# OWNERS MANUAL

# BUKH V8 SERIES ENGINE

In 2009, marine diesel engines were introduced as 6.6L V8 turbo charged, common rail, intercooled marine engines for light duty commercial and pleasure craft applications.
The production was transferred to BUKH A/S, in 2018 and relocated to Denmark.

The lightweight and high performance 6.6L base engine is upgraded with high quality BUKH marine parts.

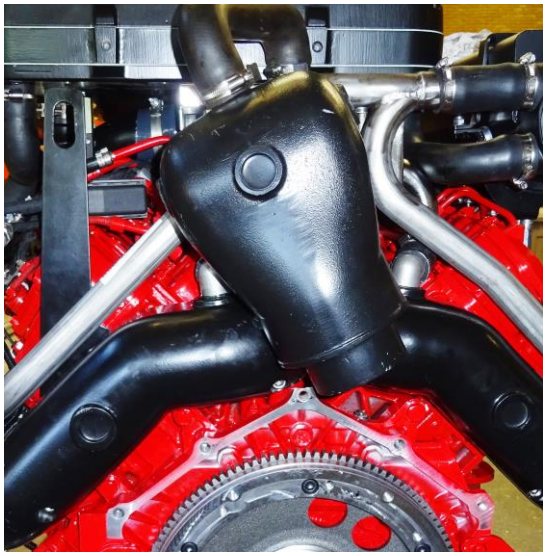
The BUKH V8 is a marine certified SOLAS engine built for optimal marine safety.

BUKH is ISO 9001 2015 certified which allows us to produce high quality marine engines.

BUKH V8 engines are built by trained personnel, according to our quality specifications.

BUKH V8 engines are quality inspected and tested before they leave the BUKH factory.

The BUKH V8 engine has been tested on a high power engine test bench, to assure that torque and power is in accordance with BUKH specifications.



## Identification

BUKH V8 series engines have an engine number.

| | |
|---|---|
| Example: | **BBPS DK** 00 **19 1654** |
| | |
| Where first letter is | **B** for **B**UKH |
| then | **B** for **B**oat engine |
| and | **P** for **P**ropulsion drive |
| followed by | **S** for **S**olas marine approved. |
| and | **DK** states manufactured in **DK**, Denmark. |
| and after 00 | **19** for year 2019 |
| And last | Last four digits are **ID** numbers |

**Before first engine start**

Due to safety restrictions some BUKH V8 engines are shipped without oil and coolant.

Please check oil and coolant levels.
Please ensure sufficient sea water cooling flow.

## Break in procedure

The BUKH V8 series engines need break-in time before being operating to its full potential. This is due to the design characteristics of the base engine.

Follow the recommendations below:

**0-5hrs:** Use varied load and engine speed but do not load the engine above 50% throttle and keep engine speed below 2500 rpm. (2500 1/min.)
Do not stay at one load and engine speed configuration for more than 30 minutes.

**5-10hrs:** Use varied load and engine speed but do not load the engine above 60% throttle and keep maximum engine speed below 2800 rpm. Do not stay at one load and engine speed configuration for more than 30 minutes.
A few short wide open throttle trials up to 3600 rpm are allowed for performance trials.

**Do oil and filter change after the engine has run a total of 10 hours.**

**10-30hrs:** Use varied load and engine speed. The engine can be used up to 100% throttle and 3600 rpm for shorter periods. Do not stay at one load and engine speed configuration for more than 30 minutes.

**Do oil and filter change after the engine has run a total of 30 hours.**

Use oil and filter as specified in BUKH V8 Maintenance book. This is highly important!

If you have any questions regarding this break-in procedure please consult the technical department at your local BUKH dealership or BUKH.

**Starting procedure**

**Before starting the engine always check the oil and coolant level**. Also inspect that no leaks on oil-, fuel- or cooling systems are evident.

1. Make sure gear is in neutral and that throttle is in idling position.
2. Turn ignition key to the ON position and wait for glow light to stop. This allows the automatic glow system to glow its first sequence.

DO NOT USE STARTING AIDS SUCH AS STARTING GAS, ETHER OR OTHER. (This will void any warranty.)

3. Turn the ignition key to the CRANK position to start the engine. If the engine doesn't start in 15 seconds, wait for 30 seconds and go back to step 2.

As soon as the engine starts, let it run at idle while checking oil pressure and volt reading. It's not unusual with smoke from the exhaust system just after start-up but this will stop once the engine reaches operating temperature. Glow system will automatically afterglow.

Recommended cruising engine speed for all BUKH engines is 2700-3200 rpm. although the maximum rated effect is at a higher engine speed. It is necessary to choose a propeller that will allow the engine to reach maximum engine speed at wide open throttle to not inflict unnecessary load on the engine, which could effect engine lifetime **and void warranty**. Do not exceed maximum recommended engine speed as the pump reduces the amount of injected diesel after this engine speed and engine power drops quickly.

## Winter storage

- Oil system

Change oil on the supercharger. Drain the oil from the engine, either by removing the oil plug in the oil pan or by a suction tube down the dipstick tube; remember it's always recommended to do this when the engine is at operating temperature. Tighten the plug, clean the oil dipstick and reinsert it in the tube.
Then remove the oil filter and replace it with a new unit (don't forget to pre lubricate the seal ring on the filter and prefill the filter with oil) tighten hard with manual power.
Refill the engine with new oil according to technical maintenance specifications. Check the oil level on the dipstick and if necessary add more oil to reach the correct oil level.
Start the engine and run it for a few minutes so that the new oil can lubricate all moving parts.
Turn off the engine and wait for 5 minutes.
Then recheck the oil level on the dipstick, again add more oil if necessary.

- Fuel system

Check all hoses, clamps and fittings for leakage and wear, replace if necessary. Make sure the fuel tank is full to prevent water contamination. Add "water repellent" isopropanol to the fuel system. Remove and replace the fuel filter (remember to prefill the filter with fuel as you otherwise will have issues with bleeding all the trapped air from the fuel system).

- Cooling system

Start the engine and run antifreeze mix through the raw water system. Check the freeze protection of antifreeze in the freshwater cooling system. If you need to add antifreeze make sure you allow the engine to run up to operating temperature allowing the thermostat to open and mix the added antifreeze. Never use more than 50% antifreeze. Turn off the engine and drain the raw-water system. At the same time remove the impeller from the impeller pump. Check all hoses, clamps and fittings for wear and leakage, replace if necessary. The heat exchanger, intercooler and oil cooler are exposed to raw water and should be inspected for corrosion that could lead to engine failure. It is recommended that the raw-water cooling system be cleaned and flushed every 500 hours or at least every second year.

- Exhaust system

When the winter service is completed make sure all exhaust outlets and the air filters are sealed to prevent moist/salt air from entering the engine.

- Electrical System

Remove and clean the battery/batteries. Also clean the battery cables and connecting poles. Store battery in a cold/dry ventilated environment (never below 0°C/32F) and keep it fully charged.

**Procedures after winter storage**

- Exhaust System

Remove all winter-storage-seals from exhaust and intake system.

- Electrical System

Reconnect the fully charged battery/batteries and tighten/lubricate the connectors. Check the condition of the serpentine drive system belt; replace if worn or dry.

- Cooling system

Recheck that all hoses and fittings in the raw-water system are connected and replace the impeller (be careful not to scuff the impeller, use grease). Prime the raw-water system to prevent overheating of the impeller at start-up.

- Air filter

Replace with new filter unit.

- Start-up

See starting procedures on page 3. Check for leakage of oil, fuel and water. Also check the oil level on the dipstick, if necessary fill up with oil. Let the engine idle up to operating temperature before usage or shutdown. When the operating temperature is achieved, again check for leaking fluids. It is always good to mix approx. 1% two-stroke oil into the fuel tank once a year to give the fuel system added lubrication.

## Periodic maintenance important notes

**Periodic oil change on the supercharger**.
USE ONLY oil as specified in BUKH V8 Maintenance book.
Do NOT overfill. Correct oil level is crucial.

## Emission control warranty statement

**General statement**
To retain the dependability, noise and exhaust emission control originally built into all BUKH V8 (further on referred to as BUKH or V8) engines, it is essential that the engines are installed according to the V8 installation instructions and receive periodic maintenance according to the V8 maintenance book.

The BUKH V8 engine is categorized as a commercial engine.
Expected useful life of 10 years or 10.000 hours.
See BUKH V8 Maintenance Book for correct service.

**The warranty period shall begin:**
1. On the date the machine or vessel first is delivered to the first retail purchaser or:

2. If the machine or vessel is placed in service for demonstration purposes prior to sale at retail, on the date the engine is first placed in service. Maximum demonstration period is 50h.

The emission control systems of your new V8 engine were designed, built and tested using BUKH genuine parts, accordingly, it is recommended that any replacement parts used for maintenance, repair or replacement of emission control systems be BUKH genuine parts. The owner may elect to have maintenance, replacement or repair of the emission control components and systems certified by US Environmental Protection agency performed by any repair establishment or individual and may elect to use parts other than BUKH genuine parts for such maintenance, replacement or repair without invalidating this warranty: the cost of such services or parts, however, will not be covered under the warranty.
Use of replacement parts which are not of equivalent quality may impair the effectiveness of emission control systems. If other than BUKH genuine parts are used for maintenance, the owner should obtain assurance that such parts are warranted by their manufacturer to be equivalent to genuine BUKH parts. However, the use of other than BUKH replacement parts does not invalidate the warranty on other components unless such parts cause damage to warranted parts.

Repairs and service covered by the warranty will be performed by an authorized BUKH distributor or dealer with no charge for parts or labor, including diagnosis, using BUKH genuine parts for any part of the emission control system covered by the warranty and found defective.
The emissions control parts covered by this Emission Control System Warranty are listed under" What is covered by The Emission Warranty". You are responsible for the performance of all scheduled maintenance or repairs on your new V8 engine.
BUKH may deny a warranty claim if your failure to perform maintenance resulted in the failure of a warranted part. Receipts covering the performance of regular maintenance should be retained in the event questions arise concerning maintenance. The receipts should be transferred to each subsequent owner of the machine or vessel with the emission warranted engine.

**What is not covered by the emission control system warranty.**
1. Malfunctions in any part caused by any of the following: misuse, abuse, improper adjustments, modifications, alteration, tampering, disconnection, improper or inadequate maintenance, improper installation and/or rigging or use of fuels not recommended for the engine as described in the User's Manual.

2. Damage resulting from accident, acts of nature or other events beyond the control of BUKH or any of its representatives.

3. The replacement of expendable maintenance items such as exhaust system, filters, hoses, belts, oil, thermostat, and coolant made in connection with scheduled maintenance services once these parts have been replaced.

4. Add on parts or modified items which are not approved by BUKH.

5. Consequential damage as loss of time, inconvenience, shipping of parts, engine or vessel, loss of use of machine or vessel, engine or commercial loss.

6. Any machine or vessel on which the hour record has been altered so the actual usage cannot be readily determined.

7. Damage resulting from rust or corrosion.

8. Damage caused from cooling system blockage by foreign material or from sand or debris deterioration of water pump.

9. Cosmetic or paint changes due to exposure to the elements.

10. Product is or has been used for racing at any point, even by a prior owner.

11. Marine engines operated outside the United States or Canada.

**What is covered by the emission control system warranty.**
The following is a list of items that are considered a part of the Emission Control Systems and are covered by the Emission Warranty when installed as original equipment by BUKH on engines which were built to conform to Environmental Protection Agency regulations.

IMPORTANT!
This may not include expendable maintenance items. Emission related parts requiring scheduled maintenance are warranted until their first scheduled replacement point for that part.

1. Fuel System
- Fuel injectors
- Fuel injection pump

2. Air Induction System
- Turbocharger
- Intercooler

3. Miscellaneous Items
- ECU
- Software calibration

**Customer assistance**
BUKH wishes to help assure that the Emission Control System Warranty is properly administered. In the event that you do not receive the warranty service to which you believe you are entitled under the Emission Control Systems Warranty, you should contact BUKH at the address below for assistance. If you need additional assistance or information concerning the Emission Control System Warranty, contact:

Your BUKH distributor.
BUKH distributors can be found at www.bukh.dk

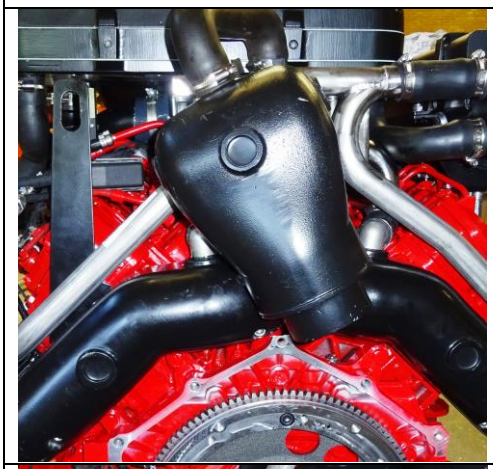
Or

**BUKH A/S**
Aabenraavej 13-17
DK-6340 Krusaa
Denmark
T: +45 74 62 20 88
E-mail: bukh@bukh.dk

**Dealer & Service directory**
**FOR LATEST UPDATE WE REFER TO www.bukh.dk**

**Exhaust manifolds**

The V8 exhaust manifolds are made of high quality cast aluminium that is heat treated, anodized, vacuum injected and powder coated for maximum corrosion resistance. Each exhaust manifold mounts to the cylinder head with metric stainless steel hexagon socket head bolts.

| Exhaust manifolds | Description |
|---|---|
|  | Picture show the centre exhaust manifold.<br><br>The centre exhaust manifold is high quality cast aluminium.<br>Vacuum injected and powder coated.<br>The center exhaust has one inner exhaust chamber and a surrounding coolant chamber for sea water.<br>Exhaust and sea water, exits the BUKH V8 engine through 2 outlets and mixes into an Ø120 mm outlet. |
|  | Picture show the exhaust manifolds.<br><br>These exhaust manifolds has one inner exhaust chamber and one surrounding coolant chamber for sea water. |
|  | Picture show the exhaust manifolds.<br><br>These stainless steel pipes lead sea water to surrounding cooling chambers in the exhaust manifolds. |

**Turbo and intercooler system**

Air induction on V8-engines includes the following parts:

- Air intake duct and air filter assembly
- Variable Geometry Turbo assembly
- Intake assembly with integrated stainless steel intercooler

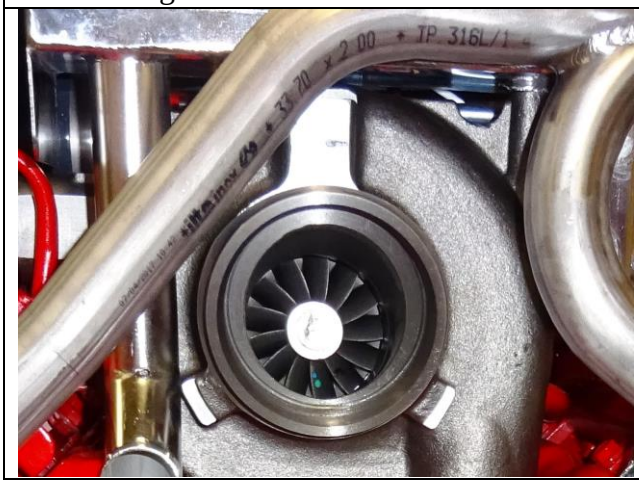
**Air intake duct and air filter assembly**

Outside air enters the induction system through a filter located on the front of the engine.
This is a bonded stainless steel mesh filter material and should be cleaned and replaced according to service intervals.
See BUKH V8 MAINTENANCE BOOK.
The air filter element mounts to the intake runner inlet with a clamp.

| Air filter unit | Description |
|---|---|
|  | Picture of the stainless steel air filter unit. |

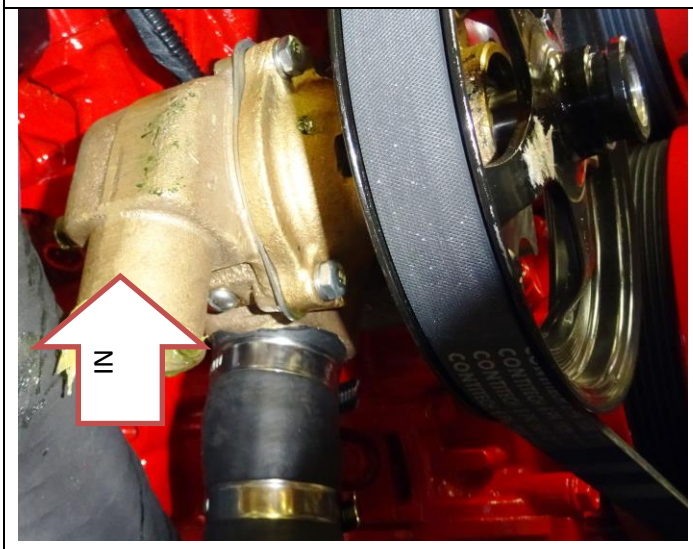
**Variable geometry turbo assembly**

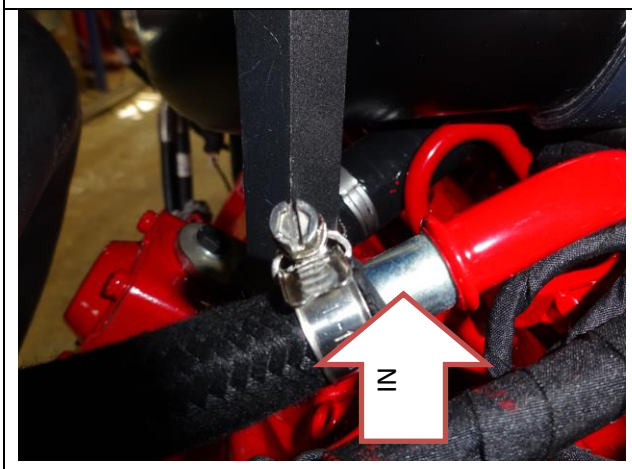
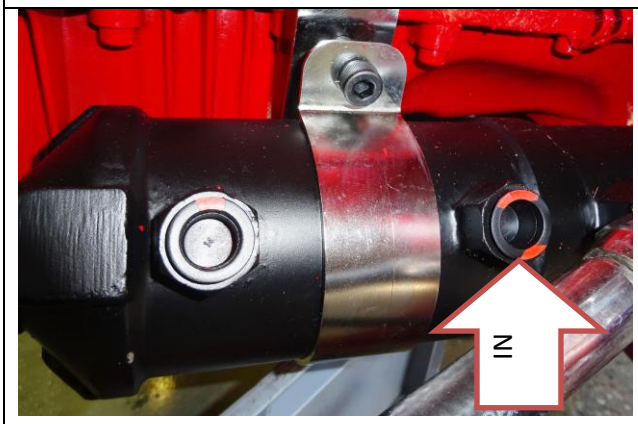
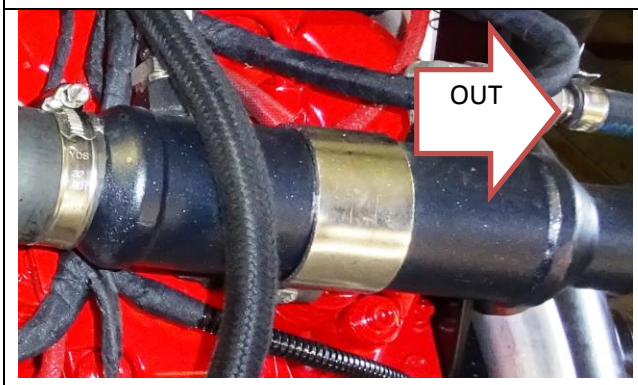
The turbocharger assembly information can be found in BUKH V8 manual. Below is an explanation of some interacting parts.

| Turbo charger | Description |
|---|---|
|  | Picture of the turbo charger.<br><br>The charger is a high quality turbo charger in stainless steel. |

**Intake assembly with integrated stainless steel intercooler**

| Intercooler assembly | Description |
|---|---|
|  | Picture of the stainless steel intercooler core with aluminium housing.<br><br>Compressed air and coolant connections.<br>Ø40 mm hoses are sea water coolant hoses. |

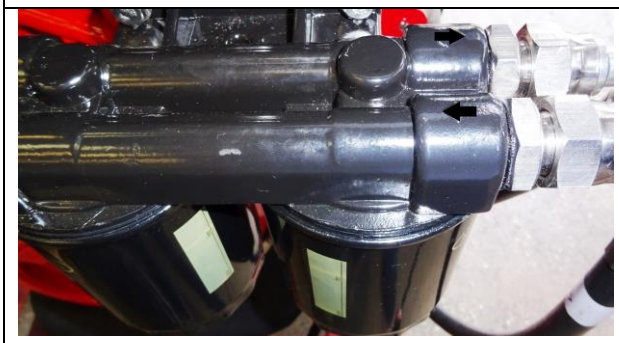
| Sea water inlet | Description |
| --- | --- |
|  | Picture of impeller pump and sea water inlet.<br><br>Ø40 mm hose connection |

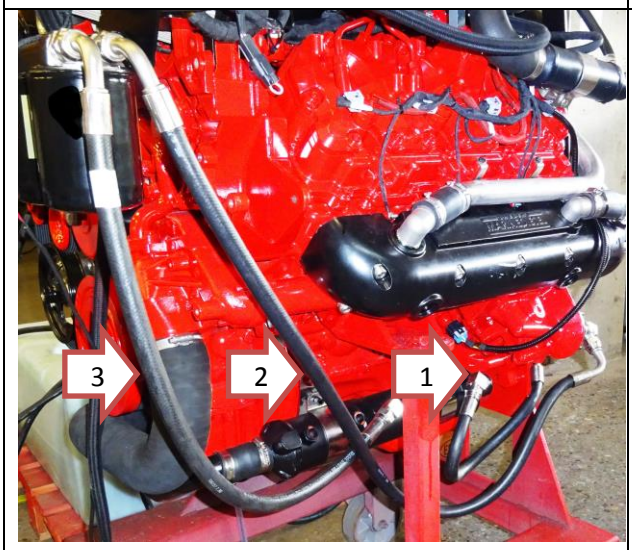
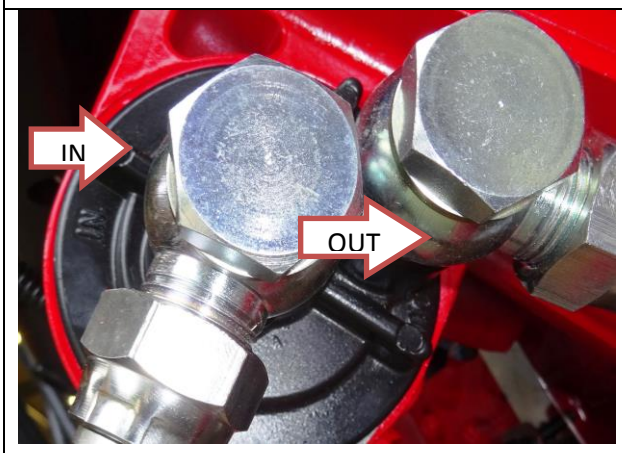
| Diesel fuel in/out. | Description |
|---|---|
|  | Picture of a diesel fuel inlet and fuel outlet.<br><br>Diesel fuel IN is Inlet from fuel tank pump.<br>Outside Ø12 mm tube.<br>Recommended 2-3 bar and max 44 °C<br><br>Return Out is a Ø10 mm tube |
|  | Picture of inlet fuel cooler.<br>Some configurations make use of the inlet fuel cooler option. Fuel cooler is sea water cooled.<br>Is such case the inlet fuel can be connected to the IN connection.<br>This connection is a hydraulic connection.<br>Guide: 3/8 inch straight ISO 228/1 G |
|  | Some configurations with outlet fuel cooler.<br>Fuel out is after the fuel cooler.<br>Fuel cooler is sea water cooled.<br>Return hose to fuel tank.<br>Hose connector is Ø10 mm. |

The return fuel must pass via the fuel cooler before returning to the tank. Raw water connection is on the impeller pump on the lower starboard side of the engine.
Please see appropriate sections for further information.

**Oil filter**

It is essential that the oil lines and oil filter are prefilled with oil before starting the engine. The lines should be connected as shown below.

| Remote engine oil filter | Description |
|---|---|
|  | Picture of a remote engine oil filter.<br><br>Engine oil in and oil out are marked with arrows on top of the oil filter house. |

| Oil hoses | Description |
|---|---|
|  | Picture of oil hose connections with remote engine oil filter and oil cooler.<br><br>1. From oil pump, out connection, to nearest oil cooler connection.<br><br>2. From oil cooler to oil in arrow, on remote oil filter house.<br><br>3. From oil out arrow connection, on oil filter house, to oil pump in connection. |
| **Oil pump connections** | **Description** |
|  | Picture of oil hose connections with remote engine oil filter and oil cooler. See IN and OUT mark.<br><br>OUT and hose 1. From oil pump out connection to nearest oil cooler connection.<br><br>IN and hose 3. From oil out arrow connection, on remote engine oil filter house, to oil pump IN connection. |

| WARNING |
| --- |
| BEFORE MOUNTING THE OIL FILTER, FILL THE OIL FILTER COMPLETELY WITH OIL. THIS IS TO ENSURE THAT THE ENGINE GETS LUBRICATED DIRECT FROM START-UP. |

# Engine Mechanical - 6.6L

## Specifications

### Fastener Tightening Specifications

| Application | Specification | |
|---|---|---|
| | Metric | English |
| A/C Compressor Bolt | 50 N·m | 37 lb ft |
| Air Cleaner Outlet Duct Clamp | 8 N·m | 71 lb in |
| Air Conditioning Compressor/Power Steering Pump Bracket Bolt | 46 N·m | 34 lb ft |
| Air Inlet Tube Nut | 25 N·m | 18 lb ft |
| Battery Cable Bracket Bolt | 12 N·m | 106 lb in |
| Battery Cable Bracket Nut | 8 N·m | 71 lb in |
| Bypass Pipe Bolt | 25 N·m | 18 lb ft |
| Camshaft Gear Bolt | 234 N·m | 173 lb ft |
| Camshaft Position Sensor Bolt | 10 N·m | 89 lb in |
| Camshaft Position Sensor Exciter Ring Bolt | 9 N·m | 80 lb in |
| Camshaft Thrust Plate Bolt | 22 N·m | 16 lb ft |
| Charged Air Cooler Bolt | 21 N·m | 15 lb ft |
| Charged Air Cooler Clamp | 8 N·m | 71 lb in |
| Connecting Rod Cap Bolt – Angular Tightening Method | 1st Step 64 N·m | 1st Step 47 lb ft |
| | 2nd Step 30 degrees | 2nd Step 30 degrees |
| | 3rd Step 30 degrees | 3rd Step 30 degrees |
| Coolant Pipe Bolt and Nut | 25 N·m | 18 lb ft |
| Coolant Tube to Water Pump Nut | 25 N·m | 18 lb ft |
| Cooling Fan Pulley | 41 N·m | 30 lb ft |
| Crankshaft Balancer Bolt | 1st Step 100 N·m | 1st Step 74 lb ft |
| | 2nd Step 90 degrees | 2nd Step 90 degrees |
| Crankshaft Bearing Cap Bolt | 1st Step 98 N·m | 1st Step 72 lb ft |
| | 2nd Step 132 N·m | 2nd Step 97 lb ft |
| | 3rd Step 30 degrees | 3rd Step 30 degrees |
| Crankshaft Bearing Cap Bolt – Angular Tightening Method | 1st Step 100 N·m | 1st Step 74 lb ft |
| | 2nd Step 90 degrees | 2nd Step 90 degrees |
| Crankshaft Bearing Cap Side Bolt | 70 N·m | 52 lb ft |
| Crankshaft Position Sensor Bolt | 10 N·m | 89 lb in |
| Crankshaft Position Sensor Spacer Bolt | 10 N·m | 89 lb in |
| Crossmember Bolt | 100 N·m | 74 lb ft |
| Cylinder Head M12 Bolt – Angular Tightening Method | 1st Step 50 N·m | 1st Step 37 lb ft |
| | 2nd Step 80 N·m | 2nd Step 59 lb ft |
| | 3rd Step 90 degrees | |
| | 4th Step 75 degrees | |
| Cylinder Head M8 Bolt | 25 N·m | 18 lb ft |
| Drive Belt Tensioner Pulley Bolt | 50 N·m | 37 lb ft |
| EGR Bracket | 25 N·m | 18 lb ft |
| EGR Bracket Bolt | 25 N·m | 18 lb ft |
| EGR Bracket to Cooler Bolt | 25 N·m | 18 lb ft |
| Electrical Harness Bracket Bolt | 10 N·m | 89 lb in |
| Engine Block Coolant Plug | 18 N·m | 13 lb ft |
| Engine Block Ground Bolt | 34 N·m | 25 lb ft |

## Fastener Tightening Specifications (cont'd)

| Application | Specification | |
|---|---|---|
| | Metric | English |
| Engine Mount Through Bolt to Frame | 75 N·m | 55 lb ft |
| Engine Mount to Block Bolts | 58 N·m | 43 lb ft |
| Engine Mount to Frame Bolt | 65 N·m | 48 lb ft |
| Engine Shield Bolt | 20 N·m | 15 lb ft |
| Exhaust Heat Shield Nut | 10 N·m | 89 lb in |
| Exhaust Manifold Bolt/Nut | 38 N·m | 28 lb ft |
| Exhaust Manifold Heat Shield Bolts | 10 N·m | 89 lb in |
| Exhaust Outlet Heat Shield Bolts | 10 N·m | 89 lb in |
| Exhaust Pipe Bracket Nut | | 39 lb ft |
| Exhaust Pipe Clamp | | 39 lb ft |
| Exhaust Pipe Heat Shield Bolts | 10 N·m | 89 lb in |
| Fan Pulley Bracket Bolt | 50 N·m | 37 lb ft |
| Flywheel Bolt – Angular Tightening Method | 1st Step 79 N·m | 1st Step 58 lb ft |
| | 2nd Step 60 degrees | 2nd Step 60 degrees |
| | 3rd Step 60 degrees | 3rd Step 60 degrees |
| Flywheel Housing Bolt | 80 N·m | 60 lb ft |
| Flywheel Housing to Upper Oil Pan Bolt | 50 N·m | 37 lb ft |
| Front Engine Cover Bolt | 25 N·m | 18 lb ft |
| Fuel Filter Bracket Bolt | 30 N·m | 22 lb ft |
| Fuel Injection Pipe Nut | 41 N·m | 30 lb ft |
| Fuel Injector Bracket Bolt | 30 N·m | 22 lb ft |
| Fuel Inlet Pipe Bracket Bolt | 21 N·m | 15 lb ft |
| Fuel Injection Pump Assembly to Cylinder Block Bolt | 25 N·m | 18 lb ft |
| Fuel Injection Pump to Bracket Bolt | 28 N·m | 20 lb ft |
| Fuel Injection Pump Drive Gear Nut | 70 N·m | 52 lb ft |
| Fuel Line Bracket Nut | 21 N·m | 15 lb ft |
| Fuel Temperature Sensor | 22 N·m | 16 lb ft |
| Fuel Pipes Bracket Bolt | 25 N·m | 18 lb ft |
| Fuel Pressure Relief Valve | 100 N·m | 74 lb ft |
| Fuel Rail Assembly Bolt | 25 N·m | 18 lb ft |
| Fuel Rail Balance Pipe Bolt | 21 N·m | 15 lb ft |
| Generator Bracket Bolt and Nut | 50 N·m | 37 lb ft |
| Generator Positive Cable Nut | 9 N·m | 80 lb in |
| Glow Plug | 18 N·m | 13 lb ft |
| Glow Plug Controller Bolt | 10 N·m | 89 lb in |
| Glow Plug Harness Bracket Bolt | 10 N·m | 89 lb in |
| Glow Plug Nut | 2 N·m | 18 lb in |
| Glow Plug Power Feed Nut | 15 N·m | 11 lb ft |
| Glow Plug Relay Assembly Bolt | 10 N·m | 89 lb in |
| Heater Outlet Pipe Bolt | 25 N·m | 18 lb ft |
| Heater Pipe Bolt | 25 N·m | 18 lb ft |
| Hood Hinge Bolt | 25 N·m | 18 lb ft |
| Idle Pulley Bolt | 50 N·m | 37 lb ft |
| Injector Bracket Bolt | 23 N·m | 16 lb ft |
| Intake Manifold Bolts/Nuts | 25 N·m | 18 lb ft |
| Oil Cooler Adapter Bolts | 25 N·m | 18 lb ft |
| Oil Cooler Adapter Nuts | 25 N·m | 18 lb ft |

## Fastener Tightening Specifications (cont'd)

| Application | Specification | |
|---|---|---|
| | Metric | English |
| Oil Cooler Assembly Bolts | 25 N·m | 18 lb ft |
| Oil Cooler Adapter Stud | 10 N·m | 89 lb in |
| Oil Drain Plug | 84 N·m | 62 lb ft |
| Oil Fill Tube Bolt | 25 N·m | 18 lb ft |
| Oil Filter | 24 N·m | 18 lb ft |
| Oil Gallery Plugs | 53 N·m | 39 lb ft |
| Oil Level Indicator Tube Bolt | 21 N·m | 15 lb ft |
| Oil Level Sensor Bolt | 10 N·m | 89 lb in |
| Oil Level Sensor Harness Bolt | 40 N·m | 29 lb ft |
| Oil Pan Bolts/Nuts – Lower | 10 N·m | 89 lb in |
| Oil Pan Bolt – Upper | 20 N·m | 15 lb ft |
| Oil Pan Skid Plate Bolt | 20 N·m | 15 lb ft |
| Oil Pressure Sensor Unit | 41 N·m | 30 lb ft |
| Oil Pressure Relief Valve | 39 N·m | 29 lb ft |
| Oil Pump Bolt | 21 N·m | 15 lb ft |
| Oil Pump Driven Gear Nut | 100 N·m | 74 lb ft |
| Oil Pump Gear Cover Bolt | 21 N·m | 15 lb ft |
| Oil Pump Pipe and Screen Assembly Bolts and Nuts | 25 N·m | 18 lb ft |
| Piston Cooling Nozzle Eye Bolt | 21 N·m | 15 lb ft |
| Positive Cable Junction Block Bracket to Power Steering Pump Bolt | 9 N·m | 80 lb in |
| Positive Crankcase Ventilation Cover Screws | 4 N·m | 35 lb in |
| Positive Crankcase Ventilation Oil Seperator Bracket Nut | 25 N·m | 18 lb ft |
| Power Steering Pump Bracket Bolt | 50 N·m | 37 lb ft |
| Power Steering Pump Bolt | 50 N·m | 37 lb ft |
| Rocker Arm Shaft Bracket Bolt | 41 N·m | 30 lb ft |
| Starter Motor Bolt | 78 N·m | 58 lb ft |
| Transmission Fill Tube Nut | 18 N·m | 13 lb ft |
| Thermostat Housing Bolts/Nuts | 25 N·m | 18 lb ft |
| Thermostat Cover Bolt | 25 N·m | 18 lb ft |
| Torque Converter Bolt | 60 N·m | 44 lb ft |
| Transmission Oil Cooler Clip Nut | 9 N·m | 80 lb in |
| Turbocharger Bolt | 108 N·m | 80 lb ft |
| Turbocharger Coolant Outlet Pipe Bracket Nut | 10 N·m | 89 lb in |
| Turbocharger Heat Shield Bolts | 10 N·m | 89 lb in |
| Turbocharger Oil Return Pipe Stud | 10 N·m | 89 lb in |
| Turbocharger Oil Supply Hose Eye Bolt | 26 N·m | 19 lb ft |
| Turbocharger Oil Return Pipe Bolts/Nuts | 25 N·m | 18 lb ft |
| Upper Oil Pan to Flywheel Housing Bolts | 20 N·m | 15 lb ft |
| Valve Adjusting Nut | 22 N·m | 16 lb ft |
| Valve Lifter Holdown Bracket Bolt | 11 N·m | 97 lb in |
| Valve Rocker Arm Cover Bolt – Lower | 10 N·m | 89 lb in |
| Valve Rocker Arm Cover Bolt – Upper | 8 N·m (Two Times) | 71 lb in (Two Times) |
| Water Outlet Bolts | 25 N·m | 18 lb ft |
| Water Pump Bolt | 25 N·m | 18 lb ft |
| Water Pump Inlet Pipe Bolts | 25 N·m | 18 lb ft |

## Engine Mechanical Specifications

| Application | Specification | |
|---|---|---|
| | Metric | English |
| General | | |
| Engine Type | 90 degree V-8 | |
| Displacement | 6.6 Liter | 402 cu in |
| RPO | LLY | |
| Bore | 103 mm | 4.0551 in |
| Stroke | 99 mm | 3.8976 in |
| Compression Ratio | 16.8:1 | |
| Engine Compression Test – Minimum | 2069 KPa | 300 psi |
| Idle Speed | 680 RPM | |
| Firing Order | 1-2-7-8-4-5-6-3 | |
| Block | | |
| Cylinder Bore Diameter – Service Limits | 103.11 mm | 4.0594 in |
| Cylinder Bore Diameter – Production Value | 103.0–103.014 mm | 4.0551–4.0557 in |
| Cylinder Bore Out-of-Round – Production Value | 0.015 mm | 0.0006 in |
| Cylinder Bore Taper – Production Value | 0.015 mm | 0.0006 in |
| Camshaft | | |
| Camshaft Bearing Inside Diameter – Service Limit | 61.07 mm | 2.4043 in |
| Camshaft Bearing Inside Diameter – Production Value | 61.00–61.03 mm | 2.4016–2.4028 in |
| Camshaft End Play – Service Limit | 0.2 mm | 0.0079 in |
| Camshaft Journal Diameter – Service Limit | 60.92 mm | 2.3984 in |
| Camshaft Journal Diameter – Production Value | 60.932–60.962 mm | 2.3990–2.4001 in |
| Camshaft Lobe Lift – Exhuast – Production Value | 5.907 mm | 0.2326 in |
| Camshaft Lobe Lift – Intake – Production Value | 7.273 mm | 0.2863 in |
| Camshaft Runout – Service Limit | 0.05 mm | 0.0020 in |
| Cooling System | | |
| Capacity Engine RPM | 270 L/min 3172 RPM | |
| Thermostat Full Open Temperature | 110 degrees C | 230 degrees F |
| Turbocharger Coolant Bypass Valve | 60 degrees C | 140 degrees F |
| Connecting Rod | | |
| Connecting Rod Bearing Clearance – Service Limit | 0.10 mm | 0.0039 in |
| Connecting Rod Bearing Clearance – Production Value | 0.036–0.077 mm | 0.0014–0.0030 in |
| Connecting Rod Bore Diameter – Bearing End – Production Value | 62.958–62.979 mm | 2.4789–2.4795 in |
| Connecting Rod Bore Diameter – Pin End – Service Limit | 34.53 mm | 1.3594 in |
| Connecting Rod Bore Diameter – Pin End – Production Value | 34.512–34.522 mm | 1.3587–1.3591 in |
| Connecting Rod Length | 163.0 mm | 6.42 in |
| Connecting Rod Side Clearance – Service Limit | 0.54 mm | 0.0213 in |
| Connecting Rod Side Clearance – Production Value | 0.31–0.49 mm | 0.0122–0.0193 in |
| Crankshaft | | |
| Connecting Rod Journal Diameter – Service Limit | 62.88 mm | 2.4756 in |
| Connecting Rod Journal Diameter – Production Value | 62.902–62.922 mm | 2.4764–2.4772 in |
| Crankshaft End Play – Service Limit | 0.54 mm | 0.0213 in |
| Crankshaft End Play – Production Value | 0.04–0.205 mm | 0.0016–0.0081 in |

## Engine Mechanical Specifications (cont'd)

| Application | Specification | |
|---|---|---|
| | Metric | English |
| Crankshaft Main Bearing Clearance – Service Limit | 0.14 mm | 0.0055 in |
| Crankshaft Main Bearing Clearance – Production Value | 0.039–0.070 mm | 0.0015–0.0028 in |
| Crankshaft Main Journal Diameter – Service Limit | 79.89 mm | 3.1453 in |
| Crankshaft Main Journal Diameter – Production Value | 79.905–79.925 mm | 3.1459–3.1466 in |
| Crankshaft Runout – Service Limit | 0.44 mm | 0.0173 in |
| Crankshaft Runout – Production Value | 0.05 mm | 0.0020 in |
| Cylinder Head | | |
| Surface Flatness – Block Deck – Service Limit | 0.2 mm | 0.0079 in |
| Surface Flatness – Block Deck – Production Value | 0.075 mm | 0.0030 in |
| Surface Flatness – Exhaust Manifold Deck – Production Value | 0.1 mm | 0.0039 in |
| Surface Flatness – Intake Manifold Deck – Production Value | 0.1 mm | 0.0039 in |
| Exhaust Manifold | | |
| Surface Flatness– Production Value | 0.3 mm | 0.0118 in |
| Intake Manifold | | |
| Surface Flatness – Production Value | 0.3 mm | 0.0118 in |
| Lubrication System | | |
| Oil Capacity – with Filter | 10 qt | 9.5 L |
| Oil Capacity – without Filter | 9.2 qt | 8.7 L |
| Oil Pressure – Minimum– Hot – at idle | 98 KPa | 14 psi |
| Oil Pressure – Minimum – 1800 RPM | 294 KPa | 42 psi |
| Oil Relief Valve Opening Pressure | 441 KPa | 64 psi |
| Piston Cooling Jet Valve Opening Pressure | 196 KPa | 29 psi |
| Oil Pump | | |
| Gear Shaft Outside Diameter – Drive – Service Limit | 19.86 mm | 0.7819 in |
| Gear Shaft Outside Diameter – Drive – Production Value | 19.947–19.960 mm | 0.7853–0.7858 in |
| Gear Shaft Outside Diameter – Driven – Service Limit | 19.86 mm | 0.7819 in |
| Gear Shaft Outside Diameter – Driven – Production Value | 19.947–19.960 mm | 0.7853–0.7858 in |
| Gear Shaft-to-Bushing – Service Limit Clearance | 0.14 mm | 0.0055 in |
| Gear-to-Cover Clearance – Drive/Driven – Service Limit | 0.109 mm | 0.0043 in |
| Gear-to-Cover Clearance – Drive/Driven – Production Value | 0.064–0.109 mm | 0.0025–0.0043 in |
| Gear-to-Housing Clearance – Drive/Driven – Service Limit | 0.22 mm | 0.0087 in |
| Gear-to-Housing Clearance – Drive/Driven – Production Value | 0.125–0.221 mm | 0.0049–0.0087 in |
| Piston Rings | | |
| Piston Ring End Gap–First Compression Ring – Service Limit | 1.37 mm | 0.0539 in |
| Piston Ring End Gap–First Compression Ring – Production Value | 0.3–0.45 mm | 0.0118–0.0177 in |
| Piston Ring End Gap–Second Compression Ring – Service Limit | 1.35 mm | 0.0531 in |
| Piston Ring End Gap–Second Compression Ring – Production Value | 0.50–0.65 mm | 0.0197–0.0256 in |
| Piston Ring End Gap–Oil Control Ring – Service Limit | 1.20 mm | 0.0472 in |
| Piston Ring End Gap–Oil Control Ring – Production Value | 0.15–0.35 mm | 0.0059–0.0138 in |
| Piston Ring to Groove Clearance–First Compression Ring – Service Limit | 0.26 mm | 0.0102 in |
| Piston Ring to Groove Clearance–First Compression Ring – Production Value | 0.08–0.17 mm | 0.0030–0.0067 in |
| Piston Ring to Groove Clearance–Second Compression Ring – Service Limit | 0.10 mm | 0.0039 in |

## Engine Mechanical Specifications (cont'd)

| Application | Specification | |
|---|---|---|
| | Metric | English |
| Piston Ring to Groove Clearance–Second Compression Ring – Production Value | 0.01–0.03 mm | 0.0004–0.0012 in |
| Piston Ring to Groove Clearance–Oil Control Ring – Service Limit | 0.12 mm | 0.0047 in |
| Piston Ring to Groove Clearance–Oil Control Ring – Production Value | 0.01–0.03 mm | 0.0004–0.0012 in |
| Pistons and Pins | | |
| Piston–Piston Diameter | 102.948–102.960 mm | 4.0531–4.0535 in |
| Piston–Piston Pin Bore Diameter | 34.504–34.512 mm | 1.3584–1.3587 in |
| Pin–Piston Pin Clearance to Piston Pin Bore – Service Limit | 0.017 mm | 0.0007 in |
| Pin–Piston Pin Clearance to Piston Pin Bore – Production Value | 0.004–0.017 mm | 0.0002–0.0007 in |
| Pin–Piston Pin Diameter – Service Limit | 34.45 mm | 1.3563 in |
| Pin–Piston Pin Diameter – Production Value | 34.495–34.5 mm | 1.3581–1.3583 in |
| Starter | | |
| Rated Output | 3.5 KW | |
| Valve System | | |
| Valves–Valve Face Angle – Production Value | 45 degrees | |
| Valves–Valve Face Width - Service Limit | 2.5 mm | 0.0984 in |
| Valves–Valve Face Width – Production Value | 2.1 mm | 0.0827 in |
| Valves–Valve Head Diameter – Exhaust | 31.0 mm | 1.22 in |
| Valves–Valve Head Diameter – Intake | 33.0 mm | 1.30 in |
| Valves–Valve Seat Angle | 45 degrees | |
| Valves–Valve Stem Diameter | 7.0 mm | 0.28 in |
| Valves–Valve Stem Oil Seal Installed Height | 6.05 mm | 0.2382 in |
| Valves–Valve Stem-to-Guide Clearance – Service Limit | 0.20 mm | 0.0079 in |
| Valves–Valve Stem-to-Guide Clearance – Exhaust – Production Value | 0.038–0.071 mm | 0.0015–0.0028 in |
| Valves–Valve Stem-to-Guide Clearance – Intake – Production Value | 0.030–0.063 mm | 0.0012–0.0025 in |
| Valves–Valve Stem-to-Guide Clearance | 0.20 mm | 0.0079 in |
| Valve Lifters/Push Rods–Push Rod Straightness | 0.8 mm | 0.0315 in |
| Rocker Arms–Valve Rocker Arm Bore Diameter | 22.010–22.035 mm | 0.8665–0.8675 in |
| Rocker Arms–Valve Rocker Arm Bore-to-Shaft Clearance – Service Limit | 0.20 mm | 0.0079 in |
| Rocker Arms–Valve Rocker Arm Bore-to-Shaft Clearance – Production Value | 0.010–0.056 mm | 0.0004–0.0022 in |
| Rocker Arms–Valve Rocker Arm Ratio – Exhaust | 1.69:1 | |
| Rocker Arms–Valve Rocker Arm Ratio – Intake | 1.36:1 | |
| Rocker Arms–Valve Rocker Arm Shaft Diameter – Service Limit | 21.85 mm | 0.8602 in |
| Rocker Arms–Valve Rocker Arm Shaft Diameter – Production Value | 21.979–22.000 mm | 0.8653–0.8661 in |
| Valve Springs–Valve Spring Free Length – Production Value | 56.6 mm | 2.2283 in |
| Valve Springs–Valve Spring Installed Height – Production Value | 41 mm | 1.6142 in |
| Valve Springs–Valve Spring Load – Exhaust – Service Limit | 275 N at 41 mm | 61.8 lb at 1.61 in |
| Valve Springs–Valve Spring load – Exhaust – Production Value | 315–363 N at 41 mm | 71–81.6 lb at 1.61 in |
| Valve Springs–Valve Spring Load – Intake – Service Limit | 306 N at 41 mm | 68.8 lb at 1.61 in |
| Valve Springs–Valve Spring Load – Intake – Production Value | 315–363 N at 41 mm | 71–81.6 lb at 1.61 in |

## Sealers, Adhesives, and Lubricants

| Application | Type of Material | GM Part Number | |
|---|---|---|---|
| | | United States | Canada |
| Sealing Cup Plug | Locktite 272T or Equivalent | 12345493 | 10953488 |
| Upper Oil Pan to Cylinder Block | Sealant | 12378521 | 88901148 |
| Flywheel Housing to Cylinder Block | Sealant | 12378521 | 88901148 |
| Engine Front Cover to Cylinder Block | Sealant | 12378521 | 88901148 |
| Lower Oil Pan to Upper Oil Pan | Sealant | 12378521 | 88901148 |
| Crankshaft Bearing Side Cap Bolts | Sealant | 12346004 | 10953480 |
| Intake Manifold to Cylinder Head | Sealant | 12378521 | 88901148 |
| Camshaft Bearing | Engine Oil | 12345634 | 993297 |
| Rocker Arm Shaft | Engine Oil | 12345634 | 993297 |
| Valve Bridge Cap | Engine Oil | 12345634 | 993297 |
| Valve Stem Seal | Engine Oil | 12345634 | 993297 |
| Valve Lifter | Engine Oil | 12345634 | 993297 |
| Piston Ring | Engine Oil | 12345634 | 993297 |
| Crankshaft Bearing | Engine Oil | 12345634 | 993297 |
| Connecting Rod Bearing | Engine Oil | 12345634 | 993297 |
| Thrust Bearing | Engine Oil | 12345634 | 993297 |
| Camshaft Bearing | Engine Oil | 12345634 | 993297 |
| Camshaft | Engine Oil | 12345634 | 993297 |
| Connecting Rod Small End Bushing | Engine Oil | 12345634 | 993297 |
| Push Rod | Engine Oil | 12345634 | 993297 |
| Crankshaft Bearing Cap Bolt | Molybdenum Disulfide | 1052948 | 992926 |
| Lithium Grease | Lubricant | 12346293 | — |
| Parts Cleaner | Cleaner | 12377981 | 10953463 |

## Connecting Rod Bearings Selection Specifications

| Connecting Rod Grade (Stamped on Connecting Rod) | Use This Bearing Color | Bearing Thickness | | Oil Clearance | |
|---|---|---|---|---|---|
| | | Metric (mm) | English (in) | Metric (mm) | English (in) |
| A | Green | 2.007 – 2.013 | 0.0790 – 0.0793 | 0.037 – 0.076 | 0.0015 – 0.0030 |
| B | Yellow | 2.011 – 2.017 | 0.0792 – 0.0794 | 0.037 – 0.076 | 0.0015 – 0.0030 |

## Cylinder Head Gasket Selection Specifications

| Cylinder Head Gasket Grade | Ti max (Piston Projection) | | Gasket Thickness | |
|---|---|---|---|---|
| | Metric (mm) | English (in) | Metric (mm) | English (in) |
| Grade A (No grade hole on the gasket) | Over 0.223 - less than 0.274 | Over 0.0088 - less than 0.0108 | 0.90–1.00 | 0.0354–0.0394 |
| Grade B (One grade hole on the gasket) | Over 0.274 - less than 0.325 | Over 0.0108 - less than 0.0128 | 0.95–1.05 | 0.0374–0.0413 |
| Grace C (Two grade holes on the gasket) | Over 0.325 - less than 0.376 | Over 0.0128 - less than 0.0148 | 1.00–1.10 | 0.0394–0.0433 |

### Crankshaft Bearings Selection Specifications

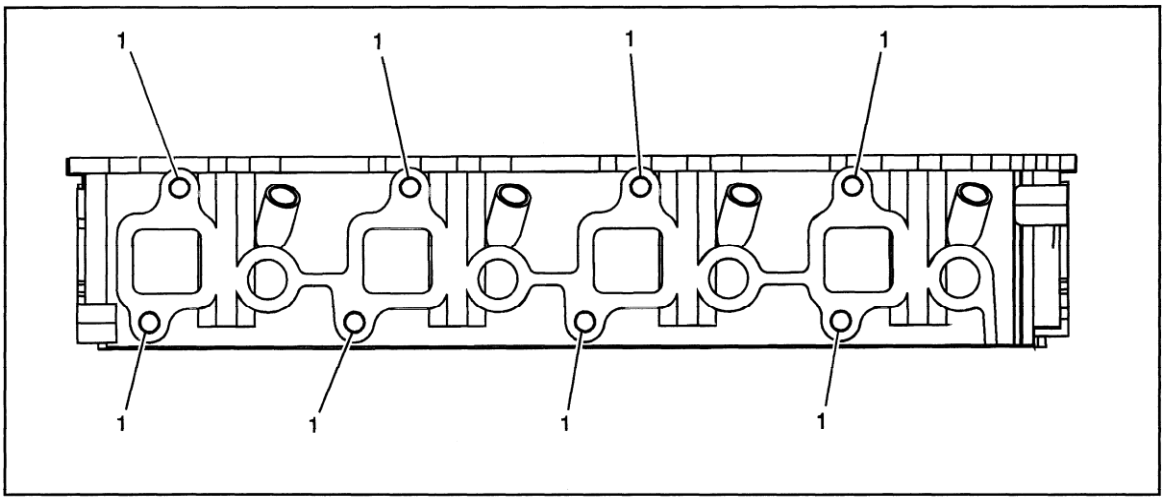
| Cylinder Block Grade | Crankshaft Journal Grade | Identification Bearing Color | Oil Clearance | |
|---|---|---|---|---|
| | | | Metric (mm) | English (in) |
| 1 | 1 | Black | 0.041–0.068 | 0.0016–0.0027 |
| 1 | 2 | Brown | 0.039–0.065 | 0.0015–0.0026 |
| 2 | 1 | Blue | 0.043–0.070 | 0.0017–0.0028 |
| 2 | 2 | Black | 0.041–0.067 | 0.0016–0.0027 |

### Valve Clearance Adjustment Specifications

| Cylinder | | Adjust at No 1 Compression Stroke TDC | | Adjust at No 1 Exhaust Stroke TDC | |
|---|---|---|---|---|---|
| Left Bank | Right Bank | Intake | Exhaust | Intake | Exhaust |
| — | 1 | X | X | — | — |
| 2 | — | — | X | X | — |
| — | 3 | X | — | — | X |
| 4 | — | — | — | X | X |
| — | 5 | X | — | — | X |
| 6 | — | X | — | — | X |
| — | 7 | — | X | X | — |
| 8 | — | — | X | X | — |

## Thread Repair Specifications

### Cylinder Head – Exhaust View

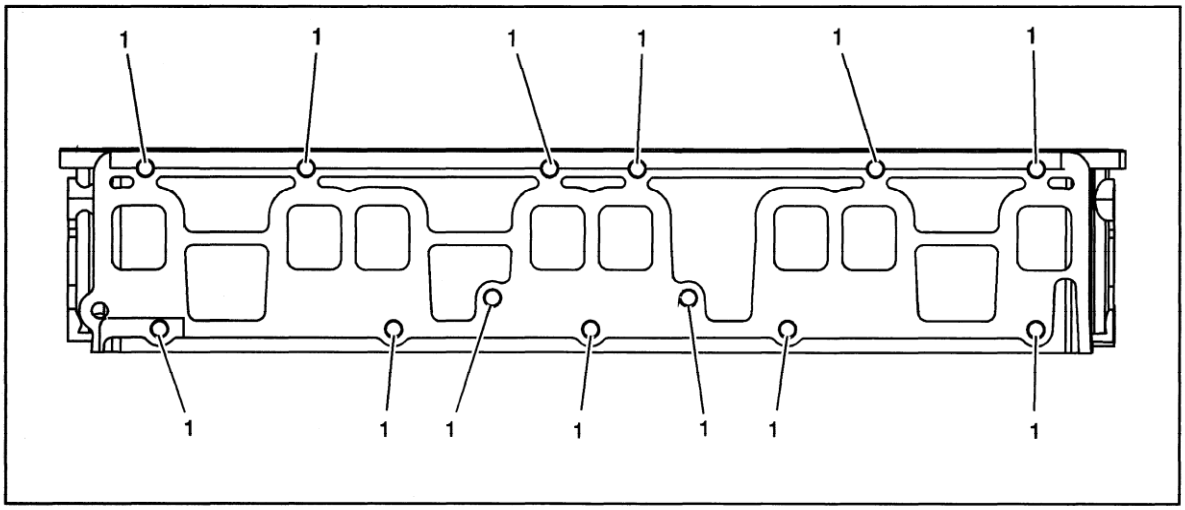



1491199

### Cylinder Head – Exhaust View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –215 | 25 | 0.985 | 21 | 0.827 |

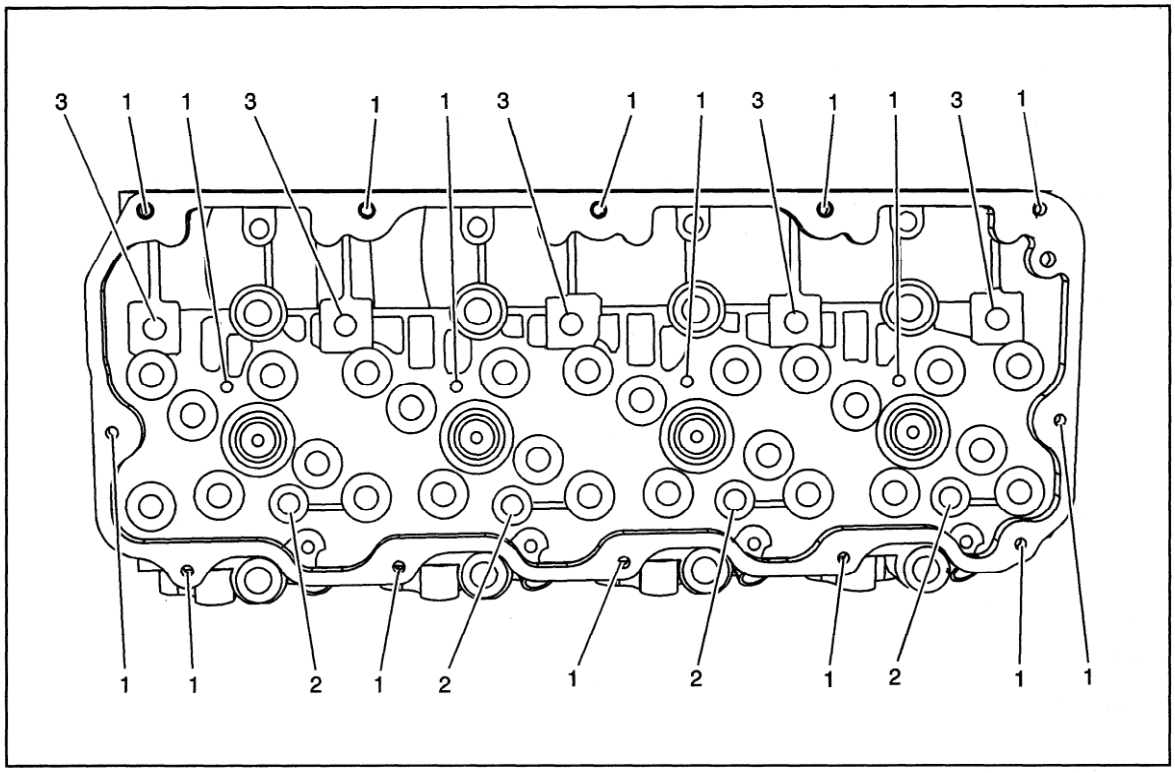
## Cylinder Head – Intake View




### Cylinder Head – Intake View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 17 | 0.669 |

## Cylinder Head – Top View

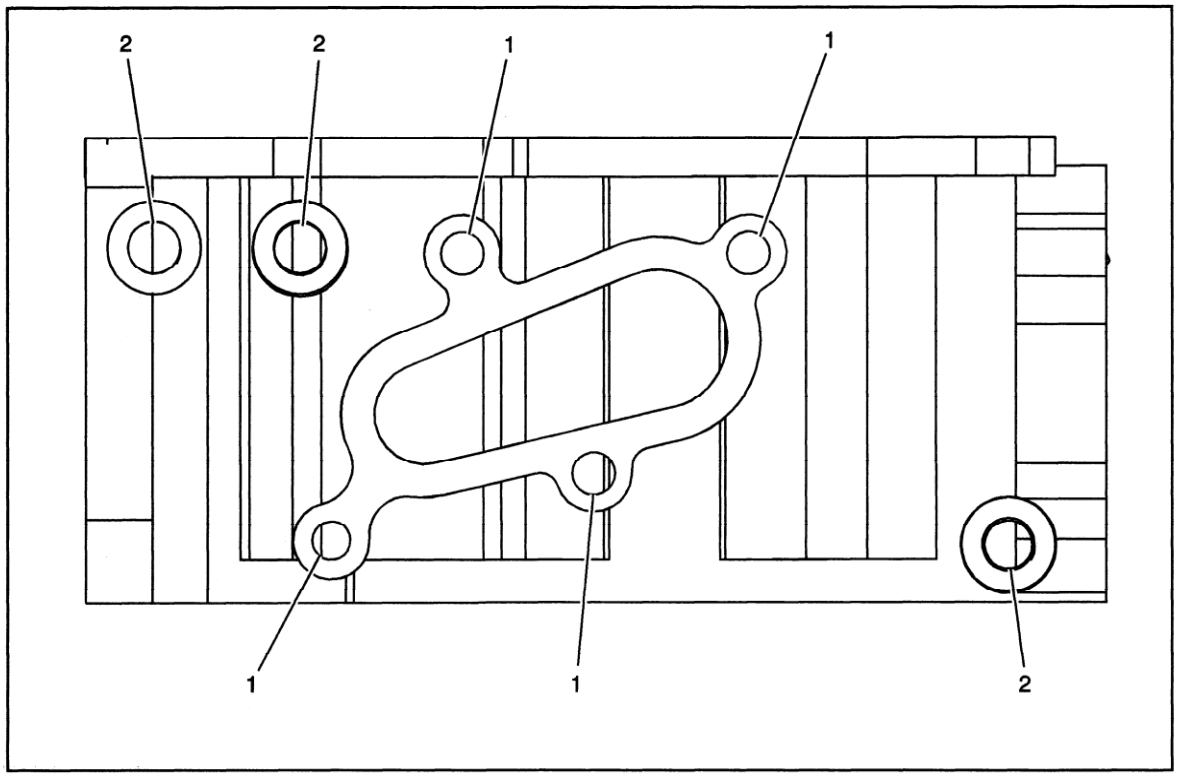



1491208

### Cylinder Head – Top View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 17 | 0.669 | 13 | 0.512 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 26 | 1.024 | 20 | 0.788 |
| 3 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –215 | 26 | 1.024 | 20 | 0.788 |

## Cylinder Head – Rear View

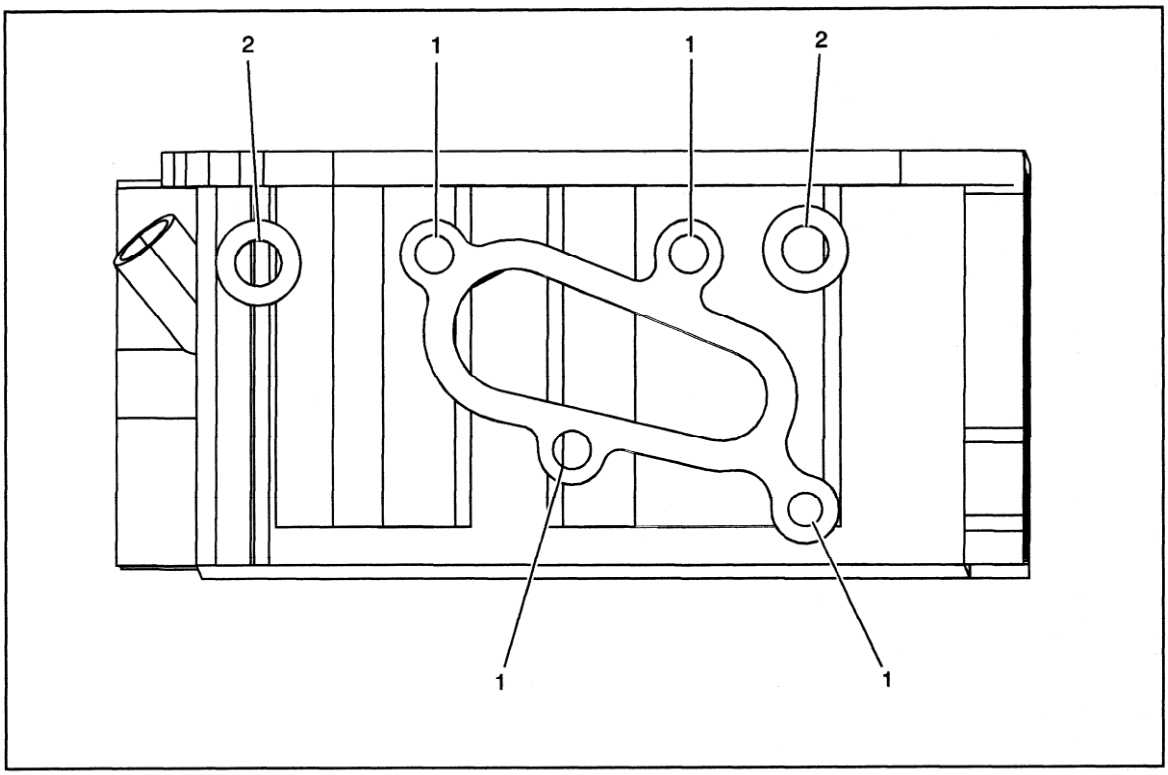



1491212

**Cylinder Head – Rear View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |
| 2 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –216 | 20 | 0.788 | 16 | 0.630 |

## Cylinder Head – Front View

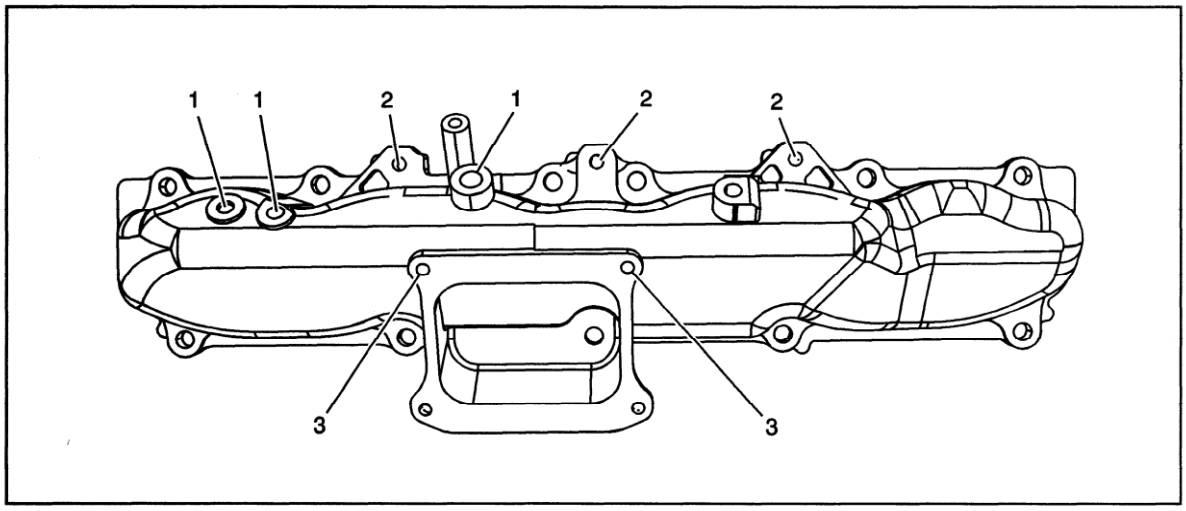



1491218

### Cylinder Head – Front View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |
| 2 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –216 | 20 | 0.788 | 16 | 0.630 |

## Intake Manifold – Right Side View

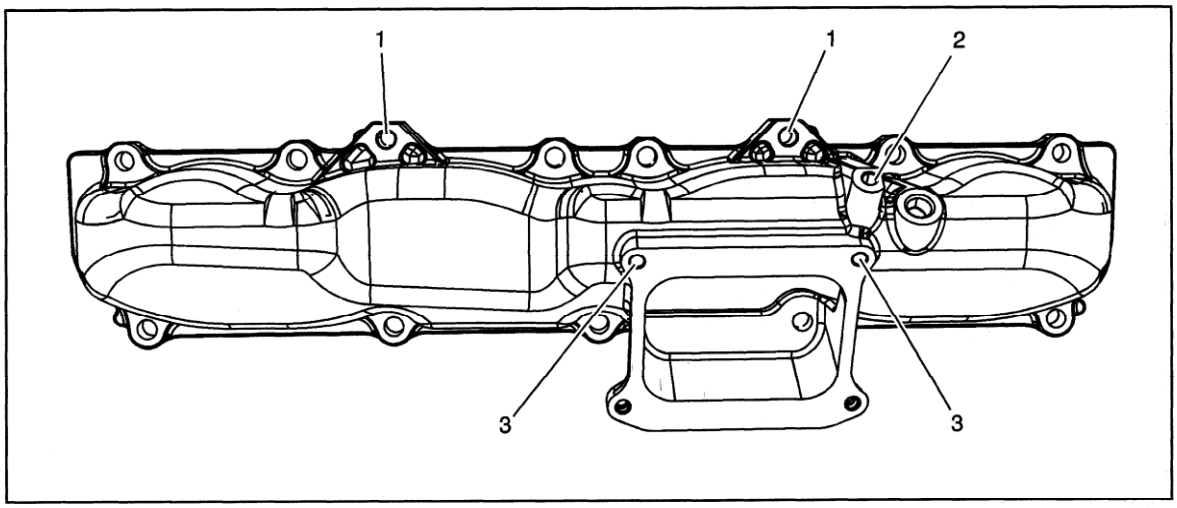



1491222

### Intake Manifold – Right Side View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –415 | 16 | 0.630 | 13 | 0.512 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |
| 3 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 16 | 0.0630 | 12 | 0.472 |

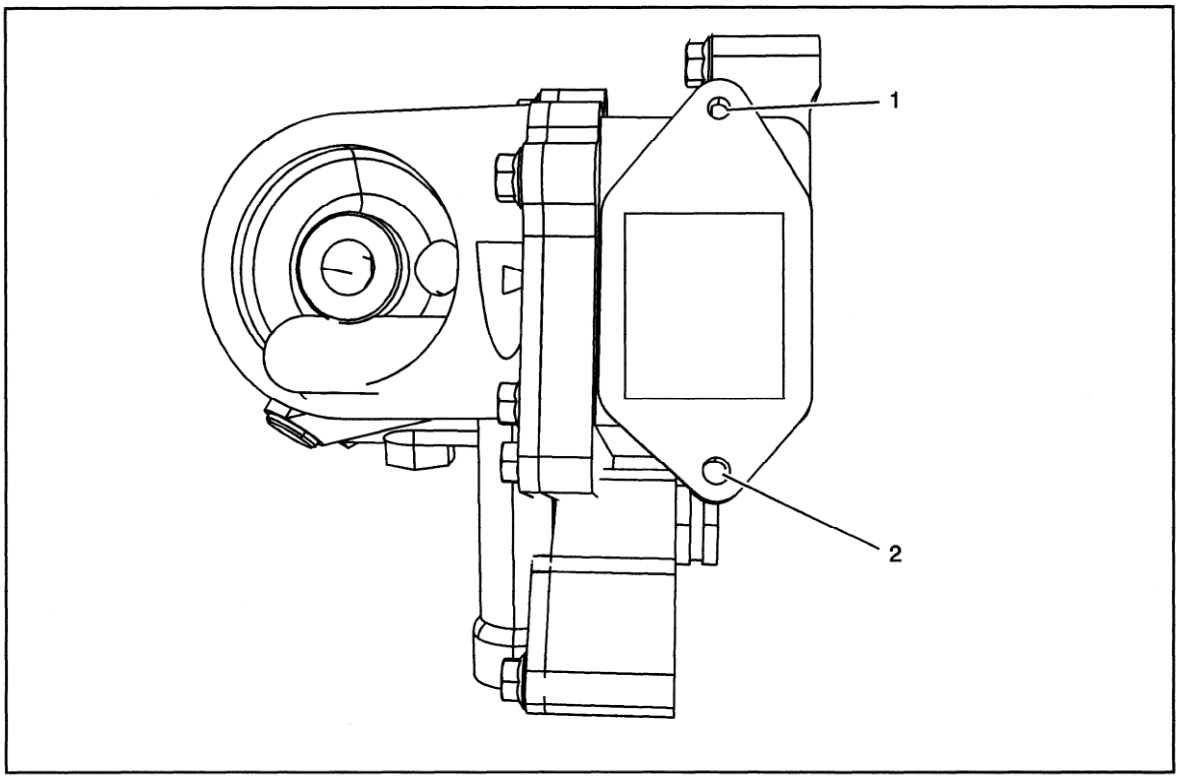
## Intake Manifold – Left Side View




### Intake Manifold – Left Side View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |
| 2 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 14 | 0.551 | 11 | 0.433 |
| 3 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 16 | 0.630 | 12 | 0.472 |

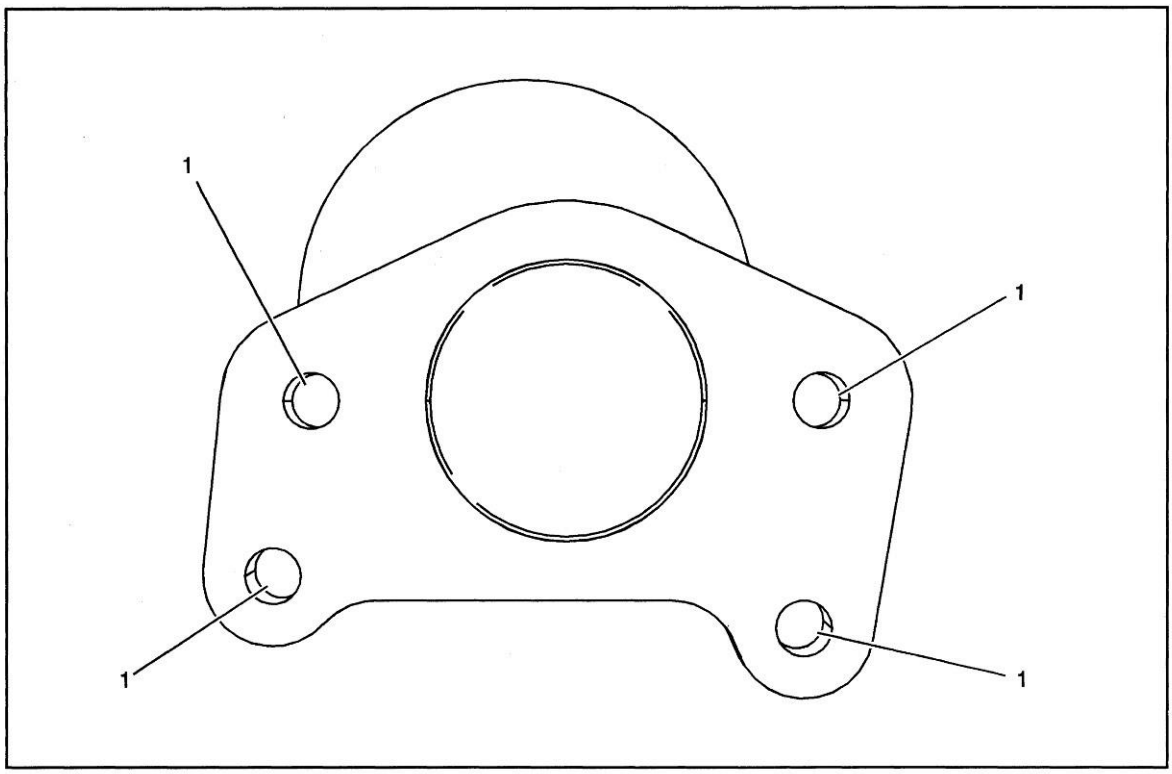
## Oil Cooler




### Oil Cooler

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 17 | 0.669 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |

## EGR Cooler – Rear View



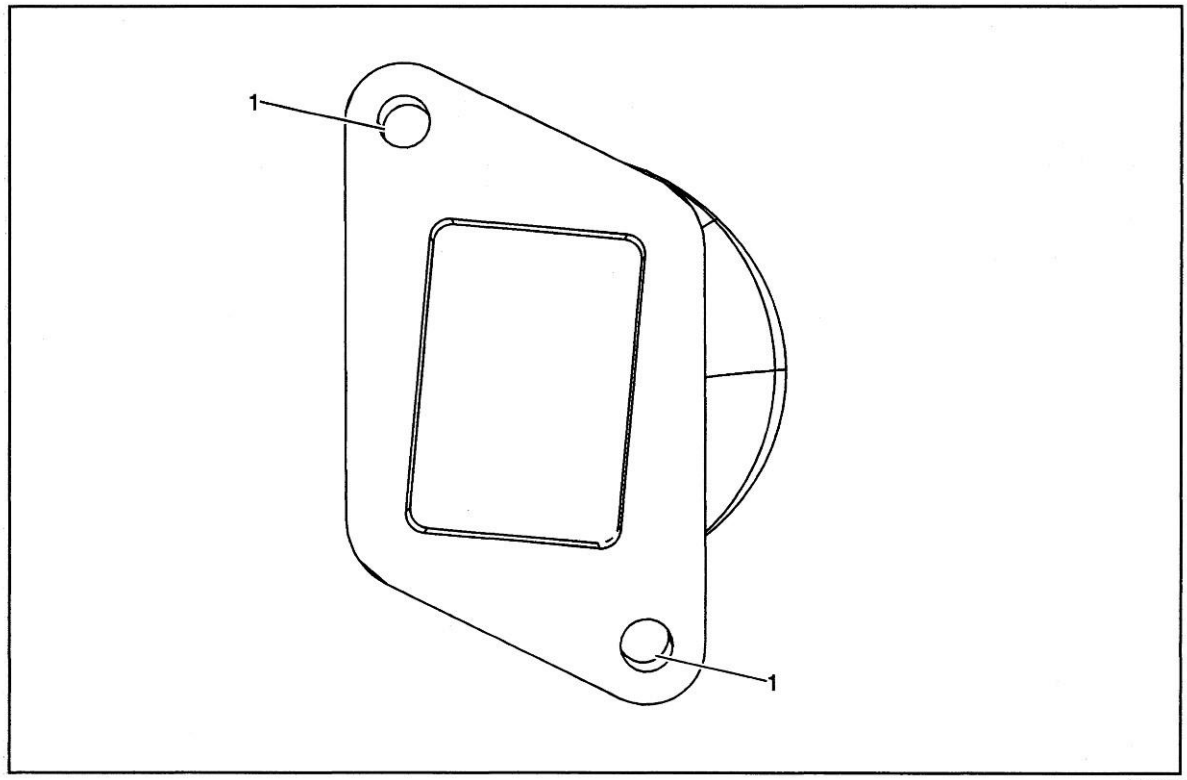

1491234

**EGR Cooler – Rear View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |

OPTIONAL

## EGR Cooler – Front View

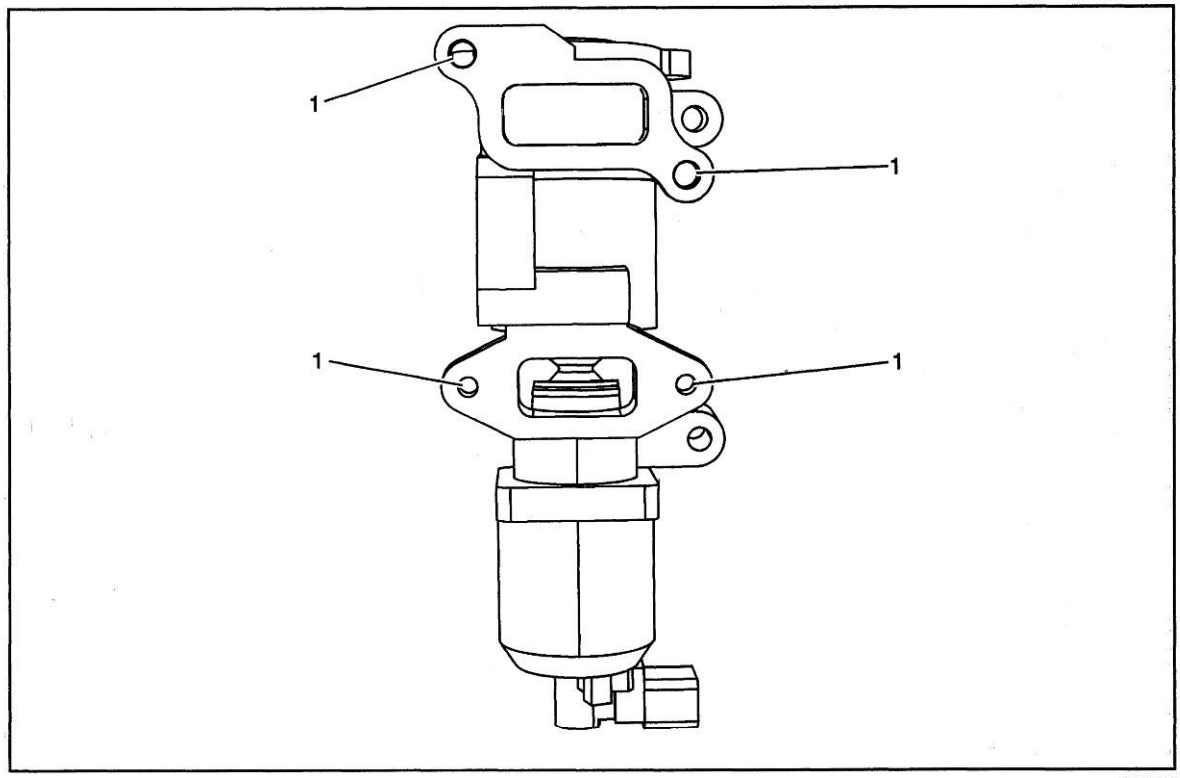



**EGR Cooler – Front View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |

OPTIONAL

## EGR – Top View



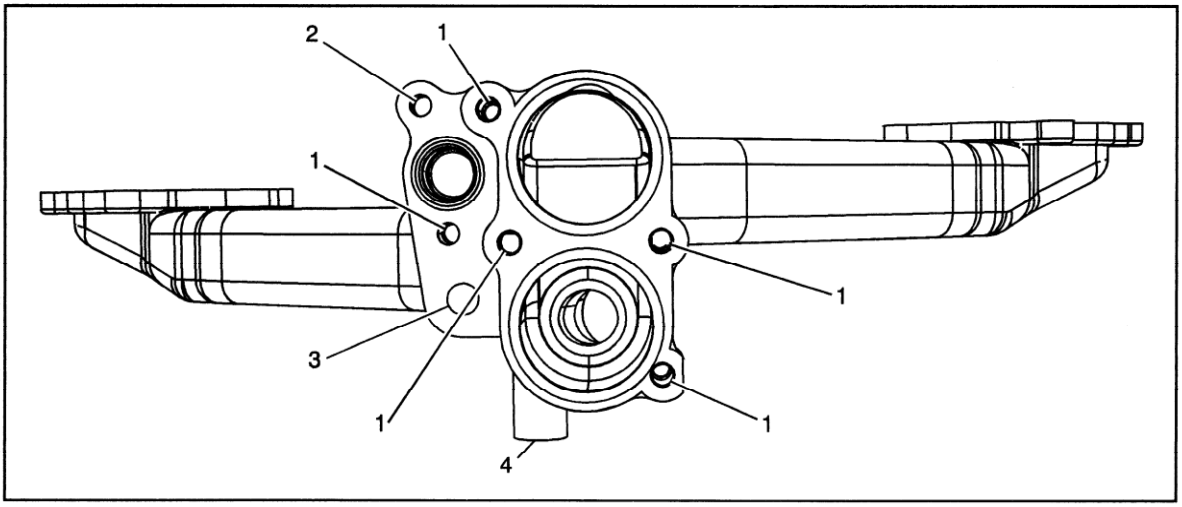

1491243

**EGR – Top View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |

OPTIONAL

## Thermostat Housing – Top View

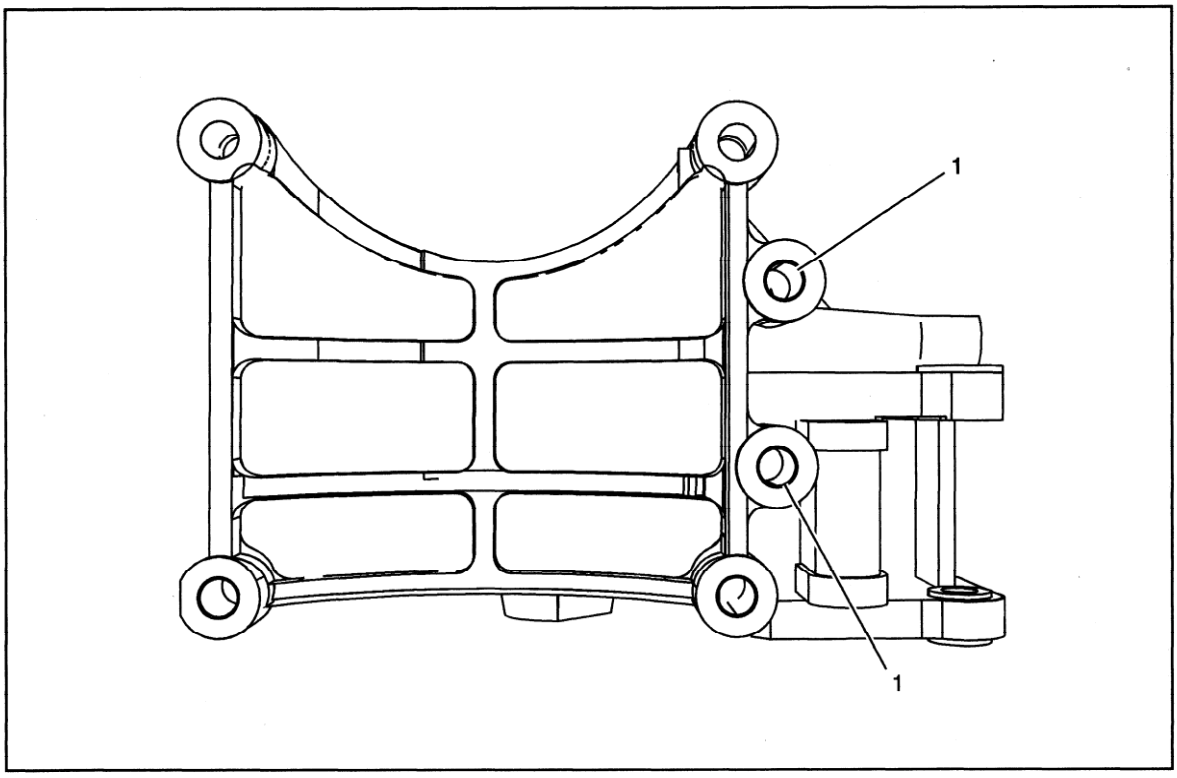



1491246

### Thermostat Housing – Top View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 17 | 0.669 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | THRU | | THRU | |
| 3 | NPT 3/8 | –2013 | N/A | N/A | –294 | –2015 | –2016 | THRU | | THRU | |
| 4 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 19 | 0.748 | 15 | 0.591 |

## AC Bracket

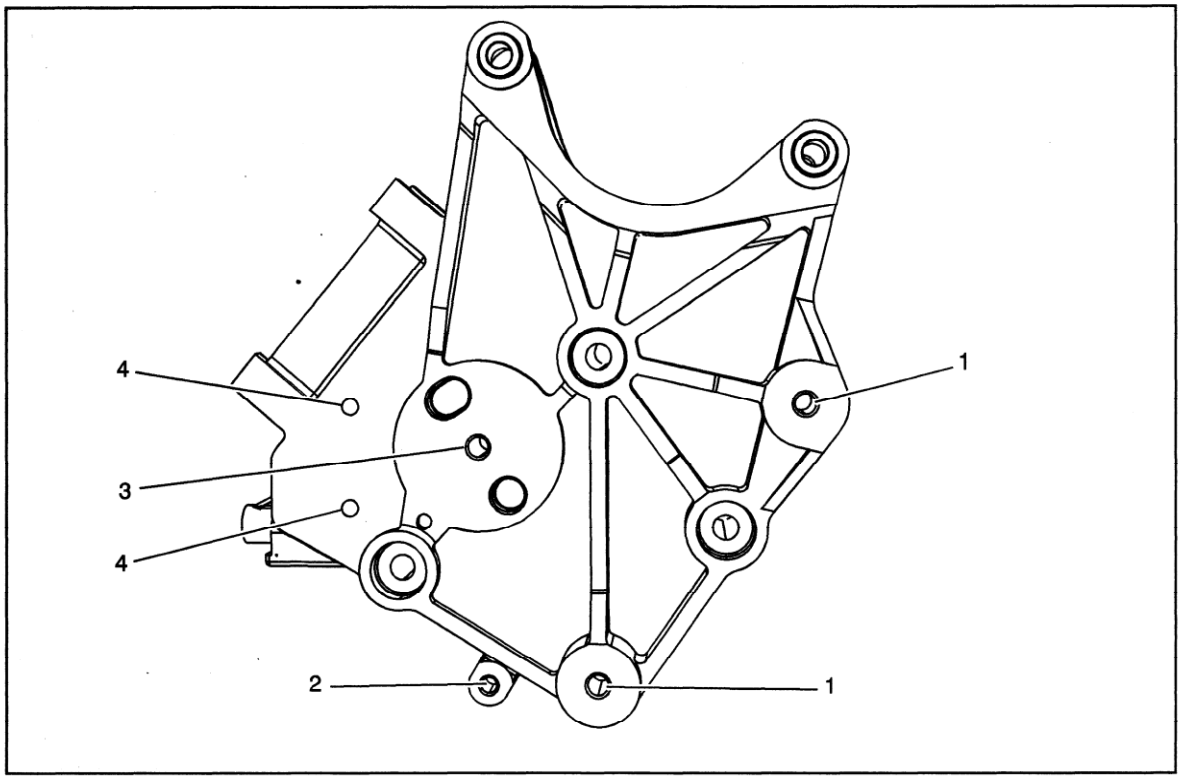



1491254

### AC Bracket

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –420 | 30 | 1.182 | 25 | 0.985 |

## Generator Bracket – Front View

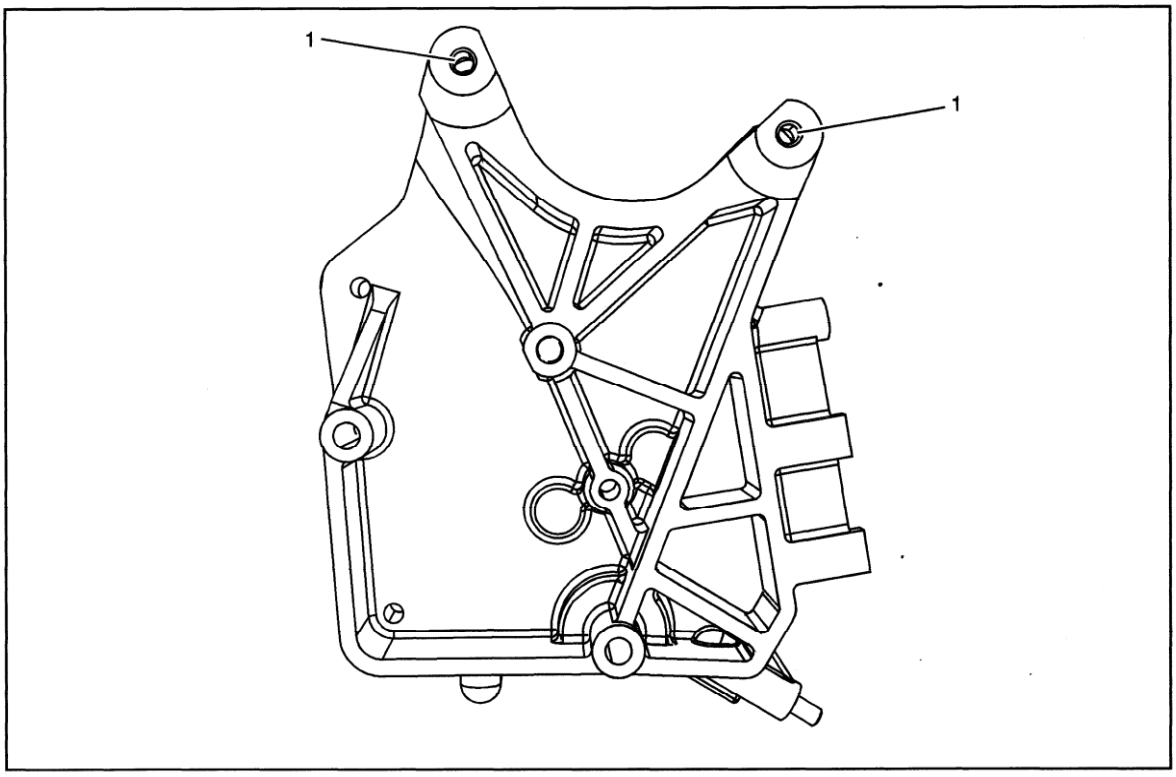



1491256

### Generator Bracket – Front View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –215 | THRU | | THRU | |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –415 | 17 | 0.669 | 12 | 0.472 |
| 3 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –420 | THRU | | 25 | 0.985 |
| 4 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 22 | 0.866 | 17 | 0.669 |

## Generator Bracket – Rear View

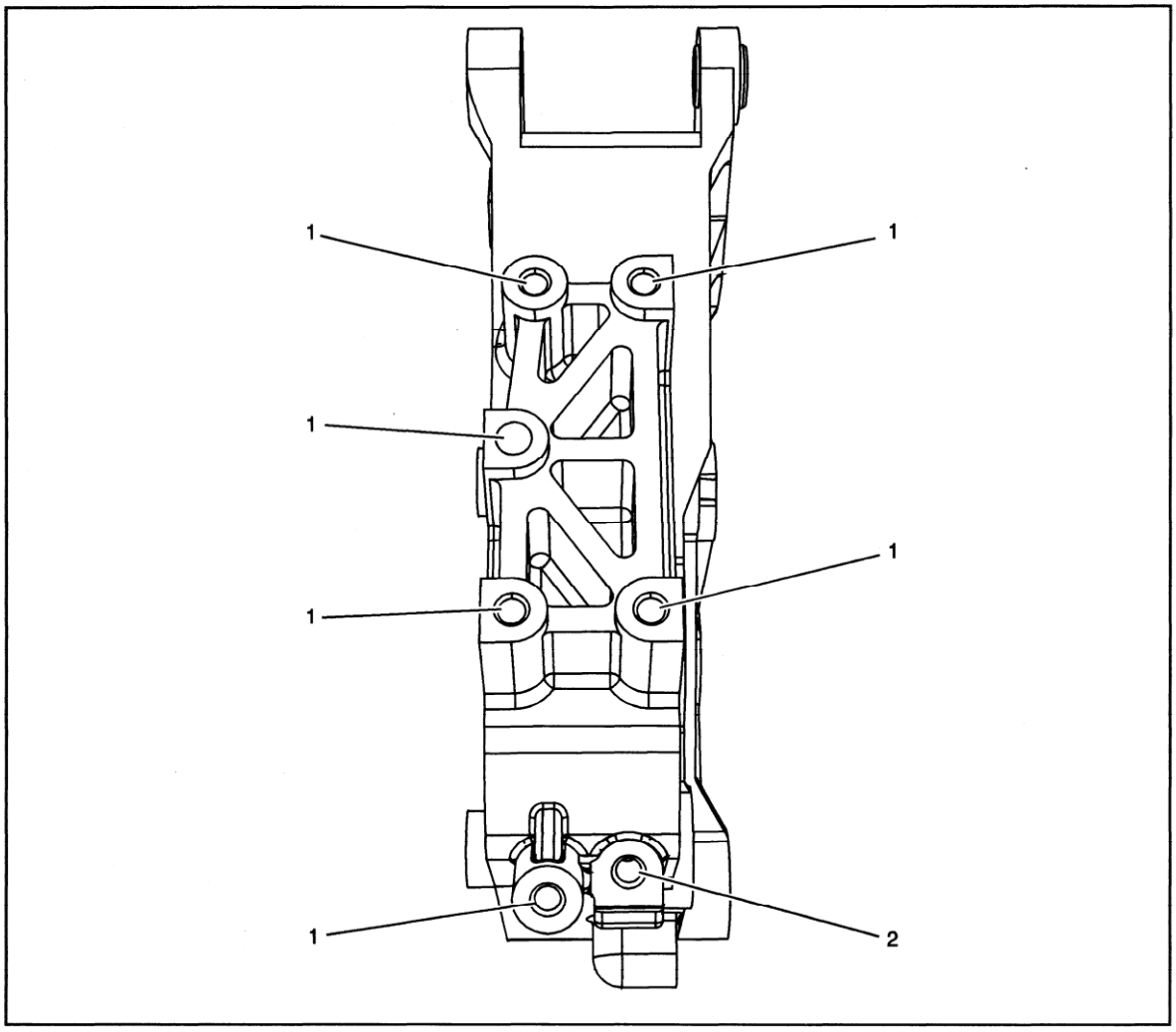



1491259

### Generator Bracket – Rear View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –215 | THRU | | THRU | |

## Generator Bracket – Side View

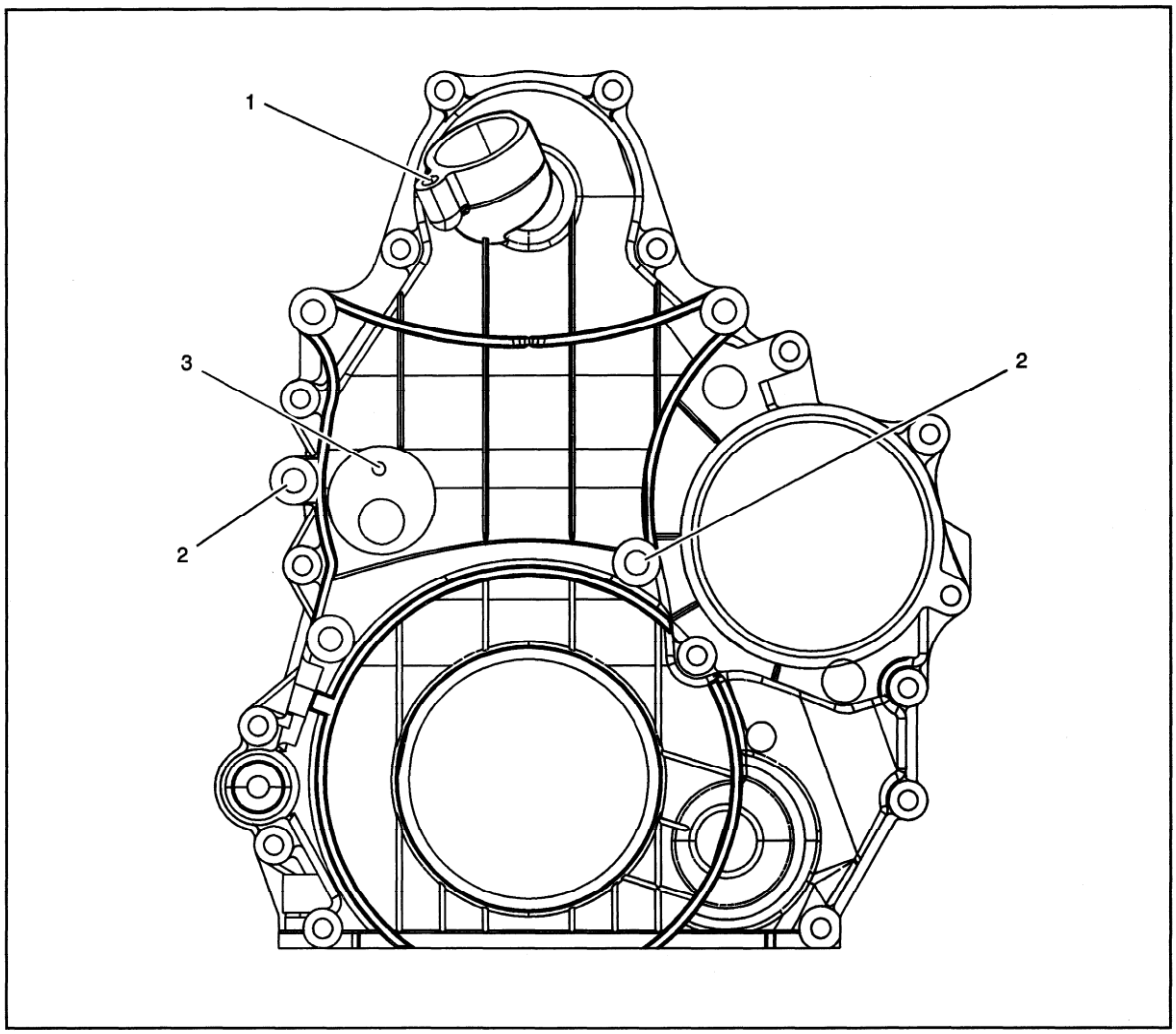



1491264

### Generator Bracket – Side View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 22 | 0.866 | 17 | 0.669 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 12 | 0.472 |

## Engine Front Cover – Front View

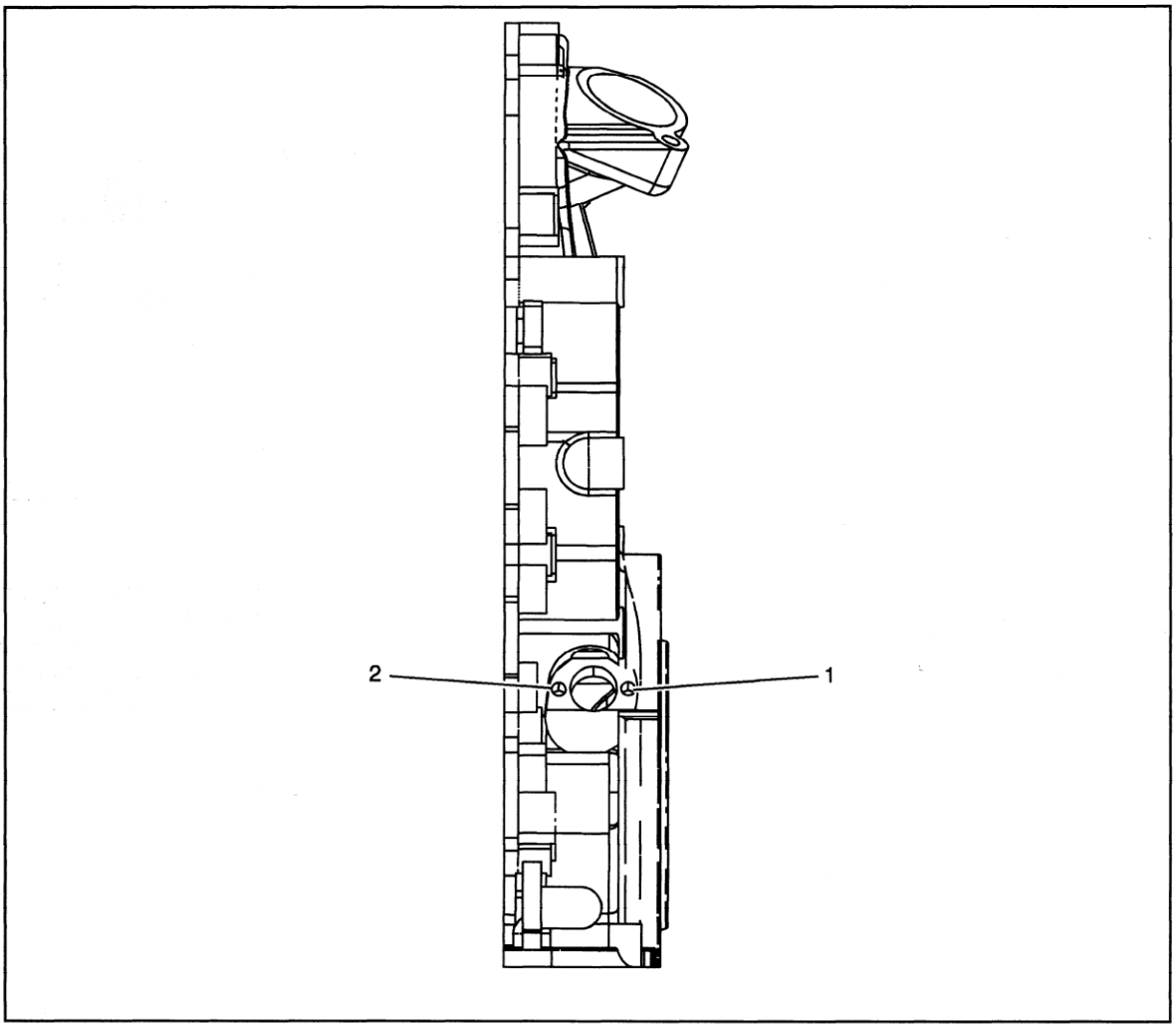



1491266

### Engine Front Cover – Front View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 19 | 0.748 | 15 | 0.591 |
| 2 | M 10 x 1.5 | –211 | –212 | N/A | –213 | –214 | –216 | 20 | 0.788 | 16 | 0.630 |
| 3 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 14 | 0.551 | 10 | 0.394 |

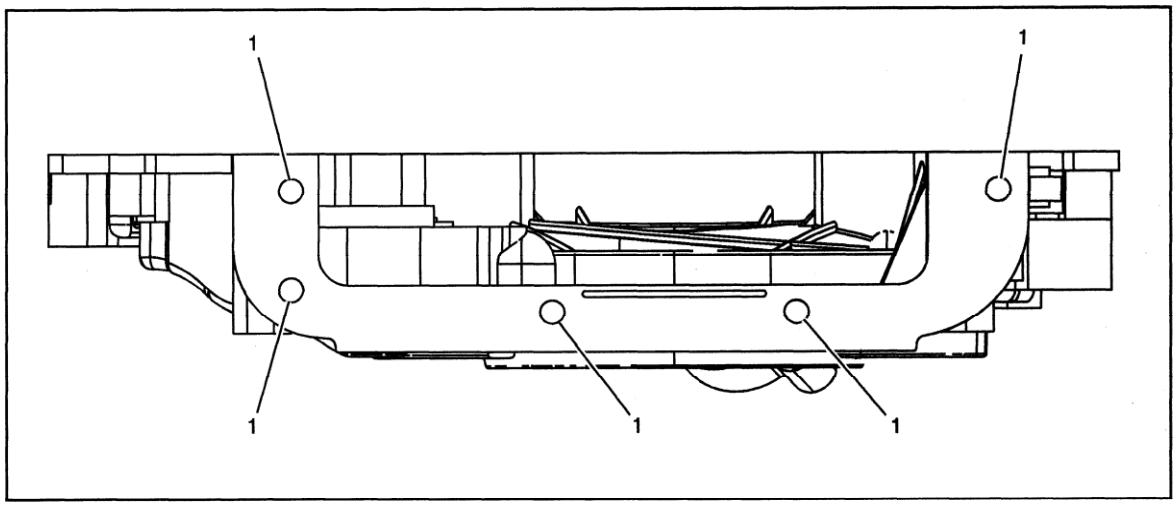
## Engine Front Cover – Side View




### Engine Front Cover – Side View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 14 | 0.551 | 10 | 0.394 |
| 2 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | THRU | | 10 | 0.394 |

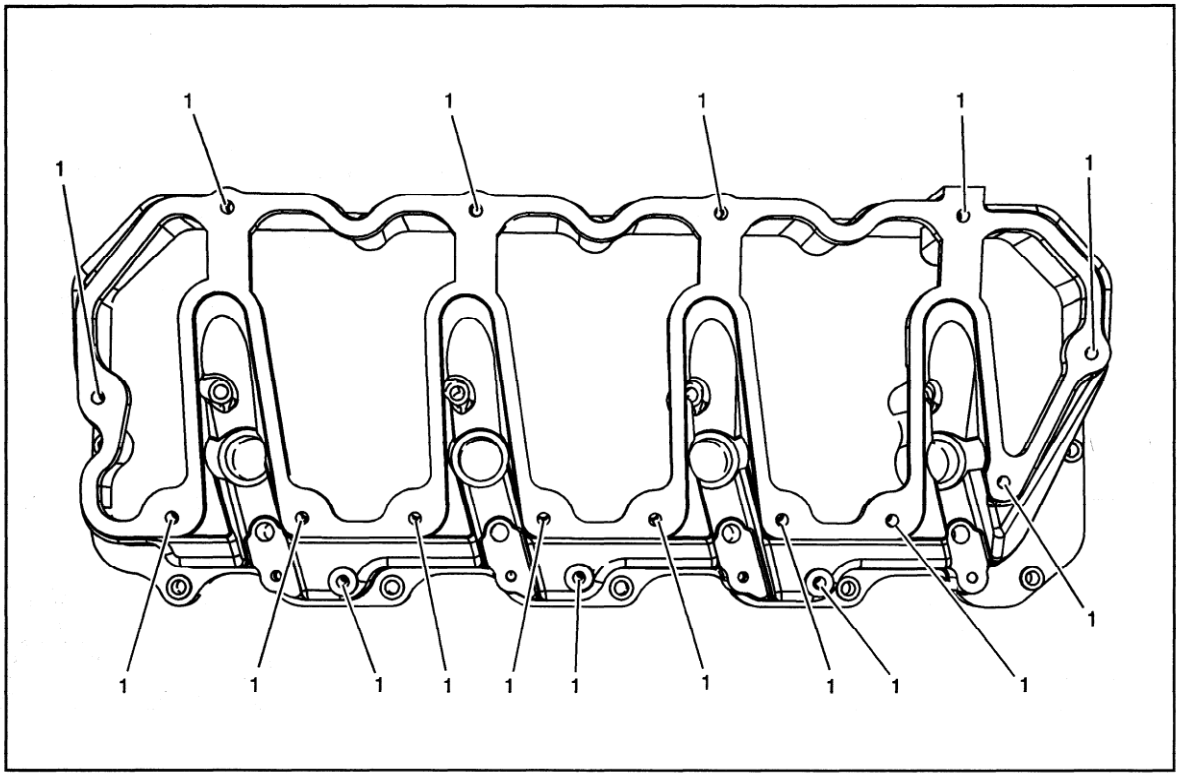
## Engine Front Cover – Bottom View




### Engine Front Cover – Bottom View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |

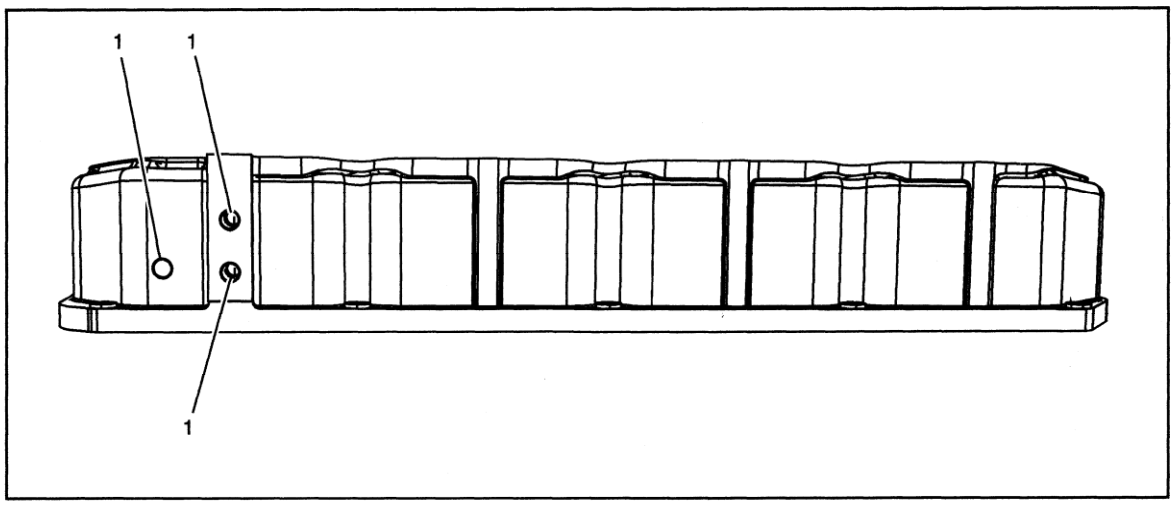
## Lower Rocker Arm Cover – Top View




### Lower Rocker Arm Cover – Top View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 18 | 0.709 | 15 | 0.591 |

## Lower Rocker Arm Cover – Side View

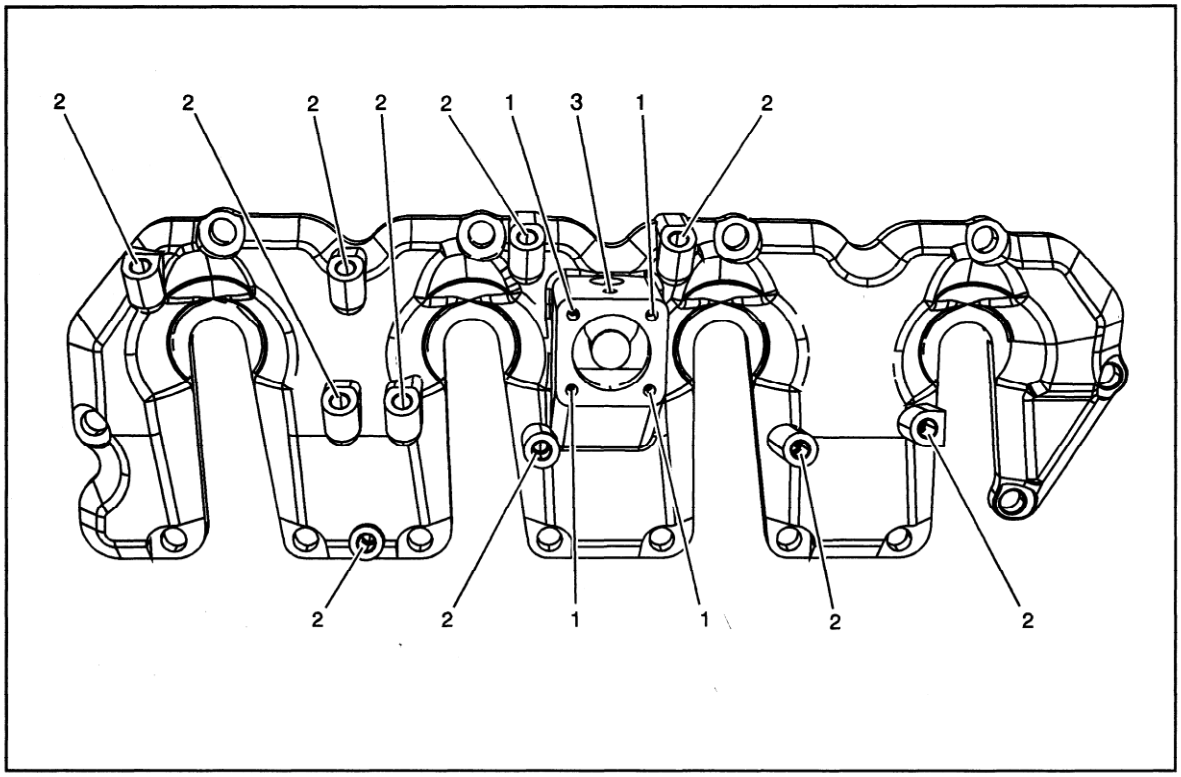



1491284

### Lower Rocker Arm Cover – Side View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 17 | 0.669 |

## Upper Rocker Arm Cover – Top View

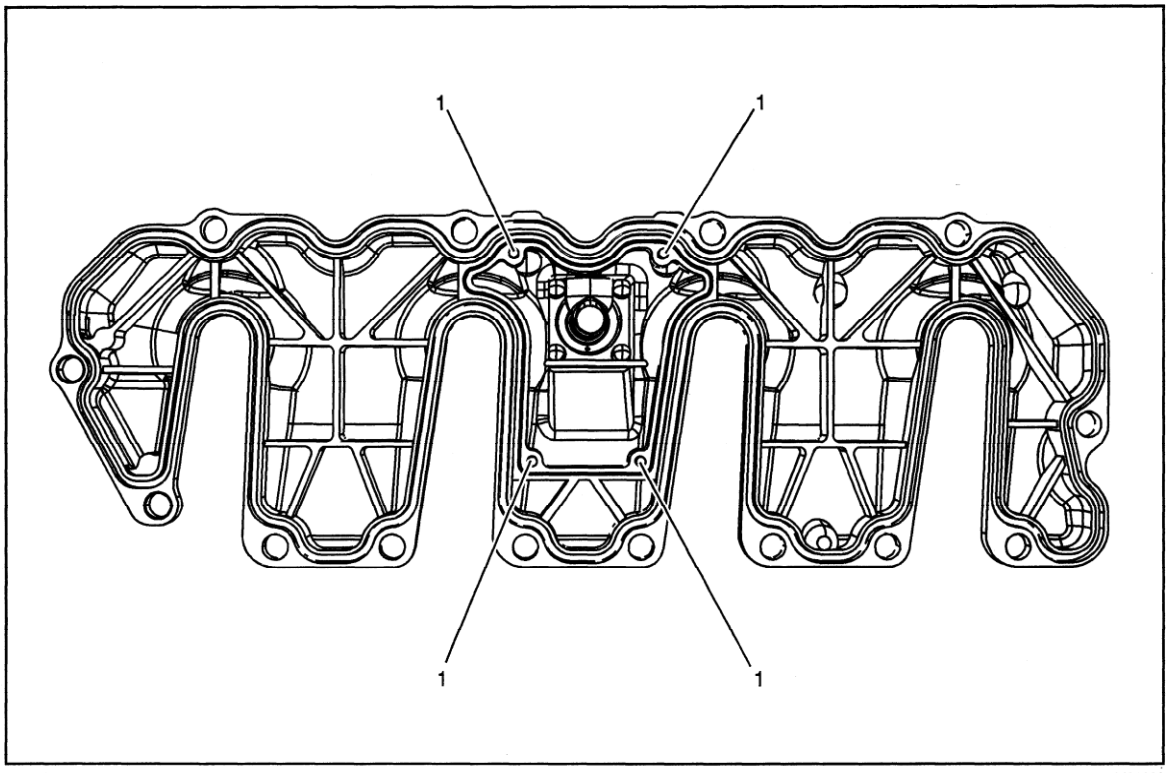



1491287

### Upper Rocker Arm Cover – Top View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 5 x 0.8 | N/A | N/A | N/A | N/A | N/A | N.A | 13 | 0.512 | 10 | 0.394 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 17 | 0.669 |
| 3 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 16 | 0.630 | 12 | 0.472 |

## Upper Rocker Arm Cover – Bottom View

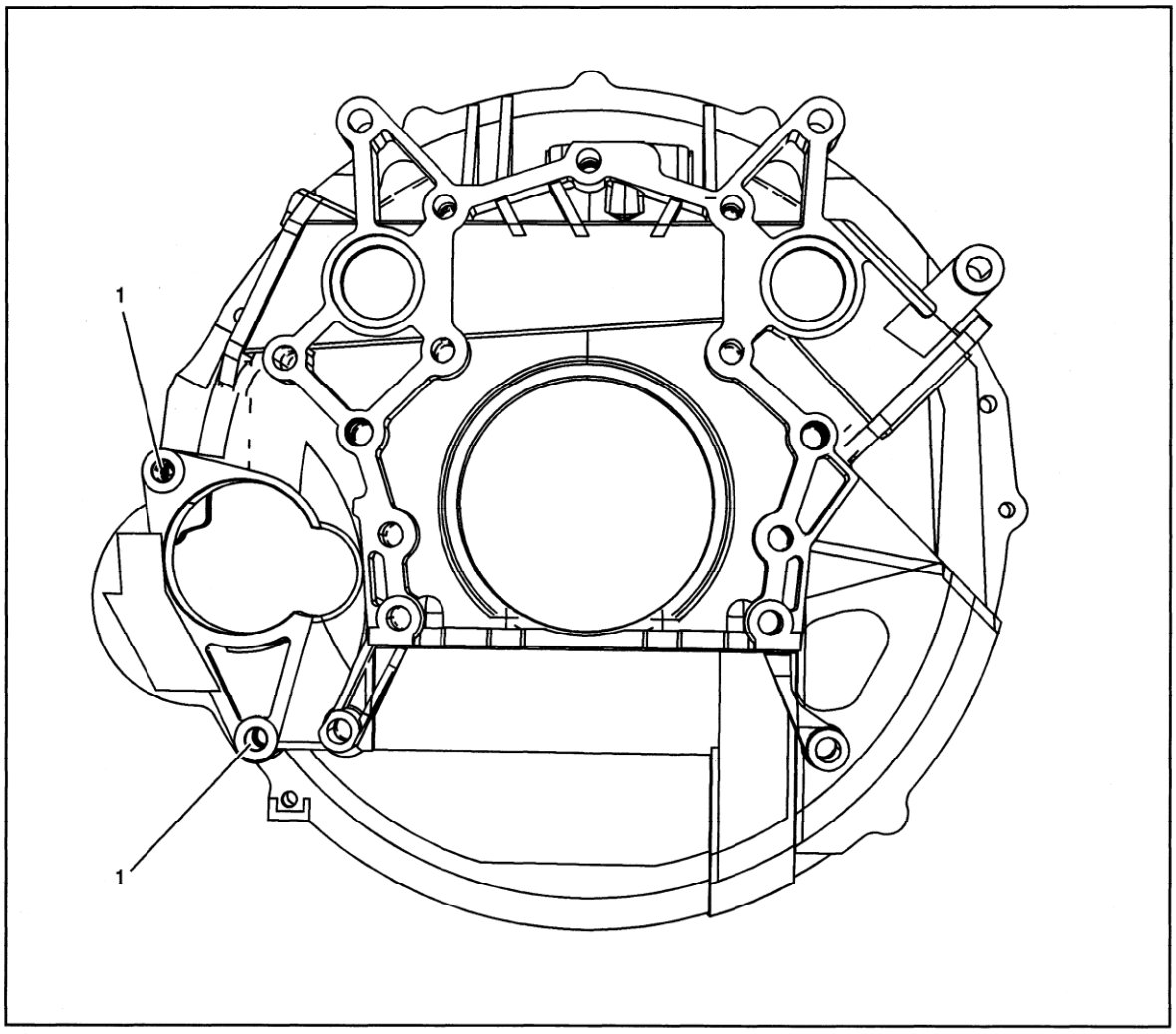



1491290

**Upper Rocker Arm Cover – Bottom View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 5 x 0.8 | N/A | N/A | N/A | N/A | N/A | N/A | 13 | 0.512 | 10 | 0.394 |

## Flywheel Housing – Rear View

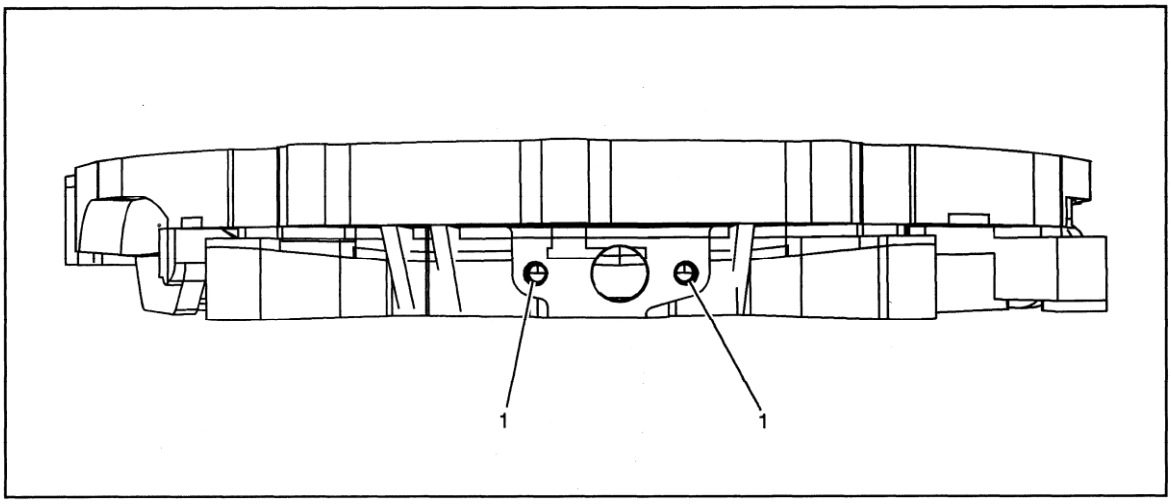



1491313

**Flywheel Housing – Rear View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 12 x 1.75 | –856 | –857 | N/A | –858 | –859 | –855 | 28 | 1.103 | 23 | 0.906 |

## Flywheel Housing – Top View

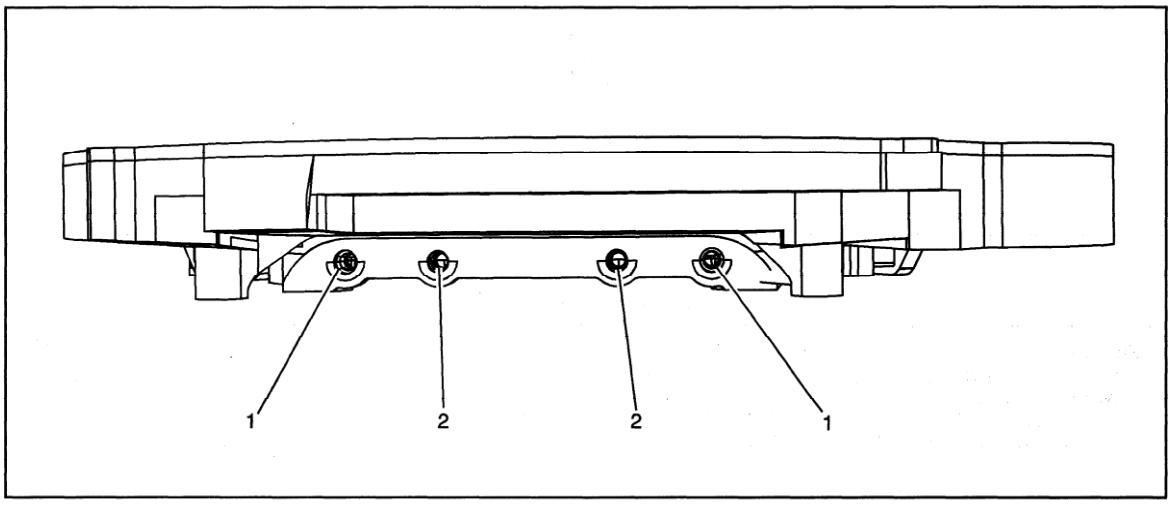



1491316

### Flywheel Housing – Top View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |

## Flywheel Housing – Bottom View

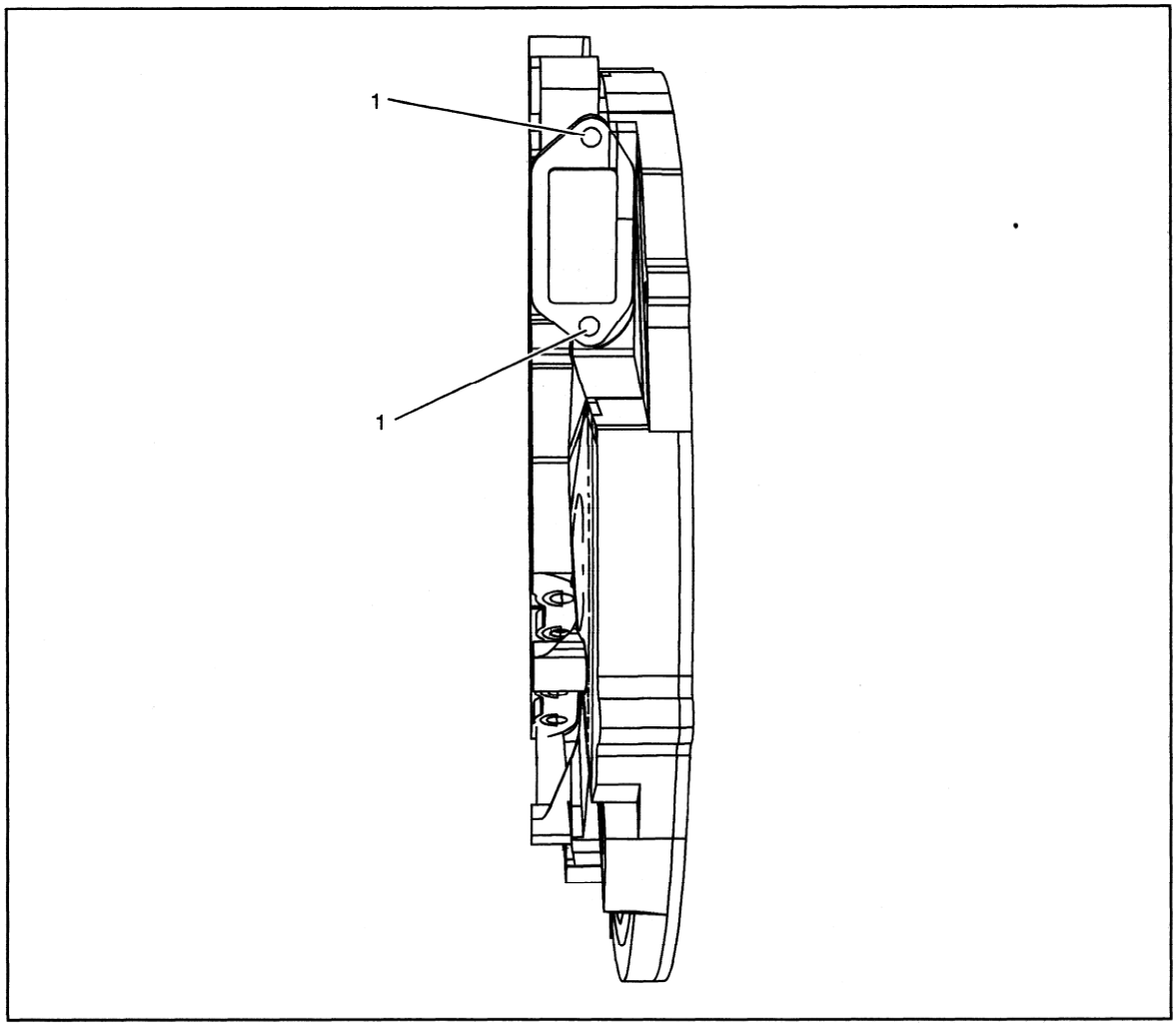



1491320

### Flywheel Housing – Bottom View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 18 | 0.709 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 14 | 0.551 |

## Flywheel Housing – Right View

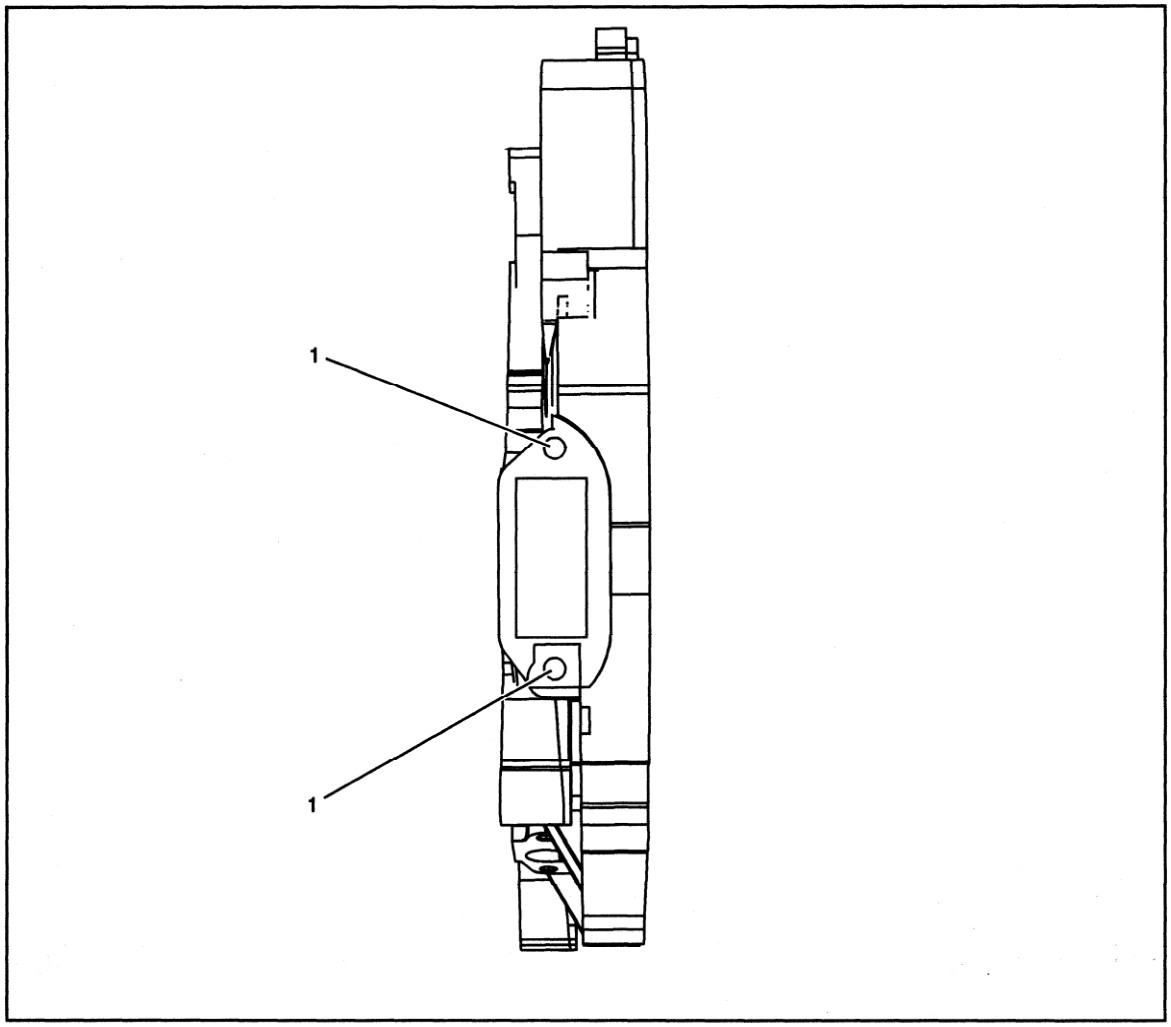



1491324

**Flywheel Housing – Right View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |

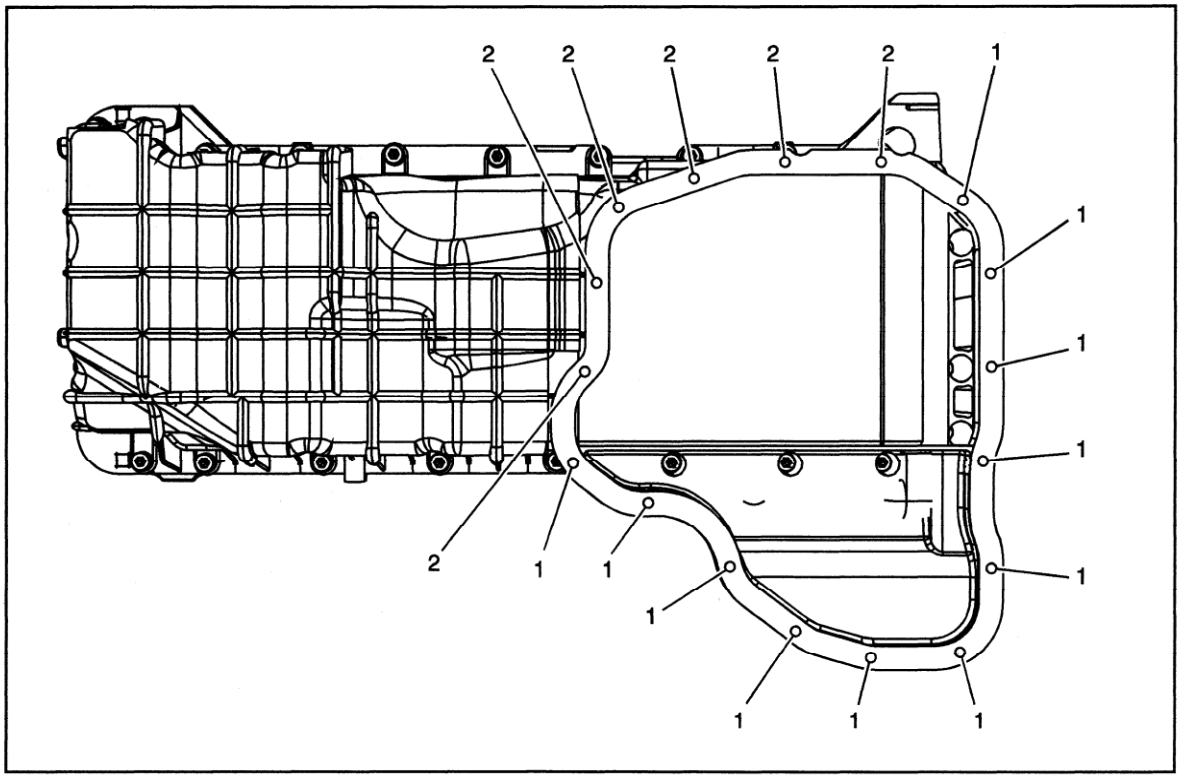
## Flywheel Housing – Left View




**Flywheel Housing – Left View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |

## Upper Oil Pan – Bottom View

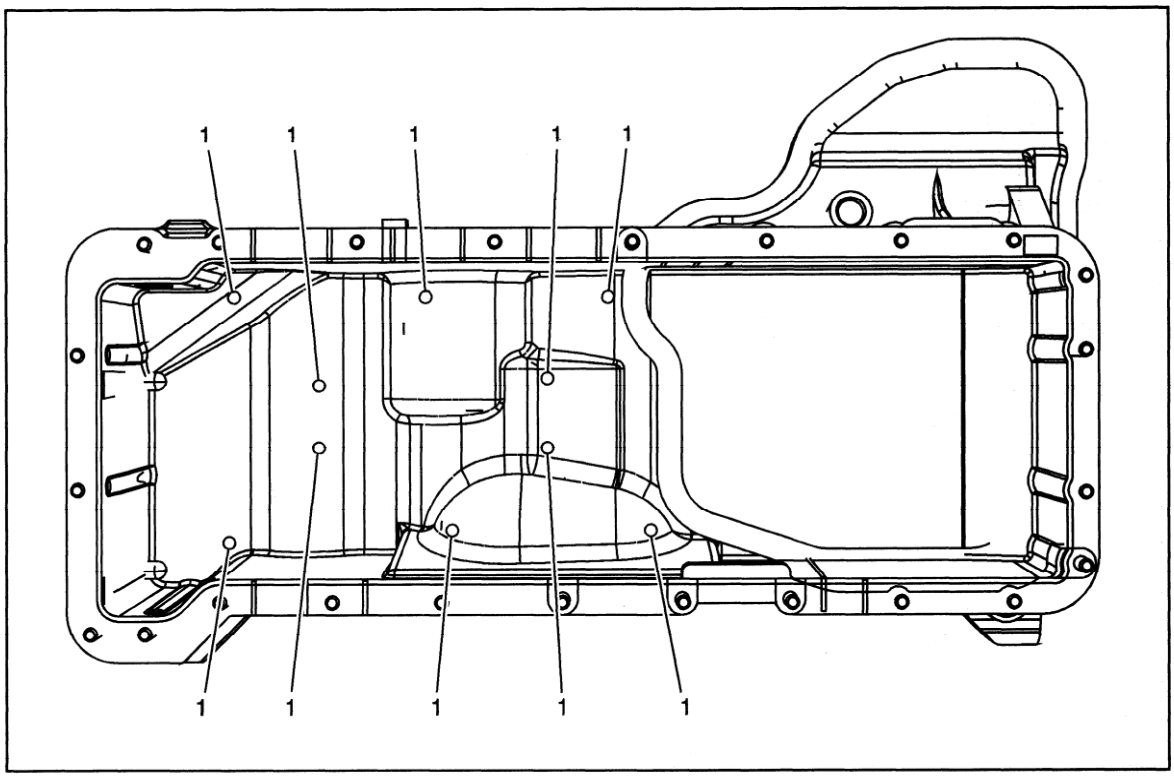



1491601

### Upper Oil Pan – Bottom View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | THRU | | THRU | |
| 2 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 17 | 0.669 | 13 | 0.512 |

## Upper Oil Pan – Top View

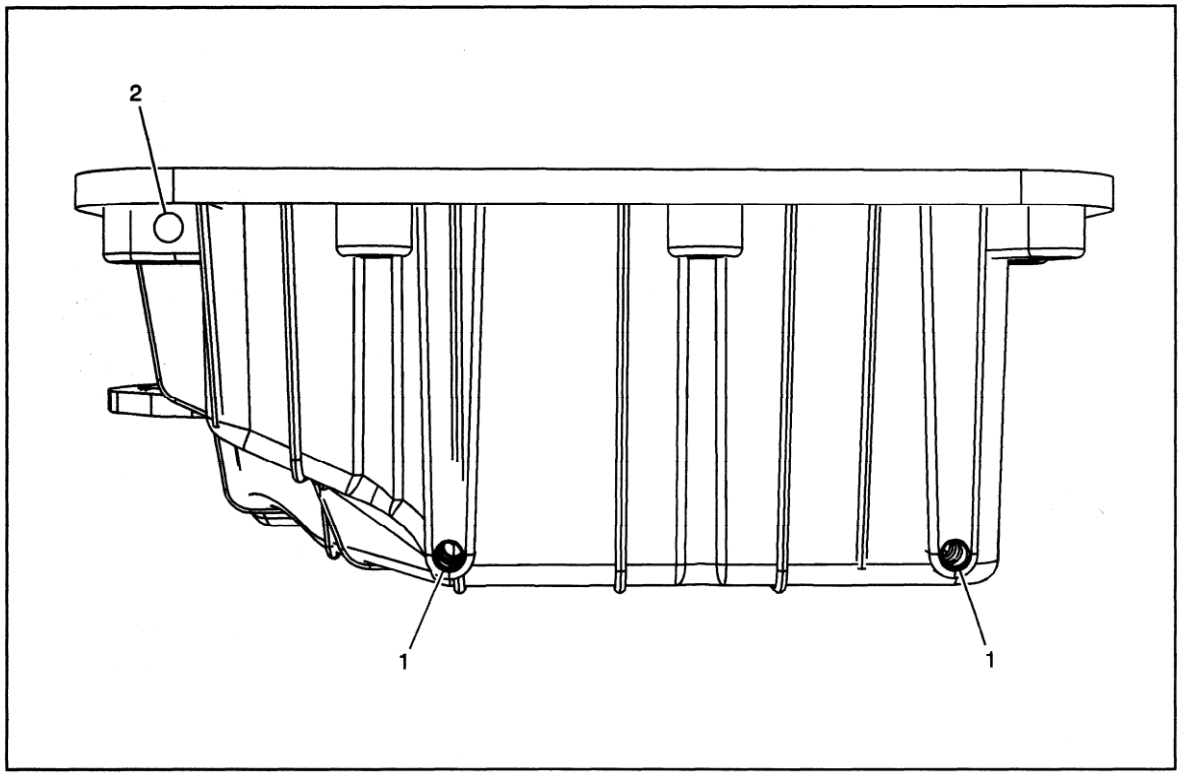



1491607

**Upper Oil Pan – Top View**

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 17 | 0.669 | 13 | 0.512 |

## Upper Oil Pan – Front View

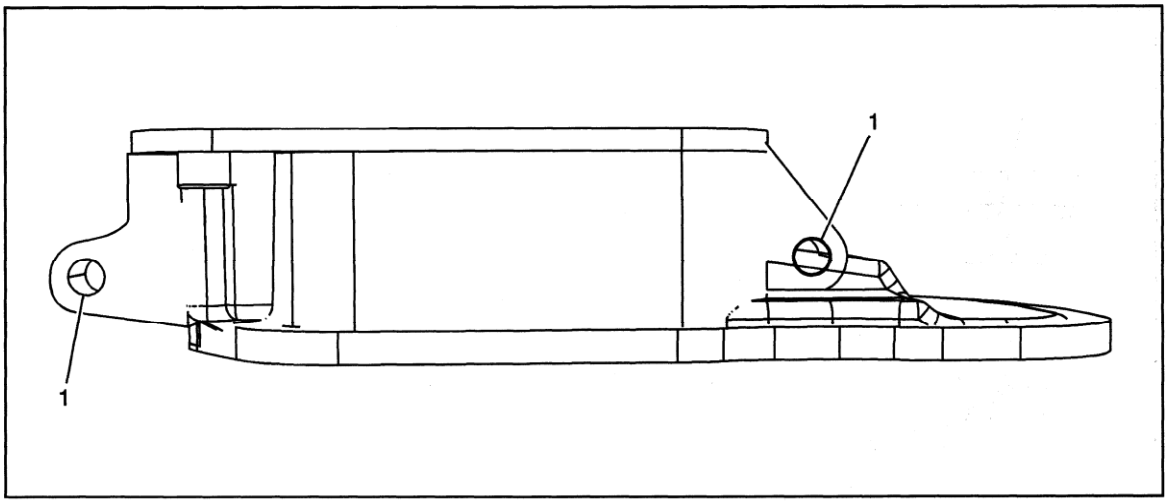



1491602

### Upper Oil Pan – Front View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 17 | 0.669 | 13 | 0.512 |
| 2 | M 8 x 1.25 | –206 | –207 | N/A | –208 | –209 | –210 | 21 | 0.827 | 17 | 0.669 |

## Upper Oil Pan – Rear View

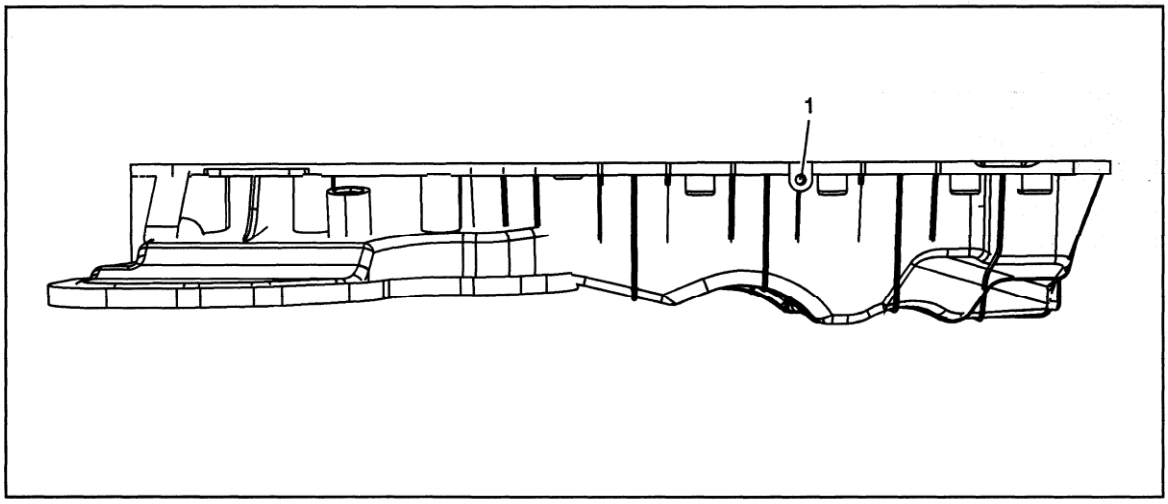



1491605

### Upper Oil Pan – Rear View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 12 x 1.75 | –856 | –857 | N/A | –858 | –859 | –855 | 22 | 0.866 | 16 | 0.630 |

## Upper Oil Pan – Side View




1491610

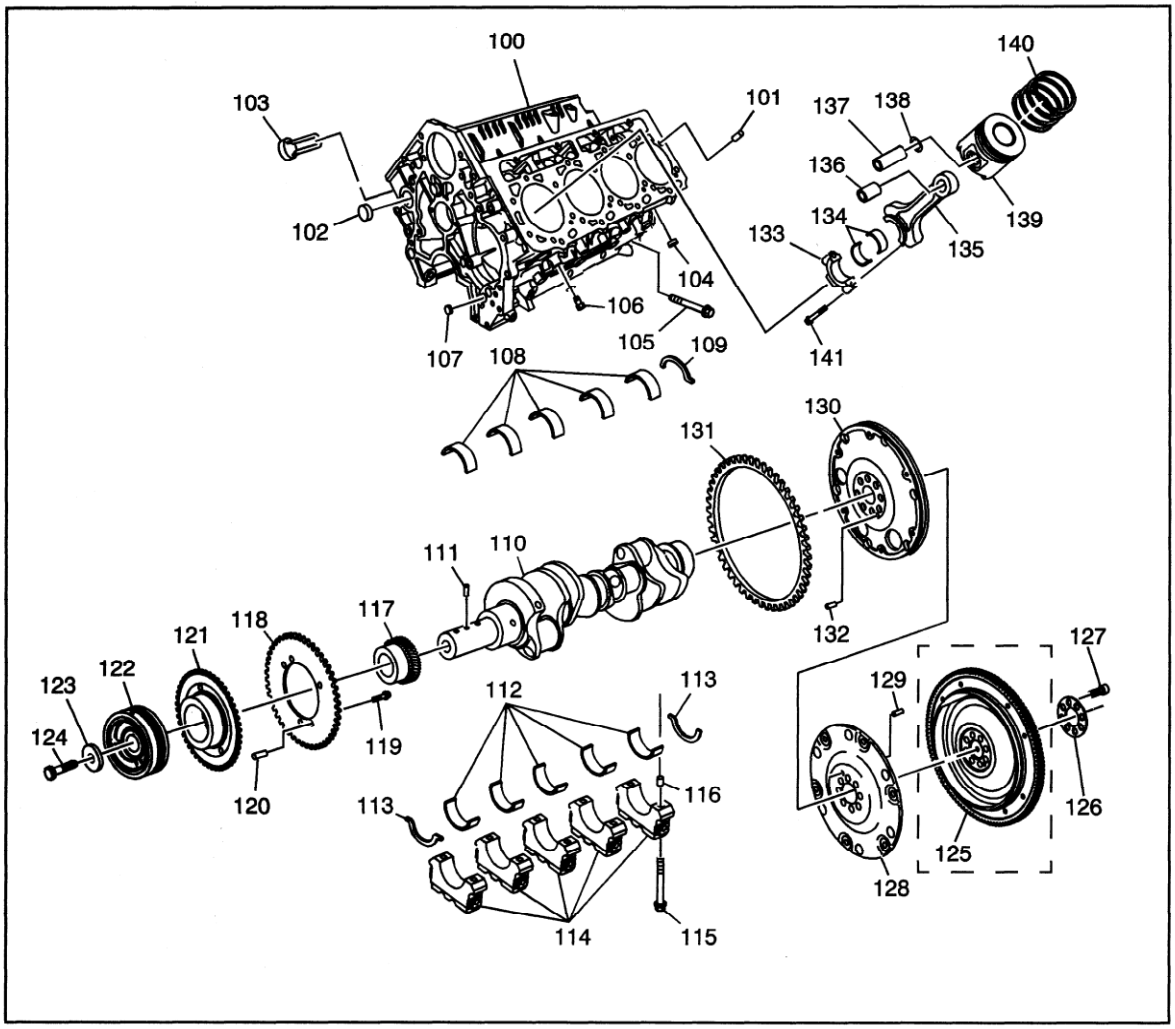
### Upper Oil Pan – Side View

| Service Hole Location | Thread Size | Drill | Counter-bore Tool | Stop Collar | Tap | Driver | Insert | Drill Depth (Max) | | Tap Depth (Min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mm | (in) | mm | (in) |
| 1 | M 6 x 1.0 | –201 | –202 | N/A | –203 | –204 | –205 | 17 | 0.669 | 13 | 0.512 |

# Component Locator

## Disassembled Views

### Engine Block, Crankshaft, Piston



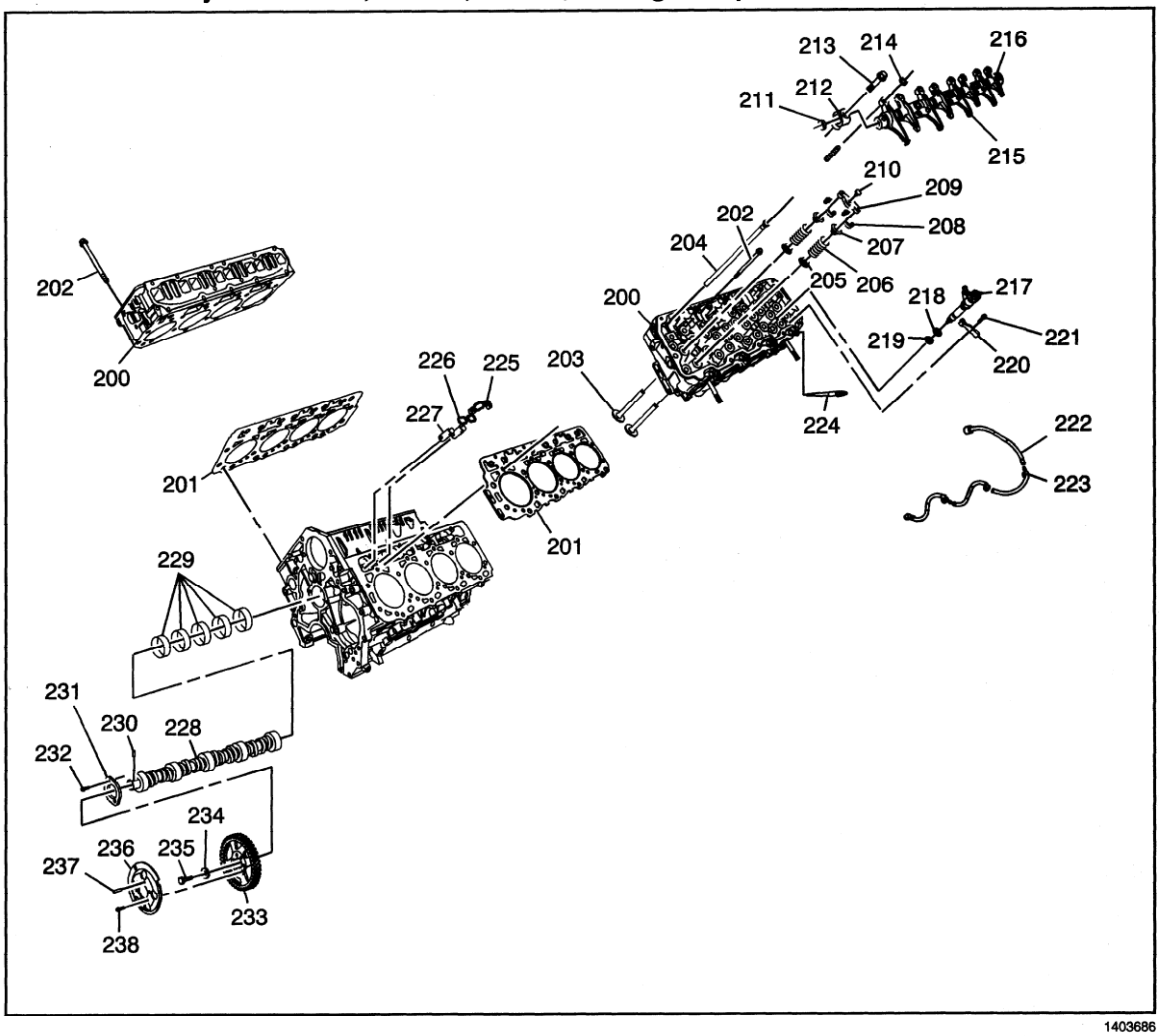

1403683

**Legend**

(100) Engine Block
(101) Dowel Pin
(102) Engine Block Plug
(103) Engine Block Heater
(104) Engine Block Plug
(105) Crankshaft Bearing Cap Bolt
(106) Engine Block Plug
(107) Engine Block Plug
(108) Upper Crankshaft Bearings
(109) Upper Thrust Bearing
(110) Crankshaft
(111) Crankshaft Pin
(112) Lower Crankshaft Bearings
(113) Lower Thrust Bearings
(114) Crankshaft Bearing Cap
(115) Crankshaft Bearing Cap Bolt
(116) Dowel Pin
(117) Crankshaft Gear
(118) Crankshaft Position Sensor Exciter Ring
(119) Crankshaft Position Sensor Exciter Ring Bolt
(120) Crankshaft Position Sensor Exciter Ring Pin
(121) Oil Pump Drive Gear
(122) Crankshaft Balancer
(123) Crankshaft Balancer Washer

(124) Crankshaft Balancer Bolt
(125) Flywheel – Manual Transmission
(126) Flywheel Washer
(127) Flywheel Bolt
(128) Flywheel Plate
(129) Dowel Pin
(130) Flywheel – Automatic Transmission
(131) Ring Gear
(132) Dowel Pin
(133) Connecting Rod Cap
(134) Connecting Rod Bearings
(135) Connecting Rod
(136) Connecting Rod Bushing
(137) Piston Pin
(138) Piston Pin Retainer
(139) Piston
(140) Piston Rings
(141) Connecting Rod Bolt

## Cylinder Head, Valves, Lifters, Timing Components, Camshaft



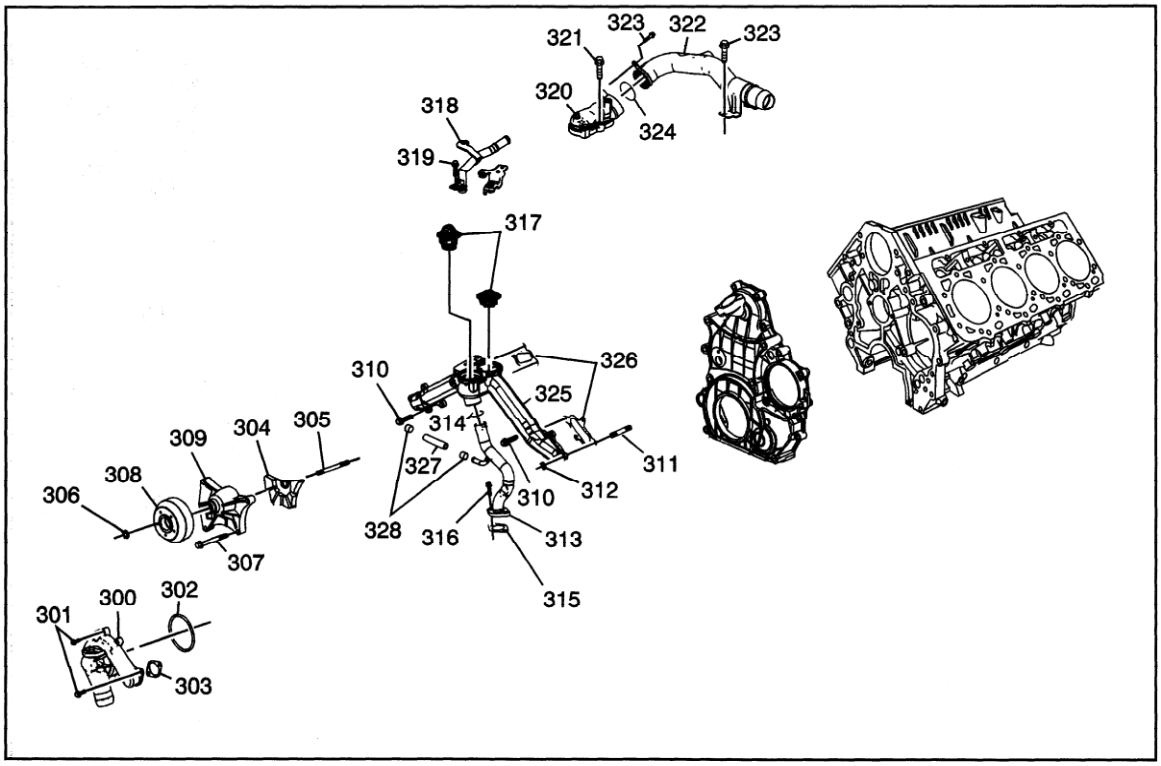

1403686

**Legend**

(200) Cylinder Head
(201) Cylinder Head Gasket
(202) Cylinder Head Bolt
(203) Exhaust Valve
(204) Pushrod
(205) Valve Spring Seat
(206) Valve Spring
(207) Valve Spring Retainer
(208) Valve Key
(209) Valve Bridge

(210) Valve Bridge Pin
(211) Rocker Arm Shaft Plug
(212) Rocker Arm Shaft Mount
(213) Rocker Arm Shaft Mount Bolt
(214) Rocker Arm Shaft Assembly Lock Nut
(215) Rocker Arm
(216) Rocker Arm Shaft Assembly
(217) Fuel Injector
(218) Fuel Injector O-ring Seal
(219) Fuel Injector Gasket
(220) Fuel Injector Bracket
(221) Fuel Injector Bracket Bolt
(222) Fuel Return Pipe
(223) Fuel Return Pipe Bolt
(224) Glow Plug
(225) Valve Lifter Guide Bracket
(226) Valve Lifter Guide
(227) Valve Lifter
(228) Camshaft
(229) Camshaft Bearings
(230) Camshaft Pin
(231) Camshaft Thrust Plate
(232) Camshaft Thrust Plate Bolt
(233) Camshaft Gear
(234) Camshaft Gear Washer
(235) Camshaft Gear Bolt
(236) Camshaft Position Sensor Exciter Ring
(237) Camshaft Position Sensor Exciter Ring Pin
(238) Camshaft Position Sensor Exciter Ring Bolt

## Cooling, Water Pump



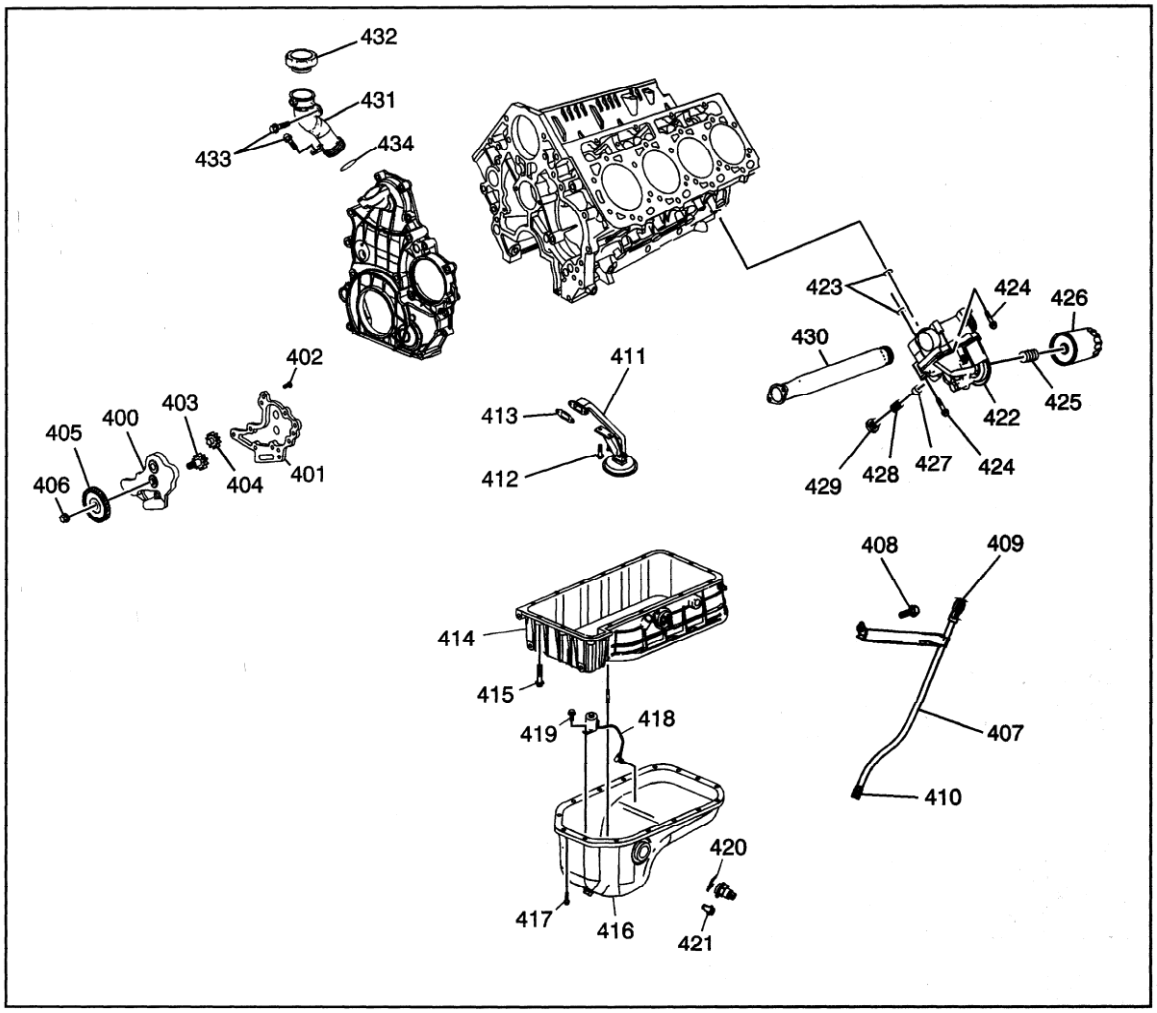

1403689

**Legend**

(300) Water Pump
(301) Water Pump Bolt
(302) Water Pump O-ring Seal
(303) Water Pump Gasket
(304) Cooling Fan Pulley Insulator
(305) Cooling Fan Pulley Stud
(306) Cooling Fan Pulley Nut
(307) Cooling Fan Pulley Bolt
(308) Cooling Fan Pulley
(309) Cooling Fan Pulley Bracket
(310) Thermostat Housing Bolt
(311) Thermostat Housing Stud
(312) Thermostat Housing Nut
(313) Thermostat Bypass Pipe
(314) Thermostat Bypass Pipe O-ring
(315) Thermostat Bypass Pipe Gasket

(316) Thermostat Bypass Pipe Bolt
(317) Thermostat
(318) Heater Pipe
(319) Heater Pipe Bolt
(320) Thermostat Cover
(321) Thermostat Cover Bolt
(322) Water Outlet
(323) Water Outlet Bolt
(324) Water Outlet O-ring Seal
(325) Thermostat Housing
(326) Thermostat Housing Gasket
(327) Thermostat Bypass Pipe Crossover Tube
(328) Thermostat Bypass Pipe Crossover Tube Clamps

## Oil Pan, Pump, Filter, Tube



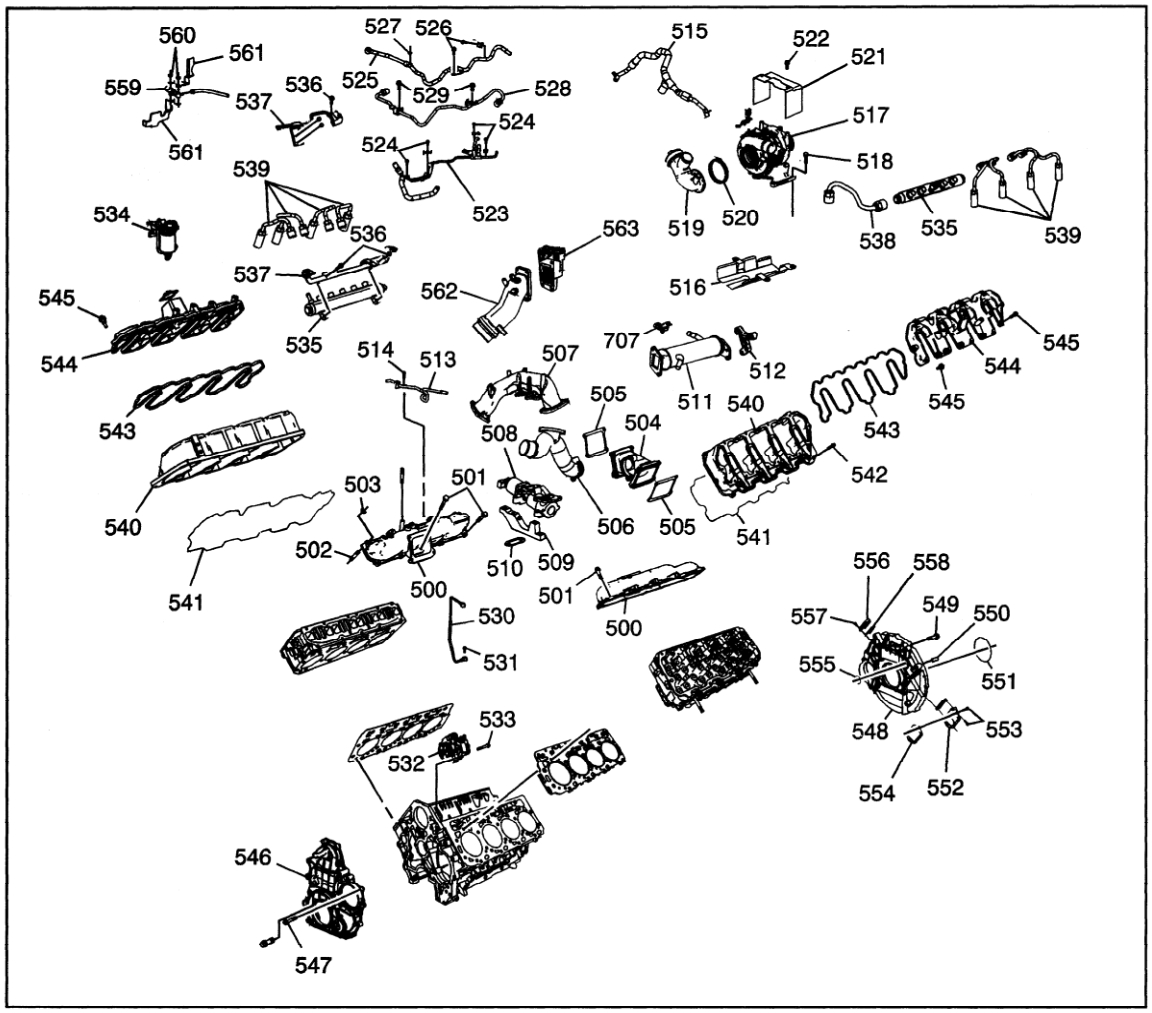

1403690

**Legend**

(400) Oil Pump Housing
(401) Oil Pump Cover
(402) Oil Pump Cover Bolt
(403) Oil Pump Drive Gear
(404) Oil Pump Driven Gear
(405) Oil Pump Gear
(406) Oil Pump Gear Nut
(407) Oil Level Indicator Tube
(408) Oil Level Indicator Tube Bolt
(409) Oil Level Indicator
(410) Oil Level Indicator Tube O-ring
(411) Oil Pump Pipe and Screen Assembly
(412) Oil Pump Pipe and Screen Assembly Bolt
(413) Oil Pump Pipe and Screen assembly Gasket

(414) Upper Oil Pan
(415) Upper Oil Pan Bolt
(416) Lower Oil Pan
(417) Lower Oil Pan Bolt
(418) Oil Level Sensor
(419) Oil Level Sensor Bolt
(420) Oil Level Sensor Retainer
(421) Oil Drain Plug
(422) Engine Oil Cooler
(423) Engine Oil Cooler O-ring
(424) Engine Oil Cooler Bolt
(425) Oil Filter Adapter
(426) Oil Filter
(427) Oil Pressure Relief Valve Spring Cup
(428) Oil Pressure Relief Valve Spring
(429) Oil Pressure Relief Valve Spring Plug
(430) Oil Cooler Tube
(431) Oil Fill Tube
(432) Oil Fill Tube Cap
(433) Oil Fill Tube Bolt
(434) Oil Fill Tube O-ring

## Intake Manifold, Rails, Covers



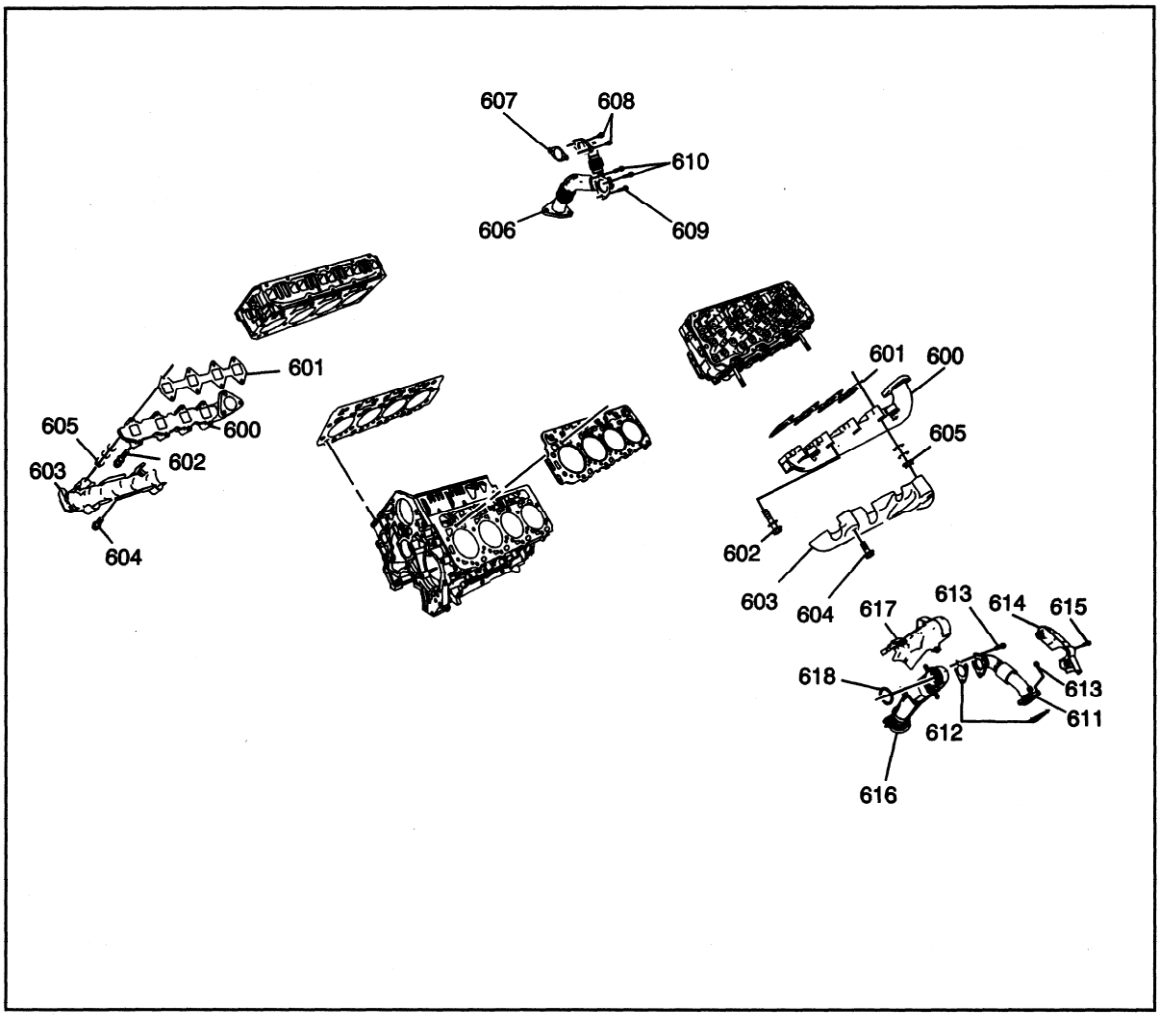

1650633

**Legend**

(500) Intake Manifold
(501) Intake Manifold Bolt
(502) Intake Manifold Stud
(503) Intake Manifold Nut
(504) Intake Manifold Crossover
(505) Intake Manifold Crossover Gasket

(506) Intake Manifold Tube
(507) Air Inlet Tube
(508) EGR
(509) EGR Bracket
(510) EGR Gasket
(511) EGR Cooler
(512) EGR Cooler Bracket
(513) Fuel Pipe
(514) Fuel Pipe Bolt
(515) PCV Hose
(516) Lower Turbocharger Heat Shield
(517) Turbocharger
(518) Turbocharger Bolt
(519) Turbocharger Air Inlet
(520) Turbocharger Air Inlet Clamp
(521) Upper Turbocharger Heat Shield
(522) Upper Turbocharger Heat Shield Bolt
(523) Fuel Inlet Pipe Assembly
(524) Fuel Inlet Pipe Assembly Bolt
(525) Fuel Feed Pipe
(526) Fuel Feed Pipe Bolt
(527) Fuel Feed Pipe Nut
(528) Fuel Rail Balance Pipe
(529) Fuel Rail Balance Pipe Bolt
(530) Turbocharger Oil Supply Line
(531) Turbocharger Oil Supply Line Bolt
(532) Fuel Injection Pump
(533) Fuel Injection Pump Bolt
(534) Fuel Filter Assembly
(535) Fuel Rail
(536) Fuel Rail Bolts
(537) Fuel Rail Bracket
(538) Fuel Injection Pump Pipe
(539) Injection Pipes
(540) Lower Valve Rocker Arm Cover
(541) Lower Valve Rocker Arm Cover Gasket
(542) Lower Valve Rocker Arm Cover Bolt
(543) Upper Valve Rocker Arm Cover Gasket
(544) Upper Valve Rocker Arm Cover
(545) Upper Valve Rocker Arm Cover Bolt
(546) Engine Front Cover
(547) Engine Front Cover Bolt
(548) Flywheel Housing
(549) Flywheel Housing Bolt
(550) Dowel Pin
(551) Crankshaft Rear Oil Seal
(552) Flywheel Housing Oil Cooler Adapter
(553) Flywheel Housing Oil Cooler Adapter Bolt
(554) Flywheel Housing Oil Cooler Adapter Gasket
(555) Flywheel Housing O-ring
(556) Flywheel Housing Cover
(557) Flywheel Housing Cover Bolt
(558) Flywheel Housing Cover Gasket
(559) Fuel Schrader Valve
(560) Fuel Schrader Valve Nuts
(561) Fuel Schrader Valve Bracket
(562) Intake Pipe
(563) Intake Heater
(707) Turbocharger Boost Sensor

## Exhaust Manifolds, EGR, Air

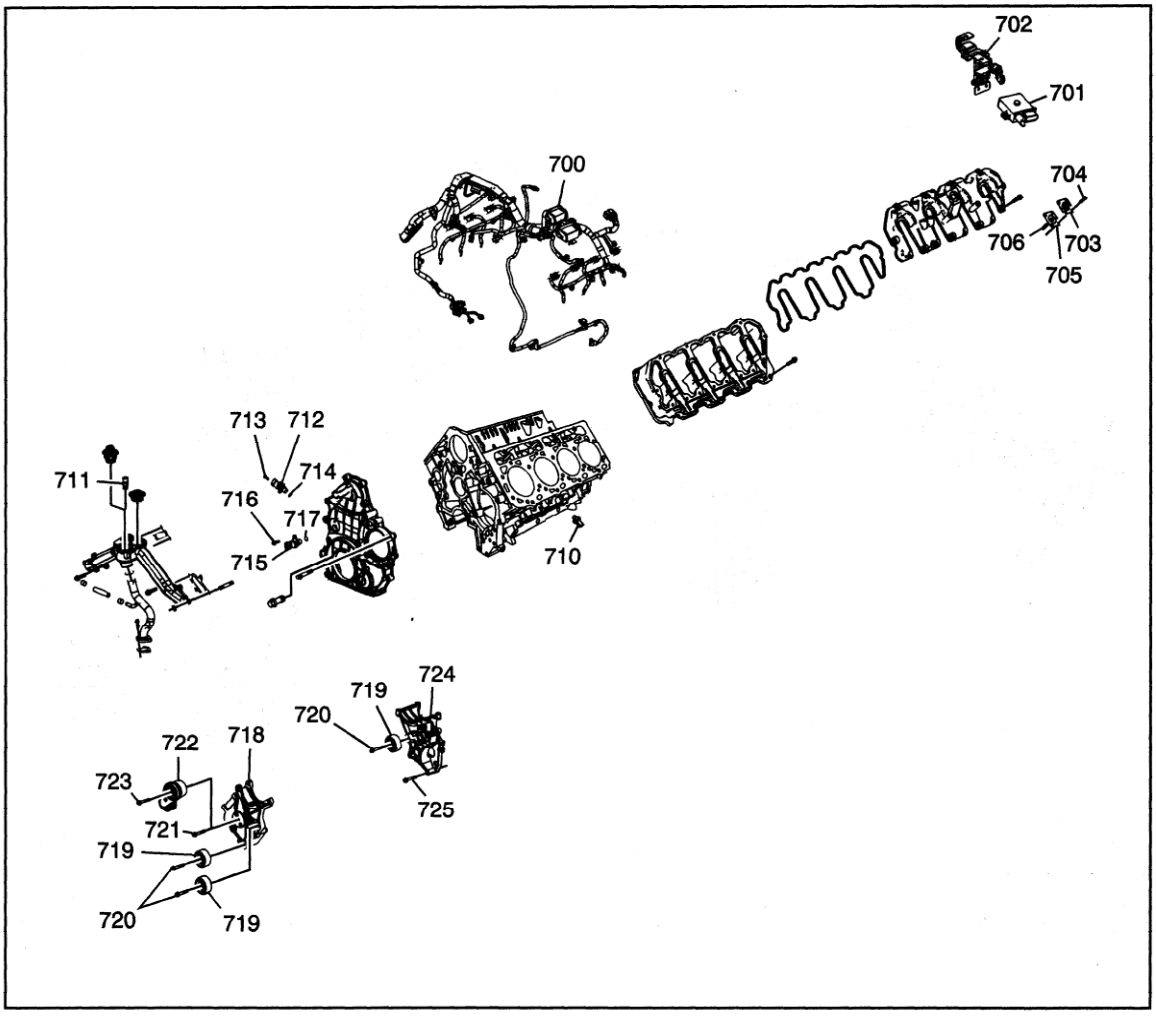



1403692

**Legend**

(600) Exhaust Manifold
(601) Exhaust Manifold Gasket
(602) Exhaust Manifold Bolt
(603) Exhaust Manifold Heat Shield
(604) Exhaust Manifold Heat Shield Bolt
(605) Exhaust Manifold Nut
(606) Exhaust Pipe
(607) Exhaust Pipe Gasket
(608) Exhaust Pipe Bolt
(609) Exhaust Pipe Stud
(610) Exhaust Pipe Nut
(611) Exhaust Crossover Pipe
(612) Exhaust Crossover Pipe Gasket
(613) Exhaust Crossover Pipe Bolt
(614) Exhaust Crossover Pipe Heat Shield
(615) Exhaust Crossover Pipe Heat Shield Bolt
(616) Exhaust Outlet Adapter
(617) Exhaust Outlet Heat Shield
(618) Exhaust Outlet Adapter Clamp

## Miscellaneous, Sensors, Ignition, Vacuum Hoses, Electrical

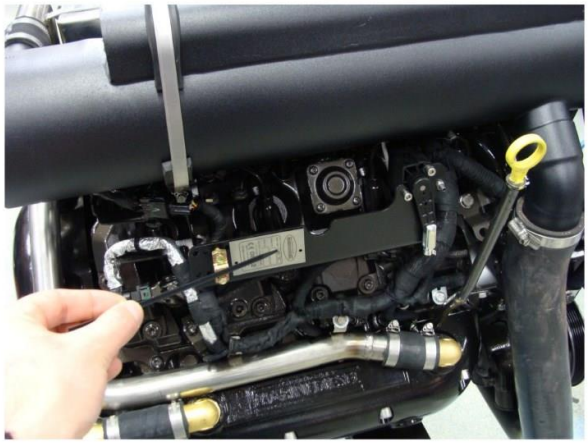



1650639

**Legend**

(700) Engine Wiring Harness
(701) Glow Plug Controller
(702) Glow Plug Controller Bracket
(703) PCV Cover
(704) PCV Cover Bolt
(705) PCV Diaphragm
(706) PCV Spring
(710) Oil Pressure Sensor
(711) Coolant Temperature Sensor
(712) Crankshaft Position Sensor
(713) Crankshaft Position Sensor Bolt
(714) Crankshaft Position Sensor O-ring
(715) Camshaft Position Sensor
(716) Camshaft Position Sensor Bolt
(717) Camshaft Position Sensor O-ring
(718) Generator Mounting Bracket
(719) Idler Pulley
(720) Idler Pulley Bolt
(721) Generator Mounting Bracket Bolt
(722) Drive Belt Tensioner
(723) Drive Belt Tensioner Bolt
(724) Power Steering Pump Bracket
(725) Power Steering Pump Bracket Bolt

## Engine Identification



Engine identification tag is located on the starboard side of the engine as shown in photo above.

# Diagnostic Information and Procedures

## Diagnostic Starting Point - Engine Mechanical

Begin the system diagnosis by reviewing the *Disassembled Views on page 6-774*, *Engine Component Description on page 6-1117*, and *Lubrication Description on page 6-1119* in Engine Mechanical - 6.6L Unit Repair Manual, and the *Drive Belt System Description on page 6-1117*. Reviewing the description and operation information will help you determine the correct symptom diagnostic procedure when a malfunction exists. Reviewing the description and operation information will also help you determine if the condition described to you by the customer is normal operation. Refer to *Symptoms - Engine Mechanical on page 6-782* in order to identify the correct procedure for diagnosing the system and where the procedure is located.

## Symptoms - Engine Mechanical

### Strategy Based Diagnostics

1. Perform the *Diagnostic Starting Point - Engine Controls on page 6-2976* in Engine Controls before using the symptom tables, if applicable.
2. Review the system operations in order to familiarize yourself with the system functions. Refer to *Disassembled Views on page 6-774*, *Engine Component Description on page 6-1117*, and *Lubrication Description on page 6-1119* in the 6.6L section of the Unit Repair Manual, and to the *Drive Belt System Description on page 6-1117*.

All diagnosis on a vehicle should follow a logical process. Strategy based diagnostics is a uniform approach for repairing all systems. The diagnostic flow may always be used in order to resolve a system problem. The diagnostic flow is the place to start when repairs are necessary. For a detailed explanation, refer to *Strategy Based Diagnosis on page 0-28* in General Information.

### Visual/Physical Inspection

- Inspect for aftermarket devices which could affect the operation of the engine.
- Inspect the easily accessible or visible system components for obvious damage or conditions which could cause the symptom.
- Check for the correct oil level, proper oil viscosity, and correct filter application.
- Verify the exact operating conditions under which the concern exists. Note factors such as engine RPM, ambient temperature, engine temperature, amount of engine warm-up time, and other specifics.
- Compare the engine sounds, if applicable, to a known good engine and make sure you are not trying to correct a normal condition.

### Intermittent

Test the vehicle under the same conditions that the customer reported in order to verify the system is operating properly.

### Symptom List

Refer to a symptom diagnostic procedure from the following list in order to diagnose the symptom:

- *Base Engine Misfire without Internal Engine Noises on page 6-783*
- *Base Engine Misfire with Abnormal Internal Lower Engine Noises on page 6-784*
- *Base Engine Misfire with Abnormal Valve Train Noise on page 6-784*
- *Base Engine Misfire with Coolant Consumption on page 6-785*
- *Base Engine Misfire with Excessive Oil Consumption on page 6-785*
- *Engine Compression Test on page 6-790*
- *Engine Noise on Start-Up, but Only Lasting a Few Seconds on page 6-786*
- *Upper Engine Noise, Regardless of Engine Speed on page 6-786*
- *Lower Engine Noise, Regardless of Engine Speed on page 6-787*
- *Engine Noise Under Load on page 6-787*
- *Engine Will Not Crank - Crankshaft Will Not Rotate on page 6-788*
- *Oil Pressure Diagnosis and Testing on page 6-793*
- *Oil Leak Diagnosis on page 6-794*
- *Drive Belt Chirping Diagnosis on page 6-796*
- *Drive Belt Squeal Diagnosis on page 6-797*

- *Drive Belt Whine Diagnosis on page 6-798*
- *Drive Belt Rumbling Diagnosis on page 6-799*
- *Drive Belt Vibration Diagnosis on page 6-800*
- *Drive Belt Falls Off Diagnosis on page 6-801*
- *Drive Belt Excessive Wear Diagnosis on page 6-802*
- *Drive Belt Tensioner Diagnosis on page 6-803*

## Base Engine Misfire without Internal Engine Noises

| Condition | Action |
|---|---|
| Abnormalities (severe cracking, bumps or missing areas) in the accessory drive belt.<br>Also worn, damaged, or misaligned accessory drive components or excessive pulley runout. | Abnormalities in the accessory drive belt and/or components may cause engine RPM variations, noises similar to a faulty lower engine and also lead to a misfire condition. A misfire code may be present without an actual misfire condition.<br>1. Inspect the accessory drive components.<br>2. Repair or replace all damaged components. |
| Loose and/or damaged crankshaft balancer | A misfire code may be present without an actual misfire condition.<br>1. Inspect crankshaft balancer and balancer bolt.<br>2. Repair or replace all damaged components. |
| Loose coupler bolts | A misfire code may be present without an actual misfire condition.<br>1. Inspect coupler bolts and flywheel.<br>2. Repair or replace all damaged components. |
| Loose and/or damaged flywheel | A misfire code may be present without an actual misfire condition.<br>1. Inspect flywheel and flywheel attaching bolts.<br>2. Repair or replace all damaged components. |
| Restricted exhaust system | A severe restriction in the exhaust flow can cause significant loss of engine performance and may set a misfire code. Possible causes of restrictions include collapsed or dented pipes, plugged mufflers and/or catalytic converters.<br>Repair or replace all damaged components. |
| Air in fuel system | 1. Inspect fuel filter, fuel system for leaks and/or restrictions.<br>2. Repair or replace all damaged components. |
| Bent and/or worn valve pushrod | 1. Inspect valve pushrod and valve rocker arm.<br>2. Repair or replace all damaged components. |
| Sticking valve | Carbon on the valve stem or valve seat may cause the valve to stick.<br>1. Inspect valves and valve guides.<br>2. Repair or replace all damaged components. |
| Damaged or misaligned timing gears | 1. Inspect timing gears.<br>2. Replace all damaged components. |
| Worn or faulty camshaft lobes | 1. Inspect camshaft lobes.<br>2. If damaged replace camshaft and all lifters. |
| Excessive piston-to-cylinder bore clearance | 1. Perform cylinder leak down and compression tests.<br>2. Inspect the piston, piston rings and cylinder bore.<br>3. Repair or replace all damaged components. |
| Faulty cylinder head gaskets and/or cracking or other damage to the cylinder heads and engine block cooling system passages. (Coolant consumption may or may not cause the engine to overheat.) | 1. Perform cylinder leak down and compression tests.<br>2. Inspect the piston, piston rings and cylinder bore.<br>3. Repair or replace all damaged components. |
| Overfilled Crankcase | 1. Check engine oil level with vehicle on a level surface.<br>2. Correct any overfilled condition.<br>3. Inspect for fuel leaks into the crankcase. Refer to *Fuel in Engine Oil on page 6-789*.<br>4. Repair any fuel leaks. |

## Base Engine Misfire with Abnormal Internal Lower Engine Noises

| Condition | Action |
|---|---|
| Abnormalities (severe cracking, bumps or missing areas) in the accessory drive belt. | Abnormalities in the accessory drive belt and/or components may cause engine RPM variations, noises similar to a faulty lower engine and also lead to a misfire condition. A misfire code may be present without an actual misfire condition.<br>1. Inspect the accessory drive components.<br>2. Repair or replace all damaged components. |
| Worn, damaged, or misaligned accessory drive components or excessive pulley runout | A misfire code may be present without an actual misfire condition.<br>1. Inspect the accessory drive components.<br>2. Repair or replace all damaged components. |
| Loose and/or damaged crankshaft balancer | A misfire code may be present without an actual misfire condition.<br>1. Inspect crankshaft balancer and balancer bolt.<br>2. Repair or replace all damaged components. |
| Loose coupler bolts | A misfire code may be present without an actual misfire condition.<br>1. Inspect coupler bolts and flywheel.<br>2. Repair or replace all damaged components. |
| Loose and/or damaged flywheel | A misfire code may be present without an actual misfire condition.<br>1. Inspect flywheel and flywheel attaching bolts.<br>2. Repair or replace all damaged components. |
| Excessive piston-to-cylinder bore clearance | 1. Perform cylinder leak down and compression tests<br>2. Inspect the piston, piston rings and cylinder bore.<br>3. Repair or replace all damaged components. |
| Excessive crankshaft thrust bearing clearance | Severely worn thrust surfaces on the crankshaft and/or thrust bearing may permit for and aft movement of the crankshaft and create a misfire code without an actual misfire condition.<br>1. Inspect the crankshaft end play and crankshaft thrust bearings.<br>2. Repair or replace all damaged components. |
| Overfilled crankcase | 1. Check engine oil level with vehicle on a level surface.<br>2. Correct any overfilled condition.<br>3. Inspect for fuel leaks into the crankcase.<br>4. Repair any fuel leaks. |

## Base Engine Misfire with Abnormal Valve Train Noise

| Condition | Action |
|---|---|
| Loose, worn or damaged rocker arm | 1. Inspect valve rocker arm and rocker arm shaft.<br>2. Repair or replace all damaged components. |
| Loose valve rocker arm attachments | 1. Inspect valve rocker arm and rocker arm shaft.<br>2. Repair or replace all damaged components. |
| Worn or damaged pushrods | 1. Inspect the pushrods for excessive wear.<br>2. Inspect the pushrods for bent condition.<br>3. Inspect the pushrods for broken tip.<br>4. Replace pushrod if any damage is found. |
| Broken valve springs | 1. Inspect valve springs.<br>2. Repair or replace all damaged components. |
| Worn and/or damaged valve rotator | 1. Inspect valve rotators.<br>2. Repair or replace all damaged components. |

## Base Engine Misfire with Abnormal Valve Train Noise (cont'd)

| Condition | Action |
|---|---|
| Sticking valve | Carbon on the valve stem or valve seat may cause the valve to stick.<br>1. Inspect valves and valve guides.<br>2. Repair or replace all damaged components. |
| Worn or faulty camshaft lobes | 1. Inspect camshaft lobes.<br>2. If damaged replace camshaft and all lifters. |
| Excessive valve lash | 1. Check the valve lash adjustment, and correct if above specifications.<br>2. Repair or replace all damaged components. |

## Base Engine Misfire with Coolant Consumption

| Inspection | Action |
|---|---|
| DEFINITION: Base engine misfire with coolant comsumption | |
| Preliminary Inspection | Verify that there are no external coolant leaks. Refer to *Loss of Coolant on page 6-1433* in Engine Cooling. |
| Isolate Affected Cylinders | • Cylinder balance test with scan tool<br>• Cooling system pressurization<br>• Inspection of glow plugs<br>• Compression test<br>• Cylinder leakdown test |
| EGR System Inspection | 1. Inspect EGR valve and intake system for evidence of coolant leakage.<br>2. Replace the EGR cooler if any problem is found. |
| Cylinder Head Gasket Leakage | • Remove cylinder heads of the affected cylinder bank and inspect for damage.<br>• Replace components as necessary. |
| Cylinder Head or Engine Block Damage | 1. Inspect the cylinder heads for cracks and warpage.<br>2. Inspect the cylinder block for damage.<br>3. Inspect the cylinder block to head mating surface for staightness.<br>4. Replace components as necessary. |

## Base Engine Misfire with Excessive Oil Consumption

| Condition | Action |
|---|---|
| Worn valve guides | 1. Inspect the valves and valve guides.<br>2. Repair or replace all damaged components. |
| Worn valve stem oil seals | 1. Inspect the valve stem oil seals.<br>2. Repair or replace all damaged components. |
| Excessive piston-to-cylinder bore clearance | 1. Perform cylinder leak down and compression tests to determine the cause.<br>2. Inspect the piston rings for low ring tension, broken or worn rings.<br>3. Inspect cylinder bore.<br>4. Repair or replace all damaged components. |

## Engine Noise on Start-Up, but Only Lasting a Few Seconds

| Condition | Action |
|---|---|
| Incorrect oil viscosity | 1. Drain the oil.<br>2. Install the correct viscosity oil. |
| Excessive piston-to-cylinder bore clearance | 1. Inspect the piston and piston skirt, connecting rod, and cylinder bore.<br>2. Repair or replace all damaged components. |
| Damaged or faulty oil filter by-pass valve | 1. Inspect the oil filter by-pass valve for proper operation.<br>2. Repair or replace as necessary. |

## Upper Engine Noise, Regardless of Engine Speed

| Condition | Action |
|---|---|
| Low oil pressure | Insufficient or poor oil supply to valve train.<br>1. Perform oil pressure test.<br>2. Repair or replace all damaged components. |
| Improper lubrication to the valve rocker arms | 1. Inspect valve rocker arm and shaft, valve pushrod, oil filter bypass valve, oil pump and pump screen, and engine block oil galleries.<br>2. Repair or replace all damaged components. |
| Excessive valve lash | 1. Check the valve lash adjustment, and correct if above specifications.<br>2. Repair or replace all damaged components. |
| Worn pushrod upper end ball | 1. Inspect pushrod end ball.<br>2. Repair or replace all damaged components. |
| Bent valve pushrod | 1. Inspect valve pushrod and valve rocker arm.<br>2. Repair or replace all damaged components. |
| Loose, worn or damaged valve rocker arm | 1. Inspect valve rocker arm and rocker arm shaft.<br>2. Repair or replace all damaged components. |
| Loose valve rocker arm attachments | 1. Inspect valve rocker arm and rocker arm shaft.<br>2. Repair or replace all damaged components. |
| Broken valve springs | 1. Inspect valve springs.<br>2. Repair or replace all damaged components. |
| Worn and/or damaged valve spring shims, seats, or keys | 1. Inspect valve spring shims, seats, and keys.<br>2. Repair or replace all damaged components. |
| Sticking valve | Carbon on the valve stem or valve seat may cause the valve to stick.<br>1. Inspect valves and valve guides.<br>2. Repair or replace all damaged components. |
| Missing or improperly positioned lifter guides | 1. Inspect lifter guides.<br>2. Repair or replace all damaged components. |
| Worn or faulty camshaft lobes | 1. Inspect camshaft lobes.<br>2. If damaged replace camshaft and all lifters. |
| Worn valve guide | 1. Inspect the valves and valve guides.<br>2. Repair or replace all damaged components. |
| Damaged or misaligned timing gears | 1. Inspect timing gears.<br>2. Replace all damaged components. |

## Lower Engine Noise, Regardless of Engine Speed

| Condition | Action |
|---|---|
| Worn accessory drive components (abnormalities such as severe cracking, bumps or missing areas in the accessory drive belt and/or misalignment of the system components.) | 1. Inspect the accessory drive components.<br>2. Repair or replace all damaged components. |
| Low oil pressure | Insufficient or poor oil supply to crankshaft and connecting rod bearings.<br>1. Perform oil pressure test.<br>2. Repair or replace all damaged components. |
| Leaking and/or sticking fuel injection nozzle (A stuck fuel injection nozzle can cause a noise similar to a damaged piston, rod or rod bearing.) | 1. Use the cylinder balance diagnostic procedure to help locate the cylinder that is the source of the noise.<br>2. If you cannot locate the cylinder that is the source of the noise, diagnose the engine for mechanical damage.<br>3. If it has been determined that the fuel injection nozzle is causing the noise, replace the fuel injection nozzle. |
| Loose and/or damaged crankshaft balancer | 1. Inspect crankshaft balancer and balancer bolt.<br>2. Repair or replace all damaged components. |
| Loose coupler bolts | 1. Inspect coupler bolts and flywheel.<br>2. Repair or replace all damaged components. |
| Loose and/or damaged flywheel | 1. Inspect flywheel and flyweel attaching bolts.<br>2. Repair or replace all damaged components. |
| Excessive piston-to-cylinder bore clearance | 1. Inspect the piston, piston rings and cylinder bore.<br>2. Repair or replace all damaged components. |
| Excessive piston pin-to-bore clearance | 1. Inspect the piston, piston pin, and the connecting rod.<br>2. Repair or replace all damaged components. |
| Misaligned or bent connecting rod | 1. Inspect connecting rod and connecting rod bearings.<br>2. Repair or replace all damaged components. |
| Excessive connecting rod bearing clearance | 1. Inspect the connecting rod bearings, connecting rods, crankshaft and crankshaft journals.<br>2. Repair or replace all damaged components. |
| Excessive crankshaft bearing clearance | 1. Inspect the crankshaft bearings and crankshaft journals.<br>2. Repair or replace all damaged components. |
| Oil pump pickup tube or screen bent or loose | 1. Inspect the oil pump pickup tube and/or screen.<br>2. Repair or repalce all damaged components. |

## Engine Noise Under Load

| Cause | Correction |
|---|---|
| Low oil pressure | Insufficient or poor oil supply to components.<br>1. Perform oil pressure test.<br>2. Repair or replace all damaged components. |
| Loose coupler bolts | 1. Inspect the coupler bolts and flywheel.<br>2. Repair or replace all damaged components. |
| Loose and/or damaged flywheel | 1. Inspect the flywheel and flywheel attaching bolts.<br>2. Repair or replace all damaged components. |
| Excessive piston-to-cylinder bore clearance | 1. Inspect the piston rings for low ring tension, broken or worn rings, inspect cylinder bore.<br>2. Repair or replace all damaged components. |
| Excessive crankshaft thrust bearing clearance | 1. Inspect the crankshaft end play and crankshaft thrust bearings.<br>2. Repair or replace all damaged components. |
| Excessive crankshaft bearing clearance | 1. Inspect the crankshaft bearings and crankshaft journals.<br>2. Repair or replace all damaged components. |

## Engine Will Not Crank - Crankshaft Will Not Rotate

| Cause | Correction |
|---|---|
| Seized accessory drive system component | 1. Remove accessory drive belt(s).<br>2. Remove the glow plugs.<br>3. Rotate crankshaft by hand at the balancer. |
| Hydraulically locked cylinder<br>• Coolant/antifreeze in cylinder<br>• Oil in cylinder<br>• Fuel in cylinder | 1. Inspect for fluid at glow plug hole.<br>2. Inspect for broken head gasket(s).<br>3. Inspect for cracked engine block or cylinder head.<br>4. Inspect for a sticking fuel injector. |
| Seized transmission or drive | 1. Remove the engine assembly.<br>2. Rotate crankshaft by hand at the balancer or flywheel location. |
| Material in cylinder:<br>• Broken valve<br>• Piston material<br>• Foreign material | 1. Inspect cylinder for damaged components and/or foreign materials.<br>2. Repair or replace as required. |
| Seized crankshaft or connecting rod bearings | 1. Inspect crankshaft and connecting rod bearings.<br>2. Repair as required. |
| Bent or broken connecting rod | 1. Inspect connecting rods.<br>2. Repair as required. |
| Broken crankshaft | 1. Inspect crankshaft.<br>2. Repair as required. |

## Coolant in Combustion Chamber

| Inspection | Action |
|---|---|
| DEFINITION: Excessive white smoke and/or coolant type odor coming from the exhaust pipe may indicate coolant in the combustion chamber. Low coolant levels, an inoperative cooling fan, or a faulty thermostat may lead to an "overtemperature" condition which may cause engine component damage. | |
| Preliminary Inspection | Verify that there are no external coolant leaks. Refer to *Loss of Coolant on page 6-1433* in Engine Cooling. |
| Isolate Affected Cylinders | • Cylinder balance test with scan tool<br>• Cooling system pressurization<br>• Inspection of glow plugs<br>• Compression test<br>• Cylinder leakdown test |
| EGR System Inspection | 1. Inspect EGR valve and intake system for evidence of coolant leakage.<br>2. Replace the EGR cooler if any problem is found. |
| Cylinder Head Gasket Leakage | • Remove cylinder heads of the affected cylinder bank and inspect for damage.<br>• Replace components as necessary. |
| Cylinder Head or Engine Block Damage | 1. Inspect the cylinder heads for cracks and warpage.<br>2. Inspect the cylinder block for damage.<br>3. Inspect the cylinder block to head mating surface for staightness.<br>4. Replace components as necessary. |

## Coolant in Engine Oil

| Cause | Correction |
|---|---|
| DEFINITION: Foamy or discolored oil or an engine oil "overfill" condition may indicate coolant entering the engine crankcase. Low coolant levels, an inoperative cooling fan, or a faulty thermostat may lead to an "overtemperature" condition which may cause engine component damage. Contaminated engine oil and oil filter should be changed.<br>1. Inspect the oil for excessive foaming or an overfill condition. Oil diluted by coolant may not properly lubricate the crankshaft bearings and may lead to component damage. Refer to *Lower Engine Noise, Regardless of Engine Speed on page 6-787*.<br>2. Inspect by performing a Cylinder Leak-Down Test. During this test, excessive air bubbles within the cooling system may indicate a faulty gasket or damaged component.<br>3. Inspect by performing a cylinder compression test. Two cylinders "side-by-side" on the engine block with low compression may indicate a failed cylinder head gasket. Refer to *Engine Compression Test on page 6-790*. | |
| Faulty cylinder head gasket | Replace the head gasket and components as required. Refer to *Cylinder Head Cleaning and Inspection on page 6-1027* and *Cylinder Head Replacement - Left on page 6-878* or *Cylinder Head Replacement - Right on page 6-880*. |
| Warped cylinder head | Replace the cylinder head gasket. Refer to *Cylinder Head Replacement - Left on page 6-878* or *Cylinder Head Replacement - Right on page 6-880*. |
| Cracked cylinder head | Replace the cylinder head and gasket. |
| Cracked engine block | Replace the components as required. |
| Cylinder head, block, or manifold porosity | Replace the components as required. |
| Leaking engine oil cooler | Replace components as required. |
| Faulty water pump | Replace components as required. |

## Fuel in Engine Oil

Definition: If fuel is suspected of leaking into the crankcase, the following procedure should be performed to verify the condition.

1. Remove the oil level indicator and allow oil to drop onto a clean white paper towel.
2. If the oil is diluted with fuel, it will become apparent as the towel wicks the fuel away from the drop of oil on the towel. The fuel will expand out in a ring around the oil droplet.
3. If fuel dilution is apparent, refer to *Fuel Leaks on page 6-3112* in engine controls, for diagnosis and repair. Inspect the vehicle for aftermarket performance accessories that may cause damage to the injection pump. After repairs are completed, perform the test again to verify the condition is corrected.
4. If no fuel dilution is present, verify the oil level and correct as needed.

## Turbocharger Whine Noise

| Condition | Action |
|---|---|
| Some whine noise is normal. Compare to a known good engine. | |
| Leaking charge air cooler/pipes/hoses | Inspect for leaks in charge air cooler/pipes/hoses using *J 46091*. |
| Worn turbocharger bearings | Visually inspect for evidence of compressor wheel to housing contact.<br>If the turbocharger bearings are worn or damaged, inspect for a *Turbocharger Lack of Oil Supply on page 6-790*. |
| Intake system leaks or obstructions | Inspect for leaks or obstructions in the intake manifolds. |

## Turbocharger Hissing Noise

| Condition | Action |
|---|---|
| Air inlet leaks or obstructions | Inspect for leaks or obstructions in the turbocharger inlet pipes/hoses. |
| Leaking charge air cooler/pipes/hoses | Inspect for leaks or obstructions in the charge air cooler/pipes/hoses using *J 46091*. |
| Leaking or restricted exhaust system | 1. Inspect for a leak in the exhaust system.<br>2. Inspect for a restricted exhaust system. |
| Intake system leaks or obstructions | 1. Inspect for leaks in the intake manifolds.<br>2. Inspect for obstructions in the intake manifolds. |

### Turbocharger Oil Leak From Compressor Seal

| Condition | Action |
|---|---|
| **Important:** Oil in the turbocharger air inlet duct,oil on the compressor wheel, and oil throughout the charge air cooler system is normal with a closed PCV system. Do not attempt repairs for this condition. | |
| Restricted air system | Inspect for clogged air filter element or restricted air inlet system. |
| Restricted exhaust system | Inspect for a restricted exhaust. |
| Leaking exhaust system. | Inspect for exhaust manifold leaks. |
| Poor oil drainage from turbocharger | Inspect for restricted turbocharger oil drain pipe. |
| Restricted crankcase ventilation system | Inspect for restricted crankcase ventilation system. |
| Worn internal engine components | Inspect for excessive blowby or engine oil consumption. |

### Turbocharger Oil Leak From Turbine Seal

| Condition | Action |
|---|---|
| Poor oil drainage from turbocharger | Inspect for a restricted turbocharger oil drain pipe. |
| Restricted crankcase ventilation system | Inspect for a restricted crankcase ventilation system. |
| Worn internal engine components | Inspect for excessive blowby or engine oil consumption. |

### Turbocharger Lack of Oil Supply

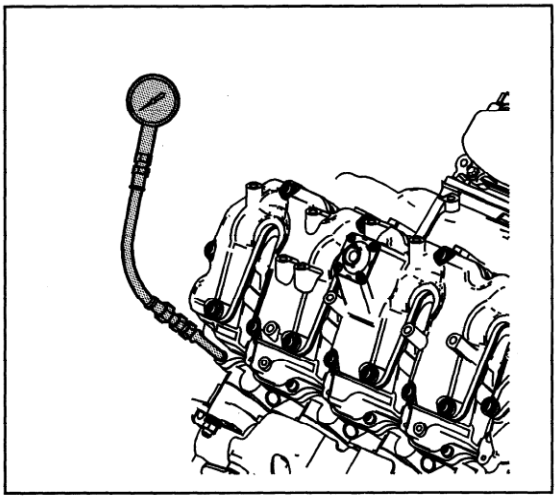
| Condition | Action |
|---|---|
| Restricted oil supply hose | Inspect for restricted turbocharger oil supply hose. |
| Spun camshaft bearing | 1. Remove the oil supply hose. Refer to *Turbocharger Oil Supply Hose Replacement on page 6-873*.<br>2. Visually inspect for correct alignment of the camshaft bearing oil hole.<br>3. Rotate the engine 1/2 turn and inspect the camshaft bearing oil hole for movement, indicating a spun camshaft bearing. |

## Engine Compression Test

### Tools Required

- *J 26999* Compression Gage
- *EN-47603* Compression Gage Adapter

1. Ensure that the vehicle's batteries are in good condition, and fully charged.
2. Operate the vehicle until the engine is at normal operating temperature.
3. Shut off engine.
4. Disconnect the crankshaft position sensor.
5. Disconnect glow plug nut; remove all 8 glow plugs. All 8 glow plugs must be removed from the engine during each cylinder test to obtain valid test results.
6. Prior to taking a compression reading, verify the cranking speed is greater than 140 RPM. If the cranking speed is below 140 RPM, repair the slow cranking speed condition before continuing with the compression test. Refer to *Engine Cranks Slowly on page 6-1783* in Engine Electrical.
7. Install the *EN-47603* in the glow plug hole for the cylinder that is being checked.



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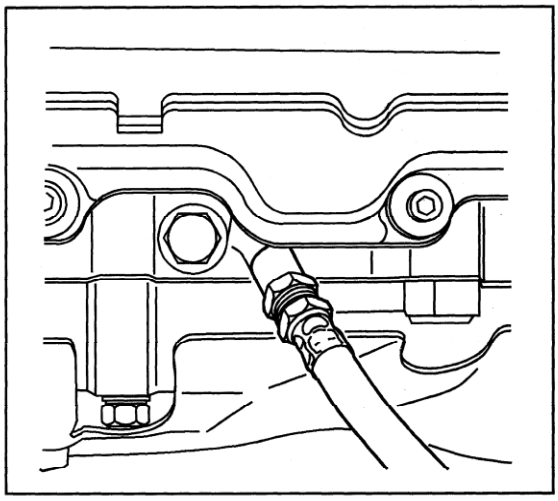
***Notice:*** Do not add oil to any cylinder during a compression test as extensive engine damage may result.

8. Connect the *J 26999* to the *EN-47603*.
9. Using the starter motor, rotate or crank the engine for 6 compression strokes, puffs, for the cylinder being tested.
10. Observe the *J 26999* and note the reading as the compression test is being performed. A normal cylinder reading will be indicated if compression builds up quickly and evenly to the specified level. An abnormal reading will be indicated if compression is low on the first compression stroke, starts increasing on the following compression strokes but does not reach the specified level.
11. Record the compression reading for the cylinder just tested.
12. Disconnect the *J 26999* from the *EN-47603* and remove adapter from the glow plug hole.
13. Repeat steps 8 through 13 for all remaining cylinders. All 8 cylinders must be tested to obtain valid test results. Record the readings.
14. The minimum compression in any one cylinder is 2069 kPa (300 psi). There should not be more than 345 kPa (50 psi) difference between a suspect cylinder and the average compression of all 8 cylinders.
    - Normal—Compression builds up quickly and evenly to the specified compression for each cylinder.
    - Piston Rings Leaking—Compression is low on the first stroke. Compression builds up with the following strokes but does not reach normal.
    - Valves Leaking—Compression is low on the first stroke. Compression usually does not build up on the following strokes.

## Cylinder Leakage Test

### Tools Required

- *J 35667-A* Cylinder Head Leakdown Tester
- *J-35667-8* Cylinder Head Leakdown Adapter



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***Caution: Refer to Battery Disconnect Caution on page P-4 in Cautions and Notices.***

**Important:** A leakage test may be performed to measure cylinder/combustion chamber leakage. High cylinder leakage may indicate one or more of the following:

- Worn, burnt, or stuck valves
- Broken valve springs
- Incorrect valve lash
- Damaged valve train components
- Damaged piston
- Worn piston rings
- Worn or scored cylinder bore
- Damaged cylinder head gasket
- Cracked or damaged cylinder head
- Cracked or damaged engine block

1. Disconnect the battery ground negative cable.
2. Remove the glow plugs.
3. Rotate the crankshaft to place the piston in the cylinder being tested at Top Dead Center (TDC) of the compression stroke.
4. Install *J-35667-8* and *J 35667-A*.

**Important:** It may be necessary to hold the crankshaft balancer bolt to prevent the engine from rotating.

5. Apply shop air pressure to *J 35667-A* and adjust according to the manufacturers instructions.

6. Record the cylinder leakage value. Cylinder leakage that exceeds 25 percent is considered excessive and may require component service. In excessive leakage situations, inspect for the following conditions:
   - Air leakage sounds at the intake manifold tube, may indicate a worn, stuck or burnt intake valve, broken valve spring, incorrect valve lash or damaged valve train components.
   - Air leakage sounds at the exhaust system tailpipe may indicate a worn, burnt, or stuck exhaust valve, broken valve spring, incorrect valve lash or damaged valve train components.
   - Air leakage sounds from the crankcase, oil level indicator tube, or oil fill tube may indicate worn piston rings, a damaged piston, a worn or scored cylinder bore, a damaged engine block or a damaged cylinder head.
   - Air bubbles in the cooling system may indicate a damaged cylinder head or gasket.
7. Perform the leakage test on the remaining cylinders and record the values.

## Oil Consumption Diagnosis

The accepted rate of oil consumption, not due to leaks, is the use of more than 0.946 liter (1 qt) within 379 liters (100 gallons) of fuel used. This rate only applies to engines under warranty, maintained in accordance with the appropriate maintenance schedule.

Oil economy should not be tested until the engine has accumulated at least 100 hours and the oil has been changed. During initial engine break-in periods before the first oil change, oil consumption may exceed 1.9 liters (2 qts) or more per 379 liters (100 gallons) of fuel used.

**Oil Consumption Diagnosis**

| Checks | Causes |
|---|---|
| Preliminary | The causes of excessive oil consumption may include the following conditions:<br>• External oil leaks<br>Refer to *Oil Leak Diagnosis on page 6-794*.<br>• Incorrect oil level or improper reading of the oil level indicator<br>Run the engine for a few minutes, allow adequate drain down time (2–3 minutes) and check for the correct engine oil level.<br>• Improper oil viscosity<br>Refer to the owners manual and use the recommended SAE grade and viscosity for the prevailing temperatures.<br>• Continuous high speed driving and/or severe usage<br>• Crankcase ventilation system restrictions or malfunctioning components<br>• Oil residue in the charge air cooler system is normal with a closed PCV system<br>• Oil Residue in the charge air cooler system is normal with a closed PCV system<br>• Worn valve guides and/or valve stems<br>• Worn or improperly installed valve stem oil seals<br>• Piston rings broken, worn, not seated properly<br>Allow adequate time for the rings to seat.<br>Replace worn piston rings as necessary.<br>• Piston and rings improperly installed or improperly fit to the cylinder bore |

## Oil Pressure Diagnosis and Testing

| Step | Action | Yes | No |
|---|---|---|---|
| DEFINITION: Low or no engine oil pressure indicates a potentially serious condition with all of the engine mechanical components. Once the cause of the low or no oil pressure condition has been identified, repair all collateral damage to the engine mechanical components as well as the initial cause of the condition. | | | |
| 1 | Check engine oil level. Use only the MD service parts brand and recommended grade of engine oil specified for the engine.<br>Is the engine oil level between ADD and FULL on the oil level indicator? | Go to *Step 2* | — |
| 2 | 1. Operate engine until it reaches normal operating temperature. Refer to *Engine Mechanical Specifications on page 6-739.*<br>2. Engine should be level.<br>3. Wait 15 minutes.<br>4. Check engine oil level. Use only the MD service parts brand and recommended grade of engine oil specified for the vehicle.<br>Is the engine oil level between ADD and FULL on the oil level indicator? | Go to *Step 3* | — |
| 3 | Operate the engine and measure the engine oil pressure with the vehicle gage or light. Refer to *Engine Mechanical Specifications on page 6-739.*<br>Is engine oil pressure within specification? | System OK | Go to *Step 4* |
| 4 | 1. Remove the oil pressure sender or engine block oil gallery plug.<br>2. Install a mechanical oil pressure gage.<br>3. Operate the engine and measure the engine oil pressure with the mechanical oil pressure gage. Refer to *Engine Mechanical Specifications on page 6-739.*<br>Is engine oil pressure within specification? | System OK | Go to *Step 5* |
| 5 | Change the engine oil and filter.<br>• Use only the MD service parts brand and recommended grade of engine oil specified for the engine. Refer to Owners' Manual.<br>• Use only the MD service parts brand and recommended type of engine oil filter specified for the engine. Refer to Owners' Manual.<br>Operate the engine and measure the engine oil pressure with the mechanical oil pressure gage. Refer to *Engine Mechanical Specifications on page 6-739.*<br>Is engine oil pressure within specification? | System OK | Go to *Step 6* |

## Oil Pressure Diagnosis and Testing (cont'd)

| Step | Action | Yes | No |
|---|---|---|---|
| 6 | 1. Inspect the engine for mechanical damage. Special interest should be shown to the following areas:<br>• Malfunctioning oil bypass valve<br>• Oil pump worn or dirty<br>• Oil pump-to-engine block bolts loose<br>• Oil pump O-ring damaged or missing<br>• Oil pump to oil pump pipe and screen assembly gasket missing or damaged<br>• Oil pump pipe and screen assembly restrictions or damaged<br>• Oil pump driven gear damaged or loose<br>• Oil pump drive gear damaged<br>• Oil cooler restrictions<br>• Oil cooler O-rings damaged or missing<br>• Excessive bearing clearances<br>• Cracked, porous or restricted oil galleries<br>• Oil gallery plugs missing or incorrectly installed<br>• Damaged or missing oil spray cooling nozzles<br>2. Inspect the engine for customer modifications.<br>Is there mechanical damage, or customer modifications to the engine? | Go to *Step 7* | Go to *Step 1* |
| 7 | Repair or replace all damaged or modified components.<br>Is the repair complete? | Go to *Step 1* | — |

## Oil Leak Diagnosis

| Step | Action | Yes | No |
|---|---|---|---|
| **Important:** You can repair most fluid leaks by first visually locating the leak, repairing or replacing the component, or by resealing the gasket surface. Once the leak is identified, determine the cause of the leak. Repair the cause of the leak as well as the leak itself. | | | |
| 1 | 1. Operate the engine until it reaches normal operating temperature.<br>2. Stop the engine.<br>3. Wait 15 minutes.<br>4. Check for drippings.<br>Are drippings present? | Go to *Step 2* | System OK |
| 2 | Can you identify the type of fluid and the approximate location of the leak? | Go to *Step 7* | Go to *Step 3* |
| 3 | 1. Visually inspect the suspected area. Use a small mirror to assist in looking at hard to see areas.<br>2. Check for leaks at the following locations:<br>• Sealing surfaces<br>• Fittings<br>• Cracked or damaged components<br>Can you identify the type of fluid and the approximate location of the leak? | Go to *Step 7* | Go to *Step 4* |
| 4 | 1. Completely clean the entire engine and surrounding components.<br>2. Apply an aerosol-type powder (baby powder, foot powder, etc.) to the suspected area.<br>3. Operate the engine for 30 minutes at normal operating temperature and at varying speeds.<br>4. Identify the type of fluid, and the approximate location of the leak, from the discolorations in the powder surface.<br>Can you identify the type of fluid and the approximate location of the leak? | Go to *Step 7* | Go to *Step 5* |

## Oil Leak Diagnosis (cont'd)

| Step | Action | Yes | No |
|---|---|---|---|
| 5 | Use *J 28428-E* in order to identify the type of fluid, and the approximate location of the leak. Refer to the manufacturer's instructions when using the tool.<br>Can you identify the type of fluid and the approximate location of the leak? | Go to *Step 7* | Go to *Step 6* |
| 6 | 1. Visually inspect the suspected area. Use a small mirror to assist in looking at hard to see areas.<br>2. Check for leaks at the following locations:<br>• Sealing surfaces<br>• Fittings<br>• Cracked or damaged components<br>Can you identify the type of fluid and the approximate location of the leak? | Go to *Step 7* | System OK |
| 7 | 1. Inspect the engine for mechanical damage and repair or replace as necessary. Special attention should be shown to the following areas:<br>• Plugged or malfunctioning crankcase ventilation system. Refer to *Crankcase Ventilation System Inspection/Diagnosis on page 6-795.*<br>• Higher than recommended fluid levels<br>• Higher than recommended fluid pressures<br>• Plugged or malfunctioning fluid filters or pressure bypass valves<br>• Improperly tightened or damaged fasteners<br>• Cracked or porous components<br>• Improper sealants or gaskets where required<br>• Improper sealant or gasket installation<br>• Damaged or worn gaskets or seals<br>• Damaged or worn sealing surfaces<br>2. Inspect the engine for customer modifications.<br>Is there mechanical damage, or customer modifications to the engine? | Go to *Step 8* | System OK |
| 8 | Repair or replace all damaged or modified components.<br>Does the engine still leak oil? | Go to *Step 1* | System OK |

## Crankcase Ventilation System Inspection/Diagnosis

| Concern | Action |
|---|---|
| **Important:** Oil in the charged air cooler, hoses, turbocharger, or intake manifolds is normal with a closed crankcase ventilation system.<br>The maximum crankcase pressure is 4 kPa or 16 in of water at 3,100 RPM measured at the oil level indicator tube. | |
| PVC check valve stuck closed | • Excessive crankcase pressure<br>• Possible oil leaks. Replace the valve. |
| Odors | Normal situation |
| Noise | Cracked hoses |
| Smoke | Damaged PCV diaphragm |
| Excessive Oil Consumption | Damaged PCV diaphragm, missing or broken spring |

# Drive Belt Chirping Diagnosis

## Diagnostic Aids

If a chirping noise occurs during engine shutdown, this is considered normal and is due to the engine's high compression. The chirping noise may be intermittent due to moisture on the drive belt or the accessory drive pulleys. In order to duplicate the customer's concern, it may be necessary to spray a small amount of water onto the drive belt. If spraying water onto the drive belt duplicates the symptom, cleaning the accessory belt pulleys may be the most probable solution.

If a chirping noise occurs during engine shutdown, this is considered normal and is due to the engine's high compression.

## Test Description

The numbers below refer to the step numbers on the diagnostic table.

2. The chirping noise may not be engine related. This step is to verify that the engine is making the noise. If the engine is not making the noise do not proceed further with this table.
3. The noise may be an internal engine noise. Remove the drive belt and operate the engine for a few seconds, this will verify if the chirping noise is related to the drive belt or not. With the drive belt removed the cooling fan will not operate and the engine may overheat. Also, DTCs may set when the engine is operated with the drive belt removed.
4. Inspect the drive belt for signs of pilling. Pilling is the small balls, pills or strings in the drive belt grooves caused by the accumulation of rubber dust.
6. Misalignment of the accessory drive pulleys may be caused from improper mounting or incorrect installation of an accessory drive component, or the pulley may be bent inward or outward from a previous repair. Test for a misaligned pulley using a straight edge in the pulley grooves across 2 or 3 pulleys. If a misaligned pulley is found, refer to that accessory drive component for the proper removal and installation procedure for that pulley.
10. Inspection of the fasteners can eliminate the possibility that a incorrect bolt, nut, spacer, or washer was installed.
12. Inspection of the accessory drive pulleys should include inspecting for bends, dents, or other damage to the pulleys that would prevent the drive belt from seating properly in the pulley grooves, or on the smooth surface of the pulley when the back side of the drive belt is used to drive the pulley.
14. Replacing the drive belt when it is not damaged or there is not excessive pilling will only be a temporary repair.

### Drive Belt Chirping Diagnosis

| Step | Action | Yes | No |
|---|---|---|---|
| ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices.<br>DEFINITION: The following items are indications of chirping:<br>• A high pitched noise that is heard once per revolution of the drive belt or a accessory drive pulley.<br>• Chirping may occur on cold damp startup conditions and will subside once the engine reaches normal operating temperature. | | | |
| 1 | Did you review the Symptoms – Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| *2* | Verify that there is a chirping noise.<br>Does the engine make the chirping noise? | Go to *Step 3* | Go to Diagnostic Aids |
| *3* | 1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>2. Operate the engine for no longer than 30–40 seconds.<br>Does the chirping noise still exist? | Go to *Engine Noise on Start-Up, but Only Lasting a Few Seconds on page 6-786* | Go to *Step 4* |
| *4* | Inspect for severe drive belt pilling exceeding 1/3 of the belt groove depth.<br>Does the drive belt grooves have pilling? | Go to *Step 5* | Go to *Step 6* |
| 5 | Clean the accessory drive belt pulleys with a suitable wire brush.<br>Were the accessory drive belt pulleys cleaned? | Go to *Step 15* | — |
| *6* | Inspect for a misaligned accessory drive pulleys.<br>Is there a misaligned pulleys? | Go to *Step 7* | Go to *Step 8* |
| 7 | Replace and/or repair the misaligned accessory drive pulleys.<br>Were the misaligned accessory drive pulleys replaced and/or repaired? | Go to *Step 15* | — |

**Drive Belt Chirping Diagnosis (cont'd)**

| Step | Action | Yes | No |
|---|---|---|---|
| 8 | Inspect for a bent or cracked accessory drive brackets.<br>Is there a bent and/or cracked accessory drive brackets? | Go to *Step 9* | Go to *Step 10* |
| 9 | Replace the bent and/or cracked accessory drive brackets.<br>Was the bent and/or cracked accessory drive brackets replaced? | Go to *Step 15* | — |
| *10* | Inspect for incorrect, loose, and/or missing fasteners.<br>Were there any incorrect, loose, and/or missing fasteners found? | Go to *Step 11* | Go to *Step 12* |
| 11 | 1. Replace any incorrect and/or missing fasteners.<br>2. Tighten any loose fasteners. Refer to *Fastener Tightening Specifications on page 6-736.*<br>Were the fasteners replaced and/or tightened? | Go to *Step 15* | Go to *Step 12* |
| *12* | Inspect for a bent accessory drive pulleys.<br>Was a bent accessory drive pulleys found? | Go to *Step 13* | Go to *Step 14* |
| 13 | Replace the bent accessory drive pulleys.<br>Was the bent accessory drive pulleys replaced? | Go to *Step 15* | — |
| *14* | Replace the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>Was the drive belt replaced? | Go to *Step 15* | — |
| 15 | 1. Clear any codes.<br>2. Run the engine in order to verify the repair.<br>Does the chirping noise still exist? | — | System OK |

## Drive Belt Squeal Diagnosis

### Diagnostic Aids

A loose or improper installation of a body or suspension component, or other items on the vehicle may cause the squeal noise.

If the squeal is intermittent, verify that it is not the accessory drive components by varying their loads, making sure they are operating to their maximum capacity. An overcharged air conditioning (A/C) system, a power steering system restriction or the incorrect fluid, or a failing generator are suggested items to inspect.

### Test Description

The number(s) below refer to the steps in the diagnostic table.

2. The squeal may not be engine related. This step is to verify that the engine is making the noise. If the engine is not making the noise, do not proceed further with this table
3. The squeal may be an internal engine noise. Remove the drive belt and operate the engine for a few seconds, this will verify if the squealing noise is related to the drive belt or an accessory drive component. With the drive belt removed the cooling fan will not be operate and the engine may overheat. Also diagnostic trouble codes (DTCs) may set when the engine is operated with the drive belt removed.
4. This test is to verify that an accessory drive components does not have a seized bearing. With the belt removed, test the bearings in the accessory drive components for smooth operation. Also test the accessory drive components with the engine operating by varying the load on the accessory drive components to verify that the components is operating properly.
5. This test is to verify that the drive belt tensioner is operating properly. If the drive belt tensioner is not operating properly, proper belt tension may not be achieved to keep the drive belt from slipping which could cause a squealing noise.
6. This test is to verify that the drive belt is not too long, which would prevent the drive belt tensioner from operating properly. Also if the incorrect length drive belt was installed, it may not be routed correctly and may be turning an accessory drive component in the incorrect direction.
7. Misalignment of the accessory drive pulleys may be caused from improper mounting or incorrect installation of a accessory drive component, or the pulley may be bent inward or outward from a previous repair. Test for a misaligned pulley using a straight edge in the pulley grooves across 2 or 3 pulleys. If a misaligned pulley is found, refer to that accessory drive component for the proper removal and installation procedure for that pulley.
8. Inspect the accessory drive pulleys to verify that they are the correct diameter or width. Using a known good vehicle, compare the accessory drive pulleys.

### Drive Belt Squeal Diagnosis

| Step | Action | Yes | No |
|---|---|---|---|
| | ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices.<br>DEFINITION: The following items are indications of drive belt squeal:<br>• A loud screeching noise that is caused by a slipping drive belt (this is unusual for a drive belt with multiple ribs)<br>• The squeal occurs when a heavy load is applied to the drive belt, such as an A/C compressor engagement, snapping the throttle, slipping on a seized pulley or a faulty accessory drive component. | | |
| 1 | Did you review the Symptoms - Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| *2* | Verify that there is a squealing noise.<br>Does the engine make the squeal noise? | Go to *Step 3* | Go to Diagnostic Aids |
| *3* | 1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>2. Operate the engine for no longer than 30 to 40 seconds.<br>Does the squealing noise still exist? | Go to *Engine Noise on Start-Up, but Only Lasting a Few Seconds on page 6-786* | Go to *Step 4* |
| *4* | Inspect for a seized accessory drive component bearing or a faulty accessory drive component.<br>Did you find and correct the condition? | Go to *Step 9* | Go to *Step 5* |
| *5* | Inspect the drive belt tensioner for proper operation. Refer to *Drive Belt Tensioner Diagnosis on page 6-803.*<br>Did you find and correct the condition? | Go to *Step 9* | Go to *Step 6* |
| *6* | Check for the correct length drive belt<br>Did you find and correct the condition? | Go to *Step 9* | Go to *Step 7* |
| *7* | Inspect for a misaligned pulley.<br>Did you find and correct the condition? | Go to *Step 9* | Go to *Step 8* |
| *8* | Inspect for an in correct size pulley.<br>Did you find and correct the condition? | Go to *Step 9* | — |
| 9 | 1. Install the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>2. Clear any codes.<br>3. Run the engine in order to verify the repair.<br>Does the squealing noise still exist? | — | System OK |

## Drive Belt Whine Diagnosis

### Diagnostic Aids

The drive belt will not cause the whine.

If the whine is intermittent, verify that it is not the accessory drive components by varying their loads, making sure they are operating to their maximum capacity. An overcharged air conditioning (A/C) system, a power steering system restriction or the incorrect fluid, or a failing generator are suggested items to inspect.

### Test Description

The numbers below refer to the steps in the diagnostic table.

3. This test is to verify that the whine is being caused by the accessory drive components. Remove the drive belt and operate the engine for a few seconds, this will verify if the whining noise is related to the accessory drive component. With the drive belt removed the cooling fan will not operate and the engine may overheat. Also diagnostic trouble codes (DTCs) may set when the engine is operated with the drive belt removed.
4. The inspection should include checking the drive belt tensioner and the drive belt idler pulley bearings. The drive belt may have to be installed and the accessory drive components operated separately by varying their loads. Refer to the suspected accessory drive component for the proper removal and replacement procedure.

**Drive Belt Whine Diagnosis**

| Step | Action | Yes | No |
|---|---|---|---|
| ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices.<br>DEFINITION: A high pitched continuous noise that may be caused by an accessory drive component failed bearing. | | | |
| 1 | Did you review the Symptoms - Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| 2 | Verify that there is a whining noise.<br>Does the engine make the whine noise? | Go to *Step 3* | Go to Diagnostic Aids |
| 3 | 1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804*.<br>2. Operate the engine for no longer than 30 to 40 seconds.<br>Does the whining noise still exist? | Go to *Engine Noise on Start-Up, but Only Lasting a Few Seconds on page 6-786* | Go to *Step 4* |
| 4 | Inspect for a failed accessory drive component bearing.<br>Did you find and correct the condition? | Go to *Step 5* | — |
| 5 | 1. Clear any codes.<br>2. Run the engine in order to verify the repair.<br>Does the whining still exist? | — | System OK |

## Drive Belt Rumbling Diagnosis

### Diagnostic Aids

Vibration from the engine operating may cause a hull component or another part of the vessel to make rumbling noise.

The drive belt may have a condition that can not be seen or felt. Sometimes replacing the drive belt may be the only repair for the symptom.

If, after replacing the drive belt and completing the diagnostic table, the rumbling is only heard with the drive belt installed, there might be an accessory drive component failure. Varying the load on the accessory drive components may aid in identifying which component is causing the rumbling noise.

### Test Description

The numbers below refer to the steps on the diagnostic table.

2. This test is to verify that the symptom is present during diagnosing. Other vessel components may cause a similar symptom.
3. This test is to verify that the drive belt is causing the rumbling. Rumbling may be confused with an internal engine noise due to the similarity in the description. Operate the engine for a few seconds, this will verify if the rumbling noise is related to the drive belt or not. With the drive belt removed the water pump will not operate and the engine may overheat. Also diagnostic trouble codes (DTCs) may set when the engine is operated with the drive belt removed.
4. Inspect the drive belt to ensure that the drive belt is not the cause of the noise. Small cracks across the ribs of the drive belt will not cause the noise. Belt separation is identified by the plys of the belt separating, this may be seen at the edge of the belt or felt as a lump in the belt.
5. Small amounts of pilling is a normal condition and acceptable. When the pilling is severe, the drive belt does not have a smooth surface for proper operation.

**Drive Belt Rumbling Diagnosis**

| Step | Action | Yes | No |
|---|---|---|---|
| ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices.<br>DEFINITION:<br>• A low pitch tapping, knocking, or thumping noise heard at or just above idle.<br>• Heard once per revolution of the drive belt or a pulleys.<br>• Rumbling may be caused from:<br>– Pilling, the accumulation of rubber dust that forms small balls (pills) or strings in the drive belt pulley groove<br>– The separation of the drive belt<br>– A damaged drive belt | | | |
| 1 | Did you review the Symptoms - Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| 2 | Verify that there is a rumbling noise.<br>Does the engine make the rumbling noise? | Go to *Step 3* | Go to Diagnostic Aids |

**Drive Belt Rumbling Diagnosis (cont'd)**

| Step | Action | Yes | No |
|---|---|---|---|
| 3 | 1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>2. Operate the engine for no longer than 30 to 40 seconds.<br>Does the rumbling noise still exist? | Go to *Engine Noise on Start-Up, but Only Lasting a Few Seconds on page 6-786* | Go to *Step 4* |
| 4 | Inspect the drive belt for damage, separation, or sections of missing ribs.<br>Were any of these conditions found? | Go to *Step 7* | Go to *Step 5* |
| 5 | Inspect for severe pilling of more than 1/3 of the drive belt groove depth.<br>Do the drive belt grooves have pilling? | Go to *Step 6* | Go to *Step 7* |
| 6 | 1. Clean the drive belt pulley(s) using a suitable wire brush.<br>2. Install the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>Did you complete the repair? | Go to *Step 8* | — |
| 7 | Install a new drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>Did you complete the replacement? | Go to *Step 8* | — |
| 8 | 1. Clear any codes.<br>2. Run the engine in order to verify the repair.<br>Does the rumbling noise still exist? | — | System OK |

## Drive Belt Vibration Diagnosis

### Diagnostic Aids

The accessory drive components can have an affect on engine vibration. An overcharged air conditioning (A/C) system, a power steering system restriction, or the incorrect fluid, or an extra load placed on the generator are suggested items to inspect. To help identify an intermittent or an improper condition, vary the loads on the accessory drive components.

### Test Description

The numbers below refer to the steps in the diagnostic table.

2. This test is to verify that the vibration is present during diagnosing. Other vehicle components may cause a similar symptom such as the exhaust system, or the drivetrain.
3. This test is to verify that the drive belt or accessory drive components may be causing the vibration. Remove the drive belt and operate the engine for a few seconds, this will verify if the vibration is related to the drive belt or not. With the drive belt removed the water pump will not operate and the engine may overheat. Also diagnostic trouble codes (DTCs) may set when the engine is operated with the drive belt removed.
4. The drive belt may cause a vibration. While the drive belt is removed this is the best time to inspect the condition of the drive belt.
6. Inspection of the fasteners can eliminate the possibility that a incorrect bolt, nut, spacer, or washer was installed.
8. This step should only be performed if the fan is driven by the drive belt. Inspect the engine cooling fan for bent, twisted, loose, or cracked blades. Inspect the fan clutch for smooth operation. Inspect for a bent fan shaft or bent mounting flange.
9. Inspect the water pump drive shaft for being bent. Also inspect the water pump bearings for smooth operation and excessive play. Compare the water pump with a known good water pump.
10. Accessory drive component brackets that are bent, cracked, or loose may put an extra strain on that accessory drive component causing it to vibrate.


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## Drive Belt Vibration Diagnosis

| Step | Action | Yes | No |
|---|---|---|---|
| | ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices.<br>DEFINITION: The following items are indications of drive belt vibration:<br>• The vibration is engine-speed related.<br>• The vibration may be sensitive to accessory load. | | |
| 1 | Did you review the Symptoms - Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| 2 | Verify that the vibration is engine related.<br>Does the engine make the vibration? | Go to *Step 3* | Go to Diagnostic Aids |
| 3 | 1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>2. Operate the engine for no longer than 30 to 40 seconds.<br>Does the engine still make the vibration? | Go to *Diagnostic Starting Point - Vibration Diagnosis and Correction on page 0-33* in Vibration Diagnosis and Correction | Go to *Step 4* |
| 4 | Inspect the drive belt for wear, damage, debris build-up and missing drive belt ribs.<br>Were any of these conditions found? | Go to *Step 5* | Go to *Step 6* |
| 5 | Install a new drive belt. Refer to *Drive Belt Replacement on page 6-804.*<br>Did you complete the replacement? | Go to *Step 11* | — |
| 6 | Inspect for incorrect, loose and/or missing fasteners.<br>Were any of these conditions found? | Go to *Step 7* | Go to *Step 8* |
| 7 | 1. Replace any incorrect and/or missing fasteners.<br>2. Tighten any loose fasteners. Refer to *Fastener Tightening Specifications on page 6-736.*<br>Were the fasteners replaced and/or tightened? | Go to *Step 11* | — |
| 8 | Inspect for damaged fan blades or a bent fan clutch shaft.<br>Did you find and correct the condition? | Go to *Step 11* | Go to *Step 9* |
| 9 | Inspect for a bent water pump shaft.<br>Did you find and correct the condition? | Go to *Step 11* | Go to *Step 10* |
| 10 | Inspect for bent or cracked accessory drive bracket(s).<br>Did you find and correct the condition? | Go to *Step 11* | — |
| 11 | 1. Clear any codes.<br>2. Run the engine in order to verify the repair.<br>Does the vibration still exist? | — | System OK |

## Drive Belt Falls Off Diagnosis

### Diagnostic Aids

If the drive belt repeatedly falls off the accessory drive belt pulleys, this may be caused by a pulley misalignment.

An extra load that is quickly applied or released by an accessory drive component may cause the drive belt to fall off. Verify that the accessory drive components are operating properly.

If the drive belt is the incorrect length, the drive belt tensioner may not maintain the proper tension on the drive belt.

### Test Description

The numbers below refer to the steps in the diagnostic table.

2. This inspection is to verify the condition of the drive belt. Damage may of occurred to the drive belt when the drive belt fell off. Inspect the drive belt for cuts, tears, sections of ribs missing, or damaged belt plys.
4. Misalignment of the accessory drive pulleys may be caused from improper mounting or incorrect installation of an accessory drive component, or the pulley may be bent inward or outward from a previous repair. Test for a misaligned pulley using a straight edge in the pulley grooves across 2 or 3 pulleys. If a misaligned pulley is found, refer to that accessory drive component for the proper removal and installation procedure of that pulley.
5. Inspection of the accessory drive pulleys should include inspecting for bends, dents, or other damage to the pulleys that would prevent the drive belt from seating properly in the pulley grooves or on the smooth surface of a pulley when the back side of the drive belt is used to drive the pulley.
6. Accessory drive component brackets that are bent or cracked will also cause the drive belt to fall off.

7. Inspection of the fasteners can eliminate the possibility that a incorrect bolt, nut, spacer, or washer was installed. Missing, loose, or incorrect fasteners may cause pulley misalignment from the accessory drive brackets moving under load. Over tightening the fasteners may cause misalignment of the accessory component brackets.

**Drive Belt Falls Off Diagnosis**

| Step | Action | Yes | No |
|---|---|---|---|
| ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices. DEFINITION: The drive belt falls off the pulleys or may not ride correctly on the pulleys. | | | |
| 1 | Did you review the Symptoms - Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| 2 | Inspect for a damaged drive belt.<br>Did you find the condition? | Go to *Step 3* | Go to *Step 4* |
| 3 | Install a new drive belt. Refer to *Drive Belt Replacement on page 6-804*.<br>Does the drive belt continue to fall off? | Go to *Step 4* | System OK |
| 4 | Inspect for misaligned accessory drive pulley.<br>Did you find and correct the condition? | Go to *Step 12* | Go to *Step 5* |
| 5 | Inspect for a bent or dented accessory drive pulley.<br>Did you find and correct the condition? | Go to *Step 12* | Go to *Step 6* |
| 6 | Inspect for a bent or a cracked accessory drive brackets.<br>Did you find and correct the condition? | Go to *Step 12* | Go to *Step 7* |
| 7 | Inspect for incorrect, loose and/or missing fasteners.<br>Were there any incorrect, loose and/or missing fasteners? | Go to *Step 8* | Go to *Step 9* |
| 8 | 1. Replace any incorrect and/or missing fasteners.<br>2. Tighten any loose fasteners. Refer to *Fastener Tightening Specifications on page 6-736*.<br>Does the drive belt continue to fall off? | Go to *Step 9* | System OK |
| 9 | Test the drive belt tensioner for correct operation.<br>Does the drive belt tensioner operate correctly? | Go to *Step 11* | Go to *Step 10* |
| 10 | Replace the drive belt tensioner. Refer to *Drive Belt Tensioner Replacement on page 6-806*.<br>Does the drive belt continue to fall off? | Go to *Step 11* | System OK |
| 11 | Inspect for failed drive belt idler and/or tensioner pulley bearings.<br>Did you find and repair the condition? | Go to *Step 12* | — |
| 12 | Run the engine in order to verify the repair.<br>Does the drive belt still fall off? | — | System OK |

## Drive Belt Excessive Wear Diagnosis

### Diagnostic Aids

Excessive wear on a drive belt is usually caused by incorrect installation or the incorrect drive belt for the application.

Minor misalignment of the accessory drive belt pulleys will not cause excessive wear, but will probably cause the drive belt to make a noise or fall off.

Excessive misalignment of the accessory drive belt pulleys will cause excessive wear and may also make the drive belt fall off.

### Test Description

The numbers below refer to the steps in the diagnostic table.

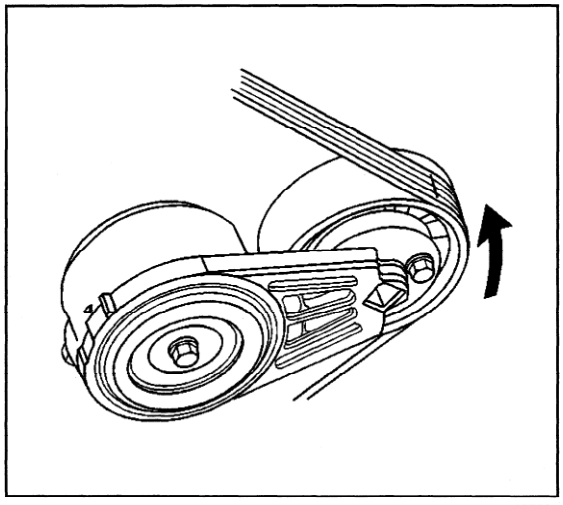
2. This inspection is to verify the drive belt is correctly installed on all of the accessory drive pulleys. Wear on the drive belt may be caused by mis-positioning the drive belt by one groove on a pulleys.
3. The installation of a drive belt that is too wide or too narrow will cause wear on the drive belt. The drive belt ribs should match all of the grooves on the pulleys.

4. This inspection is to verify the drive belt is not contacting any part of the engine or body while the engine is operating. There should be sufficient clearance when the accessory drive components load varies. The drive belt should not come in contact with an engine or a body component when snapping the throttle.

### Drive Belt Excessive Wear Diagnosis

| Step | Action | Yes | No |
|---|---|---|---|
| ***Notice:*** Refer to *Belt Dressing Notice on page P-7* in Cautions and Notices. DEFINITION: Wear at the outside ribs of the drive belt due to an incorrectly installed drive belt. | | | |
| 1 | Did you review the Symptoms - Engine Mechanical diagnostic information, and perform the necessary inspections? | Go to *Step 2* | Go to *Symptoms - Engine Mechanical on page 6-782* |
| *2* | Inspect the drive belt for proper installation. Is the drive belt installed properly? | Go to *Step 5* | Go to *Step 3* |
| *3* | Inspect for the correct drive belt. Is the correct drive belt installed? | Go to *Step 5* | Go to *Step 4* |
| *4* | Inspect the drive belt for signs of rubbing against a bracket, hose, or wiring harness. Was the drive belt rubbing against anything? | Go to *Step 6* | Go to Diagnostic Aids |
| 5 | Replace the drive belt. Refer to *Drive Belt Replacement on page 6-804.* Did you complete the replacement? | Go to *Step 6* | — |
| 6 | Run the engine in order to verify the repair. Is there still excessive drive belt wear? | — | System OK |

## Drive Belt Tensioner Diagnosis



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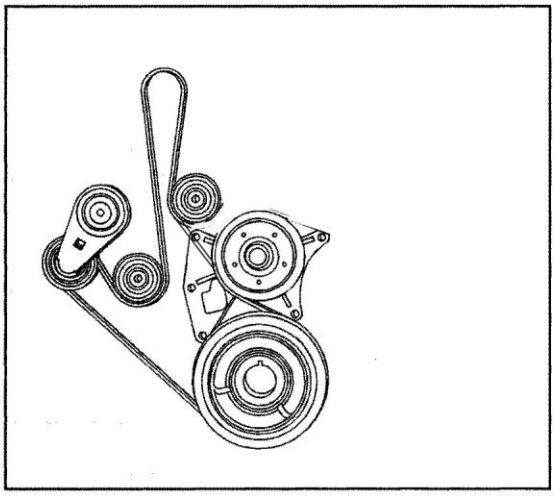
***Notice:*** Allowing the drive belt tensioner to snap into the free position may result in damage to the tensioner.

**Important:** When the engine is operating the drive belt tensioner arm will move. Do not replace the drive belt tensioner because of movement in the drive belt tensioner arm.

1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*
2. Position a 3/8-inch drive breaker bar into the drive belt tensioner opening and rotate the tensioner counterclockwise.
3. Move the drive belt tensioner through its full travel.
   - The movement should feel smooth
   - There should be no binding
   - The tensioner should return freely
4. If any binding is observed, replace the drive belt tensioner. Refer to *Drive Belt Tensioner Replacement on page 6-806.*
5. Install the drive belt. Refer to *Drive Belt Replacement on page 6-804.*

# Repair Instructions

## Drive Belt Replacement



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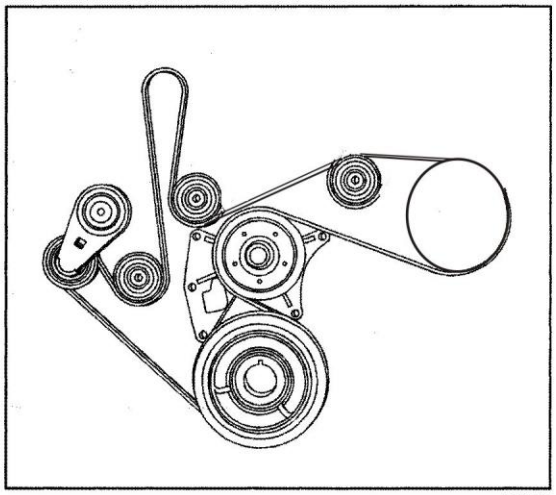


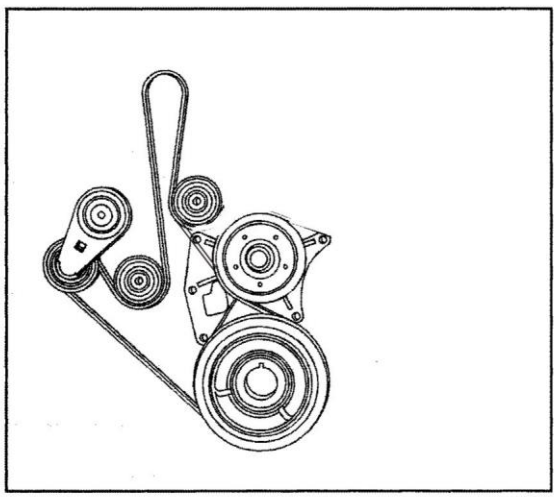
1363115

### Removal Procedure

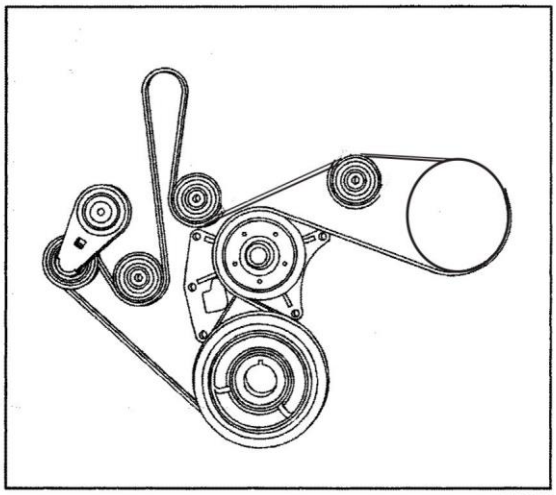
1. Remove the engine mounted fan shroud. Refer to *Fan Shroud Replacement - Upper (w/RPO HP2) on page 6-1595* or *Fan Shroud Replacement - Upper (Automatic Transmission - Diesel) on page 6-1597* or *Fan Shroud Replacement - Upper (Manual Transmission - Diesel) on page 6-1600* or *Fan Shroud Replacement - Upper (Automatic Transmission - Gasoline) on page 6-1602* or *Fan Shroud Replacement - Upper (Manual Transmission - Gasoline) on page 6-1606.*
2. Install a 3/8-inch breaker bar into the tensioner opening and rotate the tensioner counterclockwise.
3. Remove the belt from the tensioner.
4. Slowly release the tension on the tensioner arm.
5. Remove the drive belt from the drive pulleys, if equipped with a single generator.
6. Remove the drive belt from the drive pulleys, if equipped with dual generators.
7. Inspect the drive belt for excessive cracking or any visible damage and replace if necessary.

## Installation Procedure

1. Install a 3/8 inch breaker bar into the tensioner opening and rotate the tensioner counterclockwise.


1363113

2. Install the drive belt, if equipped with dual generators.
3. Route the drive belt over and/or around all the drive pulleys except for the tensioner.
4. Install the drive belt, if equipped with a single generator.
5. Route the drive belt over and/or around all the drive pulleys except for the tensioner.
6. Install the belt over and/or around the tensioner.
7. Slowly release the tension on the tensioner arm.
8. Inspect the drive belt for proper installation on and/or around all pulleys.
9. Install the engine mounted fan shroud. Refer to *Fan Shroud Replacement - Upper (w/RPO HP2) on page 6-1595* or *Fan Shroud Replacement - Upper (Automatic Transmission - Diesel) on page 6-1597* or *Fan Shroud Replacement - Upper (Manual Transmission - Diesel) on page 6-1600* or *Fan Shroud Replacement - Upper (Automatic Transmission - Gasoline) on page 6-1602* or *Fan Shroud Replacement - Upper (Manual Transmission - Gasoline) on page 6-1606*.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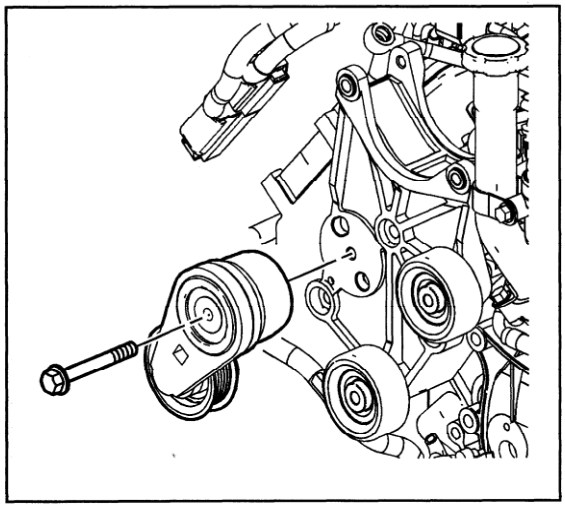
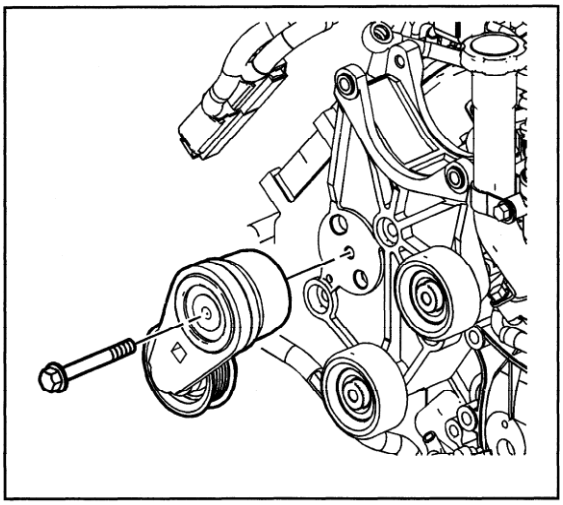


1334909

## Drive Belt Tensioner Replacement

### Removal Procedure

1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*
2. Remove the drive belt tensioner bolt.
3. Remove the drive belt tensioner.



1334909

### Installation Procedure

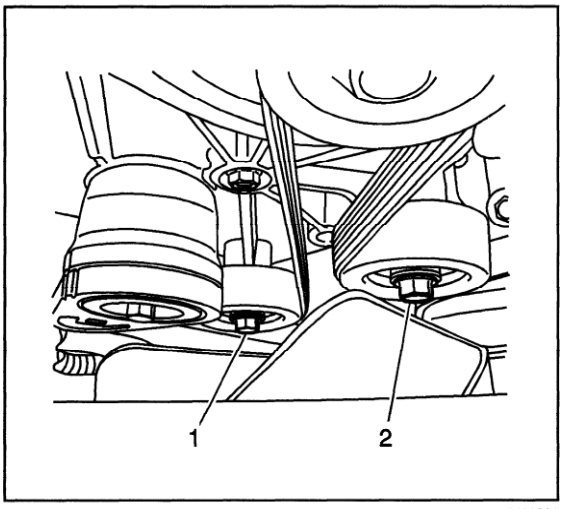
1. Install the drive belt tensioner. Align the pin with the hole in the generator bracket.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

2. Install the drive belt tensioner bolt.

   **Tighten**

   Tighten bolt to 50 N·m (37 lb ft).
3. Install the drive belt. Refer to *Drive Belt Replacement on page 6-804.*




1409331

## Drive Belt Idler Pulley Replacement

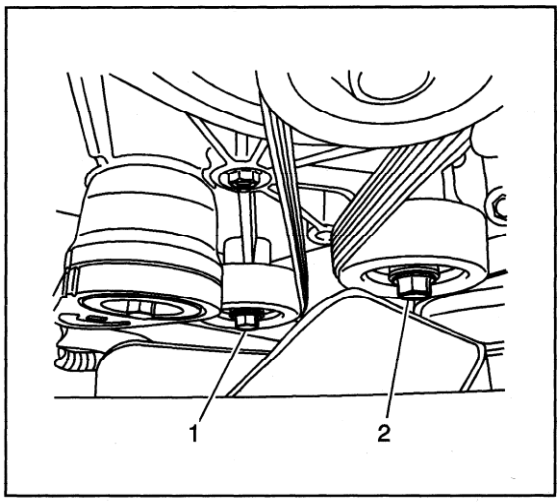
### Removal Procedure

1. Remove the drive belt. Refer to *Drive Belt Replacement on page 6-804.*
2. Remove the bolt (1) from the right side idler pulley.
3. Remove the idler pulley.
4. Remove the bolt (2) for the center idler pulley.
5. Remove the idler pulley.
6. If equipped with dual generators, remove the bolt from the left side idler pulley.
7. If equipped with dual generators, remove the idler pulley.

## Installation Procedure

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

1. Install the right side idler pulley and bolt (1).
   **Tighten**
   Tighten the bolt to 50 N·m (37 lb ft).
2. Install the center idler pulley and bolt (2).
   **Tighten**
   Tighten the bolt to 50 N·m (37 lb ft).
3. If equipped with dual generators, install the left side idler pulley and bolt.
   **Tighten**
   Tighten the bolt to 50 N·m (37 lb ft).
4. Install the drive belt. Refer to *Drive Belt Replacement on page 6-804*.



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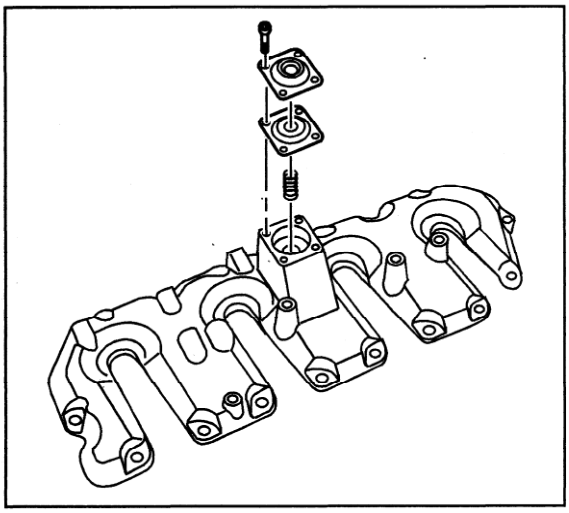
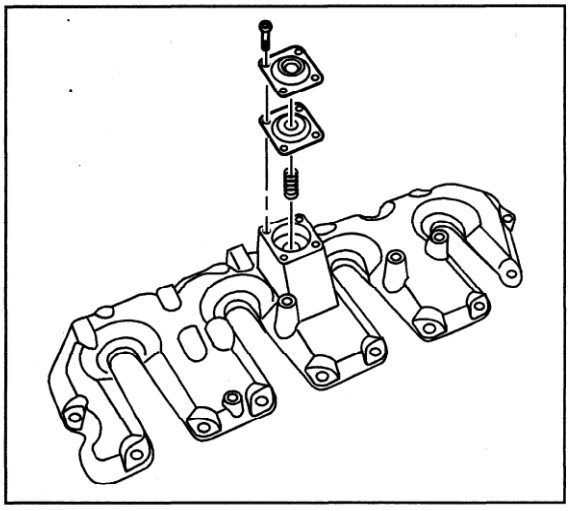


1336134

3. Remove the positive crankcase ventilation (PCV) cover screws.
4. Remove the PCV cover, diaphragm, and spring.
5. Clean and inspect the cover, diaphragm, and spring.
6. Discard the diaphragm if damage is found.



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## Installation Procedure

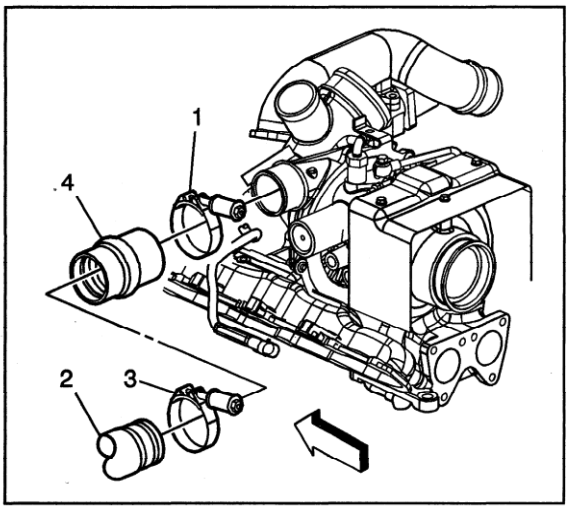
1. Install the spring, diaphragm, and cover.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

2. Install the PCV cover screws.

   **Tighten**

   Tighten the screws to 4 N·m (35 lb in).




3. Remove the tape from the turbocharger openings.

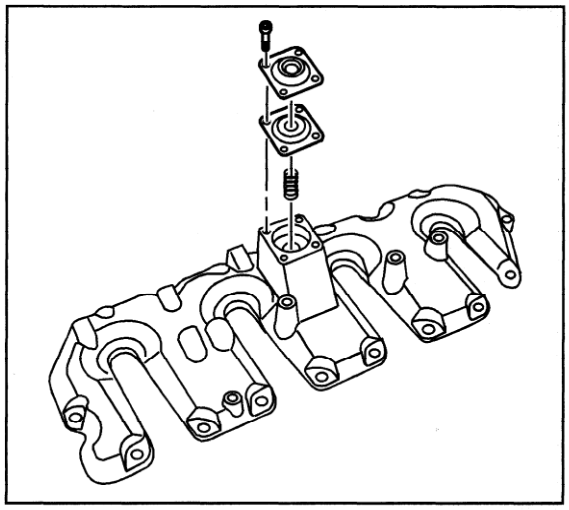
**Important:** Lubricate the end of the duct prior to installation.

4. Install the charged air cooler inlet duct connector (4) to the turbocharger.
5. Tighten the charged air cooler inlet duct connector to turbocharger clamp (1).

   **Tighten**

   Tighten the clamp to 6 N·m (53 lb in).

6. Remove the positive crankcase ventilation (PCV) cover screws.
7. Remove the PCV cover, diaphragm, and spring.
8. Clean and inspect the cover, diaphragm and spring.
9. Discard the diaphragm if damage is found.



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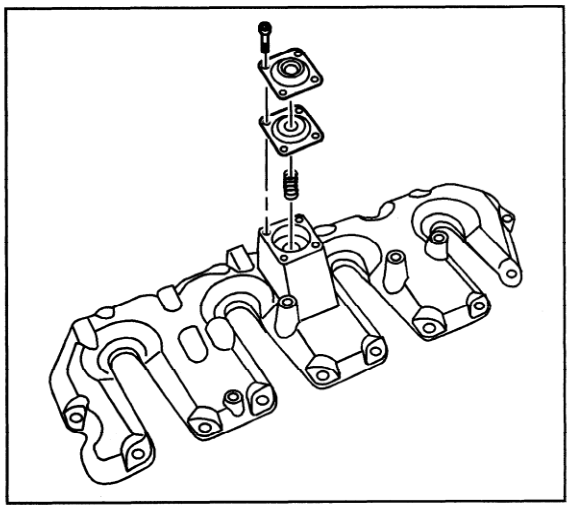

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## Installation Procedure

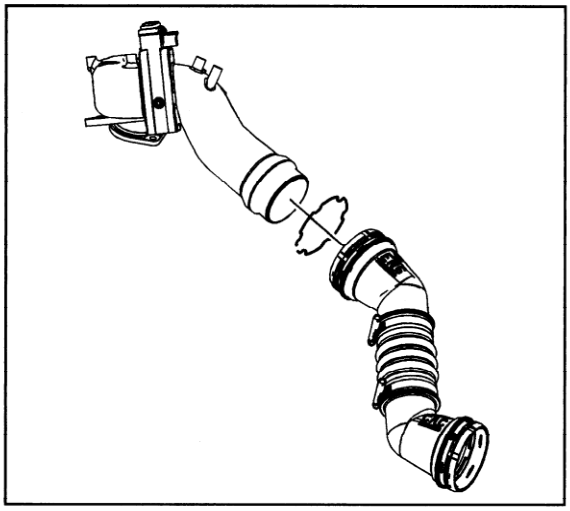
1. Install the spring, diaphragm and cover.

***Notice:*** Refer to *Fastener Notice on page P-9*.

2. Install the PCV cover screws.

   **Tighten**

   Tighten the screws to 4 N·m (35 lb in).



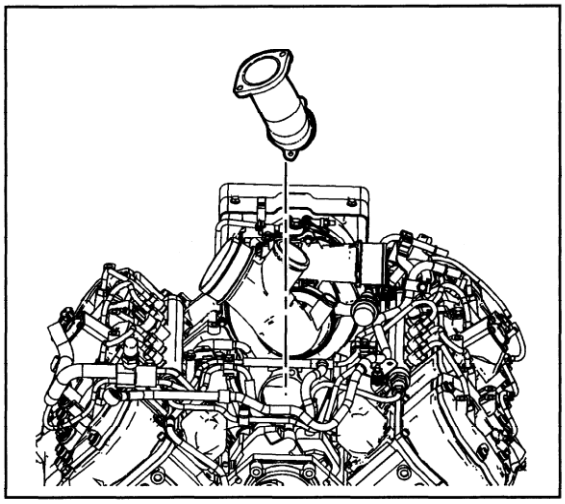
1653035

## Intake Manifold Tube Replacement

### Removal Procedure

1. Remove the intake manifold cover. Refer to *Intake Manifold Cover Replacement on page 6-807*.
2. Remove the air cleaner outlet duct. Refer to *Air Cleaner Outlet Duct Replacement on page 6-3293*.
3. Using a pick or a small flat-bladed screw driver, remove and discard the quick connect fitting clip from the charged air cooler outlet duct.
4. Remove the charged air cooler outlet duct from the intake.

5. Remove the engine harness clip from the air inlet tube.
6. Remove the air inlet tube nuts.
7. Remove the air inlet tube.
8. If necessary, remove the intake manifold tube.
9. If necessary, remove and discard the 2 O-ring seals from the tube.
10. Clean the gasket surfaces of the exhaust gas recirculation (EGR) cooler tube, intake manifold tube and inlet tube.



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## Installation Procedure

1. If necessary, install NEW O-ring seals onto the tube.
2. If necessary, install the intake manifold tube.
3. Install the air inlet tube and NEW gaskets.

***Notice:*** Refer to *Fastener Notice on page P-9*.

4. Install the air inlet tube nuts.

   **Tighten**

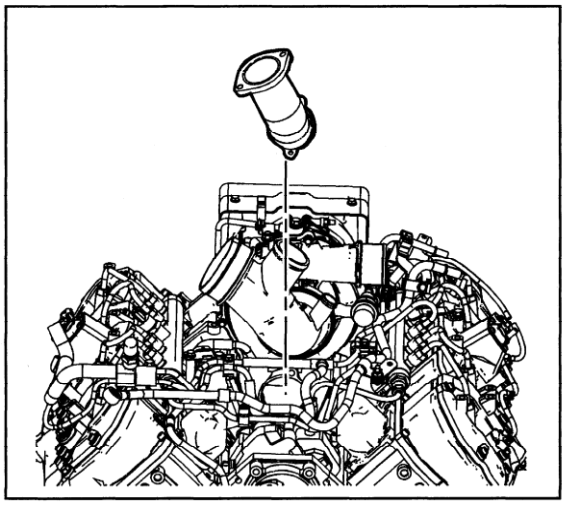
   Tighten the nuts to 25 N·m (18 lb ft).
5. Install the engine harness clip to the air inlet tube.
6. Install the air inlet tube to intake manifold tube bolt and nut.

   **Tighten**

   Tighten the bolt/nut to 10 N·m (89 lb in).
7. Install the electrical harness bolts.

   **Tighten**

   Tighten the bolts to 4 N·m (35 lb in).

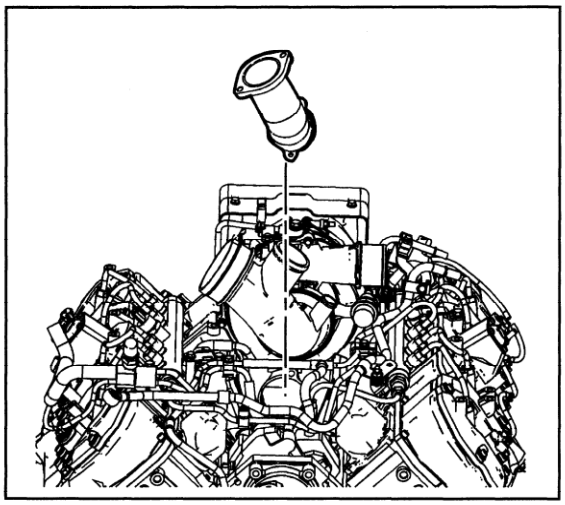


1335575

## Intake Manifold Replacement - Center

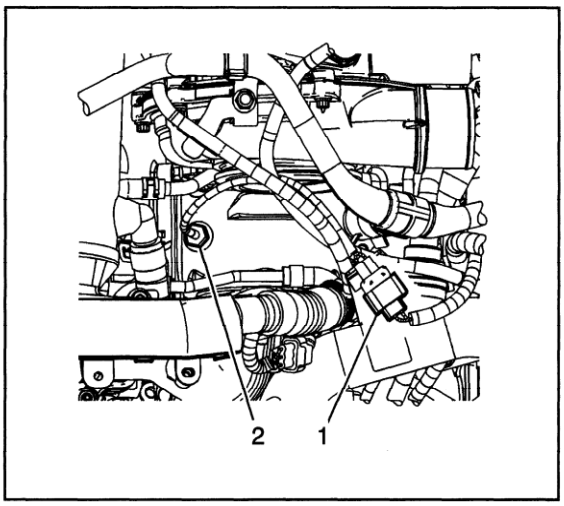
### Removal Procedure

1. Remove the exhaust gas recirculation (EGR) valve cooler tube. Refer to *Exhaust Gas Recirculation (EGR) Valve Cooler Tube Replacement on page 6-3277.*
2. Remove the intake manifold tube.
3. Remove and discard the 2 intake manifold tube gaskets.
4. Remove the turbocharger. Refer to *Turbocharger Replacement on page 6-858.*

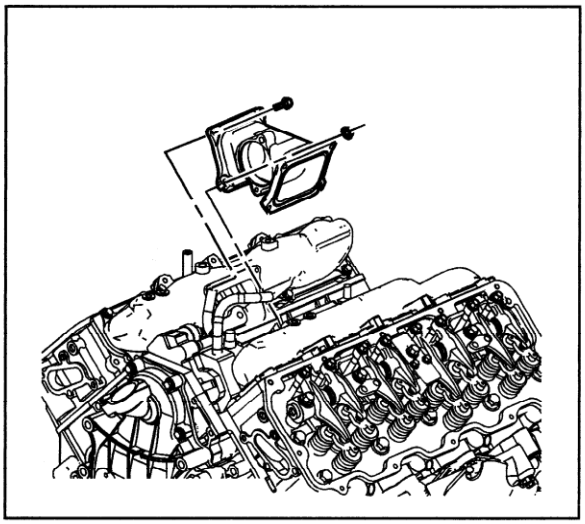


1335575

5. Disconnect the intake air temperature (IAT) sensor electrical connector (1).
6. Remove the IAT sensor (2).

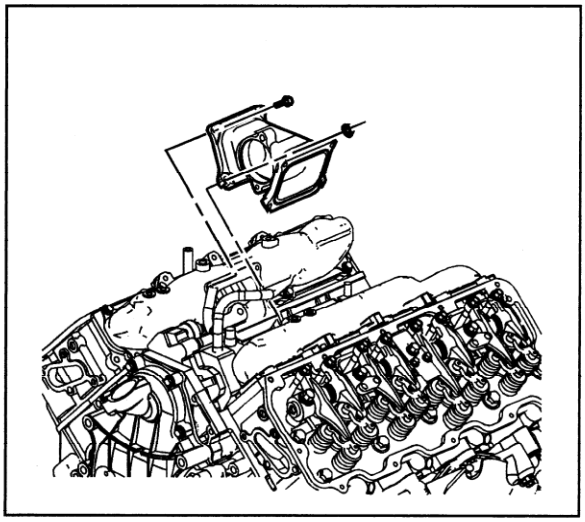



1602068



1335931

7. Remove the center intake manifold bolts/nuts.
8. Pull-up the center intake manifold in order to remove.
9. Remove and discard the gaskets.
10. Clean the center intake manifold in cleaning solvent and air dry.



1335931

## Installation Procedure

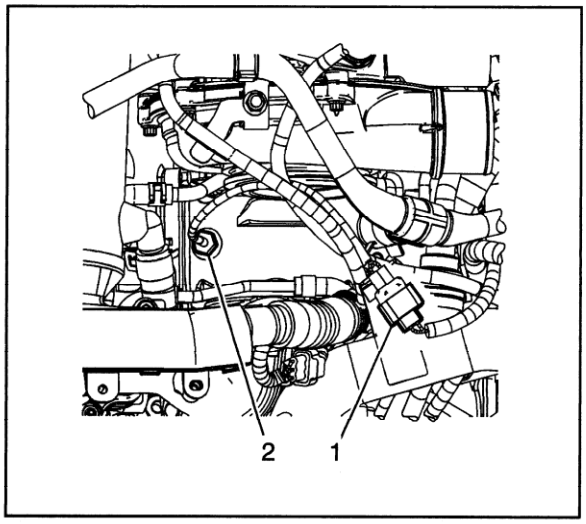
1. Install NEW center intake manifold gaskets.
2. Install the center intake manifold.

***Notice:*** Refer to *Fastener Notice on page P-9*.

3. Install the center intake manifold bolts/nuts.

   **Tighten**

   Tighten the bolts/nuts to 10 N·m (89 lb in).



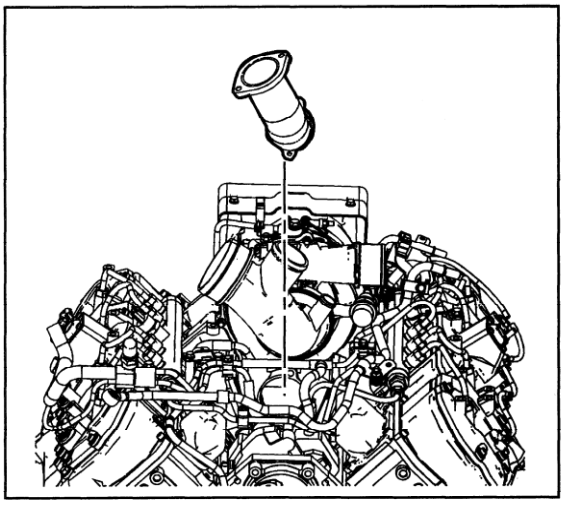

1602068

4. Install the IAT sensor (2).

   **Tighten**

   Tighten the sensor to 10 N·m (89 lb in).
5. Connect the IAT sensor electrical connector (1).
6. Install the turbocharger. Refer to *Turbocharger Replacement on page 6-858*.

7. Install 2 NEW O-rings onto the intake manifold tube.
8. Lubricate the O-rings with clean engine oil to aid in the installation.
9. Install the intake manifold tube.
10. Install the EGR valve cooler tube. Refer to *Exhaust Gas Recirculation (EGR) Valve Cooler Tube Replacement on page 6-3277*.



1335575

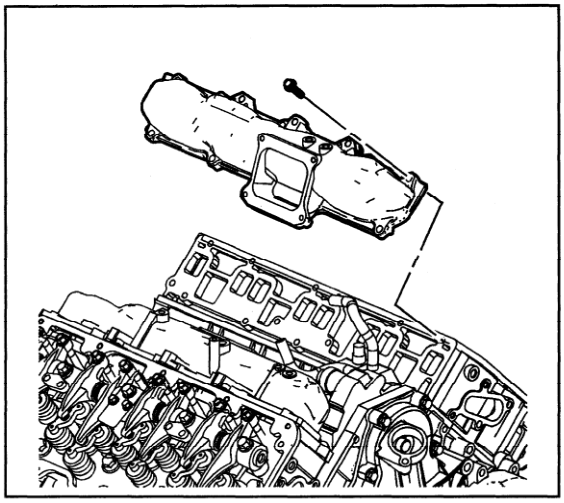
## Intake Manifold Replacement - Left

### Removal Procedure

1. Remove the center intake manifold. Refer to *Intake Manifold Replacement - Center on page 6-833*.
2. Remove the left fuel rail. Refer to *Fuel Rail Assembly Replacement - Bank 2 on page 6-3230* in Engine Controls.
3. Remove the intake manifold bolts/nuts.

**Important:** The intake manifold uses sealer. Pry at the area by the fuel rail bolt holes in order to avoid damage to the sealing surface.

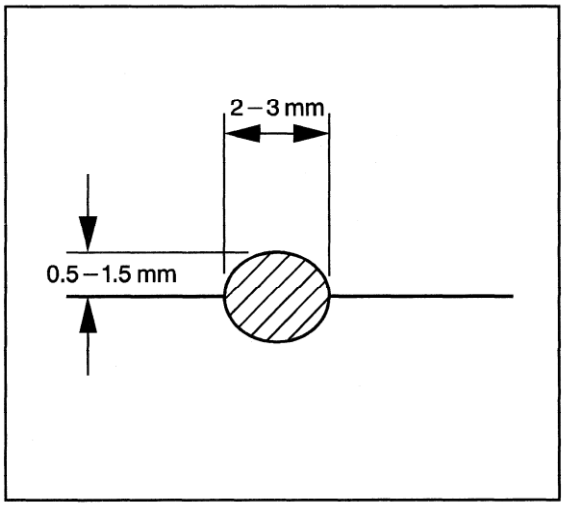
4. Remove the intake manifold.
5. To prevent entry of debris into the cylinder head, tape the openings.
6. If required, clean and inspect the intake manifold. Refer to *Intake Manifold Cleaning and Inspection on page 6-1038*.



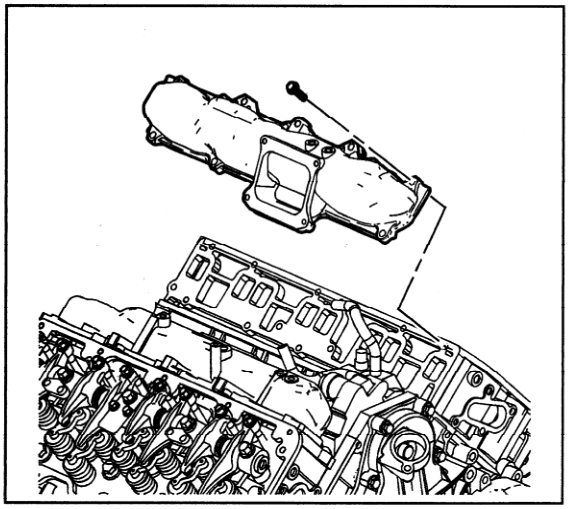
1335932

### Installation Procedure

1. Apply a 2–3 mm (1/8 in) wide, by 0.5–1.5 mm (1/16 in) high bead of sealant to the intake manifold. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.

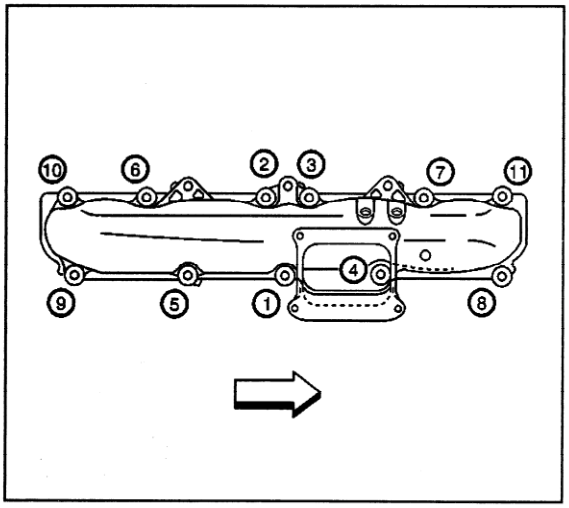



663817



1335932

2. Install the intake manifold.
3. Install the intake manifold bolts/nuts.



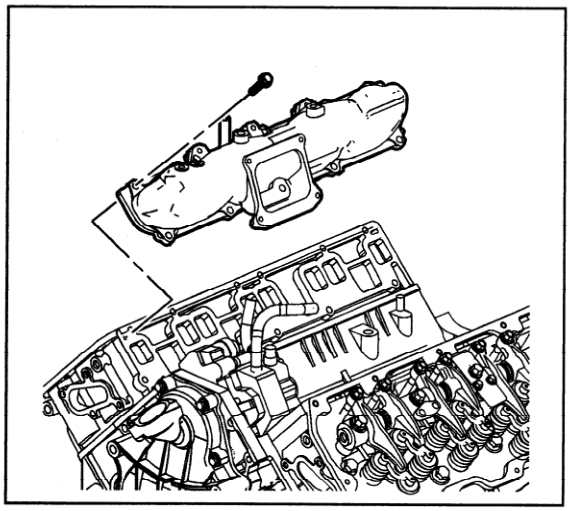

654530

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

4. Tighten the intake manifold bolts/nuts in the sequence shown.

   **Tighten**

   Tighten the bolts/nuts to 21 N·m (15 lb ft).
5. Install the left fuel rail. Refer to *Fuel Rail Assembly Replacement - Bank 2 on page 6-3230* in Engine Controls.
6. Install the center intake manifold. Refer to *Intake Manifold Replacement - Center on page 6-833*.



1335935

## Intake Manifold Replacement - Right

### Removal Procedure

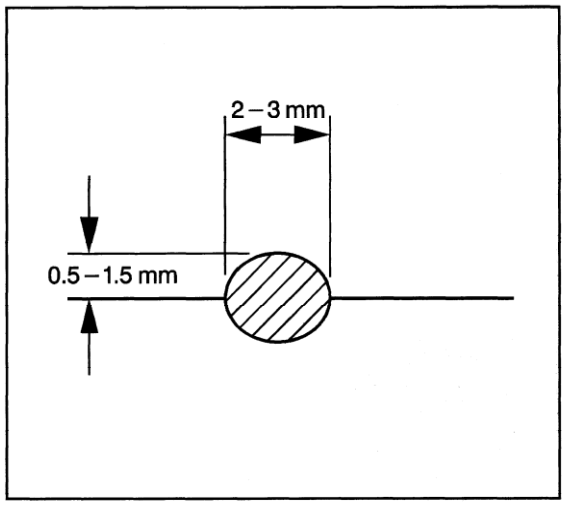
1. Remove the center intake manifold. Refer to *Intake Manifold Replacement - Center on page 6-833*.
2. Remove the right fuel rail. Refer to *Fuel Rail Assembly Replacement - Bank 1 on page 6-3221* in Engine Controls.
3. Remove the intake manifold bolts/nuts.

**Important:** The intake manifold uses sealer. Pry at the area by the fuel rail bolt holes in order to avoid damage to the sealing surfaces.

4. Remove the intake manifold.
5. To prevent entry of debris in the cylinder head tape the openings.
6. If required, clean and inspect the intake manifold. Refer to *Intake Manifold Cleaning and Inspection on page 6-1038*.

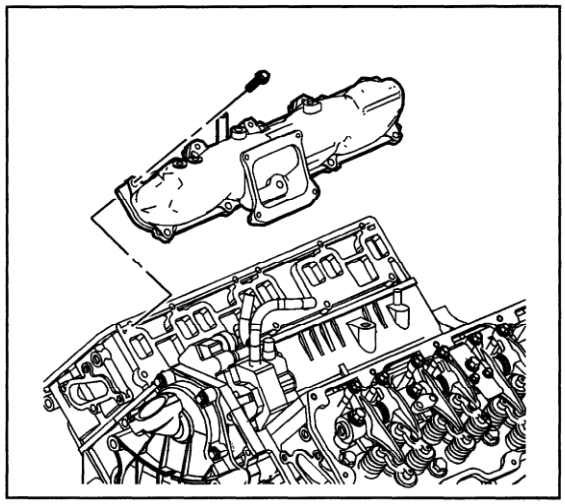
## Installation Procedure

1. Apply a 2–3 mm (1/8 in) wide, by 0.5–1.5 mm (1/16 in) high bead of sealant to the intake manifold. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.



663817

2. Install the intake manifold.
3. Install the intake manifold bolts/nuts.

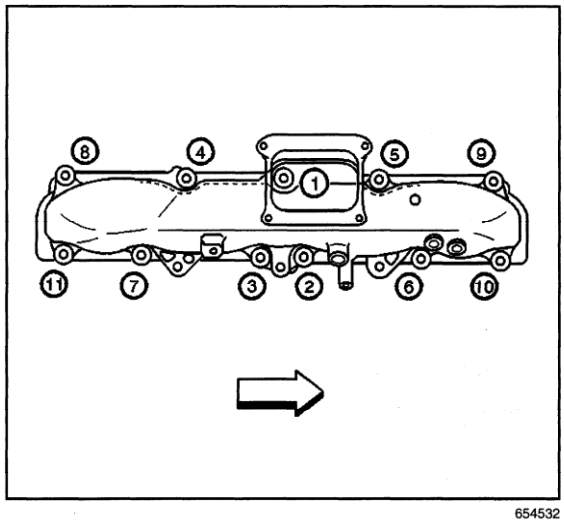

1335935

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

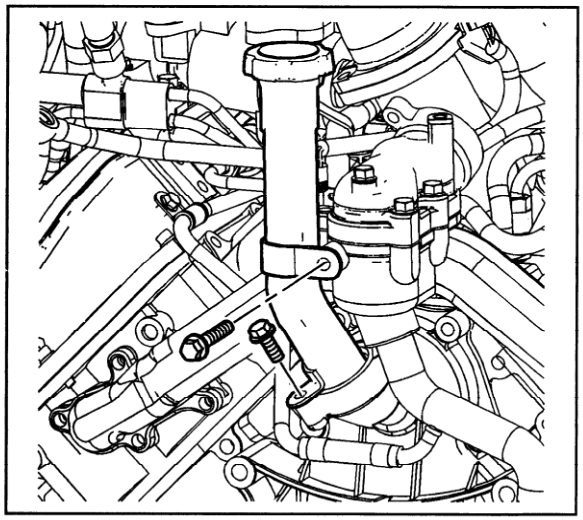
4. Tighten the intake manifold bolts/nuts in the sequence shown.

   **Tighten**

   Tighten the bolts/nuts to 21 N·m (15 lb ft).
5. Install the right fuel rail. Refer to *Fuel Rail Assembly Replacement - Bank 1 on page 6-3221* in Engine Controls.
6. Install the center intake manifold. Refer to *Intake Manifold Replacement - Center on page 6-833*.



654532

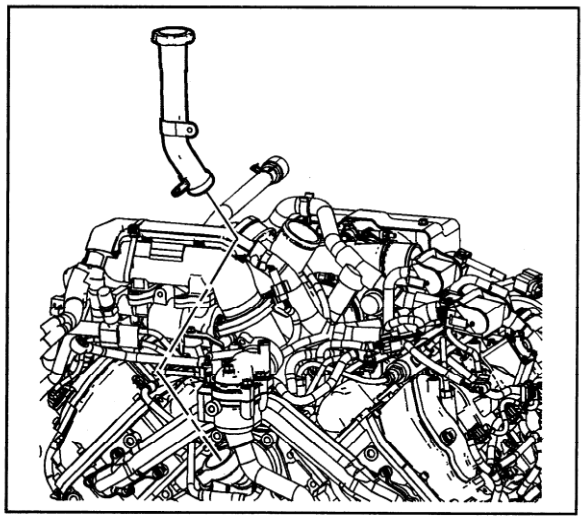


1335397

## Oil Fill Tube Replacement

### Removal Procedure

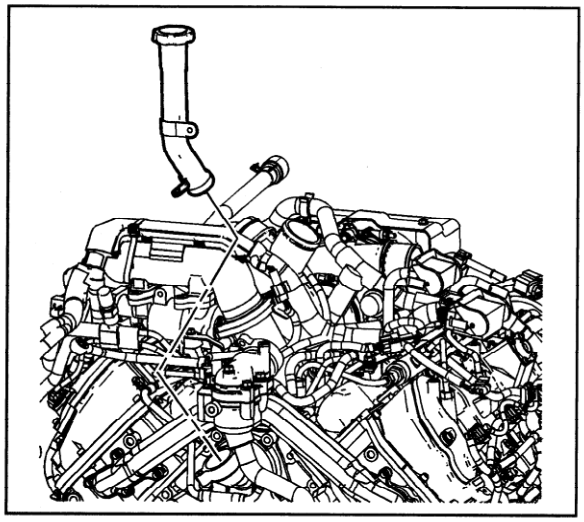
1. Remove the oil fill tube bolts.



1335401

2. Remove the oil fill tube.
3. Remove and discard the oil fill tube O-ring seal.

### Installation procedure

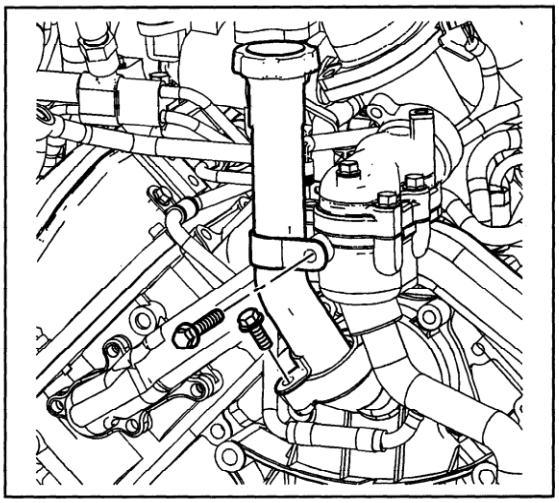


1335401

1. Install a NEW O-ring seal onto the oil fill tube.
2. Install the oil fill tube.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

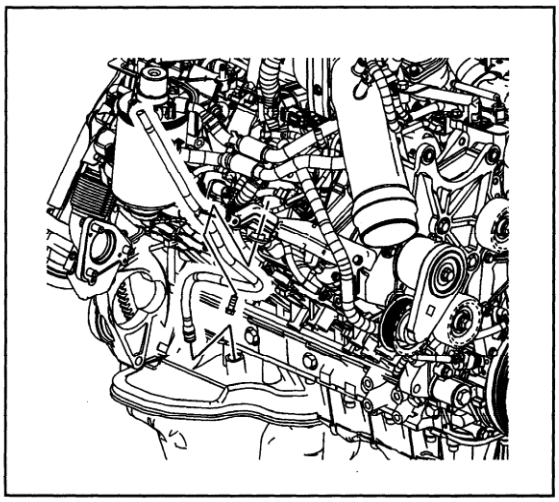
3. Install the oil fill tube bolts.
   **Tighten**
   Tighten the bolts to 21 N·m (15 lb ft).

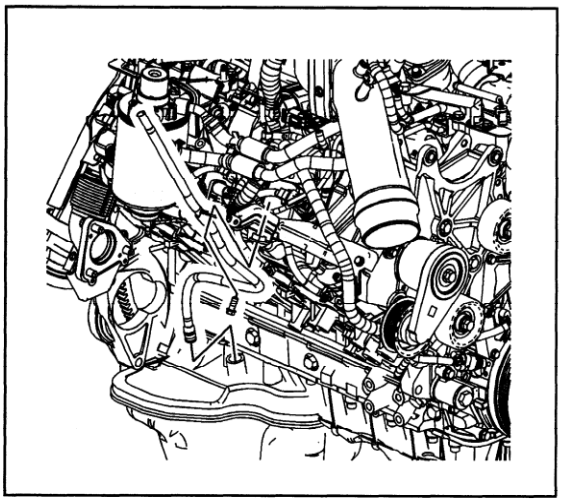

1335397

## Oil Level Indicator and Tube Replacement

### Removal Procedure

1. Remove the oil level indicator.
2. Remove the exhaust manifold. Refer to *Exhaust Manifold Replacement*
3. Remove the starter motor. Refer to *Starter Motor Replacement*
4. Remove the oil level indicator tube bolt at the indicator tube bracket.
5. Remove the oil level indicator tube and O-ring seals.
6. Remove and discard the O-ring seals.


1602062



1602062

## Installation Procedure

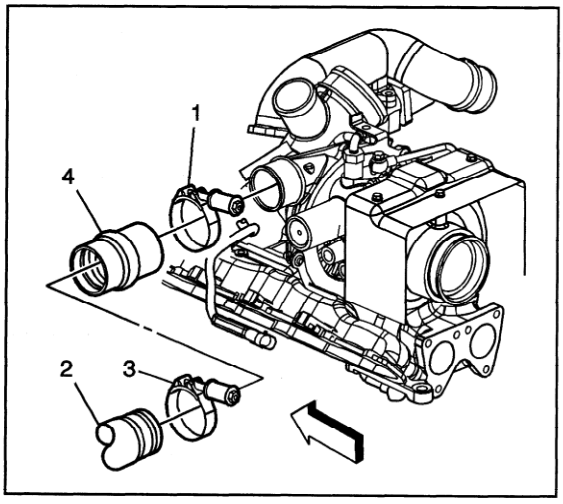
1. Install NEW O-ring seals onto the oil level indicator tube.
2. Lightly lubricate the O-ring seals with engine oil.
3. Install the oil level indicator tube.

***Notice:*** Refer to *Fastener Notice on page P-9.*

4. Install the oil level indicator tube bolt at the indicator tube bracket.

   **Tighten**

   Tighten the bolt to 21 N·m (15 lb ft).
5. Install the starter motor. Refer to *Starter Motor Replacement*
6. Install the exhaust manifold. Refer to *Exhaust Manifold Replacement*
7. Install the oil level indicator.




1334380

## Valve Rocker Arm Cover Replacement - Upper Left

### Removal Procedure

1. Remove the intake manifold cover. Refer to *Intake Manifold Cover Replacement on page 6-807.*
2. Drain the cooling system. Refer to *Draining and Filling Cooling System (w/RPO HP2) on page 6-1445* or *Draining and Filling Cooling System (w/o RPO HP2) on page 6-1447.*
3. Disconnect the negative battery cable. Refer to *Battery Negative Cable Disconnect/Connect Procedure (Single Battery) on page 6-1787* or *Battery Negative Cable Disconnect/Connect Procedure (Auxiliary Battery) on page 6-1788.*

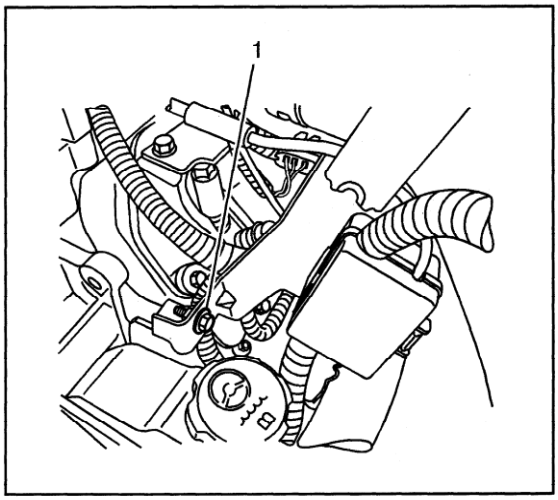
**Important:** After removing the charged air cooler duct, cover the turbocharger opening with tape in order to prevent entry of objects.

4. Loosen the charged air cooler inlet duct connector to turbocharger clamp (1).

**Important:** Do not use a screwdriver or other tool to pry the hose loose. The hose can be torn or damaged. Loosen the hose by twisting.

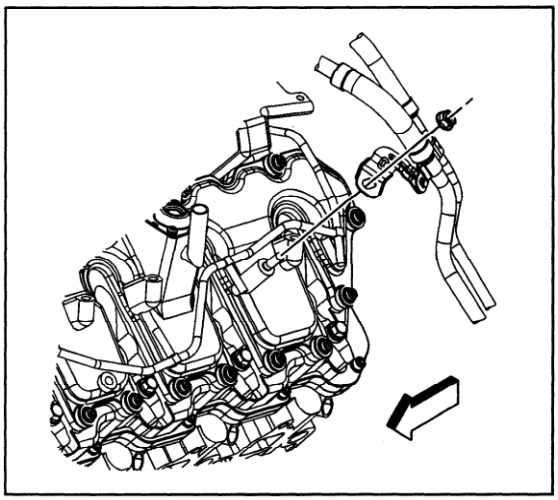
5. Remove the charged air cooler inlet duct connector (4) from the turbocharger.

6. Remove the battery cable to generator nut.
7. If equipped, remove the battery cable to the auxiliary generator.
8. Remove the battery cable harness clip from the bracket.
9. Remove the battery cable junction block bolt (1) from the power steering pump.
10. Move and secure the battery cables out of the way.

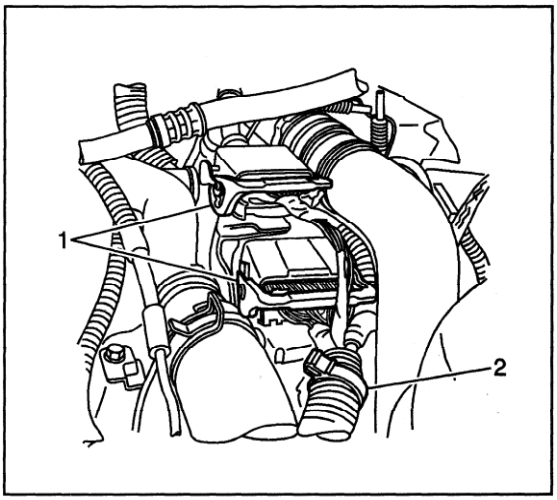


1409332

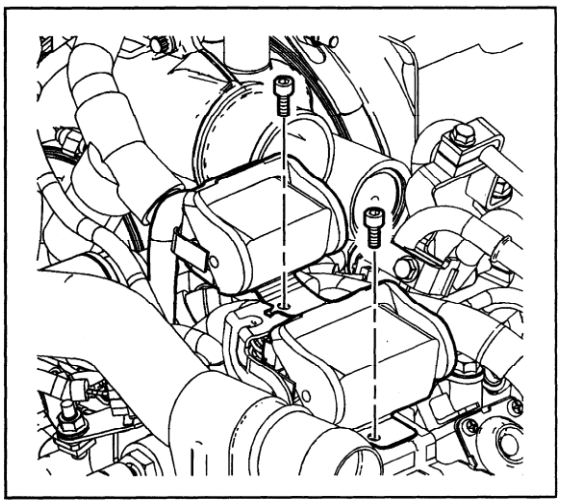
11. Disconnect the fuel lines. Refer to *Quick Connect Fitting(s) Service (Metal Collar) on page 6-3152*.
12. Remove the fuel hose bracket nut.


1378748

13. Disconnect the main engine electrical harness connectors. Lift up on the latches (1) in order to disconnect the connectors.
14. Open the harness clip (2).
15. Remove the main engine electrical harness connectors.

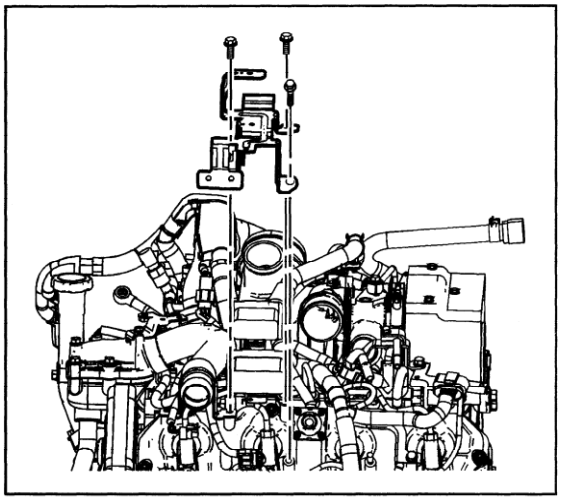


1409327



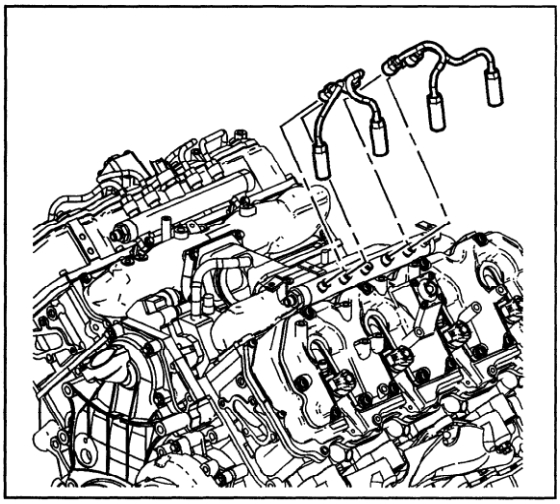
1334916

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



1334948

17. Remove the main electrical connector harness bracket bolts.
18. Remove the main electrical connector harness bracket.
19. Remove the water outlet tube. Refer to *Water Outlet Tube Replacement (6.6L (LLY) Engine) on page 6-1547*.
20. Remove the auxiliary generator, if equipped. Refer to *Generator Replacement - Auxiliary (6.6L (LLY) Engine) on page 6-1887*.
21. Remove the positive crankcase ventilation (PCV) hose/pipe. Refer to *Crankcase Ventilation Hoses/Pipes Replacement on page 6-823*.



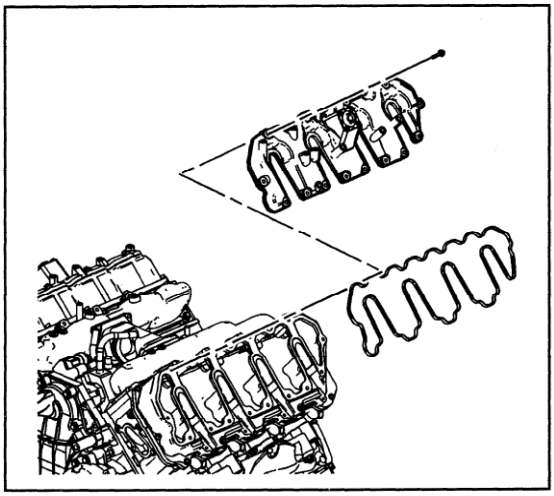
1335608

22. Prior to removing the fuel injector pipes, use compressed air to blow any debris from between the injector line and fittings. Wipe the fittings clean of debris.
23. Spray lithium grease between the fuel injector line and fittings to assist in containing any debris during removal. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.

***Notice:*** 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.

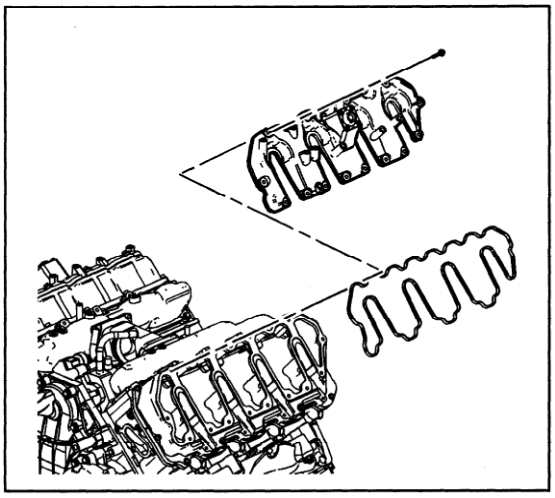
24. Remove the left fuel injector pipes.

25. Remove the upper valve rocker arm cover bolts.
26. Remove the upper valve rocker arm cover.
27. Remove the upper valve rocker arm cover gasket.
28. Inspect the upper valve rocker arm cover gasket for damage, replace if necessary. Otherwise reuse the old gasket.
29. If required, clean and inspect the upper valve rocker arm cover. Refer to *Valve Rocker Arm Cover Cleaning and Inspection - Upper on page 6-1037*.


1335635

## Installation Procedure

1. Install the valve rocker arm cover gasket.
2. Install the upper valve rocker arm cover.
3. Install the upper valve rocker arm cover bolts.

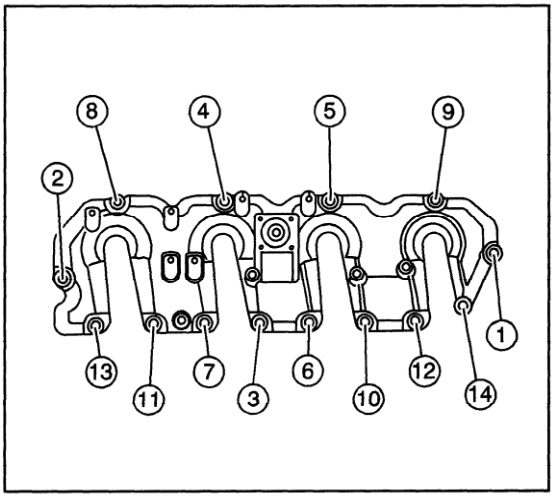

1335635

***Notice:*** Refer to *Fastener Notice on page P-9*.

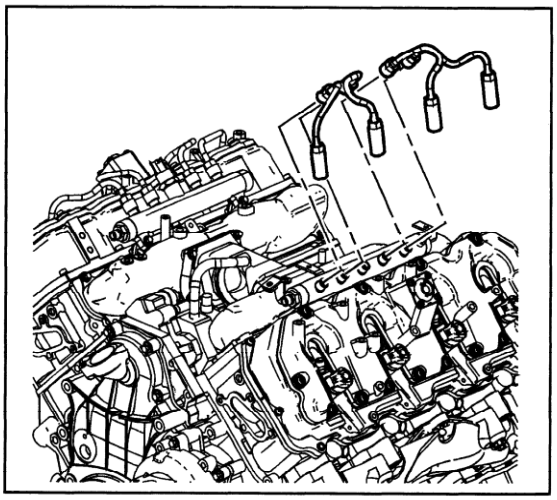
4. Tighten the upper valve rocker arm cover bolts in the sequence shown.

   **Tighten**

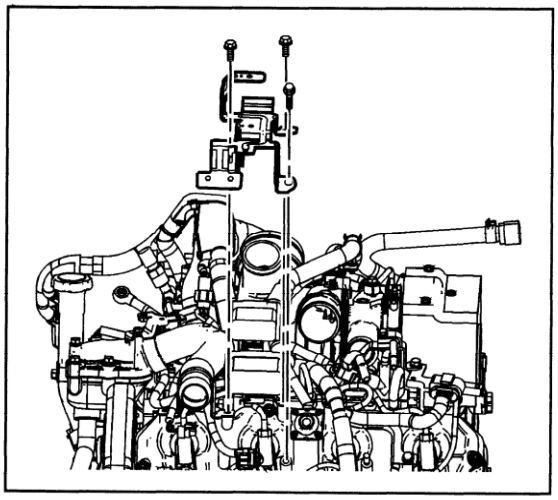
   Tighten the bolts to 8 N·m (71 lb in).



1411030



1335608



1334948

***Notice:*** Ensure proper torquing of the fuel injector line. An under-torqued fuel injector line will not seal properly and an over-torqued fuel injector line may damage the fuel injector fitting. An improperly sealed or damaged fuel injector line or fuel injector fitting will cause a fuel leak.

5. Install the left fuel injector pipes.

   **Tighten**

   Tighten the pipes to 41 N·m (30 lb ft).
6. After installing the fuel injector pipes, clean the injector pipes and apply sealant at the fittings to prevent moisture and debris from collecting between the line and fitting. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.
7. Install the water outlet tube. Refer to *Water Outlet Tube Replacement (6.6L (LLY) Engine) on page 6-1547*.
8. Install the auxiliary generator, if equipped. Refer to *Generator Replacement - Auxiliary (6.6L (LLY) Engine) on page 6-1887*.
9. Install the PCV hose/pipe. Refer to *Crankcase Ventilation Hoses/Pipes Replacement on page 6-823*.
10. Install the main electrical connector harness bracket.
11. Install the main electrical connector harness bracket bolts.

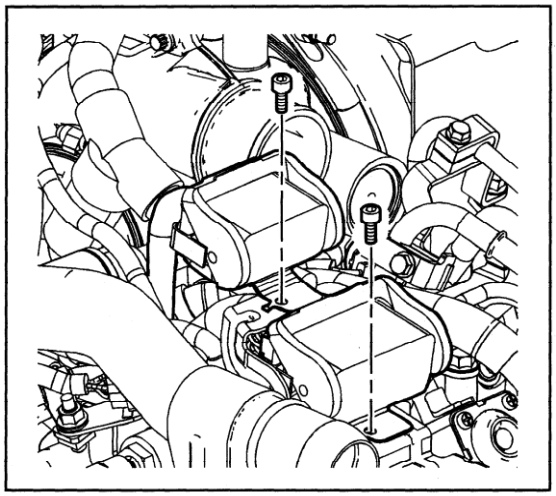
    **Tighten**

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

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

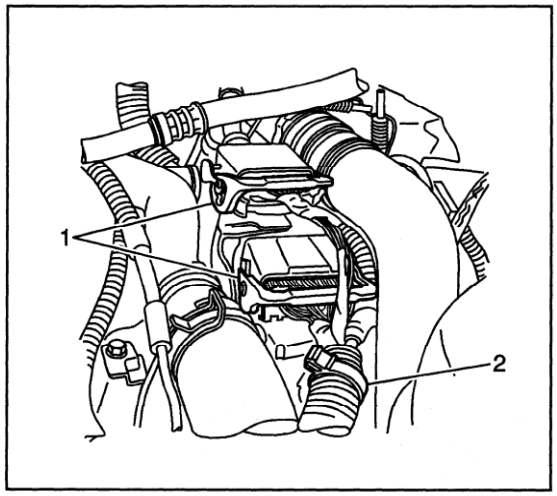
**Tighten**

Tighten the bolts to 10 N·m (89 lb in).



1334916

13. Connect the main engine electrical harness connectors.
14. Push down on the latches (1) in order to connect the connectors.
15. Close the harness clip (2).

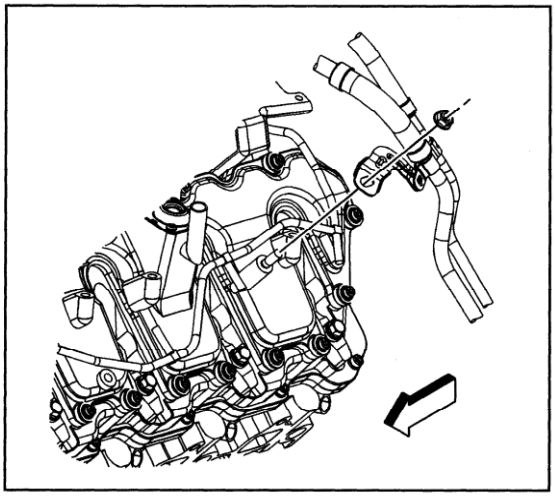



1409327

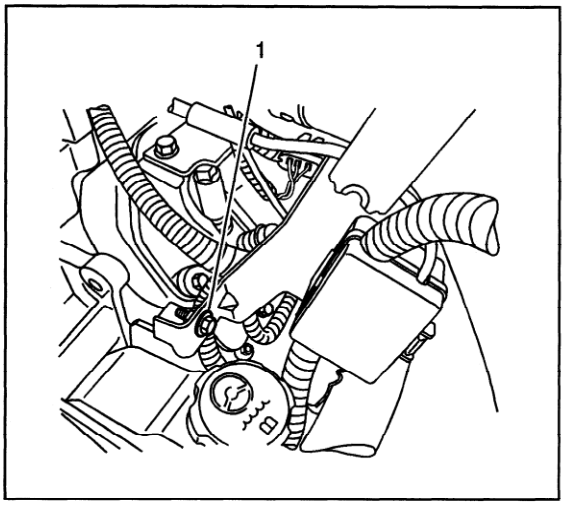
16. Connect the fuel lines. Refer to *Quick Connect Fitting(s) Service (Metal Collar) on page 6-3152*.
17. Install the fuel hose bracket nut.

**Tighten**

Tighten the nut to 21 N·m (15 lb ft).



1378748




1409332

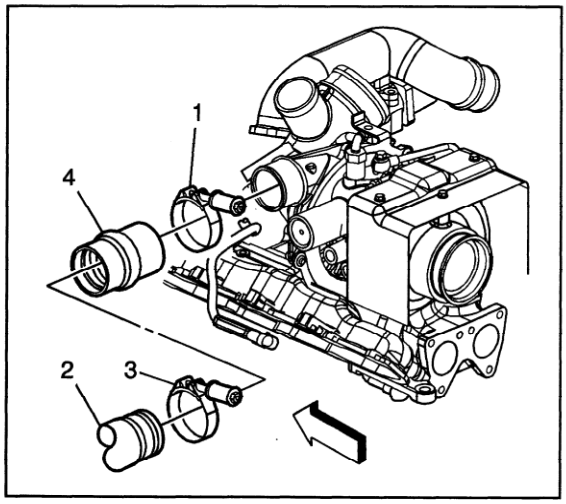
18. Position the generator positive cable.
19. Install the generator positive cable in the clip on the engine front cover.
20. Install the generator positive cable and nut.

    **Tighten**

    Tighten the nut to 9 N·m (80 lb in).
21. Install the positive battery cable junction block bracket and bolt (1) to the power steering pump.

    **Tighten**

    Tighten the bolt to 9 N·m (80 lb in).




1334380

22. Remove the tape from the turbocharger openings.

**Important:** Lubricate the end of the duct prior to installation.

23. Install the charged air cooler inlet duct connector (4) to the turbocharger.
24. Tighten the charged air cooler inlet duct connector to turbocharger clamp (1).

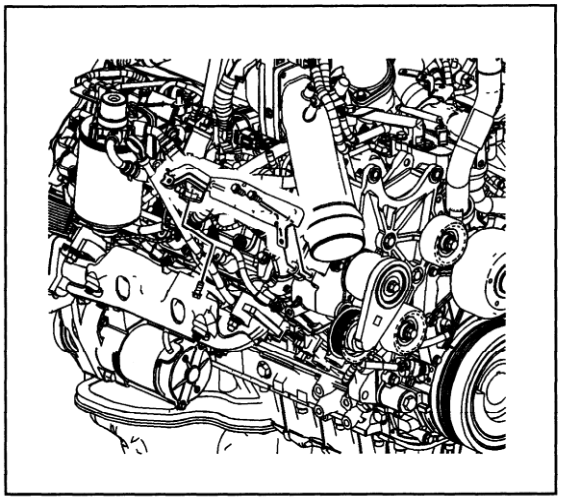
    **Tighten**

    Tighten the clamp to 6 N·m (53 lb in).
25. Fill the cooling system. Refer to *Draining and Filling Cooling System (w/RPO HP2) on page 6-1445* or *Draining and Filling Cooling System (w/o RPO HP2) on page 6-1447*.
26. Connect the negative battery cable. Refer to *Battery Negative Cable Disconnect/Connect Procedure (Single Battery) on page 6-1787* or *Battery Negative Cable Disconnect/Connect Procedure (Auxiliary Battery) on page 6-1788*.
27. Install the intake manifold cover. Refer to *Intake Manifold Cover Replacement on page 6-807*.

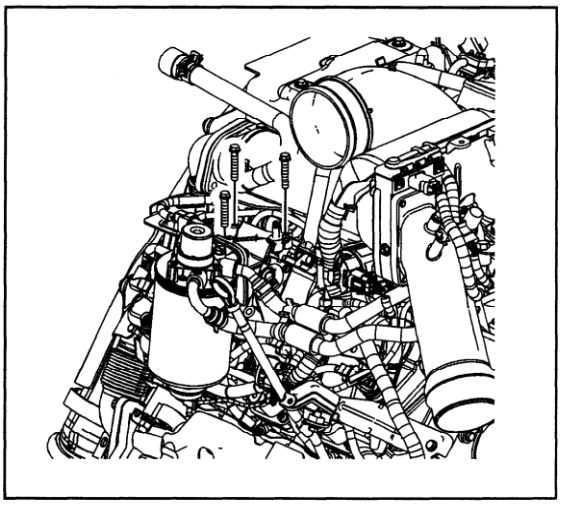
## Valve Rocker Arm Cover Replacement - Upper Right

### Removal Procedure

1. Remove the intake manifold cover. Refer to *Intake Manifold Cover Replacement on page 6-807*.
2. Remove the air cleaner outlet duct. Refer to *Air Cleaner Outlet Duct Replacement on page 6-3293*.
3. Using a pick or a small flat-bladed screwdriver, remove and discard the quick connect fitting clip from the charged air cooler outlet duct.
4. Remove the charged air cooler outlet duct from the intake.
5. Remove the exhaust gas recirculation (EGR) cooler tube. Refer to *Exhaust Gas Recirculation (EGR) Valve Cooler Tube Replacement on page 6-3277*.
6. Remove the heater outlet hose bolt from the bracket.
7. Position the heater outlet hose out of the way.
8. Remove the wiring harness retainer from the bracket.
9. Remove the oil level indicator tube bolt.
10. Remove the oil level indicator tube bracket bolts.
11. Remove the bracket.

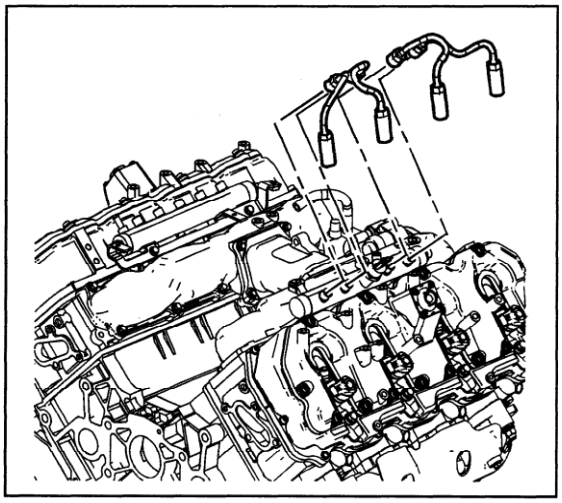


1601448



1602054

12. Remove the fuel filter bracket bolts.
13. Reposition the fuel filter with bracket.
14. Remove the positive crankcase ventilation (PCV) hose/pipe. Refer to *Crankcase Ventilation Hoses/Pipes Replacement on page 6-823*.

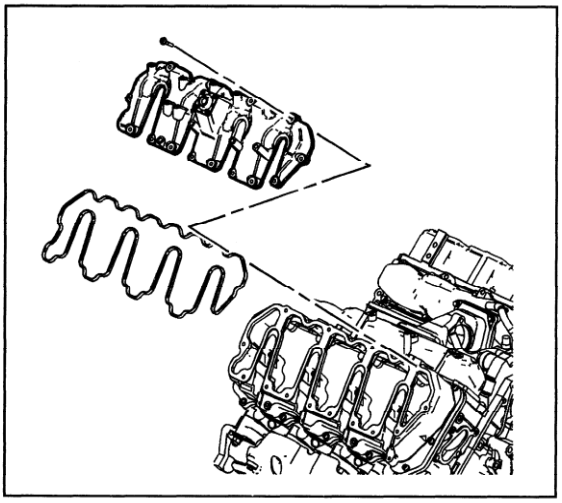


1335614

15. Prior to removing the fuel injector pipes, use compressed air to blow any debris from between the injector line and fittings. Wipe the fittings clean of debris.
16. Spray lithium grease between the fuel injector line and fittings to assist in containing any debris during removal. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.

***Notice:*** 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.

17. Remove the right fuel injector pipes.

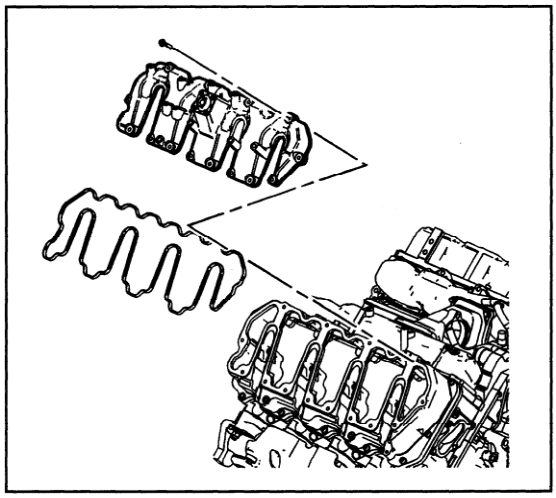


1335653

18. Remove the upper valve rocker arm cover bolts.
19. Remove the upper valve rocker arm cover.
20. Remove the upper valve rocker arm cover gasket.
21. Inspect the upper valve rocker arm cover gasket for damage, replace if necessary. Otherwise reuse the old gasket.
22. If required, clean and inspect the upper valve rocker arm cover. Refer to *Valve Rocker Arm Cover Cleaning and Inspection - Upper on page 6-1037*.

## Installation Procedure

1. Install the upper valve rocker arm cover gasket.
2. Install the upper valve rocker arm cover.
3. Install the upper valve rocker arm cover bolts.



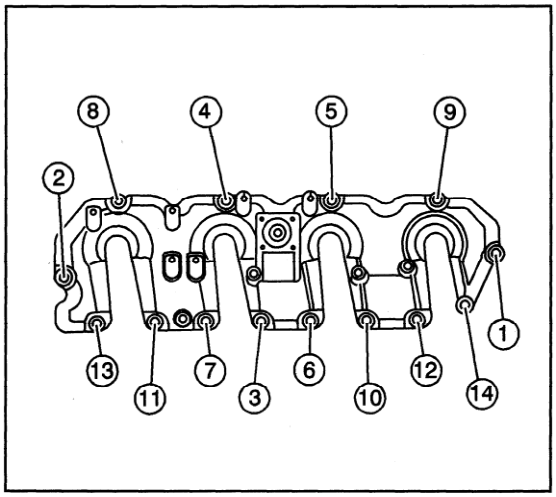
1335653

***Notice:*** Refer to *Fastener Notice on page P-9*.

4. Tighten the upper valve rocker arm cover bolts in the sequence shown.

   **Tighten**

   Tighten the bolts to 8 N·m (71 lb in).




1411030

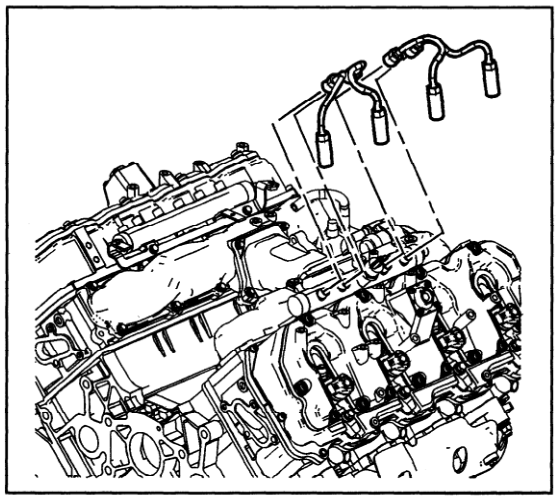
***Notice:*** Ensure proper torquing of the fuel injector line. An under-torqued fuel injector line will not seal properly and an over-torqued fuel injector line may damage the fuel injector fitting. An improperly sealed or damaged fuel injector line or fuel injector fitting will cause a fuel leak.

5. Install the fuel injector pipes.

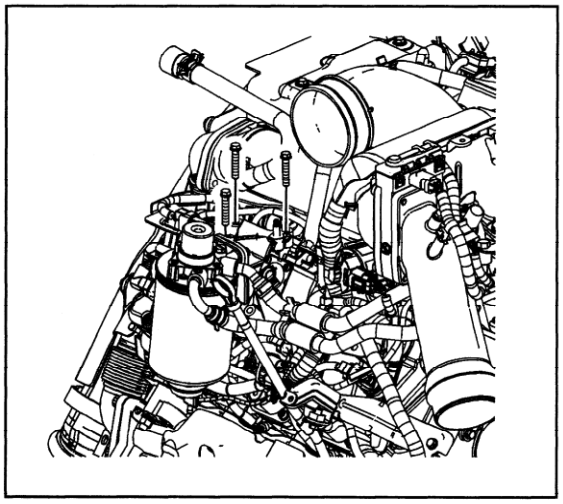
   **Tighten**

   Tighten the pipes to 41 N·m (30 lb ft).

6. After installing the fuel injector pipes, clean the injector pipes and apply sealant at the fittings to prevent moisture and debris from collecting between the line and fitting. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.



1335614



1602054

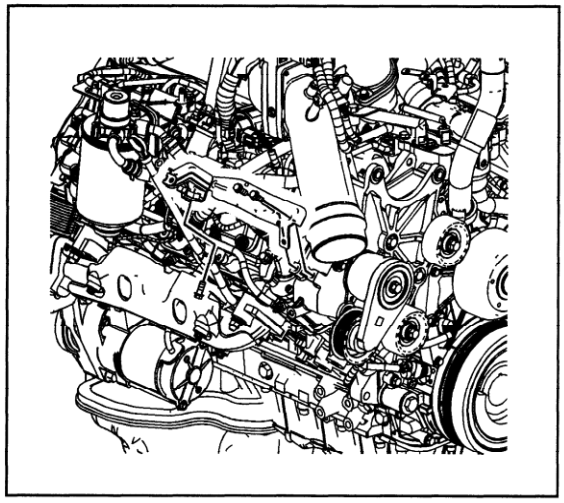
7. Install the PCV hose/pipe. Refer to *Crankcase Ventilation Hoses/Pipes Replacement on page 6-823*.
8. Position the fuel filter with bracket to the rocker cover.
9. Install the fuel filter bracket bolts.

   **Tighten**

   Tighten the bolts to 21 N·m (15 lb ft).
10. Position the heater outlet hose.
11. Install the heater hose bracket bolt to the bracket.

    **Tighten**

    Tighten the bolt to 21 N·m (15 lb ft).
12. Install the EGR cooler tube. Refer to *Exhaust Gas Recirculation (EGR) Valve Cooler Tube Replacement on page 6-3277*.



1601448

13. Install the bracket.
14. Install the oil level indicator tube bracket bolts.

    **Tighten**

    Tighten the bolts to 21 N·m (15 lb ft).
15. Install the oil level indicator tube bolt.

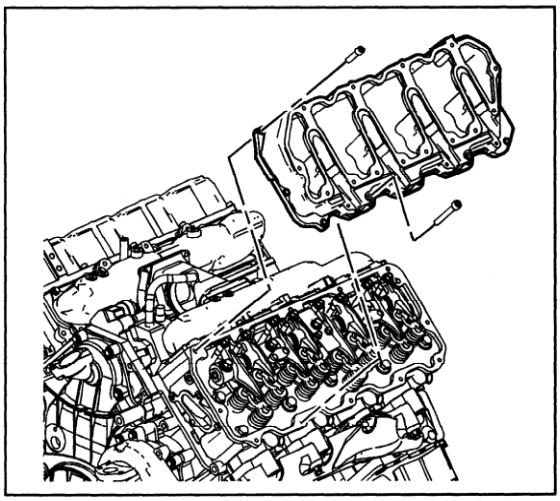
    **Tighten**

    Tighten the bolt to 21 N·m (15 lb ft).
16. Install the wiring harness retainer to the bracket.
17. Install a NEW quick connect fitting clip to the charged air cooler duct.
18. Install the charged air cooler outlet duct to the intake.
19. Install the air cleaner outlet duct. Refer to *Air Cleaner Outlet Duct Replacement on page 6-3293*.
20. Install the intake manifold cover. Refer to *Intake Manifold Cover Replacement on page 6-807*.

## Valve Rocker Arm Cover Replacement - Lower Left

### Removal Procedure

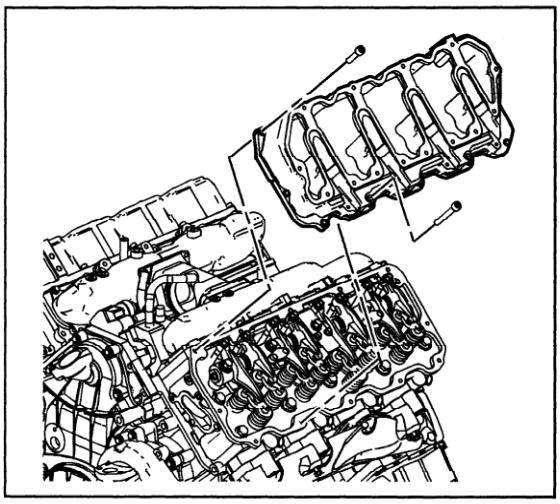
1. Remove the upper left valve rocker arm cover. Refer to *Valve Rocker Arm Cover Replacement - Upper Left on page 6-840*.
2. Remove the fuel injectors. Refer to *Fuel Injector Replacement (Left) on page 6-3251* or *Fuel Injector Replacement (Right) on page 6-3261* in Engine Controls – 6.6L (LLY).
3. Remove the lower valve rocker arm cover bolts.
4. Remove the lower valve rocker arm cover.
5. Remove the gasket from the lower valve rocker arm cover.
6. Inspect the lower valve rocker arm cover gasket for damage, replace if necessary. Otherwise reuse the old gasket.
7. If required, clean and inspect the lower valve rocker arm cover. Refer to *Valve Rocker Arm Cover Cleaning and Inspection - Lower on page 6-1037*.



1335926

### Installation Procedure

1. Install the lower valve rocker arm cover gasket.
2. Install the lower valve rocker arm cover.
3. Install the lower valve rocker arm cover bolts.



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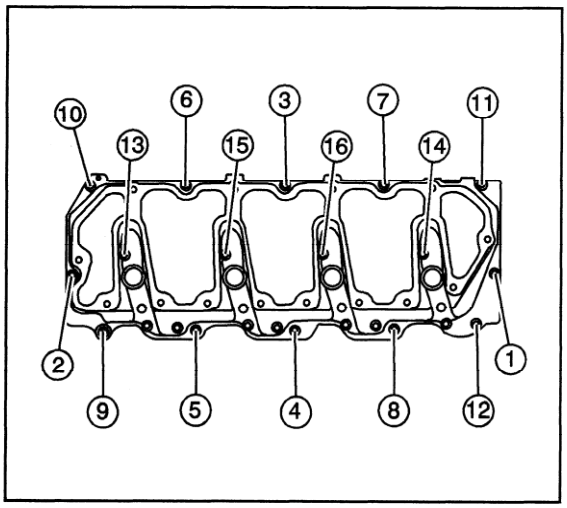


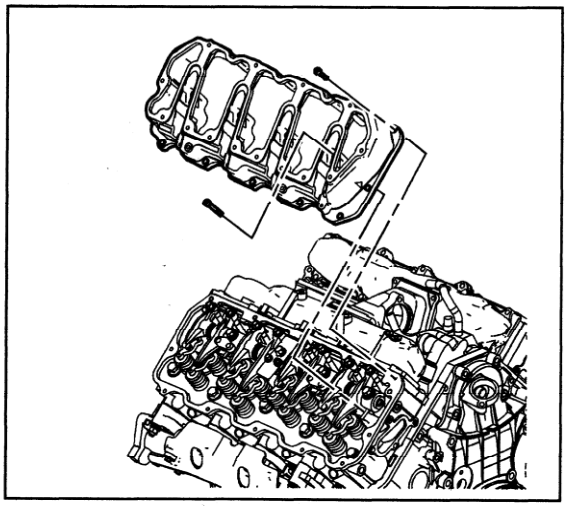

1411029

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

4. Tighten the lower valve rocker arm cover bolts in the sequence shown.

   **Tighten**

   Tighten the bolts to 10 N·m (89 lb in).
5. Install the fuel injectors. Refer to *Fuel Injector Replacement (Left) on page 6-3251* or *Fuel Injector Replacement (Right) on page 6-3261* in Engine Controls – 6.6L (LLY).
6. Install the upper left valve rocker arm cover. Refer to *Valve Rocker Arm Cover Replacement - Upper Left on page 6-840*.



1335929

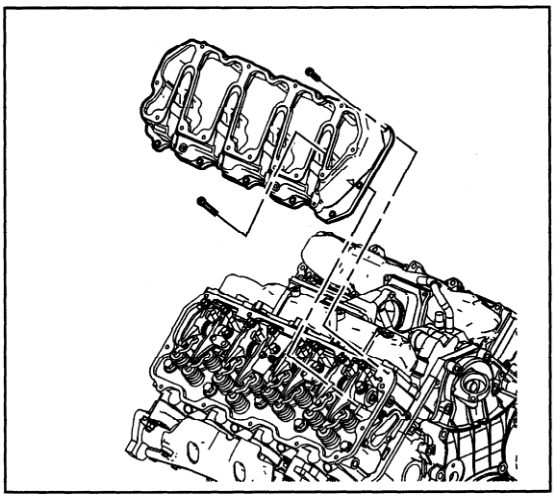
## Valve Rocker Arm Cover Replacement - Lower Right

### Removal Procedure

1. Remove the upper right valve rocker arm cover. Refer to *Valve Rocker Arm Cover Replacement - Upper Right on page 6-847*.
2. Remove the fuel injectors. Refer to *Fuel Injector Replacement (Left) on page 6-3251* or *Fuel Injector Replacement (Right) on page 6-3261* in Engine Controls – 6.6L (LLY).
3. Remove the lower valve rocker arm cover bolts.
4. Remove the lower valve rocker arm cover.
5. Remove the gasket from the lower valve rocker arm cover.
6. Inspect the lower valve rocker arm cover gasket for damage, replace if necessary. Otherwise reuse the old gasket.
7. If required, clean and inspect the lower valve rocker arm cover. Refer to *Valve Rocker Arm Cover Cleaning and Inspection - Lower on page 6-1037*.

## Installation Procedure

1. Install the lower valve rocker arm cover gasket.
2. Install the lower valve rocker arm cover.
3. Install the lower valve rocker arm cover bolts.



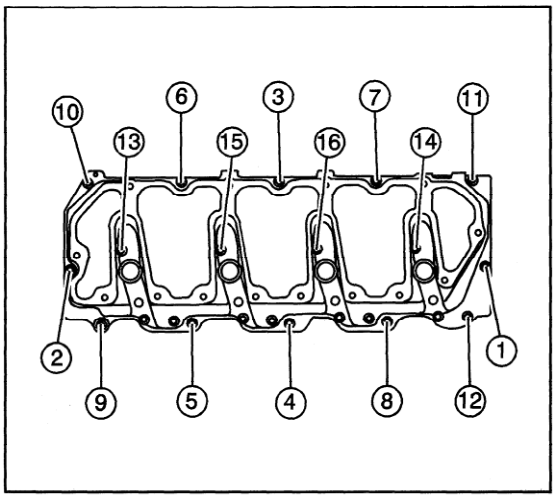
1335929

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

4. Tighten the bolts in the sequence shown.

   **Tighten**

   Tighten the bolts to 10 N·m (89 lb in).
5. Install the fuel injectors. Refer to *Fuel Injector Replacement (Left) on page 6-3251* or *Fuel Injector Replacement (Right) on page 6-3261* in Engine Controls – 6.6L (LLY).
6. Install the right upper valve rocker arm cover. Refer to *Valve Rocker Arm Cover Replacement - Upper Right on page 6-847*.

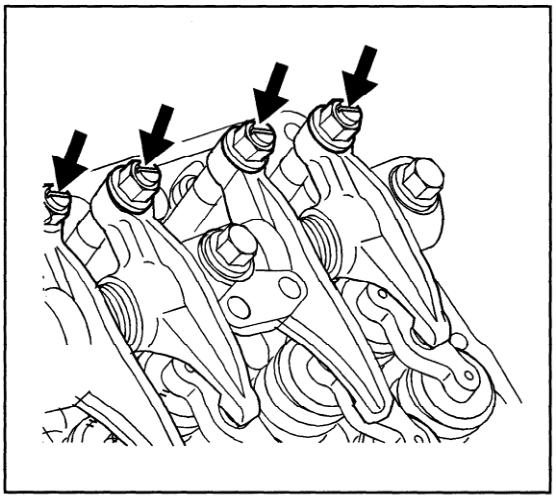



1411029

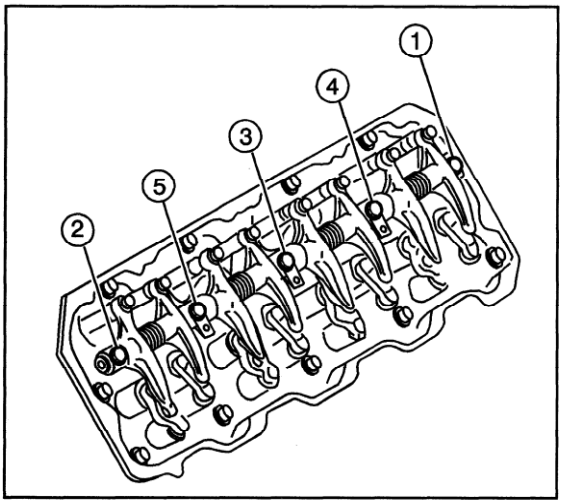
## Valve Rocker Arm, Shaft, and Push Rod Replacement

### Removal Procedure

1. Remove the lower valve rocker arm covers. Refer to *Valve Rocker Arm Cover Replacement - Lower Left on page 6-851* or *Valve Rocker Arm Cover Replacement - Lower Right on page 6-852*.
2. Loosen the valve clearance lock nuts on each rocker arm.
3. Loosen the valve clearance adjusting screw on each rocker arm in order to relieve tension on the valvetrain.

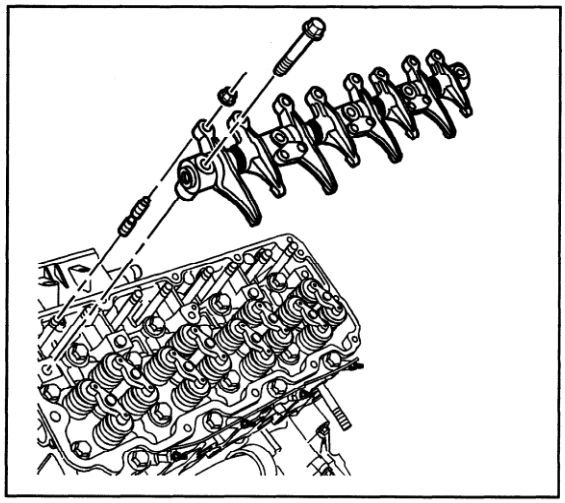


660481

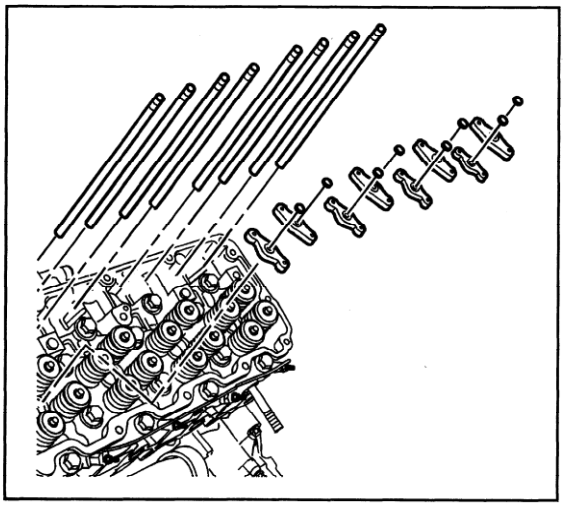


660486

4. Remove the rocker arm shaft assembly bolts in the sequence shown. Leave the bolts in the rocker arm shaft brackets.

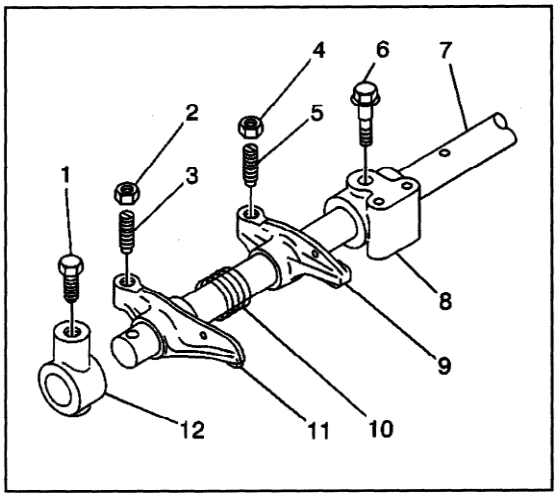

663833

5. Remove the rocker arm shaft assembly from the cylinder head.


660488

6. Remove the valve bridge pins.
7. Remove the valve bridges.
8. Remove the pushrods.

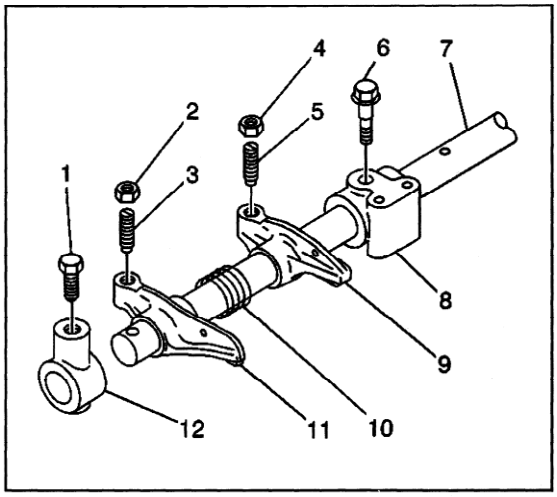
9. Remove the rocker arm shaft bracket bolts (1), if necessary.
10. Remove the bracket (12), rocker arm (11), and spring (10), if necessary.
11. Remove the remaining rocker arms, springs, and brackets, if necessary.
12. If required, clean and inspect the valve rocker arm and shaft. Refer to *Valve Rocker Arm and Shaft Cleaning and Inspection on page 6-1033*.



667358

## Installation Procedure

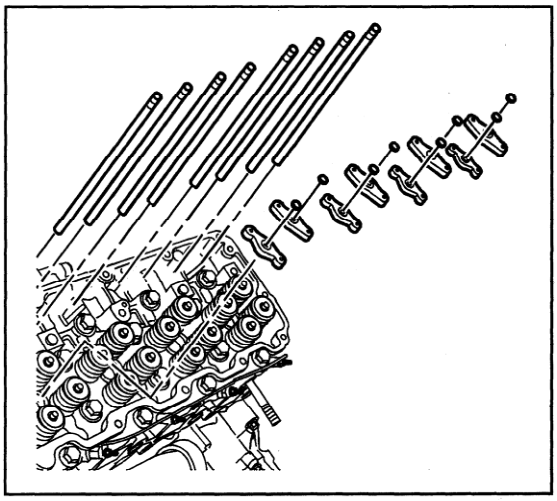
1. Lubricate the rocker arm shaft (7) and the inside of the rocker arms with clean engine oil, if necessary.
2. Install the rocker arm bracket (12) and bolt (1) on one end of the rocker arm shaft, if necessary.
3. Install the intake rocker arm (9), spring (10), exhaust rocker arm (11), and bracket (12) with bolt (1). Continue in the same sequence to the last bracket, if necessary.
4. Push the bracket (12) to compress the springs and then install the bolt (1), if necessary.

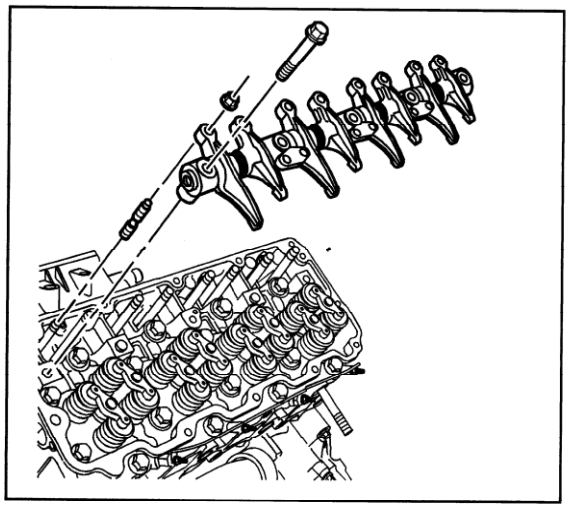


667358

5. Lubricate the top of the valves, the valve bridge stem, the valve lifter bridge, and the valve spring caps with clean engine oil.
6. Install the valve bridge.
7. Install the valve bridge pins.
8. Lubricate the valve lifter end of the pushrod with clean engine oil.
9. Install the pushrods.

   To ensure the pushrod is properly installed, gently pull up on the pushrod. Resistance should be felt from the pushrod trying to lift the valve lifter.

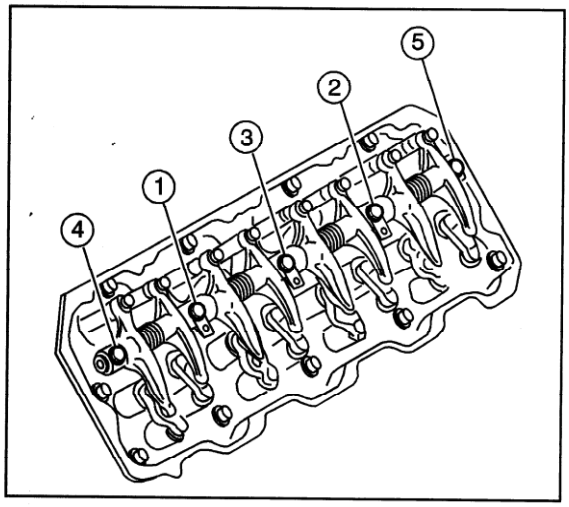

660488



663833

***Notice:*** 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.

10. Install the rocker arm shaft assembly.




721463

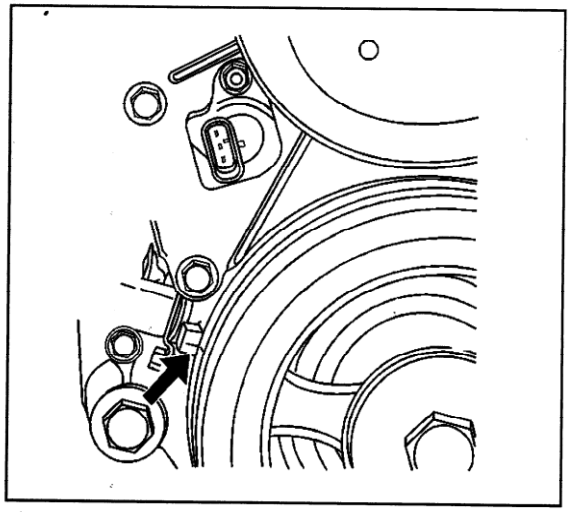
***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

11. Tighten the rocker arm shaft bolts in the sequence shown.

    **Tighten**

    Tighten the bolts to 41 N·m (30 lb ft).

12. Adjust the valve clearance. Refer to *Valve Lash Adjustment on page 6-1071*.
13. Install the lower valve rocker arm covers. Refer to *Valve Rocker Arm Cover Replacement - Lower Left on page 6-851* or *Valve Rocker Arm Cover Replacement - Lower Right on page 6-852*.

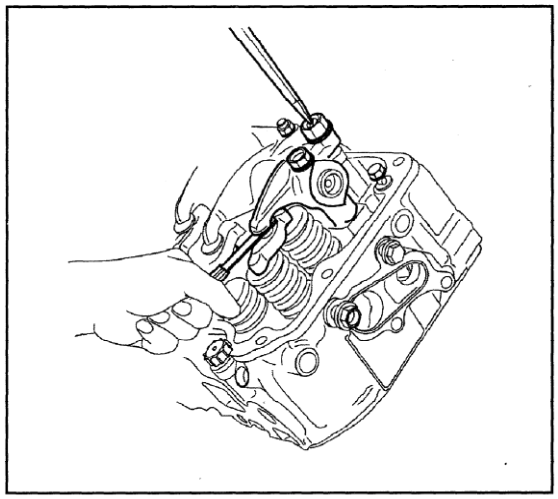


667477

## Valve Clearance Adjustment

1. Remove the fan clutch. Refer to *Fan Clutch Replacement (Diesel) on page 6-1521* or *Fan Clutch Replacement (Gasoline) on page 6-1524* in Engine Cooling.
2. Remove the upper valve rocker arm covers. Refer to *Valve Rocker Arm Cover Replacement - Upper Left on page 6-840* and *Valve Rocker Arm Cover Replacement - Upper Right on page 6-847*.
3. Rotate the crankshaft in order to bring the number 1 cylinder to top dead center (TDC) 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.

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


663897

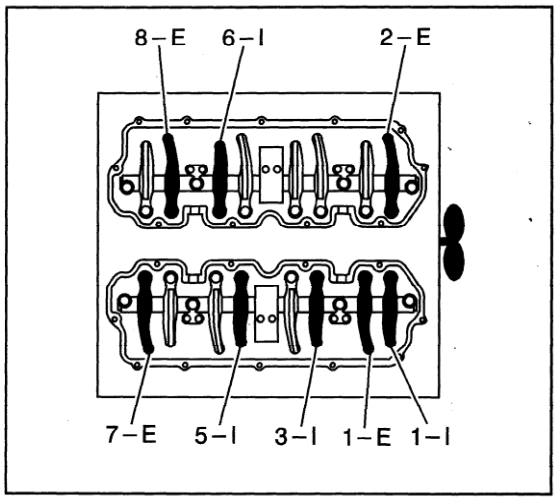
6. Adjust the valve lash to 0.3 mm (0.012 in). Refer to *Valve Clearance Adjustment Specifications on page 6-743* to determine which valves can be adjusted when the engine is at TDC.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

7. Tighten the lock nut.

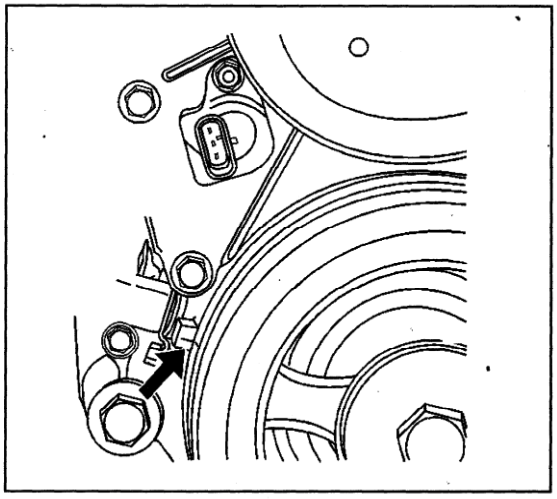
   **Tighten**

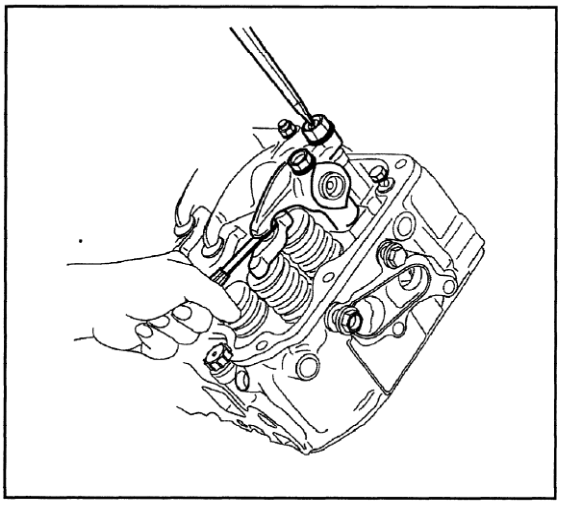
   Tighten nut to 22 N·m (16 lb ft).



663110

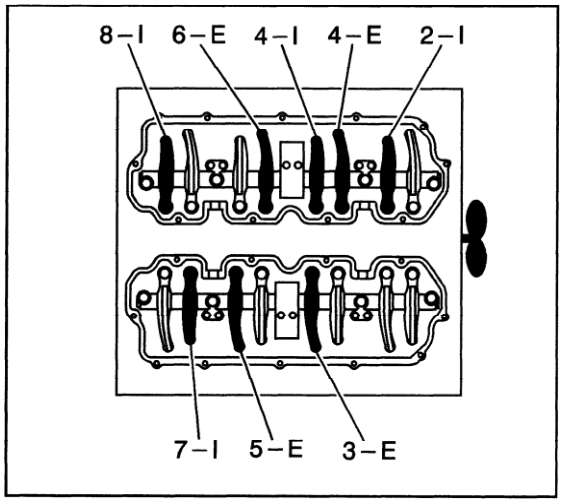
8. Rotate the crankshaft one revolution in order to bring the number 1 cylinder to TDC of the exhaust stroke.


667477



663897

9. Loosen the valve adjusting screws.
10. Insert a feeler gage between the tip of the rocker arm and the valve bridge.

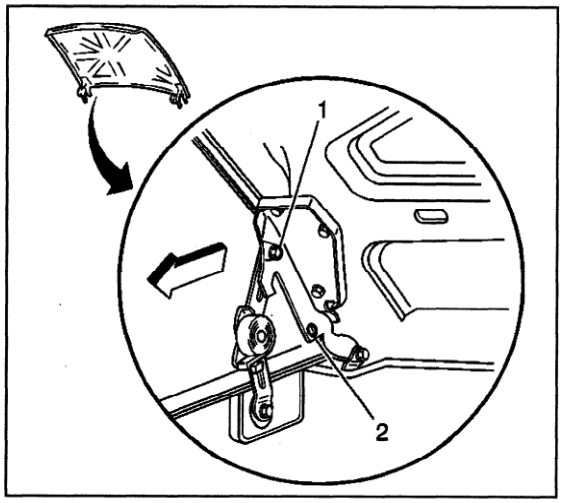



660548

11. Adjust the valve clearance to 0.3 mm (0.0112 in). Refer to *Valve Clearance Adjustment Specifications on page 6-743* to determine which valves can be adjusted when the engine is at TDC.
12. Tighten the lock nut.

    **Tighten**

    Tighten nut to 22 N·m (16 lb ft).
13. Install the upper valve rocker arm covers. Refer to *Valve Rocker Arm Cover Replacement - Upper Left on page 6-840* and *Valve Rocker Arm Cover Replacement - Upper Right on page 6-847*.
14. Install the fan clutch. Refer to *Fan Clutch Replacement (Diesel) on page 6-1521* or *Fan Clutch Replacement (Gasoline) on page 6-1524* in Engine Cooling.



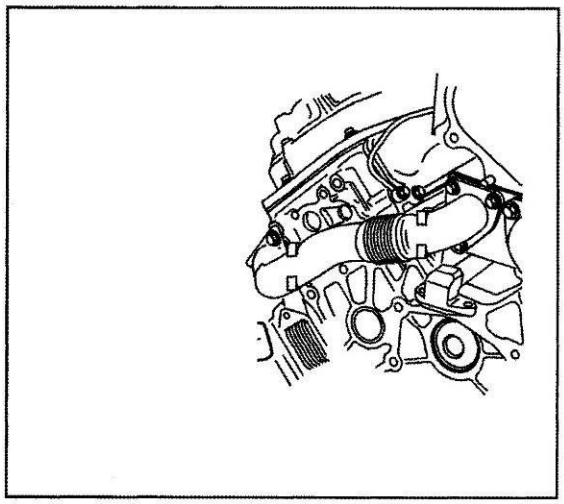

310799

## Turbocharger Replacement

### Removal Procedure

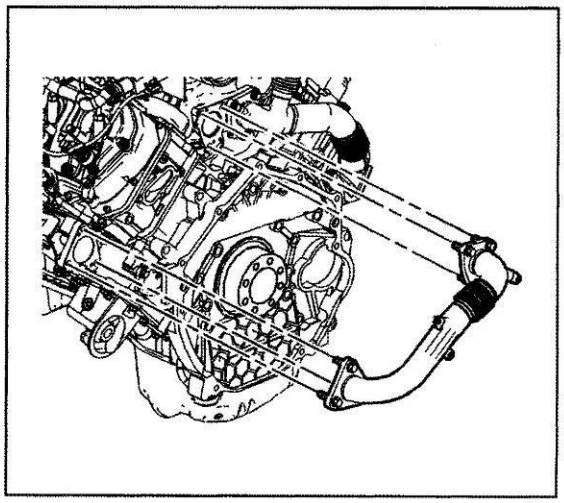
***Notice:*** If a turbocharger has failed, clean any turbocharger debris or excessive oil from the charge air cooler system before installing the new turbocharger. Failure to clean debris from the charge air cooler system will cause severe turbocharger and engine damage upon startup. Failure to clean excessive oil from the charge air cooler system may cause an engine runaway condition on startup, resulting in severe engine damage.

**Important:** If a turbocharger failure is thought to be caused due to lack of oil, the camshaft bearing should be checked. The number 4 camshaft bearing bore feeds the turbocharger oil supply (feed) pipe.



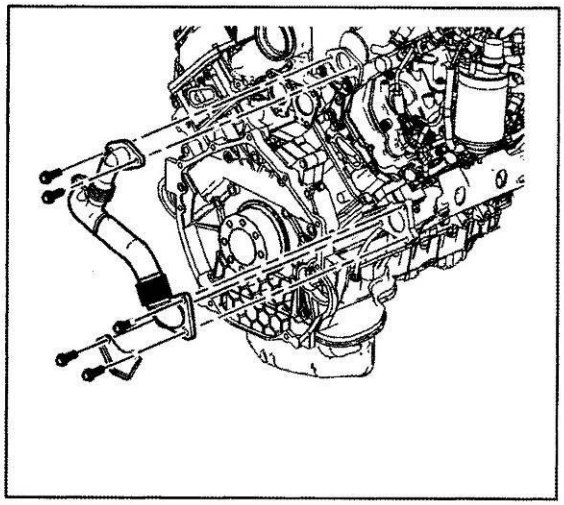
660364

7. Remove the left exhaust pipe heat shield bolts.
8.



1334832

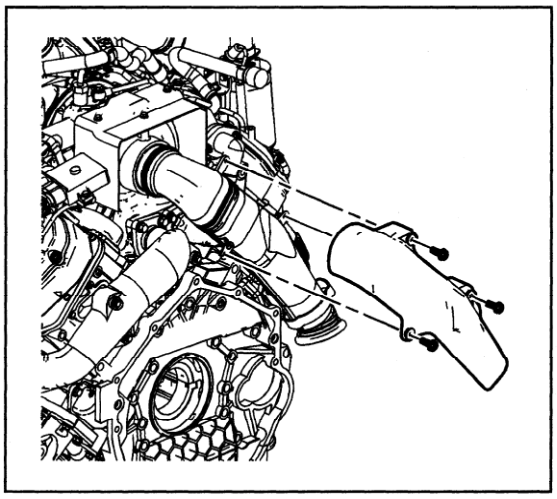
9. Remove the left exhaust pipe to exhaust manifold bolts.
10. Remove and discard the exhaust manifold gasket.



1334842

11. Remove the right exhaust pipe to exhaust manifold bolts.
12. Remove and discard the exhaust manifold gasket.

13. Remove the lower bolt for the exhaust outlet shield.
14. Drain the cooling system. Refer to *Draining and Filling Cooling System (w/RPO HP2) on page 6-1445* or *Draining and Filling Cooling System (w/o RPO HP2) on page 6-1447*.
15. Remove the air cleaner outlet duct. Refer to *Air Cleaner Outlet Duct Replacement on page 6-3293*.


1334821

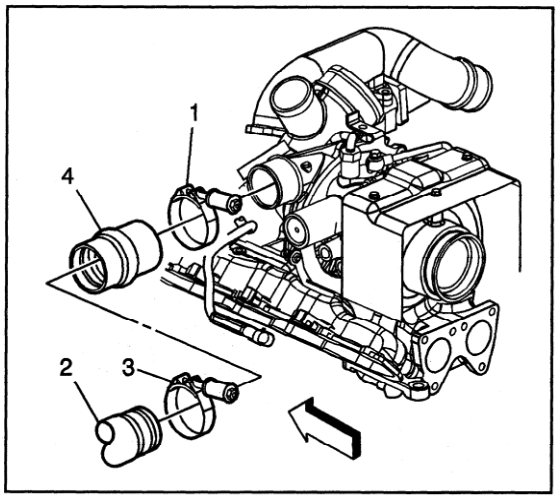
16. Using a pick or a small flat-bladed screw driver, remove and discard the quick connect fitting clip from the charged air cooler outlet duct.
17. Remove the charged air cooler outlet duct from the intake.

**Important:** After removing the charged air cooler duct, cover the turbocharger opening with tape in order to prevent entry of objects.

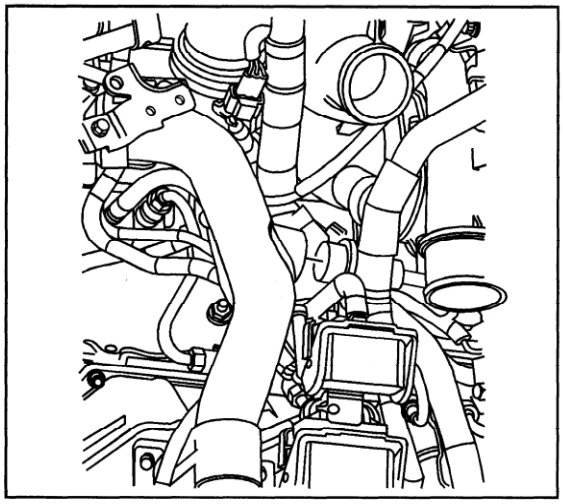
18. Loosen the charged air cooler inlet duct connector to turbocharger clamp (1).

**Important:** Do not use a screwdriver or other tool to pry the hose loose. The hose can be torn or damage. Loosen the hose by twisting.

19. Remove the charged air cooler inlet duct connector (4) from the turbocharger.

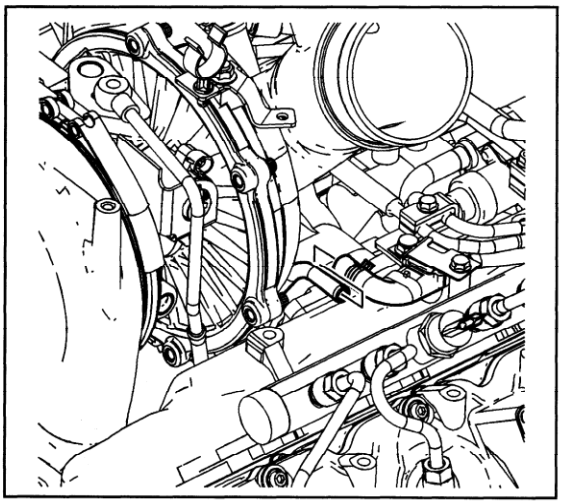


1334380



1335386

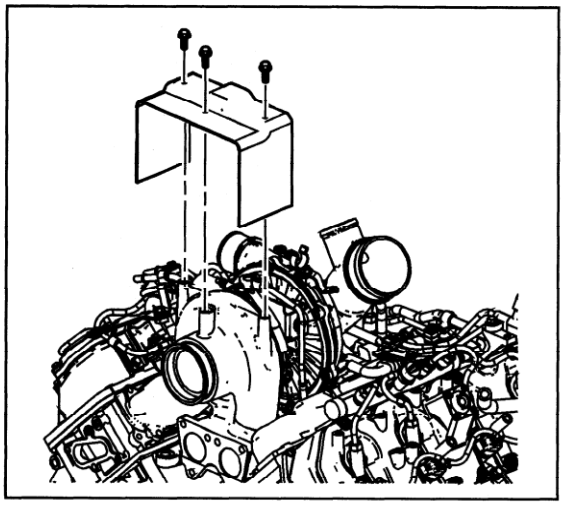
20. Remove the turbocharger inlet coolant hose from the turbocharger coolant bypass valve.



1335578

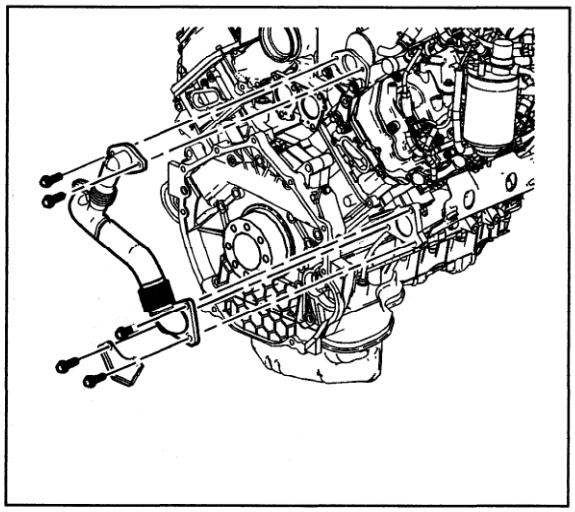
**Important:** Use care not to damage this hose during the procedure.

21. Reposition the hose clamp and remove the turbocharger outlet coolant hose from the turbocharger.
22. Remove the turbocharger outlet coolant pipe banjo bolt and washers.
23. Remove the positive crankcase ventilation (PCV) hose/pipe. Refer to *Crankcase Ventilation Hoses/Pipes Replacement on page 6-823*.



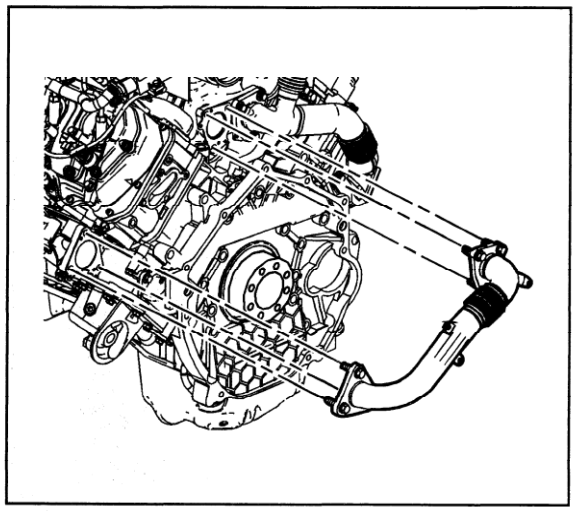
1335576

24. Remove the turbocharger upper heat shield bolts.
25. Remove the turbocharger upper heat shield.
26. Remove the remaining exhaust outlet heat shield bolts.
27. Loosen the exhaust outlet clamp.
28. Remove the exhaust outlet manifold.



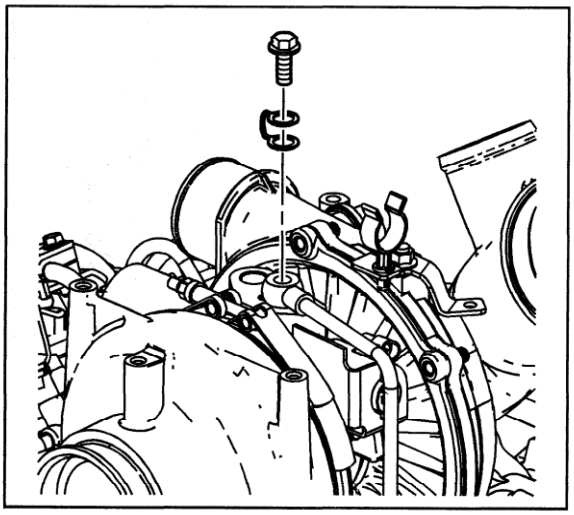
1334842

29. Remove the right exhaust pipe to turbocharger bolts.
30. Remove the right exhaust pipe.
31. Remove and discard the gasket.



1334832

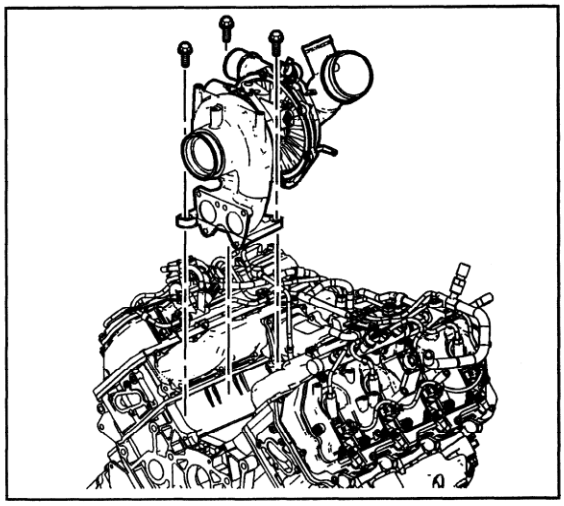
32. Remove the left exhaust pipe to turbocharger bolts.
33. Remove the left exhaust pipe.
34. Remove and discard the gasket.



1335577

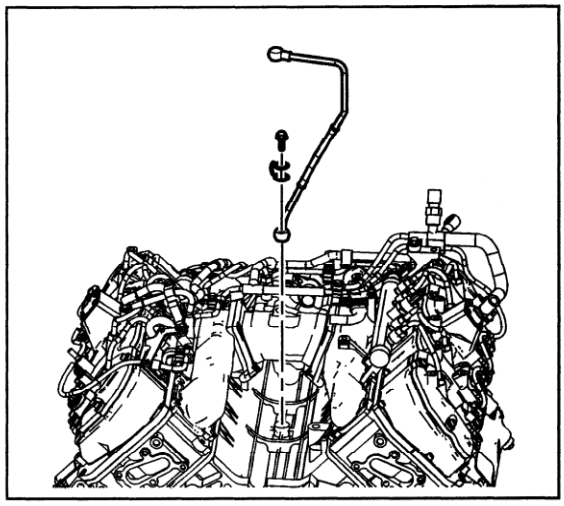
35. Remove the turbocharger oil feed pipe banjo bolt and washer.
36. Reposition the oil feed pipe out of the way.
37. Remove the turbocharger oil return pipe nuts at the top of the flywheel housing.

38. Remove the turbocharger bolts.
39. Remove the turbocharger (with the oil return pipe).
40. Remove and discard the turbocharger oil return pipe gasket at the flywheel housing.



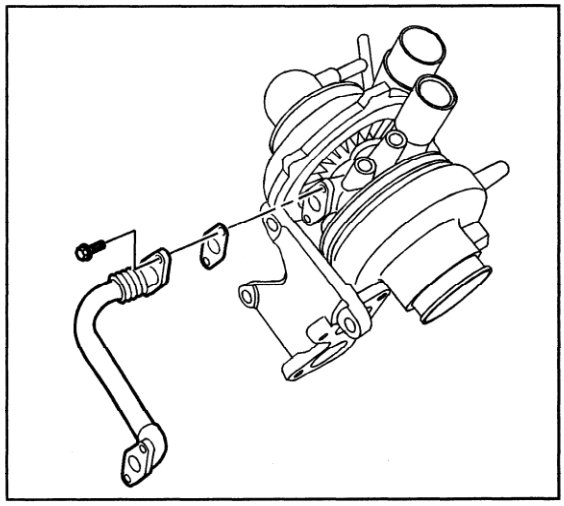
1335579

41. Remove the turbocharger lower heat shield, if necessary.
42. Remove the oil feed pipe bolt, washer, and pipe, if necessary.
43. If the turbocharger has failed, perform the following steps the verify the condition of the number 4 camshaft bearing before installing a new turbocharger.
    - 43.1. Visually inspect for correct alignment of the number 4 camshaft bearing oil hole through the turbocharger oil supply hole in the block.
    - 43.2. Turn the engine over by hand 1/2 turn and inspect for camshaft bearing movement, indicating a spun camshaft bearing.
    - 43.3. If the bearing is spun the engine MUST be replaced.

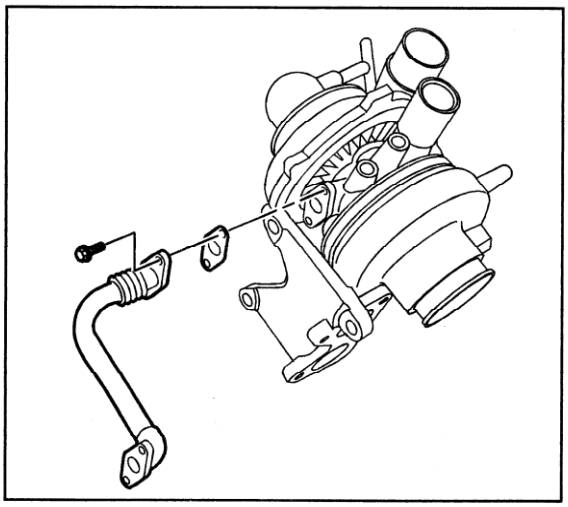


1335581

44. If replacing the turbocharger, remove the oil return pipe bolts, pipe and gasket. Discard the gasket.
45. Clean all turbocharger to engine gasket mating surfaces.
46. If required, clean and inspect the turbocharger. Refer to *Turbocharger Cleaning and Inspection on page 6-1043*



1336136



1336136

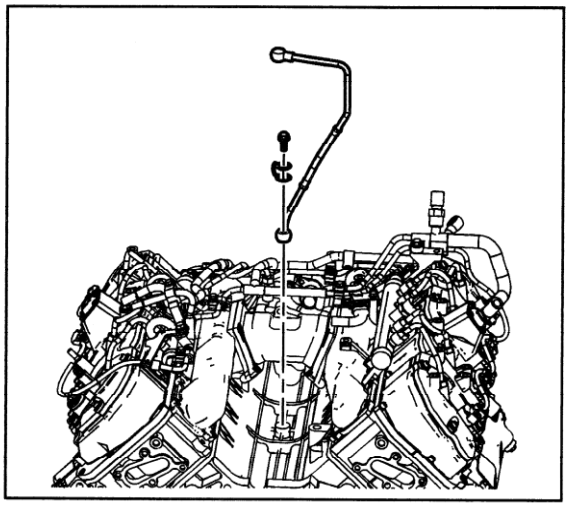
## Installation Procedure

***Notice:*** Refer to *Fastener Notice on page P-9.*

1. If the turbocharger was replaced, install the oil return pipe, bolts, and a NEW gasket.

   **Tighten**

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



1335581

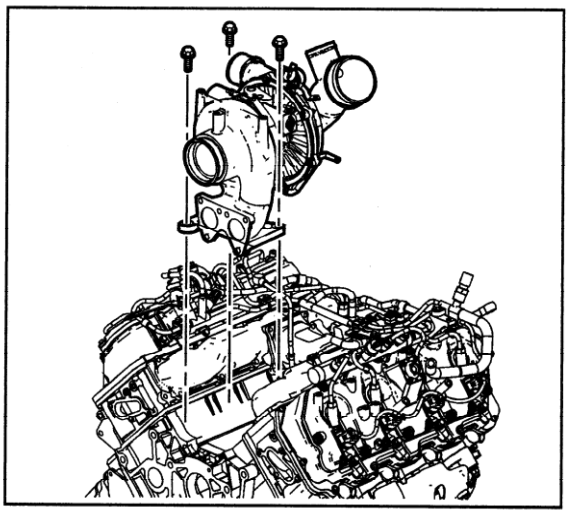
**Important:** Lubricate the washer with diesel fuel prior to installing.

2. Install the oil feed pipe, washer, and bolt, if necessary.

   **Tighten**

   Tighten the bolt to 34 N·m (25 lb ft).

3. Install the turbocharger lower heat shield, if necessary.



1335579

4. Install a NEW turbocharger oil return pipe gasket at the flywheel housing.
5. Install the turbocharger (with the oil return pipe).
6. Install the turbocharger bolts.

   **Tighten**

   Tighten the bolts to 108 N·m (80 lb ft).

7. Install the turbocharger oil return pipe nuts at the top of the flywheel housing.

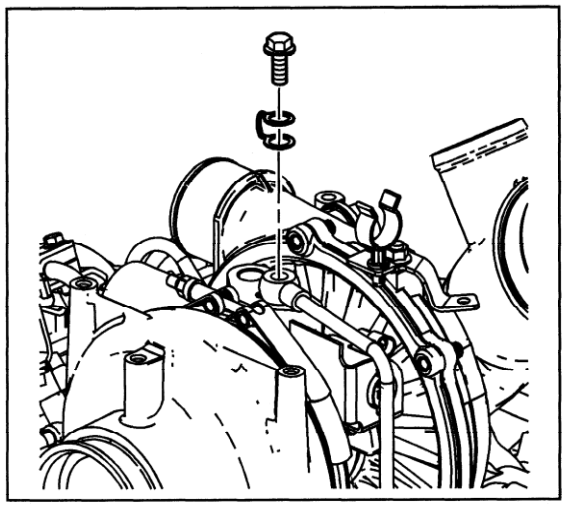
   **Tighten**

   Tighten the nuts to 25 N·m (18 lb ft).

8. If installing a NEW turbocharger, add about 120–150 cc (4–5 oz) of clean engine oil in the turbocharger oil feed pipe opening while rotating the impeller.
9. Position the oil feed pipe to the turbocharger.
10. Install a NEW turbocharger oil feed pipe washer and the banjo bolt.

    **Tighten**

    Tighten the bolt to 34 N·m (25 lb ft).

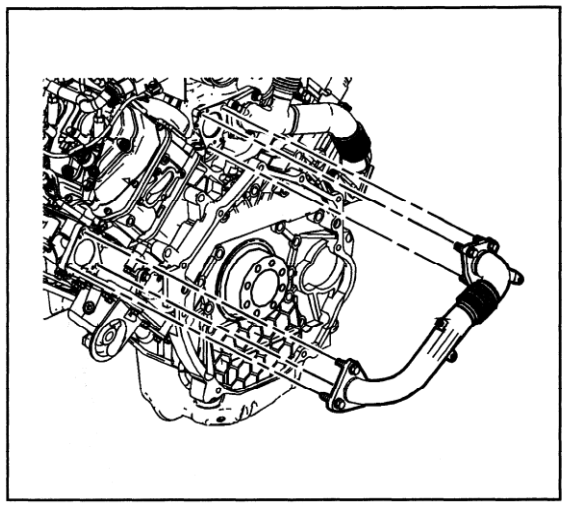


1335577

11. Install the left exhaust pipe and a NEW gasket.
12. Install the left exhaust pipe to turbocharger bolts.

    **Tighten**

    Tighten the bolt to 53 N·m (39 lb ft).



1334832

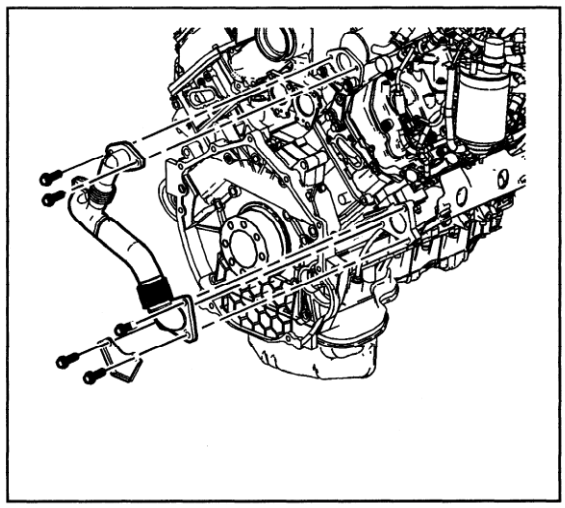
13. Install the right exhaust pipe and a NEW gasket.
14. Install the right exhaust pipe to turbocharger bolts.

    **Tighten**

    Tighten the bolt to 53 N·m (39 lb ft).
15. Install the exhaust outlet.
16. Tighten the exhaust outlet clamp.

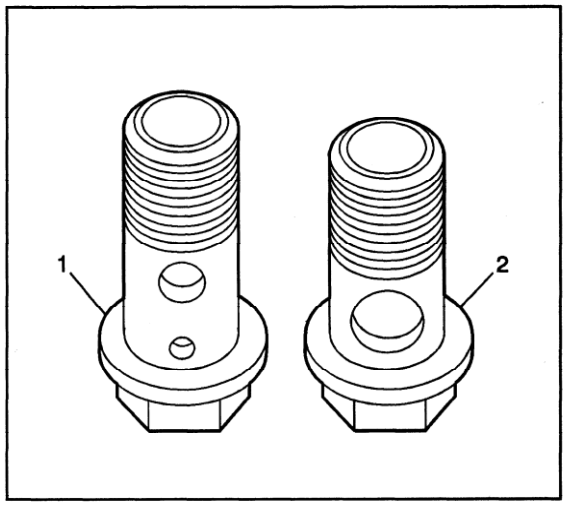
    **Tighten**

    Tighten the clamp to 15 N·m (11 lb ft).



1334842

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



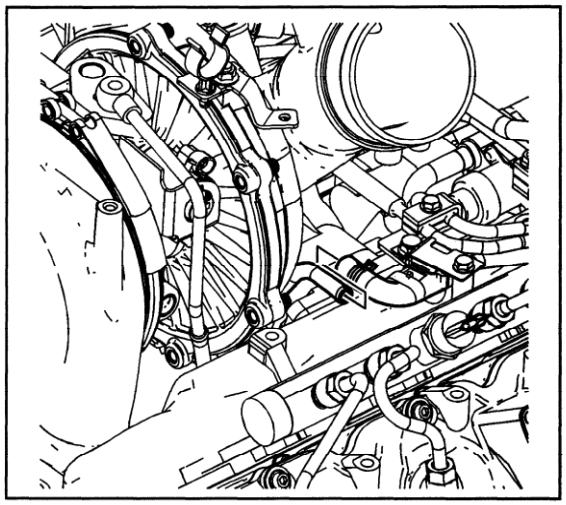
1457469

18. Install the turbocharger outlet coolant pipe banjo bolt and washers.

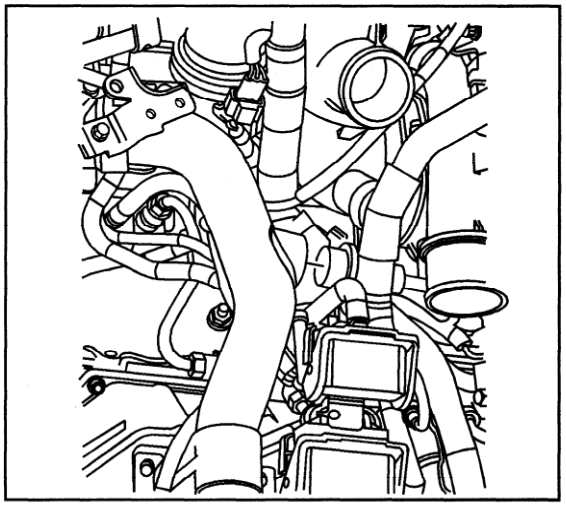
    **Tighten**

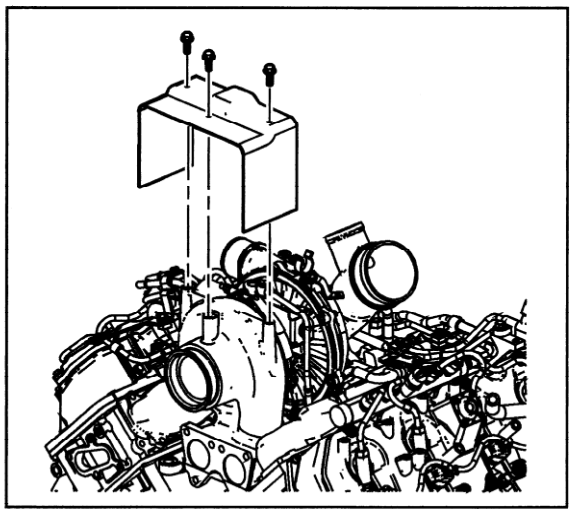
    Tighten the bolt to 26 N·m (19 lb ft).

19. Install the turbocharger outlet coolant hose to the turbocharger and position the hose clamp.


1335578

20. Install the turbocharger inlet coolant hose to the turbocharger coolant bypass valve.


1335386

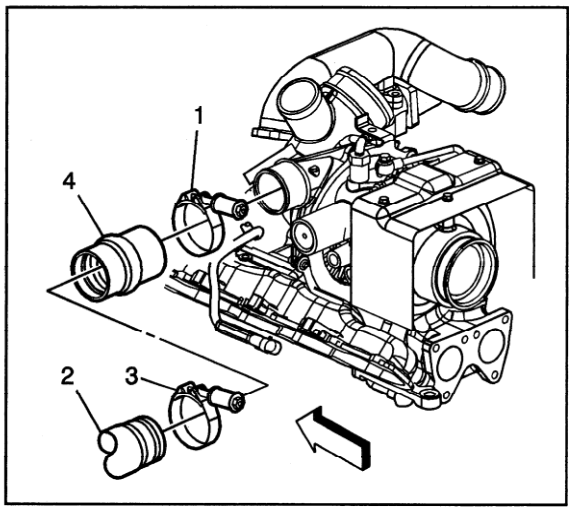


1335576

21. Install the turbocharger upper heat shield.
22. Install the turbocharger upper heat shield bolts.

    **Tighten**

    Tighten the bolt to 9 N·m (80 lb in).




1334380

23. Remove the tape from the turbocharger openings.

**Important:** Lubricate the end of the duct prior to installation.

24. Install the charged air cooler inlet duct connector (4) to the turbocharger.
25. Tighten the charged air cooler inlet duct connector to turbocharger clamp (1).

    **Tighten**

    Tighten the clamp to 6 N·m (53 lb in).
26. Install a NEW quick connect fitting clip to the charged air cooler duct.
27. Install the charged air cooler outlet duct to the intake.
28. Fill the cooling system. Refer to *Draining and Filling Cooling System*

32. Install the lower bolt for the exhaust outlet shield.

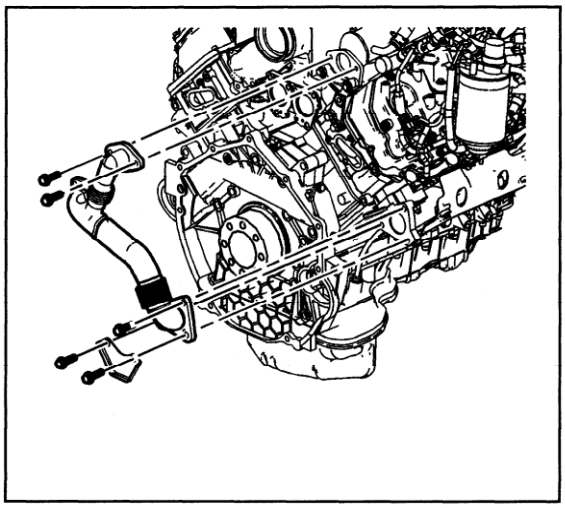
    **Tighten**

    Tighten the bolt to 8 N·m (71 lb in).

33. Install a NEW exhaust manifold gasket.
34. Install the right exhaust pipe to exhaust manifold bolts.

    **Tighten**

    Tighten the bolts to 53 N·m (39 lb ft).

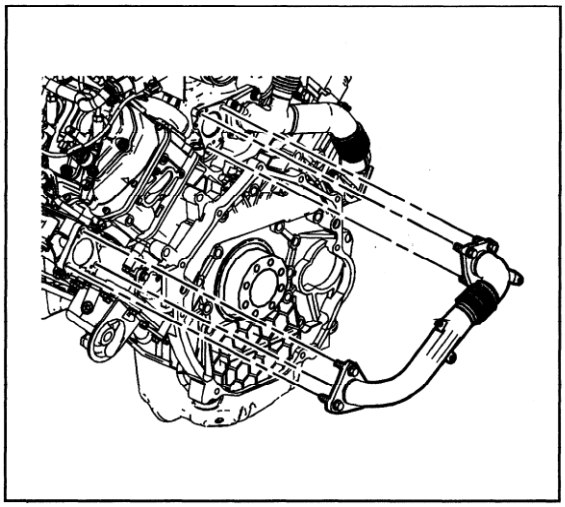


1334842

35. Install a NEW exhaust manifold gasket.
36. Install the left exhaust pipe to exhaust manifold bolts.

    **TIghten**

    Tighten the bolts to 53 N·m (39 lb ft).

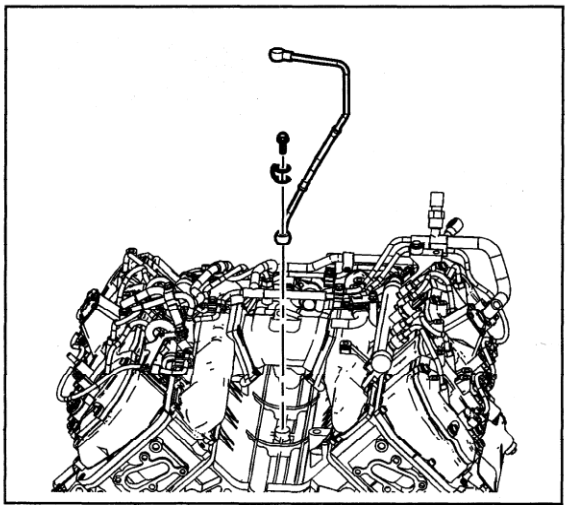


1334832

## Turbocharger Oil Supply Hose Replacement

### Removal Procedure

1. Remove the turbocharger. Refer to *Turbocharger Replacement on page 6-858*.
2. Remove the turbocharger oil feed pipe bolt.
3. Remove the oil feed pipe and washer.



1335581

### Installation Procedure

**Important:** Lubricate the NEW washer with diesel fuel before installing.

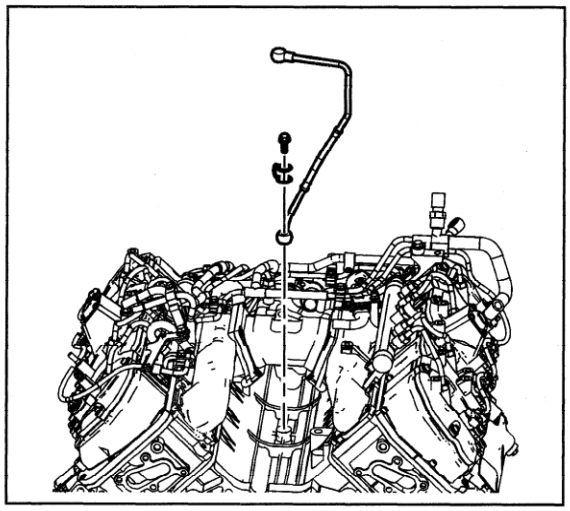
1. Position the oil feed pipe and a NEW washer into place.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

2. Install the oil feed pipe bolt.

   **Tighten**

   Tighten the bolt to 34 N·m (25 lb ft).
3. Install the turbocharger. Refer to *Turbocharger Replacement on page 6-858*.



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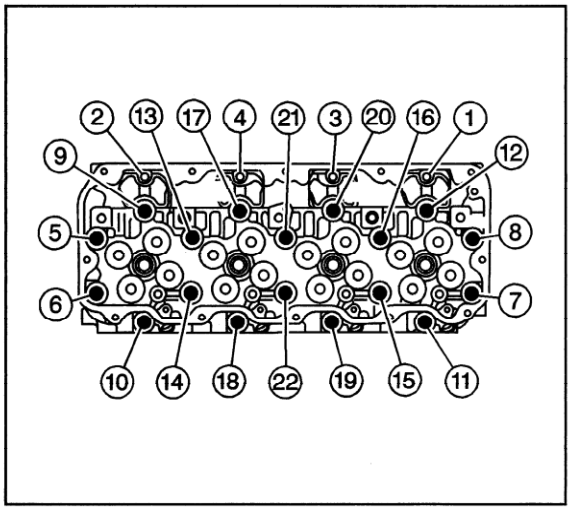
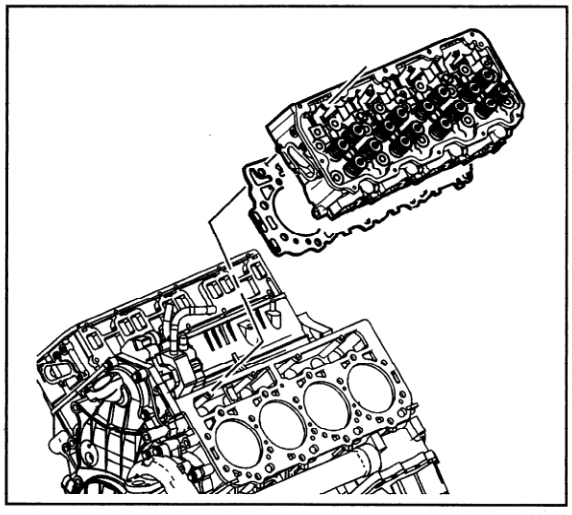


1336109


1336110

## Cylinder Head Replacement - Left

### Tools Required

*J 45059* Angle Meter

## Removal Procedure

1. Remove the thermostat housing crossover. Refer to *Thermostat Housing Crossover Replacement (6.6L (LLY) Engine) on page 6-1561* in Engine Cooling.
2. Remove the intake manifold. Refer to *Intake Manifold Replacement - Left on page 6-835*.
3. Remove the exhaust manifold. Refer to *Exhaust Manifold Replacement - Left*
4. Remove the bolt and ground straps from the rear of the cylinder head.
5. Remove the valve rocker arm shaft, pushrods, and valve bridges. Refer to *Valve Rocker Arm, Shaft, and Push Rod Replacement on page 6-853*.
6. Remove the glow plugs. Refer to *Glow Plug Replacement - Bank 2 on page 6-3271* in Engine Controls – 6.6L (LLY).
7. Remove the cylinder head bolts in the sequence shown.
8. Discard the large M12 bolts.
9. Remove the cylinder head.
10. Remove and discard the cylinder head gasket.
11. Clean the sealing surface of the engine block and the cylinder head.

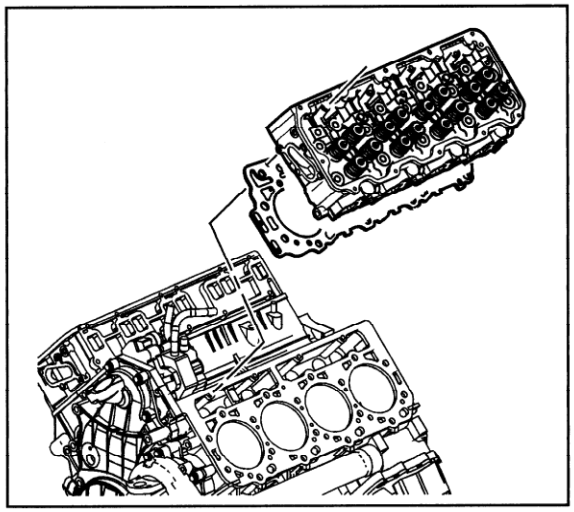
***Notice:*** Clean all dirt, debris, and coolant from the engine block cylinder head bolt holes. Failure to remove all foreign material may result in damaged threads, improperly tightened fasteners or damage to components.

12. Clean the cylinder head bolt holes in the engine block.
13. For service to the cylinder head refer to the following:
    - Refer to *Cylinder Head Disassemble on page 6-1026*.
    - Refer to *Cylinder Head Cleaning and Inspection on page 6-1027*.
    - Refer to *Cylinder Head Assemble on page 6-1031*.

## Installation Procedure

***Notice:*** 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.

1. Install the cylinder head gasket of the correct grade. Refer to *Cylinder Head Gasket Selection Specifications on page 6-742*.
2. Install the cylinder head.



1336110

***Notice:*** 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 M12 cylinder head bolts.
4. Reuse the M8 cylinder head bolts.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

5. Tighten the cylinder head bolts in the following steps using the sequence shown.

   **Tighten**

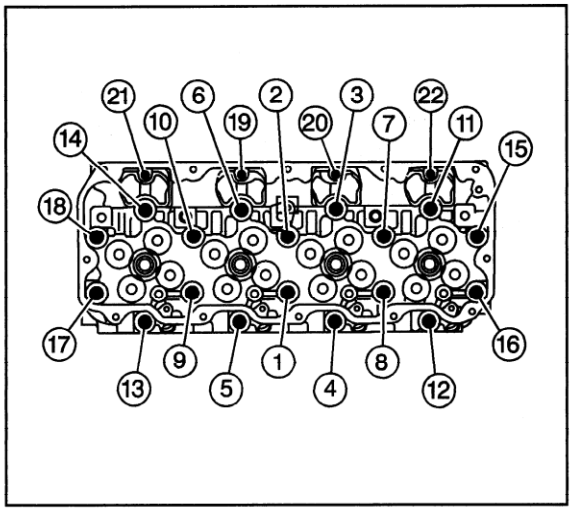
   5.1. Tighten the M12 bolts a first pass to 50 N·m (37 lb ft).
   5.2. Tighten the M12 bolts a second pass to 80 N·m (59 lb ft)
   5.3. Tighten the M12 bolts a third pass to 90 degrees, using *J 45059*.
   5.4. Tighten the M12 bolts a final pass to 75 degrees, using *J 45059*.
   5.5. Tighten the M8 bolts to 25 N·m (18 lb ft).

6. Position the ground straps to the rear of the cylinder head, and install the bolt.

   **Tighten**

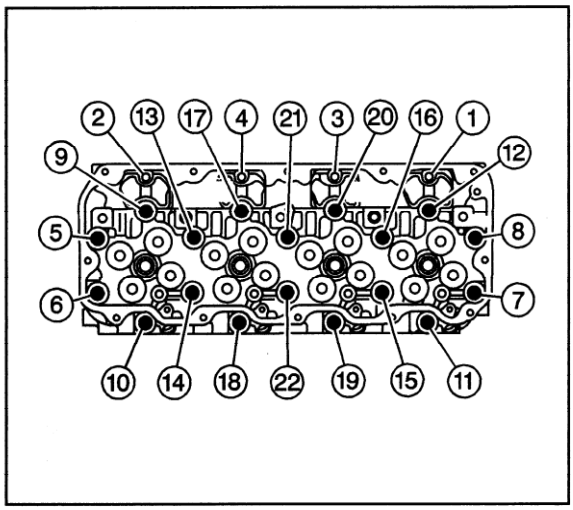
   Tighten the bolt to 34 N·m (25 lb ft).

7. Install the glow plugs. Refer to *Glow Plug Replacement - Bank 2 on page 6-3271* in Engine Controls – 6.6L (LLY).
8. Install the valve rocker arm shaft, pushrods, and valve bridges. Refer to *Valve Rocker Arm, Shaft, and Push Rod Replacement on page 6-853*.




663831

9. Install the exhaust manifold. Refer to *Exhaust Manifold Replacement - Left*
10. Install the intake manifold. Refer to *Intake Manifold Replacement - Left on page 6-835.*
11. Install the thermostat housing crossover. Refer to *Thermostat Housing Crossover Replacement (6.6L (LLY) Engine) on page 6-1561* in Engine Cooling.
12. Test the engine for normal operation.
13. Inspect for coolant, oil, or exhaust leaks.



1336109

## Cylinder Head Replacement - Right

### Tools Required

*J 45059* Angle Meter

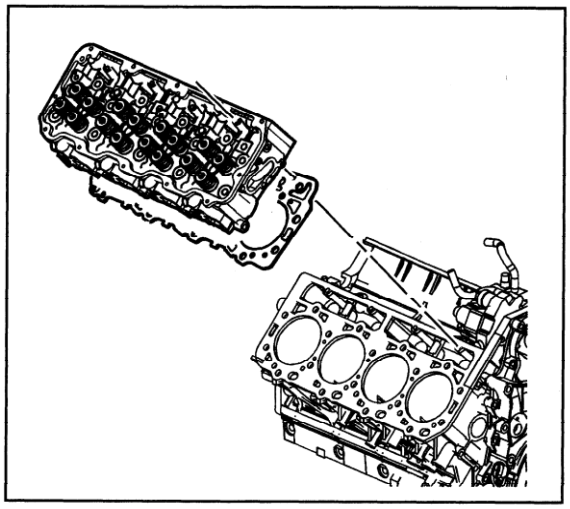
### Removal Procedure

1. Remove the thermostat housing crossover. Refer to *Thermostat Housing Crossover Replacement (6.6L (LLY) Engine) on page 6-1561* in Engine Cooling.
2. Remove the intake manifold. Refer to *Intake Manifold Replacement - Right on page 6-836.*
3. Remove the exhaust manifold. Refer to *Exhaust Manifold Replacement - Right*
4. Remove the valve rocker arm shaft, pushrods, and valve bridges. Refer to *Valve Rocker Arm, Shaft, and Push Rod Replacement on page 6-853.*
5. Remove the glow plugs. Refer to *Glow Plug Replacement - Bank 1 on page 6-3271* in Engine Controls – 6.6L (LLY).
6. Remove the cylinder head bolts in the sequence shown.
7. Discard the large M12 bolts.

8. Remove the cylinder head.
9. Remove and discard the cylinder head gasket.
10. Clean the sealing surface of the engine block and the cylinder head.

***Notice:*** Clean all dirt, debris, and coolant from the engine block cylinder head bolt holes. Failure to remove all foreign material may result in damaged threads, improperly tightened fasteners or damage to components.

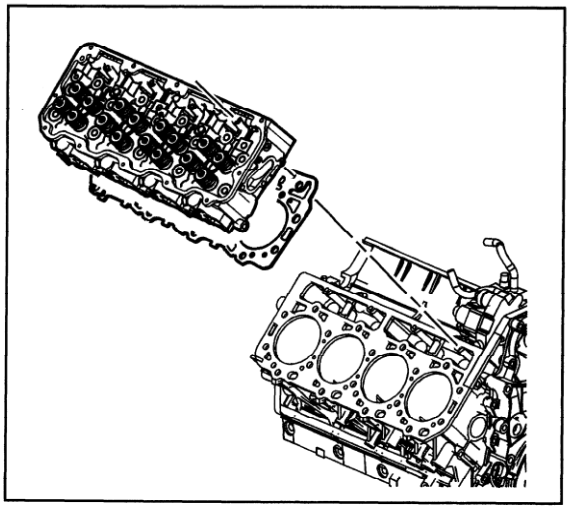
11. Clean the cylinder head bolt holes in the engine block.
12. For service to the cylinder head refer to the following:
    - Refer to *Cylinder Head Disassemble on page 6-1026*.
    - Refer to *Cylinder Head Cleaning and Inspection on page 6-1027*.
    - Refer to *Cylinder Head Assemble on page 6-1031*.

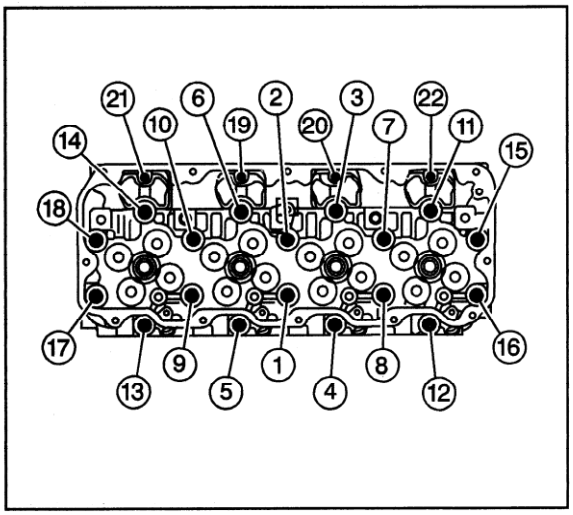

1336113

## Installation Procedure

***Notice:*** 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.

1. Install the cylinder head gasket of the correct grade. Refer to *Cylinder Head Gasket Selection Specifications on page 6-742*.
2. Install the cylinder head.


1336113



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***Notice:*** 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 the NEW M12 cylinder head bolts.
4. Reuse the M8 cylinder head bolts.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

5. Tighten the cylinder head bolts in the following steps using the sequence shown.

   **Tighten**

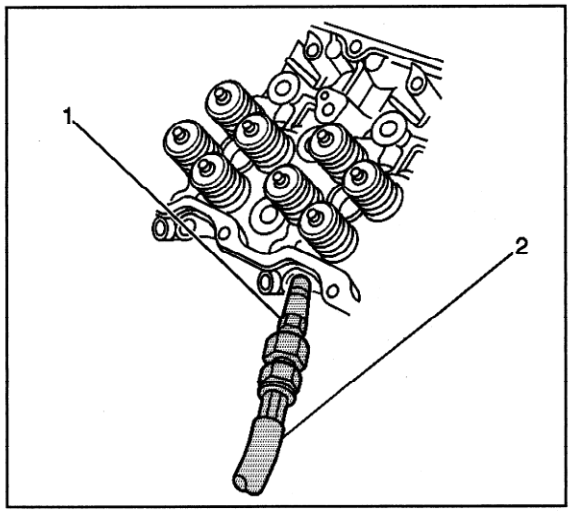
   5.1. Tighten the M12 bolts a first pass to 50 N·m (37 lb ft).
   5.2. Tighten the M12 bolts a second pass to 80 N·m (59 lb ft)
   5.3. Tighten the M12 bolts a third pass to 90 degrees, using *J 45059*.
   5.4. Tighten the M12 bolts a final pass to 75 degrees, using *J 45059*.
   5.5. Tighten the M8 bolts to 25 N·m (18 lb ft).

6. Install the valve rocker arm shaft, pushrods, and valve bridges. Refer to *Valve Rocker Arm, Shaft, and Push Rod Replacement on page 6-853*.
7. Install the glow plugs. Refer to *Glow Plug Replacement - Bank 1 on page 6-3271* in Engine Controls – 6.6L (LLY).
8. Install the right exhaust manifold. Refer to *Exhaust Manifold Replacement - Right*
9. Install the right intake manifold. Refer to *Intake Manifold Replacement - Right on page 6-836*.
10. Install the thermostat housing crossover. Refer to *Thermostat Housing Crossover Replacement (6.6L (LLY) Engine) on page 6-1561* in Engine Cooling.
11. Test the engine for normal operation.
12. Inspect for coolant, oil, or exhaust leaks.

## Valve Stem Oil Seal and Valve Spring Replacement

### Tools Required

- *J 26999* Compression Gage
- *J 26999-20* Compression Gage Adapter
- *J 44646* Valve Spring Compressor
- *J 44640* Valve Stem Seal Installer



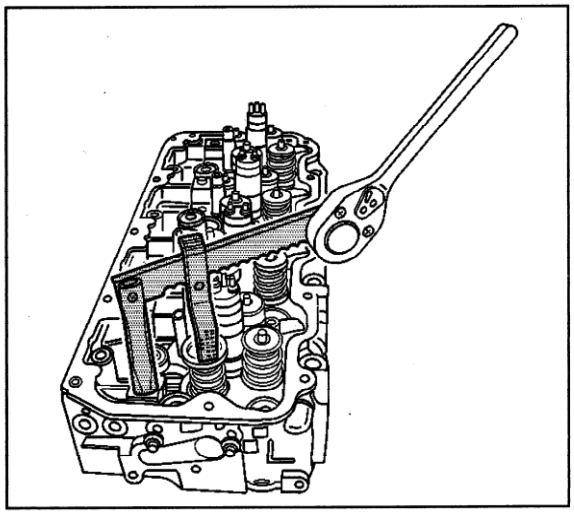
702726

### Removal Procedure

1. Remove the upper and lower fan shroud. Refer to *Fan Shroud Replacement - Lower on page 6-1608* and *Fan Shroud Replacement - Upper (w/RPO HP2) on page 6-1595* or *Fan Shroud Replacement*
2. Remove the valve rocker arm shaft, valve bridges, and pushrods for the cylinder head being serviced. Refer to *Valve Rocker Arm, Shaft, and Push Rod Replacement on page 6-853*.
3. Remove the glow plug for the cylinder requiring service. Refer to *Glow Plug Replacement - Bank 1 on page 6-3271* or *Glow Plug Replacement - Bank 2 on page 6-3271*.
4. In order to apply shop air to the cylinders use the following procedures to modify *J 26999-20* (1) and *J 26999* (2):
   - 4.1. Remove the valve core from *J 26999-20* to allow air to flow.
   - 4.2. Remove the quick connect fitting from *J 26999*.
   - 4.3. Adapt the quick connect fitting in order to use for shop air.
   - 4.4. Connect the quick connect fitting to *J 26999-20*.

**Important:** Rotate the cylinder to be serviced to the bottom of the stroke. This is to ensure that the engine does not rotate when the compressed air is applied to the cylinder being serviced.

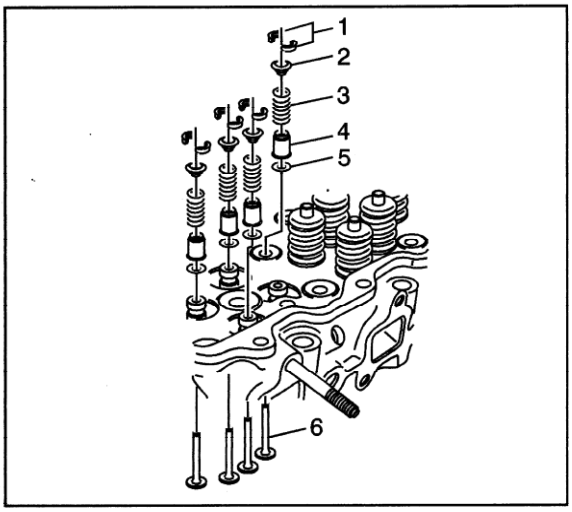
5. Install *J 26999-20* into the glow plug hole for the cylinder being serviced.
6. Apply compressed air to hold the valves in place. If the compressed air is released, the valves can drop into the cylinder.



702702

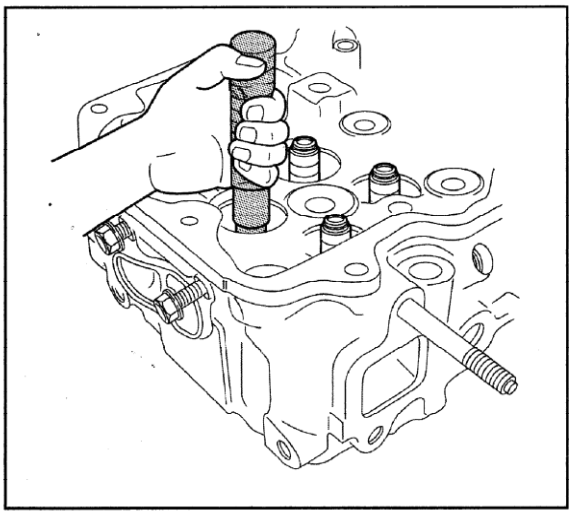
***Caution: Compressed valve springs have high tension against the valve spring compressor. Valve springs that are not properly compressed by or released from the valve spring compressor can be ejected from the valve spring compressor with intense force. Use care when compressing or releasing the valve spring with the valve spring compressor and when removing or installing the valve stem keys. Failing to use care may cause personal injury.***

7. Install *J 44646* to the rocker arm bosses on the cylinder head.
   *J 44646* should be installed in the rocker arm boss next to the cylinder being serviced. The pivot pin can be removed from the stand to allow the stand to be installed. The lever has different locating holes for the pivot pin depending on available clearance. The lever is also notched for different locations of the compressor.
8. Using *J 44646* compress the valve spring.




663504

9. Remove the valve keys (1) from the valve stem.
10. Carefully release the valve spring tension.
11. Remove the valve spring upper seat (2) and the valve spring (3).
12. Remove the valve stem oil seal (4).
13. Remove the valve spring lower seat (5).
14. Continue removing the remaining valve stem seals for the cylinder using the above procedure.



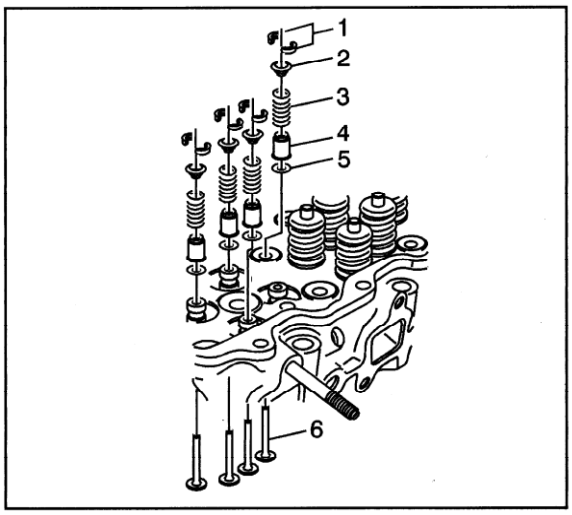
663571

## Installation Procedure

***Notice:*** Air pressure should remain applied to the cylinder for installation.

1. Install the valve spring lower seat.
2. Install the valve stem seal using *J 44640*.

3. Install the valve spring (3), the painted end of the valve spring goes toward the cylinder head.
4. Install the valve spring upper seat (2).



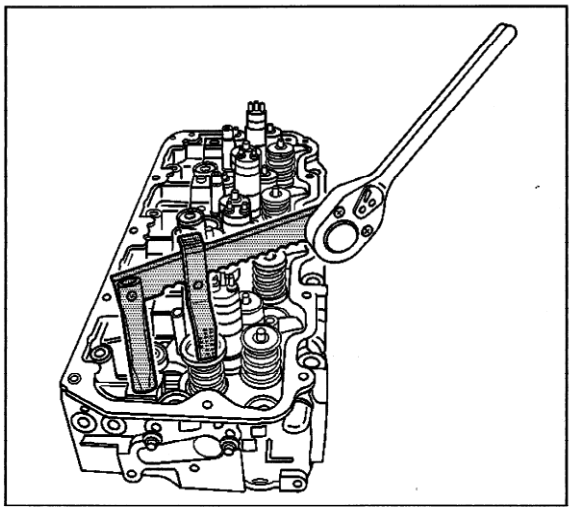
663504

***Caution: Compressed valve springs have high tension against the valve spring compressor. Valve springs that are not properly compressed by or released from the valve spring compressor can be ejected from the valve spring compressor with intense force. Use care when compressing or releasing the valve spring with the valve spring compressor and when removing or installing the valve stem keys. Failing to use care may cause personal injury.***

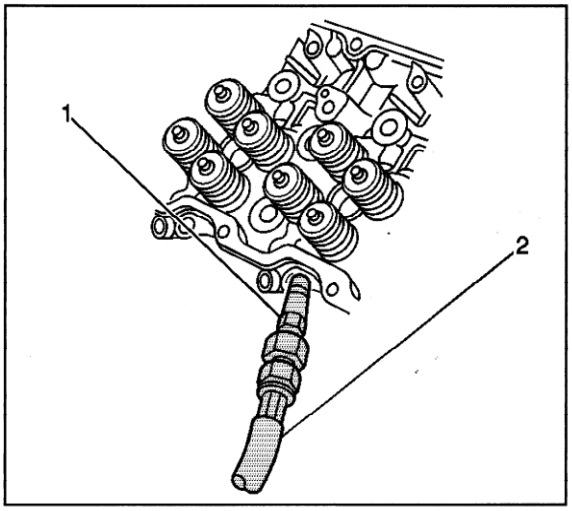
5. Using *J 44646* compress the valve spring.
6. Install the valve keys to the valve stem.

***Notice:*** The valve stem keys must correctly seat in the valve spring cap. Engine damage may occur by not installing properly.

7. Carefully release the valve spring pressure. Make sure the valve keys stay in place.
8. Continue to install the 3 remaining valve stem seals for the cylinder.


702702

9. Release the compressed air holding the valves in place.
10. Remove *J 26999-20* (1) from the glow plug hole.
11. Continue to replace the valve stem seals on the remaining cylinders using the above procedures.
12. Install the glow plug. Refer to *Glow Plug Replacement - Bank 1 on page 6-3271* or *Glow Plug Replacement - Bank 2 on page 6-3271*.
13. Install the valve rocker arm shaft, the valve bridges, and the push rods. Refer to *Valve Rocker Arm, Shaft, and Push Rod Replacement on page 6-853*.



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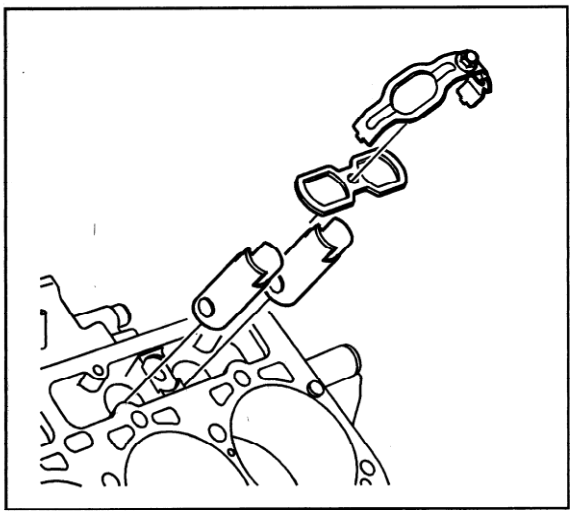

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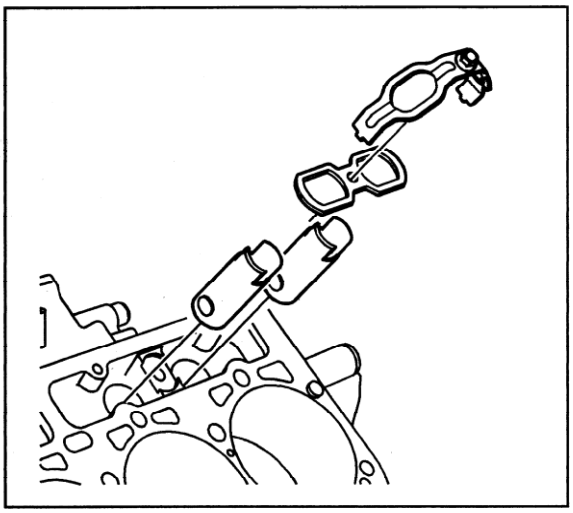


660517

## Valve Lifter Replacement

### Removal Procedure

1. Remove the cylinder head. Refer to *Cylinder Head Replacement - Left on page 6-878* or *Cylinder Head Replacement - Right on page 6-880*.
2. Loosen the valve lifter guide retainer bolts.
3. Remove the valve lifter guide retainers.
4. Remove the valve lifter guides.
5. Remove the valve lifters.
6. If required, clean and inspect the lifters. Refer to *Valve Lifters Cleaning and Inspection on page 6-1033*.

### Installation Procedure

1. Apply clean engine oil to the roller and outside of the valve lifter.
2. Install the valve lifter.
3. Install the valve lifter guides.
4. Install the valve lifter guide retainer.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

5. Install the valve lifter guide retainer bolt.

   **Tighten**

   Tighten the bolt to 11 N·m (97 lb in).
6. Install the cylinder head. Refer to *Cylinder Head Replacement - Left on page 6-878* or *Cylinder Head Replacement - Right on page 6-880*.

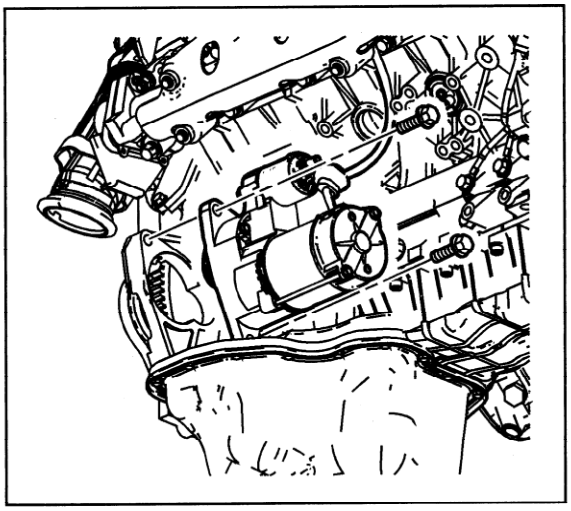
## Crankshaft Balancer Replacement

### Tools Required

*J 44643* Flywheel Holding Tool

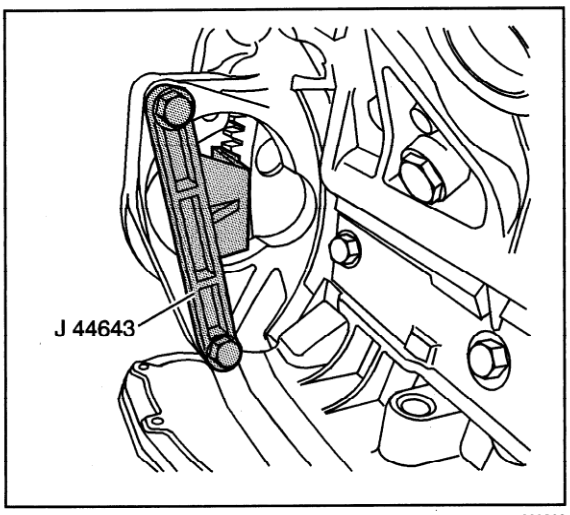
### Removal Procedure

1. Disconnect the negative battery cable. Refer to *Battery Negative Cable Disconnect/Connect Procedure (Single Battery) on page 6-1787* or *Battery Negative Cable Disconnect/Connect Procedure (Auxiliary Battery) on page 6-1788* in Engine Electrical.
2. Remove the right wheelhouse panel. Refer to *Wheelhouse Panel Replacement on page 8-51* In Body Front End.
3. Remove the starter motor bolts. Reposition the starter aside. The wiring to the starter does not require removal.



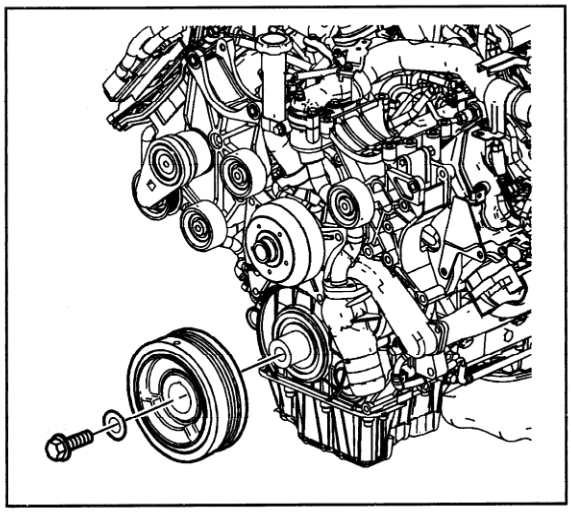
1334814

4. Install *J 44643* in order to hold the flywheel.
5. Remove the lower fan shroud. Refer to *Fan Shroud Replacement - Lower on page 6-1608* in Engine Cooling.




660308

6. Remove the crankshaft balancer bolt.
7. Remove the crankshaft balancer.
8. If required, clean and inspect the crankshaft balancer. Refer to *Crankshaft Balancer Cleaning and Inspection on page 6-1021*.



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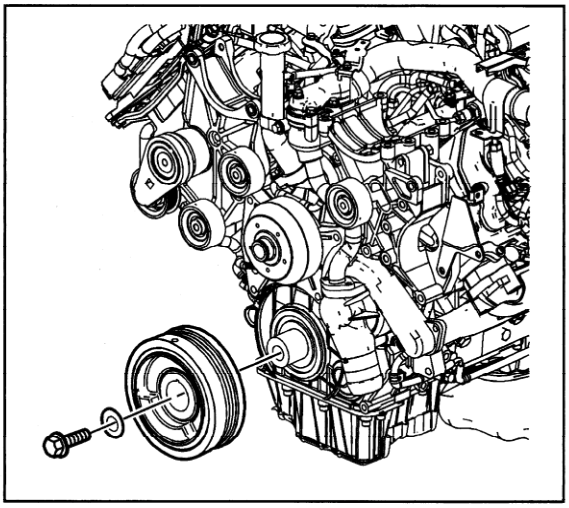


1334816

## Installation Procedure

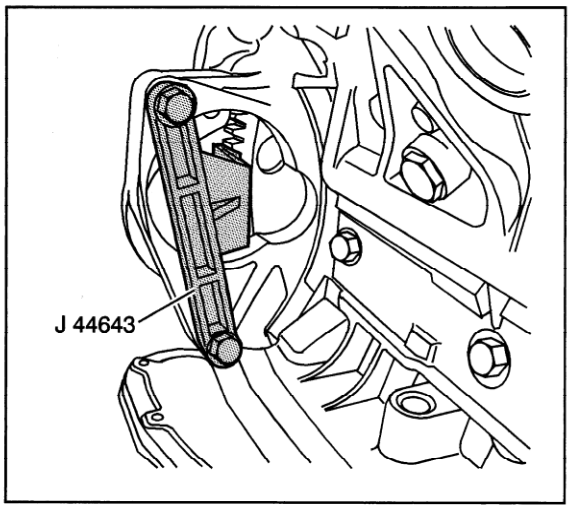
1. Lubricate the crankshaft balancer internal hub with clean engine oil.
2. Install the crankshaft balancer on the crankshaft.
3. Lubricate the crankshaft balancer bolt with clean engine oil.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

4. Install the crankshaft balancer bolt and washer.

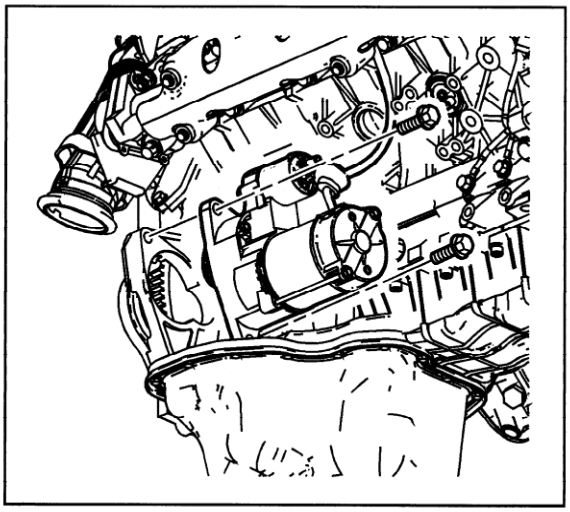
   **Tighten**

   Tighten the bolt to 353 N·m (260 lb ft).




660308

5. Remove *J 44643*.



1334814

6. Position the starter motor.
7. Install the starter motor bolts.

   **Tighten**

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

8. Install the right wheelhouse panel. Refer to *Wheelhouse Panel Replacement on page 8-51* in Body Front End.
9. Install the lower fan shroud. Refer to *Fan Shroud Replacement - Lower on page 6-1608* in Engine Cooling.
10. Connect the negative battery cable. Refer to *Battery Negative Cable Disconnect/Connect Procedure (Single Battery) on page 6-1787* or *Battery Negative Cable Disconnect/Connect Procedure (Auxiliary Battery) on page 6-1788* in Engine Electrical.

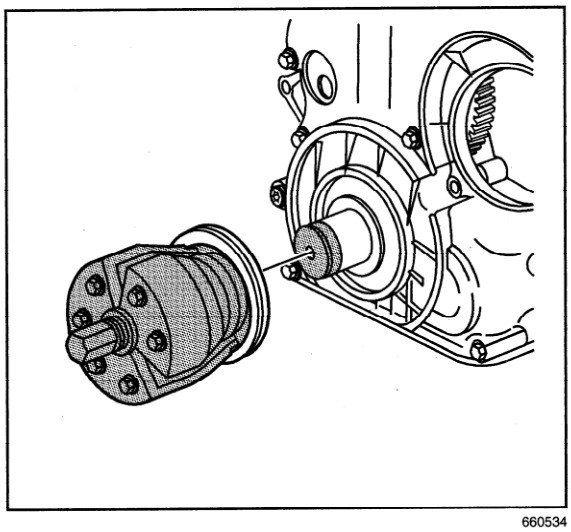
## Crankshaft Front Oil Seal Replacement

### Tools Required

- *J 44644* Crankshaft Front Oil Seal Remover
- *J 44645* Crankshaft Front Oil Seal Installer

### Removal Procedure

1. Remove the crankshaft balancer. Refer to *Crankshaft Balancer Replacement on page 6-887*.
2. Install *J 44644* to the crankshaft front oil seal. The jaws of the *J 44644* fit into the inner sleeve.
3. Using *J 44644*, remove the crankshaft front oil seal.



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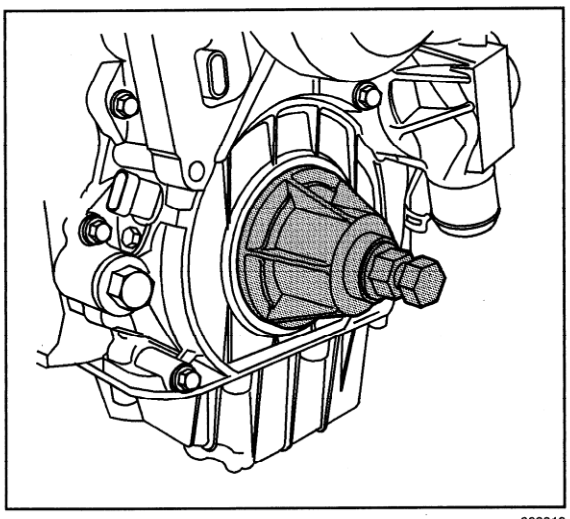
### Installation Procedure

1. Clean the front crankshaft seal bore and the crankshaft.
2. Lubricate the crankshaft sealing surface with clean engine oil.
3. Place the crankshaft front oil seal onto the crankshaft.
4. Install *J 44645* to the crankshaft.
5. Press the crankshaft front oil seal onto the crankshaft using *J 44645* until the tool bottoms out.
6. Remove *J 44645*.



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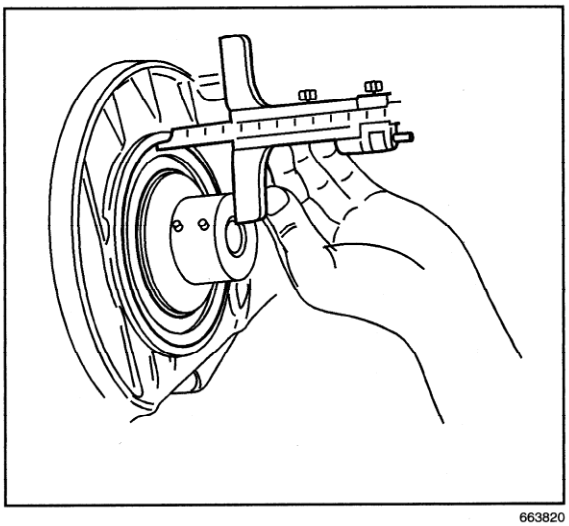
7. Measure the distance between the end of the crankshaft and the oil seal.
8. The service measurement is 43.45–44.05 mm (1.7106–1.7342 in).
9. Install the crankshaft balancer. Refer to *Crankshaft Balancer Replacement on page 6-887*.



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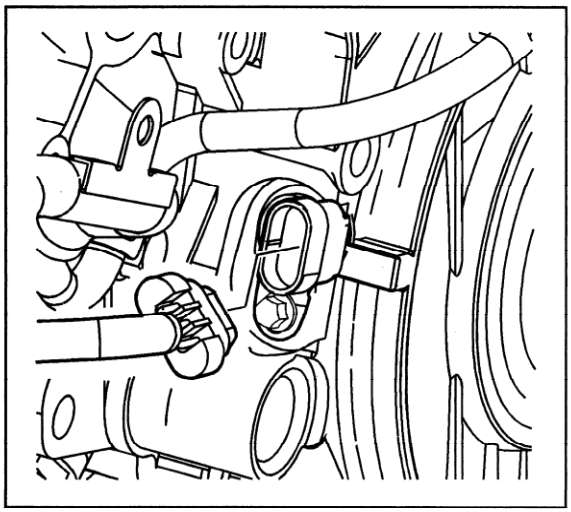

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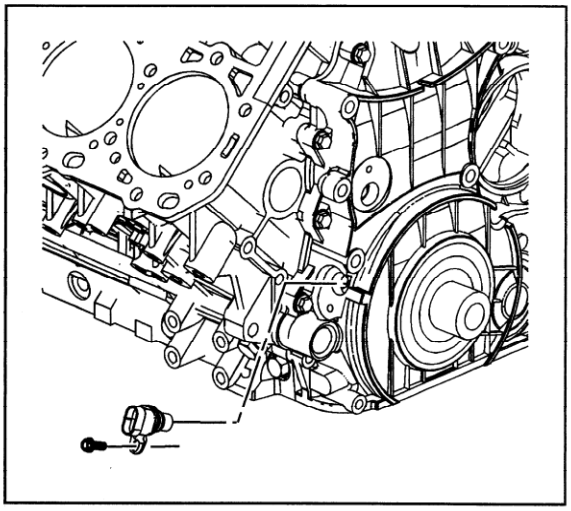


1336119

## Engine Front Cover Replacement

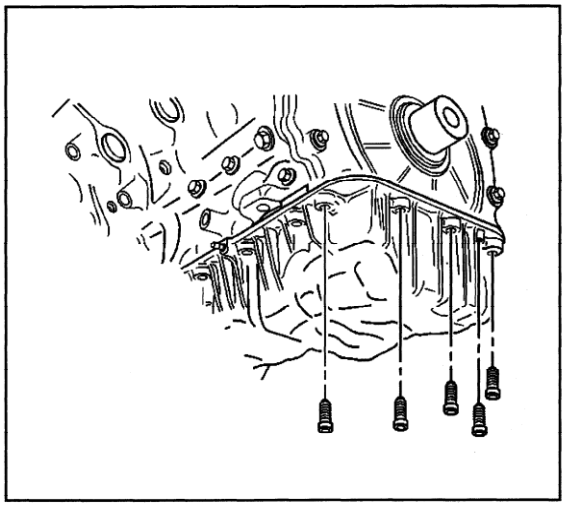
### Tools Required

*J 37228* Seal Cutter

### Removal Procedure

1. Disconnect the negative battery cable. Refer to *Battery Negative Cable Disconnect/Connect Procedure (Single Battery) on page 6-1787* or *Battery Negative Cable Disconnect/Connect Procedure (Auxiliary Battery) on page 6-1788* in Engine Electrical.
2. Remove the water pump. Refer to *Water Pump Replacement (4.3L) on page 6-1578* or *Water Pump Replacement (4.8L, 5.3L, and 6.0L) on page 6-1584* or *Water Pump Replacement (6.6L (LLY)) on page 6-1588* or *Water Pump Replacement (8.1L) on page 6-1590* in Engine Cooling.
3. Remove the crankshaft front oil seal. Refer to *Crankshaft Front Oil Seal Replacement on page 6-889.*
4. Remove the right wheelhouse panel. Refer to *Wheelhouse Panel Replacement on page 8-51* in Body Front End.
5. Disconnect the crankshaft position (CKP) sensor electrical connector.
6. Remove the CKP sensor bolt and sensor.
7. Remove the CKP sensor spacer bolts and spacer.
8. Remove and discard the O-rings from the sensor and the spacer.

9. Remove the upper oil pan to engine front cover bolts.

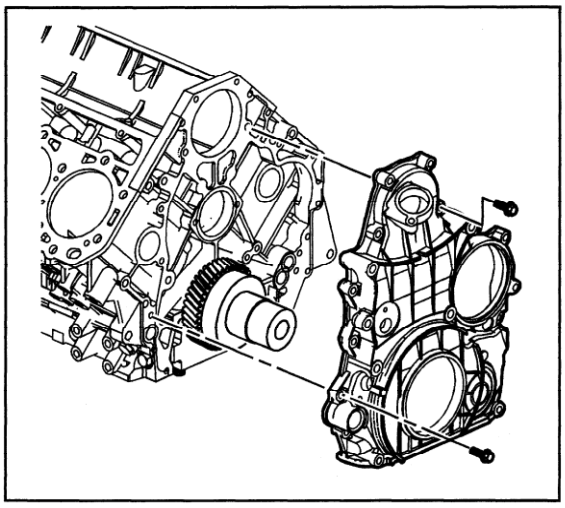


738866

10. Remove the engine front cover bolts.
11. Separate the engine front cover from the cylinder block and upper oil pan using *J 37228*.

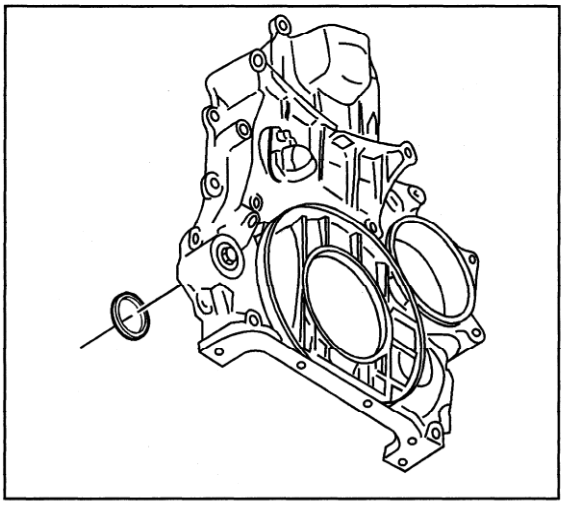
**Important:** Do not bend the turbocharger coolant pipe.

12. Remove the engine front cover.



1336120

13. If necessary, remove the pressure relief valve O-ring.
14. Clean and inspect the front cover. Refer to *Engine Front Cover Cleaning and Inspection on page 6-1036*.



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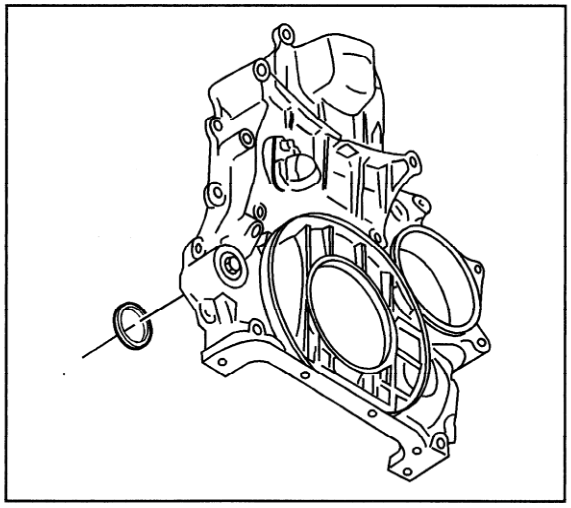


793901

## Installation Procedure

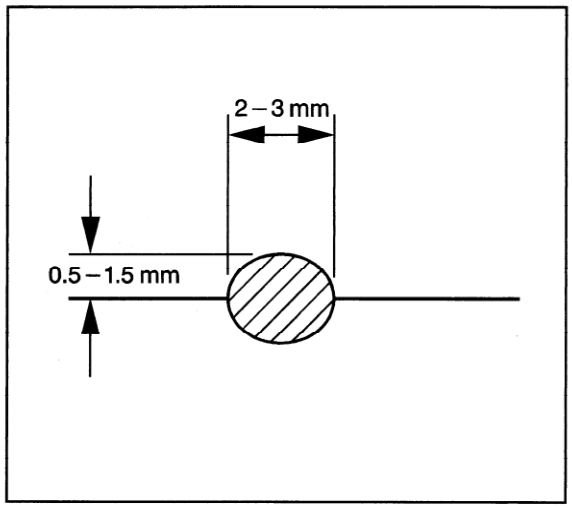
1. If necessary, install a NEW pressure relief valve O-ring.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

2. Lubricate the O-ring with engine oil.

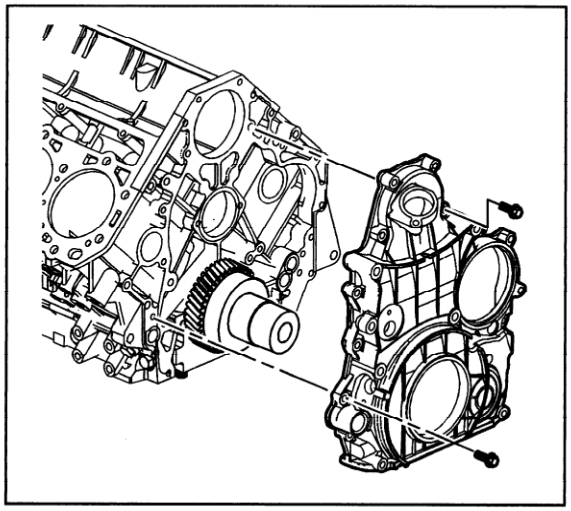
   **Tighten**

   Tighten the valve to 39 N·m (29 lb ft).




663817

3. Apply a 2–3 mm (1/8 in) wide by 0.5–1.5 mm (1/16 in) high, bead of sealant to the engine front cover sealing surface to the engine block. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.
4. Apply a 2–3 mm (1/8 in) wide by 0.5–1.5 mm (1/16 in) high, bead of sealant to the engine front cover sealing surface to the upper oil pan. Refer to *Sealers, Adhesives, and Lubricants on page 6-742* for the correct part number.



1336120

5. Install the engine front cover.
6. Install the engine front cover bolts.

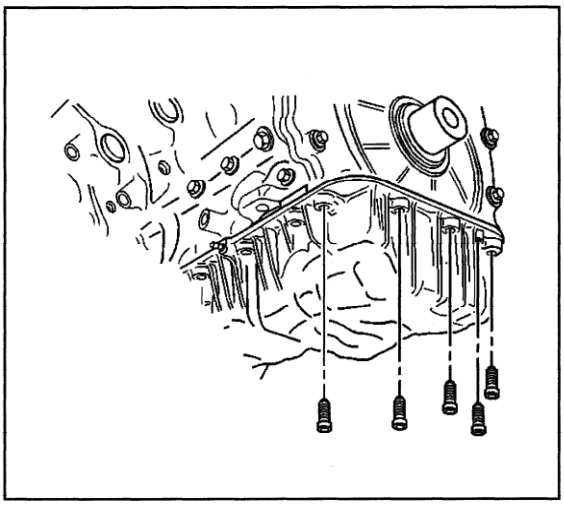
   **Tighten**

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

7. Install the upper oil pan to engine front cover bolts.

   **Tighten**

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



738866

8. Install a NEW O-ring to the CKP sensor spacer.
9. Lubricate the O-ring with clean engine oil.

**Important:** The crankshaft position sensor spacers are machined with different timing positions. However, if the crankshaft position sensor spacer requires replacement, replace with a grade “C” spacer.

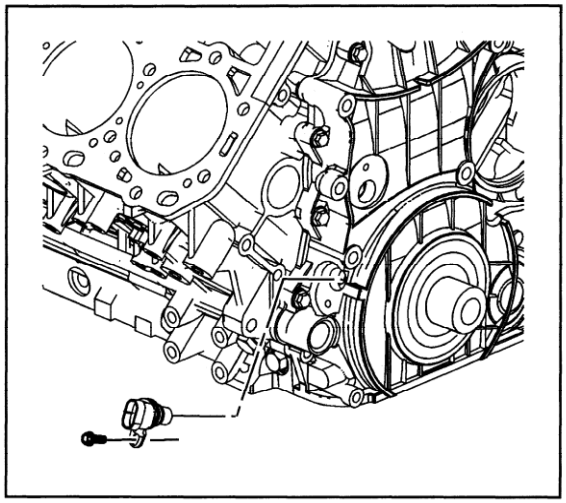
10. Install the CKP sensor spacer and bolts.

    **Tighten**

    Tighten the bolts to 10 N·m (89 lb in).
11. Install a NEW O-ring to the CKP sensor.
12. Lubricate the O-ring with clean engine oil.
13. Install the CKP sensor and bolt.

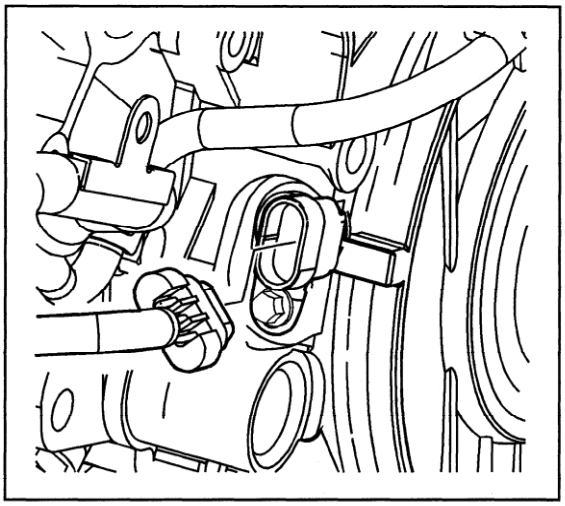
    **Tighten**

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

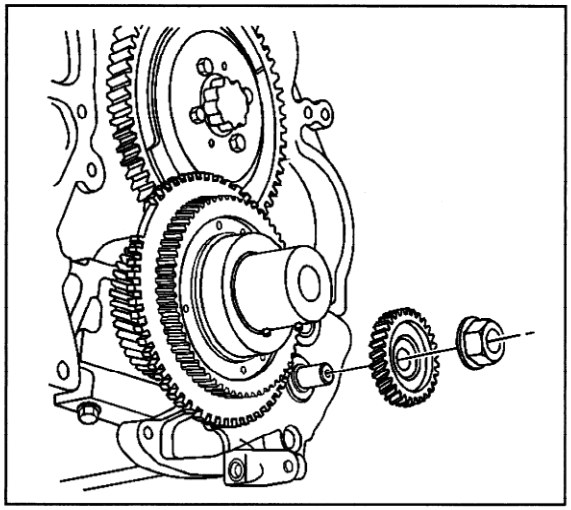


1336119

14. Connect the CKP sensor electrical connector.
15. Install the right wheelhouse panel. Refer to *Wheelhouse Panel Replacement on page 8-51* in Body Front End.
16. Install the crankshaft front oil seal. Refer to *Crankshaft Front Oil Seal Replacement on page 6-889*.
17. Install the water pump.
18. Connect the negative battery cable.



1335470



738905

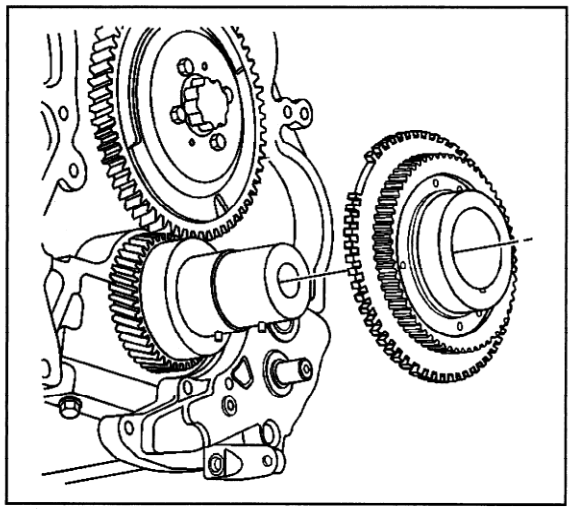
## Camshaft Reluctor Replacement

### Removal Procedure

1. Remove the engine front cover.
2. Remove the upper oil pan.

***Notice:*** 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.

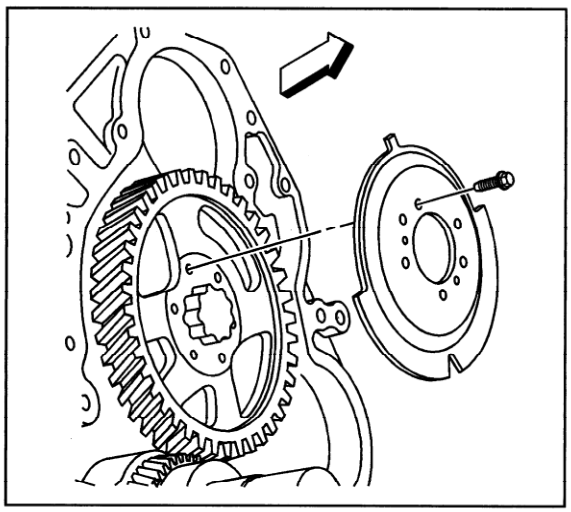
3. While holding the secondary oil pump shaft with a hex driver, remove the oil pump driven gear nut.
4. Remove the oil pump driven gear.



738904

**Important:** DO NOT remove the reluctor from the oil pump drive gear. The reluctor is timed to the gear and once removed the correct timing will be lost.

5. Remove the oil pump drive gear and crankshaft sensor reluctor.



739316

6. Remove the camshaft reluctor screws.
7. Remove the camshaft reluctor.
8. Clean and Inspect the camshaft reluctor for damage. Replace the reluctor if damage is found.

## Installation Procedure

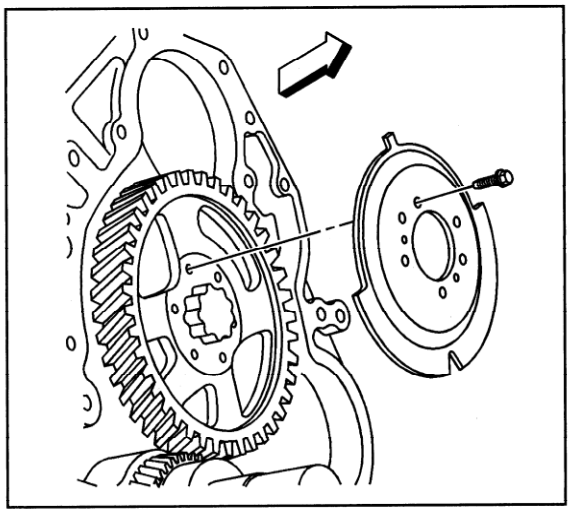
1. Position the camshaft reluctor to the camshaft gear.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

2. Install the camshaft reluctor bolts.

   **Tighten**

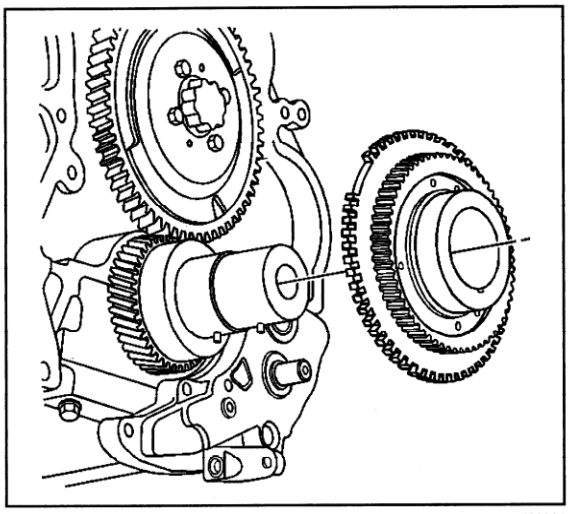
   Tighten the bolts to 9 N·m (80 lb in).



739316

**Important:** Do not damage the teeth on the reluctor.

3. Install the oil pump drive gear and reluctor to the crankshaft.



738904

4. Install the oil pump driven gear.

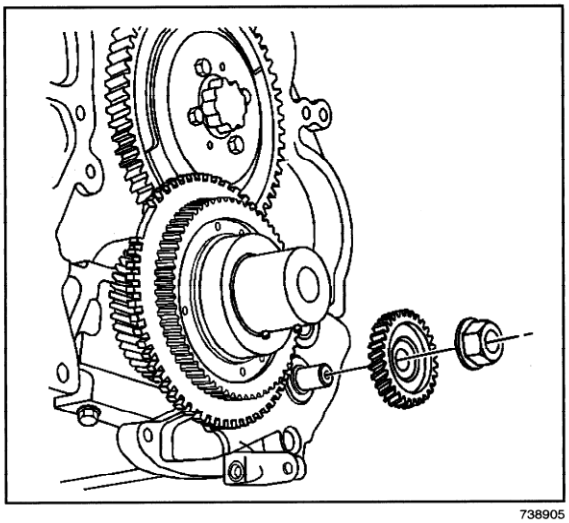
***Notice:*** Do not use an impact driver to remove or install the oil pump driven gear nut. Use of an impact driver may shear the oil pump drive gear pin in the crankshaft.

5. While holding the secondary oil pump shaft with a hex driver, install the oil pump driven gear nut.

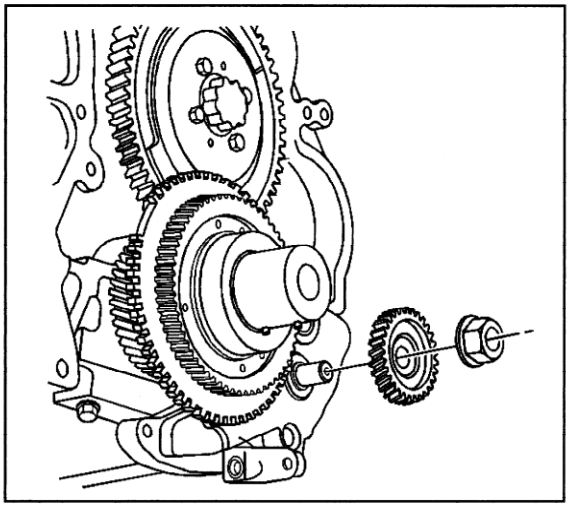
   **Tighten**

   Tighten the nut to 100 N·m (74 lb ft).

6. Install the upper oil pan.
7. Install the engine front cover.



738905



738905

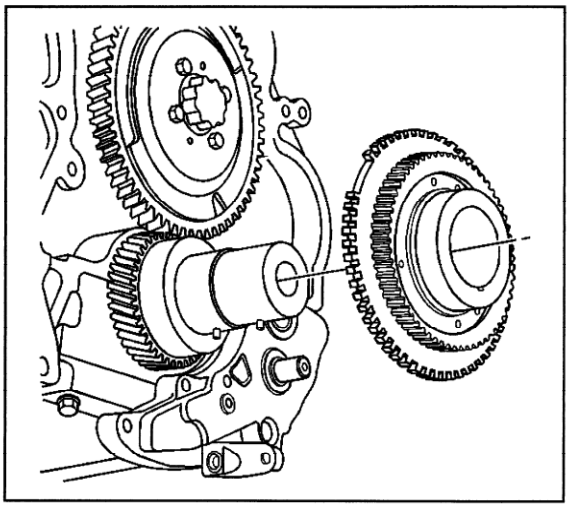
## Crankshaft Reluctor and Oil Pump Drive Gear Replacement

### Removal Procedure

1. Remove the upper oil pan.
2. Remove the engine front cover.

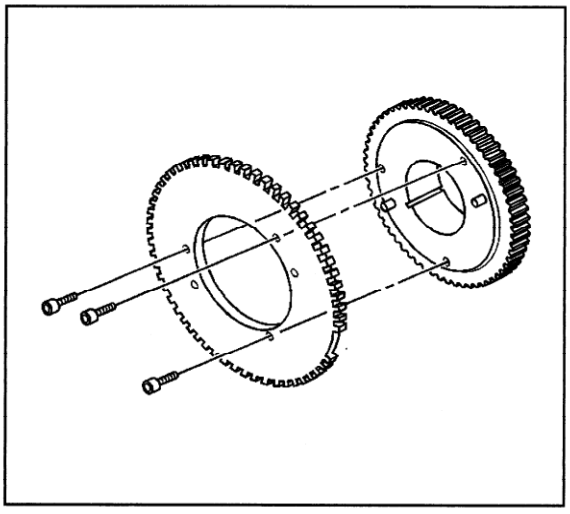
***Notice:*** Do not use an impact driver to remove or install the oil pump driven gear nut. Use of an impact driver may shear the oil pump drive gear pin in the crankshaft.

3. While holding the secondary oil pump shaft with a hex driver, remove the oil pump driven gear nut.
4. Remove the oil pump driven gear.



738904

5. Remove the oil pump drive gear and crankshaft sensor reluctor. Do not damage the crankshaft reluctor teeth.



739296

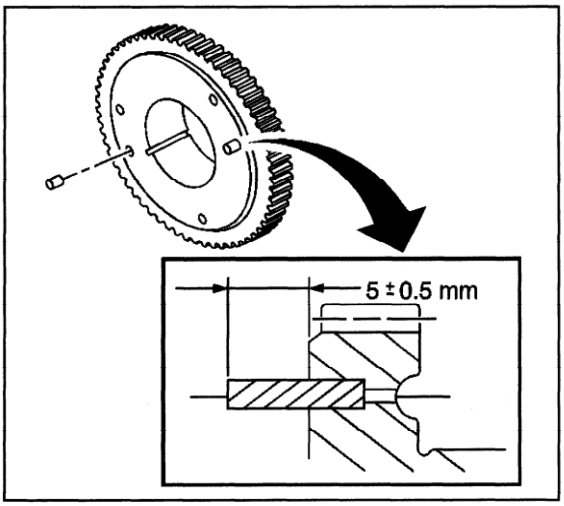
**Important:** Do not remove the reluctor from the oil pump drive gear unless replacing the reluctor or the oil pump drive gear. The reluctor is timed to the gear and once removed the correct timing will be lost.

6. Remove the crankshaft reluctor to oil pump drive gear bolts.
7. Inspect the crankshaft reluctor for the damage, bent teeth, being bent or warped.
8. Inspect the oil pump drive gear for damaged or worn teeth.
9. Inspect the oil pump drive gear crankshaft pin for wear.
10. Inspect the groove of the crankshaft pin in the oil pump drive gear for wear.
11. Replace any parts that are damaged or worn.

## Installation Procedure

**Important:** The crankshaft reluctor and the oil pump drive gear are timed at the factory. In order to re-establish proper timing, install knock pins in the oil pump drive gear if the crankshaft reluctor was removed from the oil pump drive gear. The knock pins are available through the parts department.

1. Install the knock pins in the oil pump drive gear to a height of 4.5–5.5 mm (0.177–0.217 in)

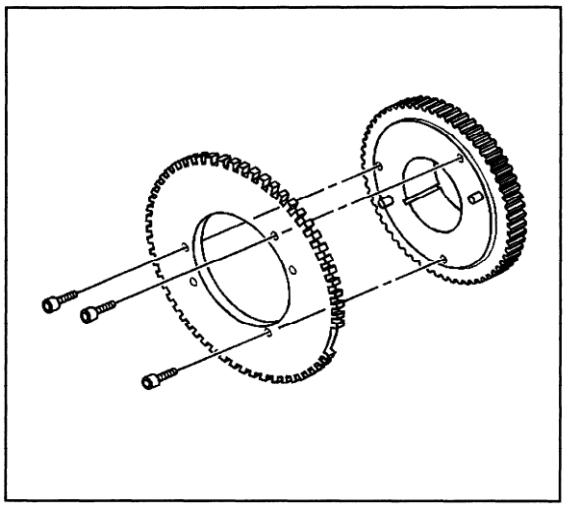


739295

2. Install the crankshaft reluctor on the oil pump drive gear. Ensure the reluctor is aligned on the knock pins.
3. Install the crankshaft reluctor bolts.

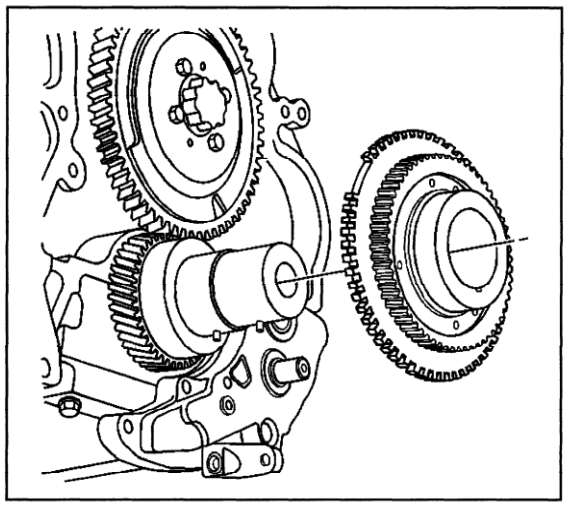
   **Tighten**

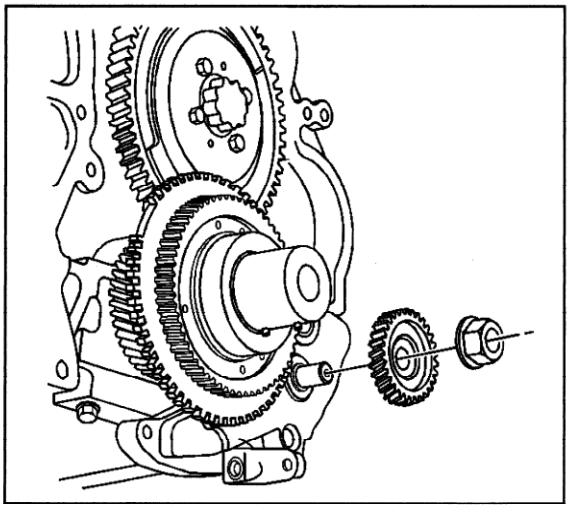
   Tighten the bolts to 8 N·m (71 lb in).


739296

**Important:** Do not damage the teeth on the crankshaft reluctor.

4. Install the oil pump drive gear and reluctor to the crankshaft.


738904



738905

5. Install the oil pump driven gear.

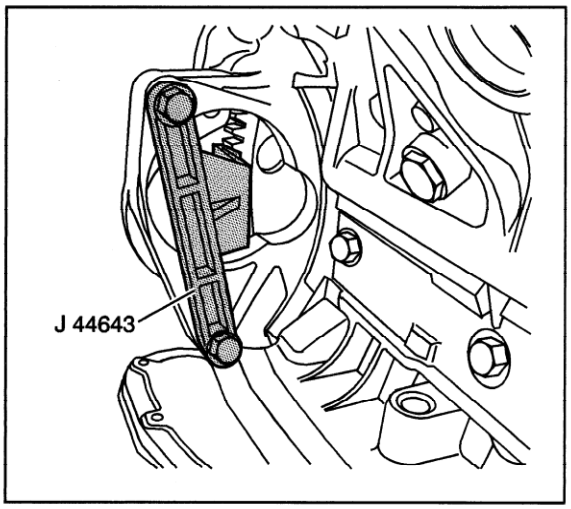
***Notice:*** Do not use an impact driver to remove or install the oil pump driven gear nut. Use of an impact driver may shear the oil pump drive gear pin in the crankshaft.

6. While holding the secondary oil pump shaft with a hex driver, install the oil pump driven gear nut.

   **Tighten**

   Tighten the nut to 100 N·m (74 lb ft).

7. Install the engine front cover.
8. Install the upper oil pan.




660308

## Camshaft Replacement

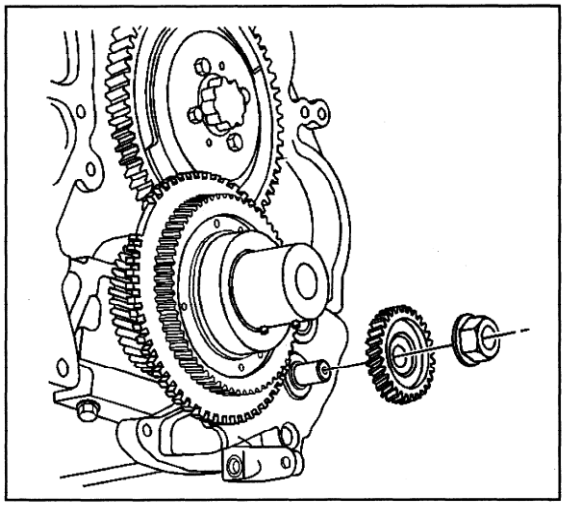
### Tools Required

- *J 44643* Flywheel Holding Tool
- *J 26900-13* Magnetic Base
- *J 26900-12* Dial Indicator

## Removal Procedure

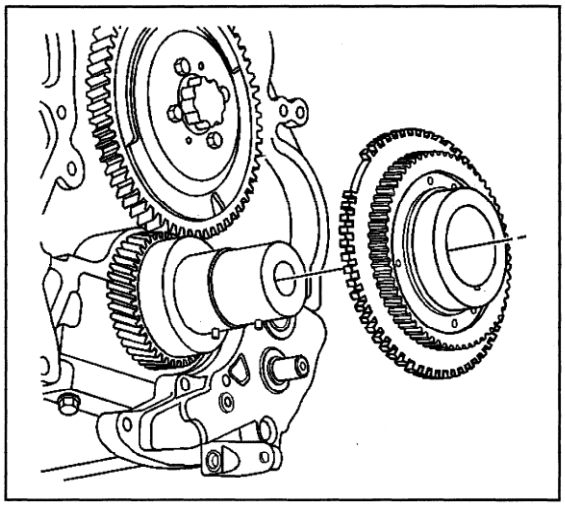
1. Remove the valve lifters.
2. Remove the charged air cooler.
3. Remove the starter.
4. Install *J 44643* flush to the flywheel opening.
5. Remove the engine front cover.

7. Remove the oil pump driven gear nut.
8. Remove the oil pump driven gear.

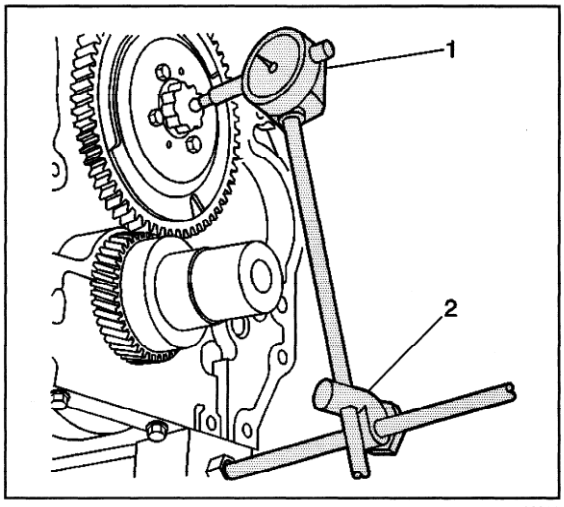

738905

**Important:** The crankshaft reluctor and the oil pump drive gear are timed together at the factory. Do not remove the crankshaft reluctor from the oil pump drive gear.

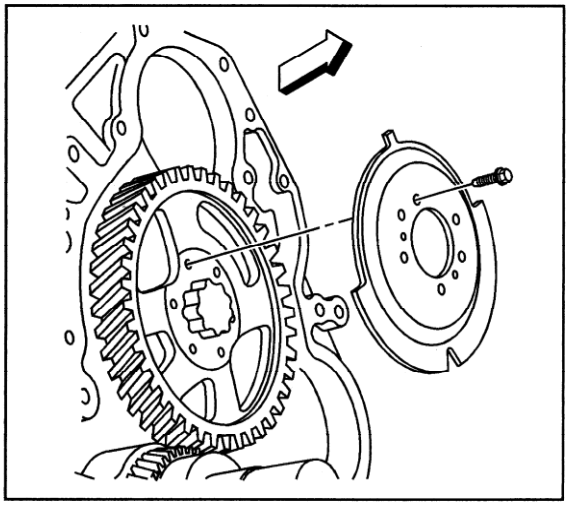
9. Remove the oil pump drive gear and crankshaft reluctor.
   - Do not remove the crankshaft reluctor bolts.
   - Do not damage the reluctor teeth.


738904

10. Using *J 26900-12* (1) and *J 26900-13* (2), measure the camshaft end play.
    - 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 gear or the camshaft thrust plate if measured value exceeds service limit.

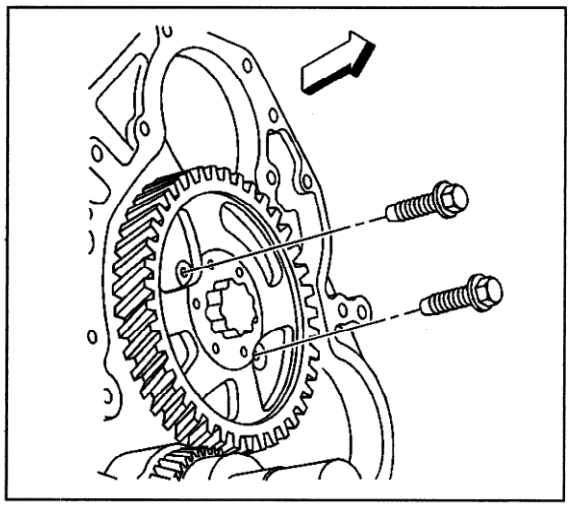


738903



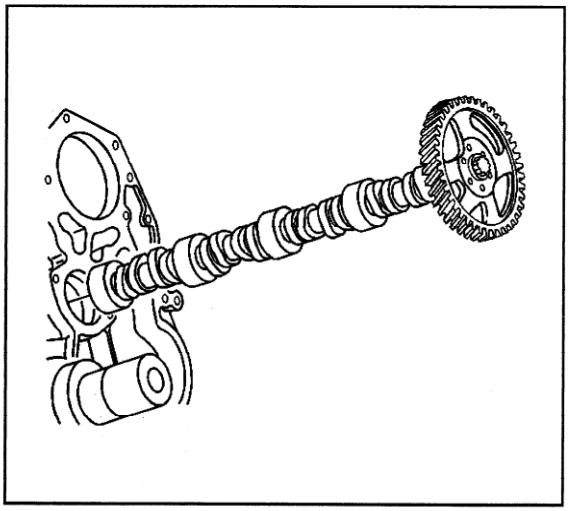
739316

11. Remove the camshaft reluctor screws.
12. Remove the camshaft reluctor.



738902

13. In order to loosen the camshaft gear bolt use *J 44643* in order to hold the engine from turning.
14. Loosen the camshaft gear bolt and leave the bolt finger tight.
15. Remove the camshaft thrust plate bolts through the holes in the camshaft gear.

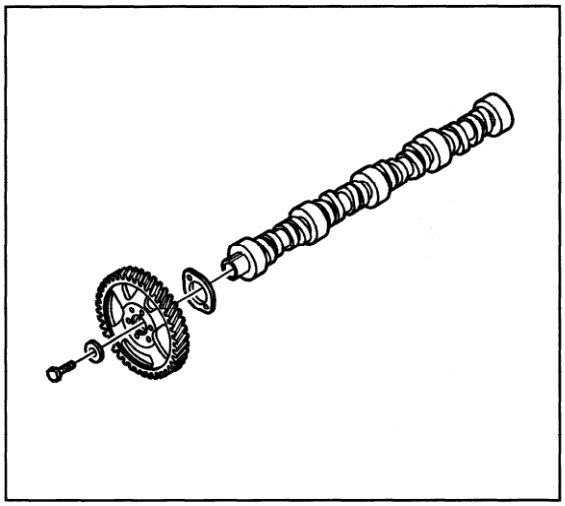


738901

16. Remove the camshaft with the camshaft gear attached.

17. Remove the camshaft gear bolt and discard.
18. Remove the camshaft gear.
19. Remove the camshaft thrust plate.
20. Clean and inspect the camshaft and bearings.

    If the camshaft bearings are worn or damaged the engine will require removal in order to replace the camshaft bearings.

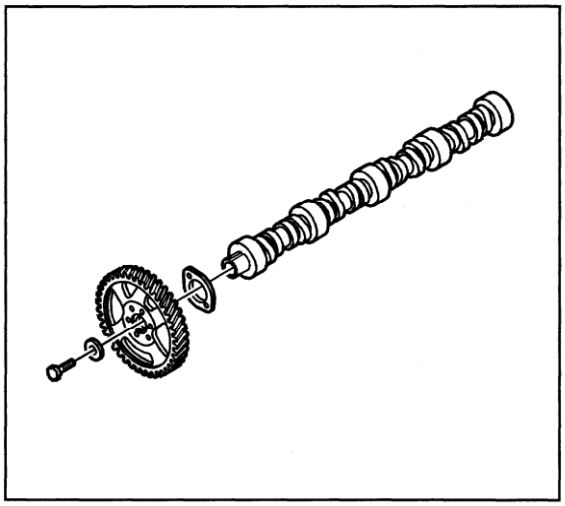


660540

## Installation Procedure

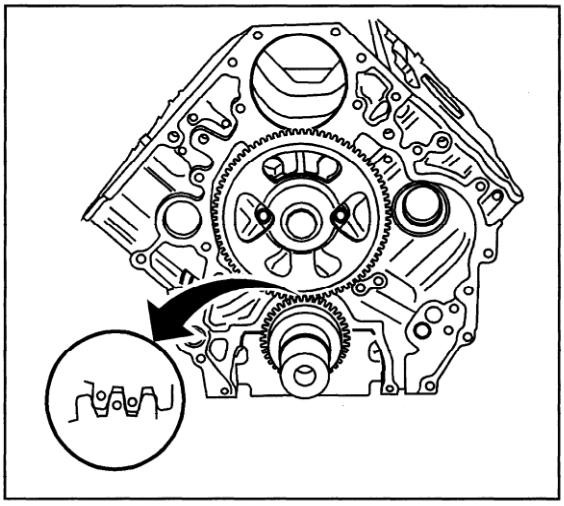
1. Install the camshaft thrust plate to the camshaft.
2. Install the camshaft driven gear.
3. Install a NEW camshaft driven gear bolt.

   Leave the bolt finger tight.

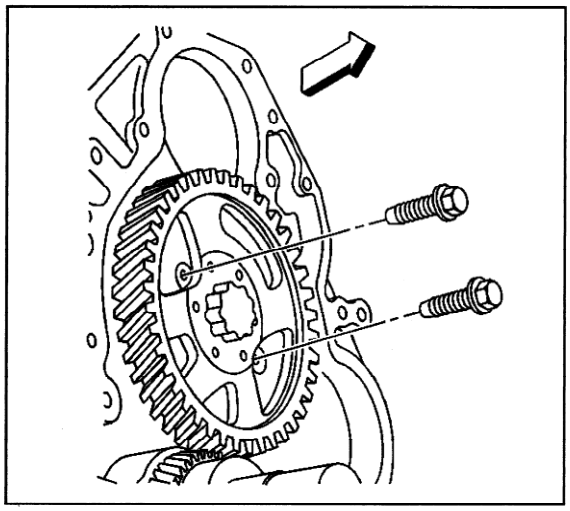


660540

4. Install the camshaft into the cylinder block, align the camshaft gear to the crankshaft gear as shown.



663813

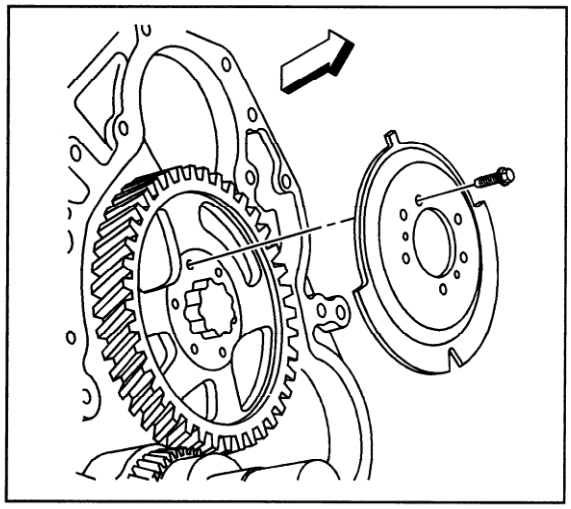


738902

5. Apply threadlock to the threads of the camshaft thrust plate bolts.
6. Install the camshaft thrust plate bolts.

   **Tighten**

   Tighten the bolts to 22 N·m (16 lb ft).

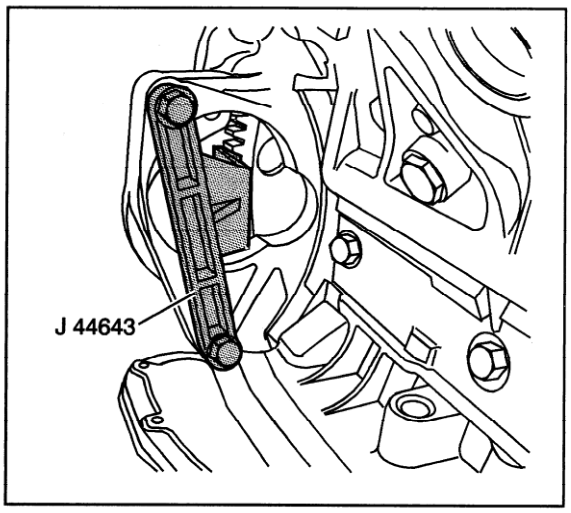


739316

7. Install the camshaft reluctor to the camshaft gear.
8. Install the camshaft reluctor bolts.

   **Tighten**

   Tighten the bolts in a cross-bolt pattern to 9 N·m (80 lb in).



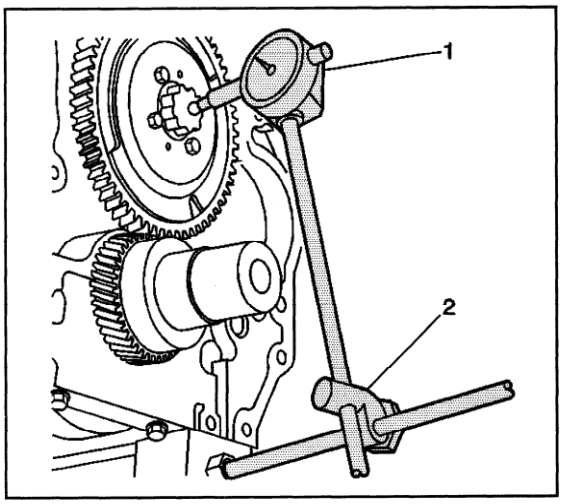

660308

9. Reinstall *J 44643* in the starter opening, if removed.
10. Install a NEW camshaft gear bolt.

    **Tighten**

    Tighten the bolt to 234 N·m (173 lb ft).

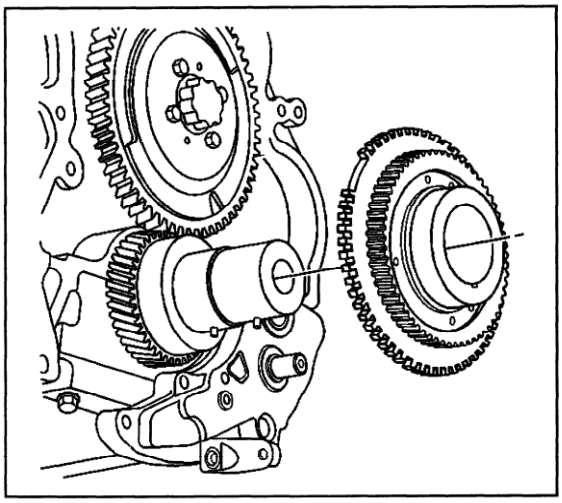
11. Using *J 26900-12* (1) and *J 26900-13* (2) measure the camshaft end play.
    - The production value is 0.050–0.114 mm (0.002–0.0045 in) and service limit is 0.20 mm (0.008 in).
    - Replace the camshaft gear or the camshaft thrust plate if measured value exceeds the service limit.



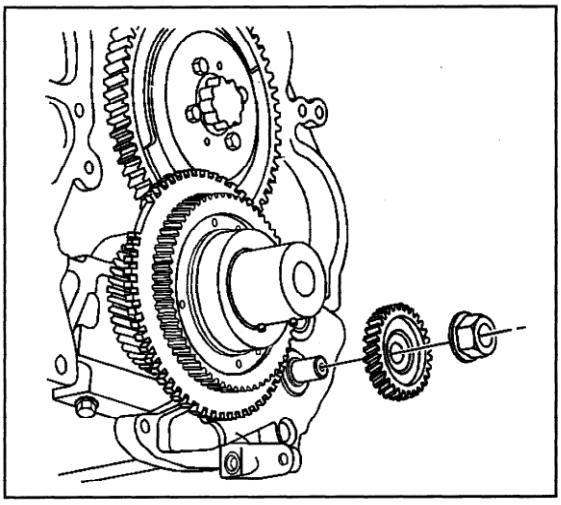
738903

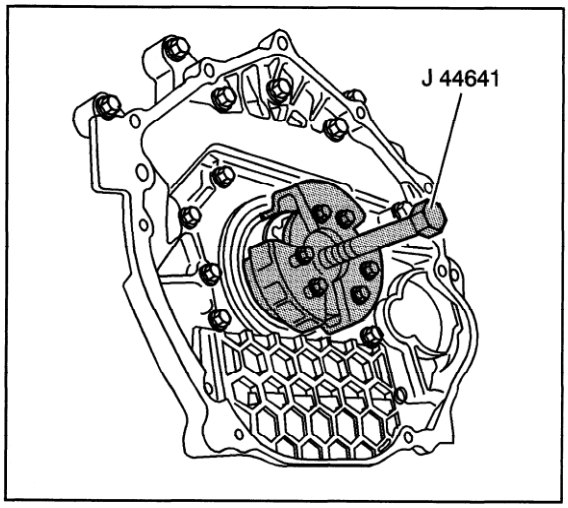
**Important:** Do not damage the teeth on the crankshaft reluctor.

12. Install the oil pump drive gear and reluctor to the crankshaft.


738904

13. Install the oil pump driven gear.
14. Install the oil pump driven gear nut.
    **Tighten**
    Tighten the nut to 100 N·m (74 lb ft).
15. Install the engine front cover.
16. Install the starter.
17. Install the charged air cooler.
18. Install the valve lifters.


738905



660312

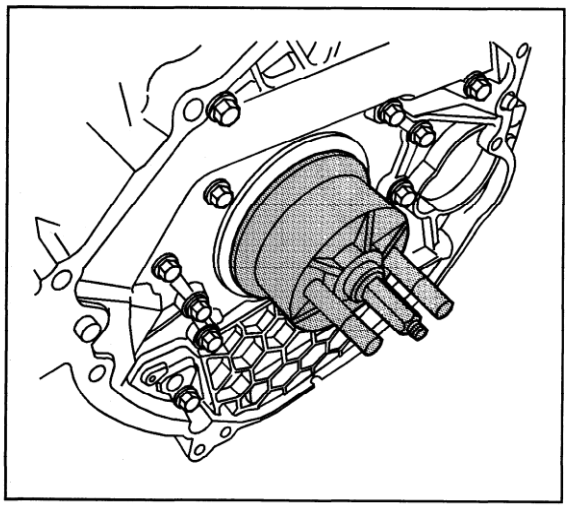
## Crankshaft Rear Oil Seal Replacement

### Tools Required

- *J 44641* Crankshaft Rear Oil Seal Remover
- *J 44642* Crankshaft Rear Oil Seal Installer

### Removal Procedure

1. Remove the flywheel.
2. Clean the area around the crankshaft rear oil seal.
3. Install *J 44641* to the crankshaft rear oil seal.
4. Remove the crankshaft rear oil seal using *J 44641*.

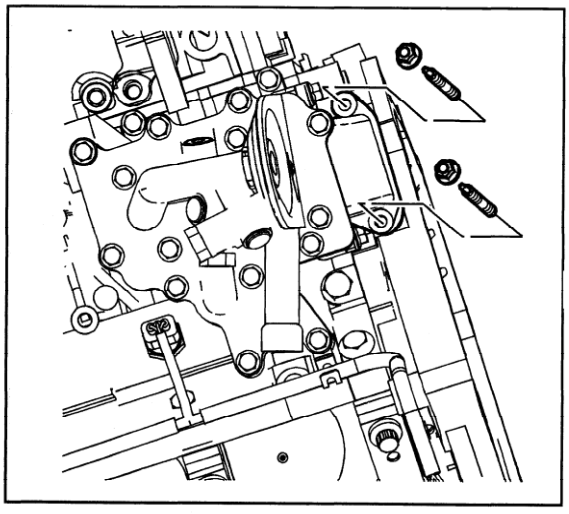

663925

### Installation Procedure

1. Ensure that the crankshaft is free of oil and dirt.
2. Clean the seal bore in the flywheel housing.
3. Position the crankshaft rear oil seal onto the crankshaft.

**Important:** *J 44642* must be fully secured to the crankshaft to ensure proper seal depth.

4. Install *J 44642* to the crankshaft.
5. Press the crankshaft rear oil seal into position using *J 44642*, the tool will bottom out when the seal reaches the proper depth.
6. Remove *J 44642*.
7. Install the flywheel.


1334852

## Engine Flywheel Housing Replacement

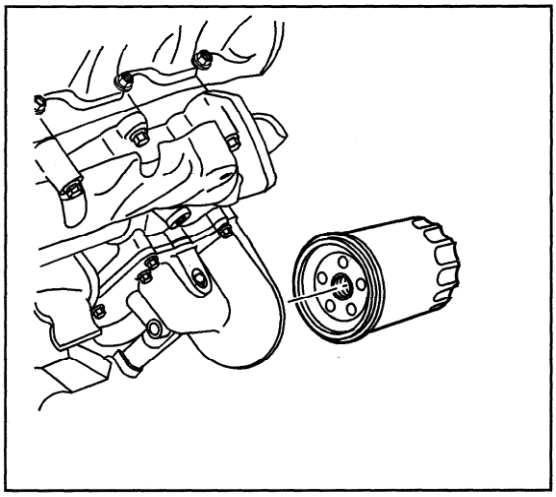
### Tools Required

*J 37228* Seal Cutter

### Removal Procedure

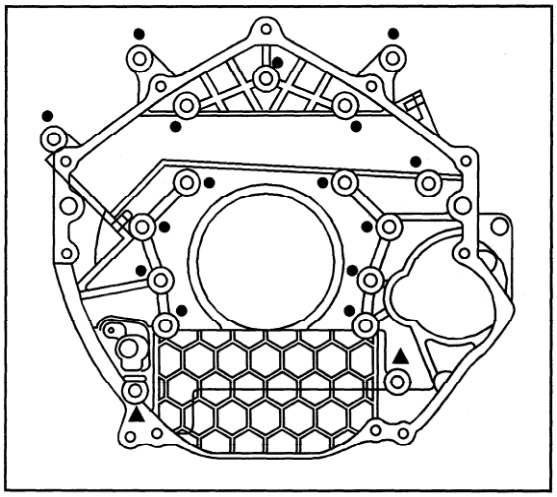
1. Drain the cooling system. Refer to *Draining and Filling Cooling System*
2. Remove the crankshaft rear oil seal.
3. Remove the turbocharger oil return pipe nuts from the top of the flywheel housing.

4. Remove the upper oil pan.
5. Remove the oil filter.



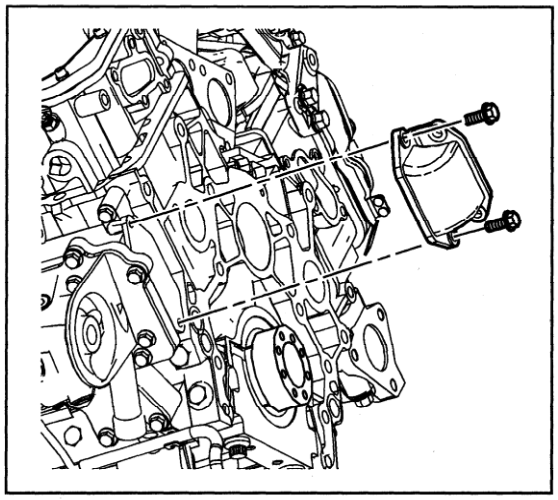
660299

6. Remove the flywheel housing bolts, denoted by the black circles.
7. Separate the flywheel from the cylinder block using *J 37228*.
8. Remove the flywheel housing.

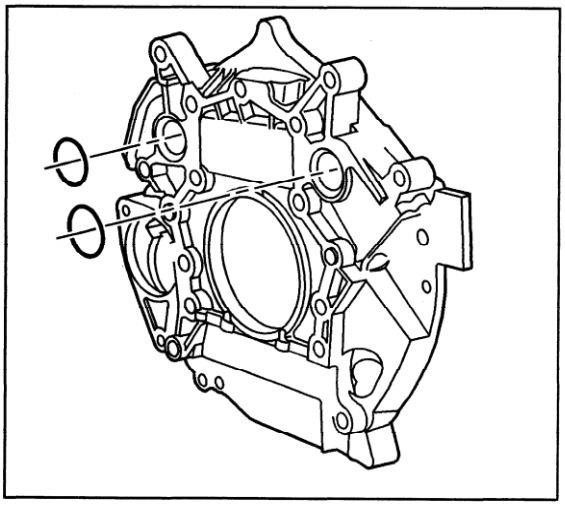


660335

9. Remove the turbocharger oil return pipe gasket from the flywheel housing.
10. Remove the oil cooler adapter bolts.
11. Remove the oil cooler adapter and gaskets.
12. If required, clean and inspect the flywheel housing.



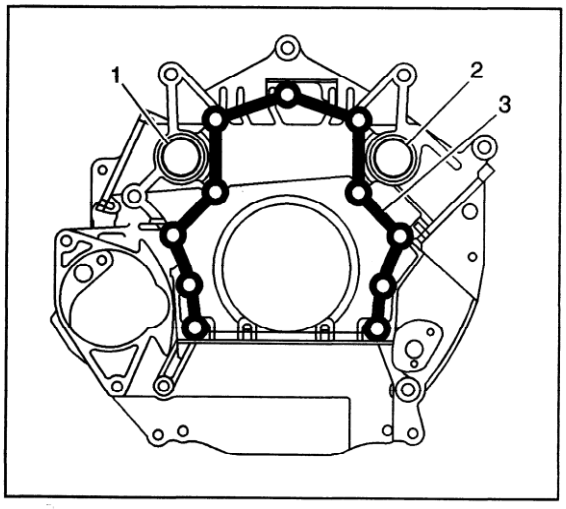
1334855



663771

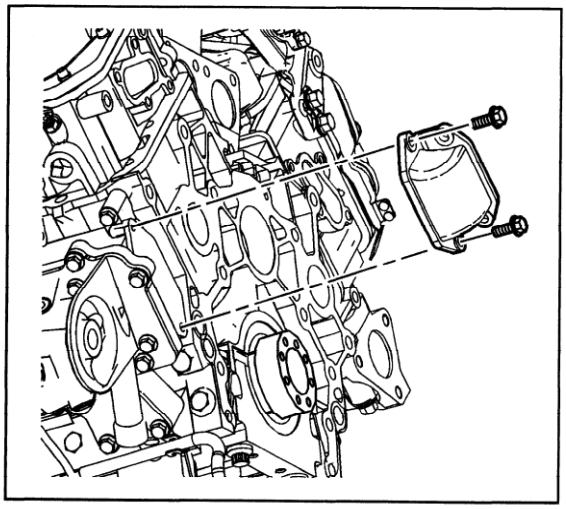
## Installation Procedure

1. Install NEW O-ring seals to the flywheel housing, if necessary.




663922

2. Apply a 2 mm (1/8 in) wide bead of sealant (3) to the flywheel housing sealing surfaces.



1334855

3. Install a NEW oil cooler adapter gasket.
4. Install a NEW oil cooler adapter to flywheel housing gasket.
5. Install the oil cooler adapter to the flywheel housing.
6. Install the oil cooler adapter bolts.

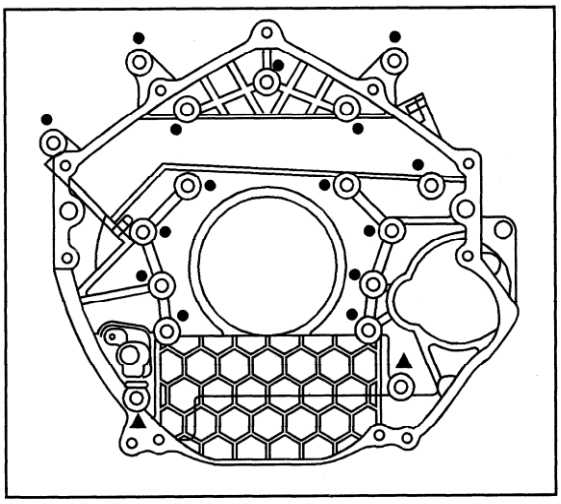
**Tighten**

Tighten the bolts/nuts to 21 N·m (15 lb ft).

7. Install the flywheel housing bolts, denoted by the black circles.

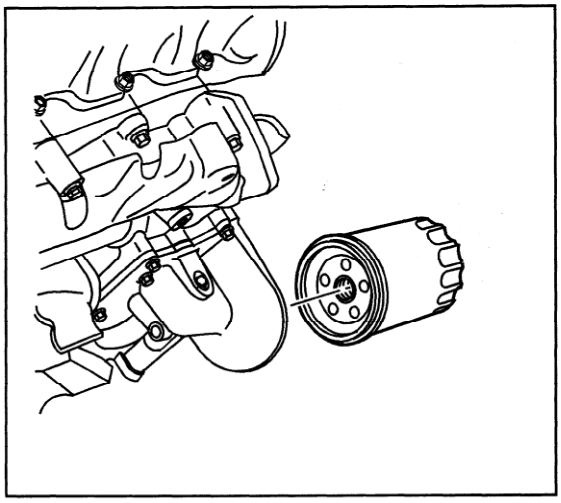
   **Tighten**

   Tighten the bolts to 90 N·m (67 lb ft).



660335

8. Install the oil filter.
9. Install the upper oil pan.

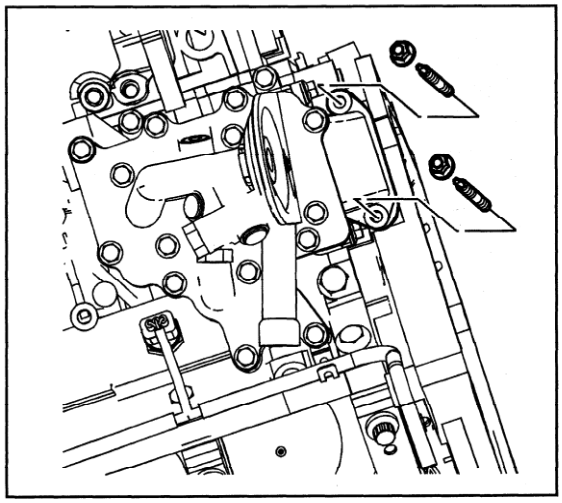


660299

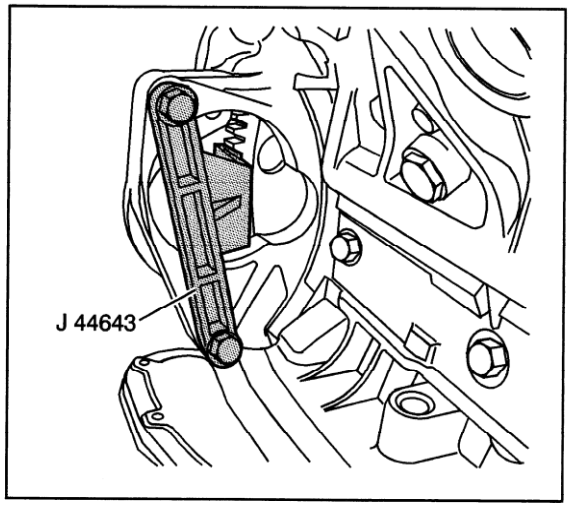
10. Install a NEW gasket to the turbocharger oil return pipe.
11. Install the turbocharger oil return pipe to flywheel housing nuts.

    **Tighten**

    Tighten the nuts to 21 N·m (15 lb ft).
12. Install the crankshaft rear oil seal.
13. Fill the cooling system.



1334852




660308

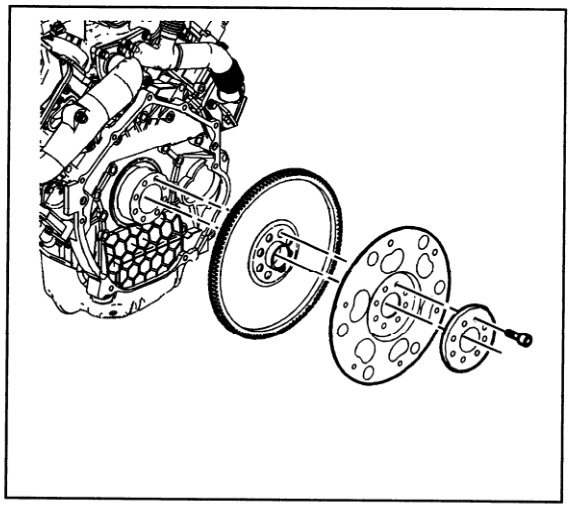
## Engine Flywheel Replacement (Automatic Transmission)

### Tools Required

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

### Removal Procedure

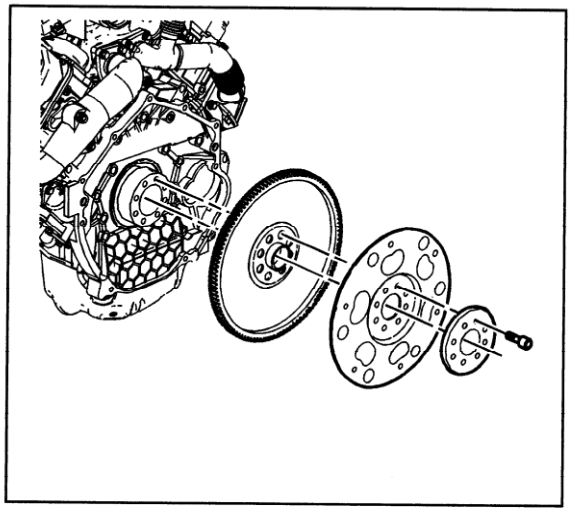
1. Remove the transmission.
2. Install *J 44643* in order to hold the flywheel.



1334818

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

3. Remove and discard the flywheel bolts.
4. Remove the flywheel washer and flywheel.



1334818

### Installation Procedure

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

**Important:** When installing the flywheel, ensure that the tapered side of the teeth are facing the starter.

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

***Notice:*** 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.

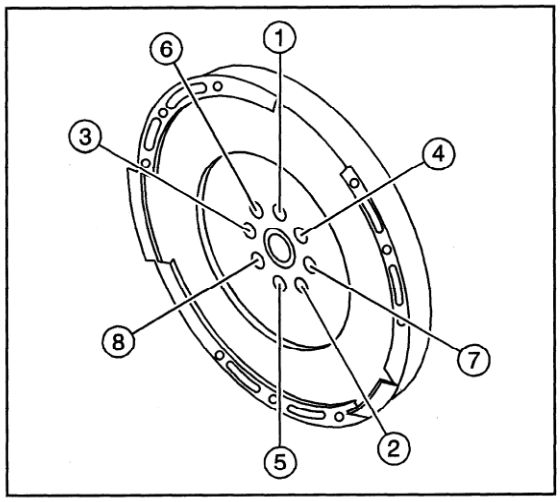
4. Tighten the flywheel bolts in the proper sequence.

   **Tighten**

   4.1. Tighten the bolts a first pass to 79 N·m (58 lb ft).

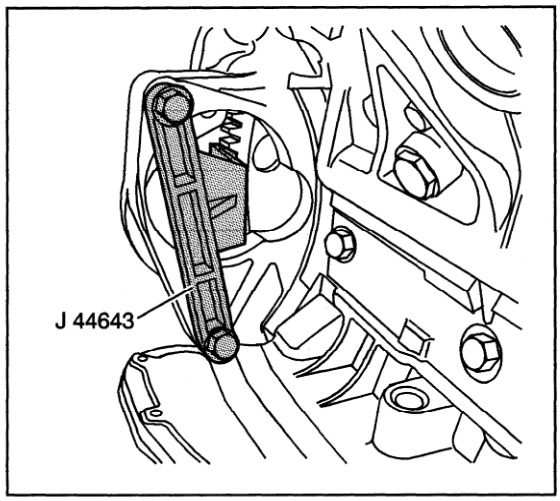
   4.2. Tighten the bolts a second pass to 60 degrees using *J 45059*.

   4.3. Tighten the bolts a final pass an additional 60 degrees using *J 45059*.

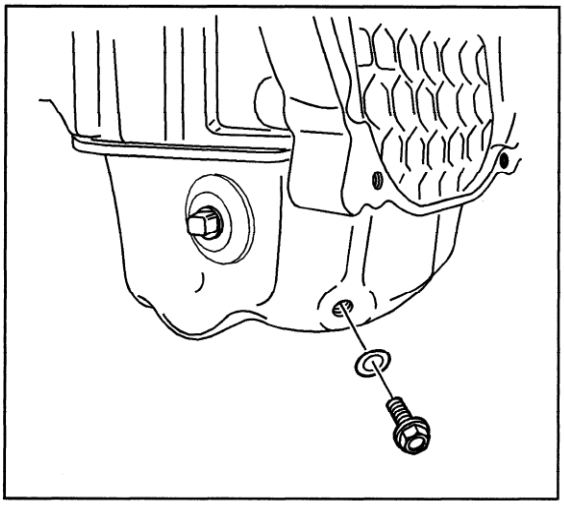


663928

5. Remove *J 44643* from the flywheel.
6. Install the transmission.



660308



660296

## Oil Pan Replacement - Lower

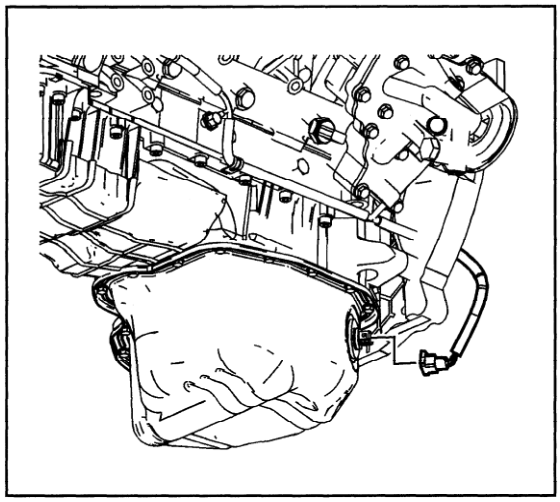
### Tools Required

*J 37228* Seal Cutter

### Removal Procedure

1. Remove engine from vessel.
2. Place a suitable container under the engine in order to drain the oil.
3. Remove the oil drain plug.
4. Drain the engine oil.

5. Disconnect the oil level sensor electrical connector.

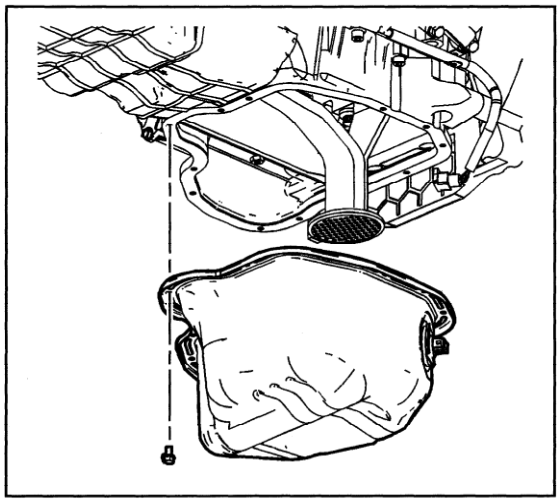


1334843

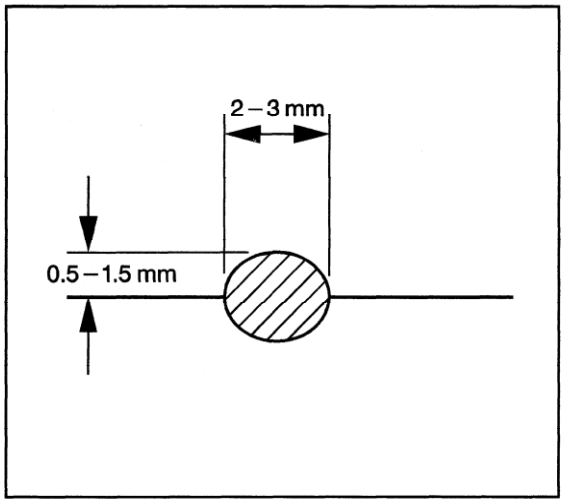
6. Remove the lower oil pan bolts/nuts.

**Important:** DO NOT damage the sealing surfaces when separating the lower oil pan from the upper oil pan.

7. Separate the lower oil pan from the upper oil pan using *J 37228*.
8. Remove the lower oil pan.
9. If necessary, clean and inspect the lower oil pan.



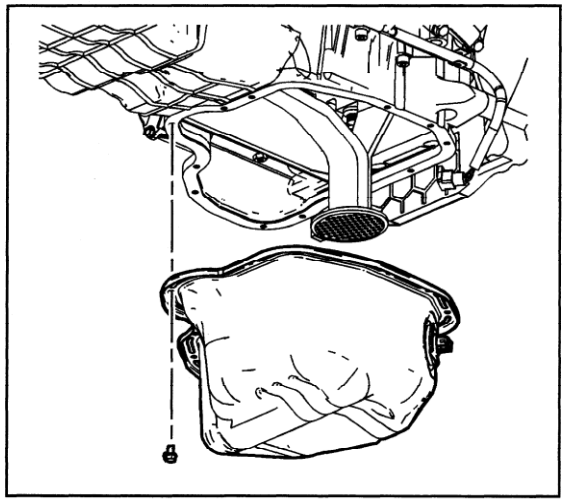
1334845



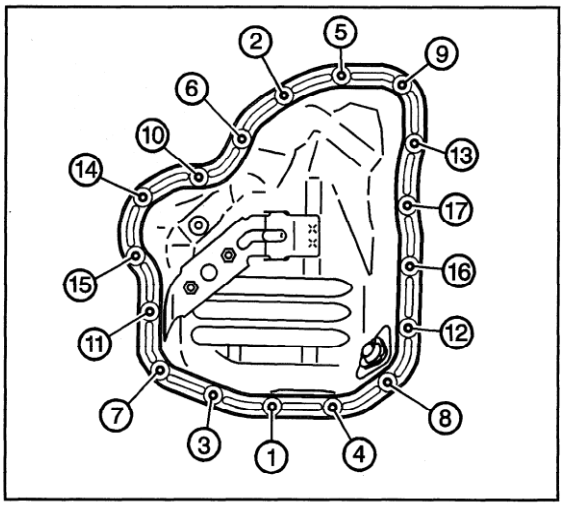
663817

## Installation Procedure

1. Apply a 2–3 mm (0.79–0.118 in) by 0.5–1.5 mm (0.02–0.06 in ) wide bead of sealant to the lower oil pan mating surface. Refer to *Sealers, Adhesives, and Lubricants*


1334845

2. Install the lower oil pan.
3. Install the lower oil pan bolts/nuts.



793979

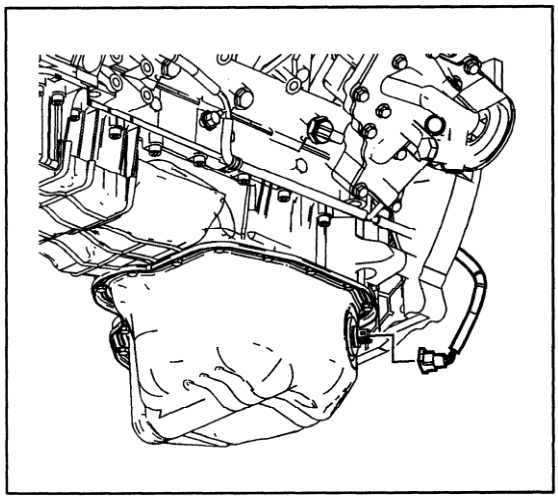
***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

4. Tighten the oil pan bolts/nuts in the sequence shown.

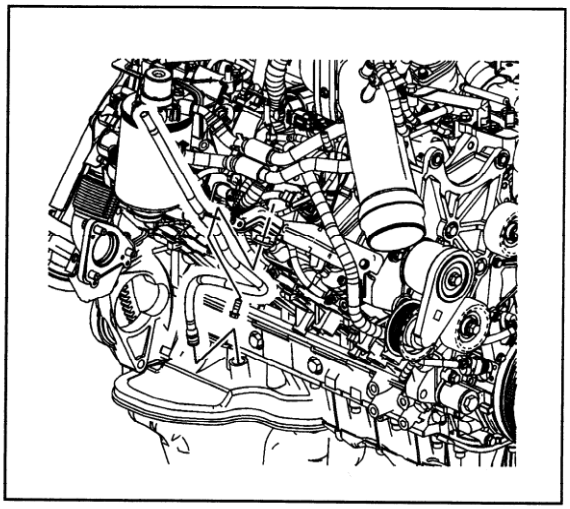
   **Tighten**

   Tighten the bolts/nuts to 10 N·m (89 lb in).

5. Connect the oil level sensor electrical connector.
6. Install NEW engine oil and a oil filter. Refer to *Engine Oil and Oil Filter Replacement on page 6-953*.
7. Mount engine back into vessel and check drive system alignment.



1334843



1602062

## Oil Pan Replacement - Upper

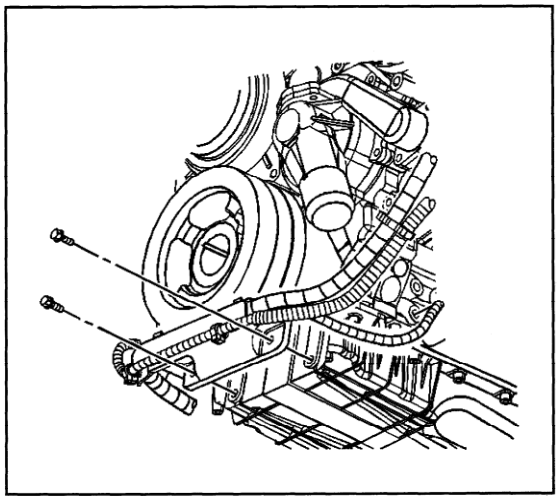
### Tools Required

*J 37228* Seal Cutter

### Removal Procedure

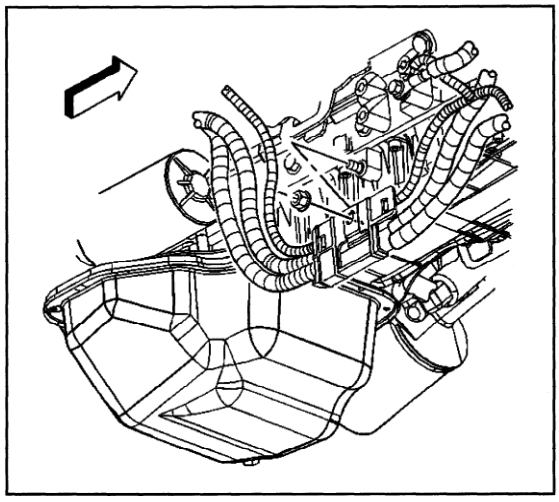
1. Remove the oil level indicator.
2. Remove the oil level indicator tube bolt from the indicator tube bracket.
3. Remove the lower oil pan. Refer to *Oil Pan Replacement*
4. Remove the engine flywheel. Refer to *Engine Flywheel Replacement*

5. Remove the battery cable bracket bolts.



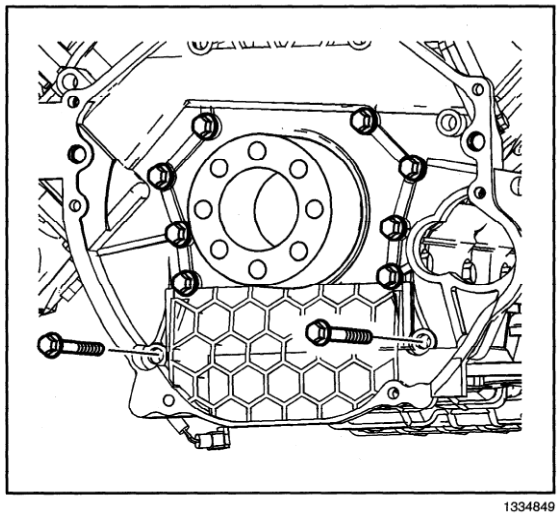
673564

6. Remove the battery cable bracket nut.

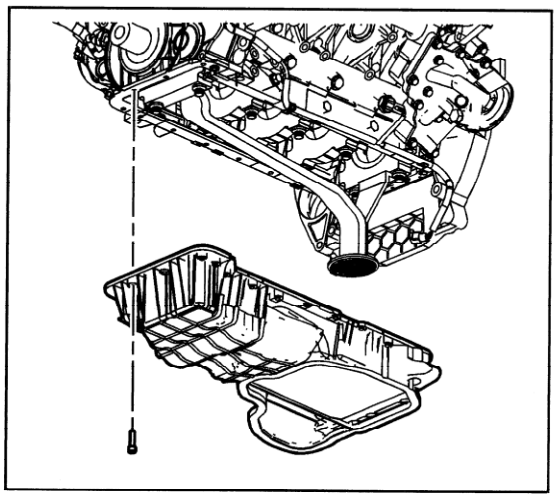


673568

7. Remove the two flywheel housing to upper oil pan bolts.

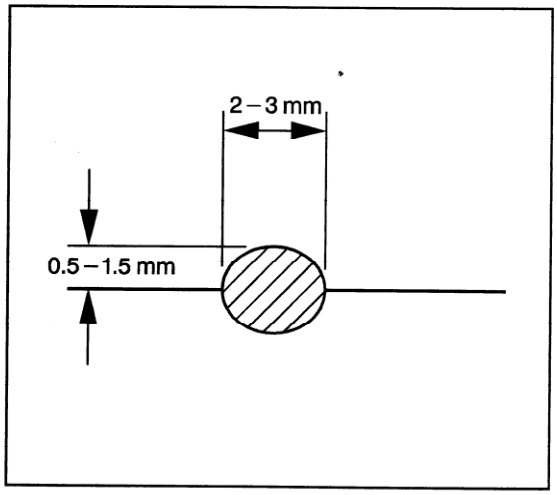


1334849



1334851

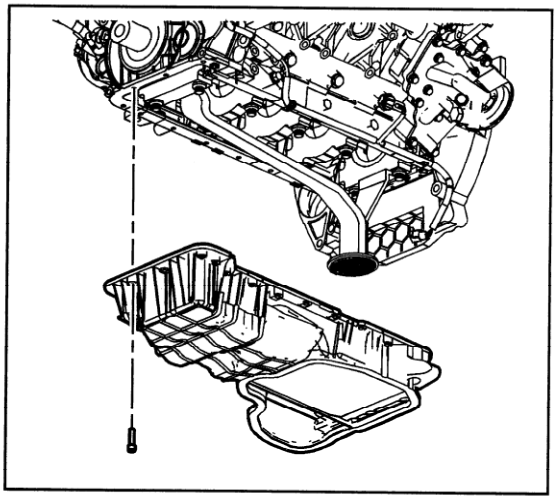
8. Remove the upper oil pan bolts and any brackets. Mark the bolt location of the bracket.
9. Separate the upper oil pan from the engine block using *J 37228*.
10. Remove the upper oil pan. The oil level indicator tube needs to be removed while lowering the upper oil pan.
11. If required, clean and inspect the upper oil pan.




663817

## Installation Procedure

1. Apply a 2–3 mm (0.79–0.118 in) wide by 0.5–1.5 mm (0.02–0.06 in) bead of sealant to the upper oil pan mating surfaces. Refer to *Sealers, Adhesives, and Lubricants*
2. Apply a 2–3 mm (0.79–0.118 in) wide by 0.5–1.5 mm (0.02–0.06 in) bead of sealant to the flywheel housing sealing surface. Refer to *Sealers, Adhesives, and Lubricants*



1334851

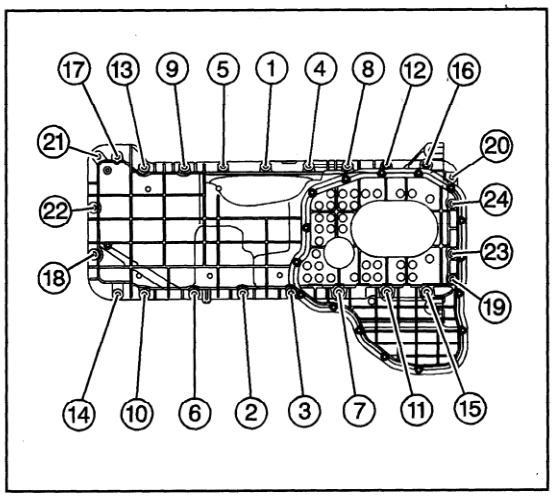
3. Install the upper oil pan to the engine block. Ensure the oil level indicator tube is installed into the upper oil pan.

***Notice:*** Refer to *Fastener Notice*

4. Install any brackets and the upper oil pan bolts in the sequence shown.

   **Tighten**

   Tighten the bolts to 20 N·m (15 lb ft).

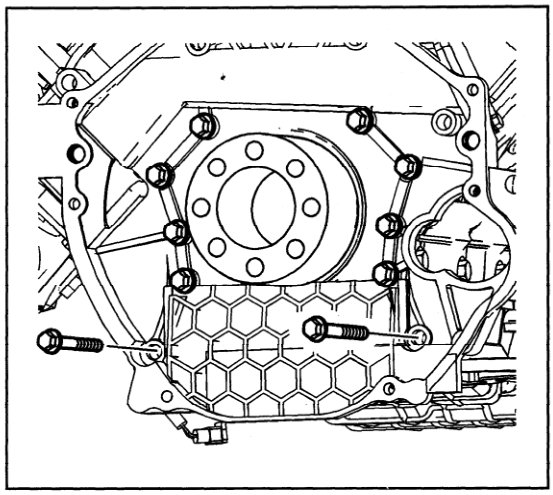



663823

5. Install the two flywheel housing to upper oil pan bolts.

   **Tighten**

   Tighten the bolts to 50 N·m (37 lb ft).

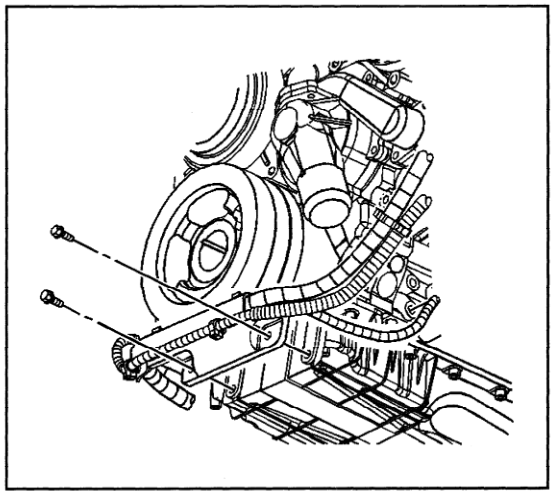


1334849

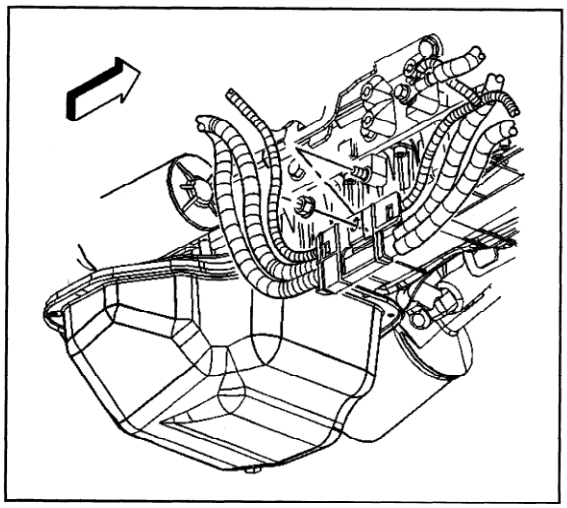
6. Install the battery cable bracket bolts.

   **Tighten**

   Tighten the bolts to 12 N·m (106 lb in).



673564

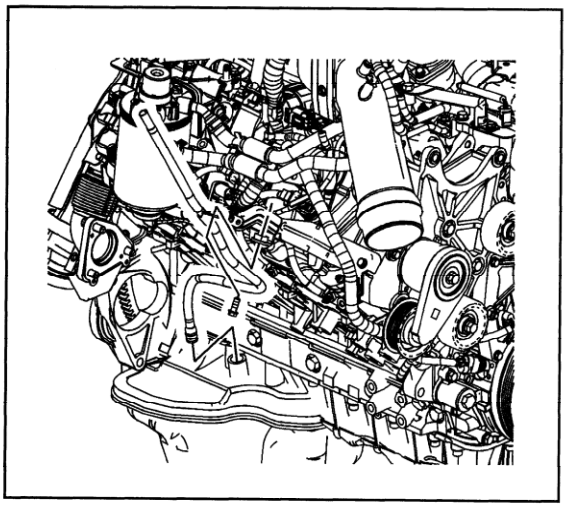


673568

7. Install the battery cable bracket nut.

   **Tighten**

   Tighten the nut to 8 N·m (71 lb in).



1602062

8. Install the engine flywheel.
9. Install the lower oil pan. Refer to *Oil Pan Replacement*
10. Mount engine back into vessel and check drive system alignment.
11. Install the oil level indicator tube bolt to the indicator tube bracket.

    **Tighten**

    Tighten the bolt to 21 N·m (15 lb ft).
12. Install the oil level indicator.
13. Fill the engine with oil. Refer to *Engine Oil and Oil Filter Replacement*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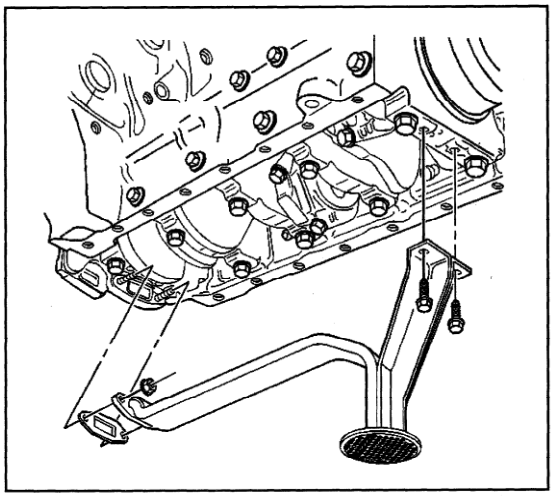
## Oil Pump Replacement

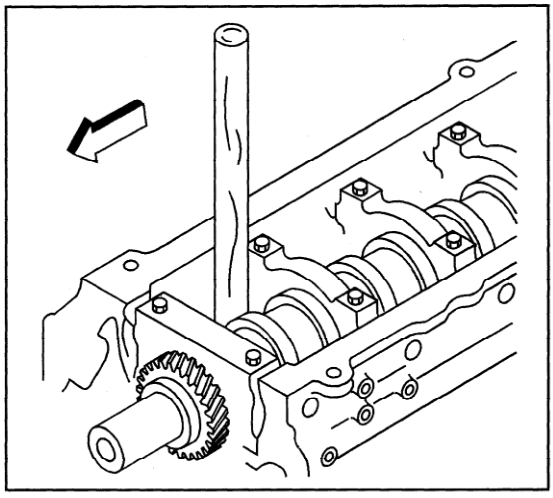
### Removal Procedure

1. Remove the flywheel housing. Refer to *Engine Flywheel Replacement*
2. Remove the engine front cover. Refer to *Engine Front Cover Replacement*
3. Remove the upper oil pan. Refer to *Oil Pan Replacement*
4. Remove the oil pump screen bolts and nuts.
5. Remove the oil pump screen.
6. Remove and discard the oil pump screen gasket.



738908

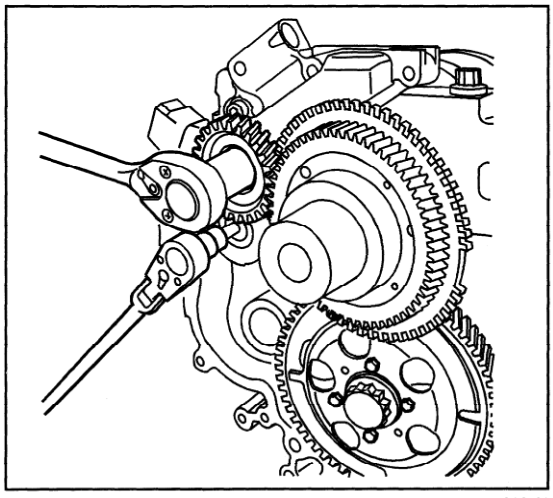
7. Block the crankshaft from turning with a wooden handle.



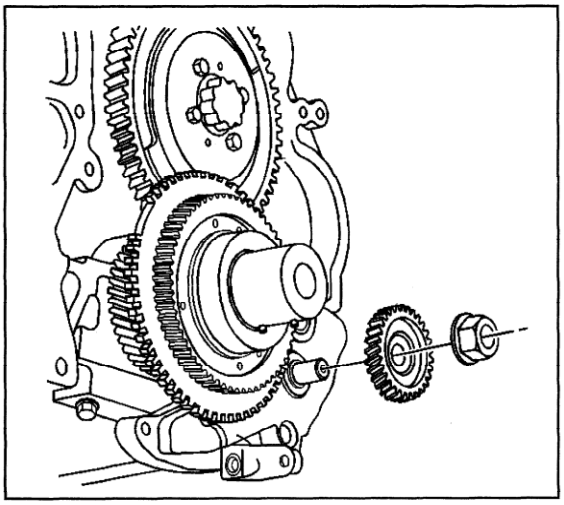
660539

**Important:** 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.

8. While holding the secondary oil pump shaft with a hex driver, remove the oil pump driven gear nut.

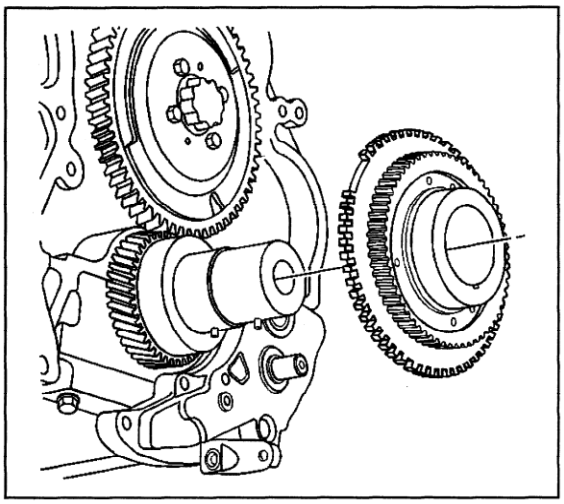


776631



738905

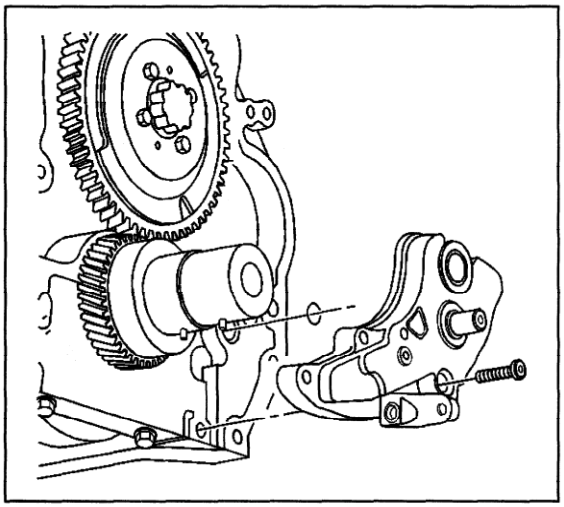
9. Remove the oil pump driven gear.



738904

**Important:** Do not damage the crankshaft reluctor. Do not remove the crankshaft reluctor to oil pump drive bolts.

10. Remove the oil pump drive gear and crankshaft reluctor.
    - Use a brass drift.
    - Tap on the back as close to the center of the reluctor.



738906

11. Remove the hex head and the allen head bolt in order to remove the oil pump.
12. Remove the oil pump.
13. Remove the O-ring seal for the oil pump.
14. If required, clean and inspect the oil pump.

## Installation Procedure

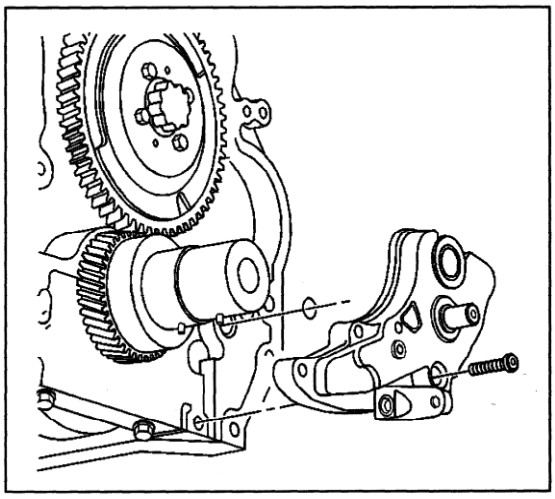
1. Install a NEW oil pump O-ring seal.
2. Install the oil pump.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

3. Install the oil pump bolts.

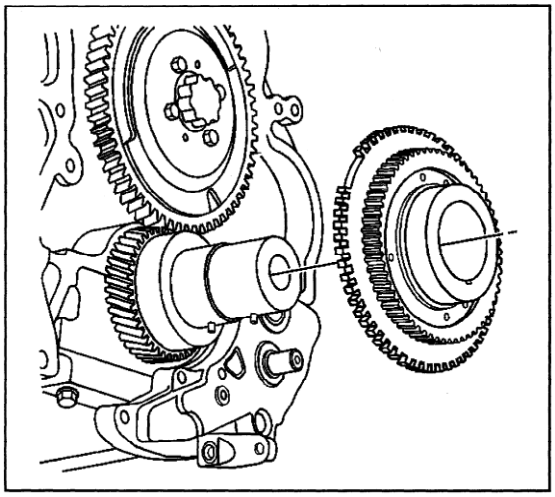
   **Tighten**

   Tighten the bolts to 21 N·m (15 lb ft).
4. Inspect the oil pump drive gear for wear.
5. Replace the oil pump drive gear pin if worn.



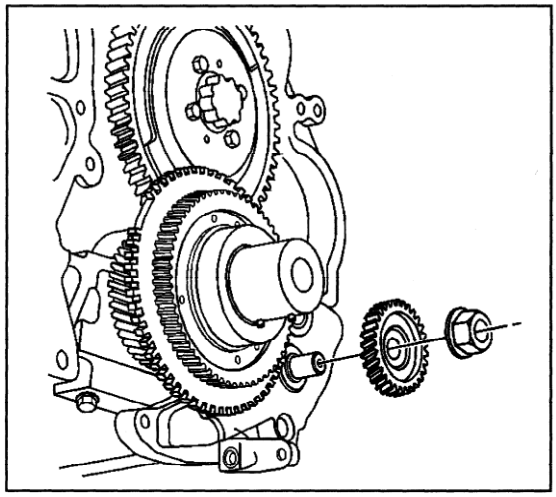
738906

6. Install the oil pump drive gear and reluctor to the crankshaft.

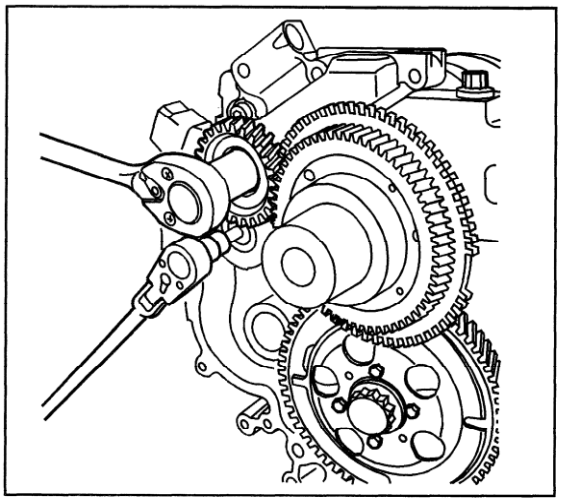


738904

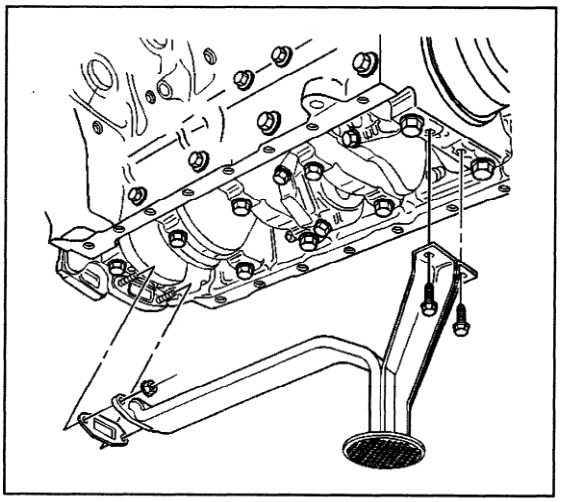
7. Install the oil pump driven gear.



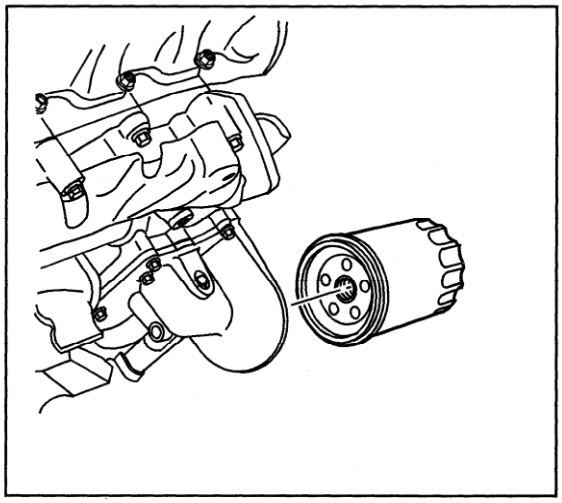
738905


776631

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


738908

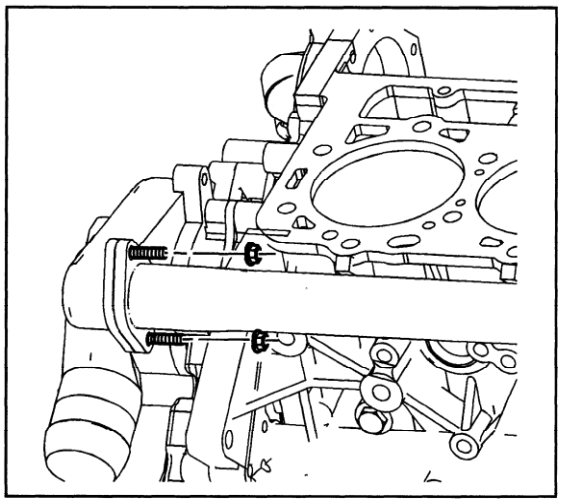
9. Install a NEW oil pump screen gasket to the oil pump.
10. Install the oil pump screen.
11. Install the oil pump screen bolts and nuts.
    **Tighten**
    Tighten the bolts/nuts to 25 N·m (18 lb ft).
12. Install the engine front cover. Refer to *Engine Front Cover Replacement*
13. Install the flywheel housing.
14. Install the upper oil pan. Refer to *Oil Pan Replacement*


660299

## Oil Filter Adapter and Oil Cooler Assembly Replacement

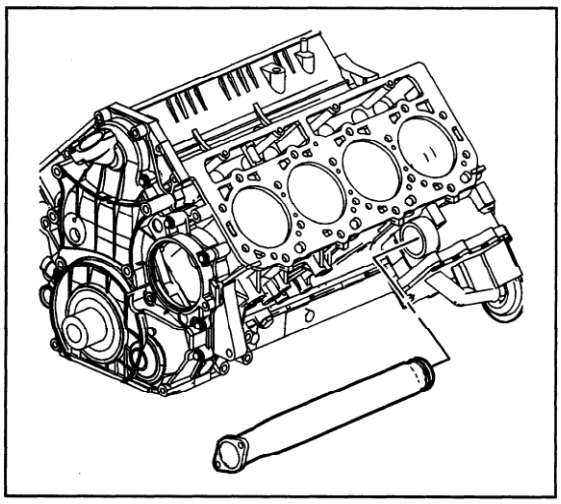
### Removal Procedure

1. Drain the engine coolant and the engine block. Refer to *Draining and Filling Cooling System*
2. If equipped, remove the oil pan skid plate bolts and plate.
3. Remove the oil filter.



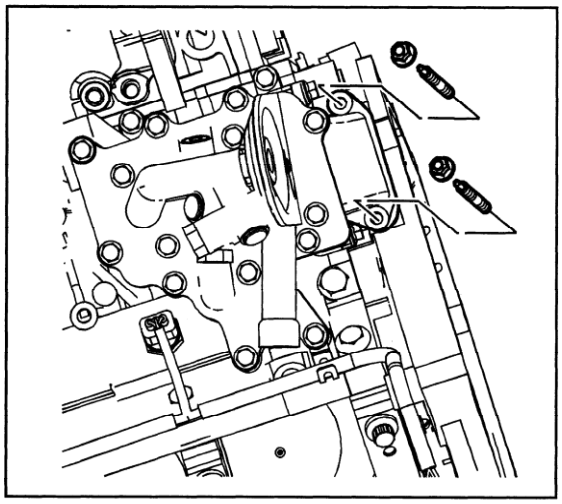
1336115

4. Remove the water pump outlet pipe nuts from the coolant pipe.
5. Remove the engine wiring harness retainer from the inner stud.



1336117

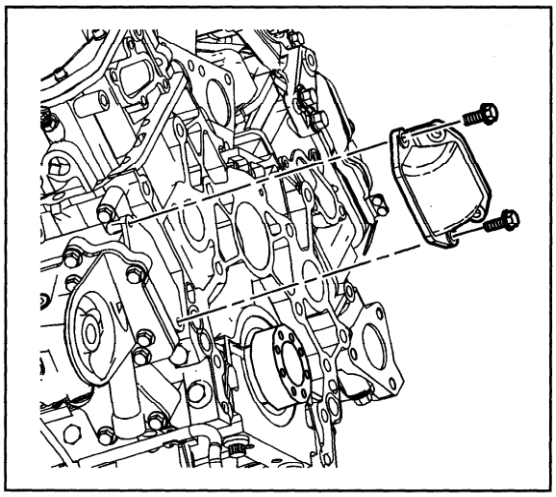
6. Remove the engine coolant pipe.
7. Remove and discard the coolant pipe O-ring.



1334852

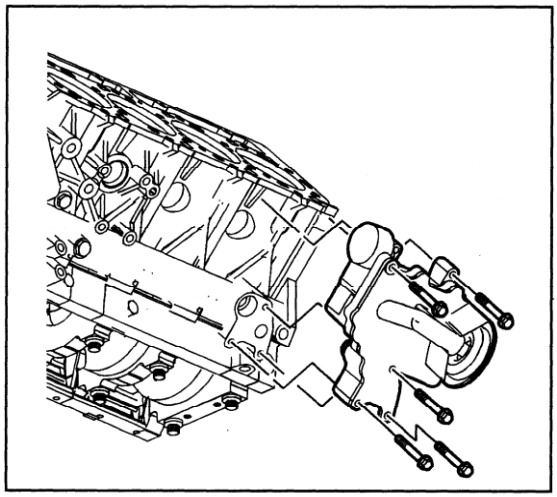
8. Remove the oil cooler adapter nuts from the flywheel housing.

9. Remove the oil cooler adapter bolts from the oil filter adapter/oil cooler.
10. Remove the oil cooler adapter.



1334855

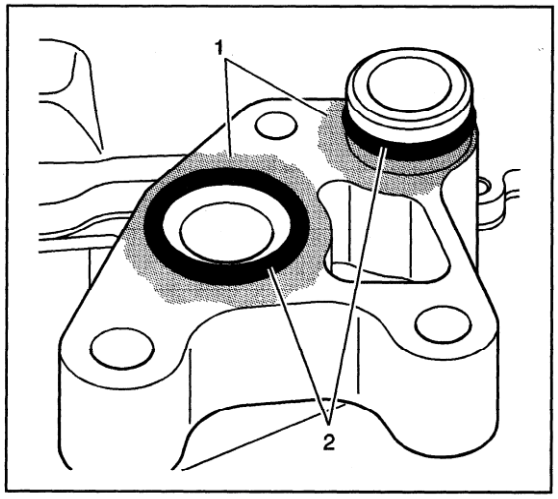
11. Remove the oil filter adapter/oil cooler bolts.
12. Remove the oil filter adapter/oil cooler.
13. Remove and discard the oil filter adapter/oil cooler O-ring seals.
14. If required, clean and inspect the oil filter adapter/oil cooler.



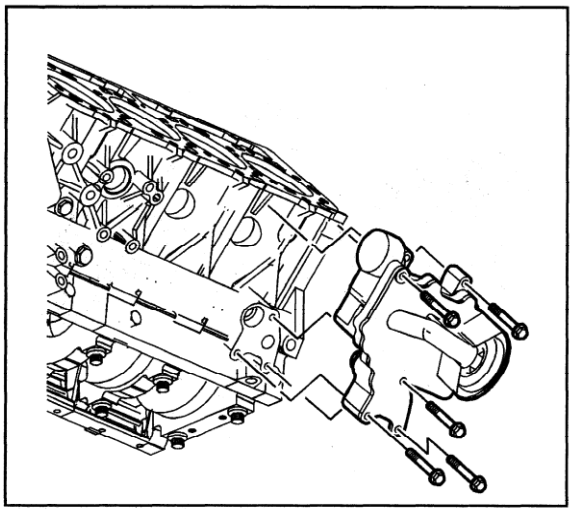
1336118

## Installation Procedure

1. Install NEW O-rings (2) to the oil filter adapter/ oil cooler.
2. Lubricate the O-rings with engine oil.
3. Apply sealer to the O-ring sealing area (1). Refer to *Sealers, Adhesives, and Lubricants*




870004



1336118

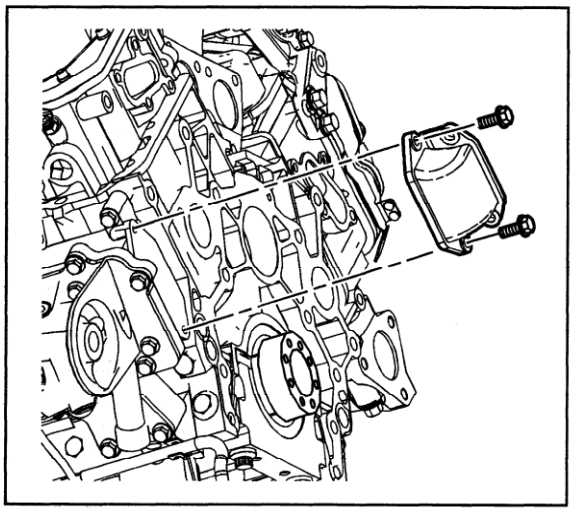
4. Install the oil filter adapter/oil cooler.

***Notice:*** Refer to *Fastener Notice*

5. Install the oil filter adapter/oil cooler bolts.

   **Tighten**

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

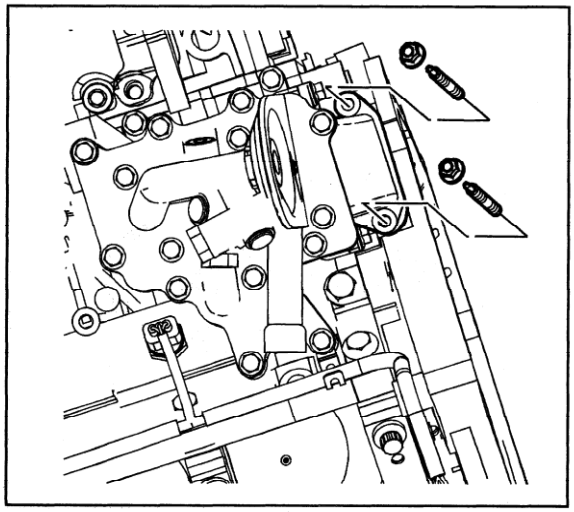


1334855

6. Install the oil cooler adapter.
7. Install the oil cooler adapter bolts to the oil filter adapter/oil cooler.

   **Tighten**

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



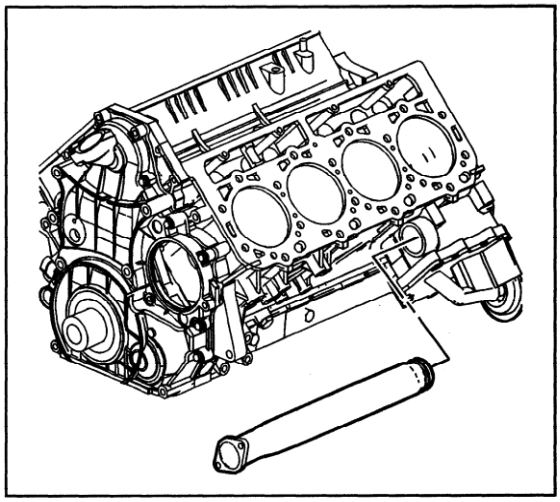
1334852

8. Install the oil cooler adapter nuts to the flywheel housing.

   **Tighten**

   Tighten the nuts to 25 N·m (18 lb ft).

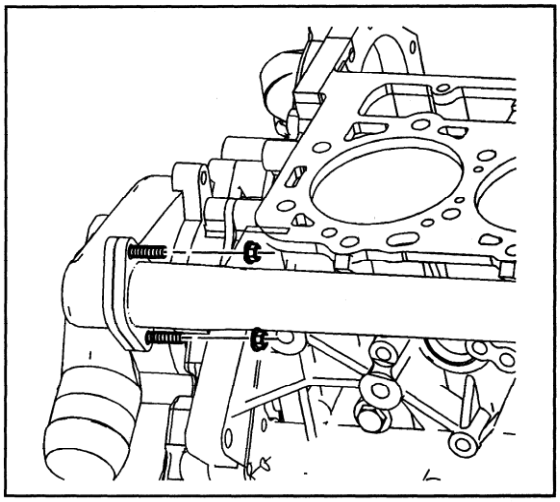
9. Install a NEW coolant pipe O-ring.
10. Lubricate the O-ring with clean engine coolant. Do not use oil or grease.
11. Install the engine coolant pipe.


1336117

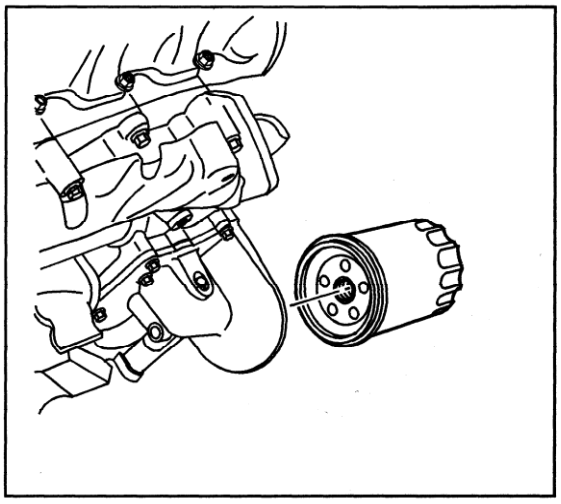
12. Install the engine wiring harness retainer to the inner stud.
13. Install the water pump outlet pipe nuts to the coolant pipe.

    **Tighten**

    Tighten the nuts to 25 N·m (18 lb ft).


1336115

14. Install the oil filter.
15. Fill the cooling system. Refer to *Draining and Filling Cooling System*
16. Inspect the engine oil level and add as necessary.


660299

## Engine Oil Pressure Sensor and/or Switch Replacement

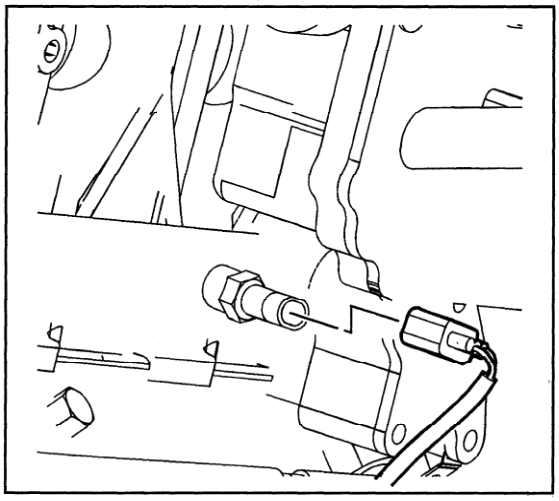
### Tools Required

*J 41712* Oil Pressure Switch Socket

### Removal Procedure

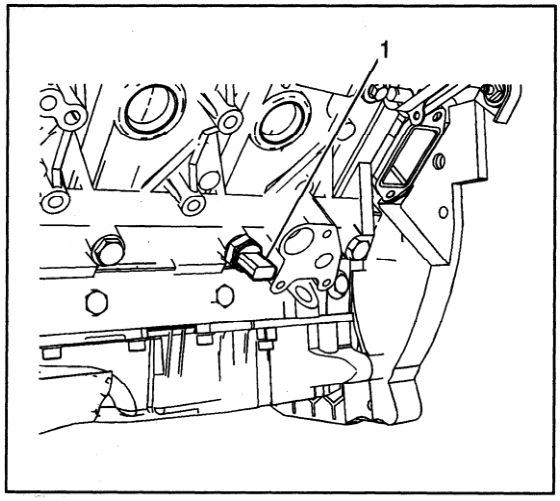
**Important:** Clean the area around the sensor. Do not allow debris to enter the engine.

1. Disconnect the oil pressure sensor electrical connector.



1335546

2. Using *J 41712*, remove the oil pressure sensor (1).




1364822

### Installation Procedure

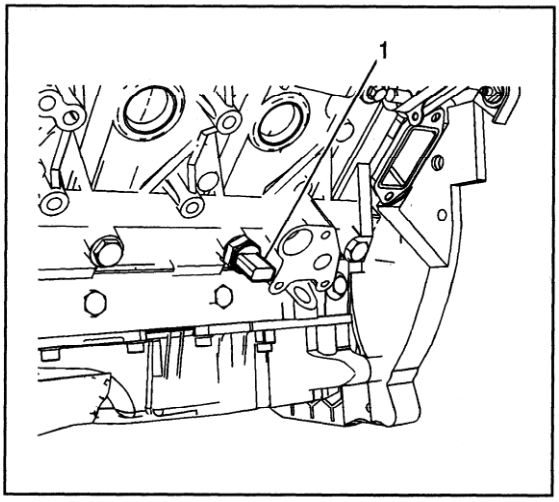
1. Apply sealant to the threads of the oil pressure sensor. Refer to *Sealers, Adhesives, and Lubricants*

***Notice:*** Refer to *Fastener Notice*

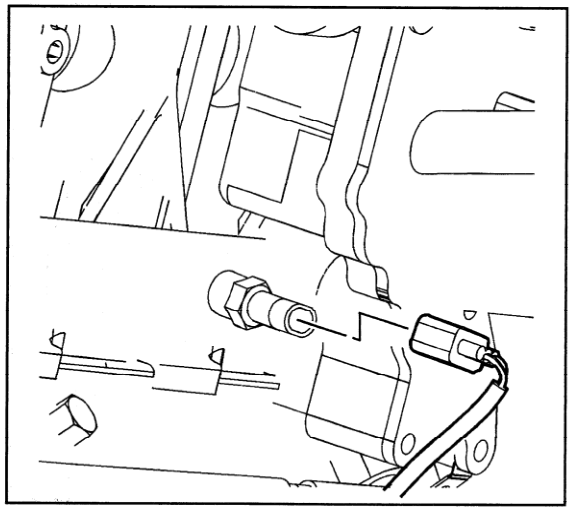
2. Using *J 41712*, install the oil pressure sensor (1).

   **Tighten**

   Tighten the sensor to 30 N·m (22 lb ft).

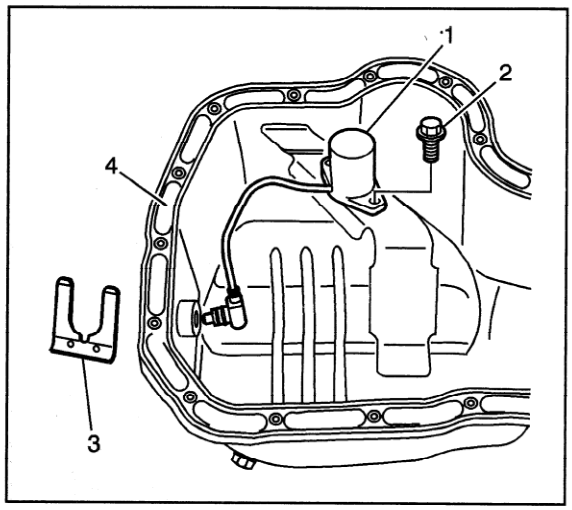



1364822



1335546

3. Connect the oil pressure sensor electrical connector.
4. Check and add engine oil if necessary.

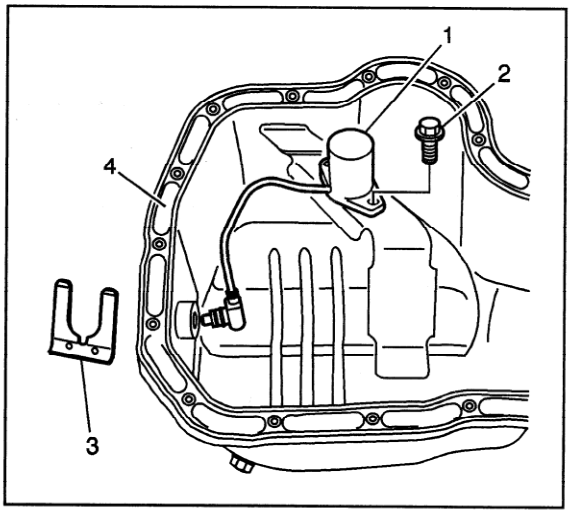



663624

## Engine Oil Level Sensor and/or Switch Replacement

### Removal Procedure

1. Remove the lower oil pan. Refer to *Oil Pan Replacement*
2. Remove the oil level sensor clip (3).
3. Remove the oil level sensor bolt (2) and sensor (1).




663624

### Installation Procedure

**Important:** When routing the oil level sensor wire, ensure that the wire is routed along the side of the oil pan.

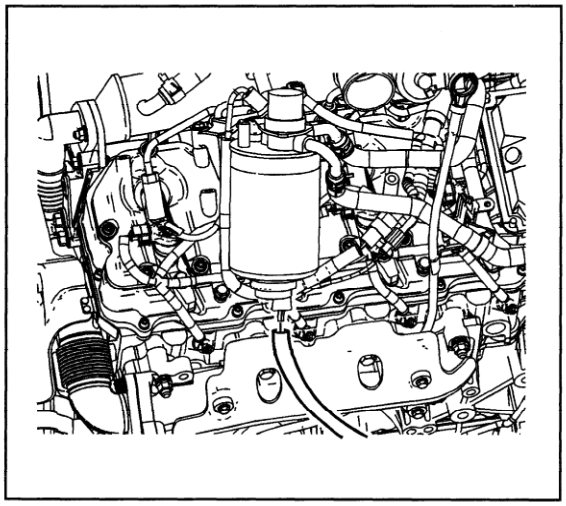
1. Install the oil level sensor (1) and bolt (2).

   **Tighten**

   Tighten the bolt to 9 N·m (80 lb in).
2. Install the oil level sensor clip (3).
3. Install the lower oil pan. Refer to *Oil Pan Replacement*

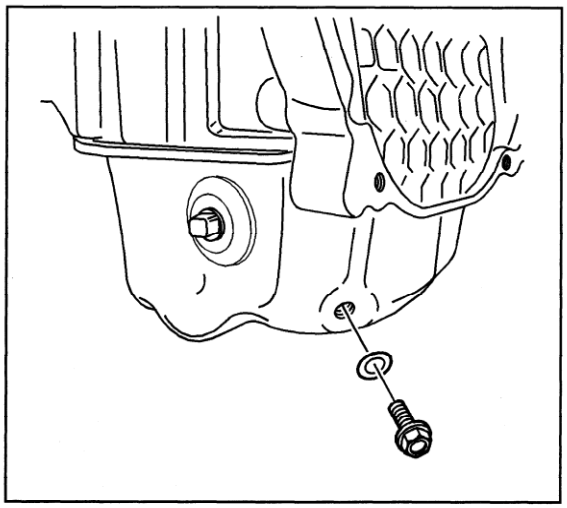
## Draining Fluids and Oil Filter Removal

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.

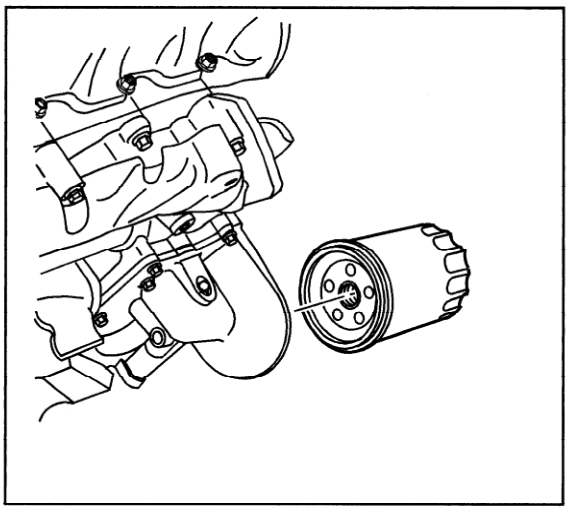


1334798

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

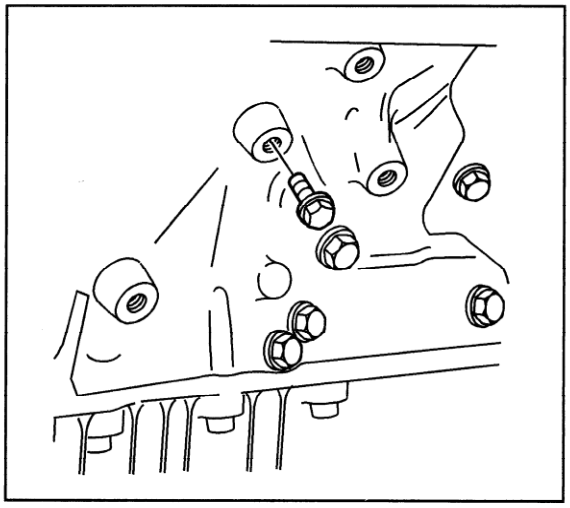


660296



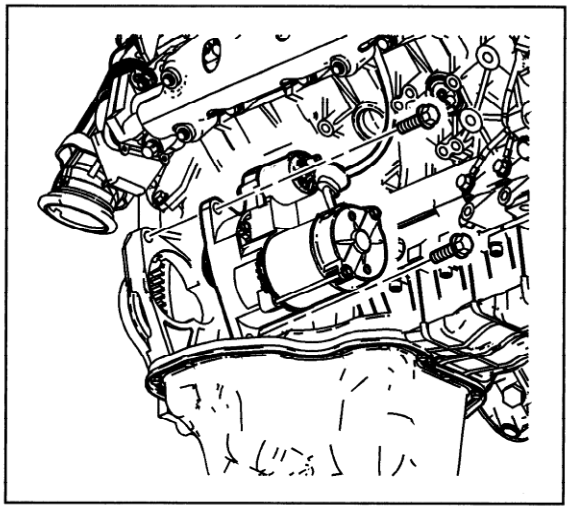
660299

4. Remove the oil filter.



1334805

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



1334814

## Starter Motor Removal

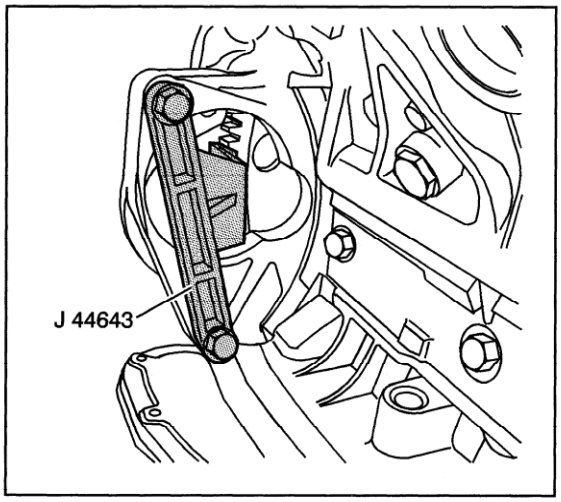
1. Remove the starter motor bolts.
2. Remove the starter motor assembly.

## Crankshaft Balancer Removal

### Tools Required

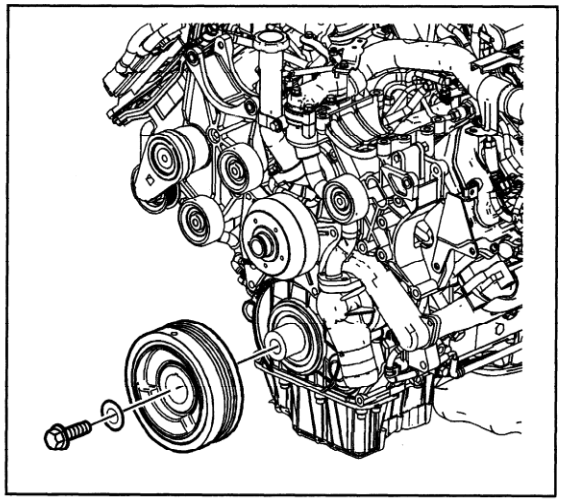
*J 44643* Flywheel Hold Tool

1. Install *J 44643* to lock the flywheel.




660308

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



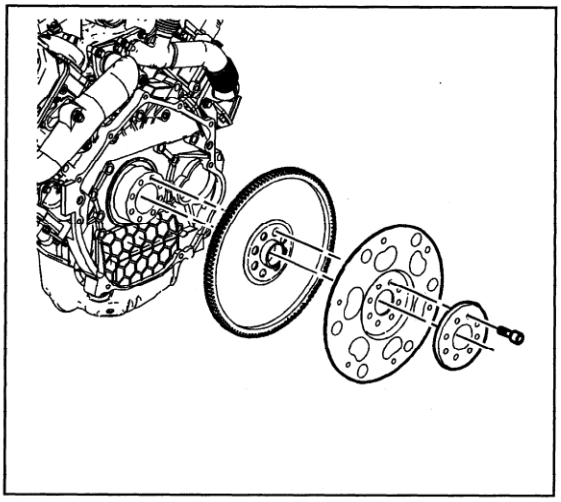
1334816

## Engine Flywheel Removal

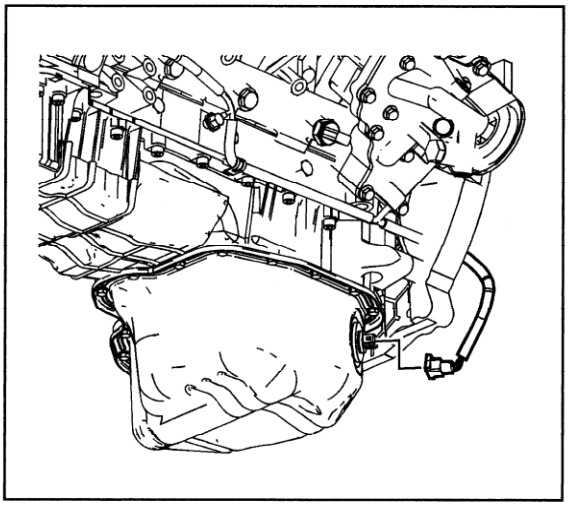
### Tools Required

*J 44643* Flywheel Hold Tool

1. Remove the flywheel mounting bolts and discard.
2. Remove the flywheel washer.
3. Remove the *J 44643*.
4. Remove the flywheel assembly.



1334818



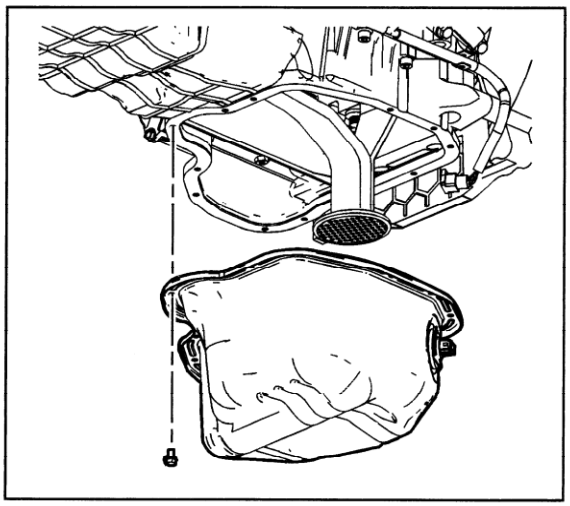
1334843

## Oil Pan Removal - Lower

### Tools Required

*J 37228* Seal Cutter

1. Disconnect the oil level sensor.

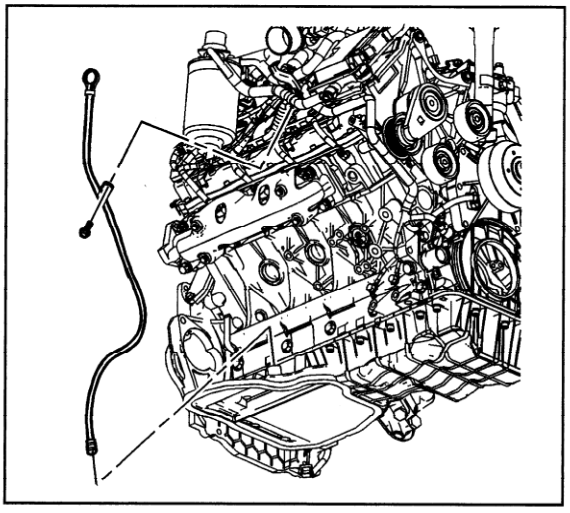


1334845

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.



1334847

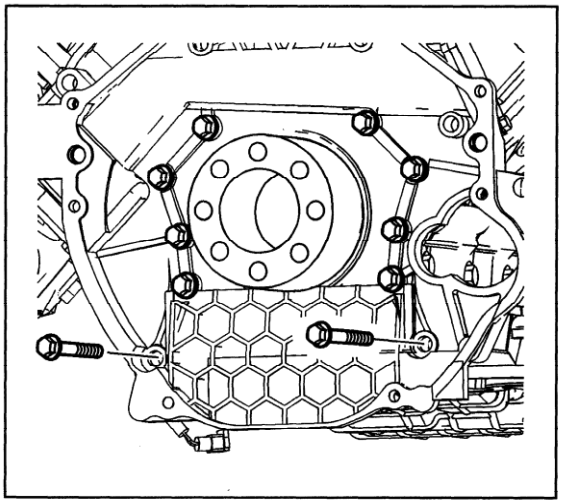
## Oil Pan Removal - Upper

### Tools Required

*J 37228* Seal Cutter

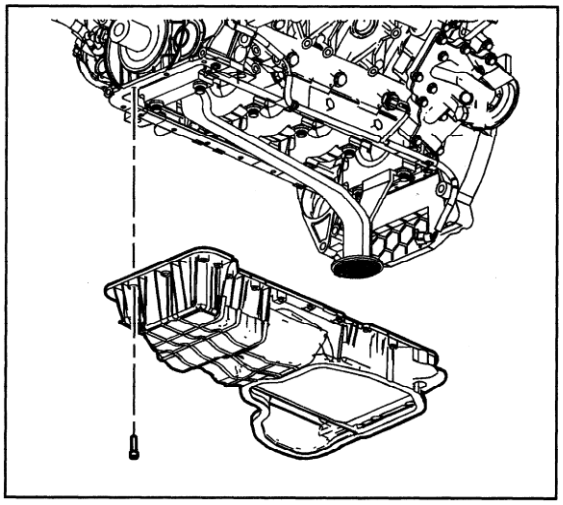
1. Remove the oil level indicator tube bracket bolt.
2. Remove the oil level indicator tube.

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



1334849

4. Remove the 24 upper oil pan bolts using a long bit 6 mm hex driver.
5. Seperate the upper oil pan from the engine block using *J 37228*.
6. Remove the upper oil pan.



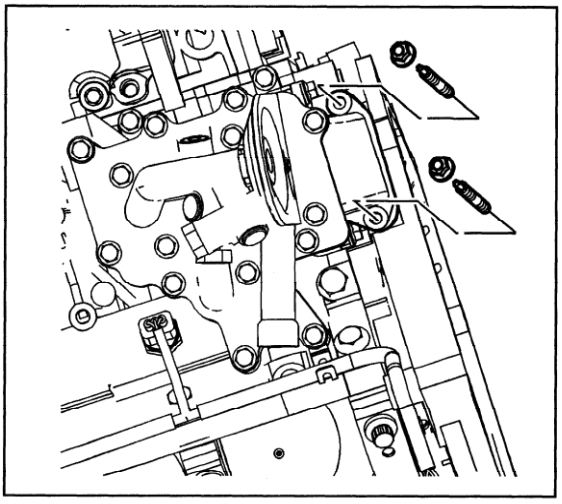
1334851

## Engine Flywheel Housing Removal

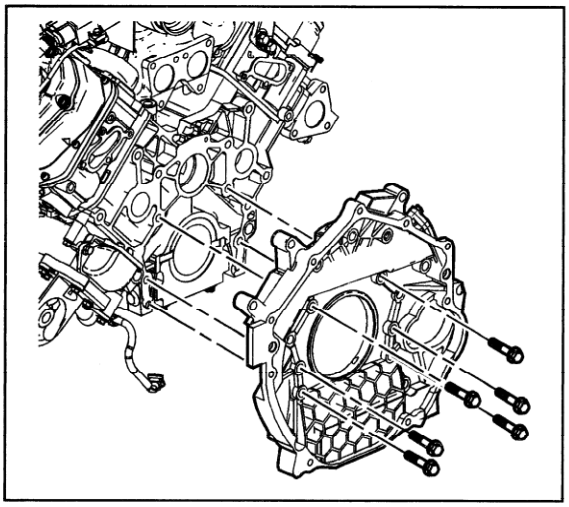
### Tools Required

*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.



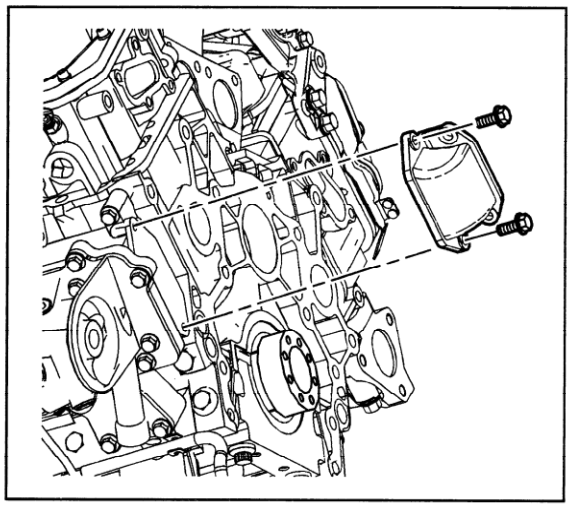
1334852



1334853

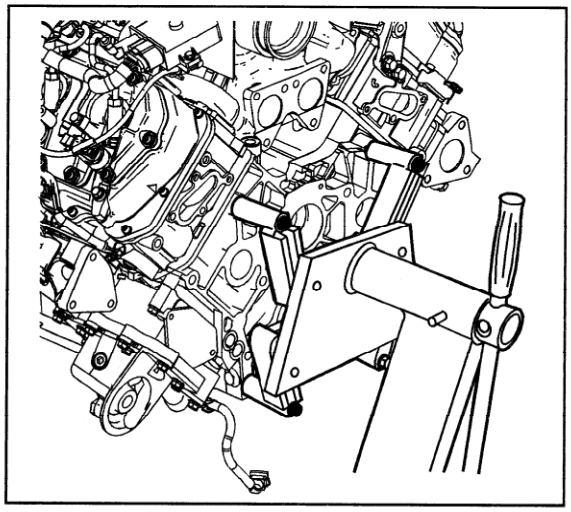
**Important:** The upper oil pan must be removed before removing the flywheel housing.

3. Remove the flywheel housing bolts.
4. Separate the flywheel housing from the cylinder block using *J 37228*.
5. Remove the flywheel housing.



1334855

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.



1334858

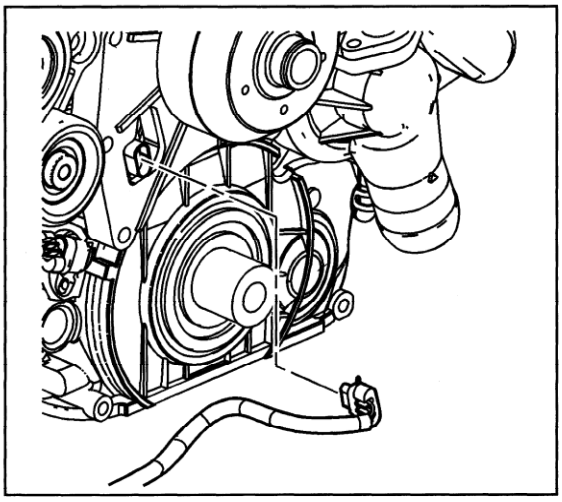
## Engine Mounting to Stand

***Caution: 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.

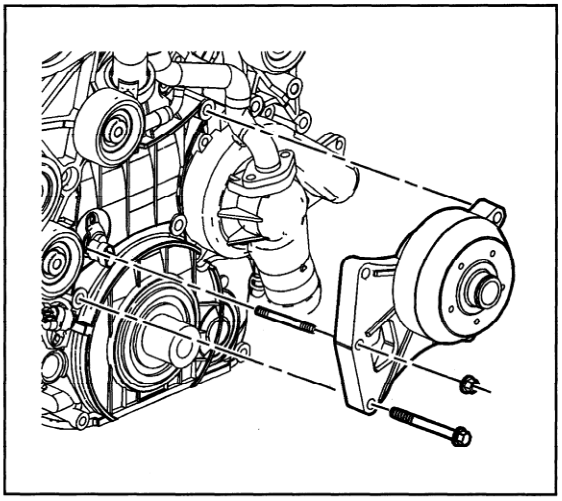
## Cooling Fan Pulley Removal

1. Disconnect the camshaft position sensor connector.



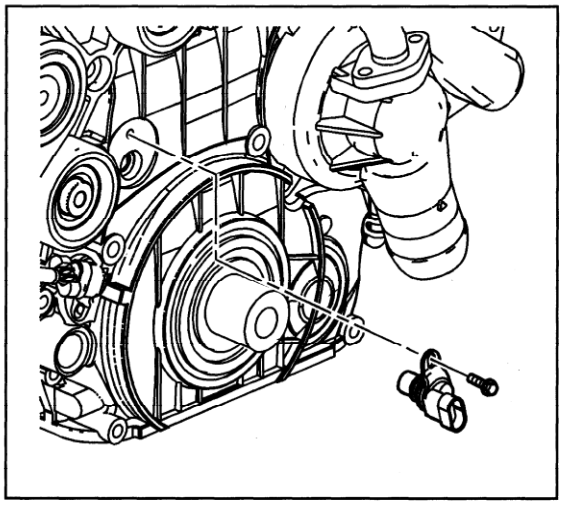
1334862

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

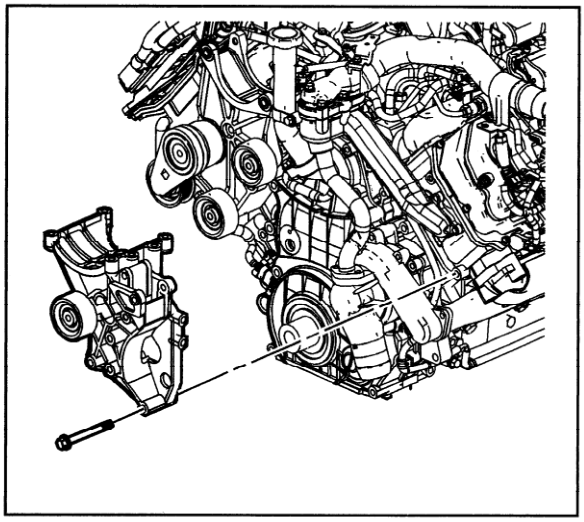


1334864

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



1334865



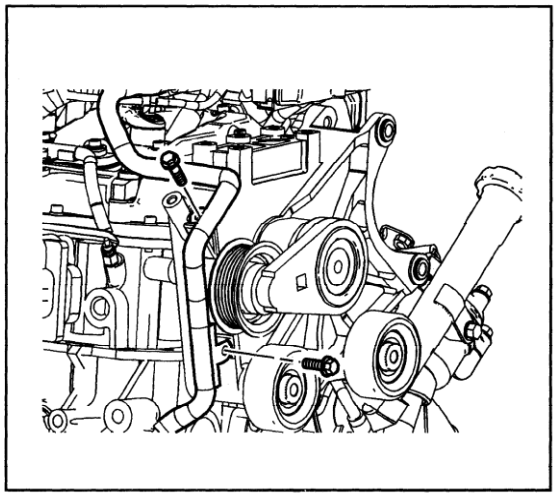
1334867

## Power Steering Pump Mounting Bracket Removal

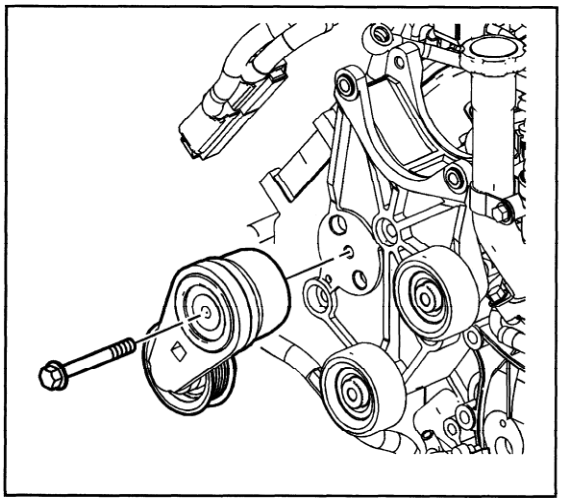
1. Remove the power steering pump mounting bracket bolts.
2. Remove the power steering pump mounting bracket.

## Drive Belt Tensioner and Generator Mounting Bracket Removal

1. Remove the electrical harness clip bolts.

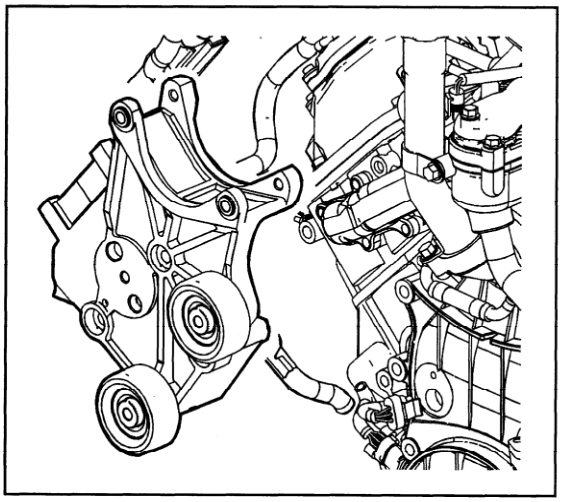


1334907



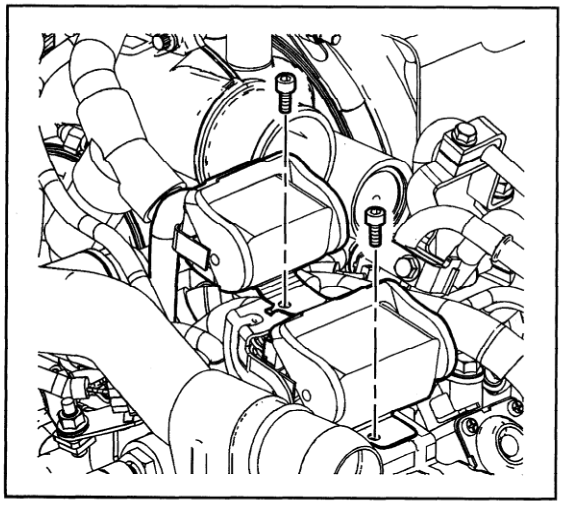
1334909

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



1334912

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

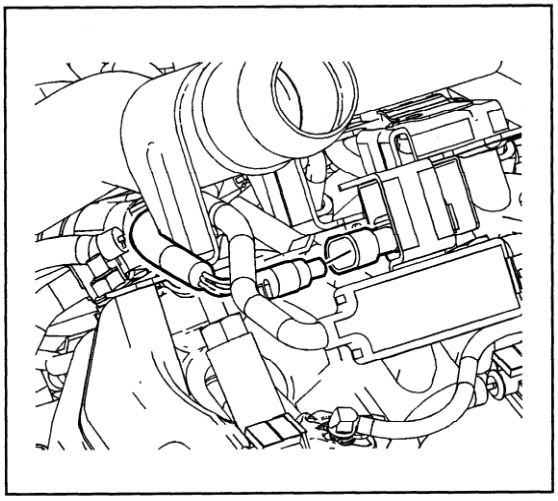


1334916

## Thermostat Housing Removal

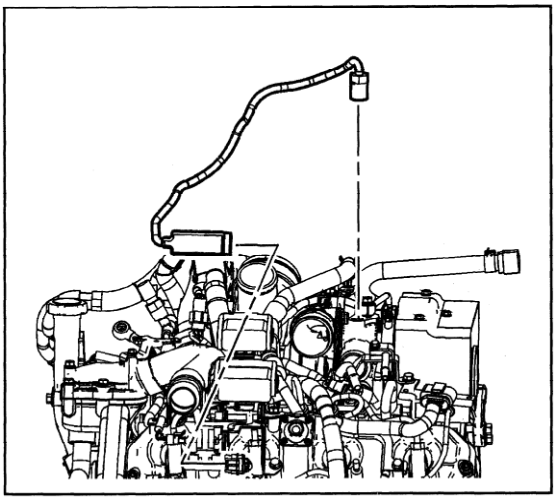
1. Remove the main engine electrical harness connector hold down bolts.

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



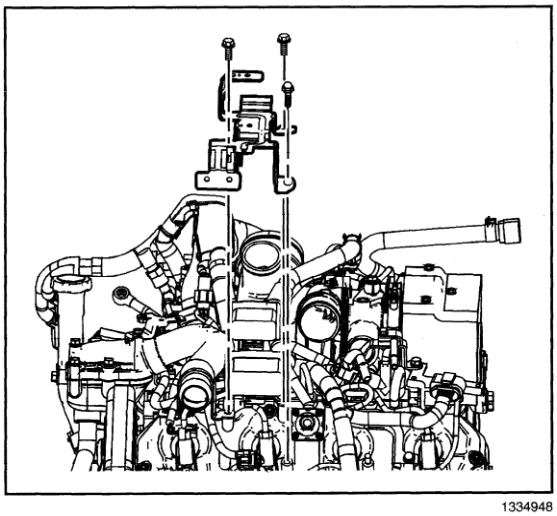
1334921

4. Disconnect and remove the turbocharger vane position sensor.

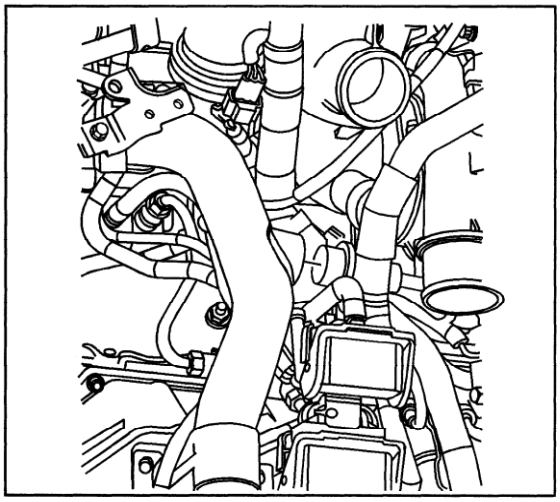


1334926

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

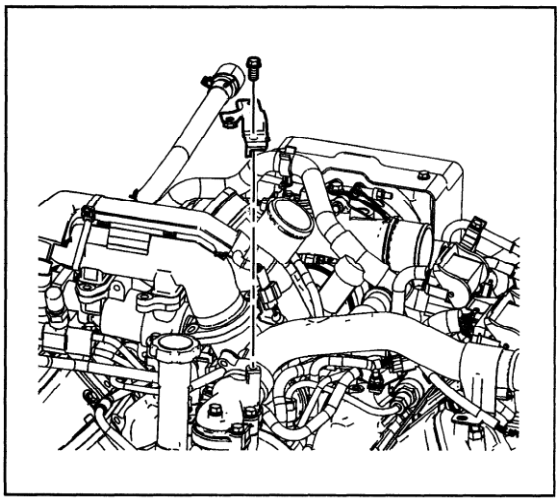


1334948



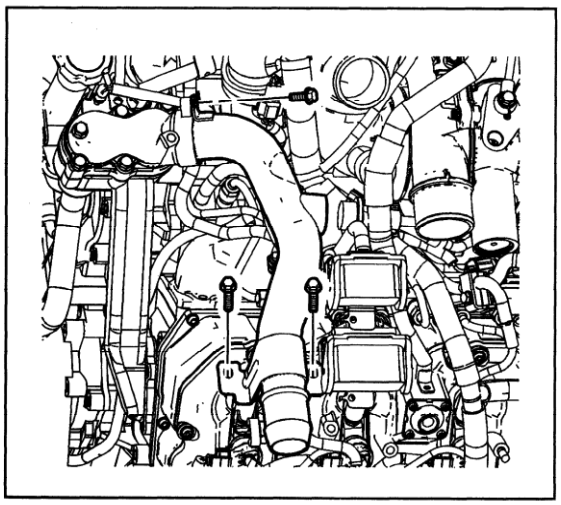
1335386

7. Disconnect the turbocharger coolant inlet hose.



1335388

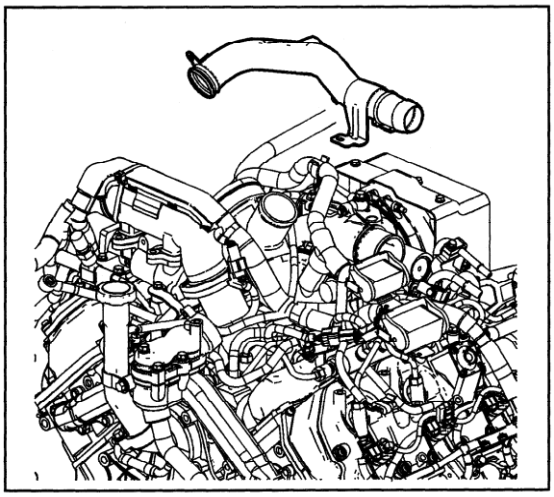
8. Remove the electrical harness bracket bolt.
9. Remove the electrical harness bracket.



1335391

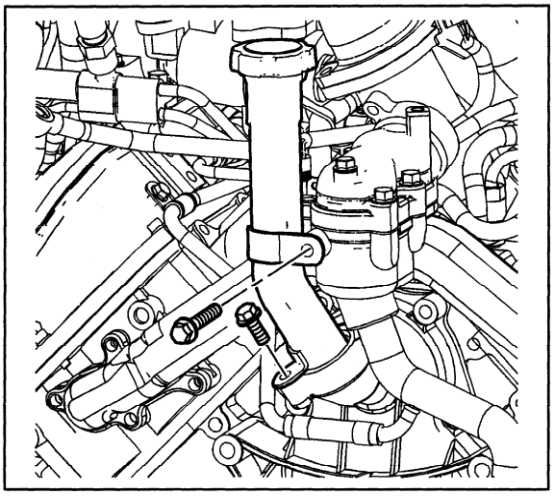
10. Remove the water outlet bolts.

11. Remove the water outlet.



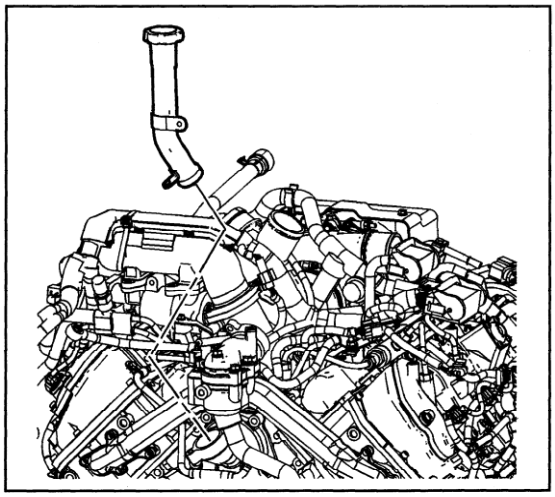
1335393

12. Remove the oil fill tube bolts.

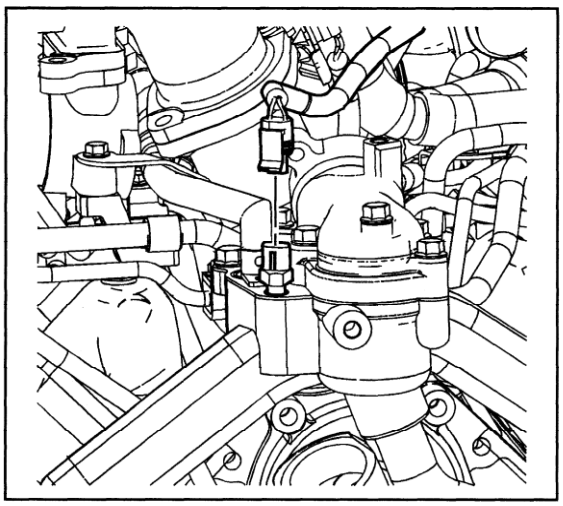


1335397

13. Remove the oil fill tube.

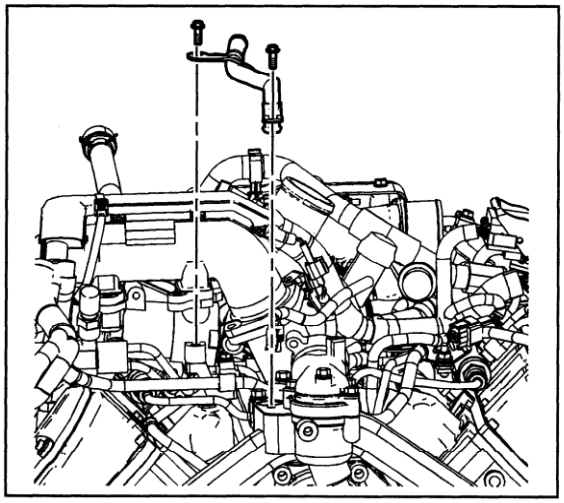


1335401



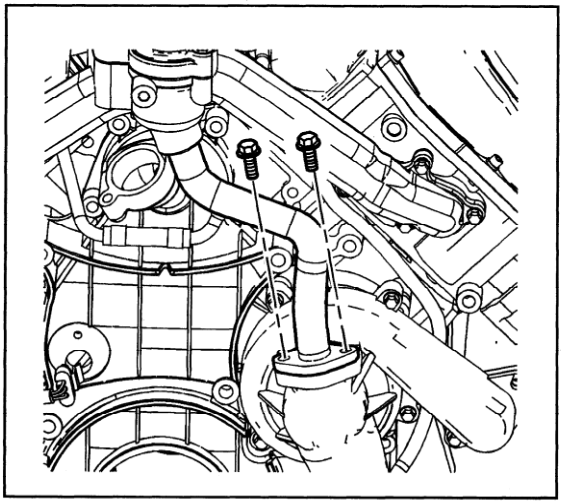
1335413

14. Disconnect the coolant temperature sensor.



1335419

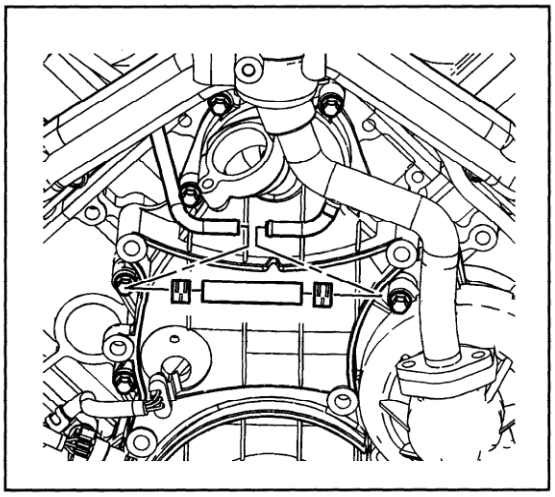
15. Remove the EGR coolant pipe bolts.
16. Remove the EGR coolant pipe.



1335424

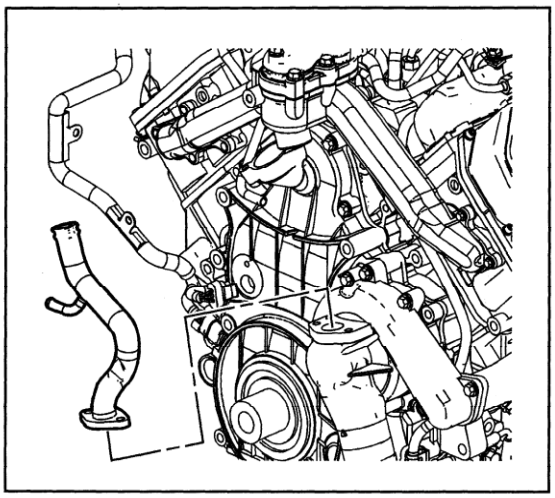
17. Remove the water pump inlet pipe bolts.

18. Remove the turbocharger coolant outlet hose and clamps.



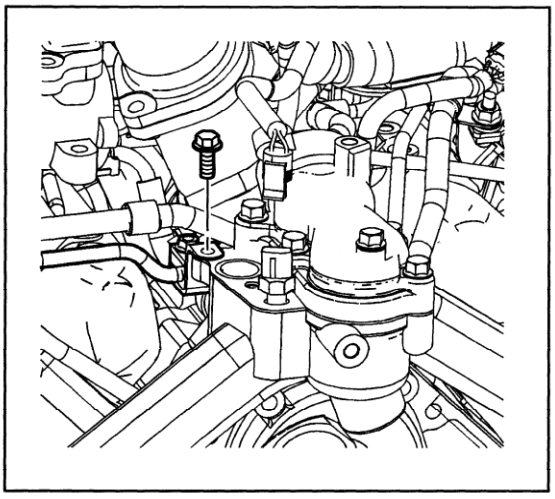
1335429

19. Remove the water pump inlet pipe.

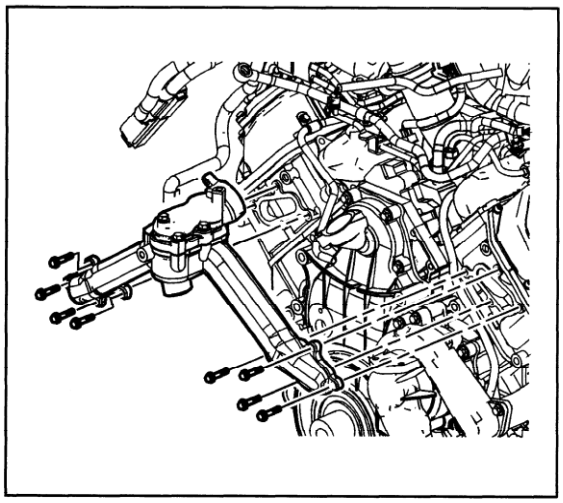


1335432

20. Remove the fuel pipe bracket bolt.

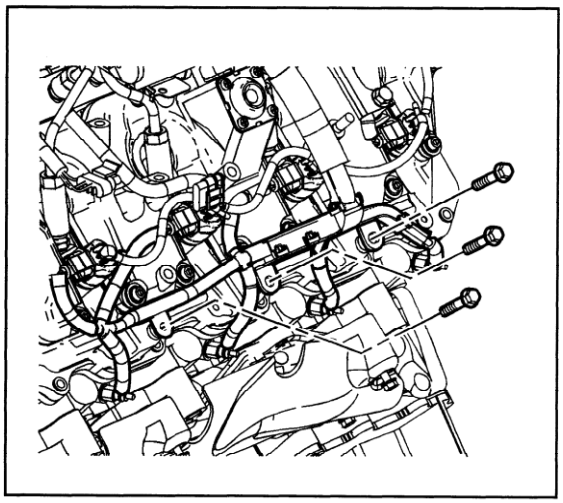


1335434



1335441

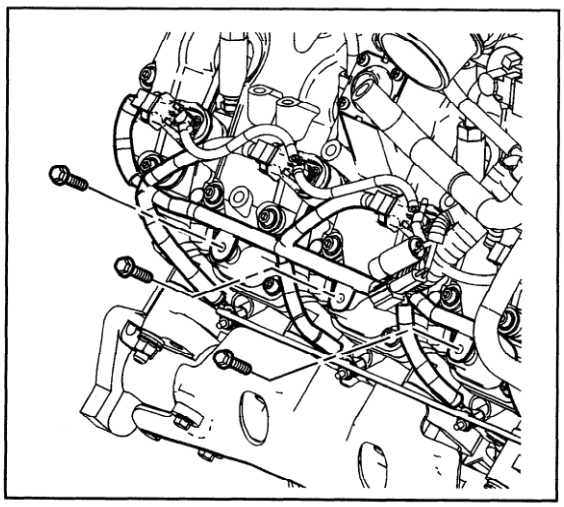
21. Remove the thermostat housing bolts.
22. Remove the thermostat housing.



1335443

## Engine Wiring Harness Assembly Removal

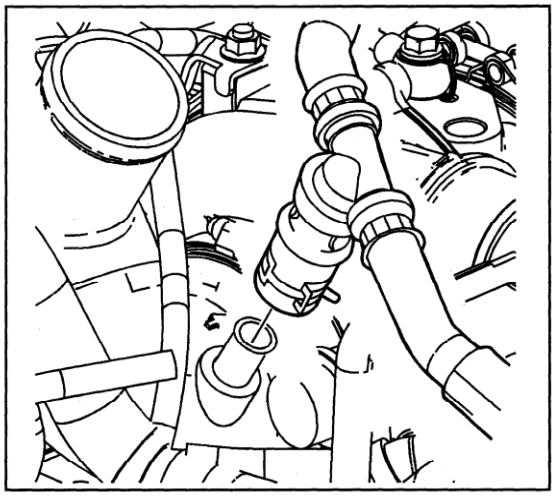
1. Remove the left glow plug harness bracket bolts.



1335450

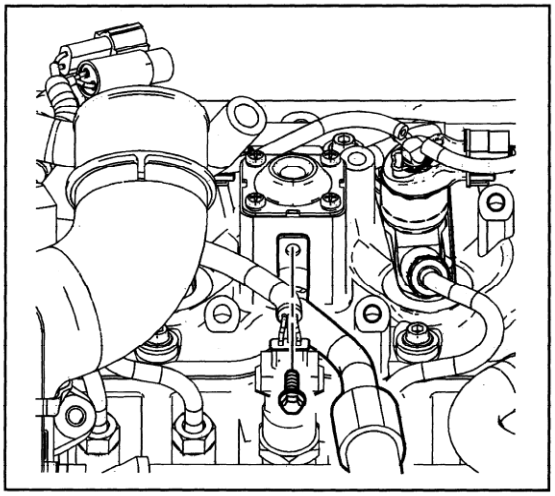
2. Remove the right glow plug harness bracket bolts.

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



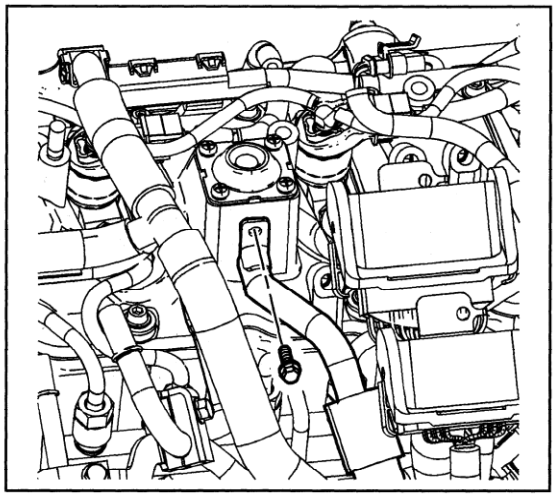
1335454

4. Remove the right PCV pipe bolt.

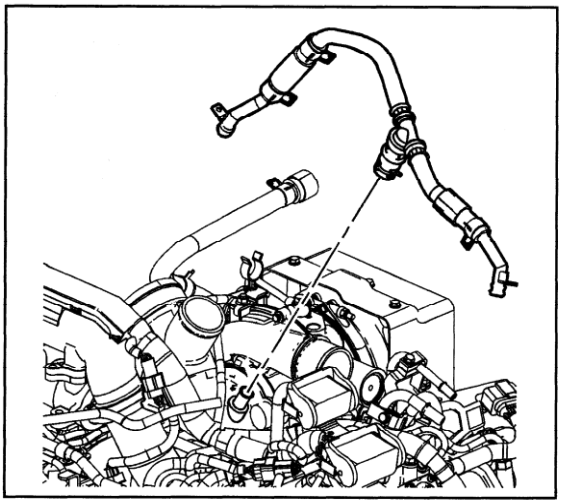


1335456

5. Remove the left PCV pipe bolt.

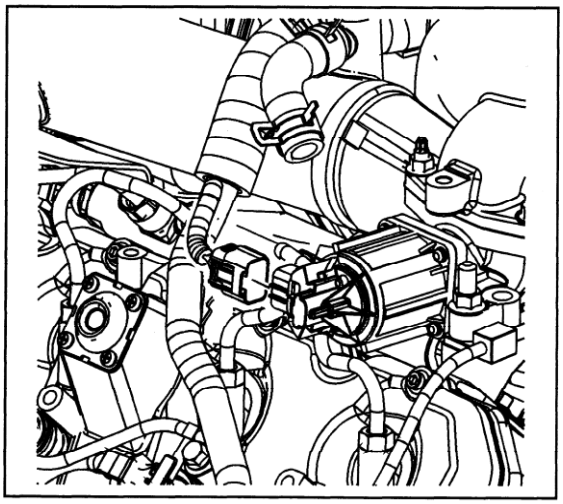


1335460



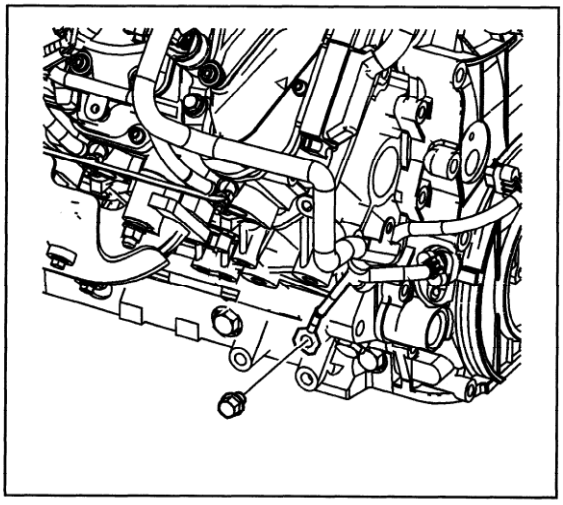
1335462

6. Remove the PCV pipe.



1662870

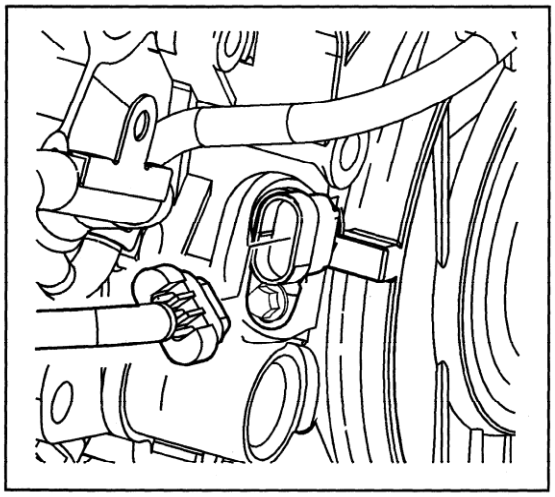
7. Disconnect the exhaust gas recirculation (EGR) valve electrical connector.



1662872

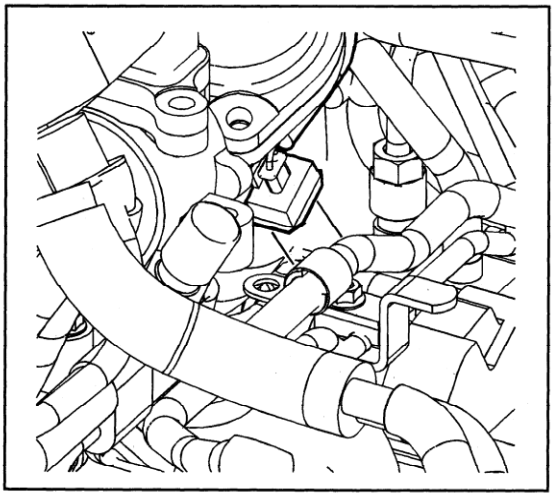
8. Remove the ground bolt.

9. Disconnect the crankshaft postion sensor electrical connector.



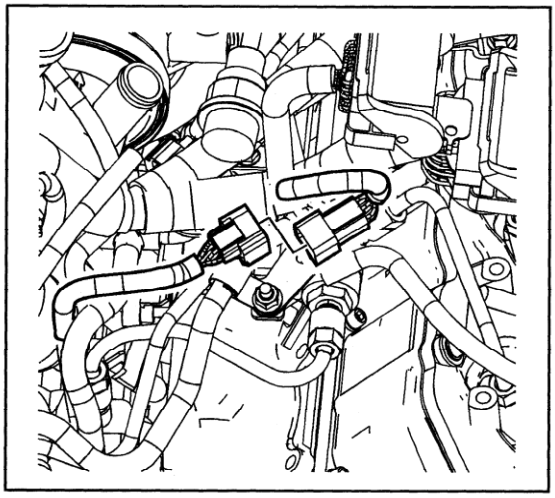
1335470

10. Disconnect the fuel pressure control valve electrical connector.

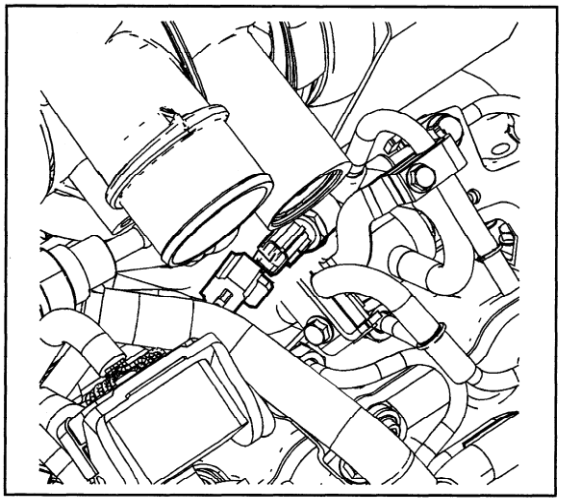


1335482

11. Disconnect the oil level sensor electrical harness connector.

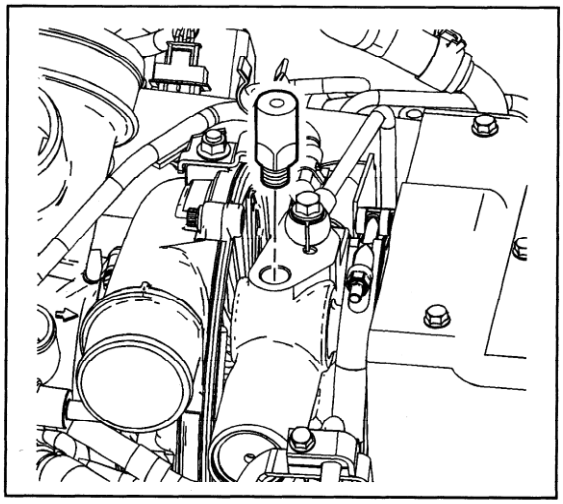


1335526



1335528

12. Disconnect the fuel temperature sensor connector.

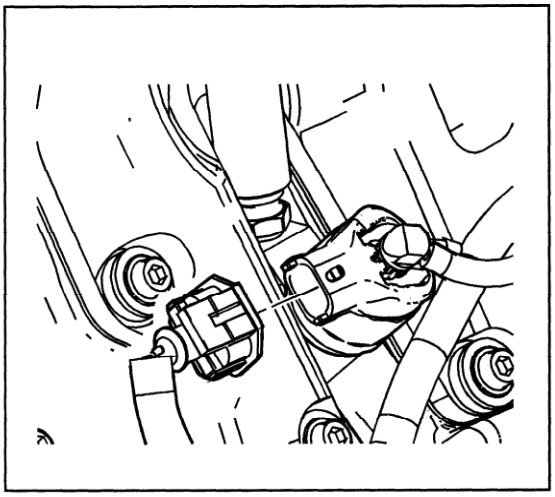


1335534

13. Disconnect and remove the turbocharger vane positon sensor.

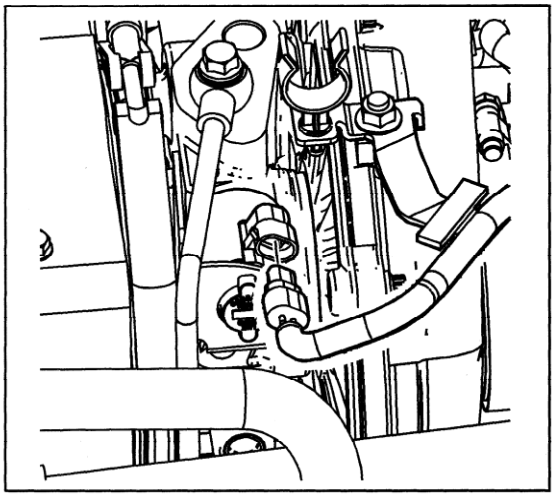
***Notice:*** Label all the injector electrical connectors before the connectors are removed in order to prevent reconnecting to the wrong injector. Failure to properly connect the injectors in the correct sequence will cause severe engine damage.

14. Disconnect the fuel injector electrical connections.



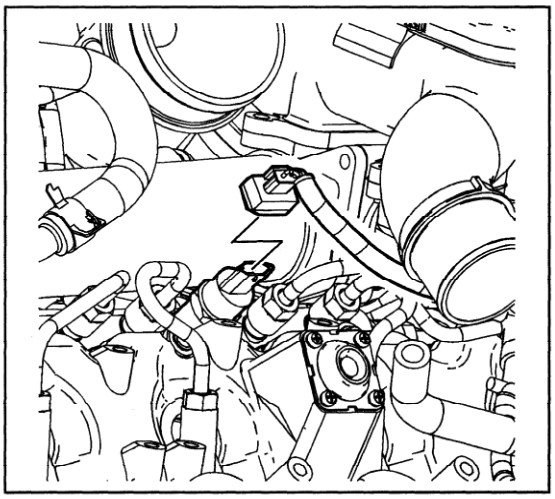
1335536

15. Disconnect the turbocharger vane control solenoid valve.

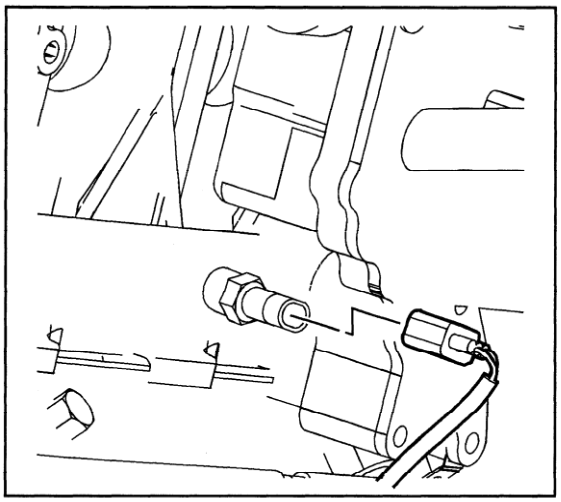


1335540

16. Disconnect the fuel rail pressure sensor.

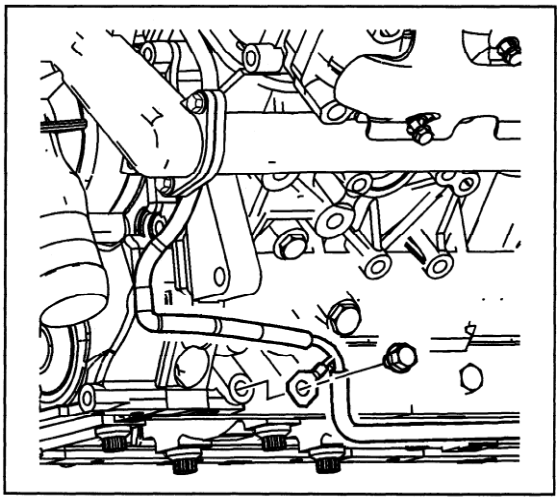


1335543



1335546

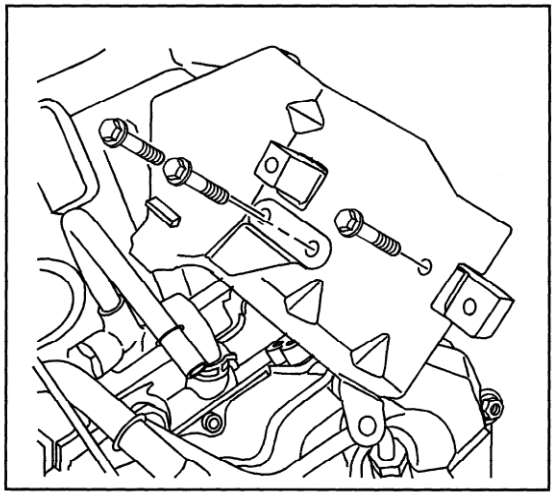
17. Disconnect the oil pressure sensor electrical connector.



1335549

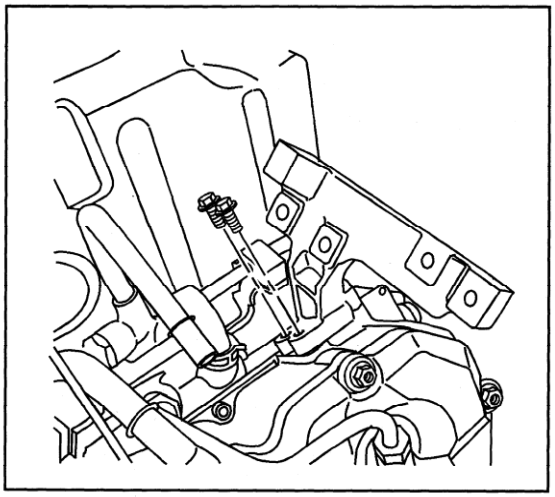
18. Remove the oil level sensor harness bolt.

19. Remove the glow plug controller bracket bolts.



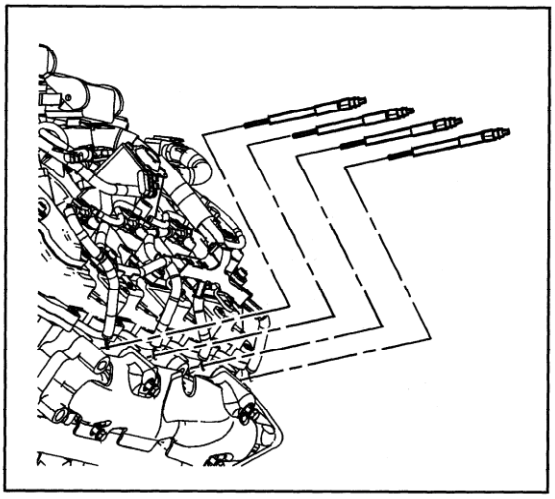
1650648

20. Remove the glow plug controller bracket.

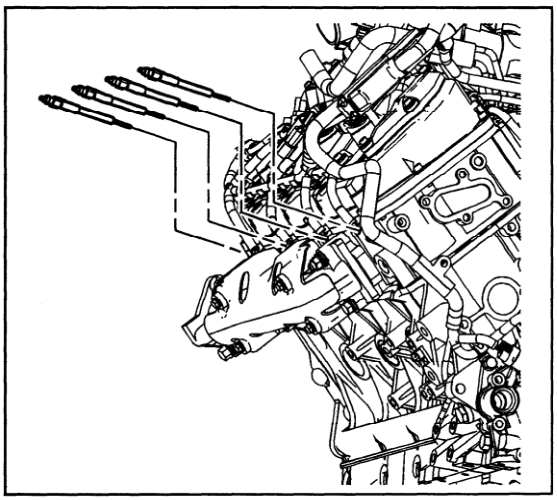


1650651

21. Remove the left glow plugs.

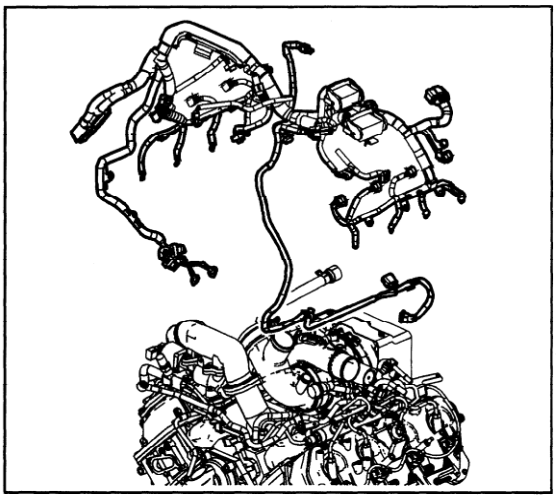


1335554



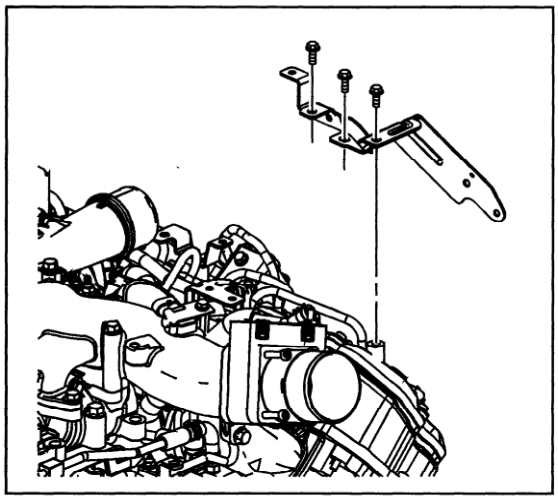
1335557

22. Remove the right glow plugs.



1335560

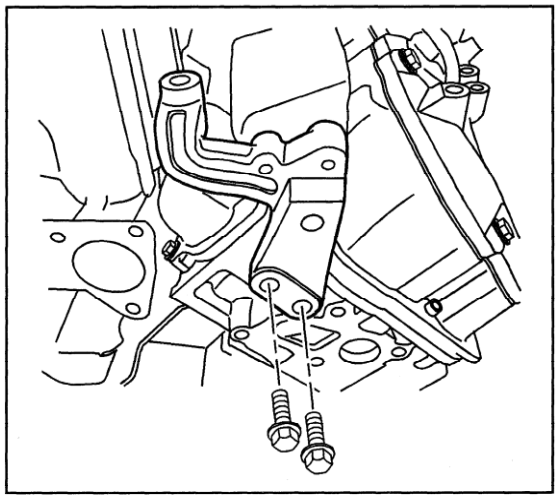
23. Remove the engine wiring harness.



1662875

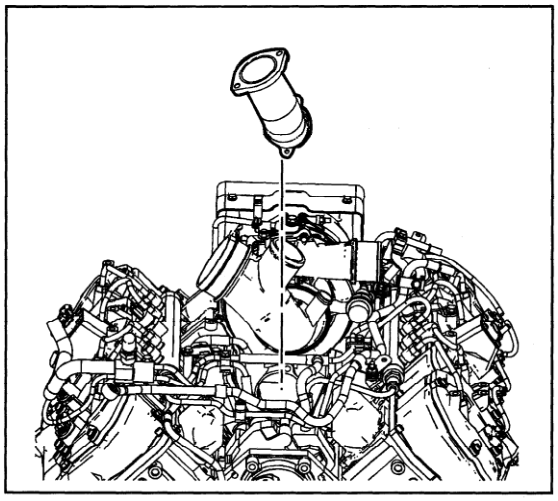
24. Remove the engine harness bracket bolts.
25. Remove the engine harness bracket.

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



1650666

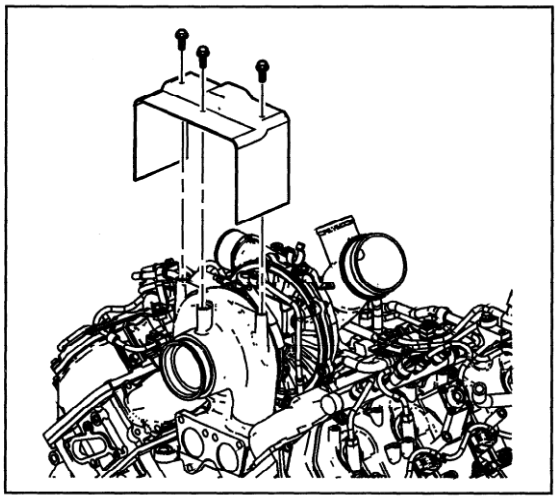
11. Remove the intake manifold tube.



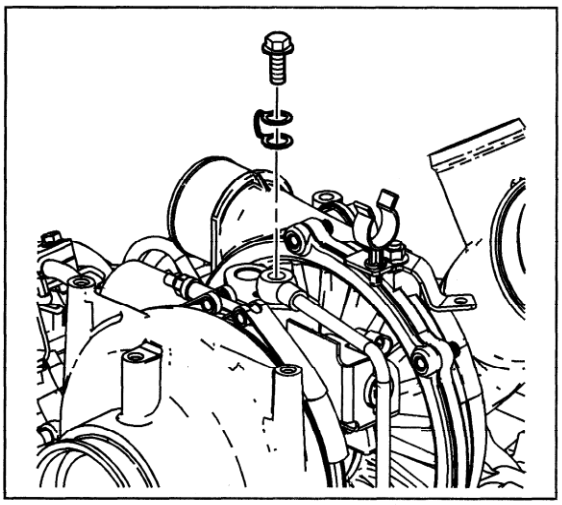
1335575

## Turbocharger Removal

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

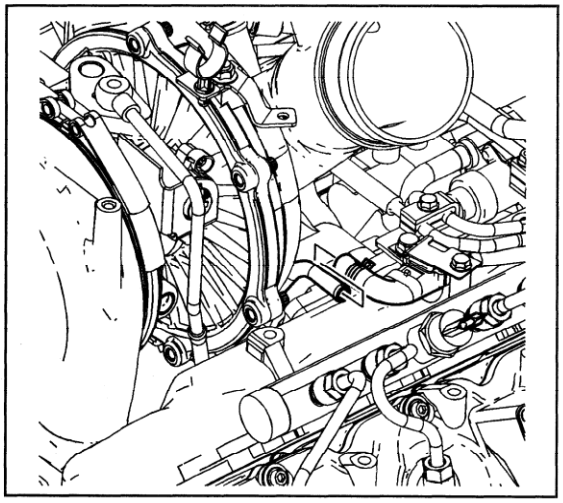


1335576



1335577

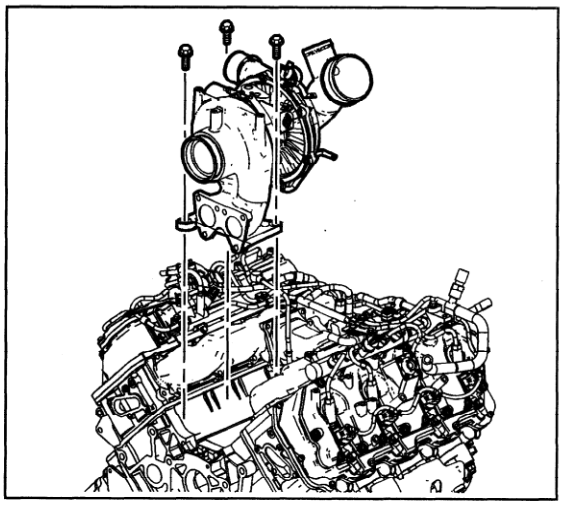
3. Remove the eye bolt and washers from the oil supply hose at the top of the turbocharger.



1335578

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

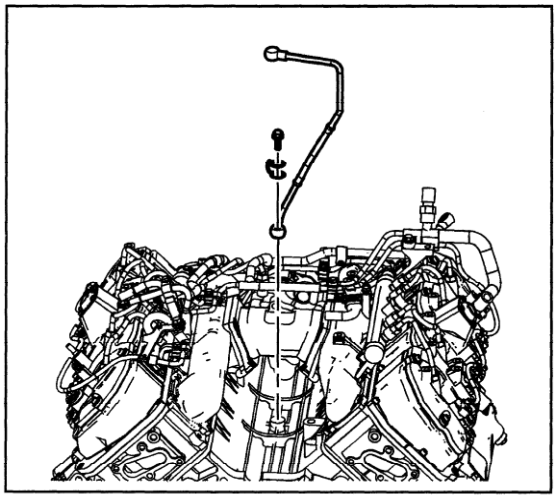
4. Loosen the hose clamp and remove the turbocharger cooling outlet hose.



1335579

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

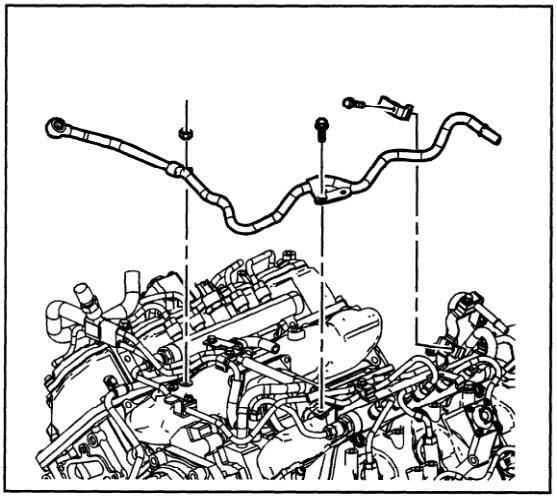
7. Remove the turbocharger lower heat shield from engine block.
8. Remove the turbocharger oil supply hose eye bolt and washers.
9. Remove the turbocharger oil supply hose.



1335581

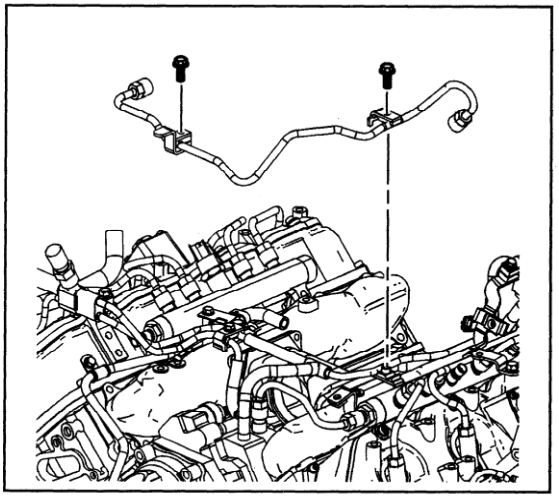
## Fuel Pipes and Fuel Rail Removal

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

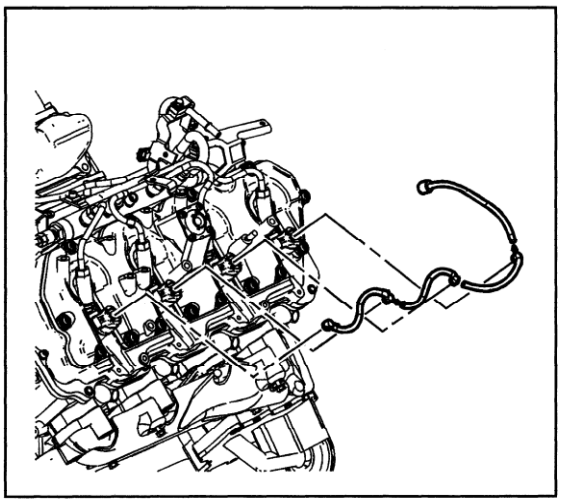


1335584

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.

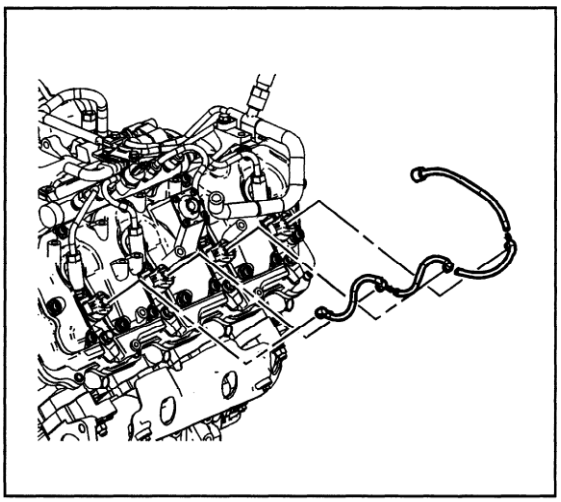


1335586



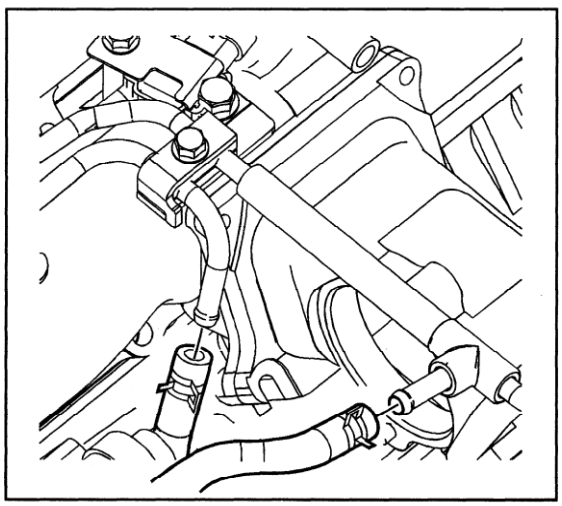
1335588

6. Remove the left fuel return hose.



1335592

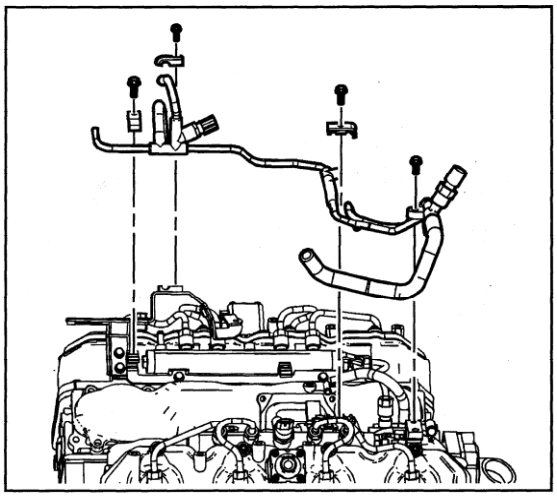
7. Remove the right fuel return hose.



1335595

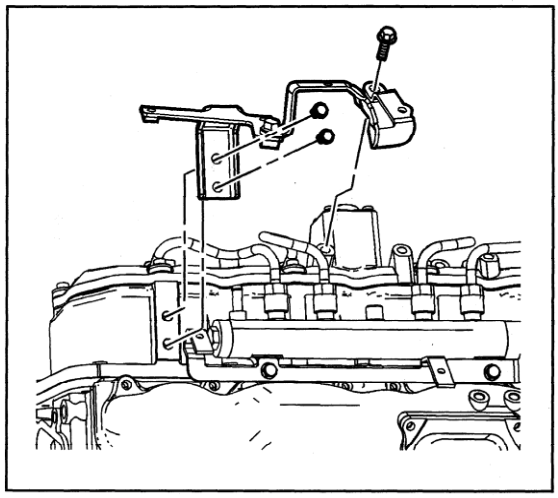
8. Disconnect the fuel hoses from the fuel injector pump.

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



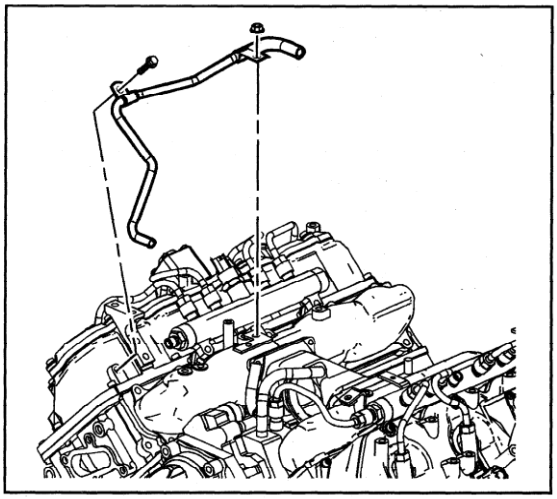
1335596

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

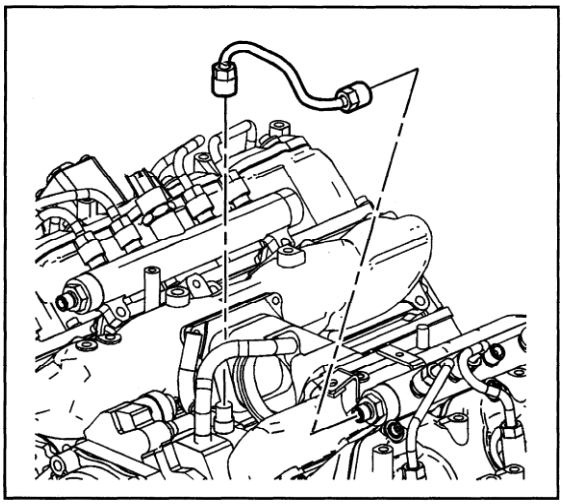


1835598

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

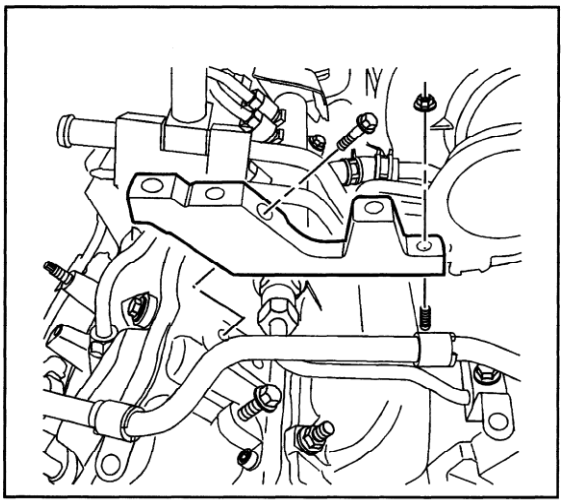


1335600



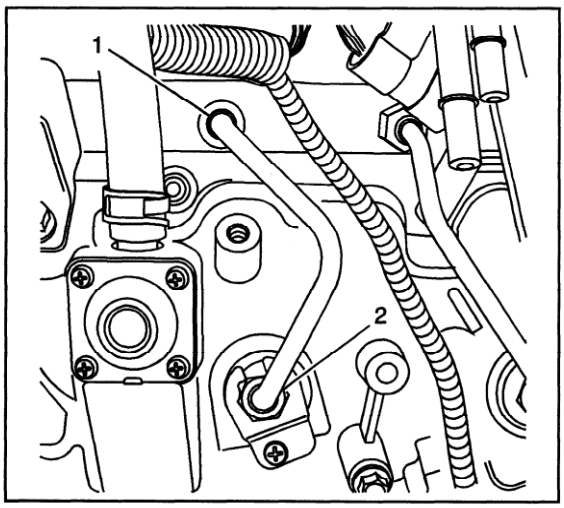
1335603

15. Remove the left fuel rail to pump pipe.



1650670

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



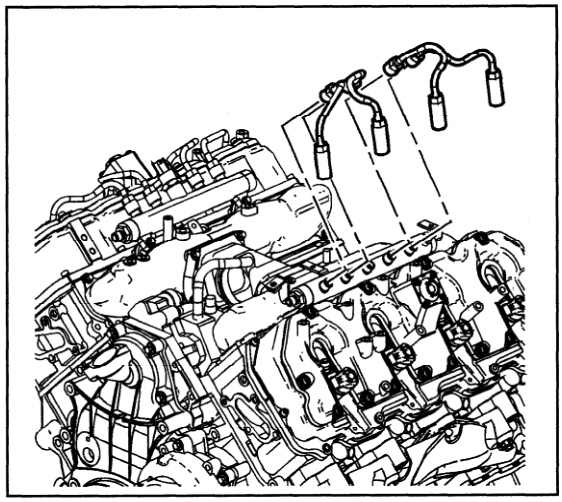

1336209

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

***Notice:*** 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.

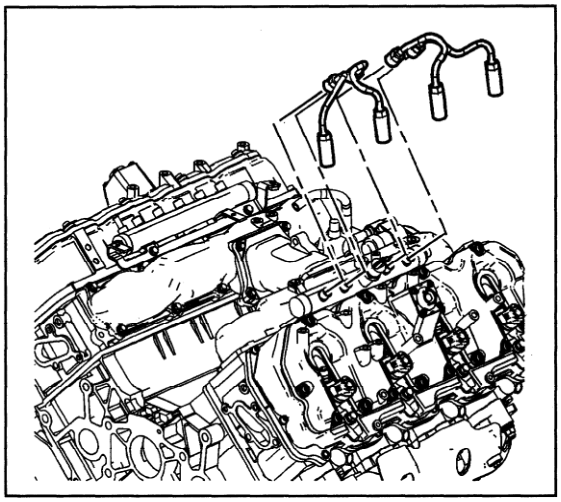
19. Spray lithium grease between the fuel injector line and fitting to contain any debris during removal.

20. Remove the left fuel injector pipes.



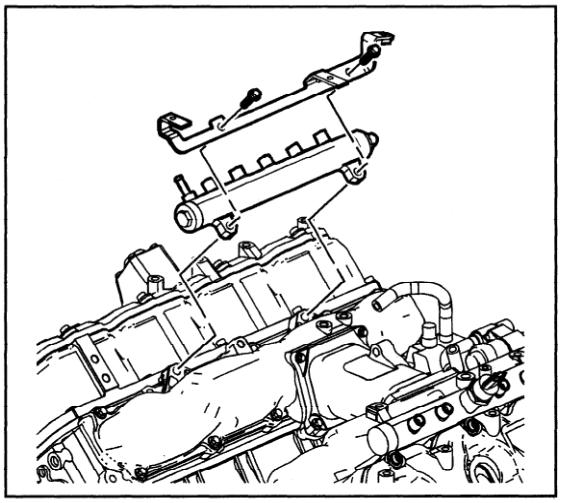
1335608

21. Remove the right fuel injector pipes.

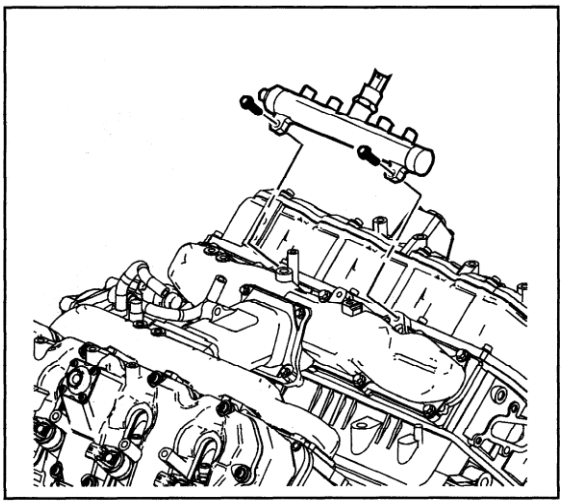


1335614

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

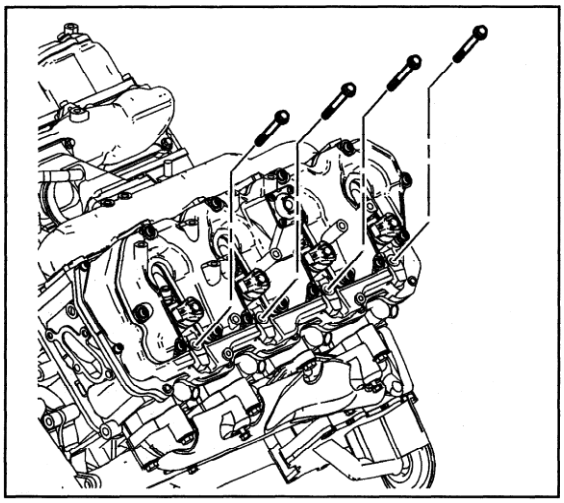


1335616



1335617

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



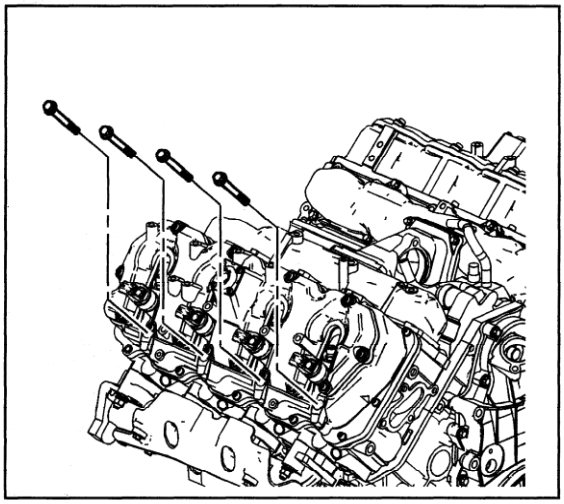
1335618

## Fuel Injectors Removal

### Tools Required

*J-46594* Fuel Injector Remover

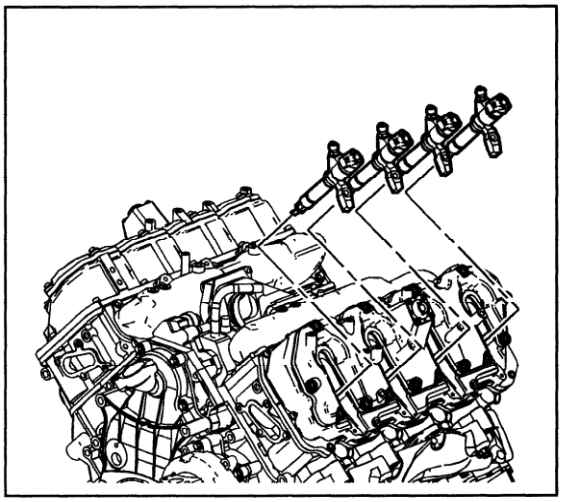
1. Remove the left fuel injector bracket bolts.



1335619

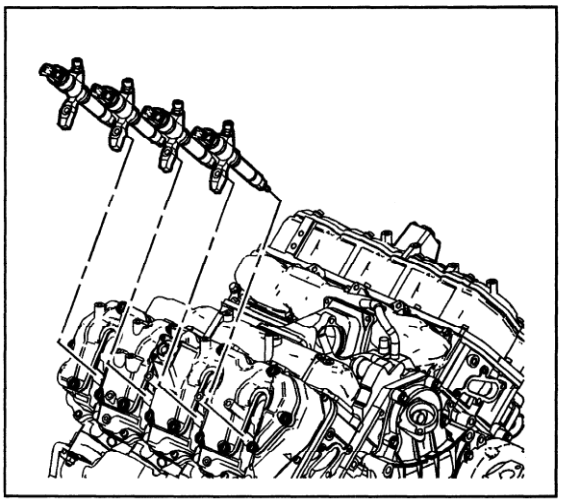
2. Remove the right fuel injector bracket bolts.

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.



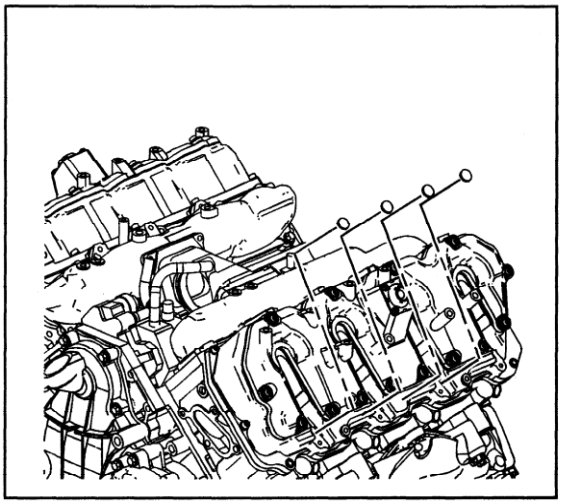
1335621

7. Remove the right fuel injectors with brackets.

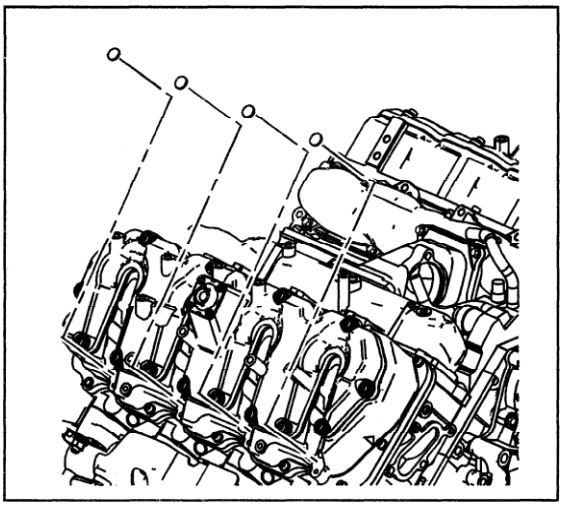


1335625

8. Remove the left injector bracket pins.

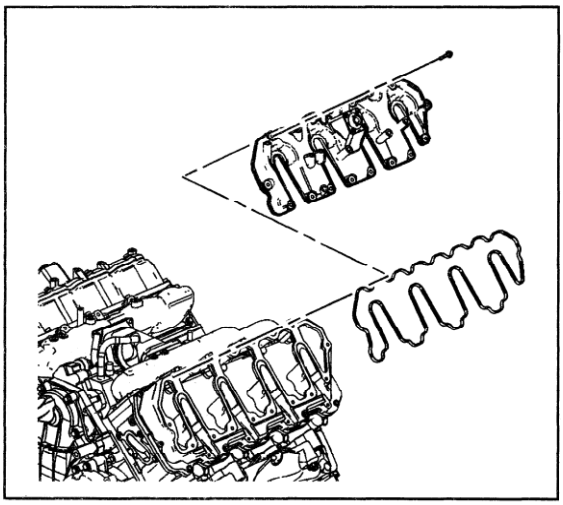


1335627



1335628

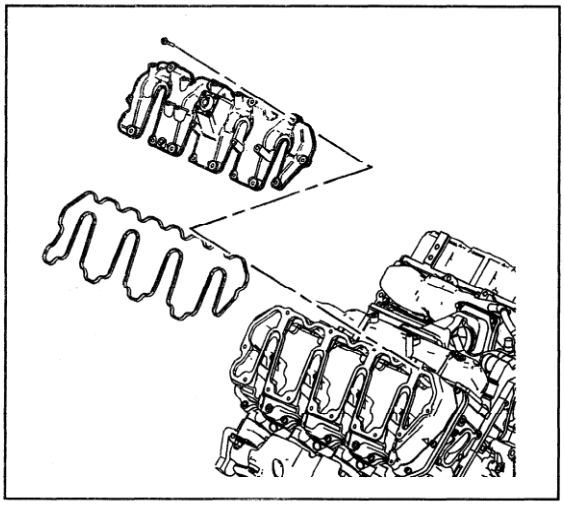
9. Remove the right injector bracket pins.
10. Remove the copper washer from the injector bore and discard.
11. Remove the O-ring from the injector and discard.



1335635

## Valve Rocker Arm Cover Removal - Upper Left

1. Remove the left upper valve rocker arm cover bolts.
2. Remove the left upper valve rocker arm cover.



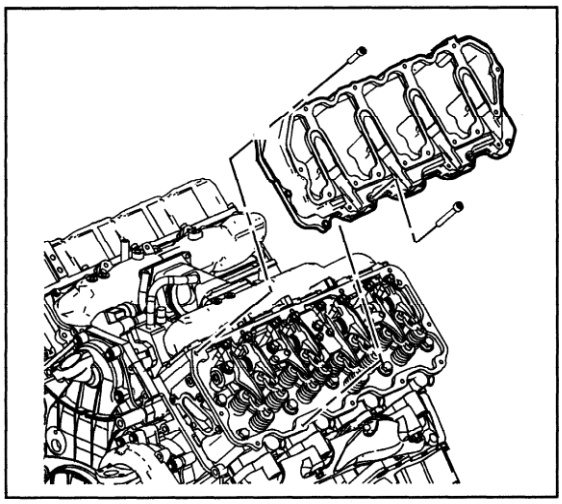
1335653

## Valve Rocker Arm Cover Removal - Upper Right

1. Remove the right upper valve rocker arm cover bolts.
2. Remove the right upper valve rocker arm cover.

## Valve Rocker Arm Cover Removal - Lower Left

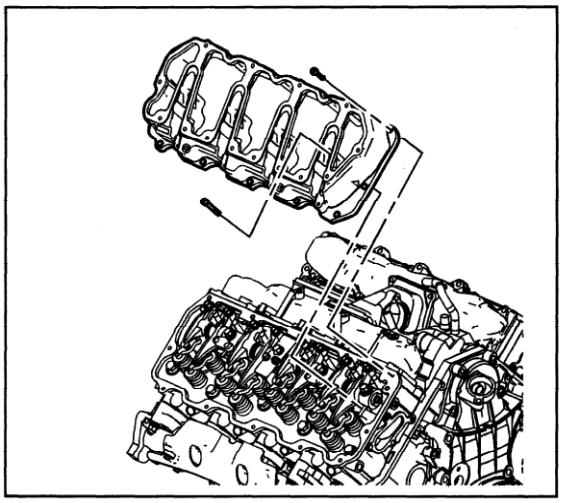
1. Remove the left lower valve rocker arm cover bolts.
2. Remove the left lower valve rocker arm cover.



1335926

## Valve Rocker Arm Cover Removal - Lower Right

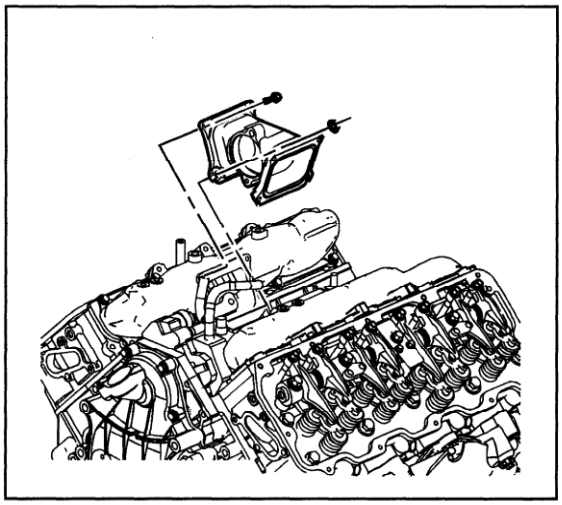
1. Remove the right lower valve rocker arm cover bolts.
2. Remove the lower valve rocker arm cover.



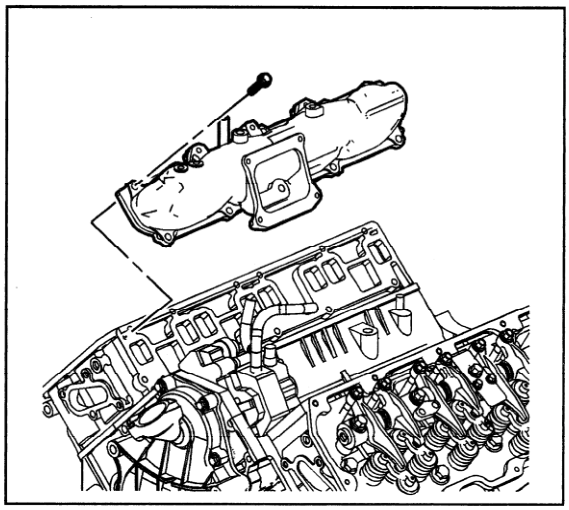
1335929

## Intake Manifold Crossover Removal

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



1335931



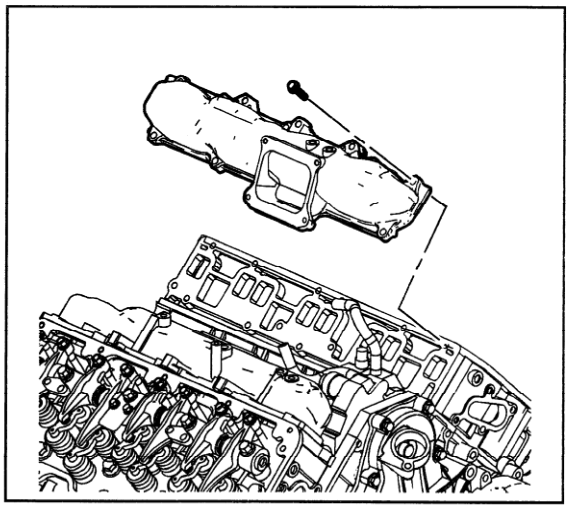
1335935

## Intake Manifold Removal - Right

### 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.



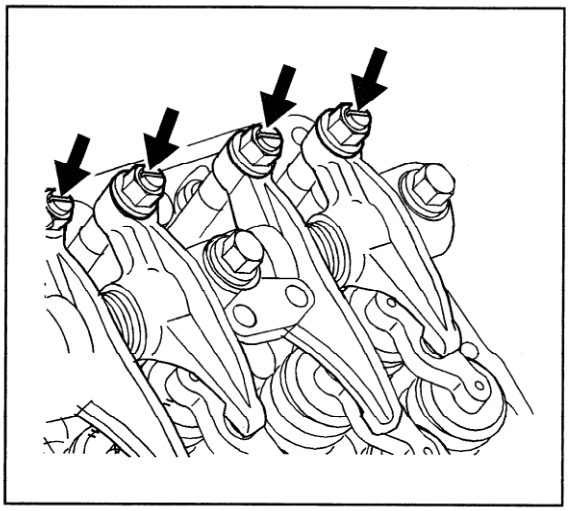
1335932

## Intake Manifold Removal - Left

### 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.

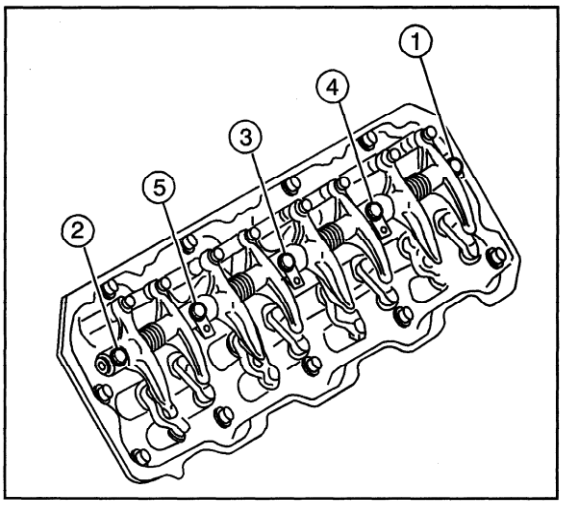


660481

## Valve Rocker Arm, Shaft, and Push Rod Removal

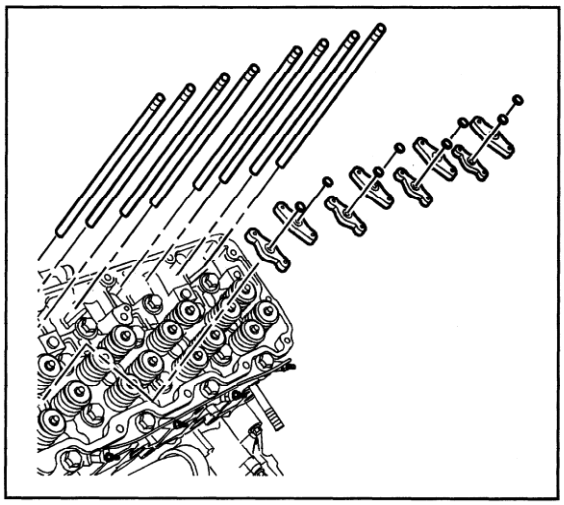
1. Loosen the valve clearance lock nuts on each rocker arm.
2. Loosen the valve clearance adjusting screw on each rocker arm to relieve tension on the valve train.

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



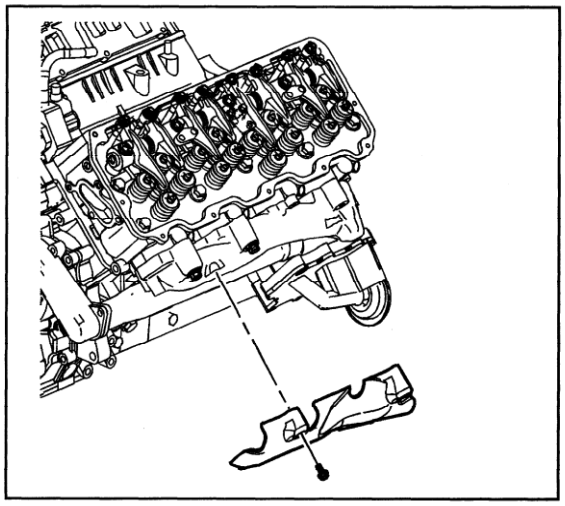
660486

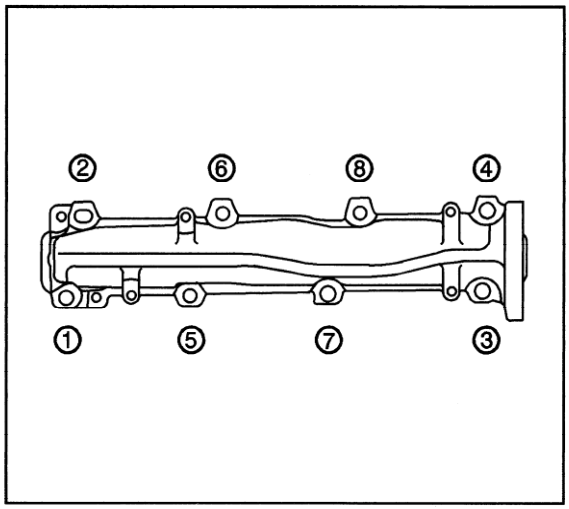
5. Remove the valve bridge pins.
6. Remove the valve bridges.
7. Remove the pushrods.


660488

## Exhaust Manifold Removal - Left

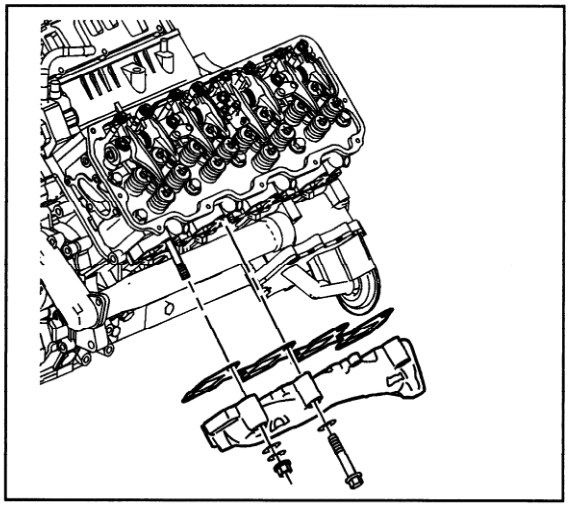
1. Remove the exhaust manifold heat shield bolts.
2. Remove the exhaust manifold heat shield.


1335937

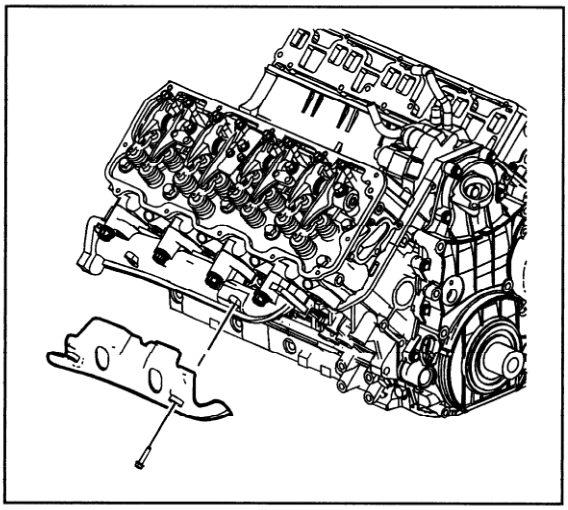


1335939

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


1336105

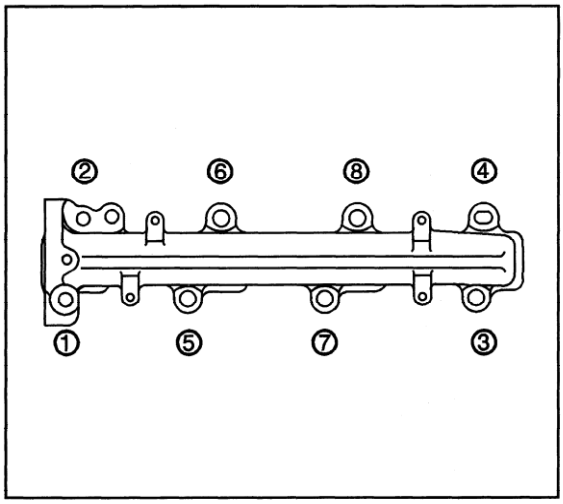
4. Remove the left exhaust manifold and gasket.


1336106

## Exhaust Manifold Removal - Right

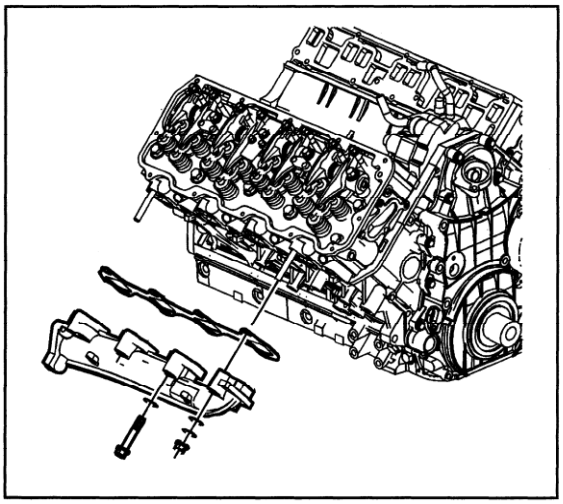
1. Remove the exhaust manifold heat shield bolts.
2. Remove the exhaust manifold heat shield.

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



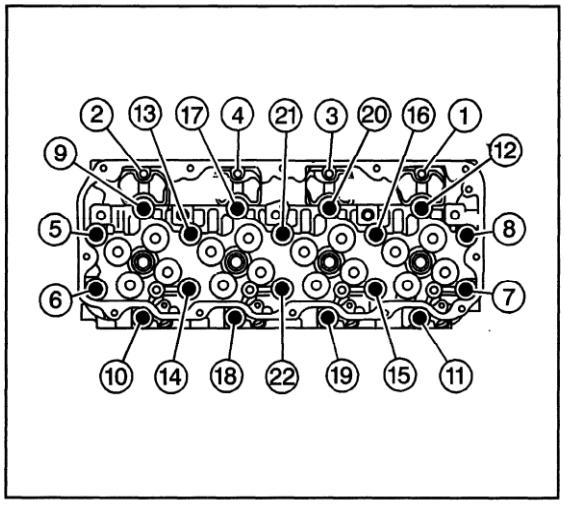
1336107

4. Remove the right exhaust manifold and gasket.

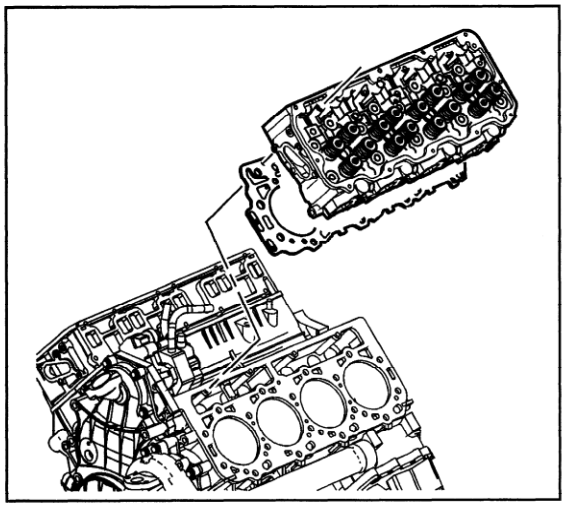

1336106

## Cylinder Head Removal - Left

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

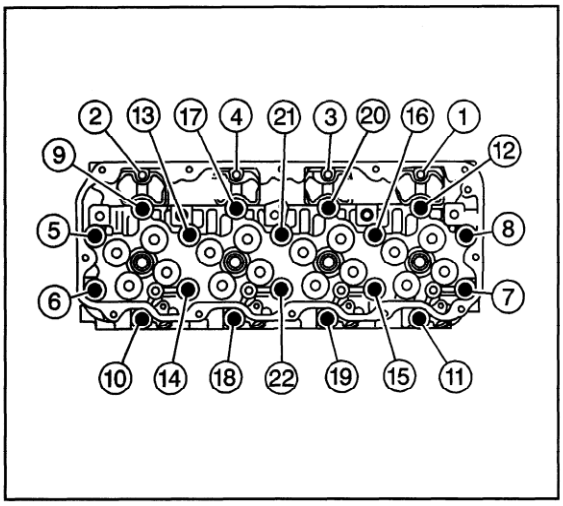


1336109



1336110

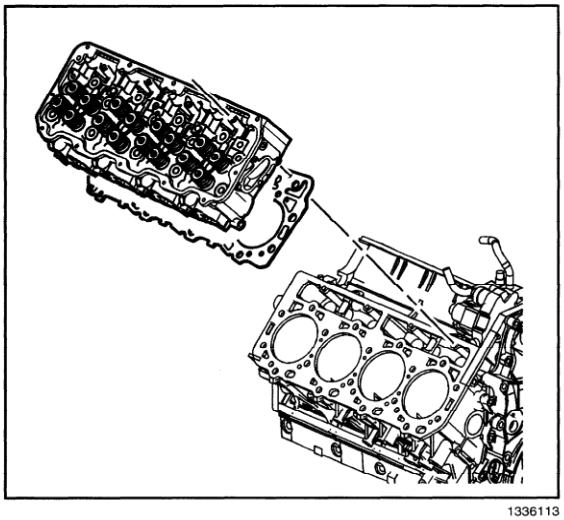
3. Remove the left cylinder head assembly.
4. Remove the left cylinder head gasket.




1336109

## Cylinder Head Removal - Right

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

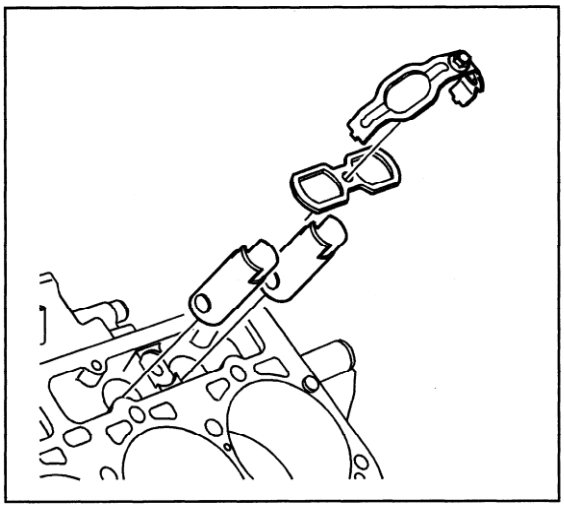


1336113

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

## Valve Lifter Removal

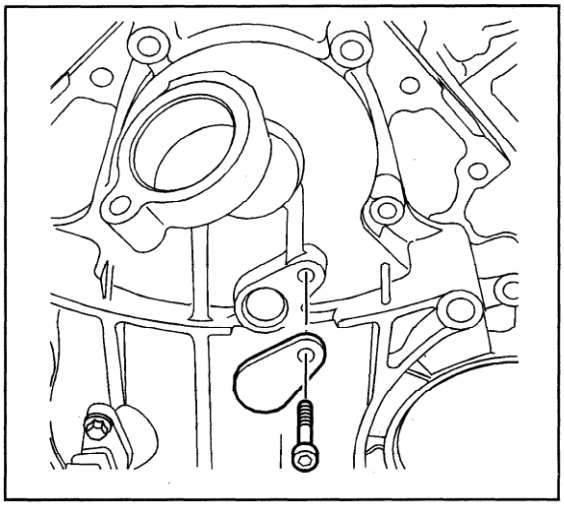
1. Loosen the valve lifter guide hold down bracket bolts.
2. Remove the valve lifter guide hold down brackets.
3. Remove the valve lifter guides.
4. Remove the valve lifters.



660517

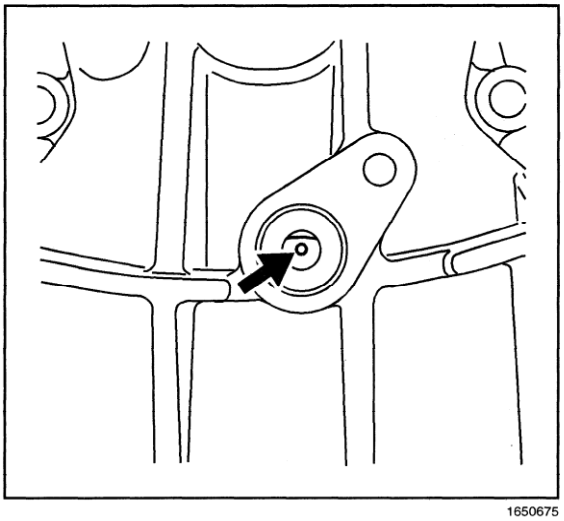
## Fuel Injection Pump Removal

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

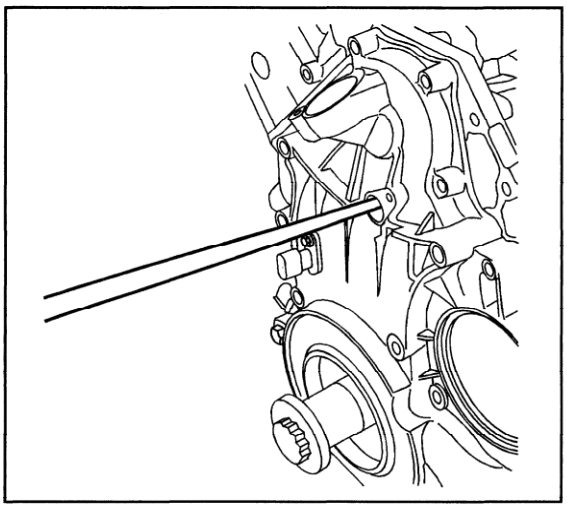


1650673

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

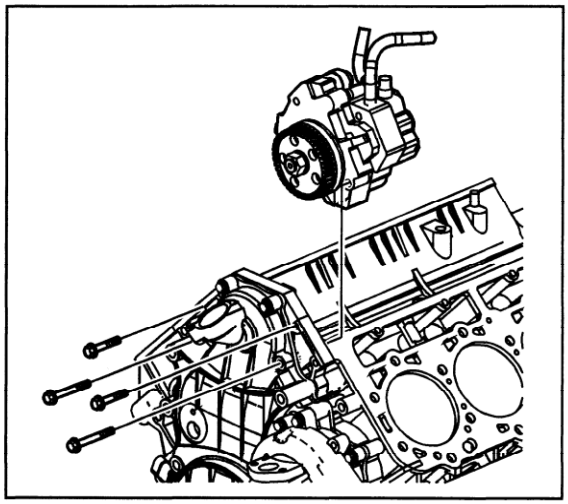


1650675



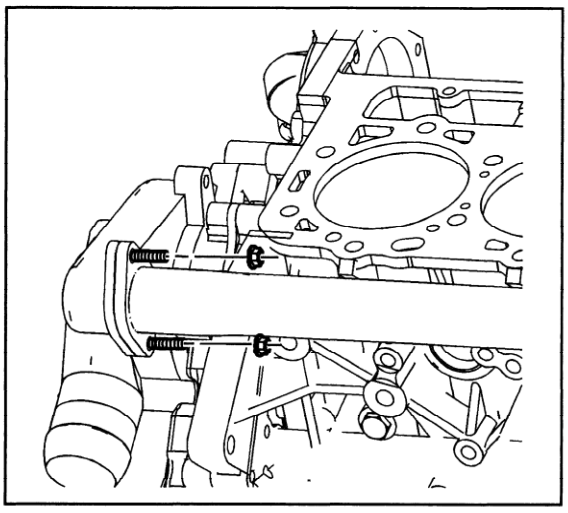
1650676

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.



1336114

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

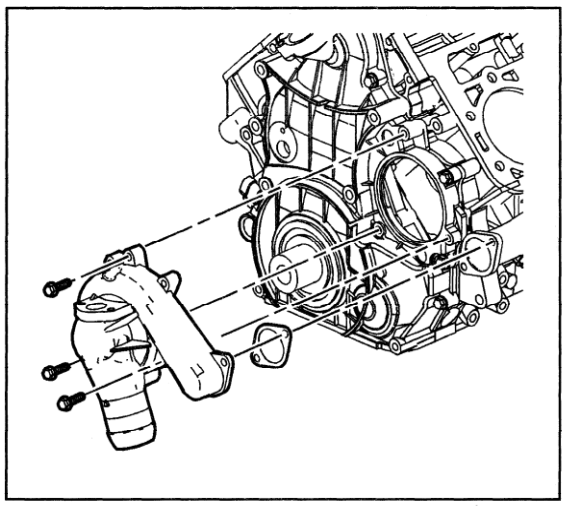


1336115

## Water Pump Removal

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

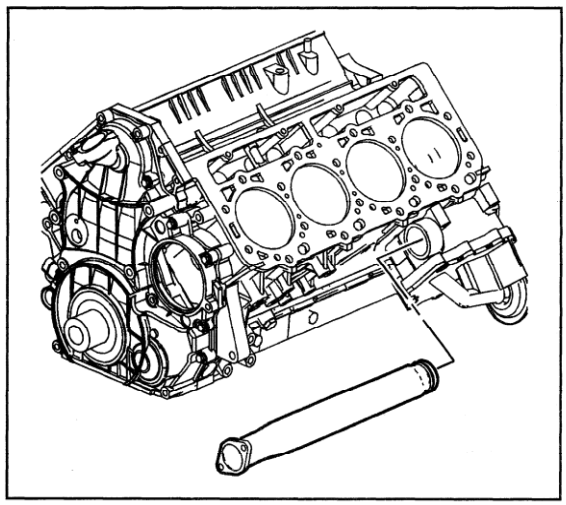
2. Remove the water pump bolts.
3. Remove the water pump assembly.
4. Remove the water pump seal and discard.
5. Remove the engine coolant pipe gasket and discard.



1336116

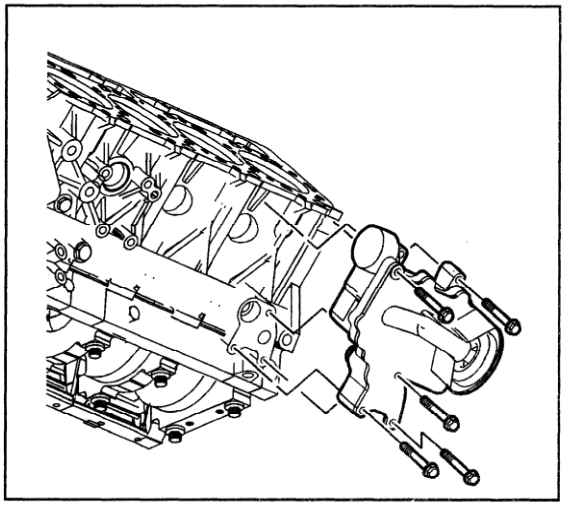
## Oil Filter Adapter and Oil Cooler Assembly Removal

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

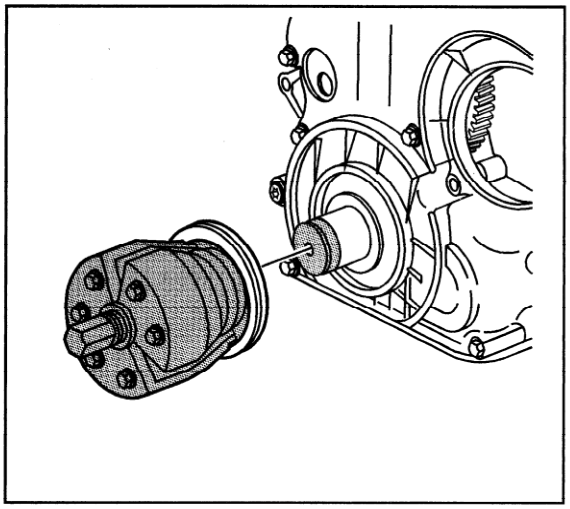


1336117

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



1336118



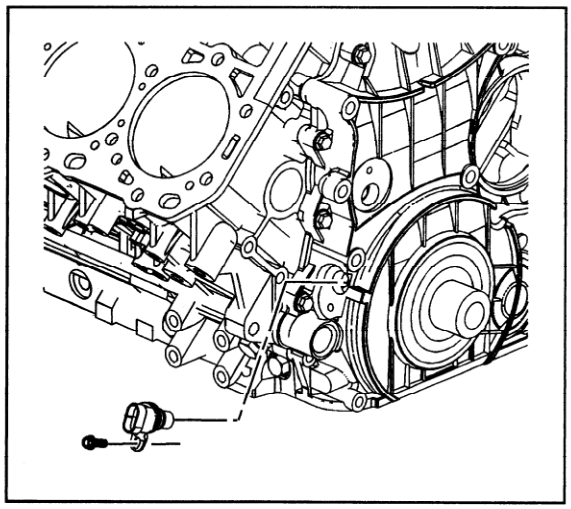
660534

## Crankshaft Front Oil Seal Removal

### Tools Required

*J 44644* Crankshaft Front Oil Seal Remover

1. Install the *J 44644* to the crankshaft front oil seal.
2. Remove crankshaft front oil seal using *J 44644*.



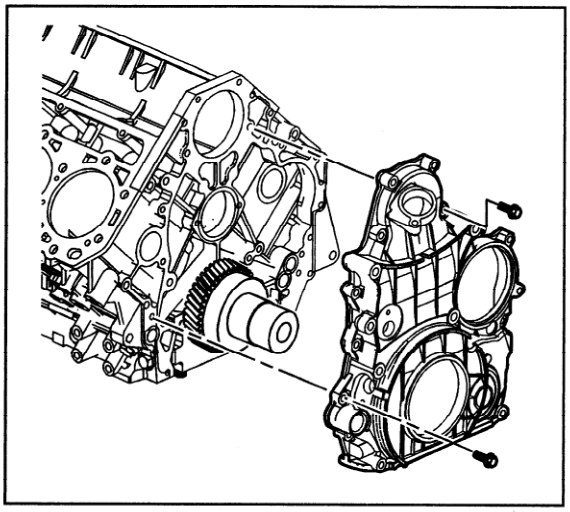
1336119

## Engine Front Cover Removal

### Tools Required

*J 37228* Seal Cutter

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

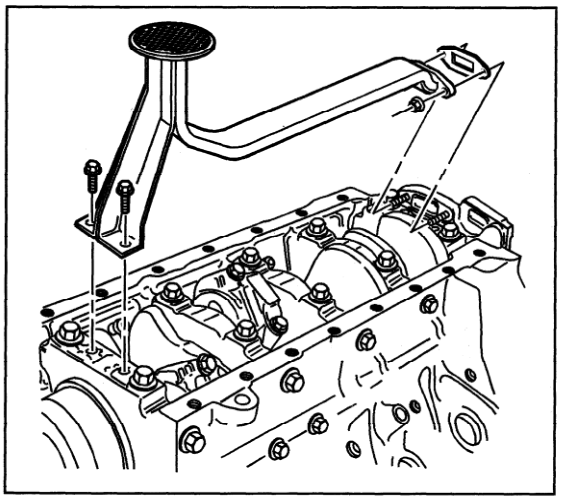


1336120

3. Remove the engine front cover bolts.
4. Separate the engine front cover from the cylinder block using *J 37228*.
5. Remove the engine front cover.

## Oil Pump 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.



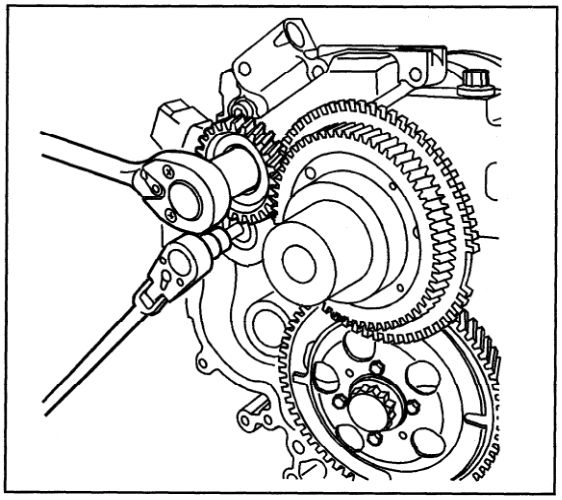
660531

## Oil Pump Removal

***Notice:*** 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.

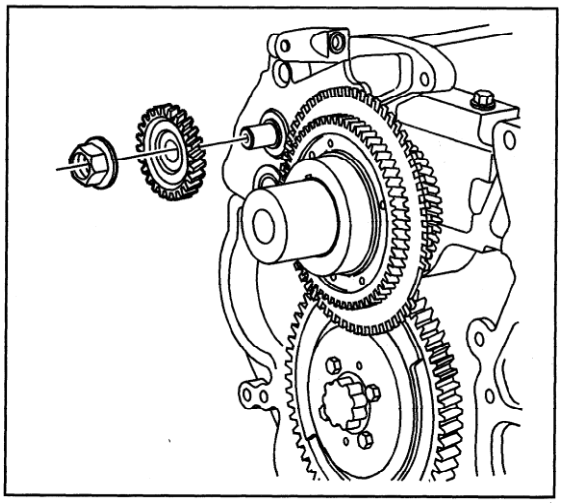
**Important:** Look for an "L" on the end of the oil pump shaft. If there is an "L" present, the nut and shaft have left hand threads. Service the nut accordingly.

1. While holding the secondary oil pump shaft with a hex driver, remove the oil pump driven gear nut.

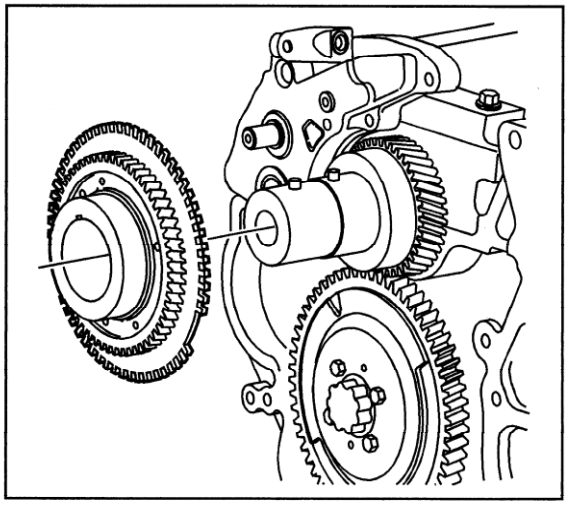


776631

2. Remove the oil pump driven gear.



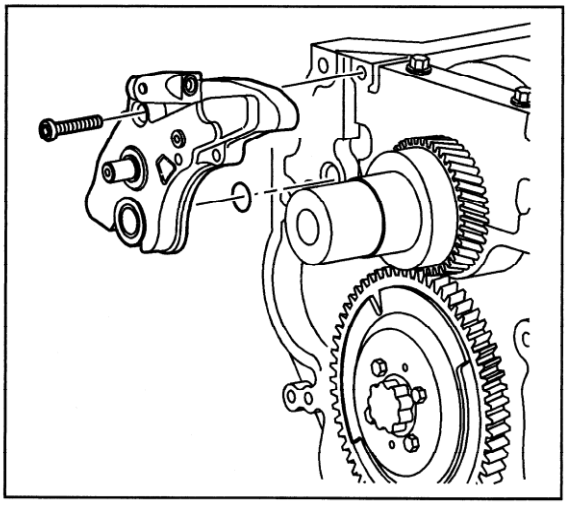
660532



660339

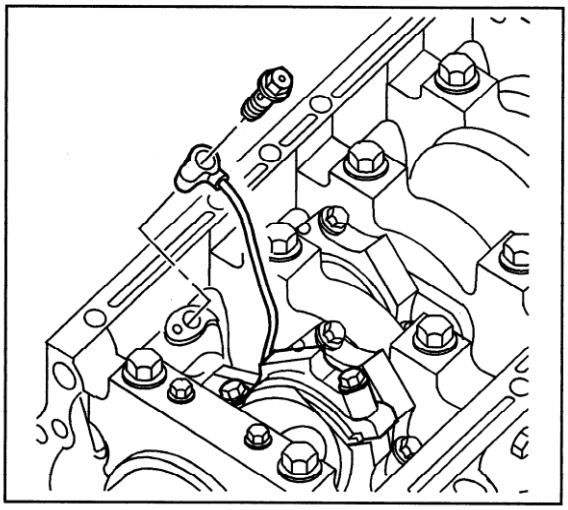
**Important:** Do not damage the crankshaft sensor reluctor teeth.

3. Remove the oil pump drive gear and crank sensor reluctor assembly.



660533

4. Remove the oil pump bolts.
5. Remove the oil pump.
6. Remove the O-ring and discard.



660543

## Piston Oil Cooling Nozzle Removal

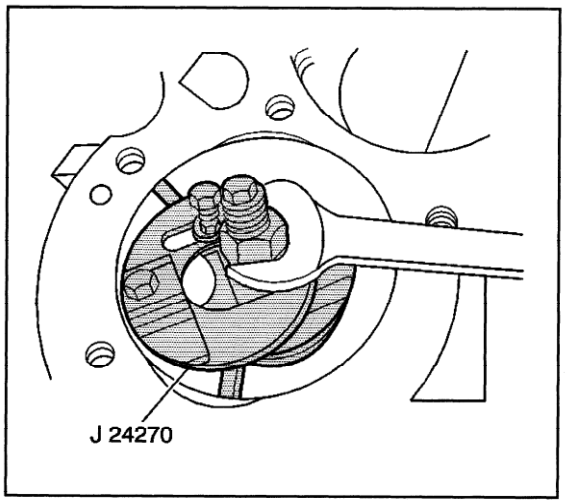
1. Rotate crankshaft as necessary to obtain access to piston oil cooling nozzles.
2. Remove the piston oil cooling nozzle eye bolt.
3. Remove the piston oil cooling nozzle.

## Piston, Connecting Rod, and Bearing Removal

### Tools Required

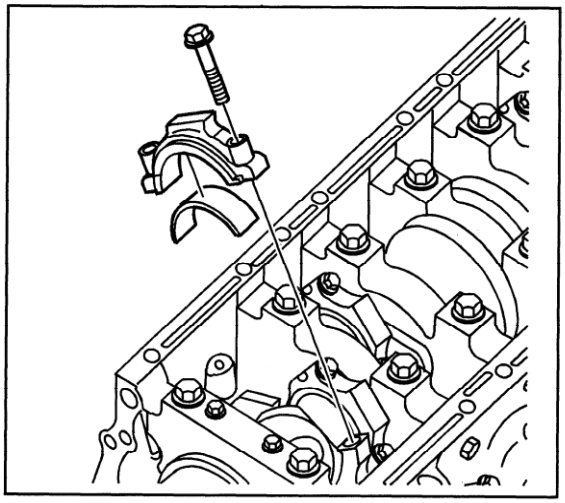
*J 24270* Ridge Reamer

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.



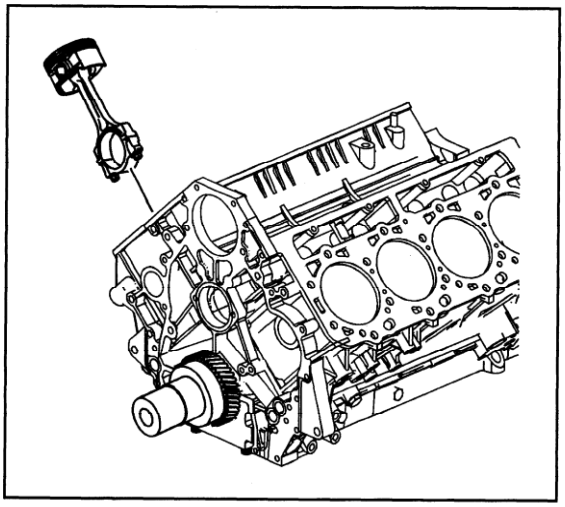

11497

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.

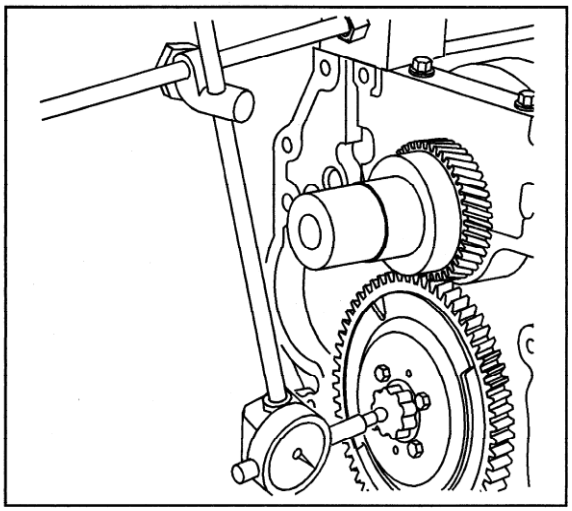


660550

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



1336121



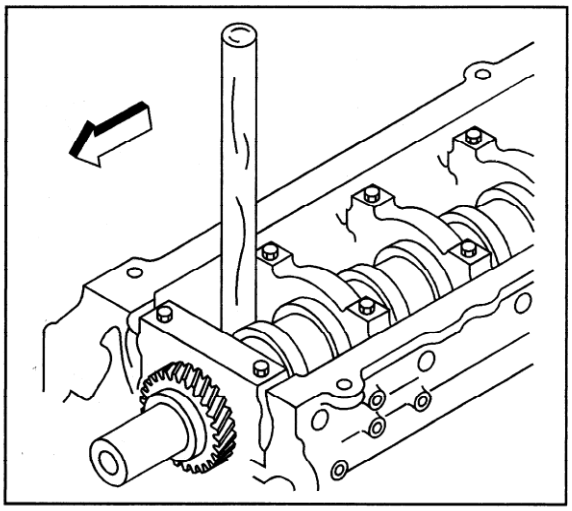
663816

## Camshaft Removal

### Tools Required

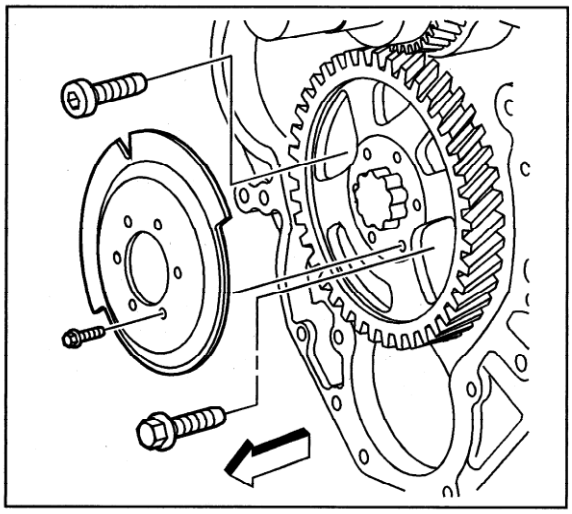
*J 7872* Dial Indicator Set

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.



660539

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



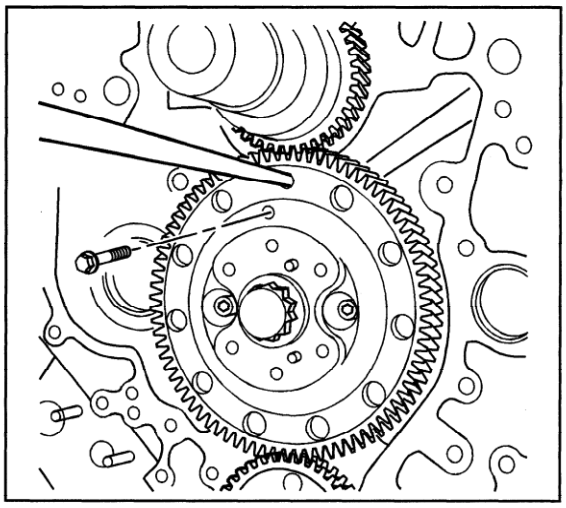
663091

4. Remove the camshaft exciter ring bolts.

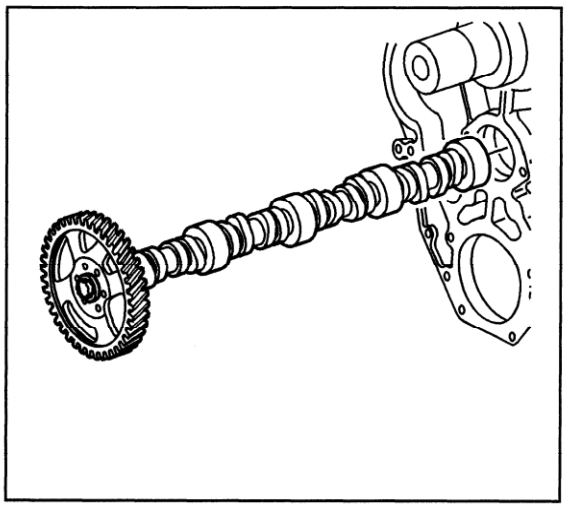
**Important:** The two piece cam gear must be bolted together to prevent the spring tension from unloading upon removal.

5. Remove the camshaft exciter ring.

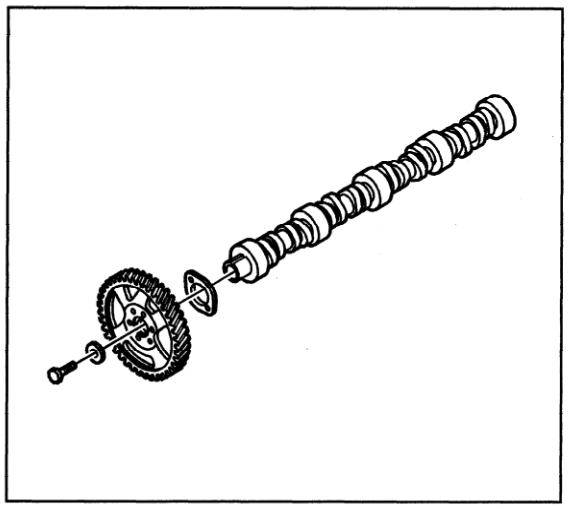
6. Align the threaded hole with a suitable tool and install an exciter ring bolt to secure the spring tension.
7. Remove the camshaft thrust plate bolts through the holes in the camshaft gear.

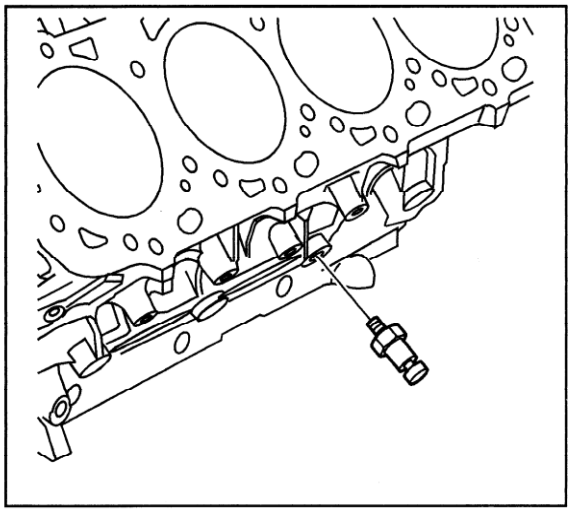

1650679

8. Remove the camshaft with the camshaft gear attached.


663093

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


660540



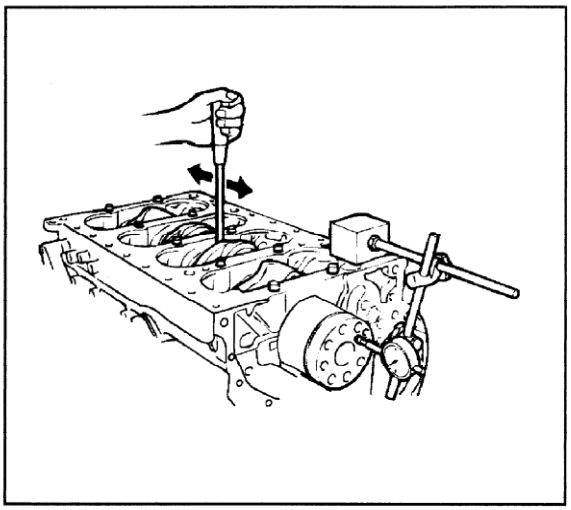
881732

## Crankshaft and Bearings Removal

### Tools Required

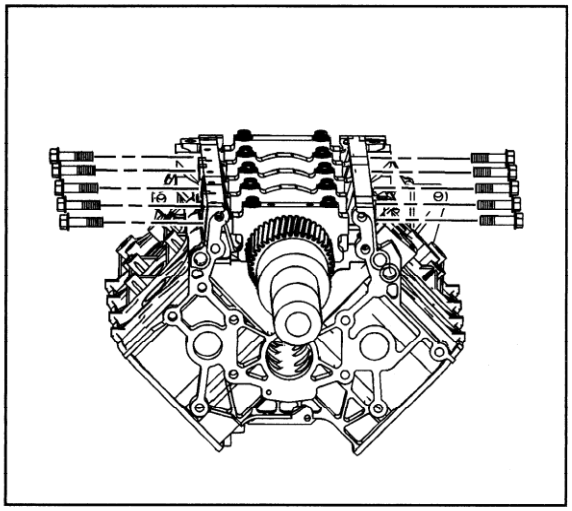
*J 7872* Dial Indicator Set

1. Remove the oil pressure sensor.



660558

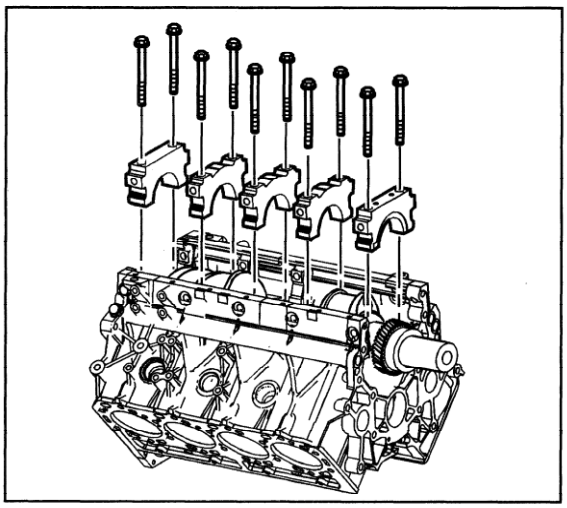
2. Measure crankshaft end play using *J 7872*. The production value is 0.04–0.205 mm (0.0016–0.0081 in) and the service limit is 0.54 mm (0.0213 in). Replace the thrust bearings upon reassembly if the measured value exceeds the service limit.



1336122

3. Remove the crankshaft bearing cap side bolts.

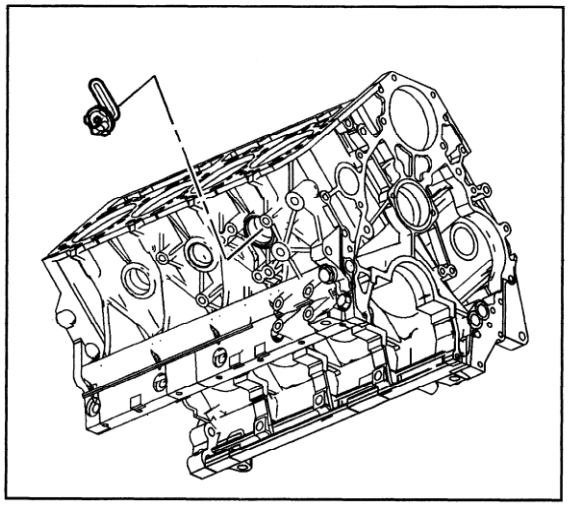
4. Remove the crankshaft bearing cap bolts.
5. Remove the crankshaft bearing caps.
6. Set the bolts aside for use in plastic gauging if needed.
7. Remove the crankshaft assembly.
8. Remove the crankshaft bearings from the engine block and the bearing caps.
9. Mark crankshaft bearings and caps so they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



1336123

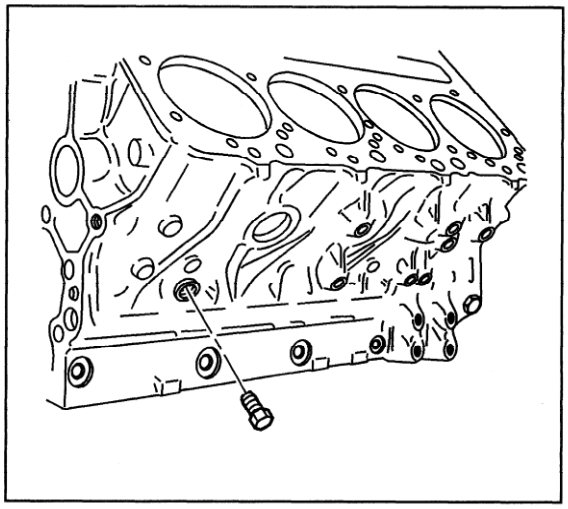
## Engine Block Cleaning and Inspection

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

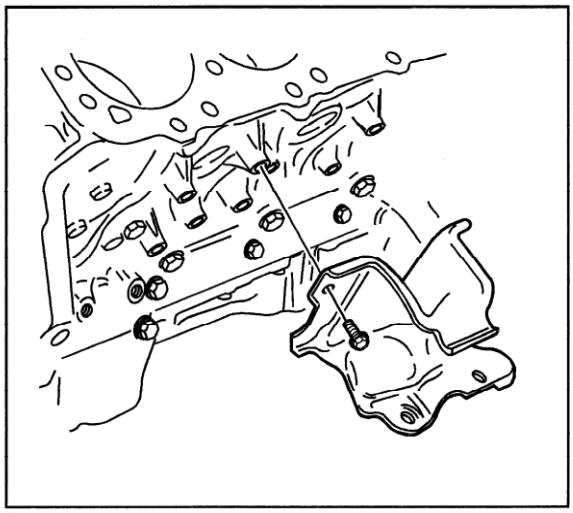


1336124

3. Remove the oil gallery plugs.

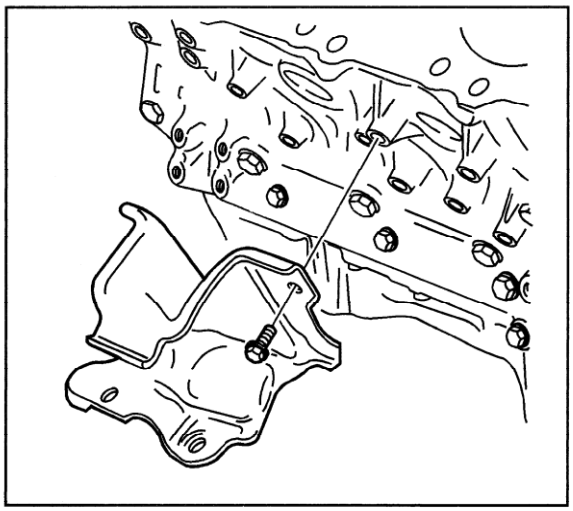


663096



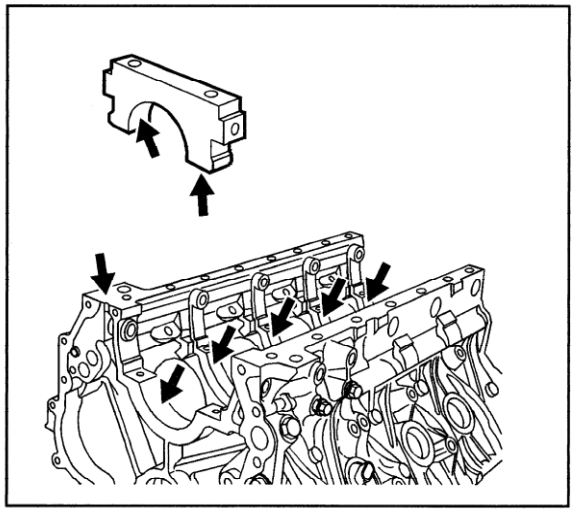
881734

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



663100

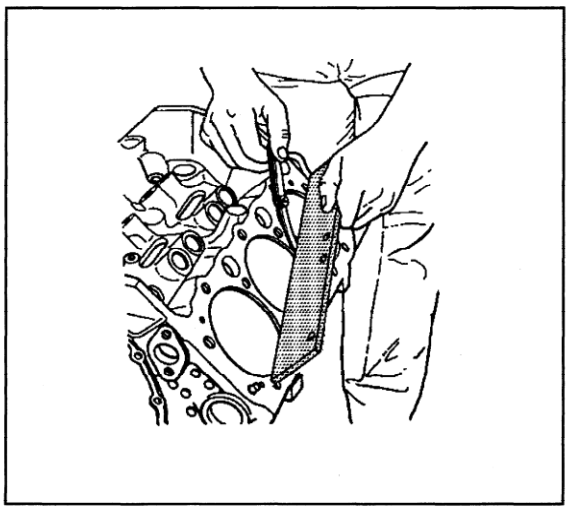
6. Remove the right engine mount bolts.
7. Remove the right engine mount.
8. Clean the sealing material from the gasket mating surfaces of the block.
9. Clean the block in cleaning solvent.
10. Flush the engine block with clean water or steam.
11. Clean the oil passages.
12. Clean the cylinder bores.
13. 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.



663103

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

18. 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.
19. Apply sealer to the oil gallery plugs.



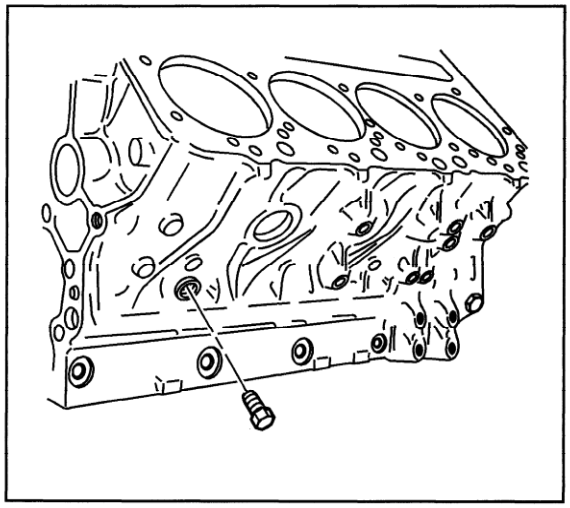
35209

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

20. Install the oil gallery plugs.

    **Tighten**

    Tighten the oil gallery plugs to 53 N·m (39 lb ft).

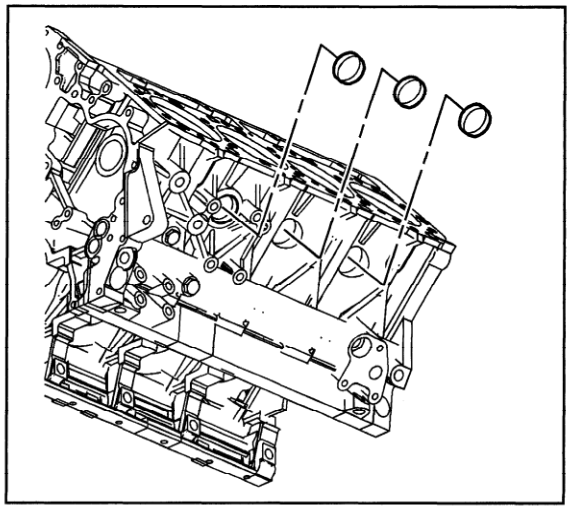


663096

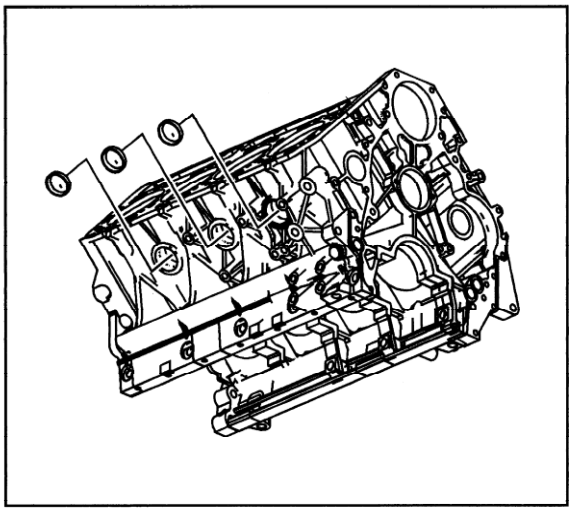
21. Install the left engine block coolant plugs.

    **Tighten**

    Tighten the left engine block coolant plugs to 18 N·m (13 lb ft).



1336125

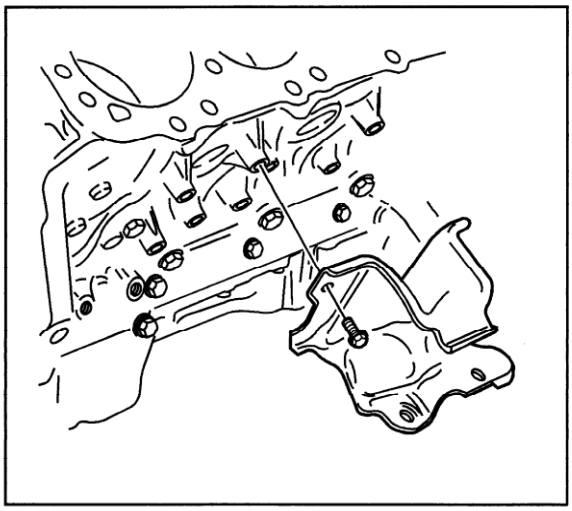


1397816

22. Install the right engine block coolant plugs.

**Tighten**

Tighten the right engine block coolant plugs to 18 N·m (13 lb ft).

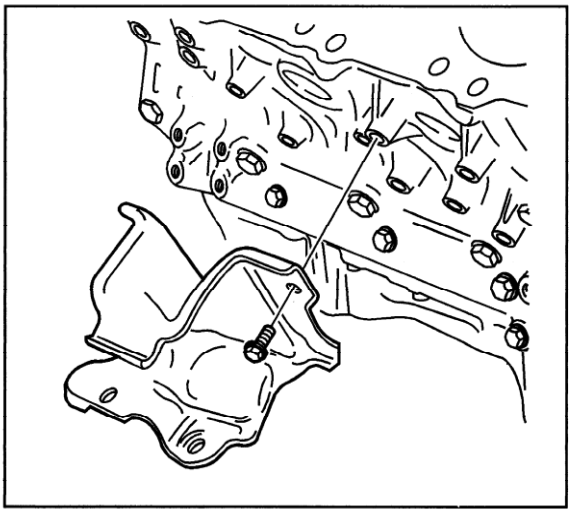


881734

23. Install the left engine mount and engine mount bolts.

**Tighten**

Tighten the engine mount bolts to 58 N·m (43 lb ft).



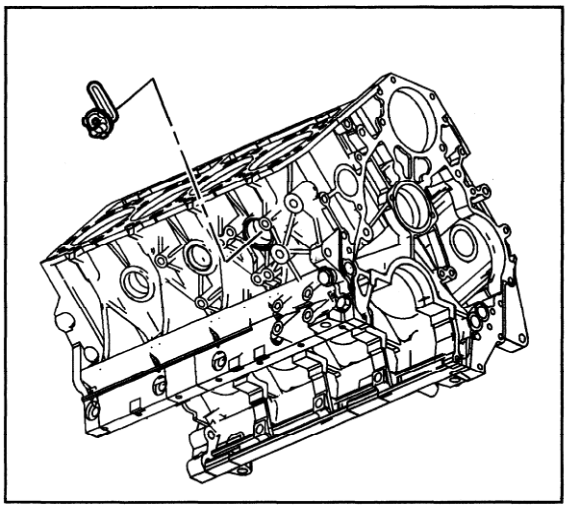
663100

24. Install the right engine mount and engine mount bolts.

**Tighten**

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

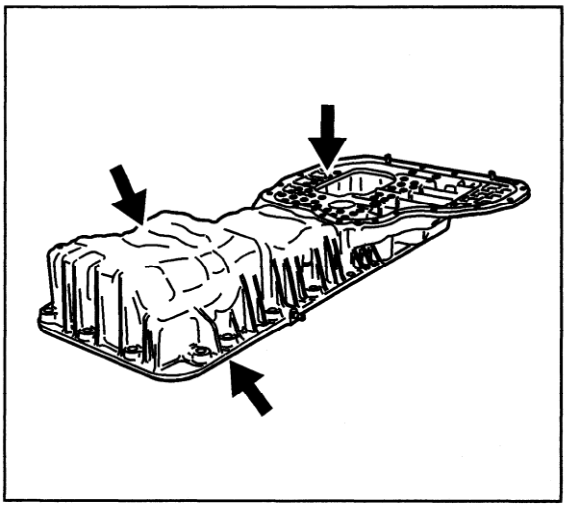
25. Install a new O-ring to the block heater.
26. Lubricate the O-ring with engine coolant.
27. Install the engine block heater.



1336124

## Oil Pan Cleaning and Inspection - Upper

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.



663126

## Camshaft and Bearings Cleaning and Inspection

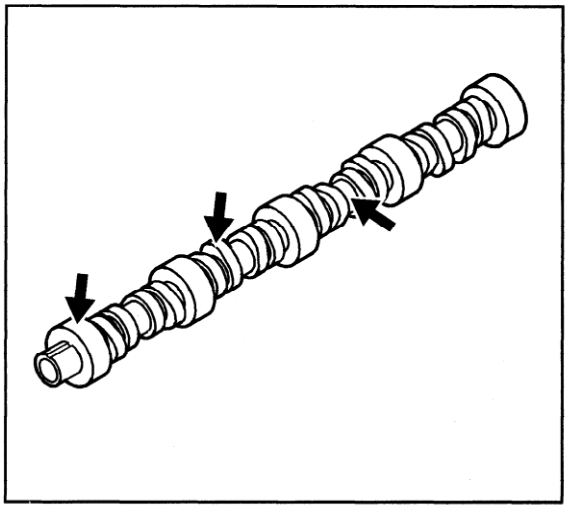
### Tools Required

*J 7872* Dial Indicator Set

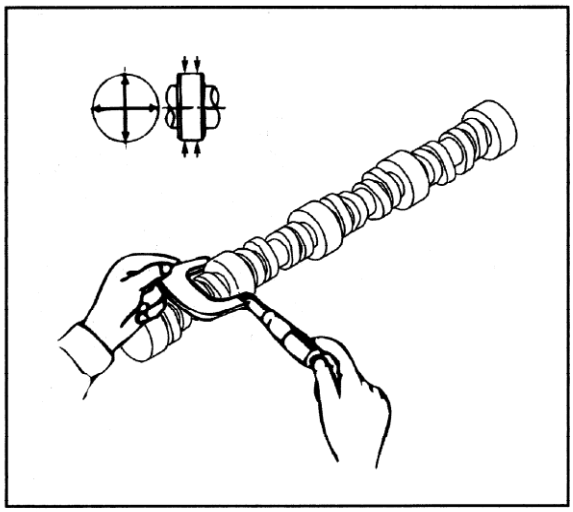
1. Clean the camshaft.

**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

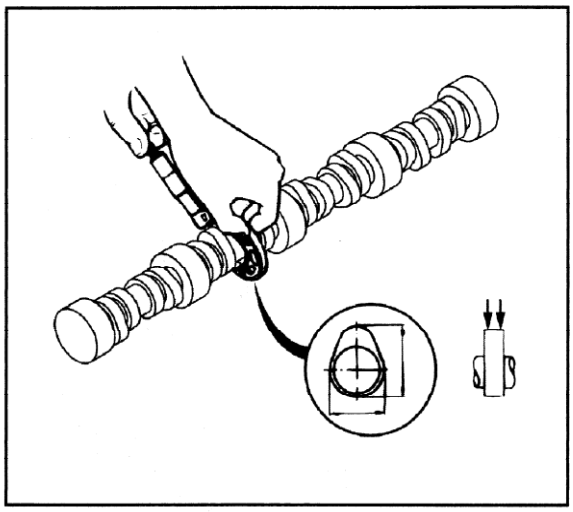


663113



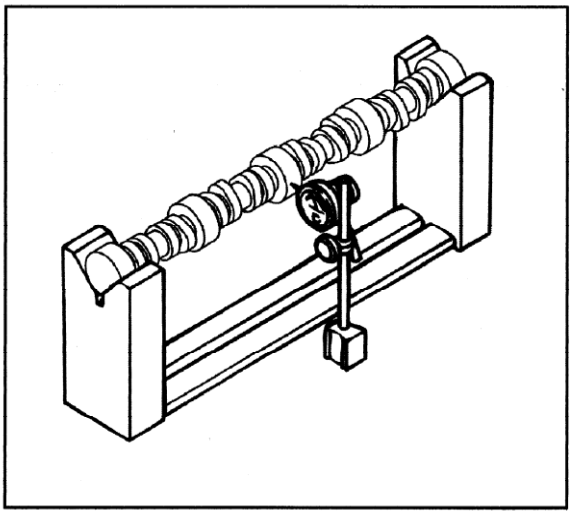
663114

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.



663119

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.



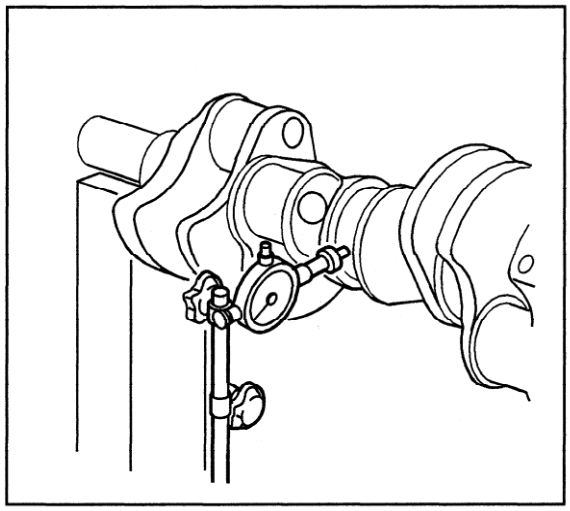
663121

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 Bearings Cleaning and Inspection

- *J 7872* Dial Indicator Set
- *J 45059* Angle Meter

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.
3. Measure the crankshaft run out.
   - Mount the crankshaft in wooden V-blocks.
   - Set *J 7872* on the center of the crankshaft journal.
   - Turn the crankshaft in the normal direction of rotation.
   - 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.



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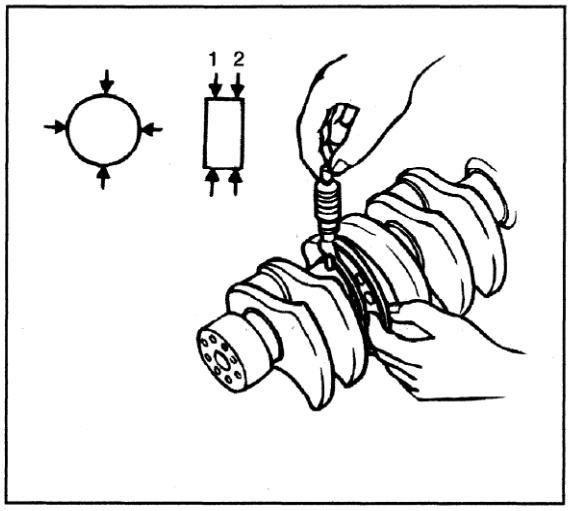
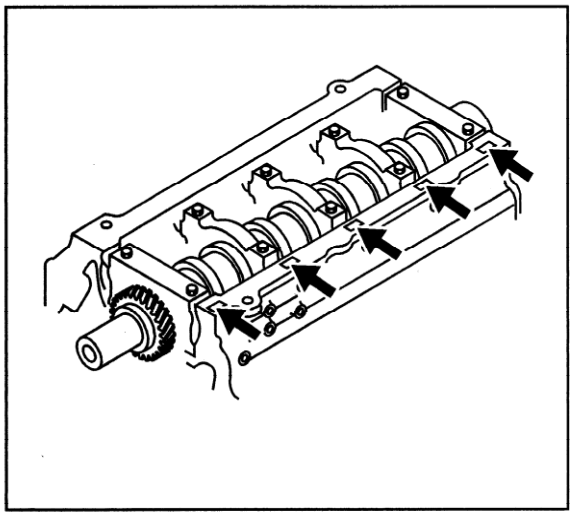



663132

## Crankshaft Bearing Selection

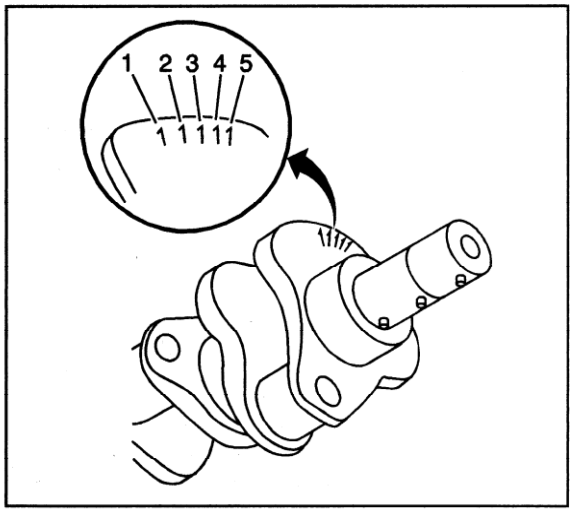
There are two methods for selecting the proper size crankshaft bearings. The first one is to select the bearing grade (color code) based on the cylinder block grade and the crankshaft journal grade from the Crankshaft Bearing Grade chart. The second is the plastic gauge method.



663785

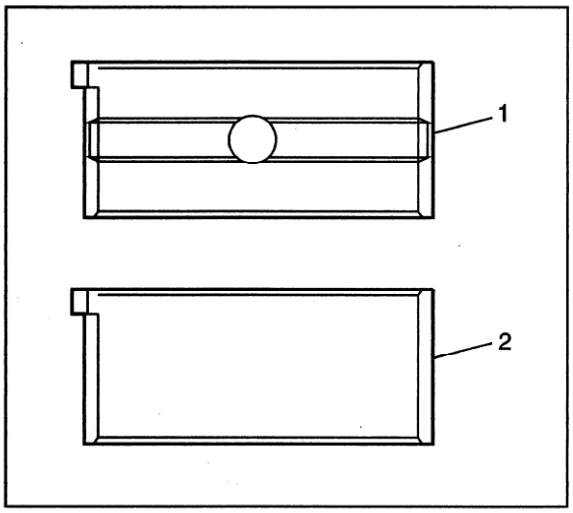
## Crankshaft Bearing Selection Grade Chart Method

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




663786

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




663789

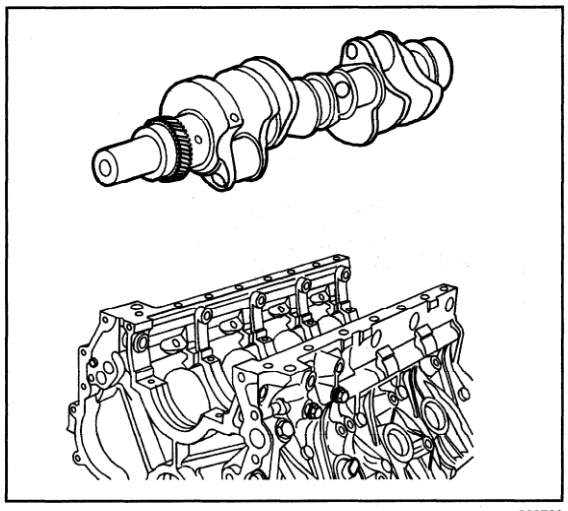
## Crankshaft Bearing Selection Plastic Gage Method

### Tools Required

*J 45059* Angle Meter

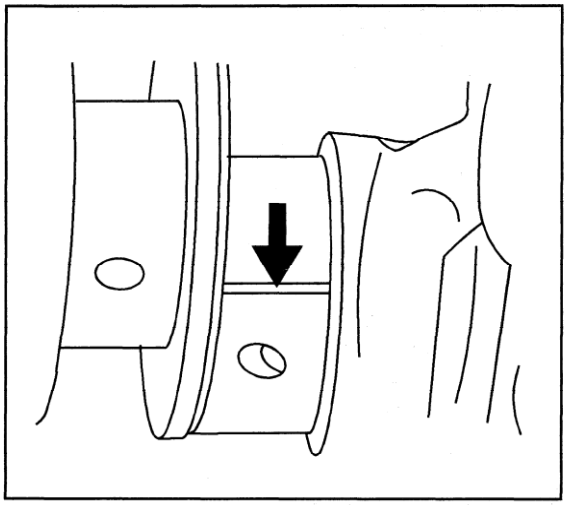
1. Clean the cylinder block bearing fitting surfaces.
2. Clean the crankshaft and upper bearings (1) and lower bearings (2).
3. Install the bearings into the cylinder block and the bearing caps.

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



663790

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



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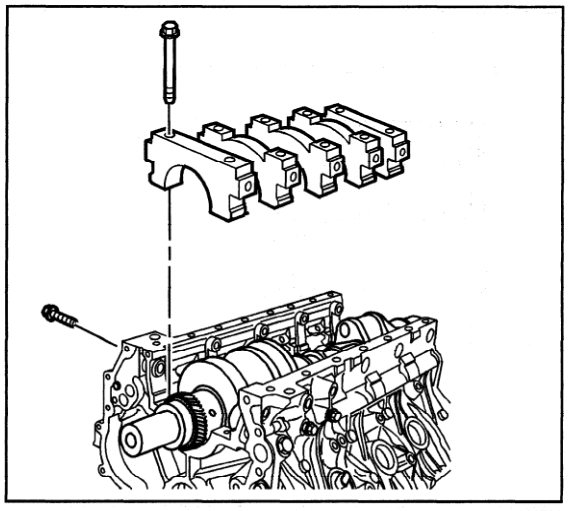
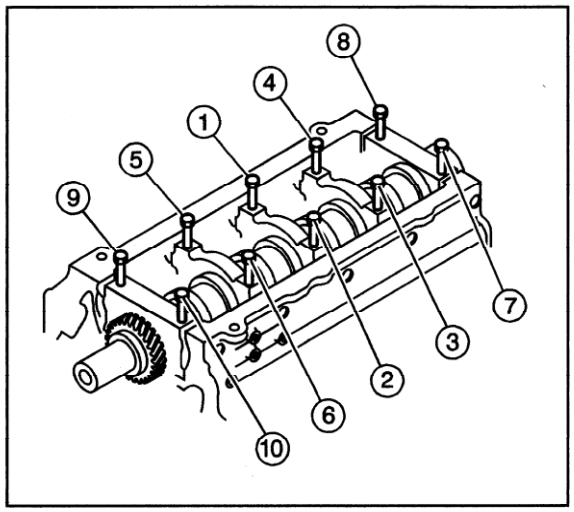
7. Install the crankshaft bearing caps.



663793



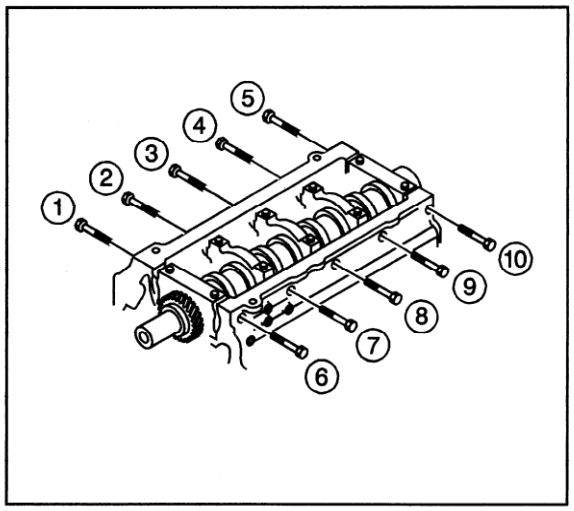
663796

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

8. Install the crankshaft bearing cap bolts.
9. Tighten the crankshaft bearing cap bolts in the proper sequence.

   **Tighten**

   - 1st step 98 N·m (72 lb ft).
   - 2nd step 132 N·m (97 lb ft).
   - 3rd step 30 degrees using *J 45059*.

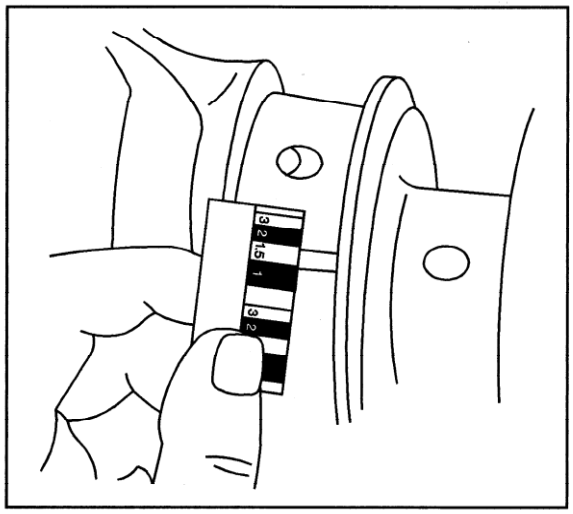


663798

10. Install the crankshaft bearing cap side bolts.

    **Tighten**

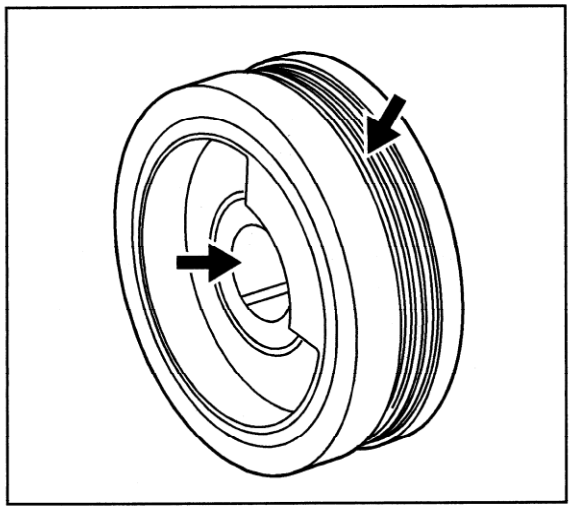
    Tighten the crankshaft bearing cap side bolts in the proper sequence to 70 N·m (52 lb ft).
11. Remove the crankshaft bearing cap bolts.
12. Remove the crankshaft bearing caps.


500656

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

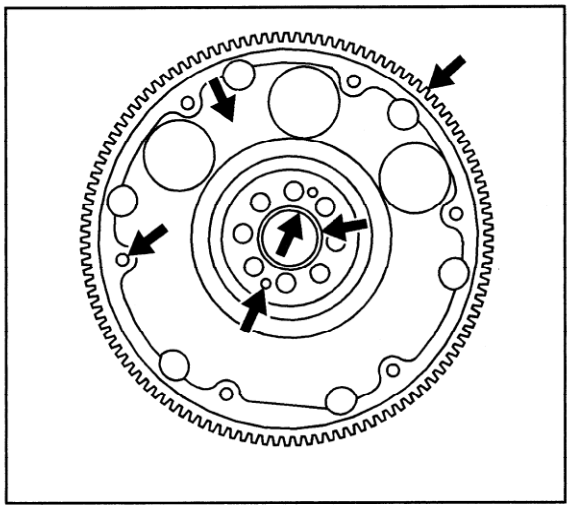
1. Clean the crankshaft balancer.
2. Inspect the crankshaft balancer for damage to belt drive surface and to crankshaft balancer hub.
3. Inspect the balancer hub groove for damage or wear.
4. Replace the crankshaft balancer if any concerns exist.



1336127

## Engine Flywheel Cleaning and Inspection

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.



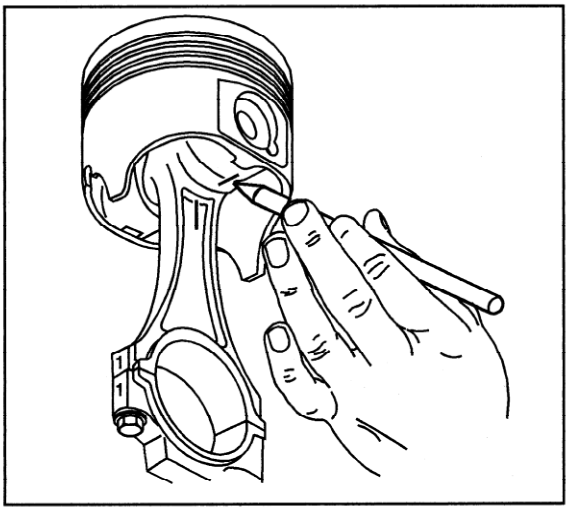
663136

## Piston and Connecting Rod Disassemble

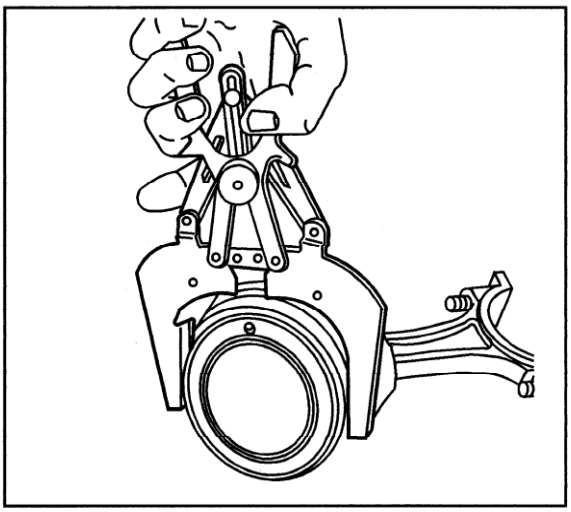
### Tools Required

*J 43654* Piston Pin Retainer Remover/Installer

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

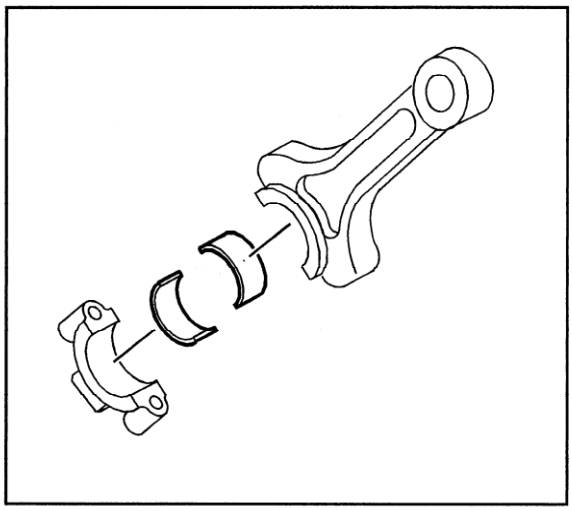


663138



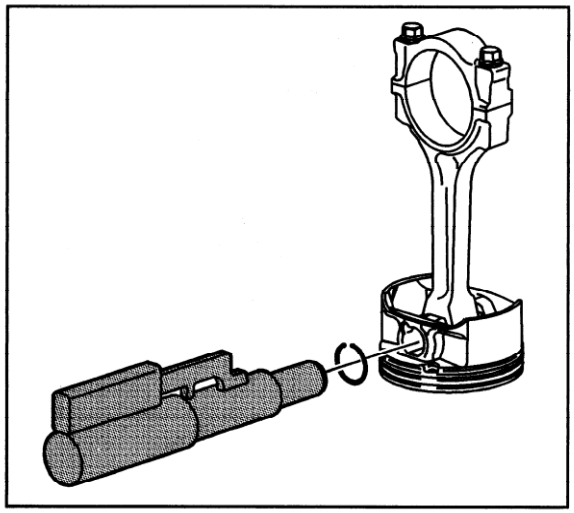
637689

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



663781

3. Remove the connecting rod bearing inserts.

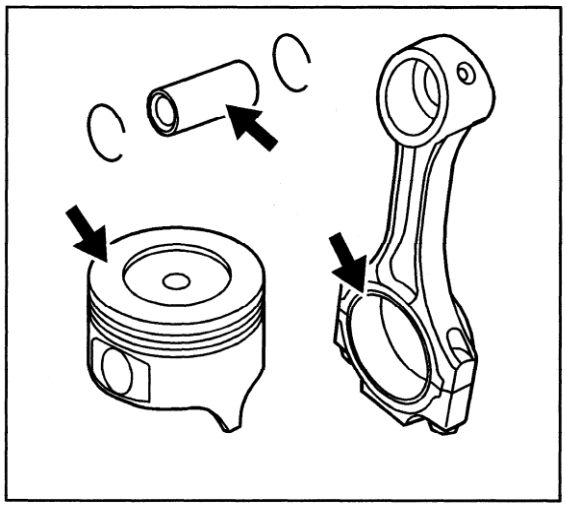


637736

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.

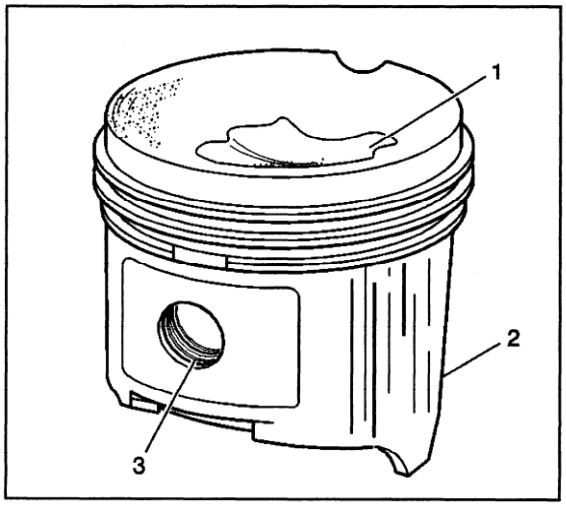
## Piston, Connecting Rod, and Bearings Cleaning and Inspection

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



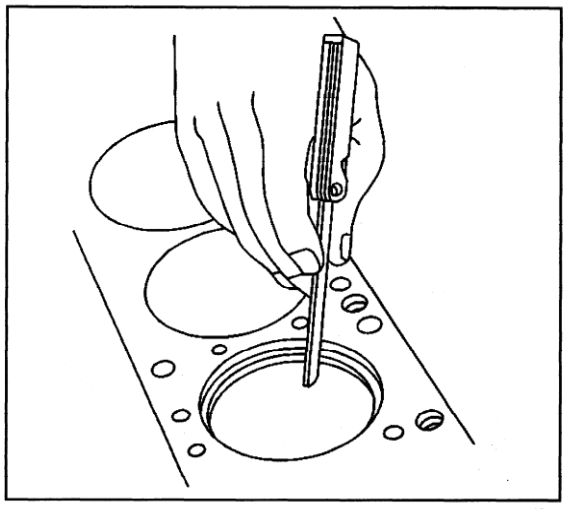
663495

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




156168

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.



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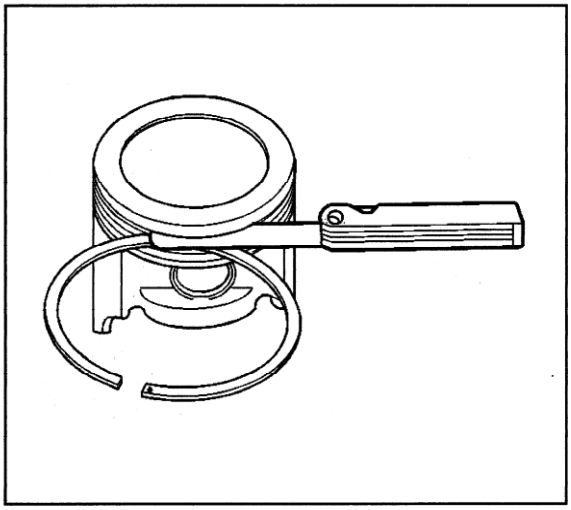
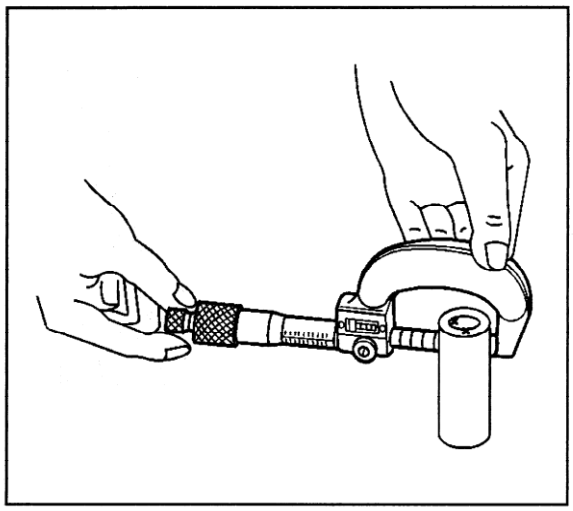


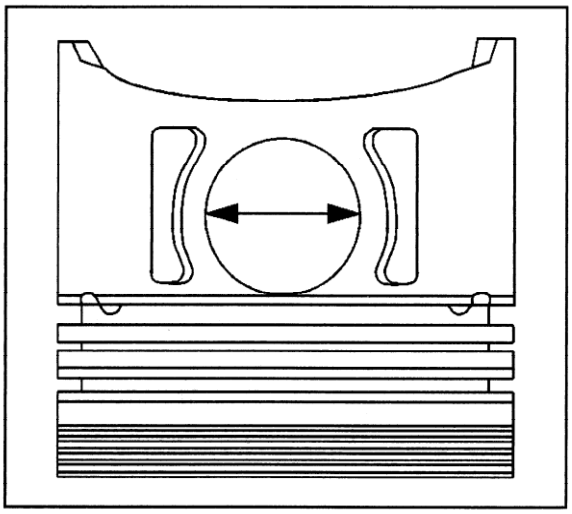
22934

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.



4976

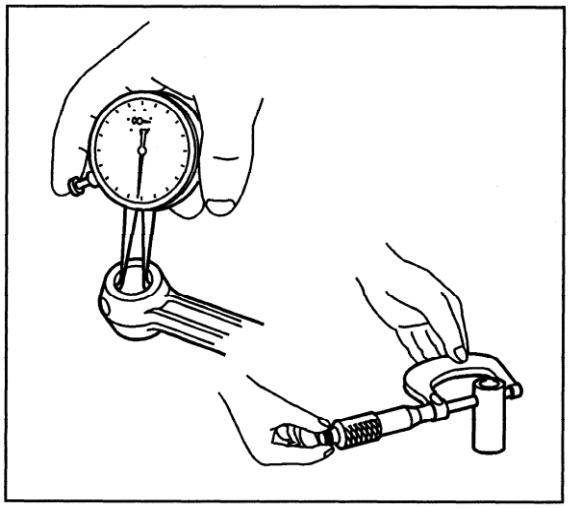
5. Measure the piston pin outside diameter.
   - Measure the piston pin outside diameter at several points.
   - The production value is 34.495–34.50 mm (1.3581–1.3563 in) and the service limit is 34.450 mm (1.3563 in).
   - Replace the piston pin if the measured value is less than the service limit.



4975

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.



663497

## Piston and Connecting Rod Assemble

### Tools Required

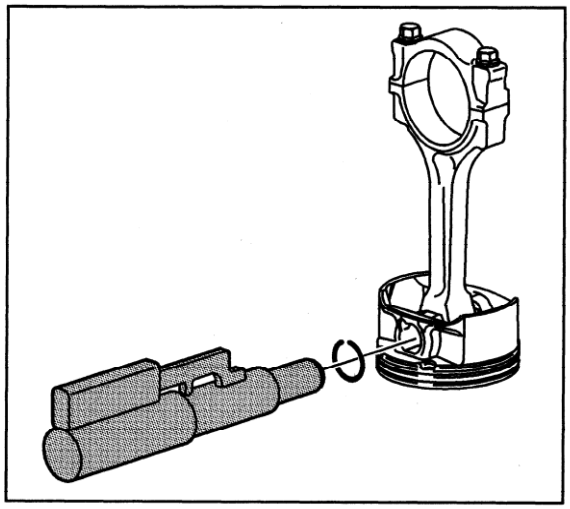
*J 43654* Piston Pin Retainer Remover/Installer

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.



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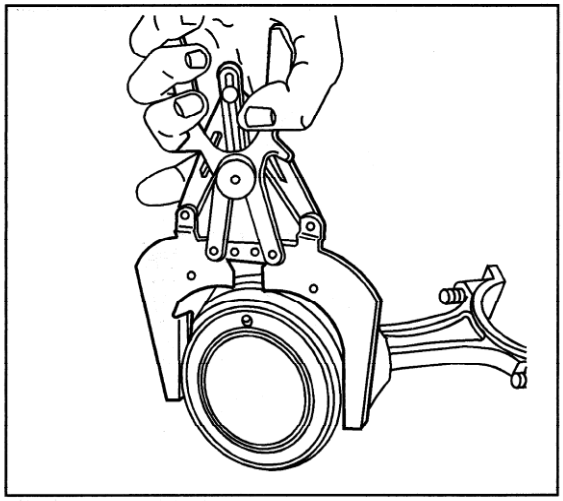
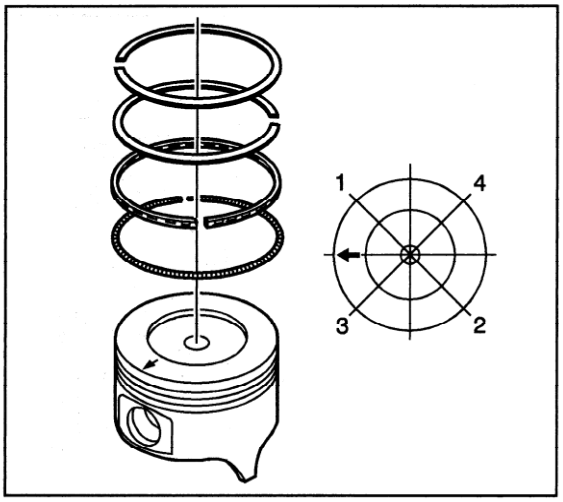


637689

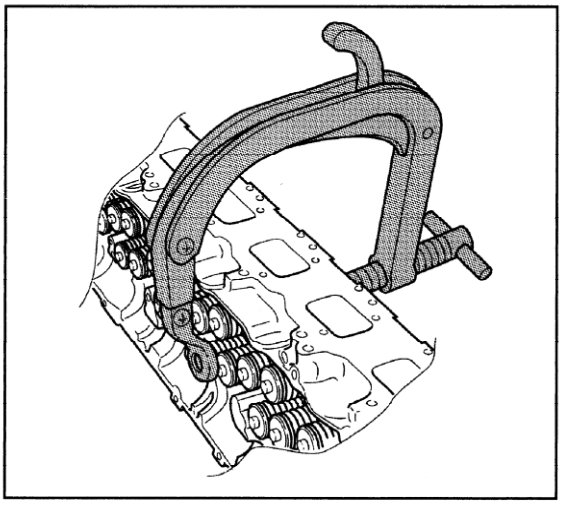
4. Apply engine oil to the piston ring grooves.
5. Install the piston rings using a piston ring expander.




663499

**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.



663501

## Cylinder Head Disassemble

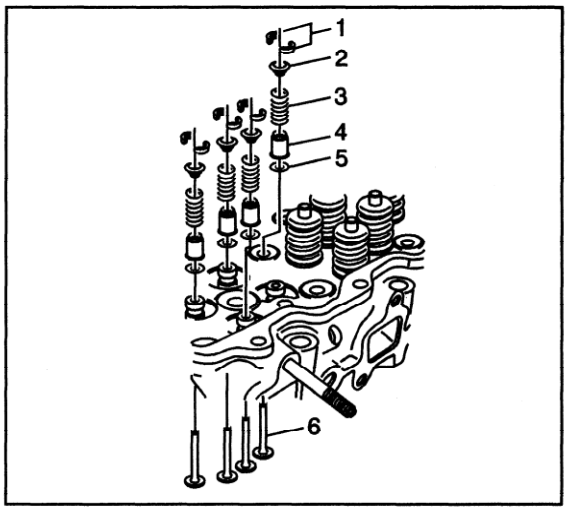
### Tools Required

*J 8062* Valve Spring Compressor

*J 38820* Valve Stem Oil Seal Remover

1. Use the *J 8062* to compress the valve spring.

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).



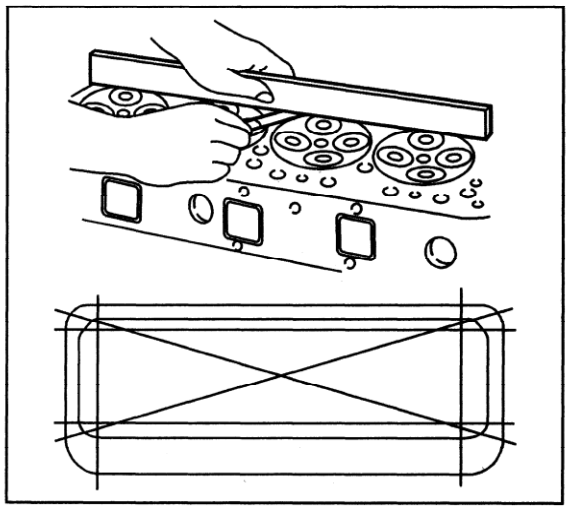
663504

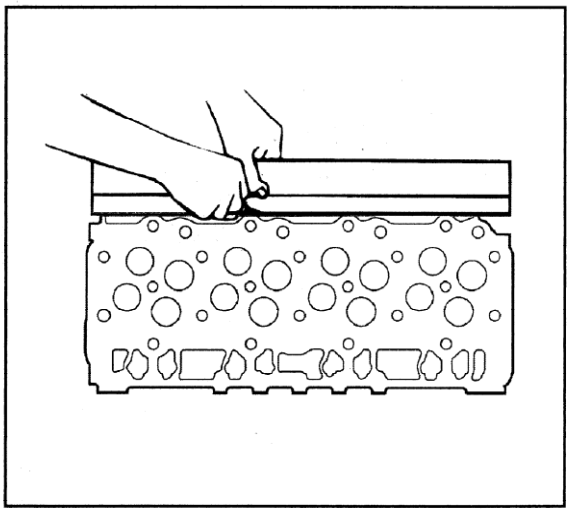
## Cylinder Head Cleaning and Inspection

### Tools Required

- *J 9666* Valve Spring Tester
- *EN-47909* Injector Bore and Sleeve Cleaning Kit

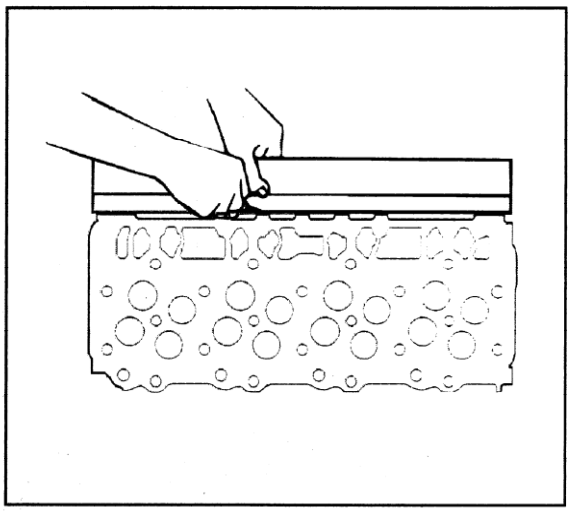
1. Clean the cylinder head of all foreign material. Do not use a motorized wire brush on any gasket sealing surface.
2. Clean the threaded holes.
3. Clean the injector bores using *EN-47909*.
4. Inspect the cylinder head for the following:
   - Damage to the gasket surfaces
   - Damage to the threaded 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.


663506



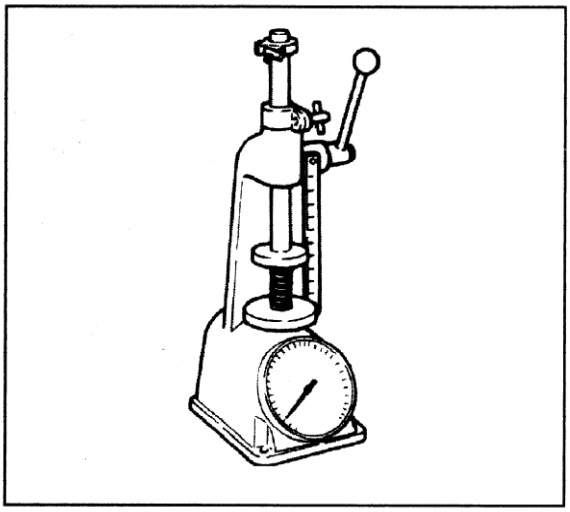
663510

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.



663513

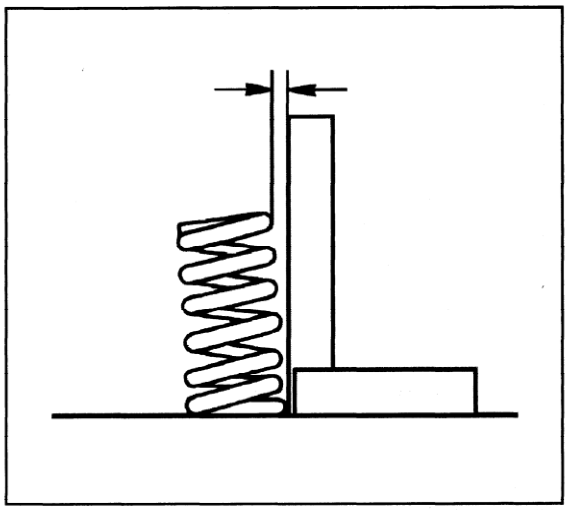
7. Measure the cylinder head intake manifold deck for warpage. A cylinder head intake manifold deck with warpage in excess of 0.3 mm (0.011 in) within a 493 mm (19.41 in) area must be replaced.



663516

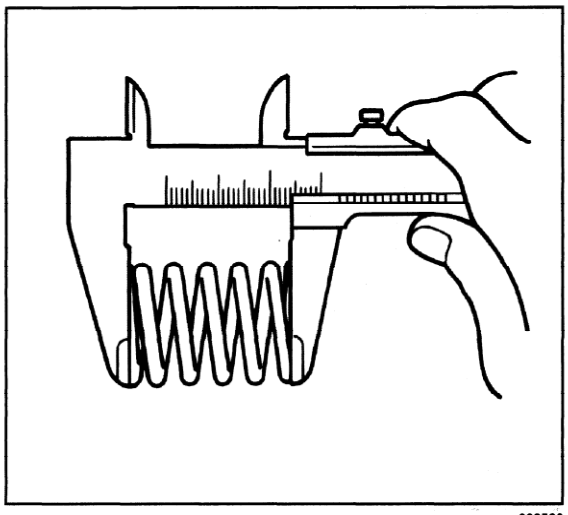
8. Measure the valve spring tension using *J 9666*. Replace the valve spring if the valve spring tension is less than 315.5 N (7.09 lb) at 41 mm (1.6142 in)

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



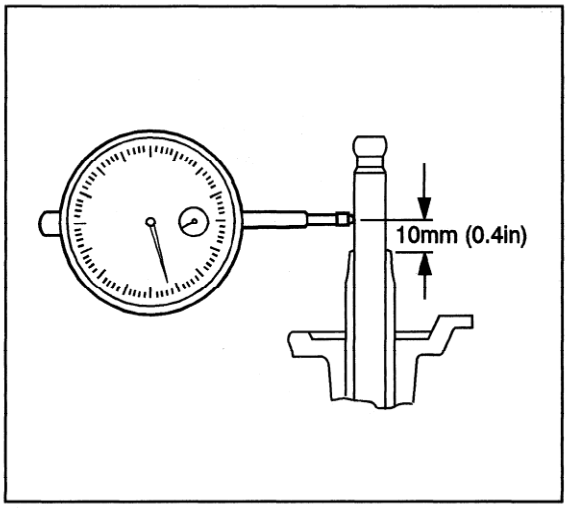
663518

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.

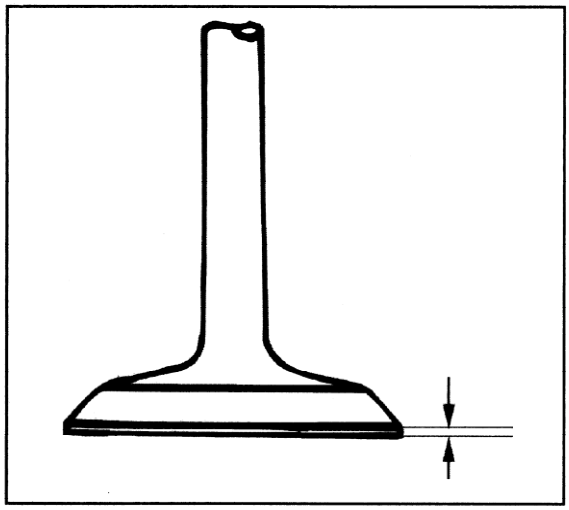


663520

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

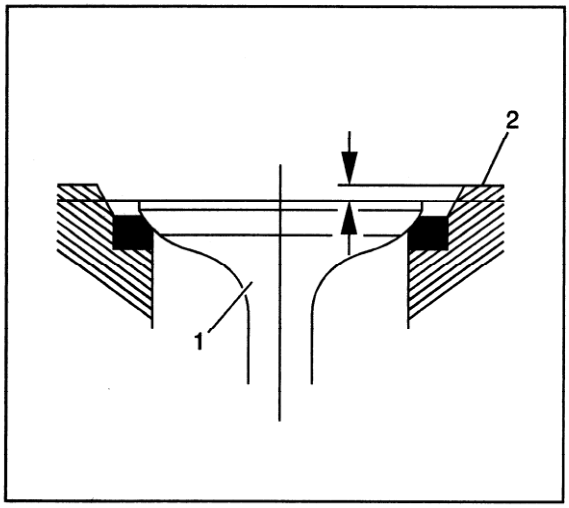



663524



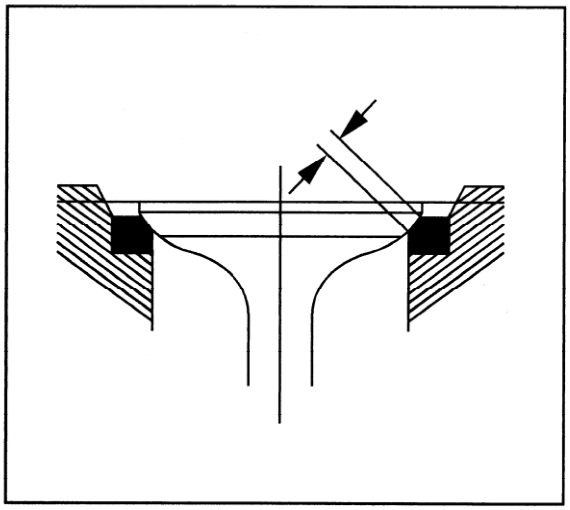
663529

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.




663532

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.

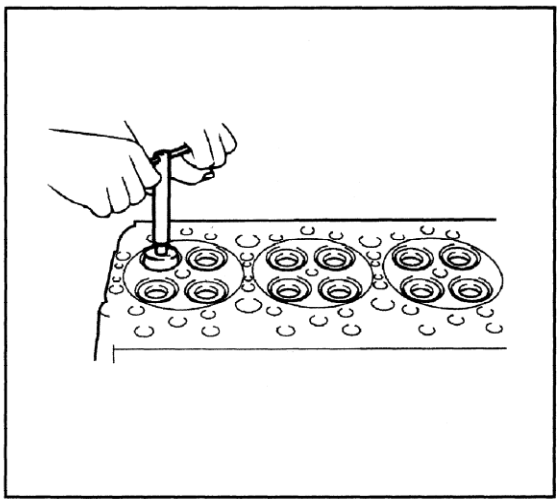


663535

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.

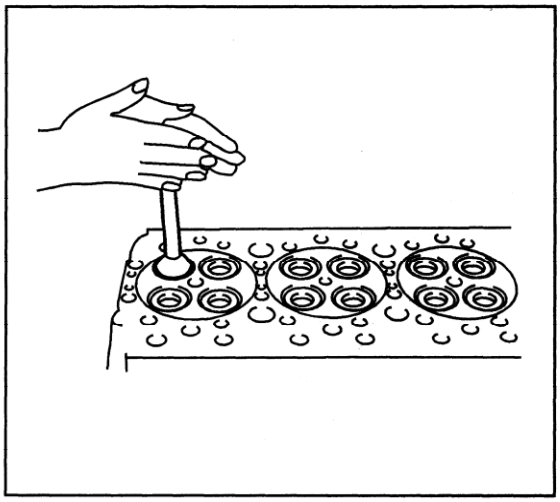
## Valve and Seat Grinding

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.



663566

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.



663569

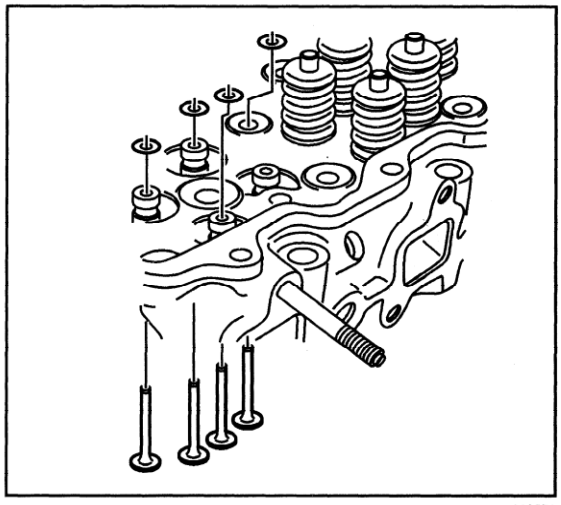
## Cylinder Head Assemble

### Tools Required

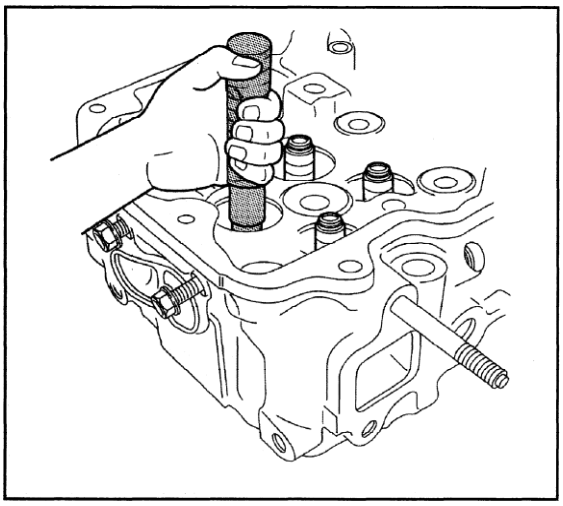
- *J 44640* Valve Stem Seal Installer
- *J 8062* Valve Spring Compressor

**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.

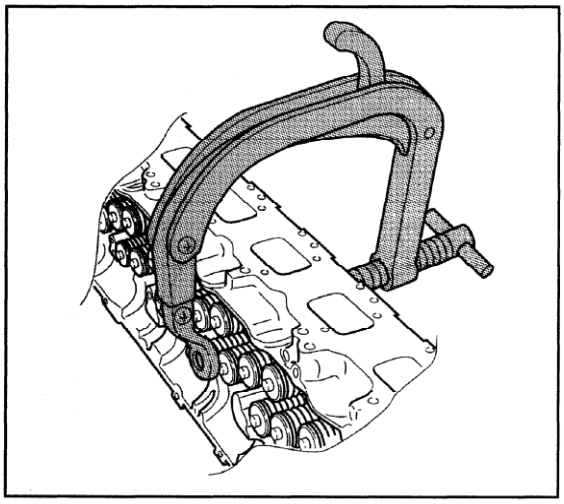


663570



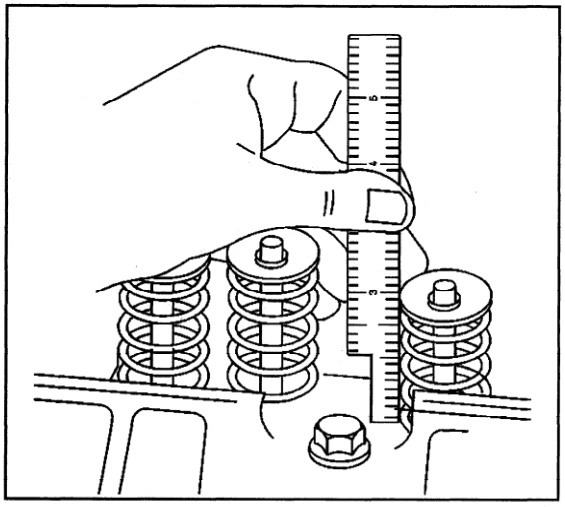
663571

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.



663501

6. Use the *J 8062* to compress the valve spring.
7. Install the valve keys.
8. Remove the *J 8062* from the cylinder head.

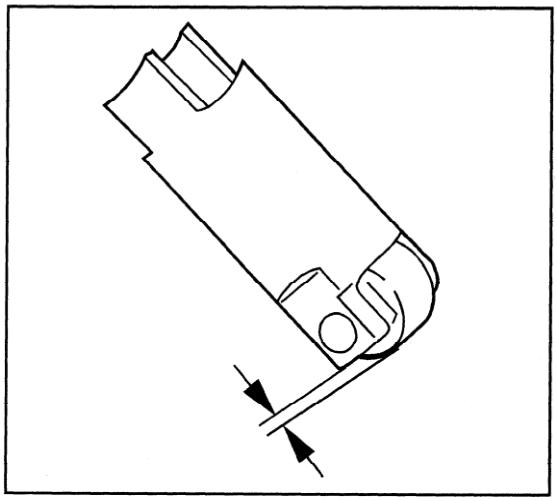


64315

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

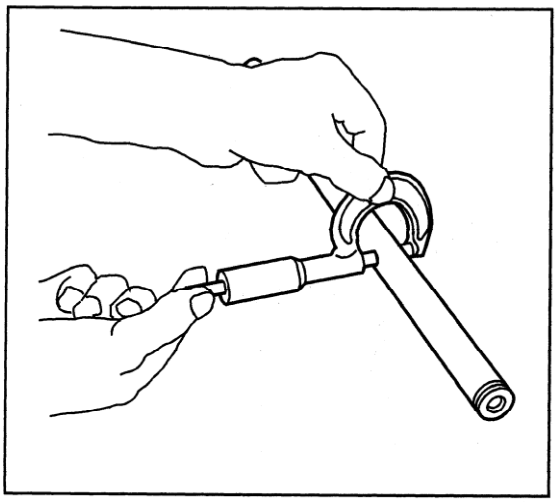
1. Push the roller towards the roller lifter body and measure the distance between the bottom of the roller and the roller lifter body. The production value is 0.989–1.0 mm (0.0389–0.0394 in) and the service limit is 0.9 mm (0.0354 in).
2. Replace the valve lifter if the measurement exceeds the service 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



663574

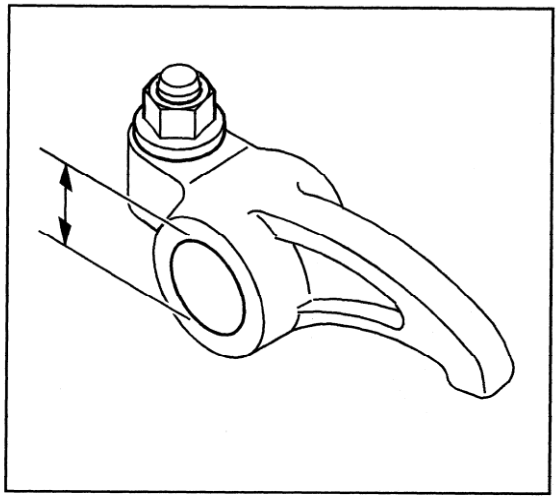
## Valve Rocker Arm and Shaft Cleaning and Inspection

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.



715777

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.
   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.



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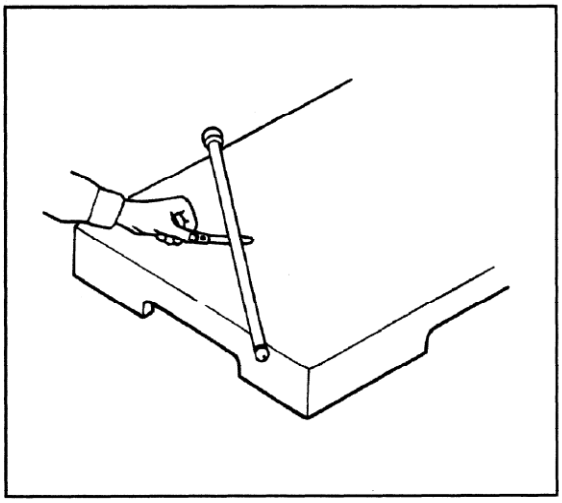

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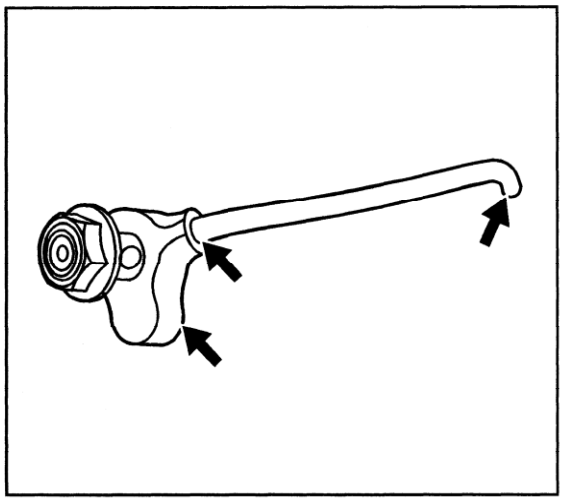
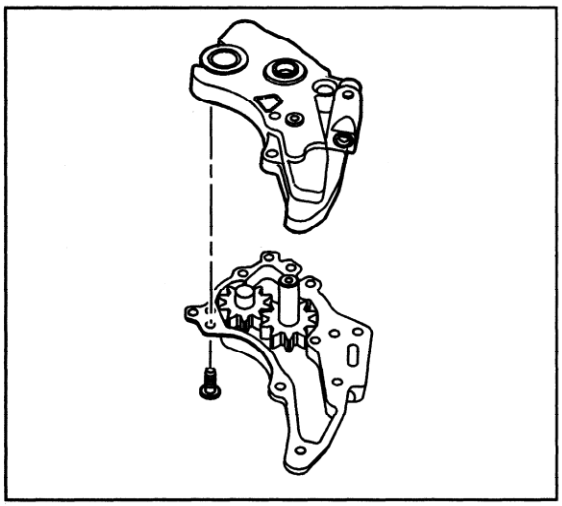
6. Measure the pushrods for warpage.
7. Replace the pushrod if the warpage exceeds 0.8 mm (0.031 in).



663592

## 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.

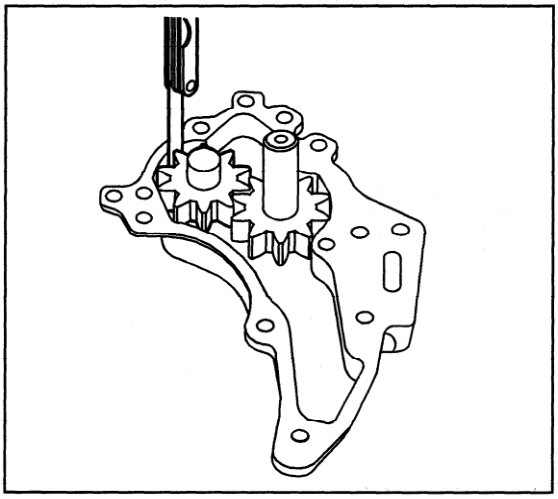


663597

## Oil Pump Cleaning and Inspection

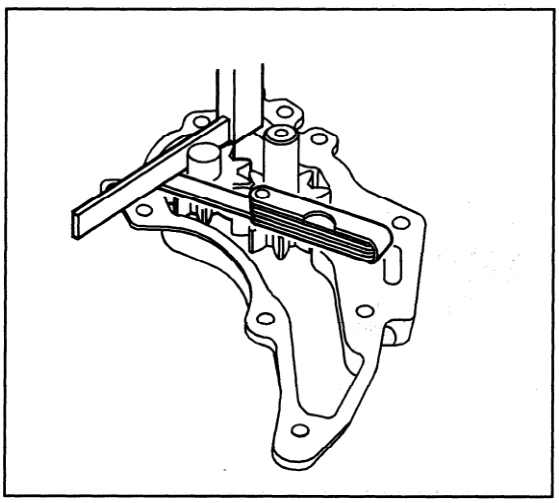
1. Remove the oil pump gear cover bolts.
2. Remove the oil pump gear cover.

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.



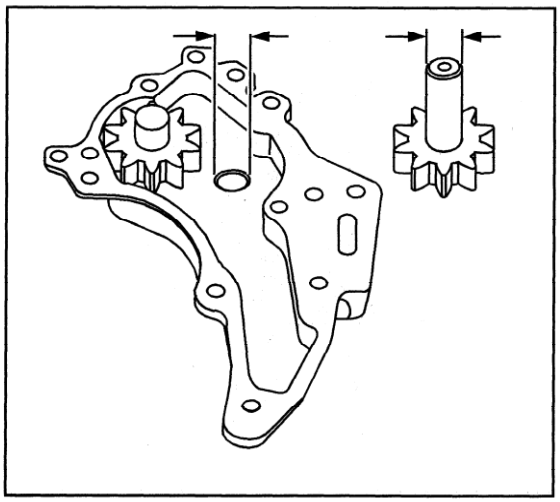
663599

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.

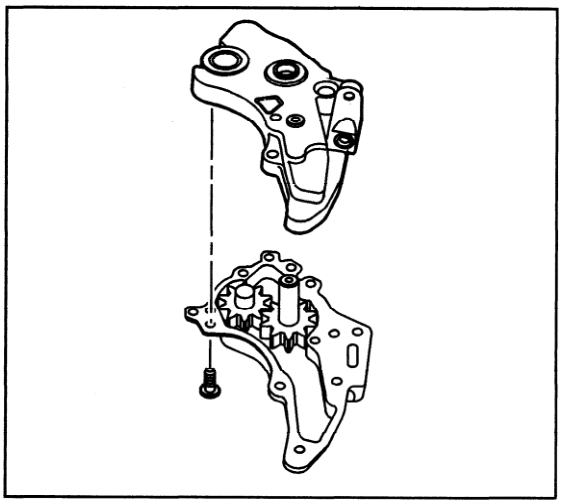


663603

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.



663609



663597

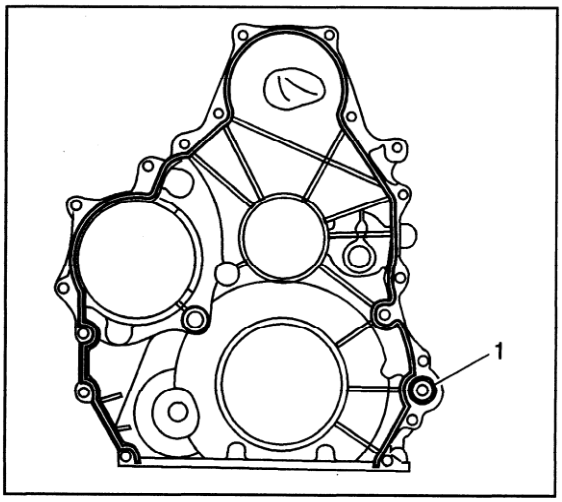
9. Install the oil pump gear cover to the oil pump assembly.

***Notice:*** Refer to *Fastener Notice*

10. Install the oil pump gear cover bolts.

    **Tighten**

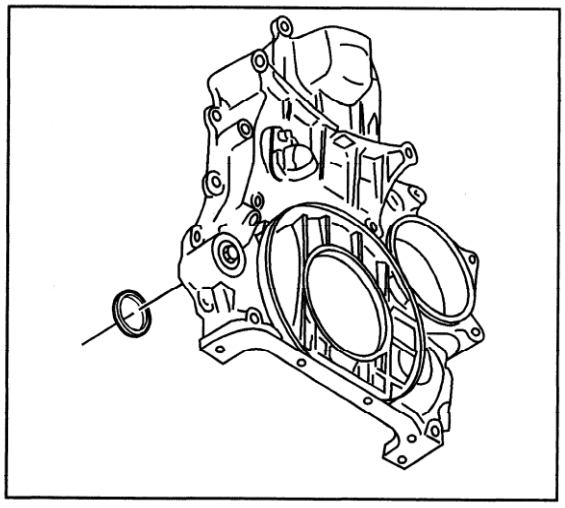
    Tighten the oil pump gear cover bolts to 21 N·m (15 lb ft).




663614

## 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.



793901

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

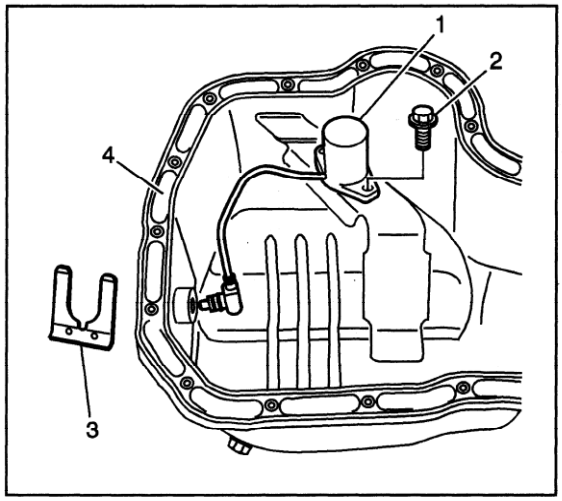
9. Install the oil pressure relief valve with a new O-ring.

    **Tighten**

    Tighten the oil pressure relief valve to 39 N·m (29 lb ft).

## Oil Pan Cleaning and Inspection - Lower

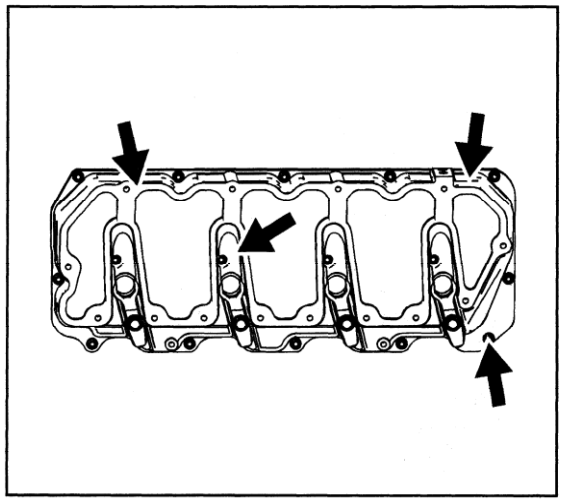
1. Remove the oil level sensor (1) and retaining clip (3).
2. Clean the lower oil pan (4). Remove any sludge or other deposits.
3. Clean the lower oil pan mating surface.
4. Inspect the lower oil pan (4) for dents or distortion.
5. Inspect the lower oil pan mating surface for damage.
6. Replace the lower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



663624

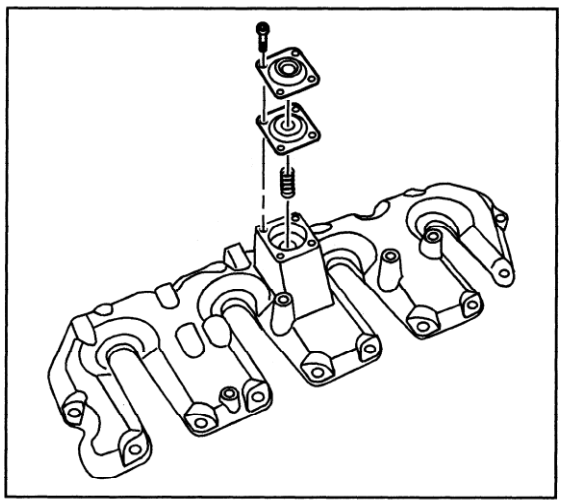
## Valve Rocker Arm Cover Cleaning and Inspection - Lower

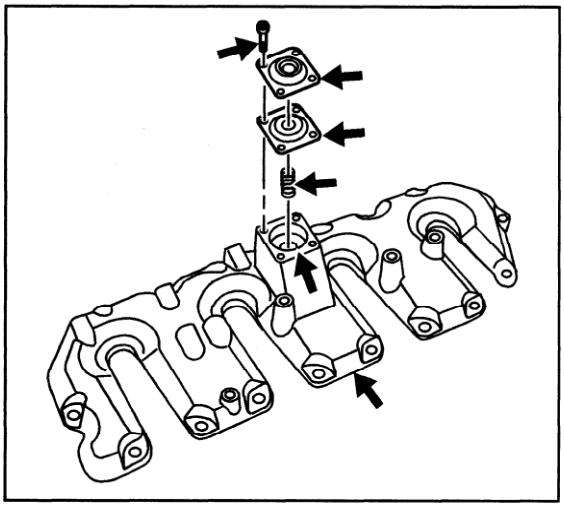
1. Remove the grommets.
2. Clean the lower valve rocker arm cover. Remove any sludge or other deposits.
3. Clean the lower valve rocker arm cover mating surfaces.
4. Inspect the lower valve rocker arm cover for cracks or other damage.
5. Inspect the lower valve rocker arm cover mating surfaces for damage.
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.


1413510

## Valve Rocker Arm Cover Cleaning and Inspection - Upper

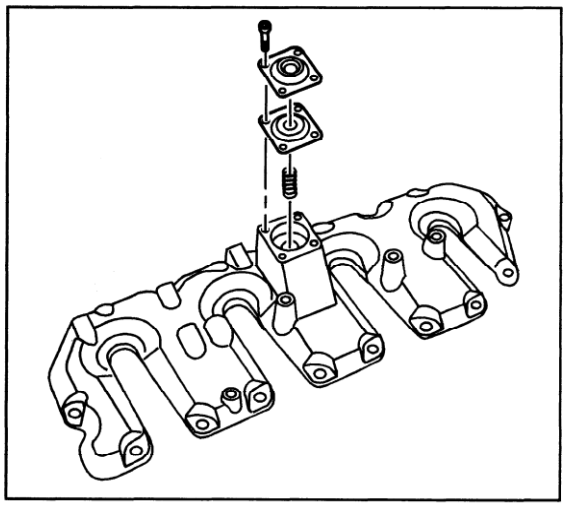
1. Remove the PCV cover screws.
2. Remove the PCV cover, diaphragm, and spring.


1336134



1336135

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



1336134

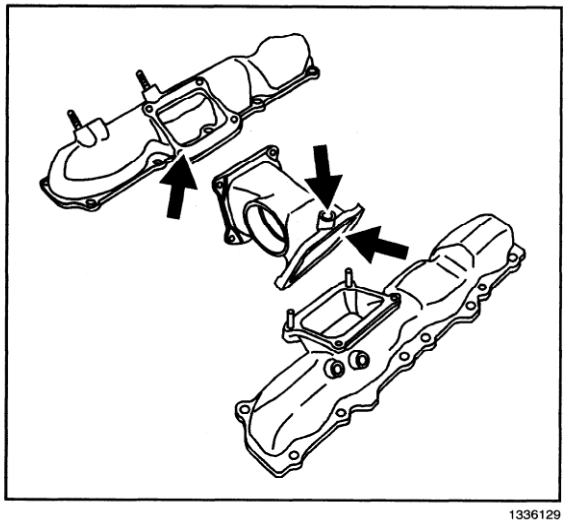
8. Inspect the PCV cover, diaphragm, and spring for damage.
9. Install the PCV spring.
10. Install the PCV diaphragm.
11. Install the PCV cover.

***Notice:*** Refer to *Fastener Notice*

12. Install the PCV cover screws.

    **Tighten**

    Tighten the PCV cover screws to 4 N·m (35 lb in).

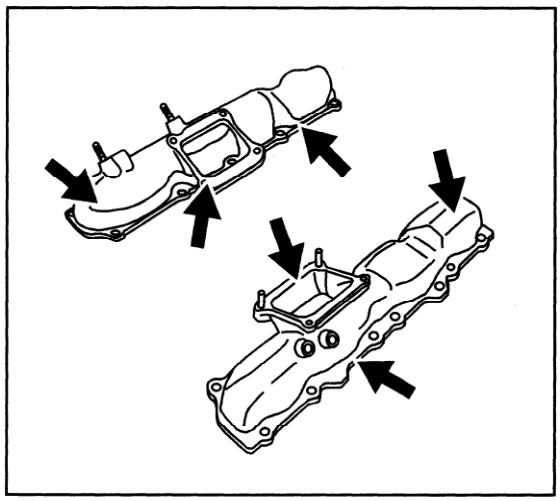


1336129

## Intake Manifold Cleaning and Inspection

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

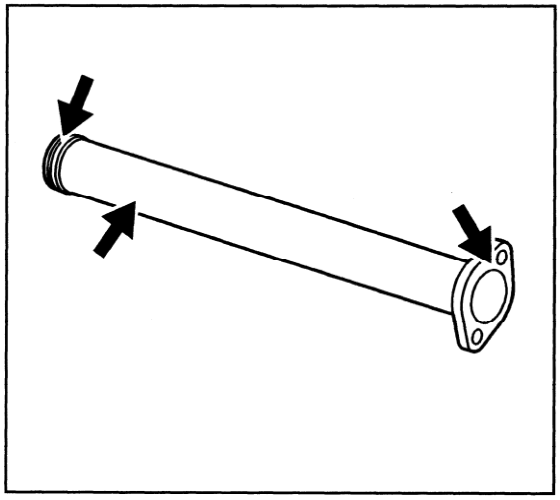
3. Clean the intake manifolds.
4. Clean the intake manifold mating surfaces.
5. Inspect the intake manifolds for cracks.
6. Inspect the intake manifold mating surfaces for damage.
7. Replace the intake manifolds if any damage is found.



1336130

## 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.



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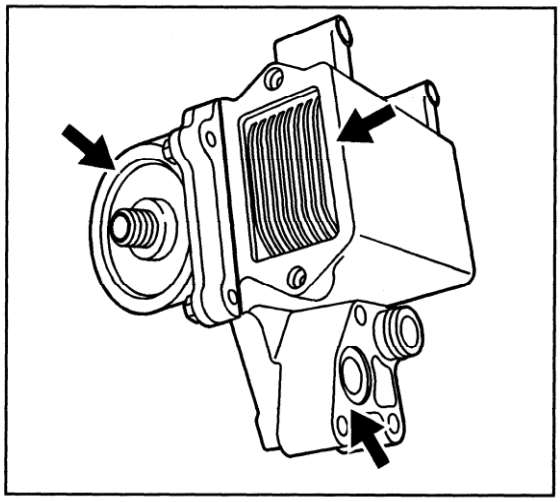
4. Clean the oil filter adapter.
5. Inspect the oil filter adapter mating surfaces for damage.
6. Replace the O-rings.



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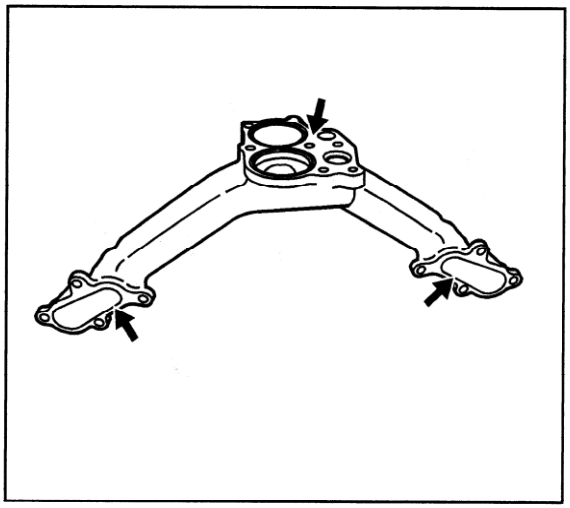
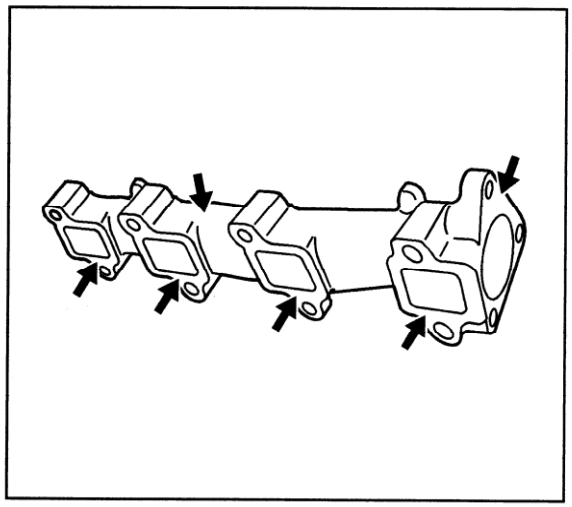


663758

## Thermostat Housing Cleaning and Inspection

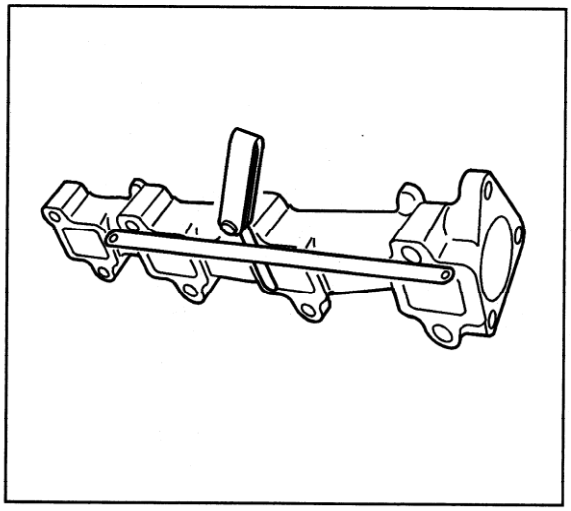
1. Clean the thermostat housing.
2. Clean the thermostat housing mating surfaces.
3. Inspect the thermostat housing for cracks.
4. Inspect the thermostat housing mating surfaces for damage.
5. Replace the thermostat housing if any damage is found.



663760

## 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.



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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.

***Notice:*** Refer to *Fastener Notice*

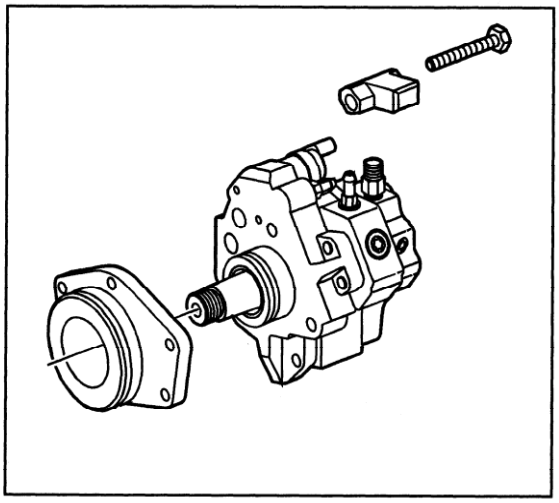
8. Install the exhaust manifold heat shield bolts.

   **Tighten**

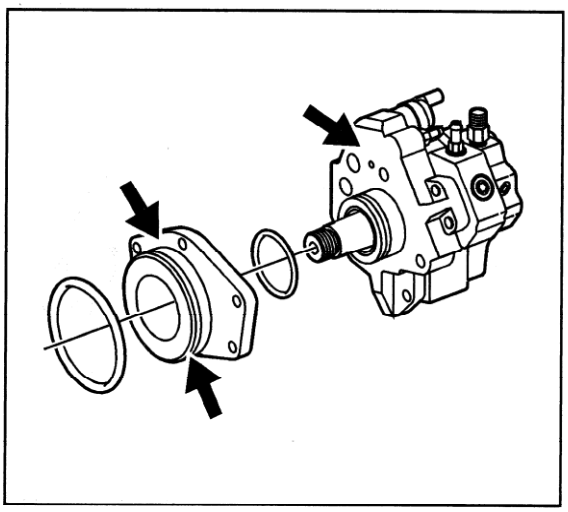
   Tighten the exhaust manifold heat shield bolts to 8 N·m (71 lb in).

## Fuel Injection Pump Cleaning and Inspection

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

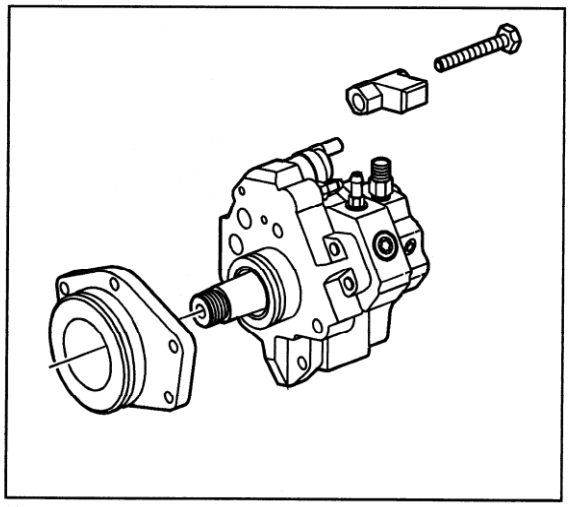


663766



663767

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.



663766

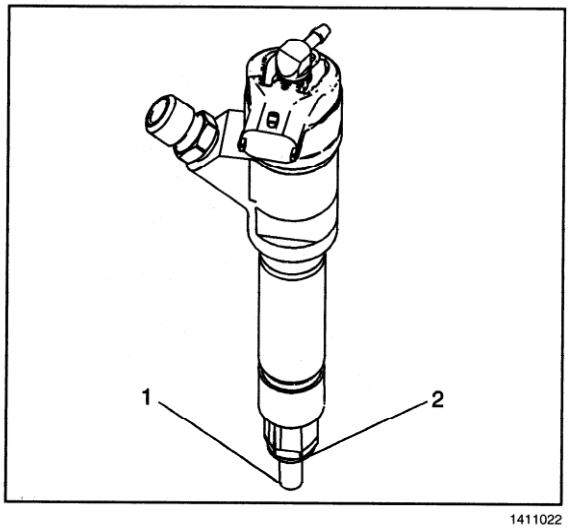
12. Install the fuel injection pump adapter to the fuel injection pump.

***Notice:*** Refer to *Fastener Notice*

13. Install the fuel injection pump adapter bolts.

    **Tighten**

    Tighten the fuel injection pump adapter bolts to 21 N·m (15 lb ft).




1411022

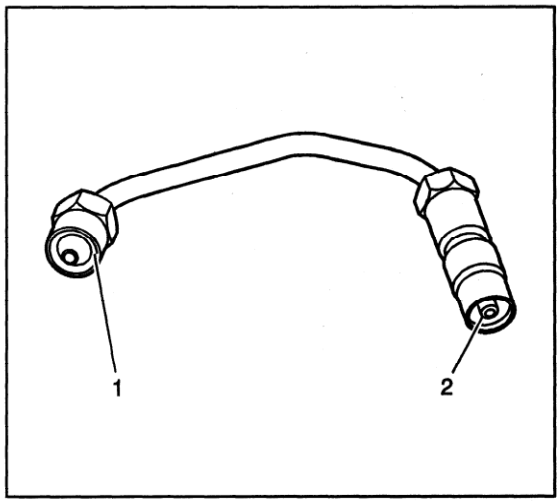
## Fuel Injector Cleaning and Inspection

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

***Notice:*** 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.



1336212

## Turbocharger Cleaning and Inspection

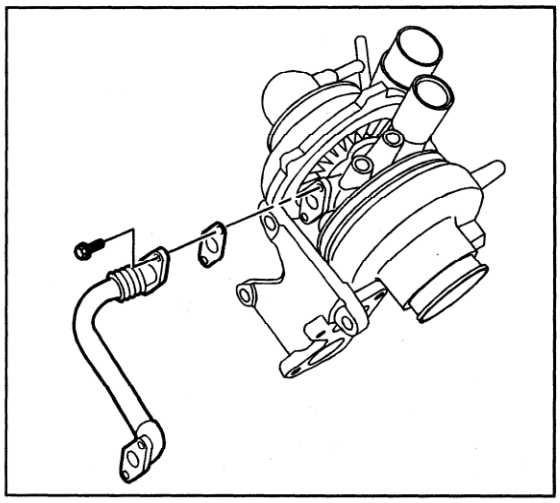
Completely inspect the turbocharger and all other engine components that may cause similar conditions before replacing the turbocharger.

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

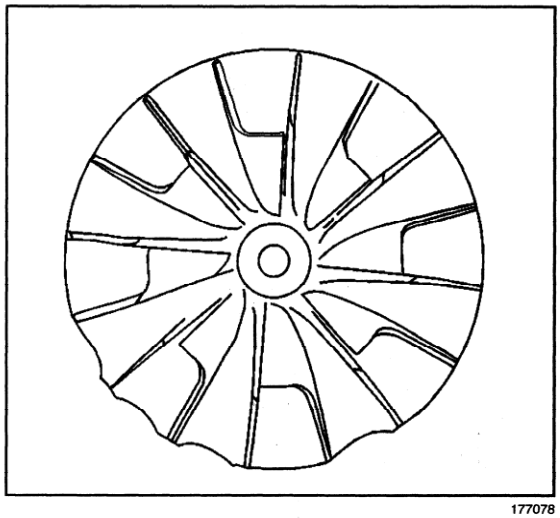
The turbocharger is serviced as a complete unit.

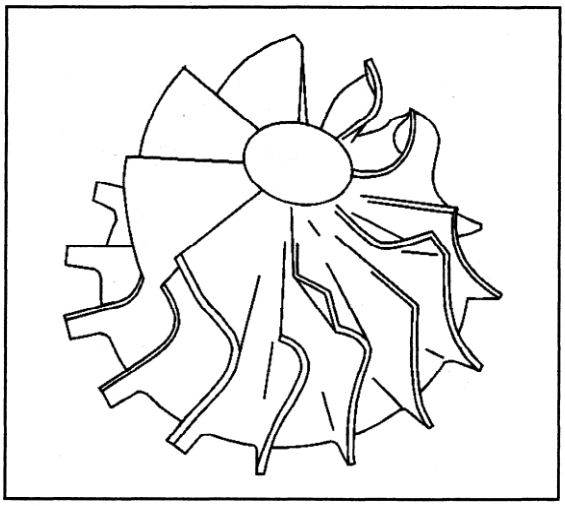
**Important:** Oil residue on the turbocharger compressor wheel is normal with a closed PCV system.

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


1336136

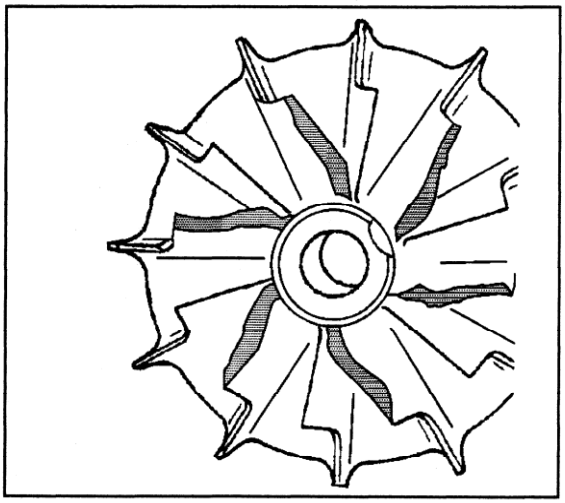
4. Inspect for damage to the compressor wheel, compared to a normal compressor wheel.


177078



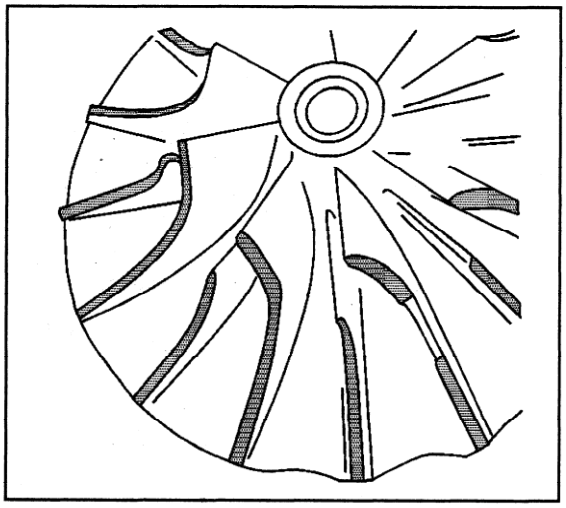
177081

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



177083

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



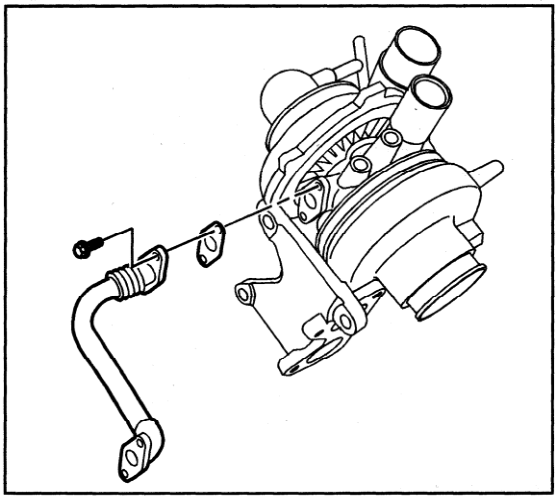
177086

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**

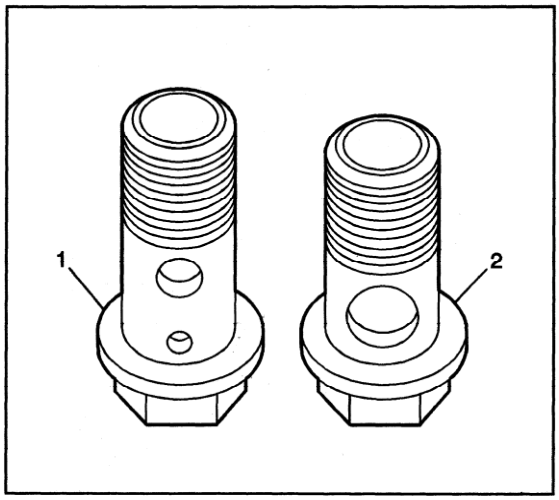
    Tighten the turbocharger oil return pipe bolts to 21 N·m (15 lb ft).



1336136

**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.

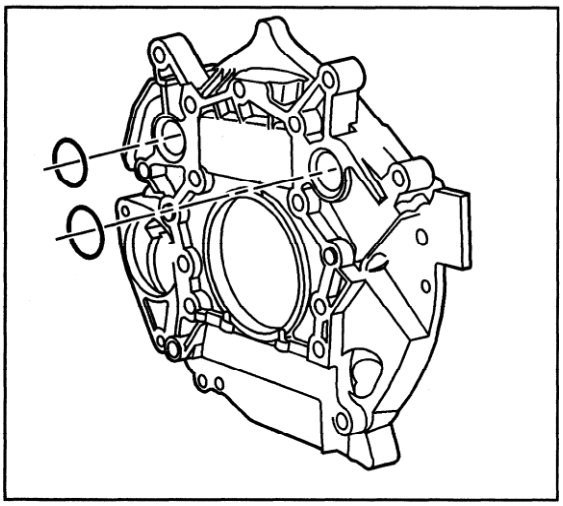



1457469

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**

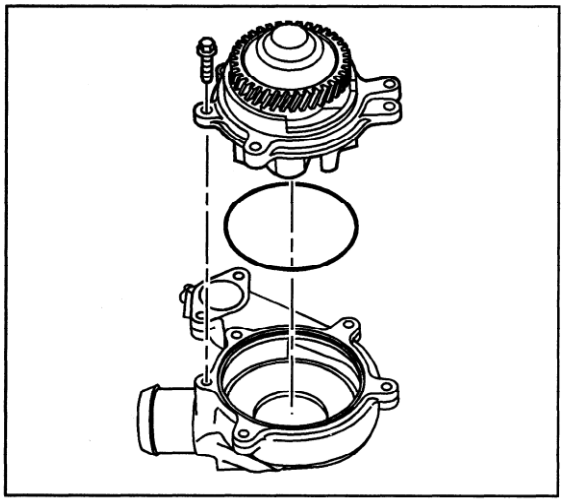
    Tighten the inlet duct clamp to 5 N·m (44 lb in).



663771

## Engine Flywheel Housing Cleaning and Inspection

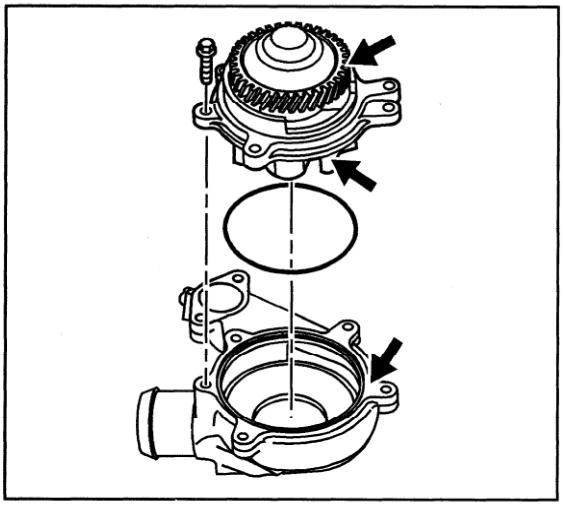
1. Remove the O-rings from the flywheel housing and discard.
2. Clean the flywheel housing.
3. Clean the flywheel housing mating surfaces.
4. Clean the flywheel housing O-ring sealing area.
5. Inspect the flywheel housing for cracks.
6. Inspect the flywheel housing mating surfaces for damage.
7. Inspect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



663772

## 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.



663773

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.

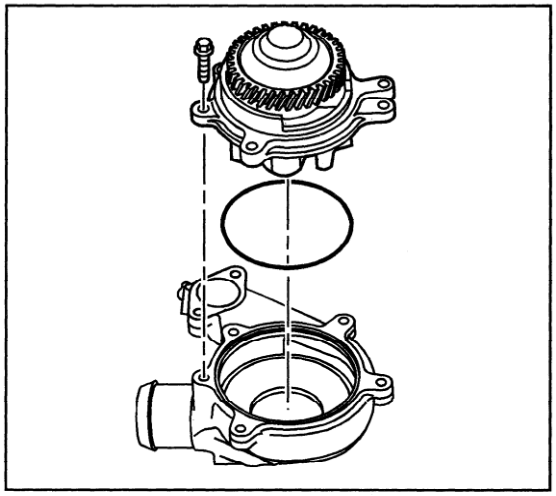
***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

15. Install the water pump to water pump housing bolts.

    **Tighten**

    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.



663772

## Thread Repair

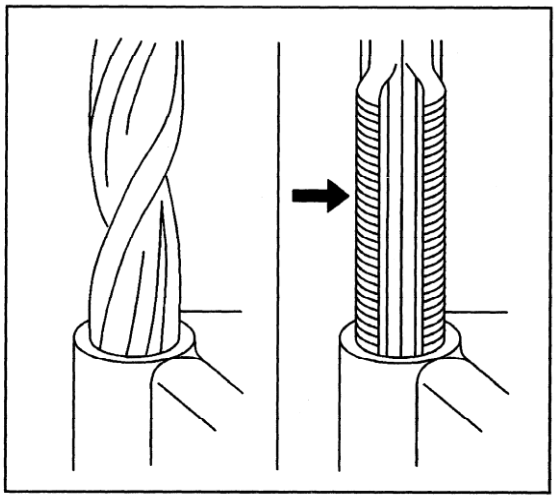
General purpose thread repair kits are available commercially.

***Caution: Refer to Safety Glasses Caution***

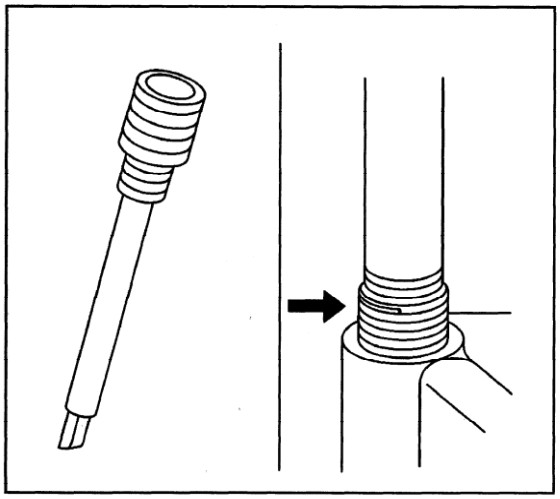
**Important:** Refer to the thread repair kit manufacturer's instructions regarding the size of the drill and which tap to use.

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.



4962

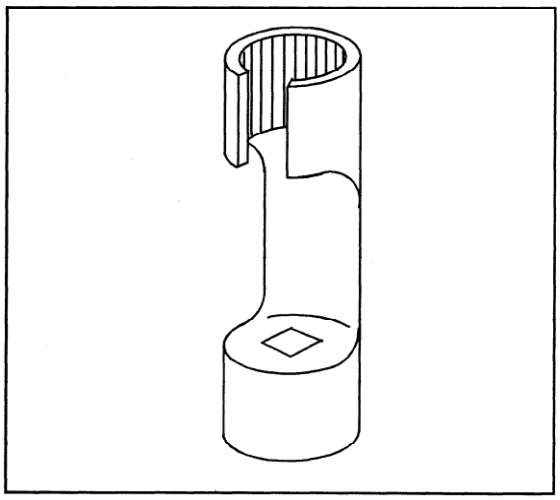


4963

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.

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

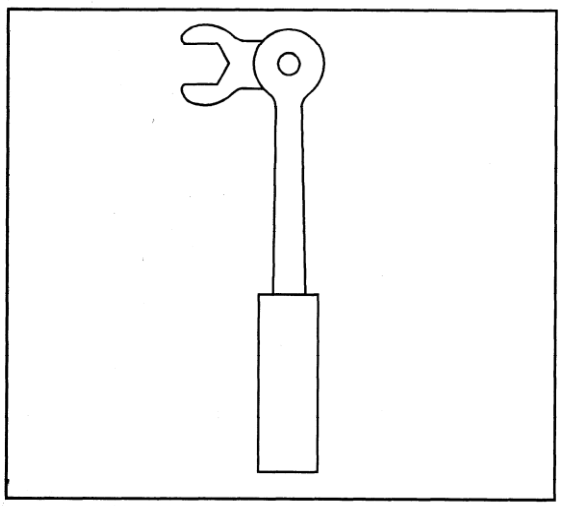
9. Lubricate the thread insert with clean engine oil – except when installing in aluminum – and install the thread insert.
10. If the tang of the thread insert does not break off when backing out the thread insert installer, break off the tang using a drift punch.



663909

## Fuel Line Torque Procedure

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*

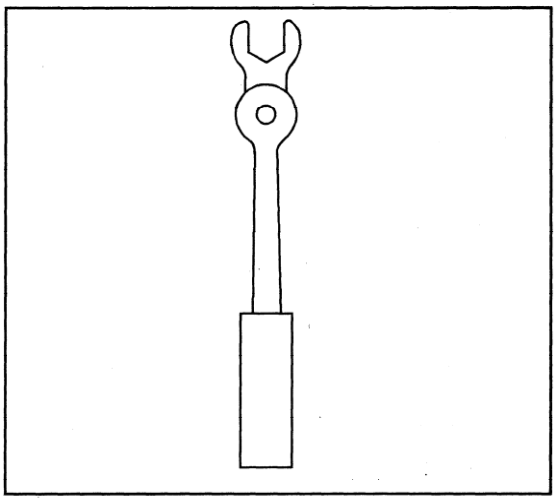


663912

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.

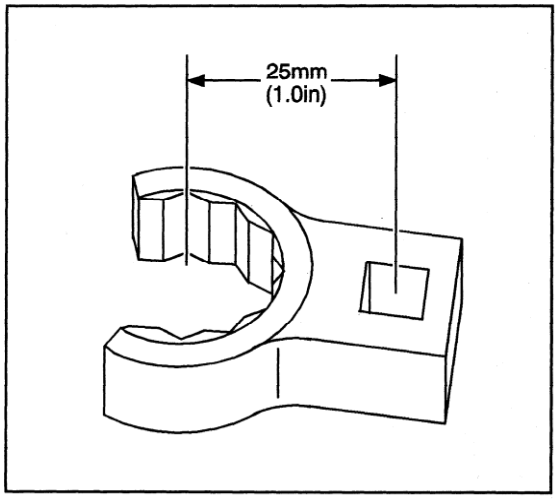
- If the crows foot is kept perpendicular (90 degrees) to the torque wrench during the entire tightening procedure, then the torque wrench can be set to the listed torque specification. Refer to *Fastener Tightening Specifications*

- 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.


663916

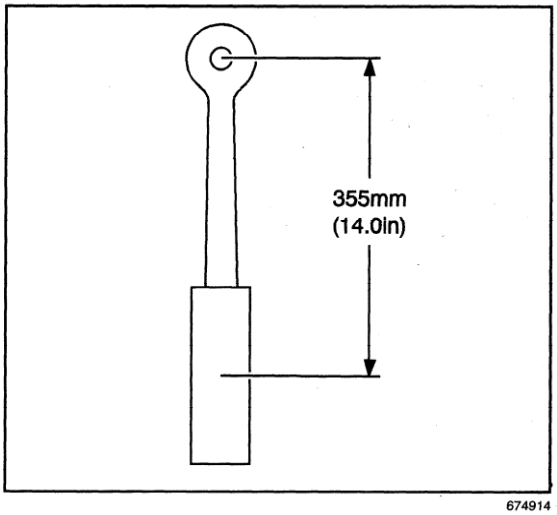
If it is necessary to position a crows foot in line with the torque wrench, the procedure for adjusting the torque specification is as follows:

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



674910

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.



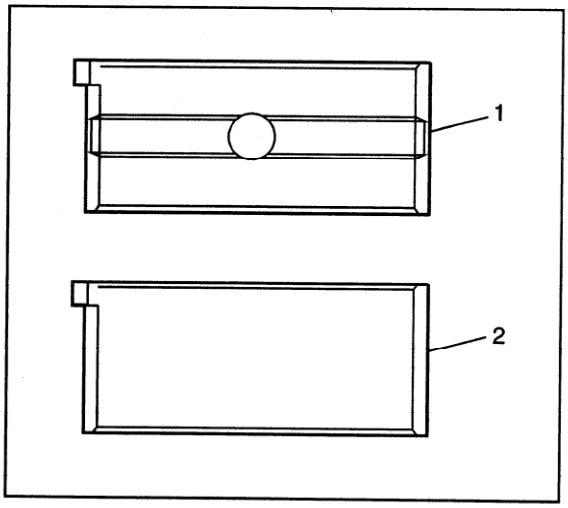
674914

### Example

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



663789

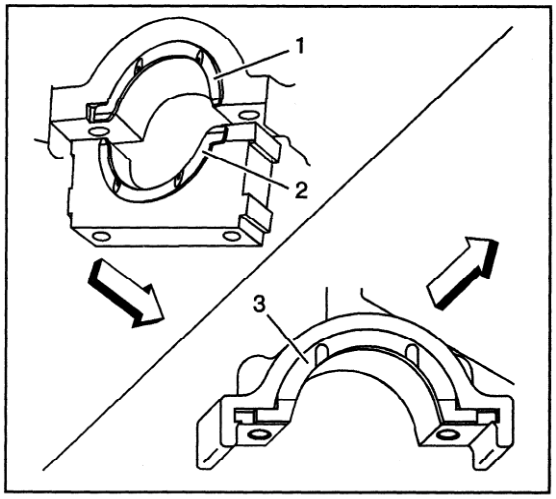
## Crankshaft and Bearings Installation

### Tools Required

*J 45059* Angle Meter

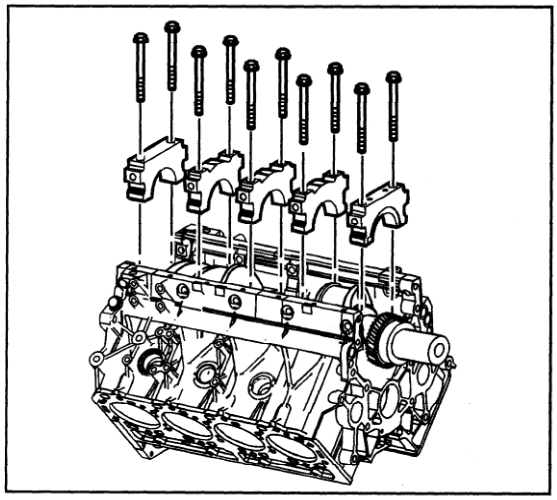
1. Install the upper crankshaft bearings into the cylinder block. The bearing halves to be inserted into the crankshaft main bearing saddle have a wide groove and oil hole in the center of the bearing (1).
2. Install the lower crankshaft bearings into the crankshaft bearing caps. The bearing halves to 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).



663800

7. Install the remaining four crankshaft bearing caps.

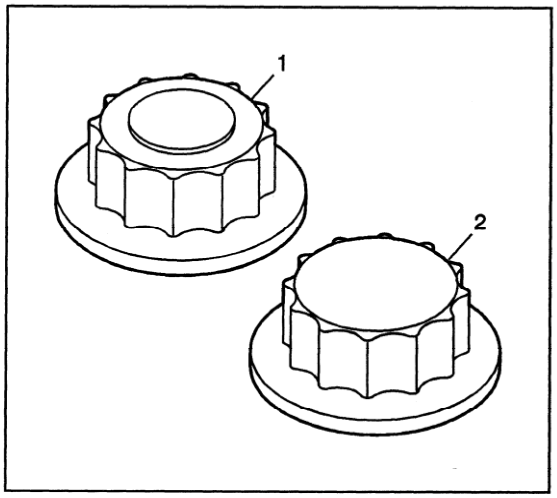

1336123

***Notice:*** 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.

***Notice:*** Refer to *Fastener Notice*

**Important:** 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 determime 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.

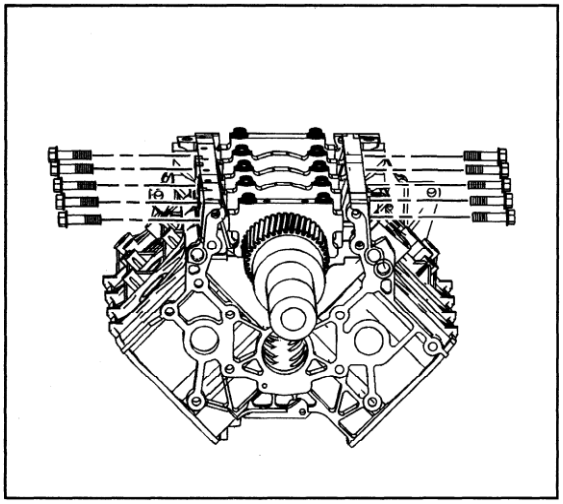


1704773

9. Tighten the crankshaft bearing cap bolts in the proper sequence.

   **Tighten**

   - 1st step 98 N·m (72 lb ft).
   - 2nd step 132 N·m (97 lb ft).
   - 3rd step 30 degrees using *J 45059*.

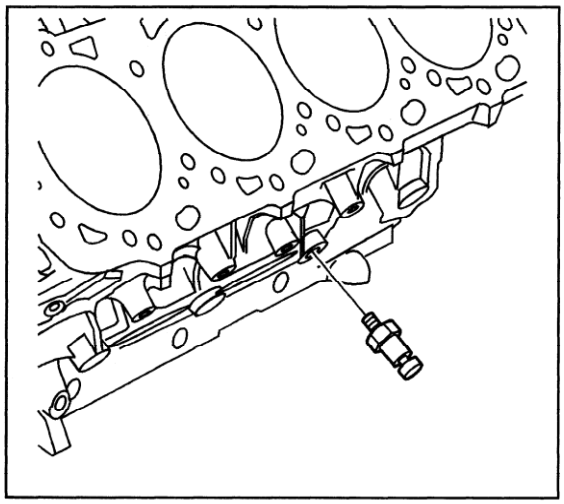


1336122

10. Clean the crankshaft bearing side cap bolt threads, sealing flange and mounting holes with P/N 12377981 or equivalent. Dry the bolts and mounting holes with compressed air.
11. Apply P/N 12346004 to the threads and sealing flange of the bolts.
12. Install the ten bolts.

    **Tighten**

    Tighten the crankshaft bearing cap side bolts to 70 N·m (52 lb ft).



881732

13. Install the oil pressure sensor.

    **Tighten**

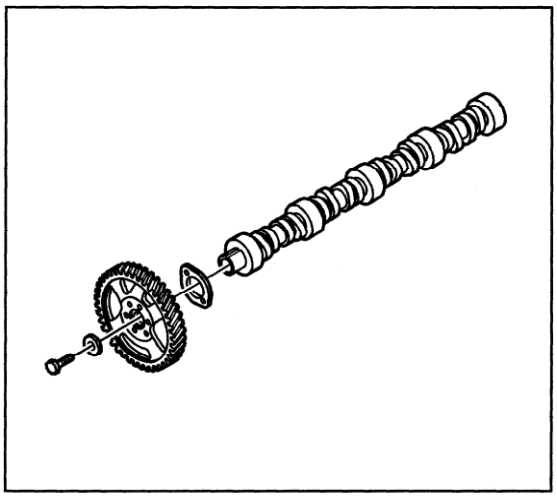
    Tighten the oil pressure sensor to 41 N·m (30 lb ft).

## Camshaft Installation

### Tools Required

*J 7872* Dial Indicator Set

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.



660540

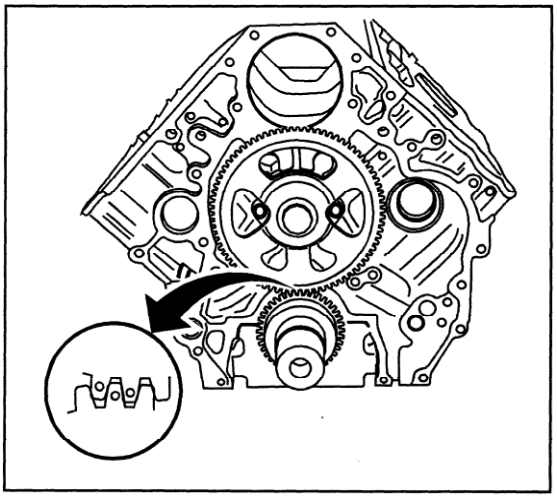
4. Install the camshaft and gear assembly into the cylinder block, aligning the camshaft gear to the crankshaft gear as shown.

***Notice:*** Refer to *Fastener Notice*

5. Install the camshaft thrust plate bolts.

   **Tighten**

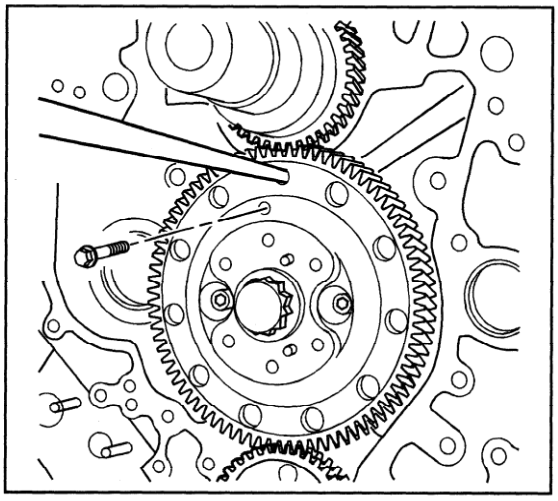
   Tighten the camshaft thrust plate bolts to 22 N·m (16 lb ft).



663813

**Important:** 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.



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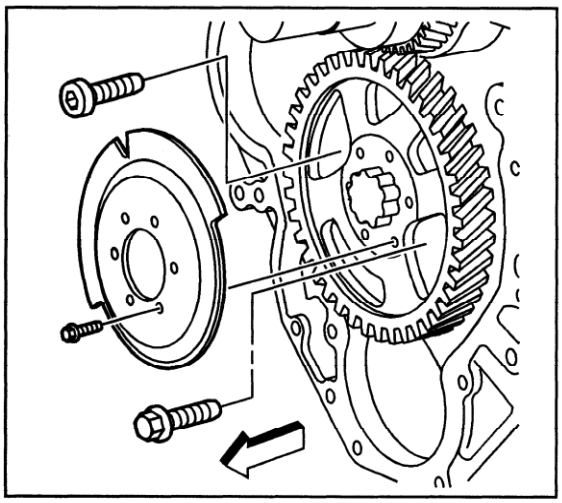
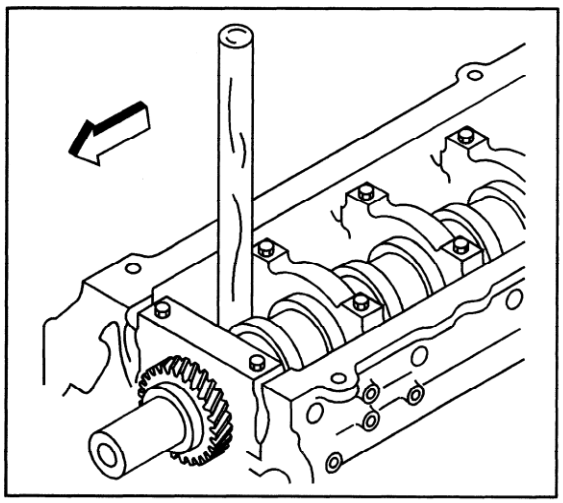


663091

7. Install the camshaft position sensor exciter ring to the camshaft gear.
8. Install the camshaft position sensor exciter ring bolts.

   **Tighten**

   Tighten the camshaft position sensor exciter ring bolts to 9 N·m (80 lb in).

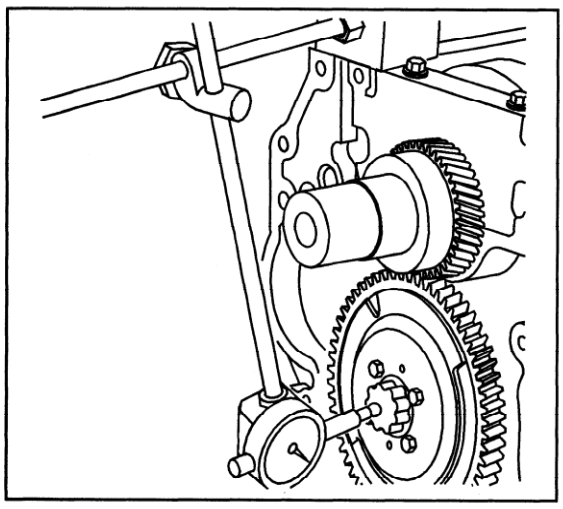


660539

9. Block the crankshaft from turning using a wooden handle.
10. Install the new camshaft gear bolt.

    **Tighten**

    Tighten the new camshaft gear bolt to 234 N·m (173 lb ft).



663816

11. Measure the camshaft end play with *J 7872*.
    - 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.

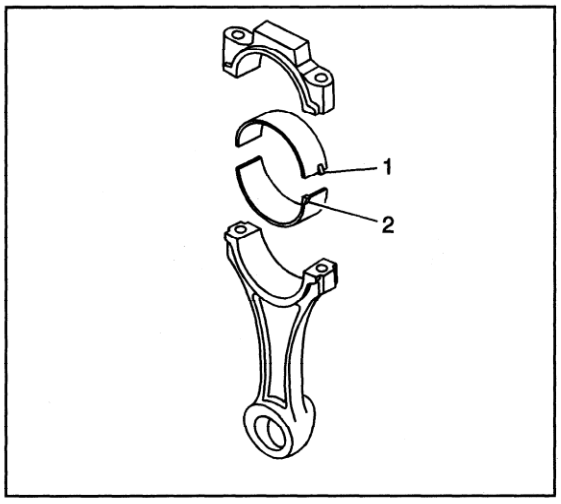
## Piston, Connecting Rod, and Bearing Installation

### Tools Required

- *J 8037* Piston Ring Compressor
- *J 45059* Angle Meter

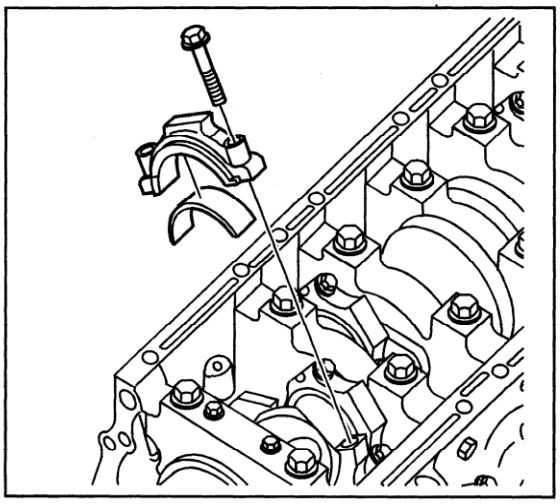
**Important:** The connecting rod bearing with the notch all the way out against the edge of the bearing (2) is the connecting rod bearing. The connecting rod bearing with the notch "in board" (1) is the connecting rod cap bearing.

1. Select the connecting rod bearing according to the *Connecting Rod Bearings Selection Specifications*
2. Position the crankshaft so the connecting rod journal is opposite the piston and connecting rod assembly being installed.

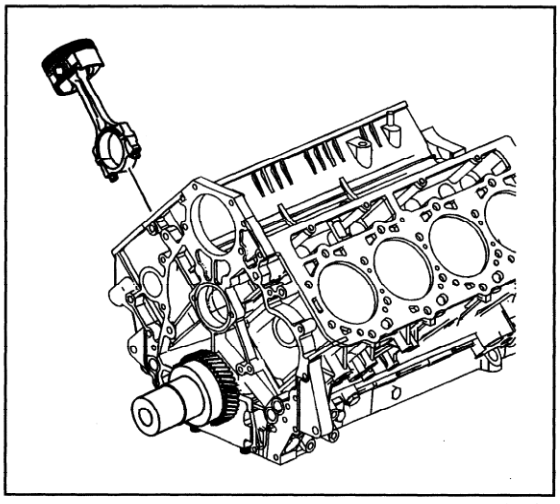


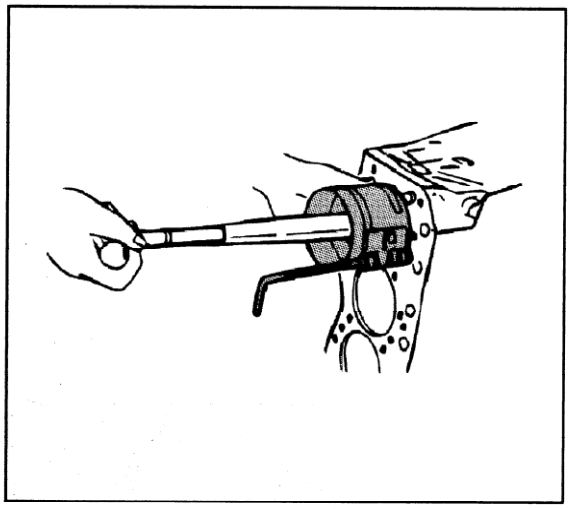
880613

3. Install the connecting rod bearing inserts.
4. Lubricate the cylinder wall and piston rings with engine oil.
5. Install the *J 8037* to the piston to compress the piston rings.


660550

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

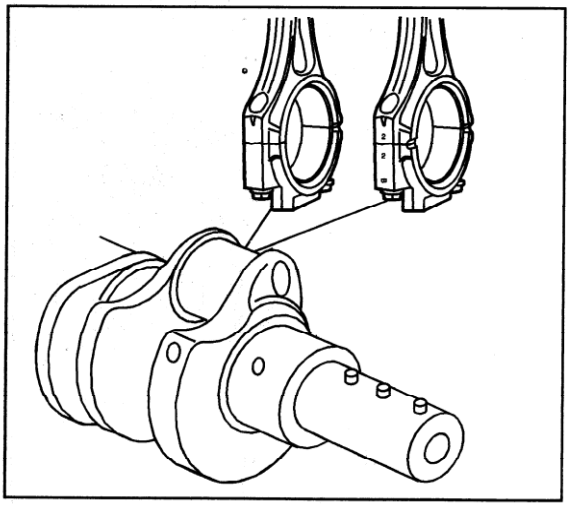

1336121



663806

***Notice:*** 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.



663809

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.

***Notice:*** Refer to *Fastener Notice*

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.

    **Tighten**

    11.1. 1st step 64 N·m (47 lb ft)

    11.2. 2nd step 30 degrees using *J 45059*

    11.3. 3rd step 30 degrees using *J 45059*
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.

***Notice:*** 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.

    **Tighten**

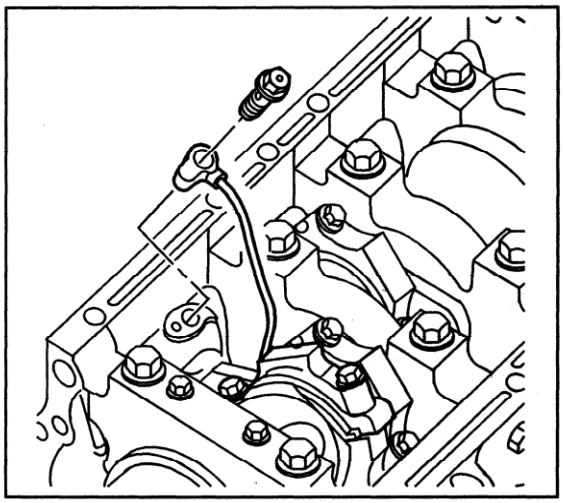
    19.1. 1st step 64 N·m (47 lb ft)

    19.2. 2nd step 30 degrees using *J 45059*

    19.3. 3rd step 30 degrees using *J 45059*

## Piston Oil Cooling Nozzle Installation

1. Install the piston oil cooling nozzle.



660543

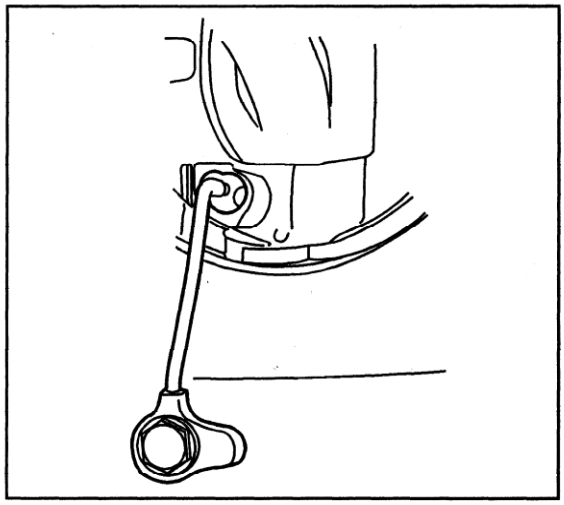
***Notice:*** The piston oil cooling nozzle must be aligned to direct oil towards the oil inlet hole on the bottom of the piston. Improper alignment of the piston oil cooling nozzle will allow insufficient oil lubrication to the piston and cause severe engine damage.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

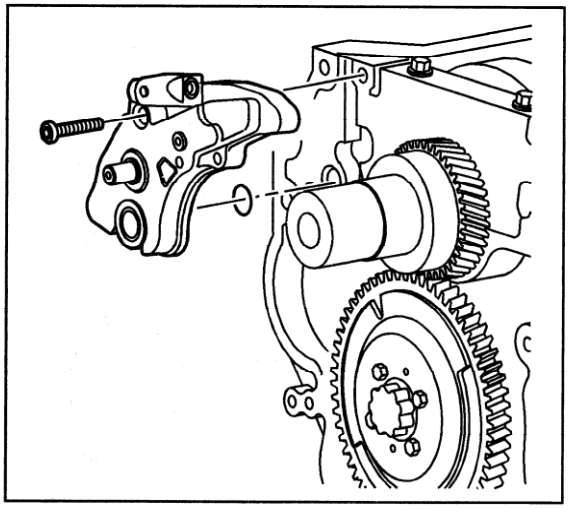
2. Install the piston oil cooling nozzle bolt.

   **Tighten**

   Tighten the piston oil cooling nozzle bolts to 21 N·m (15 lb ft).



663810



660533

## Oil Pump Installation

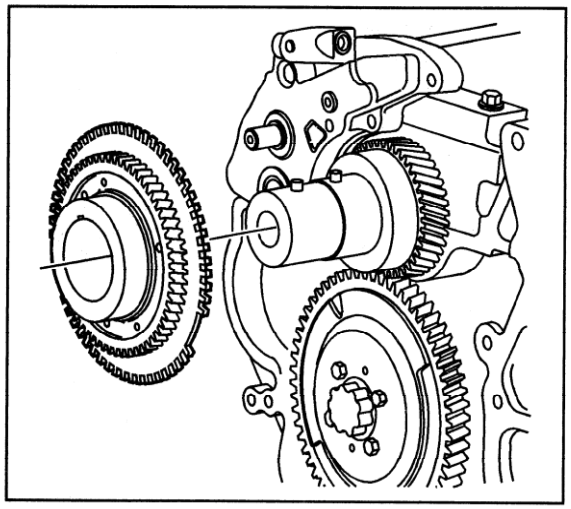
1. Install a new O-ring to the engine block.
2. Lubricate the O-ring with engine oil.
3. Install the oil pump.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

4. Install the oil pump bolts.

   **Tighten**

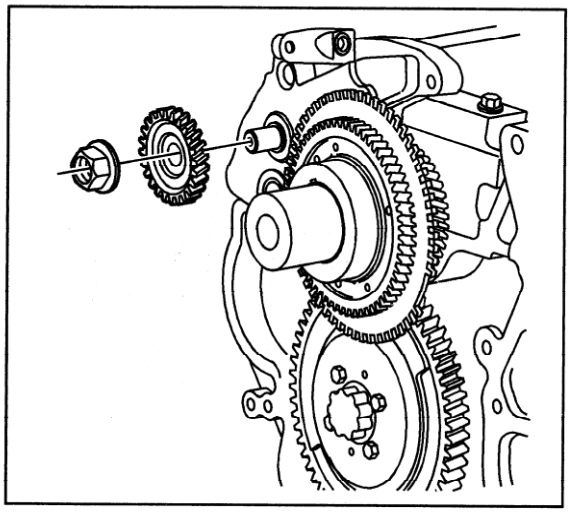
   Tighten the oil pump bolts to 21 N·m (15 lb ft).



660339

**Important:** Do not damage the crankshaft sensor reluctor teeth.

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



660532

6. Install the oil pump driven gear.

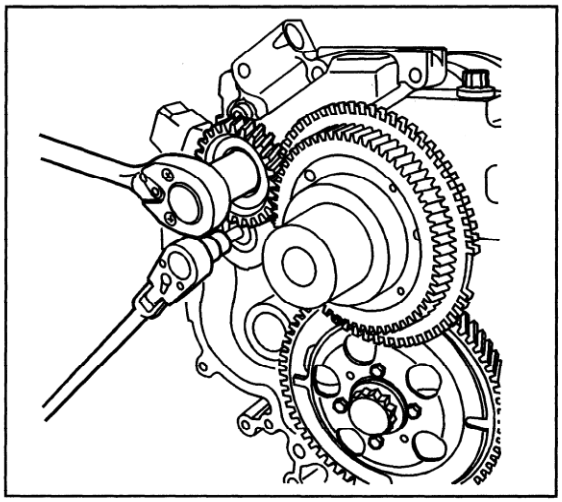
***Notice:*** Do not use an impact driver to remove or install the oil pump driven gear nut. Use of an impact driver may shear the oil pump drive gear pin in the crankshaft.

**Important:** 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**

   Tighten the oil pump driven gear nut to 100 N·m (74 lb ft).



776631

## Oil Pump Pipe and Screen Assembly Installation

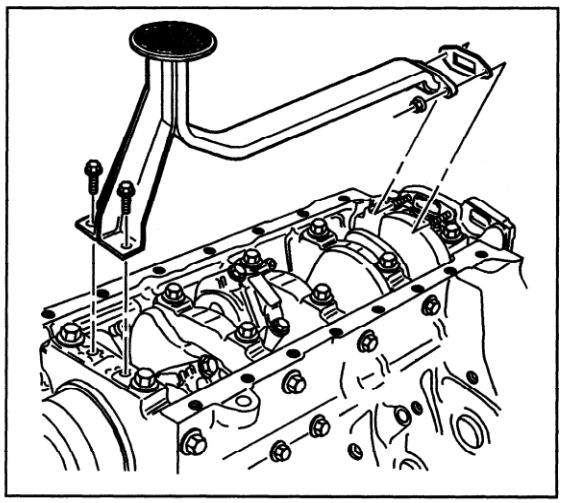
1. Install the oil pump pipe and screen gasket.
2. Install the oil pump pipe and screen.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

3. Install the oil pump pipe and screen assembly bolts and nuts.

   **Tighten**

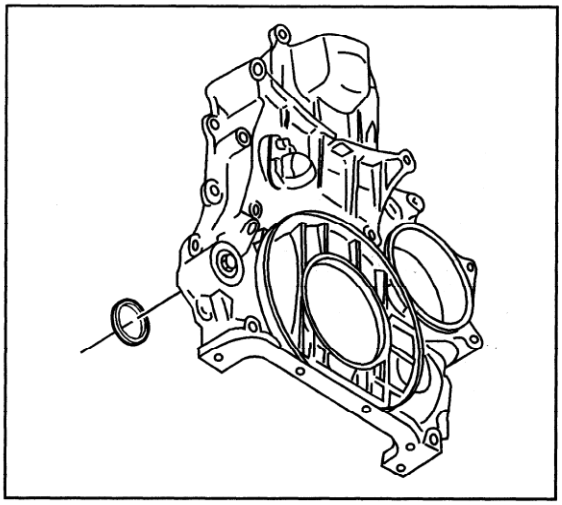
   - Tighten the oil pump pipe and screen assembly bolts to 25 N·m (18 lb ft).
   - Tighten the oil pump pipe and screen assembly nuts to 25 N·m (18 lb ft).



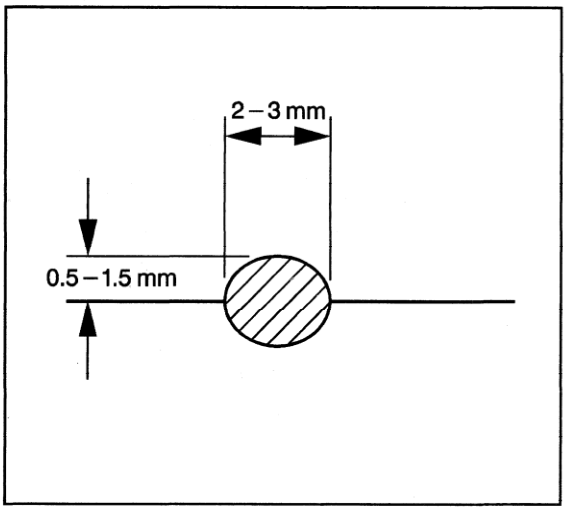
660531

## Engine Front Cover Installation

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

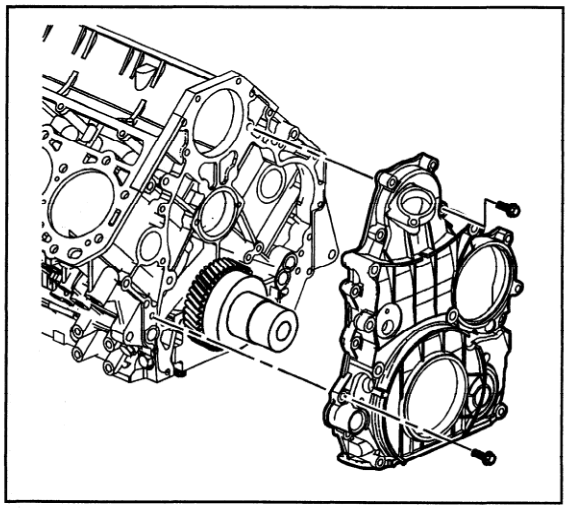


793901



663817

3. Apply a 2–3 mm wide and 0.5–1.5 mm high bead of P/N 12378521 sealant to the mating surfaces of the engine front cover.


1336120

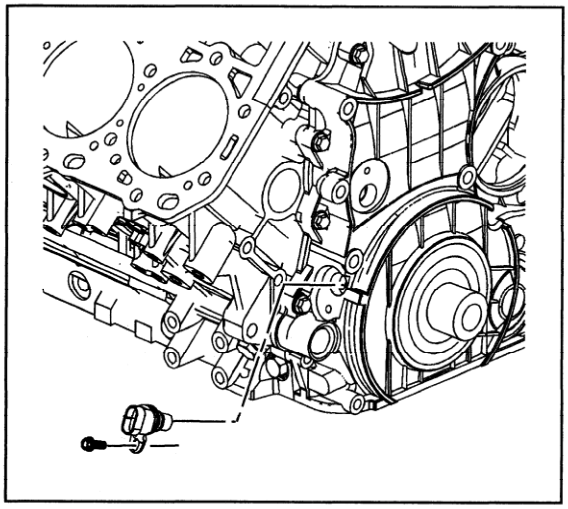
4. Install the engine front cover.

***Notice:*** Refer to *Fastener Notice*

5. Install the engine front cover bolts.

   **Tighten**

   Tighten the engine front cover bolts to 25 N·m (18 lb ft).


1336119

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.

   **Tighten**

   Tighten the crankshaft position sensor spacer bolts 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.

    **Tighten**

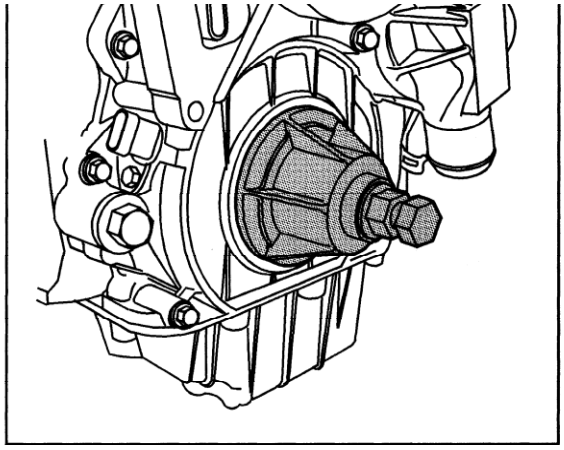
    Tighten the crankshaft position sensor bolt to 10 N·m (89 lb in).

**Installation**

**Tools Required**

*J 44645* Crankshaft Front Oil Seal Installer

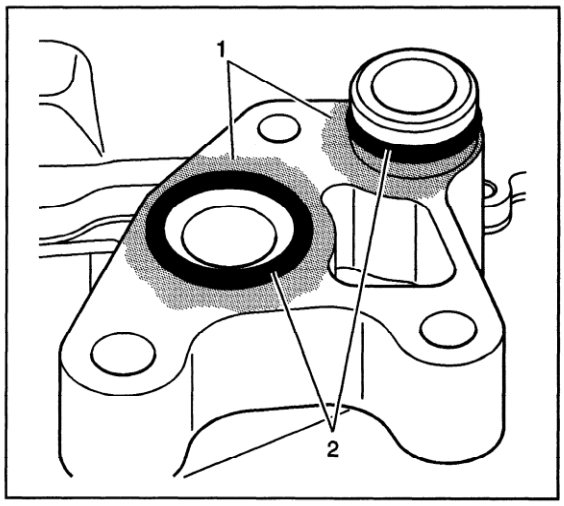
1. Lubricate the crankshaft sealing surface with engine oil.
2. Place the crankshaft front oil seal onto the crankshaft.
3. Install the *J 44645* to the crankshaft.
4. Press the crankshaft front oil seal onto the crankshaft with the *J 44645* until the tool bottoms out.
5. Remove the *J 44645*.



663819

## 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 P/N 12378521 to the O-ring sealing area (1).




870004

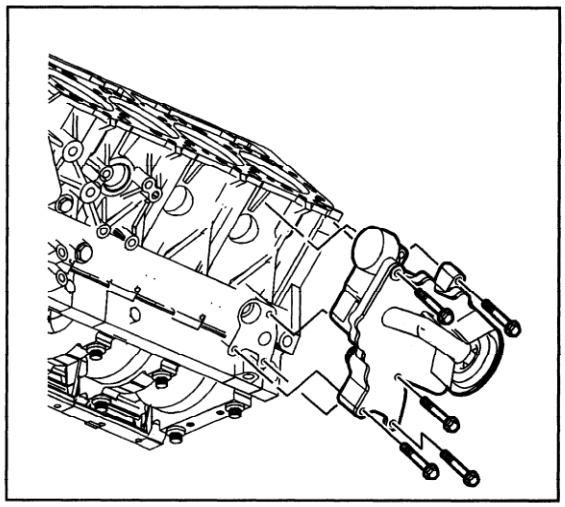
3. Install the oil filter adapter and oil cooler assembly.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

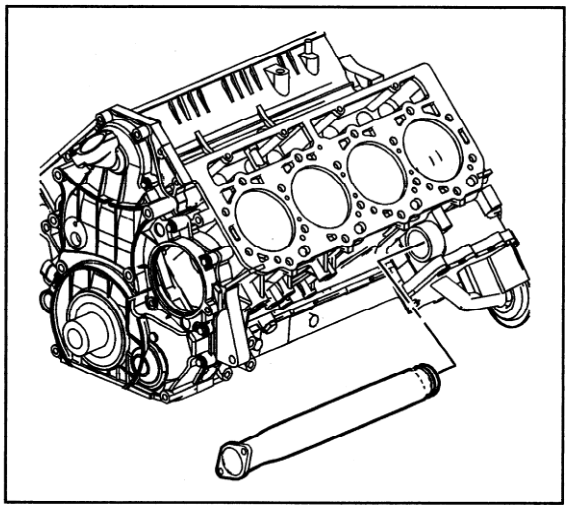
4. Install the five oil filter adapter and oil cooler assembly bolts (1).

   **Tighten**

   Tighten the oil filter adapter and oil cooler assembly bolts to 25 N·m (18 lb ft).

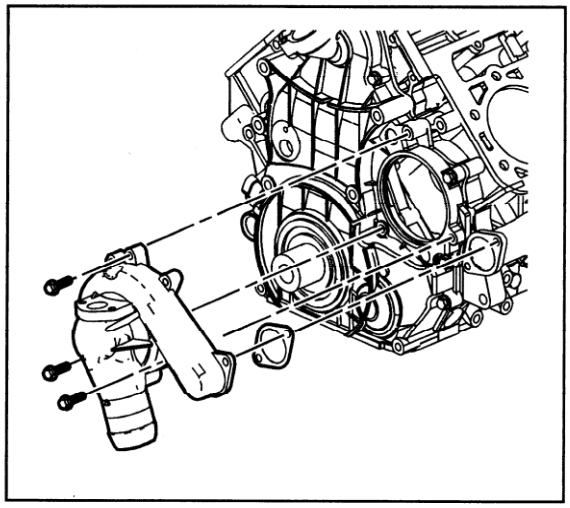


1336118



1336117

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.



1336116

## Water Pump Installation

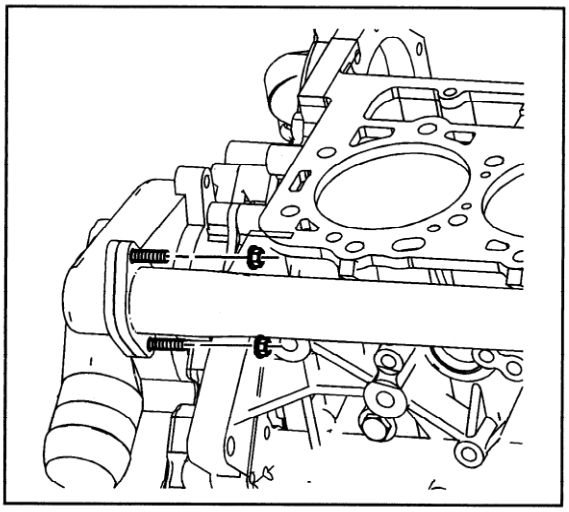
1. Lubricate the water pump O-ring with engine oil.
2. Install the engine coolant pipe gasket.
3. Install the water pump seal.
4. Install the water pump. Be sure the water pump studs align with the coolant tube.

***Notice:*** Refer to *Fastener Notice*

5. Install the water pump bolts.

   **Tighten**

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



1336115

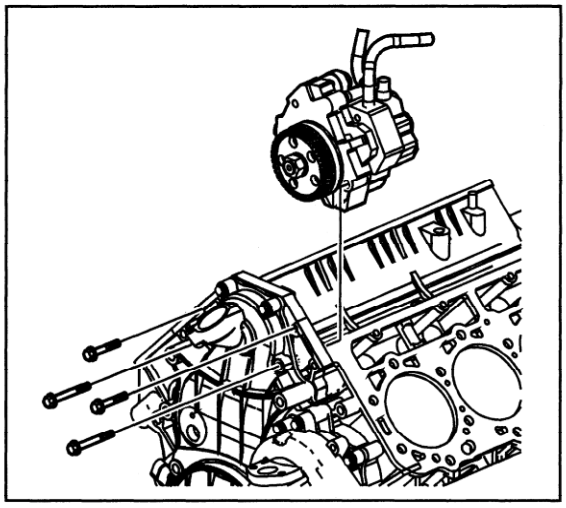
6. Install the water pump to coolant tube nuts.

   **Tighten**

   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.



1336114

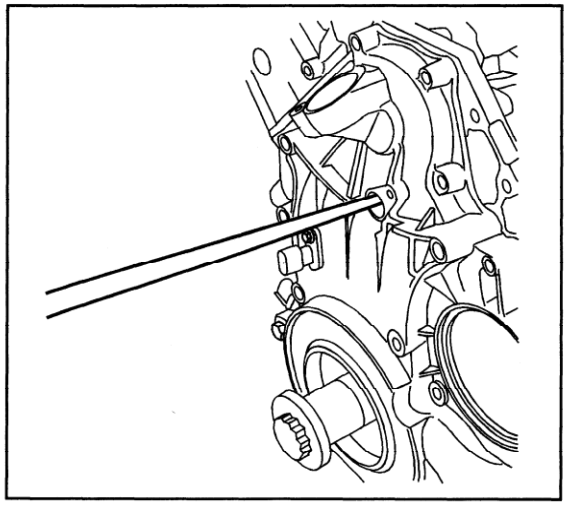
2. Use a suitable tool to unload the spring tension from the two piece cam gear. Apply pressure towards the right side of the engine while installing the fuel injection pump.
3. Install the fuel injection pump and adapter assembly.

***Notice:*** Refer to *Fastener Notice on page P-9*.

4. Install the fuel injection pump bolts.

   **Tighten**

   Tighten the fuel injection pump bolts to 25 N·m (18 lb ft).



1650676

## Valve Lifter Installation

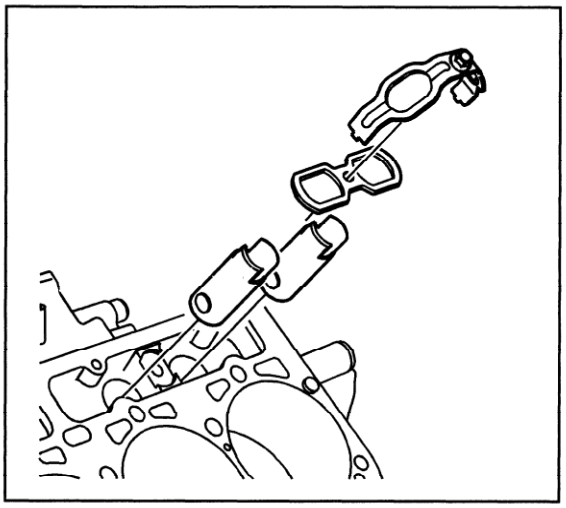
1. Install the valve lifter.
2. Install the valve lifter guides.
3. Install the valve lifter guide hold down bracket.

***Notice:*** Refer to *Fastener Notice on page P-9* in Cautions and Notices.

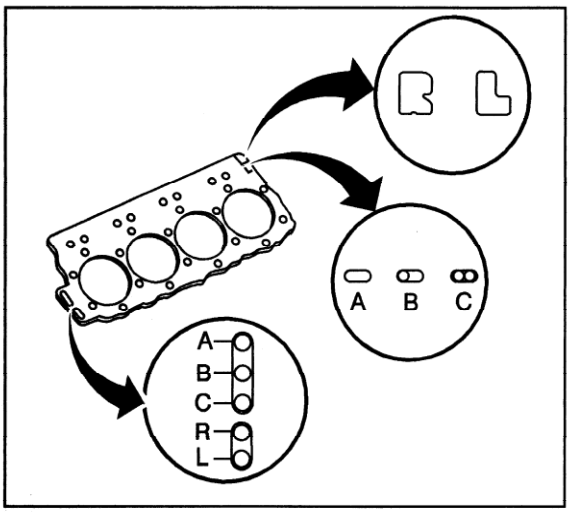
4. Install the valve lifter guide hold down bracket bolt.

   **Tighten**

   Tighten the valve lifter guide hold down bracket bolt to 11 N·m (97 lb in).



660517



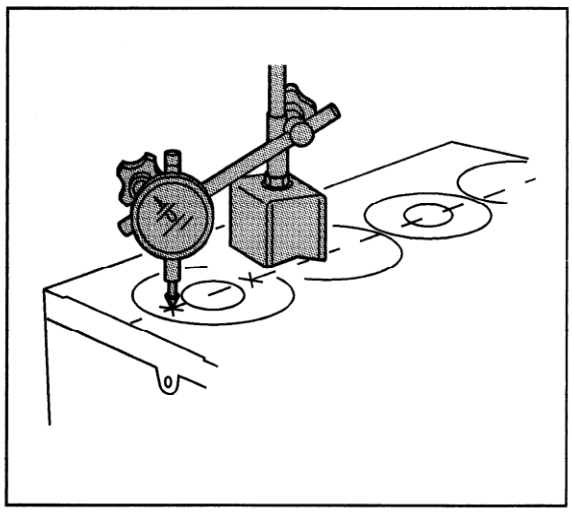
663825

## Cylinder Head Gasket Selection

### Tools Required

*J 7872* Dial Indicator Set

1. 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.
2. Be sure the piston and cylinder deck are free of carbon, gasket material, or other objects that may give you an erroneous measurement.


663829

3. Use *J 7872* to measure the piston projection across two different points on each piston.
   - 3.1. Zero the dial indicator to the cylinder deck surface.
   - 3.2. 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.
   - 3.3. Rotate the engine to roll the piston through Top Dead Center while noting the maximum reading on the dial indicator.
   - 3.4. Repeat procedure at the second measuring point on the piston.
4. Calculate the average value of piston projection for each cylinder.
5. Obtain the maximum piston projection value for that bank of cylinders.
6. Determine the gasket grade by the maximum piston projection value using the chart.
7. 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

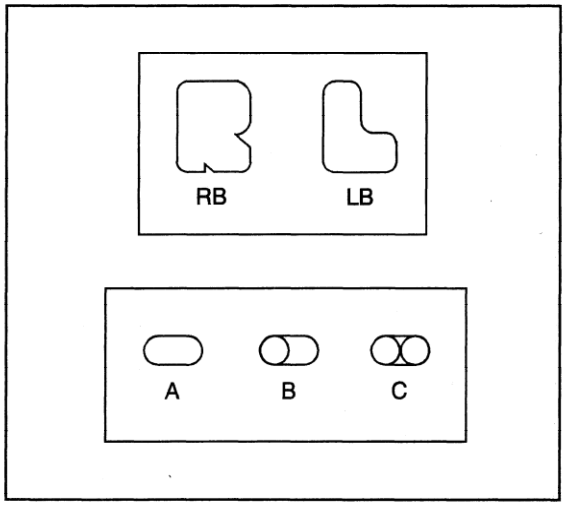
### Tools Required

*J 45059* Angle Meter

***Notice:*** 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.

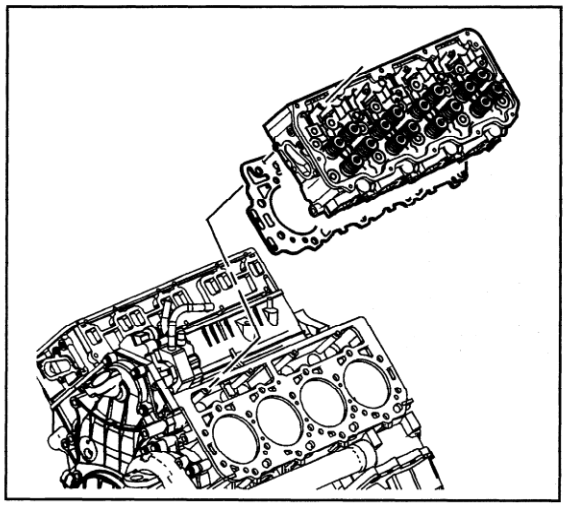
**Important:** The stamped letter R or L, must face up. R is the right bank, L is the left bank.

1. 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 on page 6-1064*.



1411025

2. Install the left cylinder head.


1336110

***Notice:*** 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.

***Notice:*** Refer to *Fastener Notice*

3. Install the NEW M12 cylinder head bolts.

   Tighten the M12 cylinder head bolts in three steps:

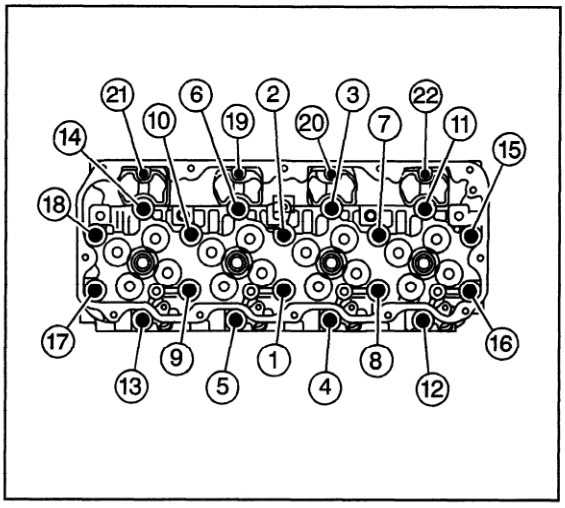
   **Tighten**

   3.1. 1st step 50 N·m (37 lb ft)

   3.2. 2nd step 80 N·m (59 lb ft)

   3.3. 3rd step tighten 90 degrees using *J 45059*

   3.4. 4th step tighten 75 degrees using *J 45059*

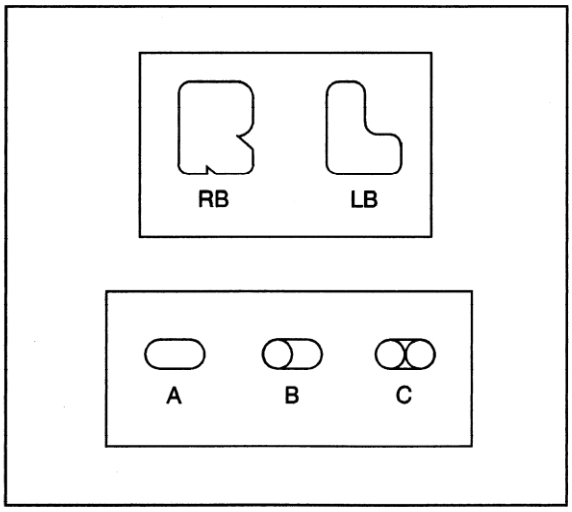


663831

4. Reuse the M8 bolts. Install the M8 bolts.

   **Tighten**

   Tighten the M8 cylinder head bolts to 25 N·m (18 lb ft).



1411025

## Cylinder Head Installation - Right

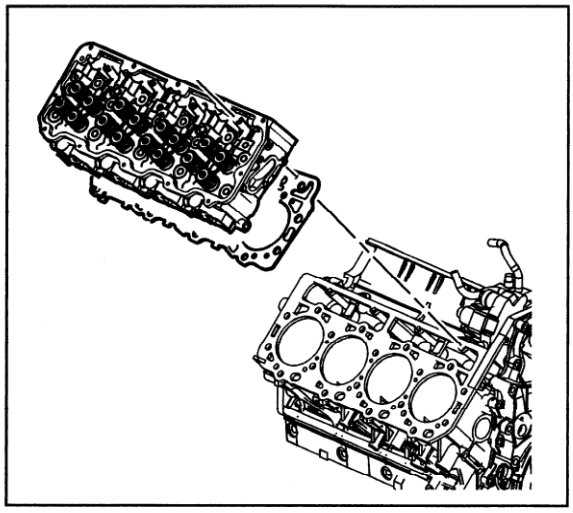
### Tools Required

*J 45059* Angle Meter

***Notice:*** 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.

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

1. 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*


1336113

2. Install the right cylinder head.

***Notice:*** 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.

***Notice:*** Refer to *Fastener Notice*

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

   Tighten the M12 cylinder head bolts in three steps:

   **Tighten**

   3.1. 1st step 50 N·m (37 lb ft)

   3.2. 2nd step 80 N·m (59 lb ft)

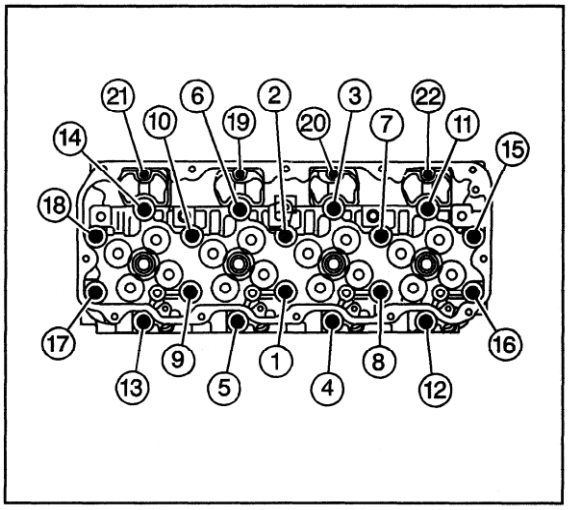
   3.3. 3rd step tighten 90 degrees using *J 45059*

   3.4. 4th step tighten 75 degrees using *J 45059*

4. Install the M8 bolts.

   **Tighten**

   Tighten the M8 cylinder head bolts to 25 N·m (18 lb ft).

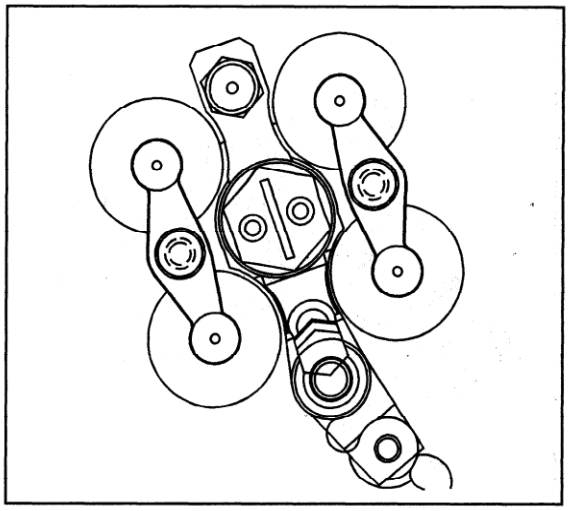


663831

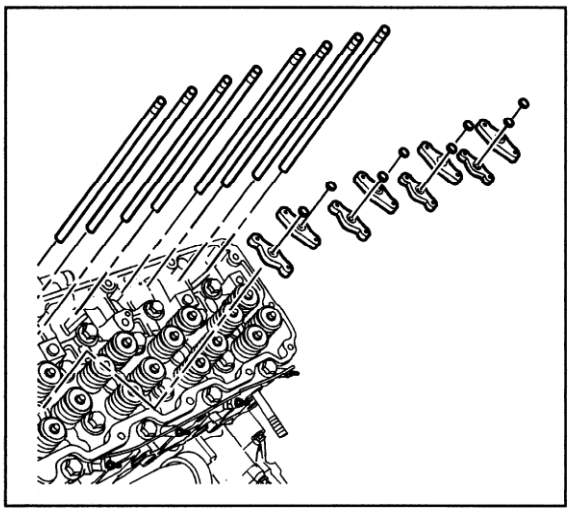
## Valve Rocker Arm, Shaft, and Push Rod Installation

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

1. Install the valve bridge.

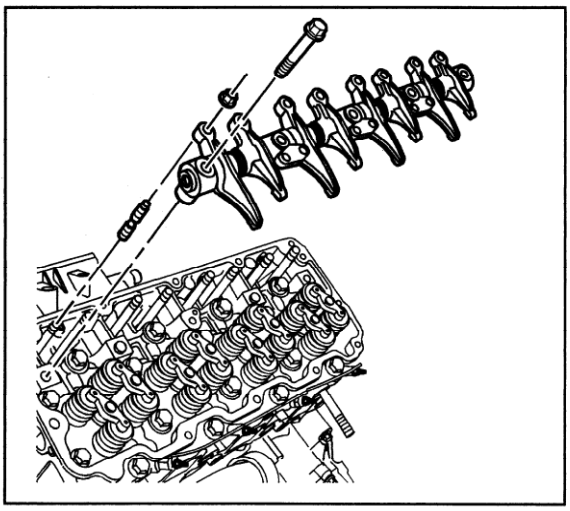


1342411



660488

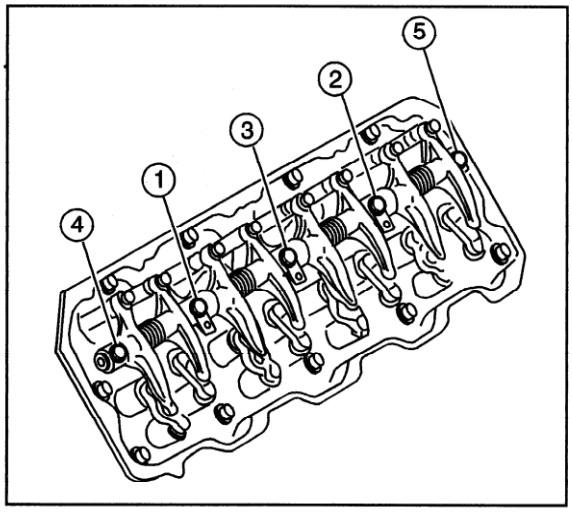
2. Install the valve bridge pins.
3. Install the pushrods.



663833

***Notice:*** 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.




721463

***Notice:*** Refer to *Fastener Notice*

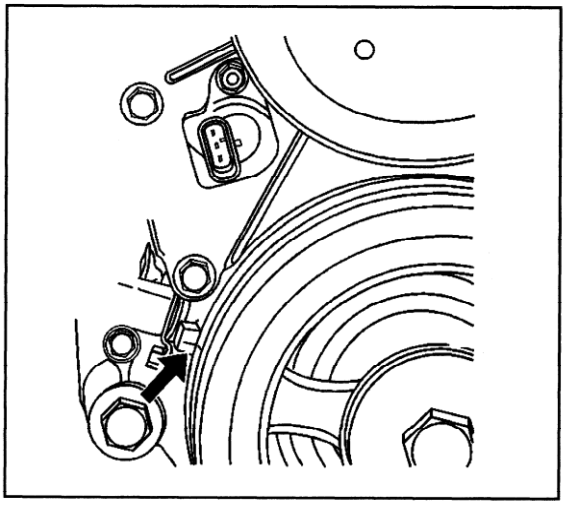
5. Install the rocker arm shaft assembly bolts.

   **Tighten**

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

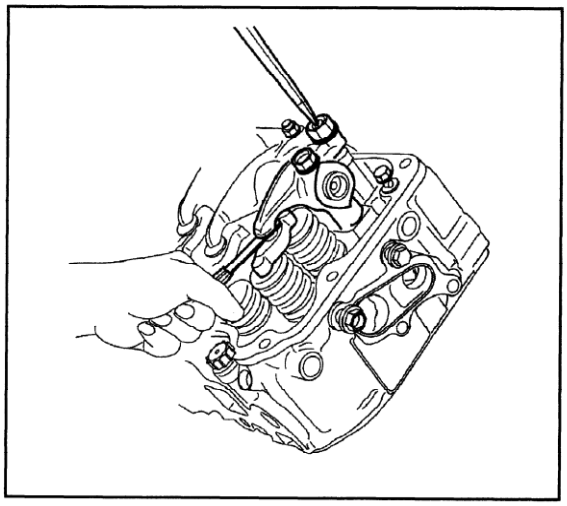
## Valve Lash Adjustment

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.



667477

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



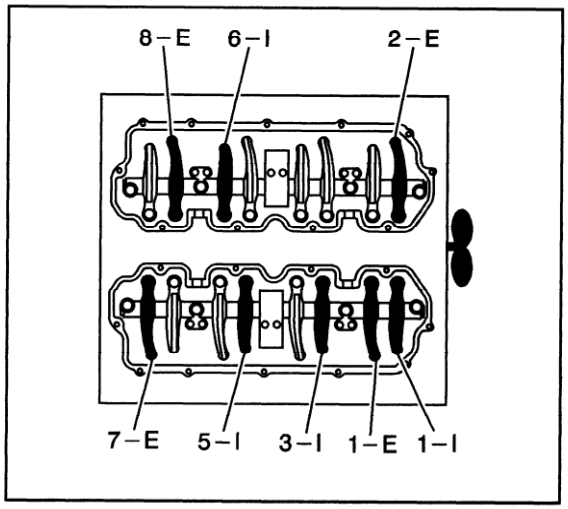
663897

***Notice:*** Refer to *Fastener Notice*

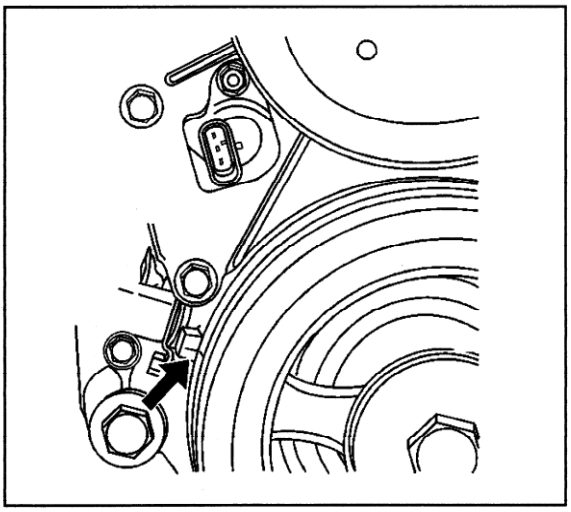
4. Adjust the valve lash to 0.3 mm (0.012 in). Refer to *Valve Clearance Adjustment Specifications* to determine which valves that can be adjusted when the engine is at Top Dead Center.

   **Tighten**

   Tighten the valve lash lock nut to 22 N·m (16 lb ft).

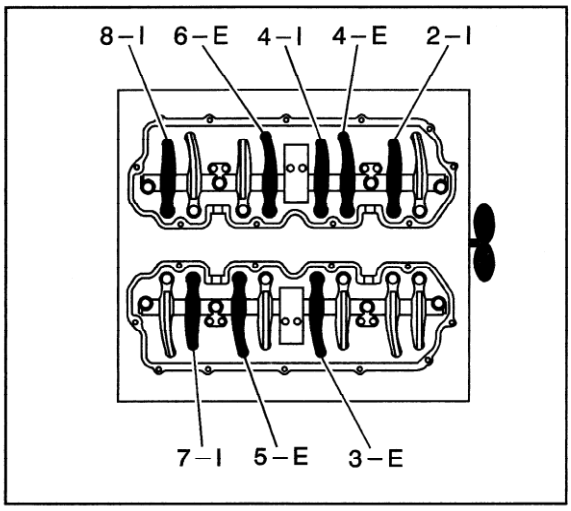



663110



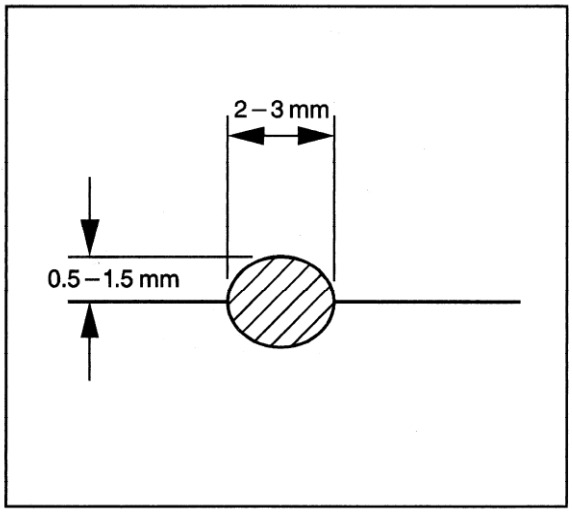
667477

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




660548

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.

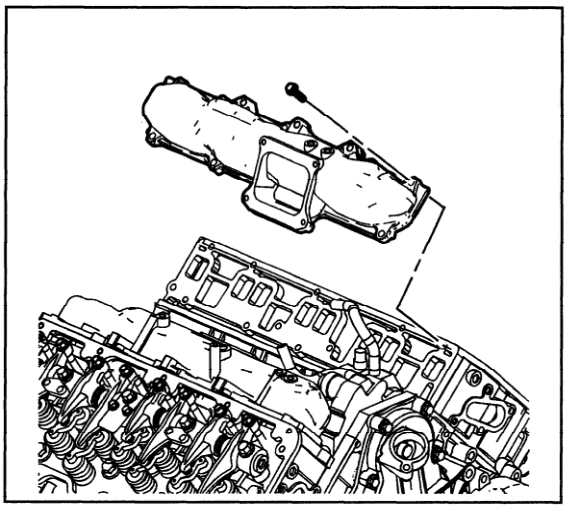



663817

## Intake Manifold Installation - Left

1. Apply a 2–3 mm wide by 0.5–1.5 mm high bead of P/N 12378521 sealant on the intake manifold mating surface.

2. Install the intake manifold.



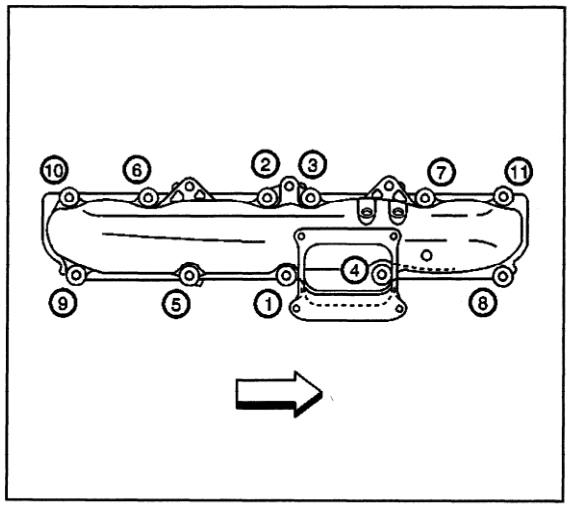
1335932

***Notice:*** Refer to *Fastener Notice*

3. Install the intake manifold bolts and nuts.

   **Tighten**

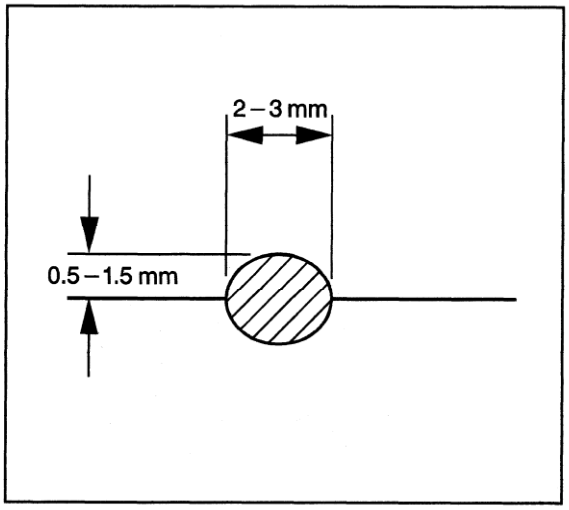
   Tighten the intake manifold bolts and nuts to 25 N·m (18 lb ft).



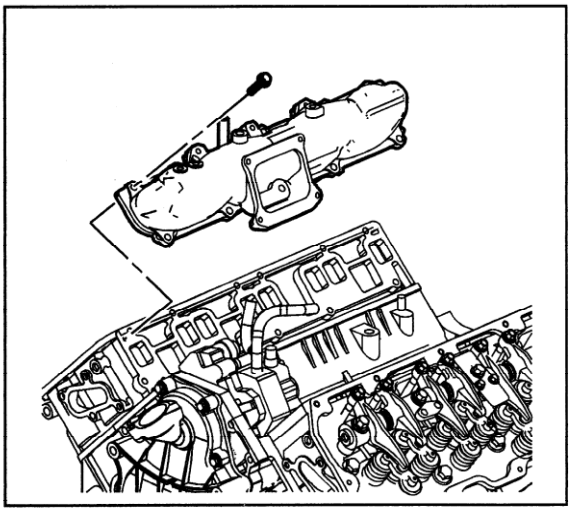

654530

## Intake Manifold Installation - Right

1. Apply a 2–3 mm wide by 0.5–1.5 mm high bead of P/N 12378521 sealant on the intake manifold mating surface.

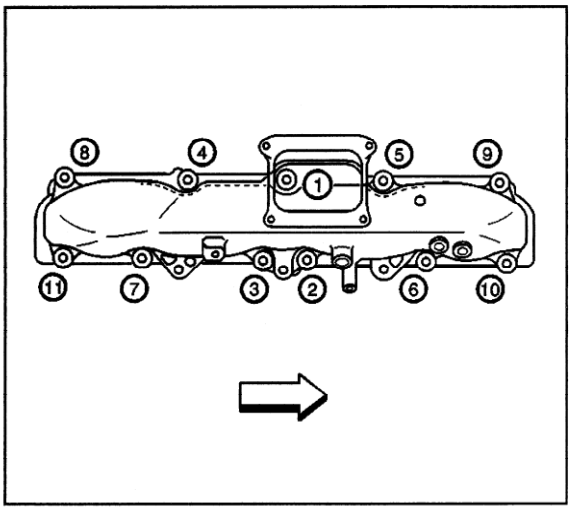



663817



1335935

2. Install the intake manifold.



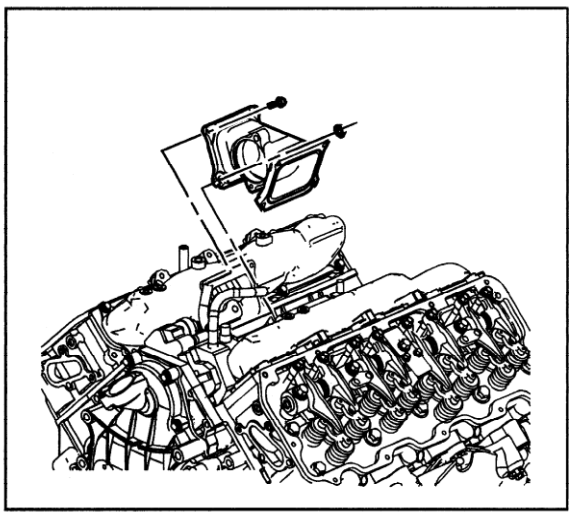

654532

***Notice:*** Refer to *Fastener Notice*

3. Install the intake manifold bolts and nuts.

   **Tighten**

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



1335931

## Intake Manifold Crossover Installation

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

***Notice:*** Refer to *Fastener Notice*

3. Install the intake manifold crossover nuts and bolts in sequence.

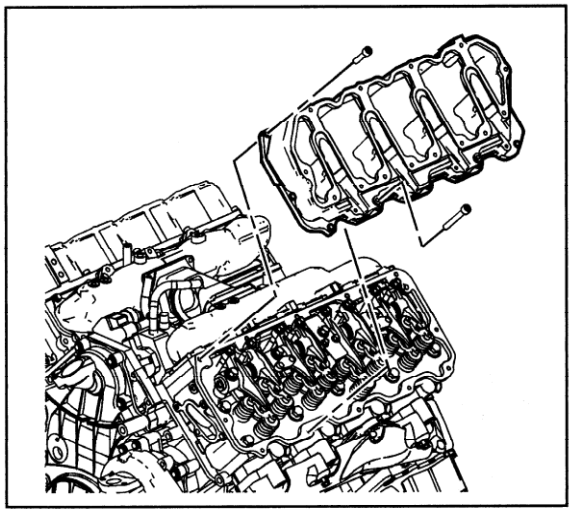
   **Tighten**

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

## Valve Rocker Arm Cover Installation - Lower Left

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

1. Install the lower valve rocker arm cover.



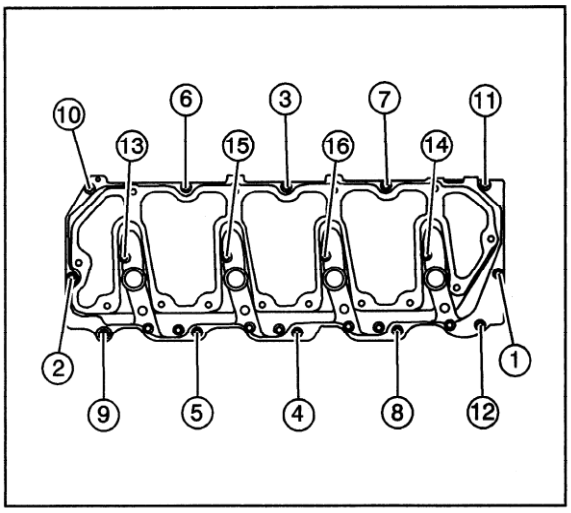
1335926

***Notice:*** Refer to *Fastener Notice*

2. Install the lower valve rocker arm cover bolts.

   **Tighten**

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

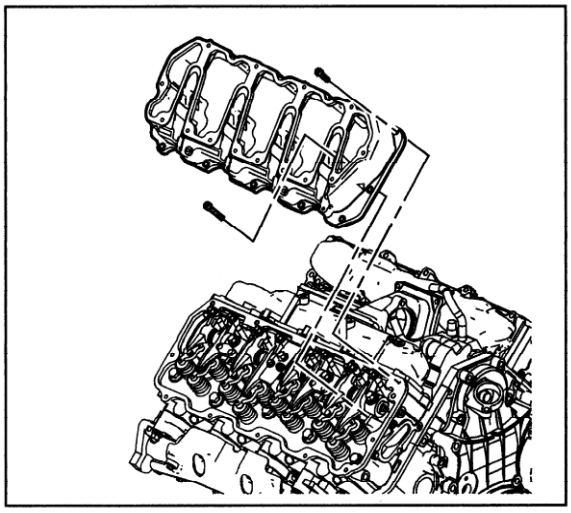



1411029

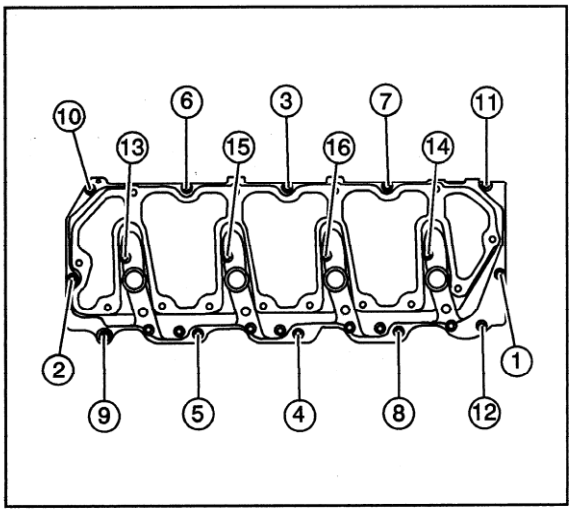
## Valve Rocker Arm Cover Installation - Lower Right

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

1. Install the lower valve rocker arm cover.



1335929



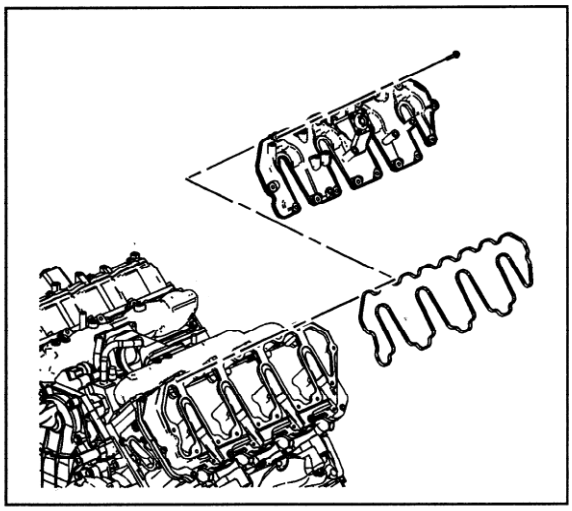
1411029

***Notice:*** Refer to *Fastener Notice*

2. Install the lower valve rocker arm cover bolts.

**Tighten**

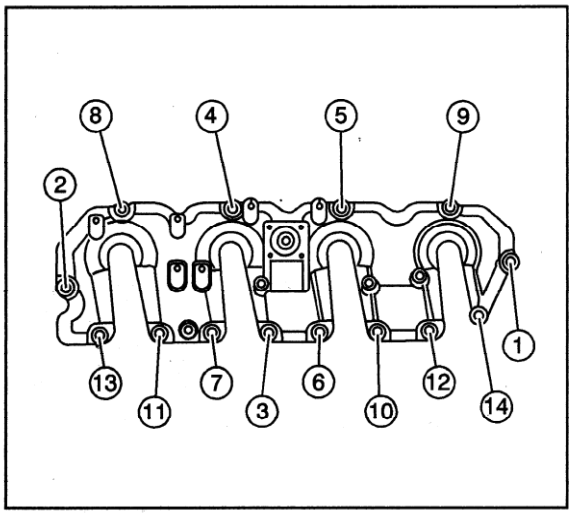
- Tighten the lower valve rocker arm cover bolts in the proper sequence to 10 N·m (89 lb in).
- Retighten the lower valve rocker arm cover bolts in the proper sequence to the same torque, 10 N·m (89 lb in).


1335635

## Valve Rocker Arm Cover Installation - Upper Left

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

1. Install the upper valve rocker arm cover.



1411030

***Notice:*** Refer to *Fastener Notice*

2. Install the upper valve rocker arm cover bolts.

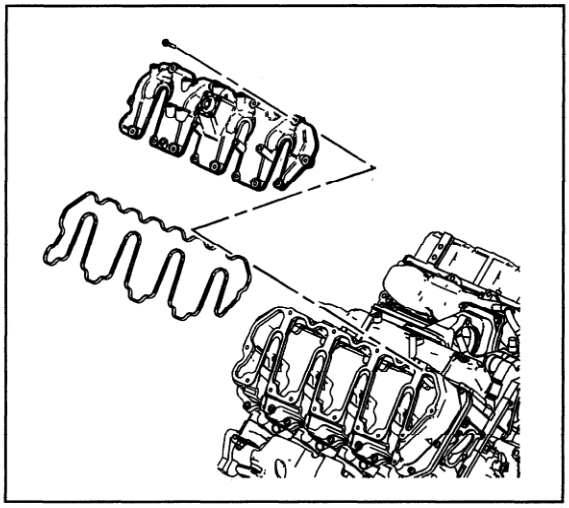
**Tighten**

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

## Valve Rocker Arm Cover Installation - Upper Right

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

1. Install the upper valve rocker arm cover.



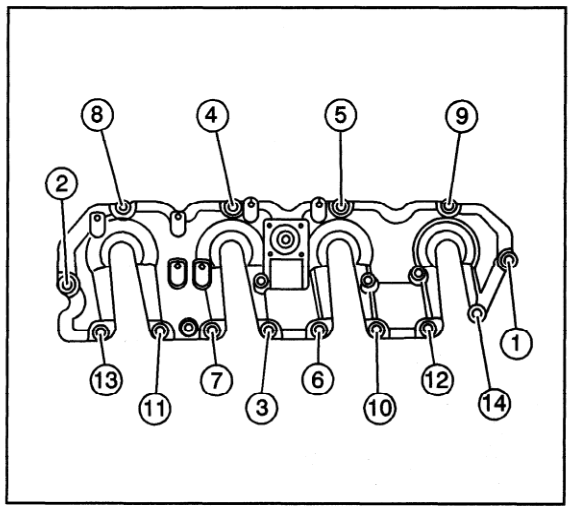
1335653

***Notice:*** Refer to *Fastener Notice*

2. Install the upper valve rocker arm cover bolts.

   **Tighten**

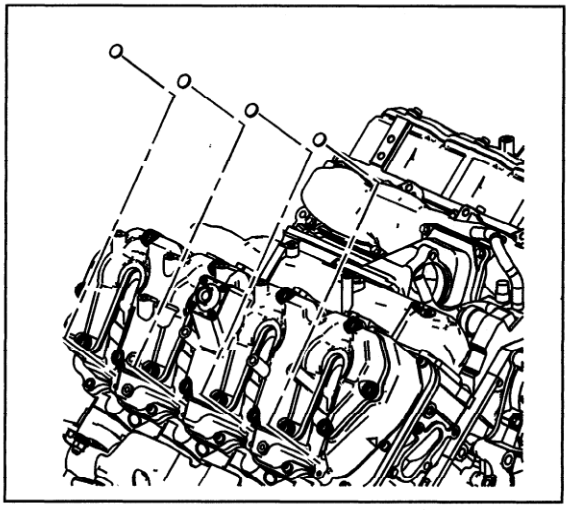
   Tighten the upper valve rocker arm cover bolts in the proper sequence to 8 N·m (71 lb in).



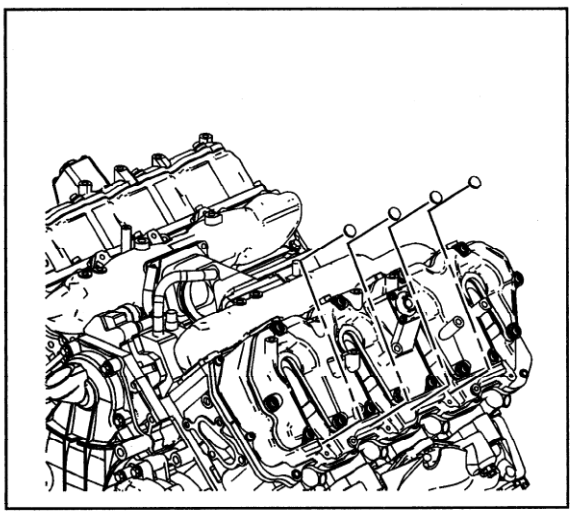

1411030

## Fuel Injectors 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.

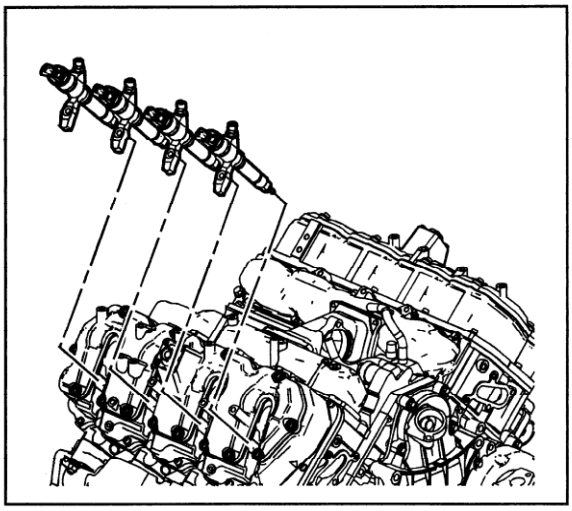


1335628



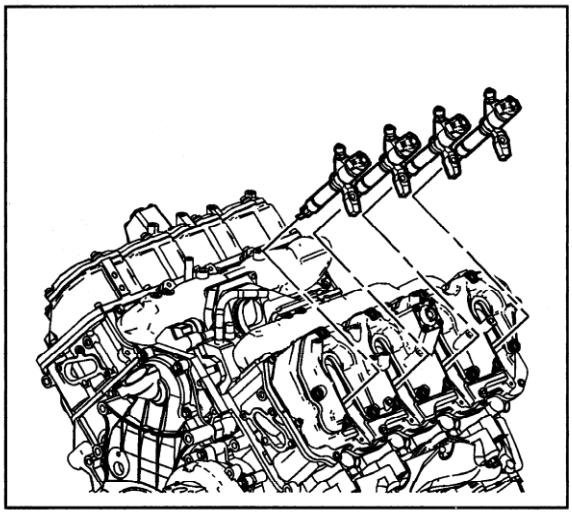
1335627

5. Install the fuel injector left bracket pin.



1335625

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



1335621

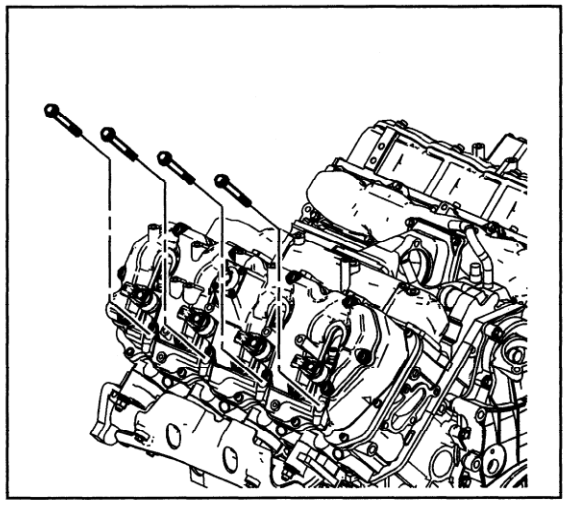
7. Install the left fuel injector with fuel injector bracket.

***Notice:*** Refer to *Fastener Notice*

8. Install the right fuel injector bracket bolts.

   **Tighten**

   Tighten the right fuel injector bracket bolts to 30 N·m (22 lb ft).

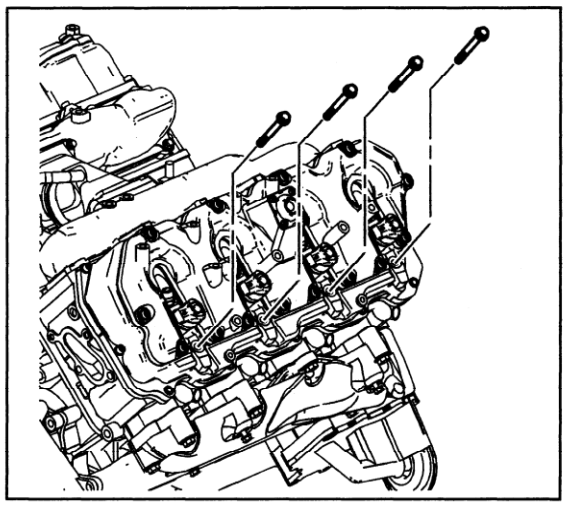


1335619

9. Install the left fuel injector bracket bolts.

   **Tighten**

   Tighten the left fuel injector bracket bolts to 30 N·m (22 lb ft).



1335618

## Fuel Pipes and Fuel Rail Installation

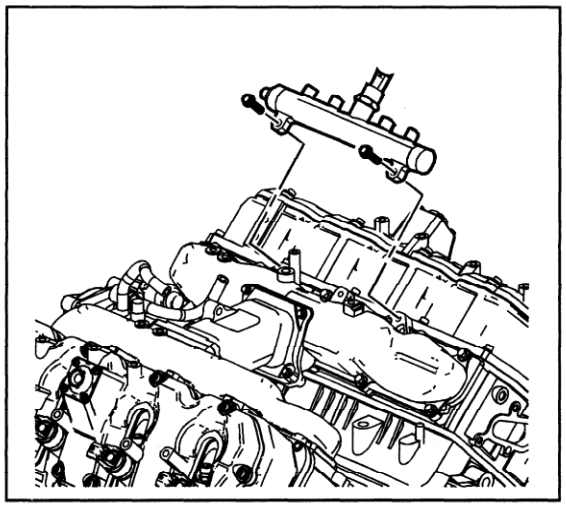
1. Install the right fuel rail.

***Notice:*** Refer to *Fastener Notice*

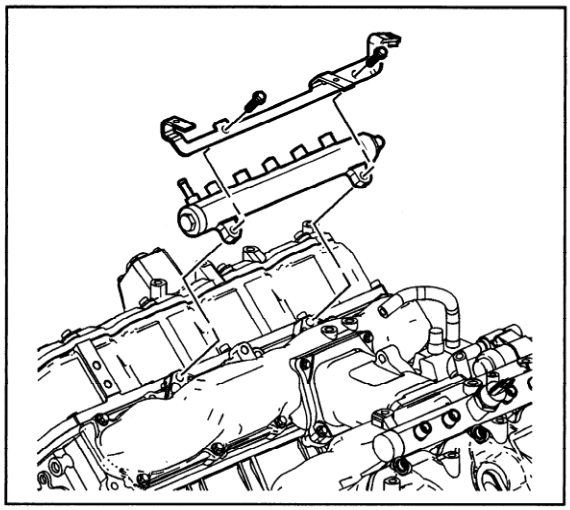
2. Install the right fuel rail mounting bolts.

   **Tighten**

   Tighten the right fuel rail mounting bolts to 25 N·m (18 lb ft).



1335617

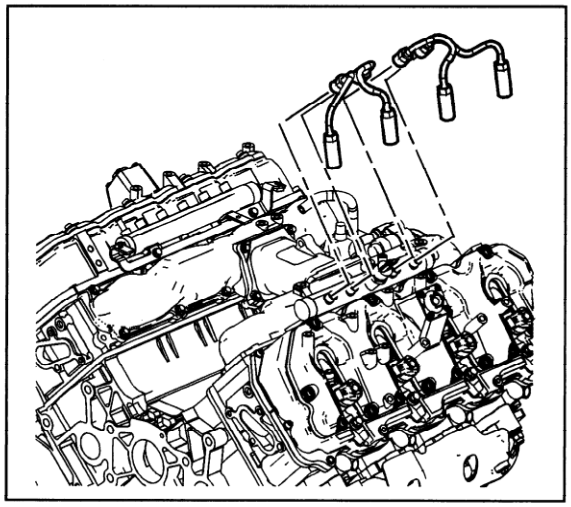


1335616

3. Install the left fuel rail.
4. Install the left fuel rail mounting bolts.

**Tighten**

Tighten the left fuel rail mounting bolts to 25 N·m (18 lb ft).



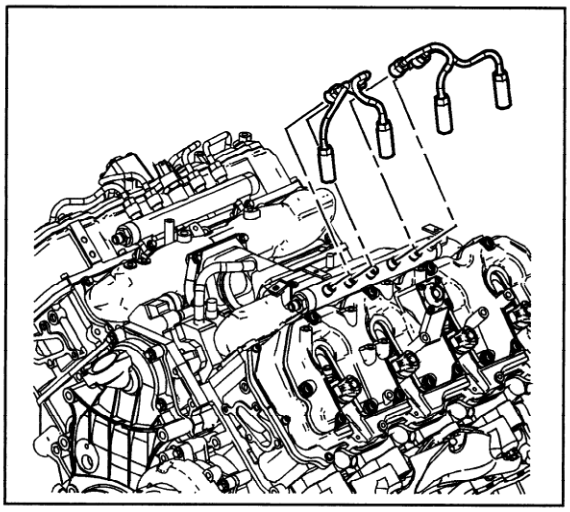
1335614

***Caution: 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.

**Tighten**

Tighten the injection pipes to 41 N·m (30 lb ft).



1335608

***Caution: 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.

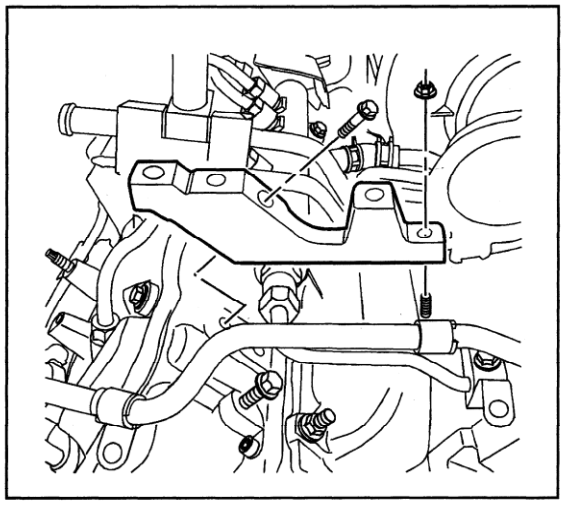
**Tighten**

Tighten the injection pipes to 41 N·m (30 lb ft).

7. Install the exhaust gas recirculation (EGR) mounting brackets.
8. Install the EGR mounting bracket bolts.

   **Tighten**

   Tighten the EGR mounting bracket bolts to 20 N·m (15 lb ft).

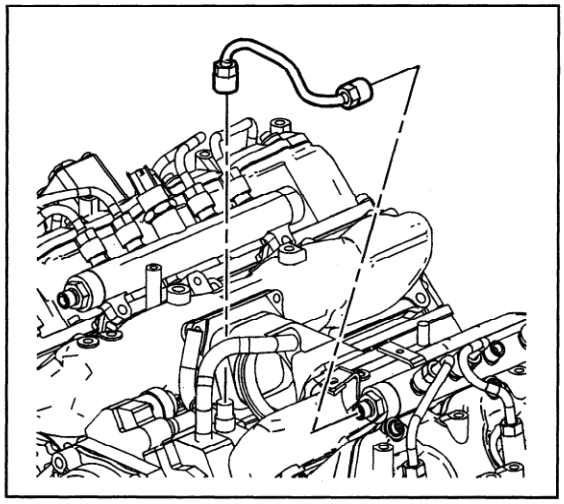


1650670

9. Install the left fuel rail to pump pipe.

   **Tighten**

   Tighten the fuel rail to pump pipe nut to 41 N·m (30 lb ft).

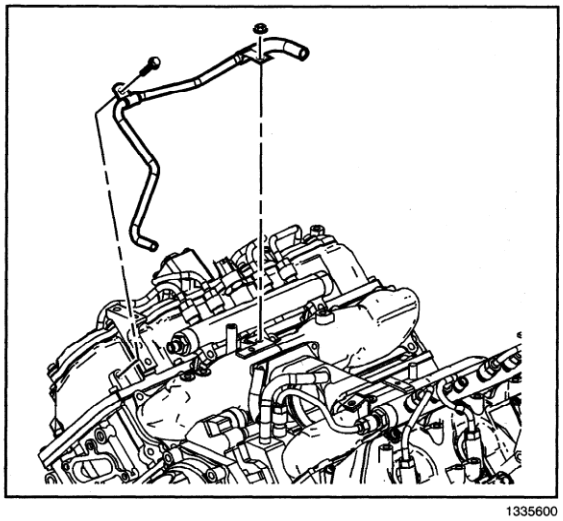


1335603

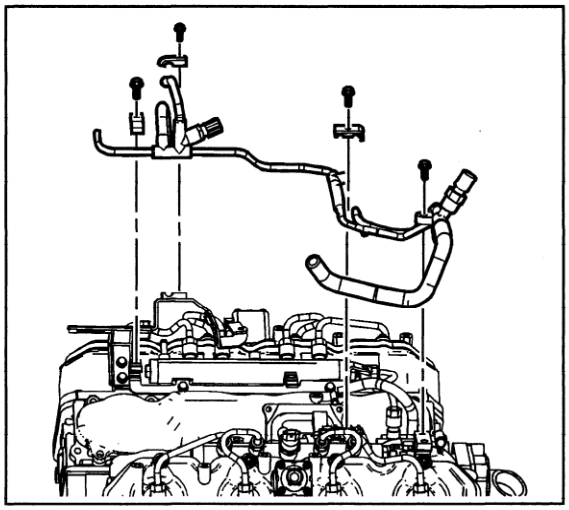
10. Install the coolant pipe.
11. Install the coolant pipe bolt and nut.

    **Tighten**

    Tighten the coolant pipe bolt and nut to 25 N·m (18 lb ft).



1335600

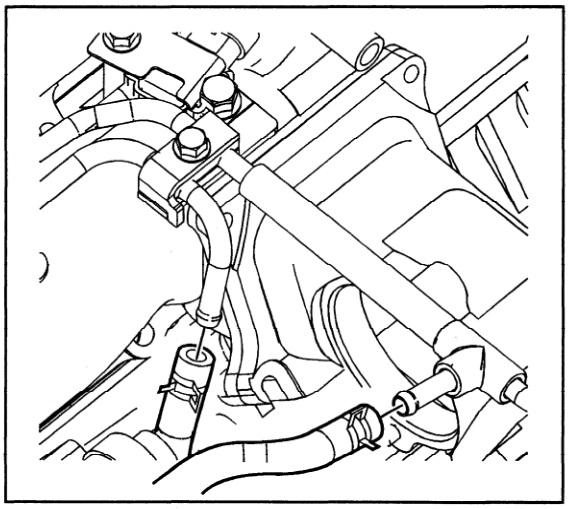


1335596

12. Install the distribution block and fuel line assembly.
13. Install the distribution block and fuel line assembly bolts.

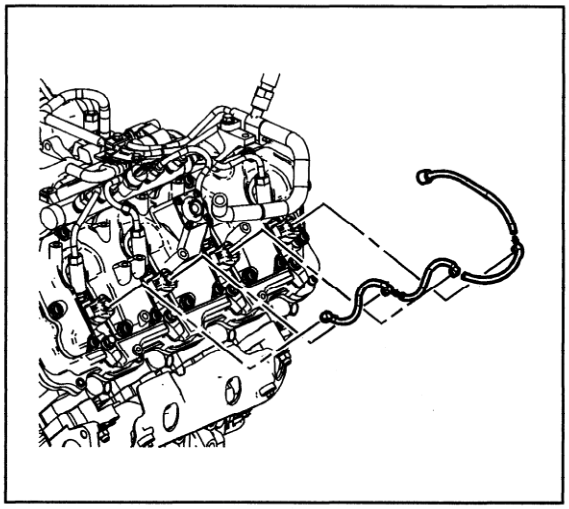
    **Tighten**

    Tighten the fuel line assembly bolts to 25 N·m (18 lb ft).



1335595

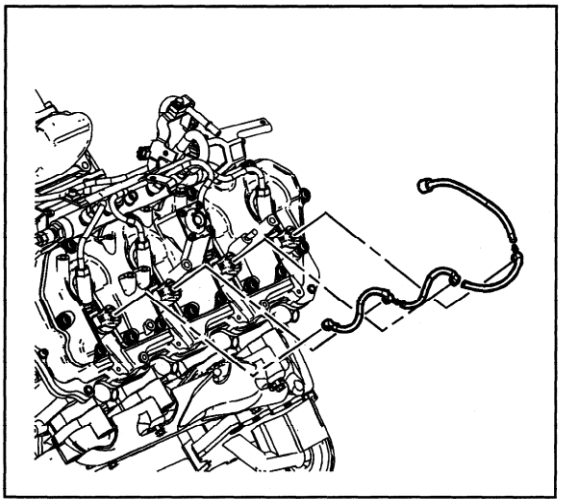
14. Connect the fuel hoses to the fuel injector pump.



1335592

15. Install the right fuel return hose.

16. Install the left fuel return hose.



1335588

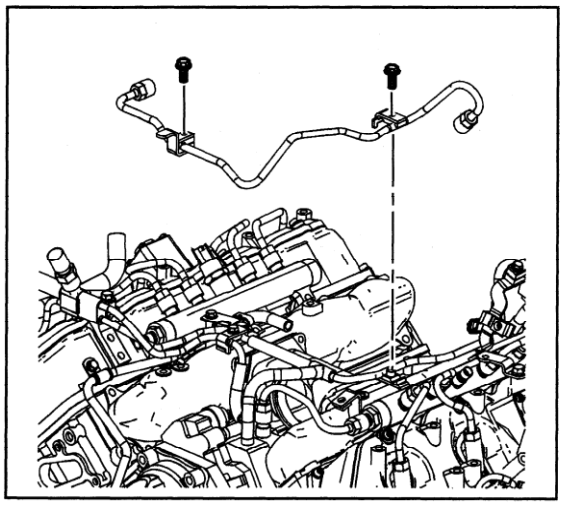
17. Install the fuel rail balance pipe.
18. Install the fuel rail balance pipe bolts.

    **Tighten**

    Tighten the fuel rail balance pipe bolts to 21 N·m (15 lb ft).
19. Connect the fuel rail balance pipe to the fuel rails.

    **Tighten**

    Tighten the fuel rail balance pipe nuts to 41 N·m (30 lb ft).

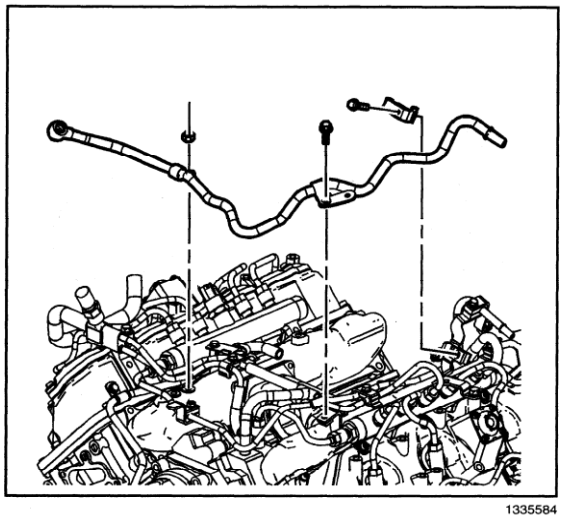


1335586

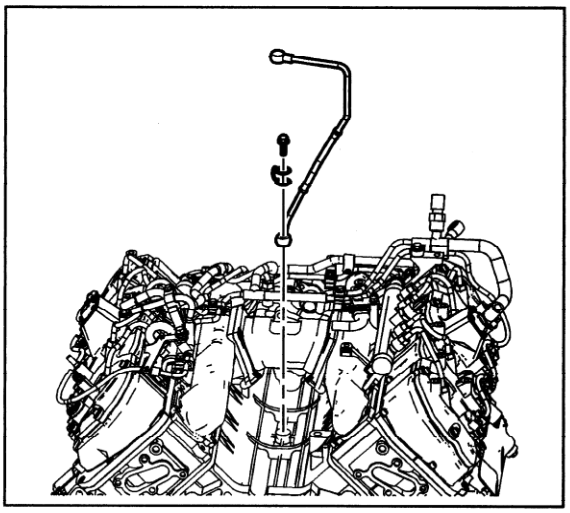
20. Install the fuel feed pipe.
21. Install the fuel feed pipe attaching nuts and bolts.

    **Tighten**

    Tighten the fuel feed pipe bolts and nut to 25 N·m (18 lb ft).



1335584



1335581

## Turbocharger Installation

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

***Notice:*** Refer to *Fastener Notice*

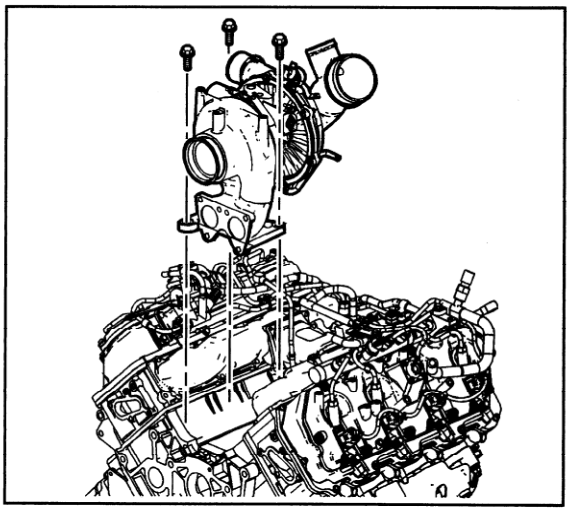
**Important:** Lubricate the washers with diesel fuel before installing.

2. Install the turbocharger oil supply line eye bolt and washers.

   **Tighten**

   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.

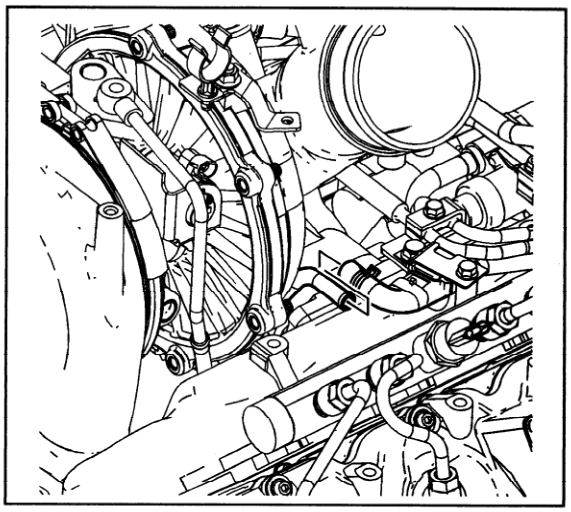


1335579

4. Install the turbocharger assembly with the oil return pipe.
5. Install the turbocharger mounting bolts.

   **Tighten**

   Tighten the turbocharger mounting bolts to 108 N·m (80 lb ft).



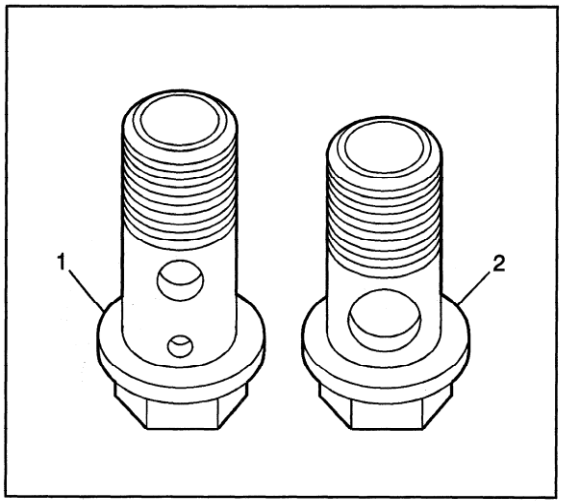
1335578

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

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

**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.

7. Install the cooling outlet hose eye bolts.



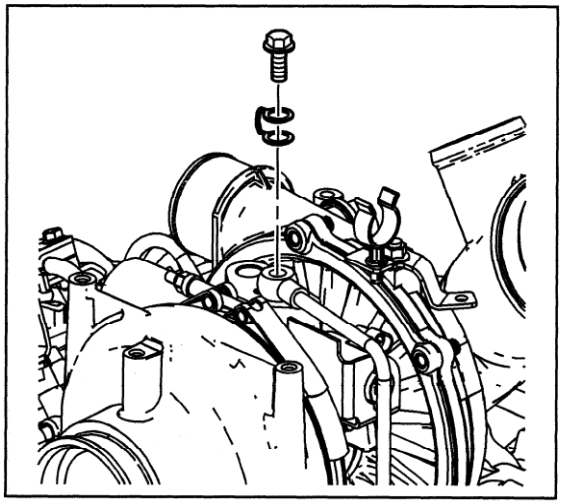
1457469

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

   Lubricate the washers with diesel fuel before installing.

   **Tighten**

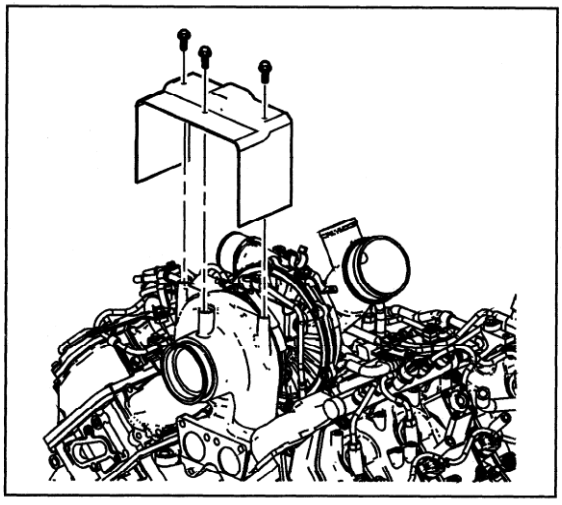
   Tighten the oil supply hose eye bolt to 26 N·m (19 lb ft).

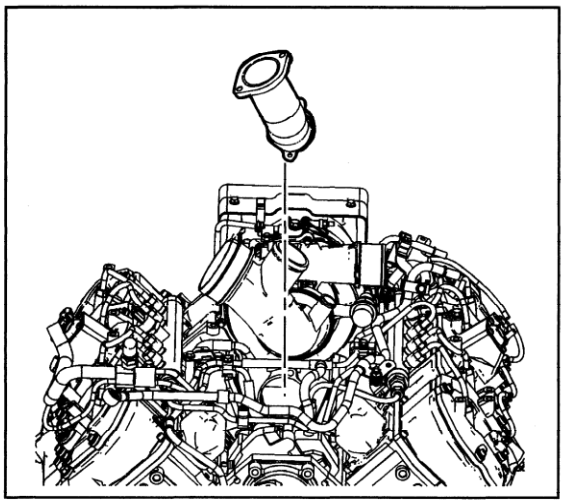

1335577

9. Install the turbocharger heat shield.
10. Install the turbocharger upper heat shield bolts.

    **Tighten**

    Tighten the turbocharger upper heat shield bolts to 10 N·m (89 lb in).

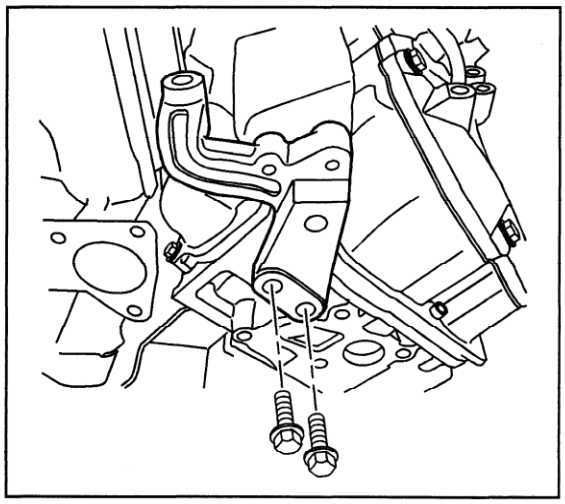

1335576



1335575

## EGR and Cooler Installation

1. Install the intake manifold tube.



1650666

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

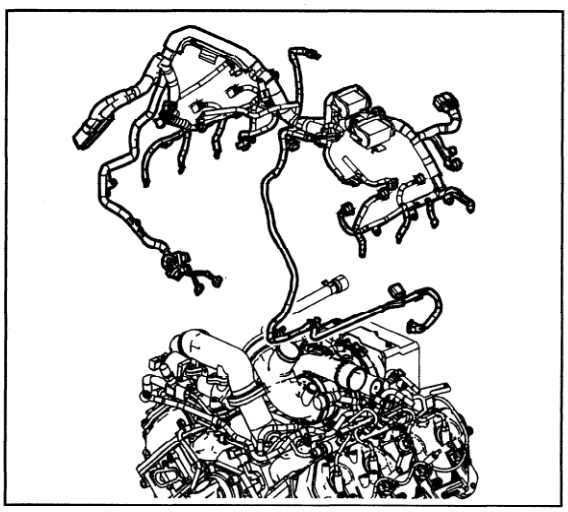
***Notice:*** Refer to *Fastener Notice on page P-9*.

3. Install the EGR cooler bracket bolts.

   **Tighten**

   Tighten the EGR cooler bracket bolts to 25 N·m (18 lb ft).

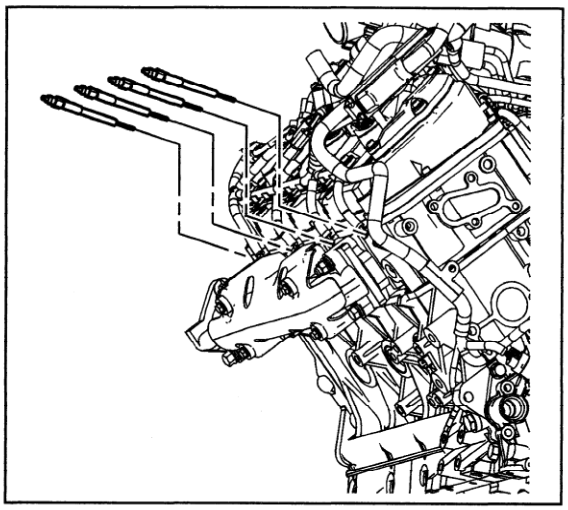
4. Install air inlet tube and air filter.



1335560

## Engine Wiring Harness Assembly Installation

1. Install the engine wiring harness assembly.



1335557

***Notice:*** Refer to *Fastener Notice*

2. Install the right glow plugs.

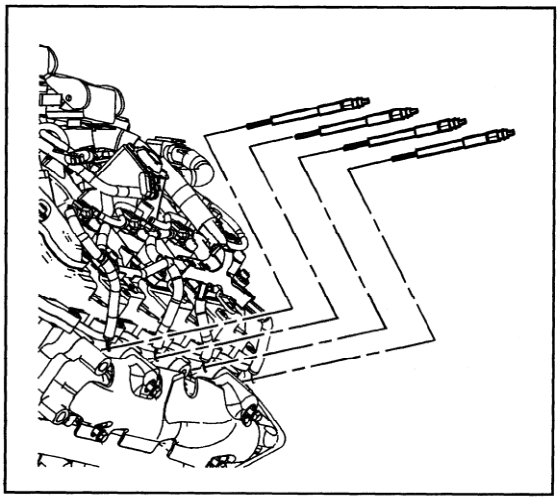
   **Tighten**

   Tighten the glow plugs to 18 N·m (13 lb ft).

3. Install the left glow plugs.

   **Tighten**

   Tighten the glow plugs to 18 N·m (13 lb ft).



1335554

4. Install the glow plug nuts.

   **Tighten**

   Tighten the glow plug nuts to 2 N·m (18 lb in).

5. Install the glow plug controller.
6. Install the glow plug controller bolts.

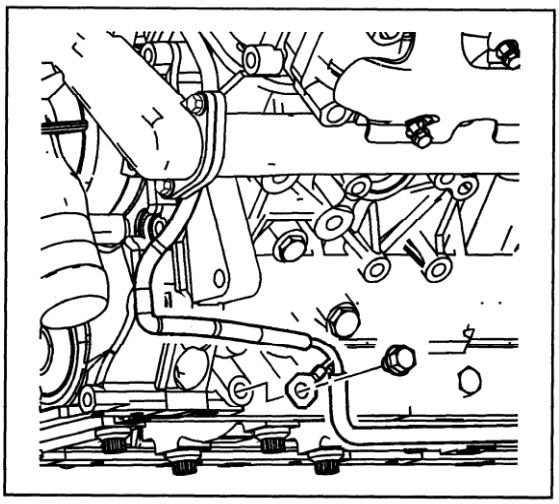
   **Tighten**

   Tighten the glow plug controller bolts to 10 N·m (89 lb in).

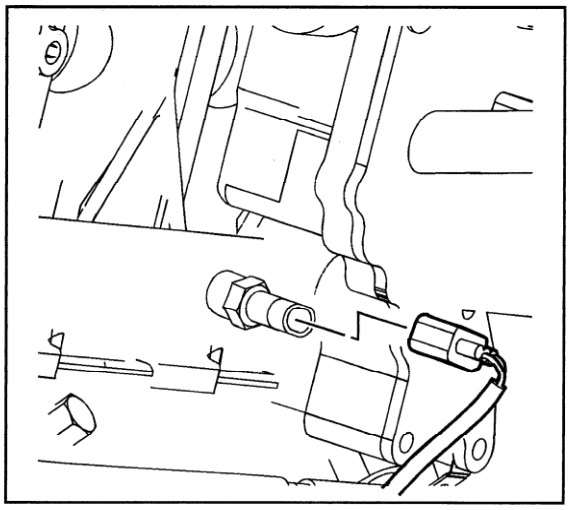
7. Install the oil level sensor harness bolt.

   **Tighten**

   Tighten the oil level sensor harness bolt to 40 N·m (29 lb ft).

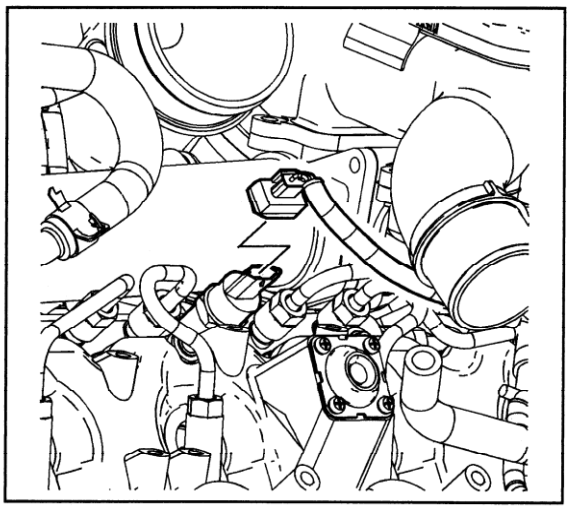


1335549



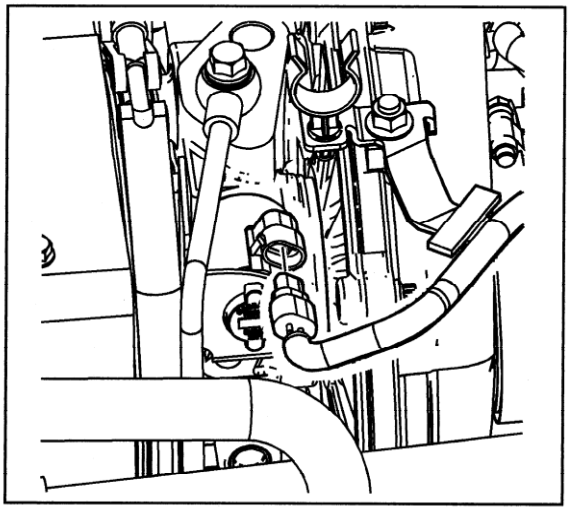
1335546

8. Connect the oil pressure sensor electrical connector.



1335543

9. Connect the fuel rail pressure sensor.

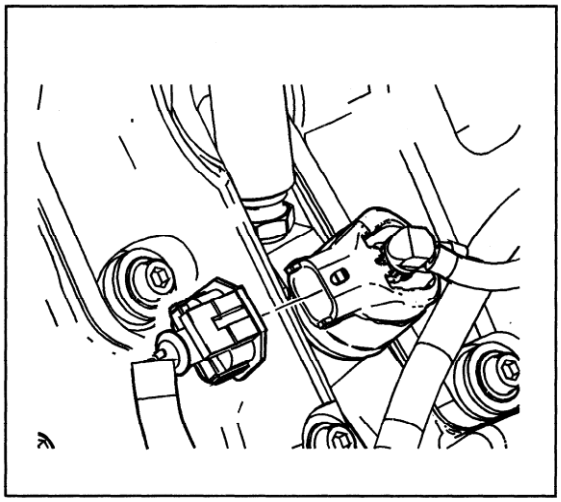


1335540

***Notice:*** 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.

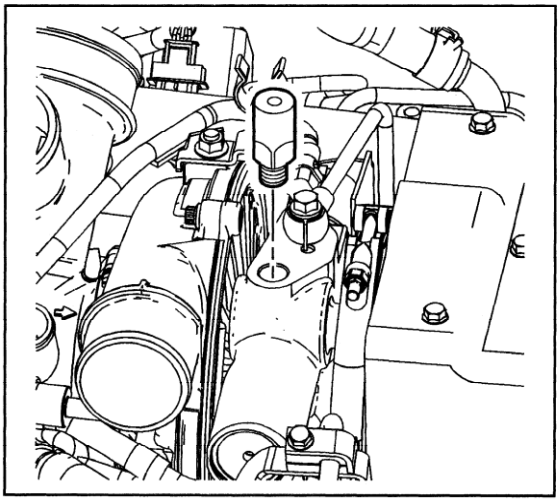


1335536

12. Connect and install the turbocharger vane position sensor.

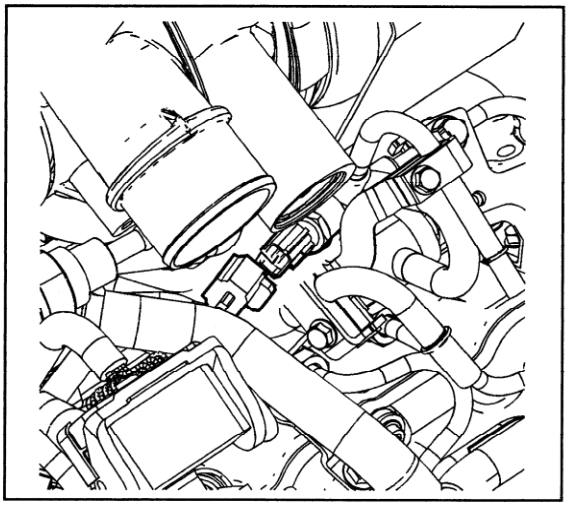
    **Tighten**

    Tighten the turbocharger vane position sensor to 23 N·m (16 lb ft).



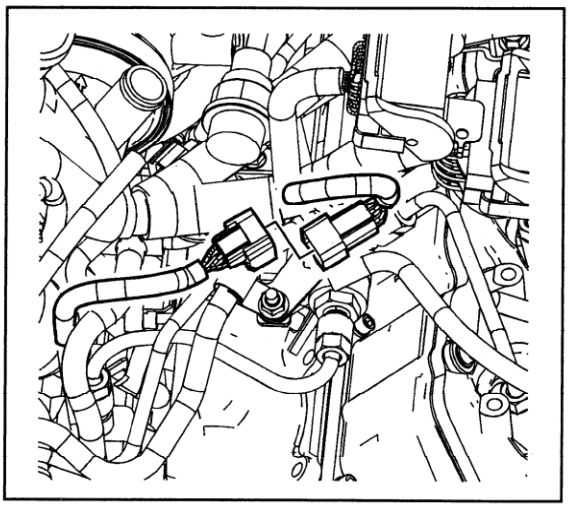
1335534

13. Connect the glow plug controller electrical connector.



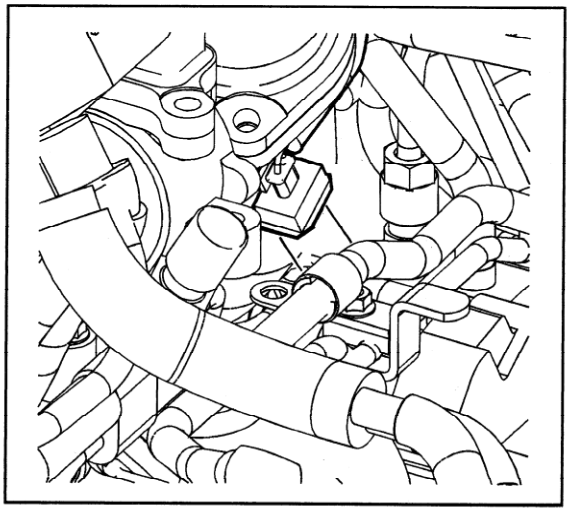
1335528

14. Connect the fuel temperature sensor connector.



1335526

15. Connect the oil level sensor electrical harness connector.

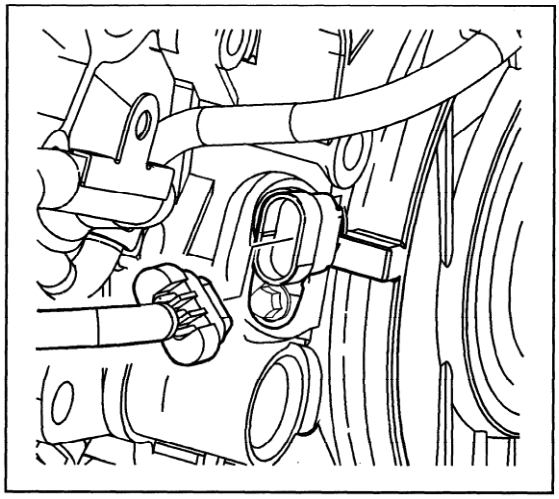


1335482

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.

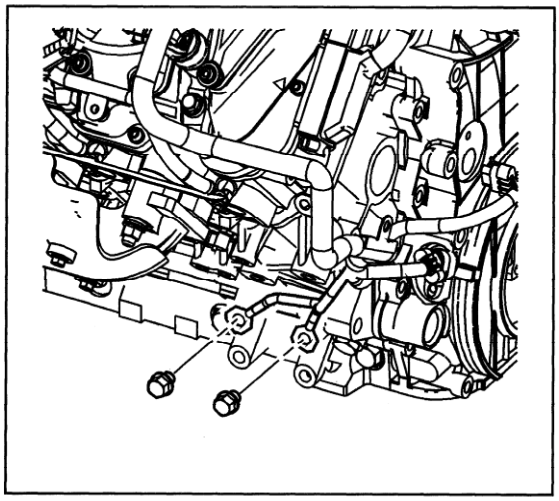


1335470

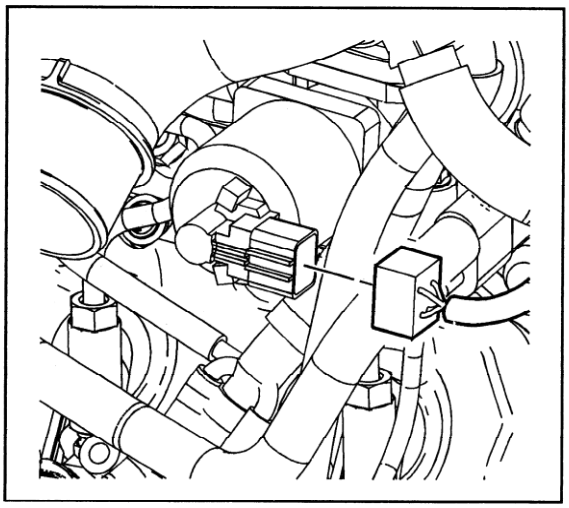
19. Install the two ground bolts.

**Tighten**

Tighten the ground bolts to 41 N·m (30 lb ft).

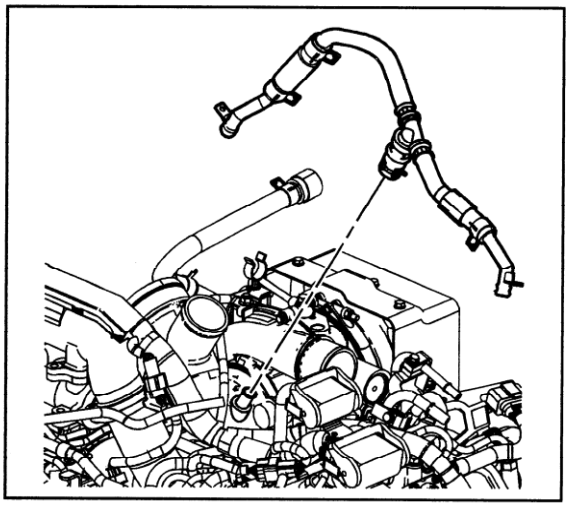


1335467



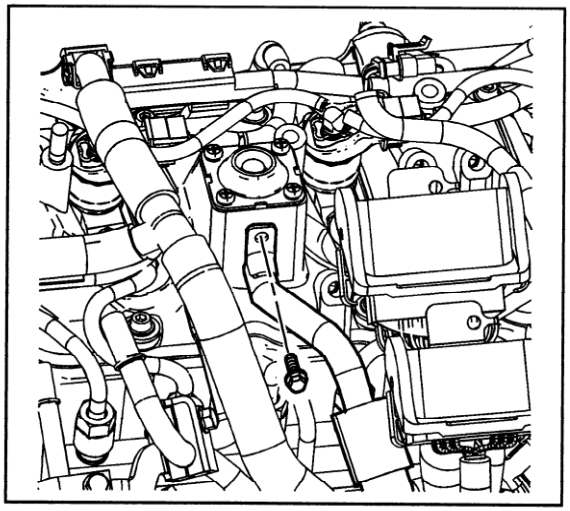
1335463

20. Connect the EGR valve electrical connector.



1335462

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



1335460

22. Install the left PCV pipe bolt.

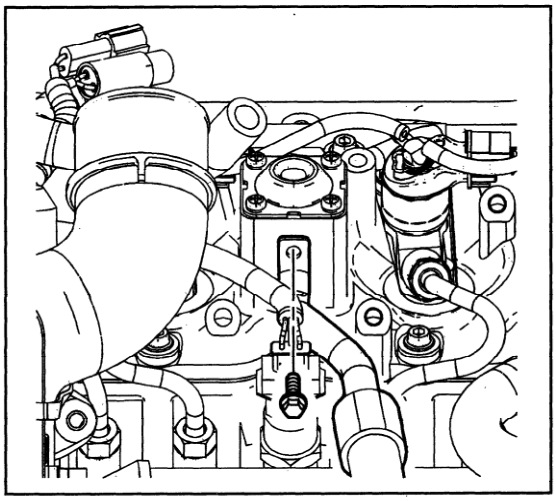
**Tighten**

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

23. Install the right PCV pipe bolt.

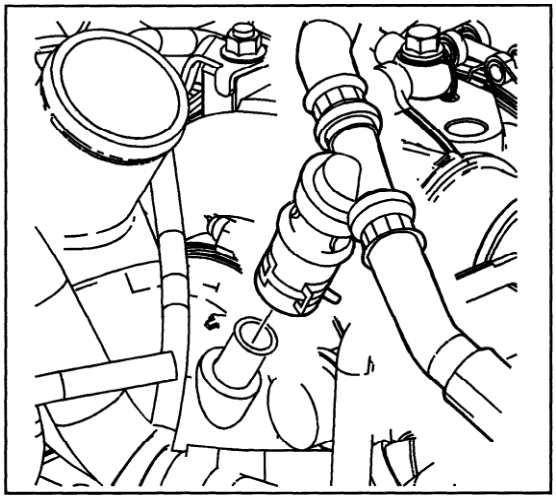
**Tighten**

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



1335456

24. Connect the PCV hose clamp.

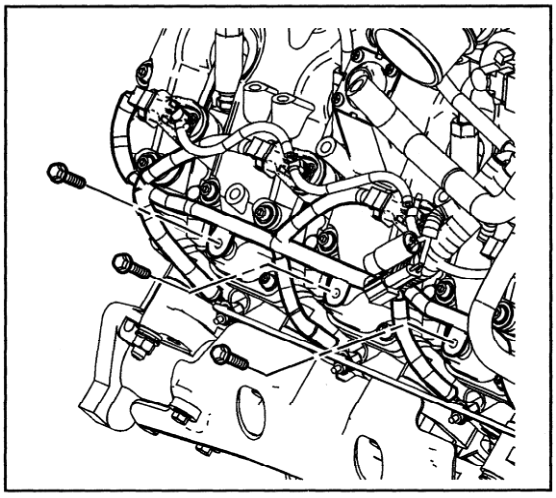


1335454

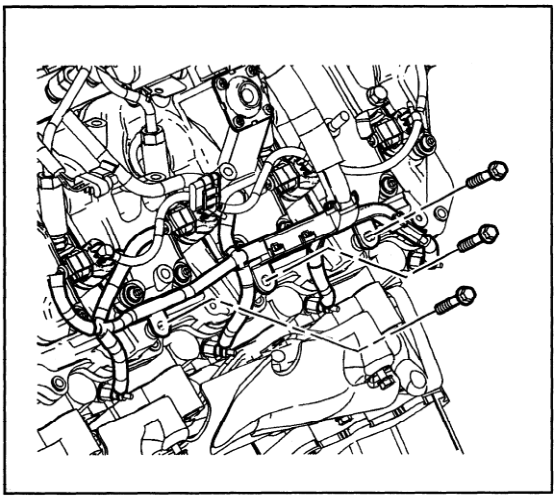
25. Install the right glow plug harness bracket bolts.

**Tighten**

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



1335450

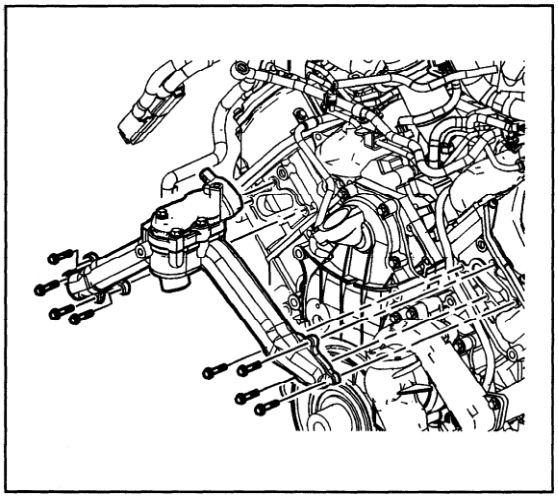


1335443

26. Install the left glow plug harness bracket bolts.

**Tighten**

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



1335441

## Thermostat Housing Installation

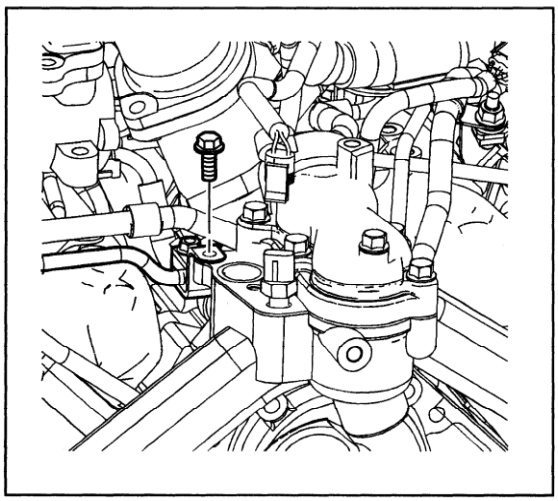
1. Install the thermostat housing.

***Notice:*** Refer to *Fastener Notice*

2. Install the thermostat housing bolts and nuts.

**Tighten**

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



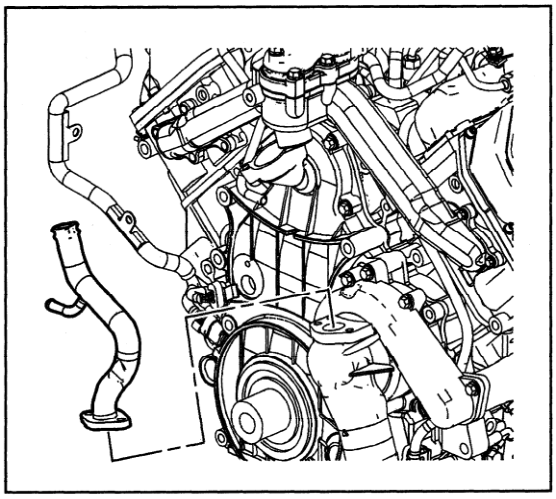
1335434

3. Install the fuel pipe bracket bolt.

**Tighten**

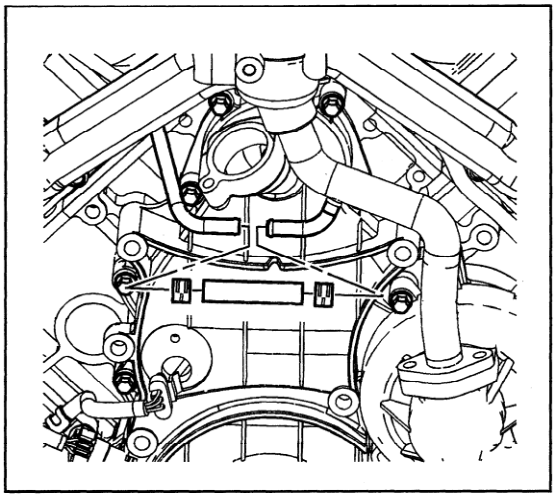
Tighten the fuel pipe bracket bolt to 25 N·m (18 lb ft).

4. Install the water pump inlet pipe.



1335432

5. Install the turbocharger coolant outlet hose and clamps.

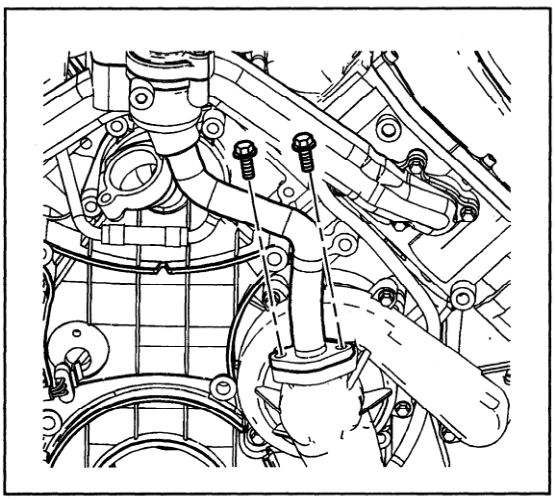


1335429

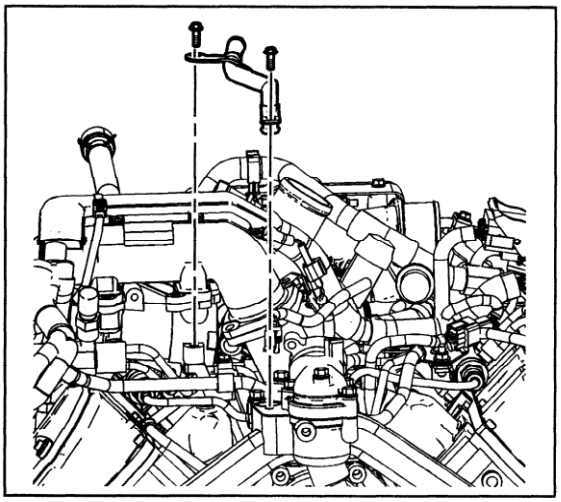
6. Install the water pump inlet pipe bolts.

**Tighten**

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



1335424

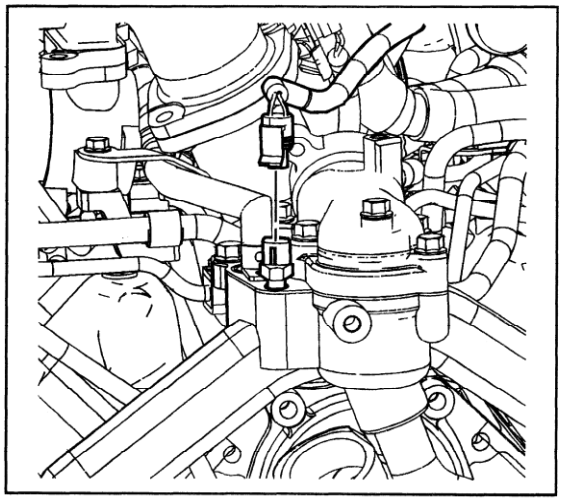


1335419

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

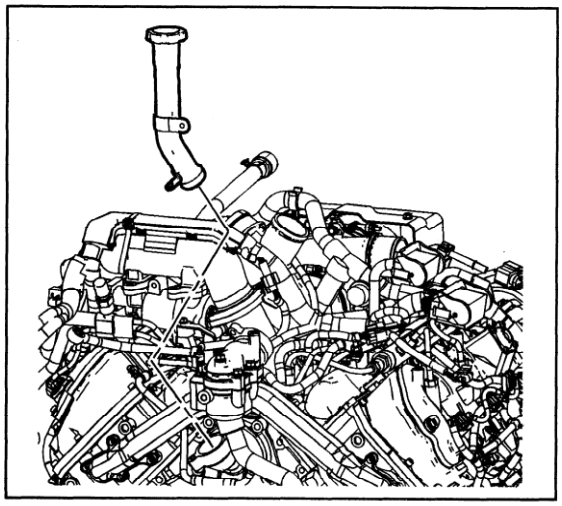
**Tighten**

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



1335413

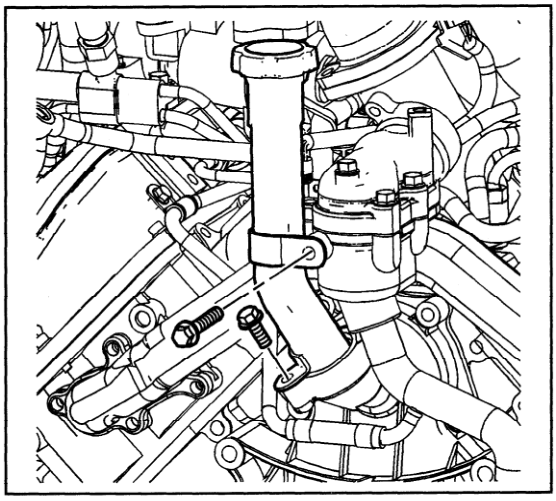
9. Connect the coolant temperature sensor.



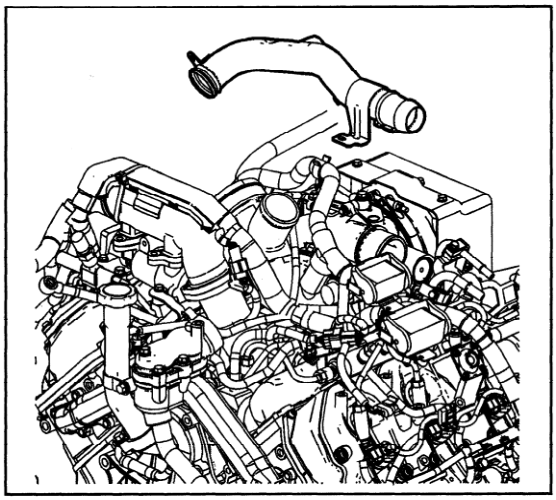
1335401

10. Install the oil fill tube.

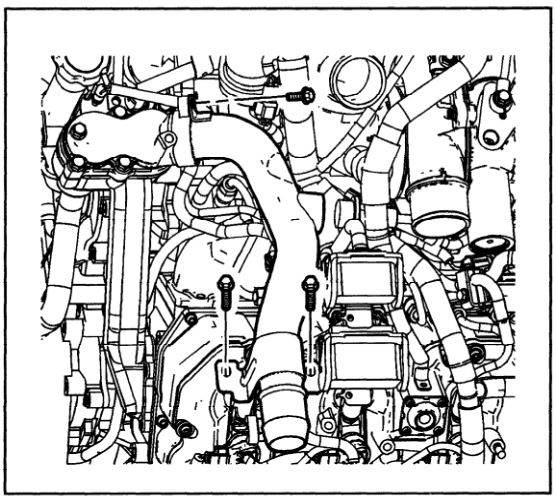
11. Install the oil fill tube bolts.
    **Tighten**
    Tighten the oil fill tube bolts to 25 N·m (18 lb ft).

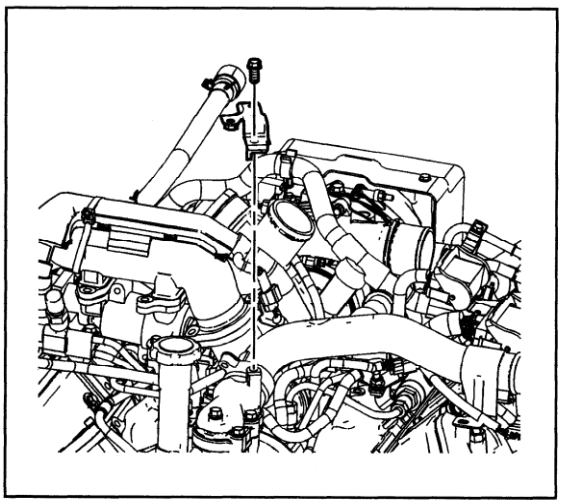

1335397

12. Install the water outlet.


1335393

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


1335391

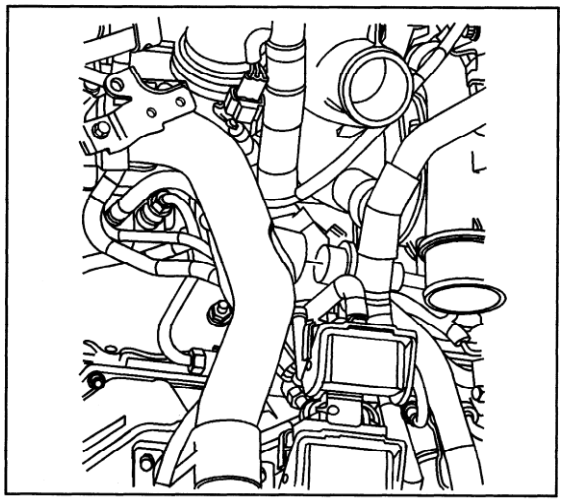


1335388

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

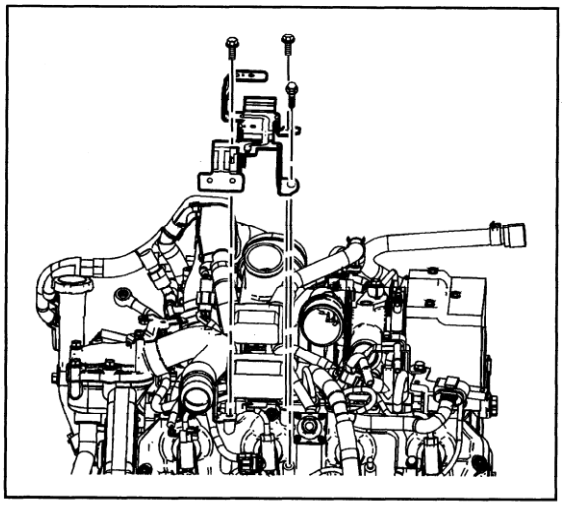
**Tighten**

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



1335386

16. Connect the turbocharger coolant inlet hose.



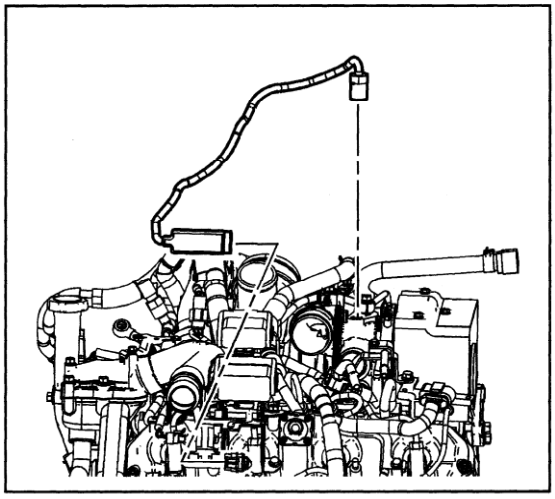
1334948

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

**Tighten**

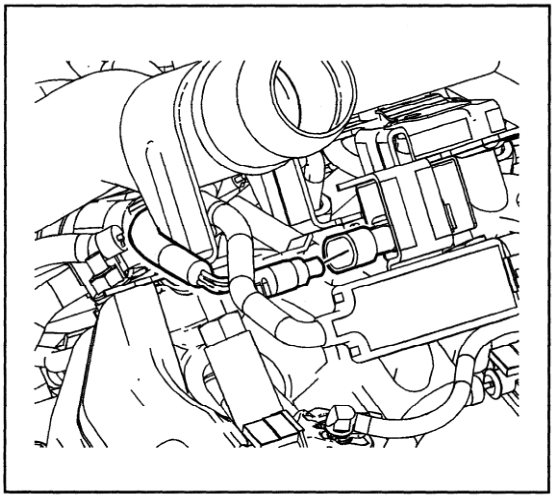
Tighten the main electrical harness bracket bolts to 10 N·m (89 lb in).

19. Connect and install the turbocharger vane position sensor.



1334926

20. Connect and install the barometric sensor.

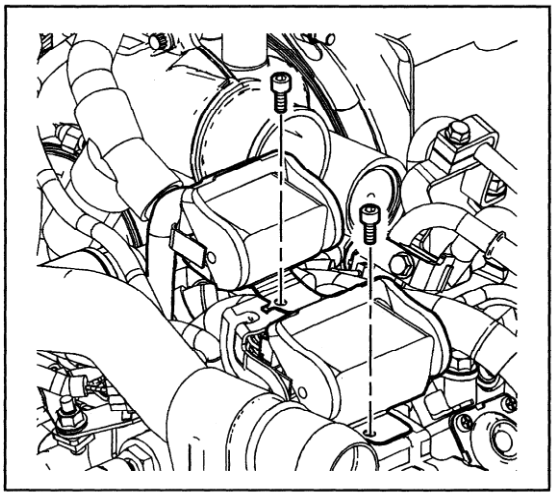


1334921

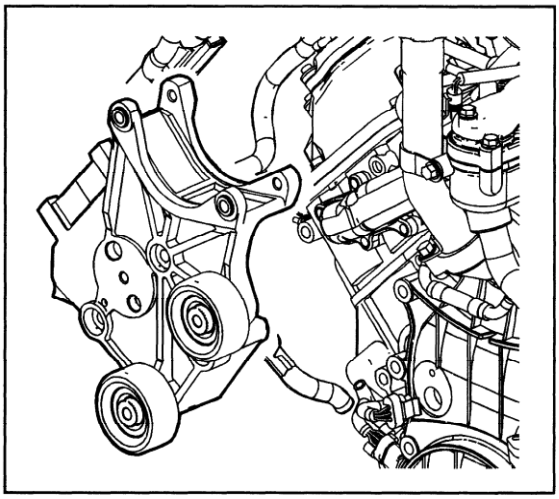
21. Install the main engine electrical harness connector hold down bolts.

**Tighten**

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



1334916



1334912

## Drive Belt Tensioner and Generator Mounting Bracket Installation

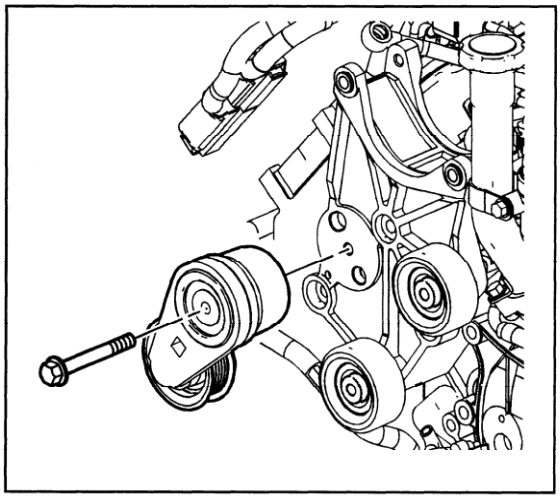
1. Install the drive belt tensioner and generator mounting bracket.

***Notice:*** Refer to *Fastener Notice*

2. Install the drive belt tensioner and generator mounting bracket bolts.

   **Tighten**

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

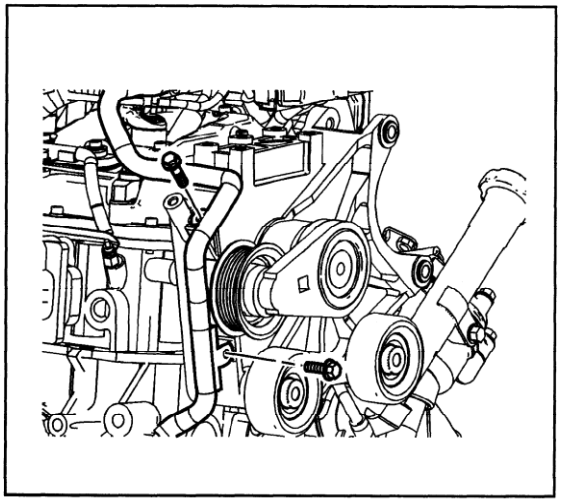


1334909

3. Install the drive belt tensioner.
4. Install the drive belt tensioner bolt.

   **Tighten**

   Tighten the drive belt tensioner bolt to 50 N·m (37 lb ft).

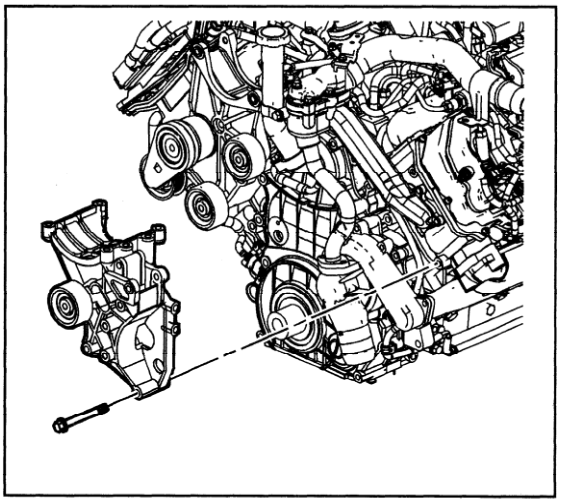


1334907

5. Install the electrical harness clip bolts.

   **Tighten**

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



1334867

## Power Steering Pump Mounting Bracket Installation

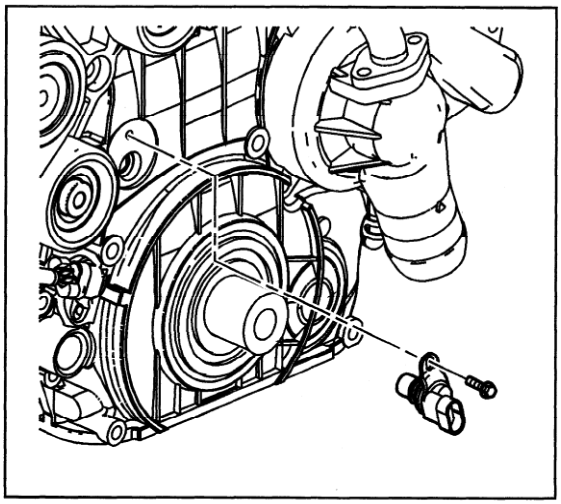
1. Install the power steering pump mounting bracket.

***Notice:*** Refer to *Fastener Notice*

2. Install the power steering pump mounting bracket bolts.

   **Tighten**

   Tighten the power steering pump mounting bracket bolts to 46 N·m (34 lb ft).



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## Cooling Fan Pulley Installation

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

***Notice:*** Refer to *Fastener Notice*

3. Install the camshaft position sensor retaining bolt.

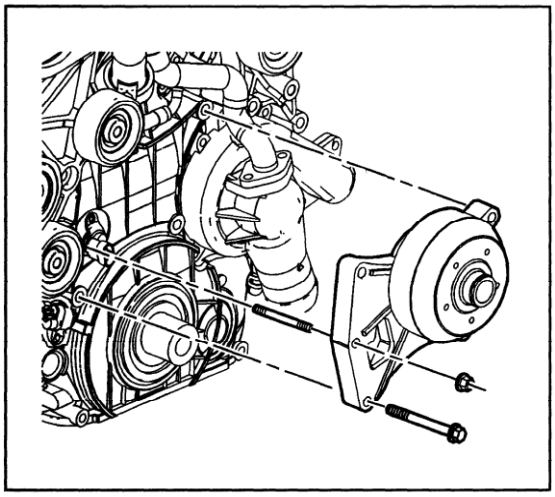
   **Tighten**

   Tighten the camshaft position sensor retaining bolt to 10 N·m (89 lb in).

4. Install the cooling fan pulley.
5. Install the cooling fan pulley bolts and nuts.

   **Tighten**

   Tighten the cooling fan pulley bolts and nuts to 41 N·m (30 lb ft).



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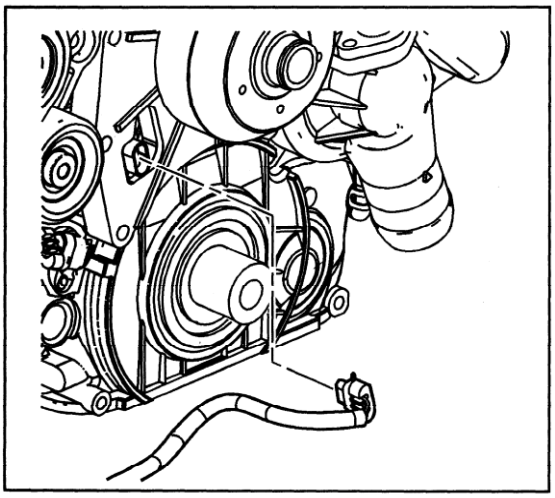
6. Connect the camshaft position sensor connector.



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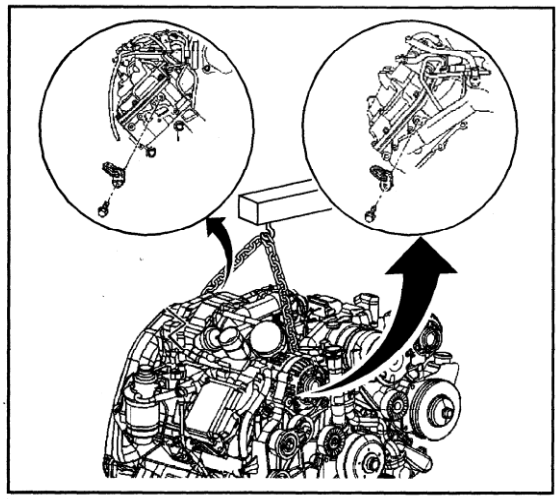
## Engine Removal from Stand

### Tools Required

*J 36857* Engine Lift Bracket

1. Bolt *J 36857* to the ends of the cylinder heads.



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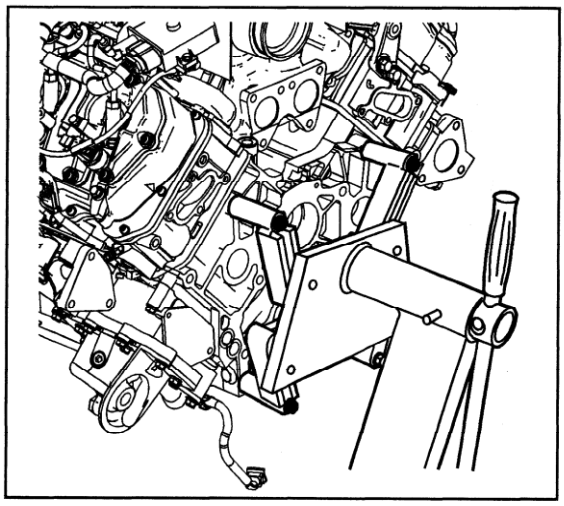

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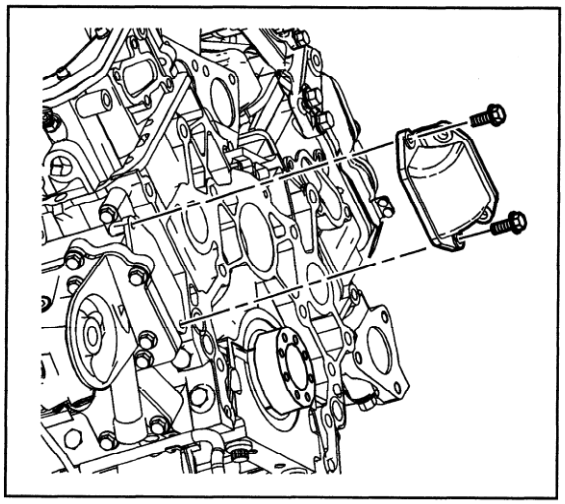
2. Lift the engine and the engine stand with a suitable hoist.
3. Remove the engine stand from the engine adapter.
4. Lower the engine to the floor. Support the engine with blocks.
5. Remove the engine adapter.



1334855

## Engine Flywheel Housing Installation

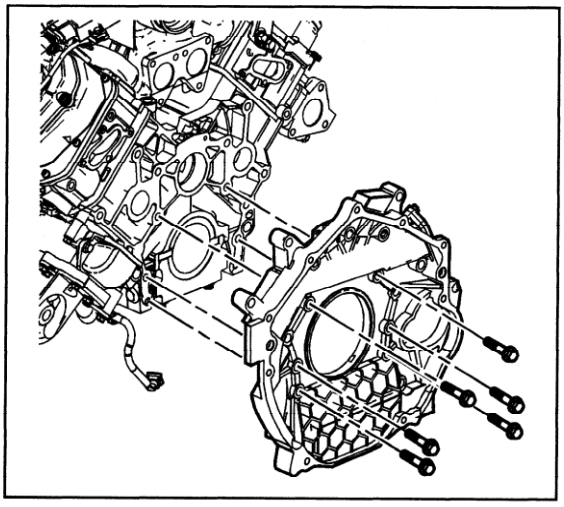
1. Install the oil cooler adapter with gaskets to the oil cooler.

***Notice:*** Refer to *Fastener Notice*

2. Install the oil cooler adapter to oil cooler bolts.

   **Tighten**

   Tighten the oil cooler adapter to oil cooler bolts to 21 N·m (15 lb ft).
3. Apply a 2–3 mm wide by 0.5–1.5 mm high bead of P/N 12378521 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.

   **Tighten**

   Tighten the flywheel housing bolts to 80 N·m (60 lb ft)

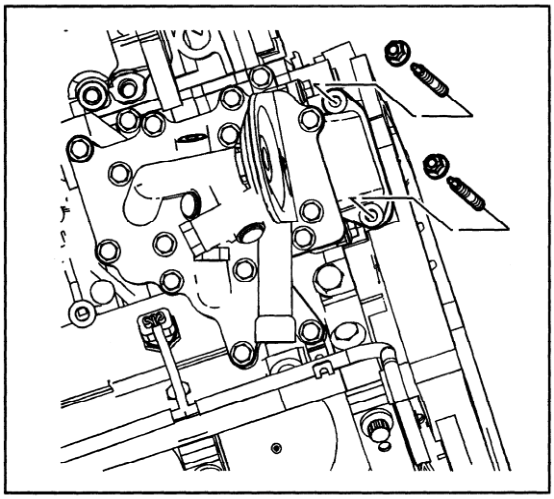
6. Install a new gasket to the turbocharger oil return pipe.
7. Install the turbocharger oil return pipe to flywheel housing studs.

   **Tighten**

   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.

   **Tighten**

   Tighten the turbocharger oil return pipe nuts to 25 N·m (18 lb ft).



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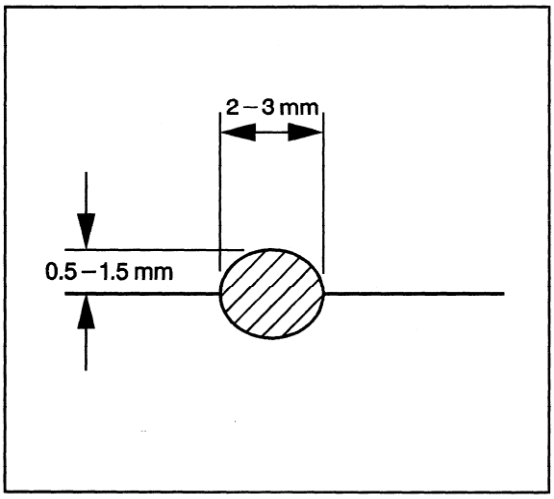
## Oil Pan Installation - Upper

1. Apply a 2–3 mm wide by 0.5–1.5 mm bead of P/N 12378521 sealant to the upper oil pan mating surfaces.

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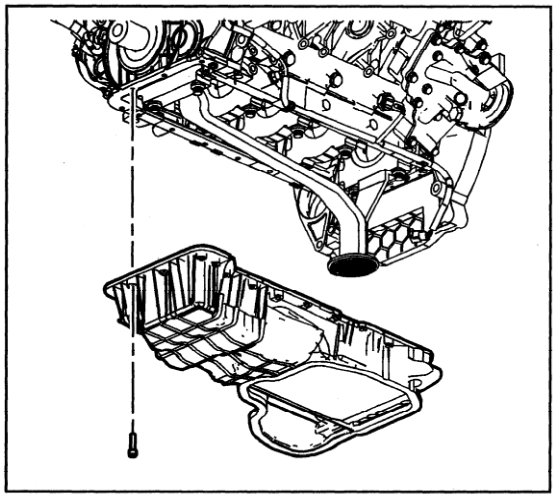
2. Install the upper oil pan to the engine block.



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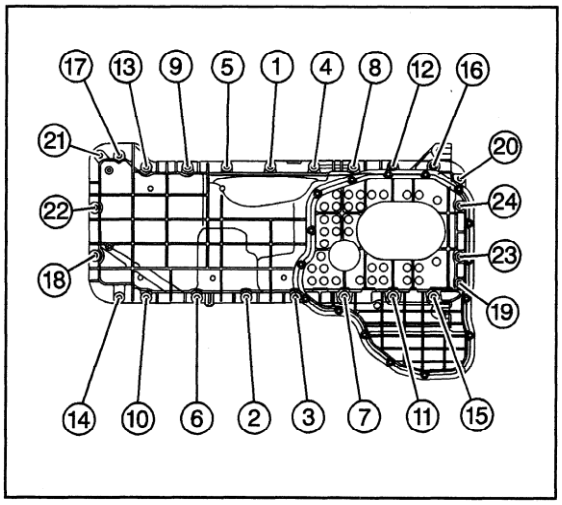

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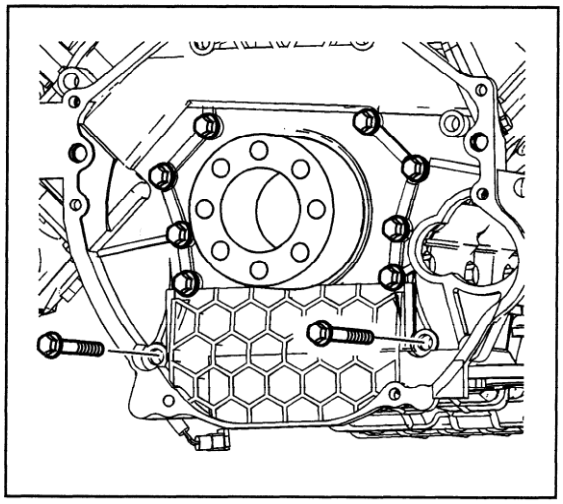
***Notice:*** Refer to *Fastener Notice*

3. Install the upper oil pan bolts.

   **Tighten**

   Tighten the upper oil pan bolts in sequence to 20 N·m (15 lb ft).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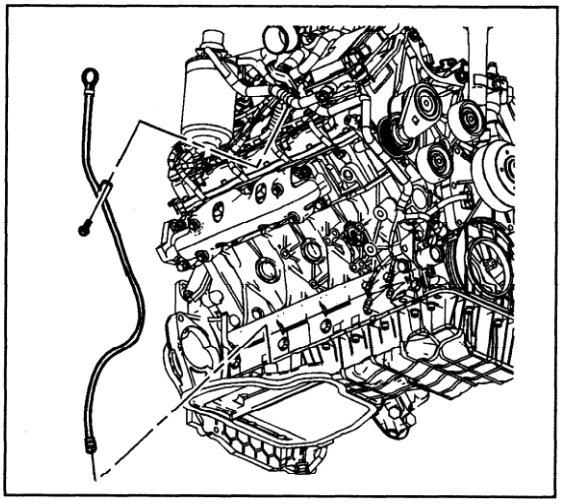
4. Install the two flywheel housing to upper oil pan bolts.

   **Tighten**

   Tighten the two flywheel housing to upper oil pan bolts to 50 N·m (37 lb ft)


1334847

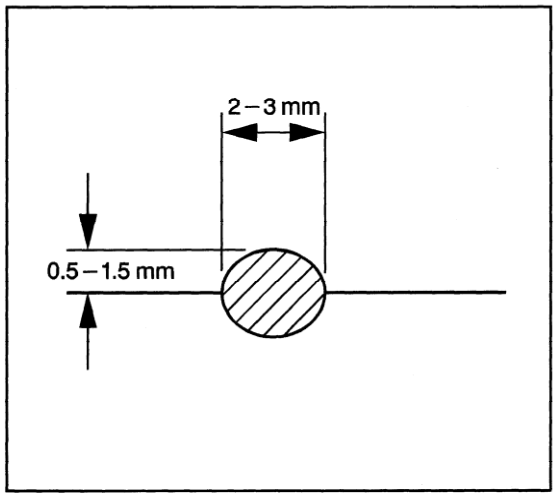
5. Install the oil level indicator tube.
6. Install the oil level indicator tube bracket bolt.

   **Tighten**

   Tighten the oil level indicator tube bracket bolt to 21 N·m (15 lb ft).

## Oil Pan Installation - Lower

1. Apply a 2–3 mm wide by 0.5–1.5 mm high bead of P/N 12378521 sealant to the lower oil pan mating surface.



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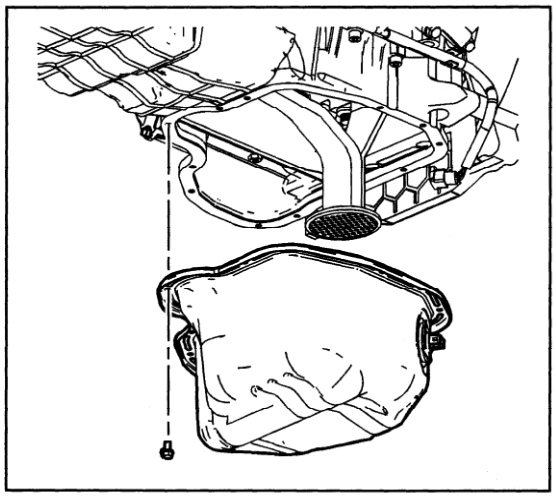
2. Install the lower oil pan.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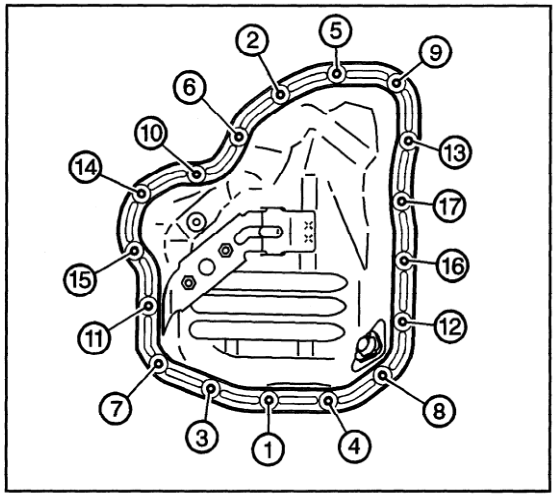
***Notice:*** Refer to *Fastener Notice*

3. Install the lower oil pan bolts and nuts.

   **Tighten**

   Tighten the lower oil pan bolts and nuts in sequence to 10 N·m (89 lb in).



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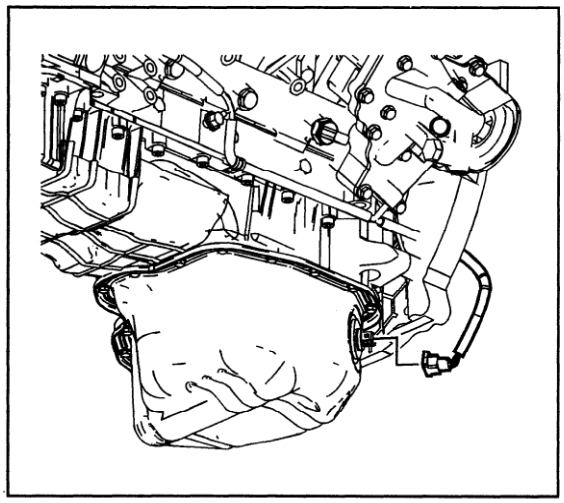

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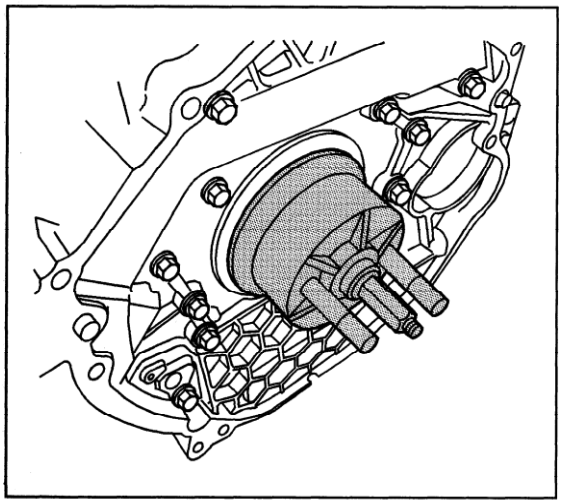
4. Connect the oil level sensor.



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## 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

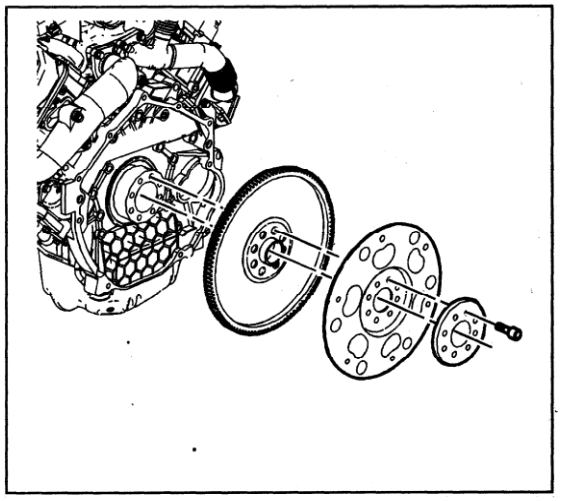
### Tools Required

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

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

***Notice:*** 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.



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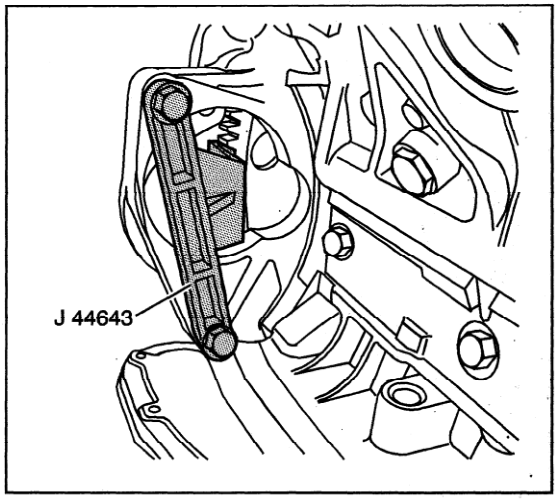
4. Install the *J 44643* to lock the flywheel.

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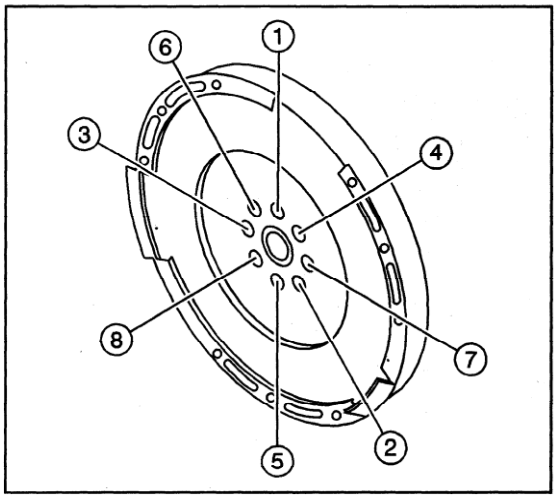
***Notice:*** Refer to *Fastener Notice*

5. Tighten the flywheel bolts in the proper sequence.

   **Tighten**

   - 1st step 79 N·m (59 lb ft).
   - 2nd step 60 degrees using *J 45059*.
   - 3rd step 60 degrees using *J 45059*.

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## 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:*** Refer to *Fastener Notice*

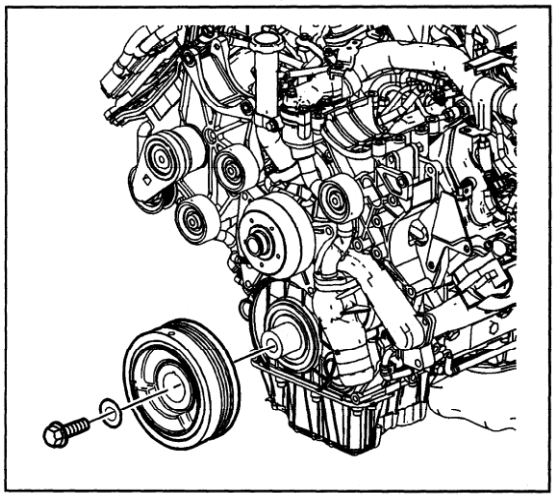
4. Install the crankshaft balancer bolt and washer.

   **Tighten**

   4.1. Tighten the bolt to 100 N·m (74 lb ft) on the first pass.

   4.2. Tighten the bolt an additional 90 degrees.

5. Remove the *J 44643*.



1334816

## Starter Motor Installation

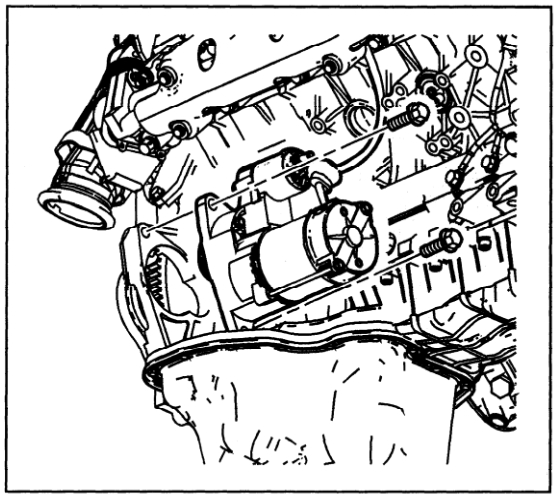
1. Install the starter motor to the flywheel housing.

***Notice:*** Refer to *Fastener Notice*

2. Install the starter motor bolts.

   **Tighten**

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



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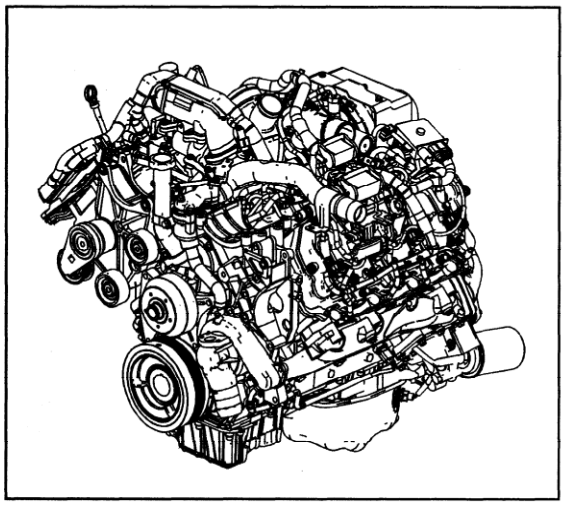

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## Engine Prelubing

### Tools Required

*J 45299* Engine Preluber

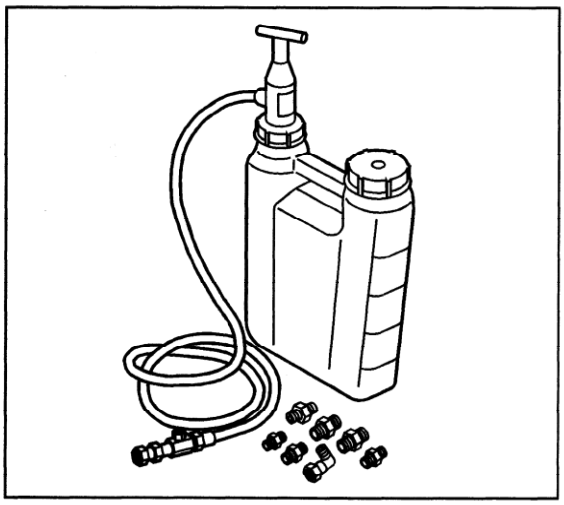
**Important:** A constant/continuous flow of clean engine oil is required to properly prime the engine. Be sure to use an approved engine oil as specified in the owners manual.

***Notice:*** Refer to *Fastener Notice*

1. Remove the engine oil filter, fill with clean engine oil, and reinstall.

   **Tighten**

   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.



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4. Install the flexible hose to the adapter and open the valve.
5. Pump the handle on *J 45299* 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.

   **Tighten**

   Tighten the oil pressure sensor to 41 N·m (30 lb ft).
8. Top–off the engine oil to the proper level.

# Description and Operation

## Crankcase Ventilation System Description

Located in both valve rocker arm covers are diaphragms to control the venting of the crankcase gases. As the pressure of the crankcase gases increase, they overcome the spring holding the diaphragm in the closed position. If a vacuum situation arises in the crankcase, the diaphragm closes the port in the valve rocker arm cover. Closing the port will prevent unfiltered air to enter the crankcase.

The crankcase gases travel from the valve rocker arm covers through hoses to a tee, where they enter the turbocharger inlet duct. Because of the use of a closed crankcase ventilation system, it is normal for oil residue to be found on the turbocharger compressor wheel and inside the charge air cooler, pipes, and hoses.

No routine maintenance is required to the crankcase ventilation system.

## Drive Belt System Description

The drive belt system consists of the following components:

- The drive belt
- The drive belt tensioner
- The drive belt idler pulley
- The crankshaft balancer pulley
- The accessory drive component mounting brackets
- The accessory drive components
  - The power steering pump, if belt driven
  - The generator
  - The water pump, if belt driven
  - The vacuum pump, if equipped
  - The air compressor, if equipped

The drive belt system may use 1 belt or 2 belts. The drive belt is thin so that it can bend backwards and has several ribs to match the grooves in the pulleys. The drive belts are made of different types of rubbers, chloroprene or EPDM, and have different layers or plys containing either fiber cloth or cords for reinforcement.

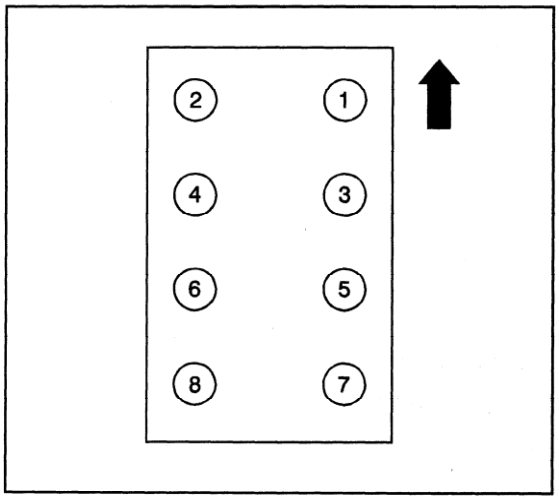
Both sides of the drive belt may be used to drive the different accessory drive components. When the back side of the drive belt is used to drive a pulley, the pulley is smooth.

The drive belt is pulled by the crankshaft balancer pulley across the accessory drive component pulleys. The spring loaded drive belt tensioner keeps constant tension on the drive belt to prevent the drive belt from slipping. The drive belt tensioner arm will move when loads are applied to the drive belt by the accessory drive components and the crankshaft.

The drive belt system may have an idler pulley, which is used to add wrap to the adjacent pulleys. Some systems use an idler pulley in place of an accessory drive component when the vehicle is not equipped with the accessory.

## Engine Component Description

### Engine Block

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The engine block utilizes a deep skirt design for increased rigidity. The cylinders are positioned in a 90 degree "V" orientation with the number one cylinder being the right front. The block is induction hardened for increased durability. The crankshaft bearing caps are cross-bolted to enhance structural rigidity.

### Upper Oil Pan

A single piece cast aluminum upper oil pan contributes to crankshaft and block rigidity while reducing overall weight.

## Crankshaft

The crankshaft is a nitride hardened steel design with five main bearings. Crankshaft thrust is controlled by the number 5 bearing.

## Connecting Rods

The connecting rods are one-piece hot forged steel. The connecting rods and caps are of a fractured split design to improve durability and reduce internal friction. The connecting rod small end is tapered cut for reduced weight and improved durability.

## Pistons

The pistons are a full-floating design. The piston pins are a slip fit in the bronze bushed connecting rod and are retained in the piston by round wire retainers. The pistons have a piston cooling oil channel cast inside of the piston. These cooling oil channels utilize an oil jet located at the bottom of the cylinder bore to direct oil into the piston channel. There are two compression rings and one oil control ring. There is a groove machined into the pistons between the first and second compression rings. This groove reduces compression ring leakage by providing an empty space for expanding gases, reducing the combustion gas pressure on the second compression ring.

## Cylinder Heads

The cylinder heads are made of aluminum for lighter weight and rapid heat dissipation. There are 4 valves per cylinder and the ports are of a high swirl design for improved combustion. The cylinder head gaskets consist of an all steel laminated construction.

## Valve Train

The engine utilizes a mechanical roller lifter for valve operation. The shaft mounted rocker arms have roller tips for reduced friction and wear. One rocker arm operates two valves simultaneously through a valve bridge.

## Fuel System

The fuel system is of a direct injection fuel rail design. A high pressure pump mounted within the valley is gear driven directly from the camshaft. This pump provides a continuous and constant high pressure fuel supply to the fuel rails. The electronically controlled fuel injectors receive their fuel supply from these fuel rails. The fuel injection control utilizes a pilot injection method to reduce the combustion noise that is common in traditional diesel engines. The pilot injection method reduces noise by supplying a small amount of fuel to the cylinder just before the normal combustion timing.

## Turbocharger

The turbocharger is water cooled for improved durability.

## Oil Cooler

The oil cooler lowers engine temperature by cooling the oil with engine coolant. Engine coolant is directed from the water pump to the oil cooler by a coolant tube. The oil filter attaches directly to the oil cooler.

## Oil Pump

The oil pump is gear driven directly from the crankshaft. The oil pump drive gear is a slip fit to the crankshaft.

## Water Pump

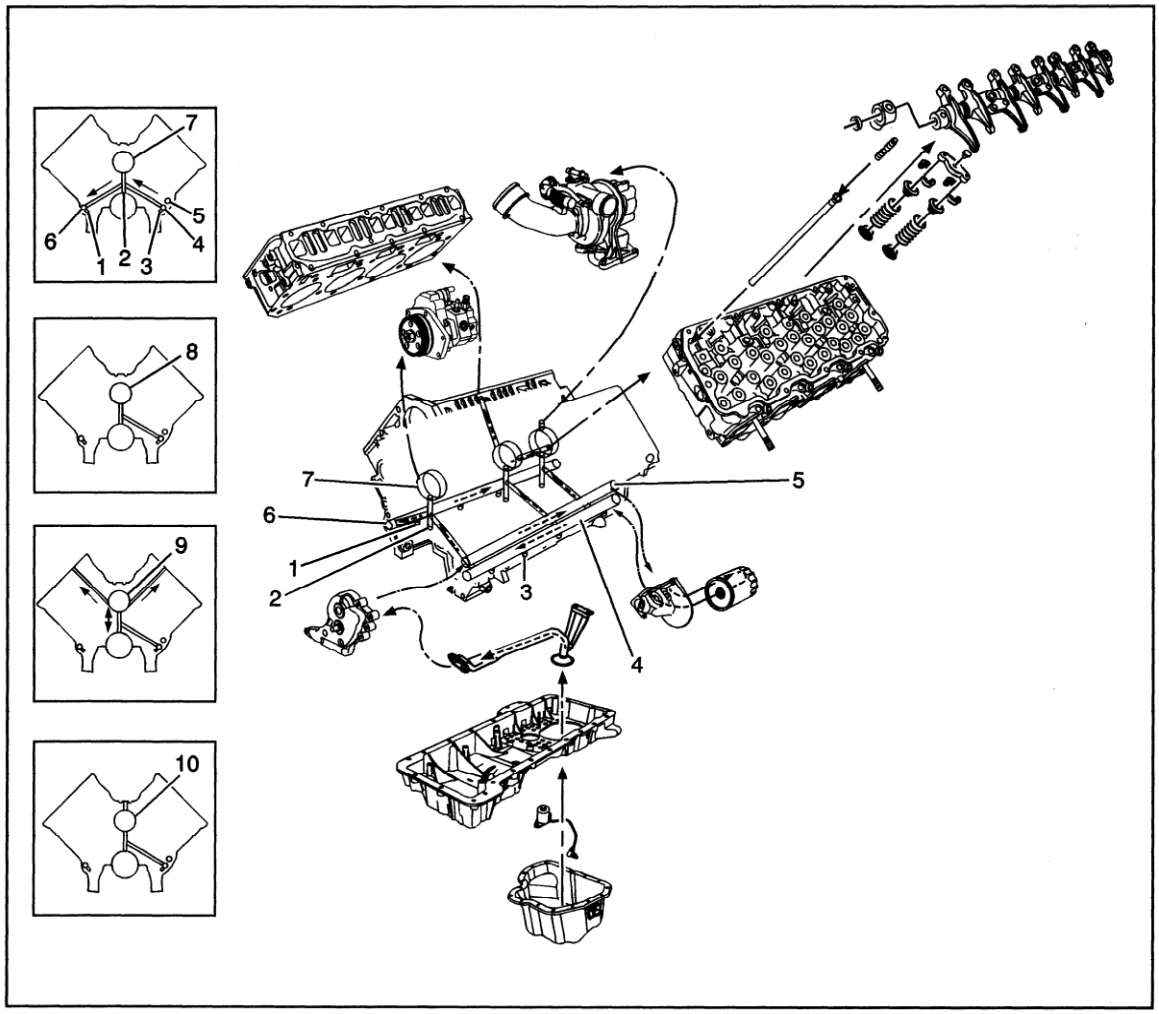
The water pump is gear driven for improved reliability.

## Engine Covers

There is a front engine cover and a flywheel housing, both are made of aluminum. The full bell flywheel housing is cross bolted to the upper oil pan. The flywheel housing also supplies a crossover passage for engine coolant. The front engine cover houses the gear train and provides a mounting surface for the cooling fan pulley assembly.

## Lubrication Description

### Lubrication Flow Schematic

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Engine lubrication is supplied by a gear type oil pump assembly. The pump is mounted on the front of the engine block and driven by the oil pump drive gear on the crankshaft. The pump gears rotate and draw oil from the oil pan sump through a pick-up screen and pipe. The oil is pressurized as it passes through the pump and is sent through the engine block oil galleries. Contained within the oil pump assembly is a safety relief valve that eliminates overpressurization. Pressurized oil is directed through the sub oil gallery (5) to the full flow oil filter where harmful contaminants are removed. Two bypass valves are incorporated into the oil cooler assembly which will permit oil flow in the event the filter or the oil cooler become restricted.

The oil is directed to the main oil gallery (4), and from the main oil gallery it flows to the piston cooling channel left bank (3), and the sub oil gallery (6) on the right bank. The sub oil gallery on the right bank supplies oil to the right bank piston cooling channel (1). Located in the front cover at the sub oil gallery (6) is an oil pressure relief valve which regulates oil pressure within operating range.

Oil flows from the main gallery (4) to the vertical crankshaft/camshaft bearing galleries (2). From the crankshaft/camshaft bearing galleries (2), the oil flows to both the camshaft bearings and the crankshaft main bearings. Oil flows from the crankshaft main bearings to the connecting rod big end.

Oil flows from the crankshaft/camshaft bearing galleries (2) to the number 1 camshaft bearing (7), where it splash lubricates the fuel injection pump gear.

Oil flows from the crankshaft/camshaft bearing galleries (2) to the number 2 and 5 camshaft bearings (8).

Oil flows from the crankshaft/camshaft bearing galleries (2) to the number 3 camshaft bearing (9), where it exits to both cylinder heads and enters the hollow rocker arm shafts. Oil flows through the rocker arm shafts and rocker arms where it lubricates the upper valve train components. Oil also flows through the rocker arms, through the passage in the valve adjusting screw, and into the hollow pushrods where it is directed to the valve lifters.

Oil flows from the crankshaft/camshaft bearing galleries (2) to the number 4 camshaft (10), where it exits into the turbocharger oil supply line to lubricate the turbocharger. Oil exiting the turbocharger is routed through the turbocharger oil return pipe and into the flywheel housing.

## Cleanliness and Care

An automobile engine is a combination of many of the following surfaces:

- Machined
- Honed
- Polished
- Lapped

The tolerances of these surfaces are measured in the ten-thousandths of an inch. When you service any internal engine part, cleanliness and care are important. Apply a liberal coating of engine oil to the friction areas during assembly in order to protect and lubricate the surfaces on initial operation. Throughout this section, practice proper cleaning and protection procedures to the machined surfaces and to the friction areas.

***Notice:*** Engine damage may result if an abrasive paper, pad, or motorized wire brush is used to clean any engine gasket surfaces.

Whenever you remove the valve train components, keep the components in order. Follow this procedure in order to install the components in the same locations and with the same mating surfaces as when removed.

***Caution: Refer to Battery Disconnect Caution on page P-4 in Cautions and Notices.***

Disconnect the negative battery cables before you perform any major work on the engine. For more information on the disconnection of the battery, refer to Engine Electrical.

## Separating Parts

**Important:** Many internal engine components will develop specific wear patterns on their friction surfaces.

When disassembling the engine, internal components MUST be separated, marked, or organized in a way to ensure reinstallation to their original location and position.

Separate, mark, or organize the following components:

- Piston and the piston pin
- Piston to the specific cylinder bore
- Piston rings to the piston
- Connecting rod to the crankshaft journal
- Connecting rod to the bearing cap

  A paint stick or etching/engraving type tool are recommended. Stamping the connecting rod or cap near the bearing bore may affect component geometry.
- Crankshaft main and connecting rod bearings
- Camshaft and valve lifters
- Valve lifters, guides, pushrods, pivot supports and rocker arms
- Valve to the valve guide
- Valve spring and shim to the cylinder head location
- Engine block main bearing cap location and direction
- Oil pump drive and driven gears

## Replacing Engine Gaskets

### Gasket Reuse and Applying Sealant

- Do not reuse any gasket unless specified.
- Gaskets that can be reused will be identified in the service procedure.
- Do not apply sealant to any gasket or sealing surface unless specified in the service procedure.

### Separating Components

- Use a rubber mallet in order to separate the components.
- Bump the part sideways in order to loosen the components.
- Bumping of the component should be done at bends or reinforced areas of the component to prevent distortion of the components.

# Section 1 – ENGINE MOUNTING

Engine Mounting

Flexible Engine Mounting

Engine Mounts

Engine Alignment

Checking Stringer Height

Suspending the Engine

Power Steering Hose Routing

Exhaust Hose Routing

## Engine Mounting

The engine bed provides a location for the engine and associated marine gear to be mounted, if it is not mounted directly on boat stringers. The engine bed or stringers should be constructed in such way as to allow even weight distribution and load transfer.

Cross braces on the engine bed or stringers may be desired in certain applications to prevent lateral movement of the engine. This bracing limits hull vibration and reduces stress on engine casting, such as mounts.

Please mount the engine with possibility for future adjustments.

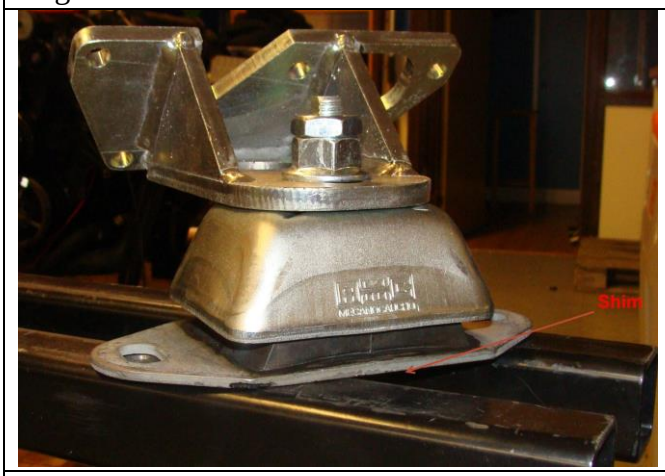
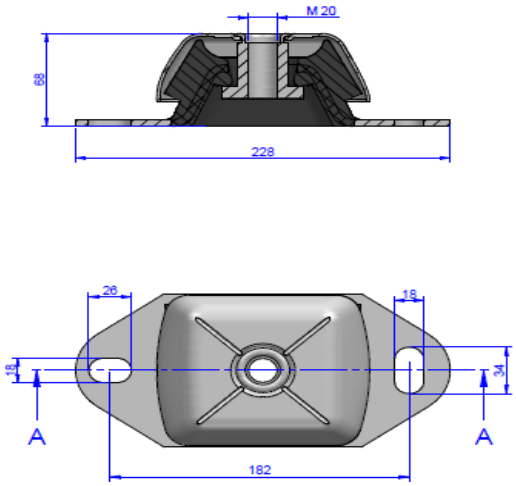
## Flexible Engine Mounting

BUKH offers BUKH V8 heavy duty & SOLAS flexible mounting for all BUKH V8 series engines.

All front mounts include provisions for isolating engine vibrations. The rear of the engine mounts to the stern drive transom plate or transmission.

**IMPORTANT: do NOT use solid engine mounts, doing so will cause severe engine damage and void warranty.**

## Engine Mounts

| Engine mount | Description |
|---|---|
|  | BUKH offers heavy duty SOLAS flexible mounting, as an option for BUKH V8 series engines. |
| Engines mount. Drawing | Description |
|  | Drawing shows key measures |

## Engine Alignment

### Checking Stringer Height

Ensure that the stringers are equal in height before installing the engine. Tying a string from the port front mount location to the starboard rear engine mount on transom assembly or transmission may check this. **Another string should be tied from starboard front to port rear. The strings should lightly touch where they** cross. If not, corrections should be made to the engine bed.

## Suspending the Engine

| Lifting bracket | Lifting bracket | Description |
|---|---|---|
|  |  | Picture of engine lifting brackets.<br>Front and rear lifting brackets on the engine are provided to allow attachment of a suitable sling.<br><br>The engine can then be lifted into position, in boat using an overhead hoist. |

To allow for final adjustments, please mount the optional, BUKH V8 flexible mountings with shims underneath.

## Power Steering Hose Routing

**When installing power steering hoses observe the following.**

- Make hydraulic connections as quickly as possible to prevent fluid leakage.
- Be careful not to cross-thread or over tighten fittings.

Power steering fluid hoses must be purchased separately. Proper routing and installation of the hoses is required to avoid problems related to power steering system.

Observe the following:

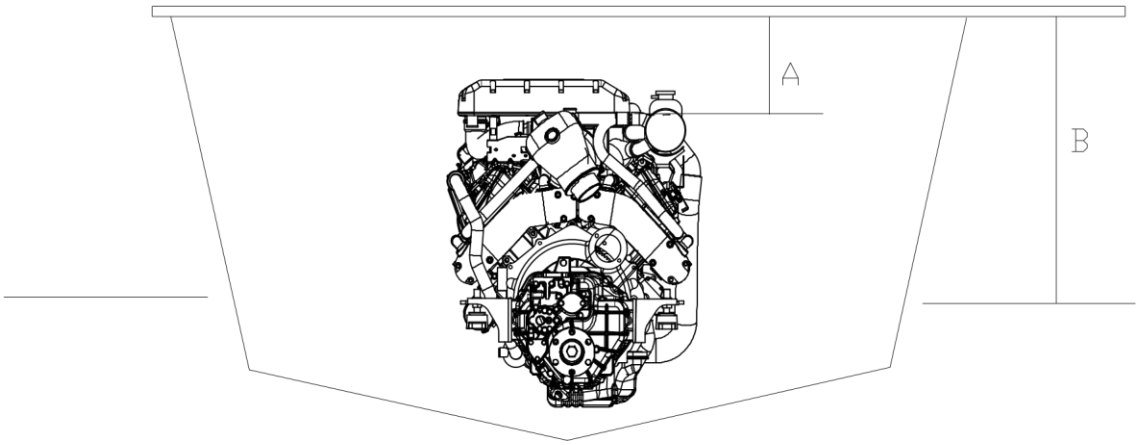
- Hoses must be secured to avoid contact with moving components.
- Torque both power steering hose fittings to 15 Nm after connecting to control valve.

**Avoid stress on the hose fittings and avoid bends on the hoses.**

# Exhaust Hose Routing

## General Information

All exhaust systems have some restriction to flow, or what is called “exhaust back pressure”, but this must remain at a minimum. The power output of an engine is directly related to the amount of exhaust that can flow out of the exhaust system. For example, engines will generally suffer approximately a 10 horsepower loss for the first 1 psi (7 kPa) of exhaust back pressure.

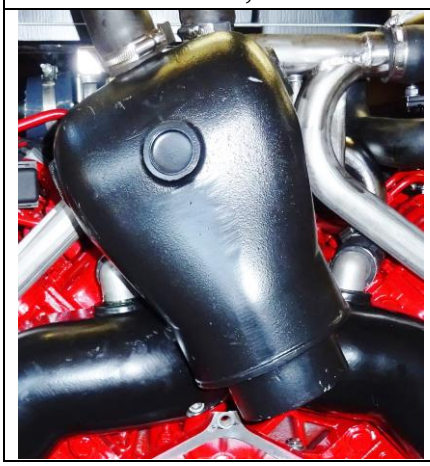
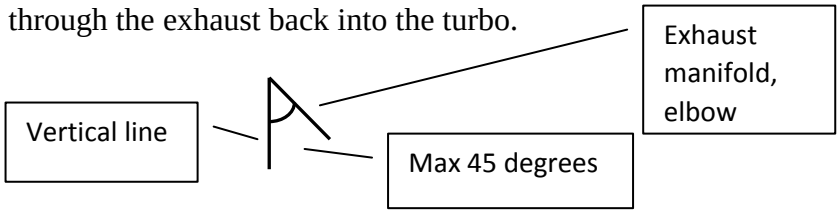



**Exhaust Elbow Height**
**A -** Measurement Between Straight Edge And Top Of Exhaust Elbow
**B -** Measurement Between Straight Edge And Water Line
**Measurement Raiser to waterline = B - A (Minimum 330 mm)**

## Through the Hull Exhaust

When designing and installing an exhaust system, in addition to other model specific requirements, BUKH requires the following to be observed:

- Exhaust fittings (flanges and outlets) must be of proper size
- Exhaust fittings must be equipped with internal water shutters.
- An exhaust flapper must be used over each outlet.
- Exhaust outlet must be slightly above the water line with boat at rest in the water and a full load aboard.
- Exhaust hoses, collectors and pipes must not be higher than exhaust elbows at any point.
- The drop in the exhaust system must be continuously sloping so that a low spot does not exist at any point in the exhaust hose or pipe.
- The exhaust system on V8 engines must have a minimum of 6° downward slope between the exhaust elbow outlet and the exhaust outlet of the boat.
- The exhaust system on V8 engines must have a minimum of 130 mm of vertical drop between the exhaust elbow outlet and the exhaust outlet of the boat.
- Minimum exhaust elbow height is 330 mm.

| Exhaust manifold, elbow | Description |
|---|---|
|  | Picture of exhaust manifold, elbow.<br>BUKH offers an Ø120 mm reinforced hose to connect to the exhaust manifold.<br><br>Make sure the exhaust manifold elbow is tilted no more than 45 degrees, from vertical, to make sure there is no water intrusion through the exhaust back into the turbo.<br>  |

# Section 2 – ENGINE COMPARTMENT

Engine Compartment

Engine Compartment Ventilation

Combustion Air Requirements

## Engine Compartment

| WARNING |
| --- |
| Boating standards (NMMA, ABYC, etc.) and Coast Guard regulations must be adhered when constructing the engine compartment. |

## Engine Compartment Ventilation

## General Information

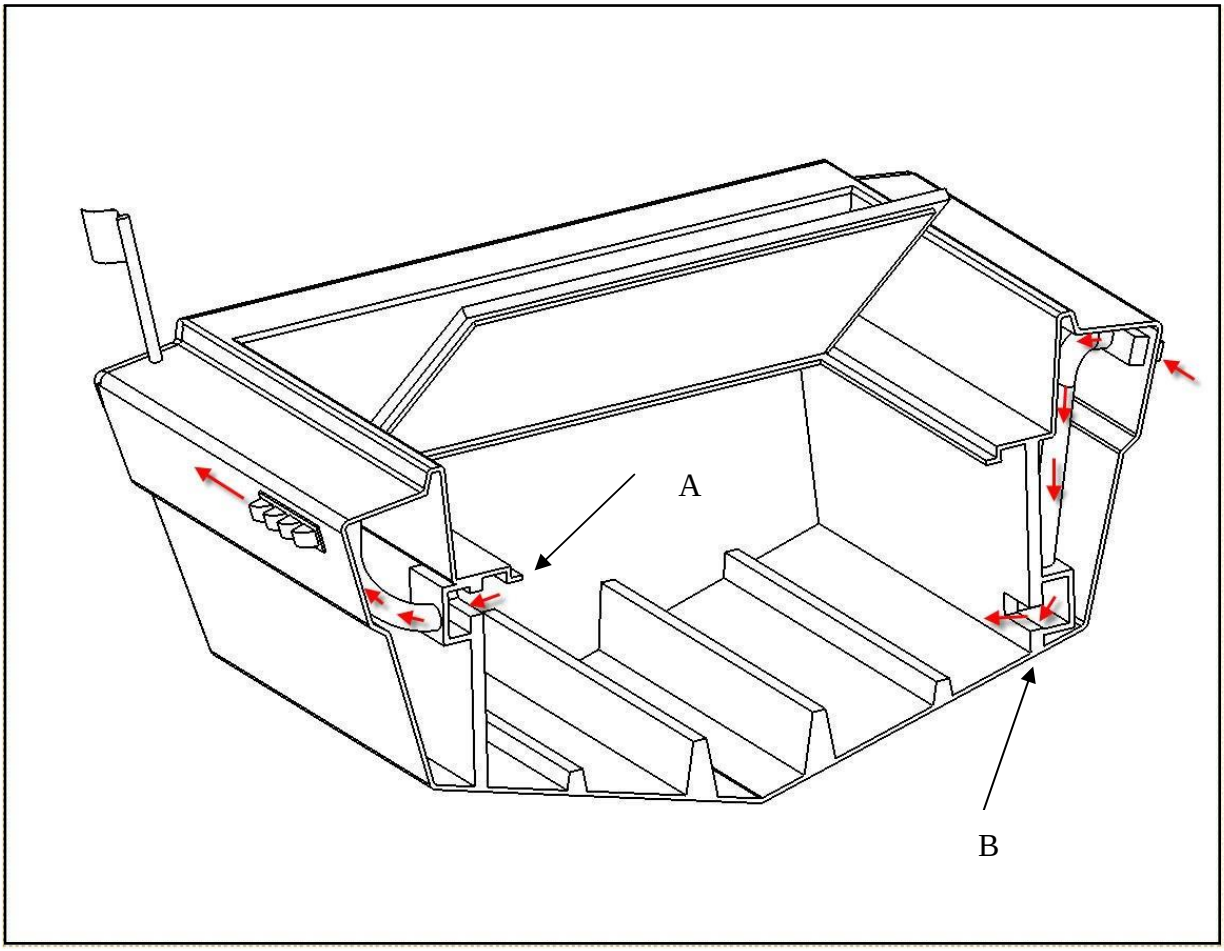
According to Boating standards (NMMA, ABYC, etc.) and Coast Guard regulations the engine compartment ventilation system has multiple tasks. Including:

- Supply the engine with combustion air.
- Maintain a low temperature in the engine compartment.
- Sufficient Ventilation of air and fumes in the engine compartment.

Fresh air should enter the engine compartment as low as possible and the heated air should be discharged from the highest point.

When sufficient ventilation is not provided, too much heat can build-up inside the engine compartment and cause vapor locking. The engine will not restart after it has been shut off for a short period of time.

For diesel engines utilizing environmentally friendly, low viscosity fuels, proper ventilation is crucial to prevent vapor locking.




A - Air should exit the engine bay at the upper section
B - Air should enter the engine bay at the lower section

The reason for this is that hot air is lighter than cold air and will exit at the top of the compartment. Once the engine is shut down such a system will auto ventilate until the engine bay temperature is at ambient level.

## Combustion Air Requirements

Engine compartments with natural draft ventilation must have vent openings of sufficient size and location to accomplish the tasks previously outlined.

**IMPORTANT: The size of ventilation openings must be increased if any auxiliary equipment is located in the engine compartment.**

The combustion air requirement (per engine) for the specified engines at Wide Open Throttle is given in the following table.

| Model | Engine Air Requirements at Wide Open Throttle |
|---|---|
| 300-400 HP | 25$m^3$/min |
| 400-500 HP | 30$m^3$/min |
| 500-550 HP | 35$m^3$/min |

Recommended open ventilation area, for combustion air only, is calculated by
1.7 X Rated engine power in KW and given in $cm^3$

Conversion factor from HP to KW is ~ 0.735.

Example for BUKH V8 - 500:
Recommended open ventilation area, for combustion air only is:
1.7 x 500 HP x 0,735 ~ 620 $cm^2$

For engine combustion air only - ***NOT*** total engine compartment ventilation requirement.

**IMPORTANT: The amount of vent area required, according to boating standards (NMMA, ABYC, etc.) and Coast Guard regulations, for *complete* (total) engine compartment ventilation must include the engine combustion air vent area plus the engine compartment ventilation requirements.**

Recommended pressure differential. The pressure differential between outside and inside the engine compartment must not exceed the following value.

| Recommended Maximum Pressure Differential at Wide Open Throttle |
|---|
| 500 Pa |

# Section 3 – FUEL DELIVERY SYSTEM

Fuel Delivery System

Fuel Tank

Fuel Lines

Additional Fuel Filter Usage

Fuel Line Fitting Installation

Fuel Return Fitting Requirements

Water Separating Fuel Filter

Fuel System Temperature and Pressure Drop

# Fuel Delivery System

| WARNING |
| --- |
| **Boating standards (NMMA, ABYC, etc.) and Coast Guard regulations must be adhered when constructing the fuel delivery system.** |

The main concern of a boat's fuel system is safety; this must be achieved through a technically sound installation and constant inspection.

The fuel system, from the filler pipe to the fuel pump, is the same in principle for all boats.

### Fuel Tank

The fuel tank is an integrated component of the boat. BUKH makes no attempt in this manual to cover all aspects of design and integration of the fuel tank in the boat due to the broad range of possible configurations. Refer to information from the tank manufacturer as well as boating standards (NMMA, ABYC, etc.) and Coast Guard regulations for complete guidelines.

Only a few points related to function and safety are listed here.

- All connections should be on the upper side of the tank.
- The tank ventilation pipe must have an inner diameter of at least 1/2 inch (12 mm) and must be fitted with a swan neck to prevent water from entering the tank.
- Fuel pickup should be at least 1 inch (25 mm) from the bottom of fuel tank to prevent picking up impurities.
- Return fuel line connection must flow freely into the top of the fuel tank, must NOT have a pipe that exits at the bottom of the fuel tank.

Some additional consideration regarding the fuel tank and fuel delivery system performance should be given to the following:

- Keep short horizontal distance, between the fuel tank and the fuel inlet fitting on the engine.
- BUKH offers a suitable optional fuel pump.
- Consider an anti-siphon device.
- Keep fuel tube length between top of the fuel tank and fuel inlet fitting on engine as short as possible. Fuel flow restriction can occur with increasing tube length.
- **When repowering from gasoline application to diesel in is important to clean out all remaining gasoline from the tank. Failure to do so may cause serious engine damage and can result in fire or explosion!**

| **Fuel Tank Bottom Versus Fuel Inlet Height (Measured from bottom of lower fuel tank to height of higher fuel inlet fitting.)** | |
|---|---|
| Less than 500 mm | Not generally a problem |
| 500 mm or more | May cause fuel delivery problems. Consider optional fuel pump. |

## Fuel Lines

The following, but not limited to the following, additional fuel connection related points, *applying to all engines unless otherwise stated*, must be considered. Refer to boating standards (NMMA, ABYC, etc.), Coast Guard regulations and/or your countries regulatory agency for complete guidelines.

- Fuel lines must be Coast Guard approved (USCG Type A1).
- All fuel lines to engine shall be at least Ø12 mm inner diameter.
- All fuel return lines from engine shall be at least Ø10 mm inner diameter.

- **On Multi-Engine Installations:** It is best to use a fuel pickup and supply line for **each** engine.
- Larger diameter (than previously specified) lines and fittings must be used on installations requiring long lines or numerous fittings.

- It is recommended that the exact route and length of the fuel lines shall be established at the first installation of the engine to prevent problems later in connecting them to the engine.
- Holes where the lines run through the bulkheads should be carefully rounded off or protected with rubber grommets. This prevents damage to the lines from abrasion.
- Fuel line(s) should be installed free of stress and firmly secured to prevent vibration and/or chafing.
- Sharp bends in fuel lines must be avoided.

- A flexible fuel line must be used to connect fuel supply line to fuel inlet fitting on engine to absorb deflection when engine is running.
- An anti-siphon device (valve) is required. An electric solenoid anti-siphon device is one of the least restrictive and is allowed by the Coast Guard.
- The maximum measured vacuum at the engine's fuel inlet must not exceed 2 inch Hg (6.8 kPa) at idle engine speed and full throttle engine speed.

## Additional Fuel Filter Usage

| CAUTION |
| --- |
| The engine fuel pump and factory installed water separating fuel filter have been carefully designed to function properly together. Do not install additional fuel filters and/or water separating fuel filters between fuel tank and engine. |

The installation of additional filters may cause fuel vapour locking.

## Fuel Line Fitting Installation

| IMPORTANT: The following information is provided to ensure proper installation of brass fittings or plugs installed into fuel pump or fuel filter base: |
| --- |
| • Apply 592 Loctite Pipe Sealant on threads of brass fittings or plugs. DO NOT USE TEFLON TAPE.<br>• Brass fittings or plugs should first be threaded into fuel pump or fuel filter base until finger tight.<br>• Fittings or plugs should then be tightened an additional 1-3/4 to 2-1/4 turns using a wrench. DO NOT OVER TIGHTEN.<br>• To prevent over tightening when installing a fuel line, the brass fittings should be held with a suitable wrench as fuel line connectors are tightened securely. |

## Fuel Return Fitting Requirements

Return fuel line is recommended to be Ø10 mm and must end in the top of the fuel tank.

There must be no restrictions on the fuel return system.

## Water Separating Fuel Filter

The engine must be installed with the water separating fuel filter supplied with the engine.
The boat's fuel supply line connects to the fuel inlet fitting (line connector), on the filter base, using a flexible fuel line. A flexible fuel line must be used to absorb deflection when the engine is operated.

## Fuel System Temperature and Pressure

The engine power output can be limited by restrictions in the boat's fuel supply system.

The V8 specifications for the boat's fuel system performance regarding fuel inlet are:

| Specifications For Fuel System Performance | |
|---|---|
| **Maximum Fuel Inlet Temperature** | **Maximum Fuel Pressure Drop. From Fuel Tank to Engine Fuel Inlet.** |
| 44°C | 1 psi |

Power output of is directly related to the amount of fuel demanded. An engine with more power output can cause a greater demand on a fuel system and therefore cause a greater fuel pressure drop. The design of the fuel system should always take into account the highest engine output offered in the boat. Doing this will help prevent performance problems related to fuel supply.

Air temperature and the RVP (Reid Vapor Pressure) of the fuel also play an important role in fuel system performance. Higher air temperature can cause higher fuel line temperature. Overall design of the fuel system and fuel line routing should take into account the highest air temperature to which the craft could be subjected. In some cases it may be necessary to measure the RVP of the fuel. Special test equipment can be used to determine the fuel's RVP or check with a local regulatory agency.

# Section 4 – COOLING SYSTEM

Cooling System

Seawater Supply and Hose Connections

Through The Hull or Transom

Seacock

Seawater Filter

Seawater Pump and Bracket

Drive Belt Routing

Water Heaters

## Cooling System

BUKH V8 engines have two separate cooling systems.
First cooling system is a sea water cooling system.
Second cooling system is a closed loop cooling system with antifreeze coolant.

Cooling system components must be constructed and sized appropriately to supply the engine with sufficient sea water under all operating conditions. Observe the following information.

## Seawater Supply and Hose Connections

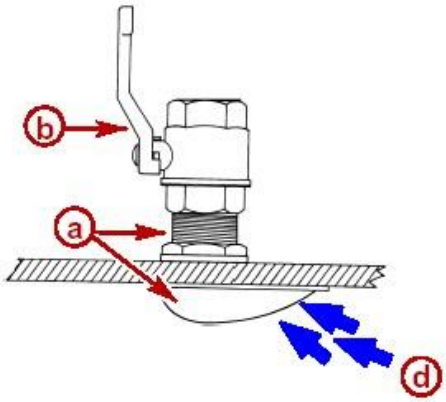
| Seawater Supply Specifications | |
|---|---|
| Seawater Pickup (through the hull or transom) Minimum Flow Rate | 230 liters per minute |
| Seawater Pickup Hose (Wire Reinforced) Inner Diameter | Ø40 mm |
| Seacock Size | Ø40 mm |
| Seawater Strainer Minimum Flow | 230 liters per minute |

**For engines combined with sterndrive. Please refer to sterndrive manual.**

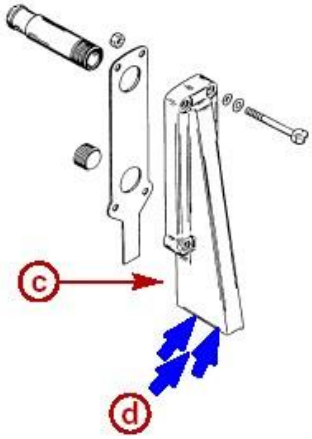
## Through the Hull or Transom

On the engine the seawater cooling hose connects to a water pickup that is mounted through the hull or transom of the boat. Refer to instructions provided by the seawater pickup manufacturer, or Installation Manual supplied with product. A seacock (water inlet valve) is recommended.

A through the hull or through the transom seawater pickup, must have an internal cross sectional area equal to or greater than seawater inlet hose to prevent restricting water flow. Pickup must be located on the boat in an area that permits an uninterrupted flow of water to the pickup. Be sure to make hose connections with double hose clamps.




**Typical Through the Hull Pickup.**




**Typical Through the Transom Pick up.**

**a -** Through the Hull Pickup
**b -** Seacock
**c -** Through the Transom Pickup
**d -** Water Flow

**IMPORTANT: Do not install water pickup directly in line with propeller, as pickup may create turbulence and allow air to flow into the "propeller slip-stream." This will cause propeller ventilation and will affect boat performance.**

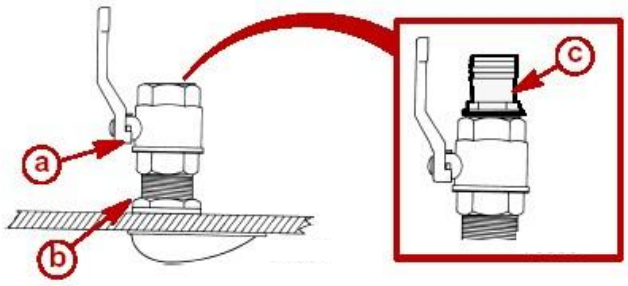
## Seawater Pickup Hose

**Through the Sterndrive Unit**
Seawater inlet hose through sterndrive is NOT recommended. Any resulting engine overheat problems will NOT be covered by BUKH warranty.

**Through the Hull or Transom**
Seawater pickup hose must be obtained separately if using a through the hull or through the transom seawater pickup. Hose must be of correct inner diameter (Refer to specifications in this document) and be a wire reinforced hose of adequate wall thickness to prevent it from collapsing from pump suction. Be sure to make hose connections with double hose clamps. Secure hose to prevent contact with any moving parts.

## Seacock

Seacock (seawater inlet valve), if used, must be installed between seawater pickup and seawater pickup pump (or sea strainer) to allow operator to shut off the seawater to flush or drain the engine, or clean the sea strainer while boat is in the water. Valve used must have an internal cross-sectional area equal to or greater than hose to prevent restricting water flow. Install valve in an area where it will be easily accessible. Support valve adequately to prevent hose fatigue. A brass ball or gate valve is required.



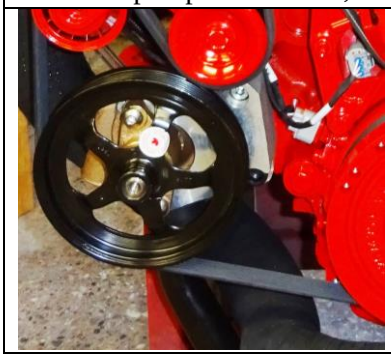

**Typical Seacock Installation**
**a -** Seacock
**b -** Seawater Pickup (Through the Hull Fitting)
**c -** Hose Connector

## Seawater Filter

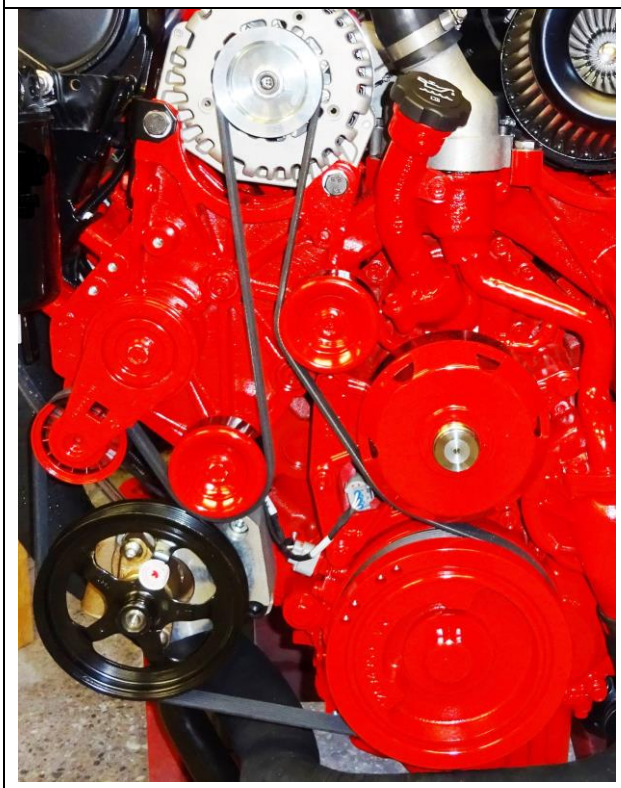
Strainer used, if equipped, must be of sufficient size to ensure that an adequate supply of water will be maintained for cooling the engine. (Refer to specifications in this document)

Seawater strainer should be installed in an area where it will be easily accessible for inspection and cleaning. Strainer must be installed in water inlet hose after the seacock (water inlet valve) to allow operator to shut off water when cleaning strainer. Hose connections must be made with double hose clamps. Secure hose to prevent contact with any moving parts.

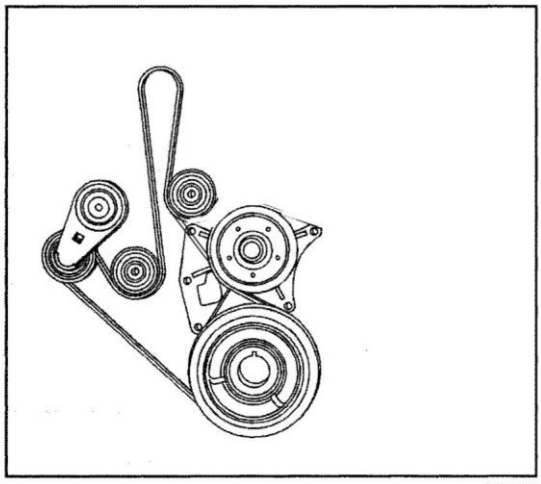
## Seawater Pump and Bracket

| Seawater pump and bracket, | Description |
|---|---|
|  | The seawater pump is installed with bracket.<br>The wheel is pressed on and aligned with laser tool. |

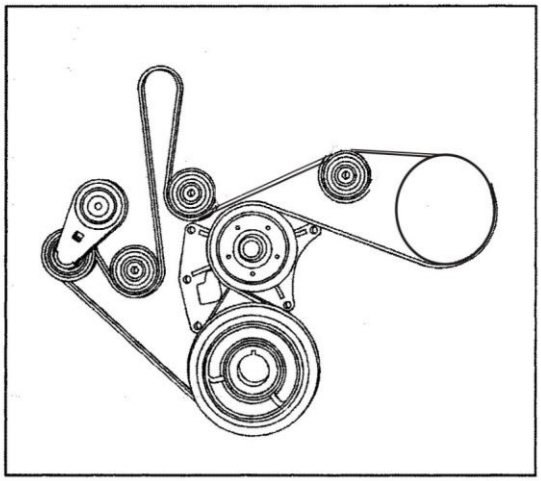
## Drive Belt Routing

| Drive belt routing | Description |
| --- | --- |
|  | The drive belt routing on one configuration of a BUKH V8 series engine. |

# Drive Belt Routing Configurations



**BUKH V8 without Power Steering**



**BUKH V8 with Power Steering**

## Water Heaters

When connecting a cabin heater or hot water heater, certain requirements must be met:

- Supply hose (from engine to heater) and return hose (from heater to engine) MUST NOT EXCEED 5/8 inch (16 mm) ID (inner diameter).
- Make heater connections ONLY at locations indicated in the following information.
- Do not reposition engine temperature switch; it must remain where installed by factory.

| CAUTION |
| --- |
| Avoid performance loss and/or possible engine damage. Engine coolant must flow continuously from the engine intake manifold to the engine water-circulating pump. NEVER close off or block the coolant flow to or from a heater.<br>All heater installations must be plumbed in series with the supply and return connections. |

| CAUTION |
| --- |
| Avoid engine overheating which could result in engine damage. On models equipped with Closed Cooling, an air pocket may form in the closed cooling system if some coolant is lost from the system and the cabin heater or hot water is mounted higher than the fill cap on the heat exchanger. Heater must be mounted lower than the fill cap of the heat exchanger on models so equipped. |

## Hose Connection

| | |
| --- | --- |
|  | To install a water heater or cabin heater you must purchase the optional water heater tube available from BUKH. This will replace the original bypass tube installed on the engine.<br>If the optional tube is installed you must circulate water to the external heater and back to the engine or the engine can overheat thus voiding warranty.<br>The heater must also be installed lower than the fill cap of the engines heat exchanger or the engine will overheat! |

# Section 5 – BATTERY and CONTROL

Battery

Battery Cables

Accessories

ECU and Relay Box

Warnings System and Alarms

Control Panel

## Battery

**Boating industry standards (ABYC, etc.), federal standards and Coast Guard regulations must be adhered to when installing battery. Be sure battery cable installed meets the pull test requirements and that positive battery terminal is properly insulated in accordance with regulations.**

**It is recommended (required in some countries) that the battery is installed in a separate ventilated case. Refer to your local regulations.**

**IMPORTANT: Engine electrical system is negative (-) ground.**

Battery should be located as close to the engine as possible.

Each engine requires its own battery for normal operation. Failure to do so will lead to an unstable voltage source. The alternator may not charge the battery properly if two engines are connected to a single battery. Battery leads should not be reversed (for example, positive to negative).

Battery minimum rating requirements depend on boat configuration and ambient conditions.

Select a battery that meets all of the following specifications:
- 12 V marine type.
- Tapered post connectors or side terminal connectors are required.
- Battery required capacity rating and CCA depends on engine usage. SOLAS, commercial or leisure conditions? The local BUKH service partner can guide you.

## Battery Cables

Battery cable gauge will change based on the length of the cable needed. Be sure to measure the length of the battery cables from battery to engine so the gauge can be determined by the chart below.

Select proper gauge (size) positive (+) and negative (–) battery cables, using chart:

| **Starter cable. Cable length** | **Cable dimension** |
|---|---|
| 1-3 m | 70 $mm^2$ |
| 3-5 m | 95 $mm^2$ |
| 5-6 m | 120 $mm^2$ |

Cable terminals must be soldered to cable ends to ensure good electrical contact. Use electrical grade (resin flux) solder only. Do not use acid flux solder as it may cause corrosion and a subsequent failure.

Starter cable.
The positive battery cable is connected to the battery positive terminal on the starter motor.

Charging and control power cable. The positive battery pole is connected directly to the black terminal box on the engine. This is done to ensure sufficient power to the engine control and to ensure charging of the battery.
Please use a suitable cable dimension to ensure proper charging of the battery.

The negative battery cable is connected to the ground on the engine block.

All of these connection points must be freed from paint to help ensure a good connection.
After connecting please grease connections to avoid corrosion or electrical contact failure.

## Accessories

Up to 3 accessory leads can be connected to the positive battery terminal (B+) stud on the starter motor. These leads must be equipped with the appropriate current overload protection. Refer to the ABYC standards or applicable industry standards for more information.

Do not attach any accessory ground (-) wires to engine block Accessory ground wires should only be attached to ground terminal (-) on battery.

## ECU and Relay Box

| ECU | Description |
|---|---|
|  | Picture of ECU, Engine Control Unit.<br><br>A plug is located on the engine ECU bracket. This will allow the instrumentation wiring harness to be connected to the engine wiring harness.<br><br>Picture of relay box. |
| **Relay box** | **Description** |
|  | Picture of relay box after black cap is removed.<br>Note position and color of fuses and pay attention to position of relays.<br>To ensure correct function of engine, relays are not to be turned.<br>Fuse 3 is 20 A for the starter.<br>Fuse 4 is 10 A for the display.<br>Fuse space 7 is free.<br>Fuse 9 is 10 A for the fuel pump at tank.<br>Other fuses are for the engine.<br><br>Center relay is the starter relay. |

## Warning System

**If warning system is activated, immediately shut down the engine by turning the key to off position.**

## Control Panel

| Control panel | Description |
|---|---|
|  | Picture of control panel.<br><br>Panel with red emergency stop.<br><br>Ignition key and engine data display screen.<br><br>Please mount control panel covered from rain and vapour. |

# Section 6 – PRE DELIVERY PREPARATION

Pre Delivery Preparation

Battery Connection

Power Steering

Boat-in-the-Water Test

Engine Idle Speed

Wide Open Throttle Test

Important Installation Notes

Pre Delivery Checklist

Cold Weather or Extended Storage Draining Instructions

## Pre Delivery Preparation

Once the engine package installation is complete, the following final steps should be taken to prepare engine package for delivery to the customer. It is the boat manufacturer's responsibility to perform these procedures, or to make arrangement with the dealer to have these procedures completed.

## Battery Connection

1. Connect engine positive (+) battery cable from the starter motor (usually RED) to positive (+) battery terminal.
2. Connect engine positive (+) charging and control power cable from the connecter box to positive (+) battery terminal.
3. Connect engine negative (-) battery cable from engine block (usually BLACK) to negative (-) battery terminal.
4. Ensure that all battery terminal connections are freed from paint, clean and tight, and then spray terminals with a battery connection sealant or grease, to retard corrosion.

## Power Steering

Use only automatic transmission fluid (ATF) in power steering system.

| CAUTION |
| --- |
| Do not run power steering dry. Pump will be damaged. |

1. Position drive unit so that it is straight back.
2. Remove fill cap from power steering pump reservoir and check fluid level.
3. Add fluid (provided with power package) as required.

**NOTE:** When the engine is started for the first time, be prepared to add fluid to pump.

Ensure that cooling system drain plugs, petcocks and hoses are installed and tight.

1. Check drive belt tension.
2. Test warning system.
3. Start engine and run at idle engine speed until water temperature is normal.
4. Watch all gauges for normal readings.
5. Turn steering wheel starboard, then port and ensure steering unit or sterndrive unit turns the correct way.
6. Inspect engine compartment for water, oil, fuel and exhaust leaks.
7. Check power steering oil level.
8. Turn steering wheel **left/port** until it stops and continue to apply pressure. If pump lugs (engine speed drops and/or power steering pump tone changes), check the following.
    a. Check for an obstruction between gimbal ring and gimbal housing and all moving steering components.
    b. Ensure steering lever is not contacting cutout in transom. If contact is being made, modify cutout.
9. Turn steering wheel **right/starboard** until it stops and continue to apply pressure. If pump lugs (Engine speed drops and/or power steering pump tone changes), check the following.
    a. Check same items as (8.) above.
10. Check steering cable end dimension with cable FULLY EXTENDED.
11. Check power steering fluid level.
12. Turn engine OFF.
13. Remove cap/dipstick from power steering pump. Check fluid level and add as necessary.

## Boat-in-the-Water Test

| CAUTION |
| --- |
| Avoid engine damage. Ensure that cooling water is supplied to the engine if it will be operated with the boat out of the water. |

## Engine Idle Speed

Engine should idle at 600-700 rpm. with engine at normal operating temperature.
If idle speed is incorrect and the vessel has an external throttle lever, proceed as follows:

1. Turn off the engine. Please do not adjust with engine running.
2. External throttle lever is set to engine idle speed. With engine shut off.
3. Check lever positions and adjust the external lever cable. Please do not adjust screws on engine lever.
4. Still ensure engine is shut off
5. External throttle lever is set to full engine speed. With engine shut off.
6. Check lever positions and adjust the external lever cable. Please do not adjust screws on engine lever.

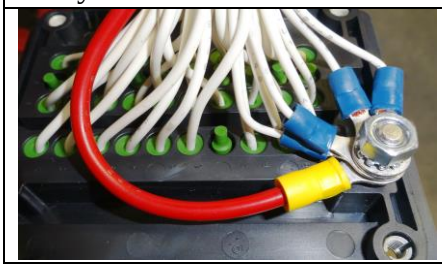
## Wide Open Throttle Test

**IMPORTANT: To operate engine at full throttle before the break-in period is complete, follow this procedure.**

- Start engine and operate at idle engine speed until normal operating temperature is reached.
- Run boat up on plane.
- Advance engine in 200 engine speed/rpm increments, until engine reaches its maximum rated engine speed.

## Common Cause of Problems

- Please make careful notes on mounting battery cables of the correct dimensions, failure to comply with this will make the engine difficult to start.
- Engines are shipped without oil, make sure you fill the engine with oil and check the level before starting. At the same time also ALWAYS check the supercharger oil and coolant levels.
- Engines delivered with remote oil filter re locators: Make sure you prefill the oil lines and oil filter before you start the engine. This is to prevent engine damage.
- Make sure you use minimum 10 mm inner diameter return hose. Make sure that there is no restrictions and that the return fuel can flow freely into the top of the fuel tank. Improper installation of fuel return will cause hard starting, rough idle, high fuel consumption and poor engine performance.
- Make sure you use minimum 12 mm inner diameter fuel feed hose/line and that this is of adequate quality so that it doesn't get flat from the fuel feed pump suction. If the fuel feed hose/line get flat from suction the engine will lose engine speed and performance instantly even if it may not run rough.
- You MUST use double hose clamps on all fuel line fittings to prevent air penetrating into the fuel system.
- Do NOT use Teflon tape or other to seal fuel or oil fitting, use only Loctite 518 and use it on ALL fuel and oil fittings to prevent leakage or air penetration into the fuel system.
- Make sure you have adequate ventilation for the fuel tank as the engine fuel system otherwise can cause vacuum in the tank. Improper ventilation will lead to hard starting and poor engine performance.
- Make sure the engine room is well ventilated or power loss may occur, se specifications in section 2, air intake system.
- When installing the engine extension harness it is important to connect the + main lead in this harness to the other electrical system under the instrument panel, this giving + a direct feed from the boats battery, this to ensure that not all power goes through the engine extension harness. This to prevent losses in the extension harness from the engine, failure to comply may result in glow system problems and severe engine damage.

| Display | Description |
|---|---|
|  | Picture of display panel with BUKH V8 engine parameters.<br><br>Please mount display where rain and vapour can be prevented from entering. |
| **Relay box** | **Description** |
|  | Picture of wire side of the relay box.<br>Red wire from battery 12V is connected to relay box.<br>Make sure a 12V wire is connected from this connection through extension harness to Control panel. |

- It is HIGHLY recommended that you use a separate minimum Ø40 mm, inner diameter, water intake for the engine and NOT the water pickup on sterndrives. Historical experience has indicated issues resulting in high engine temperature running conditions resulting from congested sterndrive inlets. We have found that adding the through hull inlet ensures adequate water flow to the engine and prevents issues arising in the future. The BUKH warranty does NOT cover engine overheat related problems.
- It is HIGHLY recommended that the engine exhaust be run through the transom and NOT run exhaust through the sterndrive as this will lead to excessive back pressure.
- It is MANDATORY that all V8 engines are propped according to BUKH recommendations. Over-propping of the boat induces excessive loading of the engine which will generate excessive exhaust temperatures and resulting reduction of engine longevity. Propping must be completed such that the engine is capable of achieving the specified maximum engine speed rating, while loaded at the heaviest condition for the vessel. BUKH warranty does NOT cover any resulting issues related to over-propping.

Please see BUKH V8 Official Warranty Information and hand in a warranty registration form on www.bukh.dk

## Cold Weather or Extended Storage

| CAUTION |
| --- |
| If the engine will not be used for an extended period of time or will be exposed to freezing temperatures, drain water from seawater section of cooling system.<br>Water MUST BE drained to prevent corrosion and freeze damage to engine. |

| CAUTION |
| --- |
| If boat is to remain in the water, seacock, if so equipped, must remain closed until engine is to be restarted to prevent water from flowing back into seawater cooling system. If boat is not fitted with a seacock, water inlet hose must be disconnected and plugged to prevent water from flowing into cooling system and/or boat. As a precautionary measure, attach a tag to the ignition switch or steering wheel with the warning that the seacock must be opened or the water inlet hose reconnected prior to starting the engine. |

IMPORTANT: Boat must be as level as possible to ensure complete draining of cooling system.