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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.

This WSG-1068 engine incorporates a closed-type crankcase ventilation system.

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.

<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;"></td> <td>Serial Number: 01234-05-00</td> </tr> <tr> <td>Model Number: WSG-1068I-6007-AA</td> <td></td> </tr> <tr> <td>Base Engine Code: 0C-680-AA</td> <td>Build Date: 01-18-2000</td> </tr> <tr> <td colspan="2">Distributor S.O. Number: FORD POWER PRODUCTS</td> </tr> </table> <p align="center">FPP01103</p> <p align="center"><b>Prior 2001</b></p>		Serial Number: 01234-05-00	Model Number: WSG-1068I-6007-AA		Base Engine Code: 0C-680-AA	Build Date: 01-18-2000	Distributor S.O. Number: FORD POWER PRODUCTS		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;"></td> <td>Serial Number: 37827-1-04-98</td> </tr> <tr> <td>Model Number: XXX-XXX</td> <td></td> </tr> <tr> <td>Base Engine Code: 6C-276-AA</td> <td>Base Engine Build Date: 01/02/2001</td> </tr> <tr> <td>Distributor S.O. Number:</td> <td>Reference:</td> </tr> </table> <p align="center"><b>2001</b></p>		Serial Number: 37827-1-04-98	Model Number: XXX-XXX		Base Engine Code: 6C-276-AA	Base Engine Build Date: 01/02/2001	Distributor S.O. Number:	Reference:
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Model Number: XXX-XXX																	
Base Engine Code: 6C-276-AA	Base Engine Build Date: 01/02/2001																
Distributor S.O. Number:	Reference:																

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

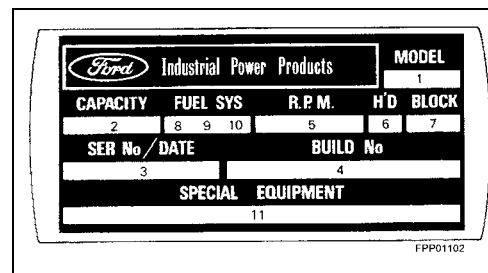
**Engine Code Decal**

An engine code decal is attached to the engine front cover. The symbol code on the decal identifies each engine for determining parts usage.

<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;"><b>ENGINE CODE</b></td> <td></td> </tr> <tr> <td style="width: 15%; text-align: center;"><b>ENGINE PLANT CODE</b></td> <td></td> </tr> <tr> <td style="width: 15%; text-align: center;"><b>ENGINE BUILD DATE</b></td> <td></td> </tr> </table> <p align="center"> <b>JA</b>                  SG612AB                  E                  MADE IN ESSEX, CANADA                  11/07/99             </p> <p align="center"><b>E = ESSEX</b></p>	<b>ENGINE CODE</b>		<b>ENGINE PLANT CODE</b>		<b>ENGINE BUILD DATE</b>		<p align="right">FPP03502</p>
<b>ENGINE CODE</b>							
<b>ENGINE PLANT CODE</b>							
<b>ENGINE BUILD DATE</b>							

**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.

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.

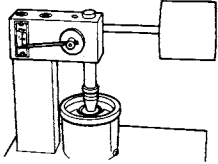
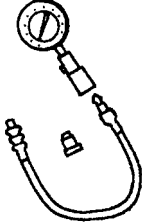
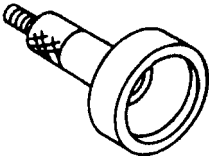
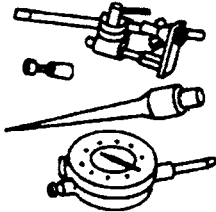
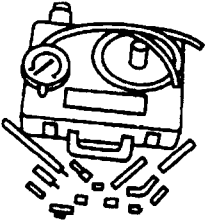

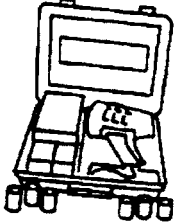

**Parts and Service**

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**

<b>Condition</b>	<b>Possible Source</b>	<b>Action</b>
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 lash adjuster 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.
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.

## WSG-1068 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

### **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.

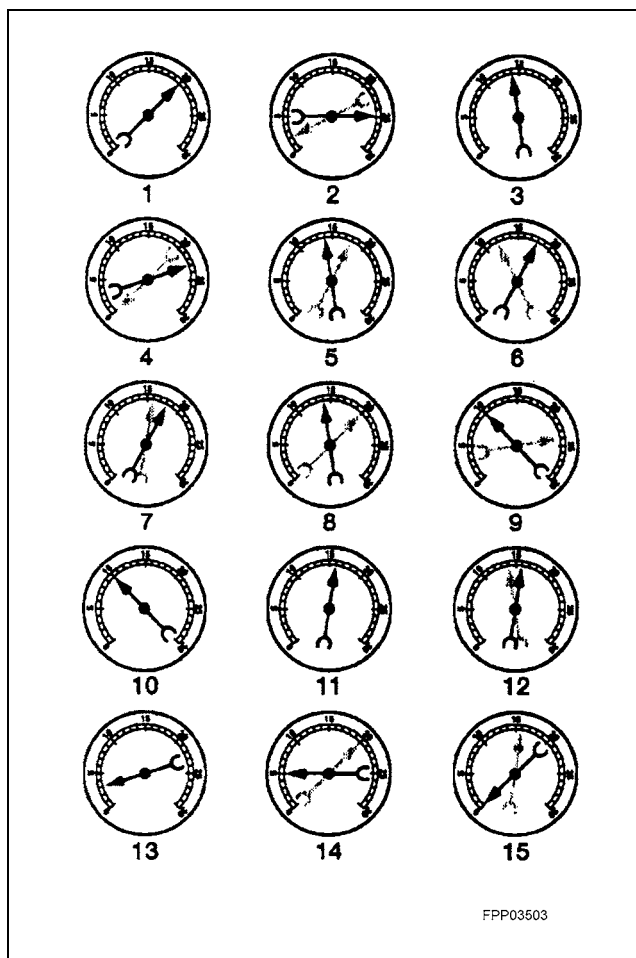
The reading should be steady. If necessary, adjust the gauge damper control (where used) if the needle is fluttering rapidly. Adjust the damper until the needle moves easily without excessive flutter.

**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 transmission 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***

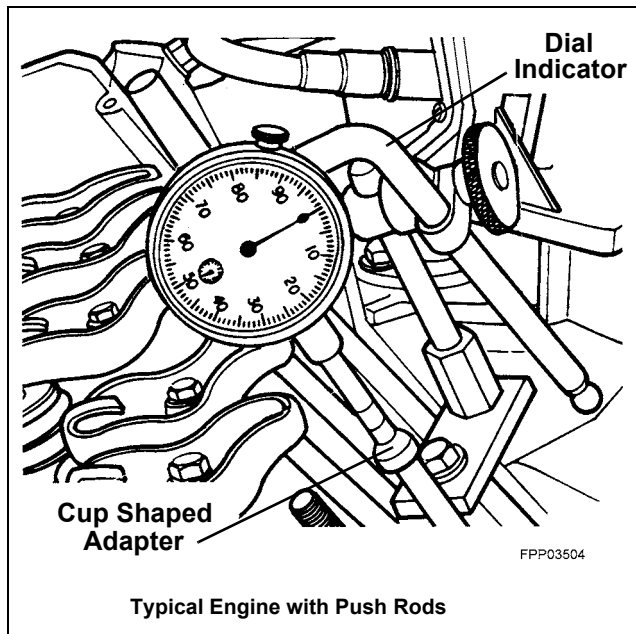
- Check for plugged oil drain back holes.
- Check for missing or damaged valve stem seals or guide mounted valve stem seals.

If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1200 rpm with the transmission 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. Remove the rocker arm seat bolts, rocker arm seat and rocker arms.



3. Make sure the lash adjuster is seated against camshaft. Install the dial Indicator with Bracketry so the ball socket adapter of the indicator is on top of the hydraulic lash adjuster or the Cup Shaped Adapter is on top of the push rod and in the same plane as the lash adjuster push rod movement.
4. Remove the spark plugs.
5. 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 hydraulic lash adjuster is on the base circle of the camshaft lobe. At this point, the hydraulic lash adjuster will be in its lowest position. If checking during engine assembly, turn the crankshaft using a socket or ratchet.
6. 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.

7. Compare the total lift recorded on the dial indicator with specifications.
8. To check the accuracy of the original dial indicator reading, continue to rotate the crankshaft until the indicator reads zero.
9. 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.

10. Install the rocker arm seats, rocker arms and rocker arm seat bolts.
11. Install the valve covers.
12. Install the spark plugs.

## Hydraulic Lash Adjuster

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

- excessive 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:

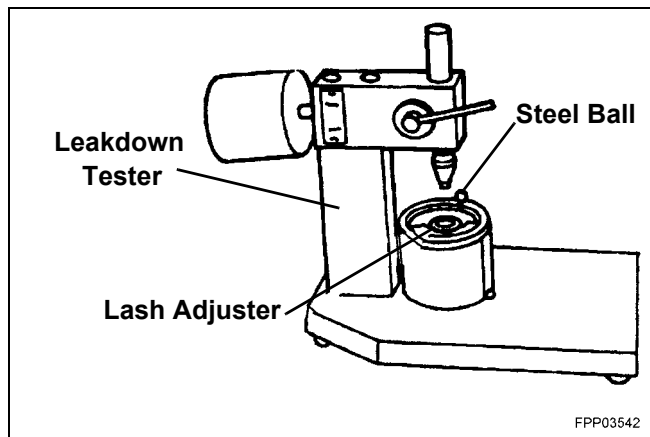
### Leakdown Testing

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

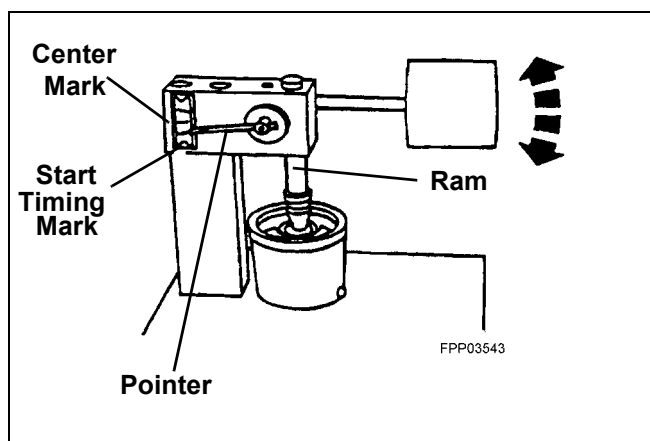
1. Clean the lash adjuster to remove all traces of engine oil.

**NOTE:** lash adjusters/lash adjuster cannot be checked with engine oil in them. Use only testing fluid. New hydraulic lash adjusters/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 tappet/lash adjuster and compress Hydraulic Tappet 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/lash adjuster 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



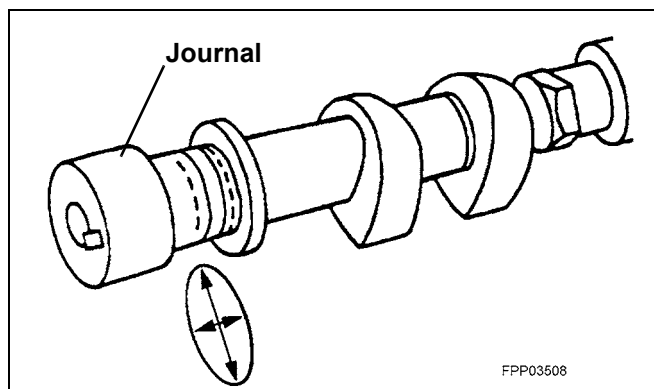
**WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT, DO NOT OPERATE THE ENGINE WITH THE HOOD OPEN UNTIL THE FAN BLADE HAS BEEN EXAMINED FOR POSSIBLE CRACKS AND SEPARATION.**

**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

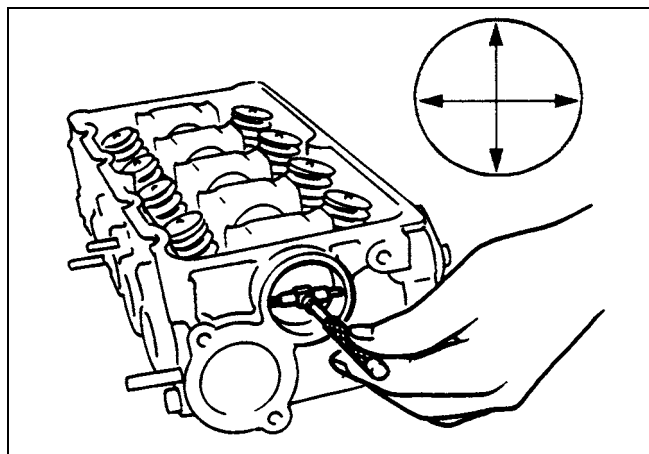
- Measure each camshaft journal diameter in two directions.
- If it is out of specification, replace as necessary.



### Camshaft Journal Clearance

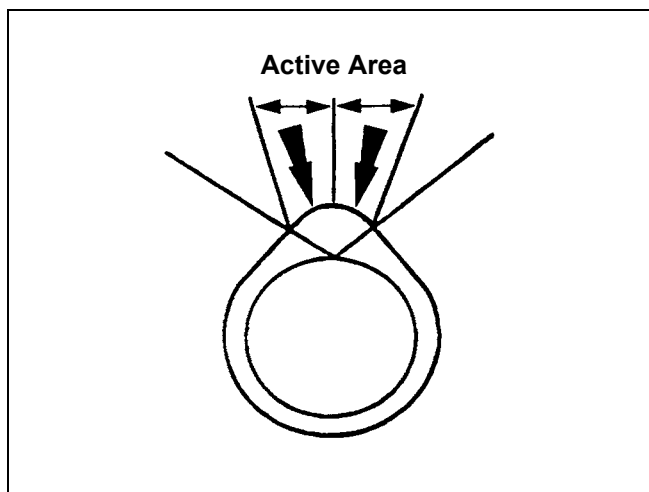
**NOTE:** The camshaft journals must meet specifications before checking camshaft journal clearance.

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



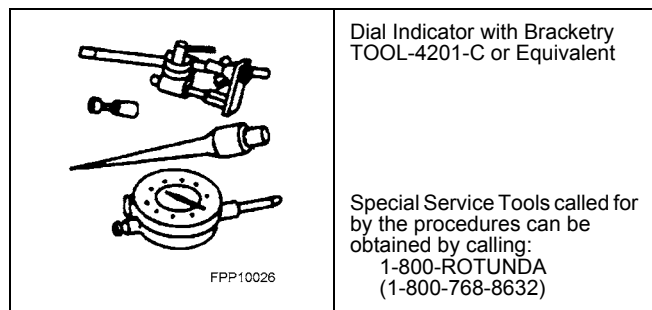
### Camshaft Lobe Surface

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

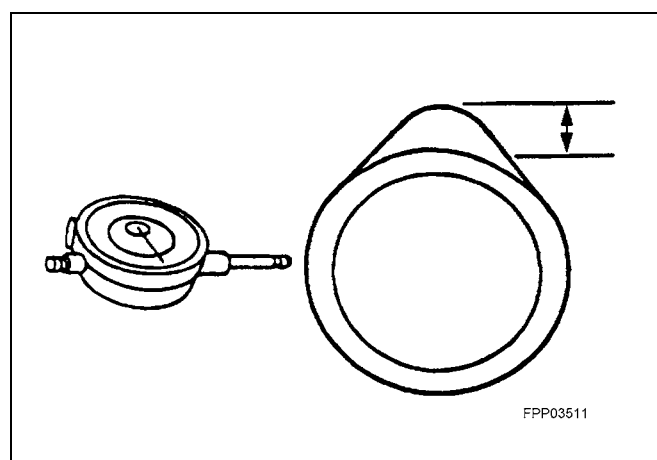


### Camshaft Lobe Lift

#### Special Tool(s)



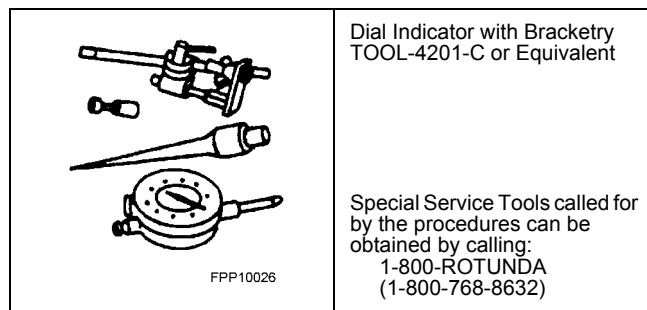
1. Use the Dial Indicator with Bracketry to measure camshaft intake lobe lift.



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.

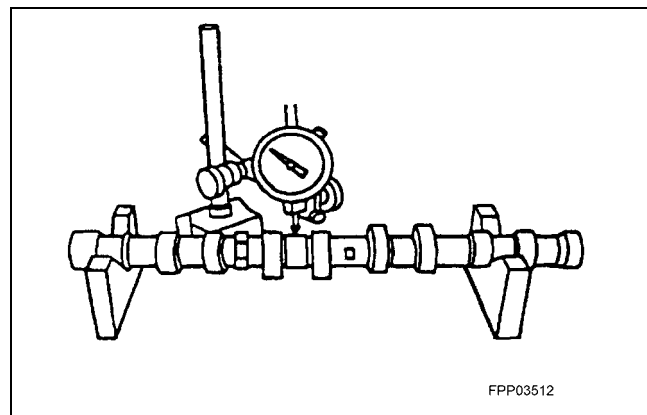
### Camshaft Runout

#### Special Tool(s)



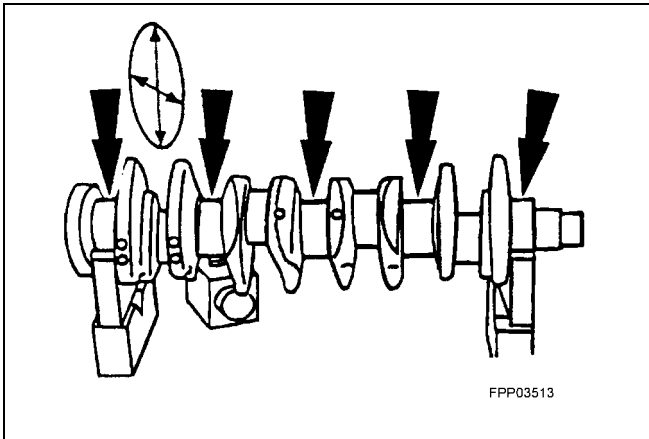
**NOTE:** Camshaft journals must be within specifications before checking runout.

- 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.



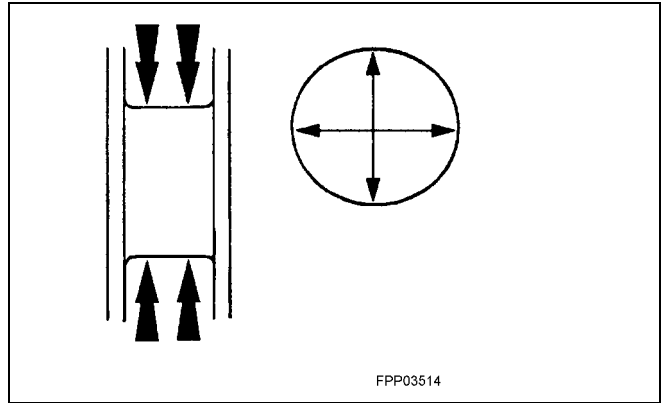
### Crankshaft Main Bearing Journal Diameter

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



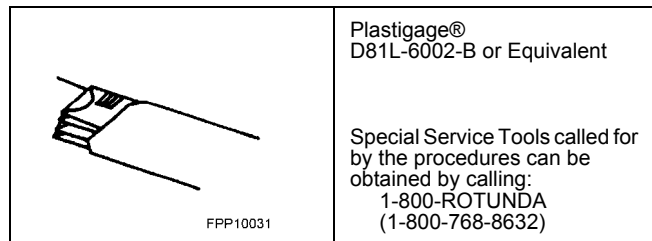
### Crankshaft Main Bearing Journal Taper

- 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.



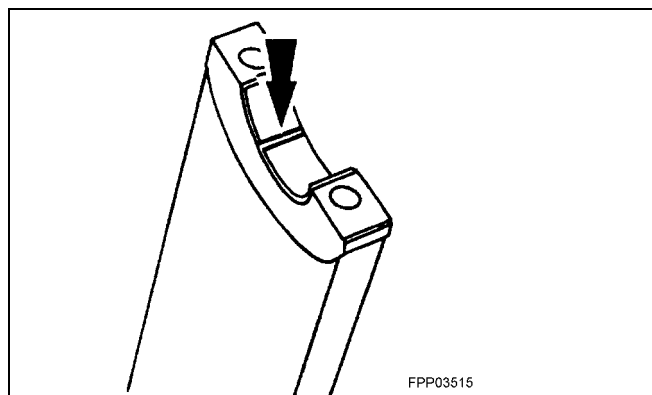
## Crankshaft Main Bearing Journal Clearance

### Special Tool(s)



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

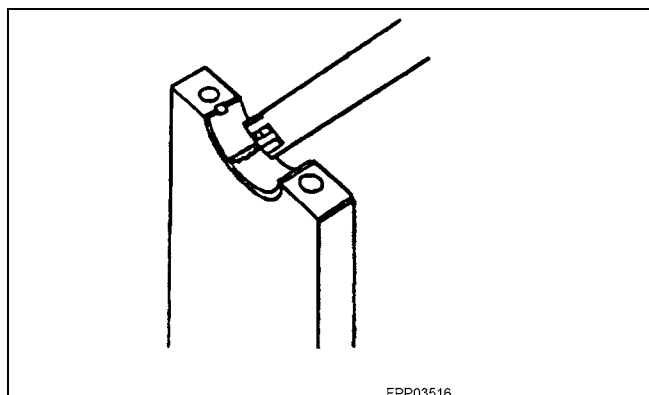
1. Remove the crankshaft main bearing caps and bearings.
2. Lay a piece of Plastigage® across the face of each crankshaft main surface.



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

3. Install and remove the crankshaft main bearing cap.

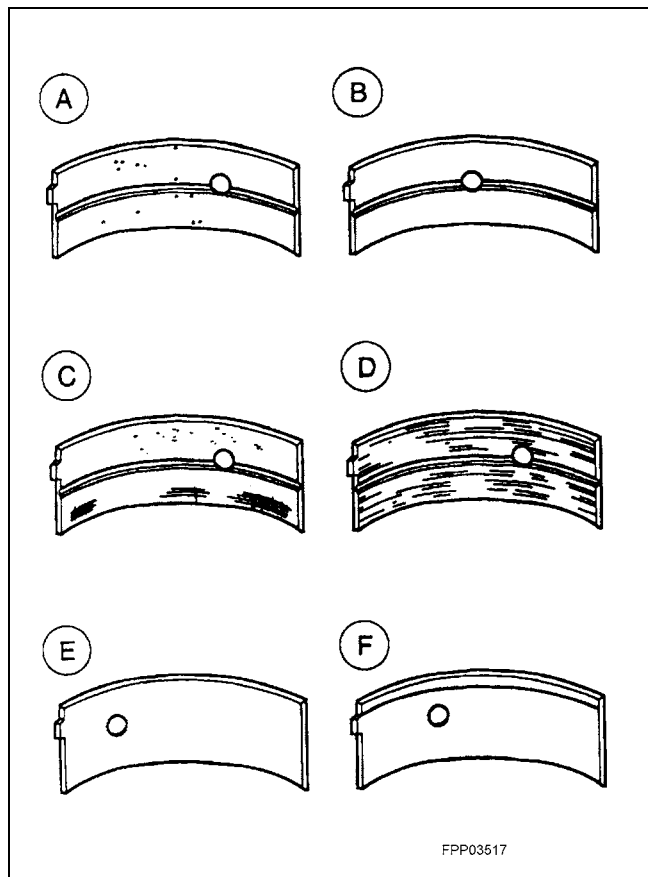
4. Verify the crankshaft journal clearance.
  - If it is out of specification, replace as necessary



### Bearing Inspection

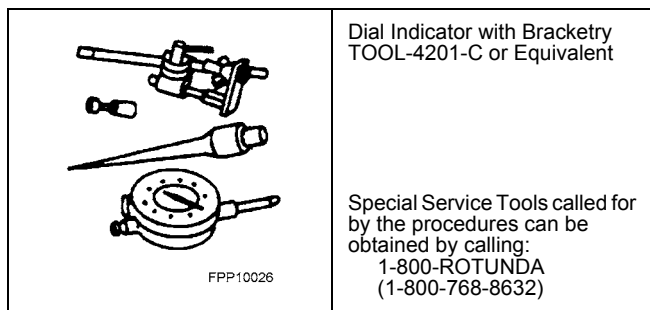
Inspect bearings for the following defects. Possible causes are shown:

- 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)

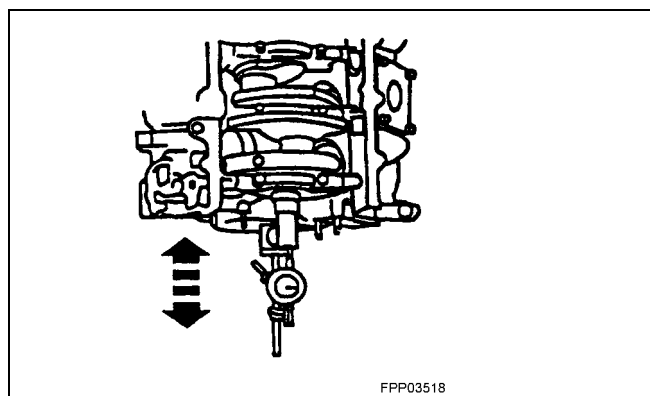


## Crankshaft End Play

### Special Tool(s)



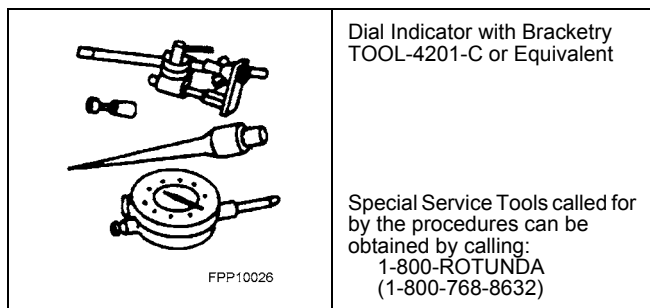
1. Measure the crankshaft end play. Use the Dial Indicator with Bracketry to measure crankshaft end play.
2. Position the crankshaft to the rear of the cylinder block.
3. Zero the Dial Indicator with Bracketry.



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

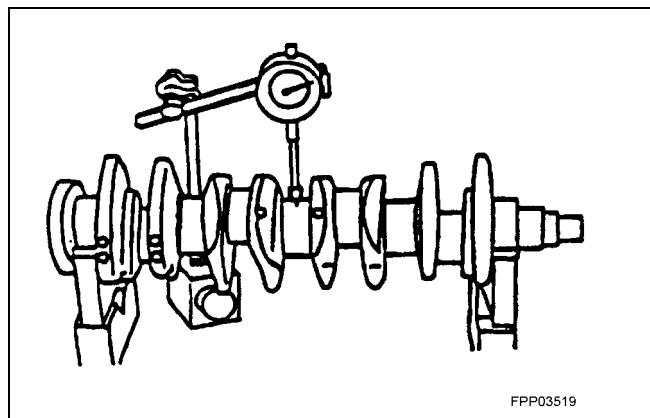
### Special Tool(s)



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

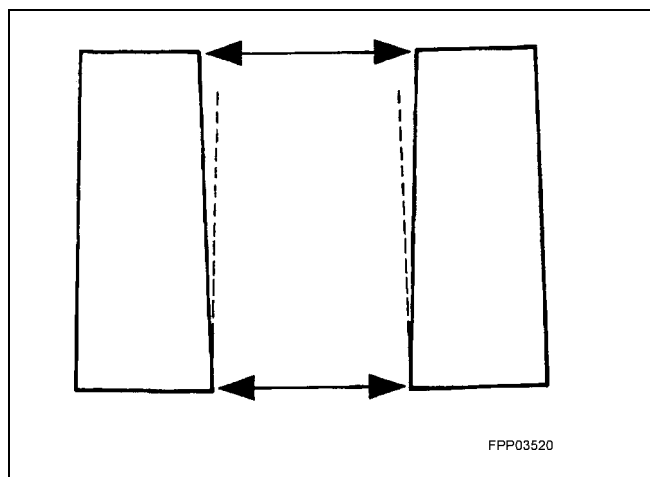
Use the Dial Indicator with Bracketry to measure the crankshaft runout.

- 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.



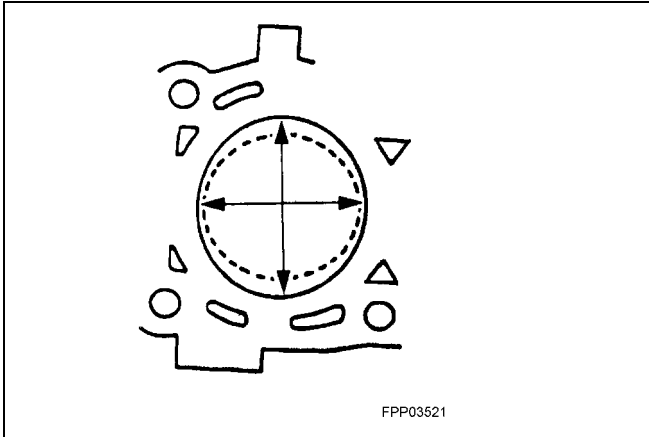
## Cylinder Bore Taper

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.

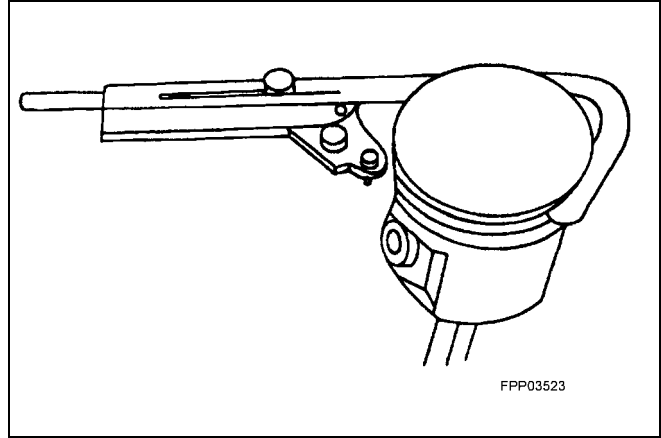


### Cylinder Bore Out-of-Round

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.

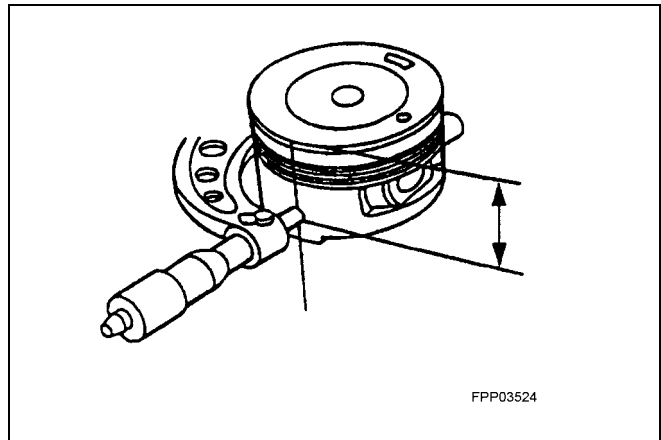
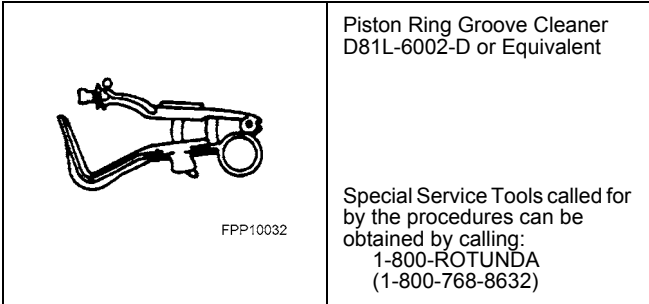


### Piston Diameter

- Measure the piston skirt diameter.

### Piston Inspection

#### Special Tool(s)

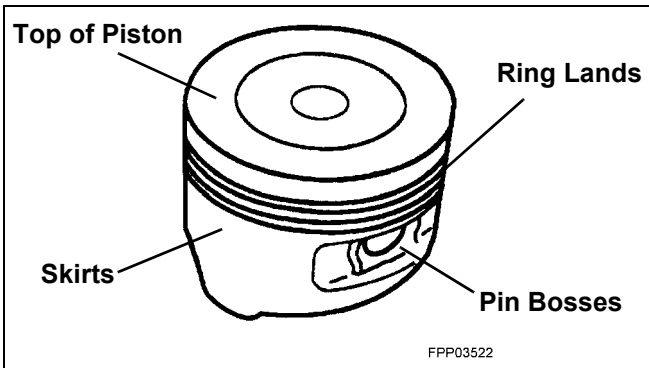


**CAUTION: Do not use a caustic cleaning solution or a wire brush to clean the pistons or possible damage can occur.**

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.

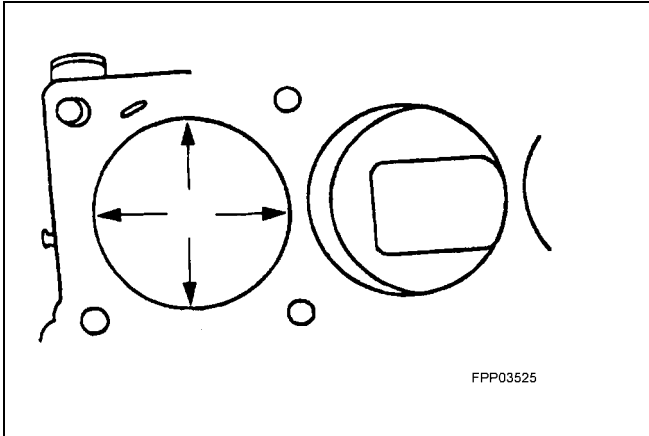


2. Use the Piston Ring Groove Cleaner to clean the piston ring grooves.

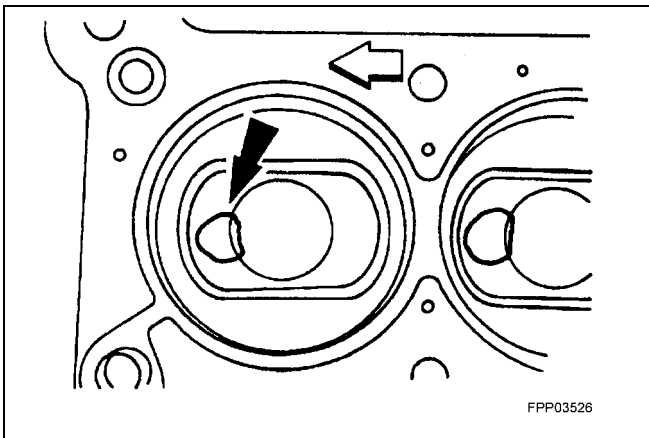
### Piston Selection

**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.



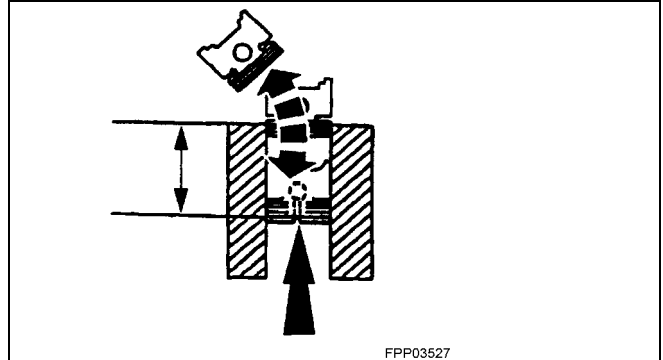
2. Choose the piston with the proper paint color.
  - Red – in the lower third of the size range.
  - Blue – in the middle third of the size range.
  - Yellow – in the upper third of the size range.

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

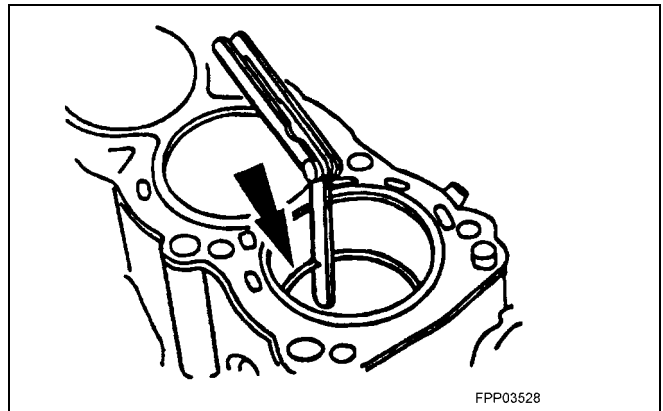
**CAUTION:** Piston rings should not be transferred from one piston to another to prevent damage to cylinder worn or piston.

**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.



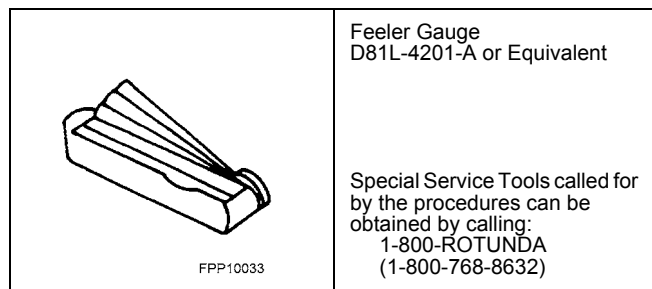
### Piston Ring End Gap

#### Special Tool(s)

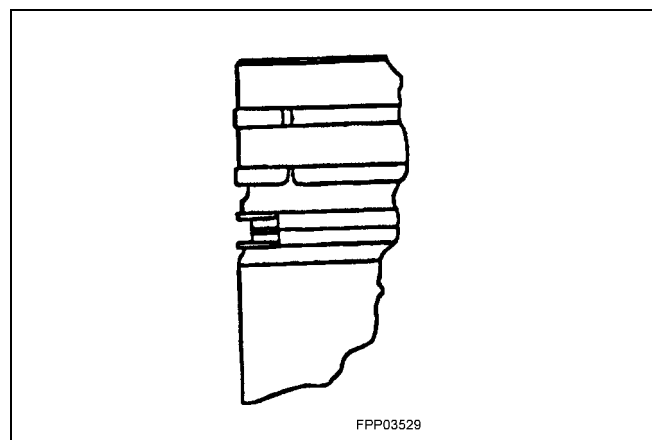
<p>FPP10033</p>	<p>Feeler Gauge D81L-4201-A or Equivalent</p> <p>Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)</p>
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### Piston Ring-to-Groove Clearance

#### Special Tool(s)

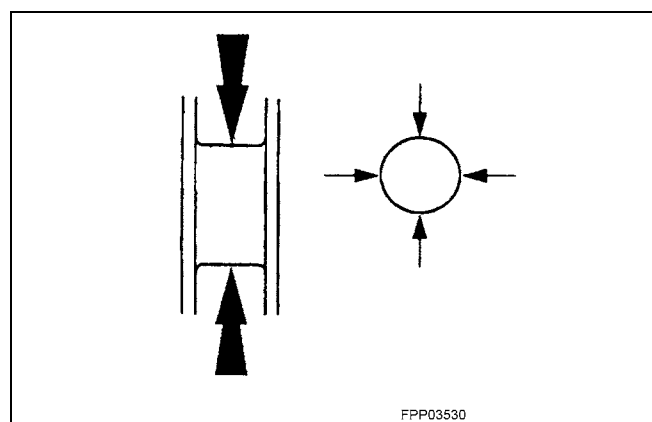


1. Inspect for a stop in the grooves.
2. Measure the piston-to-groove clearance.



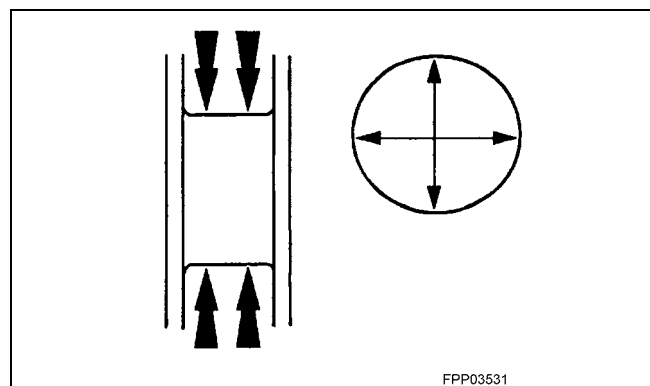
### Crankshaft Connecting Rod Journal Diameter

- 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.

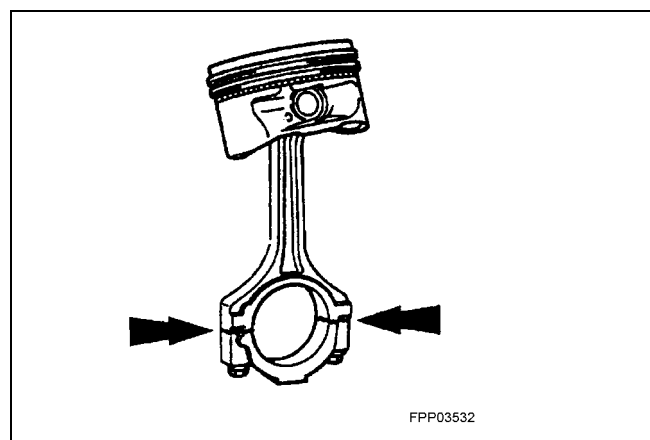


### Connecting Rod Cleaning

**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.

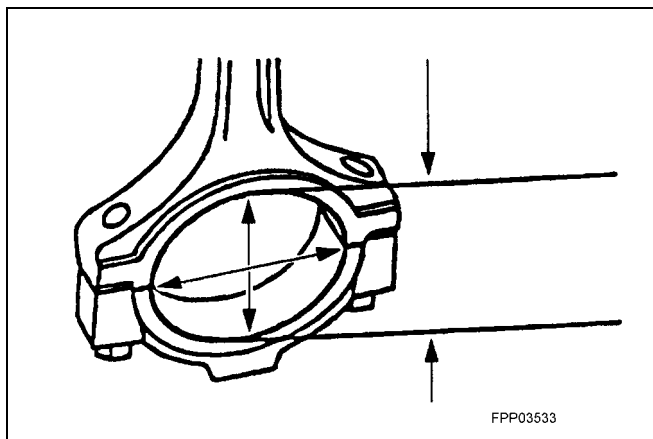
- Mark and separate the parts and clean with solvent. Clean the oil passages.



### Connecting Rod Larger End Bore

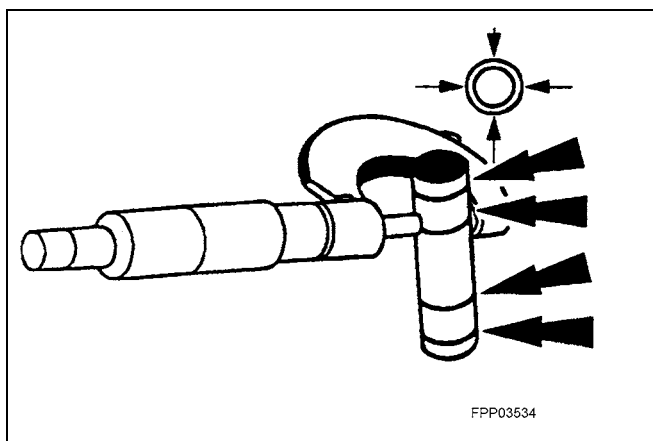
**CAUTION:** The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

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



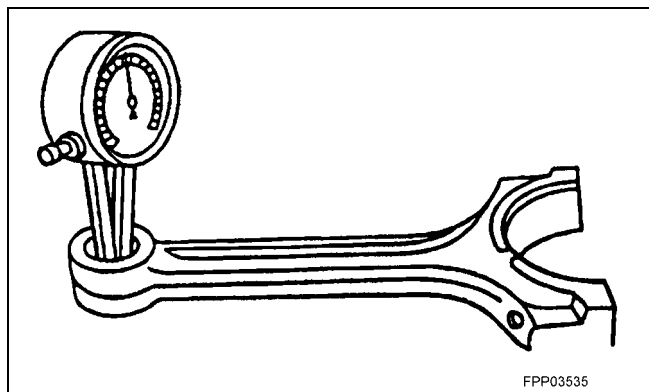
### Piston Pin Diameter

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



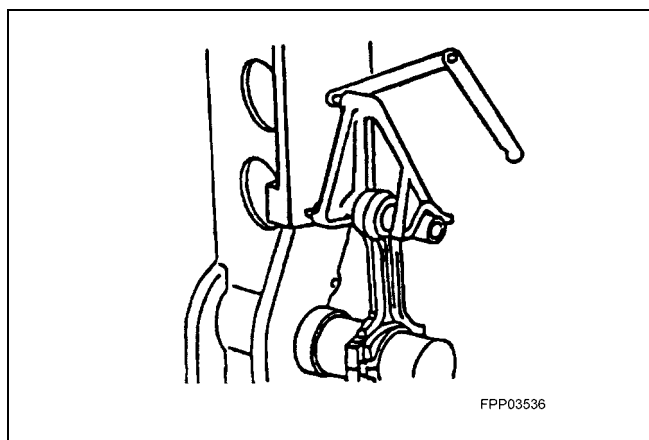
### Connecting Rod Bushing Diameter

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



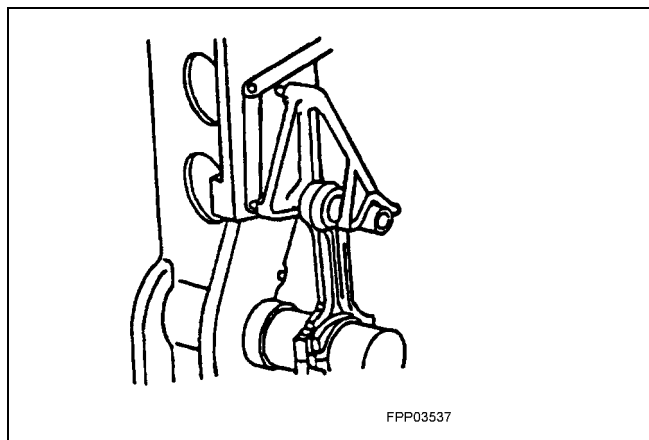
### Connecting Rod Bend

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



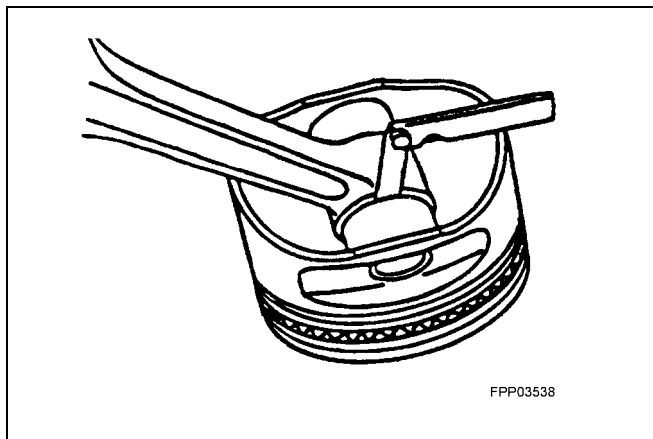
### Connecting Rod Twist

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

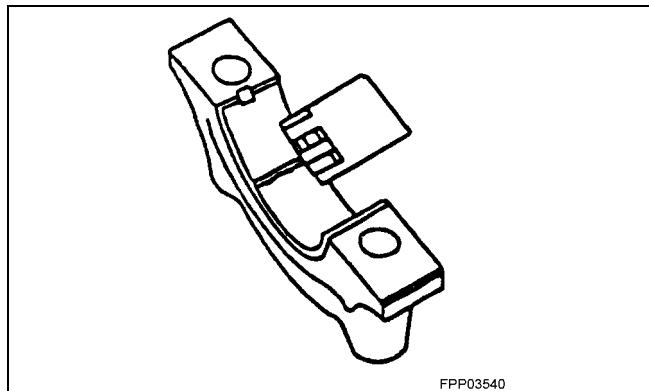


### Connecting Rod Piston Pin Side Clearance

- 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

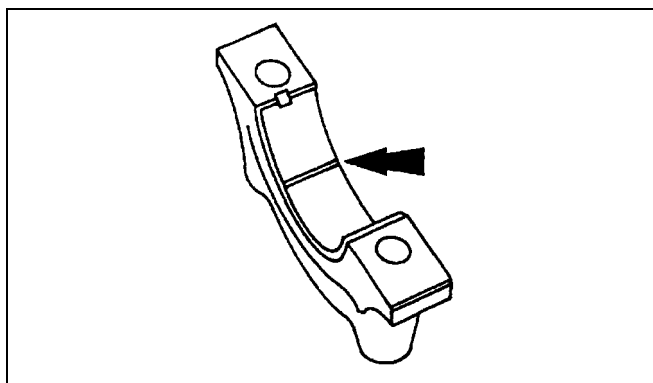
#### Special Tool(s)

<p>FPP10031</p>	<p>Plastigage® D81L-6002-B 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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**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.

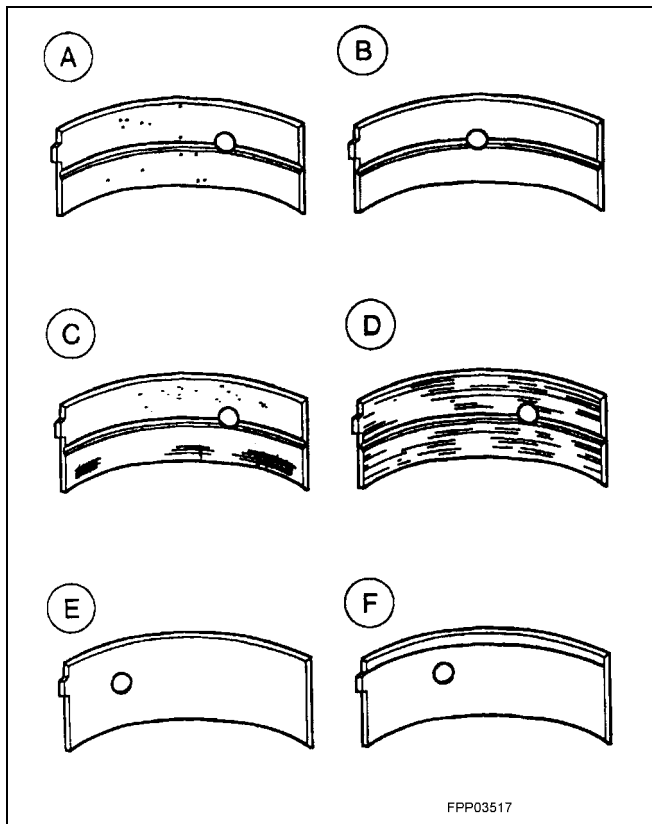


**NOTE:** Do not turn the crankshaft during this step.

### Bearing Inspection

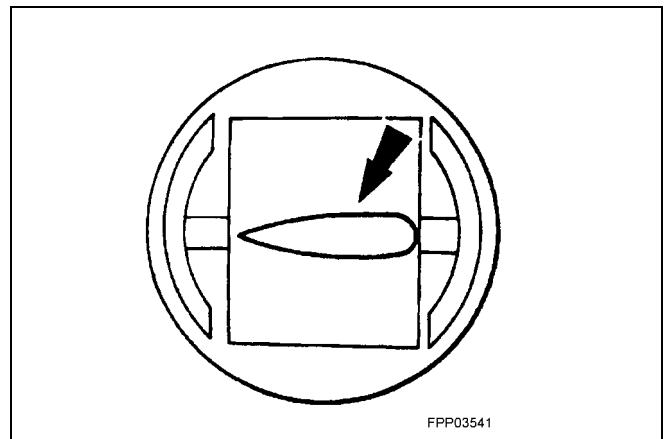
Inspect bearings for the following defects. Possible causes are shown:

- 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)



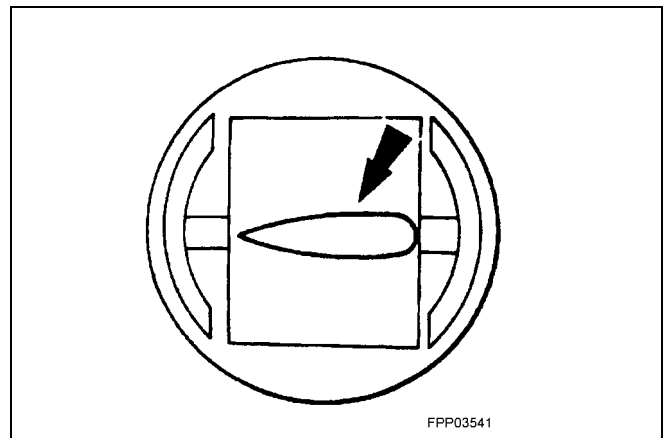
### Roller Follower Inspection

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



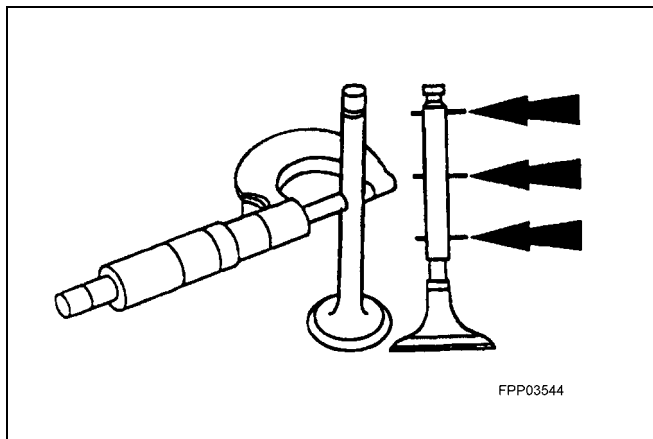
### Hydraulic Lash Adjuster Inspection

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

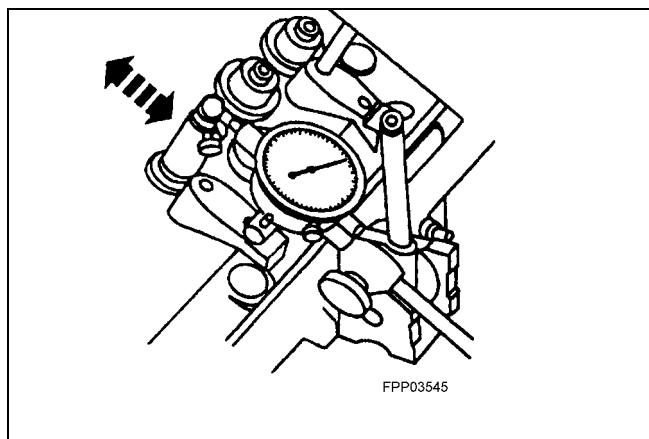


### Valve Stem Diameter

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



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 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.

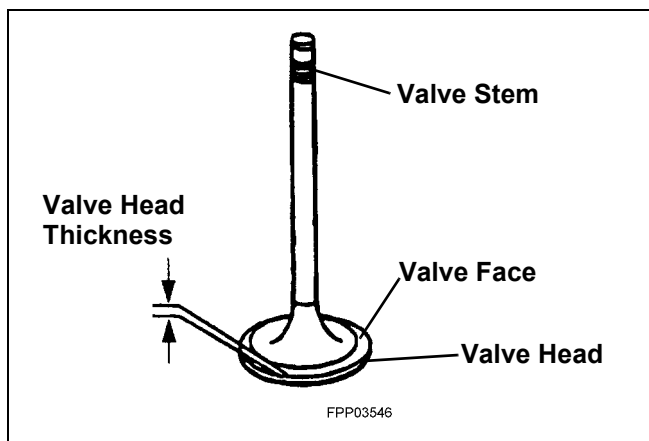
**NOTE:** If necessary, use a magnetic base.

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.

### Valve Inspection

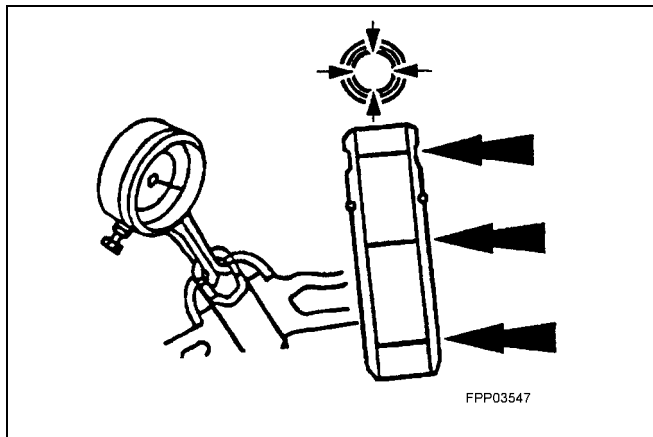
Inspect the following valve areas:

- 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.



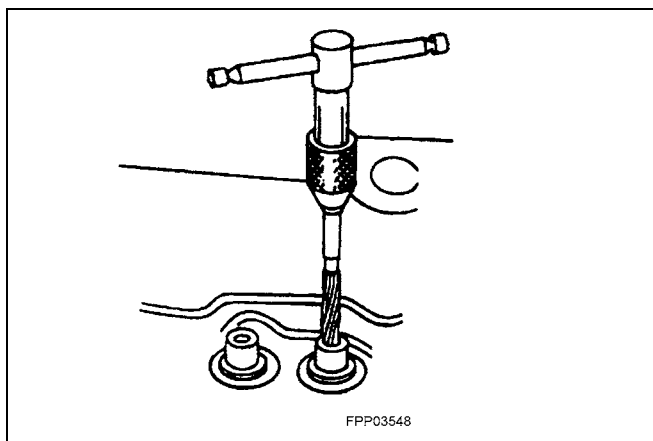
### Valve Guide Inner Diameter

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

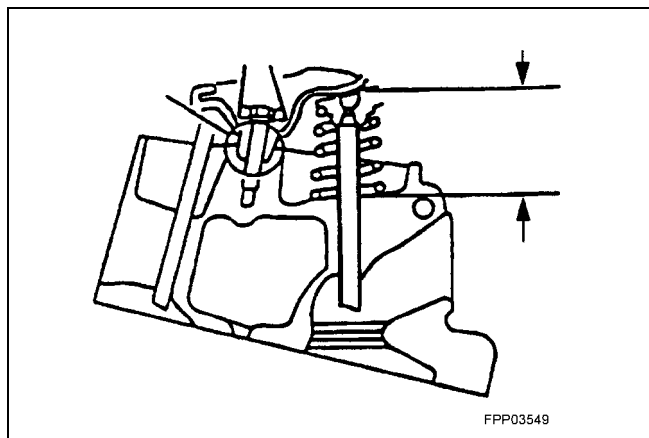
1. Use a hand-reaming kit to ream the valve guide.



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

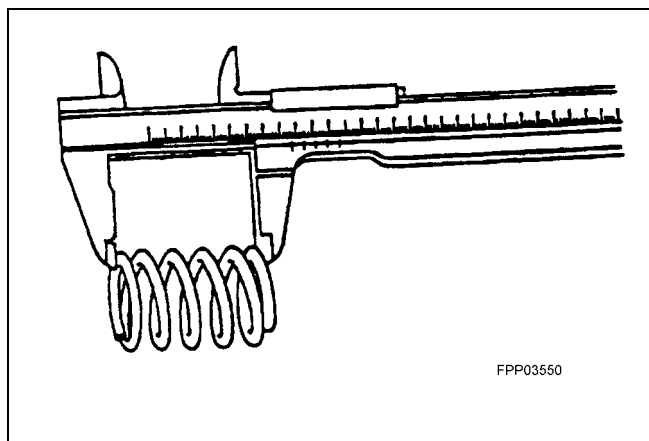
### Valve Spring Installed Length

- Measure the installed length of each valve spring.



### Valve Spring Free Length

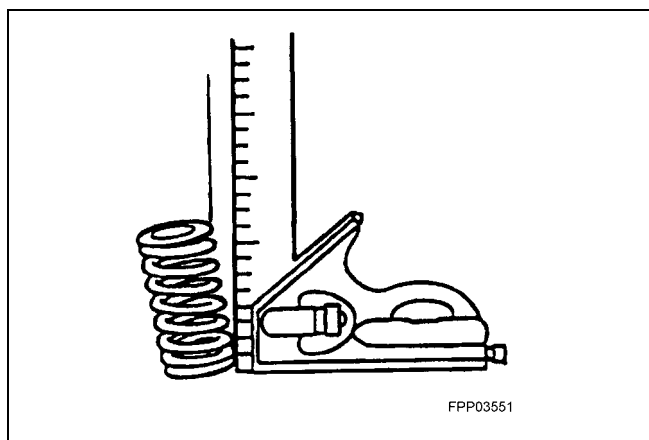
- Measure the free length of each valve spring.



### Valve Spring Out-of-Square

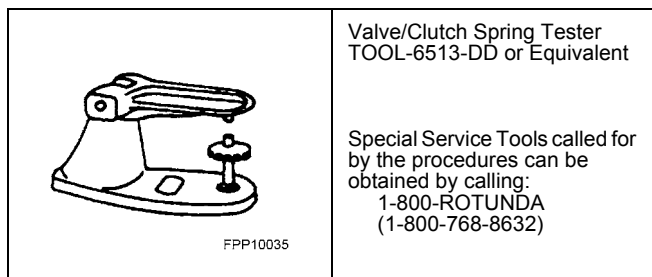
Measure the out-of-square on each valve spring.

- 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.

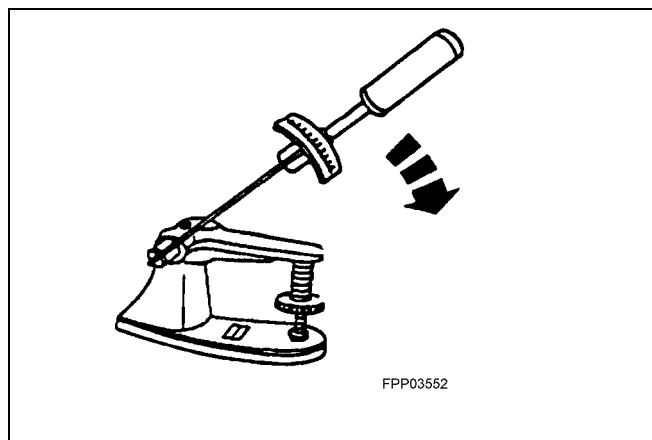


### Valve Spring Compression Pressure

#### Special Tool(s)



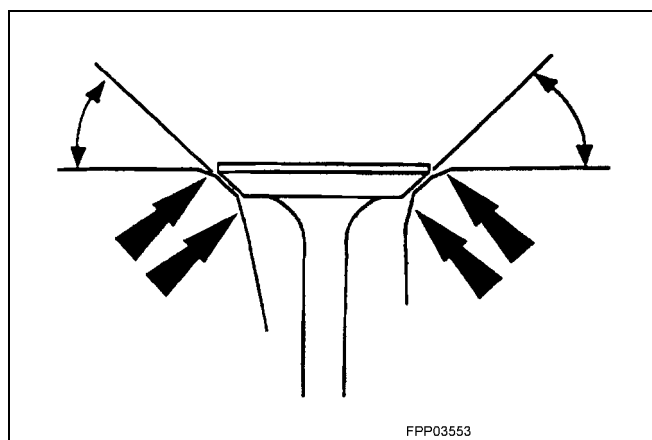
- Use the Valve/Clutch Spring Tester to check the valve springs for proper strength at the specified valve spring length.



### Valve and Seat Refacing Measurements

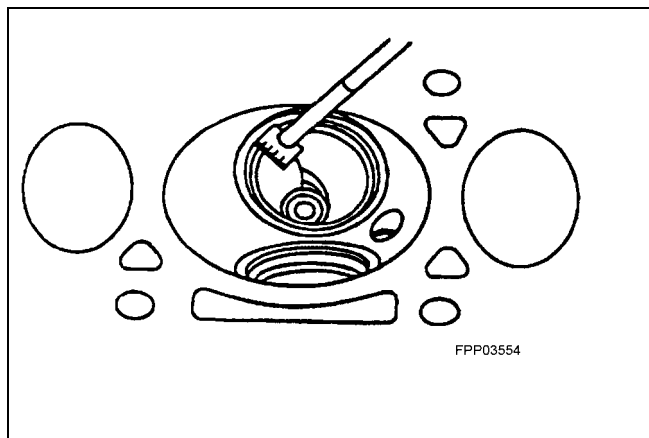
**NOTE:** After grinding valves or valve seats, check valve clearance.

- Check the valve seat and valve angles.



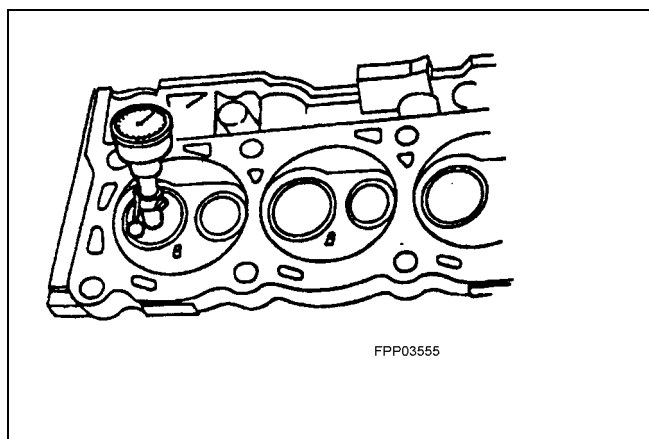
### Valve Seat Width

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



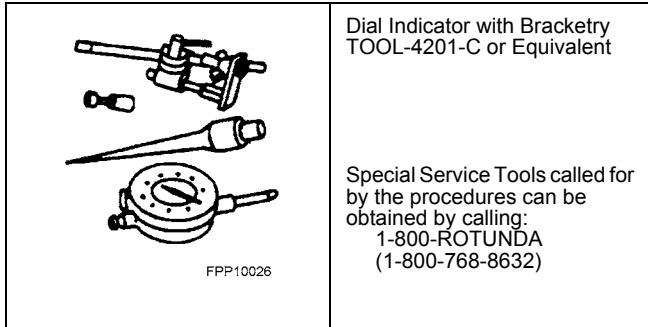
### Valve Seat Runout

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

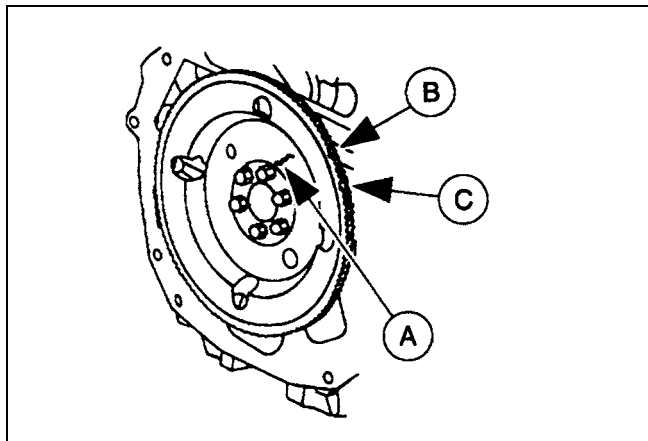


### Flywheel Inspection

#### Special Tool(s)

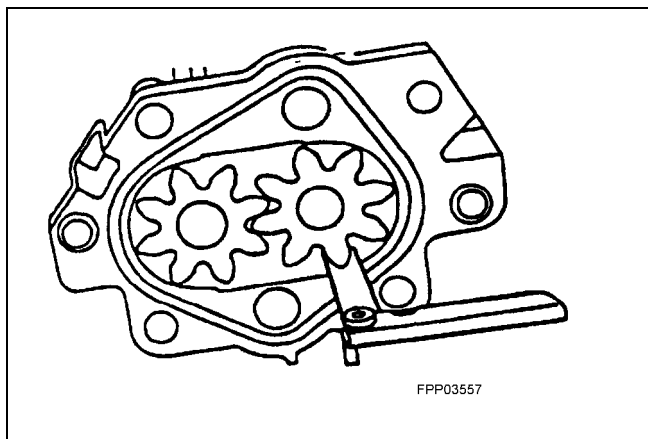


1. Inspect the flywheel for:
  - Cracks (A).
  - Worn ring gear teeth (B).
  - Chipped or cracked ring gear teeth (C).
2. Inspect the flywheel ring gear runout.



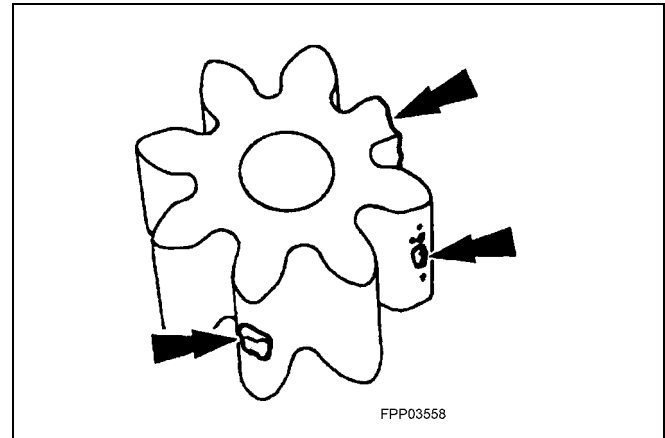
### Oil Pump Gear Radial Clearance

- Measure the clearance between the rotor and the pump housing.



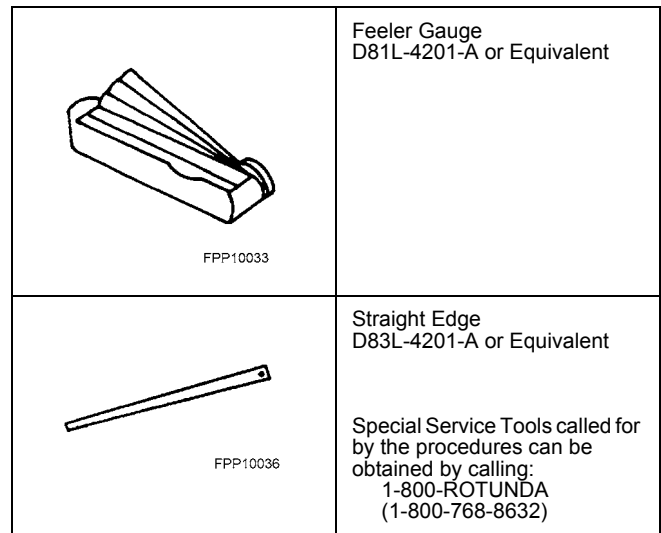
### Oil Pump Rotor Inspection

- Inspect the oil pump rotor tips for damage or wear.

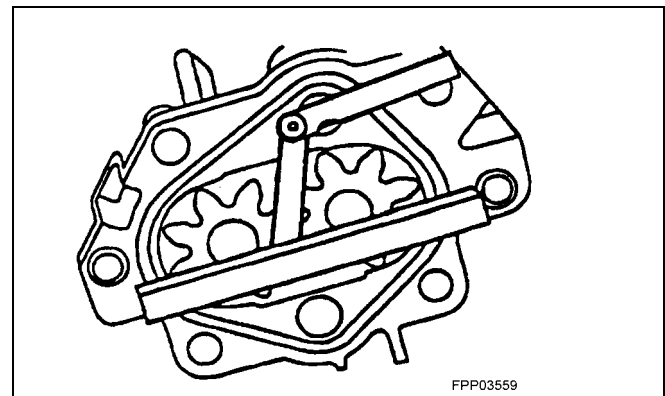


### Oil Pump Side Clearance

#### Special Tool(s)

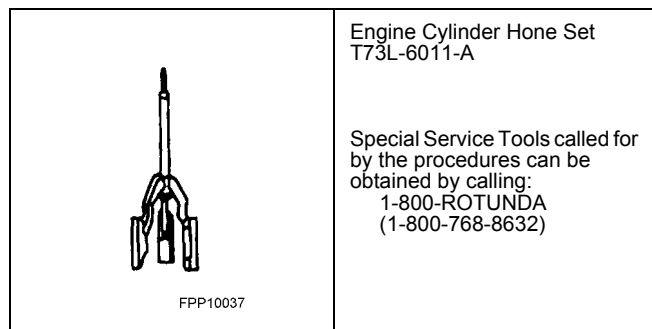


- Place the Straight Edge across the top of the oil pump and rotors and use the Feeler Gauge to measure the clearance between the rotors and the Straight Edge.



## Cylinder Bore Honing

### Special Tool(s)

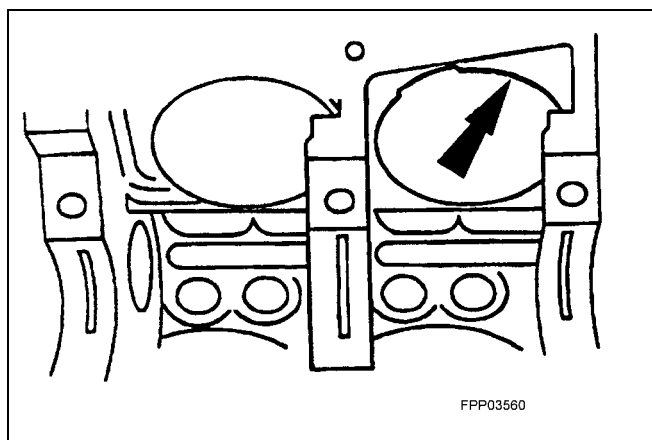


**NOTE:** Before any cylinder bore is honed, all main bearing caps must be installed so the crankshaft bearing bores will not become distorted.

**NOTE:** To correct taper or out-of-round, hone 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.



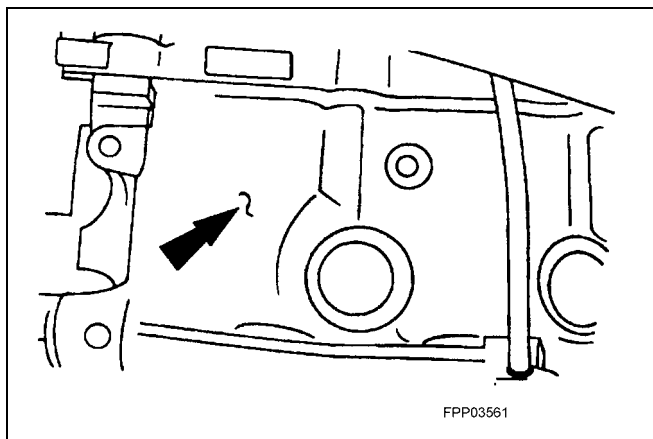
## Cylinder Bore Cleaning

**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.

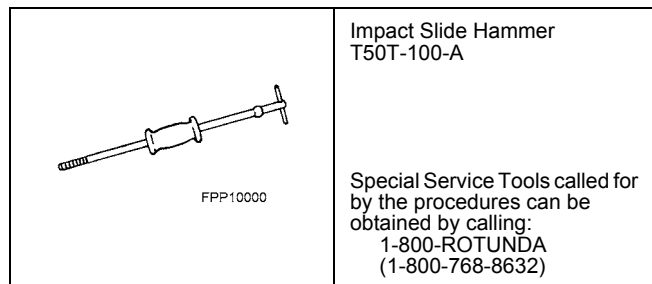


Repair porosity defects with an epoxy sealer meeting Ford specification M3D35-A (E).

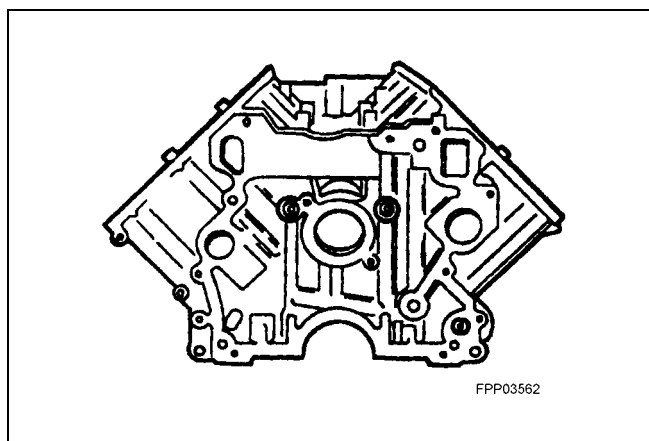
1. Clean the surface to be repaired to a bright, oil-free metal surface.
2. Chamfer or undercut the repair area to a greater depth than the rest of the cleaned surface. Solid metal must surround the area to be repaired.
3. Apply the epoxy sealer and heat-cure with a 250-watt lamp placed 254 mm (10 inches) 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.



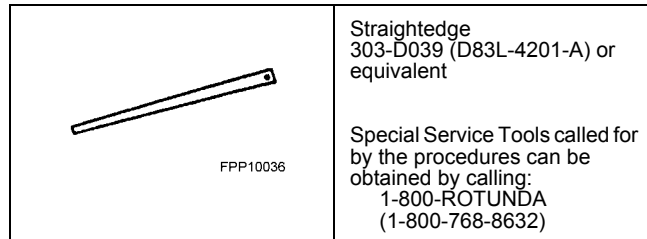
2. Inspect the cylinder block plug bore for any damage that would interfere with the proper sealing of the plug. If the cylinder block plug bore is damaged, bore for the next oversize plug.

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

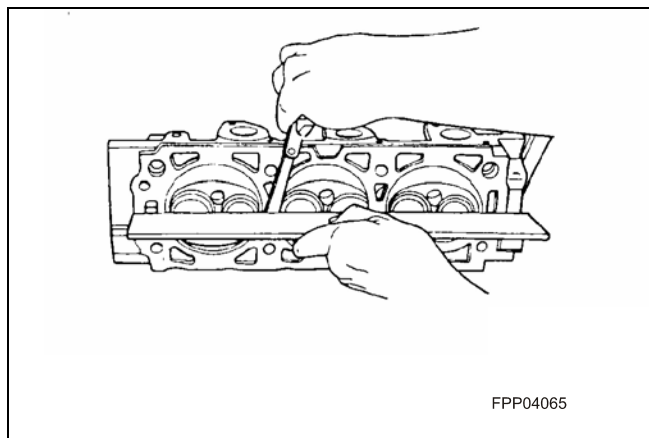
3. Coat the cylinder block core plug and bore lightly with Threadlock® 262 E2FZ-19554-B or equivalent meeting Ford specification WSK-M2G351-A6 and install the cylinder block core plug.

## Cylinder Head - Distortion

### Special Tool(s)



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

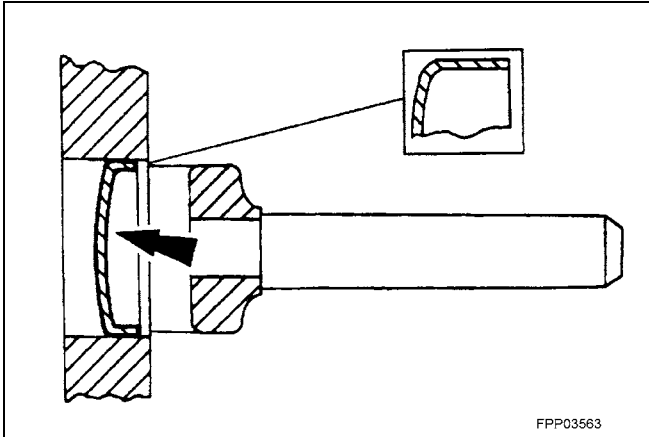


**Cylinder Block Core Plug – Cup-Type**

**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.



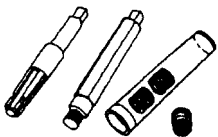
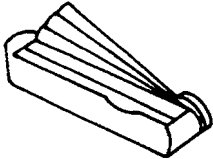
**Cylinder Block Core Plug – Expansion-Type**

**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)

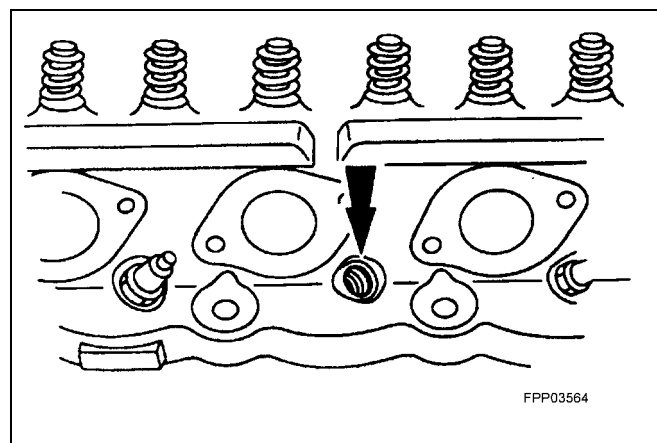
 <p>FPP10038</p>	<p>Tapersert Installation Kit 107-R0921 or Equivalent</p>
 <p>FPP10033</p>	<p>Feeler Gauge D81L-4201-A or Equivalent</p> <p>Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)</p>

**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.

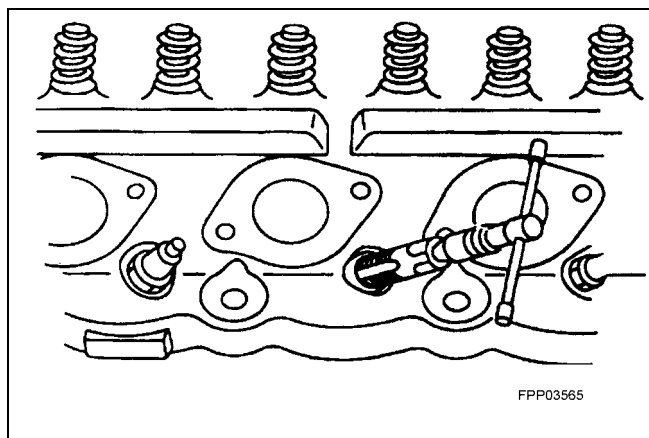
**CAUTION:** Do not use power or air-driven tools for finishing taperserts.

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

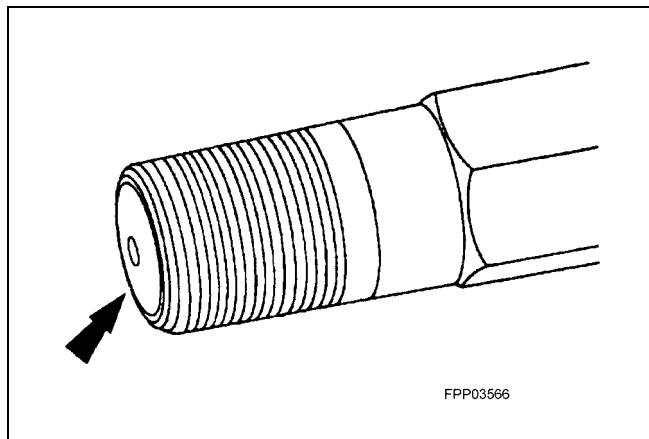
1. Clean the spark plug seat and threads.



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

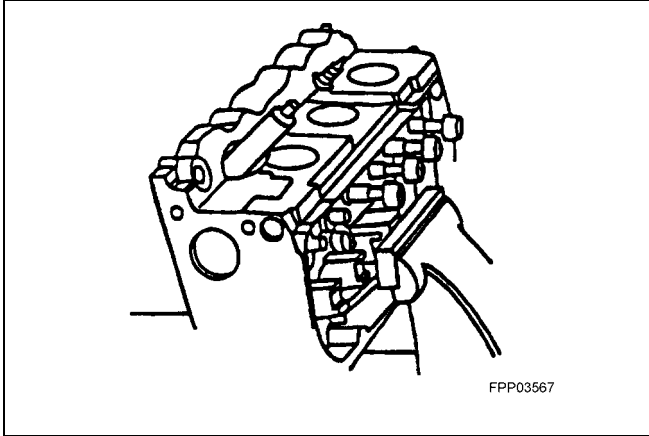


3. Continue cutting the threads and applying oil until the stop ring bottoms against the spark plug seat.
4. Remove the tap and metal chips.
5. Coat the threads of the mandrel with cutting oil. Thread the tapersert onto the mandrel until one thread of the mandrel extends beyond the tapersert.

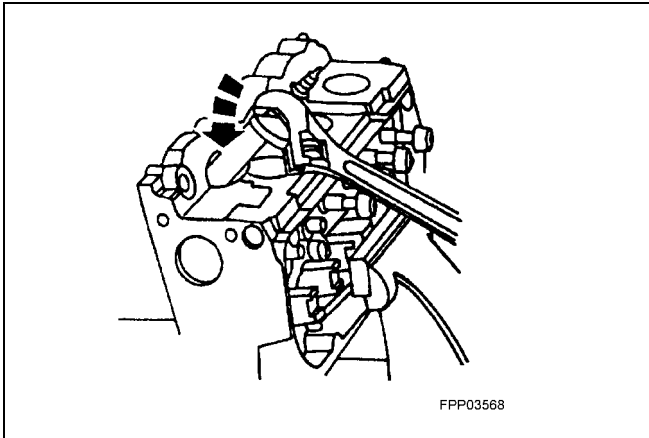


**NOTE:** A properly installed tapersert will be either flush with or 1.0 mm (0.039 inch) below the spark plug gasket seat.

6. Tighten the tapersert into the spark plug hole.



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



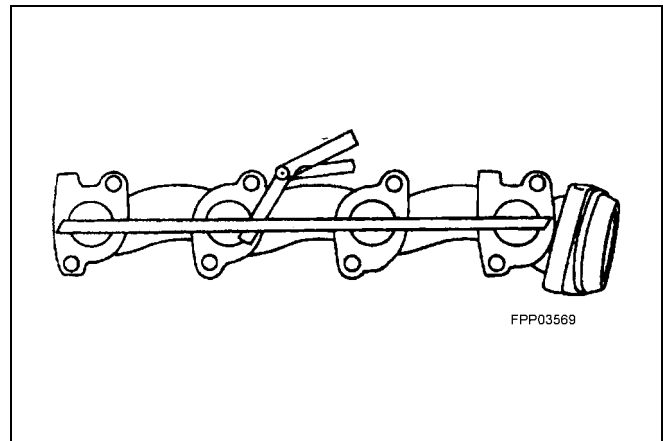
## Exhaust Manifold Straightness

### Special Tool(s)

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

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

**NOTE:** The exhaust manifold shown is a typical exhaust manifold.



## 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.