

Service

Engine

Engine Model:

General Motors 8.1 L Powertrain

Generator Set Models:
80-125 kW

CAUTION

Caution: To reduce the chance of personal injury and/or property damage, carefully observe the instructions that follow.

The service manual of General Motors Powertrain is intended for use by professional, qualified technicians. Attempting repairs or service without the appropriate training, tools, and equipment could cause injury to you or others, damage the equipment, or cause the equipment to operate improperly.

Proper equipment and repair are important to the safety of the service technician and to the safe, reliable operation of the equipment. If you need to replace a part, use the same part number or an equivalent part. Do not use a replacement part of lesser quality.

The service procedures recommended and described in this service manual are effective methods of performing service and repair. Some of the procedures require the use of tools that are designed for specific purposes.

Accordingly, any person who intends to use a replacement part, a service procedure, or a tool that is not recommended by General Motors Powertrain must first establish that there is no jeopardy to personal safety or the safe operation of the equipment.

This manual contains various *Cautions* and *Notices* that must be observed carefully to reduce the risk of personal injury during service or repair. Improper service or repair may damage the equipment or render the equipment unsafe. These *Cautions* and *Notices* are not exhaustive. General Motors Powertrain cannot possibly warn of all the potentially hazardous consequences of failure to follow these instructions.

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This service manual provides the service technician with information to service the General Motors Powertrain engines.

In general, this manual covers the service of the engine and associated standard equipment. In some cases, the engine is supplied with accessories and equipment unique to the application. If service information is required on such unique accessories or equipment, contact the generator set manufacturer who will forward the proper information or advise the service technician where it can be obtained.

The information in this manual is grouped in sections according to the type of work being performed. The various sections are indicated in the Table of Contents of the manual.

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This manual is a reproduction of a General Motors Powertrain publication and contains information pertaining to industrial generator set engines. Some information pertains to other applications of the engine. The accuracy and completeness of information is the sole responsibility of General Motors Powertrain.

The descriptions and specifications contained in this manual were in effect at the time the book was released by General Motors Powertrain. The generator set manufacturer and General Motors Powertrain reserve the right to discontinue models or change specs or design at any time without notice and without incurring obligation.

Notes

Definition of Caution, Notice, and Important

The diagnosis and repair procedures in the GM Powertrain Service Manual contain both general and specific Cautions, Notices, and Important. GM Powertrain is dedicated to the presentation of service information that helps the technician diagnose and repair the systems necessary for the proper operation of the equipment; however, certain procedures may present a hazard to the technician if they are not followed in the recommended manner. Cautions, Notices, and Important are elements designed to prevent these hazards; however, not all hazards can be foreseen. This information is placed at strategic locations within the service manual and is designed to prevent the following:

- Serious bodily injury to the technician.
- Damage to the equipment.
- Unnecessary equipment repairs.
- Unnecessary component repairs.
- Improper repair or replacement equipment components. Any caution or notice that appears in general information is referenced from the individual service categories.

Caution Defined

When encountering a Caution, you will be asked to take a necessary action or avoid a prohibited action. If a Caution is not heeded, the following consequences may occur:

- Serious bodily injury to the technician.
- Serious bodily injury to other technicians in the workplace area.
- Serious bodily injury to the equipment operator if the equipment has been improperly repaired.

Notice Defined

Notices call special attention to a necessary action or to a prohibited action. If a Notice is not heeded, the following consequences may occur:

- Damage to the equipment.
- Unnecessary equipment repairs.
- Unnecessary component replacement.
- Improper operation or performance of the system or component under repair.
- Damage to any systems or components that are dependent upon the proper operation of the system or component under repair.
- Improper operation or performance of any systems or components that are dependent upon the proper operation or performance of the system or component under repair.
- Damage to fasteners, basic tools, or special tools.
- Leaks of coolant, lubricant, or other vital fluids.

Important Defined

Important statements emphasize a necessary characteristic of a diagnostic or repair procedure. *Important* statements are designed to do the following:

- Clarify a procedure.
- Present additional information for accomplishing a procedure.
- Give insight into the reason or reasons for performing a procedure in the manner recommended.
- Present information that will help to accomplish a procedure in a more effective manner.
- Present information that gives the technician the benefit of past experience in accomplishing a procedure with greater ease.

Battery Disconnect Caution

Caution: Disconnect the battery cables before working on the engine. Remove the negative (-) lead first when disconnecting the battery. Reconnect the negative (-) last when reconnecting the battery.

Moving Parts and Hot Surfaces Caution

Caution: Avoid contact with moving parts and hot surfaces while working around a running engine to prevent physical injury.

Safety Glasses Caution

Caution: Always wear safety glasses to avoid eye damage.

Belt Drive Notice

Notice: Do not use belt dressing on the drive belt. Belt dressing causes the breakdown of the composition of the drive belt. Failure to follow this recommendation will damage the drive belt.

Component Fastener Tightening Notice

Notice: Replacement components must be the correct part number for the application. Components requiring the use of the thread-locking compound, lubricants, corrosion inhibitors, or sealants are identified in the service procedure. Some replacement components may come with these coatings already applied. Do not use these coatings on components unless specified. These coatings can affect the final torque, which may affect the operation of the component. Use the correct torque specifications when installing components to avoid damage.

Fastener Notice

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

Special Fastener Notice

Notice: This bolt is designed to permanently stretch when tightened. The correct part number fastener must be used to replace this type of fastener. Do not use a bolt that is stronger in this application. If the correct bolt is not used, the parts will not be tightened correctly. The system or the components may be damaged.

Section 1 Specifications

1.1 Fastener Tightening Specs

Application	Spec
Accessory drive belt tensioner bolt, Nm (ft. lb.)	50 (37)
Air cleaner outlet duct clamp, Nm (in. lb.)	4 (35)
Battery cable channel bolt, Nm (in. lb.)	9 (80)
Camshaft position sensor bolt, Nm (in. lb.)	12 (106)
Camshaft retainer bolt, Nm (in. lb.)	12 (106)
Camshaft sprocket bolt, Nm (ft. lb.)	30 (22)
Connecting rod nut, first pass, Nm (ft. lb.)	30 (22)
Connecting rod nut, final pass	90°
Crankshaft balancer bolt, Nm (ft. lb.)	255 (189)
Crankshaft bearing cap inner bolts, first pass, Nm (ft. lb.)	30 (22)
Crankshaft bearing cap inner bolts, final pass	90°
Crankshaft bearing cap outer bolts/studs, first pass, Nm (ft. lb.)	30 (22)
Crankshaft bearing cap outer bolts/studs, final pass	80°
Crankshaft oil deflector nut, Nm (ft. lb.)	50 (37)
Crankshaft position sensor bolt, Nm (in. lb.)	12 (106)
Crossbar bolt, Nm (ft. lb.)	100 (74)
Cylinder head bolts, in sequence	
First pass, Nm (ft. lb.)	30 (22)
Second pass, Nm (ft. lb.)	30 (22) +120°
Final pass, long bolts #1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, 17	60°
Final pass, medium bolts #15, 16	45°
Final pass, short bolts #4, 5, 12, 13	30°
Cylinder head coolant hole plug, Nm (ft. lb.)	50 (37)
Drive belt idler pulley bolt, Nm (ft. lb.)	50 (37)
EGR cover nut, Nm (ft. lb.)	22 (16)
EGR cover stud, Nm (in. lb.)	7 (62)
Engine block coolant drain M28 plug, left front, Nm (ft. lb.)	60 (44)
Engine block coolant drain plug, sides, Nm (ft. lb.)	30 (22)
Engine block heater, Nm (ft. lb.)	50 (37)
Engine block oil gallery, front plug, Nm (ft. lb.)	20 (15)
Engine block oil gallery, rear plug, Nm (ft. lb.)	30 (22)
Engine block oil gallery, side plug, Nm (ft. lb.)	30 (22)
Engine block oil gallery, top plug, Nm (ft. lb.)	20 (15)
Engine coolant temperature (ECT) sensor, Nm (ft. lb.)	50 (37)
Engine coolant temperature (ECT) sensor bracket bolt, Nm (ft. lb.)	50 (37)
Engine harness bolt, Nm (in. lb.)	5 (44)
Engine harness ground bolt, Nm (ft. lb.)	16 (12)
Engine harness stud, Nm (in. lb.)	10 (89)
Engine mount bolt-to-engine bracket, Nm (ft. lb.)	50 (37)
Engine mount-to-engine bracket bolt, Nm (ft. lb.)	50 (37)
Engine mount frame bracket through bolt, Nm (ft. lb.)	75 (55)
Engine mount frame side mount bolt, Nm (ft. lb.)	65 (50)
Engine shield bolt, Nm (ft. lb.)	20 (15)
Engine sight shield bracket nut, Nm (in. lb.)	5 (44)
Engine wiring harness bolt, Nm (ft. lb.)	16 (12)
EVAP purge valve bolt, Nm (in. lb.)	8 (71)

Application	Spec
Exhaust manifold center bolt, Nm (ft. lb.)	35 (26)
Exhaust manifold nut, Nm (ft. lb.)	16 (12)
Exhaust manifold stud, Nm (ft. lb.)	20 (15)
Exhaust manifold heat shield bolt, Nm (ft. lb.)	25 (18)
Exhaust manifold heat shield nut, Nm (ft. lb.)	25 (18)
Flywheel bolt, first pass, Nm (ft. lb.)	40 (30)
Flywheel bolt, second pass, Nm (ft. lb.)	80 (59)
Flywheel bolt, final pass, Nm (ft. lb.)	100 (74)
Front cover bolt, first pass, Nm (in. lb.)	6 (53)
Front cover bolt, final pass, Nm (in. lb.)	12 (106)
Fuel rail bolt/stud, Nm (in. lb.)	12 (106)
Ignition coil bolt, Nm (in. lb.)	12 (106)
Ignition coil wiring harness bolt, Nm (in. lb.)	12 (106)
Intake manifold bolts, in sequence, first pass, Nm (in. lb.)	5 (44)
Intake manifold bolts, in sequence, second pass, Nm (in. lb.)	8 (71)
Intake manifold bolts, in sequence, third pass, Nm (in. lb.)	12 (106)
Intake manifold bolts, in sequence, final pass, Nm (ft. lb.)	15 (11)
J42847 flywheel holding tool bolt, Nm (ft. lb.)	50 (37)
Knock sensor, Nm (ft. lb.)	20 (15)
Knock sensor heat shield bolt, Nm (in. lb.)	12 (106)
Lift bracket bolt, Nm (ft. lb.)	40 (30)
MAP sensor bolt, Nm (in. lb.)	12 (106)
Oil cooler hose fittings, Nm (ft. lb.)	23 (17)
Oil fill tube bolt, Nm (in. lb.)	12 (106)
Oil filter, Nm (ft. lb.)	38 (28)
Oil filter fitting, Nm (ft. lb.)	66 (49)
Oil level indicator tube bolt, Nm (ft. lb.)	25 (18)
Oil level sensor, Nm (ft. lb.)	20 (15)
Oil pan bolt, first pass, Nm (in. lb.)	10 (89)
Oil pan bolt, final pass, Nm (ft. lb.)	25 (18)
Oil pan drain plug, Nm (ft. lb.)	28 (21)
Oil pan skid plate bolt, Nm (ft. lb.)	20 (15)
Oil pressure gauge sensor, Nm (ft. lb.)	30 (22)
Oil pump bolt, Nm (ft. lb.)	75 (56)
Oil pump cover bolt, Nm (in. lb.)	12 (106)
Oil pump drive bolt, Nm (ft. lb.)	25 (18)
Spark plug, Nm (ft. lb.)	30 (22)
Thermostat housing bolt/stud, Nm (ft. lb.)	30 (22)
Throttle body nut, Nm (in. lb.)	10 (89)
Throttle body stud, Nm (in. lb.)	12 (106)
Valve lifter guide retainer bolt, Nm (ft. lb.)	25 (18)
Valve rocker arm cover bolt, first pass, Nm (in. lb.)	6 (53)
Valve rocker arm cover bolt, final pass, Nm (in. lb.)	12 (106)
Valve rocker arm nut, Nm (ft. lb.)	35 (26)
Valve rocker arm stud, Nm (ft. lb.)	50 (37)
Water crossover bolt, Nm (ft. lb.)	50 (37)
Water pump bolt, first pass, Nm (ft. lb.)	25 (18)
Water pump bolt, final pass, Nm (ft. lb.)	50 (37)
Water pump pulley bolt, Nm (ft. lb.)	25 (18)

1.2 Engine Mechanical Specs

Application	Spec
General	
Engine type	V8
Displacement, L (CID)	8.1 (496)
RPO	L18
Bore, mm (in.)	107.95 (4.25)
Stroke, mm (in.)	111.00 (4.37)
Compression ratio	9:1:1
Firing order	1-8-7-2-6-5-4-3
Spark plug gap, mm (in.)	1.52 (0.060)
Block, mm (in.)	
Crankshaft main bearing bore diameter	74.606–74.622 (2.9372–2.9379)
Cylinder bore diameter, production	107.950–107.968 (4.2500–4.2507)
Cylinder bore diameter, service	107.94–107.99 (4.2496–4.2516)
Cylinder bore out-of-round, production, max. minus min. bore diameter	0.018 (0.0007)
Cylinder bore out-of-round, service, max. minus min. bore diameter	0.05 (0.002)
Cylinder bore taper, production	0.018 (0.0007)
Cylinder bore taper, service thrust axis	0.05 (0.002)
Cylinder bore taper, service pin axis	0.05 (0.002)
Cylinder head deck height from centerline of crankshaft	259.875–260.125 (10.231–10.241)
Cylinder head deck surface flatness, entire face	0.10 (0.004)
Cylinder head deck surface flatness, within 150 mm (6 in.)	0.05 (0.002)
Valve lifter bore diameter	21.417–21.443 (0.843–0.844)
Camshaft, mm (in.)	
Bearing inside diameter	49.548–49.573 (1.9507–1.9517)
Journal diameter	49.472–49.522 (1.9477–1.9497)
Lobe lift, exhaust	6.973–7.075 (0.2745–0.2785)
Lobe lift, intake	6.924–7.026 (0.2726–0.2766)
Runout, production	0.051 (0.002)
Runout, service	0.076 (0.003)
Connecting rod, mm (in.)	
Bearing clearance, production	0.033–0.068 (0.0013–0.0027)
Bearing clearance, service	0.033–0.081 (0.0013–0.0032)
Side clearance	0.384–0.686 (0.0151–0.0270)
Crankshaft, mm (in.)	
Connecting rod journal diameter	55.854–55.870 (2.1990–2.1996)
Connecting rod journal out-of-round, production	0.0102 (0.0004)
Connecting rod journal taper, production	0.0102 (0.0004)
Crankshaft end play	0.127–0.350 (0.005–0.0138)

Application	Spec
Crankshaft main bearing clearance, #1, #2, #3, #4, production	0.022–0.057 (0.0008–0.0022)
Crankshaft main bearing clearance, #5, production	0.034–0.069 (0.0013–0.0027)
Crankshaft main bearing clearance, #1, #2, #3, #4, service	0.022–0.089 (0.0008–0.0035)
Crankshaft main bearing clearance, #5, service limit	0.035–0.102 (0.0014–0.0040)
Crankshaft main bearing journal diameter	69.805–69.822 (2.7482–2.7489)
Crankshaft main journal out-of-round, production	0.0102 (0.0004)
Crankshaft main journal taper, production	0.0102 (0.0004)
Crankshaft runout, production	0.05 (0.002)
Crankshaft runout, service	0.065 (0.0026)
Cylinder head, mm (in.)	
Height/thickness	259–875–260.125 (10.231–10.241)
Surface flatness, block deck	0.05 (0.002)
Surface flatness, exhaust manifold deck	0.102 (0.004)
Surface flatness, intake manifold deck	0.08 (0.003)
Exhaust manifold	
Surface flatness, mm (in.)	0.254 (0.01)
Lubrication system	
Oil capacity without filter, L (qt.)	5.7 (6)
Oil pressure, minimum, kPa (psi)	34 (5) @ 1000 rpm
Oil pressure, maximum, kPa (psi)	690 (10) @ 2000 rpm
Piston rings	
Piston ring end gap, mm (in.)	
First compression ring, production	0.30–0.45 (0.012–0.018)
First compression ring, service	0.450–0.675 (0.018–0.027)
Second compression ring, production	0.450–0.650 (0.018–0.025)
Second compression ring, service	0.675–0.975 (0.027–0.039)
Oil control ring, production	0.249–0.759 (0.0098–0.0299)
Oil control ring, service	0.373–1.138 (0.015–0.045)
Piston ring to groove clearance, mm (in.)	
First compression ring	0.031–0.074 (0.0012–0.0029)
Second compression ring	0.031–0.074 (0.0012–0.0029)
Oil control ring	0.051–0.203 (0.002–0.008)
Piston	
Diameter	Not measurable (see Section 5.1.7 comment)
Piston to bore clearance	Interference fit
Piston pin, mm (in.)	
Clearance to connecting rod bore	0.049–0.020 (0.0019–0.0007) interference
Diameter	26.416–26.419 (1.0400–1.0401)

Application	Spec
Valve system	
Valves	
Face angle, exhaust	45°
Face angle, intake	45°
Head diameter, exhaust, mm (in.)	43.69 (1.72)
Head diameter, intake, mm (in.)	55.63 (2.19)
Lash, exhaust	Net lash
Lash, intake	Net lash
Seat angle, exhaust	46°
Seat angle, intake	46°
Seat runout, exhaust, mm (in.)	0.050 (0.002)
Seat runout, intake, mm (in.)	0.050 (0.002)
Seat width, exhaust, mm (in.)	1.651-2.159 (0.060-0.095)
Seat width, intake, mm (in.)	0.8-1.2 (0.03-0.06)
Stem diameter, exhaust, mm (in.)	9.431-9.449 (0.3713-0.3720)
Stem diameter, intake, mm (in.)	9.436-9.454 (0.3715-0.3722)
Stem-to-guide clearance, production exhaust, mm (in.)	0.30-0.079 (0.0012-0.0031)

Application	Spec
Stem-to-guide clearance, production intake, mm (in.)	0.025-0.074 (0.0010-0.0029)
Stem-to-guide clearance, service exhaust, mm (in.)	0.030-0.104 (0.0012-0.0041)
Stem-to-guide clearance, service intake, mm (in.)	0.025-0.099 (0.0010-0.0039)
Rocker arms	
Valve rocker arm ratio	1:70:1
Valve springs	
Free length, mm (in.)	56.35 (2.218)
Installed height, mm (in.)	45.923-46.685 (1.808-1.838)
Load, closed, N (lbf.)	381-419 (86-94) @ 45.923 mm (1.808 in.)
Load, open, N (lbf.)	962-1058 (216-236) @ 33.985 mm (1.338 in.)

1.3 Sealers, Adhesives, and Lubricant Specs

Application	Material Type	GM Part Number	
		U.S.	Canada
Block heater threads	Sealant	12346004	10953480
Camshaft rear bearing hole plug	Sealant	12377901	10953504
Crankshaft position sensor bolt	Thread adhesive	12345493	10953488
Crankshaft rear bearing cap	Sealant	1052942	10953466
Cylinder head bolt threads	Sealant	12346004	10953480
Cylinder head coolant hole plug	Sealant	12346004	10953480
Engine block coolant drain plugs	Sealant	12346004	10953480
Engine block oil gallery plugs	Sealant	12346004	10953480
Engine coolant temperature (ETC) sensor threads	Sealant	12346004	10953480
Engine front cover	Sealant	12346286	10953472
Engine oil supplement	Lubricant	1052367	992869
Intake manifold	Sealant	12346141	10953433
Intake manifold bolt threads	Thread adhesive	12345382	10953489
Intake manifold engine block/cylinder head	Sealant	12346141	10953433
Knock sensor threads	Sealant	12346004	10953480
Oil cooler hose fittings	Sealant	12346004	10953480
Oil fill tube	Sealant	9985409	9985409
Oil pan corners	Sealant	12346286	10953472
Oil pressure sensor threads	Sealant	12346004	10953480
Purge solenoid bolt	Thread adhesive	12345493	10953488
Valve rocker arm stud threads	Sealant	12346004	10953480
Water pump bolt threads	Sealant	12346004	10953480

1.4 Component Locator

1.4.1 Disassembled Views

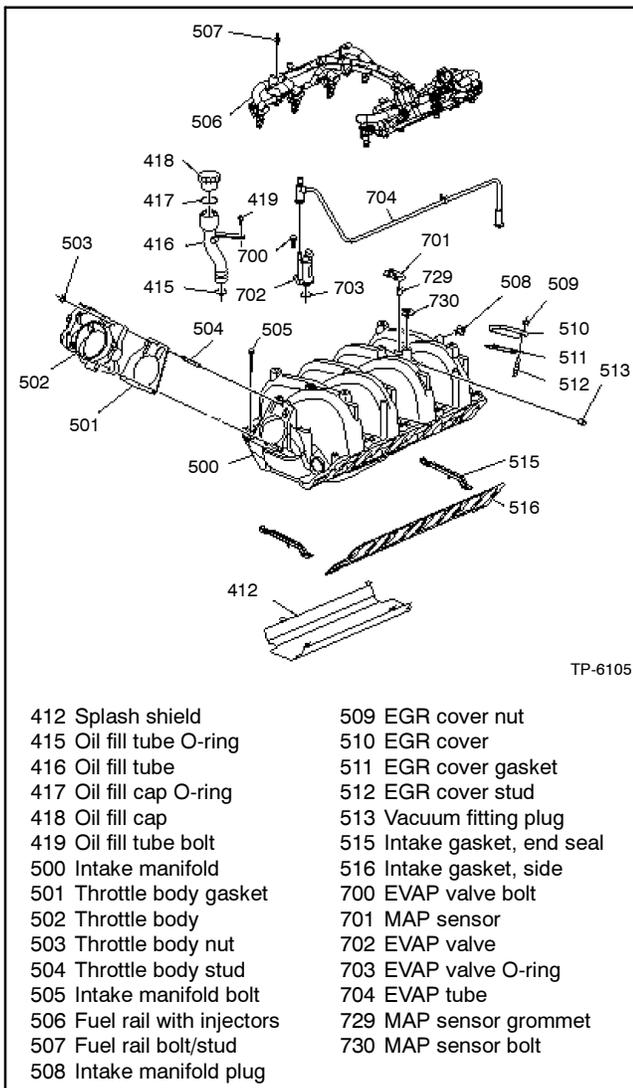


Figure 1-1 Intake Manifold/Upper Engine

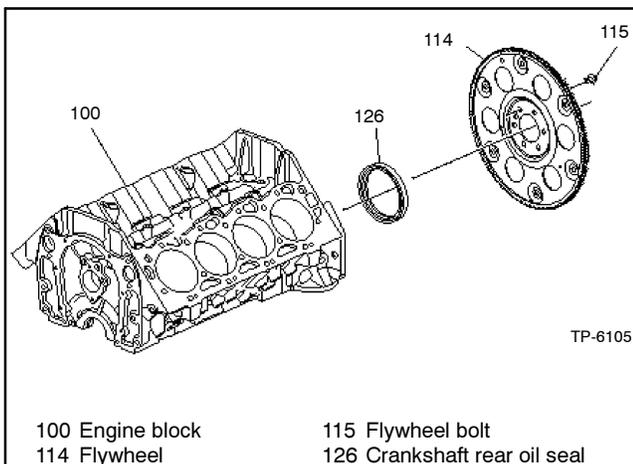


Figure 1-2 Engine Rear

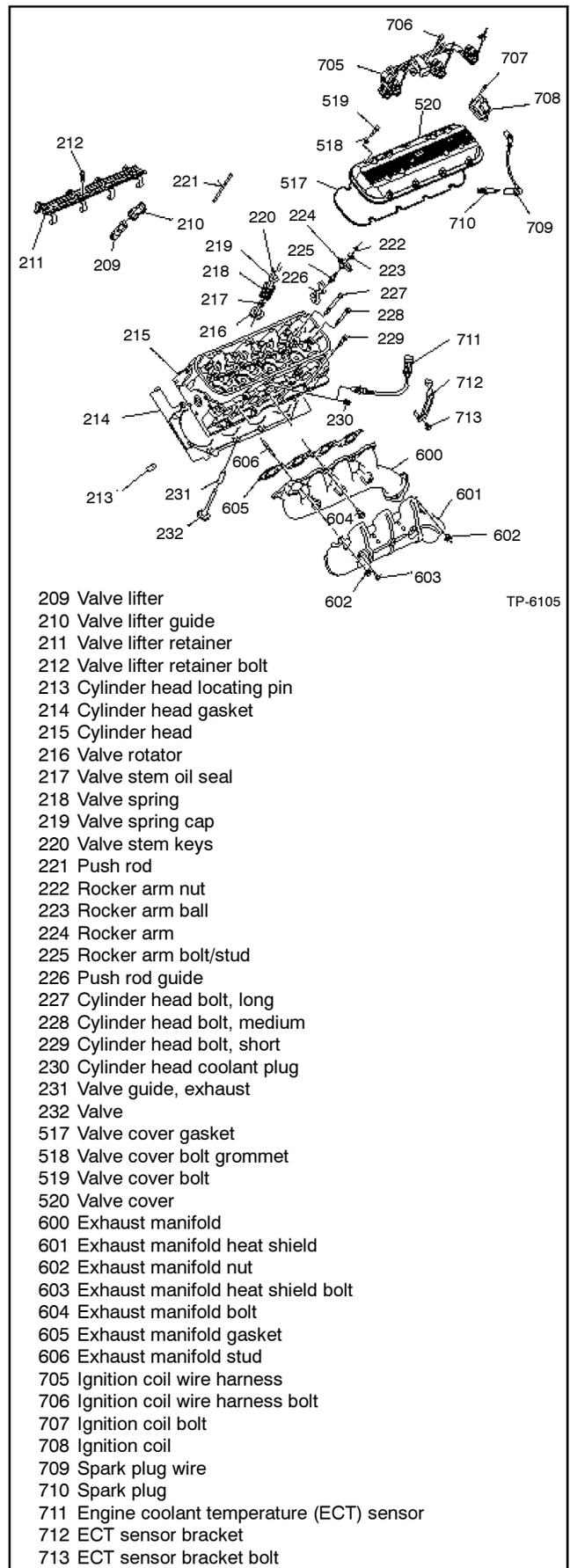
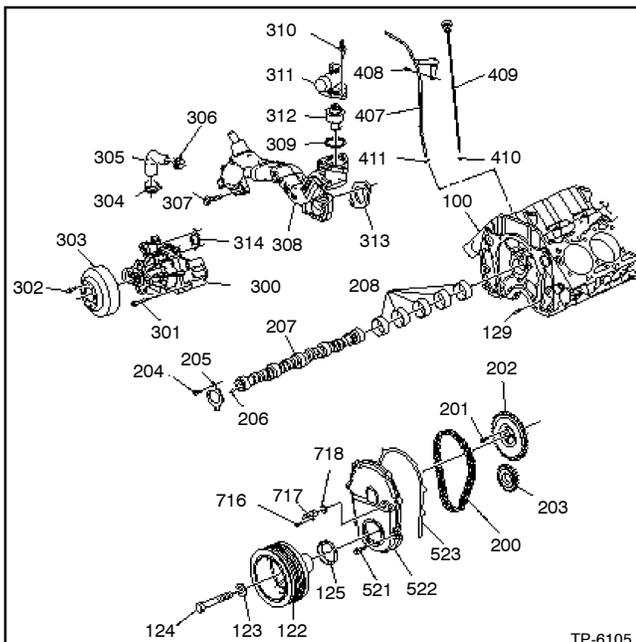


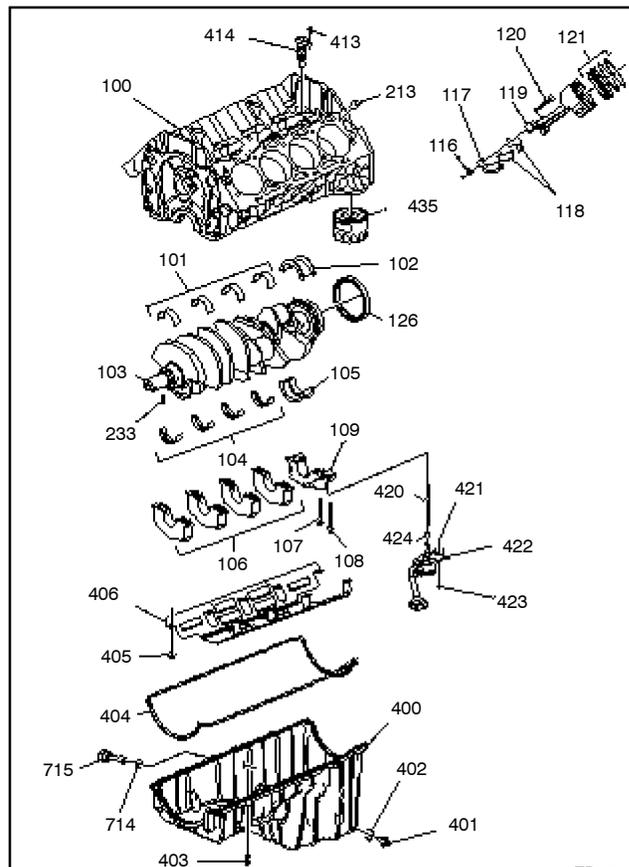
Figure 1-3 Cylinder Head/Upper Engine



TP-6105

- 100 Engine block
- 122 Crankshaft balancer
- 123 Crankshaft balancer bolt washer
- 124 Crankshaft balancer bolt
- 125 Crankshaft front oil seal
- 129 Front cover locating pin
- 200 Timing chain
- 201 Camshaft sprocket bolt
- 202 Camshaft sprocket
- 203 Crankshaft sprocket
- 204 Camshaft retainer bolt
- 205 Camshaft retainer
- 206 Camshaft sprocket locating pin
- 207 Camshaft
- 208 Camshaft bearings
- 300 Water pump
- 301 Water pump bolt
- 302 Water pump pulley bolt
- 303 Water pump pulley
- 304 Water pump bypass hose clamp
- 305 Water pump bypass hose
- 306 Water pump bypass hose clamp
- 307 Water crossover bolt
- 308 Water crossover
- 309 Thermostat O-ring
- 310 Thermostat housing bolt/stud
- 311 Thermostat housing
- 312 Thermostat
- 313 Water crossover gasket
- 314 Water pump gasket
- 407 Oil level indicator tube
- 408 Oil level indicator tube bolt
- 409 Oil level indicator
- 410 Oil level indicator O-ring
- 411 Oil level indicator tube O-ring
- 521 Front cover bolt
- 522 Front cover
- 523 Front cover gasket
- 716 Camshaft position sensor bolt
- 717 Camshaft position sensor
- 718 Camshaft position sensor O-ring

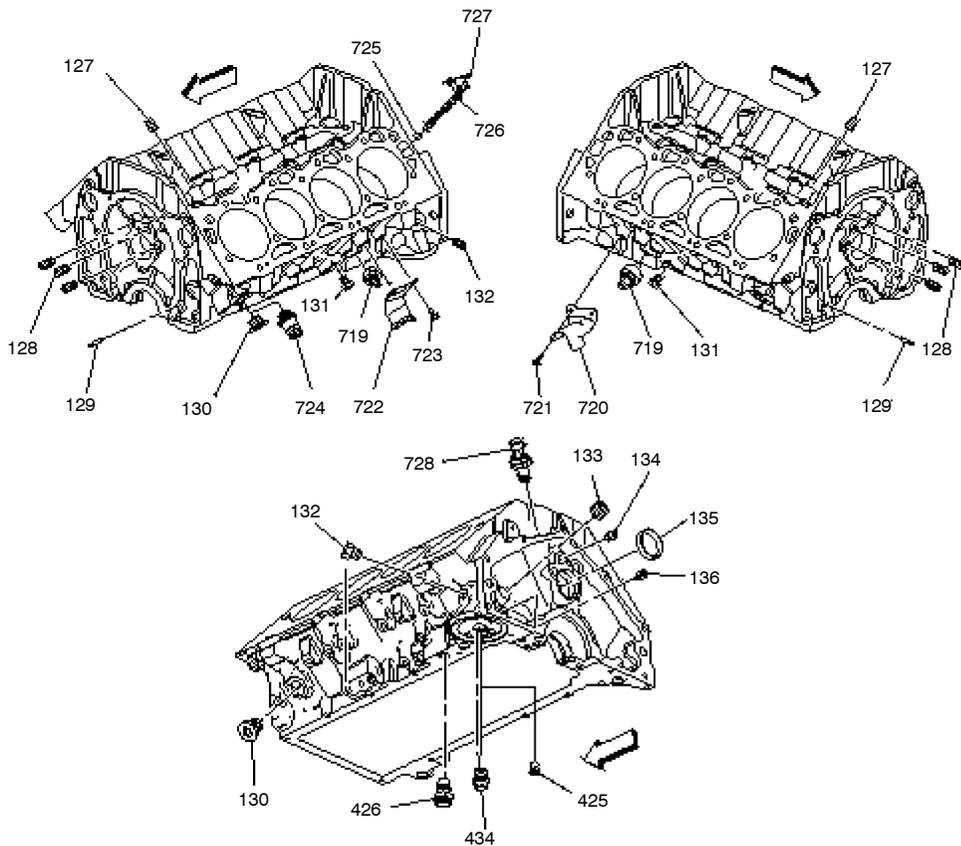
Figure 1-4 Engine Front



TP-6105

- 100 Engine block
- 101 Crankshaft main bearings, upper
- 102 Crankshaft thrust bearing, upper
- 103 Crankshaft
- 104 Crankshaft main bearings, lower
- 105 Crankshaft thrust bearings, lower
- 106 Crankshaft bearing cap
- 107 Crankshaft bearing cap bolt
- 108 Crankshaft bearing cap bolt/stud
- 109 Crankshaft bearing cap, thrust
- 116 Connecting rod nut
- 117 Connecting rod cap
- 118 Connecting rod bearings
- 119 Piston and connecting rod assembly
- 120 Connecting rod bolt
- 121 Piston rings
- 126 Crankshaft rear oil seal
- 213 Cylinder head locating pin
- 233 Crankshaft sprocket locating pin
- 400 Oil pan
- 401 Oil pan drain plug
- 402 Oil pan drain plug O-ring
- 403 Oil pan bolt
- 404 Oil pan gasket
- 405 Crankshaft oil deflector nut
- 406 Crankshaft oil deflector
- 413 Oil pump drive bolt
- 414 Oil pump drive
- 420 Oil pump drive shaft
- 421 Oil pump locating pin
- 422 Oil pump
- 423 Oil pump bolt
- 424 Oil pump drive shaft retainer
- 435 Oil filter
- 714 Oil level sensor O-ring
- 715 Oil level sensor

Figure 1-5 Lower Engine Assembly



TP-6105

- | | | |
|--------------------------------------|-------------------------------------|---------------------------------------|
| 127 Oil gallery plug, top | 135 Camshaft hole plug | 722 Knock sensor heat shield, left |
| 128 Oil gallery plug, front | 136 Oil gallery plug, rear | 723 Knock sensor heat shield bolt |
| 129 Front cover locating pin | 425 Oil filter bypass valve | 724 Block coolant heater |
| 130 Coolant drain plug | 426 Oil cooler fitting | 725 Crankshaft position sensor O-ring |
| 131 Oil gallery plug, side | 434 Oil filter fitting | 726 Crankshaft position sensor |
| 132 Oil gallery plug, left side rear | 719 Knock sensor | 727 Crankshaft position sensor bolt |
| 133 Oil gallery plug, rear | 720 Knock sensor heat shield, right | 728 Oil pressure sensor |
| 134 Oil gallery plug, rear | 721 Knock sensor heat shield bolt | |

Figure 1-6 Engine Block Plugs/Sensors

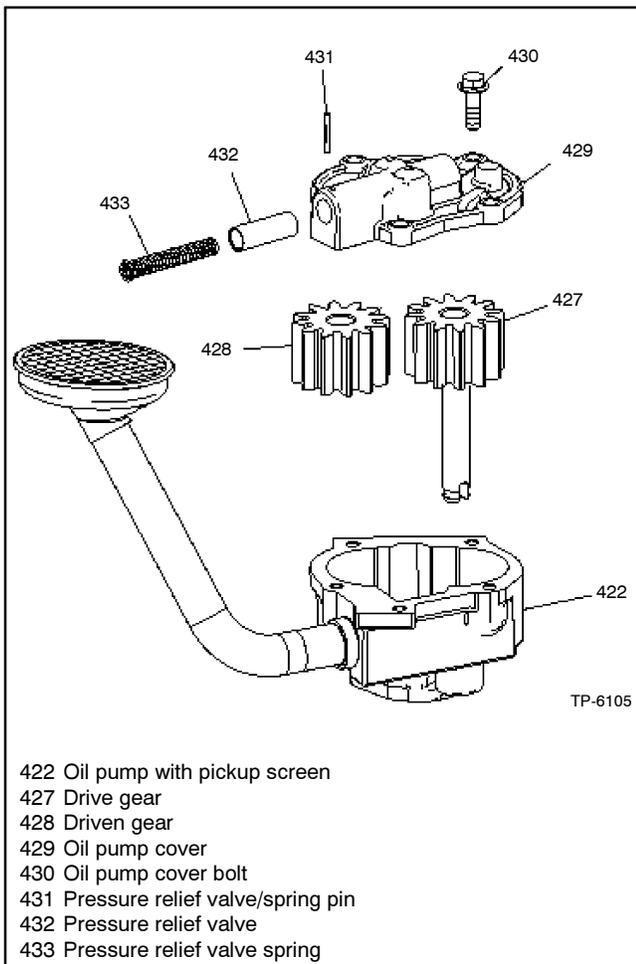
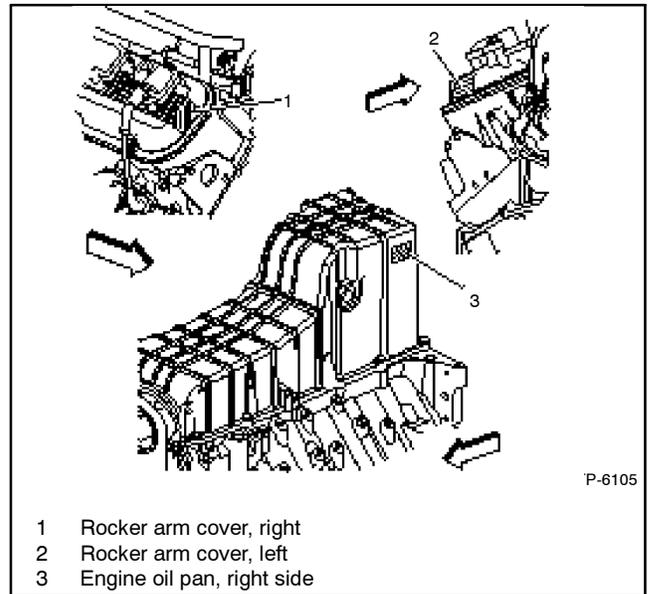


Figure 1-7 Oil Pump Assembly

1.4.2 Engine Identification

The engine identification number is located in three locations. There are labels on the front of the right rocker arm cover, the rear of the left rocker arm cover, and the right side of the engine oil pan. The engine identification number is used to track and identify the engine prior to installation.



Notes

Section 2 Description and Operation

2.1 Crankcase Ventilation System Description

The crankcase ventilation system has no serviceable components; routine maintenance of the system is not required.

A closed crankcase ventilation system is used to provide a more complete scavenging of crankcase vapors. The air cleaner supplies the fresh air through a filter to the crankcase. The crankcase mixes the fresh air blowby gases. This mixture then passes through a pipe/passage located in the intake manifold.

2.2 Drive Belt System Description

The drive belt system consists of the following components:

- Drive belt
- Drive belt tensioner
- Drive belt idler pulley
- Crankshaft balancer pulley
- Accessory drive component mounting brackets
- Accessory drive components:
 - Engine alternator
 - Engine cooling fan, if belt driven
 - Water pump, if belt driven

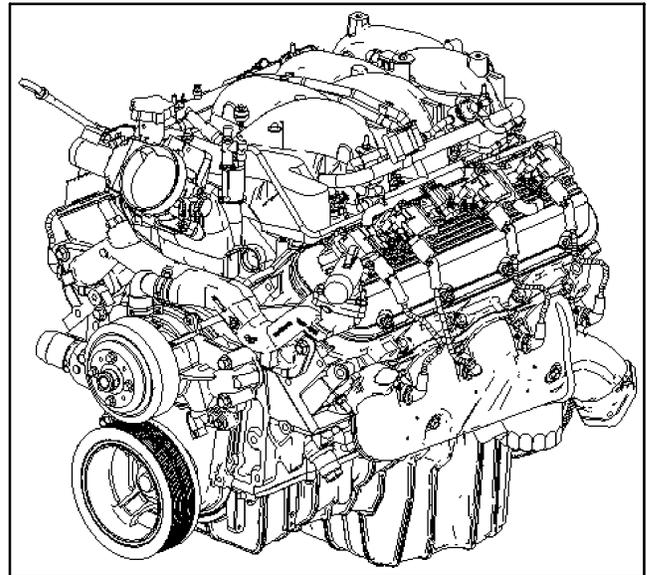
The drive belt system may use one or two belts. The drive belt is thin so that it can bend backwards and has several ribs to match the grooves in the pulleys. There also may be a V-belt style belt used to drive certain accessory drive components. The drive belts are made of different types of rubbers — chloroprene or EPDM — and have different layers or plies 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, used to add wrap to the adjacent pulleys. Some systems use an idler pulley in place of an accessory drive component when the engine is not equipped with the accessory.

2.3 Engine Component Description



2.3.1 Cylinder Block

The engine block is made of cast iron and has eight cylinders arranged in a V-shape with four cylinders in each bank. The engine block is a one-piece casting with the cylinders encircled by coolant jackets.

2.3.2 Cylinder Head

The cylinder heads are made of cast iron and have parent metal intake valve guides and intake valve seats. The cast iron exhaust valve guides and powdered metal valve seats are pressed into the exhaust ports. A spark plug is located between the valves in the side of the cylinder head. The water crossover pipe attaches to the front of each cylinder head.

2.3.3 Camshaft

A steel camshaft is supported by five bearings pressed into the engine block. The camshaft sprocket is mounted to the front of the camshaft and is driven by the crankshaft sprocket through a camshaft timing chain.

Motion from the camshaft is transmitted to the valves by hydraulic roller valve lifters, valve push rods, and ball-pivot type rocker arms. A spiral gear machined into the camshaft near the rear journal drives a shaft assembly that operates the oil pump driveshaft assembly. Ignition synchronization with the camshaft is provided by a physical feature integral with the camshaft sprocket.

2.3.4 Crankshaft

The crankshaft is made of cast nodular iron. The crankshaft is supported by five crankshaft bearings. The crankshaft bearings are retained by the crankshaft bearing caps. The crankshaft bearing caps are machined with the engine block for proper alignment and clearance. The crankshaft bearing caps are retained by two bolts and two studs each. The number five crankshaft bearing at the rear of the engine block is the end thrust bearing. The four connecting rod journals, two rods per journal, are spaced 90 degrees apart. The crankshaft position sensor reluctor ring is pushed onto the rear of the crankshaft. The crankshaft position sensor reluctor is constructed of powdered metal. The reluctor ring has an interference fit onto the crankshaft and an internal keyway for correct positioning.

2.3.5 Pistons and Connecting Rods

The pistons are cast aluminum alloy that use two compression rings and one oil control ring assembly. The piston pins are a floating fit in the pistons and the piston pins are retained by a press fit in the connecting rod assembly. The pistons are coated to create an interference fit into the cylinder. The connecting rods are forged steel and have precision insert type crankpin bearings. The piston and connecting rod is only serviced as an assembly.

2.3.6 Valve Train

The valve train is a ball pivot type. Motion is transmitted from the camshaft through the hydraulic roller valve lifters and tubular valve push rods to the valve rocker arms. The valve rocker arm pivots on a ball to open the valve. The hydraulic roller valve lifters keep all parts of the valve train in constant contact. Each valve lifter acts as an automatic adjuster and maintains zero lash in the valve train. This eliminates the need for periodic valve adjustment. The valve rocker arm stud and nut retains the valve rocker arm and ball seat. The valve rocker arm stud is threaded into the cylinder head. The valve stem seal is pressed over the valve guide of the cylinder head.

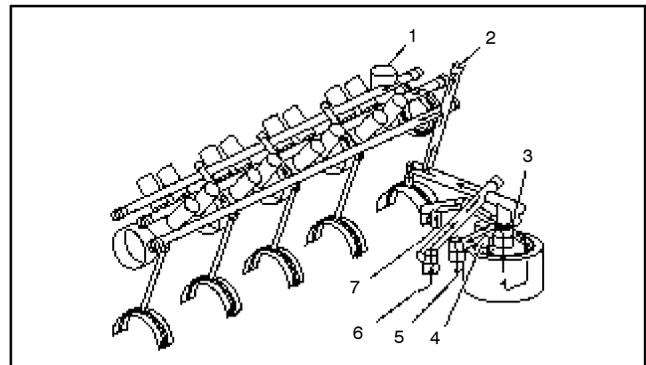
2.3.7 Intake Manifold

The intake manifold is a one-piece design. The intake manifold is made of cast aluminum. The throttle body is attached to the front of the intake manifold. The fuel rail assembly with eight separate fuel injectors is retained to the intake manifold by four studs. The fuel injectors are seated in their individual manifold bores with O-ring seals to provide sealing. A Manifold Absolute Pressure (MAP) sensor is mounted on the top of the intake manifold and sealed by an O-ring seal. The MAP sensor is held in place with a retainer bolt. The evaporative emission canister solenoid is located in the front of the intake manifold. The positive crankcase ventilation (PCV) system is internally cast into the intake manifold. There is not a PCV valve. A splash shield is installed under the intake manifold. The shield prevents hot oil from contacting the bottom of the intake manifold, maintaining air inlet charge density.

2.3.8 Exhaust Manifold

The two exhaust manifolds are constructed of cast stainless steel. The exhaust manifolds direct exhaust gases from the combustion chambers to the exhaust system.

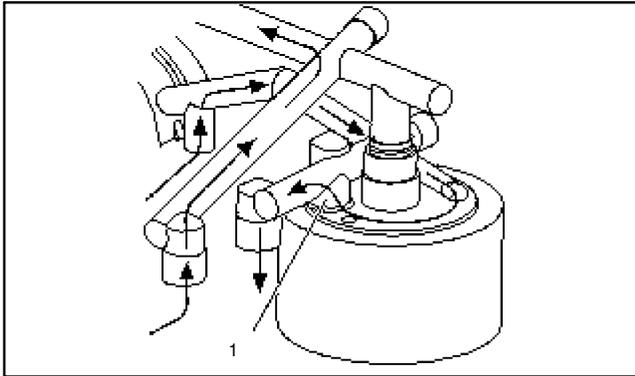
2.4 Lubrication Description



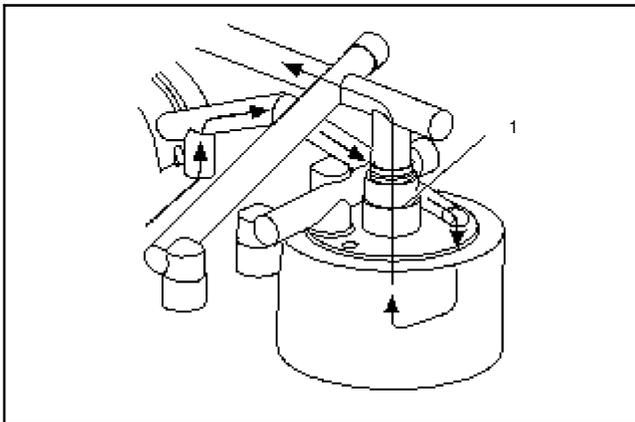
The gear-type oil pump is driven through an extension driveshaft. The extension driveshaft is driven by the oil pump drive, which is gear driven by the camshaft. The oil is drawn from the oil pan through a pickup screen and tube, into the oil pump (7). Pressurized oil flows through the oil filter, into the oil cooler (5), back into the engine (6), up to the oil pressure gauge port (2) and rear crankshaft bearing, and is then distributed to the upper oil galleries. Oil must flow around the oil pump drive (1) to reach the right side valve lifters properly.

The oil is delivered through internal passages to lubricate camshaft and crankshaft bearings and to provide lash control in the hydraulic valve lifters. Oil is metered from the valve lifters through the valve push rods to lubricate the valve rocker arms and ball pivots. Oil returning to the oil pan from the cylinder heads and the front camshaft bearing lubricates the camshaft timing chain, crankshaft, and camshaft sprockets. There are two bypass valves located in the engine block, above the oil filter; the oil filter bypass valve (4) and the oil cooler bypass valve (3).

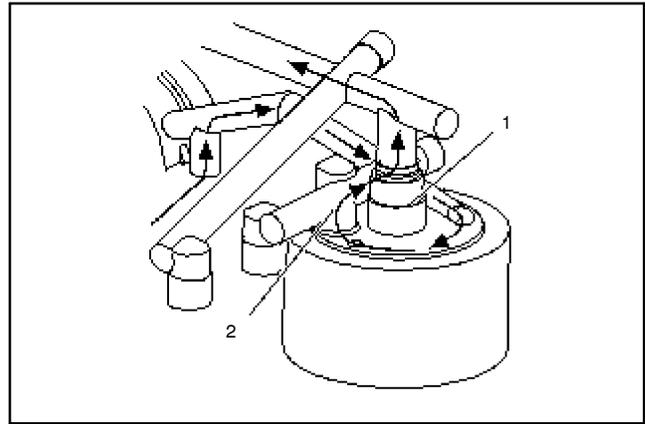
If the oil filter becomes plugged, pressurized oil is diverted around the top of oil filter. The oil filter bypass valve (1) is forced open, allowing the oil to continue on to the oil cooler and engine oil passages. No oil filtration occurs because the oil is not allowed into the oil filter.



If the oil cooler flow becomes blocked, either from a plugged oil cooler or blocked or kinked oil cooler line, the oil cooler bypass valve (1) is forced open, allowing oil to flow directly into the engine oil passages. Oil does not flow into or out of the engine oil cooler.



If both the oil filter and the oil cooler are plugged, the pressurized oil is routed around the top of the oil filter, through the oil filter bypass valve (2), through the oil cooler bypass valve (1), and directly into the engine oil passages. Lubrication still occurs, but the oil is not filtered or directed through the oil cooler.



2.5 Cleanliness and Care

- Throughout this section, it should be understood that proper cleaning and protection of machined surfaces and friction areas is part of the repair procedure. This is considered standard shop practice even if not specifically stated.
- When any internal engine parts are serviced, care and cleanliness is important.
- When components are removed for service, they should be marked, organized, or retained in a specific order for reassembly.
- At the time of installation, components should be installed in the same location and with the same mating surface as when removed.
- An engine is a combination of many machined, honed, polished, and lapped surfaces with tolerances that are measured in millimeters or thousandths of an inch. These surfaces should be covered or protected to avoid component damage.
- A liberal coating of clean engine oil should be applied to friction areas during assembly.
- Proper lubrication will protect and lubricate friction surfaces during initial operation.

2.6 Separating Parts

Important: Many internal engine components will develop specific wear patterns on their friction surfaces.

When disassembling the engine, separate, mark, or organize internal components in a way to ensure reinstallation to original location and position.

Separate, mark, or organize the following components:

- Piston to the specific cylinder bore
- Piston rings to the piston
- Connecting rod to the crankshaft journal
- Connecting rod to the bearing cap
- Crankshaft and connecting rod bearings
- Camshaft and valve lifters
- Valve lifters, guides, push rods, pivot supports, and rocker arms
- Valve to the valve guide
- Valve spring and shim to the cylinder head location
- Engine block crankshaft bearing cap location and direction
- Oil pump drive and driven gears

2.7 Engine Gasket Replacement

2.7.1 Reusing Gasket 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.

2.7.2 Separating Components

- Use a rubber mallet to separate components.
- Bump the part sideways 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.

2.7.3 Cleaning Gasket Surfaces

- Use care to avoid gouging or scraping the sealing surfaces.
- Use a plastic or wood scraper to remove all the sealant from the components. Do not use any other method or technique to remove the sealant or the gasket material from a part.
- Do not use abrasive pads, sand paper, or power tools to clean the gasket surfaces. These methods of cleaning can cause damage to the component sealing surfaces.

- Abrasive pads also produce a fine grit that the oil filter cannot remove from the engine oil. This fine grit is an abrasive and can cause internal engine damage.

2.7.4 Assembling Components

- Assemble components using only the sealant (or equivalent) specified in the service procedure.
- Sealing surfaces must be clean and free of debris or oil.
- Specific components such as crankshaft oil seals or valve stem oil seals may require lubrication during assembly.
- Components requiring lubrication will be identified in the service procedure.
- Apply only the amount of sealant specified in the service procedure to a component.
- Do not allow the sealant to enter into any blind threaded holes, as the sealant may prevent the fastener from clamping properly or cause component damage when tightened.

Important: Do not overtighten the fasteners.
- Tighten the fasteners to the proper specifications.

2.8 RTV and Anaerobic Sealer Use

2.8.1 Sealant Types

Important: Use the correct sealant and amount of sealant in the proper location to prevent oil leaks, coolant leaks, or loosening of the fasteners. *Do not* interchange the sealants. Use only the sealant (or equivalent) as specified in the service procedure.

The following two major types of sealant are commonly used in engines:

- Aerobic sealant—Room Temperature Vulcanizing (RTV)
- Anaerobic sealant, which include the following:
 - Gasket eliminator
 - Pipe
 - Thread-lock

2.8.2 Aerobic Type Room Temperature Vulcanizing Sealant

Aerobic type RTV sealant cures when exposed to air. This type of sealant is used where two components (such as the intake manifold and the engine block) are assembled together.

Use the following information when using RTV sealant:

- Do not use RTV sealant in areas where extreme temperatures are expected. These areas include:
 - The exhaust manifold
 - The head gasket
 - Any other surfaces where a different type of sealant is specified in the service procedure
- Always follow all the safety recommendations and the directions that are on the RTV sealant container.
- Use a plastic or wood scraper to remove all the RTV sealant from the plastic and aluminum components.

Important: Do not allow the RTV sealant to enter any blind threaded holes as it may prevent the fasteners from clamping properly or cause damage when the fastener is tightened.

- The surfaces to be sealed must be clean and dry.
- Use a RTV sealant bead size as specified in the service procedure.
- Apply the RTV sealant bead to the inside of any bolt holes areas.
- Assemble the components while the RTV sealant is still wet to the touch (within 3 minutes). Do not wait for the RTV sealant to skin over.
- Tighten the fasteners in sequence (if specified) and to the proper torque specifications. *Do not* overtighten the fasteners.

2.8.3 Anaerobic Type Gasket Eliminator Sealant

Anaerobic type gasket eliminator sealant cures in the absence of air. This type of sealant is used where two rigid parts (such as castings) are assembled together. When two rigid parts are disassembled and no sealant or gasket is readily noticeable, the two parts were

probably assembled using an anaerobic type gasket eliminator sealant.

Use the following information when using gasket eliminator sealant:

- Always follow all the safety recommendations and directions that are on the gasket eliminator sealant container.
- Apply a continuous bead of gasket eliminator sealant to one flange. The surfaces to be sealed must be clean and dry.

Important: Do not allow the gasket eliminator sealant to enter any blind threaded holes, as the gasket eliminator sealant may prevent the fasteners from clamping properly, seating properly, or cause damage when the fastener tightened.

- Apply the gasket eliminator sealant evenly to get a uniform thickness of the gasket eliminator sealant on the sealing surface.

Important: Gasket eliminator sealed joint fasteners that are partially torqued and the gasket eliminator sealant allowed to cure more than 5 minutes may result in incorrect shimming and sealing of the joint.

- Tighten the fasteners in sequence (if specified) and to the proper torque specifications. *Do not* overtighten the fasteners.
- After properly tightening the fasteners, remove the excess gasket eliminator sealant from the outside of the joint.

2.8.4 Anaerobic Type Thread-Lock Sealant

Anaerobic type thread-lock sealant cures in the absence of air. This type of sealant is used for thread-locking and sealing of bolts, fittings, nuts, and studs. This type of sealant cures only when confined between two close fitting metal surfaces.

Use the following information when using thread-lock sealant:

- Always follow all safety recommendations and directions on the thread-lock sealant container.
- The threaded surfaces to be sealed must be clean and dry.

- Apply the thread-lock sealant as specified on the thread-lock sealant container.

Important: Fasteners that are partially torqued and the thread-lock sealant allowed to cure more than 5 minutes may result in incorrect clamp load of assembled components.

- Tighten the fasteners in sequence (if specified) and to the proper torque specifications. *Do not* overtighten the fasteners.

2.8.5 Anaerobic Type Pipe Sealant

Anaerobic type pipe sealant cures in the absence of air and remains pliable when cured. This type of sealant is used where two parts are assembled together and require a leakproof joint.

Use the following information when using pipe sealant:

- Do not use pipe sealant in areas where extreme temperatures are expected. These areas include:
 - The exhaust manifold
 - The head gasket
 - Surfaces where a different sealant is specified
- Always follow all the safety recommendations and the directions that are on the pipe sealant container.
- The surfaces to be sealed must be clean and dry.
- Use a pipe sealant bead of the size or quantity as specified in the service procedure.

Notice: Do not allow the sealant to enter a blind hole. The sealant may prevent the fastener from achieving proper clamp load, cause component damage when the fastener is tightened, or lead to component failure.

- Apply the pipe sealant bead to the inside of any bolt hole areas.
- Apply a continuous bead of pipe sealant to one sealing surface.
- Tighten the fasteners in sequence (if specified) and to the proper torque specifications. *Do not* overtighten the fasteners.

2.9 Tools and Equipment

Special tools are listed and illustrated throughout this section with a complete listing at the end of the manual. These tools (or their equivalents) are specially designed to quickly and safely accomplish the operations for

which they are intended. The use of these special tools will also minimize possible damage to engine components. Some precision measuring tools are required for inspection of certain critical components. Torque wrenches and a torque angle meter are necessary for the proper tightening of various fasteners.

To properly service the engine assembly, the following items should be readily available:

- Approved eye protection and safety gloves
- A clean, well-lit, work area
- A suitable parts cleaning tank
- A compressed air supply
- Trays or storage containers to keep parts and fasteners organized
- An adequate set of hand tools
- Approved engine repair stand
- An approved engine lifting device that will adequately support the weight of the components

2.10 Thread Repair

Tools Required: J 39345 Thread Repair Kit

The following procedure is used to accomplish proper and durable thread repairs in the cylinder head and the cylinder block, using *J 39345*.

Important: Take appropriate precautions to assure that machining chips will not remain inside the engine. For example, block all intake passages, oil drainback holes, and exhaust passages with a towel or tape before performing thread repairs.

1. Select the proper size drill as indicated in the schematic charts found in the thread repair specifications for the hole being repaired.

2. Drill out the damaged threads to the original depth or completely through for through holes.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

3. Apply compressed air, with a shop towel wrapped around the air spout, to retain the chips forced out of the hole.

4. Select the correct size tap, using the appropriate chart for the hole being repaired.

5. Coat the tap and the hole with spray machining oil.

6. Tap the hole to the original depth. To clean the threads, reverse the rotation of the tap periodically.

7. Use solvent to clean out all of the chips.
8. Apply compressed air, with a shop towel wrapped around the air spout, to retain the chips forced out of the hole.
9. Tap the hole again to clean the threads. The tap should thread in with little resistance.

Important: Make sure all of the chips are cleared from the hole.

10. Use solvent to clean out all of the chips.
11. Apply compressed air, with a shop towel wrapped around the air spout, to retain the chips forced out of the hole.
12. Use a flashlight to confirm that all of the chips are removed from the hole.
13. Continue to clean the hole until all of the chips are cleared.
14. Install the heli-coil insert as follows:
 - a. To determine the correct size installation tool and length insert, refer to the appropriate picture and chart.
 - b. Screw the insert on the mandrel of the installation tool until the driving tang is fully engaged in the driving contour.
 - c. Coat the insert with spray machining oil.
 - d. Install the insert as follows:
 - Slide the prewinder over the mandrel and insert.
 - Rotate the mandrel clockwise until one or two threads of the insert are threaded into the prewinder.
 - Place the insert in position on the threaded hole being repaired.
 - Rotate the mandrel clockwise until the insert is flush with the top surface of the threaded hole.
 - Remove the prewinder except when repairing cylinder head bolts.
 - Continue to install the insert until reaching the original thread depth.
 - Remove the mandrel.
 - e. Remove the driving tang from the thread insert as follows. Remove the tang to allow passage of the fastener through the insert.

- Place the square end of the punch, no chamfer, on the tang after installation.
- Strike the punch sharply with the hammer. The tang will break off at the notch.

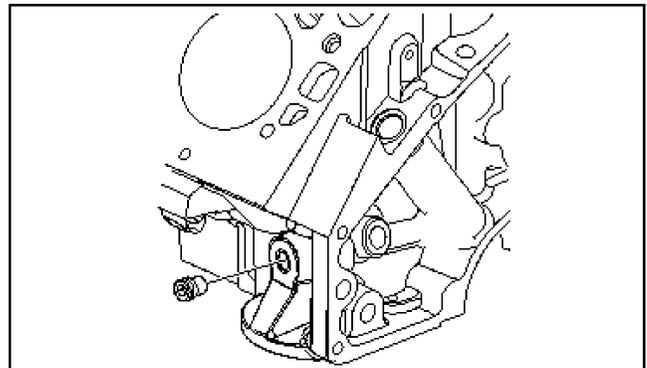
15. Clean the hole using compressed air. Take appropriate steps to assure that chips are not blown into the engine.

2.11 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. Repair or replace components not within manufacturer's specification.
- 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.

2.12 Engine Prelubing

Tools Required: J 45299 Engine Preluber



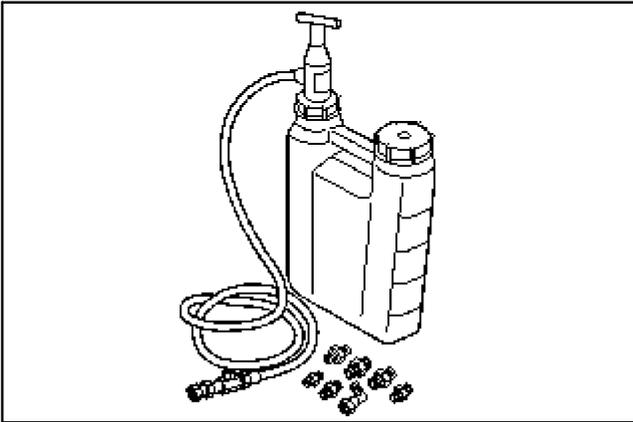
Important: A constant and continuous flow of clean engine oil is required to properly prime the engine. Be sure to use an approved engine oil as specified in the owners manual.

1. Remove the engine oil filter, fill with clean engine oil.

Notice: Refer to Fastener Notice in Cautions and Notices.

2. Install the oil filter. Tighten the oil filter to 38 Nm (28 ft. lb.).

3. Locate the oil gallery plug on the left side of the engine block above the oil filter housing.
4. Install the 1/4-18 adapter Part No. 509373.



5. Install the flexible hose to the adapter and open the valve.
6. Pump the handle on *J 45299* to flow a minimum of 1–1.9 L (1–2 qt.) of engine oil. Observe the flow of engine oil through the flexible hose and into the engine assembly.
7. Close the valve and remove the flexible hose and adapter from the engine.
8. Install the gallery plug to the engine. Tighten the oil gallery plug to 30 Nm (22 ft. lb.).
9. Top-off the engine oil to the proper level.

Section 3 Diagnostic Information and Procedures

3.1 Diagnostic Starting Point, Engine Mechanical

Begin the system diagnosis by reviewing Section 1.4.1, Disassembled Views, Section 2.3, Engine Component Description, Section 2.4, Lubrication Description, and Section 2.2, Drive Belt System Description. Reviewing the description and operation information will help determine the correct symptom diagnostic procedure when a malfunction exists. Reviewing the description and operation information will also help determine if the condition described by the customer is normal operation. See Section 3.2, Symptoms, Engine Mechanical, to identify the correct procedure for diagnosing the system and where the procedure is located.

3.2 Symptoms, Engine Mechanical

3.2.1 Strategy Based Diagnostics

1. Perform a diagnostic system check before using the symptom tables, if applicable.
2. Review the system operations to familiarize yourself with system functions. See Section 1.4.1, Disassembled Views, Section 2.3, Engine Component Description, Section 2.2, Drive Belt System Description, and Section 2.4, Lubrication Description.

All diagnosis on an engine should follow a logical process. Strategy-based diagnostics is a uniform approach for repairing all systems. The diagnostic flow may always be used 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 in General Information.

3.2.2 Visual/Physical Inspection

- Inspect for aftermarket devices that could affect the operation of the Engine.
- Inspect the easily accessible or visible system components for obvious damage or conditions that 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 warmup 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.

3.2.3 Intermittent

Test the engine under the same conditions that the customer reported to verify the system is operating properly.

3.3 Base Engine Misfire Without Internal Engine Noises

Cause	Correction
<p>Abnormalities such as severe cracking, bumps, or missing areas in the accessory drive belt.</p> <p>Abnormalities in the accessory drive system and/or components may cause engine rpm variations and lead to a misfire diagnostic trouble code (DTC). A misfire code may be present without an actual misfire condition.</p>	<p>Replace the drive belt. See Section 9.1.1, Drive Belt Replacement, Accessory.</p>
<p>Worn, damaged, or misaligned accessory drive components or excessive pulley runout.</p> <p>A misfire code may be present without an actual misfire condition.</p>	<p>Inspect the components, repair or replace as required.</p>
<p>Loose or improperly installed engine flywheel or crankshaft balancer.</p> <p>A misfire code may be present without an actual misfire condition.</p>	<p>Repair or replace the flywheel and/or balancer as required. See Section 6.6.1, Engine Flywheel Replacement or Section 6.1.1, Crankshaft Balancer Replacement.</p>
<p>Restricted exhaust system.</p> <p>A severe restriction in the exhaust flow can cause significant loss of engine performance and may set a DTC. Possible causes of restrictions include collapsed or dented pipes or plugged mufflers.</p>	<p>Repair or replace as required.</p>
<p>Improperly installed or damaged vacuum hoses.</p>	<p>Repair or replace as required.</p>
<p>Improper sealing between the intake manifold and cylinder heads or throttle body.</p>	<p>Replace the intake manifold, gaskets, cylinder heads, and/or throttle body as required.</p>
<p>Improperly installed or damaged MAP sensor.</p> <p>The sealing grommet of the MAP sensor should not be torn or damaged.</p>	<p>Repair or replace the MAP sensor as required.</p>
<p>Worn or loose rocker arms.</p>	<p>Repair or replace the valve rocker arms as required.</p>
<p>Worn or bent push rods.</p>	<p>Replace the push rods.</p>
<p>Sticking valves.</p> <p>Carbon buildup on the valve stem can cause the valve not to close properly.</p>	<p>Repair or replace as required.</p>
<p>Excessively worn or misaligned timing chain.</p>	<p>Repair or replace the timing chain, camshaft retainer, and sprockets as required.</p>
<p>Worn camshaft lobes.</p>	<p>Replace the camshaft and valve lifters.</p>
<p>Excessive oil pressure.</p> <p>A lubrication system with excessive oil pressure may lead to excessive valve lifter pump-up and loss of compression.</p>	<ul style="list-style-type: none"> • Perform an oil pressure test. See Section 3.18, Oil Pressure Diagnosis and Testing. • Repair or replace the oil pump as required.
<p>Faulty cylinder head gaskets and/or cracking or other damage to the cylinder heads and engine block cooling system passages.</p> <p>Coolant consumption may or may not cause the engine to overheat.</p>	<ul style="list-style-type: none"> • Inspect for spark plugs saturated by coolant. See Spark Plug Inspection in Engine Controls. • Perform a pressure test to the cooling system. See Loss of Coolant in Engine Cooling. • Inspect the cylinder heads, engine block, and/or head gaskets. See Section 3.13, Coolant in Combustion Chamber. • Repair or replace as required.
<p>Worn piston rings.</p> <p>Oil consumption may or may not cause the engine to misfire.</p>	<ul style="list-style-type: none"> • Inspect the spark plugs for oil deposits. See Spark Plug Inspection in Engine Controls. • Inspect the cylinders for a loss of compression. See Section 3.15, Engine Compression Test. • Perform cylinder leakdown and compression testing to identify the cause. See Section 3.16, Cylinder Leakage Test. • Repair or replace as required.
<p>A damaged crankshaft reluctor wheel.</p> <p>A damaged crankshaft reluctor wheel can result in different symptoms depending on the severity and location of the damage.</p> <ul style="list-style-type: none"> • Systems with electronic communications, DIS or coil per cylinder, and severe reluctor ring damage may exhibit periodic loss of crankshaft position, stop delivering a signal, and then resync the crankshaft position. • Systems with electronic communication, DIS or coil per cylinder, and slight reluctor ring damage may exhibit no loss of crankshaft position and no misfire may occur. However, a P0300 DTC may be set. • Systems with mechanical communications and severe reluctor ring damage may cause additional pulses and effect fuel and spark delivery to the point of generating a P0300 DTC or P0336. 	<p>Replace the sensor and/or crankshaft reluctor wheel as required.</p>

3.4 Base Engine Misfire With Abnormal Internal Lower Engine Noises

Cause	Correction
Abnormalities such as severe cracking, bumps, or missing areas in the accessory drive belt. Abnormalities in the accessory drive system 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.	Replace the drive belt. See Section 9.1.1, Drive Belt Replacement, Accessory.
Worn, damaged, or misaligned accessory drive components or excessive pulley runout. A misfire code may be present without an actual misfire condition.	Inspect the components, repair or replace as required.
Loose or improperly installed engine flywheel or crankshaft balancer. A misfire code may be present without an actual misfire condition.	Repair or replace the flywheel and/or balancer as required. See Section 6.6.1, Engine Flywheel Replacement or Section 6.1.1, Crankshaft Balancer Replacement.
Worn piston rings. Oil consumption may or may not cause the engine to misfire.	<ul style="list-style-type: none"> Inspect the spark plugs for oil deposits. See Spark Plug Inspection in Engine Controls. Inspect the cylinders for a loss of compression. See Section 3.15, Engine Compression Test. Perform cylinder leakdown and compression testing to identify the cause. See Section 3.16, Cylinder Leakage Test. Repair or replace as required.
Worn crankshaft thrust bearings. Severely worn thrust surfaces on the crankshaft and/or thrust bearing may permit fore and aft movement of the crankshaft and create a DTC without an actual misfire condition.	<ul style="list-style-type: none"> Check the crankshaft endplay. Replace the crankshaft and/or bearings as required.

3.5 Base Engine Misfire With Abnormal Valve Train Noise

Cause	Correction
Worn or loose rocker arms.	Repair or replace the valve rocker arms as required.
Worn or bent push rods.	Replace the push rods.
Sticking valves. Carbon buildup on the valve stem can cause the valve not to close properly.	Repair or replace as required.
Excessively worn or misaligned timing chain.	Repair or replace the timing chain, camshaft retainer, and sprockets as required.
Worn camshaft lobes.	Replace the camshaft and valve lifters.
Sticking lifters.	Replace as required.

3.6 Base Engine Misfire With Coolant Consumption

Cause	Correction
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.	<ul style="list-style-type: none"> Inspect for spark plugs saturated by coolant. See Spark Plug Inspection in Engine Controls. Perform a pressure test to the cooling system. See Loss of Coolant in Engine Cooling. Perform cylinder leakdown test. See Section 3.16, Cylinder Leakage Test. Inspect the cylinder heads and engine block for damage to the coolant passages and/or a faulty head gasket. See Section 3.13, Coolant in Combustion Chamber. Repair or replace as required.

3.7 Base Engine Misfire With Excessive Oil Consumption

Cause	Correction
Leaking intake gaskets.	Repair or replace the intake manifold bolts and/or gaskets as required.
Worn valves, valve guides, and/or valve stem oil seals.	<ul style="list-style-type: none"> Inspect the spark plugs for oil deposits. See Spark Plug Inspection in Engine Controls. Repair or replace as required.
Worn piston rings. Oil consumption may or may not cause the engine to misfire.	<ul style="list-style-type: none"> Inspect the spark plugs for oil deposits. See Spark Plug Inspection in Engine Controls. Inspect the cylinders for a loss of compression. See Section 3.15, Engine Compression Test. Perform cylinder leakdown and compression testing to identify the cause. See Section 3.16, Cylinder Leakage Test. Repair or replace as required.

3.8 Engine Noise on Startup, Only Lasting a Few Seconds

Cause	Correction
<p>Important:: A cold piston knock that disappears in 1.5 minutes should be considered acceptable. A cold engine knock usually disappears when the specific cylinder's secondary ignition circuit is grounded out during diagnosis.</p> <p>A light rattle/tapping noise may indicate a valve train, upper engine, concern, or a low rumble/knocking may indicate a crankshaft or piston, lower engine, concern.</p>	
Incorrect oil level. Too high an oil level will cause aeration within the oil.	Add or remove oil as required to achieve proper level.
Incorrect oil filter without antidrainback feature.	Install the correct oil filter.
Incorrect oil viscosity.	<ul style="list-style-type: none"> Drain the oil. Install the correct viscosity oil.
High valve lifter leakdown rate.	Replace the valve lifters as required.
Worn crankshaft thrust bearing.	<ul style="list-style-type: none"> Check the crankshaft endplay. Inspect the thrust bearing and crankshaft. Repair or replace as required.
Damaged or faulty oil filter bypass valve.	<ul style="list-style-type: none"> Inspect the oil filter bypass valve for proper operation. Repair or replace as required.

3.9 Upper Engine Noise, Regardless of Engine Speed

Cause	Correction
<p>Important: A cold piston knock that disappears in 1.5 minutes should be considered acceptable. A cold engine knock usually disappears when the specific cylinder's secondary ignition circuit is grounded out during diagnosis.</p> <p>A light rattle/tapping noise may indicate a valve train, upper engine, concern.</p>	
Plugged oil filter.	Replace the oil filter.
Low oil pressure.	<ul style="list-style-type: none"> • Verify proper oil level. • Perform an oil pressure test. See Section 3.18, Oil Pressure Diagnosis and Testing. • Repair or replace as required.
Loose and/or worn valve rocker arm attachments.	<ul style="list-style-type: none"> • Inspect the valve rocker arm stud, nut, or bolt. • Repair or replace as required.
Worn valve rocker arm.	Replace the valve rocker arm.
Worn push rod guide plate.	Replace as required.
Bent or damaged push rod.	<p>Inspect the following components and replace as required:</p> <ul style="list-style-type: none"> • Valve rocker arm. • Valve push rod. • Valve lifter.
Improper lubrication to the valve rocker arms.	<p>Inspect the following components and replace as required:</p> <ul style="list-style-type: none"> • Valve rocker arm. • Valve push rod. • Valve lifter. • Oil filter bypass valve. • Oil pump and pump screen. • Engine block oil galleries.
Broken valve spring.	Replace the valve spring.
Worn and/or damaged valve rotators.	Replace the valve rotators as required.
Worn or dirty valve lifters.	Replace the valve lifters.
Stretched or broken timing chain and/or damaged sprocket teeth.	Replace the timing chain and sprockets.
Worn engine camshaft lobes.	<ul style="list-style-type: none"> • Inspect the engine camshaft lobes. • Replace the camshaft and valve lifters as required.
Worn valve guides or valve stems.	<p>Inspect the following components and replace as required:</p> <ul style="list-style-type: none"> • Valves. • Valve guides.
<p>Stuck valves.</p> <p>Carbon on the valve stem or valve seat may cause the valve to stick.</p>	<p>Inspect the following components and replace as required:</p> <ul style="list-style-type: none"> • Use GM top engine cleaner, GM P/N1050002 (Canadian P/N992872) to eliminate the carbon deposits following manufacturer's instructions. • Valves. • Valve guides.

3.10 Lower Engine Noise, Regardless of Engine Speed

Cause	Correction
<p>Important: A cold piston knock that disappears in 1.5 minutes should be considered acceptable. A cold engine knock usually disappears when the specific cylinder's secondary ignition circuit is grounded out during diagnosis.</p> <p>A light rattle/knocking noise may indicate a crankshaft or piston, lower engine, concern.</p>	
Low oil pressure.	<ul style="list-style-type: none"> • Verify proper oil level. • Perform an oil pressure test. See Section 3.18, Oil Pressure Diagnosis and Testing. • Repair or replace damaged components as required.
Worn accessory drive components. Abnormalities such as severe cracking, bumps, or missing areas in the accessory drive belt and/or misalignment of system components.	<ul style="list-style-type: none"> • Inspect the accessory drive system. • Repair or replace as required.
Loose or damaged crankshaft balancer.	<ul style="list-style-type: none"> • Inspect the crankshaft balancer. • Repair or replace as required.
Detonation or spark knock.	Verify the correct operation of the ignition controls system. See Detonation/Spark Knock in Engine Controls.
Loose or damaged flywheel.	Repair or replace the flywheel.
Damaged oil pan, contacting the oil pump screen. An oil pan that has been damaged may improperly position the oil pump screen, preventing proper oil flow to the oil pump.	<ul style="list-style-type: none"> • Inspect the oil pan. • Inspect the oil pump screen. • Repair or replace as required.
Oil pump screen loose, damaged, or restricted.	<ul style="list-style-type: none"> • Inspect the oil pump screen. • Repair or replace as required.
Excessive piston-to-cylinder bore clearance.	<ul style="list-style-type: none"> • Inspect the piston and cylinder bore. • Repair as required.
Excessive piston pin-to-bore clearance.	<ul style="list-style-type: none"> • Inspect the piston, piston pin, and the connecting rod. • Repair or replace as required.
Excessive connecting rod bearing clearance.	Inspect the following components and repair as required: <ul style="list-style-type: none"> • Connecting rod bearings. • Connecting rods. • Crankshaft. • Crankshaft journals.
Excessive crankshaft bearing clearance.	Inspect the following components and repair as required: <ul style="list-style-type: none"> • Crankshaft bearings. • Crankshaft journals.
Incorrect piston, piston pin, and connecting rod installation.	<ul style="list-style-type: none"> • Verify that pistons, piston pins, and connecting rods are installed correctly. • Repair as required.

3.11 Engine Noise Under Load

Cause	Correction
<p>Important: A cold piston knock that disappears in 1.5 minutes should be considered acceptable. A cold engine knock usually disappears when the specific cylinder's secondary ignition circuit is grounded out during diagnosis.</p> <p>A light rattle/knocking noise may indicate a crankshaft or piston, lower engine, concern.</p>	
Low oil pressure.	<ul style="list-style-type: none"> • Perform an oil pressure test. See Section 3.18, Oil Pressure Diagnosis and Testing. • Repair or replace as required.
Detonation or spark knock.	Verify the correct operation of the ignition controls system. See Detonation/Spark Knock in Engine Controls.
Cracked flywheel.	<ul style="list-style-type: none"> • Inspect the flywheel bolts and flywheel. • Repair as required.
Excessive connecting rod bearing clearance.	Inspect the following components and repair as required: <ul style="list-style-type: none"> • Connecting rod bearings. • Connecting rods. • Crankshaft.
Excessive crankshaft bearing clearance.	Inspect the following components and repair as required: <ul style="list-style-type: none"> • Crankshaft bearings. • Crankshaft journals. • Cylinder block crankshaft bearing bore.

3.12 Engine Will Not Crank, Crankshaft Will Not Rotate

Cause	Correction
Seized accessory drive system component or starter motor.	<ol style="list-style-type: none"> 1. Remove the accessory drive belt or belts and/or starter motor. 2. Rotate crankshaft by hand at the balancer or flywheel location.
Broken timing chain.	<ul style="list-style-type: none"> • Inspect the timing chain, gears, and crankshaft sprocket locating pin. • Repair as required.
Seized camshaft.	<ul style="list-style-type: none"> • Inspect camshaft and camshaft bearings. • Repair as required.
Bent valve in cylinder head.	<ul style="list-style-type: none"> • Inspect valves and cylinder heads. • Repair as required.
Hydraulically locked cylinder: <ul style="list-style-type: none"> • Coolant/antifreeze in cylinder. • Oil in cylinder. • Fuel in cylinder. 	<ol style="list-style-type: none"> 1. Remove spark plugs and check for fluid. 2. Inspect for sticking fuel injector. 3. Inspect for broken head gasket or gaskets. 4. Inspect for cracked engine block or cylinder head.
Material in cylinder: <ul style="list-style-type: none"> • Broken valve. • Piston material. • Foreign material. 	<ul style="list-style-type: none"> • Inspect cylinder and cylinder head for damaged components and/or foreign materials. • Repair or replace as required.
Seized crankshaft or connecting rod bearings.	<ul style="list-style-type: none"> • Inspect crankshaft and connecting rod bearings. • Repair as required.
Bent or broken connecting rod.	<ul style="list-style-type: none"> • Inspect connecting rods. • Repair as required.
Broken crankshaft.	<ul style="list-style-type: none"> • Inspect crankshaft. • Repair as required.

3.13 Coolant in Combustion Chamber

Cause	Correction
<p>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 that may cause engine component damage.</p> <ol style="list-style-type: none"> 1. A slower than normal cranking speed may indicate coolant entering the combustion chamber. See Section 3.12, Engine Will Not Crank, Crankshaft Will Not Rotate. 2. Remove the spark plugs and inspect for spark plugs saturated by coolant or coolant in the cylinder bore. 3. Inspect by performing a cylinder leakdown test. During this test, excessive air bubbles within the coolant may indicate a faulty gasket or damaged component. See Section 3.16, Cylinder Leakage Test. 4. 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. See Section 3.15, Engine Compression Test. 	
Faulty cylinder head gasket.	Replace the head gasket and components as required. See Section 4.7.4, Cylinder Head Cleaning and Inspection, and Section 4.7.6, Cylinder Head Replacement, Left, or Section 4.7.9, Cylinder Head Replacement, Right.
Cracked cylinder head.	Replace the cylinder head and gasket.
Cracked engine block.	Replace the components as required.
Cylinder head or engine block porosity.	Replace the components as required.
Warped cylinder head.	Machine the cylinder head to the proper flatness, if applicable, and replace the cylinder head gasket. See Section 4.7.4, Cylinder Head Cleaning and Inspection.
Defective external oil cooler.	Replace the components as required.

3.14 Coolant in Engine Oil

Cause	Correction
<p>Definition: Foamy or discolored oil or an engine oil overfill condition may indicate coolant in the engine crankcase. Low coolant levels, an inoperative cooling fan, or a faulty thermostat may lead to an overtemperature condition that may cause engine component damage. Contaminated engine oil and oil filter should be changed.</p> <ol style="list-style-type: none"> 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. See Section 3.10, Lower Engine Noise, Regardless of Engine Speed. 2. Inspect by performing a cylinder leakdown test. During this test, excessive air bubbles within the coolant may indicate a faulty gasket or damaged component. See Section 3.16, Cylinder Leakage Test. 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. See Section 3.15, Engine Compression Test. 	
Faulty cylinder head gasket.	Replace the head gasket and components as required. See Section 4.7.4, Cylinder Head Cleaning and Inspection, and Section 4.7.6, Cylinder Head Replacement, Left, or Section 4.7.9, Cylinder Head Replacement, Right.
Cracked cylinder head.	Replace the cylinder head and gasket.
Cracked cylinder liner or engine block.	Replace the components as required.
Cylinder head or engine block porosity.	Replace the components as required.
Cylinder head, block, or manifold porosity.	Replace the components as required.
Warped cylinder head.	Machine the cylinder head to the proper flatness, if applicable, and replace the cylinder head gasket. See Section 4.7.4, Cylinder Head Cleaning and Inspection.
Faulty external engine oil cooler.	Replace the components as required.

3.15 Engine Compression Test

1. Disconnect the ignition coil wire harness connector at the front of the engine on the left cylinder bank and at the rear of the engine at the right cylinder bank.
2. Disconnect the fuel injector electrical harness connector at the rear of the intake manifold.
3. Remove the spark plugs.
4. Block the throttle plate wide open.
5. Charge the battery if the battery is not fully charged.
6. Start with the compression gauge at zero. Crank the engine through four compression strokes (four puffs).
7. Make the compression check the same for each cylinder. Record the reading.

The minimum compression in any one cylinder should not be less than 70% of the highest cylinder. No cylinder should read less than 690 kPa (100 psi). For example, if the highest pressure in any one cylinder is 1035 kPa (150 psi), the lowest allowable pressure for any other cylinder would be 725 kPa (105 psi).

$$1035 \times 70\% = 725 \quad (150 \times 70\% = 105)$$

8. If some cylinders have low compression, inject approximately 15 ml (1 tablespoon) of engine oil into the combustion chamber through the spark plug hole.
 - 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 then builds up with the following strokes but does not reach normal. Compression improves considerably when you add oil.
 - Valves Leaking—Compression is low on the first stroke. Compression usually does not build up on the following strokes. Compression does not improve much when you add oil.
 - If two adjacent cylinders have lower than normal compression, and injecting oil into the cylinders does not increase the compression, the cause may be a head gasket leaking between the two cylinders.

3.16 Cylinder Leakage Test

Tools Required:

J 35667-A Cylinder Head Leakdown Tester or equivalent

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 or burnt valves
- Broken valve springs
- Stuck valve lifters
- Incorrect valve lash
- Damaged piston
- Worn piston rings
- Worn or scored cylinder bore
- Damaged cylinder head gasket
- Cracked or damaged cylinder head
- Cracked or damaged engine block

Caution: See Battery Disconnect Caution in Cautions and Notices.

1. Disconnect the battery ground negative cable.
2. Remove the spark 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-A* or equivalent.

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

5. Apply shop air pressure to *J 35667-A* and adjust according to the manufacturer's instructions.
6. Record the cylinder leakage value. Cylinder leakage that exceeds 25% is considered excessive and may require component service. In excessive leakage situations, inspect for the following conditions:
 - Air leakage sounds at the throttle body or air inlet hose that may indicate a worn or burnt intake valve or a broken valve spring.
 - Air leakage sounds at the exhaust system tailpipe that may indicate a worn or burnt exhaust valve or a broken valve spring.

- Air leakage sounds from the crankcase, oil level indicator tube, or oil fill tube that 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 a damaged cylinder head gasket.

7. Perform the leakage test on the remaining cylinders and record the values.

3.17 Oil Consumption Diagnosis

Excessive oil consumption, not due to leaks, is the use of more than 0.95 L (1 qt.) of engine oil within 379 L (100 gal.) of fuel used. However, during initial engine break-in periods, 5000–6500 km (3000–4000 mi.), oil consumption may exceed 1.9 L (2 qt.) or more per 379 L (100 gal.) of fuel used. The causes of excessive oil consumption include the following conditions:

- External oil leaks. Tighten bolts and/or replace gaskets and oil seals as necessary.
- Incorrect oil level or improper reading of oil level indicator. With the engine on a level surface, allow adequate drain down time and check for the correct oil level.
- Improper oil viscosity. Use recommended SAE viscosity for the prevailing temperatures.
- Continuous high speed driving and/or severe usage.
- Crankcase ventilation system restrictions or malfunctioning components.
- Valve guides and/or valve stem oil seals worn or the seal omitted. Ream guides and install oversize service valves and/or new valve stem oil seals.
- Piston rings broken, improperly installed, worn, or not seated properly. Allow adequate time for rings to seat. Replace broken or worn rings as necessary.
- Piston improperly installed or piston size is incorrectly selected.

3.18 Oil Pressure Diagnosis and Testing

1. With the engine on a level surface, allow adequate drain down time, 2–3 minutes, and measure for the proper engine oil level. Too high an oil level will cause aeration within the oil.

Add the recommended grade engine oil and fill the crankcase until the oil level measures FULL on the oil level indicator.

2. Operate the engine and verify low or no oil pressure on the engine oil pressure gauge or oil indicator light. Listen for a noisy valve train or knocking noise.
3. Inspect for the following:
 - a. Engine oil diluted by moisture or unburned fuel mixtures.
 - b. Improper engine oil viscosity for the expected temperature.
 - c. Incorrect or faulty oil pressure gauge sensor.
 - d. Incorrect or faulty oil pressure gauge.

- e. Plugged oil filter.
- f. Malfunctioning oil filter bypass valve.
4. Remove the oil pressure gauge sensor or another engine block oil gallery plug.
5. Install an oil pressure gauge and measure the engine oil pressure.
6. If the engine oil pressure is below specifications, inspect the engine for one or more of the following:
 - a. Oil pump worn or dirty.
 - b. Malfunctioning oil pump pressure relief valve.
 - c. Oil pump screen loose, plugged, or damaged.
 - d. Excessive bearing clearance or worn bearings.
 - e. Cracked, porous or restricted oil galleries.
 - f. Engine block oil gallery plugs missing or incorrectly installed.
 - g. Broken valve lifters.

3.19 Oil Leak Diagnosis

Step	Action	Yes	No
Important: 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. 2. Place the engine on a level surface, over a large sheet of paper or other clean surface. 3. Wait 15 minutes. 4. Check for drippings. 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 10	Go to Step 3
3	1. Visually inspect the suspected area. Use a small mirror to assist in looking at hard-to-see areas. 2. Check for leaks at the following locations: <ul style="list-style-type: none"> • Sealing surfaces. • Fittings. • Cracked or damaged components. Can you identify the type of fluid and the approximate location of the leak?	Go to Step 10	Go to Step 4
4	1. Completely clean the entire engine and surrounding components. 2. Operate at normal operating temperature and at varying loads. 3. Place the engine on a level surface, over a large sheet of paper or other clean surface. 4. Wait 15 minutes. 5. Identify the type of fluid and the approximate location of the leak. Can you identify the type of fluid and the approximate location of the leak?	Go to Step 10	Go to Step 5
5	1. Visually inspect the suspected area. Use a small mirror to assist in looking at hard-to-see areas. 2. Check for leaks at the following locations: <ul style="list-style-type: none"> • Sealing surfaces. • Fittings. • Cracked or damaged components. Can you identify the type of fluid and the approximate location of the leak?	Go to Step 10	Go to Step 6

Step	Action	Yes	No
6	<p>1. Completely clean the entire engine and surrounding components.</p> <p>2. Apply an aerosol-type powder, baby powder, foot powder, etc., to the suspected area.</p> <p>3. Operate at normal operating temperature and at varying loads.</p> <p>4. Identify the type of fluid and the approximate location of the leak from the discolorations in the powder surface.</p> <p>Can you identify the type of fluid and the approximate location of the leak?</p>	Go to Step 10	Go to Step 7
7	<p>1. Visually inspect the suspected area. Use a small mirror to assist in looking at hard-to-see areas.</p> <p>2. Check for leaks at the following locations:</p> <ul style="list-style-type: none"> • Sealing surfaces. • Fittings. • Cracked or damaged components. <p>Can you identify the type of fluid and the approximate location of the leak?</p>	Go to Step 10	Go to Step 8
8	<p>Use J 28428-E High Intensity Black Light Kit to identify the type of fluid and the approximate location of the leak. Refer to the manufacturer's instructions when using the tool.</p> <p>Can you identify the type of fluid and the approximate location of the leak?</p>	Go to Step 10	Go to Step 9
9	<p>1. Visually inspect the suspected area. Use a small mirror to assist in looking at hard-to-see areas.</p> <p>2. Check for leaks at the following locations:</p> <ul style="list-style-type: none"> • Sealing surfaces. • Fittings. • Cracked or damaged components. <p>Can you identify the type of fluid and the approximate location of the leak?</p>	Go to Step 10	System OK
10	<p>1. Inspect the engine for mechanical damage. Special attention should be shown to the following areas:</p> <ul style="list-style-type: none"> • Higher than recommended fluid levels. • Higher than recommended fluid pressures. • Plugged or malfunctioning fluid filters or pressure bypass valves. • Plugged or malfunctioning engine ventilation system. • Improperly tightened or damaged fasteners. • Cracked or porous components. • Improper sealants or gaskets where required. • Improper sealant or gasket installation. • Damaged or worn gaskets or seals. <p>2. Inspect the engine for customer modifications.</p> <p>Is there mechanical damage or customer modifications to the engine?</p>	Go to Step 11	System OK
11	<p>Repair or replace all damaged or modified components.</p> <p>Does the engine still leak oil?</p>	Go to Step 1	System OK

3.20 Crankcase Ventilation System Inspection/Diagnosis

A plugged positive crankcase ventilation (PCV) pipe/passage way may cause:

- Rough idle.
- Oil leaks.
- Sludge in the engine.

3.21 Drive Belt Chirping Diagnosis

3.21.1 Diagnostic Aids

The chirping noise may be intermittent due to moisture on the drive belt(s) or the accessory drive pulley(s). To duplicate the customer's concern, it may be necessary to spray a small amount of water onto the drive belt(s). If spraying water onto the drive belt(s) duplicates the symptom, cleaning the accessory drive pulley(s) may be the most probable solution.

A loose or improper installation of other item(s) on the engine may also cause the chirping noise.

3.21.2 Test Description

1. The chirping noise may not be engine related. See item 2 in following table. 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 items in table.
2. The noise may be an internal engine noise. Remove the drive belt(s) and operate the engine for a few seconds to verify if the chirping noise is related to the drive belt(s). With the drive belt(s)

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(s) removed. See item 3 in following table.

3. Inspect all drive belt(s) for signs of pilling. Pilling is the small balls, pills, or strings in the drive belt grooves caused from the accumulation of rubber dust. See item 4 in following table.
4. Misalignment of the accessory drive pulley(s) 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 accessory drive pulley using a straight edge in the pulley grooves across two or three pulleys. If a misaligned pulley is found, refer to that accessory drive component for the proper removal and installation procedure for that pulley. See item 6 in following table.
5. Inspection of the fasteners can eliminate the possibility that an incorrect bolt, nut, spacer, or washer was installed. See item 10 in following table.
6. Inspection of the accessory drive pulley(s) should include inspecting for bends, dents, or other damage to the pulley(s) that would prevent the drive belt(s) from not 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. See item 12 in following table.
7. Replacing the drive belt(s) when it is not damaged or there is not excessive pilling will only be a temporary repair. See item 14 in following table.

Step	Action	Yes	No
Notice: See Belt Dressing Notice in Cautions and Notices. Definition: The following items are indications of chirping: <ul style="list-style-type: none"> • High pitched noise that is heard once per revolution of the drive belt(s) or an accessory drive pulley. • Chirping may occur on cold damp startup conditions and will subside once the engine reaches normal operating temperature. 			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Verify that there is a chirping noise. Does the engine make the chirping noise?	Go to Step 3	Go to Diagnostic Aids
3	1. Remove the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. 2. Operate the engine for no longer than 30-40 seconds. Does the chirping noise still exist?	Go to Section 3.8, Engine Noise on Startup, But Only Lasting a Few Seconds	Go to Step 4
4	Inspect for severe drive belt pilling exceeding 1/3 of the drive belt groove depth. Do the drive belt grooves have pilling?	Go to Step 5	Go to Step 6
5	Clean the accessory drive belt pulley(s) with a suitable wire brush. Was the accessory drive pulley(s) cleaned?	Go to Step 15	—
6	Inspect for misaligned accessory drive pulley(s). Is there a misaligned accessory drive pulley(s)?	Go to Step 7	Go to Step 8
7	Replace and/or repair the misaligned accessory drive pulley(s). Was the misaligned accessory drive pulley(s) replaced and/or repaired?	Go to Step 15	—
8	Inspect for a bent or cracked accessory drive bracket(s). Did you find any bent or cracked accessory drive brackets.	Go to Step 9	Go to Step 10
9	Replace any bent and/or cracked accessory drive bracket(s). Was the bent and/or cracked accessory drive bracket(s) replaced?	Go to Step 15	Go to Step 10
10	Inspect for incorrect, loose, and/or missing fasteners. Were any incorrect, loose, and/or missing fasteners found?	Go to Step 11	Go to Step 12
11	Replace any incorrect and/or missing fasteners Tighten any loose fasteners. See Section 1.1, Fastener Tightening Specs. Were the fasteners replaced and/or tightened?	Go to Step 15	—
12	Inspect for a bent accessory drive pulley(s). Was a bent accessory drive pulley(s) found?	Go to Step 13	Go to Step 14
13	Replace the bent accessory drive pulley(s). Was the bent accessory drive pulley(s) replaced?	Go to Step 15	—
14	Replace the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. Was the drive belt(s) replaced?	Go to Step 15	—
15	1. Clear any codes. 2. Run the engine to verify the repair. Does the chirping noise still exist?	Go to Step 1	System OK

3.22 Drive Belt Squeal Diagnosis

3.22.1 Diagnostic Aids

A loose or improper installation of other item(s) on the engine may cause the squeal noise.

If the squeal noise is intermittent, verify that it is not the accessory drive component(s) by varying their load(s), making sure they are operating to their maximum capacity. A failing engine alternator is a suggested item to inspect.

3.22.2 Test Description

1. The squeal may not be engine related. See item 2 in following table. 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 items in table.
2. The squeal may be an internal engine noise. Remove the drive belt(s) and operate the engine for a few seconds to verify if the squealing noise is related to the drive belt(s) or an accessory drive component. With the drive belt(s) removed, the water pump will not operate and the engine may overheat. Also DTCs may set when the engine is operated with the drive belt(s) removed. See item 3 in following table.
3. This test is to verify that an accessory drive component(s) does not have a seized bearing. With the belt(s) removed, test the bearings in the accessory drive component(s) for smooth operation. Also test the accessory drive component(s) with the engine operating by varying the load on the accessory drive component(s) to verify that the component(s) is operating properly. See item 4 in following table.
4. This test is to verify that the drive belt(s) tensioner(s) is operating properly. If the drive belt(s) tensioner(s) is not operating properly, proper belt tension may not be achieved to keep the drive belt(s) from slipping causing a squeal noise. See item 5 in following table.
5. This test is to verify that the drive belt(s) is not too long, which would prevent the drive belt(s) tensioner(s) from operating properly. Also if the incorrect length drive belt(s) was installed, it may not be routed correctly and may be turning an accessory drive component in the incorrect direction. See item 6 in following table.
6. Misalignment of the accessory drive pulley(s) 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 two or three pulleys. If a misaligned pulley is found, refer to that accessory drive component for the proper removal and installation procedure for that pulley. See item 7 in following table.
7. Inspect the accessory drive pulley(s) to verify that they are the correct diameter or width. See item 8 in following table.

Step	Action	Yes	No
<p>Notice: See Belt Dressing Notice in Cautions and Notices.</p> <p>Definition: The following items are indications of drive belt squeal:</p> <ul style="list-style-type: none"> • A loud screeching noise that is caused by a slipping drive belt(s) (unusual for a drive belt with multiple ribs). • The squeal occurs when a heavy load is applied to the drive belt such as snapping the throttle, slipping on a seized pulley, or a faulty drive belt component. 			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Verify that there is a squeal noise. Does the engine make the squeal noise?	Go to Step 3	Go to Diagnostic Aids
3	1. Remove the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. 2. Operate the engine for no longer than 30-40 seconds. Does the squealing noise still exist?	Go to Section 3.8, Engine Noise on Startup, But Only Lasting a Few Seconds	Go to Step 4
4	Inspect for a seized accessory drive component bearing or a faulty accessory drive component. Do the drive belt grooves have pilling?	Go to Step 9	Go to Step 5
5	Inspect the drive belt tensioner for proper operation. See Section 3.28, Drive Belt Tensioner Diagnosis. Did you find and correct the condition?	Go to Step 9	Go to Step 6
6	Check for the correct length drive belt(s). Did you find and correct the condition?	Go to Step 9	Go to Step 7
7	Inspect for misaligned pulley. Did you find and correct the condition?	Go to Step 9	Go to Step 8
8	Inspect for an incorrect size pulley. Did you find and correct the condition?	Go to Step 9	—
9	1. Install the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. 2. Clear any codes. 3. Run the engine to verify the repair. Does the squealing noise still exist?	Go to Step 1	System OK

3.23 Drive Belt Whine Diagnosis

3.23.1 Diagnostic Aids

The drive belt(s) will not cause the whine. If the whine is intermittent, verify that it is not the accessory drive component(s) by varying their loads, making sure they are operating to their maximum capacity. A failing generator is a suggested items to inspect.

3.23.2 Test Description

1. This test is to verify that the whine is being caused by the accessory drive component(s). See Item 3 in following table. Remove the drive belt(s) and

operate the engine for a few seconds to verify if the whining noise is related to the accessory drive component. With the drive belt(s) removed, the water pump will not operate and the engine may overheat. Also DTCs may set when the engine is operated with the drive belt(s) removed.

2. The inspection should include checking the drive belt tensioner and the drive belt idler pulley bearings. The drive belt(s) 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 installation procedure. See Item 4 in following table.

Step	Action	Yes	No
Notice: See Belt Dressing Notice in Cautions and Notices.			
Definition: A high pitched continuous noise that may be caused by an accessory drive component failed bearing.			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Verify that there is a whining noise. Does the engine make the whining noise?	Go to Step 3	Go to Diagnostic Aids
3	1. Remove the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. 2. Operate the engine for no longer than 30-40 seconds. Does the whining noise still exist?	Go to Section 3.8, Engine Noise on Startup, But Only Lasting a Few Seconds	Go to Step 4
4	1. Inspect for a failed accessory drive component bearing. 2. Install the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. Did you find and correct the condition?	Go to Step 5	—
5	1. Clear any codes. 2. Run the engine to verify the repair. Does the whining noise still exist?	Go to Step 1	System OK

3.24 Drive Belt Rumbling Diagnosis

3.24.1 Diagnostic Aids

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

The drive belt(s) may have a condition that cannot be seen or felt. Sometimes replacing the drive belt(s) may be the only repair for the symptom.

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

3.24.2 Test Description

1. This test is to verify that the symptom is present during diagnosing. Other components may cause a similar symptom.

2. This test is to verify that the drive belt(s) is causing the rumbling. Rumbling may be confused with an internal engine noise due to the similarity in the description. Remove only one drive belt at a time if engine has multiple drive belts. Operate engine for a few seconds as this will verify if the rumbling noise is related to the drive belt(s). With drive belt(s) removed, the water pump will not operate and engine may overheat. Also DTCs may set when the engine is operated with the drive belt(s) removed. See item 3 of following table.

3. Inspect the drive belt(s) to ensure that the drive belt(s) is not the cause of the noise. Small cracks across the ribs of the drive belt(s) will not cause the noise. Belt separation is identified by the plies of the belt separating; seen at the edge of the belt or felt as a lump in the belt. See item 4 of following table.

4. Small amounts of pilling is a normal condition and acceptable. When the pilling is severe, the drive belt(s) does not have a smooth surface for proper operation. See item 5 of following table.

Step	Action	Yes	No
Notice: See Belt Dressing Notice in Cautions and Notices. Definition: The following items are indications of drive belt rumbling: <ul style="list-style-type: none"> • A low pitch tapping, knocking, or thumping noise heard at or just above idle. • Heard once per revolution of the drive belt(s) or pulley(s). • Rumbling may be caused from: <ul style="list-style-type: none"> • Pilling, the accumulation of rubber dust that forms small balls (pills), or strings in the drive belt(s) pulley groove. • Separation of the drive belt(s). • Damaged drive belt(s). 			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Verify that there is a rumbling noise. Does the engine make the rumbling noise?	Go to Step 3	Go to Diagnostic Aids
3	1. Remove the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. 2. Operate the engine for no longer than 30-40 seconds. Does the rumbling noise still exist?	Go to Section 3.8, Engine Noise on Startup, But Only Lasting a Few Seconds	Go to Step 4
4	Inspect the drive belt(s) for damage, separation, or sections of missing ribs. Was any of these conditions found?	Go to Step 7	Go to Step 5
5	Inspect for severe drive belt pilling exceeding 1/3 of the drive belt groove depth. Do the drive belt grooves have pilling?	Go to Step 6	Go to Step 7
6	1. Clean the drive pulleys using a suitable wire brush. 2. Reinstall the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. Did you complete the repair?	Go to Step 8	—
7	Install a new drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. Did you complete the replacement?	Go to Step 8	—
8	1. Clear any codes. 2. Run the engine to verify the repair. Does the rumbling noise still exist?	Go to Step 1	System OK

3.25 Drive Belt Vibration Diagnosis

3.25.1 Diagnostic Aids

The accessory drive components may have an affect on engine vibration. To help identify an intermittent or an improper condition, vary the loads on the accessory drive components.

3.25.2 Test Description

1. This test is to verify that the vibration is present during diagnosing. Other engine components may cause a similar symptom such as the exhaust system. See item 2 in following table.
2. This test is to verify that the drive belt(s) or accessory drive components may be causing the vibration. Remove the drive belt(s) and operate the engine for a few seconds to verify if the vibration is related to the drive belt(s). With the drive belt(s) removed, the water pump will not operate and the engine may overheat. Also DTCs may set when the engine is operated with the drive belt(s) removed. See item 3 in following table.
3. The drive belt(s) may cause a vibration. When the drive belt(s) is removed, inspect the condition of the drive belt(s). See item 4 in following table.
4. Inspection of the fasteners can eliminate the possibility that a incorrect bolt, nut, spacer, or washer was installed. See item 6 in following table.
5. This step should only be performed if the fan is driven by the drive belt(s). 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. See item 8 in following table.
6. 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. See item 9 in following table.
7. Accessory drive component brackets that are bent, cracked, or loose may put an extra strain on that accessory drive component causing it to vibrate. See item 10 in following table.

Step	Action	Yes	No
Notice: See Belt Dressing Notice in Cautions and Notices. Definition: The following items are indications of drive belt vibration: <ul style="list-style-type: none"> • Vibration is engine-speed related. • The vibration may be sensitive to accessory load. 			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Verify that the vibration is engine related. Does the engine make the vibration?	Go to Step 3	Go to Diagnostic Aids
3	1. Remove the drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. 2. Operate the engine for no longer than 30-40 seconds. Does the engine still make the vibration?	Go to Section 3.8, Engine Noise on Startup, But Only Lasting a Few Seconds	Go to Step 4
4	Inspect the drive belt(s) for wear, damage, debris buildup, and missing belt ribs. Was any of these conditions found?	Go to Step 5	Go to Step 6
5	Install a new drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. Did you complete the replacement?	Go to Step 11	—
6	Inspect for incorrect, loose, and/or missing fasteners. Were any incorrect, loose, and/or missing fasteners found?	Go to Step 7	Go to Step 8
7	Replace any incorrect and/or missing fasteners. Tighten any loose fasteners. See Section 1.1, Fastener Tightening Specs. Were the fasteners replaced and/or tightened?	Go to Step 11	—
8	Inspect for damaged fan blades or a bent fan clutch shaft. Did you find and correct the condition?	Go to Step 11	Go to Step 9
9	Inspect for a bent water pump drive shaft. Did you find and correct the condition?	Go to Step 11	Go to Step 10
10	Inspect for a bent or cracked accessory drive bracket(s). Did you find and correct the condition?	Go to Step 11	—
11	1. Clear any codes. 2. Run the engine to verify the repair. Does the rumbling noise still exist?	Go to Step 1	System OK

3.26 Drive Belt Falls Off Diagnosis

3.26.1 Diagnostic Aids

If the drive belt(s) repeatedly falls off the accessory drive pulley(s), a pulley may be misaligned.

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

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

3.26.2 Test Description

1. This inspection is to verify the condition of the drive belt(s). Damage may have occurred to the drive belt(s) when the drive belt(s) fell off the pulleys. Inspect the drive belt(s) for cuts, tears, sections of ribs missing, or damaged belt plies. See item 2 in following table.
2. Misalignment of the accessory drive pulley(s) 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 two or three pulleys. If a misaligned pulley is found, refer to that accessory drive component for the proper removal and installation procedure of that pulley. See item 4 in following table.
3. Inspection of the accessory drive pulley(s) should include inspecting for bends, dents, or other damage 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 belt(s) is used to drive the pulley. See item 5 in following table.
4. Accessory drive component brackets that are bent or cracked will also cause the drive belt(s) to fall off. See item 6 in following table.
5. 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 bracket(s) moving under load. Overtightening the fasteners may cause misalignment of the accessory component bracket(s). See item 7 in following table.

Step	Action	Yes	No
Notice: See Belt Dressing Notice in Cautions and Notices. Definition: The drive belt falls off the pulleys or may not ride correctly on the pulleys.			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Inspect for a damaged drive belt(s). Was a damaged drive belt(s) found?	Go to Step 3	Go to Step 4
3	Install a new drive belt(s). See Section 9.1.1, Drive Belt Replacement, Accessory. Does the drive belt(s) continue to fall off?	Go to Step 4	System OK
4	Inspect for a misaligned accessory drive pulley(s). 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(s). Did you find and correct the condition?	Go to Step 12	Go to Step 6
6	Inspect for a bent or cracked accessory drive bracket(s). Did you find and correct the condition?	Go to Step 12	Go to Step 7
7	Inspect for incorrect, loose, and/or missing fasteners. Were any incorrect, loose, and/or missing fasteners found?	Go to Step 8	Go to Step 9
8	Replace any incorrect and/or missing fasteners. Tighten any loose fasteners. See Section 1.1, Fastener Tightening Specs. Does the drive belt(s) continue to fall off?	Go to Step 9	System OK
9	Test the drive belt tensioner for correct operation. See Section 3.28, Drive Belt Tensioner Diagnosis. Does the drive belt tensioner operate correctly?	Go to Step 11	Go to Step 10
10	Replace the drive belt tensioner. See Section 9.1.2, Drive Belt Tensioner Replacement, Accessory. Does the drive belt(s) continue to fall off?	Go to Step 11	System OK
11	Inspect for a failed drive belt(s) idler and/or tensioner pulley(s) bearing. Did you find and repair the condition?	Go to Step 12	—
12	Run the engine to verify the repair. Does the drive belt still fall off?	Go to Step 1	System OK

3.27 Drive Belt Excessive Wear Diagnosis

3.27.1 Diagnostic Aids

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

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

Excessive misalignment of the accessory drive pulley(s) will cause excessive wear and may also make the drive belt(s) fall off.

3.27.2 Test Description

1. This inspection is to verify that the drive belt(s) is correctly installed on all of the accessory drive pulley(s). Wear on the drive belt(s) may be caused by mispositioning the drive belt(s) by one or more grooves on a pulley(s). See item 2 in following table.
2. The installation of a drive belt(s) that is too wide or too narrow will cause wear on the drive belt(s). The drive belt(s) ribs should match all of the grooves on the pulleys. See item 3 in following table.
3. This inspection is to verify the drive belt(s) 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(s) should not come in contact with an engine or a body component when snapping the throttle. See item 4 in following table.

Step	Action	Yes	No
Notice: See Belt Dressing Notice in Cautions and Notices.			
Definition: Wear at the outside ribs of the drive belt(s) due to incorrect installation of the drive belt(s).			
1	Did you review Section 3.2, Symptoms, Engine Mechanical, for diagnostic information and perform the necessary inspections?	Go to Step 2	Go to Section 3.2, Symptoms, Engine Mechanical
2	Inspect the drive belt(s) for proper installation. Is the drive belt(s) installed properly?	Go to Step 5	Go to Step 3
3	Inspect for the drive belt(s). Is the correct drive belt(s) installed?	Go to Step 5	Go to Step 4
4	Inspect the drive belt(s) for signs of rubbing against a bracket, hose, or wiring harness. Was the drive belt(s) rubbing against anything?	Go to Step 6	Go to Diagnostic Aids
5	Replace the drive belt(s). See Section 9.1.2, Drive Belt Tensioner Replacement, Accessory. Did you complete the replacement?	Go to Step 6	—
6	Run the engine to verify the repair. Is there still excessive drive belt wear?	Go to Step 1	System OK

3.28 Drive Belt Tensioner Diagnosis

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

1. Remove the drive belt(s). Refer to Section 9.1.1, Drive Belt Replacement, Accessory.
2. Position a hex head socket on the belt tensioner pulley bolt head.
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(s). Refer to Section 9.1.2, Drive Belt Tensioner Replacement, Accessory.
5. Install the drive belt(s). Refer to Section 9.1.1, Drive Belt Replacement, Accessory.

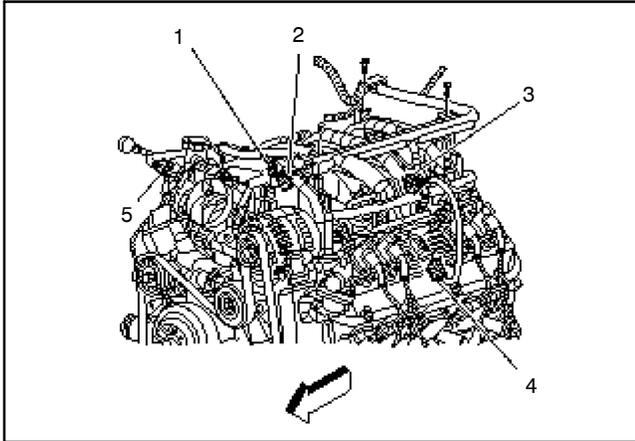
Section 4 Cylinder Head and Valves

4.1 Valve Rocker Arm Cover

4.1.1 Replacement, Left

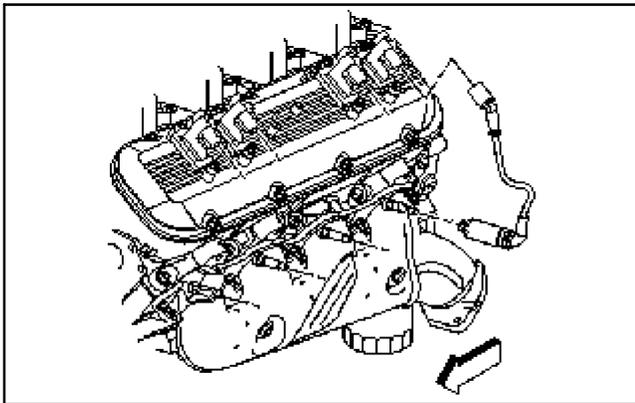
Removal Procedure

1. Remove the connector position assurance (CPA) retainer from the ignition coil electrical connector.



2. Disconnect the ignition coil harness electrical connector (4).

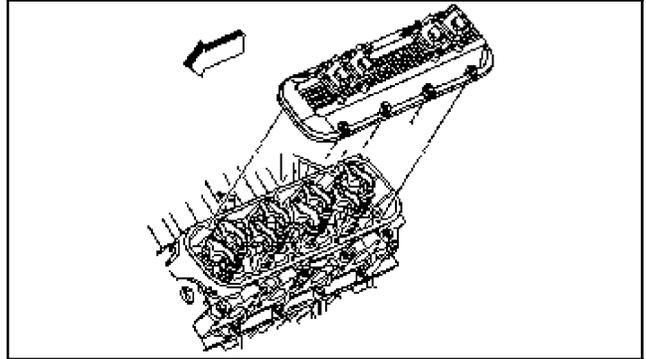
Important: Twist the spark plug boot 1/2 turn to release the boot. Pull on the spark plug boot only. Do not pull on the spark plug wire or the wire could be damaged.



3. Remove the spark plug wires from the spark plugs and ignition coils.

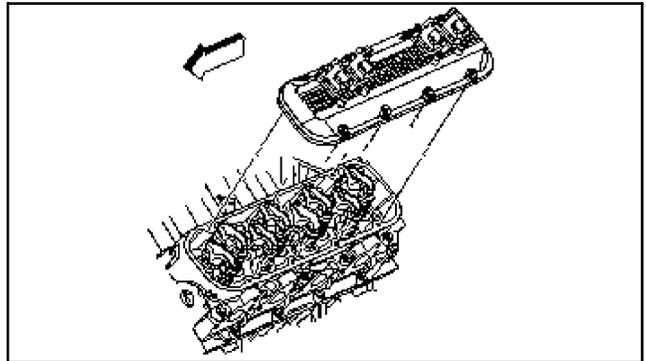
4. Remove the valve rocker arm cover bolts.
5. Remove the valve rocker arm cover.

Important: Valve rocker arm cover gaskets are reusable. Replace the gasket only if damaged.



6. Inspect the valve rocker arm cover gasket for cuts or damage.
7. Clean and inspect the valve rocker arm cover. Refer to Section 4.1.3, Valve Rocker Arm Cover Cleaning and Inspection.

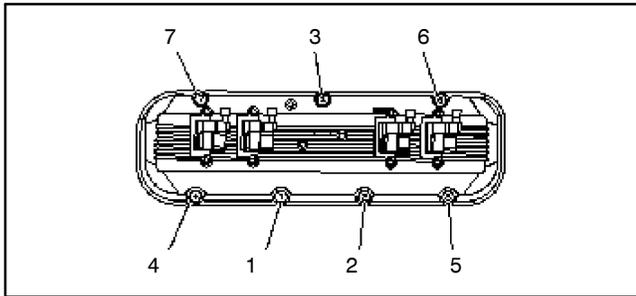
Installation Procedure



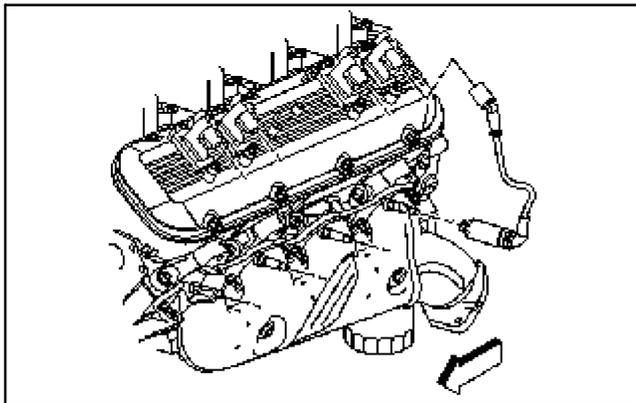
1. Install a new valve rocker arm cover gasket if the gasket was removed from the rocker arm cover.
2. Install the valve rocker arm cover.
3. Install the valve rocker arm cover bolts.

Notice: Refer to Fastener Notice in Cautions and Notices.

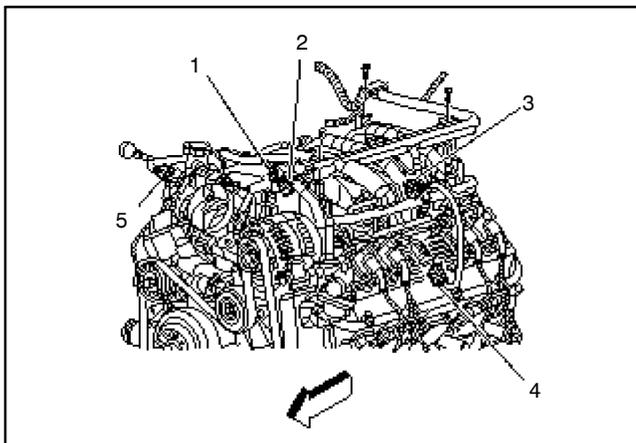
4. Tighten the valve rocker arm cover bolts in the sequence shown, using two passes as shown.
 - a. Tighten the bolts a first pass to 6 Nm (53 in. lb.).
 - b. Tighten the bolts a final pass to 12 Nm (106 in. lb.).



Important: Fully install the spark plug wire by pushing on the exposed end of the spark plug boot. Do not push the spark plug wire onto the spark plug by using the metal heat shield.

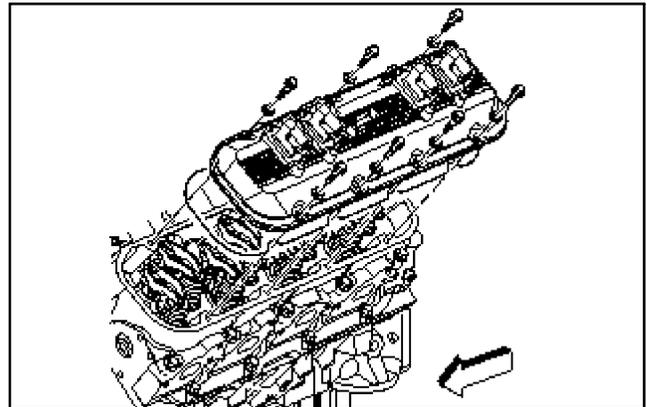


5. Install the spark plug wires to the spark plugs and ignition coils.
6. Connect the ignition coil harness electrical connector (4).



7. Install the CPA retainer to the ignition coil electrical connector.

4.1.2 Removal, Left

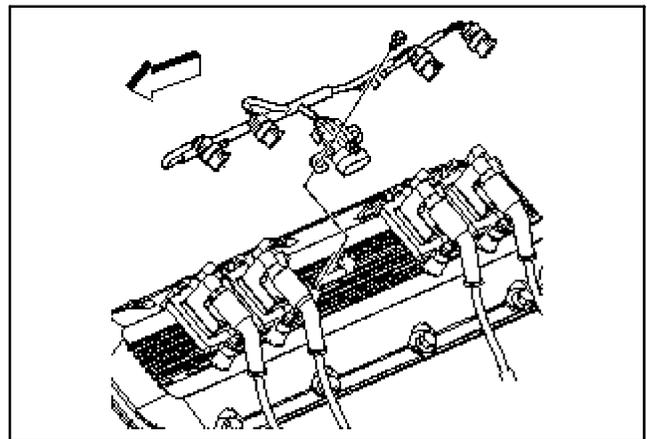


1. Remove the valve rocker arm cover bolts.
2. Remove the valve rocker arm cover.

Important: The valve rocker arm cover gasket may be reused if not removed from valve rocker arm cover.

3. Replace the valve rocker arm cover gasket if cut or damaged.

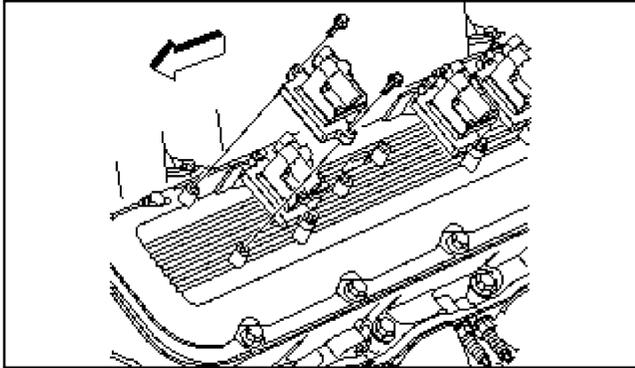
4.1.3 Cleaning and Inspection



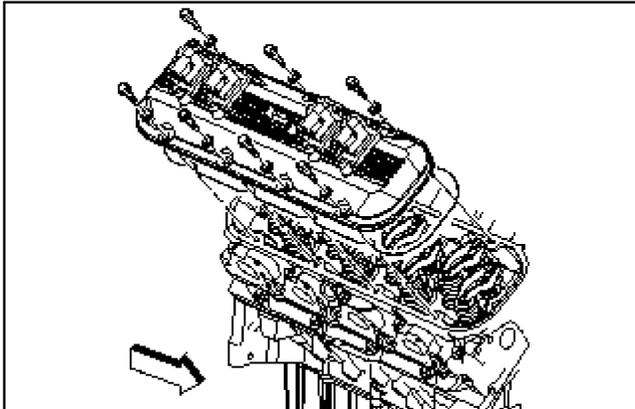
Notice: To ensure correct reinstallation, mark the ignition wiring harness connectors for cylinders one and three, and cylinders six and eight prior to disconnection. Failure to reconnect the ignition wiring harness connectors to the proper ignition coils may result in serious engine damage.

Notice: This component is initially installed using a self-tapping bolt(s). Care should be taken when removing and/or installing the self-tapping bolt(s). Failure to use care when removing and/or installing the self-tapping bolt(s) can lead to damage and unnecessary replacement of the self-tapping bolt(s) and/or the component the self-tapping bolt(s) is threaded into.

1. Remove the white wiring harness clip locks.
2. Disconnect the ignition coil wiring harness from the ignition coils.
3. Remove ignition coil wiring harness retainer bolts.



4. Open the two wiring harness retainers and remove the ignition coil wiring harness.
5. Remove the ignition coil bolts.
6. Remove the ignition coils.



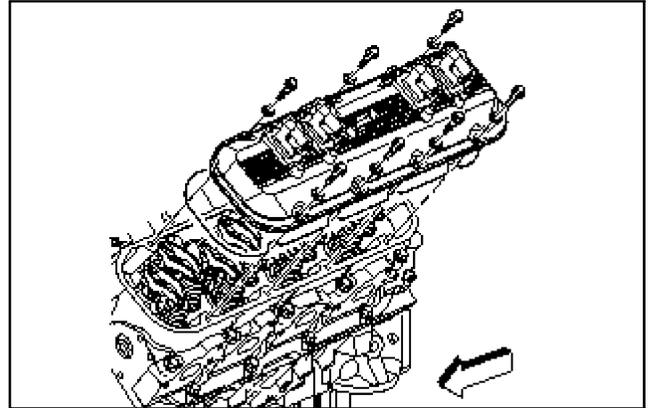
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

Important: Do not clean or submerge the ignition coils in solvent.

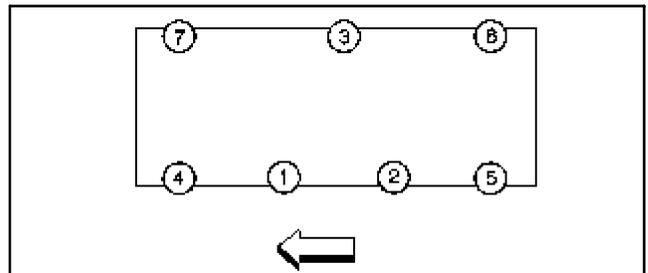
Remove the ignition coils before cleaning the cover in solvent. To prevent damage to the gasket, minimize solvent contact with the gaskets.

7. Clean the valve rocker arm cover in solvent.
8. Dry the covers with compressed air.

4.1.4 Installation, Left

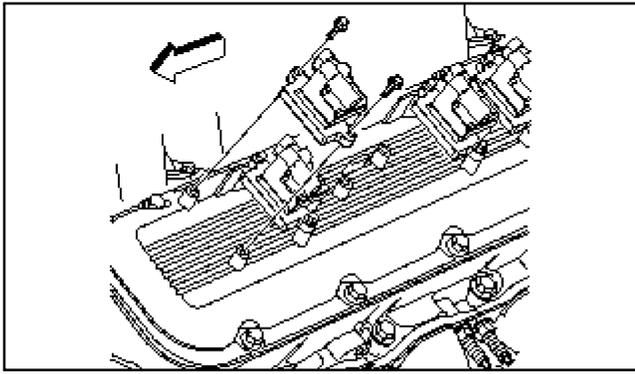


1. Install a new valve rocker arm cover gasket if the gasket was removed from the valve rocker arm cover.
2. Install the valve rocker arm cover.
3. Install the valve rocker arm cover bolts.



Notice: Refer to Fastener Notice in Cautions and Notices.

4. Tighten the valve rocker arm cover bolts in sequence using two passes.
 - a. Tighten the valve rocker arm cover bolts a first pass to 6 Nm (54 in. lb.).
 - b. Tighten the valve rocker arm cover bolts a final pass to 12 Nm (106 in. lb.).
5. Inspect the covers for the following:
 - Gouges or damage to the sealing surfaces.
 - Cracking or damage to the valve cover gasket.
 - Debris or damage to the bolt hole threads.

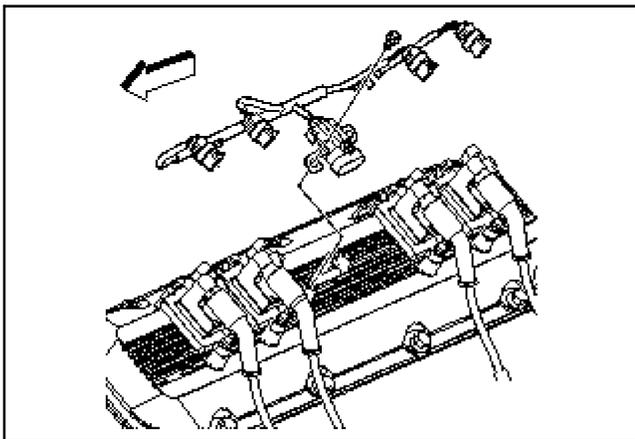


Notice: This bolt is a self-tapping bolt. If installing this bolt into a new component, installation of the bolt may be difficult. Ensure that the bolt is not over-torqued during the initial installation (thread cutting). Failure to limit torque can lead to bolt failure.

6. Install the ignition coils.

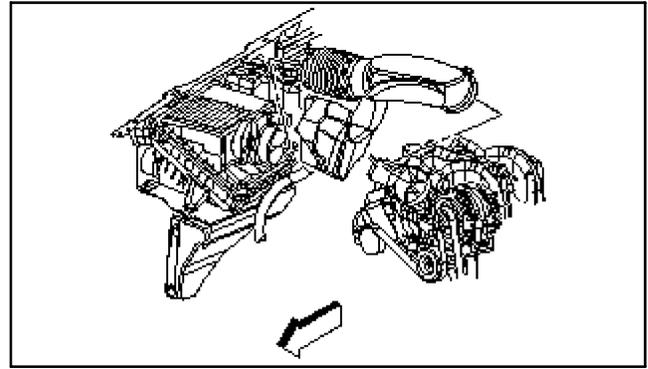
Notice: Refer to Fastener Notice in Cautions and Notices.

7. Install the ignition coil bolts. Tighten the ignition coil bolts to 12 Nm (106 in. lb.).



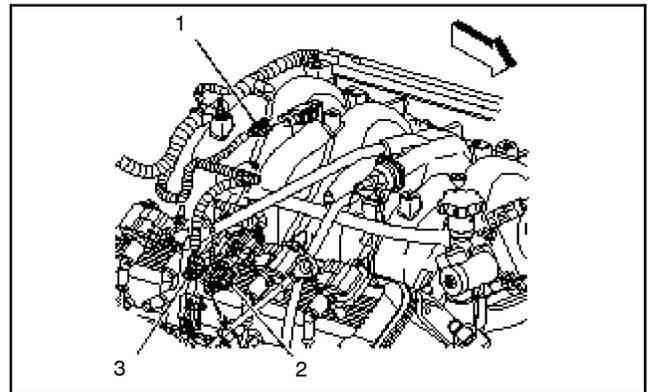
8. Install and secure the ignition coil wiring harness into the two wiring harness retainers.
9. Install the ignition coil wiring harness retainer bolts. Tighten the ignition coil wiring harness retainer bolts to 12 Nm (106 in. lb.).
10. Connect the ignition coil wiring harness to the ignition coils, making sure the connectors for cylinders 1 and 3 and cylinders 6 and 8 are connected to the corresponding ignition coils.
11. Install the white wiring harness clip locks.

4.1.5 Replacement, Right

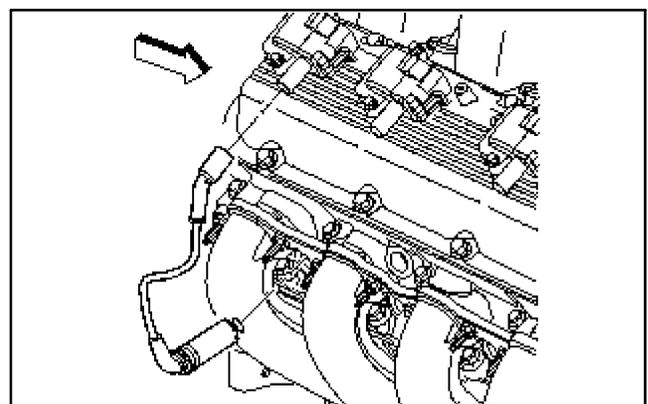


Removal Procedure

1. Loosen the clamps at the throttle body and air cleaner.
2. Remove the air cleaner outlet duct.

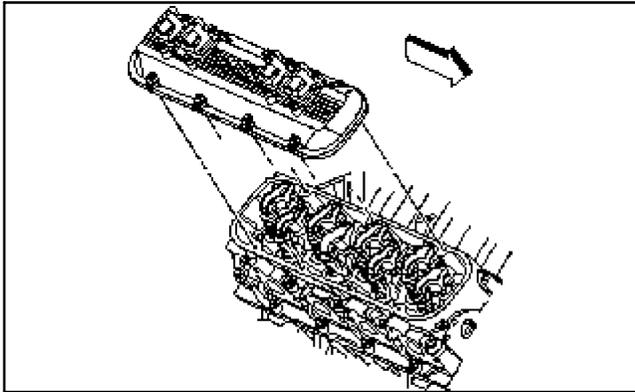


3. Remove the connector position assurance (CPA) retainer from ignition coil electrical connector (2).
4. Disconnect the ignition coil harness electrical connector (2).
5. Disconnect the engine coolant temperature (ECT) sensor electrical connector (3).



Important: Twist the spark plug boot one-half turn to release the boot. Pull on the spark plug boot only. Do not pull on the spark plug wire or the wire could be damaged.

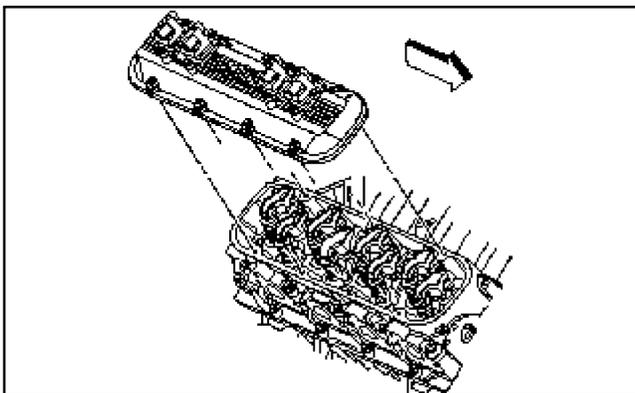
- Remove the spark plug wires from the ignition coils.



- Loosen the valve rocker arm cover bolts.
- Remove the valve rocker arm cover.

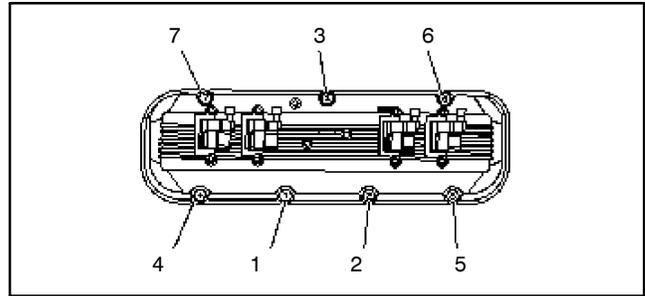
Important: The valve rocker arm cover gasket may be reused if not removed from the valve rocker arm cover.
- Replace the valve rocker arm cover gasket if cut or damaged.
- Clean and inspect the valve rocker arm cover. Refer to Section 4.1.3, Valve Rocker Arm Cover Cleaning and Inspection.

Installation Procedure

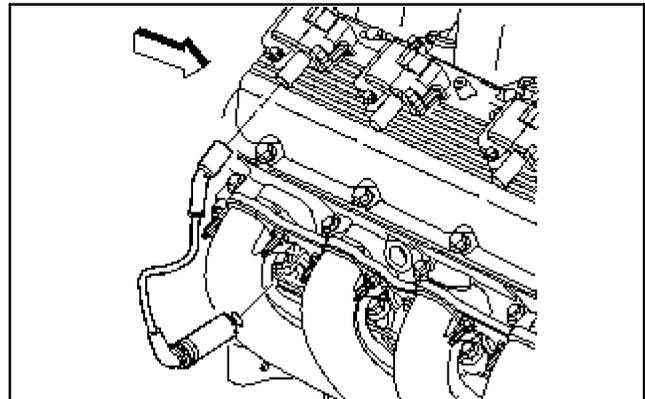


- Install a *new* valve rocker arm cover gasket, if necessary.
- Install the valve rocker arm cover.

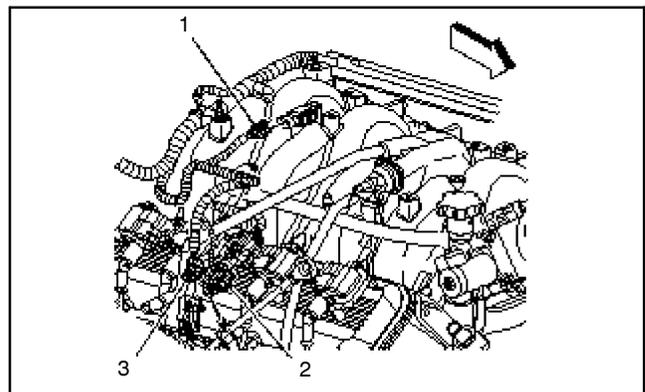
Notice: Refer to Fastener Notice in Cautions and Notices.



- Tighten the valve rocker arm cover bolts in sequence using two passes as shown.
 - Tighten the bolts a first pass to 6 Nm (53 in. lb.).
 - Tighten the bolts a final pass to 12 Nm (106 in. lb.).

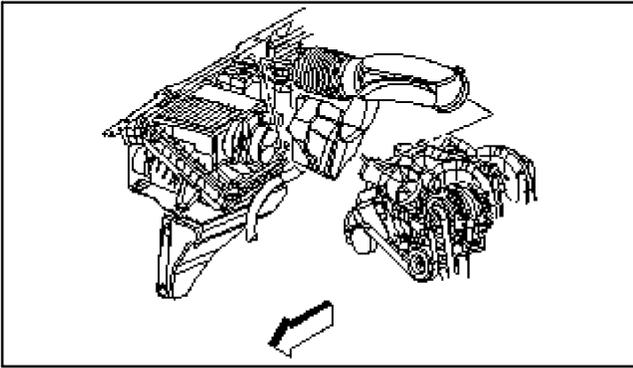


- Install the spark plug wires to the ignition coils.
- Connect the ECT sensor electrical connector (3).



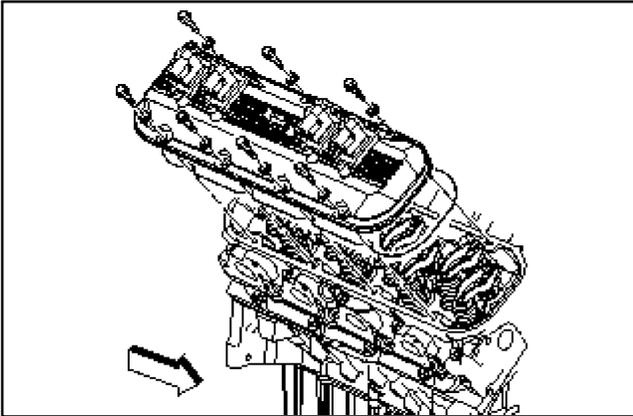
- Connect the ignition coil harness electrical connector (2).

7. Install the CPA retainer to the ignition coil electrical connector (2).
8. Install the air cleaner outlet duct.



9. Tighten the clamps at the throttle body and air cleaner. Tighten the clamps to 4 Nm (35 in. lb.).

4.1.6 Removal, Right

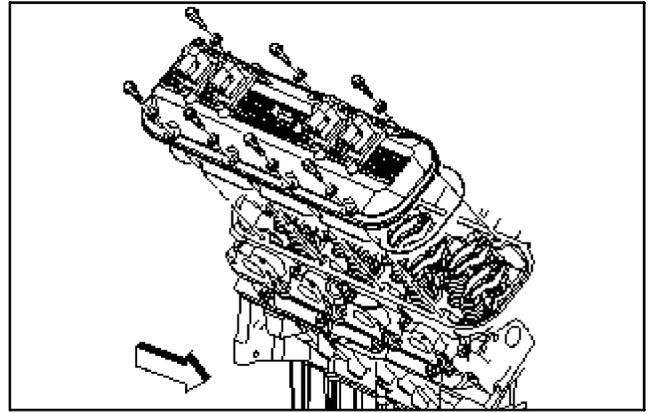


1. Remove the valve rocker arm cover bolts.
2. Remove the valve rocker arm cover.

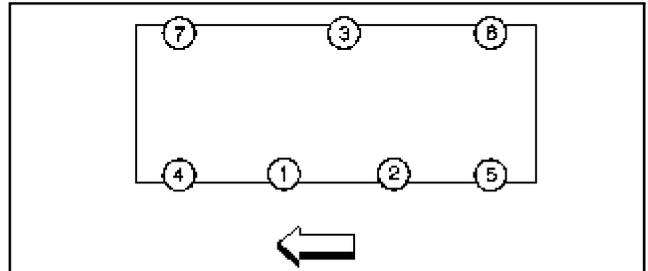
Important: The valve rocker arm cover gasket may be reused if not removed from the valve rocker arm cover.

3. Replace the valve rocker arm cover gasket if cut or damaged.

4.1.7 Installation, Right



1. Install a new valve rocker arm cover gasket if the gasket was removed from the valve rocker arm cover.
2. Install the valve rocker arm cover.
3. Install the valve rocker arm cover bolts.



Notice: Refer to Fastener Notice in Cautions and Notices.

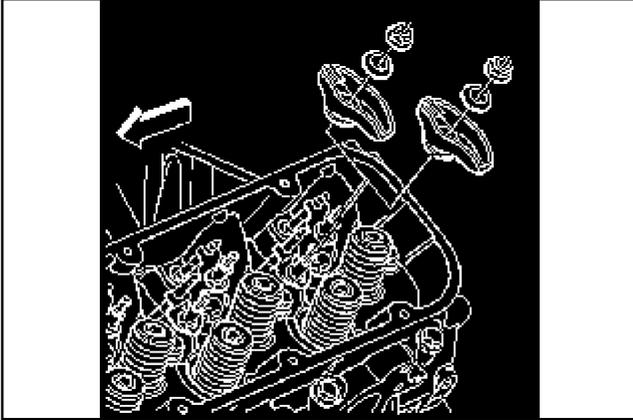
4. Tighten the valve rocker arm cover bolts in sequence using two passes.
 - a. Tighten the valve rocker arm cover bolts a first pass to 6 Nm (54 in. lb.).
 - b. Tighten the valve rocker arm cover bolts a final pass to 12 Nm (106 in. lb.).

4.2 Valve Rocker Arm and Push Rod

4.2.1 Replacement

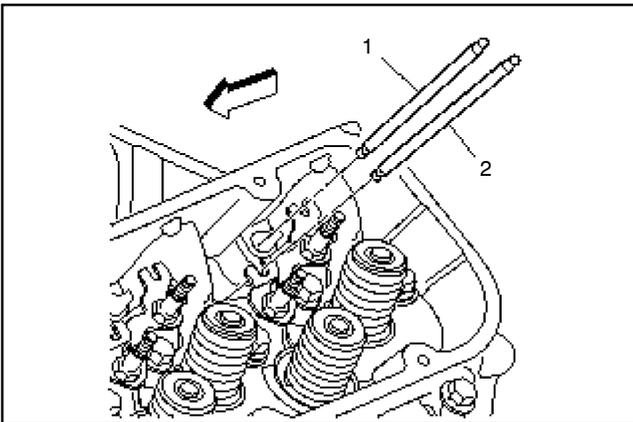
Removal Procedure

Important: Mark, organize, and sort the cylinder head components. Return the components to their original location during reassembly.

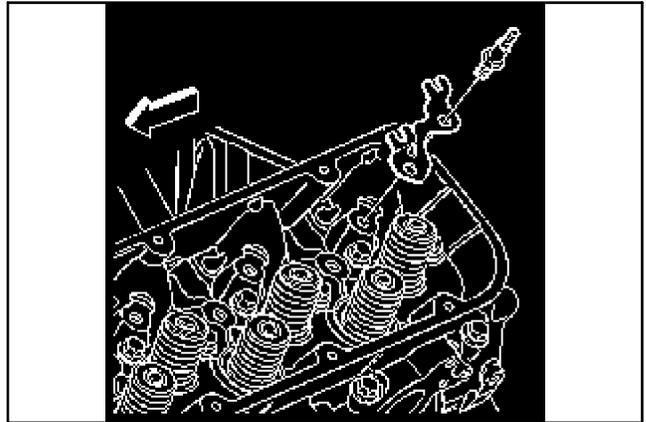


1. Remove the valve rocker arm cover. Refer to Section 4.1.1, Valve Rocker Arm Cover Replacement, Left, and/or Section 4.1.5, Valve Rocker Arm Cover Replacement, Right.
2. Remove the valve rocker arm nuts, the valve rocker arm balls, and valve rocker arms.

Important: The exhaust valve push rods (2) are longer than the intake valve push rods (1).



3. Remove the valve push rods.



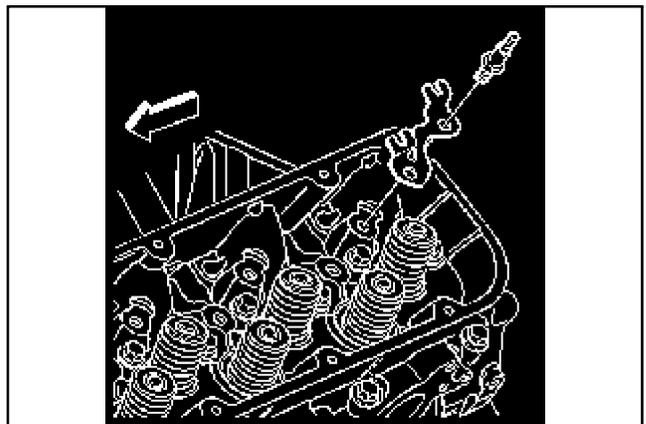
4. Remove the valve rocker arm studs and push rod guides.
5. Clean and inspect the valve rocker arms and push rods. Refer to Section 4.2.3, Valve Rocker Arm and Push Rod Cleaning and Inspection.

Installation Procedure

Important: Keep parts in order. Parts must be put back from where they were removed.

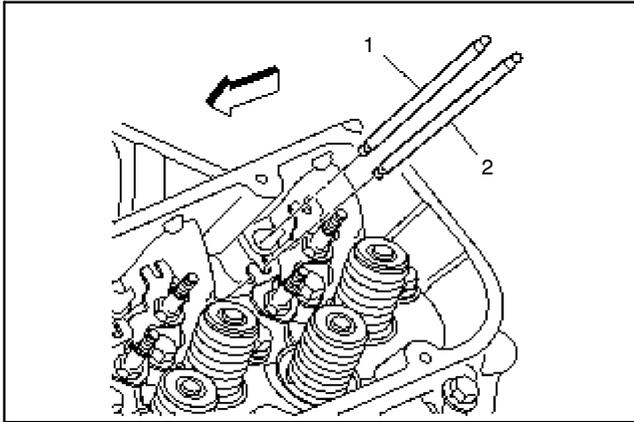
1. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the valve rocker arm stud-to-cylinder head threads.

Notice: Refer to Fastener Notice in Cautions and Notices.

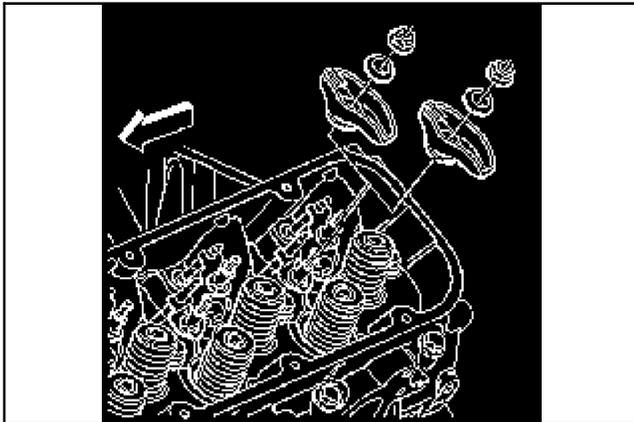


2. Install the push rod guides and valve rocker arm studs. Tighten the studs to 50 Nm (37 ft. lb.).

Important: The exhaust valve push rods (2) are longer than the intake valve push rods (1).



3. Install the valve push rods.
4. Coat the valve rocker arm and valve rocker arm ball bearing surfaces with lubricant, GM Part No. U.S. 12345501/Canadian 992704, or equivalent.



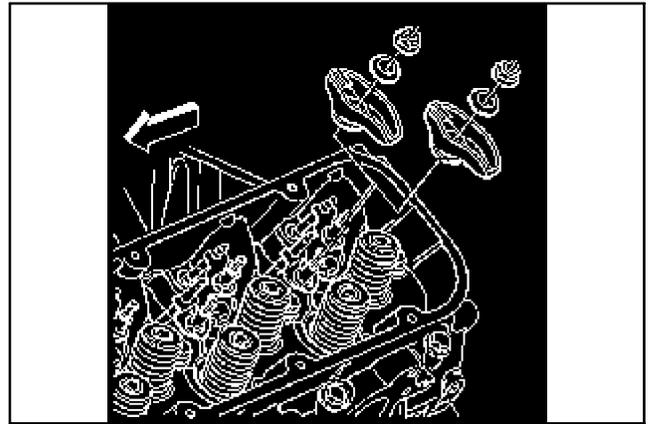
5. Install the valve rocker arms, the valve rocker arm balls, and the valve rocker arm nuts.

Tighten the nuts slowly to 35 Nm (26 ft. lb.) while guiding the tips of the rocker arms over the tips of the valves.

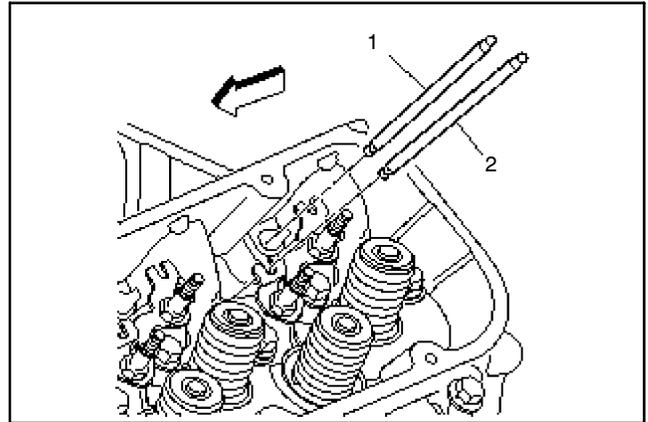
6. Install the valve rocker arm cover. Refer to Section 4.1.1, Valve Rocker Arm Cover Replacement, Left, or Section 4.1.5, Valve Rocker Arm Cover Replacement, Right.

4.2.2 Removal

Important: Mark, organize, and sort the cylinder head components. Return the components to their original location during reassembly. Make an organizer rack from a piece of wood.

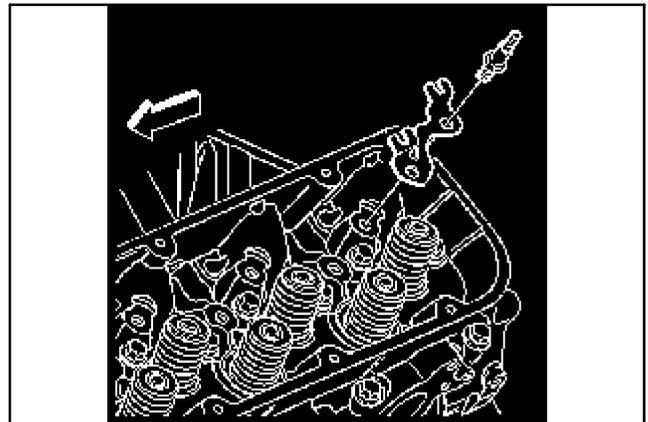


1. Remove the valve rocker arm nuts, the valve rocker arm balls, and the valve rocker arms.



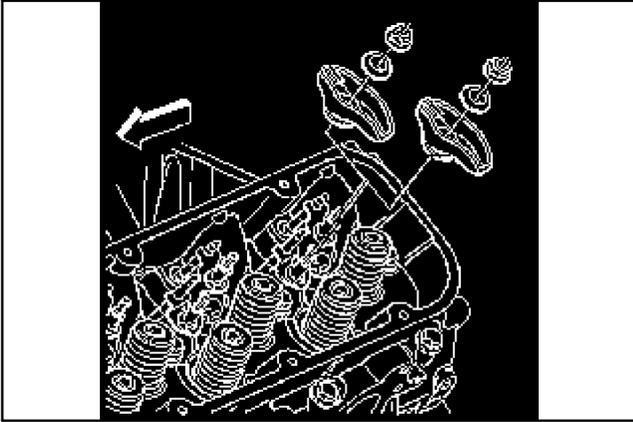
Important: The exhaust valve push rods (2) are longer than the intake valve push rods (1).

2. Remove the valve push rods.



3. Remove the valve rocker arm studs and push rod guides.

4.2.3 Cleaning and Inspection

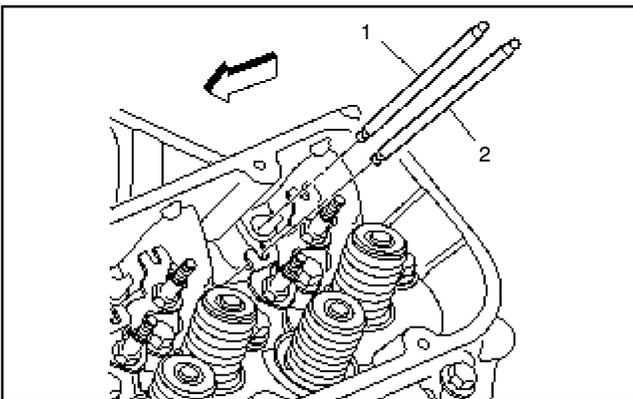


Important: Sort or organize parts that are to be reused to return them to their original location.

1. Clean the components with cleaning solvent.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

2. Dry the components with compressed air.
3. Inspect the valve rocker arms for wear or scoring in the ball area.
4. Inspect the valve rocker arm push rod sockets and valve stem tip mating surfaces.
5. Inspect the valve rocker arm ball for wear or scoring. These surfaces should be smooth with no scoring or exceptional wear.
6. Inspect the push rods (1, 2) for worn or scored ends. These surfaces should be smooth with no scoring or exceptional wear.



7. Inspect the push rods for bends. Roll the push rod on a flat surface to determine if the push rod is bent. If it rolls smoothly, it is okay. If the push rod does not roll smoothly, replace the push rod.

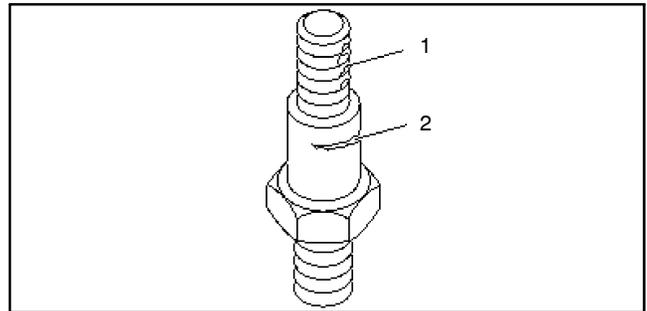
8. Inspect the push rod oil passages for restrictions.

- Clean the push rod tube with compressed air.
- Inspect by looking through the push rod tube for obstructions. A clear push rod will allow light through.
- Replace push rod(s) that cannot be cleaned.

Important: A light contact mark on the rocker arm stud is normal. A noticeable groove in the rocker arm stud is excessive wear and the rocker arm stud should be replaced.

9. Inspect rocker arm studs for following conditions:

- Damaged threads (1).
- Excessive wear or damage made from contact between the rocker arm and rocker arm stud (2).

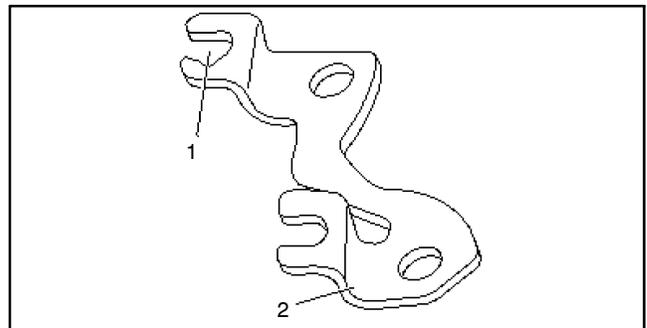


10. Replace valve rocker arm studs with excessive wear and/or damage.

11. Inspect the push rod guides for the following conditions:

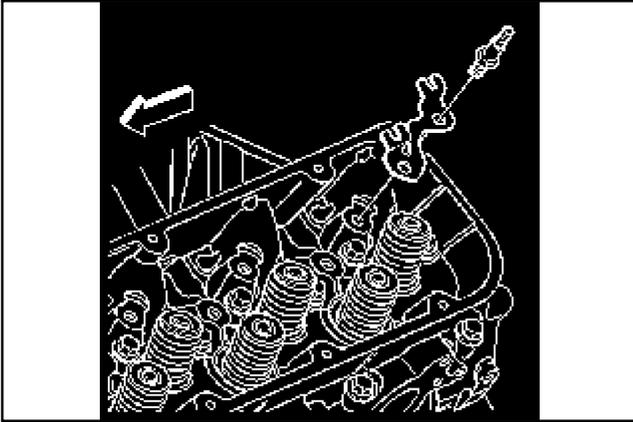
- Wear between the push rod and the push rod guide (1).
- Bent push rod guide (2).
- Cracks.

12. Replace push rod guides with excessive wear and/or damage.



4.2.4 Installation

Important: Keep the parts in order. Parts must be put back from where they were removed.



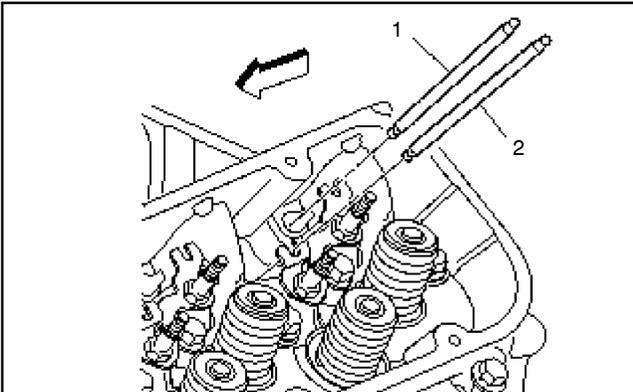
1. Apply sealer, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the valve rocker arm stud-to-cylinder head threads.

Apply the sealer to a minimum of six threads.

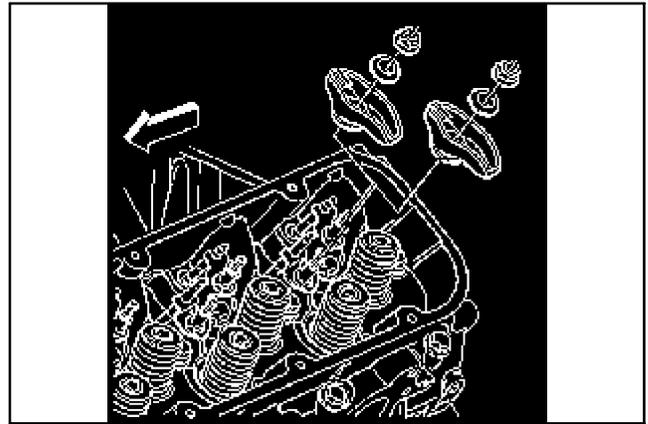
Notice: Refer to Fastener Notice in Cautions and Notices.

2. Install the push rod guides and valve rocker arm studs onto the cylinder head. Tighten the valve rocker arm studs to 50 Nm (37 ft. lb.).

Important: The 8.1 L engine uses different length intake and exhaust valve push rods. The exhaust valve push rods (2) are longer than the intake valve push rods (1).



3. Install the valve push rods.



4. Coat the valve rocker arm and valve rocker arm ball bearing surfaces with clean engine oil.
5. Install the valve rocker arms, the valve rocker arm balls, and the valve rocker arm nuts.

Tighten the valve rocker arm nuts slowly to 35 Nm (26 ft. lb.) while guiding the tips of the rocker arms over the tips of the valves.

4.3 Valve Stem Oil Seal and Valve Spring Replacement

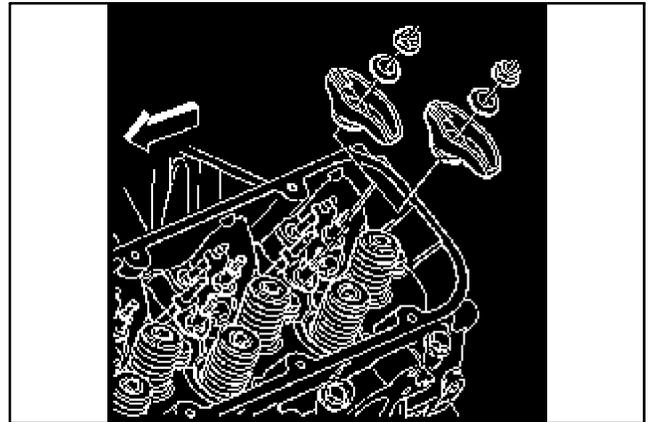
Tools Required:

J 5892-D Valve Spring Compressor

J 22794 Spark Plug Port Adapter

J 43105 Valve Stem Seal Installer

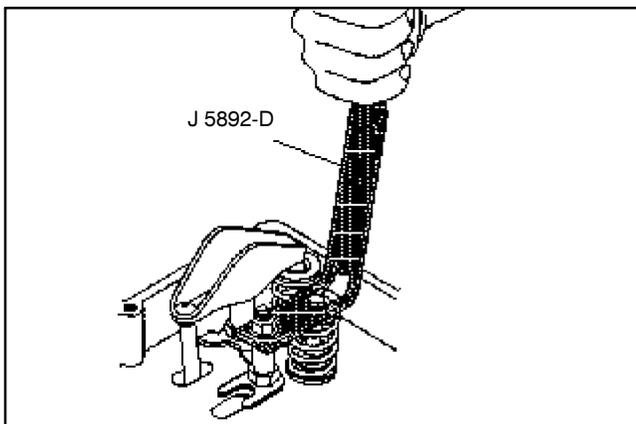
Removal Procedure



1. Remove the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.

Important: Rotate the piston in the cylinder being serviced to the bottom of its stroke to ensure that the engine does not rotate when the compressed air is applied.

2. Rotate the crankshaft until both valves are closed before installing compressed air into the cylinder.
3. Remove the spark plug from the cylinder being serviced.
4. Remove the valve stem keys as follows:
 - a. Install *J 22794* into the spark plug hole.
 - b. Apply compressed air into the cylinder to hold the valves closed.
 - c. Lightly tap the valve spring cap to loosen the valve stem keys.
 - d. Install *J 5892-D* to the cylinder head.

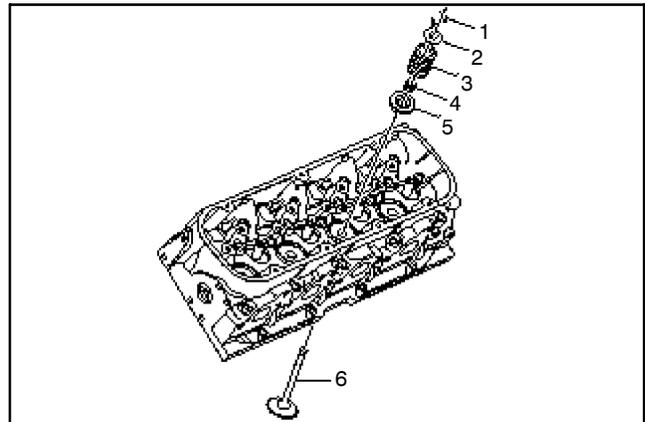


- e. Install the valve rocker arm nut.

Important: Tighten the valve rocker arm nut enough to hold *J 5892-D* in place.
 - f. Using *J 5892-D*, compress the valve spring.
5. Remove the valve stem keys (1).

Important: Do not release the compressed air from the cylinder being worked on. The valve will fall into the cylinder bore.

6. Slowly release *J 5892-D*.



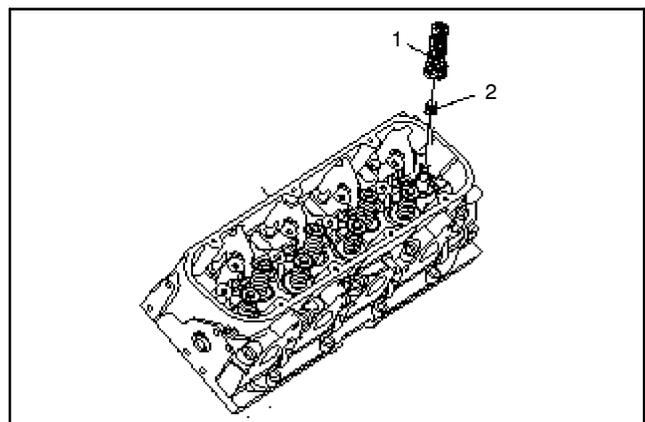
7. Remove *J 5892-D* from the cylinder head.
8. Remove valve spring cap (2) and valve spring (3).
9. Remove the valve stem oil seal (4).

Installation Procedure

1. Lubricate the valve stem and outside diameter of the valve guide seal with clean engine oil.
2. Lubricate the rotators with clean engine oil.

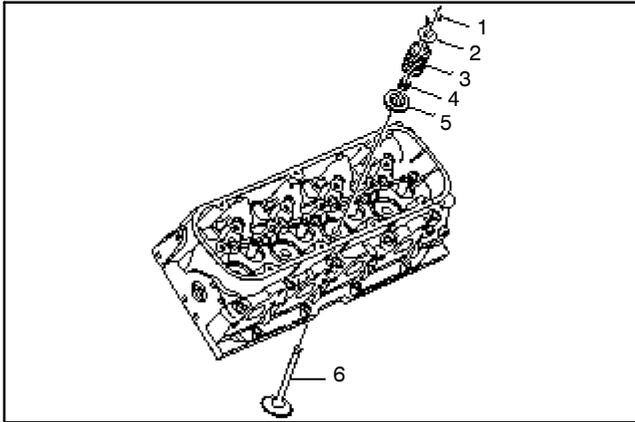
Important: When installing valve seals, use *J 43105* to achieve correct installation. Failure to use *J 43105* may cause excessive oil consumption.

3. Install the valve stem oil seal (2) over the valve tip and onto the valve guide using *J 43105*. Tap the valve stem seal onto the valve guide until *J 43105* fully seats the seal.

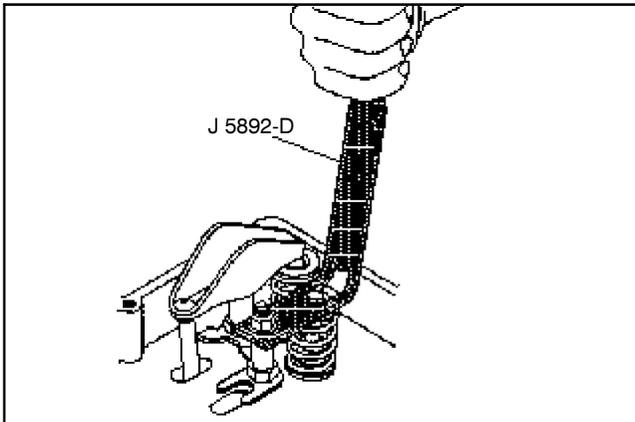


4. Install the valve spring cap and the spring.

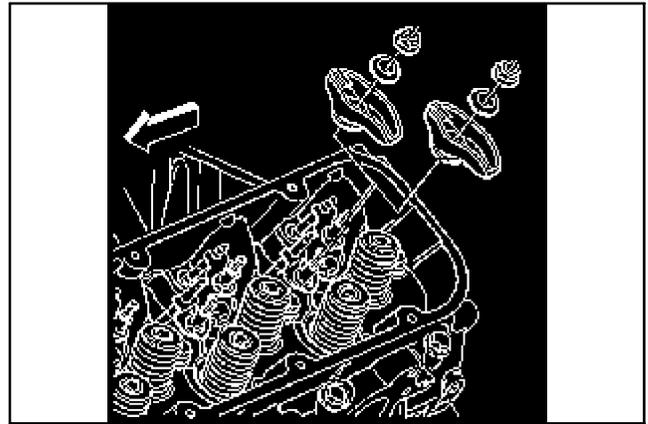
Important: When installing valve springs, install the small end of the valve spring up.



5. Install the valve spring (3).
6. Install the valve spring cap (2).
7. Using *J 5892-D*, compress the valve spring.



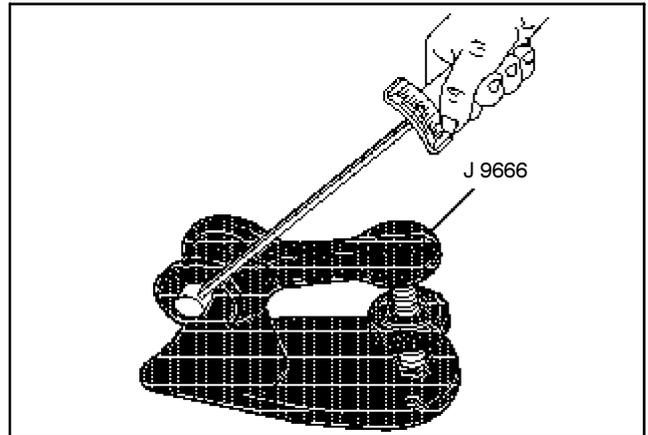
8. Install the valve stem keys as follows:
 - a. Apply a small amount of clean grease to hold the valve stem keys in place.
 - b. Carefully release *J 5892-D*. Make sure the valve stem keys do not move.
 - c. Remove *J 5892-D* from the valve assembly.
 - d. Remove compressed air from the cylinder being worked on.
9. Install the spark plug. Refer to *Spark Plug Replacement* in Engine Controls.



10. Install the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.

4.4 Valve Spring Inspection and Measurement

1. Inspect the valve springs for broken coils or coil ends.
2. Use *J 9666* to measure valve spring force. Refer to Section 1.2, Engine Mechanical Specs.

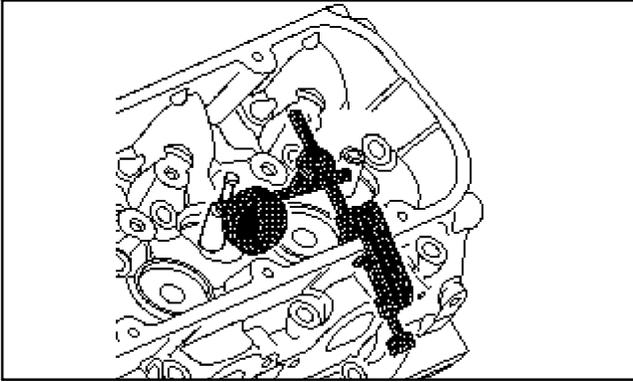


Important: Add a maximum of one shim up to 0.726 mm (0.030 in.) thick to increase tension.

3. If the valve spring tension is low, use a shim to increase tension.
4. Recheck the valve spring tension. Replace a valve spring that does not meet specifications.

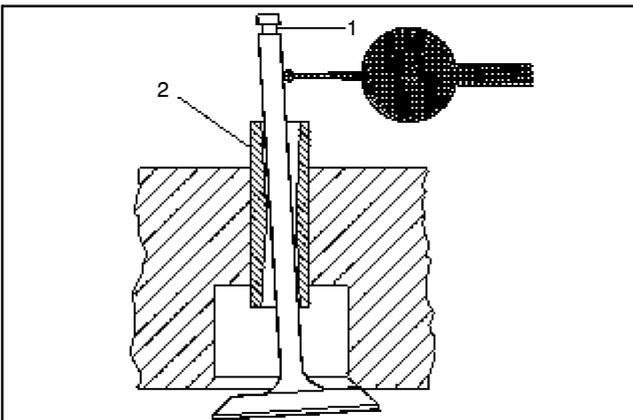
Valve Guide Measurement Procedure

Important: Excessive valve stem-to-guide clearance may cause excessive oil consumption and may also cause a valve to break. Insufficient clearance will result in noisy and sticky functioning of the valve and will disturb the engine assembly smoothness.



1. Measure the valve stem-to-guide clearance.
 - a. Clamp *J 8001* on the exhaust port side of the cylinder head.

Important: The indicator stem must contact the side of valve stem just above the valve guide.
 - b. Locate the indicator so that the movement of the valve stem from side to side, crosswise to the cylinder head, will cause a direct movement of the indicator stem.
 - c. Drop the valve head about 1.6 mm (0.064 in.) off the valve seat.
 - d. Use light pressure when moving the valve stem from side to side to obtain a clearance reading. Refer to Section 1.2, Engine Mechanical Specs.
2. Repair valve guide (2) with excessive clearance. Refer to Section 4.5, Valve Guide Reaming/Valve and Seat Grinding.

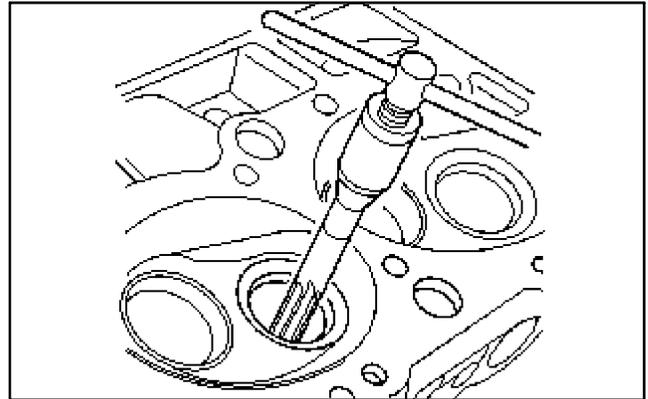


3. Replace the cylinder head if the valve guide cannot be repaired or reamed to accept an oversize valve stem.

4.5 Valve Guide Reaming/Valve and Seat Grinding

Valve Guide Reaming Procedure for Oversized Valve Stems

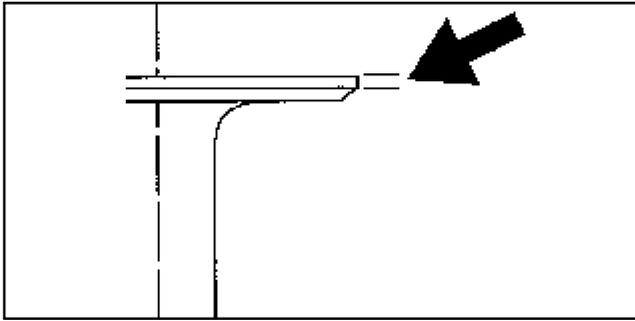
Notice: The exhaust valve guides are replaceable components and must be serviced properly. Press the exhaust valve guide out and into the cylinder head in the proper directions. Remove the old exhaust valve guide by pressing out toward the combustion chamber side of the cylinder head. Install the new exhaust valve guide by pressing from the combustion chamber side of the cylinder head. Failure to press the exhaust valve guide out and into the cylinder head in the proper directions will damage the cylinder head.



1. Ream the valve guide as necessary to achieve proper valve stem-to-guide clearance with the new, oversized valve stems.
2. Always recondition the valve seat after reaming the valve guide bores or installing new valves.
3. Replace the cylinder head if the valve guide cannot be repaired or reamed to accept an oversize valve stem.

Valve Reconditioning Procedure

1. Replace the valve if the valve stem shows excessive wear or is warped.



Important: Several different types of equipment are available for reconditioning valves. Use the manufacturer's recommended equipment to obtain the proper results.

2. Reface pitted valves on a valve refacing machine to ensure the correct relationship between the head and the stem.
3. Replace the valve if the edge of the head is less than 0.79 mm (0.031 in.) thick after grinding.

Valve Seat Reconditioning Procedure

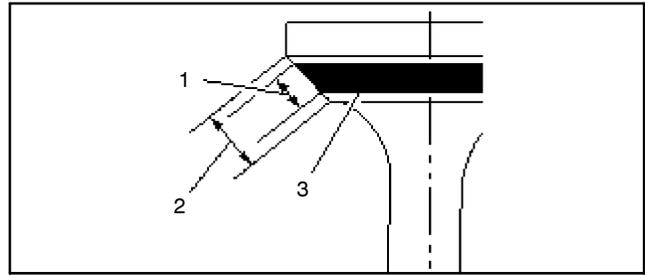
Important: Several different types of equipment are available for reconditioning valve seats. Use the manufacturer's recommended equipment to obtain the proper results.

Important: Always recondition the valve seat after reaming the valve guide bores or installing new valves.

1. Recondition the valve seats.
2. The valves must seat perfectly for the engine to deliver optimum power and performance.
3. Ensure that the valve seat and valve are not shrouded after valve seat reconditioning. Adequate flow past the valve seat and valve is essential for cooling the valve head and valve seat area.
4. Correct contact (1) between each valve and its seat in the cylinder head is also essential to ensure that the heat in the valve head is properly carried away.

Important: Regardless of what type of equipment is used, it is essential that the valve guide bores are free from carbon or dirt to ensure the proper centering of the pilot in the guide.

5. The valve seats should be concentric to within 0.050 mm (0.002 in.) total indicator runout.

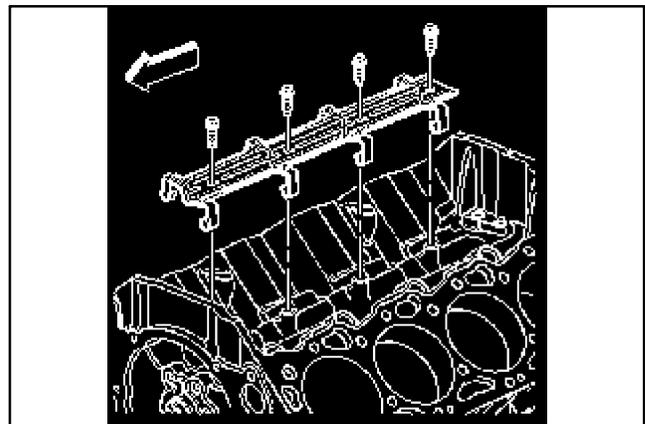


4.6 Valve Lifter

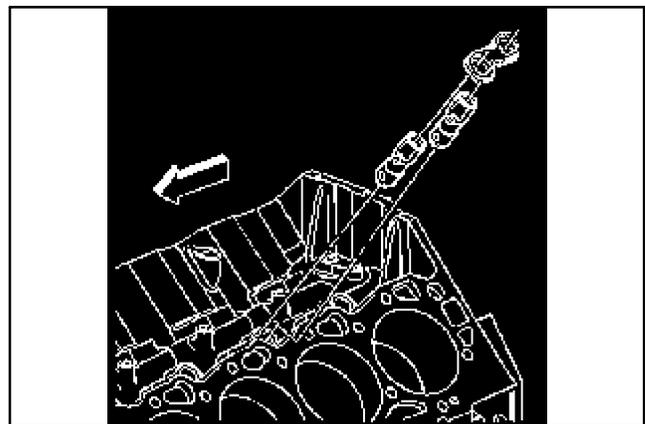
4.6.1 Replacement

Tools Required: J 3049-A Valve Lifter Remover

Removal Procedure



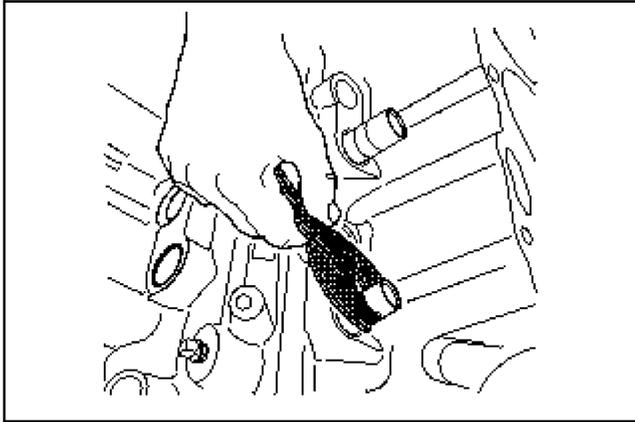
1. Remove the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.
2. Remove the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.
3. Remove the valve lifter guide retainer bolts and retainer.



4. Remove the valve lifter guides.

Important: Mark, sort, or organize the valve lifters and guides for installation in their original location.

5. Remove the valve lifters.
6. Some valve lifters may be stuck in their bore due to gum or varnish deposits. Remove using *J 3049-A*.



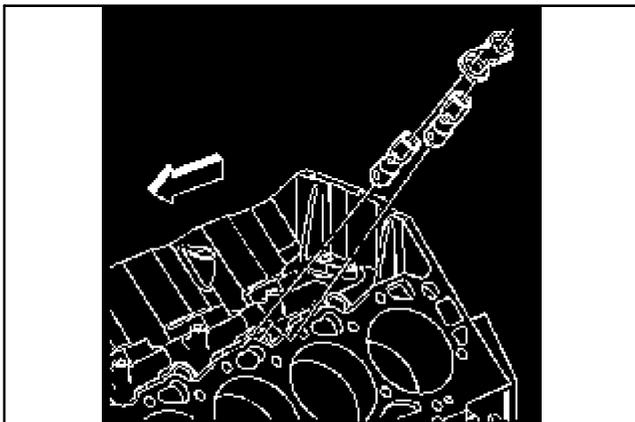
7. Clean and inspect the valve lifters. Refer to Section 4.6.3, Valve Lifters and Guides Cleaning and Inspection.

Installation Procedure

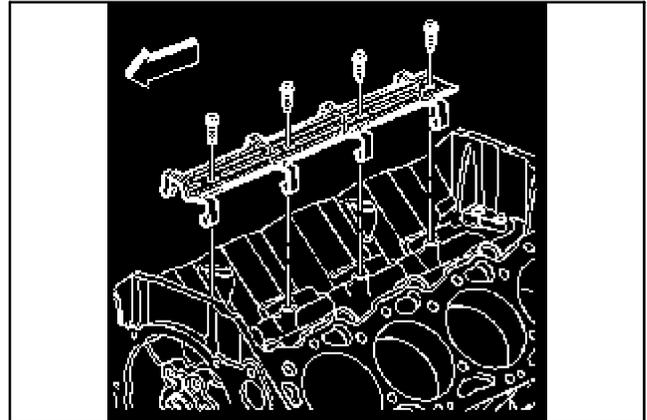
Important: If a new camshaft is installed, replace all the valve lifters.

1. Coat the valve lifter rollers with lubricant, GM Part No. U.S. 12345501/Canadian 992704, or equivalent.

Important: If reusing the valve lifters, install the lifters in their original location. The valve lifter guide retainer must contact all of the valve lifter guides. If the lifter guide retainer is bent, replace the valve lifter guide retainer.



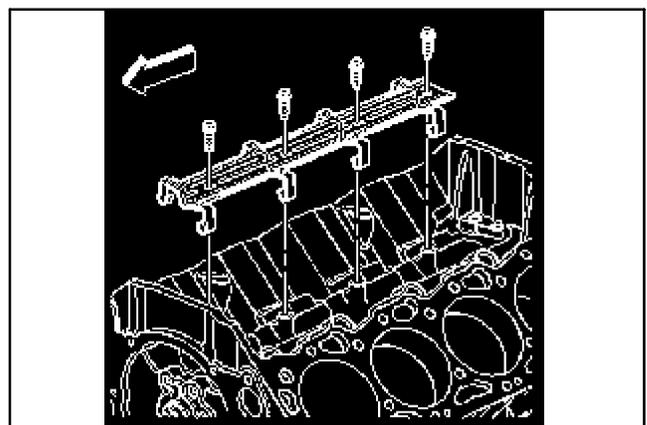
2. Install the valve lifters.
3. Install the valve lifter guides over the flats on the valve lifters, making sure the rollers of the valve lifters are properly aligned with the camshaft lobes.



4. Install the valve lifter guide retainer.
Notice: Refer to Fastener Notice in Cautions and Notices.
5. Install the valve lifter guide retainer bolts. Tighten the valve lifter guide retainer bolts to 25 Nm (18 ft. lb.).
6. Install the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement. Install the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.

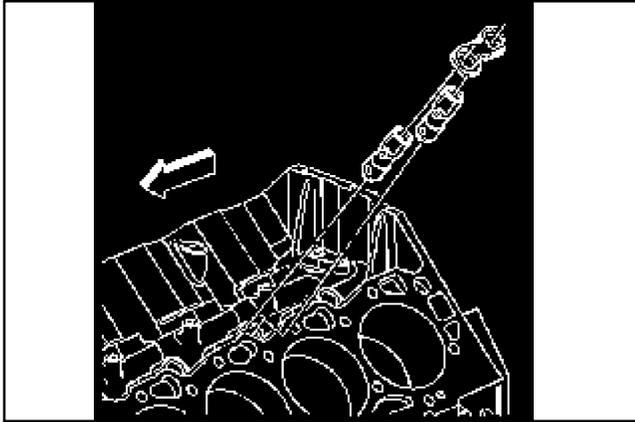
4.6.2 Removal

Tools Required: J 3049-A Valve Lifter Remover



Important: Mark, sort, or organize the valve lifters and guides for return to their original location during assembly.

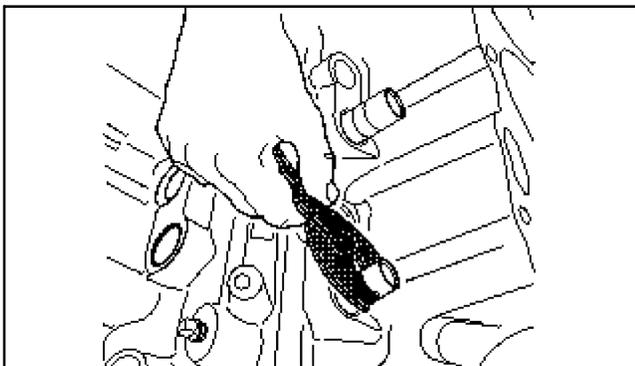
1. Remove the valve lifter guide retainer bolts and retainer.



2. Remove the valve lifter guides.

Important: Place the valve lifters in the organizer rack or tag them in a way to ensure they can be returned to the valve lifter bore from which they were removed.

3. Remove the valve lifters.



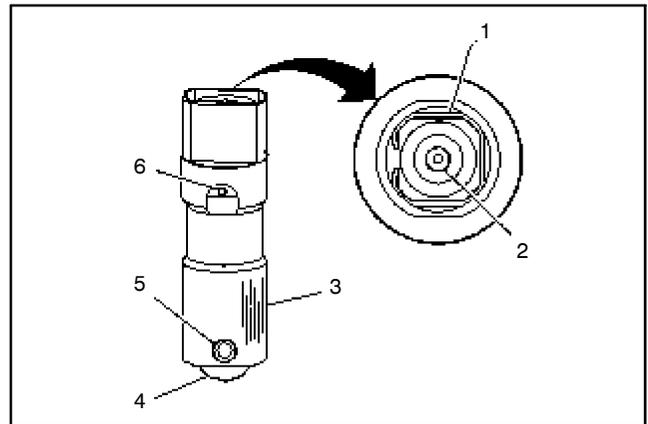
4. Some valve lifters may be stuck in their bore due to gum or varnish deposits. These valve lifters can be removed using *J 3049-A*.

4.6.3 Valve Lifters and Guides Cleaning and Inspection

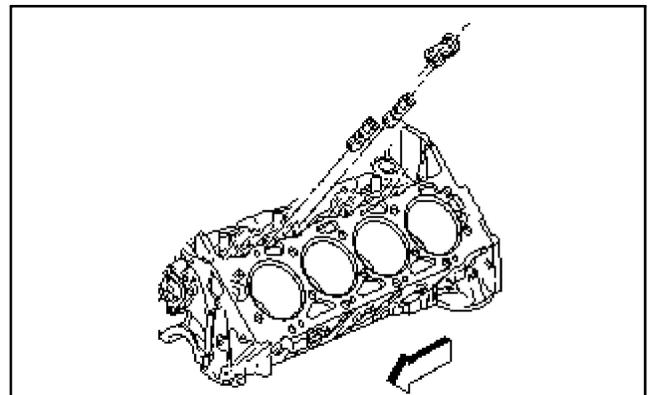
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

Important: Sort or organize parts that are to be reused to return them to their original location.

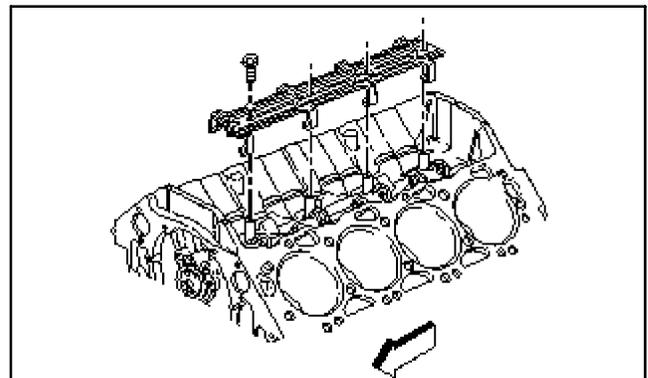
1. Dry the components with compressed air.
2. Inspect the valve lifters for the following:
 - A damaged, mispositioned, or broken clip (1).
 - A scored or worn push rod socket (2).



- A severely scuffed or worn lifter body (3). If the valve lifter body shows scuffing or wear, inspect the engine block valve lifter bores for wear or damage.
 - Flat spots on the roller (4).
 - A loose pin (5).
 - A plugged oil hole (6).
3. If flat spots are found on the lifter(s), inspect the corresponding lobe on the camshaft for damage.

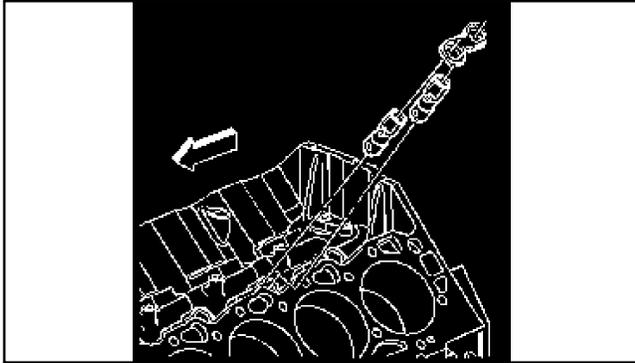


4. Inspect the valve lifter guides for the following:
 - Excessive guide slot side wear.
 - Cracks or damage.



5. Inspect the valve lifter guide retainer for the following:
 - Wear, damage, or stress cracking in the leg areas.
 - Wear or damage around the retainer bolt holes.

4.6.4 Installation

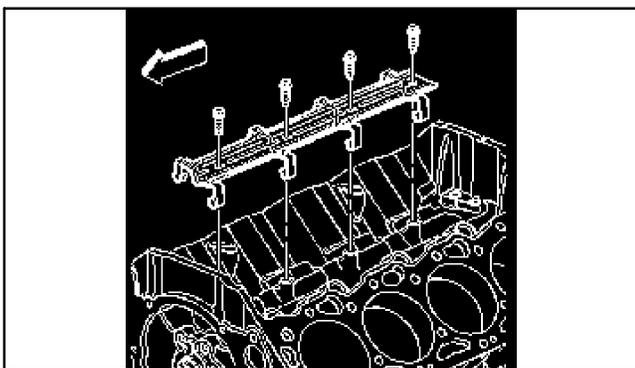


Important: If a new camshaft is installed, replace all the valve lifters.

1. Coat the valve lifter rollers with clean engine oil.

Important: If reusing the valve lifters, install in their original location. The valve lifter guide retainer must contact all of the valve lifter guides. If the valve lifter guide retainer is bent, replace the valve lifter guide retainer.

2. Install the valve lifters.
3. Install the valve lifter guides over the flats on the valve lifters, making sure the rollers of the valve lifters are properly aligned with the camshaft lobes.



4. Install the valve lifter guide retainer.

Notice: Refer to Fastener Notice in Cautions and Notices.

5. Install the valve lifter guide retainer bolts. Tighten the valve lifter guide retainer bolts to 25 Nm (18 ft. lb.).

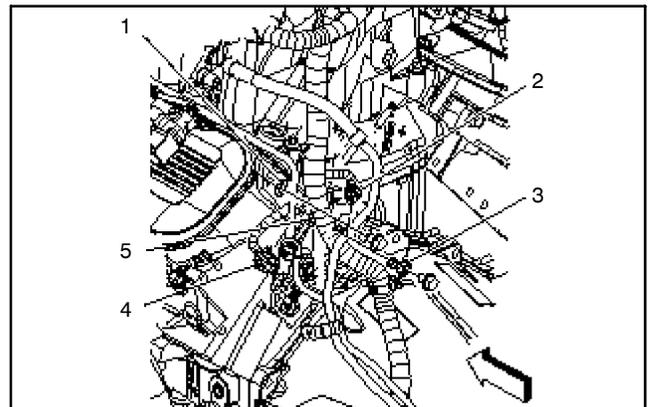
4.7 Cylinder Head

4.7.1 Replacement, Left

Tools Required: J 45059 Angle Meter

Removal Procedure

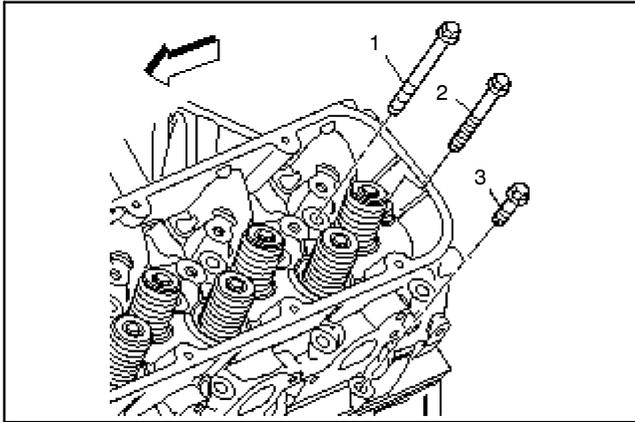
1. Remove the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.
2. Remove the water crossover. Refer to Section 9.3, Water Crossover.
3. Remove the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.
4. Remove the engine harness ground bolts.
5. Reposition the engine harness grounds (1 and 5) and ground strap (4) from the cylinder head.



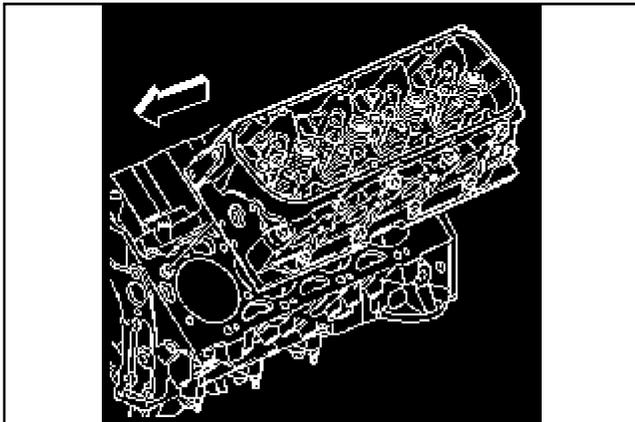
6. Remove the exhaust manifold. Refer to Section 10.2, Exhaust Manifold.

7. Remove and discard the cylinder head bolts (1, 2, and 3).

Important: Place the cylinder head on two wood blocks to prevent damage to the sealing surfaces.

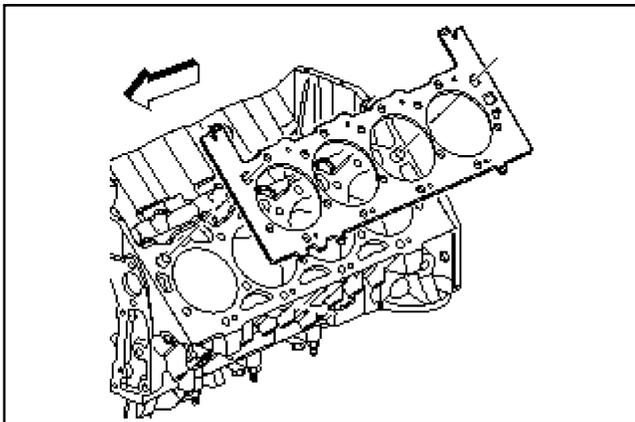


8. Remove the cylinder head.



9. Remove and discard the cylinder head gasket.

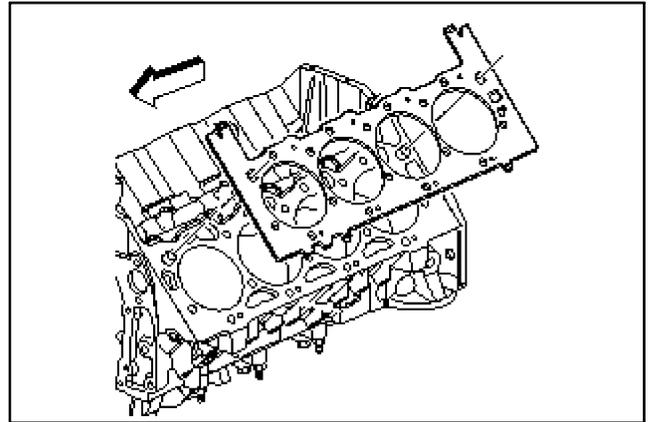
10. Clean and inspect the cylinder head. Refer to Section 4.7.4, Cylinder Head Cleaning and Inspection.



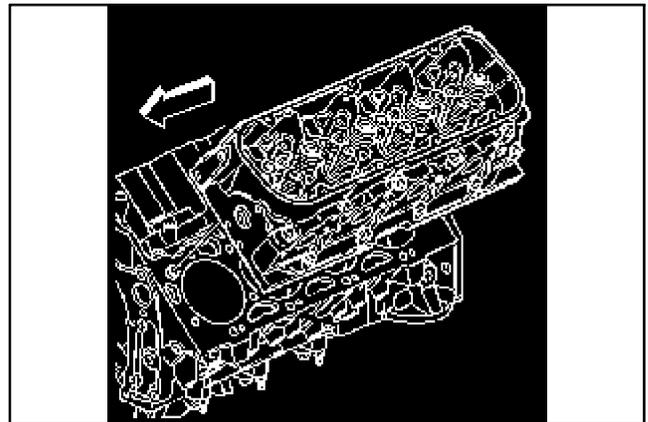
Installation Procedure

Important: Make sure the threaded holes in the engine block are clean and not damaged. Do not use sealer on any engines that use a composition type gasket. Align the cylinder head gasket locating marks to face up. Ensure that the head gasket tabs are located over the numbers 1 and 2 cylinders for correct installation.

1. Place a *new* cylinder head gasket into position.



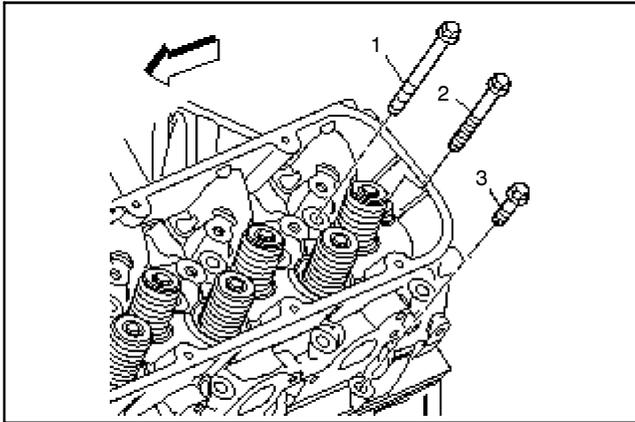
2. Install the cylinder head.



Notice: Do not reuse the cylinder head bolts. Use *new* cylinder head bolts. The cylinder head bolts are torque-to-yield bolts and cannot be reused after the initial torque is applied. During the initial torque of the cylinder head bolt, the cylinder head bolt is stretched to achieve proper clamp load. Proper clamp load will not be achieved if a used cylinder head bolt is torqued again. A stretched cylinder head bolt can also break when torqued. Failure to replace used cylinder head bolts with *new* cylinder head bolts can lead to improper clamp loads and extensive engine damage.

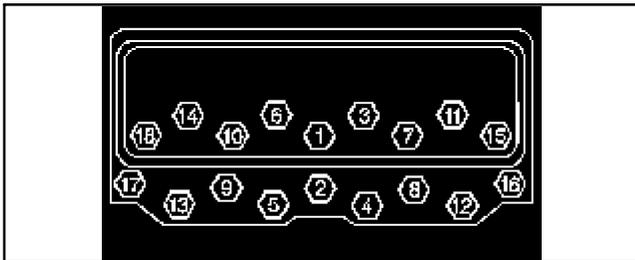
Important: Apply sealer to a minimum of eight threads starting at the point of the cylinder head bolt.

3. If not preapplied to the *new* cylinder head bolts, apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the cylinder head bolts.
4. Install the cylinder head bolts (1, 2, and 3).



Notice: Refer to Fastener Notice in Cautions and Notices.

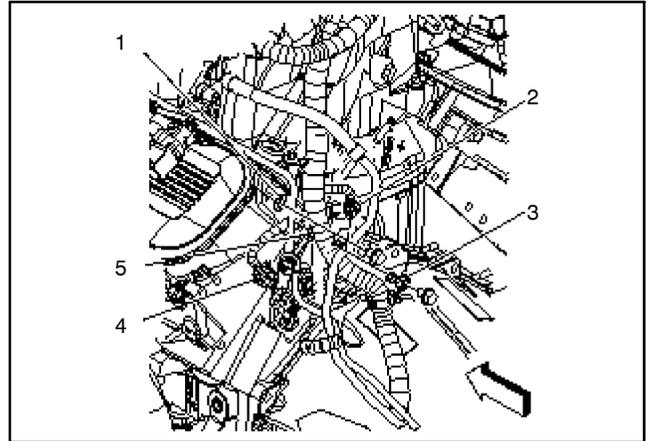
Important: The long bolts are used in locations 1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, and 17. The medium length bolts are used in locations 15 and 18. The short bolts are used in locations 4, 5, 12, and 13.



5. Tighten the cylinder head bolts.
 - a. Tighten the bolts a first pass in sequence to 30 Nm (22 ft. lb.).
 - b. Tighten the bolts a second pass in sequence to 30 Nm (22 ft. lb.), then an additional 120° using *J 45059*.
 - c. Tighten the bolts a final pass in sequence using *J 45059* as listed.

Bolt	Tighten:
1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, 17	Additional 60°
15, 18	Additional 45°
4, 5, 12, 13	Additional 30°

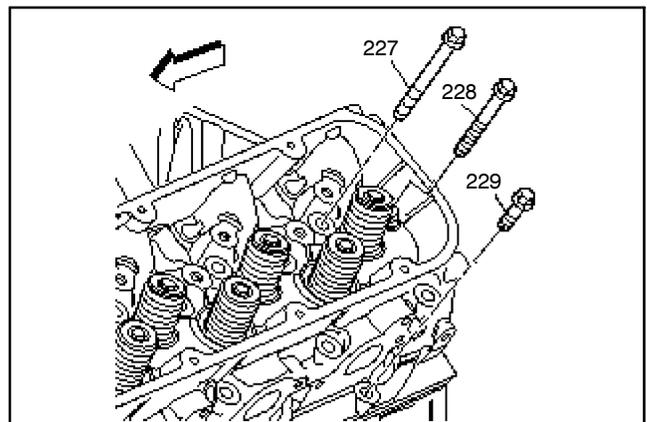
6. Install the exhaust manifold. Refer to Section 10.2, Exhaust Manifold.
7. Install the water crossover. Refer to Section 9.3, Water Crossover.
8. Position the engine harness grounds (1 and 5) and ground strap (4) to the cylinder head.



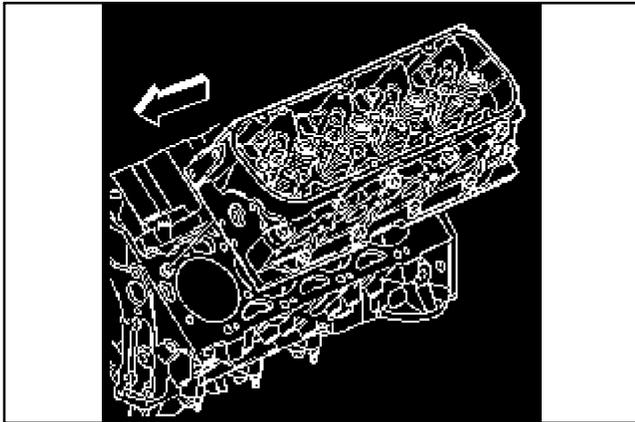
9. Install the engine harness ground bolts. Tighten the bolts to 16 Nm (12 ft. lb.).
10. Install the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.
11. Install the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.

4.7.2 Removal, Left

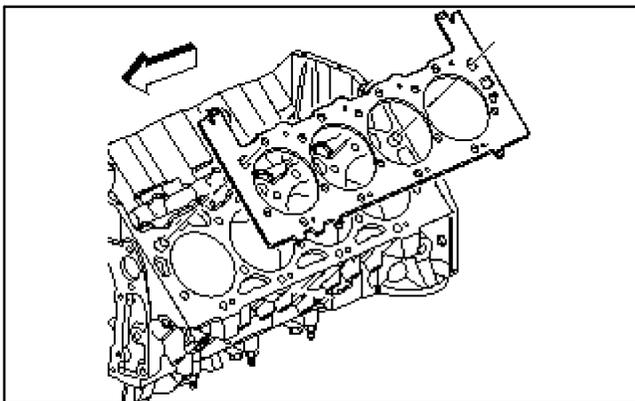
1. Remove and discard the eighteen cylinder head bolts (227, 228, 229).



Notice: After removal, place the cylinder head on two wood blocks to prevent damage to the sealing surfaces.



2. Remove the cylinder head.



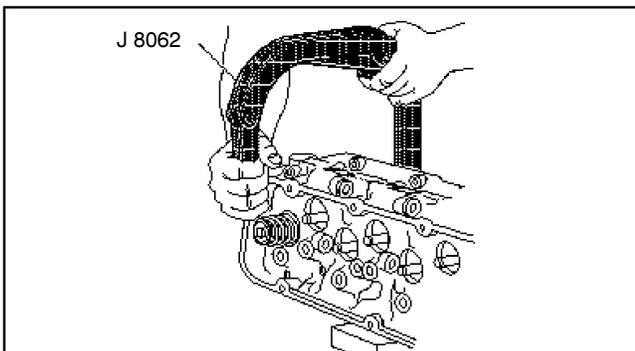
3. Remove the cylinder head gasket.

4. Discard the cylinder head gasket.

4.7.3 Disassemble

Tools Required:
J 8062 Valve Spring Compressor, Head Off

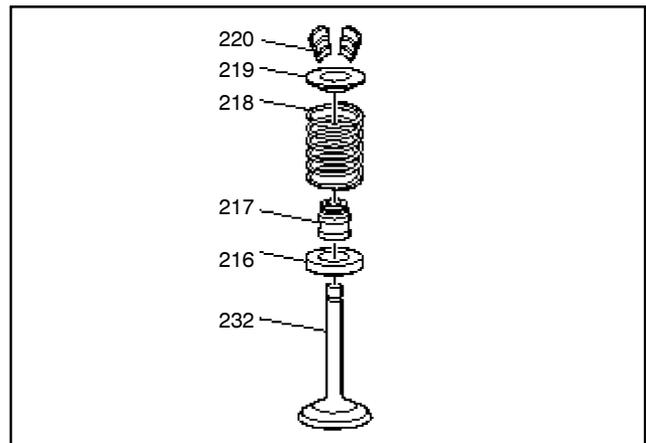
Caution: Refer to Safety Glasses Caution in Cautions and Notices.



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.

Important: Mark, sort, or organize components for return to their original locations.

1. Use *J 8062* to compress the valve springs.
2. Remove the valve stem keys (220).

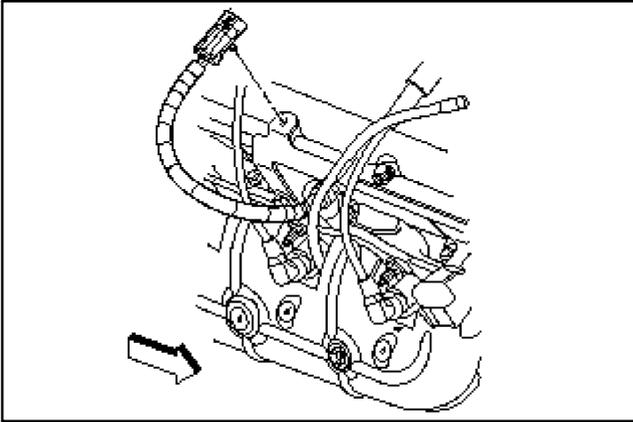


3. Release and remove *J 8062*.
4. Remove the cap (219).
5. Remove the valve spring (218).
6. Remove the valve stem seal (217) from the valve guide.
7. Remove the valve rotator (216).

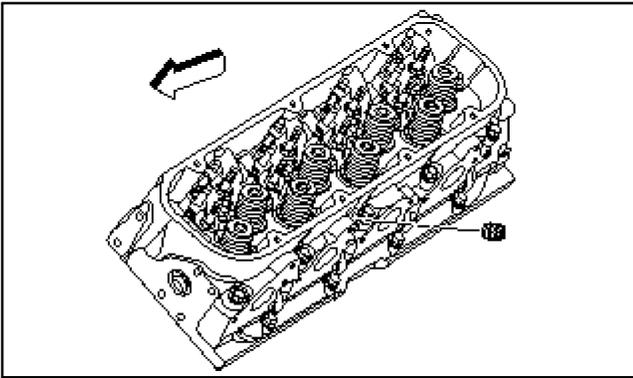
Important: To prevent damage to the valve guide, small burrs on the valve tip and at the stem key groove that interfere with the valve removal can be lightly filed with a fine file or stone to facilitate valve removal.

8. Remove the valve (232).

9. Disconnect the engine coolant temperature (ECT) sensor from the bracket.



10. Remove the ECT sensor from the cylinder head.
11. Remove the ECT sensor bracket and bolt.
12. Remove the cylinder head coolant hole plug from the cylinder head.



4.7.4 Cleaning and Inspection

Tools Required:

J 8089 Carbon Removal Brush

J 9666 Valve Spring Tester

J 8001 Dial Indicator Set

Cleaning Procedure

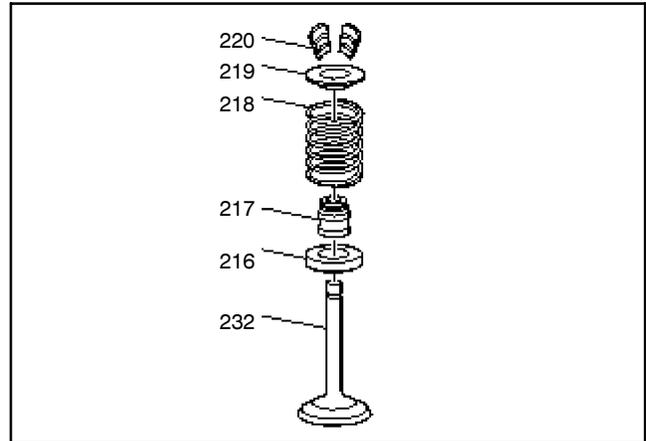
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

Important: Mark, sort, or organize components for return to their original locations.

1. Clean the valve stems and heads on a buffing wheel.
2. Clean the following components in solvent:
 - Valve stem keys (220).
 - Valve spring cap (219).

- Valve spring (218).
- Valve Rotators (216).
- Valve (232).
- Cylinder head.

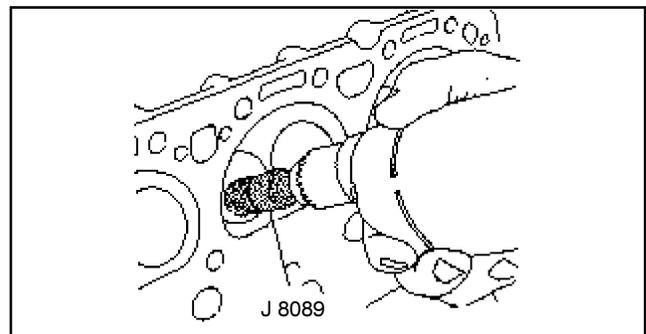
Caution: Refer to Safety Glasses Caution in Cautions and Notices.



3. Dry the components with compressed air.

Important: Be careful not to damage the chamber or the valve seat.

4. Use *J 8089* to clean carbon from the combustion chambers.



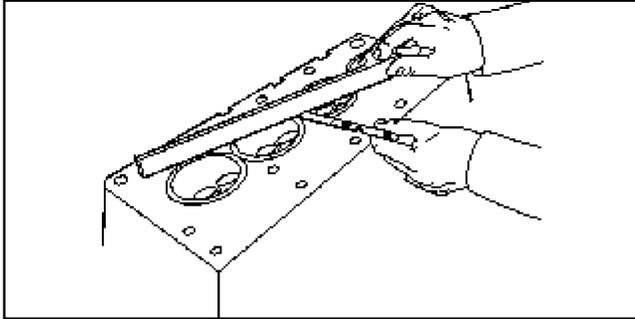
Visual Inspection Procedure

Inspect the cylinder head for the following conditions:

- Damaged gasket surfaces.
- Damage to threaded bolt holes.
- Burnt or eroded areas in the combustion chamber.
- Cracks in the exhaust ports and combustion chambers.
- External cracks in the water chamber.
- Restrictions in the intake or exhaust passages.
- Restrictions in the cooling system passages.

Flatness Measurement Procedure

1. Measure the cylinder head for warpage with a straight edge and feeler gauge.
2. Repair or replace a cylinder head block deck with warpage in excess of 0.050 mm (0.002 in.) within a 150.0 mm (6.0 in.) area.

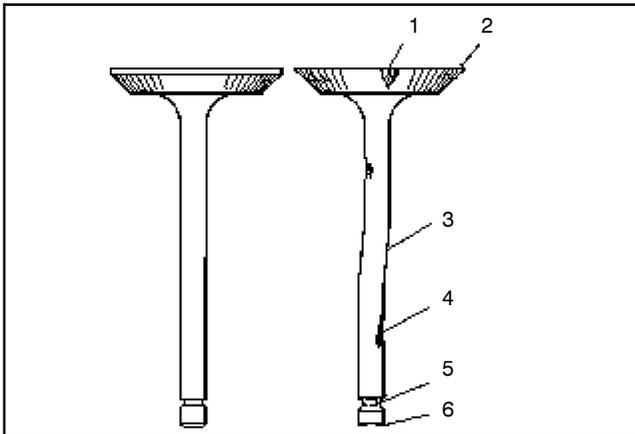


- Repair or replace a cylinder head exhaust manifold deck with an overall warpage in excess of 0.102 mm (0.004 in.).
- Repair or replace a cylinder head intake manifold deck with warpage in excess of 0.080 mm (0.003 in.).
- Resurface a cylinder head block deck up to 0.305 mm (0.012 in.) maximum removal.

Important: Excessive cylinder head resurfacing will affect compression ratio and emission control.

3. Replace a cylinder head that requires excessive resurfacing.

Valve Inspection Procedure

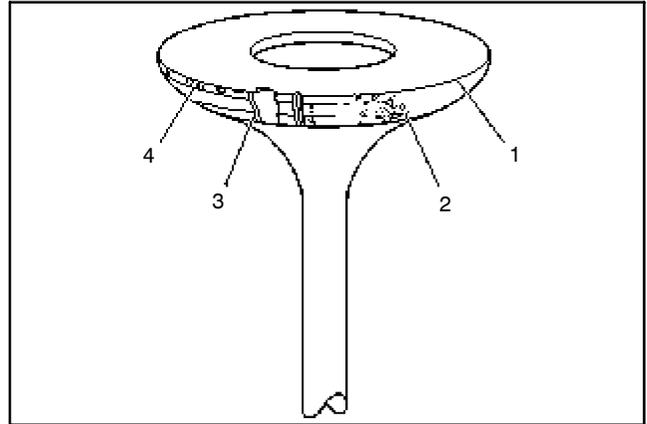


1. Inspect the valves for the following conditions:
 - Burnt or damaged areas (1).
 - Undersized valve margin (2).
 - Bent stem (3).
 - Scoring or other damage to the stem (4).

- Worn key groove (5).
- Worn stem tip (6).

2. Inspect the valve contact surface for the following conditions:

- Undersized margin (1).
- Pitted surface (2).
- Burnt or eroded areas (3).
- Acceptable edge, margin (4).



Important: Minor imperfections of the valve may be corrected during reconditioning.

3. Replace valves with excessive damage.

4.7.5 Assemble

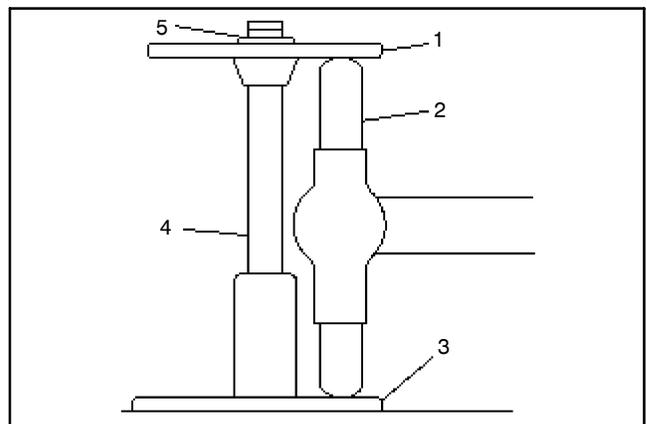
Tools Required:

J 8062 Valve Spring Compressor

J 43105 Valve Stem Seal Installer

Checking Valve Spring Installed Height

1. Install the valve rotator (3), valve (4), valve spring cap (1), and valve stem keys (5) into the cylinder head.



- Using a snap gauge or inside micrometer, measure the distance from the top of the valve rotator to the bottom of the valve spring cap. Refer to Section 1.2, Engine Mechanical Specs, for proper valve spring installed height specifications.

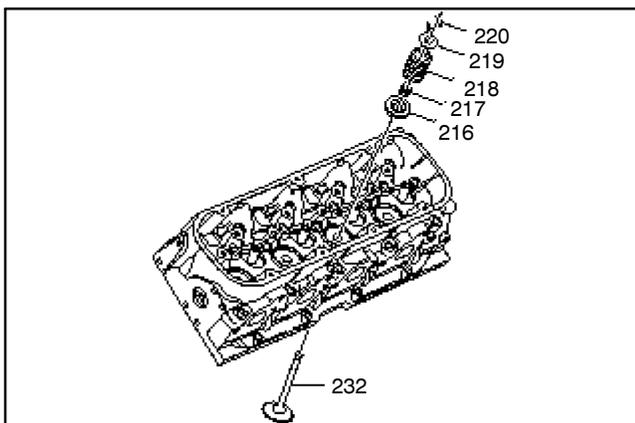
Important:

- Never shim the spring to obtain an installed height under the specified amount.
 - Install the valve spring seat shims under the rotator, between the rotator and the cylinder head spring seat.
 - Add a maximum of one valve spring seat shim, up to 0.726 mm (0.030 in.) thick, to achieve the valve spring installed height specification.
 - The combination of valve spring seat shims to correct valve spring installed height and valve spring tension should not exceed 1.524 mm (0.060 in.) thick.
- Install a valve spring seat shim if the valve spring installed height measurement is above the specification.
 - Recheck the valve spring installed height and replace the cylinder head if the valve spring installed height cannot be obtained.

Valve Installation

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

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.



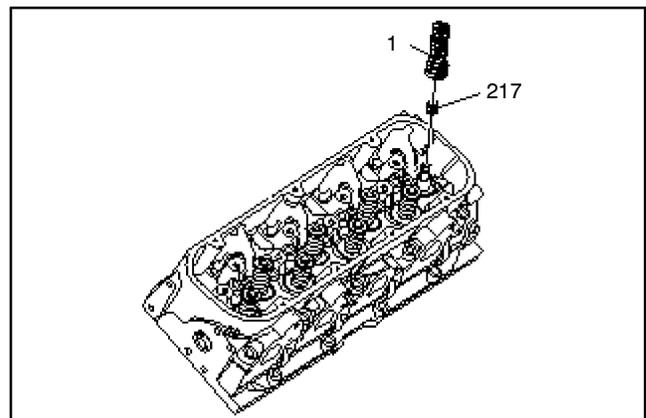
- Lubricate the valve stems (232) with clean engine oil.
- Insert the valves into their proper locations.
- Install the necessary valve spring shims onto the cylinder head, if applicable.
- Lubricate the rotators (216) with clean engine oil.
- Install the rotators over the guide and on top of the cylinder head or valve spring shims, if applicable.

Important: When installing valve stem oil seals onto the valve guides, take care not to tear the seal lip.

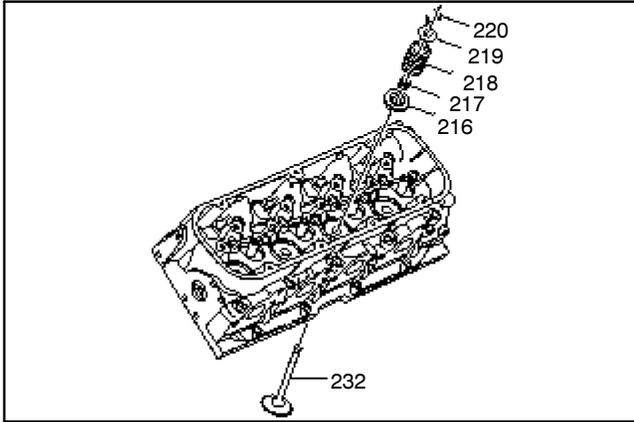
Important: When installing valve seals, use *J 43105* to achieve correct installation. Failure to use *J 43105* may cause excessive oil consumption.

- Lubricate the valve stem seal and the outside diameter of the valve guide with clean engine oil.
- Install the valve stem oil seals (217) over the valve tip and onto the valve guides using *J 43105* (1). Tap the valve stem seal onto the valve guide until *J 43105* fully seats the seal.

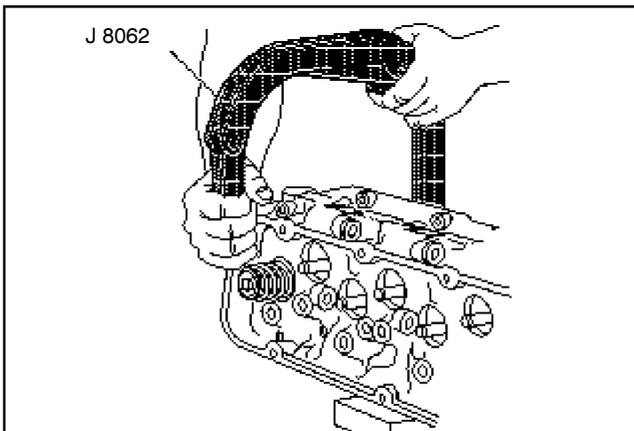
Important: When installing valve springs, install the small end of the valve spring up.



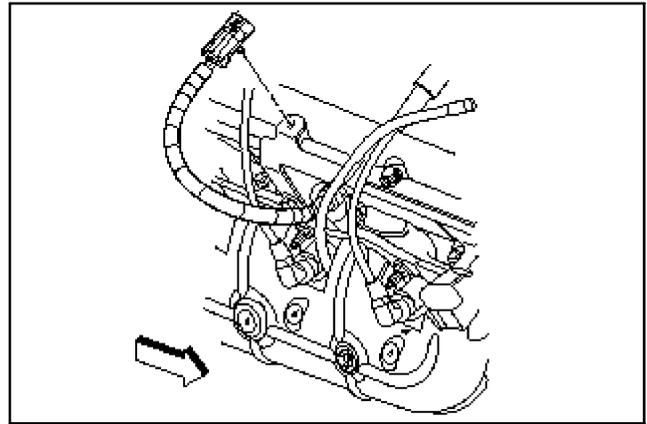
8. Install the valve springs (218).
9. Install the valve spring caps (219).



10. Use *J 8062* to compress the valve spring. Compress the spring enough to clearly see the valve stem key grooves of the valve.
11. Install the valve stem keys.
 - Use grease to hold the keys in place.
 - Ensure that the keys seat properly in the upper groove of the valve stem.
12. Release and remove *J 8062*.



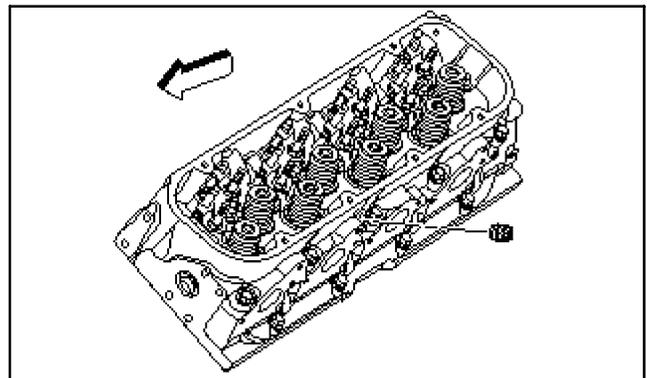
13. Lightly tap the end of the valve stem with a plastic-faced hammer to seat the keys.



14. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the engine coolant temperature (ECT) sensor.

Notice: Refer to Fastener Notice in Cautions and Notices.

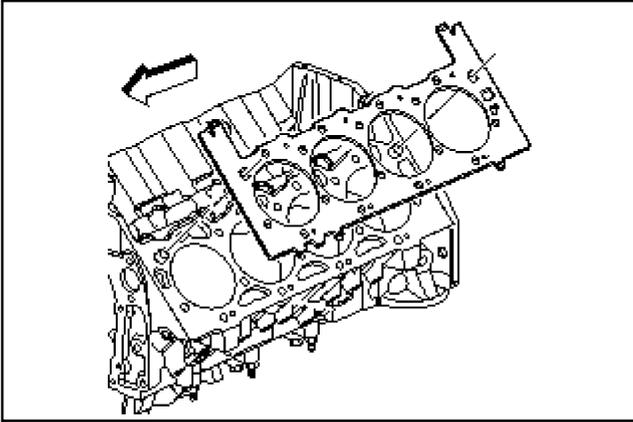
15. Install the ECT sensor into the right cylinder head. Tighten the ECT sensor to 50 Nm (37 ft. lb.).
16. Install the ECT sensor bracket and bolt. Tighten the ECT sensor bracket bolt to 50 Nm (37 ft. lb.).



17. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the cylinder head coolant hole plug.
18. Install the cylinder head coolant hole plug into the left cylinder head. Tighten the cylinder head coolant hole plug to 50 Nm (37 ft. lb.).

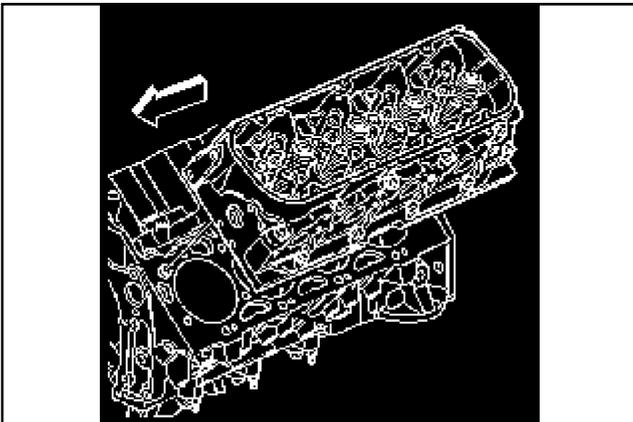
4.7.6 Installation, Left

Tools Required: J 45059 Angle Meter



Notice: Do not use a sealant or adhesive when installing this component. Use of a sealant or adhesive can cause improper sealing. A component that is not sealed properly can leak, leading to extensive engine damage.

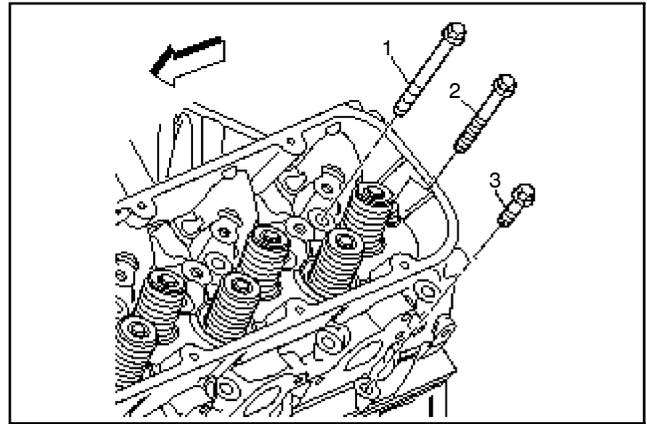
1. Place the cylinder head gasket in position over the cylinder head locating pins.



Important: Guide the cylinder head carefully into place over the locating pins and the cylinder head gasket.

2. Install the cylinder head to the block.

Notice: Do not reuse the cylinder head bolts. Use *new* cylinder head bolts. The cylinder head bolts are torque-to-yield bolts and cannot be reused after the initial torque is applied. During the initial torque of the cylinder head bolt, the cylinder head bolt is stretched to achieve proper clamp load. Proper clamp load will not be achieved if a used cylinder head bolt is torqued again. A stretched cylinder head bolt can also break when torqued. Failure to replace the used cylinder head bolts with *new* cylinder head bolts can lead to improper clamp loads and extensive engine damage.



Important: Apply sealer to a minimum of eight threads starting at the point of the cylinder head bolt.

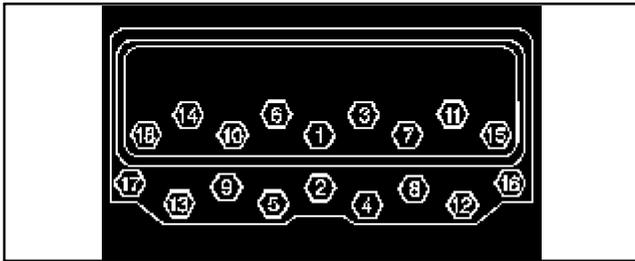
3. If not preapplied to the new cylinder head bolts, apply sealer, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the cylinder head bolts. Refer to Section 2.8, RTV and Anaerobic Sealer Use.

Notice: Refer to Fastener Notice in Cautions and Notices.

Notice: Do not reuse a cylinder head gasket after the initial clamping loads are applied. The initial tightening sequence procedure of the cylinder head bolts compresses the cylinder head gasket. If any bolt must be loosened after the initial sequence is started, replace the cylinder head gasket. Failure to replace the cylinder head gasket can lead to cylinder head bolt breakage or cylinder head gasket failure. A broken cylinder head bolt or failed cylinder head gasket can lead to extensive engine damage.

Notice: Follow the cylinder head bolt tightening sequence. The final angle tightening sequence of the cylinder head bolts varies depending on the length of the cylinder head bolt. Failure to angle tighten the specific length bolt the proper number of degrees can lead to cylinder head bolt failure or improper clamping load of the cylinder head gasket. Cylinder head bolt or cylinder head gasket failure can lead to extensive engine damage.

Important: The long bolts are used in locations 1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, and 17. The medium length bolts are used in locations 15 and 18. The short bolts are used in locations 4, 5, 12, and 13.



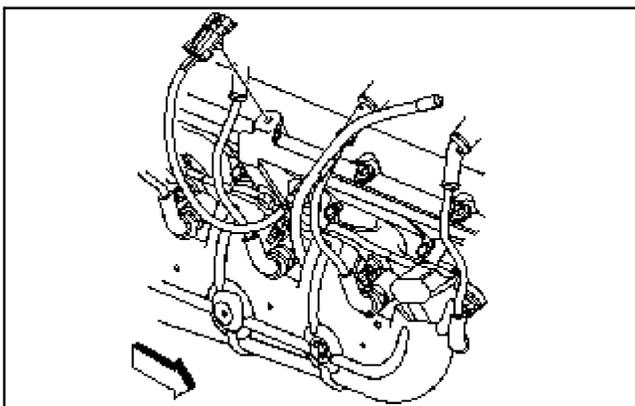
4. Install the cylinder head bolts.
5. Tighten:
 - a. Tighten the bolts a first pass in sequence to 30 Nm (22 ft. lb.).
 - b. Retighten the bolts in a second pass in sequence to 30 Nm (22 ft. lb.), then an additional 120° using *J 45059*.
 - c. Tighten the bolts a final pass in sequence using *J 45059* as listed.

Bolt	Tighten:
1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, 17	Additional 60°
15, 18	Additional 45°
4, 5, 12, 13	Additional 30°

4.7.7 Replacement, Right

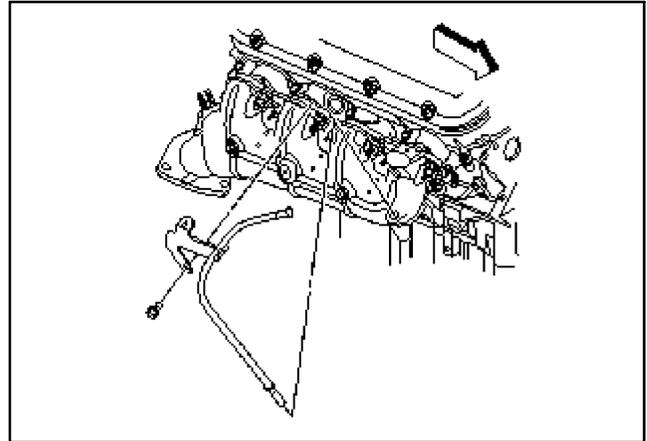
Tools Required: *J 45059* Angle Meter

Removal Procedure

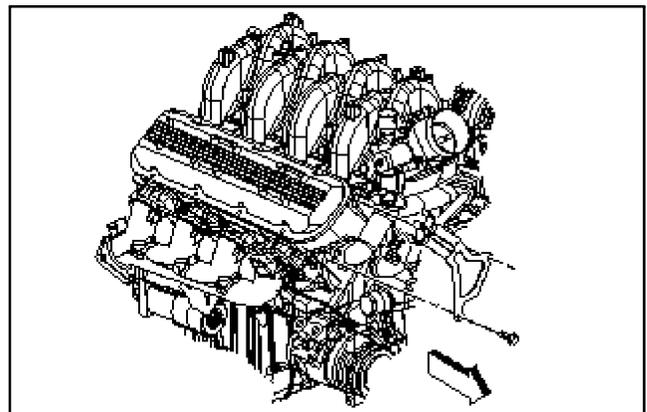


1. Drain the cooling system. Refer to Section 9, Cooling System and Drive Belts.
2. Remove the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.

3. Remove the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.
4. Remove the engine coolant temperature (ECT) sensor clip from the bracket.
5. Remove the ECT sensor from the cylinder head.



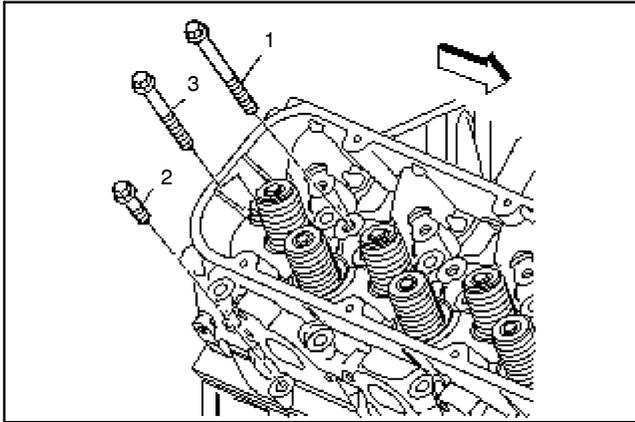
6. Remove the indicator tube bolt.
7. Remove the indicator tube bracket.
8. Remove the O-ring seal from the indicator tube.



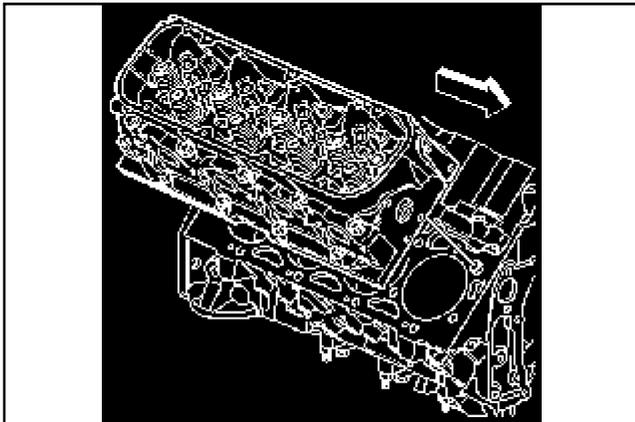
9. Remove the heater inlet and outlet hoses from the hose bracket.
10. Remove the heater hose bracket bolts and bracket from the cylinder head.
11. Remove the water crossover. Refer to Section 9.3, Water Crossover.
12. Remove the exhaust manifold. Refer to Section 10.2, Exhaust Manifold.

13. Remove and discard the cylinder head bolts (1, 2, and 3).

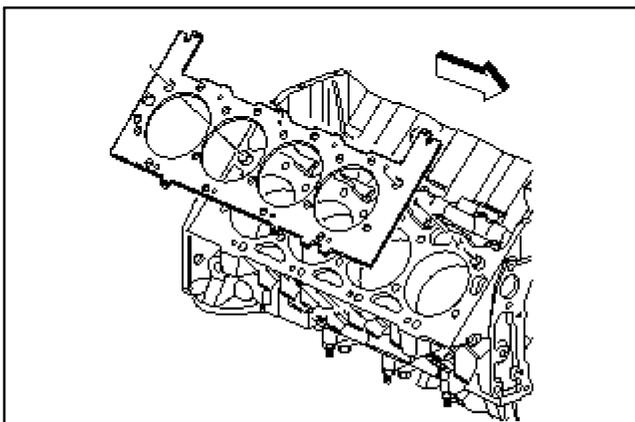
Important: Place the cylinder head on two wood blocks to prevent damage to the sealing surface.



14. Remove the cylinder head.



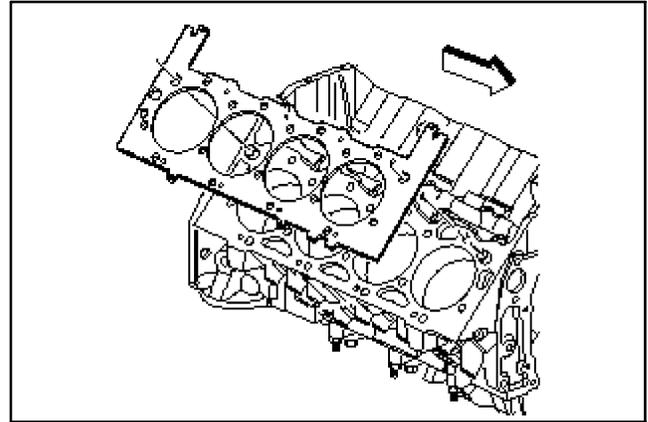
15. Remove and discard the cylinder head gasket.



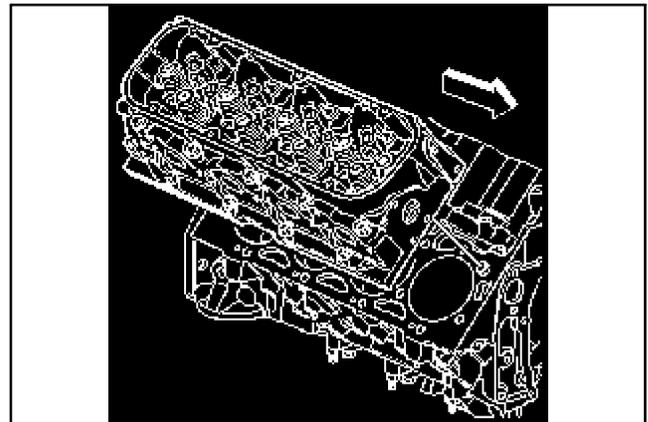
16. Clean and inspect the cylinder head. Refer to Section 4.7.4, Cylinder Head Cleaning and Inspection.

Installation Procedure

Important: Make sure the threaded holes in the engine block are clean and not damaged. Do not use sealer on any engines that use a composition type gasket. Align the cylinder head gasket locating mark to face up. Ensure that the head gasket tabs are located over the numbers 1 and 2 cylinders for correct installation.



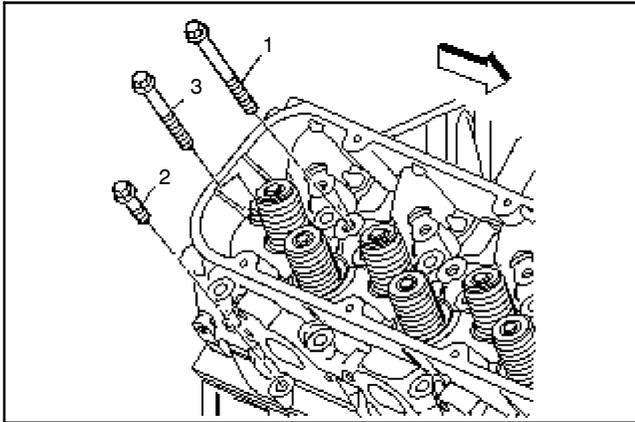
1. Place a *new* cylinder head gasket into position.
2. Install the cylinder head.



Notice: Do not reuse the cylinder head bolts. Use *new* cylinder head bolts. The cylinder head bolts are torque-to-yield bolts and cannot be reused after the initial torque is applied. During the initial torque of the cylinder head bolt, the cylinder head bolt is stretched to achieve proper clamp load. Proper clamp load will not be achieved if a used cylinder head bolt is torqued again. A stretched cylinder head bolt can also break when torqued. Failure to replace the used cylinder head bolts with *new* cylinder head bolts can lead to improper clamp loads and extensive engine damage.

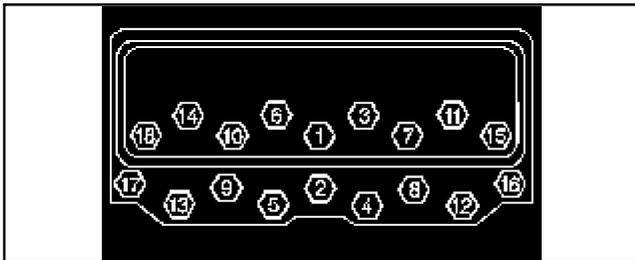
Important: Apply sealer to a minimum of eight threads starting at the point of the cylinder head bolt.

3. If not preapplied to the new cylinder heads bolts, apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the cylinder head bolts.
4. Install the cylinder head bolts (1, 2, and 3).



Notice: Refer to Fastener Notice in Cautions and Notices.

Important: The long bolts are used in locations 1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, and 17. The medium length bolts are used in locations 15 and 18. The short bolts are used in locations 4, 5, 12, and 13.

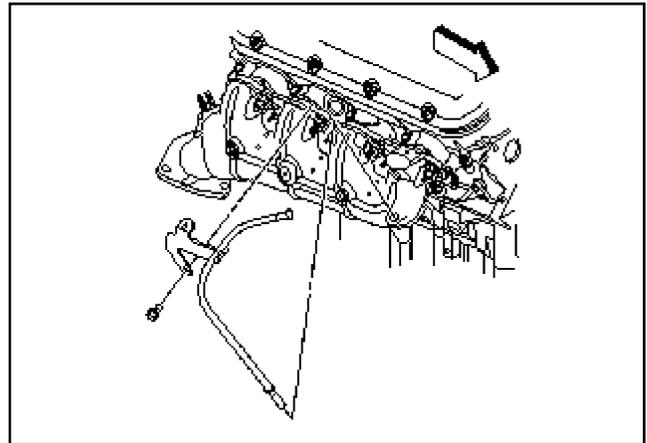
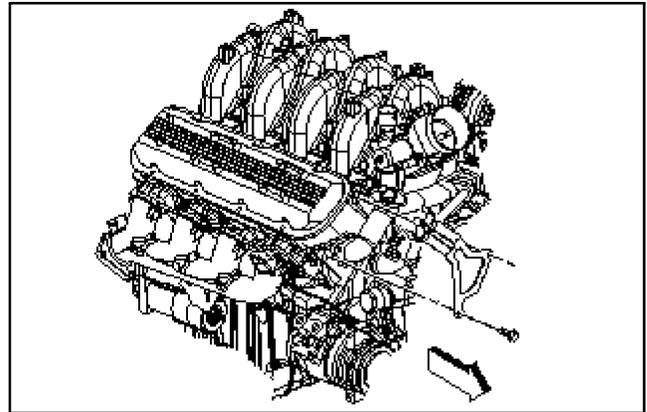


5. Tighten the cylinder head bolts.
 - a. Tighten the cylinder head bolts a first pass in sequence to 30 Nm (22 ft. lb.).
 - b. Tighten the cylinder head bolts a second pass in sequence to 30 Nm (22 ft. lb.) then an additional 120° using *J 45059*.
 - c. Tighten the bolts a final pass in sequence using *J 45059* as listed.

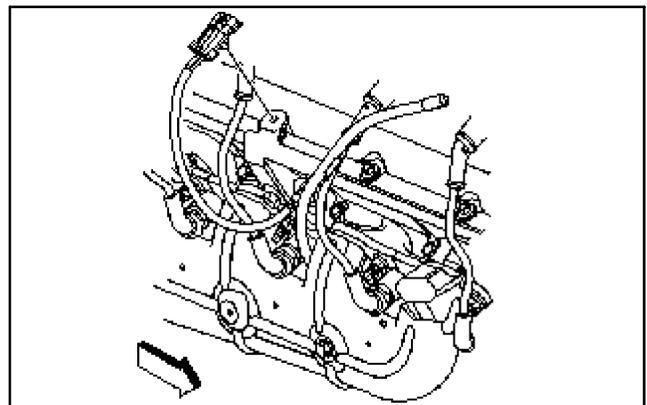
Bolt	Tighten:
1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, 17	Additional 60°
15, 18	Additional 45°
4, 5, 12, 13	Additional 30°

6. Install the exhaust manifold. Refer to Section 10.2, Exhaust Manifold.

7. Install the water crossover. Refer to Section 9.3, Water Crossover.



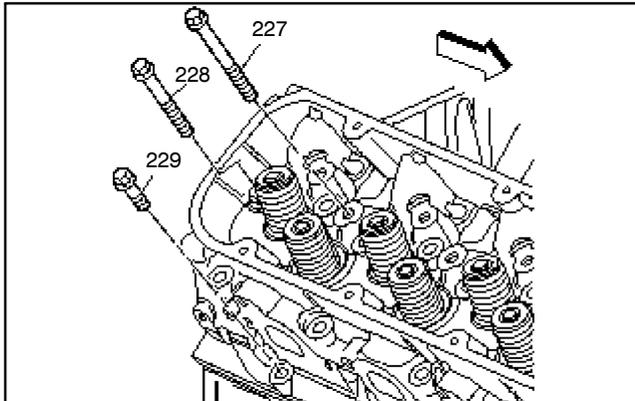
8. Install a *new* O-ring seal onto the indicator tube.
9. Install the indicator tube into the oil pan.
10. Align the indicator tube bracket with the bolt hole in the block.
11. Install the indicator tube bolt. Tighten the bolt to 50 Nm (37 ft. lb.).



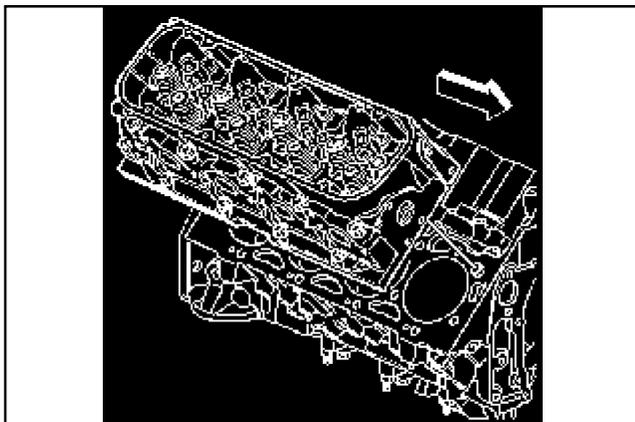
12. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the ECT sensor.
13. Install the ECT sensor to the cylinder head. Tighten the ECT sensor to 20 Nm (15 ft. lb.).
14. Install the ECT sensor clip to the bracket.
15. Install the valve rocker arms and push rods. Refer to Section 4.2.1, Valve Rocker Arm and Push Rod Replacement.
16. Install the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.
17. Drain the cooling system. Refer to Section 9, Cooling System and Drive Belts.

4.7.8 Removal, Right

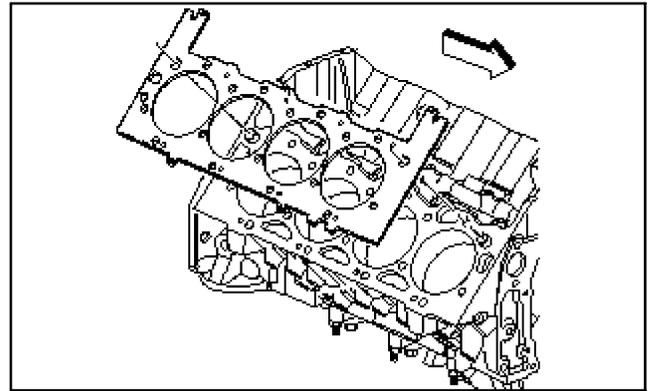
1. Remove and discard the eighteen cylinder head bolts (227, 228, 229).



Notice: After removal, place the cylinder head on two wood blocks to prevent damage to the sealing surfaces.



2. Remove the cylinder head.

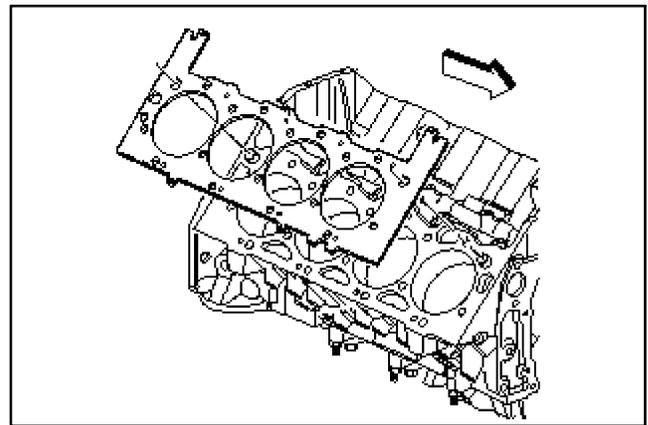


3. Remove the cylinder head gasket.
4. Discard the cylinder head gasket.

4.7.9 Installation, Right

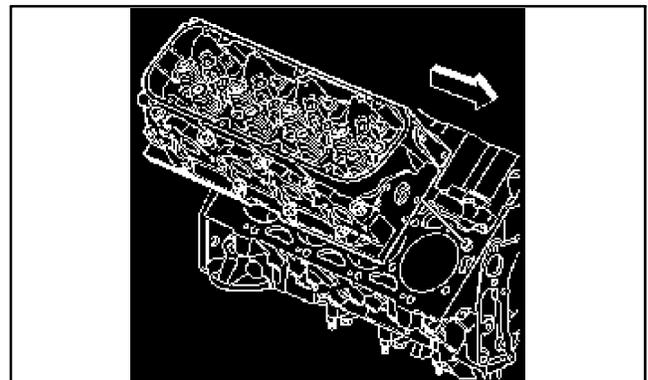
Tools Required: J 45059 Angle Meter

Notice: Do not use a sealant or adhesive when installing this component. Use of a sealant or adhesive can cause improper sealing. A component that is not sealed properly can leak, leading to extensive engine damage.



1. Place the cylinder head gasket in position over the cylinder head locating pins.

Important: Guide cylinder head carefully into place over the locating pins and the cylinder head gasket.

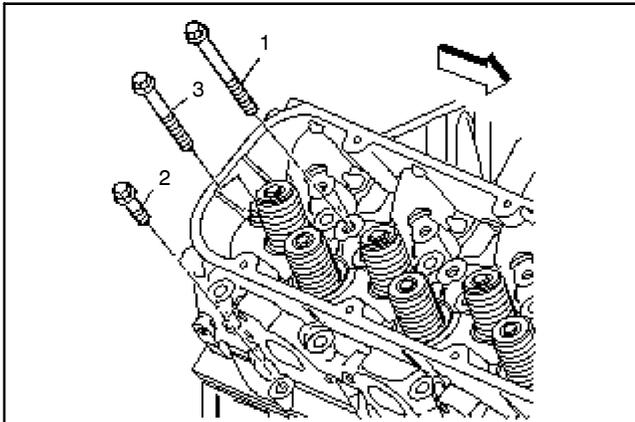


2. Install the cylinder head to the block.

Notice: Do not reuse the cylinder head bolts. Use *new* cylinder head bolts. The cylinder head bolts are torque-to-yield bolts and cannot be reused after the initial torque is applied. During the initial torque of the cylinder head bolt, the cylinder head bolt is stretched to achieve proper clamp load. Proper clamp load will not be achieved if a used cylinder head bolt is torqued again. A stretched cylinder head bolt can also break when torqued. Failure to replace the used cylinder head bolts with *new* cylinder head bolts can lead to improper clamp loads and extensive engine damage.

Important: Apply sealer to a minimum of eight threads starting at the point of the cylinder head bolt.

3. If not preapplied to the new cylinder head bolts (1–3), apply sealer, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the cylinder head bolts. Refer to Section 2.8, RTV and Anaerobic Sealer Use.

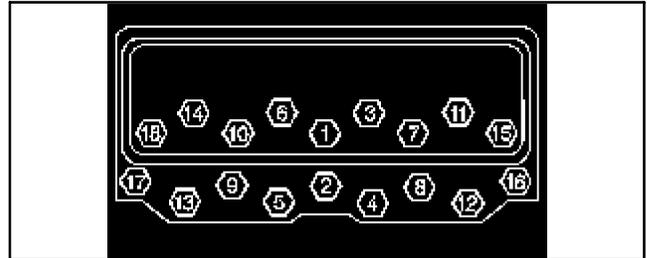


Notice: Refer to Fastener Notice in Cautions and Notices.

Notice: Do not reuse a cylinder head gasket after the initial clamping loads are applied. The initial tightening sequence procedure of the cylinder head bolts compresses the cylinder head gasket. If any bolt must be loosened after the initial sequence is started, replace the cylinder head gasket. Failure to replace the cylinder head gasket can lead to cylinder head bolt breakage or cylinder head gasket failure. A broken cylinder head bolt or failed cylinder head gasket can lead to extensive engine damage.

Notice: Follow the cylinder head bolt tightening sequence. The final angle tightening sequence of the cylinder head bolts varies depending on the length of the cylinder head bolt. Failure to angle tighten the specific length bolt the proper number of degrees can lead to cylinder head bolt failure or improper clamping load of the cylinder head gasket. Cylinder head bolt or cylinder head gasket failure can lead to extensive engine damage.

Important: The long bolts are used in locations 1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, and 17. The medium length bolts are used in locations 15 and 18. The short bolts are used in locations 4, 5, 12, and 13.



Install the cylinder head bolts.

4. Tighten:

- Tighten the bolts a first pass in sequence to 30 Nm (22 ft. lb.).
- Retighten the bolts a second pass in sequence to 30 Nm (22 ft. lb.), then an additional 120° using *J 45059*.
- Tighten the bolts a final pass in sequence using *J 45059* as listed.

Bolt	Tighten:
1, 2, 3, 6, 7, 8, 9, 10, 11, 14, 16, 17	Additional 60°
15, 18	Additional 45°
4, 5, 12, 13	Additional 30°

Section 5 Engine Block, Pistons, and Connecting Rods

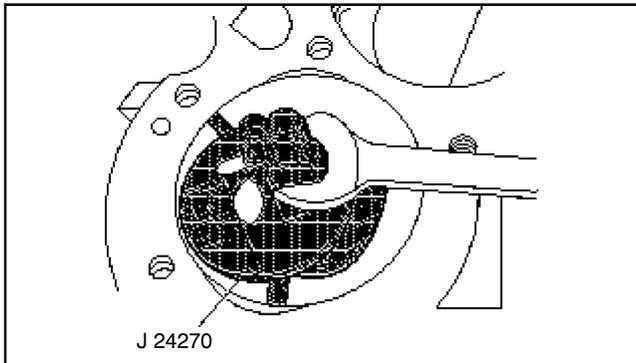
5.1 Piston, Connecting Rod, and Bearing

5.1.1 Removal

Tools Required:

J 24270 Cylinder Bore Ridge Reamer

J 42846 Crankshaft Protector Button

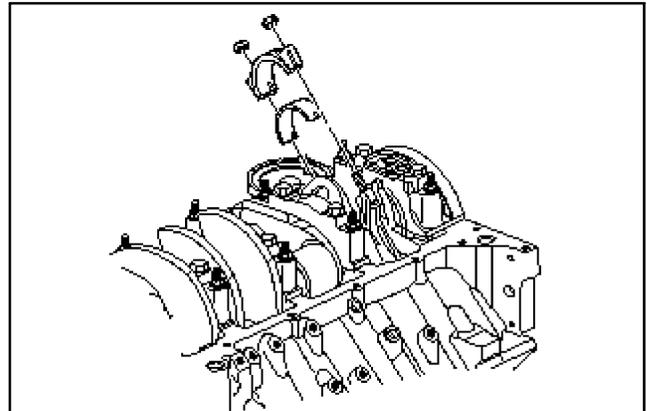


Important: Do not remove the excessive material from the cylinder bore. Excessive removal of material may require cylinder boring to the next oversize.

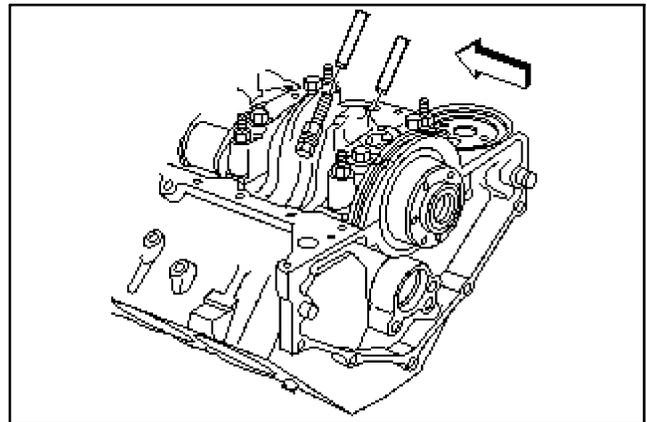
1. Remove the cylinder bore ridge as necessary.
 - a. Install J 42846 onto the front of the crankshaft to rotate the crankshaft.
 - b. Rotate the crankshaft until the piston is at the bottom of the stroke (BDC).
 - c. Place a cloth on top of the piston.
 - d. Perform the cutting operation with J 24270. Refer to the manufacturer's instructions before using J 24270.
 - e. Remove J 24270.
 - f. Rotate the crankshaft until the piston is at top dead center (TDC).
 - g. Remove the cloth and the cuttings.
 - h. Repeat the procedure for each piston.

Important: Place matching marks or numbers on the connecting rods and the connecting rod caps. Assemble the connecting rod caps to their original connecting rods.

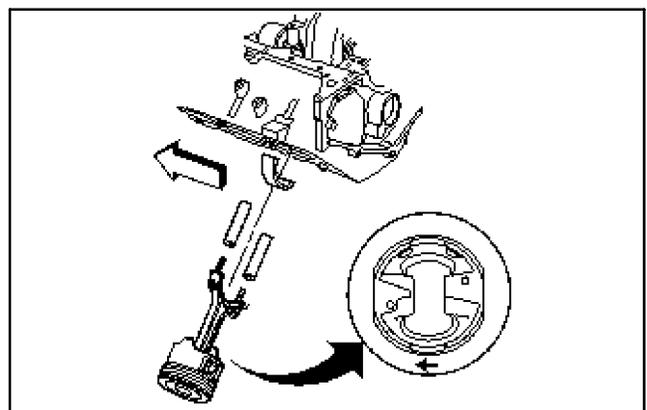
Important: When connecting rod bearings are removed, install *new* bearings during assembly.



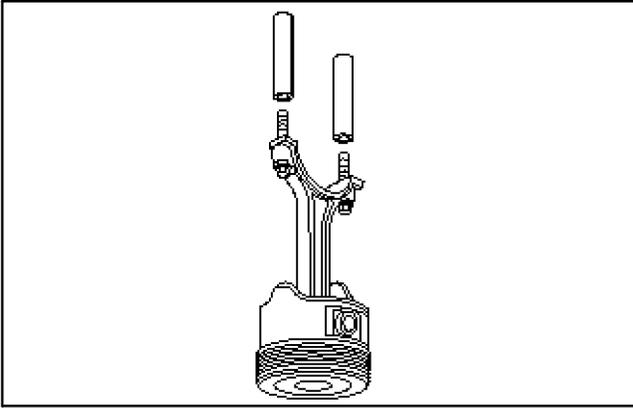
2. Remove the connecting rod nuts.
3. Remove the connecting rod cap and the connecting rod lower bearing.



4. Install rubber fuel line onto the connecting rod bolts to prevent contact with the crankshaft journal.



- Remove the piston, connecting rod, and connecting rod upper bearing.



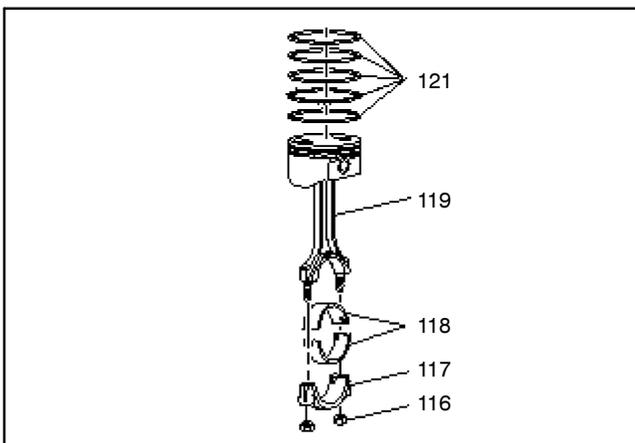
- Remove the rubber fuel line from the connecting rod bolts.
- Remove the remaining piston and the connecting rod assemblies.
- Remove *J 42846* from the front of the crankshaft.

5.1.2 Piston and Connecting Rod Disassemble

Important: The piston and connecting rod are only serviced as an assembly. If a new piston or connecting rod is required, use a complete piston/connecting rod assembly.

Important: Use new connecting rod nuts when the pistons are reinstalled in the engine.

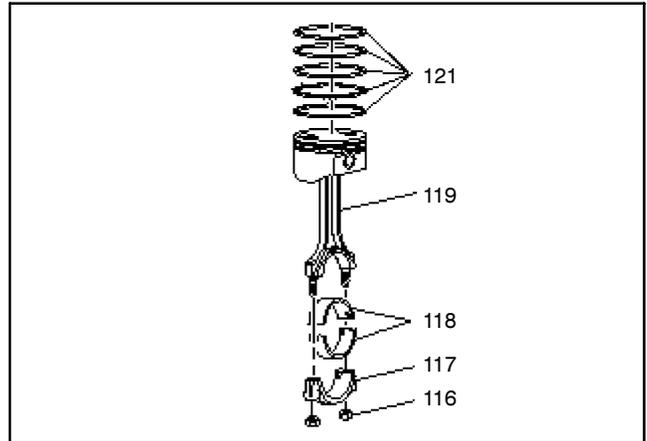
Remove the piston rings (121) from the piston.



5.1.3 Cleaning and Inspection

Important: The piston diameter *cannot* be measured due to the piston coating. Do *not* measure the piston diameter.

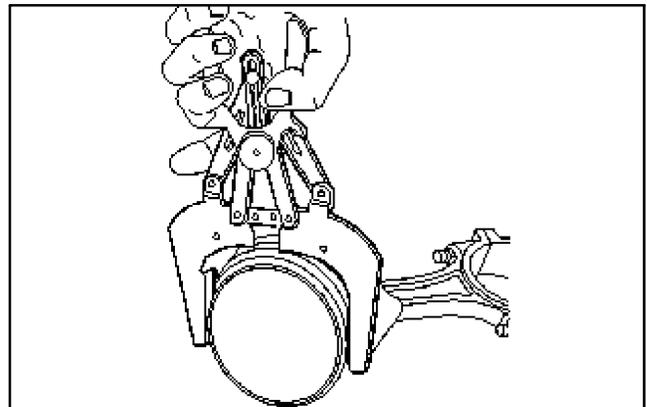
Important: Measurement of all components should be taken with the components at room temperature. Do not use a wire brush to clean any part of the piston.



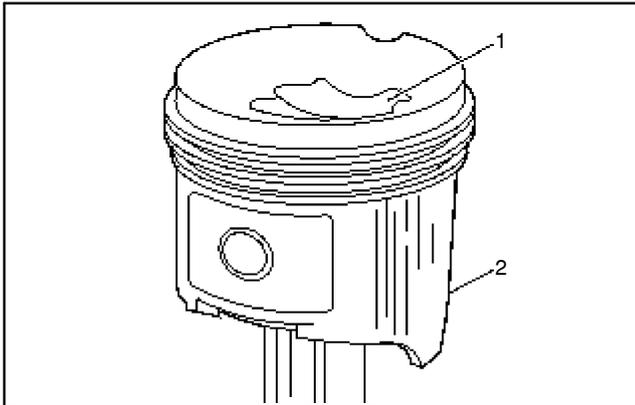
- Clean the piston and connecting rod (119) and connecting rod cap (117) in solvent.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

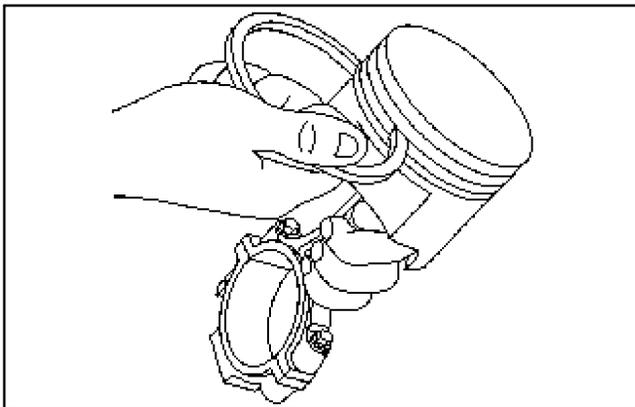
- Dry the components with compressed air.
- Clean the piston ring grooves with a suitable ring groove cleaning tool.



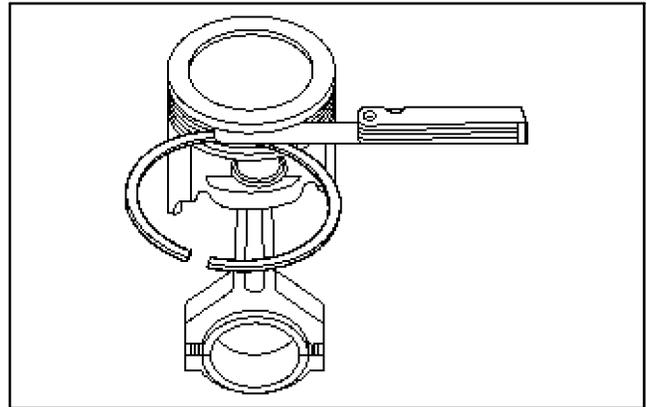
4. Clean the piston oil lubrication holes and slots.
5. Inspect the piston for the following conditions:
 - Eroded areas (1) on the top of the piston.
 - Scuffed or damaged skirt (2).



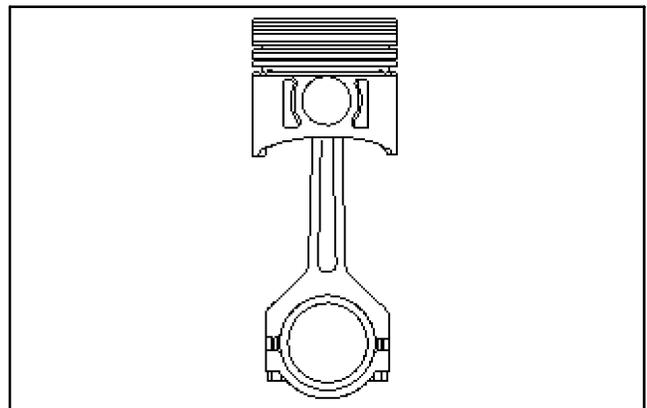
- Cracks in the piston ring lands, the piston skirt, or the pin bosses.
 - Piston ring grooves for nicks, burrs, or other warpage that may cause the piston ring to bind.
6. Inspect the piston pin for scoring, wear, or other damage.



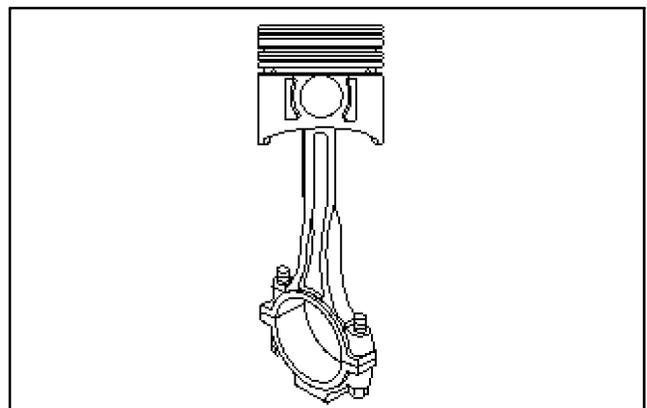
7. Measure the piston ring-to-piston ring groove side clearance. Refer to Section 1.2, Engine Mechanical Specs.
 - a. Insert the edge of the piston ring into the piston ring groove. Roll the piston ring completely around the piston.
 - b. If binding is caused by a distorted piston ring groove, *minor* imperfections may be removed with a fine file.
 - c. If binding is caused by a distorted piston ring, replace the piston ring.



8. Measure the piston ring side clearance with a feeler gauge.
9. If the side clearance is too small, try another piston ring set. Refer to Section 1.2, Engine Mechanical Specs.
10. If the proper piston ring-to-piston ring groove clearance cannot be achieved, replace the piston and pin assembly.

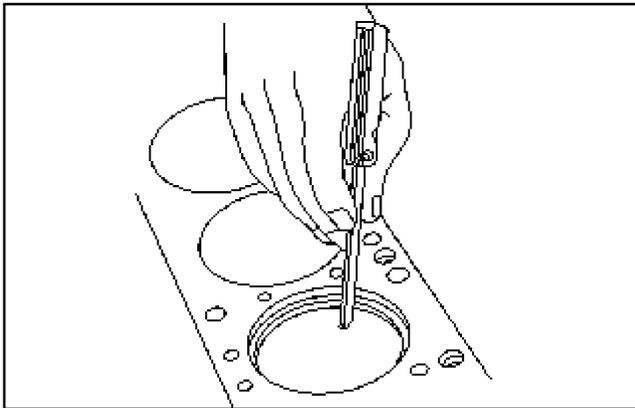


11. Inspect the connecting rod for an out-of-round bearing bore.



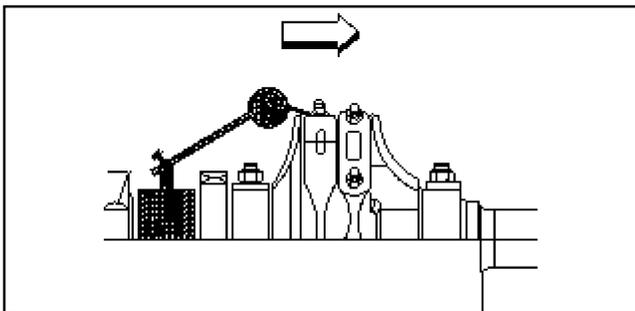
12. Inspect the connecting rod for twisting.
13. Inspect the connecting rod for damage to the connecting rod bolt threads.

Important: Fit each compression ring to the cylinder in which it will be used.



14. Measure the piston compression ring end gap.
 - a. Place the compression ring into the cylinder bore.
 - b. Push the compression ring into the cylinder bore to approximately 6.5 mm (0.25 in.) above the ring travel. The ring must be square to the cylinder wall.
 - c. Use a feeler gauge to measure the end gap.
 - d. Select another size ring set if the end gap exceeds specifications.

5.1.4 Connecting Rod Side Clearance Measurement



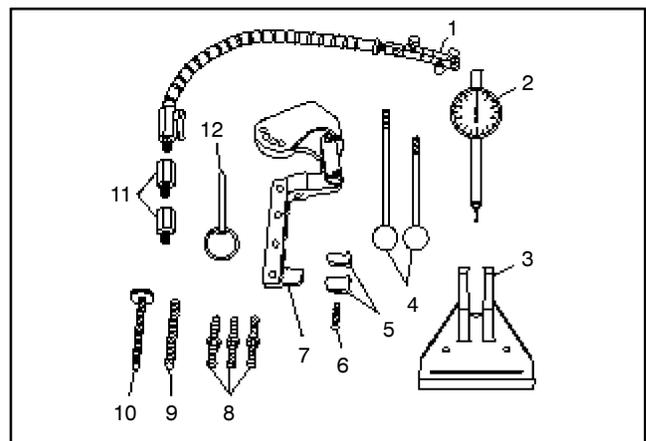
Important: To properly measure the connecting rod side clearance, install the piston/connecting rod assembly and bearings into the engine block and tighten the connecting rod nuts to specifications. Refer to Section 5.1.8, Piston, Connecting Rod, and Bearing Installation.

1. Install *J 7872* or equivalent to the cylinder block, with the dial indicator plunger against the side of the pair of connecting rods.
2. With the connecting rods pushed forward, zero the dial indicator. Firmly move the pair of connecting rods side to side and read the measurement on the dial indicator. An optional method is to insert a feeler gauge between the connecting rod caps and measure the connecting rod side clearance. Refer to Section 1.2, Engine Mechanical Specs.

5.1.5 Connecting Rod Bearing Clearance Measurement Using *J 43690/J 43690-100*

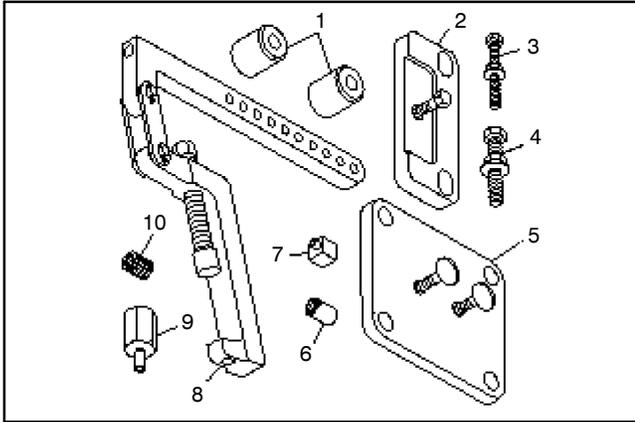
Tools *J 43690* and adapter kit *J 43690-100* have been developed as a more accurate method to measure connecting rod bearing clearances. The instructions below provide an overview of tool setup and usage. For more detailed information, refer to the tool instruction sheets as supplied by the tool manufacturer.

J 43690 Rod Bearing Clearance Checking Tool



- *J 43690-20* Swivel Base (1).
- *J 43690-19* Dial Indicator (2).
- *J 43690-2* Base (3).
- *J 43690-5, -6* Handle (4).
- *J 43690-10, -11* Foot (5).
- 280307 Screw (6).
- *J 43690-1* Pivot Arm Assembly (7).
- *J 43690-3, -7, -8* Screws (8).
- 280319 Screw (9).
- 280311 Screw (10).
- *J 43690-17, -18* Adapter (11).
- 280310 Pin (12).

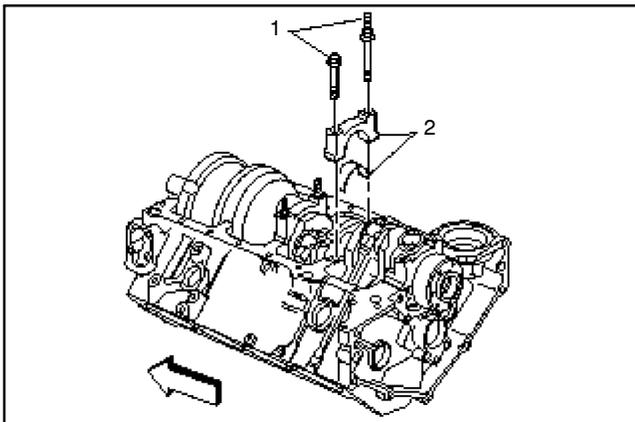
J 43690-100 Rod Bearing Clearance Checking Tool, Adapter Kit



- J 43690-104 Spacer (1).
- J 43690-105 Retainer Plate (2).
- 505478 Bolt (3).
- 511341 Bolt (4).
- J 43690-106 Retainer Plate (5).
- J 43690-107 Cap (6).
- J 43690-102 Foot (7).
- J 43690-101 Pivot Arm Assembly (8).
- J 43690-103 Adapter (9).
- 505439 Adapter (10).

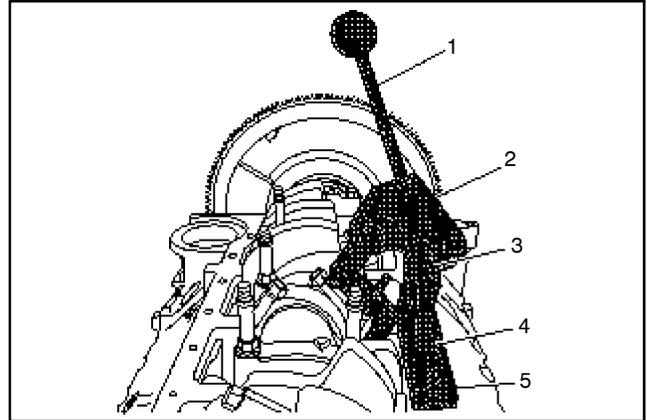
Important: The crankshaft must be secure with no movement or rotation to obtain an accurate reading.

1. Rotate the crankshaft until the journal/connecting rod to be measured is in the 12 o'clock position.
2. Remove bearing cap bolts (1).
3. Remove the bearing half and bearing cap (2).
4. Insert a piece of paper card stock onto the crankshaft journal.
5. Install the bearing half and cap (2) and bolts (1). Refer to Section 1.1, Fastener Tightening Specs.

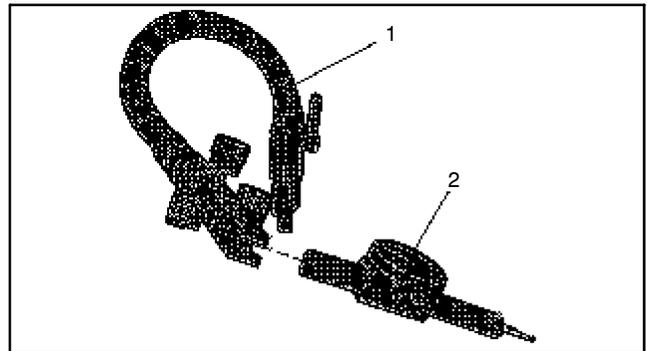


6. Install the following:

- J 43690-2 (5).
- J 43690-8 (4).
- J 43690-1 (2).
- 280310 (3).
- J 43690-5 (1).



7. Install the swivel base (1) and dial indicator (2).

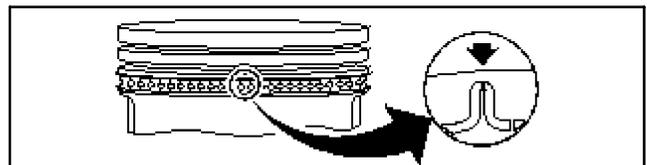


8. Adjust per the manufacturers instructions and measure the connecting rod bearing clearance.

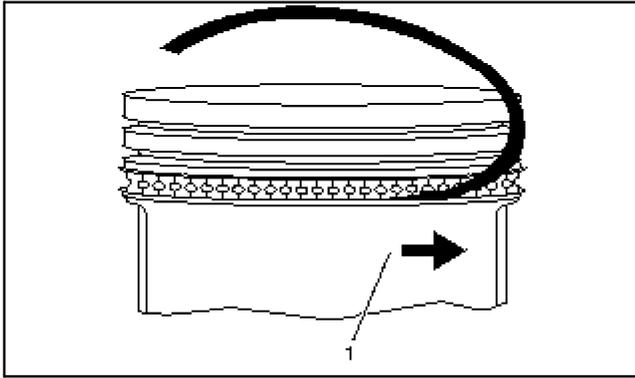
A connecting rod with a clearance in excess of 0.081 mm (0.0032 in.) is considered excessive. Service components as required.

5.1.6 Piston and Connecting Rod Assemble

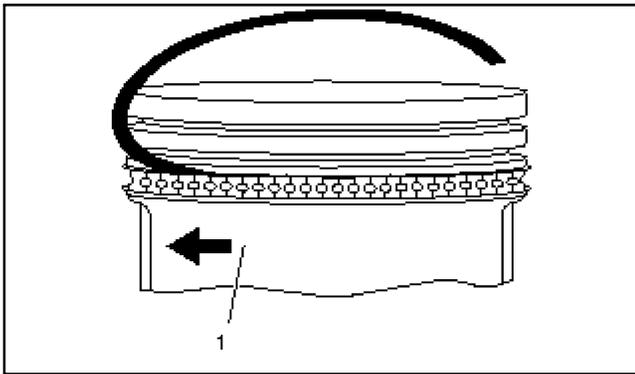
Notice: Use a piston ring expander to install the piston rings. The rings may be damaged if expanded more than necessary.



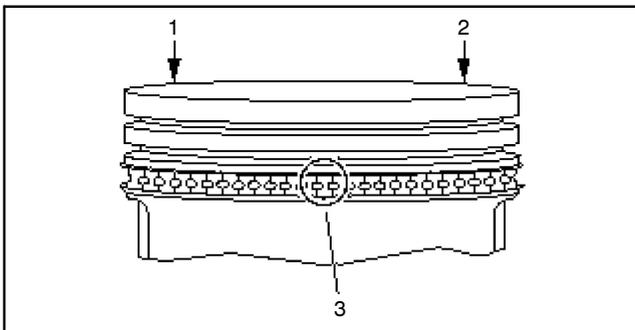
1. Install the lower oil control piston ring spacer onto the piston.
2. Install the lower oil control piston ring onto the piston (1).



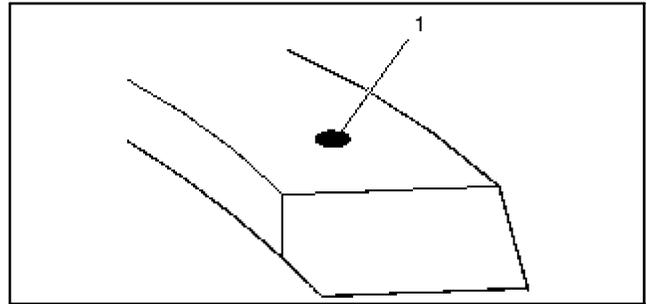
3. Install the upper oil control piston ring onto the piston (1).



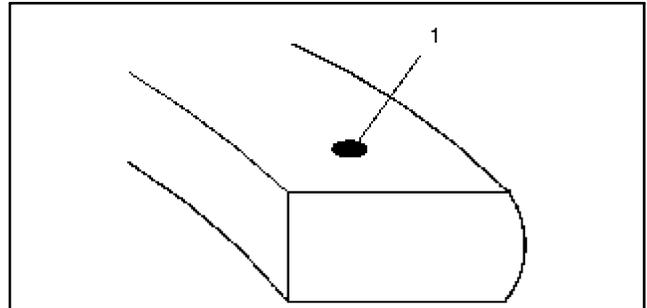
4. Space the oil control piston ring end gaps a minimum of 90° apart (1, 2, 3).



5. Install the lower compression piston ring onto the piston (1). The mark on the side of the piston ring should face the top of the piston.



6. Install the upper compression piston ring onto the piston. The mark (1) on the side of the piston ring should face the top of the piston.



7. Space the compression piston ring end gaps 120° apart.

5.1.7 Cylinder Boring and Honing

Boring Procedure

Important: The coating on the piston allows for an interference fit between the cylinder and the bore. The piston diameter *cannot* be measured accurately because the piston coating is not a consistent thickness. Do *not* measure the piston diameter.

To select the correct piston for installation, measure the cylinder bore. If the cylinder bore diameter is within service specifications, install the original piston/connecting rod assembly or a new, standard size piston/connecting rod assembly. A used piston/connecting rod assembly may be reinstalled if, after cleaning and inspection, the piston is not damaged. If the cylinder bore is *not* within specifications, resize the cylinder to accept a new, oversized piston.

Important: If you do not check the cylinder block, the boring bar may be tilted, this may result in incorrect rebored cylinder wall to crankshaft angle.

1. Before you use any type of boring bar, clean the top of the cylinder block to remove any dirt or burrs.
2. Carefully follow the instructions furnished by the manufacturer regarding use of equipment.
3. When you rebore cylinders, make sure all crankshaft bearing caps are in place.
 - Tighten the bearing caps to the proper torque to avoid distortion of the bores in the final assembly.
 - Remove the crankshaft prior to cylinder boring.
4. When you take the final cut with a boring bar, leave 0.03 mm (0.001 in.) on the diameter for finish honing. This gives the required position to the cylinder clearance specifications. (Carefully perform the honing and boring operation to maintain the specified clearances between pistons, rings, and cylinder bores).

- Repeatedly check the cylinder bore for fit with the selected oversized piston.
 - All measurements of the cylinder bore should be made with the components at normal room temperature.
3. To eliminate taper in the cylinder, when honing, make full strokes of the hone in the cylinder. Repeatedly check the measurement at the top, the middle, and the bottom of the bore.
 - The finish marks should be clean but not sharp.
 - The finish marks should be free from embedded particles and torn or folded metal.
 4. When finished, the reconditioned cylinder bores should have less than or meet the specified out-of-round or taper requirements.
 5. After final honing and before the piston is checked for fit, clean the bores with hot water and detergent.
 - a. Scrub the bores with a stiff bristle brush and rinse the bores thoroughly with hot water. Do not allow any abrasive material to remain in the cylinder bores.

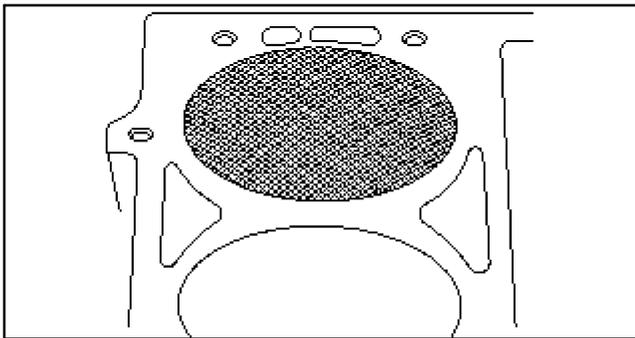
Abrasive material may cause premature wear of new piston rings and cylinder bores.

Abrasive material will contaminate the engine oil and may cause premature wear of the bearings.

- b. After washing the cylinder bore, dry the bore with a clean shop towel.

6. Perform final measurements of the cylinder bore.
7. Permanently mark the piston for the specific cylinder to which it has been fitted.
8. Apply clean engine oil to each cylinder bore to prevent rusting.

Honing Procedure



Important: Always remove all bearings and components from engine block before cleaning, boring or honing the engine block.

1. When honing the cylinders, follow manufacturer's recommendations for equipment use, cleaning, and lubrication.
 - Use only clean, sharp stones of the proper grade for the amount of material you remove.
 - Dull, dirty stones cut unevenly and generate excessive heat.
 - Do not hone to a final grade with a coarse or medium-grade stone.
 - Leave sufficient metal so that all stone marks may be removed with fine grade stones.
 - The rehone surface finish should be 0.25–0.50 micrometer (10–20 microinch).
 - Perform final honing with a fine-grade stone and hone the cylinder in a cross hatch pattern at 20°–30° to obtain the proper clearance.
2. During the honing operation, thoroughly clean the cylinder bore.

5.1.8 Installation

Tools Required:

J 8037 Piston Ring Compressor

J 8087 Cylinder Bore Gauge

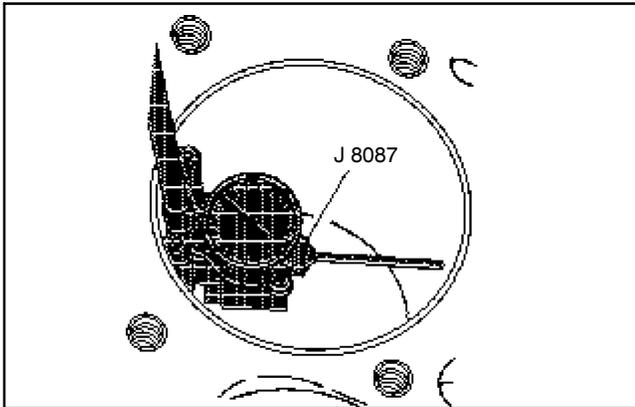
J 45059 Angle Meter

Piston Selection

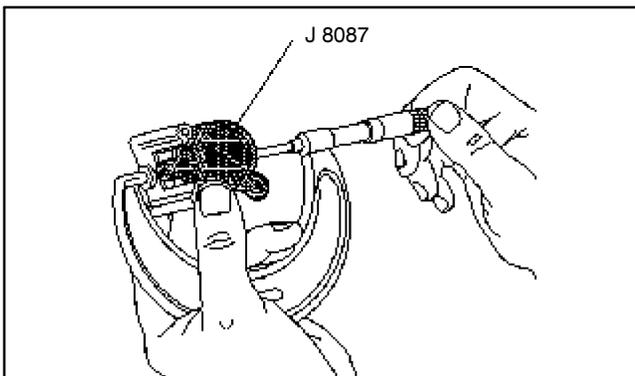
Important: The coating on the piston allows for an interference fit between the cylinder and the bore. The piston diameter cannot be measured accurately because the piston coating is not a consistent thickness. Do *not* measure the piston diameter.

To select the correct piston for installation, measure the cylinder bore. If the cylinder bore diameter is within service specifications, install the original piston/connecting rod assembly or a new, standard size piston/connecting rod assembly. A used piston/connecting rod assembly may be reinstalled if, after cleaning and inspection, the piston is not damaged. If the cylinder bore is *not* within specifications, resize the cylinder to accept a new, oversized piston.

For proper piston fit, the engine block cylinder bores should not have excessive wear or taper.



1. Inspect the engine block cylinder bore. Refer to Section 5.2.2, Engine Block Cleaning and Inspection.
2. Inspect the piston/connecting rod assembly for damage. Refer to Section 5.1.3, Piston, Connecting Rod, and Bearings Cleaning and Inspection.
3. Use *J 8087* and measure the cylinder bore diameter. Refer to Section 5.2.2, Engine Block Cleaning and Inspection.



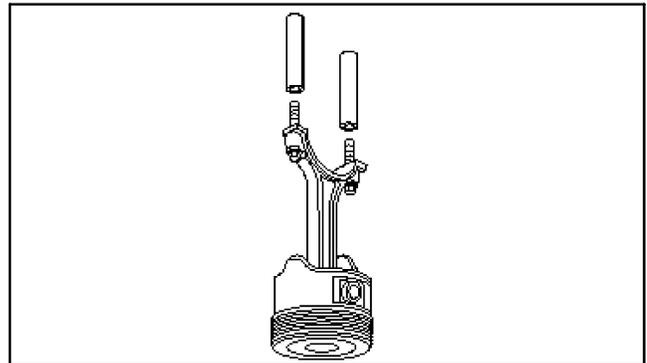
4. Measure *J 8087* with a micrometer and record the reading.
5. Compare the cylinder bore measurement to the specifications. Refer to Section 1.2, Engine Mechanical Specs.

- a. If the cylinder bore is within specifications, select the original piston or a new, original size piston.
- b. If the cylinder bore is not within specifications, select the next oversized piston/connecting rod assembly, then bore and hone the cylinder bore to fit the oversize piston.

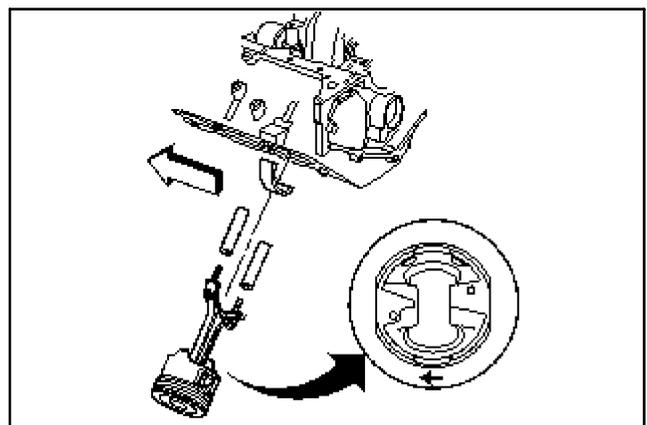
Piston Installation

1. Coat the following components with clean engine oil:
 - The piston.
 - The piston rings.
 - The cylinder bore.
 - The bearing surfaces.
2. Install rubber fuel line onto the connecting rod bolts.

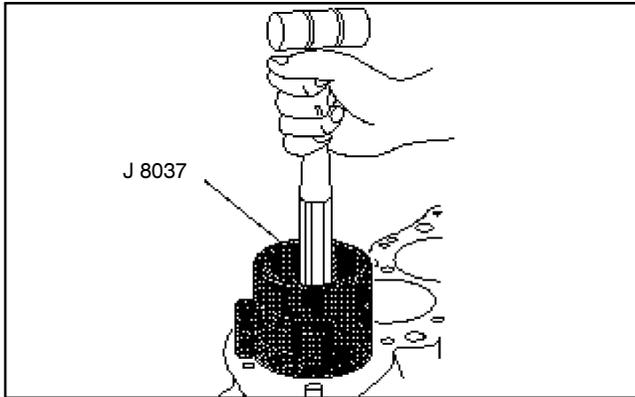
Important: The mark on the top of the piston must face the front of the engine block. When assembled, the flanges on the connecting rod and cap should face to the front of block on the left bank and to the rear of block on the right bank.



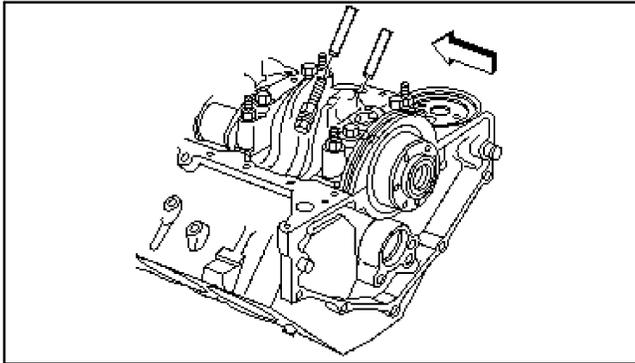
3. Install the piston, connecting rod and upper connecting rod bearing through the top of the engine block.



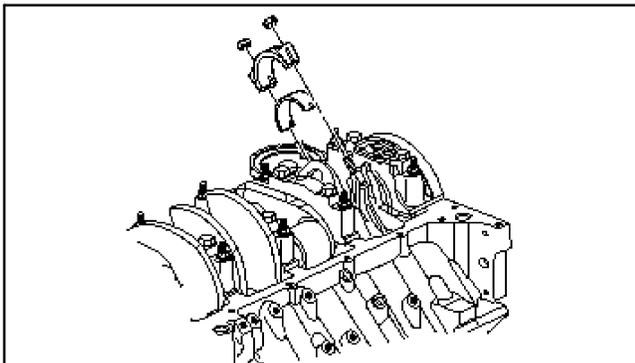
4. Install *J 8037* onto the piston and compress the piston rings.



5. Use *J 8037* and lightly tap the top of the piston with a wooden hammer handle.
6. Hold *J 8037* firmly against the engine block until all of the piston rings have entered the cylinder bore.



7. Use the rubber fuel line to guide the connecting rod onto the crankshaft journal.
8. Remove the rubber fuel line.



9. Install the connecting rod cap and lower connecting rod bearing.

Notice: Refer to Fastener Notice in Cautions and Notices.

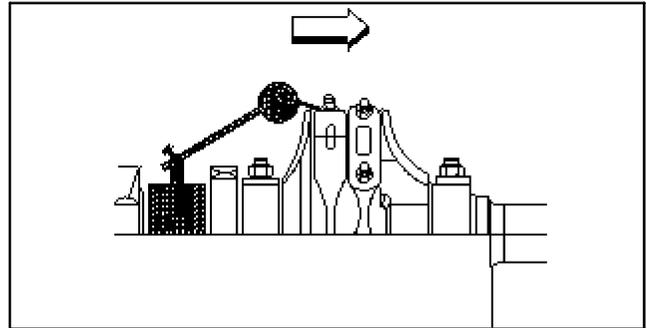
Important: When installing the piston/connecting rod assembly, install *new* connecting rod nuts.

10. Install the new connecting rod nuts.

11. Tighten:

Tighten the connecting rod nuts a first pass to 30 Nm (22 ft. lb.).

Tighten the connecting rod nuts an additional 90° using *J 45059*.



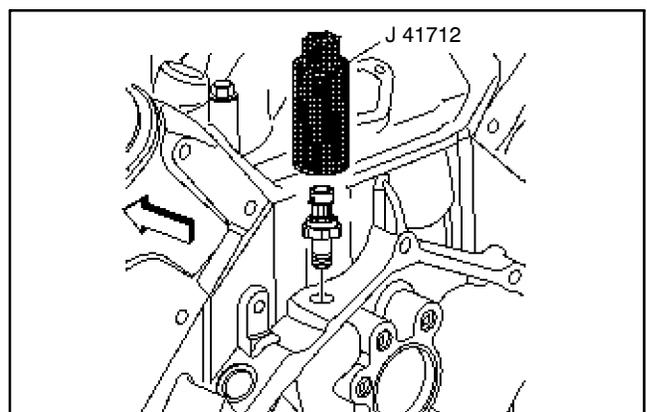
12. After the piston and connecting rod assemblies have been installed, lightly tap each connecting rod assembly, parallel to the crankpin, to make sure that they have side clearance.

13. Use a feeler gauge or a dial indicator to measure the side clearance between the connecting rod caps. The rod side clearance should be 0.384–0.686 mm (0.0151–0.0270 in.).

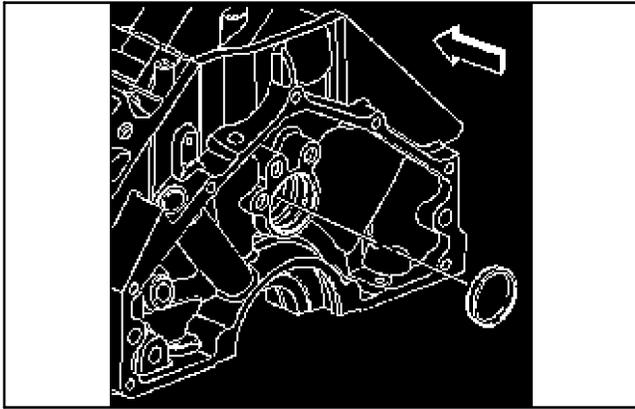
5.2 Engine Block

5.2.1 Plug Removal

Tools Required: J 41712 Oil Pressure Switch Socket



1. Remove the oil pressure switch using *J 41712*.

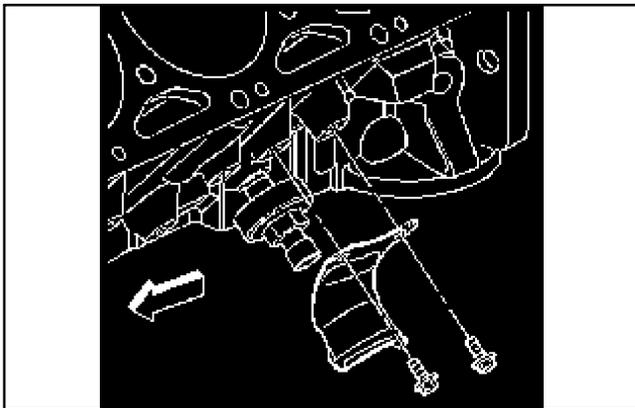


2. Remove the camshaft rear bearing hole plug:

- a. Obtain a suitable self-threading screw.
- b. Drill a hole into the plug.
- c. Install the self-threading screw.
- d. Pull on the plug until it has left the bore.

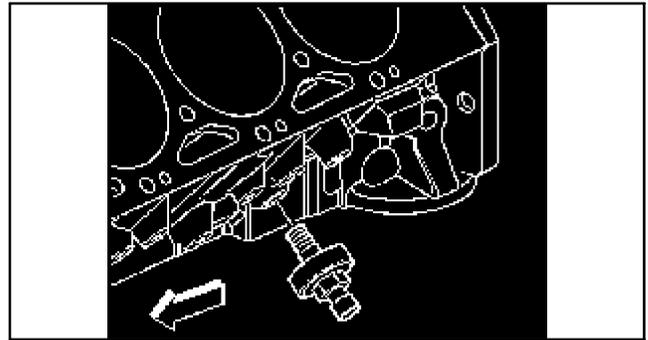
Important: Use care not to damage the camshaft bearings.

- e. An alternate method to remove the plug would be to insert a long shaft or bar through the front of the engine and drive the plug from the bore.



3. Remove the left side knock sensor heat shield bolts.

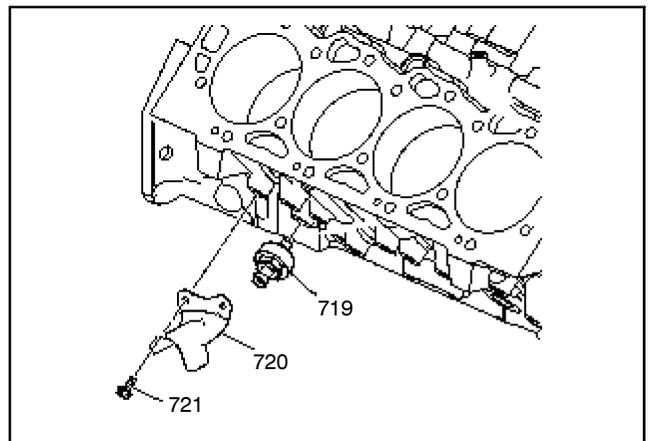
4. Remove the left side knock sensor heat shield.



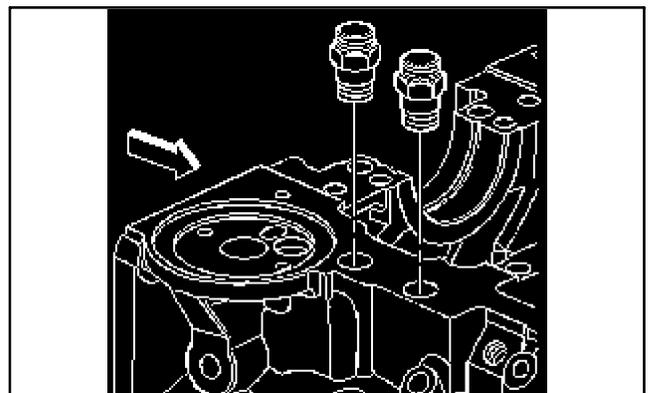
5. Remove the left side knock sensor.

6. Remove the right side knock sensor heat shield (720) and bolts (721).

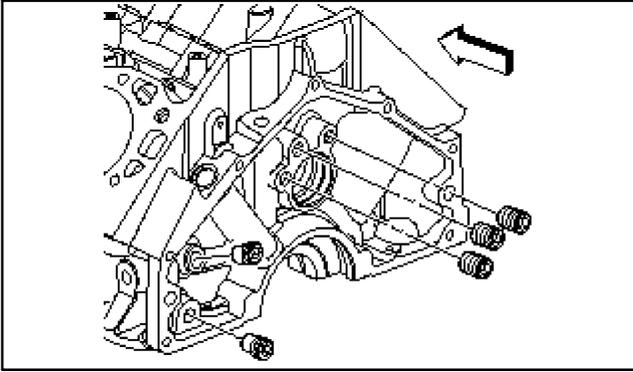
7. Remove the right side knock sensor (719).



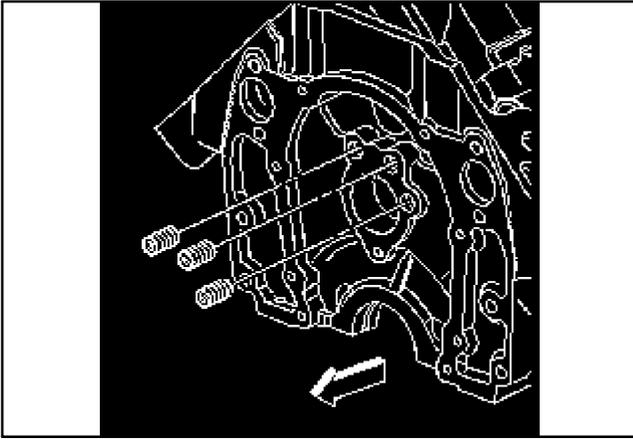
8. Remove the engine block oil cooler hose fittings.



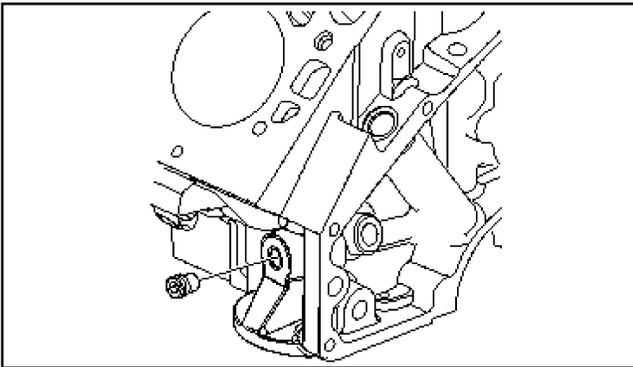
9. Remove the rear oil gallery plugs.



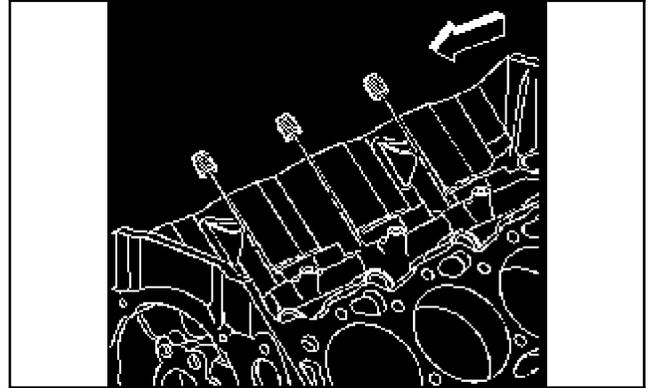
10. Remove the front oil gallery plugs.



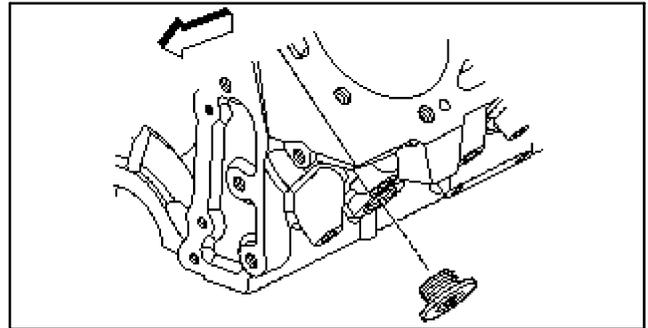
11. Remove the left side oil gallery plug.



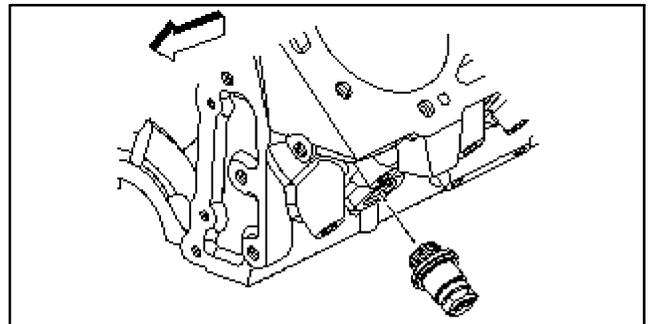
12. Remove the top oil gallery plugs.



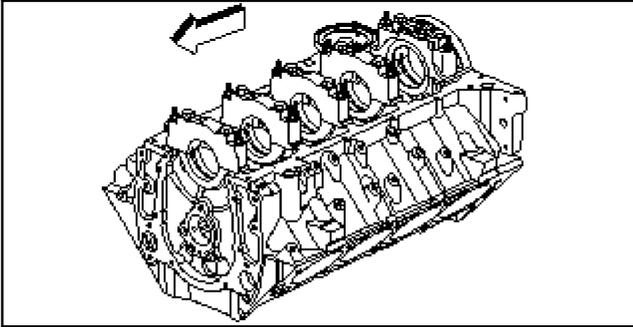
13. Remove the engine coolant hole plug.



14. Remove the engine block heater, if equipped.



5.2.2 Cleaning and Inspection

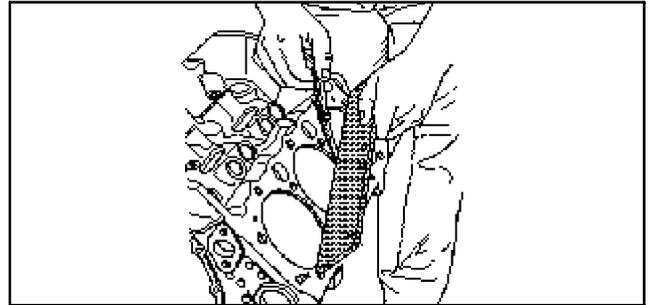


1. Boil the cylinder block in caustic solution.
2. Flush the cylinder block with clean water or steam.
3. Clean the following areas:
 - All gasket surfaces; refer to Section 2.7, Engine Gasket Replacement.
 - Cylinder bores; remove excessive cylinder ring ridge as required.
 - Main bearing caps.
 - Oil galleries; remove all sludge or restrictions.
 - Scale deposits from the coolant passages.
 - All dirt or debris from threaded bolt holes.

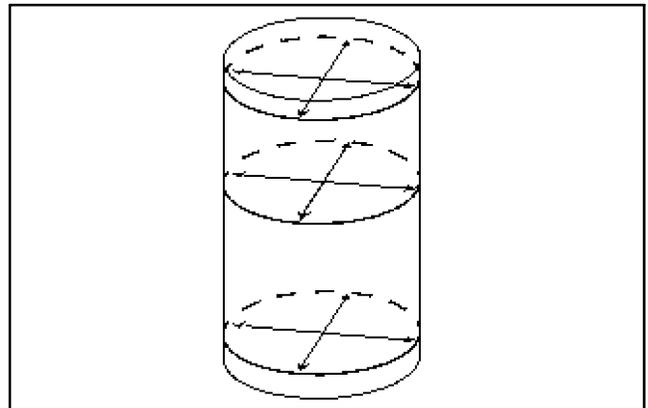
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

4. Dry the block with compressed air.
5. Lubricate the cylinder bores with clean engine oil to prevent rusting.
6. Inspect the engine block for the following conditions:
 - Gasket surfaces for deep gouges or other damage.
 - Crankshaft bearing bores for wear.
 - The surfaces where the crankshaft bearings contact the crankshaft bearing bore must be smooth.
 - All crankshaft bearing bores must be round and uniform in inside diameter (ID) at all the bearing supports.
 - If a crankshaft bearing cap is damaged and requires replacement, refer to Section 6.3.2, Crankshaft and Bearings Cleaning and Inspection.

- Camshaft bearing bores for wear or damage.
- Valve lifter bores for scuffing or wear.
- Engine block for cracks or other damage.
- Cylinder walls for scoring or gouges.
- Coolant jackets for cracks.
- Crankshaft bearing webs for cracks.
- Engine mount bosses for damage.
- The oil passages for restrictions.



7. Inspect the engine block cylinder head deck for flatness using a straight edge and a feeler gauge. The surface must be flat within 0.100 mm (0.004 in.).

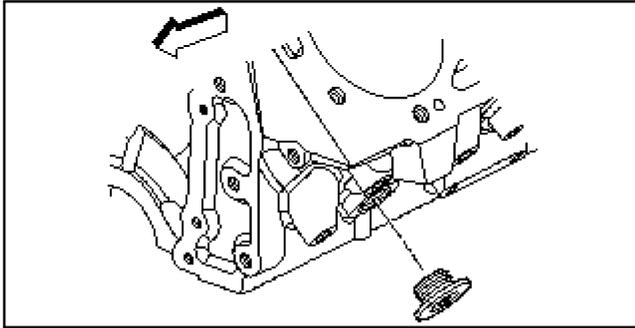


8. Use a bore gauge to measure the cylinder bore for taper, out-of-round, and oversize. Slide the bore gauge up and down throughout the length of the cylinder bore. Check the bore both parallel and perpendicular to the centerline of the crankshaft at the top, center, and bottom of the bore. A cylinder bore that measures 107.940–107.990 mm (4.249–4.251 in.) may be serviced with a standard size piston/connecting rod assembly. Service a cylinder bore that exceeds the maximum diameter with an oversized piston/connecting rod assembly.

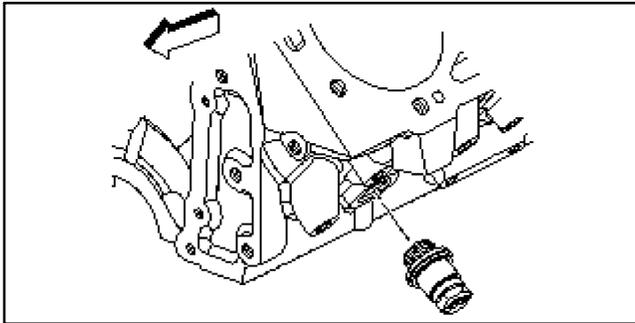
5.2.3 Plug Installation

Tools Required: J 41712 Oil Pressure Switch Socket

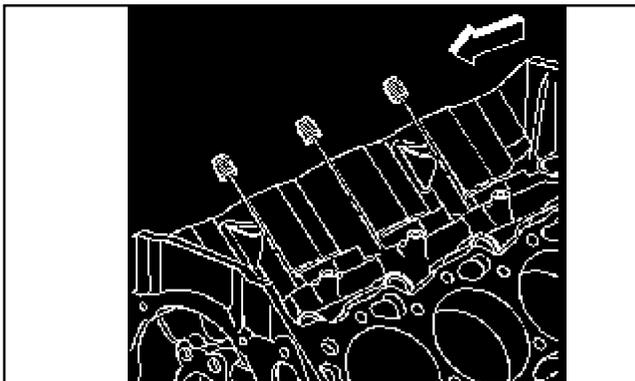
Notice: Refer to Fastener Notice in Cautions and Notices.



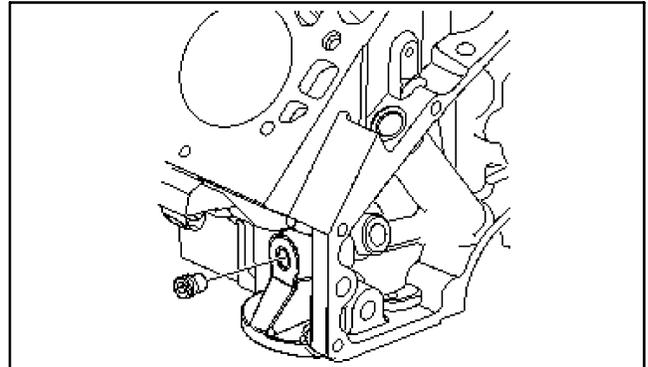
1. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the coolant hole plug.
2. Install the engine coolant hole plug into the block. Tighten the engine coolant hole plug to 60 Nm (40 ft. lb.).



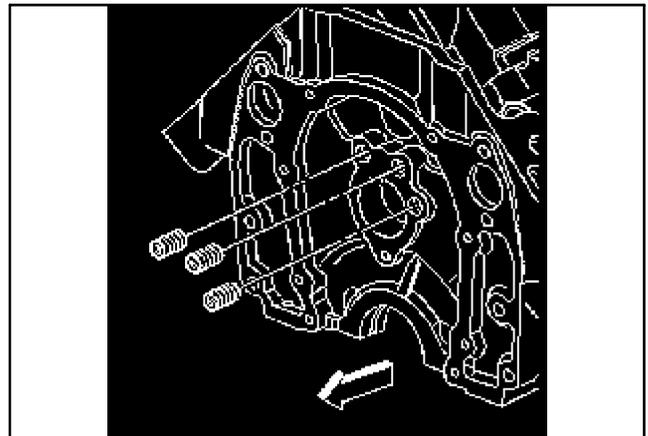
3. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the engine block heater, if applicable.
4. Install the engine block heater into the block. Tighten the engine block heater to 50 Nm (37 ft. lb.).



5. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the oil gallery plugs.
6. Install the engine block top oil gallery plugs. Tighten the top oil gallery plugs to 20 Nm (15 ft. lb.).

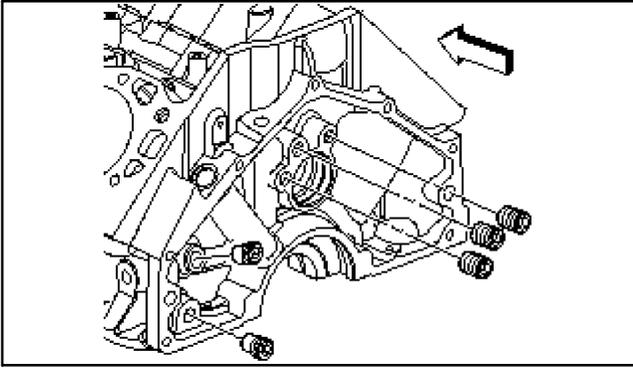


7. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the oil gallery plug.
8. Install the engine block left side oil gallery plug. Tighten the left oil gallery plug to 30 Nm (22 ft. lb.).



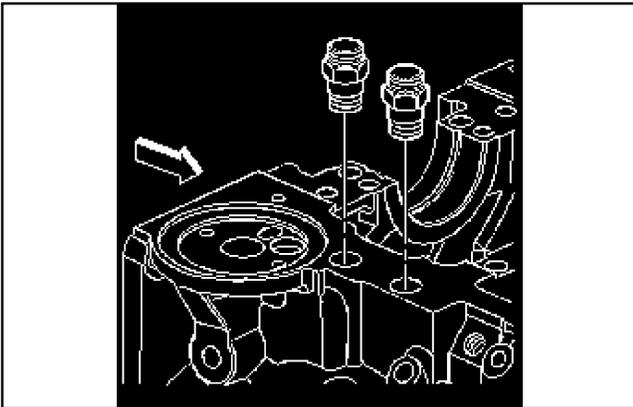
9. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the oil gallery plugs.

10. Install the front oil gallery plugs. Tighten the front oil gallery plugs to 30 Nm (22 ft. lb.).



11. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the oil gallery plugs.

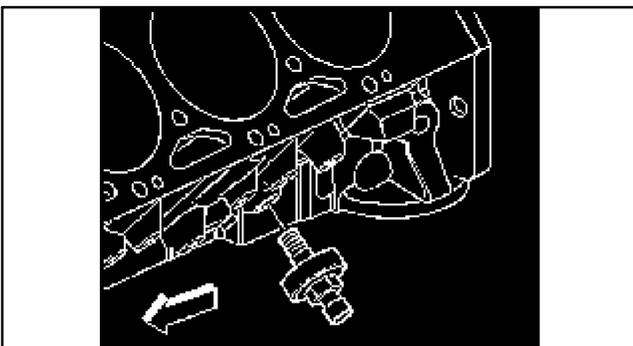
12. Install the rear oil gallery plugs. Tighten the rear oil gallery plugs to 20 Nm (15 ft. lb.).



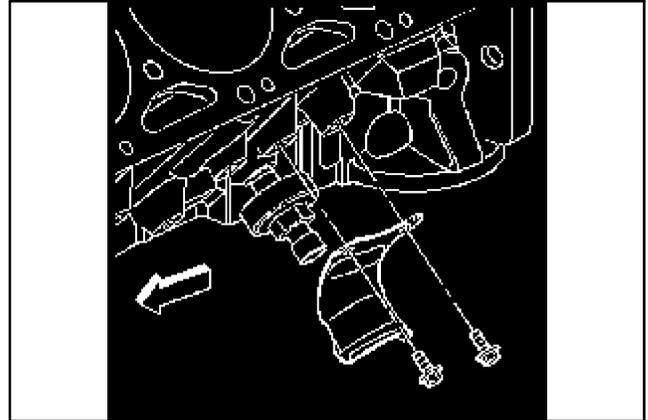
13. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the engine block oil cooler hose fittings.

14. Install the engine block oil cooler hose fittings. Tighten the engine block oil cooler hose fittings to 23 Nm (17 ft. lb.).

Important: Do not overtighten the knock sensor.



15. Install the left knock sensor to the engine block. Tighten the left knock sensor to 20 Nm (15 ft. lb.).



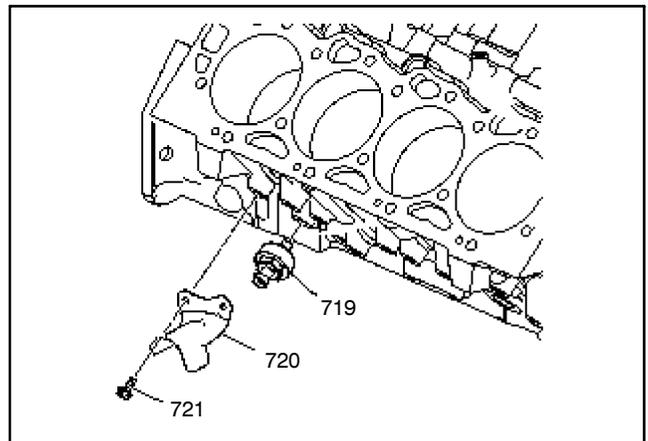
16. Install the left side knock sensor heat shield.

17. Install the left side knock sensor heat shield bolts. Tighten the bolts to 12 Nm (106 in. lb.).

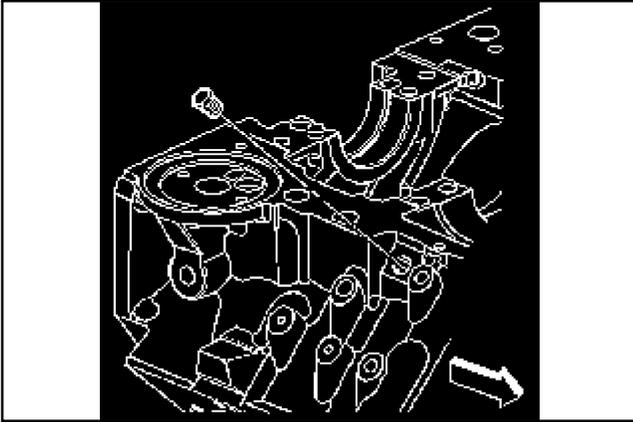
Important: Do not overtighten the knock sensor.

18. Install the right knock sensor (719) to the engine block. Tighten the right side knock sensor to 20 Nm (15 ft. lb.).

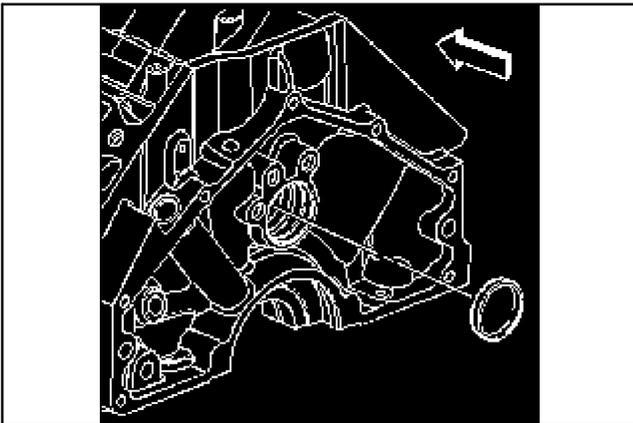
19. Install the right side knock sensor heat shield (720) and bolts (721). Tighten the bolts to 12 Nm (106 in. lb.).



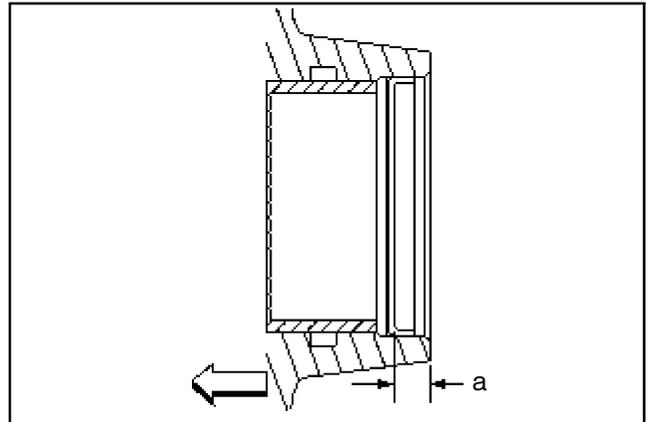
20. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the engine block coolant drain hole plugs.



21. Install the engine block coolant drain hole plugs. Tighten the coolant drain hole plugs to 30 Nm (22 ft. lb.).

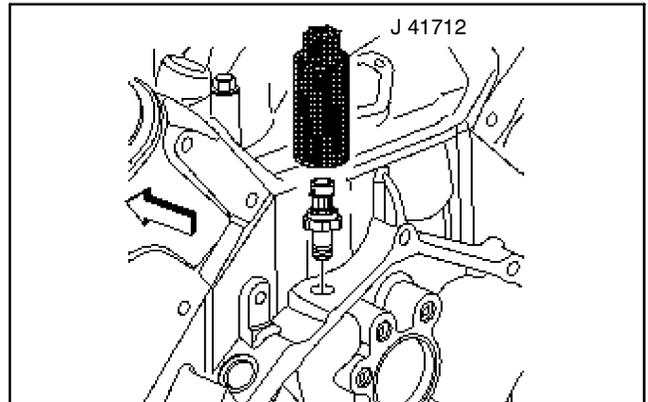


22. Apply sealer, GM Part No. U.S. 12377901/ Canadian 10953504, to the outside diameter of the new camshaft rear bearing hole plug.



23. Install the *new* camshaft rear bearing hole plug to the proper depth of (a) 7.600–6.200 mm (0.299–0.244 in.).

24. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the oil pressure sensor.



25. Install the oil pressure sensor. Using *J 41712*, tighten the oil pressure sensor to 30 Nm (22 ft. lb.).

Notes

Section 6 Crankshaft, Main Bearings, and Flywheel

6.1 Crankshaft Balancer

6.1.1 Replacement

Tools Required:

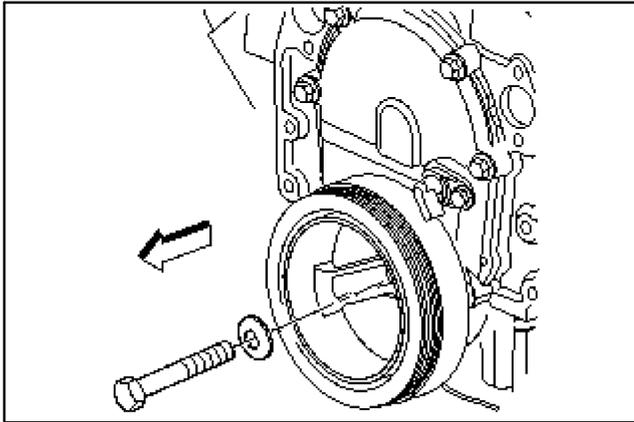
J 38416-B Harmonic Balancer Remover

J 42845 Crankshaft Balancer Installer

J 42846 Crankshaft Balancer Protector Button

J 42847 Flywheel Holding Tool

Removal Procedure

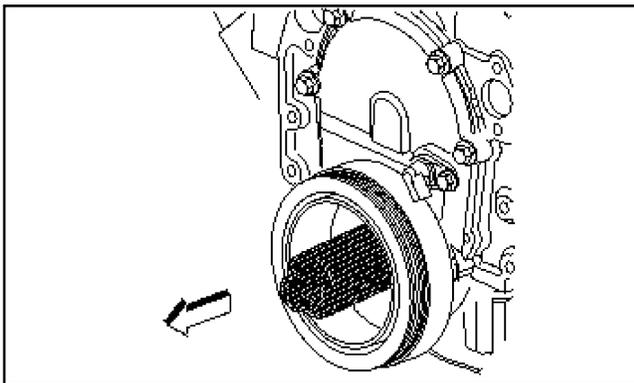


1. Remove the fan.
2. Remove the starter motor.

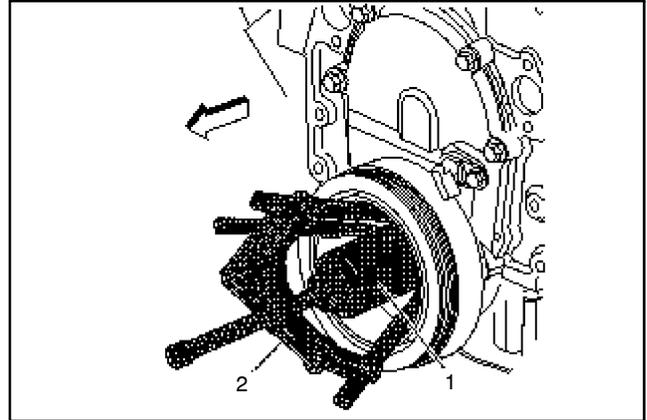
Notice: Refer to Fastener Notice in Cautions and Notices.

Important: Ensure that the teeth of the flywheel holding tool engage the engine flywheel teeth.

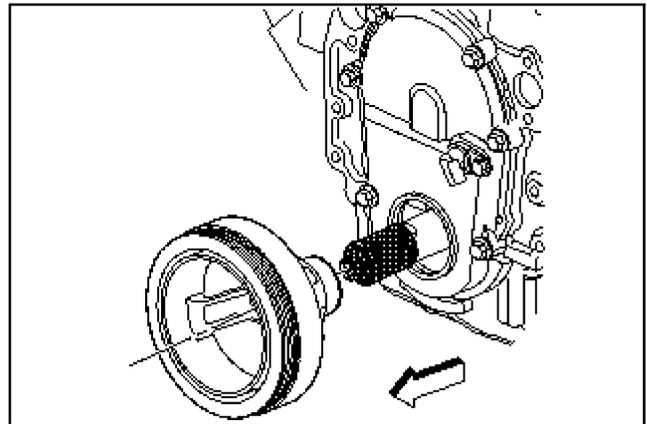
3. Install *J 42847* to the starter bolt holes. Tighten *J 42847* bolts to 50 Nm (37 ft. lb.).
4. Remove the crankshaft balancer bolt and washer.



5. Install *J 42846* onto the end of the crankshaft.



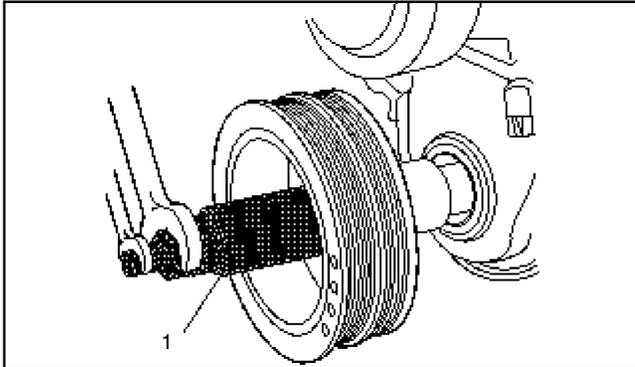
6. Install *J 38416-B* (2) onto *J 42846* (1) to remove the crankshaft balancer. Place legs of *J 38416-B* into the recesses cast into the backside of the balancer inner hub.
7. Tighten the center screw of *J 38416-B* until the crankshaft balancer is clear of the crankshaft nose.



8. Remove the crankshaft balancer.
9. Remove *J 42846* from the end of the crankshaft.

Installation Procedure

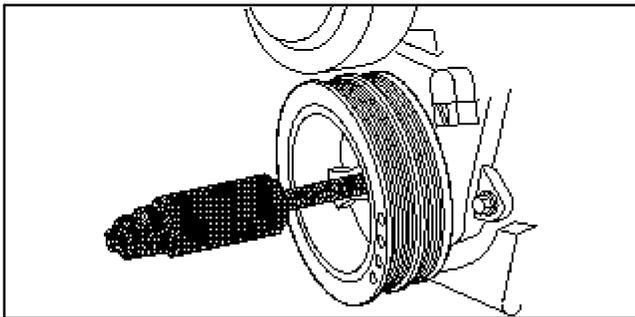
Important: Position the balancer onto the end of the crankshaft as straight as possible prior to tool installation. Apply grease or clean engine oil to the inside of the crankshaft balancer or the end of the crankshaft to prevent galling during assembly.



1. Install the balancer onto the end of the crankshaft.
2. Install *J 42845* to the crankshaft balancer.

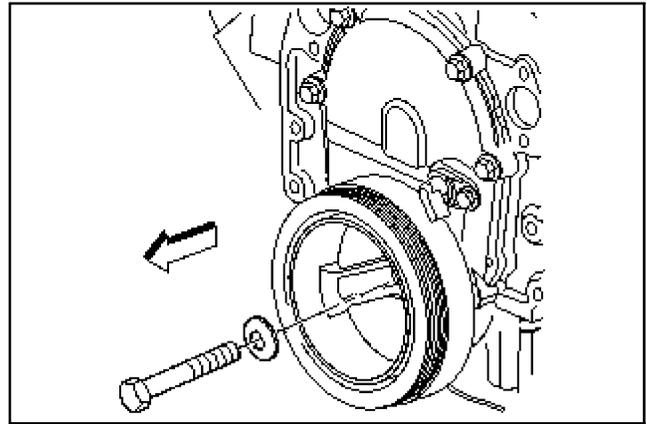
Important: Apply the lubricant that comes with *J 42845* each time the tool is used. Failure to lubricate *J 42845* may prevent the balancer from installing completely.

3. Using *J 42845*, install the balancer.
4. Tighten *J 42845* until the crankshaft balancer is completely seated against the crankshaft sprocket.



5. Remove *J 42845* from the crankshaft.

Notice: Refer to Fastener Notice in Cautions and Notices.



6. Install the crankshaft bolt and washer to the crankshaft. Tighten the crankshaft balancer bolt to 255 Nm (189 ft. lb.).
7. Remove *J 42847*.
8. Install the starter motor.
9. Install the fan.

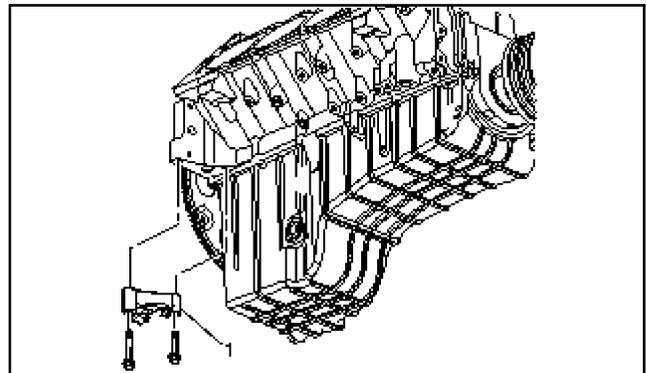
6.1.2 Removal

Tools Required:

J 38416-B Harmonic Balancer Remover

J 42846 Crankshaft Protector Button

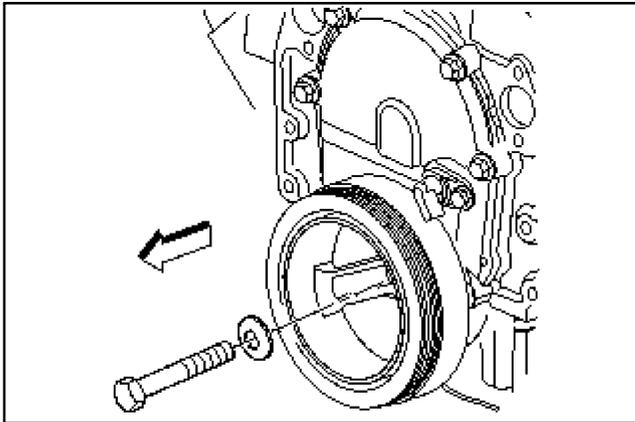
J 42847 Flywheel Holding Tool



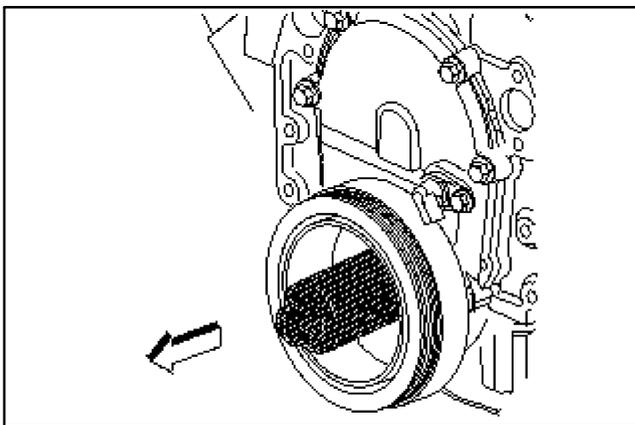
Notice: Refer to Fastener Notice in Cautions and Notices.

Important: Ensure that the teeth of the flywheel holding tool engage the engine flywheel teeth.

1. Install *J 42847* (1) to the starter bolt holes. Tighten *J 42847* bolts to 50 Nm (37 ft. lb.).

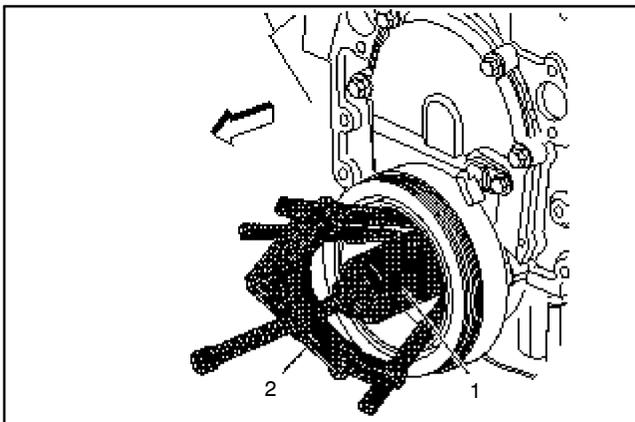


2. Remove the crankshaft balancer bolt and washer.

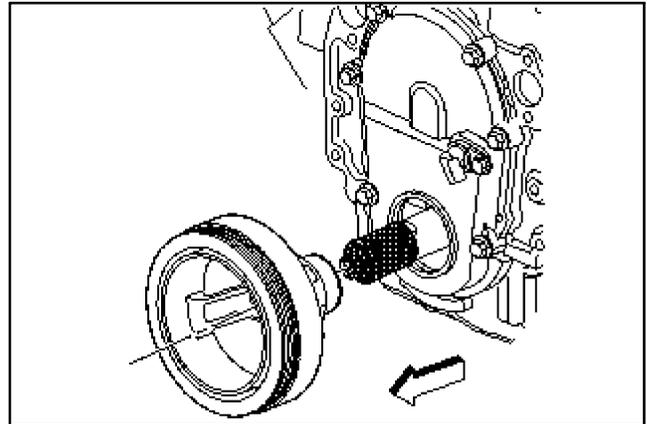


3. Install *J 42846* onto the end of the crankshaft.

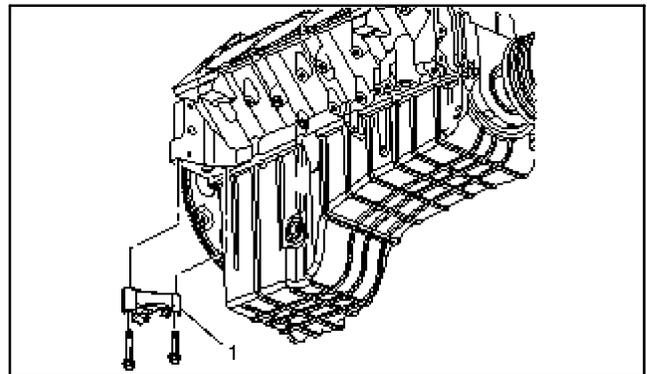
4. Install *J 38416-B* (2) to remove the crankshaft balancer. Place the legs of *J 38416-B* into the recesses cast into the back side of the balancer inner hub.



5. Tighten the center screw of *J 38416-B* until the crankshaft balancer is removed from the end of the crankshaft.



6. Remove *J 38416-B*.
7. Remove the crankshaft balancer.
8. Remove *J 42846* from the end of the crankshaft.
9. Remove *J 42847* (1).



6.1.3 Cleaning and Inspection

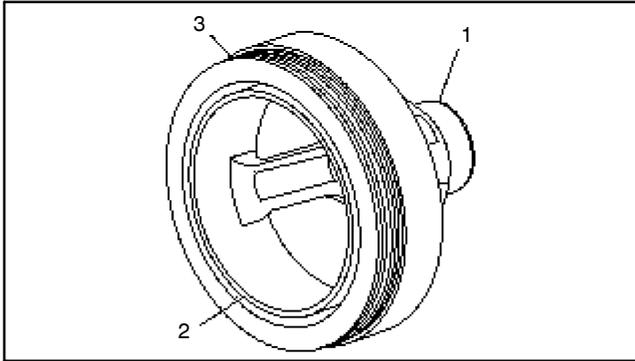
1. Clean the crankshaft balancer in solvent.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

2. Dry the crankshaft balancer with compressed air.

3. Inspect the crankshaft balancer for the following:

- Damaged belt grooves (3).
- Debris in the belt grooves (3).
- Worn, grooved, or damaged hub seal surface (1). Remove minor imperfections on the hub seal surface with a polishing compound or a fine grade of emery cloth. Replace a crankshaft balancer hub seal surface with excessive scoring, grooves, rust, or other damage.
- Worn, chunking, or deteriorated rubber between the hub and pulley (2).



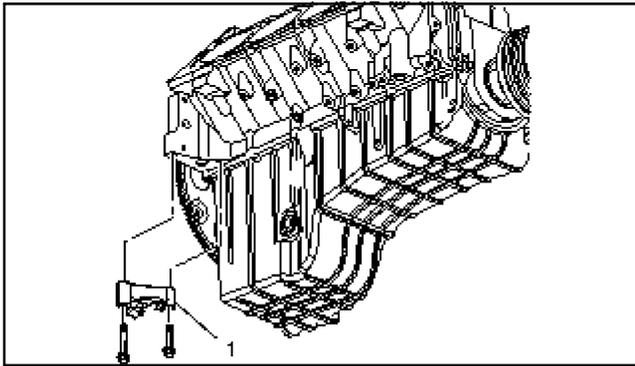
4. Repair or replace crankshaft balancer as necessary.

6.1.4 Installation

Tools Required:

J 42845 Crankshaft Balancer Installer

J 42847 Flywheel Holding Tool

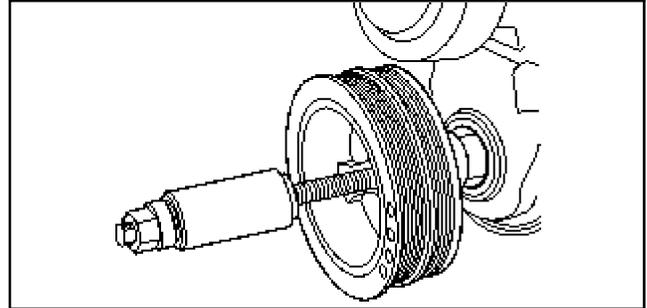


Notice: Refer to Fastener Notice in Cautions and Notices.

Important: Ensure that the teeth of the flywheel holding tool engage the engine flywheel teeth. Position the

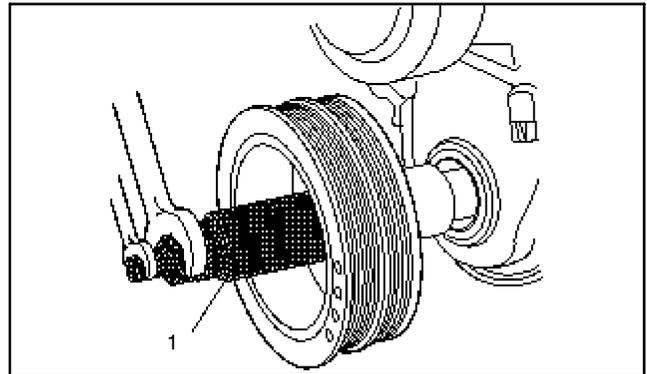
balancer onto the end of the crankshaft as straight as possible prior to tool installation.

1. Install *J 42847* (1) to the starter bolt holes. Tighten *J 42847* bolts to 50 Nm (37 ft. lb.).



Important: Apply grease or clean engine oil to the inside of the crankshaft balancer or the end of the crankshaft to prevent galling during assembly.

2. Install the balancer onto the end of the crankshaft.

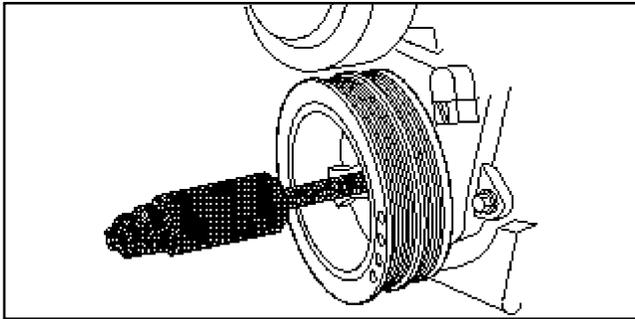


Important: Apply the lubricant that comes with *J 42845* each time the tool is used. Failure to lubricate *J 42845* may prevent the balancer from installing completely.

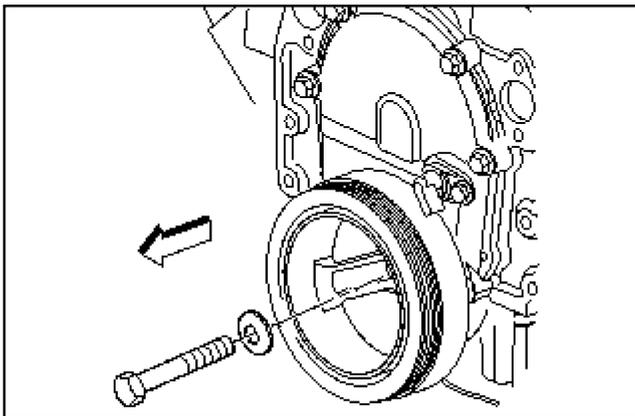
3. Use *J 42845* (1) to install the balancer.

Notice: Ensure the crankshaft balancer is installed to the proper depth. Seat the crankshaft balancer nose against the crankshaft sprocket. Failure to install the crankshaft balancer properly may result in improper torque to the crankshaft balancer bolt. An improperly torqued crankshaft balancer bolt may loosen causing serious engine damage.

4. Tighten *J 42845* until the crankshaft balancer is completely seated against the crankshaft sprocket.

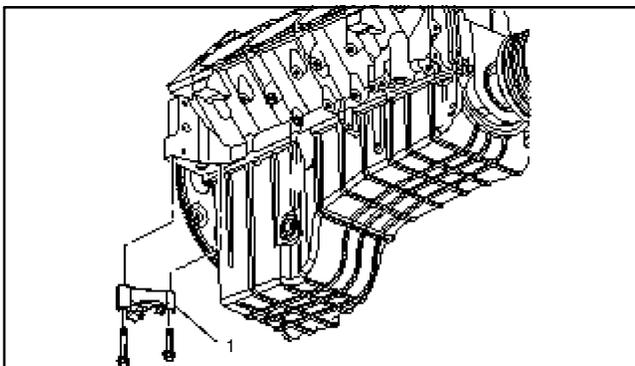


5. Remove *J 42845* from the crankshaft.



6. Install the crankshaft balancer washer and bolt. Tighten the crankshaft balancer bolt to 255 Nm (189 ft. lb.).

7. Remove *J 42847* (1).



6.2 Crankshaft Oil Seal

6.2.1 Replacement, Front

Tools Required:

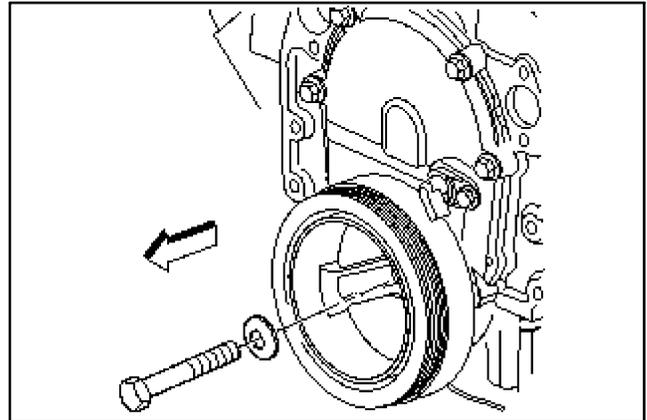
J 42851 Front Cover Oil Seal Installer

Removal Procedure

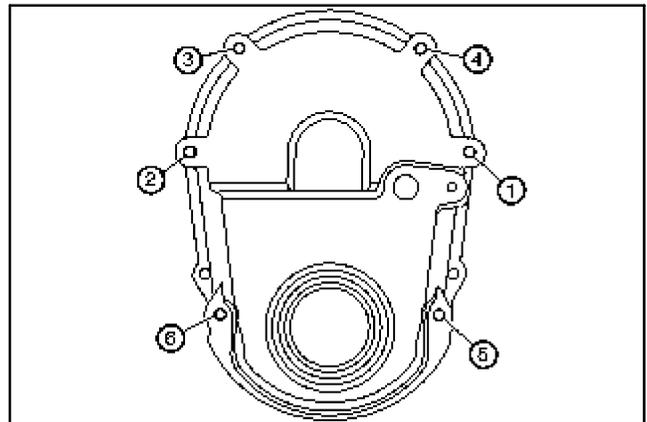
1. Remove the crankshaft balancer. Refer to Section 6.1.1, Crankshaft Balancer Replacement.

Important: Use care not to damage the engine front cover or the crankshaft sealing area when removing the crankshaft front cover oil seal.

2. Remove the crankshaft front cover oil seal.



Installation Procedure



1. Coat the crankshaft front cover oil seal with clean engine oil.
2. Using *J 42851*, install the oil seal.
3. Remove *J 42851*.
4. Install the crankshaft balancer. Refer to Section 6.1.1, Crankshaft Balancer Replacement.

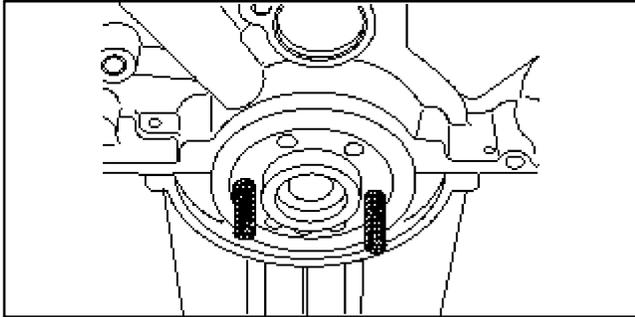
6.2.2 Replacement, Rear

Tools Required:

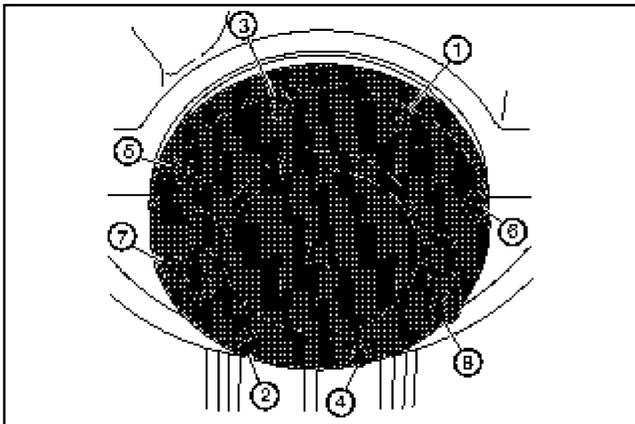
J 43320 Crankshaft Rear Seal Puller

J 42849 Crankshaft Rear Seal Installer

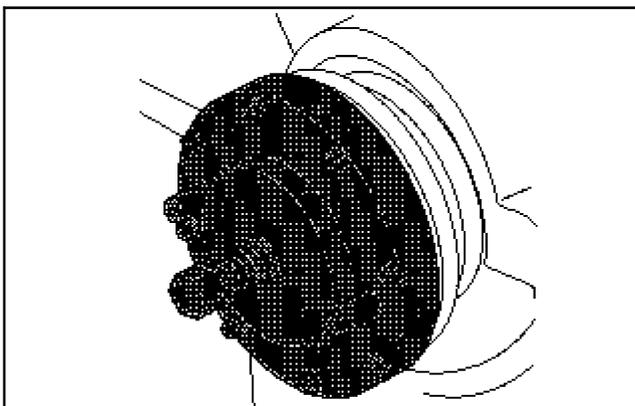
Removal Procedure



1. Remove the flywheel. Refer to Section 6.6.1, Engine Flywheel Replacement.
2. Install the guide pins from *J 43320* into the crankshaft.



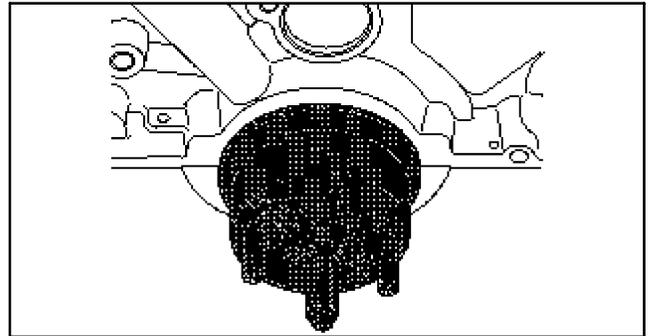
3. Install *J 43320* over the guide pins.
4. Using a suitable drill, insert eight of the self-drilling sheet metal screws into the rear crankshaft seal, using a crisscross pattern. The self-tapping screws are included with *J 43320*.



5. Thread the center bolt of *J 43320* into the crankshaft to remove the seal.
6. Remove the guide pins from the crankshaft.

Installation Procedure

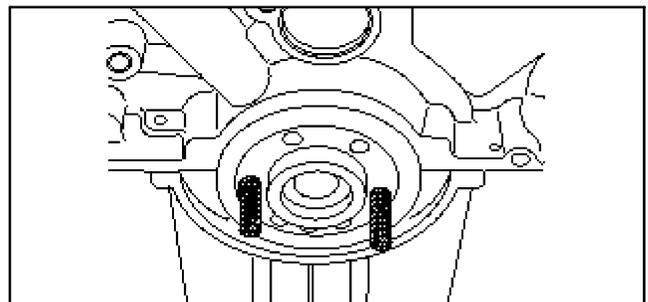
1. Make sure the crankshaft is free of grit, loose rust, and burrs. Correct as needed.



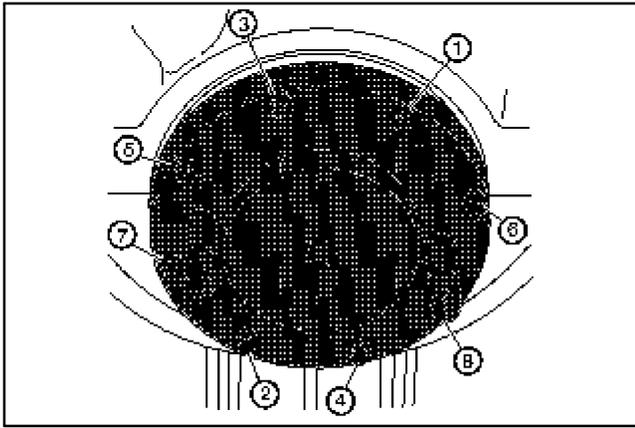
2. Apply a very light film of oil onto the crankshaft sealing surface. *Do not* apply oil to the sealing surface of the engine block.
3. Install the seal onto *J 42849*.
4. Position *J 42849* against the crankshaft. Thread the attaching screws into the tapped holes in the crankshaft.
5. Tighten the screws securely with a screwdriver to ensure that the seal is installed squarely over the crankshaft.
6. Rotate the center nut until *J 42849* bottoms.
7. Remove *J 42849*.
8. Install the flywheel. Refer to Section 6.6.1, Engine Flywheel Replacement.

6.2.3 Removal, Rear

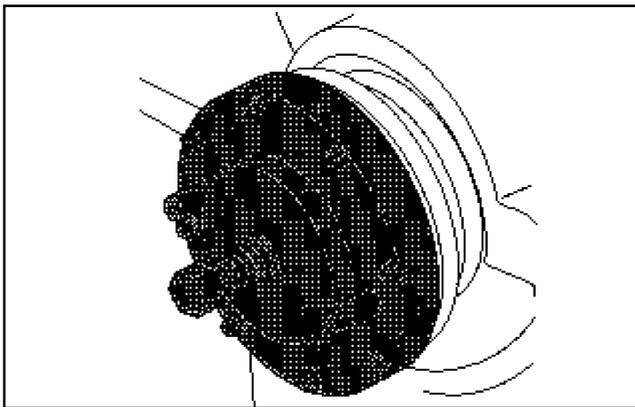
Tools Required: *J 43320 Crankshaft Rear Seal Puller*



1. Install *J 43320* guide pins into the crankshaft.
2. Install *J 43320* over the guide pins.



- Using a suitable drill, insert eight of the self-drilling sheet metal screws (1–8) into the rear crankshaft seal using a crisscross pattern. The self-drilling screws are included with *J 43320*.

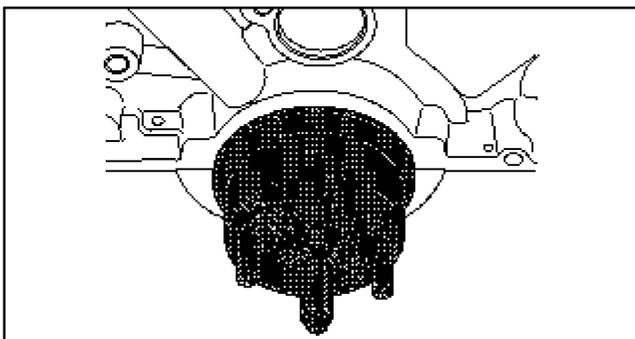


- Thread the center bolt of *J 43320* into the crankshaft to remove the seal.
- Remove *J 43320* guide pins from the crankshaft.

6.2.4 Installation, Rear

Tools Required:

J 42849 Crankshaft Rear Seal Installer



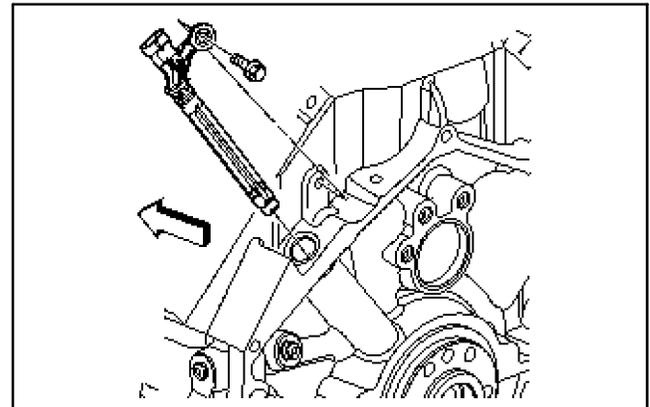
Important: Crankshaft rear oil seal and engine flywheel installation requires adequate space for installation. If the engine stand does not allow suitable space to use

J 42849, install the crankshaft rear oil seal and engine flywheel with the engine properly supported on the floor.

- Make sure the crankshaft rear chamfer is free of grit, loose rust, and burrs. Correct as needed.
- Apply a very light film of oil onto the crankshaft sealing surface. *Do not* apply oil to the sealing surface of the engine block.
- Install the seal on *J 42849*.
- Position *J 42849* against the crankshaft. Thread the attaching screws into the tapped holes in the crankshaft.
- Tighten the screws securely with a screwdriver to ensure that the seal is installed squarely over the crankshaft.
- Rotate the center nut until *J 42849* bottoms.
- Remove *J 42849*.

6.3 Crankshaft and Bearings

6.3.1 Removal

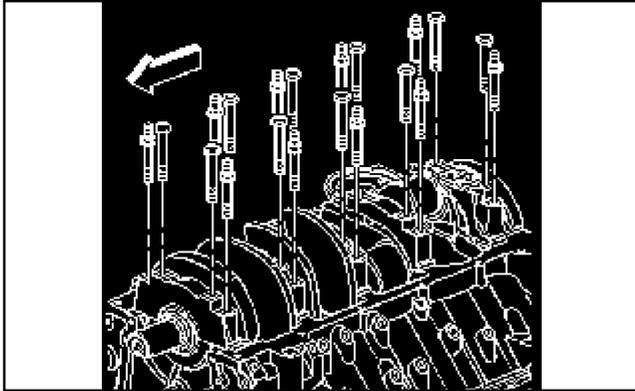


Notice: To prevent damage to the crankshaft position sensor reluctor wheel/ring, use care when removing or installing this component.

Important: The crankshaft position sensor is designed to contact the reluctor wheel of the crankshaft. Wear may be noticeable on the end of the sensor.

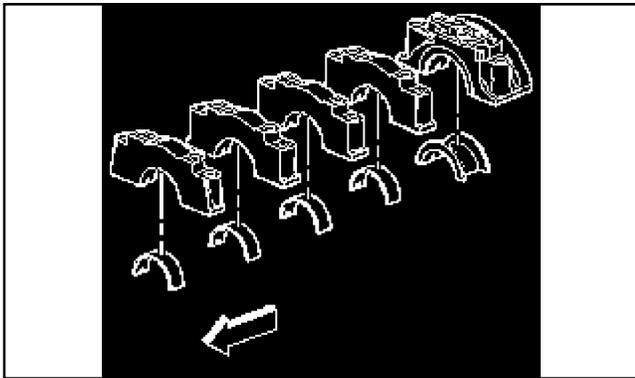
- Remove the crankshaft position sensor bolt.
- Apply penetrating oil to the crankshaft position sensor-to-engine block mating surface. Allow the penetrating oil to soak for several minutes to help loosen the O-ring from the engine block.

3. Twist the sensor to loosen the O-ring seal. When removing the sensor, pull the sensor straight out of the engine block at the same angle the sensor was installed.
4. Inspect both crankshaft position sensor O-ring for cuts, cracks, tears, or damage. Replace the O-ring as needed.



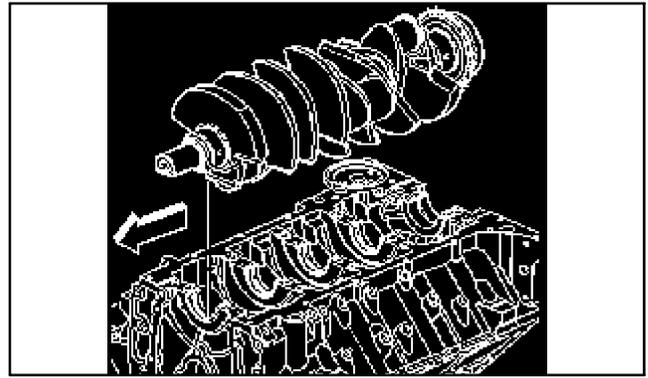
Important: Crankshaft bearing caps are machined with the engine block for the proper clearances. Mark or identify each crankshaft bearing cap location and direction before removal. Reinstall crankshaft bearing caps in their original locations.

5. Remove the crankshaft bearing cap bolts and studs.

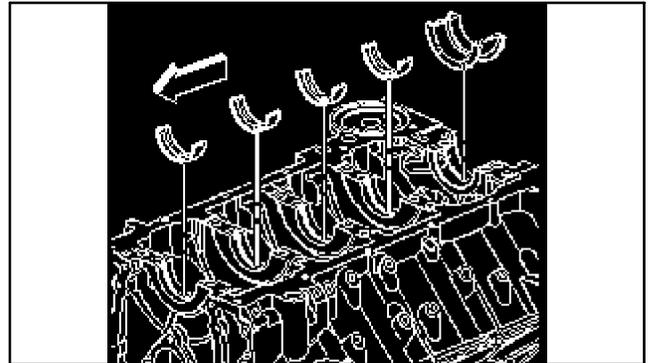


6. Remove the crankshaft bearing caps.
7. Remove the crankshaft lower bearings from the crankshaft bearing caps.

Important: Care should be taken when removing the crankshaft so that the crankshaft position sensor reluctor ring is not damaged.



8. Remove the crankshaft.



9. Remove the crankshaft upper bearings from the engine block.

6.3.2 Cleaning and Inspection

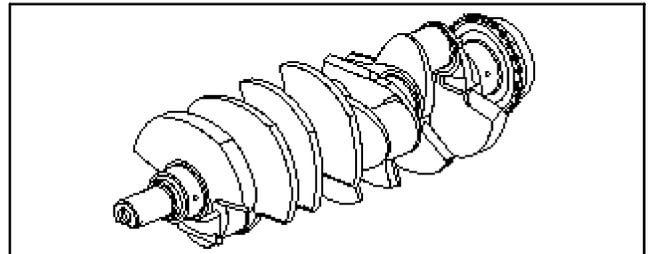
Tools Required:

J 7872 Magnetic Base Dial Indicator

J 43690 Rod Bearing Clearance Checking Tool

J 43690-100 Rod Bearing Clearance Checking Tool, Adapter Kit

J 45059 Angle Meter

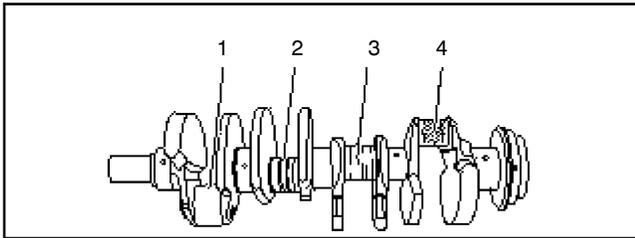


Important: Use care when handling the crankshaft. Avoid damage to the bearing surfaces.

1. Clean the crankshaft in solvent. Remove all sludge or restrictions from the oil passages.

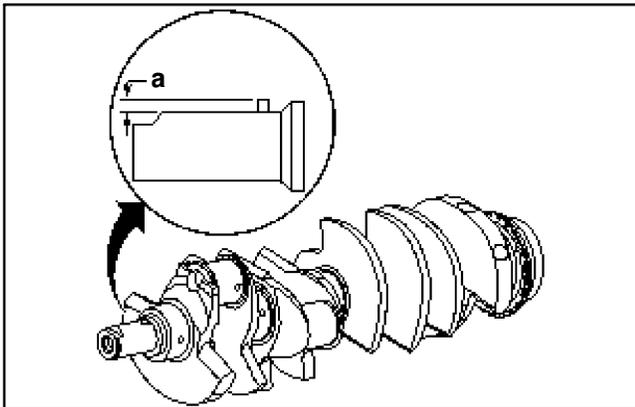
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

2. Dry the crankshaft and bearings with compressed air.
3. Inspect the crankshaft for the following conditions:
 - Crankshaft journals (1) should be smooth with no evidence of scoring or damage.
 - Deep grooves (2).
 - Scratches or uneven wear (3).
 - Pitted surfaces (4).



- Wear or damage to the thrust journal surfaces.
- Scoring or damage to the rear seal surface.
- Restrictions to oil passages.
- Damage to threaded bolt holes.

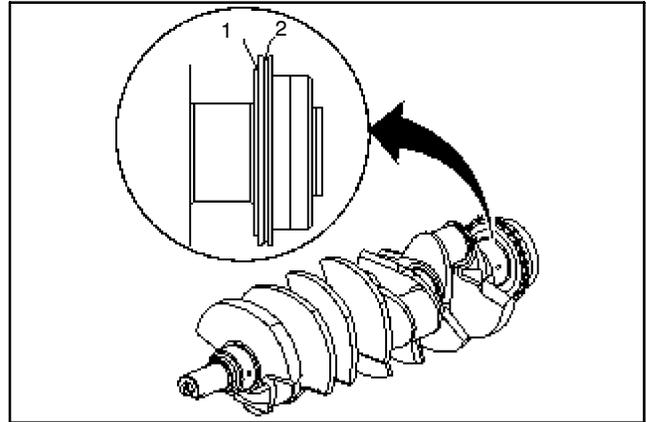
Important: The crankshaft pin is a pressed-in-place roll pin. The pin only needs to be removed from the crankshaft if the pin is damaged.



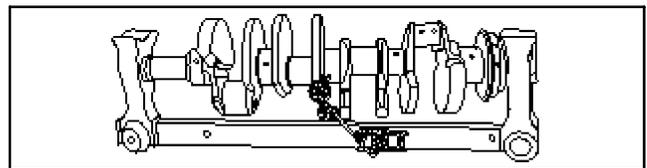
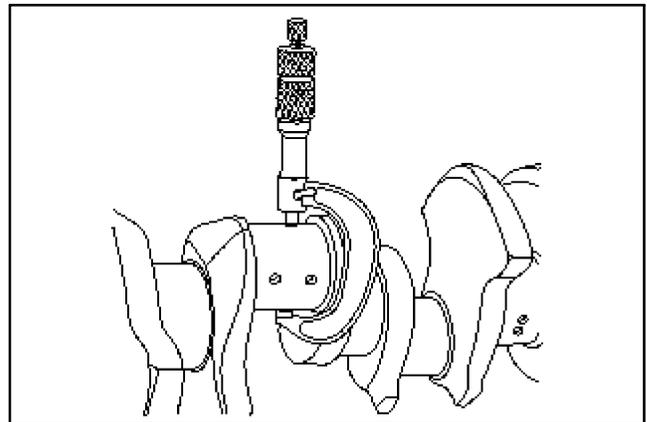
4. Inspect the crankshaft pin for damage:
 - Measure for proper installed height (a). Correct height is 2.00–2.25 mm (0.078–0.088 in.).
 - Replace the crankshaft pin if it is damaged.

Important: *Do not* attempt to remove the crankshaft reluctor wheels. If the reluctor wheels are damaged and/or removed, replace the crankshaft.

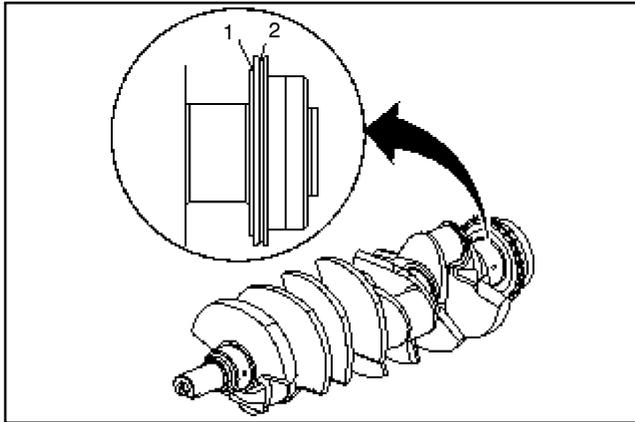
5. Inspect the reluctor wheels for cracked, bent, or broken teeth.
 - Measure between the crankshaft shoulder and the front reluctor wheel (1).
 - Measure between the front and rear reluctor wheels (2).
 - The maximum allowable gap is 0.15 mm (0.006 in.).



6. Measure the crankshaft main journals and the crankpins for out-of-round and taper.

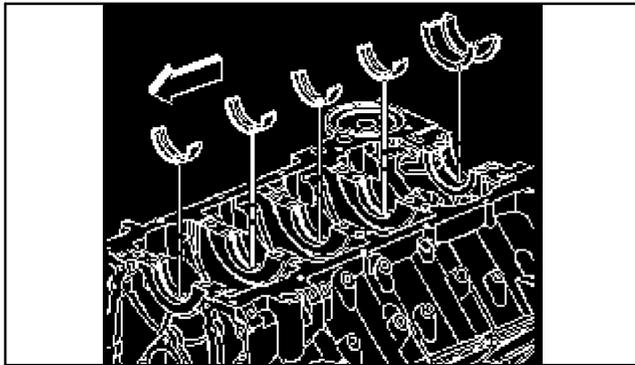


7. Using a suitable fixture, support the crankshaft.
 - a. Measure the crankshaft runout using *J 7872*.
 - b. Crankshaft runout should not exceed 0.051 mm (0.002 in.).
8. Inspect the crankshaft thrust wall surface for wear (1) and/or excessive runout (2). Refer to Section 1.2, Engine Mechanical Specs.



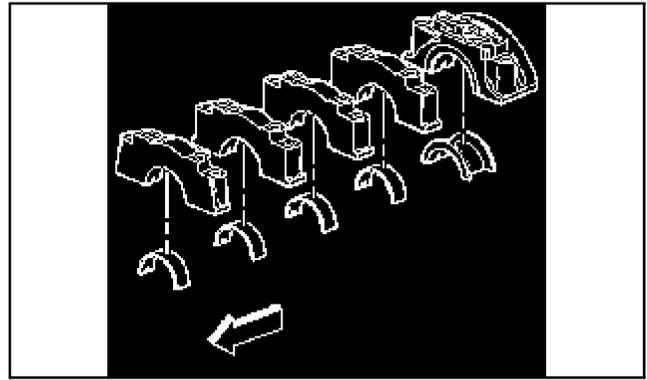
6.3.3 Installation

Tools Required:
J 8001 Dial Indicator Set
J 45059 Angle Meter

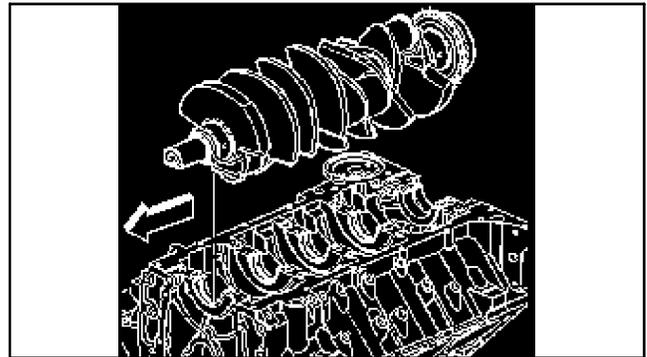


Important:

- Lubricate the crankshaft bearings and crankshaft with clean engine oil.
 - If undersized bearings are used, ensure that the bearings are fitted to the proper journals.
1. Install the crankshaft upper bearings into the block. Apply clean engine oil to the bearing surfaces.

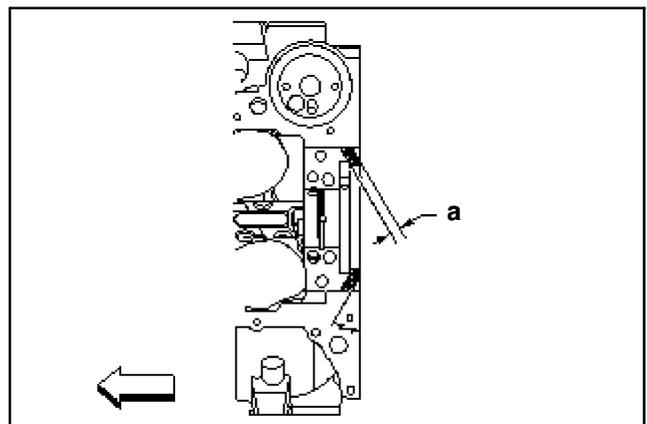


2. Install the crankshaft lower bearings into the crankshaft bearing caps. Apply clean engine oil to the bearing surfaces.



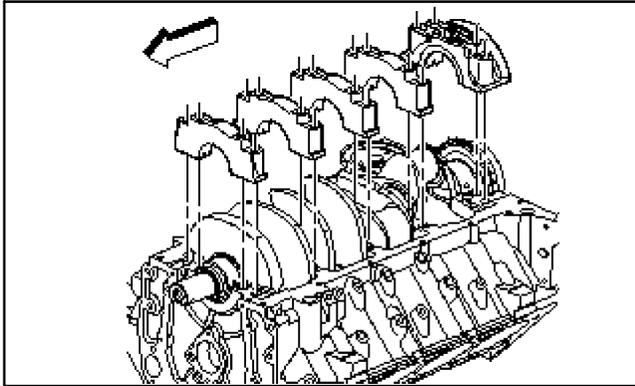
Notice: To prevent damage to the crankshaft position sensor reluctor wheel/ring, use care when removing or installing this component.

3. Install the crankshaft.



Important: Seat the bearing caps within 60 minutes of applying the sealer. Tighten the bearing cap fasteners within 5 minutes of the bearing caps being installed onto the engine block.

4. Apply a 13 mm (0.500 in.) light film of sealant (a), GM Part No. U.S. 1052942/Canadian 10953466 or equivalent, to the rear bearing cap sealing face or to the rear bearing cap channel of the engine block. Apply the sealant to the bearing cap mating surface and bearing cap channel from the rear seal bore to the oil pan surface.

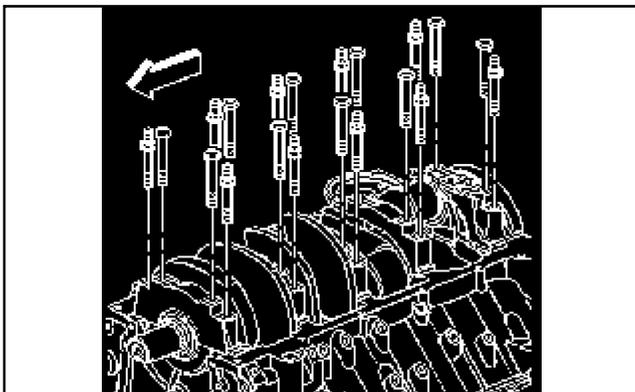


Notice: To prevent the possibility of cylinder block or crankshaft bearing cap damage, tap the crankshaft bearing caps into the cylinder block cavity using a brass, lead, or leather mallet before the attaching bolts are installed. Do not use attaching bolts to pull the crankshaft bearing caps into the seats. Failure to use this process may damage a cylinder block or a bearing cap.

Notice: The crankshaft position sensor reluctor wheel/ring is not serviced separately. Do not repair the crankshaft position sensor reluctor wheel/ring. If the crankshaft position sensor reluctor ring is damaged, replace the crankshaft assembly.

Important: Ensure that the triangle symbols on the crankshaft bearing caps are facing the front of the engine.

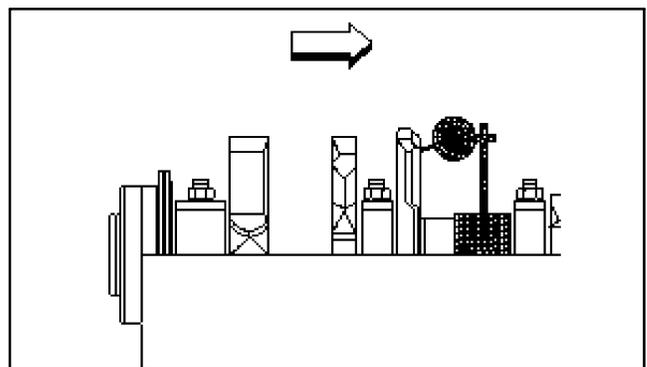
5. Install the crankshaft bearing caps in the original location as previously marked.



Notice: Refer to Fastener Notice in Cautions and Notices.

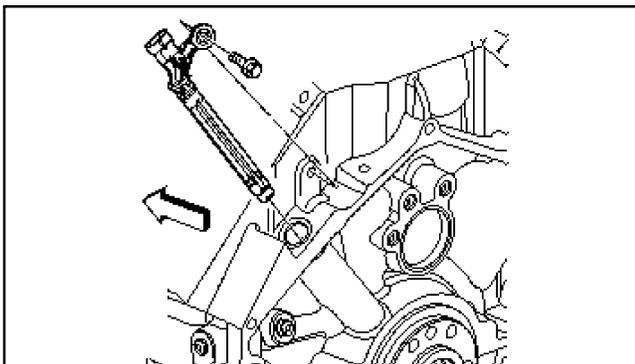
Important: Tighten the crankshaft bearing cap inner bolts before tightening the crankshaft bearing cap outer studs.

6. Install the bearing cap bolts and studs.
7. Tighten:
 - a. Tighten the bearing cap 1–4 inner bolts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the bearing cap 1–4 outer studs a first pass to 30 Nm (22 ft. lb.).
 - c. Tighten the bearing cap 1–4 inner bolts a final pass an additional 90° using *J 45059*.
 - d. Tighten the bearing cap 1–4 outer studs a final pass an additional 80° using *J 45059*.
 - e. Tighten the bearing cap 5 bolts and studs to 30 Nm (22 ft. lb.).
 - f. Loosen the bearing cap 5 bolts and studs.
 - g. Tighten the bearing cap 5 bolts and studs to 5 Nm (44 in. lb.).
8. Thrust the crankshaft firmly rearward.
9. Thrust the crankshaft firmly forward.
10. Tighten:
 - a. Tighten the bearing cap 5 inner bolts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the bearing cap 5 outer studs a first pass to 30 Nm (22 ft. lb.).
 - c. Tighten the bearing cap 5 inner bolts a final pass an additional 90° using *J 45059*.
 - d. Tighten the bearing cap 5 outer bolts a final pass an additional 80° using *J 45059*.



11. Measure the crankshaft end play as follows:

- a. Install *J 8001* or equivalent to the cylinder block with the dial indicator plunger against one of the counterweights of the crankshaft.
- b. Firmly thrust the end of the crankshaft first rearward then forward. This will line up the rear crankshaft bearing and the crankshaft thrust surfaces.
- c. With the crankshaft pushed forward, zero the dial indicator. Move the crankshaft rearward and read the end play measurement on the dial indicator. An optional method is to insert a feeler gauge between the crankshaft and the bearing surface and measure the clearance. Refer to Section 1.2, Engine Mechanical Specs.
- d. If the correct end play cannot be obtained, inspect for the following conditions:
 - Verify that the correct size crankshaft bearing has been installed. Refer to Section 1.2, Engine Mechanical Specs.
 - Inspect the crankshaft thrust wall surface or surfaces for wear and/or excessive runout. Refer to Section 1.2, Engine Mechanical Specs.
- e. Inspect the crankshaft for binding. Turn the crankshaft to check for binding. If the crankshaft does not turn freely, loosen the crankshaft bearing bolts and studs, one cap at a time, until the tight bearing is located. The following condition or conditions could cause a lack of clearance at the bearing:
 - Burrs on the crankshaft bearing cap.
 - Foreign material between the bearing and the block.
 - Foreign material between the bearing and the bearing cap.
 - A faulty crankshaft bearing.
 - Improper size bearing.



Important:

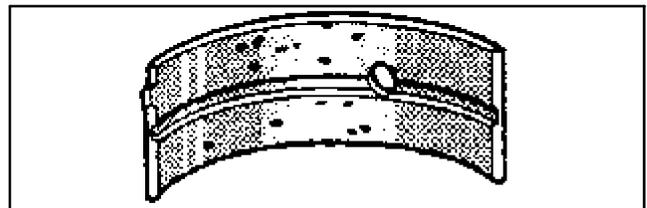
- Ensure that the crankshaft position sensor is fully seated against the crankshaft reluctor ring. The upper flange on the sensor **MAY NOT** seat against the engine block.
- The crankshaft position sensor bolt has a thread sealant applied to the threads. The thread sealant may have come off during the removal of the bolt. Ensure that the bolt hole is clean of any debris before installing the crankshaft sensor bolt.

12. Inspect both crankshaft position sensor O-rings for cuts, cracks, tears, or damage. Replace the O-rings as needed. Lubricate the crankshaft position sensor O-rings with clean engine oil.
13. Install the crankshaft position sensor into the block. There may be a slight resistance as the O-rings seat into the engine block.
14. Apply thread adhesive, GM Part No. U.S. 12345493/Canadian 10953488 or equivalent, to the crankshaft position sensor bolt.
15. Install the crankshaft position sensor bolt. Tighten the crankshaft position sensor bolt to 12 Nm (106 in. lb.).

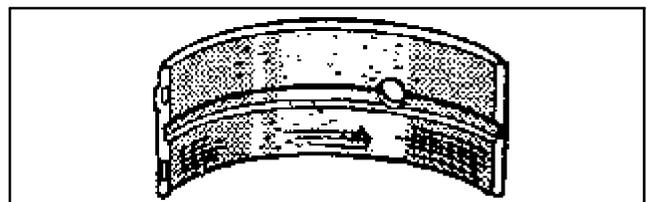
6.4 Crankshaft and Connecting Rod Bearing

6.4.1 Inspection

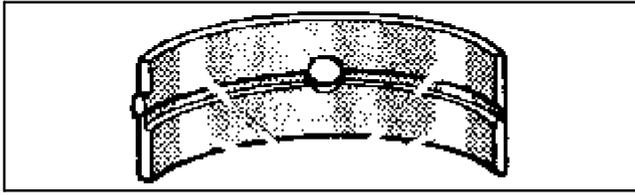
Important: Inspect the crankshaft and connecting rod bearings only to determine what kind of damage or failure has occurred. Always install *new* bearings after the bearings have been removed.



1. Inspect the bearings for craters or pockets. Flattened sections on the bearing halves also indicate fatigue.



2. Inspect the bearings for excessive scoring or discoloration.
3. Inspect the bearings for dirt or debris embedded into the bearing material.



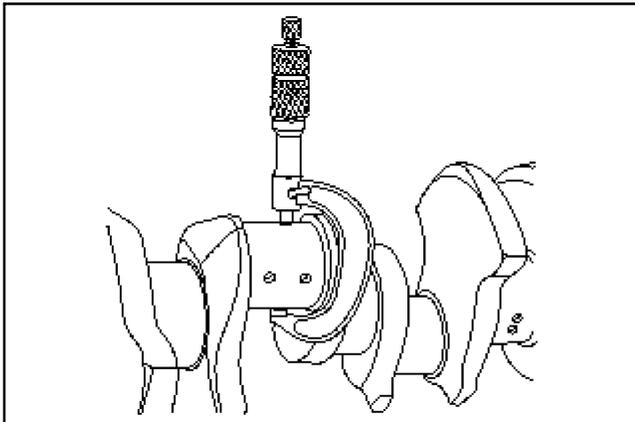
4. Inspect the bearings for improper seating indicated by bright, polished sections of the bearings.

6.4.2 Clearance Measurement

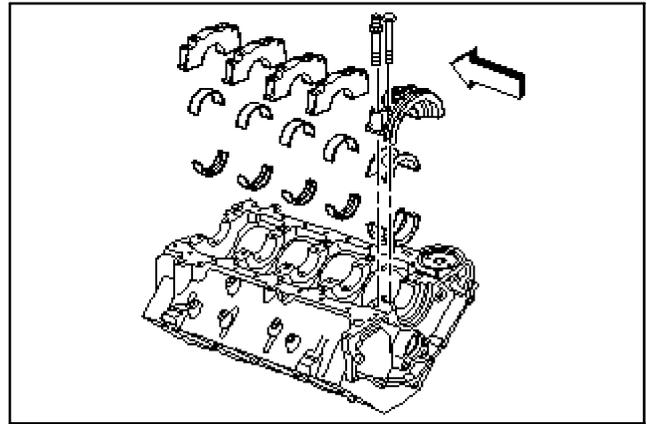
The crankshaft and connecting rod bearings are of the precision insert type and do not use shims for adjustment. Replace crankshafts with journals that measure less than minimum specifications.

Micrometer Method for Crankshaft Bearings

Important: When bearings are removed, install *new* bearings during reassembly.



1. Measure the crankshaft main journal diameter with a micrometer a minimum of four places along the length approximately 90° apart and average the measurements.
2. Determine the taper and the out-of-round. Refer to Section 1.2, Engine Mechanical Specs.



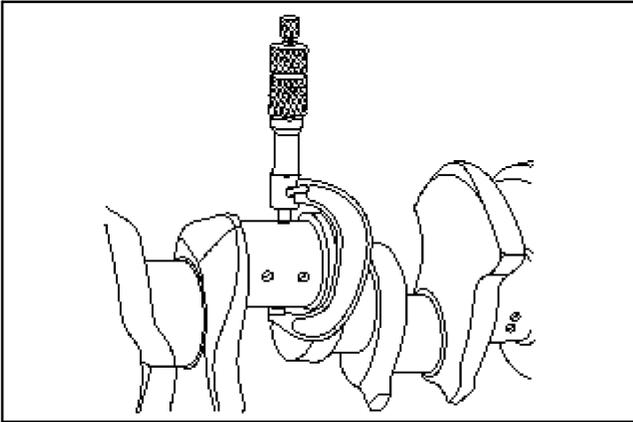
3. Install the *new* crankshaft bearings into the crankshaft bearing caps and the engine block.

Notice: Refer to Fastener Notice in Cautions and Notices.

Important: Tighten the inner crankshaft bearing cap bolts before tightening the outer crankshaft bearing cap studs.

4. Install the bearing cap bolts and studs.
 - a. Tighten the bearing cap 1–5 inner bolts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the bearing cap 1–5 outer studs a first pass to 30 Nm (22 ft. lb.).
 - c. Tighten the bearing cap 1–5 inner bolts a final pass an additional 90° using *J 45059*.
 - d. Tighten the bearing cap 1–5 outer studs a final pass an additional 80° using *J 45059*.
5. Measure the crankshaft bearing inside diameter (ID) using an inside micrometer. Measure at a minimum of four places and average the measurements.
6. To determine the crankshaft bearing clearance, subtract the crankshaft journal diameter from the crankshaft bearing ID.
7. Compare the crankshaft bearing clearance to the specifications. Refer to Section 1.2, Engine Mechanical Specs.
8. If the crankshaft bearing clearances exceeds specifications, install undersize crankshaft bearings to achieve the correct clearance.
9. Measure the new crankshaft bearing ID using an inside micrometer.
10. Replace the crankshaft if the proper clearances cannot be obtained with standard size bearings.

Micrometer Method for Connecting Rod Bearings



Important: When bearings are removed, install *new* bearings during reassembly.

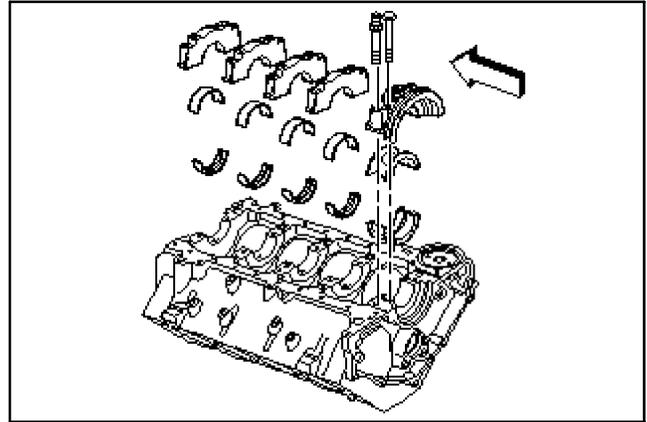
1. Measure the crankpin diameter with a micrometer a minimum of four places along the length, approximately 90° apart, and average the measurements.
2. Determine the taper and the out-of-round. Refer to Section 1.2, Engine Mechanical Specs.
3. Install the *new* connecting rod bearings into the connecting rod cap and the connecting rod.

Notice: Refer to Fastener Notice in Cautions and Notices.

Important: Use the original connecting rod nuts for clearance measurement. During final assembly, use new connecting rod nuts to obtain correct fastener tightening.

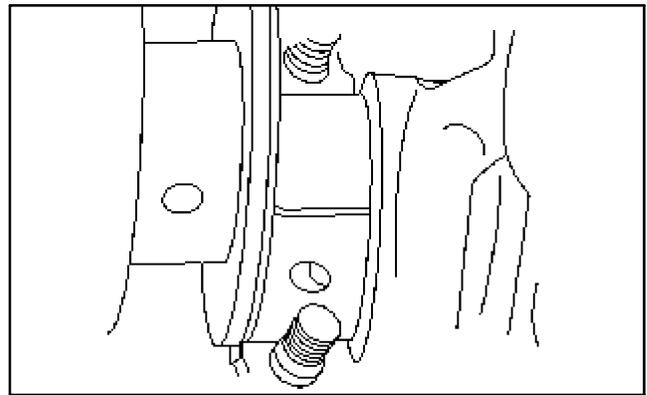
4. Install the connecting rod cap and the original, used nuts.
 - a. Tighten the connecting rod nuts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the connecting rod nuts a second pass an additional 90° using *J 45059*.
5. Measure the connecting rod bearing ID using an inside micrometer.
6. Compare the connecting rod bearing clearance specifications. Refer to Section 1.2, Engine Mechanical Specs.
7. If the connecting rod bearing clearances exceed specifications, replace components as required.

Plastic Gauge Method for Crankshaft Bearings



Important: When bearings are removed, install *new* bearings during reassembly.

1. Install the crankshaft and the new crankshaft bearings into the block, making sure not to damage the reluctor rings of the crankshaft.



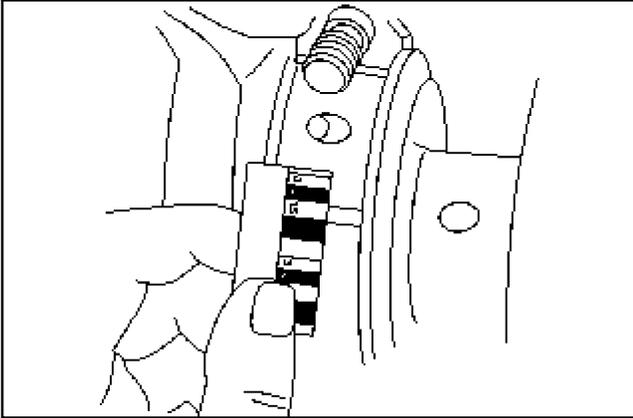
2. Install the gauging plastic the full width of the crankshaft journal.

Notice: Refer to Fastener Notice in Cautions and Notices.

Important: Tighten the inner crankshaft bearing cap bolts before tightening the outer crankshaft bearing cap studs. The crankshaft journal and the crankshaft bearing surface must be free from oil to obtain a correct measurement. Do not allow the crankshaft to rotate while performing measurement or an incorrect measurement will be obtained.

3. Install the bearing cap bolts and studs.
 - a. Tighten the bearing cap 1–5 inner bolts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the bearing cap 1–5 outer studs a first pass to 30 Nm (22 ft. lb.).

- c. Tighten the bearing cap 1–5 inner bolts a final pass an additional 90° using *J 45059*.
 - d. Tighten the bearing cap 1–5 outer studs a final pass an additional 80° using *J 45059*.
4. Remove the crankshaft bearing cap bolts and the crankshaft bearing caps. The gauging plastic may adhere to either the crankshaft journal or the crankshaft bearing surfaces.



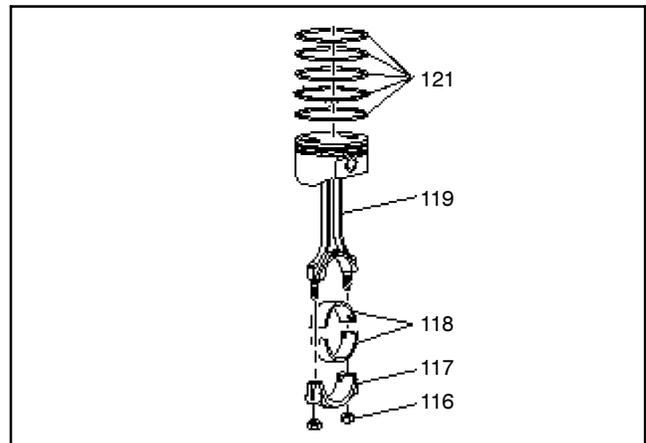
5. On the edge of the gauging plastic envelope is a graduated scale. Without removing the gauging plastic, measure compressed width at widest point.
6. If the flattened gauging plastic tapers toward the middle or the ends, there may be a difference in clearance indicating taper, low spot, or other irregularity of the crankshaft bearing or the crankshaft journal.
 - Normally the crankshaft journals wear evenly and are not out-of-round. However, if a crankshaft bearing is being fit to an out-of-round 0.0254 mm (0.001 in.) maximum crankshaft journal, fit to the maximum diameter of the crankshaft journal.
 - If the crankshaft bearing is fitted to the minimum diameter and the crankshaft journal is excessively out-of-round, the interference between the crankshaft bearing and the crankshaft journal will result in rapid crankshaft bearing failure.
7. Compare the crankshaft bearing clearance to the specifications. Refer to Section 1.2, Engine Mechanical Specs.
8. If the crankshaft bearing clearances exceeds specifications, replace components as required.

9. Measure the new crankshaft bearing ID using the same method.
10. Replace the crankshaft if the proper clearances cannot be obtained with standard size bearings.
11. Remove the flattened gauging plastic.
12. Measure the remaining crankshaft journals.

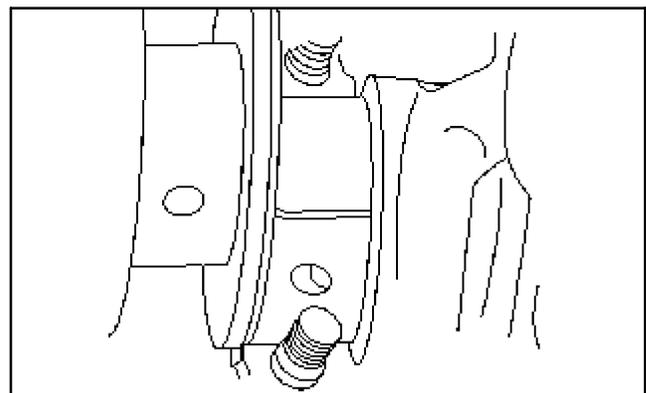
Plastic Gauge Method for Connecting Rod Bearings

Important: When bearings are removed, install *new* bearings during reassembly.

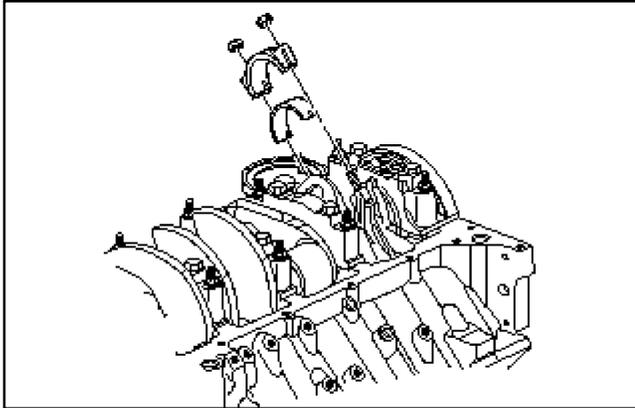
1. Install the connecting rod bearings (118) into the connecting rod (119) and the connecting rod cap (117).



2. Using rubber fuel line over the connecting rod bolts, install the piston and connecting rod assembly onto the crankpin journal.



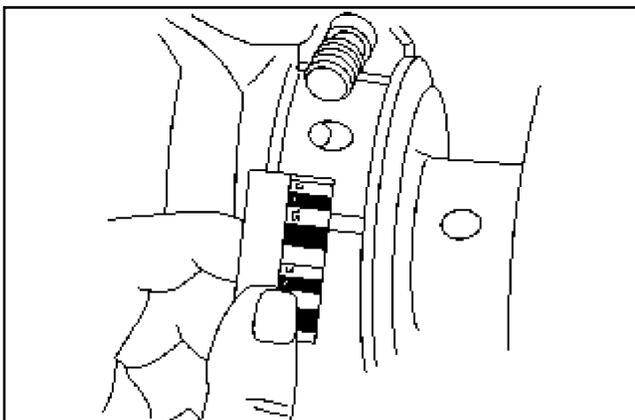
3. Install the gauging plastic the full width of the crankpin journal.



Notice: Refer to Fastener Notice in Cautions and Notices.

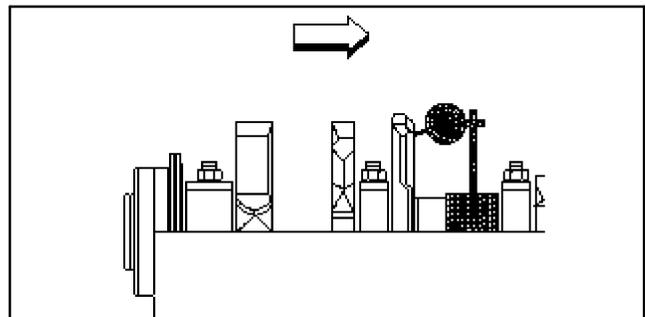
Important: Use the original connecting rod nuts for clearance measurement. During final assembly, use new connecting rod nuts to obtain correct fastener tightening.

4. Install the connecting rod cap and the original, used nuts.
 - a. Tighten the connecting rod nuts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the connecting rod nuts a second pass an additional 90° using *J 45059*.
5. Remove the connecting rod nuts and cap. The gauging plastic may adhere to either the crankpin journal or the connecting rod bearing surface.
6. On the edge of the gauging plastic envelope is a graduated scale. Without removing the gauging plastic, measure the compressed width at the widest point.



7. If the flattened gauging plastic tapers toward the middle or the ends, there may be a difference in clearance indicating taper, low spot or other irregularity of the crankshaft bearing or the crankpin journal.
8. Normally the crankpin journals wear evenly and are not out-of-round. However, if a connecting rod bearing is being fitted to an out-of-round 0.0254 mm (0.001 in.) maximum crankpin journal, be sure to fit to the maximum diameter of the crankpin journal. If the connecting rod bearing is fitted to the minimum diameter and the crankpin journal is excessively out-of-round, the interference between the connecting rod bearing and the crankpin journal will result in rapid connecting rod bearing failure.
9. Compare the connecting rod bearing clearance to the specifications. Refer to Section 1.2, Engine Mechanical Specs.
10. If the connecting rod bearing clearances exceed specifications, replace components as required.
11. Remove the flattened gauging plastic.
12. Measure the remaining crankpin journals.

6.5 Crankshaft End Play Measurement



Important: To properly measure the crankshaft end play, install the crankshaft, bearings, bearing caps, and fasteners into the engine block and tighten the bolts to specifications. Refer to Section 6.3.3, Crankshaft and Bearings Installation.

1. Install *J 7872* or equivalent to the cylinder block with the dial indicator plunger against one of the counterweights of the crankshaft.
2. Firmly thrust the end of the crankshaft first rearward then forward. This will line up the rear crankshaft bearing and the crankshaft thrust surfaces.

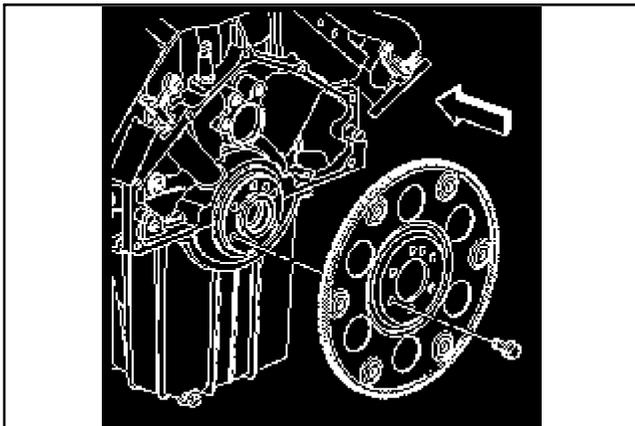
3. With the crankshaft pushed forward, zero the dial indicator. Move the crankshaft rearward and read the endplay measurement on the dial indicator. An optional method is to insert a feeler gauge between the crankshaft and the bearing surface and measure the clearance. Refer to Section 1.2, Engine Mechanical Specs.
4. If the correct end play cannot be obtained, inspect the crankshaft thrust wall surface or surfaces for wear and/or excessive runout.
5. Inspect the crankshaft for binding. Turn the crankshaft to check for binding. If the crankshaft does not turn freely, loosen the crankshaft bearing bolts and studs, one cap at a time, until the tight bearing is located. The following condition or conditions could cause a lack of clearance at the bearing:
 - Burrs on the crankshaft bearing cap.
 - Foreign matter between the crankshaft bearing and the block or the crankshaft bearing cap.
 - A faulty crankshaft bearing.

6.6 Engine Flywheel

6.6.1 Replacement

Removal Procedure

1. Remove the engine flywheel bolts.
2. Remove the engine flywheel.
3. Clean and inspect the engine flywheel. Refer to Section 6.6.3, Engine Flywheel Cleaning and Inspection.

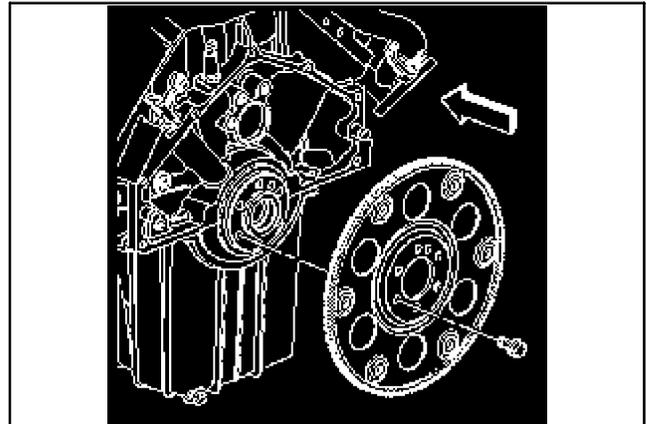


Installation Procedure

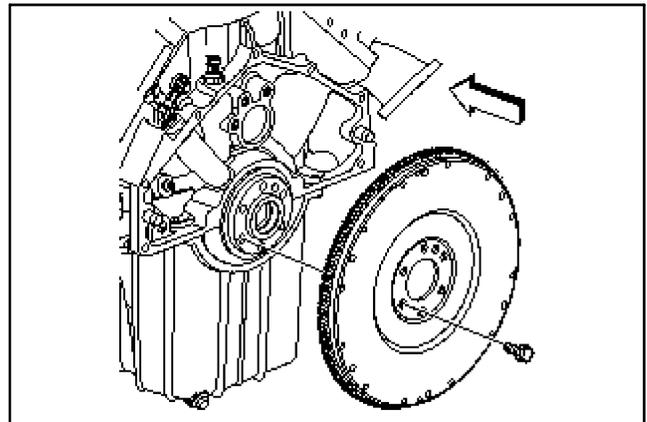
Important: Make sure the flywheel is installed correctly. Engine Side is stamped on the flywheel to aid with installation.

Notice: Refer to Fastener Notice in Cautions and Notices.

1. Install the engine flywheel bolts.
 - a. Tighten bolts a first pass to 40 Nm (30 ft. lb.).
 - b. Tighten bolts a second pass to 80 Nm (59 ft. lb.).
 - c. Tighten bolts a final pass to 100 Nm (74 ft. lb.).



6.6.2 Removal



Important: The flywheel may need to be tapped with a non-metallic mallet from the engine side due to a slight interference fit to the crankshaft.

1. Remove the engine flywheel bolts.
2. Remove the engine flywheel.

6.6.3 Cleaning and Inspection

1. Clean the engine flywheel in solvent.

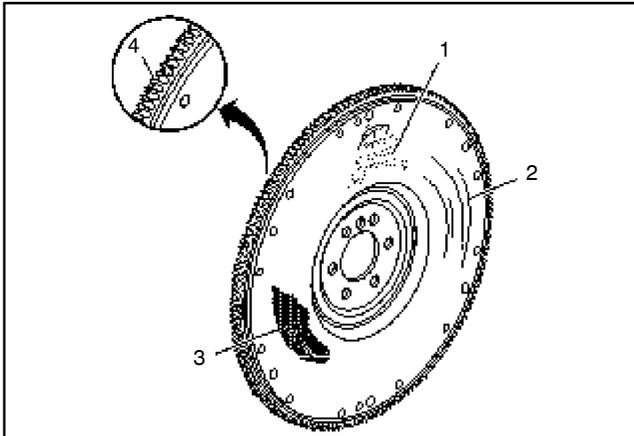
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

2. Dry the engine flywheel with compressed air.

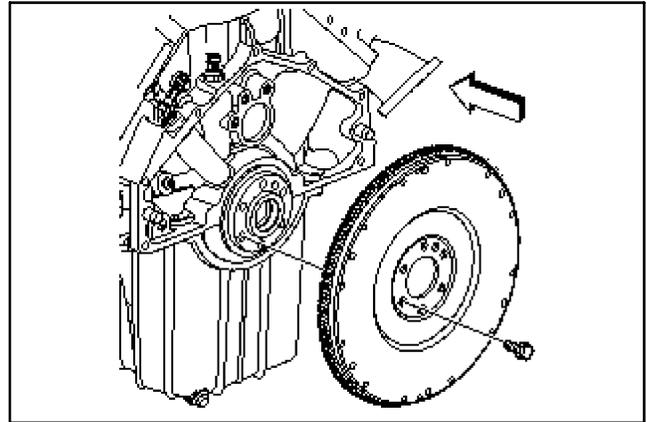
3. Inspect the manual transmission engine flywheel for the following conditions:

- Pitted surface (1).
- Scoring or grooves (2).
- Rust or other surface damage (3).
- Damaged ring gear teeth (4).
- Loose or improperly positioned ring gear.

The ring gear has an interference fit onto the engine flywheel and should be positioned completely against the flange of the engine flywheel.



6.6.4 Installation



1. Install the engine flywheel.

Notice: Refer to Fastener Notice in Cautions and Notices.

2. Install the engine flywheel bolts. Tighten the fasteners following a crisscross pattern.

- Tighten the engine flywheel bolts a first pass to 40 Nm (30 ft. lb.).
- Tighten the engine flywheel bolts a second pass to 80 Nm (59 ft. lb.).
- Tighten the engine flywheel bolts a final pass to 100 Nm (74 ft. lb.).

Section 7 Camshaft and Timing Gear Train

7.1 Engine Front Cover

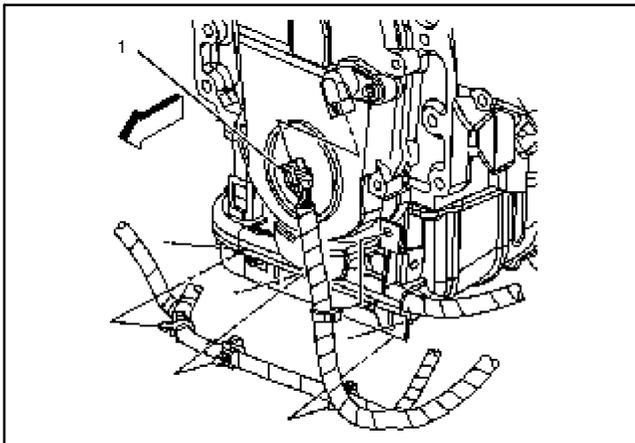
7.1.1 Replacement

Tools Required:

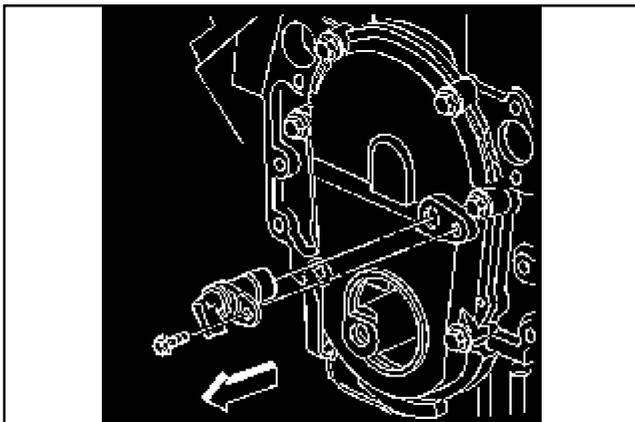
J 42851 Front Cover Oil Seal Installer

Removal Procedure

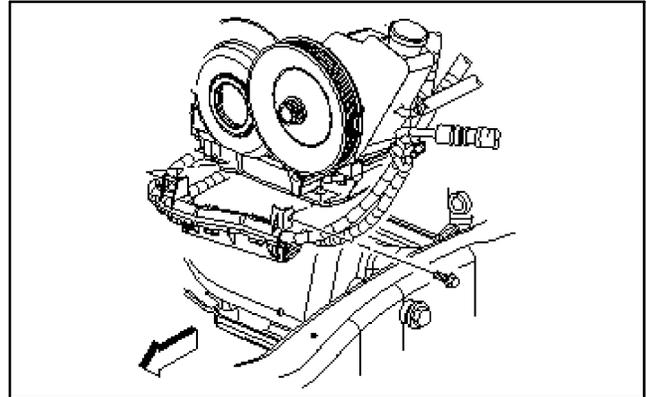
1. Remove the water pump. Refer to Section 9.2, Water Pump.
2. Remove the crankshaft balancer. Refer to Section 6.1, Crankshaft Balancer Replacement.



3. Disconnect the camshaft position (CMP) sensor electrical connector (1).
4. Remove the engine harness clips from the battery cable channel.

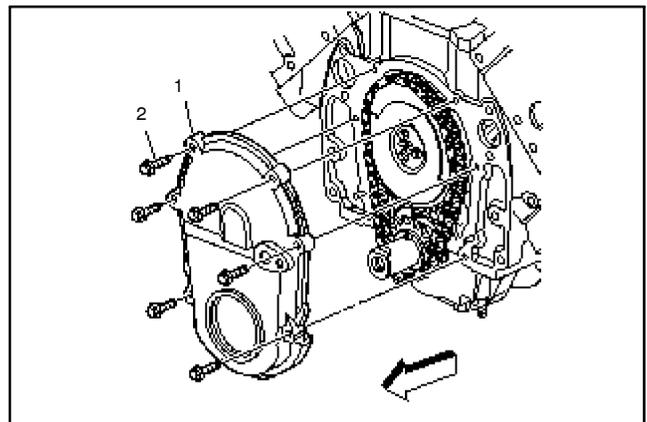


5. Remove the CMP sensor bolt.
6. Remove the CMP sensor.



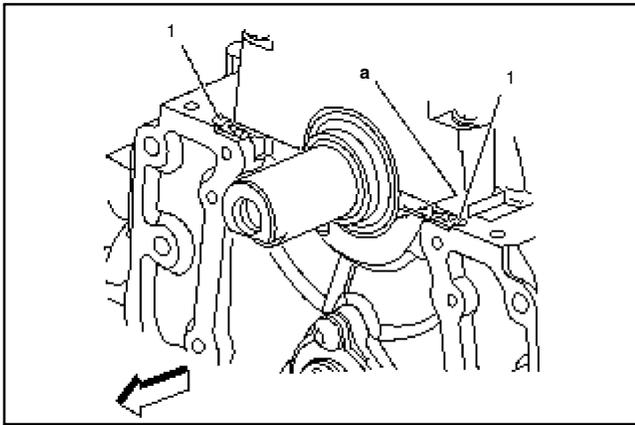
7. Remove the battery cable channel bolt.
8. Remove and reposition the battery cable channel.
9. Remove the engine front cover bolts (2).
10. Remove the engine front cover (1).

Important: The engine front cover gasket is reusable.



11. Remove the engine front cover gasket.
12. Remove the crankshaft front oil seal from the front cover.

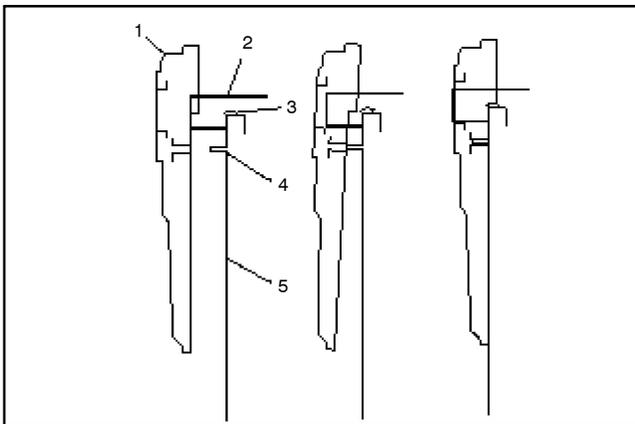
Installation Procedure



1. Install a *new* crankshaft front oil seal using *J 42851*.
2. Lubricate the sealing surface of the crankshaft front oil seal with clean engine oil.

Important: Install the engine front cover and tighten the fasteners while the sealant is still wet to the touch.

3. Apply sealant, GM Part No. U.S. 12346286/ Canadian 10953472 or equivalent, in two places (1) on the engine block where the front cover meets the oil pan.



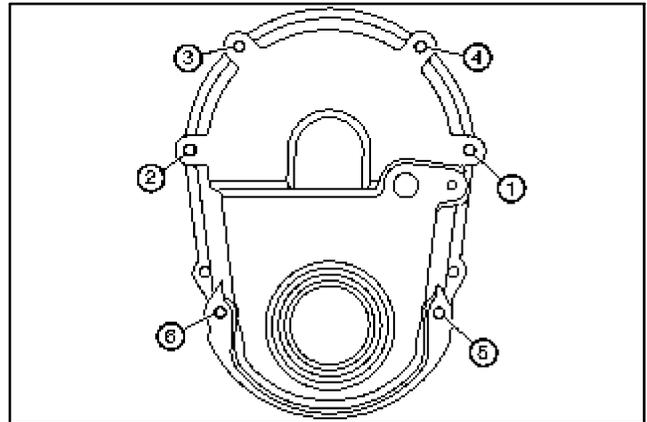
4. Install engine front cover gasket into front cover.

Important: Use the following method when installing the engine front cover. Failure to follow the instructions will push the sealant out, which may cause an oil leak.

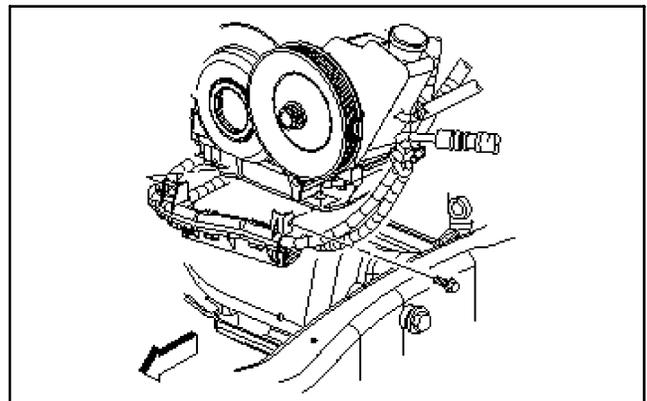
5. Install the front cover and gasket.

- a. Hold the front cover (1) up to the crankshaft (2).
 - b. Lift the front cover (1) while sliding the cover over the crankshaft (2).
 - c. Slide the front cover toward the engine block (5) while keeping the cover raised.
 - d. Lower the cover down over the dowel pin (4), allowing front cover to rest on the sealant (3).
6. Install the engine front cover bolts.

Notice: Refer to Fastener Notice in Cautions and Notices.

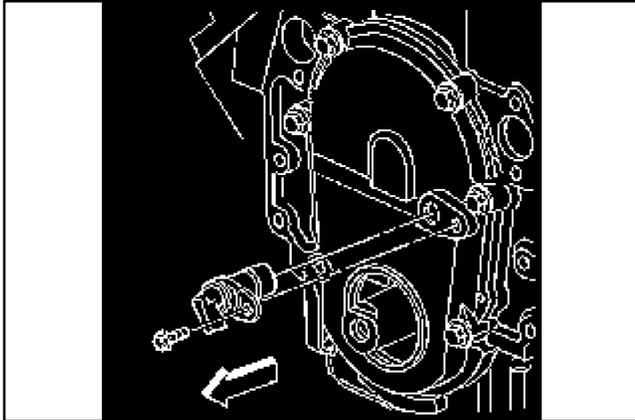


7. Tighten the engine front cover bolts.
 - a. Tighten the engine front cover bolts in sequence a first pass to 6 Nm (53 in. lb.).
 - b. Tighten the engine front cover bolts in sequence a final pass to 12 Nm (106 in. lb.).

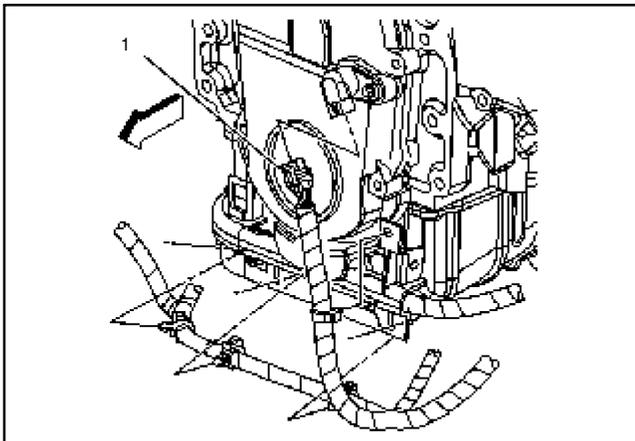


8. Position the battery cable channel into place.

9. Install the battery cable channel bolt. Tighten the battery cable channel bolt to 9 Nm (80 in. lb.).

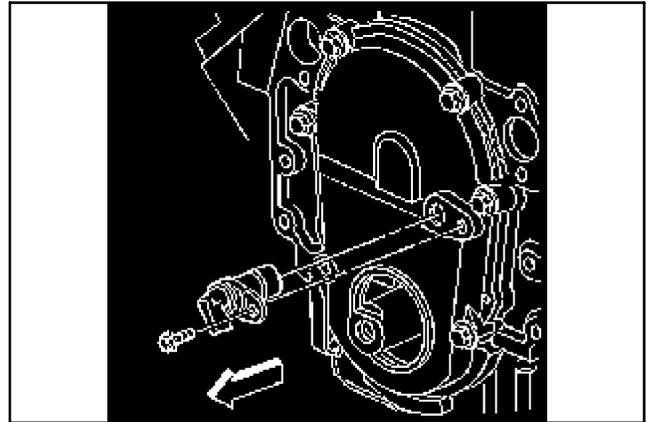


10. Inspect the CMP sensor O-ring for cuts, cracks, tears, or damage. Replace as needed.
11. Apply a light film of clean engine oil to the CMP sensor O-ring.
12. Install the CMP sensor. Install the CMP sensor bolt. Tighten the CMP sensor bolt to 12 Nm (106 in. lb.).
13. Install the engine harness clips to the battery cable channel.
14. Connect the CMP sensor electrical connector (1).



15. Install the crankshaft balancer. Refer to Section 6.1, Crankshaft Balancer Replacement.
16. Install the water pump. Refer to Section 9.2, Water Pump.

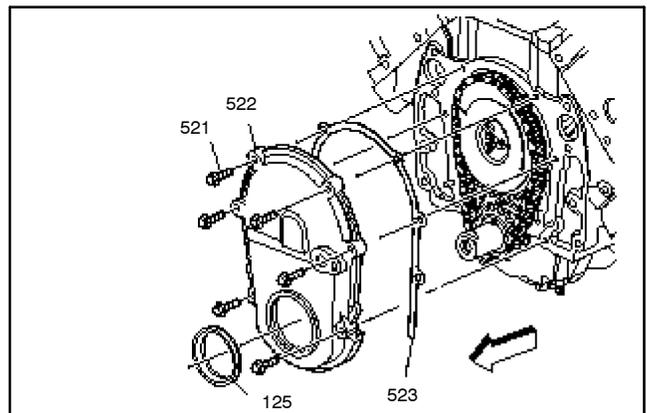
7.1.2 Removal



Notice: This component is initially installed using a self-tapping bolt(s). Care should be taken when removing and/or installing the self-tapping bolt(s). Failure to use care when removing and/or installing the self-tapping bolt(s) can lead to damage and unnecessary replacement of the self-tapping bolt(s) and/or the components.

1. Remove the camshaft position sensor bolt.
2. Remove the camshaft position sensor.
3. Inspect the camshaft position sensor O-ring for cuts, cracks, tears, or damage. Replace the O-ring as required.
4. Remove the engine front cover bolts (521).
5. Remove the engine front cover (522).

Important: The engine front cover gasket is reusable.



6. Remove the engine front cover gasket (523).
7. Remove the crankshaft front oil seal (125) from the engine front cover.

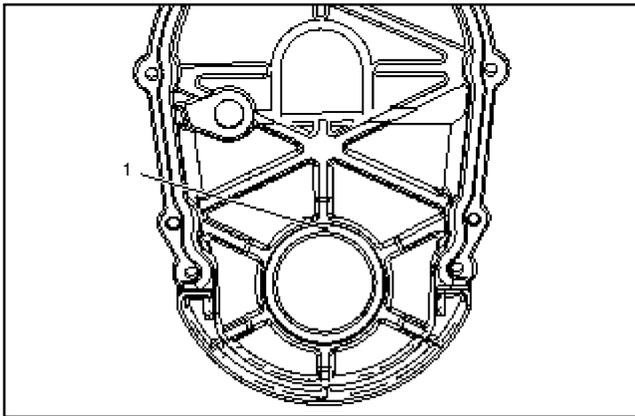
7.1.3 Installation

Tools Required:

J 42851 Front Cover Oil Seal Installer

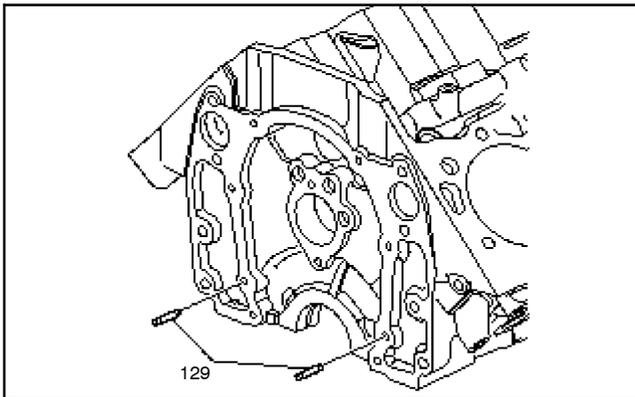
1. Lubricate the outer sealing surface of the crankshaft front oil seal lightly with clean engine oil. DO NOT lubricate the inner portion of the seal.
2. Position the *new* crankshaft front oil seal in the engine front cover so that the mark (1) on the rear of the seal is in the 12 o'clock position.

Second design oil seals will not have an alignment mark on the rear face. The seal may be installed in any position.

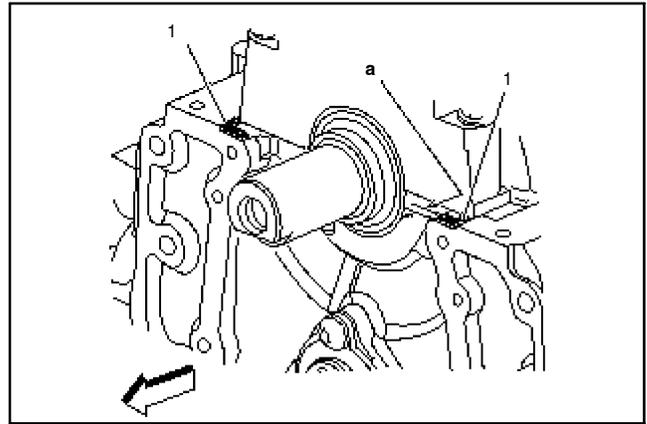


3. Install the crankshaft front oil seal using J 42851.
4. Install the front cover locating pins (129), if required.

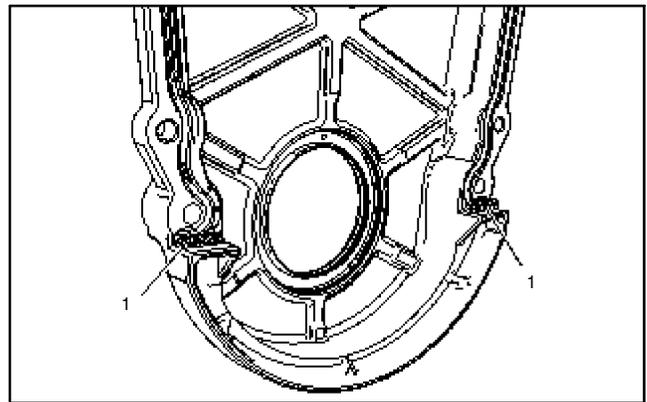
Important: Install the engine front cover and tighten the fasteners while the sealant is still wet to the touch.



5. Apply a 3–4 mm (0.12–0.16 in.) bead of sealant (a) GM Part No. U.S. 12346286/Canadian 10953472 or equivalent, in two sealant points (1) on the engine block where the front cover meets the oil pan.



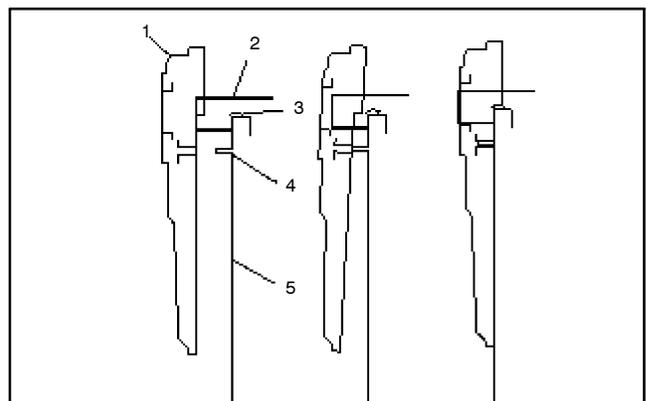
6. Apply a 3–4 mm (0.12–0.16 in.) bead of sealant, GM Part No. U.S. 12346286/Canadian 10953472 or equivalent, in 2 sealant points (1) across the flange where the gasket ends at the bottom of the front cover.



7. Install the engine front cover gasket into the front cover.

Important: Use the following method when installing the engine front cover. Failure to follow the instructions will push the sealant out, which may cause an oil leak.

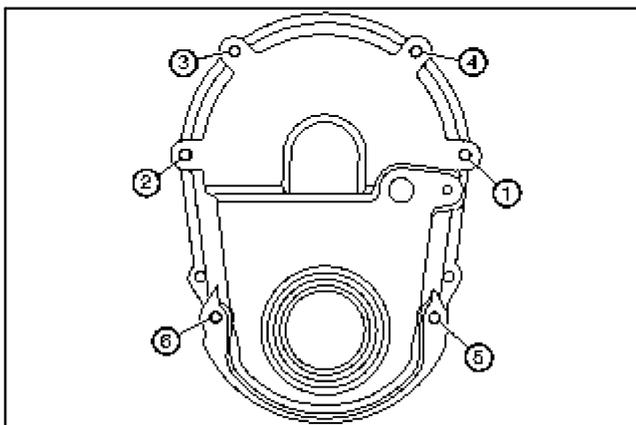
8. Install the engine front cover.



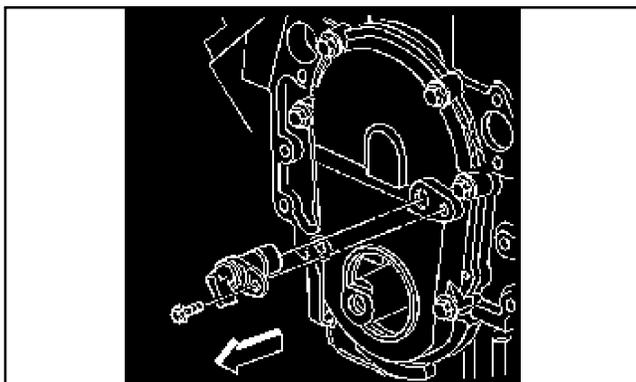
- a. Hold the front cover (1) up to the crankshaft (2).
- b. Lift the front cover (1) while sliding the cover over the crankshaft (2).
- c. Slide the front cover toward the engine block (5) while keeping the cover raised.
- d. Lower the cover down over the dowel pin (4), allowing the front cover to rest on the sealant (3).

Notice: Refer to Fastener Notice in Cautions and Notices.

9. Install the engine front cover bolts.
 - a. Tighten the engine front cover bolts in sequence a first pass to 6 Nm (53 in. lb.).
 - b. Tighten the engine front cover bolts in sequence a final pass to 12 Nm (106 in. lb.).



10. Inspect the camshaft position sensor O-ring for cuts, cracks, tears, or damage. Replace the O-ring as needed.



11. Apply a light film of clean engine oil to the camshaft position sensor O-ring.
12. Install the camshaft position sensor.

Notice: This bolt is a self-tapping bolt. If installing this bolt into a new component, installation of the bolt may be difficult. Ensure that the bolt is not over-torqued during the initial installation (thread cutting). Failure to limit torque can lead to bolt failure.
13. Install the camshaft position sensor bolt. Tighten the camshaft position sensor bolt to 12 Nm (106 in. lb.).

7.2 Timing Chain and Sprockets

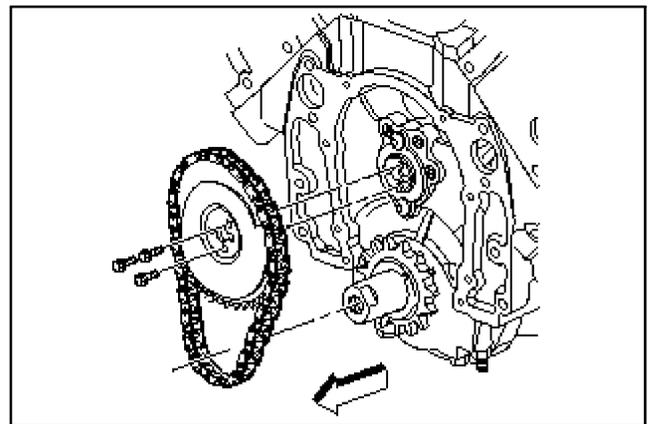
7.2.1 Replacement

Tools Required:

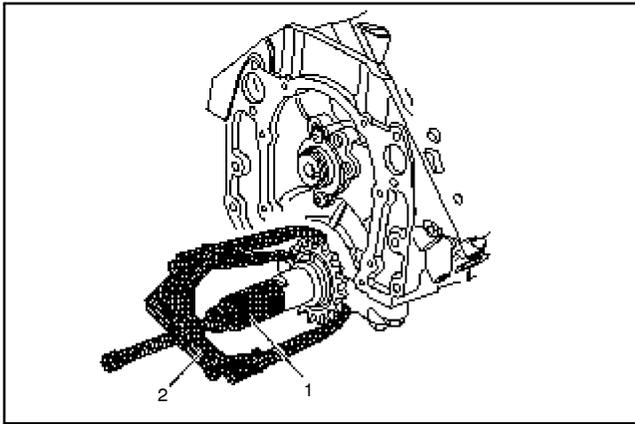
J 22102 Crankshaft Sprocket Installer

J 42846 Crankshaft Protector Button

Removal Procedure

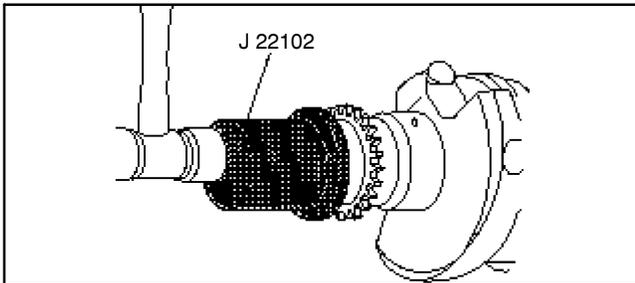


1. Remove the engine front cover. Refer to Section 7.1, Engine Front Cover Replacement.
2. Align the timing marks on the camshaft and crankshaft sprockets.
3. Remove the camshaft sprocket bolts.
4. Remove the camshaft sprocket and timing chain.

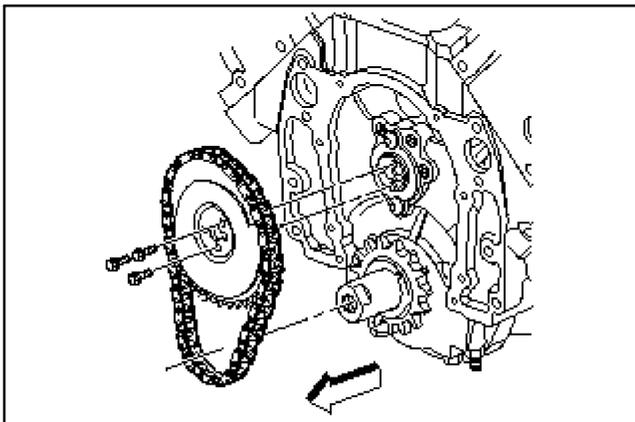


5. Install *J 42846* (1) into the end of the crankshaft.
6. Remove the crankshaft sprocket using a suitable three jaw puller.
7. Clean and inspect the timing chain and sprockets. Refer to Section 7.2.3, Timing Chain and Sprockets Cleaning and Inspection.

Installation Procedure



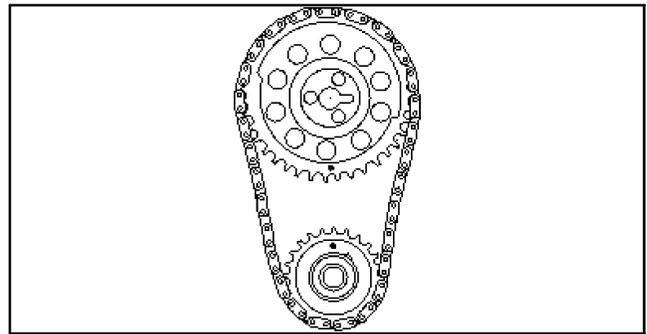
1. Use *J 22102* to install the crankshaft sprocket. Align the keyway of the crankshaft sprocket with the crankshaft pin.
2. Remove *J 22102*.
3. Rotate the crankshaft until the crankshaft sprocket alignment mark is in the 12 o'clock position.



Important:

- Install the camshaft sprocket with the alignment mark in the 6 o'clock position.
- The sprocket teeth must mesh with the timing chain to prevent damage to the camshaft retainer.
- Do not use a hammer to install the camshaft sprocket onto the camshaft. To do so may damage the camshaft.

4. Install the camshaft sprocket and timing chain.



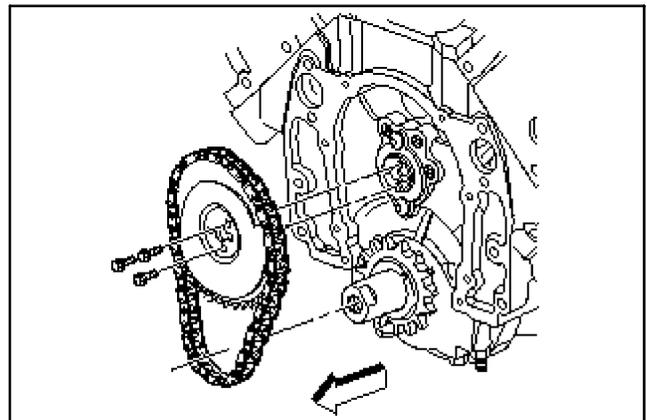
5. Ensure that the crankshaft sprocket is aligned at the 12 o'clock position and the camshaft sprocket is aligned at the 6 o'clock position.

Notice: Refer to Fastener Notice in Cautions and Notices.

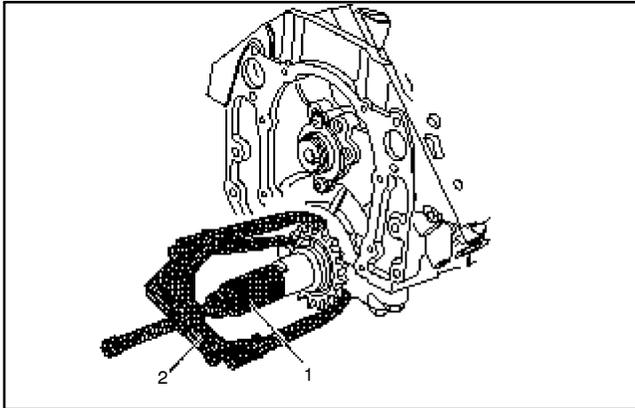
6. Install the camshaft sprocket bolts.
 - a. Tighten the bolts a first pass to 30 Nm (22 ft. lb.).
 - b. Tighten the bolts a final pass to 30 Nm (22 ft. lb.).
7. Install the engine front cover. Refer to Section 7.1, Engine Front Cover Replacement.

7.2.2 Removal

Tools Required: J 42846 Crankshaft Protector Button

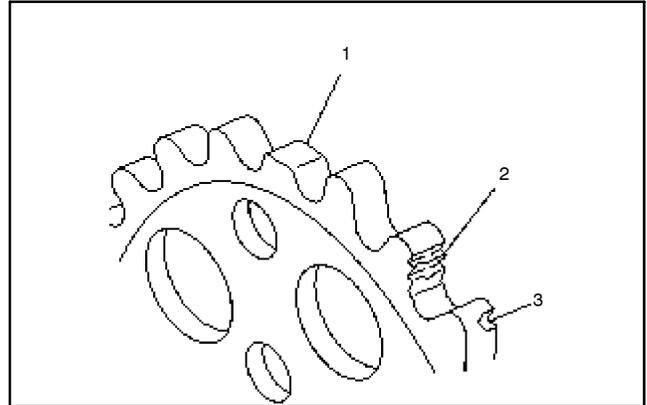


1. Measure the camshaft timing chain free play. If the chain can be moved back and forth in excess of 16 mm (0.625 in.), replace the chain and sprockets.
2. Remove the camshaft sprocket bolts.
3. Remove the camshaft sprocket and the timing chain.
4. Install *J 42846* (1) into the end of the crankshaft.
5. Remove the crankshaft sprocket using a three jaw puller (2).

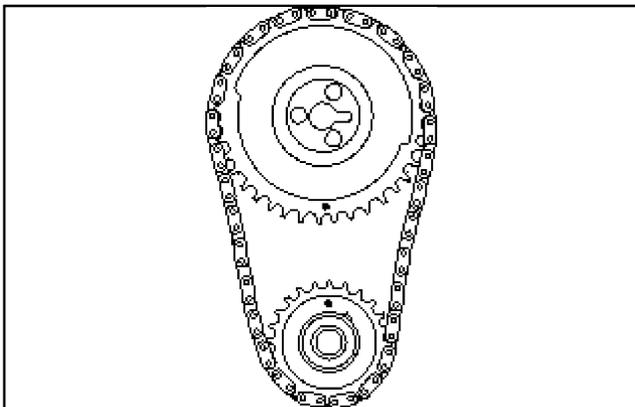


Important: If the sprocket or sprockets must be replaced, replace both sprockets to ensure that timing chain centerline alignment is maintained.

4. Inspect the camshaft and crankshaft sprockets for the following conditions:
 - Worn teeth (1).
 - Damaged teeth (2).
 - Chipped teeth (3).
 - Uneven wear on one edge of the teeth.
 - Worn valleys between the sprocket teeth.
 - Crankshaft sprocket keyway for wear.



7.2.3 Cleaning and Inspection



1. Clean the camshaft timing components in solvent.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

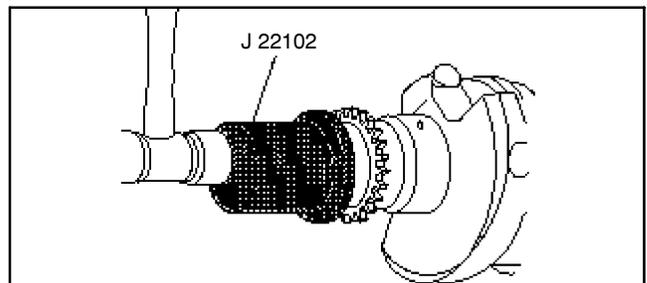
2. Dry the components with compressed air.
3. Inspect the camshaft timing chain for binding or wear.

7.2.4 Installation

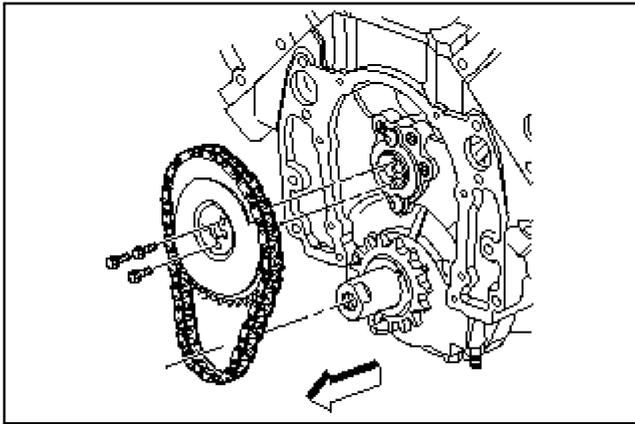
Tools Required:

J 22102 Front Cover Aligner and Seal Installer

1. Use *J 22102* to install the crankshaft sprocket. Align the keyway of the crankshaft sprocket with the crankshaft pin.



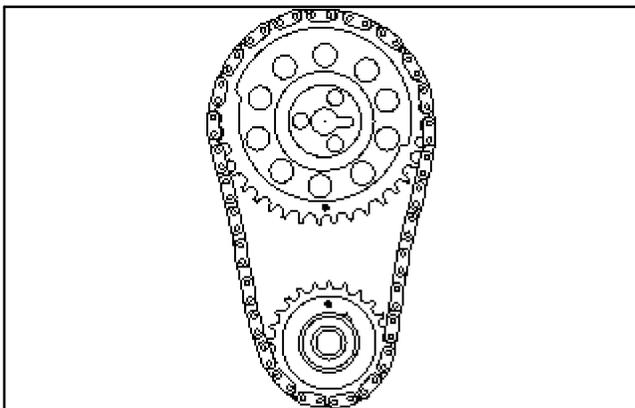
2. Inspect the sprocket pin for proper installation. Refer to Section 6.3.2, Crankshaft and Bearings Cleaning and Inspection.
3. Rotate the crankshaft until the crankshaft sprocket alignment mark is in the 12 o'clock position.



Notice: Do not hammer the camshaft sprocket onto the camshaft. To do so may dislodge the rear camshaft plug and damage the camshaft.

Important: Install the camshaft sprocket with the alignment mark in the 6 o'clock position. Important: The sprocket teeth must mesh with the timing chain to prevent damage to the camshaft retainer.

4. Install the camshaft sprocket and timing chain.



5. Ensure that the crankshaft sprocket is aligned at the 12 o'clock position and the camshaft sprocket is aligned at the 6 o'clock position.

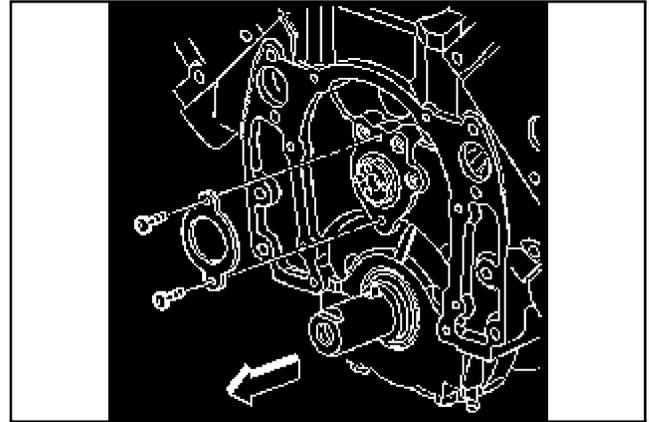
Notice: Refer to Fastener Notice in Cautions and Notices.

6. Install camshaft sprocket bolts. Tighten the three camshaft sprocket bolts to 30 Nm (22 ft. lb.).

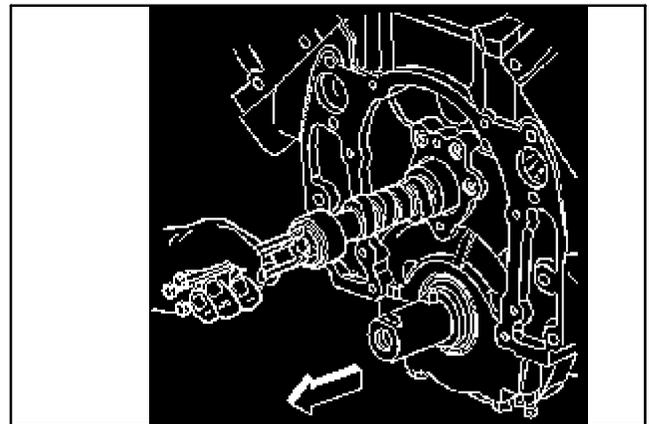
7.3 Camshaft

7.3.1 Replacement

Removal Procedure

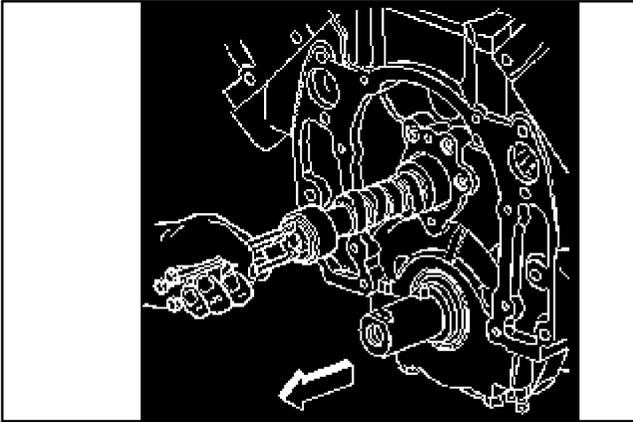


1. Remove the valve lifters. Refer to Section 4.6, Valve Lifter Replacement.
2. Remove the timing chain and sprocket. Refer to Section 7.2, Timing Chain and Sprockets Replacement.
3. Remove the camshaft retainer bolts.
4. Remove the camshaft retainer.



5. Install three 8-1.25 x 100 mm bolts into the camshaft front bolt holes.
6. Using the bolts as a handle, carefully rotate and pull the camshaft out of the engine block.
7. Remove the bolts from the front of the camshaft.
8. Clean and inspect the camshaft. Refer to Section 7.3.4, Camshaft and Bearings Cleaning and Inspection.

Installation Procedure

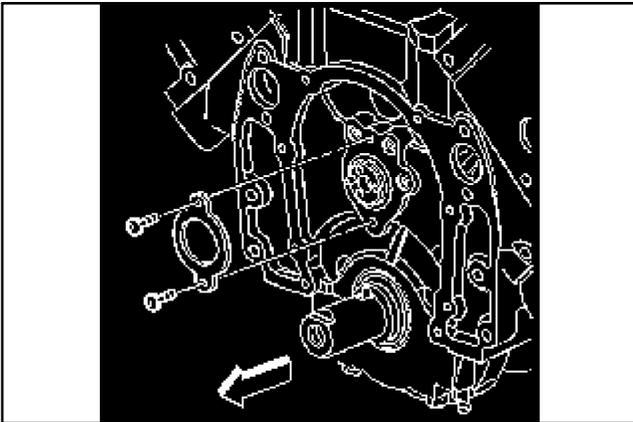


1. Apply lubricant, GM Part No. U.S. 12345501/ Canadian 992704 or equivalent, to the following components:

- Camshaft lobes.
- Camshaft bearing journals.
- Camshaft bearings.

Notice: All camshaft journals are the same diameter, so care must be used in removing or installing the camshaft to avoid damage to the camshaft bearings.

2. Install three 8-1.25 x 100 mm bolts into the camshaft threaded bolt holes.
3. Using the bolts as a handle, carefully install the camshaft.
4. Remove the bolts from the front of the camshaft.

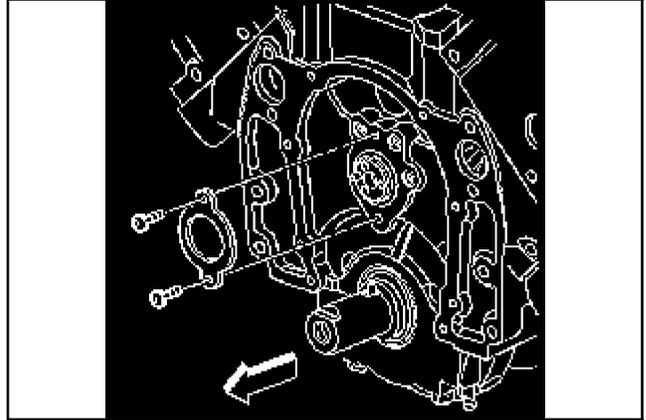


Notice: Refer to Fastener Notice in Cautions and Notices.

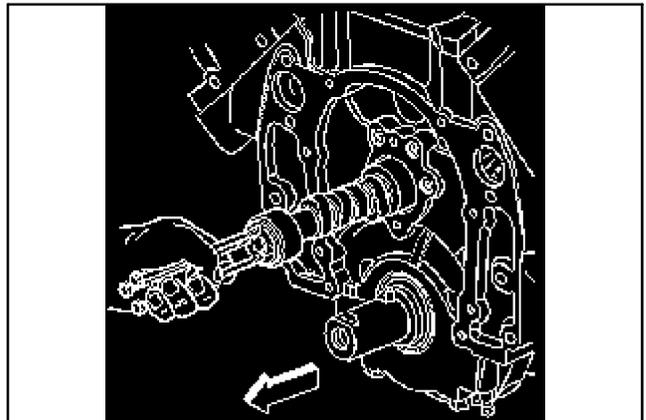
5. Install the camshaft retainer and bolts. Tighten the bolts to 12 Nm (106 in. lb.).

6. Install the timing chain and sprocket. Refer to Section 7.2, Timing Chain and Sprockets Replacement.
7. Install the valve lifters. Refer to Section 4.6, Valve Lifter Replacement.

7.3.2 Removal



1. Remove the camshaft retainer bolts.
2. Remove the camshaft retainer.



3. Install three 8-1.25 x 100 mm bolts in the camshaft front bolt holes.

Notice: All camshaft journals are the same diameter, so care must be used in removing or installing the camshaft to avoid damage to the camshaft bearings.

4. Using the bolts as a handle, carefully rotate and pull the camshaft out of the engine block.
5. Remove the bolts from the front of the camshaft.

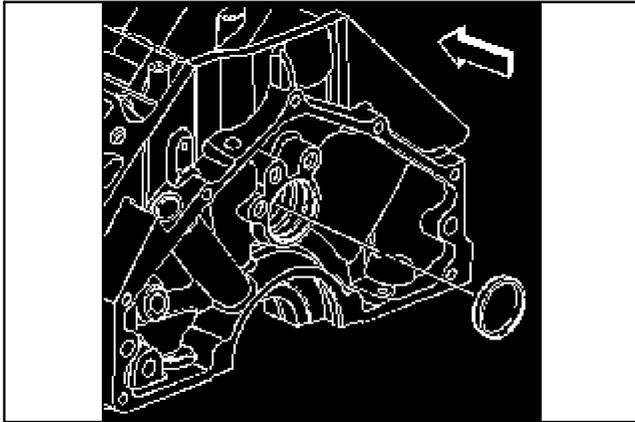
7.3.3 Bearing Removal

Tools Required:

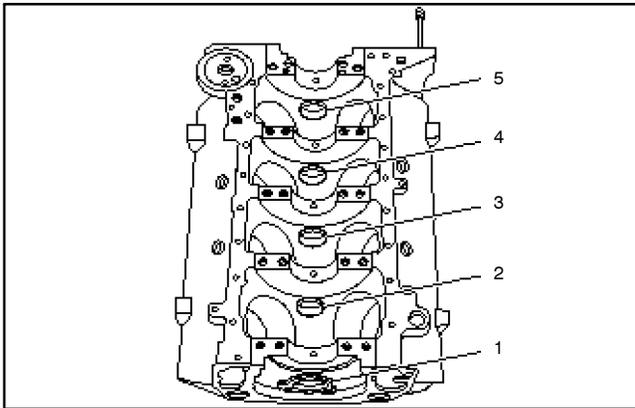
J 33049 Camshaft Bearing Service Set

1. Remove the rear camshaft plug, if not previously removed. Insert a long bar through the front of the engine and drive the plug out of the rear bore.

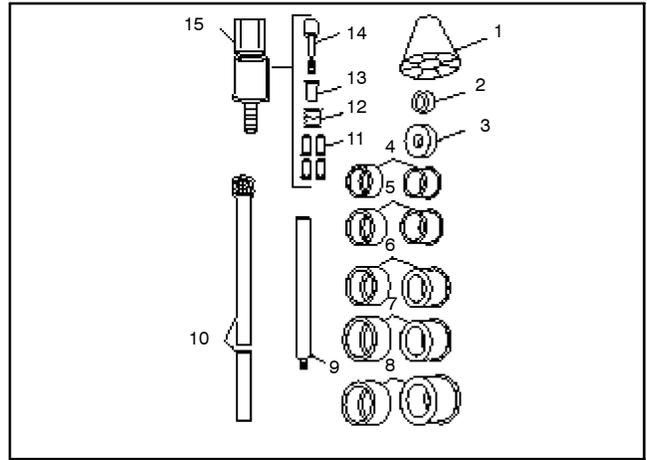
Important: A loose camshaft bearing may be caused by an enlarged, out-of-round, or damaged engine block bearing bore.



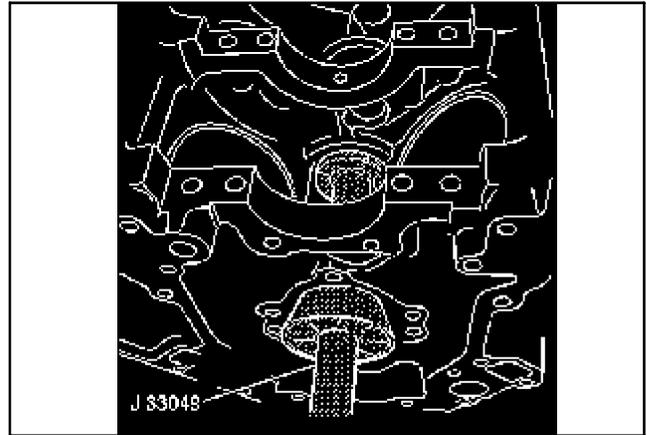
2. Prior to bearing removal, inspect the camshaft bearings for loose fit in the engine block bearing bores (positions 1–5).



3. Select the expanding driver (4–8) and washer (2 or 3) from *J 33049*.

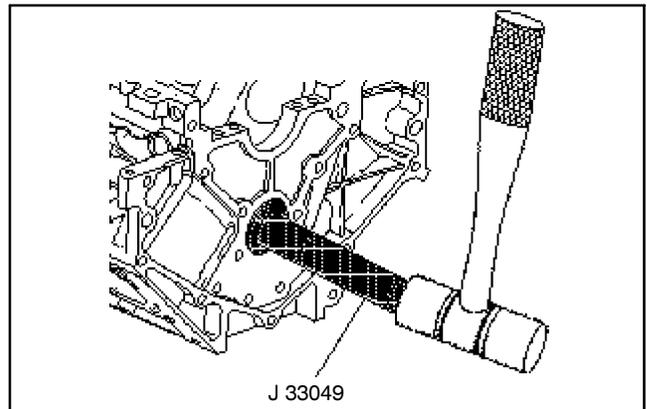


4. Assemble *J 33049*.



Important: Remove the inner bearings in positions 2, 3, and 4 first. The outer bearings in positions 1 and 5 serve as a guide for *J 33049*.

5. Insert *J 33049* through the front of the engine block and into the bearing.



6. Tighten the expander assembly nut until snug.
7. Push the guide cone into the front camshaft bearing in position 1 to align *J 33049*.
8. Drive the inner bearings in positions 2, 3, and 4 from their block bores.
9. Assemble *J 33049* handle, expanding driver, and washer.
10. Insert *J 33049* into the outer camshaft bearings.
11. Drive the outer bearings from the bore.

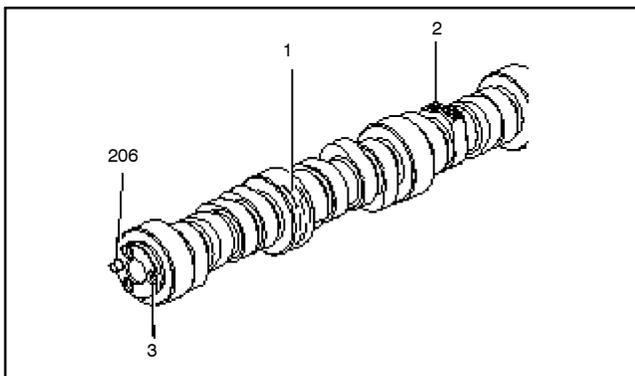
7.3.4 Camshaft and Bearings Cleaning and Inspection

Tools Required: J 7872 Magnetic Base Dial Indicator

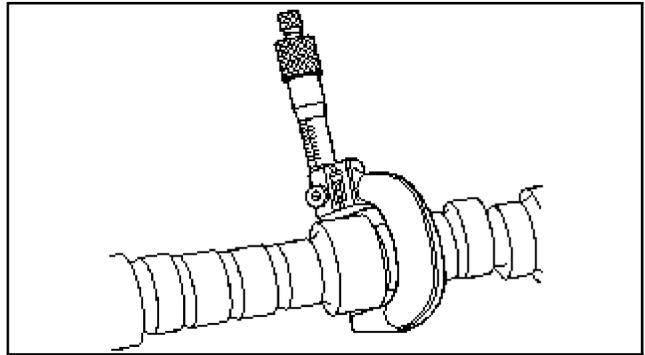
1. Clean the camshaft in solvent.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

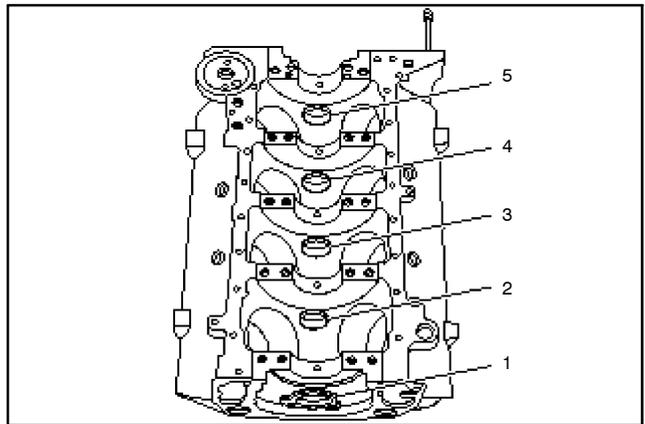
2. Dry the camshaft with compressed air.
3. Inspect the camshaft retainer plate for damage.
4. Inspect the camshaft for the following conditions:
 - Camshaft bearing journals (1) that are:
 - Worn
 - Scored
 - Damaged
 - Worn camshaft lobes (2).
 - Damaged sprocket bolt threads (3).
 - Damaged sprocket pin (206).



5. Measure the camshaft journals with a micrometer. Refer to Section 1.2, Engine Mechanical Specs.



6. Measure for excessive camshaft runout using *J 7872*.
 - a. Mount the camshaft in a suitable fixture.
 - b. Use *J 7872* to measure for a bent camshaft. Refer to Section 1.2, Engine Mechanical Specs.
7. Replace the camshaft if runout exceeds specifications.
8. Inspect the camshaft bearings 1–5 for serviceability.

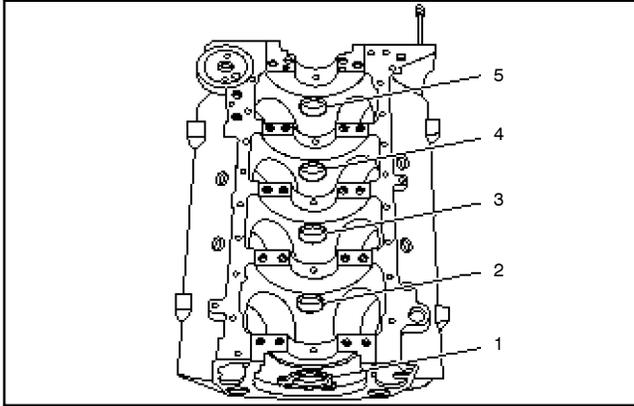


9. Replace the camshaft bearings if necessary. Refer to Section 7.3.3, Camshaft Bearing Removal, and Section 7.3.5, Camshaft Bearing Installation.

7.3.5 Bearing Installation

Tools Required: J 33049 Camshaft Bearing Service Set

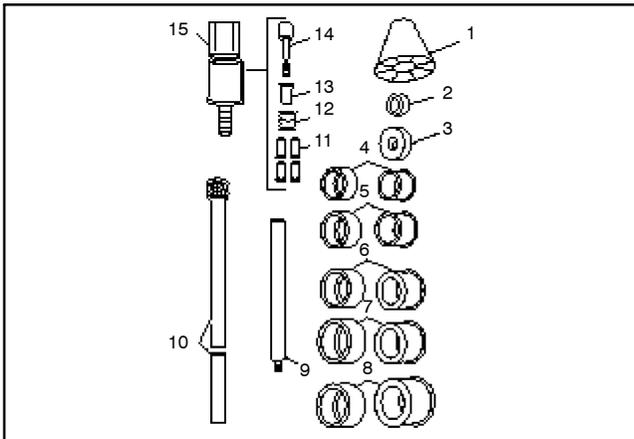
Important: The outer camshaft bearings (positions 1 and 5) must be installed first. These bearings serve as guides for the tool and help center the inner bearings during the installation process.



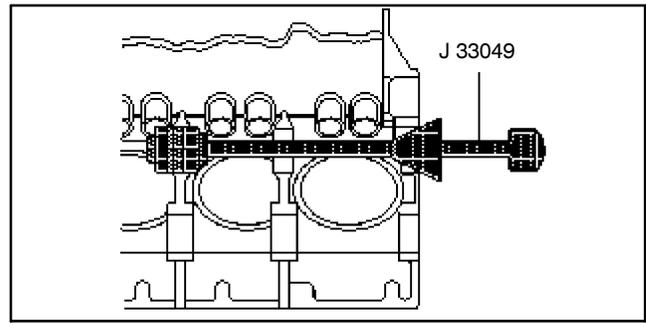
Ensure the correct camshaft bearing fits into the proper bore. The camshaft bearing bores may vary in size.

Ensure that the camshaft bearing lubrication hole or holes align with the oil gallery hole or holes in the block. On some engines, the oil holes may be difficult to locate. Verify that the holes are aligned.

1. Assemble the tool handle (10), expanding driver (4–8) and washer (2 or 3).



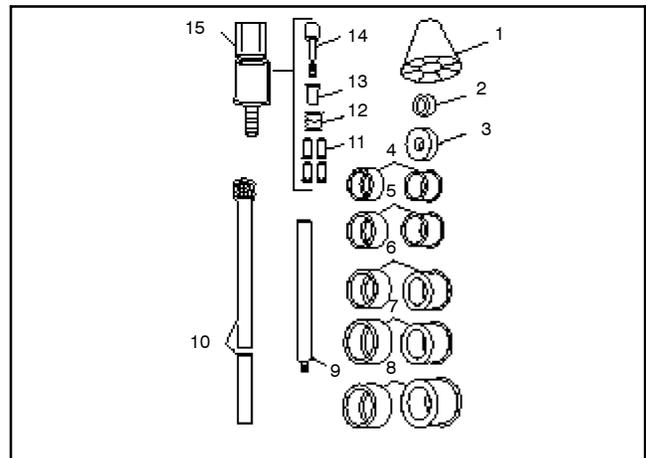
2. Insert *J 33049* tool into the engine block end camshaft bearings.



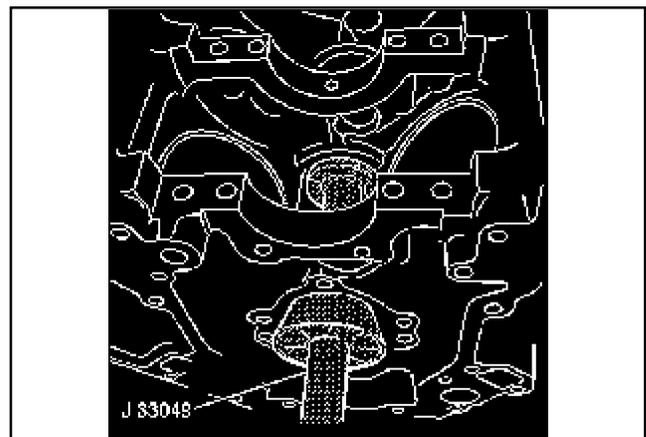
Notice: Do not shim, scrape, or file bearing inserts. Do not touch the bearing surface of the insert with bare fingers. Skin oil and acids will etch the bearing surface.

Important: An improperly aligned camshaft bearing oil gallery hole will restrict oil flow to the bearing and the camshaft journal.

3. Drive the end bearings into the bore.
4. Select the expanding driver (4–8) and washer (2 or 3) from *J 33049*.



5. Assemble the tool.
6. Insert *J 33049* tool through the front of the engine block and to the inner bearing bores.



7. Install the bearing onto the expanding driver.
8. Tighten the expander assembly nut until the tool is snug in the bearing.

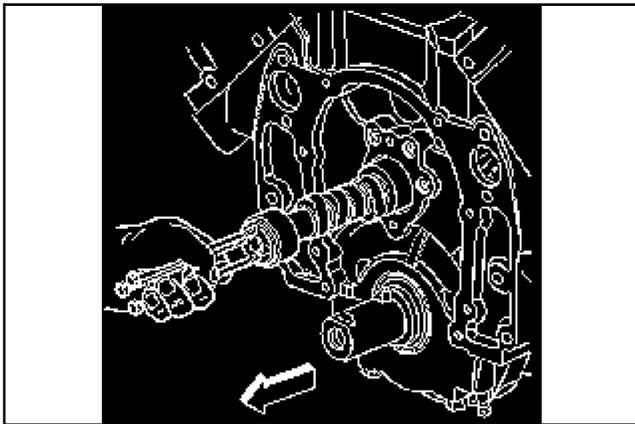
Important: The camshaft bearing oil holes must align with the oil galleries in the engine block.

After installation of the camshaft bearings, inspect the camshaft bearing oil holes for proper alignment with the oil galleries.

An improperly aligned camshaft bearing oil gallery hole will restrict oil flow to the bearing and the camshaft journal.

9. Align the oil lubrication hole in the bearing with the oil galleries in the engine block.
10. Push the guide cone into the front camshaft bearing bore to align the tool.
11. Drive the bearing into the bore.

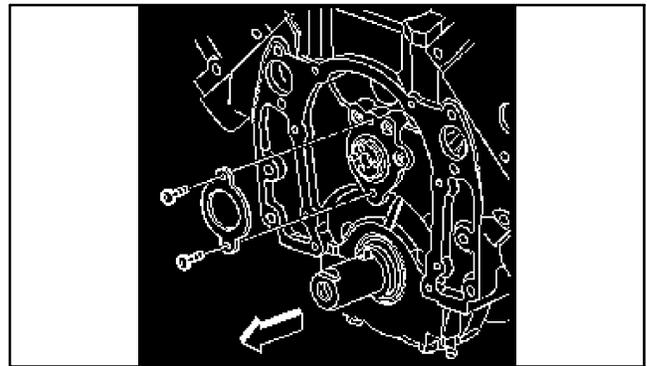
7.3.6 Installation



1. Lubricate the following components with clean engine oil.
 - The camshaft lobes.
 - The camshaft bearing journals.
 - The camshaft bearings.

Notice: All camshaft journals are the same diameter, so care must be used in removing or installing the camshaft to avoid damage to the camshaft bearings.

2. Install the three 8-1.25 x 100 mm bolts in the camshaft front bolt holes.
3. Using the bolts as a handle, install the camshaft.
4. Remove the three bolts from the front of the camshaft.



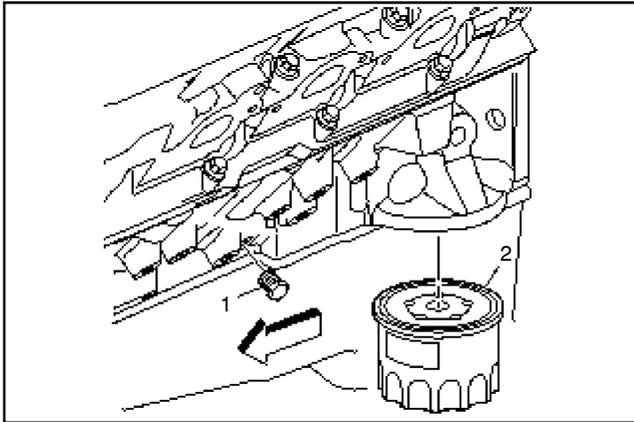
5. Install the camshaft retainer.

Notice: Refer to Fastener Notice in Cautions and Notices.
6. Install the camshaft retainer bolts. Tighten the camshaft retainer bolts to 12 Nm (106 in. lb.).

Notes

Section 8 Lubrication System

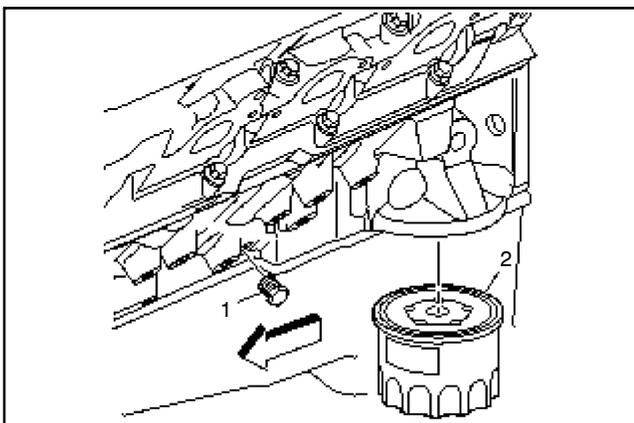
8.1 Draining Fluids and Oil Filter Removal



1. Remove the oil pan drain plug.
2. Drain the engine oil.
3. Remove the oil filter (2).
4. Remove the left engine coolant drain hole plug (1) and the right engine coolant drain hole plug.
5. Drain the engine coolant.

8.2 Engine Oil and Oil Filter Replacement

Removal Procedure

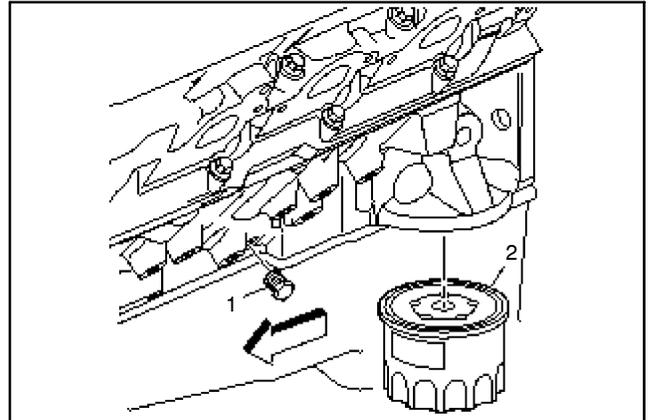


1. Remove the oil pan drain plug and allow the engine oil to drain completely.
2. Clean the oil pan drain plug surface.
3. Remove the oil filter (2) from the engine block and allow the engine oil to drain completely.

4. Clean the oil filter surface.

Installation Procedure

1. Install a new oil filter (2) to the engine block. Tighten the oil filter according to the oil filter manufacturer's instructions printed on the oil filter box.



Notice: Refer to Fastener Notice in Cautions and Notices.

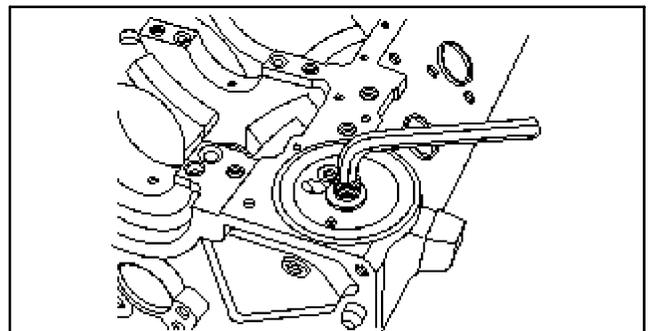
2. Install the oil pan drain plug. Tighten the oil pan drain plug to 28 Nm (21 ft. lb.).
3. Fill the engine with oil. Refer to Section 1, Specifications.

8.3 Oil Filter Adapter

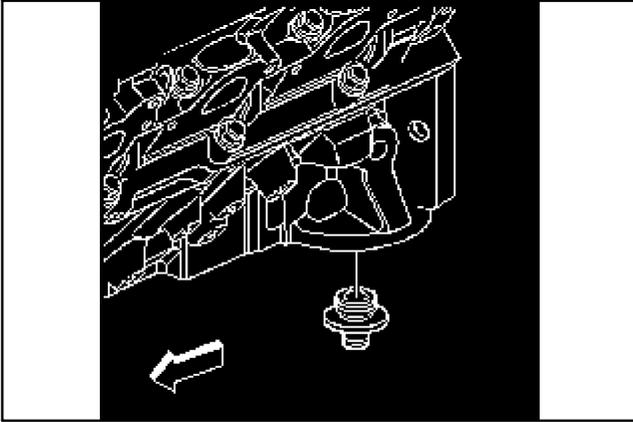
8.3.1 Bypass Valve Assembly Replacement

Removal Procedure

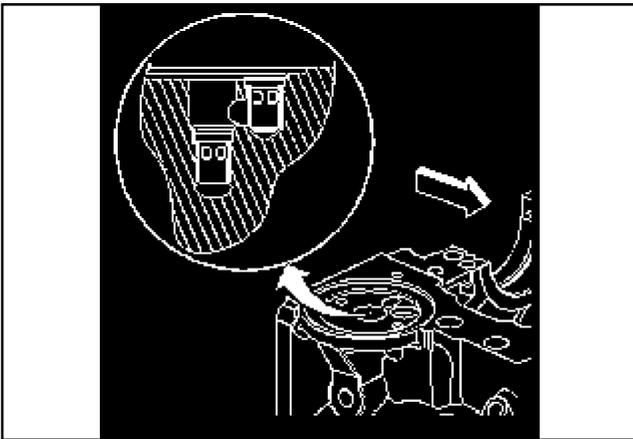
1. Remove the engine oil filter. Refer to Section 8.2, Engine Oil and Oil Filter Replacement.



2. Loosen the oil filter fitting using a hex wrench.



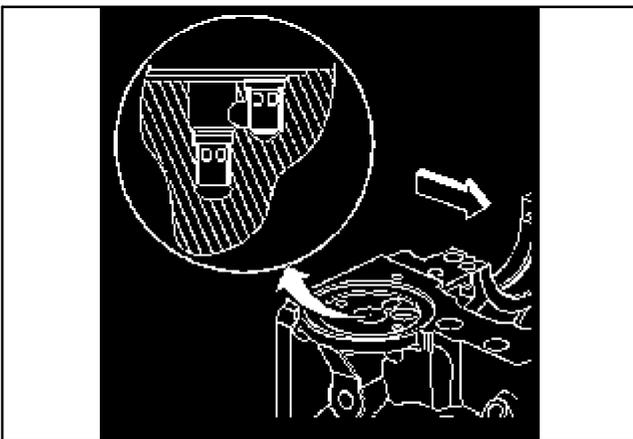
3. Remove the oil filter fitting.



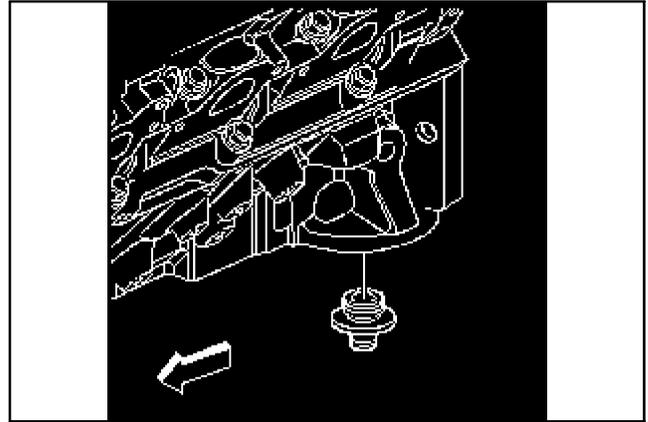
4. Remove the oil filter bypass valves. Unstake the tangs on the oil bypass valves and remove with long nose pliers.

5. Discard the oil bypass valves.

Installation Procedure



1. Install *new* oil bypass valves. Stake the tangs on the new oil bypass valves.



2. Inspect oil filter fitting and replace as necessary.

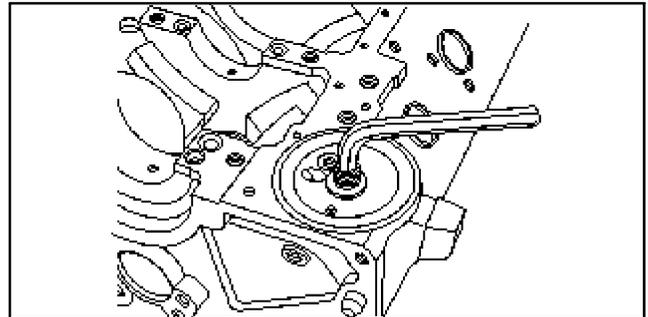
Notice: Refer to Fastener Notice in Cautions and Notices.

3. Install the oil filter fitting. Tighten the oil filter fitting to 66 Nm (49 ft. lb.).

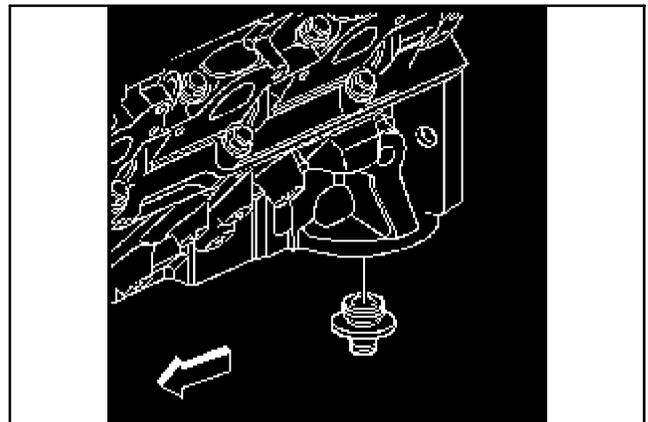
4. Install the oil filter. Refer to Section 8.2, Engine Oil and Oil Filter Replacement.

8.3.2 Removal

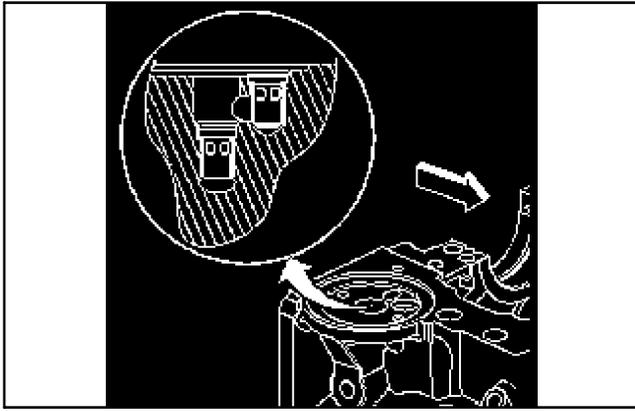
1. Loosen the oil filter fitting using a hex wrench.



2. Remove the oil filter fitting.



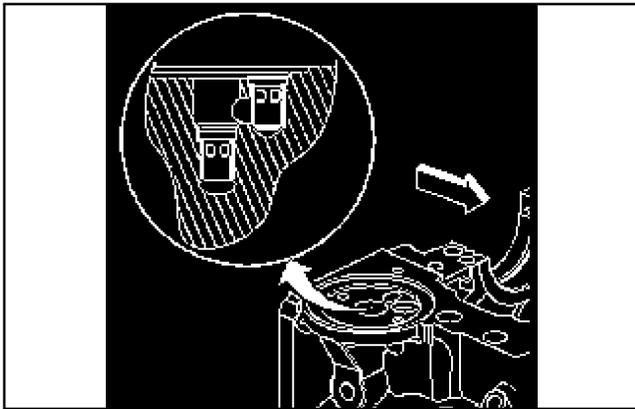
3. Inspect the oil filter fitting and replace if necessary.



4. Remove the oil bypass valves (if required). Unstake the tangs on the oil bypass valves and remove with long nose pliers.

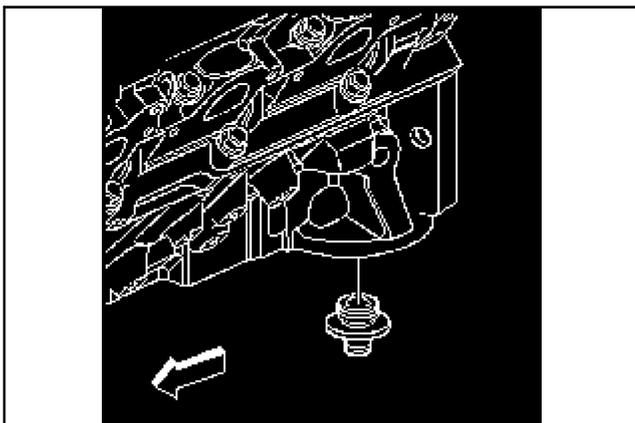
5. Discard the oil bypass valves, if removed.

8.3.3 Installation



1. If removed, install the new oil bypass valves. Stake the tangs on the oil bypass valves.

Notice: Refer to Fastener Notice in Cautions and Notices.

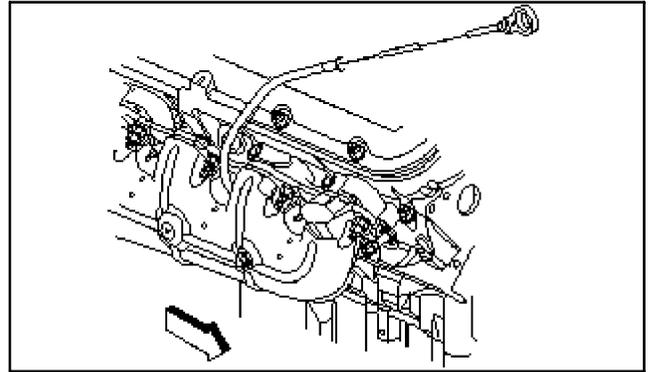


2. Install the oil filter fitting. Tighten the oil filter fitting to 66 Nm (49 ft. lb.).

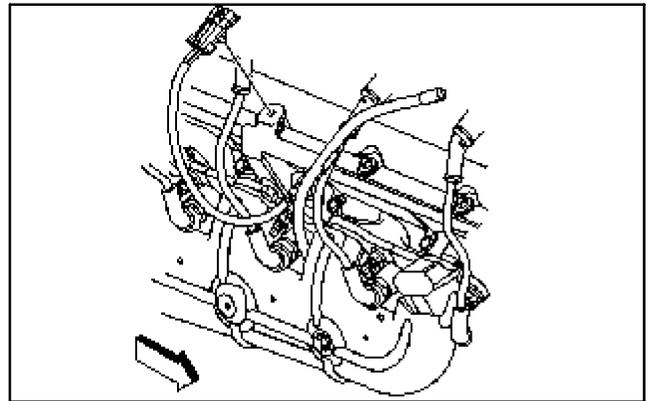
8.4 Oil Level Indicator and Tube

8.4.1 Replacement

Removal Procedure

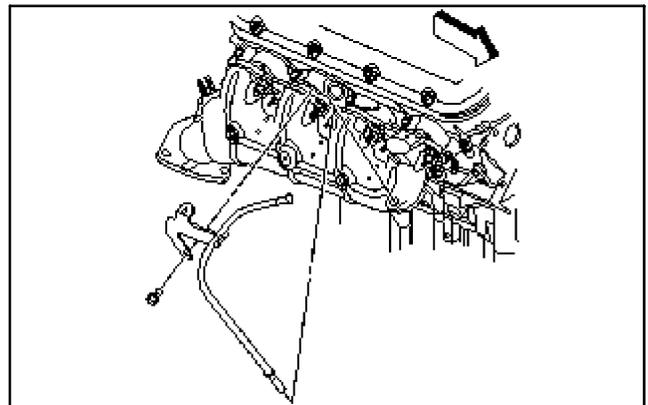


1. Remove the oil level indicator from the indicator tube.



2. Disconnect the engine coolant temperature (ECT) sensor electrical connector.

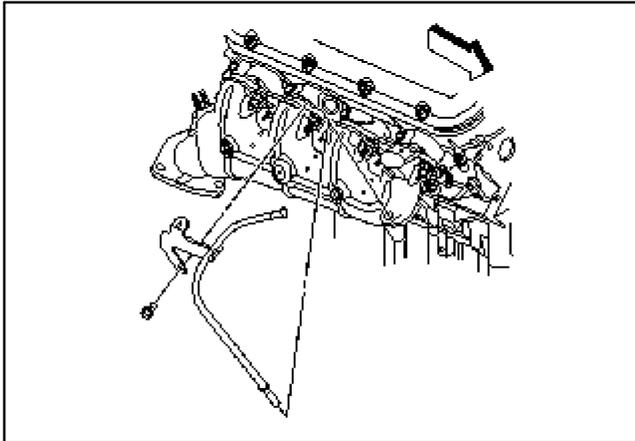
3. Remove the ECT sensor connector from the indicator tube.



4. Remove the indicator tube bolt.
5. Remove the indicator tube bracket.
6. Remove the O-ring seal from the indicator tube.

Installation Procedure

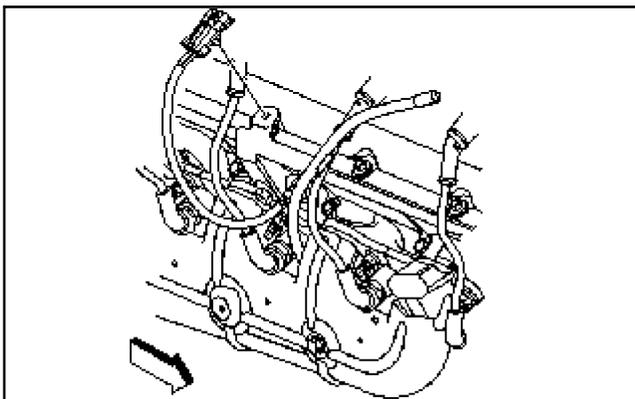
Important: Make sure the indicator tube does not come in contact with spark plug wires. Ensure that the spark plug wires are routed around the indicator tube.



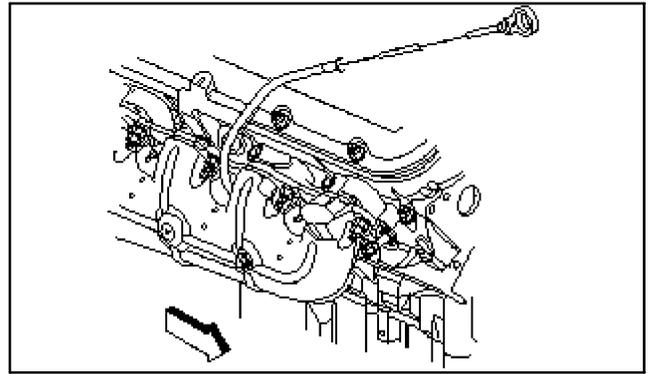
1. Install a *new* O-ring seal onto the indicator tube.
2. Install the indicator tube into the oil pan.
3. Align the indicator tube bracket with the bolt hole in the block.

Notice: Refer to Fastener Notice in Cautions and Notices.

4. Install the indicator tube bolt. Tighten the bolt to 50 Nm (37 ft. lb.).

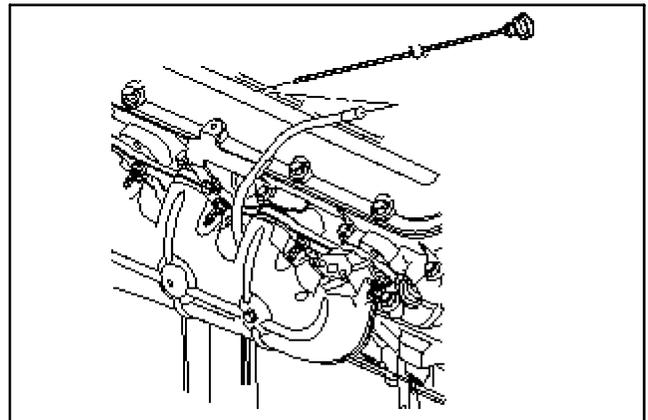


5. Install the ECT sensor connector to the indicator tube.
6. Connect the ECT sensor electrical connector.

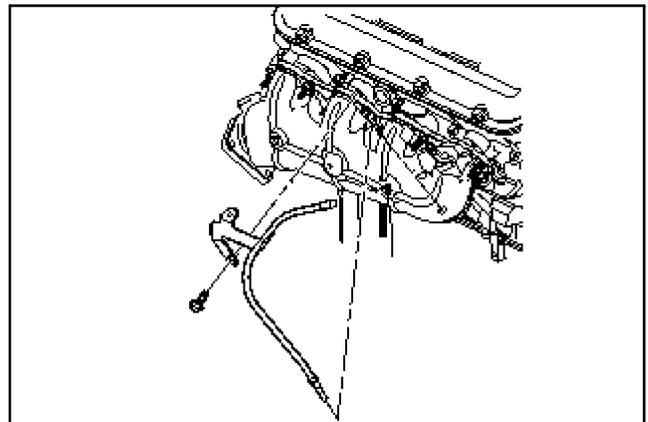


7. Install the oil level indicator to the indicator tube.

8.4.2 Removal



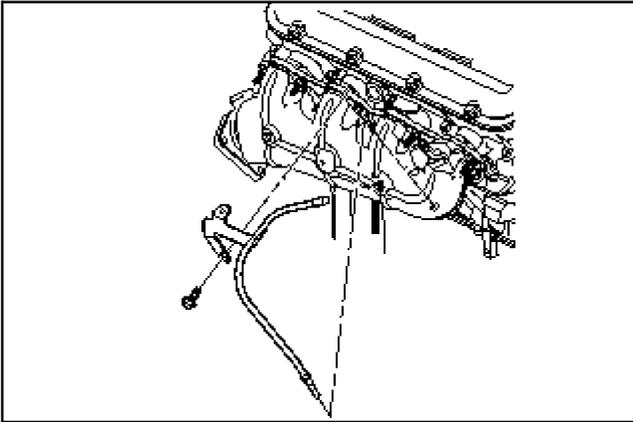
1. Remove the oil level indicator from the oil level indicator tube.



2. Remove the oil level indicator tube bolt.
3. Remove the oil level indicator tube from the oil pan.
4. Remove the O-ring seal from the oil level indicator tube.

8.4.3 Installation

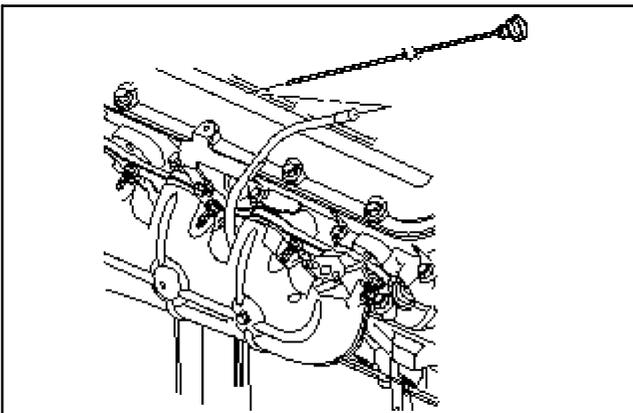
Important: Ensure that the oil level indicator tube does not come in contact with the spark plug wires. Route the spark plug wires around the oil level indicator tube.



1. Install a *new* O-ring seal onto the oil level indicator tube.
2. Install the oil level indicator tube into the oil pan.
3. Install the oil level indicator tube bracket to the exhaust manifold stud.

Notice: Refer to Fastener Notice in Cautions and Notices.

4. Install the oil level indicator tube bracket bolt. Tighten the oil level indicator tube bolt to 25 Nm (18 ft. lb.).



5. Install the oil level indicator into the oil level indicator tube.

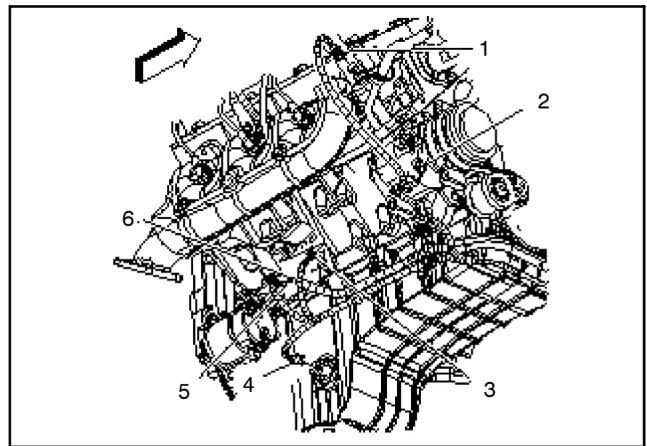
8.5 Oil Pan

8.5.1 Replacement

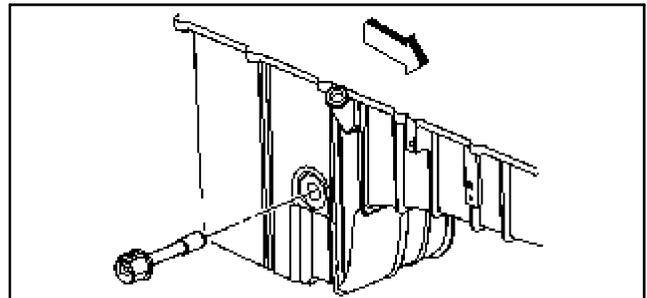
Removal Procedure

Important: Do not raise the engine by the crankshaft balancer to perform this service procedure. Damage to the crankshaft balancer or the crankshaft may occur.

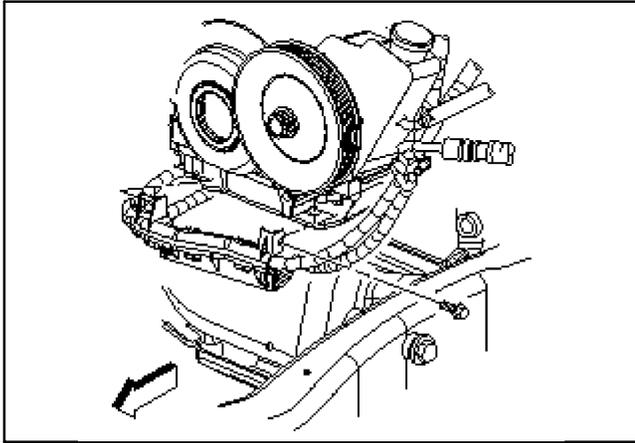
1. Remove the starter motor.
2. Drain the engine oil. Refer to Section 8.2, Engine Oil and Oil Filter Replacement.
3. Remove the oil level indicator. Refer to Section 8.4, Oil Level Indicator and Tube Replacement.



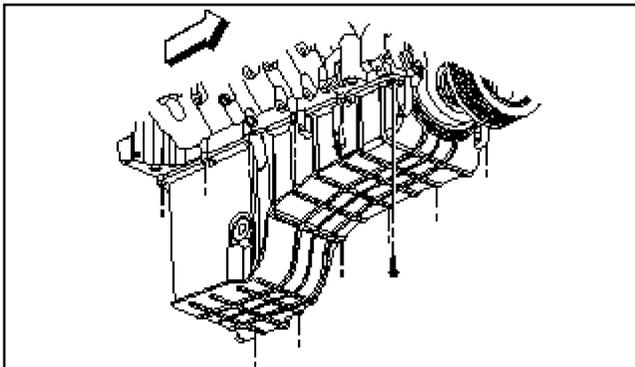
4. Disconnect oil level sensor electrical connector (4).
5. Remove the engine harness clip from the oil pan.
6. Remove the oil level sensor from the oil pan.



7. Remove the battery cable channel bolt.
8. Remove and reposition the battery cable channel.

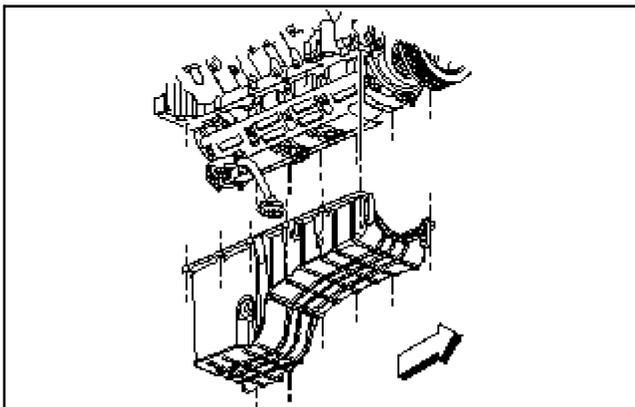


9. Remove the oil pan bolts.



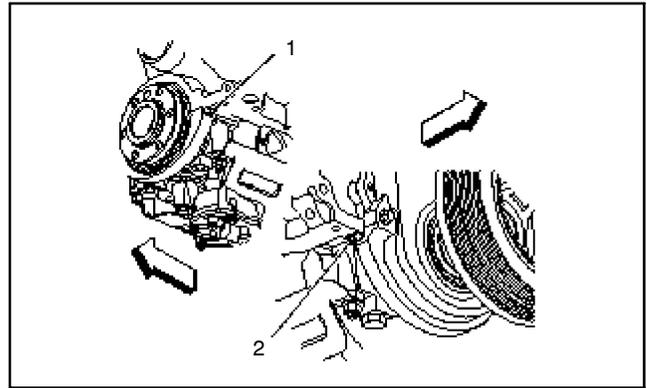
Important: The oil pan gasket is reusable if not cut or damaged.

10. Remove the oil pan (1) and gasket (2).

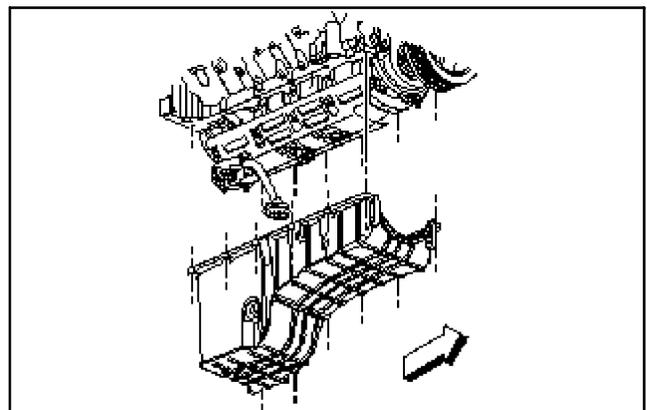


Installation Procedure

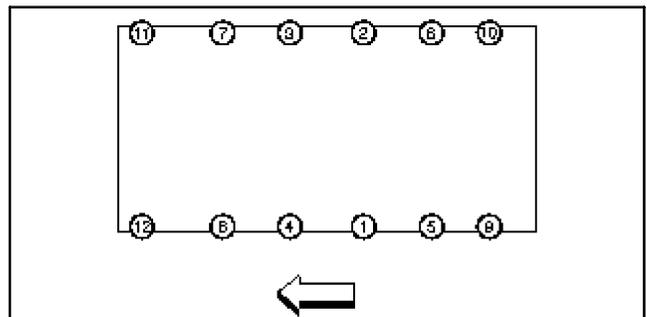
Important: Install the oil pan within 5 minutes of the sealer being applied or the sealer will begin to cure, causing an inadequate seal.



1. Apply sealant, GM Part No. U.S. 2346286/ Canadian 10953472 or equivalent, to the sides of the front (2) and rear (1) crankshaft bearing caps, on both the left and right sides (four locations total).



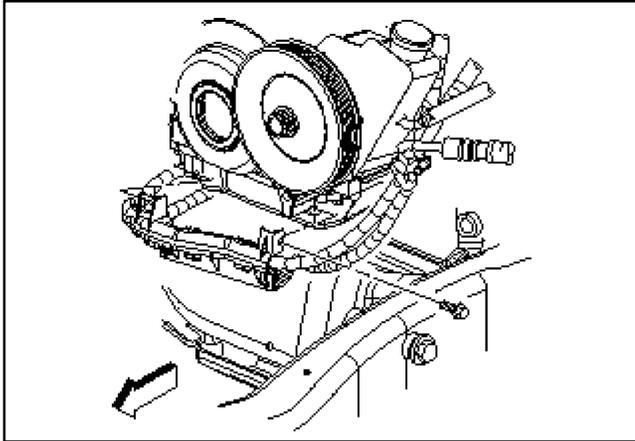
2. Install a *new* oil pan gasket into the oil pan groove, if required.
3. Install the oil pan.
4. Install the oil pan bolts.



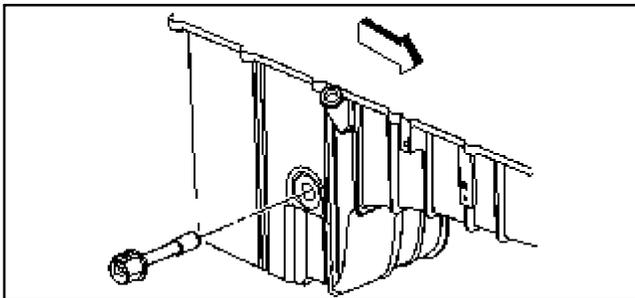
Notice: Refer to Fastener Notice in Cautions and Notices.

5. Tighten the oil pan bolts.
 - a. Tighten the bolts a first pass in sequence to 10 Nm (89 in. lb.).

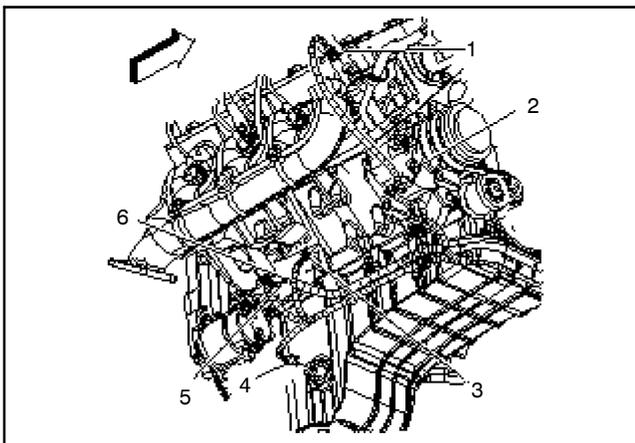
- b. Tighten the bolts a final pass in sequence to 25 Nm (18 ft. lb.).



6. Position the battery cable channel into place.
7. Install the battery cable channel bolt. Tighten the bolt to 9 Nm (80 in. lb.).
8. Install the oil level sensor to the oil pan. Tighten the sensor to 20 Nm (15 ft. lb.).

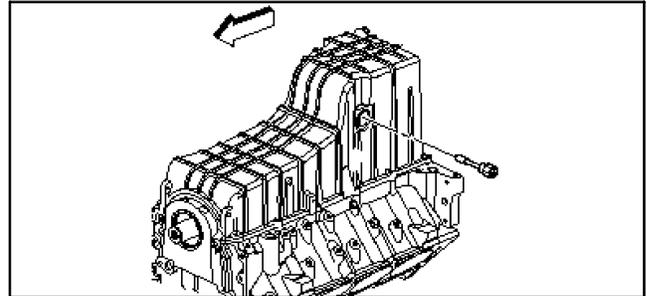


9. Install the engine harness clip to the oil pan.

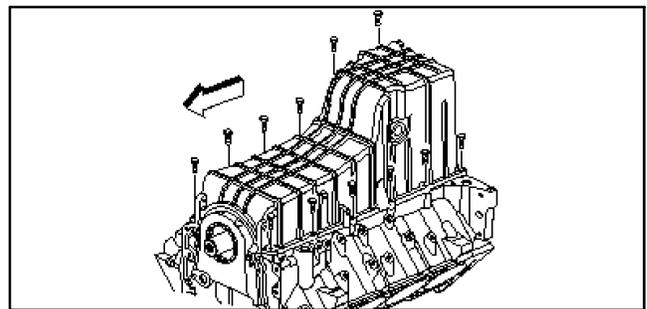


10. Connect oil level sensor electrical connector (4).
11. Install the oil level indicator. Refer to Section 8.4, Oil Level Indicator and Tube Replacement.
12. Fill the engine with oil. Refer to Section 8.2, Engine Oil and Oil Filter Replacement.
13. Install the starter motor.

8.5.2 Removal



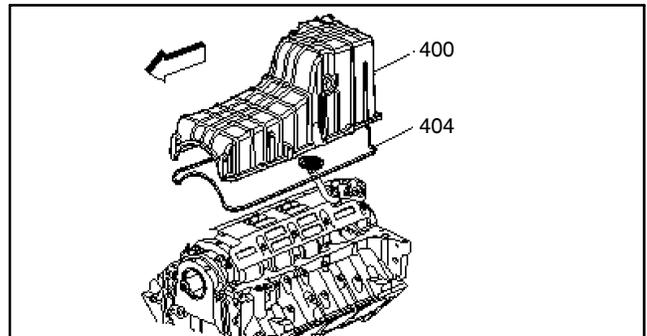
1. Remove the oil level sensor from the oil pan.



2. Remove the oil pan bolts.

Important: The oil pan gasket is reusable if not cut or damaged.

3. Remove the oil pan (400) and the oil pan gasket (404).



8.5.3 Cleaning and Inspection

1. Remove the oil pan gasket (404) from the groove in the oil pan (400).
2. Clean the oil pan in solvent.

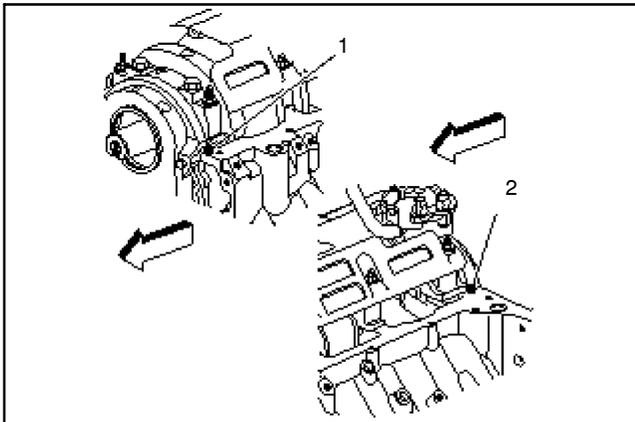
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

3. Dry with compressed air.
4. Inspect the oil pan for the following conditions:
 - Damaged threads in the drain plug hole.
 - Gouges or damage to oil pan sealing surfaces.
 - Cracks or damage to the exterior of the oil pan.
 - Damage to the oil level indicator tube area.
 - Damage to the oil pan gasket.

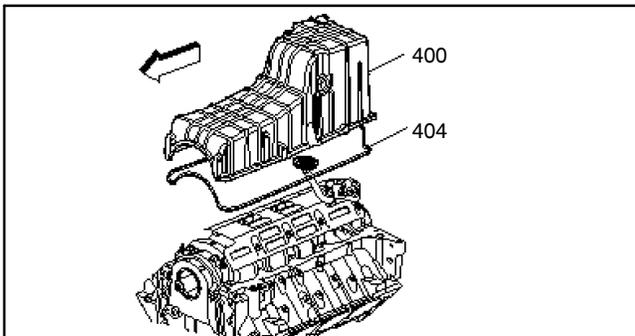
8.5.4 Installation

Important: Install the oil pan within 5 minutes of the sealer being applied or the sealer will begin to cure, causing an inadequate seal.

1. Apply sealant, GM Part No. U.S. 12346286/ Canadian 10953472, to the side of the front cover (1) and rear (2) crankshaft bearing cap, on both the left and right sides (four locations total).



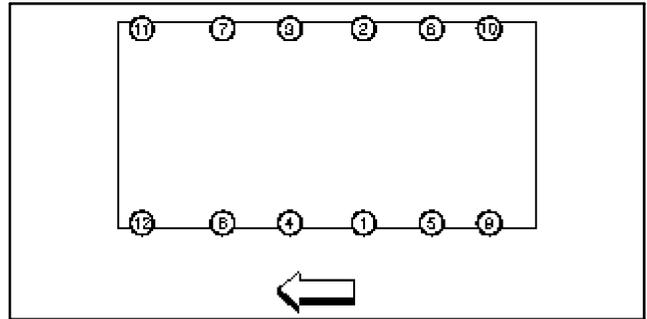
2. Install the new oil pan gasket (404) into the oil pan groove.



3. Install the oil pan (400).

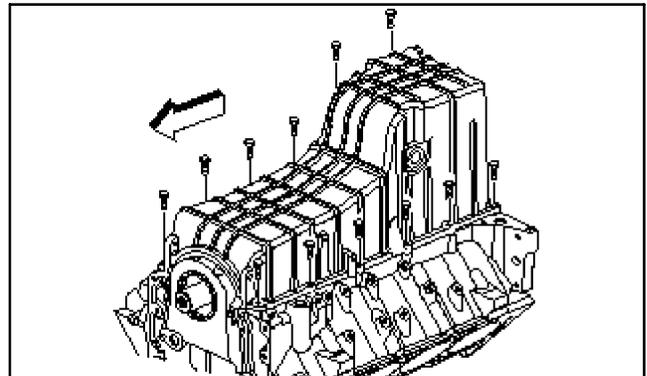
Notice: Refer to Fastener Notice in Cautions and Notices.

4. Install the oil pan bolts (1–12).



5. Tighten the oil pan bolts in sequence.

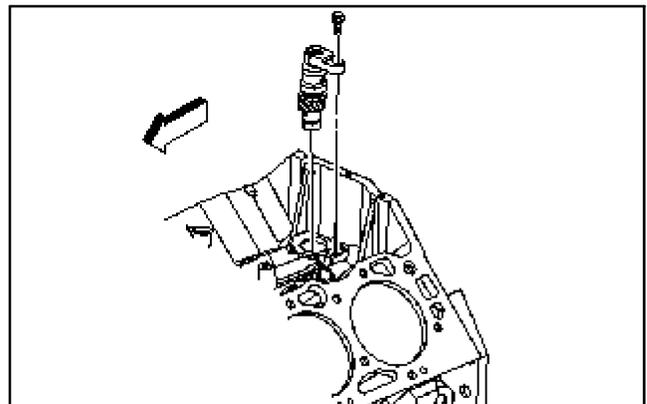
- a. Tighten the oil pan bolts a first pass in sequence to 10 Nm (89 in. lb.).
- b. Tighten the oil pan bolts a final pass in sequence to 25 Nm (18 ft. lb.).



8.6 Oil Pump

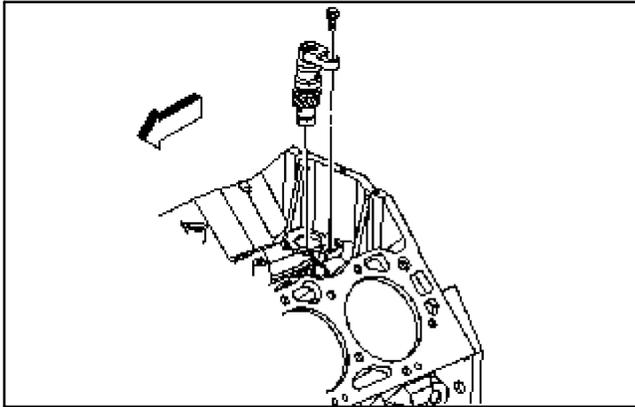
8.6.1 Drive Replacement

Removal Procedure



1. Remove the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.
2. Remove the oil pump drive bolt.
3. Remove the oil pump drive.
4. Clean and inspect the oil pump drive. Refer to Section 8.6.8, Oil Pump Drive Cleaning and Inspection.

Installation Procedure



1. Apply grease to the oil pump drive gear for ease of assembly.

Important: Correct alignment of the oil pump drive and oil pump driveshaft is critical. Make sure both components mate correctly or engine damage may occur.

2. Line up the oil pump drive, making sure that the oil pump is fully seated in the engine block.

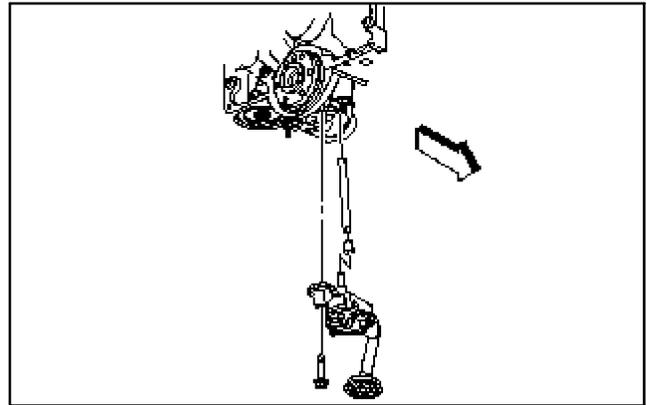
Notice: Refer to Fastener Notice in Cautions and Notices.

3. Install the oil pump, making sure that the oil pump drive is fully seated in the engine block. Tighten the bolt to 25 Nm (18 ft. lb.).
4. Install the intake manifold. Refer to Section 10.1.1, Intake Manifold Replacement.

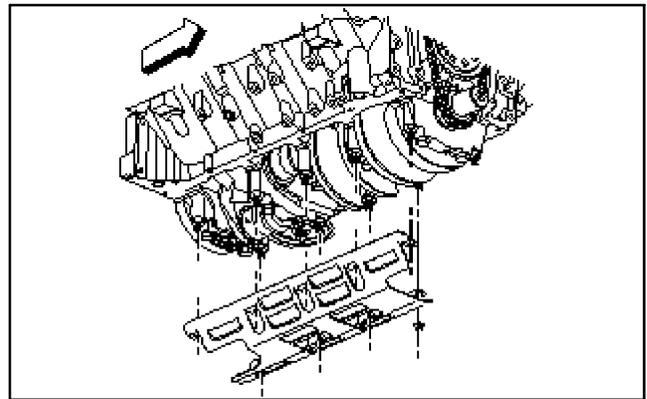
8.6.2 Replacement

Removal Procedure

1. Remove the oil pan. Refer to Section 8.5.1, Oil Pan Replacement.
2. Remove the oil pump bolt.



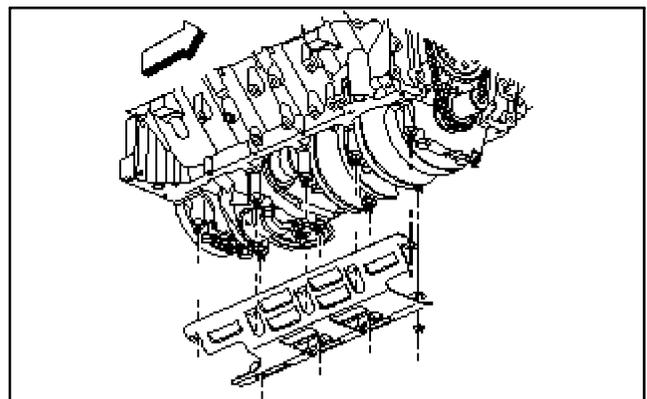
3. Remove and separate the oil pump, retainer, and drive shaft.
4. Discard the drive shaft retainer.



5. Remove the crankshaft oil deflector nuts.
6. Remove the crankshaft oil deflector.
7. Clean and inspect the oil pump. Refer to Section 8.6.6, Oil Pump Cleaning and Inspection.

Installation Procedure

Important: When installing the oil pump, always replace the retainer between the oil pump and the shaft.

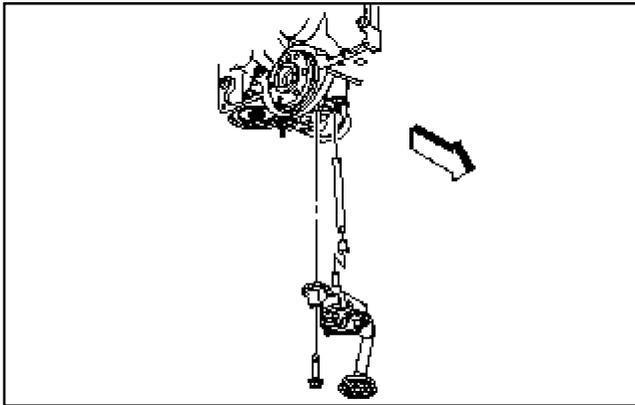


1. Install the crankshaft oil deflector.

Notice: Refer to Fastener Notice in Cautions and Notices.

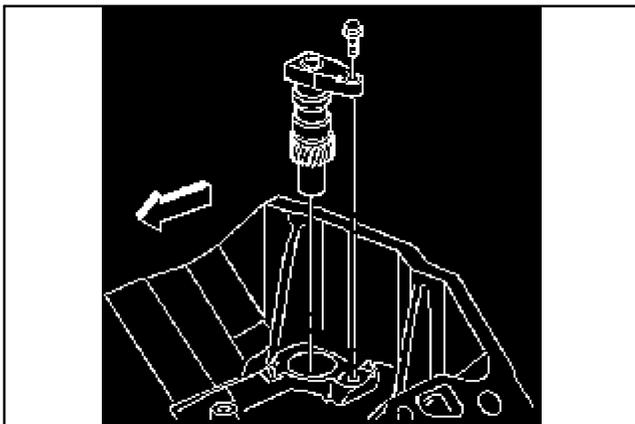
2. Install the crankshaft oil deflector nuts. Tighten the nuts to 50 Nm (37 ft. lb.).

Important: During assembly, install a *new* oil pump driveshaft retainer. Slightly heat the retainer above room temperature for ease of installation onto the oil pump driveshaft.



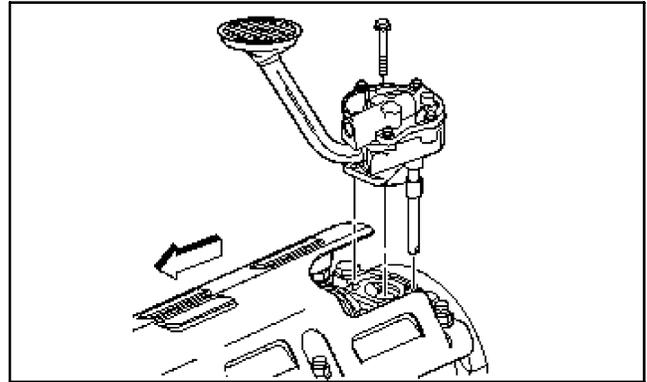
3. Assemble the oil pump, driveshaft, and a *new* retainer.
4. Install the oil pump assembly. Position the oil pump onto the locating pins.
5. Install the oil pump bolt. Tighten the bolts to 75 Nm (56 ft. lb.).
6. Install the oil pan. Refer to Section 8.5.1, Oil Pan Replacement.

8.6.3 Drive Removal

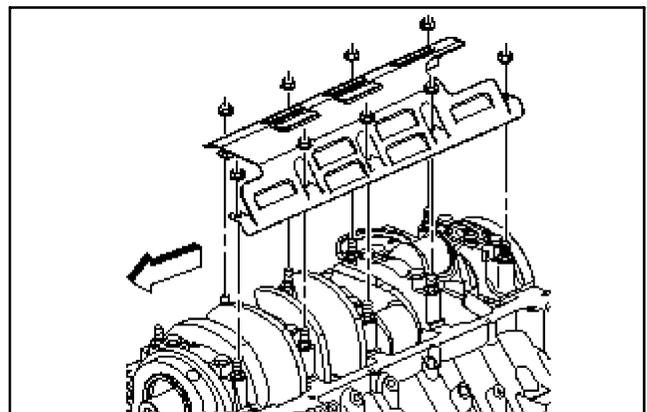
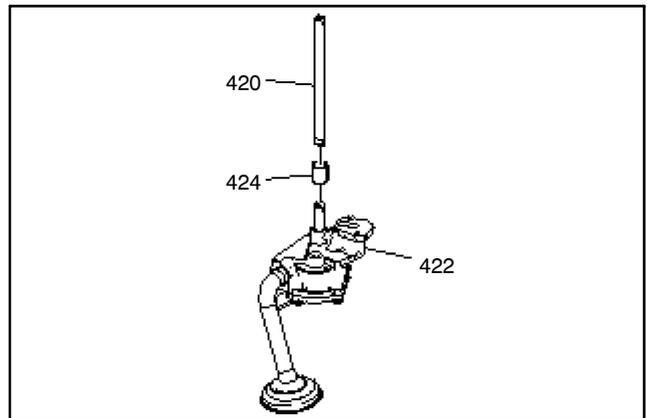


1. Remove the oil pump drive bolt.
2. Remove the oil pump drive.

8.6.4 Oil Pump, Pump Screen, and Deflector Removal



1. Remove the bolt that attaches the oil pump to the crankshaft rear bearing cap.
2. Remove the oil pump, driveshaft, and retainer from the crankshaft rear bearing cap.
3. Separate the oil pump (422), driveshaft (420), and retainer (424).
4. Discard the driveshaft retainer (424).

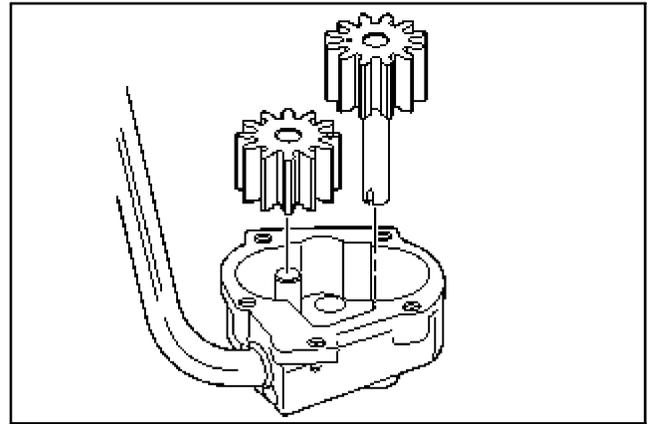
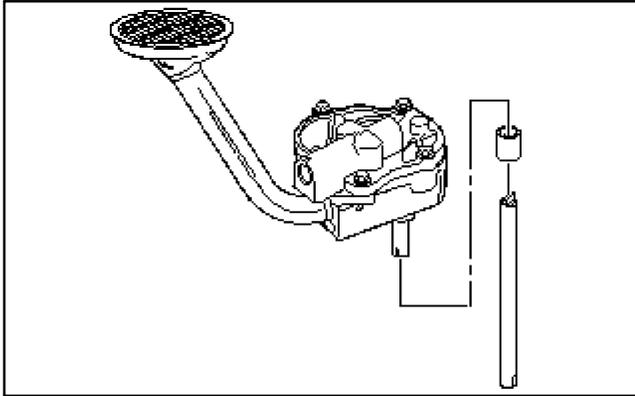


5. Remove the crankshaft oil deflector nuts.
6. Remove the crankshaft oil deflector.

8.6.5 Disassemble

Important: The oil pump pipe has a press fit into the oil pump. *Do not* remove the pipe from the oil pump. The pipe and oil pump are serviced as a complete assembly.

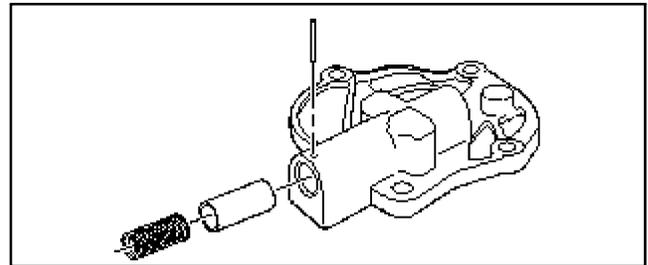
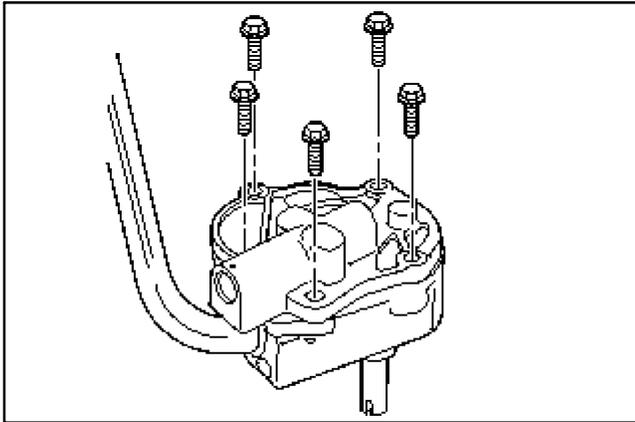
1. Remove the oil pump driveshaft and retainer.



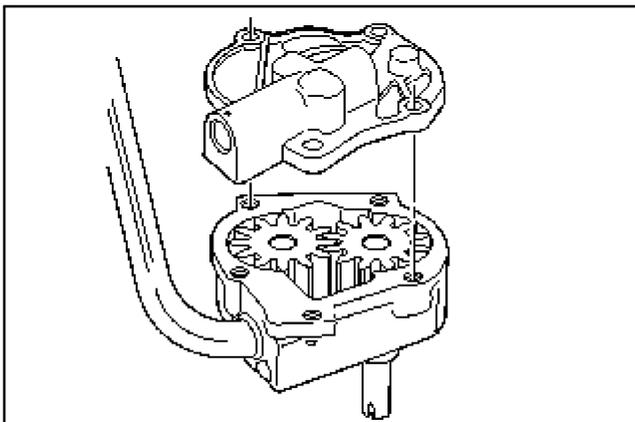
5. Remove the following items:

- Retaining pin.
- Pressure relief spring.
- Pressure relief valve.

2. Remove the oil pump cover bolts.



3. Remove the pump cover.

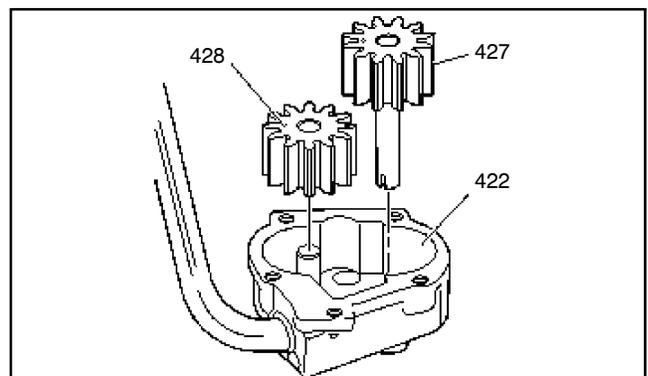


4. Remove the drive gear and the driven gear. Match mark the gear teeth for reassembly.

8.6.6 Cleaning and Inspection

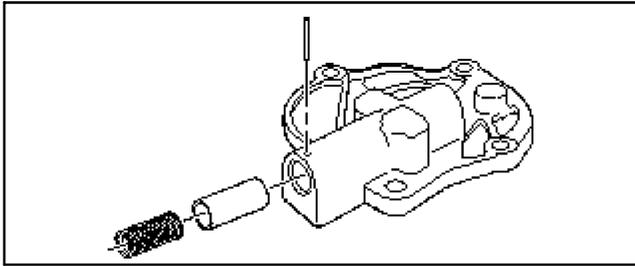
Caution: Refer to Safety Glasses Caution in Cautions and Notices.

1. Clean the oil pump components in cleaning solvent.
2. Dry the components with compressed air.
3. Inspect the gears (427, 428) for the following:
 - Scoring.
 - Chipping.
 - Galling.
 - Excessive wear.



4. Inspect the oil pump housing (422) for the following:

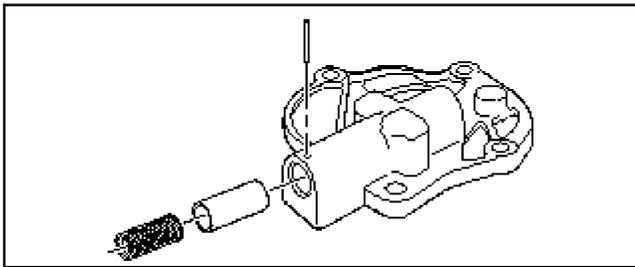
- Damaged bolt hole threads.
- Worn oil pump driveshaft bore.
- Scoring or excessive wear within the housing.
- Worn driven gear shaft.



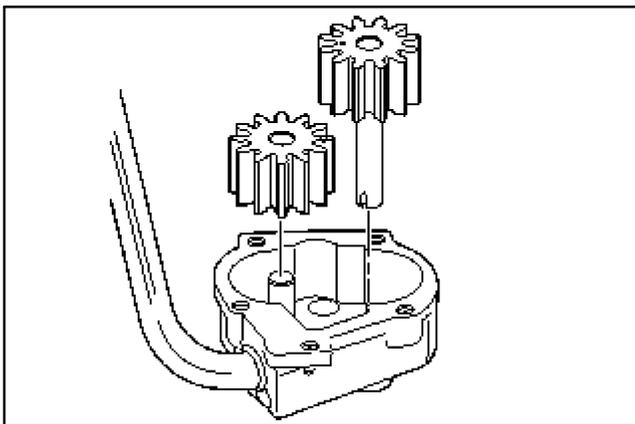
5. Inspect for a collapsed pressure relief spring.
6. Inspect the pressure relief valve for scoring or wear. The valve should move freely within the bore of the housing.

8.6.7 Assemble

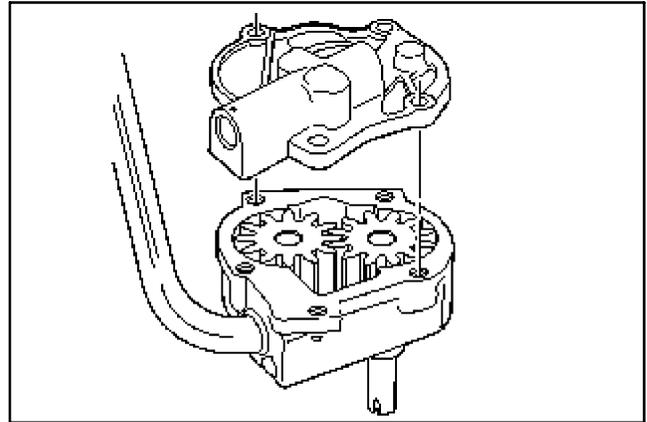
Important: Replace the pressure relief valve spring when reusing the oil pump.



1. Install the following items:
- Pressure relief valve.
 - Pressure relief spring.
 - Retaining pin.

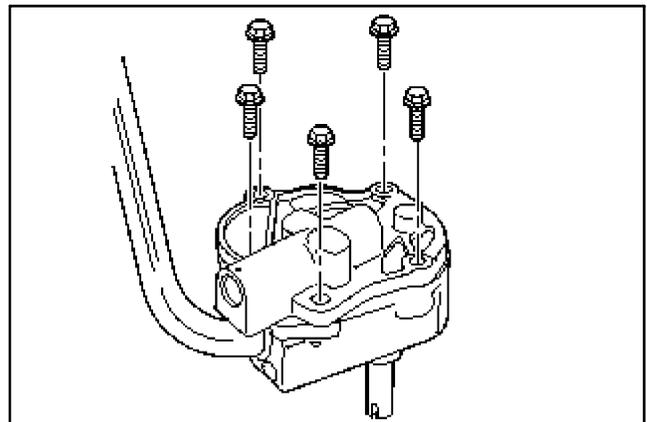


2. Coat the drive gear, the driven gear, and the housing gear surfaces with clean engine oil.
3. Install the drive gear and the driven gear into the pump body. Align the matching marks on the gears. Install the smooth side of the gear toward the pump cover.



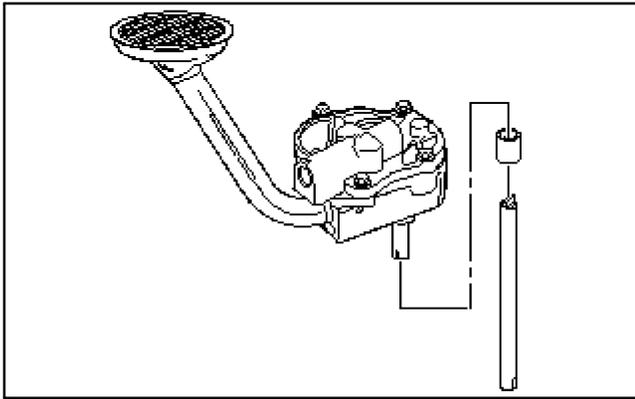
4. Install the oil pump cover.

Notice: Refer to Fastener Notice in Cautions and Notices.



5. Install the oil pump cover bolts. Tighten the oil pump cover bolts to 12 Nm (106 in. lb.).
6. Inspect the oil pump for smoothness of operation by turning the oil pump driveshaft by hand.

Notice: Ensure the oil pump driveshaft is inspected for wear and/or damage and replaced, if necessary. An excessively worn or damaged oil pump driveshaft may fail, causing severe engine damage.

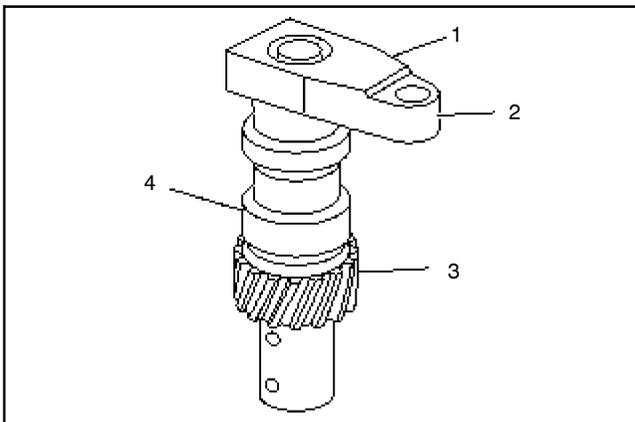


7. Install the oil pump driveshaft and the new retainer.

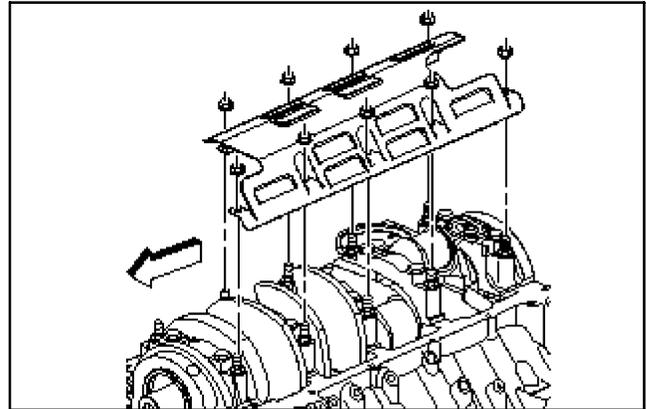
8.6.8 Drive Cleaning and Inspection

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

1. Clean the oil pump drive in cleaning solvent.
2. Dry the oil pump drive with compressed air.
3. Inspect the oil pump drive (1) for the following conditions:
 - Excessive play in the oil pump drive bearing.
 - Damage to the oil pump drive clamp bolt hole (2).
 - Damaged gear (3) for the following:
 - Chipping.
 - Galling.
 - Wear.
 - Damage to the oil pump drive shaft tang.
4. Damage to the oil pump drive body (4).
5. If the oil pump drive is to be reused, lubricate the bearing with clean engine oil and apply grease to all gear teeth (3).



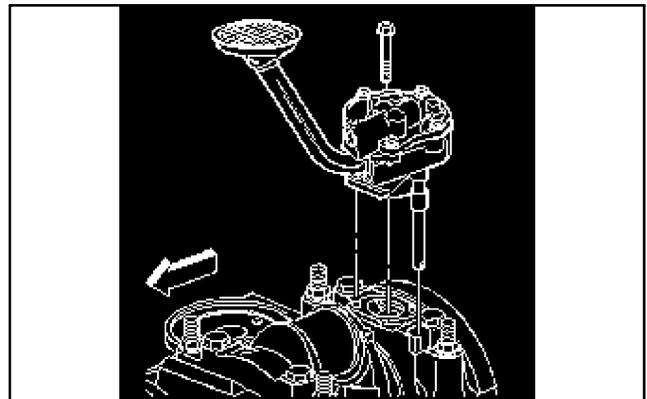
8.6.9 Oil Pump, Pump Screen, and Deflector Installation



1. Install the crankshaft oil deflector.

Notice: Refer to Fastener Notice in Cautions and Notices.

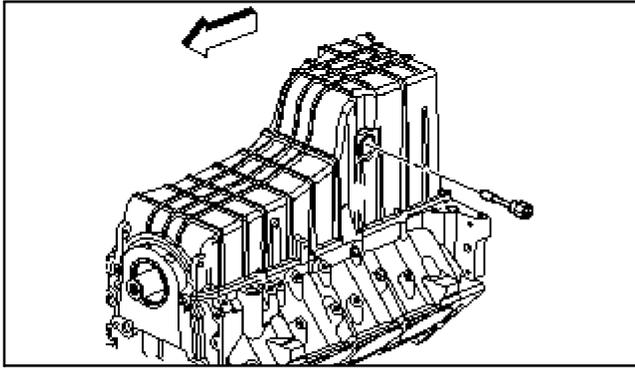
2. Install the crankshaft oil deflector nuts. Tighten the crankshaft oil deflector nuts to 50 Nm (37 ft. lb.).



Important: During assembly, install a *new* oil pump driveshaft retainer. Slightly heat retainer above room temperature for ease of installation onto the oil pump driveshaft.

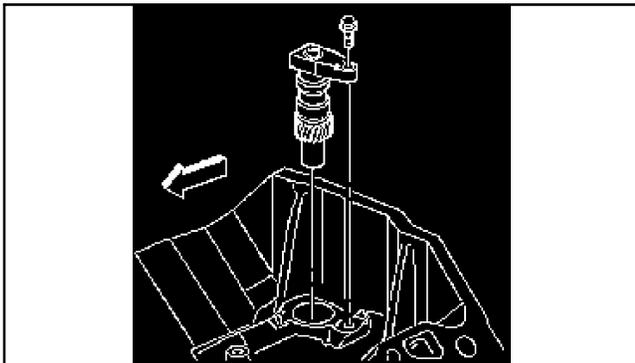
3. Install clean engine oil into the oil pump through the outlet oil hole. Rotate the pump in both directions to prime and lubricate.
4. Assemble the oil pump, driveshaft, and a *new* retainer.
5. Install the oil pump assembly. Position the oil pump onto the locating pins.

6. Install the bolt attaching the oil pump to the rear crankshaft bearing cap. Tighten the oil pump bolt to 75 Nm (55 ft. lb.).
7. Pour clean engine oil into the oil pump pickup screen.
8. Install the oil pan drain plug. Tighten the oil pan drain plug to 28 Nm (21 ft. lb.).
9. Lubricate the oil level sensor O-ring with engine oil.



10. Install the oil level sensor. Tighten the oil level sensor to 20 Nm (15 ft. lb.).

8.6.10 Drive Installation



1. Apply grease to the oil pump drive gear for ease of assembly.

Notice: Ensure both components are aligned correctly or serious engine damage will occur.

2. Line up the oil pump drive gear with the oil pump drive shaft.

3. Install the oil pump drive, making sure that the oil pump drive is fully seated in the engine block.

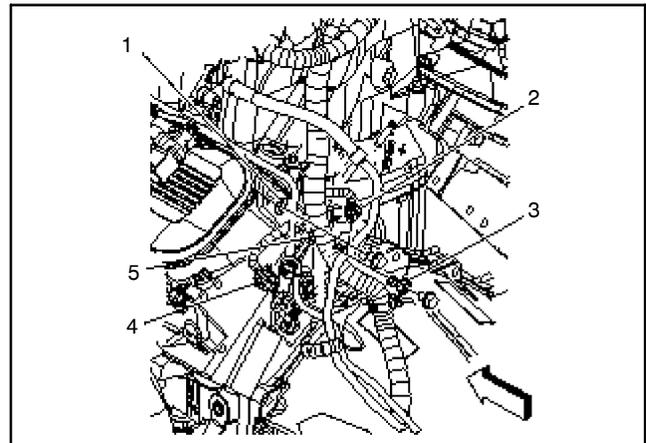
Notice: Refer to Fastener Notice in Cautions and Notices.

4. Install the oil pump drive bolt. Tighten the oil pump drive bolt to 25 Nm (18 ft. lb.).

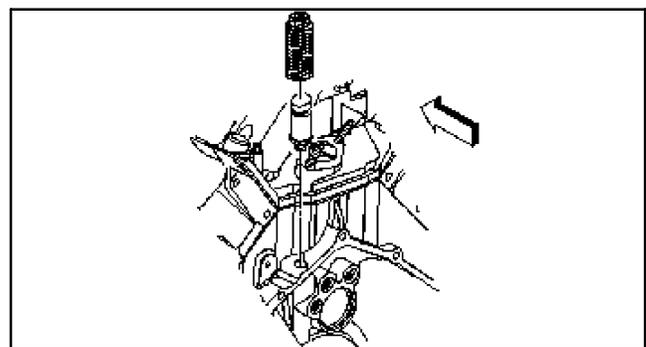
8.7 Engine Oil Pressure Sensor and/or Switch Replacement

Tools Required: J 41712 Oil Pressure Sensor Socket

Removal Procedure



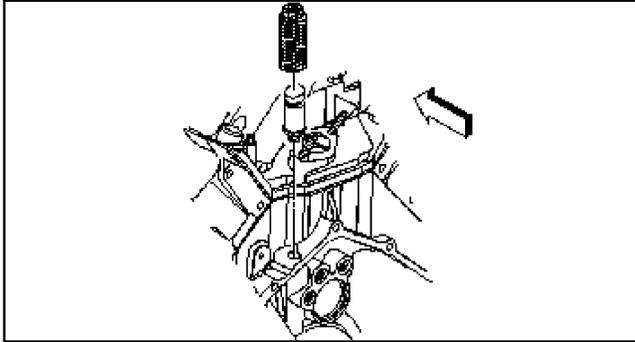
1. Disconnect the oil pressure sensor electrical connector (2).
2. Using *J 41712* or equivalent, remove the oil pressure sensor.



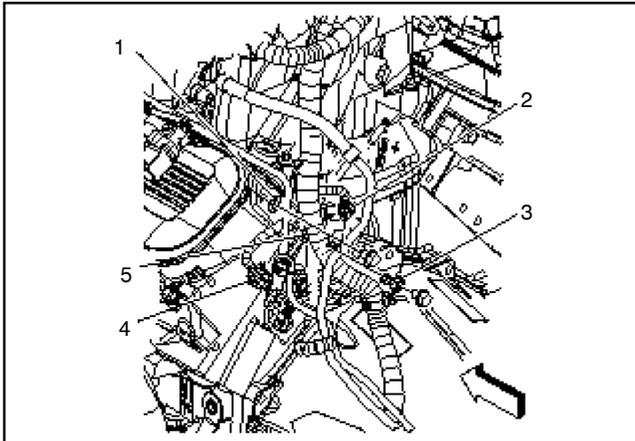
Installation Procedure

1. Apply sealant, GM Part No. U.S. 12346004/ Canadian 10953480 or equivalent, to the threads of the oil pressure sensor.

Notice: Refer to Fastener Notice in Cautions and Notices.



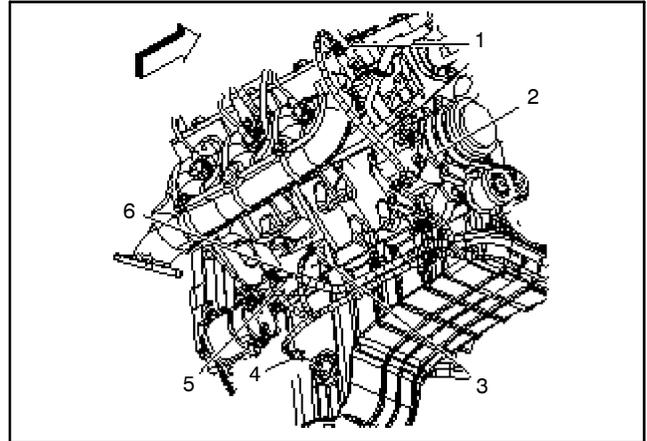
2. Using *J 41712* or equivalent, install the oil pressure sensor. Tighten the sensor to 30 Nm (22 ft. lb.).
3. Connect the oil pressure sensor electrical connector (2).



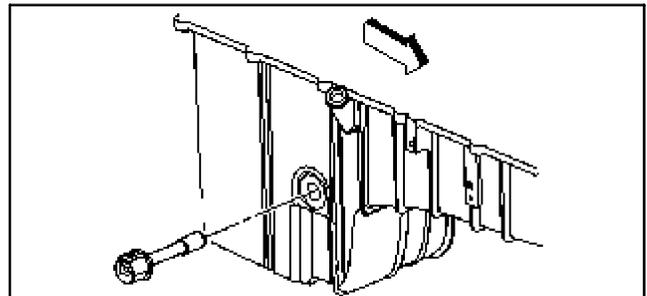
8.8 Engine Oil Level Sensor and/or Switch Replacement

Removal Procedure

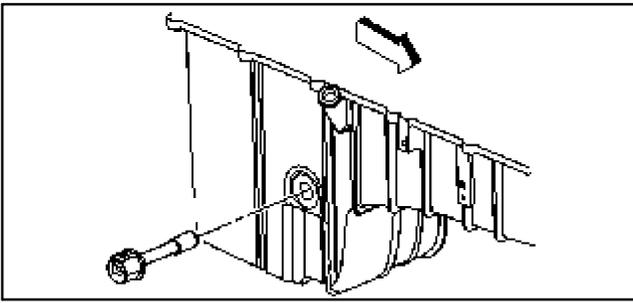
1. Drain the engine oil. Refer to Section 8.2, Engine Oil and Oil Filter Replacement.
2. Disconnect the oil level sensor electrical connector (4).



3. Remove the oil level sensor from the oil pan.



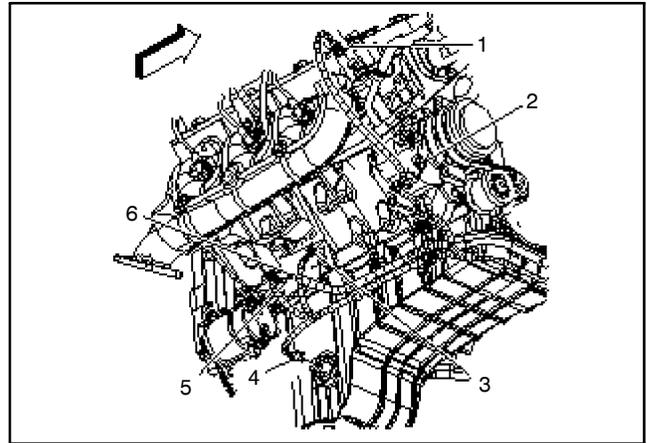
Installation Procedure



Notice: Refer to Fastener Notice in Cautions and Notices.

1. Install the oil level sensor to the oil pan. Tighten the sensor to 20 Nm (15 ft. lb.).
2. Connect the oil level sensor electrical connector (4).

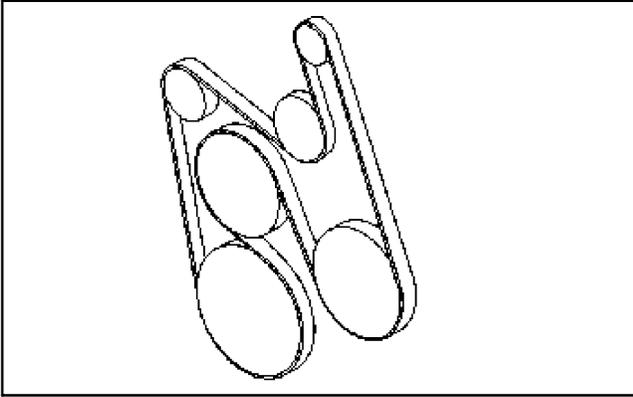
3. Fill the engine oil. Refer to Section 8.2, Engine Oil and Oil Filter Replacement.



Section 9 Cooling System and Drive Belts

9.1 Drive Belt

9.1.1 Replacement, Accessory



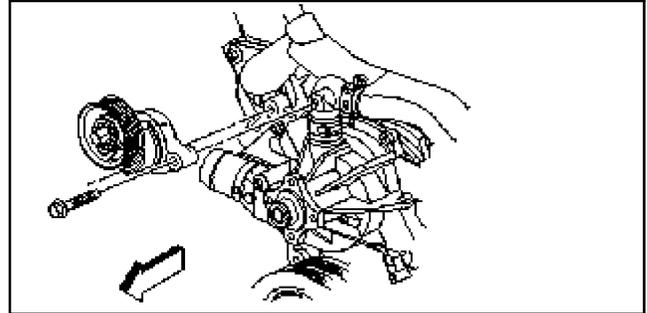
Removal Procedure

1. Install a breaker bar with hex head socket to the drive belt tensioner bolt.
2. Rotate the drive belt tensioner clockwise to relieve tension on the belt.
3. Remove the belt from the pulleys and the drive belt tensioner.
4. Slowly release the tension on the drive belt tensioner.
5. Remove the breaker bar and socket from the drive belt tensioner bolt.
6. Clean and inspect the belt surfaces of all pulleys.

Installation Procedure

1. Route the drive belt around all the pulleys except the idler pulley.
2. Install the breaker bar with hex head socket to the belt tensioner bolt.
3. Rotate the belt tensioner clockwise to relieve the tension on the tensioner.
4. Install the drive belt under the idler pulley.
5. Slowly release the tension on the belt tensioner.
6. Remove the breaker bar and socket from the belt tensioner bolt.
7. Inspect the drive belt for proper installation and alignment.

9.1.2 Tensioner Replacement, Accessory



Removal Procedure

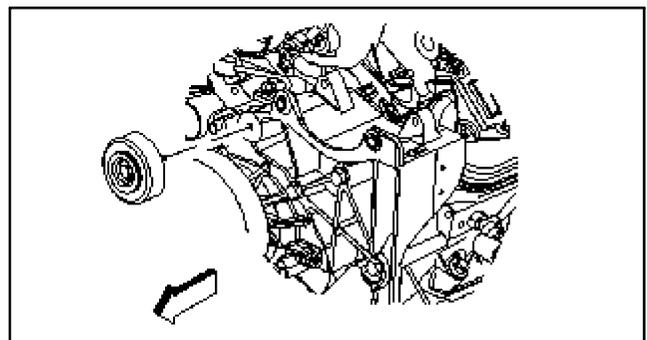
1. Remove the accessory drive belt. Refer to Section 9.1.1, Drive Belt Replacement, Accessory.
2. Remove the drive belt tensioner bolts.
3. Remove the drive belt tensioner.

Installation Procedure

1. Install the drive belt tensioner.
2. Install the drive belt tensioner bolts.

Notice: Refer to Fastener Notice in Cautions and Notices.
3. Tighten the drive belt tensioner bolts. Tighten the accessory drive belt tensioner bolts to 50 Nm (37 ft. lb.).
4. Install the accessory drive belt. Refer to Section 9.1.1, Drive Belt Replacement, Accessory.

9.1.3 Idler Pulley Replacement



Removal Procedure

1. Loosen the drive belt idler pulley bolt.
2. Remove the accessory drive belt. Refer to Section 9.1.1, Drive Belt Replacement, Accessory.
3. Remove the drive belt idler pulley.

Installation Procedure

1. Install the drive belt idler pulley and bolt to the engine alternator bracket. Snug bolt finger tight.

Notice: Refer to Fastener Notice in Cautions and Notices.

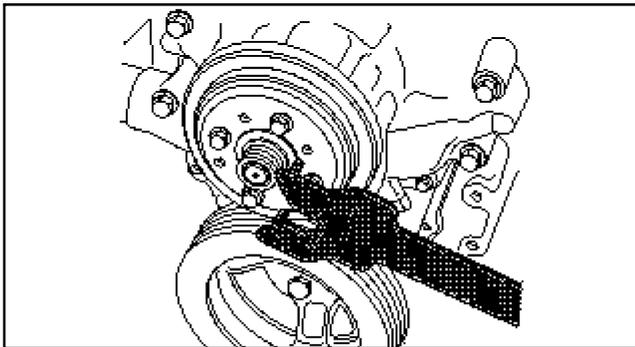
2. Install the accessory drive belt. Refer to Section 9.1.1, Drive Belt Replacement, Accessory. Tighten the drive belt idler pulley bolt to 50 Nm (37 ft. lb.).

9.2 Water Pump

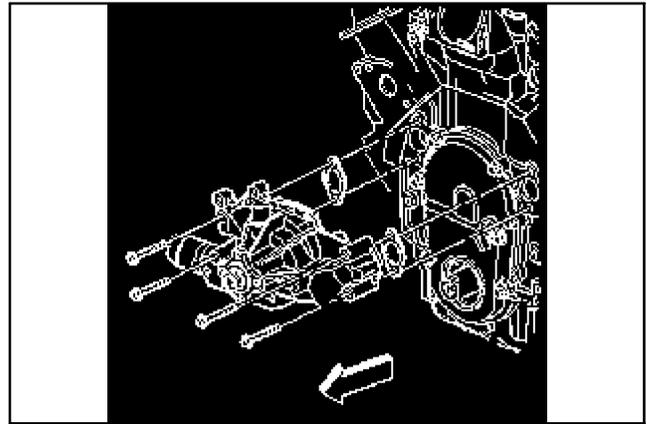
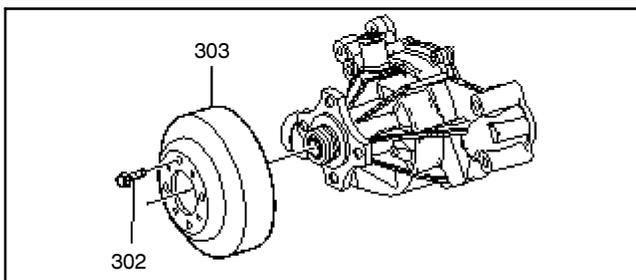
9.2.1 Removal

Tool Required:

J 41240 Fan Clutch Remover and Installer

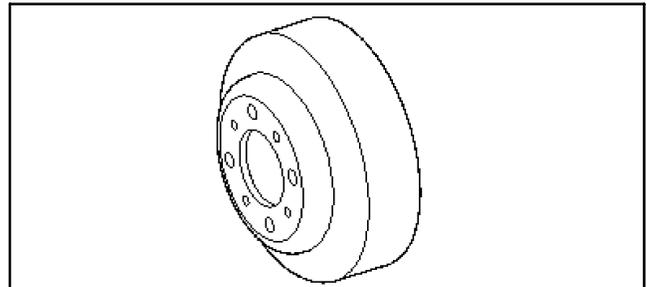


1. Use *J 41240* to retain the water pump pulley.
2. Remove the water pump pulley bolts (302) and pulley (303).



3. Remove the water pump bolts.
4. Remove the water pump.
5. Remove the water pump gaskets.

9.2.2 Cleaning and Inspection

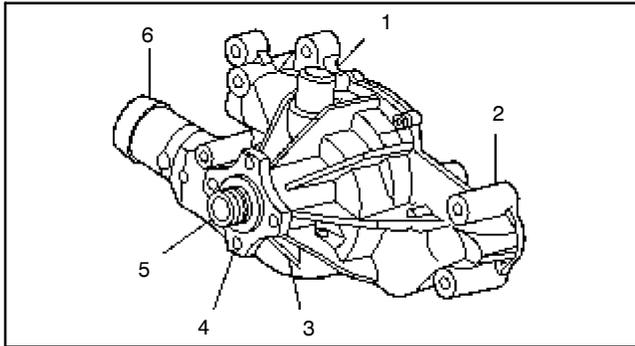


1. Inspect the water pump pulley for damage at the belt contact area and the pulley-to-water pump mounting surface.

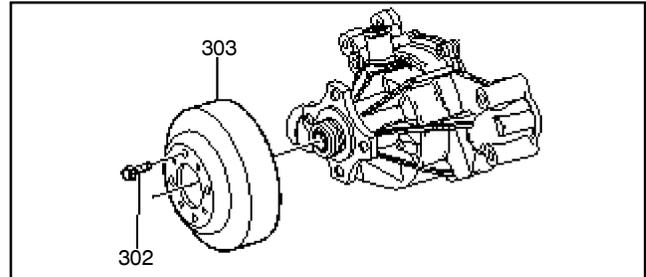
Important: Do not immerse the water pump in solvent. The solvent may enter the water pump's permanently lubricated bearings and cause premature bearing failure.

2. Clean all excess dirt and debris from the water pump housing.
3. Inspect the water pump for the following:
 - Leakage at the hose fitting (1).
 - Leakage at the water pump weep hole (3). A stain around the weep hole is acceptable. If leakage occurs, dripping with the engine running and the cooling system pressurized, replace the water pump.
 - Gasket sealing surfaces (2) for excessive scratches or gouging.
 - Restrictions within internal coolant passages (6).

- Excessive side-to-side play in the pulley shaft. If shaft end play exceeds 0.381 mm (0.015 in.), replace the water pump.
- Rotate the pump shaft by hand and inspect for roughness of operation. If the hub wobbles, is noisy, or feels rough when rotated, replace the water pump. The shaft and fan hub must turn straight and smoothly.
- Damage to threaded bolt holes (4).
- Damage to the fan clutch mounting threads (5).



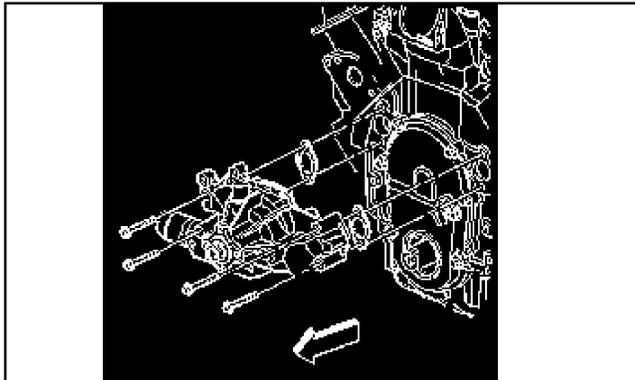
2. Install the water pump bolts.
3. Tighten:
 - a. Tighten the water pump bolts a first pass to 25 Nm (18 ft. lb.).
 - b. Tighten the water pump bolts a final pass to 50 Nm (37 ft. lb.).
4. Install the water pump pulley (303) and bolts (302).



5. Use *J 41240* to retain the water pump pulley. Tighten the water pump pulley bolts to 25 Nm (18 ft. lb.).

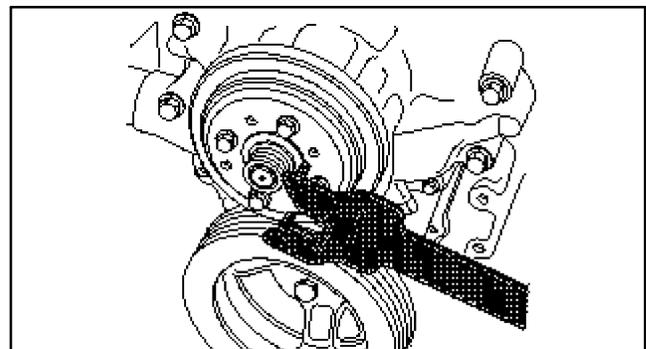
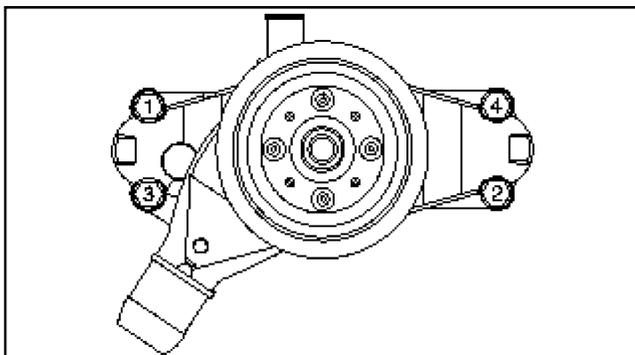
9.2.3 Installation

Tools Required:
J 41240 Fan Clutch Remover and Installer



1. Install the water pump and gaskets.

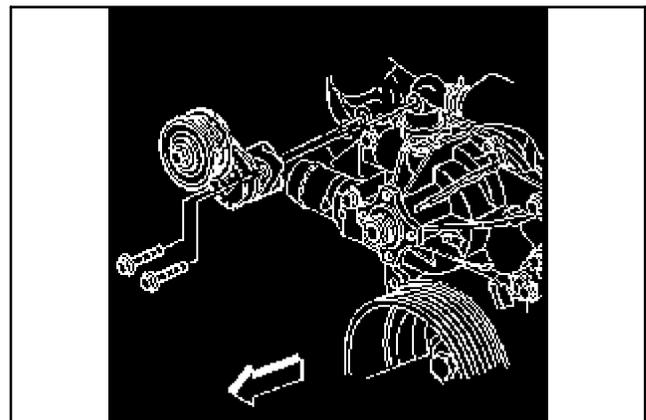
Notice: Refer to Fastener Notice in Cautions and Notices.



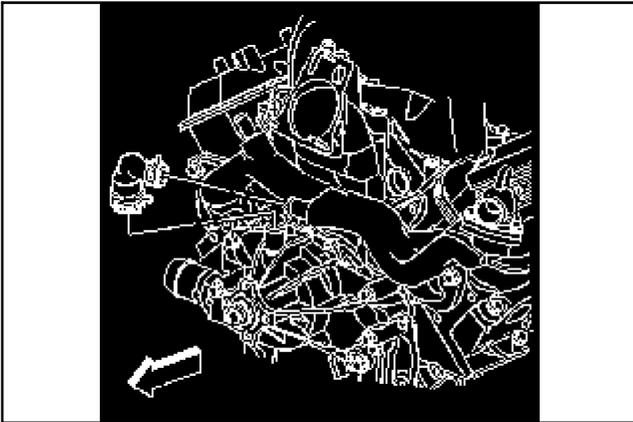
9.3 Water Crossover

9.3.1 Removal

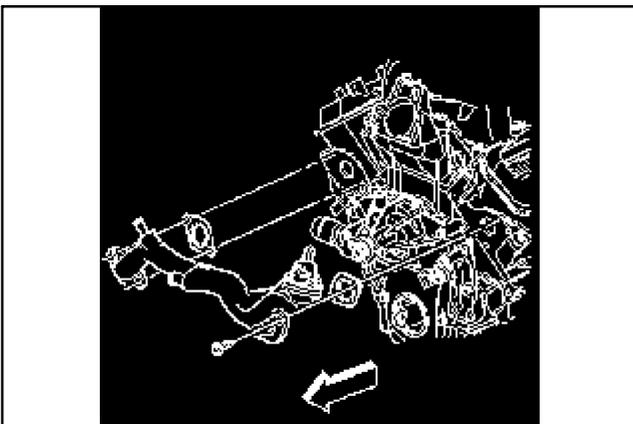
1. Remove the drive belt tensioner bolts.



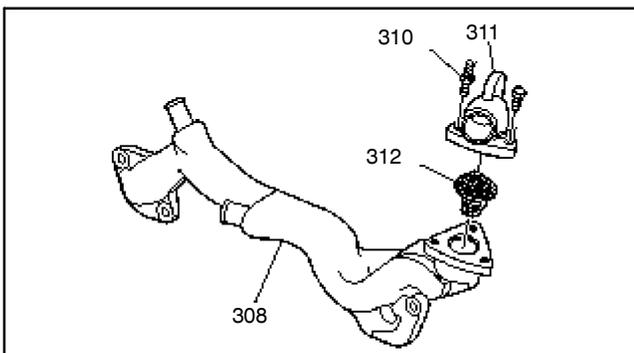
2. Remove the drive belt tensioner.



3. Remove the coolant bypass hose and clamps.



4. Remove the coolant crossover bolts.
5. Remove the coolant crossover.
6. Remove the coolant crossover gaskets.



7. Remove the thermostat housing bolts/studs (310).
8. Remove the thermostat housing (311).
9. Remove the thermostat (312) from the coolant crossover (308).

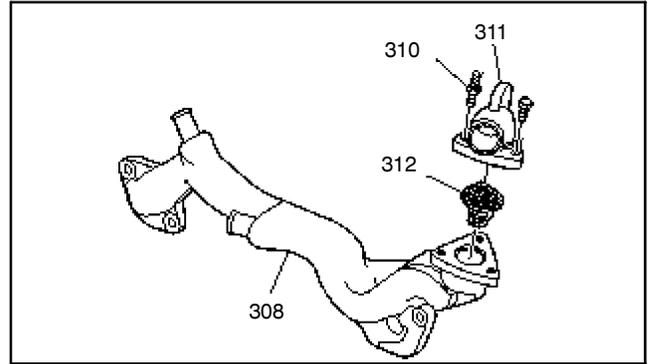
9.3.2 Cleaning and Inspection

Cleaning Procedure

1. Clean the water crossover (308) and thermostat housing (311) in solvent.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

2. Dry the components with compressed air.

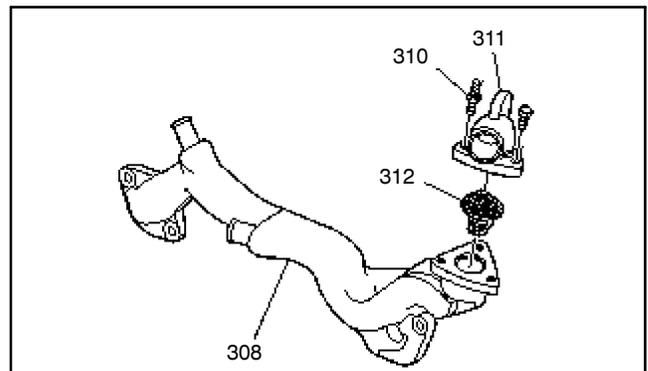


Inspection Procedure

1. Inspect the water crossover (308) for the following:
 - Corrosion or damage to the gasket sealing surfaces.
 - Corrosion or damage to the bypass hose fitting.
 - Corrosion or damage to the heater hose fitting.
 - Corrosion or damage to the threads of the water outlet.
2. Inspect the thermostat housing (311) for corrosion or damage.

9.3.3 Installation

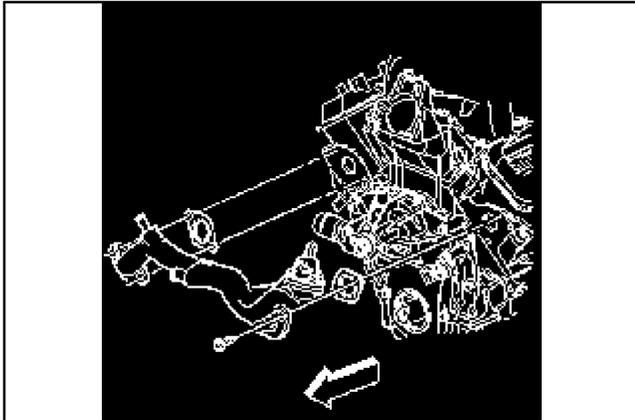
1. Install the thermostat (312) with the seal into the water crossover (308).



2. Install the thermostat housing (311).

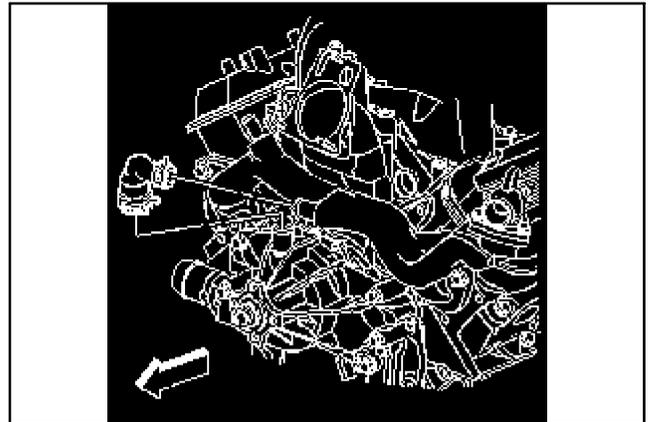
Notice: Refer to Fastener Notice in Cautions and Notices.

3. Install the thermostat housing bolts (310). Tighten the bolts to 30 Nm (22 ft. lb.).

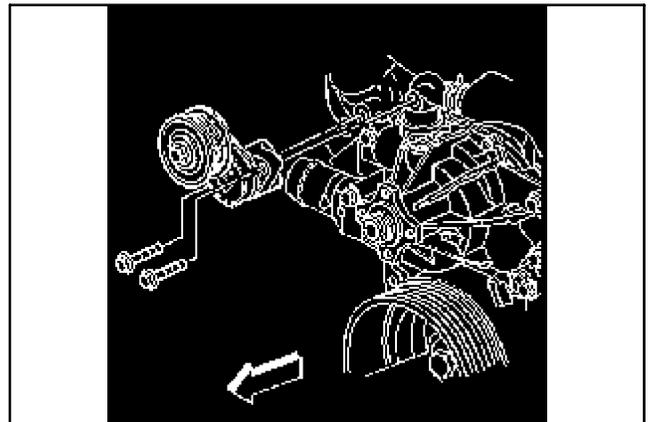


4. Install the gaskets and the water crossover.
5. Install the bolts. Tighten the water crossover bolts to 50 Nm (37 ft. lb.).

Important: Properly position the bypass hose clamps to avoid water pump pulley interference. Tighten the bolts to 30 Nm (22 ft. lb.).



6. Install the thermostat bypass hose and clamps. Tighten the bolts to 30 Nm (22 ft. lb.).



7. Install the drive belt tensioner.
8. Install the drive belt tensioner bolts. Tighten the drive belt tensioner bolts to 50 Nm (37 ft. lb.).

Notes

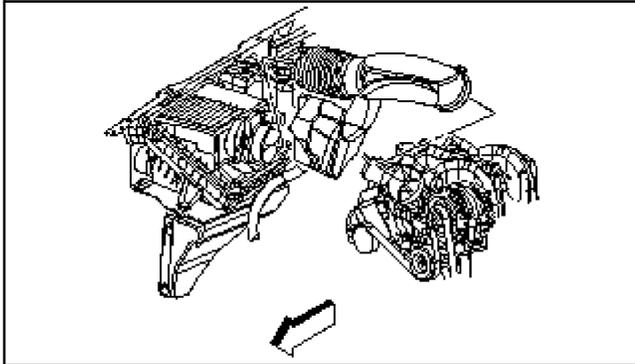
Section 10 Air Intake and Exhaust System

10.1 Intake Manifold

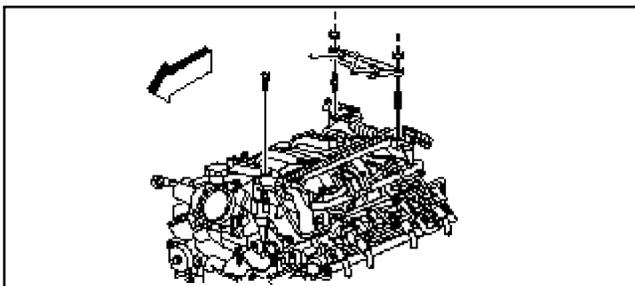
10.1.1 Replacement

Removal Procedure

Important: The intake manifold, throttle body, fuel rail, and injectors may be removed as an assembly. If not servicing the individual components, remove the manifold as a complete assembly.

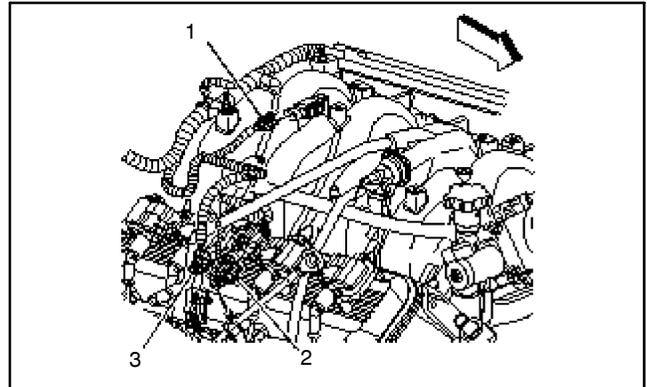


1. Loosen the clamps at the throttle body and air cleaner.
2. Remove the air cleaner outlet duct.

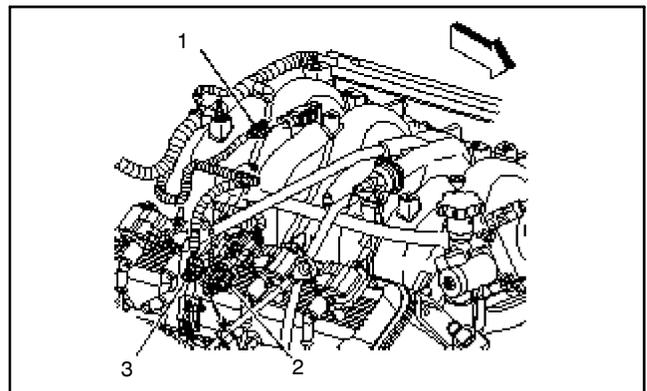


3. Relieve the fuel system pressure.
4. Disconnect the fuel feed and return pipes.
5. Disconnect the engine harness clips from the studs on the front of dash.

6. Disconnect the following electrical connectors:
 - Pressure cycling switch (1).
 - Surge tank switch (2).
 - Mass airflow (MAF) sensor (3).



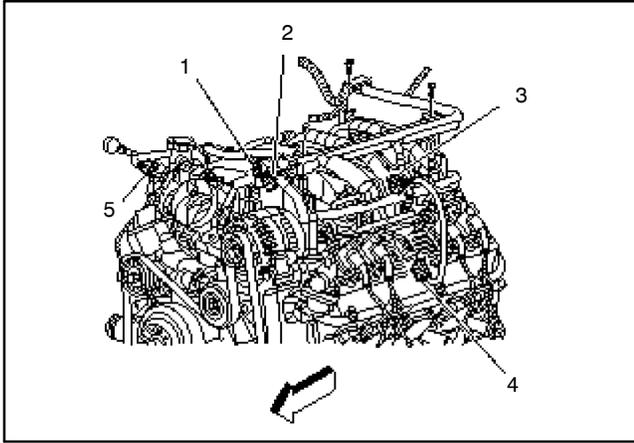
7. Reposition the engine harness branch to top of engine.
8. Remove the connector position assurance (CPA) retainer at the ignition coil harness.
9. Disconnect the following electrical connectors:
 - Manifold absolute pressure (MAP) sensor (1).
 - Ignition coil harness (2).
 - Engine coolant temperature (ECT) sensor (3).



10. Remove the engine harness bolt and studs.
11. Remove the CPA retainer at the ignition coil harness.

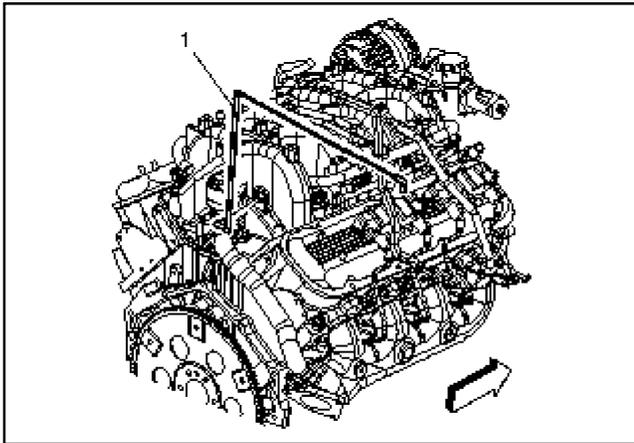
12. Disconnect the following electrical connectors:

- Engine alternator (2).
- Injector harness (3).
- Ignition coil harness (4).
- Electronic throttle control (ETC) (5).
- Purge valve solenoid (1).

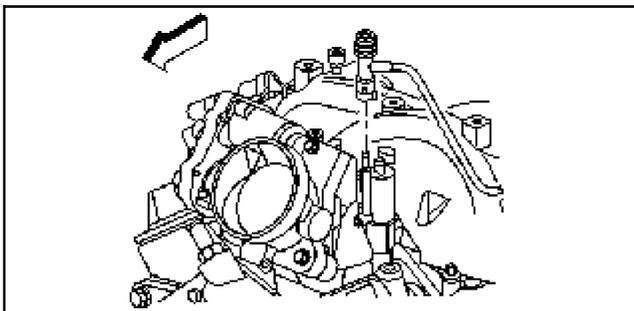


13. Reposition the engine harness to the drivers side of the engine compartment.

14. Remove the bypass valve vacuum hose (1) from the intake manifold.



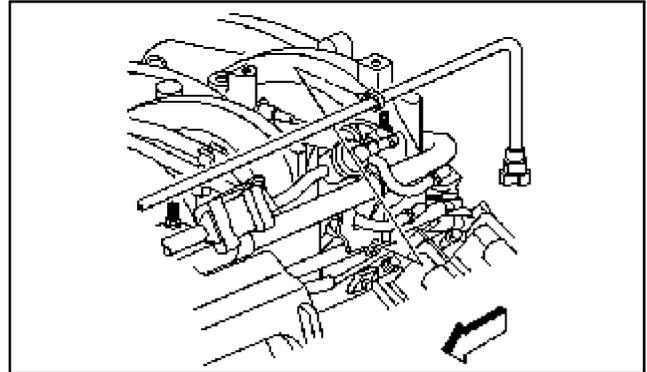
15. Disconnect the evaporative emission (EVAP) tube from the purge solenoid.



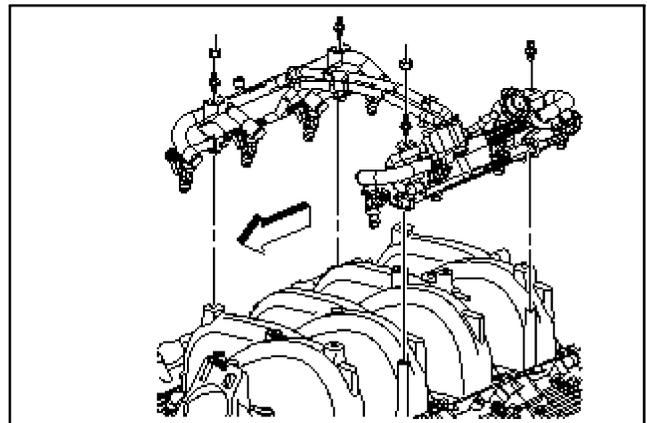
16. Unclip the EVAP tube from the fuel rail.

17. Disconnect the EVAP tube from the vent pipe at the rear of the engine.

18. Remove the EVAP tube.

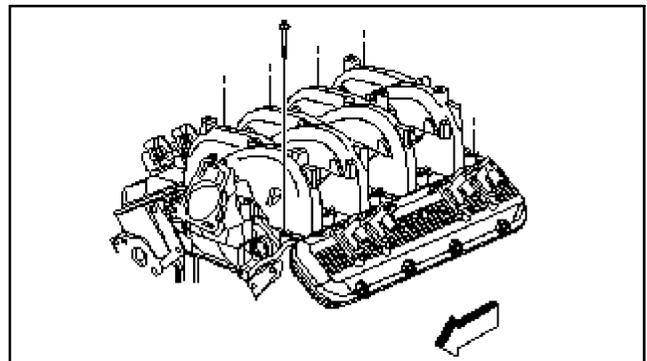


19. If replacing the intake manifold, remove the fuel rail studs.

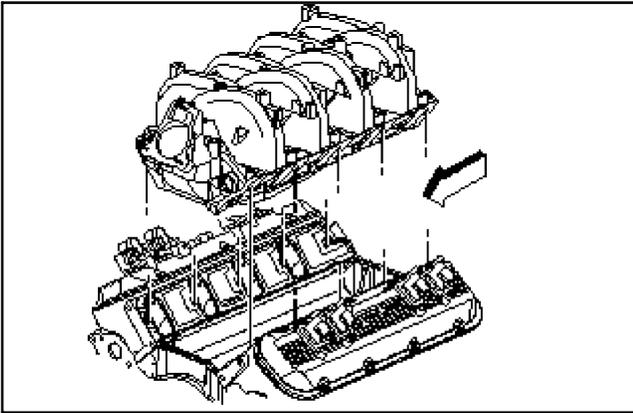


20. Remove the fuel rail.

Important: Do not attempt to loosen the manifold by prying under the gasket surface with any tool.

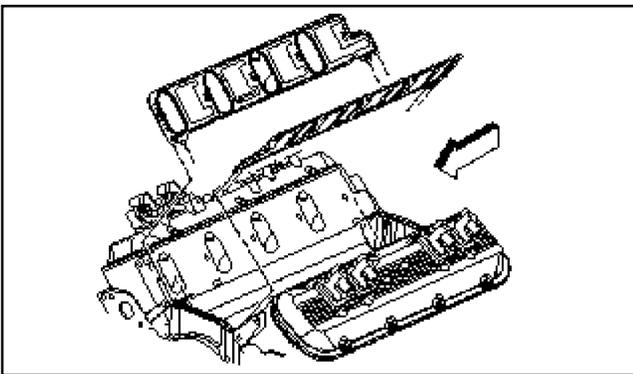


21. Remove the intake manifold bolts.

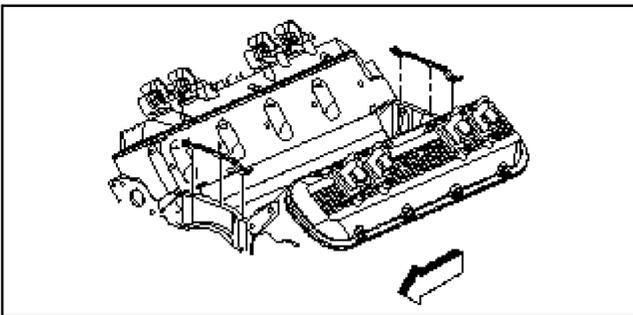


22. Remove the intake manifold.

Important: The intake manifold gaskets are not reusable.

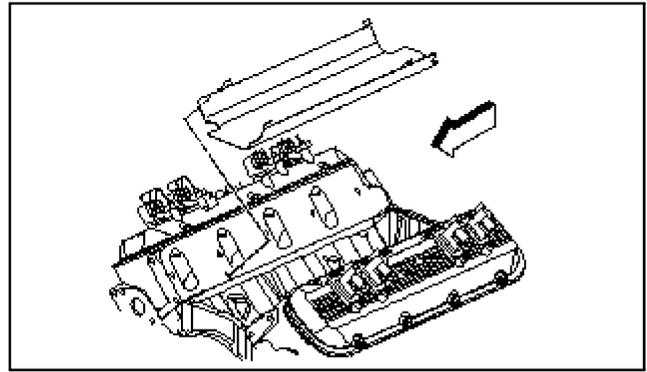


23. Remove and discard the intake manifold side gaskets.



24. Remove and discard the intake manifold end seals.

Important: The splash shield is secured using a snap-in fit. Do not distort the splash shield. The splash shield is reusable.

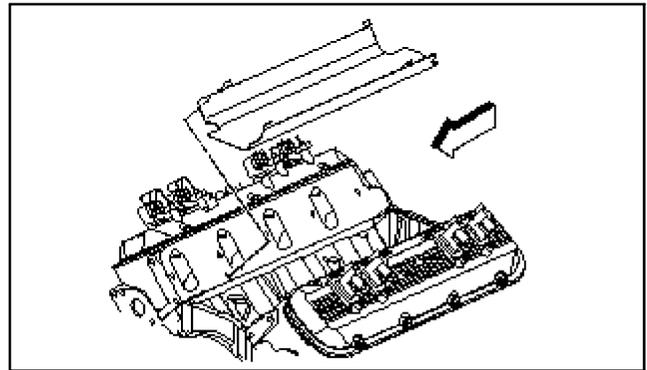


25. Remove the splash shield.

26. If replacing the intake manifold, refer to Section 10.1.3, Intake Manifold Disassemble.

27. Clean and inspect the intake manifold. Refer to Section 10.1.4, Intake Manifold Cleaning and Inspection.

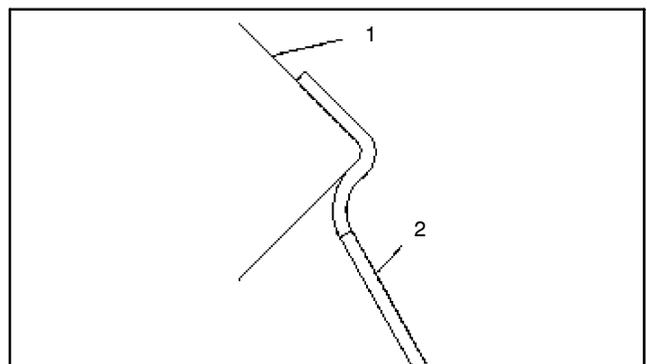
Installation Procedure



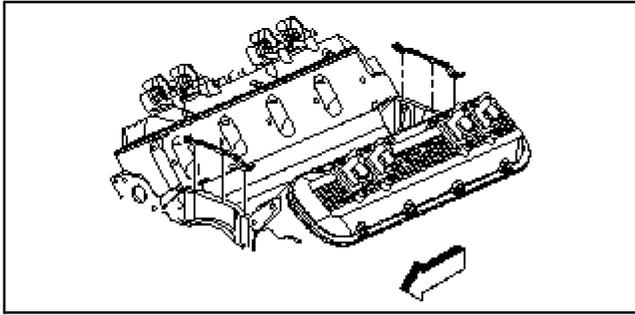
1. If replacing the intake manifold, refer to Section 10.1.5, Intake Manifold Assemble.

2. Install the splash shield.

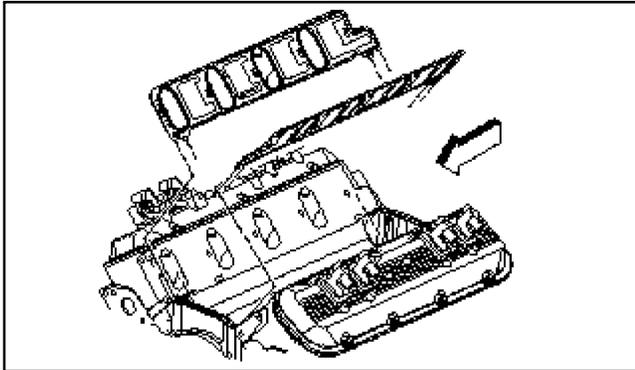
3. Ensure the splash shield (2) snap fits between the cylinder heads (1).



4. Install the *new* intake manifold end seals.

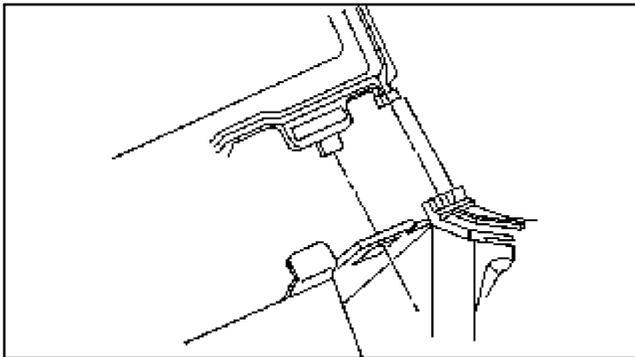


5. Install the *new* intake manifold side gaskets.

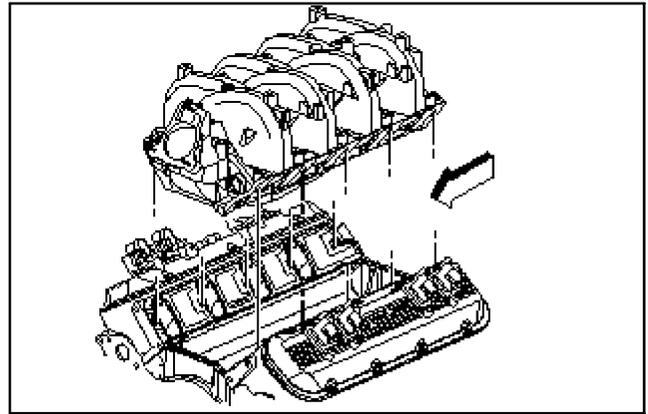


6. Ensure the intake manifold gasket tabs align with the hole in the head gasket.

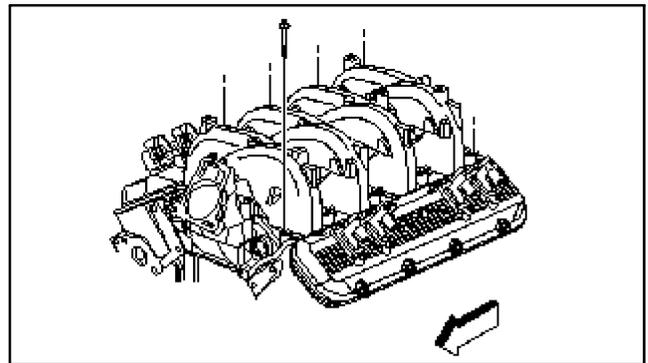
7. Ensure the intake manifold gasket tabs align with the slot in the intake manifold end seals.



8. Install the intake manifold.

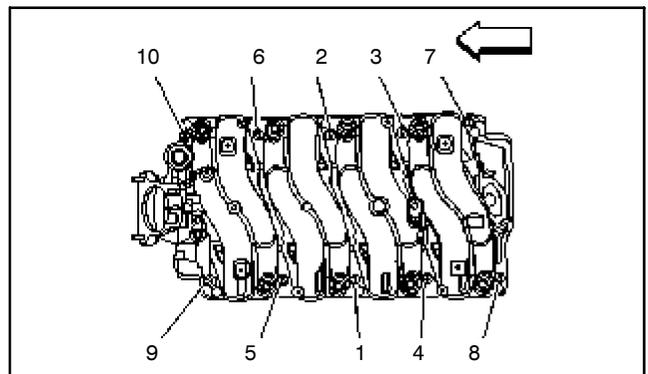


9. Apply thread-lock, GM Part No. U.S. 12345382/ Canadian 10953489 or equivalent, to a minimum of eight threads of the intake manifold bolts.



10. Install the intake manifold bolts.

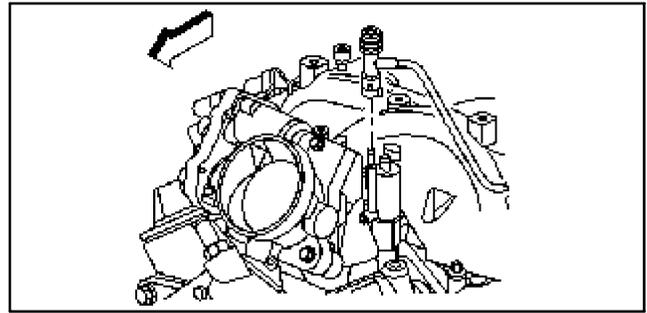
Notice: Refer to Fastener Notice in Cautions and Notices.



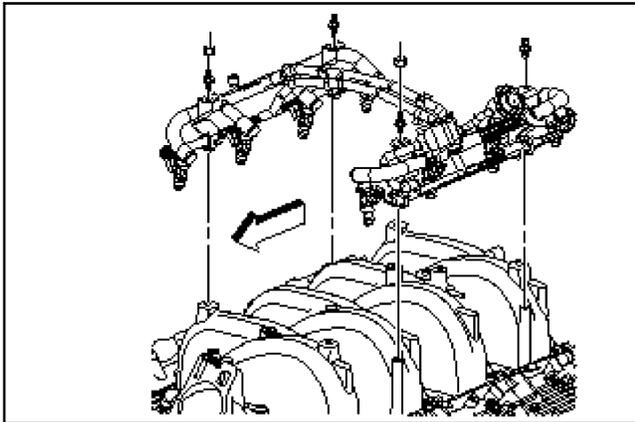
11. Tighten the intake manifold bolts in the sequence shown using four passes.

- a. Tighten the bolts a first pass to 5 Nm (44 in. lb.).
- b. Tighten the bolts a second pass to 8 Nm (71 in. lb.).
- c. Tighten the bolts a final pass to 12 Nm (106 in. lb.).

Important: Lubricate the fuel injector O-ring seals with clean engine oil and install onto the spray tip of each injector.

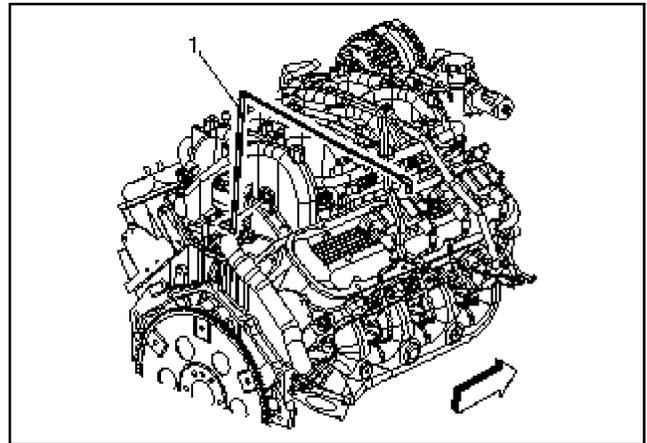


18. Install the bypass valve vacuum hose (1) to the intake manifold.



12. If replacing the intake manifold, install the fuel rail.

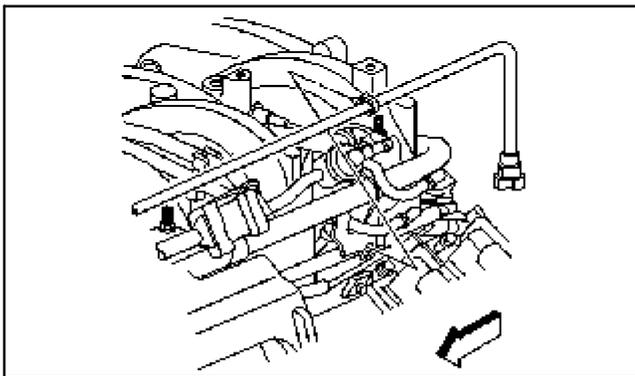
13. Install the fuel rail studs. Tighten the studs to 12 Nm (106 in. lb.).



19. Position the engine harness over the engine compartment.

20. Connect the following electrical connectors:

- Engine alternator (2).
- Injector harness (3).
- Ignition coil harness (4).
- ETC (5).
- Purge valve solenoid (1).

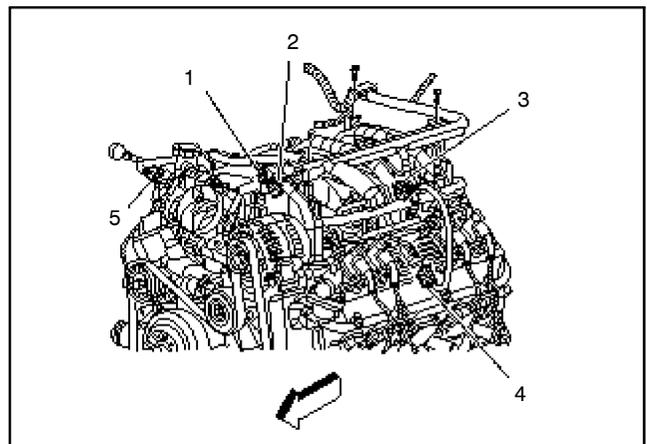


14. Install the EVAP tube.

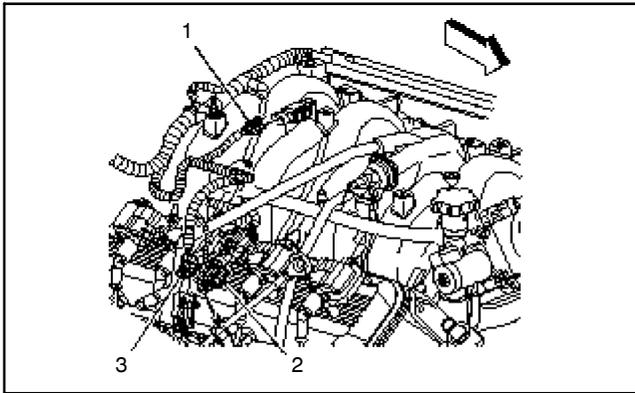
15. Connect the EVAP tube to the vent pipe at the rear of the engine.

16. Clip the EVAP tube to the fuel rail.

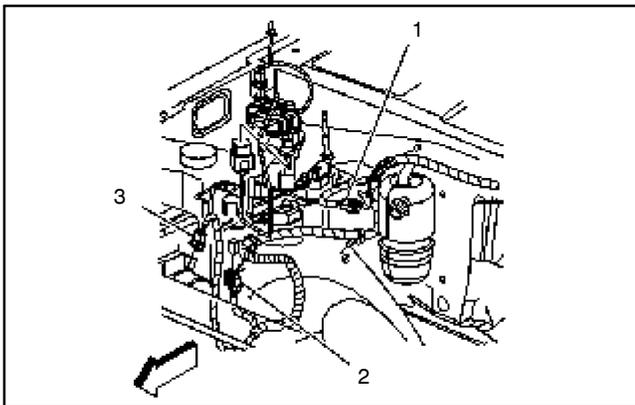
17. Connect the EVAP tube to the purge solenoid.



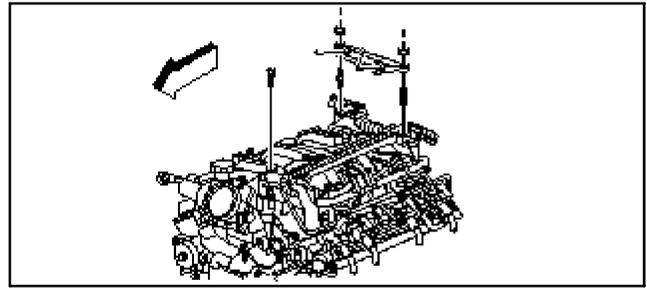
21. Install the CPA retainer at the ignition coil harness.
22. Install the engine harness bolt and studs.
 - a. Tighten the bolt to 5 Nm (44 in. lb.).
 - b. Tighten the studs to 10 Nm (89 in. lb.).
23. Connect the following electrical connectors:
 - MAP sensor (1).
 - Ignition coil harness (2).
 - ECT sensor (3).



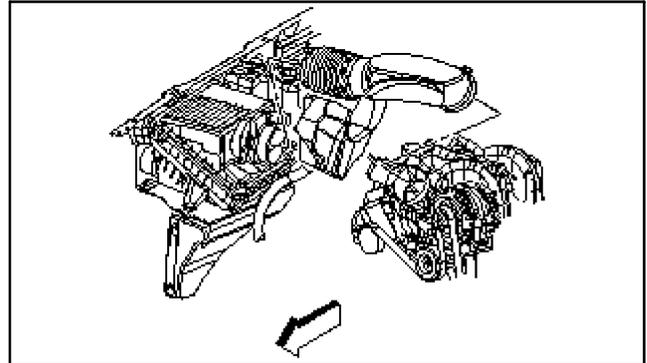
24. Install the CPA retainer at the ignition coil harness.
25. Position engine harness branch over the top of engine.
26. Connect the following electrical connectors:
 - Pressure cycling switch (1).
 - Surge tank switch (2).
 - MAF sensor (3).



27. Connect the engine harness clips to the studs on the front of dash.
28. Connect the fuel feed and return pipes.



29. Install the air cleaner outlet duct.

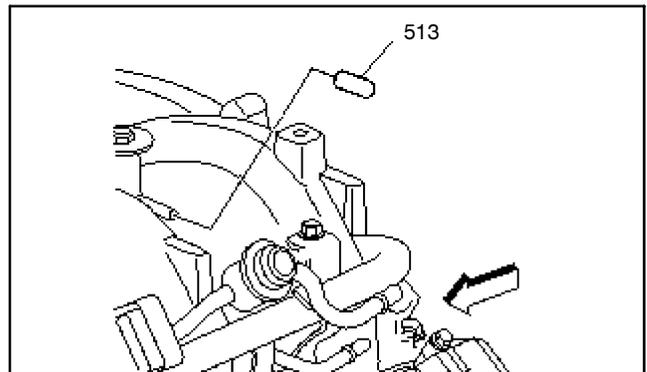


30. Tighten the clamps at the throttle body and air cleaner.

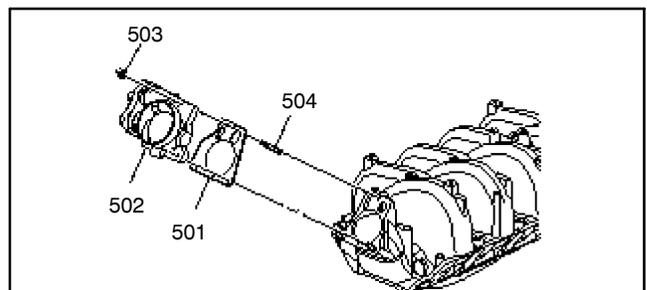
Tighten the clamps to 4 Nm (35 in. lb.).

10.1.2 Removal

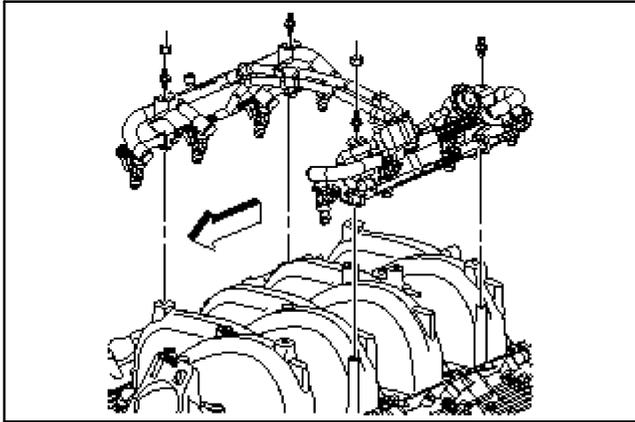
1. Remove the vacuum plug (513), if required.



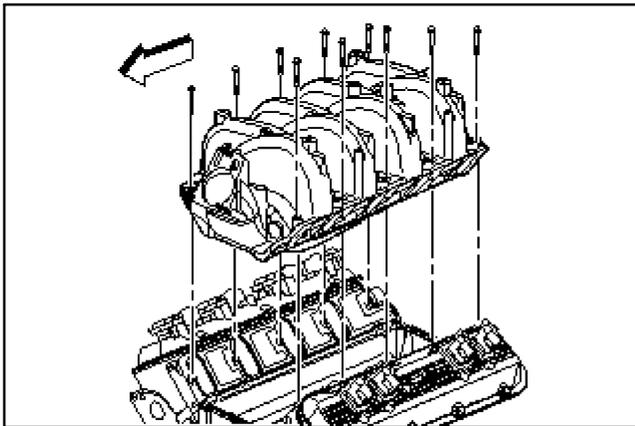
2. Remove the throttle body nuts (503).



3. Remove the throttle body (502) and gasket (501).
4. Remove the studs (504), if required.



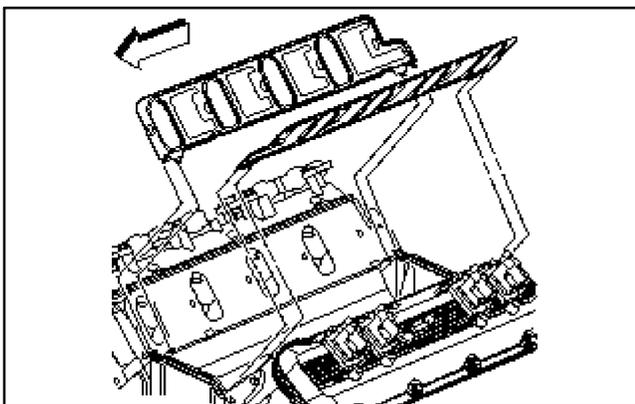
5. Remove the fuel injection fuel rail bolts/studs.
6. Remove the fuel injection fuel rail with injectors.



7. Remove the intake manifold bolts.

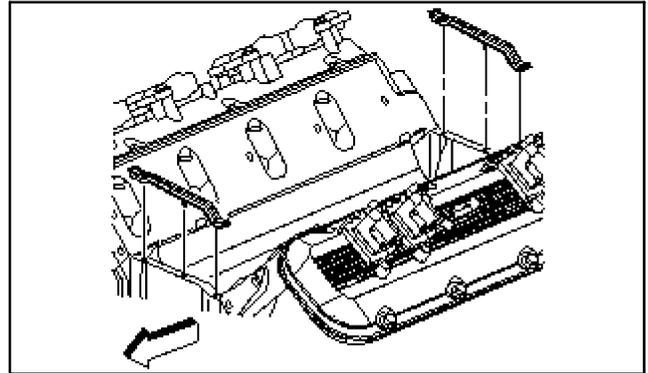
Important: Do not attempt to loosen the manifold by prying under the gasket surface with any tool.

8. Remove the intake manifold.

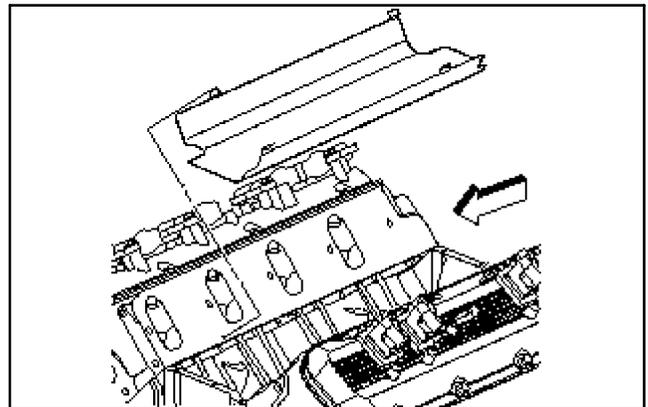


Important: The intake manifold gaskets are not reusable.

9. Remove and discard the intake manifold side gaskets.



10. Remove and discard the intake manifold end seals.

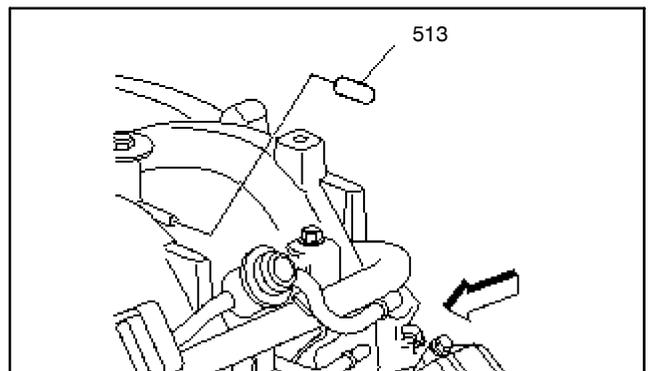


Important: The splash shield is secured using a snap-in fit. Do not distort the splash shield. The splash shield is reusable.

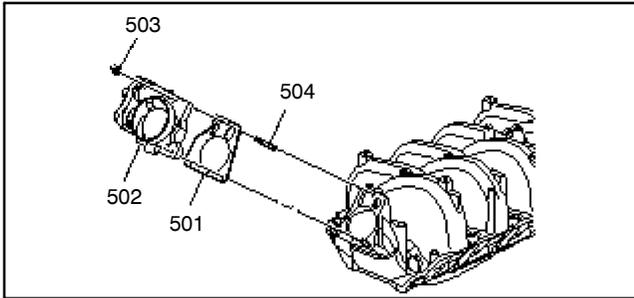
11. Remove the splash shield.

10.1.3 Disassemble

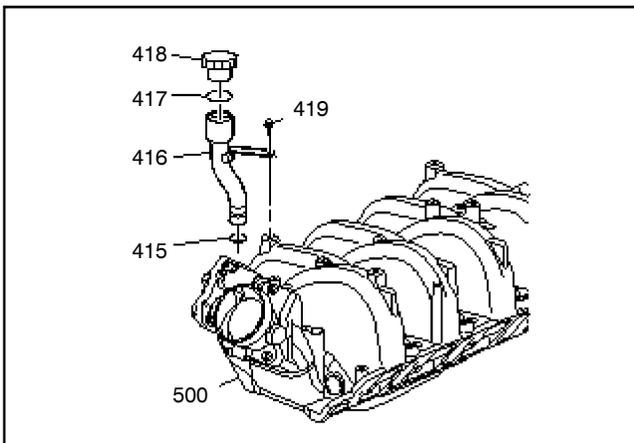
1. Remove the vacuum plug (513).



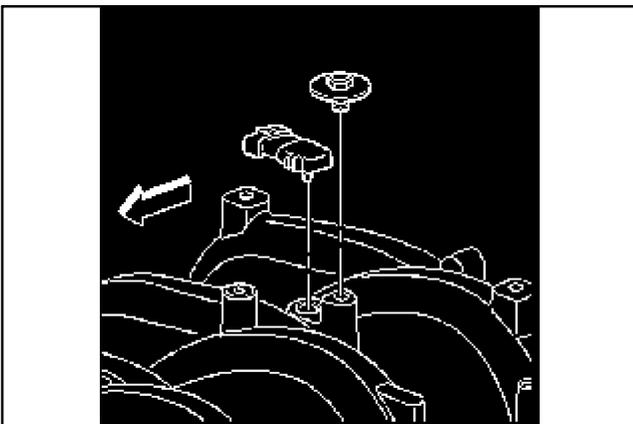
2. Remove the throttle body nuts (503).
3. Remove the throttle body (502) and gasket (501).
4. Discard the gasket.
5. Remove the throttle body studs (504), if required.



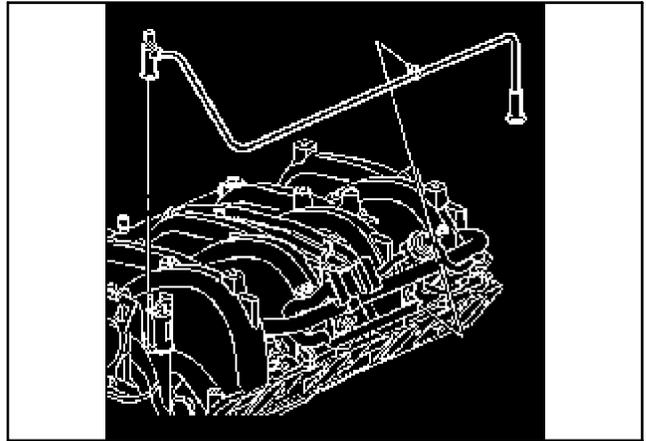
6. Remove the oil fill cap (418).
7. Remove the oil fill tube (416) and bolt (419).



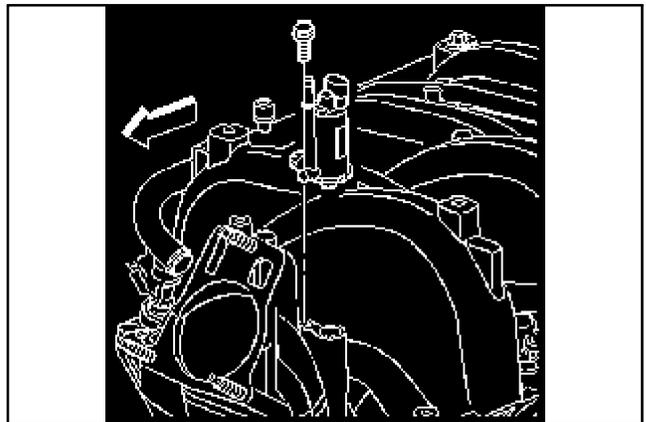
8. Remove the MAP sensor bolt and MAP sensor.
9. Inspect the MAP sensor grommet for damage.



10. Remove the EVAP tube.



11. Remove the EVAP purge valve and bolt.



12. Inspect the O-ring seal for damage. Replace as needed.

10.1.4 Cleaning and Inspection

Important: Do not reuse the lower intake manifold gaskets or end seals.

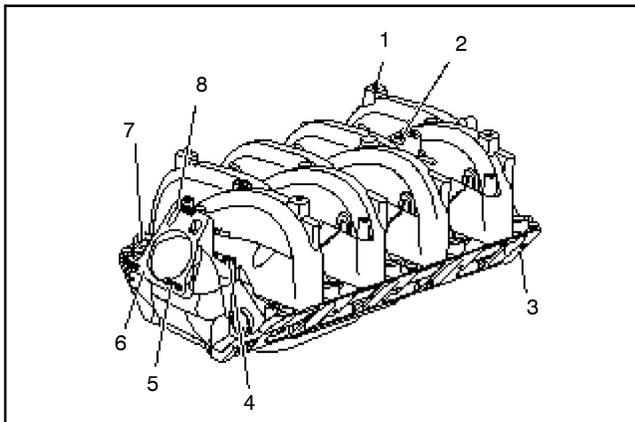
1. Clean the intake manifold in an approved solvent.
 - Clean debris out of all bolt holes. Clean the intake manifold gasket sealing surfaces.
 - Clean all intake manifold ports.

Caution: Refer to Safety Glasses Caution in Cautions and Notices.

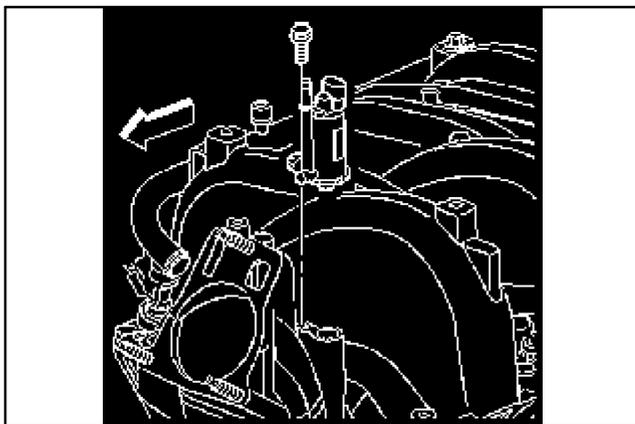
2. Dry the intake manifold with compressed air.

3. Inspect the following:

- Intake manifold bolt holes (1) for cracks and/or damage.
- MAP sensor sealing surface (2) for damage.
- Purge solenoid sealing surface (4) for damage. The purge solenoid bolt has a sealer that may come off during removal of the bolt. Ensure all sealant is removed from the bolt hole.
- Intake manifold-to-cylinder head sealing surfaces (3) for damage.
- Throttle body studs (5) for damage. Replace as necessary.
- Throttle body mounting surface (6) for damage.
- Oil fill tube hole (7) for signs of leakage. Reseal as necessary.
- PCV port (8) for debris or varnish buildup.



10.1.5 Assemble



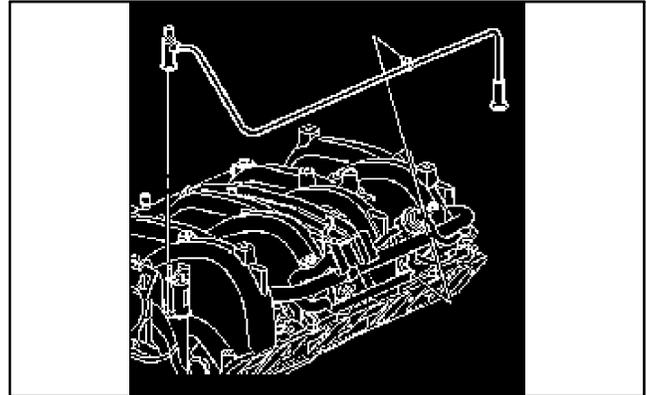
1. Apply a very light film of clean engine oil to the EVAP valve O-ring seal.

2. Install the EVAP valve.

3. Apply thread sealer, GM Part No. U.S. 12345493/ Canadian 10953488 or equivalent, to the threads of the purge solenoid bolt.

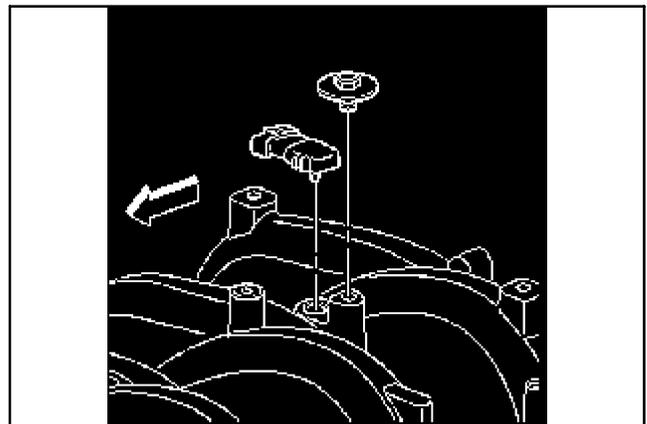
Notice: Refer to Fastener Notice in Cautions and Notices.

4. Install the EVAP valve bolt. Tighten the bolt to 8 Nm (71 in. lb.).



5. Install the EVAP tube.

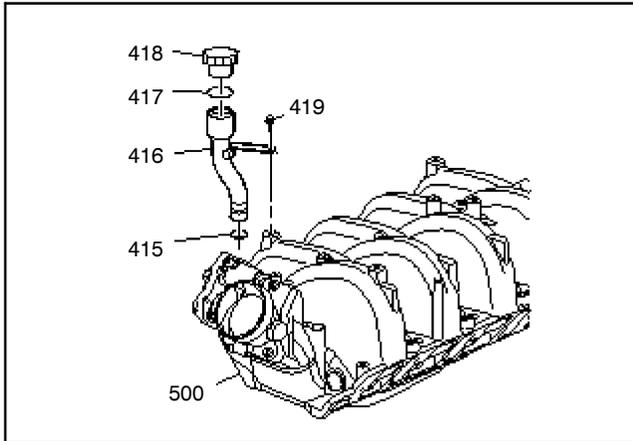
Important: Lubricate the port of the MAP sensor with clean engine oil. Avoid dipping the sensor port directly into the lubricant or using a solid type of lubricant as it may block the vacuum port signal.



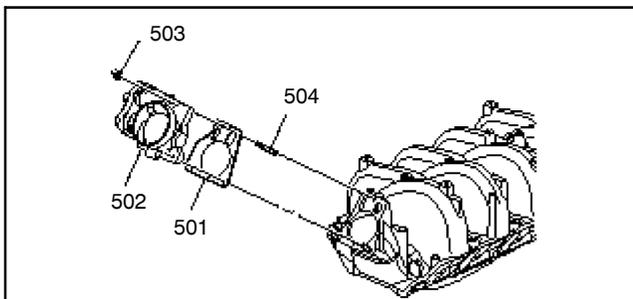
6. Install the MAP sensor.

7. Install the MAP sensor bolt. Tighten the MAP sensor bolt to 12 Nm (106 in. lb.).

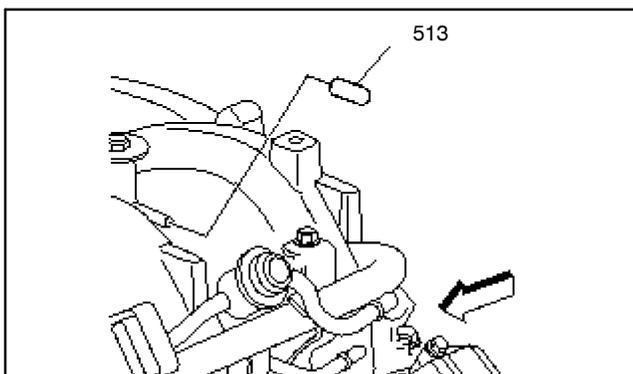
8. Lubricate the O-ring seal (415) of the oil fill tube with clean engine oil.
9. Install the oil fill tube (416).
10. Install the oil fill tube bolt (419). Tighten the oil fill tube bolt to 12 Nm (106 in. lb.).
11. Install the oil fill cap (418).



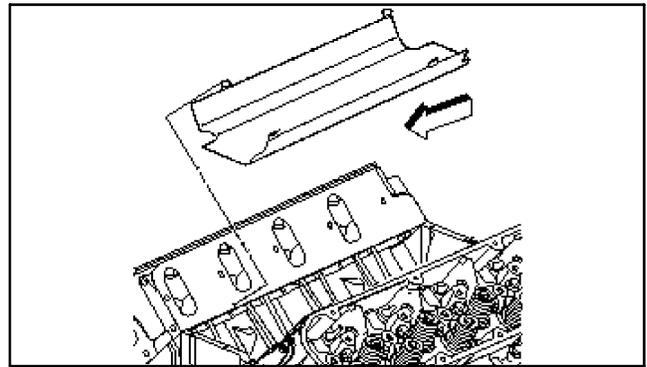
12. Install the throttle body gasket (501).
13. Install the throttle body (502).
14. Install the throttle body nuts (503). Tighten the throttle body nuts to 10 Nm (89 in. lb).



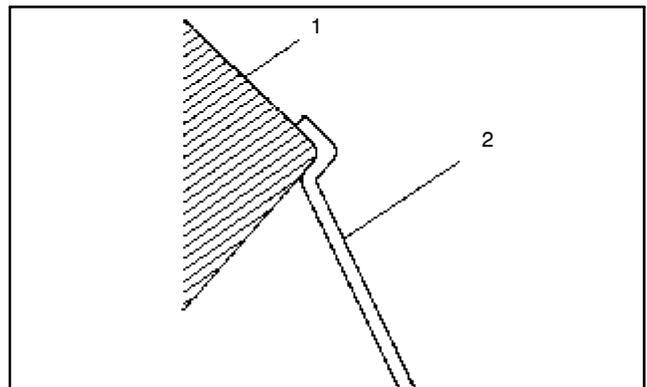
15. Install the vacuum plug (513).



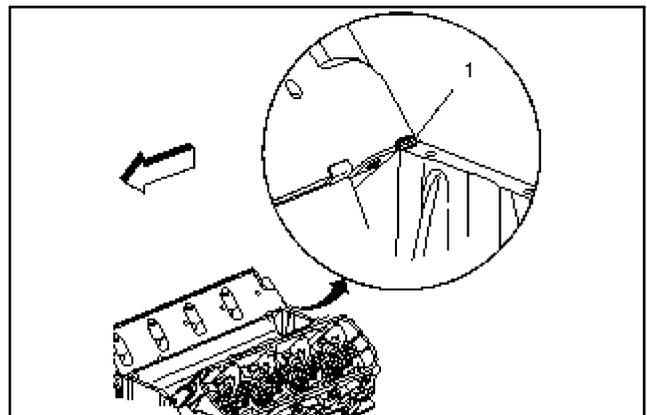
10.1.6 Installation



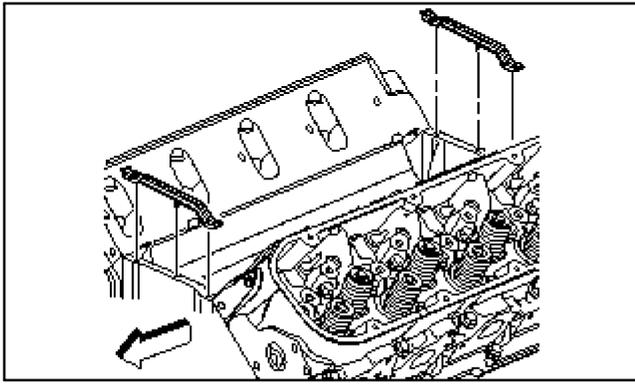
1. Install the splash shield.



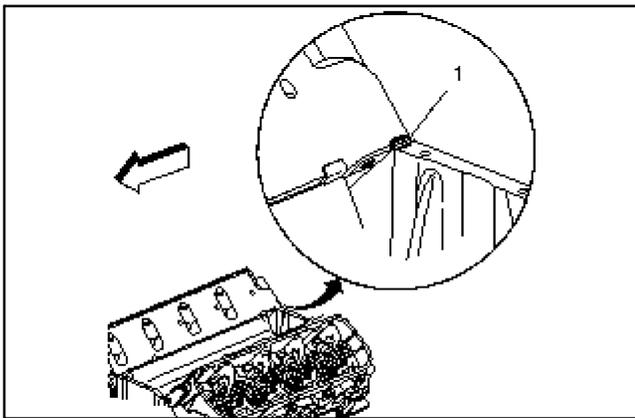
2. Ensure the splash shield (2) snap fits between the cylinder heads (1).



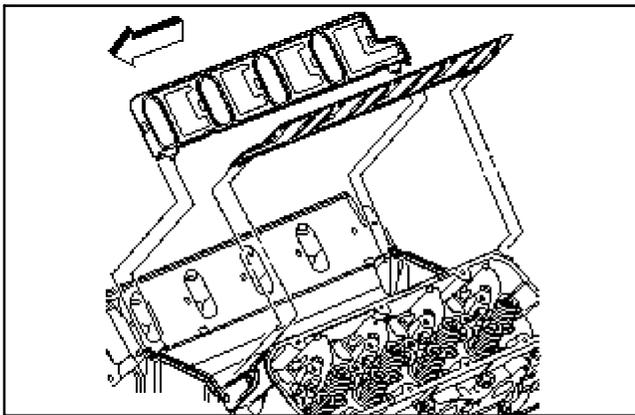
3. Apply a 5 mm (0.2 in.) bead of GM Part No. U.S. 12346141/Canadian 10953433 sealer (1) to the four engine block/cylinder head locations.
4. Install the new intake manifold end seals.



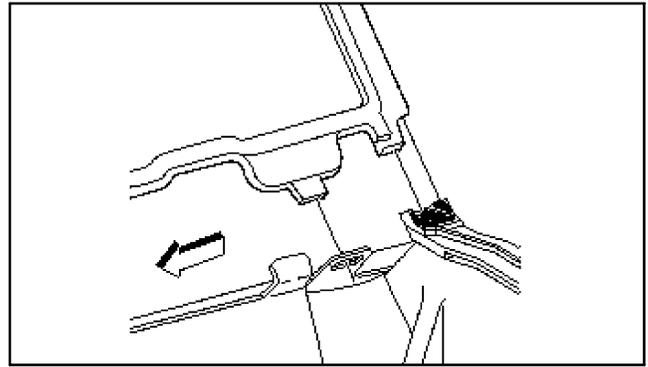
5. Apply a 5 mm (0.2 in.) bead of GM Part No. U.S. 12346141/Canadian 10953433 sealer (1) onto the end seals at the four engine block/cylinder head locations.



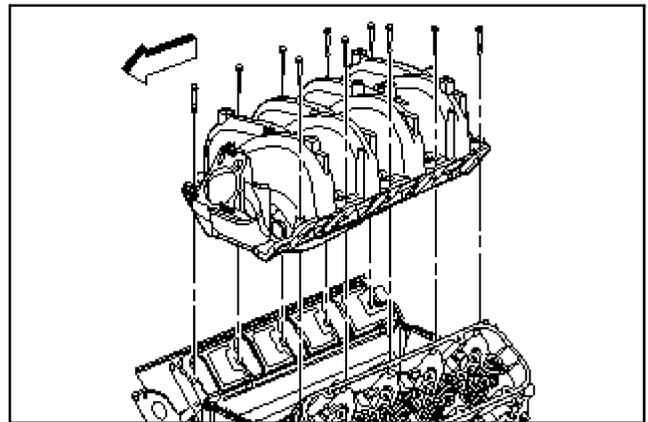
6. Install the new intake manifold side gaskets onto the cylinder heads.



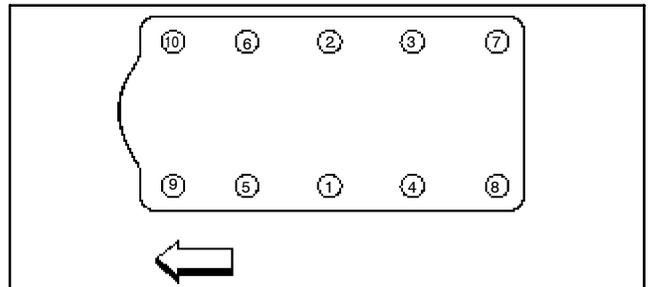
7. Ensure the intake manifold gasket tabs align with the hole in the head gasket.



8. Ensure the intake manifold gasket tabs align with the slot in the intake manifold end seals.



9. Install the intake manifold onto the engine block.



Notice: Ensure the intake manifold does not shift as the intake manifold bolts are tightened in the proper sequence. Failure to follow the entire intake manifold bolt tightening sequence exactly may result in an oil leak and serious engine damage.

Important: Complete the entire intake manifold tightening sequence promptly due to the anaerobic thread adhesive. Complete the final pass of the tightening sequence before the adhesive starts to cure or false torque readings and ineffective thread locking may result.

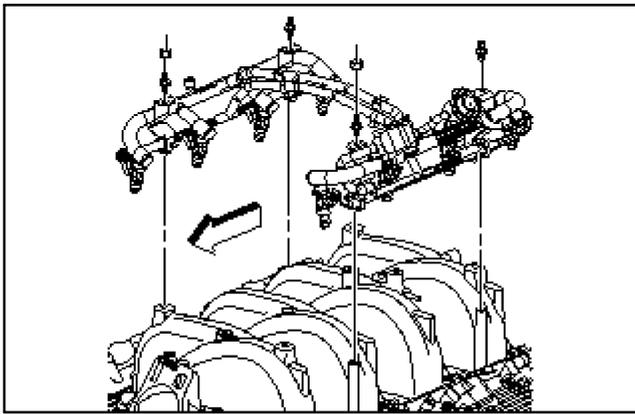
Important: *Do not* reuse intake manifold bolts. Install *new* intake manifold bolts during assembly.

10. Install the *new* intake manifold bolts.

Notice: Refer to Fastener Notice in Cautions and Notices.

11. Tighten the intake manifold bolts in sequence, using four passes.

- a. Tighten the intake manifold bolts a first pass in sequence to 5 Nm (44 in. lb.).
- b. Tighten the intake manifold bolts a second pass in sequence to 8 Nm (71 in. lb.). Inspect the intake manifold joints for signs of intake manifold shifting. Correct as required.
- c. Tighten the intake manifold bolts a third pass in sequence to 12 Nm (106 in. lb.).
- d. Tighten the intake manifold bolts a final pass in sequence to 15 Nm (11 ft. lb.).

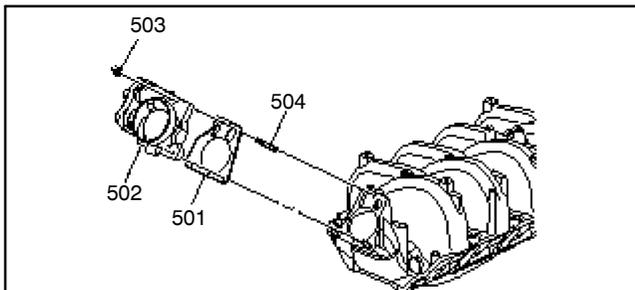


Important: Lubricate the injector O-ring seals with clean engine oil and install onto the spray tip end of each injector.

12. Install the fuel injection fuel rail with injectors.

13. Install the fuel injection fuel rail bolts/studs.

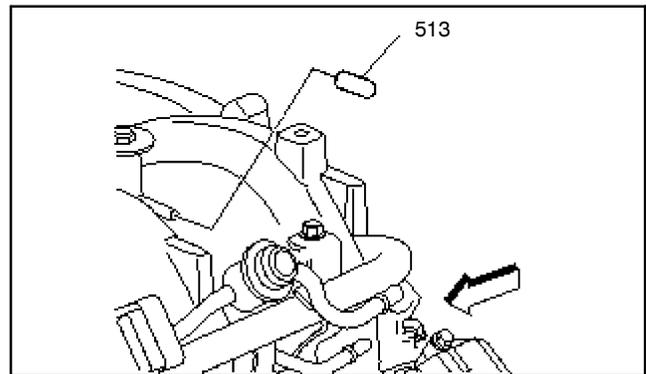
Tighten the fuel injection fuel rail bolts/studs to 12 Nm (106 in. lb.).



14. Install the throttle body gasket (501) and throttle body (502).

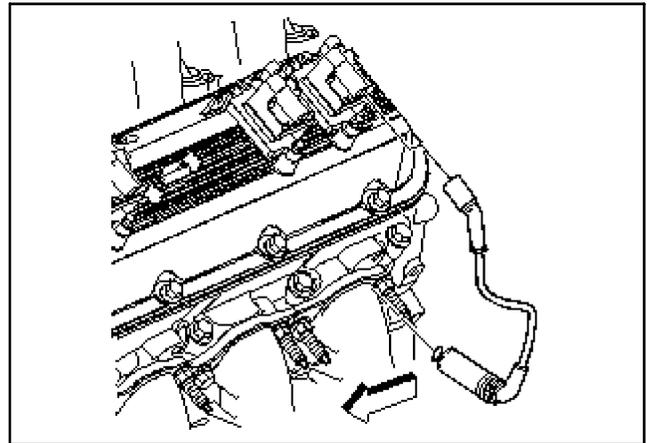
15. Install the throttle body nuts (503). Tighten the throttle body nuts to 10 Nm (89 in. lb.).

16. Install the vacuum plug (513).



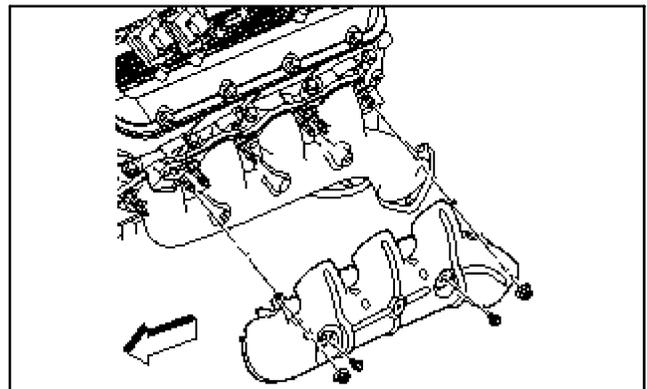
10.2 Exhaust Manifold

10.2.1 Removal, Left



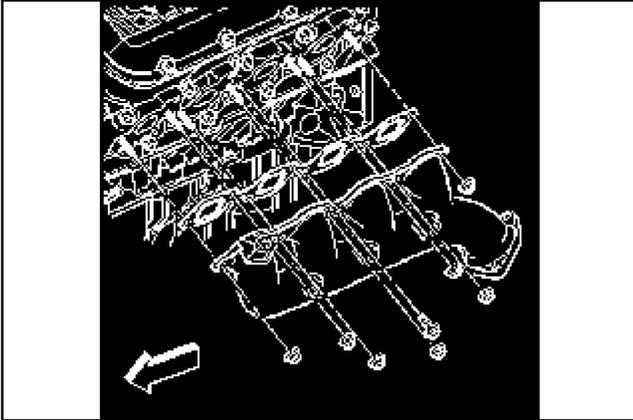
Notice: Twist the spark plug boot 1/2 turn to release the boot. Pull on the spark plug boot only. Do not pull on the spark plug wire or the wire could be damaged.

1. Remove the spark plug wires from the spark plugs and ignition coils.



2. Remove the exhaust manifold heat shield bolts and nuts.

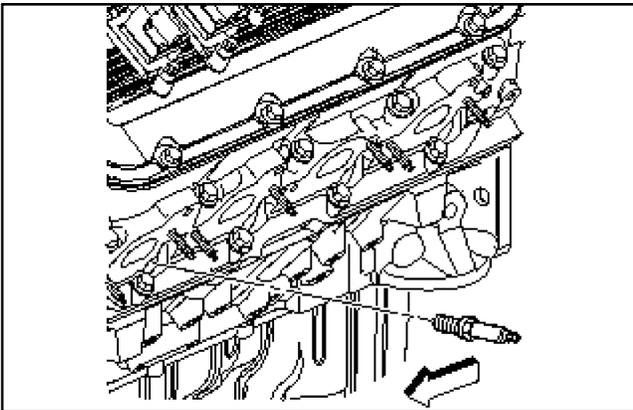
3. Remove the exhaust manifold heat shield.



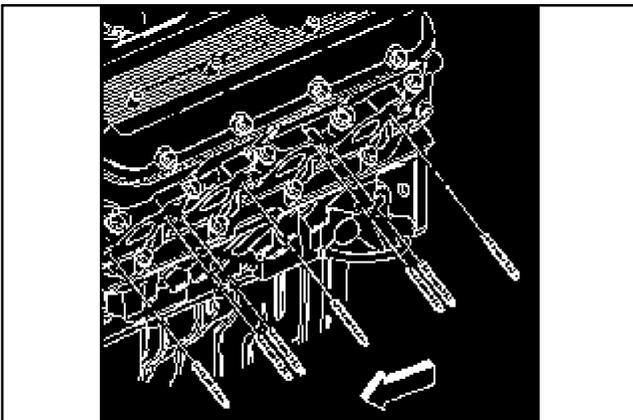
4. Remove the exhaust manifold nuts and center bolt.

5. Remove the exhaust manifold.

6. Remove the exhaust manifold gasket.



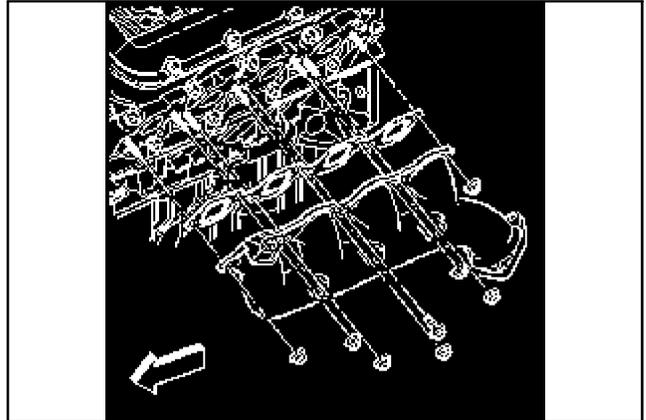
7. Remove the spark plugs, if required.



8. Remove the exhaust manifold studs, if required.

10.2.2 Cleaning and Inspection

1. Clean the exhaust manifolds in solvent.

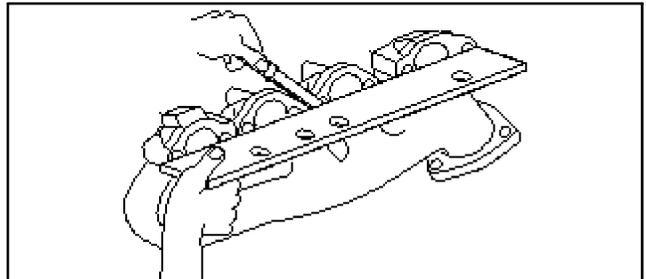


Caution: Refer to Safety Glasses Caution in Cautions and Notices.

2. Dry the components with compressed air.

3. Inspect the exhaust manifolds for the following:

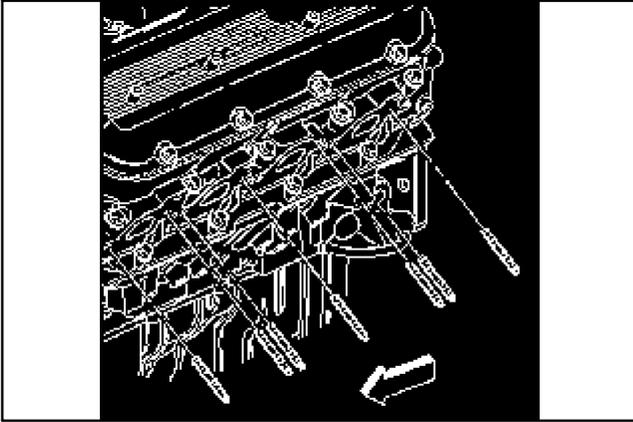
- Damage to the gasket sealing surfaces.
- Damage to the exhaust manifold studs.
- Broken or damaged heat shields.
- Cracks in the exhaust manifold.
- Restrictions within the exhaust passages.



4. Measure the alignment or surface flatness of the exhaust manifold flanges using a straight edge and a feeler gauge. Exhaust manifold surface flatness must not exceed 0.254 mm (0.01 in.).

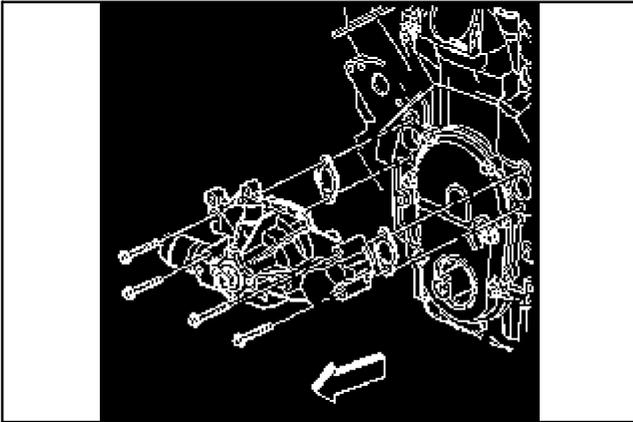
5. If the surface flatness is not within specifications, the exhaust manifold is warped and must be replaced.

10.2.3 Installation, Left

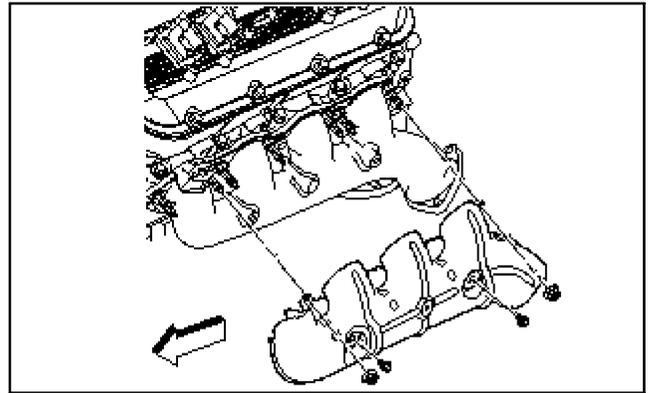


Notice: Refer to Fastener Notice in Cautions and Notices.

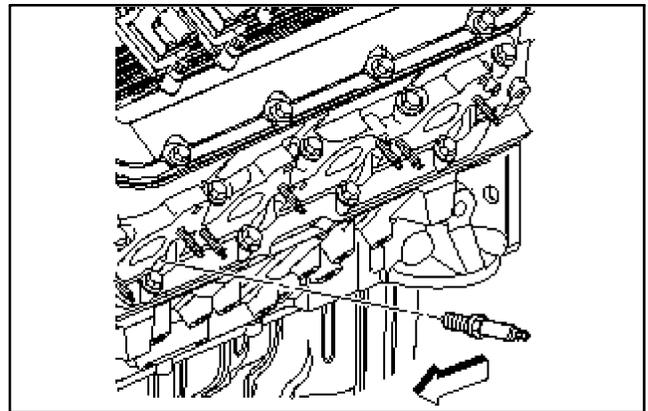
1. Install the exhaust manifold studs into the cylinder head, if necessary. Tighten the exhaust manifold studs to 20 Nm (15 ft. lb.).



2. Install the *new* left exhaust manifold gasket.
3. Install the left exhaust manifold.
4. Install the left exhaust manifold nuts and center bolt.
 - a. Tighten the left exhaust manifold center bolt to 35 Nm (26 ft. lb.).
 - b. Tighten the left exhaust manifold nuts to 16 Nm (12 ft. lb.).



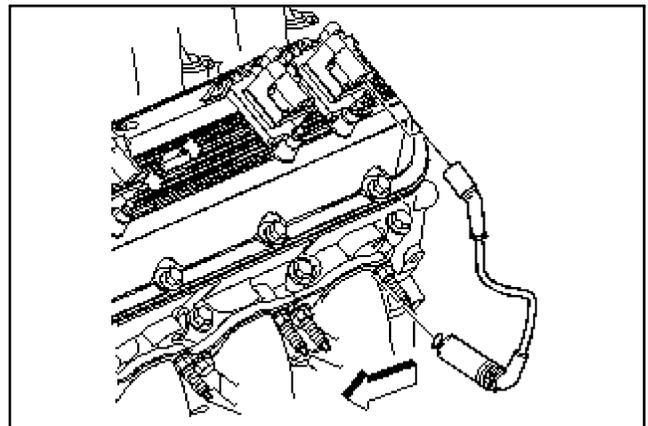
5. Install the left exhaust manifold heat shield.
6. Install the left exhaust manifold heat shield bolts and nuts. Tighten the left exhaust manifold heat shield bolts and nuts to 25 Nm (18 ft. lb.).



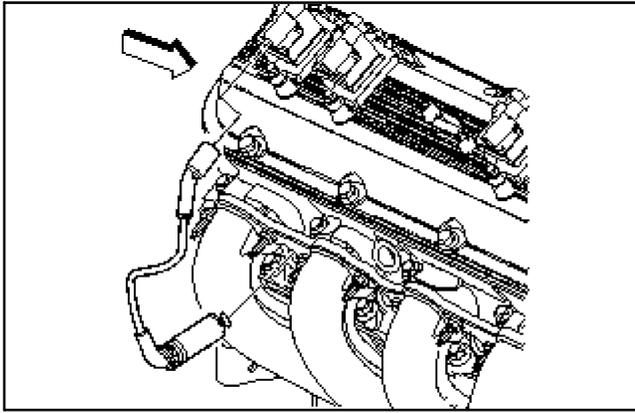
7. Install the left spark plugs. Tighten the left spark plugs to 30 Nm (22 ft. lb.).

Important: Fully install the spark plug wire by pushing on the exposed end of the spark plug boot. Do not push the spark plug wire on to the spark plug by using the metal heat shield.

8. Install the left spark plug wires to the spark plugs and ignition coils.

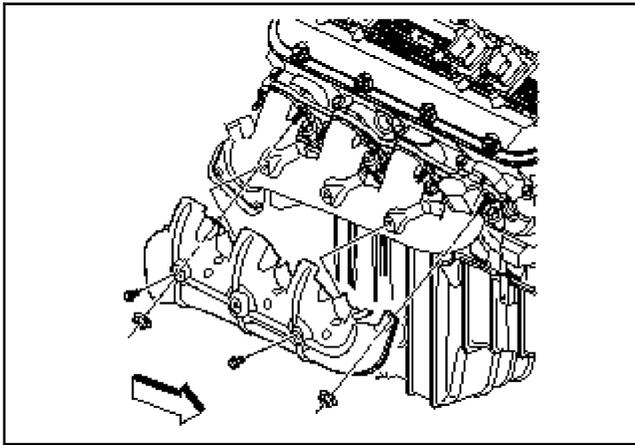


10.2.4 Removal, Right



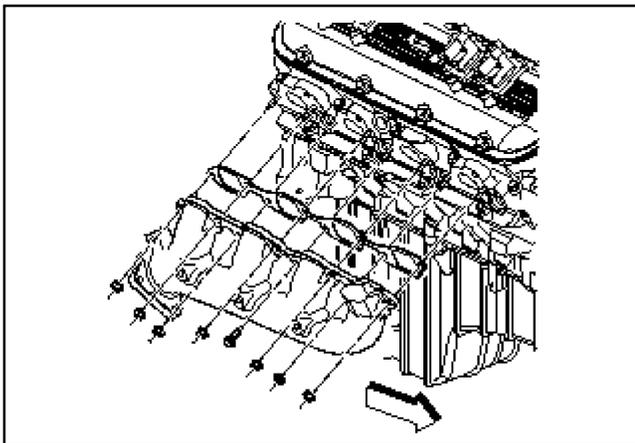
Notice: Twist the spark plug boot 1/2 turn to release the boot. Pull on the spark plug boot only. Do not pull on the spark plug wire or the wire could be damaged.

1. Remove the spark plug wires from the spark plugs and ignition coils.

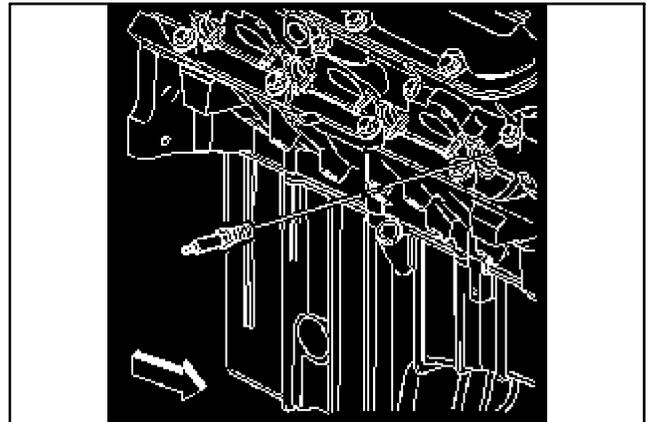


2. Remove the exhaust manifold heat shield bolts and nuts.

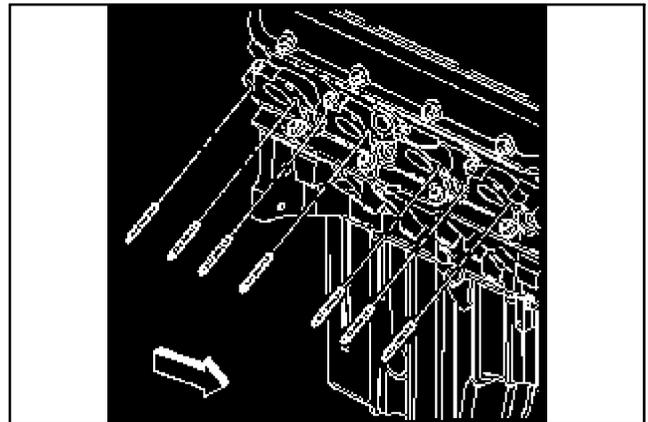
3. Remove the exhaust manifold heat shield.



4. Remove the exhaust manifold nuts and center bolt.
5. Remove the exhaust manifold.
6. Remove the exhaust manifold gasket.

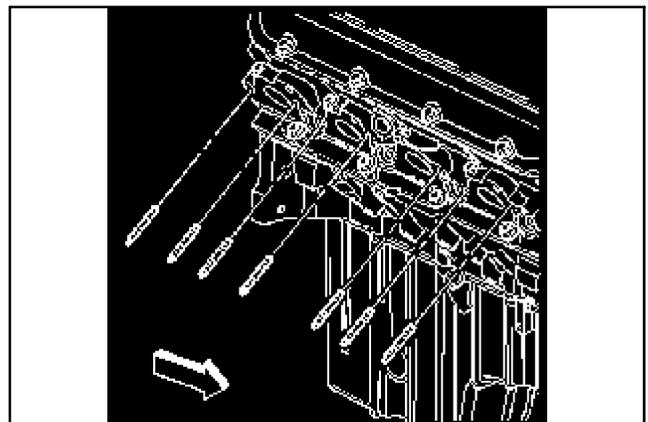


7. Remove the spark plugs, if required.



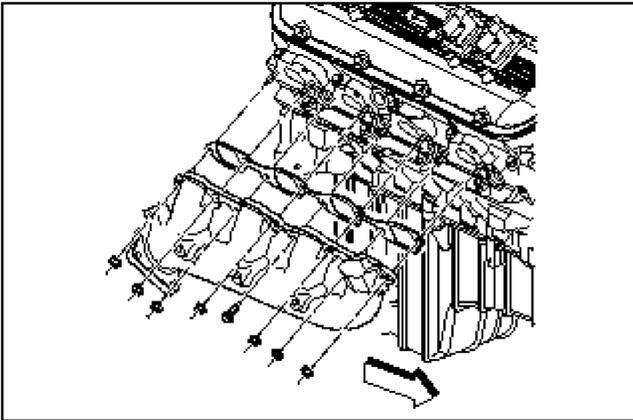
8. Remove the exhaust manifold studs, if required.

10.2.5 Installation, Right

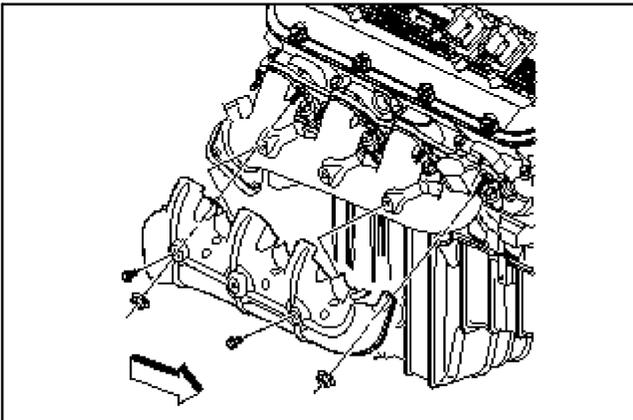


Notice: Refer to Fastener Notice in Cautions and Notices.

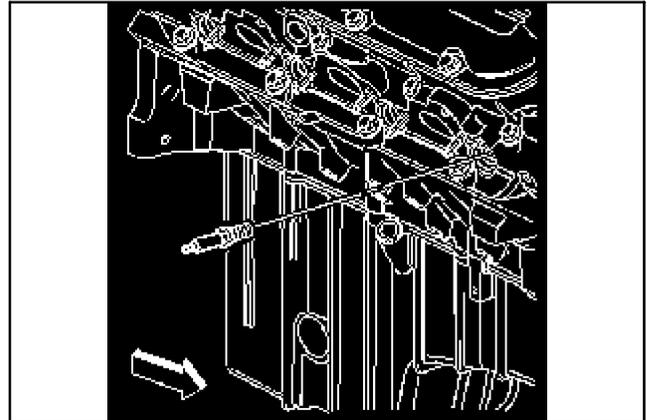
1. Install the exhaust manifold studs into the cylinder head, if necessary. Tighten the exhaust manifold studs to 20 Nm (15 ft. lb.).



2. Install the *new* right exhaust manifold gasket.
3. Install the right exhaust manifold.
4. Install the right exhaust manifold nuts and center bolt.
 - a. Tighten the right exhaust manifold center bolt to 35 Nm (26 ft. lb.).
 - b. Tighten the right exhaust manifold nuts to 16 Nm (12 ft. lb.).

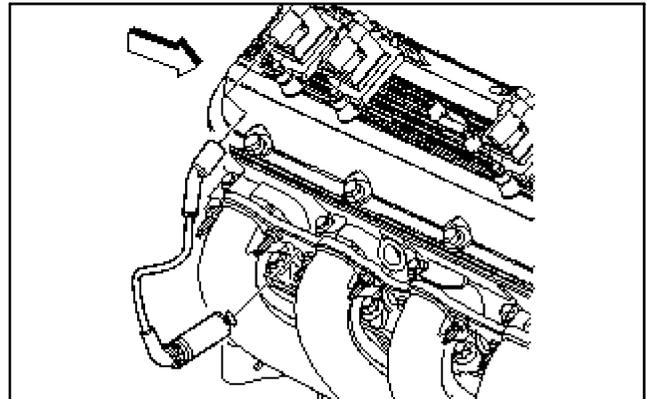


5. Install the right exhaust manifold heat shield.
6. Install the right exhaust manifold heat shield bolts and nuts. Tighten the right exhaust manifold heat shield bolts and nuts to 25 Nm (18 ft. lb.).



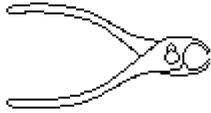
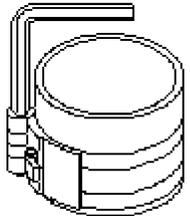
7. Install the right spark plugs. Tighten the right spark plugs to 30 Nm (22 ft. lb.).

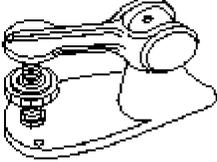
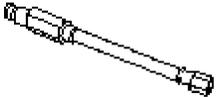
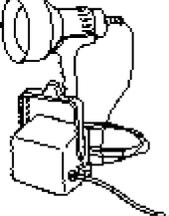
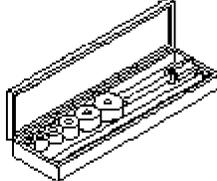
Important: Fully install the spark plug wire by pushing on the exposed end of the spark plug boot. Do not push the spark plug wire on to the spark plug by using the metal heat shield.

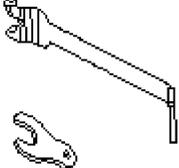
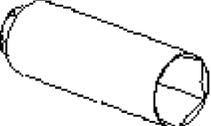
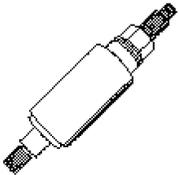
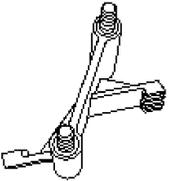
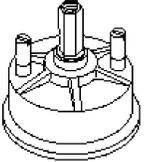


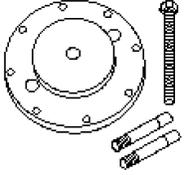
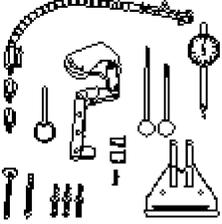
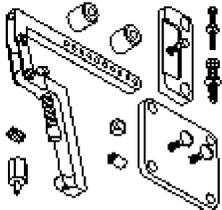
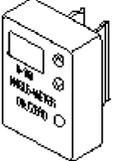
8. Install the right spark plug wires to the spark plugs and ignition coils.

Section 11 Special Tools and Equipment

Tool	Tool Description	Illustration
J 3049-A	Valve lifter remover	
J 5892-D	Valve spring compressor	
J 7872	Magnetic base dial indicator	
J 8001	Dial indicator set	
J 8037	Piston ring compressor	
J 8062	Valve spring compressor, head off	
J 8087	Cylinder bore gauge	
J 8089	Carbon removal brush	

Tool	Tool Description	Illustration
J 9666	Valve spring tester	
J 22102	Front cover aligner and seal installer	
J 22794	Spark plug port adapter	
J 24270	Cylinder bore ridge reamer	
J 28428-E	High intensity black light	
J 33049	Camshaft bearing service set	
J 35667-A	Cylinder head leakdown tester	
J 36857	Engine lift bracket Attach to the rear of the right cylinder head and to the front of the left cylinder head.	
J 38414-B	Harmonic balancer remover	

Tool	Tool Description	Illustration
J 39345	Thread repair kit	
J 41240	Fan clutch wrench	
J 41712	Oil pressure switch socket	
J 42845	Crankshaft balancer installer	
J 42846	Crankshaft protector button	
J 42847	Flywheel holding tool	
J 42849	Crankshaft rear seal installer	

Tool	Tool Description	Illustration
J 42851	Front cover oil seal installer	
J 43105	Valve stem seal installer	
J 43320	Crankshaft rear seal puller	
J 43690	Rod bearing clearance checking tool. See Section 5.1.5 for individual components.	
J 43690-100	Rod bearing clearance checking tool, adapter kit. See Section 5.1.5 for individual components.	
J 45059	Angle meter	
J 45299	Engine preluber	

