Service

Engine

Engine Models:

KG2204 Naturally Aspirated
KG2204T Turbocharged
Liquefied Petroleum Gas (LPG)/Propane/ Natural Gas (NG) Fueled

ISO 9001 KOHLER POWER SYSTEMS NATIONALLY REGISTERED

KOHLER. Power Systems

TP-6902 5/16a

INTRODUCTION

This manual provides service instructions for KOHLER Engine Models KG2204 and KG2204T. Keep this manual with the equipment for future reference. Refer to the KG2204 and KG2204T Operation and Maintenance Manual for detailed information on operating and maintaining the engine.

Information in this publication represents data available at the time of print. KOHLER Co. reserves the right to change this publication and the products represented without notice and without any obligation or liability whatsoever.

This engine operates on either Propane, Liquefied Petroleum Gas (LPG), or Natural Gas (NG) which are extremely flammable and explosive. Installation and repair of LPG/NG systems must be performed only by qualified LPG/NG technicians. Read this manual and carefully follow all procedures and safety precautions to ensure proper equipment operation and to avoid bodily injury.

Regular maintenance is very important to safe and efficient operation. Inspect the engine often and perform required maintenance at prescribed intervals. Service work must be performed by appropriately skilled and suitably-trained maintenance personnel familiar with engine diagnostics and repair.

Unless otherwise specified, all units of measurement are metric, followed by the Imperial (U.S.) equivalent.

IMPORTANT

Read all safety precautions and instructions carefully before operating or servicing equipment. Refer to operating instruction of equipment that this engine powers. Ensure engine is stopped and level before performing any maintenance or service.

California Proposition 65

⚠ WARNING

Engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm.

1.0 SAFETY AND GENERAL INFORMATION

2.0 GENERAL SPECIFICATIONS

3.0 ENGINE

4.0 SPECIAL TOOLS

1.0 SAFETY AND GENERAL INFORMATION

SAFETY ALERTS

⚠ DANGER

Danger indicates the presence of a hazard that *will cause severe personal injury, death*, or *substantial property damage*.

⚠ WARNING

Warning indicates the presence of a hazard that *can cause severe personal injury, death,* or *substantial property damage*.

⚠ CAUTION

Caution indicates the presence of a hazard that *will* or *can cause minor personal injury* or *property damage*.

NOTICE

Notice communicates installation, operation, or maintenance information that is safety related but not hazard related.

NOTE:

A Note is used to inform you of important installation, operation, or maintenance information.

SAFETY INFORMATION FOR THIS ENGINE

⚠ WARNING

Carbon monoxide can cause severe nausea, fainting, or death.

Avoid inhaling exhaust fumes.

Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.

⚠ WARNING

Risk of Fire. Can cause severe injury or death.

Do not smoke or permit flames or sparks near fuels or the fuel system.

⚠ WARNING

Avoid possible death or serious injury! Pinch and entanglement hazards! Never check drive belt tension while the engine is running.

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

⚠ WARNING

Rotating parts can cause severe injury.

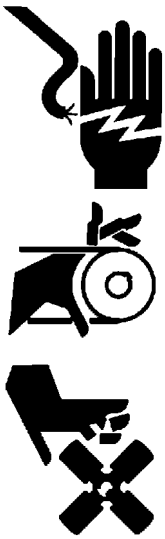
Stay away while the engine is in operation.

Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate the engine with covers, shrouds, or guards removed.

⚠ WARNING

Hot coolant and steam. Can cause severe injury or death.

Before removing the pressure cap, stop the engine and allow it to cool. Then loosen the pressure cap to relieve pressure.



⚠ WARNING

Accidental starts can cause severe injury or death.

Disconnect and ground spark plug leads before servicing.

Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug leads. 2) Disconnect negative (–) battery cable from battery.

Before disconnecting negative (–) ground cable, make sure all switches are OFF. If ON, a spark will occur at the ground cable terminal which could cause an explosion if hydrogen gas or LPG/NG fuel vapors are present.

⚠ WARNING

Explosive fuel can cause fires and severe burns.

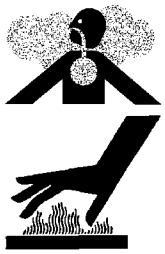
If a gaseous odor is detected, ventilate the area and contact an authorized service technician.

LPG (Liquefied Petroleum Gas) is extremely flammable and tends to settle in low areas where a spark or flame could ignite the gas. Do not start or operate this engine in a poorly ventilated area where leaking gas could accumulate and endanger the safety of persons in the area.

NG (Natural Gas) is extremely flammable, is lighter than air, and rises, Do not start or operate this engine in a poorly ventilated are where leaking gas could accumulate and endanger the safety of persons in the area.

To ensure personal safety, installation and repair of LPG/NG fuel supply systems must be performed only by qualified LPG/NG system technicians. Improperly installed and maintained LPG/NG equipment could cause the fuel supply system or other components to malfunction, causing gas leaks.

Observe federal, state, and local laws governing LPG/NG fuel, storage, and systems.



⚠ WARNING

Handling caustic engine fluids and chemical products. Can cause severe chemical burns, nausea, fainting, or death.

Most chemicals such as used engine oil, antifreeze/coolant, rustproofing agent, inhibiting oil, degreasing agent, spray paint, and adhesives are hazardous to health. Read and follow the user information found on the packaging. Avoid inhalation and skin contact. Use only in well-ventilated areas and use a protective mask when spraying. Store engine fluids and chemical products in a locked cabinet. Contact your local recycling center for disposal information and locations.

Fire-damaged or burned O-rings may cause the formation of hydrofluoric acid. Contact with hydrofluoric acid may cause severe skin irritation and chemical burns. O-rings and other fluoroelastomer seals exposed to fire or temperatures above 316 °C (600 °F) (i.e., during welding) may decompose forming hydrofluoric acid. Avoid inhalation or skin contact. Do not incinerate O-rings. Dispose of O-ring waste material in a responsible manner.

⚠ WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

⚠ WARNING

Airborne particles. Can cause severe injury or blindness.

Wear protective goggles and clothing when using power tools, hand tools, or compressed air.

⚠ WARNING

Explosive fuel vapors. Can cause severe injury or death.

Use extreme care when handling, storing, and using fuels.

Gas fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check the LPG vapor or natural gas fuel system for leakage by using a soap and water solution with the fuel system test pressurized to 6–8 ounces per square inch (10–14 inches water column). Do not use a soap solution containing either ammonia or chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

Used engine oil. Contact with used engine oil may cause severe skin irritation. Repeated and prolonged skin exposure may have other health risks. Used engine oil is a suspected carcinogen. Avoid contact with skin. Thoroughly wash your hands and nails with soap and water shortly after handling used engine oil. Wash or dispose of clothing or rags containing used engine oil. Dispose of used engine oil in a responsible manner. Contact your local recycling center for disposal information and locations.

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

KNOW YOUR ENGINE

Product identification numbers determine service parts. Record the product identification numbers in the spaces below immediately after unpacking the products so that the numbers are readily available for future reference.

Engine Identification

Record the product identification information from the engine nameplate.

Model Designation: _____

Serial Number: _____

RELATED LITERATURE

Literature Type	Part Number
KOHLER Models KG2204 and KG2204T Operation and Maintenance Manual	TP-6901
KOHLER Models KG2204 and KG2204T Service Manual / Troubleshooting / Diagnostics	TP-6903
KOHLER Models KG2204 and KG2204T Service Parts Manual	TP-6904

SERVICE PARTS

Contact a KOHLER authorized distributor/dealer for all maintenance, service, and engine parts. To find a KOHLER authorized distributor/dealer, visit KOHLERPower.com or call 1-800-2444 (U.S. and Canada).

SERVICE ASSISTANCE

For professional advice on power system requirements and conscientious service, please contact your nearest authorized Kohler distributor/dealer.

- Consult the Yellow Pages.
- Visit the Kohler Power Systems website at KohlerPower.com.
- Look at the labels and decals on your Kohler product or review the appropriate literature or documents included with the product.
- Call toll free in the US and Canada 1-800-544-2444.
- Outside the US and Canada, call the nearest regional office.

Headquarters Europe, Middle East, Africa (EMEA)
Kohler Power Systems Netherlands B.V.
Kristallaan 1
4761 ZC Zevenbergen
The Netherlands
Phone: (31) 168 331630
Fax: (31) 168 331631

Asia Pacific
Power Systems Asia Pacific Regional Office
Singapore, Republic of Singapore
Phone: (65) 6264-6422
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China
North China Regional Office, Beijing
Phone: (86) 10 6518 7950
(86) 10 6518 7951
(86) 10 6518 7952
Fax: (86) 10 6518 7955
East China Regional Office, Shanghai
Phone: (86) 21 6288 0500
Fax: (86) 21 6288 0550

India, Bangladesh, Sri Lanka
India Regional Office
Bangalore, India
Phone: (91) 80 3366208
(91) 80 3366231
Fax: (91) 80 3315972

Japan, Korea
North Asia Regional Office
Tokyo, Japan
Phone: (813) 3440-4515
Fax: (813) 3440-2727

Latin America
Latin America Regional Office
Lakeland, Florida, USA
Phone: (863) 619-7568
Fax: (863) 701-7131

MODEL KG2204 ENGINE SIDE VIEWS

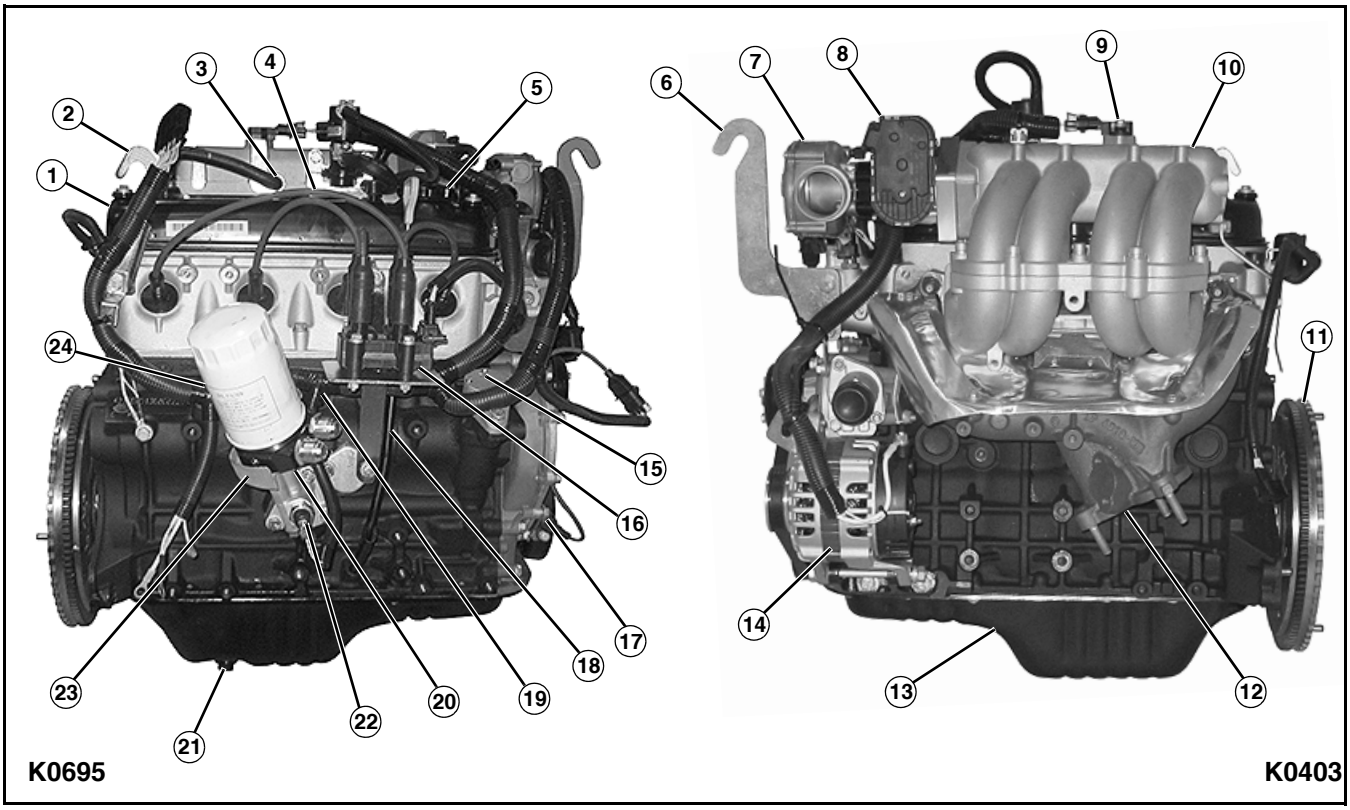


Figure 1-1

1	Rocker Arm Cover	7	Air-Fuel Mixer	13	Oil Pan	19	Knock Sensor (if equipped with turbocharger)
2	Rear Hanger	8	Throttle Body	14	Battery Charging Alternator	20	Oil Cooler Adapter
3	Crankcase Breather	9	TMAP Sensor[1]	15	Oil Pump Drive	21	Oil Pan Drain Plug
4	Spark Plug Wires	10	Intake Manifold	16	Ignition Coil	22	Oil Pressure Sender
5	Oil Filler Cap	11	Flywheel	17	Crankshaft Position Sensor	23	Oil Filter Base
6	Front Hanger	12	Exhaust Manifold	18	Oil Dipstick and Tube	24	Oil Filter

1) Air Temperature / Manifold Absolute Pressure (TMAP)

MODEL KG2204 FRONT AND REAR VIEWS

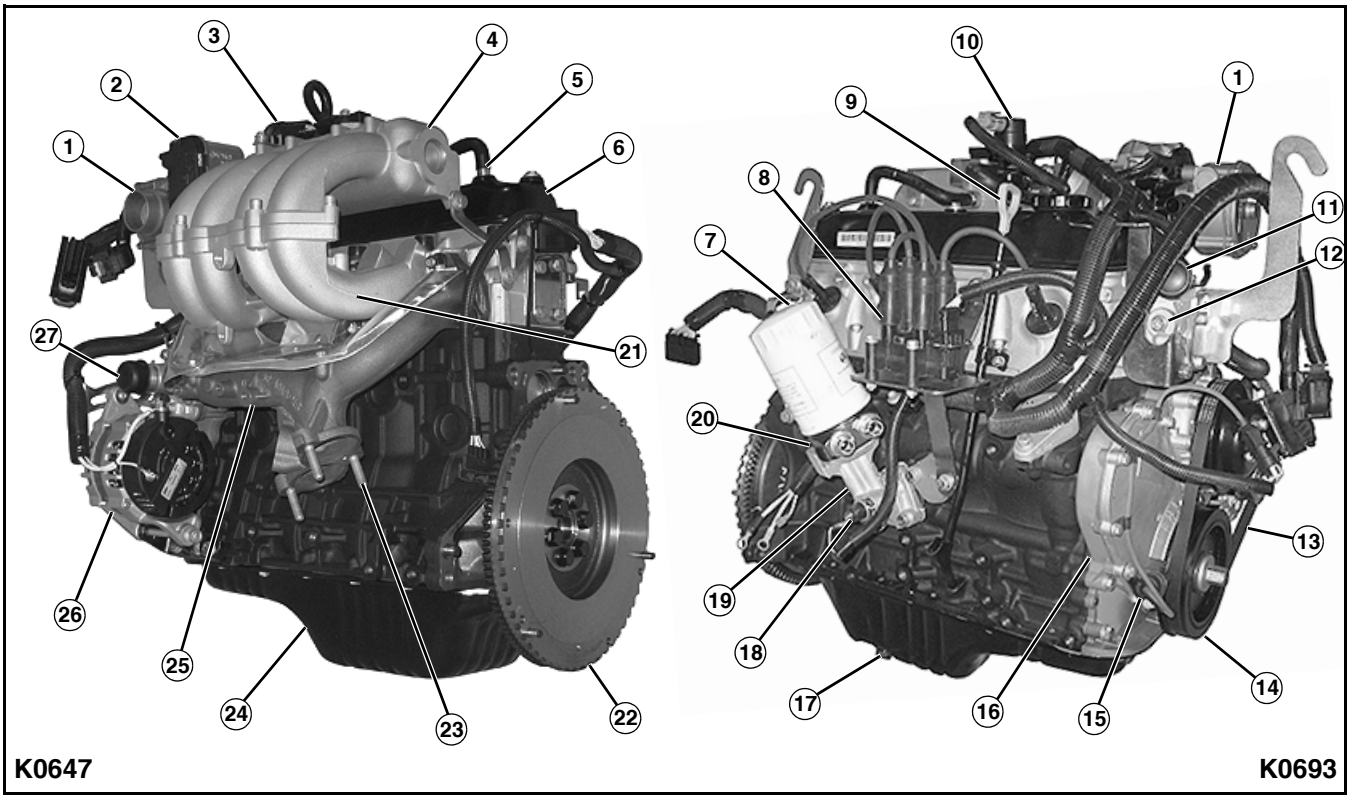


Figure 1-2

1	Air-Fuel Mixer	8	Ignition Coil	15	Crankshaft Position Sensor	22	Flywheel
2	Throttle Body	9	Oil Dipstick	16	Timing Cover	23	Exhaust Manifold Studs
3	TMAP Sensor	10	Fuel Control Valve	17	Oil Drain Plug	24	Oil Pan
4	Upper Intake Manifold	11	Upper Coolant Outlet	18	Oil Pressure Sensor (PGS)	25	Exhaust Manifold
5	PCV Valve	12	Coolant Temperature Sensor	19	Oil Filter Base	26	Battery Charging Alternator
6	Rocker Arm Cover	13	Drive Belt	20	Oil Cooler Adapter	27	Water Pump Inlet
7	Oil Filter	14	Vibration Dampener	21	Lower Intake Manifold		

MODEL KG2204T ENGINE SIDE VIEWS

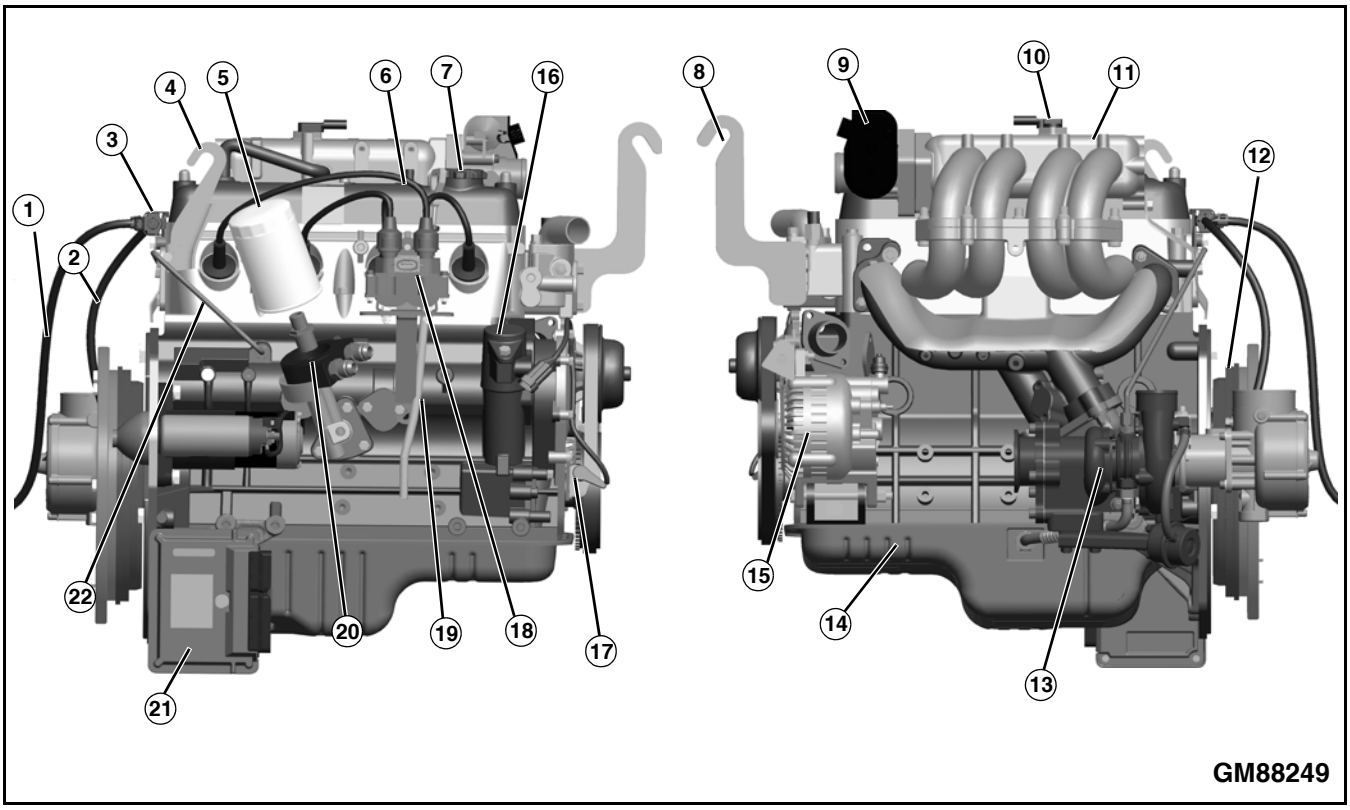


Figure 1-3

1	Regulator to FCV Hose	9	Throttle Body	16	Oil Pump Drive
2	FCV to Mixer Hose	10	TMAP Sensor[1]	17	Crankshaft Position Sensor
3	Fuel Control Valve	11	Intake Manifold	18	Ignition Coil
4	Rear Hanger	12	Flywheel	19	Oil Dipstick and Tube
5	Oil Filter	13	Turbocharger	20	Oil Cooler Adapter and Stand-off
6	Spark Plug Wires	14	Oil Pan	21	Engine Control Module
7	Oil Filler Cap	15	Battery Charging Alternator	22	Turbo Oil Feed Line
8	Front Hanger				

1) Air Temperature / Manifold Absolute Pressure (TMAP)

MODEL KG2204T FRONT AND REAR VIEWS

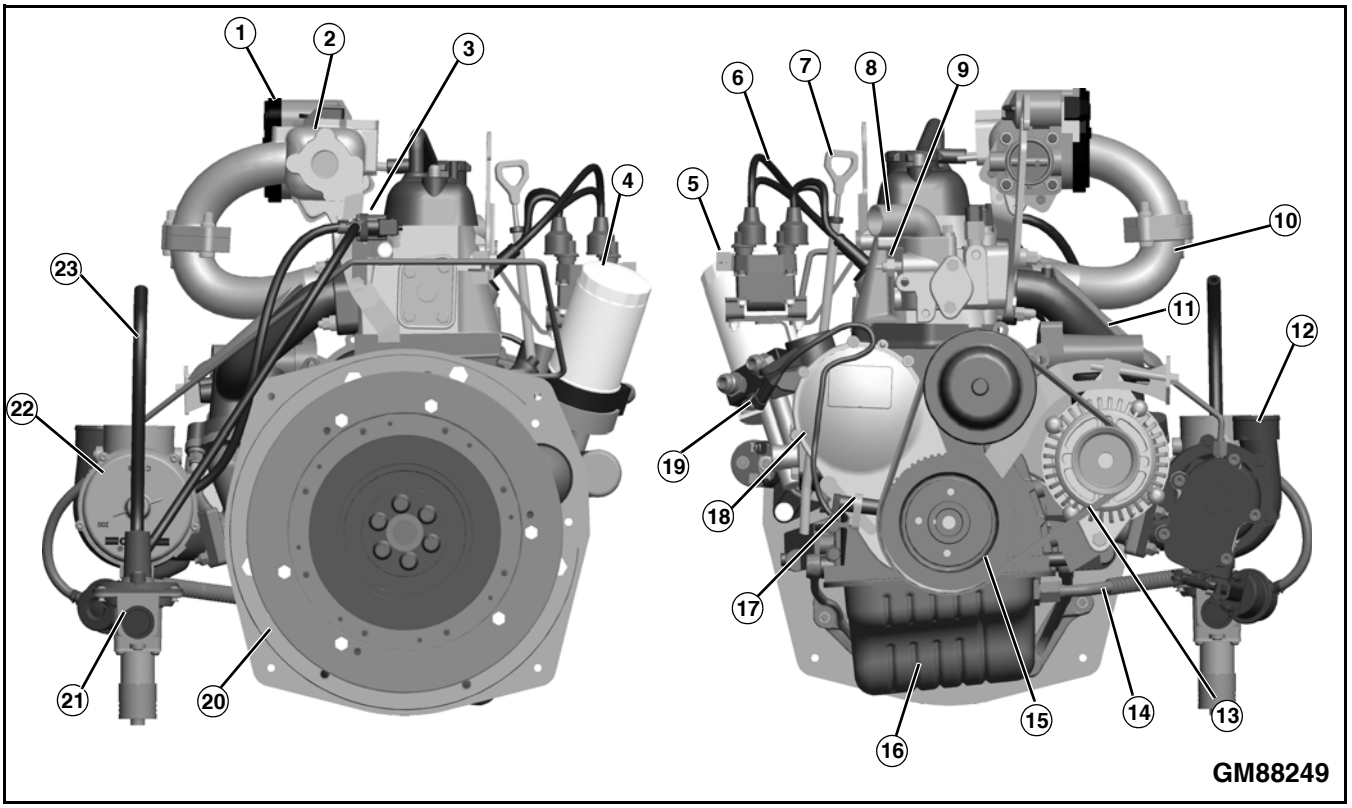


Figure 1-4

1	Throttle Body	9	Coolant Temperature Sensor	17	Crankshaft Position Sensor
2	Upper Intake Manifold	10	Lower Intake Manifold	18	Timing Cover
3	Fuel Control Valve	11	Turbo Oil Feed Line	19	Oil Pressure Sensor
4	Oil Filter	12	Turbocharger	20	Flywheel
5	Coil	13	Drive Belt	21	Dual Fuel Regulator (DFR)
6	Spark Plug Wires	14	Turbo Oil Return Line	22	Air-Fuel Mixer (AFM)
7	Oil Dipstick	15	Vibration Dampener	23	DFR Breather Hose
8	Upper Coolant Outlet	16	Oil Pan		

2.0 GENERAL SPECIFICATIONS

ENGINE SPECIFICATIONS

Item	Specifications	
Engine Model	KG2204	KG2204T
Block Type	I-4	
Number of Cylinders	4	
Cylinder Bore	91 mm (3.5 in.)	
Piston Stroke	86 mm (3.4 in.)	
Displacement	2.2 L (134.25 $in.^3$)	
Rated Output	30 kW (40 HP) @ 1800 rpm	47.8 kW (64.1 HP) @ 1800 rpm
Fuel Type	Propane, Liquid Petroleum Gas (LPG) or Natural Gas (NG).	
Oil Type / Weight	KOHLER synthetic engine oil, SAE Class SJ or higher. Weight: variable per ambient temperature. See “Fluid Specifications” on page 19.	
Oil Dry Fill Capacity	4.2 L (4.4 qt.)	
Rotating Direction of Crankshaft	Counterclockwise (face to flywheel)	
Compression Ratio	10.5:1	
Cylinder Fire Order	1-3-4-2	
Lubricating Style	Pressurized	
Starting Style	Electric	
Net Weight (Dry)	145 kg (320 lb.)	
Overall Dimensions (L x W x H)	826 x 547 x 647 mm (32.5 x 21.5 x 25.5 in.)	
Aspiration	Natural	Turbocharged
Charge Air Cooler	NA	Aluminum core

SPECIFICATIONS OF MAIN COMPONENTS

Item	Specifications	
	KG2204	KG2204T
Oil Filter/ Breather	Paper, Rocker Arm Covers, Top Oil Filter	
Oil Pump	Rotor type	
Water Pump	Centrifugal type; no fan	
Flywheel	Flywheel with attachment provisions for flywheel adapter (KOHLER part number GM88832)	
Thermostat Settings	Valve open at 76°C (169°F) Valve lift fully open at 88°C (190°F)	
Alternator	Rated voltage 14 V, rated current 90 A	
Electric Starter	1.2 kW, speed reduction type	
Ignition System	Electronic	
Spark Plug	GM92785 Screw thread M14 x 1.25	GM100158 (use only Kohler genuine service parts)

ADJUSTMENT SPECIFICATIONS

Item	Specifications	
	KG2204	KG2204T
Spark Plug Gap	0.9–1.0 mm (0.036–0.040 in.)	0.7–0.8 mm (0.028–0.031 in.)
Drive Belt Tension at pressure of 98 N (22 lb)	Deflection of a new belt is 5–7 mm (0.20–0.28 in.) Deflection of a used belt is 7–8 mm (0.28–0.31 in.)	
Fuel Pressure Regulator	Nonadjustable, LPG or NG selectable	
Throttle	Nonadjustable, ECM controlled	
Air–Fuel Mixer	Tamper-proof; nonadjustable	
Fuel Control Valve	Nonadjustable	

FLUID SPECIFICATIONS

Oil Recommendations

NOTE:

- *Do not mix different brands or types of oil.*
- *Do not over-fill or under-fill the engine's lubrication system. See "Engine Specifications" in Section 2.*

Use oil that displays the American Petroleum Institute (API) Starbrust certification mark FOR GASOLINE ENGINES on the container. Do not use straight-weight oils recommended for industrial or stationary engines. CC or CD classification oils, even when labeled HEAVY DUTY or For Natural Gas Engines are not acceptable.

Synthetic oil is recommended for use in LPG/NG fueled engines. We recommend the use of KOHLER engine oils for best performance.

In colder climates such as the United States and Canada, use SAE-30. For warmer climates, select oil viscosity based on the ambient air temperature at the time of operation. See Figure 2-1.

Ambient Temperature	Engine Oil Type
-18°C (0°F) and above	SAE 10W-30
Below -18°C (0°F)	SAE 5W-30

Figure 2-1: Engine Oil Selection

Grease Recommendations

The alternator and starter bearings on this engine must be lubricated with a high-quality lithium based automotive grease.

Coolant Recommendations

Use only a mixture of 50% long life coolant and 50% clean, softened water to inhibit rust/corrosion and prevent freezing.

A solution of 50% long life coolant provides freezing protection to –37°C (–34°F) and overheating protections to 149°C (300°F). A coolant solution with less than 50% long life coolant may not provide adequate freezing and overheating protection. Do not mix long life coolants and conventional coolants. **Do not mix different types and/or colors of long life coolants.**

NOTE:

Fuel system components are not adjustable and cannot be serviced. Contact your authorized KOHLER authorized distributor/dealer for replacements.

STANDARD TORQUE SPECIFICATIONS

American Standard Fasteners Torque Specifications					
Size	Torque Measurement	Assembled into Cast Iron or Steel			Assembled into Aluminum Grade 2 or 5
		Grade 2	Grade 5	Grade 8	
8-32	N•m (in. lb.)	1.8 (16)	2.3 (20)	—	See Note 3
10-24	N•m (in. lb.)	2.9 (26)	3.6 (32)	—	
10-32	N•m (in. lb.)	2.9 (26)	3.6 (32)	—	
1/4-20	N•m (in. lb.)	6.8 (60)	10.8 (96)	14.9 (132)	
1/4-28	N•m (in. lb.)	8.1 (72))	12.2 (108)	16.3 (144)	
5/16-18	N•m (in. lb.)	13.6 (120)	21.7 (192)	29.8 (264)	
5/16-24	N•m (in. lb.)	14.9 (132)	23.1 (204)	32.5 (288)	
3/8-16	N•m (ft. lb.)	24.0 (18)	38.0 (28)	53.0 (39)	
3/8-24	N•m (ft. lb.)	27.0 (20)	42.0 (31)	60.0 (44)	
7/16-14	N•m (ft. lb.)	39.0 (29)	60.0 (44)	85.0 (63)	
7/16-20	N•m (ft. lb.)	43.0 (32)	68.0 (50)	95.0 (70)	
1/2-13	N•m (ft. lb.)	60.0 (44)	92.0 (68)	130.0 (96)	
1/2-20	N•m (ft. lb.)	66.0 (49)	103.0 (76)	146.0 (108)	
9/16-12	N•m (ft. lb.)	81.0 (60)	133.0 (98)	187.0 (138)	
9/16-18	N•m (ft. lb.)	91.0 (67)	148.0 (109)	209.0 (154)	
5/8-11	N•m (ft. lb.)	113.0 (83)	183.0 (135)	259.0 (191)	
5/8-18	N•m (ft. lb.)	128.0 (94)	208.0 (153)	293.0 (216)	
3/4-10	N•m (ft. lb.)	199.0 (147)	325.0 (240)	458.0 (338)	
3/4-16	N•m (ft. lb.)	222.0 (164)	363.0 (268)	513.0 (378)	
1-8	N•m (ft. lb.)	259.0 (191)	721.0 (532)	1109.0 (818)	
1-12	N•m (ft. lb.)	283.0 (209)	789.0 (582)	1214.0 (895)	

NOTE:

1. The torque values above are general guidelines. always use the torque values specified in the service manuals and/or assembly drawings when they differ from above torque values.
2. The torque values above are based on new plated threads. Increase torque values by 15% if non-plated threads are used.
3. Hardware threaded into aluminum must have either two diameters of thread engagement or a 30% or more reduction in the torque to prevent stripped threads.
4. Torques values are calculated as equivalent stress loading on American hardware with an approximate preload of 90% of the yield strength and a friction coefficient of 0.125.

Metric Fasteners Torque Specifications					
Size	Torque Measurement	Assembled into Cast Iron or Steel			Assembled into Aluminum Grade 5.8 or 8.8
		Grade 5.8	Grade 8.8	Grade 10.9	
M6 x 1.00	N•m (ft. lb.)	6.2 (4.6)	12 (9)	13.6 (10)	See Note 3
M8 x 1.25	N•m (ft. lb.)	15.0 (11)	29.6 (22)	33.0 (24)	
M8 x 1.00	N•m (ft. lb.)	16.0 (11)	24.0 (18)	34.0 (25)	
M10 x 1.50	N•m (ft. lb.)	30.0 (22)	52.5 (39)	65.0 (48)	
M10 x 1.25	N•m (ft. lb.)	31.0 (23)	47.0 (35)	68.0 (50)	
M12 x 1.75	N•m (ft. lb.)	53.0 (39)	80.0 (59)	115.0 (85)	
M12 x 1.50	N•m (ft. lb.)	56.0 (41)	85.0 (63)	122.0 (90)	
M14 x 2.00	N•m (ft. lb.)	83.0 (61)	135.0 (100)	180.0 (133)	
M14 x 1.50	N•m (ft. lb.)	87.0 (64)	133.0 (98)	190.0 (140)	
M16 x 2.00	N•m (ft. lb.)	127.0 (94)	194.0 (143)	278.0 (205)	
M16 x 1.50	N•m (ft. lb.)	132.0 (97)	201.0 (148)	287.0 (212)	
M18 x 2.50	N•m (ft. lb.)	179.0 (132)	273.0 (201)	390.0 (288)	
M18 x 1.50	N•m (ft. lb.)	189.0 (140)	289.0 (213)	413.0 (305)	

NOTE:

1. The torque values above are general guidelines. Always use the torque values specified in the service manuals and/or assembly drawings when they differ from above torque values.
2. The torque values above are based on new plated threads. Increase torque values by 15% if non-plated threads are used.
3. Hardware threaded into aluminum must have either two diameters of thread engagement or a 30% or more reduction in the torque to prevent stripped threads.
4. Torques values are calculated as equivalent stress loading on American hardware with an approximate preload of 90% of the yield strength and a friction coefficient of 0.125.

3.0 ENGINE

INTRODUCTION

The KG2204 and KG2204T are a four-stroke internal combustion engine specifically designed for use in stationary power generating applications.

The engine is certified to operate on either Propane, Liquefied Petroleum Gas (LPG), or Natural Gas (NG) fuels depending on user requirements. System configuration is factory preset for NG. Instructions for switching to LPG are provided within this chapter.

The fuel system on this engine uses a closed loop design. As the engine runs, sensors located at various points within the system provide continuous operating feedback to the Engine Control Module (ECM). The ECM adjusts the engine speed and fuel supply in response to changes in the applied load, surrounding air temperature, operating temperature of the engine, and amount of oxygen present in the exhaust.

Refer to the equipment Operation Manual for specific information on how fault codes are displayed.

REPAIR SPECIFICATIONS

Item	Specifications
Compression Pressure	Standard 1379 kPa (200 psi) Limit 1241 kPa (180 psi)
Thermostat Specifications	Start to Open 76°C (169°F). Fully Open 88°C (190°F)
Ignition Wire Resistance	25k Ohms (Maximum)
Drive Belt Tension	Applied Test Pressure 98 N (22 lbf.) Belt Deflection - New 5–7 mm (0.20–0.28 in.) Belt Deflection - Used 7–8 mm (0.28–0.31 in.)
Spark Plug Gap	KG2204: 0.9–1.0 mm (0.036–0.040 in.) KG2204T: 0.7–0.8 mm (0.028–0.031 in.)
Intake Manifold Distortion Limit	0.40 mm (0.0157 in.)
Exhaust Manifold Distortion Limit	0.40 mm (0.0157 in.)
Cylinder Head Warpage—Maximum	Combustion Chamber Surface 0.15 mm (0.0059 in.) Intake/Exhaust Manifold Surface 0.10 mm (0.0039 in.)
Cylinder Block Warpage—Maximum	0.05 mm (0.0019 in.)

Item	Specifications
Rocker Arm Specifications	Rocker Arm—Inside Diameter (Bore) 18.500–18.513 mm (0.7283–0.7288 in.) Rocker Arm Shaft—Outside Diameter 18.467–18.482 mm (0.7270–0.7276 in.) Rocker Arm—Standard Oil Clearance 0.018–0.046 mm (0.0007–0.0018 in.) Rocker Arm—Maximum Oil Clearance 0.08 mm (0.0031 in.)
Valve Specifications	Valve Guide Bushing—Inside Diameter 8.010–8.030 mm (0.3153–0.3161 in.) Intake Valve—Valve Stem Diameter 7.970–7.985 mm (0.3137–0.3143 in.) Exhaust Valve—Valve Stem Diameter 7.965–7.98 mm (0.3135–0.3141 in.) Intake Valve—Standard Oil Clearance 0.025–0.060 mm (0.0009–0.0023 in.) Exhaust Valve—Standard Oil Clearance 0.030–0.065 mm (0.0011–0.0025 in.) Intake Valve—Maximum Oil Clearance 0.10 mm (0.0039 in.) Exhaust Valve—Maximum Oil Clearance 0.12 mm (0.0047 in.)
Valve Margin Specifications	Intake Valve—Standard Margin Thickness 1.0–1.4 mm (0.0393–0.0551 in.) Exhaust Valve—Standard Margin Thickness 1.3–1.7 mm (0.0511–0.0669 in.) Intake Valve—Minimum Margin Thickness 0.5 mm (0.0196 in.) Exhaust Valve—Minimum Margin Thickness 0.8 mm (0.0314 in.)
Valve Specifications	Intake Valve—Standard Overall Length 108.2 mm (4.2598 in.) Exhaust Valve—Standard Overall Length 108.5 mm (4.2716 in.) Intake Valve—Minimum Overall Length 107.7 mm (4.2401 in.) Exhaust Valve—Minimum Overall Length 108.0 mm (4.2519 in.)
Valve Seat—Contact Width	1.2–1.6 mm (0.0472–0.0629 in.)
Intake And Exhaust Valve Face Angle	44.5° Angle
Valve Spring—Free Length	46.75–47.25 mm (1.8208–1.8602 in.)
Valve Spring—Squareness Limit	<2.0 mm (0.0787 in.)

Item	Specifications
Valve Spring Specifications	Valve Spring—Installed Height 40.6 mm (1.5984 in.) Valve Spring—Tension 282–345 N (63.4–77.56 lbf.)
Pushrod—Maximum Runout	0.30 mm (0.0118 in.)
Valve Guide Specifications	Valve Guide Bore—Standard Valve Guide 13.000–13.027 mm (0.5118–0.5129 in.) Valve Guide Bore—Resize Dimensions 13.050–13.077 mm (0.5138–0.5148 in.) Valve Guide Bore—Oversize Valve Guide 13.050–13.077 mm (0.5129–0.5138 in.) Valve Guide Bore—Maximum Valve Guide Bore Size 13.077 mm (0.5129 in.)
Valve Guide—Installed Height	20.31 mm (0.080 in.)
Lifter Bore Inside Diameter	21.412–21.443 mm (0.843–0.844 in.)
Valve Lifter Outside Diameter	21.387–21.400 mm (0.8420–0.8425 in.)
Lifter Bore Oil Clearance	Standard 0.012–0.056 mm (0.0004–0.0022 in.) Maximum 0.10 mm (0.0039 in.)
Timing Chain Slack	Applied Test Pressure 98 N (72 lbf.) Maximum Chain Slack 13.5 mm (0.531 in.)
Tensioner Thickness	Standard Thickness 15.0 mm (0.59 in.) Minimum Thickness 12.5 mm (0.49 in.)
Damper Thickness	Standard Thickness 6.6 mm (0.259 in.) Minimum Thickness 5 mm (0.196 in.)
Sprocket Diameter (With Chain)	Crankshaft Chain Sprocket 59 mm (2.32 in.) Camshaft Chain Sprocket 114 mm (4.48 in.)
Chain Elongation—Maximum	Test Tension 49 N (36 lbf.) Chain Length 291.4 mm (11.47 in.)
Camshaft Runout—Maximum	0.06 mm (0.0023 in.)

Item	Specifications
Camshaft Lobe Height	Standard Intake 38.620–38.720 mm (1.5205–1.5244 in.) Exhaust 38.629– 38.729 mm (1.5208–1.5248 in.) Minimum Intake 38.26 mm (1.5062 in.) Exhaust 38.27 mm (1.5066 in.)
Camshaft Journal Diameter	Standard (from the front side) No. 1 46.459–46.475 mm (1.8291–1.8297 in.) No. 2 46.209–46.225 mm (1.8192–1.8199 in.) No. 3 45.959–45.975 mm (1.8094–1.8100 in.) No. 4 45.709–45.725 mm (1.7996–1.8002 in.) No. 5 45.459–45.475 mm (1.7897–1.7904 in.)
Camshaft Thrust Plate Clearance	Standard 0.07–0.22 mm (0.00270–0086 in.) Maximum 0.30 mm (0.0118 in.)
Camshaft Bearing Bore Specifications	Standard (from the front of the cylinder block) No. 1 46.500–46.540 mm (1.8307–1.8323 in.) No. 2 46.250–46.290 mm (1.8209–1.8224 in.) No. 3 46.000–46.040 mm (1.8110–1.8126 in.) No. 4 45.750–45.790 mm (1.8012–1.8028 in.) No. 5 45.500–45.540 mm (1.7913–1.7929 in.)
Camshaft Bearing Clearances	Standard 0.025–0.081 mm (0.0010–0.0032 in.) Maximum 0.10 mm (0.0039 in.)
Oil Pump Driven Rotor-to-Pump Body Clearance	Standard 0.1–0.15 mm (0.0039–0.0059 in.) Limit 0.2 mm (0.008 in.)

Item	Specifications
Oil Pump Rotor Side Clearance	Standard 0.03–0.07 mm (0.0012–0.0028 in.) Limit 0.15 mm (0.0059 in.)
Oil Pump Rotor Tip Clearance	Standard 0.07–0.12 mm (0.0028–0.0047 in.) Limit 0.2 mm (0.008 in.)
Connecting Rod Thrust Clearance	Standard 0.160–0.312 mm (0.006–0.012 in.) Maximum 0.35 mm (0.013 in.)
Crankshaft Thrust Clearance	Standard 0.020–0.220 mm (0.0007–0.0086 in.) Maximum 0.30 mm (0.011 in.)
Crankshaft Thrust Washer Thickness	2.044–2.490 mm (0.0804–0.0806 in.)
Crankshaft Main Journal Oil Clearance	Standard 0.020–0.051mm (0.0007–0.0020 in.) Maximum 0.10 mm (0.039 in.)
Connecting Rod Journal Oil Clearance	Standard Clearance 0.020–0.051 mm (0.0007–0.002 in.) Maximum Clearance 0.10 mm (0.0039 in.)
Connecting Rod Bend—Maximum	0.05 mm per 100 mm (0.0019 in. per 3.93 in.)
Connecting Rod Twist—Maximum	0.05 mm per 100 mm (0.0019 in. per 3.93 in.)
Piston Ring-to-Piston Ring Land Clearance	0.030–0.070 mm (0.0011–0.0027 in.)
Piston Ring End Gap	Standard No. 1 0.22–0.51 mm (0.0086–0.020 in.) No. 2 0.15–0.47 mm (0.0059–0.018 in.) Oil (Side rail) 0.20–0.70 mm (0.0078-0.0027 in.) Maximum No. 1 1.11 mm (0.043 in.) No. 2 1.07 mm (0.042 in.) Oil (Side rail) 1.10 mm (0.043 in.)
Piston Pin Specifications	Piston Pin Bore—Diameter 22.010–22.016 mm (0.8665–0.08667 in.) Piston Pin—Diameter 22.003–22.006 mm (0.8662–0.8664 in.) Piston Pin Oil Clearance 0.004–0.013 mm (0.0002–0.0005 in.)

Item	Specifications
Piston Specifications—Diameter	Standard Group 1 90.938–90.948 mm (3.5802–3.5806 in.) Group 2 90.948–90.958 mm (3.5806–3.5810 in.) Group 3 90.958–90.968 mm (3.5810–3.5814 in.) Oversize Piston 91.425–91.955 mm (3.599–3.620 in.) Cylinder Bore-to-Piston—Clearance 0.065–0.085 mm (0.0025–0.0033 in.)
Main Journal And Crank Pin Diameter	Main Journal Diameter 57.985–58.000 mm (2.282–2.283 in.) Crank Pin Diameter 47.985–48.000 mm (1.8891–1.8897 in.)
Main Journal And Crank Pin Taper And Runout—Maximum	0.02 mm (0.0007 in.)
Crankshaft Circle Runout—Maximum	0.06 mm (0.0023 in.)
Cylinder Deck Warpage—Maximum	0.05 mm (0.002 in)
Standard Cylinder Bore Diameter	Standard Group 1 91.000–91.010 mm (3.5820–3.5830 in.) Group 2 91.010–91.020 mm (3.5830–3.5834 in.) Group 3 91.020–91.030 mm (3.5834–3.5838 in.) Maximum Diameter 91.23 mm (3.591 in.)
Oversize Cylinder Bore Diameter	+0.50 mm Piston Diameter 91.50–92.24 mm (3.602–3.631 in.) Maximum Diameter 92.24 mm (3.631 in.)

REPAIR TORQUE SPECIFICATIONS

Item	N•m	ft.lb.
Water Pump Bolt And Nut	18 N•m	13 ft.lb.
Spark Plugs KG2204 KG2204T	 18 N•m 25 N•m	 13.3 ft.lb. 18.4 ft.lb.
Intake Manifold Flange Nut	20 N•m	15 ft.lb.
Exhaust Manifold Flange Nut	20 N•m	15 ft.lb.
Flywheel Bolt	85 N•m	63 ft.lb.
Crankshaft Vibration Dampener Bolt	160 N•m	118 ft.lb.
Rear Crankshaft Seal Retainer Bolt	12 N•m	9 ft.lb.
Oil Pan Bolt And Nut	13 N•m	10 ft.lb.
Oil Drain Plug	20–25 N•m	15–18 ft.lb.
Oil Pump Drive Bolt	13 N•m	10 ft.lb.
Cylinder Head Bolt M12 Bolts (10 Used) M8 Bolts (3 Used)	 88–98 N•m 19–25 N•m	 64.90–72.28 ft.lb 14.01–18.44 ft.lb.
Rocker Arm Shaft Bolts	25–32 N•m	18.5–23.6 ft.lb.
Camshaft Sprocket Bolt	90 N•m	66 ft.lb.
Camshaft Thrust Plate Bolt	18 N•m	13 ft.lb.
Camshaft Timing Gear Bolt	91 N•m	67 ft.lb.
Chain Tensioner Bolt	18 N•m	13 ft.lb.
Chain Damper Bolt	18 N•m	13 ft.lb.
Timing Cover Bolt	18 N•m	13 ft.lb.
Oil Pump Cover Bolt	8 N•m	5.8 ft.lb.
Connecting Rod Cap	49 N•m	36 ft.lb.
Main Bearing Cap Bolt	79 N•m	58 ft.lb.
Turbocharger Exhaust Flange Adapter Stud Exhaust Flange Adapter to Turbo Nut Ex. Flange Adapter to Ex. Manifold Nut	 20 ± 3 N•m 28 ± 3 N•m 70 ± 5 N•m	 15 ± 2 ft.lb. 21 ± 2 ft.lb. 52 ± 3 ft.lb.
Oil Drain Line Fitting to Oil Sump Fitting Oil Drain Line to Turbo Bearing Housing	62 ± 3 N•m 10 ± 1 N•m	46 ± 2 ft.lb. 7 ± 1 ft.lb.
Oil Feed Line Fitting to Turbo Bearing Housing	16± 1 N•m	12 ± 1 ft.lb.

TROUBLESHOOTING

Problem	Possible Cause	Solution
Will Not Start	No fuel	Check fuel supply.
	Incorrect fuel	Make sure fuel system is configured properly for LPG or NG supply.
	Dirty/restricted fuel system	Check fuel system and clean components as needed.
	Incorrect oil level	Check engine oil level; add as needed.
	Engine overloaded	Disconnect or reduce loads.
	Faulty spark plug	Inspect, adjust, or replace as needed.
Black smoke from exhaust	Clogged air filter	Replace air filter.
	Overloaded engine	Reduce engine load.
	Idle low	Increase idle speed. Replace rings.
	Bad valve seal	Replace valve seals.
White smoke from exhaust	Worn or stuck rings	Replace rings and/or rebuild engine.
	Worn out cylinders	Rebore cylinders/rebuild engine.
	Defective thermostat	Check and/or replace thermostat.
Oil pressure too low	Bearing shells of bearing cap—piston rod—rocker worn out.	Replace defective parts and/or rebuild engine.
	Low oil level	Add oil to crankcase as needed.
	Defective oil pressure gauge or sending unit.	Replace oil pressure gauge and/or oil pressure sending unit.
	Excessively diluted oil	Change oil and filter with correct viscosity oil.
Excessive oil consumption	Worn out or stuck rings	Replace rings.
	Worn out cylinders	Rebore/rebuild engine.
	Worn out valve guides	Replace valve guides, Refurbish cylinder heads.
	Bad valve seals	Replace valve seals.
	Bearing shells of bearing cap—piston rod—rocker worn out	Replace defective parts and/or rebuild engine.
	Cylinder head gasket damage	Replace cylinder head gasket.
	High oil level	Drain excess oil from oil pan.
	Low idle	Adjust idle.

Problem	Possible Cause	Solution
Engine overheats	Insufficient engine coolant	Add engine coolant.
	Defective fan, radiator, radiator cap, and/or thermostat	Inspect and/or replace defective parts.
	Defective or worn water pump	Replace water pump.
	Accessory drive belt loose or worn	Replace or adjust accessory drive belt.
	Heat exchange surface of the radiator blocked/clogged	Properly clean radiator.
	Cylinder head gasket damaged	Replace cylinder head gasket.
High noise level	Excessive valve clearances	Adjust valve clearances.
	Bearing shells of bearing caps—piston rod—rocker worn out	Replace defective parts and/or rebuild engine.
	Cylinder head gasket damage	Replace cylinder head gasket.

Turbo engine-specific potential problems

Knocks or Pings	Boost pressure too high	Check for stuck wastegate, check for leak in wastegate boost line.
	Excessive intake manifold temperature	Check charge air cooler for debris and clean as needed.
Lacks power	Air induction system leak	Inspect air induction system.
	Damaged turbocharger	Inspect turbocharger compressor and turbine blades for damage and/or contact against housing.
Erratic operation	Air induction system leak	Inspect air induction system.

TEST AND ADJUSTMENTS

CYLINDER COMPRESSION TEST

NOTE:

If output reduction, excessive oil consumption, or extremely bad fuel consumption is observed, measure the cylinder compression pressure.

1. Run the engine until it is warm, and then turn the engine off.

COOLANT TEMPERATURE

Standard

80°C or more

(176°F or more)

2. Remove all spark plugs from cylinder head.
3. Disconnect electrical connections at coil pack.
4. Compression test measurement:

NOTICE
Run the starter motor to discharge foreign matters from cylinders before the compression pressure measurement. **Always use a fully charged battery to keep the engine speed at 250 rpm or above.**

a. Insert the compression gauge into the spark plug hole.

b. Fully open the throttle.

c. Crank the engine over by using the starter motor and measure the compression pressure.

COMPRESSION PRESSURE

Standard

1379 kPa (200 psi)

Limit

1241 kPa (180 psi)

d. Repeat steps 1 through 3 (above) for all cylinders and inspect the pressure differences.

e. If the compression pressure is below the limit (See “Repair Specifications” on page 23) or if the compression pressure in any cylinder is deviated beyond the pressure difference limit, add a small amount of engine oil through the spark plug hole, and repeat steps 1 through 3.

1) If the pressure rises after the addition of engine oil, the piston rings and/or cylinder bore may be worn or damaged.

2) If the pressure is still low after the addition of engine oil, a valve seizure, valve contact defect, or pressure leak from the gasket may be the reason.

f. Connect electrical connectors at coil pack.

g. Install spark plugs to cylinder head.

ENGINE DISASSEMBLY AND ASSEMBLY

ENGINE DISASSEMBLY

The following sequence is suggested when a complete disassembly for overhaul is required. Refer to the appropriate section for removal, inspection and repair of the individual engine components.

Procedure	Reference
Drain coolant and oil.	See “Engine Specifications” on page 17 for capacities.
Mount engine on an appropriate repair stand.	See “Engine Specifications” on page 17 for weight of engine.
Remove drive belt and alternator.	See “Drive Belt Removal and Installation” on page 45 and See “Alternator Removal and Installation” on page 47.
Remove thermostat and water pump.	See “Thermostat Removal and Installation” on page 43 and “Water Pump Removal and Installation” on page 41.
Remove spark plugs and spark plug tubes.	See “Spark Plug Removal and Installation” on page 48 and “Remove and Install Spark Plug Tubes” on page 49.
Remove ignition wire harness, ignition coil and ignition coil mounting bracket.	See “Ignition Wire Removal and Installation” on page 45, “Ignition Coil Removal and Installation” on page 49 and “Ignition Coil Mounting Bracket Removal and Installation” on page 50.
Remove the air-fuel mixer and throttle body.	See “Air-Fuel Mixer and Throttle Body Removal and Installation” on page 51.
Remove turbocharger (KG2204T engine only).	See “Turbocharger Removal and Replacement (KG2204T only)” on page 54.
Remove upper and lower intake manifold.	See “Upper Intake Manifold Removal and Installation” on page 59 and “Intake Manifold Removal and Installation” on page 56.
Remove exhaust manifold.	See “Exhaust Manifold Removal and Installation” on page 62.
Remove flywheel.	See “Remove and Install Flywheel” on page 63.
Remove vibration dampener.	See “Remove and Install Crankshaft Vibration Dampener” on page 65.
Remove crankshaft position sensor.	See “Remove and Install Crankshaft Position Sensor” on page 64.
Remove front and rear crankshaft seals.	See “Remove and Install Front Crankshaft Seal” on page 67 and “Remove and Install Rear Crankshaft Seal” on page 68.
Remove rocker arm cover.	See “Remove and Install Rocker Arm Cover” on page 70.

Procedure	Reference
Remove oil pump drive, oil filter and oil filter base.	See “Oil Pump Drive Removal and Installation” on page 72, “Oil Filter Removal and Installation” on page 74 and “Oil Filter Base Removal and Installation” on page 75.
Remove rocker arm assembly and push rods.	See “Rocker Arm Assembly—Removal and Installation” on page 83.
Remove cylinder head.	See “Cylinder Head Removal and Installation” on page 81.
Disassemble cylinder head.	See “Valves—Removal and Installation” on page 86 and “Valve Guides—Removal and Installation” on page 93.
Remove camshaft and related components.	See appropriate procedure in “Cylinder Block” on page 95: • Remove valve lifters. • Remove timing chain cover. • Remove timing chain tensioner and dampener. • Remove timing chain and gears. • Remove thrust plate and camshaft. • Remove timing chain gear housing. • Remove camshaft bearings.
Remove oil pan.	See “Remove and Install Oil Pan” on page 71.
Disassemble cylinder block and components.	Use the appropriate procedure. See “Cylinder Block” in Section 3. • Remove oil pump and oil pump pick-up. • Remove connecting rod bearing caps and bearings. • Remove connecting rods and pistons. • Remove main bearing caps. • Remove crankshaft. • Inspect crankshaft. • Measure crankshaft journals and bearing ID. • Measure crankshaft circle runout. • Remove main bearings from main caps and block. • Check cylinder block deck for warpage. • Inspect cylinder bore. • Check cylinder taper. • Remove oil and coolant galley plugs.

Procedure	Reference
Disassemble connecting rods and piston assemblies.	Use the appropriate procedure. See “Cylinder Block” in Section 3. • Disassemble connecting rods from pistons. • Check connecting rods for bend or twist. • Clean pistons. • Check piston ring grooves. • Check piston ring gap. • Check piston pins. • Check piston skirts.

ENGINE ASSEMBLY

The following assembly sequence is suggested when engine has been completely disassembled. Be sure to check runout specifications, clearance tolerances, torques, etc., as engine is assembled. Refer to the appropriate repair section when assembling engine components.

NOTE:

Refer to the torque and adjustment specifications for the corresponding components throughout the assembly.

Assemble connecting rods and pistons.	Use the appropriate procedure. See “Cylinder Block” in Section 3. • Assemble connecting rods, piston pins and pistons. • Install piston rings.
Assemble cylinder block and components.	Use the appropriate procedure. See “Cylinder Block” in Section 3. • Install oil and coolant galley plugs. • Install upper main bearings in cylinder block. • Install lower main bearings into caps. • Install thrust washers. • Install crankshaft. • Install piston and connecting rod assemblies. • Install oil pump and oil pump pick-up.
Install rear crankshaft seal.	See “Remove and Install Rear Crankshaft Seal” on page 68.
Install oil pan.	See “Remove and Install Oil Pan” on page 71.
Install camshaft and related components.	See appropriate procedure in “Cylinder Block” on page 95. • Install camshaft bearings. • Install timing chain gear housing. • Install camshaft and thrust plate. • Install timing chain and gears. • Install timing chain tensioner and dampener. • Install timing chain cover. • Install valve lifters.
Install front crankshaft seal.	See “Remove and Install Front Crankshaft Seal” on page 67.
Install valve guides.	See “Valve Guides—Removal and Installation” on page 93.
Install valves.	See “Valves—Removal and Installation” on page 86.
Install cylinder head.	See “Cylinder Head Removal and Installation” on page 81.
Install push rods and rocker arm assembly.	See “Rocker Arm Assembly—Removal and Installation” on page 83.
Install rocker arm cover.	See “Remove and Install Rocker Arm Cover” on page 70.

Install oil pump drive and oil filter base.	See “Oil Pump Drive Removal and Installation” on page 72 and “Oil Filter Base Removal and Installation” on page 75.
Install crankshaft position sensor.	See “Remove and Install Crankshaft Position Sensor” on page 64.
Install water pump and thermostat.	See “Water Pump Removal and Installation” on page 41 and “Thermostat Removal and Installation” on page 43.
Install crankshaft vibration dampener.	See “Remove and Install Crankshaft Vibration Dampener” on page 65.
Install flywheel.	See “Remove and Install Flywheel” on page 63.
Install exhaust manifold.	“Exhaust Manifold Removal and Installation” on page 62.
Install intake manifold.	See “Intake Manifold Removal and Installation” on page 56 and “Upper Intake Manifold Removal and Installation” on page 59.
Install turbocharger (KG2204T only).	See “Turbocharger Removal and Replacement (KG2204T only)” on page 54.
Install air-fuel mixer and throttle body.	See “Air-Fuel Mixer and Throttle Body Removal and Installation” on page 51.
Install coil mounting bracket, ignition coil, and ignition wire harness.	See “Ignition Coil Mounting Bracket Removal and Installation” on page 50, “Ignition Coil Removal and Installation” on page 49, and “Ignition Wire Removal and Installation” on page 45.
Install spark plug tubes and spark plugs.	See “Spark Plug Removal and Installation” on page 48 and “Remove and Install Spark Plug Tubes” on page 49.
Install alternator and drive belt.	See “Alternator Removal and Installation” on page 47 and “Drive Belt Removal and Installation” on page 45.
Install oil filter.	See “Oil Filter Removal and Installation” on page 74.
Remove from engine repair stand and install.	See appropriate instructions.
Refill coolant and engine oil.	See “Fluid Specifications” on page 19.

EXTERNAL COMPONENTS

⚠ WARNING

Carbon monoxide can cause severe nausea, fainting, or death.

Avoid inhaling exhaust fumes.

Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.

⚠ WARNING

Risk of fire. Can cause severe injury or death.

Do not smoke or permit flames or sparks near fuels or the fuel system.

⚠ WARNING

Avoid possible death or serious injury! Pinch and entanglement hazards! Never check drive belt tension while the engine is running.

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

⚠ WARNING

Rotating parts can cause severe injury.

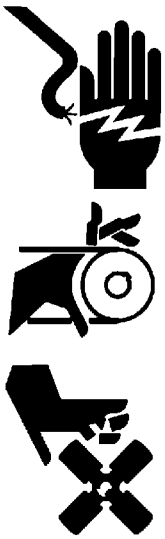
Stay away while the engine is in operation.

Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate the engine with covers, shrouds, or guards removed.

⚠ WARNING

Hot coolant and steam. Can cause severe injury or death.

Before removing the pressure cap, stop the engine and allow it to cool. Then loosen the pressure cap to relieve pressure.



⚠ WARNING

Accidental starts can cause severe injury or death.

Disconnect and ground spark plug leads before servicing.

Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug leads. 2) Disconnect negative (–) battery cable from battery.

Before disconnecting negative (–) ground cable, make sure all switches are OFF. If ON, a spark will occur at the ground cable terminal which could cause an explosion if hydrogen gas or LPG/NG fuel vapors are present.

⚠ WARNING

Explosive fuel can cause fires and severe burns.

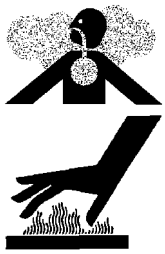
If a gaseous odor is detected, ventilate the area and contact an authorized service technician.

LPG (Liquefied Petroleum Gas) is extremely flammable and tends to settle in low areas where a spark or flame could ignite the gas. Do not start or operate this engine in a poorly ventilated area where leaking gas could accumulate and endanger the safety of persons in the area.

NG (Natural Gas) is extremely flammable, is lighter than air, and rises, Do not start or operate this engine in a poorly ventilated are where leaking gas could accumulate and endanger the safety of persons in the area.

To ensure personal safety, installation and repair of LPG/NG fuel supply systems must be performed only by qualified LPG/NG system technicians. Improperly installed and maintained LPG/NG equipment could cause the fuel supply system or other components to malfunction, causing gas leaks.

Observe federal, state, and local laws governing LPG/NG fuel, storage, and systems.



⚠ WARNING

Handling caustic engine fluids and chemical products. Can cause severe chemical burns, nausea, fainting, or death.

Most chemicals such as used engine oil, antifreeze/coolant, rustproofing agent, inhibiting oil, degreasing agent, spray paint, and adhesives are hazardous to health. Read and follow the user information found on the packaging. Avoid inhalation and skin contact. Use only in well-ventilated areas and use a protective mask when spraying. Store engine fluids and chemical products in a locked cabinet. Contact your local recycling center for disposal information and locations.

Fire-damaged or burned O-rings may cause the formation of hydrofluoric acid. Contact with hydrofluoric acid may cause severe skin irritation and chemical burns. O-rings and other fluoroelastomer seals exposed to fire or temperatures above 316 °C (600 °F) (i.e., during welding) may decompose forming hydrofluoric acid. Avoid inhalation or skin contact. Do not incinerate O-rings. Dispose of O-ring waste material in a responsible manner.

⚠ WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

⚠ WARNING

Airborne particles. Can cause severe injury or blindness.

Wear protective goggles and clothing when using power tools, hand tools, or compressed air.

⚠ WARNING

Explosive fuel vapors. Can cause severe injury or death.

Use extreme care when handling, storing, and using fuels.

Gas fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check the LPG vapor or natural gas fuel system for leakage by using a soap and water solution with the fuel system test pressurized to 6–8 ounces per square inch (10–14 inches water column). Do not use a soap solution containing either ammonia or chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

Used engine oil. Contact with used engine oil may cause severe skin irritation. Repeated and prolonged skin exposure may have other health risks. Used engine oil is a suspected carcinogen. Avoid contact with skin. Thoroughly wash your hands and nails with soap and water shortly after handling used engine oil. Wash or dispose of clothing or rags containing used engine oil. Dispose of used engine oil in a responsible manner. Contact your local recycling center for disposal information and locations.

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

WATER PUMP REMOVAL AND INSTALLATION

Removal

1. Drain cooling system.
2. Remove alternator. See “Alternator Removal and Installation” on page 47.

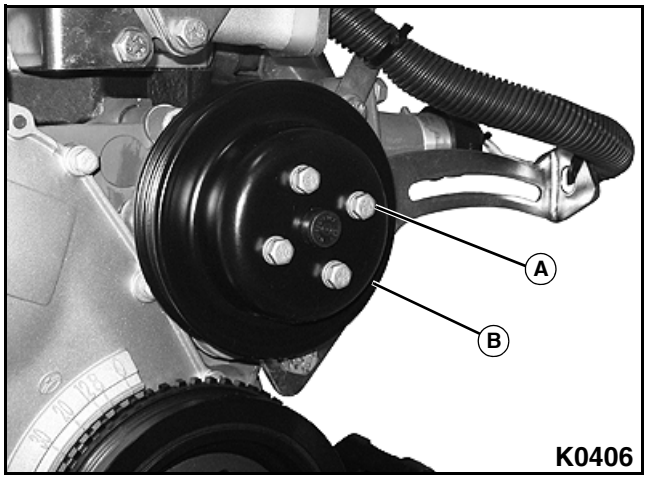


Figure 3-1

3. Remove four water pump drive pulley mounting bolts, flat washers, and lock washers (A). **See Figure 3-1.**
4. Remove water pump drive pulley (B) from water pump.

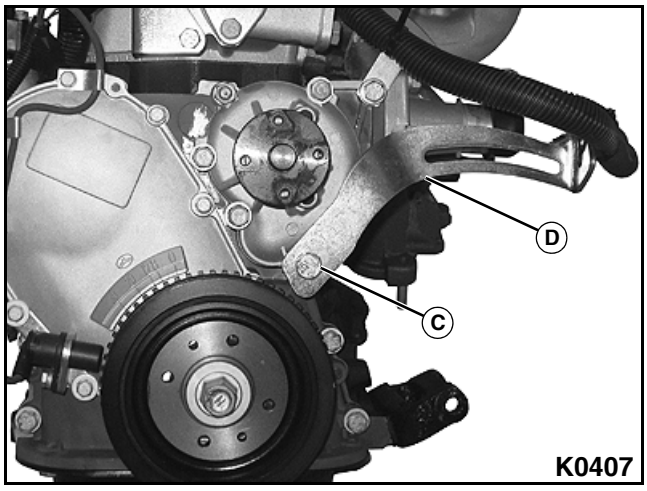


Figure 3-2

5. Remove upper alternator mounting bracket bolt (C) and remove upper alternator mounting bracket (D) from water pump. **See Figure 3-2.**

NOTE:

Take notice of water pump bolt length differences during removal.

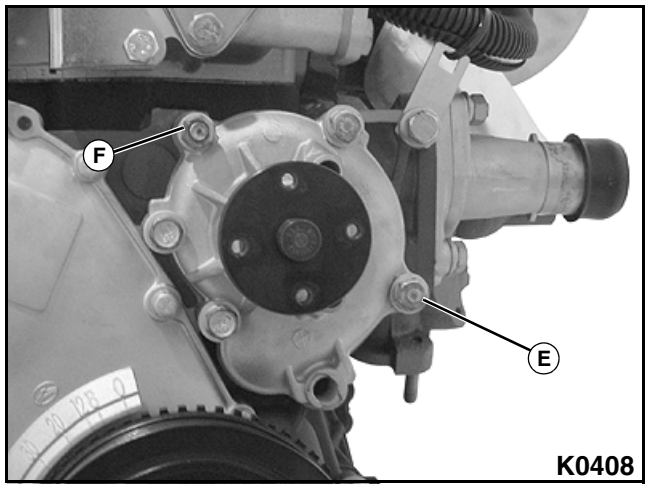


Figure 3-3

6. Remove four water pump mounting bolts (E). **See Figure 3-3.**
7. Remove water pump mounting nut, flat washer, and lock washer (F) from water pump.
8. Lightly tap water pump with a soft face hammer and remove water pump from engine.

Inspection

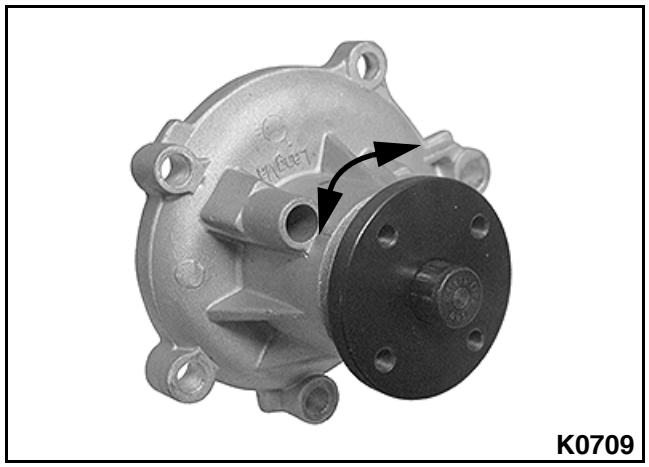


Figure 3-4

1. Inspect water pump bearing for excess play by pulling upward on water pump pulley hub and rotate side to side. The bearing should feel smooth and rotate freely. **See Figure 3-4.**
2. Inspect impeller. Impeller should not be bent or show signs of rubbing, or corrosion.
3. Inspect weep hole for leakage of coolant.

4. Inspect gasket sealing flange for cracks or distortion.
5. Clean water pump housing and water pump of old gasket material.
6. If inspection reveals damage, leakage, or wear, replace water pump.

Installation

1. If installing new water pump, check new water pump gasket sealing surface for nicks or burrs. Remove nicks or burrs if needed.
2. Install new water pump gasket to cylinder block.
3. Install water pump to cylinder block.

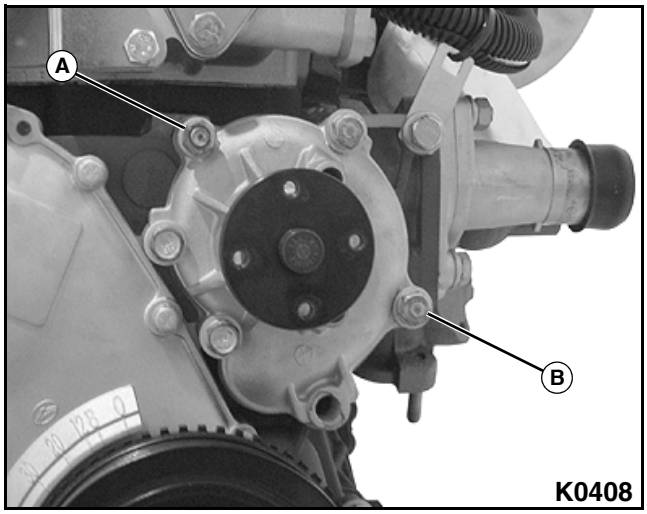


Figure 3-5

4. Install water pump mounting nut, lock washer, and flat washer (A) to water pump. Do not tighten at this time. **See Figure 3-5.**
5. Install four water pump mounting bolts, lock washers, and flat washers (B) to water pump as noted during removal. Torque mounting bolts and nut to specification.

   Water Pump Bolt and Nut Torque

   18 N•m (13 ft.lb.)

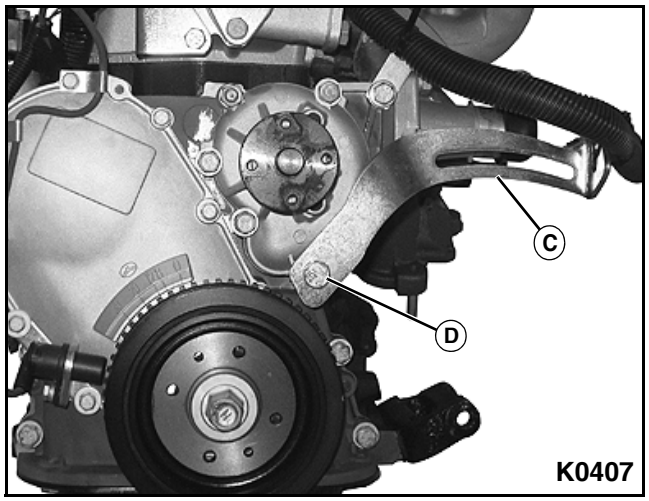


Figure 3-6

6. Install upper alternator mounting bracket (C) with bolt (D). Do not tighten bolt at this time. **See Figure 3-6.**

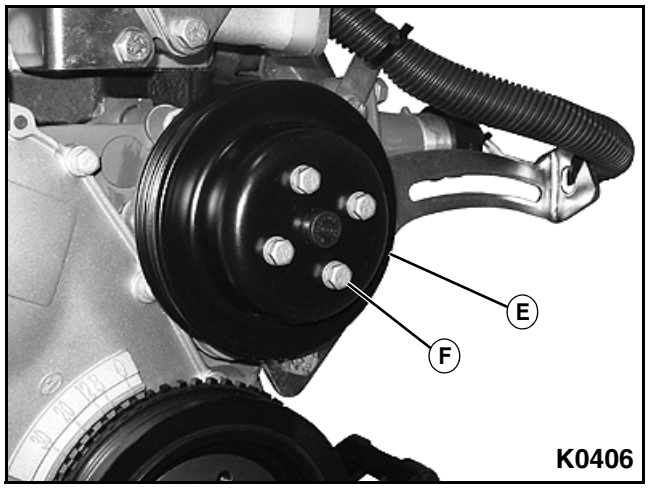


Figure 3-7

7. Install water pump drive pulley (E) to water pump with four mounting bolts, lock washers, and flat washers (F). Tighten bolts. **See Figure 3-7.**
8. Install alternator. See “Alternator Removal and Installation” on page 47.

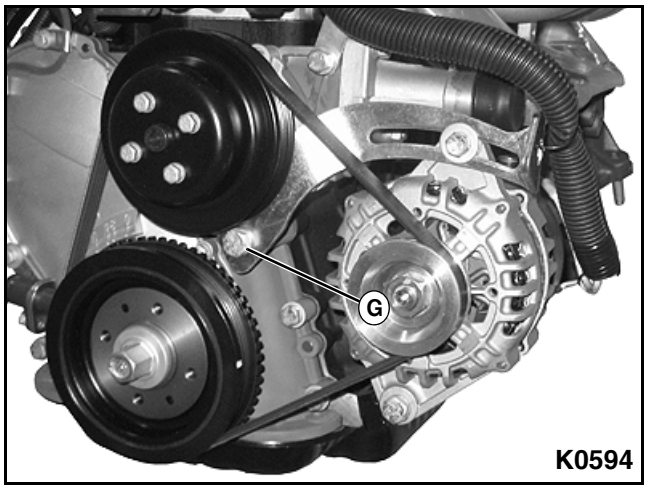


Figure 3-8

NOTE:

Bolt (G) securing the upper alternator bracket is also a water pump mounting bolt and must be torqued to specification. ***See Figure 3-8.***

9. Torque upper alternator mounting bracket bolt (G).

   Water Pump Bolt and Nut Torque

   18 N•m (13 ft.lb.)

10. Fill cooling system.
11. Run engine and check for leaks.

THERMOSTAT REMOVAL AND INSTALLATION

Removal

1. Drain cooling system.

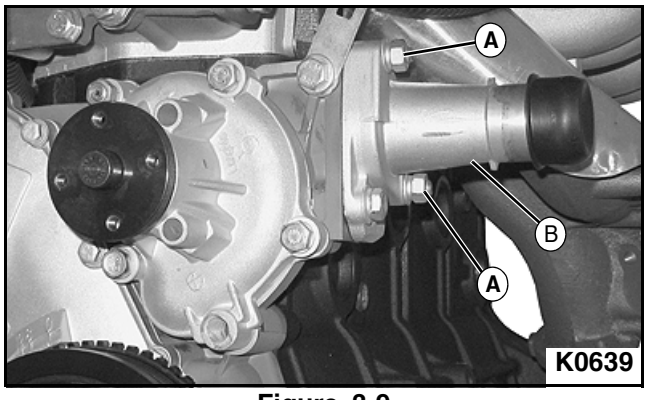


Figure 3-9

2. Remove thermostat housing mounting nuts, flat washers, and lock washers (A). **See Figure 3-9.**
3. Remove thermostat housing from water pump housing (**B**).

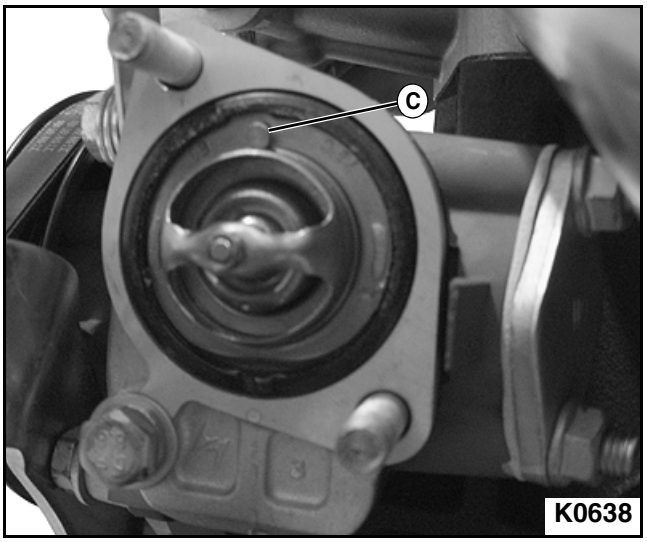


Figure 3-10

NOTE:

Take notice of thermostat air bleed (C) orientation. Air bleed hole must be positioned at approximately the ten to eleven o'clock position. ***See Figure 3-10.***

4. Remove thermostat from water pump housing.
5. Thoroughly clean water pump housing.

Thermostat Check

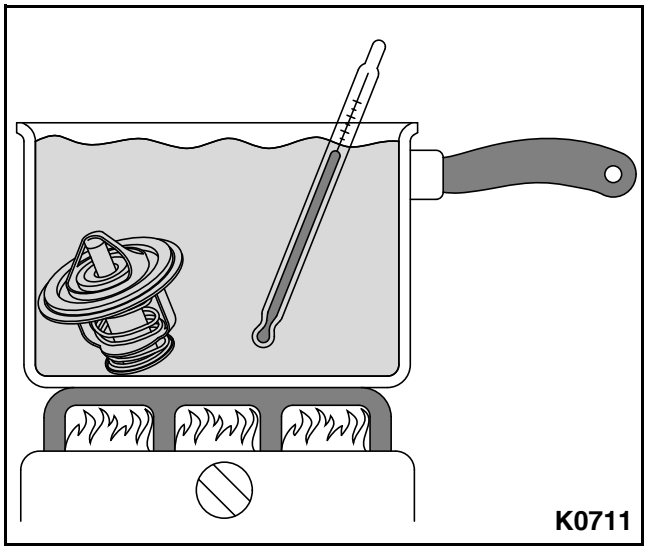


Figure 3-11: Testing Thermostat

1. Place thermostat in a pot of water along with a thermometer. **See Figure 3-11.**
2. Apply heat and observe the opening temperature on thermometer.

   THERMOSTAT SPECIFICATIONS

   Start to Open

   76 °C (169 °F).

   Fully Open

   88 °C (190 °F)
3. If thermostat does not open as specified, replace thermostat.

Installation

NOTICE
Ensure O-ring is installed to thermostat.

NOTE:

Thermostat MUST be installed "spring" end first. Air bleed (A) must be positioned at approximately the ten to eleven o'clock position. ***See Figure 3-12.***

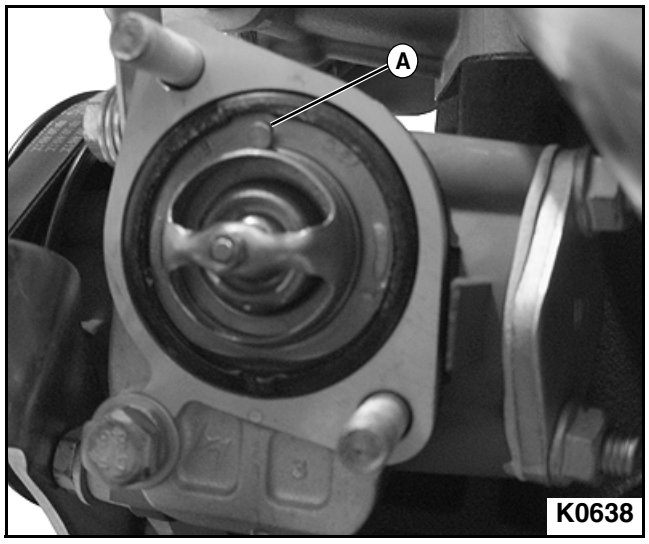


Figure 3-12

1. Install thermostat into water pump housing. **See Figure 3-12.**

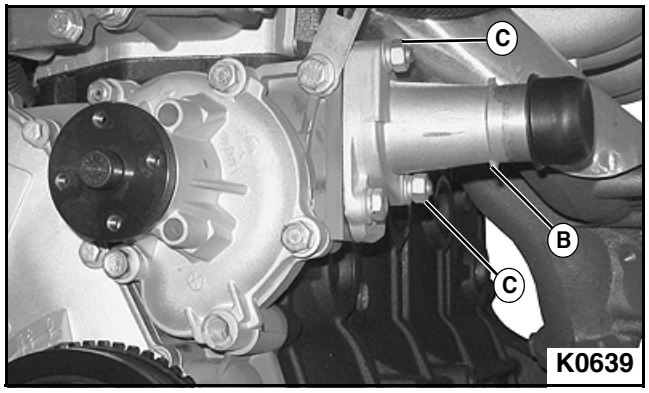


Figure 3-13

2. Install thermostat housing (B) over thermostat. **See Figure 3-13.**
3. Install thermostat housing mounting nuts, flat washers, and lock washers (C).
4. Fill cooling system.
5. Run engine and check for leaks.

IGNITION WIRE REMOVAL AND INSTALLATION

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

Removal

NOTICE

Identify and tag ignition wires for reference during installation. Ignition wires MUST be installed correctly.

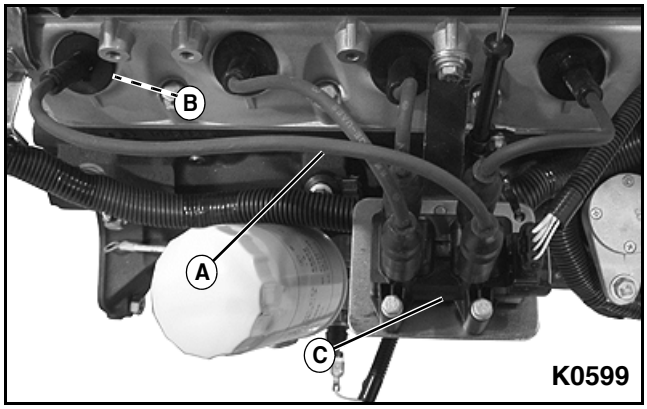


Figure 3-14

1. Clean dirt and debris away from ends of ignition wires.
2. Firmly grasp ends of ignition wire (A) at spark plug (B) and coil (C). Using a twisting motion, remove wire from spark plug and coil. **See Figure 3-14.**
3. Repeat for remaining ignition wires.

Inspection

1. Inspect ignition wires or cuts, abrasions, burning or missing boots.
2. If inspection reveals damage or wear, replace ignition wire.
3. Inspect the resistance of each ignition wire using an ohmmeter set to read a minimum of 25k Ohms. Attach ohmmeter leads to spark plug and ignition coil ends of ignition wire. If reading exceeds specification, replace ignition wire.

Ignition Wire Resistance

25k Ohms (Maximum)

Installation

NOTICE

Ignition wires MUST be installed correctly. Use identification on ignition wires from removal.

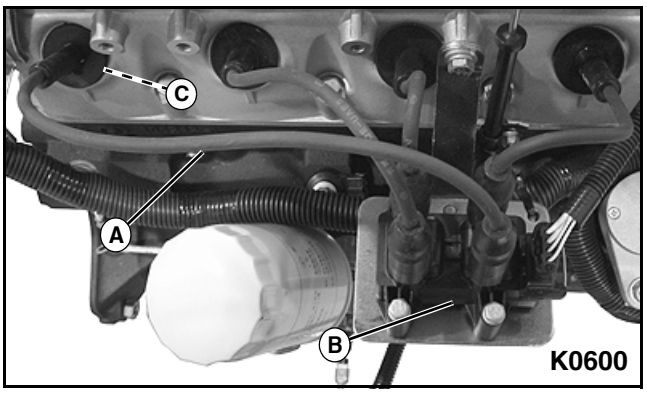


Figure 3-15

1. Connect ignition wire (A) to ignition coil (B) and spark plug (C) by firmly pressing ignition wire onto terminals. **See Figure 3-15.**
2. Repeat for remaining ignition wires.

DRIVE BELT REMOVAL AND INSTALLATION

Removal

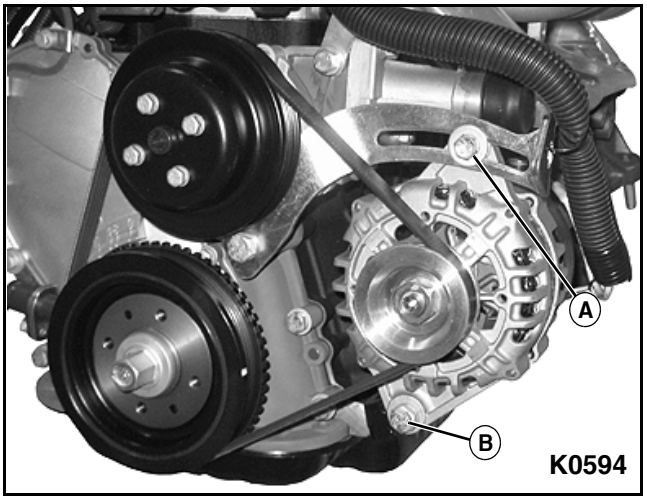


Figure 3-16

1. Loosen upper (A) and lower (B) alternator mounting bolts and rotate alternator towards cylinder block. **See Figure 3-16.**
2. Remove drive belt from drive pulleys.

Inspection

1. Inspect drive belt for cracks or stretching. If inspection reveals cracks or stretching, replace drive belt.
2. Inspect drive pulleys for defects and wear. If inspection reveals defective or worn drive pulleys, replace drive pulleys.

Installation

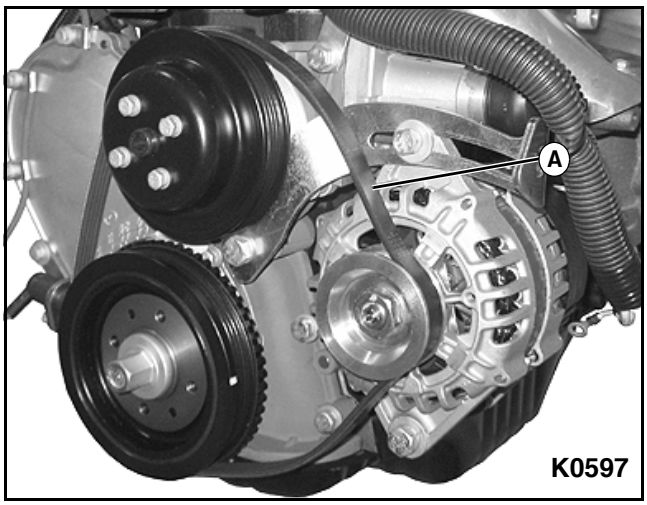


Figure 3-17

1. Install drive belt (A) as shown. **See Figure 3-17.**

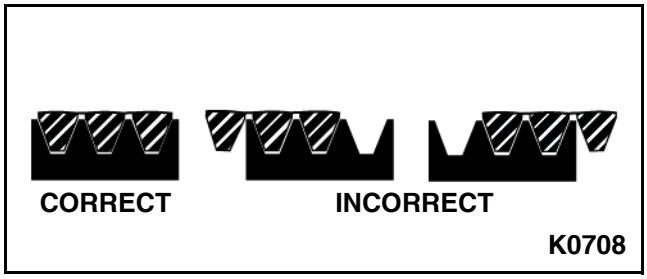


Figure 3-18

2. Check drive belt for correct alignment. If alignment is incorrect, severe damage to drive belt may occur. **See Figure 3-18.**
3. Rotate alternator away from cylinder block to remove slack in drive belt.

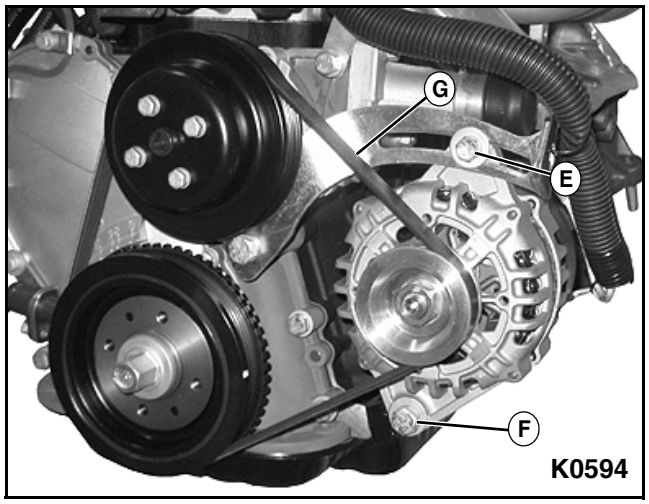


Figure 3-19

4. Tighten upper alternator mounting bolt (E), then tighten lower alternator mounting bolt (F). **See Figure 3-19.**
5. Check the drive belt tension at the midpoint (G) between the pulleys.
   - Apply specified force to the drive belt at its midpoint. At the same time, measure the amount of deflection of the drive belt at its midpoint. Deflection should be within specification.

     DRIVE BELT TENSION

     Applied Test Pressure

     98 N (22 lbf.)

     Belt Deflection - New

     5–7 mm (0.20–0.28 in.)

     Belt Deflection - Used

     7–8 mm (0.28–0.31 in.)
6. If the amount of deflection is out of specification, adjust the drive belt tension.

ALTERNATOR REMOVAL AND INSTALLATION

Removal

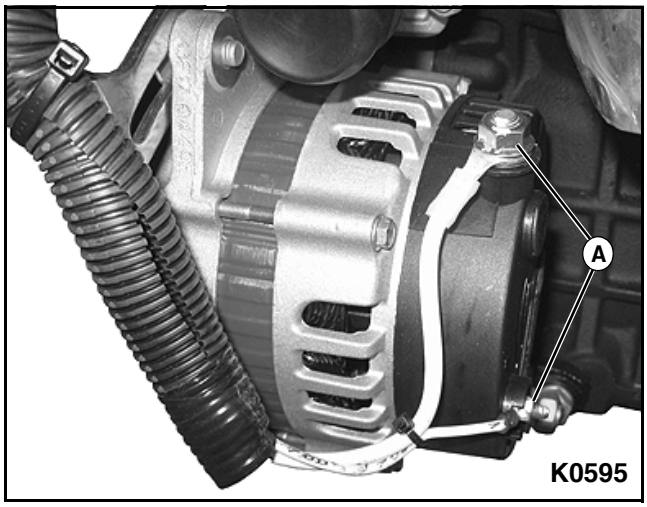


Figure 3-20

1. Disconnect negative battery cable from battery.
2. Disconnect all electrical connections (A) from alternator. **See Figure 3-20.**
3. Remove drive belt. See “Drive Belt Removal and Installation” on page 45.

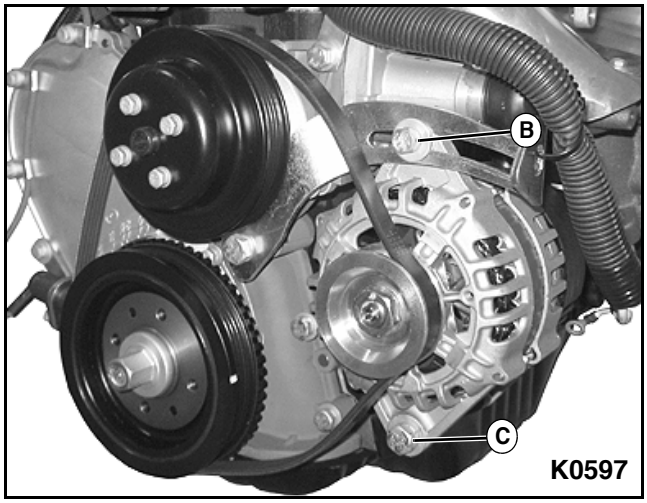


Figure 3-21

4. Support alternator and remove upper (B) and lower (C) alternator mounting bolts. Remove alternator from alternator mounting brackets. **See Figure 3-21.**

Inspection

1. Inspect alternator drive pulley for defects and wear. Damaged or worn drive pulleys must be replaced.
2. Inspect alternator bearing for excess play by pulling upward on alternator pulley and rotate side to side. The bearing should feel smooth and rotate freely.
3. Inspect all electrical connections for corrosion or damage.
4. Replace alternator if needed.

Installation

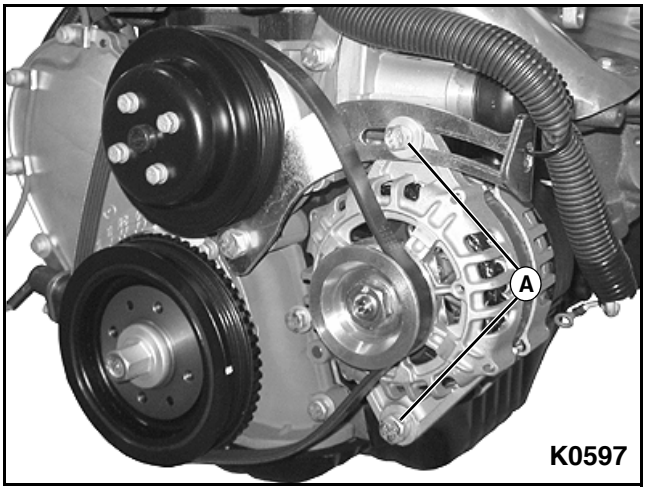


Figure 3-22

1. Install alternator to alternator mounting brackets and install two mounting bolts (A). Do not tighten bolts at this time. **See Figure 3-22.**
2. Install drive belt. See “Drive Belt Removal and Installation” on page 45.

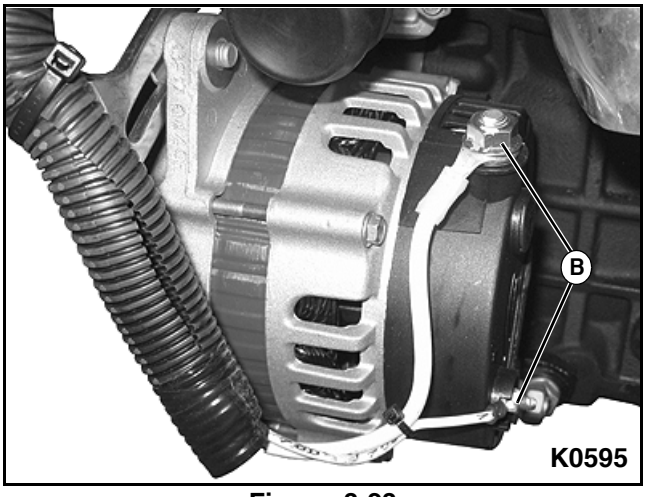


Figure 3-23

3. Connect all electrical connections (B) to alternator. **See Figure 3-23.**
4. Connect negative battery cable to negative battery terminal.

SPARK PLUG REMOVAL AND INSTALLATION

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

Removal

1. Disconnect ignition wires from spark plugs. See “Ignition Wire Removal and Installation” on page 45.

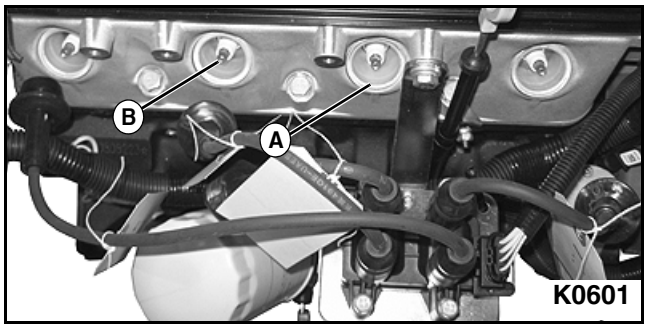


Figure 3-24

2. Clean the inside of the spark plug tubes (A). **See Figure 3-24.**
3. Using a spark plug socket, remove spark plugs (B) from cylinder head by rotating spark plug counterclockwise.

Inspection

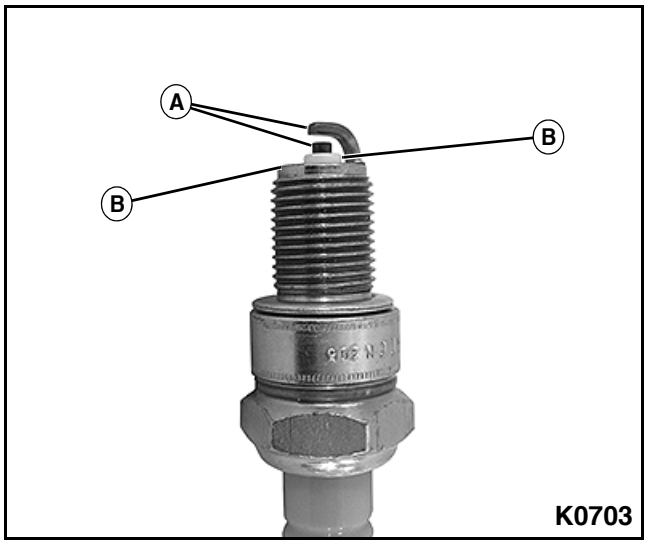


Figure 3-25

1. Inspect spark plug electrodes (A) for wear. **See Figure 3-25.**
   - Spark plug electrodes should have sharp pronounced edges.
   - Rounded or missing electrodes are indications that spark plugs must be replaced.
2. Check color of the deposits (B) on spark plug.
   - Tan to brown is normal deposit color.
   - Dark brown to black is an overfueling or cold engine operating deposit color.
   - Very light tan to white is an underfueling or overheating engine operating deposit color.

Installation

1. Replace worn spark plugs with exact replacement spark plugs. Use Kohler genuine service parts.

   Spark Plugs

KG2204	GM92785
KG2204T	GM100158

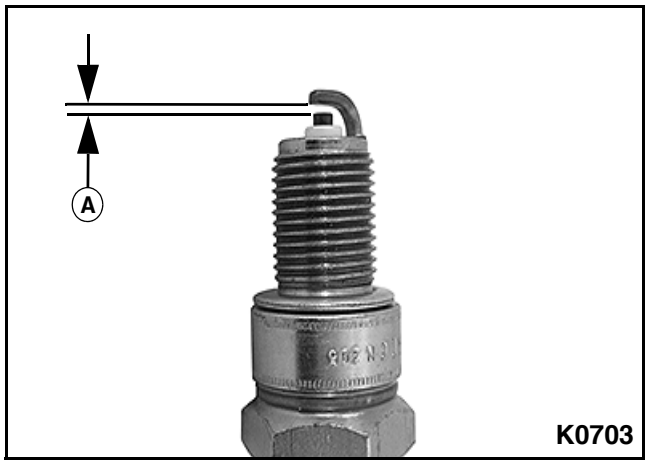


Figure 3-26

2. Check electrode gap (A) using a wire feeler gauge and adjust electrode gap to specification before installation. **See Figure 3-26.**

   Spark Plug Electrode Gap

KG2204	0.9–1.0 mm (0.036–0.040 in.)
KG2204T	0.7–0.8 mm (0.028–0.031 in.)

3. Install spark plug and torque spark plug to specification.

   Spark Plug Torque

KG2204	18 N•m (13 ft.lb.)
KG2204T	25 N•m (18.4 ft.lb.)

4. Connect ignition wire to spark plug. See “Ignition Wire Removal and Installation” on page 45.
5. Repeat procedure for remaining spark plugs.

REMOVE AND INSTALL SPARK PLUG TUBES

Removal

1. Remove spark plug wires from cylinder head.
2. Remove spark plugs from cylinder head.

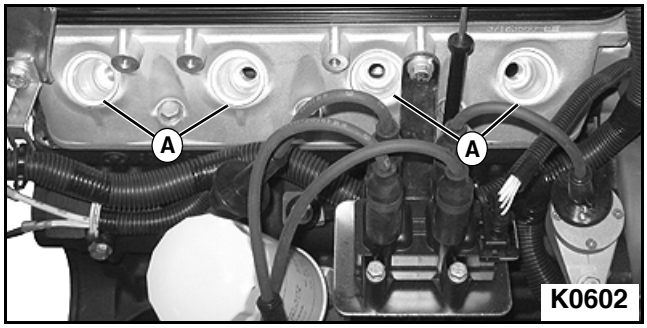


Figure 3-27

3. Remove spark plug tubes from cylinder head (A). **See Figure 3-27.**

Installation

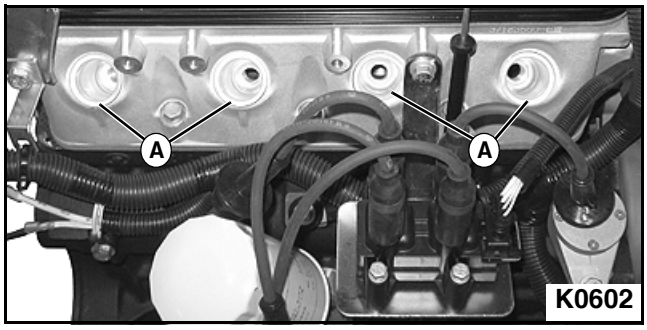


Figure 3-28

1. Install spark plug tubes (A) to cylinder head. **See Figure 3-28.**
2. Install spark plugs to cylinder head.
3. Install spark plug wires to cylinder head.

IGNITION COIL REMOVAL AND INSTALLATION

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

Removal

1. Disconnect ignition wires from ignition coil. See “Ignition Wire Removal and Installation” on page 45.

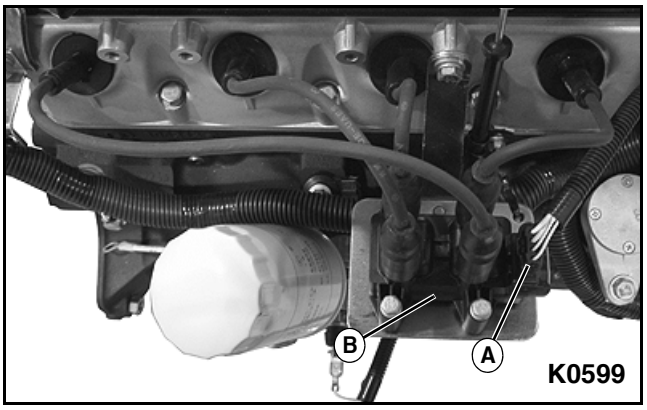


Figure 3-29

2. Disconnect electrical connector (A) from ignition coil (B). **See Figure 3-29.**

NOTE:

Record orientation of coil, flat washers, and lock washers for assembly.

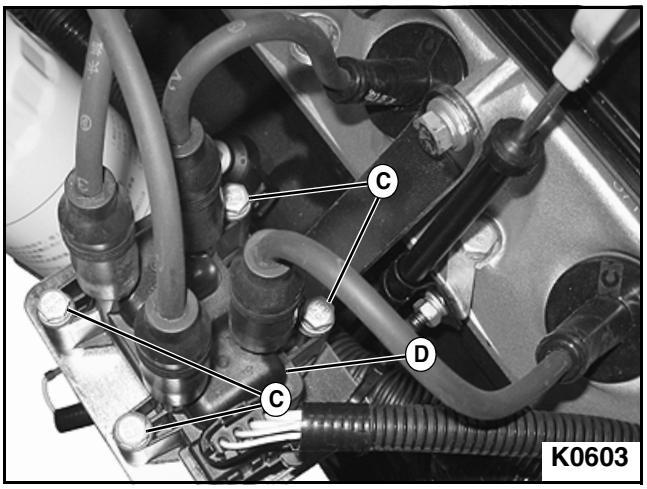


Figure 3-30

3. Remove four ignition coil mounting bolts, flat washers, lock washers, and nuts (C) from ignition coil (D). **See Figure 3-30.**
4. Remove ignition coil from ignition coil mounting bracket.

Installation

NOTE:

Ensure that coil is positioned as noted previously during the removal process.

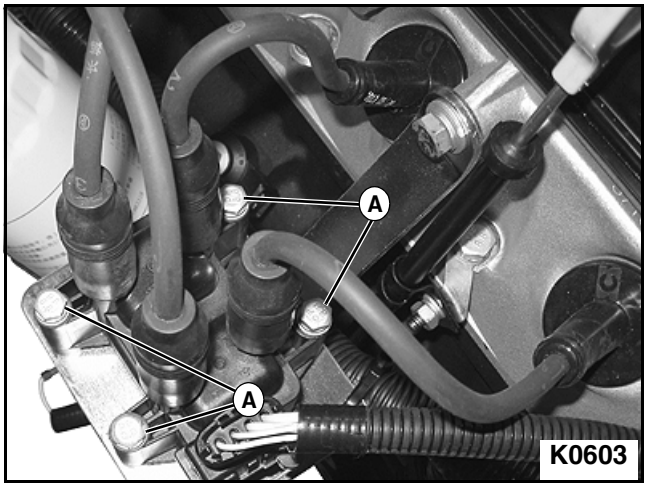


Figure 3-31

1. Install ignition coil to ignition coil mounting bracket using four ignition coil mounting bolts, flat washers, lock washers, and nuts (A). **See Figure 3-31.**

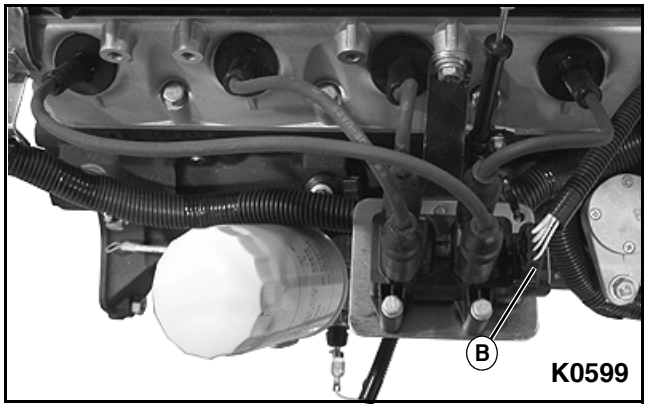


Figure 3-32

2. Connect electrical connector (B) to ignition coil. **See Figure 3-32.**
3. Connect ignition wires to ignition coil. See “Ignition Wire Removal and Installation” on page 45.

IGNITION COIL MOUNTING BRACKET REMOVAL AND INSTALLATION

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

Removal

1. Remove ignition coil. See “Ignition Coil Removal and Installation” on page 49.

NOTE:

Take notice and record coil mounting bracket bolt length and wire tie location during removal.

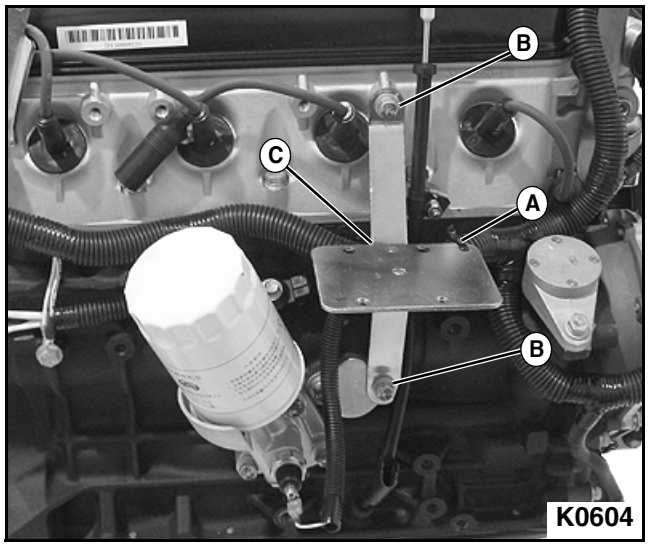


Figure 3-33

2. Remove wire tie (A) holding engine harness to coil bracket. **See Figure 3-33.**
3. Remove ignition coil mounting bracket bolts, flat washers, and lock washers (B) from ignition coil mounting bracket (C). Remove ignition coil mounting bracket from cylinder block.

Installation

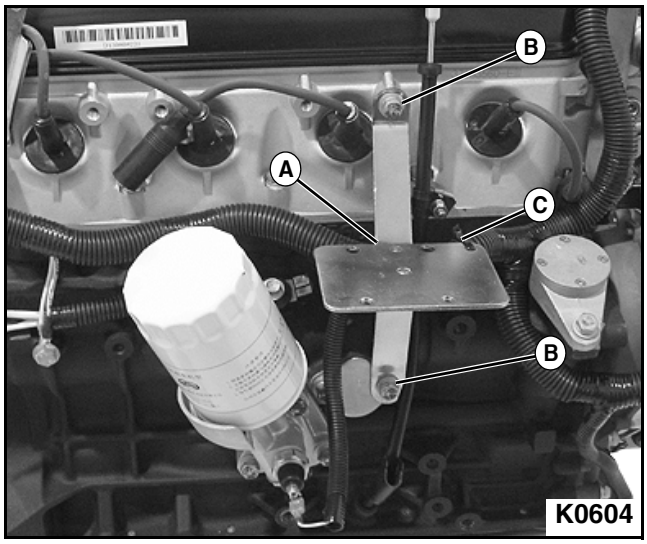


Figure 3-34

1. Install ignition coil mounting bracket (A) to engine with mounting bolts, flat washers, and lock washers (B) as noted during removal. **See Figure 3-34.**
2. Install wire tie (C).
3. Install ignition coil to ignition coil mounting bracket. See “Ignition Coil Removal and Installation” on page 49.

AIR-FUEL MIXER AND THROTTLE BODY REMOVAL AND INSTALLATION

⚠ WARNING

Explosive fuel can cause fires and severe burns.

If a gaseous odor is detected, ventilate the area and contact an authorized service technician.

LPG (Liquefied Petroleum Gas) is extremely flammable and tends to settle in low areas where a spark or flame could ignite the gas. Do not start or operate this engine in a poorly ventilated area where leaking gas could accumulate and endanger the safety of persons in the area.

NG (Natural Gas) is extremely flammable, is lighter than air, and rises, Do not start or operate this engine in a poorly ventilated are where leaking gas could accumulate and endanger the safety of persons in the area.

To ensure personal safety, installation and repair of LPG/NG fuel supply systems must be performed only by qualified LPG/NG system technicians. Improperly installed and maintained LPG/NG equipment could cause the fuel supply system or other components to malfunction, causing gas leaks.

Observe federal, state, and local laws governing LPG/NG fuel, storage, and systems.

NOTICE

A hex wrench will need to be modified in order to loosen the four mounting bolts securing the air/fuel mixer valve and throttle body assembly to the upper intake manifold due to lack of space.

Removal

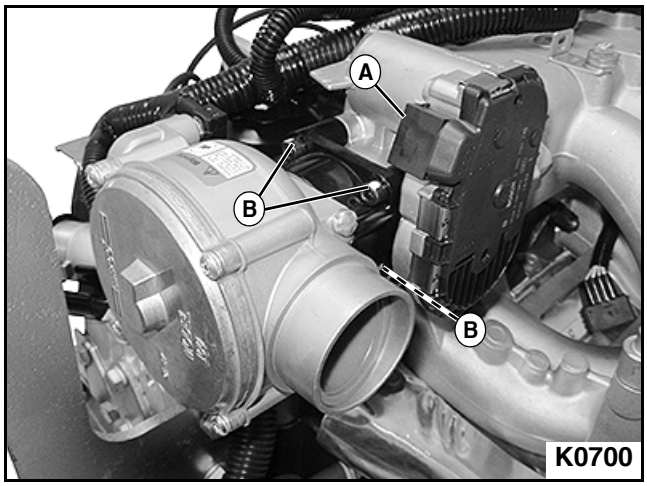


Figure 3-35

NOTE: On turbocharged engines, the air-fuel mixer is located on the turbocharger. See TP-6903 for instructions to remove and replace the air-fuel mixer on turbocharged engines, if necessary.

1. Remove electrical connection at throttle body from throttle position sensor (A). **See Figure 3-35.**
2. Loosen four socket head cap (B) screws securing the air-fuel mixer valve and throttle body assembly to the upper intake manifold. Remove air-fuel mixer valve and throttle body as a unit from the upper intake manifold. **See Figure 3-35.**

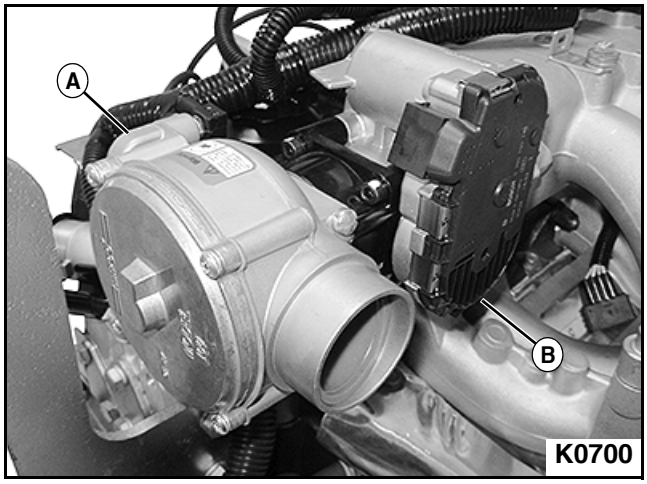


Figure 3-36

3. Separate the air-fuel mixer valve (A) from the throttle body (B) by using a rotational motion as pulling apart. Use caution not to damage O-rings. **See Figure 3-36.**

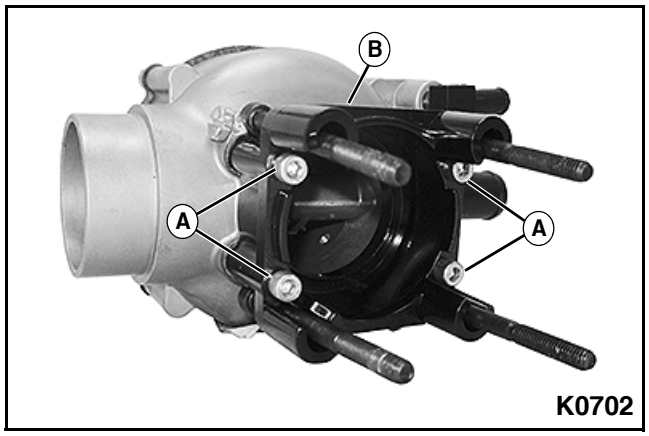


Figure 3-37

4. Remove four socket head cap screws (A) securing air-fuel mixer to throttle body adapter (B) and remove adapter. **See Figure 3-37.**

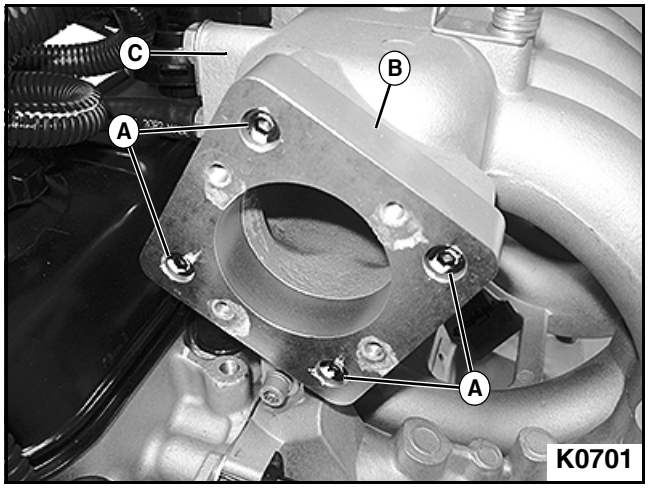


Figure 3-38

5. Remove four socket head cap screws (A) securing throttle body to upper intake manifold adapter (B) and remove adapter from the upper intake manifold (C). **See Figure 3-38.**

Installation

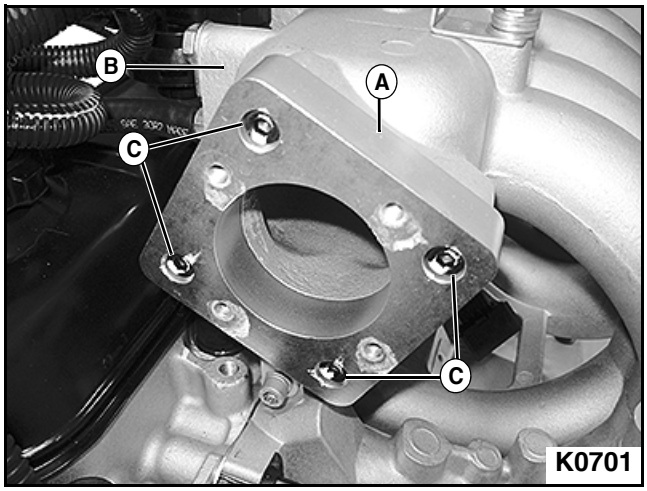


Figure 3-39

1. Install the throttle body upper intake manifold adapter (A) to the upper intake manifold (B). Secure with four socket head cap screws (C). **See Figure 3-39.**

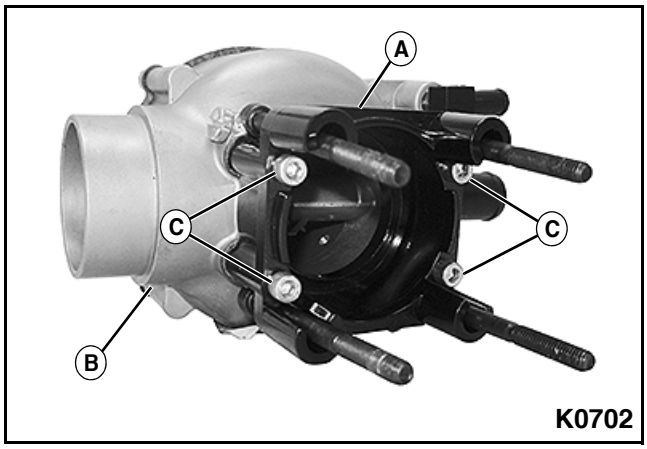


Figure 3-40

2. Install the air-fuel mixer and throttle body adapter (A) to the air-fuel mixer valve (B). Secure with four socket head cap screws (C). **See Figure 3-40.**
3. Use a lubricant on O-rings. Install the throttle body into the air-fuel mixer valve adapter. Use caution not to damage O-rings.

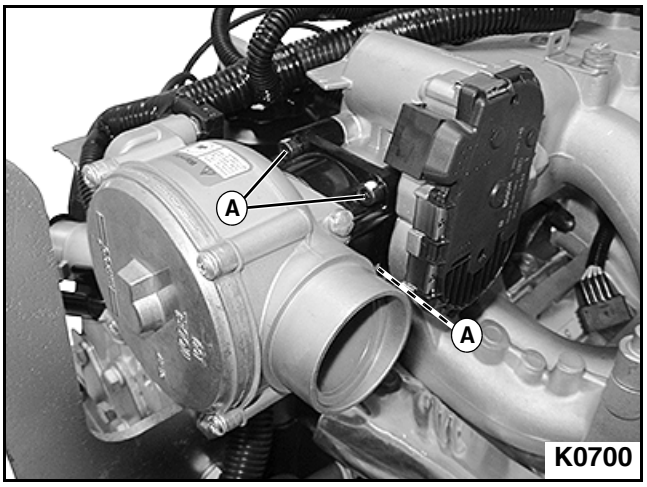


Figure 3-41

4. Install the air-fuel mixer valve and throttle body to the upper intake manifold as a unit. Secure with four socket head cap screws (A). **See Figure 3-41.**

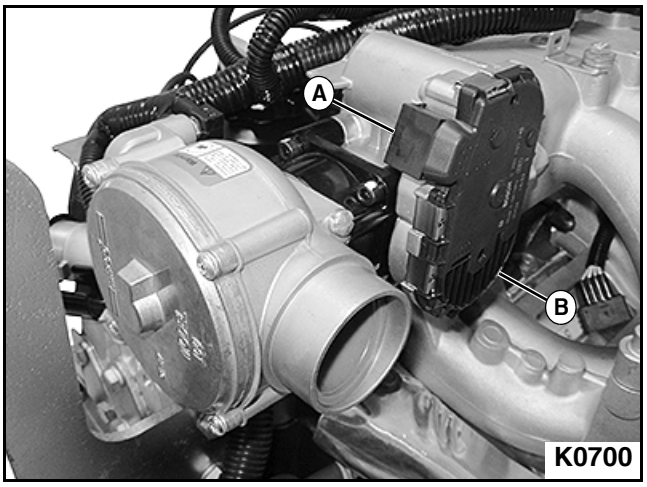


Figure 3-42

5. Install electrical connection at throttle body (A) to throttle position sensor (B). **See Figure 3-42.**

TURBOCHARGER REMOVAL AND REPLACEMENT (KG2204T ONLY)

Turbocharger Removal

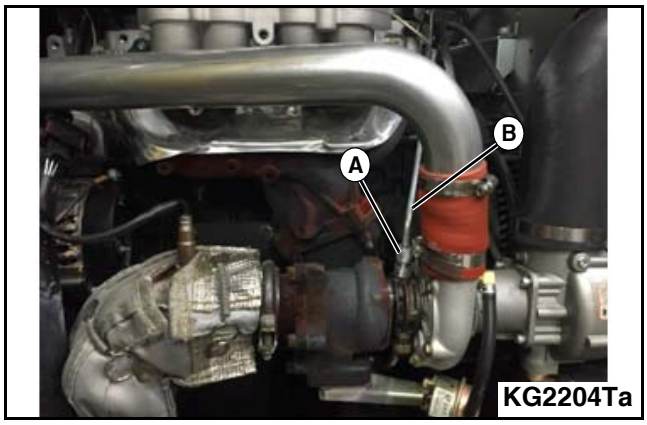


Figure 3-43

1. Drain the oil from the engine.
2. Disconnect the nut (A) on the turbocharger oil feed line fitting. Pull the oil feed line (B) slightly away from the fitting. **See Figure 3-43.**

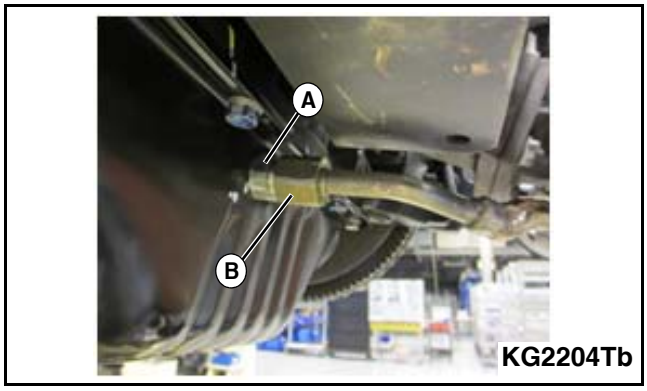


Figure 3-44

3. Using a wrench to hold the oil drain fitting in place, loosen and disconnect the nut (A) on the turbocharger oil drain line fitting (B). Pull the turbocharger oil drain line away from the fitting. **See Figure 3-44.**

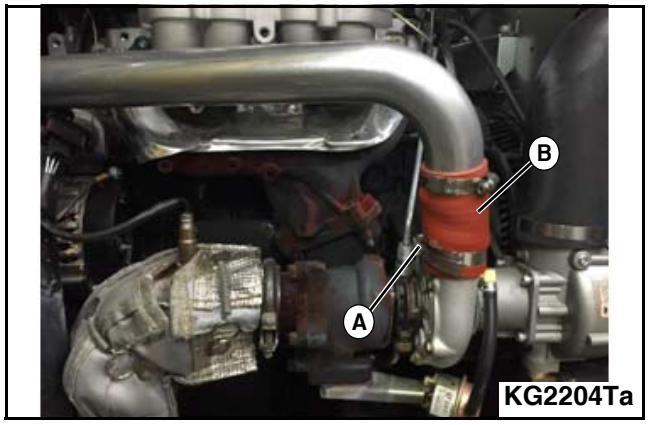


Figure 3-45

4. Loosen the hose clamp (A) on the turbocharger compressor discharge. Disconnect the hose (B) from the turbocharger compressor discharge. **See Figure 3-45.**

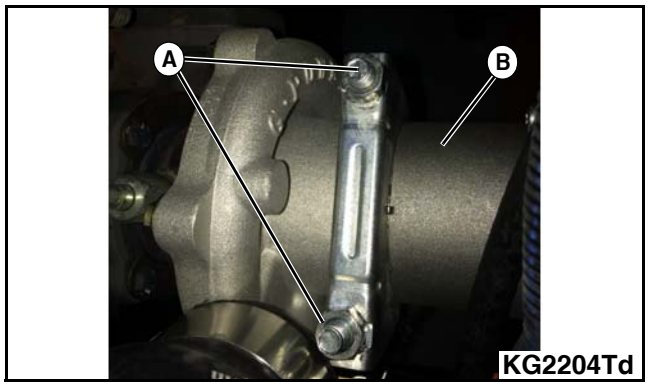


Figure 3-46

5. Remove the two nuts (A) on the clamp on the turbocharger compressor inlet adapter. Remove the clamp and disconnect the inlet adapter (B). **See Figure 3-46.**

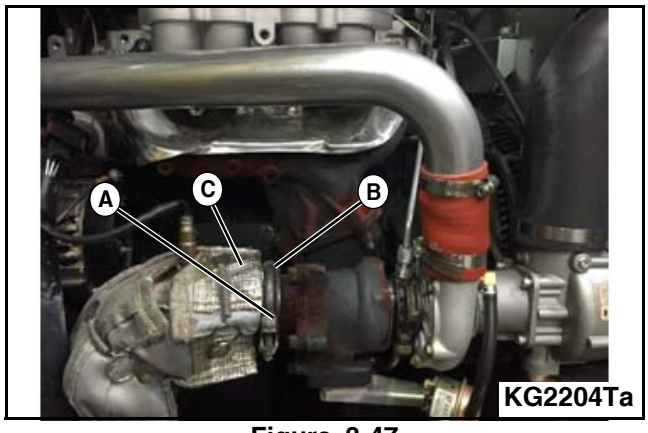


Figure 3-47

6. Remove the bolt (A) on the v-band clamp on the turbocharger outlet adapter. Remove the clamp (B) and then remove the exhaust pipe (C) from the turbocharger outlet adapter. **See Figure 3-47.**

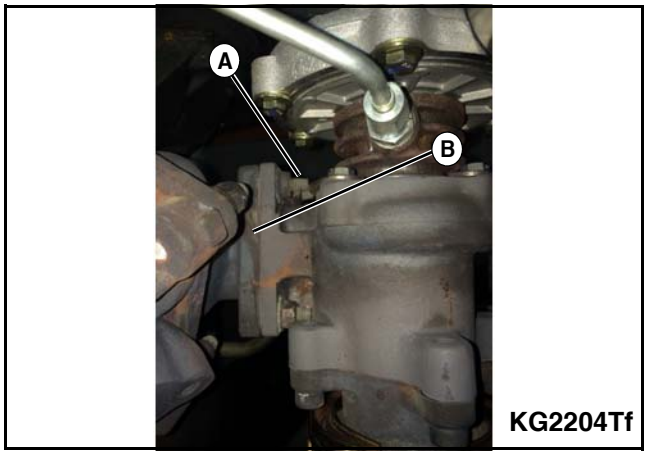


Figure 3-48

7. Remove the four nuts (A) on the turbocharger exhaust adapter flange. Remove the turbocharger from the exhaust adapter flange and remove the flange adapter gasket (B). **See Figure 3-48.**

Turbocharger Installation

NOTE:

See the engine parts catalog for replacement part numbers as needed.

Reverse steps of the removal process.

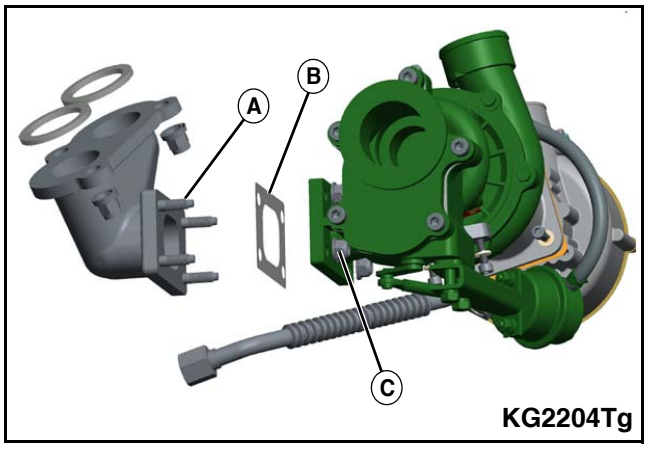


Figure 3-49

1. Remove the existing exhaust studs and install four new studs (A) into the exhaust flange adapter. Tighten to 20 ±3 N•m (14.8 ± 2 ft.lb.). Install the new exhaust flange adapter gasket (B). Install the turbocharger onto the exhaust flange adapter. Assemble four new nuts (C) onto exhaust flange adapter studs and tighten to 28 ±3 N•m (21 ± 2 ft.lb.). **See Figure 3-49.**

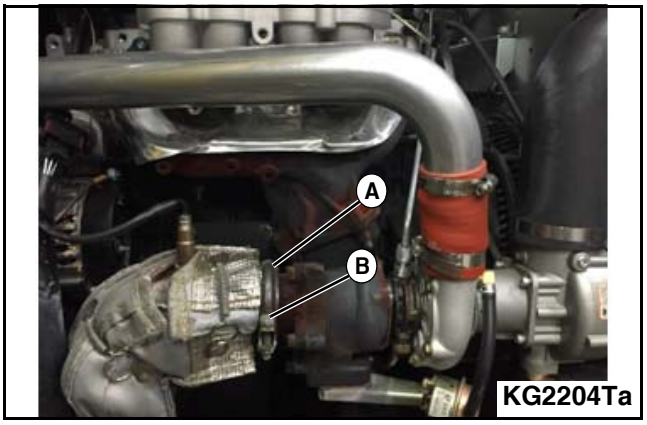


Figure 3-50

2. Connect the exhaust pipe to the turbocharger outlet and install the v-band clamp (A). Install the clamp bolt (B) and tighten to 20 N•m (14.8 ± 2 ft.lb.). **See Figure 3-50.**

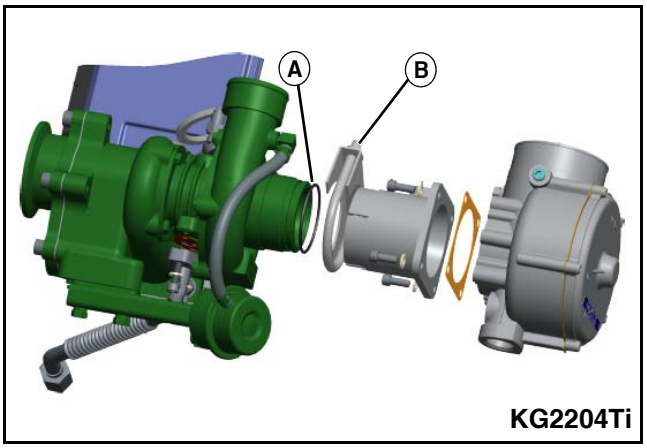


Figure 3-51

3. Inspect the O-ring (A) on the turbocharger compressor inlet and replace if damaged. Connect the inlet adapter to the turbocharger compressor inlet. Install the clamp onto the inlet adapter using two nuts. Tighten the nuts (B) to 14 ±1 N•m (10 ±1 ft.lb.). **See Figure 3-51.**

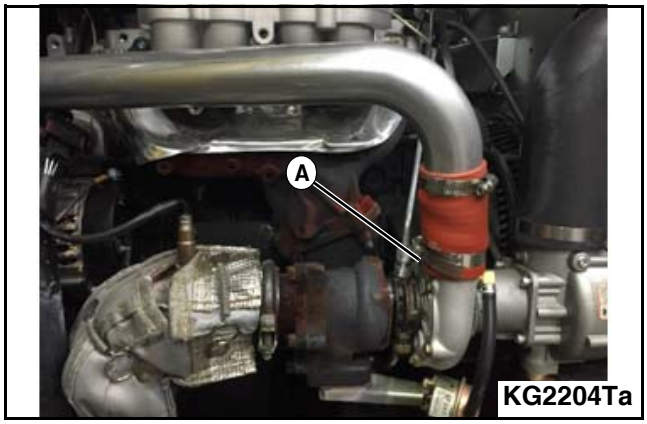


Figure 3-52

4. Connect the turbocharger compressor discharge hose to the turbocharger compressor outlet. Tighten the hose clamp (A) onto the hose (4.5 N•m [3.3 ft.lb.]). **See Figure 3-52.**

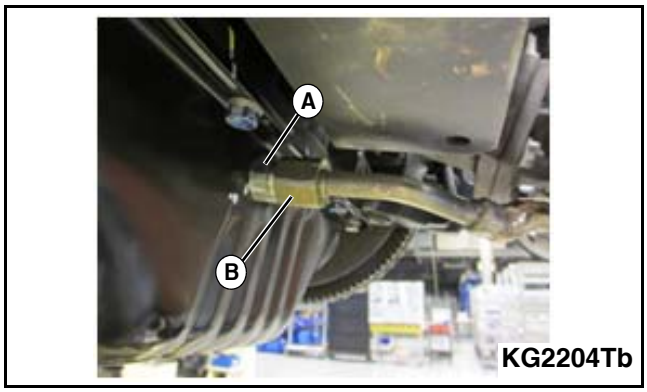


Figure 3-53

5. Connect the turbo oil drain line to the fitting in the oil pan. Apply a light coating of engine oil to the fitting thread. Thread the nut onto the fitting by hand. Use a wrench to hold the fitting (A) adjacent to the oil pan in place while tightening the nut (B) onto the fitting to 62 ± 3 N•m (46 ± 2 ft.lb.). **See Figure 3-53.**

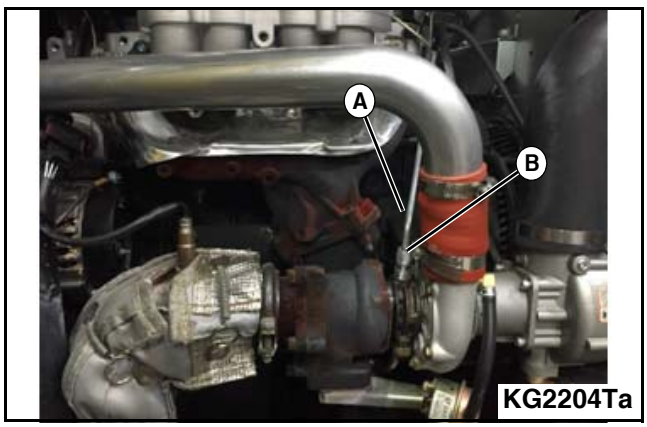


Figure 3-54

6. Connect the turbo oil feed line (A) onto the fitting on the turbocharger. Apply a light coating of engine oil to the fitting thread. Tighten the nut (B) onto the fitting to 16 ± 1 N•m (11.8 ± 1 ft.lb.). **See Figure 3-54.**

INTAKE MANIFOLD REMOVAL AND INSTALLATION

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

Removal

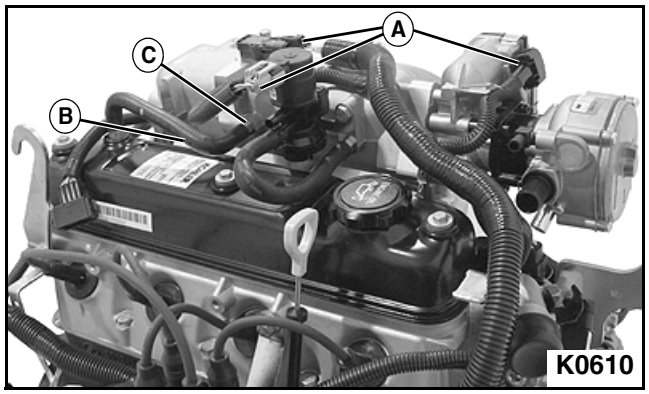


Figure 3-55

1. Disconnect three electrical connectors (A) from intake manifold sensors. **See Figure 3-55.**
2. Disconnect PCV hose (B) from intake manifold port (C). Close all openings.

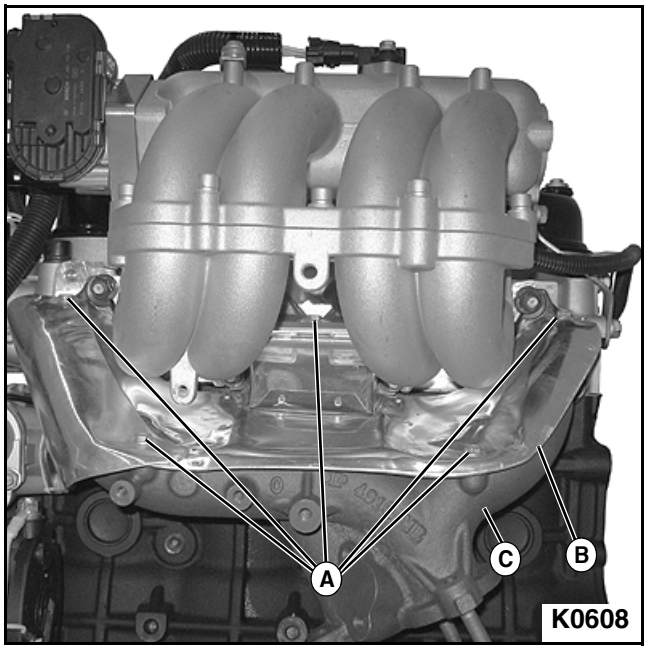


Figure 3-56

3. Remove five heat shield mounting bolts and flat washers (A) from heat shield (B). **See Figure 3-56.**
4. Remove heat shield from exhaust manifold (C).

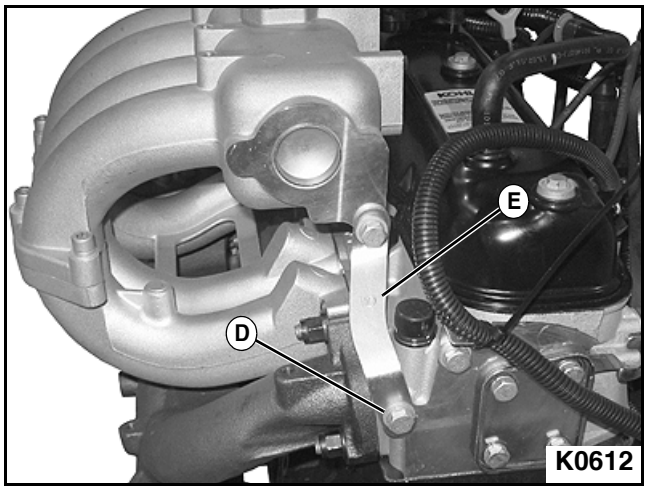


Figure 3-57

5. Remove bolt, flat washer, and lock washer (D) from intake manifold-to-cylinder head support bracket (E). **See Figure 3-57.**

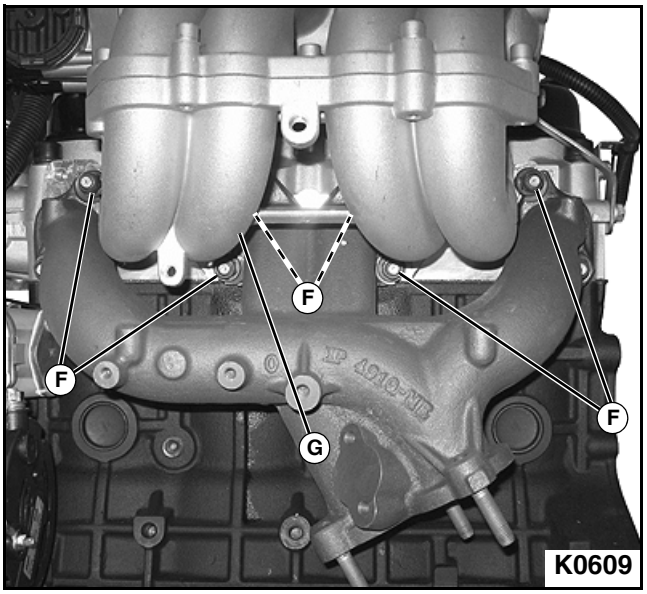


Figure 3-58

6. Remove six intake manifold flange nuts (F) and remove intake manifold (G) from cylinder head. **See Figure 3-58.**

NOTICE

Do not use harsh cleaning operations to clean intake manifold or cylinder head. Use of air buffers and steel scrapers may remove intake manifold or cylinder head material damaging intake manifold and/or cylinder head.

Inspection

1. Inspect intake manifold for cracks, corrosion holes, or erosion around the gasket area.
2. If inspection reveals any damage, replace intake manifold.

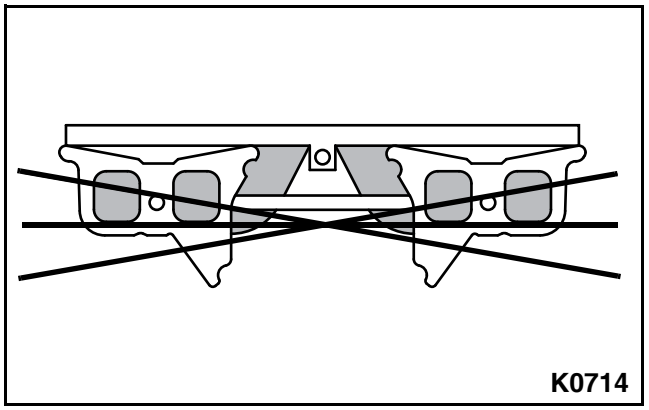


Figure 3-59

3. Inspect intake manifold for distortion using a straight edge and feeler gauge as shown. **See Figure 3-59.**
4. If intake manifold distortion exceeds specification, resurfacing or replacement of intake manifold is required.

   Intake Manifold Distortion Limit

   0.40 mm (0.0157 in.)
5. Inspect intake/exhaust manifold gasket for damage. If inspection reveals damage, remove exhaust manifold and replace intake/exhaust manifold gasket. See “Exhaust Manifold Removal and Installation” on page 62.

Installation

NOTE:

If exhaust manifold was removed, it must be installed before installation of intake manifold. See “Exhaust Manifold Removal and Installation” on page 62.

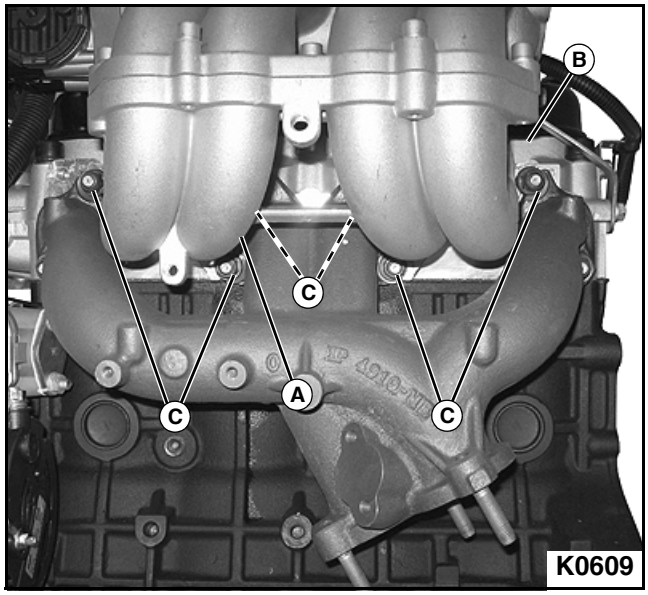


Figure 3-60

1. Install intake manifold (A) to cylinder head (B) with six flange nuts (C). **See Figure 3-60.**
2. Torque intake manifold flange nuts to specification.

   Intake Manifold Flange Nut Torque

   20 N•m (15 ft.lb.)

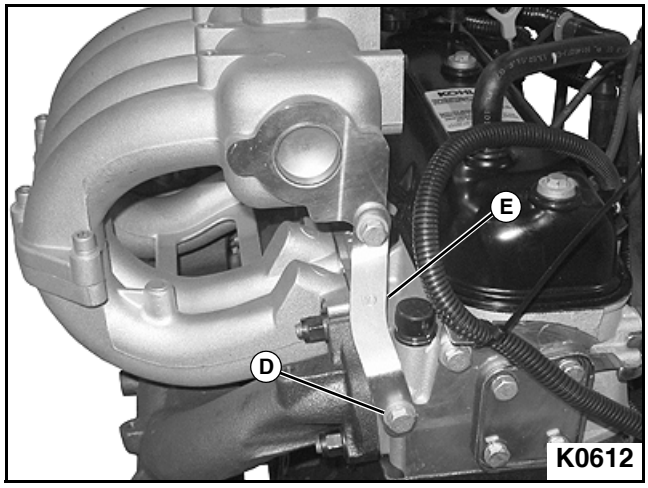


Figure 3-61

3. Install bolt, flat washer, and lock washer (D) to intake manifold-to-cylinder head support bracket (E). Tighten bolt. **See Figure 3-61.**

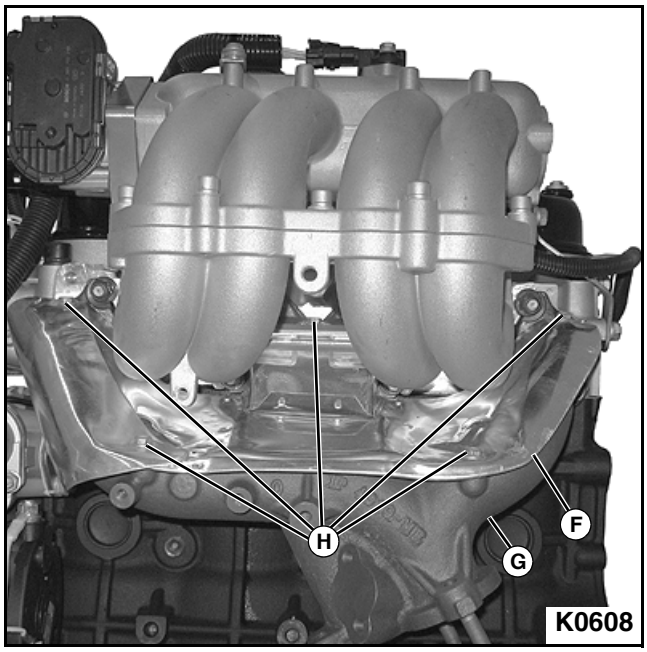


Figure 3-62

4. Install heat shield (F) to exhaust manifold (G) with five mounting bolts and flat washers (H). Tighten bolts. **See Figure 3-62.**

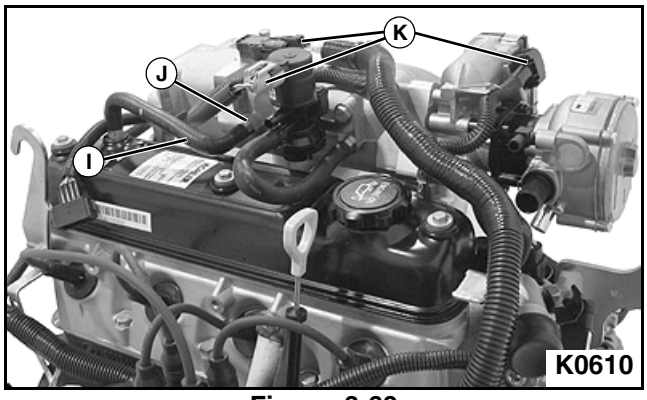


Figure 3-63

5. Connect PCV hose (I) to intake manifold port (J). **See Figure 3-63.**
6. Connect three electrical connectors (K) to intake manifold sensors.

UPPER INTAKE MANIFOLD REMOVAL AND INSTALLATION

WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

Removal

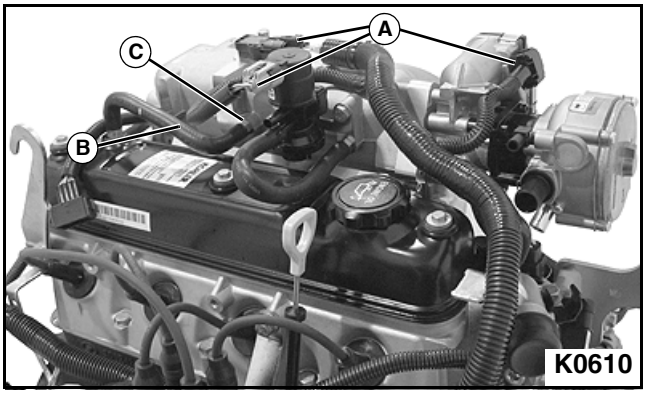


Figure 3-64

1. Disconnect three electrical connectors (A) from intake manifold sensors. **See Figure 3-64.**
2. Disconnect PCV hose (B) from intake manifold port (C). Close all openings.

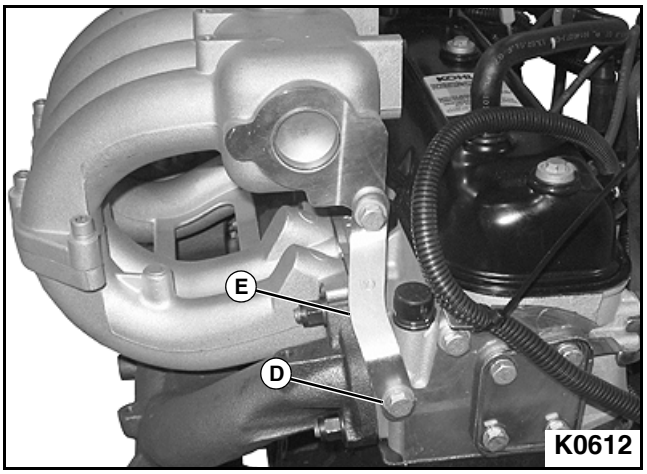


Figure 3-65

3. Remove bolt, flat washer, and lock washer (D) from intake manifold-to-cylinder head mounting bracket (E). **See Figure 3-65.**

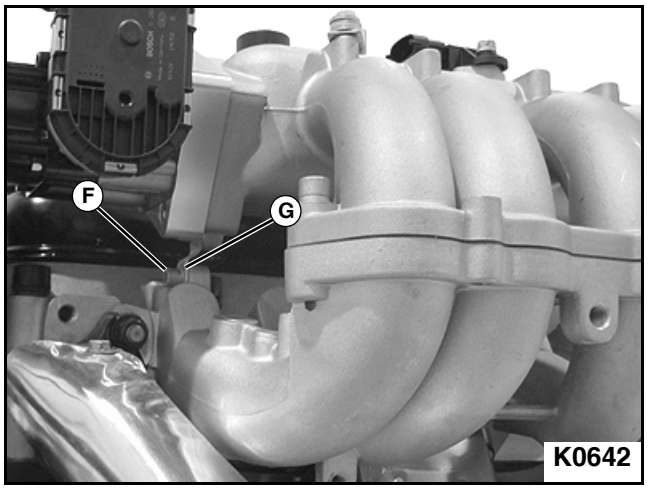


Figure 3-66

4. Remove mounting bolt (F) securing upper intake manifold to bracket (G). **See Figure 3-66.**

NOTE:

Take notice of upper intake mounting bolt length differences during removal for reference during installation.

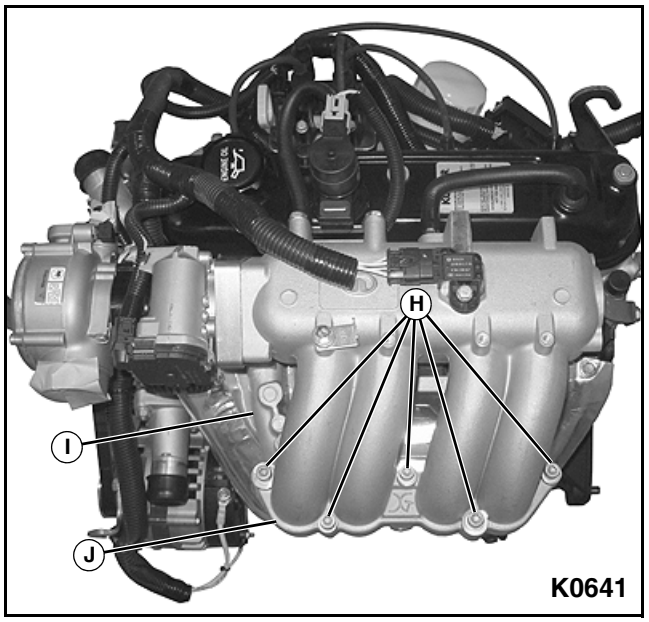


Figure 3-67

5. Remove five bolts, flat washers, and lock washers (H) securing upper intake (I) to lower intake manifold (J). **See Figure 3-67.**
6. Remove upper intake manifold from lower intake manifold. Cap/plug all openings.

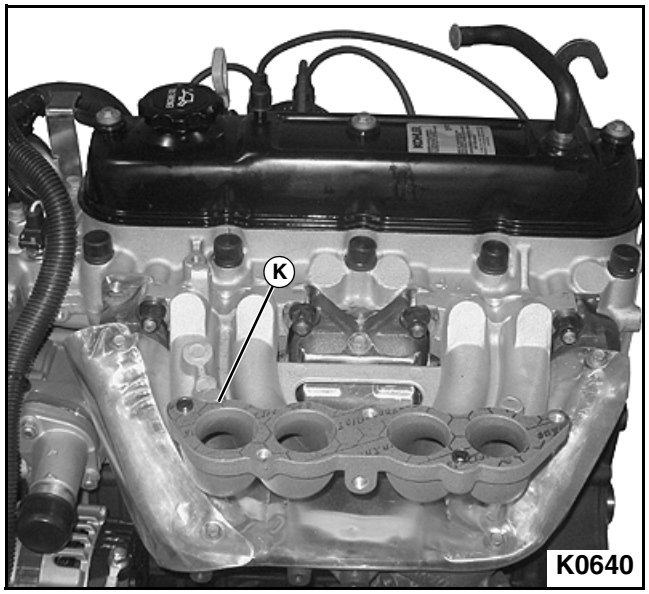


Figure 3-68

7. Remove old intake manifold gasket (K) from lower intake manifold. **See Figure 3-68.**

NOTICE

Do not use harsh cleaning operations to clean upper and lower intake manifolds. Use of air buffers and steel scrapers can remove intake manifold material very quickly, damaging intake manifolds.

8. Clean gasket surfaces.

Inspection

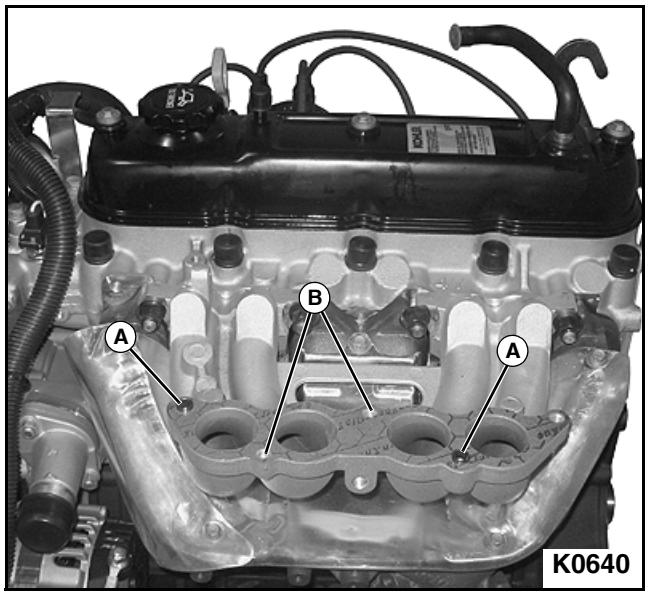


Figure 3-69

1. Inspect alignment pins (A) for distortion or looseness. **See Figure 3-69.**

- If inspection reveals distortion, replace alignment pins.
- If inspection reveals loose alignment pins, lightly tap alignment pins back into lower intake manifold with a soft faced hammer.

2. Inspect mounting bolt holes (B) for cracks or stripped threads. **See Figure 3-69.**
3. If inspection of bolt holes reveals cracks, replace lower intake manifold. If inspection reveals stripped bolt hole threads, repair bolt hole threads.

Installation

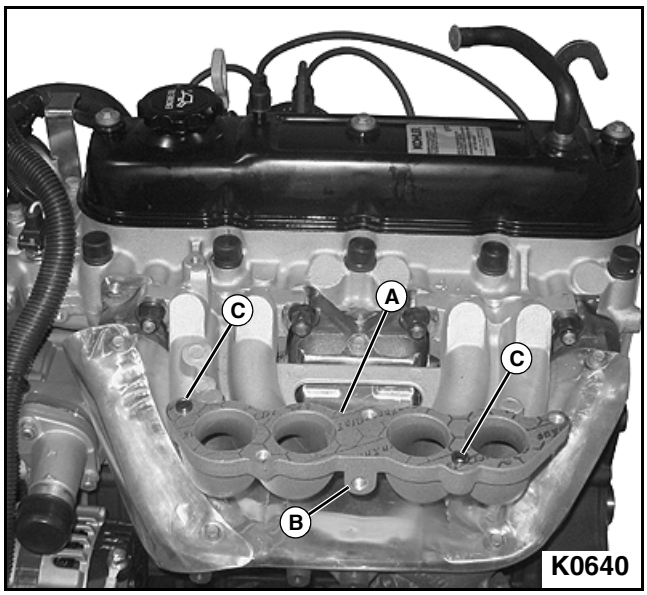


Figure 3-70

1. Install new upper-to-lower intake manifold gasket (A) to lower intake manifold (B). **See Figure 3-70.**

NOTICE
Ensure upper intake is properly positioned on lower intake alignment pins (C) or damage may occur.

2. Install upper intake to lower intake.

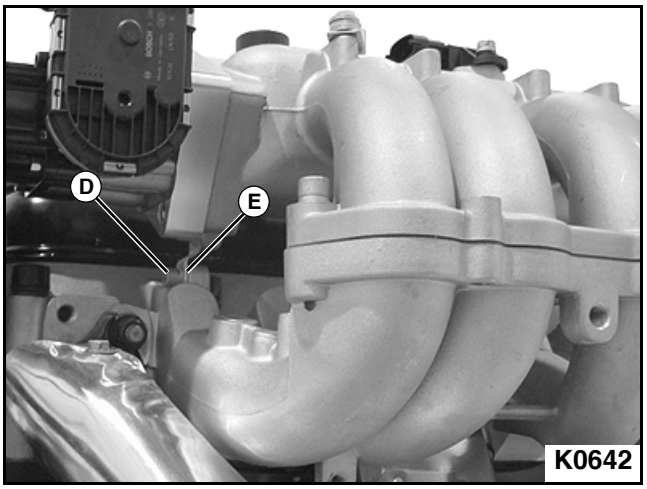


Figure 3-71

3. Install mounting bolt (D) securing upper intake manifold to bracket (E). Do not tighten bolt at this time. **See Figure 3-71.**

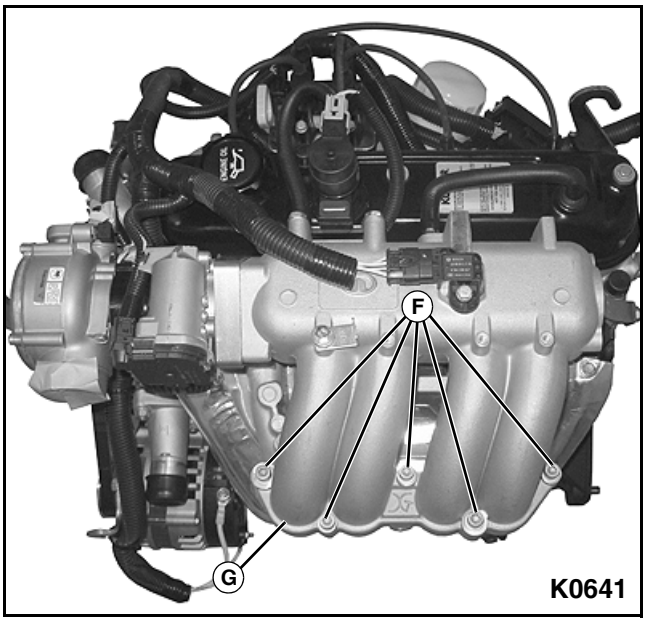


Figure 3-72

4. Install five bolts, flat washers, and lock washers (F) to upper intake manifold (G) as noted during removal. Tighten bolts. **See Figure 3-72.**

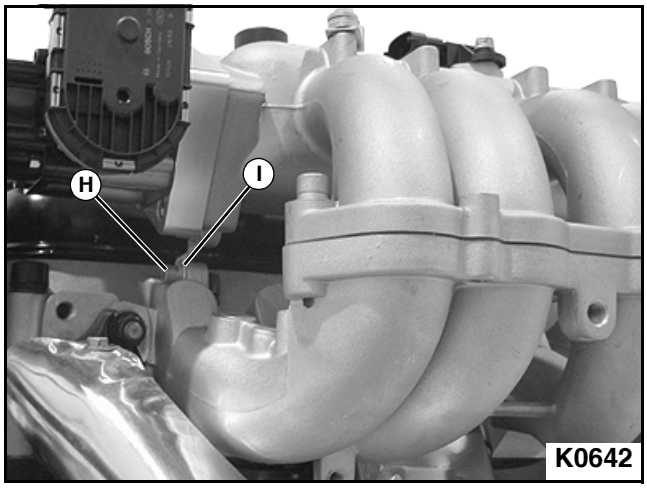


Figure 3-73

5. Tighten mounting bolt (H) securing upper intake manifold to bracket (I). **See Figure 3-73.**

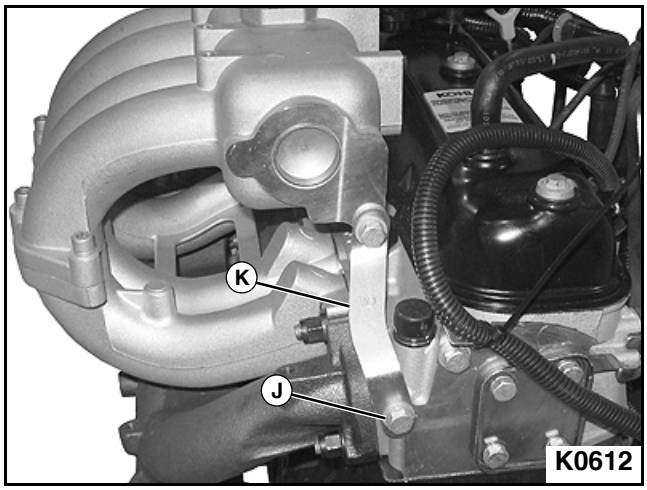


Figure 3-74

6. Install rear intake manifold-to-cylinder head mounting bracket bolt, flat washer, and lock washer (J) to manifold-to-cylinder head mounting bracket (K). Tighten bolt. **See Figure 3-74.**

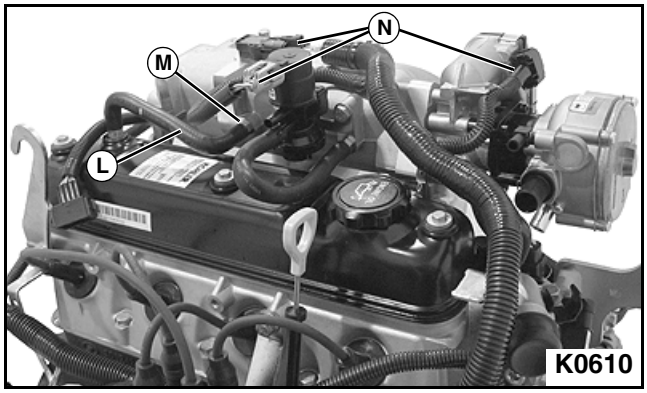


Figure 3-75

7. Connect PCV hose (L) to intake manifold port (M). **See Figure 3-75.**
8. Connect three electrical connectors (N) to intake manifold sensors.

EXHAUST MANIFOLD REMOVAL AND INSTALLATION

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

Removal

1. Remove intake manifold. See “Intake Manifold Removal and Installation” on page 56.

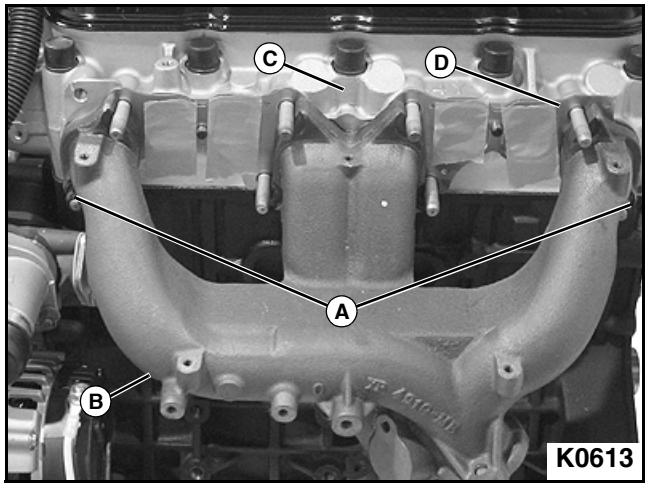


Figure 3-76

2. Remove two exhaust manifold flange nuts (A) and remove exhaust manifold (B) from cylinder head (C). **See Figure 3-76.**
3. Remove intake/exhaust manifold gasket (D) from cylinder head. Close all openings.

NOTICE

Do not use harsh cleaning operations to clean intake manifold or cylinder head. Use of air buffers and steel scrapers may remove intake manifold and cylinder head material, damaging intake manifold and cylinder head.

4. Remove intake/exhaust manifold gasket (D) from intake/exhaust manifolds and cylinder head (C). Close all openings.

Inspection

1. Inspect exhaust manifold for cracks, rust holes, or erosion around the gasket area.
2. If inspection reveals cracks, rust holes or erosion around gasket area, replace intake manifold.

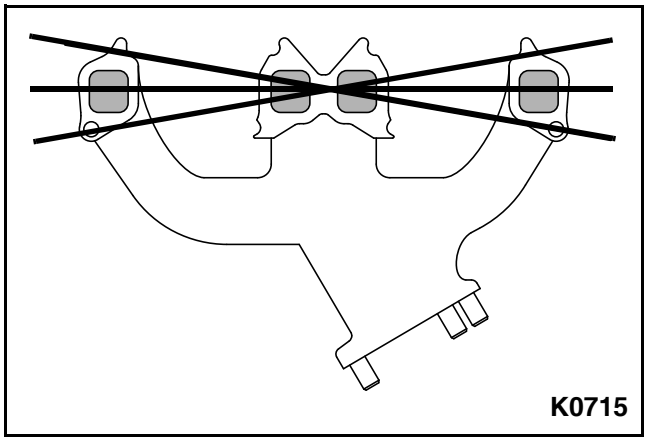


Figure 3-77

3. Inspect exhaust manifold for distortion using a straightedge and feeler gauge as shown. **See Figure 3-77.**
4. If exhaust manifold distortion exceeds specification, resurfacing or replacement of exhaust manifold is required.

   Exhaust Manifold Distortion Limit

   0.40 mm (0.0157 in.)
5. Inspect exhaust manifold to pipe mounting studs for being loose, broken, or have stripped threads.
6. If exhaust pipe mounting studs are loose, broken, or have stripped threads, tighten or replace manifold to pipe mounting studs.

Installation

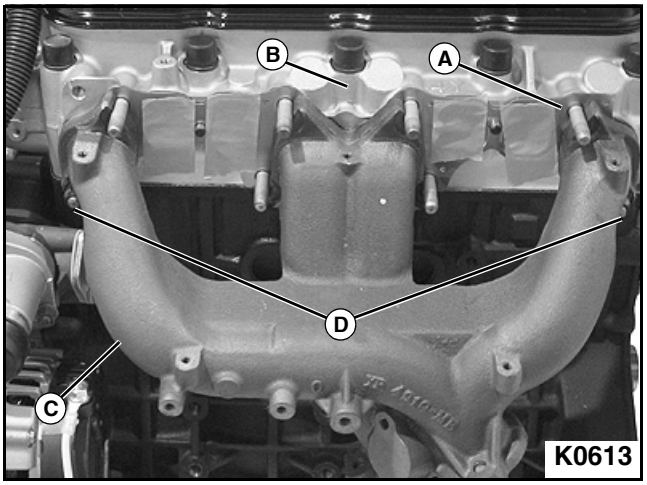


Figure 3-78

1. Install new intake/exhaust manifold gasket (A) to cylinder head (B). **See Figure 3-78.**
2. Install exhaust manifold (C) to cylinder head with two flange nuts (D).
3. Torque exhaust manifold flange nuts.

   Exhaust Manifold Flange Nut Torque

   20 N•m (15 ft.lb.)
4. Install intake manifold to cylinder head. See “Intake Manifold Removal and Installation” on page 56.

REMOVE AND INSTALL FLYWHEEL

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

Removal

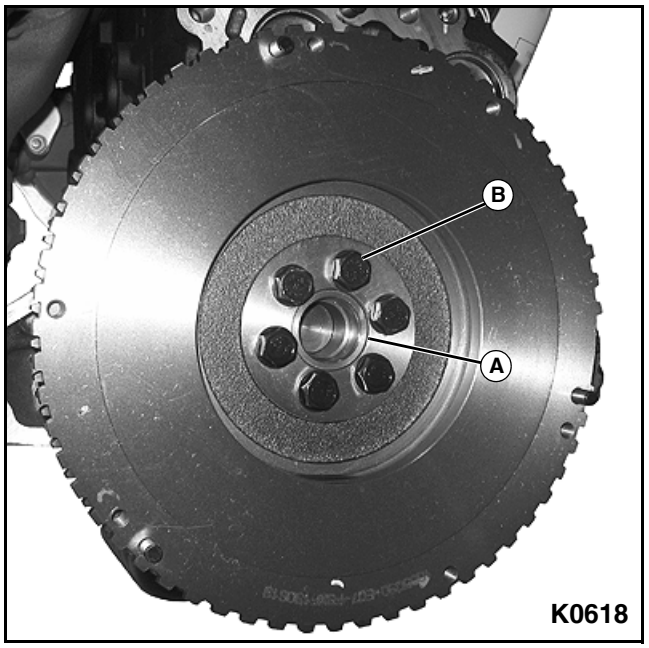


Figure 3-79

1. Mark flywheel to crankshaft (A) for proper indexing during assembly. **See Figure 3-79.**
2. Remove six flywheel mounting bolts (B) from flywheel.
3. Remove flywheel from crankshaft.

Installation

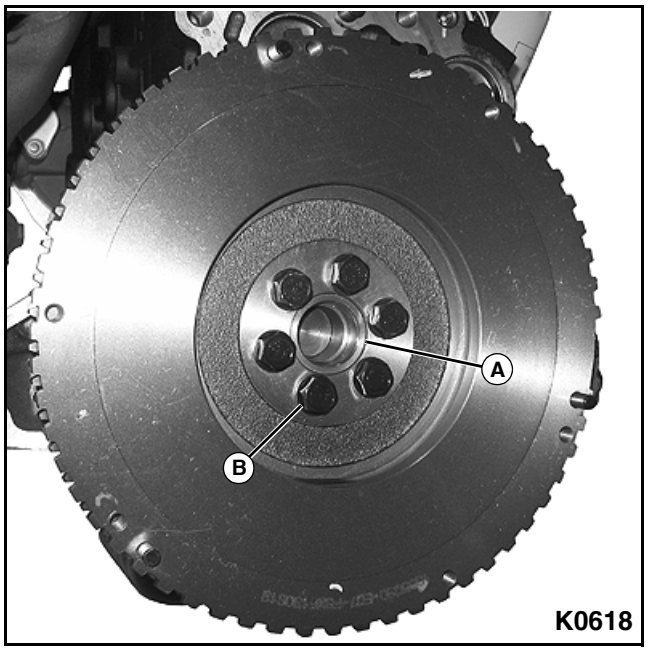


Figure 3-80

1. Install flywheel to crankshaft as marked (A) during removal. **See Figure 3-80.**
2. Install six flywheel mounting bolts (B). Torque bolts to specification. **See Figure 3-80.**

   Flywheel Bolt Torque

   85 N•m (63 ft.lb.)
3. Run engine and check for leaks.

REMOVE AND INSTALL CRANKSHAFT POSITION SENSOR

Removal

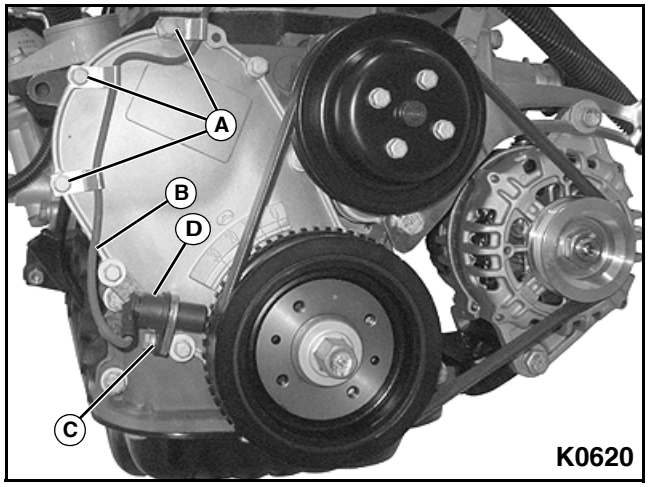


Figure 3-81

1. Remove three electrical harness clamp bolts, flat washers, and lock washers (A) from crankshaft position sensor wiring harness (B). **See Figure 3-81.**
2. Remove mounting bolt, flat washer, and lock washer (C) from crankshaft position sensor (D) and remove sensor.

Installation

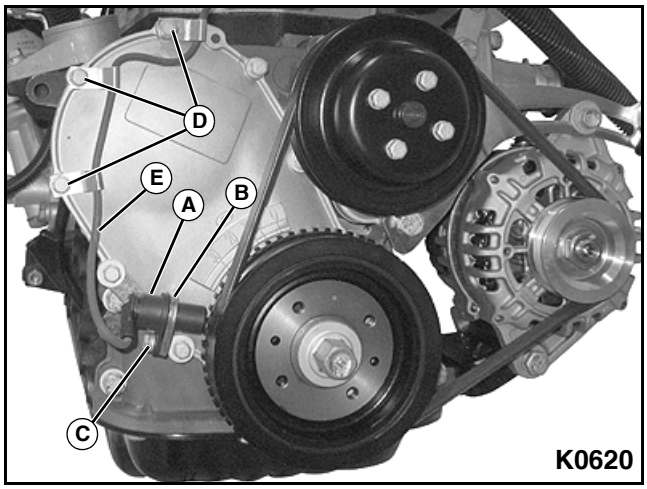


Figure 3-82

1. Install crankshaft position sensor (A) to mounting bracket (B). **See Figure 3-82.**
2. Install mounting bolt, flat washer, and lock washer (C) to crankshaft position sensor.
3. Install three electrical harness clamp bolts, flat washers, and lock washers (D) to crankshaft position sensor wiring harness (E).

REMOVE AND INSTALL CRANKSHAFT VIBRATION DAMPENER

Removal

1. Remove drive belt. See “Drive Belt Removal and Installation” on page 45.

NOTE:

Use care not to damage crankshaft position sensor when removing crankshaft vibration dampener.

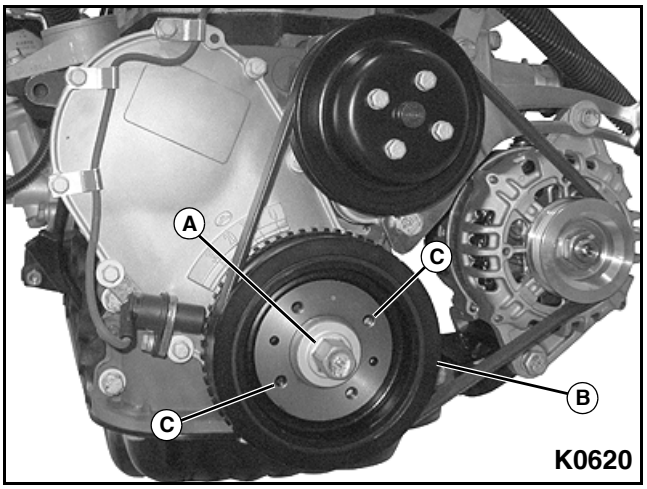


Figure 3-83

2. Remove mounting bolt (A) from crankshaft vibration dampener (B). **See Figure 3-83.**

NOTICE

Do not use a jaw puller on the outside of the crankshaft vibration dampener. Damage will occur to the crankshaft vibration dampener if jaw puller is used.

Failure to use a center pilot to protect threads in crankshaft end will result in damage to crankshaft.

3. Install a puller with center pilot to the center hub bolt holes (C) of crankshaft vibration dampener.
4. Remove crankshaft vibration dampener from crankshaft.

Inspection

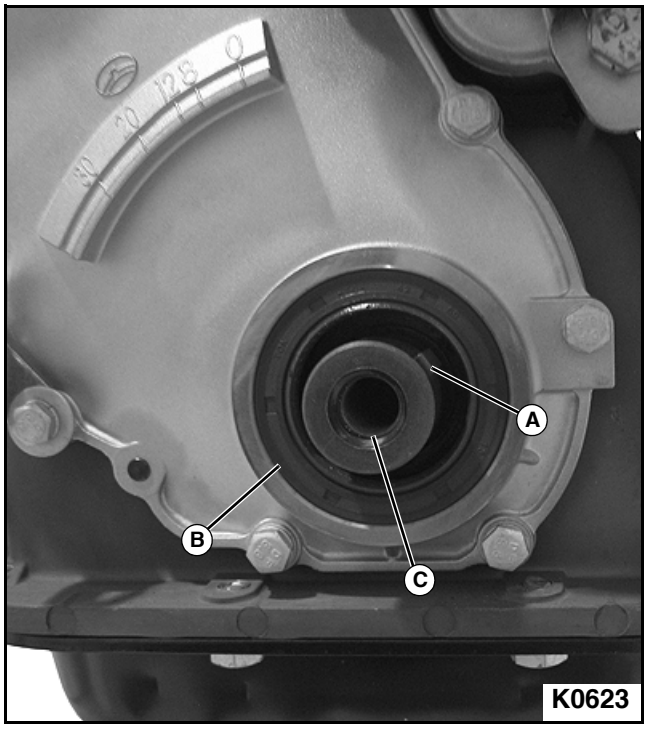


Figure 3-84

1. Inspect crankshaft key (A) for wear or damage. If crankshaft key is worn or damaged, replace crankshaft key. **See Figure 3-84.**
2. Inspect front crankshaft seal (B). If seal lip is damaged or worn, replace front crankshaft seal. See “Remove and Install Front Crankshaft Seal” on page 67.
3. Inspect crankshaft threads (C). If inspection reveals threads are damaged, repair threads.
4. Inspect crankshaft vibration dampener mounting bolt threads. If inspection reveals threads are damaged, replace crankshaft vibration dampener mounting bolt.

Figure 3-85

5. Inspect condition of crankshaft vibration dampener keyway (A) for wear or damage. **See Figure 3-85.**
6. Inspect condition of sealing surface (B) of crankshaft vibration dampener for seal cutting.
7. Inspect condition of crankshaft position sensor reluctor ring teeth (C).
8. Inspect the rubber ring of crankshaft vibration dampener for separation from center hub.
9. Inspect condition of drive belt pulley.
10. If inspection reveals wear or damage, replace crankshaft vibration dampener.

Installation

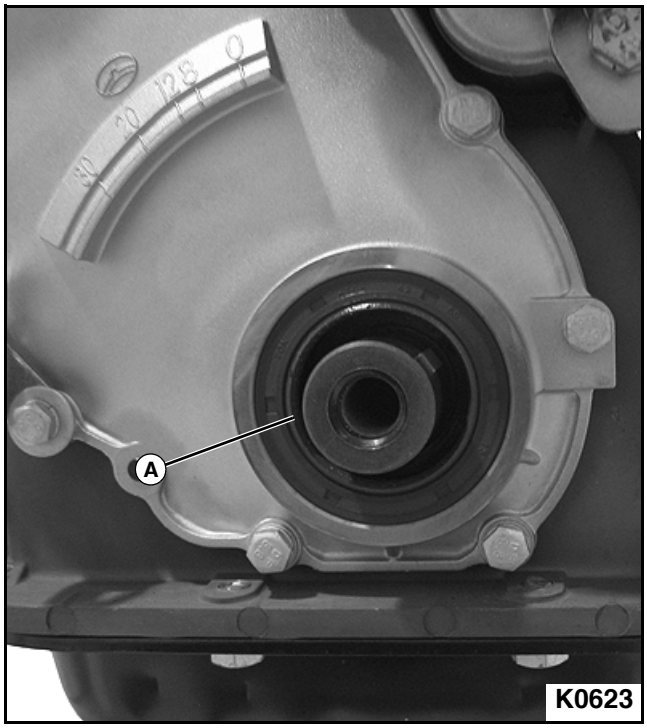


Figure 3-86

1. Lubricate front crankshaft seal lip (A) and sealing surface of crankshaft vibration dampener with clean engine oil. **See Figure 3-86.**

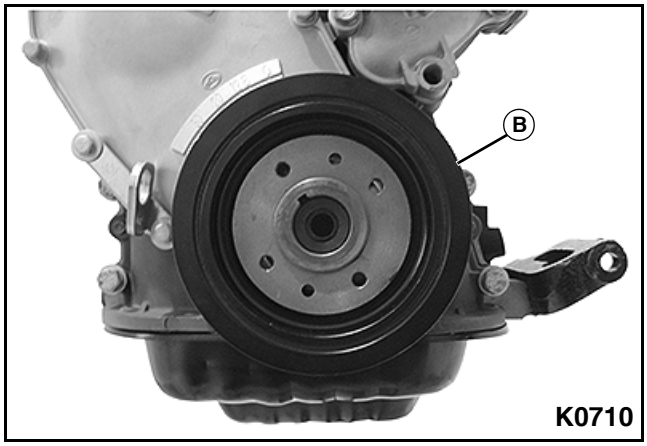


Figure 3-87

2. Carefully install crankshaft vibration dampener to crankshaft so as not to damage front crankshaft seal. Tap crankshaft vibration dampener with a soft face hammer to seat dampener to crankshaft. **See Figure 3-87.**

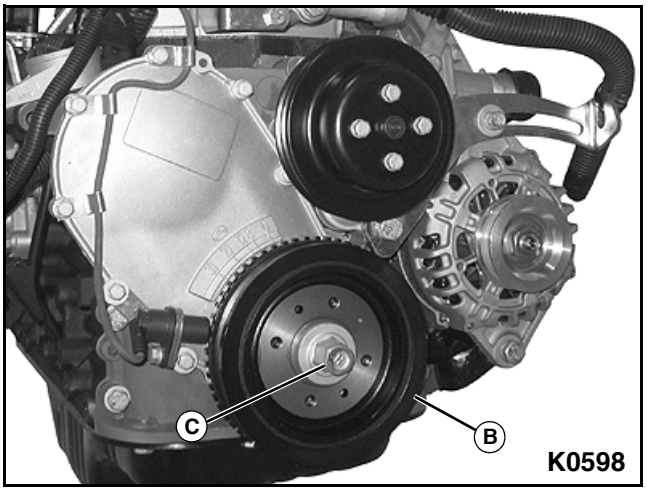


Figure 3-88

3. Install crankshaft vibration dampener mounting bolt (C) to crankshaft and dampener (B). **See Figure 3-88.**
4. Torque crankshaft vibration dampener mounting bolt to specification. **See Figure 3-88.**

   Crankshaft Vibration Dampener Bolt Torque

   160 N•m (118 ft.lb.)
5. Install drive belt. See “Drive Belt Removal and Installation” on page 45.

REMOVE AND INSTALL FRONT CRANKSHAFT SEAL

Removal

1. Remove drive belt. See “Drive Belt Removal and Installation” on page 45.
2. Remove crankshaft vibration dampener. See “Remove and Install Crankshaft Vibration Dampener” on page 65.

NOTICE

Failure to use a center pilot to protect threads in crankshaft end will result in damage to crankshaft.
Timing chain cover damage will occur if puller is inserted past the front crankshaft seal and is allowed to hook on timing chain cover.
Do not nick or scratch crankshaft with seal puller.
Note orientation of seal lip.

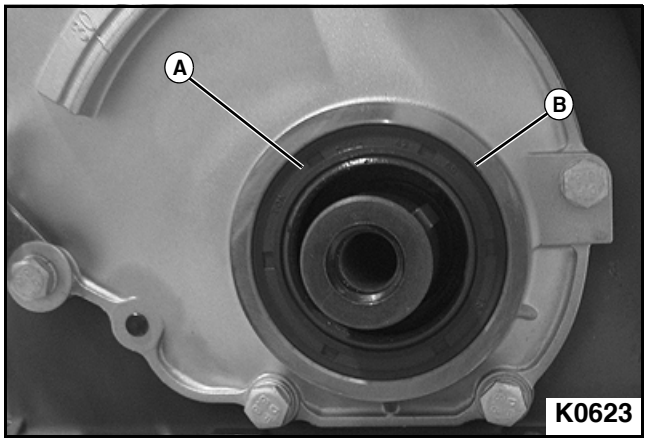


Figure 3-89

3. Remove front crankshaft seal (A) using a seal puller or equivalent tool. **See Figure 3-89.**
4. Clean timing chain cover (B) of any sealer or old crankshaft seal.

Installation

NOTE:

Install new front crankshaft seal oriented as noted during removal.

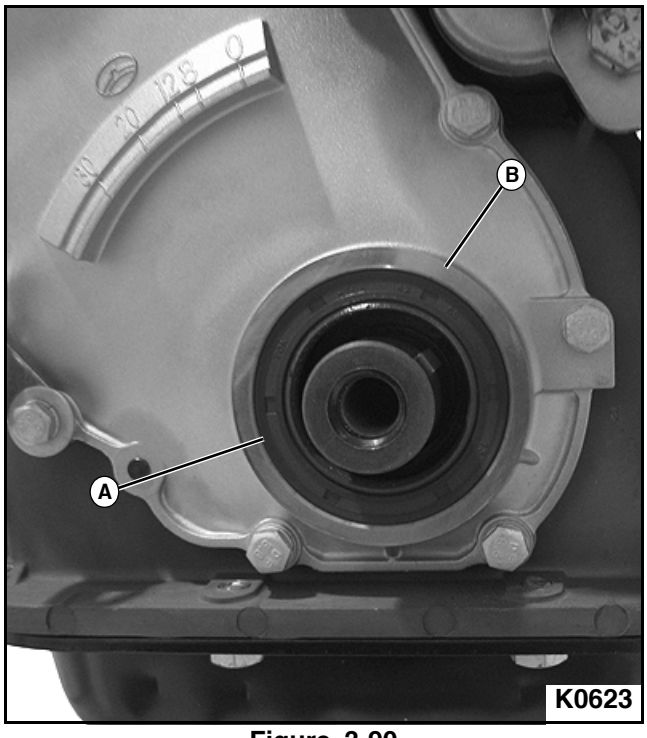


Figure 3-90

1. Drive front crankshaft seal (A) into timing chain cover (B) with seal driver or equivalent tool until seal is flush with timing chain cover. **See Figure 3-90.**
2. Install crankshaft vibration dampener. See “Remove and Install Crankshaft Vibration Dampener” on page 65.
3. Install drive belt. See “Drive Belt Removal and Installation” on page 45.
4. Run engine and check for leaks.

REMOVE AND INSTALL REAR CRANKSHAFT SEAL

Removal

1. Remove flywheel. See “Remove and Install Flywheel” on page 63.

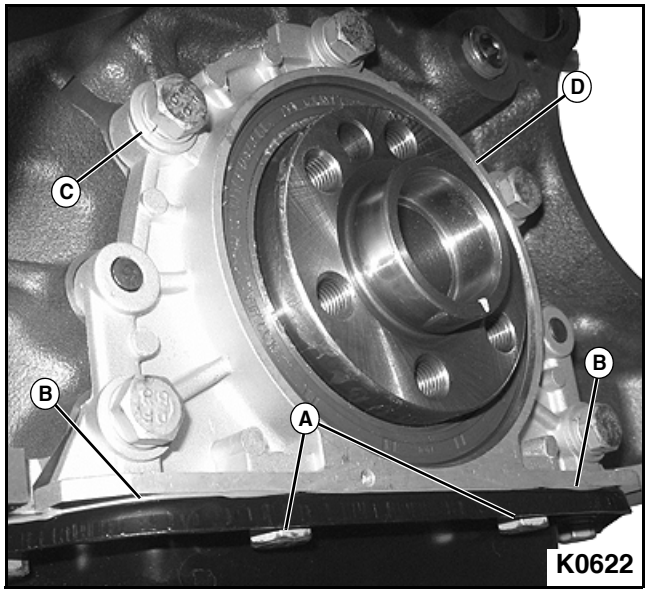


Figure 3-91

2. Remove two rear engine oil pan mounting bolts (A). **See Figure 3-91.**
3. Using a sharp blade, cut sealant (B) between engine oil pan and rear crankshaft seal retainer.
4. Remove five rear crankshaft seal retainer-to-cylinder block mounting bolts, flat washers, and lock washers (C) from rear crankshaft seal retainer (D).
5. Remove rear crankshaft seal retainer from cylinder block.

NOTE:

Take notice of seal lip orientation for installation.

6. Remove rear crankshaft seal from seal retainer using a seal driver or equivalent tool.
7. Clean rear crankshaft seal retainer and cylinder block of old gasket.
8. Clean engine oil pan of old sealant.
9. Check crankshaft for any burrs or imperfections that may damage new seal. Remove with emery paper if necessary.

Installation

NOTE:

Install new rear crankshaft seal oriented as noted during removal.

1. Using a seal driver or equivalent tool, install rear crankshaft seal into rear crankshaft seal retainer until flush with outer face of rear crankshaft seal retainer.

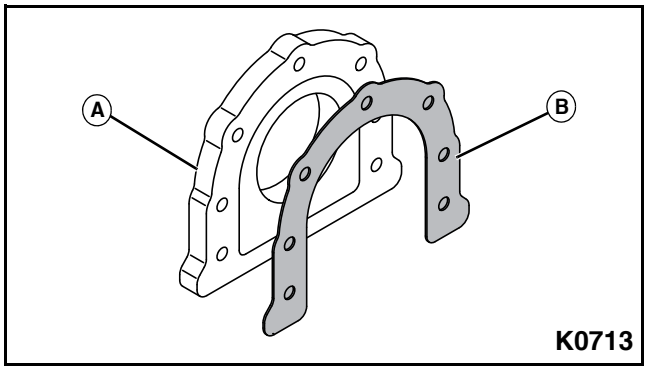


Figure 3-92

2. Install new gasket (B) between rear crankshaft seal retainer (A) and cylinder block. **See Figure 3-92.**

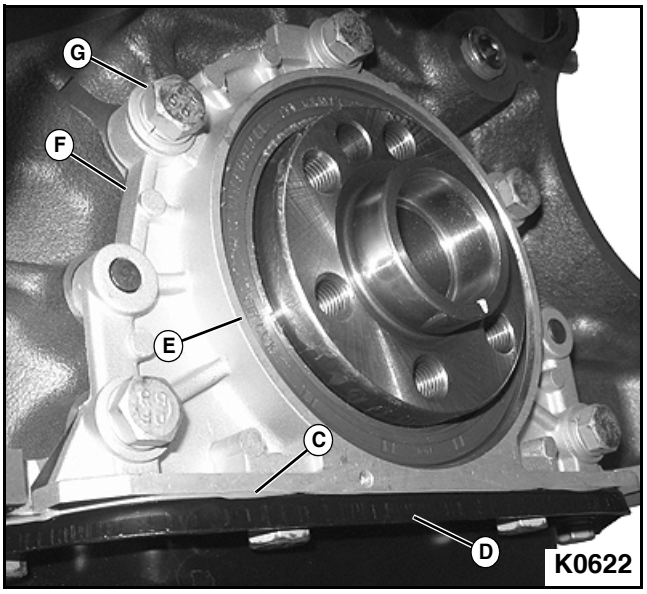


Figure 3-93

3. Run a 3 mm bead of sealant (C) along the top center of the engine oil pan flange (D). **See Figure 3-93.**
4. Lubricate lip of rear crankshaft seal (E) and crankshaft with clean engine oil.
5. Carefully install rear crankshaft seal retainer assembly (F) over crankshaft.
6. Secure rear crankshaft seal retainer to cylinder block with five mounting bolts, flat washers, and lock washers (G). Torque bolts to specification.

   Rear Crankshaft Seal Retainer Bolt Torque

   12 N•m (9 ft.lb.)

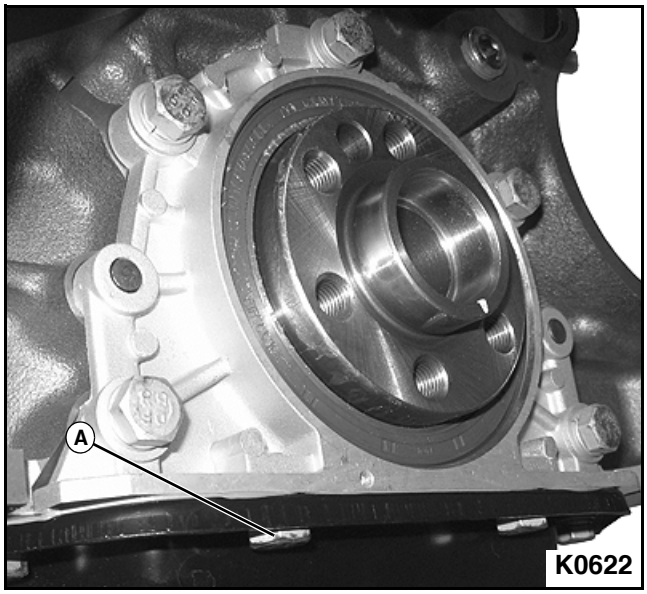


Figure 3-94

7. Install two rear engine oil pan-to-rear crankshaft seal retainer mounting bolts (A). **See Figure 3-94.**
8. Install flywheel. See “Remove and Install Flywheel” on page 63.

REMOVE AND INSTALL ROCKER ARM COVER

Removal

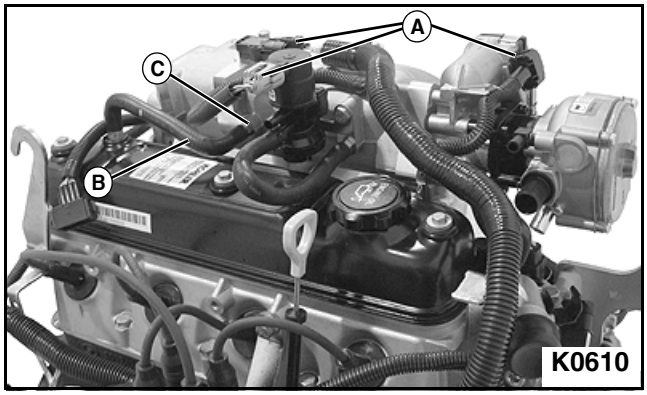


Figure 3-95

1. Disconnect three electrical connectors (A) from intake manifold sensors and set wiring harness aside. **See Figure 3-95.**
2. Disconnect PCV hose (B) from intake manifold port (C). Close all openings.

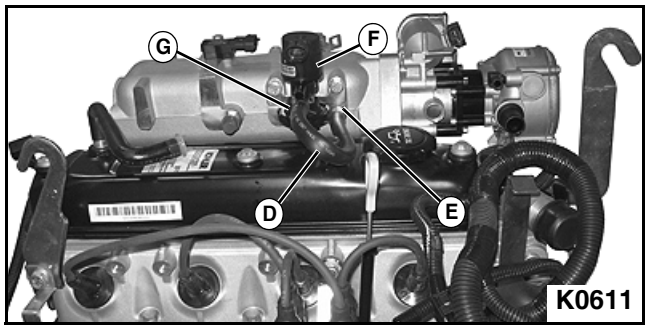


Figure 3-96

3. Disconnect fuel control valve vacuum hose (D) from intake manifold port (E). Close all openings. **See Figure 3-96.**
4. Pull fuel control valve (F) straight up to remove from fuel control valve mounting bracket (G).

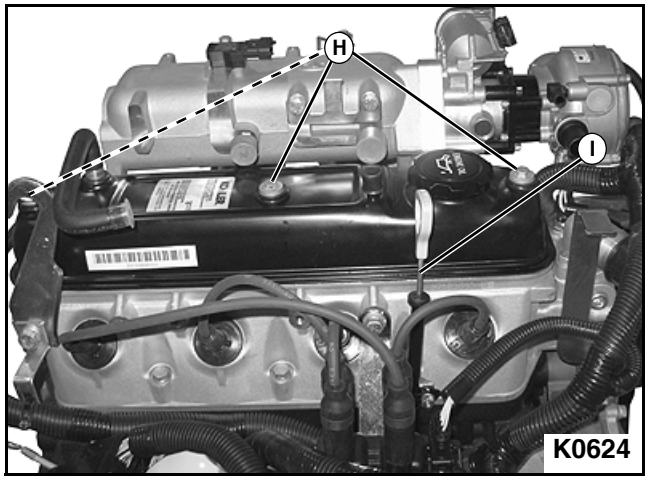


Figure 3-97

5. Remove three rocker arm cover mounting nuts and oil seals (H). **See Figure 3-97.**
6. Remove engine oil dipstick (I).

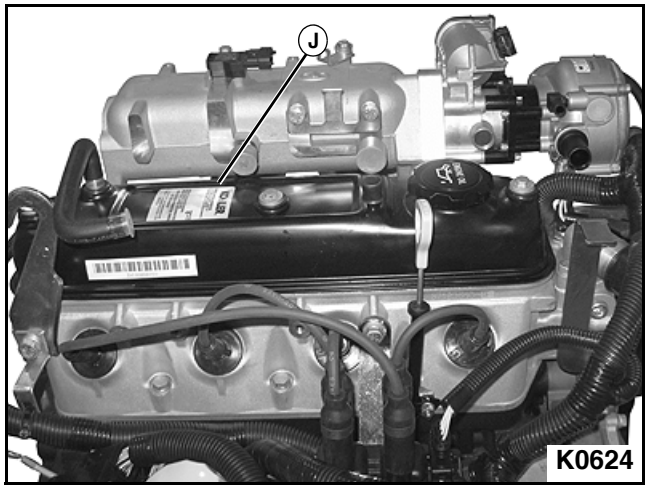


Figure 3-98

7. Remover rocker arm cover (J) from cylinder head. **See Figure 3-98.**

Inspection

1. Inspect rocker arm cover gasket and mounting nut seals for hardness, cracks, and splits.
2. Replace rocker arm cover gasket or seals if inspection reveals damage.

Installation

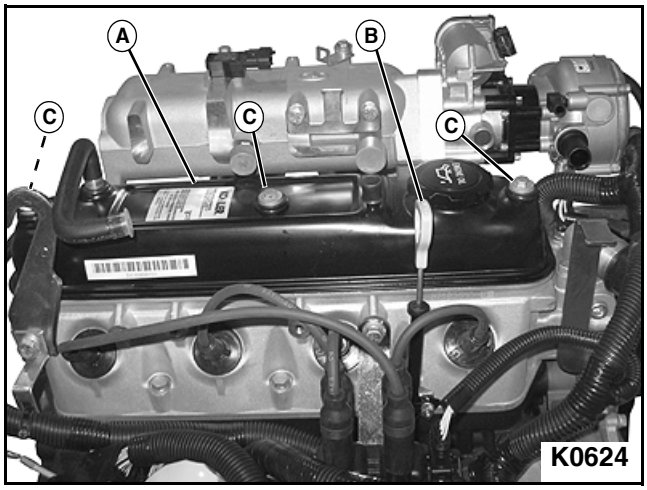


Figure 3-99

1. Install rocker arm cover (A) to cylinder head. **See Figure 3-99.**
2. Install engine oil dipstick (B).
3. Install three seals and mounting nuts (C). Tighten rocker arm cover nuts.

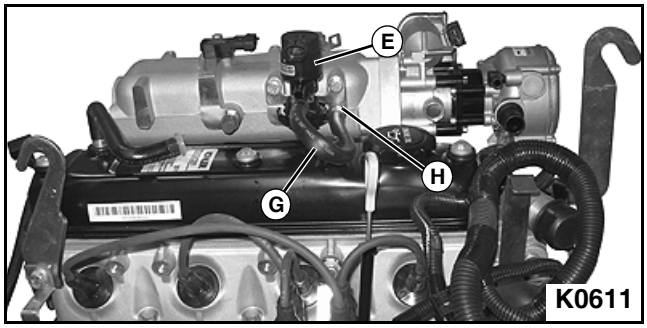


Figure 3-100

4. Push fuel control valve (E) straight down onto fuel control valve mounting bracket. **See Figure 3-100.**
5. Connect fuel control valve vacuum hose (G) to intake manifold port (H).

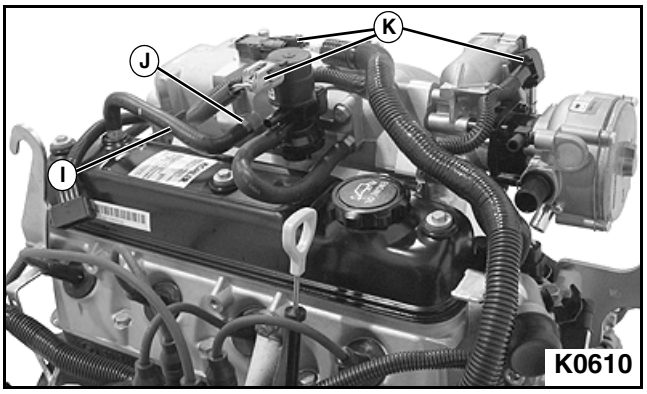


Figure 3-101

6. Connect PCV hose (I) to intake manifold port (J). **See Figure 3-101.**
7. Connect three electrical connectors (K) to intake manifold sensors.

REMOVE AND INSTALL OIL PAN

Removal

1. Drain engine oil.

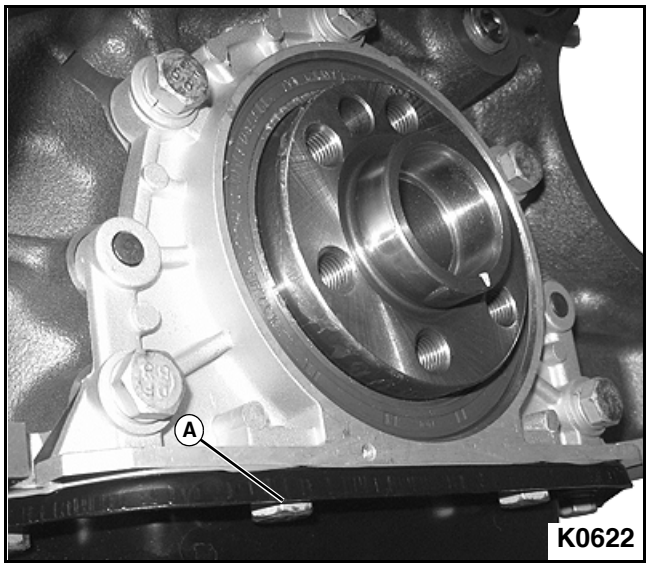


Figure 3-102

2. Remove 16 oil pan mounting bolts, flat washers, and lock washers (A) from oil pan. **See Figure 3-102.**
3. Remove two oil pan mounting nuts, flat washers, and lock washers from oil pan.

NOTICE

Do not pry oil pan loose from cylinder block. Damage will occur to sealing flange of oil pan if sealant is not cut.

4. To remove oil pan from cylinder block, cut sealant with a sharp blade or equivalent tool.
5. Clean old sealant from oil pan and cylinder block.
6. Clean any debris from inside oil pan and engine.

Installation

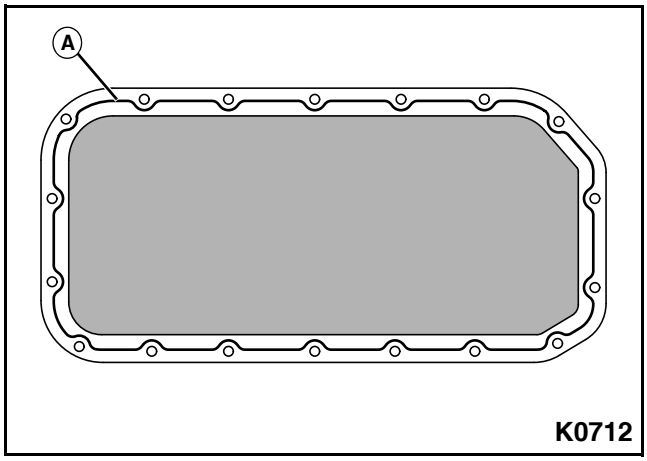


Figure 3-103

1. Install new sealant material (A) to oil pan in a 3 mm (0.12 in.) bead. Overlap starting and ending points of application. **See Figure 3-103.**
2. Install oil pan to cylinder block with two nuts, flat washers, and lock washers. Lightly tighten nuts.
3. Install 16 oil pan mounting bolts, flat washers, and lock washers to oil pan. Torque oil pan bolts and nuts to specification.

   Oil Pan Bolt and Nut Torque

   13 N•m (10 ft.lb.)
4. Install oil pan drain plug to oil pan. Torque oil drain plug to specification.

   Oil Drain Plug Torque

   20-25 N•m (15–18 ft.lb.)
5. Fill engine oil to specification See “Fluid Specifications” on page 19.

OIL PUMP DRIVE REMOVAL AND INSTALLATION

Removal

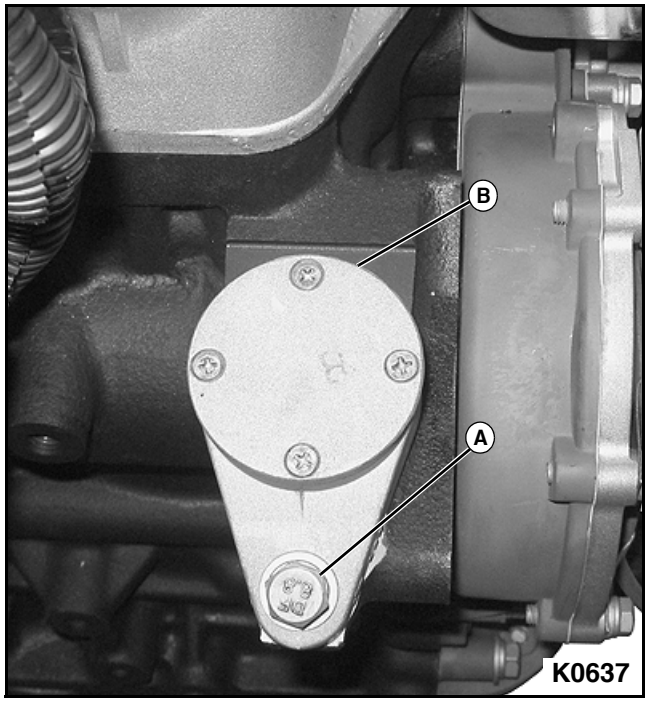


Figure 3-104

1. Remove mounting bolt, flat washer, and lock washer (A) from oil pump drive (B). **See Figure 3-104.**
2. Pull oil pump drive (B) from cylinder block. Cover opening.

Inspection

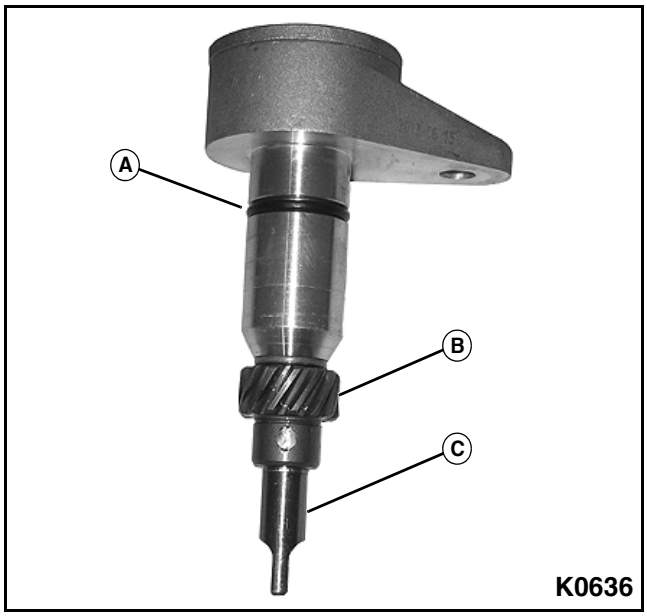


Figure 3-105

1. Inspect condition of oil pump drive sealing O-ring (A). **See Figure 3-105.**
2. Inspect condition of gear teeth (B) for wear or damage.
3. Inspect condition of oil pump drive shaft (C) for wear or damage.
4. If inspection reveals wear or damage, replace oil pump drive assembly.

Installation

Figure 3-106

1. Lubricate oil pump drive sealing O-ring (A) with clean engine oil. **See Figure 3-106.**

NOTICE

When installing oil pump drive to oil pump, do not force oil pump drive into cylinder block. Oil pump drive will set flush with cylinder block when fully engaged to oil pump.

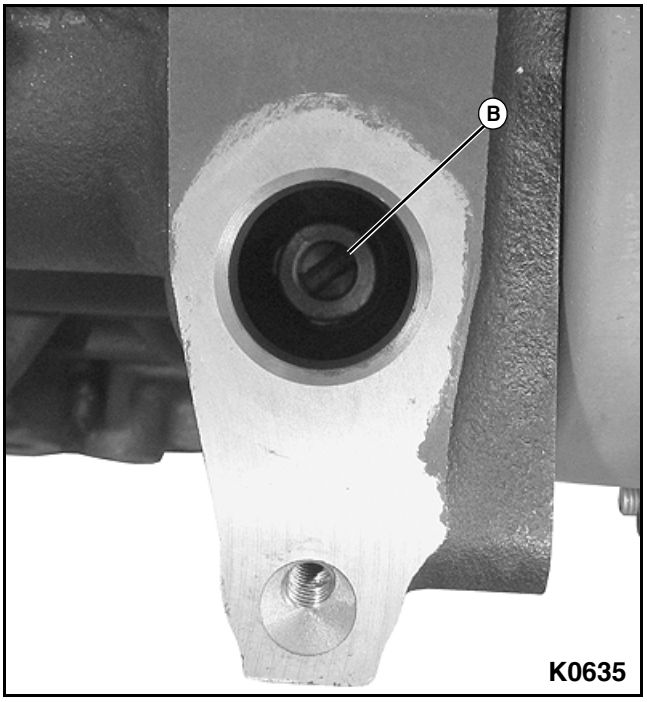


Figure 3-107

2. Install oil pump drive to cylinder block and align slot in oil pump (B) with tab on bottom of pump drive. **See Figure 3-107.**

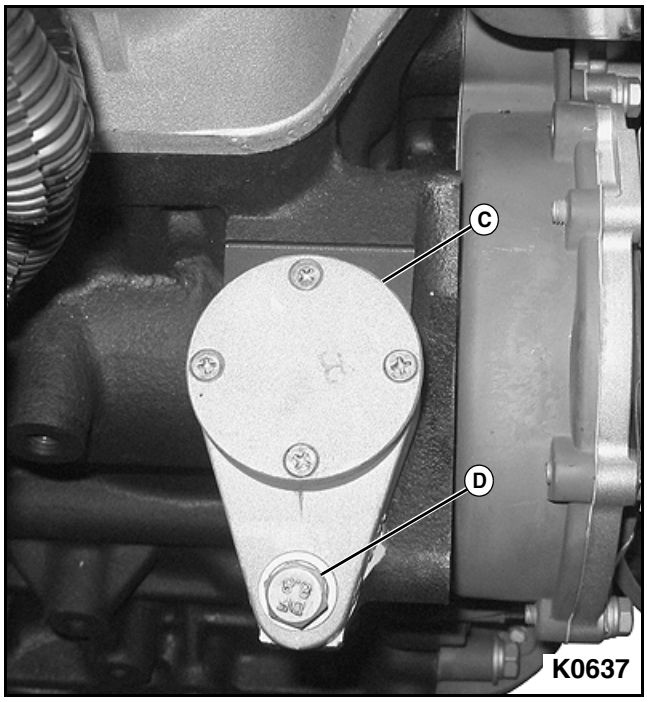


Figure 3-108

3. Secure oil pump drive (C) to cylinder block using bolt, flat washer, and lock washer (D). Tighten bolt to specification. **See Figure 3-108.**

   Oil Pump Drive Bolt Torque

   18 N•m (13 ft.lb.)

OIL FILTER REMOVAL AND INSTALLATION

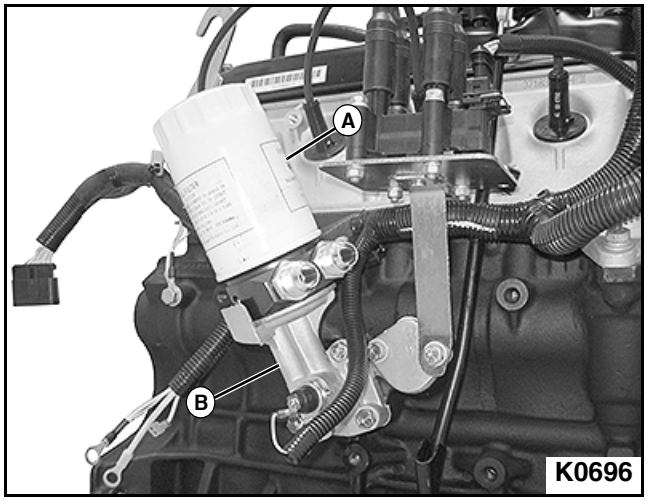


Figure 3-109

Removal

1. Using an oil filter wrench or equivalent tool, turn oil filter (A) counter clockwise and remove from oil filter base (B). **See Figure 3-109.**

Inspection

1. Ensure old oil filter gasket is not stuck to oil filter base.
2. Clean oil filter base gasket sealing area with a clean shop towel.
3. If equipped, tighten oil cooler adapter center standoff nut.

   Oil Cooler Adapter Center Standoff Nut Torque

   40 N•m (29.5 ft.lb.)

Installation

1. Replace oil filter with exact replacement or equivalent new oil filter.
2. Lubricate oil filter gasket with clean engine oil.

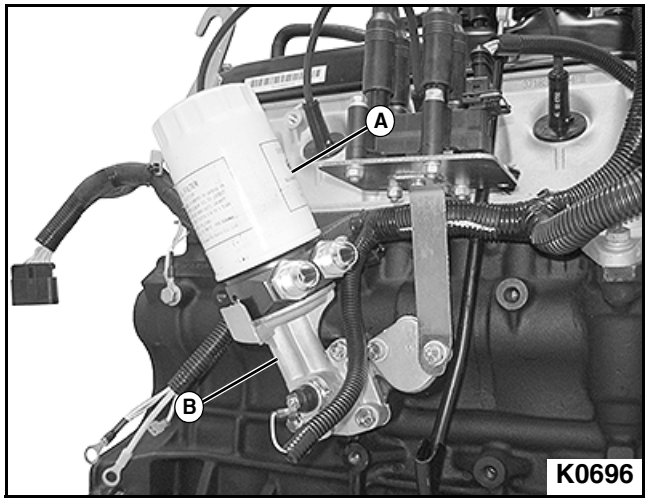


Figure 3-110

3. Install oil filter (A) to oil filter base (B) by turning clockwise until oil filter gasket makes contact with oil filter base. **See Figure 3-110.**

NOTE:

See oil filter manufacturer's specifications for proper tightening of oil filter. Do not overtighten oil filter.

OIL FILTER BASE REMOVAL AND INSTALLATION

Removal

1. Remove oil filter. See “Oil Filter Removal and Installation” on page 74.

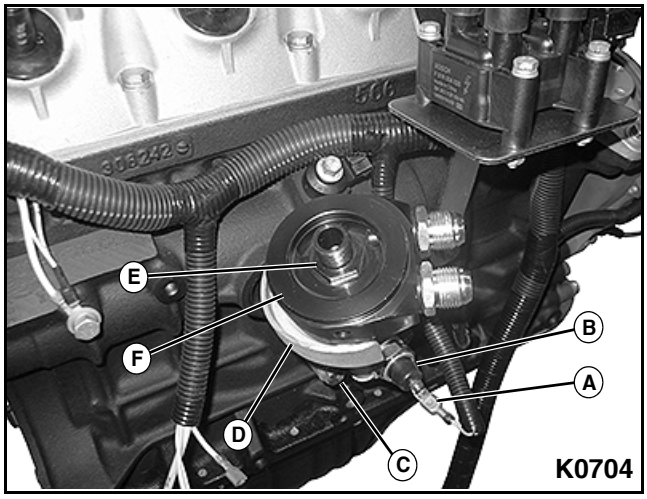


Figure 3-111

2. Disconnect electrical connection (A) from oil pressure sensor (B). **See Figure 3-111.**
3. If equipped: Remove oil cooler adapter center standoff nut (E) and oil cooler adapter (F).
4. Remove three mounting bolts (C) from oil filter base (D) and remove oil filter base from cylinder block. Close all openings.

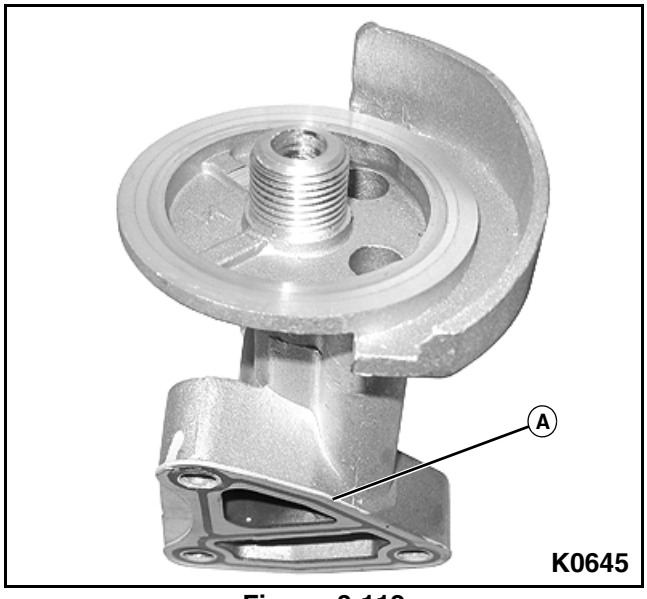


Figure 3-112

5. Remove old gasket (A) from oil filter base. **See Figure 3-112.**

Inspection

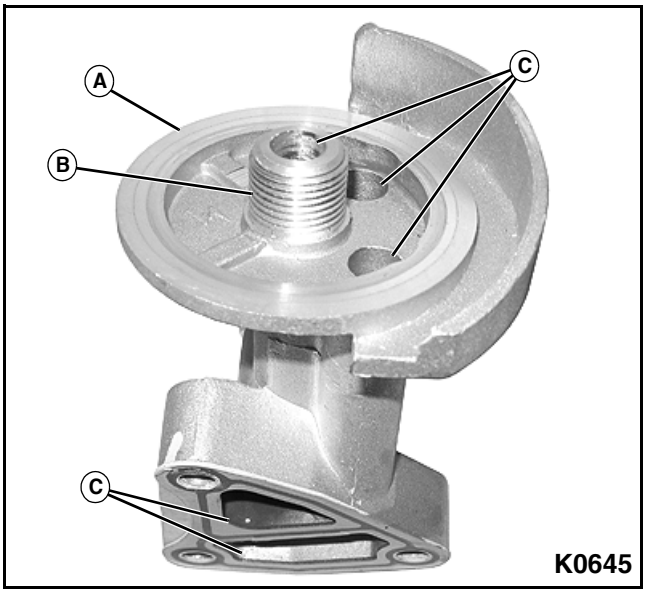


Figure 3-113

1. Inspect oil filter base (A) for cracks. **See Figure 3-113.**
2. Inspect oil filter mounting threads (B) for damage.
3. If inspection reveals cracks or damaged threads, replace oil filter base.
4. Clean oil filter base oil passages (C).

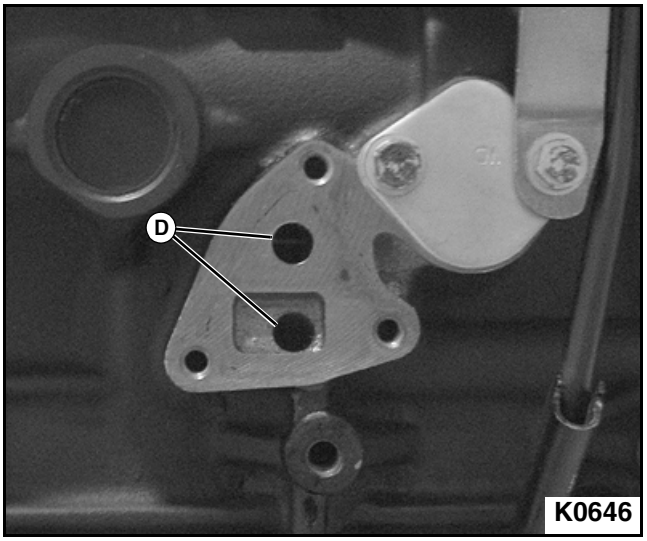


Figure 3-114

5. Ensure oil passages (D) of cylinder block are clean. **See Figure 3-114.**

Installation

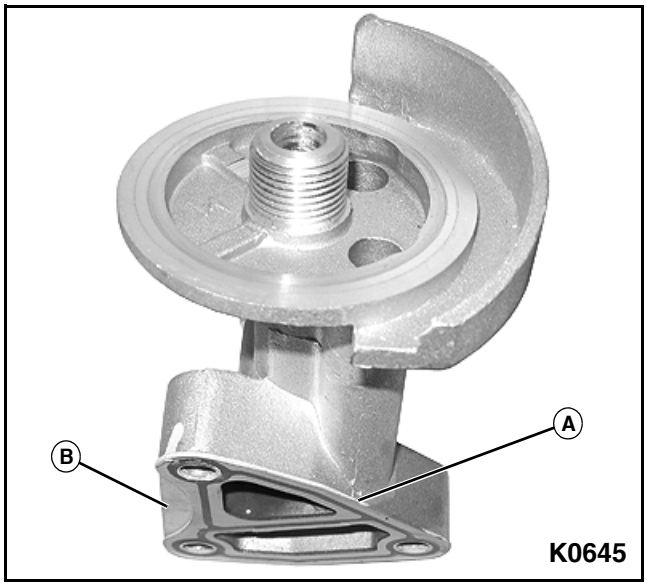


Figure 3-115

1. Install new gasket (A) on oil filter base (B). **See Figure 3-115.**

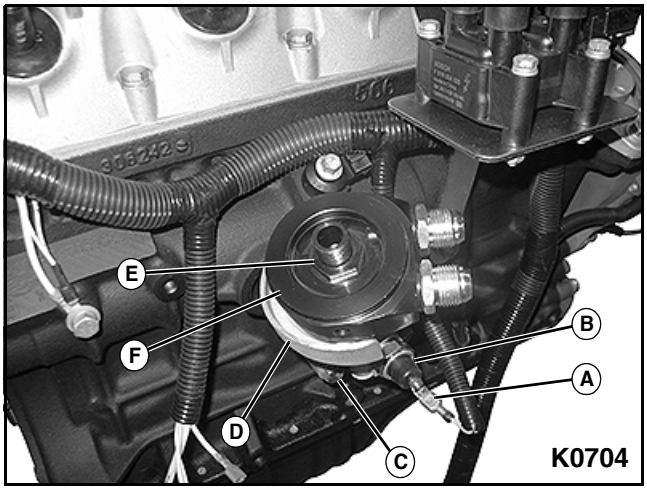


Figure 3-116

2. If equipped: Install oil cooler adapter (F) and tighten center standoff nut (E). **See Figure 3-116.**

   Oil Cooler Adapter Center Standoff Nut Torque

   40 N•m (29.5 ft.lb.)
3. Install oil filter base (D) to cylinder block with three bolts, flat washers, and lock washers (C). Tighten bolts.
4. Connect electrical connection (A) to oil pressure sensor (B).
5. Install oil filter. See “Oil Filter Removal and Installation” on page 74.
6. Start engine and check for leaks.

CYLINDER HEAD

⚠ WARNING

Carbon monoxide can cause severe nausea, fainting, or death.

Avoid inhaling exhaust fumes.

Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.

⚠ WARNING

Risk of fire. Can cause severe injury or death.

Do not smoke or permit flames or sparks near fuels or the fuel system.

⚠ WARNING

Avoid possible death or serious injury! Pinch and entanglement hazards! Never check drive belt tension while the engine is running.

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

⚠ WARNING

Rotating parts can cause severe injury.

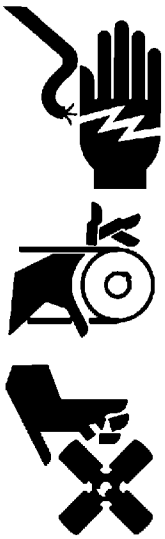
Stay away while the engine is in operation.

Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate the engine with covers, shrouds, or guards removed.

⚠ WARNING

Hot coolant and steam. Can cause severe injury or death.

Before removing the pressure cap, stop the engine and allow it to cool. Then loosen the pressure cap to relieve pressure.



⚠ WARNING

Accidental starts can cause severe injury or death.

Disconnect and ground spark plug leads before servicing.

Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug leads. 2) Disconnect negative (–) battery cable from battery.

Before disconnecting negative (–) ground cable, make sure all switches are OFF. If ON, a spark will occur at the ground cable terminal which could cause an explosion if hydrogen gas or LPG/NG fuel vapors are present.

⚠ WARNING

Explosive fuel can cause fires and severe burns.

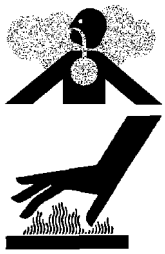
If a gaseous odor is detected, ventilate the area and contact an authorized service technician.

LPG (Liquefied Petroleum Gas) is extremely flammable and tends to settle in low areas where a spark or flame could ignite the gas. Do not start or operate this engine in a poorly ventilated area where leaking gas could accumulate and endanger the safety of persons in the area.

NG (Natural Gas) is extremely flammable, is lighter than air, and rises, Do not start or operate this engine in a poorly ventilated are where leaking gas could accumulate and endanger the safety of persons in the area.

To ensure personal safety, installation and repair of LPG/NG fuel supply systems must be performed only by qualified LPG/NG system technicians. Improperly installed and maintained LPG/NG equipment could cause the fuel supply system or other components to malfunction, causing gas leaks.

Observe federal, state, and local laws governing LPG/NG fuel, storage, and systems.



⚠ WARNING

Handling caustic engine fluids and chemical products. Can cause severe chemical burns, nausea, fainting, or death.

Most chemicals such as used engine oil, antifreeze/coolant, rustproofing agent, inhibiting oil, degreasing agent, spray paint, and adhesives are hazardous to health. Read and follow the user information found on the packaging. Avoid inhalation and skin contact. Use only in well-ventilated areas and use a protective mask when spraying. Store engine fluids and chemical products in a locked cabinet. Contact your local recycling center for disposal information and locations.

Fire-damaged or burned O-rings may cause the formation of hydrofluoric acid. Contact with hydrofluoric acid may cause severe skin irritation and chemical burns. O-rings and other fluoroelastomer seals exposed to fire or temperatures above 316 °C (600 °F) (i.e., during welding) may decompose forming hydrofluoric acid. Avoid inhalation or skin contact. Do not incinerate O-rings. Dispose of O-ring waste material in a responsible manner.

⚠ WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

⚠ WARNING

Airborne particles. Can cause severe injury or blindness.

Wear protective goggles and clothing when using power tools, hand tools, or compressed air.

⚠ WARNING

Explosive fuel vapors. Can cause severe injury or death.

Use extreme care when handling, storing, and using fuels.

Gas fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check the LPG vapor or natural gas fuel system for leakage by using a soap and water solution with the fuel system test pressurized to 6–8 ounces per square inch (10–14 inches water column). Do not use a soap solution containing either ammonia or chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

Used engine oil. Contact with used engine oil may cause severe skin irritation. Repeated and prolonged skin exposure may have other health risks. Used engine oil is a suspected carcinogen. Avoid contact with skin. Thoroughly wash your hands and nails with soap and water shortly after handling used engine oil. Wash or dispose of clothing or rags containing used engine oil. Dispose of used engine oil in a responsible manner. Contact your local recycling center for disposal information and locations.

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

⚠ WARNING

Cleaning Solvents can cause severe injury or death.

Use only in well ventilated areas away from ignition sources.

Carburetor cleaners and solvents are extremely flammable. Follow cleaner manufacturer's warnings and instructions on its proper and safe use. Never use gasoline as a cleaning agent.

CYLINDER HEAD COMPONENTS

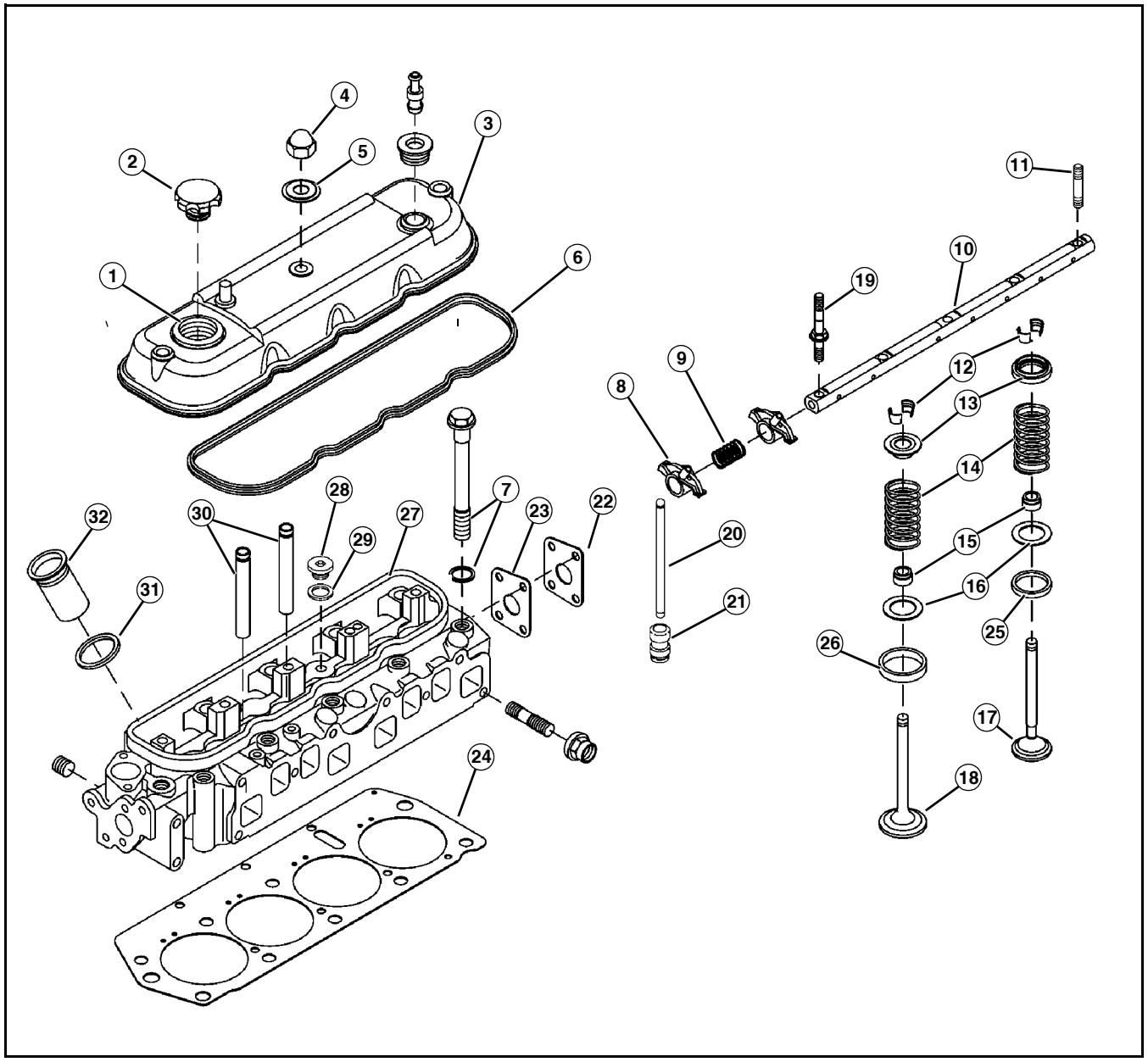


Figure 3-117: Cylinder Head Component Location.

1	Oil Fill Cap Seal	12	Spring Retainer Locks	23	Cylinder Head Rear Plate Gasket
2	Oil Fill Cap	13	Valve Spring Retainers	24	Cylinder Head Gasket
3	Rocker Arm Cover	14	Valve Springs	25	Valve Seat Exhaust
4	Nut	15	Oil Seal	26	Valve Seat Intake
5	Seal Washer	16	Valve Spring Seat	27	Cylinder Head
6	Rocker Cover Gasket	17	Intake Valve	28	Plug
7	Head Bolt Assembly	18	Exhaust Valve	29	Seal
8	Rocker Arm	19	Stud Bolt	30	Valve Guide
9	Spring	20	Pushrod	31	Spark Plug Tube Seal
10	Rocker Arm Shaft	21	Hydraulic Valve Lifter	32	Spark Plug Tube
11	Stud	22	Cylinder Head Rear Plate		

CYLINDER HEAD REMOVAL AND INSTALLATION

Removal

1. Drain cooling system.
2. Remove intake manifold. See “Intake Manifold Removal and Installation” on page 56.
3. Remove exhaust manifold. See “Exhaust Manifold Removal and Installation” on page 62.
4. Remove rocker arm cover. See “Remove and Install Rocker Arm Cover” on page 70.
5. Remove rocker arm shaft. See “Rocker Arm Assembly—Removal and Installation” on page 83.

NOTE:

Identify and tag push rods for correct order and orientation during installation.

6. Remove push rods from lifters.

NOTE:

Arrow points to front of engine assembly.

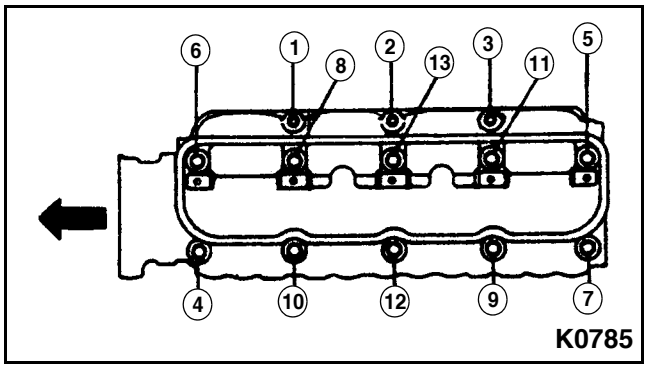


Figure 3-118

7. Loosen cylinder head mounting bolts in three steps in sequence as shown. **See Figure 3-118.**
8. Lightly tap cylinder head with a soft face hammer to loosen cylinder head from cylinder block.

NOTICE

Do not set cylinder head down on machined surfaces unless precautions are taken to avoid scratching machined surfaces.

9. Remove cylinder head from cylinder block.

NOTICE

Do not use harsh cleaning operations to clean cylinder head or block. Use of air buffers and steel scrapers may remove material damaging head or block.

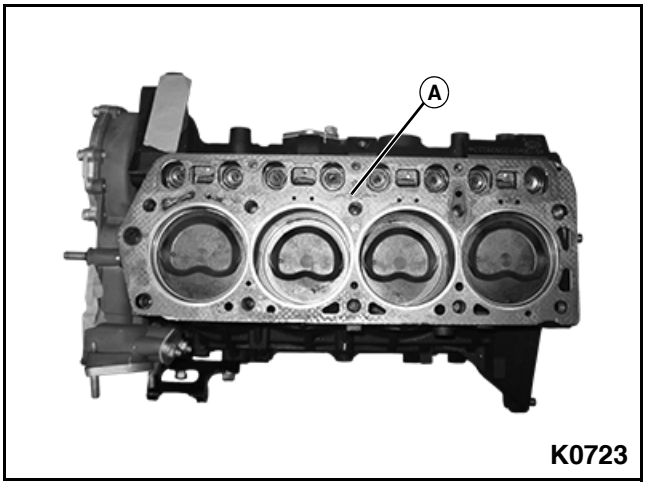


Figure 3-119

10. Clean old head gasket from cylinder block (A). Avoid getting gasket material into lifter bores, water jackets and bolt holes. **See Figure 3-119.**
11. Clean old head gasket from cylinder head.

Inspection

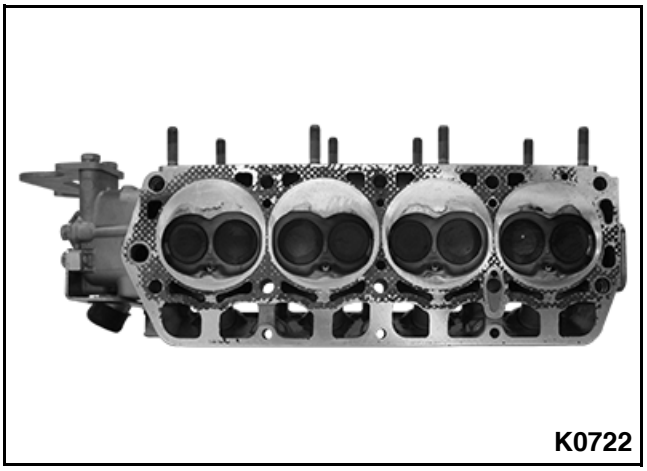


Figure 3-120

1. Using a wire brush, completely remove all carbon deposits from cylinder head. **See Figure 3-120.**

NOTICE

Cracks may develop in areas between cylinders and between valves (A and B) commonly.

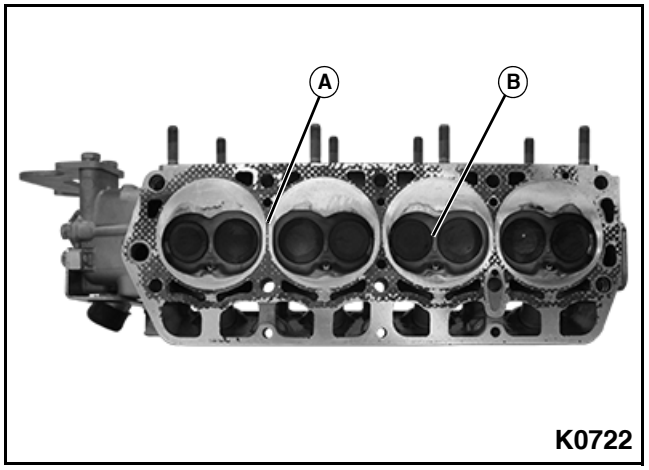


Figure 3-121

2. Inspect cylinder head for cracks. If any cracks are found, replace cylinder head. **See Figure 3-121.**
3. Inspect spark plug hole threads. If spark plug hole threads are damaged, repair threads.

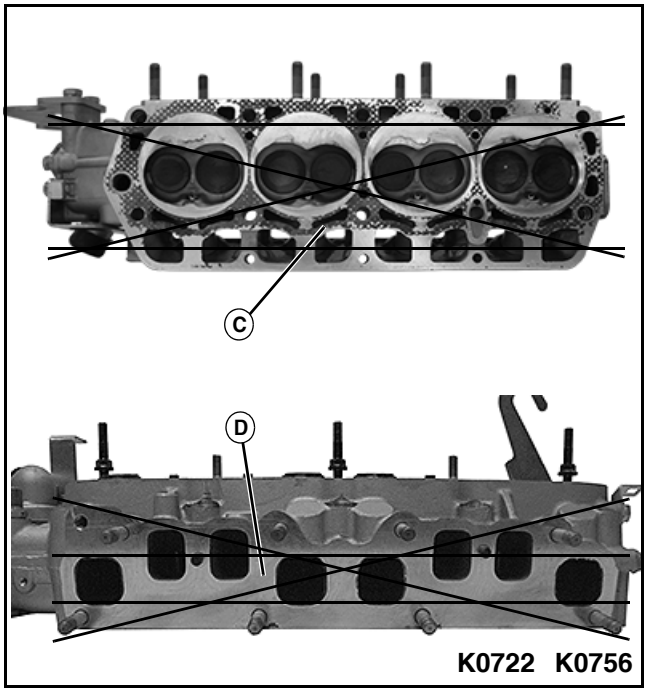


Figure 3-122

4. Inspect cylinder head for warpage at cylinder block side (C) and at intake/exhaust manifold side (D) using a straightedge and feeler gauge. **See Figure 3-122.**

CYLINDER HEAD WARPAGE—MAXIMUM

Combustion Chamber Surface

0.15 mm (0.0059 in.)

Intake/Exhaust Manifold Surface

0.10 mm (0.0039 in.)

5. If cylinder head is not within specification, cylinder head must be replaced.
6. Install new cylinder head bolts. Do not reuse old cylinder head bolts.
7. Inspect cylinder head bolt holes in cylinder block for obstructions and damaged threads by running a thread chaser down the bolt holes.

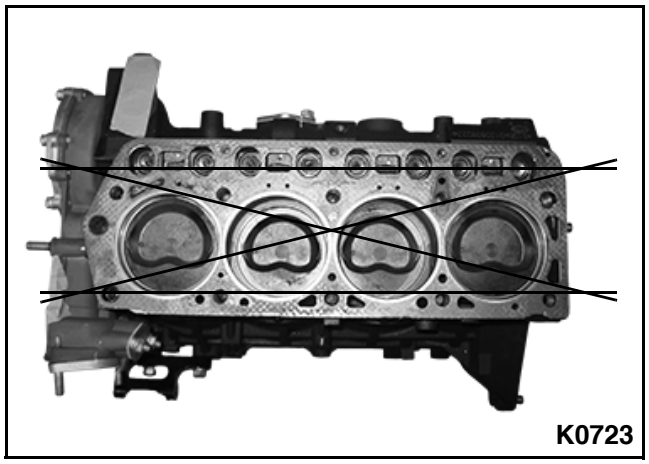


Figure 3-123

8. Inspect cylinder block deck for warpage using a straightedge and feeler gauge as shown. **See Figure 3-123.**

CYLINDER BLOCK WARPAGE—MAXIMUM

0.05 mm (0.0019 in.)

9. If cylinder block deck is out of specification, cylinder block deck must be machined or cylinder block must be replaced.

Installation

NOTE:

Arrow points to front of engine assembly.
Ensure head gasket is positioned as noted during removal.

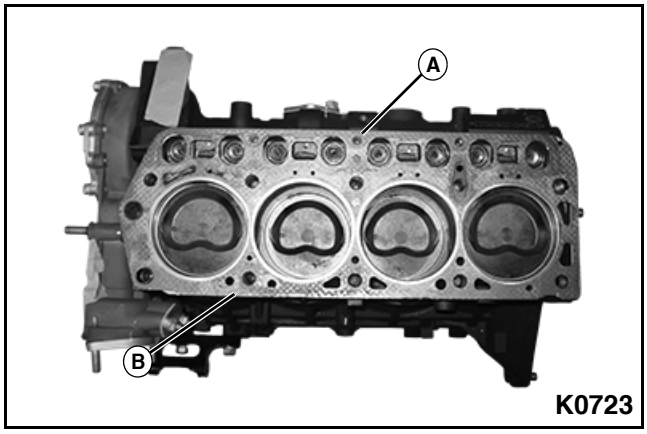


Figure 3-124

1. Install new head gasket (A) to a clean cylinder block deck (B). **See Figure 3-124.**

NOTICE

Use caution when installing cylinder head. Do not drag cylinder head over head gasket, or head gasket damage will occur.

2. Install cylinder head to cylinder block.
3. Lightly lubricate head bolts with clean engine oil.
4. Install cylinder head mounting bolts to cylinder head.

NOTE:

Arrow points to front of engine assembly.

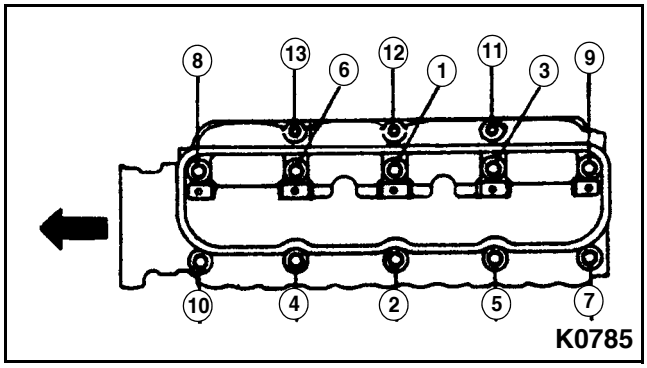


Figure 3-125

5. Torque cylinder head mounting bolts to specification in three steps in sequence shown. **See Figure 3-125.**

CYLINDER HEAD BOLT—TORQUE

M12 Bolts (10 used)

88–98 N•m (64.90–72.28 ft.lb.)

M8 Bolts (3 used)

19–25 N•m (14.01–18.44 ft.lb.)

6. Install push rods to lifters as noted during removal.
7. Install rocker arm shaft. See “Rocker Arm Assembly—Removal and Installation” on page 83.
8. Install rocker arm cover. See “Remove and Install Rocker Arm Cover” on page 70.
9. Install exhaust manifold. See “Exhaust Manifold Removal and Installation” on page 62.
10. Install intake manifold. See “Intake Manifold Removal and Installation” on page 56.
11. Fill cooling system. See “Fluid Specifications” on page 19.

ROCKER ARM ASSEMBLY—REMOVAL AND INSTALLATION

⚠ WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

Removal

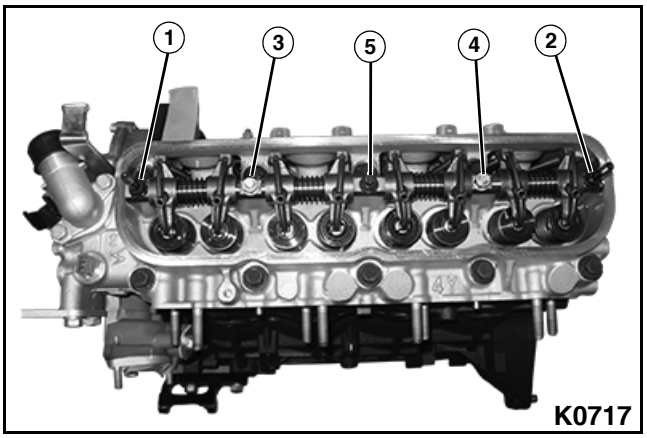


Figure 3-126: Rocker Arm Fastener Sequence

1. Loosen the rocker arm shaft fasteners in steps using sequence shown. Repeat this sequence until the pressure from the valve springs has been released. **See Figure 3-126.**

NOTE:

The rocker arms have light spring pressure applied to keep them in place over the valves. Use care when removing the rocker arm shaft from the cylinder head.

2. Remove the fasteners and then remove the rocker arm shaft from the cylinder head.

Inspection

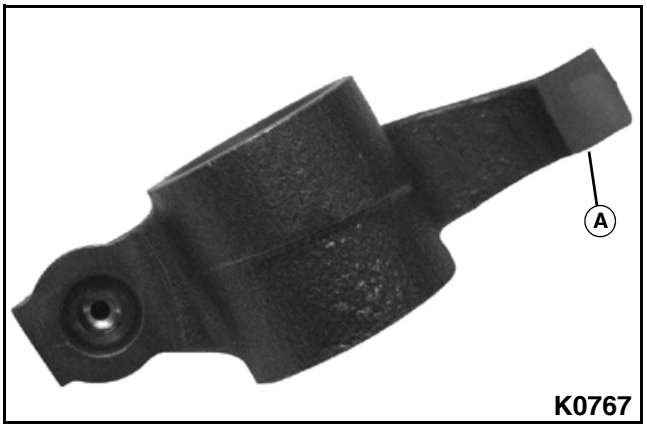


Figure 3-127

1. Inspect the valve-contact surface (A) of the rocket arm for wear. Grind this surface or replace arm rocker if necessary. **See Figure 3-127.**

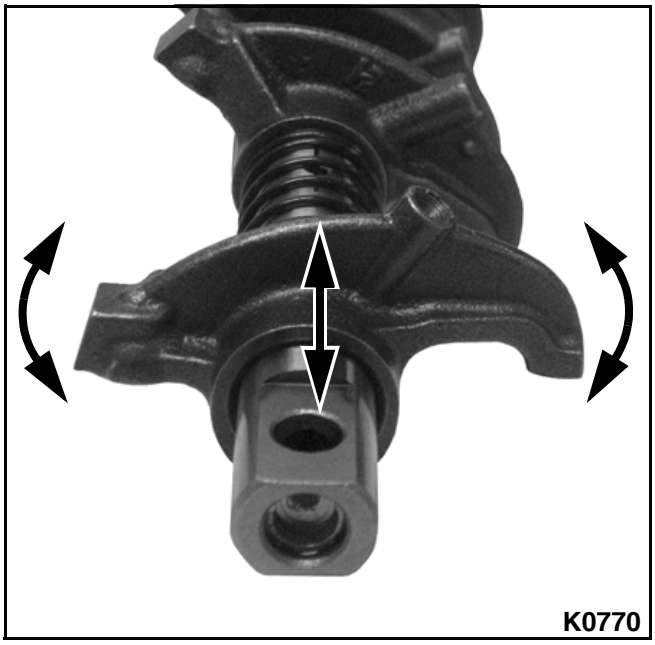


Figure 3-128: Checking the Rocker Arm-to-Shaft Clearance

2. Inspect the rocker arm-to-shaft clearance by moving each rocker arm as shown, checking for movement. **See Figure 3-128.**

NOTE:

During disassembly, arrange the rocker arm shaft components in the correct sequence for assembly.

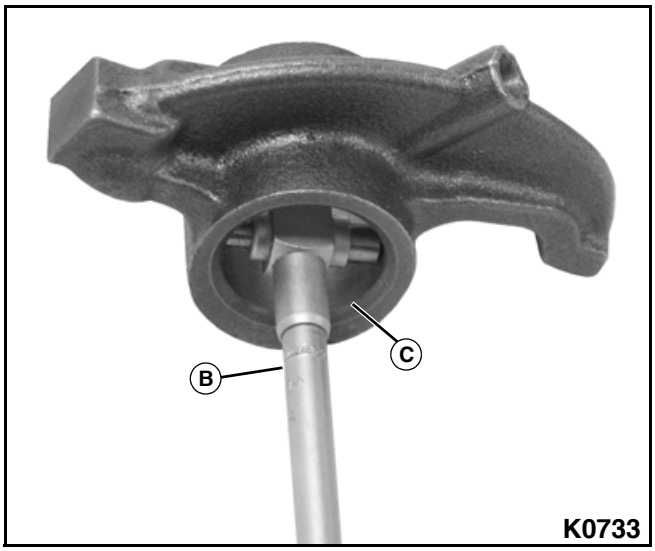


Figure 3-129: Measuring the Rocker Arm Shaft Bore

3. If movement is felt, disassemble and measure the inside diameter (bore) (C) of the rocker arm, using the appropriate bore gauge (B). **See Figure 3-129.**

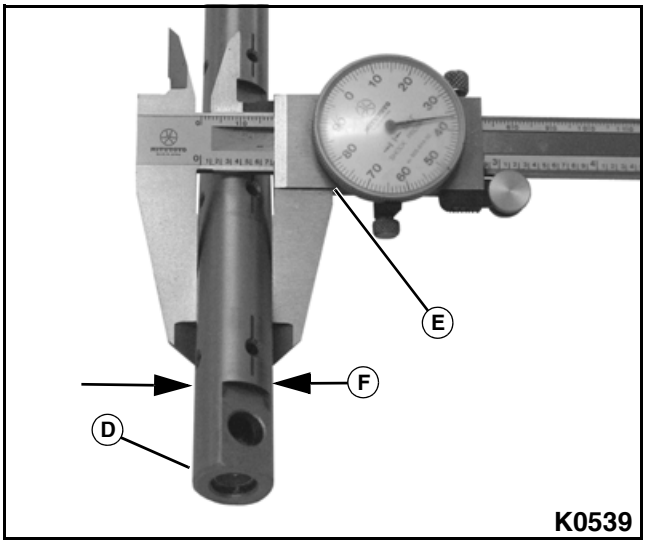


Figure 3-130: Measuring the Rocker Arm Shaft Outside Diameter

4. Measure the rocker arm shaft (D) outside diameter (F) using a caliper (E). Two measurements should be taken, the second at 90° from the first measurement. Use the larger measurement for calculations. **See Figure 3-130.**

ROCKER ARM SPECIFICATIONS

Rocker Arm—Inside Diameter (Bore)

18.500–18.513 mm (0.7283–0.7288 in.)

Rocker Arm Shaft—Outside Diameter

18.467–18.482 mm (0.7270–0.7276 in.)

Rocker Arm—Standard Oil Clearance

0.018–0.046 mm (0.0007–0.0018 in.)

Rocker Arm—Maximum Oil Clearance

0.08 mm (0.0031 in.)

If the oil clearance is not within specification, replace rocker arm and rocker arm shaft.

Installation

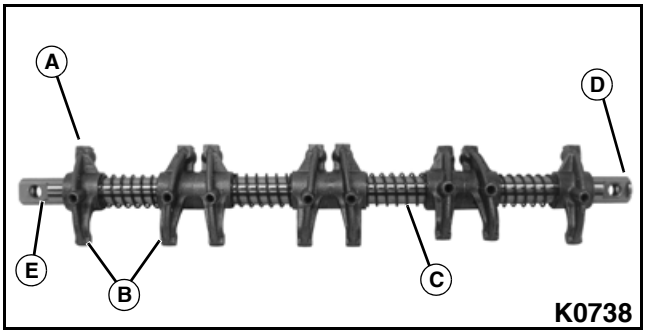


Figure 3-131: Rocker Arm Assembly and Installation

1. Arrange the rocker arms (A) into pairs with the valve contact surface (B) angled in. **See Figure 3-131.**
2. Compress the springs (C) with the rocker arms and install the rocker arm support tool to hold the rocker arms and springs in place during assembly.
3. When installing the rocker arm assembly on the cylinder head, the raised lip (D) on the rocker arm shaft (E) must be to the rear and facing up as shown.

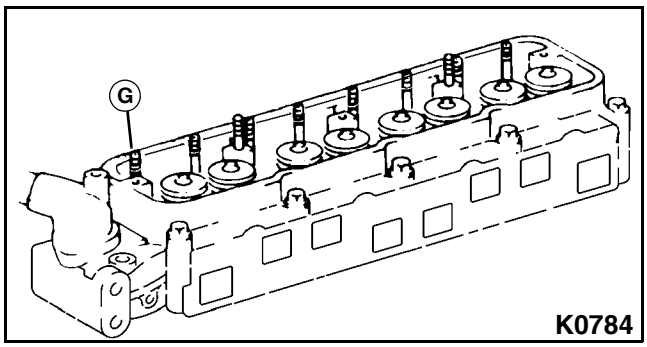


Figure 3-132

NOTICE

When installing the pushrods, make sure the pushrod is fully seated in the hydraulic valve lifter.

4. Install the pushrods (G) into the hydraulic valve lifters. **See Figure 3-132.**
5. Install the rocker arm assembly on the cylinder head, aligning the pushrods with the rocker arms, and install the fasteners.

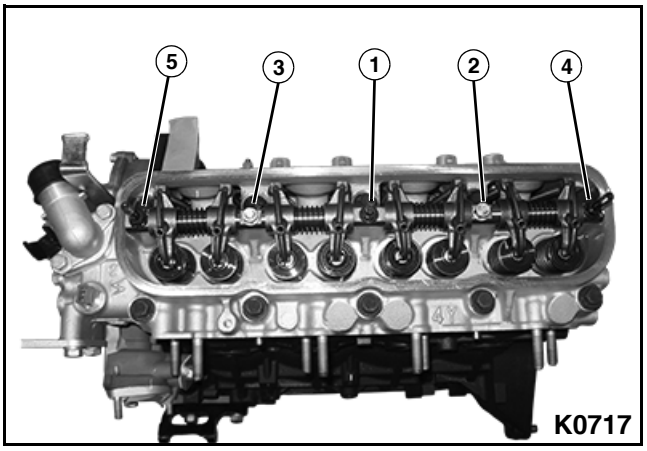


Figure 3-133: Rocker Arm Assembly Tightening Sequence

NOTICE

The following step must be done to evenly distribute spring pressure to the components and prevent damage to rocker arm assembly and pushrods.

6. Tighten the rocker arm fasteners in the sequence shown in several steps to specification. **See Figure 3-133.**

   ROCKER ARM SHAFT ASSEMBLY—TORQUE

   25–32 N•m (18–24 ft.lb.)

7. Remove the rocker arm support tools and the pushrod alignment tools.

VALVES—REMOVAL AND INSTALLATION

WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

Removal

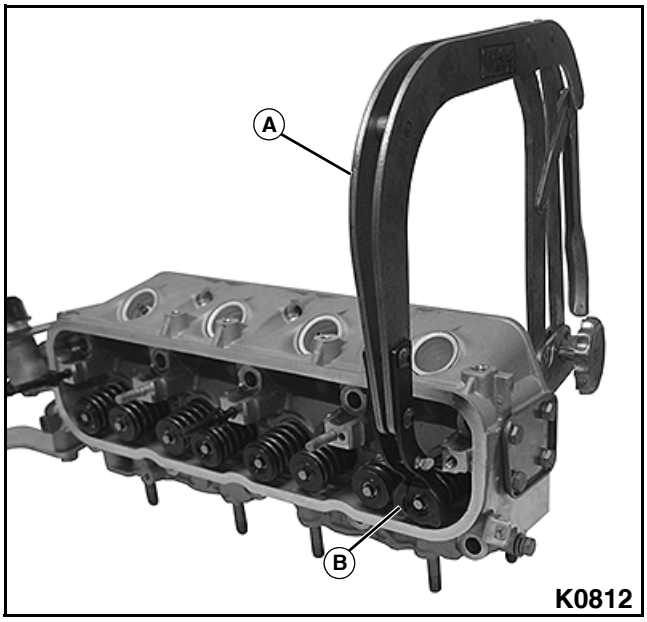


Figure 3-134: Valve Spring Compressor

1. Remove the valves from the cylinder head using a valve spring compressor (A) to compress the valve spring (B) to remove the valve retainers. **See Figure 3-134.**

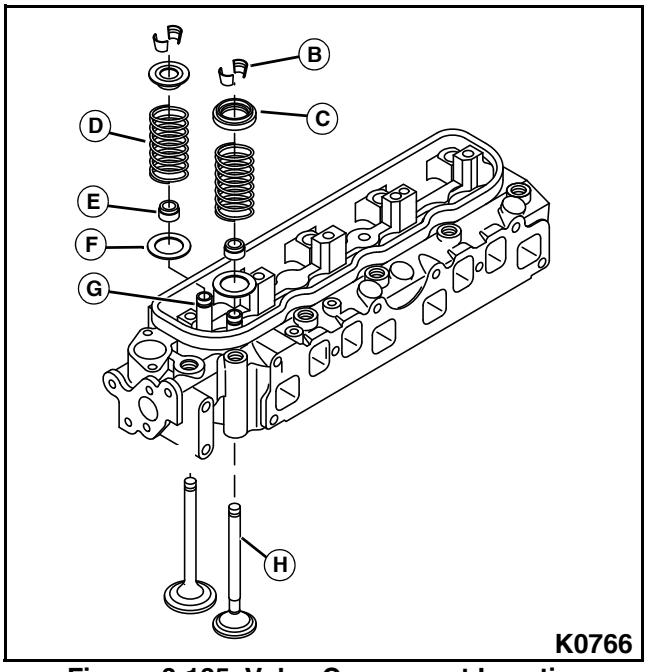


Figure 3-135: Valve Component Location

2. Compress the valve spring (D) enough to remove the spring retainer locks (B). **See Figure 3-135.**
3. Remove the spring retainer locks.

4. Remove the tension on the valve spring and remove the spring retainer (C), the valve spring, and the valve spring seat (F).
5. Remove the valve (H).
6. Remove the valve seal (E) and discard.

Installation

NOTICE

The exhaust valve assemblies utilize a rotating spring retainer that is not compatible with the intake valves. Engine damage can occur if rotating spring retainers are used with the intake valves.

1. Clean out the valve guide with a brush (A) before installing the valves.

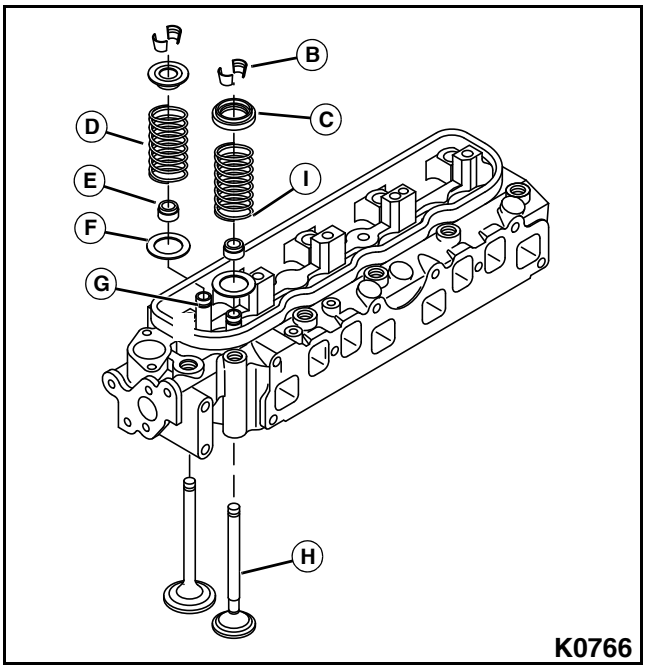


Figure 3-136

2. Apply a light layer of assembly lubricant to the valve (H) stem before inserting into the valve guide (G). **See Figure 3-136.**
3. Install the valve into the valve guide (G).
4. Place the oil seal installation sleeve (if provided) over the valve stem. Apply a thin layer of assembly lubricant to the top of the sleeve and install the oil seal (E) over the sleeve until it reaches the top of the valve guide. Press the oil seal into place using the appropriate oil seal installation tool.
5. Apply a light coat of assembly lubricant and install the valve spring seat (F).

NOTICE

The painted portion of the valve spring MUST face the head.

6. Install the valve spring (D) with the painted end (I) facing the cylinder head.

NOTICE

The exhaust valve assembly uses a rotating valve spring retainer that allows the exhaust valve to rotate.

Do not install this retainer on the intake valve assembly, or engine failure may result.

7. Apply a thin layer of assembly lubricant to the spring retainer (C) and install over the valve spring.

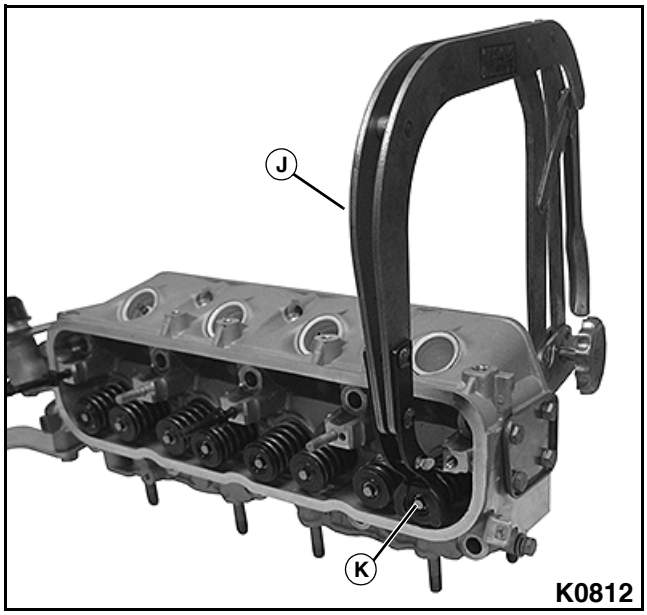


Figure 3-137

⚠ WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

NOTE:

Apply a small amount of assembly lubricant to the insides of the valve spring retainer locks to aid in assembly and to hold in place during the release of the valve spring.

8. Using an appropriate valve spring compressor (J), compress the valve spring to gain enough clearance, and install the valve spring retainer locks (K). **See Figure 3-137.**
9. Slowly release the valve spring compressor, making sure that the valve spring retainer locks remain seated.
10. Using a soft-faced hammer, tap the top of the valve stem to seat the valve spring retainer locks into the locking grooves of the valves.

CYLINDER HEAD COMPONENT INSPECTION

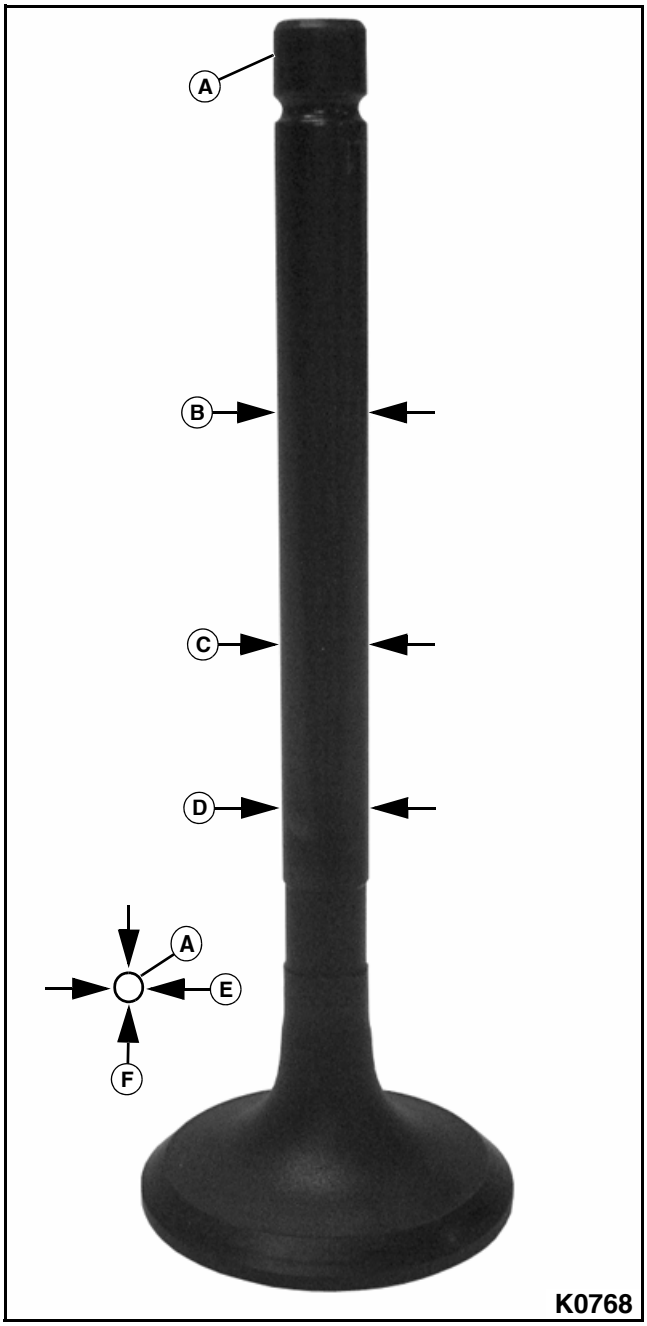


Figure 3-138

1. Measure the valve stem (A) at the top (B), middle (C), and bottom (D) of the valve stem. Record the measurement from the first direction (E). **See Figure 3-138.**

2. Rotate the valve 90° and measure the valve stem a second time, beginning again at the top, then middle, and bottom of the valve stem. Record the measurements from the second direction (F). If the valve stem measurements do not meet specifications, shown on the following page, replace the valve.

NOTE:

Valve guide shown removed from cylinder head for clarity only.

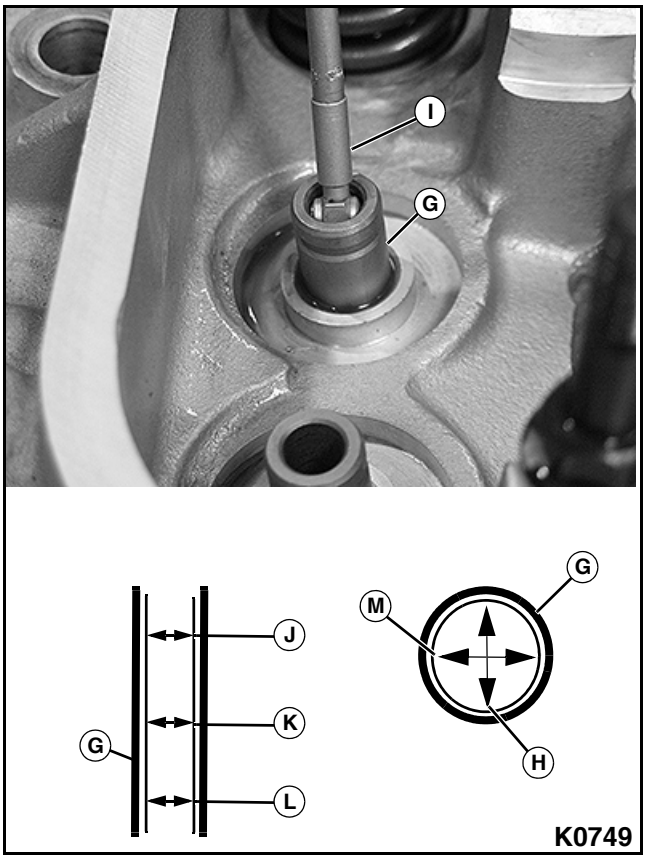


Figure 3-139: Measure the Inside Diameter of the Valve Guide

3. Measure the inside diameter of the valve guide (G) at the top (J), middle (K), and bottom (L) in the first direction (H). **See Figure 3-139.**
4. Measuring in the second direction, rotating 90° (M), measure the top, middle, and bottom of the valve guide.
5. Check the oil clearance between the valve stem and the valve guide. The oil clearance must be within specification.

VALVE SPECIFICATIONS

Valve Guide Bushing—Inside Diameter

8.010–8.030 mm (0.3153–0.3161 in.)

Intake Valve—Valve Stem Diameter

7.970–7.985 mm (0.3137–0.3143 in.)

Exhaust Valve—Valve Stem Diameter

7.965–7.98 mm (0.3135–0.3141 in.)

Intake Valve—Standard Oil Clearance

0.025–0.060 mm (0.0009–0.0023 in.)

Exhaust Valve—Standard Oil Clearance

0.030–0.065 mm (0.0011–0.0025 in.)

Intake Valve—Maximum Oil Clearance

0.10 mm (0.0039 in.)

Exhaust Valve—Maximum Oil Clearance

0.12 mm (0.0047 in.)

6. If valves or valve guides do not meet specification, replace the valve and the valve guide.
7. Clean and inspect valve for pits, grooves, and carbon buildup.

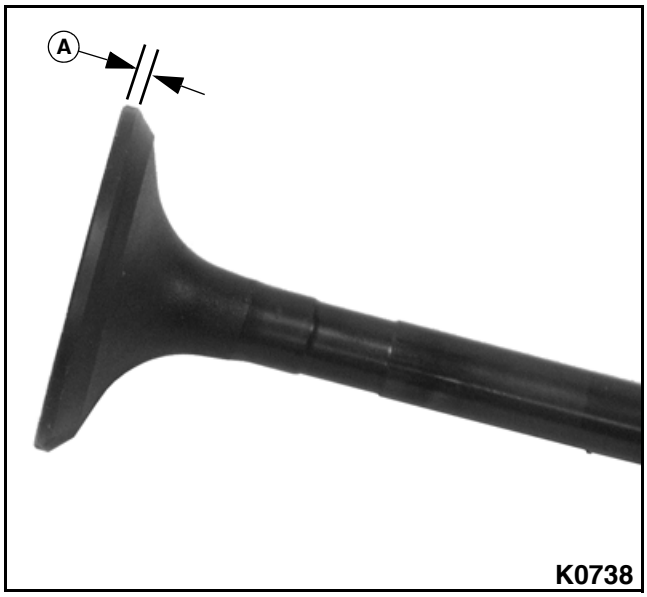


Figure 3-140: Valve Margin Thickness

8. Check the valve margin thickness (A). **See Figure 3-140.**

VALVE MARGIN SPECIFICATIONS

Intake Valve—Standard Margin Thickness

1.0–1.4 mm (0.0393–0.0551 in.)

Exhaust Valve—Standard Margin Thickness

1.3–1.7 mm (0.0511–0.0669 in.)

Intake Valve—Minimum Margin Thickness

0.5 mm (0.0196 in.)

Exhaust Valve—Minimum Margin Thickness

0.8 mm (0.0314 in.)

If the margin thickness specification is less than the minimum value, replace the valve.

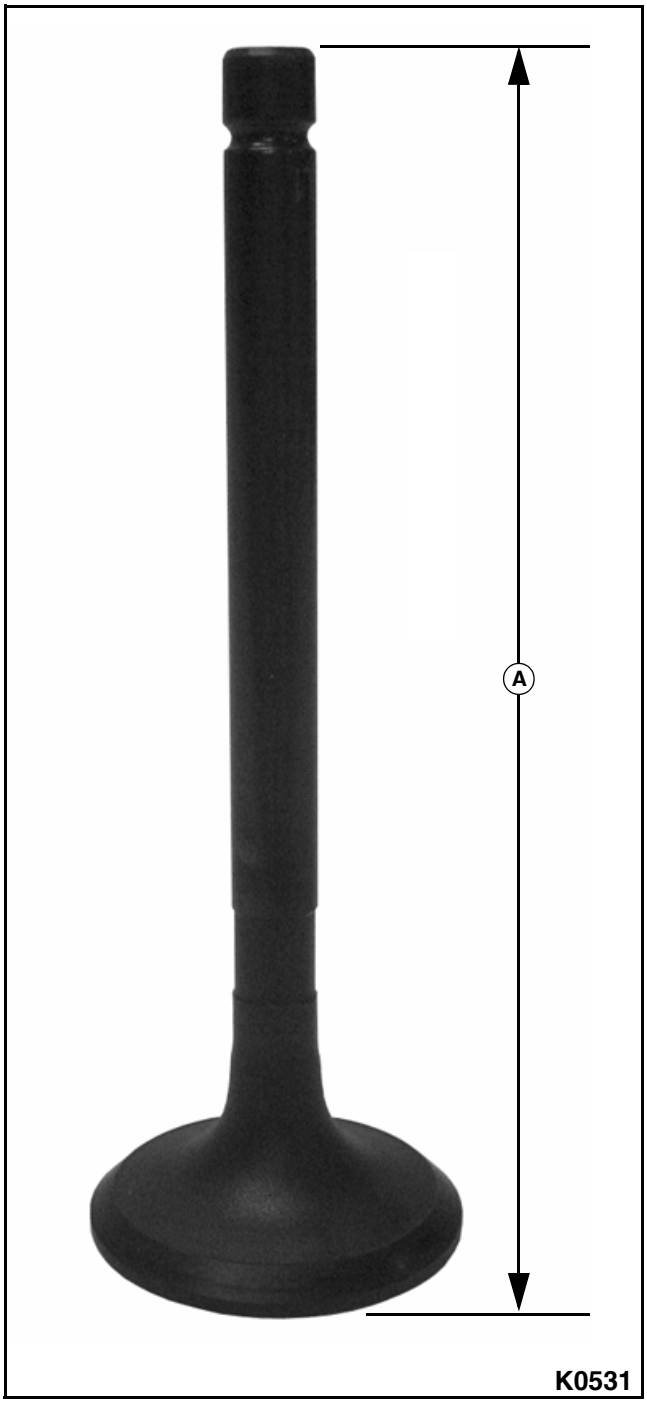


Figure 3-141

9. Measure the overall valve length (A). **See Figure 3-141.**

VALVE SPECIFICATIONS

Intake Valve—Standard Overall Length

108.2 mm (4.2598 in.)

Exhaust Valve—Standard Overall Length

108.5 mm (4.2716 in.)

Intake Valve—Minimum Overall Length

107.7 mm (4.2401 in.)

Exhaust Valve—Minimum Overall Length

108.0 mm (4.2519 in.)

If the valve length does not meet the minimum length specification, replace the valve.

Valve and Valve Seat—Contact Check

Check valve seats for wear, damage, and carbon buildup. Only grind the valve seat, if necessary, enough to remove pits, grooves, and carbon buildup.

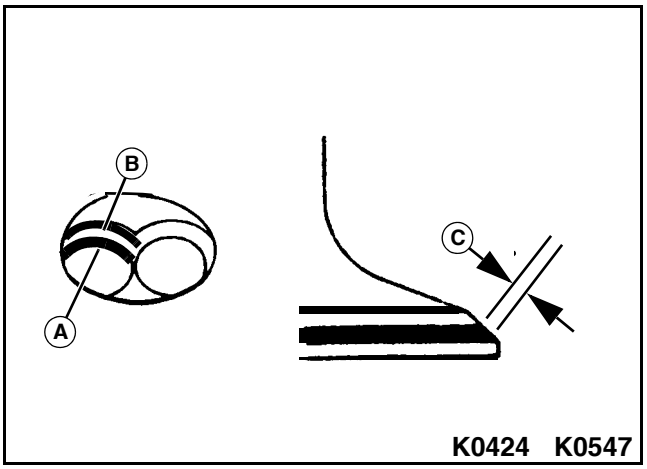


Figure 3-142

1. Apply a thin layer of layout dye to the valve seat surface (A). **See Figure 3-142.**
2. Install the valve and lightly apply pressure to the valve. Check the valve contact pattern with the valve seat (B).
3. The valve face surface must show blue in the middle all the way around the seat, with a contact surface width (C) that is within specification.

VALVE SEAT—CONTACT WIDTH

1.2–1.6 mm (0.0472–0.0629 in.)

If the seat circle from the previous steps does not produce results within specification, an adjustment is needed.

Valve Seat Grinding and Lapping

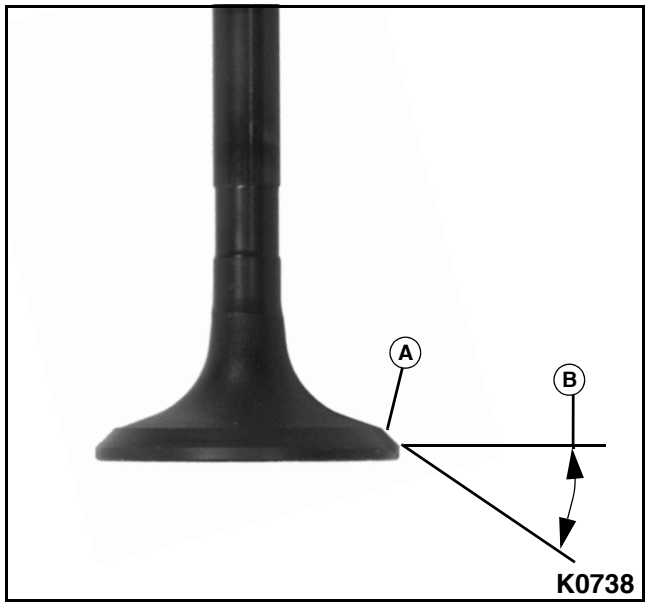


Figure 3-143

1. Check to make sure the valve face (A) meets the specified valve face angle (B). Grind the valve only enough to remove pits and carbon from the valve face if necessary. **See Figure 3-143.**

INTAKE AND EXHAUST VALVE FACE ANGLE

44.5° Angle

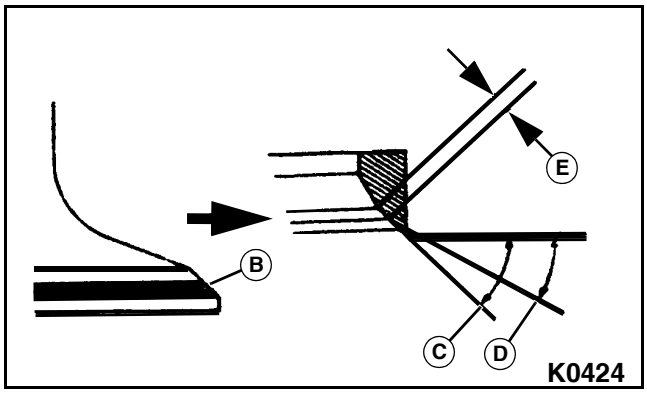


Figure 3-144

2. If the seat circle (B) is closer to the top side of the valve face, grind seat with 30° (D) and 45° (C) milling cutter, while maintaining the contact width (E). **See Figure 3-144.**

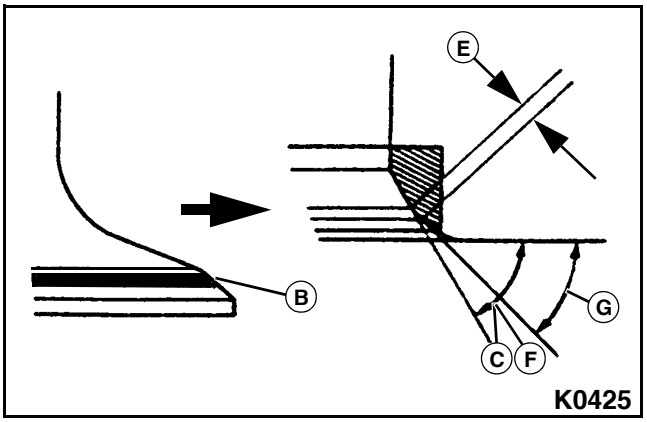


Figure 3-145

3. If seat circle (B) is closer to the lower side of the valve face surface, grind the seat with a 60° (C) and 45° (G) milling cutter for the intake seats. For the exhaust, grind the seat with a 65° (F) and 45° (G) milling cutter, while maintaining the contact width (E). **See Figure 3-145.**
4. Using a valve lapping tool and lapping compound, lap the valve into the seat by hand and check that there is no leakage between the valve and the seat. Clean the valve, valve guide, and valve seat completely before assembly.

Valve Spring—Inspection

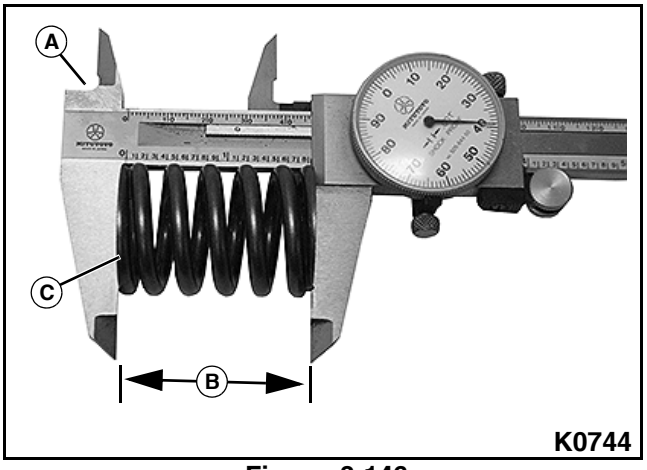


Figure 3-146

1. Using a caliper (A), measure the free length (B) of the valve spring (C). The free length should be within specification. **See Figure 3-146.**

VALVE SPRING—FREE LENGTH

46.75–47.25 mm (1.8208–1.8602 in.)

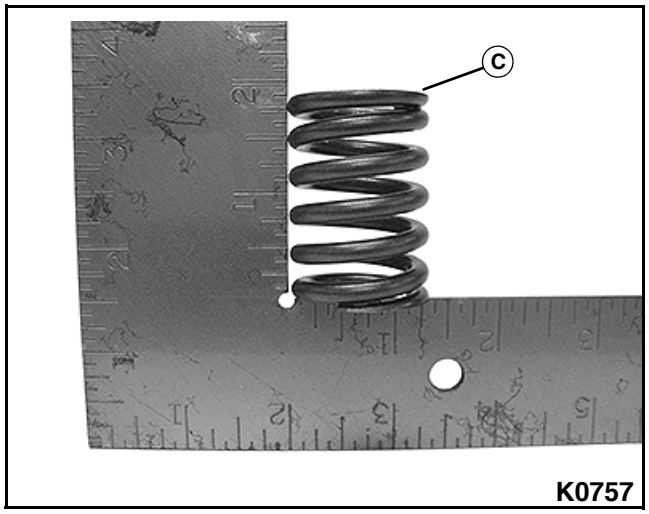


Figure 3-147

2. Using a steel square, check the valve spring (C) for squareness on a flat surface. The valve spring should be within specification. **See Figure 3-147.**

VALVE SPRING—SQUARENESS LIMIT

<2.0 mm (0.0787 in.)

3. Measure the tension of the valve spring at the specified installed height.

VALVE SPRING SPECIFICATIONS

Valve Spring—Installed Height

40.6 mm (1.5984 in.)

Valve Spring—Tension

282–345 N (63.4–77.56 lbf.)

If any of the valve spring specifications are not met, replace the valve spring.

Pushrods—Inspection

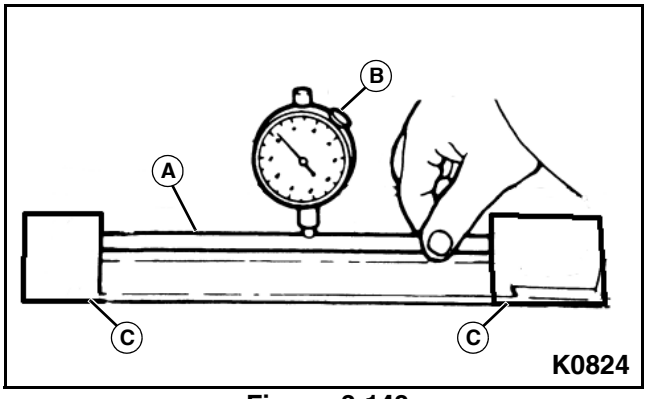


Figure 3-148

1. Place the push rod (A) on a pair of V-blocks (C). Using a dial indicator (B), measure the runout on the dial indicator gauge by slowly rotating the pushrod and observing the reading on the dial indicator (B). **See Figure 3-148.**

PUSHROD—MAXIMUM RUNOUT

0.30 mm (0.0118 in.)

If the measured runout is greater than the specified maximum runout, replace the push rod.

⚠ WARNING

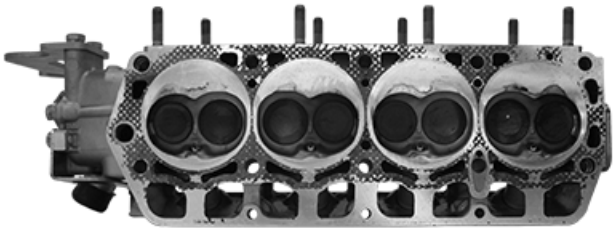
Airborne particles. Can cause severe injury or blindness.

Wear protective goggles and clothing when using power tools, hand tools, or compressed air.

2. Check push rod oil hole for obstructions. Clean as needed.

VALVE GUIDES—REMOVAL AND INSTALLATION

Removal



K0722

Figure 3-149

1. Before removing valve guides, clean any carbon deposits from inside the intake and exhaust ports of the cylinder head. **See Figure 3-149.**

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

2. To remove damaged valve guides, gradually heat the cylinder head to 80–100°C (176–212°F).

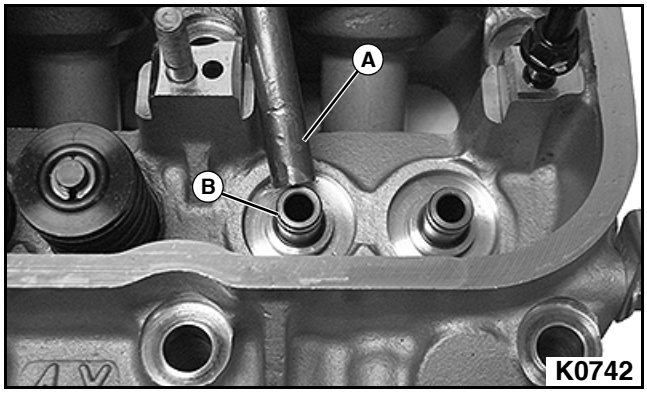


Figure 3-150: Break Off the Top of the Valve Guide

3. Using a brass drift (A), break off the top of the valve guide (B). **See Figure 3-150.**

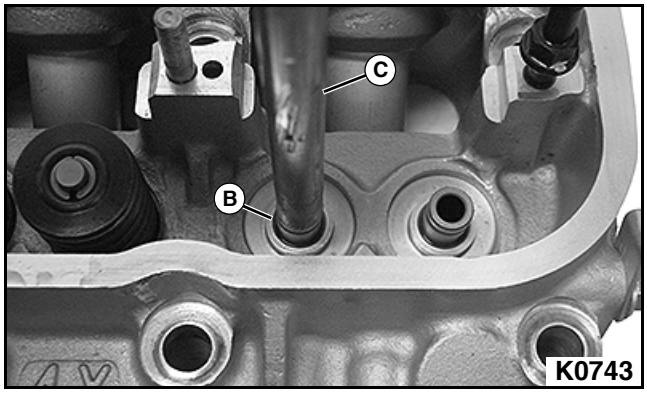


Figure 3-151: Removing the Valve Guide

4. Remove the valve guide (B) using a hammer with the proper valve guide driver (C). **See Figure 3-151.**

Installation

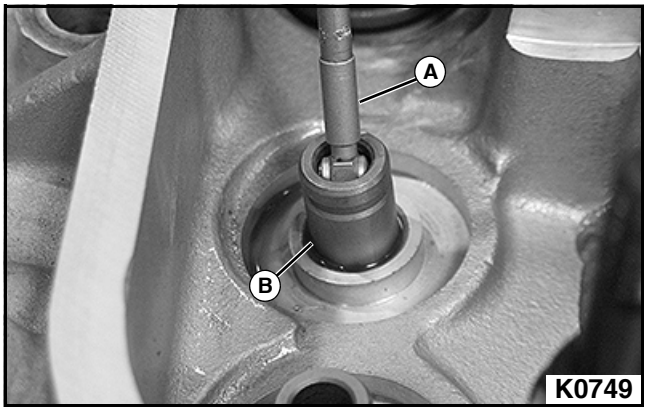


Figure 3-152

1. Using a bore gauge (A), measure the valve guide bore (B) in the cylinder head to determine valve guide size. **See Figure 3-152.**
   a. If the valve guide bore is within the standard valve guide bore specification, use a standard size valve guide.
   b. If the valve guide bore exceeds oversize valve guide bore specification, use a reamer to correct the valve guide bore to specification and install an oversize valve guide.
   c. If the valve guide bore exceeds the maximum specified bore dimension, replace the cylinder head.

   VALVE GUIDE SPECIFICATIONS

   Valve Guide Bore—Standard Valve Guide

   13.000–13.027 mm (0.5118–0.5129 in.)

   Valve Guide Bore—Resize Dimensions

   13.050–13.077 mm (0.5138–0.5148 in.)

   Valve Guide Bore—Oversize Valve Guide

   13.050–13.077 mm (0.5129–0.5138 in.)

   Valve Guide Bore—Maximum Valve Guide Bore Size

   13.077 mm (0.5129 in.)

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

2. Before installing valve guides, gradually heat the cylinder head to 80–100°C (176–212°F).

NOTICE

The valve guides must be installed to align with the valve guide bore. Improperly installed valve guides can damage the valve guide and the cylinder head.

NOTE:

To aid in valve guide installation, the valve guides may be placed in a freezer or other cold environment prior to installation.

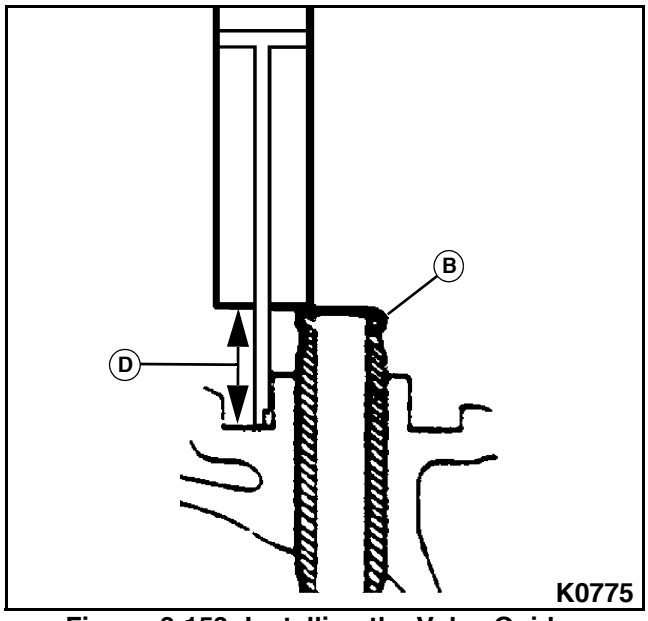


Figure 3-153; Installing the Valve Guides

3. Apply a light layer of assembly lubricant to the valve guide (B) and install the valve guide into the valve guide bore using the valve guide drive and a hammer. **See Figure 3-153.**
4. Drive the valve guide into the cylinder head until it has reached proper installed height (D).

   VALVE GUIDE—INSTALLED HEIGHT

   20.31 mm (0.080 in.)

CYLINDER BLOCK

⚠ WARNING

Carbon monoxide can cause severe nausea, fainting, or death.

Avoid inhaling exhaust fumes.

Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.

⚠ WARNING

Risk of fire. Can cause severe injury or death.

Do not smoke or permit flames or sparks near fuels or the fuel system.

⚠ WARNING

Avoid possible death or serious injury! Pinch and entanglement hazards! Never check drive belt tension while the engine is running.

⚠ CAUTION

Electrical shock can cause injury.

Do not touch wires while engine is running.

⚠ WARNING

Hot parts can cause severe burns.

Do not touch engine while operating or just after stopping.

Never operate engine with heat shields or guards removed.

⚠ WARNING

Rotating parts can cause severe injury.

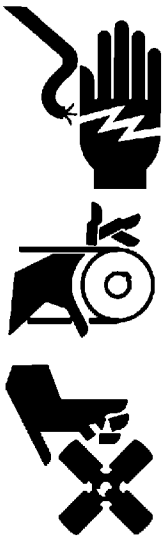
Stay away while the engine is in operation.

Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate the engine with covers, shrouds, or guards removed.

⚠ WARNING

Hot coolant and steam. Can cause severe injury or death.

Before removing the pressure cap, stop the engine and allow it to cool. Then loosen the pressure cap to relieve pressure.



⚠ WARNING

Accidental starts can cause severe injury or death.

Disconnect and ground spark plug leads before servicing.

Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug leads. 2) Disconnect negative (–) battery cable from battery.

Before disconnecting negative (–) ground cable, make sure all switches are OFF. If ON, a spark will occur at the ground cable terminal which could cause an explosion if hydrogen gas or LPG/NG fuel vapors are present.

⚠ WARNING

Explosive fuel can cause fires and severe burns.

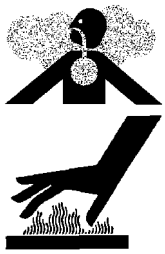
If a gaseous odor is detected, ventilate the area and contact an authorized service technician.

LPG (Liquefied Petroleum Gas) is extremely flammable and tends to settle in low areas where a spark or flame could ignite the gas. Do not start or operate this engine in a poorly ventilated area where leaking gas could accumulate and endanger the safety of persons in the area.

NG (Natural Gas) is extremely flammable, is lighter than air, and rises, Do not start or operate this engine in a poorly ventilated are where leaking gas could accumulate and endanger the safety of persons in the area.

To ensure personal safety, installation and repair of LPG/NG fuel supply systems must be performed only by qualified LPG/NG system technicians. Improperly installed and maintained LPG/NG equipment could cause the fuel supply system or other components to malfunction, causing gas leaks.

Observe federal, state, and local laws governing LPG/NG fuel, storage, and systems.



⚠ WARNING

Handling caustic engine fluids and chemical products. Can cause severe chemical burns, nausea, fainting, or death.

Most chemicals such as used engine oil, antifreeze/coolant, rustproofing agent, inhibiting oil, degreasing agent, spray paint, and adhesives are hazardous to health. Read and follow the user information found on the packaging. Avoid inhalation and skin contact. Use only in well-ventilated areas and use a protective mask when spraying. Store engine fluids and chemical products in a locked cabinet. Contact your local recycling center for disposal information and locations.

Fire-damaged or burned O-rings may cause the formation of hydrofluoric acid. Contact with hydrofluoric acid may cause severe skin irritation and chemical burns. O-rings and other fluoroelastomer seals exposed to fire or temperatures above 316 °C (600 °F) (i.e., during welding) may decompose forming hydrofluoric acid. Avoid inhalation or skin contact. Do not incinerate O-rings. Dispose of O-ring waste material in a responsible manner.

⚠ WARNING

Spring-loaded parts. Can cause severe personal injury or property damage.

Wear protective goggles when servicing spring-loaded parts. Hold parts securely during disassembly.

⚠ WARNING

Airborne particles. Can cause severe injury or blindness.

Wear protective goggles and clothing when using power tools, hand tools, or compressed air.

⚠ WARNING

Explosive fuel vapors. Can cause severe injury or death.

Use extreme care when handling, storing, and using fuels.

Gas fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check the LPG vapor or natural gas fuel system for leakage by using a soap and water solution with the fuel system test pressurized to 6–8 ounces per square inch (10–14 inches water column). Do not use a soap solution containing either ammonia or chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

Used engine oil. Contact with used engine oil may cause severe skin irritation. Repeated and prolonged skin exposure may have other health risks. Used engine oil is a suspected carcinogen. Avoid contact with skin. Thoroughly wash your hands and nails with soap and water shortly after handling used engine oil. Wash or dispose of clothing or rags containing used engine oil. Dispose of used engine oil in a responsible manner. Contact your local recycling center for disposal information and locations.

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

CAMSHAFT

Remove Valve Lifters

1. Remove the valve lifter with a piece of metal wire from the top of the cylinder block.

NOTICE
Always keep the valve lifters upright and in correct order.

Inspect Valve Lifters

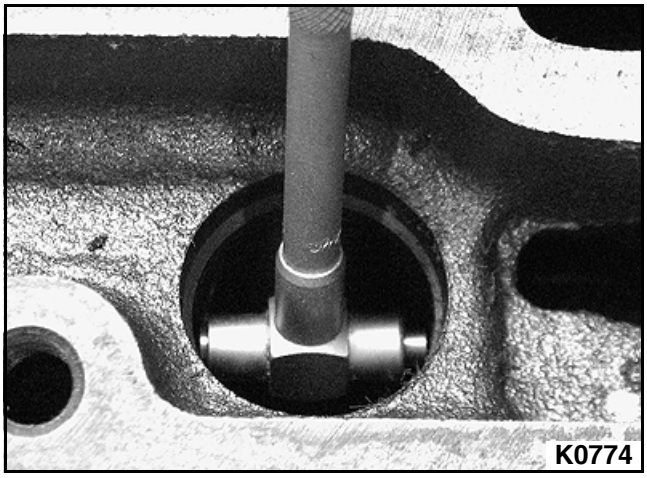


Figure 3-154

1. Use a snap gauge to measure the valve lifter bore diameter. **See Figure 3-154.**

LIFTER BORE INSIDE DIAMETER

21.412–21.443 mm (0.843–0.844 in.)

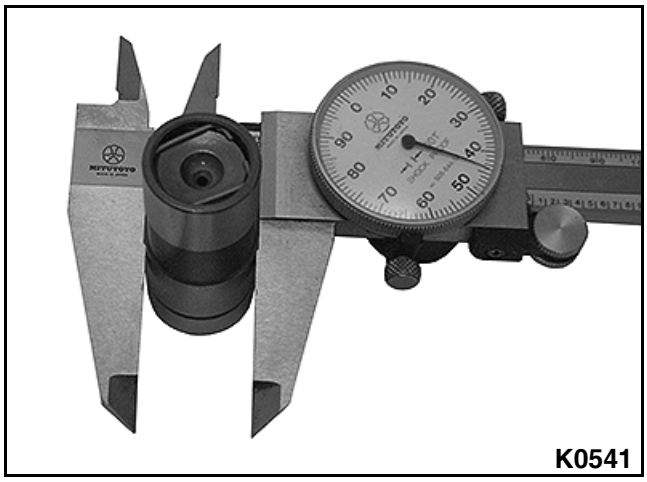


Figure 3-155

2. Use a micrometer to measure the valve lifter outside diameter. **See Figure 3-155.**

VALVE LIFTER OUTSIDE DIAMETER

21.387–21.400 mm (0.8420–0.8425 in.)

3. Calculate the difference between the valve lifter hole inside diameter and valve lifter outside diameter.

LIFTER BORE OIL CLEARANCE

Standard

0.012~0.056 mm (0.0004–0.0022 in.)

Maximum

0.10 mm (0.0039 in.)

4. If the clearance is greater than maximum specification, replace the valve lifters.

Remove Timing Chain Cover

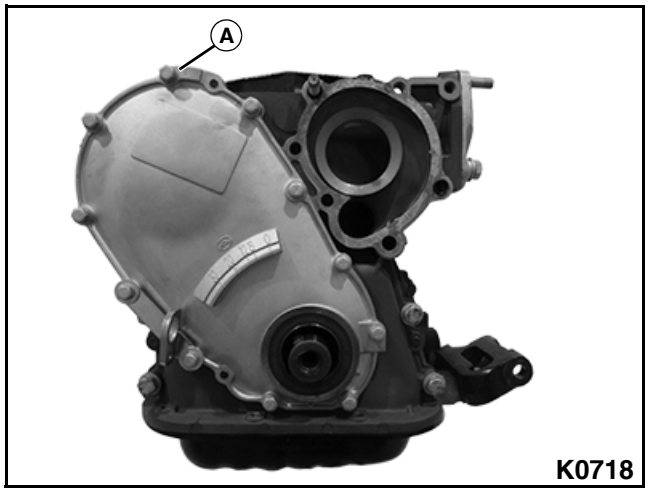


Figure 3-156

1. Remove eleven bolts, lock washers, and flat washers. Leave the timing pick-up sensor bracket attached to timing chain cover. **See Figure 3-156.**
2. Remove timing chain cover from engine.

Check Timing Chain Slack

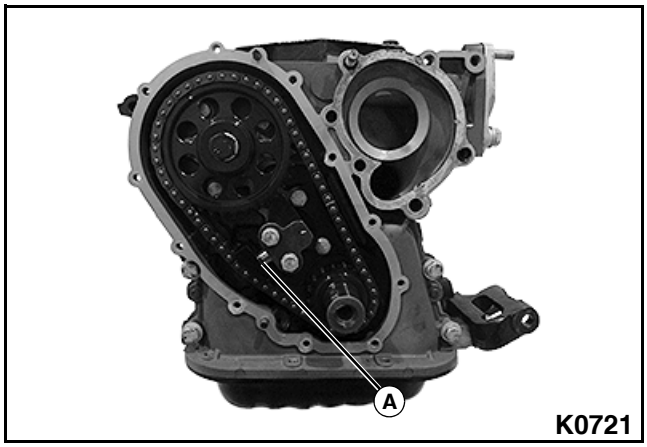


Figure 3-157

1. Using a tension gauge, measure the slack of the timing chain. **See Figure 3-157.**

TIMING CHAIN SLACK

Applied Test Pressure

98 N (72 lbf.)

Maximum Chain Slack

13.5 mm (0.531 in.)

2. If the slack is greater than maximum specification, replace the timing chain and sprockets.

Remove Timing Chain Tensioner and Damper

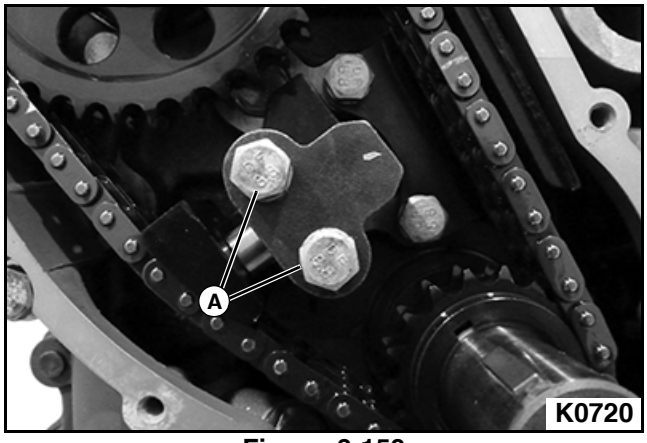


Figure 3-158

1. Remove two bolts (A) securing timing chain tensioner to cylinder block and remove tensioner. **See Figure 3-158.**

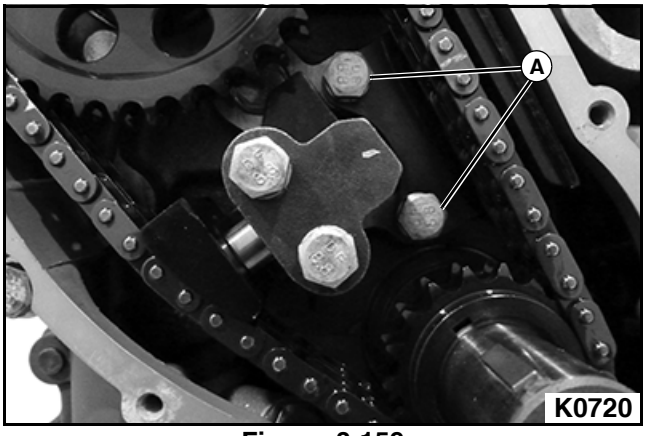


Figure 3-159

2. Remove two bolts (A) securing timing chain damper to cylinder block and remove damper. **See Figure 3-159.**

Check Timing Chain Tensioner and Damper

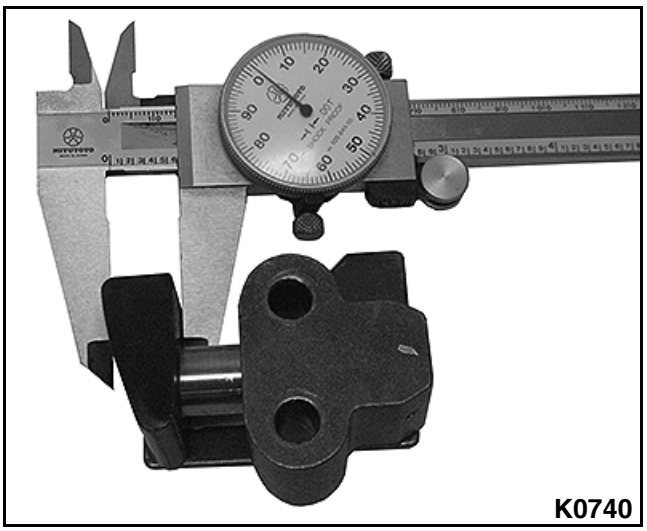


Figure 3-160

1. Using calipers, measure the tensioner thickness. **See Figure 3-160.**

TENSIONER THICKNESS

Standard Thickness

15.0 mm (0.59 in.)

Minimum Thickness

12.5 mm (0.49 in.)

2. If the thickness is less than minimum specification, replace the tensioner or its parts. When replacing or reinstalling tensioner, fill tensioner body with oil.

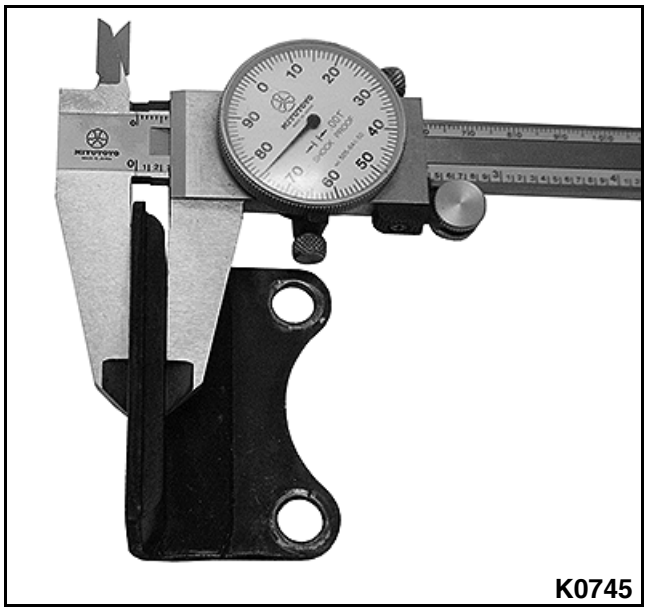


Figure 3-161

1. Using a caliper, measure the damper thickness. **See Figure 3-161.**

DAMPER THICKNESS

Standard Thickness

6.6 mm (0.259 in.)

Minimum Thickness

5 mm (0.196 in.)

2. If damper thickness is less than minimum specification, replace damper.

Remove Timing Chain and Gears

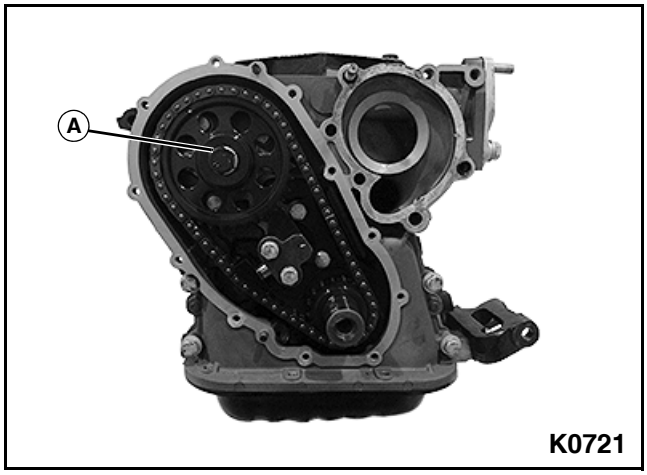


Figure 3-162

1. Remove one retaining bolt, lock washer, and flat washer (A) fastening camshaft sprocket to camshaft. **See Figure 3-162.**
2. Remove timing chain tensioner and damper. See “Remove Timing Chain Tensioner and Damper” on page 99.
3. Using an appropriate gear puller, remove the camshaft sprocket. Do not damage the camshaft or sprocket.
4. Using an appropriate gear puller, remove the crankshaft timing chain gear. Do not damage crankshaft or sprocket.

Inspect Timing Chain and Gear

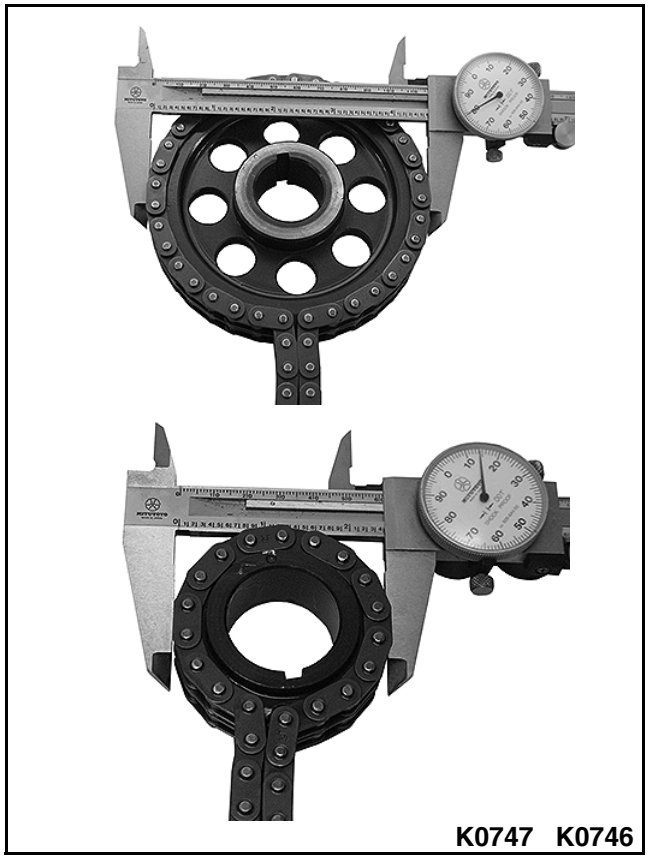


Figure 3-163

1. Using a caliper, measure the sprocket diameter with the chain installed to the sprocket. **See Figure 3-163.**

SPROCKET DIAMETER (WITH CHAIN)

Crankshaft Chain Sprocket

59 mm (2.32 in.)

Camshaft Chain Sprocket

114 mm (4.48 in.)

2. If the diameter is less than minimum specification, replace the chain and two sprockets.

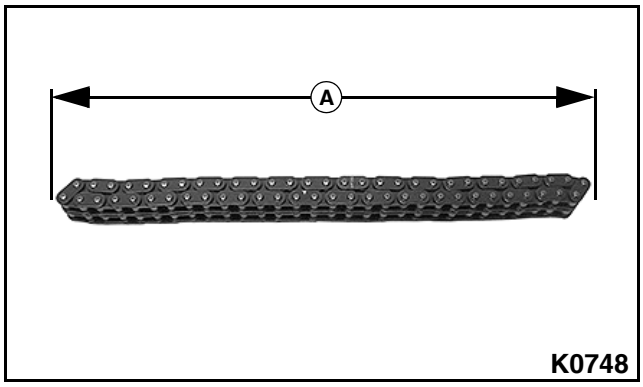


Figure 3-164

3. Measure the chain length (A) with the chain fully stretched. **See Figure 3-164.**
4. Make the same measurements pulling at three or more places selected at random.

CHAIN ELONGATION—MAXIMUM

Test Tension

49 N (36 lbf.)

Chain Length

291.4 mm (11.47 in.)

5. If the elongation is greater than maximum specification, replace the chain.

Remove Thrust Plate and Camshaft

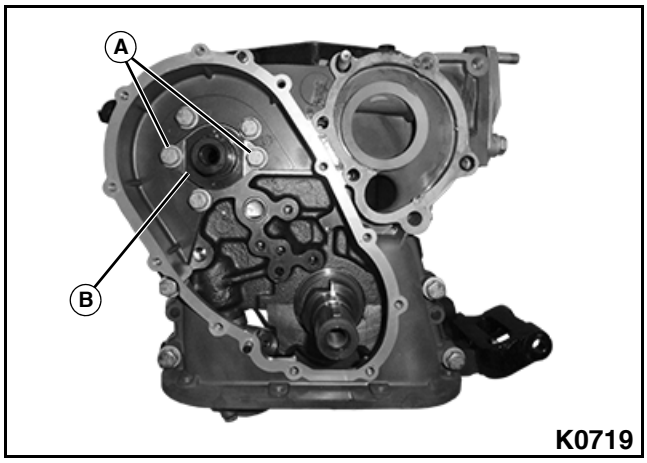


Figure 3-165

1. Remove two bolts (A), and remove the thrust plate (B). Note direction of thrust plate to camshaft. **See Figure 3-165.**

NOTICE
Do not damage the camshaft bearings, camshaft lobes, or camshaft journals when removing camshaft.

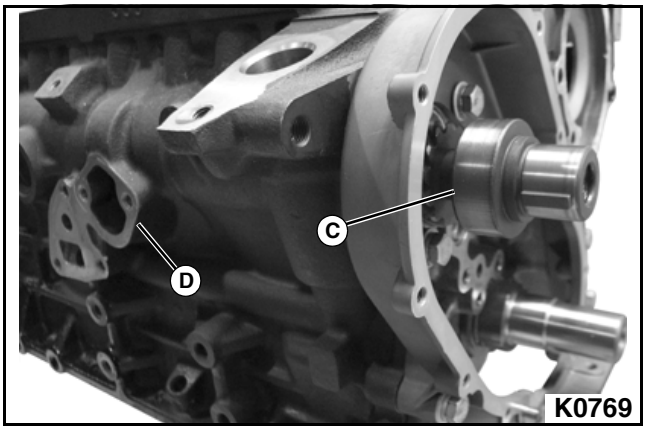


Figure 3-166

2. Guide camshaft (C) from cylinder block through front of engine, also using mechanical fuel pump provision (D) on the side of cylinder block to prevent damage to camshaft or camshaft bearings. **See Figure 3-166.**

Inspect Camshaft

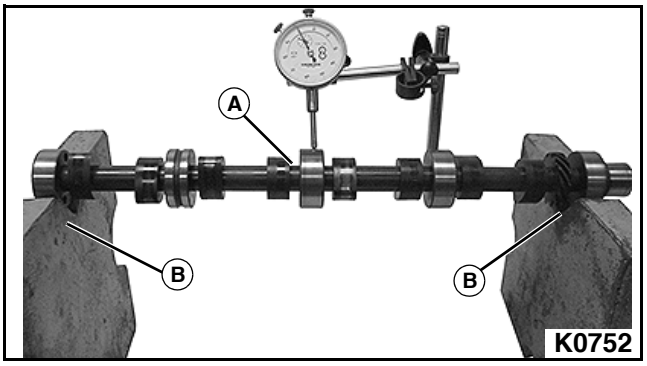


Figure 3-167

1. Place the camshaft on V-blocks (B) and measure the runout at the center journal (A). **See Figure 3-167.**

CAMSHAFT RUNOUT—MAXIMUM

0.06 mm (0.0023 in.)

2. If the circle runout is greater than maximum specification, replace the camshaft.

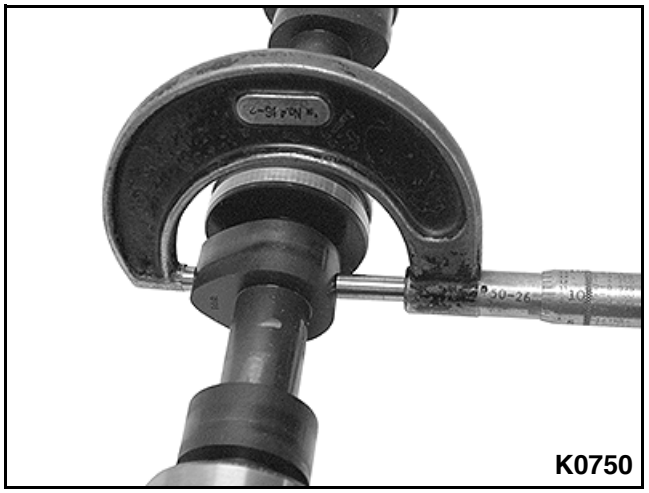


Figure 3-168

1. Using a micrometer, measure the cam lobe height at the large end with the bevel. **See Figure 3-168.**

CAMSHAFT LOBE HEIGHT

Standard

Intake 38.620–38.720 mm (1.5205–1.5244 in.)

Exhaust 38.629– 38.729 mm (1.5208–1.5248 in.)

Minimum

Intake 38.26 mm (1.5062 in.)

Exhaust 38.27 mm (1.5066 in.)

2. If the lobe height is less than minimum specification, replace the camshaft.

Figure 3-169

3. Use a micrometer and measure the camshaft journal outside diameter. Record measurements for reference. **See Figure 3-169.**

CAMSHAFT JOURNAL DIAMETER

Standard (from the front side)

No. 1 46.459–46.475 mm (1.8291–1.8297 in.)

No. 2 46.209–46.225 mm (1.8192–1.8199 in.)

No. 3 45.959–45.975 mm (1.8094–1.8100 in.)

No. 4 45.709–45.725 mm (1.7996–1.8002 in.)

No. 5 45.459–45.475 mm (1.7897–1.7904 in.)

4. If the camshaft journal diameter is not within specification, check the oil clearance of the bearings. See “Inspect Camshaft Bearings” on page 103.

Checking Camshaft Thrust

1. Install the thrust plate and camshaft sprocket to the camshaft.
2. Install and torque the camshaft sprocket mount bolt to specification.

CAMSHAFT SPROCKET BOLT—TORQUE

90 N•m (66 ft.lb.)

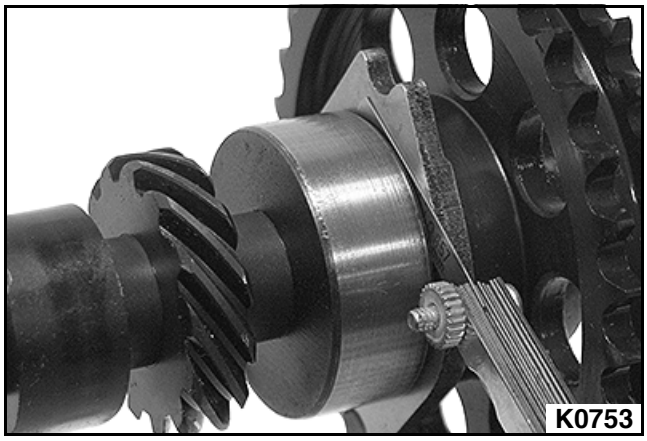


Figure 3-170

3. Using a feeler gauge, measure the thrust clearance between the thrust plate and camshaft. **See Figure 3-170.**

CAMSHAFT THRUST PLATE CLEARANCE

Standard

0.07–0.22 mm (0.00270–0086 in.)

Maximum

0.30 mm (0.0118 in.)

4. If the clearance is greater than maximum specification, replace the thrust plate, if necessary, replace the camshaft.

Remove Timing Chain Gear Housing

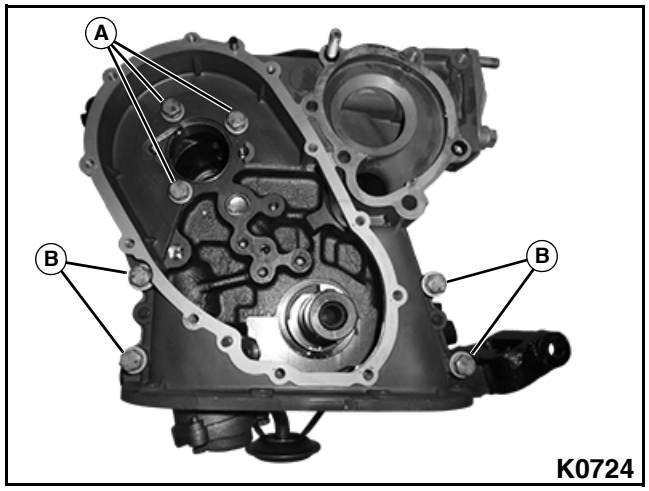


Figure 3-171

1. Remove three bolts, lock washers, and flat washers (A), from the inside of the timing chain housing. **See Figure 3-171.**
2. Remove four bolts, lock washers, and flat washers (B), from the outside of the timing chain housing.
3. Remove the timing chain housing.

Inspect Camshaft Bearings

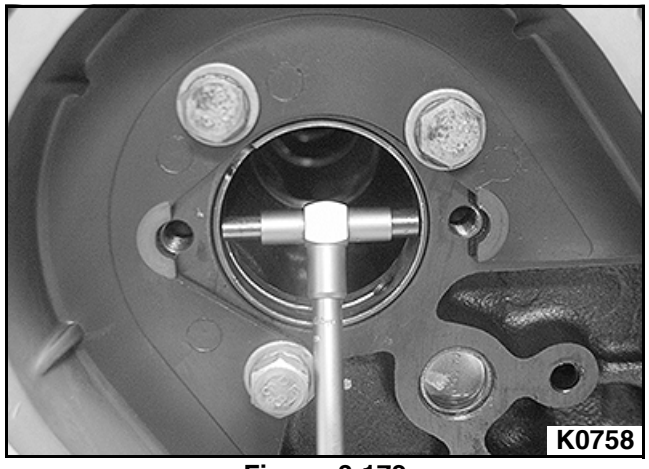


Figure 3-172

1. Using a dial bore micrometer, measure the inside diameter of the camshaft bearing with the bearing installed in cylinder block. **See Figure 3-172.**

CAMSHAFT BEARING BORE SPECIFICATIONS

Standard (from the front of the cylinder block)

No. 1 46.500–46.540 mm (1.8307–1.8323 in.)
No. 2 46.250–46.290 mm (1.8209–1.8224 in.)
No. 3 46.000–46.040 mm (1.8110–1.8126 in.)
No. 4 45.750–45.790 mm (1.8012–1.8028 in.)
No. 5 45.500–45.540 mm (1.7913–1.7929 in.)

2. Replace camshaft if not within specification.
3. Calculate the difference between the measured bearing inside diameter and camshaft journal outside diameter.

CAMSHAFT BEARING CLEARANCE SPECIFICATIONS

Standard

0.025–0.081 mm (0.0010–0.0032 in.)

Maximum

0.10 mm (0.0039 in.)

4. If the maximum specification is exceeded, regrind or replace the camshaft.

Remove Camshaft Bearings

NOTICE
All camshaft bearings have different outside diameter.

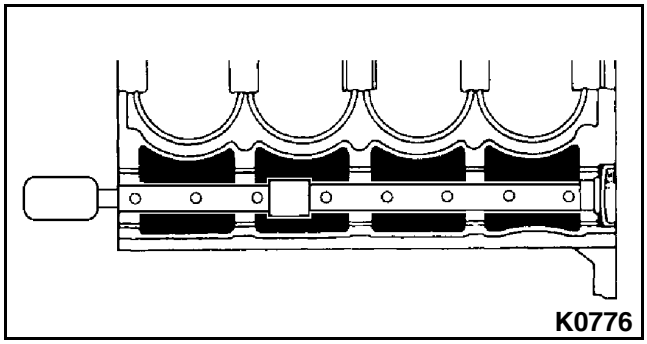


Figure 3-173

1. Use a block plug removal tool to remove the tight plug from the rear of the cylinder block behind number five camshaft bearing. **See Figure 3-173.**

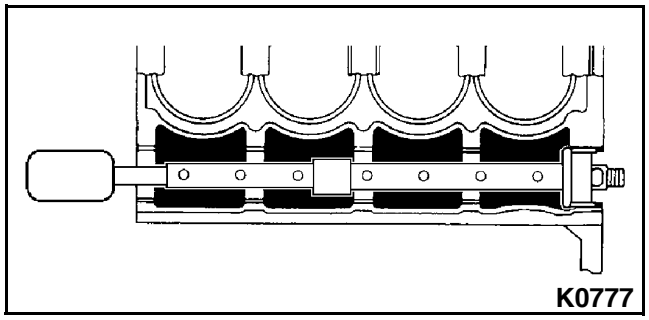


Figure 3-174

2. Using a camshaft bearing removal tool, remove the camshaft bearings. **See Figure 3-174.**

Install Camshaft Bearings

NOTICE

Oil holes in cam bearings MUST be aligned with oil holes in cylinder block or engine damage will occur.

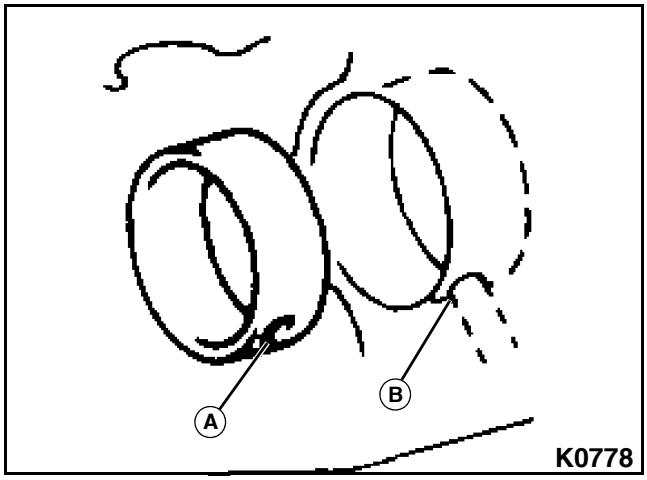


Figure 3-175

1. Align oil holes of the cylinder block (B) and camshaft bearings (A). **See Figure 3-175.**

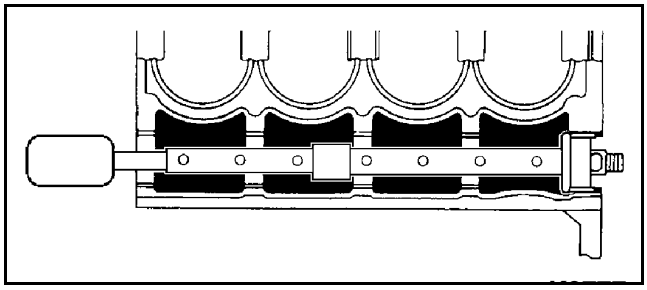


Figure 3-176

2. Using a camshaft bearing installation tool, install the camshaft bearings. **See Figure 3-176.**
3. Coat sealant on the tight plug installation surface of the cylinder block.

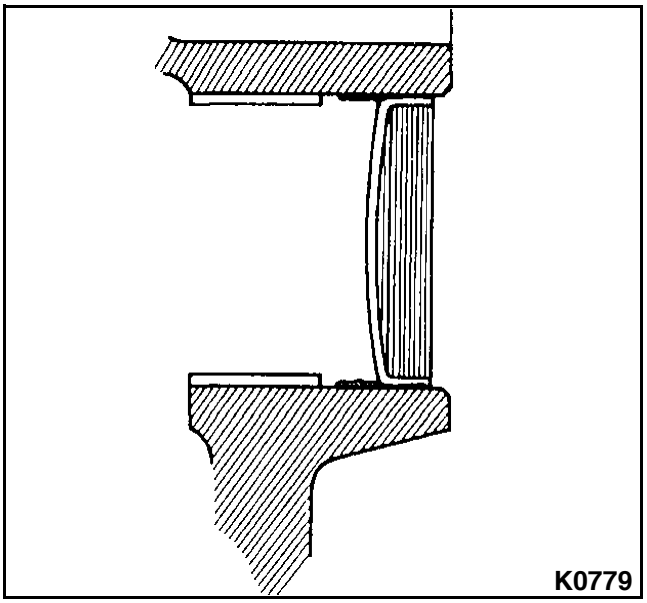


Figure 3-177

4. Use a hammer to drive in the tight plug until it is flush with the cylinder block end surface. **See Figure 3-177.**

Install Timing Chain Gear Housing

NOTICE

Do not damage the camshaft bearings, camshaft lobes, or camshaft journals when installing camshaft.

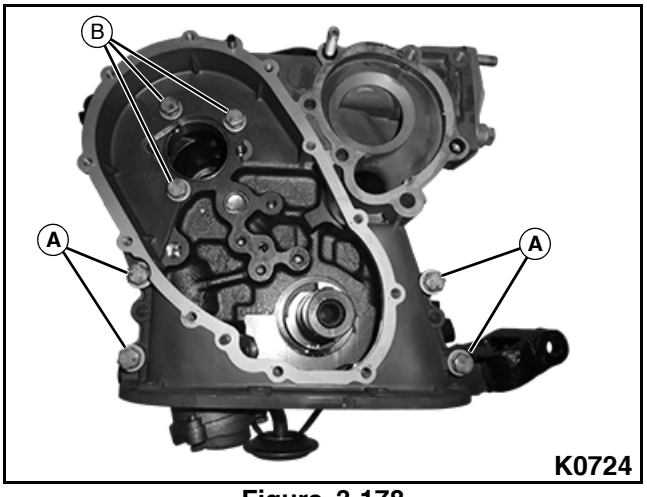


Figure 3-178

1. Install new gasket and timing chain gear housing to cylinder block.
2. Install four outer housing bolts, lock washers, and flat washers (A). **See Figure 3-178.**
3. Install three inner housing bolts, lock washers, and flat washers (B).

Install Camshaft and Thrust Plate

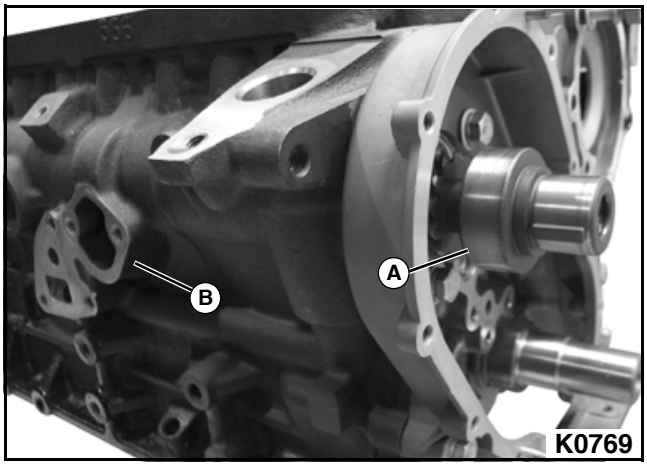


Figure 3-179

1. Guide camshaft (A) in to cylinder block through front of engine, also using mechanical fuel pump provision (B) on the side of cylinder block to prevent damage to camshaft or camshaft bearings.

NOTICE

Thrust plate must be installed facing proper direction. Dimples must face front of engine (C). See Figure 3-180.

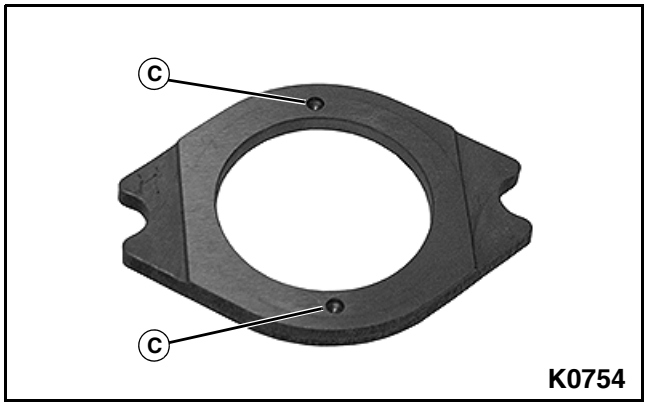


Figure 3-180

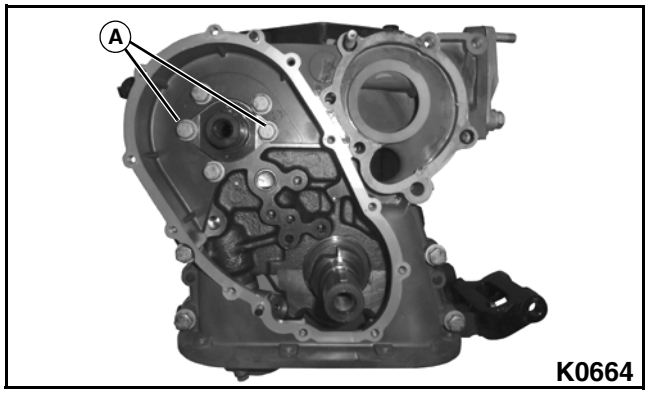


Figure 3-181

2. Install the camshaft thrust plate to the cylinder block, using two bolts, lock washers, and flat washers (A). **See Figure 3-181.**
3. Torque camshaft thrust plate bolts to specification.

CAMSHAFT THRUST PLATE BOLT—TORQUE

17.6 N•m (13 ft.lb.)

Install Timing Chain and Gears

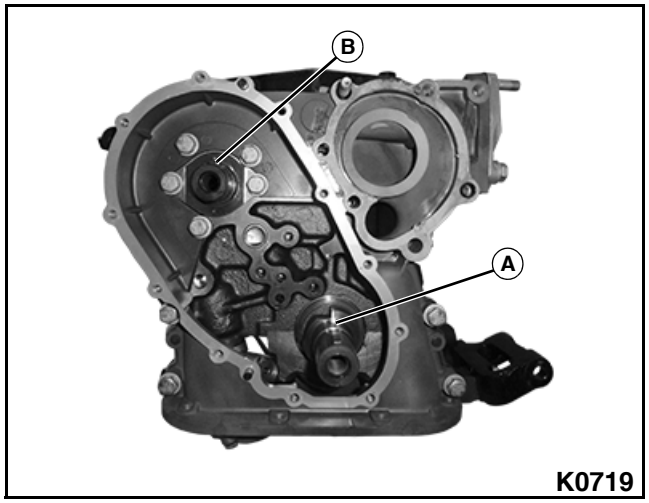


Figure 3-182

1. Rotate the crankshaft to bring the crankshaft key to the top position (A). **See Figure 3-182.**
2. Rotate the camshaft to align the camshaft key with the timing mark at the top of the thrust plate (B).

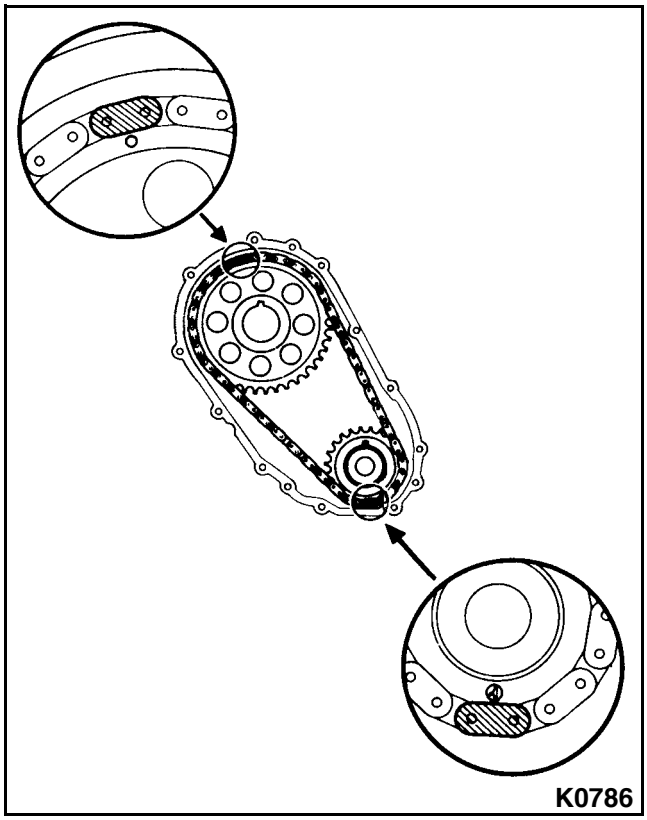


Figure 3-183

NOTICE

Match the mark on each timing gear with the corresponding timing mark on the timing chain.

3. Assemble the crankshaft timing gear, camshaft timing gear, and timing chain. **See Figure 3-183.**
4. Install the timing chain and timing gears at the same time.
5. Coat the thread and seat surface of the camshaft timing gear bolt with clean engine oil.
6. Install the camshaft timing gear bolt securing the camshaft timing gear to the camshaft.

Figure 3-184

7. Holding the crankshaft from rotating, torque the camshaft timing gear bolt to specification. **See Figure 3-184.**

CAMSHAFT TIMING GEAR BOLT—TORQUE

90.2 N•m (67 ft.lb.)

Install Timing Chain Tensioner and Damper

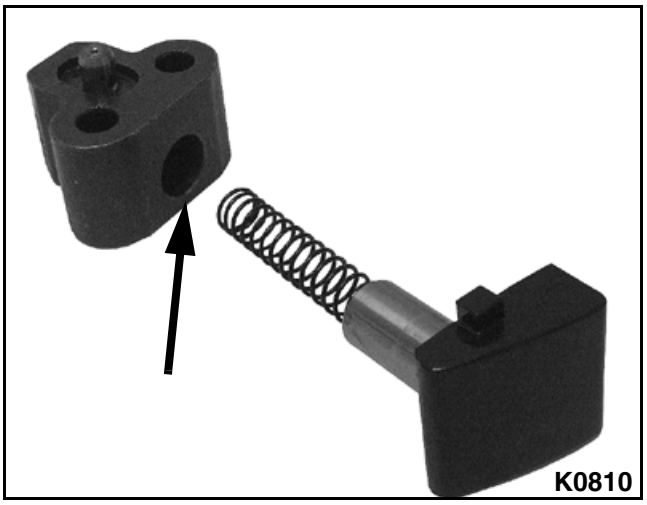


Figure 3-185

1. Fill timing chain tensioner body with clean engine oil prior to installing to the cylinder block. **See Figure 3-185.**

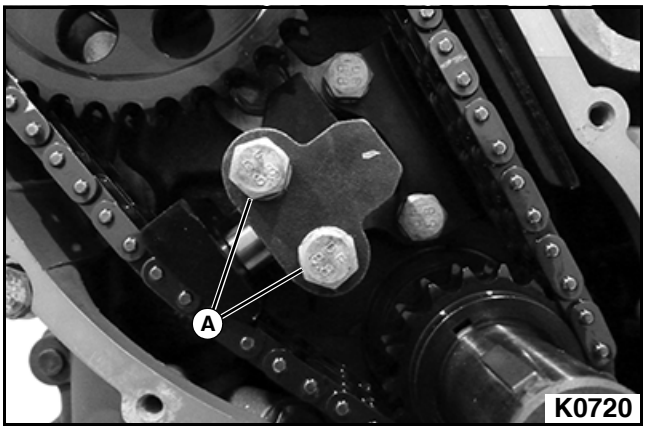


Figure 3-186

2. Install the timing chain tensioner to the cylinder block secure with two bolts, lock washers, and flat washers (A). **See Figure 3-186.**
3. Torque bolts to specification.

CHAIN TENSIONER BOLT—TORQUE

17.6 N•m (13 ft.lb.)

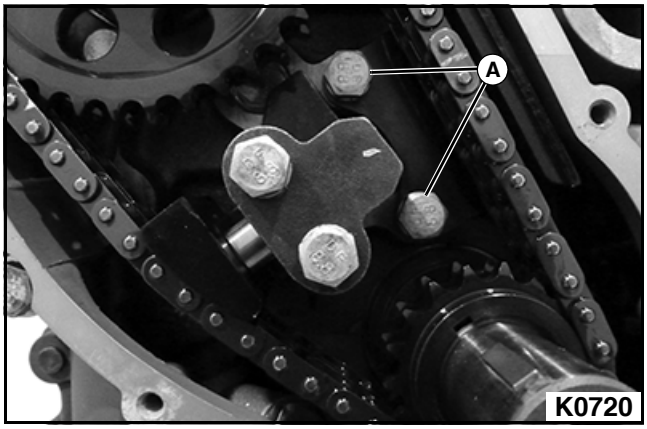


Figure 3-187

1. Install the timing chain vibration damper to the cylinder block with two bolts, lock washers, and flat washers (A). **See Figure 3-187.**
2. Torque damper bolts to specification.

CHAIN DAMPER BOLT—TORQUE

17.6 N•m (13 ft.lb.)

Install Timing Cover

1. Install a new timing chain cover gasket to the timing chain housing.

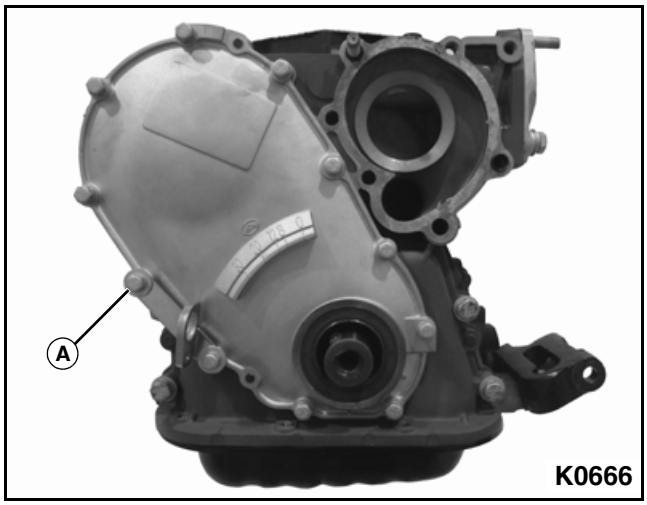


Figure 3-188

2. Install the timing chain cover to the timing chain housing and secure with eleven bolts, lock washers, and flat washers (A). **See Figure 3-188.**
3. Torque bolts to specification.

TIMING COVER BOLT—TORQUE

17.6 N•m (13 ft.lb.)

Install Lifters

1. Prior to installing the valve lifters to the cylinder block, bleed the air from the valve lifter body. Place the valve lifter into a container of clean engine oil, compress the piston of the lifter to release any air in the lifter body and filling with engine oil.
2. Use a wire with its tip bent to an “L” shape. Carefully insert the valve lifter into the valve lifter hole.

CYLINDER BLOCK, CRANKSHAFT, CONNECTING RODS, AND PISTONS

Remove Oil Pump and Oil Pump Pick-up

Oil pump installs at the bottom and front of cylinder block, driven by oil pump drive device.

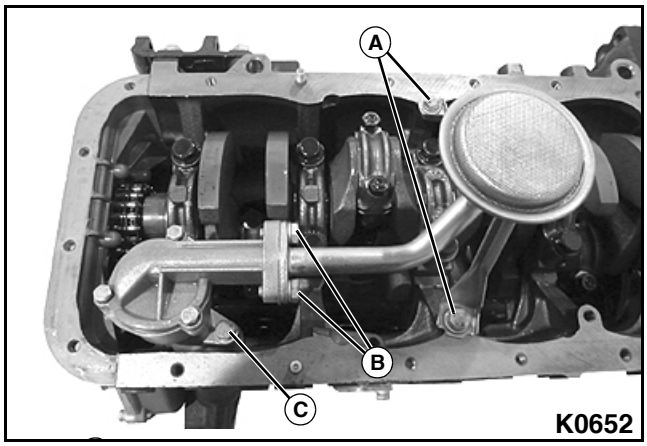


Figure 3-189

1. Remove two bolts, lock washers, and flat washers securing the oil pump pick-up tube to the cylinder block (A). **See Figure 3-189.**
2. Remove two bolts and lock washers securing the oil pump pick-up tube at the suction side of the oil pump housing (B).
3. Remove the oil pump pick-up tube from the oil pump housing.
4. Remove one bolt and flat washer securing the oil pump to the cylinder block (C).
5. Remove the oil pump from the cylinder block.

Disassemble and Inspect Oil Pump

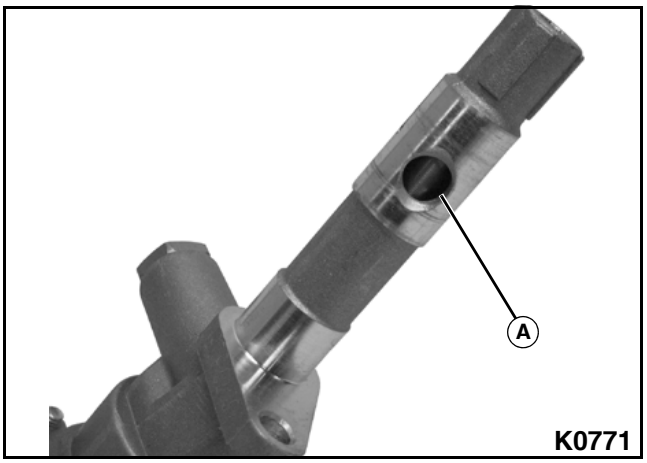


Figure 3-190

1. Using a screwdriver, immerse the oil strainer in oil and turn the oil pump shaft clockwise. Oil should come out of the oil outlet hole (A). **See Figure 3-190.**
2. Close the oil outlet hole with your thumb and turn the oil pump shaft as before. The oil pump shaft should be difficult to turn.

   If there is very little to no resistance, replace the oil pump.
3. Remove the three oil pump cover bolts and then remove the oil pump cover.

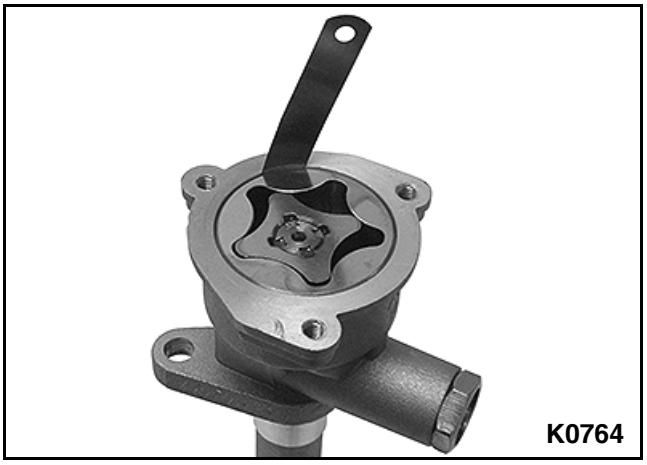


Figure 3-191

4. Use a thickness gauge to measure the clearance between the driven rotor and pump body. **See Figure 3-191.**

OIL PUMP DRIVEN ROTOR-TO-PUMP BODY CLEARANCE

Standard

0.1–0.15 mm (0.0039–0.0059 in.)

Limit

0.2 mm (0.008 in.)

If the clearance exceeds the limit, replace the rotors as a set.

If necessary, replace the whole oil pump assembly.

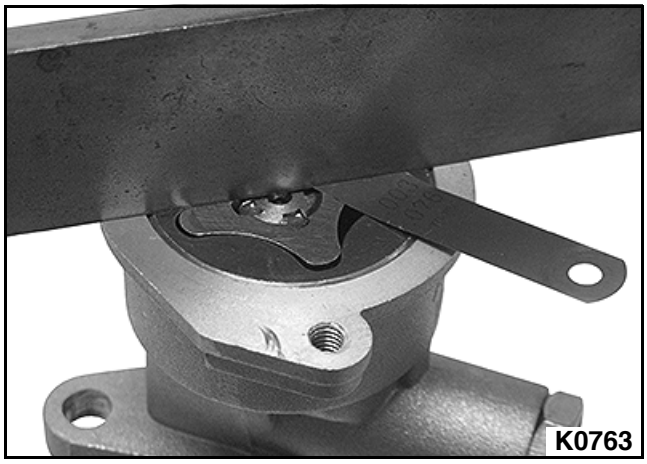


Figure 3-192

5. Use a straight edge and thickness gauge to measure the rotor side clearance. **See Figure 3-192.**

OIL PUMP ROTOR SIDE CLEARANCE

Standard

0.03–0.07 mm (0.0012–0.0028 in.)

Limit

0.15 mm (0.0059 in.)

If the clearance exceeds the limit, replace the rotors as a set.

If necessary, replace the whole oil pump assembly.

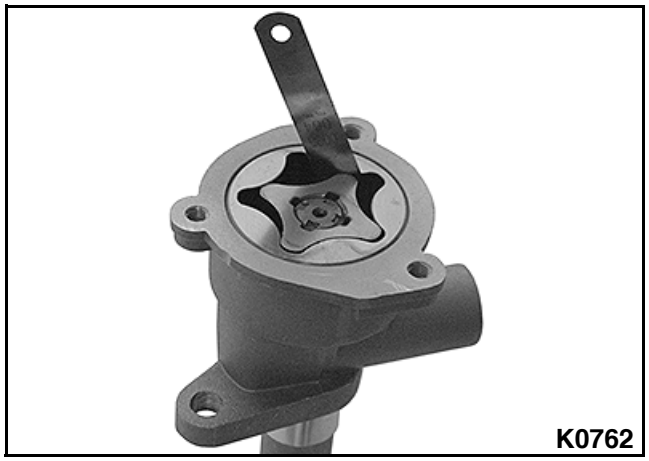


Figure 3-193

6. Use the thickness gauge and measure the tip clearance between the drive and driven rotors. **See Figure 3-193.**

OIL PUMP ROTOR TIP CLEARANCE

Standard

0.07–0.12 mm (0.0028–0.0047 in.)

Limit

0.2 mm (0.008 in.)

If the clearance exceeds the limit, replace the rotors as a set.

If necessary, replace the whole oil pump assembly.

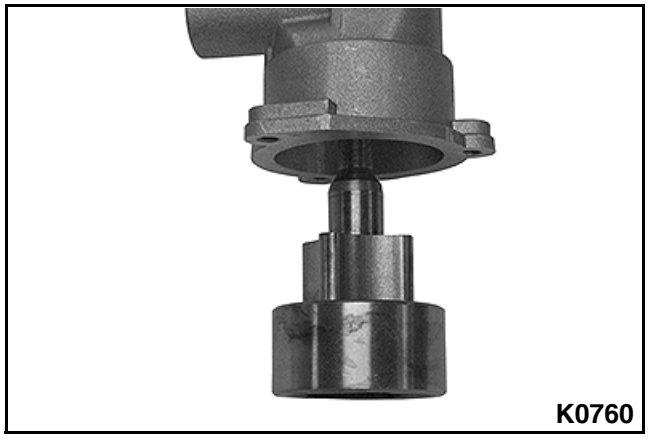


Figure 3-194

7. Remove the drive and driven rotors from the pump body. **See Figure 3-194.**

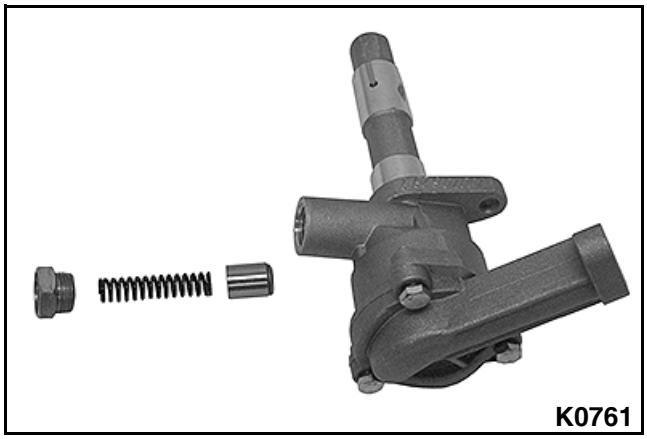


Figure 3-195

8. Remove the plug, spring, and relief valve from the oil pump body. **See Figure 3-195.**

Assemble Oil Pump

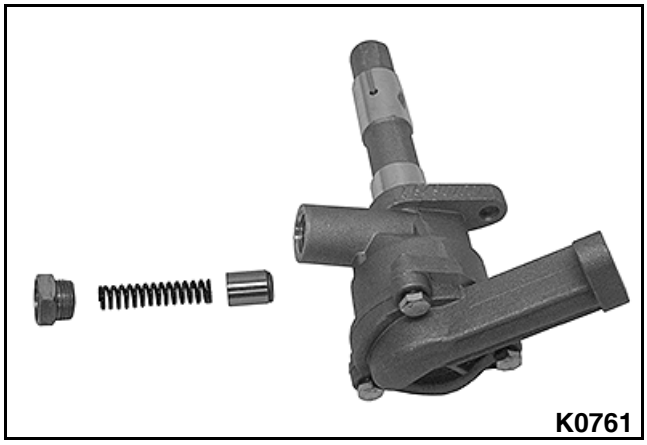


Figure 3-196

1. Install the relief valve, spring, and plug into the oil pump body. **See Figure 3-196.**

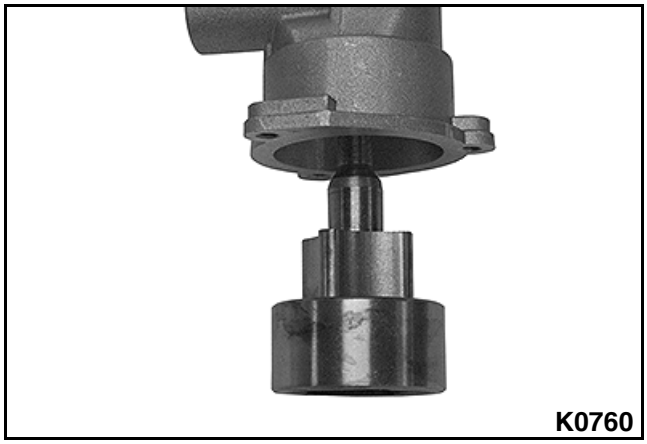


Figure 3-197

2. Install the driven and drive rotors to the pump body. **See Figure 3-197.**
3. Install oil pump cover and three bolts.
4. Torque bolts to specification.

OIL PUMP COVER BOLT—TORQUE

8 N•m (5.8 ft.lb.)

Install Oil Pump

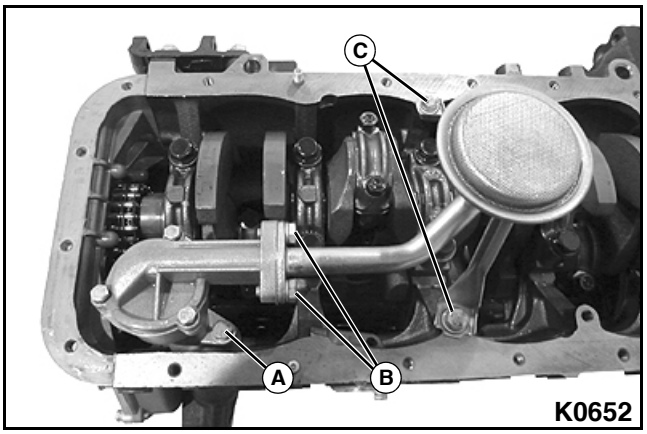


Figure 3-198

1. Install the oil pump to the cylinder block.
2. Install one bolt and flat washer securing the oil pump to the cylinder block (A). **See Figure 3-198.**
3. Install the oil pump pick up tube to the oil pump housing.
4. Install two bolts and lock washers securing the oil pump pick up tube at the suction side of the oil pump housing (B).
5. Install two bolts, lock washers, and flat washers securing the oil pump pick up tube to the cylinder block (C).

Check Connecting Rod Thrust Clearance

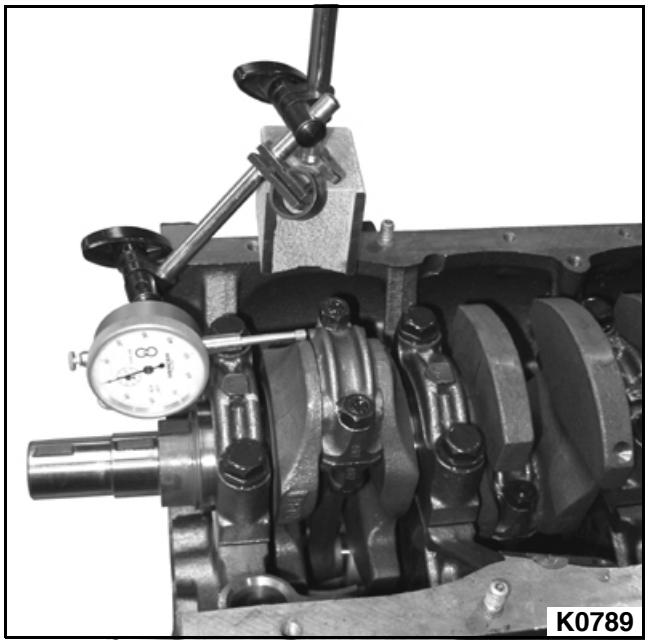


Figure 3-199

1. Using a dial indicator, measure the thrust clearance while moving the connecting rod back and forth. **See Figure 3-199.**

   CONNECTING ROD THRUST CLEARANCE

   Standard

   0.160–0.312 mm (0.006–0.012 in.)

   Maximum

   0.35 mm (0.013 in.)

2. If the clearance is greater than maximum, replace the connecting rod assembly.

Check Crankshaft Thrust Clearance

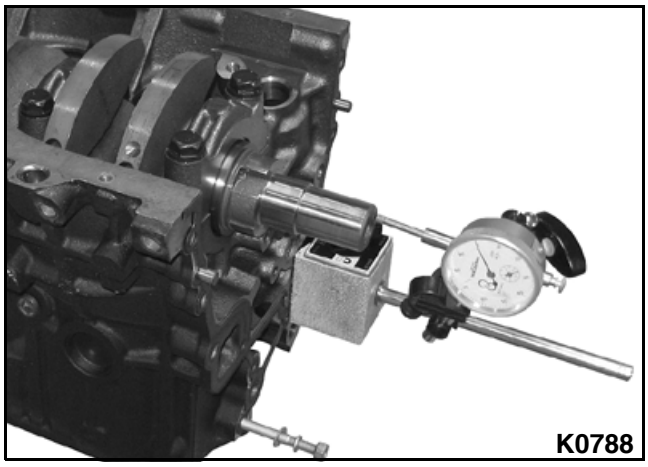


Figure 3-200

1. Using micrometer or dial indicators measure the thrust clearance between the crankshafts back and forth with a screwdriver. **See Figure 3-200.**

   CRANKSHAFT THRUST CLEARANCE

   Standard

   0.020–0.220 mm (0.0007–0.0086 in.)

   Maximum

   0.30 mm (0.011 in.)

2. If the clearance is greater than maximum, replace the thrust washers.

   CRANKSHAFT THRUST WASHER TICKNESS

   2.044–2.490 mm (0.0804–0.0806 in.)

Check Bearing Oil Clearance

Main Bearings

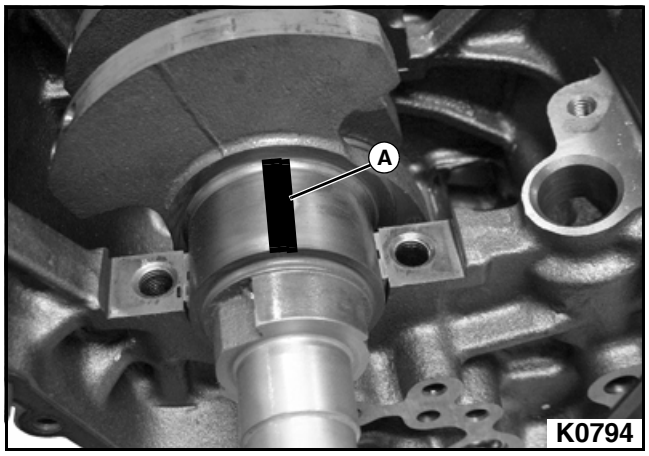


Figure 3-201

1. Check oil clearance between crankshaft main journal and main bearing using a plastic indicator strip (A). **See Figure 3-201.**

   CRANKSHAFT MAIN JOURNAL OIL CLEARANCE

   Standard

   0.020–0.051 mm (0.0007–0.0020 in.)

   Maximum

   0.10 mm (0.039 in.)

2. If the clearance is greater than maximum specification, replace the main bearings. If necessary, grind or replace the crankshaft.

Connecting Rod Bearings

NOTICE

There are matching marks on the side of connecting rod body and cap, do not exchange with others.

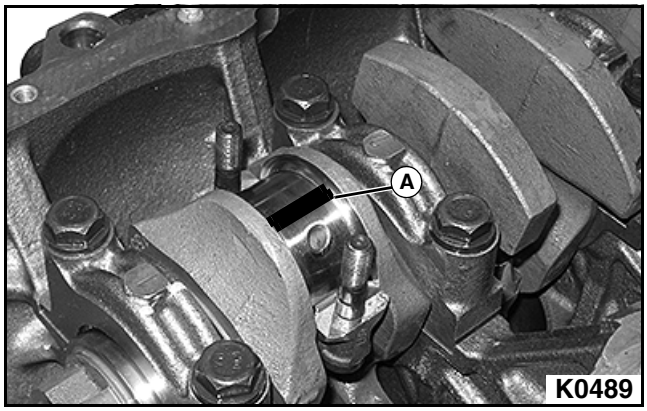


Figure 3-202

1. Check oil clearance between connecting-rod bearing and crank pin using a plastic indicator strip (A). **See Figure 3-202.**

CONNECTING ROD JOURNAL OIL CLEARANCE

Standard Clearance

0.020–0.051 mm (0.0007–0.002 in.)

Maximum Clearance

0.10 mm (0.0039 in.)

2. If the clearance is greater than the maximum specification, replace the bearings. If necessary, grind or replace the crankshaft.

Remove Connecting Rods and Pistons

1. Remove carbon from the top of cylinder bore with a scraper or ridge reamer. Remove loose material from cylinders.

NOTICE

There are matching marks on the side of connecting rod body and cap, do not exchange with others.

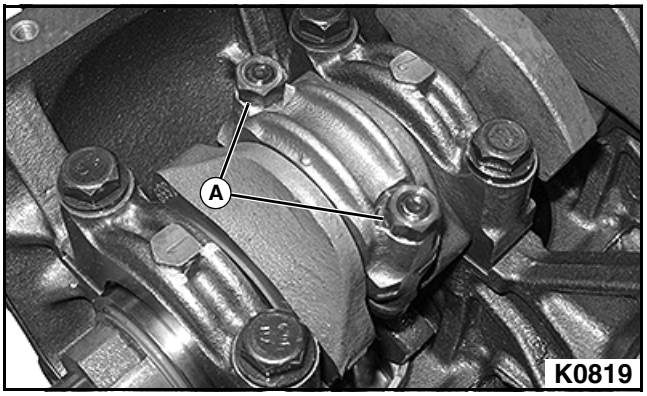


Figure 3-203

2. Remove two nuts and washers (A) securing connecting rod cap to connecting rod with bearing in place. **See Figure 3-203.**
3. Remove connecting rod cap from connecting rod and crankshaft.
4. Cover the connecting rod bolts with vinyl hoses. Gently tap piston through top of cylinder block from the bottom as not to damage the crank pin.
5. Remove pistons and rods from engine.

NOTICE

The removed pistons, connecting rod caps, and bearings should be arranged in the order of corresponding cylinders.

Remove Connecting Rod Bearings from Connecting Rods

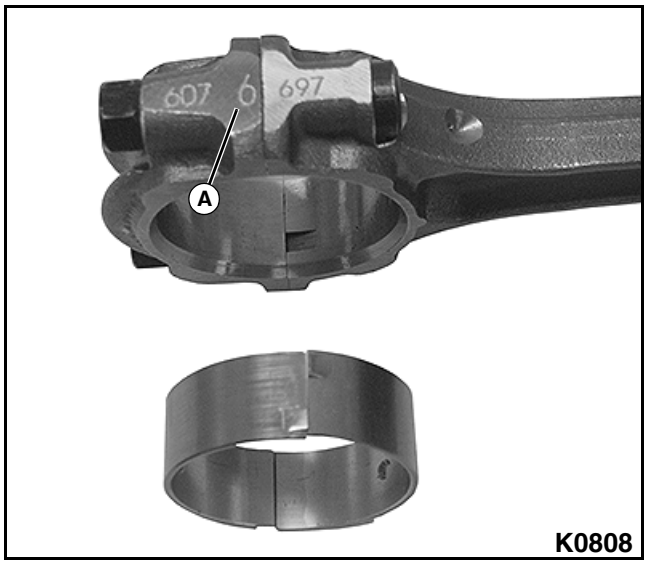


Figure 3-204

Connecting-rod big hole diameter and bearing are divided into 3 groups, marked with “6”, “7”, and “8” (A). Keep bearings in pairs when removed. **See Figure 3-204.**

NOTICE

Replace the same number of connecting rod bearings as that of new connecting rod caps.

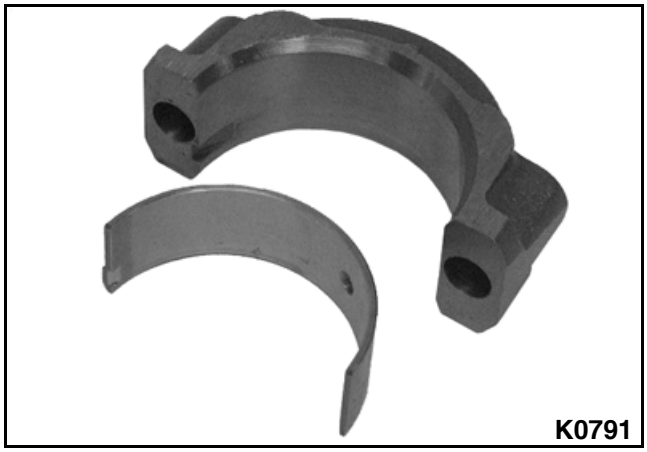


Figure 3-205

1. Remove bearings from connecting rods and connecting rod caps. **See Figure 3-205.**

Disassemble Connecting Rod and Piston Assembly

NOTICE

Removed pistons, piston rings, and piston pins shall be used in original combinations before removal.

Arrange the removed pistons, piston pins, piston rings, and connecting rods in order of the corresponding cylinders.

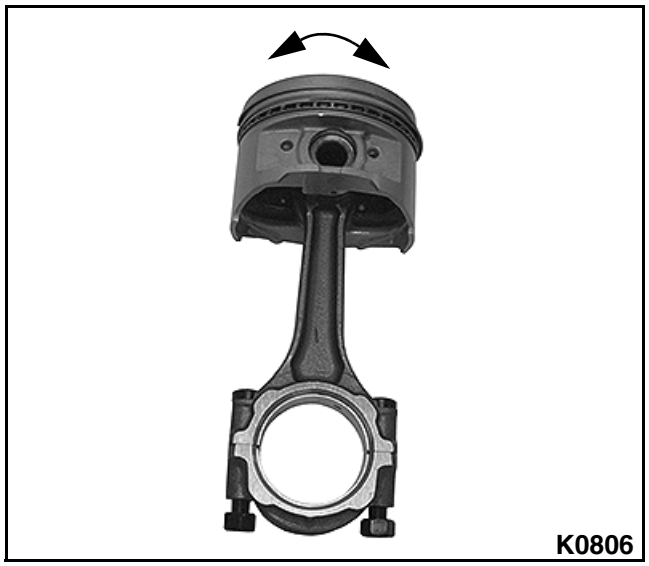


Figure 3-206

1. Move the piston to check for smooth movement. **See Figure 3-206.**
2. If obstruction, looseness, or heavy movement is observed, replace the piston subassembly.

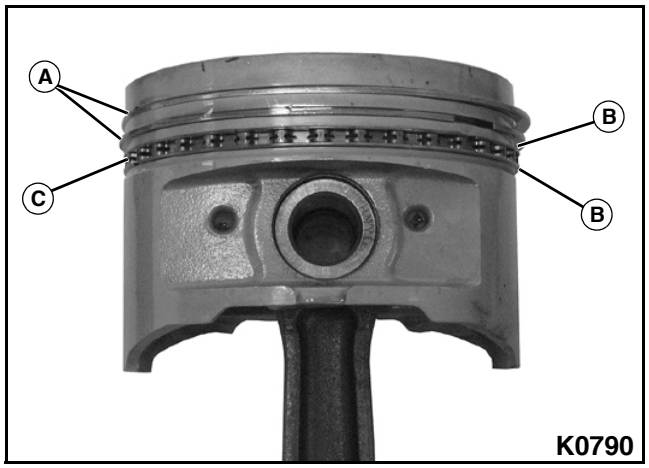


Figure 3-207

3. Remove two compression rings (A) from the piston using a piston ring expansion tool. **See Figure 3-207.**
4. Manually remove two side rails (B) and oil ring expander (C). **See Figure 3-207.**
5. Arrange the removed piston rings in the order of the corresponding cylinders.
6. Remove the piston pin from the piston rod assembly at room temperature, using the proper piston pin removal tool.

Check Connecting Rods for Bend or Twist

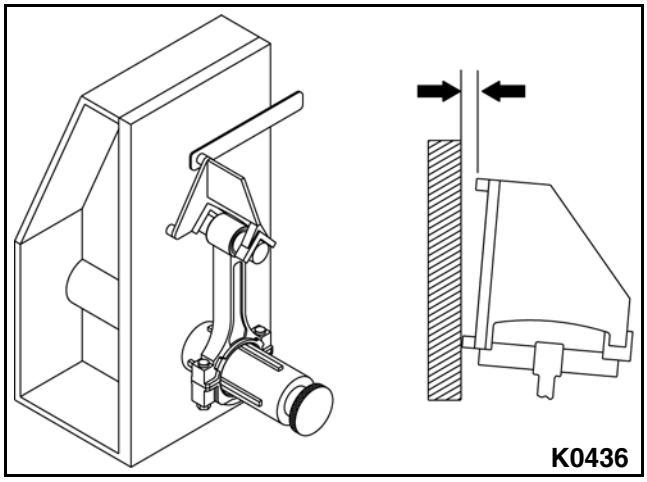


Figure 3-208

1. Using a rod aligner, check the connecting rod alignment for bend or twist. **See Figure 3-208.**

   CONNECTING ROD BEND—MAXIMUM

   0.05 mm per 100 mm (0.0019 in. per 3.93 in.)
2. If bend is greater than maximum specification, replace the connecting rod assembly.

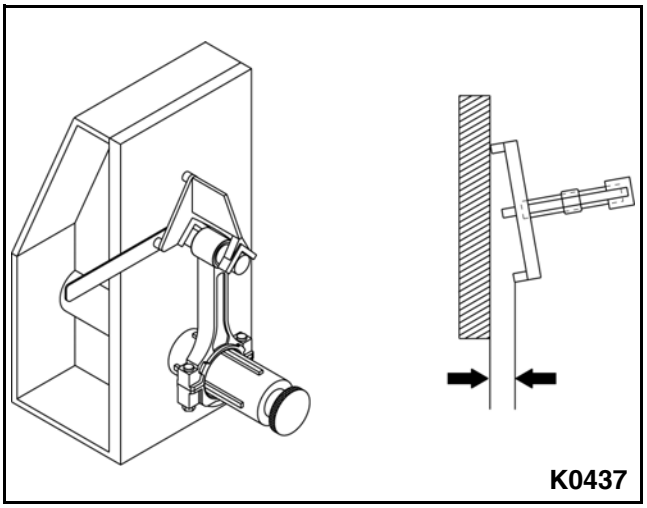


Figure 3-209

CONNECTING ROD TWIST—MAXIMUM

0.05 mm per 100 mm (0.0019 in. per 3.93 in.)

3. If twist is greater than maximum specification, replace the connecting rod assembly.

Clean Pistons

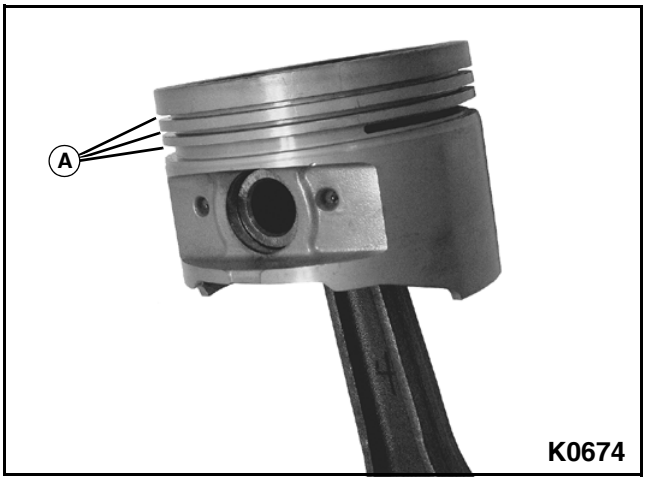


Figure 3-210

1. Clean piston ring grooves (A) using a piston ring groove cleaning tool or an old piston ring. **See Figure 3-210.**

NOTICE

When washing pistons, always use a stiff bristle brush–NOT A WIRE BRUSH–to loosen carbon residue.

DO NOT bead blast ring groove area.

2. Clean pistons by any of the following methods:
   - Immersion-solvent “D-Part.”
   - Hydra-Jet Rinse Gun.
   - Hot water with liquid detergent soap.

   If cleaning with hot water and liquid detergent, soak pistons in a 50 percent solution of liquid household detergent and hot water for 30 to 60 minutes. Use a stiff bristle brush–NOT A WIRE BRUSH–to loosen carbon residue. Dry with compressed air.

Check Piston Ring Grooves

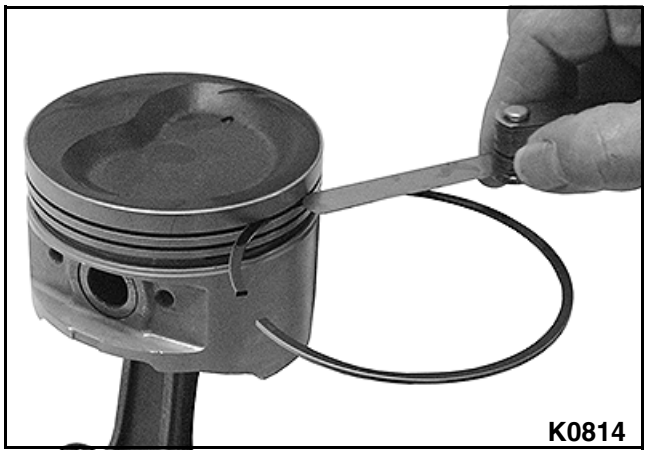


Figure 3-211

1. Inspect piston ring grooves and piston ring lands for wear. **See Figure 3-211.** If there is wear or damage, repair or replace piston as necessary.
2. Using a feeler gauge, measure the clearance between the piston ring land and piston ring.

   PISTON RING-TO-PISTON RING LAND CLEARANCE

   0.030–0.070 mm (0.0011–0.0027 in.)
3. If the clearance is not within specification, replace the piston.

Check Piston Ring Gap

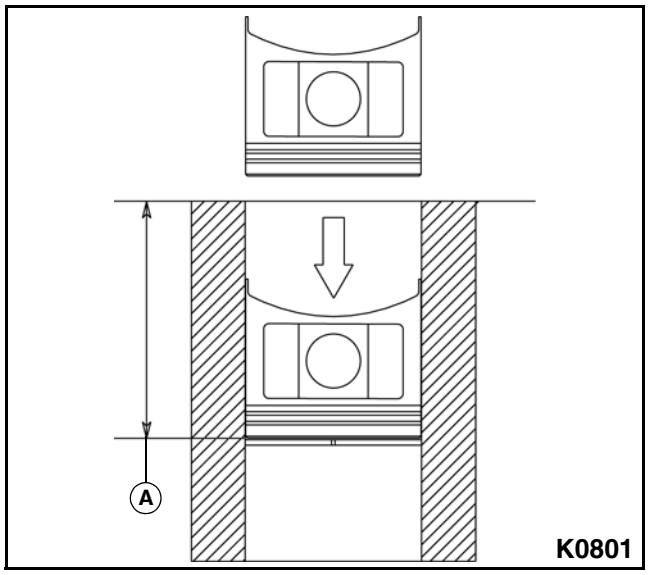


Figure 3-212

1. Insert the piston ring into the cylinder bore. Using a piston, push the piston ring a little beyond the bottom of the ring travel of the cylinder bore, 110 mm (4.33 in.) from the top of the cylinder block (A). **See Figure 3-212.**

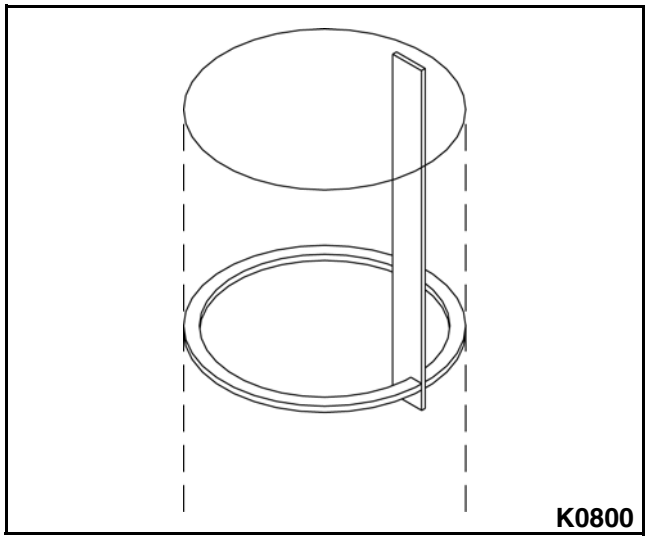


Figure 3-213

2. Using a feeler gauge, measure the piston ring end gap. **See Figure 3-213.**

PISTON RING END GAP

Standard

No.1 0.22–0.51 mm (0.0086–0.020 in.)

No.2 0.15–0.47 mm (0.0059–0.018 in.)

Oil (Side rail) 0.20–0.70 mm (0.0078-0.0027 in.)

Maximum

No.1 1.11 mm (0.043 in.)

No.2 1.07 mm (0.042 in.)

Oil (Side rail) 1.10 mm (0.043 in.)

Check Piston Pins

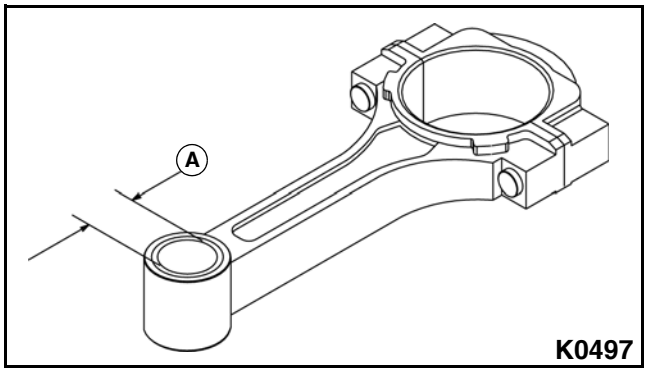


Figure 3-214

1. Check inside diameter (A) of pin bore in piston with a bore gauge. **See Figure 3-214.**

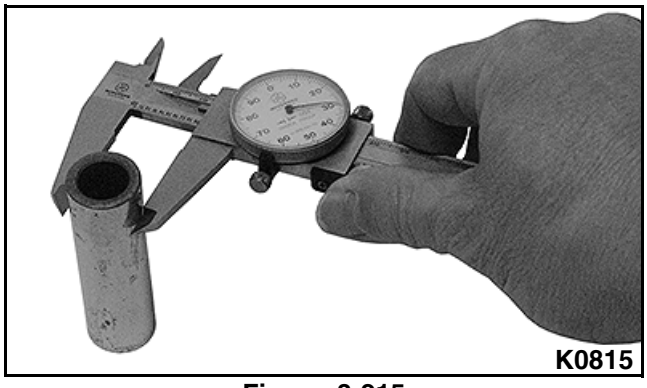


Figure 3-215

2. Using a micrometer, check piston pin diameter. **See Figure 3-215.**

PISTON PIN SPECIFICATIONS

Piston Pin Bore—Diameter

22.010–22.016 mm (0.8665–0.08667 in.)

Piston Pin—Diameter

22.003–22.006 mm (0.8662–0.8664 in.)

PISTON PIN OIL CLEARANCE

0.004–0.013 mm (0.0002–0.0005 in.)

Check Piston Skirts

NOTICE

Piston diameter is grouped into three groups. Same as cylinder bore diameter. Grouping mark is located on top of piston.

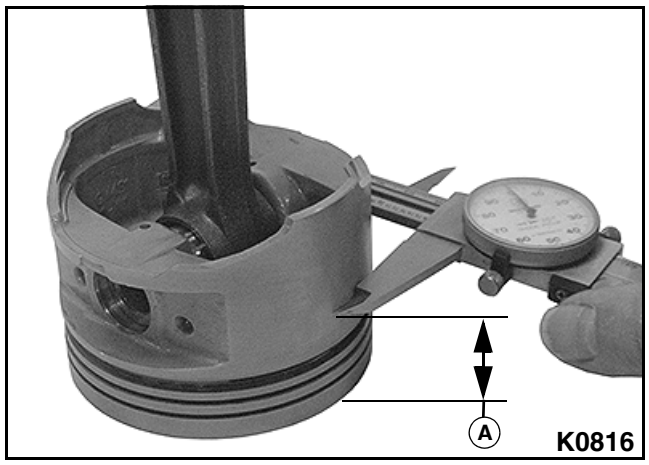


Figure 3-216

1. Using a micrometer, measure the piston diameter at plumb angles to the piston pin centerline, 24 mm (0.945 in.) from the piston head (A). **See Figure 3-216.**

PISTON SPECIFICATIONS—DIAMETER

Standard

Group 1

90.938–90.948 mm (3.5802–3.5806 in.)

Group 2

90.948–90.958 mm (3.5806–3.5810 in.)

Group 3

90.958–90.968 mm (3.5810–3.5814 in.)

Oversize Piston

91.425–91.955 mm (3.599–3.620 in.)

Cylinder Bore-to-Piston—Clearance

0.065–0.085 mm (0.0025–0.0033 in.)

2. If the clearance is not within specification, replace the piston, or re-bore all four cylinders and replace all four pistons.

Assemble Piston and Connecting Rods

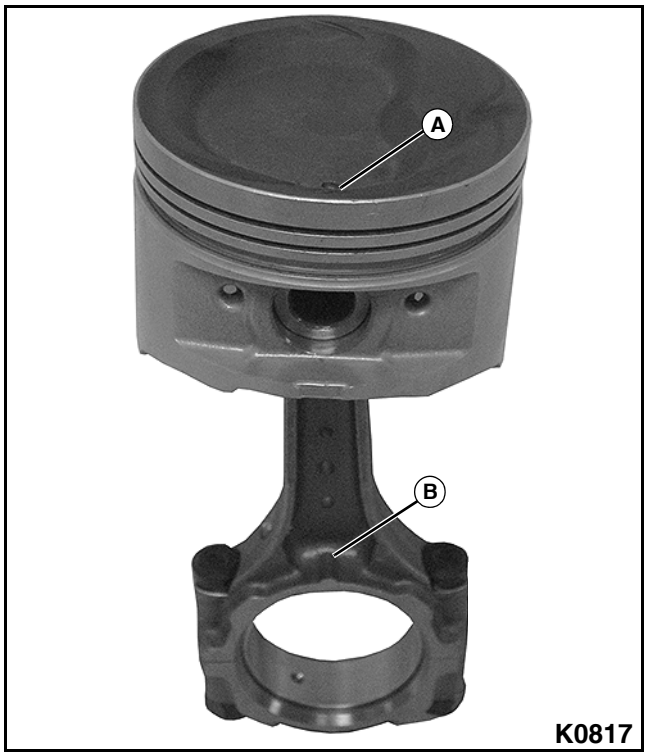


Figure 3-217

1. There are matching marks on the side of connecting rod body and cap, do not exchange with others. The protrusion on the connecting body (B) and cap should be in the same side with concave point positioned on the top of piston (A), and towards front of engine. **See Figure 3-217.**
2. Coat engine oil on the piston pin and piston hole in piston.
3. Use an appropriate press to press the piston pin into the piston at room temperature.

Install Piston Rings

1. Manually install the oil ring expander and two side rails.

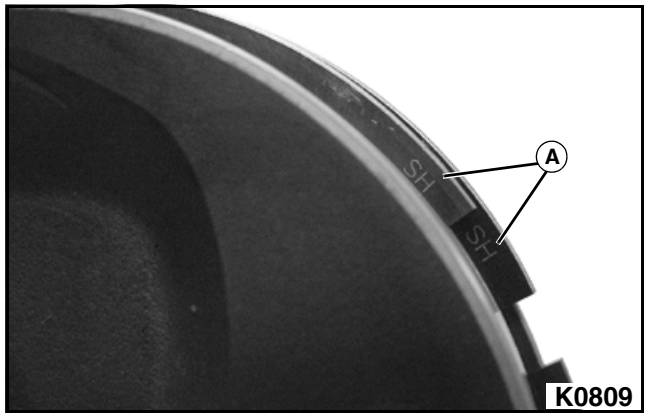
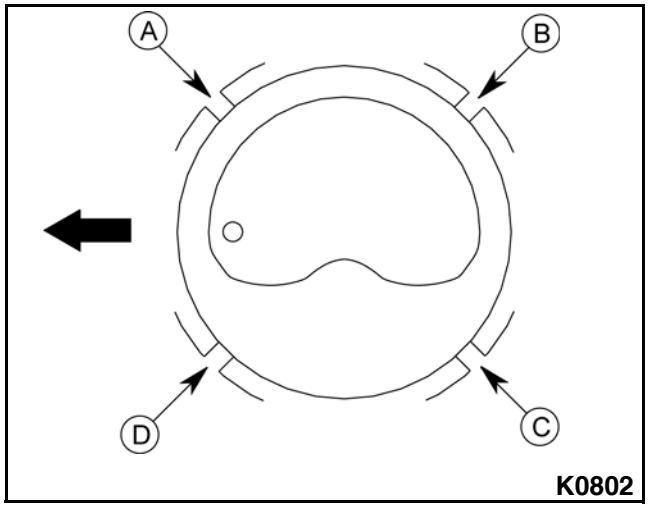


Figure 3-218

2. Use a piston ring expansion tool and install two piston rings, with the stamped marks (A) facing upward. **See Figure 3-218.**

NOTE:

Arrow points to front of engine assembly.



A) 2nd Ring
B) Upper Rail
C) 1st Ring and Oil Lining Ring
D) Lower Rail

Figure 3-219

3. Position the piston ring ends as illustrated. **See Figure 3-219.**

Install Piston and Connecting Rod Assembly

1. Coat engine oil on the cylinder bores, piston outer circumferences, and bearing surfaces.
2. Cover connecting rod bolts with vinyl tubing to prevent damage of the cylinders and the crankshaft.
3. Check piston ring joint positions.

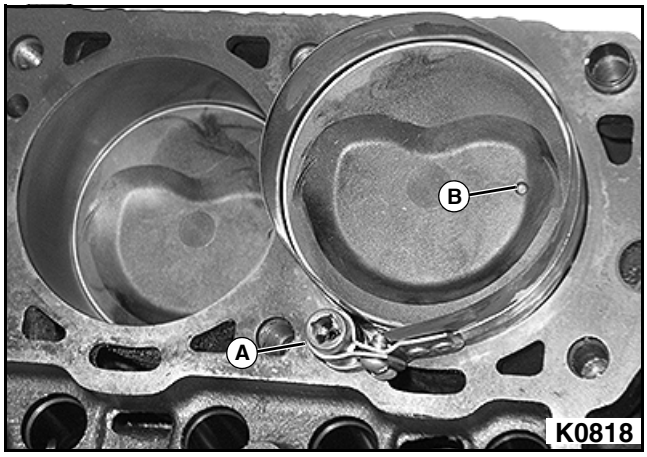


Figure 3-220

4. Using a piston ring compressor (A), with the front marks (B) facing the front side of engine, insert each piston connecting rod into the cylinder block. **See Figure 3-220.**

NOTICE

The piston and the block combination shall be the same as before disassembly.

5. Check the matching marks punched at the time of removal.

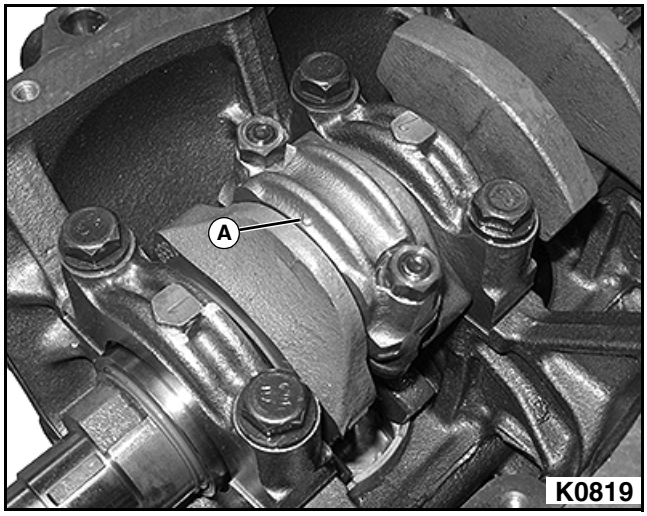


Figure 3-221

6. Place the bearing cap front mark (A) facing the front side, and install the bearing cap to the connecting rod. **See Figure 3-221.**
7. Slightly coat engine oil on the connecting rod threaded portion and nut bottom surface.
8. Alternately tighten the left and right nuts equally in several steps.

   CONNECTING ROD CAP—TORQUE

   49 N•m (36 ft.lb.)

NOTICE

Connecting rod thrust clearance can only be checked as connecting rod assemblies are installed as pairs.

9. Check the connecting rod thrust clearance. SEE PAGE: 112.

Remove Main Bearing Caps

Main bearing bore is grouped in three groups, first to fifth main bearing bore-grouping marks are on the bottom surface of the cylinder block, rear end and right side.

NOTE:

Arrow points to front of engine assembly.

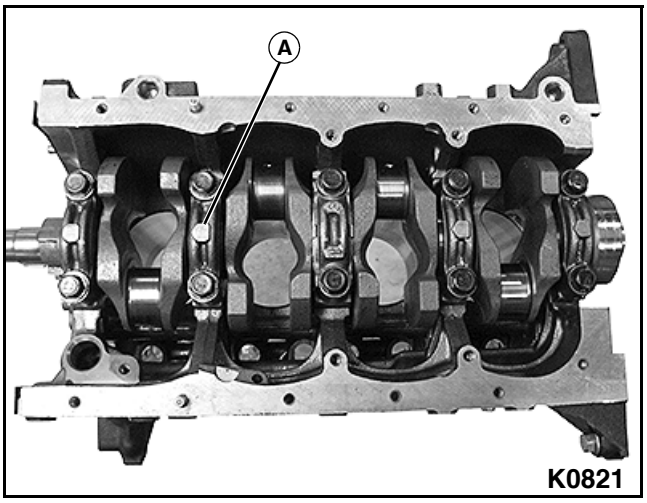


Figure 3-222

1. Check main bearing caps for arrows (A) cast in main bearing cap, and numbers stamped on cap and oil pan rail. If there are no numbers, stamp corresponding numbers on cap and oil pan rail to ensure correct placement of bearing caps during reassembly. **See Figure 3-222.**
2. Loosen two main bearing cap bolts and washers.

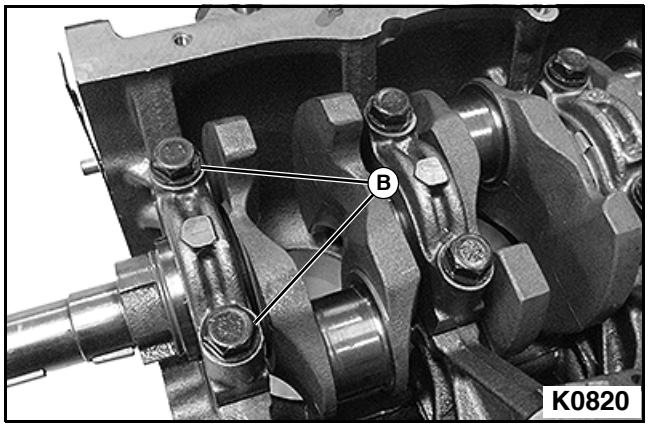


Figure 3-223

3. Remove main bearing caps by extending cap screws (B) and forcing heads of screws together. Wiggle bearing cap back and forth while applying an upward force with cap screws until free from main bearing cap support. **See Figure 3-223.**

Remove Crankshaft

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

1. Carefully raise crankshaft out of cylinder block.
2. Clean crankshaft, especially oil passages, using solvent and compressed air.
3. Place crankshaft on clean V-blocks.

Inspect Crankshaft

- Thoroughly clean and visually inspect crankshaft. Clear all restrictions from all oil passages.
- Inspect crankshaft for signs of load stress, cracks, scoring, or journal scratches. Replace crankshaft if cracks are found.
- Check each journal for excessive overheating or discoloration. If either condition exists, replace crankshaft since heat treatment has probably been destroyed.
- Inspect the keyway for evidence of cracks or wear. Replace crankshaft as necessary.
- Carefully inspect the rear hub of the crankshaft in the area of the wear sleeve contact surface for evidence of a rough or grooved condition. Any imperfections in this area will result in oil leakage. Slight ridges may be cleaned up with emery cloth or crocus cloth.
- Carefully check the crankshaft for cracks in the area of rod journal holes and at journal fillets. Replace crankshaft if any cracks are found.

Measure Crankshaft Journals and Bearing ID

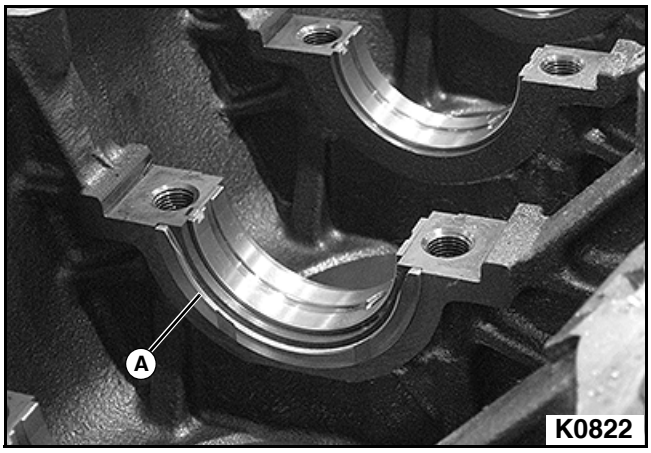


Figure 3-224

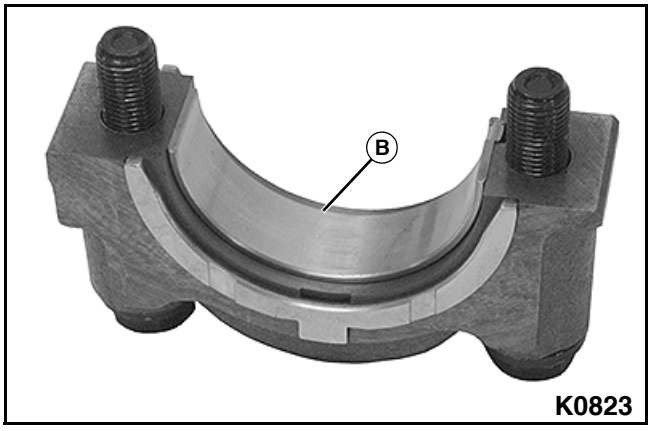


Figure 3-225

1. With crankshaft removed from cylinder block (A), assemble main bearing caps with bearing inserts (B). Be sure inserts are installed correctly.
2. Install main bearing caps to the cylinder block.
3. Tighten main bearing caps screws to specification.

   MAIN BEARING CAP BOLT—TORQUE

   79 N•m (58 ft.lb.)
4. Measure main bearing assembled ID at several points with a inside micrometer.

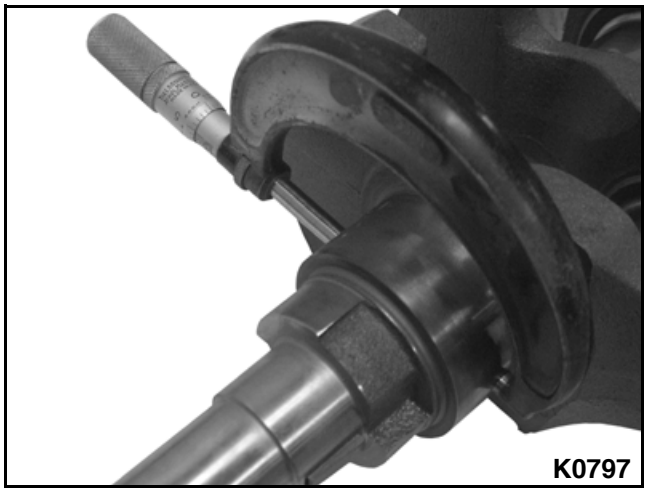


Figure 3-226: Measure Main Bearing Journal

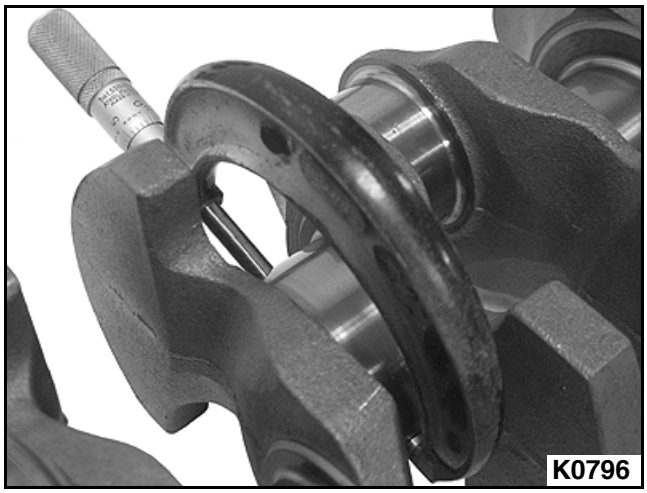


Figure 3-227: Measure Crank Pin

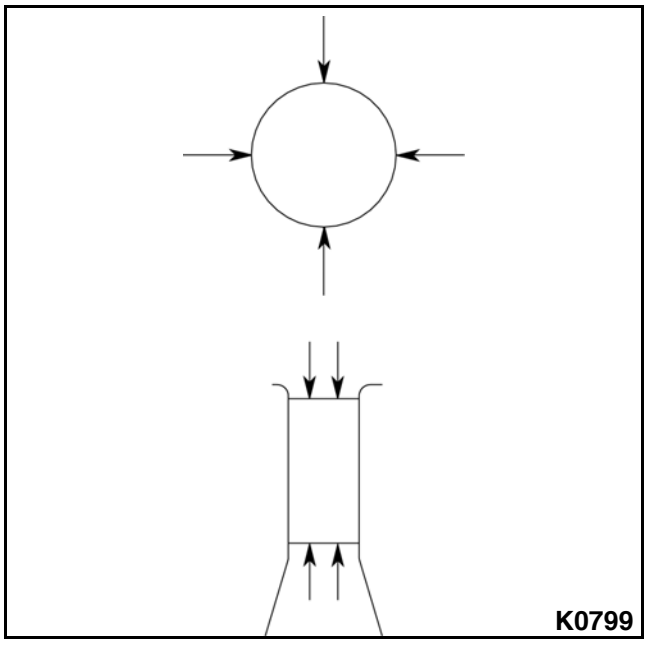


Figure 3-228

5. Using a micrometer, measure the diameter of each main journal and crank pin. **See Figures 3-226, 3-227, and 3-228.**

MAIN JOURNAL AND CRANK PIN DIAMETER

Main Journal Diameter

57.985–58.000 mm (2.282–2.283 in.)

Crank Pin Diameter

47.985–48.000 mm (1.8891–1.8897 in.)

6. If the diameter is not within specification, check the oil clearance.
7. If taper and runout is greater than the maximum specification, grind or replace the crankshaft.

MAIN JOURNAL AND CRANK PIN TAPER AND RUNOUT—MAXIMUM

0.02 mm (0.0007 in.)

8. Measure crankshaft OD and connecting rod journal OD at several points around each journal.
9. Compare measurements with specifications given.

Check Crankshaft Circle Runout

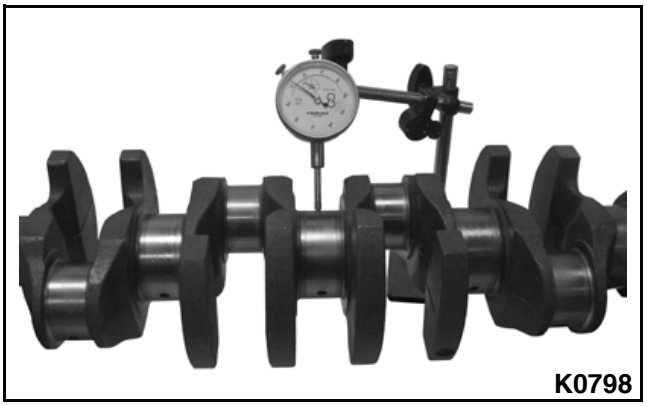


Figure 3-229

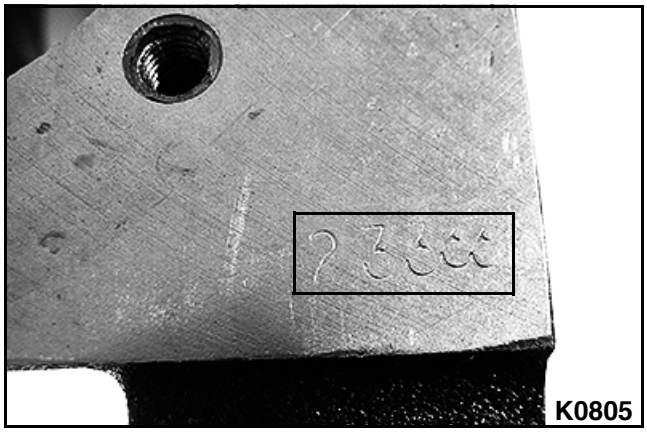
1. Inspect the crankshaft for circle runout.
2. Place the crankshaft on V-blocks. Using a dial indicator, measure the circle runout at the center main journal. **See Figure 3-229.**

CRANKSHAFT CIRCLE RUNOUT—MAXIMUM

0.06 mm (0.0023 in.)

3. If the circle runout is greater than maximum specification, replace the crankshaft.

Remove Main Bearings from Main Caps and Block



NOTE:

Main bearing bore is grouped in three groups. First to fifth main bearing bore-grouping marks are on the bottom surface of the cylinder block, rear end and right side. Main bearings are divided into three groups also, matching the main bearing bore group.

Main bearing caps can not interchange; direction can not be reversed. There are arrows cast on top of the main cap, also sequence numbers on top of caps.

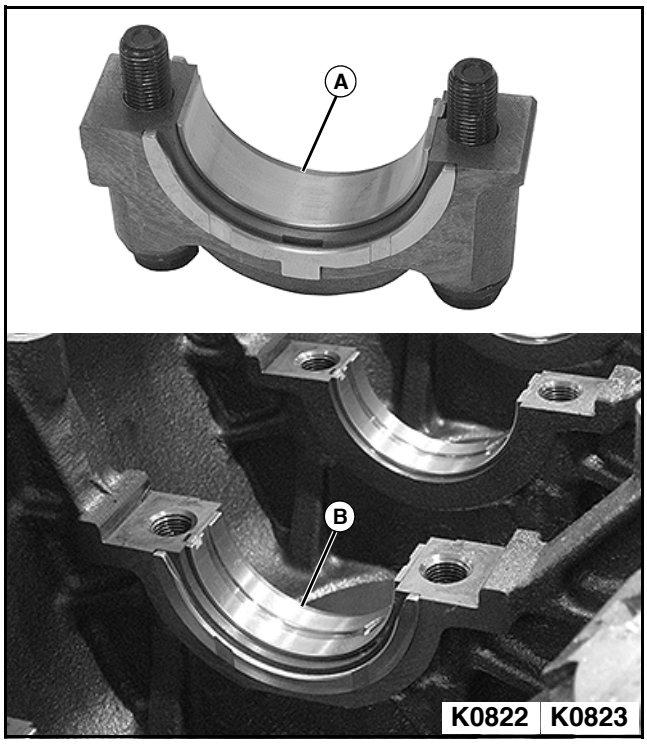


Figure 3-230

1. If main bearing inserts are to be replaced, remove inserts (A) from main bearing caps. Otherwise, leave bearing inserts in caps until assembled ID has been measured. See “Check Bearing Oil Clearance” on page 112.
2. If main bearing inserts are to be replaced, remove inserts (B) from cylinder block. Otherwise, leave bearing inserts in block until assembled ID has been measured.

Check Cylinder Block Deck for Warpage

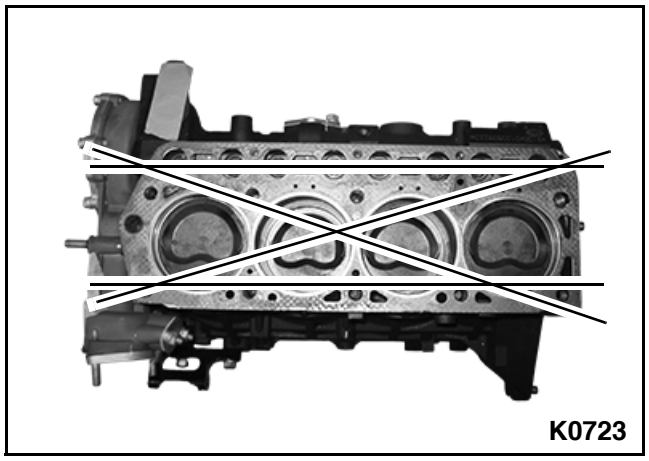


Figure 3-231

1. Check cylinder block deck for warpage. Using a precision straight edge and feeler gauge, check the cylinder block deck surface connecting the cylinder head for warpage. **See Figure 3-231.**

   CYLINDER DECK WARPAGE—MAXIMUM

   0.05 mm (0.002 in)
2. If deck surface warpage is greater than the maximum specification, surface grind the deck with plane grinder toothful or replace the cylinder block.

NOTICE

If the limit is exceeded, regrind the top surface of the cylinder block or replace the cylinder block.

Cylinder Bore Visual Inspection

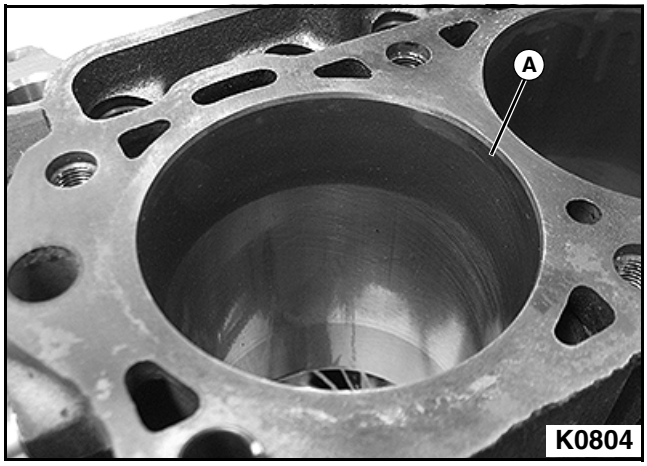


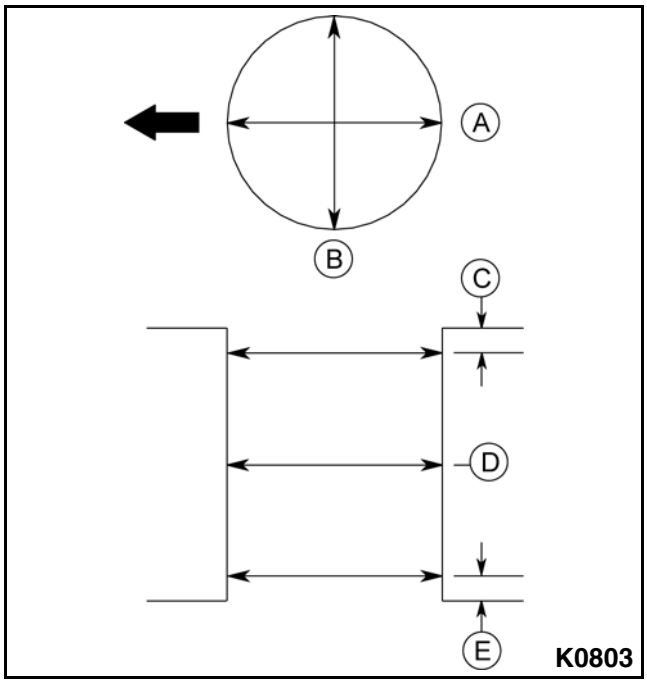
Figure 3-232

- Check the cylinder bore (A) for surface defects. If any excessive damage or cracks are found rebore cylinder or replace cylinder block. **See Figure 3-232.**
- If there are deep score marks lengthwise on the cylinder bores, all four cylinders will need to be rebored.

Check Cylinder Taper

NOTE:

Arrow points to front of engine assembly.



A) Axial Direction
B) Thrust Direction
C) 10 mm
D) Middle
E) 10 mm

Figure 3-233

1. Using a dial bore gauge, measure the cylinder bore diameter at positions A, B and C in the thrust and axial directions. **See Figure 3-233.**

   STANDARD CYLINDER BORE DIAMETER

   Standard

   Group 1

   91.000–91.010 mm (3.5820–3.5830 in.)

   Group 2

   91.010–91.020 mm (3.5830–3.5834 in.)

   Group 3

   91.020–91.030 mm (3.5834–3.5838 in.)

   Maximum Diameter

   91.23 mm (3.591 in.)
2. If the cylinder bore diameter is greater than maximum specification, rebore all four cylinders, if necessary, replace the cylinder block.

   OVERSIZE CYLINDER BORE DIAMETER

   +0.50 mm Piston Diameter

   91.50–92.24 mm (3.602–3.631 in.)

   Maximum Diameter

   92.24 mm (3.631 in.)
3. If diameter is greater than this maximum specification, replace cylinder block.

Disassemble Cylinder Block

1. Remove all water galley plugs from cylinder block.
2. Remove all oil galley plugs from cylinder block.

Cylinder Block Cleaning and Inspection

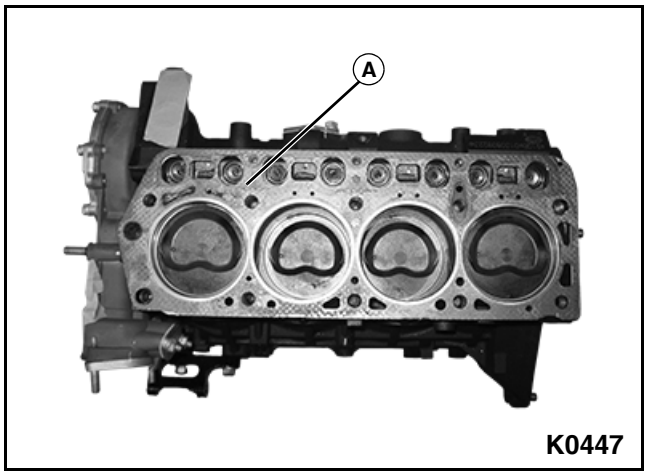


Figure 3-234

1. Use a scraper and remove any gasket material or sealant remaining on the cylinder block (A). **See Figure 3-234.**
2. Clean each part of the cylinder block with a solvent.

Install Main Bearings

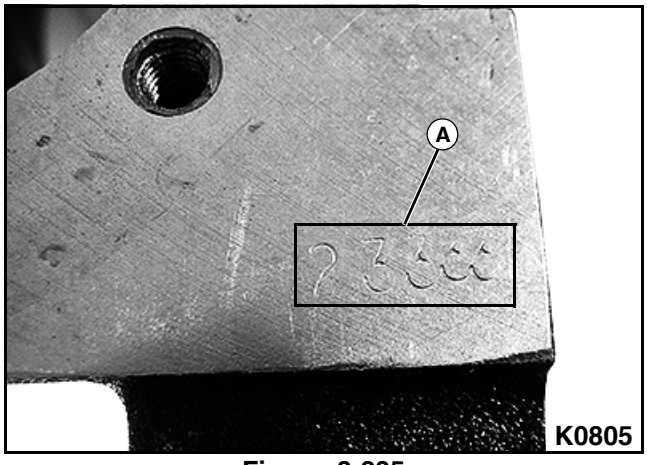


Figure 3-235

Main bearing bore is grouped in 3 groups. First to fifth main bearing bore-grouping marks are on the bottom surface of the cylinder block, rear end and right side (A). Main bearings are divided into 3 groups also, matching main bearing bore group. **See Figure 3-235.**

NOTICE
Keep the bearing outer surfaces (in contact with the cylinder block or bearing caps) free from oil.

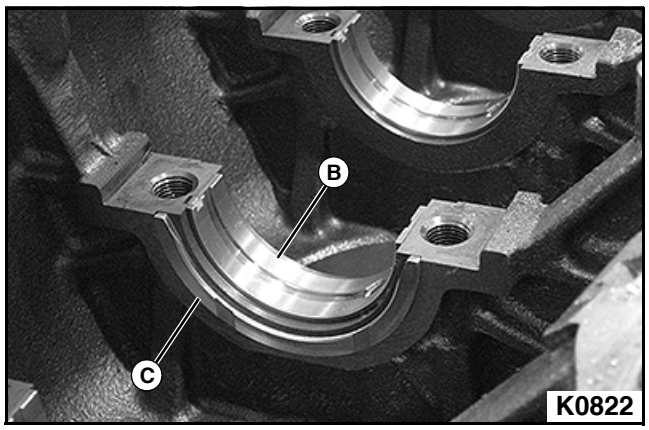


Figure 3-236

1. Install the upper bearing (B) which has an oil groove on the whole periphery, with the cylinder block oil hole and lock groove as the guide. **See Figure 3-236.**
2. Install the upper thrust washers (C) to the No. 3 journal supporting portion, with the oil grooves facing outward.

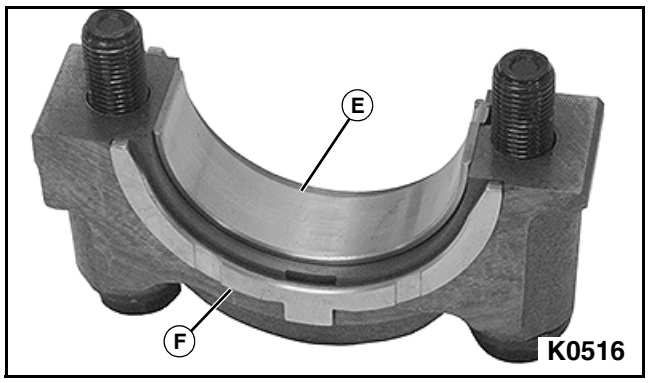


Figure 3-237

3. Install the lower bearing (E) by fitting with the bearing cap lock groove. **See Figure 3-237.**
4. Install the lower thrust washers (F) to the No. 3 bearing cap, with the oil grooves facing outward.

NOTICE
Coat engine oil on the rear face of the thrust washer to prevent falling.

Install Crankshaft

⚠ CAUTION

Damaging crankshaft and flywheel can cause personal injury!

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from the engine. Always observe and use precautions when installing flywheel.

1. Coat engine oil on the upper bearings and install the crankshaft.

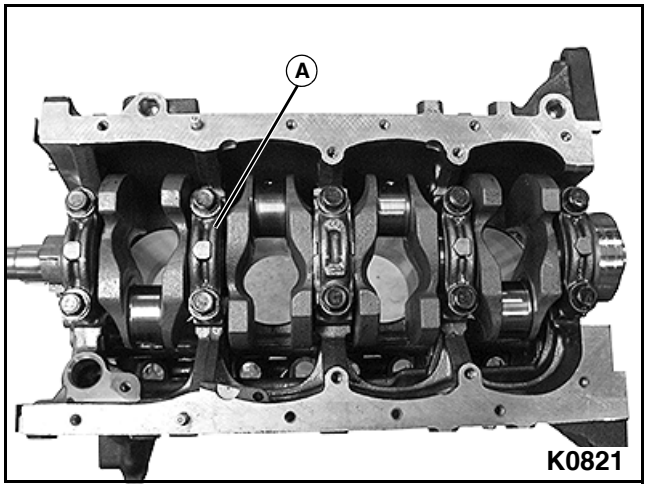


Figure 3-238

2. Coat engine oil on the lower bearing surfaces. Install the bearing caps (A) to the corresponding code positions, with the front marks on the front side.**See Figure 3-238.**
3. Coat engine oil thinly on the bearing cap bolt threads and seat surfaces. Loosely install bearing cap bolts.

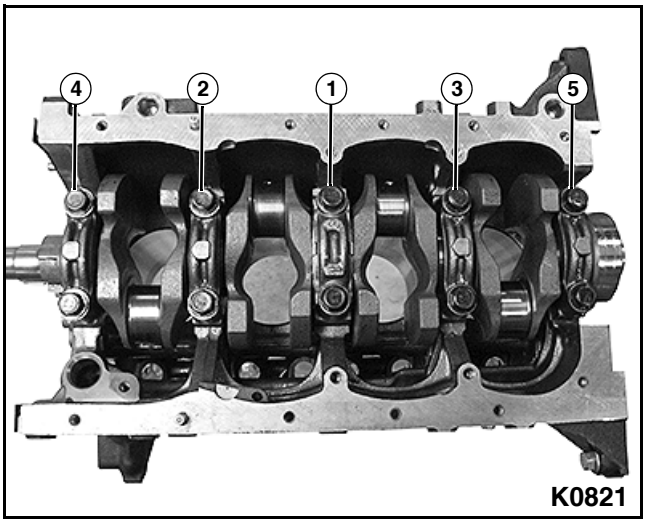


Figure 3-239

4. Evenly tighten ten bearing cap bolts on the left and right sides in the illustrated order little by little in several steps. **See Figure 3-238.**

   MAIN BEARING CAP BOLT—TORQUE

   8.00 kg-m (58 ft.lb.)
5. After tightening the bearing caps, check that the crankshaft rotates smoothly.
6. Inspect the crankshaft thrust clearance.

Complete Final Assembly

Install all fittings and plugs to engine as removed. Install all external components to engine. See “Engine Assembly” on page 36.

4.0 SPECIAL TOOLS

TOOLS AND EQUIPMENT

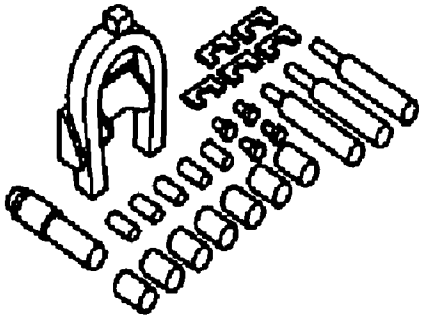
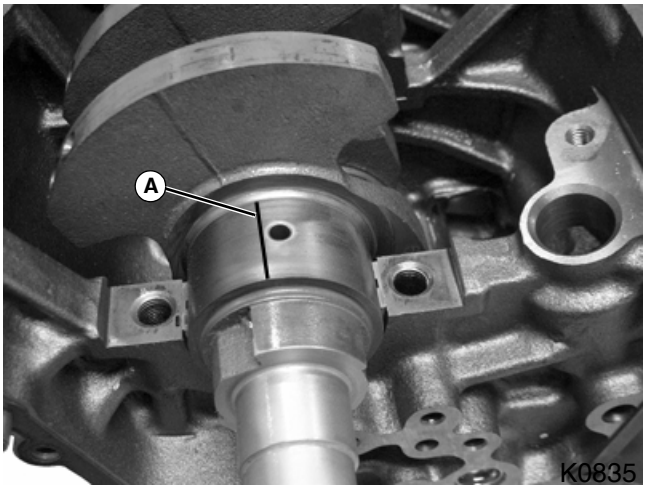
Special tools are listed and illustrated throughout this section with a complete listing at the end of the section.

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:

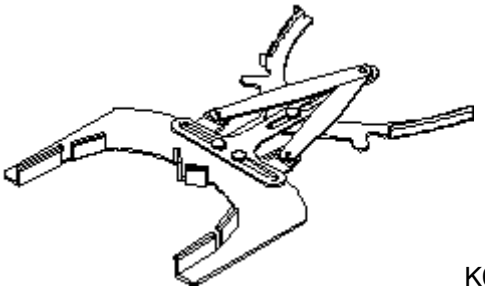
- Approved eye protection and safety gloves.
- A clean, well-lit work area.
- A suitable parts cleaning tank.
- A compressed air supply.
- Trays or storage containers to keep parts and fasteners organized.
- An adequate set of hand tools.
- Approved engine repair stand.
- An approved engine lifting device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

 K0825	Vibration Dampener Puller
 K0826	Valve Spring Compressor

 K0833	Cylinder Bore Gauge
 K0834	Valve Spring Tester
 K0627	Ridge Reamer

 K0828	Universal Seal Installer Set
 K0684	Piston Pin Remover Set
 K0835	Plastic Clearance Checking Strips (A)

 K0829	Micrometer Set
 K0830	Dial Indicator Set
 K0831	Piston Ring Compressor

 K0832	Camshaft Bearing Remover / Installer Set
 K0836	Piston Ring Groove Cleaner

NOTES

KOHLER.
Power Systems

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