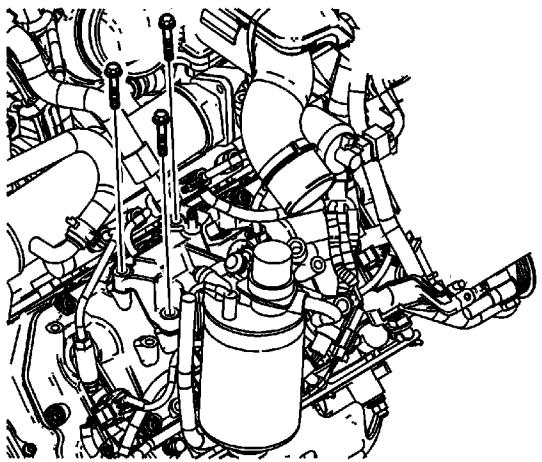
Fuel Filter Assembly Removal



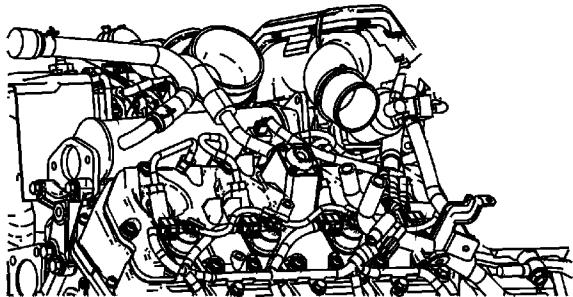
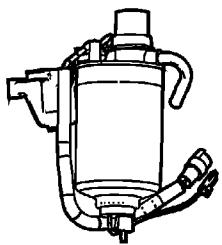
1. Remove the fuel hoses.



2. Disconnect the fuel filter assembly connectors.

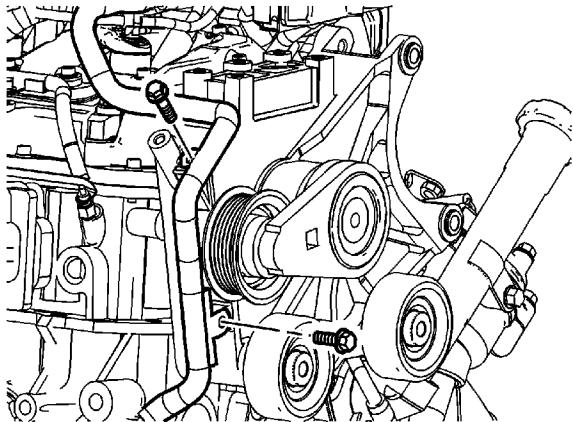


3. Remove the fuel filter bracket bolts.

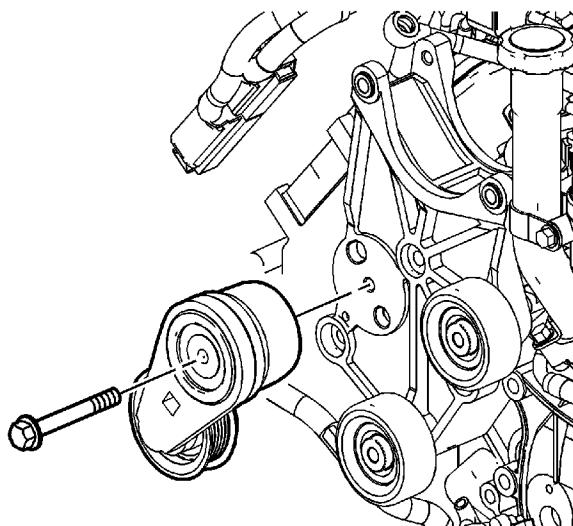


4. Remove the fuel filter assembly.

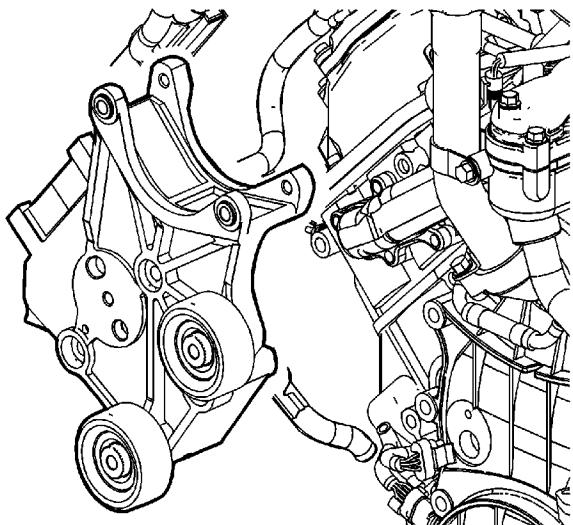
Generator and Drive Belt Tensioner Bracket Removal



1. Remove the electrical harness clip bolts.

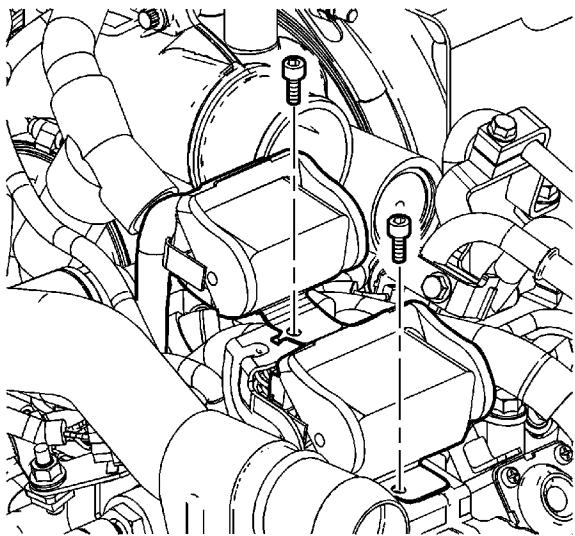


2. Remove the drive belt tensioner bolt.
3. Remove the drive belt tensioner.

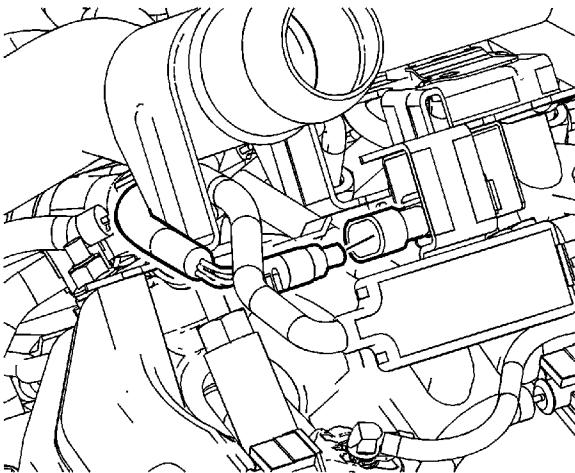


4. Remove the drive belt tensioner and generator mounting bracket bolts.
5. Remove the drive belt tensioner and generator mounting bracket.

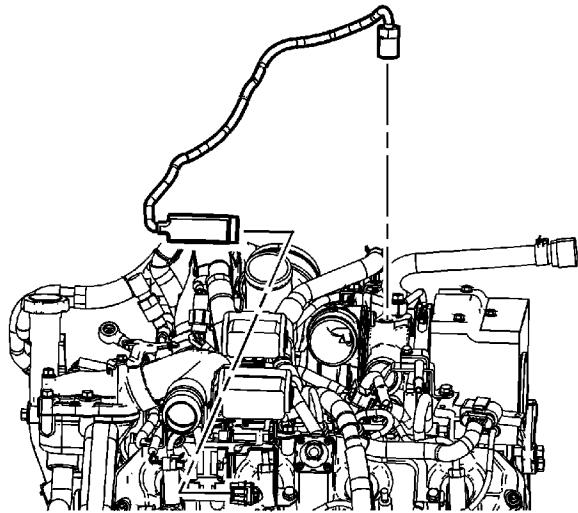
Engine Coolant Thermostat Housing Removal



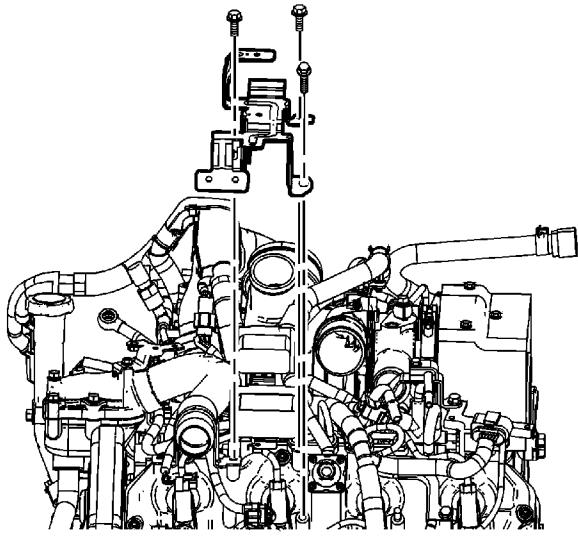
1. Remove the main engine electrical harness connector hold down bolts.



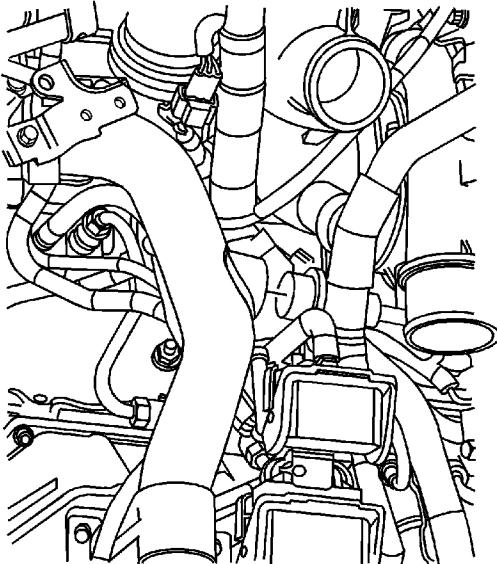
2. Remove the main engine electrical harness connectors.
3. Disconnect and remove the barometric sensor.



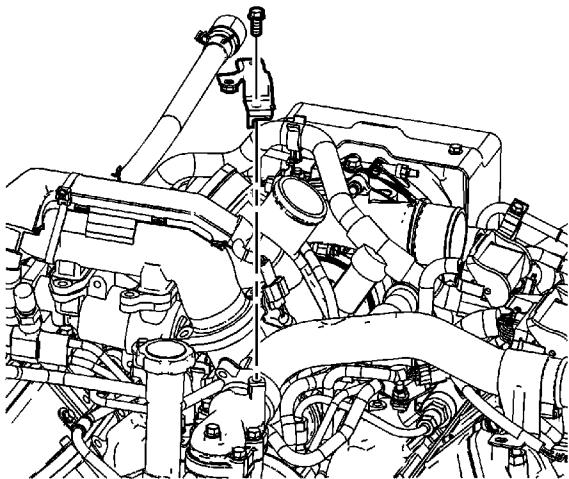
4. Disconnect and remove the turbocharger vane position sensor.



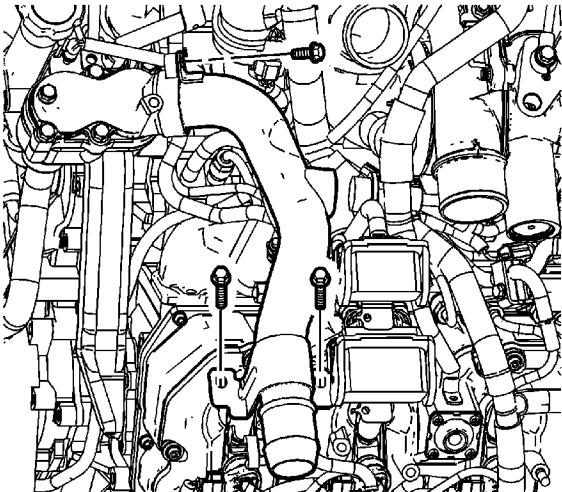
5. Remove the main electrical harness bracket bolts.
6. Remove the main electrical harness bracket.



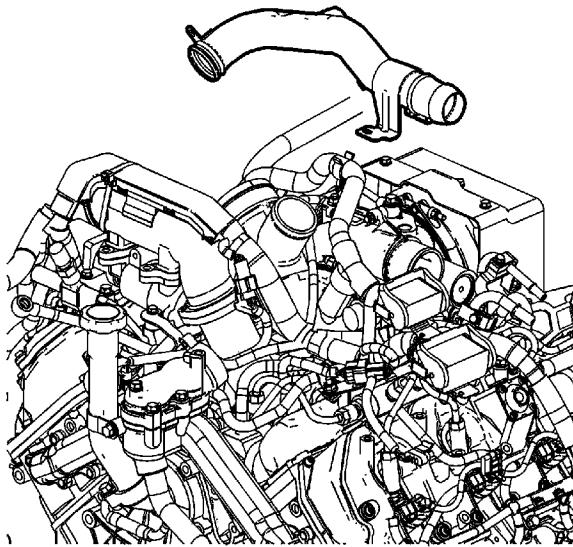
7. Disconnect the turbocharger coolant inlet hose.



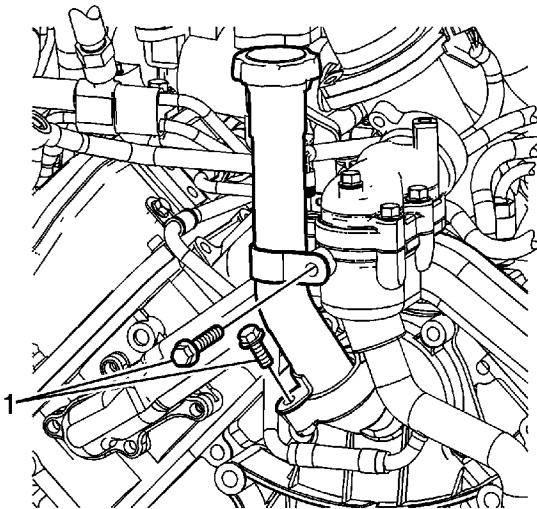
8. Remove the electrical harness bracket bolt.
9. Remove the electrical harness bracket.



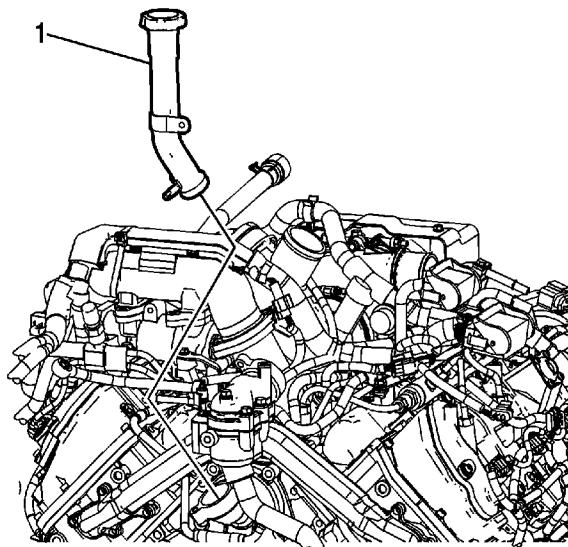
10. Remove the water outlet bolts.



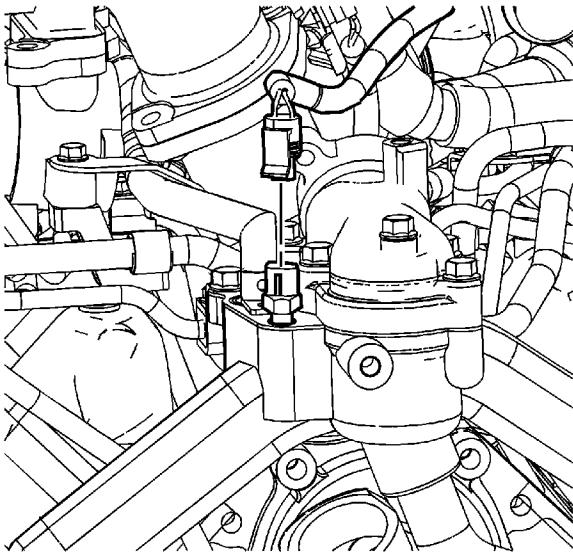
11. Remove the water outlet.



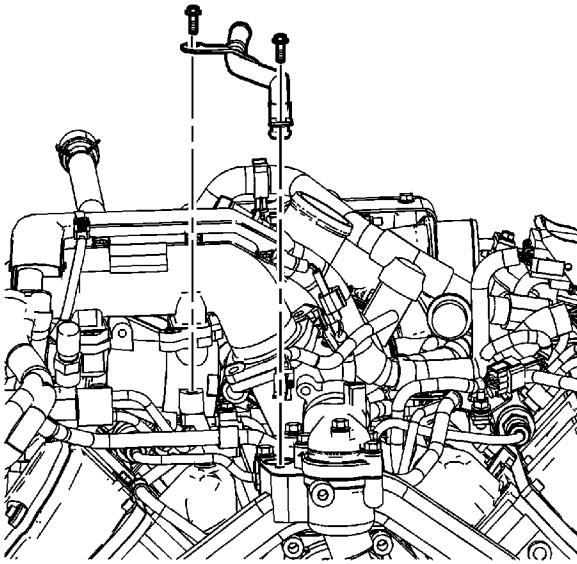
12. Remove the oil fill tube bolts.



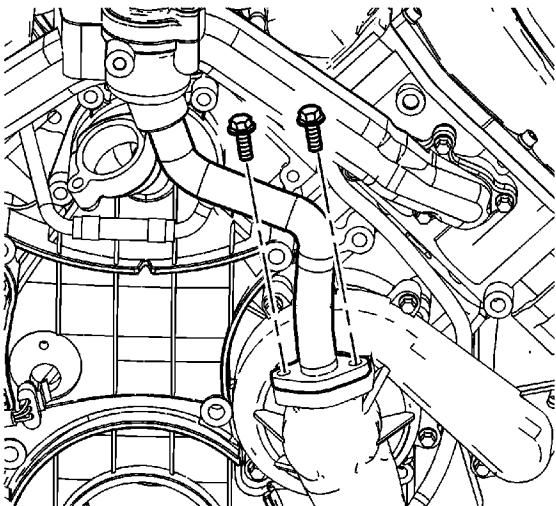
13. Remove the oil fill tube.



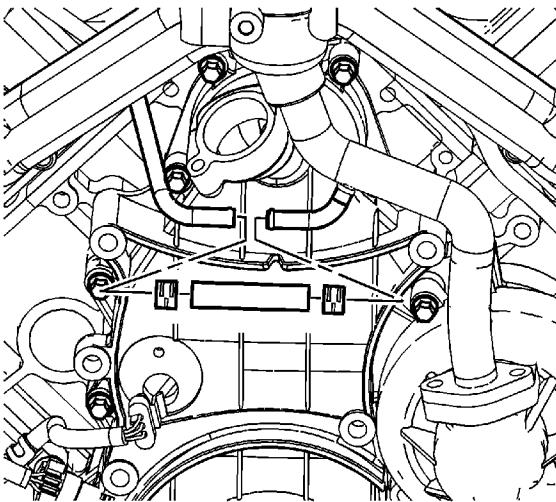
14. Disconnect the coolant temperature sensor.



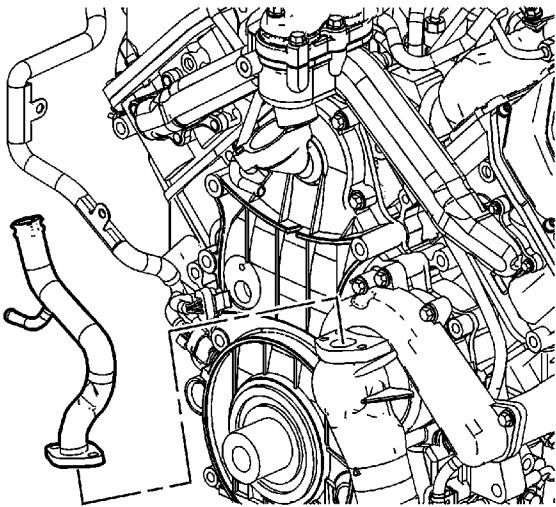
15. Remove the EGR coolant pipe bolts.
16. Remove the EGR coolant pipe.



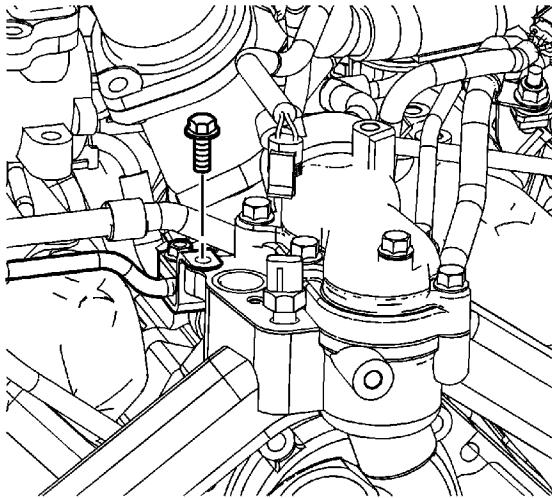
17. Remove the water pump inlet pipe bolts.



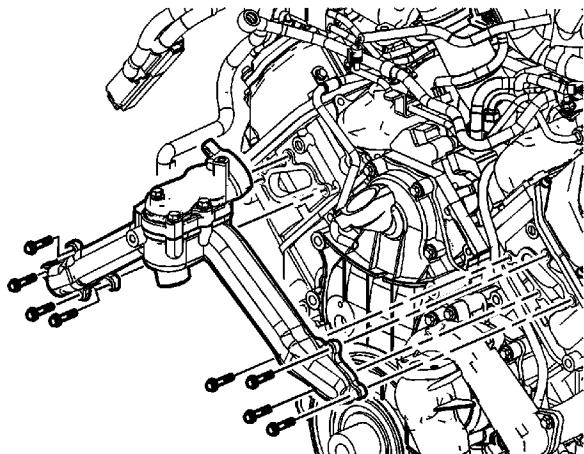
18. Remove the turbocharger coolant outlet hose and clamps.



19. Remove the water pump inlet pipe.

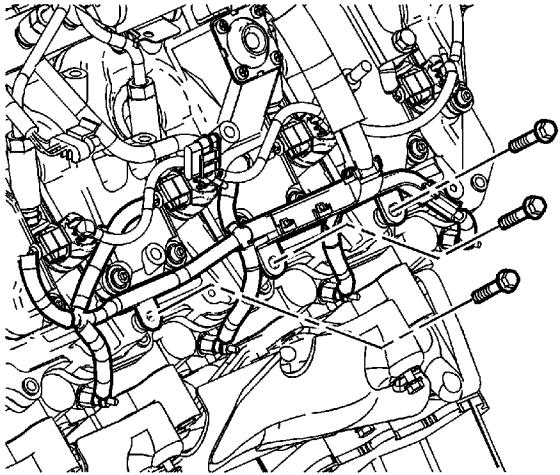


20. Remove the fuel pipe bracket bolt.

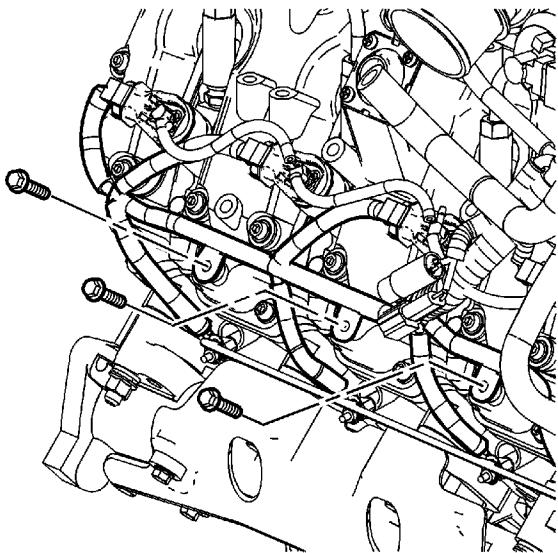


21. Remove the thermostat housing bolts.
22. Remove the thermostat housing.

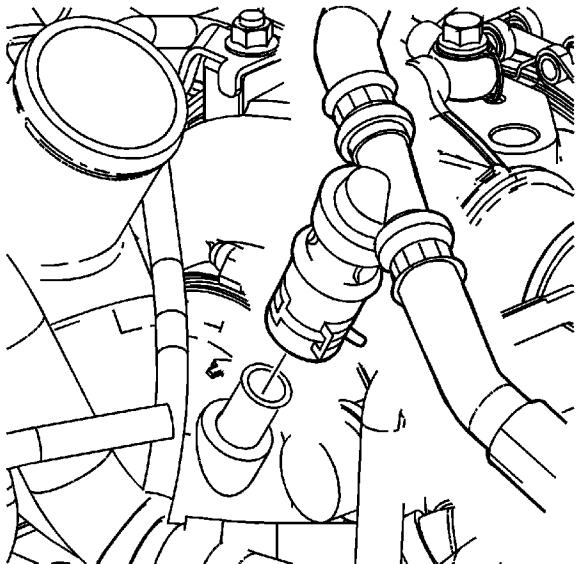
Engine Wiring Harness Assembly Removal



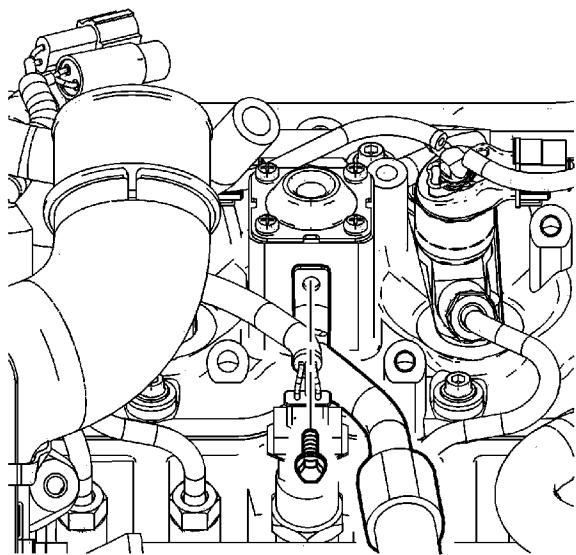
1. Remove the left glow plug harness bracket bolts.



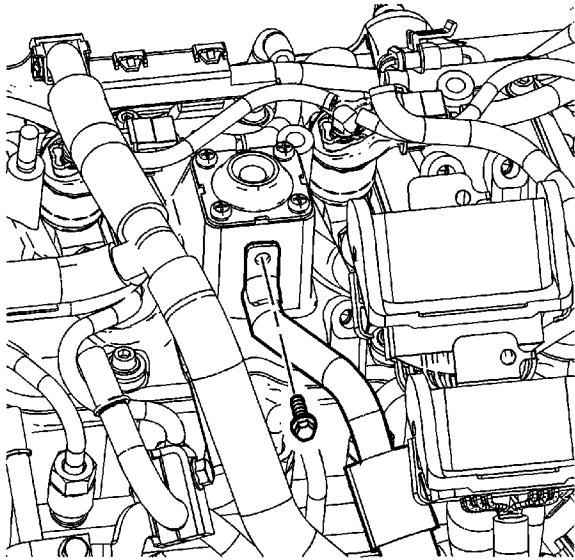
2. Remove the right glow plug harness bracket bolts.



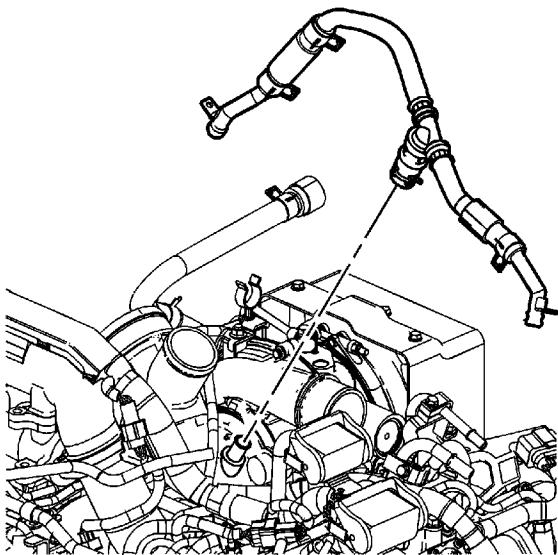
3. Disconnect the positive crankcase ventilation (PCV) hose clamp.



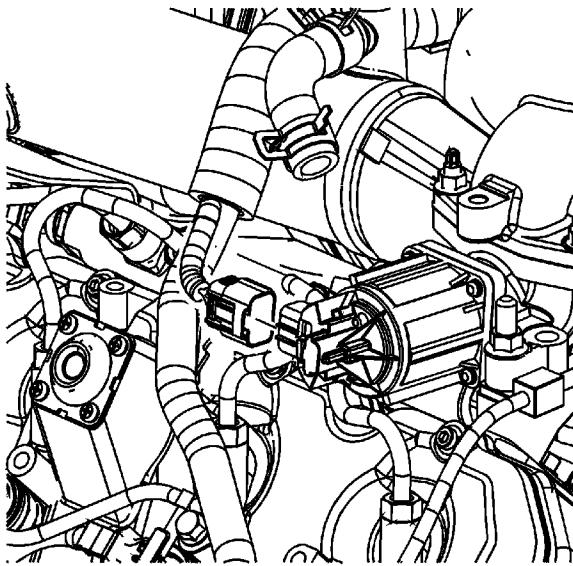
4. Remove the right PCV pipe bolt.



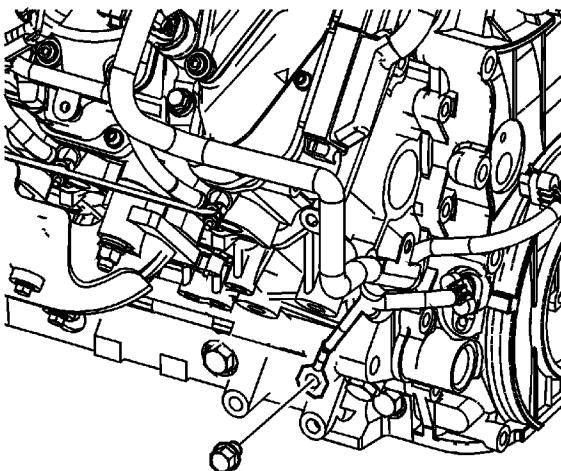
5. Remove the left PCV pipe bolt.



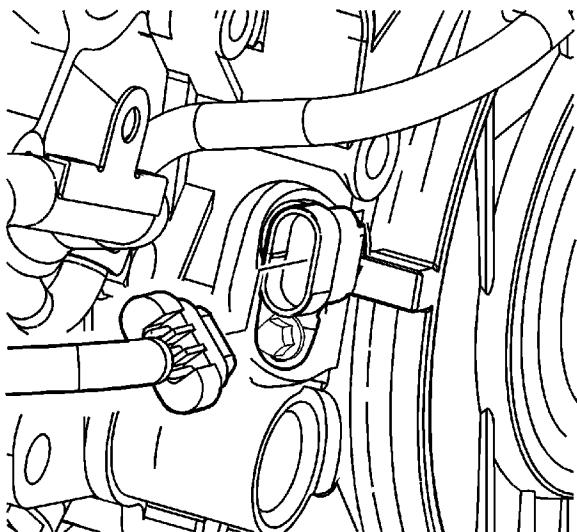
6. Remove the PCV pipe.



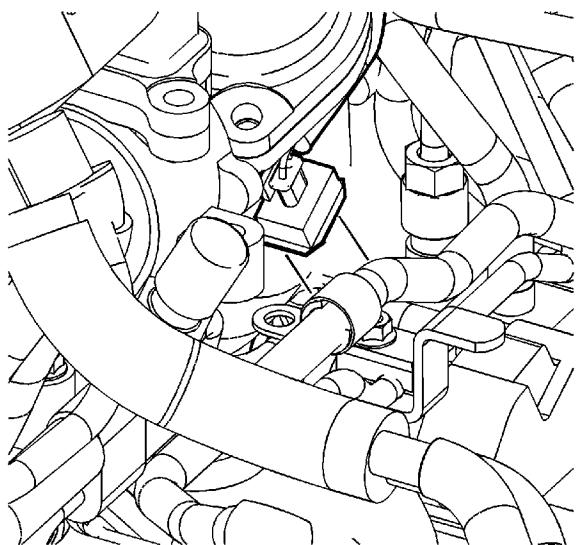
7. Disconnect the exhaust gas recirculation (EGR) valve electrical connector.



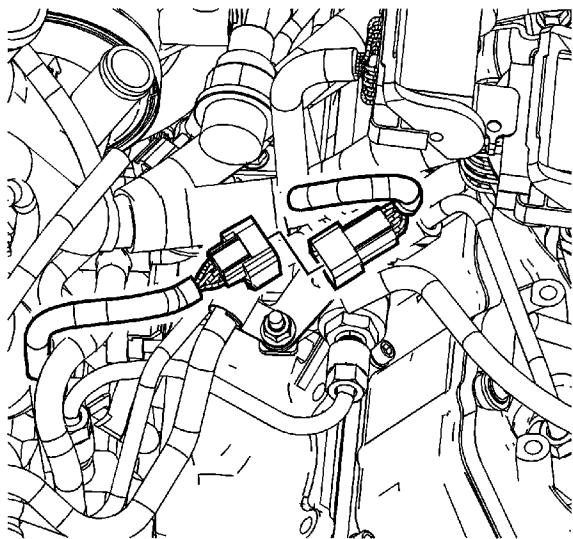
8. Remove the ground bolt.



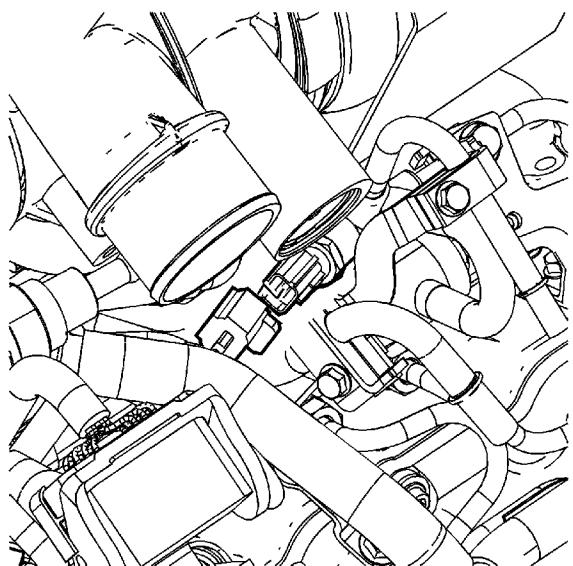
9. Disconnect the crankshaft position sensor electrical connector.



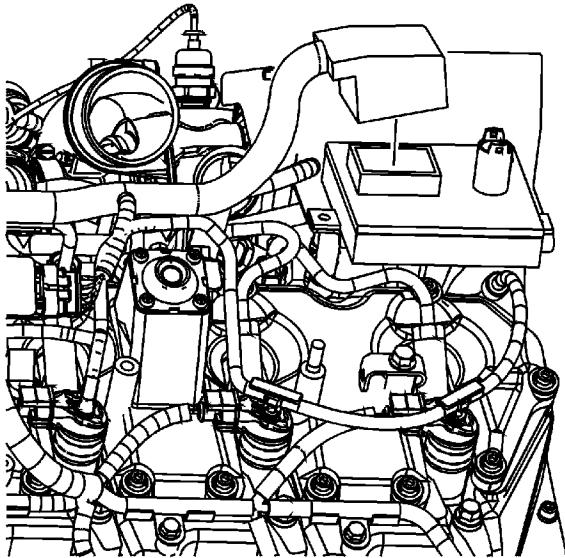
10. Disconnect the fuel pressure control valve electrical connector.



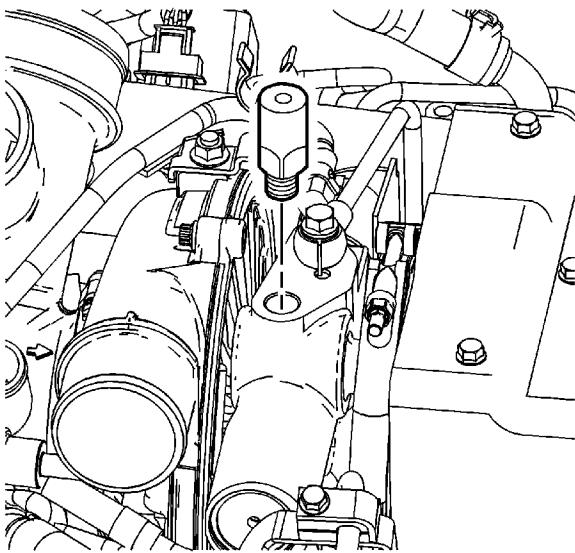
11. Disconnect the oil level sensor electrical harness connector.



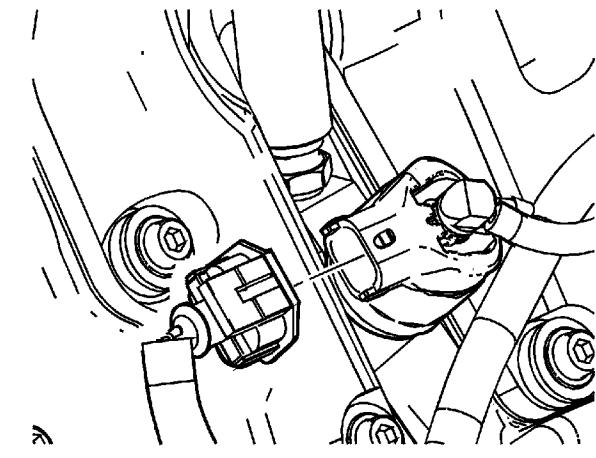
12. Disconnect the fuel temperature sensor connector.



13. Disconnect the glow plug controller electrical connector.

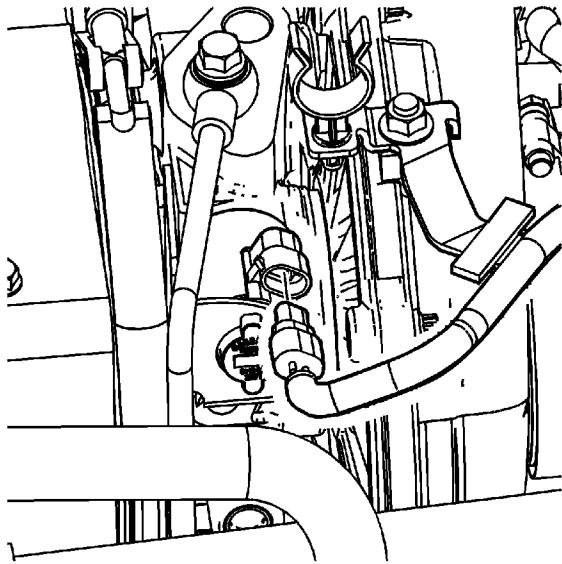


14. Disconnect and remove the turbocharger vane position sensor.

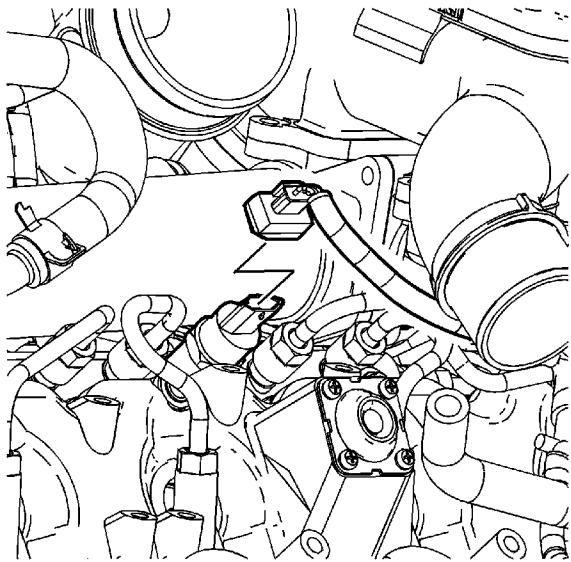


Caution: Label all the injector electrical connectors before the connectors are removed in order to prevent reconnecting to the wrong injector. Failure to properly connect the injectors in the correct sequence will cause severe engine damage.

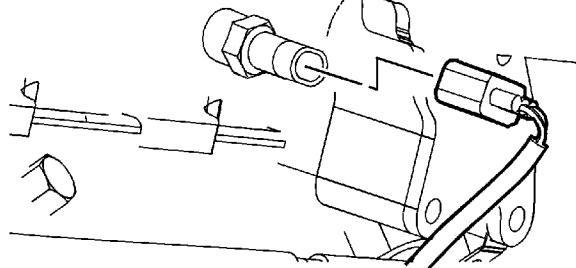
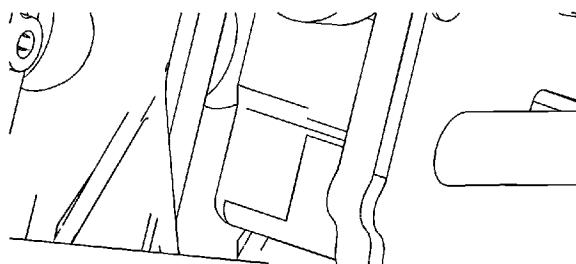
15. Disconnect the fuel injector electrical connections.



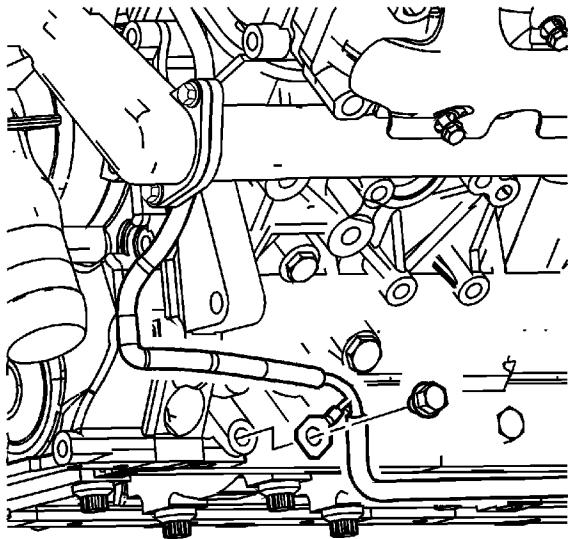
16. Disconnect the turbocharger vane control solenoid valve.



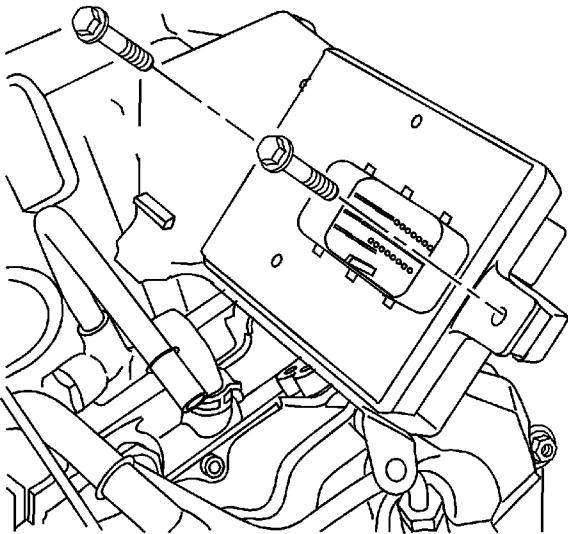
17. Disconnect the fuel rail pressure sensor.



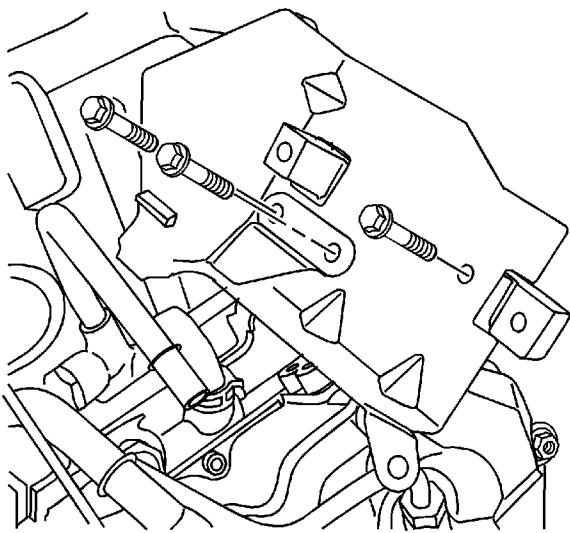
18. Disconnect the oil pressure sensor electrical connector.



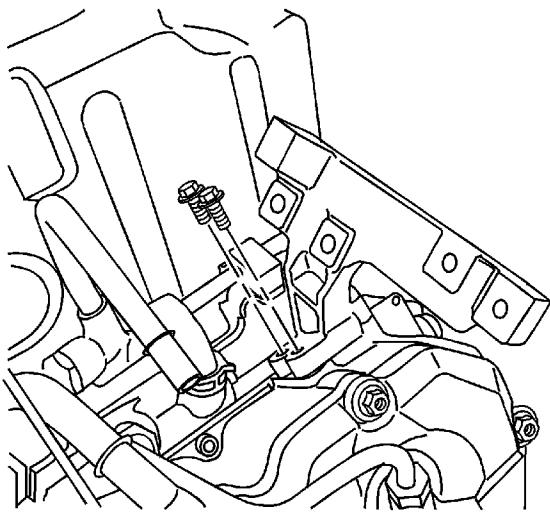
19. Remove the oil level sensor harness bolt.



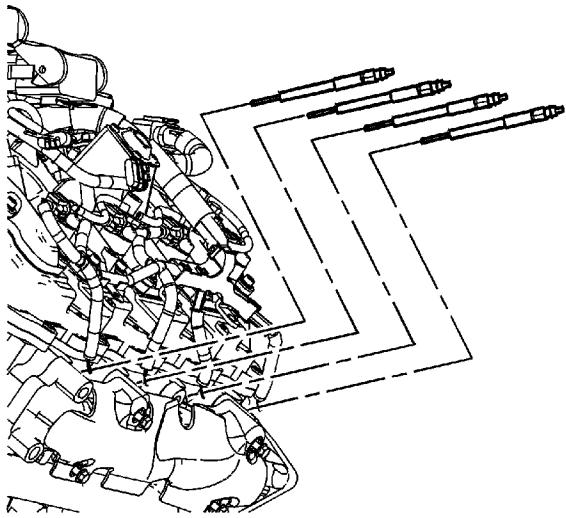
20. Remove the glow plug controller bolts.
21. Remove the glow plug controller.
22. Remove the glow plug controller shield bolts.
23. Remove the glow plug controller shield.



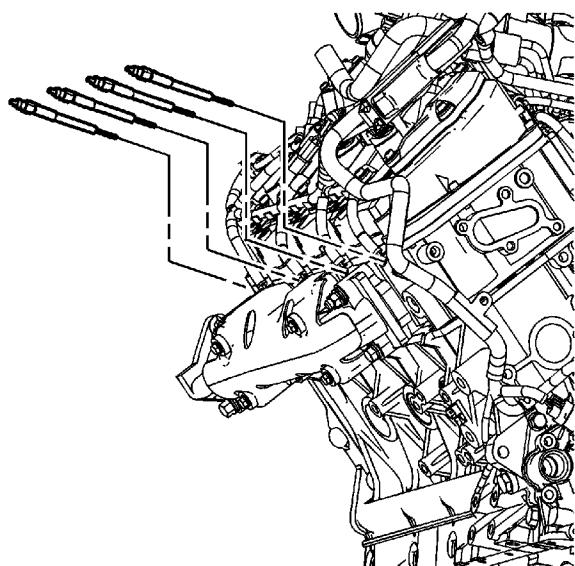
24. Remove the glow plug controller bracket bolts.



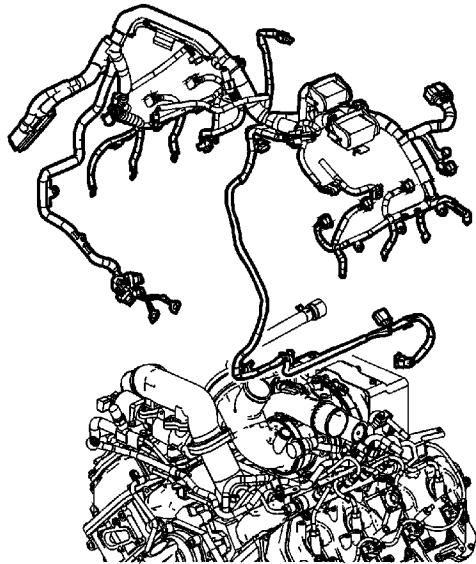
25. Remove the glow plug controller bracket.



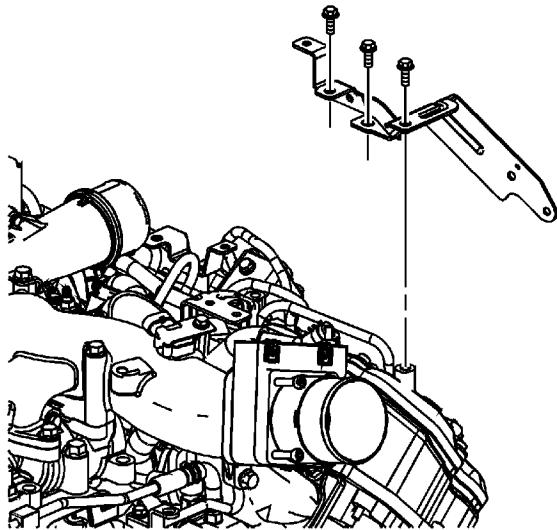
26. Remove the left glow plugs.



27. Remove the right glow plugs.

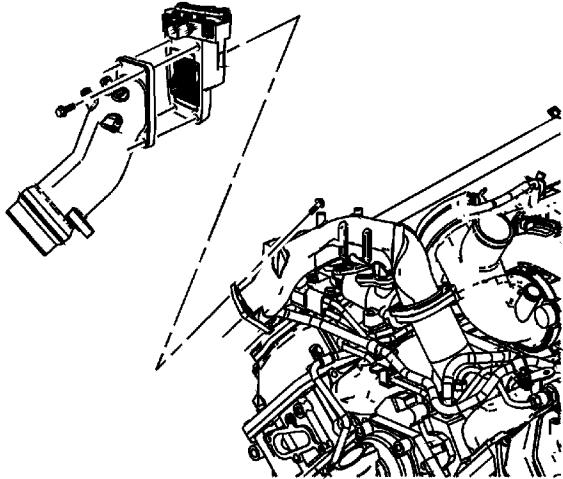


28. Remove the engine wiring harness.

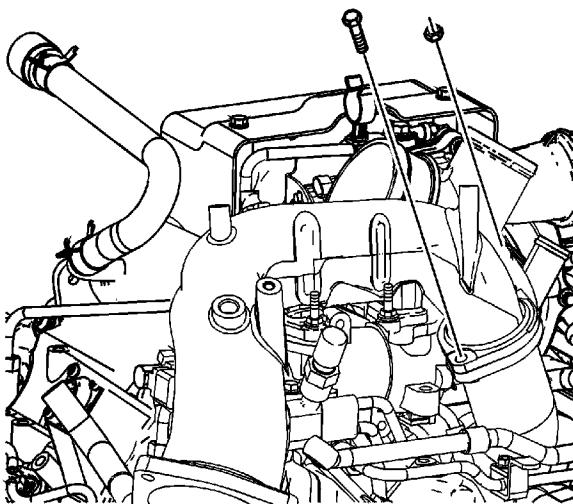


29. Remove the engine harness bracket bolts.
30. Remove the engine harness bracket.

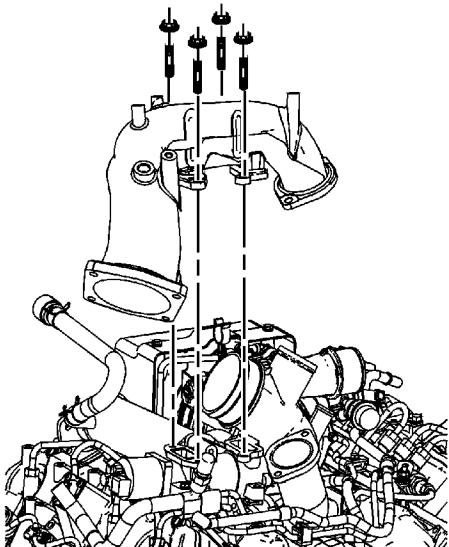
Exhaust Gas Recirculation Valve and Cooler Removal



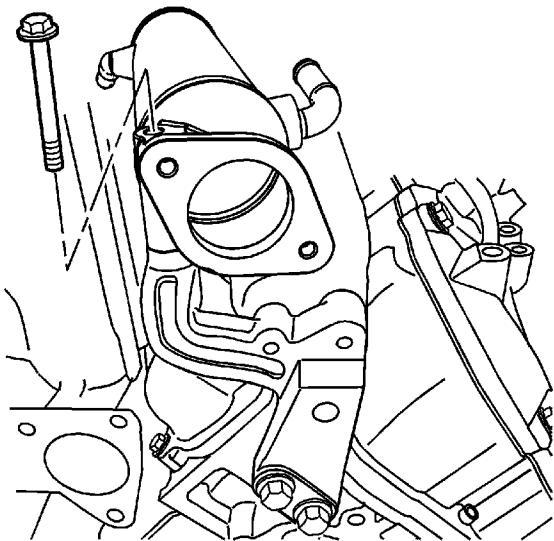
1. Remove the intake pipe to air inlet tube bolts.
2. Remove the intake pipe.
3. Remove the intake heater.



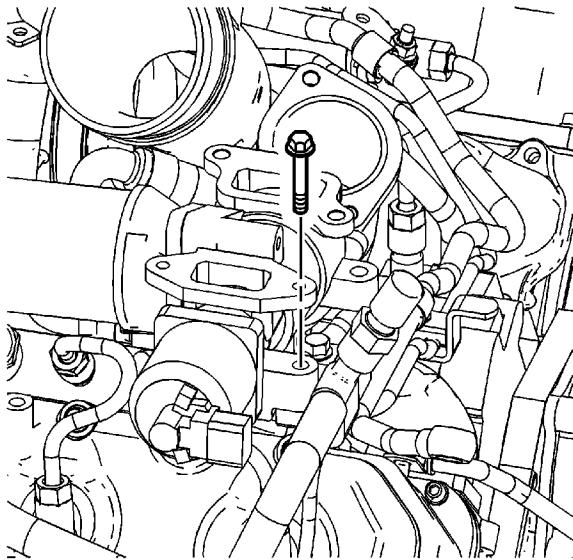
4. Remove the air inlet tube to intake manifold tube bolt and nut.



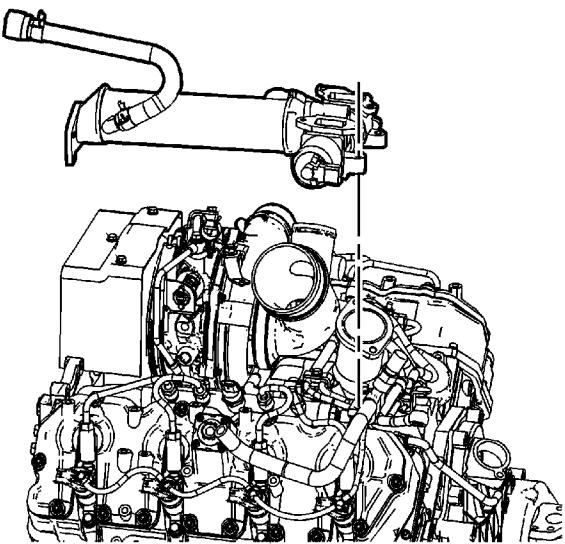
5. Remove the air inlet tube nuts.
6. Remove the air inlet tube.



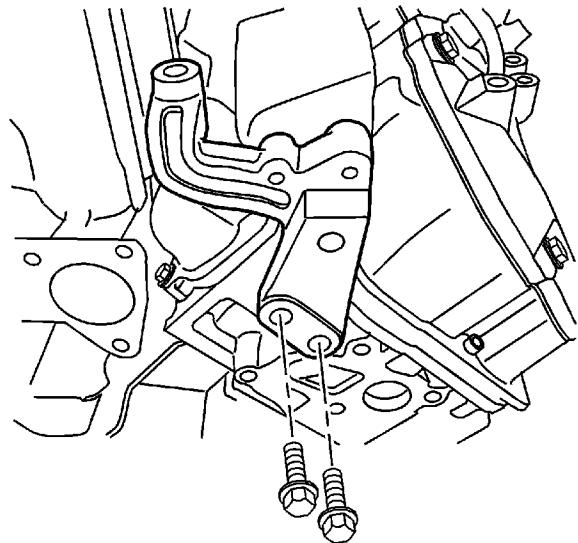
7. Remove the rear EGR cooler bolts.



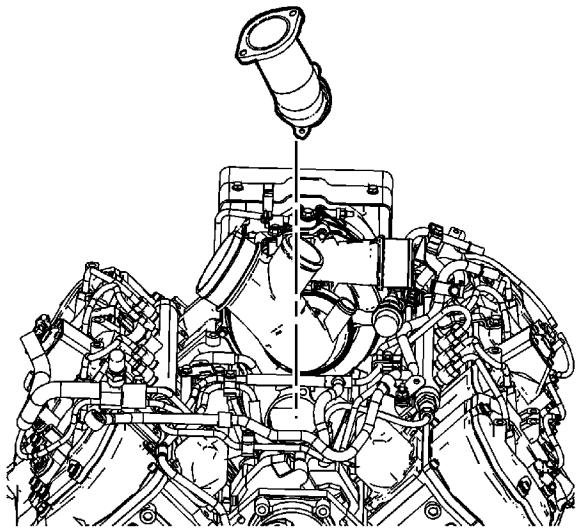
8. Remove the EGR mount bolt.



9. Remove the EGR and cooler.

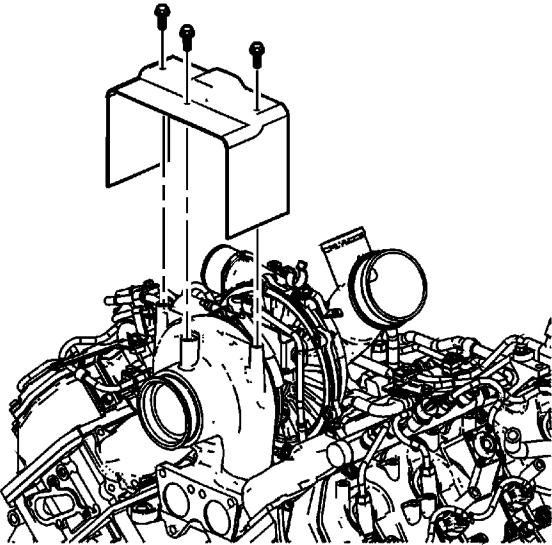


10. Remove the EGR cooler bracket bolts.
11. Remove the EGR cooler bracket.

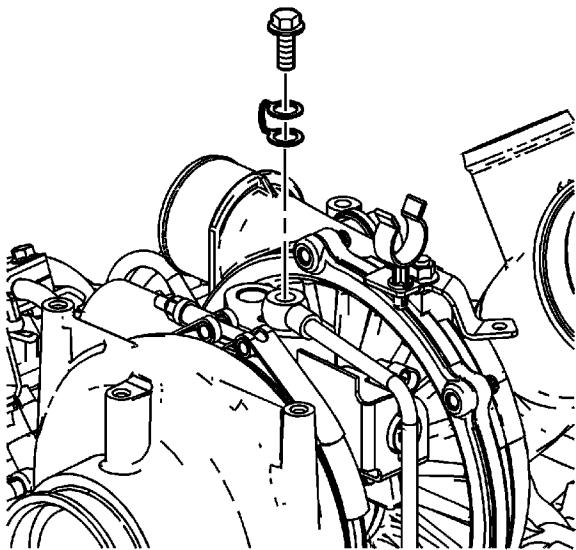


12. Remove the intake manifold tube.

Turbocharger Removal



1. Remove the turbocharger upper heat shield bolts.
2. Remove the turbocharger upper heat shield.

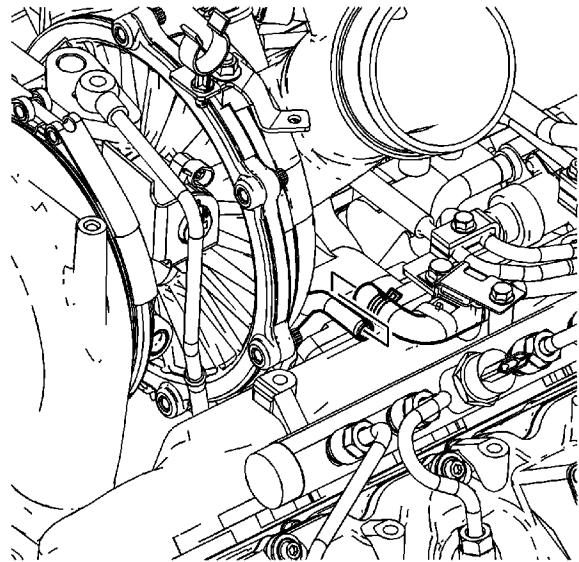


Caution: Do not twist the turbocharger oil feed pipe. Twisting of the feed pipe will result in the collapse and deformation of the plastic pipe, restricting oil flow and causing turbocharger damage. During turbocharger replacement, gently push the oil feed pipe towards the front of the engine to clear the turbocharger. Assistance may be required to keep the pipes clear of

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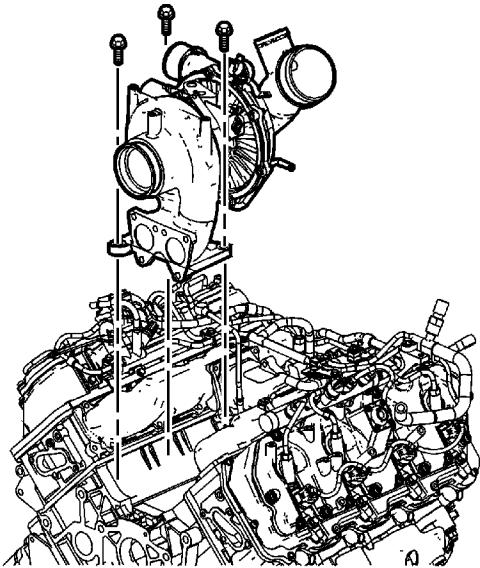
the turbocharger during removal or installation.

3. Remove the eye bolt and washers from the oil supply hose at the top of the turbocharger.

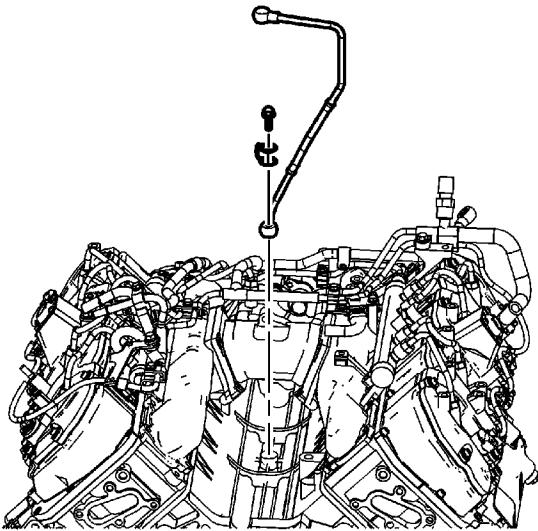


Note: Use care not to damage this hose during the procedure.

4. Loosen the hose clamp and remove the turbocharger cooling outlet hose.



5. Remove the turbocharger mounting bolts.
6. Remove the turbocharger assembly with the oil return pipe.

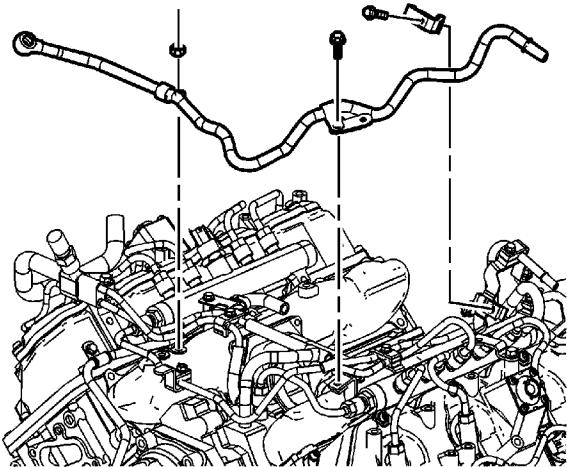


7. Remove the turbocharger lower heat shield from engine block.

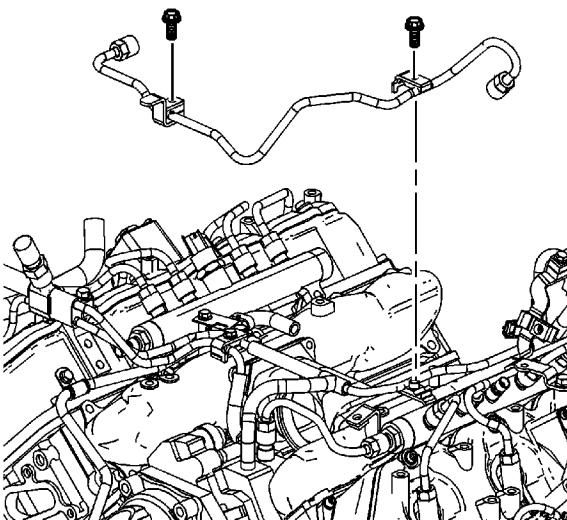
Caution: Do not twist the turbocharger oil feed pipe. Twisting of the feed pipe will result in the collapse and deformation of the plastic pipe, restricting oil flow and causing turbocharger damage. During turbocharger replacement, gently push the oil feed pipe towards the front of the engine to clear the turbocharger. Assistance may be required to keep the pipes clear of the turbocharger during removal or installation.

8. Remove the turbocharger oil supply hose eye bolt and washers.
9. Remove the turbocharger oil supply hose.

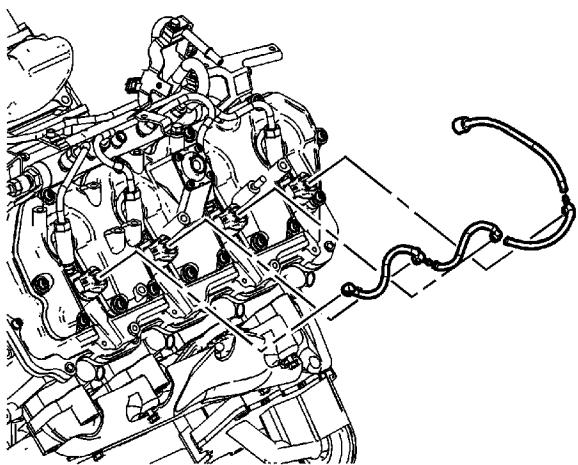
Fuel Pipes and Fuel Rail Removal



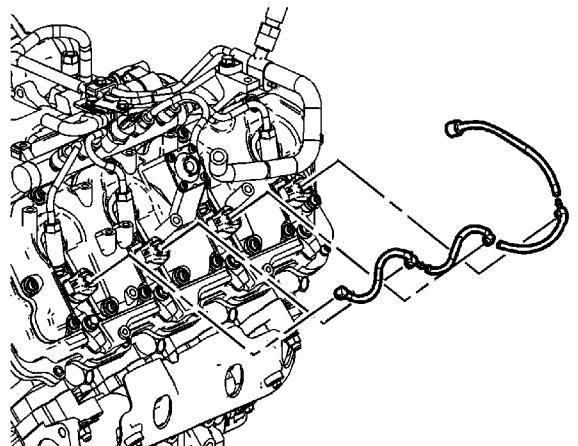
1. Remove the fuel feed pipe attaching nuts and bolts.
2. Remove the fuel feed pipe.



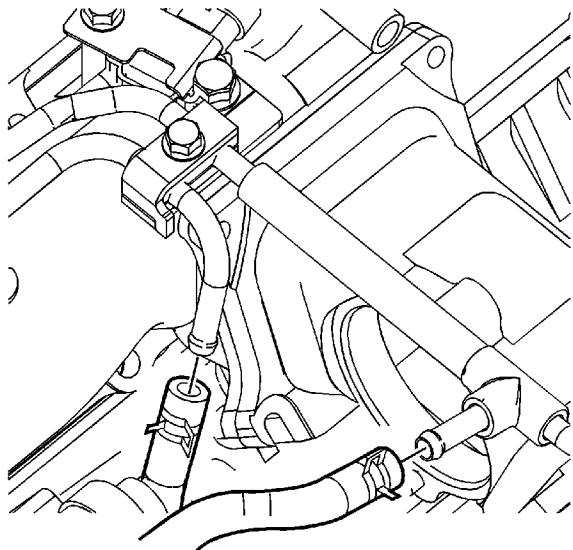
3. Disconnect the fuel rail balance pipe from fuel rails.
4. Remove the fuel rail balance pipe bolts.
5. Remove the fuel rail balance pipe.



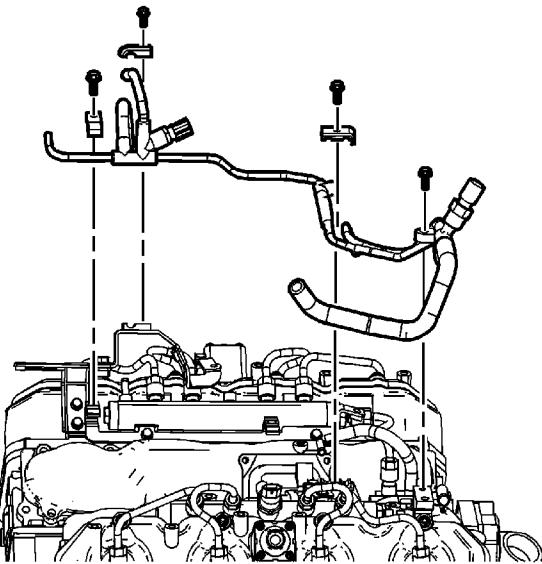
6. Remove the left fuel return hose.



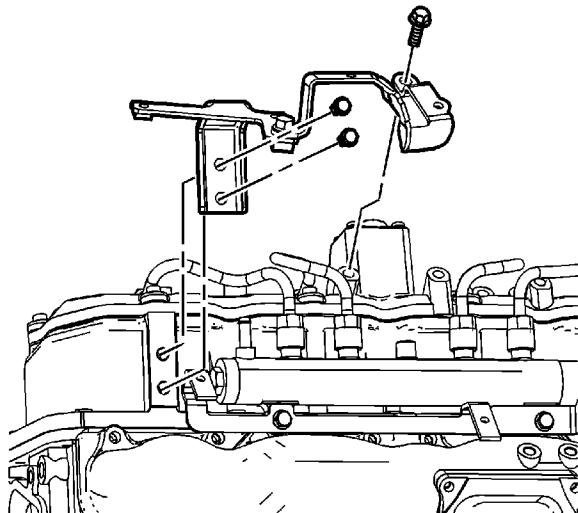
7. Remove the right fuel return hose.



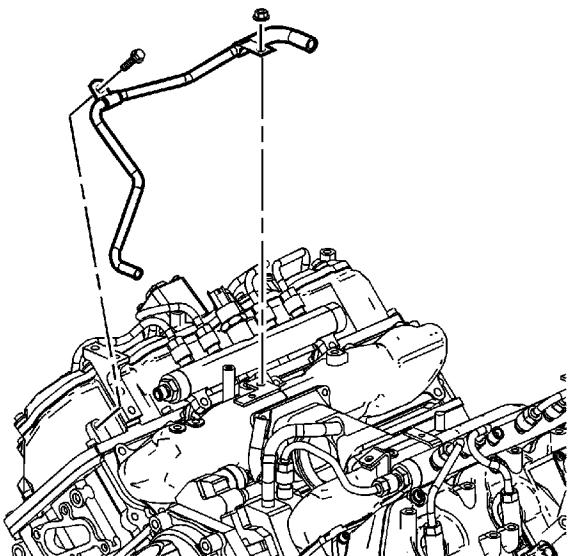
8. Disconnect the fuel hoses from the fuel injector pump.



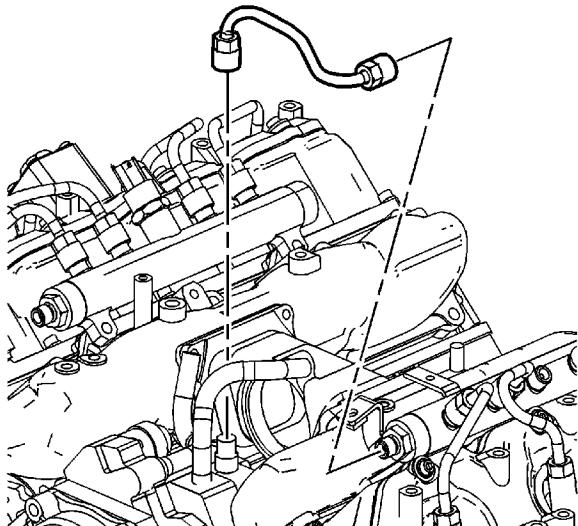
9. Remove the distribution block and fuel line assembly bolts.
10. Remove the distribution block and fuel line assembly.



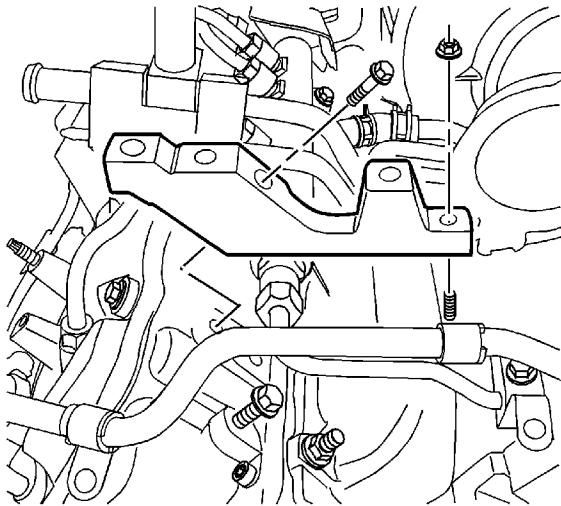
11. Remove the fuel pipe assembly bracket bolts.
12. Remove the fuel pipe assembly bracket.



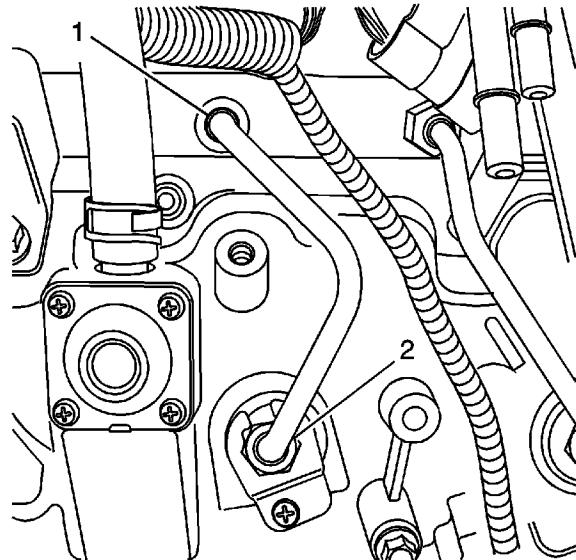
13. Remove the coolant pipe bolt and nut.
14. Remove the coolant pipe.



15. Remove the left fuel rail to pump pipe.



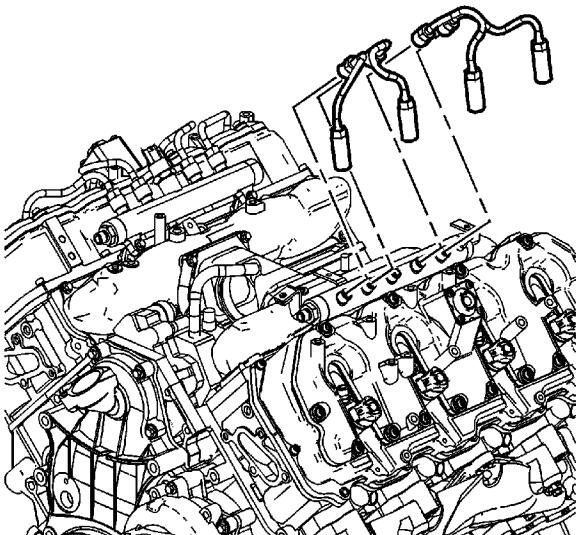
16. Remove the EGR mounting bracket bolt and nut.
17. Remove the EGR mounting bracket.



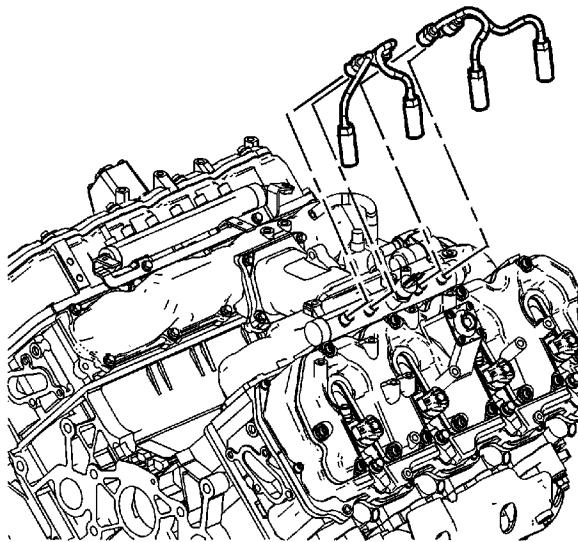
18. Using compressed air to blow away any debris between the fuel injector line and the fittings (1, 2). Wipe clean the fittings (1) of debris.

Caution: DO NOT use compressed air to clean debris from the fuel injector inlet after the fuel line is removed. Using compressed air can allow debris to enter the fuel injector inlet and damage the fuel injector.

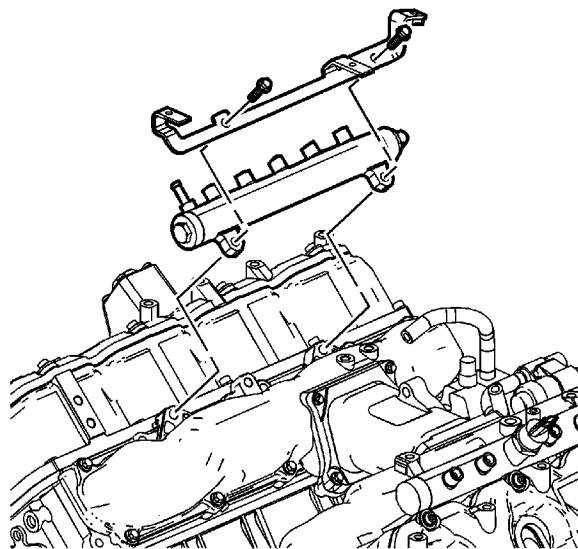
19. Spray lithium grease, GM P/N 12346293 or equivalent, between the fuel injector line and fitting (1, 2) to contain any debris during removal.



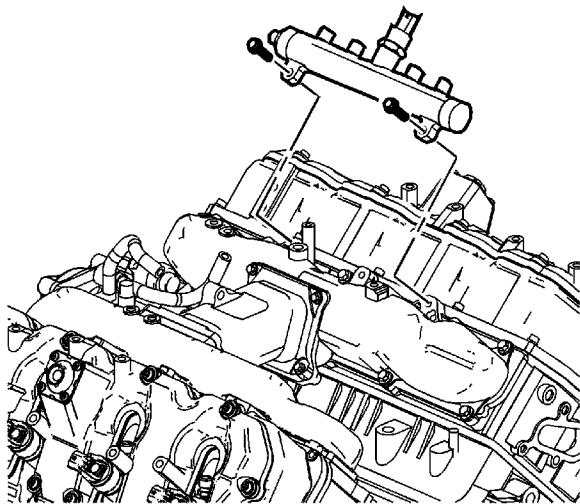
20. Remove the left fuel injector pipes.



21. Remove the right fuel injector pipes.



22. Remove the left fuel rail and bracket bolts.
23. Remove the left fuel rail and bracket.

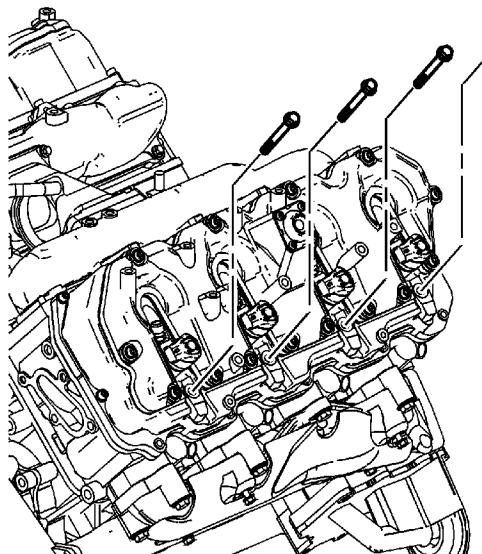


24. Remove the right fuel rail bolts.
25. Remove the right fuel rail.

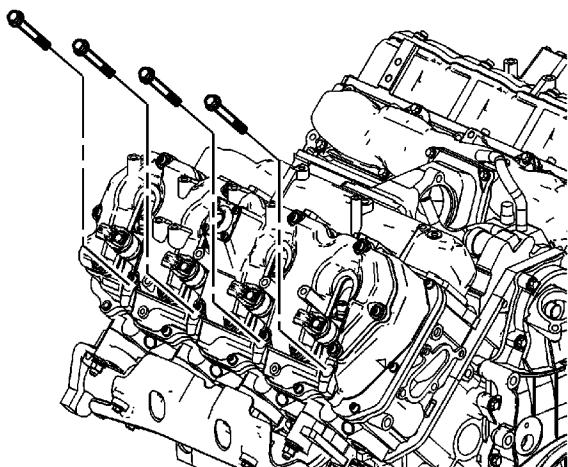
Fuel Injector Removal

Tools Required

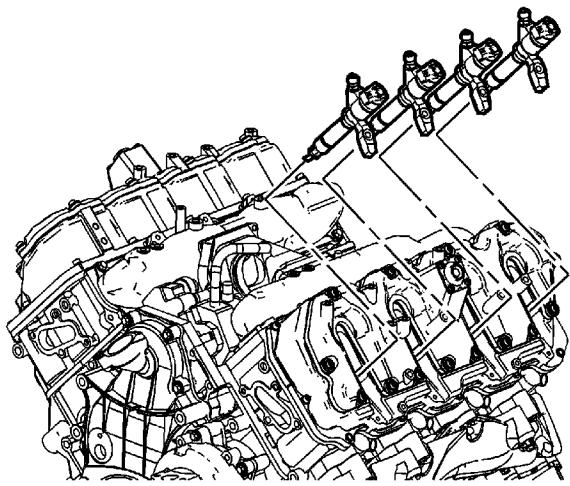
[J-46594](#) Fuel Injector Remover



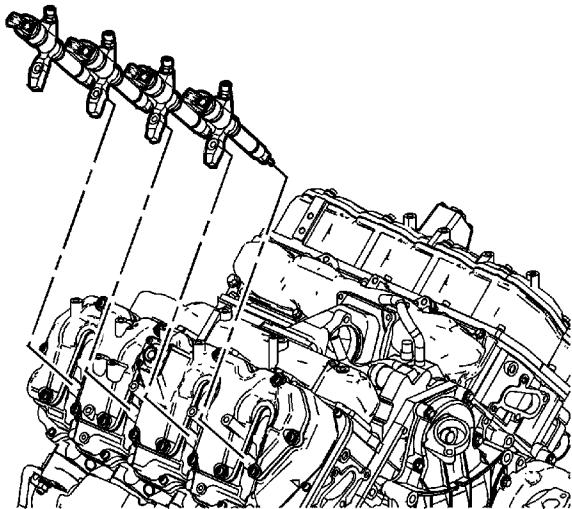
1. Remove the left fuel injector bracket bolts.



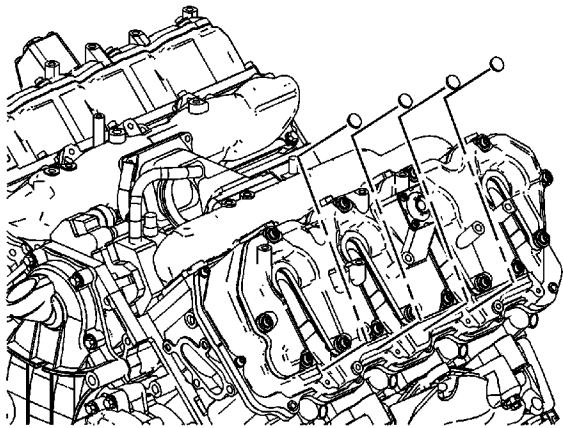
2. Remove the right fuel injector bracket bolts.



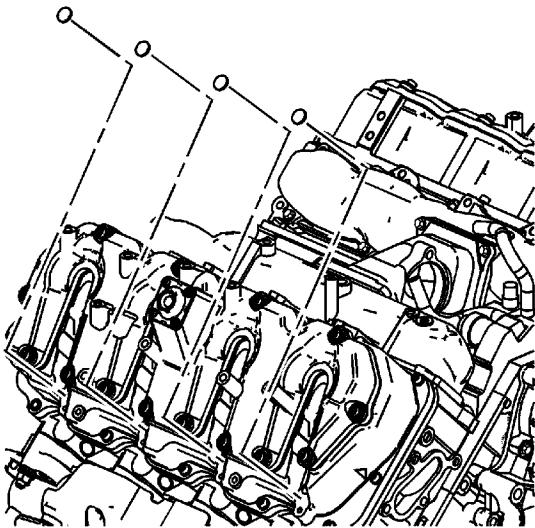
3. Install the [J-46594](#) into the fuel injector brackets.
4. Pull back on [J-46594](#) in one steady motion, until the fuel injector breaks free from its seat.
5. Remove the [J-46594](#).
6. Remove the left fuel injectors with brackets.



7. Remove the right fuel injectors with brackets.

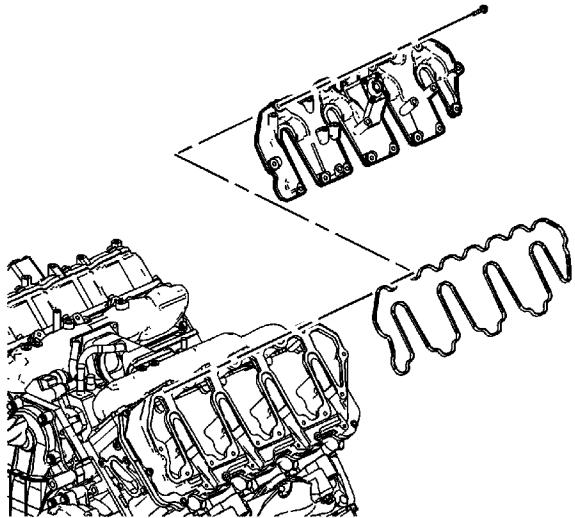


- 
8. Remove the left injector bracket pins.



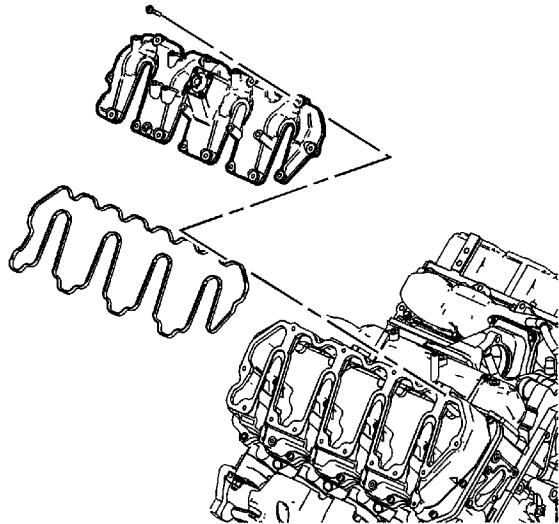
- 
9. Remove the right injector bracket pins.
 10. Remove the copper washer from the injector bore and discard.
 11. Remove the O-ring from the injector and discard.

Valve Rocker Arm Cover Removal - Upper Left Side



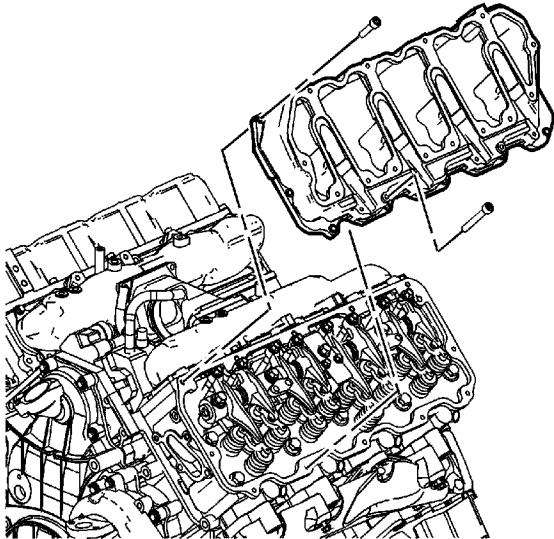
1. Remove the left upper valve rocker arm cover bolts.
2. Remove the left upper valve rocker arm cover.
3. Remove and discard the valve rocker arm cover gasket, valve rocker arm cover grommets and valve rocker arm cover bolts if they are serviced with the grommet.

Valve Rocker Arm Cover Removal - Upper Right Side



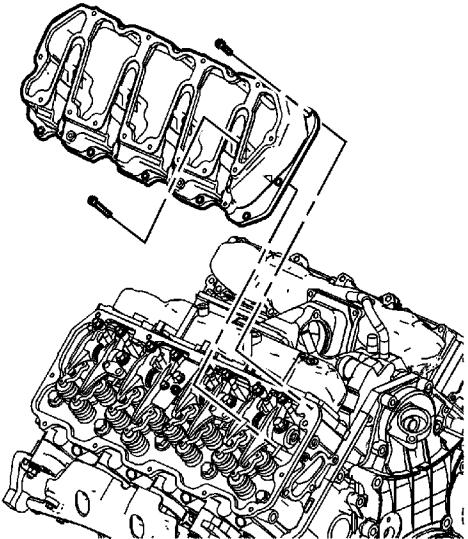
1. Remove the right upper valve rocker arm cover bolts.
2. Remove the right upper valve rocker arm cover.
3. Remove and discard the valve rocker arm cover gasket, valve rocker arm cover grommets and valve rocker arm cover bolts if they are serviced with the grommet.

Valve Rocker Arm Cover Removal - Lower Left Side



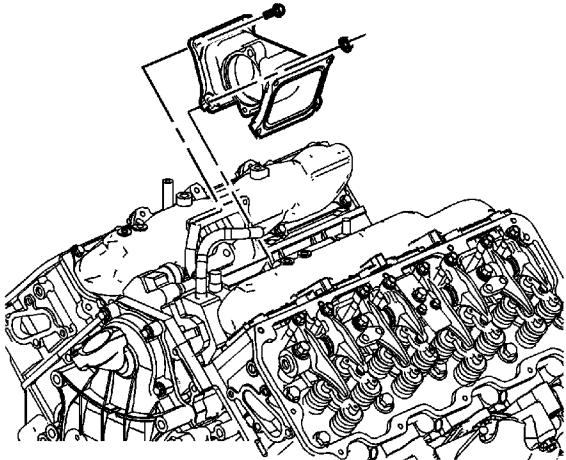
1. Remove the left lower valve rocker arm cover bolts.
2. Remove the left lower valve rocker arm cover.
3. Remove and discard the valve rocker arm cover gasket, valve rocker arm cover grommets and valve rocker arm cover bolts if they are serviced with the grommet.

Valve Rocker Arm Cover Removal - Lower Right Side



1. Remove the right lower valve rocker arm cover bolts.
2. Remove the lower valve rocker arm cover.
3. Remove and discard the valve rocker arm cover gasket, valve rocker arm cover grommets and valve rocker arm cover bolts if they are serviced with the grommet.

Intake Manifold Crossover Removal

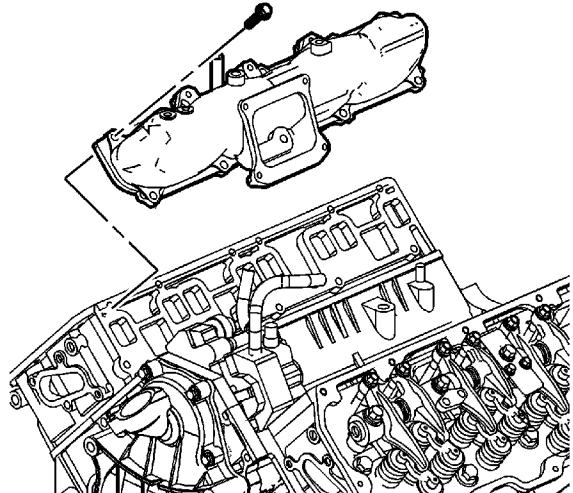


1. Remove the intake manifold crossover bolts and nuts.
2. Remove the intake manifold crossover.

Intake Manifold Removal - Right Side

Tools Required

[J 37228](#) Seal Cutter

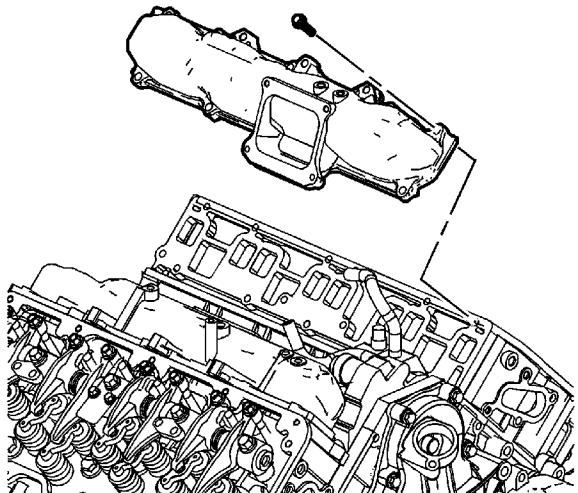


1. Remove the right intake manifold bolts. Do not forget to remove the bolt inside the intake manifold tube.
2. Separate the intake manifold from the cylinder head using [J 37228](#).
3. Remove the right intake manifold.

Intake Manifold Removal - Left Side

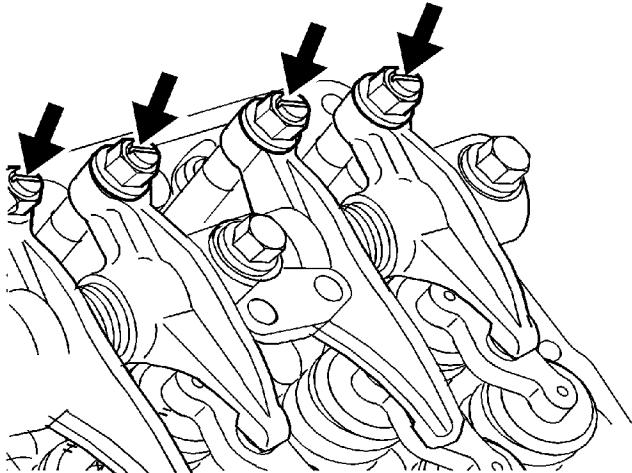
Tools Required

[J 37228](#) Seal Cutter

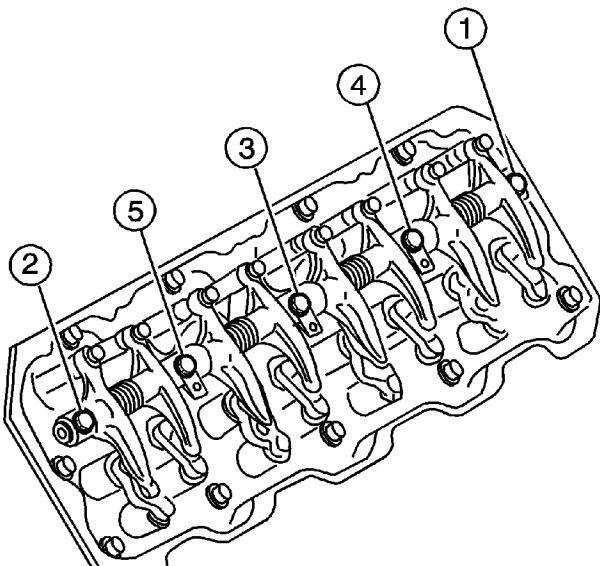


1. Remove the left intake manifold bolts. Do not forget to remove the bolt inside the intake manifold tube.
2. Separate the intake manifold from the cylinder head using [J 37228](#).
3. Remove the left intake manifold.

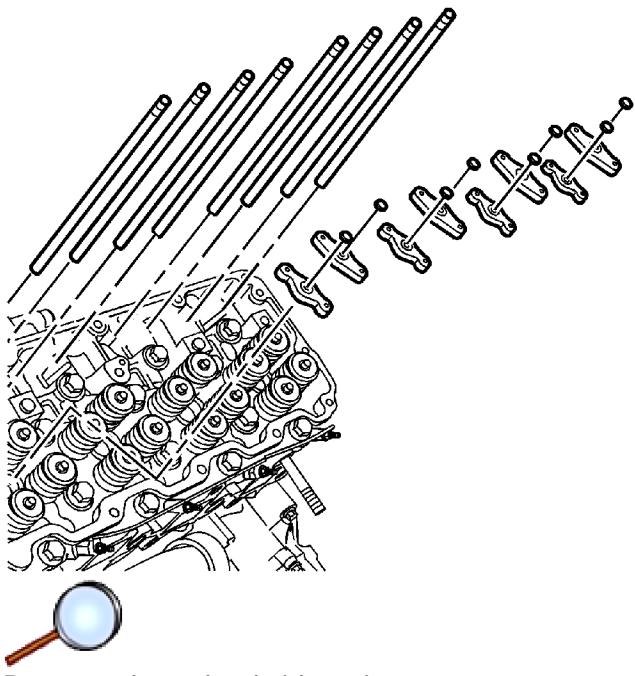
Valve Rocker Arm, Shaft, and Push Rod Removal



1. Loosen the valve clearance lock nuts on each rocker arm.
2. Loosen the valve clearance adjusting screw on each rocker arm to relieve tension on the valve train.



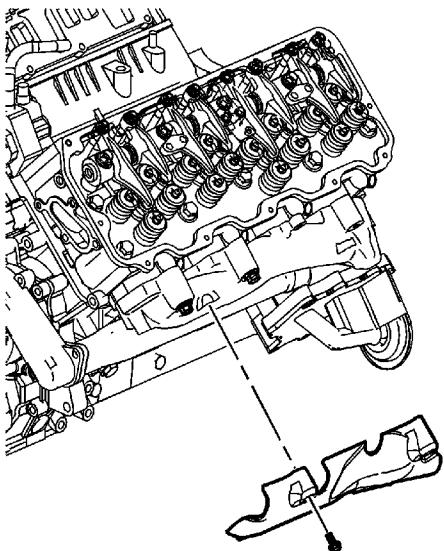
3. Remove the rocker arm shaft assembly bolts in the proper sequence.
4. Remove the rocker arm shaft assembly from the cylinder head.



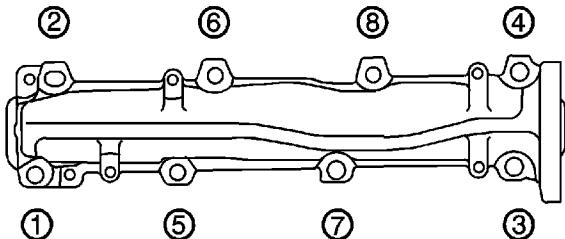
- 5. Remove the valve bridge pins.
- 6. Remove the valve bridges.
- 7. Remove the pushrods.



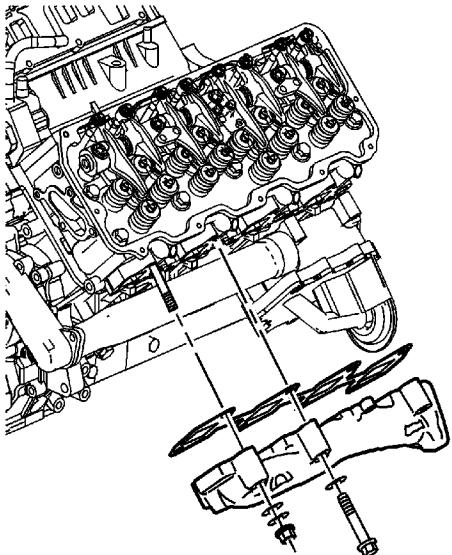
Exhaust Manifold Removal - Left Side



1. Remove the exhaust manifold heat shield bolts.
2. Remove the exhaust manifold heat shield.

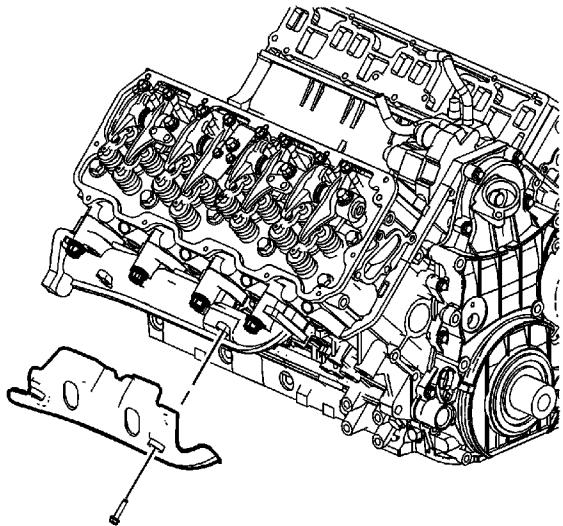


3. Remove the left exhaust manifold bolts and nuts in the proper sequence.

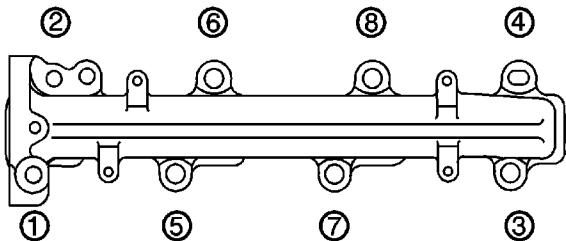


4. Remove the left exhaust manifold and gasket.

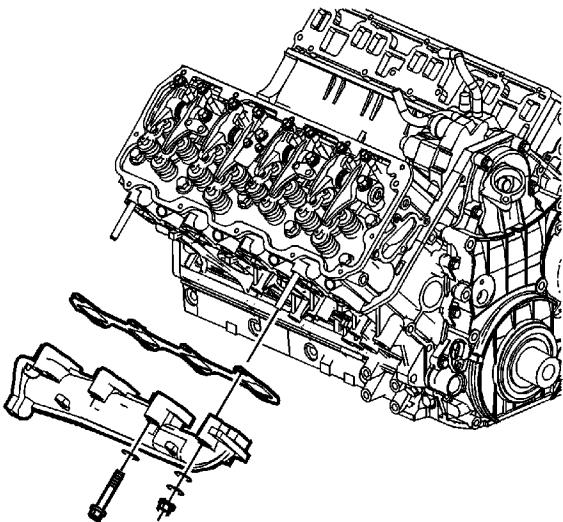
Exhaust Manifold Removal - Right Side



1. Remove the exhaust manifold heat shield bolts.
2. Remove the exhaust manifold heat shield.

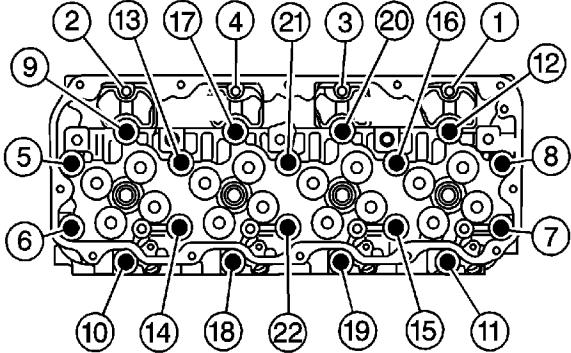


3. Remove the right exhaust manifold bolts and nuts in the proper sequence.

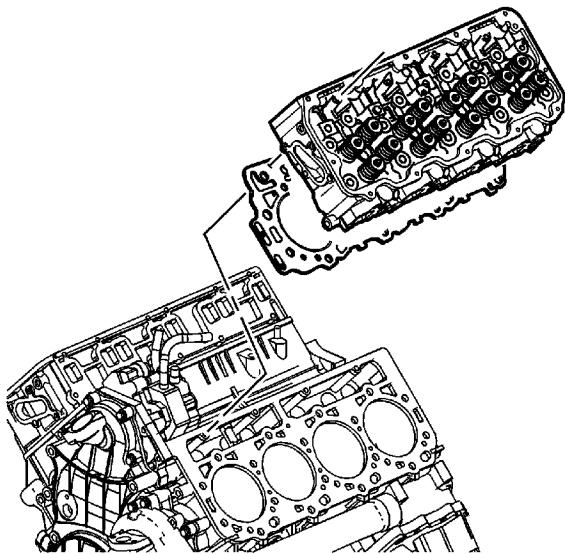


4. Remove the right exhaust manifold and gasket.

Cylinder Head Removal - Left Side

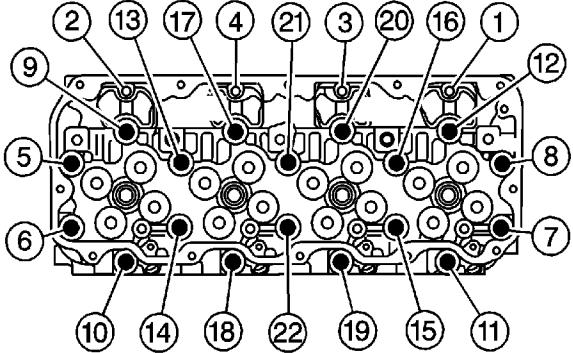


1. Remove the cylinder head bolts in the proper sequence.
2. Discard the large M12 bolts.

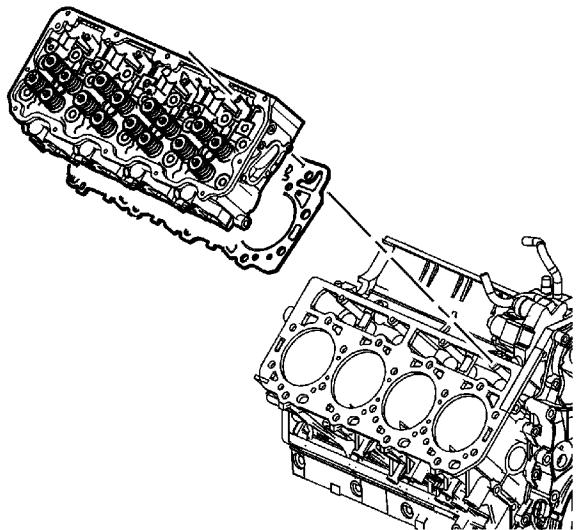


3. Remove the left cylinder head assembly.
4. Remove the left cylinder head gasket.

Cylinder Head Removal - Right Side

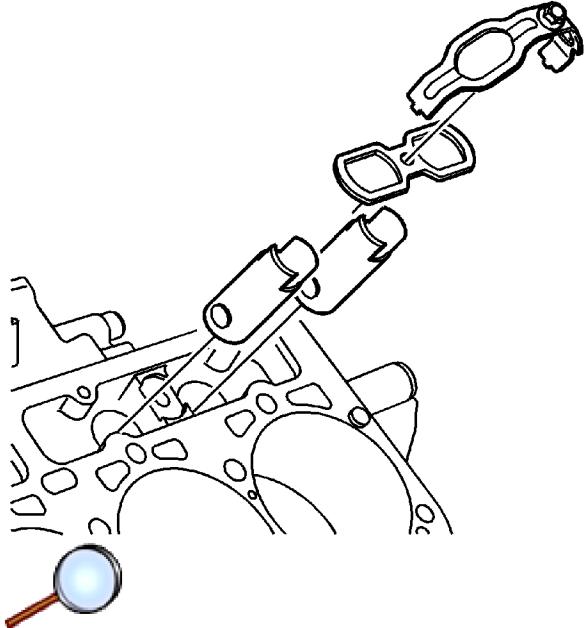


1. Remove the cylinder head bolts in the proper sequence.
2. Discard the large M12 bolts.



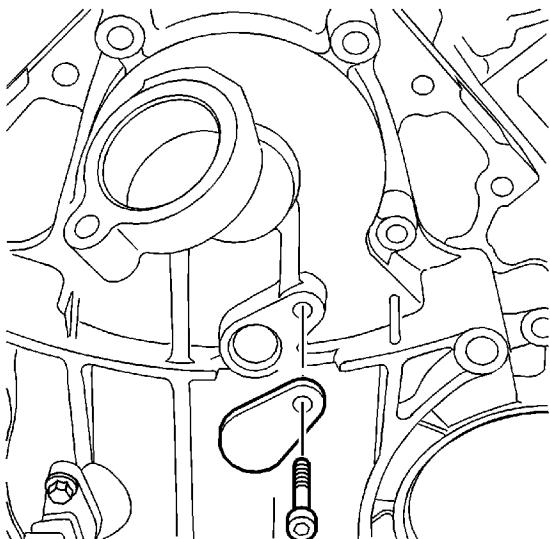
3. Remove the right cylinder head assembly.
4. Remove the right cylinder head gasket.

Valve Lifter Removal

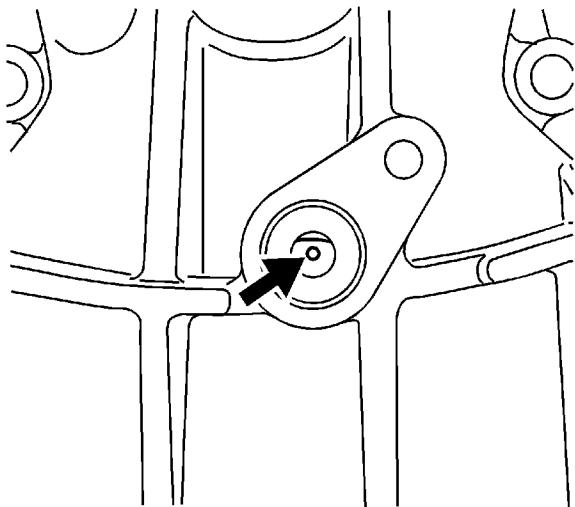


1. Loosen the valve lifter guide hold down bracket bolts.
2. Remove the valve lifter guide hold down brackets.
3. Remove the valve lifter guides.
4. Remove the valve lifters.

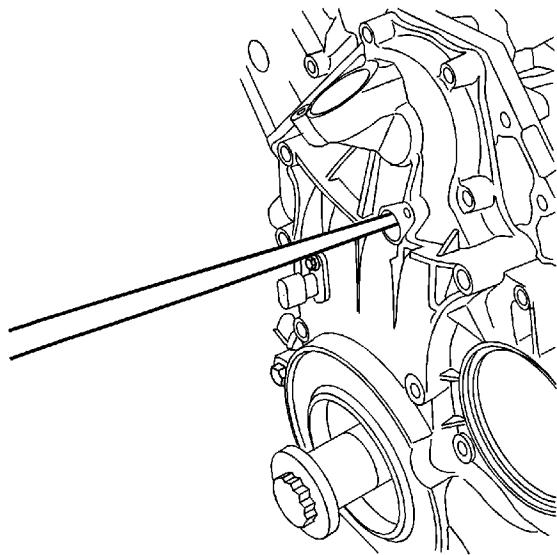
Fuel Injection Pump Removal



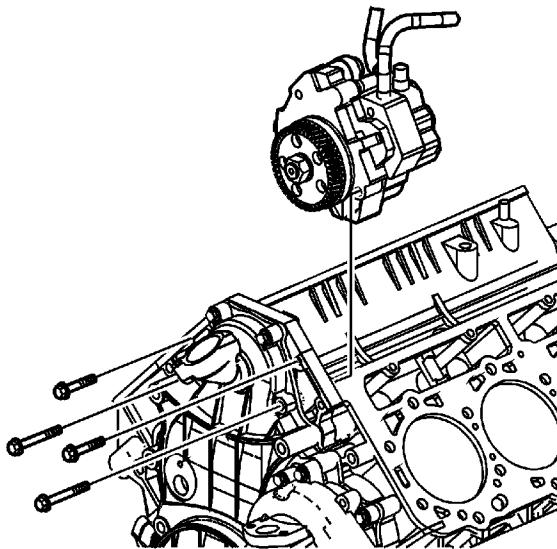
1. Remove the camshaft gear access hole cover bolt.
2. Remove the camshaft gear access hole cover.



3. Rotate the crankshaft until the camshaft gear tension relief hole is in line with the front cover access hole.

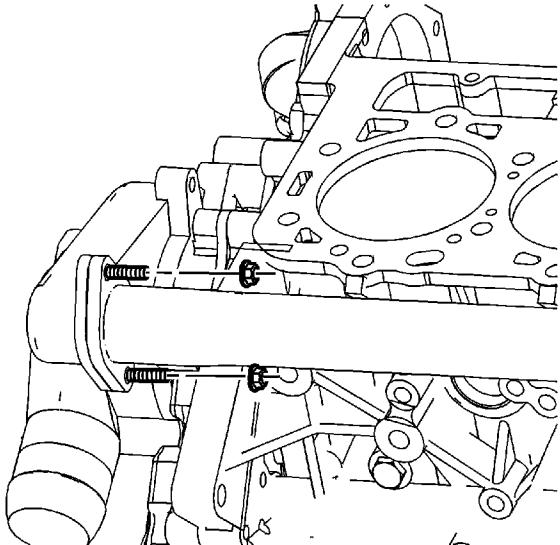


4. Use a suitable tool to unload the spring tension from the two piece cam gear. Apply pressure towards the right side of the engine while removing the injection pump.

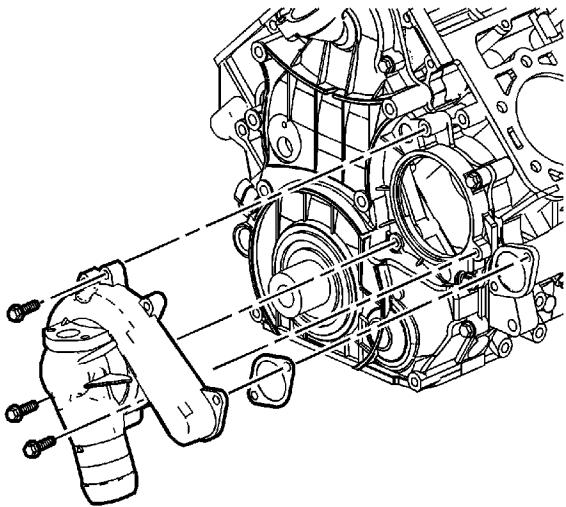


5. Remove the four fuel injection pump bolts.
6. Remove the fuel injection pump.

Water Pump Removal

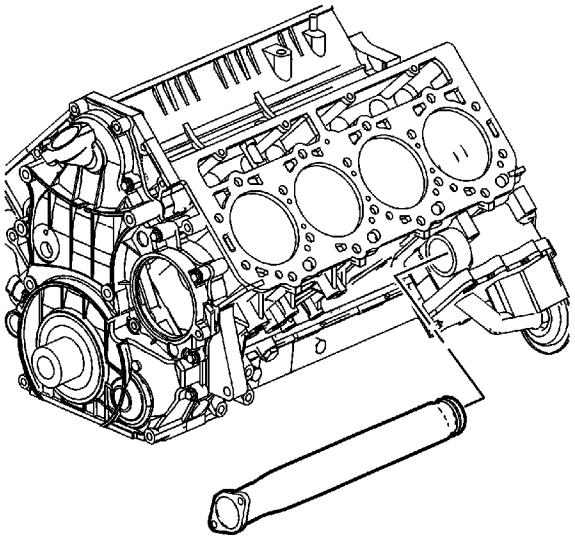


1. Remove the engine coolant pipe to water pump nuts.

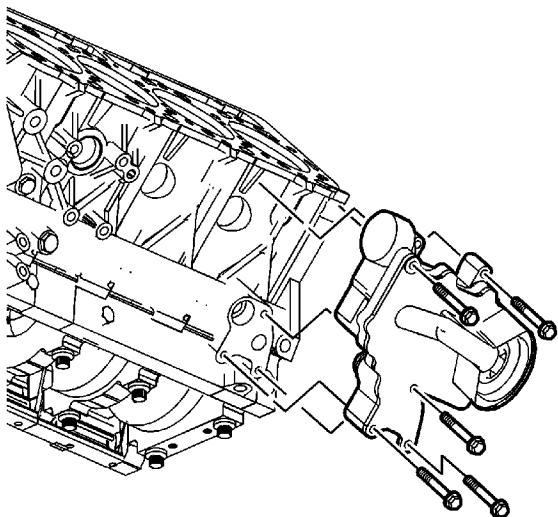


2. Remove the water pump bolts.
3. Remove the water pump assembly.
4. Remove the water pump seal and discard.
5. Remove the engine coolant pipe gasket and discard.

Oil Filter Adapter and Oil Cooler Assembly Removal



1. Remove the engine coolant pipe.
2. Remove the engine coolant pipe O-ring and discard.

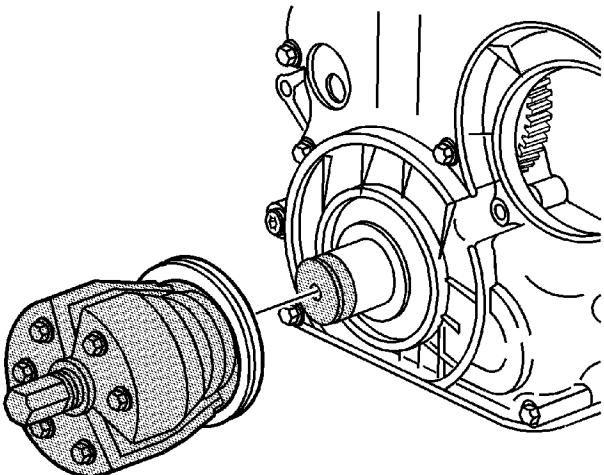


3. Remove the five oil filter adapter and oil cooler assembly bolts.
4. Remove the oil filter adapter and oil cooler assembly.

Crankshaft Front Oil Seal Removal

Tools Required

[J 44644](#) Crankshaft Front Oil Seal Remover

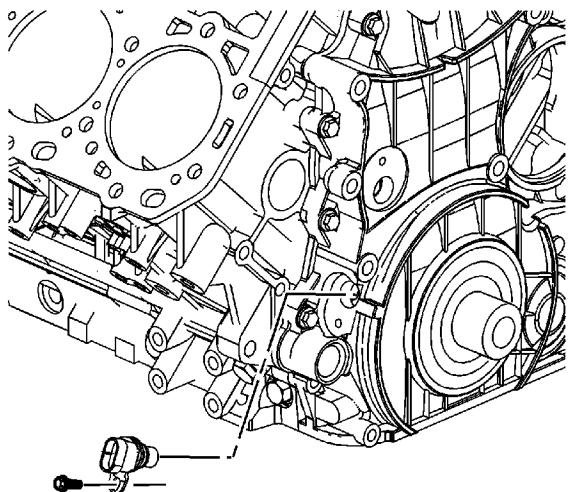


1. Install the button of [J 44644](#) into the crankshaft.
2. Press the jaws of [J 44644](#) into the felt portion of the seal far enough to engage the inner lip of the seal.
3. While holding the jaws of [J 44644](#) tightly to the seal's inner sleeve, tighten the jaw bolts.
4. Remove the crankshaft rear oil seal using the [J 44644](#).

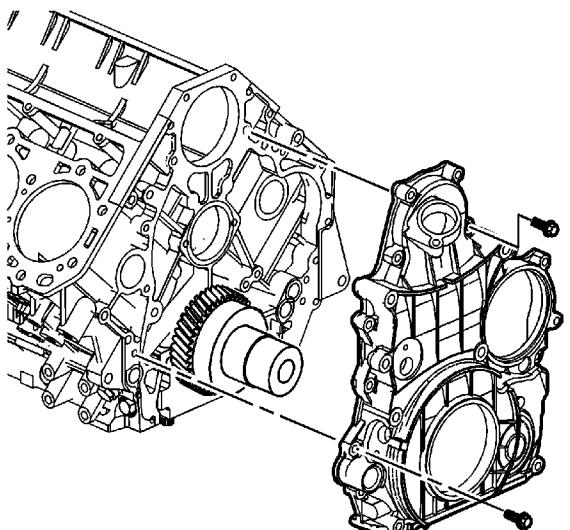
Engine Front Cover Removal

Tools Required

[J 37228](#) Seal Cutter



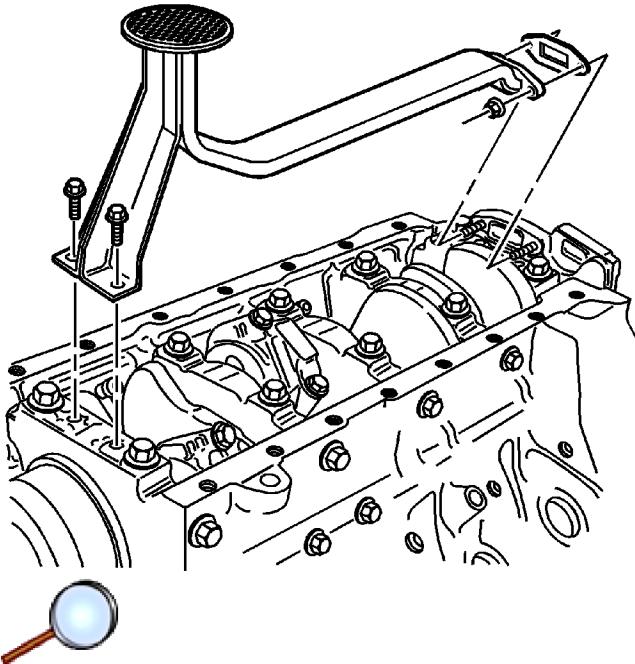
1. Remove the crankshaft position sensor bolt.
2. Remove the crankshaft position sensor.



3. Remove the engine front cover bolts.
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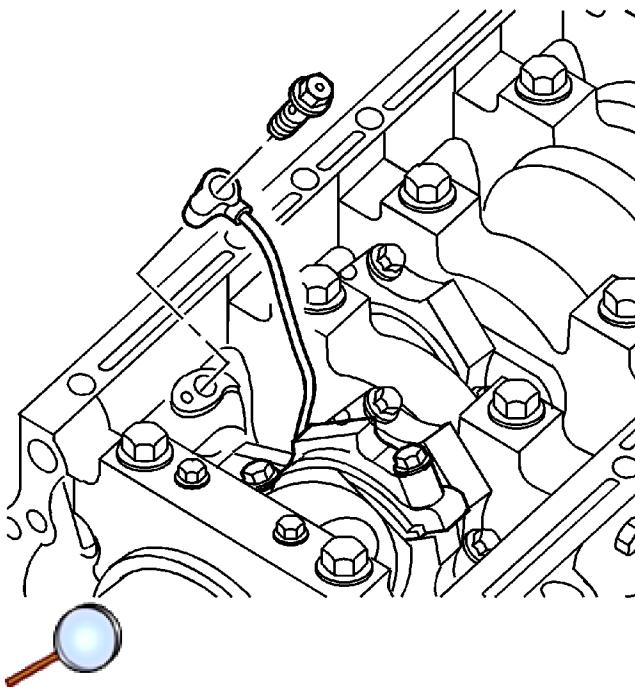
4. Separate the engine front cover from the cylinder block using [J 37228](#) .
5. Remove the engine front cover.

Oil Pump Suction Pipe and Screen Assembly Removal



1. Remove the oil pump pipe and screen assembly bolts and nuts.
2. Remove the oil pump pipe and screen assembly.
3. Remove the oil pump pipe and screen assembly gasket and discard.

Piston Oil Cooling Nozzle Removal

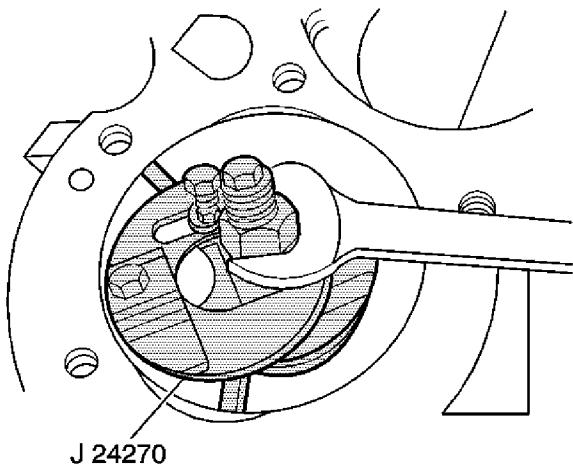


1. Rotate crankshaft as necessary to obtain access to piston oil cooling nozzles.
2. Remove the piston oil cooling nozzle eye bolt.
3. Remove the piston oil cooling nozzle.

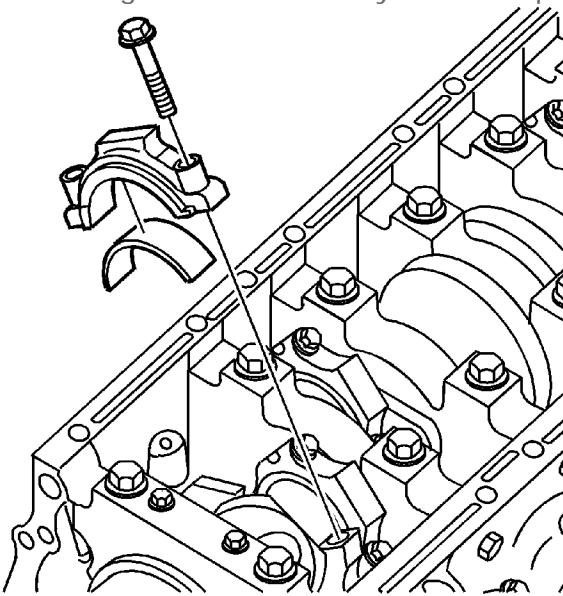
Piston, Connecting Rod, and Bearing Removal

Tools Required

[J 24270](#) Ridge Reamer



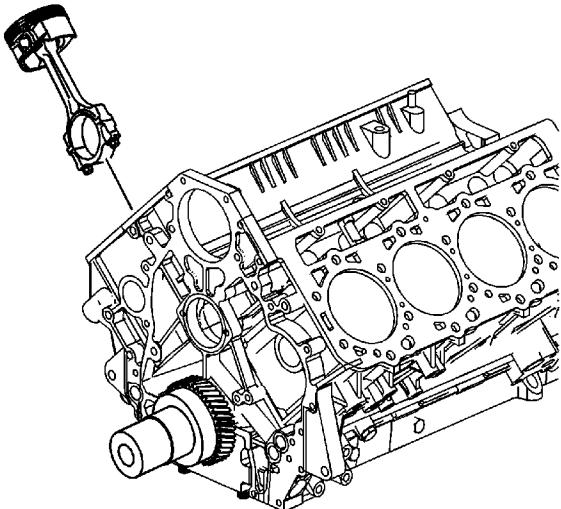
1. Rotate the crankshaft to place the piston at the bottom of the piston stroke.
2. Place a cloth on top of the piston.
3. Use the [J 24270](#) to remove the ridge at the top of the cylinder bore.
4. Remove cloth.
5. Remove cutting debris from the cylinder and piston.



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6. Remove the connecting rod cap bolts. Set the bolts aside for use in plastic gauging if needed. New bolts will be used for final assembly.
7. Remove the connecting rod cap.
8. Remove the bearing insert from connecting rod.

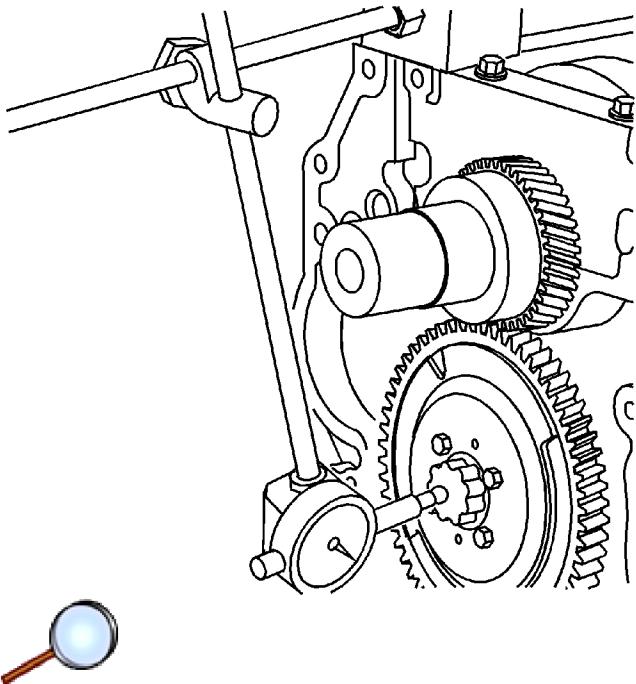


9. Push piston assembly out of cylinder.
10. Reassemble the connecting rod bearing, cap, and bolts upon removal.

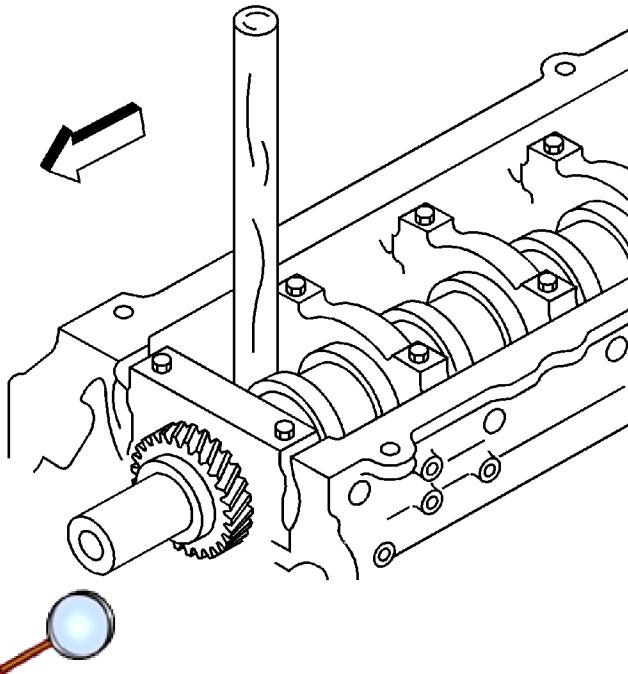
Camshaft Removal

Tools Required

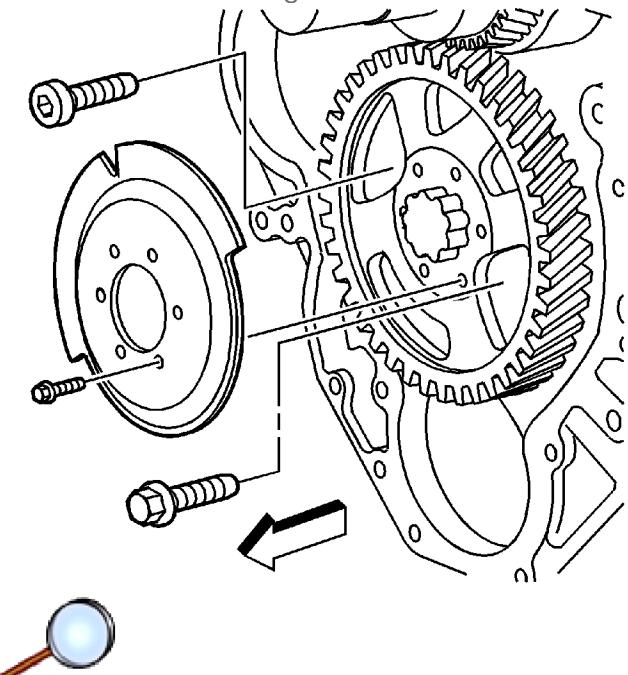
[J 7872](#) Dial Indicator Set



1. Measure the camshaft end play using [J 7872](#) .
 - The production value is 0.050-0.114 mm (0.002-0.0045 in) and service limit is 0.20 mm (0.008 in).
 - Replace the camshaft or the camshaft thrust plate if the measured value exceeds the service limit.



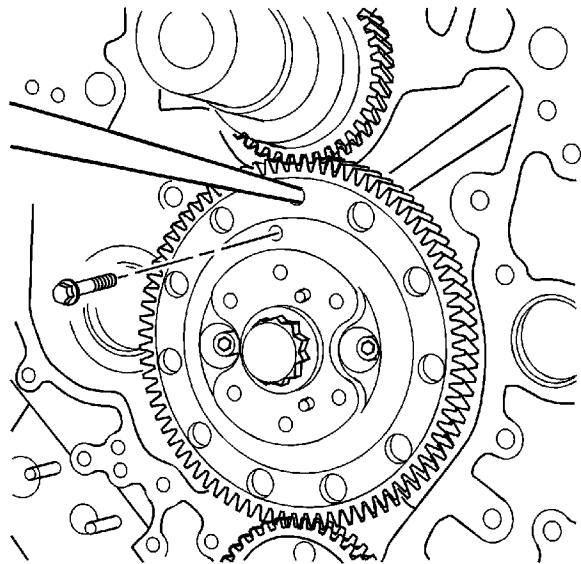
2. Block the crankshaft from turning with a wooden handle.
3. Loosen the camshaft gear bolt and leave the bolt finger tight.



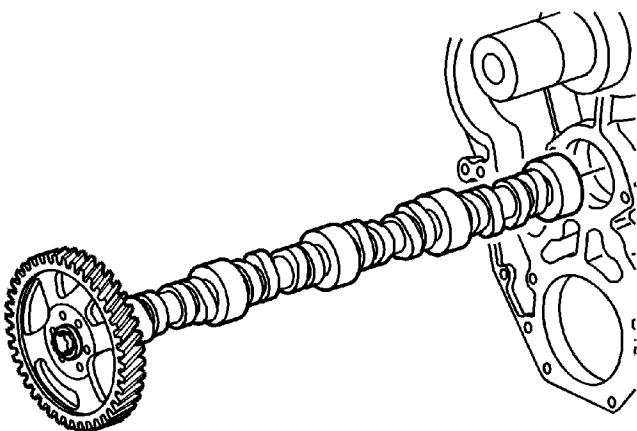
4. Remove the camshaft exciter ring bolts.

Important: The two piece cam gear must be bolted together to prevent the spring tension from unloading upon removal.

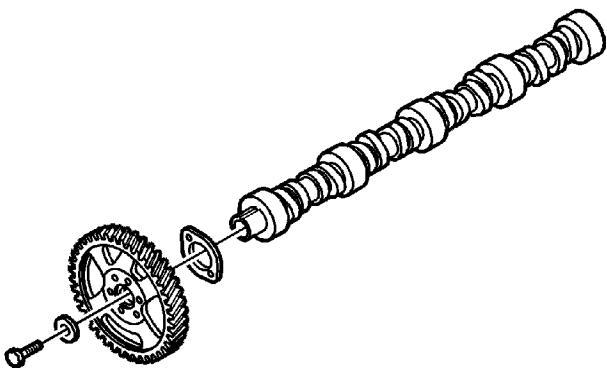
5. Remove the camshaft exciter ring.



6. Align the threaded hole with a suitable tool and install an exciter ring bolt to secure the spring tension.
7. Remove the camshaft thrust plate bolts through the holes in the camshaft gear.



8. Remove the camshaft with the camshaft gear attached.

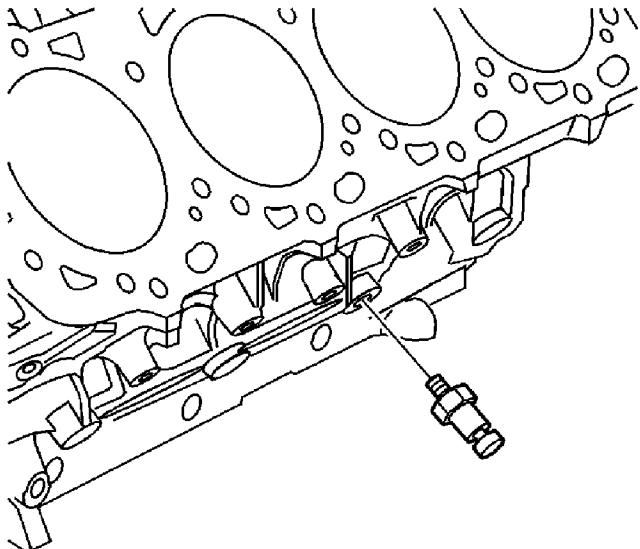


9. Remove the camshaft gear bolt and washer.
10. Remove the camshaft gear.
11. Remove the camshaft thrust plate.

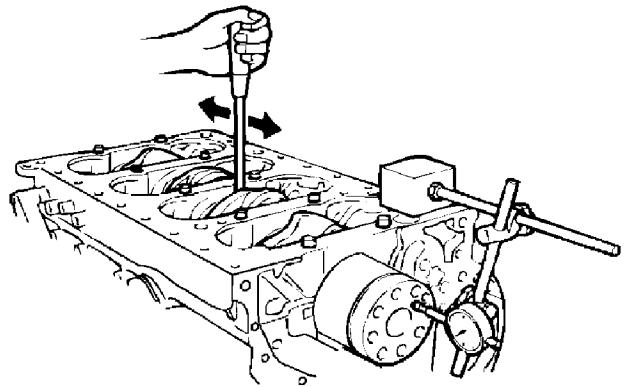
Crankshaft and Bearing Removal

Tools Required

[J 7872 Dial Indicator Set](#)



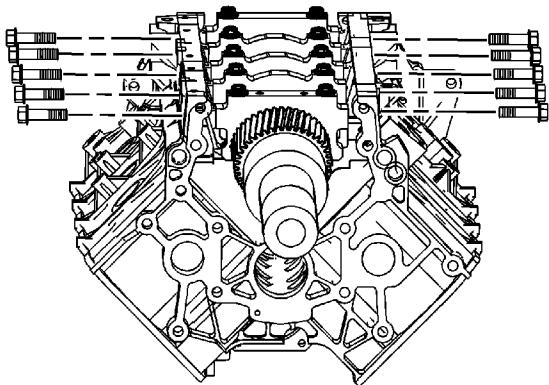
1. Remove the oil pressure sensor.



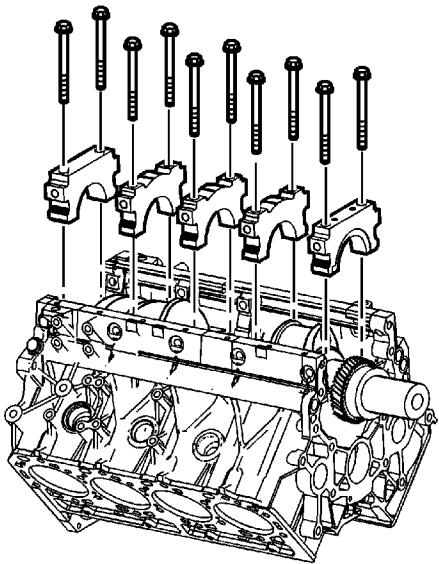
2. Measure crankshaft end play using [J 7872](#). The production value is 0.04-0.205 mm (0.0016-0.0081 in) and the service limit is 0.54 mm (0.0213 in). Replace the thrust bearings upon completion.

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reassembly if the measured value exceeds the service limit.



3. Remove the crankshaft bearing cap side bolts.

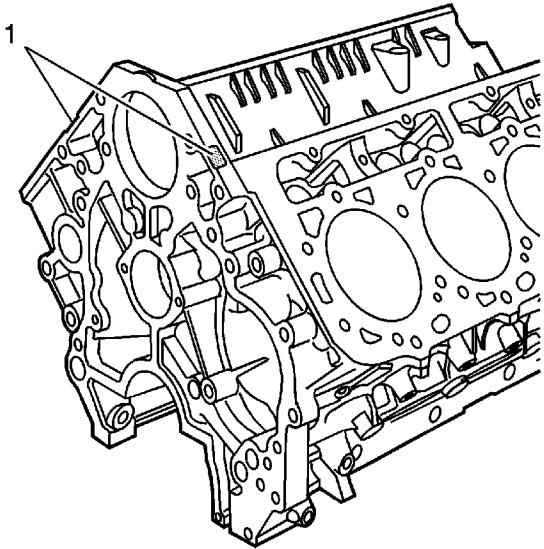


4. Remove the crankshaft bearing cap bolts.
5. Remove the crankshaft bearing caps.
6. Set the bolts aside for use in plastic gauging if needed.
7. Remove the crankshaft assembly.
8. Remove the crankshaft bearings from the engine block and the bearing caps.
9. Mark crankshaft bearings and caps so they may be installed in their original position.

Engine Block Cleaning and Inspection

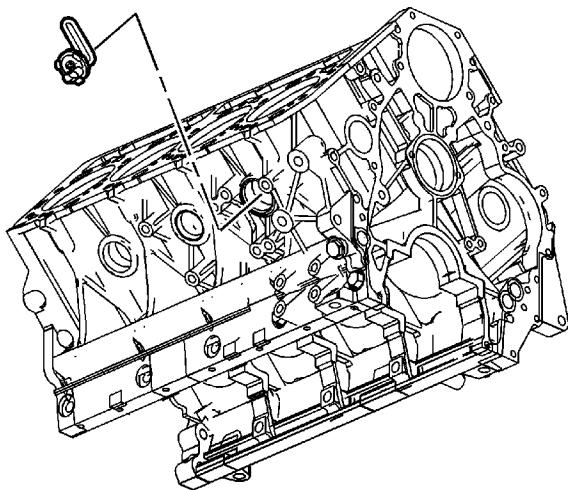
Note: All remanufactured cylinder blocks are steel stamped on both sides of the fuel pressure pump boss. The stamp indicates whether the cylinder is standard or over-bored, and if the deck is standard or has been milled.

Stamped ID	Cylinders Bore Size (in.)	Top Deck (STD or Milled)
SS	STD	STD
01S	0.010	STD
02S	0.020	STD
03S	0.030	STD
SM	STD	Milled
01M	0.010	Milled
02M	0.020	Milled
03M	0.030	Milled

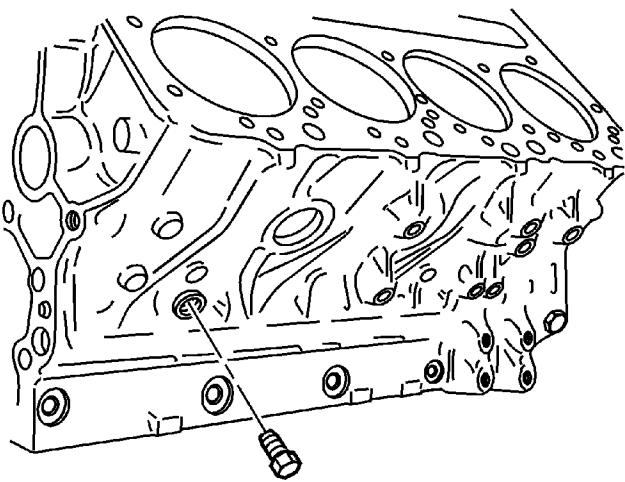


1. Inspect the block for stampings (1) indicating cylinder overbore or a milled deck.

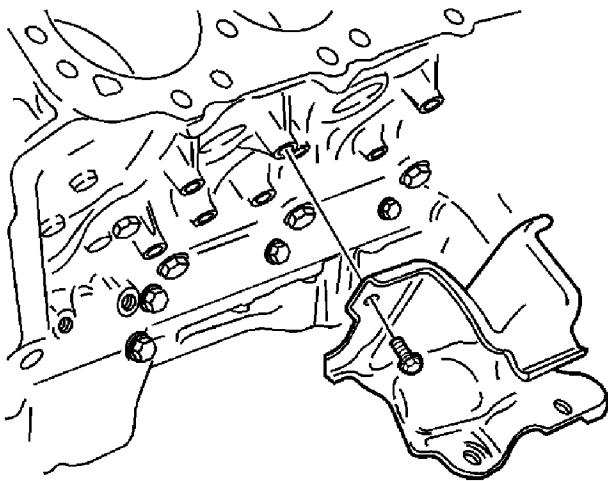
Note: If the block has no stampings, the block has a standard bore and deck.



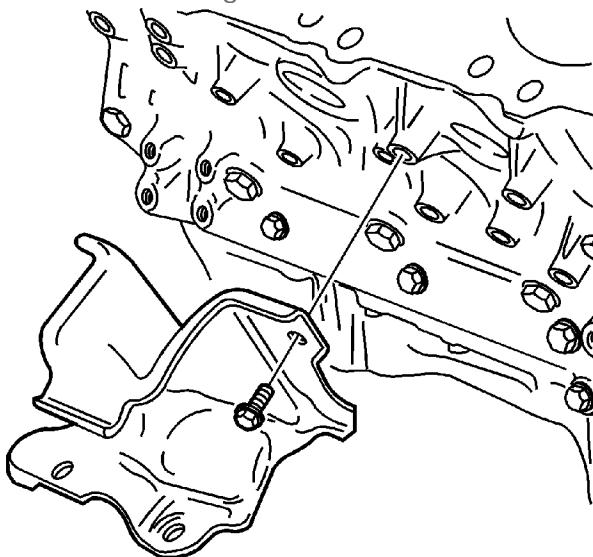
2. Remove the engine block heater.
3. Remove the O-ring from the block heater and discard.



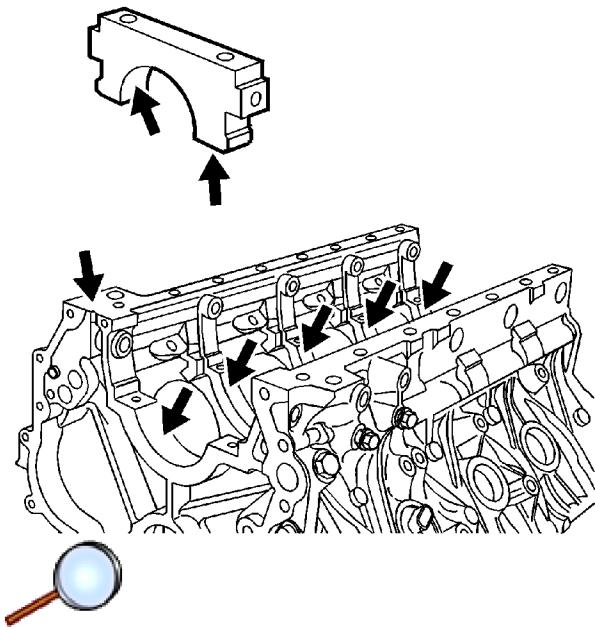
4. Remove the oil gallery plugs.



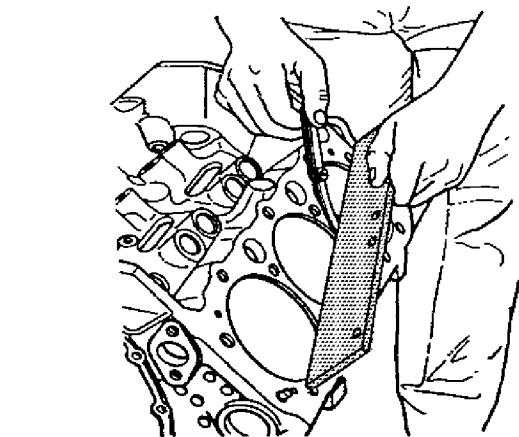
5. Remove the left engine mount bolts.
6. Remove the left engine mount.



7. Remove the right engine mount bolts.
8. Remove the right engine mount.
9. Clean the sealing material from the gasket mating surfaces of the block.
10. Clean the block in cleaning solvent.
11. Flush the engine block with clean water or steam.
12. Clean the oil passages.
13. Clean the cylinder bores.
14. Inspect the block for cracks. Use the Magnaflux Spot check dye method, or the equivalent.
 - Inspect the cylinder walls.
 - Inspect the coolant jackets.
 - Inspect the crankshaft bearing webs.

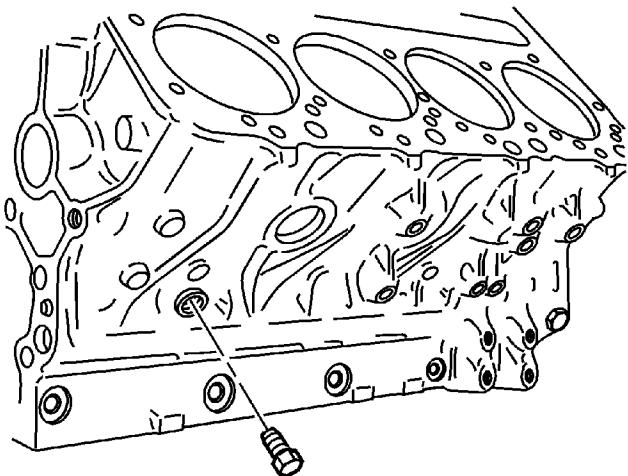


15. Inspect the crankshaft bearing bores and caps. The crankshaft bearing bore inside diameters should be round and uniform at all of the bearing supports.
16. Inspect the area where the crankshaft bearing inserts contact the crankshaft bearing bore. This area must be free of burrs and scratches.
17. Inspect the engine mount bosses.
18. Inspect the cylinder head gasket mating surfaces for pitting.

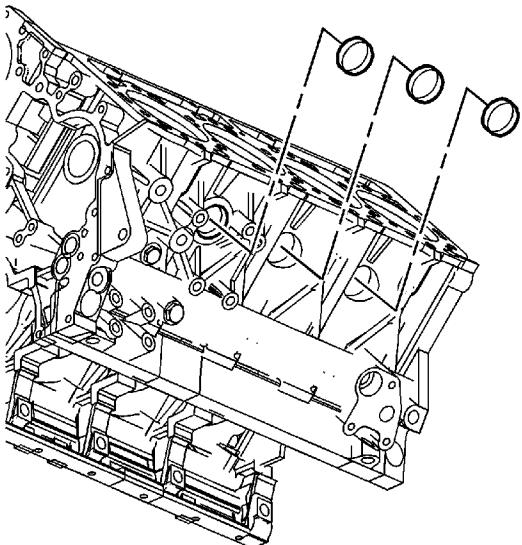


- 
19. Inspect the engine block to cylinder head gasket surface area for warping. Use a straight edge and feeler gauge. Replace the block if it is warped more than 0.15 mm (0.006 in) longitudinally or more than 0.08 mm (0.003 in) transversely.
 20. Apply sealer to the oil gallery plugs.

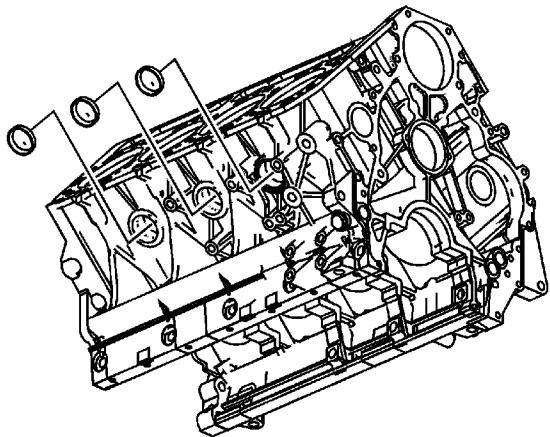
Caution: Refer to [Fastener Caution](#) in the Preface section.



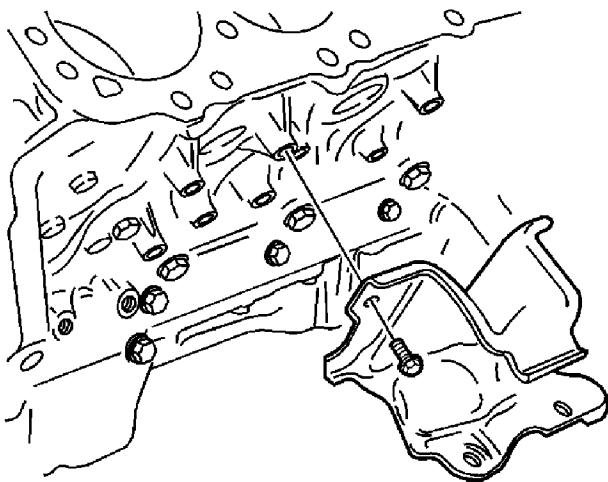
21. Install the oil gallery plugs and tighten to **53 N·m (39 lb ft)**.



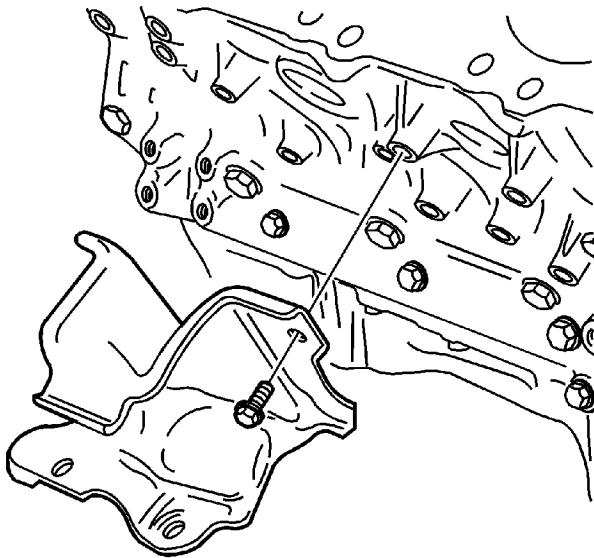
22. Install the left engine block coolant plugs and tighten to **18 N·m (13 lb ft)**.



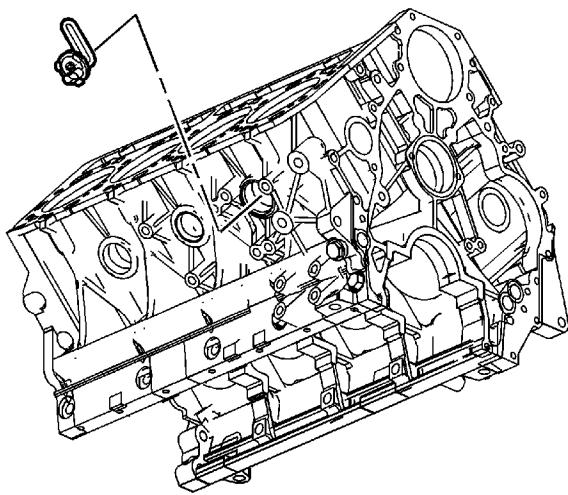
23. Install the right engine block coolant plugs and tighten to **18 N·m (13 lb ft)**.



24. Install the left engine mount and engine mount bolts. Tighten the engine mount bolts to **58 N·m (43 lb ft)**.

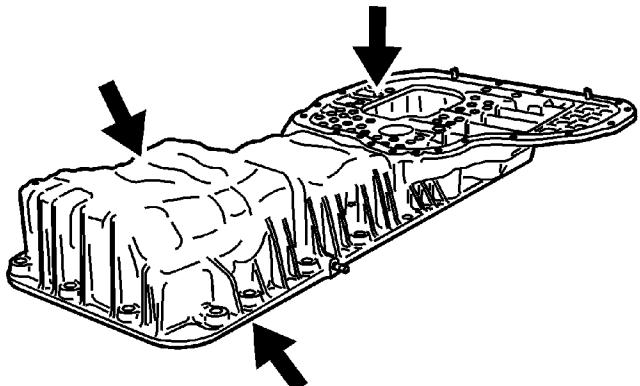


25. Install the right engine mount and engine mount bolts. Tighten the right engine mount bolts to **58 N·m (43 lb ft)**.



26. Install a new O-ring to the block heater.
27. Lubricate the O-ring with engine coolant.
28. Install the engine block heater.

Upper Oil Pan Cleaning and Inspection

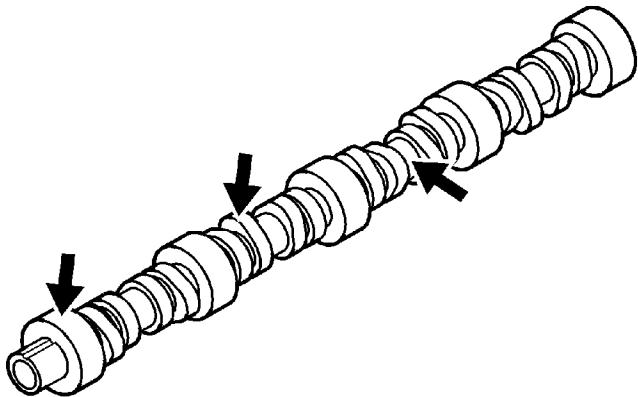


1. Clean the upper oil pan.
2. Carefully clean the sealer from the threaded holes.
3. Inspect the upper oil pan for cracks.
4. Inspect the upper oil pan sealing surfaces for damage.
5. Replace the upper oil pan if any damage is found.

Camshaft and Bearings Cleaning and Inspection

Tools Required

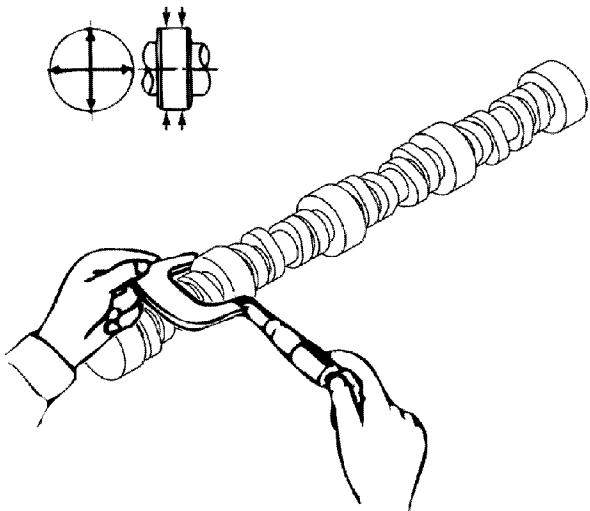
[J 7872](#) Dial Indicator Set



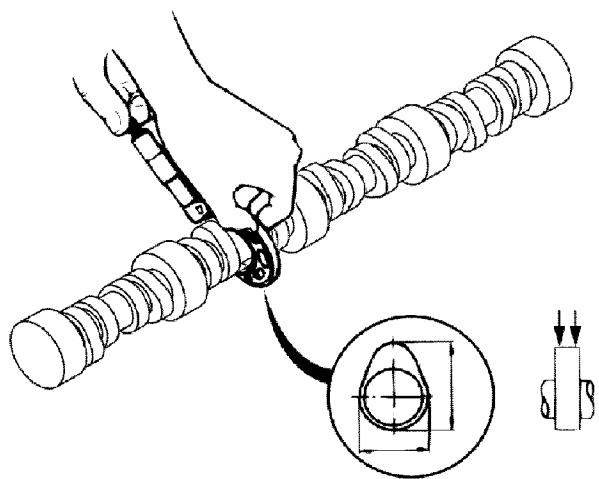
1. Clean the camshaft.

Important: The camshaft bearings are not serviceable. If the camshaft bearings are damaged, the engine must be replaced.

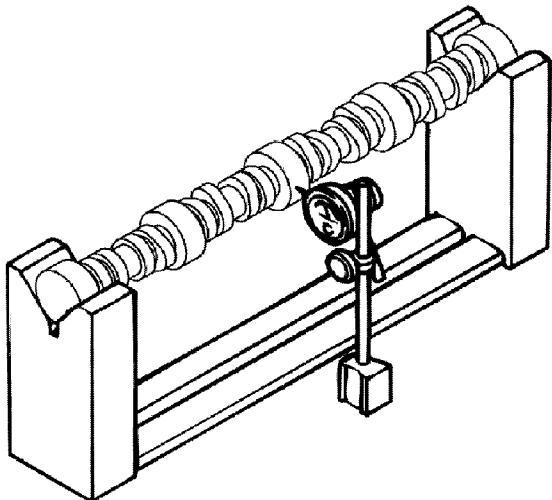
2. Visually inspect the camshaft bearings in the engine block for the following conditions:
 - Scoring
 - Nicks
 - Damage caused by lack of lubrication
 - Misaligned oil feed holes



3. Measure the camshaft journal diameter.
- The production value is 60.932-60.962 mm (2.3990-2.4001 in) and service limit is 60.920 mm (2.3984 in).
 - Replace the camshaft if the measured value is less than service limit.



4. Measure the camshaft lobe lift. The production value for intake is 7.273 mm (0.2863 in).
5. The production value for exhaust is 5.907 mm (0.2326 in).
6. Replace the camshaft if the measured value is less than the service limit.



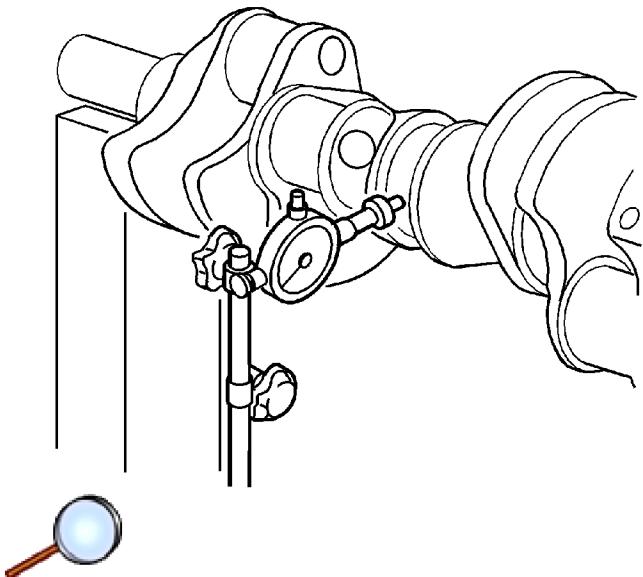
7. Measure the camshaft runout.
 - Mount the camshaft on the V-blocks.
 - Use [J 7872](#) to measure the camshaft runout.
 - The runout service limit is 0.05 mm (0.0020 in).
8. Replace the camshaft if the run-out is over the service limit.

Crankshaft and Bearing Cleaning and Inspection

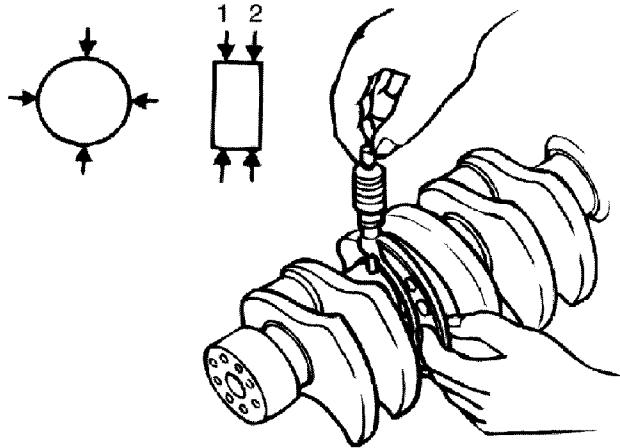
Special Tools

- J7872 Dial Indicator Set
- J45059 Angle Meter

For equivalent regional tools, refer to [Special Tools](#).



1. Clean the crankshaft and bearings.
2. Inspect the crankshaft for the following conditions.
 - Excessive wear or damage on the surface of the crankshaft journals.
 - Excessive wear or damage to the crankshaft gear.
 - Excessive wear or damage on the oil seal fitting surface.
 - Inspect the oil ports for obstructions.
 - Replace the crankshaft if there is excessive wear or damage to the journals, oil seal fitting surface or to the crankshaft gear.
3. Measure the crankshaft run out.
 - 3.1. Mount the crankshaft in wooden V-blocks.
 - 3.2. Set J7872 set on the center of the crankshaft journal.
 - 3.3. Turn the crankshaft in the normal direction of rotation.
 - 3.4. Record readings. The production value is 0.05 mm (0.0020 in) and the service limit is 0.44 mm (0.0173 in).



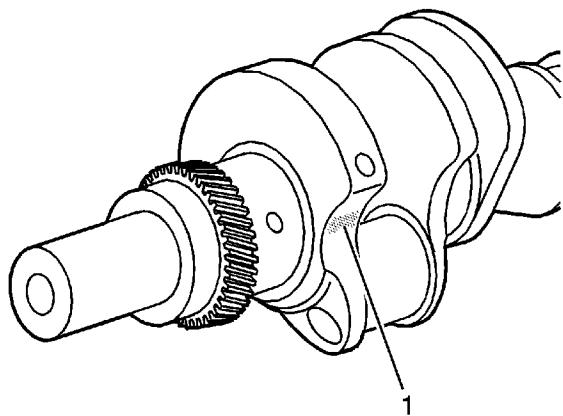
4. Measure the crankshaft journal diameter across four points.
 - The crankshaft journal outside diameter is 79.905-79.925 mm (3.1459-3.1466 in) and the service limit is 79.89 mm (3.1453 in).
 - Replace the crankshaft if the measured value is less than the service limit.
5. Measure the crankpin outside diameter across four points.
 - The crankpin outside diameter is 62.902-62.922 mm (2.4765-2.4772 in) and the service limit is 62.88 mm (2.4756 in).
 - Replace the crankshaft if the measured value is less than the service limit.

Crankshaft Bearing Selection

There are two methods for selecting the proper size crankshaft bearings. The first one is to select the bearing grade (color code) based on the cylinder block grade and the crankshaft journal grade from the Crankshaft Bearing Grade chart. The second is the plastic gauge method.

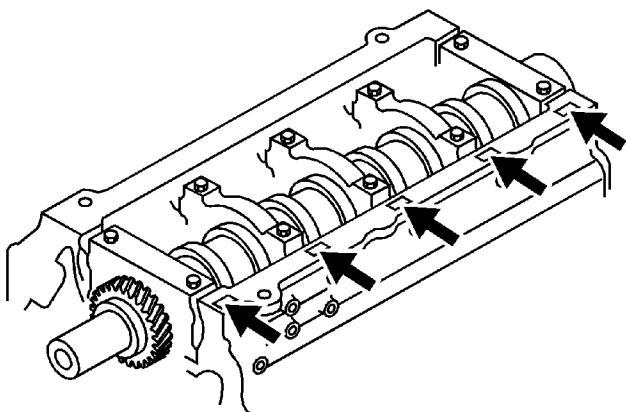
Crankshaft Bearing Selection Grade Chart Method

Stamp ID	Main Journal	Conn. Rod Journal
No Stamp	STD	STD
M20 R20	0.020 in	0.020 in

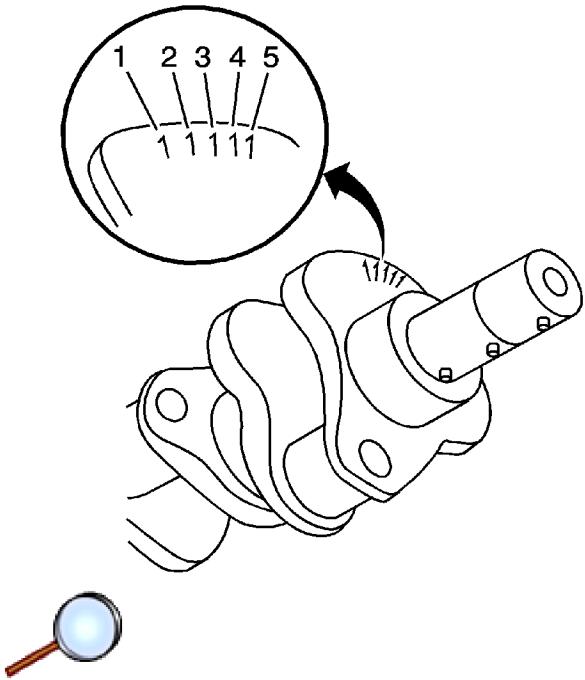


Note: All crankshafts that have been machined have a steel stamping (1) on the 1st counterweight.

1. Inspect the crankshaft for stamping (1) indicating undersized main and/or rod journals.



2. The cylinder block grade is indicated on the right lower portion of the cylinder block.



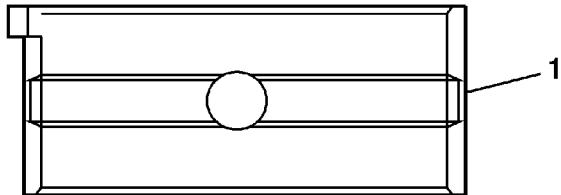
3. The crankshaft journal grade is indicated on the number 1 crankshaft counterweight.
4. Match the cylinder block grade and the crankshaft journal grade, refer to [Crankshaft Bearing Selection Specifications](#).
5. From the Crankshaft Bearing Grade chart, determine which bearing grade (color code) is required.
6. Verify the crankshaft bearing clearance using the plastic gage method.

Crankshaft Bearing Selection Plastic Gage Method

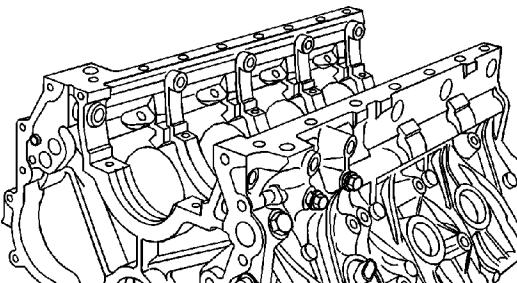
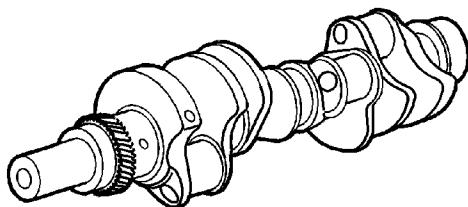
Special Tools

J 45059 Angle Meter

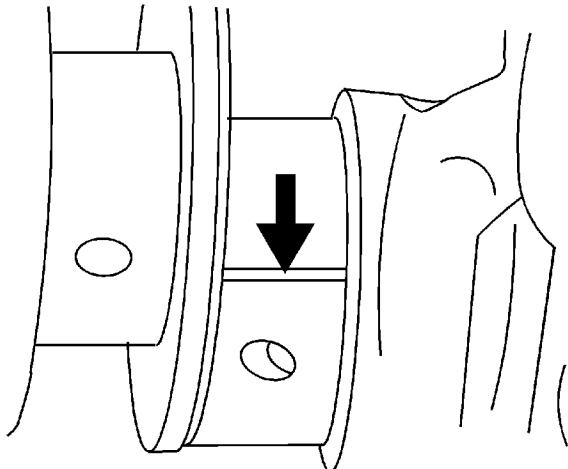
For equivalent regional tools, refer to [Special Tools](#).



1. Clean the cylinder block bearing fitting surfaces.
2. Clean the crankshaft and upper bearings (1) and lower bearings (2).
3. Install the bearings into the cylinder block and the bearing caps.

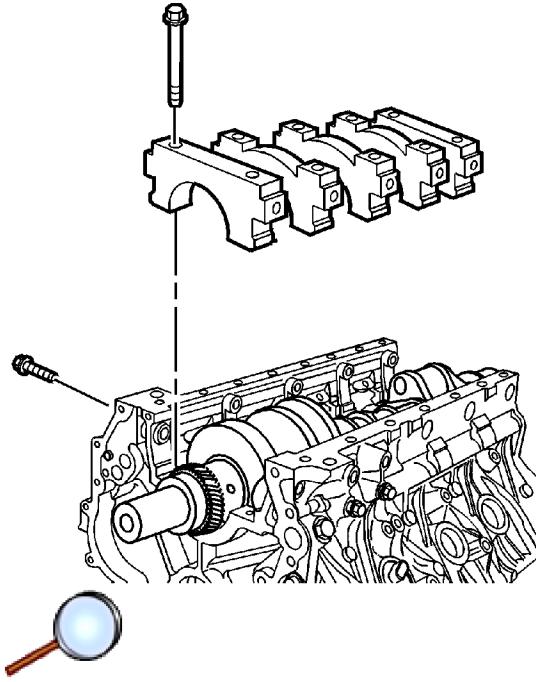


4. Install the crankshaft into the cylinder block.
5. Rotate the crankshaft approximately 30 degrees to seat the bearings.



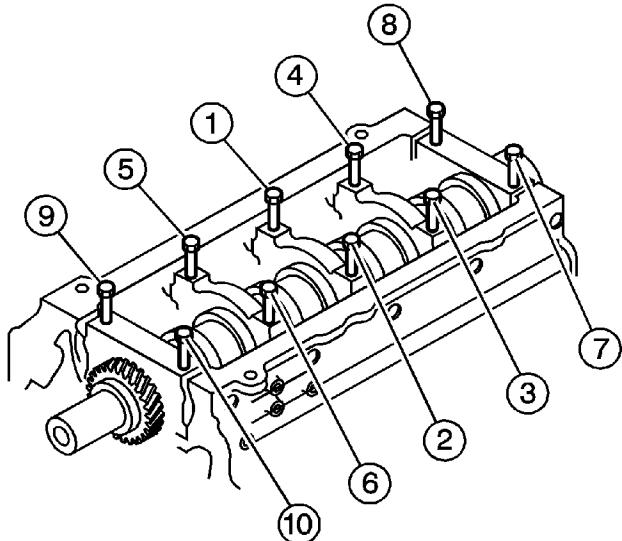
Note: Do not allow the crankshaft to rotate at any time during bearing cap installation and tightening or the plastic gauge measurement will be inaccurate.

6. Place the plastic gage over the crankshaft journal across the full width of the bearing.

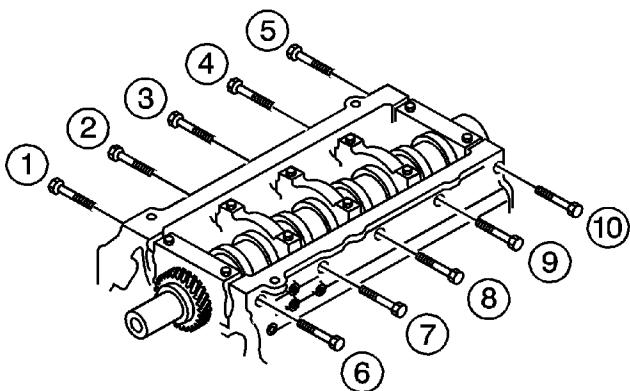


7. Install the crankshaft bearing caps.

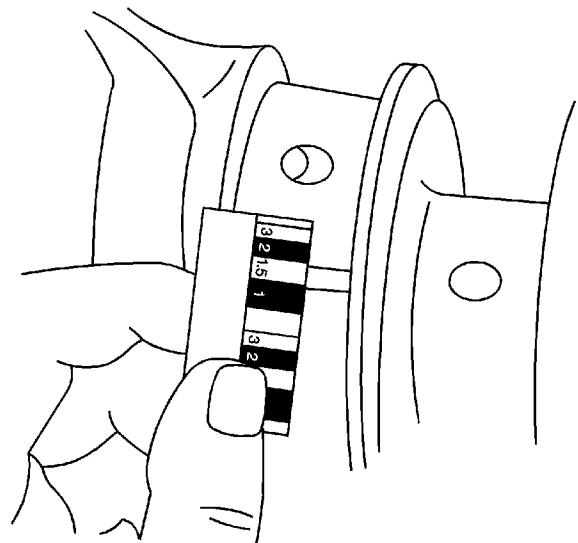
Caution: Refer to [Fastener Caution](#) in the Preface section.



8. Install the crankshaft bearing cap bolts.
9. Tighten the crankshaft bearing cap bolts in the proper sequence.
 - 9.1. 1st step **98 N·m (72 lb ft)**.
 - 9.2. 2nd step **132 N·m (97 lb ft)**.
 - 9.3. 3rd step **30 degrees** using *J 45059* meter .

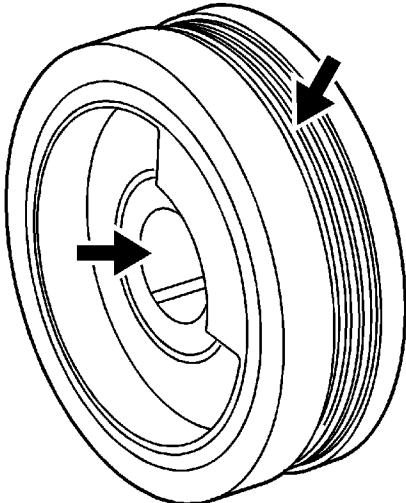


10. Install the crankshaft bearing cap side bolts. Tighten the crankshaft bearing cap side bolts in the proper sequence to **70 N·m (52 lb ft)**.
11. Remove the crankshaft bearing cap bolts.
12. Remove the crankshaft bearing caps.



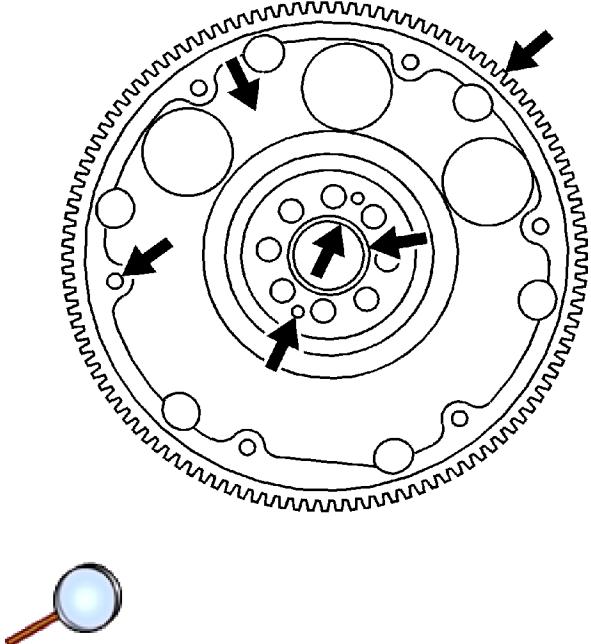
13. Compare the width of the plastic gauge with the scale printed on the plastic gauge container.
14. Select the crankshaft bearing grade that provides the proper oil clearances. The production specification for crankshaft bearing clearance is 0.039-0.070 mm (0.0015-0.0028 in) and the service limit is 0.014 mm (0.0055 in).

Crankshaft Balancer Cleaning and Inspection



1. Clean the crankshaft balancer.
2. Inspect the crankshaft balancer for damage to belt drive surface and to crankshaft balancer hub.
3. Inspect the balancer hub groove for damage or wear.
4. Replace the crankshaft balancer if any concerns exist.

Engine Flywheel Cleaning and Inspection



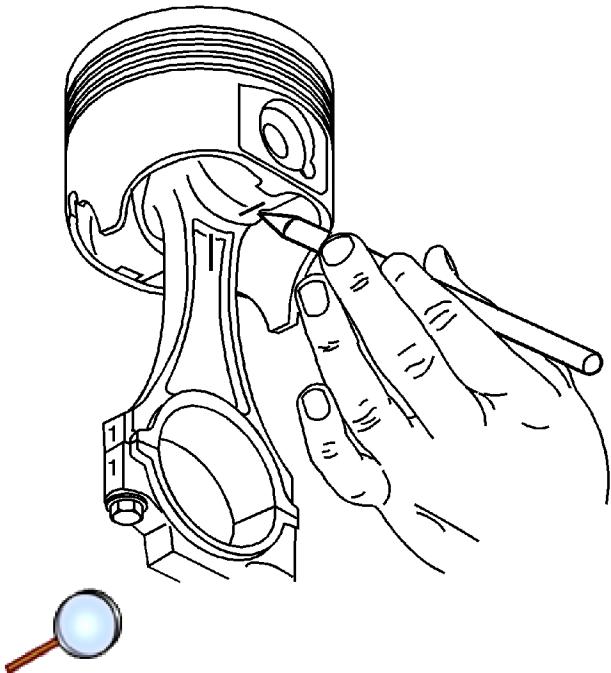
Important: In order to maintain the proper component balance, contact surface taper, and heat transfer, manual transmission flywheels are NOT to be machined.

1. Clean the flywheel assembly.
2. Inspect the flywheel assembly for cracks or excessive wear on the teeth.
3. Replace the flywheel assembly if any concerns exist.

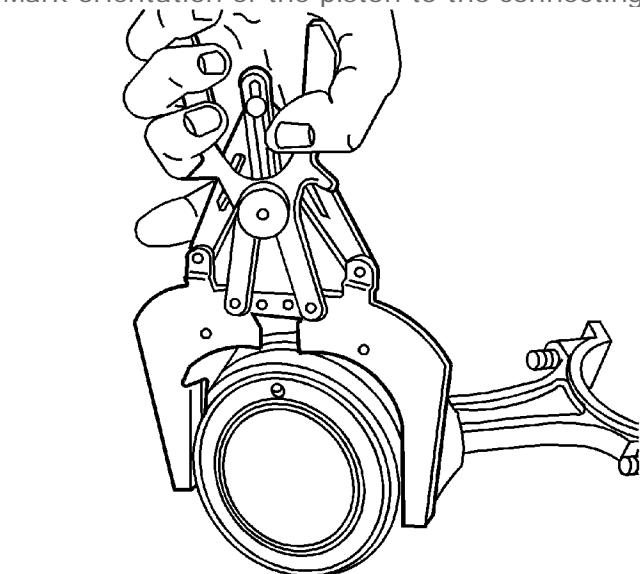
Piston and Connecting Rod Disassemble

Tools Required

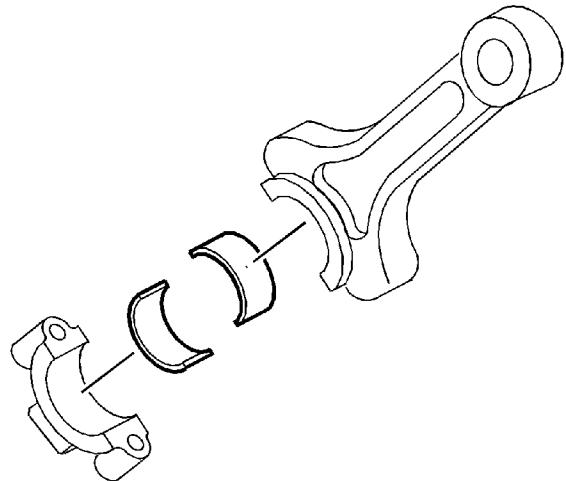
[J 43654](#) Piston Pin Retainer Remover/Installer



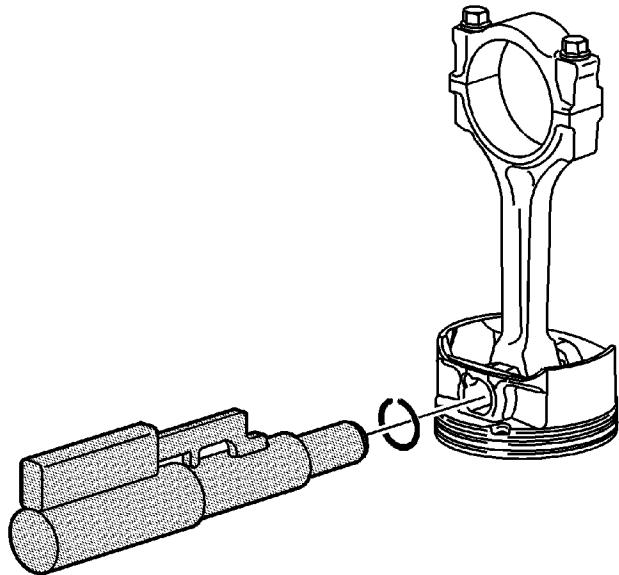
1. Mark orientation of the piston to the connecting rod.



2. Remove the piston rings using a piston ring expander.

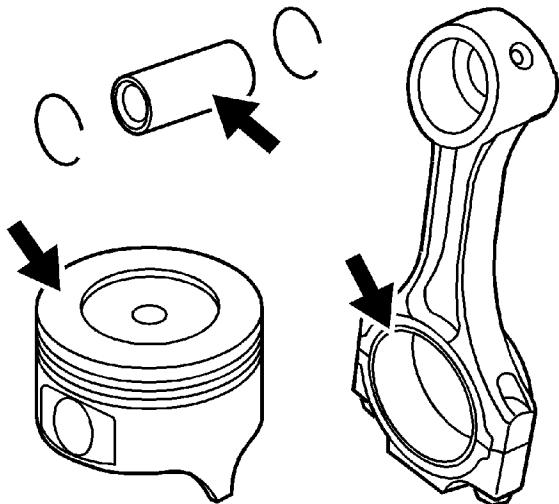


3. Remove the connecting rod bearing inserts.

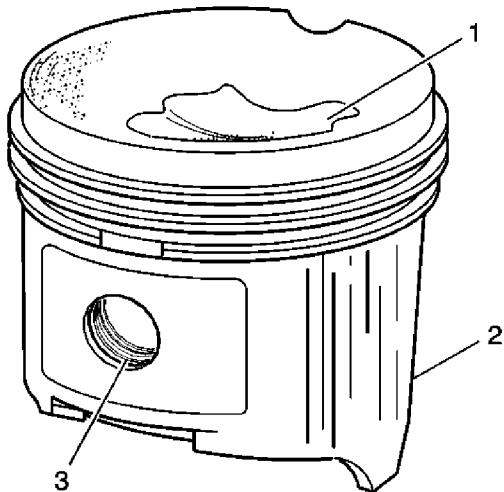


4. Use [J 43654](#) to remove the piston pin retainers.
5. Remove the piston pin. The pin is a full-floating style and should slide from the piston.
6. Remove the piston from the connecting rod.

Piston, Connecting Rod, and Bearing Cleaning and Inspection



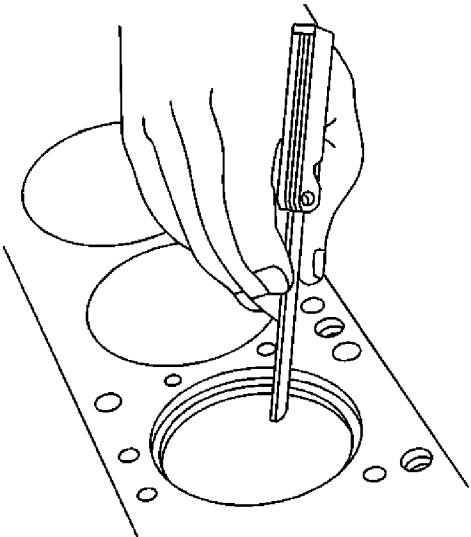
1. Clean the deposits from the following components:
 - Connecting rod and bearings
 - Piston
 - Piston pin



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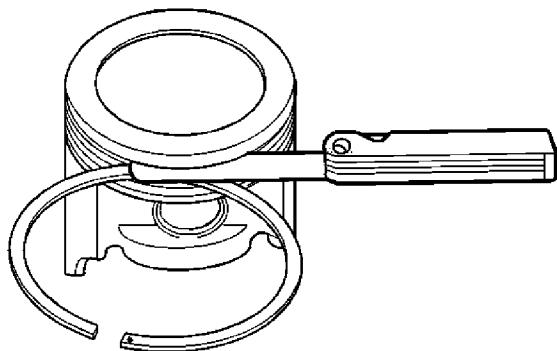
2. Inspect the piston for the following conditions:

- Scoring on the piston skirt (2)
- Scoring in the piston pin area (3)
- Cracks (1)
- Broken ring groove lands

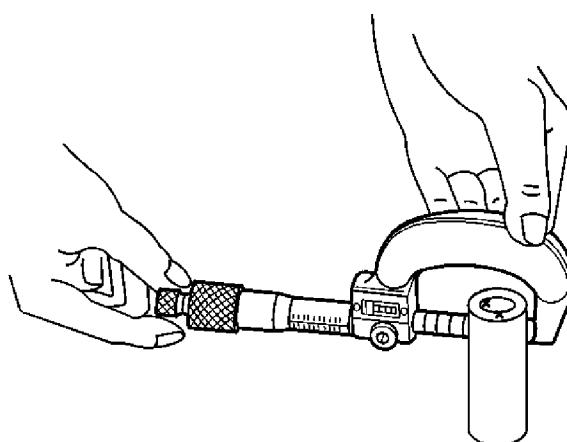


3. Measure the piston ring end gap.

- Use a piston to square the piston ring near the top of the cylinder.
- Use a feeler gauge to measure the piston ring gap.
- The 1st compression ring production gap is 0.30-0.45 mm (0.0118-0.0177 in) and the service limit is 1.37 mm (0.0539 in).
- The 2nd compression ring production gap is 0.50-0.65 mm (0.0197-0.0256 in) and the service limit is 1.35 mm (0.0531 in).
- The oil ring production gap is 0.15-0.35 mm (0.0059-0.0138 in) and the service limit is 1.20 mm (0.0472 in).
- Replace the piston ring if the measured value exceeds the service limit.

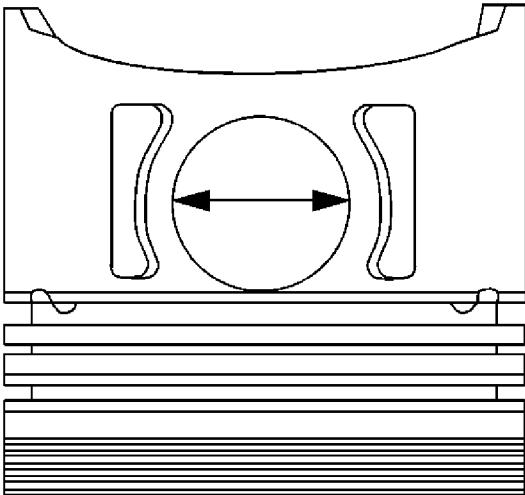


4. Measure the piston ring to piston ring groove clearance.
 - Use a feeler gauge to measure the clearance between the piston ring and the piston ring groove at several points around the piston.
 - The 1st compression ring production clearance is 0.08-0.17 mm (0.0030-0.0007 in) and the service limit is 0.26 mm (0.0102 in).
 - The 2nd compression ring production clearance is 0.01-0.03 mm (0.0004-0.0012 in) and the service limit is 0.10 mm (0.0039 in).
 - The oil ring production clearance is 0.01-0.03 mm (0.0004-0.0012 in) and the service limit is 0.12 mm (0.0047 in).
 - Replace the piston ring if the measured value exceeds the service limit.

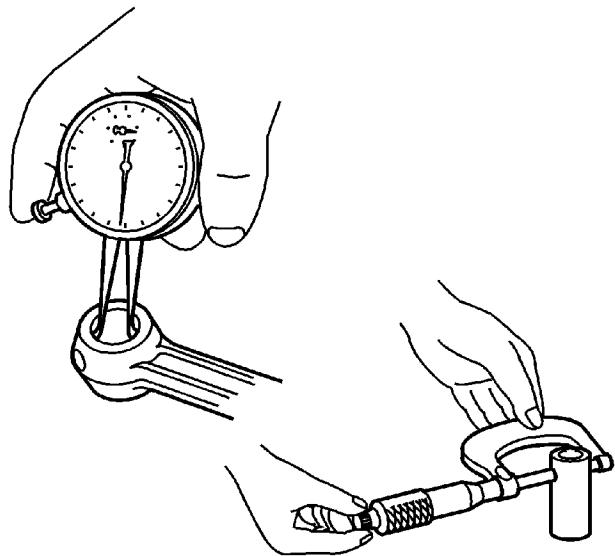


5. Measure the piston pin outside diameter.

- Measure the piston pin outside diameter at several points.
- The production value is 34.495-34.50 mm (1.3581-1.3563 in) and the service limit is 34.450 mm (1.3563 in).
- Replace the piston pin if the measured value is less than the service limit.



6. Measure the piston pin to piston pin bore clearance.
 - Measure the piston pin bore.
 - Subtract the piston pin measurement that was taken previously from the piston pin bore measurement. The difference between these two measurements will be the piston pin to piston pin bore clearance.
 - The production clearance is 0.004-0.017 mm (0.0002-0.0007 in) and the service limit is 0.017 mm (0.0007 in).
 - If the piston pin to piston pin bore clearance is beyond specifications then replace the piston.

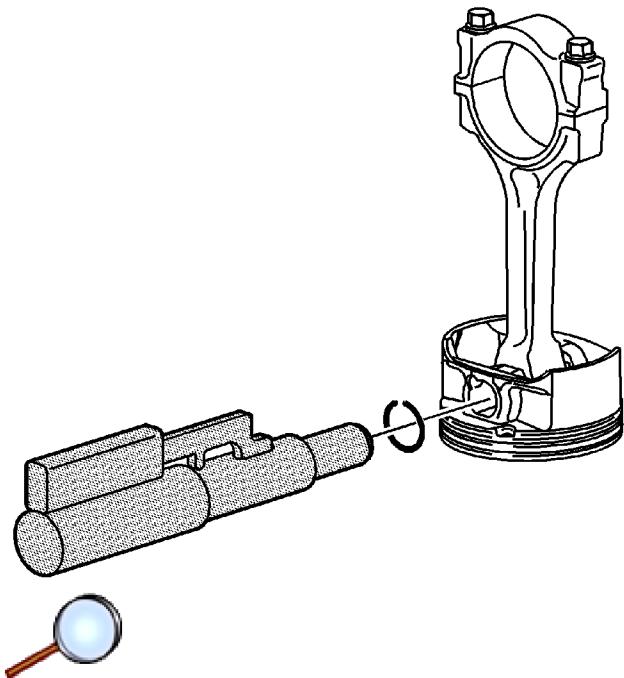


7. Measure the piston pin to connecting rod small end clearance.
 - Measure the inside diameter of the connecting rod small end.
 - Subtract the piston pin measurement that was taken previously from the connecting rod small end measurement. The difference between these two measurements will be the piston pin to connecting rod clearance.
 - The production clearance is 0.012-0.027 mm (0.0005-0.0011 in) and the service limit is 0.08 mm (0.0031 in).
 - Replace the connecting rod if the piston pin to connecting rod small end clearance is beyond specifications. The connecting rod small end bushing is not serviceable.

Piston and Connecting Rod Assemble

Tools Required

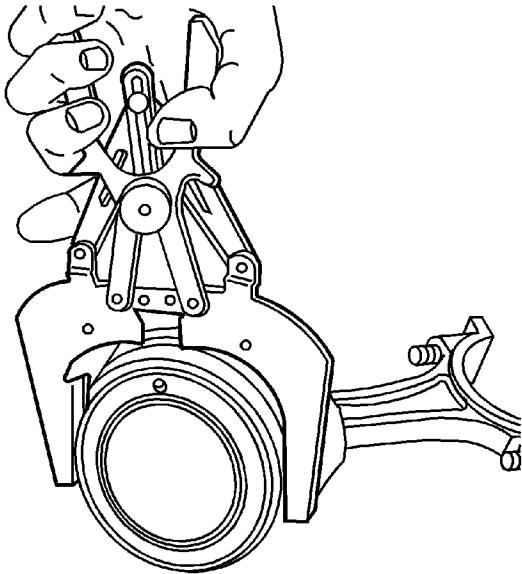
[J 43654](#) Piston Pin Retainer Remover/Installer



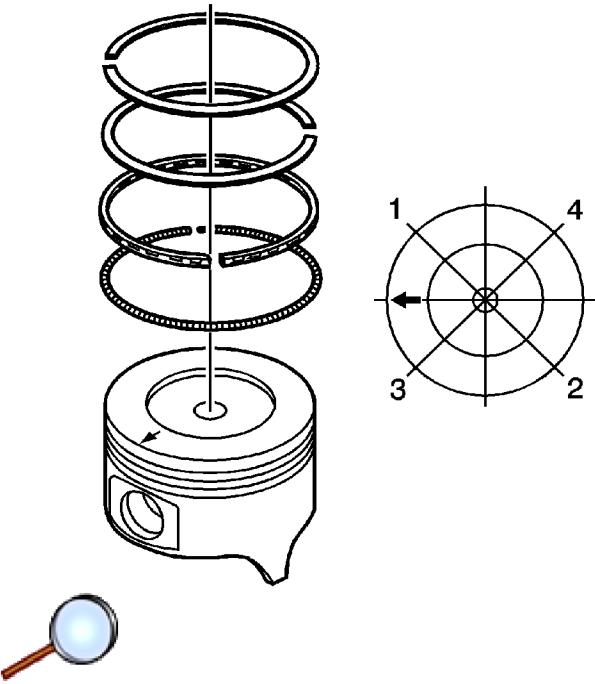
1. Apply engine oil to the connecting rod small end bushing and to the piston pin bore of the piston.
2. Install the piston pin into the piston and connecting rod.

Important:

- For the right bank piston and connecting rod assemblies, reassemble so the grade mark on the connecting rod faces the right side of the engine and the piston front mark faces the front of the engine.
 - For the left bank piston and connecting rod assemblies, reassemble so the grade mark on the connecting rod faces the left side of the engine and the piston front mark faces the front of the engine.
3. Install the piston pin retaining rings.



-  4. Apply engine oil to the piston ring grooves.
- 5. Install the piston rings using a piston ring expander.



Important: The 2N mark on the 2nd compression ring must face upwards. The piston has a groove between the 1st and the 2nd compression rings to allow for expansion of blowby gases. No ring is to be installed in this groove.

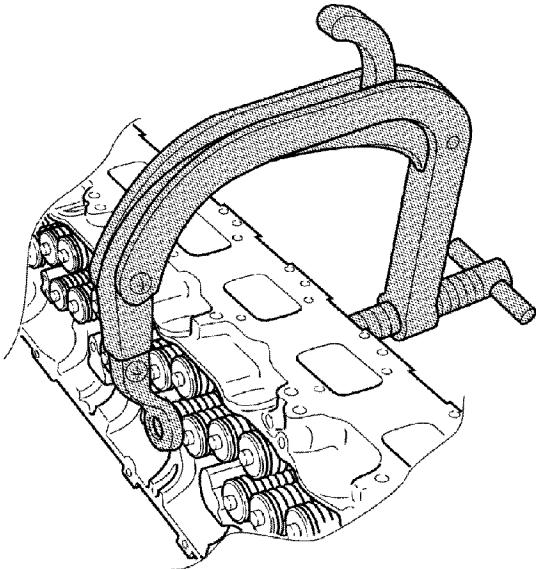
- 6. Orientate the piston ring end gaps as illustrated.

Cylinder Head Disassemble

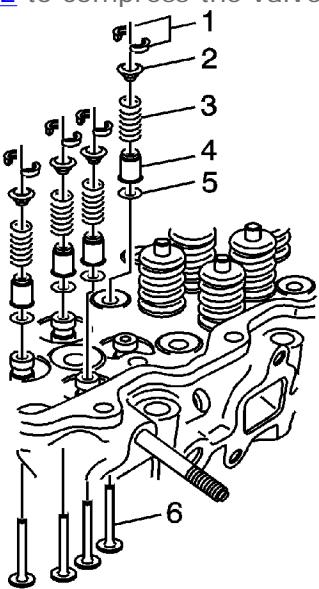
Tools Required

[J 8062](#) Valve Spring Compressor

[J 38820](#) Valve Stem Oil Seal Remover



1. Use the [J 8062](#) to compress the valve spring.



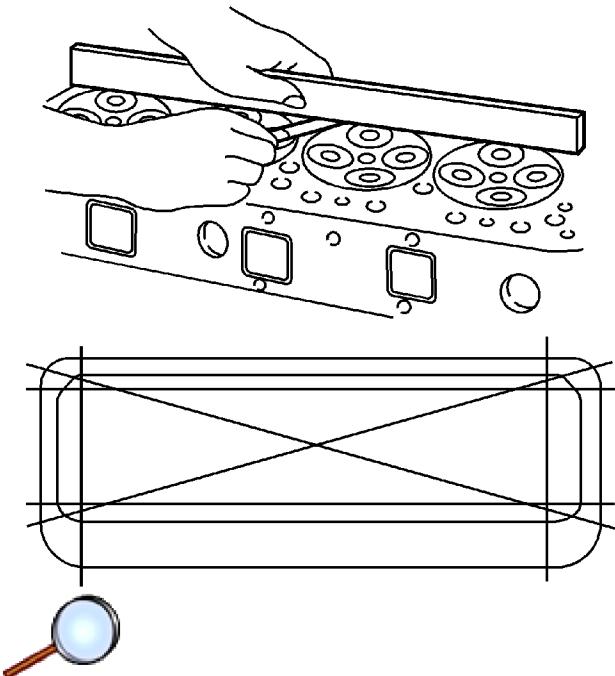
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2. Remove the valve keys (1).
3. Remove the [J 8062](#) from the cylinder head.
4. Remove the valve spring upper seat (2).
5. Remove the valve spring (3).
6. Remove the valve (6).
7. Remove the valve stem seal (4) using [J 38820](#).
8. Remove the valve spring lower seat (5).

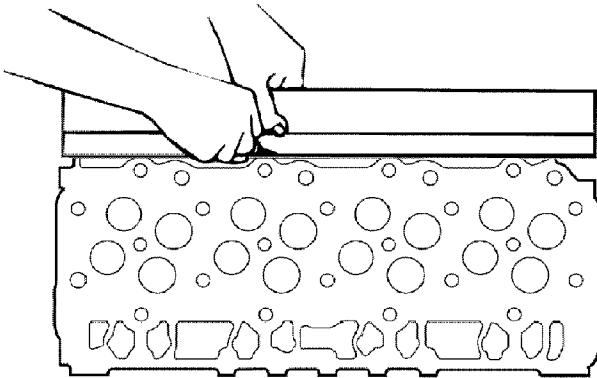
Cylinder Head Cleaning and Inspection

Tools Required

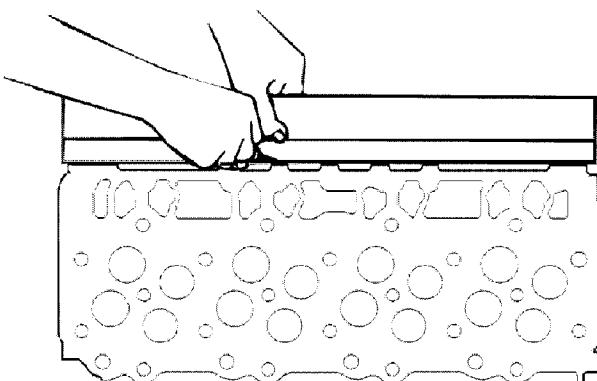
- [J 9666](#) Valve Spring Tester
- [EN-47909](#) Injector Bore and Sleeve Cleaning Kit



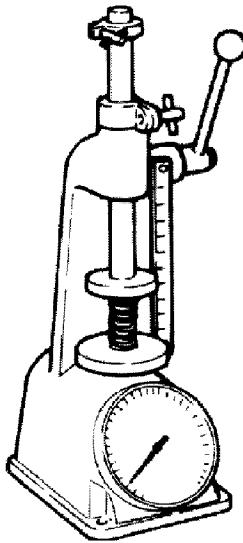
1. Clean the cylinder head of all foreign material. Do not use a motorized wire brush on any gasket sealing surface.
2. Clean the threaded holes.
3. Clean the injector bores using [EN-47909](#) .
4. Inspect the cylinder head for the following:
 - Damage to the gasket surfaces
 - Damage to the threaded bolt holes
 - Cracks in the exhaust ports
 - External cracks in the water chamber
 - Cracks between the valve seats
 - Restrictions in the intake or exhaust passages
 - Restrictions in the cooling system passages
 - Rusted, damaged or leaking core plugs
5. Measure the cylinder head for warpage with a straight edge and a feeler gauge. A cylinder head block deck with warpage in excess of 0.075 mm (0.0030 in) within a 516.5 mm (20.33 in) area must be replaced.



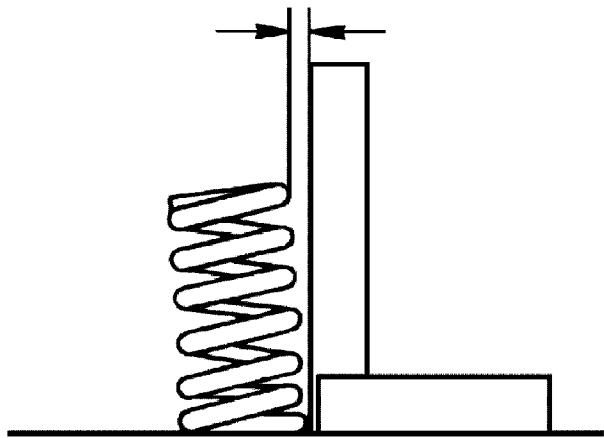
6. Measure the cylinder head exhaust manifold deck for warpage. A cylinder head exhaust manifold deck with warpage in excess of 0.1 mm (0.0039 in) within a 453 mm (17.83 in) area must be replaced.



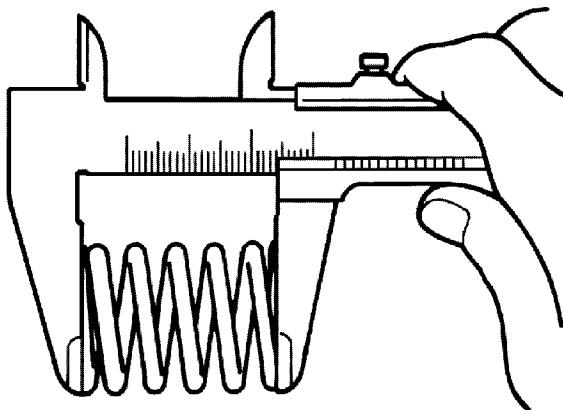
7. Measure the cylinder head intake manifold deck for warpage. A cylinder head intake manifold deck with warpage in excess of 0.3 mm (0.011 in) within a 493 mm (19.41 in) area must be replaced.



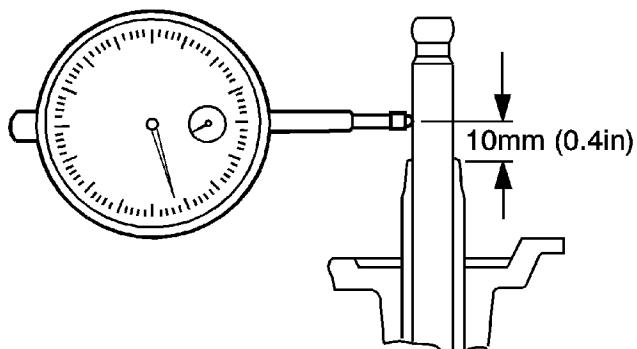
8. Measure the valve spring tension using [J 9666](#). Replace the valve spring if the valve spring tension is less than 275 N (61.8 lb) at 41 mm (1.6142 in)



9. Measure the valve spring for squareness. Replace the valve spring if squareness is beyond 2.0 mm (0.0787 in).

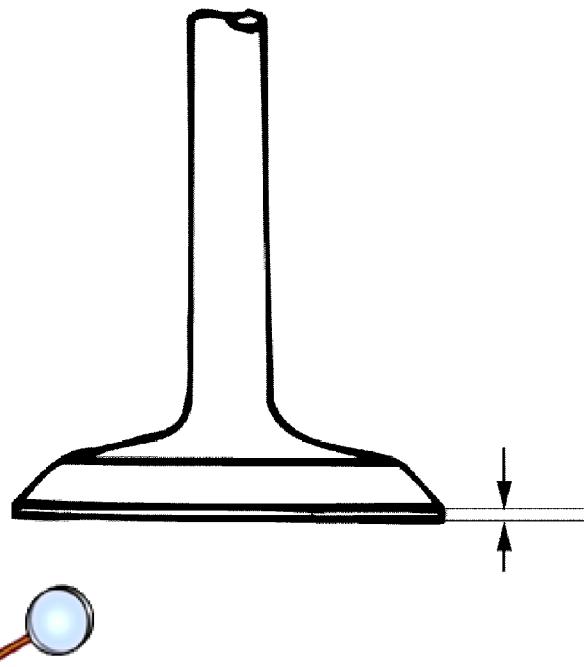


10. Measure the valve spring free length. The production free length is 56.6 mm (2.2283 in).
11. Measure the valve stem to guide clearance.
 - 11.1. Set a dial indicator to the valve stem measuring point.
 - 11.2. Move the valve stem from side to side while reading the total movement on the dial indicator. If the measured valve exceeds 0.20 mm (0.0079 in), replace the cylinder head.

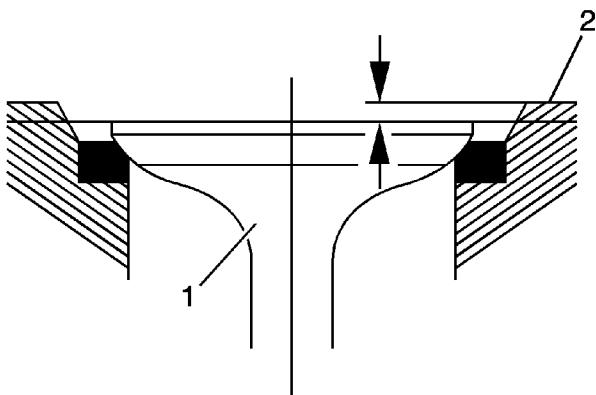


12. If the valve stem to guide clearance is over 0.25 mm (0.098 in) for the exhaust valve guides or 0.20 mm (0.0079 in) for the intake valve guides, the cylinder head must be replaced.
13. Inspect the valves for the following:
 - Bent valve stem
 - Scored valve stem

- Worn valve key grooves
- Pitted surfaces

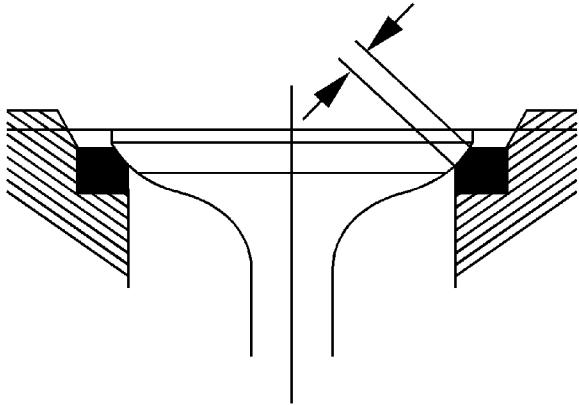


14. Measure the valve margin. The intake valve production margin is 1.2 mm (0.0472 in) and the service limit is 0.88 mm (0.0346 in). The exhaust valve production margin is 1.0 mm (0.0394 in) and the service limit is 0.73 mm (0.0287 in). Replace the valve if the valve margin is below the service limit.



15. Measure the valve depression.
- 15.1. Insert a new valve into the cylinder head (1).
 - 15.2. Use a depth gage or a straight edge to measure the valve depression from the cylinder head gasket surface (2). The intake valve depression is 0.6 mm (0.0236 in) and the service limit is 2.5 mm (0.0984 in). The exhaust valve depression is 0.9 mm

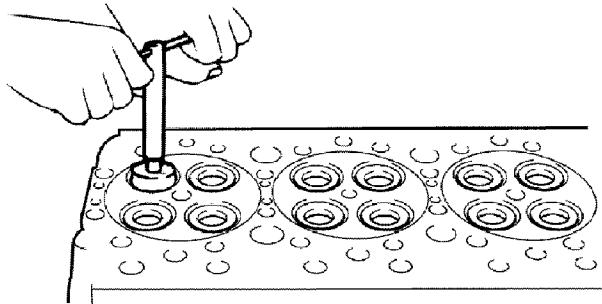
(0.0354 in) and the service limit is 2.0 mm (0.0787 in). Recondition the valve seat if the valve depression is above specifications.



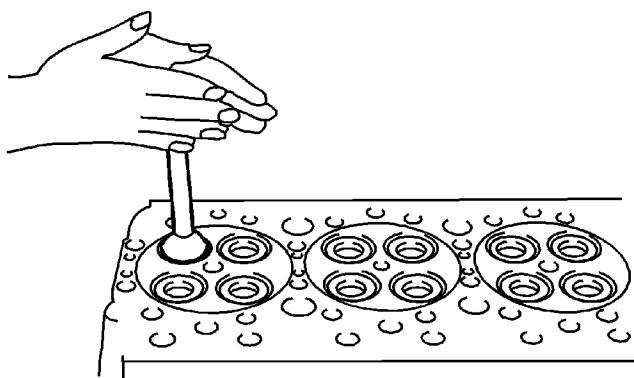
16. Measure the valve contact width.

- Inspect the valve contact area for roughness or unevenness.
- The intake valve contact width is 2.1 mm (0.0827 in) and the service limit is 2.5 mm (0.0984 in).
- The exhaust valve contact width is 2.1 mm (0.0827 in) and the service limit is 2.5 mm (0.0984 in).
- Recondition the valve seats to bring the contact width into specifications.

Valve and Seat Grinding



1. Remove the carbon from the valve guide and valve seat surface.
2. Resurface the valve face to 45 degrees. If valve margin falls below specifications after resurfacing then discard valve.
3. Use a suitable tool to bring the valve contact width to the standard value. The valve seat angle is 45 degrees.

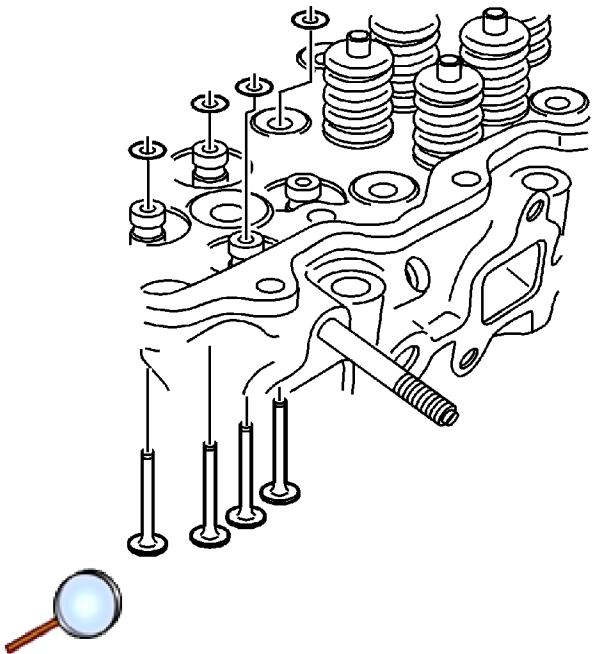


4. Apply valve lapping compound to the valve seat surface.
5. Insert the valve into the cylinder head.
6. Turn the valve back and forth in its seat to lap the valve face to the valve seat.

Cylinder Head Assemble

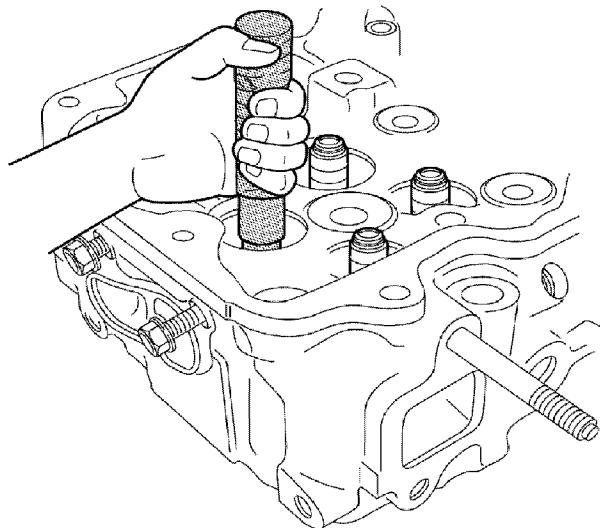
Tools Required

- [J 44640](#) Valve Stem Seal Installer
- [J 8062](#) Valve Spring Compressor

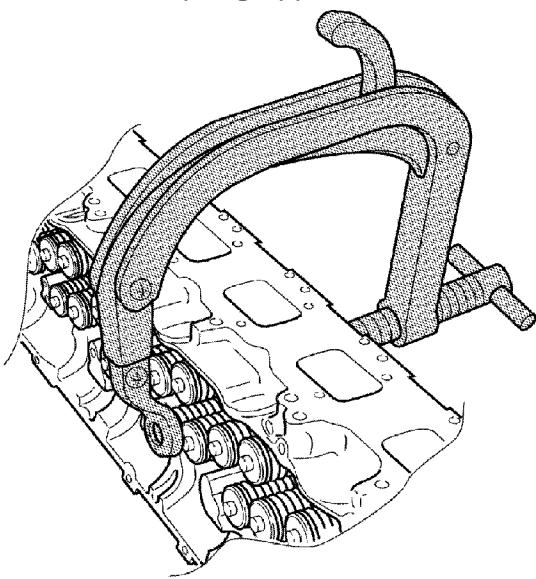


Important: Lubricate the valve stem with clean engine oil before installing.

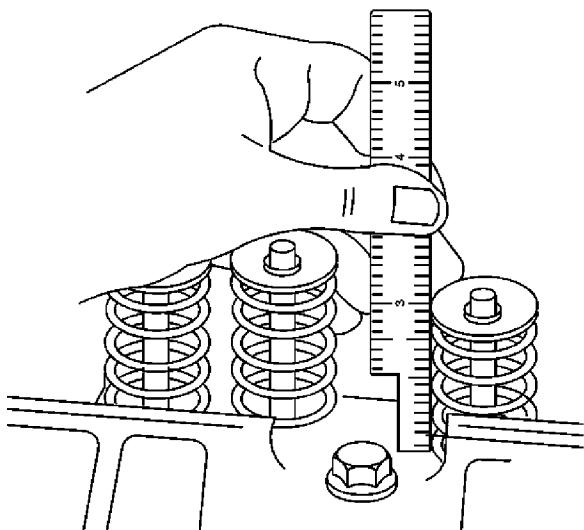
1. Install the valves into the cylinder head.
2. Install the valve spring lower seat.



3. Install the valve stem seal using [J 44640](#).
4. Install the valve spring with the painted end towards the cylinder head.
5. Install the valve spring upper seat.

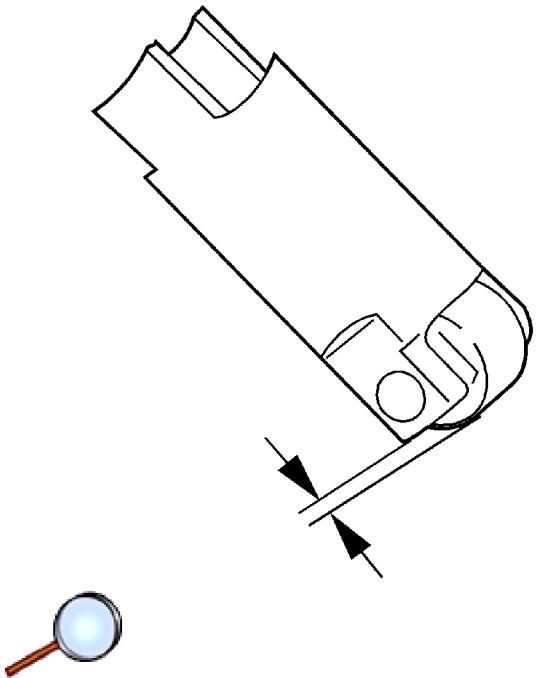


6. Use the [J 8062](#) to compress the valve spring.
7. Install the valve keys.
8. Remove the [J 8062](#) from the cylinder head.



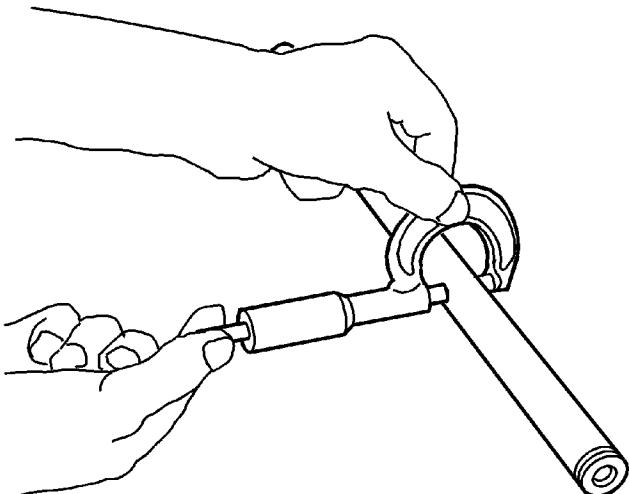
9. Measure the valve installed height using a ruler. Measure from the base of the valve spring to the top of the valve. Refer to [Engine Mechanical Specifications](#).
10. Install the remaining valves, springs, and other components.

Valve Lifters Cleaning and Inspection

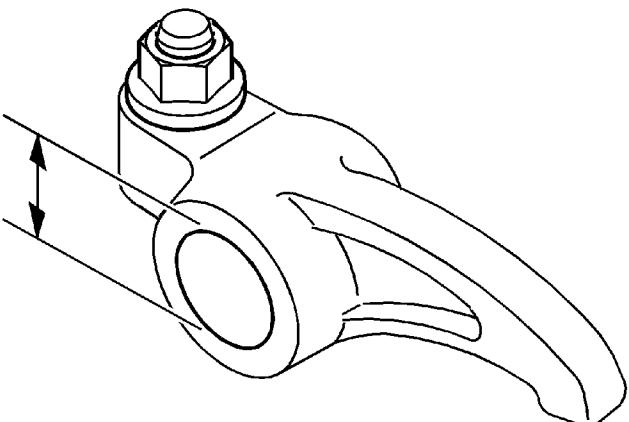


- 1. Push the roller towards the roller lifter body and measure the distance between the bottom of the roller and the roller lifter body. The production value is 0.989-1.0 mm (0.0389-0.0394 in) and the service limit is 0.9 mm (0.0354 in).
- 2. Replace the valve lifter if the measurement exceeds the service limit.
- 3. Inspect the valve lifters for the following:
 - The valve lifter body for scuffing and wear
 - The valve lifter roller assembly for wear
 - The valve lifter roller for smooth rotation

Valve Rocker Arm and Shaft Cleaning and Inspection



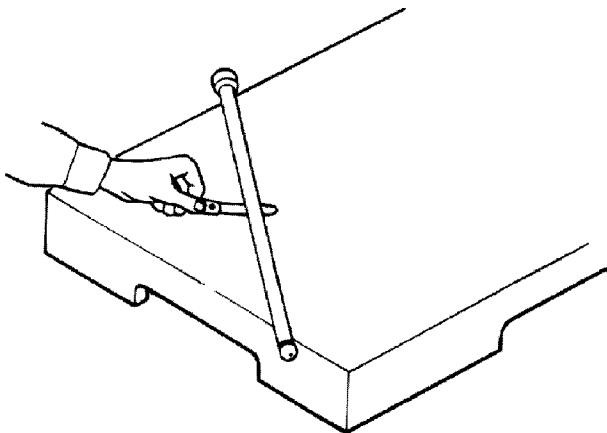
1. Measure the rocker arm shaft outside diameter where the rocker arm is located. The production value is 21.979-22.0 mm (0.8653-0.8661 in) and the service limit is 21.85 mm (0.8602 in).
2. Replace the rocker arm shaft if the measured value is less than the service limit.



3. Measure the rocker arm inside diameter. The production value is 22.01-22.035 mm (0.8665-0.8675 in).
4. Calculate the rocker arm shaft to rocker arm clearance.

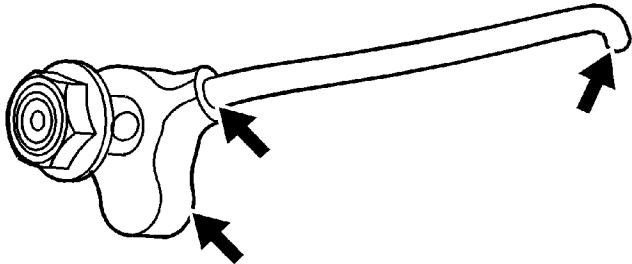
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- 4.1. Subtract the rocker arm shaft outside diameter from the rocker arm inside diameter.
- 4.2. Replace the rocker arm if the rocker arm shaft to rocker arm clearance is over 0.2 mm (0.0079 in).
5. Inspect the valve lash adjusting screw and lock nut for damage. Replace the valve lash adjusting screw if any damage is found.



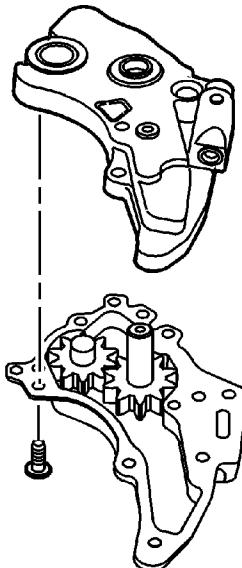
- 
6. Measure the pushrods for warpage.
 7. Replace the pushrod if the warpage exceeds 0.8 mm (0.031 in).

Piston Oil Cooling Nozzle Cleaning and Inspection

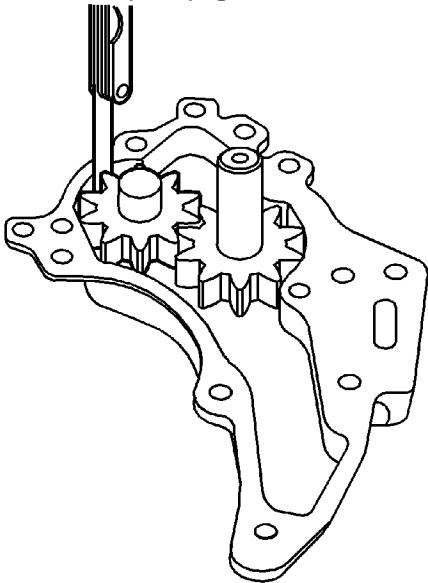


1. Inspect the piston oil cooling nozzle for damage.
2. Replace the piston oil cooling nozzle if any damage is found.

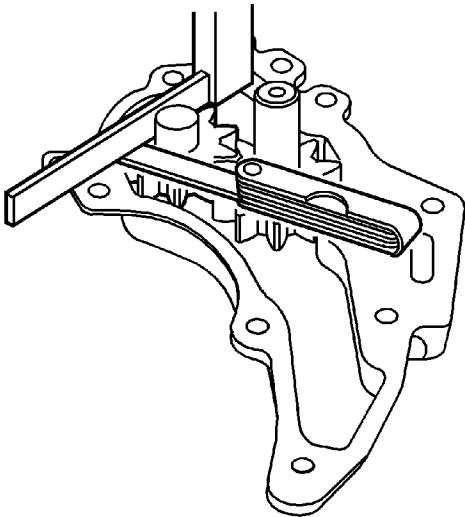
Oil Pump Cleaning and Inspection



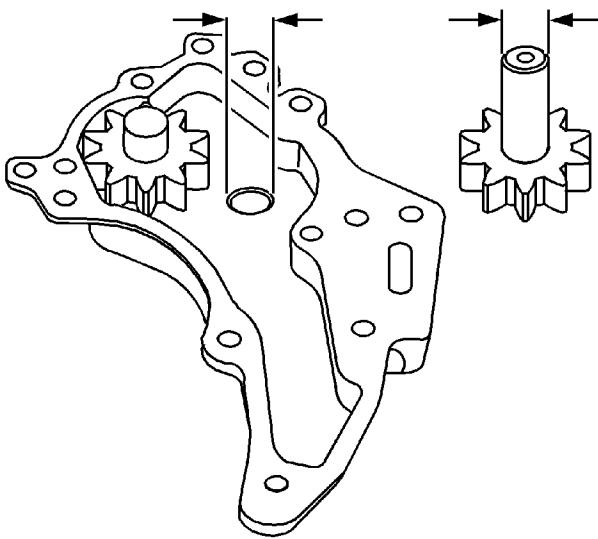
1. Remove the oil pump gear cover bolts.
2. Remove the oil pump gear cover.



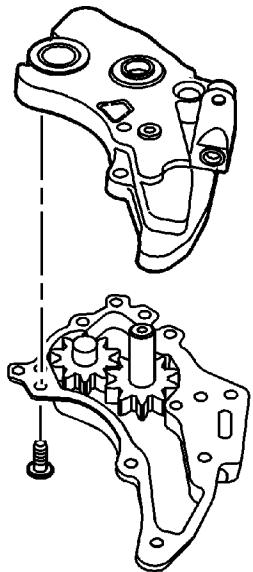
3. Use a feeler gauge to measure the clearance between the gear teeth and the oil pump housing. The production clearance is 0.125-0.221 mm (0.0049-0.0087 in) and the service limit is 0.221 mm (0.0087 in).
4. Replace the oil pump assembly if the clearance exceeds the service limit.



5. Use a feeler gauge and a straightedge to measure the clearance between the side of the gear and the cover. The production clearance is 0.064-0.109 mm (0.0025-0.0043 in) and the service limit is 0.109 mm (0.0043 in).
6. Replace the oil pump assembly if the clearance exceeds the service limit.



7. Calculate the driven gear shaft to bushing clearance.
 - 7.1. Measure the driven gear shaft outside diameter. The production specification is 19.947-19.960 mm (0.7853-0.7858 in) and the service limit is 19.86 mm (0.7819 in).
 - 7.2. Measure the driven gear bushing inside diameter. The production value is 20 mm (0.7874 in).
 - 7.3. Calculate the driven gear shaft to bushing clearance. The service limit is 0.14 mm (0.0055 in)
8. Replace the oil pump assembly if the clearance exceeds the service limit.

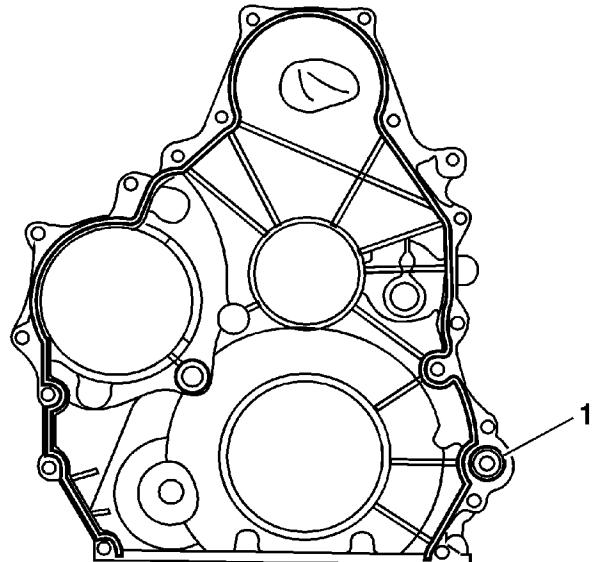


9. Install the oil pump gear cover to the oil pump assembly.

Caution: Refer to [Fastener Caution](#) in the Preface section.

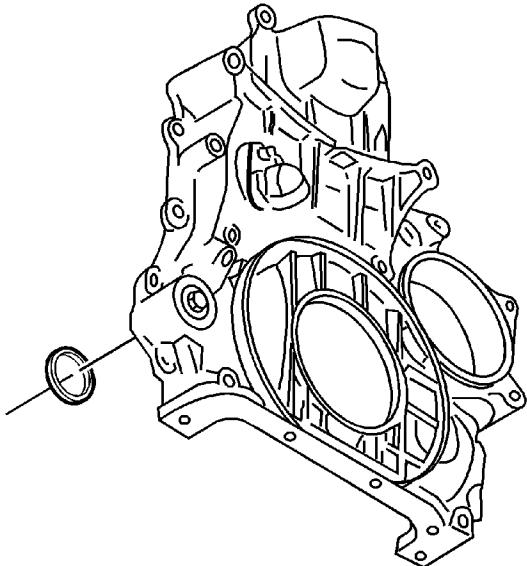
10. Install the oil pump gear cover bolts and tighten to **21 N·m (15 lb ft)**.

Engine Front Cover Cleaning and Inspection



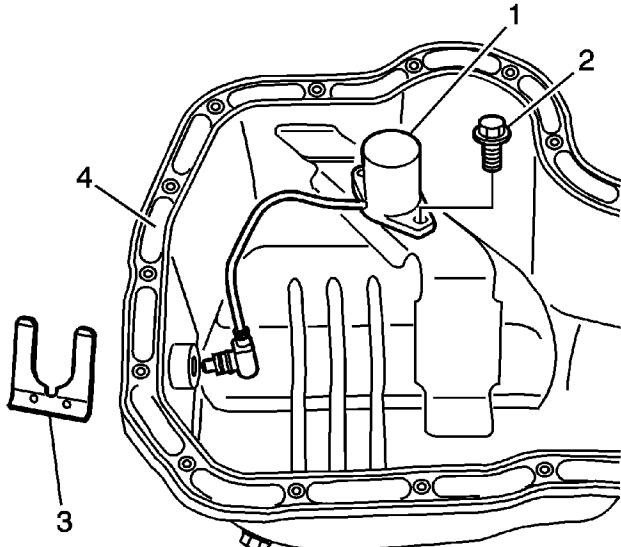
1. Remove the O-ring (1) from the engine front cover.
2. Remove the oil pressure relief valve from the engine front cover.
3. Clean the engine front cover.
4. Clean the engine front cover mating surfaces.
5. Inspect the engine front cover mating surfaces for damage.
6. Inspect the engine front cover O-ring sealing surface for damage.
7. Inspect the crankshaft front oil seal bore for damage.
8. Replace the engine front cover if any damage is found.

Caution: Refer to [Fastener Caution](#) in the Preface section.



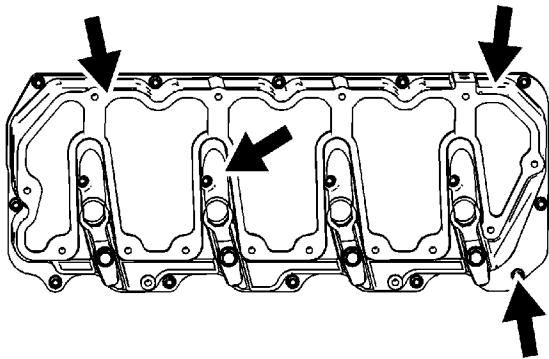
9. Install the oil pressure relief valve with a new O-ring and tighten to **39 N·m (29 lb ft)**.

Lower Oil Pan Cleaning and Inspection



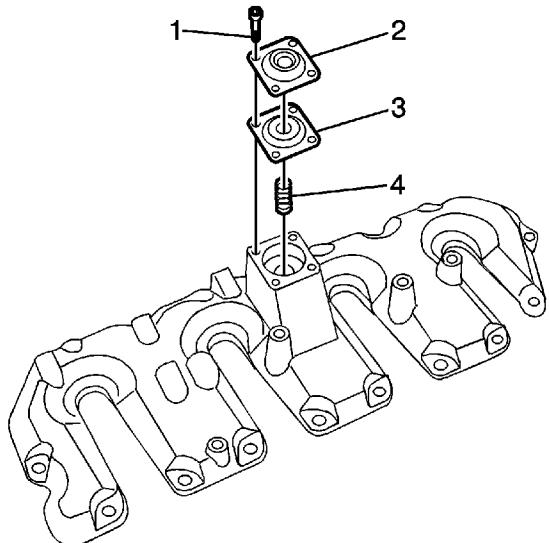
1. Remove the oil level sensor (1) and retaining clip (3).
2. Clean the lower oil pan (4). Remove any sludge or other deposits.
3. Clean the lower oil pan mating surface.
4. Inspect the lower oil pan (4) for dents or distortion.
5. Inspect the lower oil pan mating surface for damage.
6. Replace the lower oil pan (4) if any damage is found.
7. Install the oil level sensor (1) and retaining clip (3).

Valve Rocker Arm Cover Cleaning and Inspection - Lower

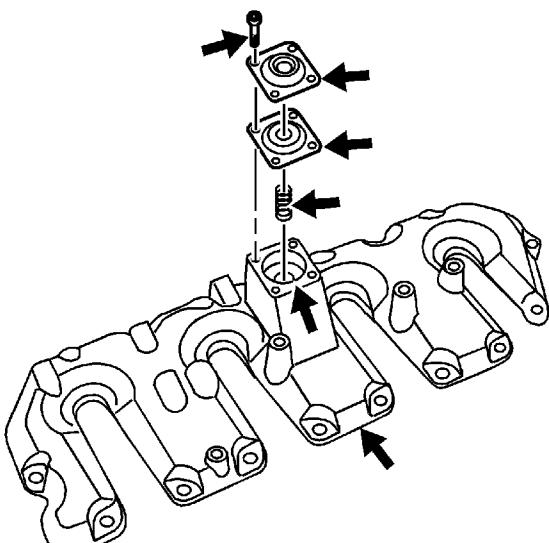


1. Remove the grommets.
2. Clean the lower valve rocker arm cover. Remove any sludge or other deposits.
3. Clean the lower valve rocker arm cover mating surfaces.
4. Inspect the lower valve rocker arm cover for cracks or other damage.
5. Inspect the lower valve rocker arm cover mating surfaces for damage.
6. Replace the lower valve rocker arm cover if any damage is found.
7. Inspect the grommets for damage.
8. Replace the grommets if any damage is found.
9. Install the grommets.

Valve Rocker Arm Cover Cleaning and Inspection - Upper



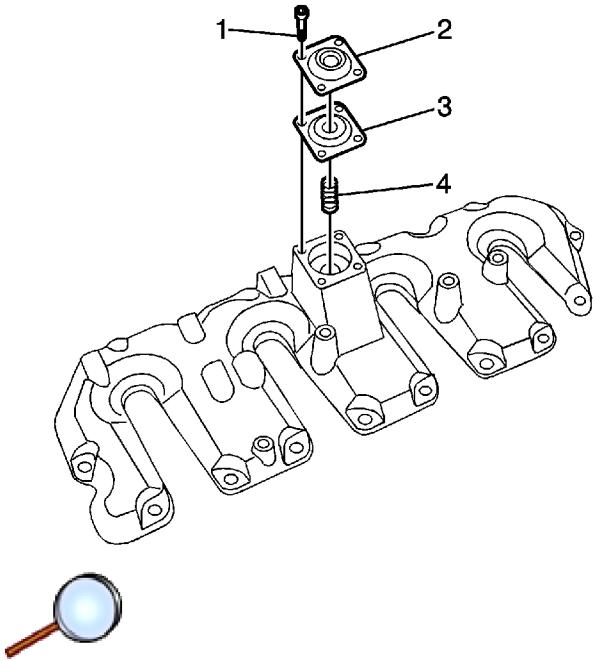
1. Remove the PCV cover screws (1).
2. Remove the PCV cover (2), diaphragm (3), and spring (4).



3. Clean the upper valve rocker arm cover. Remove any sludge or other deposits.
4. Clean the upper valve rocker arm cover mating surface.
5. Inspect the upper valve rocker arm cover for cracks or other damage.
6. Inspect the upper valve rocker arm cover mating surfaces for damage.

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7. Replace the upper valve rocker arm cover if any damage is found.

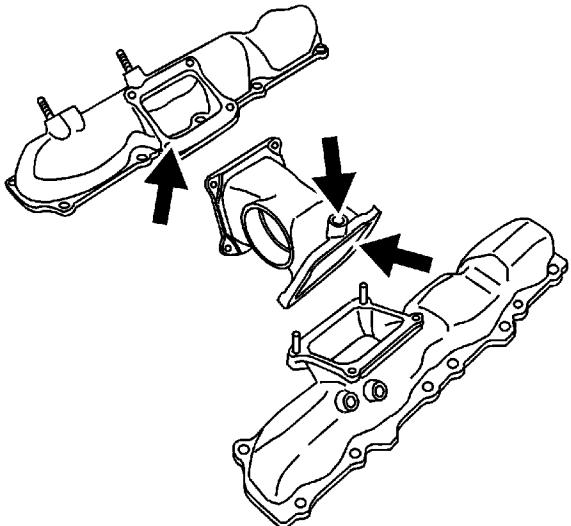


8. Inspect the PCV cover (2), diaphragm (3), and spring (4) for damage.
9. Install the PCV spring.
10. Install the PCV diaphragm.
11. Install the PCV cover.

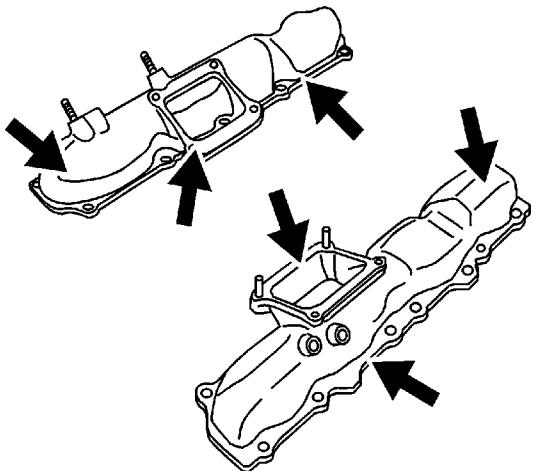
Caution: Refer to [Fastener Caution](#) in the Preface section.

12. Install the PCV cover screws (1) and tighten to **4 N·m (35 lb in)**.

Intake Manifold Cleaning and Inspection



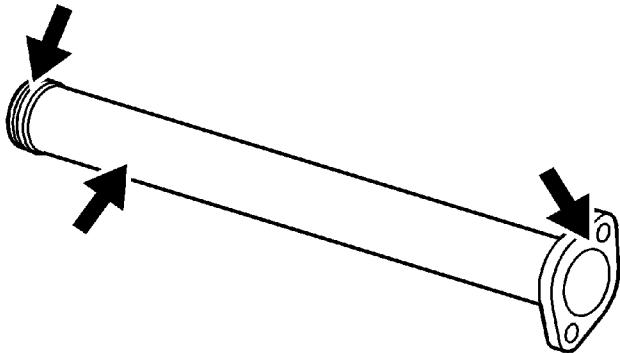
1. Clean the intake manifold crossover.
2. Clean the intake manifold mating surfaces.



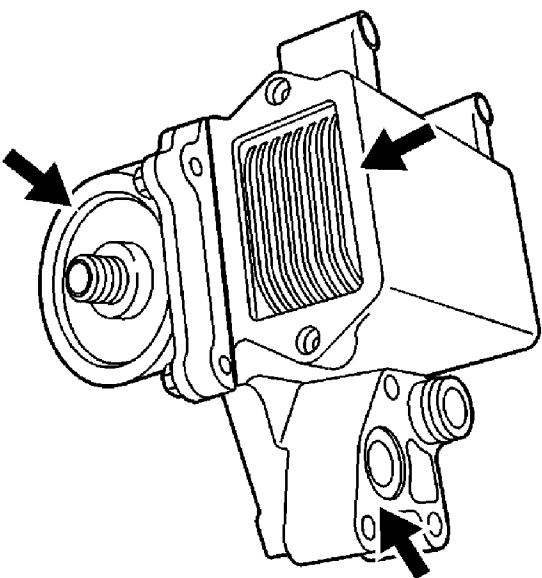
3. Clean the intake manifolds.
4. Clean the intake manifold mating surfaces.
5. Inspect the intake manifolds for cracks.
6. Inspect the intake manifold mating surfaces for damage.
7. Replace the intake manifolds if any damage is found.

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Oil Filter Adapter and Oil Cooler Assembly Cleaning and Inspection



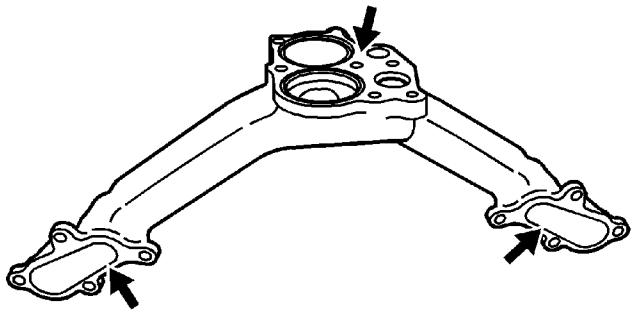
1. Clean the coolant tube.
2. Inspect the coolant tube for cracks.
3. Inspect the coolant tube mating surfaces for damage.



4. Clean the oil filter adapter.
5. Inspect the oil filter adapter mating surfaces for damage.
6. Replace the O-rings.

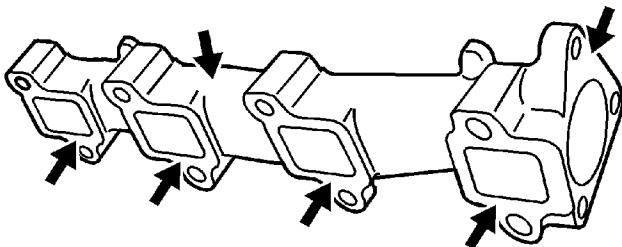
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Engine Coolant Thermostat Housing Cleaning and Inspection

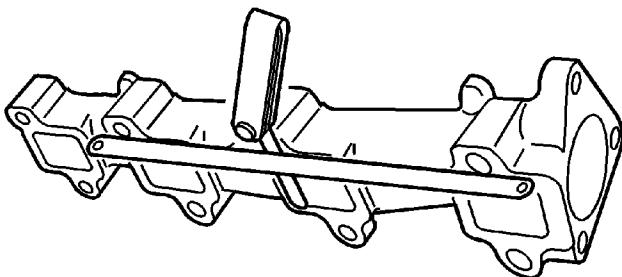


1. Clean the thermostat housing.
2. Clean the thermostat housing mating surfaces.
3. Inspect the thermostat housing for cracks.
4. Inspect the thermostat housing mating surfaces for damage.
5. Replace the thermostat housing if any damage is found.

Exhaust Manifold Cleaning and Inspection



1. Clean the exhaust manifold.
2. Clean the exhaust manifold mating surfaces.
3. Inspect the exhaust manifold for cracks.
4. Inspect the exhaust manifold mating surfaces for damage.
5. Replace the exhaust manifold if any damage is found.



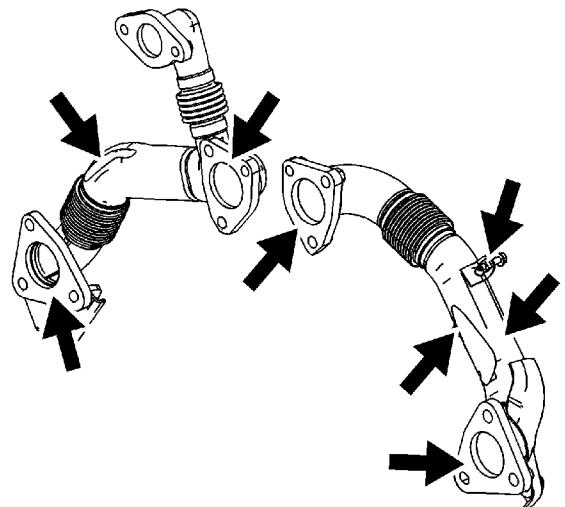
6. Measure the exhaust manifold flange for warpage with feeler gauge and a straightedge. Replace the exhaust manifold if the warpage is more than 0.3 mm (0.0118 in).
7. Install the exhaust manifold heat shield.

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Caution: Refer to [Fastener Caution](#) in the Preface section.

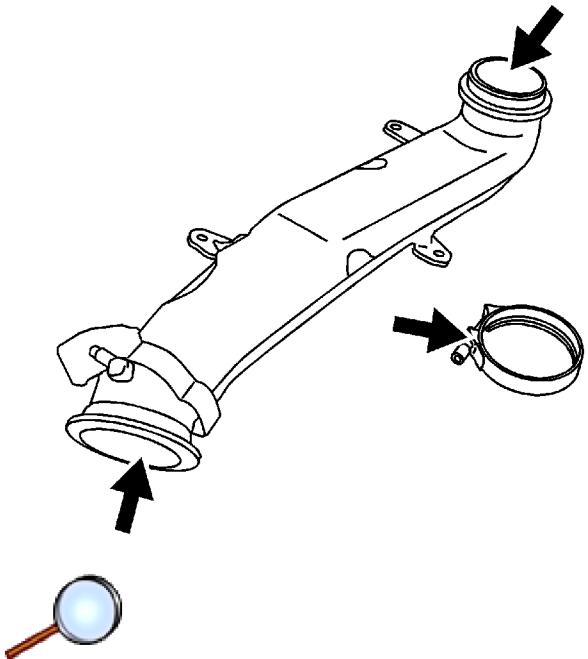
8. Install the exhaust manifold heat shield bolts and tighten to **8 N·m (71 lb in)**.

Exhaust Pipe Cleaning and Inspection



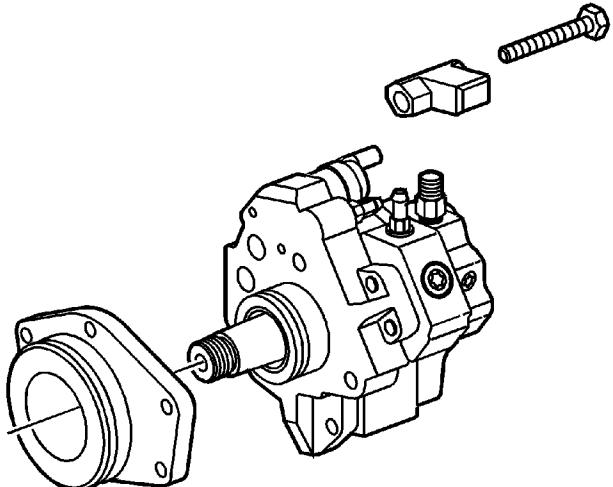
1. Clean the exhaust pipe.
2. Clean the exhaust pipe mating surfaces.
3. Inspect the exhaust pipe for dents or cracks.
4. Replace the exhaust pipe if any damage is found.

Exhaust Outlet Cleaning and Inspection

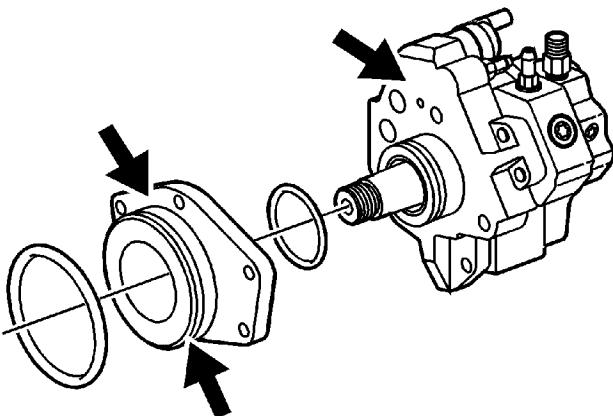


- 1. Clean the exhaust outlet.
- 2. Clean the exhaust outlet mating surfaces.
- 3. Inspect the exhaust outlet for dents or cracks.
- 4. Replace the exhaust outlet if any damage is found.

Fuel Injection Pump Cleaning and Inspection

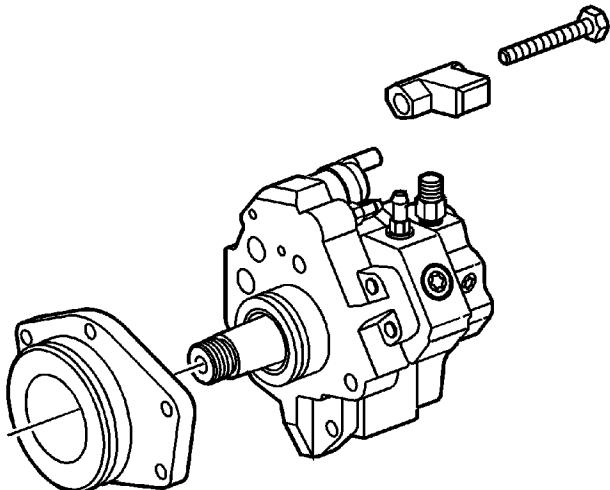


1. Remove the fuel injection pump adapter bolts.
2. Remove the fuel injection pump adapter.



3. Remove the O-ring from the fuel injection pump and discard.
4. Remove the O-ring from the fuel injection pump adapter and discard.
5. Clean the fuel injection pump adapter mating surfaces.
6. Clean the fuel injection pump mating surfaces.
7. Inspect the fuel injection pump and adapter for damage.
8. Replace component if any damage is found.

9. Install a new O-ring onto fuel injection pump.
10. Install a new O-ring onto fuel injection pump adapter.
11. Lubricate the O-rings with engine oil.

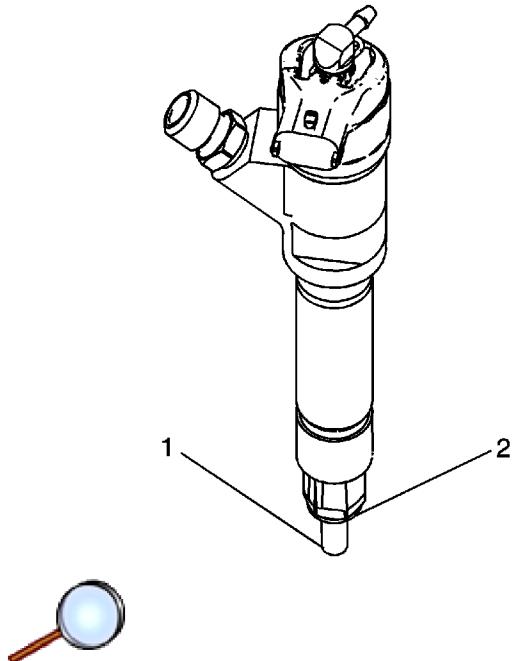


12. Install the fuel injection pump adapter to the fuel injection pump.

Caution: Refer to [Fastener Caution](#) in the Preface section.

13. Install the fuel injection pump adapter bolts and tighten to **21 N·m (15 lb ft)**.

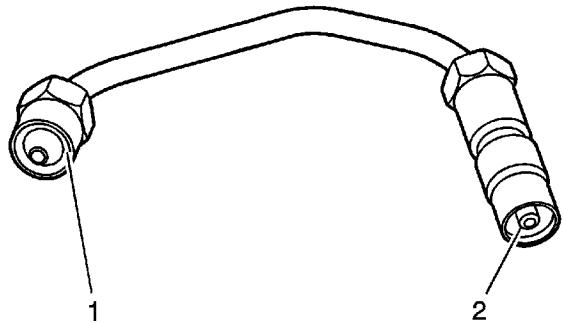
Fuel Injector Cleaning and Inspection



1. Use a soft bristle non-metallic brush and top engine cleaner, GM P/N 1052626 or equivalent, to remove any deposits from the nozzle tip (1) and the copper washer sealing area (2) before reinstallation.

Caution: The fuel injector must be cleaned with the proper cleaning equipment. DO NOT use abrasive cleaning methods, such as a metallic brush, to remove deposits. Cleaning an injector with improper tools will damage the fuel injector.

2. Inspect the fuel injector nozzle tip (1) for cracks, dents, or other damage.
3. Inspect the nozzle tip (1) for any signs of discoloration - dark yellow, tan, or blue due to excessive heat.
4. Replace the injector if any damage is found.



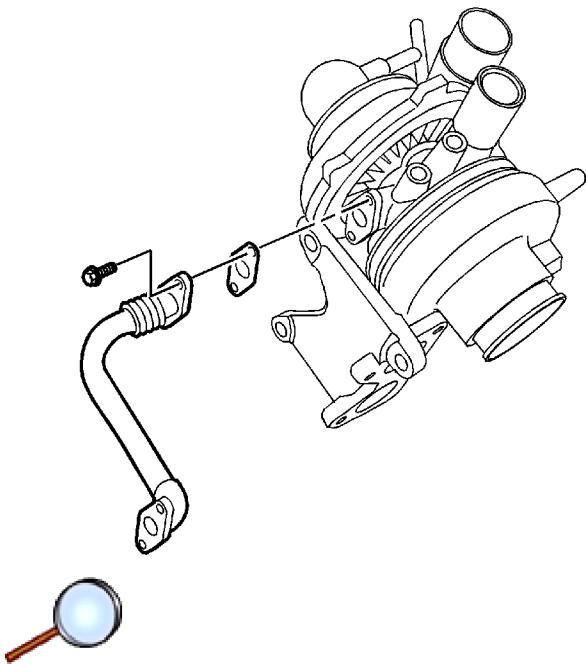
5. Clean the fuel injector high pressure line.
6. Inspect the fuel injector high pressure line for excessive corrosion or damage to the sealing surfaces (1, 2). Replace the line if any damage is found.

Turbocharger Cleaning and Inspection

Completely inspect the turbocharger and all other engine components that may cause similar conditions before replacing the turbocharger.

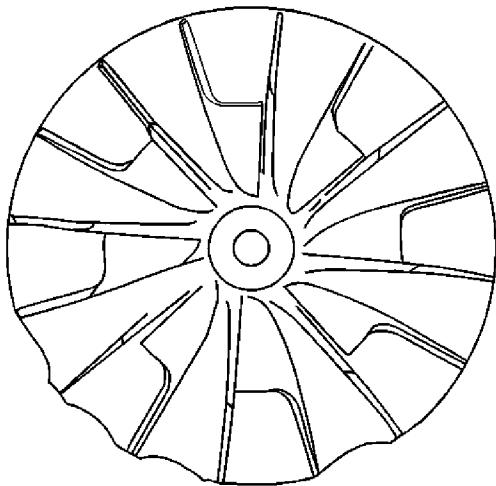
Use the following information to diagnose problems caused by the turbocharger.

The turbocharger is serviced as a complete unit.

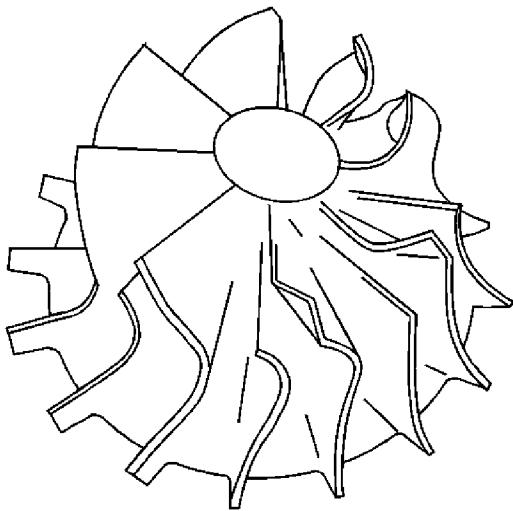


Important: Oil residue on the turbocharger compressor wheel is normal with a closed PCV system.

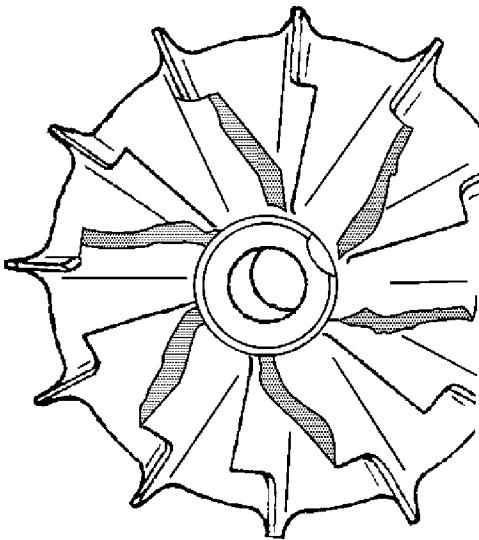
1. Remove the turbocharger oil return pipe bolts.
2. Remove the turbocharger oil return pipe and gasket.
3. Clean mating surfaces.



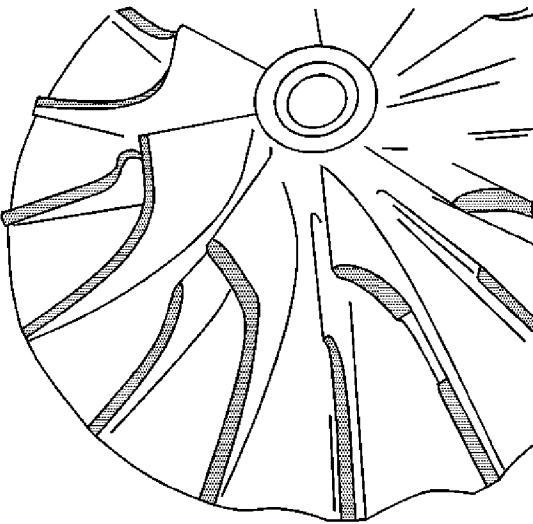
4. Inspect for damage to the compressor wheel, compared to a normal compressor wheel.



5. Inspect for damage to the compressor wheel, by a soft object.



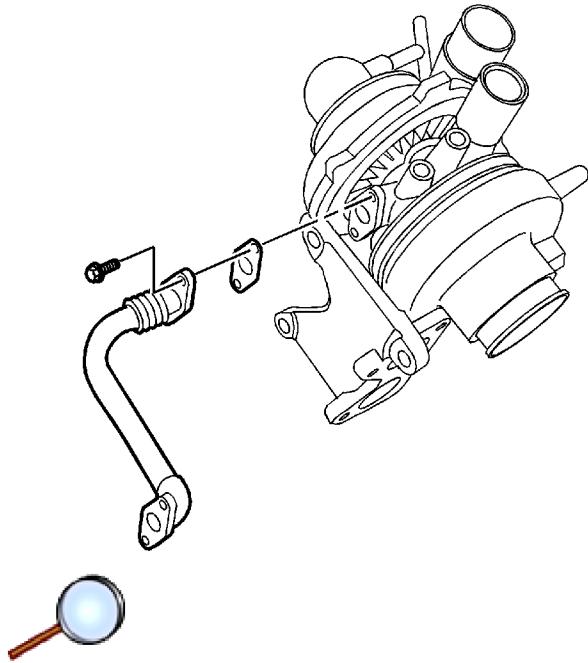
6. Inspect for damage to the compressor wheel, by a hard object.



7. Inspect compressor blades for heavy rubbing.

Ensure that the following conditions do not exist on the compressor wheel blades:

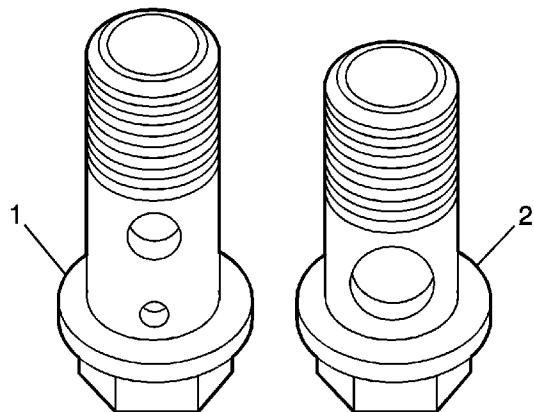
- Cracks
 - Bends
 - Erosion of the blades
 - Broken blades
8. Check the housing for signs of rubbing.



9. Install the turbocharger oil return pipe and new gasket.
10. Install the turbocharger oil return pipe bolts.

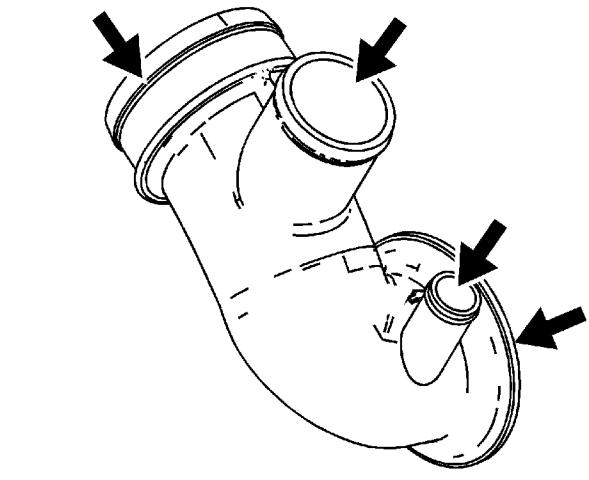
Tighten

Tighten the turbocharger oil return pipe bolts to 21 N·m (15 lb ft).



Important: If the cooling outlet hose eye bolts were removed, install the longer bolt (1) with two holes, in the top location. Install the shorter bolt (2) in the lower location.

11. Inspect the coolant outlet lines for damage.

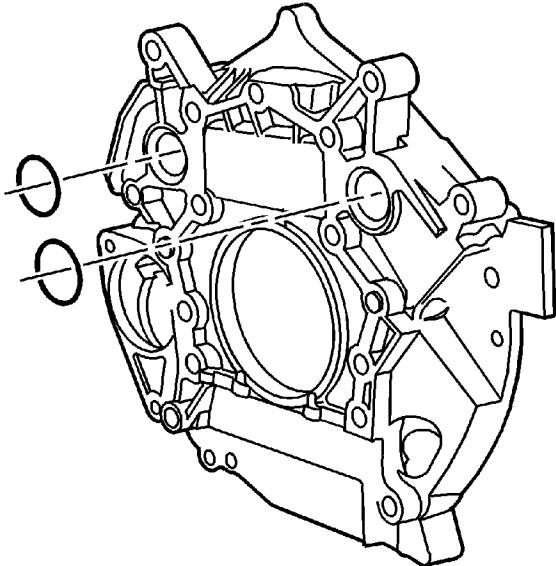


12. Clean the turbocharger inlet duct.
13. Clean the turbocharger inlet duct mating surfaces.
14. Inspect the turbocharger inlet duct for cracks.
15. Inspect the turbocharger inlet duct mating surfaces for damage.
16. Replace the turbocharger inlet duct if any damage is found.

Tighten

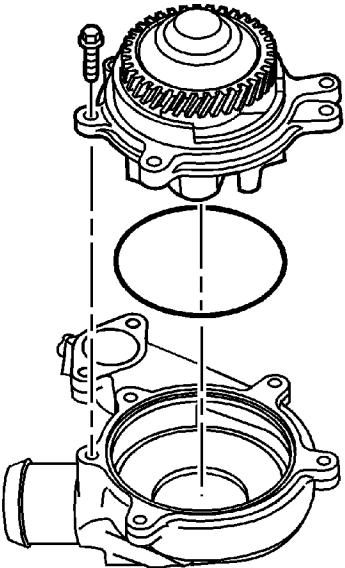
Tighten the inlet duct clamp to 5 N·m (44 lb in).

Engine Flywheel Housing Cleaning and Inspection

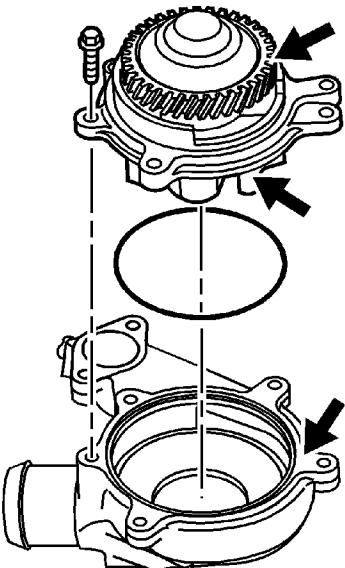


1. Remove the O-rings from the flywheel housing and discard.
2. Clean the flywheel housing.
3. Clean the flywheel housing mating surfaces.
4. Clean the flywheel housing O-ring sealing area.
5. Inspect the flywheel housing for cracks.
6. Inspect the flywheel housing mating surfaces for damage.
7. Inspect the crankshaft rear oil seal bore for damage.
8. Replace the flywheel housing if any damage is found.

Water Pump Cleaning and Inspection

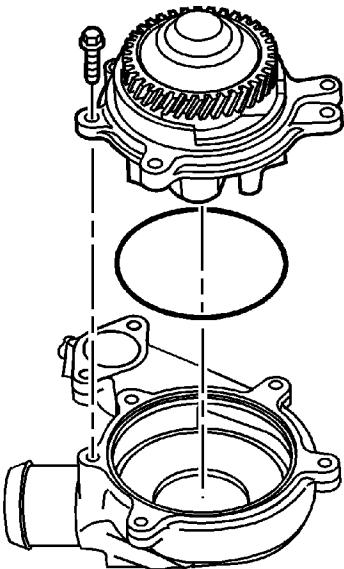


1. Remove the O-ring from the water pump and discard.
2. Remove the water pump to water pump housing bolts.
3. Remove the water pump from the water pump housing.
4. Remove the O-ring from the water pump housing and discard.



5. Clean the water pump assembly.
6. Clean the water pump mating surfaces.
7. Inspect the water pump gear for damage.
8. Inspect the water pump mating surfaces for damage.

9. Inspect the water pump shaft for looseness.
10. Inspect the water pump assembly for damage.
11. Replace the water pump if any damage is found.

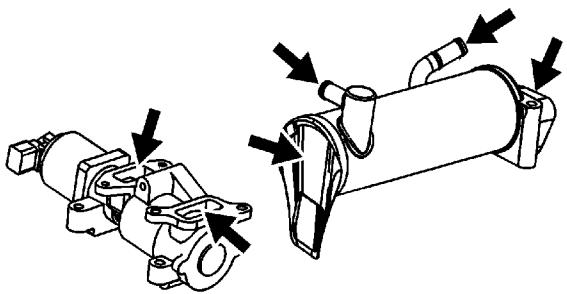


12. Install a new O-ring to the water pump housing.
13. Lubricate the O-ring with engine coolant.
14. Install the water pump to the water pump housing.

Caution: Refer to [Fastener Caution](#) in the Preface section.

15. Install the water pump to water pump housing bolts. Tighten the water pump to water pump housing bolts to **21 N·m (15 lb ft)**.
16. Install a new O-ring to the water pump.

Exhaust Gas Recirculation Valve Cooler Cleaning and Inspection

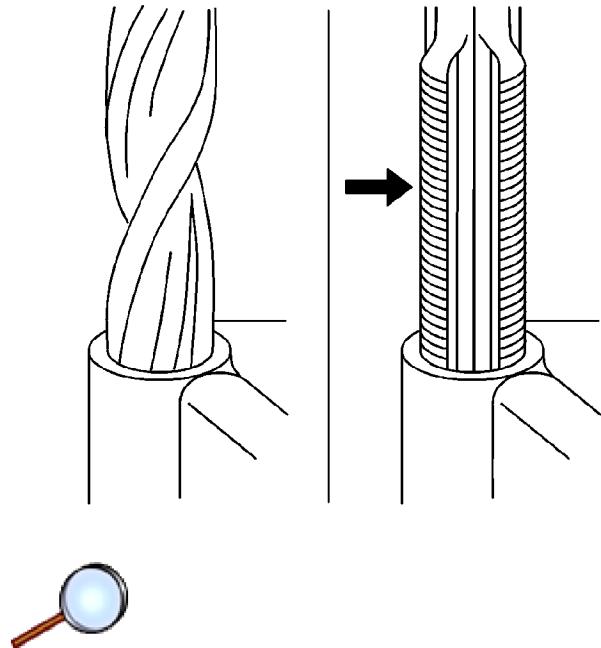


1. Remove the exhaust gas recirculation (EGR) cooling hoses.
2. Clean and inspect the EGR gasket surfaces.
3. Clean and inspect the EGR and cooler.
4. Replace the EGR or cooler if damaged.

Thread Repair

General purpose thread repair kits are available commercially.

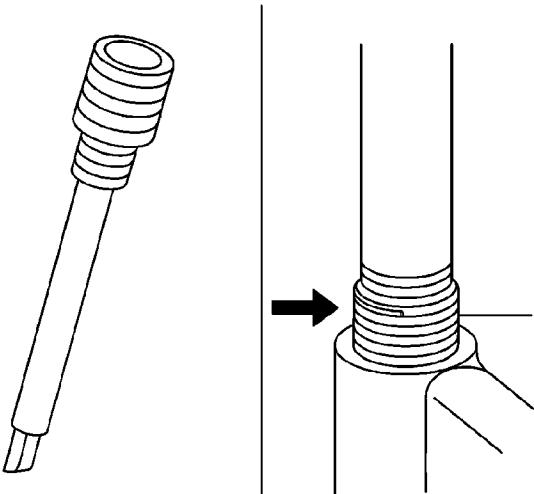
Warning: Refer to [Safety Glasses Warning](#) in the Preface section.



Note: Refer to the thread repair kit manufacturer's instructions regarding the size of the drill and which tap to use.

Always avoid any buildup of chips. Back out the tap every few turns and remove the chips.

1. Determine the size, the pitch, and the depth of the damaged thread.
2. Adjust the stop collars on the cutting tool as needed. Tap the stop collars to the required depth.
3. Drill out the damaged thread.
4. Remove the chips.
5. Apply clean engine oil to the top thread.
6. Use the tap in order to cut new thread.
7. Clean the thread.

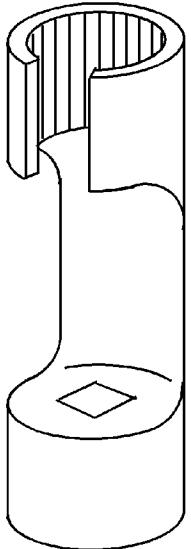


8. Screw the thread insert onto the mandrel of the thread insert installer. Engage the tang of the thread insert onto the end of the mandrel.

Note: The thread insert should be flush to 1 turn below the surface.

9. Lubricate the thread insert with clean engine oil - except when installing in aluminum - and install the thread insert.
10. If the tang of the thread insert does not break off when backing out the thread insert installer, break off the tang using a drift punch.

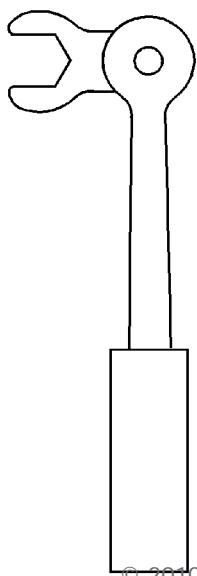
Fuel Line Torquing



The torque of a fuel line fitting is critical to prevent fuel leaks in a high pressure direct injection fuel system. The preferred method is through the use of a flare nut socket. With the use of a flare nut socket, the torque wrench can be set to the listed torque specification. Refer to [Fastener Tightening Specifications](#).

If a crows foot is used to torque the fuel lines, then special attention to the position of the crows foot in relation to the torque wrench is required.

•

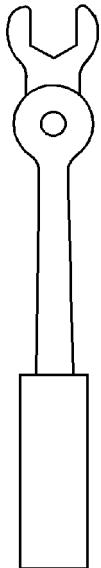


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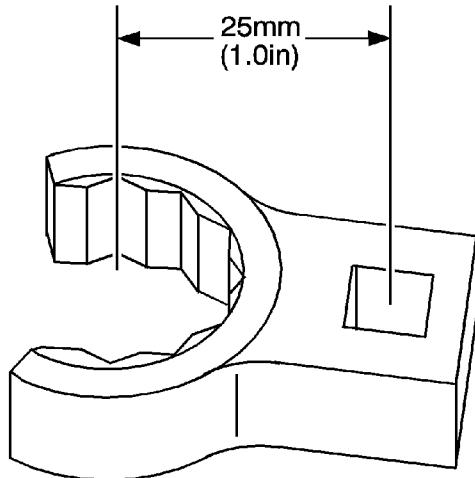
- | If the crows foot is kept perpendicular (90 degrees) to the torque wrench during the entire tightening procedure, then the torque wrench can be set to the listed torque specification. Refer to [Fastener Tightening Specifications](#).

-

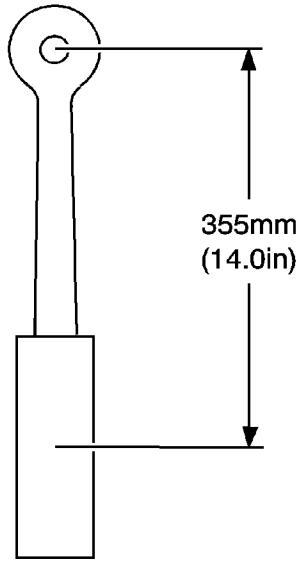


- | If the crows foot is positioned straight with the torque wrench, then the torque setting needs to be corrected to compensate for the increased leverage.
- | If the crows foot is held at any position other than 90 degrees or inline to the wrench, more complex corrections of the torque setting are required, and therefore, positioning the crows foot in this manner is not recommended.

If it is necessary to position a crows foot in line with the torque wrench, the procedure for adjusting the torque specification is as follows:



1. Measure the distance between the center of the crows foot wrench end to the center of the square drive hole.



2. Measure the length of the torque wrench from the center of the square drive to the center of the handle.
3. Divide the measurement of the crows foot length by the torque wrench length. This figure is the percentage of additional torque, over the torque wrench setting, that will be applied to the fitting.
4. Subtract the results of step 3 from the number 1. This figure is the percentage of the listed torque specification that the torque wrench should be set to.
5. Multiply the results of step 4 by the listed torque setting. Refer to [Fastener Tightening Specifications](#). This figure is the proper setting the torque wrench should be set at when using a crows foot in line with the torque wrench.

Example

1. Crows foot measurement = 25 mm (1.0 in)
2. Torque wrench measurement = 355 mm (14.0 in)
3. $25 \text{ mm} / 355 \text{ mm} (1.0 \text{ in} / 14.0 \text{ in}) = 0.07$, or 7 %
4. $1 - 0.07 = 0.93$, or 93 %
5. $0.93 \times 41 \text{ N}\cdot\text{m} (30 \text{ lb ft}) = 38 \text{ N}\cdot\text{m} (28 \text{ lb ft})$

Service Prior to Assembly

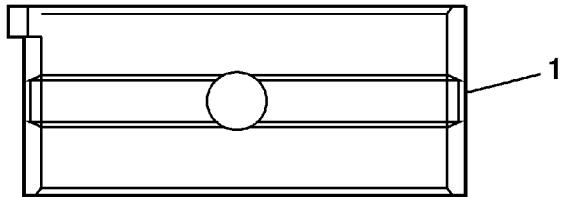
- Dirt will cause premature wear of the rebuilt engine. Clean all the components.
- Use the proper tools to measure the components when checking for excessive wear. Components not within the manufacturer's specification must be repaired or replaced.
- When the components are reinstalled into an engine, return the components to their original location, position, and direction.
- During assembly, lubricate all the moving parts with clean engine oil (unless otherwise specified). This will provide initial lubrication when the engine is first started.

Crankshaft and Bearing Installation

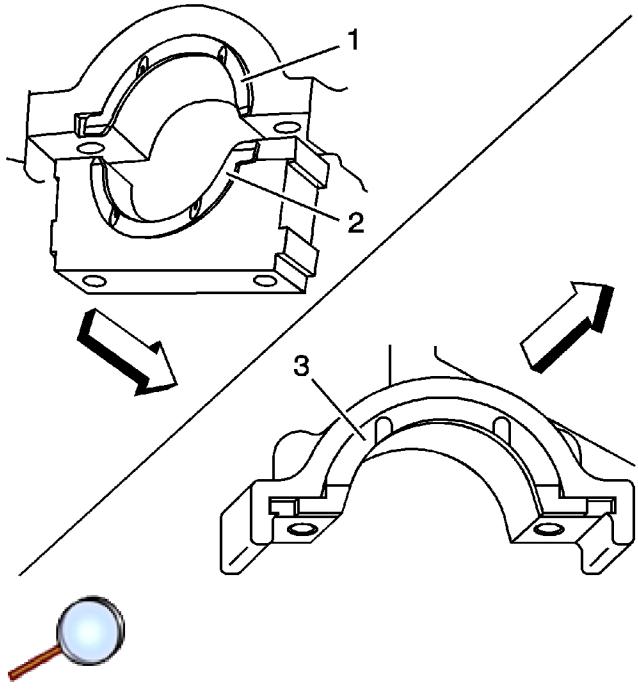
Special Tools

J 45059 Angle Meter

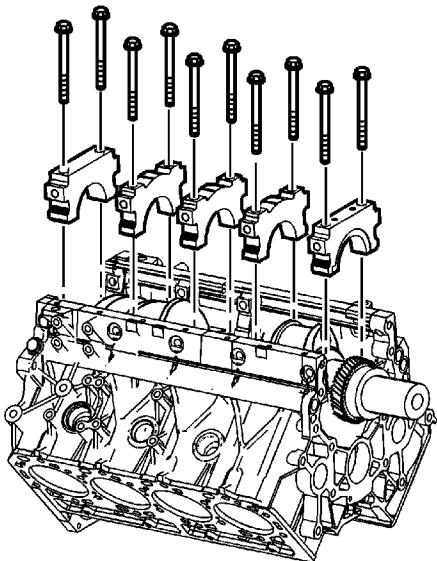
For equivalent regional tools, refer to [Special Tools](#)



1. Install the upper crankshaft bearings into the cylinder block. The bearing halves to be inserted into the crankshaft main bearing saddle have a wide groove and oil hole in the center of the bearing (1).
2. Install the lower crankshaft bearings into the crankshaft bearing caps. The bearing halves to be inserted into the crankshaft main bearing caps do NOT have an oil hole or groove in the bearing (2).

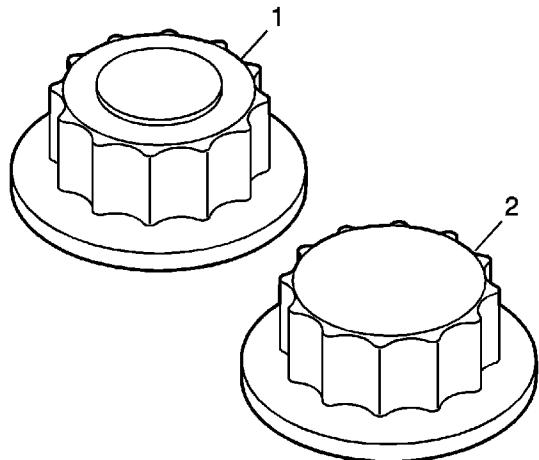


3. Install the upper thrust bearings to the cylinder block. There are two thrust bearings (1 and 3) in the cylinder block and one lower thrust bearing in the No. 5 crankshaft bearing cap (2).
4. Lubricate the crankshaft bearing surfaces with engine oil.
5. Install the crankshaft into the cylinder block.
6. Install the No. 5 crankshaft bearing cap with the lower thrust bearing (2).



7. Install the remaining four crankshaft bearing caps.

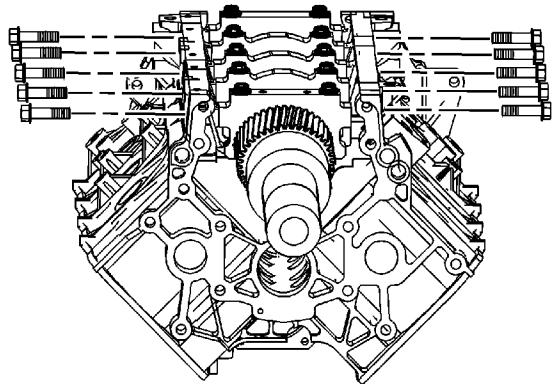
Caution: Refer to [Fastener Caution](#) in the Preface section.



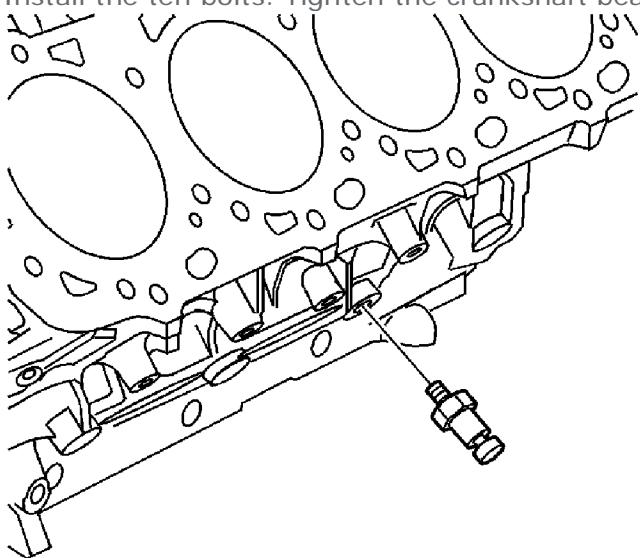
Caution: This component uses bolts with a preapplied molybdenum disulfide coating for thread lubrication. Do not remove the coating or use any additional lubricant. Improperly lubricated threads will adversely affect the bolt torque and clamp load. Improper bolt torque and clamp load can lead to engine damage.

Note: There are two different length crankshaft bearing cap bolts in production depending on the counter bore of the threaded hole/block. Using the wrong bolt may lead to improper thread engagement, bottoming out or improper clamp load. Look at the bolt head surface to determine which bolt was used in production. The bolt head will have either a raised circle (1) or it will be unmarked (2). Replace the bolt with the same type.

8. Install the NEW crankshaft bearing cap bolts.
9. Tighten the crankshaft bearing cap bolts in the proper sequence.
 - 9.1. 1st step **98 N·m (72 lb ft)**.
 - 9.2. 2nd step **132 N·m (97 lb ft)**.
 - 9.3. 3rd step 30 degrees using *J 45059* meter .



10. Clean the crankshaft bearing side cap bolt threads, sealing flange and mounting holes with GM P/N 12377981 (Canadian P/N 10953463) or equivalent. Dry the bolts and mounting holes with compressed air.
11. Apply GM P/N 12346004 (Canadian P/N 10953480) to the threads and sealing flange of the bolts.
12. Install the ten bolts. Tighten the crankshaft bearing cap side bolts to **70 N·m (52 lb ft)**.



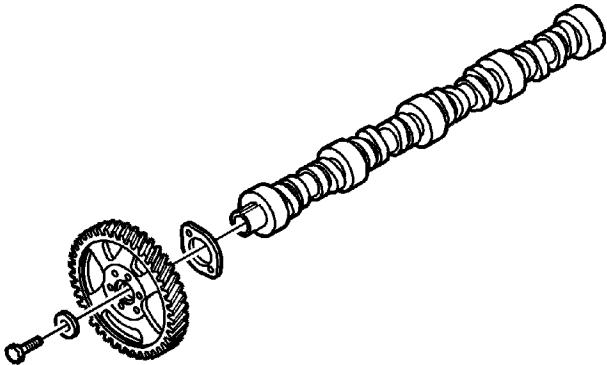
13. Install the oil pressure sensor and tighten to **41 N·m (30 lb ft)**.

Camshaft Installation

Special Tools

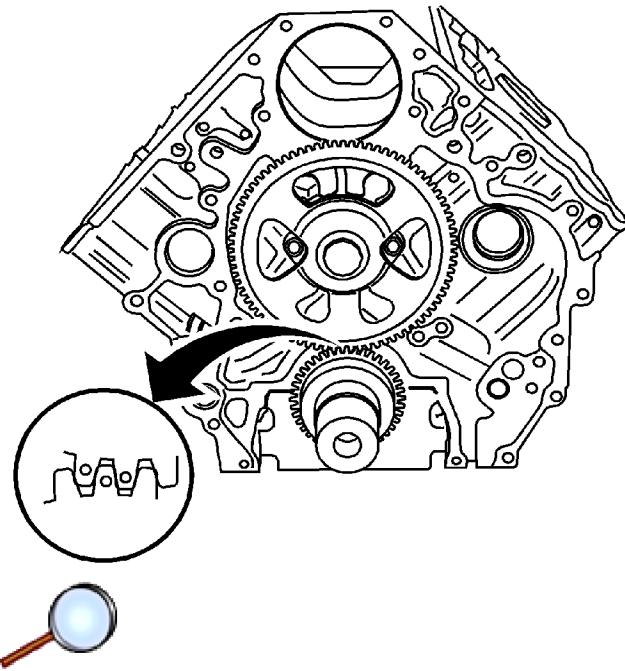
J 7872 Dial Indicator Set

For equivalent regional tools, refer to [Special Tools](#).



1. Install the camshaft thrust plate to the camshaft.
2. Install the camshaft driven gear.
3. Install a new camshaft driven gear bolt.

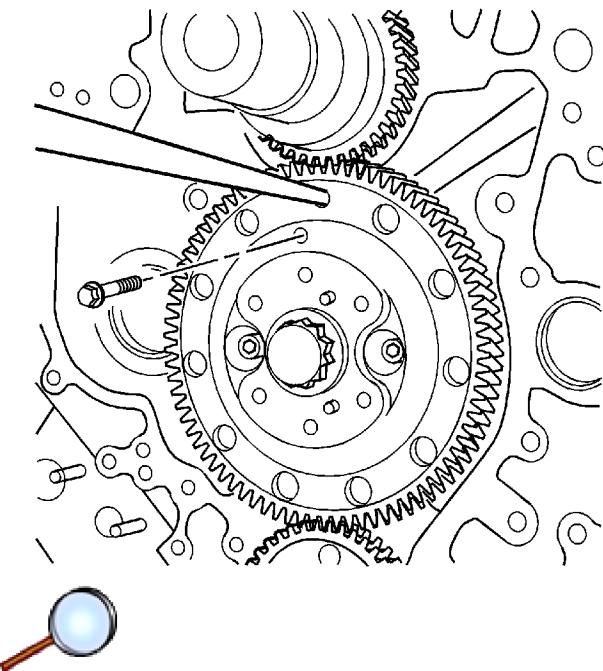
Leave the bolt finger tight.



4. Install the camshaft and gear assembly into the cylinder block, aligning the camshaft gear to the crankshaft gear as shown.

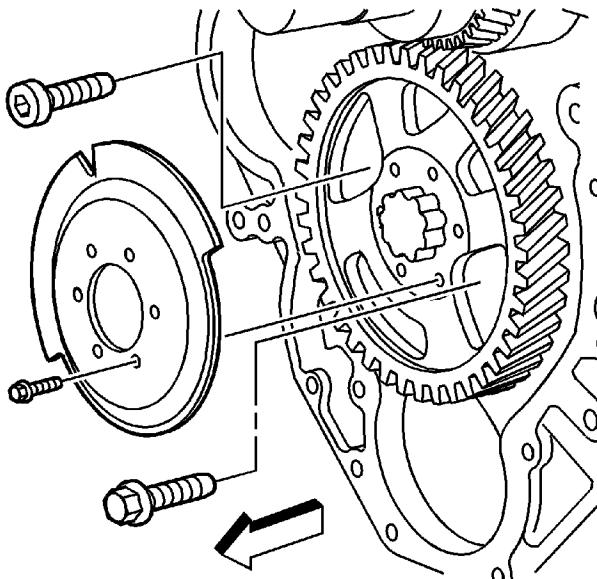
Caution: Refer to [Fastener Caution](#) in the Preface section.

5. Install the camshaft thrust plate bolts and tighten to **22 N·m (16 lb ft)**.

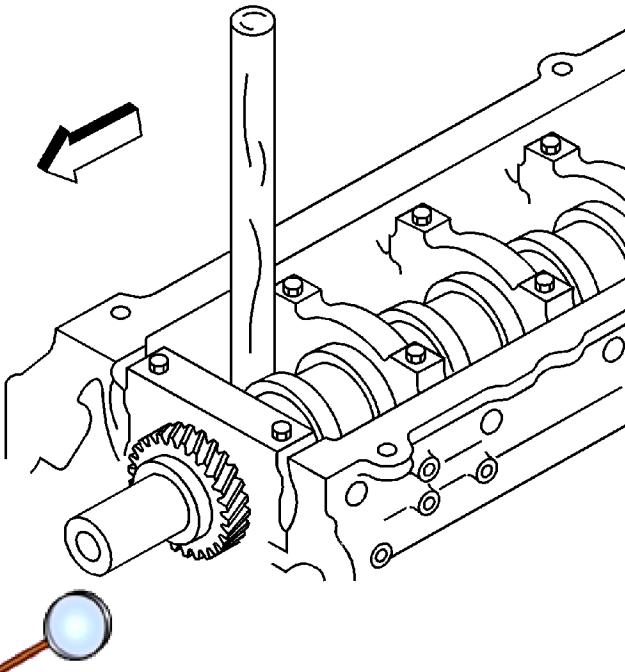


Note: Use a suitable tool to relieve the spring tension while removing the locking bolt.

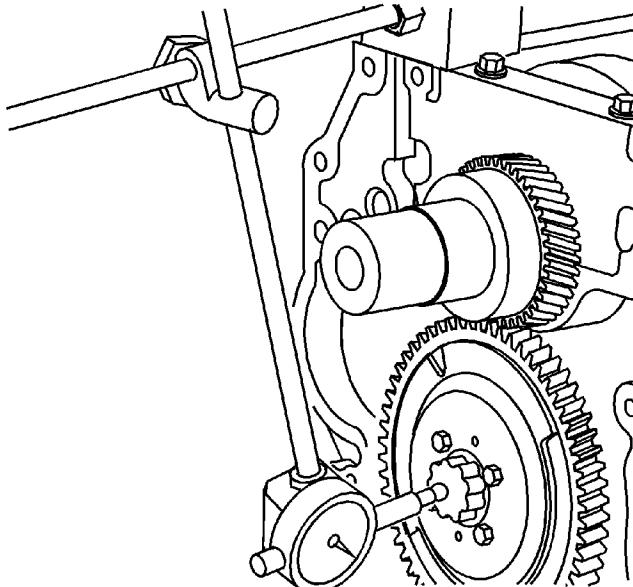
6. Remove the exciter ring bolt that was installed to hold the spring tension of the two piece cam gear.



7. Install the camshaft position sensor exciter ring to the camshaft gear.
8. Install the camshaft position sensor exciter ring bolts and tighten to **9 N·m (80 lb in)**.



9. Block the crankshaft from turning using a wooden handle.
10. Install the new camshaft gear bolt and tighten to **234 N·m (173 lb ft)**.



11. Measure the camshaft end play with *J7872 Dial Indicator Set*.

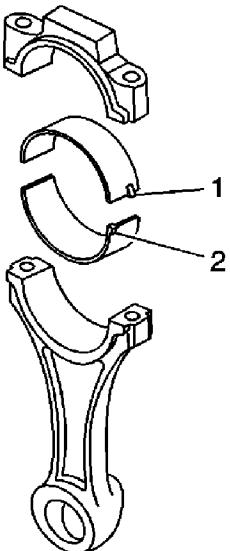
- The production value is 0.050-0.114 mm (0.0020-0.0045 in) and service limit is 0.2 mm (0.0079 in).
- Replace the camshaft gear or the camshaft thrust plate if measured value exceeds the service limit.

Piston, Connecting Rod, and Bearing Installation

Special Tools

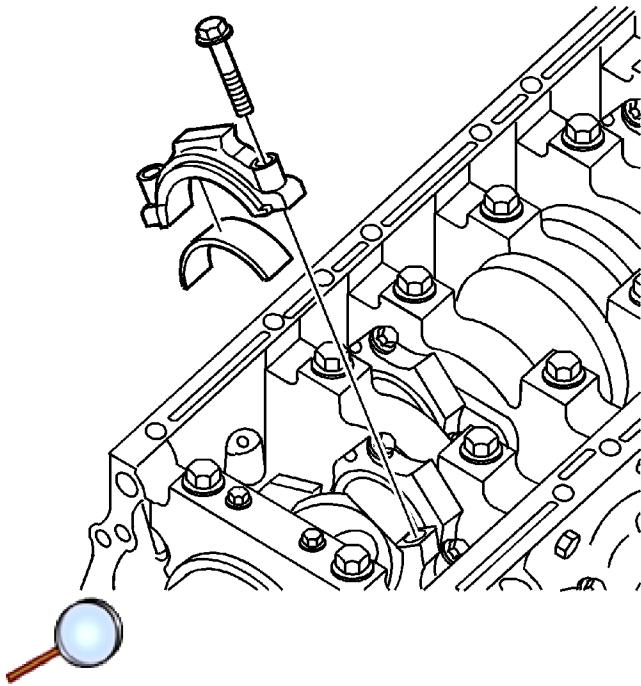
- J 8037 Piston Ring Compressor
- J 45059 Angle Meter

For equivalent regional tools, refer to [Special Tools](#).

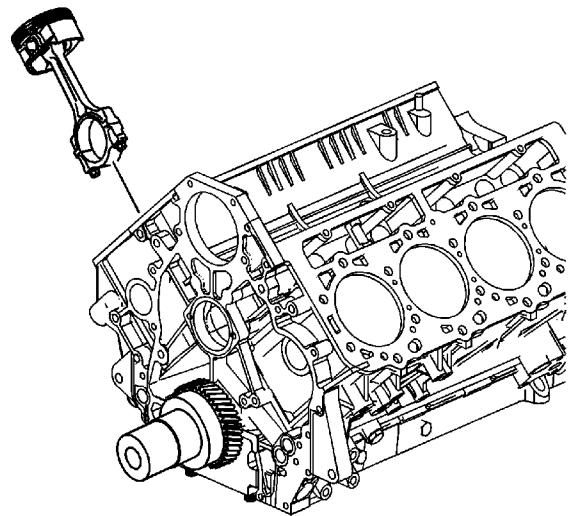


Note: The connecting rod bearing with the notch all the way out against the edge of the bearing (2) is the connecting rod bearing. The connecting rod bearing with the notch "in board" (1) is the connecting rod cap bearing.

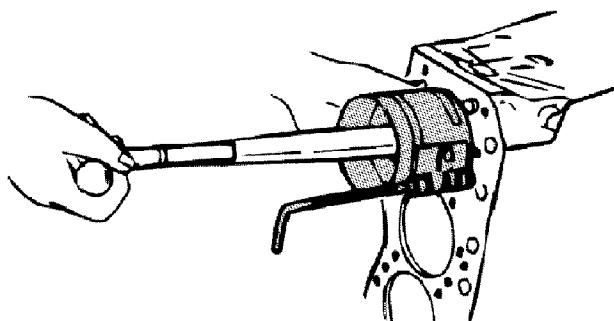
1. Select the connecting rod bearing according to the [Connecting Rod Bearings Selection Specifications](#) chart.
2. Position the crankshaft so the connecting rod journal is opposite the piston and connecting rod assembly being installed.



3. Install the connecting rod bearing inserts.
4. Lubricate the cylinder wall and piston rings with engine oil.
5. Install the *J8037* compressor to the piston to compress the piston rings.

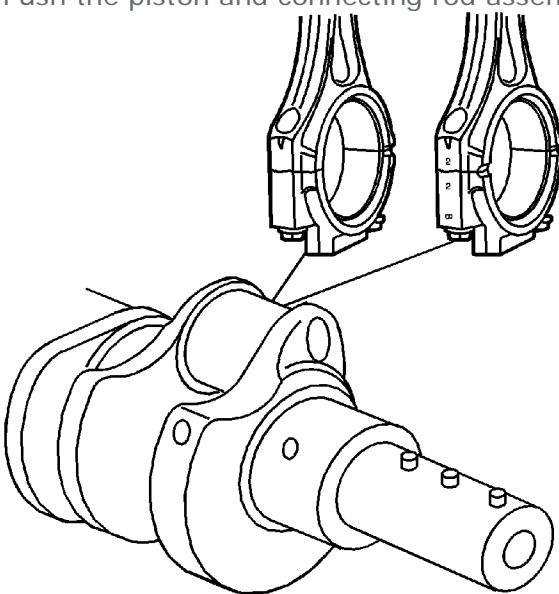


6. Orientate the piston front mark and the piston inside mark to the engine block.



Caution: The chamfered side of the connecting rod large journal ends must face away from each other on a common crankshaft journal. Placement of the chamfered side of the connecting rod large journal ends in any other direction or combination will cause damage to the crankshaft, connecting rod and connecting rod bearing.

7. Push the piston and connecting rod assembly into the engine.



8. Install the gauging plastic onto the connecting rod journal. Install the gauging plastic the full width of the journal.
9. Install the connecting rod cap with its stamped cylinder number aligned with the stamped cylinder number on the connecting rod.

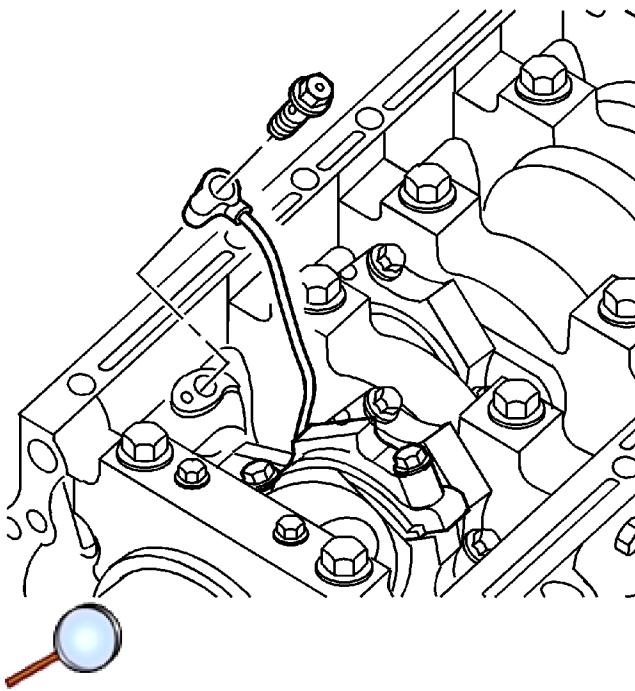
Caution: Refer to [Fastener Caution](#) in the Preface section.

10. Install the original connecting rod cap bolts for the plastic gauging. NEW bolts will be used for final assembly.
11. Tighten the bolts in three steps.
 - 11.1. 1st step **64 N·m (47 lb ft)**
 - 11.2. 2nd step **30 degrees** using *J 45059* meter
 - 11.3. 3rd step **30 degrees** using *J 45059* meter
12. Remove the connecting rod cap bolts.
13. Compare the width of the gauging plastic with the scale printed on the gauging plastic container. The connecting rod bearing clearance should be 0.10 mm (0.0039 in).
14. Discard the original connecting rod bolts once the plastic gauging is completed. NEW connecting rod bolts will be used for final assembly.
15. Carefully clean the gauging plastic from the bearing surface and the crankpin.
16. Lubricate the connecting rod bearing inserts with engine oil.
17. Install the connecting rod caps with the stamped cylinder number aligned with the stamped cylinder number on the connecting rods.

Caution: This component uses bolts with a preapplied molybdenum disulfide coating for thread lubrication. Do not remove the coating or use any additional lubricant. Improperly lubricated threads will adversely affect the bolt torque and clamp load. Improper bolt torque and clamp load can lead to engine damage.

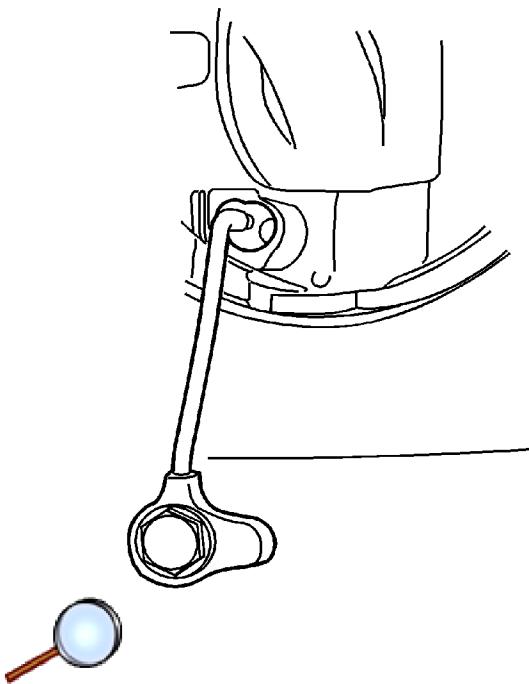
18. Install NEW connecting rod cap bolts.
19. Tighten the connecting rod cap bolts in three steps.
 - 19.1. 1st step **64 N·m (47 lb ft)**
 - 19.2. 2nd step **30 degrees** using *J 45059* meter
 - 19.3. 3rd step **30 degrees** using *J 45059* meter

Piston Oil Cooling Nozzle Installation



1. Install the piston oil cooling nozzle.

Caution: Refer to [Fastener Caution](#) in the Preface section.

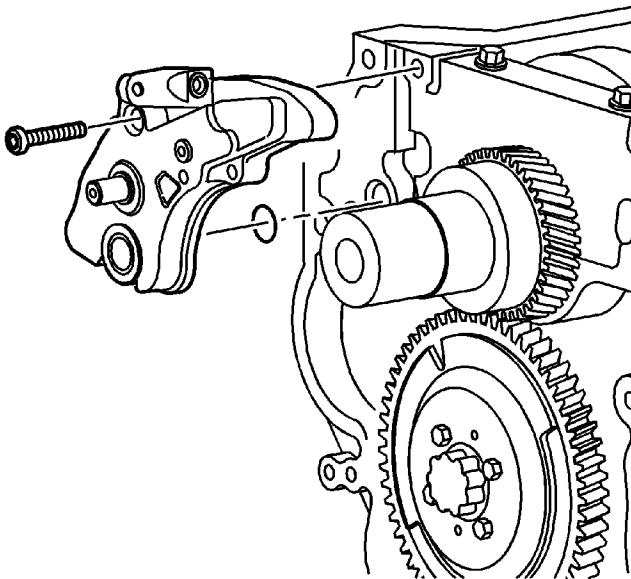


Caution: The piston oil cooling nozzle must be aligned to direct oil towards the oil inlet hole
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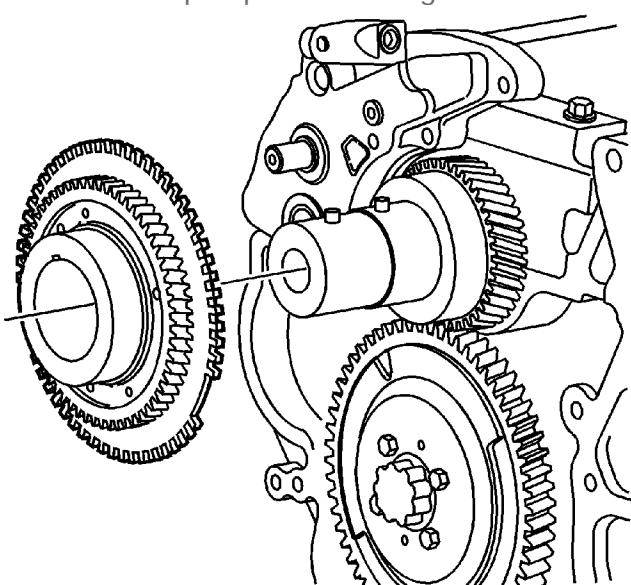
on the bottom of the piston. Improper alignment of the piston oil cooling nozzle will allow insufficient oil lubrication to the piston and cause severe engine damage.

2. Install the piston oil cooling nozzle bolt and tighten to **21 N·m (15 lb ft)**.

Oil Pump Installation



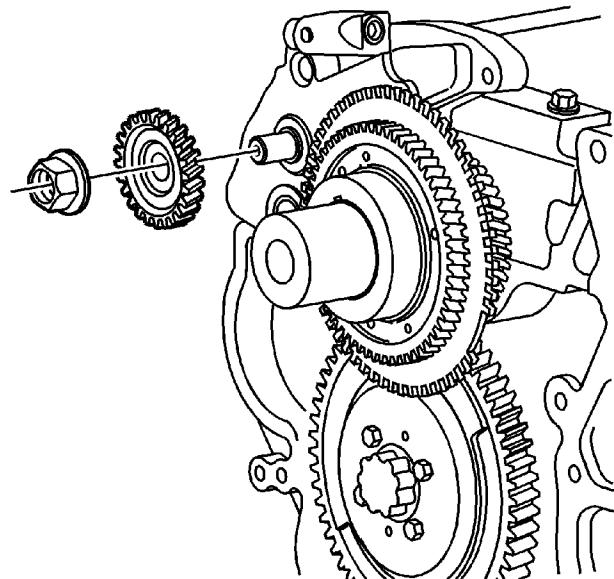
1. Install a new O-ring to the engine block.
 2. Lubricate the O-ring with engine oil.
 3. Install the oil pump.
- Caution:** Refer to [Fastener Caution](#) in the Preface section.
4. Install the oil pump bolts and tighten to **21 N·m (15 lb ft)**.



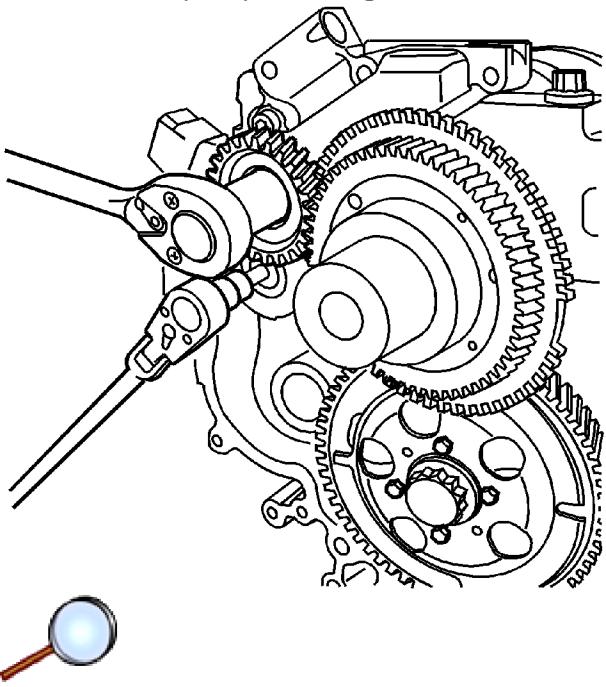
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Note: Do not damage the crankshaft sensor reluctor teeth.

5. Install the oil pump drive gear and crank sensor reluctor assembly.



6. Install the oil pump driven gear.

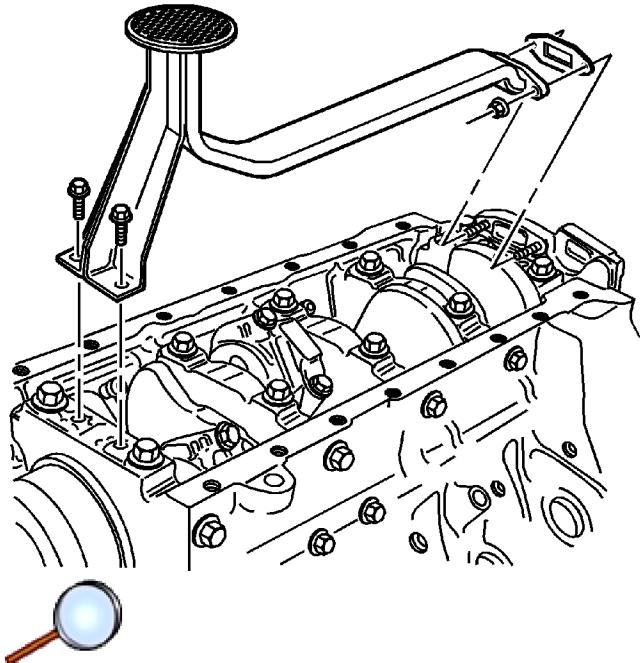


Caution: Do not use an impact driver to remove or install the oil pump driven gear nut. Use of an impact driver may shear the oil pump drive gear pin in the crankshaft.

Note: Look for an "L" on the end of the oil pump shaft. If there is an "L" present, the nut and shaft have left hand threads. Service the nut accordingly.

7. While holding the secondary oil pump shaft with a hex driver, install the oil pump driven gear nut. Tighten the oil pump driven gear nut to **100 N·m (74 lb ft)**.

Oil Pump Suction Pipe and Screen Assembly Installation

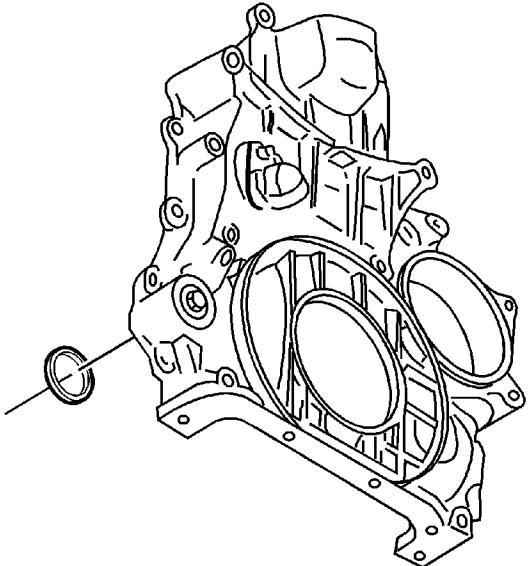


1. Install the oil pump pipe and screen gasket.
2. Install the oil pump pipe and screen.

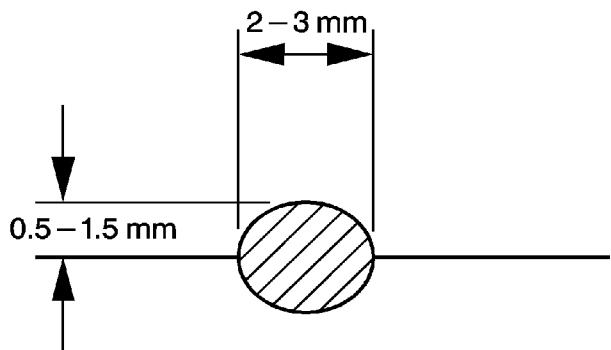
Caution: Refer to [Fastener Caution](#) in the Preface section.

3. Install the oil pump pipe and screen assembly bolts and nuts.
 - 3.1. Tighten the oil pump pipe and screen assembly bolts to **25 N·m (18 lb ft)**.
 - 3.2. Tighten the oil pump pipe and screen assembly nuts to **25 N·m (18 lb ft)**.

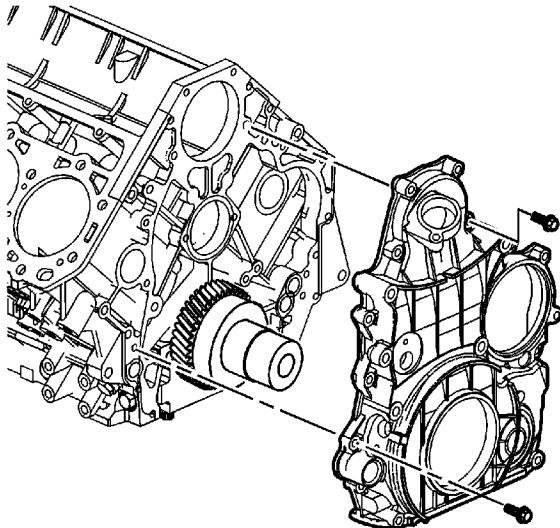
Engine Front Cover Installation



1. Install the relief valve O-ring to the engine front cover.
2. Lubricate the O-ring with engine oil.



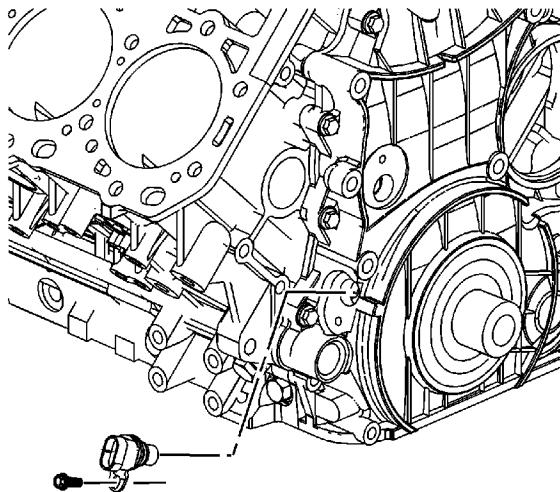
3. Apply a 2-3 mm wide and 0.5-1.5 mm high bead of GM P/N 12378521 (Canadian P/N 88901148) sealant to the mating surfaces of the engine front cover.



4. Install the engine front cover.

Caution: Refer to [Fastener Caution](#) in the Preface section.

5. Install the engine front cover bolts and tighten to **25 N·m (18 lb ft)**.

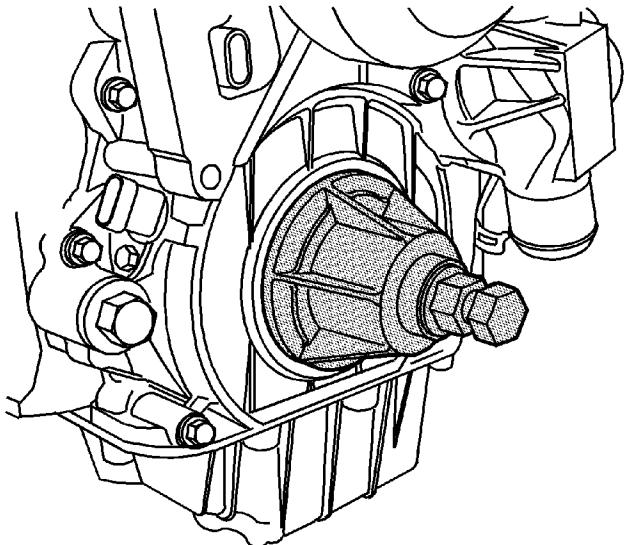


6. Install a new O-ring to the crankshaft position sensor spacer.
7. Lubricate the O-ring with engine oil.
8. Install the crankshaft position sensor spacer.
9. Install the crankshaft position sensor spacer bolts and tighten to **10 N·m (89 lb in)**.
10. Install a new O-ring to the crankshaft position sensor.
11. Lubricate the O-ring with engine oil.
12. Install the crankshaft position sensor.
13. Install the crankshaft position sensor bolt and tighten to **10 N·m (89 lb in)**.

Crankshaft Front Oil Seal Installation

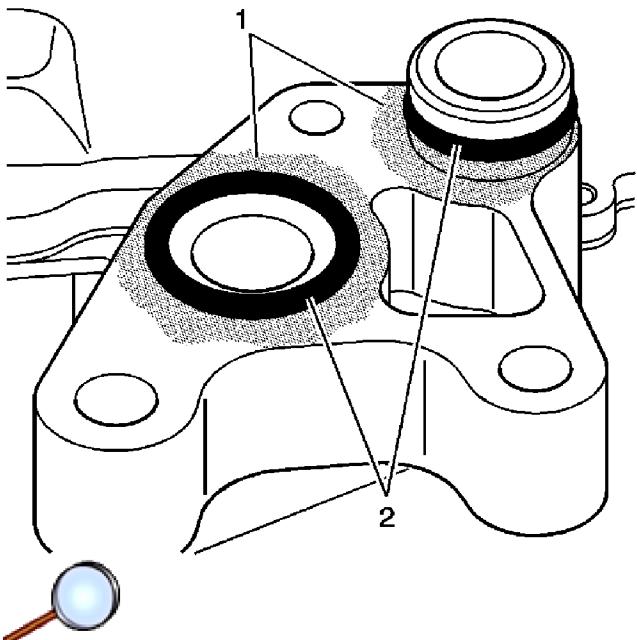
Tools Required

[J 44645](#) Crankshaft Front Oil Seal Installer

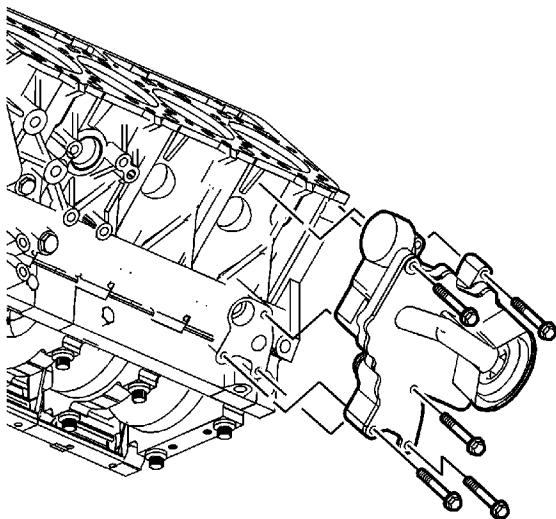


1. Lubricate the crankshaft sealing surface with engine oil.
2. Place the crankshaft front oil seal onto the crankshaft.
3. Install the [J 44645](#) to the crankshaft.
4. Press the crankshaft front oil seal onto the crankshaft with the [J 44645](#) until the tool bottoms out.
5. Remove the [J 44645](#).

Oil Filter Adapter and Oil Cooler Assembly Installation



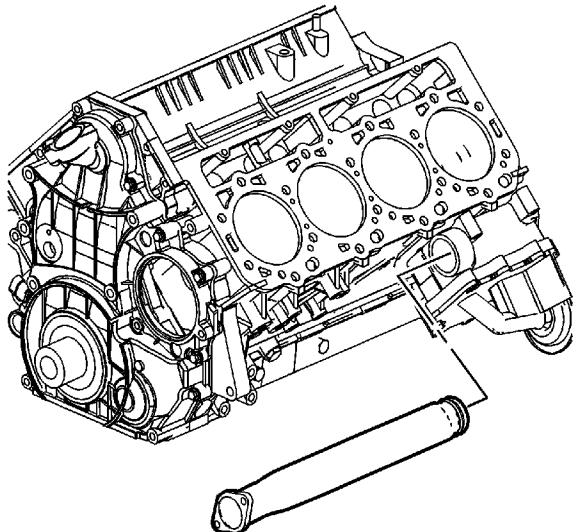
1. Install new O-rings (2) to the oil filter adapter and oil cooler assembly. Lubricate the O-rings with engine oil.
2. Apply sealer GM P/N 12378521 (Canadian P/N 88901148) to the O-ring sealing area (1).



3. Install the oil filter adapter and oil cooler assembly.

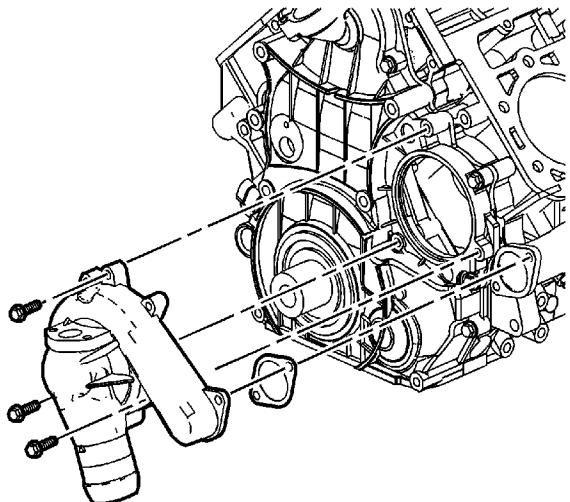
Caution: Refer to [Fastener Caution](#) in the Preface section.

4. Install the five oil filter adapter and oil cooler assembly bolts (1) and tighten to **25 N·m (18 lb ft)**.



5. Install a new O-ring onto the engine coolant pipe.
6. Lubricate the O-ring with engine coolant. Do not use oil or grease.
7. Install the engine coolant pipe to the oil filter adapter and oil cooler assembly.

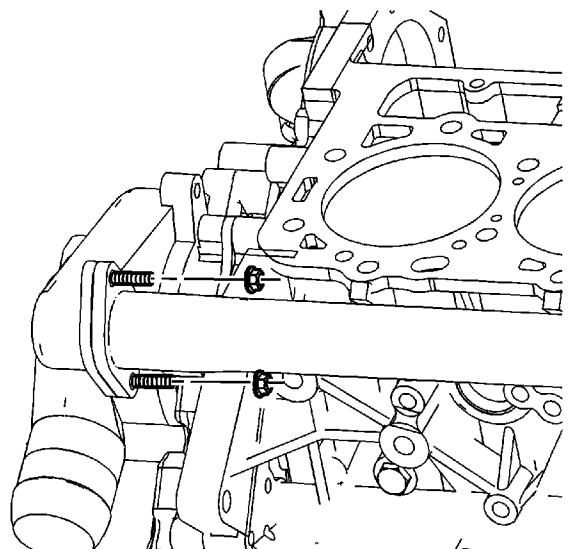
Water Pump Installation



1. Lubricate the water pump O-ring with engine oil.
2. Install the engine coolant pipe gasket.
3. Install the water pump seal.
4. Install the water pump. Be sure the water pump studs align with the coolant tube.

Caution: Refer to [Fastener Caution](#) in the Preface section.

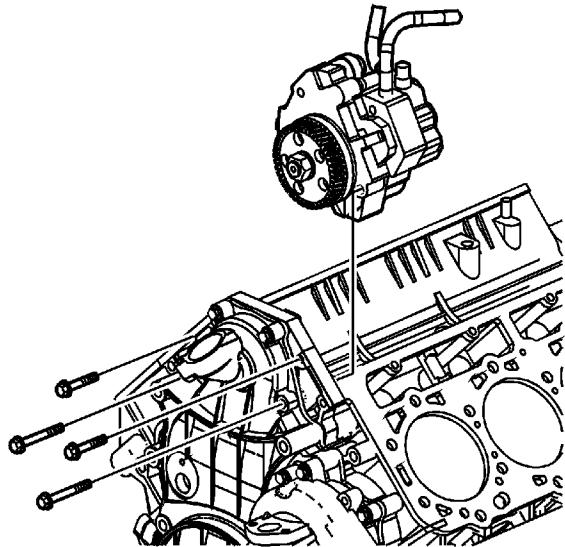
5. Install the water pump bolts and tighten to **25 N·m (18 lb ft)**.



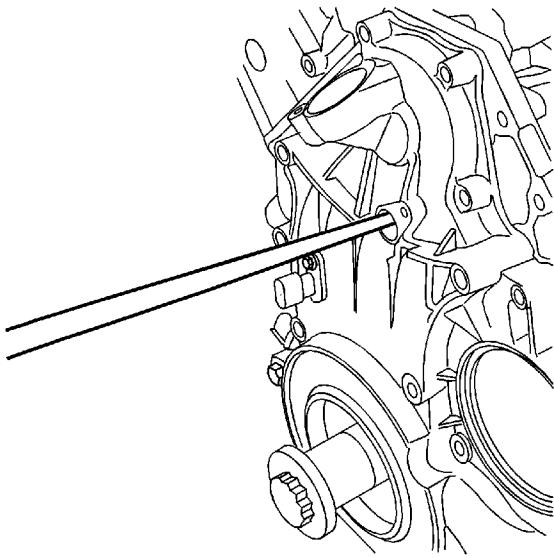


6. Install the water pump to coolant tube nuts Tighten the water pump to coolant tube nuts to **25 N·m (18 lb ft)**.

Fuel Injection Pump Installation



1. Lubricate the O-ring on the fuel injection pump adapter with engine oil.

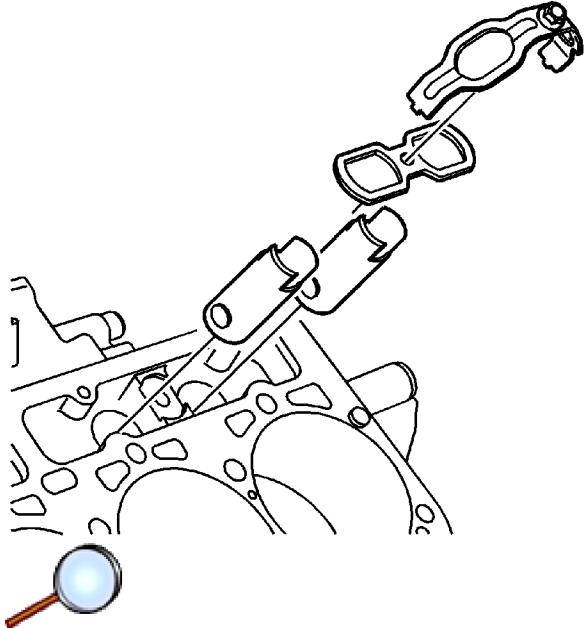


2. Use a suitable tool to unload the spring tension from the two piece cam gear. Apply pressure towards the right side of the engine while installing the fuel injection pump.
3. Install the fuel injection pump and adapter assembly.

Caution: Refer to [Fastener Caution](#) in the Preface section.

4. Install the fuel injection pump bolts and tighten to **25 N·m (18 lb ft)**.

Valve Lifter Installation



1. Install the valve lifter.
2. Install the valve lifter guides.
3. Install the valve lifter guide hold down bracket.

Caution: Refer to [Fastener Caution](#) in the Preface section.

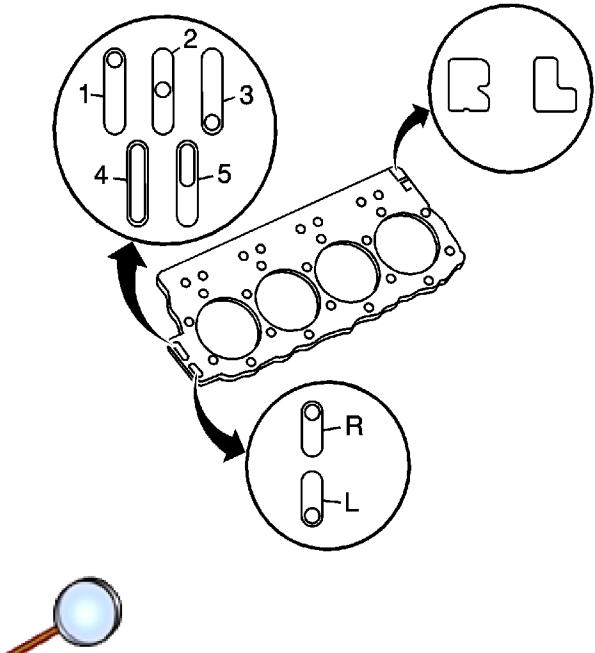
4. Install the valve lifter guide hold down bracket bolt **11 N·m (97 lb in)**.

Cylinder Head Gasket Selection

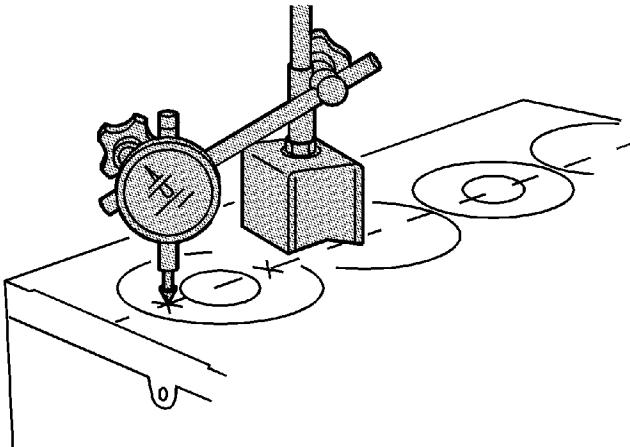
Tools Required

[J 7872 Dial Indicator Set](#)

1. If a reciprocating component (crankshaft, connecting rod, piston, or bearings) has not been replaced, install the same grade head gasket that was removed.



2. The markings on the gasket are as follows:
 - Grade A (1)
 - Grade B (2)
 - Grade C (3)
 - Block over-bored 0.010-0.030 in (0.254-0.762 mm) (4)
 - Block over-bored 0.010-0.030 in (0.254-0.762 mm) and deck milled 0.008 in (0.203 mm) (5)
3. The cylinder head gasket thickness is determined by the piston head projection from the cylinder block deck surface. There are cylinder head gaskets available in three different thicknesses. Follow the procedure below and refer to [Cylinder Head Gasket Selection Specifications](#) to determine what gasket to use for each bank of cylinders.
4. Be sure the piston and cylinder deck are free of carbon, gasket material, or other objects that may give you an erroneous measurement.



5. Use [J 7872](#) to measure the piston projection across two different points on each piston.
 - 5.1. Zero the dial indicator to the cylinder deck surface.
 - 5.2. Place the dial indicator pointer on the piston top. Be sure the pointer is directly above the piston pin centerline to prevent inaccurate readings from piston rocking.
 - 5.3. Rotate the engine to roll the piston through Top Dead Center while noting the maximum reading on the dial indicator.
 - 5.4. Repeat procedure at the second measuring point on the piston.
6. Calculate the average value of piston projection for each cylinder.
7. Obtain the maximum piston projection value for that bank of cylinders.
8. Determine the gasket grade by the maximum piston projection value using the chart.
9. If the difference between the highest measured piston head projection and the lowest measured piston projection, within one bank of cylinders, exceeds 0.1 mm (0.0039 in), then the following items need to be checked.
 - Connecting rod to piston pin clearance
 - Piston to piston pin clearance

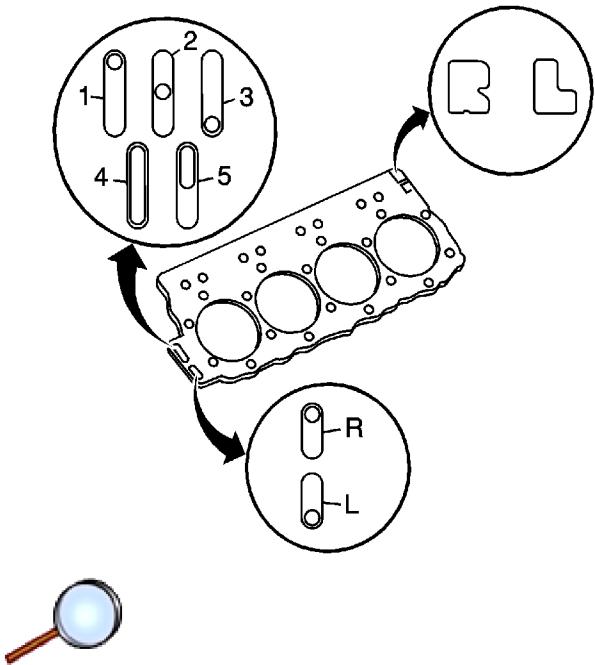
If any of the above clearances are beyond specifications, then refer to the appropriate section for repair. If all of the above clearances are within the service limits but the piston projection variation is over 0.1 mm (0.0039 in), then replace the connecting rod and piston assembly.

Cylinder Head Installation - Left Side

Special Tools

J 45059 Angle Meter

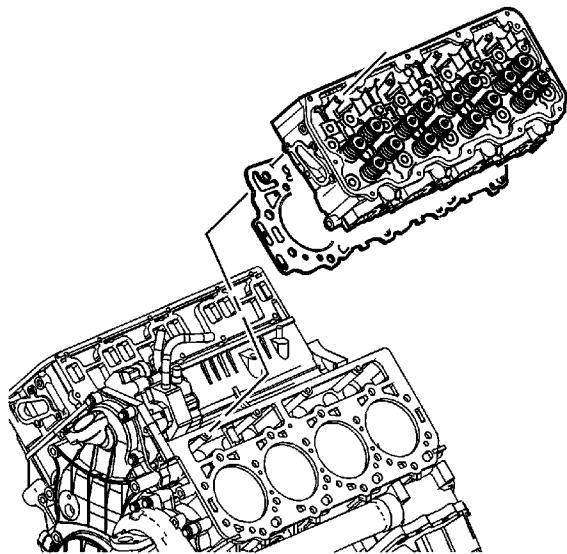
For equivalent regional tools, refer to [Special Tools](#).



Caution: The left and right cylinder head gaskets are not interchangeable. Improper placement of the cylinder head gasket will block coolant and oil passages. Blocked coolant and oil passages will cause severe engine damage.

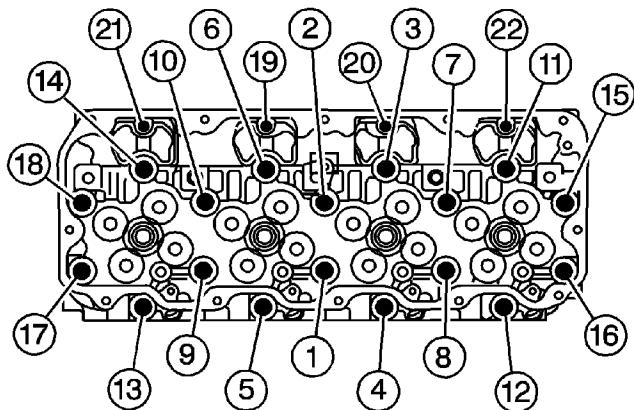
Note: The stamped letter, R or L, must face up. R is the right bank, L is the left bank.

1. The markings on the gasket are as follows:
 - Grade A (1)
 - Grade B (2)
 - Grade C (3)
 - Block over-bored 0.010-0.030 in (0.254-0.762 mm) (4)
 - Block over-bored 0.010-0.030 in (0.254-0.762 mm) and deck milled 0.008 in (0.203 mm) (5)
2. Install the left cylinder head gasket of the correct grade. The left and right cylinder head gaskets are not interchangeable. Refer to [Cylinder Head Gasket Selection](#).



3. Install the left cylinder head.

Caution: Refer to [Fastener Caution](#) in the Preface section.



Caution: This component uses bolts with a preapplied molybdenum disulfide coating for thread lubrication. Do not remove the coating or use any additional lubricant. Improperly lubricated threads will adversely affect the bolt torque and clamp load. Improper bolt torque and clamp load can lead to engine damage.

4. Install the NEW M12 cylinder head bolts.

Tighten the M12 cylinder head bolts in three steps:

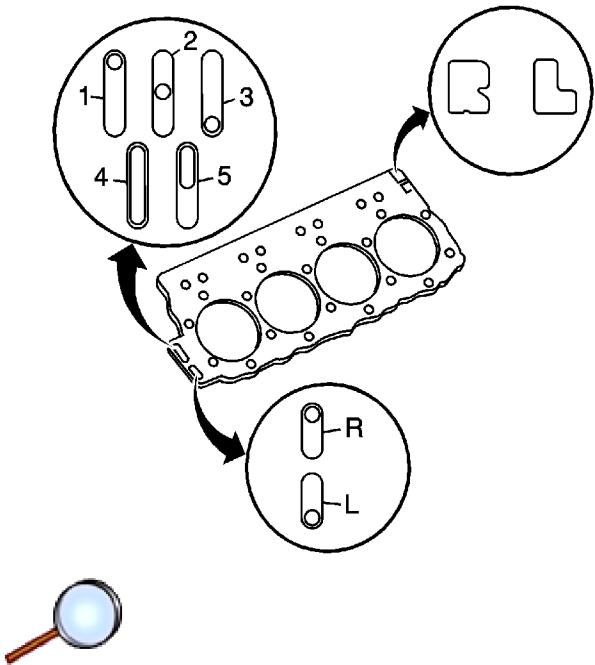
- 4.1. 1st step **50 N·m (37 lb ft)**
- 4.2. 2nd step **80 N·m (59 lb ft)**
- 4.3. 3rd step tighten **60 degrees** using *J 45059* meter
- 4.4. 4th step tighten **60 degrees** using *J 45059* meter
5. Reuse the M8 bolts. Install the M8 bolts and tighten the M8 cylinder head bolts to **25 N·m (18 lb ft)**.

Cylinder Head Installation - Right Side

Special Tools

J 45059 Angle Meter

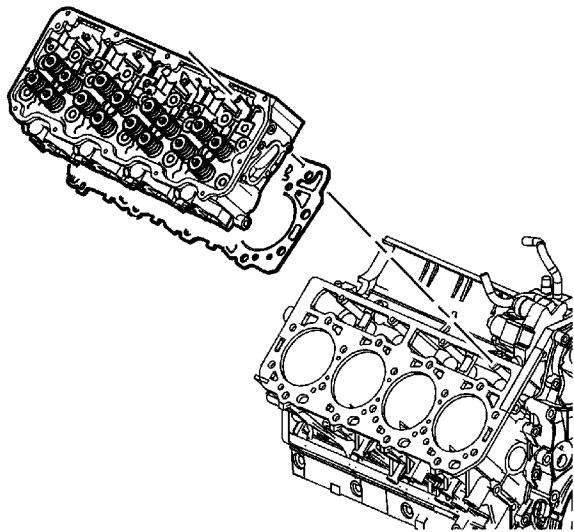
For equivalent regional tools, refer to [Special Tools](#).



Caution: The left and right cylinder head gaskets are not interchangeable. Improper placement of the cylinder head gasket will block coolant and oil passages. Blocked coolant and oil passages will cause severe engine damage.

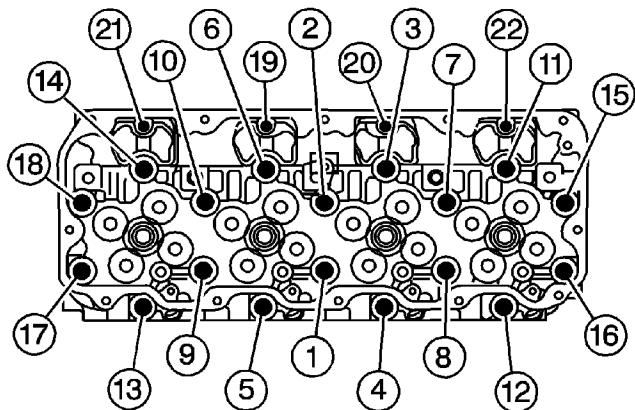
Note: The stamped letter, R or L, must face up. R is the right bank, L is the left bank.

1. The markings on the gasket are as follows:
 - Grade A (1)
 - Grade B (2)
 - Grade C (3)
 - Block over-bored 0.010-0.030 in (0.254-0.762 mm) (4)
 - Block over-bored 0.010-0.030 in (0.254-0.762 mm) and deck milled 0.008 in (0.203 mm) (5)
2. Install the right cylinder head gasket of the correct grade. The left and right cylinder head gaskets are not interchangeable. Refer to [Cylinder Head Gasket Selection](#).



-  3. Install the right cylinder head.

Caution: Refer to [Fastener Caution](#) in the Preface section.



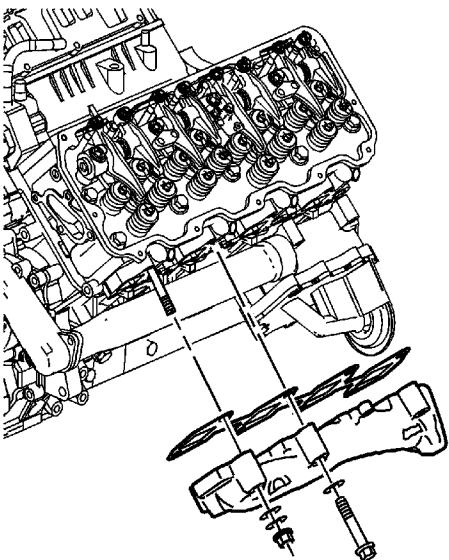
Caution: This component uses bolts with a preapplied molybdenum disulfide coating for thread lubrication. Do not remove the coating or use any additional lubricant. Improperly lubricated threads will adversely affect the bolt torque and clamp load. Improper bolt torque and clamp load can lead to engine damage.

4. Install the NEW M12 cylinder head bolts. Reuse the M8 bolts.

Tighten the M12 cylinder head bolts in three steps:

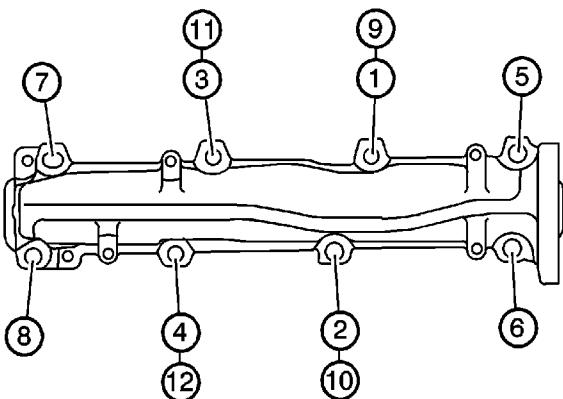
- 4.1. 1st step **50 N·m (37 lb ft)**
- 4.2. 2nd step **80 N·m (59 lb ft)**
- 4.3. 3rd step tighten **60 degrees** using *J 45059* meter
- 4.4. 4th step tighten **60 degrees** using *J 45059* meter
5. Install the M8 bolts. Tighten the M8 cylinder head bolts to **25 N·m (18 lb ft)**.

Exhaust Manifold Installation - Left Side



1. Install the exhaust manifold gasket.
2. Install the exhaust manifold.

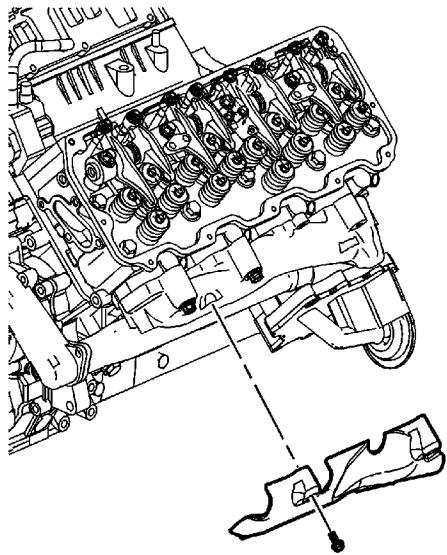
Caution: Refer to [Fastener Caution](#) in the Preface section.



3. Install the exhaust manifold bolts and nuts.

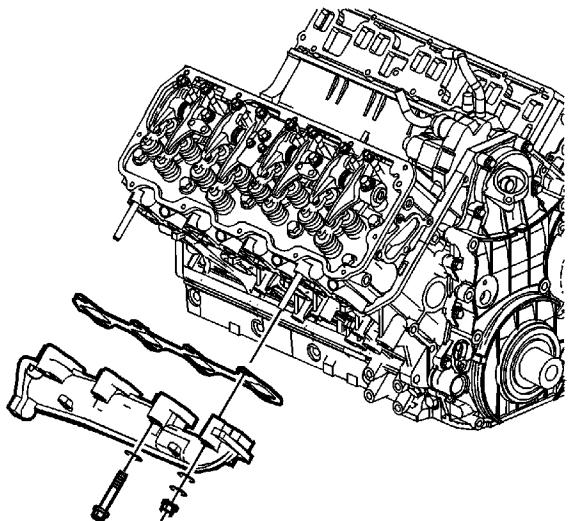
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- 3.1. Tighten the exhaust manifold bolts and nuts to **57 N·m (42 lb ft)** in the proper sequence.
- 3.2. Tighten the center exhaust manifold bolts and nuts an additional pass to **57 N·m (42 lb ft)** in sequence.



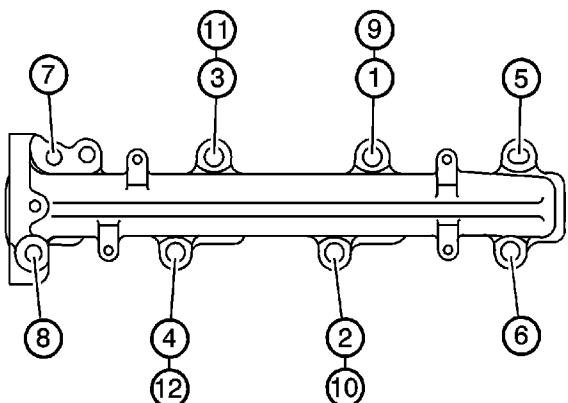
4. Install the exhaust manifold heat shield.
5. Install the exhaust manifold heat shield bolts and tighten to **10 N·m (89 lb in)**.

Exhaust Manifold Installation - Right Side



1. Install the exhaust manifold gasket.
2. Install the exhaust manifold.

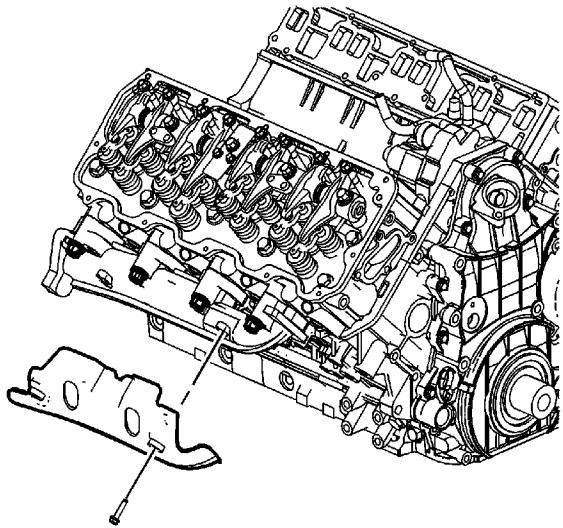
Caution: Refer to [Fastener Caution](#) in the Preface section.



3. Install the exhaust manifold bolts and nuts.

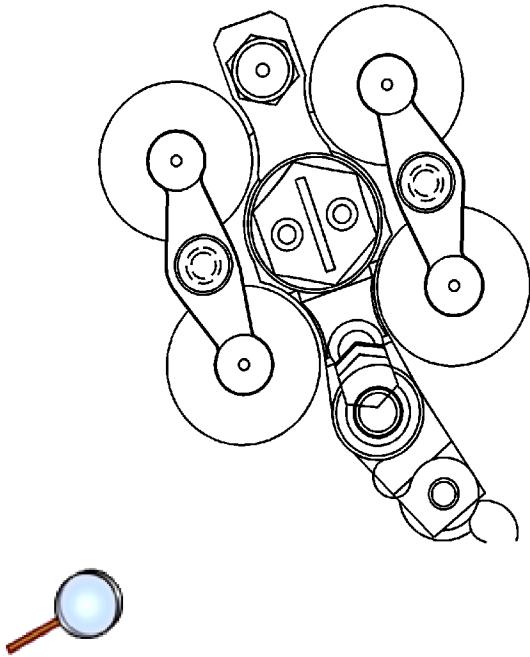
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- 3.1. Tighten the exhaust manifold bolts and nuts to **57 N·m (42 lb ft)** in the proper sequence.
- 3.2. Tighten the center exhaust manifold bolts and nuts an additional pass to **57 N·m (42 lb ft)** in sequence.



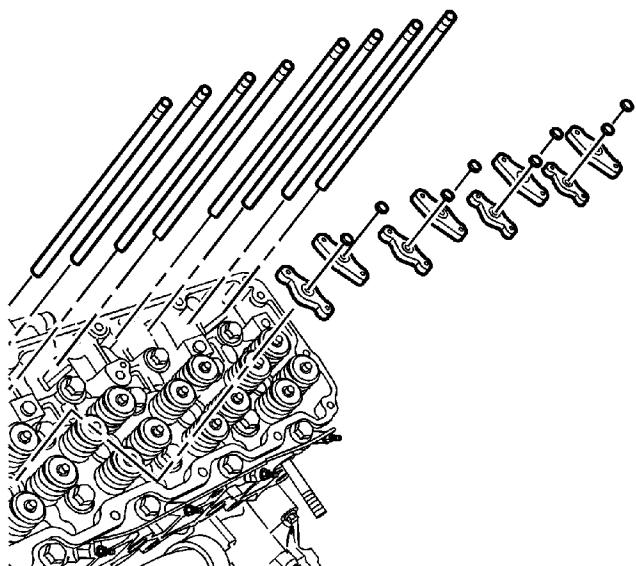
- 
4. Install the exhaust manifold heat shield.
 5. Install the exhaust manifold heat shield bolts and tighten to **10 N·m (89 lb in)**.

Valve Rocker Arm, Shaft, and Push Rod Installation

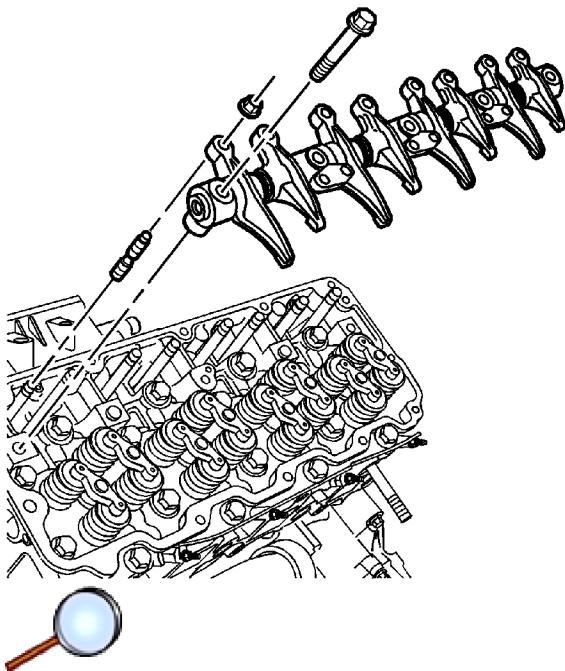


Note: Install the valve bridge with the expansion side of bridge away from the injector.

1. Install the valve bridge.



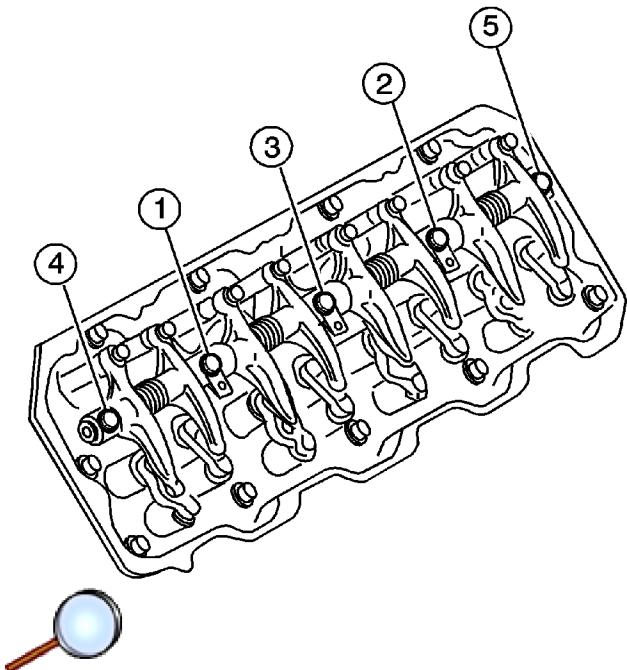
2. Install the valve bridge pins.
3. Install the pushrods.



Caution: The pushrods must be correctly seated in the valve lifter and valve rocker arms before the rocker arm shaft assembly is torqued into place. Improper seating of the pushrods can cause damage to the pushrods or the valve rocker arm shaft assembly components.

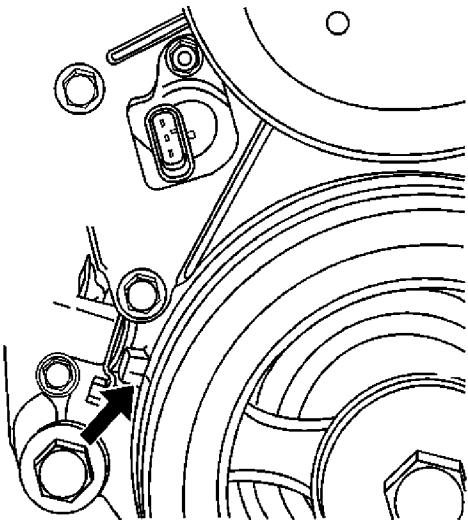
4. Install the rocker arm shaft assembly.

Caution: Refer to [Fastener Caution](#) in the Preface section.

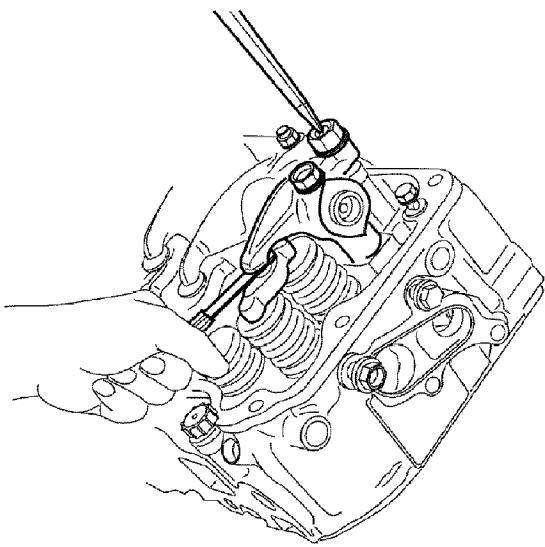


5. Install the rocker arm shaft assembly bolts. Tighten the rocker arm shaft assembly bolts in the proper sequence. Tighten the rocker arm shaft bolts to **41 N·m (30 lb ft)**.

Valve Clearance Adjustment



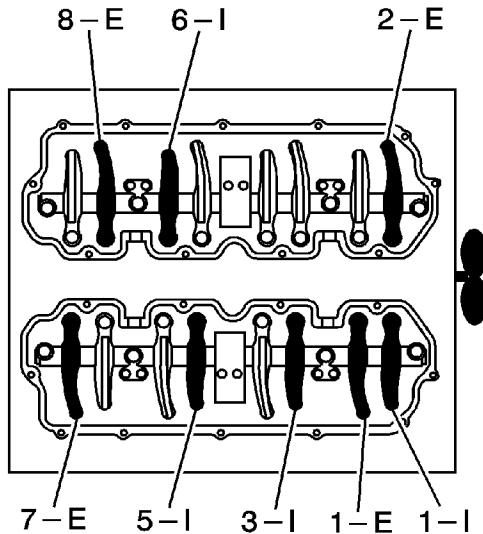
1. Rotate the crankshaft to bring the number 1 cylinder at the top dead center of the compression stroke. The number 1 cylinder is the front cylinder on the right bank. The mark on the crankshaft balancer should be aligned with the mark on the engine.



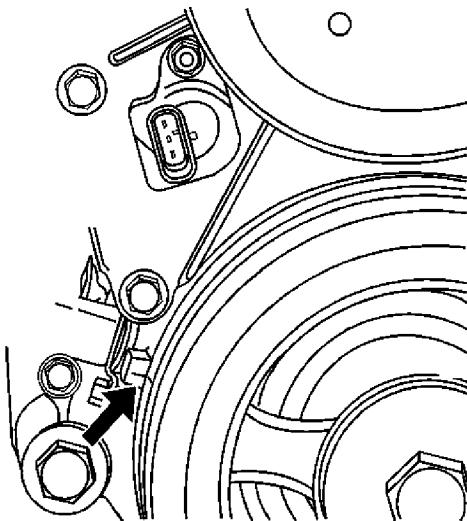
2. Loosen the valve adjusting screws.
3. Insert a feeler gauge between the tip of the rocker arm and the valve bridge.

Caution: Refer to [Fastener Caution](#) in the Preface section.

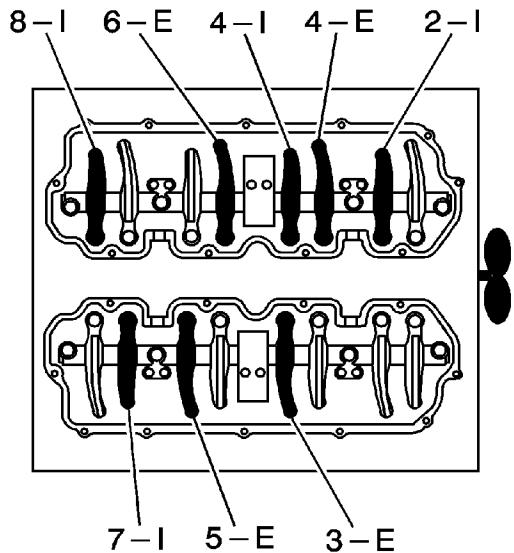
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4. Adjust the valve lash to 0.3 mm (0.012 in). Refer to [Valve Clearance Adjustment Specifications](#) to determine which valves that can be adjusted when the engine is at Top Dead Center. Tighten the valve lash lock nut to **22 N·m (16 lb ft)**.

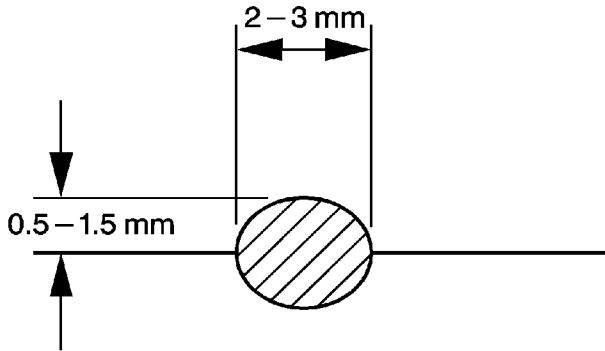


5. Rotate the crankshaft one revolution to bring the number 1 cylinder at Top Dead Center of the exhaust stroke.

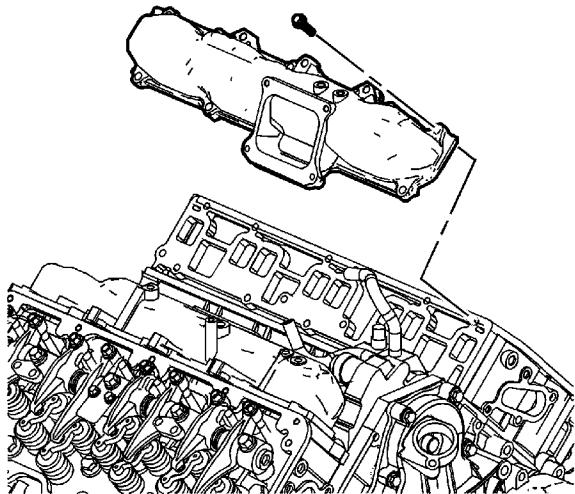


6. Adjust the valve lash to 0.3 mm (0.012 in). Refer to [Valve Clearance Adjustment Specifications](#) to determine which valves that can be adjusted when the engine is at Top Dead Center. Tighten the valve lash lock nut to **22 N·m (16 lb ft)**.

Intake Manifold Installation - Left Side

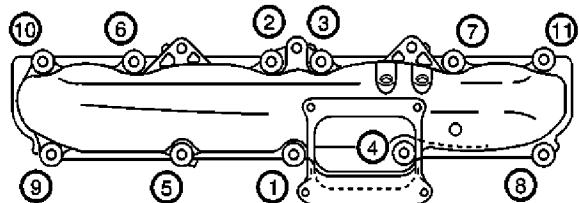


1. Apply a 2-3 mm wide by 0.5-1.5 mm high bead of GM P/N 12378521 (Canadian P/N 88901148) sealant on the intake manifold mating surface.



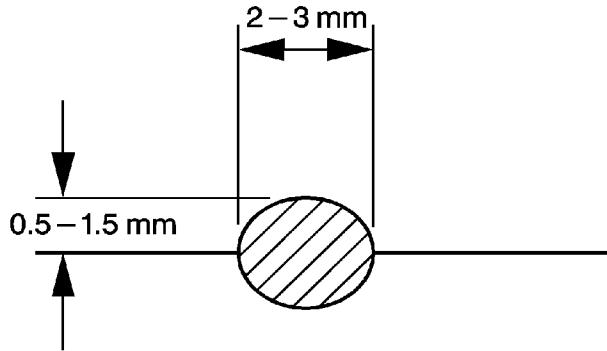
2. Install the intake manifold.

Caution: Refer to [Fastener Caution](#) in the Preface section.

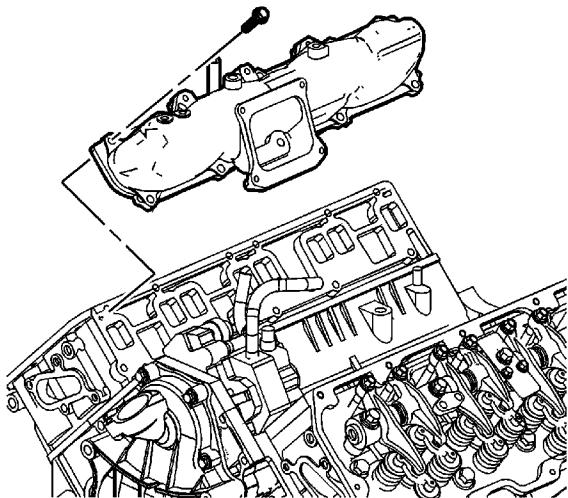


3. Install the intake manifold bolts and nuts and tighten to **25 N·m (18 lb ft)**.

Intake Manifold Installation - Right Side

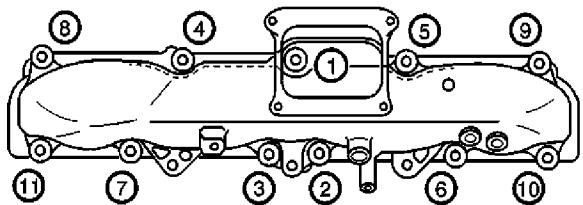


1. Apply a 2-3 mm wide by 0.5-1.5 mm high bead of GM P/N 12378521 (Canadian P/N 88901148) sealant on the intake manifold mating surface.



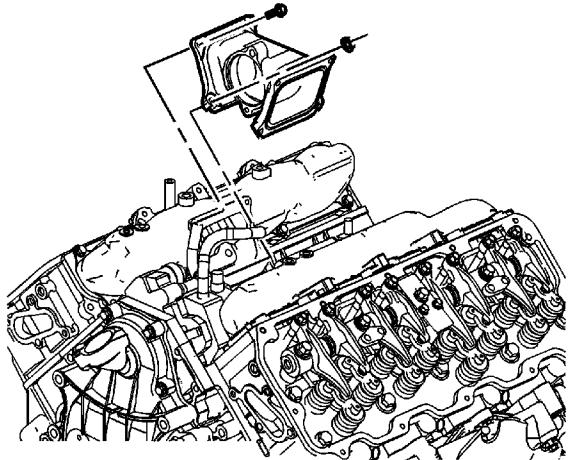
2. Install the intake manifold.

Caution: Refer to [Fastener Caution](#) in the Preface section.



3. Install the intake manifold bolts and nuts and tighten to **25 N·m (18 lb ft)**.

Intake Manifold Crossover Installation

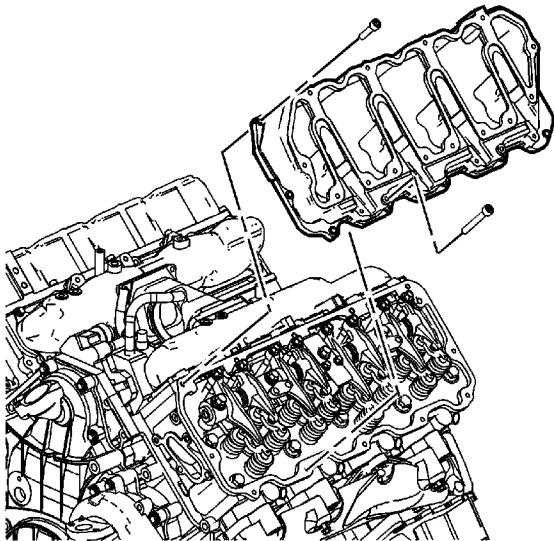


1. Install the intake manifold crossover gaskets.
2. Install the intake manifold crossover.

Caution: Refer to [Fastener Caution](#) in the Preface section.

3. Install the intake manifold crossover nuts and bolts in sequence. Tighten the intake manifold crossover nuts and bolts to **10 N·m (89 lb in)**.

Valve Rocker Arm Cover Installation - Lower Left Side

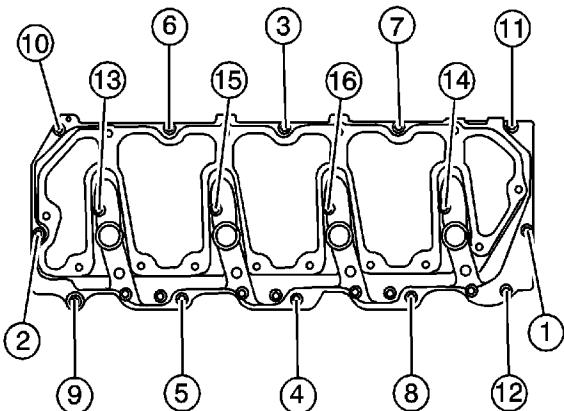


1. Install NEW valve rocker arm cover grommets and use NEW valve rocker arm cover bolts if they are serviced with the grommet.

Note: The gasket may be reused if it is not torn, cracked, stretched, or swollen.

2. Install the lower valve rocker arm cover.

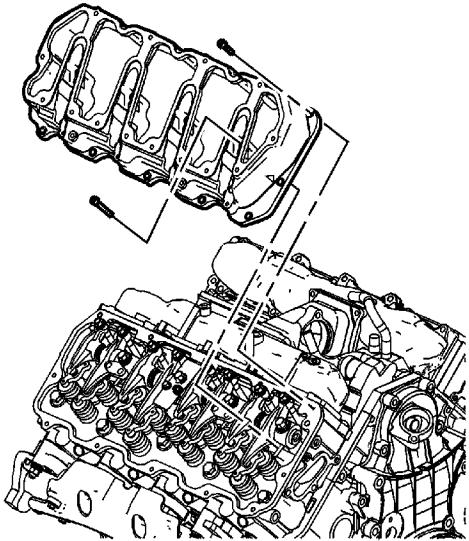
Caution: Refer to [Fastener Caution](#) in the Preface section.





3. Install the lower valve rocker arm cover bolts.
 - 3.1. Tighten the lower valve rocker arm cover bolts in the proper sequence to **10 N·m (89 lb in)**.
 - 3.2. Retighten the lower valve rocker arm cover bolts in the proper sequence to the same torque, **10 N·m (89 lb in)**.

Valve Rocker Arm Cover Installation - Lower Right Side

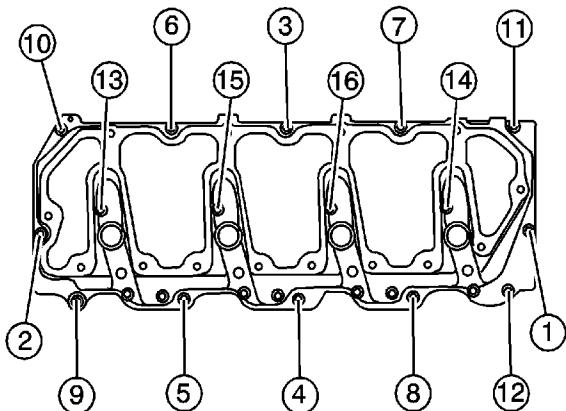


1. Install NEW valve rocker arm cover grommets and use NEW valve rocker arm cover bolts if they are serviced with the grommet.

Note: The gasket may be reused if it is not torn, cracked, stretched, or swollen.

2. Install the lower valve rocker arm cover.

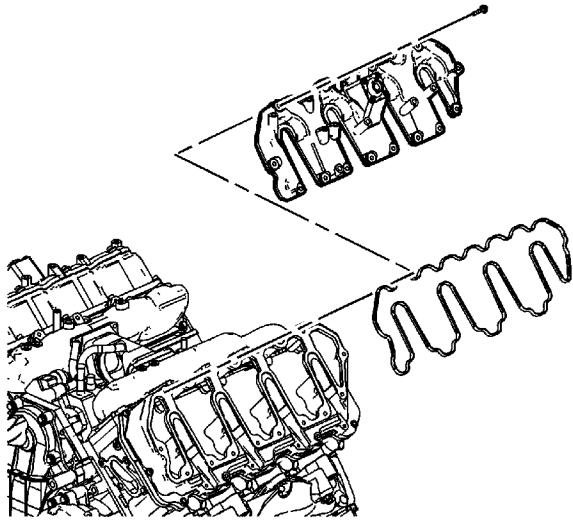
Caution: Refer to [Fastener Caution](#) in the Preface section.





3. Install the lower valve rocker arm cover bolts.
 - 3.1. Tighten the lower valve rocker arm cover bolts in the proper sequence to **10 N·m (89 lb in)**.
 - 3.2. Retighten the lower valve rocker arm cover bolts in the proper sequence to the same torque, **10 N·m (89 lb in)**.

Valve Rocker Arm Cover Installation - Upper Left Side

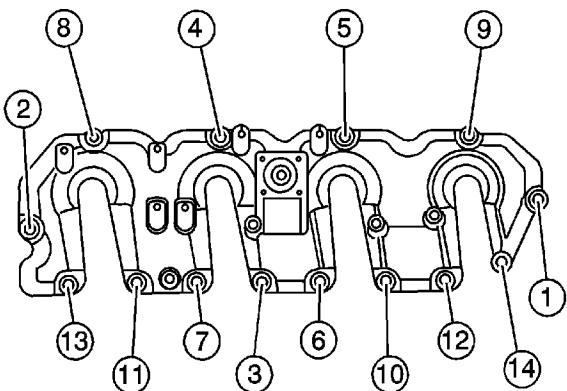


1. Install NEW valve rocker arm cover grommets and use NEW valve rocker arm cover bolts if they are serviced with the grommet.

Note: The gasket may be reused if it is not torn, cracked, stretched, or swollen.

2. Install the upper valve rocker arm cover.

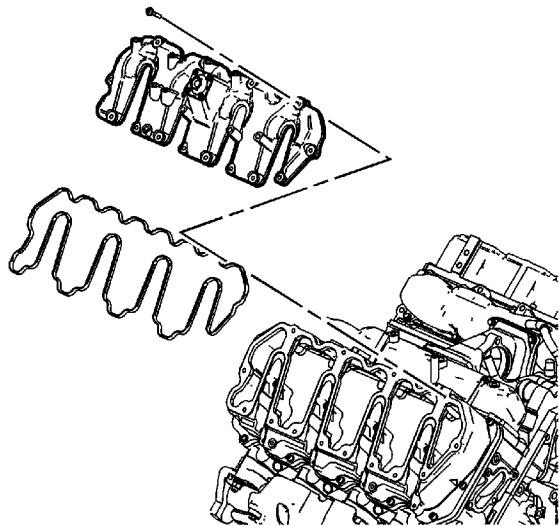
Caution: Refer to [Fastener Caution](#) in the Preface section.





3. Install the upper valve rocker arm cover bolts. Tighten the upper valve rocker arm cover bolts to **8 N·m (71 lb in)**.

Valve Rocker Arm Cover Installation - Upper Right Side

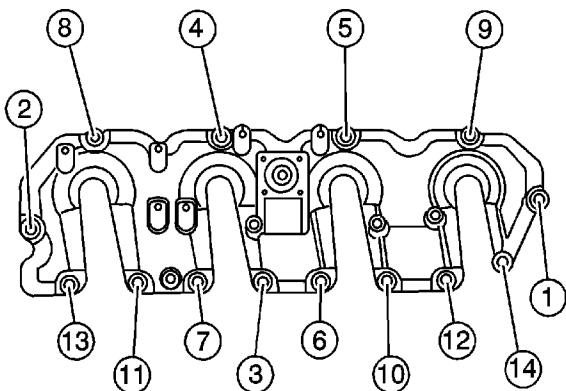


1. Install NEW valve rocker arm cover grommets and use NEW valve rocker arm cover bolts if they are serviced with the grommet.

Note: The gasket may be reused if it is not torn, cracked, stretched, or swollen.

2. Install the upper valve rocker arm cover.

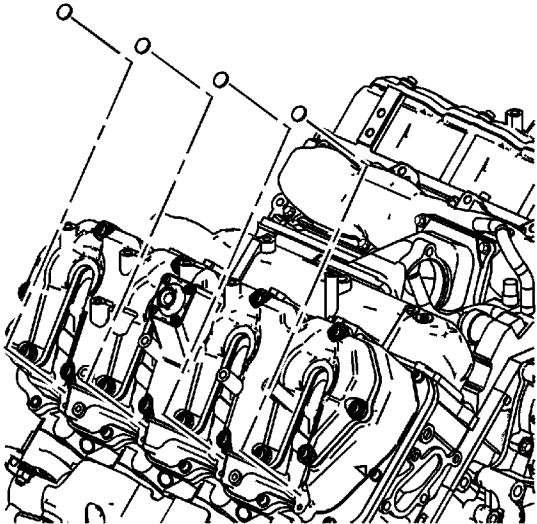
Caution: Refer to [Fastener Caution](#) in the Preface section.



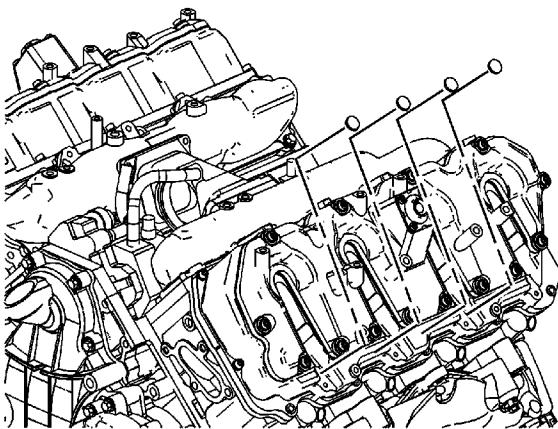


3. Install the upper valve rocker arm cover bolts. Tighten the upper valve rocker arm cover bolts in the proper sequence to **8 N·m (71 lb in)**.

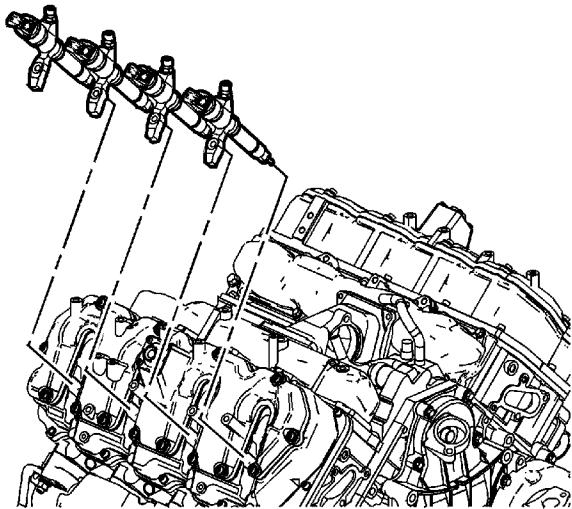
Fuel Injector Installation



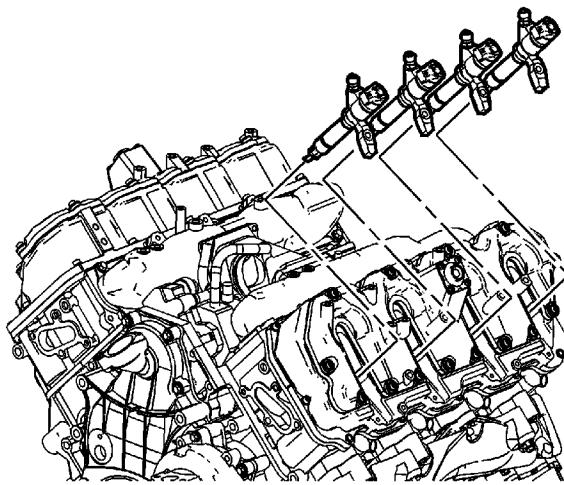
1. Install a new O-ring onto the fuel injector.
2. Lubricate the O-ring with engine oil.
3. Install a new copper washer into the fuel injector bore in the cylinder head.
4. Install the fuel injector right bracket pin.



5. Install the fuel injector left bracket pin.

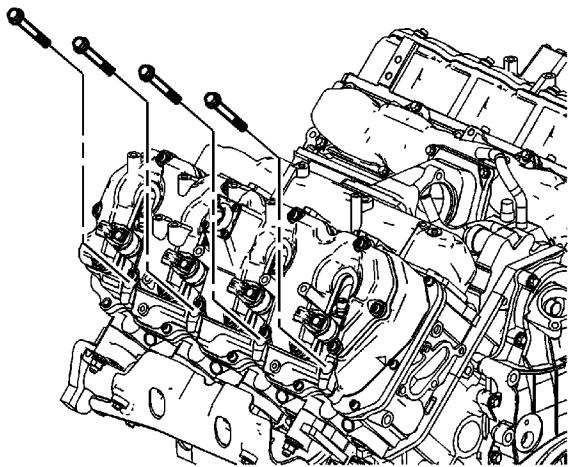


6. Install the right fuel injector with fuel injector bracket.

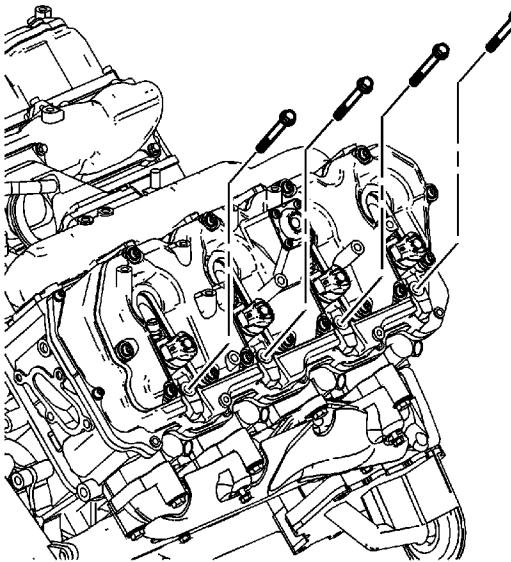


7. Install the left fuel injector with fuel injector bracket.

Caution: Refer to [Fastener Caution](#) in the Preface section.

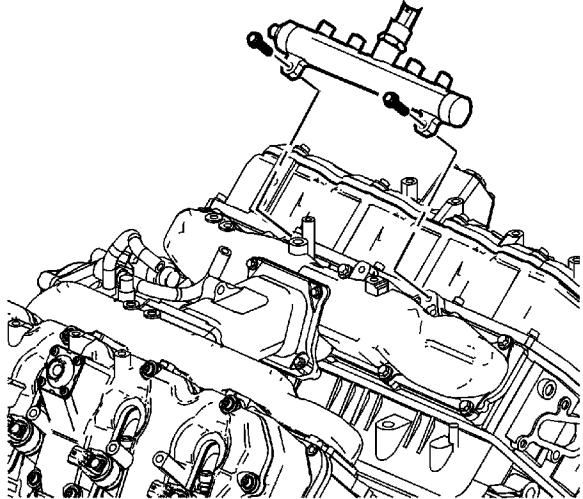


8. Install the right fuel injector bracket bolts and tighten to **30 N·m (22 lb ft)**.



9. Install the left fuel injector bracket bolts and tighten to **30 N·m (22 lb ft)**.

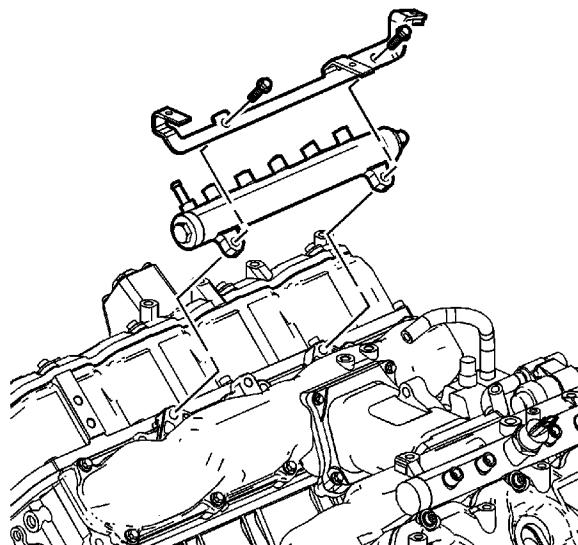
Fuel Pipes and Fuel Rail Installation



1. Install the right fuel rail.

Caution: Refer to [Fastener Caution](#) in the Preface section.

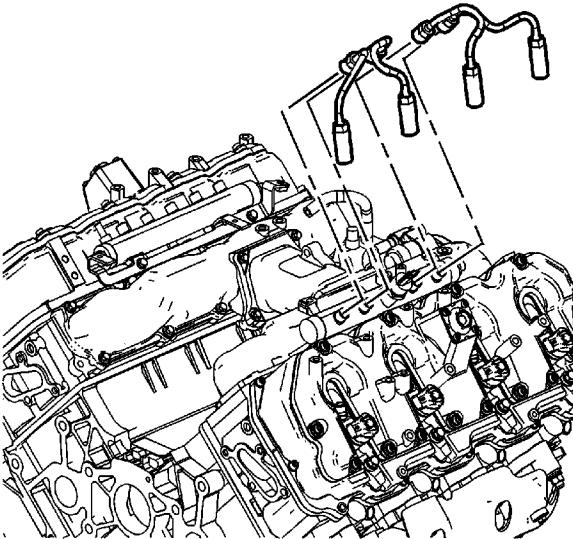
2. Install the right fuel rail mounting bolts and tighten to **25 N·m (18 lb ft)**.



3. Install the left fuel rail.

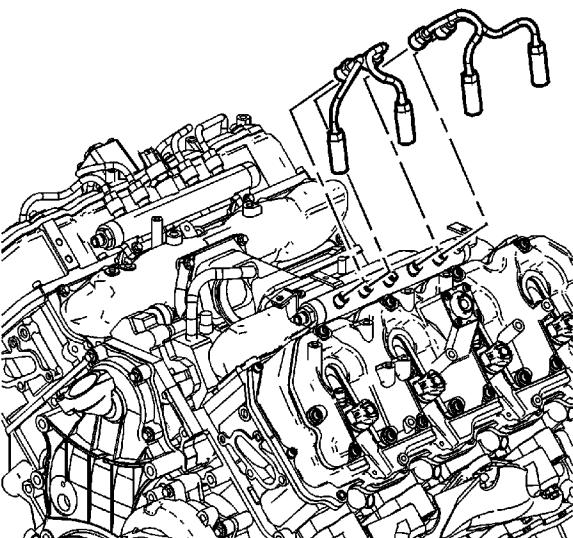
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4. Install the left fuel rail mounting bolts and tighten to **25 N·m (18 lb ft)**.



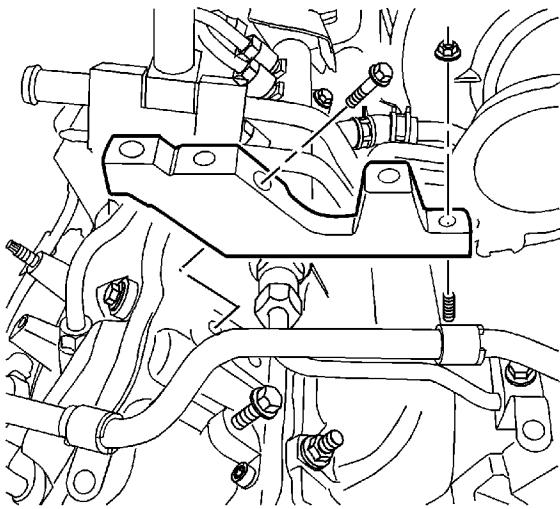
Warning: Improper torque methods of the fuel lines will result in fuel leaks and possible damage to the engine. Failure to follow proper fuel line fitting torque methods could result in serious personal injury.

5. Install the injection pipes to the right bank and tighten to **41 N·m (30 lb ft)**.

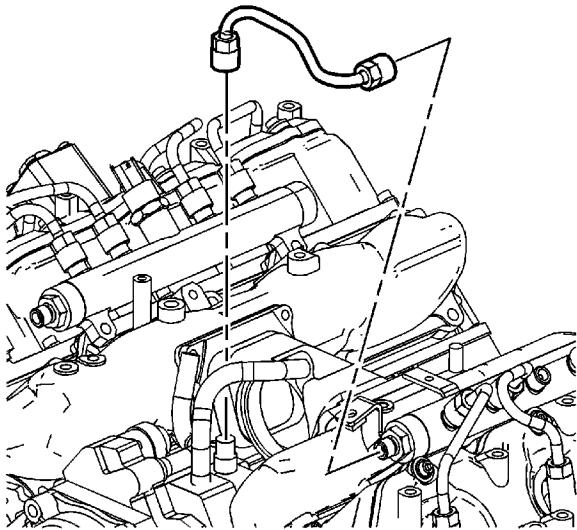


Warning: Improper torque methods of the fuel lines will result in fuel leaks and possible damage to the engine. Failure to follow proper fuel line fitting torque methods could result in serious personal injury.

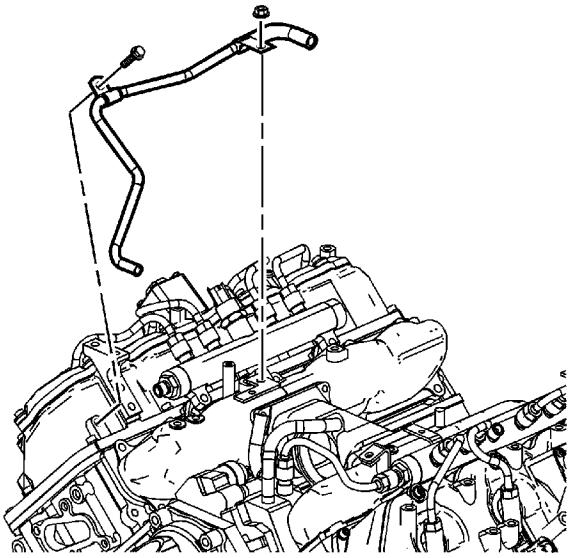
6. Install the injection pipes to the left bank and tighten to **41 N·m (30 lb ft)**.



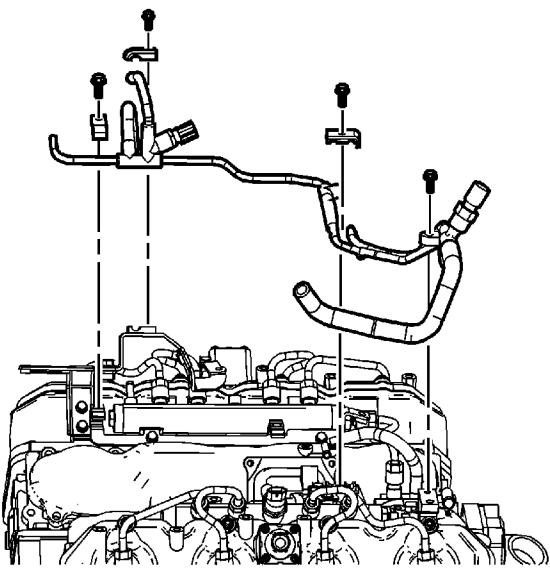
7. Install the exhaust gas recirculation (EGR) mounting brackets.
8. Install the EGR mounting bracket bolts and tighten to **20 N·m (15 lb ft)**.



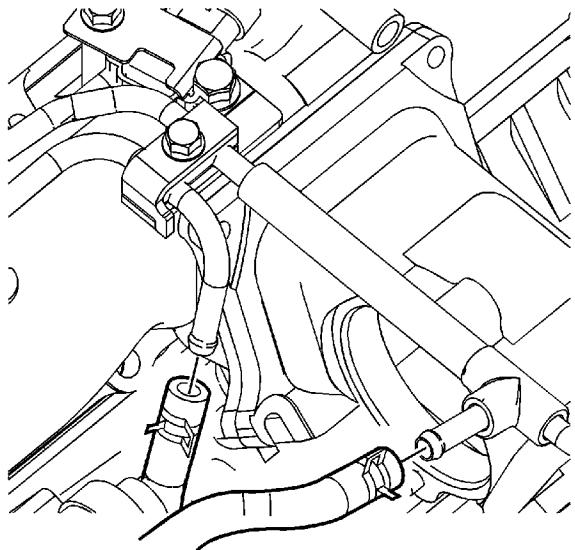
9. Install the left fuel rail to pump pipe and tighten to **41 N·m (30 lb ft)**.



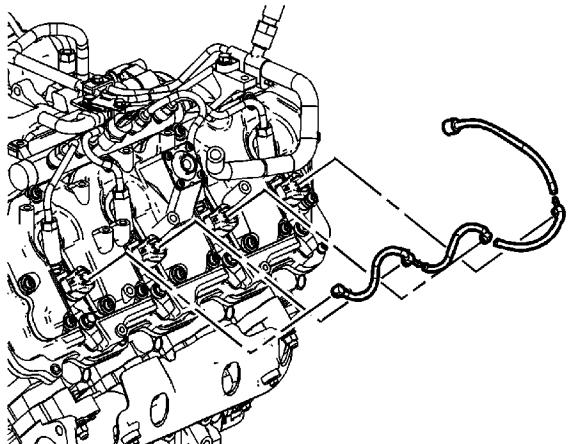
10. Install the coolant pipe.
11. Install the coolant pipe bolt and nut and tighten to **25 N·m (18 lb ft)**.



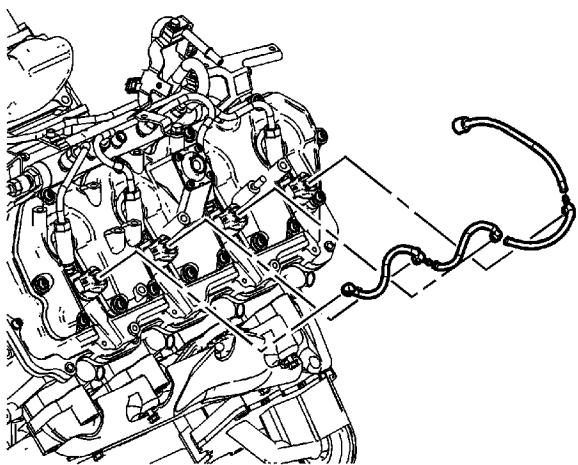
12. Install the distribution block and fuel line assembly.
13. Install the distribution block and fuel line assembly bolts. Tighten the fuel line assembly bolts to **25 N·m (18 lb ft)**.



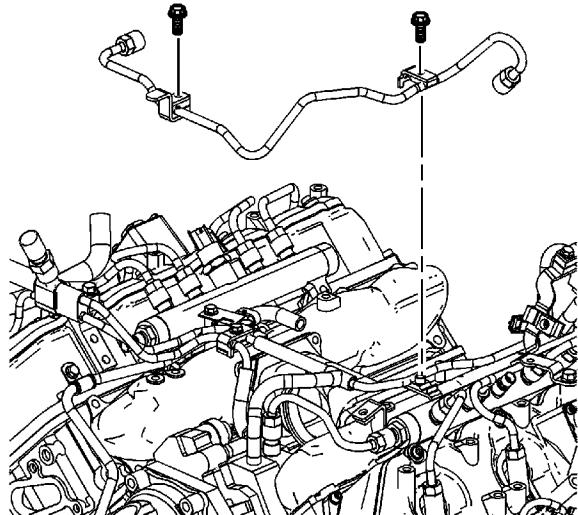
14. Connect the fuel hoses to the fuel injector pump.



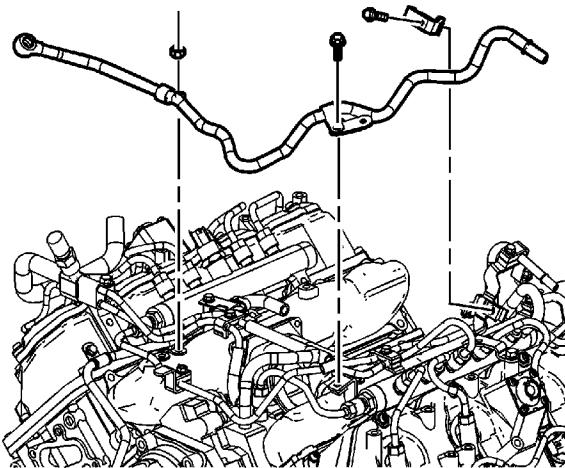
15. Install the right fuel return hose.



16. Install the left fuel return hose.

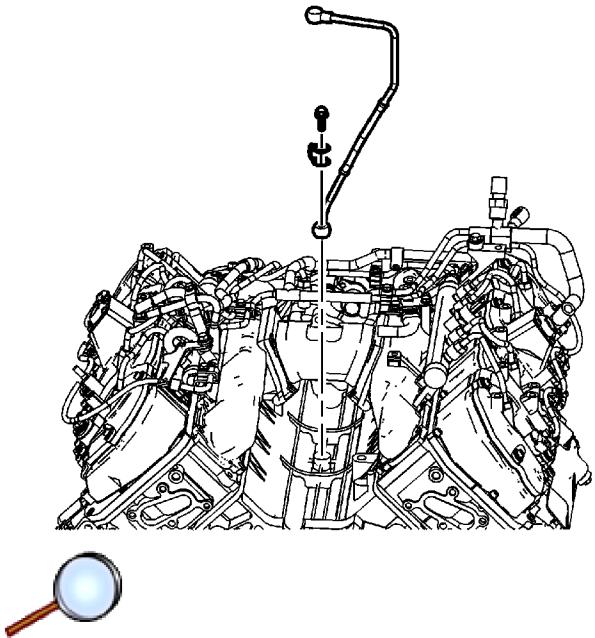


17. Install the fuel rail balance pipe.
18. Install the fuel rail balance pipe bolts and tighten to **21 N·m (15 lb ft)**.
19. Connect the fuel rail balance pipe to the fuel rails. Tighten the fuel rail balance pipe nuts to **41 N·m (30 lb ft)**.



20. Install the fuel feed pipe.
21. Install the fuel feed pipe attaching nuts and bolts. Tighten the fuel feed pipe bolts and nut to **25 N·m (18 lb ft)**.

Turbocharger Installation



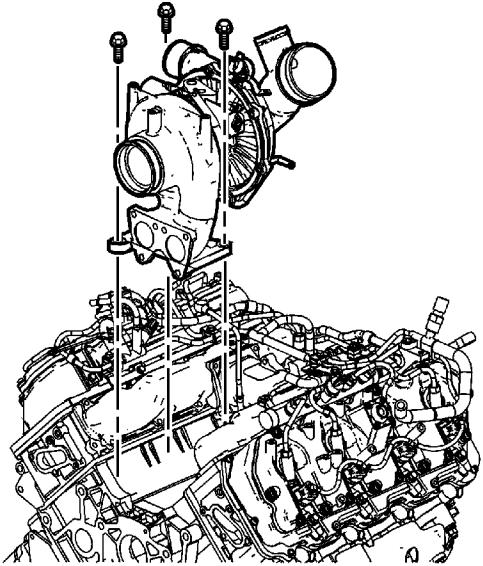
Caution: Do not twist the turbocharger oil feed pipe. Twisting of the feed pipe will result in the collapse and deformation of the plastic pipe, restricting oil flow and causing turbocharger damage. During turbocharger replacement, gently push the oil feed pipe towards the front of the engine to clear the turbocharger. Assistance may be required to keep the pipes clear of the turbocharger during removal or installation.

1. Install the turbocharger oil supply line to the engine block.

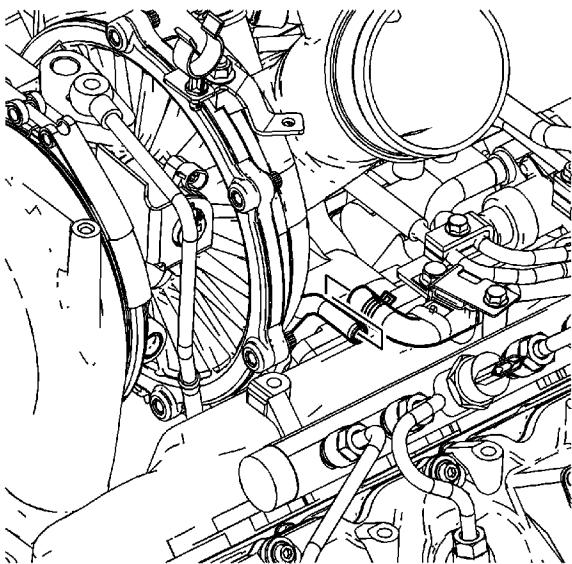
Caution: Refer to [Fastener Caution](#) in the Preface section.

Note: Lubricate the washers with diesel fuel before installing.

2. Install the turbocharger oil supply line eye bolt and washers. Tighten the turbocharger oil supply line eye bolt to **26 N·m (19 lb ft)**.
3. Install the turbocharger lower heat shield to the engine block.

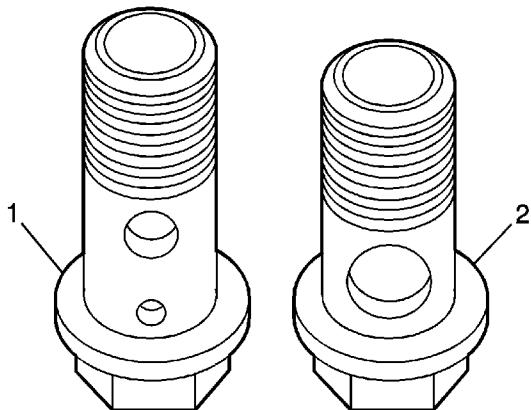


4. Install the turbocharger assembly with the oil return pipe.
5. Install the turbocharger mounting bolts and tighten to **108 N·m (80 lb ft)**.



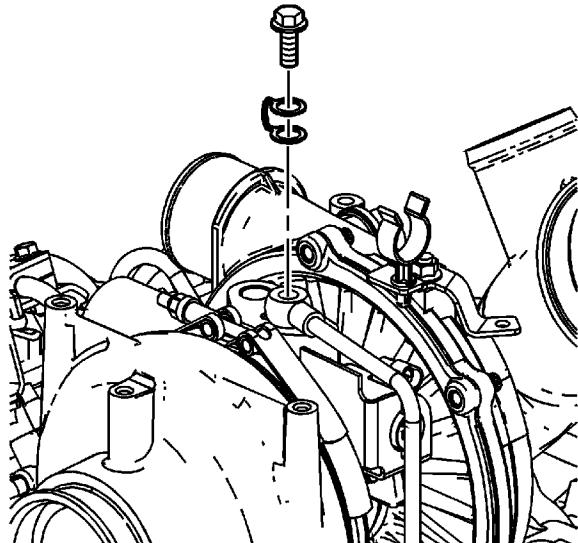
Note: Use care not to damage this hose during the procedure.

6. Install the turbocharger cooling outlet hose and tighten hose clamp.



Note: If the cooling outlet hose eye bolts were removed, install the longer bolt (1) with two holes, in the top location. Install the shorter bolt (2) in the lower location.

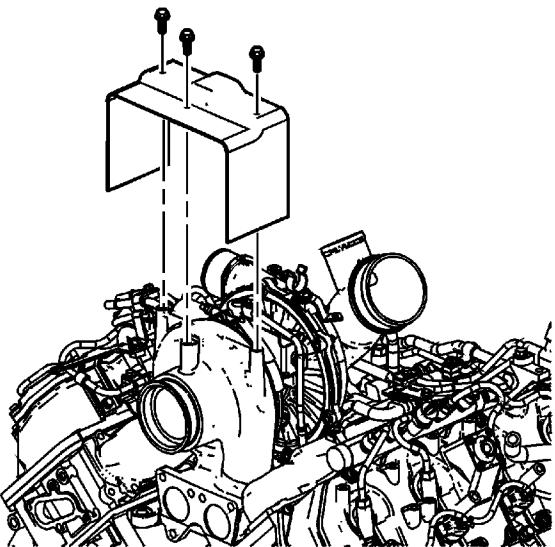
7. Install the cooling outlet hose eye bolts.



Caution: Do not twist the turbocharger oil feed pipe. Twisting of the feed pipe will result in the collapse and deformation of the plastic pipe, restricting oil flow and causing turbocharger damage. During turbocharger replacement, gently push the oil feed pipe towards the front of the engine to clear the turbocharger. Assistance may be required to keep the pipes clear of the turbocharger during removal or installation.

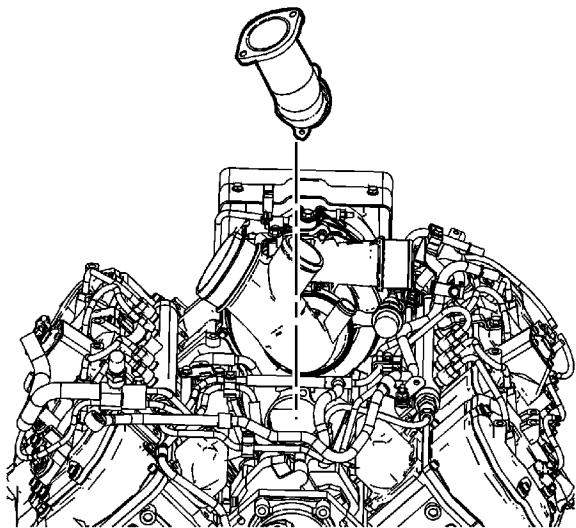
8. Install the oil supply line eye bolt and washers to the turbocharger.

Lubricate the washers with diesel fuel before installing. Tighten the oil supply hose eye bolt to **26 N·m (19 lb ft)**.

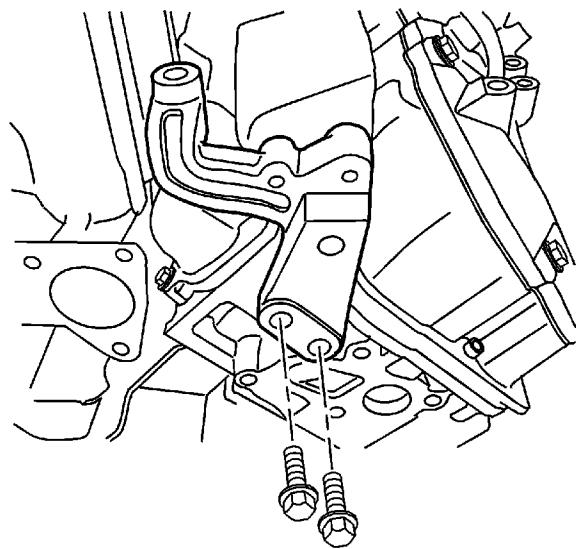


9. Install the turbocharger heat shield.
10. Install the turbocharger upper heat shield bolts and tighten to **10 N·m (89 lb in)**.

Exhaust Gas Recirculation Valve and Cooler Installation



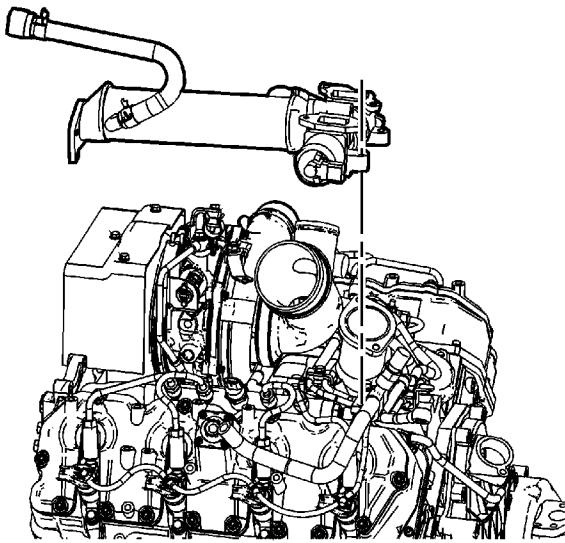
1. Install the intake manifold tube.



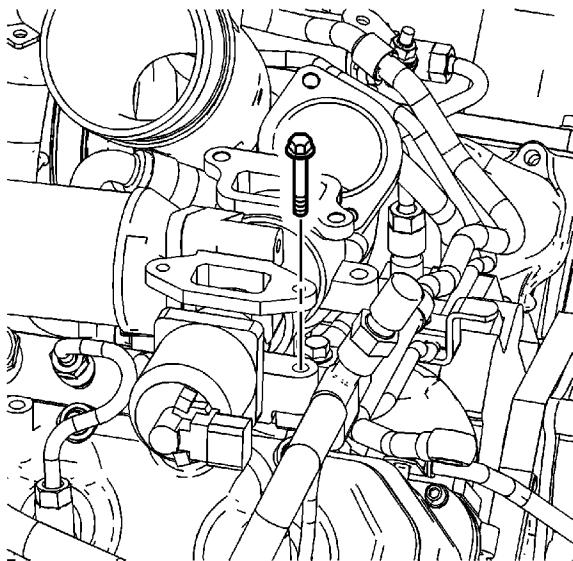
2. Install the exhaust gas recirculation (EGR) cooler bracket.

Caution: Refer to [Fastener Caution](#) in the Preface section.

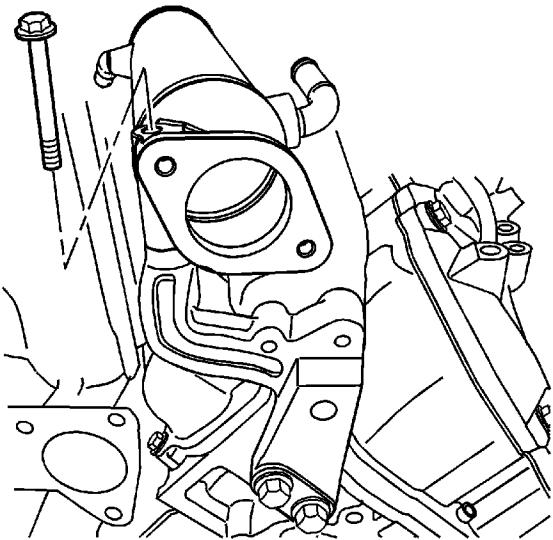
3. Install the EGR cooler bracket bolts and tighten to **25 N·m (18 lb ft)**.
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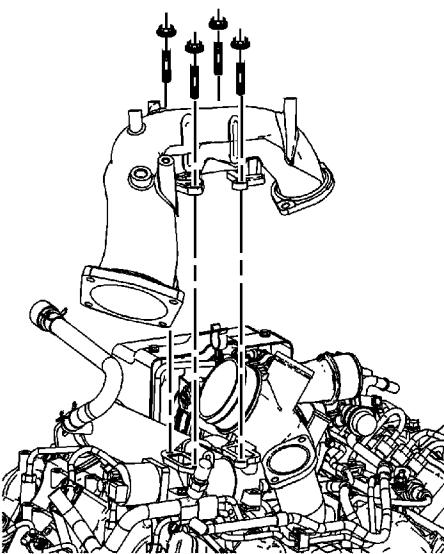
4. Install the EGR and cooler.



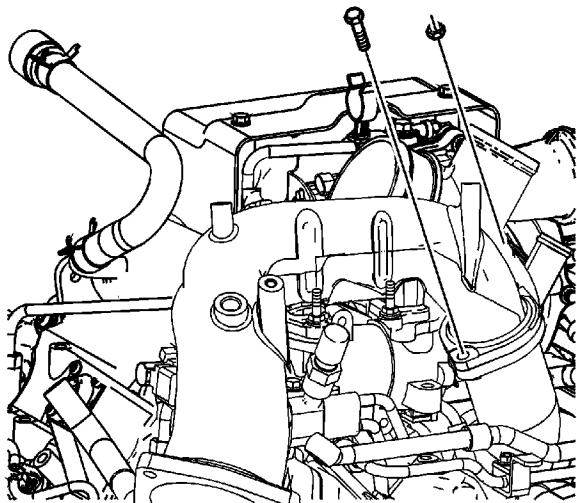
5. Install the EGR mount bolt and tighten to **50 N·m (37 lb ft)**.



6. Install the top EGR cooler bolts and tighten to **25 N·m (18 lb ft)**.

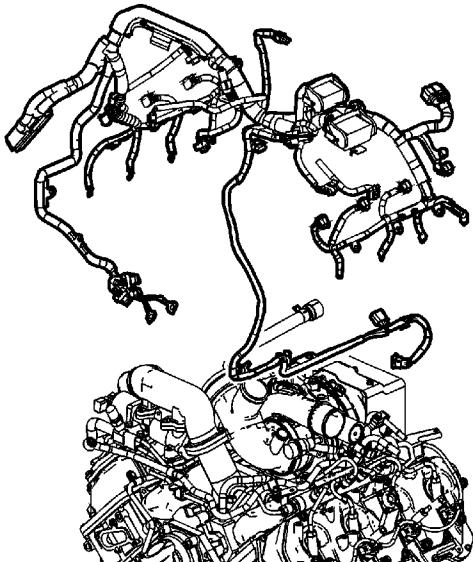


7. Install the air inlet tube.
8. Install the air inlet tube nuts and tighten to **25 N·m (18 lb ft)**.



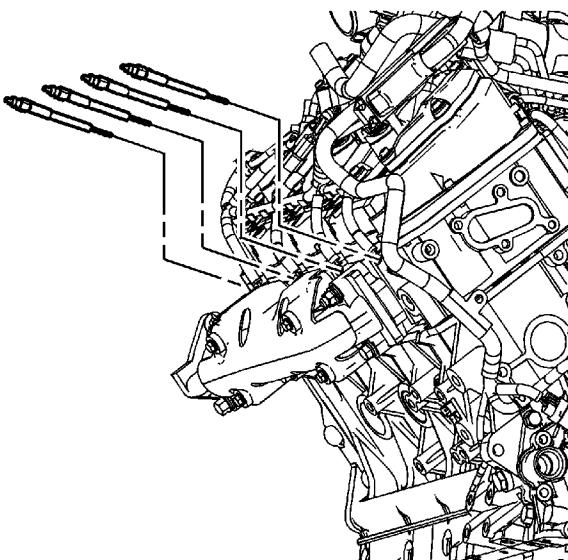
9. Install the air inlet tube to intake manifold tube bolt and nut. Tighten the air inlet tube to intake manifold tube bolt and nut to **25 N·m (18 lb ft)**.

Engine Wiring Harness Assembly Installation

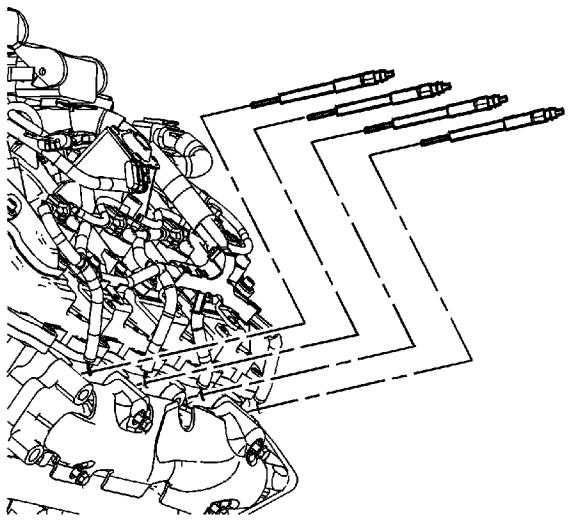


1. Install the engine wiring harness assembly.

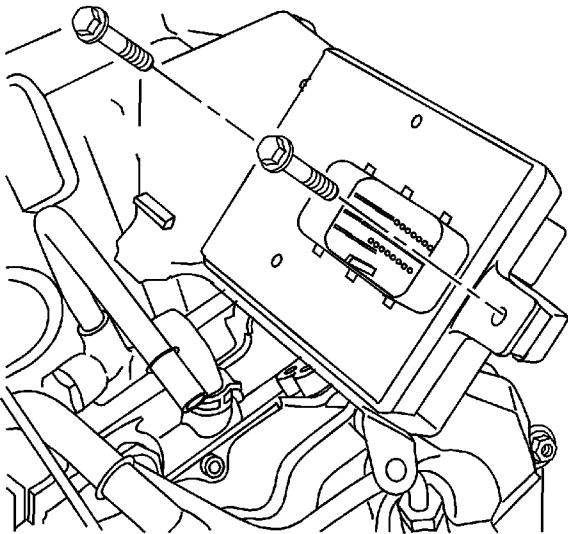
Caution: Refer to [Fastener Caution](#) in the Preface section.



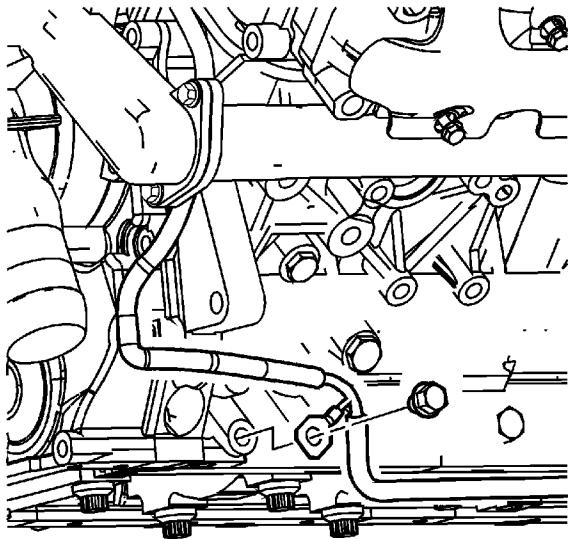
2. Install the right glow plugs and tighten to **18 N·m (13 lb ft)**.
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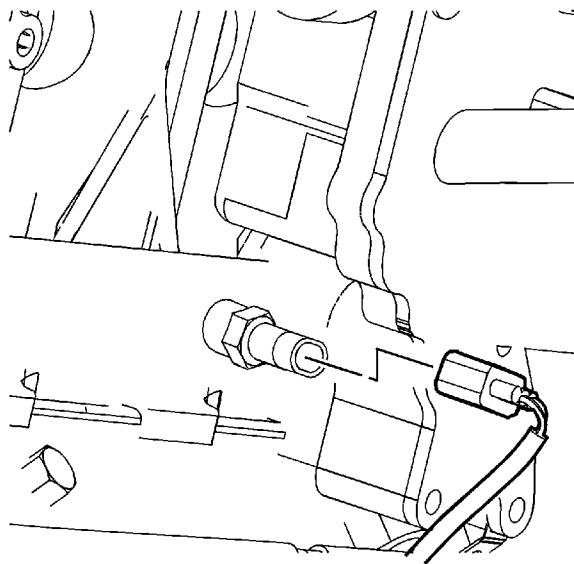
3. Install the left glow plugs tighten to **18 N·m (13 lb ft)**.



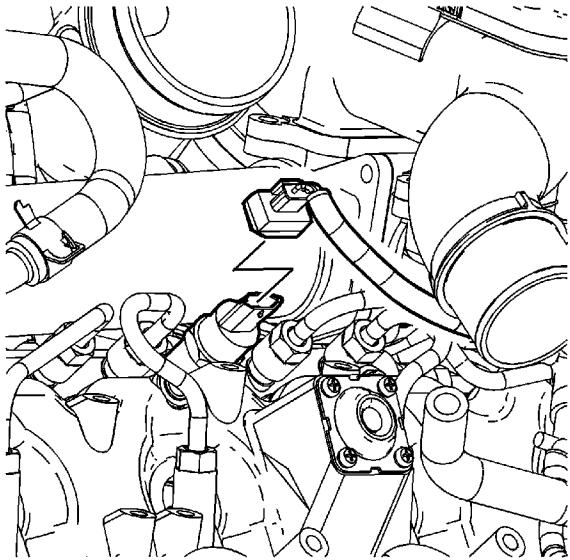
4. Install the glow plug nuts and tighten to **2 N·m (18 lb in)**.
5. Install the glow plug controller.
6. Install the glow plug controller bolts and tighten to **10 N·m (89 lb in)**.



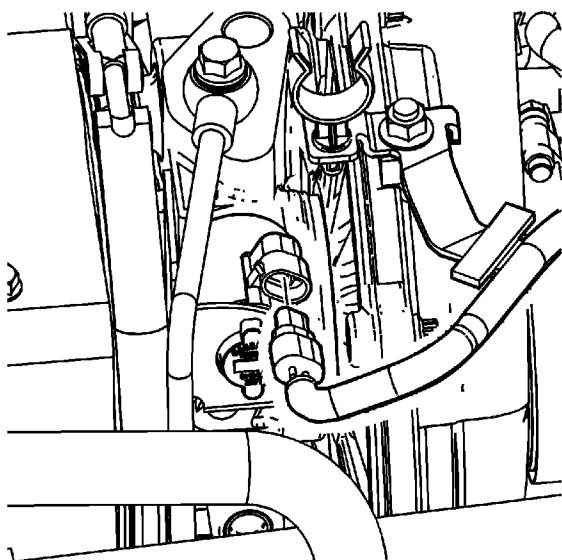
7. Install the oil level sensor harness bolt and tighten to **40 N·m (29 lb ft)**.



8. Connect the oil pressure sensor electrical connector.

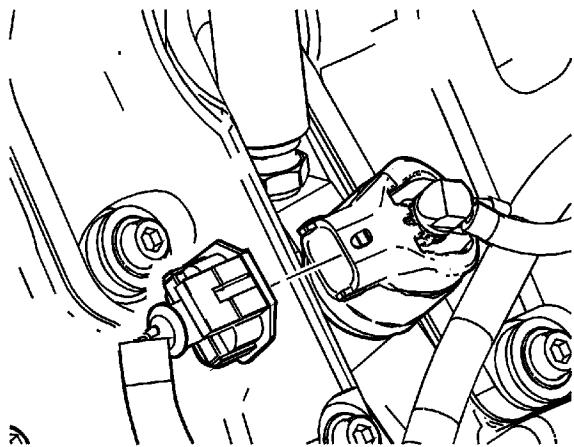


- 
9. Connect the fuel rail pressure sensor.

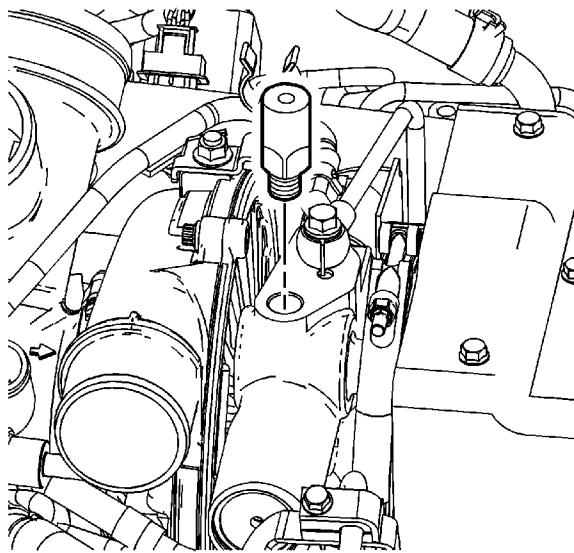


Caution: Label all the injector electrical connectors before the connectors are removed in order to prevent reconnecting to the wrong injector. Failure to properly connect the injectors in the correct sequence will cause severe engine damage.

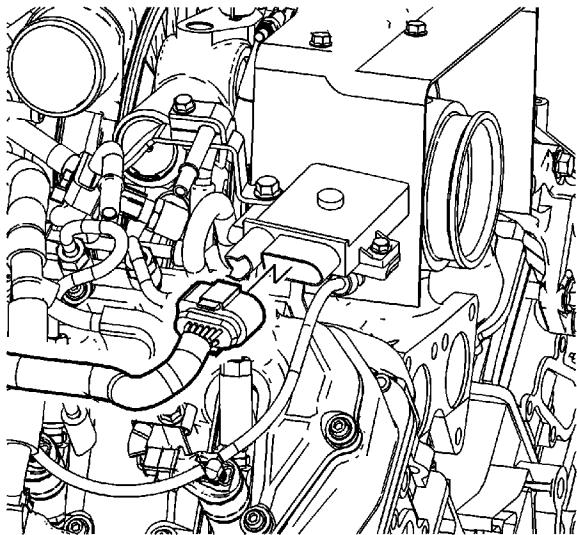
10. Connect the turbocharger vane control solenoid valve.



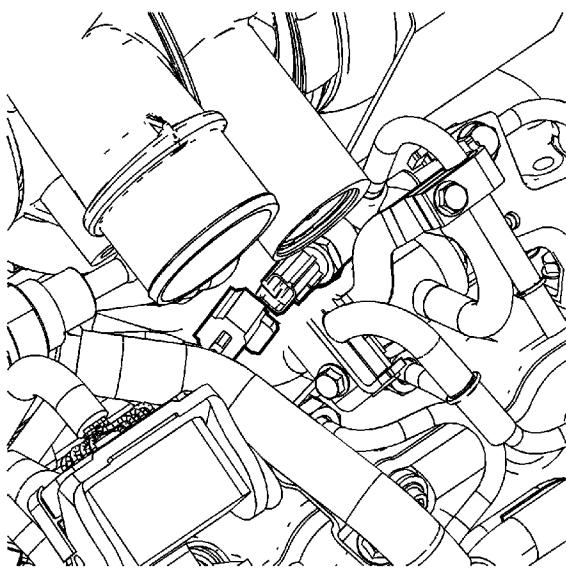
11. Connect the fuel injector electrical connections.



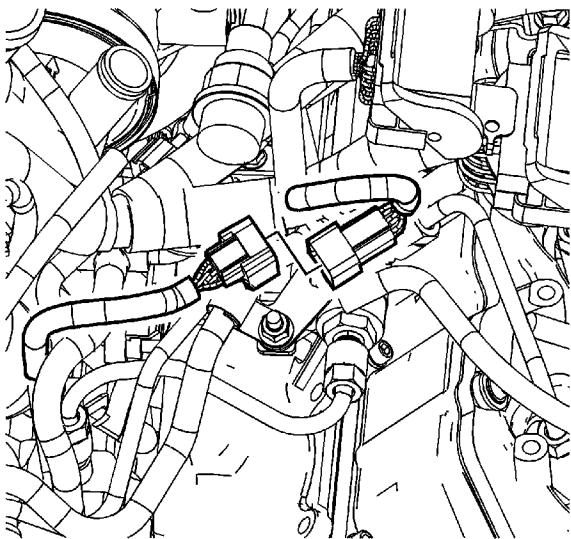
12. Connect and install the turbocharger vane position sensor. Tighten the turbocharger vane position sensor to **23 N·m (16 lb ft)**.



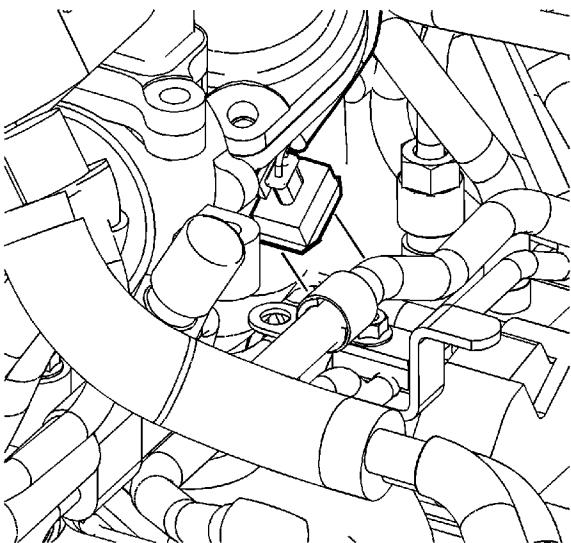
13. Connect the glow plug controller electrical connector.



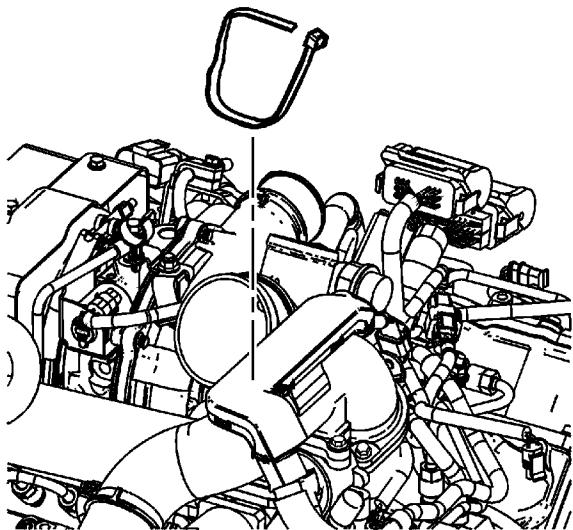
14. Connect the fuel temperature sensor connector.



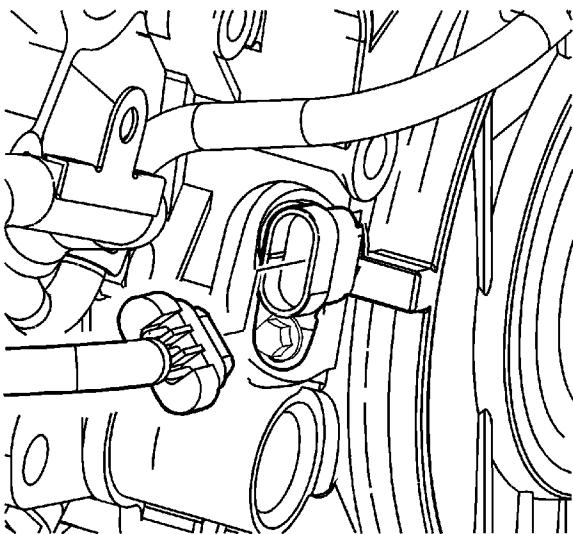
15. Connect the oil level sensor electrical harness connector.



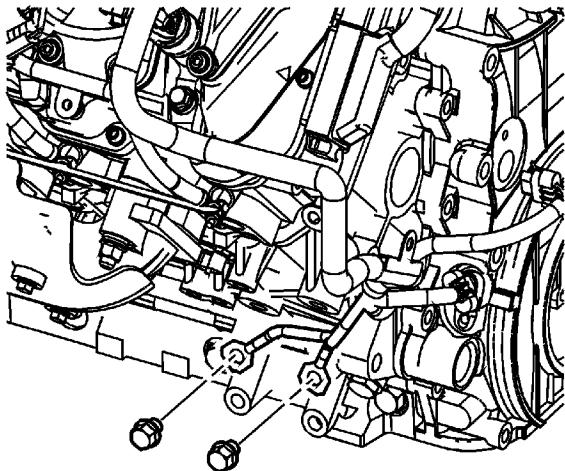
16. Connect the fuel pressure control valve electrical connector.



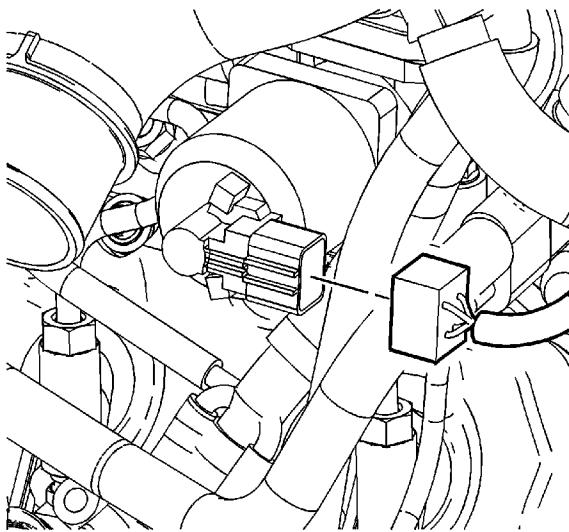
17. Install the tie strap to the electrical harness.



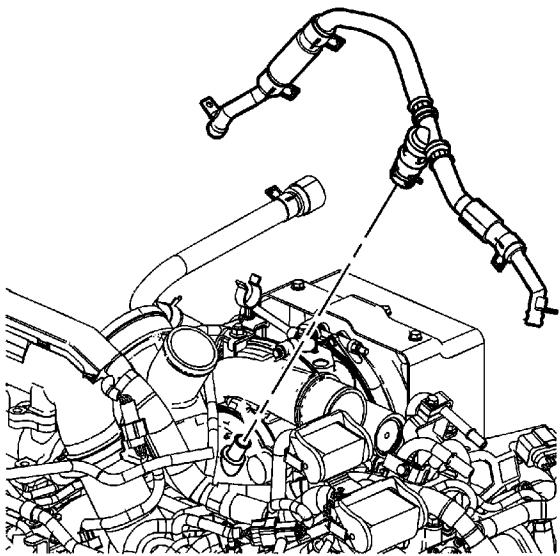
18. Connect the crankshaft position sensor electrical connector.



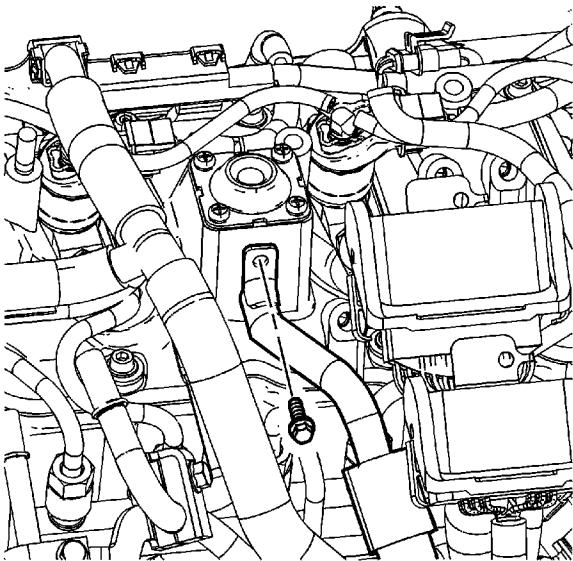
19. Install the two ground bolts and tighten to **41 N·m (30 lb ft)**.



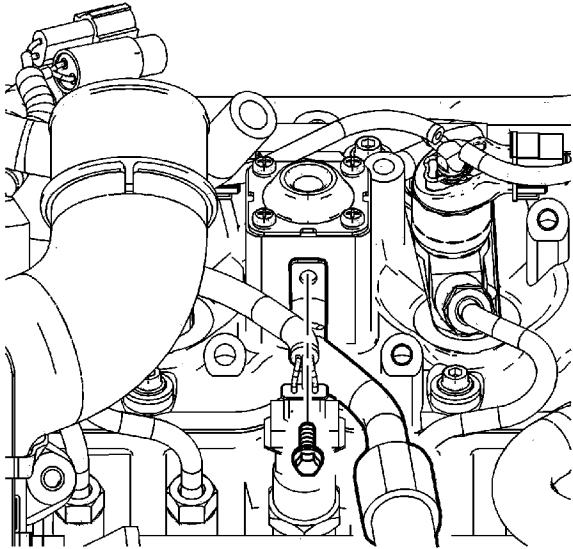
20. Connect the EGR valve electrical connector.



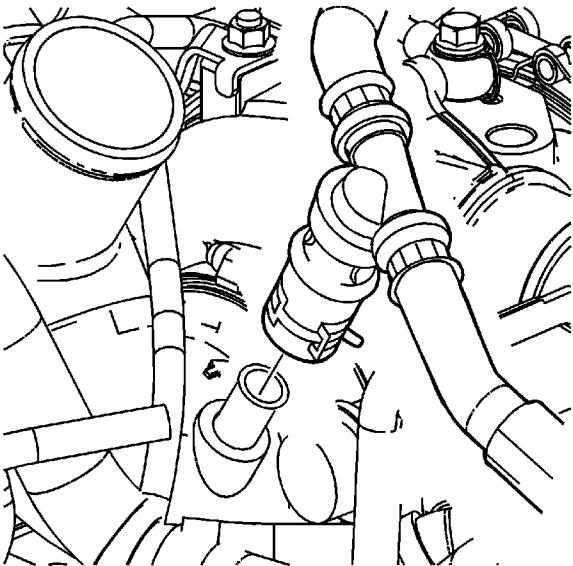
21. Install the positive crankcase ventilation (PCV) pipe.



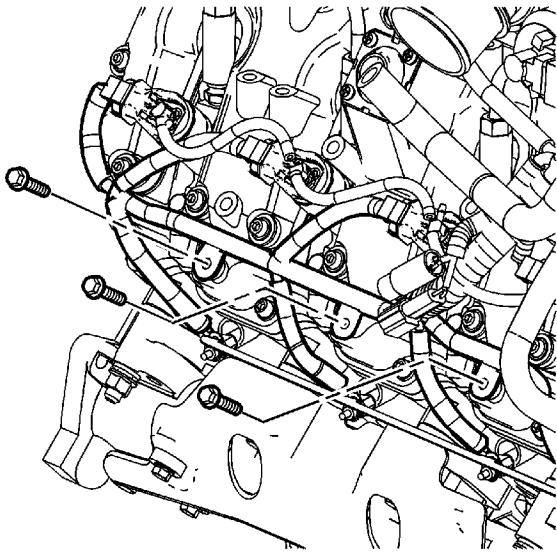
22. Install the left PCV pipe bolt and tighten to **25 N·m (18 lb ft)**.



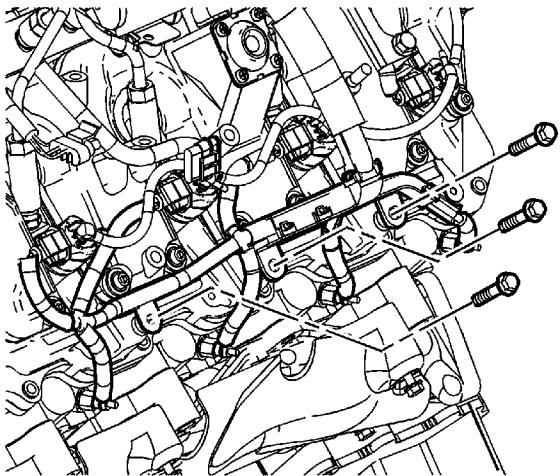
23. Install the right PCV pipe bolt and tighten to **25 N·m (18 lb ft)**.



24. Connect the PCV hose clamp.

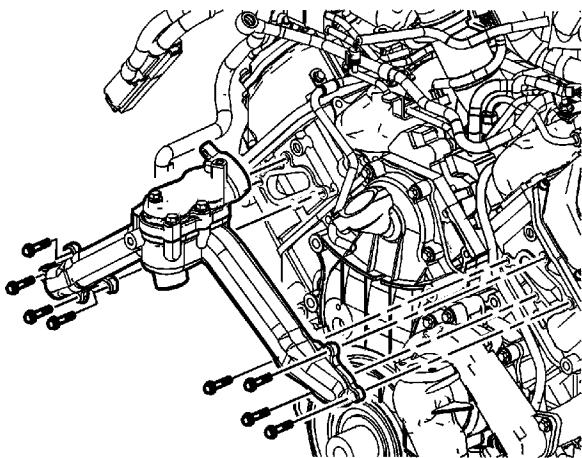


25. Install the right glow plug harness bracket bolts and tighten to **10 N·m (89 lb in)**.



26. Install the left glow plug harness bracket bolts and tighten to **10 N·m (89 lb in)**.

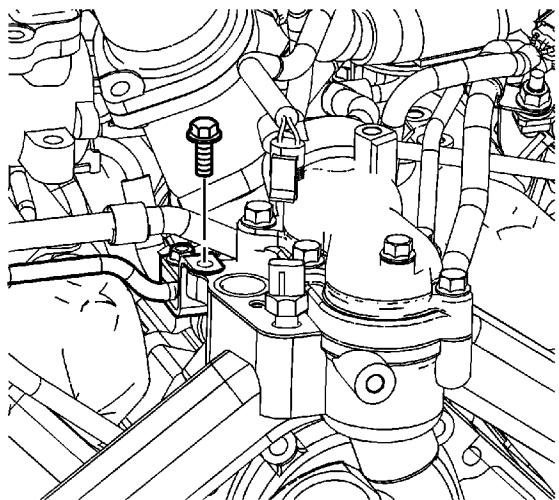
Engine Coolant Thermostat Housing Installation



1. Install the thermostat housing.
2. Install the thermostat housing bolts and nuts.

Tighten

Tighten the thermostat housing bolts and nuts to 25 N·m (18 lb ft).

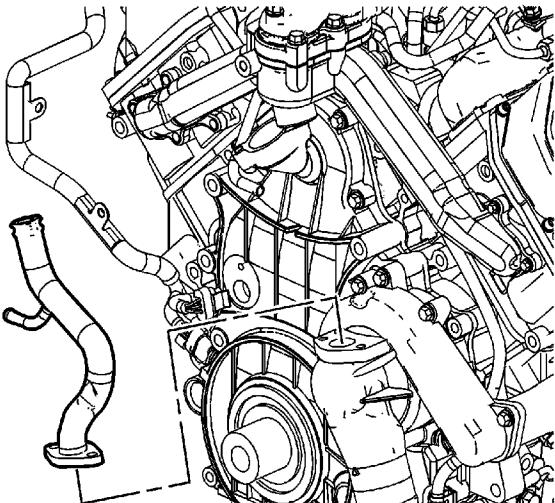




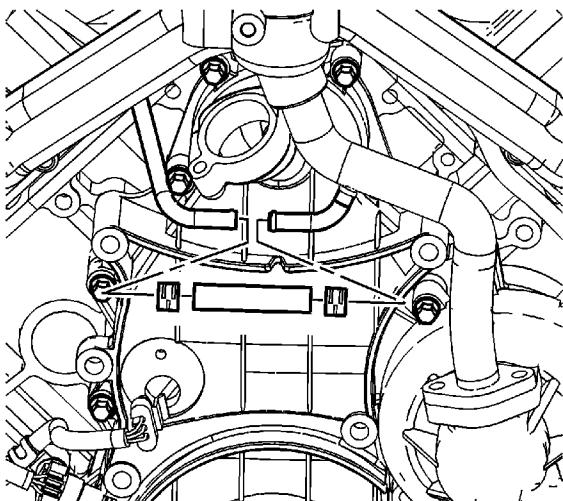
3. Install the fuel pipe bracket bolt.

Tighten

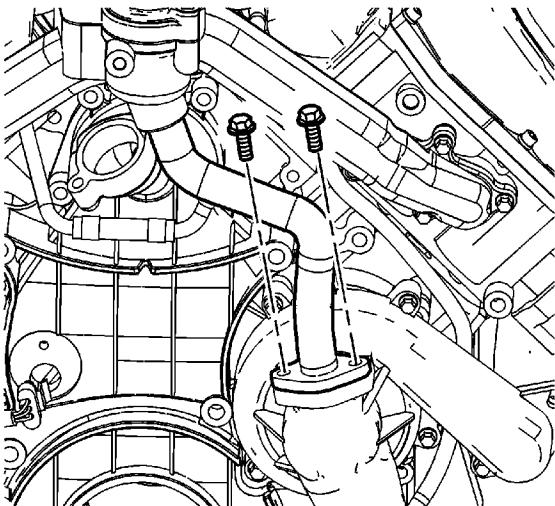
Tighten the fuel pipe bracket bolt to 25 N·m (18 lb ft).



4. Install the water pump inlet pipe.



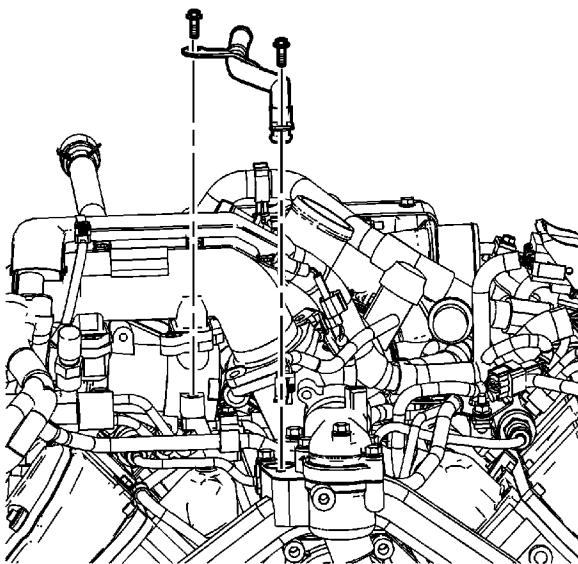
5. Install the turbocharger coolant outlet hose and clamps.



-  6. Install the water pump inlet pipe bolts.

Tighten

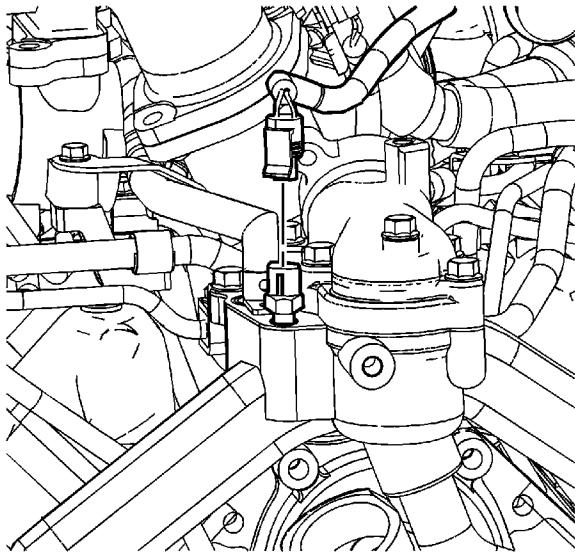
Tighten the water pump inlet pipe bolts to 25 N·m (18 lb ft).



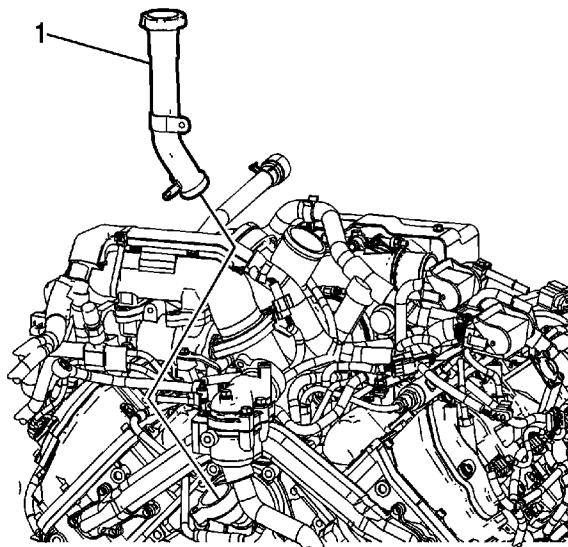
-  7. Install the EGR coolant pipe.
- 8. Install the EGR coolant pipe bolts.

Tighten

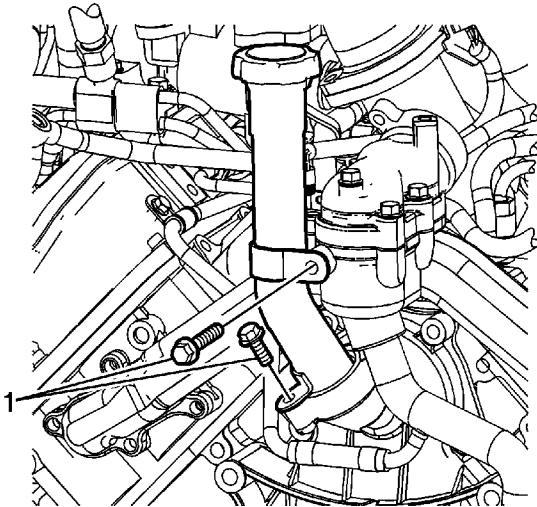
Tighten the EGR coolant pipe bolts to 25 N·m (18 lb ft).



9. Connect the coolant temperature sensor.



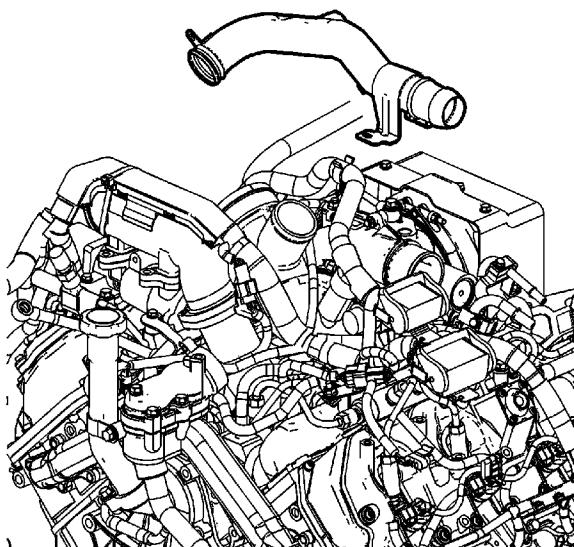
10. Install the oil fill tube.



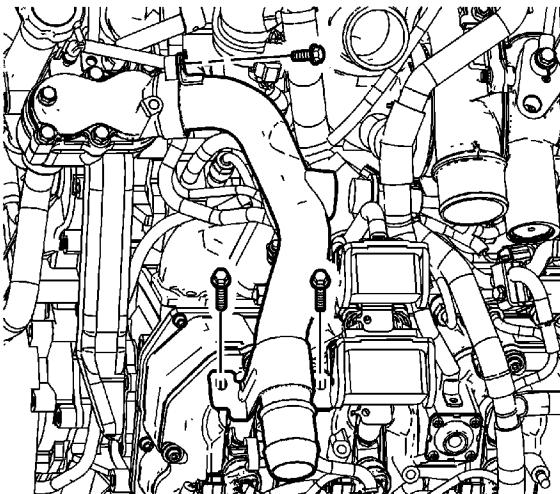
11. Install the oil fill tube bolts.

Tighten

Tighten the oil fill tube bolts to 25 N·m (18 lb ft).



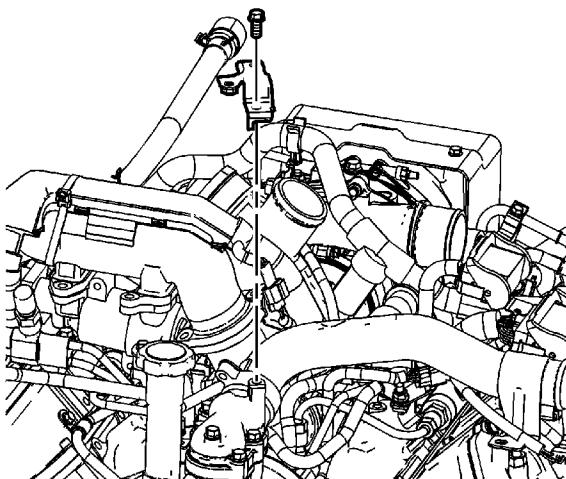
12. Install the water outlet.



13. Install the water outlet bolts.

Tighten

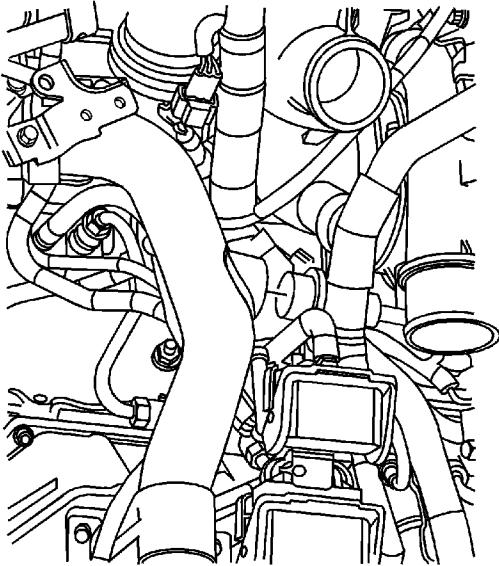
Tighten the water outlet bolts to 25 N·m (18 lb ft).



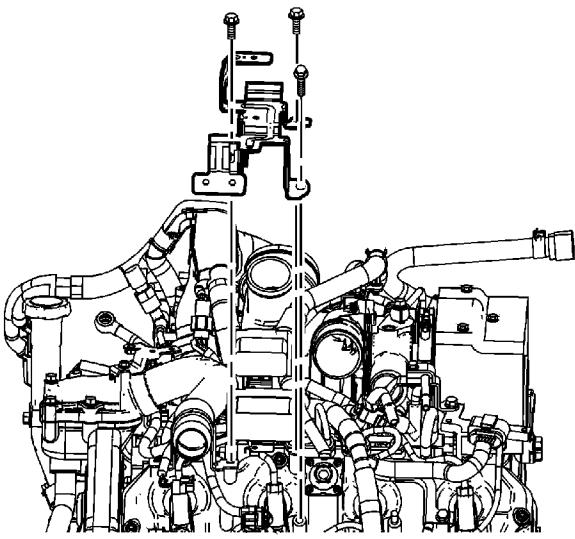
14. Install the electrical harness bracket.
15. Install the electrical harness bracket bolt.

Tighten

Tighten the electrical harness bracket bolt to 10 N·m (89 lb in).



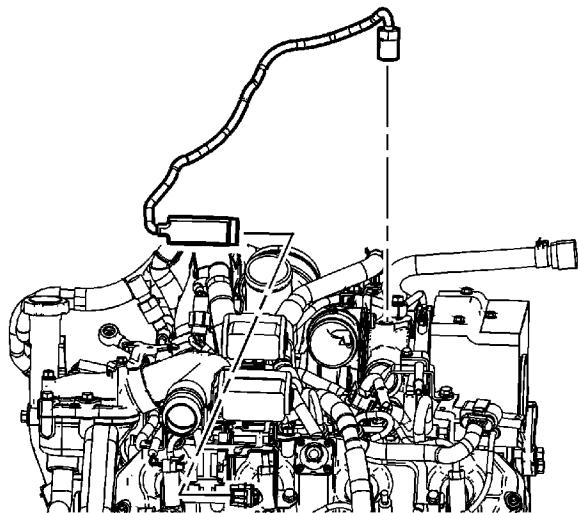
16. Connect the turbocharger coolant inlet hose.



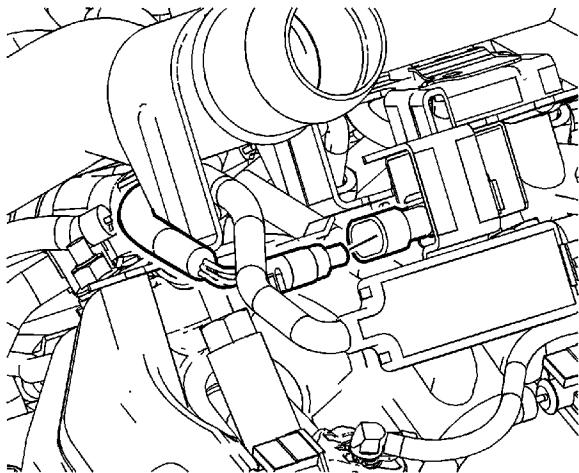
17. Install the main electrical harness bracket.
18. Install the main electrical harness bracket bolts.

Tighten

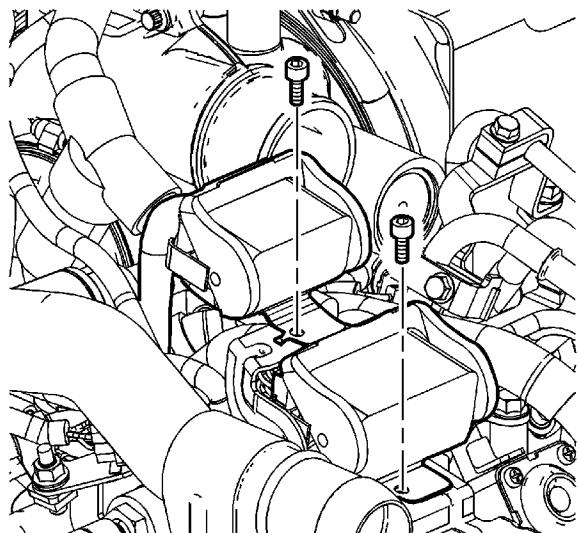
Tighten the main electrical harness bracket bolts to 10 N·m (89 lb in).



19. Connect and install the turbocharger vane position sensor.



20. Connect and install the barometric sensor.

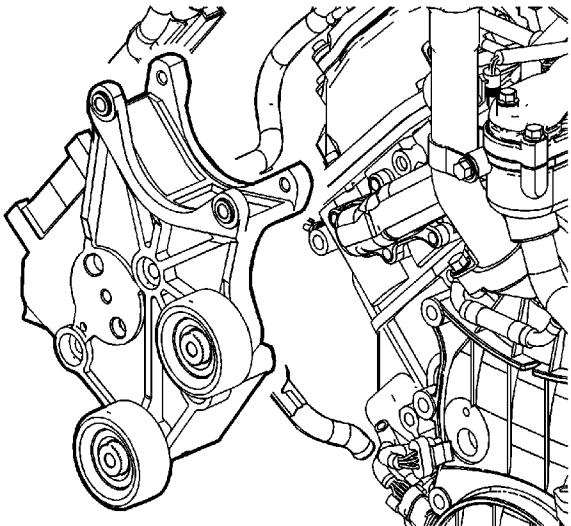


21. Install the main engine electrical harness connector hold down bolts.

Tighten

Tighten the main electrical harness connector hold down bolts to 10 N·m (89 lb in).

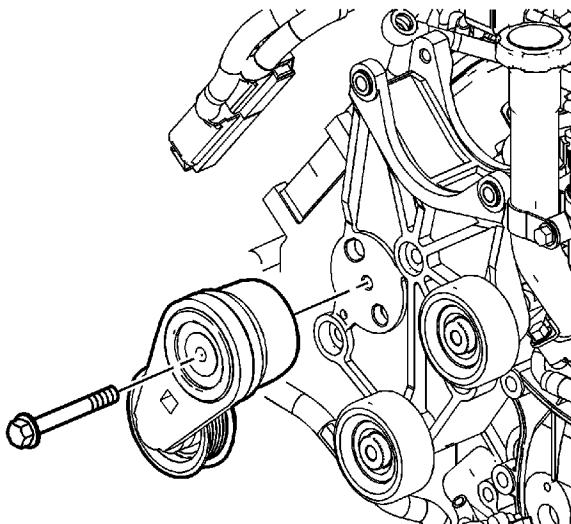
Generator and Drive Belt Tensioner Bracket Installation



1. Install the drive belt tensioner and generator mounting bracket.

Caution: Refer to [Fastener Caution](#) in the Preface section.

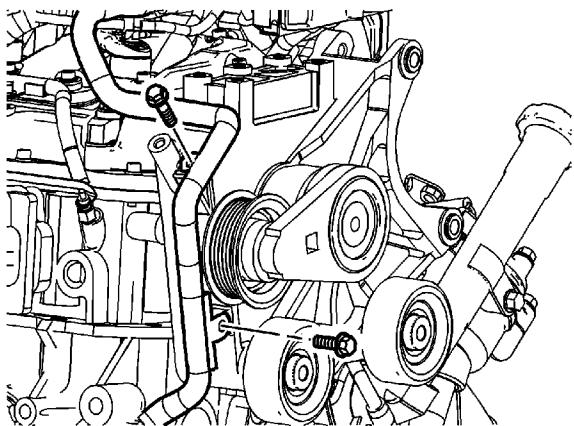
2. Install the drive belt tensioner and generator mounting bracket bolts. Tighten the drive belt tensioner and generator mounting bracket bolts to **50 N·m (37 lb ft)**.



3. Install the drive belt tensioner.

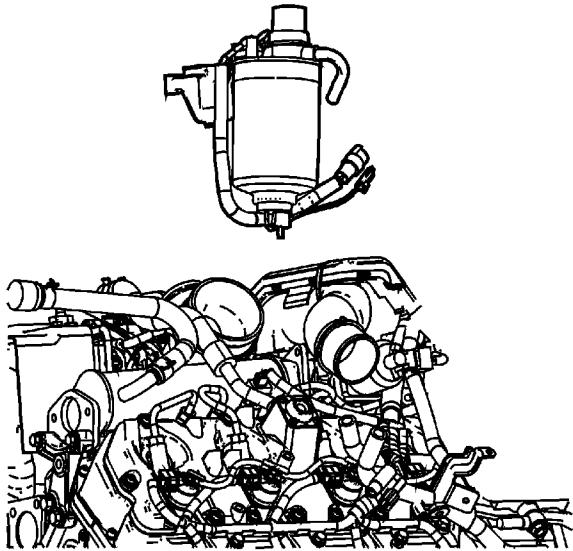
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4. Install the drive belt tensioner bolt and tighten to **50 N·m (37 lb ft)**.



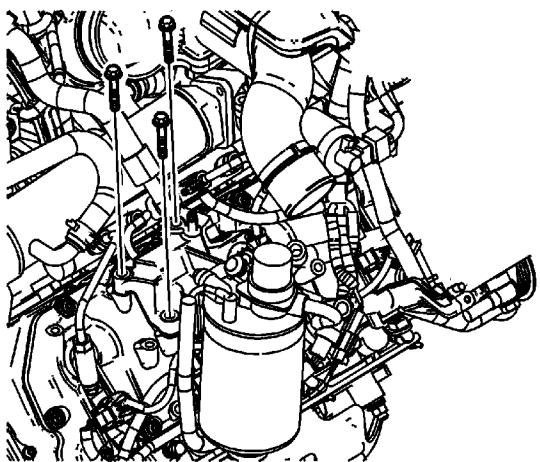
5. Install the electrical harness clip bolts and tighten to **10 N·m (89 lb in)**.

Fuel Filter Assembly Installation



1. Install the fuel filter assembly.

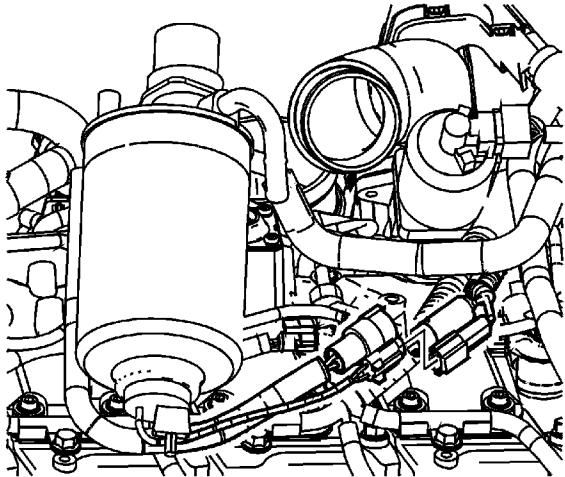
Caution: Refer to [Fastener Caution](#) in the Preface section.



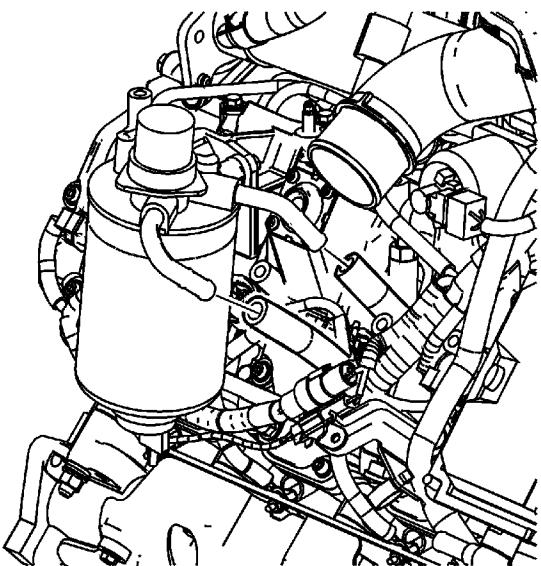
2. Install the fuel filter bracket bolts.

Tighten

Tighten the fuel filter bracket bolts to 21 N·m (15 lb ft).

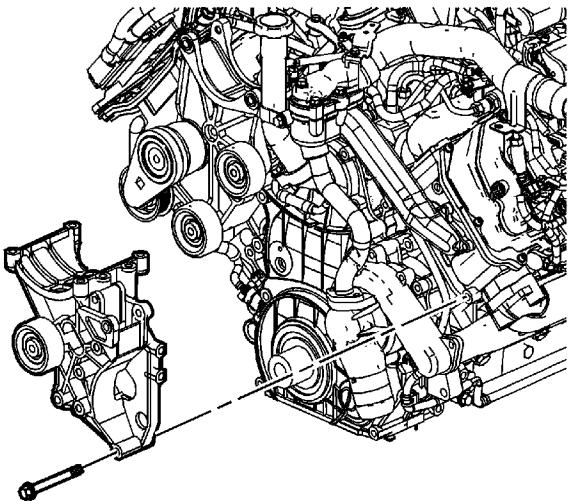


3. Connect the fuel filter assembly connectors.



4. Install the fuel hoses.

Power Steering Pump Mounting Bracket Installation

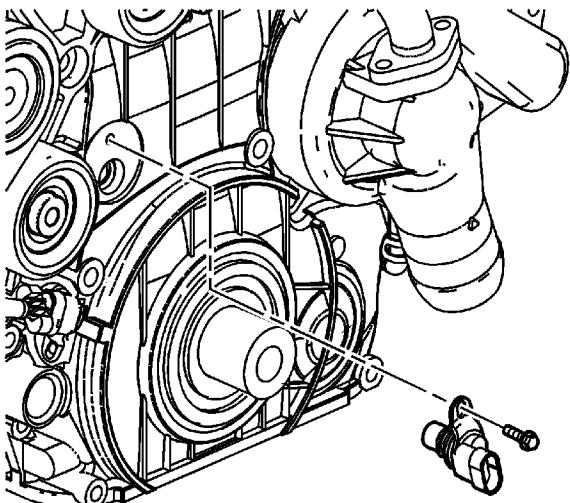


1. Install the power steering pump mounting bracket.

Caution: Refer to [Fastener Caution](#) in the Preface section.

2. Install the power steering pump mounting bracket bolts and tighten to **46 N·m (34 lb ft)**.

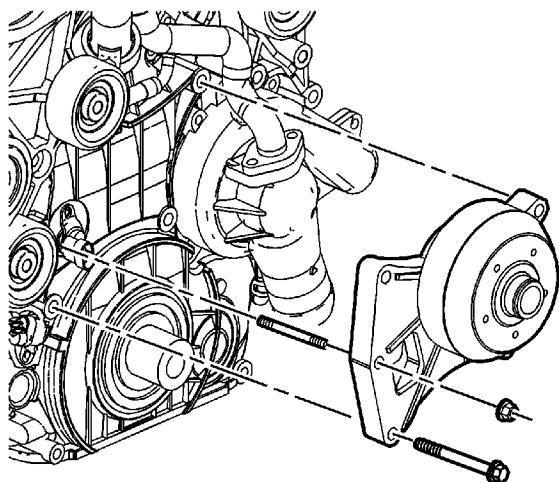
Cooling Fan Pulley Installation



1. Lubricate the camshaft position sensor O-ring with engine oil.
2. Install the camshaft position sensor.

Caution: Refer to [Fastener Caution](#) in the Preface section.

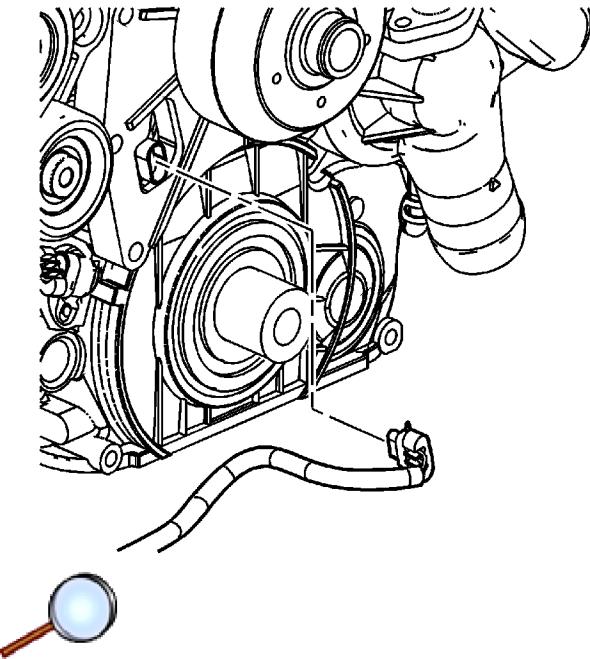
3. Install the camshaft position sensor retaining bolt and tighten to **10 N·m (89 lb in)**.



4. Install the cooling fan pulley.

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5. Install the cooling fan pulley bolts and nuts and tighten to **41 N·m (30 lb ft)**.



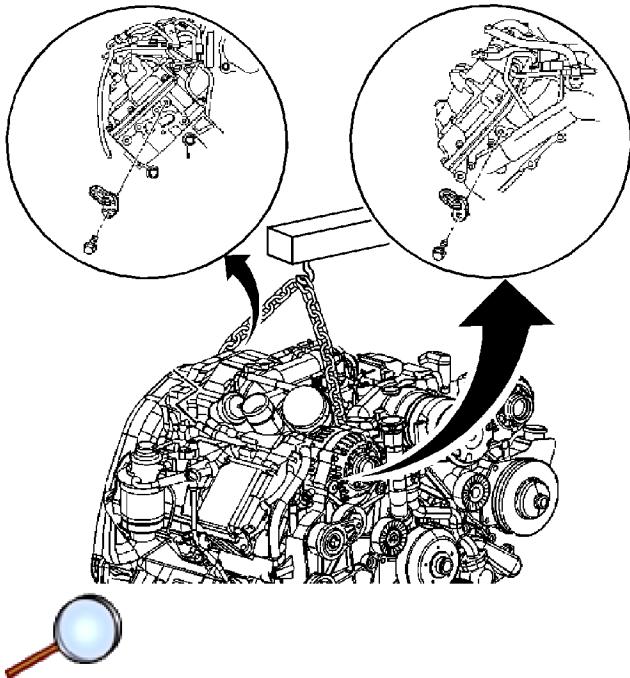
6. Connect the camshaft position sensor connector.



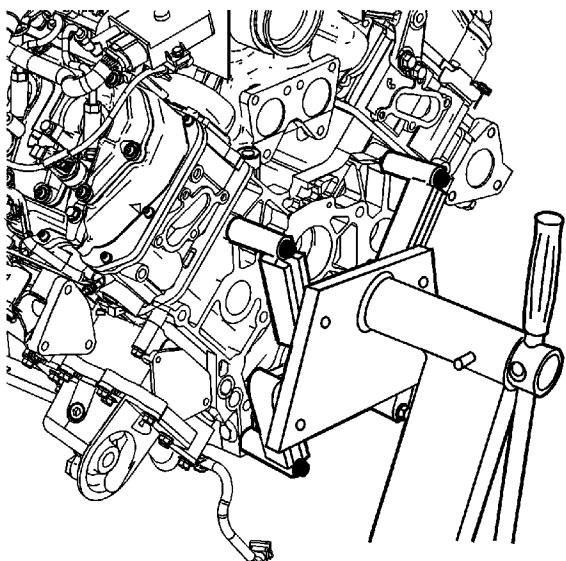
Engine Removal from Stand

Tools Required

[J 36857](#) Engine Lift Bracket



1. Bolt [J 36857](#) to the ends of the cylinder heads.

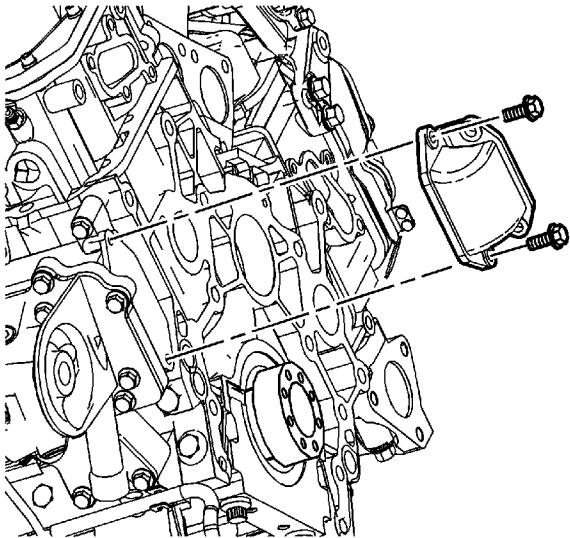


2. Lift the engine and the engine stand with a suitable hoist.
3. Remove the engine stand from the engine adapter.

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4. Lower the engine to the floor. Support the engine with blocks.
5. Remove the engine adapter.

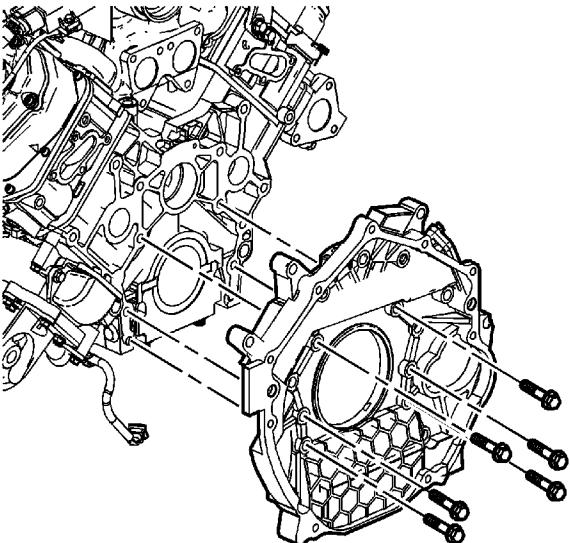
Engine Flywheel Housing Installation



1. Install the oil cooler adapter with gaskets to the oil cooler.

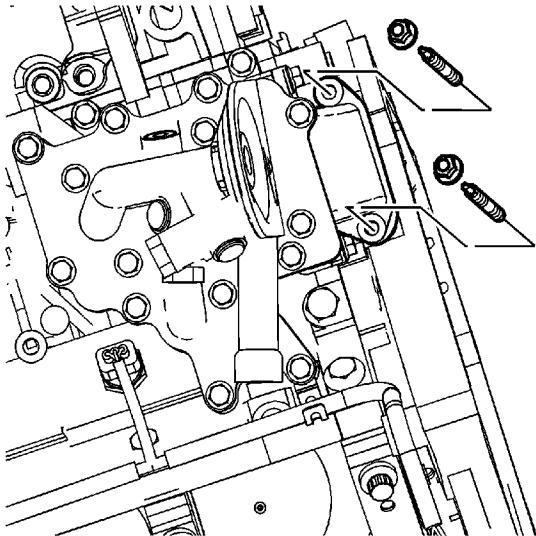
Caution: Refer to [Fastener Caution](#) in the Preface section.

2. Install the oil cooler adapter to oil cooler bolts and tighten to **21 N·m (15 lb ft)**.
3. Apply a 2-3 mm wide by 0.5-1.5 mm high bead of GM P/N 12378521 (Canadian P/N 88901148) sealant to the engine block mating surface.



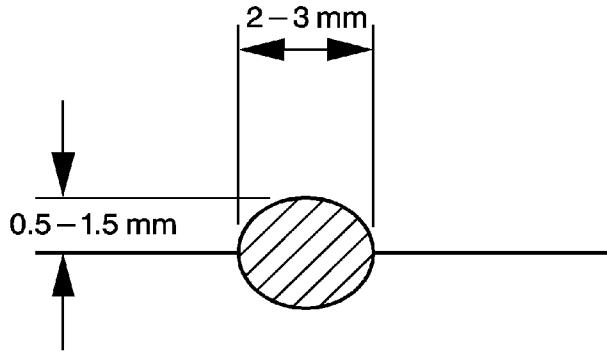
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4. Install the flywheel housing to the cylinder block.
5. Install the flywheel housing bolts and tighten to **80 N·m (60 lb ft)**.

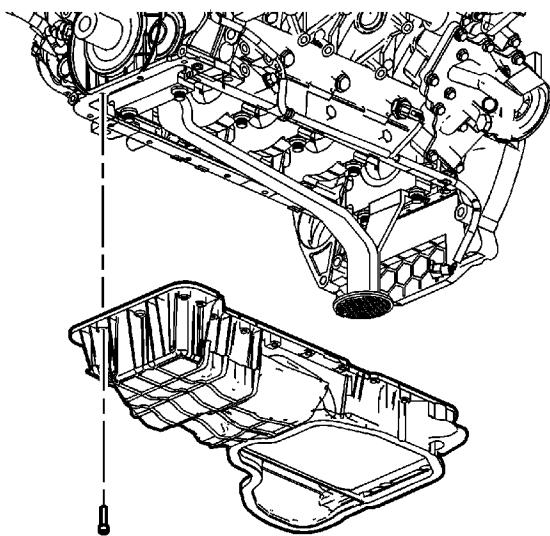


6. Install a new gasket to the turbocharger oil return pipe.
7. Install the turbocharger oil return pipe to flywheel housing studs. Tighten the turbocharger oil return pipe to flywheel housing studs to **10 N·m (89 lb in)**.
8. Install the turbocharger oil return pipe nuts and tighten to **25 N·m (18 lb ft)**.

Upper Oil Pan Installation

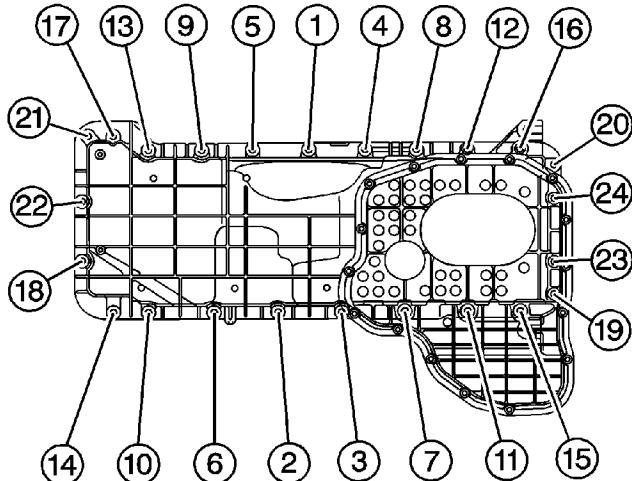


-  1. Apply a 2-3 mm wide by 0.5-1.5 mm bead of GM P/N 12378521 (Canadian P/N 88901148) sealant to the upper oil pan mating surfaces.

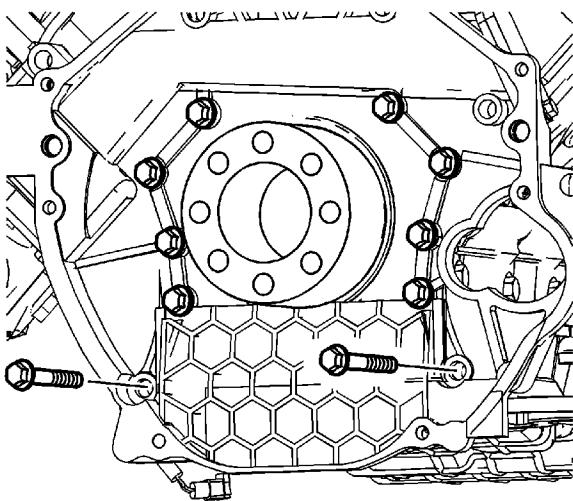


-  2. Install the upper oil pan to the engine block.

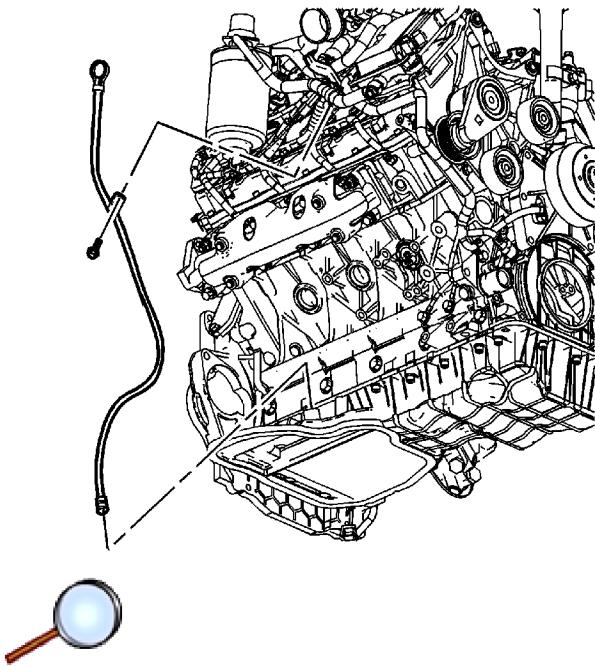
Caution: Refer to [Fastener Caution](#) in the Preface section.



3. Install the upper oil pan bolts. Tighten the upper oil pan bolts in sequence to **20 N·m (15 lb ft)**.



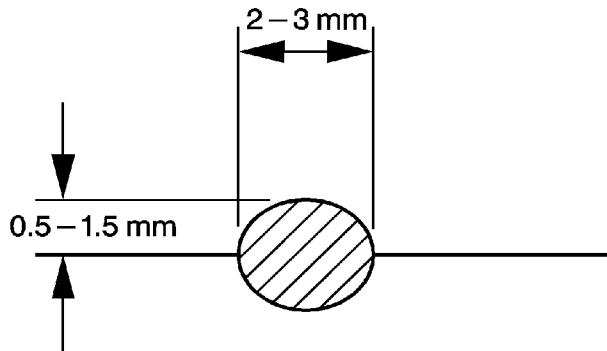
4. Install the two flywheel housing to upper oil pan bolts and tighten to **50 N·m (37 lb ft)**.



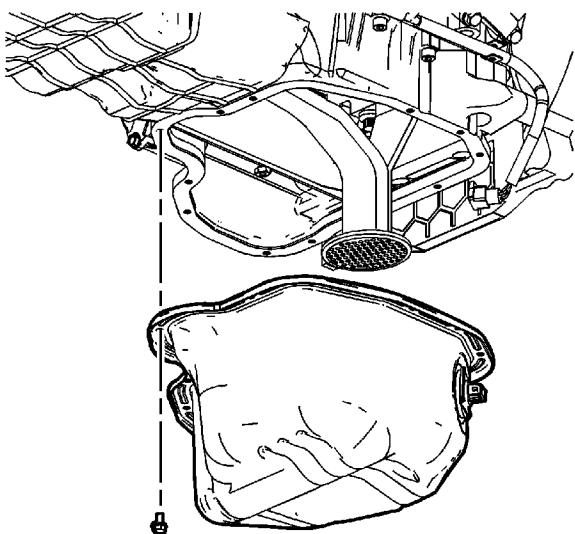
5. Install the oil level indicator tube.
6. Install the oil level indicator tube bracket bolt and tighten to **21 N·m (15 lb ft)**.



Lower Oil Pan Installation

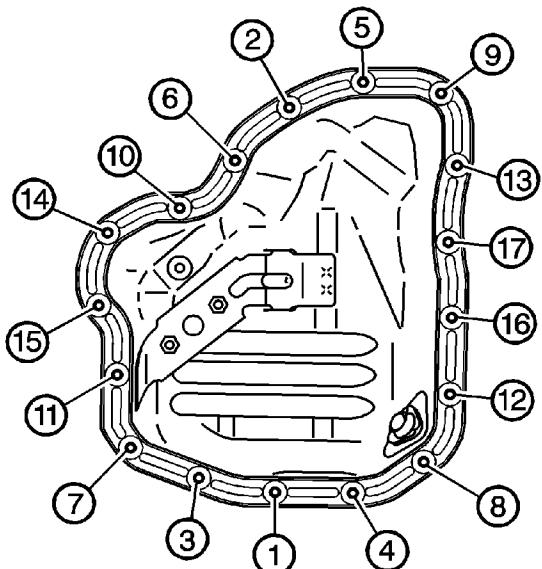


-  1. Apply a 2-3 mm wide by 0.5-1.5 mm high bead of GM P/N 12378521 (Canadian P/N 88901148) sealant to the lower oil pan mating surface.

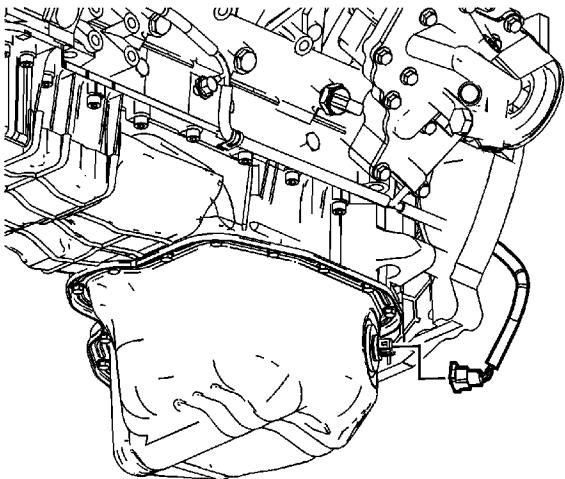


-  2. Install the lower oil pan.

Caution: Refer to [Fastener Caution](#) in the Preface section.

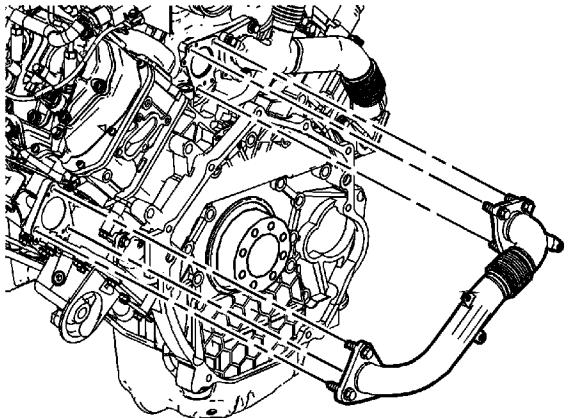


3. Install the lower oil pan bolts and nuts and tighten to **10 N·m (89 lb in)**.



4. Connect the oil level sensor.

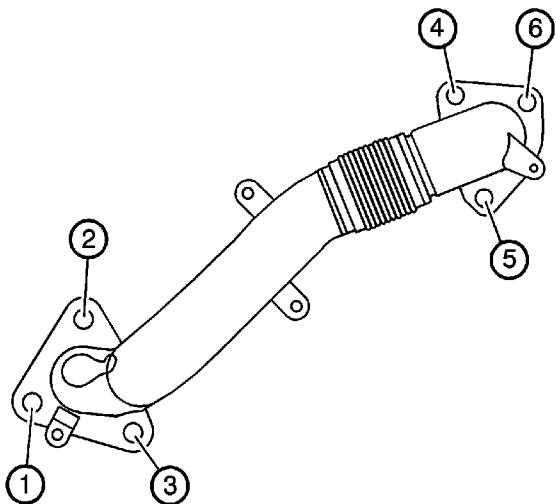
Exhaust Pipe Installation - Left Side



Note: Position the exhaust pipe gaskets with the tabs as shown. Failure to do so will cause improper alignment of the gaskets and result in exhaust leaks.

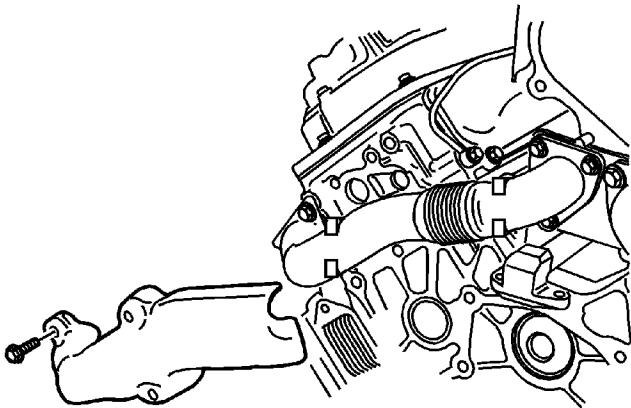
1. Install the exhaust pipe with gaskets.
2. Install the exhaust pipe to turbocharger bolts.

Caution: Refer to [Fastener Caution](#) in the Preface section.



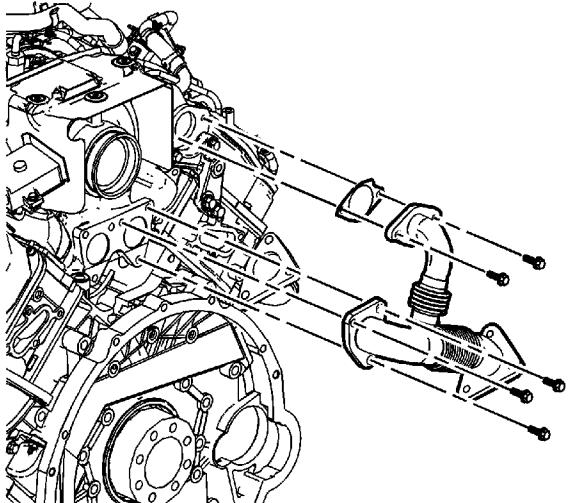


3. Install the exhaust pipe to exhaust manifold bolts. Tighten the exhaust pipe bolts to **53 N·m (39 lb ft)** in the proper sequence.



4. Install the exhaust pipe heat shield.
5. Install the exhaust pipe heat shield bolts and tighten to **10 N·m (89 lb in)**.

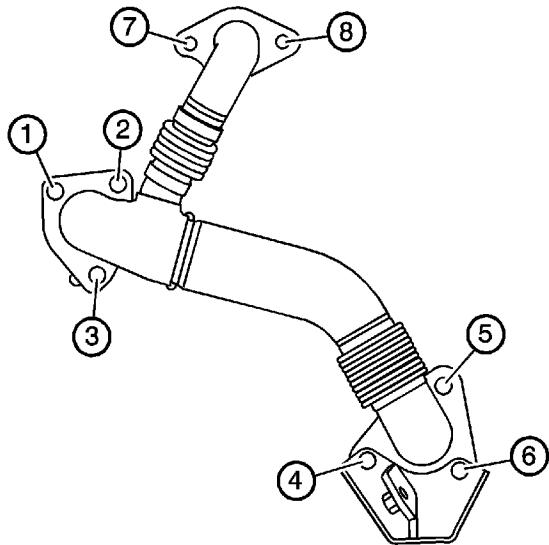
Exhaust Pipe Installation - Right Side



Note: Position the exhaust pipe gaskets with the tabs as shown. Failure to do so will cause improper alignment of the gaskets and result in exhaust leaks.

1. Install the exhaust pipe with gaskets.
2. Install the exhaust outlet bracket.
3. Install the exhaust pipe to turbocharger bolts.

Caution: Refer to [Fastener Caution](#) in the Preface section.



4. Install the exhaust pipe to exhaust manifold bolts in sequence.

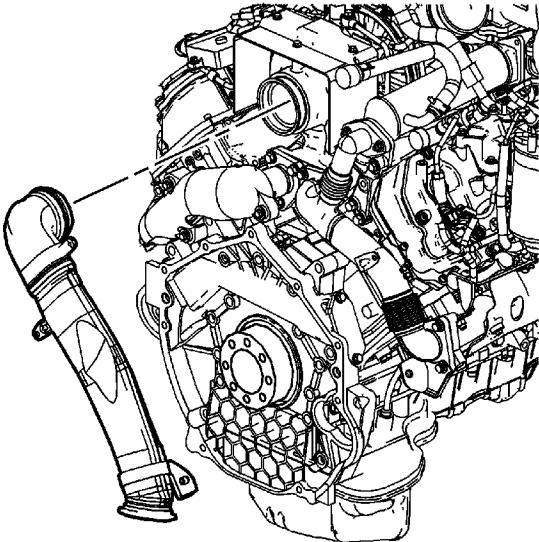
Tighten

Tighten the exhaust pipe bolts to 53 N·m (39 lb ft) in sequence.

Tighten

Tighten the exhaust pipe to EGR cooler nuts to 26 N·m (19 lb ft).

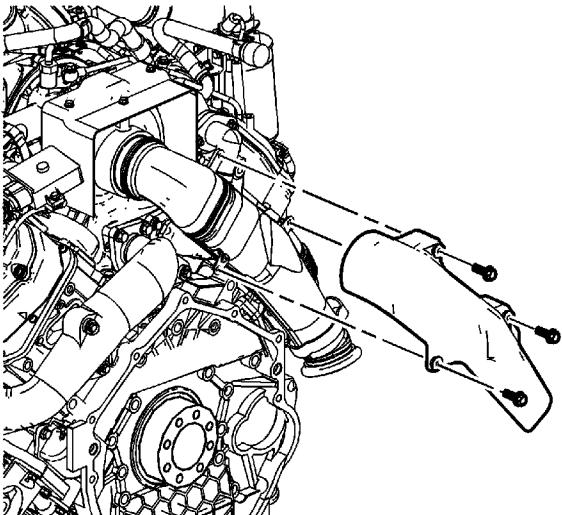
Exhaust Outlet Installation



1. Install the exhaust outlet.

Caution: Refer to [Fastener Caution](#) in the Preface section.

2. Install the exhaust outlet clamp and tighten to **15 N·m (11 lb ft)**.



3. Install the exhaust outlet to right exhaust pipe bracket bolt and tighten to **34 N·m (25 lb ft)**.

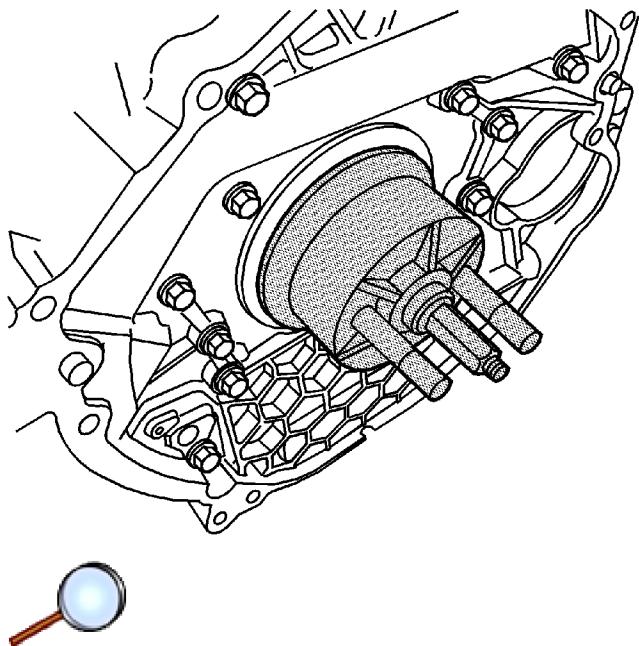
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4. Install the exhaust outlet heat shield.
5. Install the exhaust outlet heat shield bolts and tighten to **10 N·m (89 lb in)**.

Crankshaft Rear Oil Seal Installation

Tools Required

[J 44642](#) Crankshaft Rear Oil Seal Installer



1. Place the crankshaft rear oil seal onto the crankshaft.

Important: The [J 44642](#) must be fully secured to the crankshaft to ensure proper seal depth.

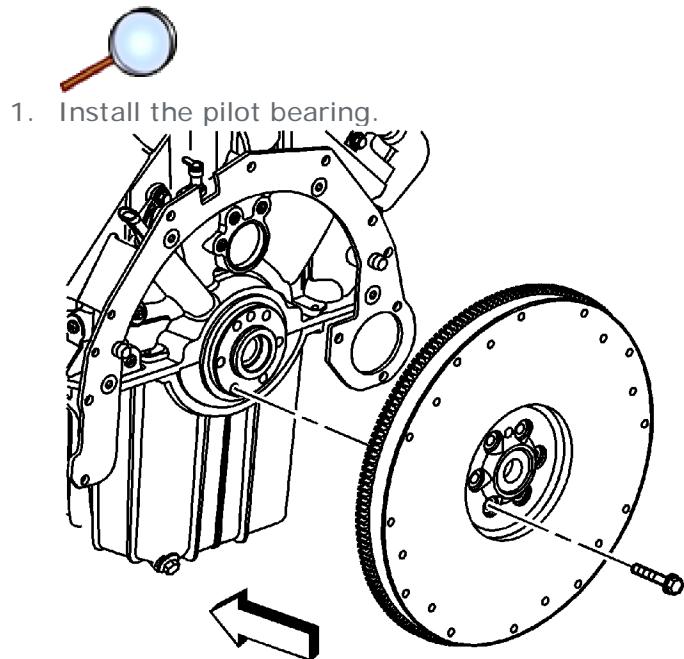
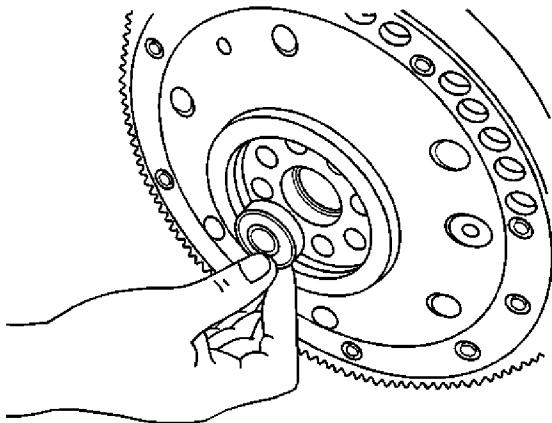
2. Install the [J 44642](#) to the crankshaft.
3. Press the crankshaft rear oil seal into position using the [J 44642](#). The [J 44642](#) will bottom out when the seal reaches the proper depth.
4. Remove the [J 44642](#).

Engine Flywheel Installation (Manual Transmission)

Special Tools

- *J 44643* Flywheel Hold Tool
- *J 45059* Angle Meter

For equivalent regional tools, refer to [Special Tools](#).



1. Install the pilot bearing.



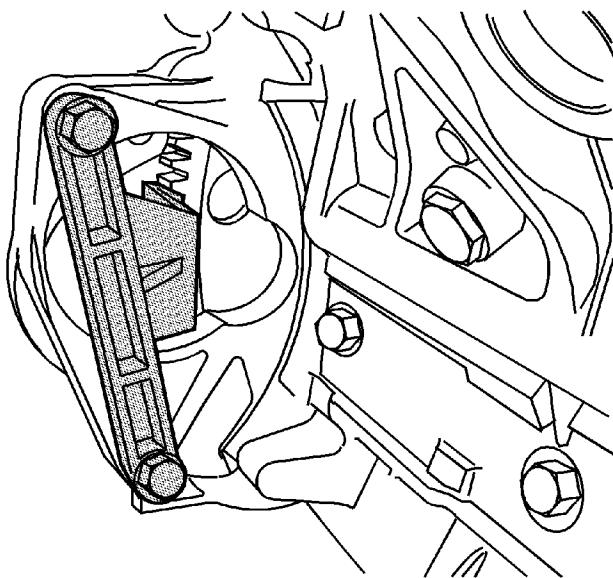
Warning: When removing, handling or installing this component wear protective gloves. The sharp edges on the component may be very sharp and may cause injury.

2. Install the flywheel.

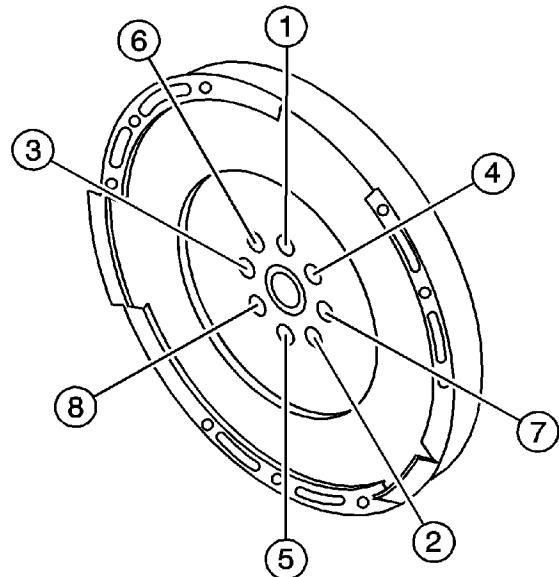
Caution: Refer to [Fastener Caution](#) in the Preface section.

Caution: This component uses bolts with a preapplied molybdenum disulfide coating for thread lubrication. Do not remove the coating or use any additional lubricant. Improperly lubricated threads will adversely affect the bolt torque and clamp load. Improper bolt torque and clamp load can lead to engine damage.

3. Loosely install NEW flywheel bolts.



4. Install J44643 tool to hold the flywheel from rotating.



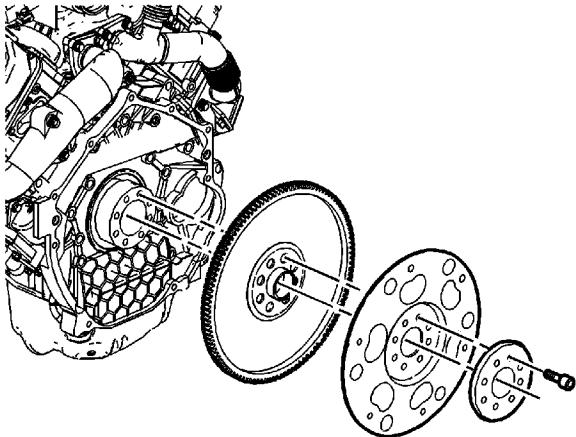
5. Use the following steps and the proper sequence to tighten the flywheel bolts:
 - 5.1. Tighten the flywheel bolts to **79 N·m (59 lb ft)**.
 - 5.2. Tighten the flywheel bolts to **60 degrees** using the *J 45059* meter .
 - 5.3. Tighten the flywheel bolts again to **60 degrees** using the *J 45059* meter .
6. Remove *J 44643* tool .

Engine Flywheel Installation (Automatic Transmission)

Special Tools

- *J 44643* Flywheel Hold Tool
- *J 45059* Angle Meter

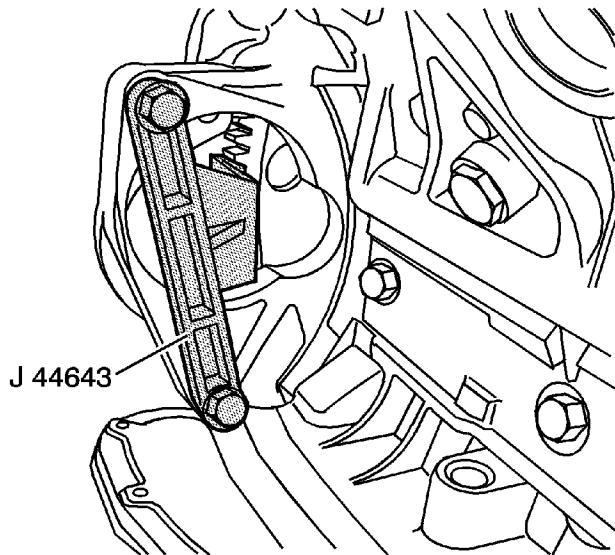
For equivalent regional tools, refer to [Special Tools](#).



1. Install the flywheel to the crankshaft.
2. Install the flywheel washer to the flywheel with the beveled side facing the engine.

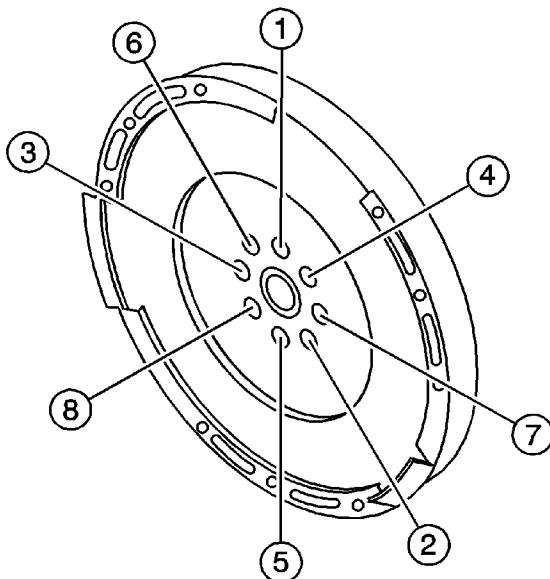
Caution: This component uses bolts with a preapplied molybdenum disulfide coating for thread lubrication. Do not remove the coating or use any additional lubricant. Improperly lubricated threads will adversely affect the bolt torque and clamp load. Improper bolt torque and clamp load can lead to engine damage.

3. Install NEW flywheel bolts.



4. Install the *J 44643* tool to lock the flywheel.

Caution: Refer to [Fastener Caution](#) in the Preface section.

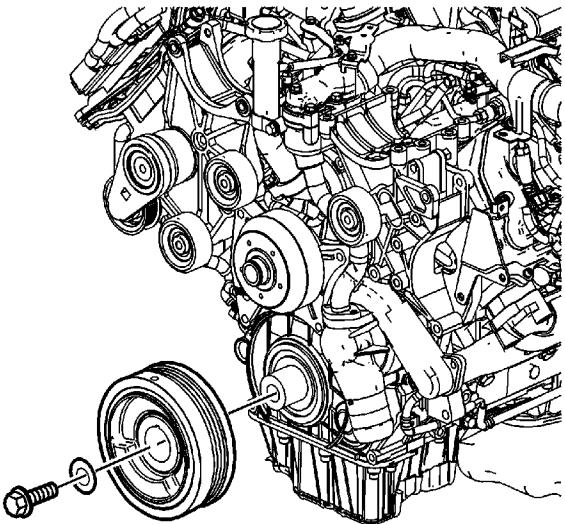


5. Tighten the flywheel bolts in the proper sequence.
 - 5.1. 1st step **79 N·m (59 lb ft)**.
 - 5.2. 2nd step **60 degrees** using *J 45059* meter .
 - 5.3. 3rd step **60 degrees** using *J 45059* meter .

Crankshaft Balancer Installation

Tools Required

[J 44643](#) Flywheel Hold Tool



1. Lightly lubricate the crankshaft balancer internal hub with engine oil.
2. Install the crankshaft balancer to the crankshaft.
3. Lightly lubricate the crankshaft balancer bolt with engine oil.

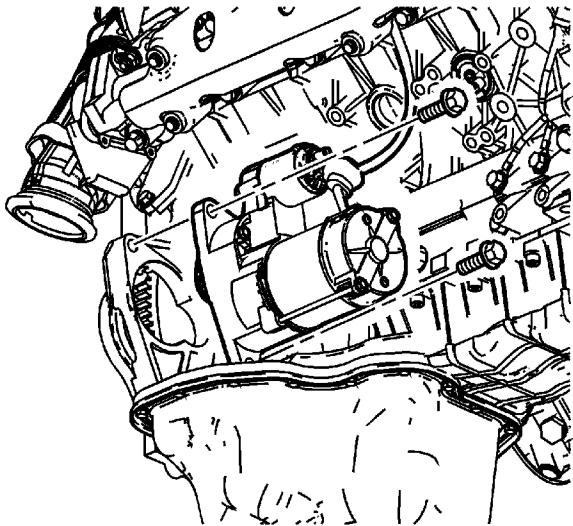
Notice: Use the correct fastener in the correct location. Replacement fasteners must be the correct part number for that application. Fasteners requiring replacement or fasteners requiring the use of thread locking compound or sealant are identified in the service procedure. Do not use paints, lubricants, or corrosion inhibitors on fasteners or fastener joint surfaces unless specified. These coatings affect fastener torque and joint clamping force and may damage the fastener. Use the correct tightening sequence and specifications when installing fasteners in order to avoid damage to parts and systems.

4. Install the crankshaft balancer bolt and washer.

Tighten

1. Tighten the bolt to 100 N·m (74 lb ft) on the first pass.
 2. Tighten the bolt an additional 105 degrees.
5. Remove the [J 44643](#).

Starter Installation



1. Install the starter motor to the flywheel housing.

Notice: Use the correct fastener in the correct location. Replacement fasteners must be the correct part number for that application. Fasteners requiring replacement or fasteners requiring the use of thread locking compound or sealant are identified in the service procedure. Do not use paints, lubricants, or corrosion inhibitors on fasteners or fastener joint surfaces unless specified. These coatings affect fastener torque and joint clamping force and may damage the fastener. Use the correct tightening sequence and specifications when installing fasteners in order to avoid damage to parts and systems.

2. Install the starter motor bolts.

Tighten

Tighten the starter bolts to 78 N·m (58 lb ft).

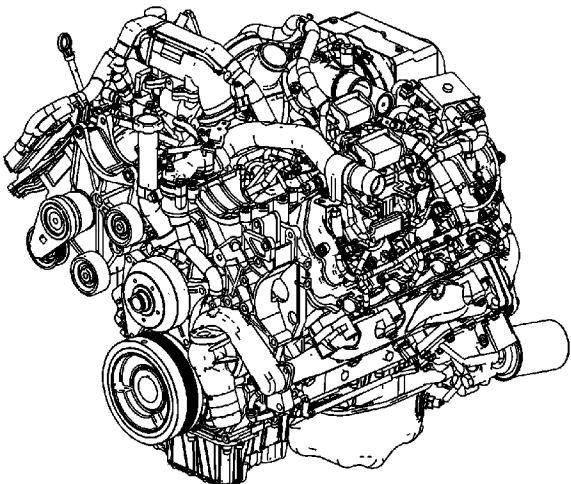
Engine Prelubing

Special Tools

J 45299 Engine Preluber

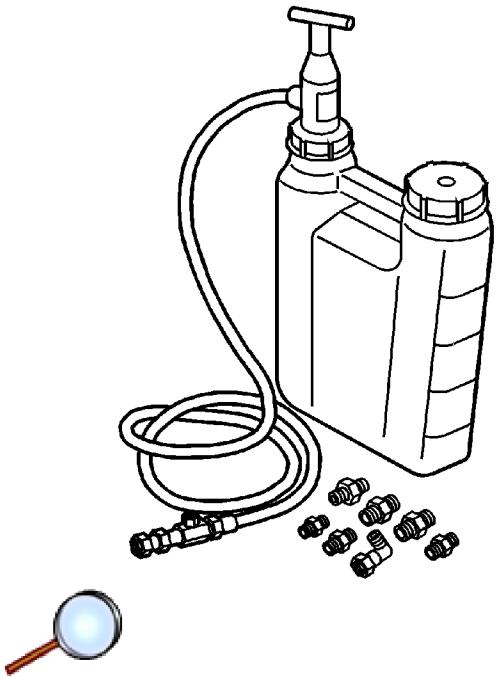
For equivalent regional tools, refer to [Special Tools](#).

Caution: Refer to [Fastener Caution](#) in the Preface section.



Note: A constant/continuous flow of clean engine oil is required to properly prime the engine. Be sure to use an approved engine oil as specified in the owners manual.

1. Remove the engine oil filter, fill with clean engine oil, and reinstall. Tighten the oil filter to **24 N·m (18 lb ft)**.
2. Remove the oil pressure sensor.
3. Install the M16 x 1.5 adapter P/N 509375.



4. Install the flexible hose to the adapter and open the valve.
5. Pump the handle on *J45299* preluber to flow a minimum of 1-2 quarts of engine oil. Observe the flow of engine oil through the flexible hose and into the engine assembly.
6. Close the valve and remove the flexible hose and adapter from the engine.
7. Install the oil pressure sensor and tighten to **41 N·m (30 lb ft)**.
8. Top off the engine oil to the proper level.