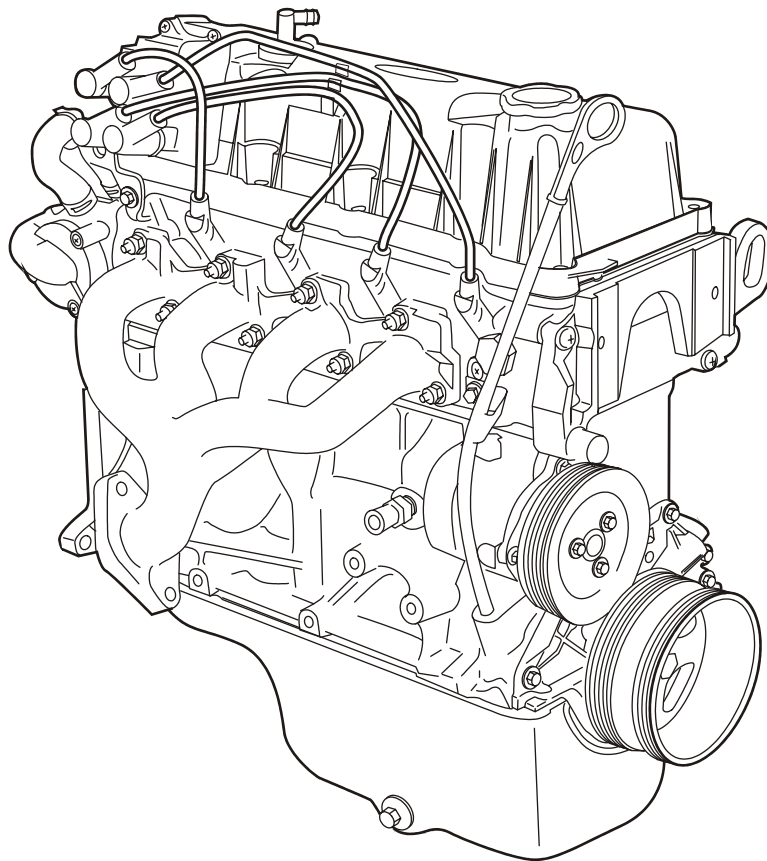




TSG-416

1.6 LITER

INDUSTRIAL ENGINE SERVICE MANUAL



PRELIMINARY

FPP-194-355

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GENERAL INFORMATION

Introduction

This section covers various engine tests, adjustments, service procedures and cleaning/inspection procedures. Engine assembly and service specifications appear at the end of the Section 02.

For engine disassembly, assembly, installation, adjustment procedures and specifications, refer to Section 02.

To maintain the required performance level, the fuel system, ignition system and engine must be kept in good operating condition and meet recommended adjustment specifications.

Before replacing damaged or worn engine components such as the crankshaft, cylinder head, valve guide, valves, camshaft or cylinder block, make sure part(s) is not serviceable.



WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE, DO NOT OPERATE THE ENGINE UNTIL THE FAN BLADE HAS FIRST BEEN EXAMINED FOR POSSIBLE CRACKS OR SEPARATION.

CAUTION: Use of abrasive grinding discs to remove gasket material from the engine sealing surfaces during repair procedures can contribute to engine damage and wear. Airborne debris and abrasive grit from the grinding disc may enter the engine through exposed cavities causing premature wear and eventual engine damage.

Ford Power Products does not recommend using abrasive grinding discs to remove engine gasket material. Use manual gasket scrapers for removing gasket material from the engine sealing surfaces.

Take added care to prevent scratching or gouging aluminum sealing surfaces.

Safety Notice

There are numerous variations in procedures, techniques, tools and parts for servicing equipment, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this Manual must first establish that neither personal safety nor equipment integrity are compromised by the choice of methods, tools or parts.

Notes, Cautions, and Warnings

As you read through the procedures, you will come across NOTES, CAUTIONS, and WARNINGS. Each one is there for a specific purpose. NOTES gives you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the equipment. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on the equipment.



GENERAL WARNINGS:

TO HELP AVOID INJURY:

- **ALWAYS WEAR SAFETY GLASSES FOR EYE PROTECTION.**
- **USE SAFETY STANDS WHENEVER A PROCEDURE REQUIRES YOU TO BE UNDER THE EQUIPMENT.**
- **BE SURE THAT THE IGNITION SWITCH IS ALWAYS IN THE OFF POSITION, UNLESS OTHERWISE REQUIRED BY THE PROCEDURE.**
- **SET THE PARKING BRAKE (IF EQUIPPED) WHEN WORKING ON THE EQUIPMENT. IF YOU HAVE AN AUTOMATIC TRANSMISSION, SET IT IN PARK (ENGINE OFF) OR NEUTRAL (ENGINE ON) UNLESS INSTRUCTED OTHERWISE FOR A SPECIFIC OPERATION. PLACE WOOD BLOCKS (4" X 4" OR LARGER) TO THE FRONT AND REAR SURFACES OF THE TIRES TO PROVIDE FURTHER RESTRAINT FROM INADVERTENT EQUIPMENT MOVEMENT.**
- **OPERATE THE ENGINE ONLY IN A WELL VENTILATED AREA TO AVOID THE DANGER OF CARBON MONOXIDE.**
- **KEEP YOURSELF AND YOUR CLOTHING AWAY FROM MOVING PARTS WHEN THE ENGINE IS RUNNING, ESPECIALLY THE FAN BELTS.**
- **TO PREVENT SERIOUS BURNS, AVOID CONTACT WITH HOT METAL PARTS SUCH AS THE RADIATOR, EXHAUST MANIFOLD, TAIL PIPE, CATALYTIC CONVERTER AND MUFFLER.**
- **DO NOT SMOKE WHILE WORKING ON THE EQUIPMENT.**
- **ALWAYS REMOVE RINGS, WATCHES, LOOSE HANGING JEWELRY, AND LOOSE CLOTHING BEFORE BEGINNING TO WORK ON THE EQUIPMENT. TIE LONG HAIR SECURELY BEHIND THE HEAD.**
- **KEEP HANDS AND OTHER OBJECTS CLEAR OF THE RADIATOR FAN BLADES. ELECTRIC COOLING FANS CAN START TO OPERATE AT ANY TIME BY AN INCREASE IN UNDERHOOD TEMPERATURES, EVEN THOUGH THE IGNITION IS IN THE OFF POSITION. THEREFORE, CARE SHOULD BE TAKEN TO ENSURE THAT THE ELECTRIC COOLING FAN IS COMPLETELY DISCONNECTED WHEN WORKING UNDER THE HOOD.**

Battery Handling and Charging

The handling and correct use of lead acid batteries is not as hazardous provided that sensible precautions are observed and that operatives have been trained in their use and are adequately supervised.

It is important that all labelling on the battery is carefully read, understood and complied with. The format of the following symbols and labels is common to most brands of lead acid battery.



	Explosive gases		Read relevant instructions
	Eye protection must be WORN.		Keep away from children
	No smoking or naked flames.		Do not dispose of as household waste.
	Corrosive acid		Recycle (via recognized disposal system).
	Flush eyes immediately when contacted with acid		Electrical current may cause injury to personnel
	Caution/important notice.		

NOTE: Observe all manufacturers' instructions when using charging equipment.

CAUTION: Batteries should not be charged in the vehicle or equipment. May damage electrical components.

Forward

This book contains operating and maintenance instructions for the engine(s) listed on the title page.

The life of your engine unit and the delivery of the high performance built into it will depend on the care it receives throughout its life. It is the operator's responsibility to ensure that the engine is correctly operated and that the maintenance operations outlined in this book are carried out regularly after the specified hours of operation have been reached. We consider it to be in your interests to enlist the aid of an authorized Ford Power Products Distributor not only when repairs are required but also for regular maintenance. Distributors are listed at the back of this manual.

Regular maintenance will result in minimal operating costs.

Engines manufactured by Ford Motor Company are available through Ford Power Products Distributors. When in need of parts or service, contact your local Authorized Distributor. In overseas territories, in the event of difficulties, communicate directly with the supervising Ford affiliated Company in your area whose address appears at the end of this book.

Where the terms "Right" or "Left" occur in this publication, they refer to the respective sides of the engine when viewed from the rear or flywheel end.

Pistons and valves are numbered from the front or timing cover end of the engine commencing at No. 1.


You may find that your engine assembly includes optional equipment not specifically covered in the following text. Nevertheless, the maintenance procedures outlined in this book still apply to your engine.

Engine Identification

Because Ford Power Products markets such a wide range of industrial engines – manufactured both in the U.S. and overseas – it is important that you have as complete identification of the engine as possible in order to provide the correct replacement parts. New engines being shipped include a standard parts listing describing the parts which does not tell the owner the part number. It remains a distributor function to identify the part number. The key to identifying the engine is the identification decal mounted on the engine rocker cover. That decal provides not only the engine serial number, but also the exact model or type, options and S.O. (Special Order). The combination of that data permits you to isolate the precise engine, build level and customer so you can determine the correct replacement parts.

U.S.A. Engine Identification Decal


An identification Decal is affixed to the valve cover of the engine. The decal contains the engine serial number which identifies this unit from all others. Use all numbers when seeking information or ordering replacement parts for this engine.

 Power Products	Serial Number: 01-01-000123	
	Model Number: TSG-416L- 6005-BA	
Base Engine Code: 2U1L-6005-BA	Build Date: 01-01-2003	
Distributor S.O. Number: 1.6L ENGINE		

For a handy reference, this information is recorded on your Ford Power Products Operations Engine Registration copy (Form #194-103-D).

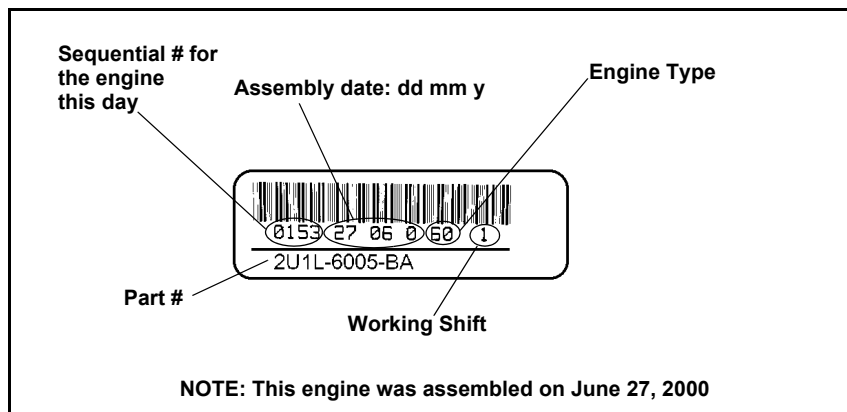
U.S.A. Emission Decal

The emission decal is affixed to the valve cover on all certified engines over 25 horsepower distributed in the State of California with an engine build date after January 1st, 2001. The decal identifies that the engine is compliant with California's Air Resources Board's (ARB) Large Spark Ignited (LSI) Engine Regulations. Use all numbers when seeking information or ordering replacement parts for this engine.

		Y U 1 L - 9 C 4 8 5 - B A
IMPORTANT ENGINE INFORMATION		
THIS ENGINE IS EQUIPPED WITH ELECTRONIC ENGINE CONTROL SYSTEMS. ENGINE IDLE SPEED, IDLE MIXTURE, AND IGNITION TIMING ARE NOT ADJUSTABLE. SEE OWNERS MANUAL FOR MORE INFORMATION.		
THIS ENGINE IS CERTIFIED TO THE 2002 CALIFORNIA REGULATIONS FOR OFF-ROAD LARGE SPARK-IGNITION ENGINES. THIS ENGINE IS CERTIFIED TO OPERATE ON GASOLINE AND LIQUID PETROLEUM GAS.		
CATALYST	1FMXB02.5GAA 1.6L TWC HO2S SFI SPARK PLUG: AWSF32EE GAP:.042-.046	

Engine Build Identification Label

The TSG-416 Engine Build Identification Label is located on the front side of the valve cover near the oil level indicator. This label contains assembly information as shown below.



European Service Identification plate

This plate is fixed to the engine in a prominent position. Panels 1 to 11 on the plate shown to the right, refer to various engine details as listed below:

1. Engine model identification.
2. Engine capacity.
3. **Serial No:** This identifies the engine as supplied by Power Products Engineering.

Date: The two letters following the serial No. indicate the year and month in which the specified build components were assembled - refer to the chart below:

NOTE: These markings should not be confused with any that may be stamped or etched into the crankcase of the basic engine.

The diagram shows a rectangular identification plate with the following layout:

- Top left: Ford logo and "Industrial Power Products"
- Top right: "MODEL" followed by a box containing the number "1".
- Second row: "CAPACITY" (box 2), "FUEL SYS" (boxes 8, 9, 10), "R.P.M." (box 5), "H'D" (box 6), "BLOCK" (box 7).
- Third row: "SER No / DATE" (box 3) and "BUILD No" (box 4).
- Bottom section: "SPECIAL EQUIPMENT" followed by a box containing the number "11".
- Bottom right corner: "FPP01102"

YEAR		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1997	U	B	R	A	G	C	K	D	E	L	Y	S	T
1998	V	J	U	M	P	B	R	A	G	C	K	D	E
1999	W	L	Y	S	T	J	U	M	P	B	R	A	G
2000	X	C	K	D	E	L	Y	S	T	J	U	M	P
2001	Y	B	R	A	G	C	K	D	E	L	Y	S	T
2002	Z	J	U	M	P	B	R	A	G	C	K	D	E
2003	A	L	Y	S	T	J	U	M	P	B	R	A	G
2004	B	C	K	D	E	L	Y	S	T	J	U	M	P
2005	C	B	R	A	G	C	K	D	E	L	Y	S	T
2006	D	J	U	M	P	B	R	A	G	C	K	D	E

NOTE: The letters I, O and Q are not used in the year column. The letter representing the month repeats every five years.

4. Selective Build Number indicates the complete specification. The digit to the extreme right hand side is the build chart issue number.
5. Engine operating rpm. An asterisk denotes speed set by customer.
6. Not applicable.
7. Not applicable.
8. Applicable to diesel engines only.
9. Applicable to diesel engines only.
10. Applicable to diesel engines only.
11. This box is provided for Equipment Manufacturers' use when extra equipment is fitted outside of the Ford Motor Company. Reference should be made to the Equipment Manufacturer for any information or parts required.

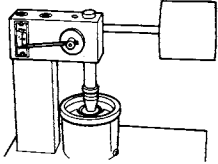
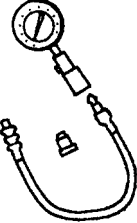
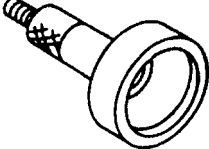
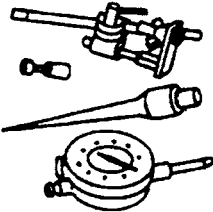
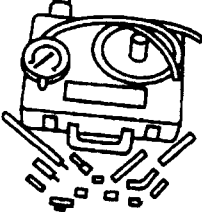



Parts and Service

Replacement parts can be obtained through your local Ford Power Products Distributors listed in the back portion of this manual. They also may be found in the yellow pages under "Engines" or contact Ford Power Products.

Ford Power Products Distributors are equipped to perform major and minor repairs. They are anxious to see that all of your maintenance and service needs are quickly and courteously completed.

DIAGNOSIS AND TESTING

Special Tools

 <p>FPP10023</p>	<p>Commercially Available Leakdown Tester</p>	 <p>FPP10024</p>	<p>Compression Tester 014-00707 or Equivalent</p>
 <p>FPP10025</p>	<p>Cup Shaped Adapter TOOL-6565-AB or Equivalent</p>	 <p>FPP10026</p>	<p>Dial Indicator with Bracketry TOOL-4201-C or Equivalent</p>
 <p>FPP10027</p>	<p>Engine Cylinder Leak Detection/Air Pressurization Kit 014-00705 or Equivalent</p>	 <p>FPP10028</p>	<p>Engine Oil Pressure Gauge T73L-6600-A</p>
 <p>FPP10029</p>	<p>12 Volt Master UV Diagnostic Inspection Kit 164-R0756 or Equivalent</p>	 <p>FPP10030</p>	<p>Vacuum/Pressure Tester 164- R0253 or Equivalent</p>

Special Service Tools called for by the procedures can be obtained by calling:
1-800-ROTUNDA (1-800-768-8632).

Inspection and Verification

1. Verify the customer concern by operating the engine to duplicate the condition.
2. Visually inspect for obvious signs of mechanical and electrical damage:
 - Engine coolant leaks.
 - Engine oil leaks.
 - Fuel leaks.
 - Damaged or severely worn pads.
 - Loose mounting bolts, studs, and nuts.
3. If the inspection reveals obvious concerns that can be readily identified, repair as required.
4. If the concerns remain after the inspection, determine the symptoms and go to the symptom chart.

Symptom Chart

Condition	Possible Source	Action
Difficult Starting	Damaged starting system.	Refer to Section 07.
	Damaged charging system/battery.	Refer to Section 06.
	Burnt valve.	Replace valve.
	Worn piston.	Replace piston and pin.
	Worn piston rings or worn cylinder.	Repair or replace cylinder blocks.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Damaged fuel system.	Refer to Section 04.
	Damaged ignition system.	Refer to Section 03.
	Damaged hydraulic tappet or hydraulic lash adjuster.	Replace tappet or lash adjuster.
Poor Idling	Damaged hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Improper valve-to-valve seat contact.	Replace valve or valve seat.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Malfunctioning or damaged fuel system.	Refer to Section 04 of this manual.
	Malfunctioning or damaged ignition system.	Refer to Section 03 of this manual.
	Malfunctioning or damaged IAC motor or system.	Refer to Section 03 of this manual.
Abnormal combustion	Damaged hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Burnt or sticking valve.	Repair or replace valve.
	Weak or broken valve spring	Replace valve spring
	Carbon accumulation in combustion chamber.	Eliminate carbon buildup.
	Malfunctioning or damaged fuel system	Refer to Section 04 of this manual.
	Malfunctioning or damaged ignition system.	Refer to Section 03 of this manual.
Excessive Oil Consumption	Worn piston ring groove.	Replace piston and pin.
	Sticking piston rings.	Repair or replace piston rings.
	Worn piston or cylinders.	Repair or replace piston or cylinder blocks.
	Worn valve stem seal.	Replace valve stem seal.
	Worn valve stem or valve guide.	Replace valve stem and guide.
	Leaking oil.	Repair oil leakage.

TSG-416 GENERAL INFORMATION

Condition	Possible Source	Action
Engine Noise	Excessive main bearing oil clearance.	Adjust clearance or replace main bearing.
	Seized or heat damaged main bearing.	Replace main bearing.
	Excessive crankshaft end play.	Replace crankshaft thrust main bearing.
	Excessive connecting rod bearing oil clearance.	Replace connecting rod.
	Heat damaged connecting rod bearing.	Replace connecting rod bearing.
	Damaged connecting rod bushing.	Replace connecting rod bushing.
	Worn cylinder.	Repair or replace cylinder blocks.
	Worn piston or piston pin.	Replace piston or piston pin.
	Damaged piston rings.	Replace piston rings.
	Bent connecting rod.	Replace connecting rod.
	Malfunctioning hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Excessive hydraulic lash adjuster or hydraulic lash adjuster clearance.	Adjust clearance or replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Broken valve spring.	Replace valve spring.
	Excessive valve guide clearance.	Repair clearance or replace valve guide/stem.
	Malfunctioning or damaged cooling system.	Refer to Section 05.
	Malfunctioning or damaged fuel system.	Refer to Section 04.
	Leaking exhaust system.	Repair exhaust leakage.
	Improper drive belt tension.	Refer to Section 05.
	Malfunctioning generator bearing.	Refer to Section 06 for diagnosis and testing of the generator.
	Loose timing chain/belt.	Adjust or replace timing chain/belt.
	Damaged timing belt tensioner.	Replace timing belt tensioner.
	Malfunctioning water pump bearing.	Replace water pump.
Insufficient Power	Malfunctioning hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Compression leakage at valve seat.	Repair or replace valve, valve seat or cylinder head.
	Seized valve stem.	Replace valve stem.
	Weak or broken valve spring.	Replace valve spring.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Cracked or distorted cylinder head.	Replace cylinder head.
	Damaged, worn or sticking piston ring(s).	Repair or replace piston ring(s).
	Worn or damaged piston.	Replace piston.
	Malfunctioning or damaged fuel system.	Refer to Section 04.
	Malfunctioning or damaged ignition system.	Refer to Section 03.
	Damaged or plugged exhaust system.	Repair or replace exhaust system.

Engine Oil Leaks

NOTE: When diagnosing engine oil leaks, the source and location of the leak must be positively identified prior to service.

Prior to performing this procedure, clean the cylinder block, cylinder heads, valve covers, oil pan and flywheel with a suitable solvent to remove all traces of oil.

Fluorescent Oil Additive Method

Use the 12 Volt Master UV Diagnostic Inspection Kit to perform the following procedure for oil leak diagnosis.

1. Clean the engine with a suitable solvent to remove all traces of oil.
2. Drain engine oil crankcase and refill with recommended oil, premixed with Diesel Engine Oil Dye 164-R3705 meeting Ford specification ESE-M9C103-B1 or equivalent. Use a minimum 14.8 ml (0.5 ounce) to a maximum 29.6 ml (1 ounce) of fluorescent additive to all engines. If the oil is not premixed, fluorescent additive must first be added to crankcase.
3. Run the engine for 15 minutes. Stop the engine and inspect all seal and gasket areas for leaks using the 12 Volt Master UV diagnostic Inspection Kit. A clear bright yellow or orange area will identify the leak. For extremely small leaks, several hours may be required for the leak to appear.
4. If necessary, pressurize the main oil gallery system to locate leaks due to improperly sealed, loose or cocked plugs.
5. Repair all leaks as required.

Pressure Method

The crankcase can be pressurized to locate oil leaks. The following materials are required to fabricate the tool to be used:

- air supply and air hose
- air pressure gauge that registers pressure in 4 kPa (1 psi) increments
- air line shutoff valve
- appropriate fittings to attach the above parts to oil fill, PCV grommet hole and crankcase ventilation tube
- appropriate plugs to seal any openings leading to the crankcase
- a solution of liquid detergent and water to be applied with a suitable applicator such as a squirt bottle or brush

Fabricate the air supply hose to include the air line shutoff valve and the appropriate adapter to permit the air to enter the engine through the crankcase ventilation tube. Fabricate the air pressure gauge to a suitable adapter for installation on the engine at the oil filler opening.

Testing Procedure

- Open the air supply valve until the pressure gauge maintains 34 kPa (5 psi).
- Inspect sealed or gasketed areas for leaks by applying a solution of liquid detergent and water over areas for formation of bubbles which indicates leakage.

Leakage Points - Above Engine

Examine the following areas for oil leakage.

- valve cover gaskets
- intake manifold gaskets
- cylinder head gaskets
- oil bypass filter
- oil level indicator tube connection
- oil pressure sensor

Leakage Points - Under Engine

- oil pan gaskets
- oil pan sealer
- oil pan rear seal
- engine front cover gasket
- crankshaft front seal
- crankshaft rear oil seal
- crankshaft main bearing cap side bolts
- oil pump and filter body

Leakage Points - with Flywheel Removed

NOTE: Air leakage in the area around a crankshaft rear oil seal does not necessarily indicate a crankshaft rear oil seal leak. However, if no other cause can be found for oil leakage, assume that the crankshaft rear oil seal is the cause of the oil leak.

NOTE: Light foaming equally around valve cover bolts and crankshaft seals is not detrimental; no repairs are required.

- crankshaft rear oil seal
- rear main bearing cap parting line
- rear main bearing cap and seals
- flywheel mounting bolt holes (with flywheel installed)
- camshaft rear bearing covers or pipe plugs at the end of oil passages

Oil leaks at crimped seams in sheet metal parts and cracks in cast or stamped parts can be detected when pressurizing the crankcase.

Compression Tests

Compression Gauge Check

1. Make sure the oil in the crankcase is of the correct viscosity and at the proper level and that the battery is properly charged. Operate until the engine is at normal operating temperature. Turn the ignition switch to the OFF position, then remove all the spark plugs.
2. Set the throttle plates in the wide-open position.
3. Install a Compression Tester in the No. 1 cylinder.
4. Install an auxiliary starter switch in the starting circuit. With the ignition switch in the OFF position, and using the auxiliary starter switch, crank the engine a minimum of five compression strokes and record the highest reading. Note the approximate number of compression strokes required to obtain the highest reading.
5. Repeat the test on each cylinder, cranking the engine approximately the same number of compression strokes.

Test Results

The indicated compression pressures are considered within specification if the lowest reading cylinder is within 75 percent of the highest reading. Refer to the Compression Pressure Limit Chart.

If one or more cylinders reads low, squirt approximately one tablespoon of clean engine oil meeting Ford specification ESE-M2C153-E on top of the pistons in the low-reading cylinders. Repeat the compression pressure check on these cylinders.

Compression Pressure Limit Chart

MAX-MIN kPa (psi)	MAX-MIN kPa (psi)	MAX-MIN kPa (psi)	MAX-MIN kPa (psi)
924 - 696 (134 - 101)	1131 - 848 (164 - 123)	1338 - 1000 (194 - 146)	1154 - 1158 (224 - 168)
938 - 703 (136 - 102)	1145 - 855 (166 - 124)	1351 - 1014 (196 - 147)	1558 - 1165 (226 - 169)
952 - 717 (138 - 104)	1158 - 869 (168 - 126)	1365 - 1020 (198 - 148)	1572 - 1179 (228 - 171)
965 - 724 (140 - 106)	1172 - 876 (170 - 127)	1379 - 1034 (200 - 150)	1586 - 1186 (230 - 172)
979 - 738 (142 - 107)	1186 - 889 (172 - 129)	1303 - 1041 (202 - 151)	1600 - 1200 (232 - 174)
933 - 745 (144 - 109)	1200 - 903 (174 - 131)	1407 - 1055 (204 - 153)	1055 - 1207 (153 - 175)
1007 - 758 (146 - 110)	1214 - 910 (176 - 132)	1420 - 1062 (206 - 154)	1627 - 1220 (154 - 177)
1020 - 765 (148 - 111)	1227 - 917 (178 - 133)	1434 - 1075 (208 - 156)	1641 - 1227 (238 - 178)
1034 - 779 (150 - 113)	1241 - 931 (180 - 135)	1448 - 1083 (210 - 157)	1655 - 1241 (240 - 180)
1048 - 786 (152 - 114)	1225 - 936 (182 - 136)	1462 - 1089 (212 - 158)	1669 - 1248 (242 - 181)
1062 - 793 (154 - 115)	1269 - 952 (184 - 138)	1476 - 1103 (214 - 160)	1682 - 1262 (244 - 183)
1076 - 807 (156 - 117)	1282 - 965 (186 - 140)	1489 - 1117 (216 - 162)	1696 - 1269 (246 - 184)
1089 - 814 (158 - 118)	1296 - 972 (188 - 141)	1503 - 1124 (218 - 163)	1710 - 1202 (248 - 186)
1103 - 872 (160 - 120)	1310 - 979 (190 - 142)	1517 - 1138 (220 - 165)	1724 - 1289 (250 - 187)
1110 - 834 (161 - 121)	1324 - 993 (192 - 144)	1631 - 1145 (222 - 166)	

Interpreting Compression Readings

1. If compression improves considerably, with the addition of oil, piston rings are faulty.
2. If compression does not improve with oil, valves are sticking or seating improperly.
3. If two adjacent cylinders indicate low compression pressures and squirting oil on each piston does not increase compression, the head gasket may be leaking between cylinders. Engine oil or coolant in cylinders could result from this condition.

Use the Compression Pressure Limit Chart when checking cylinder compression so that the lowest reading is within 75 percent of the highest reading.

Cylinder Leakage Detection

When a cylinder produces a low reading, use of the Engine Cylinder Leak Detection/Air Pressurization Kit will be helpful in pinpointing the exact cause.

The leakage detector is inserted in the spark plug hole, the piston is brought up to dead center on the compression stroke, and compressed air is admitted.

Once the combustion chamber is pressurized, a special gauge included in the kit will read the percentage of leakage. Leakage exceeding 20 percent is excessive.

While the air pressure is retained in the cylinder, listen for the hiss of escaping air. A leak at the intake valve will be heard in the throttle body. A leak at the exhaust valve can be heard at the tail pipe. Leakage past the piston rings will be audible at the positive crankcase ventilation (PCV) connection. If air is passing through a blown head gasket to an adjacent cylinder, the noise will be evident at the spark plug hole of the cylinder into which the air is leaking. Cracks in the cylinder blocks or gasket leakage into the cooling system may be detected by a stream of bubbles in the radiator.

Oil Leak and Valve Stem Seal Test

The cylinder leakage detector tests for engine oil leaks and checks the valve stem seals for leakage.

1. Plug all crankcase openings except the one used for connecting the leakage detector.
2. Connect the Engine Cylinder Leak Detection/Air Pressurization Kit to a crankcase opening (an oil level indicator tube is convenient). Adjust the air pressure to approximately 34 kPa (5 psi).
3. Using a solution of liquid soap and water, brush the solution along the gasket sealing surfaces and bearing seals. Look for bubbles or foam.
4. Remove the spark plugs and rotate the crankshaft slowly with a wrench. Check for large amounts of air escaping into the cylinders as each intake valve and exhaust valve opens.
5. The spark plugs on the leaking cylinders will probably show deposits of burned oil.

Intake Manifold Vacuum Test

Bring the engine to normal operating temperature. Connect the Vacuum/Pressure Tester to the intake manifold. Run the engine at the specified idle speed.

The vacuum gauge should read between 51-74 kPa (15-22 in-Hg) depending upon the engine condition and the altitude at which the test is performed. Subtract 4.0193 kPa (1 in-Hg) from the specified reading for every 304.8 m (1,000 feet) of elevation above sea level.

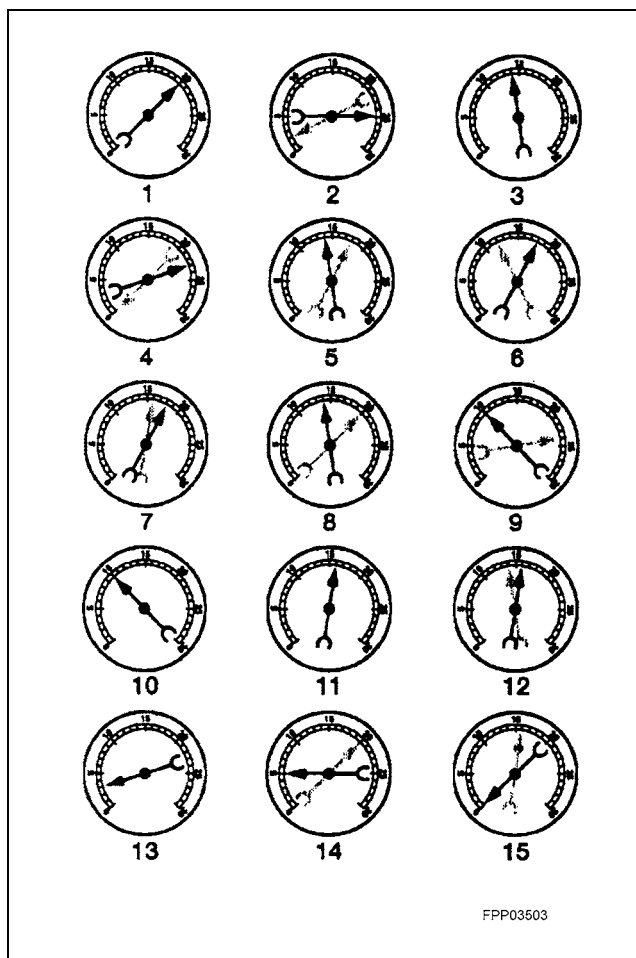
The reading should be steady. If necessary, adjust the gauge damper control (where used) if the needle is fluttering rapidly. Adjust the damper until the needle moves easily without excessive flutter.

Interpreting Vacuum Gauge Readings

A careful study of the vacuum gauge reading while the engine is idling will help pinpoint trouble areas. Always conduct other appropriate tests before arriving at a final diagnostic decision. Vacuum gauge readings, although helpful, must be interpreted carefully.

Most vacuum gauges have a normal band indicated on the gauge face.

The following are potential gauge readings. Some are normal; others should be investigated further.



FPP03503

1. **NORMAL READING:** Needle between 51-74 kPa (15-22 in-Hg) and holding steady.
2. **NORMAL READING DURING RAPID ACCELERATION AND DEACCELERATION:** When the engine is rapidly accelerated (dotted needle), the needle will drop to a low reading (not to zero). When the throttle is suddenly released, the needle will snap back up to a higher than normal figure.
3. **NORMAL FOR HIGH-LIFT CAMSHAFT WITH LARGE OVERLAP:** The needle will register as low as 51 kPa (15 in-Hg) but will be relatively steady. Some oscillation is normal.

4. **WORN RINGS OR DILUTED OIL:** When the engine is accelerated (dotted needle), the needle drops to 0 kPa (0 in-Hg). Upon deceleration, the needle runs slightly above 74 kPa (22 in-Hg).
5. **STICKING VALVES:** When the needle (dotted) remains steady at a normal vacuum but occasionally flicks (sharp, fast movement) down and back about 13 kPa (4 in-Hg), one or more valves may be sticking.
6. **BURNED OR WARPED VALVES:** A regular, evenly-spaced, downscale flicking of the needle indicates one or more burned or warped valves. Insufficient hydraulic lash adjuster or hydraulic lash adjuster (HLA) clearance will also cause this reaction.
7. **POOR VALVE SEATING:** A small but regular downscale flicking can mean one or more valves are not seating.
8. **WORN VALVE GUIDES:** When the needle oscillates over about a 13 kPa (4 in-Hg) range at idle speed, the valve guides could be worn. As engine speed increases, the needle will become steady if guides are responsible.
9. **WEAK VALVE SPRINGS:** When the needle oscillation becomes more violent as engine rpm is increased, weak valve springs are indicated. The reading at idle could be relatively steady.
10. **LATE VALVE TIMING:** A steady but low reading could be caused by late valve timing.
11. **IGNITION TIMING RETARDING:** Retarded ignition timing will produce a steady but somewhat low reading.
12. **INSUFFICIENT SPARK PLUG GAP:** When spark plugs are gapped too close, a regular, small pulsation of the needle can occur.
13. **INTAKE LEAK:** A low, steady reading can be caused by an intake manifold or throttle body gasket leak.
14. **BLOWN HEAD GASKET:** A regular drop of fair magnitude can be caused by a blown head gasket or warped cylinder head-to-cylinder block surface.
15. **RESTRICTED EXHAUST SYSTEM:** When the engine is first started and is idled, the reading may be normal, but as the engine rpm is increased, the back pressure caused by a clogged muffler, kinked tail pipe or other concerns will cause the needle to slowly drop to 0 kPa (0 in-Hg). The needle then may slowly rise. Excessive exhaust clogging will cause the needle to drop to a low point even if the engine is only idling.

When vacuum leaks are indicated, search out and correct the cause. Excess air leaking into the system will upset the fuel mixture and cause concerns such as rough idle, missing on acceleration or burned valves. If the leak exists in an accessory unit such as the power brake booster, the unit will not function correctly. Always fix vacuum leaks.

Excessive Engine Oil Consumption

The amount of oil an engine uses will vary with the way the equipment is driven in addition to normal engine-to-engine variation. This is especially true during the first 340 hours or 16,100 km (10,000 miles) when a new engine is being broken in or until certain internal engine components become conditioned. Engines used in heavy-duty operation may use more oil. The following are examples of heavy-duty operation:

- severe loading applications
- sustained high speed operation

Engines need oil to lubricate the following internal components:

- cylinder block, cylinder walls
- pistons, piston pins and rings
- intake and exhaust valve stems
- intake and exhaust valve guides
- all internal engine components

When the pistons move downward, a thin film of oil is left on the cylinder walls. As the engine is operated, some oil is also drawn into the combustion chambers past the intake and exhaust valve stem seals and burned.

The following is a partial list of conditions that can affect oil consumption rates:

- engine size
- operator driving habits
- ambient temperature
- quality and viscosity of the oil

Operating under varying conditions can frequently be misleading. An engine that has been run for short hours or in below-freezing ambient temperatures may have consumed a "normal" amount of oil. However, when checking engine oil level, it may measure up to the full mark on the oil level dipstick due to dilution (condensation and fuel) in the engine crankcase. The engine might then be run at high speeds where the condensation and fuel boil off. The next time the engine oil is checked, it may appear that a liter (quart) of oil was used in about 3 to 3-1/2 hours. This perceived 3 to 3-1/2 hours per liter (quart) oil consumption rate causes customer concern even though the actual overall oil consumption rate is about 50 hours per liter (quart).

Make sure the selected engine oil meets Ford specification WSS-M2C153-F and the recommended API performance category "SJ" or higher and SAE viscosity grade as shown in the equipment Owner's or Operators Engine handbook. It is also important that the engine oil is changed at the intervals specified. Refer to the Engine Operator's handbook.

Oil Consumption Test

The following diagnostic procedure is used to determine the source of excessive internal oil consumption.

NOTE: Oil use is normally greater during the first 300 hours of service. As hours increase, oil use generally decreases. Engines in normal service should get at least 31.7 hours per quart (900 miles per quart) after 300 hours of service. High speeds, heavy loads, high ambient temperature and other factors may result in greater oil use.

1. Determine customer's engine load habits, such as sustained high speed operation, extended idle, heavy work loads and other considerations.
2. Verify that the engine has no external oil leak as described under Engine Oil Leaks in the Diagnosis and Testing portion of this section.
3. Verify that the engine has the correct oil level dipstick.
4. Verify that the engine is not being run in an overfilled condition. Check the oil level at least five minutes after a hot shutdown with the engine/vehicle parked on a level surface. In no case should the level be above the top of the cross-hatched area and the letter F in FULL. If significantly overfilled, perform steps 5 through 9. If not proceed to step 10.
5. Drain the engine oil, remove and replace the oil bypass filter and refill with one quart less than the recommended amount.
6. Run the engine for three minutes (10 minutes if cold), and allow the oil to drain back for at least five minutes with the engine/vehicle on a level surface.
7. Remove oil level dipstick and wipe clean.

CAUTION: Do not wipe with anything contaminated with silicone compounds.

8. Reinstall the oil level dipstick, being sure to seat it firmly in the oil level indicator tube. Remove the oil level dipstick and draw a mark on the back (unmarked) surface at the indicated oil level. This level should be about the same as the ADD mark on the face of the oil level dipstick.
9. Add one quart of oil. Restart the engine and allow to idle for at least two minutes. Shut off the engine and allow the oil to drain back for at least five minutes. Mark the oil level dipstick, using the procedure above. This level may range from slightly below the top of the cross-hatched area to slightly below the letter F in FULL.
10. Record the vehicle mileage or hours.

11. Instruct the customer to run engine as usual and perform the following:
 - Check the oil level regularly at intervals of 3 to 3-1/2 hours.
 - Return to the service point when the oil level drops below the lower (ADD) mark on the oil level dipstick.
 - Add only full quarts of the same oil in an emergency. Note the mileage at which the oil is added.
 12. Check the oil level under the same conditions and at the same location as in Steps 7-9.
 - Measure the distance from the oil level to the UPPER mark on the oil level dipstick and record.
 - Measure the distance between the two scribe marks and record.
 - Divide the first measurement by the second.
 - Divide the hours run during the oil test by the result. This quantity is the approximate oil consumption rate in hours per quart.
 13. If the oil consumption rate is unacceptable, proceed to next step.
 14. Check the positive crankcase ventilation (PCV) system. Make sure the system is not plugged.
 15. Check for plugged oil drain-back holes in the cylinder heads and cylinder blocks.
 16. If the condition still exists after performing the above steps, proceed to next step.
 17. Perform a cylinder compression test or perform a cylinder leak detection test with Engine Cylinder Leak Detection/Air Pressurization Kit. This can help determine the source of oil consumption such as valves, piston rings or other areas.
- NOTE:** After determining if worn parts should be replaced, make sure correct replacement parts are used.
18. Check valve guides for excessive guide clearances. REPLACE all valve stem seals after verifying valve guide clearance.
 19. Worn or damaged internal engine components can cause excessive oil consumption. Small deposits of oil on the tips of spark plugs can be a clue to internal oil consumption. If internal oil consumption still persists, proceed as follows:
 - Remove the engine from the vehicle and place it on an engine work stand. Remove the intake manifolds, cylinder heads, oil pan and oil pump.
 - Check piston ring clearance, ring gap and ring orientation. Repair as required.
 - Check for excessive bearing clearance. Repair as required.
 20. Perform the oil consumption test to confirm the oil consumption concern has been resolved.

Oil Pressure Test

1. Disconnect and remove the oil pressure sensor from the engine.
2. Connect the Engine Oil Pressure Gauge and Transmission Test Adapter to the oil pressure sender oil gallery port.
3. Run the engine until normal operating temperature is reached.
4. Run the engine at 3000 rpm and record the gauge reading.
5. The oil pressure should be within specifications.
6. If the pressure is not within specification, check the following possible sources:
 - insufficient oil
 - oil leakage
 - worn or damaged oil pump
 - oil pump screen cover and tube
 - excessive main bearing clearance
 - excessive connecting rod bearing clearance

Valve Train Analysis – Static

With engine off and valve cover removed, check for damaged or severely worn parts and correct assembly. Make sure correct parts are used with the static engine analysis as follows.

Rocker Arm

- Check for loose mounting bolts, studs and nuts.
- Check for plugged oil feed in the rocker arms or cylinder head.

Camshaft Roller Followers and Hydraulic Lash Adjusters

- Check for loose mounting bolts on camshaft carriers.
- Check for plugged oil feed in the camshaft roller followers, hydraulic lash adjusters (HLA) or cylinder heads.

Camshaft

- Check for broken or damaged parts.
- Check the bolts on the intake manifold.

Valve Springs

- Check for broken or damaged parts.

Valve Spring Retainer and Valve Spring Retainer Keys

- Check for proper seating of the valve spring retainer key on the valve stem and in valve spring retainer.

Valve Spring Retainer Keys

- Check for proper seating on the valve stem.

Valves and Cylinder Head

- Check the head gasket for proper installation.
- Check for plugged oil drain back holes.
- Check for worn or damaged valve tips.
- Check for missing or damaged guide-mounted valve stem seal.
- Check collapsed lash adjuster gap.
- Check installed valve spring height.
- Check for missing or worn valve spring seats.
- Check for plugged oil metering orifice in cylinder head oil reservoir (if equipped).

Static checks (engine off) are to be made on the engine prior to the dynamic procedure.

Valve Train Analysis – Dynamic

Start the engine and, while idling, check for proper operation of all parts. Check the following:

Rocker Arm

- Check for plugged oil in the rocker arms or cylinder head.
- Check for proper overhead valve train lubrication.

If insufficient oiling is suspected, accelerate the engine to 1200 rpm \pm 100 rpm with the PTO in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and rocker arms are well oiled or, with the valve covers off, oil splash may overshoot the rocker arms. If oiling is insufficient for this to occur, check oil passages for blockage.

Positive Rotator and Valve Spring Retainer Keys

- Check for proper operation of positive rotator.

Valves and Cylinder Head

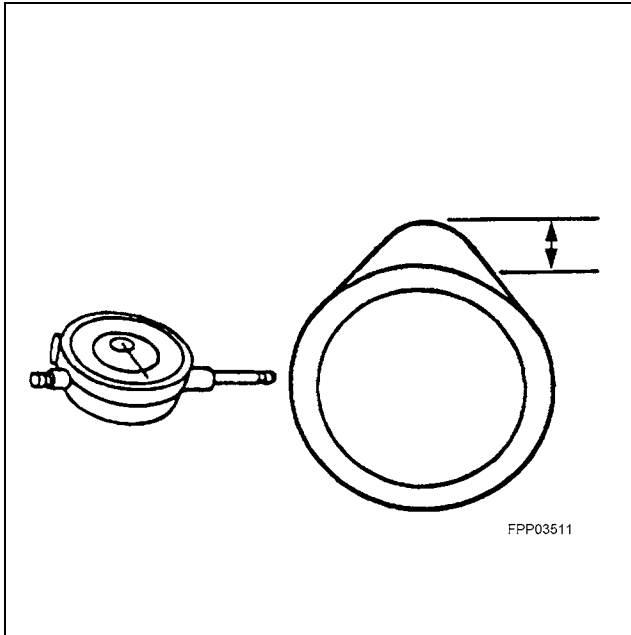
- Check for plugged oil drain back holes.
- Check for missing or damaged valve stem seals or guide mounted valve stem seals.

If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1200 rpm with the PTO in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and camshaft roller followers are well oiled. With the valve covers off, some oil splash may overshoot camshaft roller followers.

Camshaft Lobe Lift

Check the lift of each lobe in consecutive order and make a note of the readings.

1. Remove the valve covers.
2. Install the dial Indicator with Bracketry so the plunger is on top of the camshaft lobe and in the same plane as the camshaft lobe movement.



3. Remove the spark plugs.
4. Connect an auxiliary starter switch in the starting circuit. Crank the engine with the ignition switch in the OFF position. Bump the crankshaft over until the indicator plunger is on the base circle of the camshaft lobe. At this point, the lobe lift will be in its lowest position. If checking during engine assembly, turn the crankshaft using a socket or ratchet.
5. Zero the dial indicator. Continue to rotate the crankshaft slowly until the camshaft lobe is in the fully-raised position (highest indicator reading).

NOTE: If the lift on any lobe is below specified service limits, the camshaft and any component operating on worn lobes must be replaced.

6. Compare the total lift recorded on the dial indicator with specifications.
7. To check the accuracy of the original dial indicator reading, continue to rotate the crankshaft until the indicator reads zero.
8. Remove the dial indicator, adapter and auxiliary starter switch.

CAUTION: After installing rocker arms, do not rotate the crankshaft until lash adjusters have had sufficient time to bleed down. To do otherwise may cause serious valve damage. Manually bleeding-down lash adjusters will reduce waiting time.

9. Install the valve covers.
10. Install the spark plugs.

Hydraulic Valve Lash Adjuster

Hydraulic lash adjuster noise can be caused by any of the following:

- excessively collapsed lash adjuster gap
- sticking lash adjuster plunger
- lash adjuster check valve not functioning properly
- air in lubrication system
- leakdown rate too rapid
- excessive valve guide wear

Excessive collapsed lash adjuster gap can be caused by loose rocker arm seat bolts/nuts, incorrect initial adjustment or wear of lash adjuster face, or worn roller lash adjusters, push rod, rocker arm, rocker arm seat or valve tip. With lash adjuster collapsed, check gap between the valve tip and the rocker arm to determine if any other valve train parts are damaged, worn or out of adjustment.

A sticking lash adjuster plunger can be caused by dirt, chips or varnish inside the lash adjuster.

A lash adjuster check valve that is not functioning can be caused by an obstruction such as dirt or chips that prevent it from closing when the camshaft lobe is lifting the lash adjuster. It may also be caused by a broken check valve spring.

Air bubbles in the lubrication system will prevent the lash adjuster from supporting the valve spring load. This can be caused by too high or too low an oil level in the oil pan or by air being drawn into the system through a hole, crack or leaking gasket on the oil pump screen cover and tube.

If the leakdown time is below the specified time for used lash adjusters, noisy operation can result. If no other cause for noisy lash adjusters can be found, the leakdown rate should be checked and any lash adjusters outside the specification should be replaced.

Assembled lash adjusters can be tested with Hydraulic lash adjuster Leakdown Tester to check the leakdown rate. The leakdown rate specification is the time in seconds for the plunger to move a specified distance while under a 22.7 kg (50 lb.) load. Test the lash adjusters as follows:

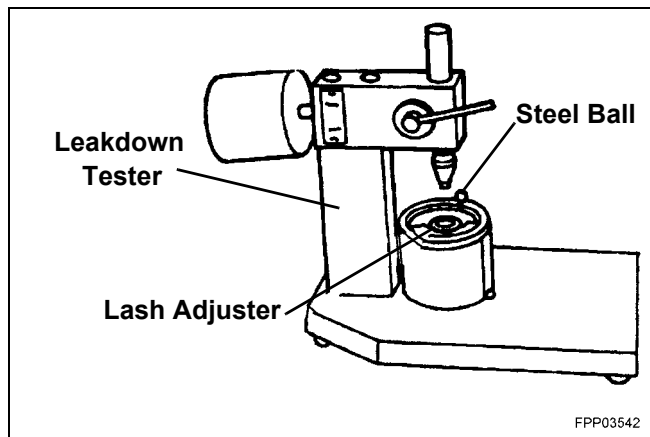
Leakdown Testing

NOTE: Do not mix parts from different hydraulic lash adjusters. Parts are select-fit and are not interchangeable.

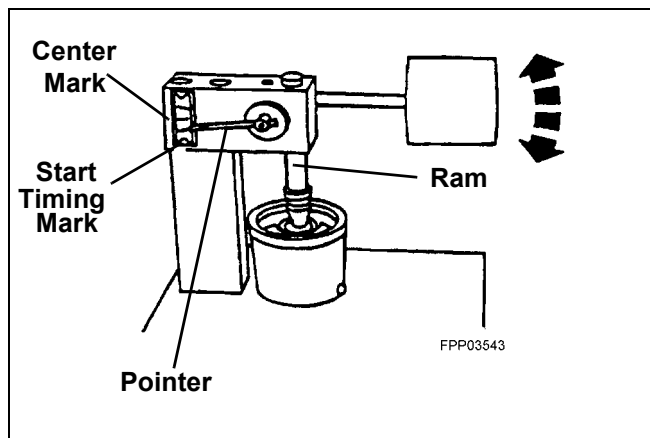
1. Clean the lash adjuster to remove all traces of engine oil.

NOTE: Lash adjusters cannot be checked with engine oil in them. Use only testing fluid. New hydraulic lash adjusters are already filled with testing fluid.

2. Place the lash adjuster in the tester with the plunger facing upward. Position the steel ball provided in the plunger cap. Add testing fluid to cover the hydraulic lash adjuster and compress Leakdown Tester until the hydraulic lash adjuster is filled with testing fluid and all traces of air bubbles have disappeared. The fluid can be purchased from the tester's manufacturer. Using kerosene or any other fluid will not provide an accurate test.



3. Adjust the length of the ram so the pointer is just below the start timing mark when the ram contacts the hydraulic lash adjuster. Start Timing as the pointer passes the start timing mark and end timing as the pointer reaches the center mark.



4. A satisfactory lash adjuster must have a leakdown rate (time in seconds) within specified minimum and maximum limits.
5. If the lash adjuster is not within specification, replace it with a new lash adjuster. Do not disassemble and clean new lash adjusters before testing because oil contained in the new lash adjuster is test fluid.
6. Remove the fluid from the cup and bleed the fluid from the lash adjuster by working the plunger up and down. This step will aid in depressing the lash adjuster plungers when checking valve clearance.

GENERAL SERVICE PROCEDURES



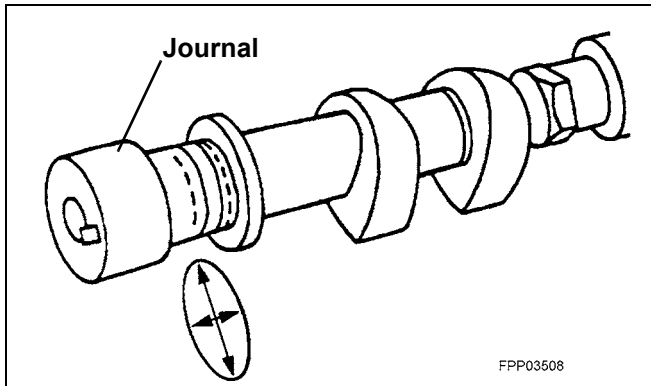
WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT, DO NOT OPERATE THE ENGINE WITH THE HOOD OPEN UNTIL THE FAN BLADE HAS BEEN EXAMINED FOR POSSIBLE CRACKS AND SEPARATION.

NOTE: Specifications show the expected minimum or maximum condition.

NOTE: If a component fails to meet the specifications, it is necessary to replace or refinish. If the component can be refinished, wear limits are provided as an aid to making a decision. Any component that fails to meet specifications and cannot be refinished must be replaced.

Camshaft Journal Diameter

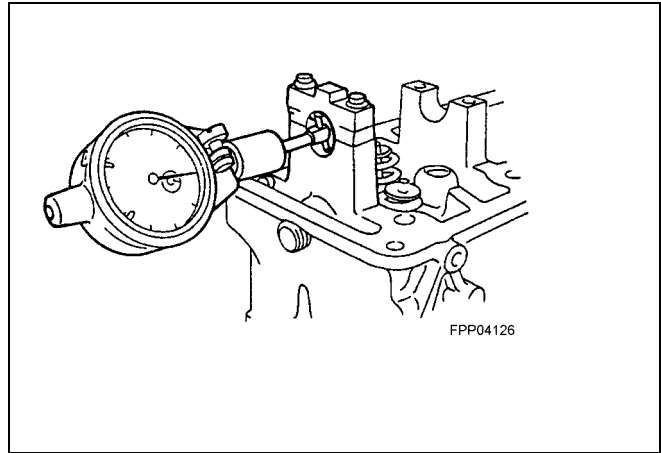
- Measure each camshaft journal diameter in two directions.
- If it is out of specification, replace as necessary.



Camshaft Journal Clearance

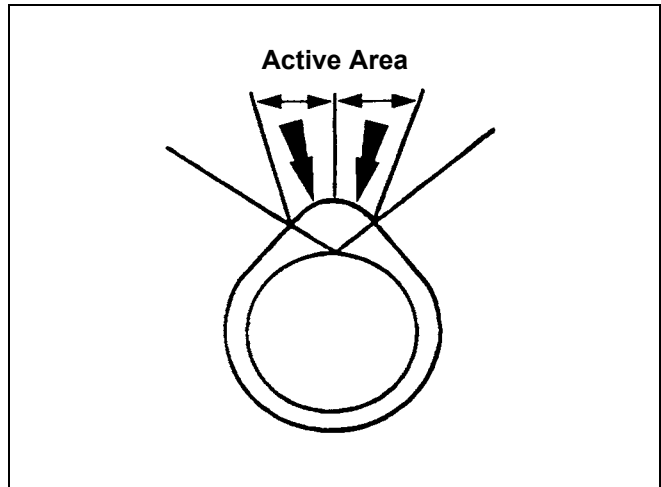
NOTE: The camshaft journals must meet specifications before checking camshaft journal clearance.

- Measure each camshaft bearing in two directions.
- Subtract the camshaft journal diameter from the camshaft bearing diameter



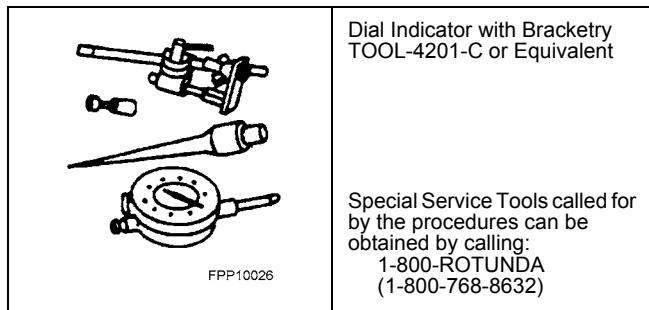
Camshaft Lobe Surface

- Inspect camshaft lobes for pitting or damage in the active area. Minor pitting is acceptable outside the active area

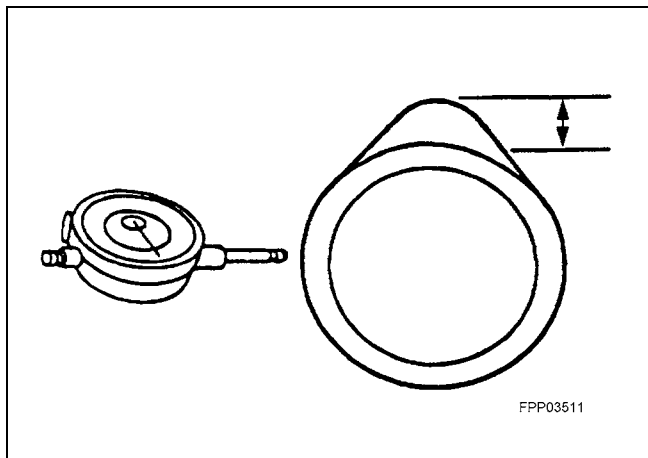


Camshaft Lobe Lift

Special Tool(s)



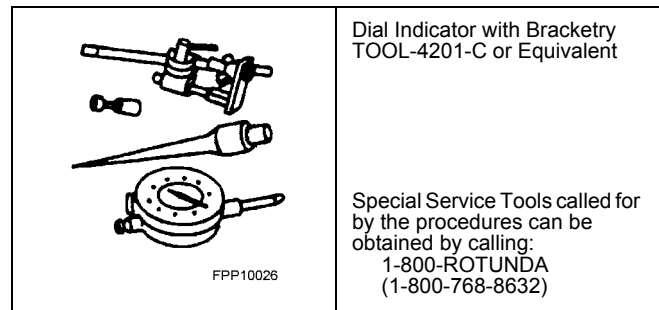
1. Use the Dial Indicator with Bracketry to measure camshaft intake lobe lift.



2. Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the camshaft lobe lift.
3. Use the Dial Indicator with Bracketry to measure camshaft exhaust lobe lift.
4. Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the camshaft lobe lift.

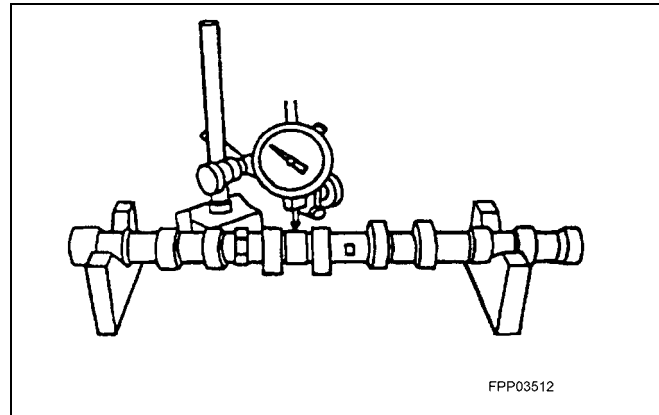
Camshaft Runout

Special Tool(s)



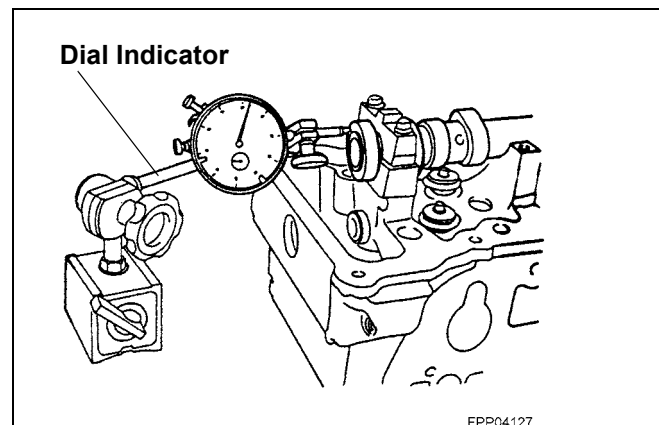
NOTE: Camshaft journals must be within specifications before checking runout.

- Use the Dial Indicator with Bracketry to measure the camshaft runout.
- Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading.



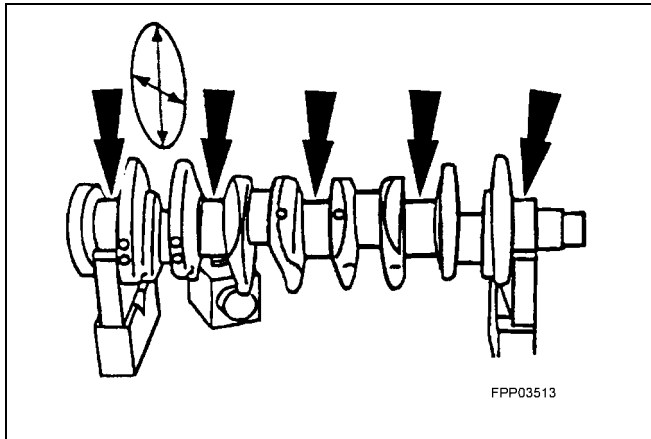
Camshaft End Play

- Move camshaft to the rear.
- Zero dial indicator.
- Move camshaft to the front.
- Compare end play with specifications.

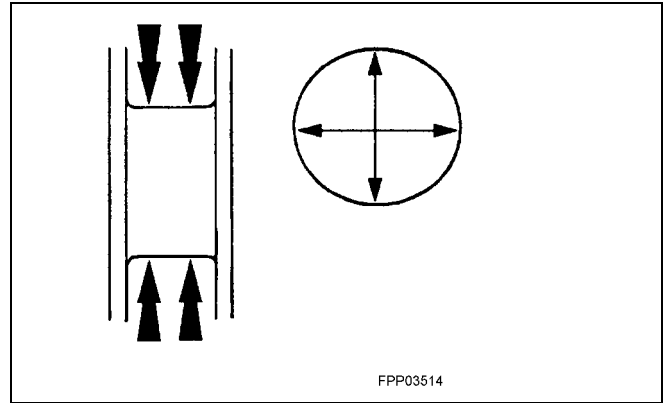


Crankshaft Main Bearing Journal Diameter

- Measure each of the crankshaft main bearing journal diameters in at least two directions.
- If it is out of specification, replace as necessary.

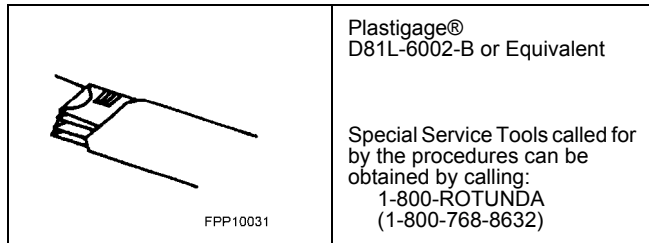
**Crankshaft Main Bearing Journal Taper**

- Measure each of the crankshaft main bearing journal diameters in at least two directions at each end of the main bearing journal.
- If it is out of specifications, replace as necessary.



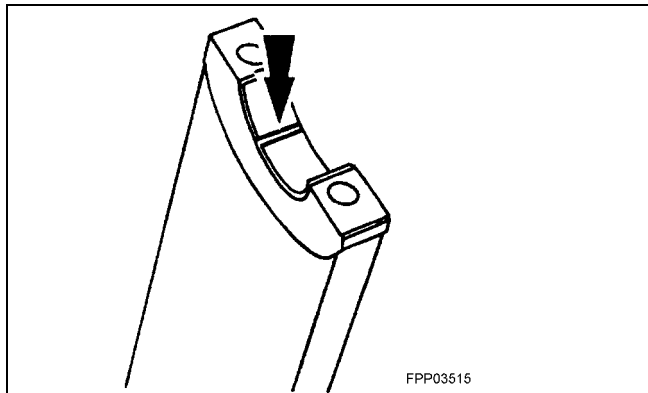
Crankshaft Main Bearing Journal Clearance

Special Tool(s)



NOTE: Crankshaft main bearing journals must be within specifications before checking journal clearance.

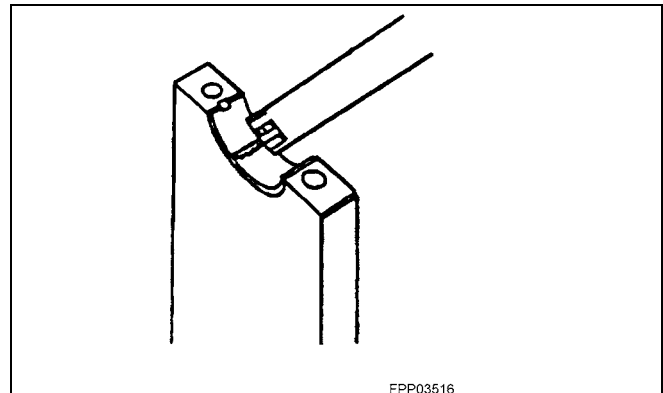
1. Remove the crankshaft main bearing caps and bearings.
2. Lay a piece of Plastigage® across the face of each crankshaft main surface.



NOTE: Do not turn the crankshaft while doing this procedure.

3. Install and remove the crankshaft main bearing cap.

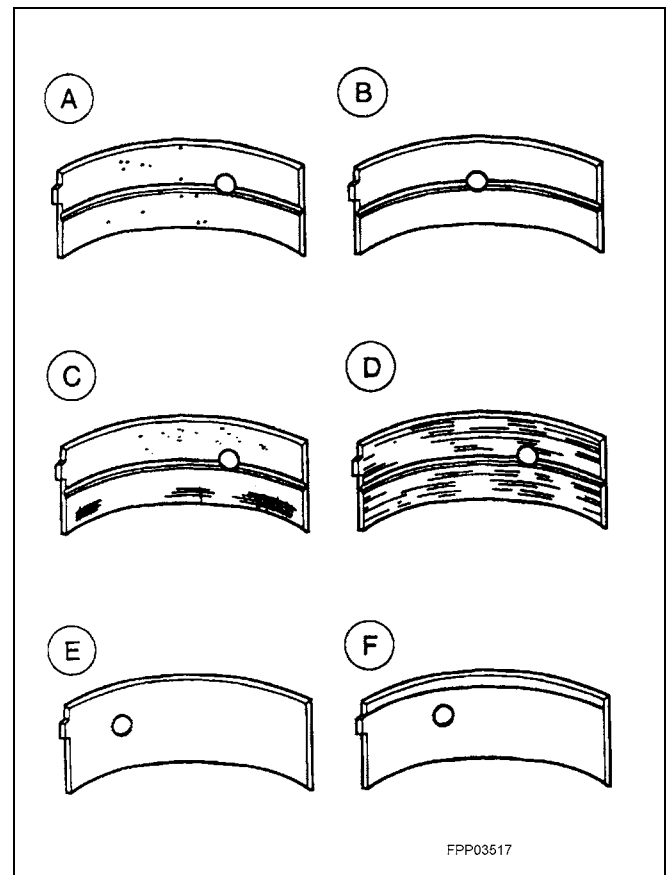
4. Verify the crankshaft journal clearance.
 - If it is out of specification, replace as necessary



Bearing Inspection

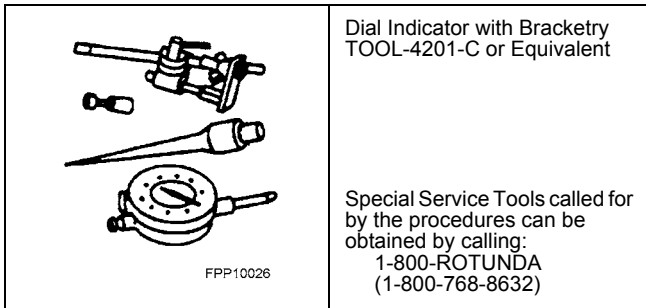
Inspect bearings for the following defects. Possible causes are shown:

- Cratering – fatigue failure (A)
- Spot polishing – improper seating (B)
- Scratching – dirty (C)
- Base exposed – poor lubrication (D)
- Both edges worn – journal damaged (E)
- One edge worn – journal tapered or bearing not seated (F)

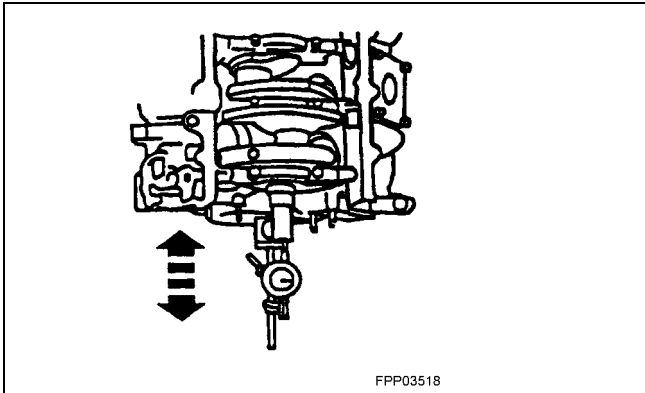


Crankshaft End Play

Special Tool(s)



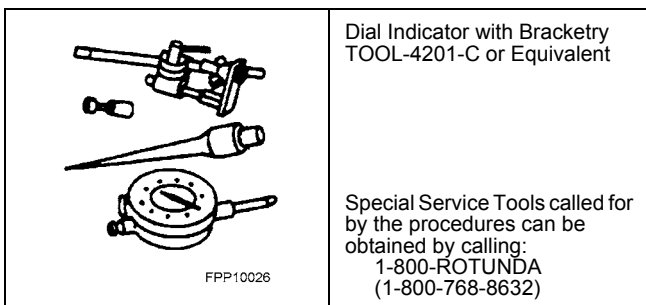
1. Measure the crankshaft end play. Use the Dial Indicator with Bracketry to measure crankshaft end play.
2. Position the crankshaft to the rear of the cylinder block.
3. Zero the Dial Indicator with Bracketry.



4. Move the crankshaft to the front of the cylinder block. Note and record the camshaft end play.
 - If camshaft end play exceeds specifications, replace the crankshaft thrust washers or thrust bearing.

Crankshaft Runout

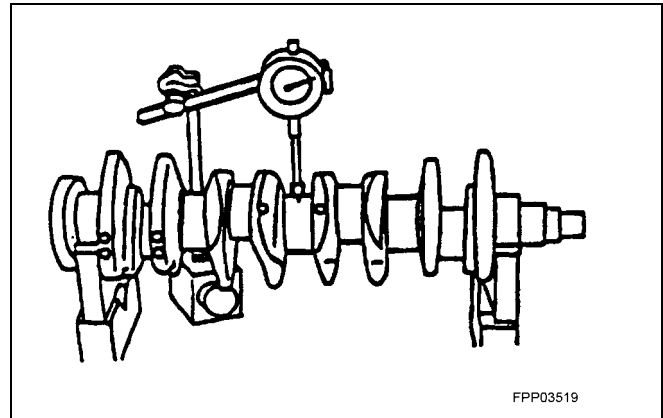
Special Tool(s)



NOTE: Crankshaft main bearing journals must be within specifications before checking runout.

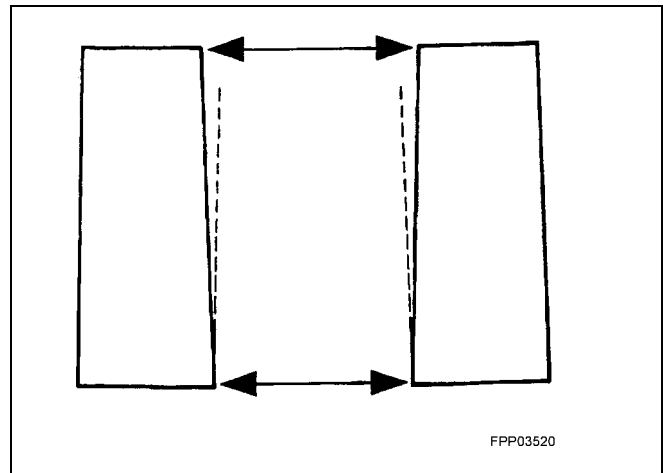
Use the Dial Indicator with Bracketry to measure the crankshaft runout.

- Rotate the crankshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the crankshaft runout. If it is out of specification, replace as necessary.



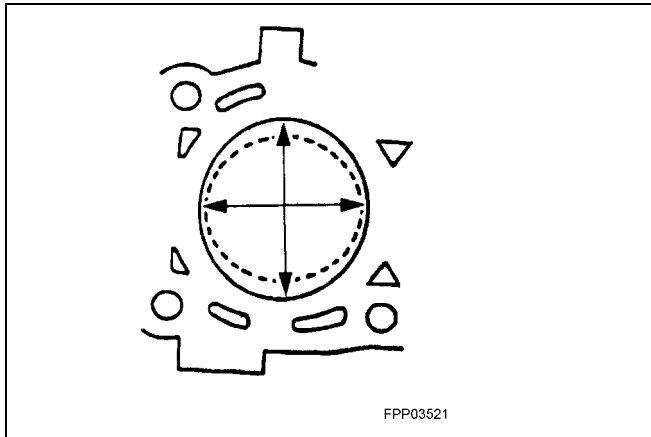
Cylinder Bore Taper

Measure the cylinder bore at the top and bottom. Verify the cylinder bore is within the wear limit. The difference indicates the cylinder bore taper. Bore the cylinder to the next oversize.

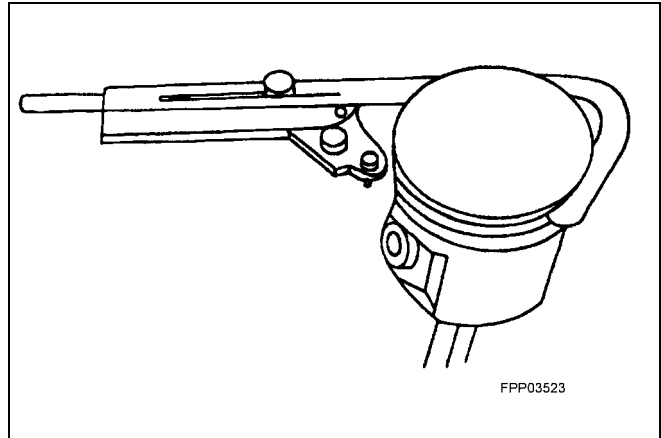


Cylinder Bore Out-of-Round

Measure the cylinder bore in two directions. The difference is the out-of-round. Verify the out-of-round is within the wear limit and bore the cylinder to the next oversize limit.

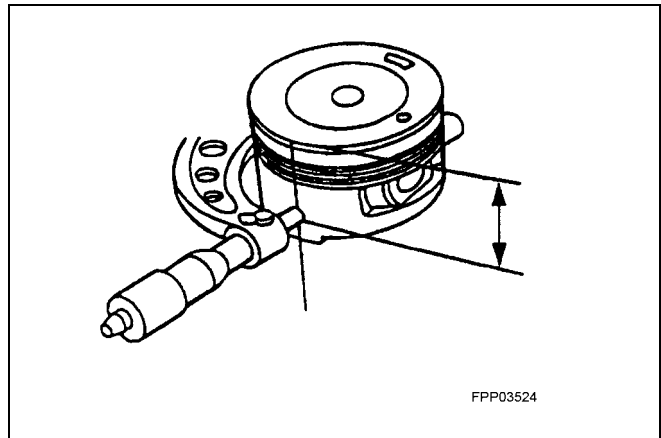


- Make sure the oil ring holes are clean.



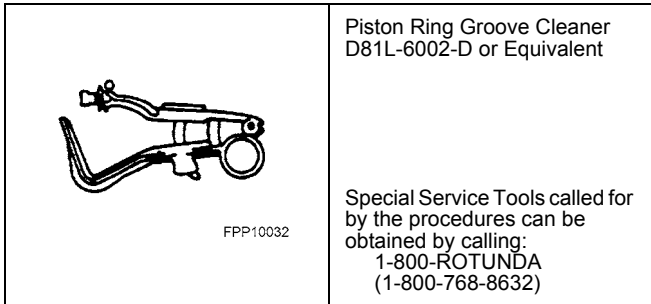
Piston Diameter

- Measure the piston skirt diameter.



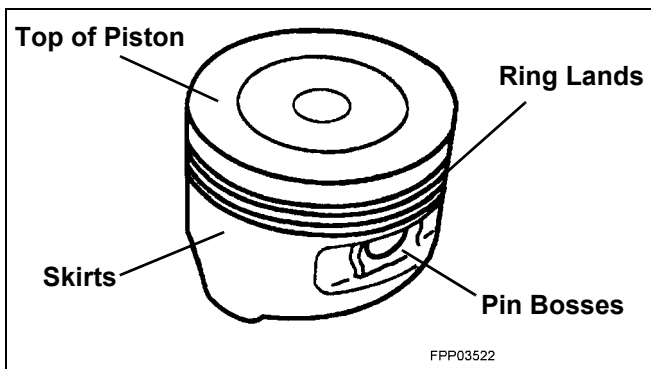
Piston Inspection

Special Tool(s)



CAUTION: Do not use a caustic cleaning solution or a wire brush to clean the pistons or possible damage can occur.

1. Clean and inspect the ring lands, skirts, pin bosses, and the tops of the pistons. If wear marks or polishing is found on the piston skirt, check for a bent or twisted connecting rod.



Piston to Cylinder Bore Clearance

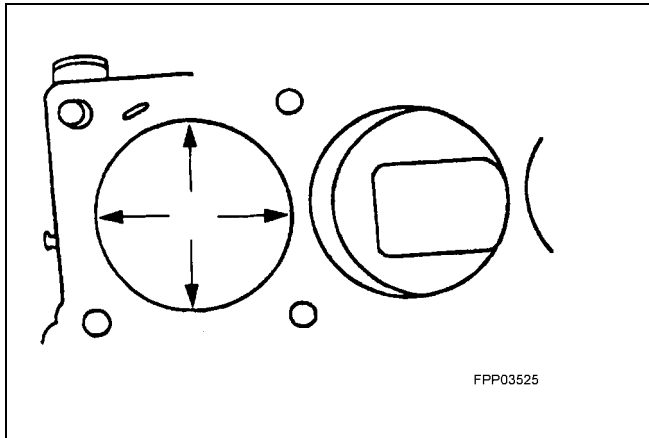
Subtract the piston diameter from the cylinder bore diameter to find the piston-to-cylinder bore clearance.

2. Use the Piston Ring Groove Cleaner to clean the piston ring grooves.

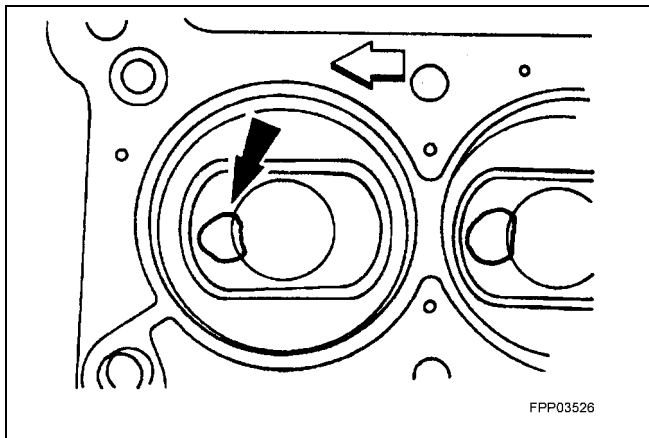
Piston Selection

NOTE: The cylinder bore must be within the specifications for taper and out-of-round before fitting a piston.

1. Select a piston size based on the cylinder bore.



NOTE: For precision fit, new pistons are divided into three categories within each size range based on their relative position within the range. A paint spot on the new pistons indicates the position within the size range.



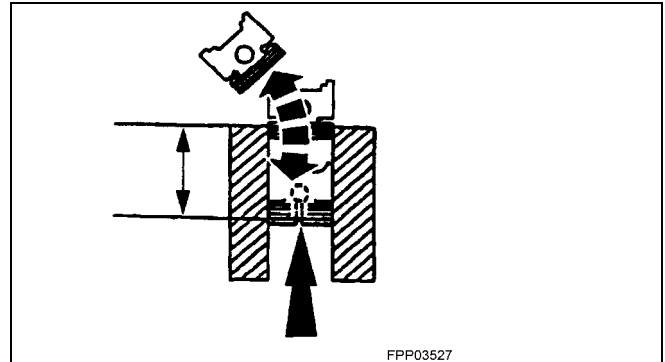
2. Choose the piston with the proper paint color.
 - Red – in the lower third of the size range.
 - Blue – in the middle third of the size range.
 - Yellow – in the upper third of the size range.

CAUTION: Use care when fitting piston rings to avoid possible damage to the piston ring or the cylinder bore.

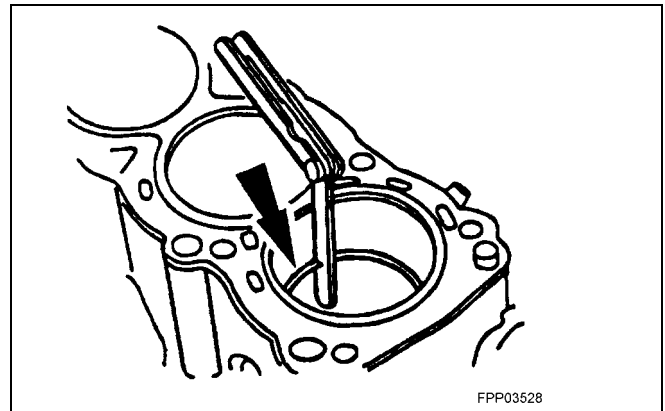
CAUTION: Piston rings should not be transferred from one piston to another to prevent damage to cylinder worn or piston.

NOTE: Cylinder bore must be within specification for taper and out-of-round to fit piston rings.

1. Use a piston without rings to push a piston ring in a cylinder to the bottom of ring travel.



2. Use a feeler gauge to measure the top piston ring end gap and the second piston ring end gap.



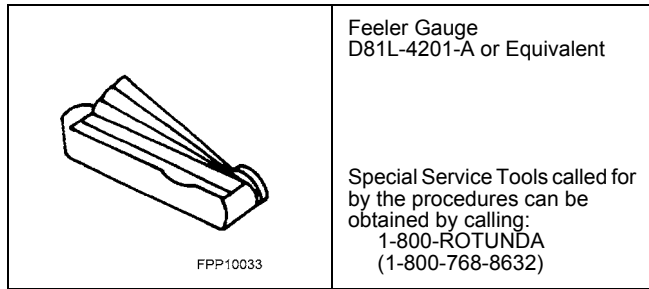
Piston Ring End Gap

Special Tool(s)

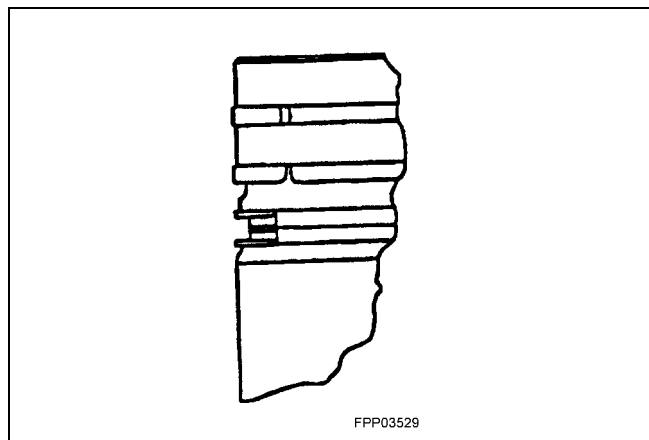
<p>FPP10033</p>	<p>Feeler Gauge D81L-4201-A or Equivalent</p> <p>Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)</p>
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Piston Ring-to-Groove Clearance

Special Tool(s)

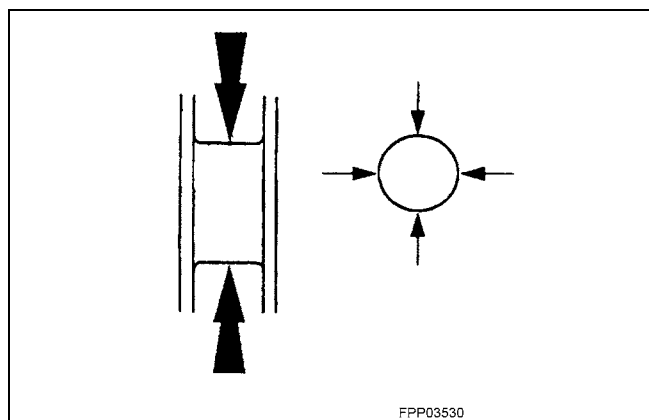


1. Inspect for a stop in the grooves.
2. Measure the piston-to-groove clearance.



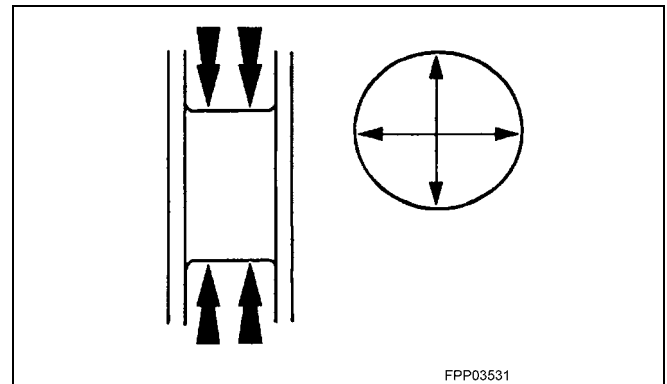
Crankshaft Connecting Rod Journal Diameter

- Measure the crankshaft connecting rod journal diameters in at least two directions perpendicular to one another. The difference between the measurements is the out-of-round. Verify the journal is within the wear limit specification.



Crankshaft Connecting Rod Journal Taper

- Measure the crankshaft rod journal diameters in two directions perpendicular to one another at each end of the connecting rod journal. The difference in the measurements from one end to the other is the taper. Verify measurement is within the wear limit.

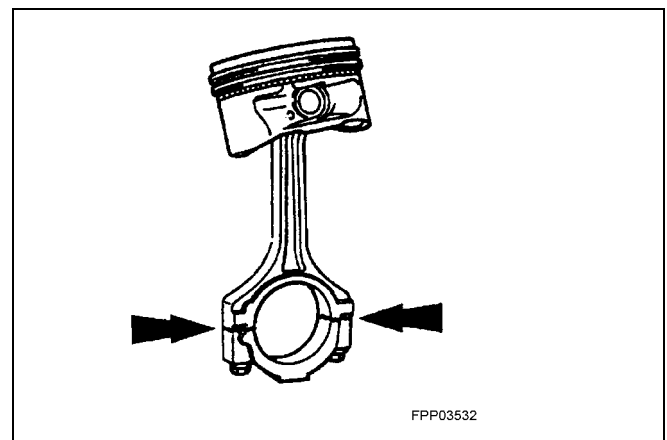


Connecting Rod Cleaning

CAUTION: Do not use a caustic cleaning solution or damage to connecting rods can occur.

NOTE: The connecting rod large end is mechanically split or cracked to produce a unique parting face. This produces a locking joint. Parts are not interchangeable.

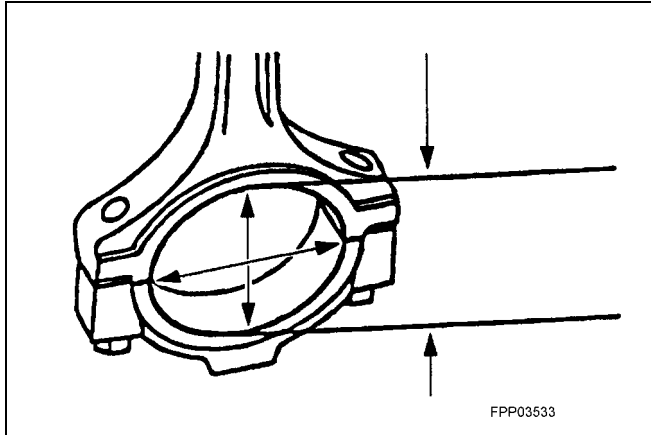
- Mark and separate the parts and clean with solvent. Clean the oil passages.



Connecting Rod Larger End Bore

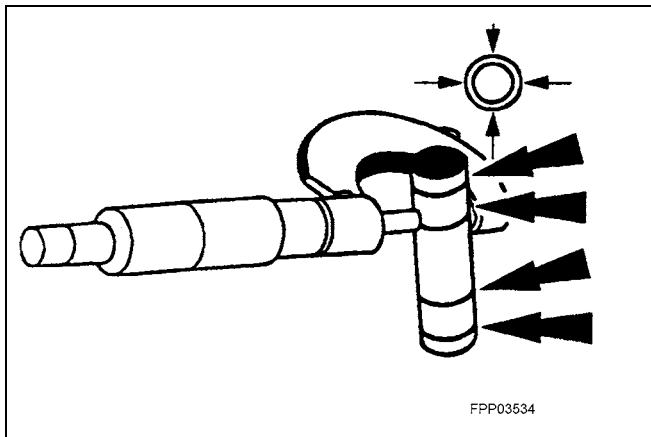
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

- Measure the bore in two directions. The difference is the connecting rod bore out-of-round. Verify the out-of-round is within specification.



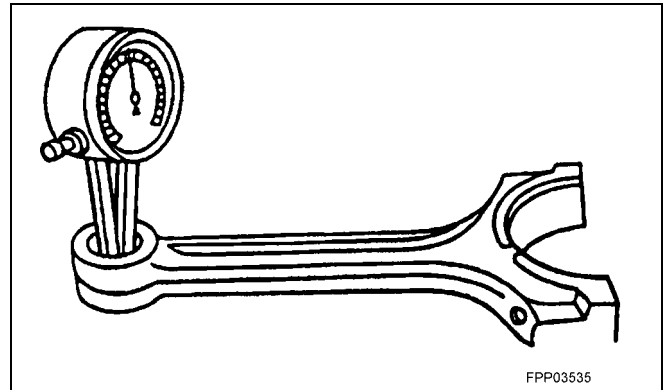
Piston Pin Diameter

- Measure the piston pin diameter in two directions at the points shown. Verify the diameter is within specifications.



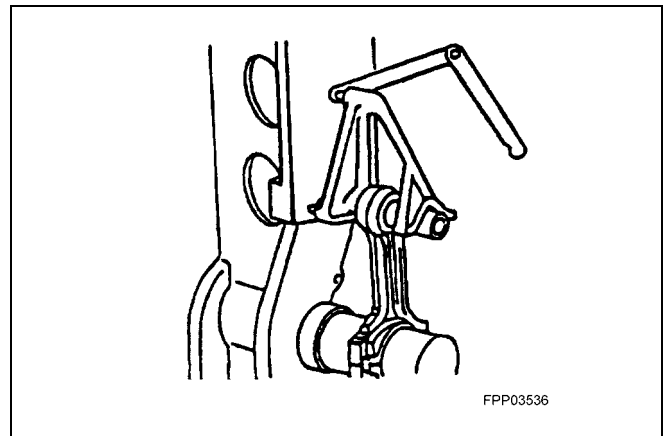
Connecting Rod Bushing Diameter

- Measure the inner diameter of the connecting rod bushing. Verify the diameter is within specification.



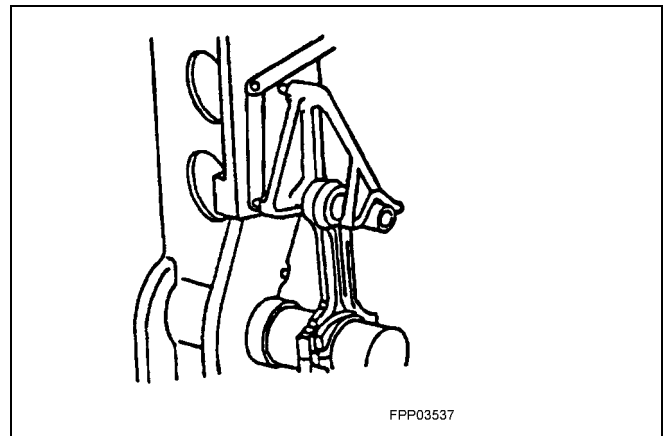
Connecting Rod Bend

- Measure the connecting rod bend on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the bend measurement is within specification.



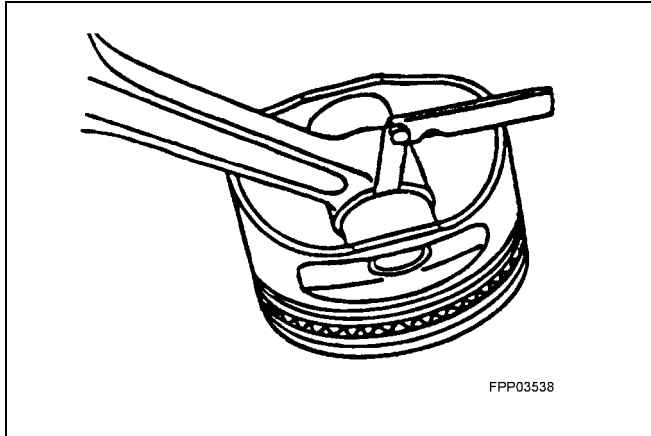
Connecting Rod Twist

- Measure the connecting rod twist on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the measurement is within specification.

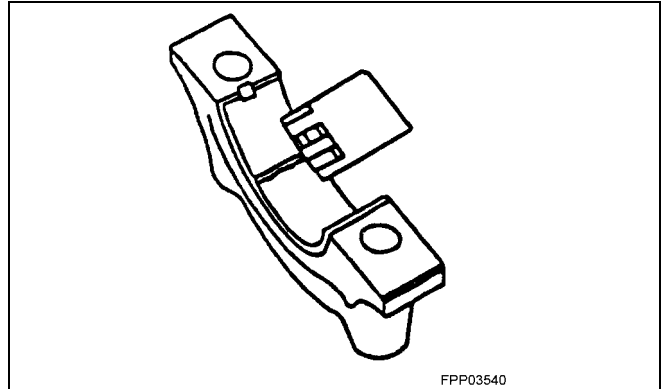


Connecting Rod Piston Pin Side Clearance

- Measure the clearance between the connecting rod and the piston. Verify the measurement is within specification.

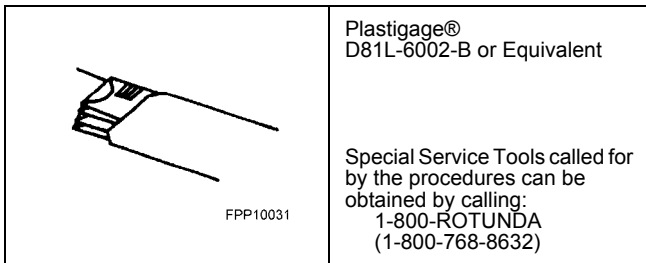


3. Install and torque to specifications, then remove the connecting rod bearing cap.
4. Measure the Plastigage® to get the connecting rod bearing journal clearance. The Plastigage® should be smooth and flat. A change width indicates a tapered or damaged connecting rod bearing or connecting rod.



Connecting Rod Journal Clearance

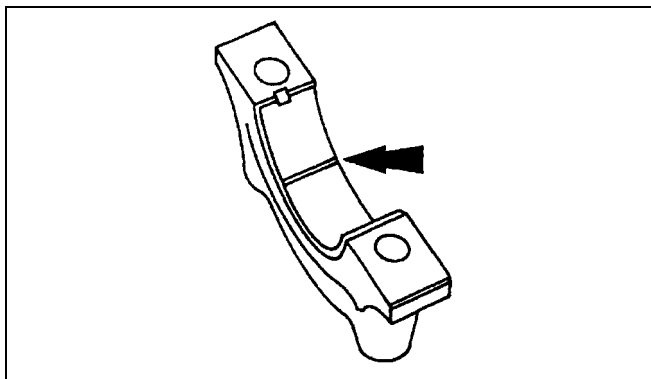
Special Tool(s)



NOTE: The crankshaft connecting rod journals must be within specifications to check the connecting rod bearing journal clearances.

CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

1. Remove the connecting rod bearing cap.
2. Position a piece of Plastigage® across the bearing surface.

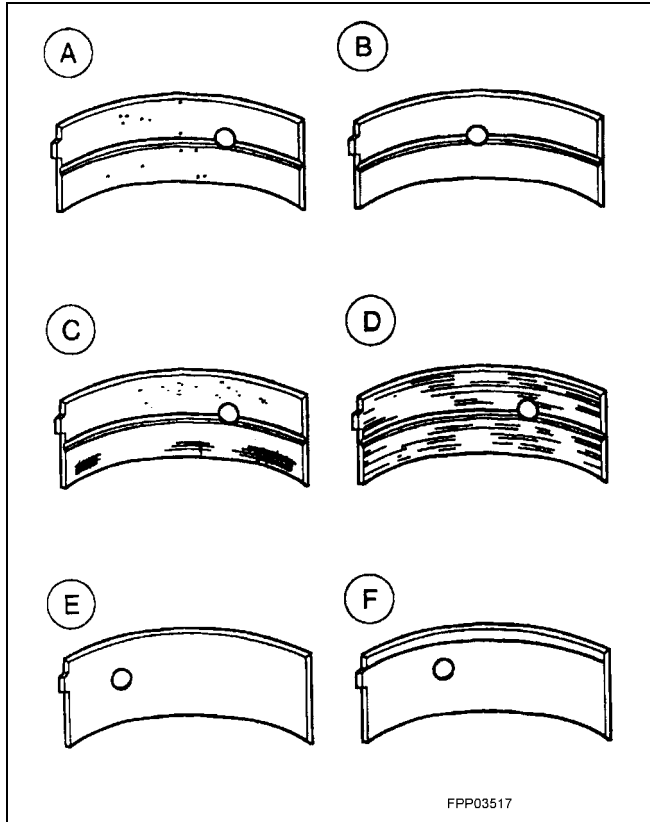


NOTE: Do not turn the crankshaft during this step.

Bearing Inspection

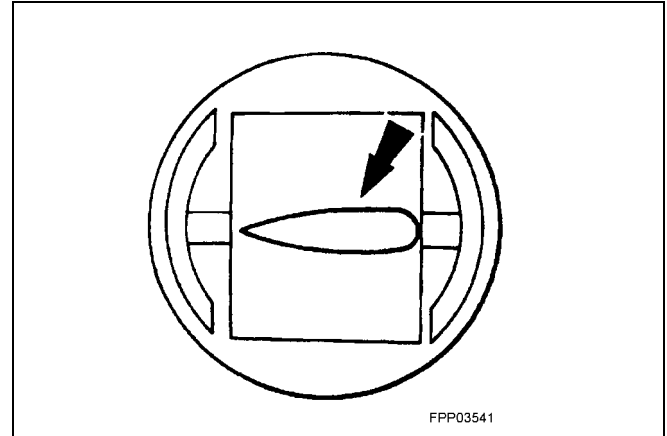
Inspect bearings for the following defects. Possible causes are shown:

- Cratering – fatigue failure (A)
- Spot polishing – improper seating (B)
- Scratching – dirty (C)
- Base exposed – poor lubrication (D)
- Both edges worn – journal damaged (E)
- One edge worn – journal tapered or bearing not seated (F)



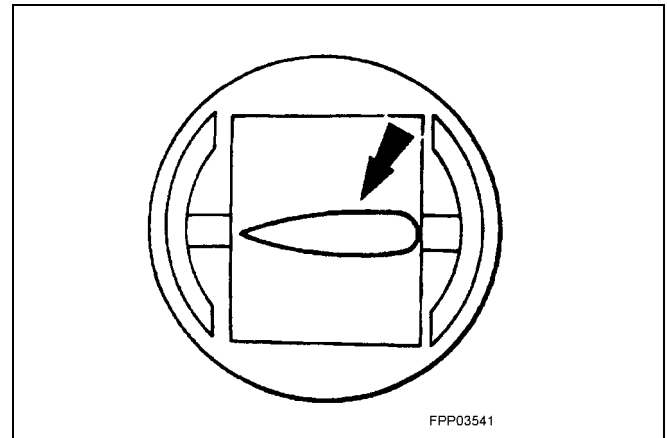
Roller Follower Inspection

- Inspect the roller for flat spots or scoring. If any damage is found, inspect the camshaft lobes and hydraulic lash adjusters for damage.



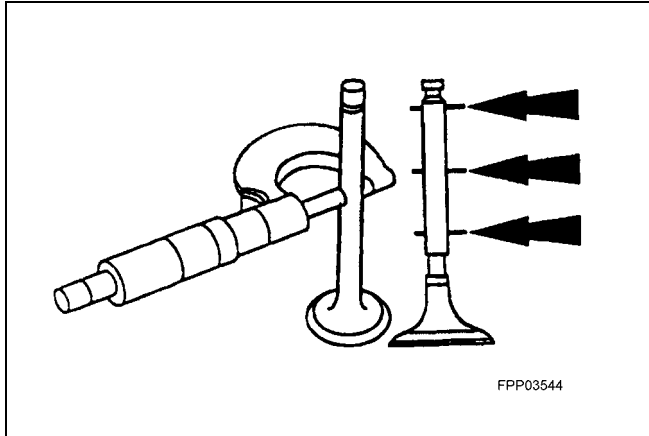
Hydraulic Lash Adjuster Inspection

- Inspect the hydraulic lash adjuster and roller for damage. If any damage is found, inspect the camshaft lobes and valves for damage.



Valve Stem Diameter

- Measure the diameter of each intake and exhaust valve stem at the points shown. Verify the diameter is within specification.



Valve Stem-to-Valve Guide Clearance

Special Tool(s)

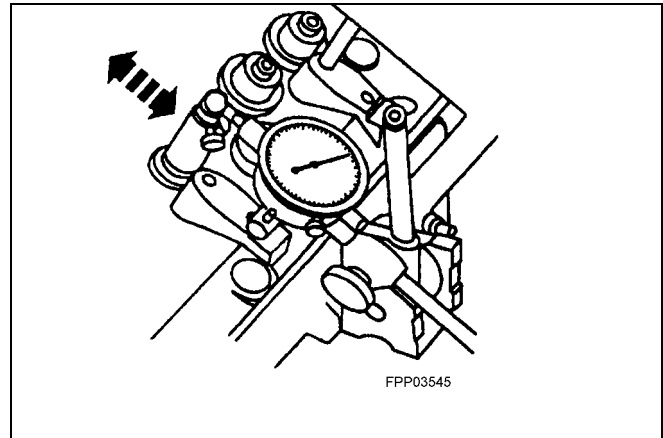
<p>FPP10026</p>	<p>Dial Indicator with Bracketry TOOL-4201-C or Equivalent</p>
<p>FPP10034</p>	<p>Valve Stem Clearance Tool TOOL-6505-E or Equivalent</p> <p>Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)</p>

NOTE: Valve stem diameter must be within specifications before checking valve stem to valve guide clearance.

NOTE: If necessary, use a magnetic base.

1. Install the Valve Stem Clearance Tool on the valve stem and install the Dial Indicator with Bracketry. Lower the valve until the Valve Stem Clearance Tool contacts the upper surface of the valve guide.

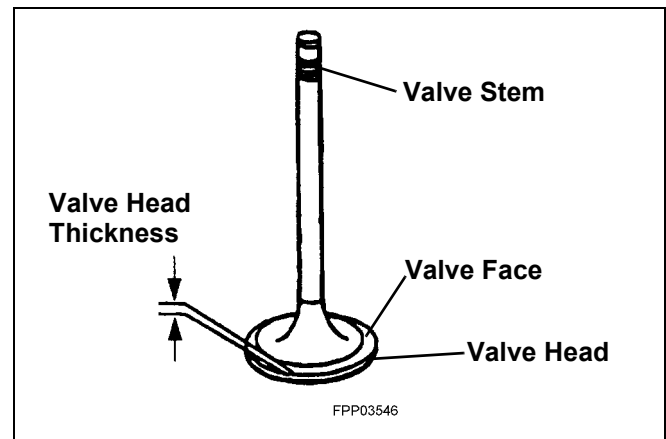
2. Move the Valve Stem Clearance Tool toward the Dial Indicator and zero the Dial Indicator. Move the Valve Stem Clearance Tool away from the Dial Indicator and note the reading. The reading will be double the valve stem-to-valve guide clearance. Valves with oversize stems will need to be installed if out of specification.



Valve Inspection

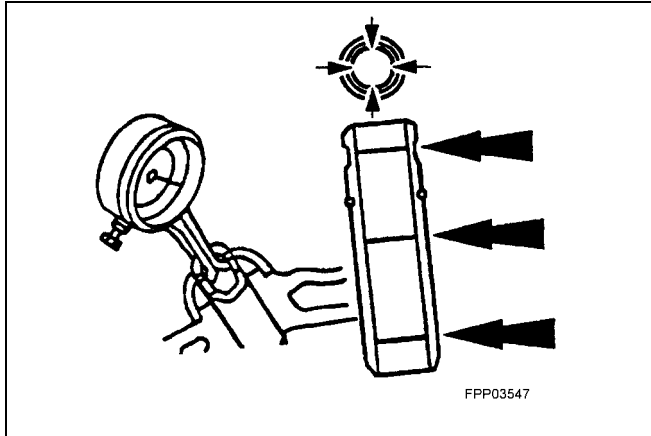
Inspect the following valve areas:

- The end of the stem for grooves or scoring.
- The valve face and the edge for pits, grooves or scores.
- The valve head for signs of burning, erosion, warpage and cracking. Minor pits, grooves and other abrasions may be removed.
- The valve head thickness for wear.



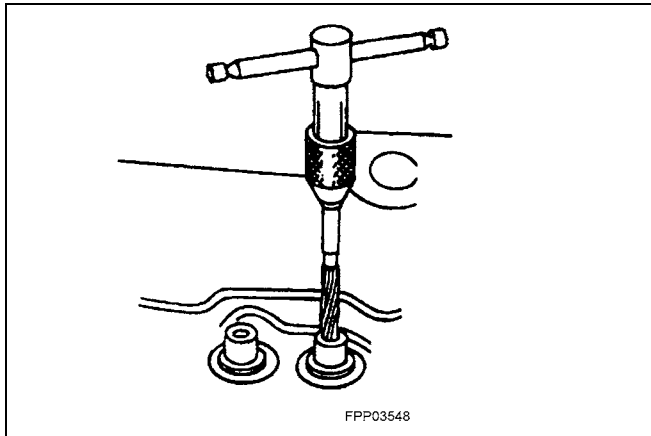
Valve Guide Inner Diameter

1. Measure the inner diameter of the valve guides in two directions where indicated.
2. If the valve guide is not within specifications, ream the valve guide and install a valve with an oversize stem or remove the valve guide and install a new valve guide.



Valve Guide Reaming

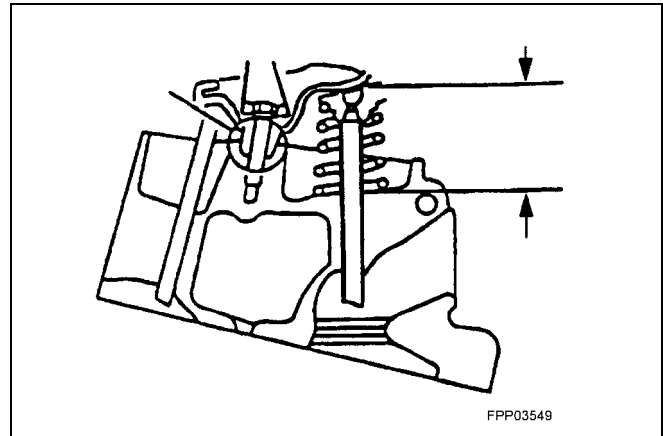
1. Use a hand-reaming kit to ream the valve guide.



2. Reface the valve seat.
3. Clean the sharp edges left by reaming.

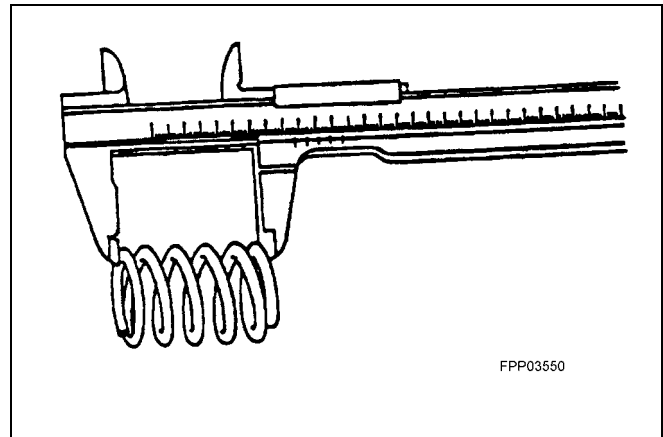
Valve Spring Installed Length

- Measure the installed length of each valve spring.



Valve Spring Free Length

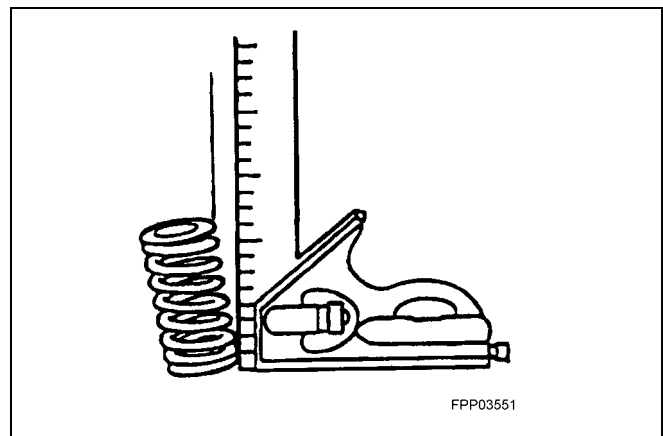
- Measure the free length of each valve spring.



Valve Spring Out-of-Square

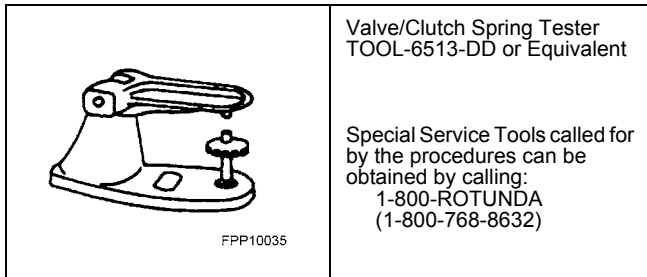
Measure the out-of-square on each valve spring.

- Turn the valve spring and observe the space between the top of the valve spring and the square. Replace the valve spring if out of specification.

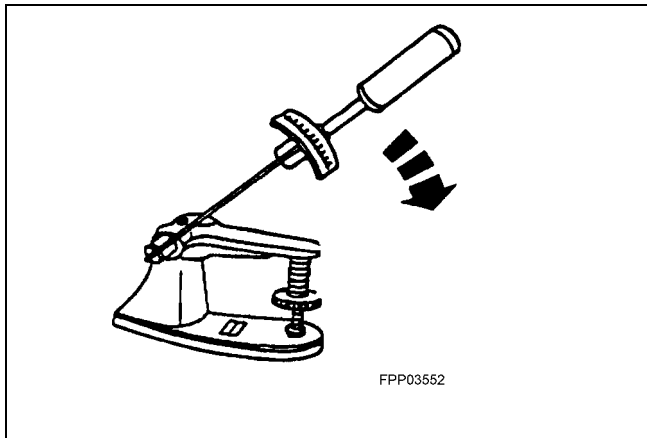


Valve Spring Compression Pressure

Special Tool(s)



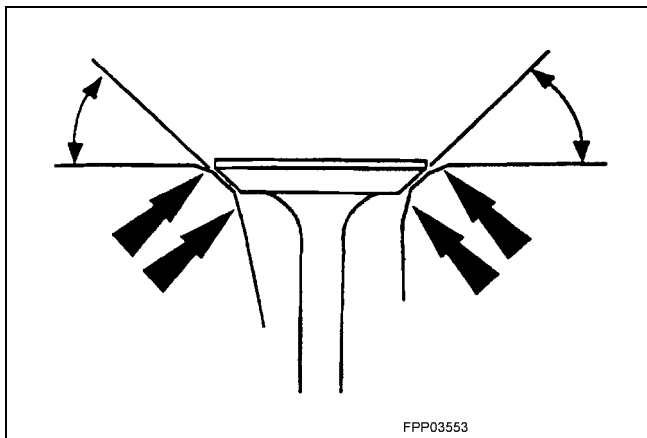
- Use the Valve/Clutch Spring Tester to check the valve springs for proper strength at the specified valve spring length.



Valve and Seat Refacing Measurements

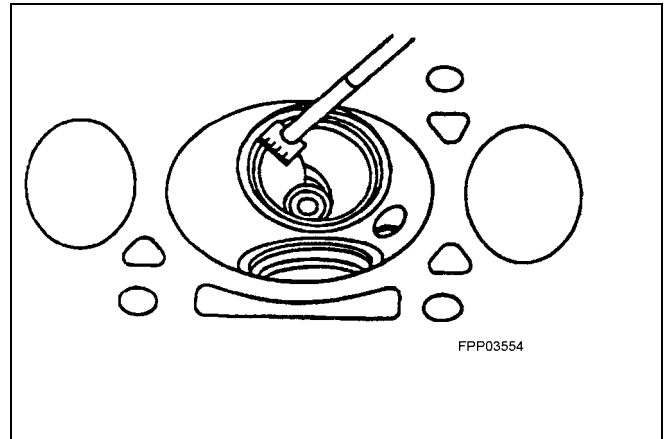
NOTE: After grinding valves or valve seats, check valve clearance.

- Check the valve seat and valve angles.



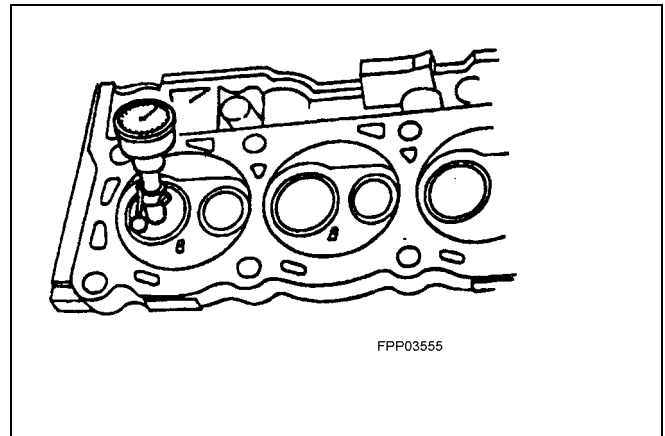
Valve Seat Width

- Measure the valve seat width. If necessary, grind the valve seat to specification.



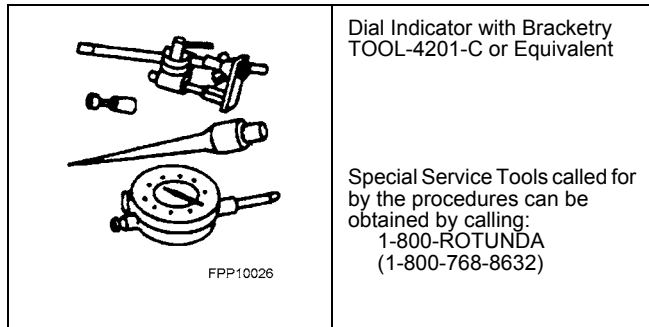
Valve Seat Runout

- Use the Valve Seat Runout Gauge to check valve seat runout.

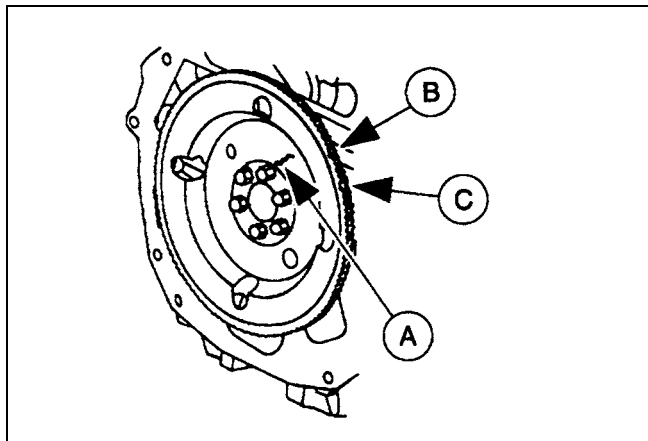


Flywheel Inspection

Special Tool(s)

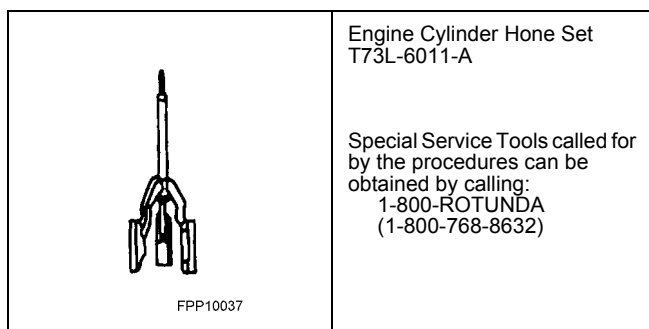


1. Inspect the flywheel for:
 - Cracks (A).
 - Worn ring gear teeth (B).
 - Chipped or cracked ring gear teeth (C).
2. Inspect the flywheel ring gear runout.



Cylinder Bore Honing

Special Tool(s)

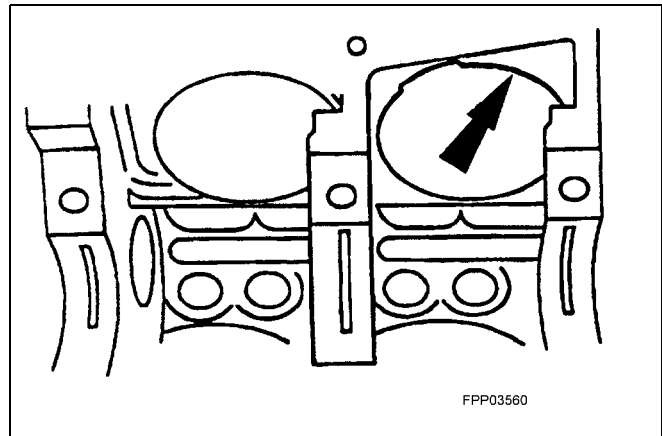


NOTE: Before any cylinder bore is honed, all main bearing caps must be installed so the crankshaft bearing bores will not become distorted.

NOTE: To correct taper or out-of-round, bore the cylinder block.

NOTE: Honing should be done when fitting new piston rings or to remove minor surface.

- Hone with the Engine Cylinder Hone Set, at a speed of 300-500 rpm and a hone grit of 180-220 to provide the desired cylinder bore surface finish.



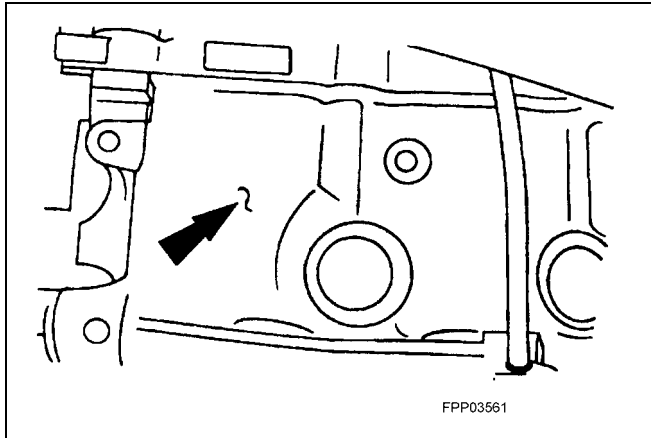
Cylinder Bore Cleaning

CAUTION: If these procedures are not followed, rusting of the cylinder bores may occur.

1. Clean the cylinder bores with soap or detergent and water.
2. Thoroughly rinse with clean water and wipe dry with a clean, lint-free cloth.
3. Use a clean, lint-free cloth and lubricate the cylinder bores.
 - Use Engine Oil XO-10W30-QSP or -DSP or equivalent meeting Ford specification ESE-M2C153-E.

Cylinder Block Repair - Cast Iron Porosity Defects

CAUTION: Do not attempt to repair cracks, areas where temperature will exceed 260°C (500°F) or areas exposed to engine coolant or oil. These areas will not repair and could cause future failure.

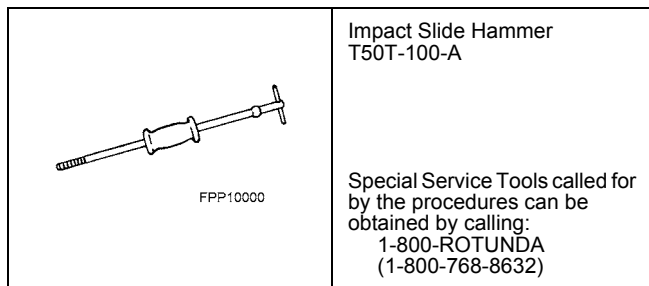


Repair porosity defects with an epoxy sealer meeting Ford specification M3D35-A (E).

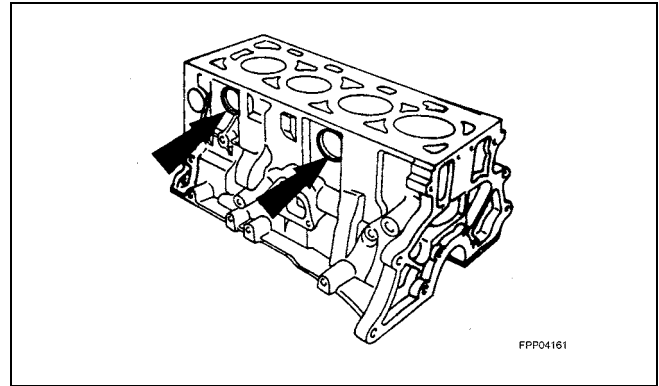
1. Clean the surface to be repaired to a bright, oil-free metal surface.
2. Chamfer or undercut the repair area to a greater depth than the rest of the cleaned surface. Solid metal must surround the area to be repaired.
3. Apply the epoxy sealer and heat-cure with a 250-watt lamp placed 254 mm (10 inches) from the repaired surface, or air dry for 10-12 hours at a temperature above 10°C (50°F).
4. Sand or grind the repaired area to blend with the general contour of the surface.
5. Paint the surface to match the rest of the cylinder block.

Cylinder Block Core Plug Replacement

Special Tool(s)



1. Use a slide hammer or tools suitable to remove the cylinder block core plug.



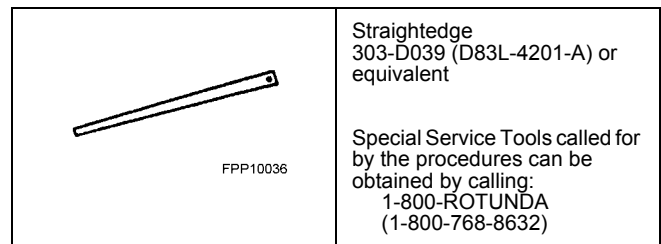
2. Inspect the cylinder block plug bore for any damage that would interfere with the proper sealing of the plug. If the cylinder block plug bore is damaged, bore for the next oversize plug.

NOTE: Oversize plugs are identified by the OS stamped in the flat located on the cup side of the plug.

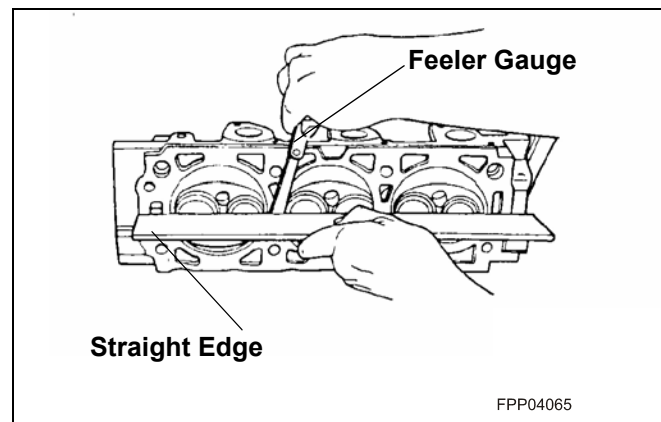
3. Coat the cylinder block core plug and bore lightly with Threadlock® 262 E2FZ-19554-B or equivalent meeting Ford specification WSK-M2G351-A6 and install the cylinder block core plug.

Cylinder Head - Distortion

Special Tool(s)



- Use a straight edge and a feeler gauge to inspect the cylinder head for flatness. Compare with specifications. If the cylinder head is distorted, install a new cylinder head.

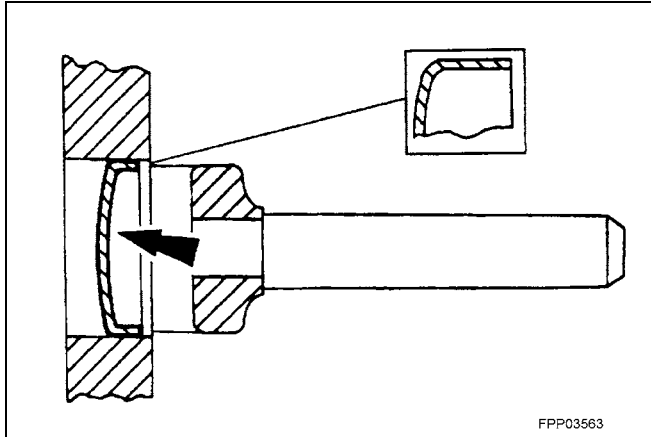


Cylinder Block Core Plug – Cup-Type

CAUTION: Do not contact the flange when installing a cup type cylinder block core plug as this could damage the sealing edge and result in leakage.

NOTE: When installed, the flanged edge must be below the chamfered edge of the bore to effectively seal the bore.

- Use a fabricated tool to seat the cup type cylinder block core plug.



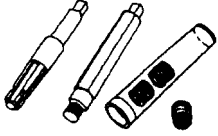
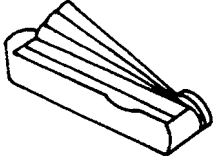
Cylinder Block Core Plug – Expansion-Type

CAUTION: Do not contact the crown when installing an expansion type cylinder block core plug. This could expand the plug before seating and result in leakage.

- Use a fabricated tool to seat the expansion type cylinder block core plug.

Spark Plug Thread Repair

Special Tool(s)

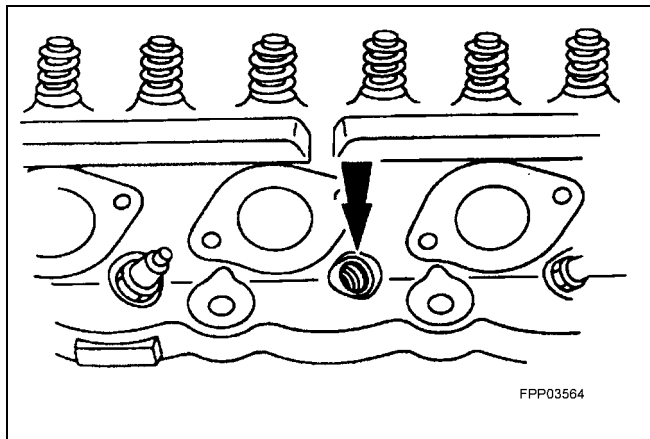
 <p>FPP10038</p>	<p>Tapersert Installation Kit 107-R0921 or Equivalent</p>
 <p>FPP10033</p>	<p>Feeler Gauge D81L-4201-A or Equivalent</p> <p>Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)</p>

CAUTION: The cylinder head must be removed from the engine before installing a tapersert. If this procedure is done with the cylinder head on the engine, the cylinder walls can be damaged by metal chips produced by the thread cutting process.

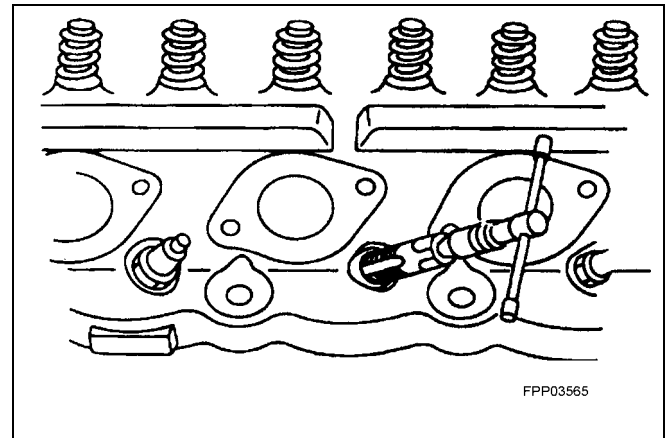
CAUTION: Do not use power or air-driven tools for finishing taperserts.

NOTE: This repair is permanent and will have no effect on cylinder head or spark plug life.

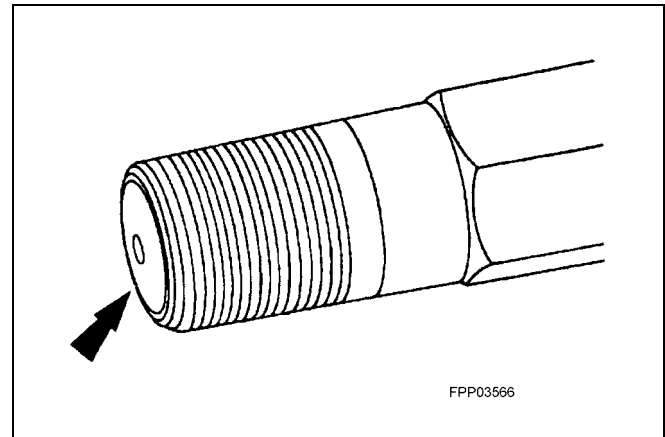
1. Clean the spark plug seat and threads.



2. Start the tap into the spark plug hole, being careful to keep it properly aligned. As the tap begins to cut new threads, apply aluminum cutting oil.

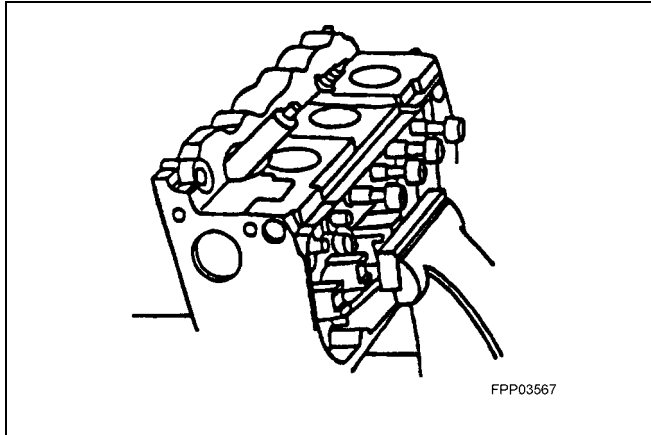


3. Continue cutting the threads and applying oil until the stop ring bottoms against the spark plug seat.
4. Remove the tap and metal chips.
5. Coat the threads of the mandrel with cutting oil. Thread the tapersert onto the mandrel until one thread of the mandrel extends beyond the tapersert.

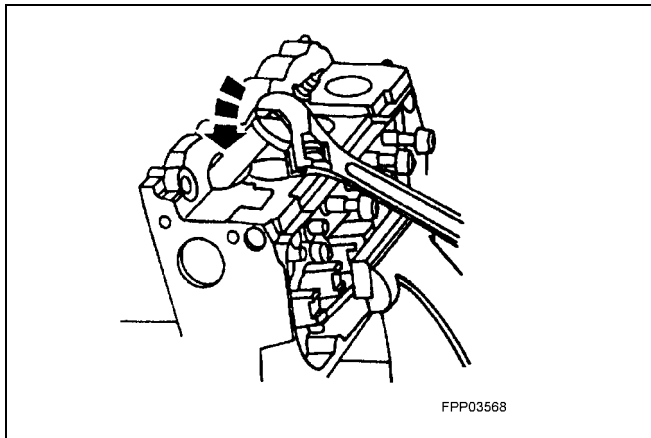


NOTE: A properly installed tapersert will be either flush with or 1.0 mm (0.039 inch) below the spark plug gasket seat.

6. Tighten the tapersert into the spark plug hole.



7. Turn the mandrel body approximately one-half turn counterclockwise and remove.

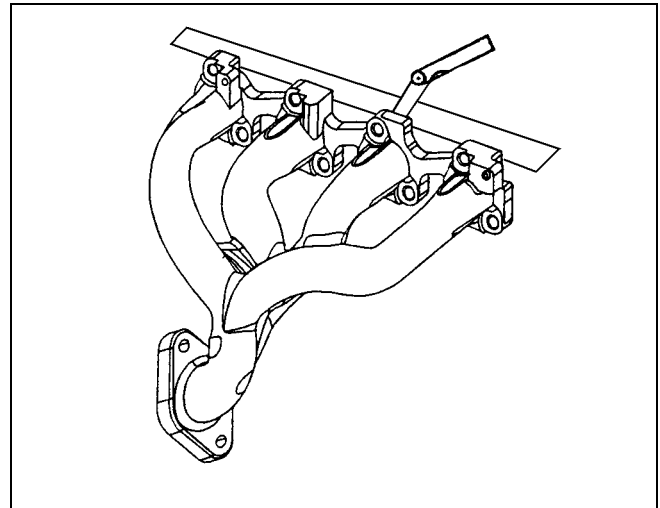


Exhaust Manifold Straightness

Special Tool(s)

<p>FPP10036</p>	<p>Straightedge 303-D039 (D83L-4201-A) or equivalent</p> <p>Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)</p>
-----------------	---

- Place the Straightedge across the exhaust manifold flanges and check for warping with a feeler gauge.



SPECIFICATIONS

GENERAL SPECIFICATIONS	
Epoxy Sealer	M3D35-A (E)
Threadlock 262 E2FZ-19554-B	WSK-M2G351-A6
Engine Oil SAE 5W30	D9AZ-19579A

NOTE: Ford Power Products industrial engines are designed to perform with engine oils that are licensed by the American Petroleum Institute (API), and oils carrying the most current API classification should be used.

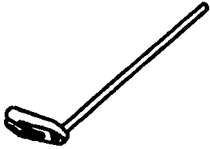

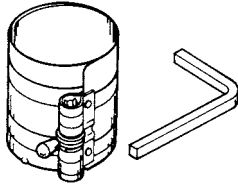
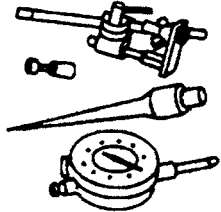
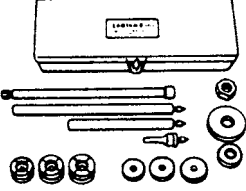
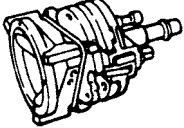
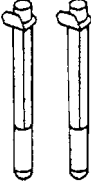

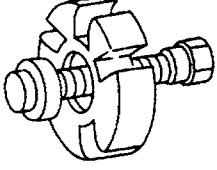
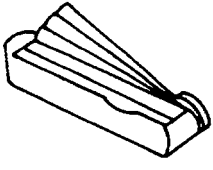
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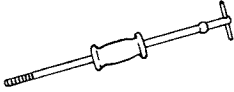
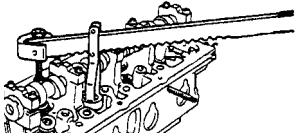
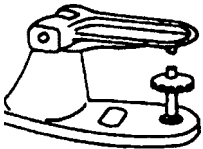
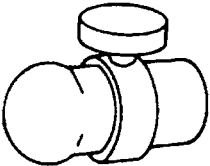
NOTE: For engine diagnosis, refer to Section 01.

GENERAL INFORMATION

Special Tools

	Valve Spring Compressor T81P-6513-A or Equivalent		Seal Remover T92C-6700-CH or Equivalent
	Piston Ring Compressor D81L-6002-C or Equivalent		Dial Indicator with Bracketry TOOL-4201-C or Equivalent
	Camshaft Bearing Set T65L-6250-A or Equivalent		Cylinder Ridge Reamer T64L-6011-EA or Equivalent
	Connecting Rod Guide Tool T93P-6136-A or Equivalent		Vibration Damper Remover Adapter T82L-6316-B or Equivalent
	Crankshaft Damper Remover T58P-6316-D or Equivalent		Feeler Gauge D81L-4201-A or Equivalent

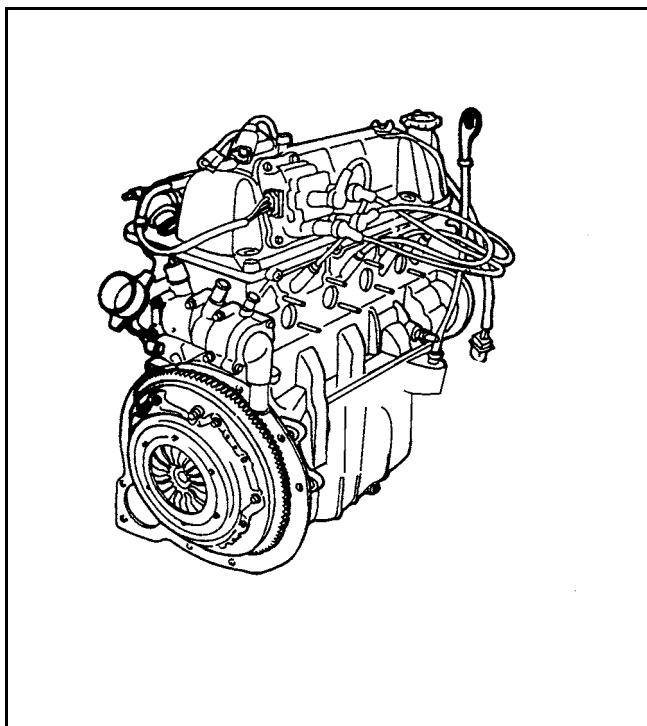
Special Tools

 <p>FPP10000</p>	<p>Impact Slide Hammer T50T-100-A or Equivalent</p>		<p>Valve Seal Tool 21-024 or Equivalent</p>
	<p>Pound/Inch Torque Wrench Purchase from Local Tool Dealer</p>		<p>Extra space</p>
 <p>FPP10035</p>	<p>Spring Tester 303-006 or TOOL-6513-DD or Equivalent</p>		<p>Extra space</p>
 <p>FPP10034</p>	<p>Valve Clearance Measuring Tool 100-002 or TOOL-6505-E or Equivalent</p>		<p>Extra space</p>
	<p>Spring Testing Fixture 21-024 or Equivalent</p>		<p>Extra space</p>

Description

The 1.6L 4 cylinder Zetec Rocam engine has been developed with the highest technology. Its main characteristics are:

- electronic controlled multipoint sequential injection
- roller finger follower camshaft
- intake manifold made of aluminum
- high resistance aluminum cylinder head
- steel oil pan.

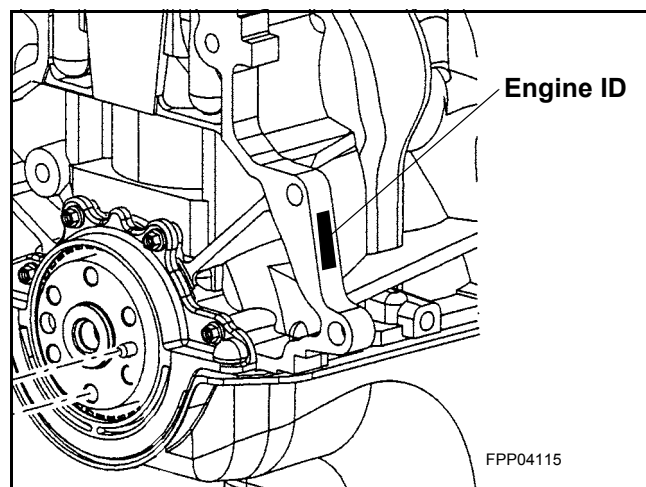


Cylinder Head

The Zetec Rocam engine cylinder head is entirely made of aluminum which improves the thermal characteristics and reduces weight. The assembly is attached using a multi layer steel gasket and 12 bolts.

Oil Pan

The Zetec Rocam engine oil pan is made of steel. The gasket must always be replaced whenever the oil pan is removed.



Engine Identification Number

The engine identification number is marked on the right side of the cylinder block as shown.

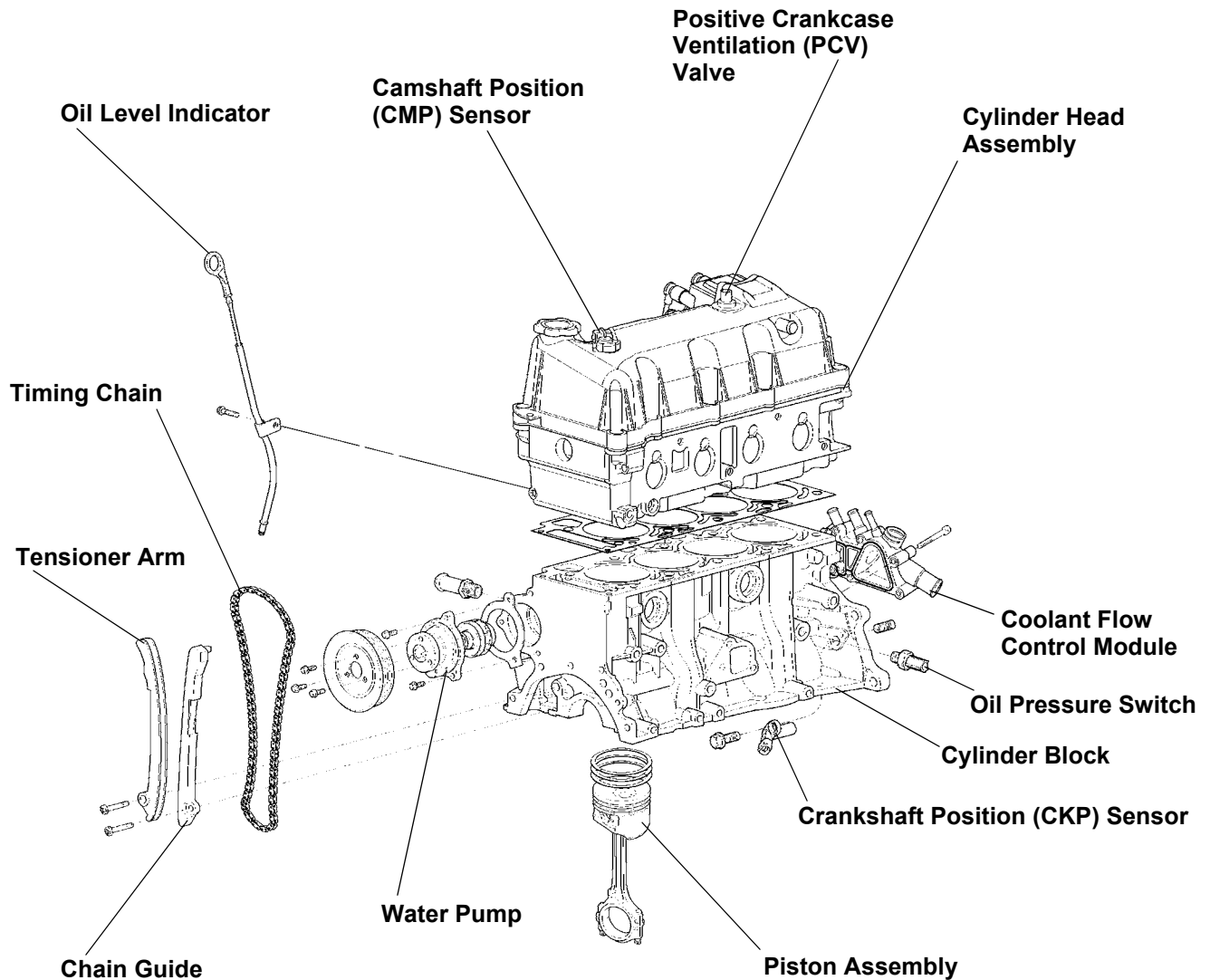
Fuel System

The electronic fuel injection (EFI) system is electronically controlled by an ECM module which carefully controls fuel-air mixture along with spark timing, depending on information received from various sensors.

Intake Manifold

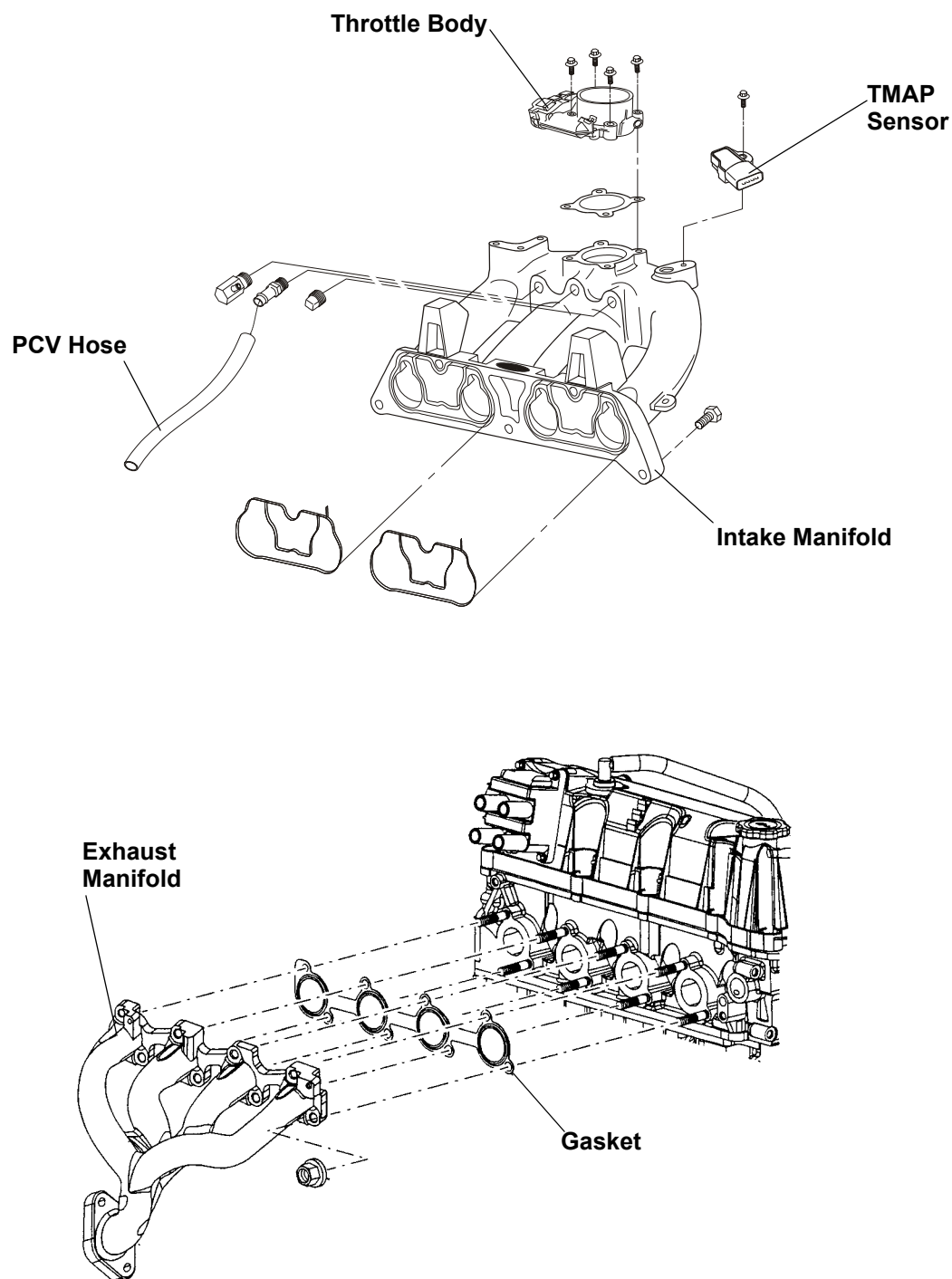
The intake manifold is made of aluminum. It consists of two pieces.

Component Location

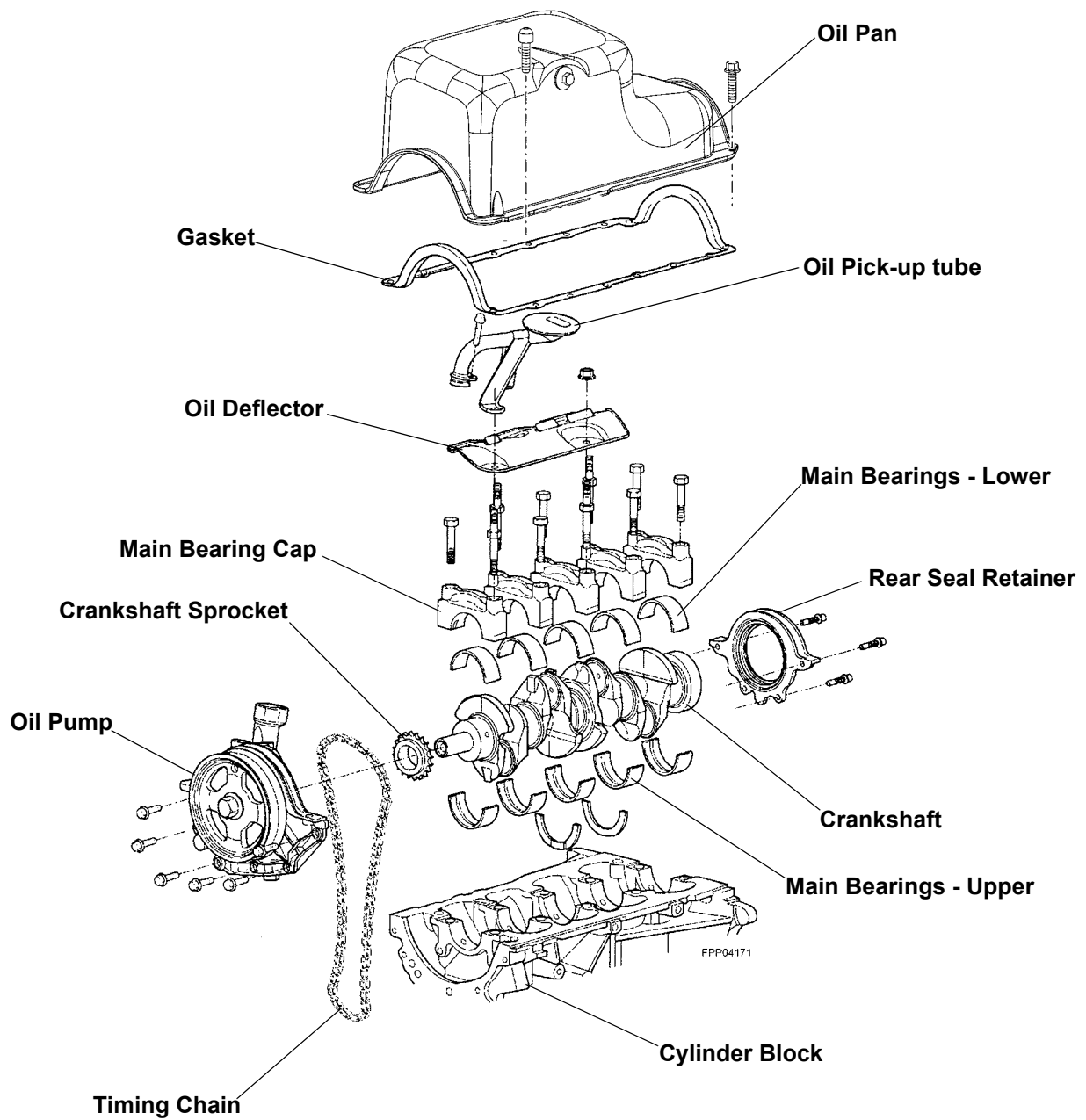


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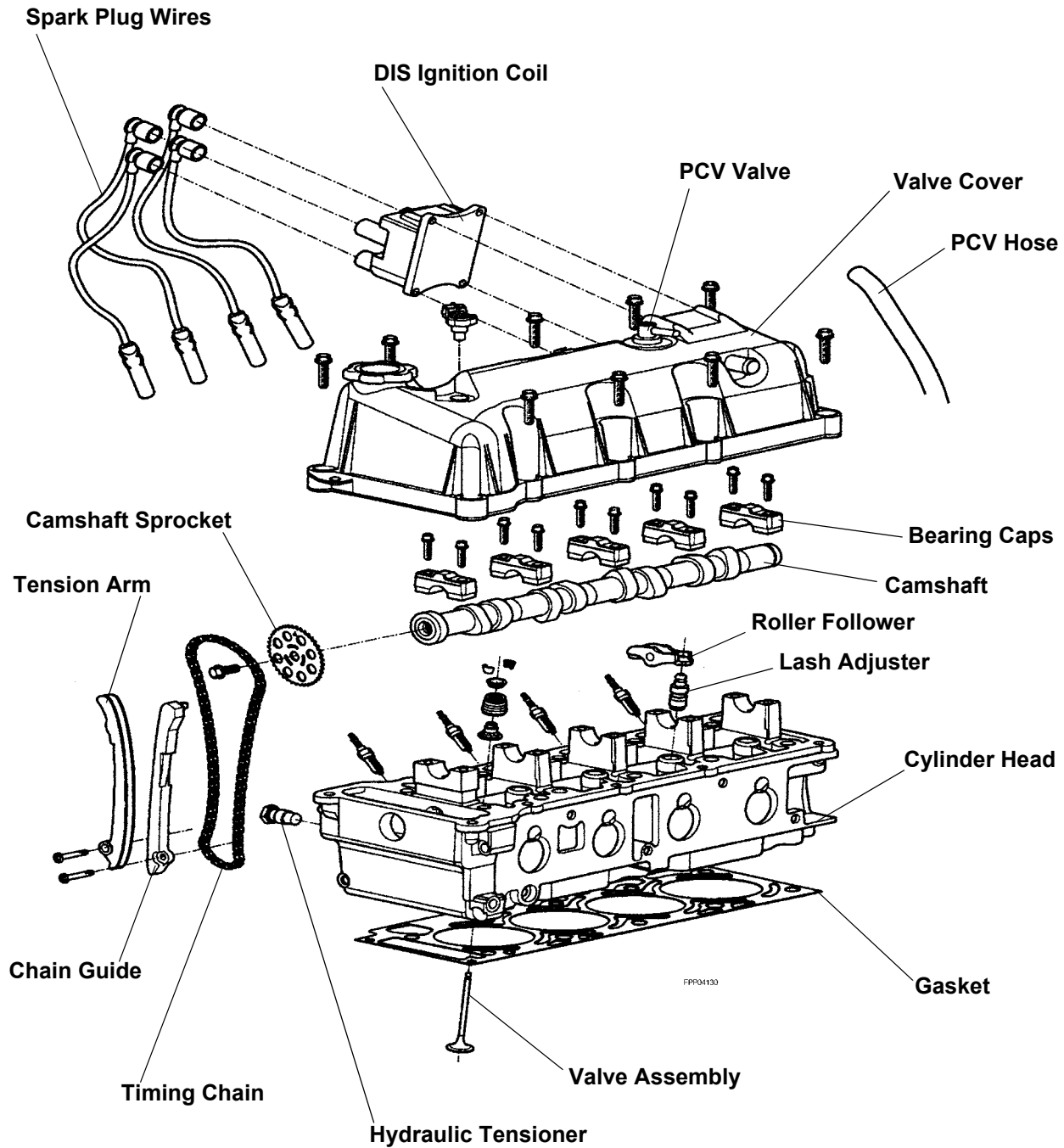
Component Location



Component Location



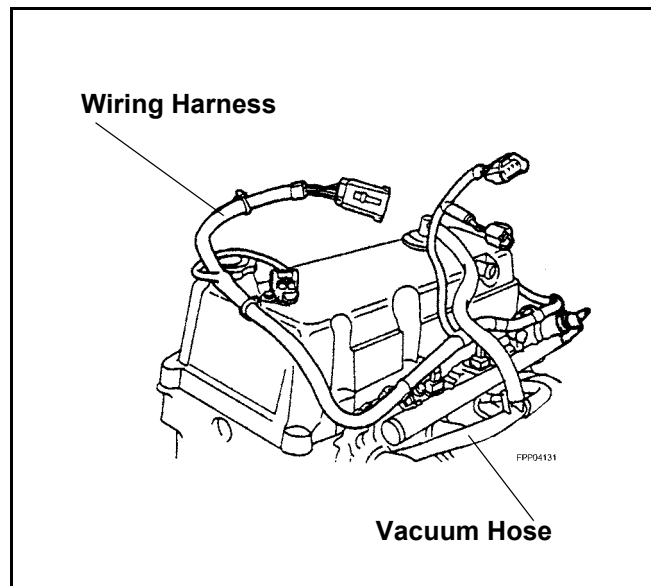
Component Location



ENGINE REPAIR

Valve Cover - Removal

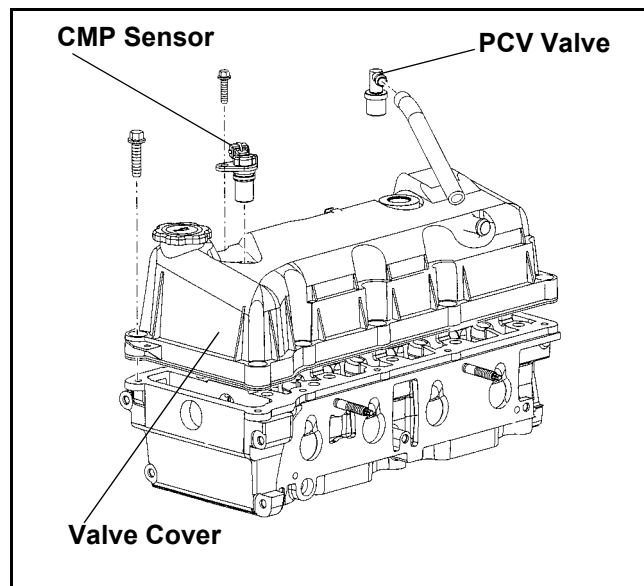
1. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.



- 2.
- 3.
4. Remove DIS coil and set aside - refer to Section 03.
5. Remove bolts.
6. Remove valve cover and gasket.

Valve Cover - Installation

1. Contact surfaces must be clean and free of oil.
2. Install a new gasket and valve cover.

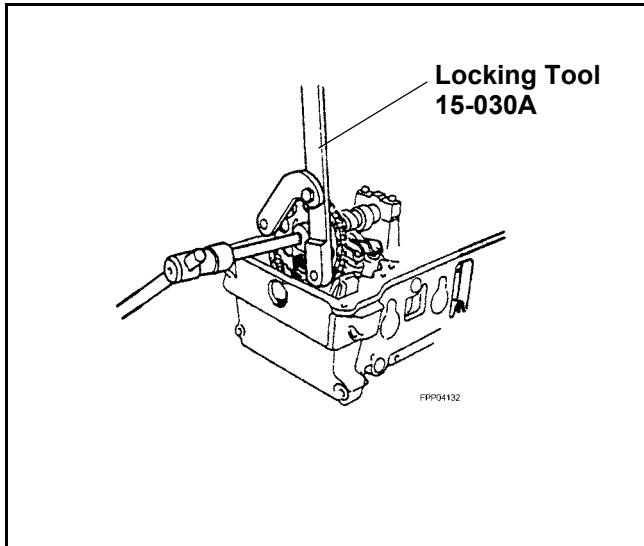


3. Install bolts. Tighten to 7 lb.ft. (9 Nm). (?any sequence ?).
4. Install DIS coil - refer to Section 03.
- 5.
- 6.
7. Reconnect any wiring and vacuum hoses removed.

Camshaft- Removal

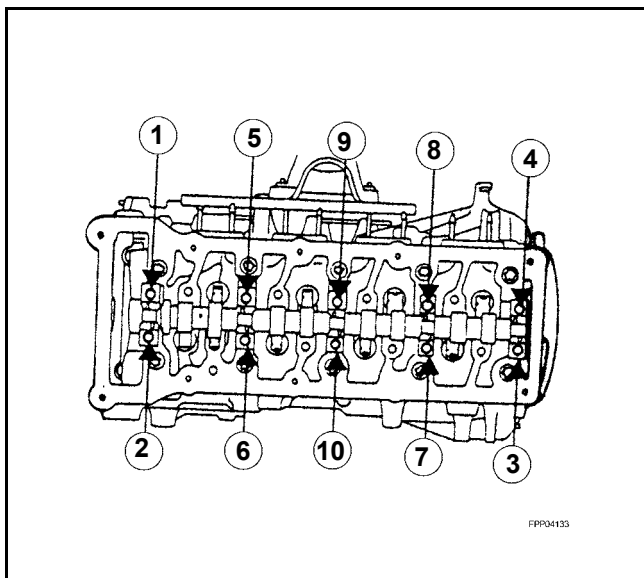
NOTE: Store components to ensure assembly in the same order as they were removed.

1. Remove valve cover -- Refer to "Valve Cover - Removal" on page 10.
2. Using tool 15-030A to lock camshaft sprocket, remove bolt.

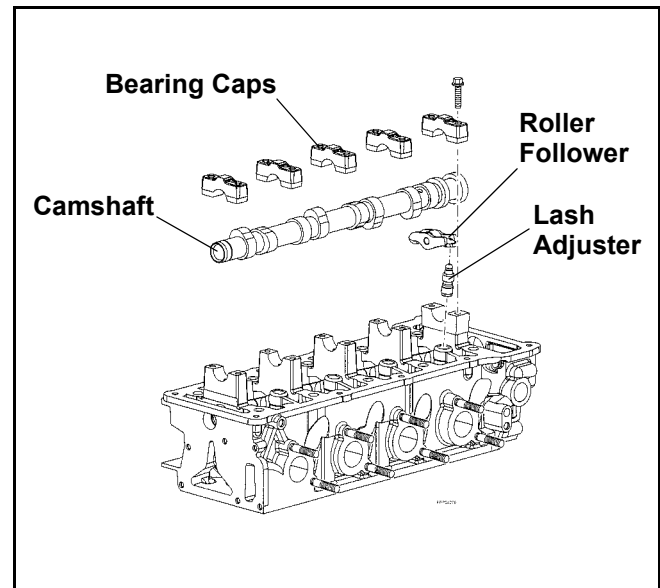


CAUTION: During camshaft removal, the camshaft sprocket and chain must remain engaged and the chain tensioned in order to keep timing links aligned. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned - refer to timing chain assembly xxx.

3. Separate camshaft sprocket and chain from camshaft while maintaining tension on the chain.
4. Remove bolts and camshaft bearing caps evenly in the sequence shown.



5. Remove camshaft, lower bearings, roller followers and lash adjusters.



6. ?

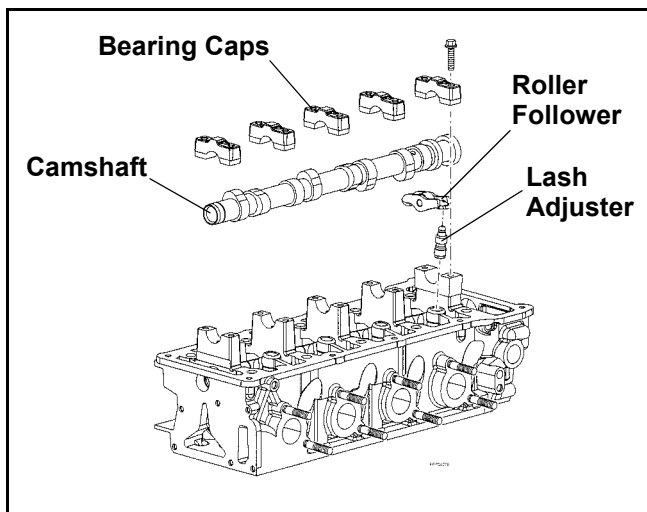
7. ?

Refer to Section 01 for camshaft and bearing service.

Camshaft - Installation

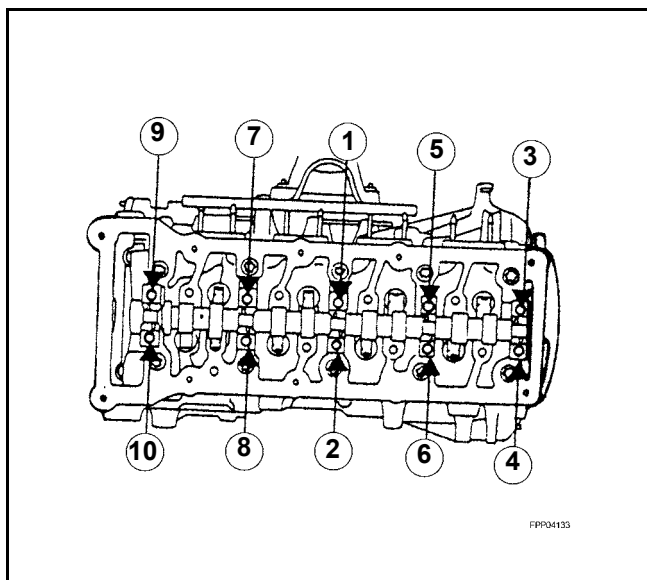
NOTE: All components must be clean and assembled in the same positions as removed. Lubricate contact surfaces with clean engine oil.

- 1.
- 2.
3. Install lash adjusters.
4. Install roller followers.



NOTE: The chamfer on the camshaft bearing caps must be facing the chain housing. Rotate camshaft so keyway will align with sprocket.

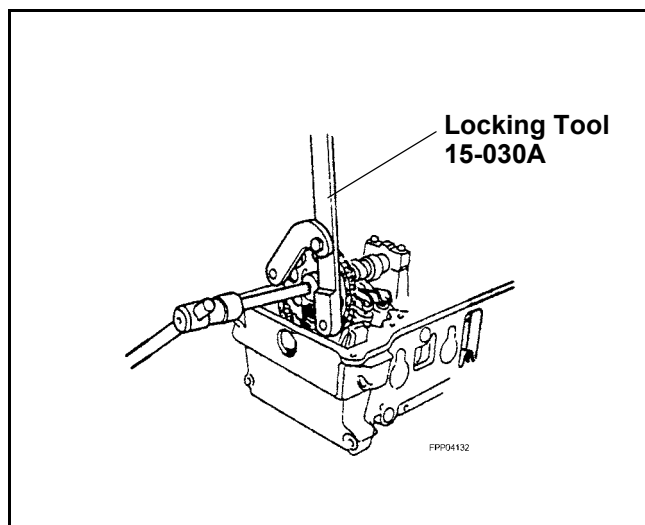
5. Carefully install camshaft, bearings, caps and bolts finger tight.
6. Tighten bolts in the sequence shown in 3 steps to 6-7 lb.ft. (8-10 Nm).



7. Install camshaft sprocket with chain onto camshaft while maintaining tension on the chain.

CAUTION: The camshaft sprocket and chain must remain engaged and the chain tensioned in order to keep timing links aligned. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned - refer to timing chain assembly xxx.

8. Using tool 15-030A, install bolt and tighten to 52-59 lb.ft. (70-80 Nm).



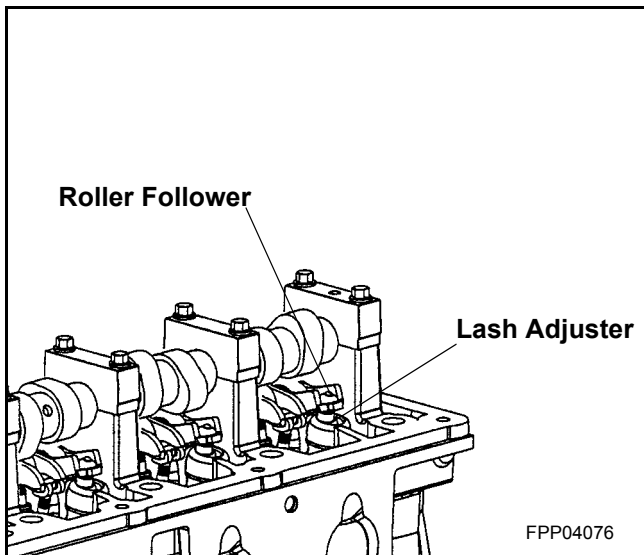
9. Install valve cover -- Refer to "Valve Cover - Installation" on page 10.

Valve Stem Seal - Removal

NOTE: If the valve or valve seat has not been damaged, the valve spring, seal, retainer or keys may be replaced by holding the affected valve closed using compressed air.

Use an appropriate air line tool installed in the spark plug hole. A minimum of 965 kPa (140 psi) line pressure is required. If air pressure does not hold the valve shut, the valve is damaged or burned and the cylinder head must be removed and serviced.

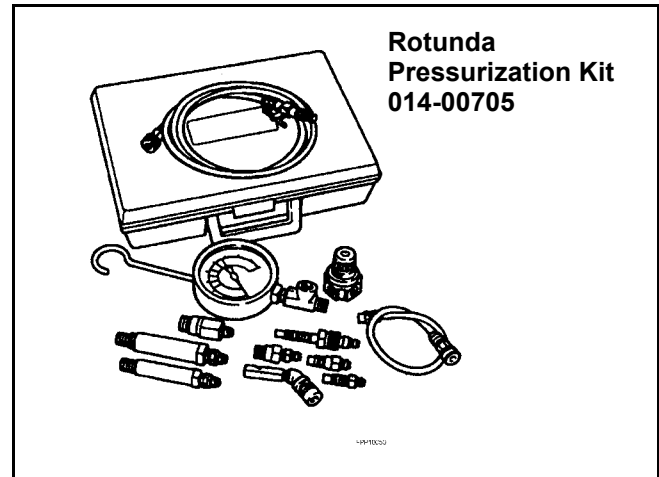
1. Remove valve cover -- Refer to "Valve Cover - Removal" on page 10.
2. Rotate the camshaft so the roller follower for the valve to be serviced is on the heel of the cam.
3. Using a suitable valve spring compressor tool, compress and hold down the valve spring. Slide out the roller follower over the lash adjuster.



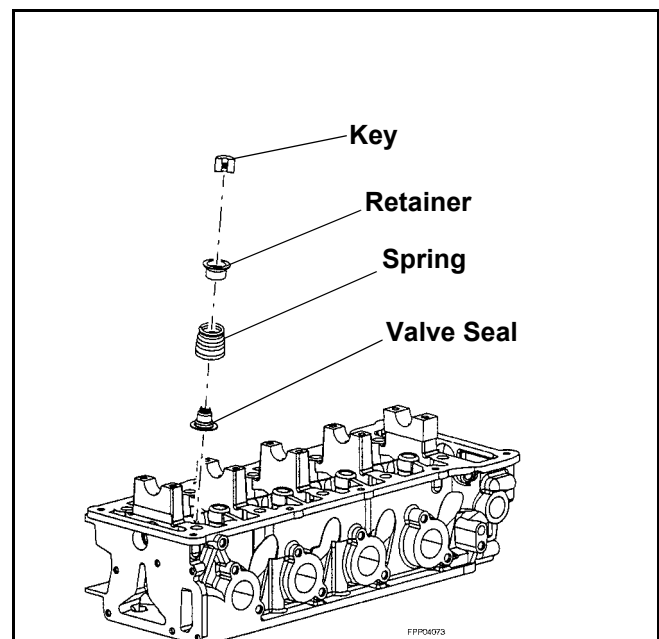
4. Replace spark plug for cylinder being serviced with an air line adapter. Mark location so spark plug is returned to the same cylinder.

CAUTION: The crankshaft may rotate when air pressure is applied. Remove all objects from fan area such as lights, extension cords, etc.

5. Turn on air supply and pressurize cylinder. Air pressure may rotate the crankshaft until the piston reaches the bottom of the stroke.



6. Using a suitable valve spring compressor, compress the valve spring and remove the keys and retainer. Remove and discard the stem seal.



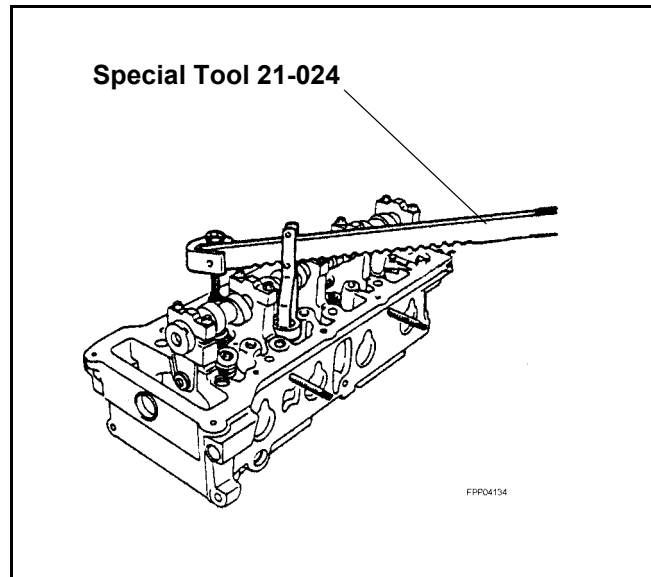
7. If air pressure has forced the piston to the bottom of the cylinder, any removal of air pressure will allow the valve(s) to drop into the cylinder. Wrap a rubber band, tape or string around the end of the valve stem in such a way to prevent the valve from falling in and to allow enough travel to check the valve for binds.
8. Inspect the valve stem for damage. Rotate the valve and check the stem tip for eccentric movement. Move the valve up and down through normal travel in the valve guide and check the stem for any binding. If the valve has been damaged, it will be necessary to remove the cylinder head as outlined in this section.

Valve Stem Seal - Installation

NOTE: All components must be clean and assembled in the same positions as removed. Lubricate contact surfaces with clean engine oil.

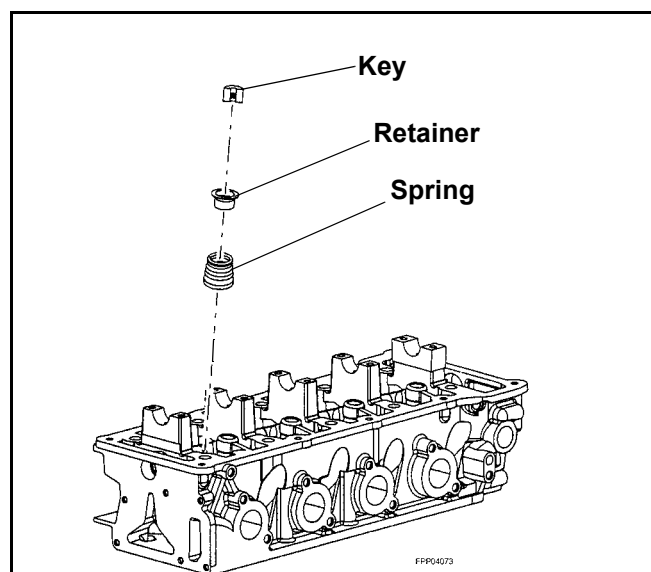
CAUTION: Valve stem seal can be cut by grooves in valve stem. A damaged seal will leak causing oil burning and valve fouling.

1. Carefully slide oil seal over valve stem.
2. Install new valve seal using special tool 21-024 (optional T95P-6565A) ??protective cap??.

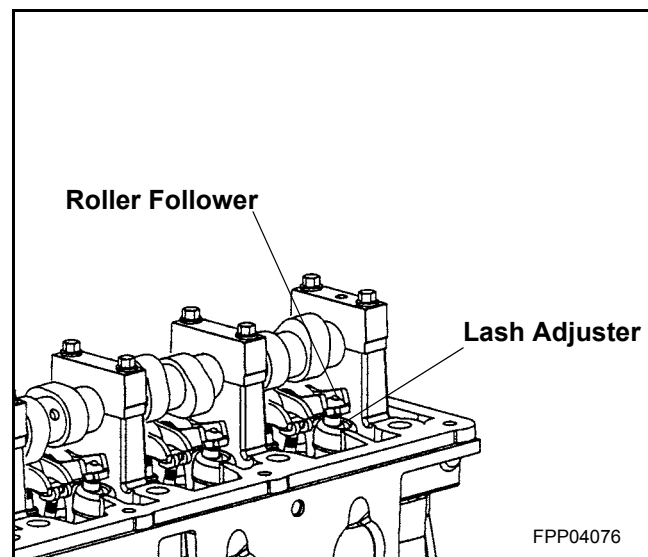


NOTE: Apply a small amount of Ford Multi-purpose Grease D0A2-19584-AA, or equivalent, meeting Ford specification ESR-M1C159-A to valve spring retainer key to hold in place during installation.

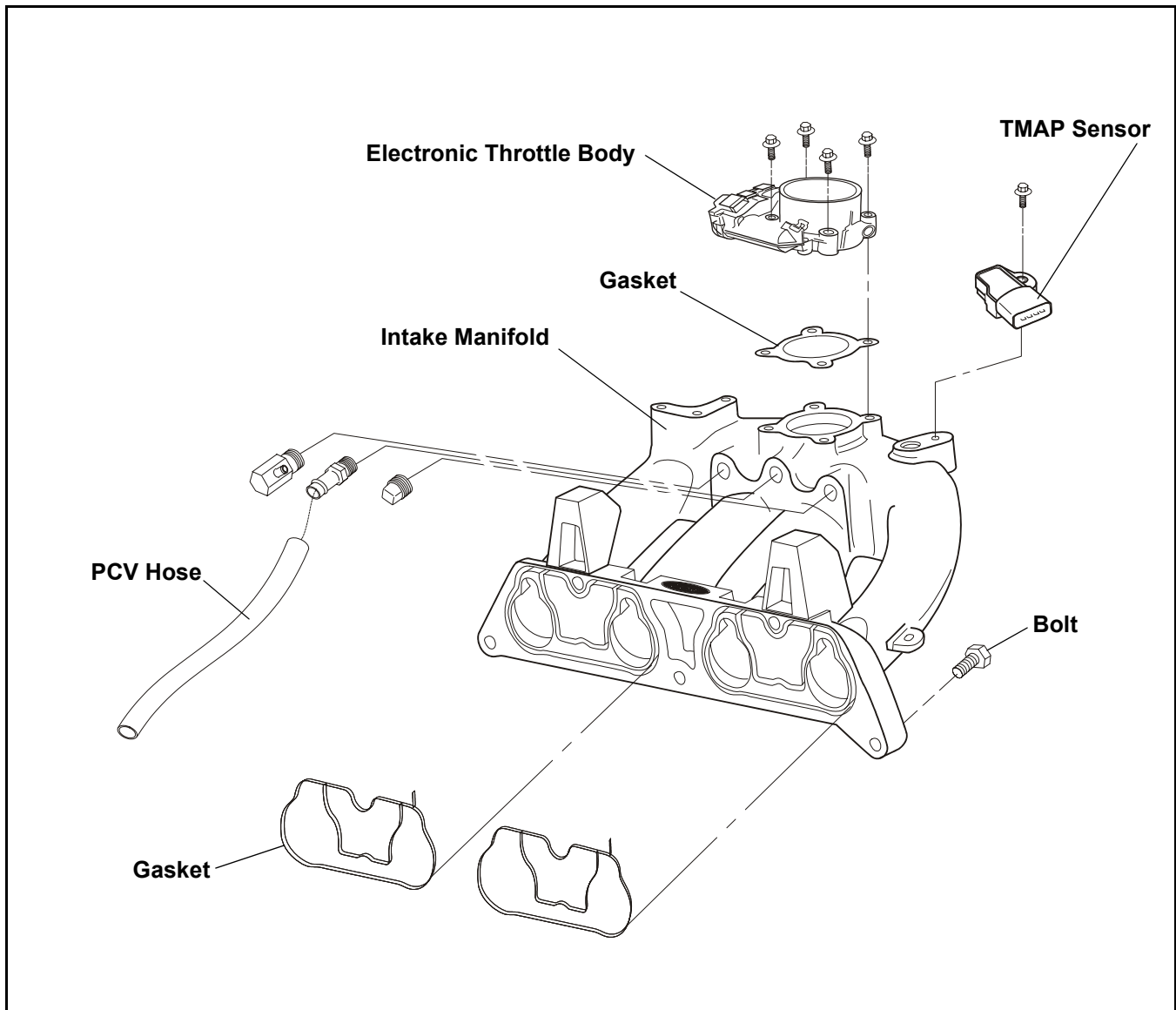
3. With cylinder pressurized and using a suitable spring compressor tool, install valve spring, retainer and locks.



4. Release air pressure and remove air adapter. Install spark plug in proper cylinder.
5. Grease contact surfaces of roller follower with Ford Multi-purpose Grease D0AZ-19584-AA, or equivalent, meeting Ford specification ESR-M1C159-A.
6. Using spring compressor, compress and hold down the valve and spring. Slide the roller finger follower into place over valve and lash adjuster. Release spring.



7. Install valve cover -- Refer to "Valve Cover - Installation" on page 10.



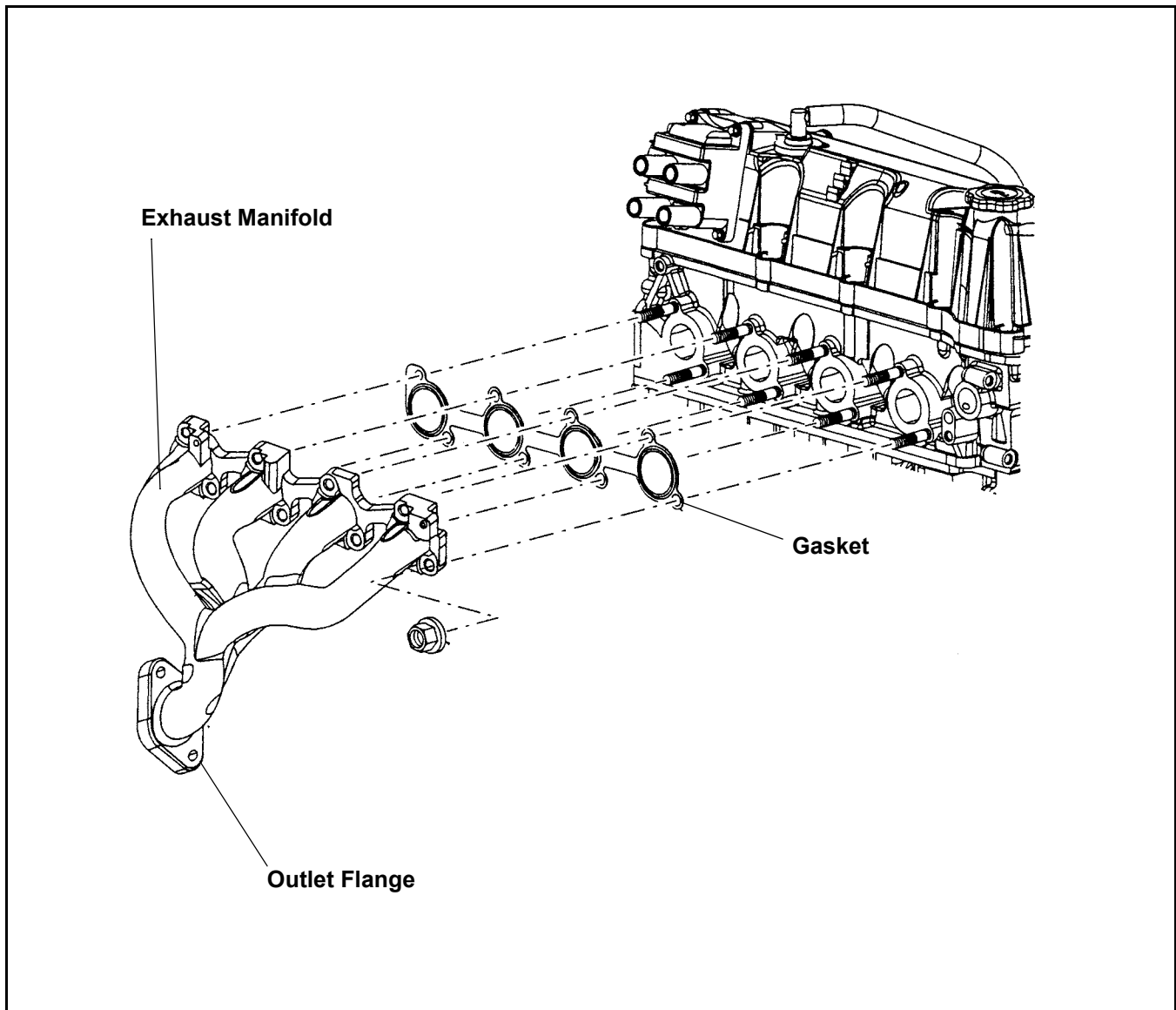
Intake Manifold - Removal

1. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.
2. Relieve fuel pressure.
3. Disconnect fuel lines from fuel rail.
4. Disconnect air intake tube.
- 5.
- 6.
7. Remove bolts, nuts and intake manifold assembly.

Intake Manifold - Installation

NOTE: All contact surfaces must be clean and free from any old gasket material.

1. Install a new gasket and intake manifold assembly.
2. Install bolts and nuts. Tighten to 6 lb.ft. (8 Nm).
- 3.
- 4.
5. Connect air intake tube.
6. Connect fuel lines to fuel rail.
7. Install any wiring and vacuum hoses that were removed. Connect and route as they were removed.



Exhaust Manifold - Removal

1. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.
2. Disconnect exhaust at outlet flange.
- 3.
- 4.
5. Remove nuts, exhaust manifold and gasket.

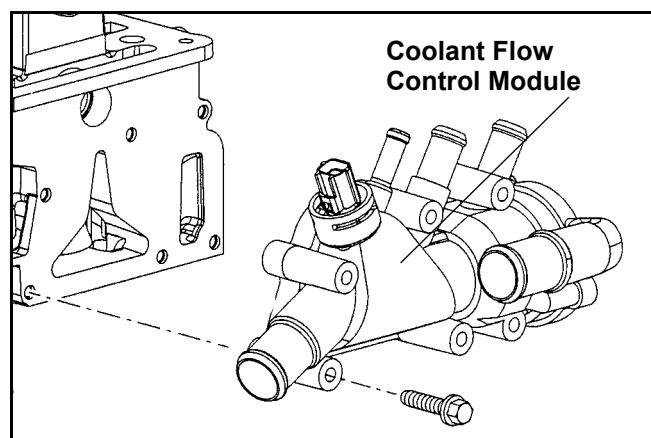
Exhaust Manifold - Installation

NOTE: All contact surfaces must be clean and free from any old gasket material.

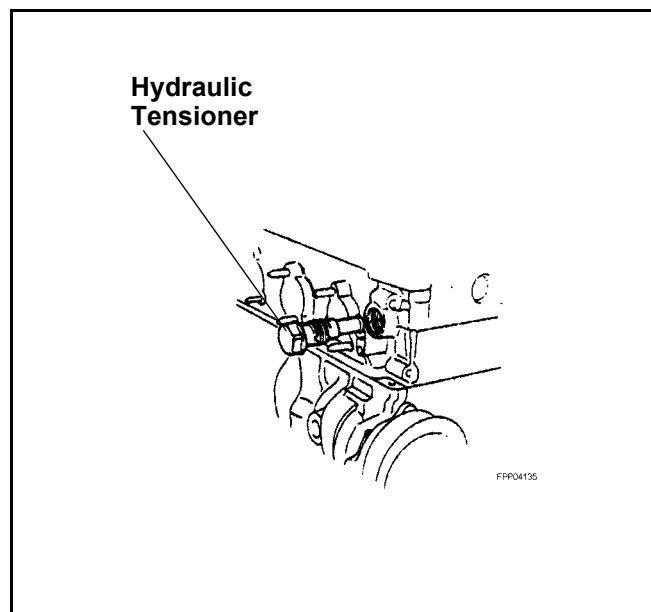
1. Install a new gasket and exhaust manifold.
2. Install nuts. Tighten to 11 lb.ft. (15 Nm).
- 3.
- 4.
5. Connect exhaust at outlet flange.
6. Tighten flange nuts to xx lb.ft. (xx Nm).
7. Install any wiring and vacuum hoses that were removed. Connect and route as they were removed.

Cylinder Head - Removal

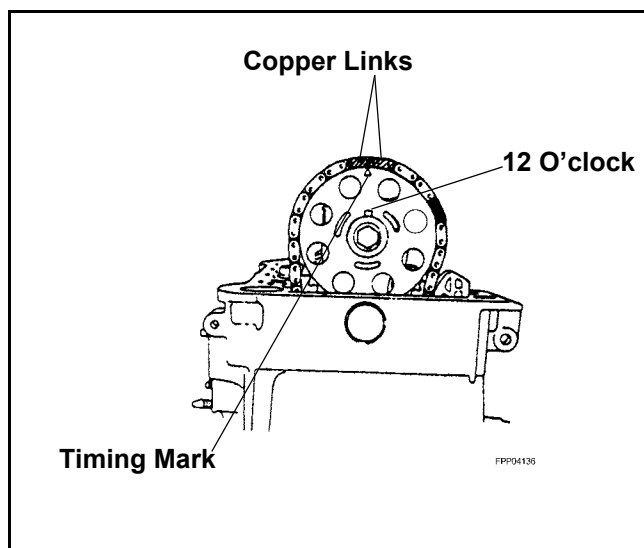
1. Drain engine oil - refer to Operator Handbook.
2. Drain engine coolant - refer to Section 05.
3. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.
4. Remove valve cover -- Refer to "Valve Cover - Removal" on page 10.
5. Remove spark plugs and wires.
6. Remove the coolant flow control module - refer to Section 05.



7. Remove bolts and nuts holding intake manifold to cylinder head. Move aside.
8. Remove heat shield ??.
9. Remove nuts at exhaust manifold. Move aside.
10. Remove oil level indicator tube bolt at cylinder head.
11. Remove timing chain hydraulic tensioner.



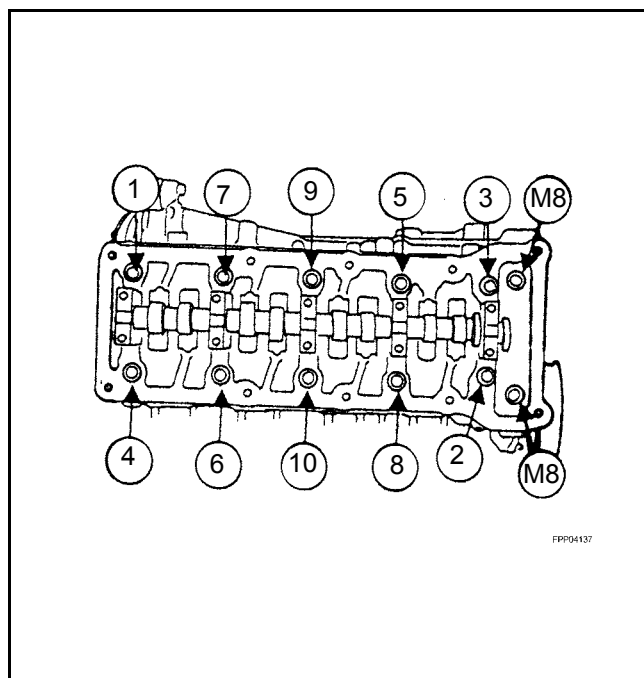
12. Rotate camshaft sprocket using tool 15-030A until the 2 copper links on timing chain are at 12 o'clock.



13. Using tool 15-030A to lock camshaft sprocket, remove bolt.

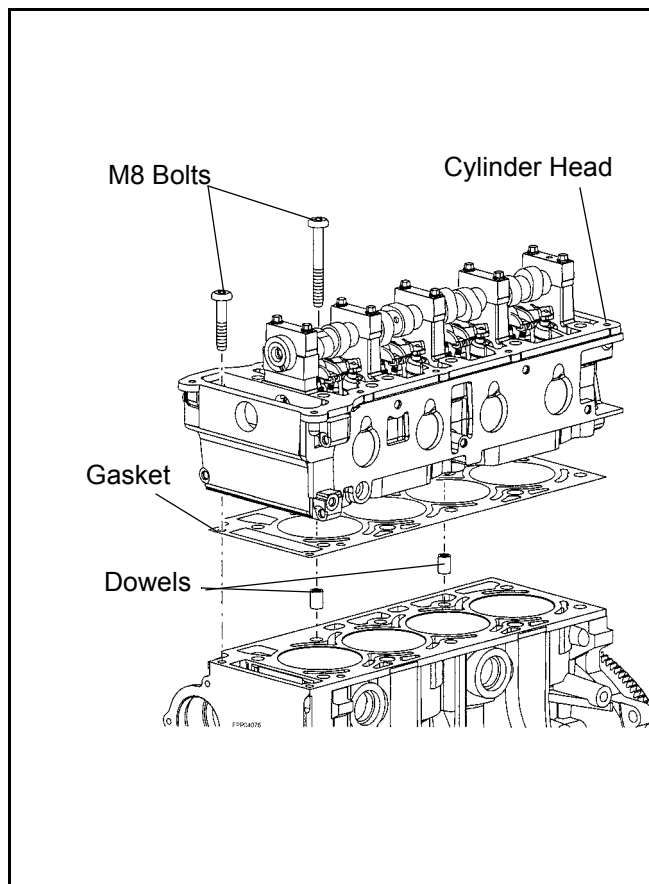
CAUTION: During cylinder head removal, the timing chain must be held up with a wire with constant tension in order to keep timing links aligned at crankshaft. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned - refer to timing chain assembly xxx.

14. Remove camshaft sprocket from chain while maintaining tension on the chain using a wire.
15. Remove the M11 cylinder head bolts in 3 phases in the sequence shown.

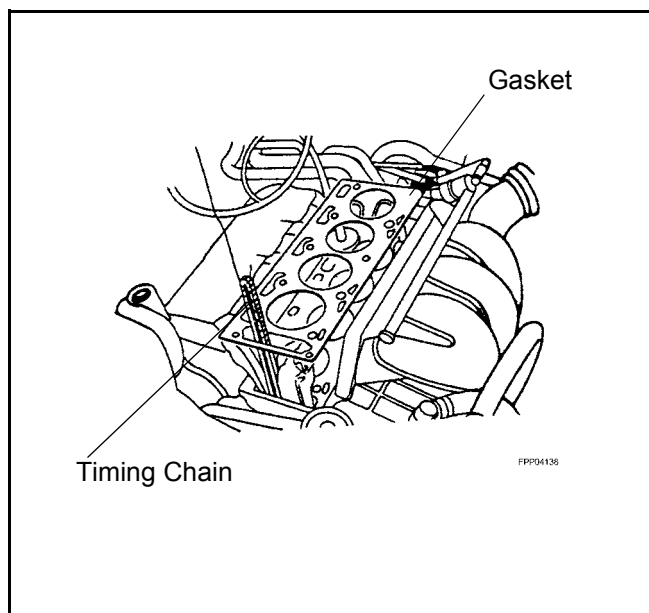


CAUTION: Be careful to avoid the bolts falling into the timing chain compartment.

16. Remove 2 M8 bolts, cylinder head and gasket.



17. Carefully remove cylinder head and gasket while maintaining tension on timing chain.



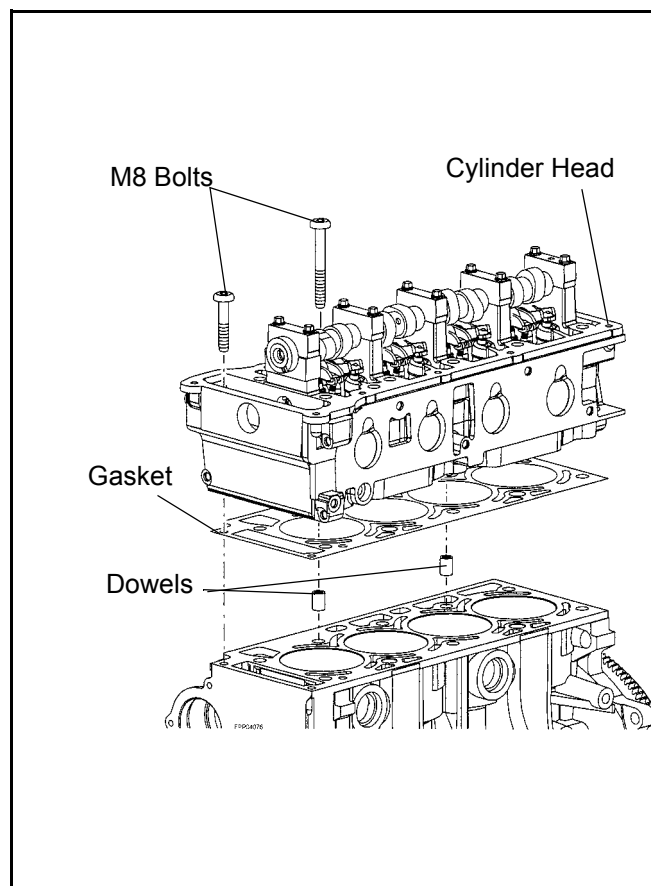
Cylinder Head - Installation

NOTE: The contact surface of the cylinder head and block must be clean and free of oil. Use new cylinder head bolts and lubricate the threads.

1. Rotate crankshaft so all pistons are **below** top dead center (TDC).

CAUTION: During cylinder head installation, the timing chain must be held up with a wire with constant tension in order to keep timing links aligned at crankshaft. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned - refer to timing chain assembly xxx.

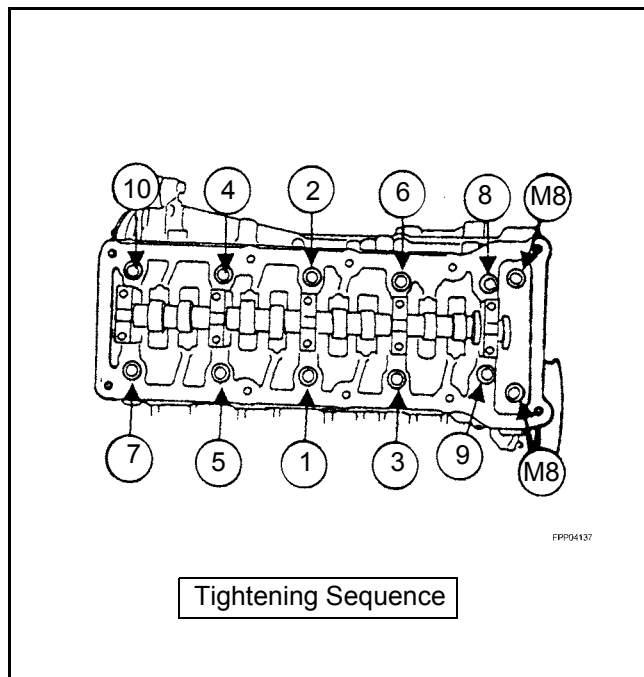
2. Carefully install dowels, a new gasket and cylinder head to the engine block while maintaining tension on the timing chain.



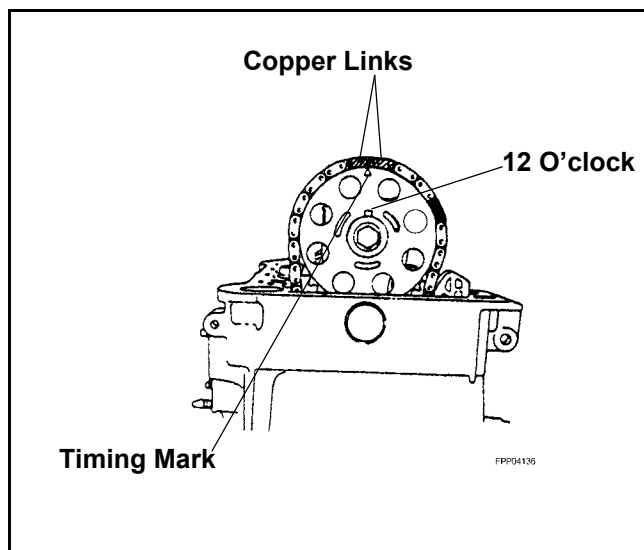
CAUTION: Be careful to avoid the bolts falling into the timing chain compartment.

3. Install new bolts using the sequence shown in the following 3 steps:

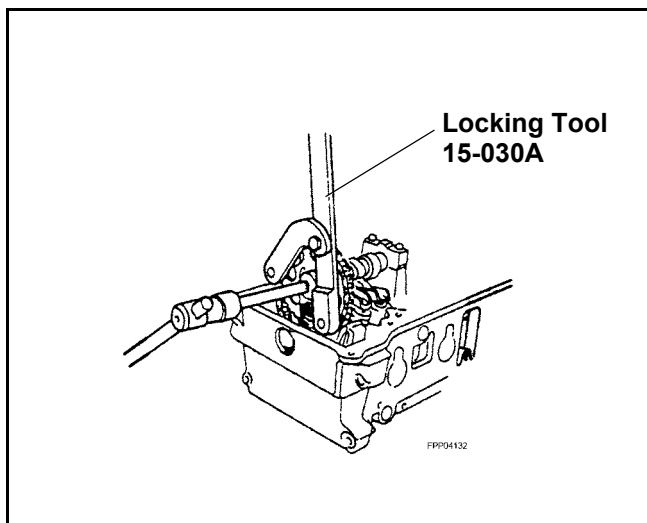
- Step 1 - tighten M11 bolts to 29.5 lb.ft. (40 Nm)
- Step 2 - tighten M8 bolts to 11 lb.ft. (15 Nm) + 45°
- Step 3 - tighten M11 bolts additional 120°



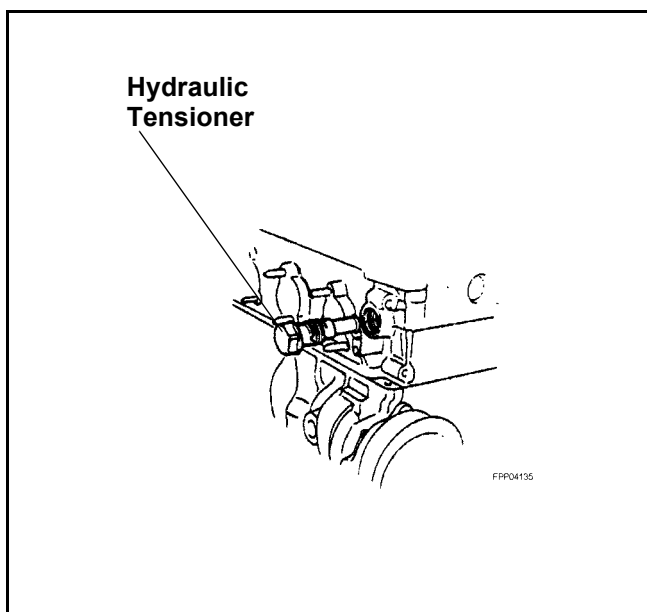
4. Carefully install sprocket into timing chain aligning timing mark with 2 copper links.



5. Using tool 15-030A, install camshaft sprocket bolt. Tighten to 92 lb.ft. (125 Nm).

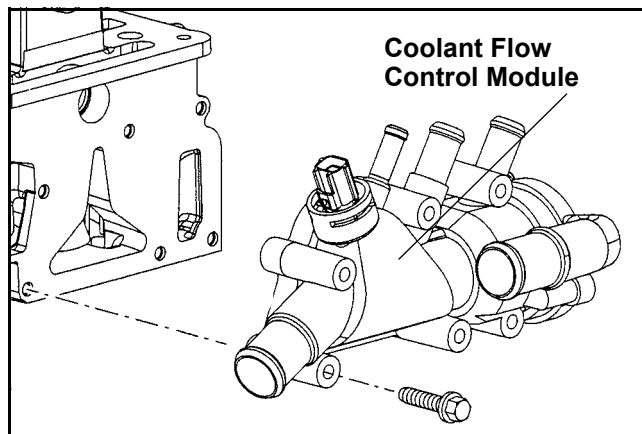


6. Install hydraulic tensioner and tighten to 30 lb.ft. (40 Nm).



7. Install oil level indicator bolt. Tighten to 15 lb.ft. (20 Nm).
8. Install exhaust manifold and nuts. Tighten nuts to 11 lb.ft. (15 Nm).
9. Install heat shield ??.
10. Install bolts and nuts holding intake manifold to cylinder head. Tighten to nuts and bolts to 13 lb.ft. (18 Nm).

11. Install the coolant flow control module - refer to Section 05.

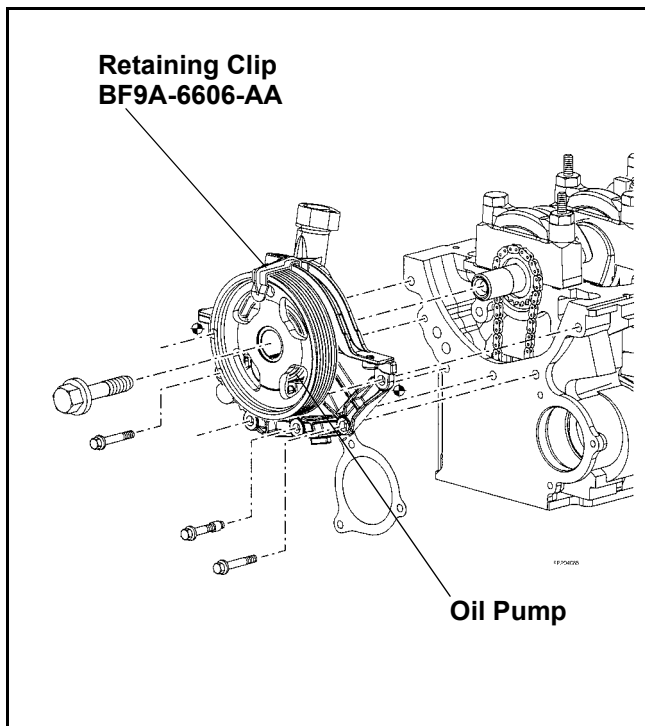


12. Install spark plugs and wires - refer to Section 03.
13. Install valve cover -- Refer to "Valve Cover - Removal" on page 10.
14. Install and route any wiring and vacuum hoses removed.
15. Fill engine with correct type and quantity of coolant - refer to Section 05.
16. Fill engine with correct type and quantity of engine oil - refer to Operator Handbook.

Oil Pump - Removal

CAUTION: The oil pump, pulley and sealer are provided as an assembly kept together by a clip (no. BF9A-6606-AA). Do not remove clip until oil pump is installed. If pulley is pushed out of the oil pump prior to oil pump installation, it will have to be repaired or replaced.

1. Remove drive belt - refer to xx.
- 2.
3. Remove water pump - refer to Section 05.
4. Insert retaining clip # BF9A-6606-AA between crankshaft pulley and oil pump to prevent pulley axial movement.



5. Remove crankshaft pulley bolt.

NOTE: Identify oil pump bolts so they may be returned to their original positions.

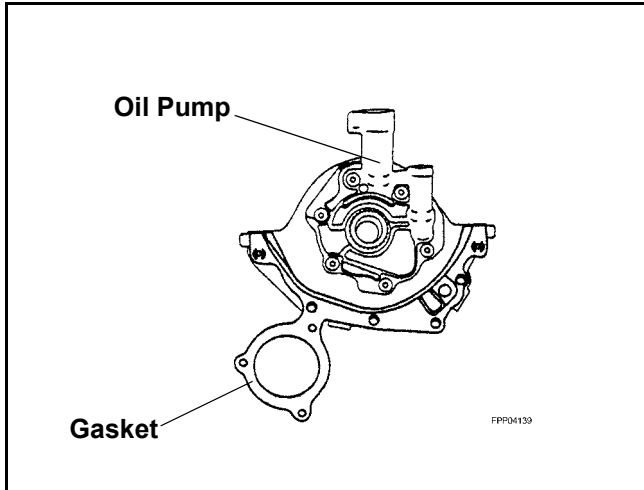
6. Remove 6 oil pump bolts, oil pump and gasket.

Oil Pump - Installation

NOTE: Contact surfaces of the oil pump and block must be clean and free of oil.

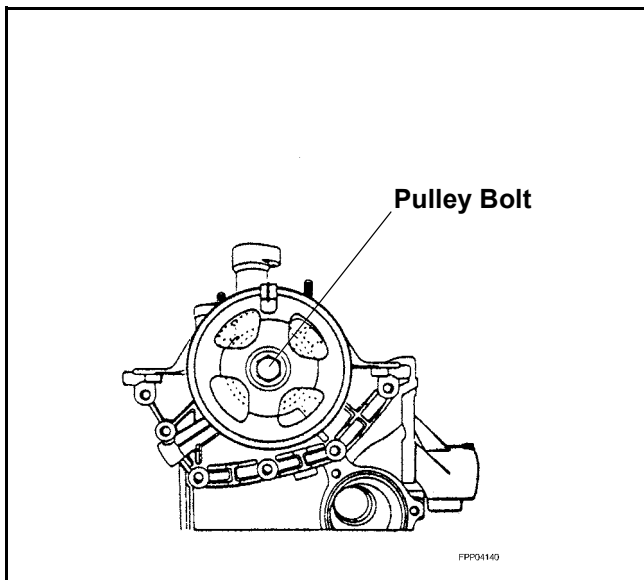
CAUTION: The oil pump, pulley and sealer are provided as an assembly kept together by a clip (no. BF9A-6606-AA). Do not remove clip until oil pump is installed. If pulley is pushed out of the oil pump prior to oil pump installation, it will have to be repaired or replaced.

1. Assemble gasket onto oil pump housing guiding it with 2 outer bolts.



CAUTION: Do not apply oil to shaft or seal. Sealing lip along with all contact surfaces must be free of oil.

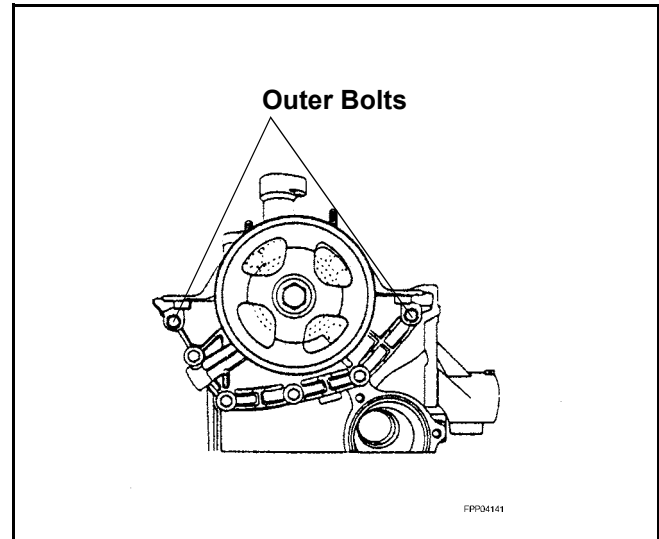
2. Place oil pump and gasket onto crankshaft.
3. Install pulley bolt and tighten to 92 lb.ft. (125 Nm).



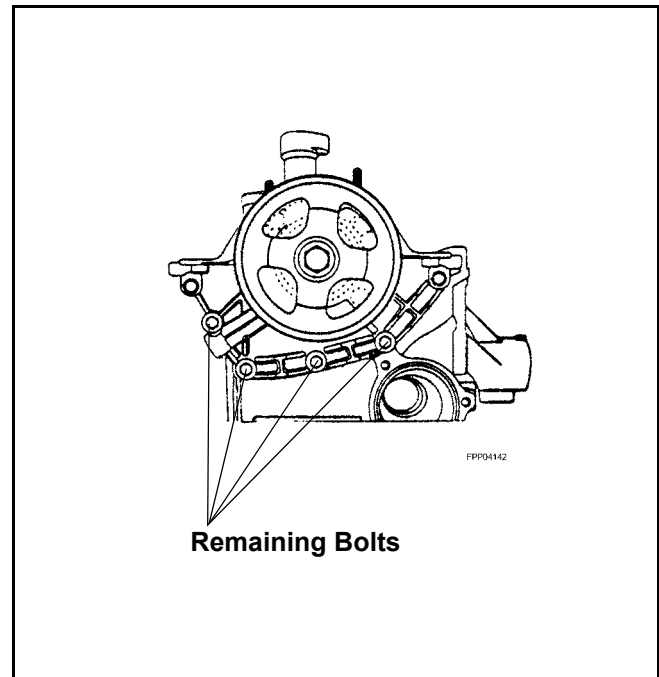
4. Remove clip.
5. Install oil pump housing bolts finger tight.

CAUTION: The oil pump housing must be positioned during tightening of the oil pump housing bolts, so that the sealing flange of the oil pump housing is within ± 0.008 in. (0.20 mm) of the block bottom sealing flanges.

6. Tighten 2 outer oil pump housing bolts to 15 lb.ft. (20 Nm).

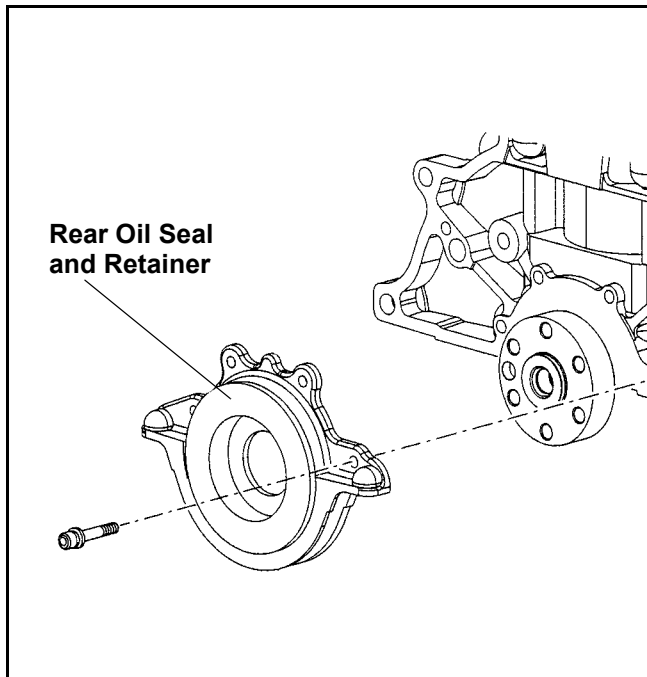


7. Tighten remaining oil pump housing bolts to 15 lb.ft. (20 Nm).



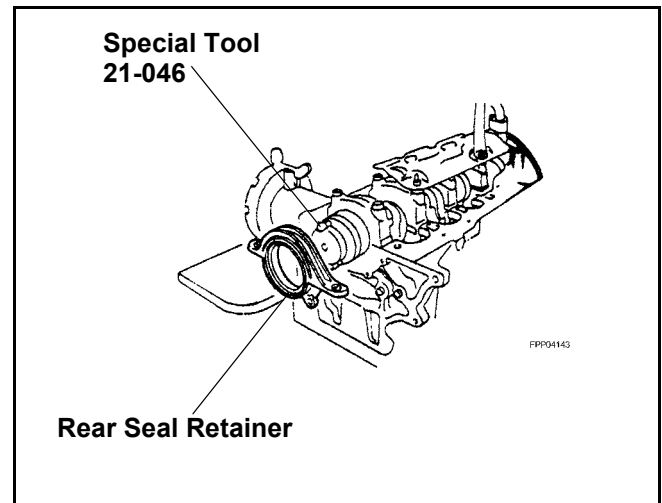
Crankshaft Rear Oil Seal - Removal

1. Remove flywheel - refer to xx.
2. ??Remove oil pan - refer to xx.??
3. Remove bolts and rear oil seal retainer.



Crankshaft Rear Oil Seal - Installation

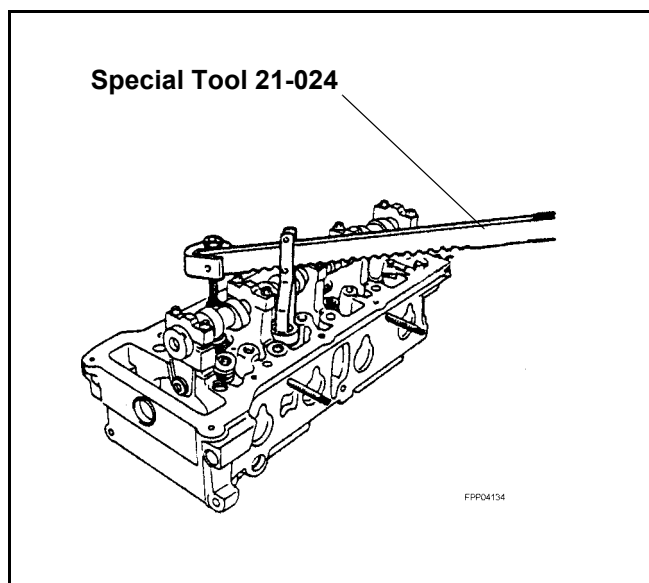
1. Install new rear seal and retainer using tool 21-046.



2. ??Install oil pan - refer to xx.??
3. Install flywheel - refer to xx.

Camshaft Follower / Hydraulic Lash Adjuster - Removal

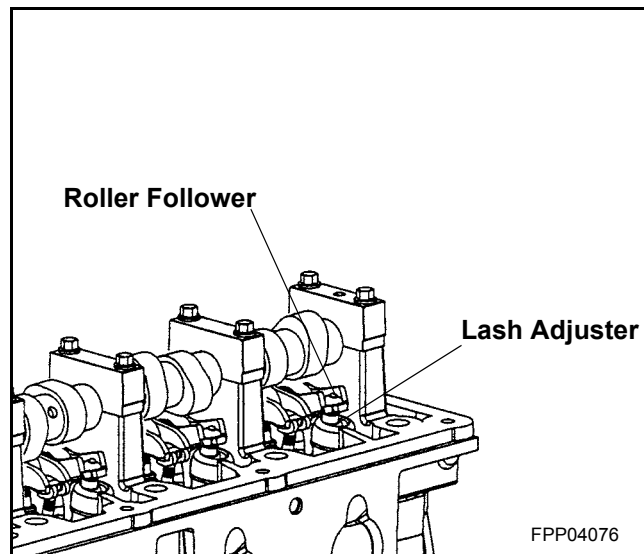
1. Remove valve cover -- Refer to "Valve Cover - Removal" on page 10.
2. Rotate the camshaft so the roller follower for the valve to be serviced is on the heel of the cam.
3. Using a suitable valve spring compressor tool, compress and hold down the valve spring. Slide out the roller follower over the lash adjuster.



4. Lift out the hydraulic lash adjuster.

Camshaft Follower / Hydraulic Lash Adjuster - Installation

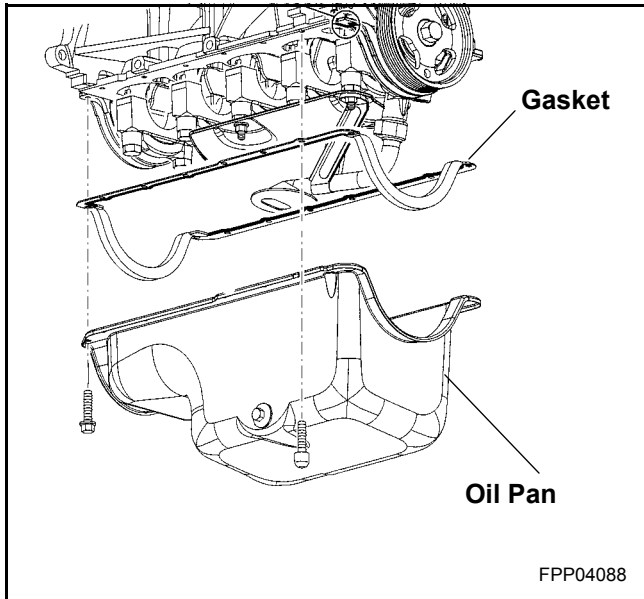
NOTE: All components must be kept clean and lubricated with clean engine oil.



1. Rotate the camshaft so the roller follower for the valve to be serviced is on the heel of the cam.
2. Install the hydraulic lash adjuster.
3. Using a suitable valve spring compressor tool, compress and hold down the valve spring. Slide in the roller follower over the lash adjuster.
4. Install valve cover -- Refer to "Valve Cover - Removal" on page 10.

Oil Pan - Removal

1. Remove bolts.
2. Remove oil pan.



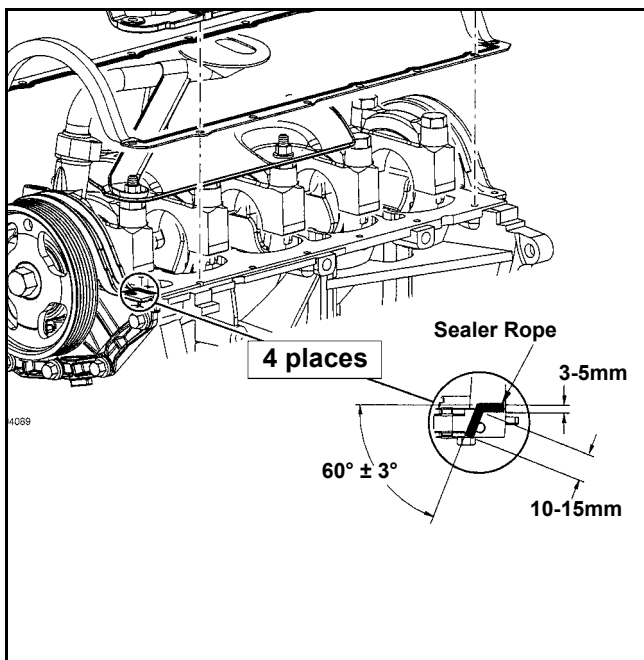
3. Remove all gasket material from pan.

CAUTION: Be careful not to contact surfaces.

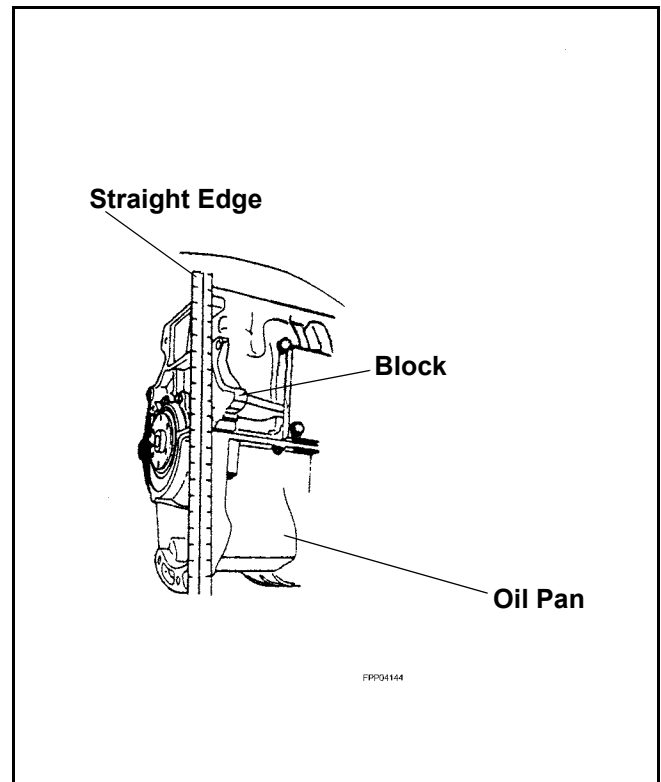
Oil Pan - Installation

CAUTION: The contact surfaces of oil pan, gasket and block must be free of oil. Do not wait more than 5 minutes to install the oil pan gasket after sealer has been applied.

1. Apply WSEM-A4 sealer (Loctite 5910) to the 4 positions as shown.

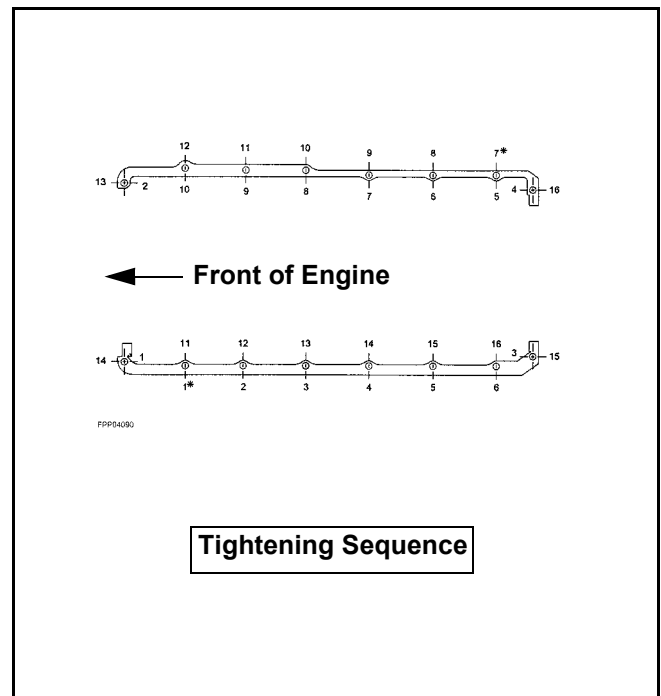


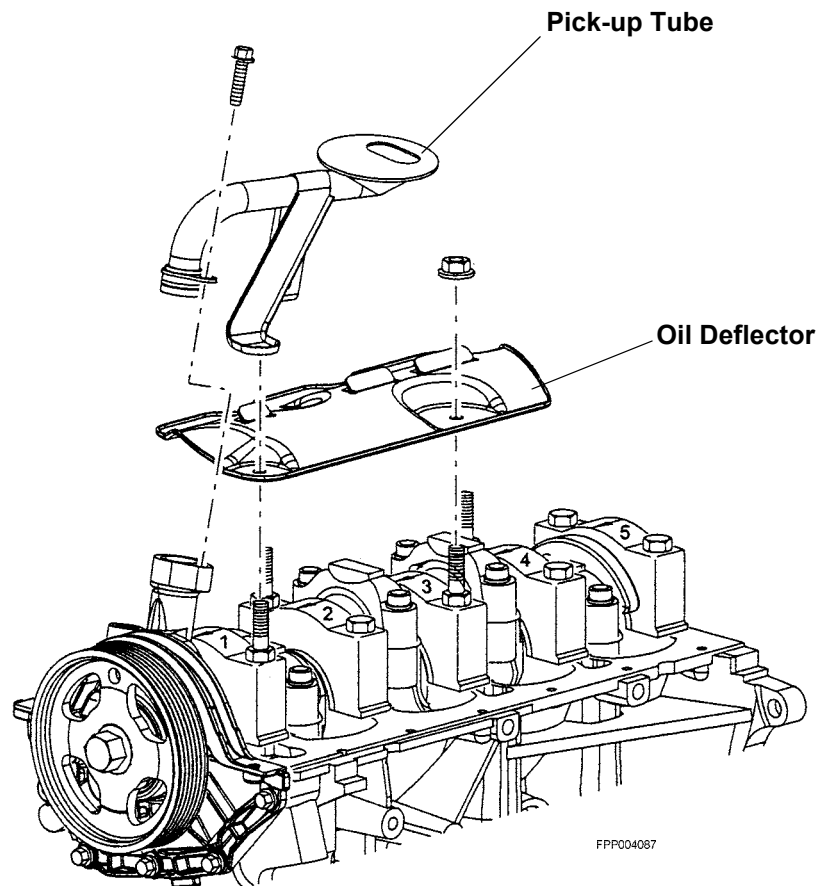
2. Install the oil pan and bolts finger tight.
3. Align oil pan with rear portion of engine block.



4. Tighten oil pan bolts in 3 steps in the sequence shown:

- enough for gasket settlement
- 5 lb.ft. (7 Nm)
- 7 lb.ft. (10 Nm)





Pick-up Tube / Deflector - Removal

- 1.
- 2.
3. Remove oil pan -- Refer to "Oil Pump - Removal" on page 21.
4. Remove 4 nuts and 1 bolt.
5. Remove pick-up tube.
6. Remove oil deflector.

Pick-up Tube / Deflector - Installation

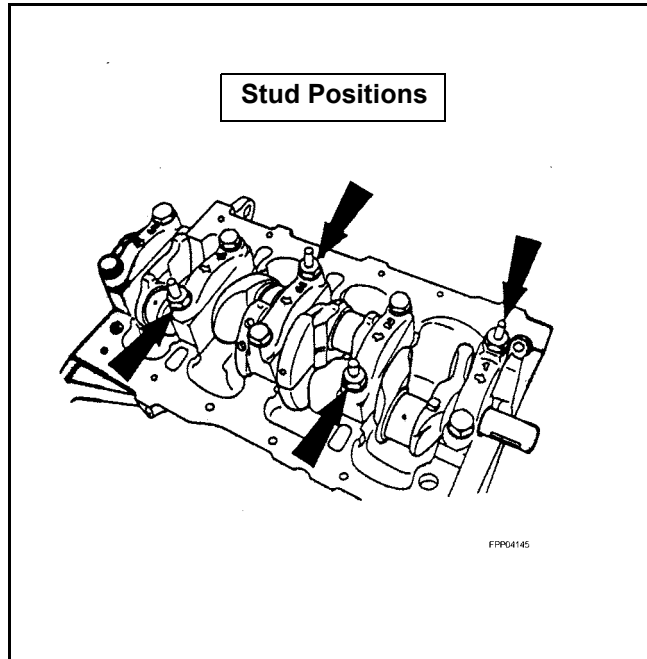
1. Install oil deflector.
2. Install pick-up tube.
3. Install 4 nuts and tighten to 14 lb.ft. (19 Nm).
4. Install bolt and tighten to 7 lb.ft. (9.5 Nm).
5. Install oil pan -- Refer to "Oil Pump - Installation" on page 22.
- 6.
- 7.

Crankshaft Main Bearings - Removal

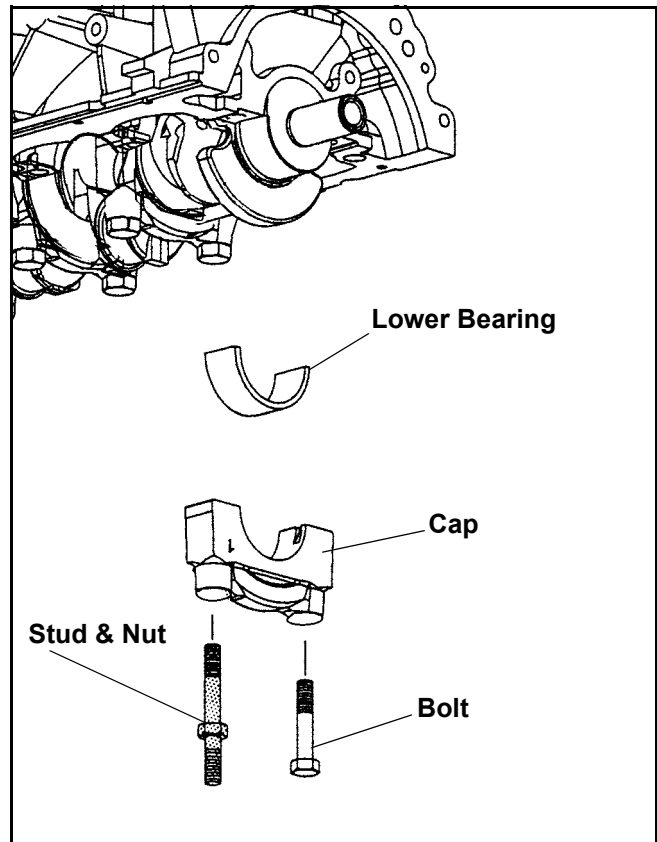
NOTE: To check bearing clearances or to select new bearings, refer to Section 01.

1. Remove oil pan -- Refer to "Oil Pan - Removal" on page 25.
2. Remove pick-up tube & deflector -- Refer to "Pick-up Tube / Deflector - Removal" on page 26.

NOTE: Replace one bearing at a time, leaving the other bearings securely fastened. Note location of studs for deflector installation.



3. Remove first main bearing cap bolts.
4. Remove cap and lower bearing.
5. Press on end of upper bearing without tang to start it out.
6. Rotate bearing out from between crankshaft and cylinder block.



Crankshaft Main Bearings - Installation

NOTE: All components must be clean and dried with compressed air or a lint free cloth. Lubricate bearing to crankshaft contact surfaces with clean engine oil.

1. Place upper bearing on crankshaft and rotate into place. Oil holes must align.
2. Place lower bearing into cap.

NOTE: Main bearing cap arrow must point to the front of the engine.

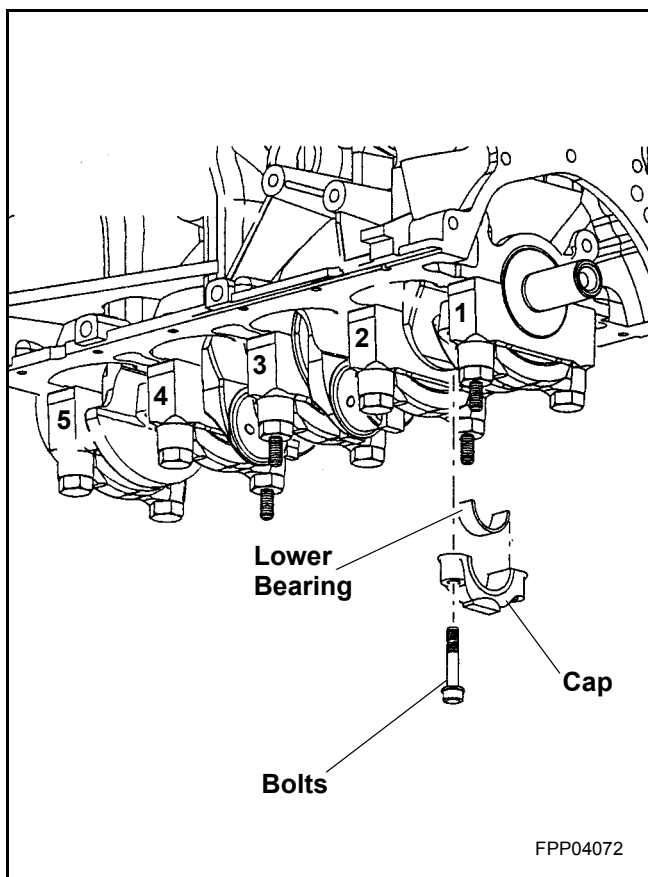
3. Install bearing cap.

CAUTION: Use new main bearing cap bolts.

4. Lightly oil new main bearing bolts or studs and install in same positions as removed. Alternately tighten in 3 steps to 70 lb.ft. (95 Nm).
5. Check crankshaft end play as outlined in Section 01.
6. Install pick-up tube and deflector -- Refer to "Pick-up Tube / Deflector - Installation" on page 26.
7. Install oil pan -- Refer to "Oil Pan - Installation" on page 25.

Connecting Rod Bearings - Removal

1. Remove oil pan -- Refer to "Oil Pan - Removal" on page 25.
2. Remove pick-up tube and deflector -- Refer to "Pick-up Tube / Deflector - Removal" on page 26.
3. Remove spark plug for cylinder being serviced.
4. Rotate crankshaft until connecting rod and bearing to be serviced is placed at the bottom of its stroke.
5. Remove two connecting rod nuts.
6. Remove connecting rod cap with lower bearing.



7. Push piston and connecting rod assembly up into bore.
8. Remove upper bearing from connecting rod.

NOTE: For bearing service refer to Section 01.

Connecting Rod Bearings - Installation

NOTE: Make sure bearing bore of connecting rod and cap and bearing journal are clean. Lubricate wear surfaces with clean engine oil.

1. Insert upper bearing into connecting rod.
2. Insert lower bearing into cap.

CAUTION: Do not scratch journal with connecting rod bolts.

3. Install cap and bolts. Tighten bolts in 2 steps:
 - Step 1 - 9 lb.ft. (12.5 Nm)
 - Step 2 - 22 lb.ft. (30 Nm) (41-94°???)
4. Install deflector and pick-up tube -- Refer to "Pick-up Tube / Deflector - Installation" on page 26.
5. Install oil pan -- Refer to "Oil Pan - Installation" on page 25.

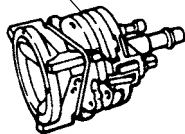
Piston - Removal

1. Remove oil pan -- Refer to "Oil Pan - Removal" on page 25.
2. Remove pick-up tube and deflector -- Refer to "Pick-up Tube / Deflector - Removal" on page 26.
3. Remove cylinder head assembly -- Refer to "Cylinder Head - Removal" on page 17.

CAUTION: Never cut into the ring travel area in excess of 0.8mm (1/32 inch) when removing ridges.

4. Turn crankshaft until piston to be removed is at the bottom of its travel and place a cloth on the piston head to collect the cuttings.
5. Remove any ridge and/or deposits from the upper end of the cylinder bores using a ridge cutter. follow the instructions furnished by the tool manufacturer.

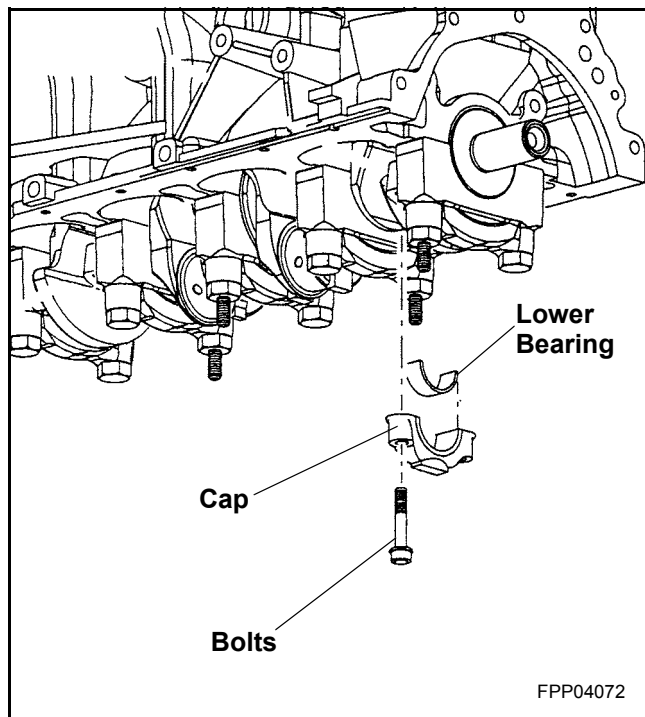
Cylinder Ridge
Reamer
T64L-6011-EA



FPP10048

NOTE: Make sure all caps are marked so that they can be installed in their original positions.

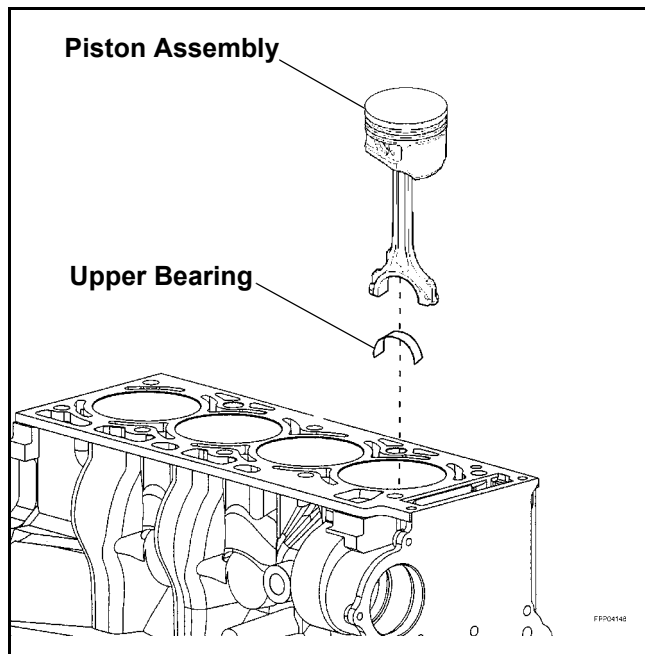
6. Remove 2 bolts, connecting rod cap and lower bearing.



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CAUTION: Avoid damage to the crankshaft journal or the cylinder wall when removing the piston and rod.

7. Push piston assembly out the top of the cylinder with the handle end of a hammer.



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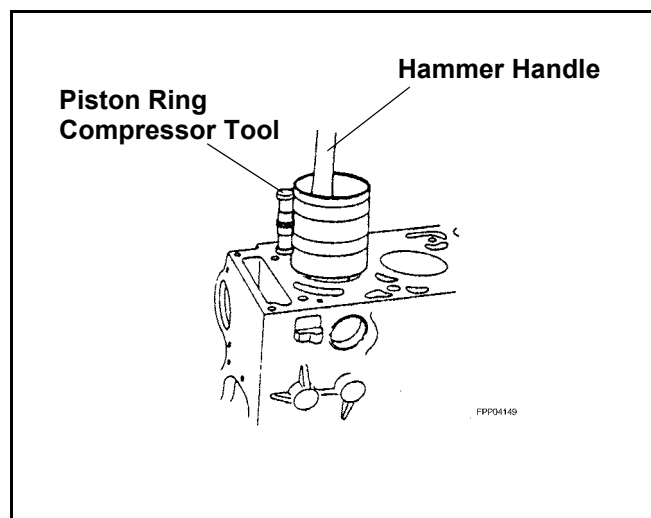
8. Remove upper bearing from connecting rod.

NOTE: For piston and bearing service - refer to Section 01.

Piston - Installation

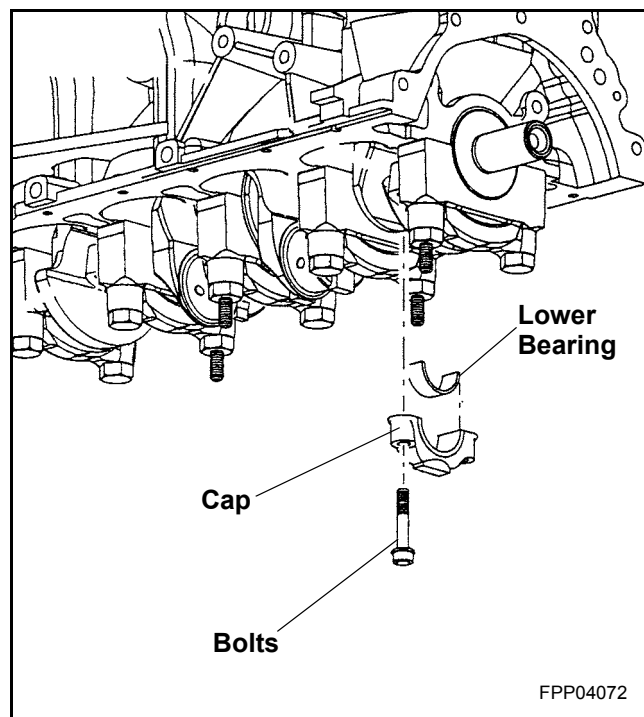
NOTE: Crankshaft journal should be at its lowest point. All components should be clean and dried with compressed air or a lint free cloth.

1. Set piston ring gaps as follows:
 - lower oil ring gap aligned with piston pin.
 - center ring gap at 90° from the oil ring gap.
 - top ring gap at 180° from the oil ring gap.
2. Lubricate piston, bearing wear surface, crankshaft journal and cylinder wall with clean engine oil.
3. Carefully install pistons with bearings into cylinder bores using a piston ring compressor and a hammer handle. Avoid damage to the crankshaft bearing journals. The arrow of the piston must point to the front of the engine. The connecting rod has the cylinder number identified in the base.



CAUTION: Use new connecting rod cap bolts and lubricate threads with clean engine oil.

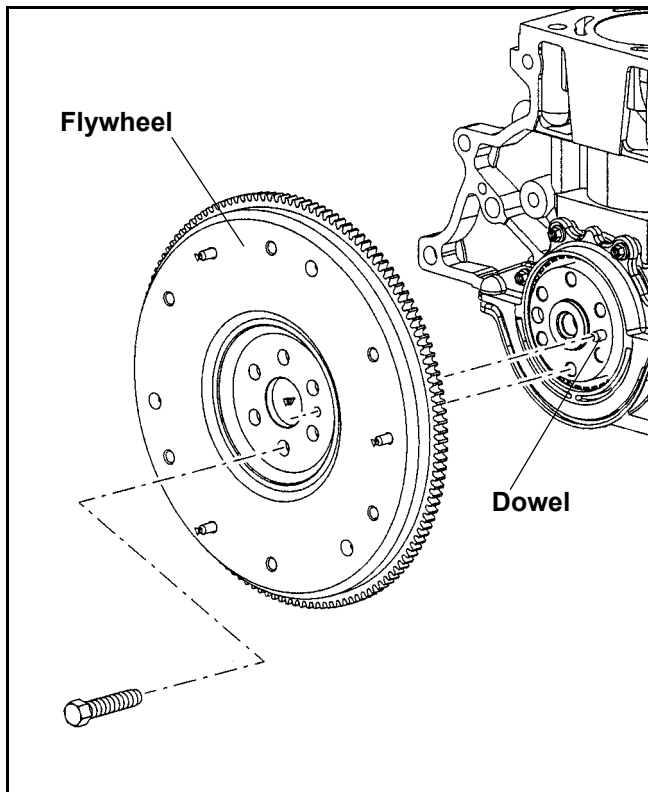
4. Install connecting rod caps with bearings (lubricate wear surface) and tighten bolts in 2 steps:
 - Step 1 - 9 lb.ft. (12.5 Nm)
 - Step 2 - 22 lb.ft. (30 Nm) (41-94°???)



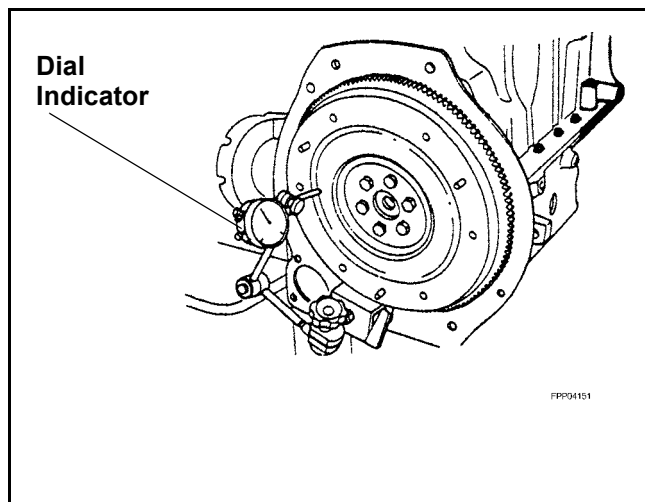
5. ??Check connecting rod side clearance??.
6. Install cylinder head assembly -- Refer to "Cylinder Head - Installation" on page 19.
7. Install pick-up tube and deflector -- Refer to "Pick-up Tube / Deflector - Installation" on page 26.
8. Install oil pan -- Refer to "Oil Pan - Installation" on page 25.

Flywheel - Removal

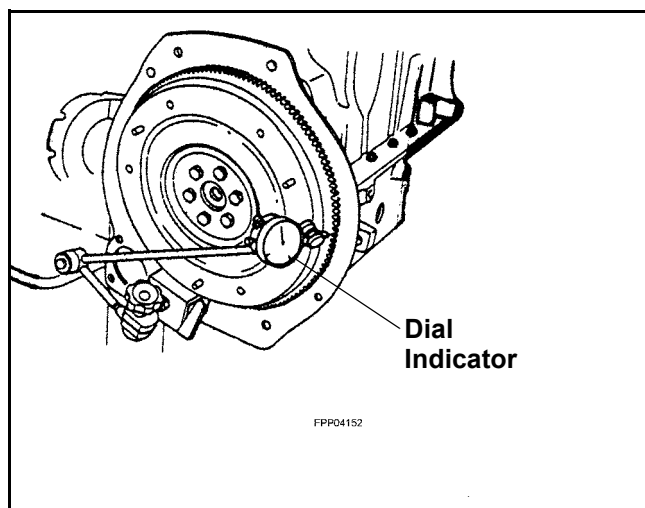
1. Remove bolts.
2. Remove flywheel.
- 3.
- 4.



3. Check flywheel runout at clutch disc surface:
 - maximum runout 0.005 in. (0.13 mm)

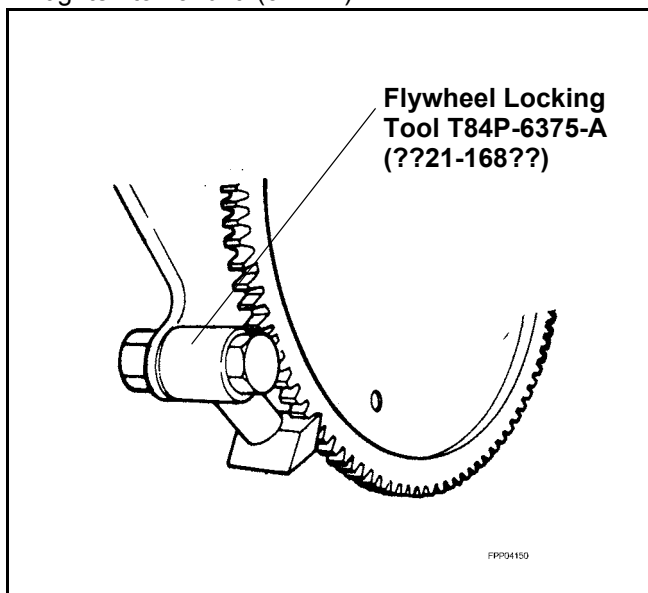


4. Check flywheel runout at gear surface:
 - maximum runout 0.024 in. (0.6 mm)



Flywheel - Installation

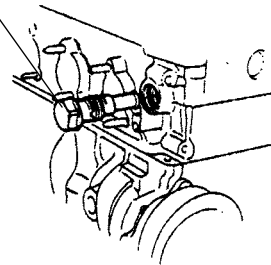
1. Install flywheel using special locking tool 21-168.
2. Lubricate bolt threads with clean engine oil and tighten to 49 lb.ft. (67 Nm).



Timing Chain and Sprockets - Removal

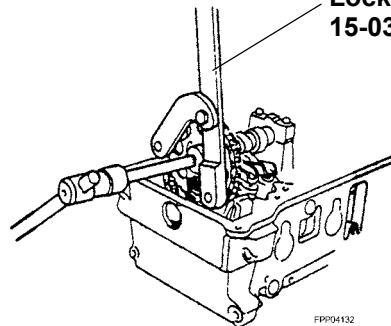
- 1.
- 2.
- 3.
4. Remove oil pump assembly -- Refer to "Oil Pump - Removal" on page 21.
5. Remove valve cover -- Refer to "Valve Cover - Removal" on page 10.
6. oil pan, water pump, ???
7. Check to see if coppered links on the timing chain are still visible. If not, identify them as follows:
 - Turn engine until timing mark on camshaft sprocket is at 12 o'clock.
 - Mark the two chain links left and right of that timing mark.
 - Mark the single chain link that is positioned on the crankshaft sprocket timing mark.
8. Remove the hydraulic tensioner.

**Hydraulic
Tensioner**



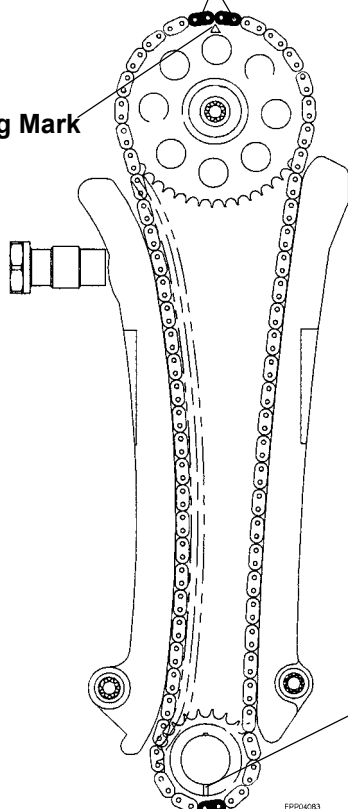
9. Using tool 15-030A to lock camshaft sprocket, remove bolt and camshaft sprocket.

**Locking Tool
15-030A**



Copper Links

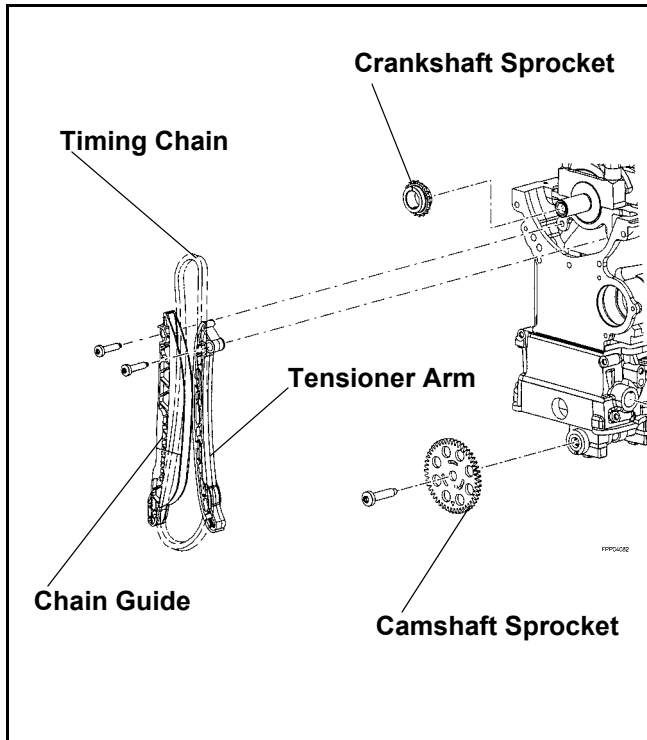
Timing Mark



Timing Mark

Copper Link

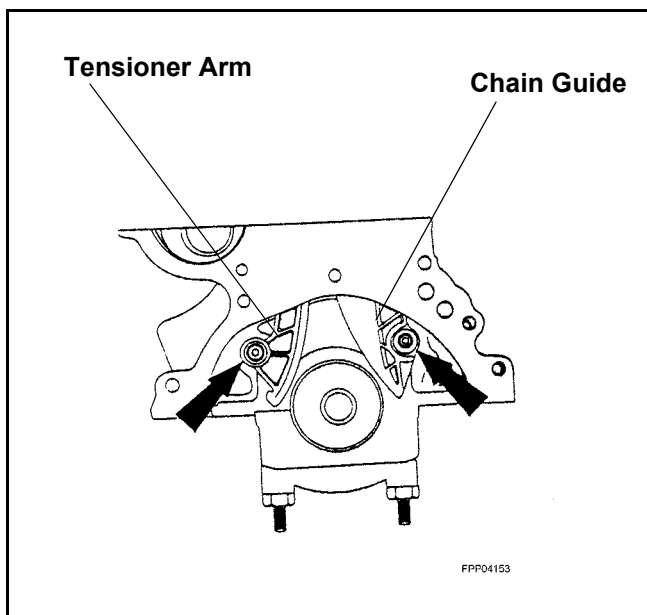
10. Remove timing chain and crankshaft sprocket.
11. Remove tensioner arm and chain guide if necessary.



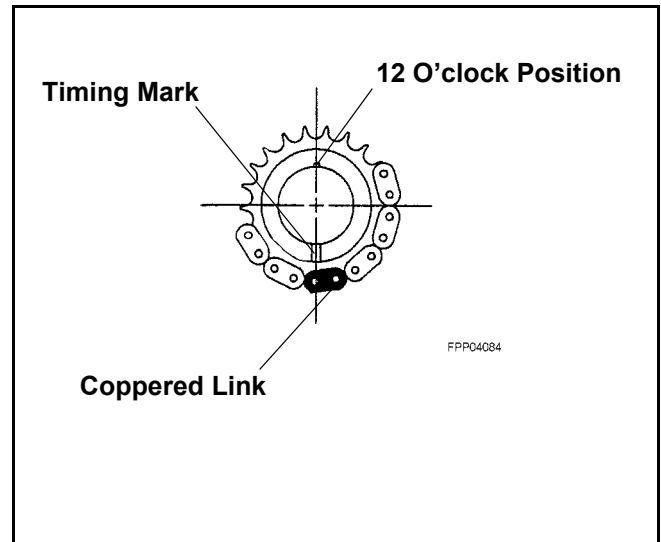
Timing Chain and Sprockets - Installation

NOTE: All components must be clean and dried with compressed air or a lint free cloth. Lubricate with clean engine oil.

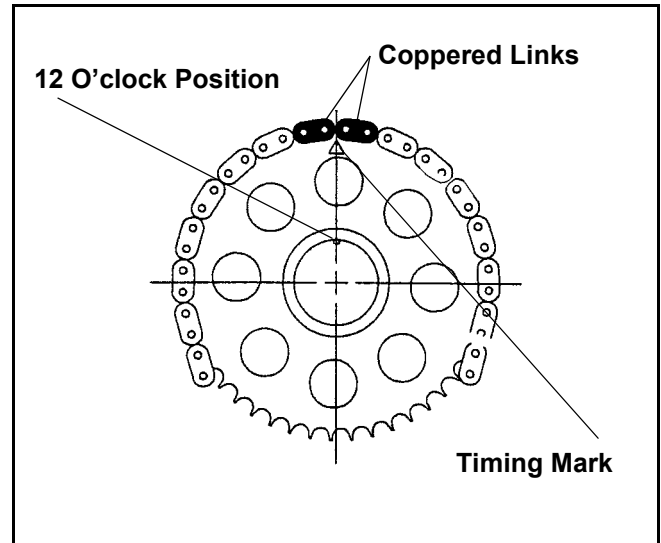
1. Install the (if removed) chain guide and the tensioner arm from the top of the engine. Install bolts finger tight.



2. Install crankshaft sprocket with key at 12 o'clock position.
3. Assemble drive chain through chain housing cavity from top of engine and onto crankshaft sprocket. Align timing mark with coppered link on drive chain.

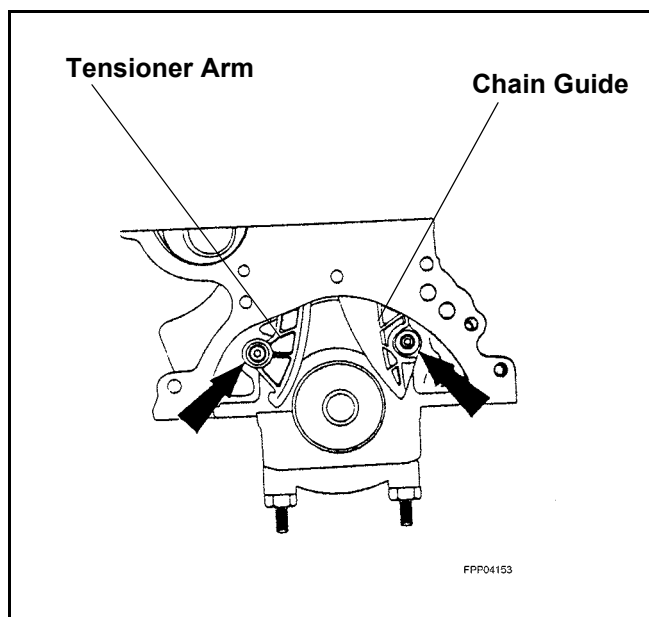


4. Insert camshaft sprocket into chain and assemble to camshaft. Position camshaft key at 12 o'clock and align timing mark between 2 coppered links on drive chain.

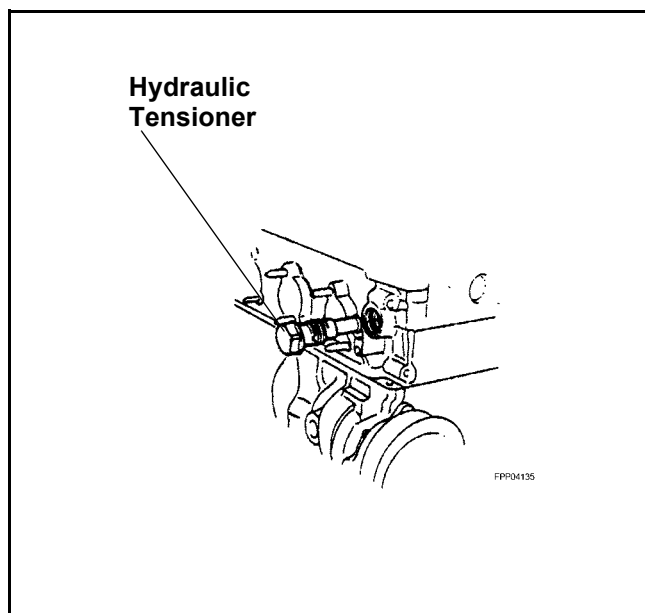


5. Install camshaft sprocket bolt and hydraulic tensioner finger tight.

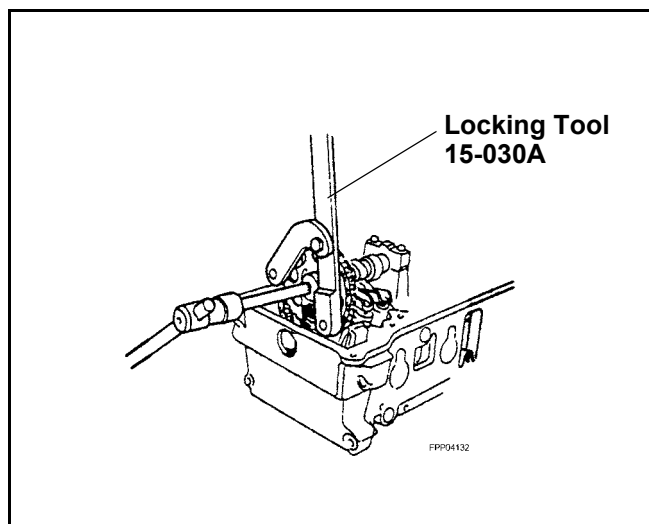
6. Tighten guide and tensioner arm bolts to 18-21 lb.ft. (24-28 Nm).



8. Tighten hydraulic tensioner to 27-32 lb.ft. (36-44 Nm).



7. Using ?? locking tool ??, tighten camshaft sprocket bolt to 52-59 lb.ft. (70-80 Nm).



9. oil pan, water pump, ???

10. Install valve cover -- Refer to "Valve Cover - Installation" on page 10.

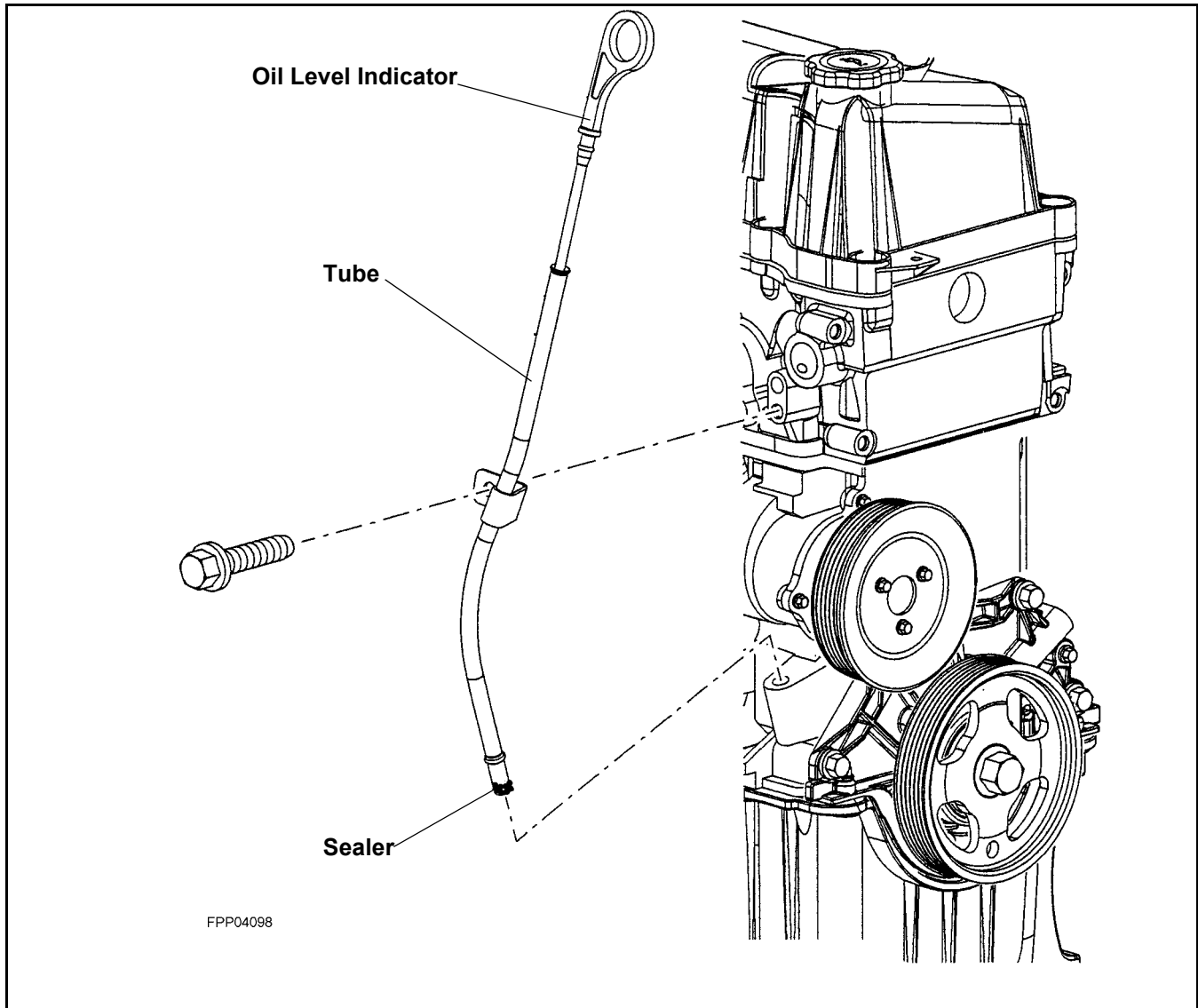
11. Install oil pump assembly -- Refer to "Oil Pump - Installation" on page 22.

12.

13.

14.

15.

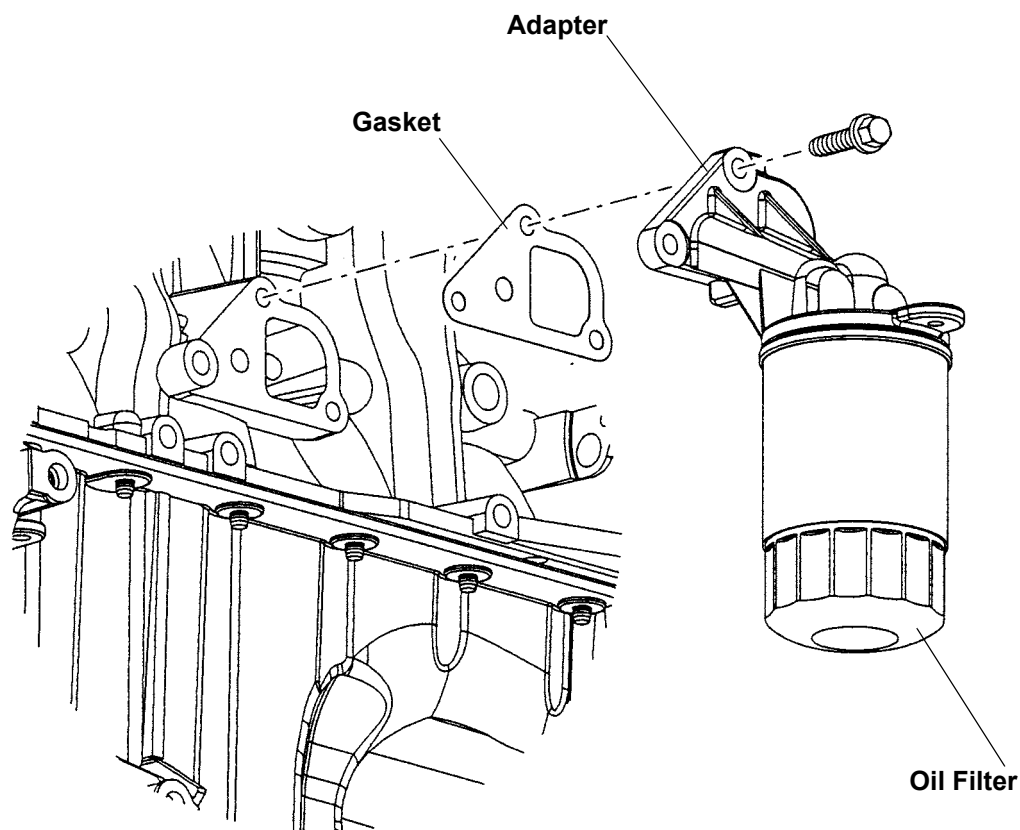


Oil Level Indicator - Removal

- 1.
2. Remove bolt.
3. Remove oil level indicator & tube.

Oil Level Indicator - Installation

1. Apply sealer WSK-M2G 349-A4 (Loctite 648) to lower end of oil level indicator tube.
2. Install tube immediately into bore.
3. Install bolt and tighten to 15 lb.ft. (20 Nm).
- 4.



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Oil Filter and Adapter - Removal

NOTE: Place oil drain pan under oil filter to catch oil drainage.

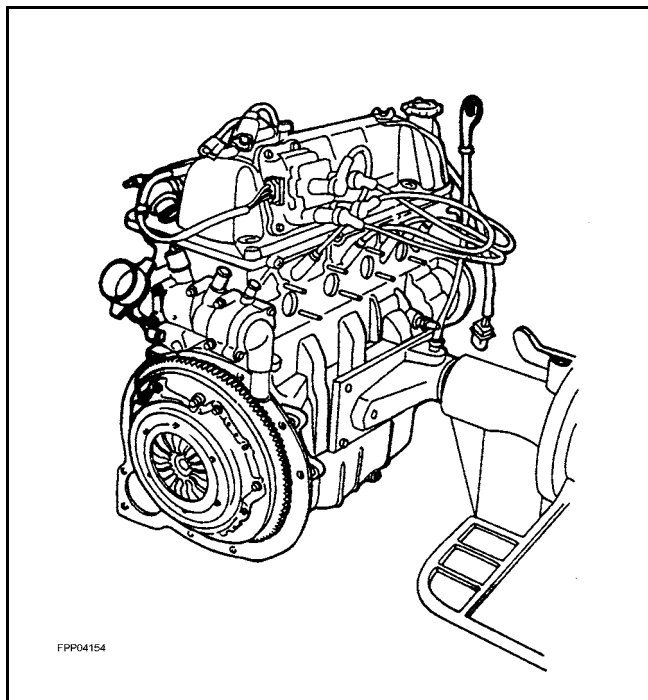
- 1.
2. Remove oil filter.
3. Remove 3 bolts.
4. Remove adapter and gasket.

Oil Filter and Adapter - Installation

1. Install a new gasket.
2. Lubricate oil seal on a new filter and install to adapter. Tighten 1 1/2 to 1 3/4 turns after first contact.
3. Install filter/adapter to block.
4. Install 3 bolts and tighten to 15 lb.ft. (20 Nm).
- 5.

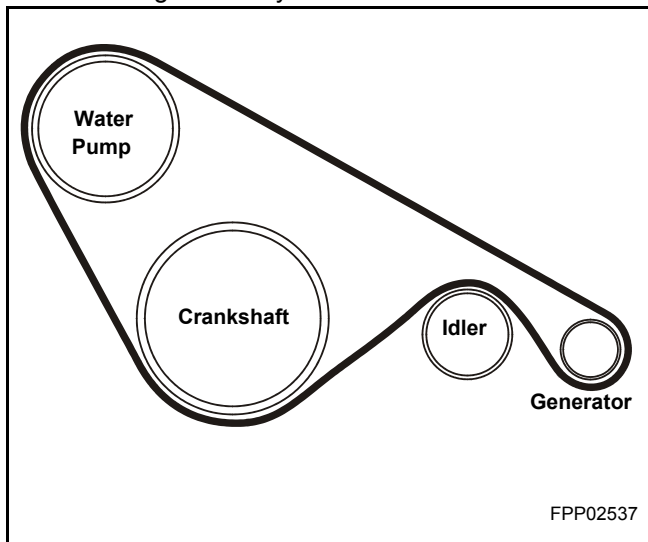
DISASSEMBLY

1. Install engine on an engine stand.

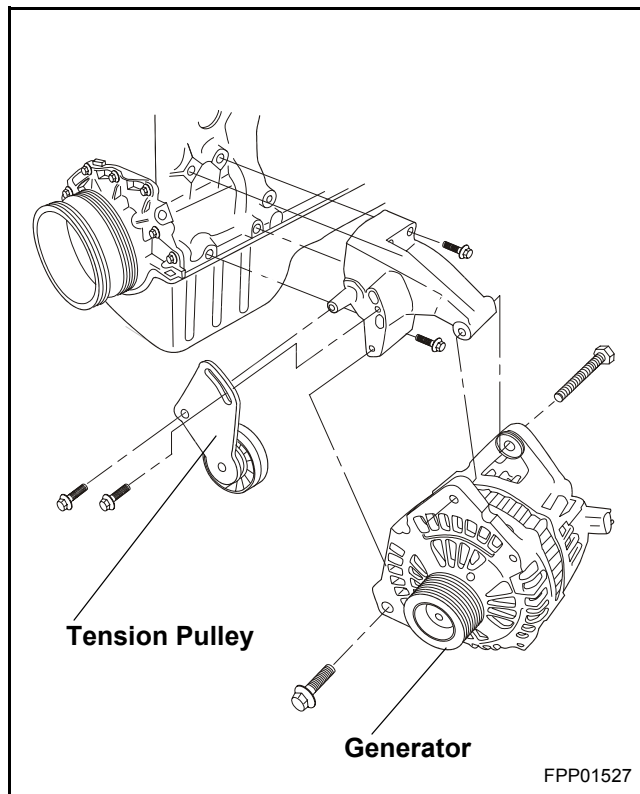


2. Drain the engine oil.

NOTE: Record drive belt routing and direction of travel for use during assembly.

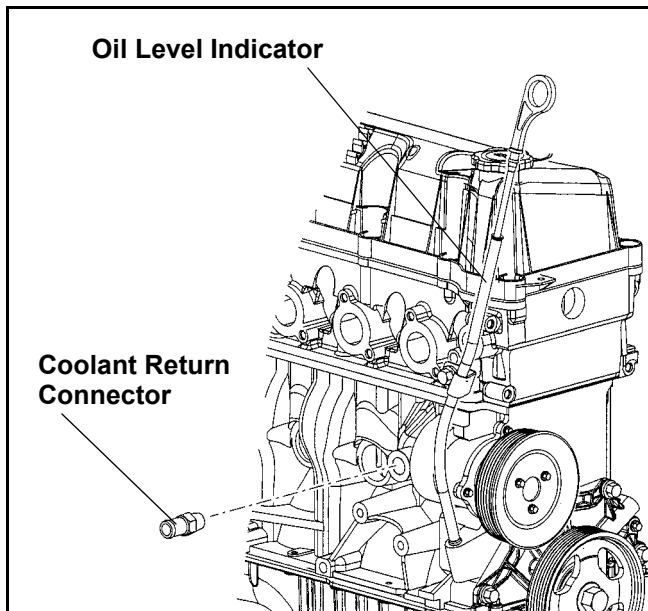


3. Loosen the tensioner pulley and remove the drive belt.



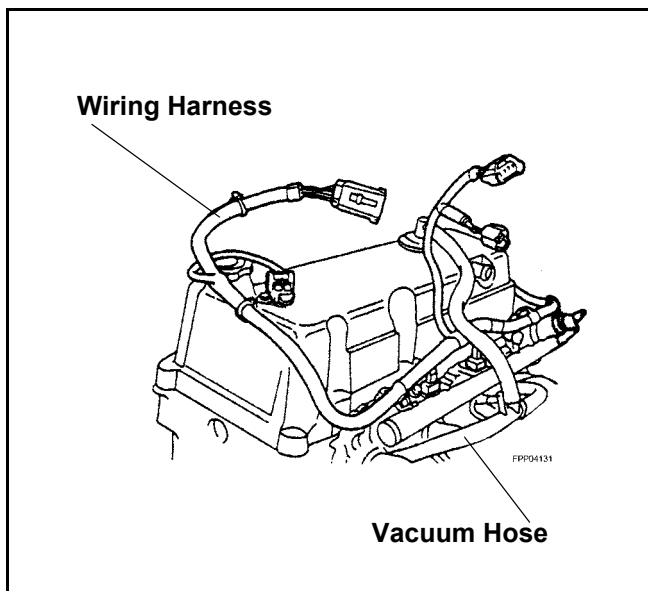
4. Disconnect wiring at generator.
5. Remove the generator.
6. Remove the generator support.

7. Remove oil level indicator tube.
8. Remove the ?return connector?.

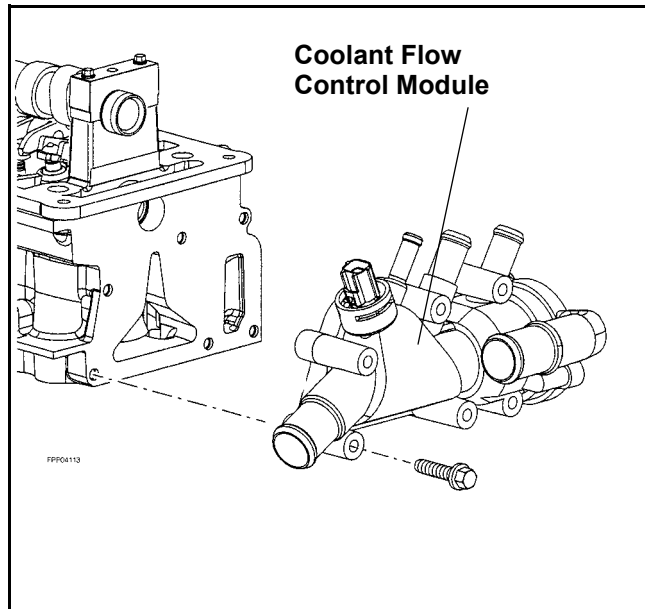


NOTE: Record routing of wiring harnesses and vacuum tubes so they may be returned to their original positions during assembly.

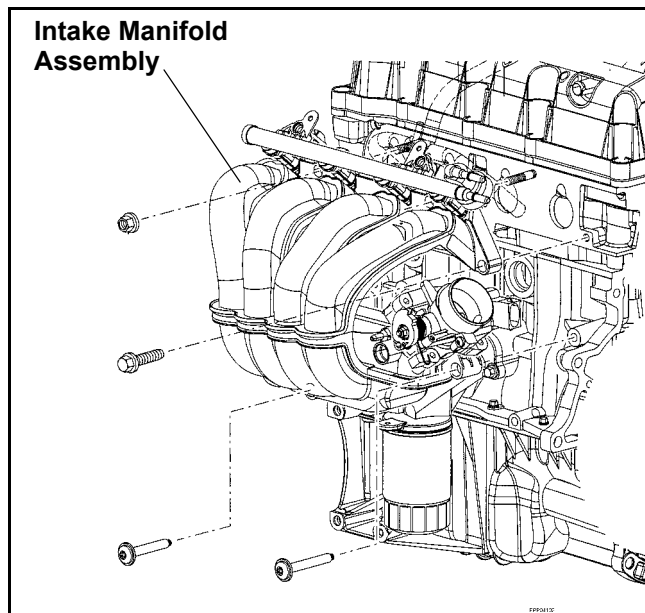
9. Remove any vacuum hoses and wiring.



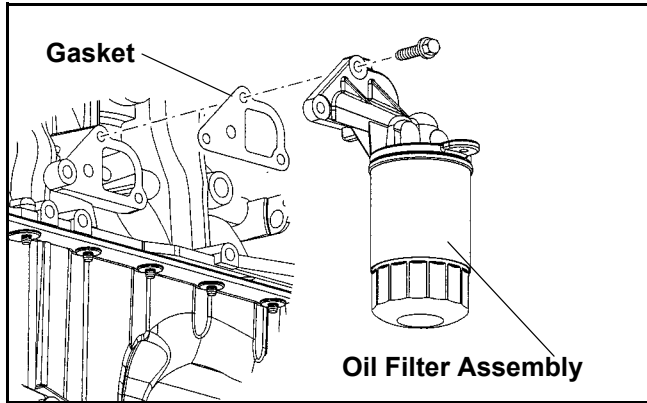
10. Remove the coolant flow control module.



11. Remove the intake manifold assembly.

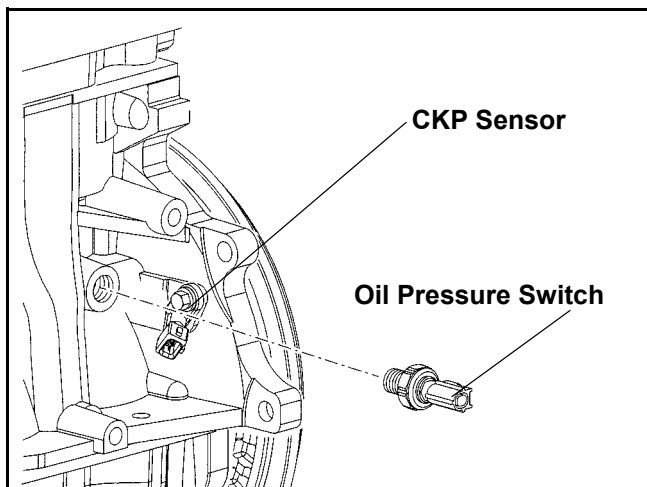


12. Remove the oil filter and support assembly.

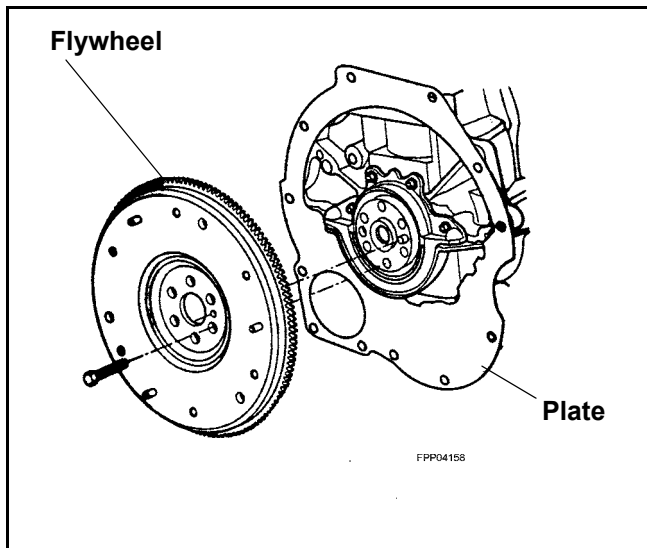


13. Remove oil pressure switch.

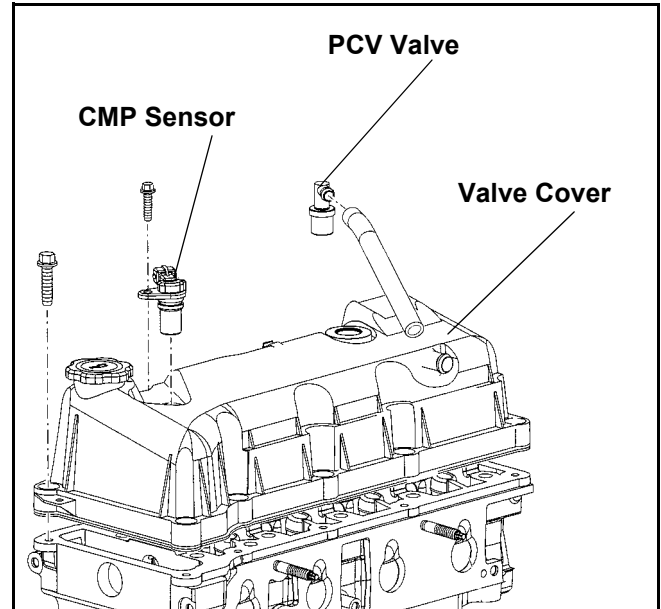
14. Remove crankshaft position (CKP) sensor.



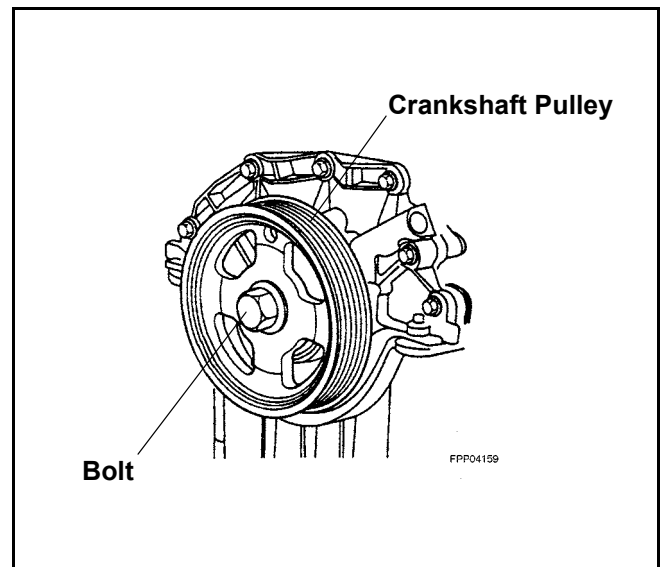
15. Remove the flywheel and flywheel plate.



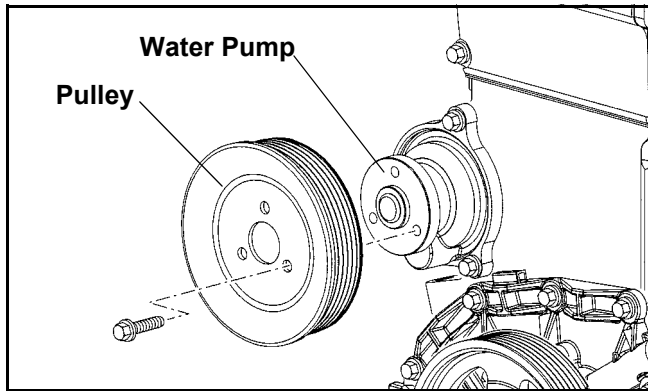
16. Remove the valve cover assembly.



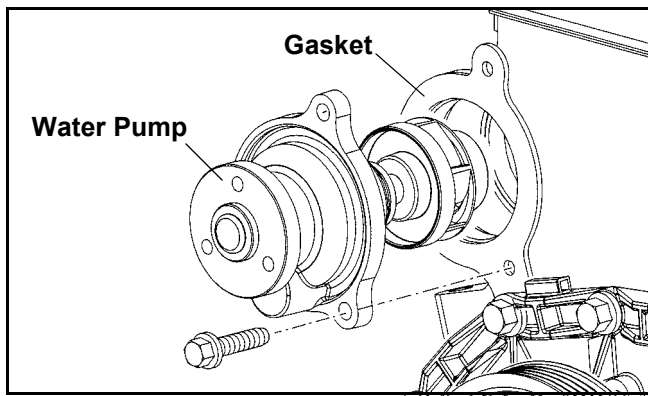
17. Loosen the crankshaft pulley bolt.



18. Remove 3 bolts and the water pump pulley.

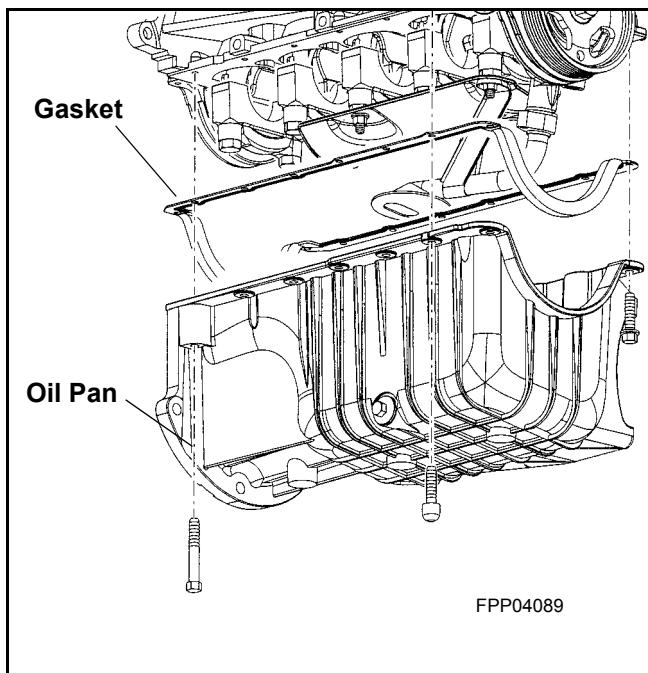


19. Remove 3 bolts, water pump and gasket.



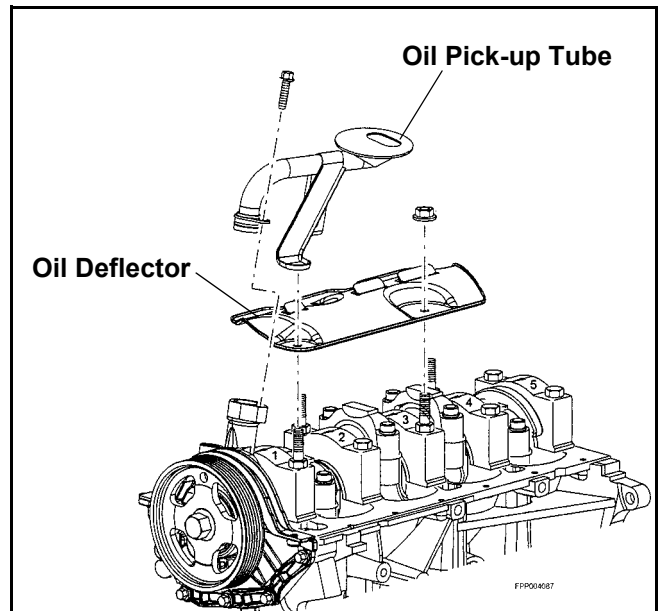
NOTE: When removing oil pan, always keep the engine in its normal upright position to avoid contamination.

20. Remove bolts, gasket and oil pan.



21. Turn the engine over 180°.

22. Remove 4 nuts, 1 bolt, oil pick-up tube and oil deflector.

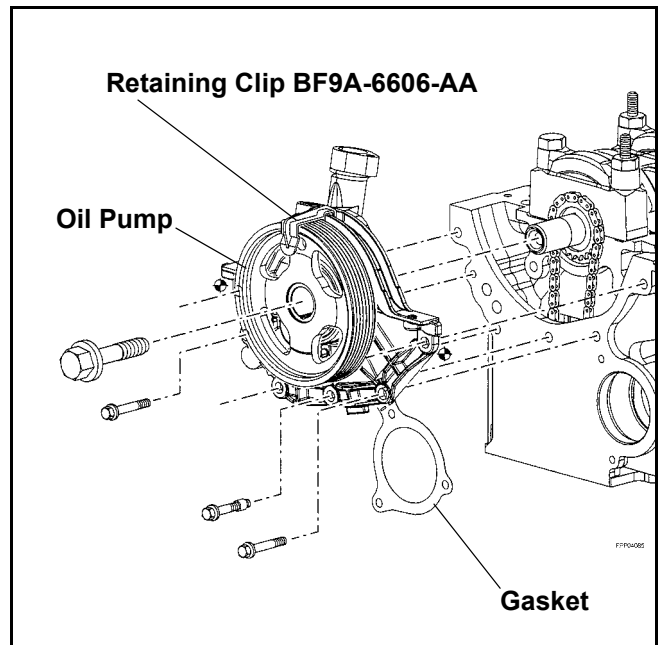


23. Insert retaining clip # BF9A-6606-AA between crankshaft pulley and oil pump to prevent pulley axial movement.

24. Remove crankshaft pulley bolt.

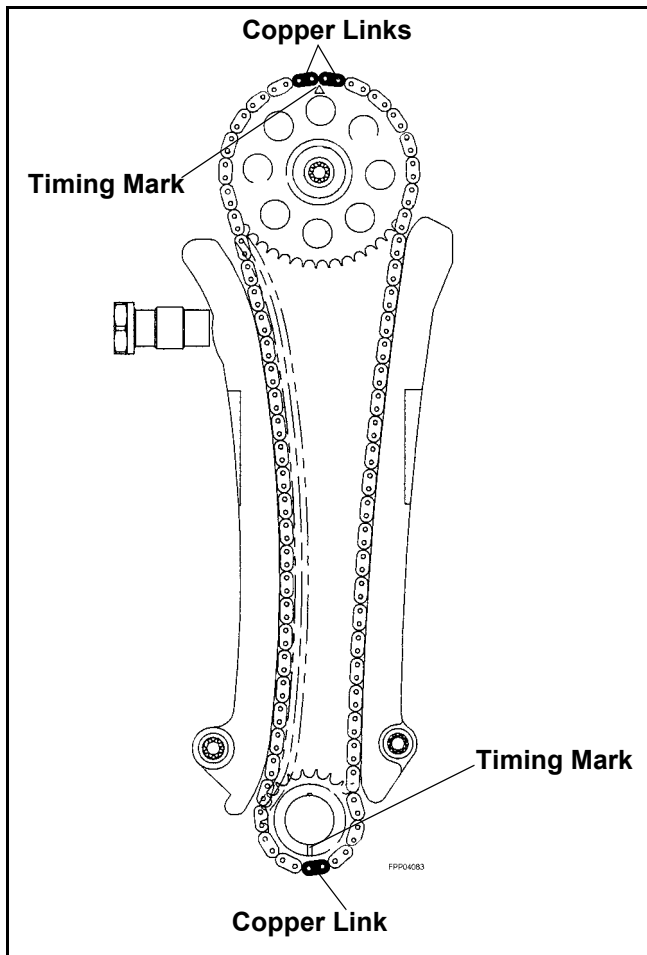
NOTE: Identify oil pump bolts so they may be returned to their original positions.

25. Remove 6 oil pump bolts, and oil pump.

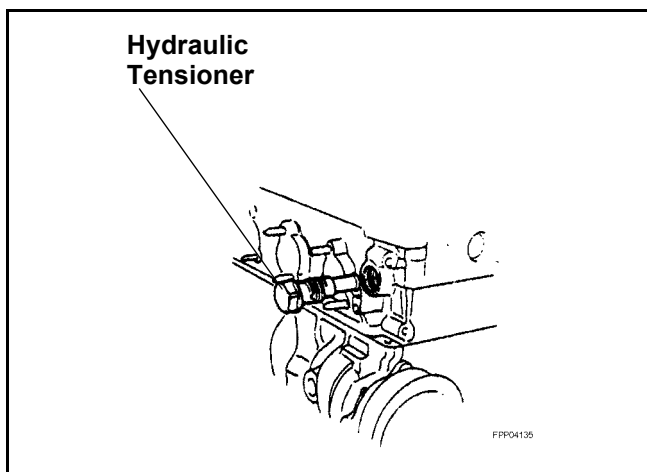


26. Check to see if coppered links on the timing chain are still visible. If not, identify them as follows:

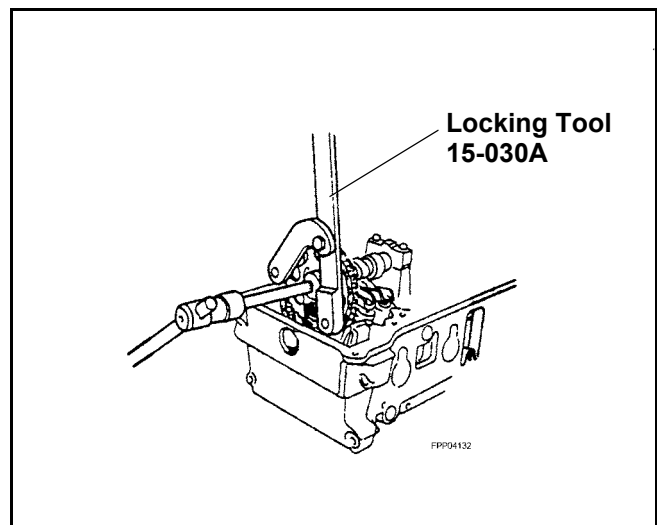
- Turn engine until timing mark on camshaft sprocket is at 12 o'clock.
- Mark the two chain links left and right of that timing mark.
- Mark the single chain link that is positioned on the crankshaft sprocket timing mark.



27. Remove the hydraulic tensioner.

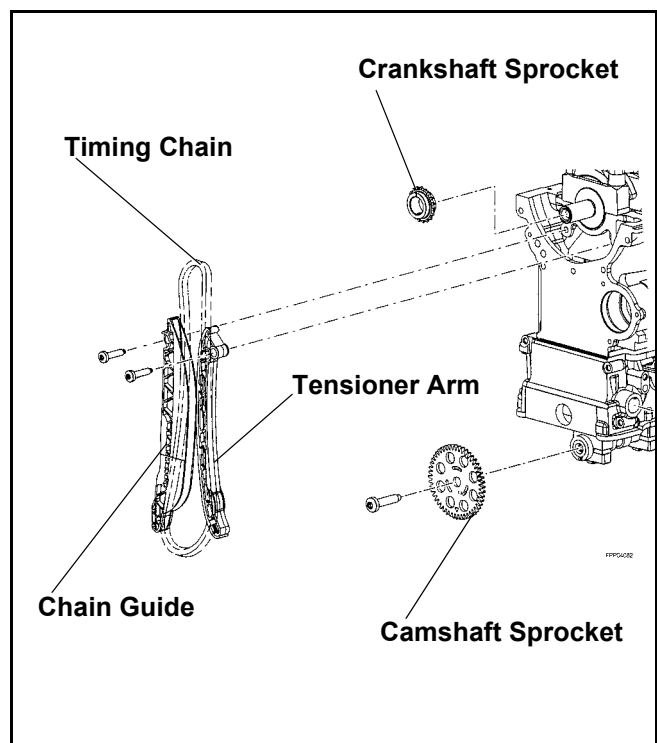


28. Using tool 15-030A to lock camshaft sprocket, remove bolt and camshaft sprocket.



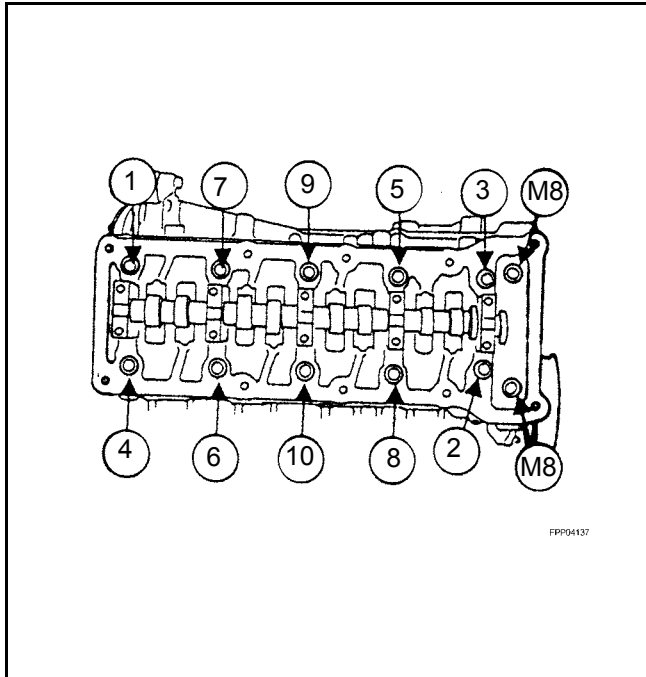
29. Remove timing chain and crankshaft sprocket.

30. Remove tensioner arm and chain guide.

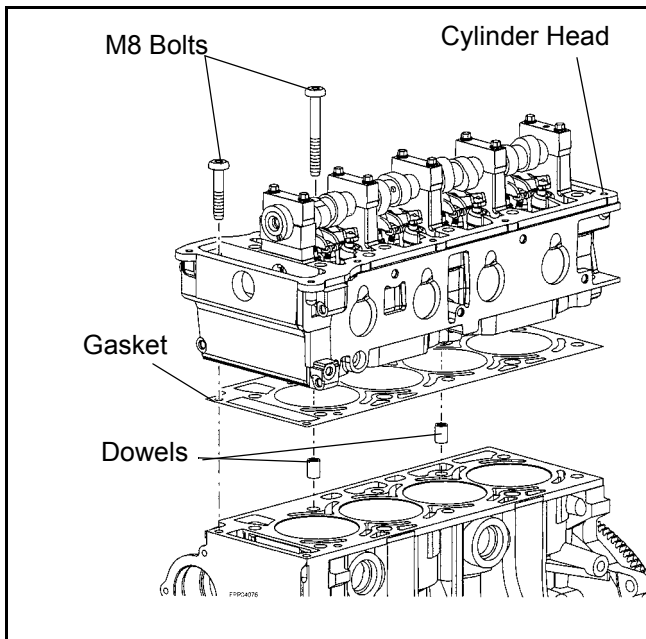


CAUTION: Keep cylinder head in the vertical position during removal to avoid warping and damage to the sealing surfaces.

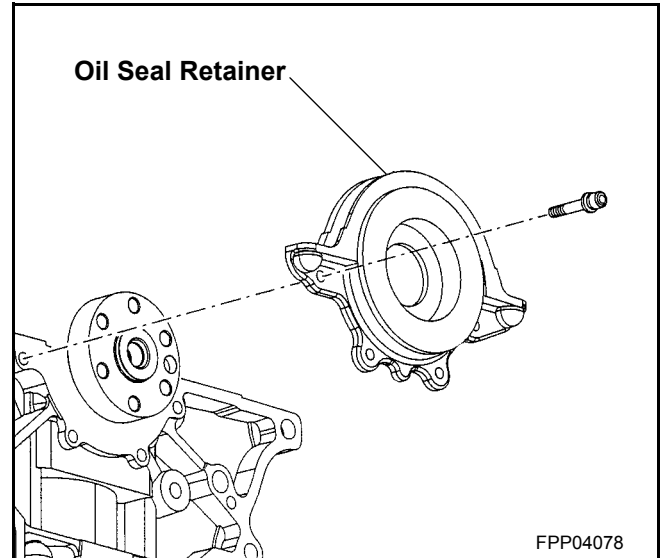
31. Remove the M11 cylinder head bolts in 3 phases in the sequence shown.



32. Remove 2 M8 bolts, cylinder head and gasket.

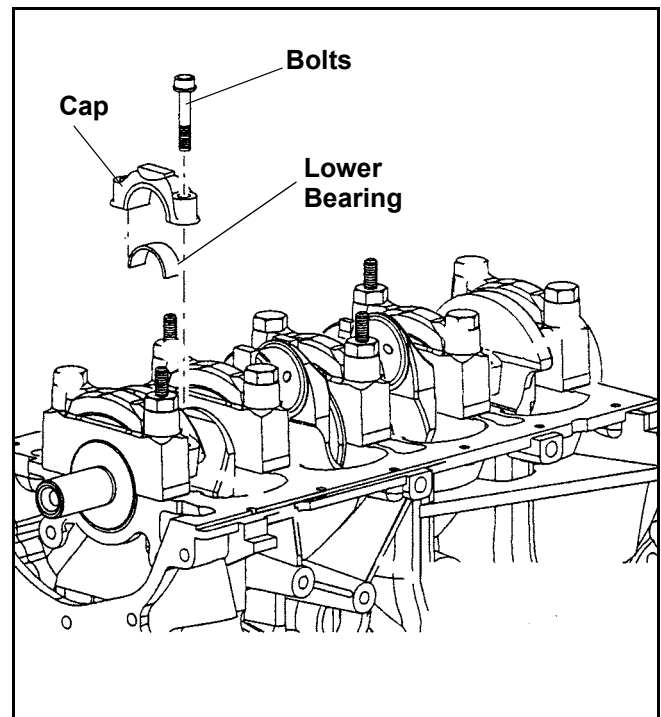


33. Remove crankshaft rear seal retainer.



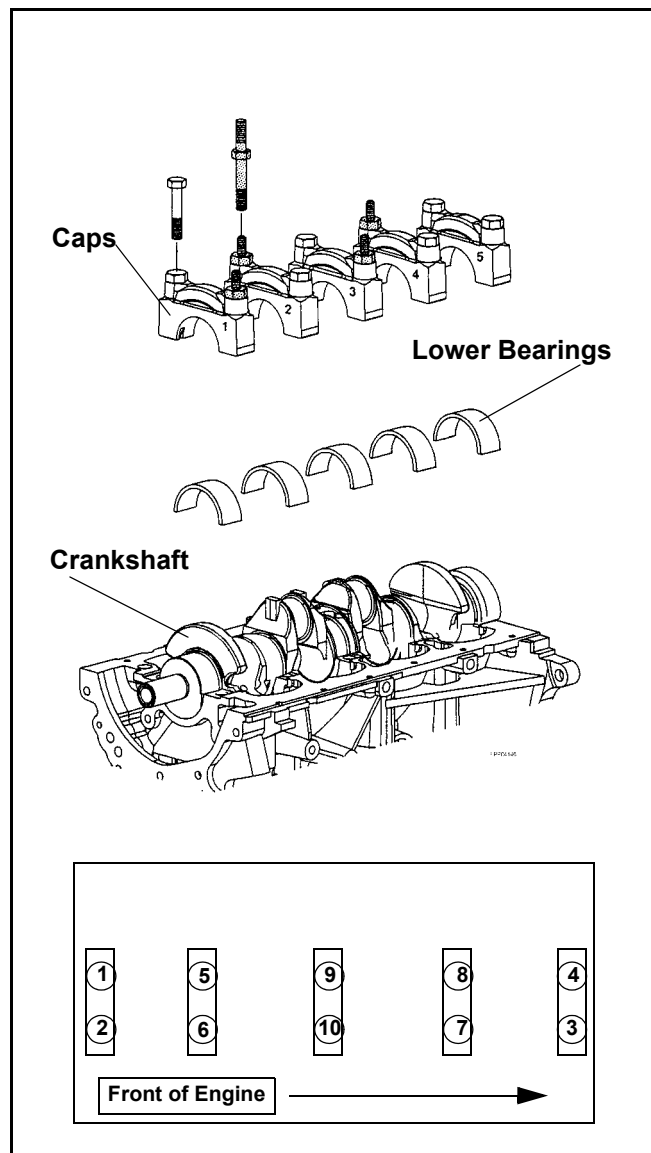
NOTE: Mark piston and cap so they may be returned to their original positions.

34. Remove 2 bolts, lower connecting rod bearing and cap. Push piston assembly out of the engine block. Repeat for other three cylinders.

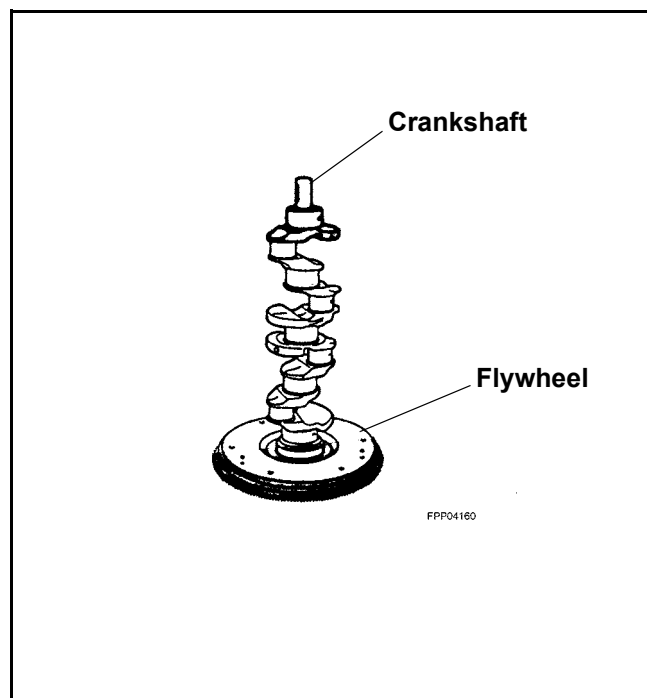


NOTE: Keep caps and bearings in order so they may be returned to their original positions.

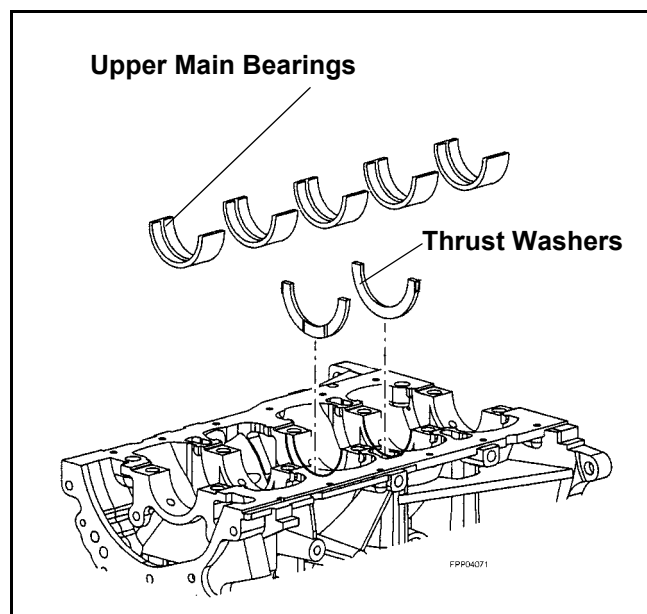
35. Remove bolts, caps and crankshaft lower main bearings in the sequence shown.



36. Carefully remove the crankshaft and install it vertically on the flywheel to avoid warp running-out.



37. Remove the 5 upper main bearings and the 2 thrust washers.



SUBASSEMBLIES

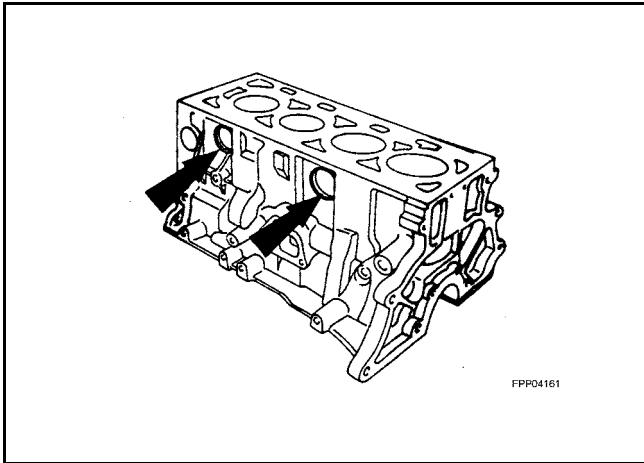
Clean crankcase and all subassemblies of all foreign material. Scrape or wire brush RTV sealant from mating surfaces. Surfaces must be kept oil free for good adhesion of fresh RTV seal (during reassembly).

NOTE: For cleaning and service information on crankcase, cylinder head, camshaft, crankshaft and bearings, Refer to Section 01.

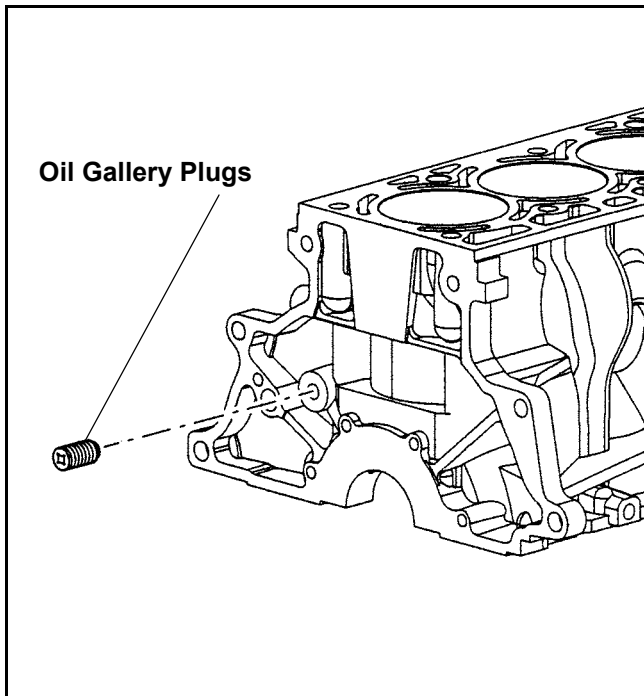
Discard gaskets and O-Rings and replace with new ones unless otherwise instructed.

Cylinder Block

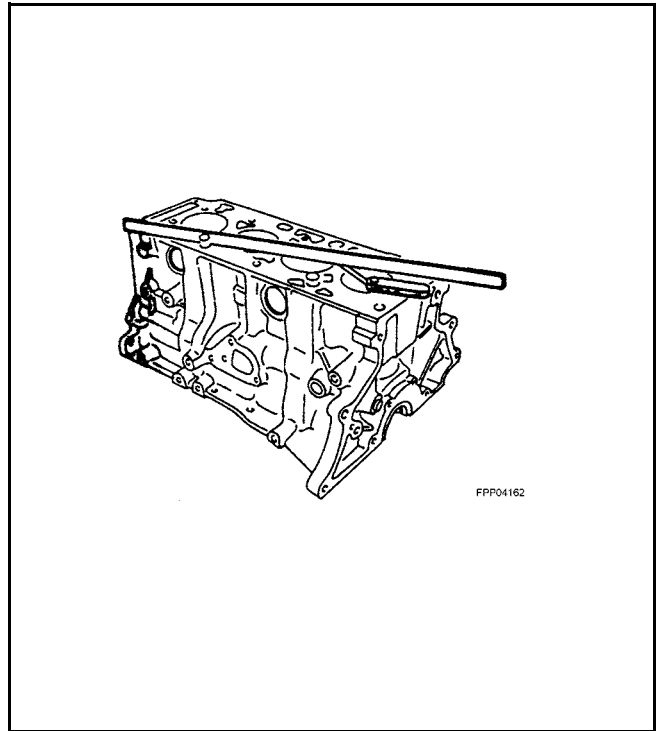
1. Remove the core plugs, if necessary.



2. Remove oil gallery plugs.



3. Check the engine block for warpage, cracks or any other damage.

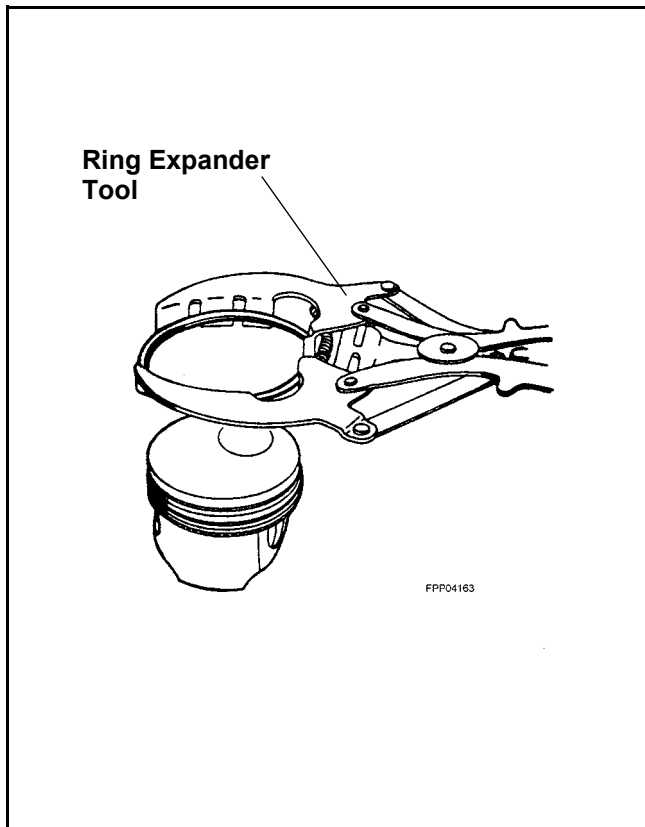


4. Coolant and oil galleries must be free of dirt and deposits.
5. Refer to Section 01 for cleaning & servicing cylinder block and core plug installation.
6. Reinstall oil gallery plugs.

Piston - Disassembly

NOTE: Store components to ensure assembly with the same rod and installation in the same cylinders from which they were removed. Refer to Section 01 for piston inspection and servicing.

1. Remove the connecting rod bearing from the connecting rod and cap.
2. Remove the piston rings using a suitable piston ring expander.

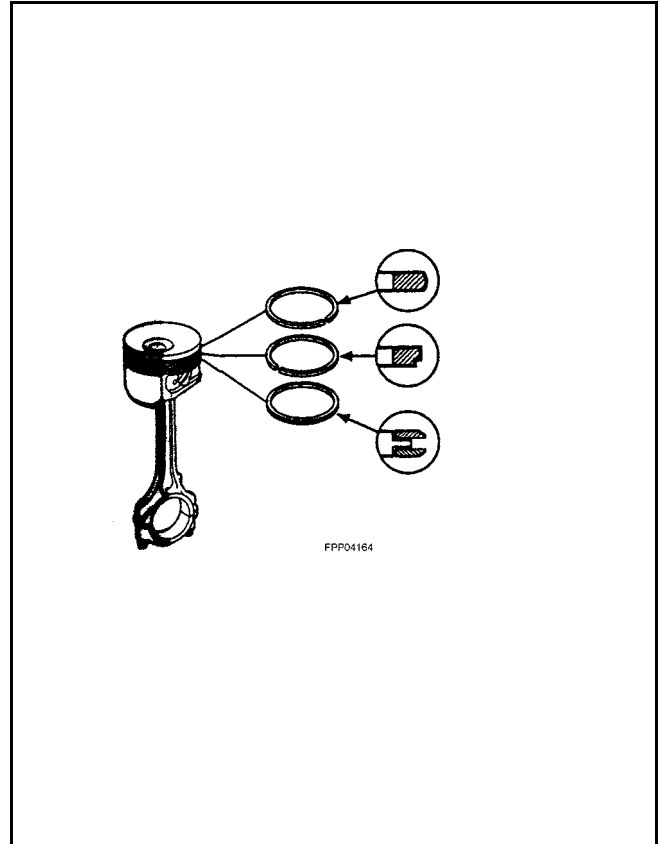


3. Remove piston pin????????????????????
- 4.

Piston - Assembly

NOTE: Apply a light coat of clean engine oil contact surfaces.

1. Assemble piston to connecting rod using ??????????
2. Install piston rings using a suitable piston ring expander.



NOTE: Check piston ring end gap and side clearance - refer to Section 01.

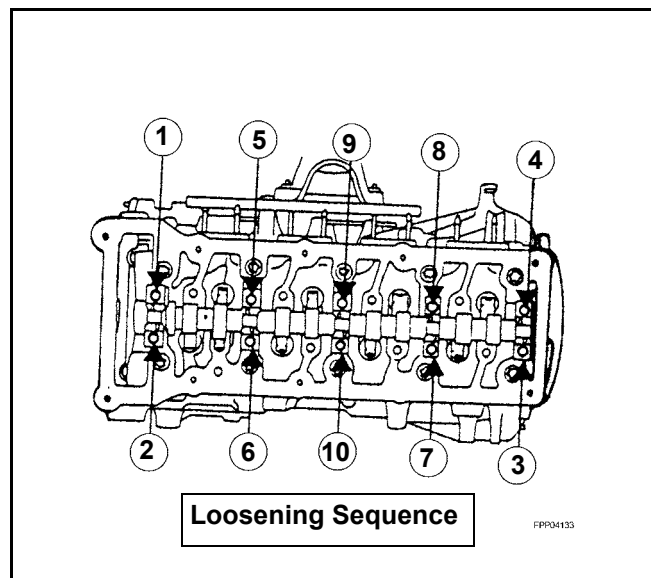
3. Install bearings into connecting rods and caps. Make sure lock slots align.

CAUTION: Make sure bearings and connecting rod bore are clean. foreign material under the inserts will distort the bearing and cause a failure.

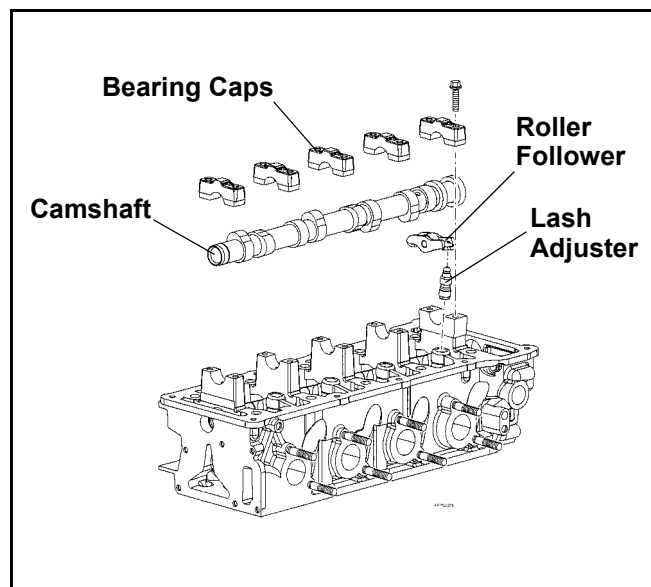
Cylinder Head - Disassembly

NOTE: Store components to ensure assembly in the same order as they were removed.

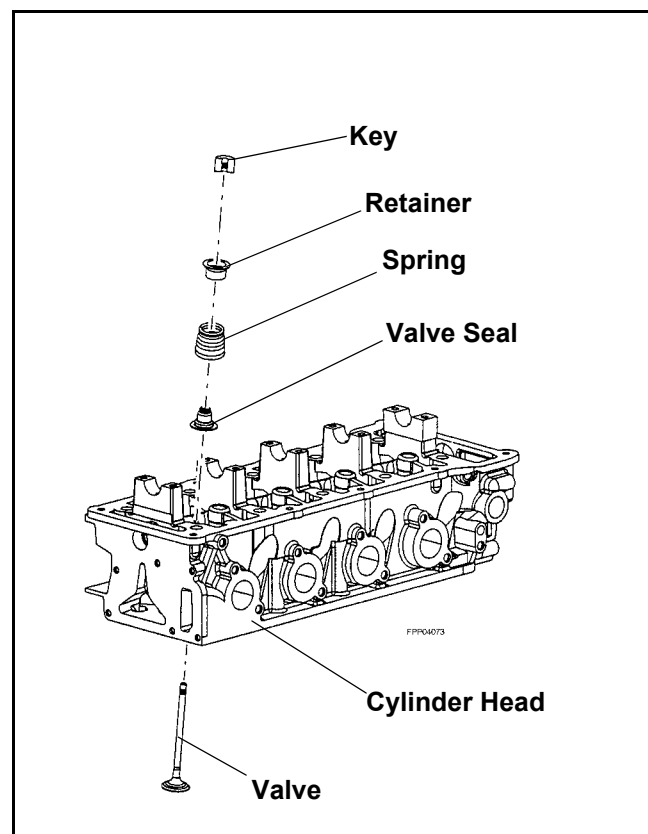
1. Remove bolts and camshaft bearing caps evenly in the sequence shown.



2. Remove camshaft.
3. Remove roller followers.
4. Remove lash adjusters.
5. Remove spark plugs.



6. Remove all valve components using a suitable valve spring compressor.



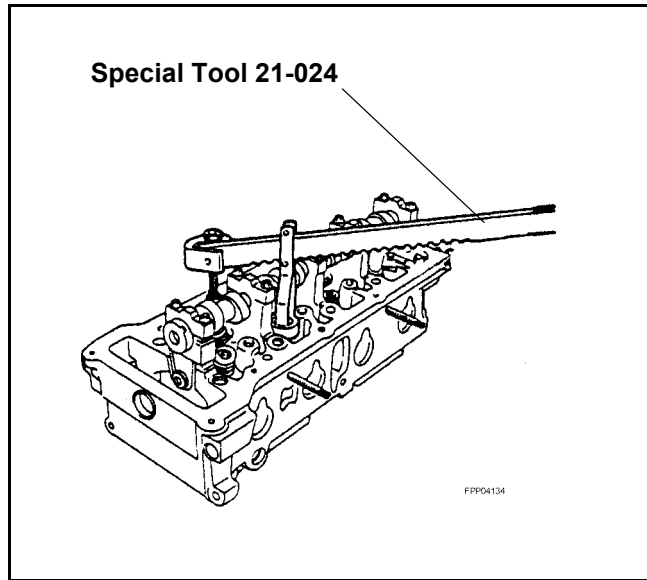
Refer to Section 01 for:

- servicing valve components, valve guide and valve seat.
- camshaft and bearing service.
- cylinder head cleaning and inspection.

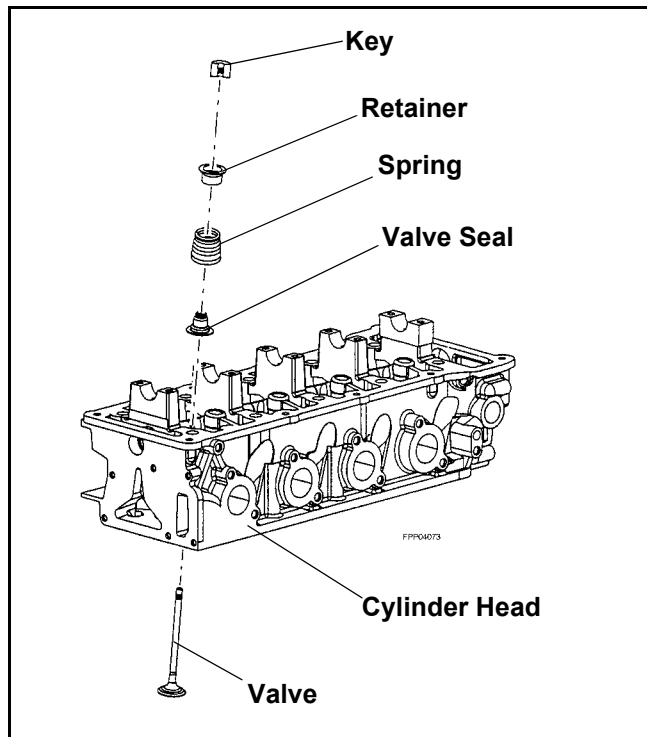
Cylinder Head - Assembly

NOTE: All components must be clean and assembled in the same positions as removed. Lubricate contact surfaces with clean engine oil.

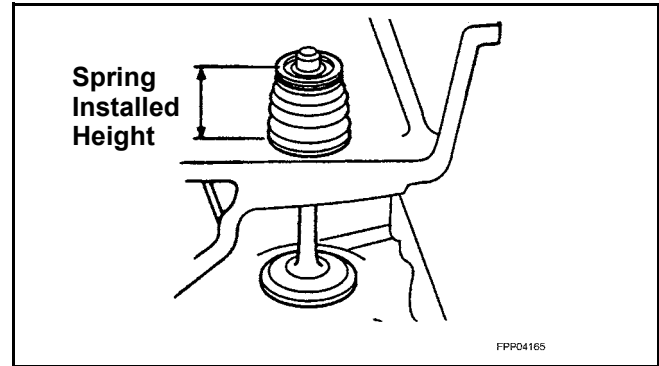
1. Check that valves move freely in valve guides.
2. Install intake and exhaust valves.
3. Install new valve seals using special tool 21-024 (optional T95P-6565A).



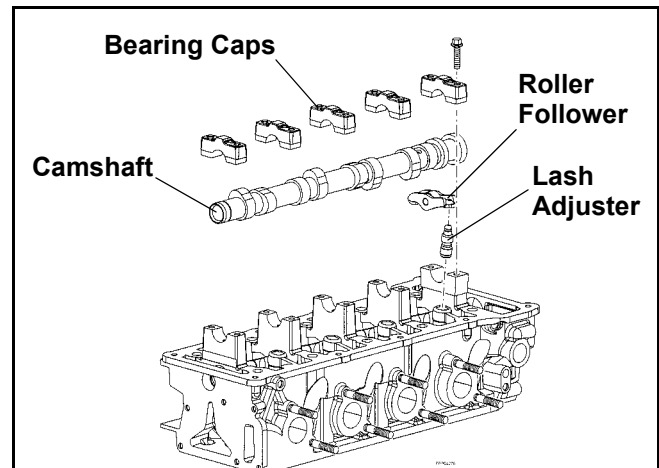
4. Using a suitable spring compressor tool, install valve springs, retainers and locks.



5. Check that spring installed height is 35.2 ± 1 mm.



6. Install lash adjusters.



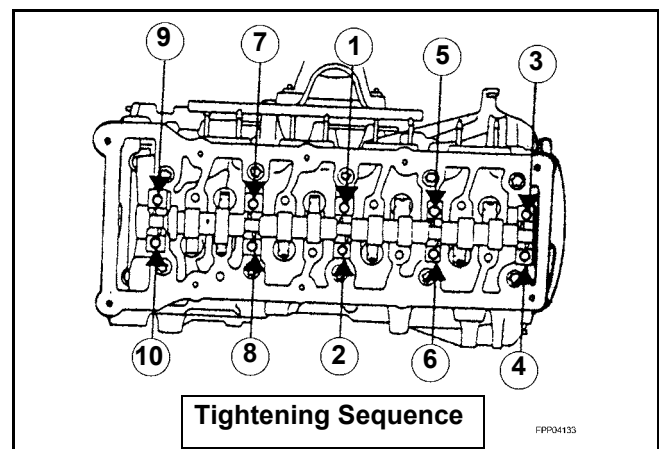
7. Install roller followers.

NOTE: The chamfer on the camshaft bearing caps must be facing the chain housing.

8. Carefully install camshaft bearings, camshaft and bearing caps with bolts finger tight.

NOTE: Rotate camshaft so key is at 12 O'clock position.

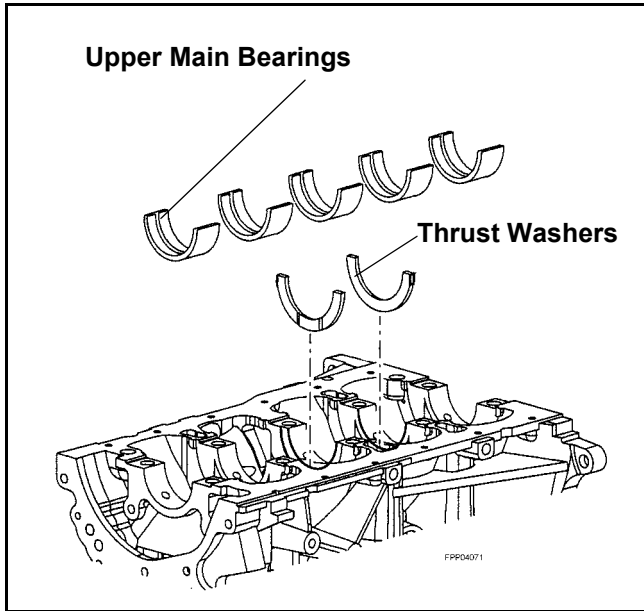
9. Tighten bolts in the sequence shown in 3 steps to 6-7 lb.ft. (8-10 Nm).



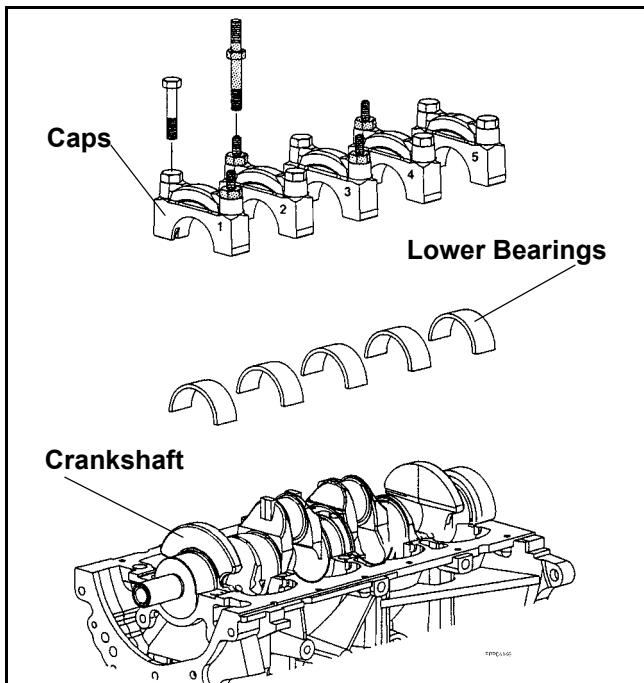
ASSEMBLY

NOTE: All components must be clean and dried with compressed air or a lint free cloth. For information on bearings & piston inspection and selection - Refer to Section 01.

1. Install upper main bearings and thrust washers to cylinder block. Lubricate the wear surfaces with clean engine oil. Make sure oil holes align.



2. Carefully install the crankshaft onto the upper bearings.
3. Assemble the lower main bearings into caps. Lubricate the wear surfaces and the bolt threads with clean engine oil.

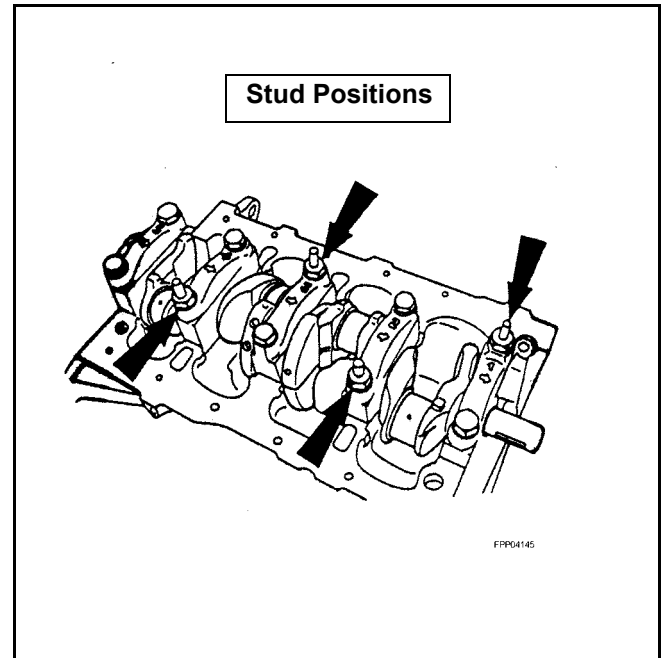


NOTE: The main bearing caps are numbered and must be assembled to corresponding numbers. The arrow on the main bearing caps must point to the front of the engine.

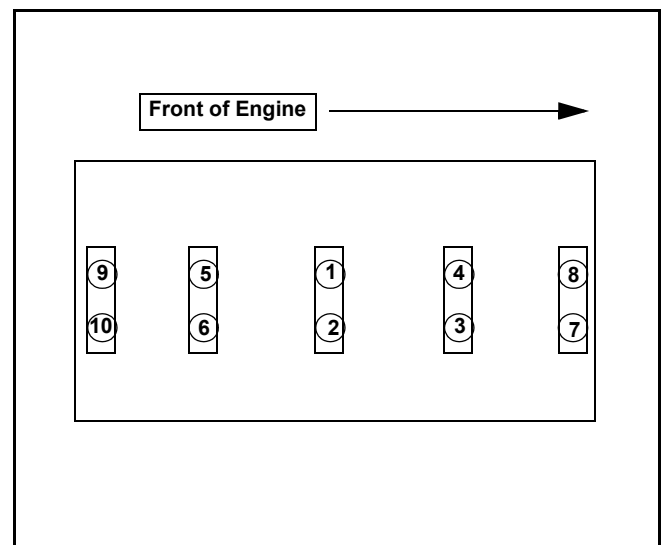
CAUTION: Use new main bearing cap bolts.

4. Install main bearing caps in the same positions as removed.

NOTE: Check the position of studs as shown.

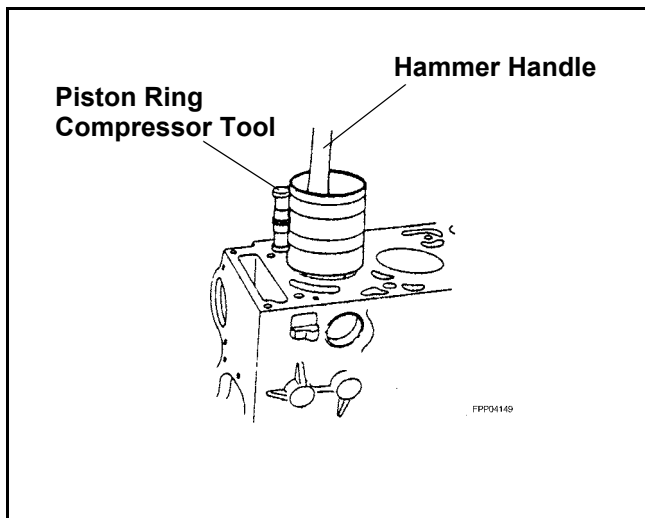


5. Tighten main bearing cap bolts/studs in sequence shown and in three steps to 70 lb.ft. (95 Nm).



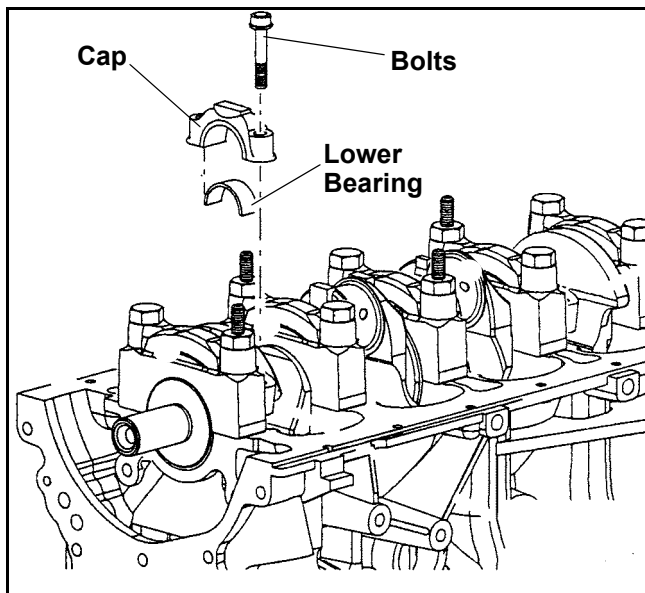
NOTE: Check crankshaft end play as outlined in Section 01.

6. Set piston ring gaps as follows:
 - lower oil ring gap aligned with piston pin.
 - center ring gap at 90° from the oil ring gap.
 - top ring gap at 180° from the oil ring gap.
7. Lubricate piston, bearing wear surface, crankshaft journal and cylinder wall with clean engine oil.
8. Carefully install pistons with bearings into cylinder bores using a piston ring compressor and a hammer handle. Avoid damage to the crankshaft bearing journals. The arrow of the piston must point to the front of the engine. The connecting rod has the cylinder number identified in the base.

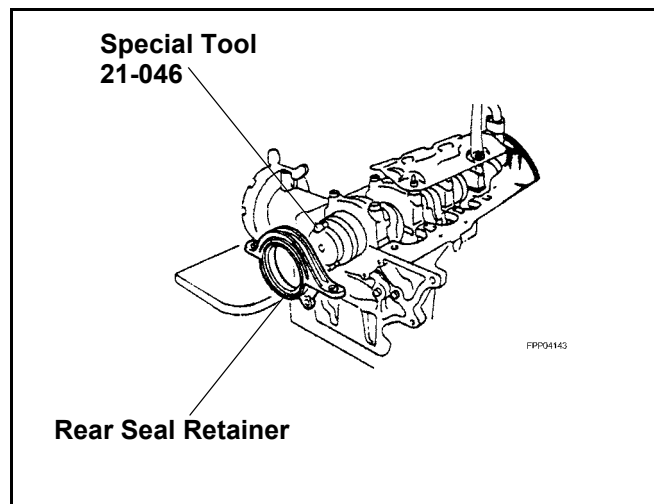


CAUTION: Use new connecting rod cap bolts and lubricate threads with clean engine oil.

9. Install connecting rod caps with bearings (lubricate wear surface) and tighten bolts in 2 steps:
 - Step 1 - 9 lb.ft. (12.5 Nm)
 - Step 2 - 22 lb.ft. (30 Nm) (41-94°???)



10. Install a new rear seal and retainer using tool 21-046.

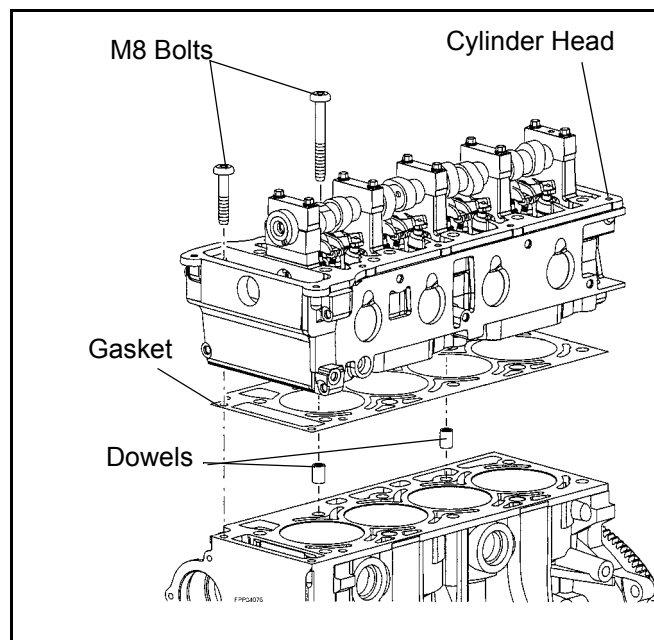


NOTE: Rear seal retainer comes on a plastic sleeve. Link plastic sleeve to crankshaft (?? 34mm ??) and push retainer to crankshaft. Plastic pins at rear side of retainer must fit to corresponding block bores. Remove plastic sleeve when done.

11. Turn engine 180° to prepare for cylinder head installation.

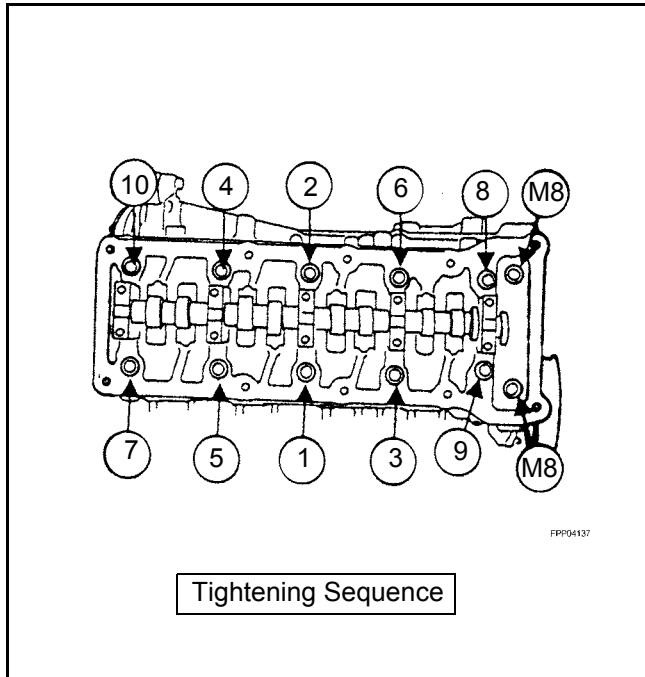
NOTE: The contact surface of the cylinder head and block must be clean and free of oil. Use new cylinder head bolts and lubricate the threads.

12. Rotate crankshaft so all pistons are **below** top dead center (TDC).
13. Install dowels and new cylinder head gasket to the engine block.
14. Carefully install the cylinder head onto the gasket.

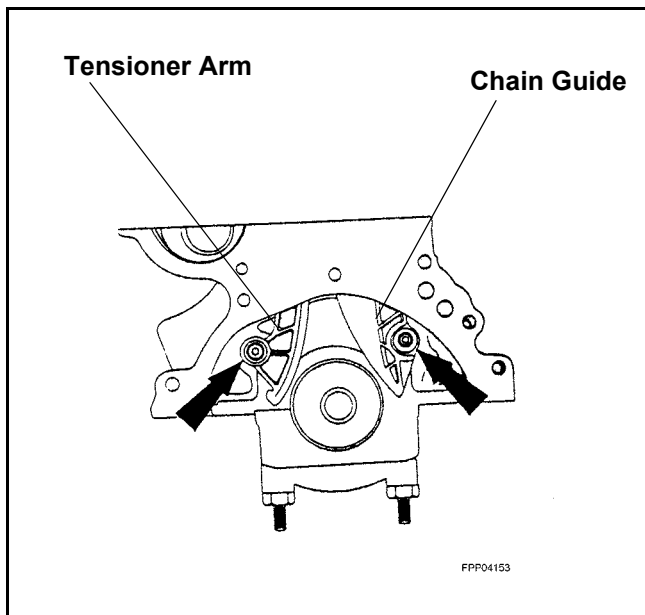


15. Install new bolts using the sequence shown in the following 3 steps:

- Step 1 - tighten M11 bolts to 29.5 lb.ft. (40 Nm)
- Step 2 - tighten M8 bolts to 11 lb.ft. (15 Nm) + 45°
- Step 3 - tighten M11 bolts additional 120°

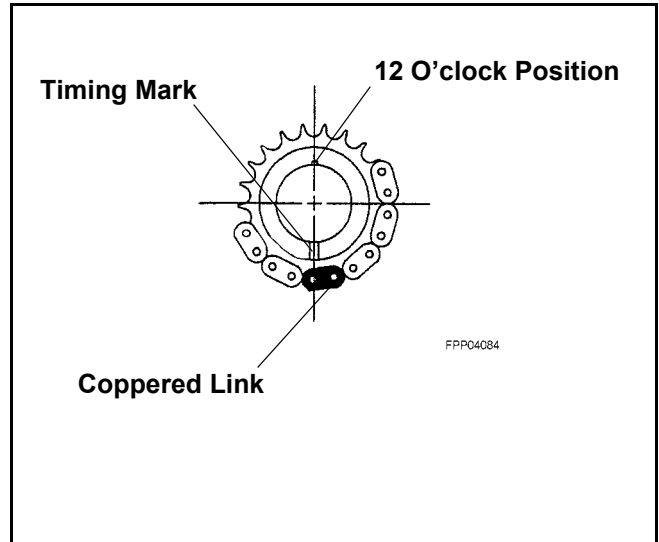


16. Install the chain guide and the tensioner arm from the top of the engine. Install bolts finger tight.

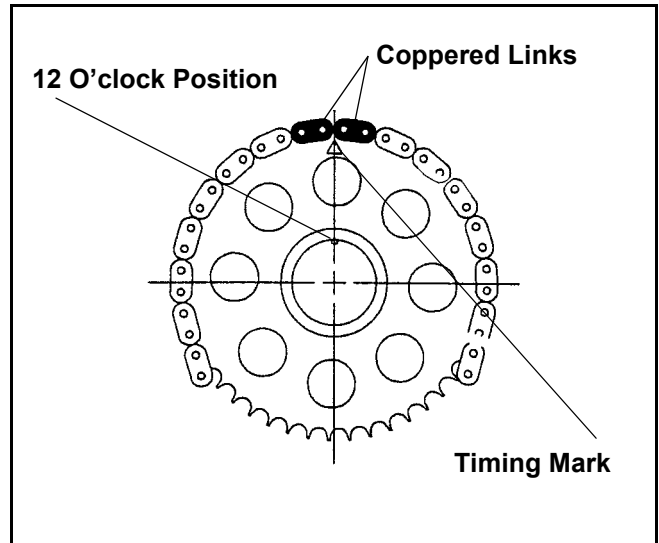


17. Install crankshaft sprocket with key at 12 o'clock position.

18. Assemble drive chain through chain housing cavity from top of engine and onto crankshaft sprocket. Align timing mark with coppered link on drive chain.



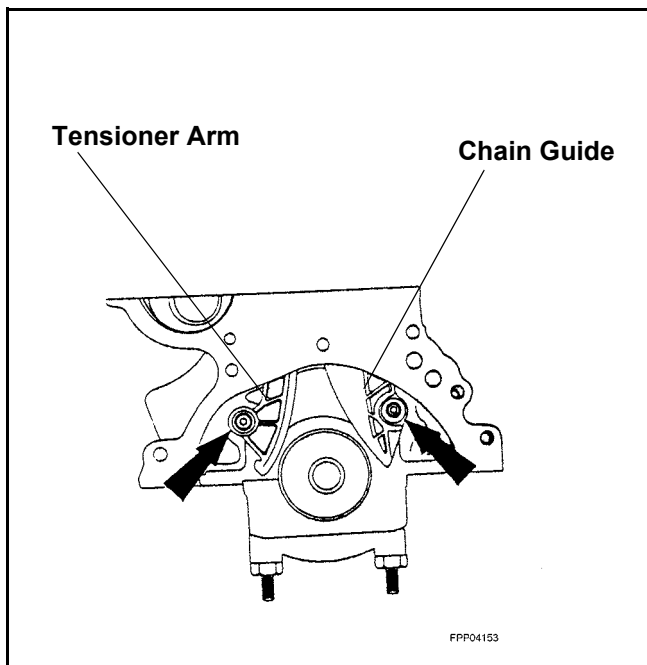
19. Insert camshaft sprocket into chain and assemble to camshaft. Position camshaft key at 12 o'clock and align timing mark between 2 coppered links on drive chain.



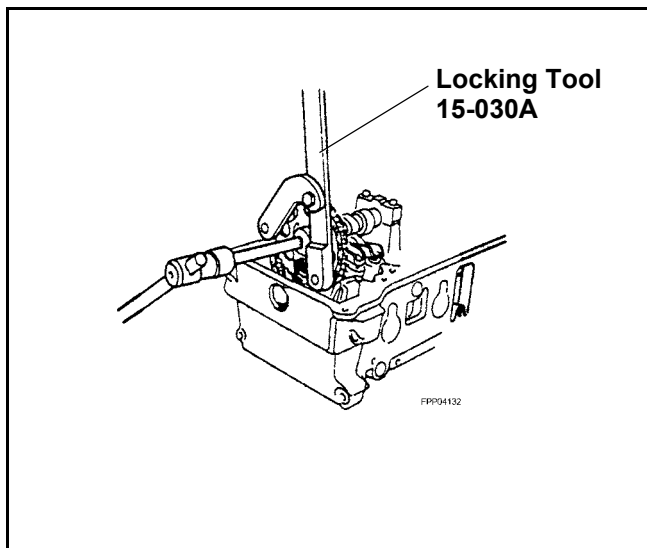
20. Install camshaft sprocket bolt and hydraulic tensioner finger tight.

TSG-416 ENGINE

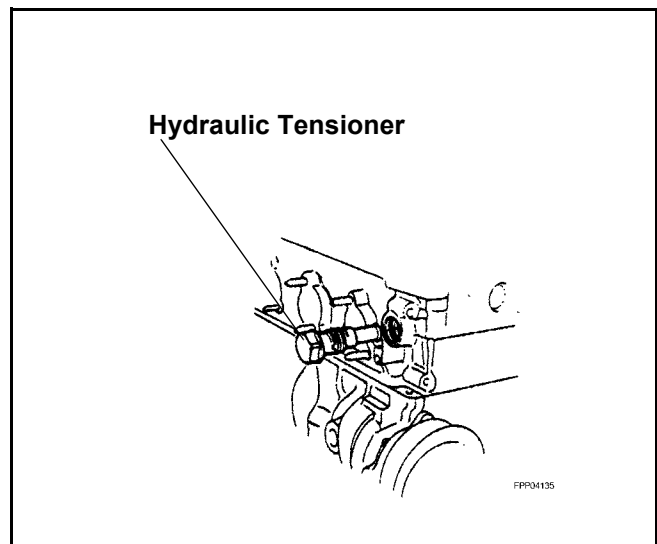
21. Tighten guide and tensioner arm bolts to 18-21 lb.ft. (24-28 Nm).



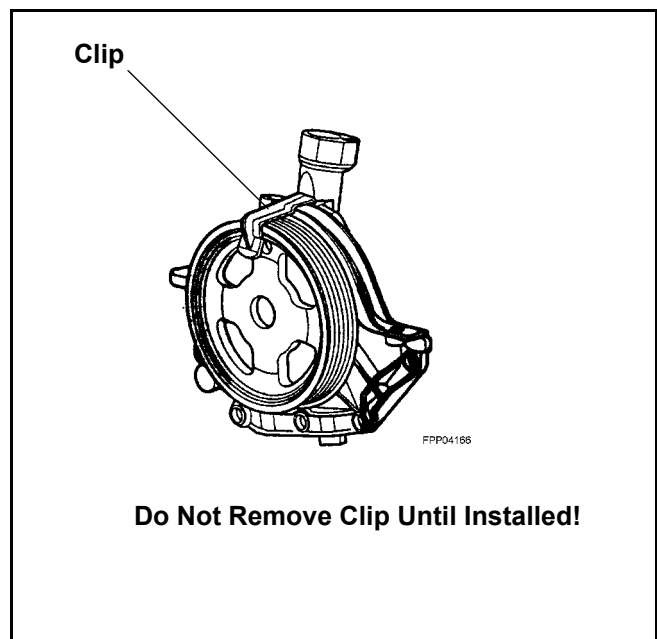
22. Using locking tool, tighten camshaft sprocket bolt to 52-59 lb.ft. (70-80 Nm).



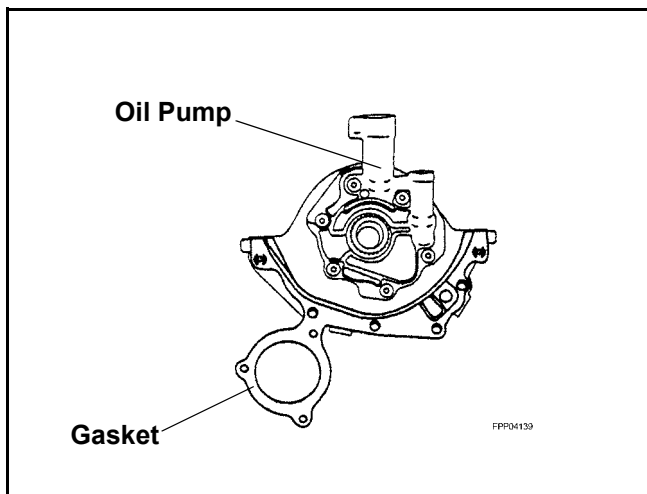
23. Tighten hydraulic tensioner to 27-32 lb.ft. (36-44 Nm).



CAUTION: The oil pump, pulley and sealer are provided as an assembly kept together by a clip (no. BF9A-6606-AA). Do not remove clip until oil pump is installed. If pulley is pushed out of the oil pump prior to oil pump installation, it will have to be ??repaired?? or replaced. (?can this pump be rebuilt?)



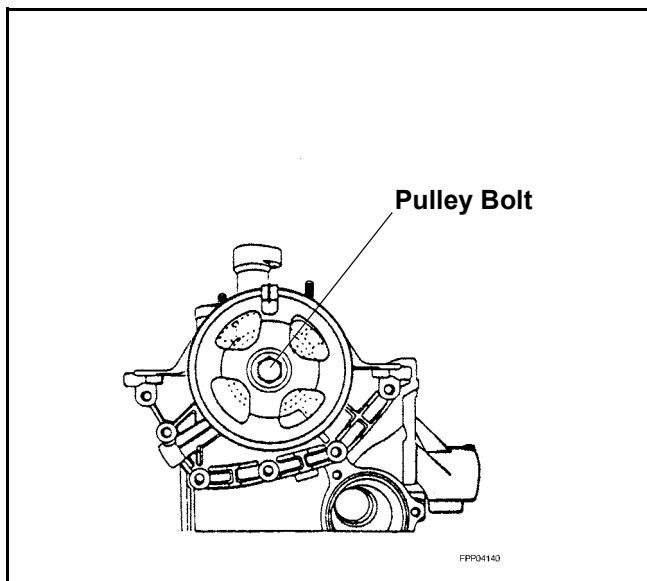
24. Assemble gasket onto oil pump housing guiding it with 2 outer bolts.



CAUTION: Do not apply oil to shaft or seal. Sealing lip along with all contact surfaces must be free of oil.

25. Place oil pump and gasket onto crankshaft.

26. Install pulley bolt and tighten to 92 lb.ft. (125 Nm).

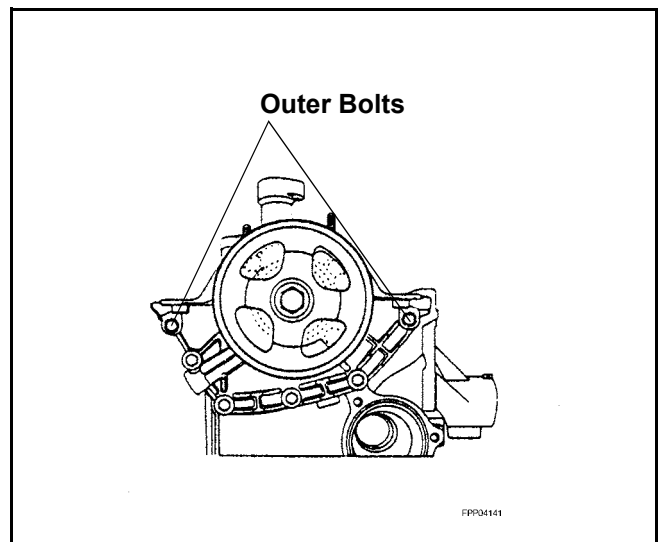


27. Remove clip.

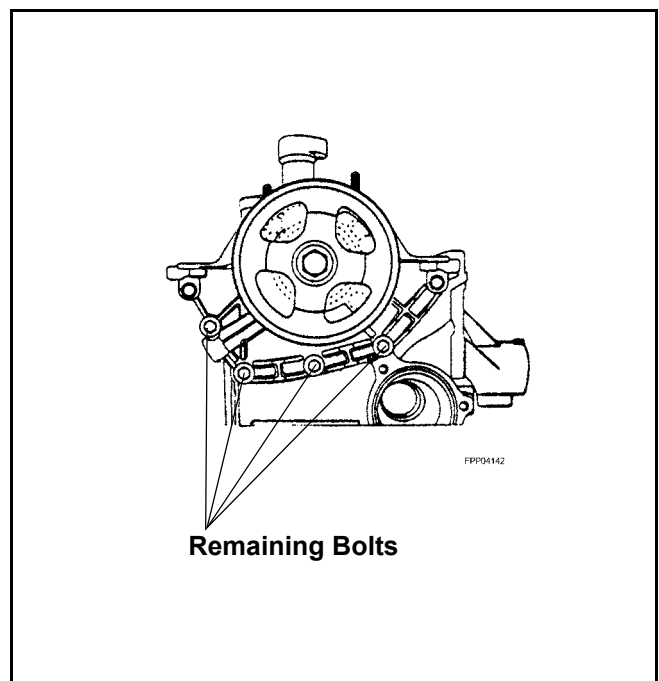
28. Install oil pump housing bolts finger tight.

CAUTION: The oil pump housing must be positioned during tightening of the oil pump housing bolts, so that the sealing flange of the oil pump housing is within ± 0.008 in. (0.20 mm) of the block bottom sealing flanges.

29. Tighten 2 outer oil pump housing bolts to 15 lb.ft. (20 Nm).

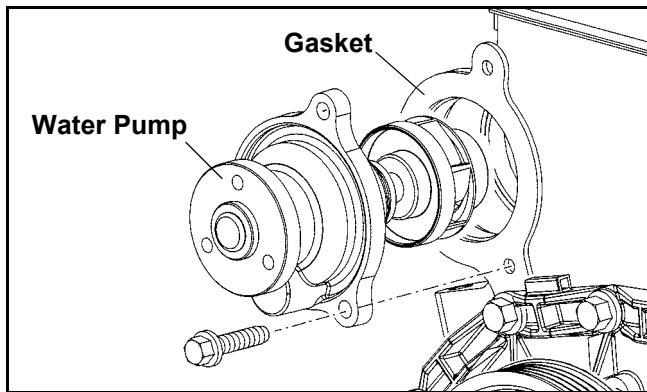


30. Tighten remaining oil pump housing bolts to 15 lb.ft. (20 Nm).



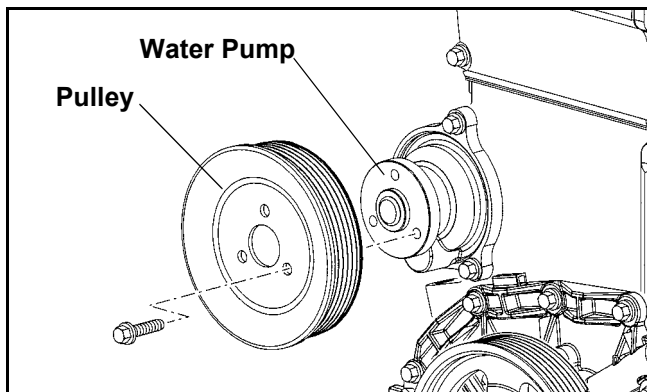
31. Install water pump.

32. Install bolts and tighten to 7 lb.ft. (10 Nm).



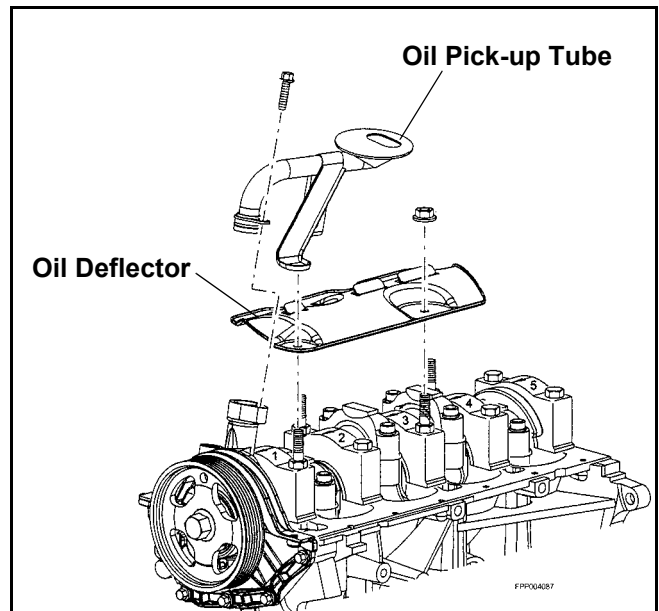
33. Install water pump pulley.

34. Install bolts and tighten to 9 lb.ft. (12 Nm).



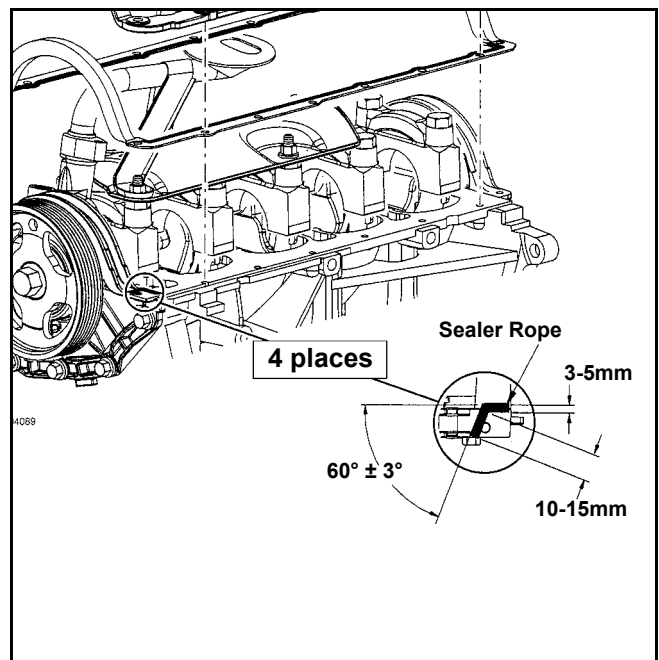
35. Install oil deflector.

36. Install oil pick-up tube.



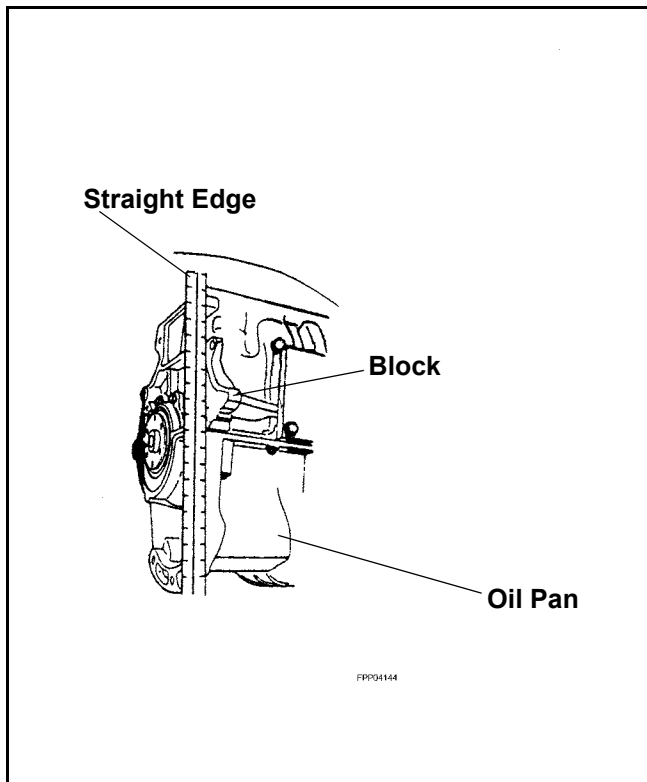
37. Tighten nuts to 14 lb.ft. (19 Nm). Tighten bolt to 7 lb.ft. (9.5 Nm).

38. Apply WSEM-A4 sealer (Loctite 5910) to the 4 positions as shown.



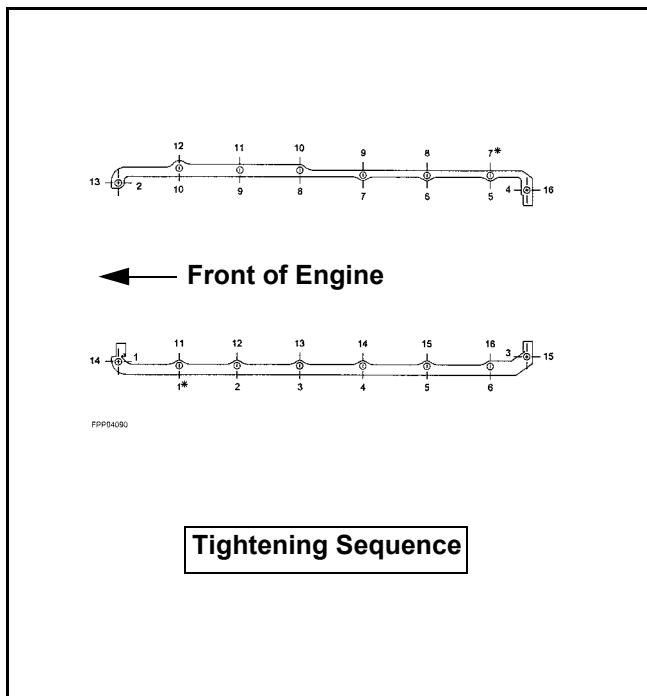
CAUTION: The contact surfaces of oil pan, gasket and block must be free of oil. Do not wait more than 5 minutes to install the oil pan gasket after sealer has been applied.

39. Install the oil pan and bolts finger tight.
40. Align oil pan with rear portion of engine block.

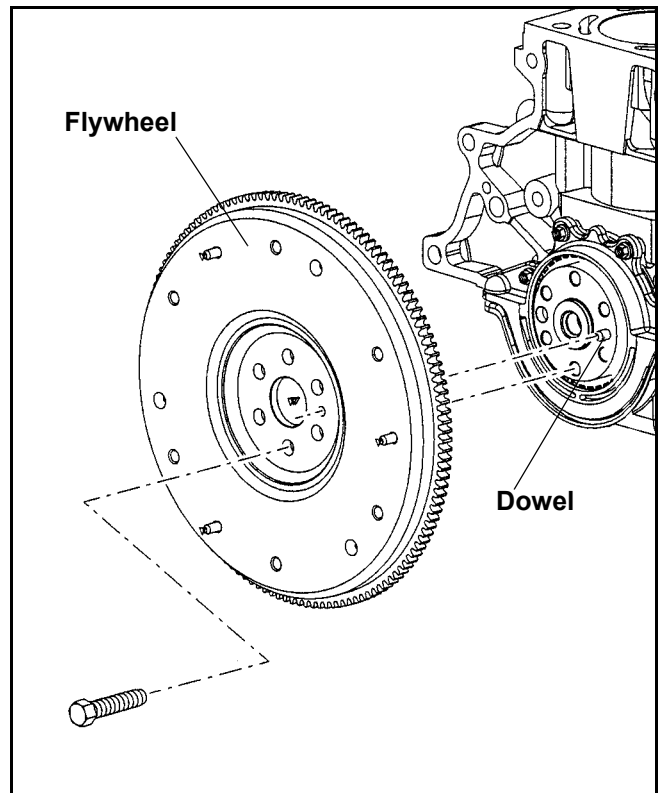


41. Tighten oil pan bolts in 3 steps in the sequence shown:

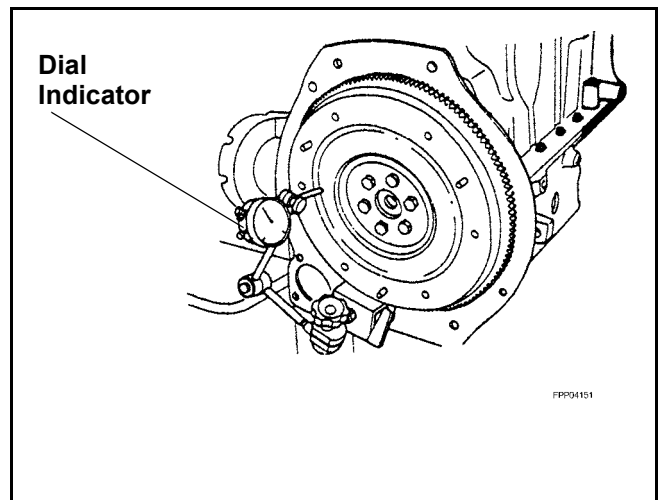
- enough for gasket settlement
- 5 lb.ft. (7 Nm)
- 7 lb.ft. (10 Nm)



42. Install the oil pan drain plug. Tighten to 18 lb.ft. (25 Nm).
43. Install flywheel using special locking tool 21-168.

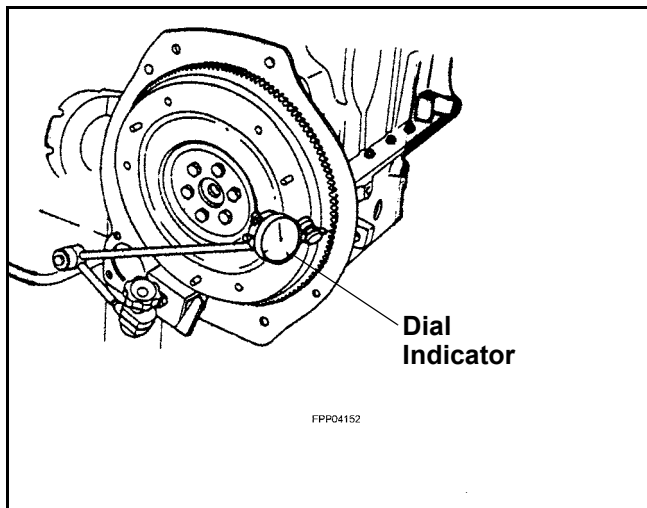


44. Lubricate bolt threads with clean engine oil and tighten to 49 lb.ft. (67 Nm).
45. Check flywheel runout at clutch disc surface:
- maximum runout 0.005 in. (0.13 mm)

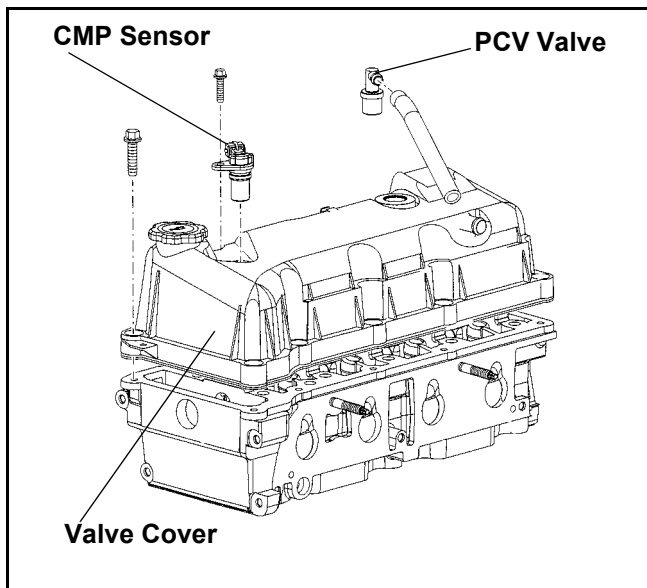


46. Check flywheel runout at gear surface:

- maximum runout 0.024 in. (0.6 mm)



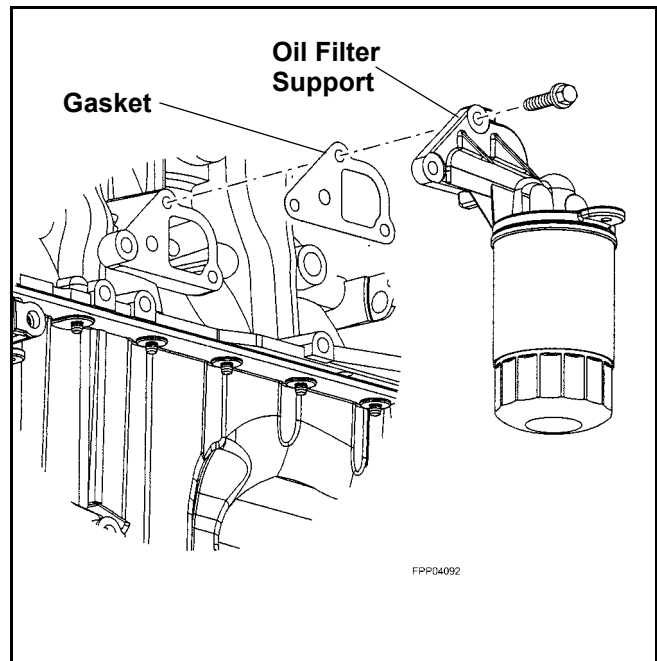
47. Install valve cover and gasket. Tighten bolts to 7 lb.ft. (9 Nm).



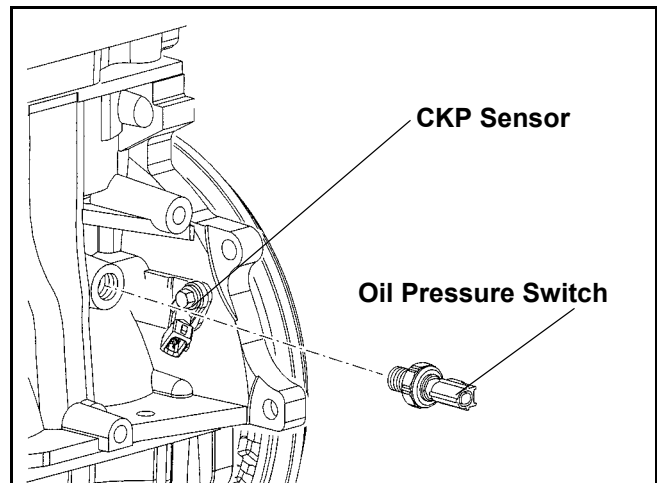
48. Apply grease WSD-M13P8-A1 (? klüberpaste? HEL46-450 ? anti-seize?) or equivalent to spark plug threads.

49. Install spark plugs and tighten to 10-13 lb.ft. (13-17 Nm).

50. Install oil filter support with new filter. Tighten bolts to 15 lb.ft. (20 Nm).

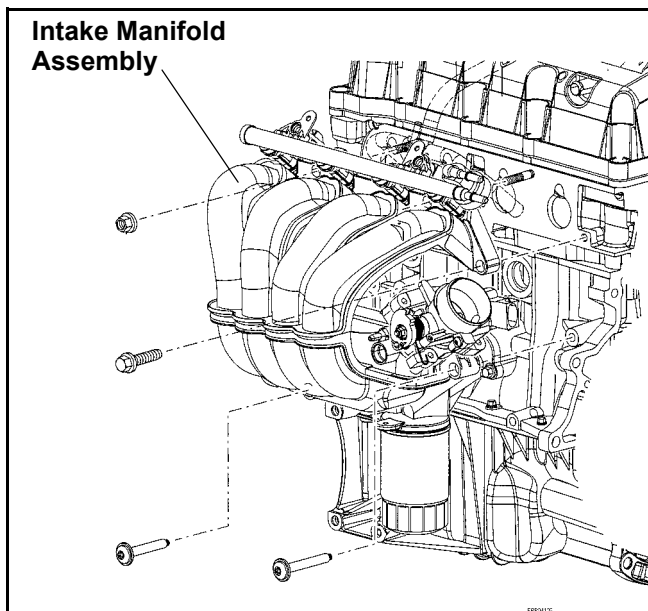


51. Install oil pressure switch and tighten to 15 lb.ft. (20 Nm).

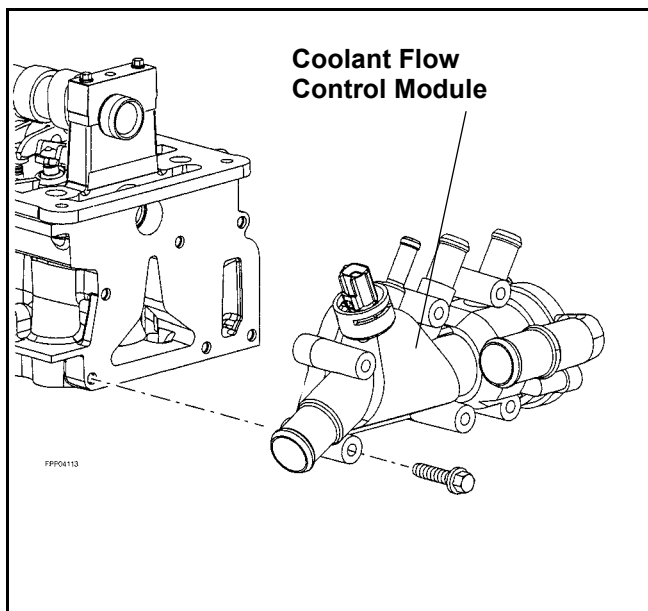


52. Install crankshaft position sensor and tighten to 3 lb.ft. (4 Nm).

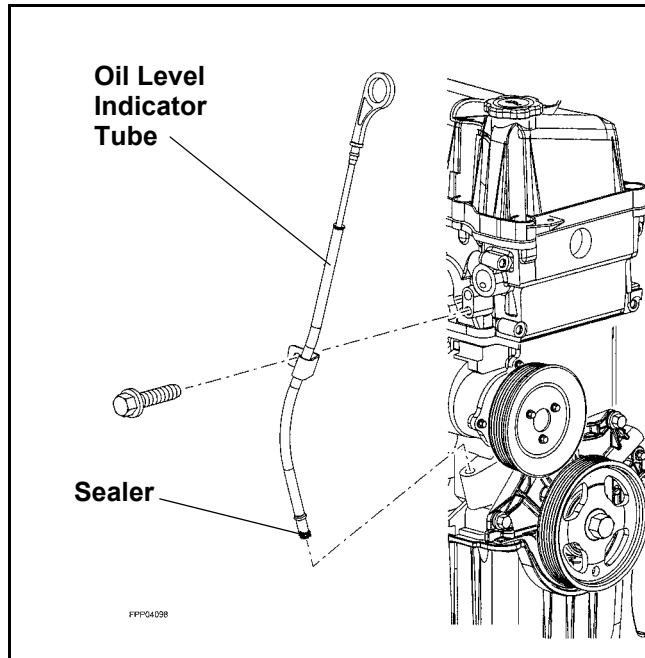
53. Install intake manifold and gasket. Tighten bolts and nuts to 6 lb.ft. (8 Nm).



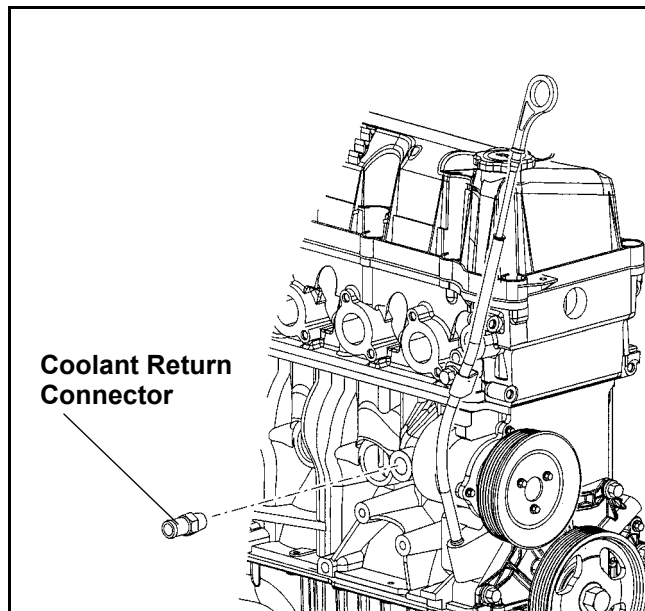
54. Install coolant flow control module and gasket. Tighten bolts to 7 lb.ft. (10 Nm).



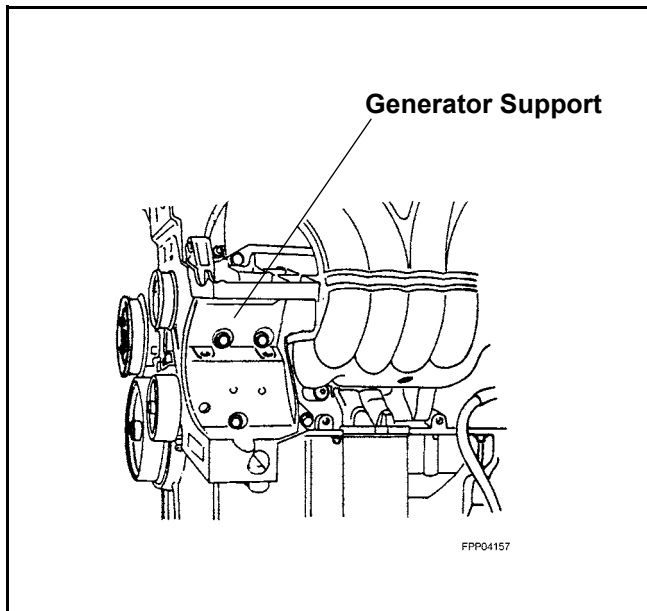
55. Apply sealer WSK-M2G 349-A4 (Loctite 648) to lower end of oil level indicator tube. Install immediately and tighten bolt to 15 lb.ft. (20 Nm).



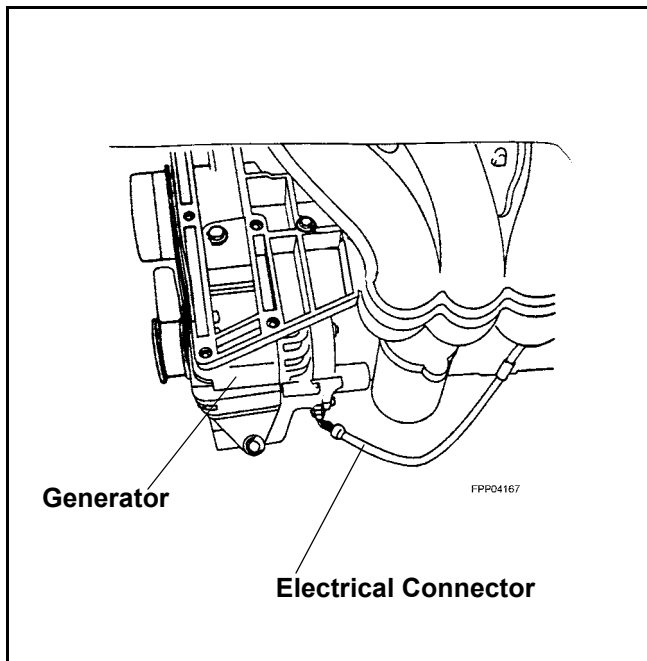
56. Apply sealer WSK-M2G 349-A7 (Loctite 243) to threads of coolant return connector. Install and tighten to 15 lb.ft. (20 Nm).



57. Install generator support. Tighten bolts to? lb.ft. (? Nm).

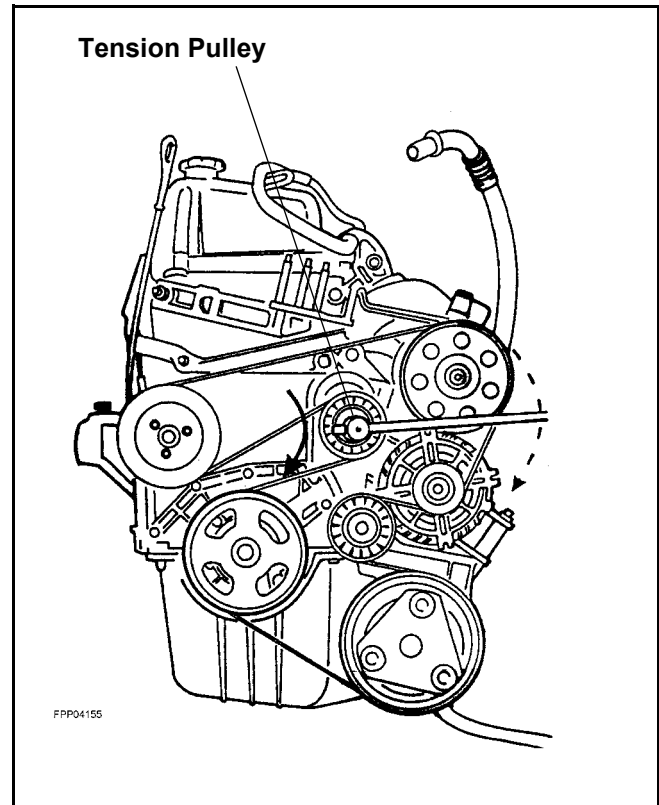


58. Install generator and electrical connectors. Tighten bolts to? lb.ft. (? Nm).

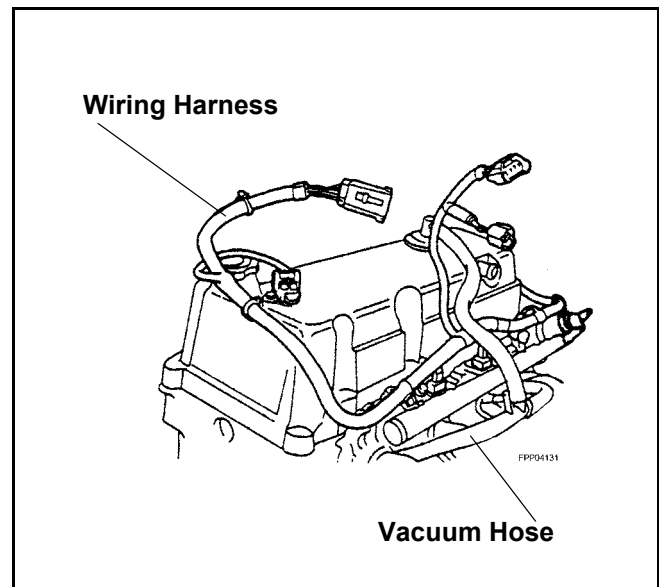


NOTE: Drive belt must be installed in the same direction of rotation as when removed.

59. Pry tensioner pulley as shown and install drive belt.



60. Install engine wiring and vacuum hoses.



61. Fill engine with clean engine oil of the correct type and quantity.

NOTE: Ford Power Products industrial engines are designed to perform with engine oils that are licensed by the American Petroleum Institute (API) and oils carrying the most current API classification should be used.

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Engine Type:	4 cylinder, 4 stroke spark ignition 90° Overhead Valve (OHV) chain driven, overhead camshaft operating the valves via roller cam followers.
Liter/CID:	1.6 / 97.5
Bore: mm (inch)	82.070 mm (3.23 in.)
Stroke: mm (inch)	75.480 mm (2.97 in.)
Number of cylinders:	4
Compression Ratio:	9.5 : 1

FUEL SYSTEM	
LPG Type: Fuel Specification:	Liquefied Petroleum Gas EN589 (European) (USA)
NG Type: Fuel Specification:	Natural Gas 38.7 MJ/m ³ (UK) 39.0 MJ/m ³ (USA)
GAS Type: Fuel Specification:	Gasoline (petrol) Electronic Fuel Injection Unleaded 87 or 89 Octane (Gasoline blends not to exceed 10% Ethanol by volume Octane Index of 87 or 89).
Fuel Pump Pressure Normal: Max:	(Part #ZU1L-9350-AA) 40 psi ?? psi

LUBRICATION SYSTEM	
Max. Oil Pressure:	Hot@2500 rpm: 275.79 - 413.69 kPa (40-60 psi)
Oil Type:	SAE 5W30 WSS-M2C205-A (API classification: SJ)
Service Oil fill capacity (including filter):	4.2 Liter (4.44 quarts)
Oil filter Type:	X56E-6714-D1A

COOLING SYSTEM	
Thermostat:	Type: Wax element Commences opening: 82.2°C (180°F) Fully open: 94.5°C (202°F)
Coolant	50% Motorcraft Super Plus 2000 plus 50% clear water Ford Specification: WSS-M97B44-D or ESE-M97B44-A

ELECTRICAL SYSTEM	
Polarity:	Negative to earth (ground)
Generator Drive Belt Tension (8K Poly Belt):	Tension is within specification if the tensioner is within the indicator markings

IGNITION	
Spark Plug	Ford Part Number: XS6F-12405-A1A (NGK TR6B-10) Gap: 0.95 - 1.05 mm
Firing Order	1-3-4-2

CRANKSHAFT	
Main journal-standard diameter	2.243 - 2.244 (56.980 - 57.000 mm)
Main journal-undersize diameter	2.233 - 2.234 (56.726 - 56.746)
Width-main journal bearing shell	
Pin Journal standard	

ITEM	Nm	FT. LB.	LB. IN.
Oil Pan Drain Plug	25	18	221.3
Spark Plugs	13-17	9.6-12.5	115-150.5
Oil Filter	11-15	8-11	97.4-132.7