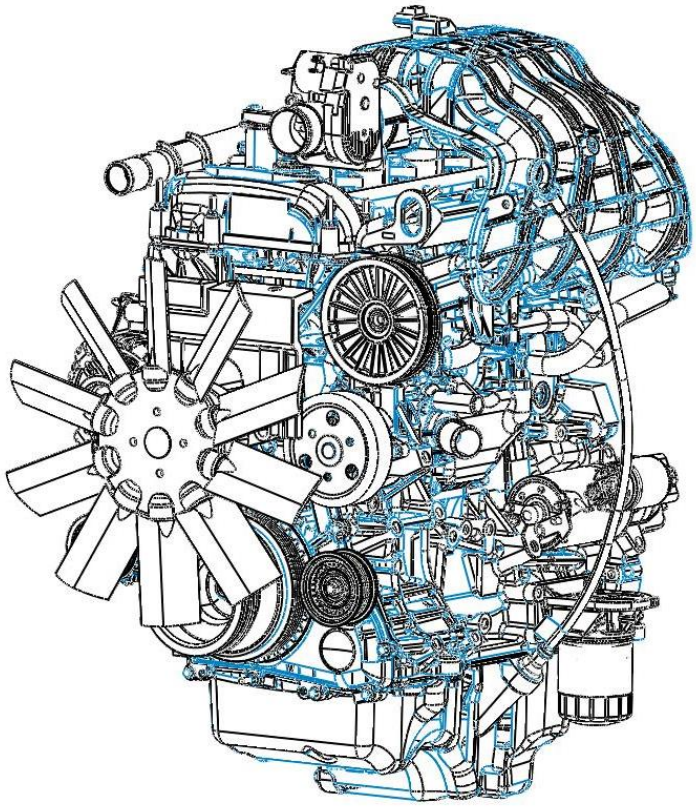
ENGINE DISTRIBUTORS INC.

MSG-425
2.5 LITER

INDUSTRIAL ENGINE SERVICE MANUAL



Powertrain Assemblies
& Components Provided
By Ford Component Sales

Ford Power Products

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Section Index

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Engine Distributors Inc (EDI)

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HEALTH & SAFETY

WARNING: THE FOLLOWING HEALTH AND SAFETY RECOMMENDATIONS SHOULD BE CAREFULLY OBSERVED

WARNING: CARRYING OUT CERTAIN OPERATIONS AND HANDLING SOME SUBSTANCES CAN BE DANGEROUS OR HARMFUL TO THE OPERATOR IF THE CORRECT SAFETY PRECAUTIONS ARE NOT OBSERVED. SUCH PRECAUTIONS ARE RECOMMENDED AT THE APPROPRIATE POINTS IN THIS BOOK. WARNING: WHILE IT IS IMPORTANT THAT THESE RECOMMENDED SAFETY PRECAUTIONS ARE OBSERVED, CARE NEAR MACHINERY IS ALWAYS NECESSARY, AND NO LIST CAN BE EXHAUSTIVE. ALWAYS BE CAUTIOUS TO AVIOD POTENTIAL SAFETY RISKS.

The following recommendations are for general guidance:

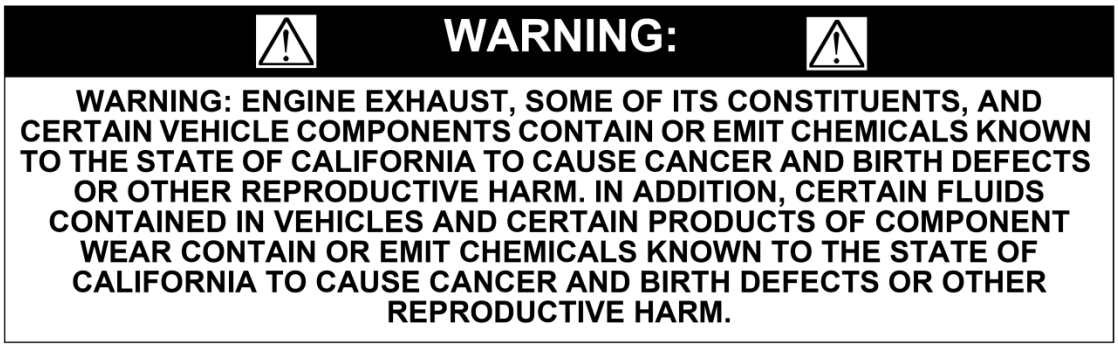
1. Always wear correctly fitting protective clothing which should be laundered regularly. Loose or baggy clothing can be extremely dangerous when working on running engines or machinery. Clothing which becomes impregnated with oil or other substances can constitute a health hazard due to prolonged contact with the skin even through underclothing.

2. So far as practicable, work on or close to engines or machinery only when they are stopped. If this is not practicable, remember to keep tools, test equipment and all parts of the body well away from the moving parts of the engine or equipment—fans, drive belts and pulleys are particularly dangerous. The electric cooling fan used on some installations is actuated automatically when the coolant reaches a specified temperature. For this reason, care should be taken to ensure that the ignition/isolating switch is OFF when working in the vicinity of the fan as an increase in coolant temperature may cause the fan suddenly to operate.

3. Avoid contact with exhaust pipes, exhaust manifolds and silencers when an engine is, or has recently been running; these can be very hot and can cause severe burns.

4. Many liquids used in engines or vehicles are harmful if taken internally or splashed into the eyes. In the event of accidentally swallowing gasoline (petrol), oil, diesel fuel, antifreeze, battery acid etc, do NOT encourage vomiting and OBTAIN QUALIFIED MEDICAL ASSISTANCE IMMEDIATELY.

Wear protective goggles when handling liquids which are harmful to the eyes; these include ammonia and battery acid. If any of these substances are splashed in the eyes, wash out thoroughly with clean water and OBTAIN QUALIFIED MEDICAL ASSISTANCE IMMEDIATELY.



IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all industrial engines as well as the personal safety of the individual doing the work. This Service Manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

MSG-425 GENERAL INFORMATION

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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 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.

Engine Distributors Inc. (EDI) 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 labeling 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.

Typical Battery Labelling

	Explosive gases		Read relevant instructions
	Eye protection must be WORN.		Keep away from children
	No smoking or naked flames.	Pb	Do not dispose of as household waste.
	Corrosive acid	LEAD RETURN RECYCLE	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.

MSG-425 GENERAL INFORMATION

Forward

This book contains service information 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. We consider it to be in your interests to enlist the aid of an authorized EDI Distributor, not only when repairs are required but also for regular maintenance. Distributors are listed at the back of this manual.

Engines manufactured by Ford Motor Company are available through EDI 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 EDI affiliated Company in your area whose address appears at the end of this book.

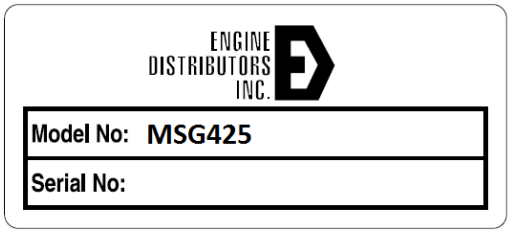
Where the terms "Right" or "Left" occur in this publication, they refer to the respective sides of the engine when viewed from the rear or flywheel end.

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 service procedures outlined in this book still apply to your engine.

Engine Identification

Because Ford Power Products markets such a wide range of industrial gasoline and diesel 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. Review the list in the back of this book, for an EDI distributor in your area. You can obtain a standard parts listing describing the parts. It remains a distributor function to identify the part number.



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.

Parts and Service

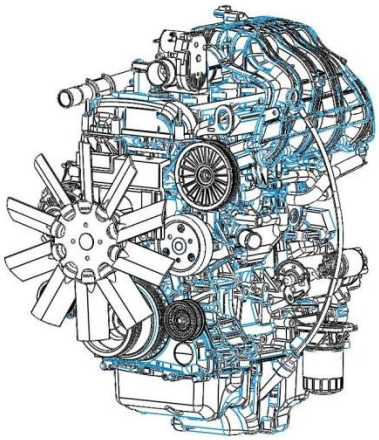
Replacement parts can be obtained through your local EDI Distributor listed in the back portion of this manual. They also may be found in the yellow pages under "Engines" or contact EDI directly at **1 800 220 2700**.

EDI 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.

Description and Operation

Section 01 of this manual covers general procedures and diagnosis of the engine system, including base engine repair procedures that would be common to most engines. Refer to Section 02 for more specific service information on the M**SG-425** engine.

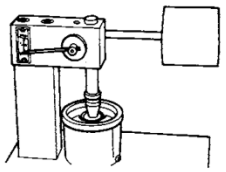
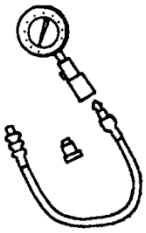
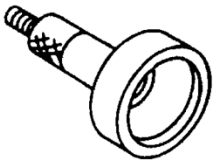
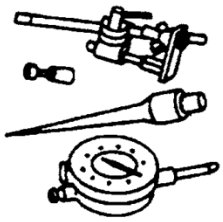
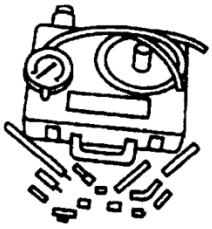
The M**SG-425** engine incorporates a closed positive crankcase ventilation system and an exhaust emission control system.



The engine's, fuel, ignition, emissions system and exhaust system all affect exhaust emission levels and must be maintained according to the maintenance schedule. Refer to the Maintenance and Operator's Handbook or contact your nearest EDI distributor listed in the back of this manual.

DIAGNOSIS AND TESTING

Special Tools

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

Special Service Tools called 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.
	Spark plugs gapped incorrectly.	Check plug gap.
	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*.
	Spark plugs gapped incorrectly.	Check plug gap.
	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*.

Condition	Possible Source	Action
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.
	Worn piston rings.	Replace piston rings.
	Plugged PCV system.	Service PCV system.

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.

PCV System Malfunction

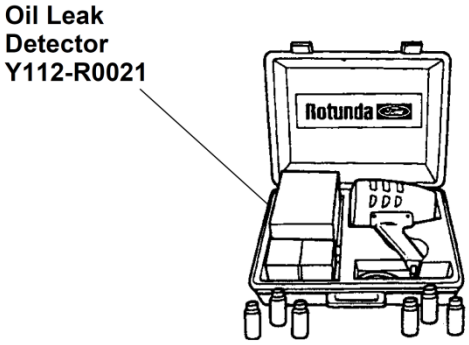
A malfunctioning Positive Crankcase Ventilation System (closed type) may be indicated by loping or rough engine idle. Do not attempt to compensate for this idle condition by disconnecting the PCV system and making an air bypass or idle speed adjustment.

CAUTION: The removal of the PCV system from the engine will adversely affect fuel economy and engine crankcase ventilation with resultant shortening of engine life.

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 a 12 Volt Master UV Diagnostic Inspection Kit, such as the Rotunda Oil Leak Detector Y112-R0021 or equivalent, 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 ESEM9C103- 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
- airline 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 airline 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.

CAUTION: Use extreme caution when pressurizing crankcase. Applying air pressure above specified pressure risks damage to seals, gaskets and core plugs. Under no circumstances should pressure be allowed to exceed 27 kPa (4 psi)

Testing Procedure

- Open the air supply valve until the pressure gauge maintains 20 kPa (3 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 filter
- oil pump (if external)
- 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

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.

- 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 (except for overhead cam)

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 such as Rotunda Compression Tester 059-R0009, or equivalent, 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.

Example Readings

If, after checking the compression pressures in all cylinders, it was found that the highest reading obtained was 1351 kPa (196 psi), and the lowest pressure reading was 1069 kPa (155 psi), the engine is within specification and the compression is considered satisfactory.

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)	

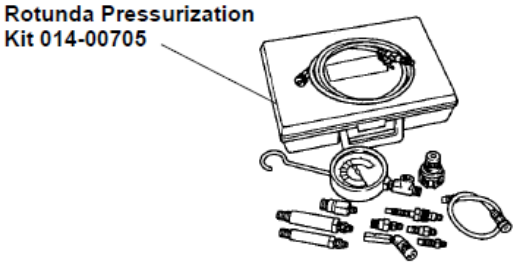
Interpreting Compression Readings

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, such as the Rotunda Pressurization Kit 014-00705, or equivalent, 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.

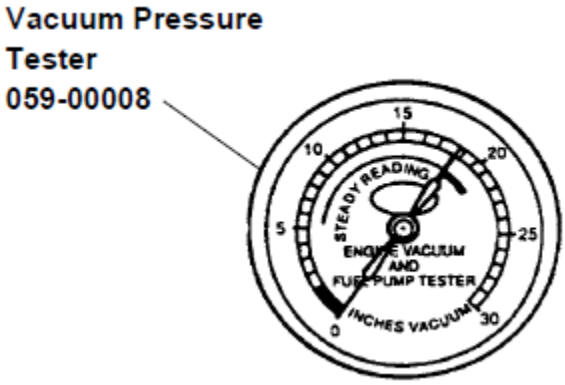
Oil Leak and Valve Stem Seal Test

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 a Vacuum/Pressure Tester, such as Rotunda Vacuum/Pressure Tester 059-00008 or equivalent, to the intake manifold. Run the engine at the specified idle speed.



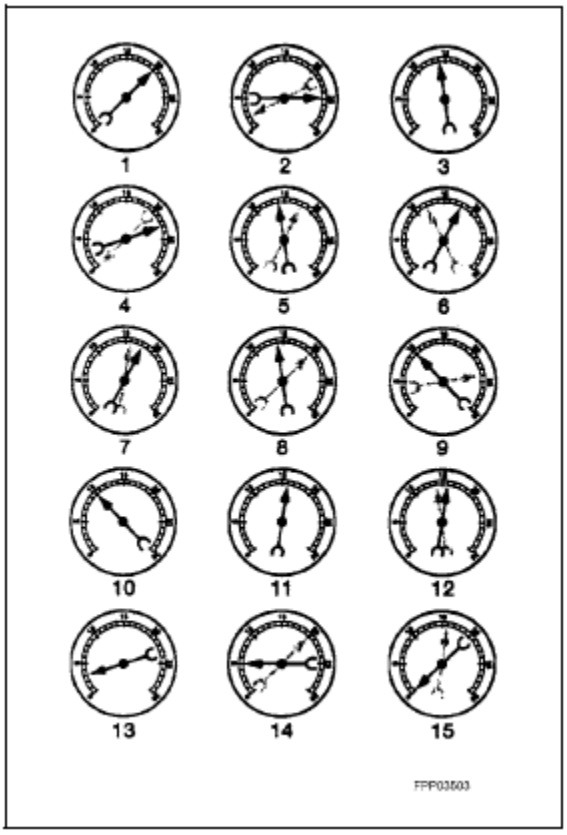
The vacuum gauge should read between 51-74 kPa (15-22 in-Hg) depending upon the engine condition and the altitude at which the test is performed. Subtract 5.5 kPa (1 in-Hg) from the specified reading for every 500 meters (1,000 feet) of elevation above sea level.

The reading should be quite 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.



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 (swings back and forth) 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 approx. 33-50 kPa (10-15 in-Hg) 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 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 – Refer to “Compression Tests” on page 12 or perform a cylinder leak detection test with Engine Cylinder Leak Detection/Air Pressurization Kit – Refer to “Cylinder Leakage Detection” on page 13. 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.

Push Rods (if equipped)

- Check for bent push rods and restricted oil passage.

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 ± 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.

Push Rods (if equipped)

- Check for bent push rods and restriction in oil passage.

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.

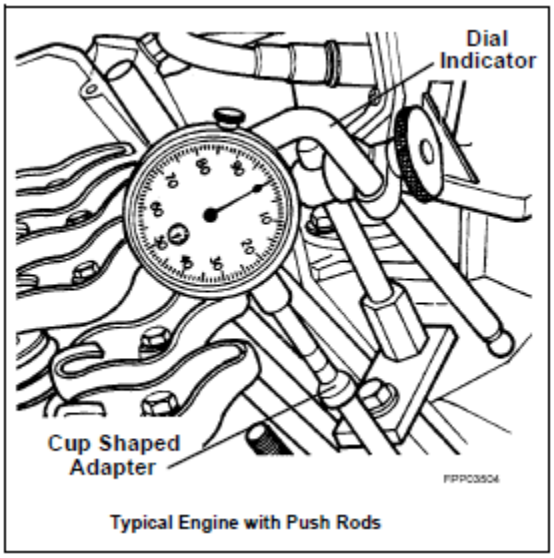
If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1200 rpm with the PTO in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and camshaft roller followers are well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

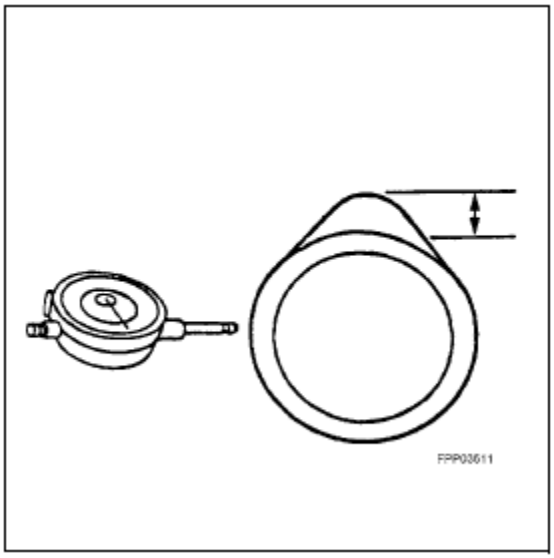
2. Remove the rocker arm seat bolts, rocker arm seat and rocker arms (if equipped).



Typical Engine with Push Rods

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. On engines with overhead cam, 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.



5. Remove the spark plugs.

6. 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 is measuring on the base circle of the camshaft lobe (in its lowest position). If checking during engine assembly, turn the crankshaft using socket or ratchet.

7. 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.

8. Compare the total lift recorded on the dial indicator with specifications.

9. To check the accuracy of the original dial indicator reading, continue to rotate the crankshaft until the indicator reads zero.

10. Remove the dial indicator, adapter and auxiliary starter switch.

11. Reinstall components as necessary.

CAUTION: 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.

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
- leak down 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 leak down 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 leak down rate should be checked and any lash adjusters outside the specification should be replaced.

Assembled lash adjusters can be tested with Hydraulic lash adjuster Leak down Tester to check the leak down rate. The leak down 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:

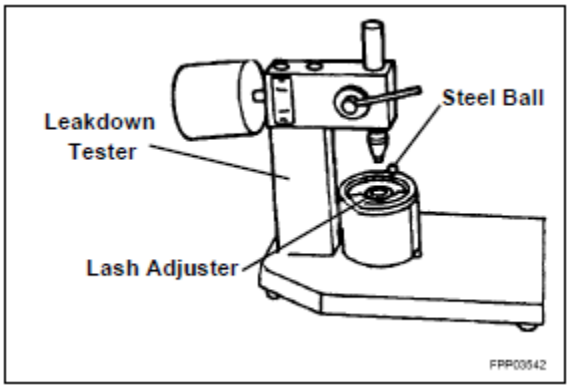
Leak down Testing

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

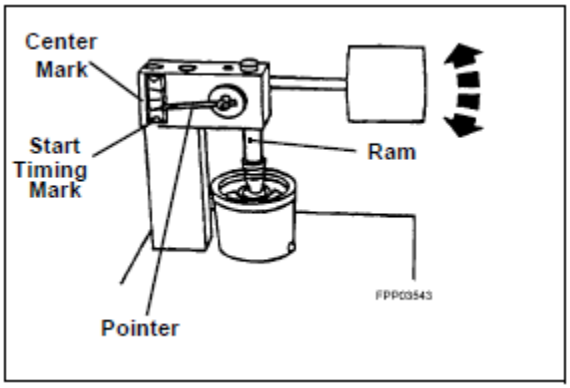
1. Clean the lash adjuster to remove all traces of engine oil.

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 Leak down 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 leak down 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

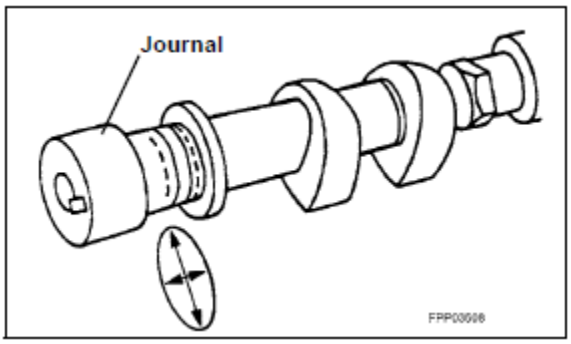
WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT, DO NOT OPERATE THE ENGINE UNTIL THE FAN BLADE HAS BEEN EXAMINED FOR POSSIBLE CRACKS AND SEPARATION.

NOTE: Illustrations are typical and may not reflect your particular engine. 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

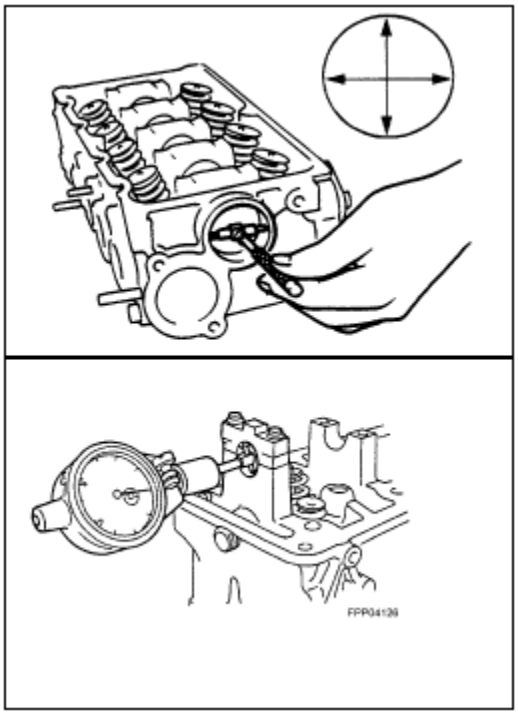
- Measure each camshaft journal diameter in two directions.
- If it is out of specification, replace as necessary.



Camshaft Journal Clearance

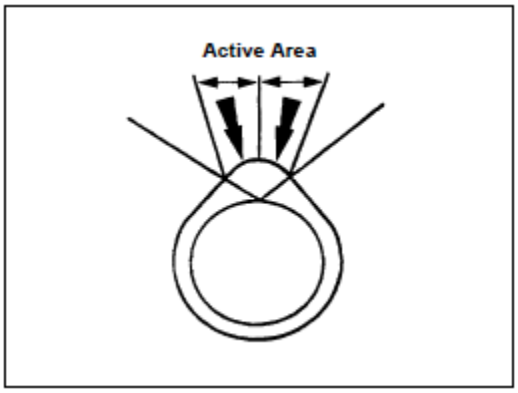
NOTE: The camshaft journals must meet specifications before checking camshaft journal clearance.

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



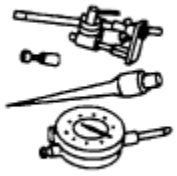
Camshaft Lobe Surface

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

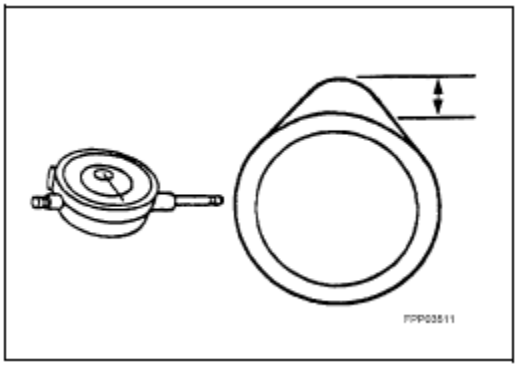


Camshaft Lobe Lift

Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

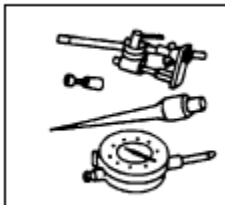
1. Use the Dial Indicator with Bracketry to measure camshaft intake lobe lift.



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.

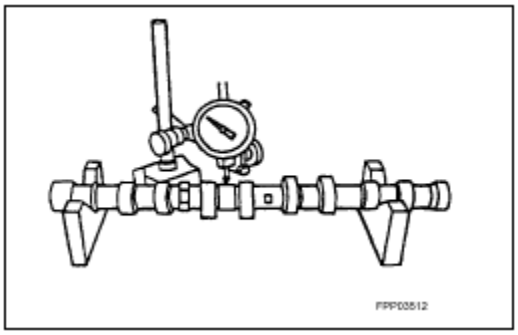
Camshaft Runout

Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

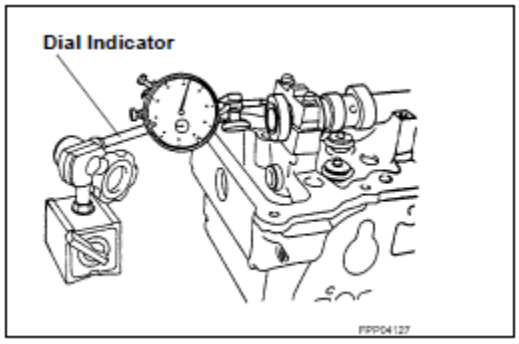
- Use the Dial Indicator with Bracketry to measure the camshaft runout.
- Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading.



Camshaft End Play

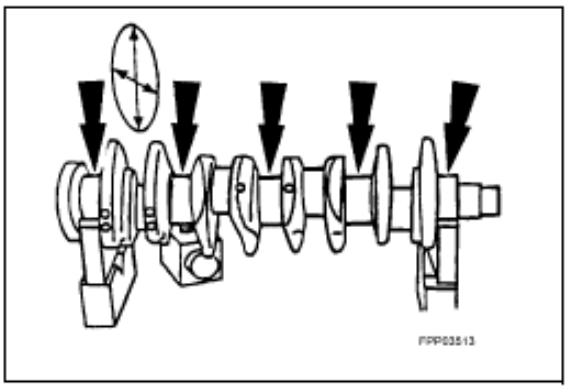
- Move camshaft to the rear.
- Zero dial indicator.
- Move camshaft to the front.
- Compare end play with specifications

.



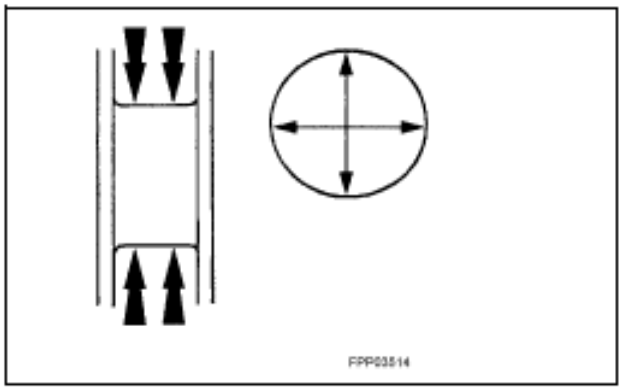
Crankshaft Main Bearing Journal Diameter

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



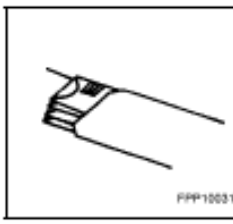
Crankshaft Main Bearing Journal Taper

- 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

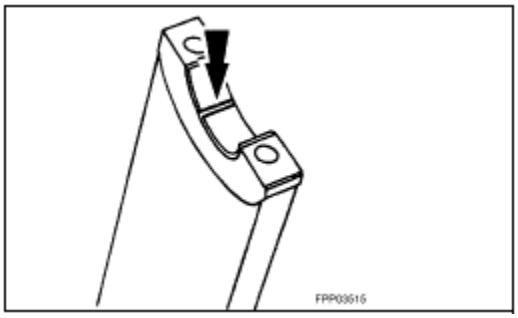
Special Tool(s)

	Plastigage® D81L-6002-B or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

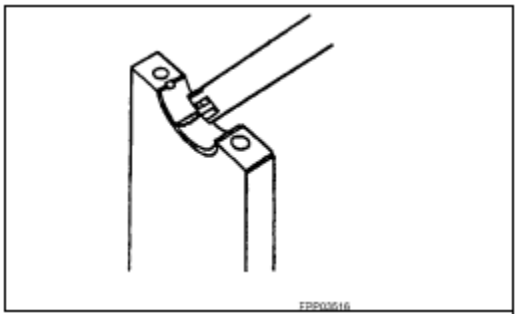
NOTE: Crankshaft main bearing journals must be within specifications before checking journal clearance.

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.



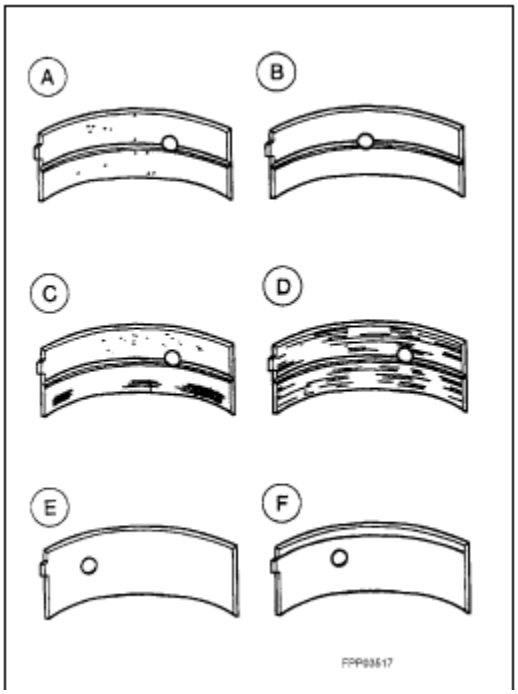
3. Install and remove the crankshaft main bearing cap.
4. Verify the crankshaft journal clearance.
   - If it is out of specification, replace as necessary



Bearing Inspection

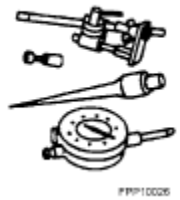
Inspect bearings for the following defects. Possible causes are shown:

- 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)

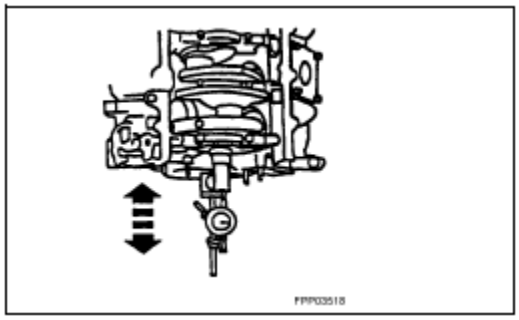


Crankshaft End Play

Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

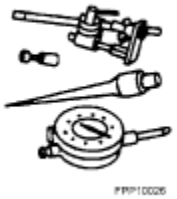
1. Measure the crankshaft end play. Use the Dial Indicator with Bracketry to measure crankshaft end play.
2. Position the crankshaft to the rear of the cylinder block.
3. Zero the Dial Indicator with Bracketry.



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

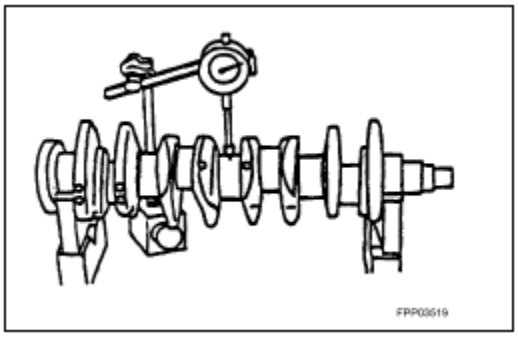
Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

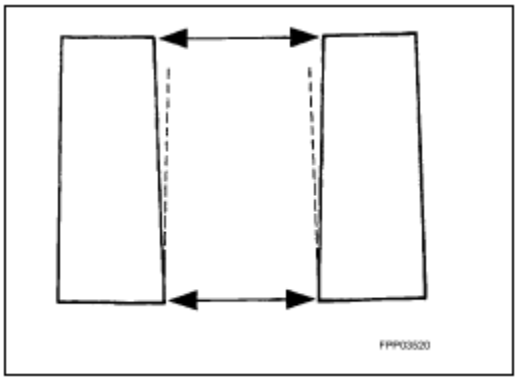
Use the Dial Indicator with Bracketry to measure the crankshaft runout.

- 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.



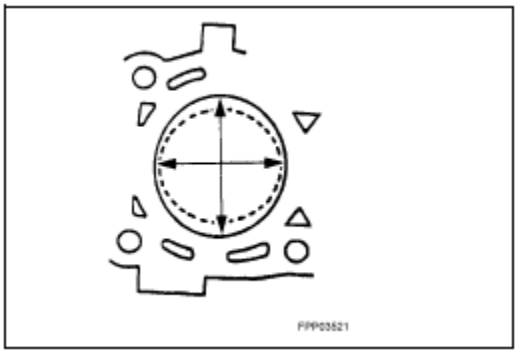
Cylinder Bore Taper

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 I within the wear limit and bore the cylinder to the next oversize limit.



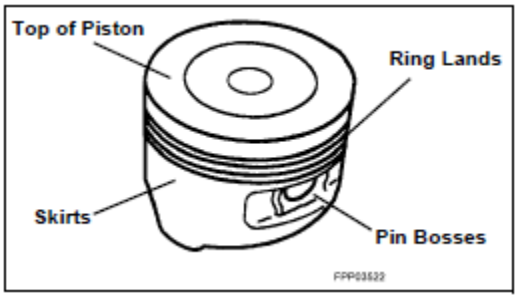
Piston Inspection

Special Tool(s)

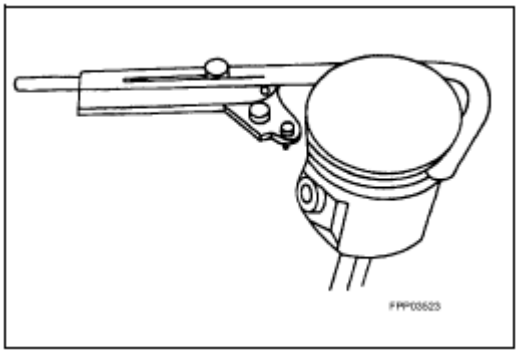
FPP10392	Piston Ring Groove Cleaner D81L-6002-D or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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.

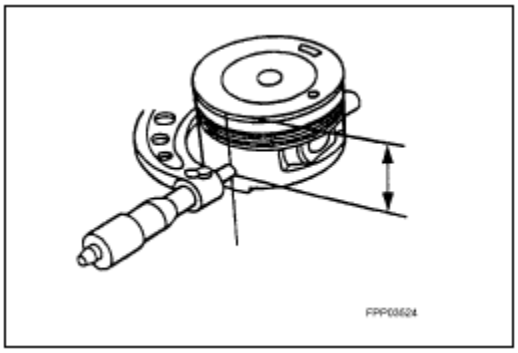


2. Use the Piston Ring Groove Cleaner to clean the piston ring grooves.
   - Make sure the oil ring holes are clean.



Piston Diameter

- Measure the piston skirt diameter.



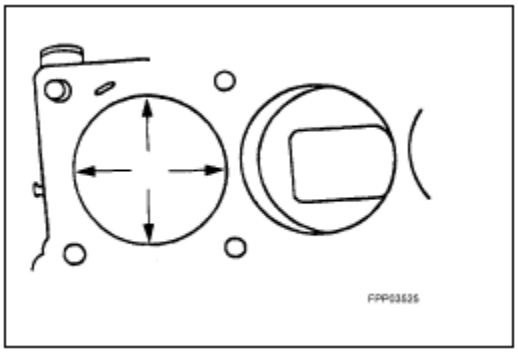
Piston to Cylinder Bore Clearance

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

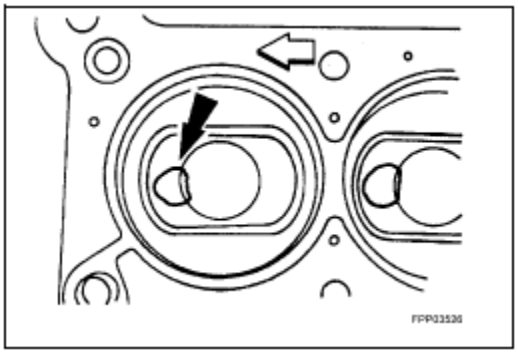
Piston Selection

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.



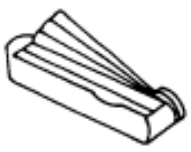
NOTE: For precision fit, new pistons are divided into three categories within each size range based on their relative position within the range. A paint spot on the new pistons indicates the position within the size range.



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.

Piston Ring End Gap

Special Tool(s)

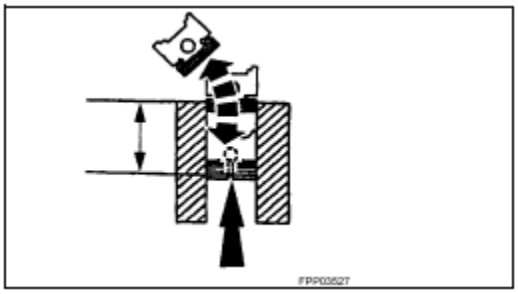
	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

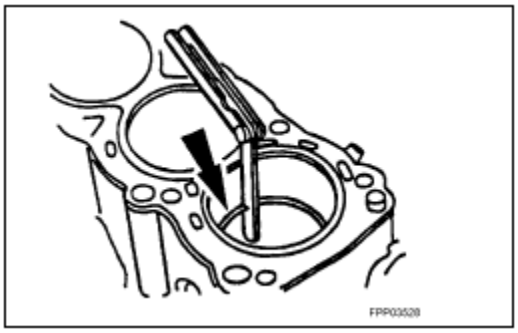
CAUTION: Piston rings should not be transferred from one piston to another to prevent damage to cylinder worn or piston.

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.

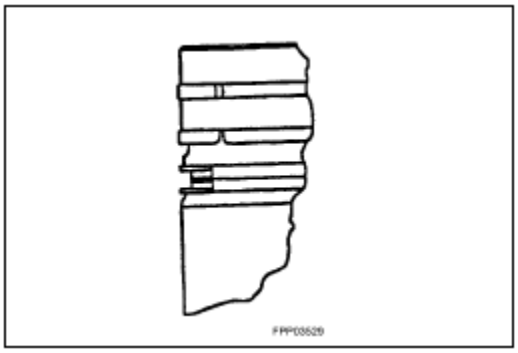


Piston Ring-to-Groove Clearance

Special Tool(s)

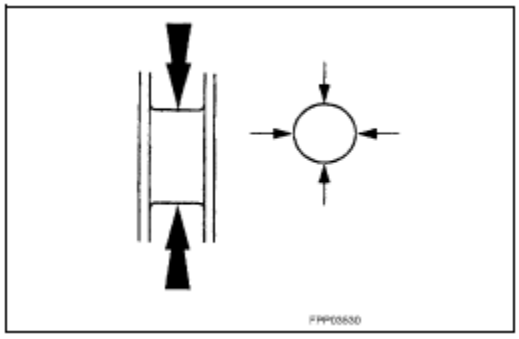
FPP10033	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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



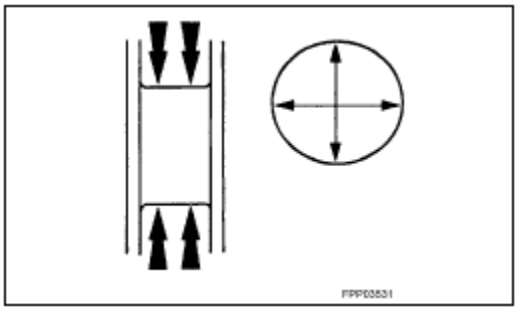
Crankshaft Connecting Rod Journal Diameter

- 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.

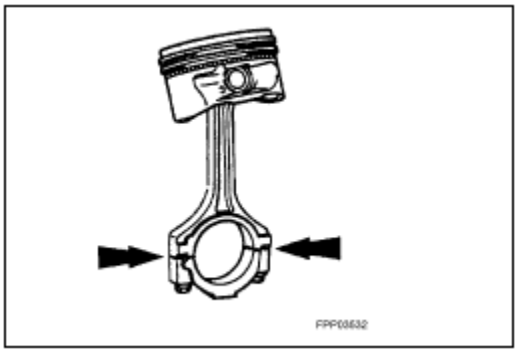


Connecting Rod Cleaning

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.

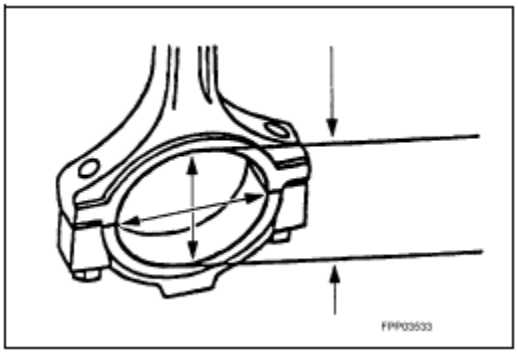
- Mark and separate the parts and clean with solvent. Clean the oil passages



Connecting Rod Larger End Bore

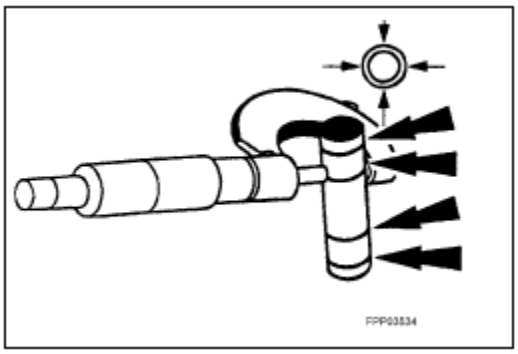
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

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



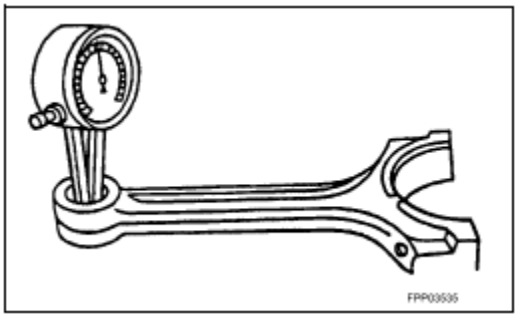
Piston Pin Diameter

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



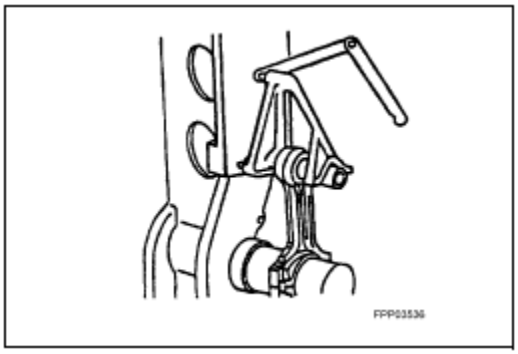
Connecting Rod Bushing Diameter

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



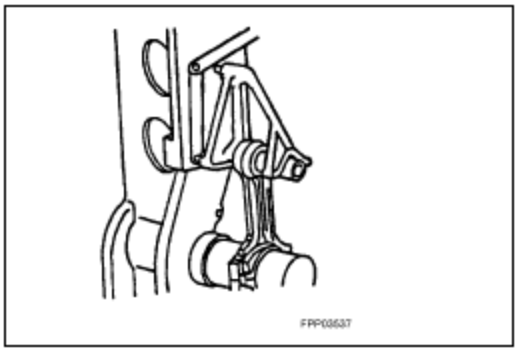
Connecting Rod Bend

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



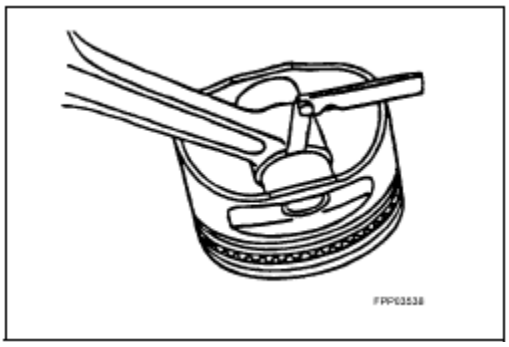
Connecting Rod Twist

- 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.



Connecting Rod Journal Clearance

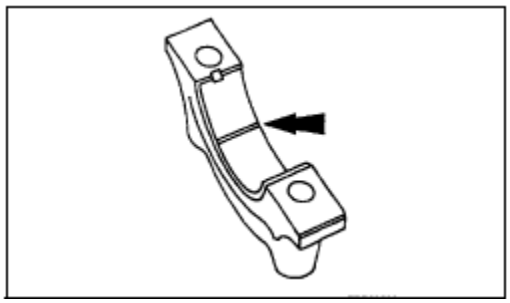
Special Tool(s)

	Plastigage® D81L-6002-B or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

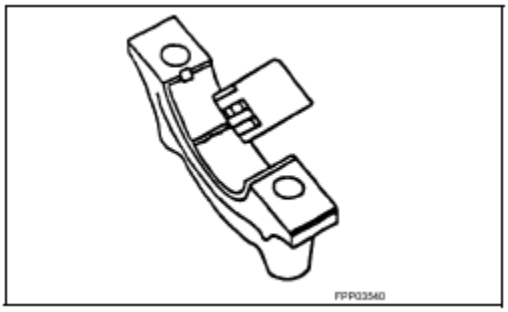
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

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



NOTE: Do not turn the crankshaft during this step.

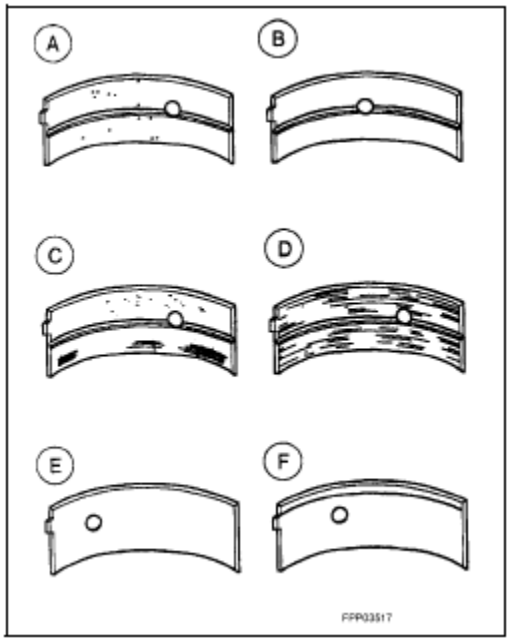
4. Install and torque to specifications, then remove the connecting rod bearing cap.
5. Measure the Plastigage® to get the connecting rod bearing journal clearance. The Plastigage® should be smooth and flat. A change width indicates a tapered or damaged connecting rod bearing or connecting rod.



Bearing Inspection

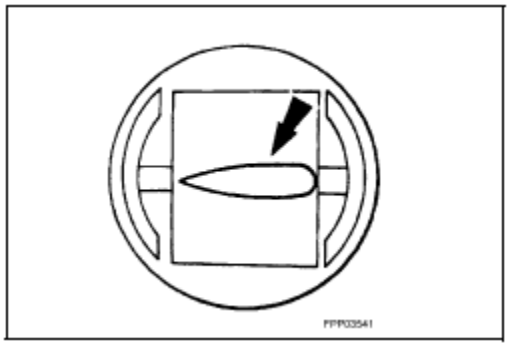
Inspect bearings for the following defects. Possible causes are shown:

- 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)



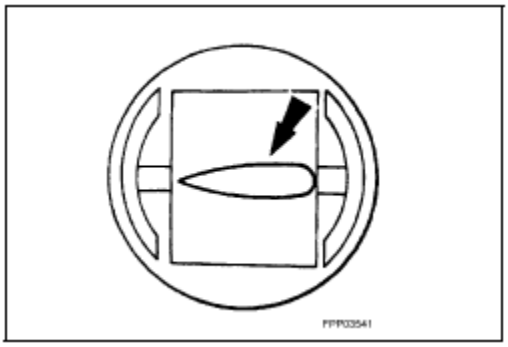
Roller Follower Inspection

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



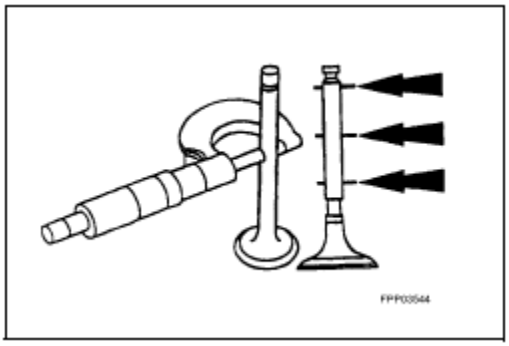
Hydraulic Lash Adjuster Inspection

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



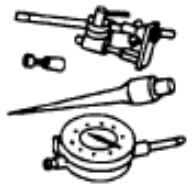
Valve Stem Diameter

- 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

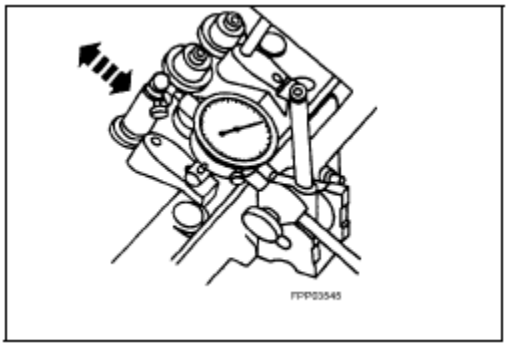
Special Tool(s)

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

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

NOTE: If necessary, use a magnetic base.

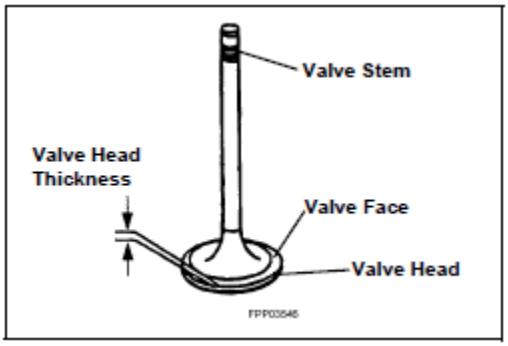
1. Install the Valve Stem Clearance Tool on the valve stem and install the Dial Indicator with Bracketry. Lower the valve until the Valve Stem Clearance Tool contacts the upper surface of the valve guide.
2. Move the Valve Stem Clearance Tool toward the Dial Indicator and zero the Dial Indicator. Move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

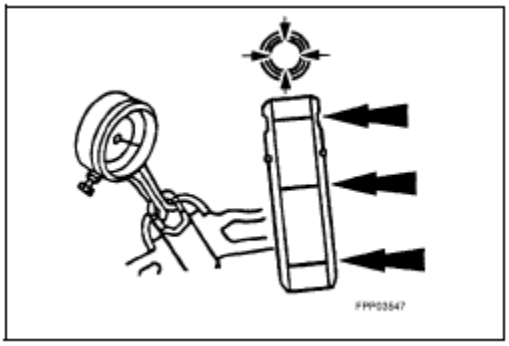
Inspect the following valve areas:

- 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.



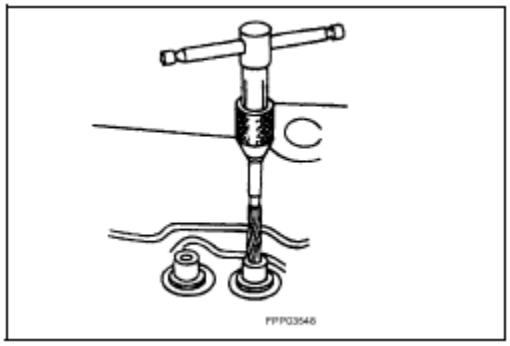
Valve Guide Inner Diameter

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

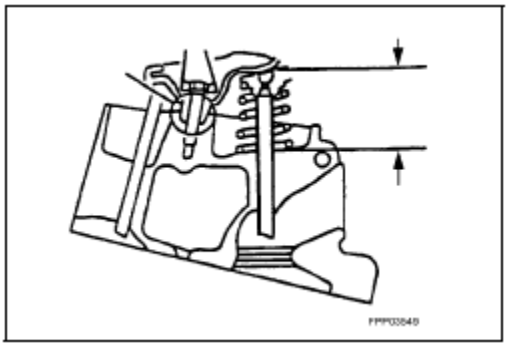
1. Use a hand-reaming kit to ream the valve guide.



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

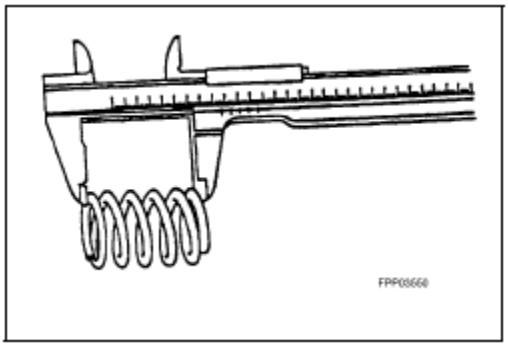
Valve Spring Installed Length

- Measure the installed length of each valve spring.



Valve Spring Free Length

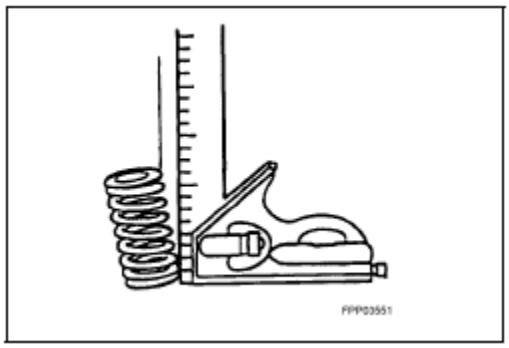
- Measure the free length of each valve spring.



Valve Spring Out-of-Square

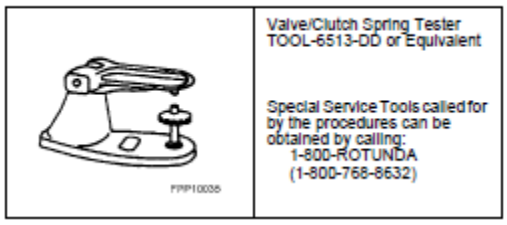
Measure the out-of-square on each valve spring.

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

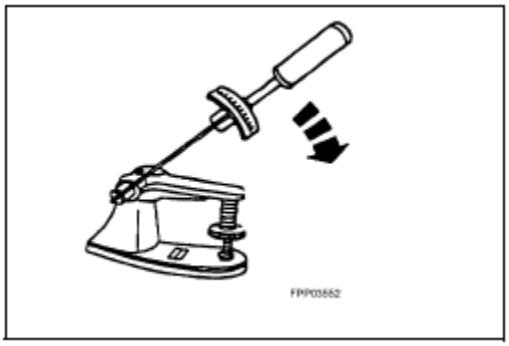


Valve Spring Compression Pressure

Special Tool(s)



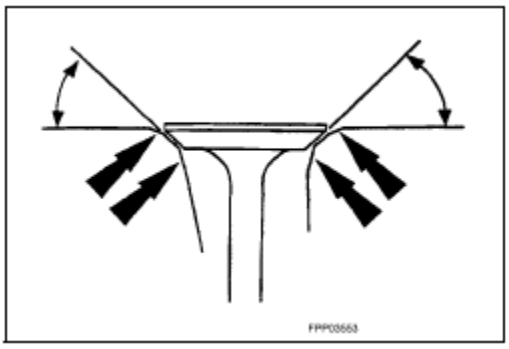
- Use the Valve/Clutch Spring Tester to check the valve springs for proper strength at the specified valve spring length.



Valve and Seat Refacing Measurements

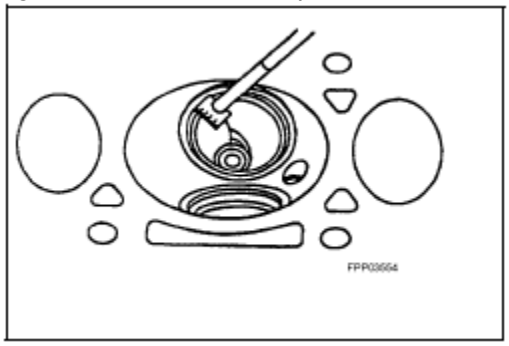
NOTE: After grinding valves or valve seats, check valve clearance.

- Check the valve seat and valve angles.



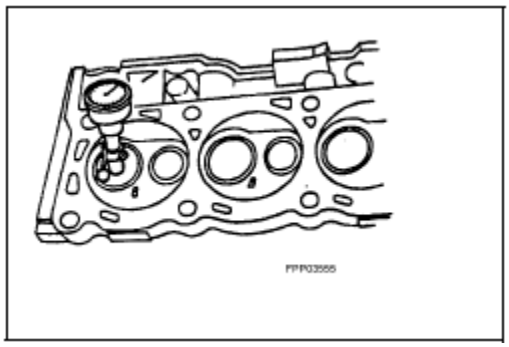
Valve Seat Width

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



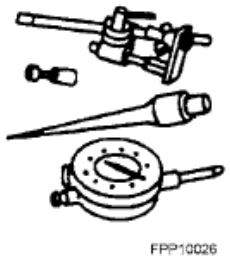
Valve Seat Runout

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

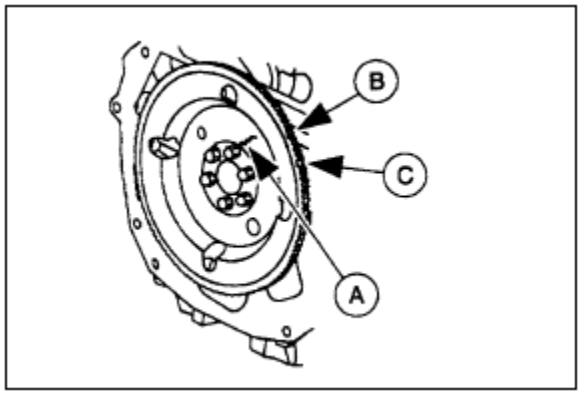


Flywheel Inspection

Special Tool(s)

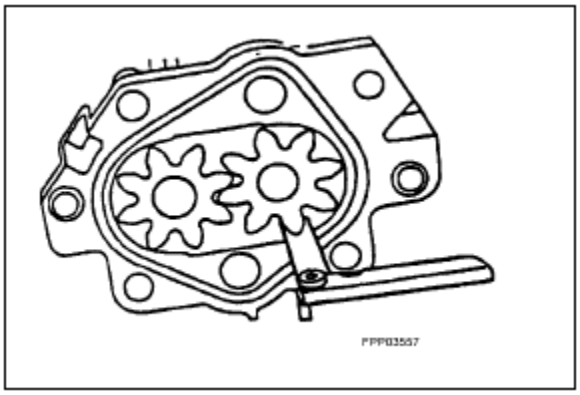
 FPP10026	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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.



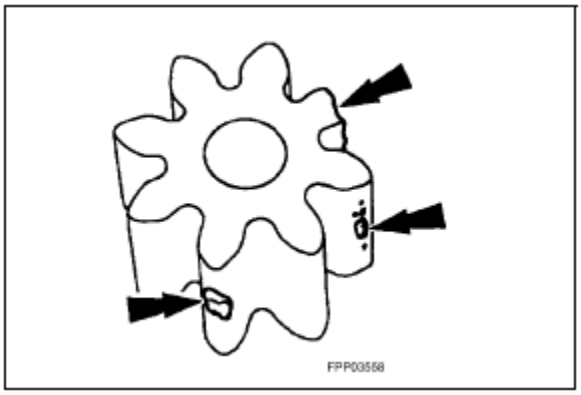
Oil Pump Gear Radial Clearance

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



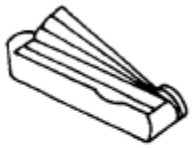
Oil Pump Rotor Inspection

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

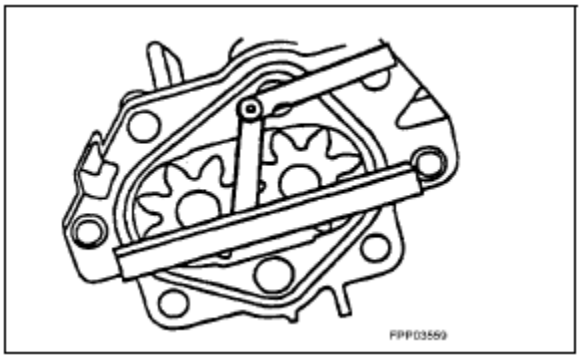


Oil Pump Side Clearance

Special Tool(s)

 FPP10033	Feeler Gauge D81L-4201-A or Equivalent
FPP10036	Straight Edge 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 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)

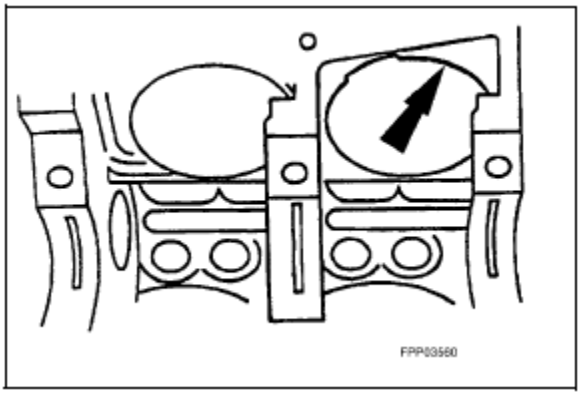
FPP10037	Engine Cylinder Hone Set T73L-6011-A Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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.



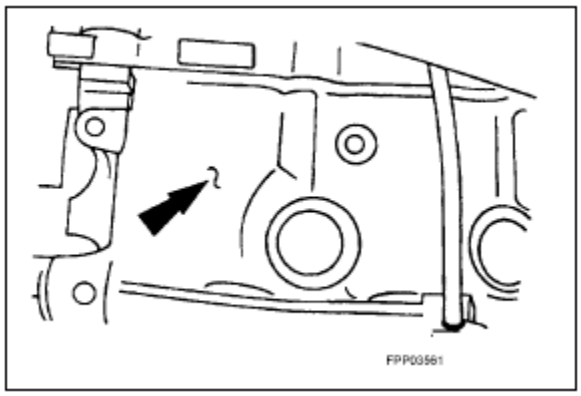
Cylinder Bore Cleaning

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 ESEM2C153-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.

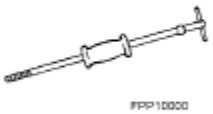


Repair porosity defects with an epoxy sealer meeting Ford specification M3D35-A (E).

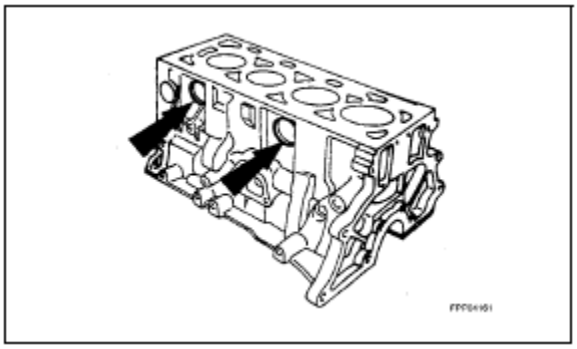
1. Clean the surface to be repaired to a bright, oil-free metal surface.
2. Chamfer or undercut the repair area to a greater depth than the rest of the cleaned surface. Solid metal must surround the area to be repaired.
3. Apply the epoxy sealer and heat-cure with a 250- watt lamp placed 254 mm (10 inches)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

 FPP10000	Impact Slide Hammer T50T-100-A Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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 interfered 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.

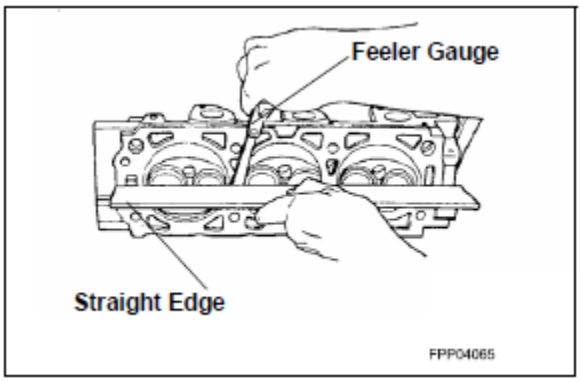
3. Coat the cylinder block core plug and bore lightly with Threadlock® 262 E2FZ-19554-B or equivalent meeting Ford specification WSK-M2G351-A6 and install the cylinder block core plug.

Cylinder Head – Distortion

Special Tool(s)

FPP10036	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)

- 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.

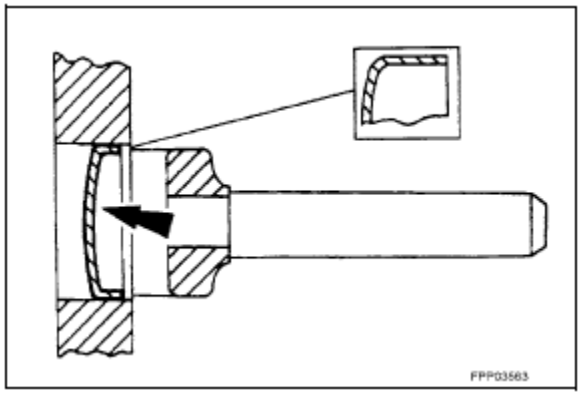


Cylinder Block Core Plug – Cup-Type

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.

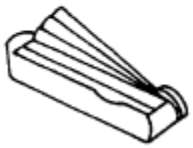


Cylinder Block Core Plug – Expansion-Type
CAUTION: Do not contact the crown when installing an expansion type cylinder block core plug. This could expand the plug before seating and result in leakage.

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

Spark Plug Thread Repair

Special Tool(s)

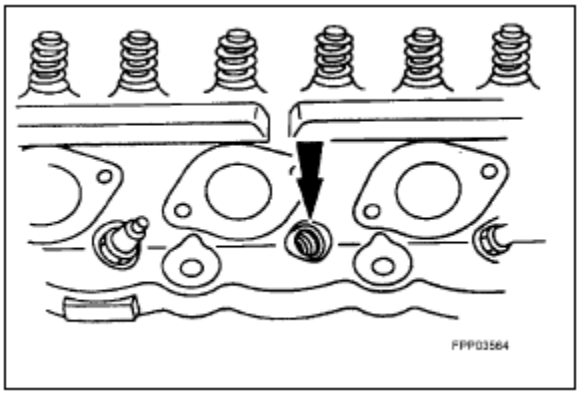
FPP10038	Tapersert Installation Kit 107-R0921 or Equivalent
 FPP10033	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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.

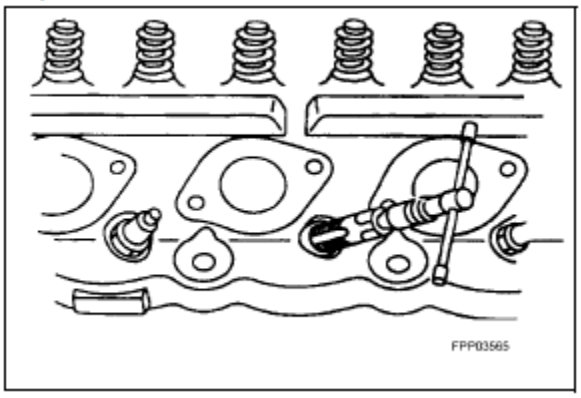
CAUTION: Do not use power or air-driven tools for finishing taperserts.

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

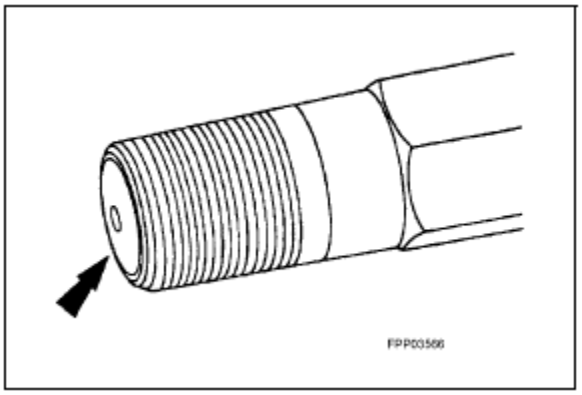
1. Clean the spark plug seat and threads.



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

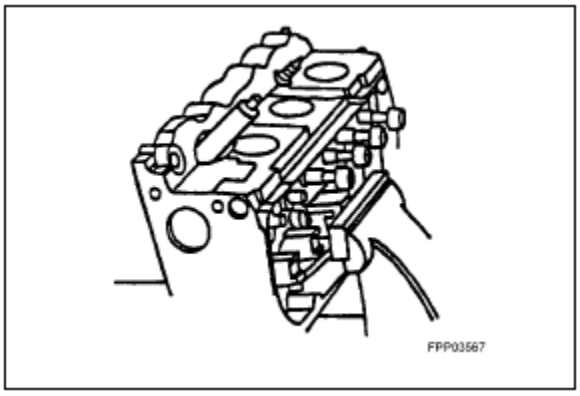


3. Continue cutting the threads and applying oil until the stop ring bottoms against the spark plug seat.
4. Remove the tap and metal chips.
5. Coat the threads of the mandrel with cutting oil. Thread the tapersert onto the mandrel until one thread of the mandrel extends beyond the tapersert.

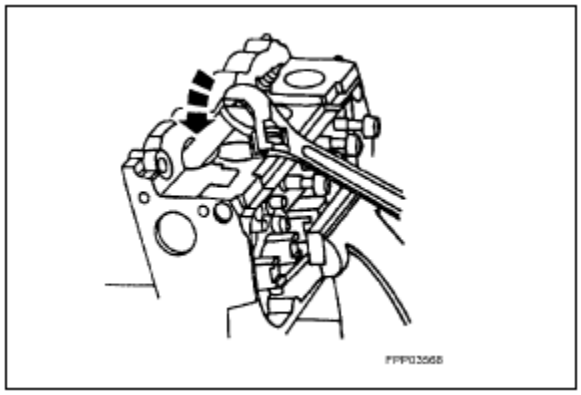


NOTE: A properly installed tapersert will be either flush with or 1.0 mm (0.039 inch) below the spark plug gasket seat.

6. Tighten the tapersert into the spark plug hole.



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



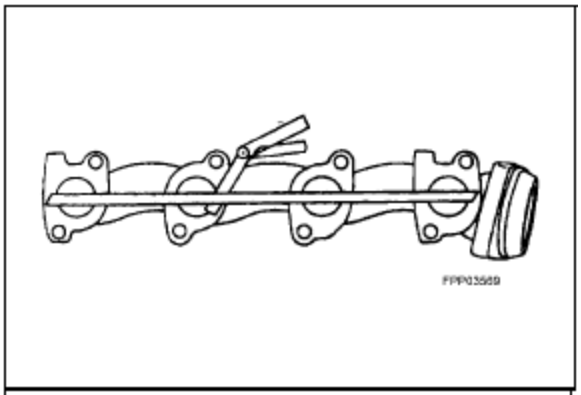
Exhaust Manifold Straightness

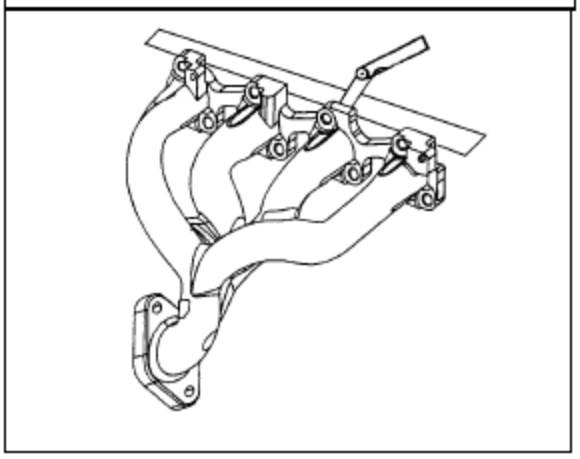
Special Tool(s)

FPP10036	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
Super Premium SAE5W20	WSS M2C930-A

NOTE: Ford 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 SJ or greater must be used.

MSG-425 ENGINE

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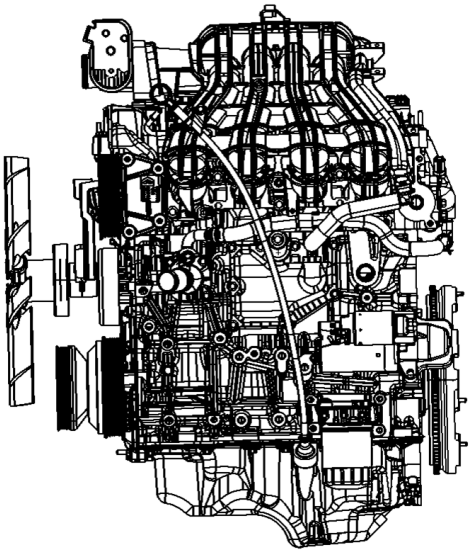
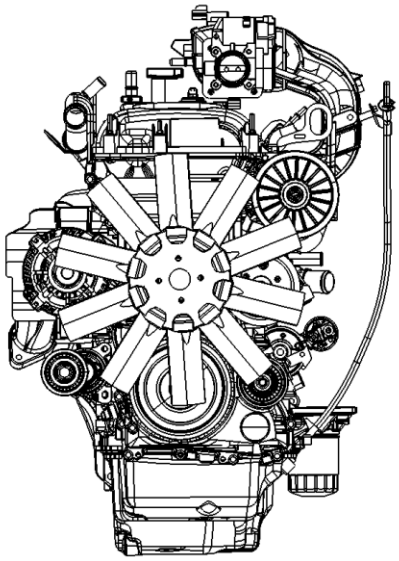
GENERAL INFORMATION



Engine

The MSG425 is a 4 valve per cylinder, dual overhead cam engine. The engine block is cast aluminum with iron cylinder liners. Connecting rods are made of sintered metal; the crankshaft is nodular iron with five main bearings. The cam cover, oil pan and front cover are also made of aluminum.



The dual camshafts are chain driven with an automatic tensioning system. The valve train components are alternate fuel ready. Spark is delivered by an individual coil on plug ignition system. A broadband knock sensor is calibrated for individual cylinder use.

All fuels are controlled in closed loop. Gasoline is delivered by sequential port fuel injection. The electronic engine management system has built in engine protection against:

- Detonation
- High coolant temperature
- Low oil pressure
- Engine over speed
- Starter engagement while engine is running.

NOTE: A set of metric wrenches are required to service the MSG425 engine.

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

Positive Crankcase Ventilation System

This engine is equipped with a positive, closed-type crankcase ventilation system, which recycles crankcase vapors to the intake manifold.

Engine Cooling System

The 2.5L engine is liquid cooled, using an engine mounted coolant pump and external radiator. This is a full flow system regulated by a thermostat, located behind the water outlet connection. The thermostat controls and maintains engine temperature.

Refer to Section 05 of this manual for more information on the cooling system.

Valves and Seats

The engines for petrol operation and LPG/CNG operation are basically identical. Because LPG/CNG is a dry fuel and combusts at a higher temperature, the valve train is under higher stress. The adaptations described below are therefore necessary. Because of the higher stress involved in LPG/CNG operation:

- The inlet valves are made of a harder material.
- The inlet and exhaust valve seats are made of a harder material.

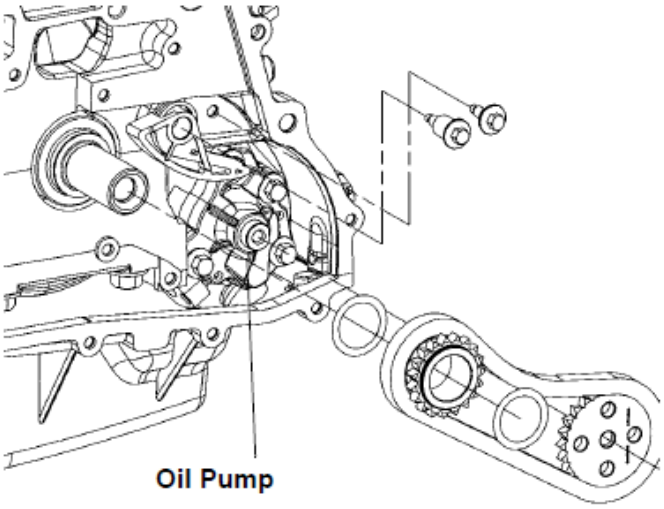
Lubrication System

The engine lubrication system consists of:

- Oil pan.
- Oil pump screen cover and tube.
- Oil pump.
- Oil filter.
- Passageways in the cylinder block, crankshaft, camshaft and cylinder head.

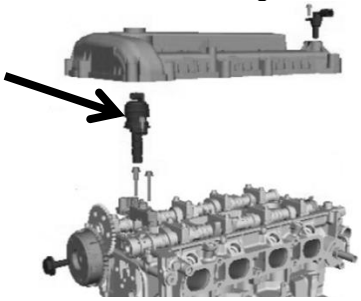
The oil pan is pressure-cast aluminum and serves as both an oil reservoir and engine bottom cover. The oil pan has reinforcing ribs which strengthen the pan, reduce engine noise transmission, and aid in oil cooling.

The oil pump is mounted to the engine block and is driven by chain from the crankshaft. Oil cooling jets spray to the underside of the piston skirt.



Variable camshaft timing (VCT)

This system is an electronically controlled camshaft adjuster that allows variable timing for the inlet camshaft.



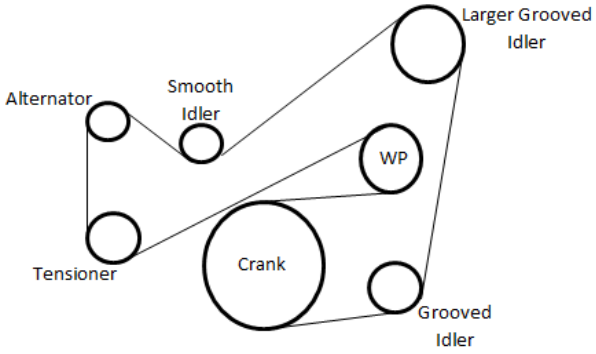
The valves are driven by a timing chain which drives the inlet camshaft timing control unit. This unit drives the associated camshafts. The timing chain is tensioned using a conventional timing chain tensioner.

Advantages of variable camshaft timing (VCT).

- Lower fuel consumption due to improved volumetric efficiency
- Enhanced engine power and torque

Drive Belt System

Engine accessories, such as the generator and water pump, are driven by a single serpentine belt. Tension is automatically adjusted by a tensioner.



The fan is remotely mounted in front of the primary FEAD and is driven by a crank pulley extension with a separate belt.

Ignition System

The ignition used on the 2.5L engine is an Electronic Distributorless Ignition System (EDIS). Individual ignition coils are located directly above each spark plug and are used to ignite the fuel in the cylinders.

Refer to Section 03 of this manual for more information on the ignition system.

Fuel System

The fuel system includes a remote mounted electric fuel pump. The pump regulates and maintains fuel flow, through an in-line fuel filter to the electronic actuator mounted on the intake manifold.

The engine can be adapted for dry fuel use. Refer to Section 04 of this manual for more information on the fuel system.

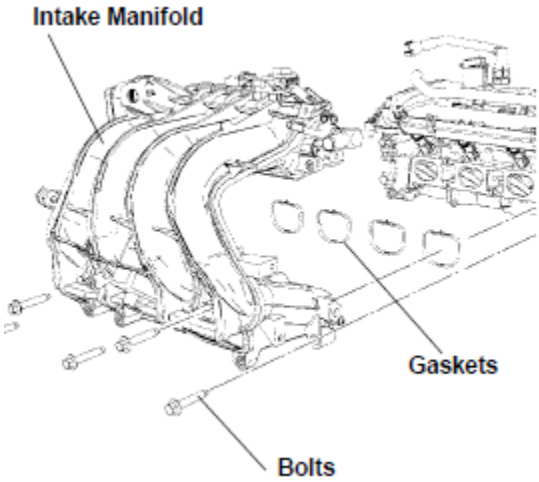
REMOVAL & INSTALLATION

Intake Manifold - Removal

1. Drain the engine cooling system -- Refer to Section 5.
2. Remove and/or disconnect components to allow access and removal of the intake manifold. Label if necessary to allow for correct reinstallation.

CAUTION: Relieve fuel system pressure before disconnecting fuel supply lines -- refer to Section 4.

3. Remove fuel supply connections -- refer to Section 4.



4. Remove 5 bolts and the intake manifold.

CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

5. Clean the sealing surface of the cylinder head with silicone gasket remover and metal surface prep.

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND META SURFACE PREP.

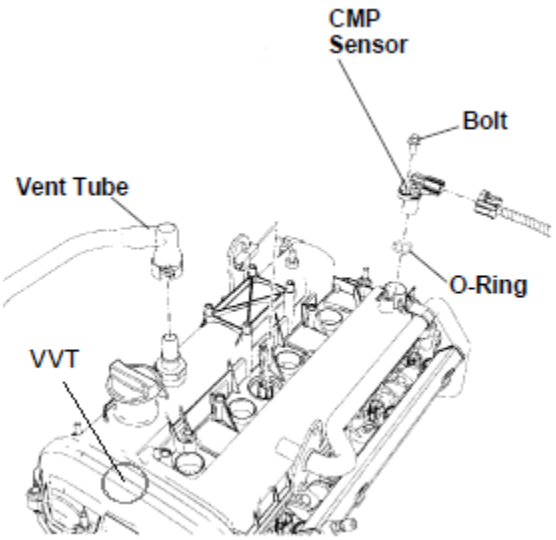
6. Remove and discard intake manifold gaskets.

Intake Manifold - Installation

1. Install new intake gaskets.
2. Position intake manifold and install 5 bolts.
   - Tighten to 18 Nm (13 lb-ft).
3. Reconnect fuel supply connections -- refer to Section 4.
4. Reinstall or connect any components that were removed or disconnected.
5. Fill and bleed the engine cooling system -- refer to Section 5.

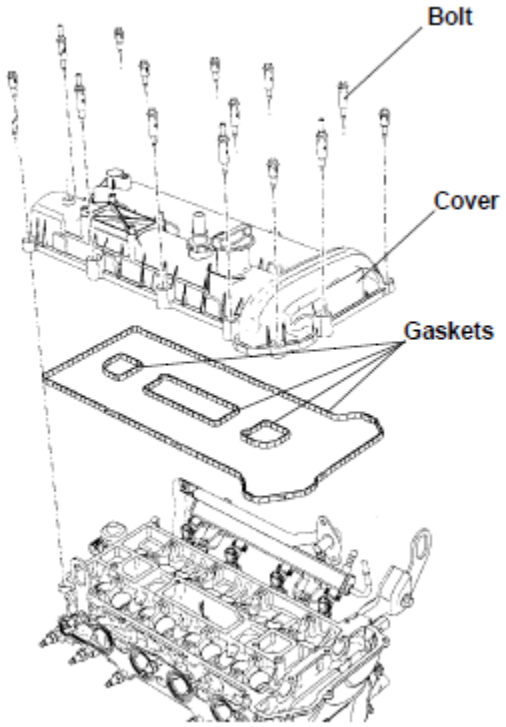
Camshaft Cover - Removal

1. Disconnect negative battery cable -- refer to Section 6.
2. Remove intake manifold -- Refer to “Intake Manifold - Removal” on page 6 of this section.
3. Remove and/or disconnect components to allow access and removal of the camshaft cover. Label if necessary to allow for correct reinstallation.



4. Disconnect VVT connector
5. Disconnect ignition coil connectors.
6. Disconnect Camshaft Position (CMP) Sensor connector.
7. Remove CMP Sensor.
8. Disconnect crankcase ventilation tube quick connect coupling.

9. Remove bolts and camshaft cover.



10. Remove and discard gaskets.

CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

11. Clean the sealing surface of the cylinder head with silicone gasket remover and metal surface prep.

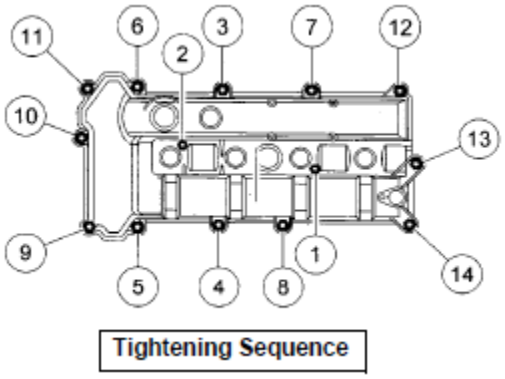
WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

Camshaft Cover - Installation

1. Install new gaskets.

2. Position camshaft cover and install bolts in sequence shown

   - Tighten to 10 Nm (89 lb-in)



Tightening Sequence

3. Reconnect crankcase ventilation tube.

NOTE: Apply clean engine oil to CMP sensor o-ring seal prior to installation.

4. Install CMP sensor and bolt.
   - Tighten to 7 Nm (62 lb-in)

5. Reconnect CMP sensor, ignition coil and CHT Sensor connectors.

6. Reinstall or connect any other components that were removed or disconnected

7. Install intake manifold -- Refer to“Intake Manifold -Installation” on page 6 of this section.

8. Reconnect negative battery cable -- refer to Section 6.

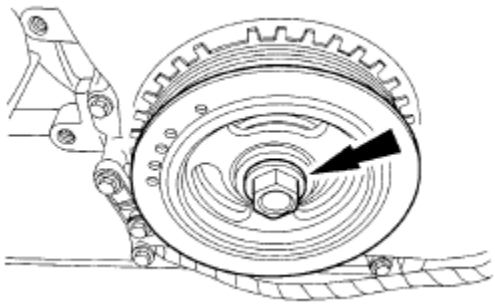
Crankshaft Pulley - Removal

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

1. Remove and/or disconnect components to allow access and removal of the crankshaft pulley. Label if necessary to allow for correct reinstallation.
2. Remove the drive belt -- refer to Section 6.
3. Remove the camshaft cover – Refer to “Camshaft Cover - Removal” on page 6 of this section.

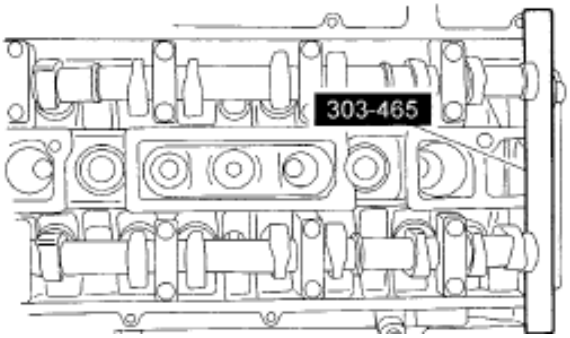
CAUTION: Failure to position the No.1 piston at top dead center (TDC) can result in damage to the engine. Turn the engine in the normal direction of rotation only.

4. Using the crankshaft pulley bolt, turn the crankshaft clockwise to position the No. 1 piston at TDC.



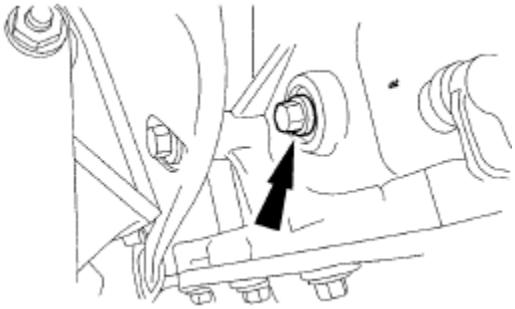
CAUTION: The special tool 303-465 is for camshaft alignment only. Using this tool to prevent engine rotation can result in engine damage.

5. Install special tool 303-465 in the slots on the rear of both camshafts.



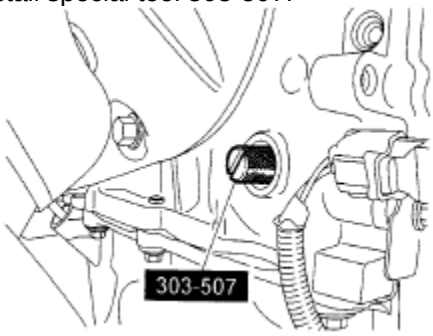
NOTE: Camshaft timing slots are offset. If special tool cannot be installed, rotate crankshaft one complete revolution clockwise to correctly position camshafts.

6. Remove plug bolt.



CAUTION: Installing special tool in this next step will prevent engine from being rotated in the clockwise direction. However, the engine can still be rotated in the counterclockwise direction. Only turn the engine in the normal direction of rotation.

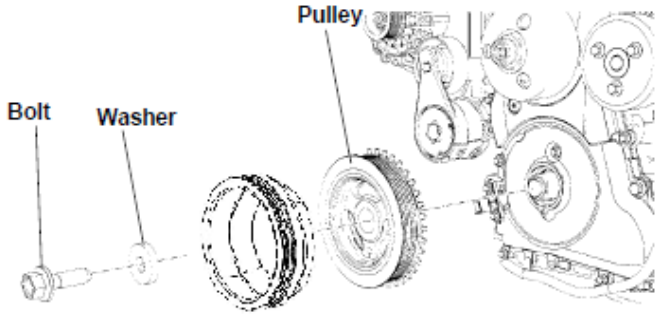
7. Install special tool 303-507.



8. Install special tools 205-126 and 205-072-02

CAUTION: Failure to hold the crankshaft pulley in place during bolt loosening can cause damage to the engine.

9. Remove bolt, washer and pulleys. Discard crankshaft pulley bolt.



Crankshaft Pulley - Installation

CAUTION: Do not reuse the crankshaft pulley bolt.

1. Apply clean engine oil on the crankshaft front seal and install crankshaft pulley, washer and hand tighten new bolt.

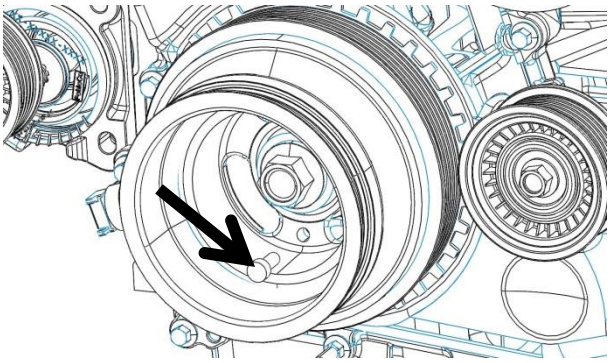
CAUTION: Only hand-tighten the bolt or damage to the front cover can occur.

NOTE: This next step will correctly align the crankshaft pulleys to the crankshaft.

2. Install a standard 6mm x 70mm bolt as shown and thread it into the front cover.

NOTE: Rotate the crankshaft pulley as necessary to align the bolt hole then align the fan drive pulleys bolt hole.

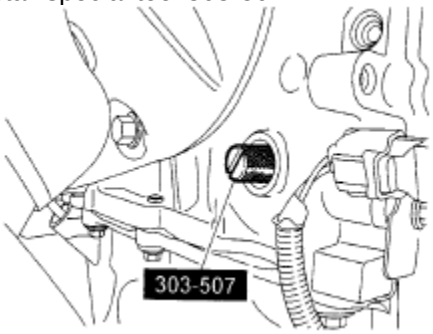
CAUTION: Failure to hold the crankshaft pulley in place during bolt tightening can cause damage to the engine front cover.



3. Remove all special tools and 6 mm bolt.

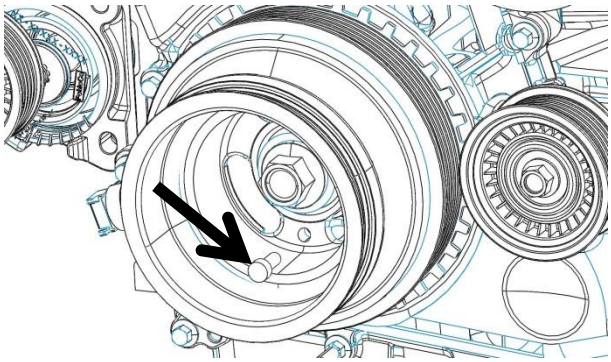
CAUTION: Only turn the engine in the normal direction of rotation.

4. Turn the engine 2 complete revolutions, and then continue to turn until piston is at TDC.
5. Install special tool 303-507.

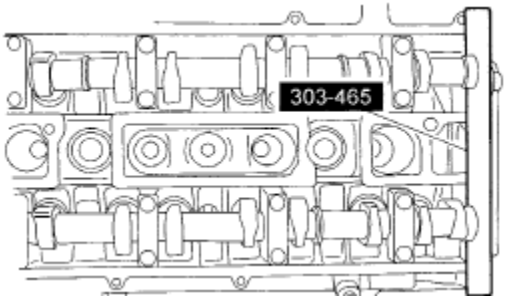


CAUTION: Only hand tighten the bolt in the next step or damage to the front cover can occur.

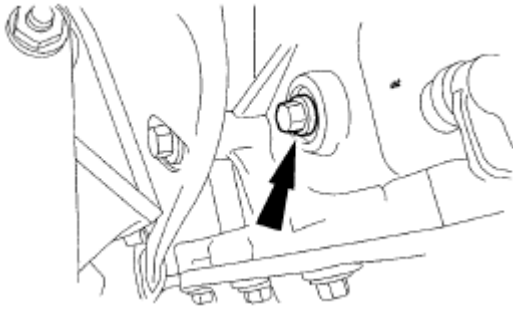
6. Using the 6mm x 70 mm bolt, check the position of the crankshaft pulley. If it is not possible to install this bolt, correct the engine timing.



7. Using special tool 303-465, check the position of the camshaft. If it is not possible to install the special tool, correct the engine timing.



8. Torque Crankshaft bolt 100Nm (74ft-lbs) then rotate additional 90 degrees. (135 if engine in JLG application)
9. Remove all special tools and 6mm bolt.
10. Install the plug bolt.
    - Tighten to 20 Nm (15 lb-ft).
11. Install camshaft cover -- Refer to “Camshaft Cover - Installation” on page 7 of this section.



12. Install accessory drive belt -- refer to Section 6.
13. Install or reconnect any other components that were removed or disconnected.

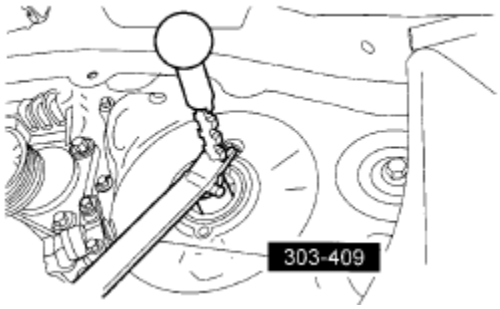
Crankshaft Front Seal - Removal

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

1. Remove and/or disconnect components to allow access and removal of the crankshaft front seal. Label if necessary to allow for correct reinstallation.
2. Remove crankshaft pulley -- Refer to"Crankshaft Pulley - Removal" on page 8 of this section.

CAUTION: Use care not to damage the engine front cover or the crankshaft when removing the seal.

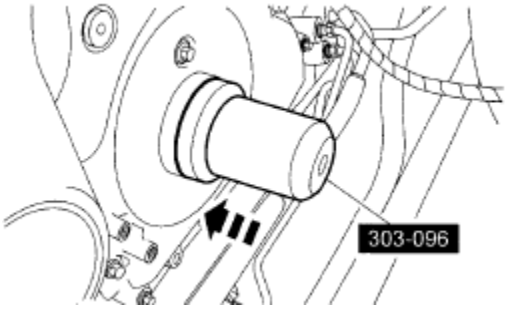
3. Using special tool 303-409, remove the crankshaft front seal.



Crankshaft Front Seal - Installation

1. Lubricate the new crankshaft front seal with clean engine oil prior to installation.

2. Using special tool 303-096, install the crankshaft front seal.



3. Install the crankshaft pulley -- Refer to "Crankshaft Front Seal - Installation" on page 10 of this section.

4. Install or reconnect any other components that were removed or disconnected.

Engine Front Cover - Removal

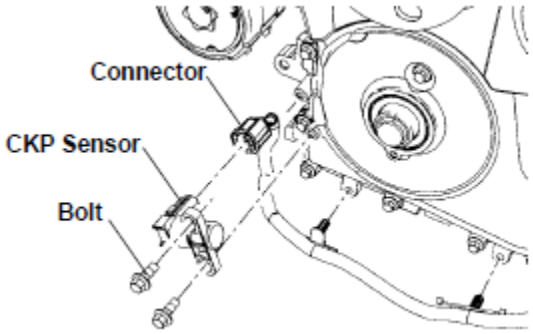
1. Disconnect the negative battery cable -- refer to Section 6.

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

2. Remove and/or disconnect components to allow access and removal of the engine front cover. Label if necessary to allow for correct reinstallation.

3. Remove the crankshaft pulley -- Refer to "Crankshaft Pulley - Removal" on page 8 of this section.

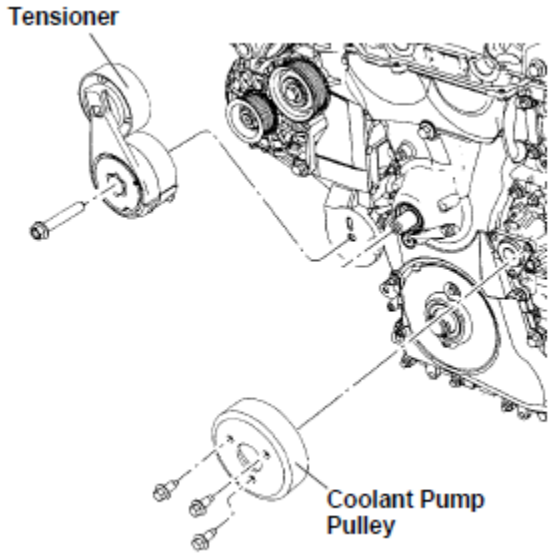
4. Disconnect Crankshaft Position (CKP) Sensor connector.



CAUTION: A new CKP Sensor must be installed whenever the old sensor is removed.

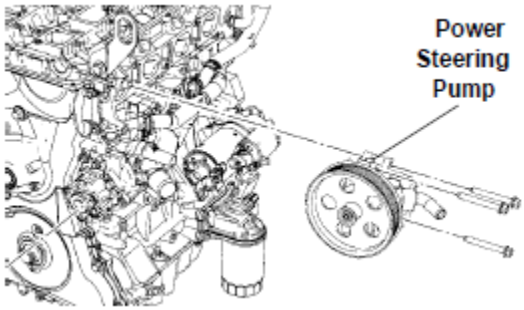
5. Remove the CKP Sensor and discard.

6. Remove bolt and accessory drive tensioner.



7. Remove the three bolts and the coolant pump pulley.

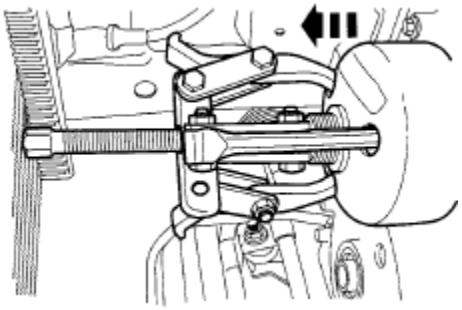
8. Remove three bolts and power steering pump/upper idler pulley and set aside.



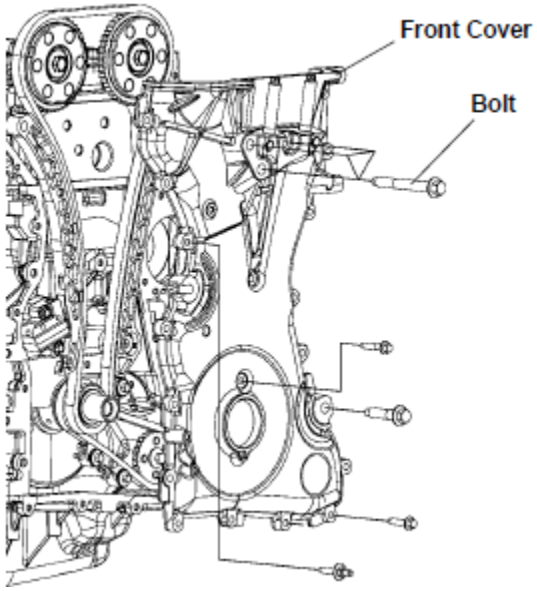
CAUTION: There is one bolt behind the cooling fan drive pulley. This bolt can be accessed by lining up one of the holes in the pulley with the bolt.

NOTE: The next step is only necessary if a new front cover is being installed.

9. Using a 3 jaw puller, remove the fan drive pulley.



10. Remove bolts and engine front cover.



CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

11. Clean the sealing surface with silicone gasket remover and metal surface prep.

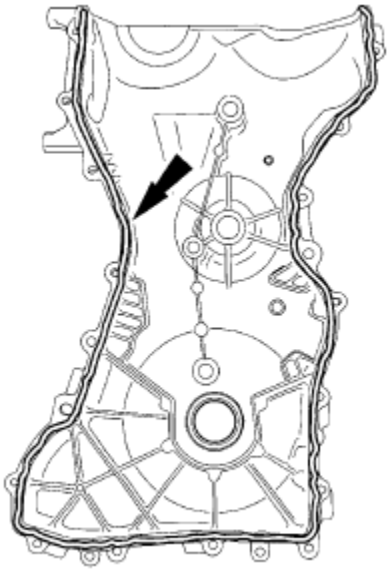
⚠

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

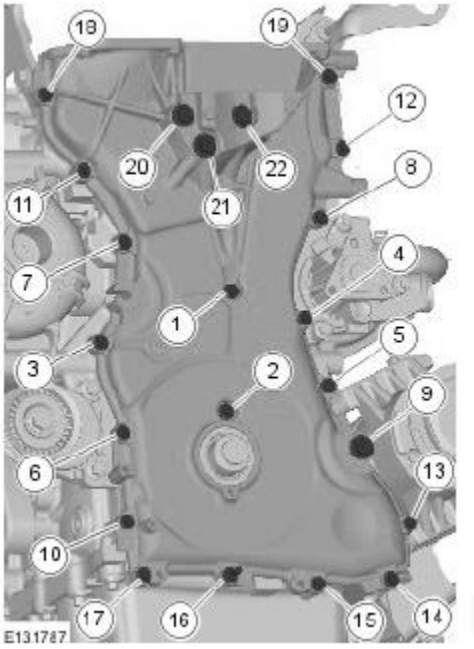
Engine Front Cover - Installation

.NOTE: If not secured within 4 minutes, the sealant must be removed and the sealing area re-cleaned as before. Refer to previous CAUTION & WARNING.

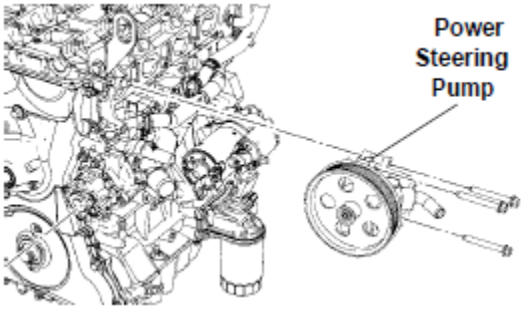
1. Apply a 3 mm (0.1 in) bead of silicone gasket and sealant to the cylinder head and oil pan joint areas and also to front cover as shown below.



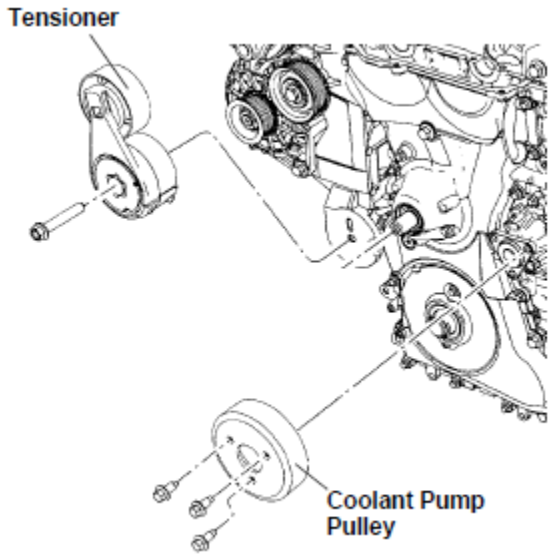
2. Install the front cover and tighten the bolts in the sequence shown to the following specifications:
   - Tighten 8 mm bolts to 10 Nm (89 lb-in)
   - Tighten 10 mm bolts to 25 Nm (18 lb-ft)
   - Tighten 13 mm bolts to 48 Nm (35 lb-ft).



3. Position the power steering pump or upper idler pulley and install the bolts:
   - Tighten to 25 Nm (18 lb-ft).



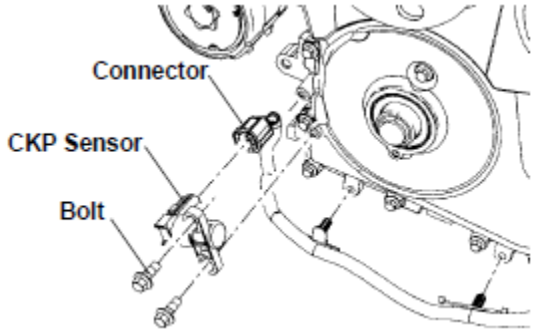
4. Position the coolant pump pulley and install the 3 bolts:
    - Tighten to 25 Nm (18 lb-ft).



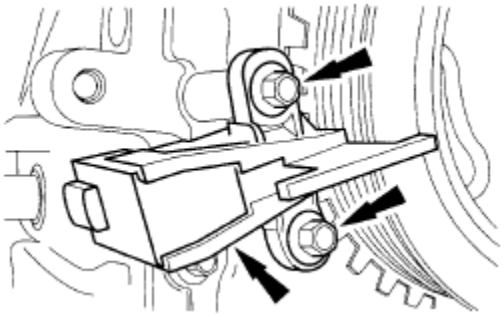
5. Install the accessory drive belt tensioner and the bolt:
    - Tighten to 50 Nm (37 lb-ft).

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

6. Install the crankshaft pulley -- Refer to “Crankshaft Pulley - Installation” on page 8 of this section.
7. Position a new CKP Sensor and loosely install the 2 bolts.



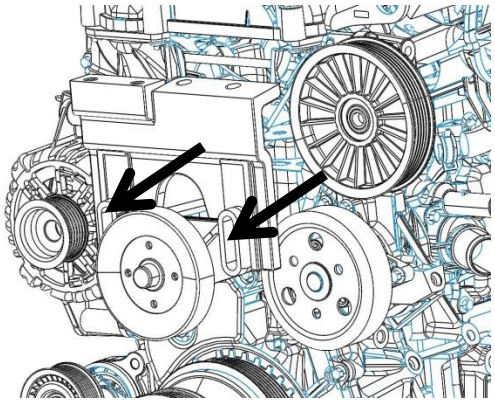
8. Adjust the CKP with the alignment tool supplied with the new sensor; 303-1417. The tool must engage a tooth of the vibration damper. Tighten 2 bolts:
    - Tighten to 7 Nm (62 lb-in).



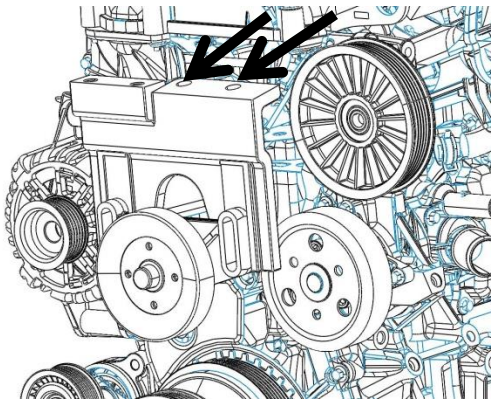
9. Connect CKP Sensor connector.
10. Connect battery negative cable -- refer to Section 6.
11. Install or reconnect any other component removed or disconnected.

Fan Drive Disassembly

1. Loosen bolts of fan bearing bracket so the bracket can slide down and the fan belt can be removed.

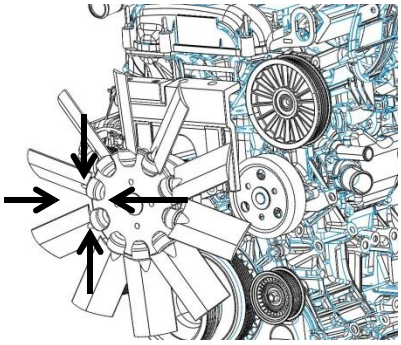


2. Remove bracket to front cover bolts.



3. The fan and brackets can then be removed from the engine and placed to the side.

Note: To remove the bracket from the engine the fan may need to be taken off.

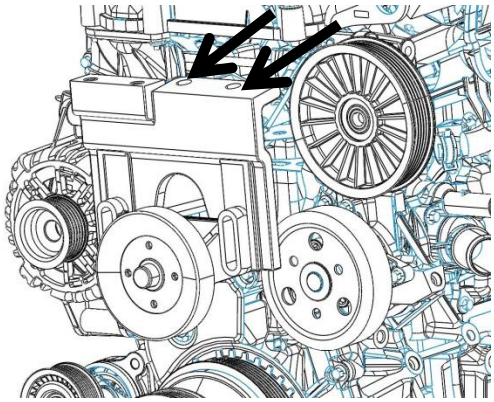


Fan Drive Assembly

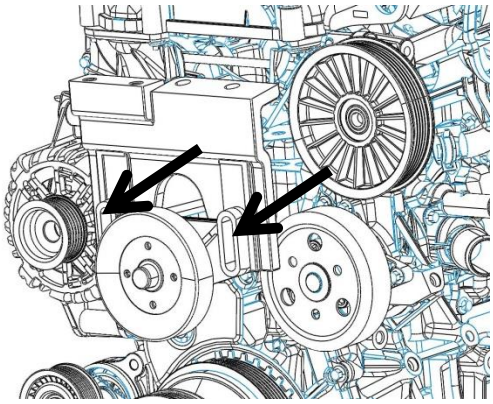
Note: These instructions assume all components of the fan drive assembly are not assembled.

Note: Some of the following steps may have to be done in an alternate order depending on the configuration of the cooling system.

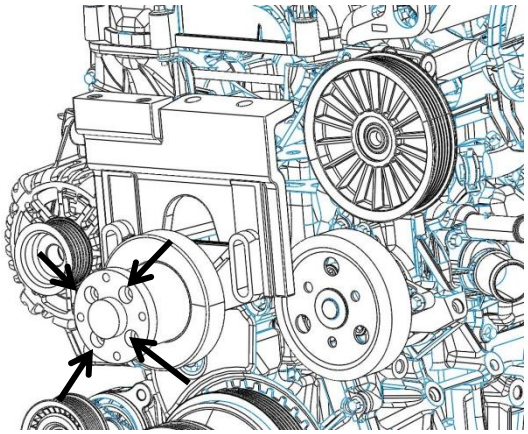
1. Bolt the bracket to the front cover of the engine.
    - Torque bolts: 42 lb-ft (58Nm)



2. Put the bearing bracket in place and thread in the M8x1.5 bolts. Do not tighten.



3. Line up the fan pulley and fan spacer with the four mounting points of the bearing bracket. Insert the M6x1.0 bolts.
    - Torque bolts: 9 lb-ft (12Nm)



4. Install fan onto the end of the fan spacer.
    - Torque bolts: 20 lb-ft (28Nm)

5. Place fan belt around fan pulley and crank extension pulley (fan drive pulley)

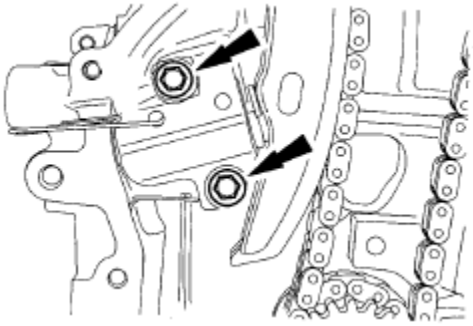
6. Evenly slide the bearing bracket up to tension the fan belt. With the belt tensioned tighten the bearing bracket bolts 20 lb-ft (28Nm).

Note: The fan belt should have some deflection in it when pressure is applied from the side. Using a belt tensioner gauge a reading of 50 – 60 lbs is recommended.

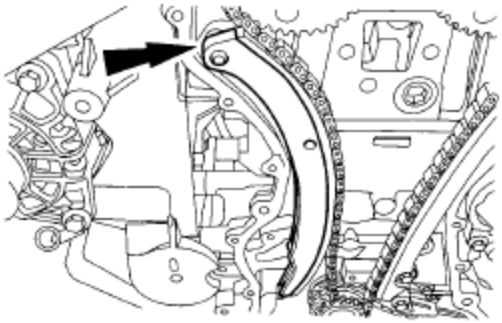
Timing Drive Components - Removal

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

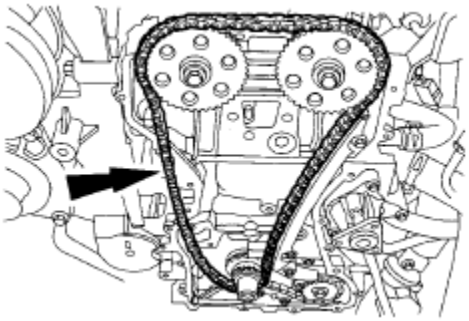
1. Remove and/or disconnect components to allow access and removal of the timing drive components. Label if necessary to allow for correct reinstallation.
2. Remove the engine front cover -- Refer to "Engine Front Cover - Removal" on page 11 of this section.
3. Compress the timing chain tensioner, and insert a paper clip into the hole. Remove the 2 bolts and the timing chain tensioner.



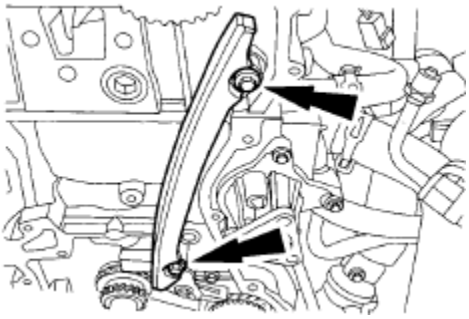
4. Remove the right timing chain guide.



5. Remove the timing chain.

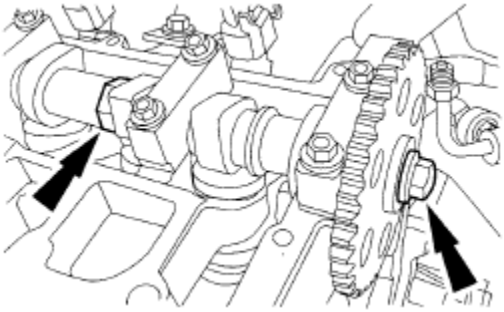


6. Remove the 2 bolts and left timing chain guide.



CAUTION: Do not rely on the Camshaft Alignment Plate to prevent camshaft rotation. Damage to the tool or the camshaft can occur.

7. If necessary, remove the bolts and the camshaft sprockets.



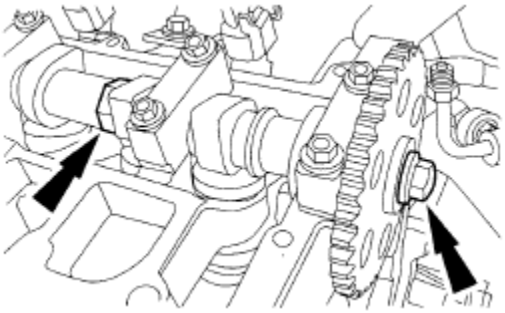
NOTE: Use the flats on the camshaft to prevent camshaft rotation.

Timing Drive Components - Installation

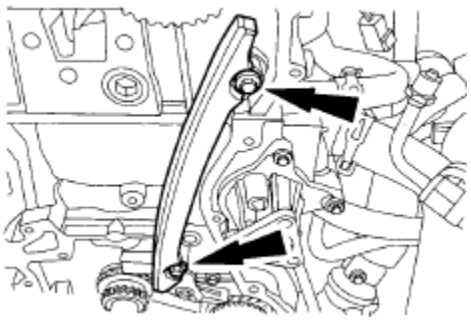
CAUTION: Do not rotate the camshafts. Damage to the valves and pistons can occur.

CAUTION: Do not rely on the Camshaft Alignment Plate to prevent camshaft rotation. Damage to the tool or the camshaft can occur.

NOTE: If the camshaft sprockets were not removed, use the flats on the camshafts to prevent camshaft rotation and loosen the sprocket bolts.

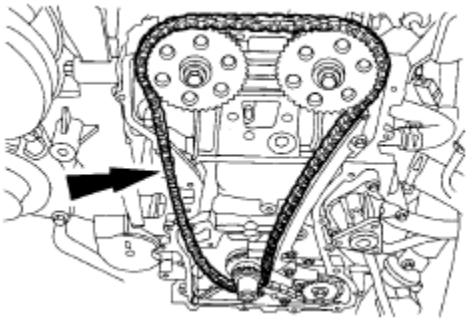


1. If removed, install the camshaft sprockets and the bolts finger tight.
2. Install the left timing chain guide and 2 bolts:

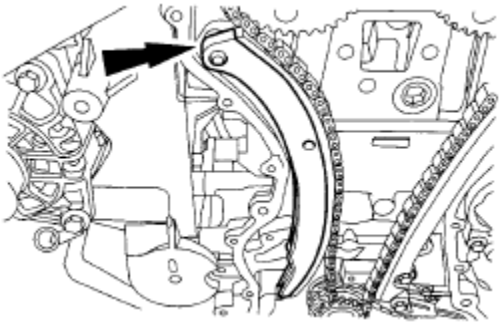


- Tighten to 10 Nm (89 lb-in).

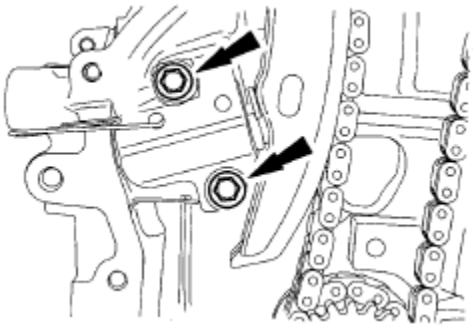
3. Install the timing chain.



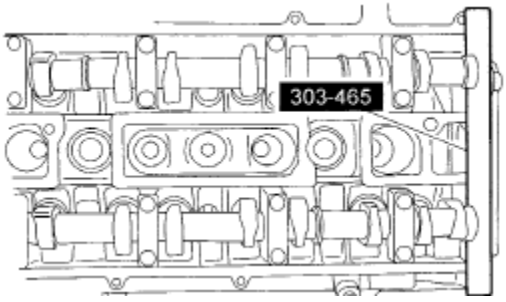
4. Install the right timing chain guide.



5. Position the timing chain tensioner and install the 2 bolts:
   - Tighten to 10 Nm (89 lb-in).
   - Remove the paper clip to release the piston.

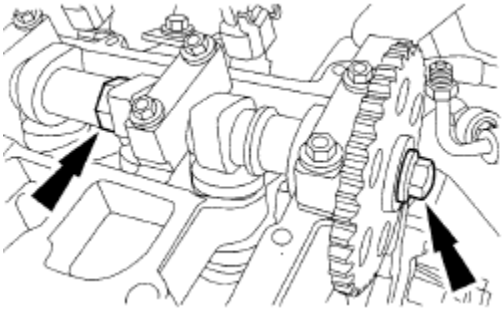


6. Install special tool 303-465.



CAUTION: Do not rely on the Camshaft Alignment Plate to prevent camshaft rotation. Damage to the tool or the camshaft can occur.

7. Using the flats on the camshaft to prevent camshaft rotation, tighten the sprocket bolts:
   - Tighten to 65 Nm (48 lb-ft).



8. Install the front cover -- Refer to “Engine Front Cover - Installation” on page 12 of this section.
9. Install or reconnect any other component removed or disconnected.

Valve Spring - Removal

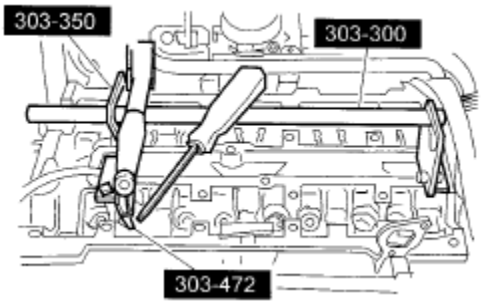
CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

1. Remove the valve tappets -- Refer to “Valve Tappet - Replacement” on page 18 of this section.

WARNING: ALWAYS WEAR PROTECTIVE GOGGLES WHEN WORKING WITH COMPRESSED AIR. THIS CAN PREVENT INJURY. FAILURE TO FOLLOW THESE INSTRUCTIONS CAN RESULT IN PERSONAL INJURY.

CAUTION: Use compressed air at 7-10 bars (100-150 psi). Do not disconnect the compressed air from the cylinder until the valve spring, valve retainer and valve spring retainer keys are installed.

1. Remove spark plug of the cylinder being serviced.
2. Using special tools, apply compressed air to the cylinder of the valve spring being removed.
3. Using special tools 303-350, 303-300 and 303-472, compress valve spring and remove the retainer keys using some grease and a small screwdriver.



4. Remove the valve spring retainer and valve spring.

NOTE: Place all parts in order to one side.

CAUTION: Keep air pressure in cylinder until valve spring is reinstalled.

Valve Spring - Installation

CAUTION: Check that there is no dirt or particles within the valve stem grooves. Check the seating of the valve collets.

1. Install the valve spring and retainer.
2. Using special tools, compress valve spring and install the valve retainer keys.
3. Release spring and check that keys are seated properly.
4. Remove air supply and all special tools.
5. Install the valve tappets -- Refer to “Valve Tappet - Replacement” on page 18 of this section
6. Install spark plug:
    - Tighten to 15 Nm (11 lb-ft).

Valve Seal - Removal

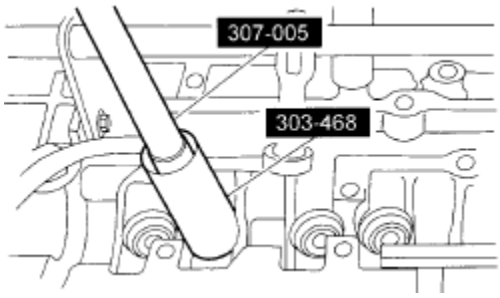
CAUTION: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning a gasket surface that enters the oil passages, coolant passages or the oil pan can cause engine failure.

1. Remove camshafts -- Refer to “Camshafts - Removal” on page 18 of this section.

CAUTION: If the camshafts and valve tappets are to be reused, mark the location of the valve tappets to make sure they are assembled in their original positions.

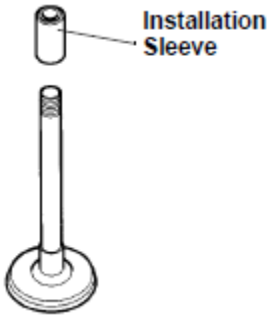
NOTE: The number on the valve tappets only reflects the digits that follow the decimal. For example, a tappet with the number 0.650 has the thickness of 3.650 mm.

2. Remove the valve tappets -- Refer to “Valve Tappet - Replacement” on page 18 of this section.
3. Remove valve spring assembly -- Refer to “Valve Spring - Removal” on page 16 of this section.
4. Using special tools 307-005 and 303-468, remove and discard the valve seal.

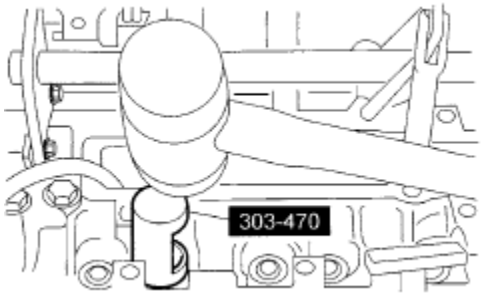


Valve Seal - Installation

1. Install the valve stem seal installation sleeve.



2. Using special tool 303-470, install a new valve seal.



3. Install valve spring -- Refer to “Valve Spring - Installation” on page 16 of this section.
4. Install tappets -- Refer to “Valve Tappet - Replacement” on page 18 of this section.

CAUTION: If reusing tappets, install in original locations.

5. Install camshafts -- Refer to “Camshafts - Installation” on page 18 of this section.
6. Repeat for each cylinder being serviced.

Valve Tappet - Replacement

CAUTION: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning a gasket surface that enters the oil passages, coolant passages or the oil pan can cause engine failure.

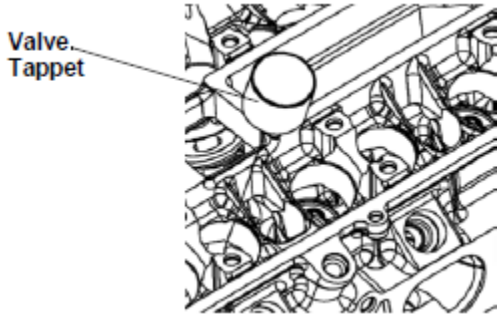
NOTE: Valve tappets are select fit and the valve clearance must be checked before removing the tappets -- Refer to “Valve Clearance Check” on page 45 of this section.

1. Remove camshafts -- Refer to “Camshafts - Removal” on page 18 of this section.

CAUTION: If the camshafts and valve tappets are to be reused, mark the location of the valve tappets to make sure they are assembled in their original positions.

NOTE: The number on the valve tappets only reflects the digits that follow the decimal. For example, a tappet with the number 0.650 has the thickness of 3.650 mm.

2. Remove and inspect valve tappets.
3. Reverse procedure to install.



NOTE: Coat valve tappets with clean engine oil prior to installation.

Camshafts – Removal

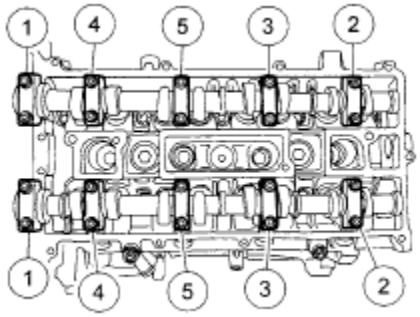
CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

1. Remove and/or disconnect components to allow access and removal of the timing drive components. Label if necessary to allow for correct reinstallation.
2. Remove timing chain and sprockets – Refer to “Timing Drive Components - Removal” on page 14 of this section.

CAUTION: Failure to follow the camshaft loosening procedure can result in damage to the camshafts.

NOTE: Note the position of the lobes on the No. 1 cylinder before removing the camshafts for assembly reference.

3. Loosen the camshaft bearing cap bolts, in sequence shown, one turn at a time.



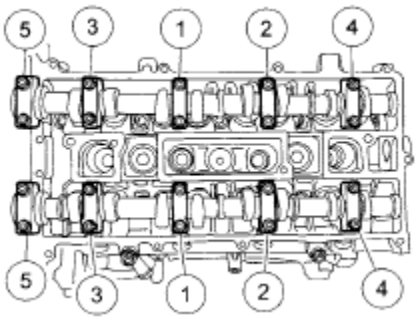
4. Repeat until all tension is released from the camshaft bearing caps.
5. Remove bearing caps and camshafts.

Camshafts – Installation

CAUTION: Install the camshafts with the alignment slots in the camshafts lined up so the camshaft alignment plate can be installed without rotating the camshafts. Make sure the lobes on the No. 1 cylinder are in the same position as noted in the removal procedure. Rotating the camshafts when the timing chain is removed, or installing the camshafts 180 degrees out of position, can cause severe damage to the valves and pistons.

NOTE: Lubricate the camshaft journals and bearing caps with clean engine oil prior to installation.

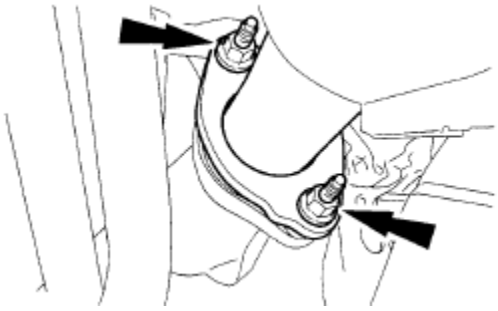
1. Install the camshafts and bearing caps. Tighten bolts in the sequence shown in 3 stages:
   - Stage 1: Tighten one turn at a time until tight
   - Stage 2: Tighten bolts to 7 Nm (62 lb-in)
   - Stage 3: Tighten bolts to 16 Nm (12 lb-ft).



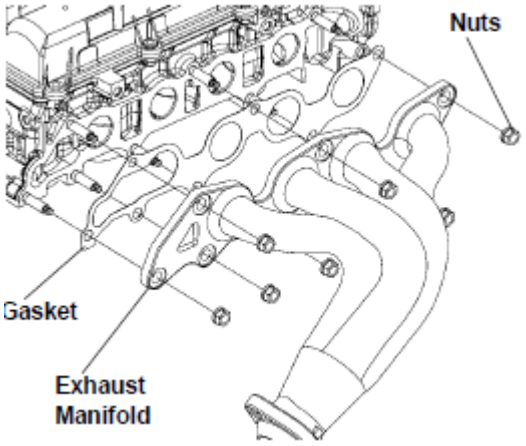
2. Install timing chain and sprockets -- Refer to “Timing Drive Components - Installation” on page 15 of this section.
3. Install or reconnect any other components removed or disconnected.

Exhaust Manifold - Removal

1. Disconnect negative battery cable -- refer to Section 6.
2. Remove and/or disconnect components to allow access and removal of the exhaust manifold. Label if necessary to allow for correct reinstallation.
3. Remove accessory drive belt -- refer to Section 6.
4. Drain the engine cooling system -- refer to Section 5.
5. Disconnect exhaust pipe from manifold.



6. Remove oil level indicator -- Refer to “Oil Level Indicator & Tube - Replacement” on page 24 of this section.
7. Remove generator support bracket -- refer to Section 6
8. Remove nuts, exhaust manifold and gasket (discard nuts and gasket)



9. Remove and discard exhaust manifold studs.
10. Inspect manifold for flatness -- refer to Section 1.

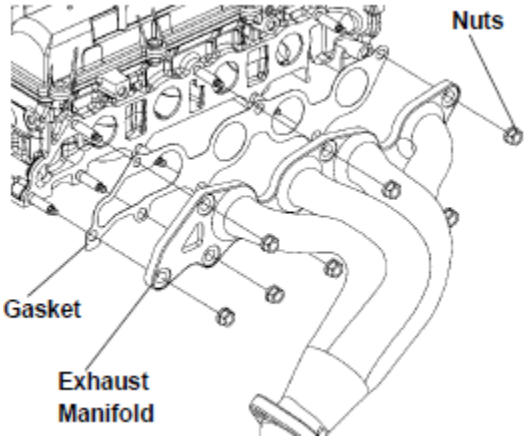
CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

11. Clean the sealing surface with silicone gasket remover and metal surface prep.

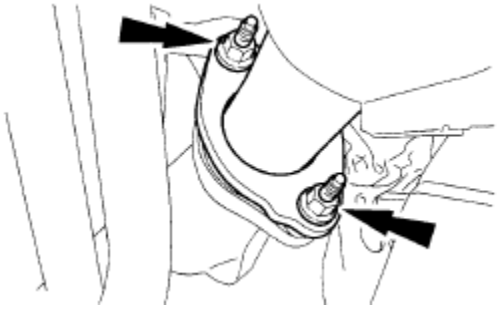
WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

Exhaust Manifold - Installation

1. Install new studs:
    - Tighten to 17 Nm (13 lb-ft).
2. Install new gasket.
3. Position exhaust manifold and install nuts:
    - Tighten to 54 Nm (40 lb-ft)



4. Install generator support bracket -- refer to Section 6.
5. Install oil level indicator -- Refer to“Oil Level Indicator & Tube - Replacement” on page 24 of this section.
6. Install exhaust pipe to manifold.



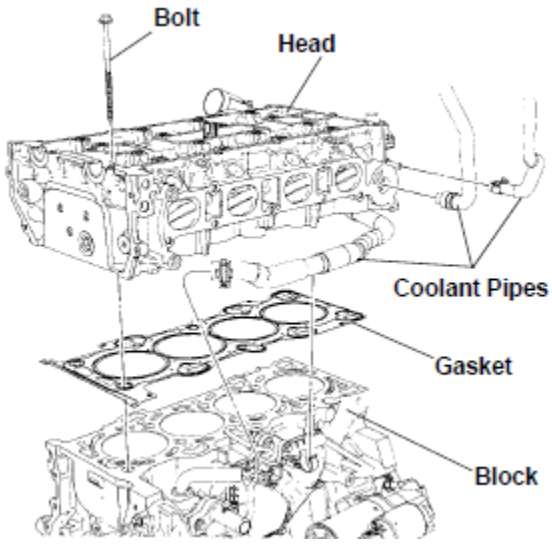
7. Install accessory drive belt -- refer to Section 6.
8. Connect battery negative cable -- refer to Section 6.
9. Install or reconnect any other components removed or disconnected.

Cylinder Head - Removal

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

1. Disconnect negative battery cable -- refer to Section 6.
2. Remove and/or disconnect components to allow access and removal of the cylinder head. Label if necessary to allow for correct reinstallation.
3. Remove camshaft cover -- Refer to “Camshaft Cove - Removal” on page 6 of this section.
4. Remove the camshafts -- Refer to “Camshafts - Removal” on page 18 of this section.
5. Remove exhaust manifold -- Refer to “Exhaust Manifold - Removal” on page 19 of this section.
6. Remove fuel rail -- refer to Section 4.

7. Remove and discard cylinder head bolts.



8. Remove and discard gasket.

9. Inspect mating surfaces -- refer to Section 1.

Cylinder Head - Installation

CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old head gasket.

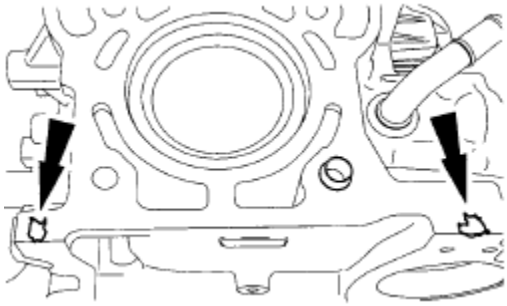
1. Clean the mating surface of cylinder head and block, with silicone gasket remover and metal surface prep. Remove all traces of gasket, sealant, oil and coolant.

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

CAUTION: Failure to follow this procedure can cause future oil leakage.

NOTE: Do not attempt to make the metal shiny. Some staining of the metal surfaces is normal.

2. Apply silicone gasket and sealant to the locations shown.



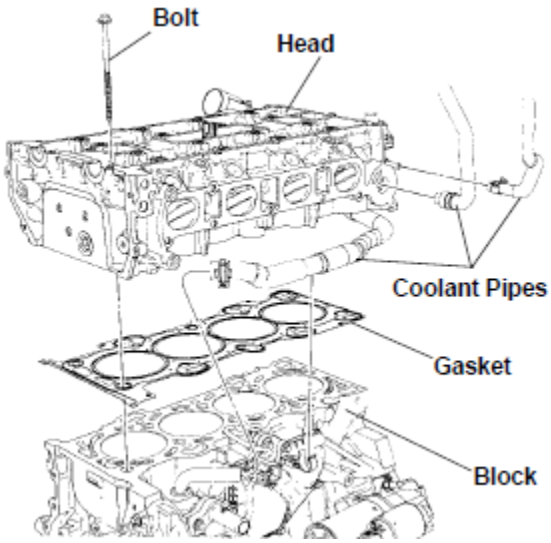
NOTE: If not secured within 4 minutes, the sealant must be removed and the sealing area recleaned as before. Refer to previous CAUTION & WARNING.

3. Install a new cylinder head gasket.

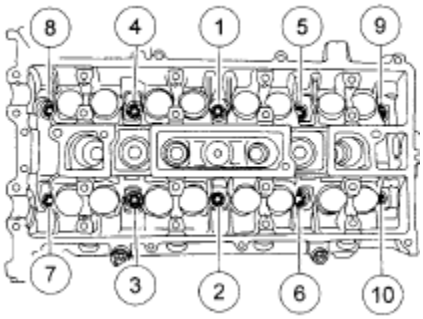
4. Lubricate new cylinder head bolts with clean engine oil.

CAUTION: Cylinder head bolts are torque-to-yield and must not be reused. New bolts must be installed.

5. Install cylinder head carefully.



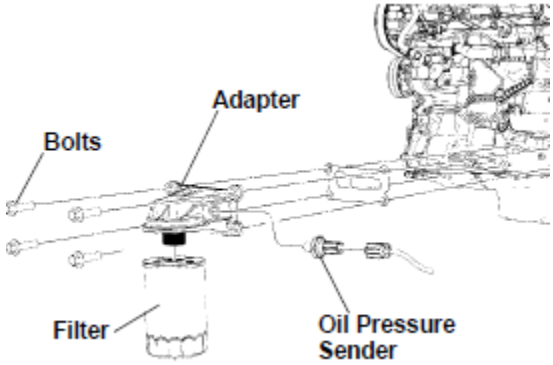
6. Tighten bolts in sequence shown in 5 stages:
    - Stage 1: Tighten to 5 Nm (44 lb-in)
    - Stage 2: Tighten to 15 Nm (11 lb-ft)
    - Stage 3: Tighten to 45 Nm (33 lb-ft)
    - Stage 4: Tighten an additional 90 degrees
    - Stage 5: Tighten an additional 90 degrees.



7. Install fuel rail -- refer to Section 4.
8. Install exhaust manifold -- Refer to “Exhaust Manifold - Installation” on page 19 of this section.
9. Install camshafts -- Refer to “Camshafts - Installation” on page 18 of this section.
10. Install camshaft cover -- Refer to “Camshaft Cover - Installation” on page 7 of this section.
11. Install or reconnect any other component that was removed or disconnected.
12. Reconnect negative battery cable -- refer to Section 6.

Oil Filter Adapter - Removal

1. Disconnect negative battery cable -- refer to Section 6.
2. Remove and/or disconnect components to allow access and removal of the oil filter adapter. Label if necessary to allow for correct reinstallation.
3. Drain the engine oil.
4. Disconnect the oil pressure sender connector.
5. Remove the oil pressure sender -- Refer to “Oil Pressure Sender - Replacement” on page 23 of this section.



6. Remove and discard the oil filter.
7. Remove 4 bolts and oil filter adapter.
8. Remove and discard the gasket.

Oil Filter Adapter - Installation

CAUTION: Do not use metal scrapers, wire brushes power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

1. Clean the mating surface of adapter and block, with silicone gasket remover and metal surface prep.

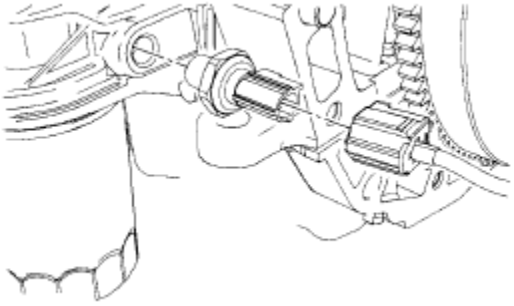
WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OFTHE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

2. Using a new gasket, install the oil filter adapter and 4 bolts:
    - Tighten to 25 Nm (18 lb-ft).
3. Install a new oil filter.
4. Apply thread sealant with PTFE to the oil pressure sender threads and install the sender:

5. Tighten to 15 Nm (11 lb-ft).
6. Connect oil pressure sender connector.
7. Fill the engine with clean engine oil.
8. Run the engine and check for leaks.
9. Install or reconnect any other component that was removed or disconnected.

Oil Pressure Sender – Replacement

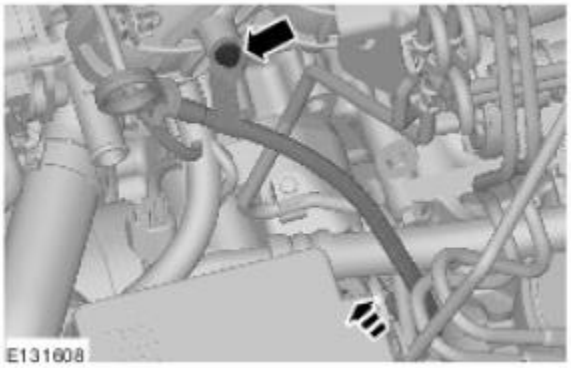
1. Disconnect negative battery cable -- refer to Section 6.
2. Remove and/or disconnect components to allow access and removal of the oil pressure sender. Label if necessary to allow for correct reinstallation.
3. Disconnect the oil pressure sender connector.
4. Remove the oil pressure sender.



5. Apply thread sealant with PTFE to the oil pressure sender threads and install the sender:
6. Tighten to 15 Nm (11 lb-ft).
7. Connect oil pressure sender connector.

Oil Level Indicator & Tube - Replacement

1. Remove and/or disconnect components to allow access and removal of the oil level indicator & tube. Label if necessary to allow for correct reinstallation.
2. Remove the oil level indicator.



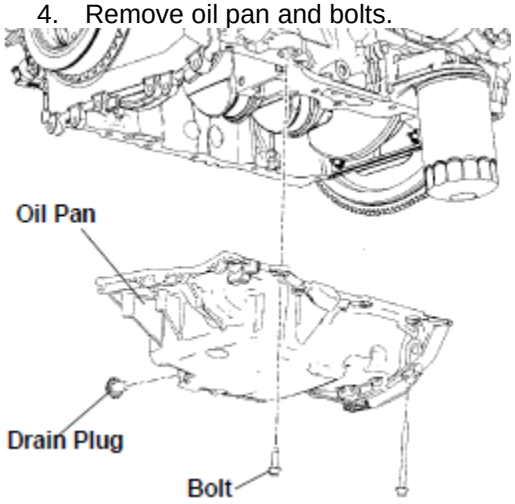
3. Remove the 2 bolts and tube.
4. Remove and discard the o-ring.
5. Reverse procedure to install:
   - Install a new o-ring
   - Apply clean engine oil to o-ring
   - Tighten bolts to 10 Nm (89 lb-in).

Oil Pan - Removal

CAUTION: Failure to follow this procedure can cause future oil leakage.

1. Remove and/or disconnect components to allow access and removal of the oil pan. Label if necessary to allow for correct reinstallation.
2. Drain the engine oil.
3. Remove oil level indicator & tube -- Refer to “Oil Level Indicator & Tube - Replacement” on page 24 of this section.

4. Remove oil pan and bolts.



CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

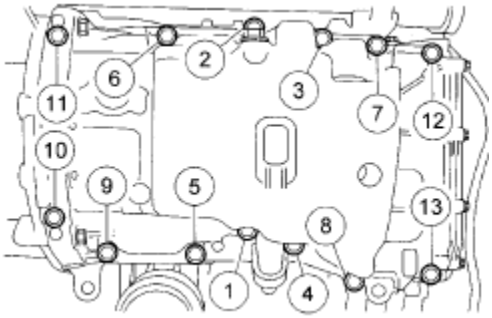
5. Clean the mating surface of oil pan and block, with silicone gasket remover and metal surface prep.

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

Oil Pan - Installation

NOTE: If not secured within 4 minutes, the sealant must be removed and the sealing area re-cleaned as before. Refer to previous CAUTION & WARNING.

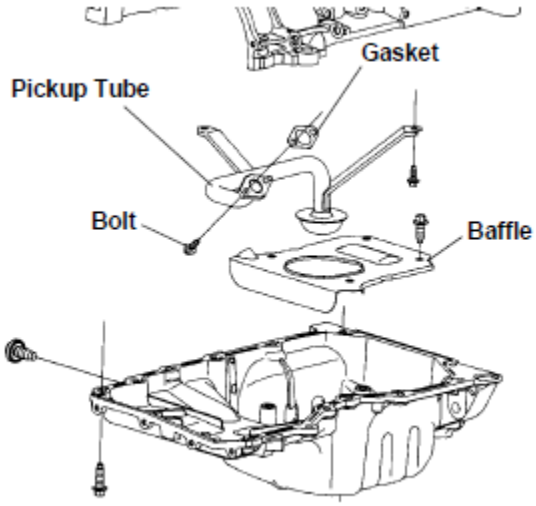
1. Apply a 2.5 mm (0.1 in) bead of silicone gasket and sealant to the oil pan. Install the oil pan and bolts in sequence shown:
   - Tighten to 25 Nm (18 lb-ft).



2. Install oil level indicator and tube -- Refer to “Oil Level Indicator & Tube - Replacement” on page 24 of this section.
3. Install drain plug:
   - Tighten to 28 Nm (21 lb-ft).
4. Fill engine with clean engine oil.
5. Install or reconnect any other component that was removed or disconnected.

Oil Pickup Tube – Replacement

1. Remove the oil pan -- Refer to “Oil Pan - Removal” on page 24 of this section.
2. Remove bolts and oil pickup tube.



3. Remove gasket and discard.

4. Clean the sealing surface with metal surface prep.

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

5. Reverse procedure to install:
   - Use a new gasket
   - Tighten bolts to 10 Nm (89 lb-in).

Oil Pump - Removal

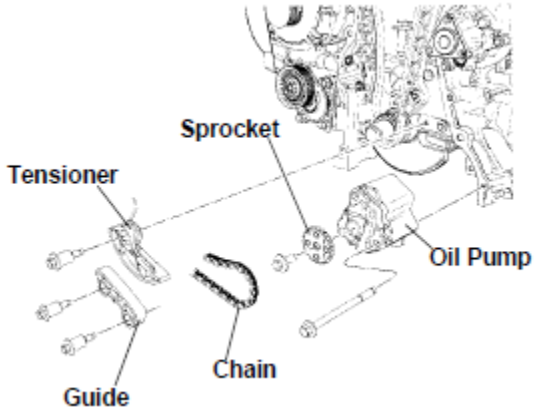
1. Remove and/or disconnect components to allow access and removal of the oil pump. Label if necessary to allow for correct reinstallation.

2. Remove engine front cover -- Refer to “Engine Front Cover - Removal” on page 11 of this section.

3. Remove oil pan -- Refer to “Oil Pan - Removal” on page 24 of this section.

4. Remove oil pickup tube -- Refer to “Oil Pickup Tube - Replacement” on page 25 of this section.

5. Release the tension on the tensioner spring and remove the bolt and tensioner



6. Remove 2 bolts and oil pump chain guide.

7. Remove oil pump chain.

8. Remove bolt and oil pump sprocket.

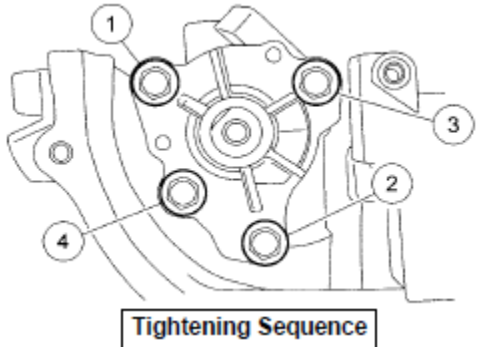
9. Remove 4 bolts and oil pump.

Oil Pump - Installation

1. Clean the oil pump and block mating surface with metal surface prep.

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

2. Install oil pump and 4 bolts in sequence shown in 2 stages:
   - Stage 1: Tighten to 10 Nm (89 lb-in)
   - Stage 2: Tighten to 20 Nm (15 lb-ft).



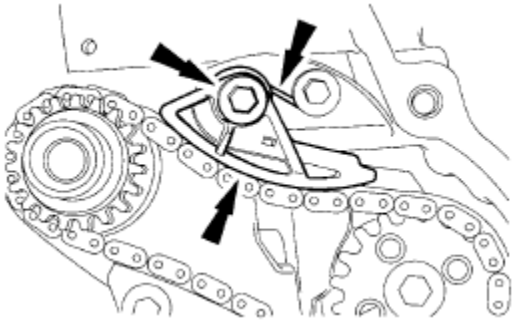
Tightening Sequence

3. Install sprocket and bolt:
   - Tighten to 25 Nm (18 lb-ft).

4. Install the chain onto the sprockets.

5. Install guide and 2 bolts:
   - Tighten to 10 Nm (89 lb-in)

6. Install tensioner and bolt:
   - Hook tensioner spring around the shoulder bolt.
   - Tighten to 10 Nm (89 lb-in).



7. Install pickup tube -- Refer to “Oil Pickup Tube - Replacement” on page 25 of this section.

8. Install oil pan -- Refer to“Oil Pan - Installation” on page 25 of this section.

9. Install engine front cover -- Refer to “Engine Front Cover - Installation” on page 12 of this section.

10. Install or reconnect any other component that was removed or disconnected.

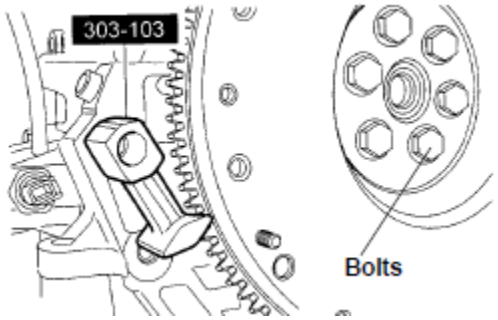
Flywheel/Flexplate – Replacement

1. Remove any components necessary to gain access to the flywheel/flexplate.

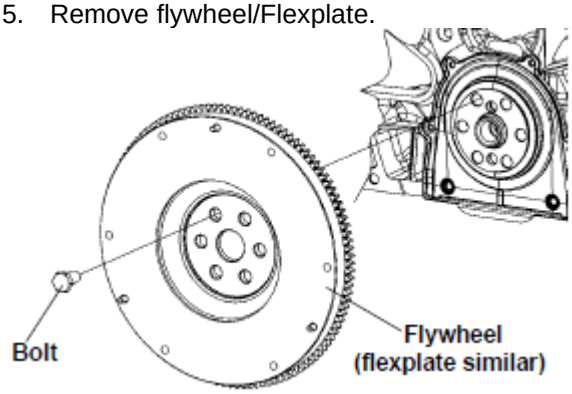
2. Remove the transmission or PTO.

3. Remove the pressure plate and clutch if equipped.

4. Remove bolts using tool 303-103.

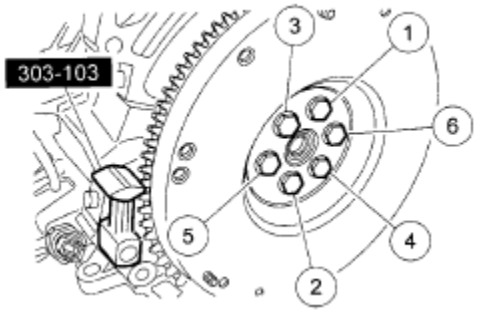


5. Remove flywheel/Flexplate.



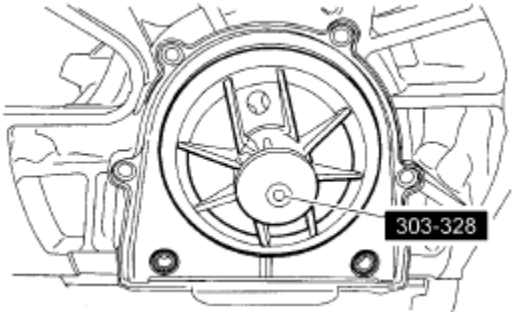
CAUTION: Special bolts are used for installation. Do not use standard bolts.

6. Reverse procedure to install. Tighten bolts in sequence shown in three stages:
   - Stage 1: Tighten to 50 Nm (37 lb-ft)
   - Stage 2: Tighten to 80 Nm (59 lb-ft)
   - Stage 3: Tighten to 112 Nm (83 lb-ft).



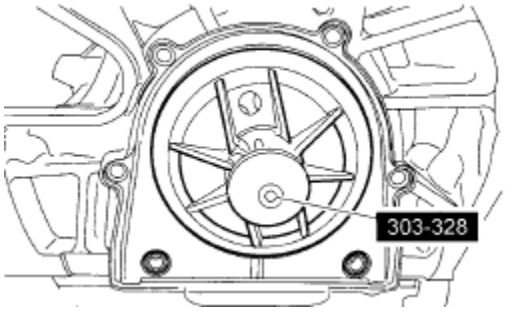
Crankshaft Rear Seal/Retainer – Removal

1. Remove and/or disconnect components to allow access and removal of the rear seal. Label if necessary to allow for correct reinstallation.
2. Remove flywheel or flexplate -- Refer to “Flywheel/ Flexplate - Replacement” on page 27 of this section.
3. Remove oil pan -- Refer to“Oil Pan - Removal” on page 24 of this section.
4. Remove bolts and retainer plate.

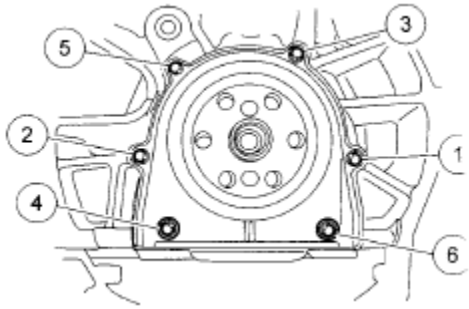


Crankshaft Rear Seal/Retainer – Installation

1. Using special tool 303-328, position rear oil seal with retainer plate onto crankshaft.



2. Install 6 bolts in the sequence shown:
   - Tighten to 10 Nm (89 lb-in).



3. Install oil pan -- Refer to “Oil Pan - Installation” on page 25 of this section.
4. Install flywheel or flexplate -- Refer to “Flywheel/ Flexplate - Replacement” on page 27 of this section.
5. Install or connect any other component removed or disconnected.

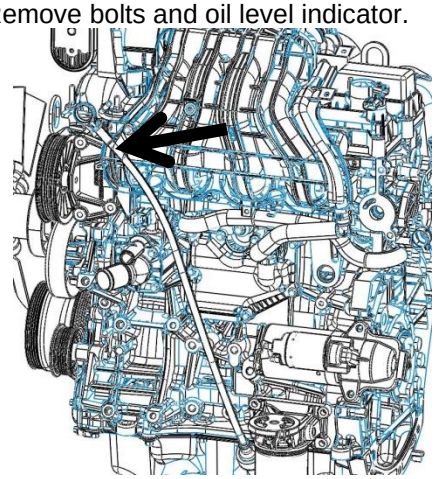
DISASSEMBLY & ASSEMBLY

Engine Disassembly

CAUTION: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces can enter the oil passages, coolant passages or the oil pan, and cause engine failure.

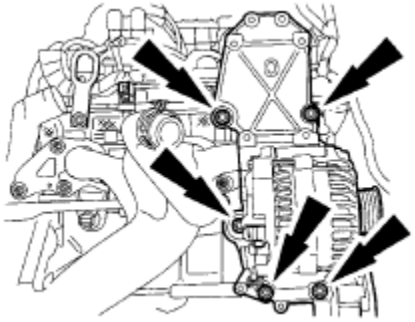
CAUTION: Due to the precision fit and timing of the balancer shaft assembly, it cannot be removed from the engine block.

1. Remove engine from equipment and mount on an engine stand -- Refer to “Flywheel/Flexplate - Replacement” on page 27 of this section.
2. Remove the drive belt.
3. Remove bolts and oil level indicator.

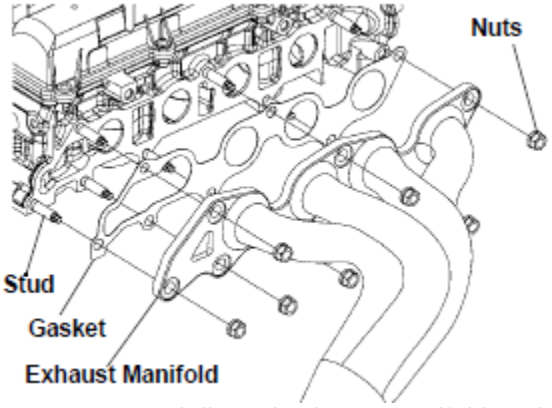


4. Remove all coolant pipes and hoses.
5. Remove A/C compressor (if equipped).

6. Remove generator and bracket assembly.



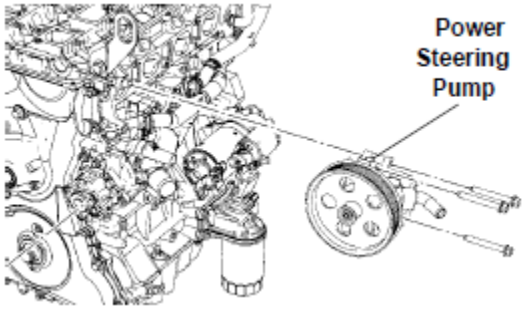
7. Remove nuts and exhaust manifold. Discard nuts.



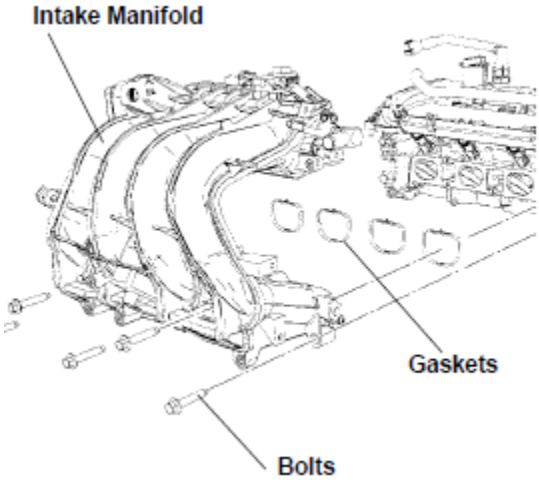
8. Remove and discard exhaust manifold gasket and studs

9. Inspect exhaust manifold for flatness -- refer to Section 1.

10. Remove 4 bolts and power steering pump or upper idler pulley.

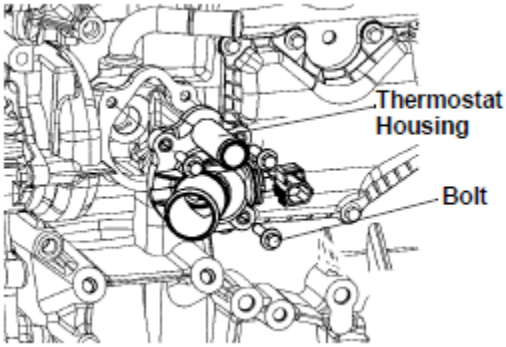


11. Remove 5 bolts and intake manifold.

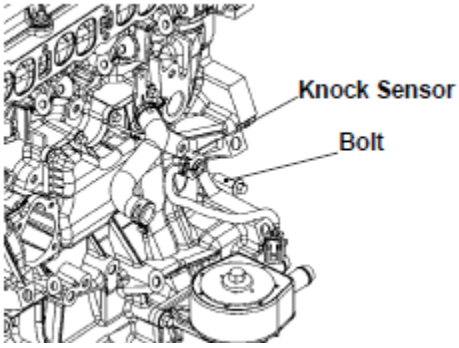


12. Remove ignition coils.

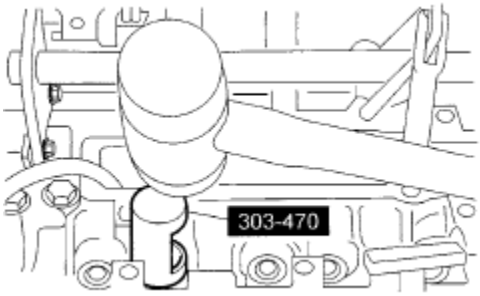
13. Remove 3 bolts and thermostat housing.



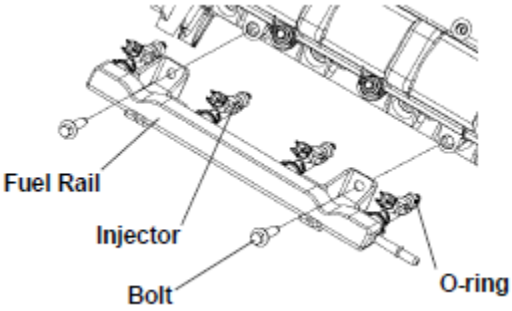
14. Remove knock sensor.



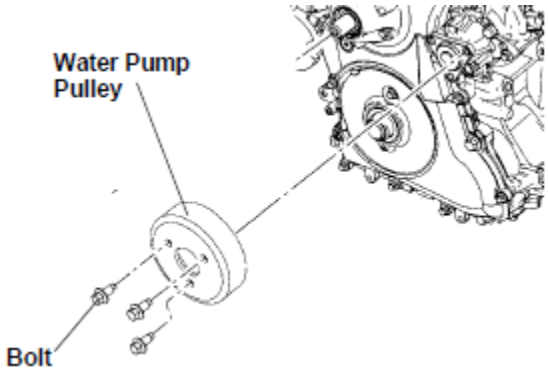
15. Remove engine vent cover.



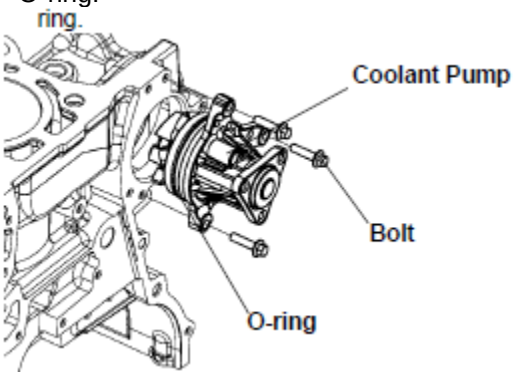
16. Remove fuel rail and injectors. Discard o-rings.



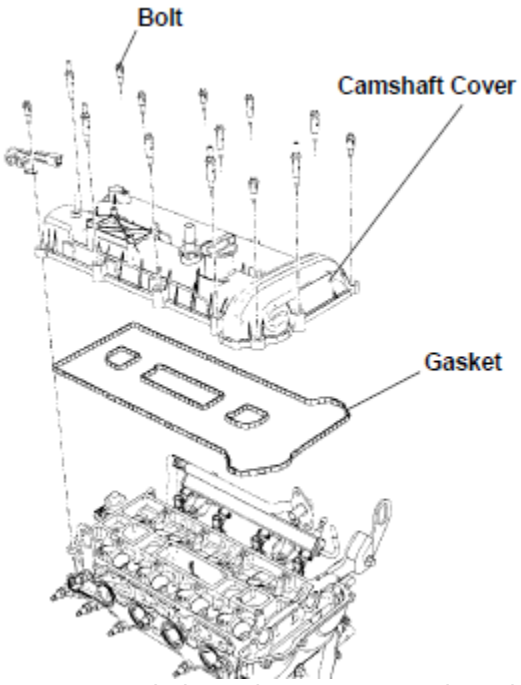
17. Remove 3 bolts and water pump pulley.



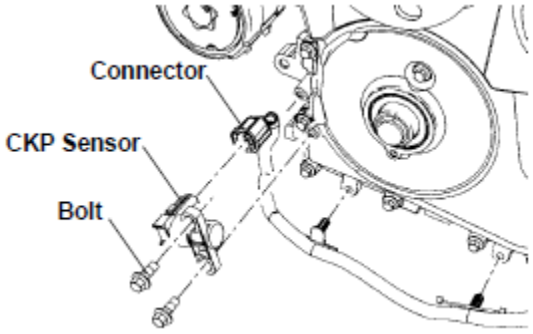
18. Remove 3 bolts and coolant pump. Discard the O-ring.



19. Remove camshaft cover.



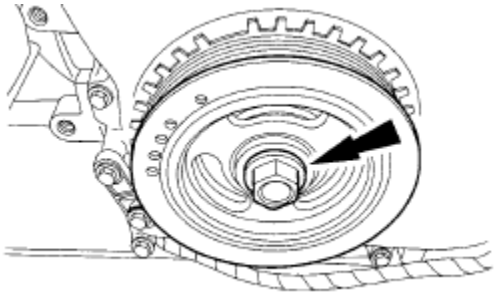
20. Remove 2 bolts and CKP sensor. Discard sensor.



CAUTION: Failure to position the No. 1 piston at top dead center (TDC) can result in damage to the engine. Turn the engine in the normal direction of rotation only.

CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

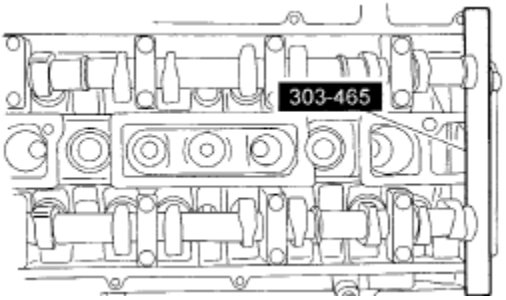
21. Using the crankshaft pulley bolt, turn the crankshaft clockwise to position the No. 1 piston at TDC.



CAUTION: The special tool 303-465 is for camshaft alignment only. Using this tool to prevent engine rotation can result in engine damage.

NOTE: The camshaft timing slots are offset. If the special tool cannot be installed, rotate the crankshaft one complete revolution clockwise to correctly position the camshafts.

22. Install special tool 303-465 in the slots on the rear of both camshafts.



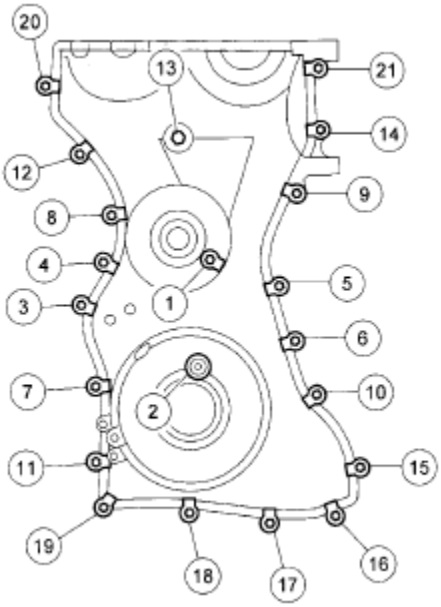
CAUTION: Failure to hold the crankshaft pulley in place during bolt loosening can cause damage to the engine.

23. Using the special tools, remove bolt, washer and crankshaft pulley. Discard the bolt.

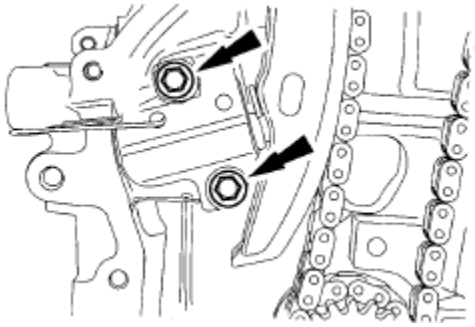
CAUTION: There is one front cover bolt behind the cooling fan drive pulley.

24. Remove bolt behind cooling fan drive pulley through one of access holes.

25. Remove all front cover bolts and front cover.

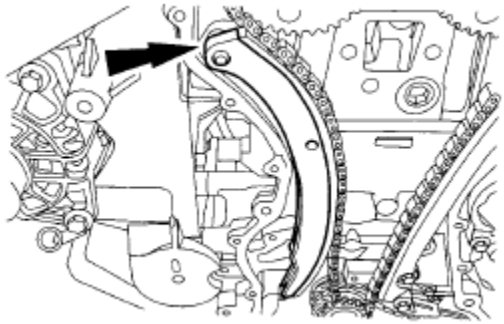


26. Compress the timing chain tensioner and insert a paper clip into the hole.

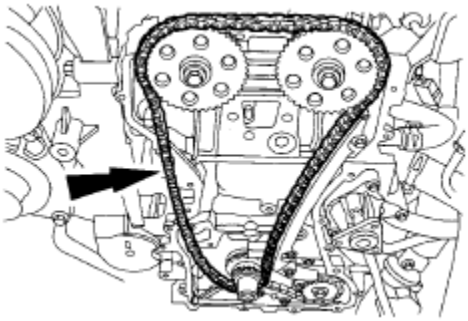


27. Remove 2 bolts and tensioner.

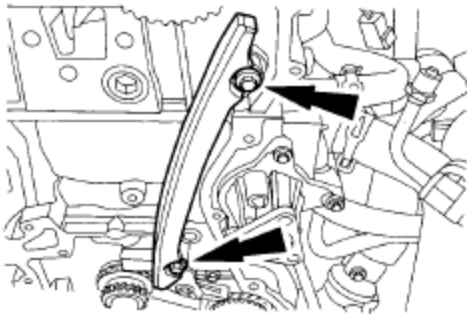
28. Remove right timing chain guide.



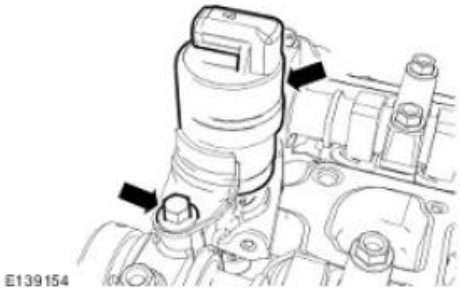
29. Remove timing chain.



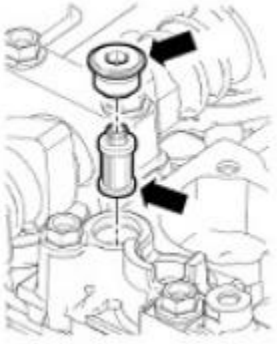
30. Remove 2 bolts and left timing chain guide.



31. Remove the bolt and the VCT solenoid.

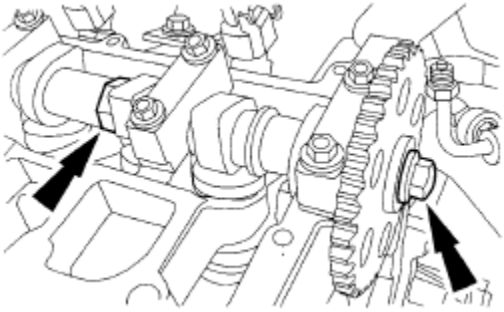


32. Remove the plug and the VCT system oil filter from the intake camshaft thrust cap.

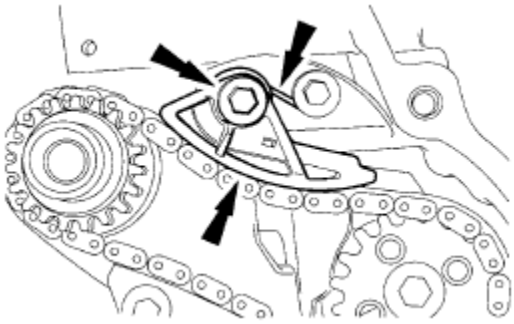


CAUTION: Do not rely on camshaft alignment plate to prevent camshaft rotation. Damage to the tool or the camshaft can occur.

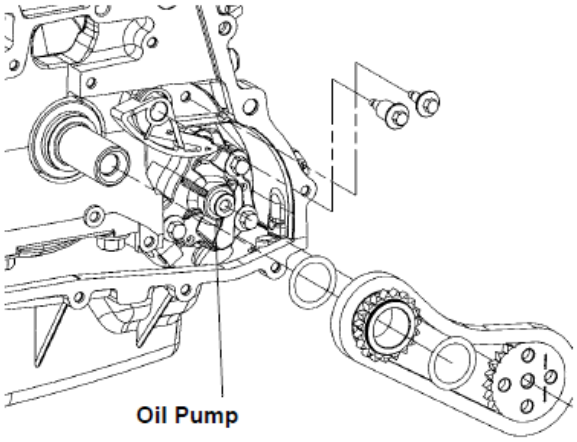
33. Using a wrench on the camshaft flats, remove bolts, washers and sprockets.



34. Release tension on oil pump chain tensioner.



35. Remove the bolt and tensioner.



36. Remove bolts and guide.

37. Holding oil pump sprocket in place, remove bolt, chain, sprockets and diamond washers.

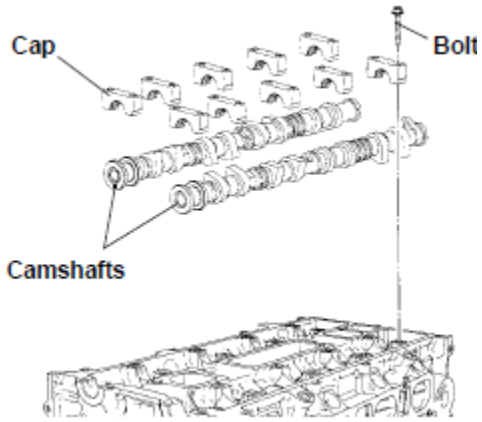
38. Remove special tool 303-465.

CAUTION: Failure to follow the camshaft loosening procedure can result in damage to the camshafts.

NOTE: Note the position of the lobes on the number one cylinder before removing the camshafts for assembly reference.

39. Remove the camshaft bearing caps as follows:
    a. Loosen the camshaft bearing cap bolts in the sequence shown one turn at a time
    b. Repeat until all the tension is released from the camshaft bearing caps.
    c. Remove the bearing caps.

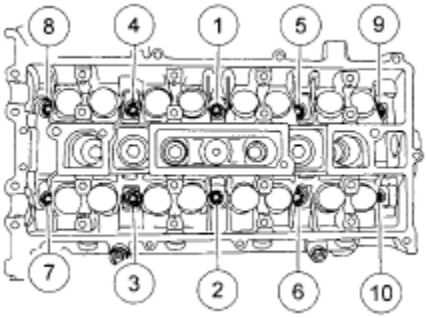
40. Remove the camshafts.



CAUTION: The cylinder head must be cool before removing it from the engine. Cylinder head warpage can result if a warm or hot cylinder head is removed.

CAUTION: The cylinder head bolts must be discarded and new bolts must be installed. They are tighten-to-yield designed and cannot be reused.

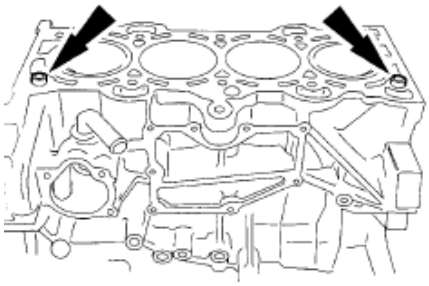
41. Remove and discard cylinder head bolts.



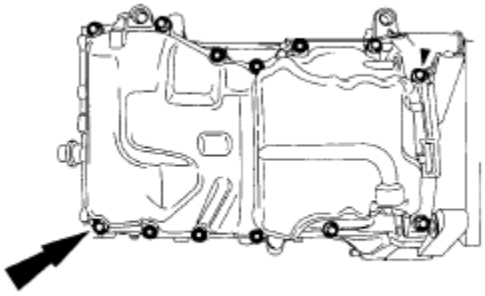
42. Remove cylinder head.

43. Remove and discard the gasket.

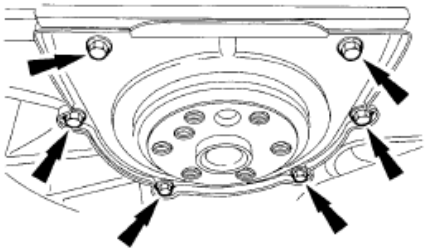
44. Remove the cylinder head alignment dowels.



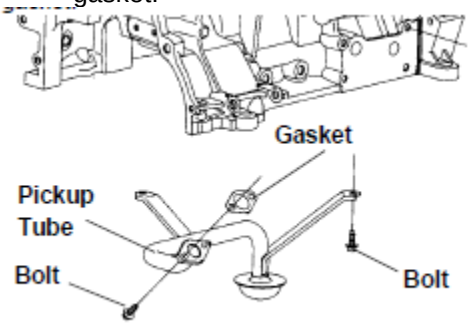
45. Remove bolts and oil pan.



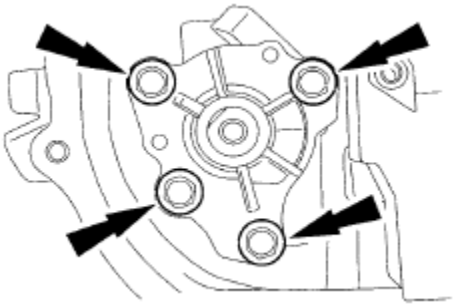
46. Remove bolts and rear seal retainer plate.



47. Remove bolts, oil pump pickup tube and discard gasket.



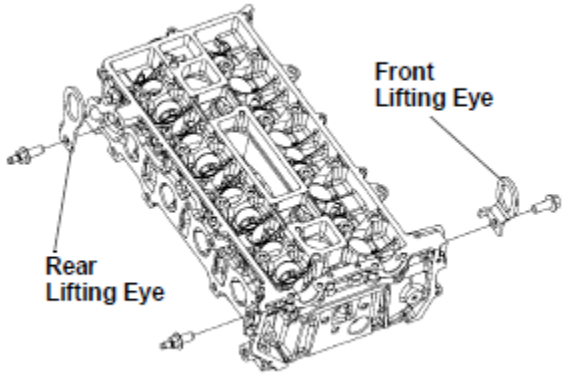
48. Remove 4 bolts and oil pump.



49. Remove and discard oil pump gasket.

Cylinder Head Disassembly

1. Remove rear lifting eye and front bracket.



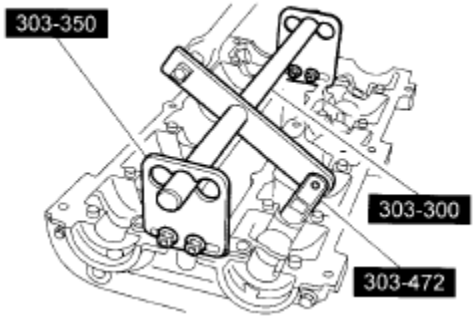
2. Remove coolant outlet pipe.

3. Remove spark plugs and discard.

CAUTION: Note location of the tappets prior to removal.

4. Remove 16 valve tappets.

5. Using special tools 303-350, 303-300 & 303-472, compress valve spring and remove valve spring retainer keys, retainers and springs.



6. Remove all special tools.

CAUTION: Note location of valves if they are to be reused.

7. Remove valves.

8. Using special tools 303-005 and 303-468, remove and discard valve stem seals.

9. Inspect valve, valve springs, retainers and keys -- refer to Section 1.

Engine Cleaning

During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces can enter the oil passages, coolant passages or the oil pan, and cause engine failure.

Place clean shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine.

CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. Use a plastic scraping tool to remove all traces of the gasket material and sealant.

CAUTION: Aluminum surfaces are soft and can be scratched easily. Never place the cylinder head gasket surface, unprotected, on a bench surface.

To clean residual sealant, oil, coolant and gasket material from sealing area, use silicone gasket remover and metal surface prep. A second application may be required if traces of silicone or gasket material remain. Allow to dry until there is no sign of wetness, or 4 minutes, whichever is longer. Failure to follow this procedure can cause future oil leakage.

WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

NOTE: Do not attempt to make metal shiny. Some staining of metal surfaces is normal.

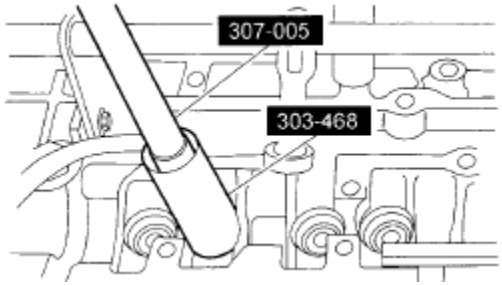
Cylinder Head Assembly

CAUTION: If installing original valves, make sure they are installed in the same position as removed.

1. Coat valve stems and guides with clean engine oil and install into cylinder head.

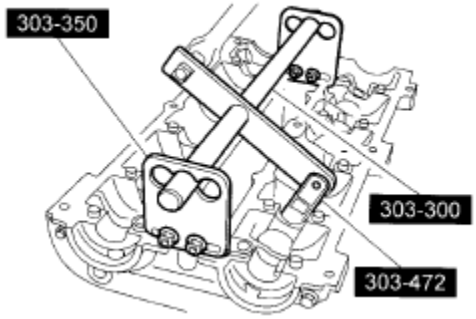
CAUTION: Use protector provided with replacement kit to prevent damage to the valve seals.

2. Using special tool 303-470, install valve seals onto the guides.



3. Position valve springs and retainers.

4. Using special tools 303-350, 303-300 and 303-472, compress valve spring and install retainer keys.



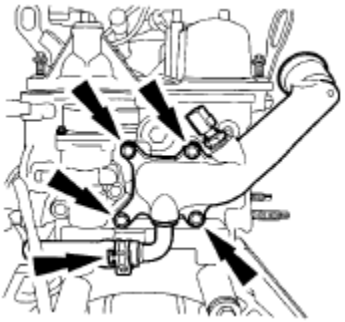
NOTE: Make sure keys are seated properly.

CAUTION: Be sure to install tappets in the same location as removed.

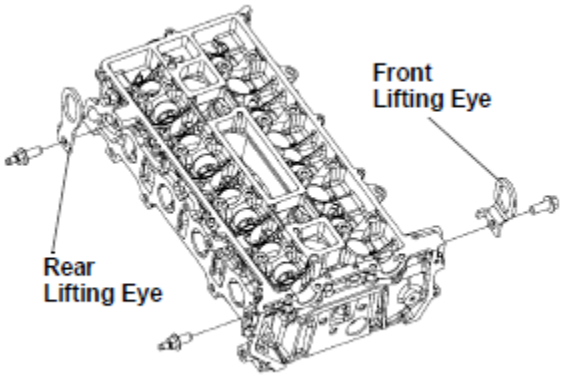
5. Install 16 valve tappets.

6. Install 4 new spark plugs (properly gapped):
   - Tighten to 15 Nm (11 lb-ft).

7. Using a new gasket, install coolant outlet pipe and 4 bolts:
   - Tighten to 10 Nm (89 lb-in).



8. Install rear lifting eye and front lifting eye bracket:
   - Tighten to 45 Nm (33 lb-ft).

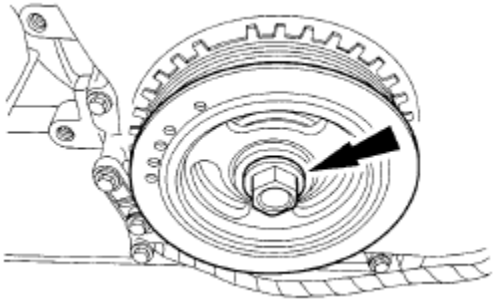


Engine Assembly

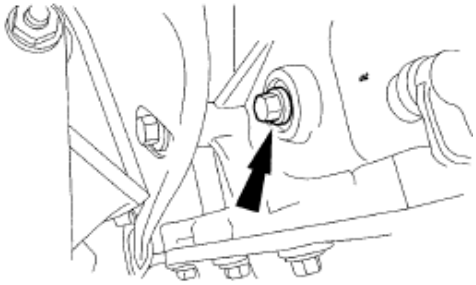
CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. For that reason, the crankshaft sprocket is also unfastened if you loosen the pulley. Therefore, the engine must be retimed each time the damper is removed. Otherwise severe damage can occur.

CAUTION: Failure to position the No. 1 piston at top dead center (TDC) can result in damage to the engine. Turn the engine in the normal direction of rotation only.

1. Using the crankshaft pulley bolt, turn the crankshaft clockwise to position the No. 1 piston on TDC>

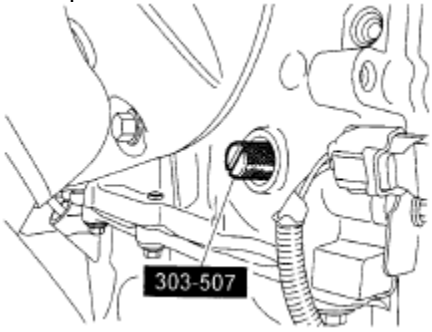


2. Remove plug bolt.

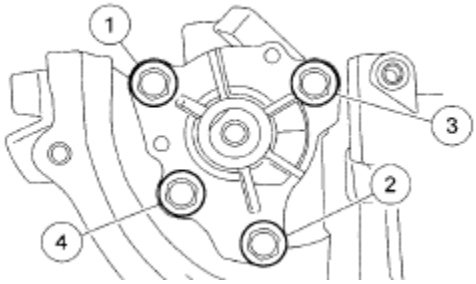


CAUTION: Only turn the engine in the normal direction of rotation. Installing the special tool in this next step will prevent the engine from being rotated in the clockwise direction. However, the engine can still be rotated in the counterclockwise direction.

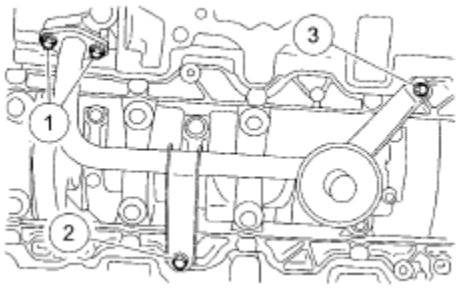
3. Install special tool 303-507.



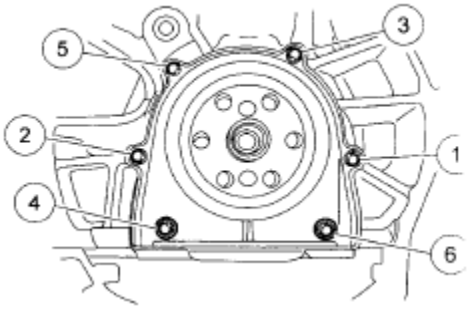
4. Position the oil pump assembly and tighten the bolts in the sequence shown in 2 stages:
   - Stage 1: Tighten to 10 Nm (89 lb-in)
   - Stage 2: Tighten to 20 Nm (15 lb-ft)



5. Position a new oil pump pickup tube gasket and the pickup tube, and tighten 4 bolts in the sequence shown:
   - Tighten to 10 Nm (89 lb-in).

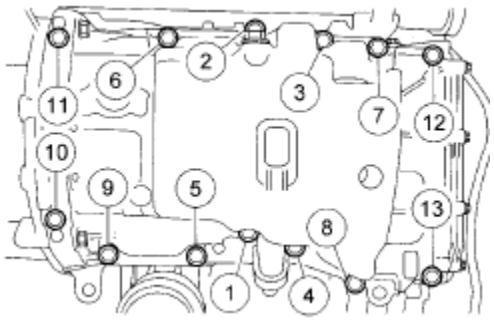


6. Using special tool 303-328, install a new crankshaft rear seal and retainer plate assembly. Tighten bolts in the sequence shown:
   - Tighten to 10 Nm (89 lb-in).

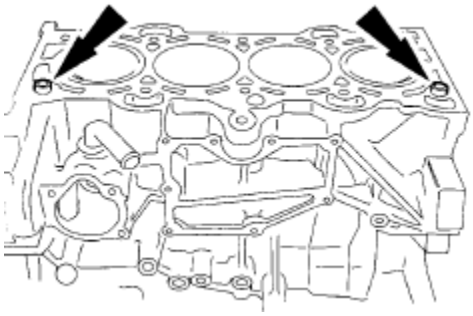


NOTE: If oil pan is not secured within 4 minutes, the sealant must be removed and the sealing area re-cleaned -- Refer to “Engine Cleaning” on page 34 of this section.

7. Apply a 2.5 mm (0.1 in) bead of silicone gasket and sealant to the oil pan. Install the oil pan and bolts. Tighten in the sequence shown:
   - Tighten to 25 Nm (18 lb-ft).



8. Install cylinder head alignment dowels until fully seated in block.



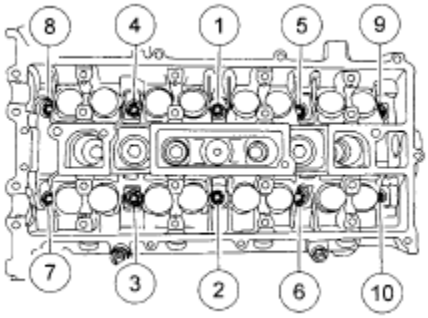
NOTE: If cylinder head is not secured within 4 minutes, the sealant must be removed and the sealing area recleaned -- Refer to “Engine Cleaning” on page 34 of this section.

9. Apply silicone gasket and sealant to the locations shown.

10. Install a new gasket and position cylinder head.

CAUTION: Do not reuse cylinder head bolts.

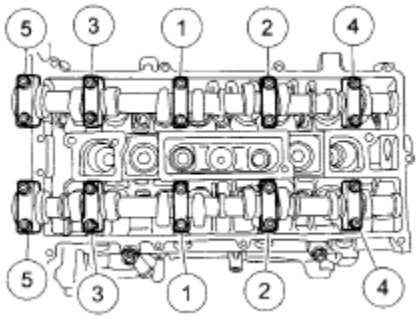
11. Lubricate new bolts and install in the sequence shown in 5 stages:
    - Stage 1: Tighten to 5 Nm (44 lb-in)
    - Stage 2: Tighten to 15 Nm (11 lb-ft)
    - Stage 3: Tighten to 45 Nm (33 lb-ft)
    - Stage 4: Tighten an additional 90 degrees (1/4 turn)
    - Stage 5: Tighten an additional 90 degrees (1/4 turn)



CAUTION: Install the camshafts with alignment slots in the camshaft lined up so the camshaft alignment plate can be installed without rotating the camshafts. Make sure the lobes on the No.1 cylinder are in the same position as noted in the disassembly procedure. Rotating the camshafts or installing the camshafts 180 degrees out of position can cause severe damage to the valves and pistons.

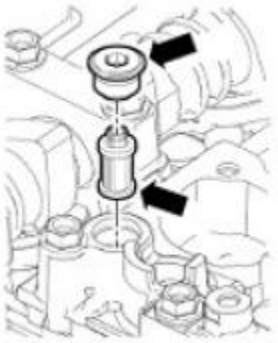
NOTE: Lubricate camshaft journals and bearing caps with clean engine oil.

12. Install the camshafts and bearing caps. Tighten bolts in sequence shown in three stages:
    - Stage 1: Tighten finger tight
    - Stage 2: Tighten to 7 Nm (62 lb-in)
    - Stage 3: Tighten to 16 Nm (12 lb-ft).

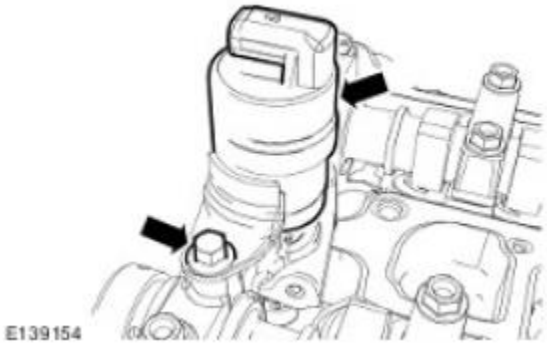


CAUTION: The crankshaft, the crankshaft sprocket and the pulley are fitted together by friction, with diamond washers between the flange faces on each part. The diamond washers must be installed correctly or severe engine damage can result.

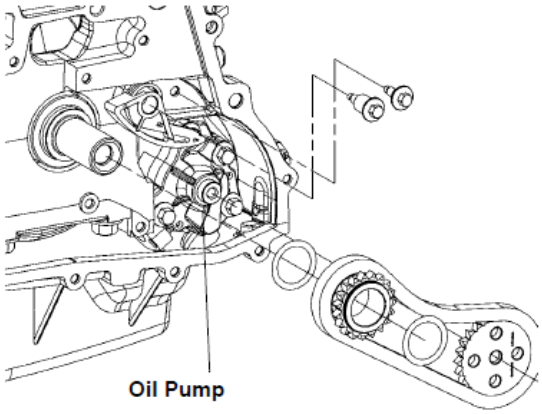
13. Install the variable camshaft timing (VCT) system oil filter and the plug in the intake camshaft thrust cap
    - Torque: 12.5 lb-ft (17Nm)



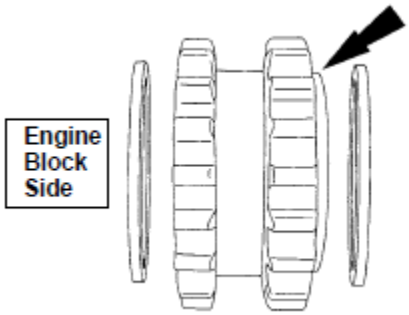
14. Install the VCT solenoid and the bolt.
    - Torque: 7.3 lb-ft (10Nm)



15. Install washers and oil pump chain and sprockets.



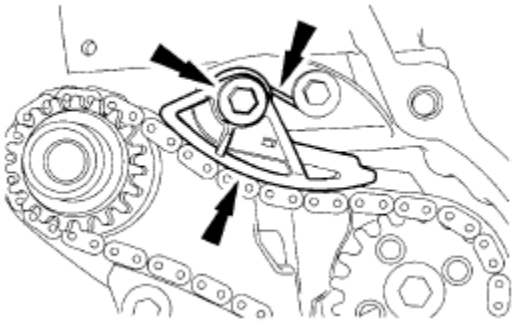
NOTE: The crankshaft sprocket flange must be facing away from the engine block.



16. Holding the oil pump chain sprocket in place, tighten oil pump sprocket bolt:
    - Tighten to 25 Nm (18 lb-ft).

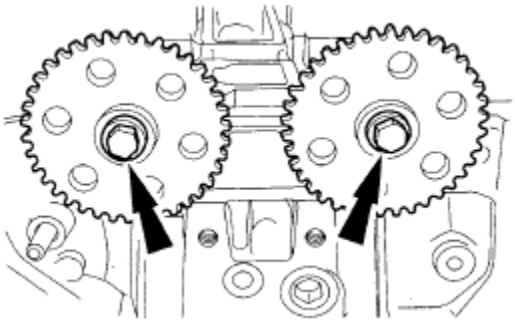
17. Install oil pump chain guide and shoulder bolt:
    - Tighten to 10 Nm (89 lb-in).

18. Install oil pump chain tensioner. Hook spring around shoulder bolt and tighten:
    - Tighten to 10 Nm (89 lb-in).



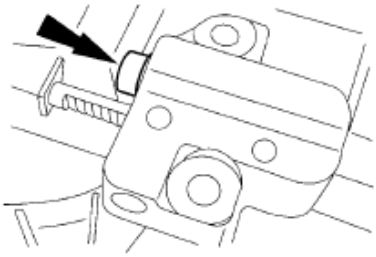
NOTE: Sprockets must turn freely on the camshafts.

19. Position camshaft sprockets and loosely install bolts.

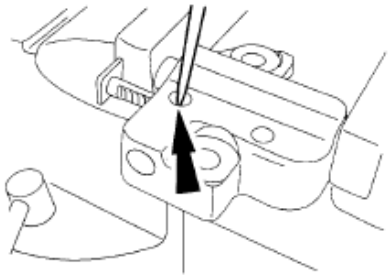


CAUTION: Do not compress the ratchet assembly. This will damage the ratchet assembly.

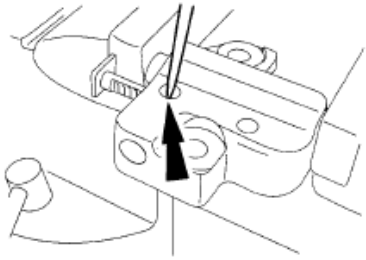
20. Using the edge of a vise, compress the timing chain tensioner plunger.



21. Using a small pick, push back and hold the ratchet mechanism.

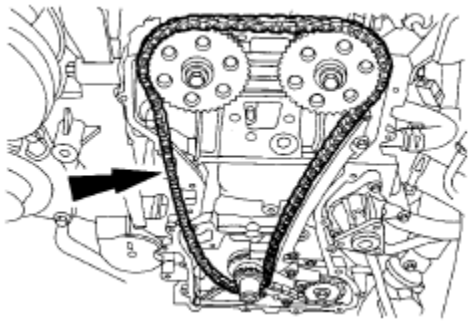


22. While holding the ratchet mechanism, push the ratchet arm back into the tensioner housing.

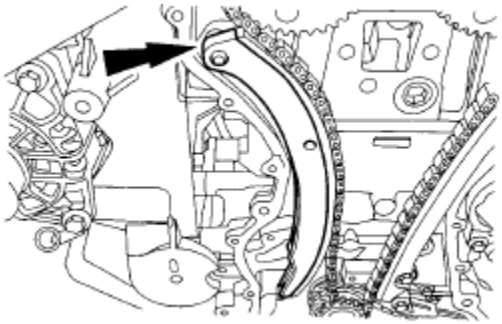


23. Install a paper clip into the hole in the tensioner housing to hold the ratchet assembly and the plunger in during installation.

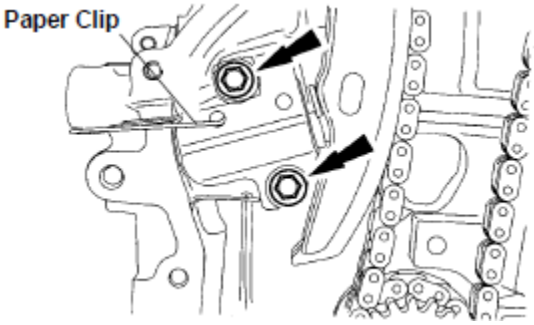
24. Install the timing chain.



25. Position timing chain guides and install guide bolts:
    - Tighten to 10 Nm (89 lb-in).

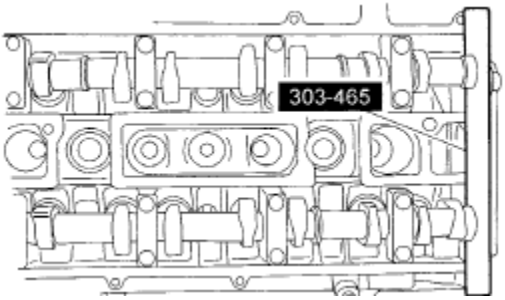


26. Install timing chain tensioner and 2 bolts. Remove the paper clip to apply tension to chain:
    - Tighten to 10 Nm (89 lb-in).

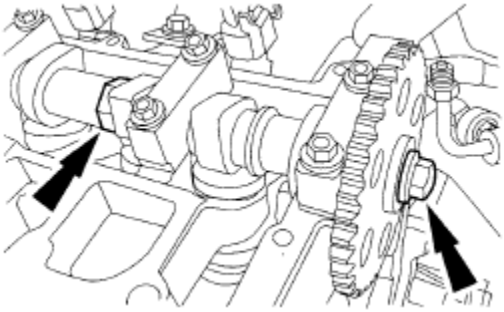


CAUTION: The special tool 303-465 is for camshaft alignment only. Using this tool to prevent engine rotation can result in engine damage.

27. Install special tool 303-465 in the timing slots on rear of both camshafts. Timing slots are offset from the centerline of the camshaft.



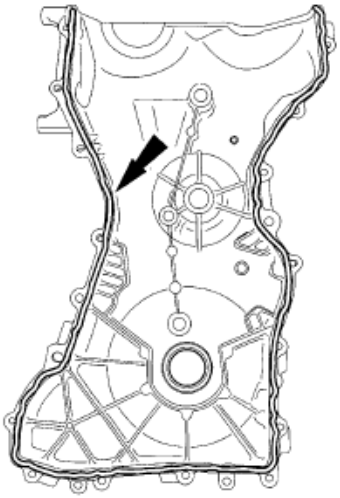
NOTE: Use a wrench on the flats between cylinders No.1 and No. 2 to hold the camshafts in place.



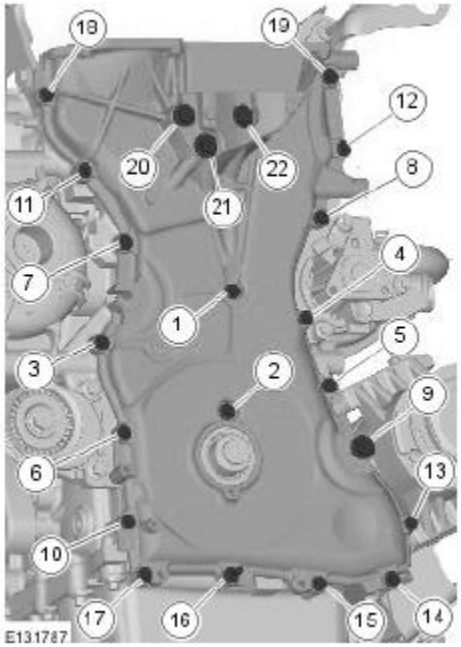
28. Tighten camshaft sprocket bolts:
    - Tighten to 65 Nm (48 lb-ft).

NOTE: If front cover is not secured within 4 minutes, the sealant must be removed and the sealing area re-cleaned -- Refer to “Engine Cleaning” on page 34 of this section.

29. Apply a 2.5 mm (0.1 in) bead of silicone gasket and sealant to the front cover, and to block as shown.



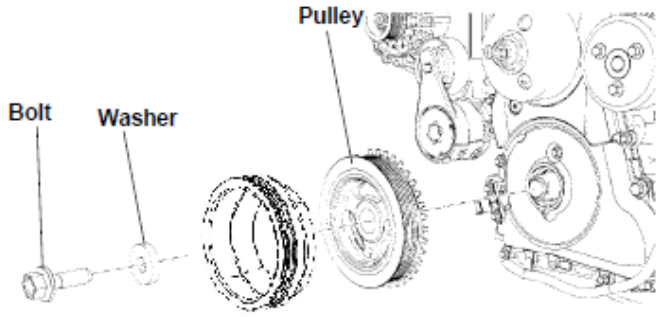
30. Install the front cover and bolts. Tighten in the sequence shown in 3 stages:
    - Stage 1: Tighten 8mm bolts to 10 nm (89 lb-in)
    - Stage 2: Tighten 10 mm bolts to 25 Nm (18 lb-ft)
    - Stage 3: Tighten 13 mm bolts to 48 Nm (35 lb-ft).



CAUTION: Do not reuse crankshaft pulley bolt.

NOTE: Apply clean engine oil to crankshaft front seal area prior to installing.

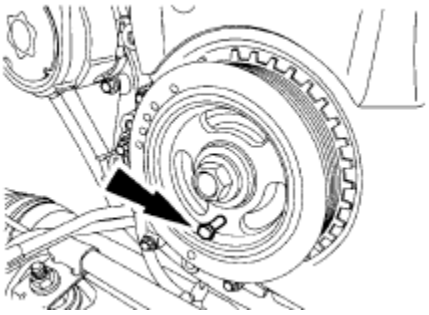
31. Install crankshaft pulley and hand-tighten bolt.



CAUTION: Only hand tighten crankshaft pulley bolt or damage to front cover can occur.

NOTE: This next step will correctly align crankshaft pulley to crankshaft.

32. Install a standard 6 mm x 18 mm bolt through the crankshaft pulley and thread it into the front cover.



33. Rotate the crankshaft pulley as necessary to align the bolt holes.

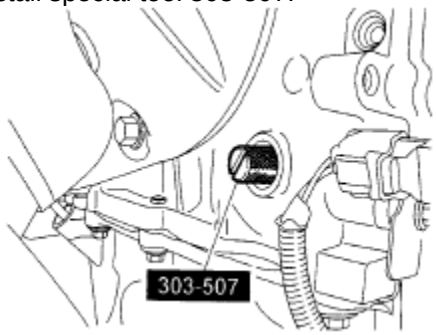
CAUTION: Failure to hold the crankshaft pulley in place during bolt tightening can cause damage to the engine front cover.

34. Remove all special tools and 6mm bolt.

CAUTION: Only turn engine in the normal direction of rotation.

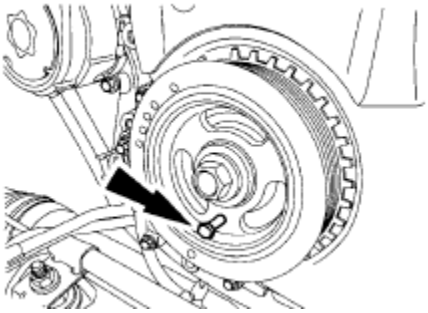
35. Turn the engine 2 complete revolutions, then continue turning in same direction until the No. 1 piston is at top dead center (TDC).

36. Install special tool 303-507.

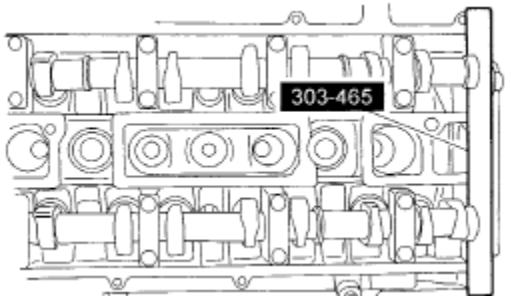


CAUTION: Only hand tighten the bolt in this next step or damage to the front cover can occur.

37. Using a 6mm x 18 mm bolt, check the position of the crankshaft pulley. If it is not possible to install the bolt, correct the engine timing.

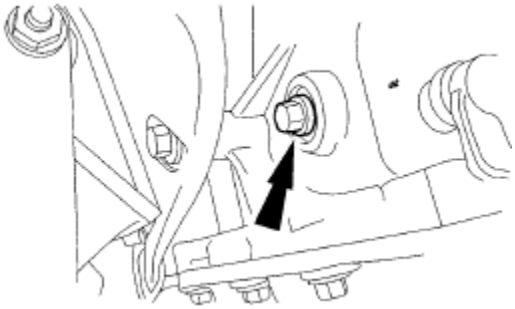


38. Using special tool 303-465, check the position of the camshafts. If it is not possible to install the special tool, correct the engine timing.

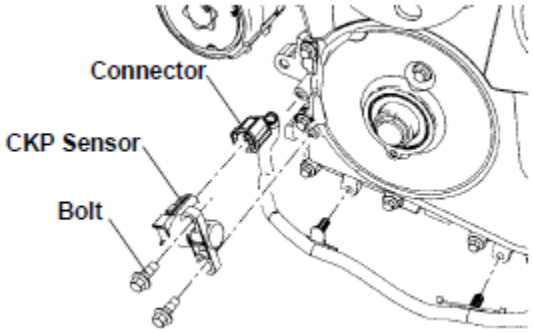


39. Remove all special tools (303-507, 303-465) and 6mm bolt.

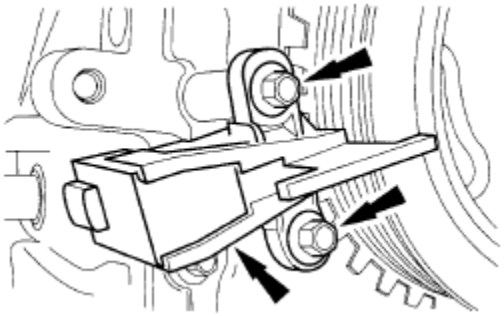
40. Install the plug bolt:
    - Tighten to 20 Nm (15 lb-ft).



41. Position a new crankshaft position (CKP) sensor and loosely install 2 bolts.



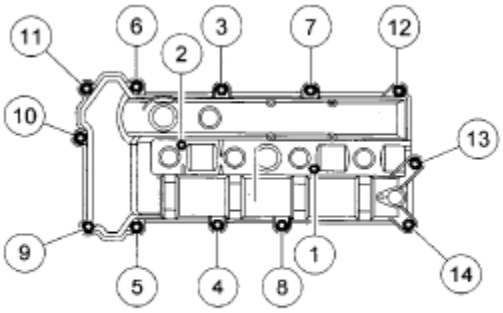
42. Using alignment tool that came with new sensor, adjust CKP alignment. The tool must engage a tooth of the damper, then tighten bolts:
    - Tighten to 7 Nm (62 lb-in).



NOTE: If camshaft cover is not secured within 4 minutes, the sealant must be removed and the sealing area re-cleaned -- Refer to “Engine Cleaning” on page 33 of this section.

43. Apply silicone gasket and sealant to the locations shown.

44. Install camshaft cover and tighten bolts in sequence show:
    - Tighten to 10 Nm (89 lb-in).

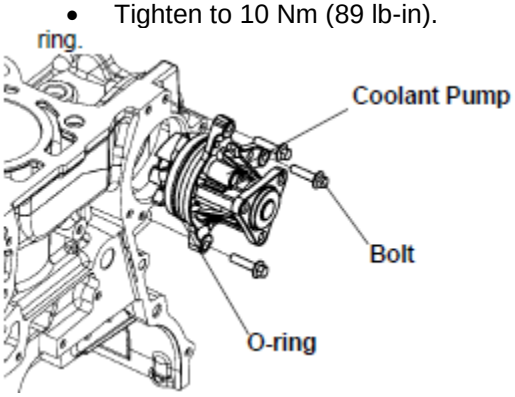


Tightening Sequence

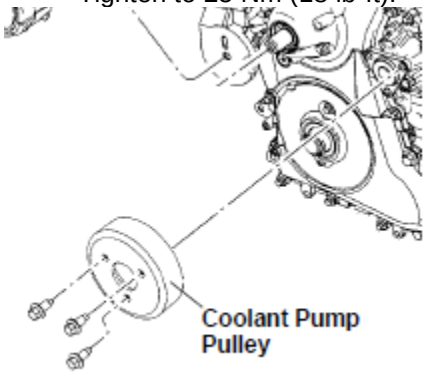
45. Install camshaft position (CMP) sensor and bolt:
    - Tighten to 7 Nm (62 lb-in).

46. Install spark plugs:
    - Tighten to 15 Nm (11 lb-ft).

47. Lubricate a new coolant pump o-ring seal with clean engine coolant and install coolant pump and 3 bolts:
    - Tighten to 10 Nm (89 lb-in).

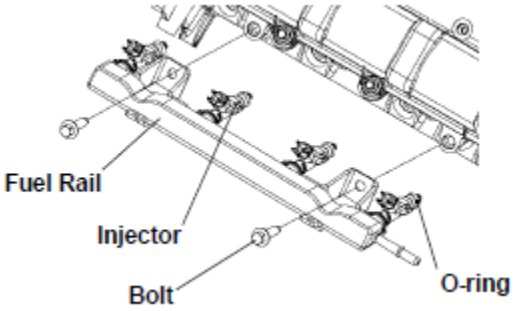


48. Install coolant pump pulley and 3 bolts:
    - Tighten to 25 Nm (18 lb-ft).



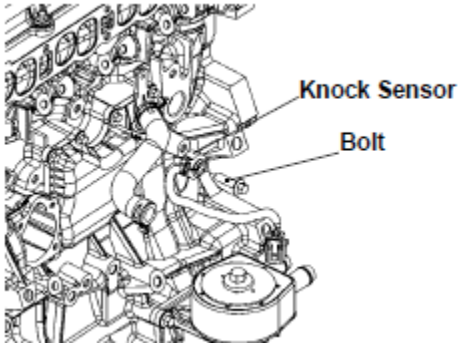
NOTE: Lubricate new fuel injector o-ring seals with clean engine oil prior to installation.

49. Using new o-ring seals, install fuel rail assembly and bolts:
    - Tighten to 25 Nm (18 lb-ft).

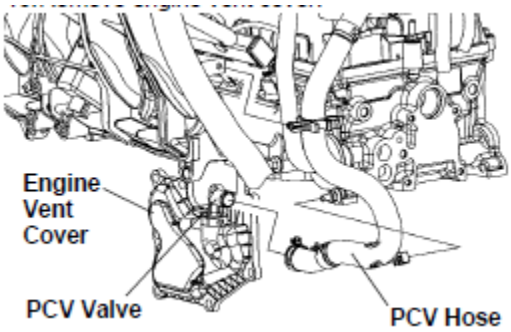


CAUTION: The knock sensor (KS) must not touch the engine vent cover.

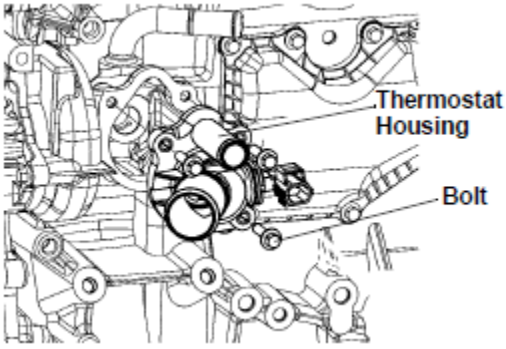
50. Install knock sensor:
    - Tighten to 20 Nm (15 lb-ft).



51. Install engine vent cover and bolts:
    - Tighten to 10 Nm (89 lb-in)



52. Using a new gasket, install thermostat, housing and 3 bolts:
    - Tighten to 10 Nm (89 lb-in).



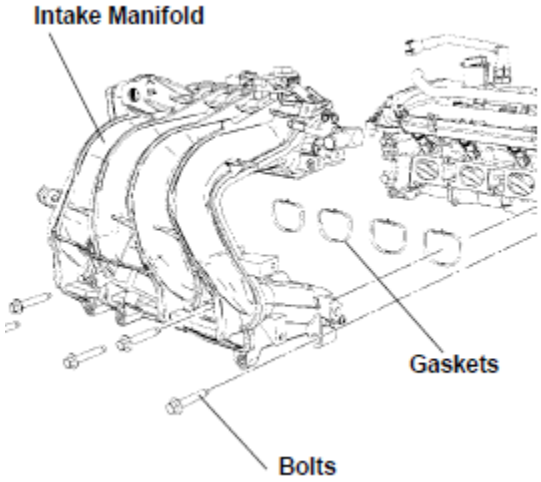
NOTE: Apply silicone dielectric compound to inside of spark plug boot area prior to installation of coils.

53. Install coils over spark plugs and tighten bolts:
    - Tighten to 10 (89 lb-in).

54. Make any connections that will not be accessible after intake manifold is installed.

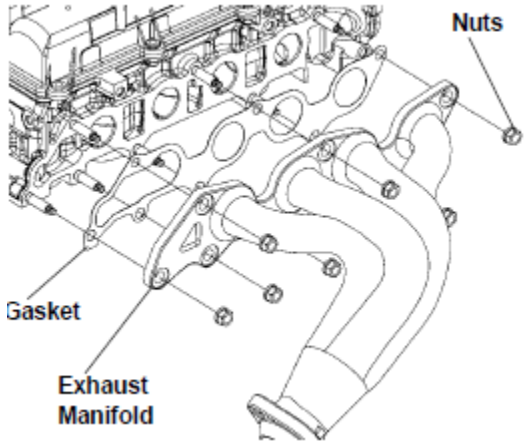
55. Inspect and install new intake manifold gaskets if necessary.

56. Install intake manifold and bolts:
    - Tighten to 18 Nm (13 lb-ft).



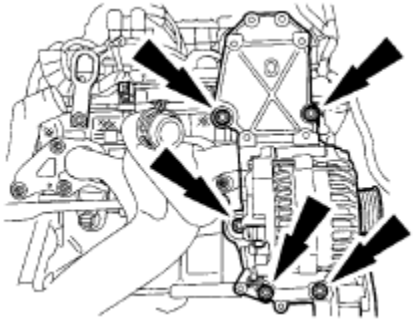
57. Install power steering pump and bolts:
    - Tighten to 25 Nm (18 lb-ft).

58. Install 7 new exhaust manifold studs:
    - Tighten to 17 Nm (13 lb-ft).

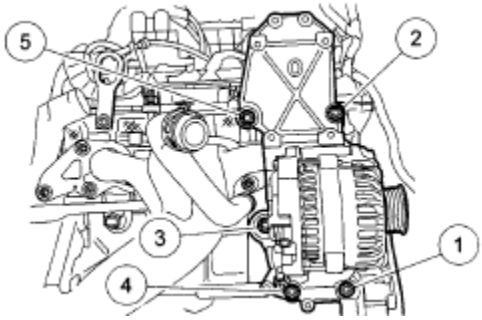


59. Position a new gasket and install exhaust manifold and 7 new nuts:
    - Tighten to 54 Nm (40 lb-ft).

60. Install generator and support bracket.

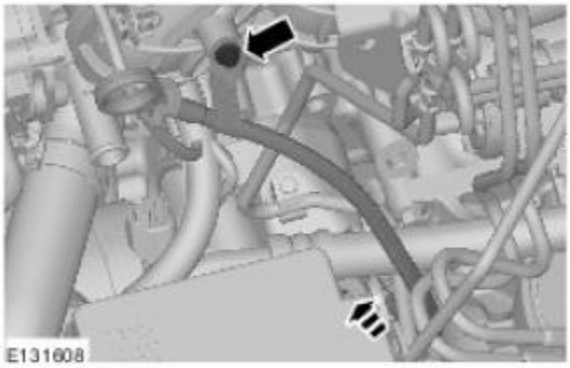


61. Tighten bolts in the sequence shown in 2 stages:
    - Stage 1: Tighten finger tight
    - Stage 2: Tighten to 47 Nm (935 lb-ft).

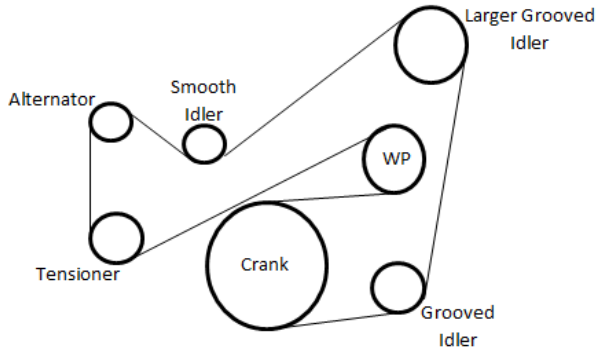


62. Install A/C compressor (if equipped) and bolts:
    - Tighten to 25 Nm (18 lb-ft).

63. Install oil level indicator tube:
    - Tighten to 10 Nm (89 lb-in).



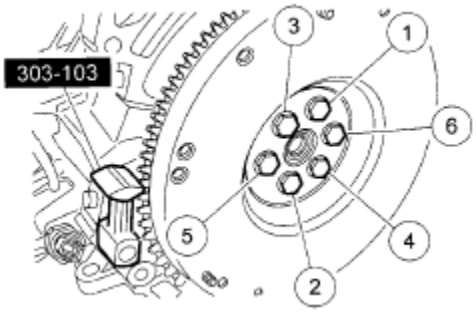
64. Install accessory drive belt.



65. Install any tubes, hoses or components removed or disconnected.

66. Remove engine from engine stand and install flywheel or flexplate.

67. Using special tool, tighten bolts in the sequence shown in 3 stages:
    - Stage 1: Tighten to 50 Nm (37 lb-ft)
    - Stage 2: Tighten to 80 Nm (59 lb-ft)
    - Stage 3: Tighten to 112 Nm (83 lb-ft).



68. Lubricate transmission input shaft pilot bearing with grease.

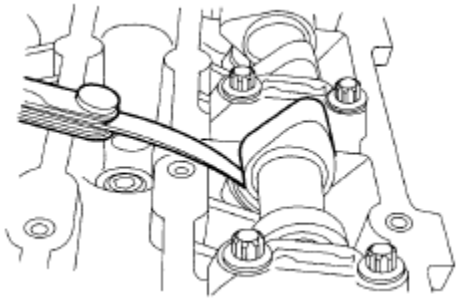
ADJUSTMENTS

Valve Clearance Check

1. Remove camshaft cover -- Refer to “Camshaft Cover - Removal” on page 6 of this section.

CAUTION: Turn the engine clockwise only, and use the crankshaft bolt only.

2. Use a feeler gauge to measure each valve’s clearance and record its location. A mid-range clearance is most desirable:
    - Intake: 0.22-0.28 mm (0.008-0.011 inch)
    - Exhaust: 0.27-0.33 mm (0.010-0.013 inch)



NOTE: Measure each valve’s clearance at base circle with lobe pointed away from the tappet, before removing camshafts. Failure to measure all clearances prior to removing camshafts will necessitate repeated removal and installation and wasted labor time.

3. Select tappets and mark location using the following formula:
    - Tappet thickness = measured clearance, plus base tappet thickness, minus most desirable thickness.

NOTE: If any tappets do not measure within specifications, install new tappets in those locations -- Refer to “Valve Tappet - Replacement” on page 18 of this section.

MSG-425 ENGINE

General Specifications

Item	Specification
Motorcraft Metal Surface Prep ZC-31	---
Silicone Gasket Remover ZC-30	---
Silicone Gasket and Sealant TA-30	WSE-M4G323-A4
Motorcraft SAE 5W-20 Premium Synthetic Blend Motor Oil XO-5W-20-QSP (in Canada Motorcraft SAE 5W-20 Super Premium Motor Oil CXO-5W20-LSP12) or equivalent	WSS-M2C930-A
Motorcraft Premium Gold Engine Coolant VC-7-A (in California, Oregon and New Mexico VC-7-B, in Canada CVC-7-A) or equivalent (yellow color)	WSS-M97B51-A1
Multi-Purpose Grease XG-4 and/or XL-5	ESB-M1C93-B
Thread Sealant with PTFE TA-24	WSK-M2G350-A2
Displacement	2.5L
No. of cylinders	4
Bore/Stroke	89/100
Firing Order	1-3-4-2
Oil Pressure (hot @ 2000rpm)	29-39psi
Oil Capacity	7 quarts including filter

Cylinder Block

Cylinder bore diameter	89.0 – 89.03 mm
Cylinder bore max out-of-round	0.008 mm
Main bearing bore diameter	57.018 – 57.040 mm
Head gasket surface flatness	0.1 mm/general and 0.05 mm/200x200

Piston

Diameter (1)	88.965 – 88.975 mm
Diameter (2)	88.975 – 88.985 mm
Diameter (3)	88.985 – 88.995 mm
Piston-to-bore clearance	0.025 – 0.045
Ring groove width – top	1.203 – 1.205 mm
Ring groove width – 2nd	1.202 – 1.204 mm
Ring groove width – oil	2.501 – 2.503 mm
Piston skirt coating thickness	0.008 – 0.016 mm

Piston Pin

Diameter	19.995 – 20.0 mm
Length	54.7 – 55.0 mm

Valve

Valve head diameter – intake	34.85 – 35.15 mm
Valve head diameter – exhaust	29.85 – 30.15 mm
Valve stem diameter – intake	5.470 – 5.485 mm
Valve stem diameter – exhaust	5.465 – 5.480 mm
Valve stem-to-guide clearance – Intake	0.0027 mm
Valve stem-to-guide clearance – Exhaust	0.0029 mm
Valve face runout	0.05 mm
Valve face angle	45 degrees

Valve Spring – Compression Pressure

Intake and exhaust (installed)	17.5kg
Intake (valve open) 8.9 mm of lift	44kg
Exhaust (valve open) 7.4 mm of lift	42kg
Free Length	44.92 mm
Assembled height	37.9mm

Cylinder Head

Cylinder head flatness	0.08 maximum overall, a maximum of 0.05 mm with 150 mm
Valve lift @ zero lash (exhaust)	7.7 mm
Valve lift @ zero lash (intake)	8.8 mm
Valve guide diameter	5.509 – 5.539 mm
Valve seat width – intake/exhaust	0.99 – 1.84 mm
Valve seat angle	45 degrees
Valve seat runout	0.075 mm
Valve lash adjuster bore diameter	31.00 – 31.03 mm
Cam bore diameter	25.015 – 25.040 mm

Crankshaft

Main bearing journal diameter	51.978 – 52.002 mm
Production Repair	51.730 – 51.750 mm
Main bearing clearance	0.016 – 0.047 mm
Connecting rod journal diameter	51.978 – 52.002 mm
Production repair	51.730 – 51.750 mm
End play	0.220 – 0.450 mm

Rings

Width – Top	1.17 – 1.185 mm
Width – 2nd	1.197 – 1.199 mm
Width – Oil	2.38 – 2.45 mm
Ring gap (in bore) – top	0.19 – 0.26 mm
Ring gap (in bore) – 2nd	0.31 – 0.46 mm
Ring gap (in bore) – oil	0.15 – 0.40 mm

Valve Tappet

Diameter	30.97 – 30.98 mm
Tappet-to-valve clearance – intake	0.22 – 0.28 mm
Tappet-to-valve clearance-exhaust	0.27 – 0.33 mm
Tappet-to-bore clearance	0.02 – 0.06 mm

Camshaft

Intake camshaft lobe lift	8.24999 mm
Exhaust camshaft lobe lift	7.80007 mm
Runout (1)a	0.03 mm
Thrust clearance	0.09 – 0.24 mm
Journal diameter	24.96 – 24.96 mm
Journal-to-bore clearance	0.035 – 0.080 mm
A – No. 3 journal supported by No. 1 and No. 5 journals	

Connecting Rod

Bearing clearance	0.027 – 0.052 mm
Bearing thickness	1.496 – 1.520 mm
Crank bore diameter	55.025 – 55.045 mm
Pin bore diameter (with bushing inserted)	20.010 – 20.021 mm
Length (center-to-center)	151.8 mm
Side clearance	1.95 – 3.05 mm
Axial clearance	0.14 – 0.36 mm

Torque Specifications

Description	Nm	Lb-ft	Lb-in
Camshaft sprocket bolt	65	48	-
Coolant outlet pipe bolts	10	-	89
Coolant pump pulley bolts	25	18	-
Coolant thermostat bolts	10	-	89
Coolant pump bolts	10	-	89
Coolant outlet (front) connector bolts	25	18	-
Crankcase ventilation cover bolts	10	-	89
Cylinder head bolts (a)	-	-	-
Crankshaft pulley bolts (a)	-	-	-
Camshaft bearing caps (a)	-	-	-
Crankshaft position sensor	7	-	62
Crankshaft oil seal retainer (a)	-	-	-
Engine ground cable-to-cylinder head stud bolt	10	-	89
Exhaust manifold-to-exhaust inlet pipe nuts	40	30	-
Engine-to-trans bolts	48	35	-
Engine front cover bolts (a)	-	-	-
Engine lifting eye bolts	45	33	-
Exhaust manifold-to-cylinder head studs	17	13	-
Exhaust manifold-to-cylinder head nuts	54	40	-
Flywheel bolts (a)	-	-	-
Generator bolts	25	18	-
Generator/AC Compressor support brackets	48	35	-
Intake manifold bolts	18	13	-
Knock sensor	20	15	-
Oil pressure switch	15	11	-

Torque Specifications (continued)

Description	Nm	Lb-ft	Lb-in
Oil level indicator tube bolt	10	-	89
Oil pump sprocket bolt	25	18	-
Oil pump pickup tube and screen bolts	10	-	89
Oil drain plug	28	21	-
Oil filter adapter bolts	25	18	-
Oil pan bolts (a)	-	-	-
Oil pump-to-cylinder block bolts	20	15	-
Oil pump chain tensioner bolts	10	-	89
Oil pump chain guide bolts	10	-	89
Power steering pump bolts	25	18	-
Power steering pressure tube nut	20	15	-
Starter motor bolts	25	18	-
Timing peg plug	20	15	-
Transmission access cover bolt	10	-	89
Torque converter to flywheel nuts	35	26	-
Transmission lines bracket bolt	28	21	-
Timing chain guide bolts	10	-	89
Timing chain tensioner bolts	10	-	89
Valve cover bolts	10	-	89
Fan Bracket to Front Cover	58	42.5	-
Fran drive bracket with bearing to bracket	28.5	21	-
Fan Spacer to bearing bracket	12	9	-
Fan to fan spacer	28.5	21	-
(a)– Refer to the procedure in this section			

MSG-425 IGNITION SYSTEM

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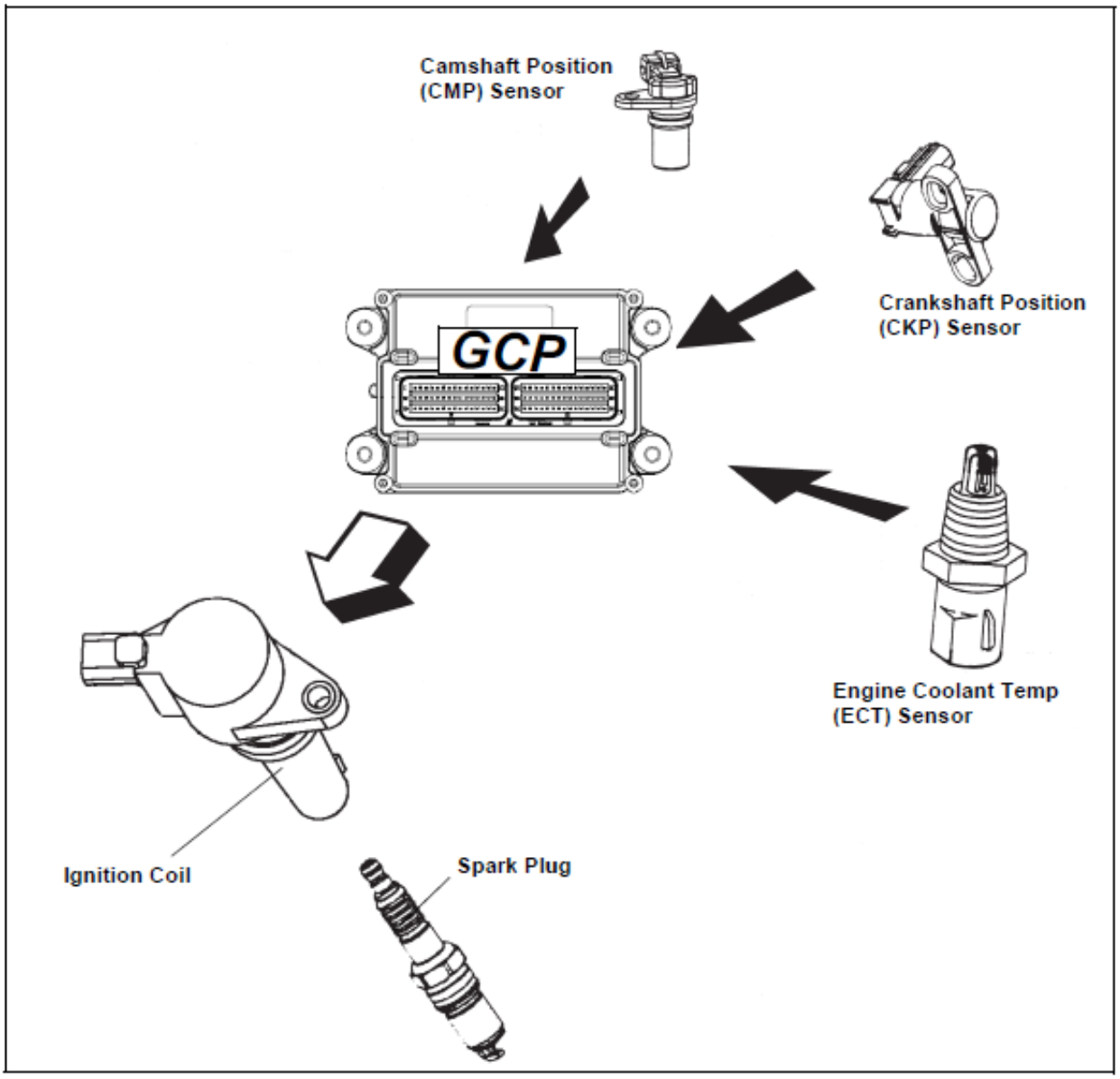
MSG-425 IGNITION SYSTEM

GENERAL INFORMATION



Description

The MSG-425 engine is equipped with an individual coil on plug electronic ignition system. The brain of this system is the Electronic Engine Control (GCP) Module which receives inputs from the following:

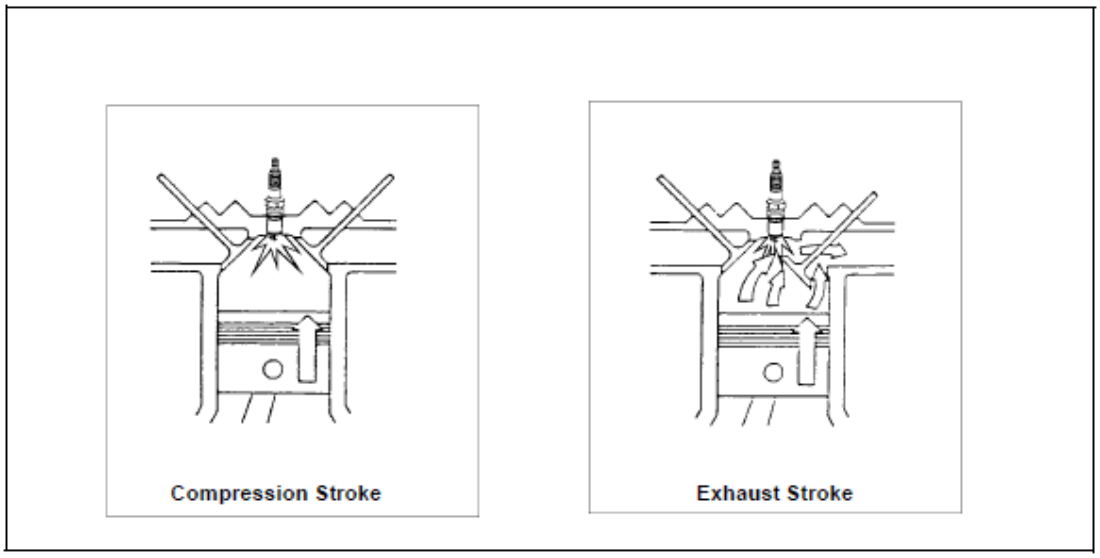
- Crankshaft Position (CKP) Sensor
- Camshaft Position (CMP) Sensor
- Engine Temperature Sensor

From these inputs, the GCP module computes spark strategy (spark advance) to obtain optimum engine performance for correct input conditions, through the following outputs:

- Ignition Coils
- Spark Plugs.

WARNING: HIGH TENSION VOLTAGE PRODUCED BY A DISTRIBUTORLESS IGNITION SYSTEM IS HIGHER THAN FOR A CONVENTIONAL IGNITION SYSTEM. WHEN CARRYING OUT SERVICE OPERATIONS ON AN ENGINE EQUIPPED WITH DISTRIBUTORLESS IGNITION, IT IS IMPORTANT TO BE AWARE OF THE ABOVE POINT AS WELL AS ALL THE USUAL SAFETY MEASURES TO PREVENT THE POSSIBILITY OF ELECTRIC SHOCKS.

MSG-425 IGNITION SYSTEM



Operation

With this system, the GCP monitors the engine speed and operating temperature and decides what degree of spark advance is correct for all of the operating conditions. Because timing is set for life inherently in the design of the engine, and there are no moving parts in the ignition system itself, no maintenance is required except for periodic spark plug checks. The system provides for fixed spark advance at start-up, for cold weather starting, and for “average value” default attention has been given to spark optimization for excellent fuel economy in the warm-up mode.

The spark plugs are paired so that one plug fires during the compression stroke and its companion plug fires during the exhaust stroke. The next time that coil is fired, the plug that was on exhaust will be on compression, and the one that was on compression will be on exhaust. The spark in the exhaust cylinder is wasted (referred to as the “waste spark”) but little of the coil energy is lost.

Engine Speed and Crankshaft Position

The crankshaft position and speed information comes to the GCP from the Crankshaft Position (CKP) Sensor, mounted near the crankshaft pulley. The CKP Sensor is triggered by teeth on a trigger wheel located on the crankshaft pulley. The pulse frequency indicates crankshaft speed and a missing tooth indicates crankshaft position.

Engine Temperature

The Engine Coolant Temperature (ECT) Sensor sends engine temperature information to the GCP. It is located in the rear coolant outlet pipe.

Fuel Octane Level Adjustment

In the event that the engine is operated on dry fuels such as natural gas, compressed natural gas (CNG), or liquefied petroleum gas (LGP), timing can be modified by GCP “Fuel Type”.

Ignition Coil Driver

The GCP switches 4 individual ignition coils on and off at the correct times to give the desired spark advance. Ignition timing is adjusted constantly by the GCP. Many factors including all the sensor inputs, affect the final ignition setting.

Run Mode

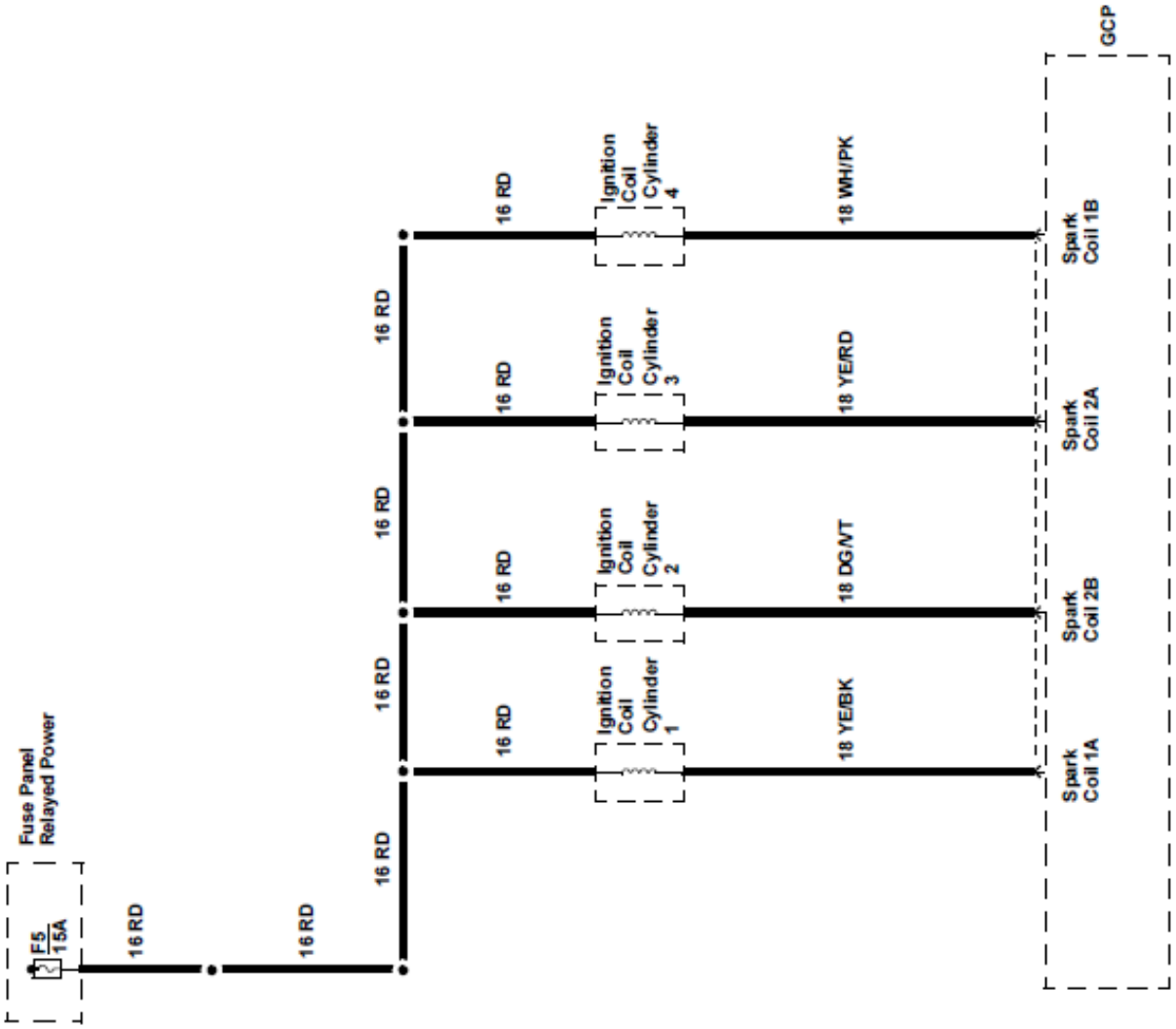
The GCP interprets engine speed above 200 rpm as Run Mode. The Base Spark advance (BSA) is calculated by the GCP processing the engine speed input.

Transient Mode

This function is to provide detonation protection when the engine load is increased rapidly by fast opening of the throttle plate.

MSG-425 IGNITION SYSTEM

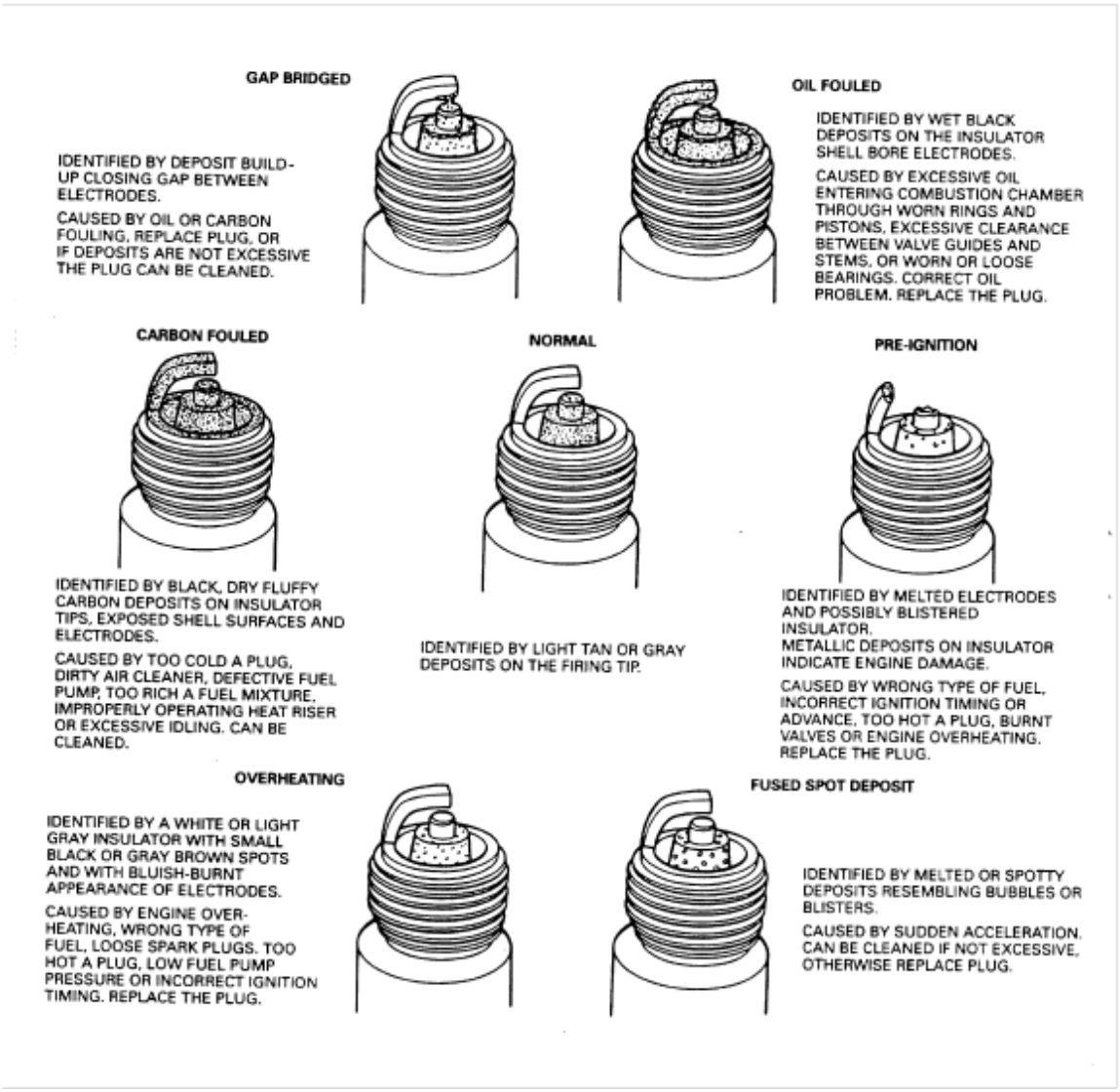
Wiring Diagram



DIAGNOSIS AND TESTING

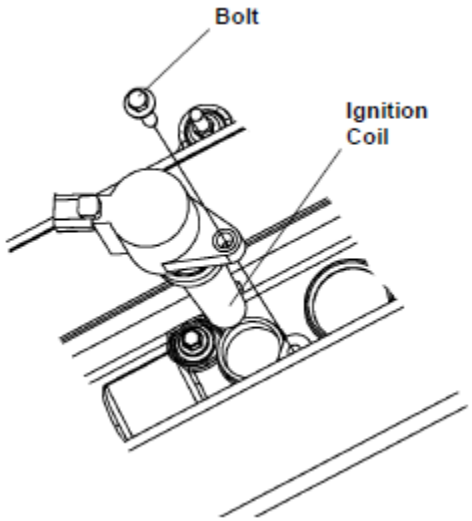
Spark Plug Inspection

Inspect the spark plug tip as in the chart below:



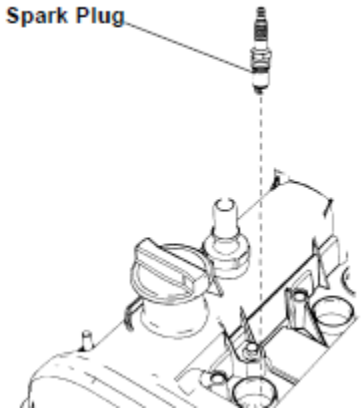
REMOVAL AND INSTALLATION

Ignition Coil - Replacement



1. Remove and/or disconnect components to allow access and removal of the ignition coil. Label if necessary to allow for correct reinstallation.
2. Disconnect electrical connector.
3. Remove bolt.
4. Remove ignition coil.
5. Reverse procedure to install:
    - Inspect for cracks, carbon tracking or dirt
    - Apply silicone dielectric compound to the inside of coil.

Spark Plug – Removal



1. Remove ignition coil -- Refer to “Ignition Coil - Replacement” on page 6 of this section.
2. Loosen spark plugs and remove any dirt or foreign material from spark plug areas of cylinder head with compressed air.
3. Remove spark plugs and mark location using a piece of masking tape.
4. Inspect condition of spark plug -- Refer to “Spark Plug Inspection” on page 7 of this section.

Spark Plug - Installation

1. Apply a few drops of engine oil to spark plug threads near tip.
2. Adjust spark plug gap to: 1.25 - 1.35 mm (0.049 - 0.053 in.).
3. Install spark plugs (to original locations) and tighten to 11 lb-ft. (15 Nm).
4. Install coil -- Refer to “Ignition Coil - Replacement” on page 6 of this section.

MSG-425 IGNITION SYSTEM

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Firing Order	1 – 3 – 4 - 2
Spark Plug	Type: AYFS-32Y-R Gap: 1.25 – 1.35 mm (0.049 – 0.053 in.)

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Spark Plugs	15	11	132
Coil bolts	8	6	71

MSG-425 FUEL SYSTEM

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CAUTIONS & WARNINGS

WARNING: DO NOT SMOKE OR CARRY LIGHTED TOBACCO OR OPEN FLAME OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENT. HIGHLY FLAMMABLE MIXTURES ARE
ALWAYS PRESENT AND MAY BE IGNITED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: FUEL IN THE FUEL SYSTEM REMAINS UNDER HIGH PRESSURE EVEN WHEN THE ENGINE IS NOT RUNNING. BEFORE REPAIRING OR DISCONNECTING ANY OF THE FUEL LINES OR FUEL SYSTEM COMPONENTS, THE FUEL SYSTEM PRESSURE MUST BE RELIEVED TO PREVENT ACCIDENTAL SPRAYING OF FUEL, CAUSING A FIRE HAZARD. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: DO NOT CARRY PERSONAL ELECTRONIC DEVICES SUCH AS CELL PHONES, PAGERS OR AUDIO EQUIPMENT OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENTS. HIGHLY FLAMMABLE MIXTURES ARE ALWAYS PRESENT AND CAN BE IGNITED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: THESE PROCEDURES INVOLVE FUEL HANDLING. BE PREPARED FOR FUEL SPILLAGE AT ALL TIMES AND ALWAYS OBSERVE FUEL HANDLING PRECAUTIONS. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

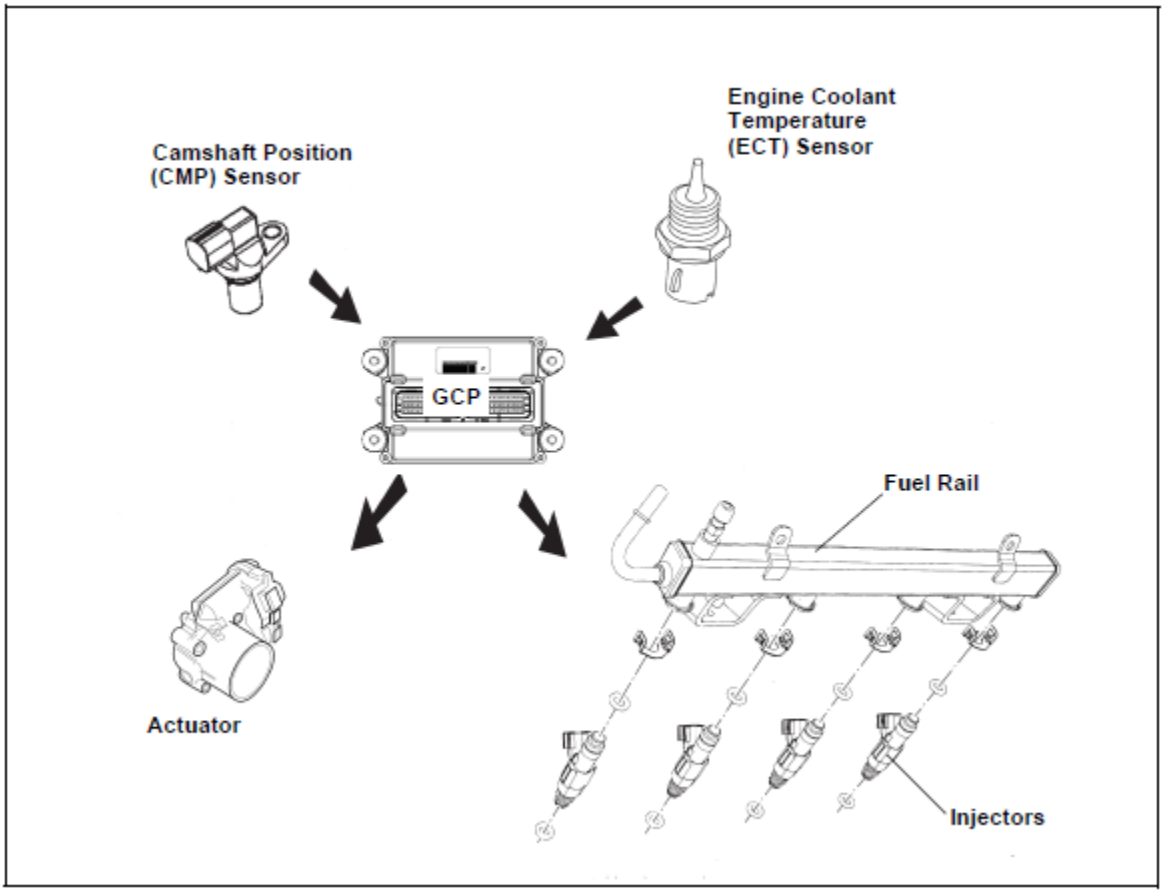
CAUTION: If the liquid or vapor tube is damaged (torn, holes or delaminated), a new tube assembly must be installed. Do not use aftermarket sleeving. Do not re-adhere loose sleeving material.

CAUTION: Fuel injection equipment is manufactured to very precise tolerances and fine clearances. It is therefore essential that absolute cleanliness is observed when working with these components. Always cap off any open orifices or tubes.

CAUTION: When reusing liquid or vapor tube connectors, make sure to use compressed air to remove any foreign material from the connector retaining clip area before separating from the tube. Apply clean engine oil to the end of the tube before inserting the tube into the connector.

CAUTION: To ensure absolute cleanliness is observed when working with fuel system components, always cap off any open orifices or tubes.

GENERAL INFORMATION - GASOLINE



Description

The fuel system delivers fuel by an electronic fuel pump. A fuel pressure regulator controls fuel pressure and also contains a fuel filter. The Electronic Control Module (GCP) uses information from various sensors and controls fuel delivery to the cylinders by individual fuel injectors mounted in the cylinder head near each intake valve. Air delivery is controlled by an actuator.

Fuel Rail

The fuel rail is mounted to the top of the engine and distributes fuel to the individual injectors. Fuel is delivered to the fuel inlet tube of the fuel rail by the fuel lines and hoses.

Fuel Injector

The fuel injector is a solenoid operated device mounted to the cylinder head. The GCP energizes the solenoid, which opens a valve to allow fuel delivery into the cylinder.

Camshaft Position (CMP) Sensor

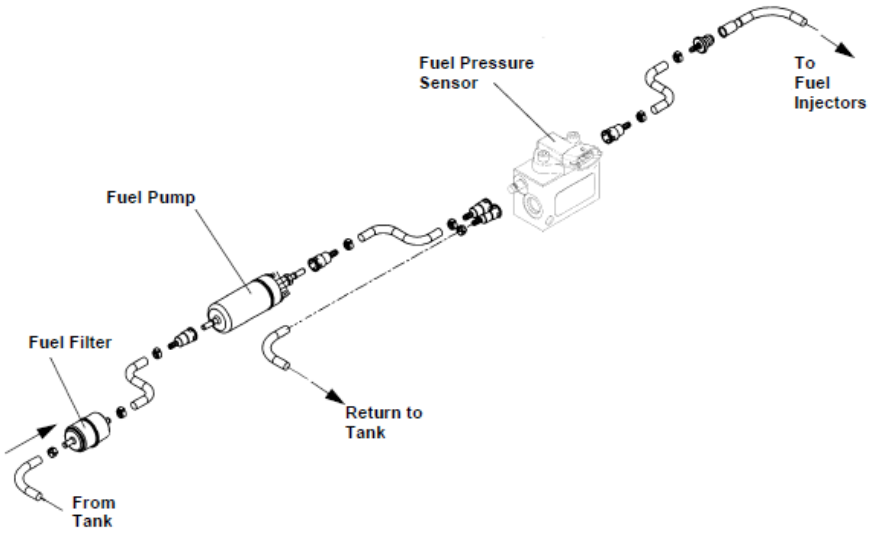
The Camshaft Position (CMP) Sensor is mounted in the camshaft cover. This signal is sent to the GCP which uses it to indicate the position of the #1 piston during its power stroke. The GCP uses the CMP signal as a “sync pulse” to trigger the injectors in the proper sequence. This allows the GCP to calculate true sequential fuel injection (SFI) mode of operation.

Engine Coolant Temperature (ECT) Sensor

The Engine Coolant Temperature (ECT) Sensor is a thermistor mounted in the engine coolant stream in the rear coolant outlet pipe. The GCP uses this information to calculate the correct air/fuel mixture which varies with engine temperature.

Actuator

The actuator controls air delivery into the cylinders. An integral Throttle Position (TP) Sensor sends a signal to the GCP indicating throttle position. The GCP calculates fuel delivery based on throttle valve angle (operator demand).



Operation

The fuel delivery system starts with the fuel in the tank. Fuel is drawn up to the fuel pump through a pre-filter. The electric fuel pump then delivers the fuel to the fuel rail and injectors. The GCP controls the fuel pump to deliver fuel pressure required by the injectors. The GCP monitors system pressure through a fuel pressure sensor.

Fuel is injected under pressure in a conical spray pattern at the opening of the intake valve. There is a return line to the tank with a small orifice to prevent vapor lock in the pump

An actuator controls air supply to the intake manifold. Governor settings are not adjustable. They can only be programmed by authorized personnel only. Contact your local EDI Distributor listed in the back of this manual for further information.

CAUTION: Do not force the throttle plate open. This may cause permanent damage to the actuator.

A pressure relief valve is located on the fuel rail. This is used to read fuel pressure and also to relieve fuel pressure prior to component replacement.

The GCP controls the amount of fuel/air delivery – refer to the Electronic Engine Control section for further information.

Fuel System Requirements

Fuel Tanks

The DOEM or OEM supplies the tanks. There must be a fuel outlet and a fuel inlet. The gas cap must also be vented per the emission installation instructions.

Wet Fuels

The following fuels must all be unleaded and clean:

- Gasoline/petrol: This engine is designed to operate on unleaded 87 or 89 octane gasolines.
- Gasohol/Ethanol: A mixture of gasoline and ethanol (grain alcohol) containing up to 10% ethanol by volume with properly formulated cosolvents and other necessary additives. Blends index of 87 or 89.
- Gasohol/Methanol: A mixture of gasoline and alcohol (wood alcohol, etc.) containing up to 5% methanol by volume with properly formulated cosolvents and other necessary additives. Blends index of 87 or 89.

Fuel Pump

The fuel pump must be mounted on the frame rail, not on the engine. It must also be mounted in packed foam.

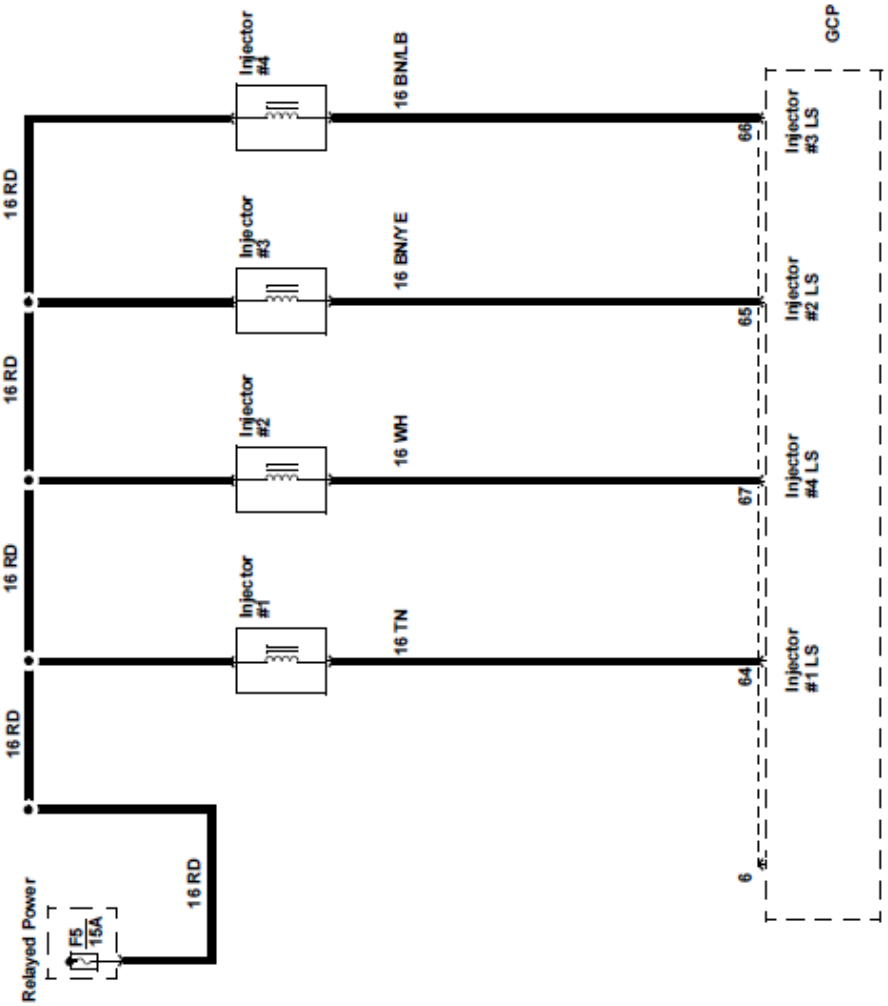
CAUTION: The electric fuel pump MUST NOT be mounted directly on the engine assembly, as engine vibration will shorten the life of the pump.

Wiring Diagrams

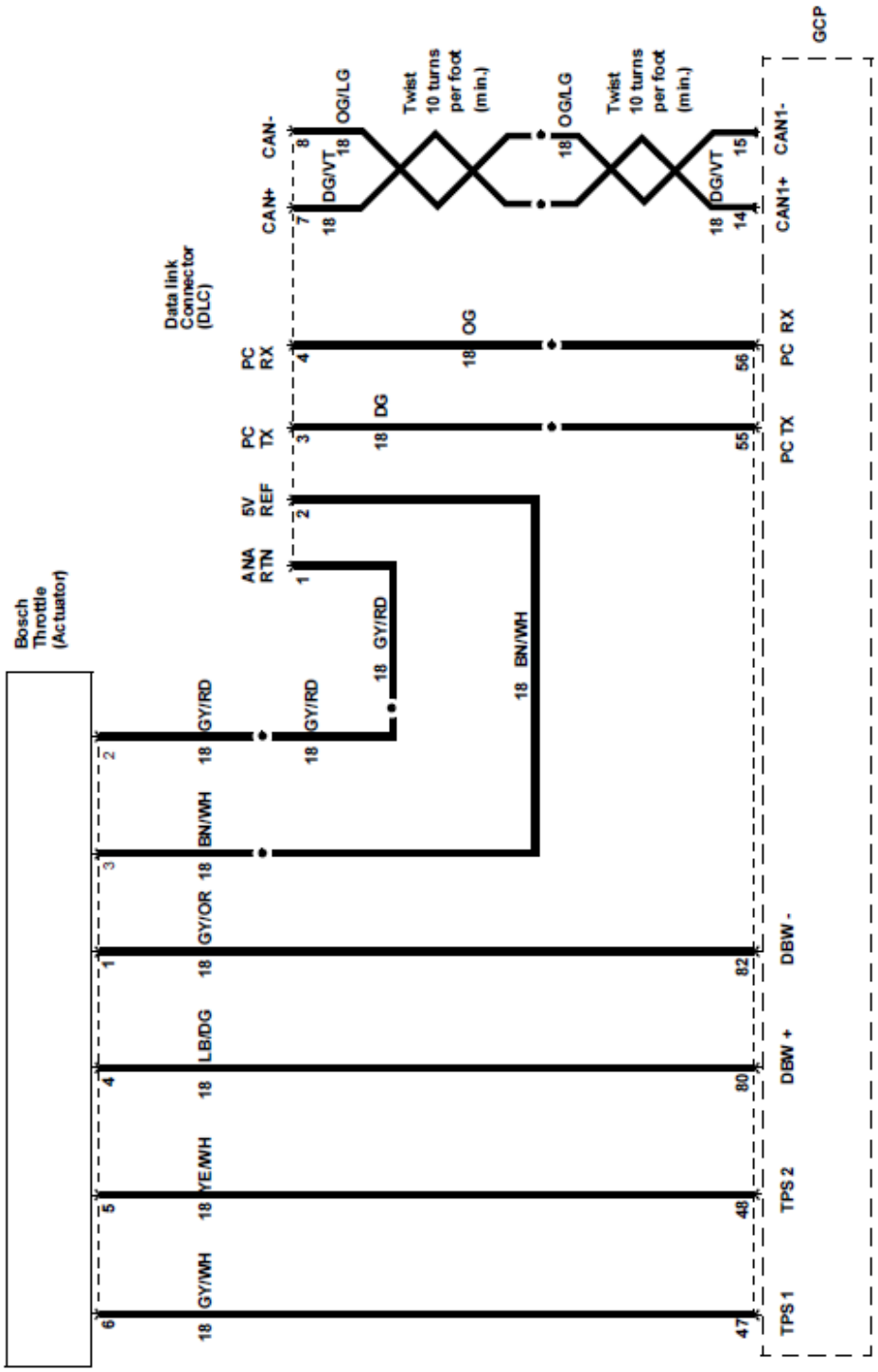
Revision Level
The following wiring schematics are taken from the wiring diagram listed below.

Title: EDI / FORD 2.5L W/GCP		
Size: D	Number: 2487000	Rev: D
Date: 11/1/2011	Drawn By: J. SUTTON	
Filename: 2487000d.sch	Sheet 1 of 1	

Fuel Injectors

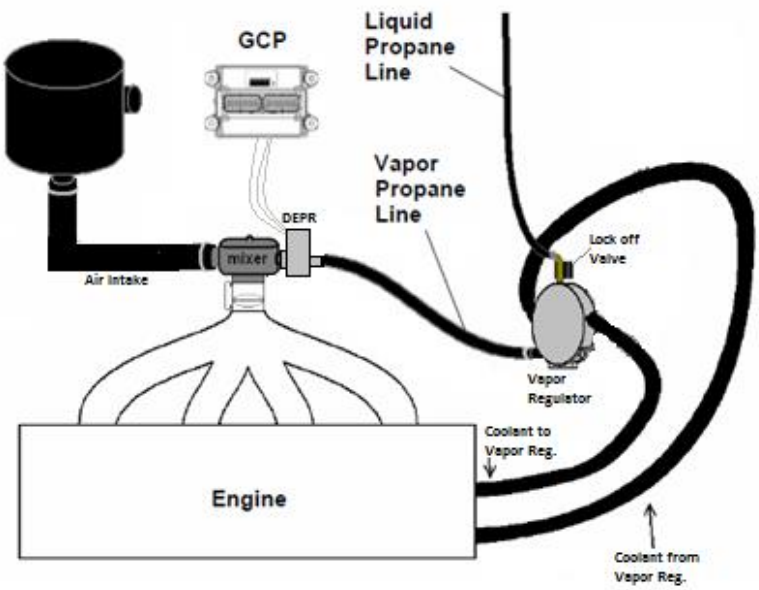


Actuator / Data Link Connector (DLC)



MSG-425 FUEL SYSTEM

GENERAL INFORMATION –

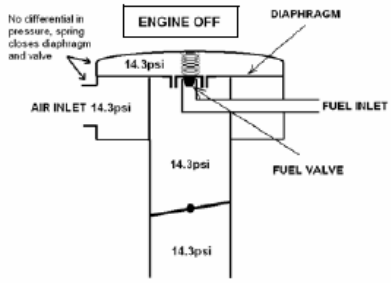


DRY FUEL

Description

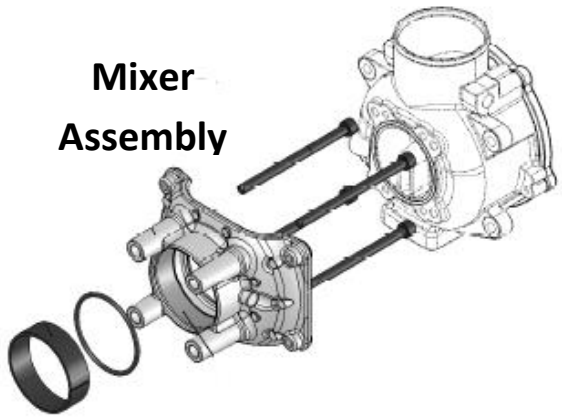
This engine with the proper fuel equipment can also operate on dry fuel such as LPG Grade HD5 and natural gas (1050 BTU/ft3). Natural Gas fuel specification must meet or exceed 38.7 MJ/m3 (UK) 39.0 MJ/m3 (USA). Vaporized propane is introduced into the engine with a

Vapor Carburetor. Pressure is regulated by an Direct Electronic Pressure Regulator (DEPR) which is controlled by the GCP. Coolant is circulated through the DEPR.



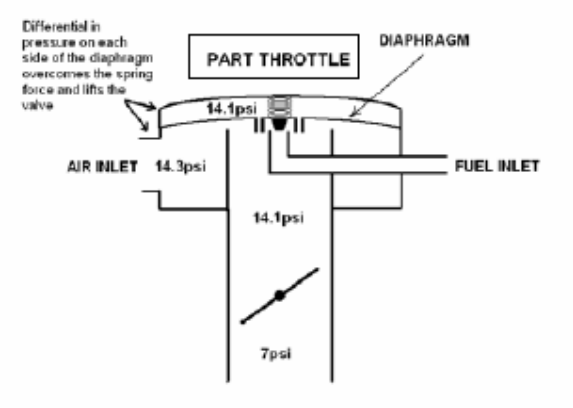
Operation

The dry fuel vapor carburetor is a device by which fuel can be added to passing air flow. The amount of fuel added is related to the amount of air passing through the carburetor.

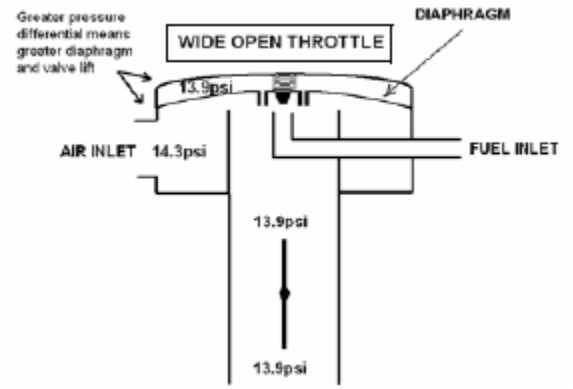


The variable venturi carburetor controls fuel flow based on a differential pressure across the diaphragm. The more air the engine demands, the lower the pressure in the throat and hence on the top of the diaphragm. When the pressure on the top of the diaphragm is low enough, the diaphragm overcomes the spring force holding it down and lifts and allows fuel to be drawn from the fuel port into the air flow into the engine.

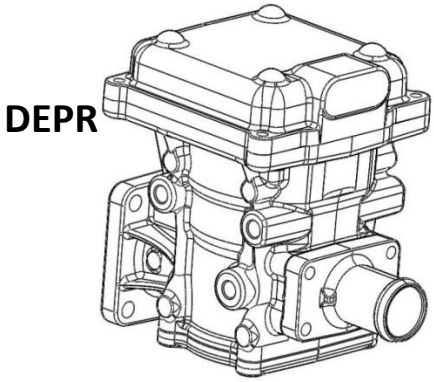
MSG-425 FUEL SYSTEM



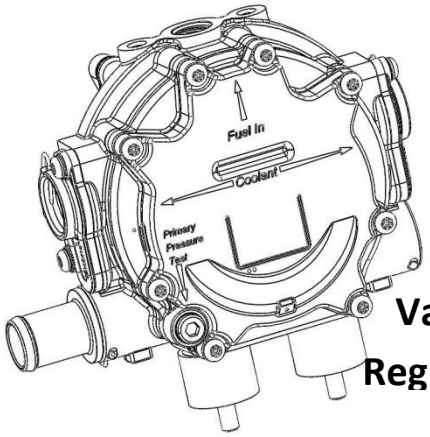
The greater the airflow into the engine, the greater the pressure drop across the diaphragm and the more lift occurs on the fuel valve. This allows more fuel to be drawn into the engine.



While the carburetor is designed to mix the fuel and air and adjust fuel to match the speed and load of the engine, it has only “ballpark” accuracy. This accuracy is not fine enough to achieve emissions targets. To achieve accurate fueling, the air inlet pressure to the carburetor is controlled by a Direct Electronic Pressure Regulator (DEPR).



The DEPR serves to control the vapor pressure to the mixer. After the propane is vaporized (vapor regulator), the DEPR monitors and controls the vapor pressure to the mixer in reference to the inlet air pressure to the carburetor (mixer).



Vapor Regulator

The DEPR receives a pressure command from the GCP called “Delta P” which is the difference between fuel vapor pressure and the air inlet pressure. This has been calibrated for all speeds and loads. There is a sensor internal to the DEPR that measures the actual “Delta P” of the delivered fuel.

The actuator of the DEPR will then adjust the fuel pressure to the carburetor so that the actual “Delta P” matches the Delta P command from the GCP.

This provides an extremely accurate open loop type of fuel control. After a preset time has passed, the engine will go into closed loop control, using information from the pre and post oxygen sensors to allow further adjustment to meet emissions regulations.

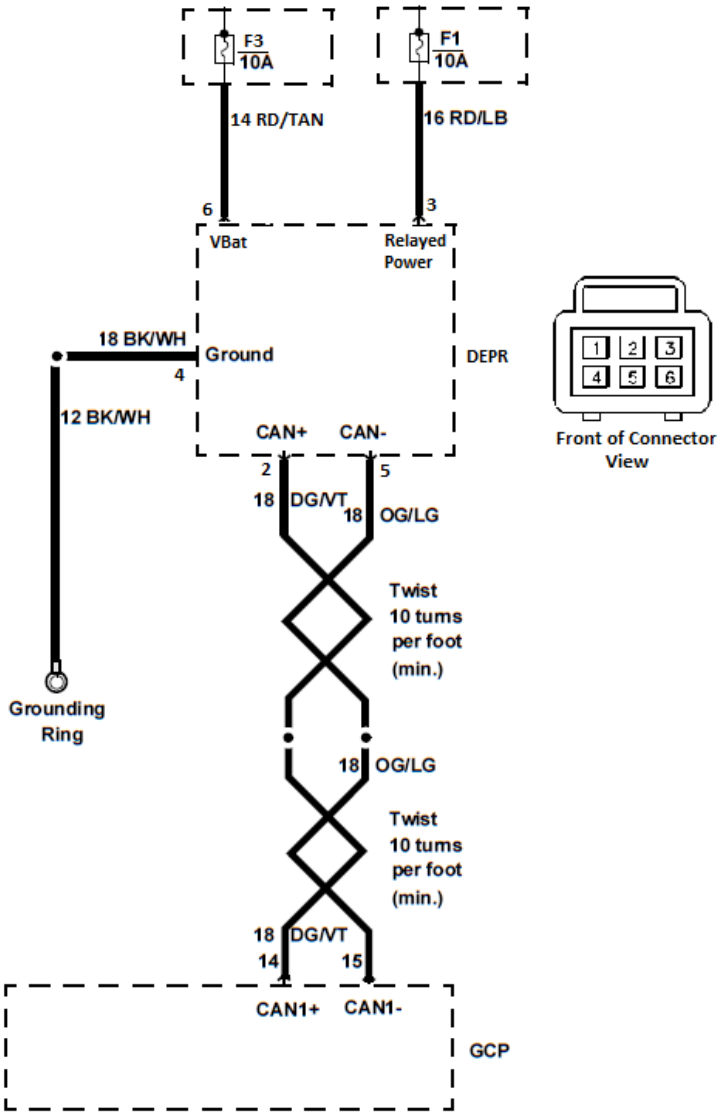
Wiring Diagrams

Revision Level

The following wiring schematics are taken from the wiring diagram labeled below.

Title: EDI / FORD 2.5L W/GCP		
Size: D	Number: 2487000	Rev: D
Date: 11/1/2011	Drawn By: J. SUTTON	
Filename: 2487000d.sch	Sheet 1 of 1	

Engine Controls – Dry Fuel DEPR



DIAGNOSIS AND TESTING - LPG

Symptom Chart

Symptom	Go to
Engine cranking but will not start	Page 12
Engine starts but has rough idle	Page 14
Engine idles with rough acceleration at load	Page 14
Engine is unable to reach full power	Page 14
Overall power loss	Page 12
Engines misses	Page 14
Backfire	Page 16
Emissions failure (Rich Mixture)	Page 17
Emissions failure (Lean Mixture)	Page 18
Engine overheats	Page 19
Engine stops running (Dies)	Page 20

Preliminary Test

This pinpoint test checklist is your guide to the most probably causes of an engine performance complaint when the malfunction is due to the fuel system.

Test Step		Result	Action to Take
1	Inspect Installation.	**Yes**	Go to Step 2..
• Check fuel hose for kinks • Check fuel hose lengths, orientation and presence of parts **Is Everything OK?**		**No**	Repair as necessary
2	Inspect Fuel system for supply leaks.	**Yes**	Repair the leak
• Key OFF • Check for leaks or damaged supply lines from the fuel tank to the fuel lock off valve **Are there any leaks present?**		**No**	Go to Step 3…
3	Inspect the Fuel system for any loose wires or hoses.	**Yes**	Repair or replace as necessary
• Key OFF • Check the fuel lockoff connection and fuel check valve connection • Check the vacuum hoses for any damage or leakage **Is there any damaged or loose wires and hoses?**		**No**	Go to step 4
4	Check for fuel system leaks	**Yes**	Repair the leak
• Key ON • Check the fuel system for leaks • Key OFF **Are there any leaks present?**		**No**	Go to step 5.
5	Check carburetor air inlet for obstructions	**Yes**	Remove the obstruction, re-install the air cleaner and attempt to start
• Remove the air cleaner **Are there any obstructions in the air inlet of the carburetor?**		**No**	Proceed to appropriate troubleshooting section

Diagnostic Charts

Perform the preliminary test before proceeding.

Engine Cranking but Will Not Start

Test Step		Result	Action to Take
1	Check fuel tank	**Yes**	Fill or replace the fuel tank. (Do not exceed 80% of liquid capacity)
Is fuel tank empty?		**No**	Go to Step 2.
2	Check fuel valve	**Yes**	Slowly open the fuel valve
Is liquid fuel valve closed?		**No**	Go to step 3.
3	Check the excess flow valve	**Yes**	Reset excess flow safety valve • Close the main fuel valve • Wait for a clicking sound from the excess flow valve indicating the valve has reset • Slowly open the main fuel valve
Is excess fuel valve tripped and closed?		**No**	Perform prelim. Test before proceeding to step 4
4	Check lockoff valve supply voltage	**Yes**	12 volts to lockoff activation circuit is open, shorted to gnd or the GCP module is faulty. Check wiring, connectors and fused for possible cause.
• Key OFF • Disconnect lock off valve connector from harness • Key ON • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**		**No**	Go to step 5.
5	Check primary fuel pressure to regulator	**Yes**	Fuel filter element may be clogged, inspect and/or replace the fuel filter. Lockoff valve may be faulty, replace the lockoff valve.
• Verfiy that 120-180 psi is going to the regulator • Check downstream of the lock off valve • Key ON **Is the pressure not in the above range?**		**No**	Go to Step 6
6	Check for icing or freezing of the regulator.	**Yes**	The presence of ice on the converter without the engine cranking indicated the possibility of a fuel leak past the primary sea of the converter. May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.
• Key ON • Check for ice or frost build up on the converter casing and outlet port • Key OFF • **Is ice present?**		**No**	

Diagnostic Aids

Fuel Lock Solenoid: The fuel lock is an electronic solenoid that is opened to allow fuel flow when the key is turned ON. High temperatures may cause the solenoid to become intermittent, not opening to supply sufficient fuel pressure.

Fuel Filter: There may be a filter element located in the inlet of the fuel lockoff valve which may become clogged and limit fuel flow, especially at low tank pressures. Check the filter and replace or clean as necessary.

Fuel Line Restrictions: The vehicle specifications table specifies the fuel line to be a certain size. If the fuel line from the tank to the fuel lock is not the proper size, or any valves or fittings with flow restrictive characteristics are used, the fuel flow will not be sufficient to the converter with low tank pressure. Correct any fuel line or fitting restrictions.

Mixer Assembly (Carburetor): It is possible that a backfire may have caused the fuel valve to partially come off of its retainer and restrict fuel, check the mixer fuel valves.

Regulator Assembly (Converter): If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

MSG-425 FUEL SYSTEM

The pinpoint tests below should be performed after the preliminary tests and "Engine Cranks but Will Not Start" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Engine Idles With Rough Acceleration At Load, Not Able to Reach Full Power or Misses

Test Step	Result	Action to Take
1 Check for icing or freezing of the regulator. • With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**	**Yes** **No**	The presence of ice on the converter with the engine running, indicates the possibility of a coolant supply problem. Check coolant level and the coolant system for leaks. Check for proper coolant type. Go to Step 2.
2 Check DEPR operation. • With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**	**Yes** **No**	Possible wiring issue, faulty ECU, or faulty DEPR, view page 9 of this section for wiring. Go to Step 3.
3 Check DEPR supply voltage • Key OFF • Disconnect DEPR electrical connector • Key ON • Check pins 3 and 6 for 12 volt supply in the harness **Is the voltage less than 11.5 volts?**	**Yes** **No**	12 volt DEPR circuit is open, shorted to gnd or the GCP module is faulty. Check wiring, connectors and fuses for possible causes. View page 9 of this section for wiring Go to step 4.
4 Check the vapor regulator operation • Engine OFF • Install a pressure gauge on the "Primary Pressure Test" port • Start and idle the engine **Did you NOT measure 3.5psi?**	**Yes** **No**	Regulator is malfunctioning, replace the regulator. Go to step 5.
5 Check fuel lock supply voltage. • Key Off • Disconnect fuellock connector from harness • Key On • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**	**Yes** **No**	12 volt fuelock activation circuit is open, shorted to ground or the GCP module is faulty. Check wiring, connectors and fuses for possible cause. Go to step 6.
6 Check the carburetor air valve for binding • With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. Pressing on the diaphragm will move the valve. **Is the air valve binding?**	**Yes** **No**	Replace the mixer. May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

Diagnostic Aids

Fuel Lock Solenoid: The fuel lock is an electronic solenoid that is opened to allow fuel flow when the key is turned ON. High temperatures may cause the solenoid to become intermittent, not opening to supply sufficient fuel pressure.

Fuel Filter: There is a filter element located in the inlet of the fuel lock which may become clogged and limit fuel flow, especially at low tank pressures. Check the filter and replace as necessary.

Mixer Assembly (Carburetor): It is possible that a backfire may have caused the fuel valve to partially come off of its retainer and restrict fuel, check the mixer fuel valves, see section 475-1 for disassembly.

Fuel Line Restrictions: The vehicle specifications table specifies the fuel line to be a certain size. If the fuel line from the tank to the fuel lock is not the proper size, or any valves or fittings with flow restrictive characteristics are used, the fuel flow will not be sufficient to the converter with low tank pressure. Correct any fuel line or fitting restrictions.

Regulator Assembly: If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

The pinpoint tests below should be performed after the preliminary tests and "Engine Backfires" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding

Engine Backfires

Test Step		Result	Action to Take
1	Check for icing or freezing of the regulator.	**Yes**	The presence of ice on the converter with the engine running, indicates the possibility of a coolant supply problem. Check coolant level and the coolant system for leaks. Check for proper coolant type.
• With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**		**No**	Go to Step 2.
2	Check DEPR operation.		Possible wiring issue, faulty ECU, or faulty DEPR. View page 9 of this section for wiring
• With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**		**Yes** **No**	Go to Step 3.
3	Check DEPR supply voltage	**Yes**	12 volt DEPR circuit is open, shorted to gnd or the GCP module is faulty. Check wiring, connectors and fuses for possible causes. View page 9 of this section for wiring
• Key OFF • Disconnect DEPR electrical connector • Key ON • Check pins 3 and 6 for 12 volt supply in the harness **Is the voltage less than 11.5 volts?**		**No**	Go to step 4.
4	Check the vapor regulator operation	**Yes**	Regulator is malfunctioning, replace the regulator.
• Engine OFF • Install a pressure gauge on the "Primary Pressure Test" port • Start and idle the engine **Did you NOT measure 3.5psi?**		**No**	Go to Step 5.
5	During startup, check for fuel lock leakage (not closing).		This would indicate the fuel lock is not closing and allowing fuel to pass in the OFF position. Replace the fuel lock.
• Close the tanks main fuel valve • Install a pressure gauge on the primary test port of the vapor regulator • Key Off • Slowly open the main fuel valve **Do you measure any fuel pressure?**		**Yes** **No**	May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

The pinpoint tests below should be performed after the preliminary tests and “Emission failure – Rick Mixture” chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Emission Failure - Rich Mixture

Test Step		Result	Action to Take
1	Check for clogged or restricted air filter. • Remove air filter • Start the engine and re-check emission levels. **Has the (rich) emission failure been eliminated?**	**Yes** **No**	This would indicate a clogged air cleaner as the cause. Replace as necessary. Go to step 2.
2	Check the carburetor air valve for binding • With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**	**Yes** **No**	Replace the mixer. Go to Step 3
3	Check DEPR operation • With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**	**Yes** **No**	DEPR is likely not malfunctioning. Possible wiring issue, faulty ECU, or faulty DEPR. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

The pinpoint tests below should be performed after the preliminary tests and "Emission failure – Lean Mixture" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Emission Failure - Lean Mixture

Test Step		Result	Action to Take
1	Check regulator fuel supply	**Yes**	The fuel filter may be restricting flow or the fuel lock may be intermittent. Go to step 2.
• Install pressure gauge on the primary test port of the vapor regulator • Start the engine to induce the failure **Is the primary pressure less than 3.5psi or fluctuating?**		**No**	Go to step 3.
2	Check fuel lock supply voltage.	**Yes**	12 volt fuelock activation circuit is open, shorted to ground or the GCP module is faulty. Check wiring, connectors and fuses for possible cause.
• Key Off • Disconnect fuellock connector from harness • Key On • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**		**No**	Go to step 3.
3	Check DEPR operation	**Yes**	Go to Step 4
• With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**		**No**	Possible wiring issue, faulty ECU, or faulty DEPR
4	Check the carburetor air valve for binding	**Yes**	Replace the mixer.
• With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**		**No**	May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

The pinpoint tests below should be performed after the preliminary tests and “Engine Overheats” chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Engine Overheats

Test Step		Result	Action to Take
1	Check for icing or freezing of the regulator.	**Yes**	The presence of ice on the converter, with the engine running, indicates the possibility of a coolant supply problem. Check Coolant level and the coolant system for leaks. Check for proper coolant type.
• With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**		**No**	Go to step 2.
2	Check the vapor regulator operation	**Yes**	Regulator is functioning properly
• Engine OFF • Install a pressure gauge on the “Primary Pressure Test” port • Start and idle the engine **Did you measure 3.5psi?**		**No**	Go to step 3
3	Check the carburetor air valve for binding	**Yes**	Replace the mixer.
• With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**		**No**	Refer to section 5 for cooling system troubleshooting.

Diagnostic Aids

Regulator Assembly (Converter & FCV): Overheating is typically related to a cooling or coolant problem. There is a possibility of a gasket leak inside the regulator, which would allow coolant to pass through to the fuel supply. This may affect the emissions if large enough. In this situation the coolant level should consistently drop, as coolant is lost through the fuel path. If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

The pinpoint tests below should be performed after the preliminary tests and “Engine stops running and dies” chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Engine Stops Running (Dies)

Test Step		Result	Action to Take
1	Check for icing or freezing of the regulator. • With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**	**Yes** **No**	The presence of ice on the converter, with the engine running, indicates the possibility of a coolant supply problem. Check Coolant level and the coolant system for leaks. Check for proper coolant type. Go to step 2.
2	Check regulator fuel supply • Install pressure gauge on primary test port of vapor regulator. • Start the engine to induce the failure **Is the primary pressure less than 3.5 psi or fluctuating?**	**Yes** **No**	The fuel filter may be clogged or the fuel lock may be intermittent. Go to step 3. Go to step 4
3	Check fuel lock supply voltage. • Key Off • Disconnect fuellock connector from harness • Key On • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**	**Yes** **No**	12 volt fuelock activation circuit is open, shorted to ground or the GCP module is faulty. Check wiring, connectors and fuses for possible cause. Go to step 4.
4	Check the carburetor air valve for binding • With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**	**Yes** **No**	Replace the mixer. May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

Diagnostic Aids

Fuel Lock Solenoid : The fuel lock is an electronic solenoid that is opened to allow fuel flow when the key is turned ON. High temperatures may cause the solenoid to become intermittent, not opening to supply sufficient fuel pressure.

Fuel Filter: There is a filter element located in the inlet of the fuel lock which may become clogged and limit fuel flow, especially at low tank pressures. Check the filter and replace as necessary.

Fuel Line Restrictions: The vehicle specifications table specifies the fuel line to be a certain size. If the fuel line from the tank to the fuel lock is not the proper size, or any valves or fittings with flow restrictive characteristics are used, the fuel flow will not be sufficient to the converter with low tank pressure. Correct any fuel line or fitting restrictions.

Mixer Assembly (Carburetor): It is possible that a backfire may have caused the fuel valve to partially come off of it's retainer and restrict fuel, check the mixer fuel valves.. Also check the mixer adapter plates for leakage past the carburetor.

Regulator Assembly (Converter & FCV): If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

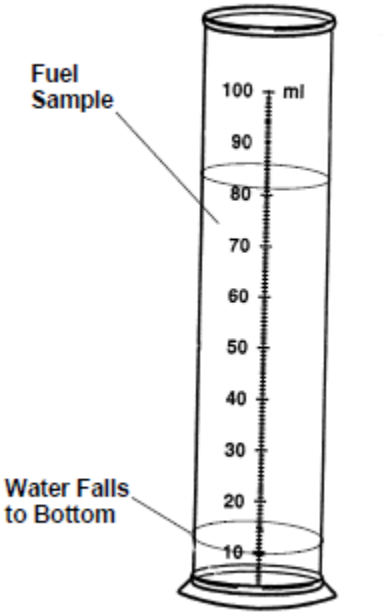
DIAGNOSIS AND TESTING – GASOLINE

NOTE: For diagnosis of Electronic Engine Control - refer to Section 08.

Visual Inspection

Check for dirt or water in the fuel tank. Water and dirt that accumulate in the fuel tank can cause a restricted fuel line, filter or a malfunction of the fuel pump.

Condensation, which is the greatest source of water entering the fuel tank, is formed by moisture in the air when it strikes the cold interior walls of the fuel tank.



Check the fuel filter. If the accumulation of dirt and water in the filter is excessive, the fuel tank should be removed and flushed, and the line from the fuel pump to the tank should be blown out.

Check fuel lines for damage. Air leakage in the fuel inlet line can cause low fuel pump pressure and volume.

Check fuel tank vent. A restricted fuel tank vent can cause low fuel pump pressure and volume and can result in collapsed inlet hoses or a collapsed fuel tank. High or low pressure are the two most likely fuel pump troubles that will affect engine performance. Low pressure will cause a lean mixture and fuel starvation at high speeds, and excessive pressure will cause high fuel consumption and possible flooding.

Fuel Pressure Check

WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Connect to the GCP display
2. Put the key in the on position.
3. On the faults page check the fuel pressure by cycling the keyswitch.
4. Fuel pressure should be as follows:
    a. Key on, Engine off (first 50 seconds): 60psia
    b. Engine running:60psia

Note: Refer to the engine controls section for GCP display setup and installation.

To check the actual fuel pressure, a gauge will have to be installed in-line of the fuel system close the fuel rail.

- Fuel pressure should be as follows:
    - Key on, Engine off (first 50 seconds): 45psig
    - Engine running: 45psig

If fuel pressure is insufficient, check for a clogged pump filter, screen or fuel filter. Also check for a break or restriction in the fuel lines. If fuel pump is inoperative, check for damaged or loose ground or improper wiring. Make sure fuel lines connections area tight and not leaking.

Note: The GCP is reading fuel pressure at the fuel block located after the fuel pump.

Fuel Pump Check

The fuel pump is modulated with a PWM signal from the GCP to precisely control the fuel pressure to the injectors. The positive side of the fuel pump will always have 12 volts with the engine running which is supplied from the fuel pump relay.

- PWM signal from the GCP is Pin 90
- If 12 volts is present ensure the wirings to the GCP for the PWM signal. If wiring is ok, possible faulty GCP.

Fuel Block Check

The fuel block monitors the fuel pressure and fuel temperature, which is what the GCP display is reading.

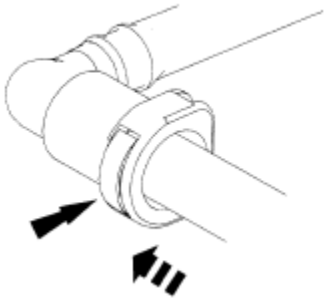
- Check wiring from the fuel block to the main engine harness
- If damaged replace the fuel block jumper harness
- Bad or diesel fuel can damage this component. Replace if known fuel contamination.
- Grounding out the fuel pump can cause the fuel pump to output ~120psia. If this is done and the GCP display does not read the higher pressure then the sensor is possibly bad. Check the wiring and if that is ok, replace the fuel block.
- If a gauge is installed in-line of the fuel rail, this reading can be checked against the fuel pressure read in the GCP display. If these do not match then a possible faulty fuel block sensor.

Quick Connect Coupling - Type I - Disconnect

WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

CAUTION: Do not use any tools. Use of tools may cause a deformity in the coupling components which can cause fuel leaks.

1. Relieve the fuel system pressure -- Refer to “Fuel Pressure Relief” on page 31 of this section.
2. Press the fuel tube quick connect coupling button and pull fuel tube to disconnect.



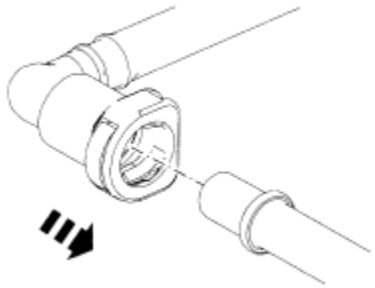
Quick Connect Coupling - Type I - Connect

1. Inspect for damage and clean fittings.

CAUTION: Make sure the fuel tube clicks into place when installing the tube. To make sure that the fuel tube is fully seated, pull on the tube.

2. Lubricate the o-ring seals with clean engine oil.

3. Install the quick connect coupling onto the tube until it is fully seated.



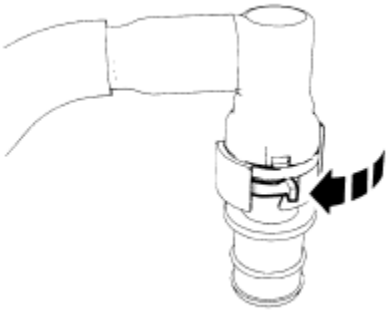
4. Pull on the fitting to make sure it is fully engaged.

Quick Connect Coupling - Type II - Disconnect

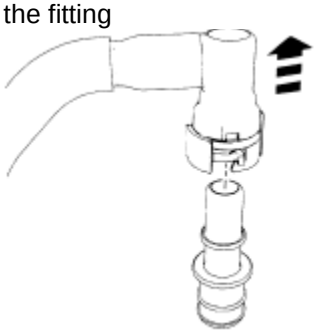
WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

CAUTION: Do not use any tools. Use of tools may cause a deformity in the coupling components which can cause fuel leaks.

1. Relieve the fuel system pressure -- Refer to “Fuel Pressure Relief” on page 31 of this section.
2. Release the locking tab on the quick connect coupling.



3. Separate the quick connect coupling from the fitting

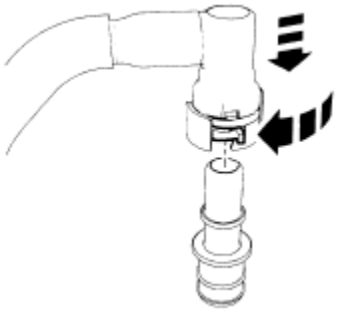


Quick Connect Coupling - Type II – Connect

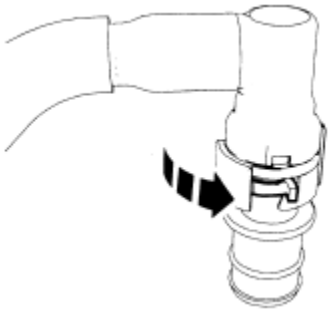
1. Inspect for damage and clean fittings.

CAUTION: Make sure the fuel tube clicks into place when installing the tube. To make sure that the fuel tube is fully seated, pull on the tube.

2. Lubricate the o-ring seals with clean engine oil.
3. Release the locking tab and install the quick connect coupling onto the fitting.



4. Position the locking tab into the latched position.



5. Pull on the fitting to make sure it is fully engaged.

REMOVAL AND INSTALLATION

Fuel Rail & Injectors - Replacement

WARNING: DO NOT SMOKE OR CARRY LIGHTED TOBACCO OR OPEN FLAME OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENT. HIGHLY FLAMMABLE MIXTURES ARE ALWAYS PRESENT AND MAY BE IGNITED, RESULTING IN POSSIBLE PERSONAL INJURY.

WARNING: FUEL IN THE FUEL SYSTEM REMAINS UNDER HIGH PRESSURE EVEN WHEN THE ENGINE IS NOT RUNNING. BEFORE WORKING ON OR DISCONNECTING ANY OF THE FUEL LINES OR FUEL SYSTEM COMPONENTS, THE FUEL SYSTEM PRESSURE MUST BE RELIEVED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

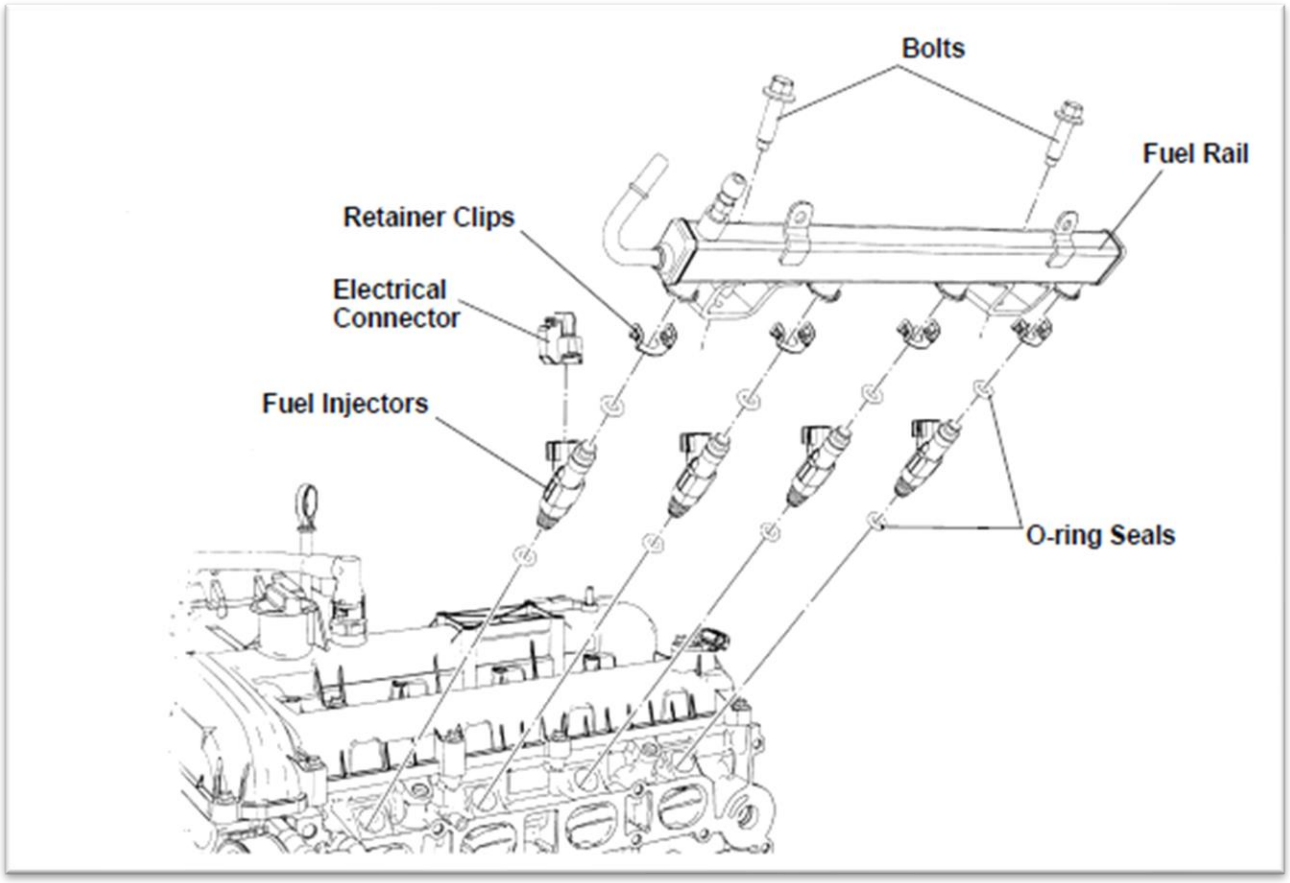
1. Disconnect the battery ground cable.
2. Remove and/or disconnect components to allow access and removal of the fuel rail & injectors. Label if necessary to allow for correct reinstallation.

CAUTION: After disconnecting fuel lines, plug the ends to prevent fuel leakage.

3. Disconnect fuel lines -- Refer to “General Service Procedures” on page 31of this section.
4. Disconnect injector electrical connectors.
5. Remove bolts.
6. Carefully remove the fuel rail and injector assembly
7. If necessary, remove the retaining clips and separate the fuel injectors from the fuel rail – discard the o-rings.

CAUTION: Use o-ring seals that are made of special fuel-resistance material. The use of ordinary o-rintg seals can cause the fuel system to leak. Do not reuse the o-ring seals

8. Reverse procedure to install:
   - Lubricate new o-rings with clean engine oil
   - Tighten fuel rail bolts to 25 Nm (18 lb-ft).

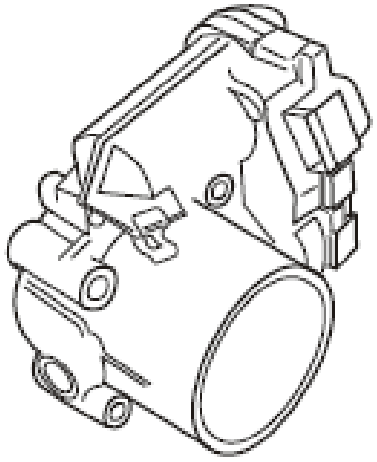


Actuator - Removal

1. Remove and/or disconnect components to allow access and removal of the actuator. Label if necessary to allow for correct reinstallation.
2. Disconnect air cleaner components from actuator.
3. Disconnect accelerator cable.
4. Disconnect electrical connectors.
5. Remove nuts.
6. Remove actuator and gasket.

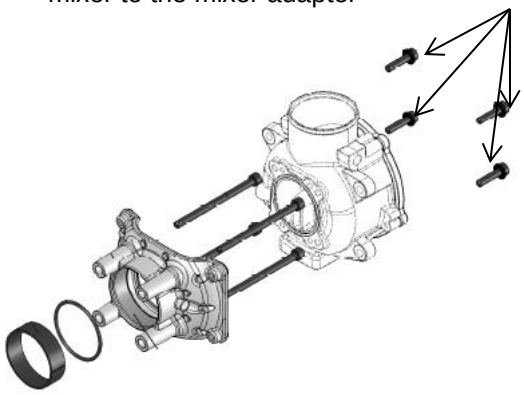
Actuator - Installation

1. Inspect gasket and install a new one if necessary.
2. Position actuator onto studs.
3. Install nuts
    - Tighten to 8 ft-lb
4. Reconnect electrical connectors.
5. Reconnect accelerator cable.
6. Reconnect air cleaner components to actuator.
7. Install or connect any other component removed or disconnected.

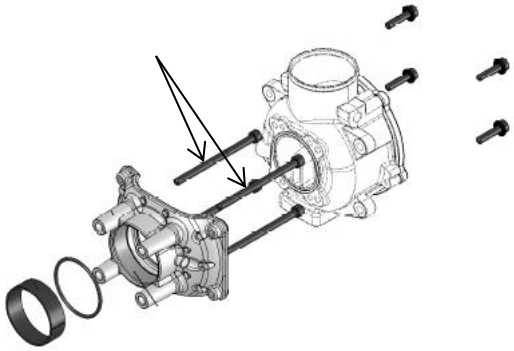


Mixer - Removal

1. Remove top four bolts that hold the mixer to the mixer adapter



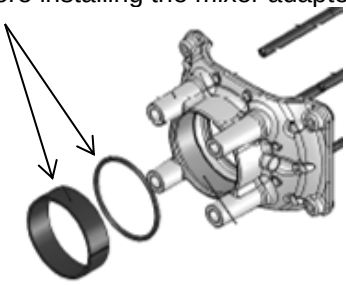
2. To Remove the Mixer adapter, unscrew the four bolts. This will also unmount the actuator



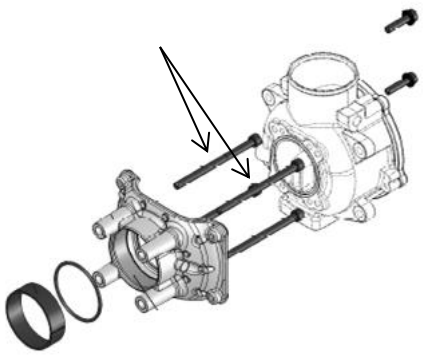
3. The DEPR can also be disconnected from the mixer via the four mounting bolts.

Mixer - Installation

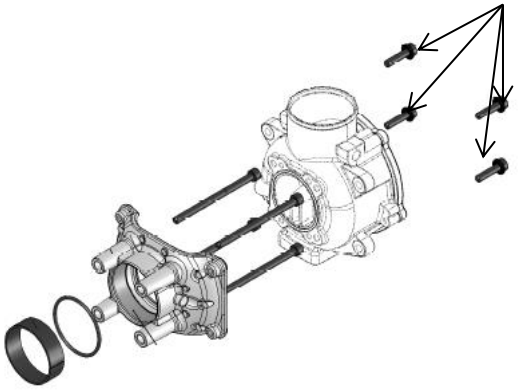
1. Reverse the removal procedure. Ensure to install the two gaskets on the actuator before installing the mixer adapter.



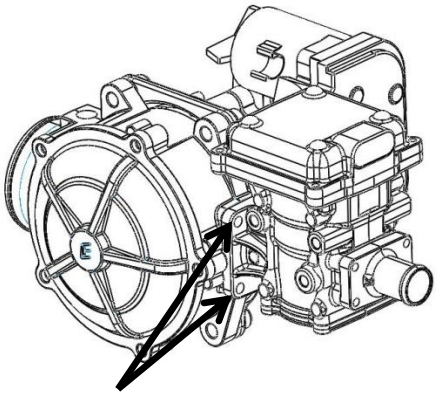
2. Mount the actuator with the mixer adapter using the four 85mm long M6x1.0 bolts. Ensure the gasket for the actuator is not damaged.
    - Tighten to 6.6lb-ft



3. Mount the mixer to the mixer adapter using the four short M6x1.0 bolts. Ensure the gasket on the mixer is not damaged.
    - Tighten to 6.6 lb-ft



4. Mount the DEPR to the mixer (if uninstalled). Ensure the rubber gasket on the DEPR is not damaged.
    - Tighten to 35 lb-in (4Nm)



Specifications

GENERAL SPECIFICATIONS	
Fuel Pressure	414-448kPA (60-65psi)
Motorcraft SAE 5W20 Super Premium	WSS-M2C930-A

Torque Specifications			
Description	Nm	Lb.ft.	Lb.in
Fuel Rail Bolts	25	18	

MSG-425 COOLING SYSTEM

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MSG-425 COOLING SYSTEM

CAUTIONS & WARNINGS

WARNING: THE RADIATOR OR DEGAS TANK IS EQUIPPED WITH A PRESSURE CAP. IT IS DANGEROUS TO REMOVE THIS WHEN THE SYSTEM IS VERY HOT.

WARNING: NEVER REMOVE THE PRESSURE RELIEF CAP WHILE THE ENGINE IS OPERATING OR WHEN THE COOLING SYSTEM IS HOT. MAY CAUSE PERSONAL INJURY OR DAMAGE TO COOLING SYSTEM OR ENGINE. TO REDUCE THE RISK OF HAVING SCALDING HOT COOLANT OR STEAM BLOW OUT OF THE DEGAS BOTTLE WHEN REMOVING THE PRESSURE RELIEF CAP, WAIT UNTIL THE ENGINE HAS COOLED DOWN TO AT LEAST 40°C (110°F).

1. Wrap a thick cloth around the pressure relief cap and turn it slowly one-half turn counterclockwise. Stepping back while the pressure is released from the cooling system.
2. When you are sure all the pressure has been released, (still with a cloth) turn counterclockwise and remove the pressure relief cap.

WARNING: ANTIFREEZE CONTAINS MONO ETHYLENE GLYCOL AND OTHER CONSTITUENTS WHICH ARE TOXIC IF TAKEN INTERNALLY AND CAN BE ABSORBED IN TOXIC AMOUNTS ON REPEATED OR PROLONGED SKIN CONTACT. PERSONS USING ANTIFREEZE ARE RECOMMENDED TO ADHERE TO THE FOLLOWING PRECAUTIONS:

- **ANTIFREEZE MUST NEVER BE TAKEN INTERNALLY. IF ANTIFREEZE IS SWALLOWED ACCIDENTALLY, MEDICAL ADVICE SHOULD BE SOUGHT IMMEDIATELY**
- **PRECAUTIONS SHOULD BE TAKEN TO AVOID SKIN CONTACT WITH ANTIFREEZE. IN THE EVENT OF ACCIDENTAL SPILLAGE ONTO THE SKIN, ANTIFREEZE SHOULD BE WASHED OFF AS SOON AS PRACTICABLE. IF CLOTHING IS SPLASHED WITH ANTIFREEZE, IT SHOULD BE REMOVED AND WASHED BEFORE BEING WORN AGAIN, TO AVOID PROLONGED SKIN CONTACT.**
- **FOR REGULAR AND FREQUENT HANDLING OF ANTIFREEZE, PROTECTIVE CLOTHING (PLASTIC OR RUBBER GLOVES, BOOTS AND IMPERVIOUS OVERALLS OR APRONS) MUST BE USED TO MINIMIZE SKIN CONTACT.**

CAUTION: Under no circumstances should the engine be started without liquid in the cooling system. This may cause permanent damage to the engine.

CAUTION: The use of straight water as a coolant will cause permanent damage to the engine.

CAUTION: Never use a cold coolant mixture to topup the radiator or degas tank of a hot engine if the coolant level is very low; this could cause serious engine damage.

CAUTION: In territories where freezing conditions may occur, the coolant should consist of a mixture of 50% plain water and 50% Motorcraft Premium Gold coolant, or equivalent. This antifreeze contains additional corrosion inhibitors designed to provide lasting protection for the engine.

CAUTION: Only this antifreeze, or proprietary antifreeze meeting Ford specification WSS-M97B51-A1 should be used when topping-up or re-filling the cooling system. Do not mix coolant types.

CAUTION: Do not add or mix an orange-colored extended life coolant, such as Motorcraft Specialty Orange engine coolant with factory filled coolant WSS-M97B44-D. Mixing Motorcraft Specialty Orange engine coolant or any orange colored extended life product, with factory filled coolant, can result in degraded corrosion protection.

CAUTION: If there is engine coolant in the engine oil or transmission fluid, the cause must be corrected and oil/fluid changed or major component damage can occur.

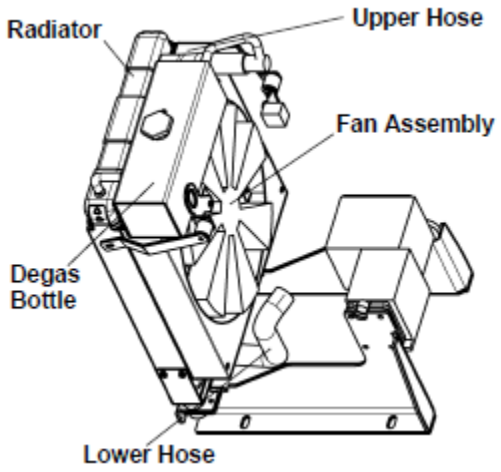
CAUTION: When removing coolant, the coolant must be recovered in a suitable, clean container for reuse. If the coolant is contaminated, it must be recycled
or disposed of correctly.

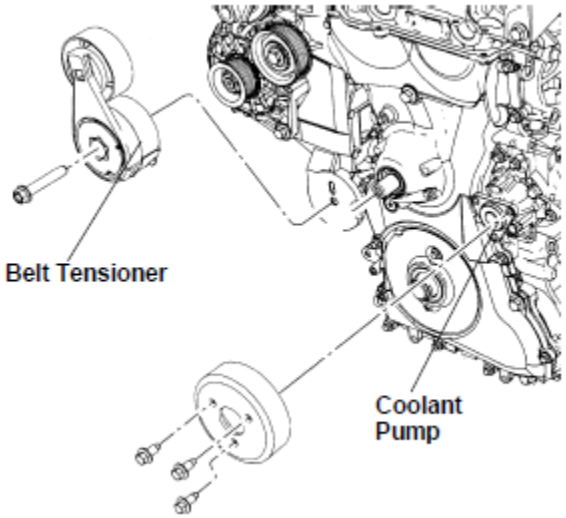
WARNING: DO NOT STAND INLINE WITH OR NEAR THE ENGINE COOLING FAN BLADE WHEN REVVING THE ENGINE. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

CAUTION: Under no circumstances should the drive belt, tensioner or pulleys be lubricated as potential damage to the belt material and tensioner dampening mechanism will occur. Do not apply any fluids or belt dressing to the drive belt or pulleys.

MSG-425 COOLING SYSTEM

GENERAL INFORMATION





Description

The cooling system consists of the following:

- Engine Coolant Temperature (ECT) Sensor
- Fan Assembly
- Radiator and Cap
- Thermostat and Housing
- Degas Bottle
- Engine Block Heater
- Coolant pump
- Coolant

Walter C. Avrea, the owner of patents 3,601,181 and RE27,965, has granted Ford Motor Company rights with respect to cooling systems covered by these patents.

The ECT Sensor is used by the GCP to obtain coolant temperature information. Refer to Section 8 for further information on this sensor.

The coolant fan blade can either draw or push air through the radiator to help cool the system coolant.

The radiator allows excess heat to be transferred to the air. The radiator tanks cannot be repaired. The radiator cap maintains system pressure. This pressure raises the boiling point of the coolant and helps prevent vapor locks in the engine block and cooling system.

The thermostat prevents coolant flow until it reaches a specified temperature. At this temperature, it will open and allow coolant flow through the engine and radiator.

The thermostat and housing are serviced as a unit. The radiator degas bottle holds a surplus coolant when the engine is hot. It also replenishes coolant back to the system as it cools. The degas bottle allows air separation during operation which reduces engine hot spots.

The coolant pump circulates the coolant through the engine block and cylinder heads to the thermostat. If th thermostat is closed, the coolant returns to the coolant pump through a bypass hose. Once the coolant reaches a specified temperature, the thermostat will open, allowing the coolant to flow to the radiator for heat transfer and back to the coolant pump inlet.

Engine coolant provides freeze and boil protection to the engine and cooling components. In order to obtain these protections, the engine coolant must be maintained at the correct concentration and fluid level in the degas bottle or coolant expansion tank.

Coolant is made up of a 50/50 mix of ethylene glycol permanent antifreeze and water. This mixture is to be used year-round with temperatures above -34.4°C (-30°F). If recycled coolant is used, it must meet Ford specification ESE-M97B44-A or WSSM97B44-D.

CAUTION: Not all coolant recycling processes produce coolant which meets Ford specification ESEM97B44- A or WSS-M97B44-D. Use of coolant that does not meet specifications may harm engine and cooling system components.

CAUTION: Do not use alcohol type antifreeze, alkaline brine solutions, or 100,000 mile, red in color antifreeze. This may cause serious engine cooling system damage.

DIAGNOSIS AND TESTING

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

Begin diagnosis by verifying the customer's concern by operating the engine to duplicate the condition. The most frequent cooling system complaints are leakage and overheating. Either of these problems will soon render the engine inoperable.

Perform a visual inspection. If the inspection reveals an obvious concern that can be readily identified, repair as necessary. If the concern remains after the inspection, determine the symptom(s) and go to the Symptom Chart. The Symptom Chart lists cooling system problems, their possible cause and recommended correction.

Visual Inspection

Check for leaks or damage at:

- all hoses, connections and hose clamps
- radiator seams, core and drain petcock
- all block core plugs and drain plugs
- edges of all cooling system gaskets
- transmission oil cooler (if equipped)
- coolant pump shaft and bushing
- thermostat, head and intake manifold gaskets
- coolant pump
- degas bottle
- heater core (if equipped)
- fan and fan clutch
- engine coolant temperature sensor and wiring
- drive belt.

NOTE: A small amount of antifreeze coming out the coolant pump weep hole may be considered normal.

Examine oil dipstick for evidence of coolant contaminated engine oil (white milky appearance). Check radiator for evidences of oil in coolant (leakage at transmission oil cooler if equipped).

Some engines use an ethylene glycol base antifreeze solution to which the manufacturers have added a dye color. The dye color makes the antifreeze solution an excellent leak detector. If this type of solution is not being used in the cooling system, a vegetable dye may be added to aid in locating external leakage.

Coolant Inspection

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

Check level and condition of coolant:

- A dark brown color could indicate a stop leak was used.
- A light or reddish brown color indicates that rust may be present in the cooling system. Flush the system and refill with the correct mixture of distilled water and premium engine coolant.
- An iridescent sheen on top of the coolant could indicate a trace of oil is entering the system.
- A milky brown color may indicate that either engine oil or transmission fluid is entering the cooling system. If transmission fluid is suspected, it may be entering through the transmission cooler in the radiator. If engine oil is suspected, the cause may an internal leak in the engine.

Coolant Range Check

If the engine coolant appearance is acceptable, test the engine coolant freezing point and concentration level.

The antifreeze concentration in a cooling system can be determined by using a suitable hydrometer or a battery/ antifreeze tester.

The freezing point should be in the range -45°C to -23°C (-50°F to -10°F). If the equipment is run in cold climates colder than -36°C (-34°F), it may be necessary to increase the coolant concentration to get adequate freeze protection.

Maximum coolant concentration is 60% coolant to 40% distilled water. If coolant tests too strong, remove some of the coolant and ad distilled water until the readings are acceptable.

Minimum coolant concentration is 40% coolant to 60% distilled water. If coolant tests too weak, drain some coolant out and add straight coolant until readings are acceptable.

Drive Belt Inspection

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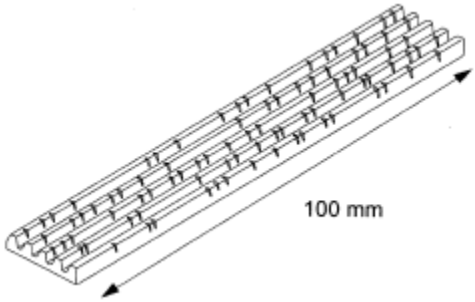
WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

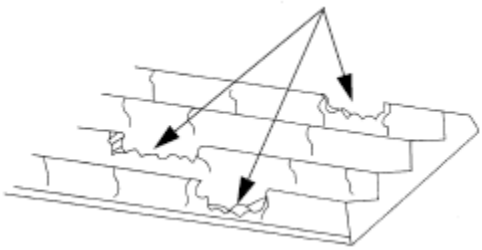
With engine running, observe the belt movement. It should respond when engine is accelerated rapidly. If tensioner moves excessively without rapid acceleration, install a new belt. If excessive movement still exists, install a new tensioner.

Visually inspect the belt for obvious signs of damage.

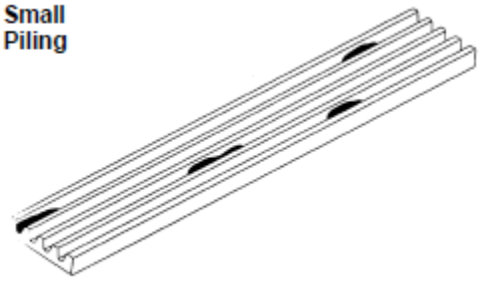
- Up to 15 cracks in a rib over a distance of 100 mm (4.0 in) can be considered acceptable.



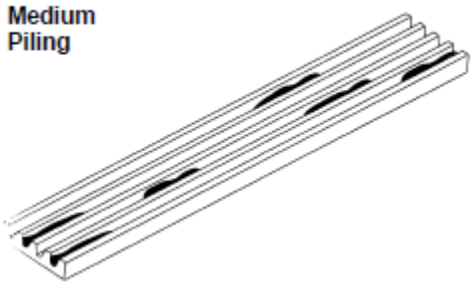
- If cracks are beyond acceptable or, any chunks are found to be missing from the ribs, a new belt must be installed.



- Small scatted deposits of rubber material (known as piling) are not a concern.



- Longer deposits building up to 50% of the rib height is also not a concern, except it can result in excessive noise.



- If heavy deposits are apparent, resulting in noise and belt instability, install a new belt.

- Drive belt squeal that is short and intermittent is expected and considered normal. Constant or reoccurring drive belt squeal can occur with a damaged pulley bearing, fluid contamination, or a loose belt.

- Also check for belt misalignment which can cause a chirping noise. If misalignment is found, check the tensioner for damage, especially the mounting pad surface. Check for a damaged pulley that wobbles. Check mounting brackets for tightness and for any interference.

- Check tensioner with a suitable release tool that it moves without sticking or binding.

- With belt off, check that all pulleys rotate freely without binding.

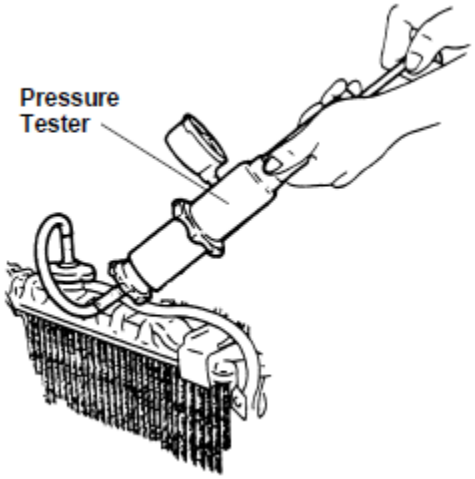
CAUTION: Incorrect drive belt installation will cause excessive drive belt wear and can cause the belt to come off the pulleys.

Symptom Chart

Refer to the following Diagnosis chart for cooling system problems, their possible cause and recommend correction.

CONDITION	POSSIBLE SOURCE	ACTION
Loss of coolant	• Pressure cap and gasket • Leakage • External leakage • Internal leakage	• Inspect, wash gasket and test. Replace only if cap will not hold pressure to specification. • Pressure test system. • Inspect hose, hose connection, radiator, edges of cooling system gaskets, core plugs and drain plugs, transmission oil cooler lines, water pump, heater system components. Repair or replace as required. • Disassembly engine as necessary – check for: cracked intake manifold, blown head gaskets, warped head or block gasket surfaces, cracked cylinder head or engine block.
Engine Overheats	• Low coolant level • Loose fan belt • Pressure cap • Radiator obstruction • Closed thermostat • Fan drive clutch • Ignition • Temp gauge or cold light • Engine • Coolant mixture	• Fill as required. Check for coolant loss. • Adjust. • Test. Replace if necessary. • Remove bugs, leaves, etc. • Test, Replace if necessary. • Test, replace if necessary. • Check timing and advance. Adjust as required. • Check electrical circuits and repair as required. • Check water pump, block for blockage. • 1/2 water and 1/2 permanent anti-freeze mixture.
Engine fails to reach normal operating temperature	• Open thermostat • Temperature gauge or cold light	• Test, replace if necessary. • Check electrical circuits and repair as required.

Cooling System Pressure Test



WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Remove the radiator cap from the radiator filler neck.

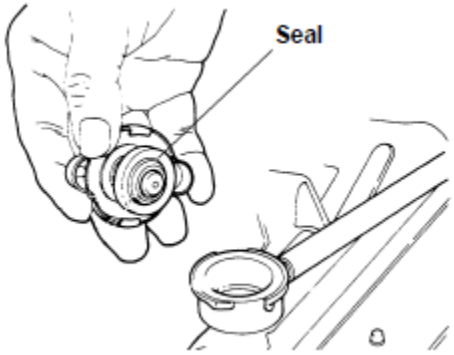
CAUTION: Do not pressurize the cooling system beyond 138 kPa (20 psi).

2. Fill the radiator as needed.
3. Fit the pressure tester to the radiator neck.
4. Pump the cooling system to a maximum of 138 kPa (20 psi) and hold for 2 minutes.
5. If the pressure drops within this time, inspect for leaks and repair as necessary.

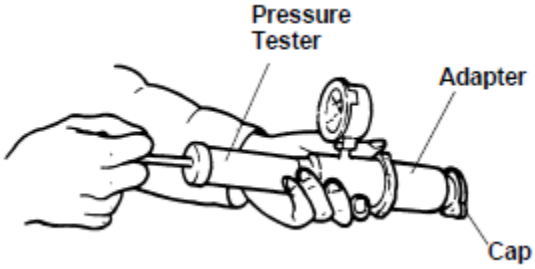
Radiator Cap Pressure Test

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Inspect radiator cap and seals for damage or deterioration - replace as necessary.



2. Fit the radiator cap to the pressure tester using an adapter.



NOTE: If the plunger of the pressure tester is depressed too fast, an incorrect pressure reading will result.

3. Slowly pump the pressure tester until the gauge stops increasing and note the highest pressure reading.

4. Release the pressure and repeat the test.

5. Install a new radiator cap if the pressure is not 124 kPa (18 psi).

Thermostat Operational Check

1. Hold thermostat up to the light.

2. Visually check the valve to be sure it is air tight.
   - Leakage of light all around the valve (at room temperature) indicates a bad thermostat.
   - A slight leakage of light at one or two locations on the perimeter of the valve is normal.

3. Place the thermostat and a thermometer in water.

4. Gradually increase the water temperature

5. Replace thermostat if it does not open at the specified temperatures:
   - Starts to open: 82°C (180°F)
   - Fully open: 97°C (206.6°F)

GENERAL SERVICE PROCEDURES

Draining the Cooling System

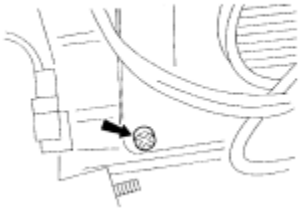
WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Remove radiator cap.

CAUTION: The coolant must be recovered in a suitable, clean container for reuse. If the coolant is contaminated, it must be recycled or disposed of correctly.

2. Open drain cock at radiator and drain old coolant from engine into a suitable container. Close the drain cock when finished

Radiator Drain Cock



3. If necessary, remove the lower radiator hose to completely drain the system. Reinstall when finished.

4. If rust, sludge or other foreign material are present in the old coolant, system should be flushed – Refer to “Flushing the Cooling System” instructions in this section.

Flushing the Cooling System

To remove rust, sludge and other foreign material from the cooling system, use Rotunda Cooling System Cleanser. Removal of such material restores cooling efficiency and avoids overheating.

Always remove the thermostat prior to pressure flushing. A pulsating or reversed direction of flushing water flow will loosen sediment more quickly than a steady flow in the normal direction of coolant flow.

In severe cases where cleaning solvents will not properly clean the cooling system for efficient operation, it will be necessary to use the pressure flushing method. Various types of flushing equipment are available. Follow manufacturer’s operating instructions.

Filling the Cooling System

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

Coolant is made up of a 50/50 mix of ethylene glycol permanent antifreeze and distilled water. This mixture is to be used year-round with temperatures above -34.4°C (-30°F). If recycled coolant is used, it must meet Ford specification ESE-M97B44-A or WSS-M97B44-D.

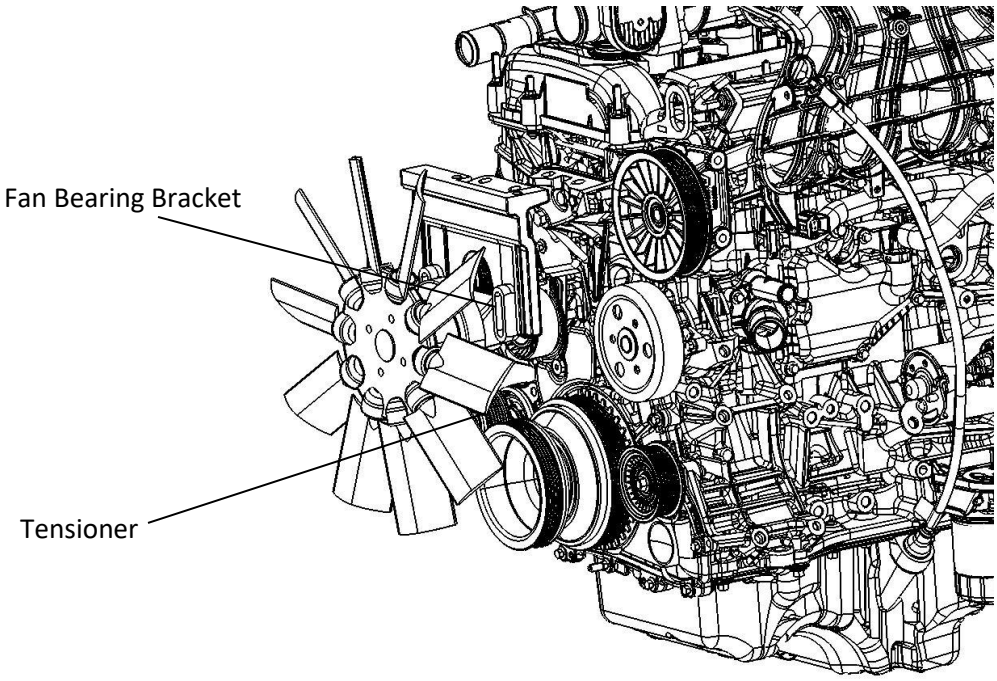
CAUTION: Not all coolant recycling processes produce coolant which meets Ford specification ESEM97B44- A or WSS-M97B44-D. Use of coolant that does not meet specifications may harm engine and cooling system components.

The engine cooling system is filled with Motorcraft Premium Gold Engine Coolant. Always refill the cooling system with the same coolant that was drained from the system, Do not mix coolant types.

CAUTION: Do not use alcohol type antifreeze, alkaline brine solutions, or 100,000 mile - red in color antifreeze. This may cause serious engine cooling system damage.

NOTE: The use of stop leak may change the color of the coolant.

1. Make sure the radiator drain cock is completely closed.
2. Fill the system with the proper coolant mix.
3. Start engine and hold at high idle engine speed for approximately 8 minutes until thermostat opens.
4. Maintain high idle for an additional 3 minutes. Add coolant as necessary.
5. Stop the engine and check for leaks.
6. Verify correct fluid level after engine cools for 20 minutes. Top off the degas bottle to “max” line.



REMOVAL AND INSTALLATION

NOTE: If a major component of the cooling system is renewed such as the radiator, water pump etc., the system should be flushed and re-filled with a 50% solution of Motorcraft Premium Gold engine coolant, or equivalent, and clean water -- Refer to “Flushing the Cooling System” on the previous page.

Fan Belt – Removal

1. Loosen two bolts holding fan bearing bracket in place.
2. Slide the bearing bracket down to loosen belt.
3. Remove belt

Drive Belt - Removal

NOTE: Note belt routing for installation purposes.

1. Rotate tensioner counterclockwise to relieve belt tension.
2. Remove belt.
3. Inspect belt and pulleys -- Refer to “Visual Inspection” of this section.

Drive Belt - Installation

1. Rotate tensioner counterclockwise to relieve tension.
2. Route belt correctly and release tensioner onto belt.
3. Run engine for a minute and then turn off.
4. Recheck belt routing and groove alignment.

Fan Belt – Installation

1. Place belt around extended crank pulley and fan pulley
2. Slide bearing bracket up to tension the belt while ensuring the bearing bracket is level.
3. Tighten bearing bracket bolts.
    - 16Nm (12 lb-ft)

Belt Tensioner – Replacement

1. Remove drive belt -- Refer to “Drive Belt - Removal” above
2. Remove bolt.
3. Remove belt tensioner.
4. Reverse procedure to install:
    - Tighten bolt to 47 Nm (35 lb-ft).

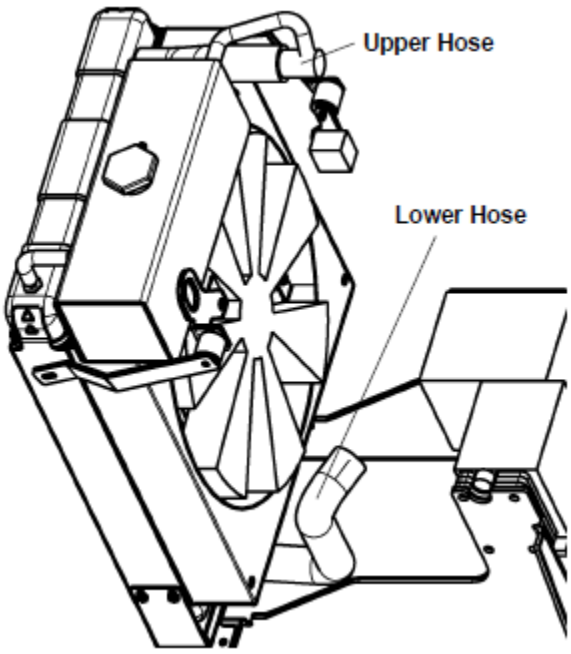
Idler Pulley - Replacement

1. Remove drive belt -- Refer to “Drive Belt - Removal” of this section.
2. Remove belt idler pulley assembly.
3. Reverse procedure to install:
    - Tighten to 47 Nm (35 lb-ft).

Radiator Hose - Removal

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Loosen the clamps at each end of the hose to be removed.
3. Slide the hose off the radiator connection and the engine water outlet connection.



Radiator Hose - Installation

1. Position the clamps at least 1/8 inch from each end of the hose.
2. Coat the connection areas with an approved water resistant sealer and slide the hose on the connection.

NOTE: Make sure the clamps are beyond the bead and placed in the center of the clamping surface of the connections.

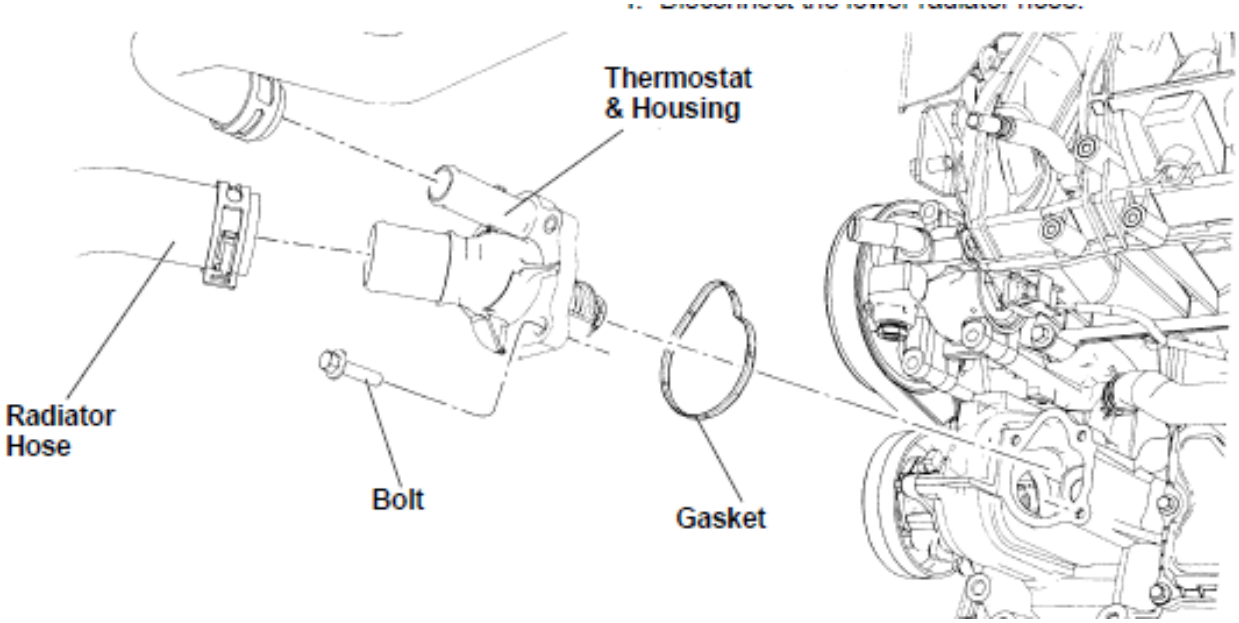
3. Tighten the clamps.
4. Fill the system with coolant -- Refer to “Filling the Cooling System” of this section.
5. Operate the engine for several minutes, then check the hoses and connections for leaks

Thermostat & Housing – Replacement

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: The thermostat and housing are serviced as an assembly.

1. Allow the engine to cool down until the coolant has lowered in temperature to below 110°F.
2. Drain the radiator so coolant level is below the thermostat -- Refer to “Draining the Cooling System” of this section.
3. Remove or disconnect components as necessary to gain access to the thermostat housing.
4. Disconnect the lower radiator hose.
5. Remove bolts and thermostat housing.
6. Reverse procedure to install
    - Clean and inspect gasket, install a new gasket if necessary.
    - Tighten bolts to 10 Nm (89 lb-in).



Coolant Pump - Replacement

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WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.

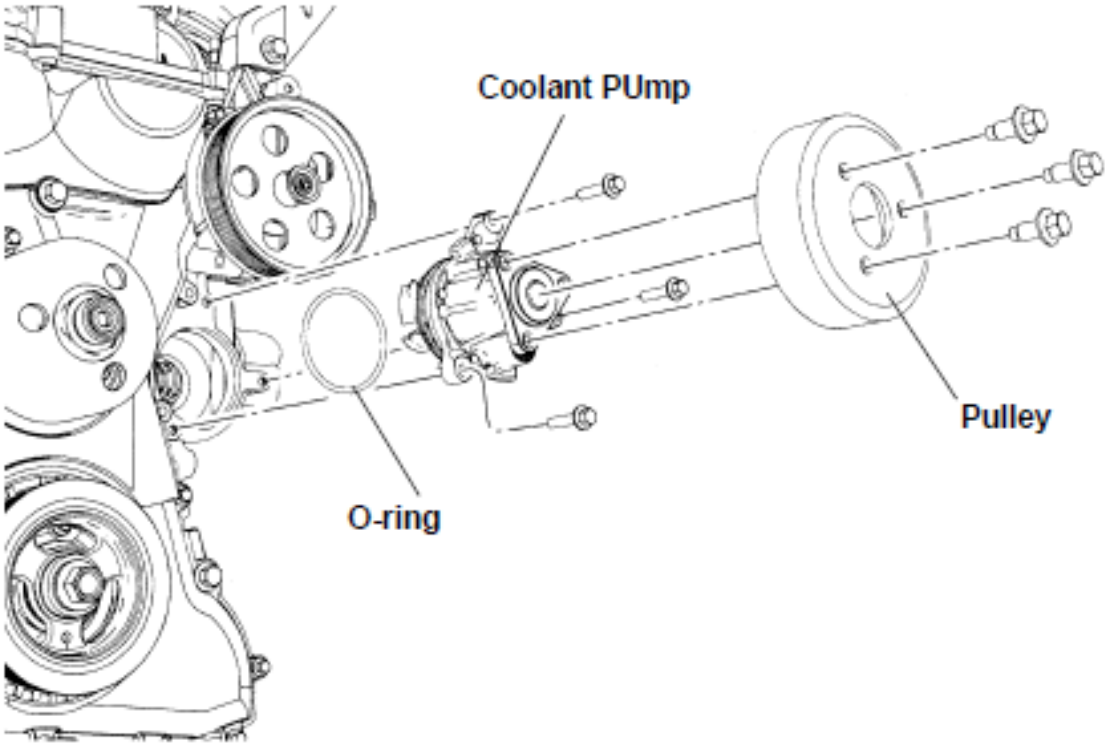
2. Remove or disconnect components as necessary to gain access to the coolant pump.

3. Remove the drive belt -- Refer to “Drive Belt - Installation” of this section.

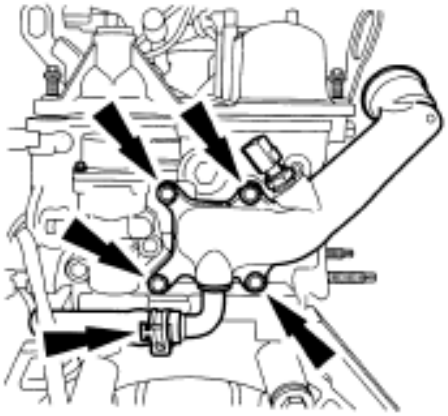
4. Remove 3 bolts and coolant pump pulley.

5. Remove 3 bolts and coolant pump.

6. Reverse procedure to install:
   - Lubricate coolant pump o-ring with clean coolant.
   - Tighten coolant pump bolts to 10 Nm (89 lb-in)
   - Tighten pulley bolts to 25 Nm (18 lb-ft)



Outlet Pipe - Replacement

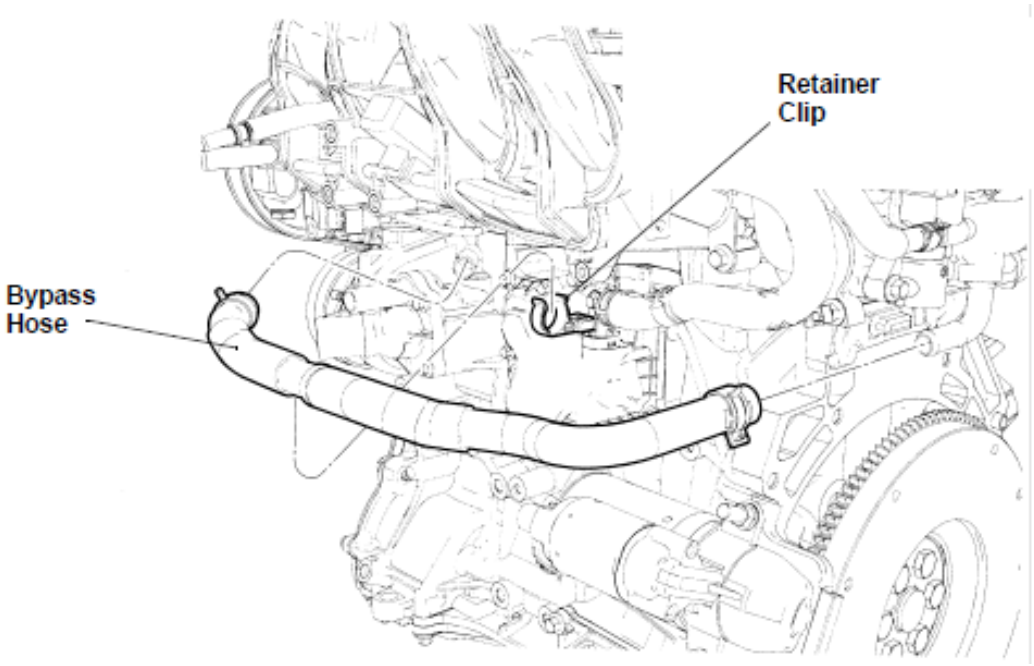


WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Remove or disconnect components as necessary to gain access to the outlet pipe.
3. Disconnect hoses from outlet pipe.
4. Disconnect electrical connector at ECT Sensor.
5. Remove bolts and outlet pipe.
6. Reverse procedure to install:
    - Clean gasket mating surfaces
    - Install new gasket
    - Tighten bolts to 10 Nm (89 lb-in).

Coolant Bypass – Replacement

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Remove or disconnect components as necessary to gain access to the bypass hose
3. Detach coolant bypass hose from the routing clip.
4. Disconnect the coolant bypass hose from the tubes.
5. Reverse procedure to install.



MSG-425 COOLING SYSTEM

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Coolant/Water Mixture	50/50
Pressure Relief Cap Opening Pressure kPa (psi)	89 – 124 kPa (13 – 18 psi)
Radiator Pressure Test	138 kPa (20 psi)
Thermostat start to open temperature	82°C (180°F)
Thermostat full open temperature	97°C (206°F)
Coolant Specification WSS-M97B51-A1	Motorcraft Premium Gold Engine Coolant

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Coolant pump pulley bolts	25	18	
Coolant pump to block bolts	10	---	89
Draincock	2	---	18
Thermostat housing bolts	10	---	89

MSG-425 CHARGING SYSTEM

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Cautions & Warnings

Typical Battery Labeling

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 labeling 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.

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

WARNING: BATTERIES NORMALLY PRODUCE EXPLOSIVE GASES WHICH CAN CAUSE PERSONAL INJURY. THEREFORE, DO NOT ALLOW FLAMES, SPARKS OR ANY IGNITED OBJECT TO COME NEAR THE BATTERY. WHEN CHARGING OR WORKING NEAR A BATTERY, ALWAYS SHIELDYOUR EYES. ALWAYS PROVIDE VENTILATION.

WARNING: WHEN LIFTING A BATTERY, ALWAYS LIFT WITH A BATTERY CARRIER OR WITH YOUR HANDS ON OPPOSITE CORNERS. EXCESSIVE PRESSURE ON THE END WALLS COULD CAUSE ACID TO SPEW THROUGH THE VENT CAPS, RESULTING IN PERSONAL INJURY.

WARNING: IT IS ESSENTIAL THAT THE WIRING CONNECTIONS TO THE GENERATOR ARE NOT REMOVED WHILE THE ENGINE IS RUNNING, AS THIS WILL RESULT IN DAMAGE TO THE REGULATOR OR PERSONAL INJURY.

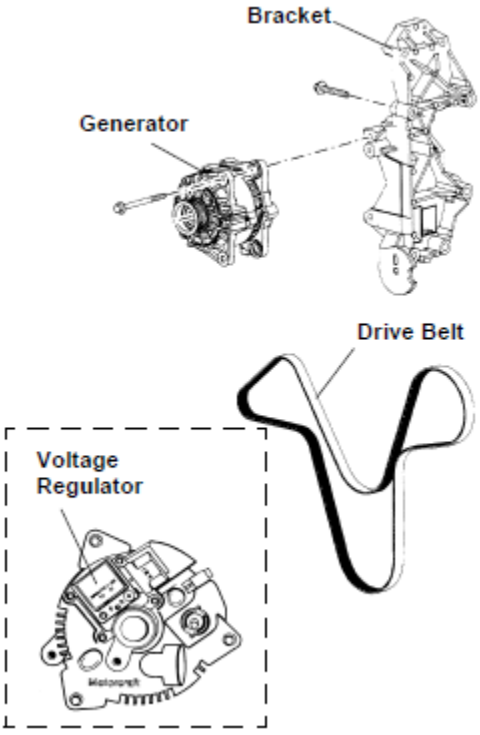
WARNING: KEEP BATTERIES OUT OF THE REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH THE SKIN OR EYES, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES AND GET PROMPT MEDICAL ATTENTION. IF ACID IS SWALLOWED, CALL A PHYSICIAN IMMEDIATELY. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

NOTE: Battery posts and cable clamps must be clean and tight for accurate meter indications.

CAUTION: Always remove the negative cable first to prevent possible arcing possibly damaging other electrical components.

MSG-425 CHARGING SYSTEM

GENERAL INFORMATION



Description

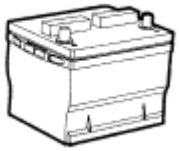
WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

The charging system consists of a generator, voltage regulator and battery. A serpentine belt drives the generator from the crankshaft pulley -- refer to Section 5 for information on the drive belt.

The generator produces alternating current which is subsequently converted to direct current
The charging rate is adjusted automatically by the built-in regulator to provide sufficient electric current to keep the battery fully charged under normal operating conditions.

Battery power

The battery is a 12 volt DC source connected in a negative ground system. There are three main functions of the battery:



- To supply power to the starter and ignition system so the engine can be cranked and started.
- To supply extra power required when the equipment load requirements exceed the supply from the charging system.
- To act as a voltage stabilizer by smoothing out or reducing temporary high voltages within the electrical system.

Operation

With the ignition on, voltage is applied to the voltage regulator. This turns the regulator on, allowing current to flow from the battery to the generator field coil.

When the engine is started, the generator begins to generate alternating current (AC) which is internally converted to direct current (DC). This current is then supplied to the equipment electrical system through the B+ terminal of the generator.

Once the generator begins generating current, a voltage signal is taken from the generator stator and fed back to the regulator. This voltage feedback signal (typically half the battery voltage) is used to turn off the warning indicator.

With the system functioning normally, the generator output current is determined and compared to a set voltage internal to the regulator, and the regulator controls the generator field current to maintain the correct generator output.

The set voltage varies with temperature and typically is higher in cold temperatures and lower in warm temperatures. This allows for better battery recharge in the winter and reduces the chance of overcharging in the summer.

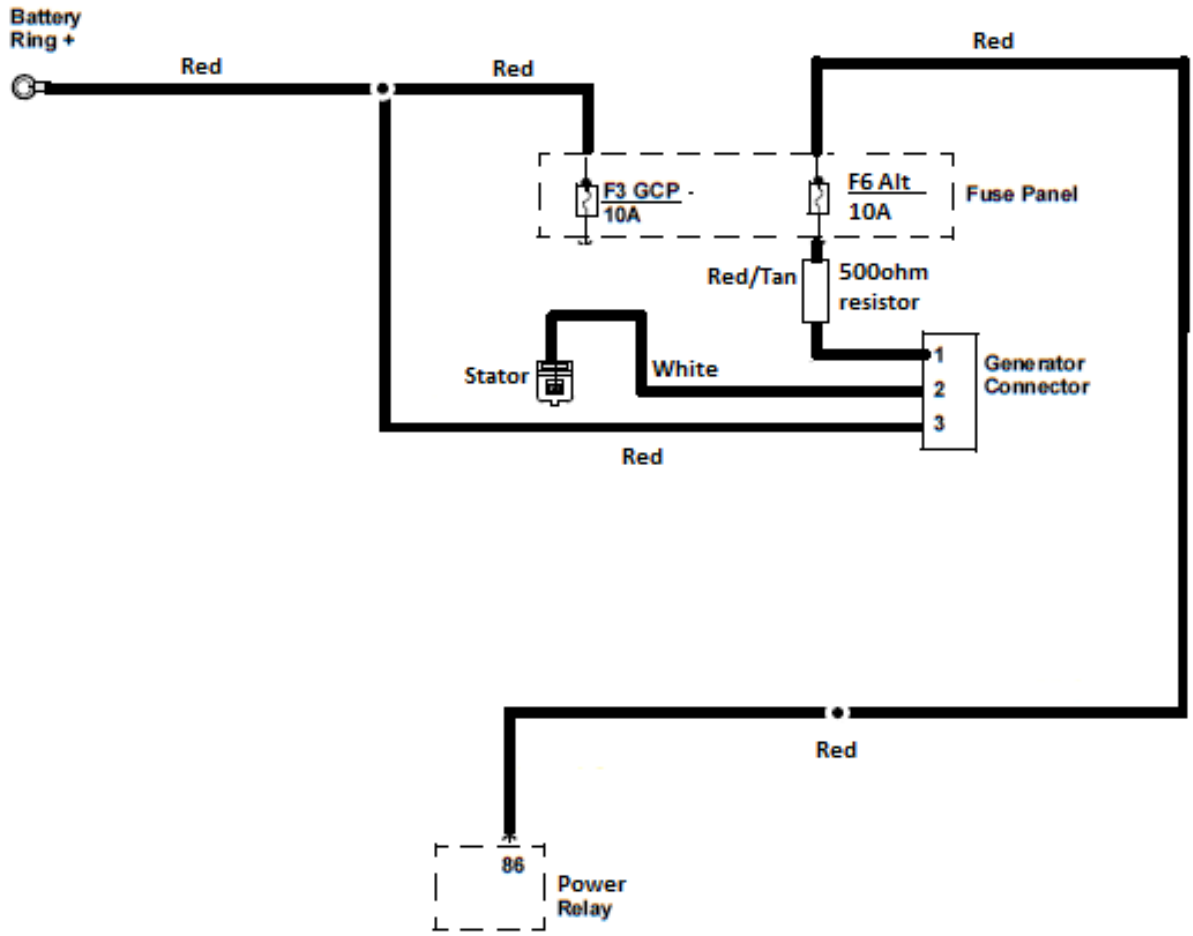
Wiring Diagram

Revision Level

The following wiring schematics are taken from the wiring diagram labeled below:

Title: EDI / FORD 2.5L W/GCP		
Size: D	Number: 2487000	Rev: D
Date: 11/1/2011	Drawn By: J. SUTTON	
Filename: 2487000d.sch	Sheet 1 of 1	

Charging System



DIAGNOSIS AND TESTING

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: When the battery is disconnected and connected, some abnormal symptoms may occur while the GCP relearns its adaptive strategy. The engine may need to run to relearn its strategy.

Preliminary Checks

Before beginning test procedures, check battery cables and generator wiring (especially grounds) for clean, tight connections. Wires and connectors should not be damaged or corroded.

Perform the following checks before any testing:

- Loose or corroded connections at battery, grounded starter motor cutout relay or engine.
- Inspect all connectors for loose or damaged pins, wires, etc.
- Make sure the batteries are at 75% state of charge (SOC) or higher. This represents an open circuit voltage (OCV) of 12.4 volts. Batteries with an OCV of 12 volts or less are either completely discharged or have a dead cell.
- Check the generator drive belt tension. This will cause low generator output.
- Check any light or indicator lamp filaments that are suspected of being open (burned out). This is done to avoid unnecessary extensive circuit checks.
- If a fuse is blown, locate the cause of the overload condition and repair it. The common procedure is as follows: isolate sections of the circuit, by disconnecting connectors, and measure the resistance to ground to find the circuit that is shorted to ground. Then locate the damaged spot in the wire or connector and repair.
- Excessive battery drain due to lamps left on, damaged or misadjusted switch, accessories left on, etc.

Warning Indicator Check

Check the operation of the charging system warning indicator as follows:

- Ignition OFF = Indicator should be OFF.
- Ignition ON, Engine OFF = Indicator should be ON.
- Ignition ON, Engine ON = Indicator should be OFF.

Symptom Chart

CONDITION	POSSIBLE SOURCE	ACTION
Dead battery. **Battery will not stay charged.** **Slow crank.** **Low battery voltage.** **No generator output.**	• Key-off battery drain. • Open/voltage drop in B+ circuit. • Open voltage drop in A circuit. • Open/high resistance in I circuit. • Voltage regulator. • Generator.	Repair as necessary
Indicator lamp on with engine running.	• Open "A" circuit. • Shorted "I" circuit. • Open/high resistance in "S" circuit. • Voltage regulator. • Generator.	Repair as necessary
Indicator lamp flickers or intermittent.	• Loose connection to generator, voltage regulator or battery. • Loose fuse or poor connection in "A" circuit. • Loose brush holder screw. • Voltage regulator. • Generator.	Repair as necessary
Battery over charging (battery voltage greater than 15.5 volts).	• Voltage drop in "A" circuit. • Voltage drop in "I" circuit • Poor ground. • Voltage regulator. • Generator.	Repair as necessary
Indicator lamp off, key on, engine not running.	• Open/high resistance in "I" circuit. • Burned out bulb • Poor ground • "S" circuit shorted to B+ • Voltage regulator. • Generator.	Repair as necessary
Generator noisy.	• Accessory drive belt. • Accessory brackets. • Bent generator pulley • Generator. • Other components.	Repair as necessary
Indicator lamp on, key off.	• Lamp circuit shorted to B+. • Improper lamp circuit wiring.	Repair as necessary

Battery Drain Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

A defective component or wiring defect may be causing a small current drain that is less than the fuse rating for the circuit so the fuse does not open. Perform the following to determine if an excessive drain is occurring:

NOTE: Batteries should be fully charged for the following test.

WARNING: DO NOT ATTEMPT THIS TEST ON A LEAD-ACID BATTERY THAT HAS RECENTLY BEEN RECHARGED. EXPLOSIVE GASES MAY CAUSE PERSONAL INJURY. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

CAUTION: To prevent damage to the meter, do not crank engine or operate accessories that draw more than 10A.

1. Allow the engine to sit with the ignition off for at least 40 minutes to allow the GCP to power down.
2. Connect a fused (10A) jumper wire between the negative battery cable and post to prevent the GCP from resetting and to catch capacitive drains.
3. Disconnect the negative battery cable without breaking the connection of the jumper wire.

NOTE: It is very important that continuity between the negative battery cable and post is not broken. If it is, the entire procedure must be repeated so the GCP can power down again.

4. Connect an ammeter between the negative battery cable and post. The meter should have a 10 amp capability.

NOTE: If after this next step, the meter settings need to be switched or the test leads need to be moved to another jack, the jumper wire must be reinstalled to avoid breaking continuity.

5. Remove the jumper wire and note the amperage draw:
   - There should not be any more than 50 mA (0.050 amp) draw.
   - If excessive, remove fuses one at a time until the circuit with the excessive draw is located.
   - Use the wiring diagram to locate any circuits that do not pass through the fuse box.
   - Disconnect the generator connections to check for an internal short causing an excessive draw.

Battery Load Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Disconnect both battery terminal cables. Check the battery visually.
2. Examine the hydrometer eye (if no eye go to next step).
   - Eye shows green - go to step 4.
   - Eye shows dark - recharge, then go to step 4.
   - Eye shows yellow - replace battery.
3. Apply a 300 amp load for 15 seconds. Turn off load and wait one minute.
   - If 12.4 volts or more - go to step 4.
   - If less than 12.4 volts - recharge, then repeat step
4. Apply a test load equal to 50% of the battery CCA rating at - 17.8° C (0°F). After 15 seconds, **with the load still applied**, measure and record terminal voltage _____. Turn the load OFF.
5. Estimate the battery temperature. If measured voltage does not meet or exceed the value shown in the following table, replace the battery.

Temp. °C	21.1°	10°	-1.1°	-9.4°	-17.8°
Temp. °F	70°	50°	30°	15°	0°
Min. Volts	9.6	9.4	9.1	8.8	8.5

6. Clean all cable ends and terminals of the battery with a wire brush.

Generator Output Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

CAUTION: To prevent damage to the generator, do not make jumper wire connections except as directed.

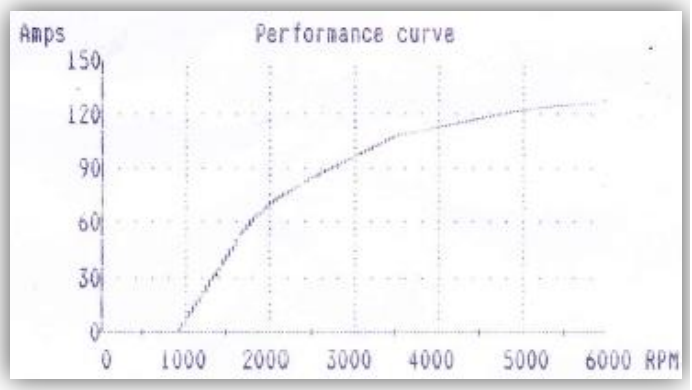
CAUTION: Do not allow any metal object to come in contact with the housing and the internal diode cooling fins with the ignition on or off. A short circuit may result and burn out the diodes.

In order to check the generator, the use of rotunda Starting and charging System Tester 078-00005 (VAT-40) or equivalent, is recommended.

NOTE: Refer to the test equipment user's manual for complete directions on examining the charging system.

NOTE: Turn off all lamps and accessories.

1. Switch the tester to ammeter function.
2. Connect the positive and negative leads of the tester to the battery.
3. Connect current probe to generator B+ terminal to measure generator output.
4. With the engine running at 2000 rpm, adjust the VAT-40 or equivalent load bank to determine the output of the generator. Generator output should be greater than values given in the graph below.



Generator Voltage Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Switch the tester to the voltmeter function.
2. Connect the positive lead to the generator A terminal connector and the negative lead to ground.
3. Turn off all electrical accessories.
4. With the engine running at 2000 rpm, check the generator voltage.
5. Voltage should be between 13.0-15.5 volts.

GENERAL SERVICE PROCEDURES

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

Battery Cleaning and Inspection

Keeping the battery top clean and dry reduces the need for service and extends battery life. Also, make certain the cable clamps are tightly fastened to the battery posts. If corrosion is found, disconnect the cables and clean clamps and posts with a wire brush. Neutralize the corrosion with a solution of baking soda and water. After installing cables, apply a small quantity of Premium Long-Life Grease XG-1-C or -K or equivalent grease meeting Ford specification ESA-M1C75-B to each battery post to help prevent corrosion.

Battery Tools

Anyone working with a battery needs the proper tools. Using the right tools will prevent damage to the battery, battery cables and battery hold down clamp.
Tools and equipment manufactured for servicing batteries have parts insulated to help prevent arcing should the tool be dropped or placed accidentally between a terminal and some other contact surface.

Clamp Puller

Use a clamp puller to remove a cable clamp from the battery terminal. With the jaws gripping the underside of the cable clamp, pull the clamp up by means of pressure exerted against the top of the battery terminal. Proper use of this tool avoids the damaging lateral or twisting forces that result when using a pry bar or pliers.

Battery Clamp Spreader

The spreader is used to expand the cable clamp after it has been removed from the terminal and the clamp bolt has been loosened. The cable clamp can then be easily placed in its correct position completely on the terminal.

Terminal Cleaning Brush

The terminal cleaning brush is designed with units to clean both tapered battery terminal and the mating surface of the cable clamp.

WARNING: GRIPPING THE END WALLS ON THE PLASTIC-CASED BATTERY COULD CAUSE ELECTROLYTE TO SPEW FROM SOME OF THE CELLS, RESULTING IN PERSONAL INJURY AND POSSIBLY CAUSE DAMAGE TO SOME OF THE INTERNAL COMPONENTS.

Use a suitable battery carrier for lifting and transporting the battery. The illustration shows a clamp-type carrier used to grip the sidewalls of the container just below the lip of the cover. The carrier is used on the sidewalls, rather than the end walls, since the sidewalls have additional strength from the inner cell partitions. This is particularly important with the plastic-cased battery which has end walls that are flexible.

Battery Charging

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: If excessive gassing or electrolyte spewing occurs during the charge, discontinue charging. The battery has reached serviceable charge. If the battery will not accept at least 5A after 20 minutes of charging, replace the battery.

WARNING: WEAR SAFETY GLASSES. BATTERY CHARGING CAN BE DANGEROUS. WHILE BEING CHARGED, THE BATTERY PRODUCES A POTENTIALLY EXPLOSIVE MIXTURE OF HYDROGEN AND OXYGEN GASSES. KEEP SPARKS, FLAMES AND LIGHTED CIGARETTES AWAY FROM BATTERIES. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH LARGE AMOUNTS OF WATER. GET MEDICAL ATTENTION.

Inspect and service any of the following pre-existing conditions before recharging a discharged battery -- Refer to “Preliminary Checks” on page 5 of this section.

Cold batteries will not readily accept a charge. Therefore, batteries should be allowed to warm up to approximately 5°C (41°F) before charging. This may require four to eight hours at room temperature depending on the initial temperature and battery size.

A battery which has been completely discharged may be slow to accept a charge initially, and in some cases may not accept charge at the normal charger setting. When batteries are in this condition, charging can be started by use of the dead battery switch on chargers so equipped.

To determine whether a battery is accepting a charge, follow charger manufacturer’s instructions for use of dead battery switch. If switch is the spring-loaded type, it should be held in the ON position for up to three minutes.

After releasing switch and with charger still on, measure battery voltage. If it shows 12 volts or higher, the battery is accepting a charge and is capable of being recharged. However, it may require up to two hours of charging with batteries colder than 5°C (41°F) before charging rate is high enough to show on the charger ammeter. It has been found that all non-damaged batteries can be charged by this procedure. If a battery cannot be charged by this procedure, it should be replaced.

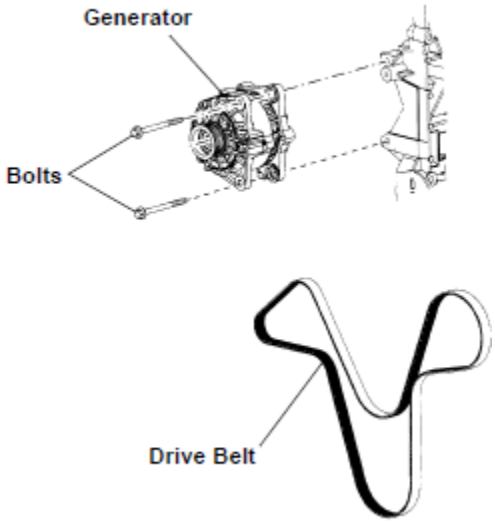
A rapid recharge procedure has been developed for recharging batteries that only need a quick recharge. This can be due to battery in-service no-start battery failures (engine will not crank due to low battery state of charge) or battery discharged due to key-off loads.

The battery can be rapidly recharged by using either of the following methods.

- Perform a two-hour charge using 20A constant current (manual setting on charger).
- Perform a two-hour charge using a constant potential (automatic setting on charger).

REMOVAL AND INSTALLATION

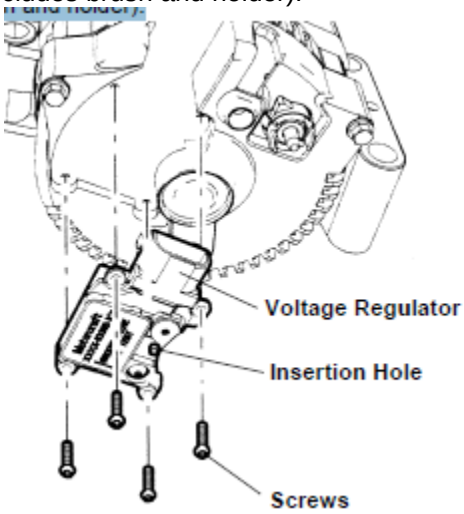
Generator – Replacement



1. Disconnect battery negative cable -- Refer to “Battery Cleaning and Inspection” on page 9 of this section.
2. Remove or disconnect any component to allow access and removal of generator.
3. Remove drive belt -- refer to cooling system section.
4. Remove 2 bolts and position the generator aside.
5. Disconnect electrical connector.
6. Remove generator.
7. Reverse procedure to install:
    - Tighten generator bolts to 25 Nm (18 lb-ft).
    - Tighten B+ terminal to 8 Nm (71 lb-in).

Voltage Regulator – Replacement

1. Remove the generator -- Refer to “Generator - Replacement” in this section.
2. Remove 4 screws and voltage regulator (includes brush and holder).

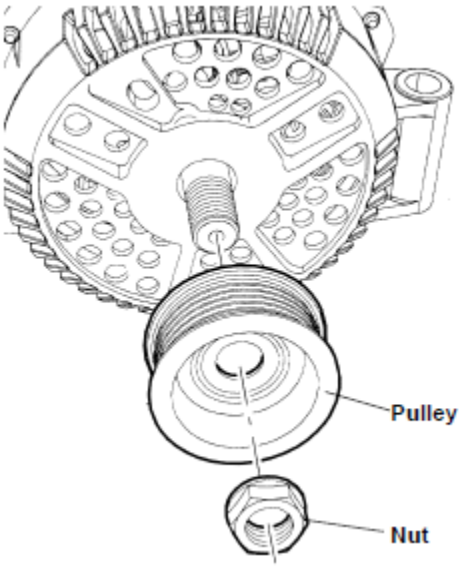


3. Reverse procedure to install:
    - Insert a wire into the insertion hole to hold the brushes during assembly. Remove wire when done.
    - Tighten screws to 3 Nm (27 lb-in).

Generator Pulley - Replacement

1. Remove generator assembly -- Refer to "Generator - Replacement" of this section.

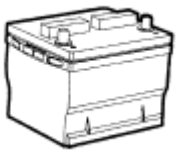
2. Remove nut.



3. Remove pulley.

4. Reverse procedure to install:
   - Tighten nut to 109 Nm (80 lb-ft).

Battery - Removal



WARNING: WHEN LIFTING PLASTIC CASED BATTERY, EXCESSIVE PRESSURE ON THE END WALLS COULD CAUSE ACID TO SPEW THROUGH THE VENT CAPS, RESULTING IN PERSONAL INJURY, DAMAGE TO THE EQUIPMENT OR BATTERY. LIFT WITH A BATTERY CARRIER OR WITH YOUR HANDS ON OPPOSITE CORNERS.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES, OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION.
IN CASE OF ACID CONTACT WITH SKIN OR EYES, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES AND GET PROMPT MEDICAL ATTENTION. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

CAUTION: Care should be taken when removing or replacing the cable clamp bolts so that the battery terminal is not subjected to any excessive lateral or twisting forces. Such forces could cause major damage to the internal components of the battery, and leakage at the terminals.

1. Remove battery cables from battery terminals (battery ground cable first).
2. Remove battery hold down components.

CAUTION: When lifting a plastic-cased battery, excessive pressure on the end walls could cause acid to spew through the vent caps, resulting in personal injury, damage to the equipment or battery. Lift with a battery carrier or with your hands on opposite corners.

3. Remove battery from equipment.

Battery - Installation

1. Clean cable terminals and battery hold down clamp with a wire brush. Replace all cables or parts that are worn or frayed.
2. Clean battery tray with a wire brush and scraper.
3. Place battery in battery tray with positive and negative cables in same position as when removed.
4. Assemble and tighten battery hold down clamp so battery is secure. Do not tighten excessively.
5. Secure cables to proper terminals. Tighten to 6 Nm (53 lb-in). Apply petroleum jelly to terminals.

Ford Motor Company strongly recommends that lead acid batteries be returned to an authorized recycling facility for disposal.

MSG-425 CHARGING SYSTEM

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Generator Output	65/110 max. amps @ 1800 – 6000 generator rpm (approx. 500 – 2000 engine rpm)
Battery	Motorcraft 12 volt 750 CCA
Battery charging voltage	13 – 15.5 volts

TORQUE SPECIFICATIONS			
Description	**Nm**	**Lb-ft**	**Lb-in**
Generator Mounting bolts	25	18	---
Regulator attachment screws	3	---	27
Battery cable nuts	6	---	53
Generator pulley nut	109	80	---
Generator wiring nuts	8	---	71

SPECIAL TOOLS	
VAT-40 Starting/charging Tester	078-00005

MSG-425 STARTER SYSTEM

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CAUTIONS & WARNINGS

WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: WHEN WORKING IN THE AREA OF THE STARTER MOTOR, BE CAREFUL TO AVOID TOUCHING HOT EXHAUST COMPONENTS. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

CAUTION: A protective cap or boot is provided over the battery input terminal and must be reinstalled after removal.

CAUTION: Be sure to disconnect the battery ground cable before repairing the starter motor.

WARNING: HYDROGEN AND OXYGEN GASES ARE PRODUCED DURING NORMAL BATTERY OPERATION. THIS GAS MIXTURE CAN EXPLODE IF FLAMES, SPARKS OR LIGHTED TOBACCO ARE BROUGHT NEAR THE BATTERY. WHEN CHARGING OR USING A BATTERY IN AN ENCLOSED SPACE, ALWAYS PROVIDE VENTILATION AND SHIELD YOUR EYES.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

WARNING: TO AVOID INJURY, USE PARTICULAR CARE WHEN CONNECTING A BOOSTER BATTERY TO A DISCHARGED BATTERY.

GENERAL INFORMATION

Description

The starter motor provides the rotation of the engine crankshaft, through the flywheel, that is needed to start the engine.

The starter system consists of:

- starter motor
- starter solenoid
- starter relay
- battery.

The starter motor is a permanent magnet, gear reduction type. It runs on 12 volts DC current.

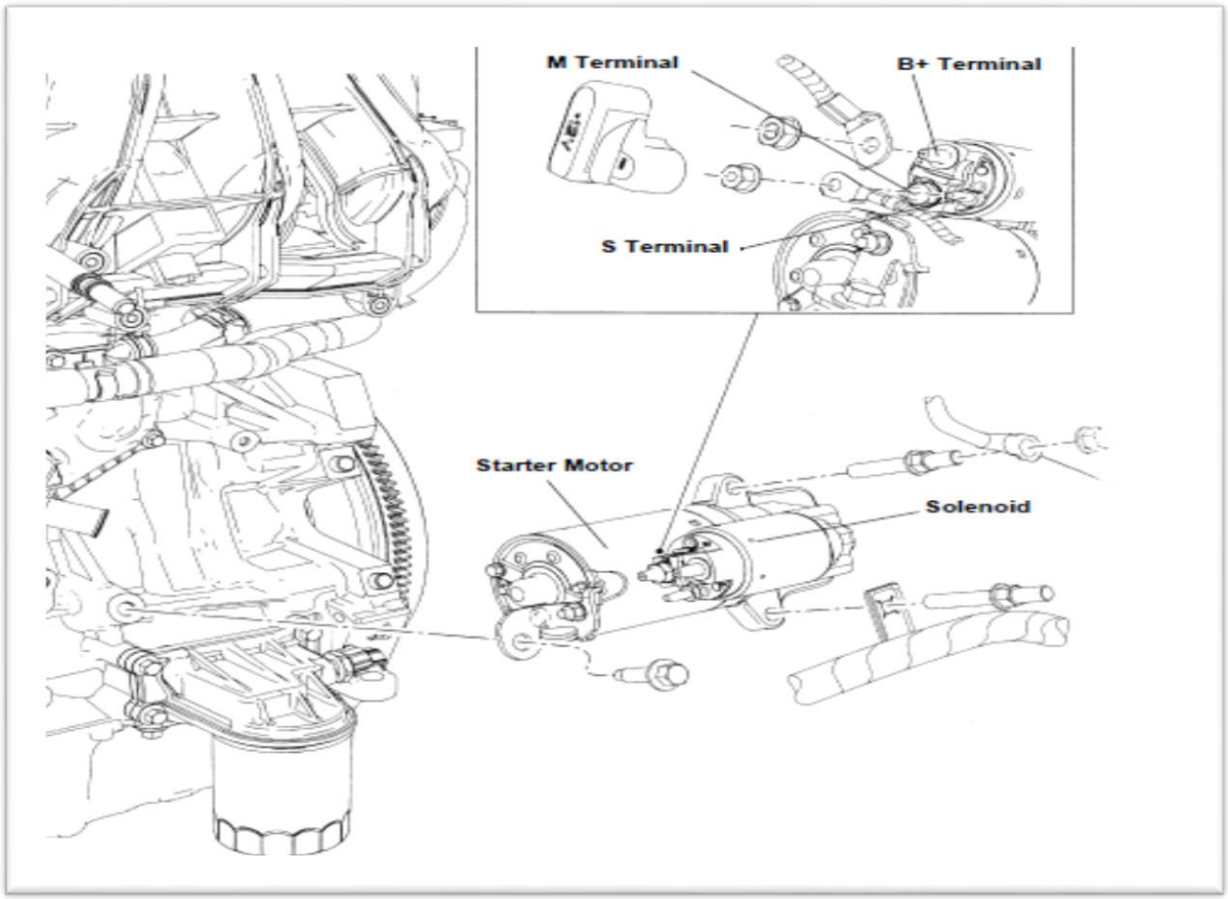
The starter solenoid is integral to the motor and a relay is also used. Refer to the charging section for information on the battery.

Operation

When the ignition is turned to the start position, the starter relay switches power to the starter solenoid, causing the starter motor to engage (transmission must be in PARK or NEUTRAL).

Battery power is always present at the starter motor B+ terminal. The starter motor relay, when energized, sends current to the starter motor “S” terminal, which causes the motor’s shaft to rotate. When the starter switch is released, a spring returns the solenoid to the released position.

The starter relay is grounded through the GCP and the power to trigger the starter is from the OEMs keyswitch. When both conditions are present the relay closes and engages the starter.

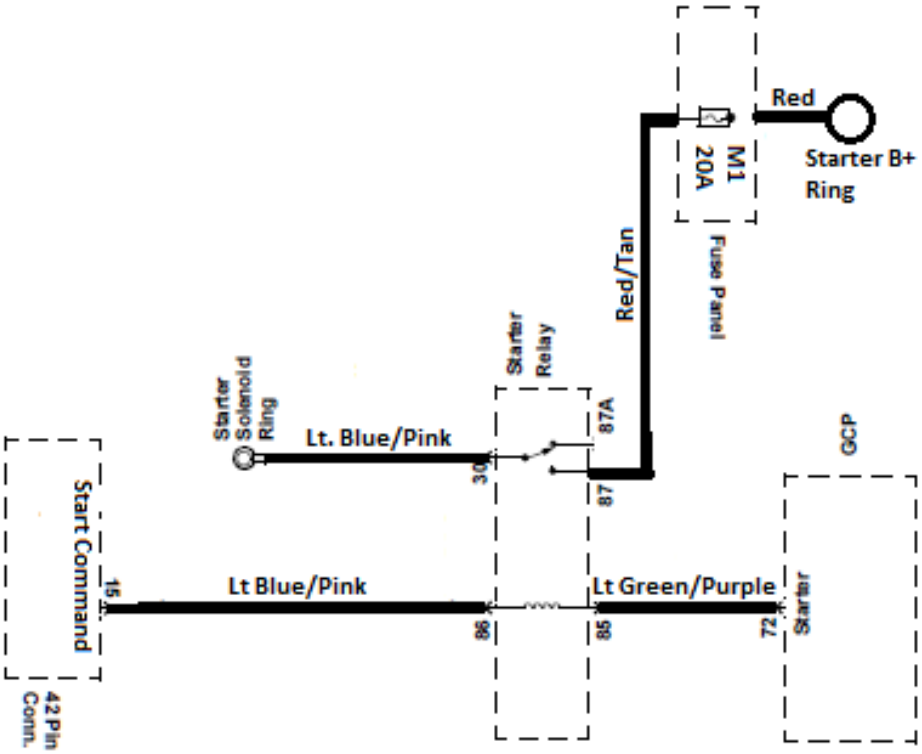


Wiring Diagram

Revision Level
The following wiring schematics are taken from the wiring diagram labeled below:

Title: EDI / FORD 2.5L W/GCP		
Size: D	Number: 2487000	Rev: D
Date: 11/1/2011	Drawn By: J. SUTTON	
Filename: 2487000d.sch	Sheet 1 of 1	

Starting System



DIAGNOSIS AND TESTING

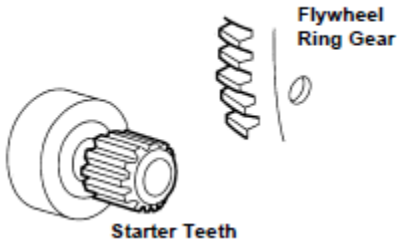
WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: When testing with a meter, always make connections with the component terminal rather than at the wiring end connector. Making connection with the wiring end connector can result in a false reading, because the meter will not pick up any high resistance between the wiring connector and the component.

Visual Inspection

CAUTION: Be sure to disconnect battery negative cable before servicing starter.

- Verify the concern by operating the starting system to duplicate the conditions.
- Inspect starting system for loose connections.
- Check the wear patterns on the starter drive and the flywheel ring gear. If the starter drive gear and the flywheel ring gear are not fully meshing or the gears are milled or damaged, replace the starter motor and if necessary, replace flywheel ring gear.



If the inspection reveals an obvious concern that can be readily identified, repair as necessary.

If the concern remains after the inspection, note condition and continue diagnosis using the symptom chart.

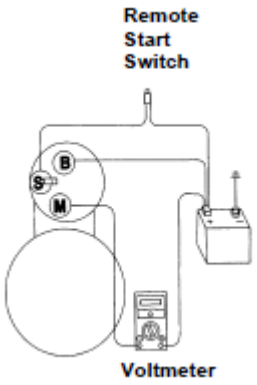
Symptom Chart

CONDITION	POSSIBLE SOURCE	ACTION
Starter does not crank (audible click may or may not be heard)	• Open fuse • Low Battery • Defective remote relay • Open circuit or high resistance in external feed circuit to starter solenoid • Defective starter • Defective neutral park switch	• Check fuse continually • Refer to battery diagnosis in charging section • Check relay • Check starter wiring • Rplace starter motor • Replace switch
Unusual starter noise	• Starter note mounted flush (cocked) • Noise from other components • Ring gear tooth damage or excessive ring gear runout • Defective starter	• Realign starter or transmission bell housing or SAE housing • Investigate other powertrain accessory noise • Replace flywheel ring gear • Replace Starter motor
Starter spins but the engine does not crank	• Starter note mounted flush (cocked) • Ring gear tooth damage	• Realign starter or transmission bell housing or SAE housing • Replace flywheel ring gear
Starter cranks but engine does not start	• Problem in fuel system • Engine related problem	• Refer to fuel system section • Refer to section 01, diagnosis and testing
Starter cranks slowly	• Low Battery • High resistance or loose connections in starter solenoid battery feed or ground circuit • Ring gear runout excessive • Defective Starter	• Charge or replace battery • Check that all connections are secure • Replace ring gear • Replace starter motor
Starter remains engaged and runs with engine	• Shorted ignition switch • Battery cable touching solenoid “S” terminal • Defective starter	• Replace ignition switch • Replace or relocate cable • Replace starter motor
Starter clicks and engages but engine will not crank	• Hydrolocked cylinder • Seized main or rod bearing	• Remove all plugs one at a time while checking for fluid in cylinders • Repair as needed – refer to sections 01

Motor Feed Circuit - Voltage Drop Test

Slow cranking is often caused by high resistance in the battery cables or connections, especially in cold weather. After all batteries check good and terminals are clean and tight, check the starter motor feed circuit:

1. Connect a remote starter switch between the starter “S” terminal and the battery positive (+) terminal.
2. Connect a digital multimeter positive lead to the battery positive (+) post. Connect negative lead to the starter solenoid “M” terminal.

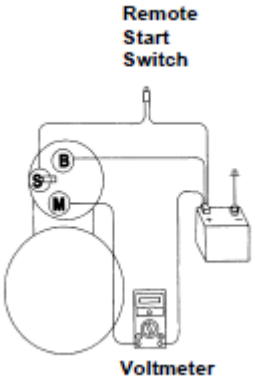


3. Engage the remote starter switch. Read and record the voltage. The voltage reading should be 0.5 volt or less.
    - If 0.5 volt or less -- refer to starter motor ground circuit test.
    - If greater than 0.5 volt, indicating excessive resistance, move the negative lead to the “B” terminal as shown and repeat the test. If voltage reading at the “B” terminal is lower that 0.5 volt, the concern is either in the connections at the starter solenoid or in the solenoid contacts. By moving the lead toward the battery and checking each mechanical connection point, the excessive voltage drop can be located. When the high reading disappears, the last mechanical point that was checked is the concern. Clean or repair as necessary.

Starter Motor - Ground Circuit Check

A slow cranking condition can be caused by resistance in the ground or return portion of the cranking circuit. Check the voltage drop in the ground circuit as follows:

1. Connect a remote starter switch between the starter solenoid “S” terminal and the battery positive (+) post.



2. Connect a digital multimeter positive (+) lead to the starter motor housing (the connection must be clean and free of rust or grease).
3. Connect the negative (-) lead of the voltmeter to the negative (-) battery terminal.
4. Engage the remote starter switch and crank the engine. Read and record the voltage reading.
    a. A reading of 0.2 volt or less indicates a good ground connection.
    b. If reading is more than 0.2 volts, clean all ground connections and retest. If still too high replace battery negative cable.

NOTE: If the voltage reading is less than 0.2 volt and the engine still cranks slowly, install a new starter motor.

GENERAL SERVICE PROCEDURES

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

Jump Starting

For cases of a starter that cranks the engine very slowly, connect a 12 volt booster battery to the system. To avoid damage to the equipment and battery or the possibility of personal injury, follow these instructions and precautions:

WARNING: HYDROGEN AND OXYGEN GASES ARE PRODUCED DURING NORMAL BATTERY OPERATION. THIS GAS MIXTURE CAN EXPLODE IF FLAMES, SPARKS OR LIGHTED TOBACCO ARE BROUGHT NEAR THE BATTERY. WHEN CHARGING OR USING A BATTERY IN AN ENCLOSED SPACE, ALWAYS PROVIDE VENTILATION AND SHIELD YOUR EYES.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO,
SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

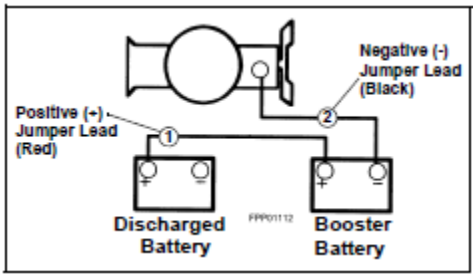
CAUTION: Do not disconnect the battery of the engine to be started. Disconnecting the battery could damage the equipment's electronic system.

WARNING: MAKING THE FINAL CABLE CONNECTION COULD CAUSE AN ELECTRICAL SPARK NEAR THE BATTERY AND COULD CAUSE AN EXPLOSION. REFER TO WARNING AT THE BEGINNING OF THE JUMP STARTING PROCEDURE.

WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER UNDERHOOD WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES.

WARNING: TO AVOID INJURY, USE PARTICULAR CARE WHEN CONNECTING A BOOSTER BATTERY TO A DISCHARGED BATTERY.

1. Position equipment so jumper cables will reach, being careful that equipment does not touch each other.



NOTE: Be sure to disconnect battery negative cable before servicing starter.

2. Connect one end of positive red jumper cable (+) 1 to positive terminal of discharged battery and other end to positive terminal of booster battery.

3. Connect one end of negative black jumper cable (-) 3 to negative terminal of booster battery. Connect other end to an engine bolthead or good metallic contact spot on engine of equipment to be started. NOT TO NEGATIVE (-) BATTERY TERMINAL.
4. Make sure jumper cables are not in way of moving engine parts.
5. Start engine with good battery. Run engine at a moderate speed.
6. Start engine with discharged battery. Follow starting instructions in the Operator handbook.
7. Completely discharged batteries may require an electrical load to initialize charging.
8. Remove cables in exact REVERSE sequence. Begin by removing negative cable from engine that had discharged battery.

If the starter does not turn the engine over, even with the booster battery attached, refer to Diagnosis.

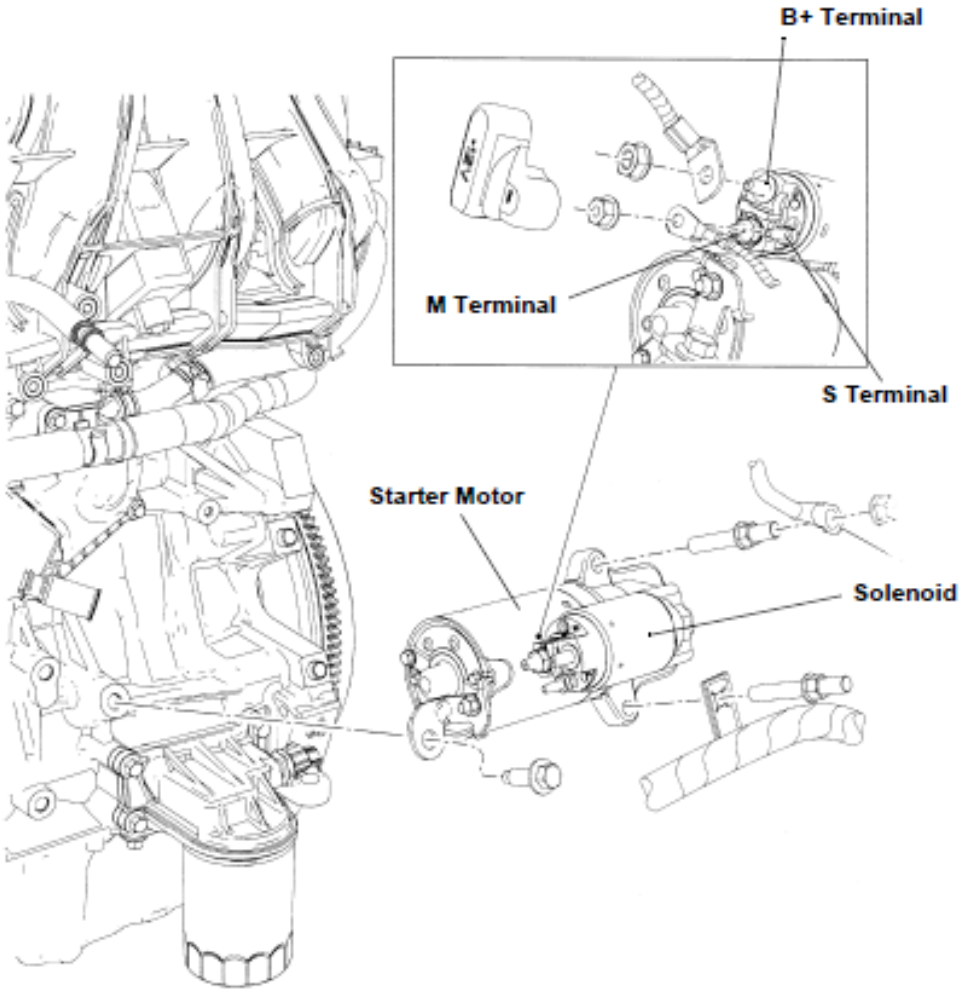
REMOVAL AND INSTALLATION

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

Starter Motor – Replacement

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Disconnect negative battery cable.
2. Remove any component to allow access and removal of the starter motor.



WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES.

3. Remove terminal cover and nuts.
4. Remove starter mount bolts.
5. Reverse procedure to install:
   - Tighten "B" and "M" nuts to 12 Nm (9 lb-ft)
   - Tighten "S" nut to 5 Nm (44 lb-in)
   - Tighten mount bolts to 25 Nm (18 lb-ft).

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Current draw NO Load	60 – 80 Amps
Current Draw Max Load	800 Amps
Minimum Stall torque (@5 volts)	14.7Nm (16lb-ft)
Cranking Speed	140 – 220 RPM

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Mounting bolts/nuts/studs	27	20	---
Battery Cable nuts	6	--	53
Solenoid Ternminal nut	5	---	44
Solenoid terminal B+ nut	12	9	---

SPECIAL TOOLS	
VAT-40 Starting/Charging Tester	078-00005

MSG-425 Engine Controls

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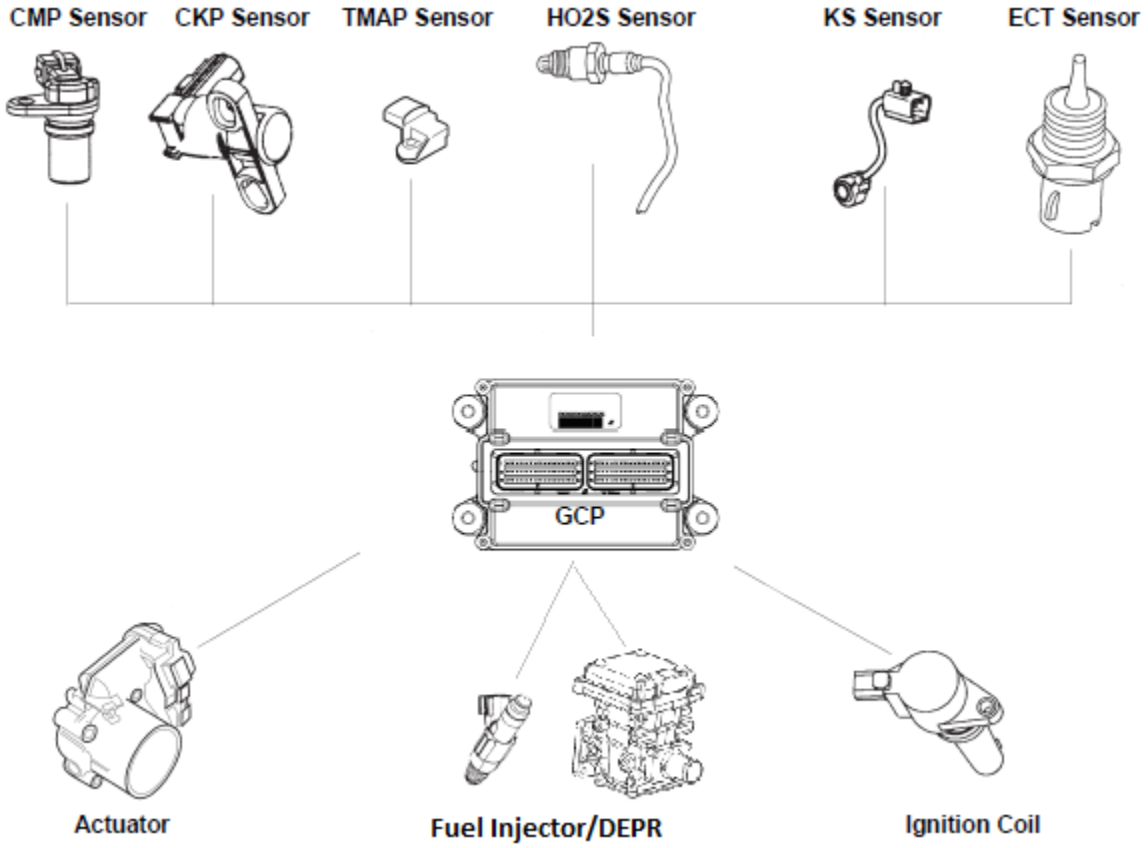
GENERAL INFORMATION
GCP and Sensors



Engine Control Module (GCP)

The Engine Control Module (GCP) has the following features:

- Programmable four speed electronic governing, throttle-by-wire or variable speed control governing.
- Programmable emergency warning/shut-down feature for high water temperature, low oil pressure, etc.
- Starter lockout.
- Auto crank
- Programmable overspeed protection
- Automatic altitude compensation.
- Sequential port fuel injection (gasoline) with pressure regulator to precisely control fuel delivery.
- Dry fuel lockout controlled by the GCP produces a reliable transition when switching fuels.
- Certified closed loop dry fuel control.
- Configurable inputs available based on customer requirements.
- Configurable outputs available based on ECT, RPM or MAP signals and customer requirements.
- Diagnostic software allows viewing of historical and active faults with on-demand diagnostics to assist technicians and reduce equipment downtime.

The Engine Control Module (GCP) engine control system is a complete engine control system for Ford industrial engines running on gasoline, propane or natural gas. Each module can be set up to run an engine on any two of the three fuels in certified closed loop control, with virtually transparent on-the-fly fuel switching.

Each module can also be set up to run on a variety of electronic governing:

- It can be programmed to provide up to four specific speeds with use of a matching toggle switch
- It can be programmed to provide an infinite variety of speeds (with customer-specified minimum and maximum) based on a variable signal input.

- It can be an electronic replacement for a throttle cable with maximum speed governing (throttle-bywire).

- Or it can switch between throttle-by-wire and a second fixed or variable input based on a neutral/ parking brake signal.

With the GCP system, a laptop and a communications cable, diagnosis becomes simpler. The technician can either view engine data with a real time graphing program, or store that data into a numeric data file.

Every time a fault is set, the laptop will give you detailed information about the fault, including:

- when it happened
- if the fault still exists
- a list of essential engine data from the time of the fault.

It can also display a 10 second graph of critical engine data, from 8 seconds before the fault occurred to two seconds after.

With many OEMs using control modules to control their machinery, the GCP has the ability to communicate engine data to and receive commands from other control modules through a Controller Area Network (CAN) link, with messages written in the J1939 protocol.

This allows large amounts of data to move throughout the machine through only two wires, and can be used to run some module based gauge packages.

The GCP also carries auxiliary features that can be programmed to control OEM devices, allowing the OEM to eliminate components from their machinery.

The GCP is also equipped with multiple safety and protection devices that protect the user and engine from hazards such as:

- over speed
- over temperature
- over voltage
- low oil pressure
- unauthorized tampering
- over cranking starter motor.

The GCP controls the following:

- Fuel metering system
- Ignition timing
- On-board diagnostics for engine functions

The GCP constantly observes the information from various sensors. The GCP controls the systems that affect engine performance. The GCP performs the diagnostic function of the system. It can recognize operational problems, alert the operator through the Malfunction Indicator Lamp (MIL), and store diagnostic trouble codes (DTC's). DTC's identify the problem areas to aid the technician in making repairs.

The GCP supplies either 5 or 12 volts to power various sensors or switches. The power is supplied through resistances in the GCP which are so high in value that a test light will not light when connected to the circuit. In some cases, even an ordinary shop voltmeter will not give an accurate reading because its resistance is too low. Therefore, a digital voltmeter with at least 10 megohms input impedance is required to ensure accurate voltage readings. The GCP controls output circuits such as the fuel injectors, electronic governor, etc., by controlling the ground or the power feed circuit through transistors or other solid state devices.

The GCP is designed to maintain exhaust emission levels to government mandated standards while providing excellent operation and fuel efficiency. The GCP monitors numerous engine functions via electronic sensors such as the throttle position (TP) sensor and the heated oxygen sensor (HO2S).

GCP Inputs (operating conditions read)

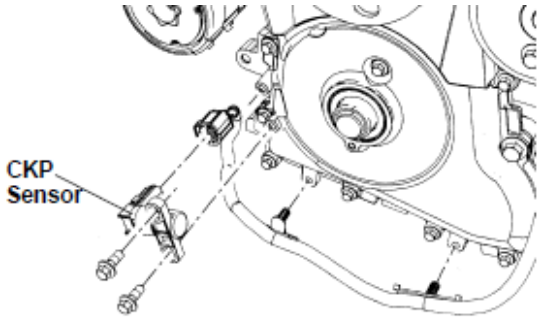
- Engine Coolant Temperature
- Crankshaft Position
- Exhaust Oxygen Content
- Manifold Absolute Pressure
- Battery Voltage
- Throttle Position / Electronic Actuator
- Fuel Pump Voltage
- Intake Air Temperature
- Camshaft Position

GCP Outputs (systems controlled)

- Fuel control (Injectors/DEPR)
- Electronic Throttle Control
- Electric Fuel Pump (gasoline)
- Diagnostics - Malfunction Indicator Lamp (check engine lamp)
- Diagnostics - Data Link Connector (DLC)
- Variable valve timing (VVT)

Crankshaft Position (CKP) Sensor

The Crankshaft Position (CKP) Sensor provides a signal used by the Engine Control Module (GCP) to calculate the ignition sequence. The sensor initiates the reference pulses which the GCP uses to calculate RPM and crankshaft position.

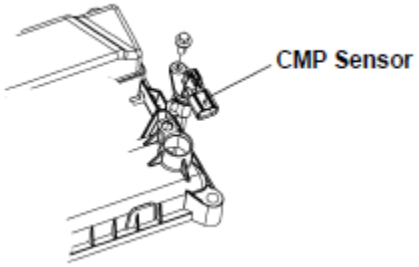


Camshaft Position (CMP) Sensor

The Camshaft Position (CMP) Sensor uses a variable reluctor sensor to detect camshaft position. The CMP signal is created as piston #1 is a pre-determined number of degrees after top dead center on the power stroke.

The Camshaft Position (CMP) Sensor sends a CMP signal to the GCP. The GCP uses this signal as a “sync pulse” to trigger the injectors in the proper sequence.
The GCP uses the CMP signal to indicate the position of the #1 piston during its power stroke. The CMP uses a Hall Effect sensor to measure piston position. This allows the GCP to calculate true sequential fuel injection (SFI) mode of operation. If the GCP detects an incorrect CMP signal while the engine is running, DTC 341 will set (CAM sync noice).

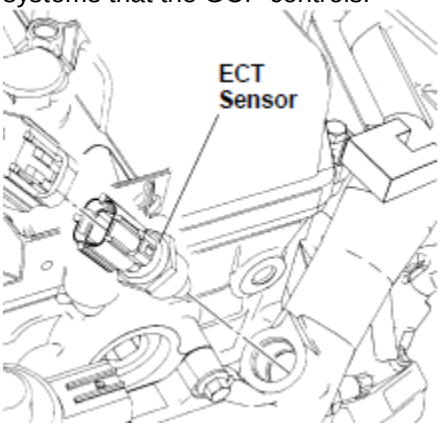
If the CMP signal is lost while the engine is running, the fuel injection system will shift to a calculated sequential fuel injection mode based on the last fuel injection pulse, and the engine will continue to run. As long as the fault (DTC 342, CAM loss) is present, the engine can be restarted. It will run in the previously established injection sequence.



Engine Coolant Temperature (ECT) Sensor

The Engine Coolant Temperature (ECT) Sensor is a thermistor (a resistor which changes value based on temperature) mounted in the engine coolant stream. Low coolant temperature produces a high resistance of 100,000 ohms at -40°C (-40°F). High temperature causes a low resistance of 70 ohms at 130°C (266°F).

The GCP supplies a 5 volt signal to the ECT sensor through resistors in the GCP and measures the voltage. The signal voltage will be high when the engine is cold and low when the engine is hot. By measuring the voltage, the GCP calculates the engine coolant temperature. Engine coolant temperature affects most of the systems that the GCP controls.



After engine start-up, the temperature should rise steadily to about 85°C (185°F). It then stabilizes when the thermostat opens. If the engine has not been run for several hours (overnight), the engine coolant temperature and intake air temperature displays should be close to each other. A fault in the engine coolant sensor circuit will set a DTC 117 or DTC 118 (Low/High Voltage.

TEM (°C)	MIN Rt (OHMS)	MAX Rt (OHMS)
-40	832,519	1017,523
-35	614,831	732,743
-30	458,848	533,255
-25	345,840	391,952
*-20	263,111	290,807
-15	199,325	220,307
-10	152,297	168,329
-5	117,311	129,659
0	91,058	100,644
5	71,168	78,660
10	56,037	61,936
15	44,435	49,113
20	35,473	39,207
*25	28,500	31,500
30	23,040	25,465
35	18,730	20,701
40	15,307	16,919
45	12,574	13,898
50	10,379	11,472
55	8,608	9,514
*60	7,171	7,925
65	6,015	6,648
70	5,068	5,602
75	4,289	4,741
80	3,645	4,029
85	3,110	3,438
90	2,664	2,945
95	2,290	2,531
100	1,976	2,184
105	1,711	1,891
110	1,486	1,642
115	1,295	1,431
*120	1,131	1,251
125	992	1,096
130	869	966
135	764	854
140	673	757
145	595	672
150	527	599

Heated Oxygen Sensor (HO2S)

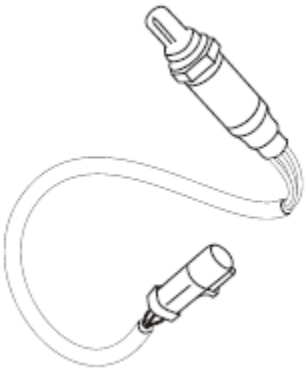
The Heated Oxygen Sensor (HO2S) is mounted in the exhaust stream where it can monitor the oxygen content of the exhaust gas. The oxygen present in the exhaust gas reacts with the sensor to produce a voltage output. This voltage should constantly fluctuate from approximately 100mV to 900 mV, when the engine is running in closed loop fuel control.

The Heated Oxygen Sensor (HO2S) voltage can be monitored on an IBM PC compatible computer with diagnostic software. By monitoring the voltage output of the oxygen sensor, the GCP calculates the pulse width command for the injectors to produce the proper combustion chamber mixture.

The 4-wire HO2S indicates whether the air/fuel ratio is rich or lean with respect to stoichiometry. The signal from this sensor contains valid air/fuel ratio information only when the sensor element has reached its normal operating temperature. The 4-wire HO2S also has an isolated case ground which goes to Signal Return (SIGRTN) either in the processor (as a dedicated HO2S ground) or as a jumper to SIGRTN in the wiring harness.

Low HO2S voltage indicates a lean mixture which will result in a rich command to compensate.

High HO2S voltage indicates a rich mixture which will result in a lean command to compensate.



Specifications

- Accuracy of measurement: ±1.5%
- Operating Temp. Range: 350°C to 850°C (sensor tip)
- Sensor Response Time: 300-1500 msec.
- Heater Current Draw: 1 A steady state
- Voltage Output:
    - 0 - 450 mV (lean exhaust gas)
    - 450 - 1000 mV (rich exhaust gas)

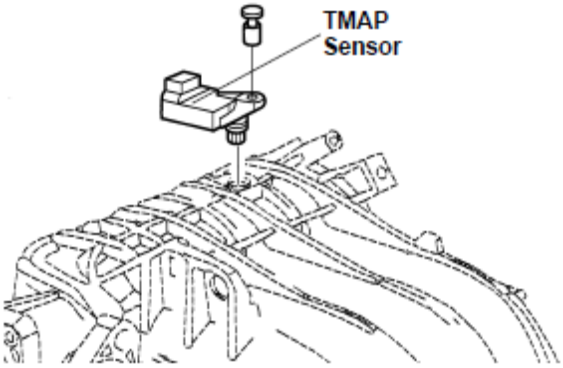
Temperature Manifold Absolute Pressure (TMAP) Sensor

The Temperature Manifold Absolute Pressure (TMAP) Sensor responds to changes in intake manifold pressure (vacuum). The TMAP sensor signal voltage to the GCP varies from below 2 volts at idle (high vacuum) to above 4 volts with the ignition ON, engine not running or at wide-open throttle (low vacuum).

The TMAP sensor consists of a pressure sensing element (capacitor) and signal conditioning electronics. The capacitor has a vacuum/pressure reference which results in one surface (diaphragm) of the capacitor being partially deflected. Further changes in pressure produce corresponding changes in the deflection of the diaphragm and therefore a change in capacitance. This capacitance change is converted to a frequency by the conditioning electronics.

The TMAP sensor is used to determine the following:

- Engine vacuum level for engine control purposes.
- Barometric pressure (BARO).



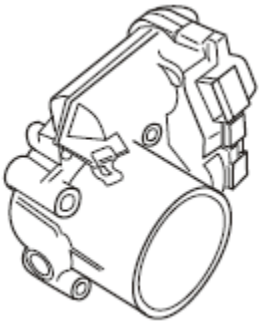
Specifications:

- Range of Measurement: 1.7 - 15.2 psi.
- Measurement Accuracy: ± 0.2 psi
- Sensor Response Time: 3-15 msec.
- Resolution: 0.02 psi

Present design: Silicon Capacitive Absolute Pressure (SCAP) sensor with a maximum operating temperature of 100°C. The output is a 50% duty cycle wave form whose frequency is proportional to the pressure input.

Throttle Position (TP) Sensor / Electronic Actuator

The Throttle Position (TP) Sensor is a dual track rotary potentiometer that uses a variable resistive element which is packaged inside a plastic housing. The resistive element varies linearly and is directly proportional to the throttle plate angle. The GCP applies reference voltage and ground to the sensor and monitors the sensor's ratio metric output voltage to determine precise throttle position. The electronic actuator has two TP outputs that the GCP monitors.



The Electronic Actuator consists of a throttle body, an electronically-actuated throttle plate, and a built-in throttle position (TP) Sensor. The Electronic Actuator also acts as an idle air control (IAC) valve. Changes in engine load are detected by the GCP by comparing manifold absolute pressure (TMAP) with throttle position. When the GCP detects a change in engine load, it can adjust idle speed by changing the PWM signal to the actuator.

As the throttle valve opens, the output increases so that at wide open throttle (WOT), the output voltage should be above 4 volts.

The GCP calculates fuel delivery based on throttle valve angle (operator demand). A hard failure in the TP sensor 5 volt reference or signal circuits for greater than 2 consecutive seconds will set a DTC 123 or DTC 223. A hard failure with the TP sensor ground circuit for more than two consecutive seconds may set DTC 222. If any (TP) DTC is set the GCP will shut down the engine immediately.

Specifications:

- Range of Measurement: 0-85° (angular)
- Measurement Accuracy: ±2% of VREF
- Resolution: 0.5° max.

Fuel System Components - Gasoline

The fuel metering system is made up of the following parts:

- The fuel injectors (gasoline)
- The fuel rail (gasoline)
- The fuel filter (gasoline)
- The GCP
- The Crankshaft Position (CKP) Sensor
- The Camshaft Position (CMP) Sensor
- The fuel pump (gasoline)
- The fuel pump relay (gasoline)
- The Direct Electronic Pressure Regulator (Gaseous Fuels)
- The Fuel Lock Off Solenoid (Gaseous Fuels)
- The Mixer (Gaseous Fuels)
- The Vapor Regulator (LPG/CNG)
- Heated Oxygen (HO2S) Sensor
- Temp/Manifold Absolute Pressure (TMAP) Sensor

The basic function of the air/fuel metering system is to control the air/fuel delivery to the engine. Fuel is delivered to the engine by individual fuel injectors mounted in the intake manifold near each intake valve.

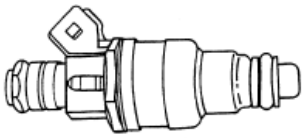
The fuel metering system starts with the fuel in the fuel tank. The fuel is drawn up to the fuel pump through a pre-filter. The electric fuel pump then delivers the fuel to the fuel rail through an in-line fuel filter. The pump is designed to provide fuel at a pressure above the pressure needed by the injectors. A fuel pressure regulator in the fuel filter assembly keeps fuel available to the fuel injectors at a constant pressure of 45psig. A return line delivers unused fuel back to the tank.

The main control sensor is the heated oxygen sensor (HO2S) located in the exhaust system. The HO2S tells the GCP how much oxygen is in the exhaust gas. The GCP changes the air/fuel ratio to the engine by controlling the amount of time that the fuel injector is “ON”. The best mixture to minimize exhaust emissions is 14.7 parts of air to 1 part of gasoline by weight, which provides the most efficient combustion. Because of the constant measuring and adjusting of the air/fuel ratio, the fuel injection system is called a “closed loop” system.

The GCP monitors signals from several sensors in order to determine the fuel needs of the engine. Fuel is delivered under one of several conditions called “modes”. All modes are controlled by the GCP. Refer to “Open Loop and Closed Loop Operation” for more information.

Fuel Injector

The Electronic Fuel Injection (EFI) fuel injector is a solenoid operated device controlled by the GCP. The GCP energizes the solenoid, which opens a valve to allow fuel delivery.

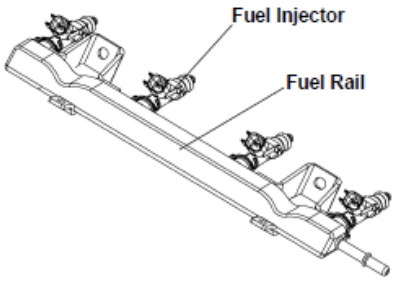


The fuel is injected under pressure in a conical spray pattern at the opening of the intake valve. Excess fuel not used by the injectors passes through the fuel pressure regulator before being returned to the fuel tank.

A fuel injector which is stuck partly open will cause a loss of fuel pressure after the engine is shut down, causing long crank times.

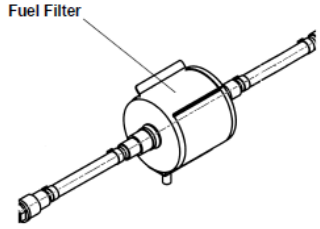
Fuel Rail

The fuel rail is mounted to the top of the engine and distributes fuel to the individual injectors. Fuel is delivered to the fuel inlet tube of the fuel rail by the fuel lines.



Fuel Filter

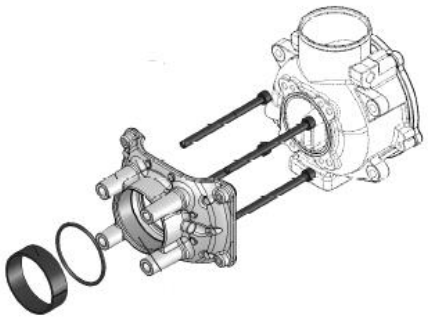
The fuel filter is an inline filter assembly. Refer to Section 4 for information on relieving fuel pressure, disconnecting fuel lines and fuel filter replacement.



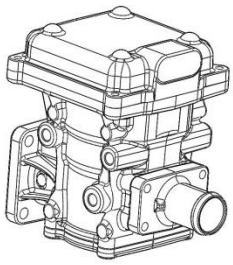
Fuel Pump Electrical Circuit
When the key is first turned "ON", the GCP energizes the fuel pump relay for two seconds to build up the fuel pressure quickly. If the engine is not started within two seconds, the GCP shuts the fuel pump off and waits until the engine is cranked. When the engine is cranked and crankshaft position signal has been detected by the GCP, the GCP supplies 12 volts to the fuel pump relay to energize the electric fuel pump.

An inoperative fuel pump will cause a "no-start" condition. A fuel pump which does not provide enough pressure will result in poor performance.

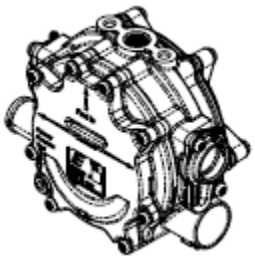
Mixer (Gaseous Fuels)
The Mixer allows air and fuel to mix together before entering the engine. Based on pressure differentials the diaphragm in the mixer will actuate allowing the proper amount of air and fuel to mixer together. This pressure differential is based on the vacuum in the intake manifold of the engine which is directly related to load.



DEPR (Direct Electronic Pressure Regulator)
The DEPR controls the fuel trim to the engine on dry fuels based on inputs to the GCP (HO2 sensor, MAP sensor, crank and cam sensors). Nominal pressure input to the DEPR is ~ 11" WC and outputs ~ 4 – 5" WC. It is mounted directly to the mixer.



Vapor Regulator
The vapor regulator is used with LPG and CNG fuels. It converts LPG from a liquid state to a gaseous state. Nominal pressure output is ~11" of WC to the DEPR.



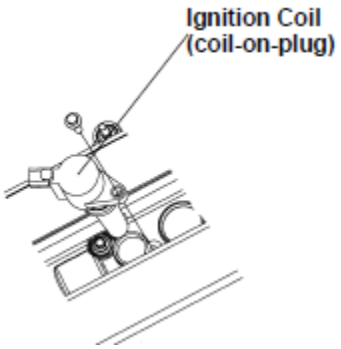
Coolant is run through the DEPR to prevent freezing of the regulator which could result in a lean fuel condition.

Fuel Lock Off Valve
The fuel lock off valve is located before the DEPR and/or the vapor regulator. It is only open during cranking and running. This prevents the intake manifold from filling with gaseous fuel which could result in a backfire. The power is constant and supplied by the power relay. The ground of the solenoid is controlled by the GCP.

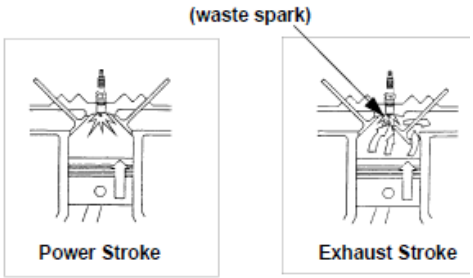
Coil-on-plug Ignition

The coil-on-plug ignition system controls fuel combustion by providing a spark to ignite the compressed air/fuel mixture at the correct time. To provide optimum engine performance, fuel economy, and control of exhaust emissions, the GCP controls the spark advance of the ignition system. Coil-on-plug ignition has the following advantages over a mechanical distributor system:

- No moving parts
- Less maintenance
- Remote mounting capability
- No mechanical load on the engine
- More coil cool down time between firing events
- Elimination of mechanical timing adjustments
- Increased available ignition coil saturation time
- Elimination of high tension wires



The coil-on-plug design has individual coils mounted directly over each spark plug. Each cylinder is paired with its opposing cylinder in the firing order, so that one cylinder on compression fires simultaneously with the opposing cylinder on exhaust. The spark that occurs in the cylinder on the exhaust stroke is referred to as a “waste spark”.



The primary coils in the coil pack are triggered by the “ignition coil feed#1” and ignition coil feed #2” signals from the GCP.

Open Loop and Closed Loop Operation

NOTE: No DTC will be set unless engine has operated in closed loop status for more than 6 seconds.

The GCP will operate in the following two modes:

- Open loop
- Closed loop

When the engine is first started, the system is in "open loop" operation. In open loop, the GCP ignores the signal from the Heated Oxygen Sensor (HO2S). It uses a pre-programmed routine to calculate the air/fuel ratio based on inputs from the TP, ECT, TMAP & CKP sensors.

The system remains in open loop until the following conditions are met:

- The ECT has reached 75°F (24°C).
- 50 seconds has elapsed since starting the engine.

After these conditions are met, the engine is said to be operating in "closed loop". In closed loop, the GCP continuously adjusts the air/fuel ratio by responding to signals from the HO2S (except at wide-open throttle). When the HO2S reports a lean condition (low sensor signal voltage), the GCP responds by increasing the "on" time of the fuel injectors, thus enriching the mixture. When the HO2S reports a rich condition (high sensor signal voltage), the GCP responds by reducing the "on" time of the fuel injectors, thus leaning out the mixture.

Adaptive Learn
Adaptive Learn is a fuel correction coefficient that is derived from the closed loop correction and is stored in the GCP's memory.

The normal purpose of the Adaptive Learn is to compensate fuel flow for the following:

- Fuel composition variance
- Engine wear
- Component variation
- Component degradation

The GCP system will operate in closed loop plus adaptive learn when the ECT reaches 165°F.

NOTE: The adaptive learn coefficient will get erased if battery power falls below 9.5 volts.

GCP Service Precautions
The GCP is designed to withstand normal current draws associated with engine operation. When servicing the GCP, observe the following guidelines:

- Do not overload any circuit.
- When testing for opens and shorts, do not ground or apply voltage to any of the GCP's circuits unless instructed to do so.
- When measuring voltages, use only a digital voltmeter with an input impedance of at least 10 megohms.
- Do not employ any non-standard practices such as charging the battery with an arc welder.
- Take proper precautions to avoid static damage to the GCP. Refer to "electrostatic Discharge Damage" for more information.

Use of Circuit Testing Tools
Do not use a test light to diagnose the engine electrical systems unless specifically instructed by the diagnostic procedures. A test light can put an excessive load on a GCP circuit and result in component damage. For voltage measurements, use only a digital voltmeter with an input impedance of at least 10 megohms.

Electrostatic Discharge Damage
Electronic components used in the GCP are often designed to carry very low voltage. Electronic components are susceptible to damage caused by electrostatic discharge. Less than 100 volts of static electricity can cause damage to some electronic components. By comparison, it takes as much as 4000 volts for a person to feel the spark of a static discharge.

There are several ways for a person to become statically charged. The most common methods of charging are by friction and induction.

An example of charging by friction is a person sliding across a seat.

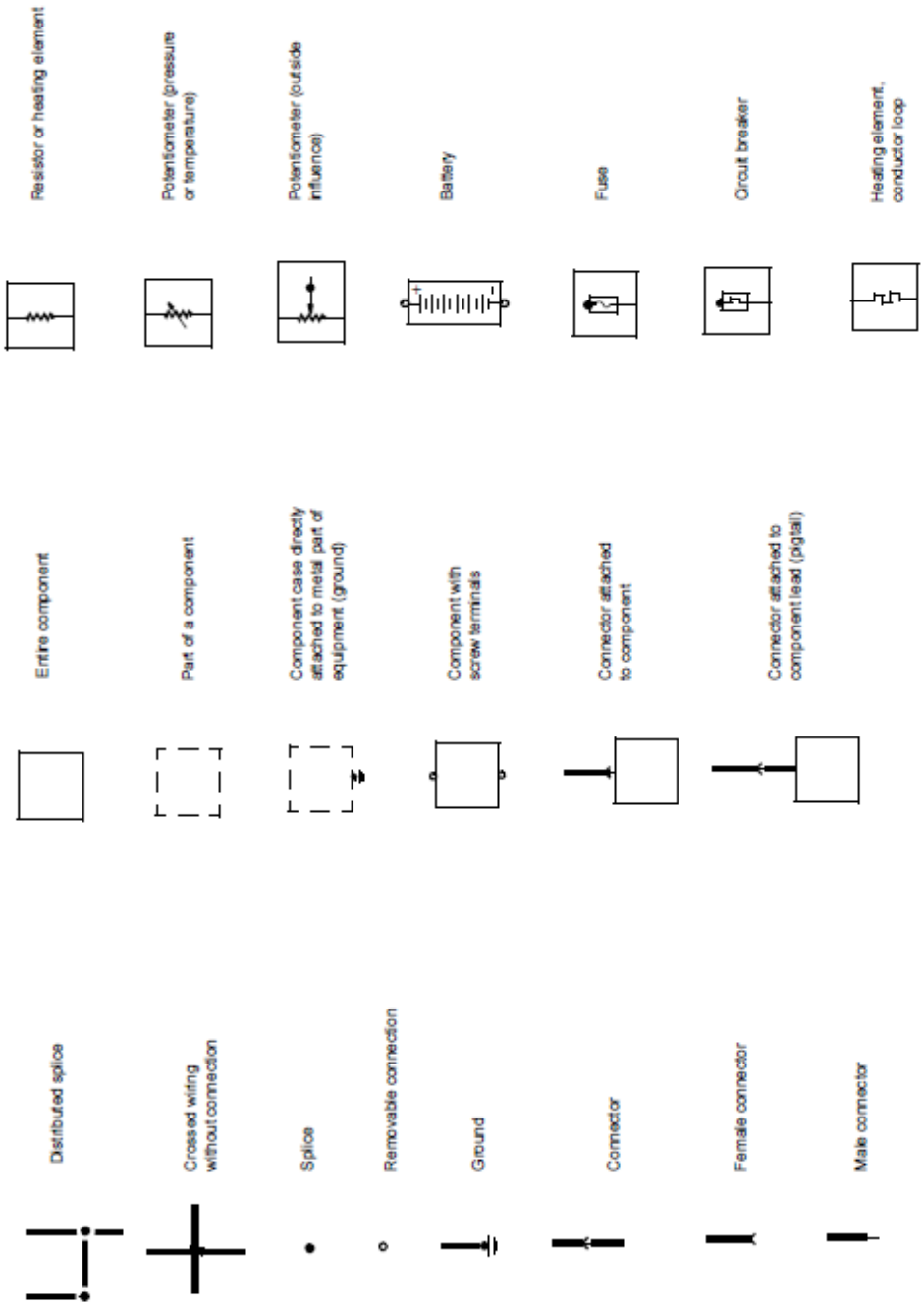
Charge by induction occurs when a person with well insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off, leaving the person highly charged with the opposite polarity. Static charges can cause damage, therefore it is important to use care when handling and testing electronic components.

CAUTION: To prevent possible electrostatic discharge damage, follow these guidelines:

- Do not touch the GCP connector pins or soldered components on the GCP board.
- Do not open the replacement part package until the part is ready to be installed.
- Before removing the part from the package, ground the package to a known good ground on the equipment.
- If the part has been handled while sliding across a seat, while sitting down from a standing position, or while walking a distance, touch a known good ground before installing the part.

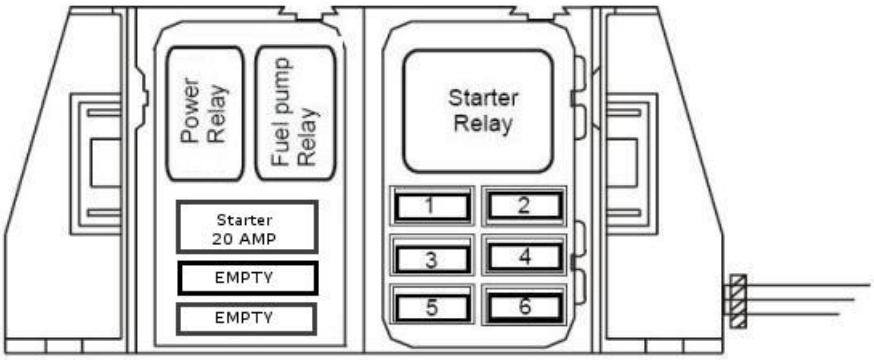
Diagrams and Schematics

Symbols



GCP - Power Distribution Box

Part of -5210120- Engine Wiring Harness



Fuse	Amps	Circuits protected
1	10	Battery Voltage to EPR
2	5	Ignition Voltage to GCP and Relays
3	10	Battery Voltage to GCP
4	15	Fuel pump
5	15	Battery Voltage out of Power Relay
6	10	Alternator

Wire Colors

Symbol	Color
BK	BLACK
BN	BROWN
BU	BLUE
DB	DARK BLUE
DG	DARK GREEN
GN	GREEN
GY	GRAY
LB	LIGHT BLUE
LG	LIGHT GREEN
NA	NATURAL
OG	ORANGE
PK	PINK
RD	RED
SR	SILVER
TN	TAN
VT	VIOLET
WH	WHITE
YE	YELLOW

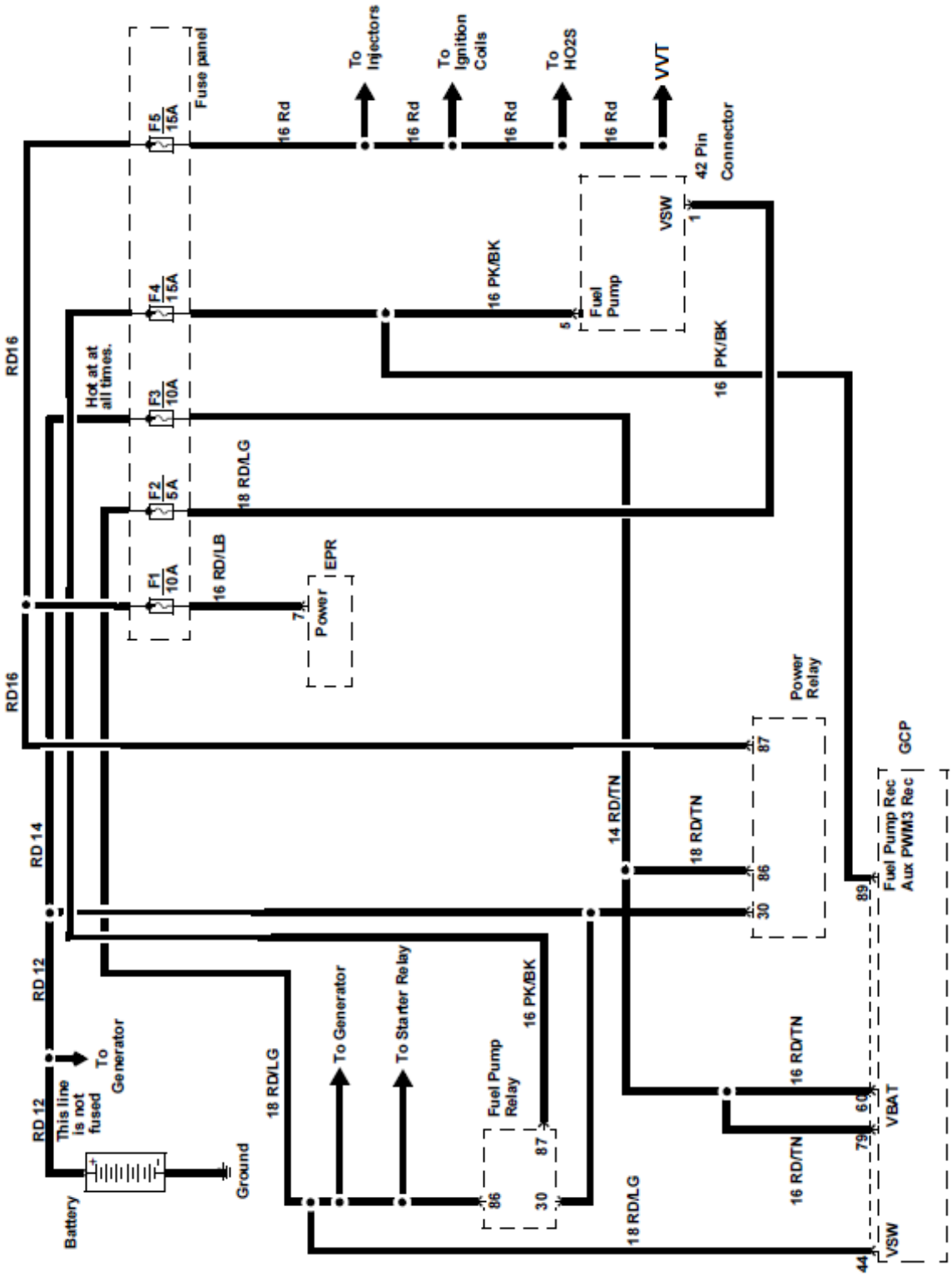
Revision Level

The following wiring schematics are taken from the wiring diagram labeled below:

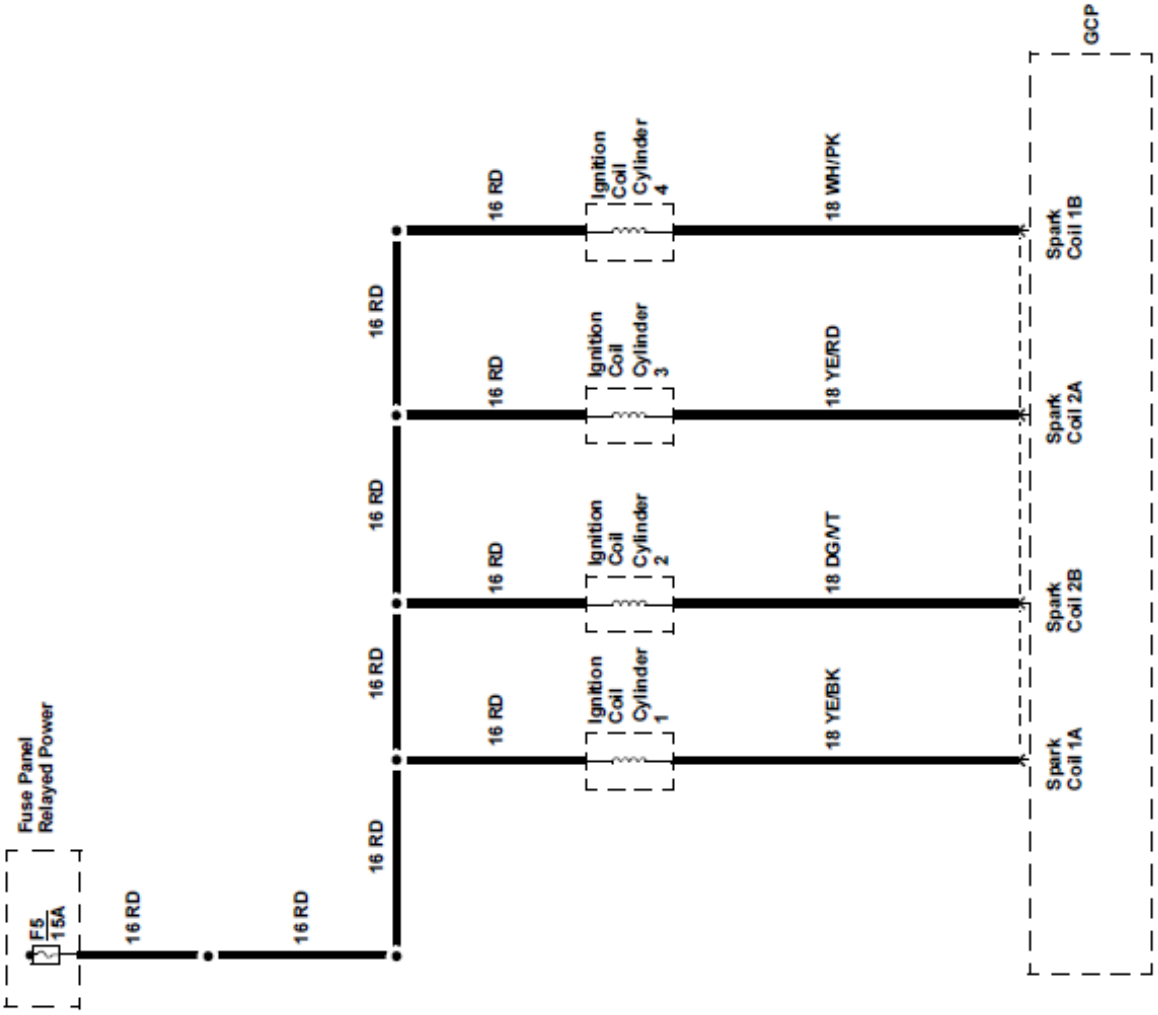
Title: EDI / FORD 2.5L W/GCP		
Size: D	Number: 2487000	Rev: D
Date: 11/1/2011	Drawn By: J. SUTTON	
Filename: 2487000d.sch	Sheet 1 of 1	

MSG-425 Engine Controls

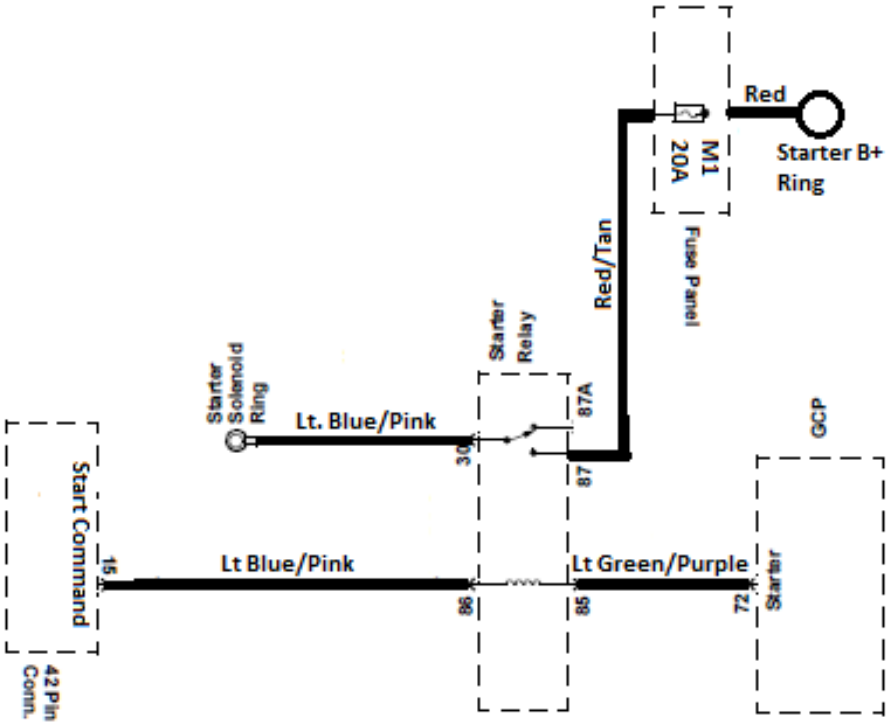
Power Distribution



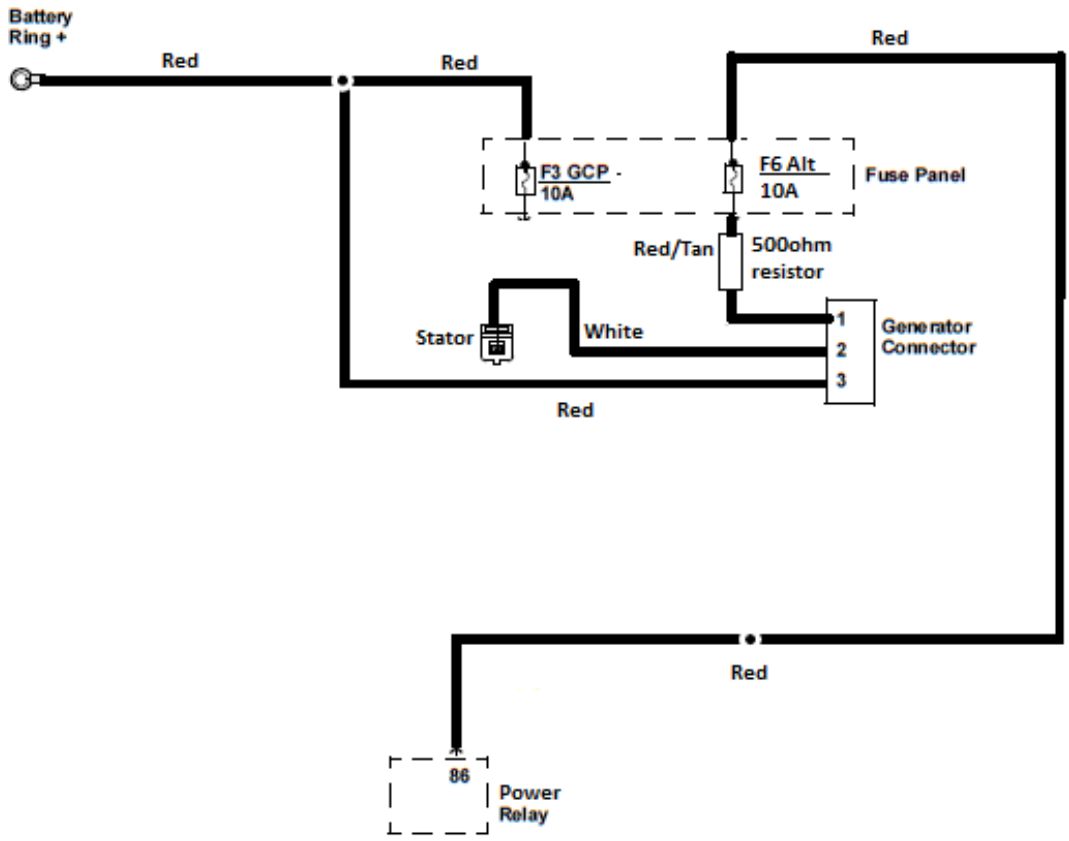
Ignition System



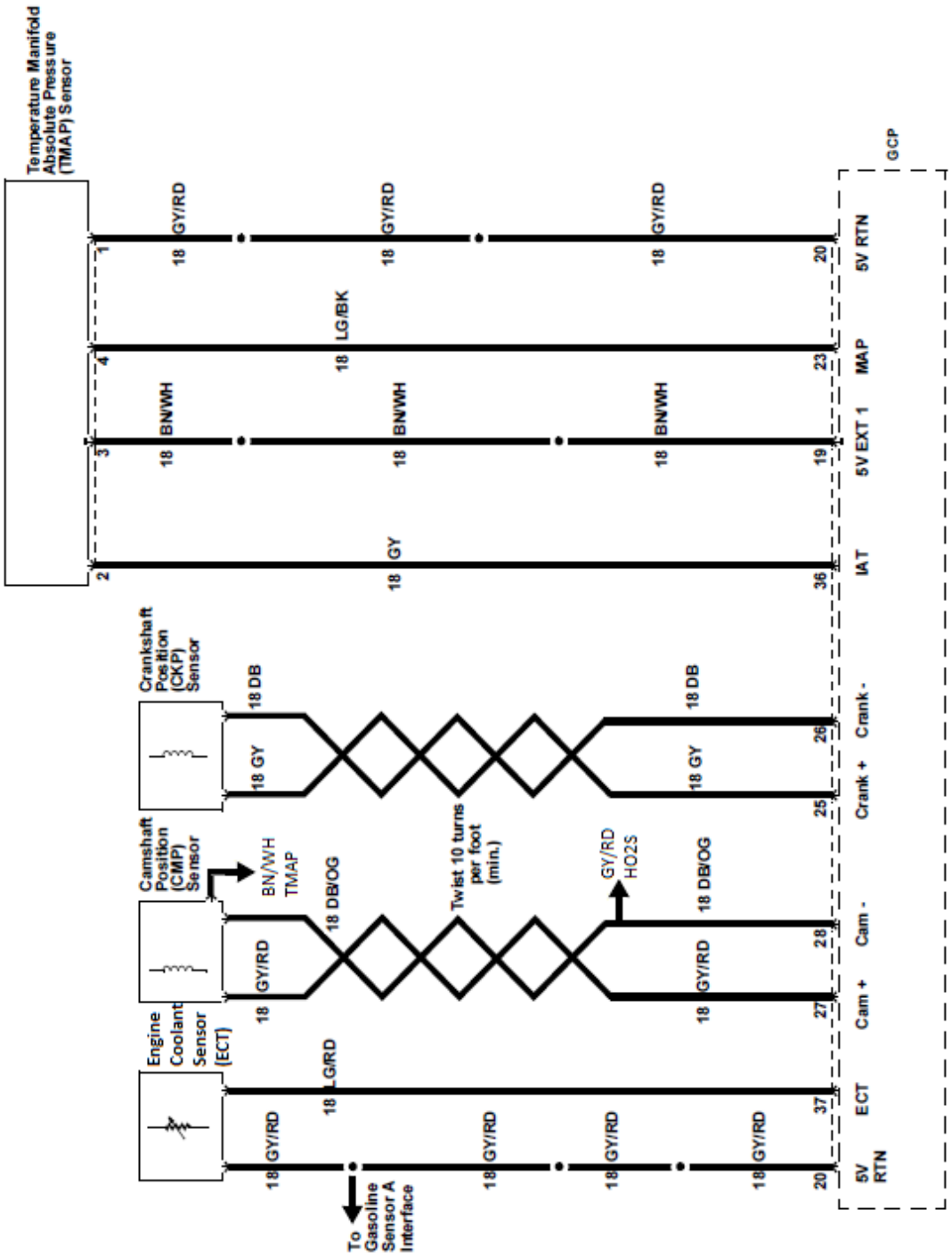
Starting System



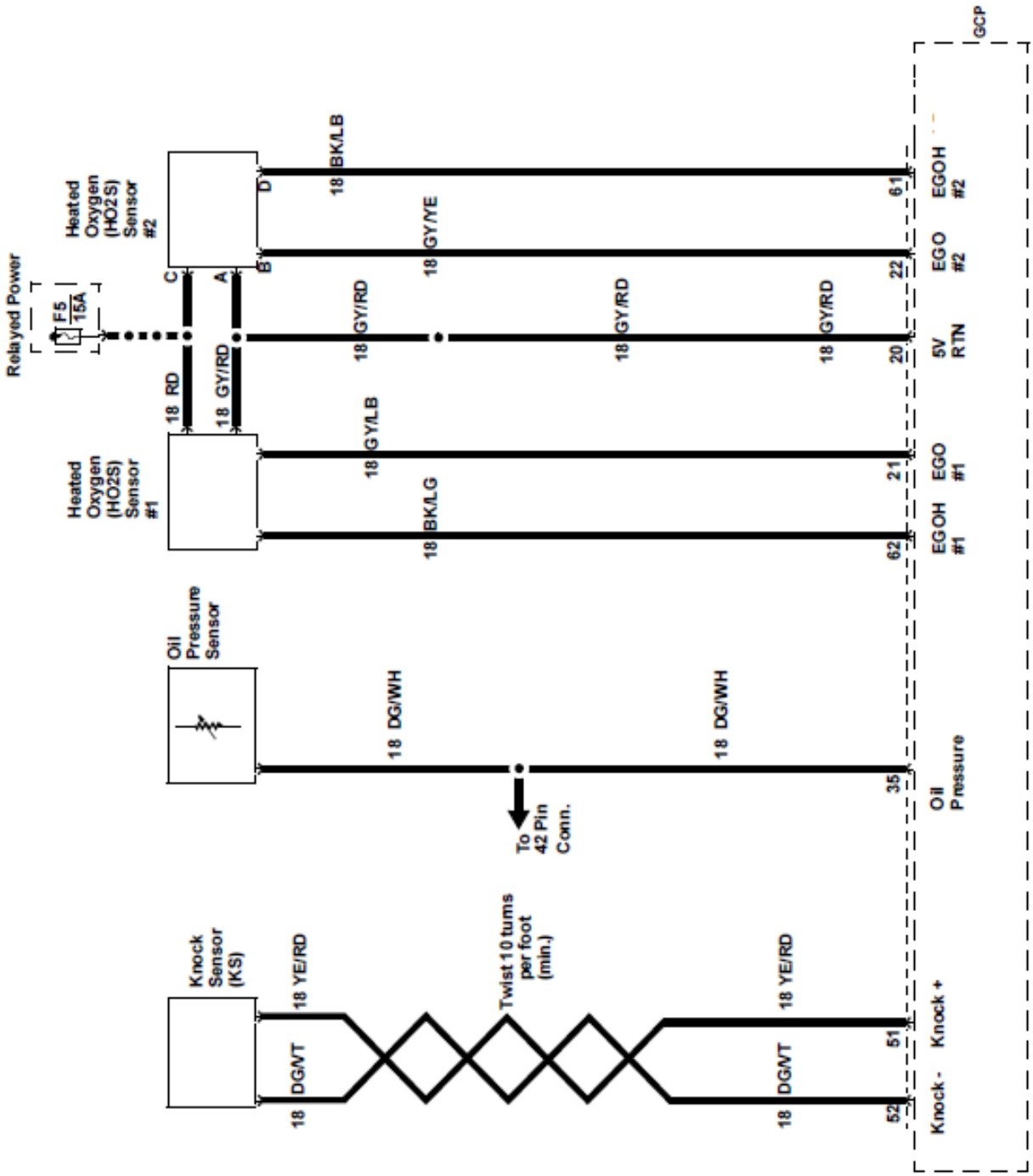
Charging System



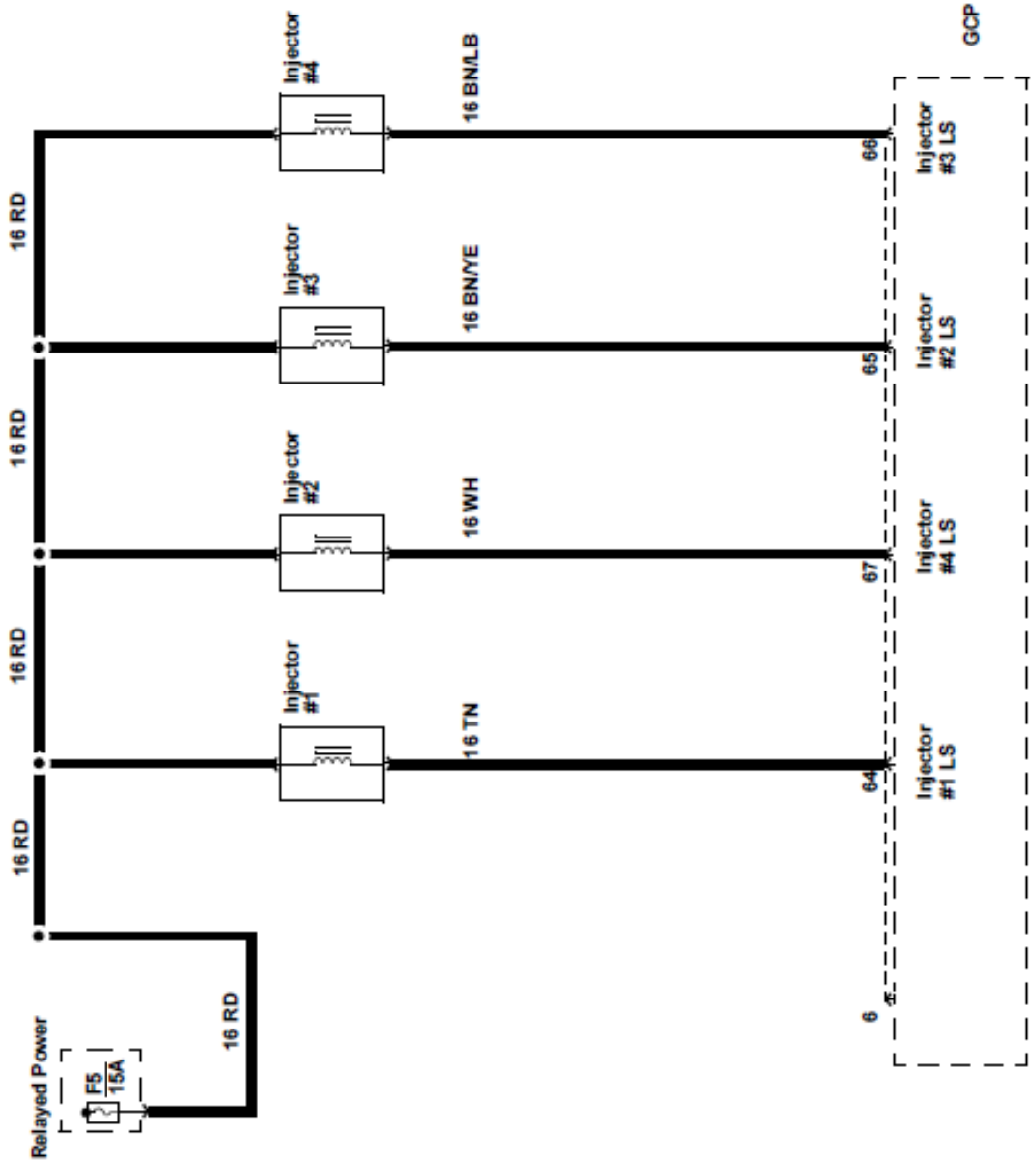
Engine Controls - Sensors (1 of 2)



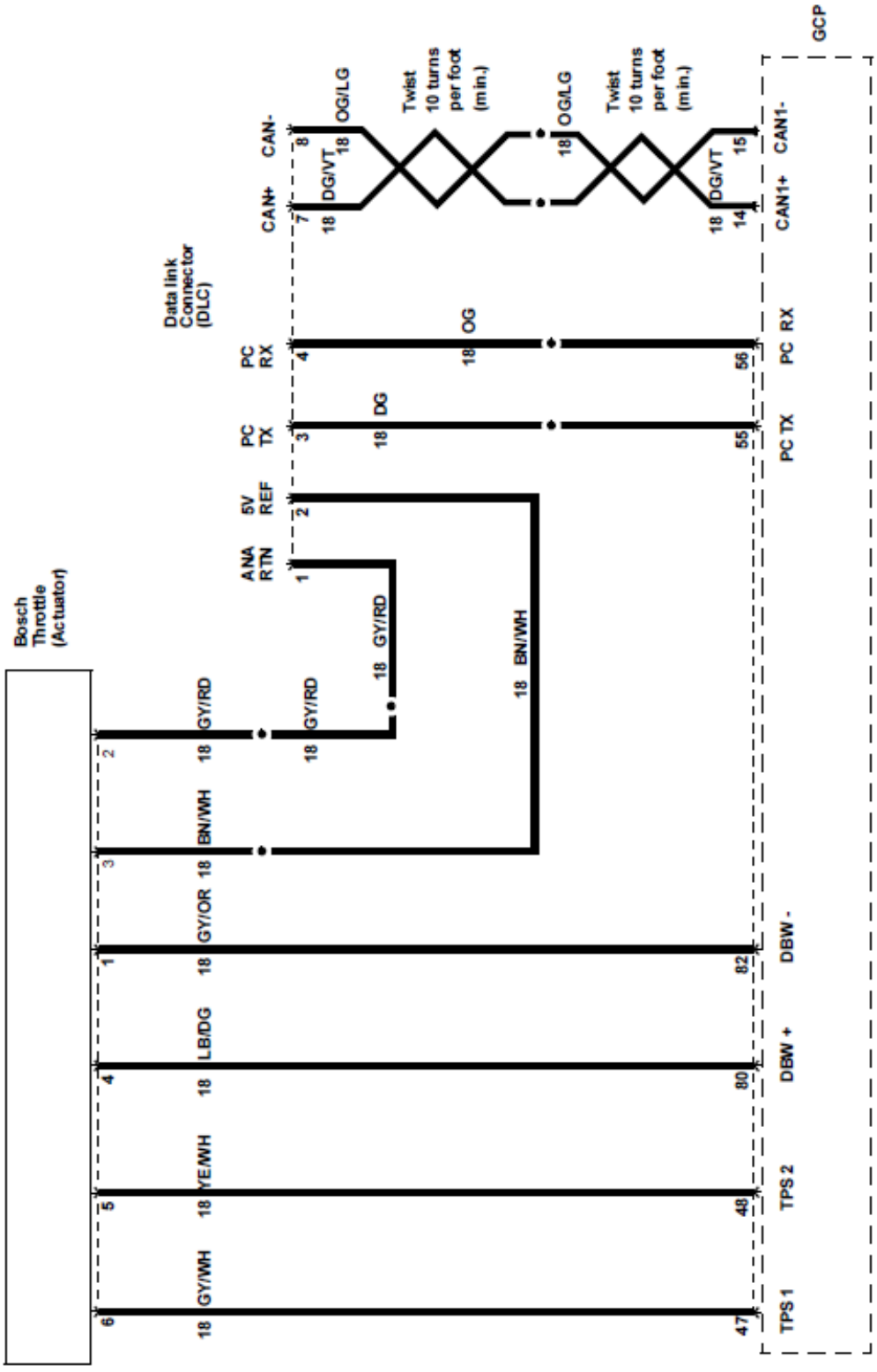
Engine Controls - Sensors (2 of 2)



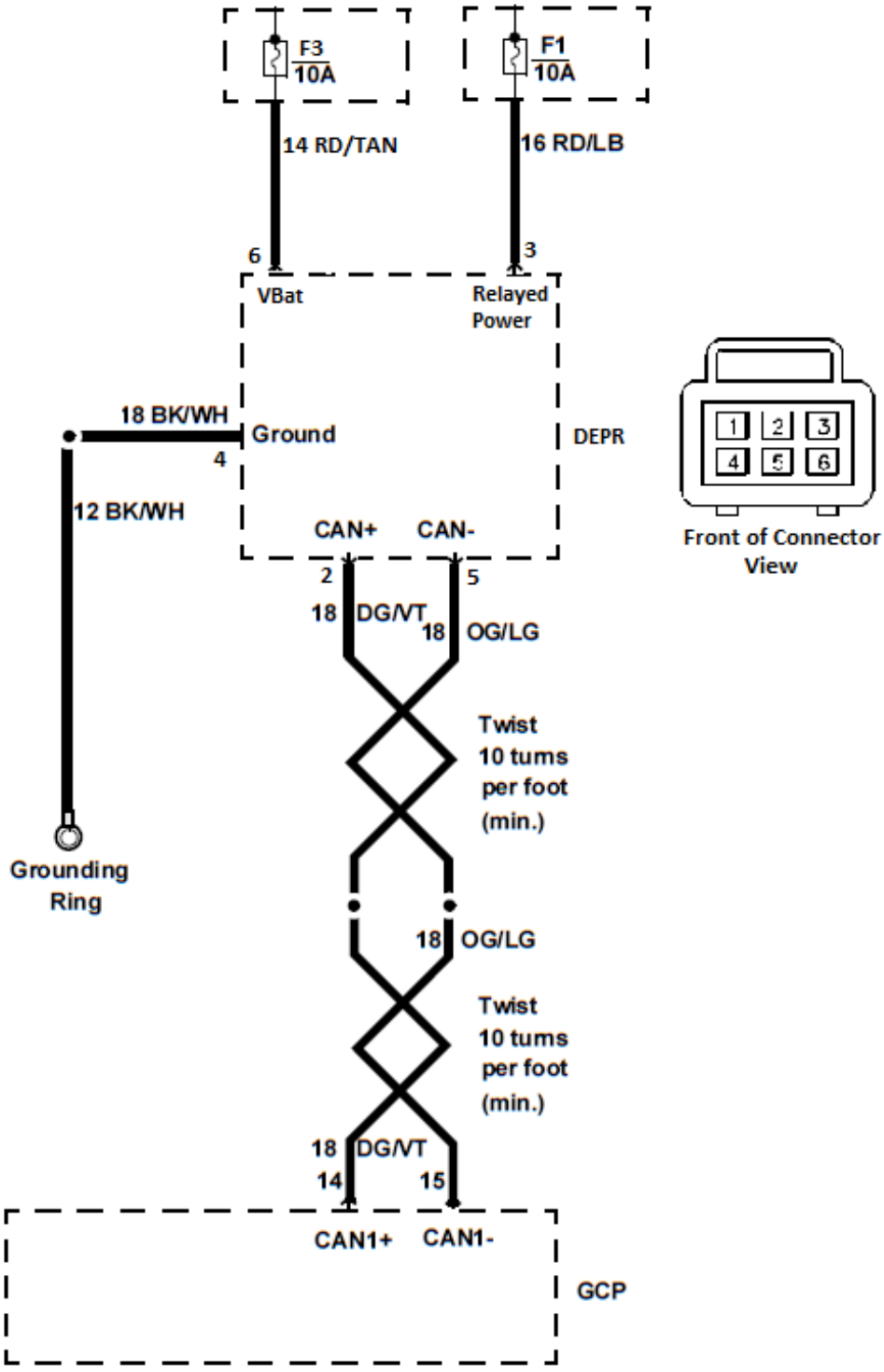
Fuel Injectors



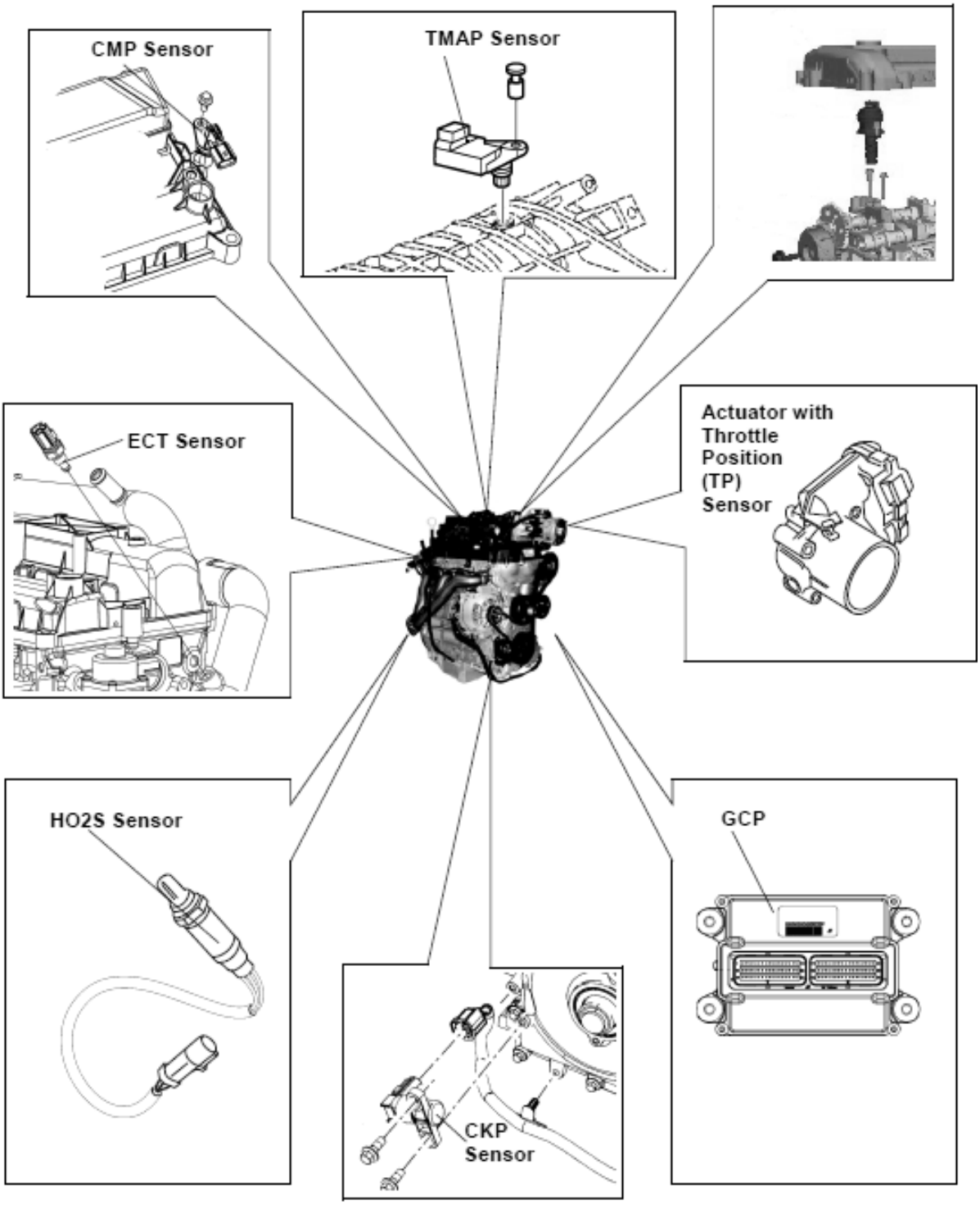
Engine Controls - Actuator / Data Link Connector (DLC)



Engine Controls - Dry Fuel DEPR



Engine Component Locator View



DIAGNOSIS AND TESTING

Diagnostic Approach

Use the following step by step approach when diagnosing an engine performance problem:

1. Verify the concern and determine if it is a deviation from normal operation.
2. Once the concern has been verified, preliminary checks can be done. Conduct a thorough visual inspection, be alert for unusual sounds or odors, and gather diagnostic trouble code (DTC) information.
3. If a diagnostic trouble code (DTC) is stored, follow the designated DTC chart exactly to make an effective repair.
4. If no DTC is stored, select the symptom from the symptom charts and follow the suggestions to complete the repair.
5. If no matching symptom is available, analyze the complaint and develop a plan for diagnostics utilizing the wiring diagrams, technical assistance and repair history.
6. Some diagnostic charts contain diagnostic aids which give additional information about a system. Be sure to use all of the information that is available to you.

GCP Diagnostic Overview

FORD Diagnostic Trouble Codes are set when the FORD system GCP runs a diagnostic self-test and the test fails. When a DTC is set, the FORD system GCP will illuminate the Malfunction Indicator Lamp (MIL) on the instrument panel and save the code in memory.

The FORD system GCP will continue to run the self-test unless the DTC is an oxygen sensor lean, oxygen sensor rich, or a GCP related DTC. If the system continues to fail the test, the lamp will stay illuminated and the DTC is current (ACTIVE). All DTC's are stored as historical faults until they are cleared. All DTC's except the GCP related DTC's will automatically clear from memory if the DTC does not reset within 50 consecutive engine run cycles.

While a Diagnostic Trouble Code is current for a sensor, the FORD system GCP may assign a default limp home value and use that value in its control algorithms. All of the FORD system diagnostic self-tests run continuously during normal engine operation.

The Diagnostic Trouble Codes can be read by using either the Malfunction Indicator Lamp (MIL) or a Laptop computer. Refer to Using a Laptop Computer to Diagnose the FORD System and Using a Diagnostic Jumper to Diagnose the FORD System, located in this section. Diagnostic Trouble Codes can be cleared from memory with a laptop computer or by turning the ignition key to the OFF position and removing the FORD system main power fuse (F3) for 15 seconds.

If more than one DTC is detected, begin with the lowest number DTC and diagnose each problem to correction unless directed to do otherwise by the fault tree. The DTC's are numbered in order of importance. Having DTC 112 and DTC 122, both concerning the oxygen sensor, is possible. By repairing DTC 112 first, the problem causing the DTC 122 may also be corrected.

On-Board Diagnostics - GCP

The diagnostic tests and circuit charts are designed to assist the technician to locate a faulty circuit or component through a process of logical decisions. The tests and charts are prepared with the requirement that the engine functioned correctly at the time of assembly and that there were not multiple faults present.

There is a continuous self-diagnosis on certain control functions. This diagnostic capability is complimented by the diagnostic procedures contained in this section. The language for communicating the source of the malfunction is a system of diagnostic trouble codes.

When a malfunction is detected by the Engine Control Module (GCP), a Diagnostic Trouble Code (DTC) is set and the Malfunction Indicator (MIL) lamp will be illuminated (refer to MIL DTC Retrieval Procedure for process description) -- Refer to "Diagnosis Using a Personal Computer" on page 26 or Palm Pilot Diagnosis, for information regarding performing GCP and engine control system diagnosis.

Engine Control Module (GCP) Limp Home Mode Strategy

The GCP has four settings for limp home mode. Depending on what Diagnostic Trouble Code (DTC) is set, one or more of the limp home modes will be in effect.

The four limp home modes are as follows:

Power Derate 1

The actuator is limited to a maximum opening of 50%. If "Power Derate 1" is active, it will remain active until the active DTC goes away.

The following DTC's will cause Power Derate 1 to take affect:

- DTC 1521: CHT/ECT higher than expected 1. (CHT/ ECT is greater than 240 °F).
- DTC 111: IAT higher than expected 1. (IAT is greater than 200°F).
- DTC 327: Knock sensor open. (1.6L and 4.2L only)
- DTC 326: Excessive knock signal. (1.6L and 4.2L only)
- DTC 2122: FPP1 high voltage.
- DTC 2123 FPP1 low voltage.
- DTC 2128: FPP2 high voltage.
- DTC 2127: FPP2 low voltage.
- DTC 1531: IVS/Brake interlock failure.

Power Derate 2

The actuator is limited to a maximum opening of 20%. If “Power Derate 2” is active, it will remain active until the active DTC goes away and the ignition input to the GCP (usually the ignition switch) is cycled.

- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.
- DTC 1171: MegaJector delivery pressure higher than expected.
- DTC 1172: MegaJector delivery pressure lower than expected.
- DTC 1173: MegaJector communication lost.
- DTC 1176: MegaJector internal actuator fault detection.
- DTC 1177: MegaJector internal circuitry fault detection.
- DTC 1178 MegaJector internal communication fault detection.
- DTC 606: COP failure (Internal GCP failure).
- DTC 1612: RTI 1 loss (internal GCP failure).
- DTC 1613: RTI 2 loss (internal GCP failure).
- DTC 1614: RTI 3 loss (internal GCP failure).
- DTC 1615: A/D loss (internal GCP failure).
- DTC 1616: Invalid interrupt (internal GCP failure).
- DTC 601: Flash checksum invalid (internal GCP failure).
- DTC 604: RAM failure (internal GCP failure).

Fault Low Rev Limit
The engine RPM will be limited to a maximum of 1600 RPM. If the “Fault Low Rev Limit” is active, it will remain active until the active DTC goes away and the ignition input to the GCP (usually the ignition switch) is cycled.

- DTC 2122: FPP1 high voltage.
- DTC 2123: FPP1 low voltage.
- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.
- DTC 1531: IVS/Brake interlock failure.

Force to Idle
The engine RPM will be limited to a maximum of 800 RPM. If the “Force to Idle” is active, it will remain active until the active DTC goes away.

- DTC 2122: FPP1 high voltage.
- DTC 2123: FPP1 low voltage.
- DTC 2128: FPP2 high voltage.
- DTC 2127: FPP2 low voltage.
- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.

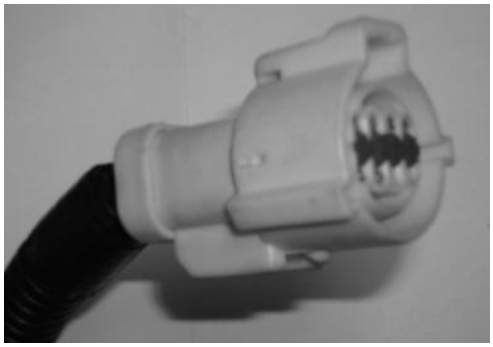
Intermittent MIL

Conditions that are only present from time to time are called intermittents. To resolve intermittents, perform the following steps:

1. Evaluate the history of DTC’s observed with this particular engine.
2. Evaluate the symptoms and conditions described by the customer.
3. Use strategy-based diagnosis, especially where it relates to the elimination of bad connectors and wiring.
4. When using a personal computer with Ford software, data-capturing capabilities are available that can assist in detecting intermittents. Review the user manual pdf document that is included on the software CD.

Malfunction Indicator Lamp (MIL) DTC Retrieval Procedure

NOTE: DTC’s can be retrieved from the engine control module (GCP) by using either the MIL or an IBM compatible personal computer with a USB port. Refer to Equipment Setup for information about using a personal computer to assist with unit diagnosis.



DTC's can be retrieved by shorting the Self-Test Input (STI) connector to ground. The STI circuit is a white/ purple wire exiting pin 3 of the 42 pin connector. If no DTC is stored with key on/engine off (KOEO), a DTC 1654 is flashed, indicating that all systems are OK.

During key on/engine running (KOER) operation, with no DTCs stored, the MIL is not illuminated. If during

KOER operation a DTC is stored, the MIL will illuminate and remain on steady if the code is active.

MIL Bulb Test

The MIL bulb test occurs KOEO with the STI connector not grounded. The MIL bulb will stay on and remain on if no DTCs are present. If DTCs are present (except DTC 1654), the MIL bulb will blink. If the MIL bulb does not illuminate when bulb test is performed, access diagnostic software and view the fault indicator on screen. If the screen fault indicator is illuminated and the MIL light is not, inspect the bulb and replace it if damaged. If bulb is OK or does not illuminate after replacement, refer to MIL circuit test procedure. Once MIL bulb illumination has been verified or established, DTCs can be extracted from the MIL as follows:

DTC Extraction

- KOEO, short the STI circuit to a known good ground. There will be a 5 second delay before DTCs begin flashing.

When extracting DTCs via the MIL the following apply:

- The flashing MIL is on for 0.4 second and off for 0.4 second.
- The MIL is off for 1.2 seconds between digits of three digit DTCs.
- The MIL is off for 2.4 seconds between DTCs.
- Each DTC repeats 3 times before the next stored DTC begins flashing
- Up to 6 DTCs can be stored.
- Once all stored DTCs are flashed, the process repeats with the first stored DTC.
- DTCs are flashed in the order in which they were set.

Once the DTC(s) is retrieved, refer to the appropriate DTC chart for explanation of what caused the DTC to set. Perform component and circuit test as required to conduct repair.

Diagnosis Using a Personal Computer

Equipment Requirements

You will need a laptop computer with a USB Port and CD drive.

- Kit for laptop part #: 5080050
  - ECOM Cable
  - Software CD

The required software is included with the kit via a CD.

Laptop Requirements:

• USB port
• 800 x 600 dpi screen
• Windows 95 or newer operating system
• No speed minimum
• 32 MB of RAM

Interface Hook-Up
For a connection to a laptop, use the below ECOM cable (5080050).

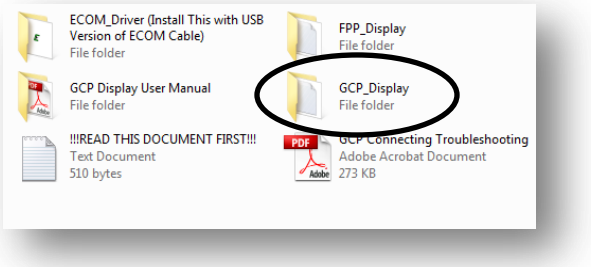
GCP Software Installation

Insert CD into CD-ROM drive.

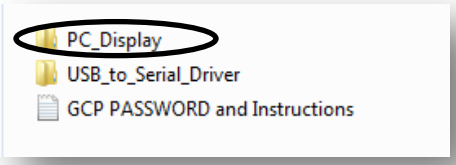
Double click “My Computer” Icon.

Double Click CD-ROM drive letter

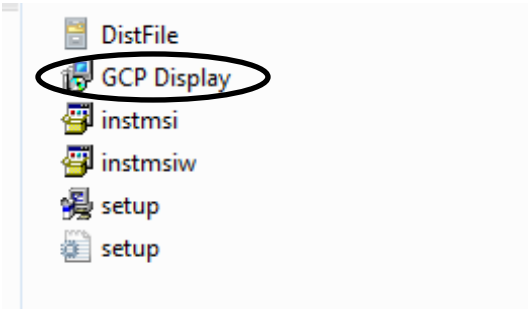
This will display the contents of the CD as shown.



Double click GCP_Display folder.

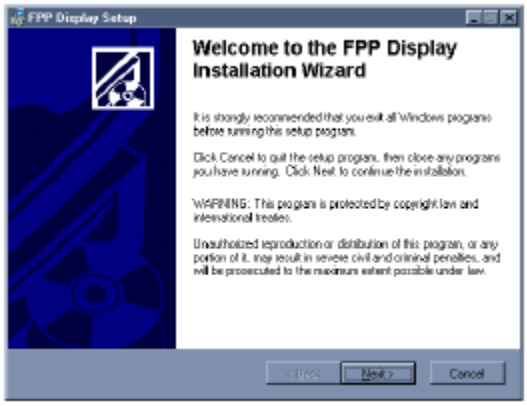


Double click the PC_Display folder.



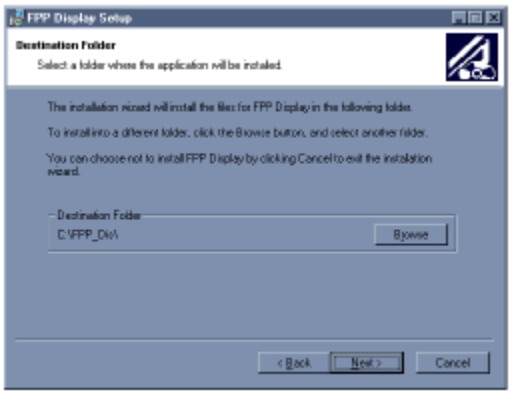
Double click the GCP_Display icon.

You will now see a welcome screen.



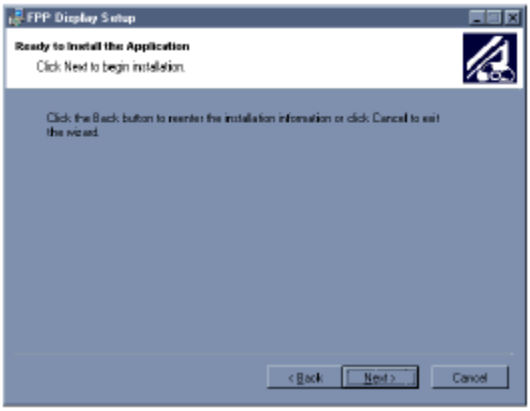
Click next.

A screen will pop up telling you the name of the destination folder.



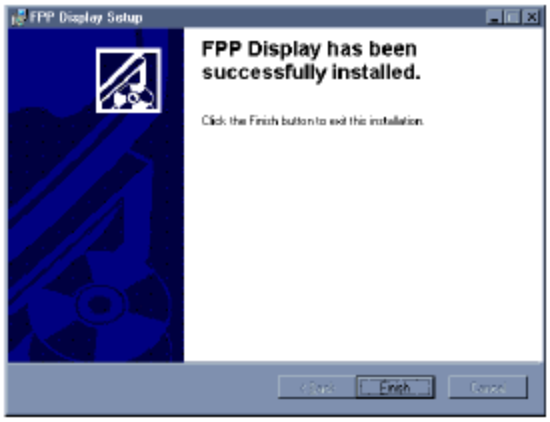
Click next.

You will now see a screen telling you it is ready to install the software.



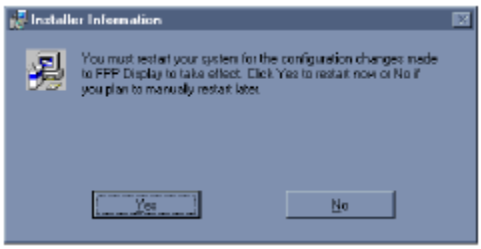
Click next.

You will see an Installation Success" screen when the software is finished installing.



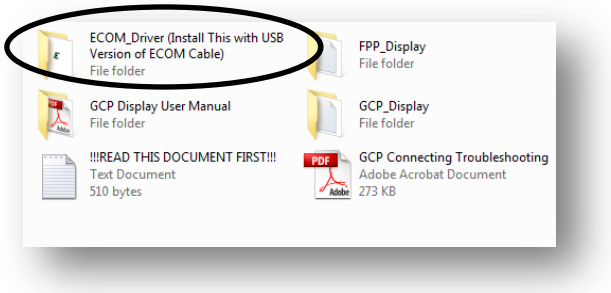
Click Finish.

A screen will pop up asking if it is ok to reboot your system.



Click No.

Go back to the main CD folder.



Double click the ECOM driver folder.

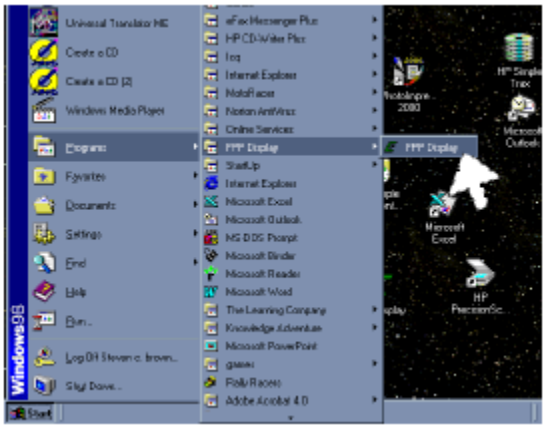
Double click the Driver Setup icon.

Follow those install instructions. Once successfully installed reboot your system.

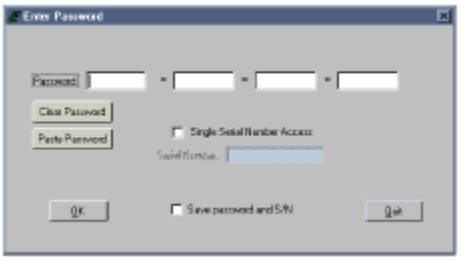
The software is now installed on your system in a folder called "GCP Display". Refer now to "Using Technicians GCP Software" in this Section.

Using GCP Software - Menu Functions

You can begin using the technicians GCP software after installation, by clicking Start - Programs - GCP Display - GCP Display as shown.



Type in the Password which can be found in the text file on the CD in the GCP Display folder.

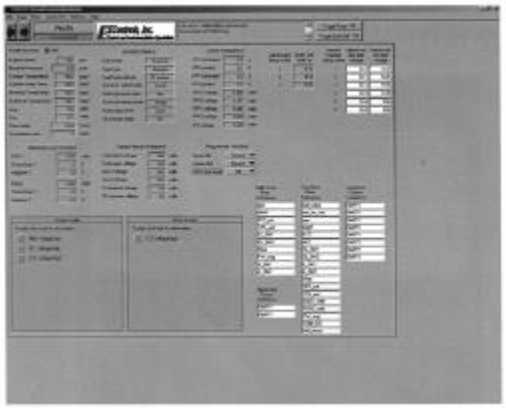


Place the ignition key in the ON position.

The GCP system Gauge screen should now appear and a green banner in the upper left hand corner will read "Connected".

Diagnostic Trouble Codes

The System Fault screen is used to view and clear DTC's, which have been set.



Checking Diagnostic Trouble Codes

The System Fault screen contains a listing of all of the Historic and Active DTC's set within the GCP system. If a DTC is stored in memory, the screen will display that fault in the Historic Faults column. If the fault condition currently exists, the DTC will also show up in the Active Faults column.

Opening Diagnostic Trouble Codes

To open a DTC, click on the DTC in the Historic Faults column. A DTC Dialog Box will pop up on the screen. The DTC Dialog Box contains the following useful information:

- If the fault occurred during the current key cycle.
- If the fault caused current engine shutdown.
- How many key cycles since the fault was active.
- Snapshot Data (explained later).
- Flight Data Recorder (explained later).

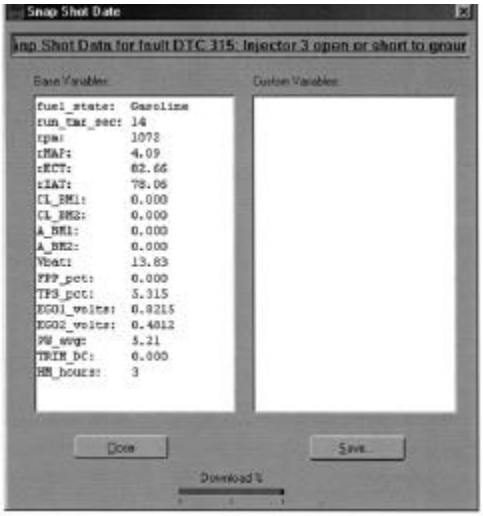
The DTC Dialogue Box also allows you to clear a single fault by clicking on the "Clear This Fault" button and it allows you to clear all faults by clicking on the "Click All Faults" button.

NOTE: Record faults before clearing them. This will aid in diagnosis.

Below is an example of a DTC Dialogue Box.

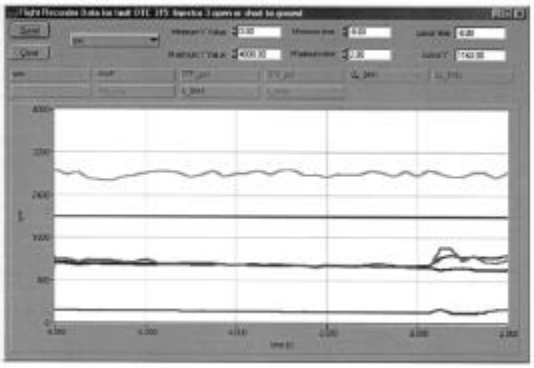
Snap Shot Data

The Snap Shot Data is a listing of specific engine system variables. These variables are recorded by the GCP at the instant the DTC sets. By clicking on the "View Snap Shot Data" button, a new window will pop up and you will be able to view these variables. Here is an example of a Snap Shot Data window.



Flight Data Recorder
The Flight Data Recorder is also a listing of specific engine system variables. These variables are recorded by the GCP for an interval of 10 seconds. The 10 second interval includes 8 seconds before the DTC sets and 2 seconds after the DTC sets. By clicking on the "View Flight Data Recorder Data" button, a new window will pop up and you will be able to view these variables.

Below is an example of a flight Data Recorder Data window.



The FAULTS screen shows the following:

- Fault Access
- System States
- DBW Variables
- Closed Loop Control
- Digital Input Voltages
- Diagnostic Modes
- Historic Faults
- Active Faults

Use the keys at the upper left corner or the "page" command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

Data Stream - Reading Sensor & Actuator Values

Most applicable sensor and actuator values are displayed on the Gauges Screen. The display shows the voltage the FORD system GCP is reading and, for sensors, the sensor value in engineering units.

This is one of three main screens (GAUGES, FAULTS AND RAW VOLTS).

The GAUGES screen shows the following:

- Manifold Absolute Pressure (MAP)
- Engine Coolant Temperature (ECT)
- Intake Air Temperature (IAT)
- Throttle Position (TP)
- Foot Pedal Position (FPP)
- Battery Voltage
- Engine speed (RPM)
- Exhaust Gas Oxygen (HO2S)
- Hour meter
- Number of continuous starts
- Run mode, power mode and fuel type

Use the keys at the upper left corner or the "page" command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

NOTE: If a DTC for a sensor is current, the engineering value for that sensor may be a default, limp home value and the voltage value will be the actual sensor voltage. Use the voltage value when performing diagnostics unless directed to do otherwise by the diagnostic trouble tree.

Plotting and Data Logging

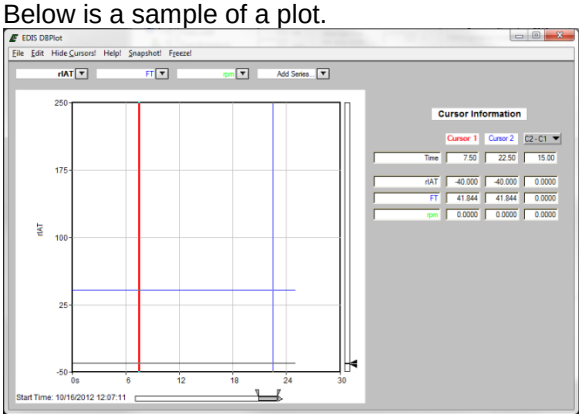
Recording the values and voltages can be a very useful tool while diagnosing engine problems. The GCP diagnostic software includes real time **plotting** and real time **logging** capabilities. These features enhance the ability to diagnose and repair possible problems with the GCP system. Both plotting and logging allows the user to record, in real time, any variable that can be seen in the GCP_Dis software. In order to record variables, the GCP_Dis software must be "Connected" to the GCP.

Plotting

To plot a variable, you must first "TAG" the variable. To do this, use the mouse to right click on the variable. The variable will highlight in green to let you know it is "TAGGED". Next, press the "P" key or click the Plot/Log button and then click the Plot Tags button to invoke the plotting feature. This begins the plot function and you can observe the plotted variables. The plot sweeps from right to left. To stop the plotting feature, simply click the "Freeze". To restart the plotter, click on the "Resume" button. The maximum number of variables that can be plotted at one time is 10. The range of the selected variables will be shown on the Y-axis and the time will be shown on the x-axis. You may change the desired time interval and sample interval for the plot by stopping the plot and typing in a new intervals.

The plot can be saved to the PC by stopping the plot and clicking "File" then "SAVE". When saving a plot, you will have to type in a filename. Plot files can later be viewed with the edis_saplot software located in the Windows Start Programs GCP_Dis folder, or the data can be viewed in Notepad or Excel.

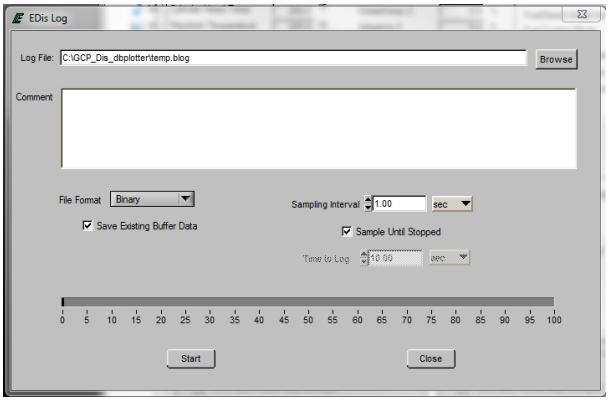
Below is a sample of a plot.



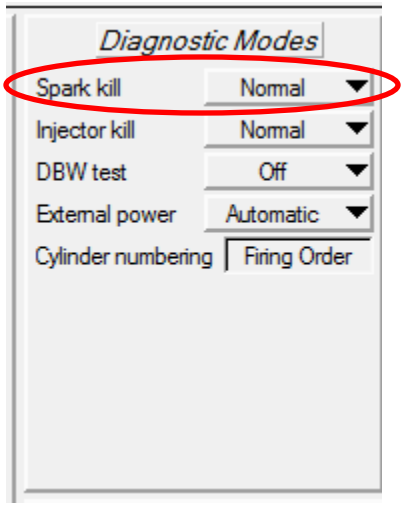
Logging

Logging variables means the variables are stored to the PC. During logging, there is no plot shown on the screen. To log variables you must first "TAG" the variables by right clicking them (same as plotting). Next, click on Plot / Log and then Log Tags. An "Edis Log" window will pop up. You can type in a custom log File name or select a custom folder to save the log file to. The default filename is "edis.log" and the default folder is GCP_Dis. The sample interval and time interval can also be changed from the default. To start logging, click on the "START" button. You will see the progress bar moving from 0 to 100%. When the logging is complete, you can close the Edis Log box or start another log file. If you start another log file, you must change the Log File name or the first log file will be overwritten. To view the contents of a saved log file, you can use Notepad or Excel.

The following are examples showing the Edis Log box before starting a log file, when running the log file the progress bar will move.



Ignition System Test



The Spark Kill diagnostic mode allows the technician to disable the ignition on individual cylinders. If the Spark Kill diagnostic mode is selected with the engine running below 1000 RPM, the minimum throttle command will lock into the position it was in when the test mode was entered. If the Spark System Test mode is selected with the engine running above 1000 RPM, the throttle will continue to operate normally.

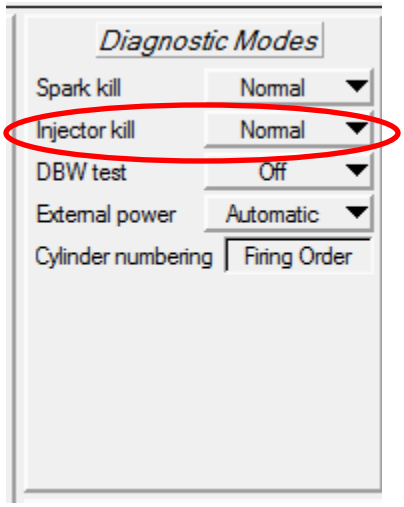
Spark kill is only available on gasoline, NOT on gaseous fuels.These diagnostic modes are found on the faults page.

Disabling Ignition Ouputs

To disable the ignition system for an individual cylinder, use the mouse to highlight the “Spark Kill” button and select the desired coil. The spark output can be re-enabled by using the mouse to highlight the “Spark Kill” button and selecting “Normal”. If the engine is running below 1000 RPM, the spark output will stay disabled for 15 seconds and then re-set. If the engine is running above 1000 RPM, the spark output will stay disabled for 5 seconds and then reset.
This test mode has a timeout of 10 seconds. Record the rpm drop related to each spark output disabled.

The Spark outputs are arranged in the order which the engine fires, not by cylinder number.

Injector Test

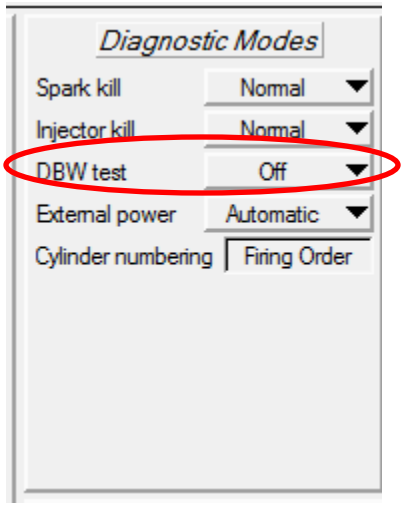


The Injector Kill mode is used to disable individual fuel injectors. If the Injector Kill mode is selected with the engine running below 1000 RPM, the minimum throttle **command** will lock into the position it was in when the test mode was entered. If the Injector Kill mode is selected with the engine running above 1000 RPM, the throttle will continue to operate normally.

Disabling Injectors

To disable an injector, use the mouse to select the desired injector. The word “Normal” will change to the Injector you have selected. The injector driver can be re-enabled by selecting again. If the engine is running below 1000 RPM, the injector driver will stay disabled for 15 seconds and then re-set. If the engine is running above 1000 RPM, the injector driver will stay disabled for 5 seconds and then re-set. Record the change in rpm or closed loop multiplier while each driver is disabled.

Throttle Test



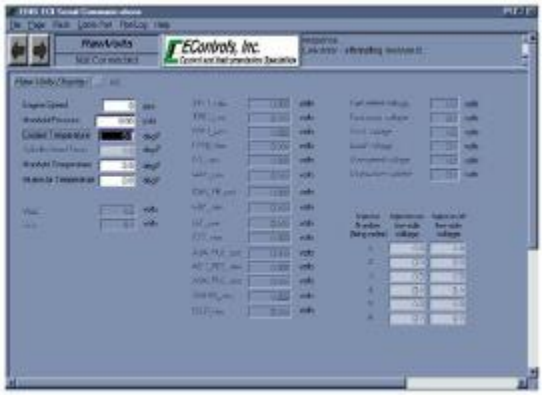
To select this test mode the engine must be off, but the key must be in the ON position.

The DBW Test mode allows the technician to control the throttle directly (without the engine running) with the foot pedal or entering a number into the “TPS Command” box. It is used during the diagnostic routines specified for FPP (foot pedal position) and TPS (throttle position sensor) related faults.

FP position displays the current position of the foot pedal as a percentage. FPP volts display the voltage that the GCP is reading from the FPP sensor.

TPS Command displays the commanded throttle position expressed as a percentage, which is being sent to the throttle. TPS Position is the actual percent of throttle opening being sent to the GCP from the throttle. TPS volts display the actual TPS signal voltage the GCP is receiving from the throttle.

RAW VOLTS Screen



The RAW VOLTS screen shows actual voltage readings from various circuits.

Use the keys at the upper left corner or the “page” command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

Visual Inspection

Perform a careful visual and physical engine inspection before performing any diagnostic procedure. Perform all necessary repairs before proceeding with additional diagnosis, this can often lead to repairing a problem without performing unnecessary steps. Use the following guidelines when performing a visual/physical inspection check:

- Inspect engine for modifications or aftermarket equipment that can contribute to the symptom; verify that all electrical and mechanical loads or accessory equipment is “OFF” or disconnected before performing diagnosis.
- Inspect engine fluids for correct levels and evidence of leaks.
- Inspect vacuum hoses for damage, leaks, cracks, kinks and improper routing, inspect intake manifold sealing surface for a possible vacuum leak.
- Inspect PCV valve for proper installation and operation.
- Inspect all wires and harnesses for proper connections and routing; bent or broken connector pins; burned, chafed, or pinched wires; and corrosion. Verify that harness grounds are clean and tight.
- Inspect GCP, sensors and actuators for physical damage.
- Inspect GCP grounds for cleanliness, tightness, and proper location.
- Inspect fuel system for adequate fuel level, and fuel quality (concerns such as proper octane, contamination, winter/summer blend).
- Inspect intake air system and air filter for restrictions.
- Inspect battery condition and starter current draw.

If no evidence of a problem is found after visual inspection has been performed, proceed to “Diagnostic System Check”

Intermittent Problems

NOTE: An intermittent problem may or may not turn on the MIL or store a DTC. Do not use the DTC charts for intermittent problems. The fault must be present to locate the problem.

NOTE: Most intermittent problems are caused by faulty electrical connections or wiring. Perform a careful visual inspection for the following conditions:

- Poor mating of the connector halves or a terminal not fully seated in the connector (backed out).
- Improperly formed or damaged terminals
- Improper contact tension. All connector terminals in the problem circuit should be carefully checked.
- Poor terminal-to-wire connections. This requires removing the terminal from the connector body to check.
- Improperly installed aftermarket equipment or accessories.

Operate the engine with accessories “OFF” and a suitable multimeter connected to the suspected circuit. An abnormal voltage when the malfunction occurs is a good indication that there is a fault in the circuit being monitored.

To check GCP for loss of diagnostic code memory, disconnect the MAP sensor connector and idle the engine until the MIL illuminates. Perform MIL DTC retrieval procedure. DTC should be stored and kept in memory when the ignition is turned “OFF”. If not, the GCP is faulty. When this test is completed, make sure that you clear the DTC from memory. An intermittent MIL with no stored DTC may be caused by the following:

- Ignition coil shorted to ground and arcing at plugs.
- MIL circuit to GCP shorted to ground.
- Poor GCP grounds.

Symptom Charts

NOTE: If you have a symptom of the pedal not working, and no DTC is set, go to the voltage screen and check pedal voltage. If pedal voltage is.75-1.25 volts, and idle validation switch says you're at idle - replace the pedal.

Engine Performance - No Load

NOTE: Items listed in the possible cause column generally do not set a diagnostic trouble code (DTC) or illuminate the MIL light.

NOTE: EDI engines are used in many different applications and equipment. When performing any system diagnosis be aware of any OEM inputs or equipment monitoring devices that may have an effect on the engine's performance or any of the engine's operating systems.

SYMPTOM	POSSIBLE CAUSE
Engine Runs Briefly and Shuts Down	• Loss of Spark • Frozen Fuel Regulator (Dry Fuel) • Low Fuel Pressure • Air Inlet Restriction • Wiring Failure • GCP Failure
Engine Cranks But No Start	• Faulty OEM Drivers Safety Shut-Off Seat Switch • Coil Power Loss • GCP Ground Loss • GCP Power Loss • Severe Vacuum Leak (Dry Fuel) • Air Inlet Restriction • Air Inlet Leak (Dry Fuel) • Fuel Lock-Off Inoperative (Dry Fuel) • Wiring Failure • Low Fuel Pressure • Ancillary Components Binding
Engine Runs Poorly	• High Fuel Pressure • Low Fuel Pressure • Contaminated Fuel • Incorrect Fuel Select Table Selected • Wrong GCP Installed • Actuator Air Blockage • Map Sensor Leak • Fuel Contaminated • Noise Suppression Capacitor Failure • Improper PCV Routing • Valve Timing • Low Cylinder Compression
Engine Cranks Slowly	• Excessive Engine Load (Hydraulic Pump Failing, Binding Ancillary Drive Components)\ • Low Battery Voltage • Incorrect Battery Specifications • Incorrect Battery Cable Size • Starter Relay • Starter Failure (Excessive Drain)
Engine Does Not Crank	• Dead Battery • Ground Loss • Ancillary Components Binding or Seized • OEM Shutdown - Oil Level Safety • Starter Lockout Relay Failure • Ignition Switch Failure • Bad Starter • Crank Control Wire Failure • Loose Connection or Corrosion

Engine Performance - While Under Load

SYMPTOM	POSSIBLE CAUSE
Engine Stalls/Quits	• Faulty OEM Drivers Safety Shut-off Seat Switch • Low Battery Voltage • Low Fuel Pressure • OEM Safety Shutdowns • Bad MAP Sensor • Air Restriction • Coil Failure • Fuel Mixer Binding (Dry Fuel)
Runs Rough	• Ground Loss • Misrouted Spark Plug Wires • Fuel System Failure • Vacuum Leak • Wiring Failure • Low Fuel Pressure • Spark Plugs Fouled • Incorrect Valve Timing
Misses	• Fuel System Failure • Misrouted Spark Plug Wires • Spark Plug Gap Too High • Spark Plugs Fouled • Cracked Spark Plug Insulator • Incorrect Valve Timing • Compression Loss
Hesitation/Stumble	• Low Fuel Pressure • Spark Plugs Fouled • MAP Sensor Vacuum Signal Loss
Surge	• Low Fuel Pressure • Map Sensor Failure • Application or Ancillary System Momentarily Binding During Load or Unload
Backfires	• Faulty OEM Drivers Safety Shut-off Seat Switch • Fouled Spark Plugs • Spark Plug Wire Broke • GCP Momentary Ground Loss • Excess Lean Condition • Fuel Lock-Off Leaking (Dry Fuel) • Intake Manifold Leak • Bad Intake Valve
Lack of Power	• Ancillary Components Binding • Intake Air Restriction • Crossed Spark Plug Wires • Spark Plugs Fouled • Fuel System Failure • Low Fuel Pressure • Low Cylinder Compression
Spark Knock	• Poor Quality or Contaminated Fuel • Carbon Build-up • Wrong Spark Plugs (Too High Heat Range) • Fuel Delivery System • PCV System • Fuel Selection Timing • Cylinder Hot Spots

Engine Concerns

SYMPTOM	POSSIBLE CAUSE
Oil System Concerns **- High Oil Consumption**	• Positive Crankcase Ventilation (PCV) System • Oil Viscosity • External Leaks • Improper Oil Dipstick • Valve Seals • Cylinder Wall Taper Excessive • Worn Piston Rings
Cooling System Concerns	• Trapped Air • Worn Drive Belt • Worn Water Pump • Stuck Thermostat • Plugged Radiator (Internal & External) • Dry Fuel System Running Rich
Exhaust System Concerns (visible smoke) **- Black Smoke** **- Blue Smoke**	 • Ignition System • Fuel Delivery System • Sticking Fuel Injector • High Fuel Pressure • PCV System • Worn Piston Rings • Worn valve guides
Fuel System Concerns	• Leaky Lines • Contaminated Fuel • Excessive Alcohol in Fuel • Incorrect Octane Rating
Engine Noise	• Low Oil Pressure • Oil Filter Restriction

Engine Control Module (GCP) – Diagnostic Trouble Codes

CAUTION: When checking codes with the diagnostic software, the DTC terminal can NOT be grounded.

CAUTION: Removing battery power before accessing diagnostic program will erase all codes recorded.

This section contains circuit description information and troubleshooting charts on all the DTC's obtained by diagnostic software or a Malfunction Indicator Lamp (MIL). When diagnostic trouble codes are obtained by a Malfunction Indicator Lamp (MIL), the following sequence will be flashed:

- 1654 will flash 3 times to indicate the beginning of the flash code display sequence.
- Any active DTC's will flash 3 times each.
- 1654 will flash 3 times indicating the end of the code display sequence.

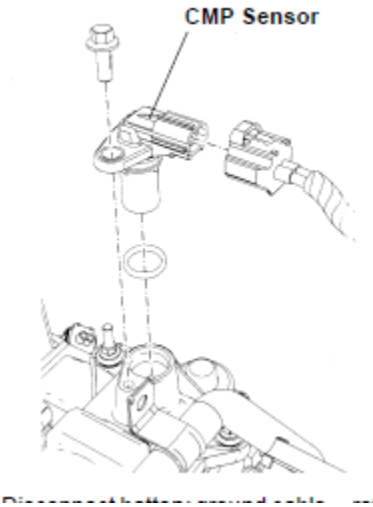
If code 1654 is the only code present, the system does not have any active codes - all systems are working fine.

If an active DTC is present, refer to the GCP diagnostic manual for code description and troubleshooting.

NOTE: If you have a symptom of the pedal not working, and no DTC is set, go to the voltage screen and check pedal voltage. If pedal voltage is .75 - 1.25 volts, and idle validation switch says you're at idle – replace the pedal.

REMOVAL AND INSTALLATION

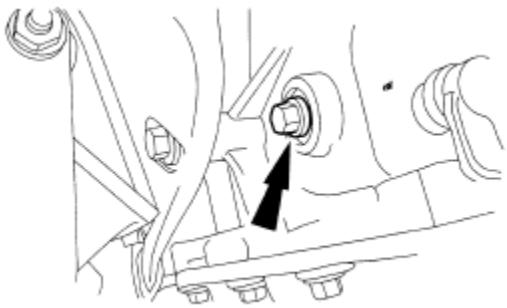
Camshaft Position (CMP) Sensor - Replacement



1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CMP Sensor.
3. Disconnect CMP electrical connector.
4. Remove bolt and CMP Sensor.
5. Reverse procedure to install:
    - Use a new o-ring seal
    - Lubricate o-ring with clean engine oil prior to installation
    - Tighten bolt to 7 Nm (62 lb-in).

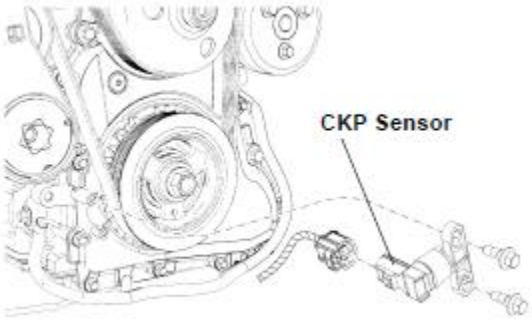
Crankshaft Position (CKP) Sensor - Removal

1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CKP Sensor.
3. Disconnect CKP electrical connector.
4. Remove plug.

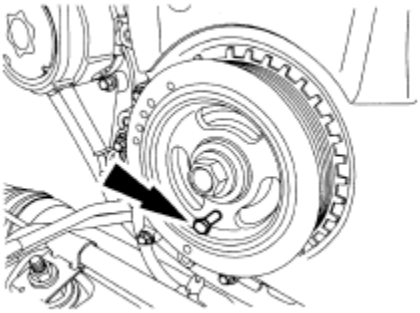


5. Install special tool 303-507 and turn the crankshaft pulley bolt to position the No. 1 cylinder at top dead center (TDC).

6. Remove 2 bolts and CKP sensor.



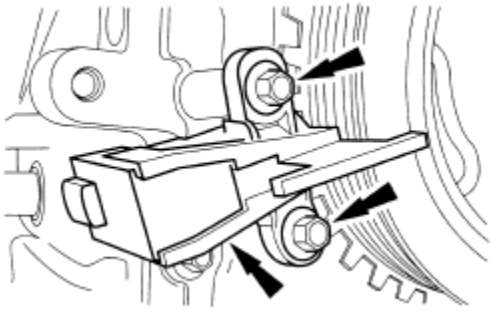
7. Install an M6 bolt in the position shown.



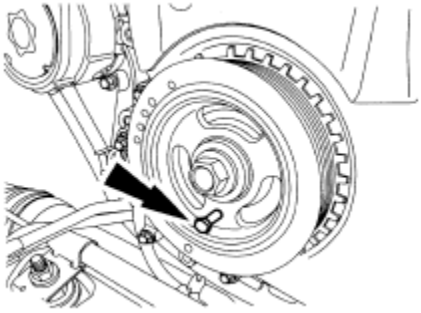
Crankshaft Position (CKP) Sensor - Installation

1. Position CKP sensor and loosely install the 2 bolts.

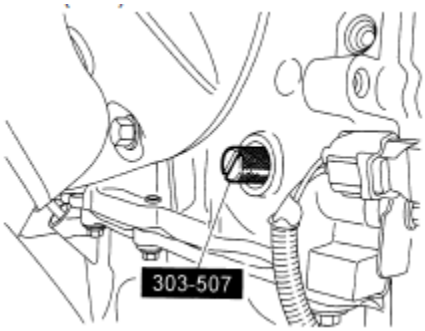
NOTE: The CKP sensor alignment tool is supplied with the new sensor and is not available separately.



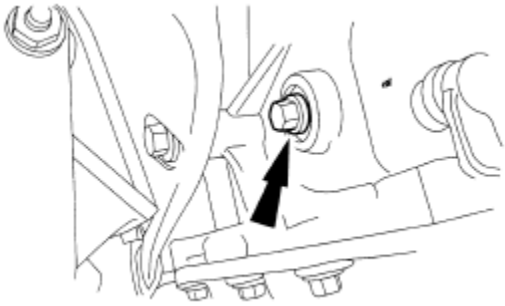
2. Adjust the CKP sensor with the alignment tool and tighten 2 bolts.
    - Tighten to 7 Nm (62 lb-in).
3. Connect CKP sensor electrical connector
4. Remove the M6 bolt.



5. Remove special tool 303-507.



6. Install the plug:
    - Tighten to 10 Nm (89 lb-in)



7. Reconnect or install any other component that was removed.

8. Reconnect battery cable -- refer to section 6.

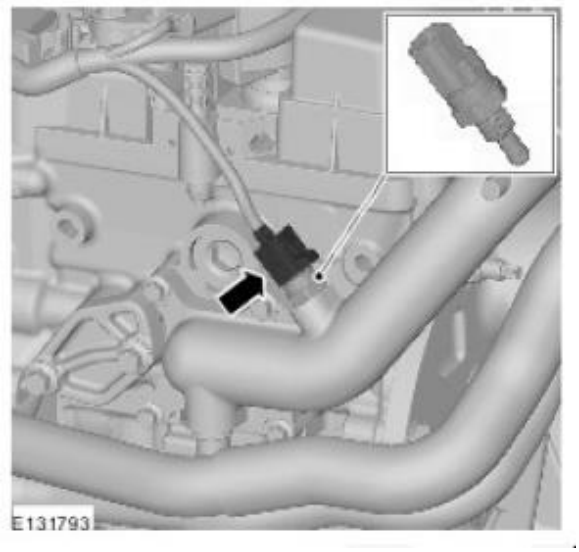
Engine Coolant Temperature (ECT) Sensor- Replacement

NOTE: Removal steps in this procedure may contain installation details.

1. Disconnect battery ground cable -- refer to section 6

NOTE: The sensor is located at the rear of the cylinder head.

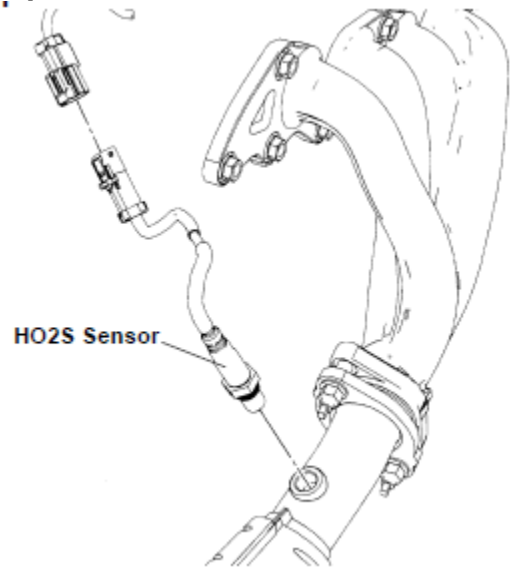
1. **NOTE:** Lubricate the O-ring seal with clean engine oil.
    - Torque: 30 Nm



Installation

1. To install, reverse the removal procedure.

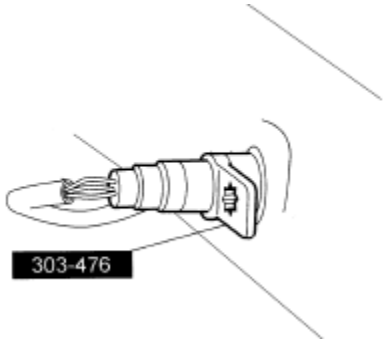
Heated Oxygen Sensor (HO2S) - Replacement



2. Disconnect battery ground cable -- refer to section 6
3. Remove or disconnect any component to allow access and removal of the HO2S Sensor.
4. Disconnect HO2S electrical connector.

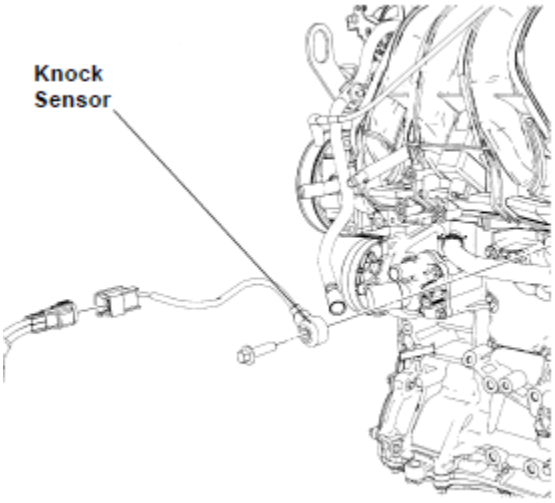
NOTE: Use penetrating oil to assist in removal.

5. Remove HO2S sensor.



6. Reverse procedure to install:
    - Apply a light coat of anti-seize lubricant to the threads of the sensor.
    - Tighten sensor to 40 Nm (30 lb-ft).

Knock Sensor (KS) – Replacement

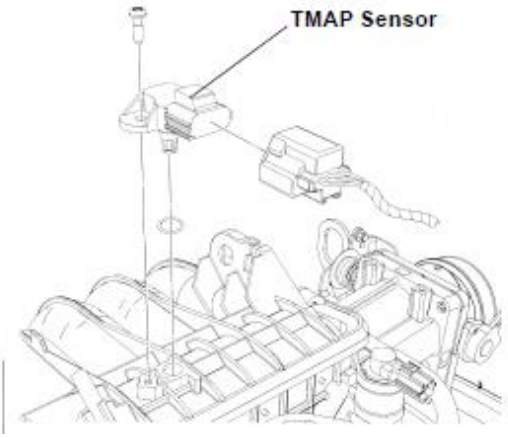


1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the knock sensor.
3. Disconnect KS sensor electrical connector.

NOTE: The KS sensor is a one-time use item and a new KS sensor must be installed.

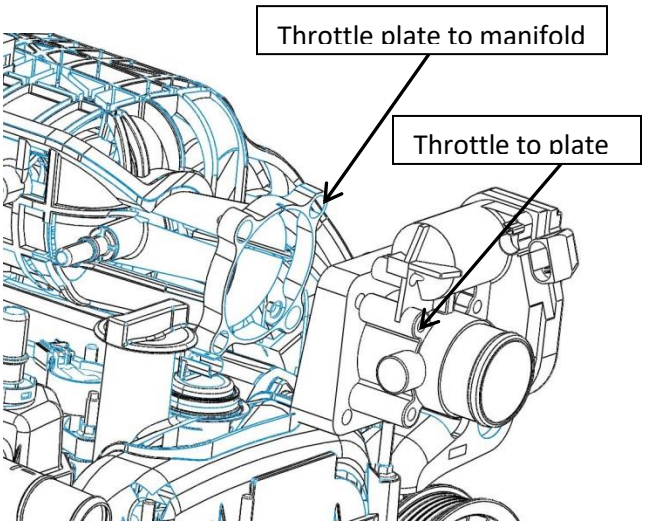
4. Remove bolt and KS sensor and discard sensor.
5. Reverse procedure to install:
    - Install a new KS sensor
    - Tighten bolt to 20 Nm (15 lb-ft).

Temperature Manifold Absolute Pressure (TMAP) Sensor - Replacement



1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the TMAP sensor.
3. Disconnect TMAP electrical connector.
4. Remove bolt and TMAP Sensor.
5. Reverse procedure to install:
    a. Use a new o-ring seal
    b. Tighten bolt to 3 Nm (2.2 lb-ft).

Actuator/Throttle Position (TP) Sensor - Replacement



Removal

NOTE: Removal steps in this procedure may contain installation details.

1. Disconnect battery ground cable -- refer to section 6
2. Disconnect the connector from the throttle
3. Remove the bolts from the throttle to the plate
4. Remove the bolts from the plate to the intake manifold
5. **NOTE:** The gasket is to be reused unless damaged.

Installation

1. To install, reverse the removal procedure.
    - Torque bolts to 10 Nm
2. The gasket between the throttle and plate is to be reused unless damaged.

MSG-425 METRICS

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MSG-425 METRICS

INTRODUCTION

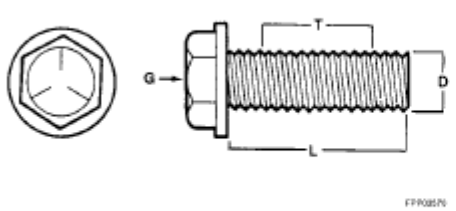
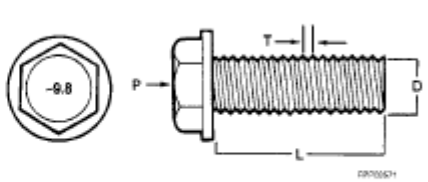
Most threaded fasteners are covered by specifications that define required mechanical properties, such as tensile strength, yield strength, proof load and hardness. These specifications are carefully considered in initial selection of fasteners for a given application. To ensure continued satisfactory vehicle performance, replacement fasteners used should be of the correct strength, as well as the correct nominal diameter, thread pitch, length, and finish.

Most original equipment fasteners (English or Metric system) are identified with markings or numbers indicating the strength of the fastener. These markings are described in the pages that follow. Attention to these markings is important to ensure that the proper replacement fasteners are used.

Further, some metric fasteners, especially nuts, are colored blue. This metric blue identification is in most cases a temporary aid for production start-up, and color will generally revert to normal black or bright after start-up.

English or Metric system fasteners are available through your Ford Parts and Service operation.

NOMENCLATURE FOR BOLTS

English System Bolt, 1/2 - 13 x 1	Metric System Bolt, M12 - 1.75 x 25
	
G = Grade Marking (bolt strength) L = Length (inches) ** T = Thread Pitch (thread/inch) D = Nominal Diameter (inches)	P = Property Class (bolt strength) * L = Length (millimeters) ** T = Thread Pitch (thread width crest to crest mm) D = Nominal Diameter (millimeters)

* The Property class is an Arabic numeral distinguishable from the slash SAE English grade system.
** The length of all bolts is measured from the underside of the head to the end.

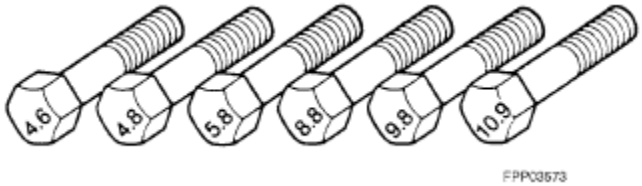
MSG-425 METRICS

BOLT STRENGTH IDENTIFICATION

English System

English (inch) bolts: Identification marks correspond to bolt strength, increasing number of slashes represent increasing strength.

Metric System



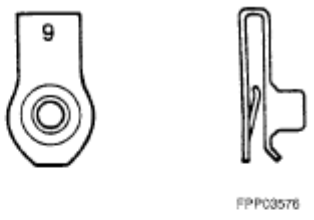
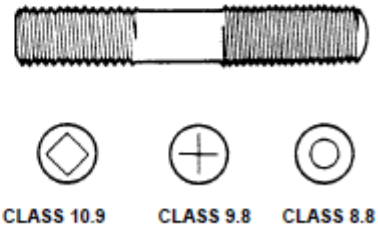
Metric (mm) bolts: Identification class numbers correspond to bolt strength, increasing numbers represent increasing strength. Common metric fastener bolt strength properties are 9.8 and 10.9 with the class identification embossed on the bolt head.

HEX NUT STRENGTH IDENTIFICATION

English System - Grade Identification	Metric System - Class Identification
HEX NUT Grade 5 (3 dots) HEX NUT Grade 8 (6 dots) FPP03574	HEX NUT Property Class 9 (Arabic 9) HEX NUT Property Class 10 (Arabic 10) FPP03575
Increasing dots represent increasing strength.	May also have blue finish or paint daub on hex flat. Increasing numbers represent increasing strength.

OTHER TYPES OF PARTS

Metric identification schemes vary by type of part, most often a variation of that used of bolts and nuts. Note that many types of English and Metric fasteners carry no special identification if they are otherwise unique.

Stamped U-Nuts	 FPP03576
Tapping, thread forming and certain other case hardened screws	FPP03577
Studs, Large studs may carry the property class number. Smaller studs use a geometric code on the end.	 FPP03578

ENGLISH/METRIC CONVERSION

TO CONVERT FROM TO	TO FROM	MULTIPLY BY DIVIDE BY
Distance		
Inches	mm	25.4
Inches	m	0.0254
feet	mm	304.8
feet	m	0.3048
yards	m	0.9144
mile	km	1.609
Area		
in^2	mm^2	645.16
$ft.^2$	m^2	0.0929
$ft.^2$	cm^2	6.45
yds^2	m^2	0.8361
Volume		
in^3	cm^3	16.3871
in^3	mm^3	16387.0
in^3	1 liter	0.016387
$yard^3$	m^3	0.7646
pint (us)	1 liter	0.47318
pint (uk)	1 liter	0.56826
quart (us)	1 liter	0.94635
gallon (us)	1 liter	3.7854
gallon (uk)	1 liter	4.5461
$ft.^3$	1 liter	28.3168
$ft.^3$	m^3	0.02832
Mass		
oz.	g	28.3495
lb.	kg	0.45359
ton	kg	907.18
ton (US)	tonne	0.90718
ton (UK)	tonne	1.01605
Density		
Force		
lbf	Newton (N)	4.44822
kilogram	Newton (N)	9.807
ounce	Newton (N)	0.2780
Pressure & Stress		
1000 kpa	Bar	1000
lbf/in^2 (psi)	kPa	6.895
lbf/in^2 (psi)	N/M^2	6894.76
lbf/in^2 (psi)	Bar	0.0689
lbf/in^2 (psi)	N/mm^2	0.00689
lbf/in^2 (psi)	mmHg	51.715
"H2O	kPa	0.2491
"H2O	mmH2O	25.4
"Hg	mmHG	25.4
ton (US)/in^2	N/mm^2	13.7894
ton (UK)/in^2	N/mm^2	15.4443
Velocity		
ft./sec.	m/s	0.3048
ft./sec.	km/h	1.09728
miles/h	m/s	0.44694
miles/h	km/h	1.609
Acceleration		
$in./sec^2$	m/s^2	0.0254
$ft./sec^2$	m/s^2	0.3048
Light		
foot candle	lumens/sq meter	10.764

TO CONVERT FROM TO	TO FROM	MULTIPLY BY DIVIDE BY
Energy		
kW.h	Joules (J)	3,600,000
lbft	Joules (J)	1.3558
Btu	Joules (J)	1055.06
Kcal	Joules (J)	4186.8
HP.h	kW.h	0.7457
PS.h	kW.h	0.7355
Temperature		
degree Farenheit (°F)	degree Celsius (°C)	(°F-32) x 0.556
Torque		
lb./ft.	Nm	1.35582
lb./in.	Nm	0.11298
Power		
HP	kW	0.7457
PS	kW	0.7355
HP	PS	1.01387
Specific Fuel Consumption		
lb./hp.h	g/kW.h	608.277
miles/gal	kilometers/liter (km/L)	0.4251
gal/miles	liters/kilometer (L/km)	2.3527

MSG-425 METRICS

DECIMAL AND METRIC EQUIVALENTS

FRACTIONS	DECIMAL INCH	METRIC MM
1/64	.015625	.397
1/32	.03125	.794
3/64	.046875	1.191
1/16	.0625	1.588
5/64	.078125	1.984
3/32	.09375	2.381
7/64	.109375	2.778
1/8	.125	3.175
9/64	.140625	3.572
5/32	.15625	3.969
11/64	.171875	4.366
3/16	.1875	4.763
13/64	.203125	5.159
7/32	.21875	5.556
15/64	.234375	5.953
1/4	.250	6.35
17/64	.265625	6.747
9/32	.28125	7.144
19/64	.296875	7.54
5/16	.3125	7.938
21/64	.328125	8.334
11/32	.34375	8.731
23/64	.359375	9.128
3/8	.375	9.525
25/64	.390625	9.922
13/32	.40625	10.319
27/64	.421875	10.716
7/16	.4375	11.113
29/64	.453125	11.509
15/32	.46875	11.906
31/64	.484375	12.303
1/2	.500	12.7
33/64	.515625	13.097
17/32	.5312S	13.494
35/64	.546875	13.891
9/16	.5625	14.288
37/64	.578125	14.684
19/32	.59375	15.081
39/64	.609375	15.478
5/8	.625	15.875
41/64	.640625	16.272
21/32	.65625	16.669
43/64	.671875	17.066
11/16	.6875	17.463
45/64	.703125	17.859
23/32	.71875	18.256
47/64	.734375	18.653
3/4	.750	19.05
49/64	.765625	19.447
25/32	.78125	19.844
51/64	.796875	20.241
13/16	.8125	20.638
53/64	.828125	21.034
27/32	.84375	21.431
55/64	.859375	21.828
7/8	.875	22.225
57/64	.890625	22.622
29/32	.90625	23.019
59/64	.921875	23.416
15/16	.9375	23.813
61/64	.953125	24.209
31/32	.96875	24.606
63/64	.984375	25.003
1	1.00	25.4

TORQUE CONVERSION

Newton Meters (Nm)	Pound Feet (lb-ft)
1	0.7376
2	1.5
3	2.2
4	3.0
5	3.7
6	4.4
7	5.2
8	5.9
9	6.6
10	7.4
15	11.1
20	14.8
25	18.4
30	22.1
35	25.8
40	29.5
50	36.9
60	44.3
70	51.6
80	59.0
90	66.4
100	73.8
110	81.1
120	88.5
130	95.9
140	103.3
150	110.6
160	118.0
170	125.4
180	132.8
190	140.1
200	147.5
225	166.0
250	184.4

Newton Meters (Nm)	Pound Feet (lb-ft)
1	1.356
2	2.7
3	4.0
4	5.4
5	6.8
6	8.1
7	9.5
8	10.8
9	12.2
10	13.6
15	20.3
20	27.1
25	33.9
30	40.7
35	47.5
40	54.2
45	61.0
50	67.8
55	74.6
60	81.4
65	88.1
70	94.9
75	101.7
80	108.5
90	122.0
100	135.6
110	149.1
120	162.7
130	176.3
140	189.8
150	203.4
160	216.9
170	230.5
180	244.0

J1930 TERMINOLOGY LIST

Certain Ford Component names have been changed in this Service Manual to conform to Society of Automotive Engineers (SAE) directive J1930.

SAE J1930 standardizes automotive component names for all vehicle manufacturers.

New Term	New Acronym	Old Terms (Acronyms)
Accelerator Pedal	AP	Accelerator
Air Cleaner	ACL	Thermac Air Cleaner
Air Cleaner Element	ACL Element	Air Cleaner Element (ACL Element)
Air Cleaner Housing	ACL Housing	Air Cleaner Housing (ACH)
Air Cleaner Housing Cover	ACL Housing Cover	Air Cleaner Housing Cover (ACL Housing Cover)
Air Conditioning	A/C	Air Conditioning (AC)
Air Conditioning Clutch	A/C Clutch	Air Conditioning Clutch (ACC)
Air Conditioning Cycling Switch	A/C Cycling Switch	Air Conditioning Cycling Switch (ACCS)
Air Conditioning Sensor	A/C Sensor	Air Conditioning Sensor (A/C Sensor)
Air Conditioning System	A/C System	Air Conditioning System (SCS)
Automatic Transaxle	A/T	Electronic Automatic Transaxle (EATX)
Automatic Transmission	A/T	Electronic Automatic Transmission (EATX)
Barometric Pressure	BARO	Barometric Pressure (BARO)
Barometric Pressure Sensor	BARO Sensor	- Absolute Pressure Sensor (APS) - Barometric Pressure Sensor (BP Sensor
Battery Positive Voltage	B+	Battery Positive Voltage (B+)
Camshaft Position	CMP	Sync Pickup
Camshaft Position Sensor	CMP Sensor	- Camshaft Position Sensor (CPS) - Camshaft Sensor - Cylinder Identification Sensor (Cylinder ID Sensor) (CID)
Canister	Canister	Canister
Carburetor	CARB	Feed Back Carburetor (FBC)
Central Multiport Fuel Injection	Central MFI	- Central Multiport Fuel Injection (CMFI) - Fuel Injection (FI)
Charge Air Cooler	CAC	- After Cooler - Inter Cooler
Closed Loop	CL	Closed Loop System (CLS)
Closed Throttle Position	CTP	Closed Throttle Position (CTP)
Closed Throttle Position Switch	CTP Switch	Closed Throttle Switch
Clutch Pedal Position	CPP	Clutch Pedal Position (CPP)
Clutch Pedal Position Switch	CPP Switch	- Clutch Engage Switch (CES) - Clutch Start Switch - Clutch Switch
Compact Disc Read Only memory	CDROM	Compact Disc Read Only Memory (CDROM)

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Continuous Fuel Injection	CFI	- Continuous Injection System (CIS) - Continuous Injection System - Electronic (continuous Injection System-E) (CIS-E) - Fuel Injection (FI) - K-Jetronic - KE-Jetronic - KE-Motronic
Continuous Fuel Injection system	CFI System	Continuous Injection System (CIS)
Continuous Trap Oxidizer	CTOX	- Continuous Trap Oxidizer (CTO) - Trap Oxidizer - Continuous (TOC)
Crankshaft Position	CKP	- Crankshaft Position (CP) - Position Indicator Pulse (PIP)
Crankshaft Position Sensor	CKP Sensor	- Crankshaft Position Sensor (CPS) - Crank Angle Sensor
Data Link Connector	DLC	- Assembly Line Communication Link (ALCL) - Assembly Line Diagnostic Link (ALDL) - Self Test Connector - Vehicle in Process Connector (VIP Connector)
Diagnostic Test Mode	DTM	Modes
Diagnostic Trouble Code	DTC	Self Test Codes
Differential Pressure Feedback Gas Recirculation System	Differential Pressure Feedback EGR System	Differential Pressure Feedback EGR System
Direct Fuel Injection	DFI	- Direct Injection (DI) - Direct Injection - Diesel (DID) - Fuel Injection (FI)
Distributor Ignition	DI	- Capacitive Discharge Ignition (CDI) - Closed Bowl Distributor - Electronic Ignition (EI) (with Distributor) - Electronic Spark Advance Control (ESAC) - High Energy Ignition (HEI) - Remote Mount Thick Film Ignition (Remote Mount TFI) - Thick Film Ignition (TFI)
Distributor Ignition Capacitor	DI Capacitor	Condenser
Distributor Ignition Control Module	Distributor ICM	Electronic Distributor Ignition System Module (EDIS Module)
Distributor Ignition System	DI System	Electronic Distributor Ignition System (EDIS)
Early Fuel Evaporation	EFE	Early Fuel Evaporation (EFE)
Electrically Erasable Programmable Read Only Memory	EEPROM	Electrically Erasable Programmable Read Only Memory (E2PROM)
Electronic Continuous Fuel Injection System	Electronic CFI System	Continuous Injection System - Electronic (Continuous Injection System-E) (CIS-E)
Electronic engine Control	Electronic EC	Electronic Engine Control (EEC)
Electronic Ignition	EI	- Computer Controlled Coil Ignition (C3I) - Distributorless Ignition (DLI) - Electronic Ignition (EI) (without distributor) - Integrated Direct Ignition (IDI)
Electronic Ignition System	EI System	- Direct Ignition System (DIS) - Distributorless Ignition System (DIS) - Electronic Distributorless Ignition System (EDIS)
Engine Control	EC	Electronic Engine Control (EEC)
Engine Control Module	ECM	Engine Control Module (ECM)

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Engine Coolant Level	ECL	Engine Coolant Level (ECL)
Engine Coolant Level Indicator	ECL Indicator	Engine Coolant Level Indicator
Engine Coolant Temperature	ECT	Engine Coolant Temperature (ECT)
Engine Coolant Temperature Sensor	ECT Sensor	- Coolant Temperature Sensor (CTS) - Engine Coolant Temperature Sender (ECT Sender)
Engine Coolant Temperature Switch	ECT Switch	Coolant Temperature Switch (CTS)
Engine Speed	RPM	- Crankshaft Speed - Revolutions Per Minute (RPM)
Engine Speed Sensor	RPM Sensor	Crankshaft Speed Sensor
Erasable Programmable Read Only Memory	EPROM	Erasable Programmable Read Only Memory (EPROM)
Evaporative Emission	EVAP	Evaporative Emission (EVAP)
Evaporative Emission Canister	EVAP Canister	- Canister - Charcoal Canister
Evaporative Emission Canister Purge	EVAP Canister Purge	- EVAP CANP - Canister Purge (CANP)
Evaporative Emission Canister Purge Valve	EVAP Canister Purge Valve	- Canister Purge Valve - Canister Purge Vacuum Switching Valve (Canister Purge VSV) - Duty Solenoid for Purge Valve - Evaporative Emission Purge Valve (EVAP Purge Valve) - Vacuum Solenoid Valve (Canister) (VSV) - Vacuum Solenoid Valve (EVAP) (VSV)
Evaporative Emission System	EVAP System	Evaporation Emission Control System (EECS)
Exhaust Gas Recirculation	EGR	Digital Exhaust Gas Recirculation (Digital EGR)
Exhaust Gas Recirculation Backpressure Transducer	EGR Backpressure Transducer	Backpressure Transducer
Exhaust Gas Recirculation Diagnostic Valve	EGR Diagnostic	EGR Diagnostic Valve
Exhaust Gas Recirculation System	EGR System	EGR System
Exhaust Gas Recirculation Temperature	EGRT	EGR Temperature
Exhaust Gas Recirculation Temperature Sensor	EGRT Sensor	Recirculated Exhaust Gas Temperature Sensor (REGTS)
Exhaust Gas Recirculation Thermal Vacuum Valve	EGR TVV	EGR Thermal Vacuum Valve (EGR TVV)
Exhaust Gas Recirculation Vacuum Regulator Solenoid	EGR Vacuum Regulator Solenoid	EGR Vacuum Regulator Solenoid (EVR Solenoid)
Exhaust Gas Recirculation Vacuum Regulator Valve	EGR Vacuum Regulator Valve	EGR Vacuum Regulator Valve (EVRV)
Exhaust Gas Recirculation Valve	EGR Valve	EGR Valve (EGRV)
Exhaust Gas Recirculation Valve Control	EGR Valve Control	EGR Valve Control (EGRVC)
Exhaust Gas Recirculation Valve Position Sensor	EGR Valve Position Sensor	EGR Valve Position Sensor (EVP Sensor)
Fan Control	FC	- Electro-Drive Fan Control (EDF Control) - Engine Coolant Fan Control - High Electro-Drive Fan Control (HEDF Control) - Radiator Fan Control
Fan Control Module	FC Module	Fan Control Module

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Fan Control Relay	FC Relay	- Fan Motor Control Relay - Radiator Fan Relay
Feedback Pressure Exhaust Gas Recirculation	Feedback Pressure EGR	Pressure Feedback Exhaust Gas Recirculation
Feedback Pressure Exhaust Gas Recirculation Sensor	Feedback Pressure EGR Sensor	Pressure Feedback Exhaust Gas Recirculation (PFE) Sensor
Flash Electrically Erasable Programmable Read Only Memory	FEEPROM	Flash EEPROM
Flash Erasable Programmable Read Only Memory	FEPROM	Flash EPROM
Flexible Fuel	FF	Flexible Fuel (FF)
Flexible Fuel Sensor	FF Sensor	- Alcohol Concentration Sensor - Fuel Concentration Sensor - Fuel Quality Sensor - Percent Alcohol Sensor - Variable Fuel Sensor
Forth Gear	4GR	Fourth Gear (4GR)
Fuel Level Sensor	Fuel Level Sensor	Fuel Sensor
Fuel Pressure	Fuel Pressure	Fuel Pressure
Fuel Pressure Regulator	Fuel Pressure Regulator	Fuel Regulator
Fuel Pump	FP	Fuel Pump (FP)
Fuel Pump Module	FP Module	- Fuel Module - Fuel Sender - Fuel Tank Unit - In Tank Module
Fuel Pump Relay	FP Relay	Fuel Pump Relay
Fuel Trim	FT	Adaptive Fuel Strategy
Generator	GEN	Alternator (ALT)
Governor	Governor	Governor
Governor Control Module	GCM	Governor Electronic Module (GEM)
Ground	GND	Ground (GRD)
Heated Oxygen Sensor	HO2S	- Heated Exhaust Gas Oxygen Sensor (HEGO Sensor) - Heated Oxygen Sensor (HOS)
High Speed Fan Control Switch	High Speed FC Switch	High speed Fan Control Switch (High Speed FC Switch)
Idle Air Control	IAC	- Idle Air Bypass Control - Idle speed Control (ISC) - Idle Speed Control Bypass air (ISC BPA)
Idle Air Control Thermal Valve	IAC Thermal Valve	Fast Idle Thermo Valve
Idle Air Control Valve	IAC Valve	- Air Valve - Fast Idle Thermo Valve - Idle Air Control Valve (IACV)
Idle Speed Control	ISC	Throttle Opener
Idle Speed Control Actuator	ISC Actuator	Idle Speed Control Actuator (ISC Actuator)
Idle Speed Control Solenoid Vacuum	ISC Solenoid Vacuum Valve	- Throttle Opener Vacuum Switching Valve (Throttle Opener VSV) - Vacuum Solenoid Valve (Throttle) (VSV)

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Ignition Control	IC	- Electronic Spark Advance (ESA) - Electronic spark Timing (EST)
Ignition Control Module	ICM	- Distributorless Ignition System Module (DIS Module) - Thick Film Ignition Module (TFI Module)
Indirect Fuel Injection	IFI	- Fuel Injection (FI) - Indirect Fuel Injection (IDFI) - Indirect Diesel Injection (IDI)
Inertia Fuel Shutoff	IFS	Inertia Fuel Shutoff (IFS)
Inertia Fuel Shutoff Switch	IFS Switch	- Inertia Switch - Inertia Fuel - Shutoff Switch
Intake Air	IA	Intake Air
Intake Air Duct	IA Duct	Intake Air Duct
Intake Air System	IA System	Air Intake System
Intake Air Temperature	IAT	- Air Charge Temperature (ACT) - Manifold Air Temperature (MAT) - Throttle Body Temperature (TBT) - Vane Air Temperature (VAT)
Intake Air Temperature Sensor	IAT Sensor	- Air Temperature Sensor (ATS) - Intake Air Temperature Sensor (IATS) - Manifold Air Temperature Sensor (MATS)
Keep Alive Random Access Memory	Keep Alive RAM	Keep Alive memory (KAM)
Knock Sensor	KS	Detonation Sensor (DS)
Long Term Fuel Trim	Long Term FT	- Block Learn Matrix (BLM) - Block Learn Memory (BLM) - Block Learn Multiplier (BLM)
Low Speed Fan Control Switch	Low Speed FC Switch	Low Speed Fan Control Switch (Low Speed FC Switch)
Malfunction Indicator Lamp	MIL	- Check Engine - Service Engine Soon
Manifold Absolute Pressure	MAP	Manifold Absolute Pressure (MAP)
Manifold Absolute Pressure Sensor	MAP Sensor	- Intake Manifold Absolute Pressure Sensor - Manifold Absolute Pressure Sensor (MAPS) - Pressure Sensor (P-Sensor)
Manifold Differential Pressure	MDP	Manifold Differential Pressure (MDP)
Manifold Differential Pressure Sensor	MDP Sensor	Vacuum Sensor (VAC Sensor)
Manifold Surface Temperature	MST	Manifold Surface Temperature (MST)
Manifold Vacuum Zone	MVZ	Manifold Vacuum Zone (MVZ)
Manifold Vacuum Zone Switch	MVZ Switch	Vacuum Switches
Mass Air Flow	MAF	- Air Flow Control (AFC) - Air Flow Meter
Mass Air Flow Sensor	MAF Sensor	- Air Flow Meter - Air Flow Sensor (AFS) - Hot Wire Anemometer
Mixture Control	MC	- Feed Back Control (FBC) - Mixture Control (M/C)
Mixture Control Solenoid	MC Solenoid	Mixture Control Solenoid (MCS)

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Multiport Fuel Injection	MFI	- D-Jetronic - Digital Fuel Injection (EFI) - Electronic Fuel Injection (EFI) - Fuel Injection (FI) - L-Jetronic - LH-Jetronic - Motronic - Multipoint Injection (MPI) - Multiport Injection (MPI) - Port Fuel Injection (PFI) - Programmed Fuel Injection (PGM-FI) - Tuned Port Injection (TPI)
Nonvolatile Random Access Memory	NVRAM	- Keep Alive Memory (KAM) - Nonvolatile Memory (NVM)
Oil Pressure Sensor	Oil Pressure Sensor	Oil Pressure Sender
Oil Pressure Switch	Oil Pressure Switch	Oil Pressure Switch
On-Board Diagnostic	OBD	Self Test
Open Loop	OL	Open Loop (OL)
Oxidation Catalytic Converter	OC	- Continuous Oxidation Catalyst (COC) - Oxidation Catalyst (OC)
Oxygen Sensor	O2S	- Exhaust Gas Oxygen Sensor (EGO Sensor, EGOS) - Exhaust Gas Sensor (EGS) - Exhaust Oxygen Sensor (EOS) - Lambda - Oxygen Sensor (O2 Sensor, OS)
Park/Neutral Position	PNP	Park/Neutral (P/N)
Park/Neutral Position Switch	PNP Switch	- Neutral Drive Switch (NDS) - Neutral Gear Switch (NGS) - Neutral Position Switch (NPS) - Neutral Safety Switch
Periodic Trap Oxidizer	PTOX	Trap Oxidizer - Periodic (TOP)
Positive Crankcase Ventilation	PCV	Positive Crankcase Ventilation (PCV)
Positive Crankcase Ventilation (Valve)	PCV Valve	Positive Crankcase Ventilation (PCV valve)
Power Steering Pressure	PSP	Power Steering Pressure (PSP)
Power Steering Pressure Switch	PSP Switch	Power Steering Pressure Switch (P/S Pressure Switch, PSPS)
Powertrain Control Module	PCM	- Electronic Control Assembly (ECA) - Electronic Control Unit 4 (ECU4) - Electronic Engine Control Processor (EEC Processor) - Microprocessor Control Unit (MCU) - Single Board Engine Control (SBEC) - Single Module Engine Control (SMEC)
Pressure Transducer Exhaust Gas Recirculation System	Pressure Transducer EGR System	Pressure Transducer EGR System
Programmable Read Only Memory	PROM	Programmable Read Only memory (PROM)
Pulsed Secondary Air Injection	PAIR	- Air Injection Reactor (AIR) - Air Injection Valve (AIV) - Pulsair - Thermactor II
Pulsed Secondary Air Injection Valve	PAIR Valve	Reed Valve
Random Access Memory	RAM	Random Access Memory (RAM)
Read Only memory	ROM	Read Only Memory (ROM)

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Relay Module	RM	Integrated Relay Module
Scan Tool	ST	Scan Tool
Secondary Air Injection	AIR	- Air Injection (AI) - Air Injection Reactor (AIR) - Thermac - Thermactor
Secondary Air Injection Bypass	AIR Bypass	- Air Management 1 (AM1) - Secondary Air Injection Bypass (AIRB) - Thermactor Air Bypass (TAB)
Secondary Air Injection Bypass Valve	AIR Bypass Valve	Secondary Air Bypass Valve (SABV)
Secondary Air Injection Check Valve	AIR Check Valve	Secondary Air Check Valve
Secondary Air Injection Control Valve	AIR Control Valve	- Air Control Valve - Secondary Air Check Valve (SACV)
Secondary Air Injection Diverter	AIR Diverter	- Air Management2 (AM2) - Secondary Air Injection Diverter (AIRD) - Thermactor Air Diverter (TAD)
Secondary Air Injection Pump	AIR Pump	Air Injection Pump (AIP)
Secondary Air Injection Switching Valve	AIR Switching Valve	Secondary Air Switching Valve (SASV)
Sequential Multiport Fuel Injection	SFI	- Fuel Injection (FI) - Sequential Electronic Fuel Injection (SEFI) - Sequential Fuel Injection (SFI)
Service Reminder Indicator	SRI	- Check Engine - Engine Maintenance Reminder (EMR) - Oxygen Sensor Indicator (OXS) - Service Engine Soon
Short Term Fuel Trim	Short Term FT	Integrator (INT)
Smoke Puff Limiter	SPL	Smoke Puff Limiter (SPL)
Supercharger	SC	Supercharger (SC)
Supercharger Bypass	SCB	Supercharger Bypass (SCB)
Supercharger Bypass Solenoid	SCB Solenoid	Supercharger Bypass Solenoid (SBS)
System Readiness Test	SRT	System Readiness Test (SRT)
Thermal Vacuum Valve	TVV	Thermal Vacuum Switch (TVS)
Third Gear	3GR	Third Gear (3GR)
Three Way Catalytic Converter	TWC	Three Way Catalytic Converter (TWC)
Three Way + Oxidation Catalytic Converter	TWC + OC	Dual Bed
Throttle Body	TB	Fuel Charging Station
Throttle Body Fuel Injection	TBI	- Central Fuel Injection (CFI) - Electronic Fuel Injection (EFI) - Fuel Injection (FI) - Monotronic - Single Point Injection (SPI)
Throttle Position	TP	Throttle Position (TP)
Throttle Position Sensor	TP Sensor	- Throttle Position Sensor (TP) - Throttle Potentiometer
Throttle Position Switch	TP Switch	Throttle Position Switch (TPS)
Torque Converter Clutch	TCC	- Converter Clutch Control (CCC) - Converter Clutch Override (CCO) - Viscous Converter Clutch (VCC)

MSG-425 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Torque Converter Clutch Relay	TCC Relay	Lock Up Relay
Torque Converter Clutch Solenoid Valve	TCC Solenoid Valve	Lock Up Solenoid Valve (LUS)
Transmission Control Module	TCM	Transmission Control Module
Transmission Range	TR	- Park, Reverse, Neutral, Drive, Low (PRNDL) - Selection Lever Position (SLP) - Transmission Range Selection (TRS)
Transmission Range Sensor	TR Sensor	Manual Lever Position Sensor (MLP Sensor)
Transmission Range Switch	TR Switch	- Manual Range Position Switch (MRPS) - Transmission Position Switch - Transmission Range Selection Switch (TRSS)
Turbocharger	TC	Turbo
Vehicle Speed Sensor	VSS	- Distance Sensor - Pulse Generator (PG)
Voltage Regulator	VR	voltage Regulator (VR)
Volume Air Flow	VAF	- Air Flow Control (AFC) - Air Flow Meter - Vane Air Flow
Volume Air Flow Sensor	VAF Sensor	- Air Flow Meter - Air Flow Sensor (AFS)
Warm Up Oxidation Catalytic Converter	WU-OC	Light Off Catalyst
Warm Up Three Way Catalytic Converter	WU-TWC	Light Off Catalyst
Wide Open Throttle	WOT	Full Throttle
Wide Open Throttle Switch	WOT Switch	Wide Open Throttle Switch (WOTS)

EDI Ford Industrial Engine Distributor List

7/27/2020

AUSTRALIA

	Deutz Australia		+61 (0)3 9549 8400

EUROPE

GERMANY	Sauer & Sohn Sauer Motive Systems	Gross Zimmerner Strasse 51 D-64807 Dieburg Germany	49-6071-206-330 49-6071-206-219
GREAT BRITAIN	Hendy Power	School Lane Chandlers Ford Industrial Estate, Eastleigh, Hampshire SO53 4DG England	44-2380-579-800 44-2380-271-471
GREAT BRITAIN	Power Torque Engineering	Herald Way, Binly, Conventry Warwichshire CV3 2RQ England	44-2476-635-757 44-2476-635-878
ITALY	Compagnia Technica Motori S.p.A.	Via Magellano 1, I-20090 Cesano Boscone, (Milano) Italy	39-02-450-581 39-02-450-582(60/62)
NETHERLANDS	My Power Products	Houtzaagmolen 41 MIJDRECHT Netherlands NL 364	03-129-758-1555

MEXICO

	Equipos y Motores Ind.	Ave. Cuitlahuac No. 700 Col. Popotla 11400 Mexico, D.F.	52-55-5341-9066

ASIA

China & Taiwan	Project Engineering, Inc.	700 Envoy Circle, Suite 704 Louisville, KY 40299, USA	01-(502)-491-9030 peiusa@aol.com
	GuangQing (Anhui) Gas Technologies Co. Ltd.	Room 1608, Xinke Building, No. 58, Feixi Road, Hefei, Anhui, 230022 China	86-(0551)-6363-6167 www.impcochina.com

NORTH AMERICA - UNITED STATES

ALABAMA	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
ALASKA	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
ARIZONA	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
ARKANSAS	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
CALIFORNIA	Smith Power Products Inc.	8 Glendale Avenue Sparks, NV 89431	P: 775-359-1713 F: 775-359-6579
COLORADA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
CONNECTICUT	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
DELAWARE	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
FLORIDA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
	Engine Distributors Inc.	2917 S. W. Second Ave. Fort Lauderdale, FL 33315	1-800-220-2700
GEORGIA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
HAWAII	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
IDAHO	Smith Power Products Inc.	4045 Transport Street Boise, ID 83705	P: 208-345-1500 F: 208-345-1619
ILLINOIS	Crosspoint	3621 West Morris St. Indianapolis, IN 46241	1-800-426-7693; 317-240-1965
INDIANA	Crosspoint	3621 West Morris St. Indianapolis, IN 46241	1-800-426-7693; 317-240-1965
IOWA	Anderson Industrial Engines Co.	5532 Center Street Ohmaha, NE 68106	402-558-8700
KENTUCKY	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
KANSAS	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700

NORTH AMERICA - UNITED STATES

LOUISIANA	Engines , Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
MAINE	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
MARYLAND	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
MASSACHUSETTS	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2701
MICHIGAN	Michigan CAT	24800 Novi Rd. Novi, MI 48375	248-349-7050
MINNESOTA	Michigan CAT	24800 Novi Rd. Novi, MI 48375	248-349-7050
MISSISSIPPI	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
MISSOURI	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
MONTANA	Smith Power Products Inc.	4045 Transport Street Boise, ID 83705	P: 208-345-1500 F: 208-345-1619
NEBRASKA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
NEVADA	Smith Power Products Inc.	8 Glendale Avenue Sparks, NV 89431	P: 775-359-1713 F: 775-359-6579
		4900 East Idaho Street Elko, NV 89801	P: 775-738-7154 F: 775-738-9325
NEW HAMPSHIRE	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
NEW JERSERY	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
NEW YORK	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
NEW MEXICO	Smith Power Products Inc.	2101 Pepsi Way Aztec, NM 87410	P: 505-333-7343
NORTH DAKOTA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
NORTH CAROLINA	Engine Distributors Inc.	303 Interstate Dr. Archdale, NC 27263	1-800-220-2700
OHIO	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
OKLAHOMA	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
OREGON	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700

NORTH AMERICA - UNITED STATES

EASTERN PENNSYLVANIA	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
WESTERN PENNSYLVANIA	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
RHODE ISLAND	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
SOUTH CAROLINA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
SOUTH DAKOTA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
TENNESSEE	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
TEXAS	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
UTAH	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
WASHINGTON	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
WEST VIRGINIA	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
WISCONSIN	Michigan CAT	24800 Novi Rd. Novi, MI 48375	248-349-7050
WYOMING	Smith Power Products Inc.	4 Layos Drive Rock Springs, WY 82901	P: 307-382-4330 F: 307-382-4354
		855 South 1500 East Vernal, UT 84078	P: 435-789-1860 F: 435-789-3259
VERMONT	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
VIRGINIA	Engine Distributors Inc.	303 Interstate Dr. Archdale, NC 27263	1-800-220-2700

NORTH AMERICA - CANADA

ALBERTA, SASKATCHEWAN	Industrial Engines Ltd.	14355 120th Ave. Edmonton, Alberta Canada, T5L 2R8	780-484-6213
ALBERTA, SASKATCHEWAN	Simson Maxwell	8750-58th Avenue, Edmonton,AB Canada T6E 6G6	1-800-374-6766
ALBERTA, SASKATCHEWAN	Simson Maxwell	467 Exploration Ave, SE Calgary, Alberta T3S 0B4	403-252-8131
BRITISH COLUMBIA	Simson Maxwell	1605 Kebet Way Port C, BC Canada V3C 5W9	1-800-374-6766
	Simson Maxwell	#12-4131 Mostar Road, Nanaimo BC, Canada V9T 5P8	1-800-374-6766
	Simson Maxwell	1846 Quinn Street, Prince George, BC Canada V2L 3H4	1-800-374-6766
MONTREAL	MARINDUSTRIAL	8550 Delmeade Montreal, QUEBEC Canada, H4T 1L7	514-342-2748
NEW BRUNSWICK, NOVA SCOTIA, NEWFOUNDLAND	DAC Industrial Engines, Inc.	10 Akerley Blvd., Unit 61 Dartmouth, NS, B3B 1J4	902-468-3765 877-468-3765
ONTARIO	MARINDUSTRIAL	3495 Laird Rd. Unit 22-23 Mississauga, ON, L5L 5S5	905-829-3004