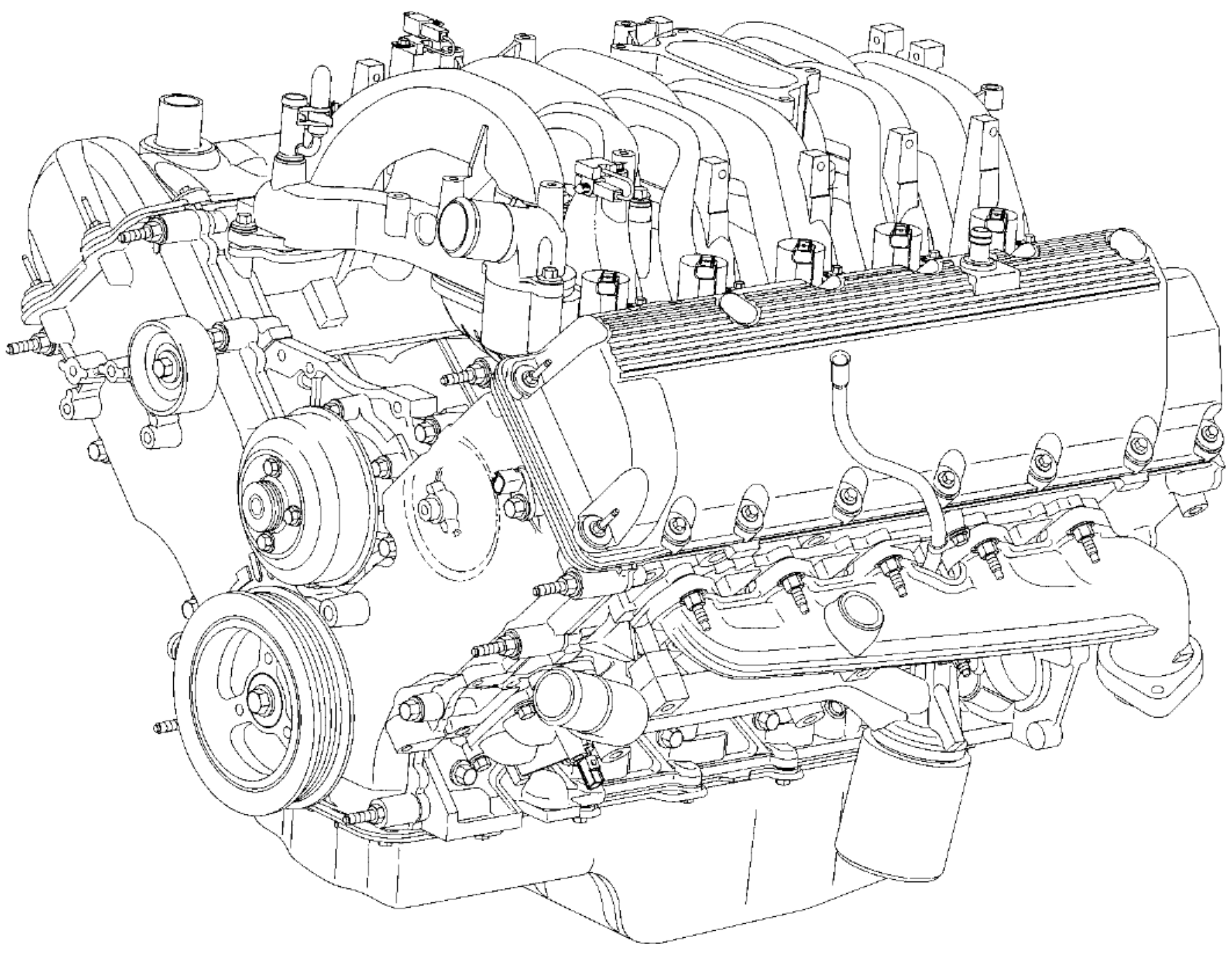
ENGINE DISTRIBUTORS INC.

WSG-1068
6.8 LITER

INDUSTRIAL ENGINE SERVICE MANUAL



EDI #1050180
March, 2009

Section Index

Engine Distributors Inc policy is one of continuous improvement and while every effort is made to ensure that this publication is up to date and correct in all respects, the right to change prices, specifications and equipment at any time without notice is reserved. Accordingly this publication is not to be regarded as a final description of any individual engine.

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. SOME 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.

WARNING:

WARNING: ENGINE EXHAUST, SOME OF ITS CONSTITUENTS, AND CERTAIN VEHICLE COMPONENTS CONTAIN OR EMIT CHEMICALS KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM. IN ADDITION, CERTAIN FLUIDS CONTAINED IN VEHICLES AND CERTAIN PRODUCTS OF COMPONENT WEAR CONTAIN OR EMIT CHEMICALS KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM.

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.

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WSG-1068 GENERAL INFORMATION

GENERAL INFORMATION

Introduction

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

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

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

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

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

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

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

Engine Distributors Inc 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.

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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.**

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Battery Handling and Charging

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

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

FPP01101

Typical Battery Labelling

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

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

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

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Forward

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

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

Regular maintenance will result in minimal operating costs.

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

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

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

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

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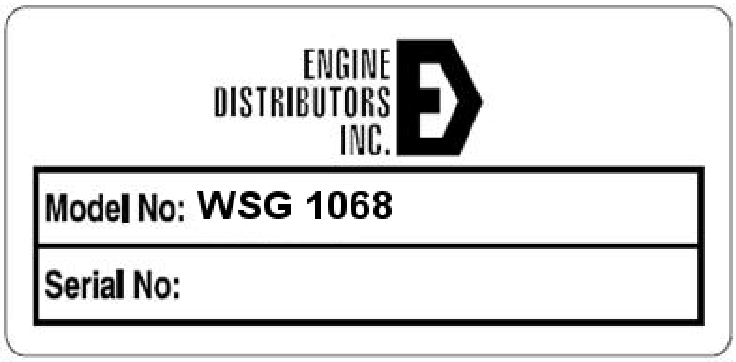
Engine Identification

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

Engine Identification Decal

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



For a handy reference, keep this information recorded in a separate location.

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Parts and Service

Replacement parts can be obtained through your local EDI Distributors listed in the back portion of this manual. They also may be found in the yellow pages under “Engines” or contact Engine Distributors.

Engine Distributors Inc 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.

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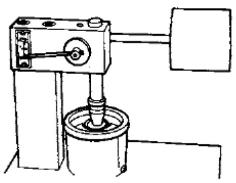
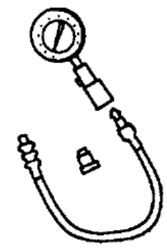
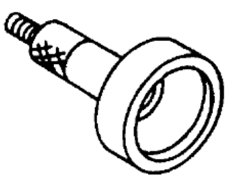
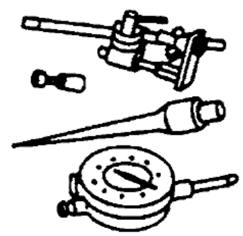
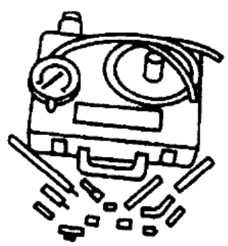
DIAGNOSIS AND TESTING

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

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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.

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Symptom Chart

Condition Possible Source Action

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

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.

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Engine Oil Leaks

prior to service.

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

Fluorescent Oil Additive Method

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

1. Clean the engine with a suitable solvent to remove all traces of oil.
2. Drain engine oil crankcase and refill with recommended oil, premixed with Diesel Engine Oil Dye 164-R3705 meeting Ford specification 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
- air line shutoff valve
- appropriate fittings to attach the above parts to oil fill, PCV grommet hole and crankcase ventilation tube
- appropriate plugs to seal any openings leading to the crankcase
- a solution of liquid detergent and water to be applied with a suitable applicator such as a squirt bottle or brush

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

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

Testing Procedure

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

Leakage Points - Above Engine

Examine the following areas for oil leakage.

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

Leakage Points - Under Engine

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

Leakage Points - with Flywheel Removed

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

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

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

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

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Compression Tests

Compression Gauge Check

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

Test Results

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

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

Compression Pressure Limit Chart

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

Interpreting Compression Readings

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

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

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Cylinder Leakage Detection

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

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

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

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

Oil Leak and Valve Stem Seal Test

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

1. Plug all crankcase openings except the one used for connecting the leakage detector.

2. Connect the Engine Cylinder Leak Detection/Air Pressurization Kit to a crankcase opening (an oil level indicator tube is convenient). Adjust the air pressure to approximately 34 kPa (5 psi).

3. Using a solution of liquid soap and water, brush the solution along the gasket sealing surfaces and bearing seals. Look for bubbles or foam.

4. Remove the spark plugs and rotate the crankshaft slowly with a wrench. Check for large amounts of air escaping into the cylinders as each intake valve and exhaust valve opens.

5. The spark plugs on the leaking cylinders will probably show deposits of burned oil.

Intake Manifold Vacuum Test

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

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

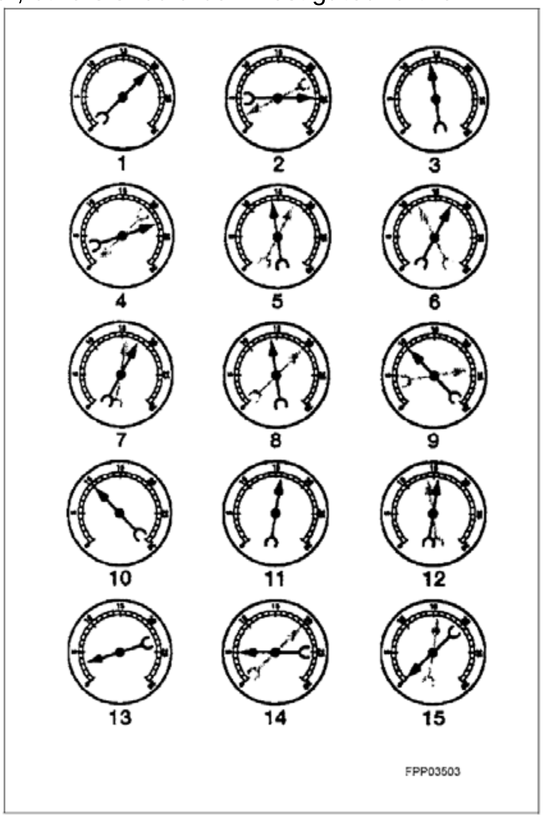
The reading should be steady. If necessary, adjust the gauge damper control (where used) if the needle is fluttering rapidly. Adjust the damper until the needle moves easily without excessive flutter.

Interpreting Vacuum Gauge Readings

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

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

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



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

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

Excessive Engine Oil Consumption

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

- severe loading applications
- sustained high speed operation

Engines need oil to lubricate the following internal components:

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

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

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

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

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

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

Oil Consumption Test

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

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

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

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

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

11. Instruct the customer to run engine as usual and perform the following:
    - Check the oil level regularly at intervals of 3 to 3-1/2 hours.
    - Return to the service point when the oil level drops below the lower (ADD) mark on the oil level dipstick.
    - Add only full quarts of the same oil in an emergency. Note the mileage at which the oil is added.
12. Check the oil level under the same conditions and at the same location as in Steps 7-9.
    - Measure the distance from the oil level to the UPPER mark on the oil level dipstick and record.
    - Measure the distance between the two scribe marks and record.
    - Divide the first measurement by the second.
    - Divide the hours run during the oil test by the result. This quantity is the approximate oil consumption rate in hours per quart.
13. If the oil consumption rate is unacceptable, proceed to next step.
14. Check the positive crankcase ventilation (PCV) system. Make sure the system is not plugged.
15. Check for plugged oil drain-back holes in the cylinder heads and cylinder blocks.
16. If the condition still exists after performing the above steps, proceed to next step.
17. Perform a cylinder compression test or perform a cylinder leak detection test with Engine Cylinder Leak Detection/Air Pressurization Kit. This can help determine the source of oil consumption such as valves, piston rings or other areas.

NOTE: After determining if worn parts should be replaced, make sure correct replacement parts are used.

18. Check valve guides for excessive guide clearances. REPLACE all valve stem seals after verifying valve guide clearance.
19. Worn or damaged internal engine components can cause excessive oil consumption. Small deposits of oil on the tips of spark plugs can be a clue to internal oil consumption. If internal oil consumption still persists, proceed as follows:
    - Remove the engine from the vehicle and place it on an engine work stand.
    - Remove the intake manifolds, cylinder heads, oil pan and oil pump.Check piston ring clearance, ring gap and ring orientation. Repair as required.
    - Check for excessive bearing clearance. Repair as required.
20. Perform the oil consumption test to confirm the oil consumption concern has been resolved.

Oil Pressure Test

1. Disconnect and remove the oil pressure sensor from the engine.

2. Connect the Engine Oil Pressure Gauge and Transmission Test Adapter to the oil pressure sender oil gallery port.

3. Run the engine until normal operating temperature is reached.

4. Run the engine at 3000 rpm and record the gauge reading.
5. The oil pressure should be within specifications.
6. If the pressure is not within specification, check the following possible sources:
    - insufficient oil
    - oil leakage
    - worn or damaged oil pump
    - oil pump screen cover and tube
    - excessive main bearing clearance
    - excessive connecting rod bearing clearance

WSG-1068 GENERAL INFORMATION

Valve Train Analysis – Static

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

Rocker Arm

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

Camshaft Roller Followers and Hydraulic Lash Adjusters

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

Camshaft

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

Valve Springs

- Check for broken or damaged parts.

Valve Spring Retainer and Valve Spring Retainer Keys

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

Valve Spring Retainer Keys

- Check for proper seating on the valve stem.

Valves and Cylinder Head

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

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

Valve Train Analysis – Dynamic

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

Rocker Arm

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

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

Positive Rotator and Valve Spring Retainer Keys

- Check for proper operation of positive rotator.

Valves and Cylinder Head

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

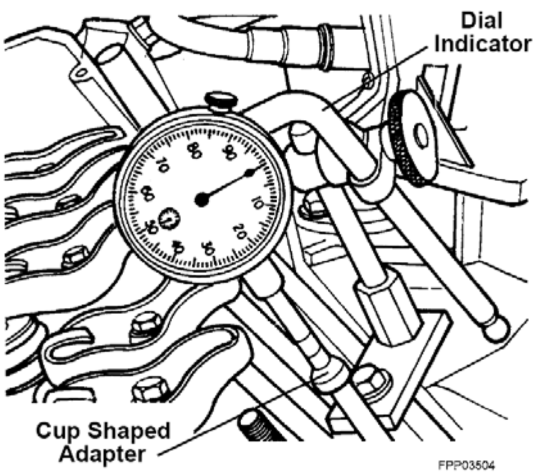
If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1200 rpm with the transmission in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and camshaft roller followers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

Camshaft Lobe Lift

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

1. Remove the valve covers.

2. Remove the rocker arm seat bolts, rocker arm seat and rocker arms.



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. Remove the spark plugs.

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

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

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

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

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

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

10. Install the rocker arm seats, rocker arms and rocker arm seat bolts.

11. Install the valve covers.

12. Install the spark plugs.

WSG-1068 GENERAL INFORMATION

Hydraulic Lash Adjuster

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

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

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

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

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

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

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

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

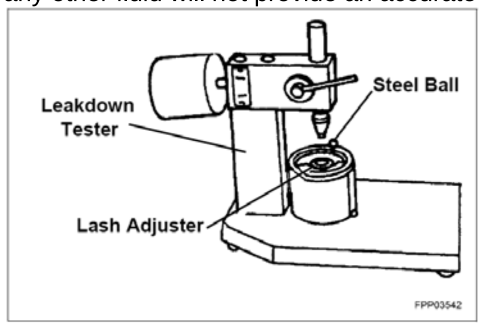
Leakdown Testing

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

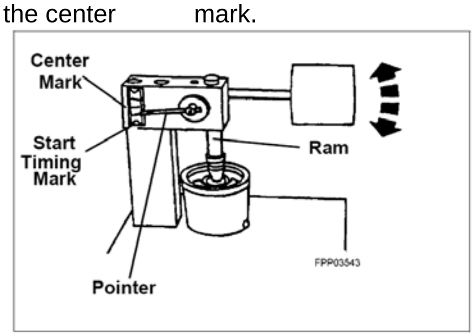
1. Clean the lash adjuster to remove all traces of engine oil.

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

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



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



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

GENERAL SERVICE PROCEDURES

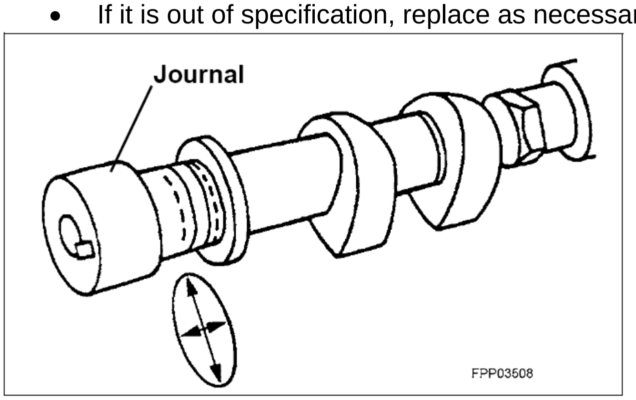
WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT, DO NOT OPERATE THE ENGINE WITH THE HOOD OPEN UNTIL THE FAN BLADE HAS BEEN EXAMINED FOR POSSIBLE CRACKS AND SEPARATION.

NOTE: Specifications show the expected minimum or maximum condition.

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

Camshaft Journal Diameter

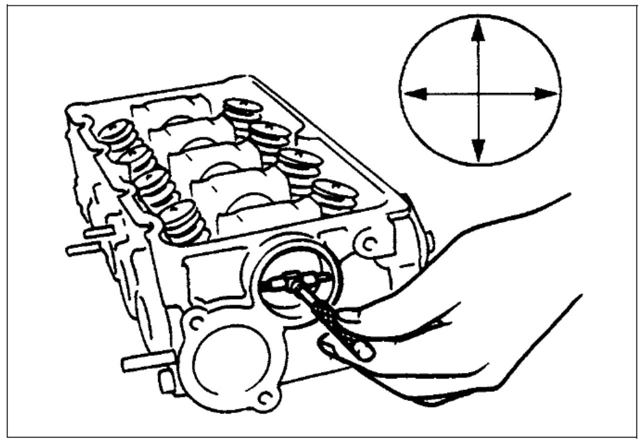
- Measure each camshaft journal diameter in two directions.
- If it is out of specification, replace as necessary.



Camshaft Journal Clearance

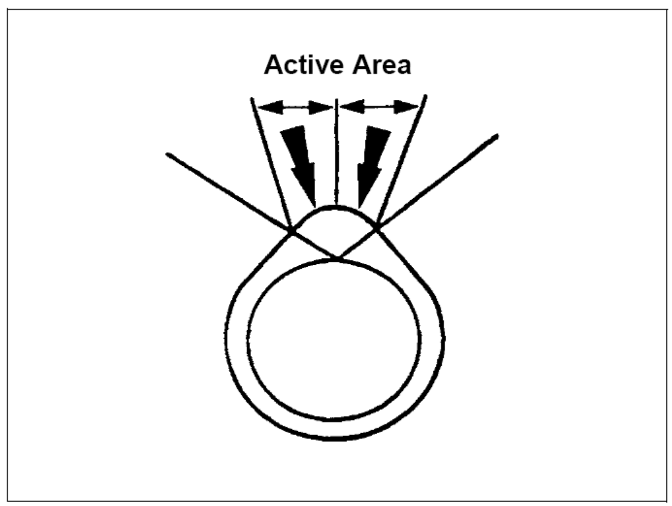
NOTE: The camshaft journals must meet specifications before checking camshaft journal clearance.

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

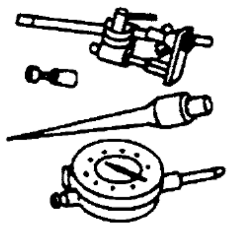


Camshaft Lobe Surface

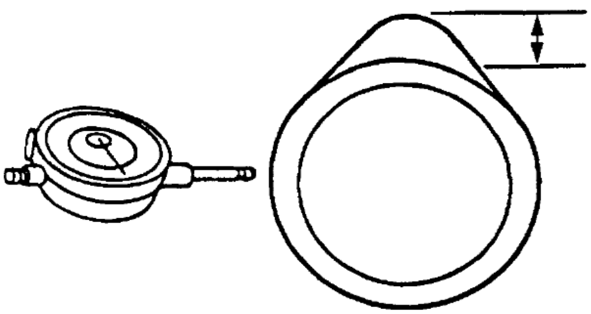
- Inspect camshaft lobes for pitting or damage in the active area. Minor pitting is acceptable outside the active area.



Camshaft Lobe Lift

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



FPP03511

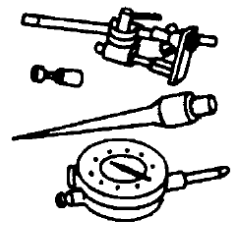
2. Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the camshaft lobe lift.

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.

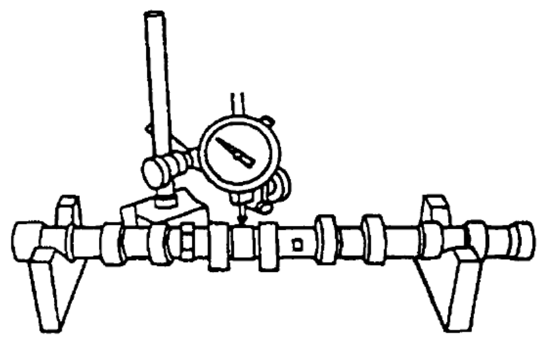
Camshaft Runout

Special Tool(s)

 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)

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.

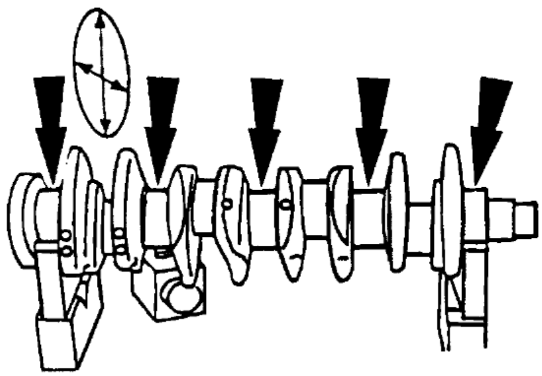


FPP03512

Crankshaft Main Bearing Journal Diameter

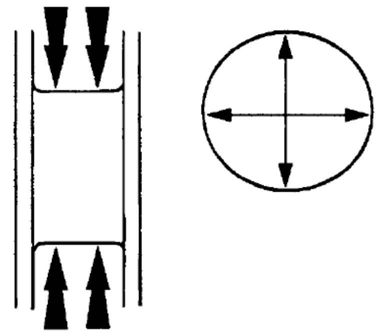
- Measure each of the crankshaft main bearing journal diameters in at least two directions.

- If it is out of specification, replace as necessary.


FPP03513

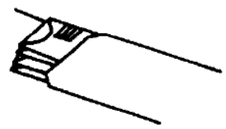
Crankshaft Main Bearing Journal Taper

- 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.


FPP03514

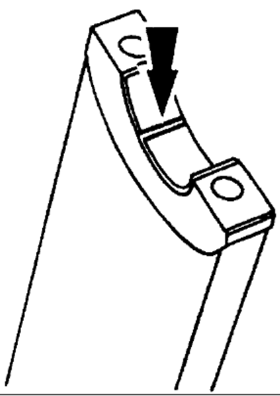
Crankshaft Main Bearing Journal Clearance

Special Tool(s)

 FPP10031	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.

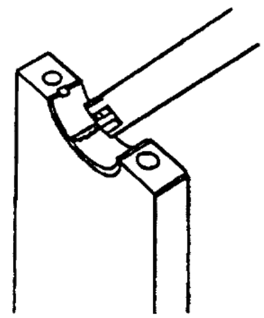


FPP03515

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

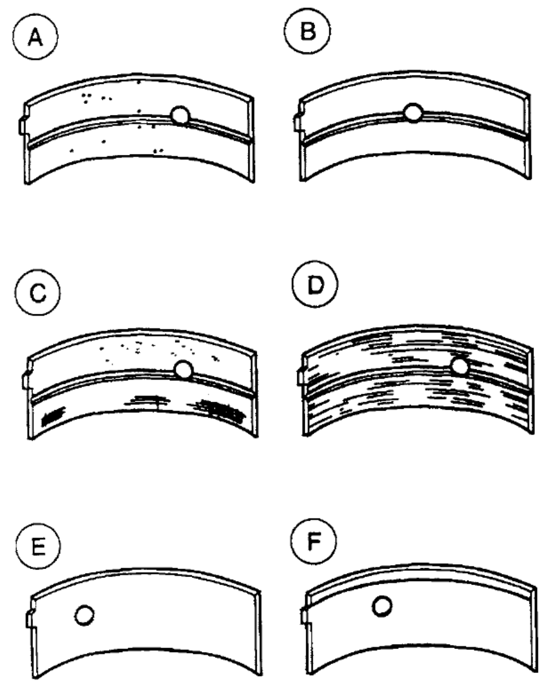


FPP03516

Bearing Inspection

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

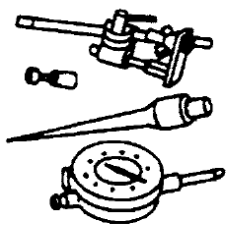
- Cratering – fatigue failure (A)
- Spot polishing – improper seating (B)
- Scratching – dirty (C)
- Base exposed – poor lubrication (D)
- Both edges worn – journal damaged (E)
- One edge worn – journal tapered or bearing not seated (F)



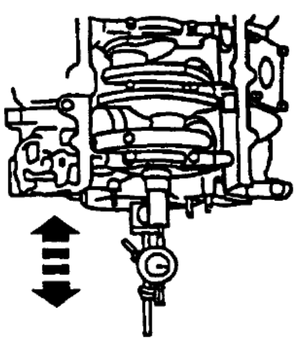
FPP03517

Crankshaft End Play

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. 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.

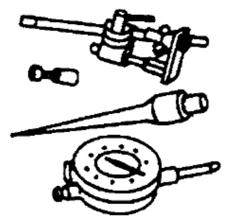


FPP03518

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

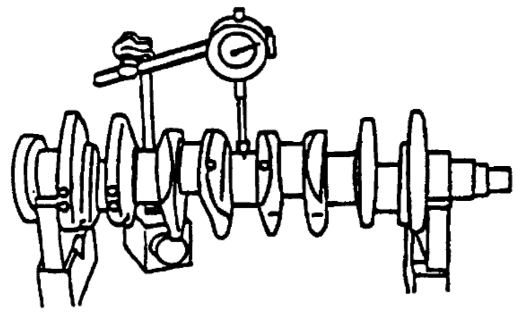
Special Tool(s)

 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)

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

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

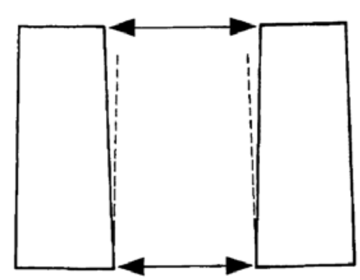
- Rotate the crankshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the crankshaft runout. If it is out of specification, replace as necessary.



FPP03519

Cylinder Bore Taper

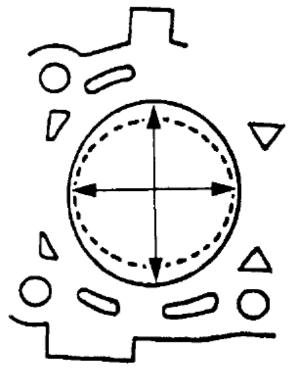
Measure the cylinder bore at the top and bottom. Verify the cylinder bore is within the wear limit. The difference indicates the cylinder bore taper. Bore the cylinder to the next oversize.



FPP03520

Cylinder Bore Out-of-Round

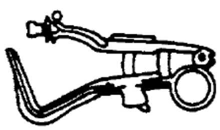
Measure the cylinder bore in two directions. The difference is the out-of-round. Verify the out-of-round is within the wear limit and bore the cylinder to the next oversize limit.



FPP03521

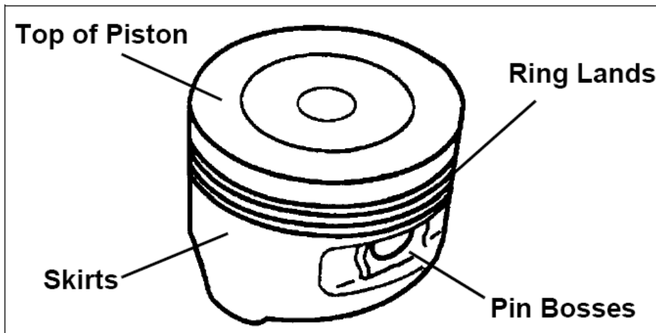
Piston Inspection

Special Tool(s)

 FPP10032	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)

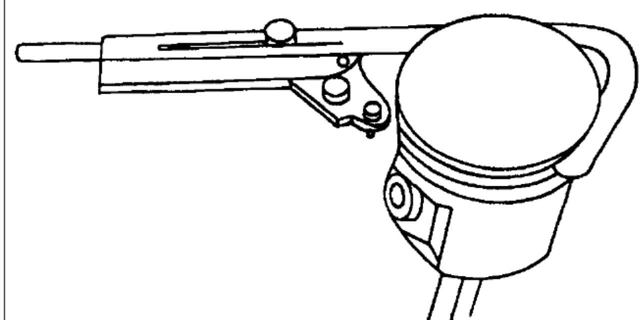
CAUTION: Do not use a caustic cleaning solution or a wire brush to clean the pistons or possible damage can occur.

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.



FPP03522

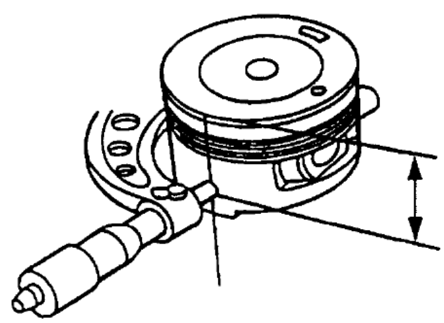
2. Use the Piston Ring Groove Cleaner to clean the piston ring grooves.
   - Make sure the oil ring holes are clean.



FPP03523

Piston Diameter

- Measure the piston skirt diameter.



FPP03524

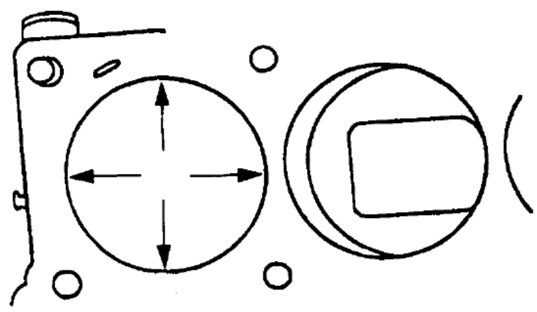
Piston to Cylinder Bore Clearance

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

Piston Selection

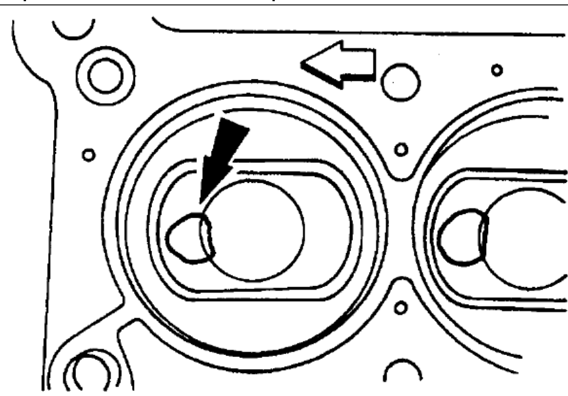
NOTE: The cylinder bore must be within the specifications for taper and out-of-round before fitting a piston.

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



FPP03525

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.

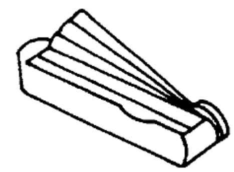


FPP03526

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)

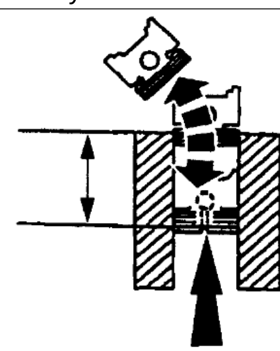
 FPP10033	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

CAUTION: 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.

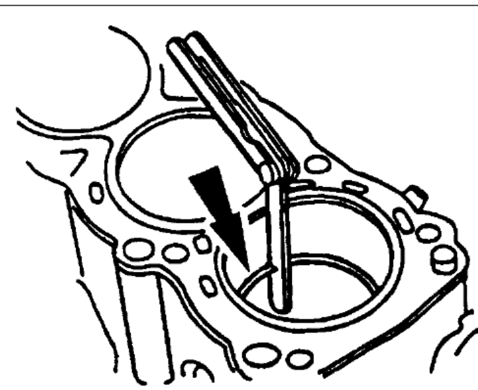
NOTE: Cylinder bore must be within specification for taper and out-of-round to fit piston rings.

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



FPP03527

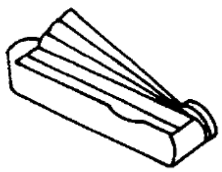
2. Use a feeler gauge to measure the top piston ring end gap and the second piston ring end gap.



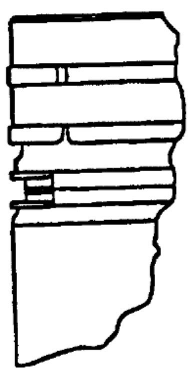
FPP03528

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)

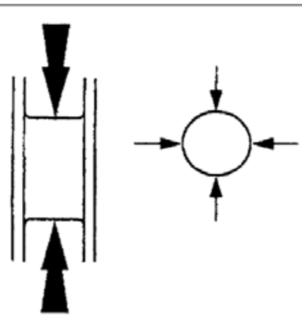
1. Inspect for a stop in the grooves.
2. Measure the piston-to-groove clearance.



FPP03529

Crankshaft Connecting Rod Journal Diameter

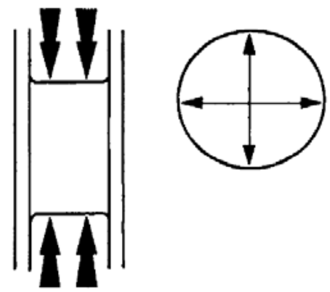
- Measure the crankshaft connecting rod journal diameters in at least two directions perpendicular to one another. The difference between the measurements is the out-of-round. Verify the journal is within the wear limit specification.



FPP03530

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.



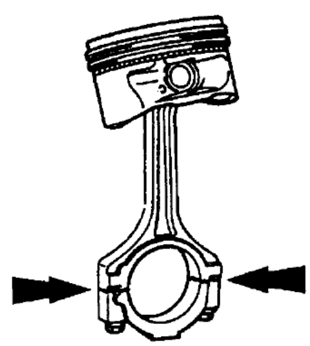
FPP03531

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.

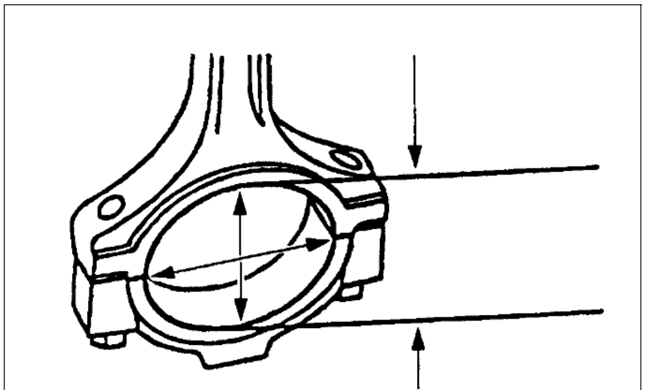


FPP03532

Connecting Rod Larger End Bore

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

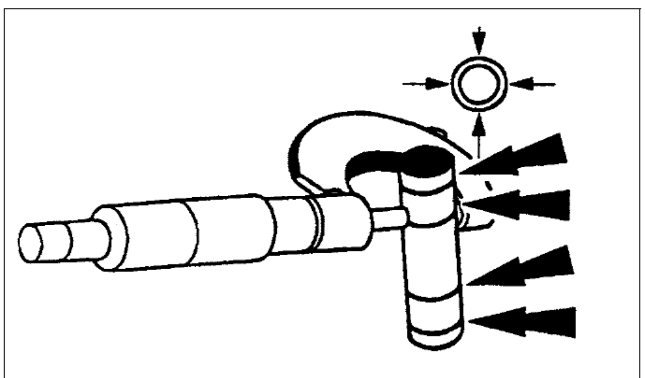
- Measure the bore in two directions. The difference is the connecting rod bore out-of-round. Verify the outof- round is within specification.



FPP03533

Piston Pin Diameter

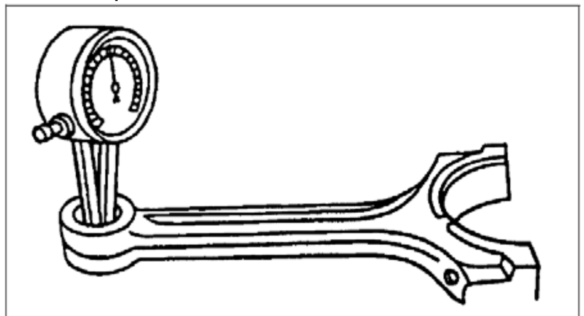
- Measure the piston pin diameter in two directions at the points shown. Verify the diameter is within specifications.



FPP03534

Connecting Rod Bushing Diameter

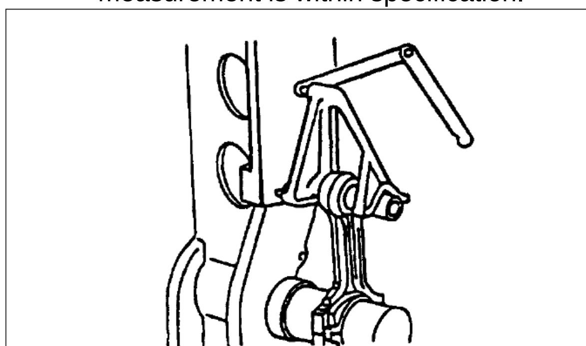
- Measure the inner diameter of the connecting rod bushing. Verify the diameter is within specification.



FPP03535

Connecting Rod Bend

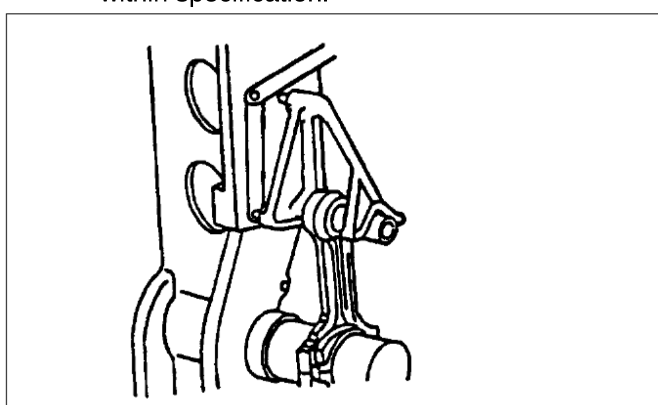
- Measure the connecting rod bend on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the bend measurement is within specification.



FPP03536

Connecting Rod Twist

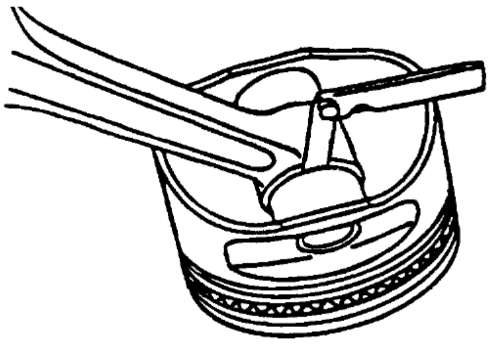
- Measure the connecting rod twist on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the measurement is within specification.



FPP03537

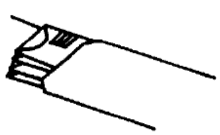
Connecting Rod Piston Pin Side Clearance

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



Connecting Rod Journal Clearance

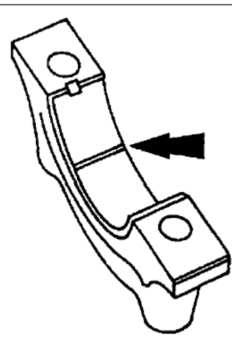
Special Tool(s)

 FPP10031	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.

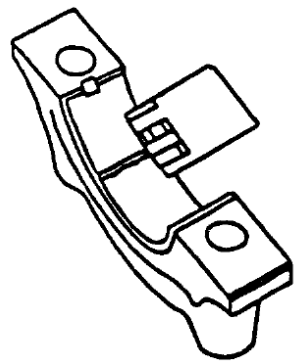
1. Remove the connecting rod bearing cap.
2. Position a piece of Plastigage® across the bearing surface.



NOTE: Do not turn the crankshaft during this step.

3. Install and torque to specifications, then remove the connecting rod bearing cap.

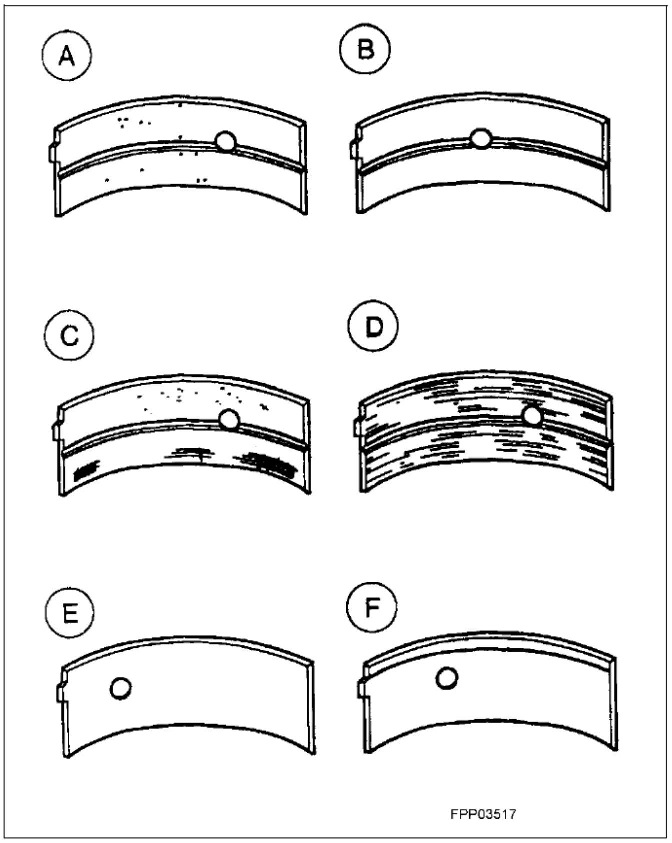
4. Measure the Plastigage® to get the connecting rod bearing journal clearance. The Plastigage® should be smooth and flat. A change width indicates a tapered or damaged connecting rod bearing or connecting rod.



Bearing Inspection

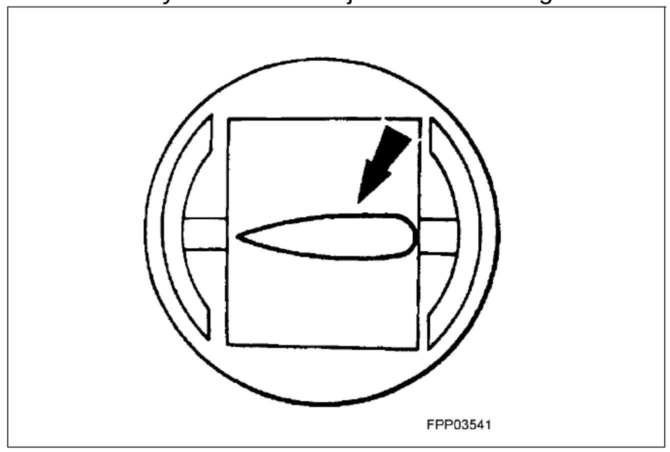
Inspect bearings for the following defects. Possible causes are shown:

- 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)



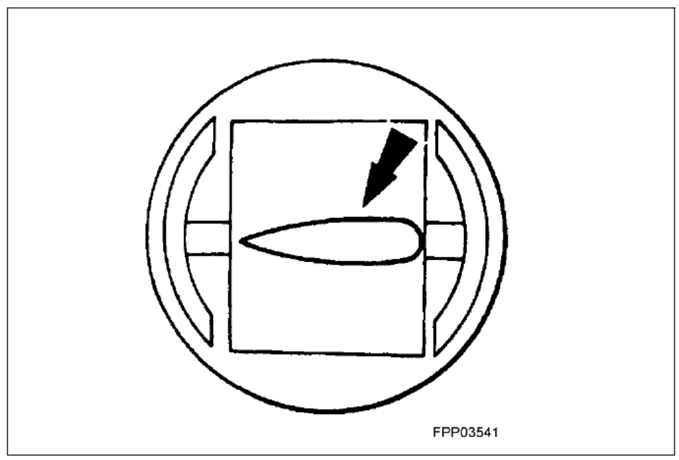
Roller Follower Inspection

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



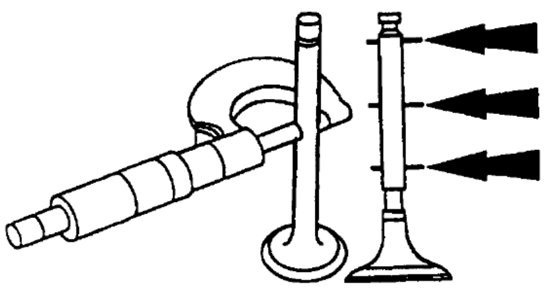
Hydraulic Lash Adjuster Inspection

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



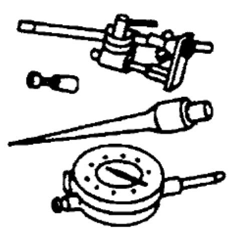
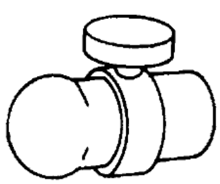
Valve Stem Diameter

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



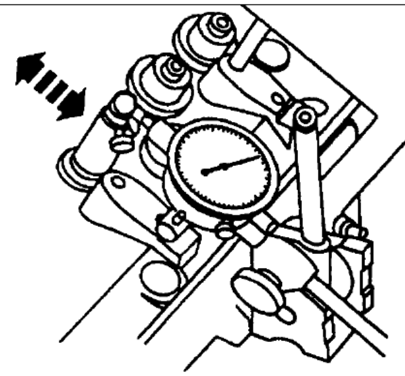
Valve Stem-to-Valve Guide Clearance

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.

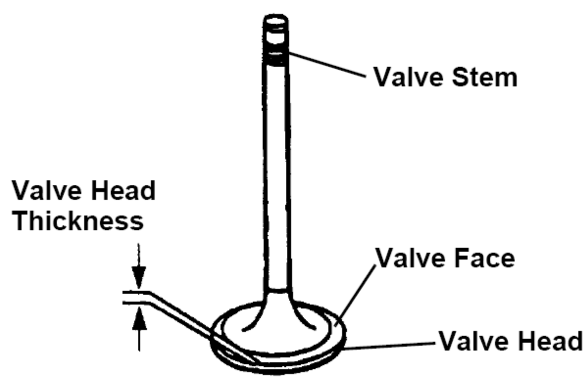
1. Install the Valve Stem Clearance Tool on the valve stem and install the Dial Indicator with Bracketry. Lower the valve until the Valve Stem Clearance Tool contacts the upper surface of the valve guide.
2. Move the Valve Stem Clearance Tool toward the Dial Indicator and zero the Dial Indicator. Move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

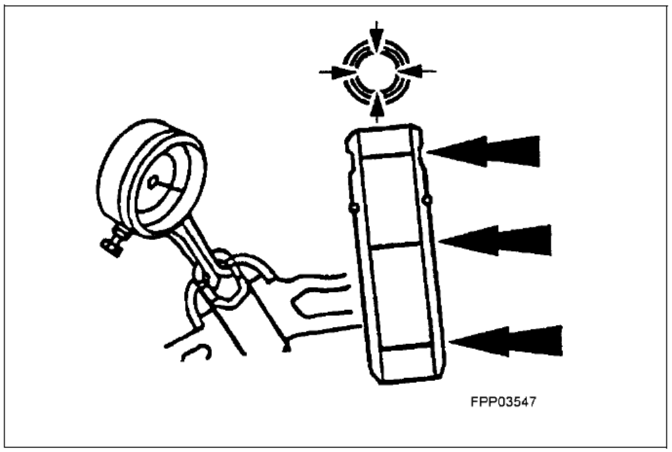
- The end of the stem for grooves or scoring.
- The valve face and the edge for pits, grooves or scores.
- The valve head for signs of burning, erosion, warpage and cracking. Minor pits, grooves and other abrasions may be removed.
- The valve head thickness for wear.



Valve Guide Inner Diameter

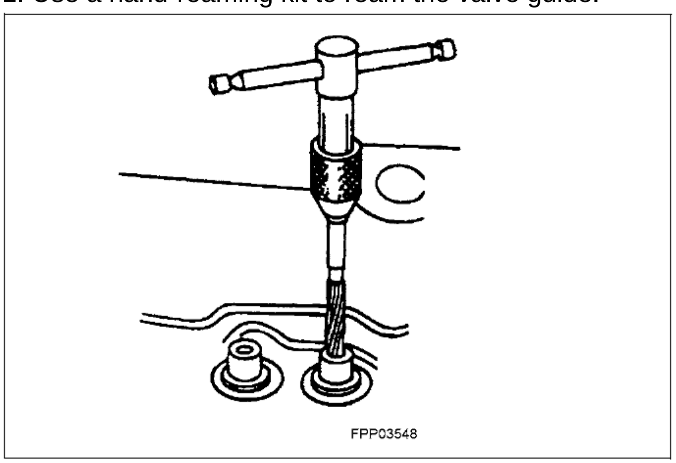
1. Measure the inner diameter of the valve guides in two directions where indicated.

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

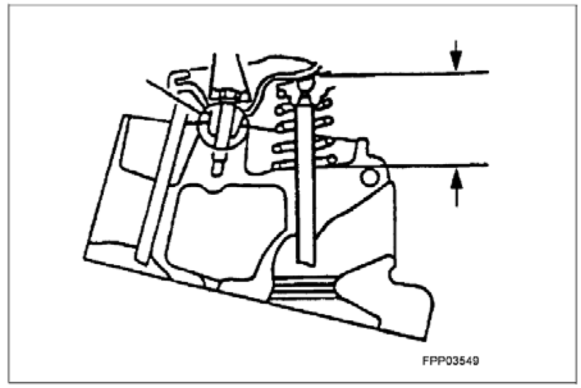
1. Use a hand-reaming kit to ream the valve guide.



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

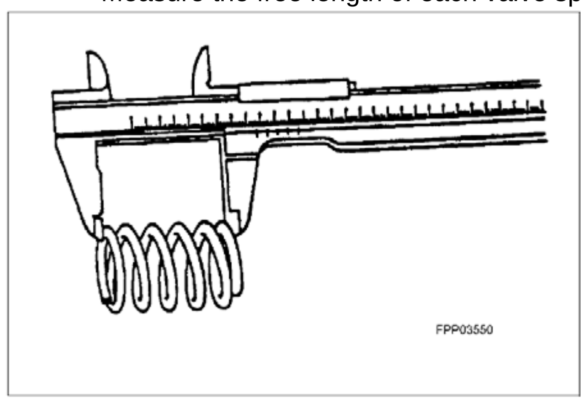
Valve Spring Installed Length

- Measure the installed length of each valve spring.



Valve Spring Free Length

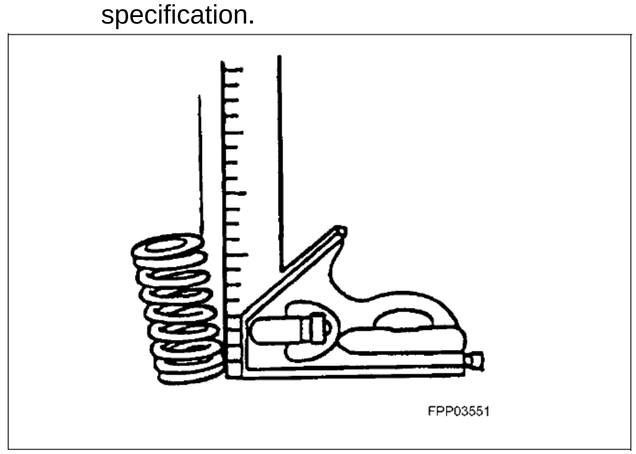
- Measure the free length of each valve spring.



Valve Spring Out-of-Square

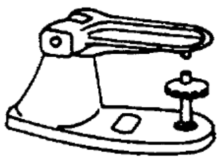
Measure the out-of-square on each valve spring.

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

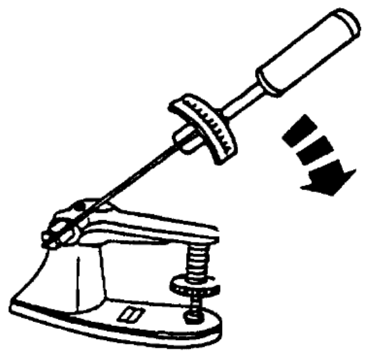


Valve Spring Compression Pressure

Special Tool(s)

 FPP10035	Valve/Clutch Spring Tester TOOL-6513-DD or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

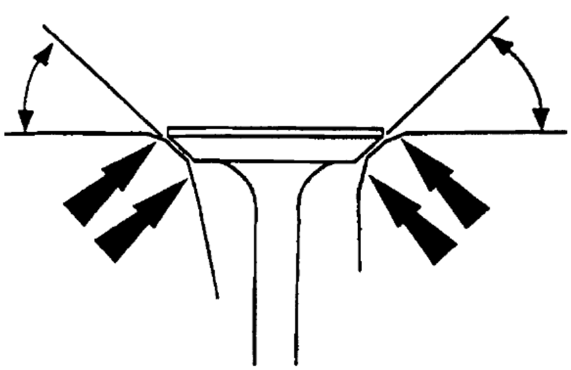


FPP03552

Valve and Seat Refacing Measurements

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

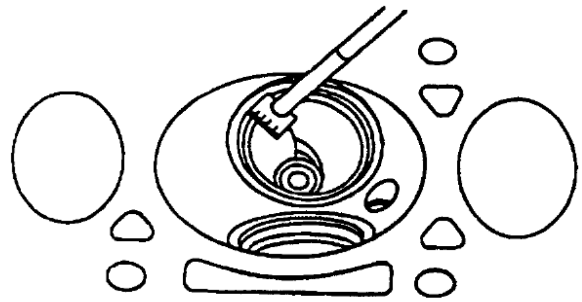
- Check the valve seat and valve angles.



FPP03553

Valve Seat Width

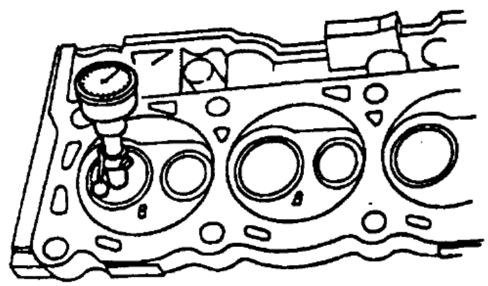
- Measure the valve seat width. If necessary, grind the valve seat to specification.



FPP03554

Valve Seat Runout

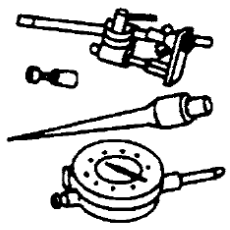
- Use the Valve Seat Runout Gauge to check valve seat runout.



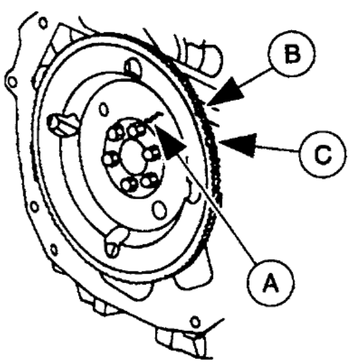
FPP03555

Flywheel Inspection

Special Tool(s)

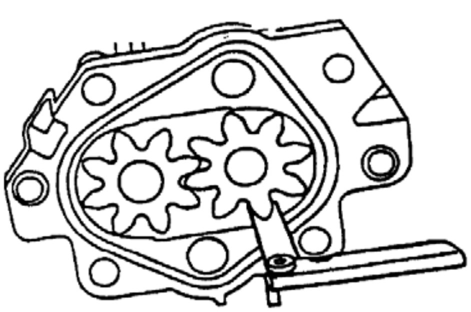
 FPP10026	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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.



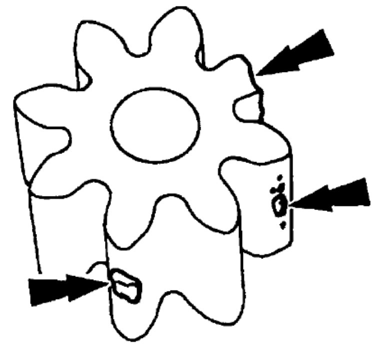
Oil Pump Gear Radial Clearance

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

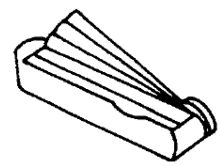
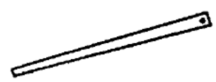

FPP03557

Oil Pump Rotor Inspection

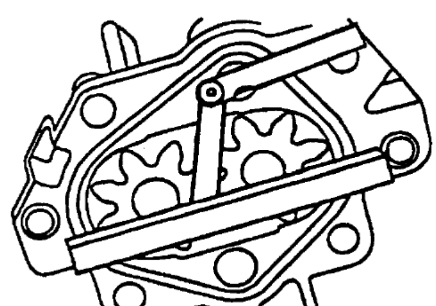
- Inspect the oil pump rotor tips for damage or wear.


FPP03558

Oil Pump Side Clearance

 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.


FPP03559

Cylinder Bore Honing

Special Tool(s)

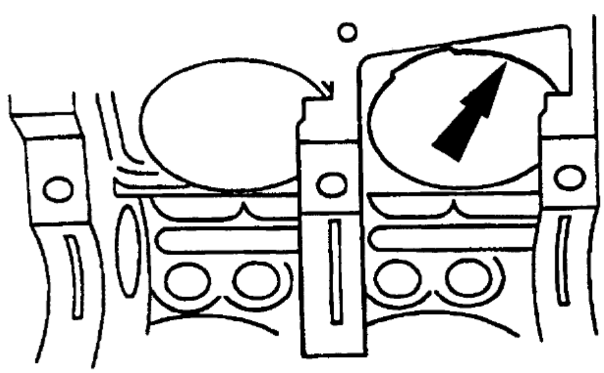
 FPP10037	Engine Cylinder Hone Set T73L-6011-A Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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.



FPP03560

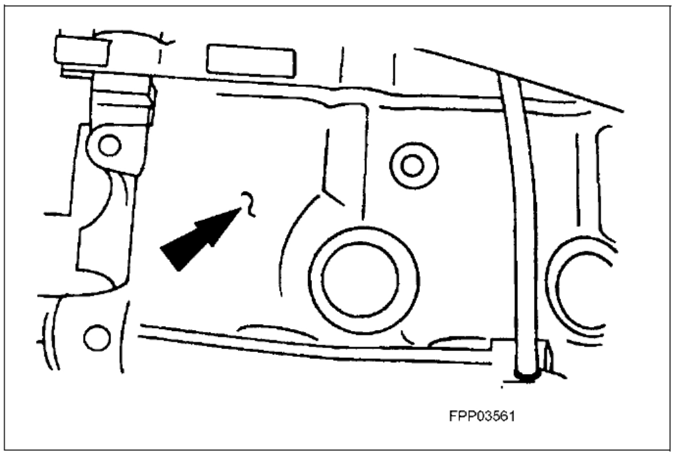
Cylinder Bore Cleaning

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.

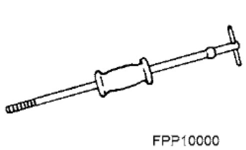


Repair porosity defects with an epoxy sealer meeting Ford specification M3D35-A (E).

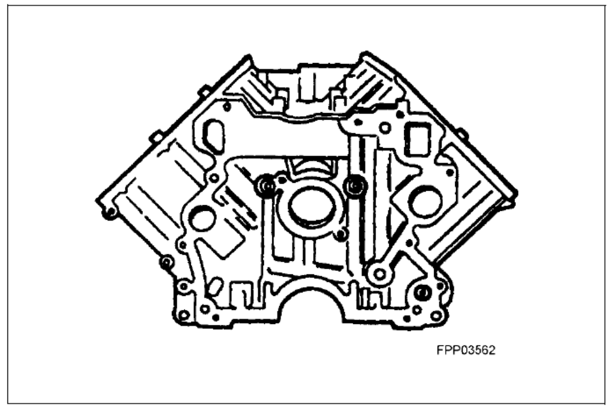
1. Clean the surface to be repaired to a bright, oil-free metal surface.
2. Chamfer or undercut the repair area to a greater depth than the rest of the cleaned surface. Solid metal must surround the area to be repaired.
3. Apply the epoxy sealer and heat-cure with a 250- watt lamp placed 254 mm (10 inches)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

	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.

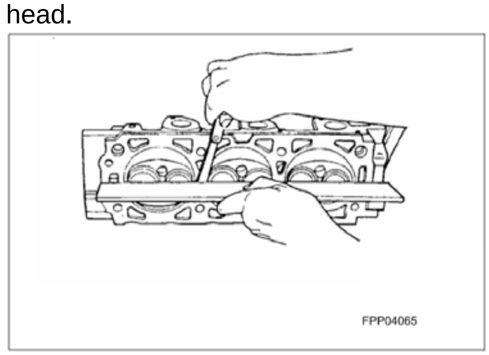
3. Coat the cylinder block core plug and bore lightly with Threadlock® 262 E2FZ-19554-B or equivalent meeting Ford specification WSK-M2G351-A6 and install the cylinder block core plug.

Cylinder Head - Distortion

Special Tool(s)

	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. If the cylinder head is distorted, install a new cylinder head.

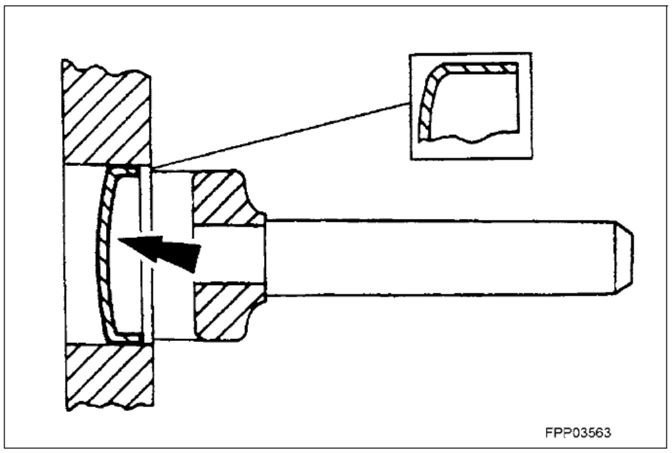


Cylinder Block Core Plug – Cup-Type

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.



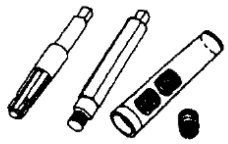
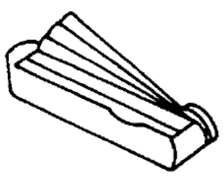
Cylinder Block Core Plug – Expansion-Type

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)

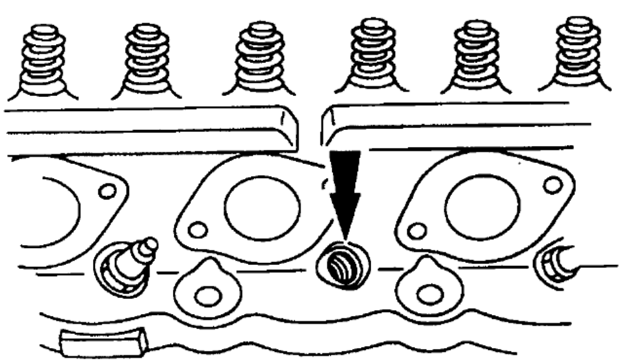
 FPP10038	Tapersert Installation Kit 107-R0921 or Equivalent
 FPP10033	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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 tapersert.

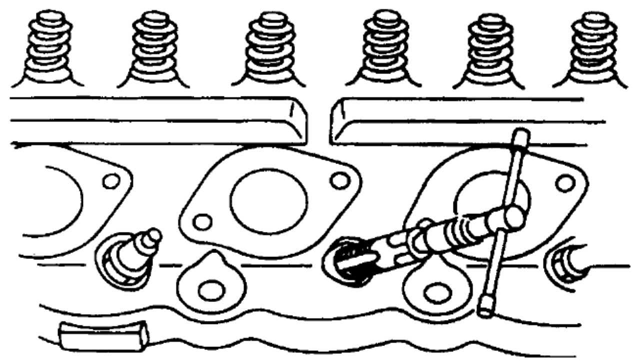
NOTE: This repair is permanent and will have no effect on cylinder head or spark plug life.

1. Clean the spark plug seat and threads.



FPP03564

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.

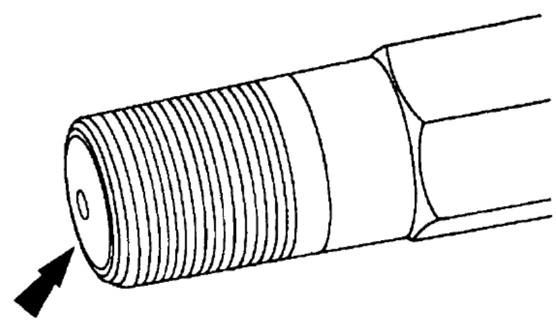


FPP03565

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.

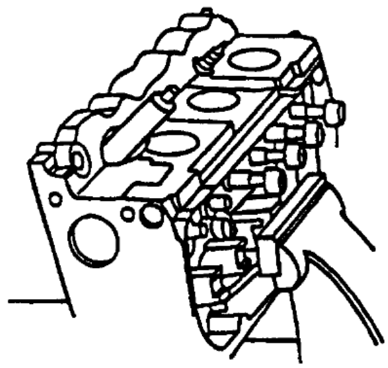
5. Coat the threads of the mandrel with cutting oil. Thread the tapersert onto the mandrel until one thread of the mandrel extends beyond the tapersert.



FPP03566

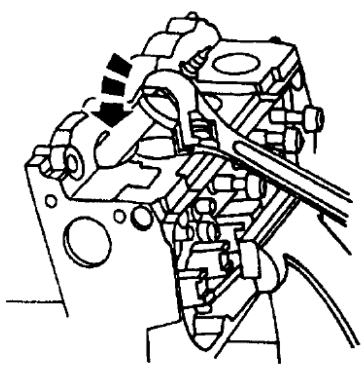
NOTE: A properly installed tapersert will be either flush with or 1.0 mm (0.039 inch) below the spark plug gasket seat.

6. Tighten the tapersert into the spark plug hole.



FPP03567

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



FPP03568

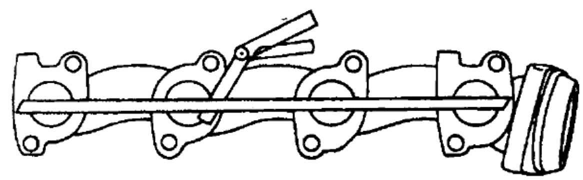
Exhaust Manifold Straightness

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.



FPP03569

SPECIFICATIONS

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

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

WSG-1068 ENGINE

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WSG-1068 ENGINE

GENERAL INFORMATION

Description

The 6.8 liter engine consists of four basic modules that can be repaired individually. Remove only those components required to repair the module.

The induction module consists of an upper and lower intake manifold (9424).

Each aluminum cylinder head module utilizes a single overhead camshaft (6250) to operate the two-valves-percylinder design. Individual ignition coils (12029) are used for each spark plug (12405).

The cylinder block module is a cast iron, 90-degree V-10 cylinder block (6010).

The basic engine components consist of the following:

- Two overhead camshafts.
- Engine dynamic balance shaft.
- Two valves per cylinder.
- Aluminum cylinder heads (6049).
- Cast iron, 90-degree V-10 cylinder block.
- Two-piece aluminum intake manifold system.

Engine Identification

It is important the engine codes and the calibration number be used when ordering parts or making inquiries about the engine.

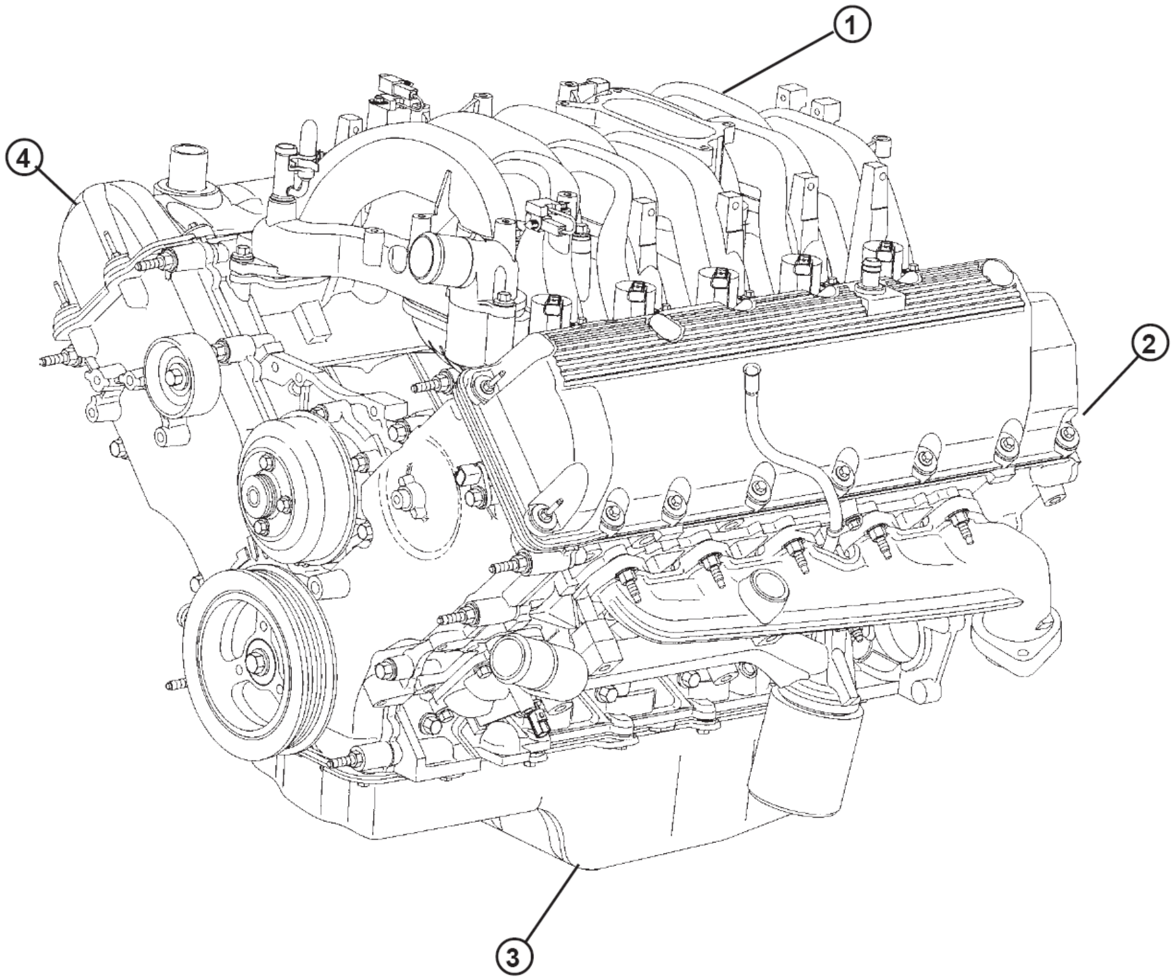
Engine Code Information

The engine code information label, located on the valve cover, contains the following:

- Engine build date.
- Engine code.

WSG-1068 ENGINE

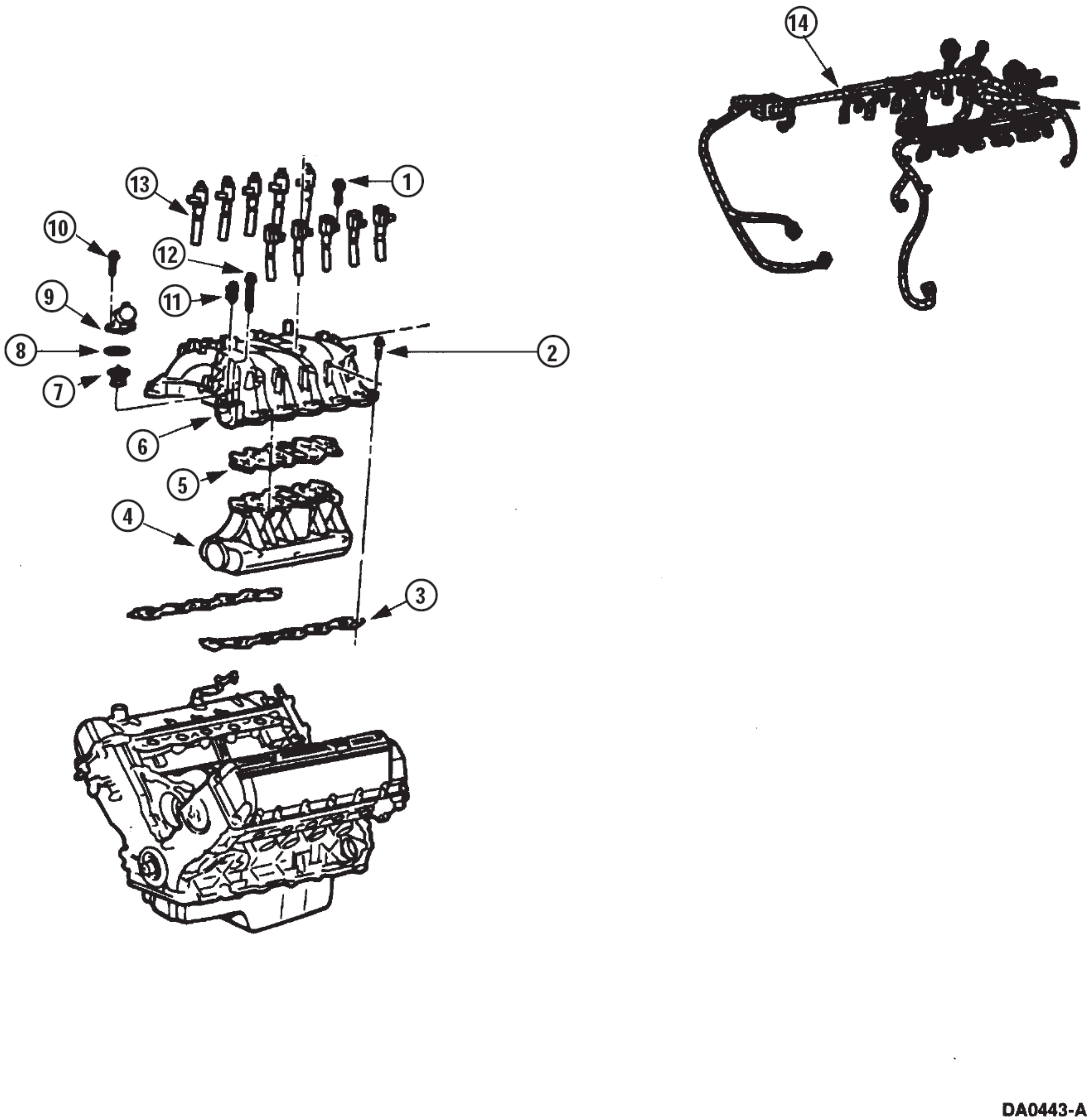
Module View



Item	Part Number	Description
1	–	Induction Module
2	–	Cylinder Head Module (LH)
3	–	Cylinder Block Module
4	–	Cylinder Head Module (RH)

WSG-1068 ENGINE

Engine Intake Components

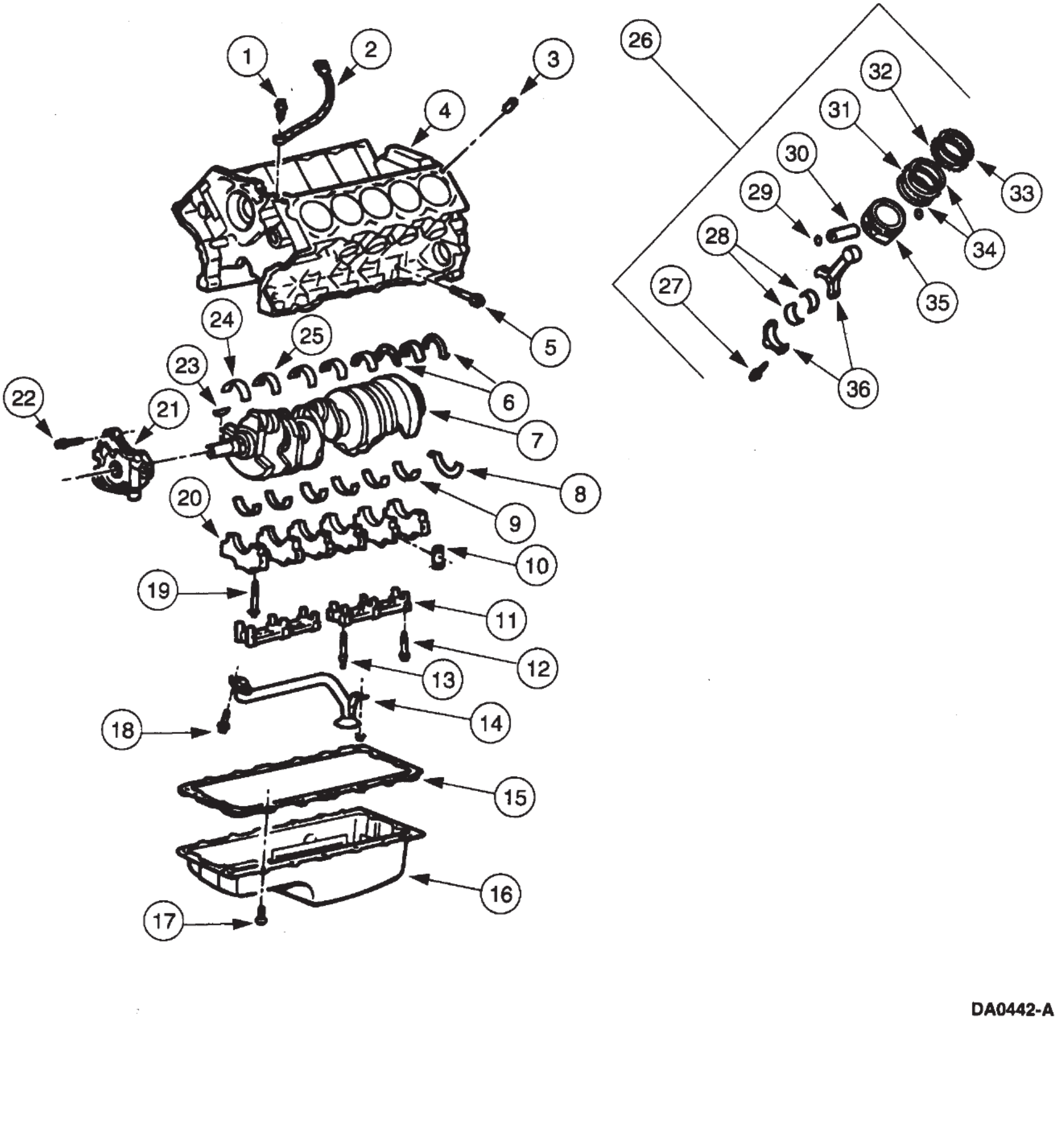


WSG-1068 ENGINE

Item	Part Number	Description
1	N606500	Bolt (10 Req'd)
2	N806156	Bolt (11 Req'd)
3	9439	Intake Manifold Gasket
4	9424	Intake Manifold
5	9461	Intake Manifold Gasket
6	9424	Intake Manifold (Upper)
7	9575	Water Thermostat
8	N806807	O-Ring Seal
9	8494	Water Outlet Connection
10	N806178	Bolt (3 Req'd)
11	10884	Water Temperature Indicator Sender Unit
12	N806178	Bolt (2 Req'd)
13	12A366	Ignition Coil and Boot (10 Req'd)
14	12B637	Ignition Harness

WSG-1068 ENGINE

Low End Components



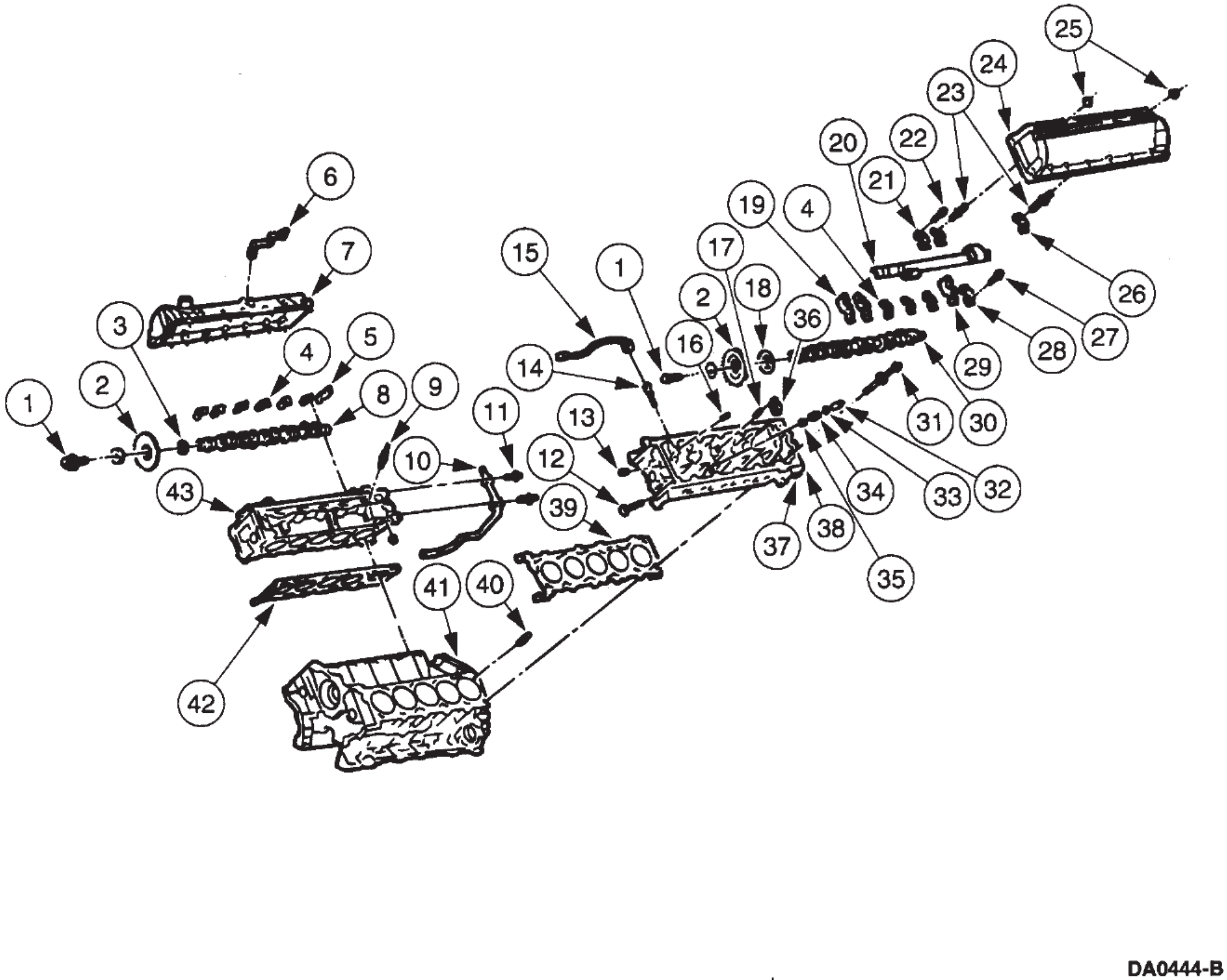
WSG-1068 ENGINE

Item	Part Number	Description
1	W500225	Bolt
2	12A699	Knock Sensor
3	N806459	Dowel (4 Req'd)
4	6010	Cylinder Block
5	6345	Crankshaft Main Bearing Cap Stud
6	6334	Crankshaft Thrust Washer (Upper) (2 Req'd)
7	6303	Crankshaft
8	6K302	Crankshaft Thrust Waster (Lower)
9	6333	Crankshaft Main Bearing (Lower)
10	6A346	Dowel
11	6F098	Support
12	N811025	Bolt
13	N811026	Stud
14	6622	Oil Pump Screen Cover and Tube
15	6710	Oil Pan Gasket
16	6675	Oil Pan
17	W701605	Bolt
18	N806155	Bolt

Item	Part Number	Description
19	6345	Crankshaft Main Bearing Cap Stud
20	6325	Crankshaft Main Bearing Cap
21	6600	Oil Pump
22	N806183	Bolt
23	N806201	Key
24	6W337	Crankshaft Upper Main Bearing Shell
25	6333	Crankshaft Main Bearing (Upper)
26	6100	Piston/Connecting Rod Assy.
27	6214	Connecting Rod Bolt
28	6211	Connecting Rod Bearing
29	6140	Piston Pin Retainer
30	6135	Piston Pin
31	6161	Piston Ring, Spacer Oil Control
32	6152	Compression Ring (Lower)
33	6150	Compression Ring (Upper)
34	6159	Piston Ring, Segment Oil Control
35	6108	Piston
36	6200	Connecting Rod

WSG-1068 ENGINE

Upper End Components



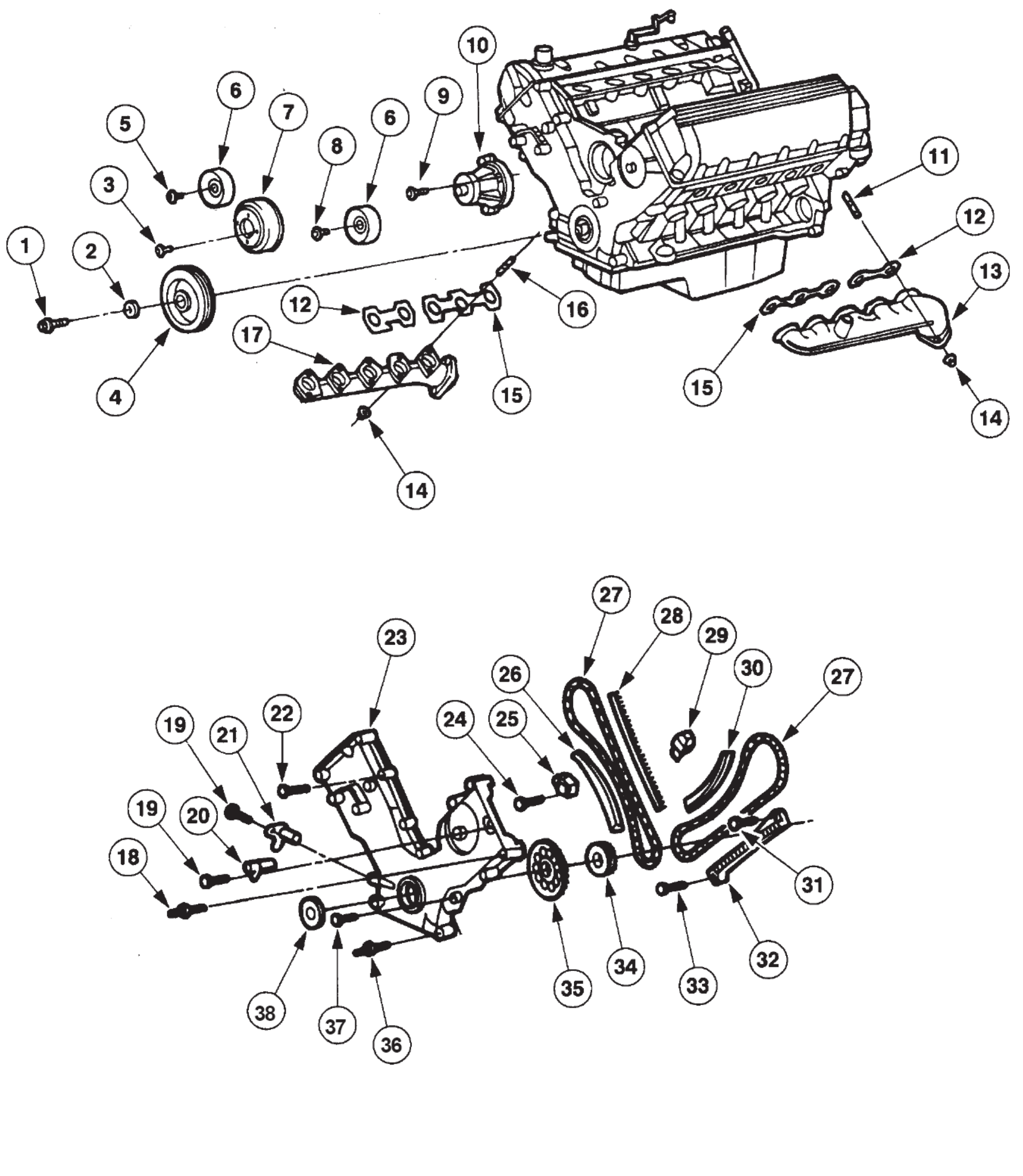
WSG-1068 ENGINE

Item	Part Number	Description
1	N811085	Bolt
2	6256	Camshaft Sprocket
3	6265	Camshaft Sprocket Spacer
4	6C268	Camshaft Bearing Cap
5	6B284	Camshaft Bearing Cap
6	6C324	Crankcase Vent Connector and Hose
7	6582	Valve Cover
8	6250	Camshaft
9	12405	Spark Plug
10	18663	Heater Water Outlet Tube
11	N808897	Bolt (2 Req'd)
12	–	Valve (Part of 6049)
13	87838	Plug (6 Req'd)
14	6G004	Cylinder Head Temperature Sensor
15	14B102	Electrical Connector
16	6F087	Cylinder Head Oil Reservoir Restrictor
17	6500	Hydraulic Lash Adjuster
18	6A303	Balance Shaft Drive Gear
19	7C272	Balance Shaft Journal
20	6A305	Balance Shaft
21	6C267	Balance Shaft Journal Cap

Item	Part Number	Description
22	N808777	Bolt (4 Req'd)
23	N808775	Bolt
24	6582	Valve Cover
25	N805320	Nut (2 Req'd)
26	6C266	Balance Shaft Journal Cap (2 Req'd)
27	N807834	Fastener (26 Req'd)
28	6B280	Camshaft Bearing Cap
29	6C266	Balance Shaft Journal (2 Req'd)
30	6250	Camshaft
31	6065	Cylinder Head Stud
32	6518	Valve Spring Retainer Key
33	6514	Valve Spring Retainer
34	6513	Valve Spring
35	6571	Valve Stem Seal
36	6564	Rocker Arm
37	87836	Plug (2 Req'd)
38	6049	Cylinder Head
39	6051	Head Gasket
40	N806459	Dowel (4 Req'd)
41	6010	Cylinder Block
42	6051	Head Gasket
43	6049	Cylinder Head

WSG-1068 ENGINE

Major Front End Components



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WSG-1068 ENGINE

Item	Part Number	Description
1	N806139	Damper Bolt
2	N806165	Washer
3	N806282	Bolt (4 Req'd)
4	6316	Front Crankshaft Damper
5	N806102	Bolt
6	12A216	Idler Pulley
7	8509	Water Pump Pulley
8	N808102	Bolt
9	–	Bolt (4 Req'd)
10	8501	Water Pump
11	811313	Stud (10 Req'd)
12	9448	Exhaust Manifold Gasket
13	9430	Exhaust Manifold
14	W701706	Bolt (10 Req'd)
15	9448	Exhaust Manifold Gasket
16	W701706	Stud (10 Req'd)
17	9430	Exhaust Manifold
18	N808140	Fastener (5 Req'd)
19	N806155	Bolt

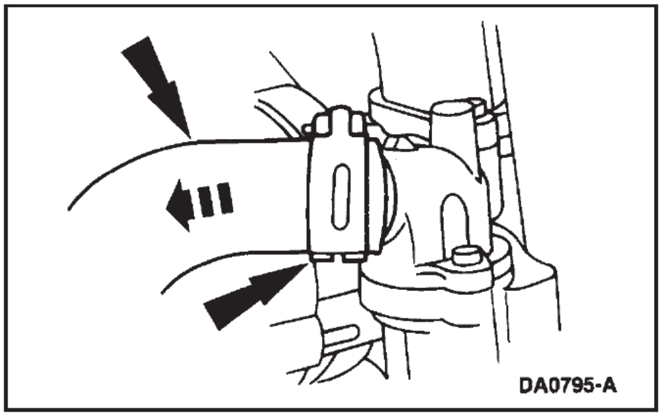
Item	Part Number	Description
21	6C315	Crankshaft Position Sensor
22	N808142	Bolt (3 Req'd)
23	6019	Engine Front Cover
24	N606543	Bolt (4 Req'd)
25	6L266	Timing Chain Tensioner (RH)
26	6L253	Timing Chain Tensioner Arm (RH)
27	6268	Timing Chain/Belt (2 Req'd)
28	6K297	Timing Chain Guide (RH)
29	6L266	Timing Chain Tensioner (LH)
30	6L253	Timing Chain Tensioner Arm (LH)
31	N605892	Bolt (3 Req'd)
32	6K297	Timing Chain Guide (LH)
33	N606427	Bolt
34	6306	Crankshaft Sprocket
35	12A227	Crankshaft Sensor Ignition Pulse Ring
36		Fasteners (2 Req'd)
37	N806177	Bolt (5 Req'd)
38	6700	Crankshaft Front Seal

DIAGNOSIS AND TESTING

Refer to Section 01 for basic mechanical concerns.

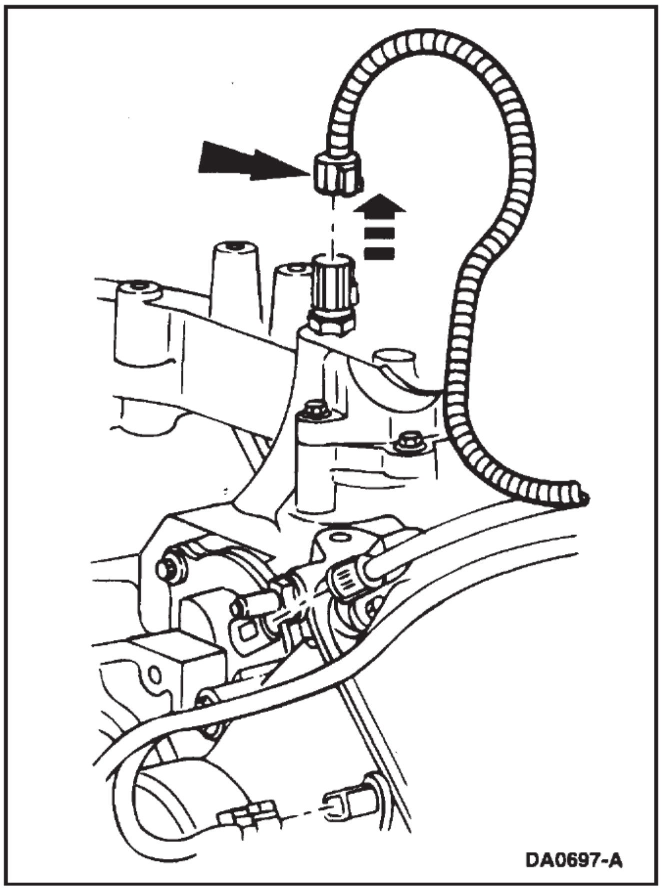
ENGINE REPAIR

Intake Manifold – Variable Resonance



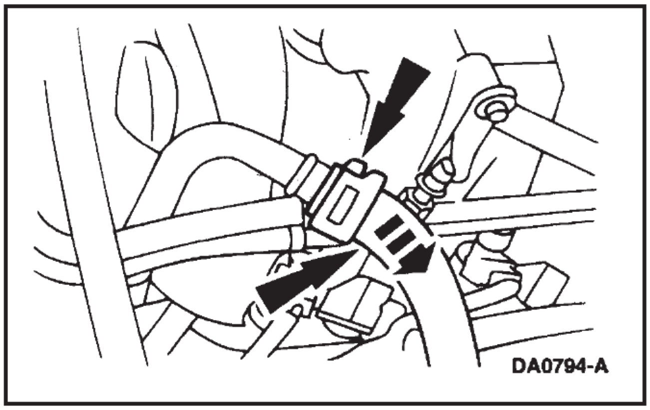
WARNING: DO NOT SMOKE OR CARRY LIGHTED TOBACCO OR OPEN FLAME OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENTS. HIGHLY FLAMMABLE MIXTURES ARE ALWAYS PRESENT AND CAN BE IGNITED, RESULTING IN POSSIBLE PERSONAL INJURY.

WARNING: FUEL IN THE FUEL SYSTEM REMAINS UNDER HIGH PRESSURE EVEN WHEN THE ENGINE IS NOT RUNNING.



Induction System (VRIS) - Removal

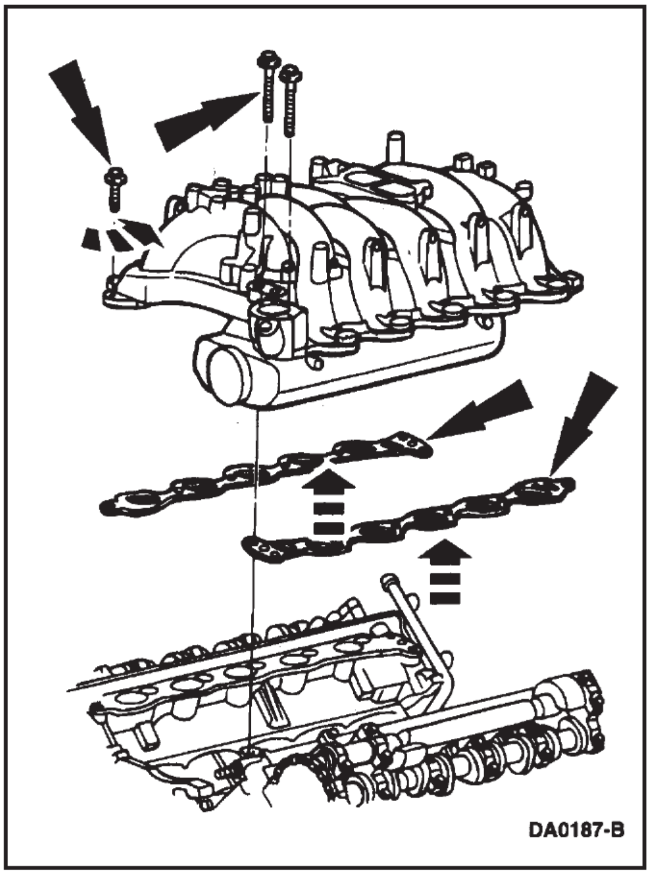
1. Disconnect the battery ground cable (14301).
2. Drain the coolant system.
3. Loosen and slide the hose clamp and disconnect the water outlet hose.
4. Remove the engine vacuum hoses.
5. Disconnect the water temperature indicator sender unit electrical connectors.
6. Disconnect and remove the ten ignition coils (12029); refer to Section 03.
7. Remove the drive belt (8620); refer to Section 05.
8. Remove the generator (GEN) (10300); refer to Section 06.



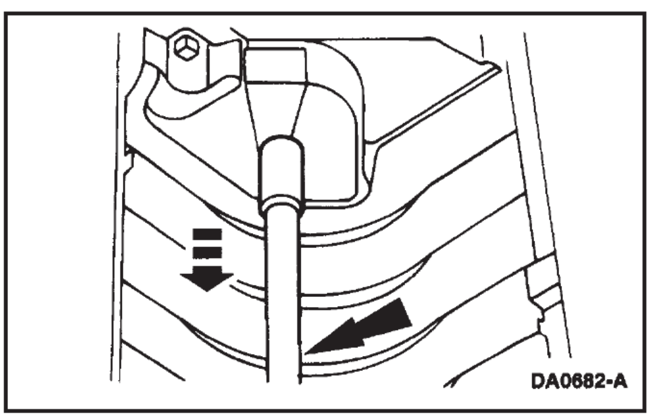
9. Disconnect the hose clamps and remove the heater water hose (18472).

10. Remove the water thermostat (8575).

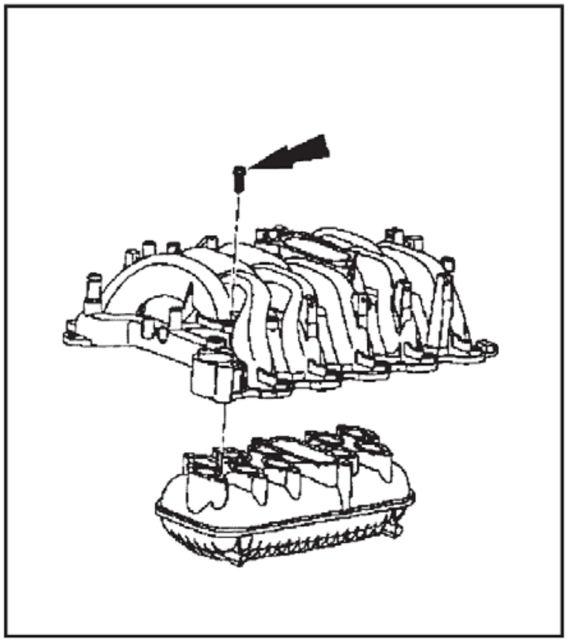
11. Remove the two studs retaining the heater water return tube.



12. Remove the bolts, the upper intake manifold and the intake manifold gasket (9439). Discard the intake manifold gaskets.



13. Pull back and remove the heater water return tube. Inspect the O-rings and replace if required.

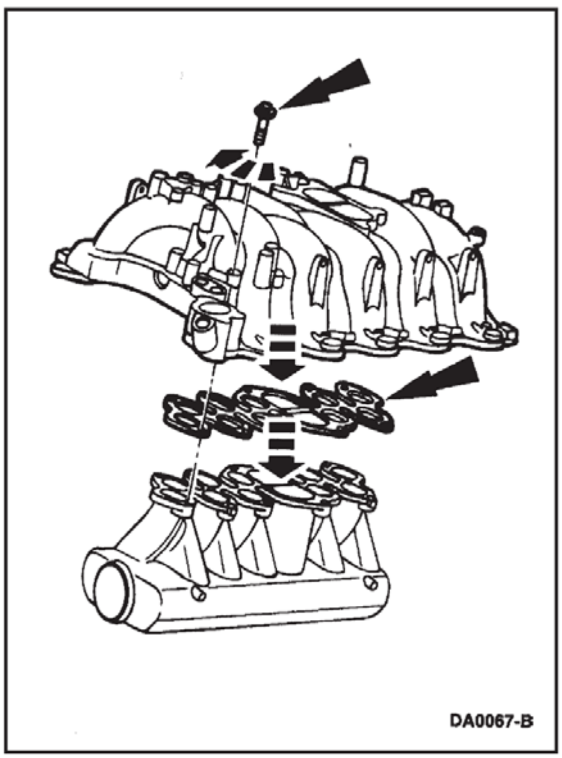


14. Separate the upper and lower intake manifolds (9424).

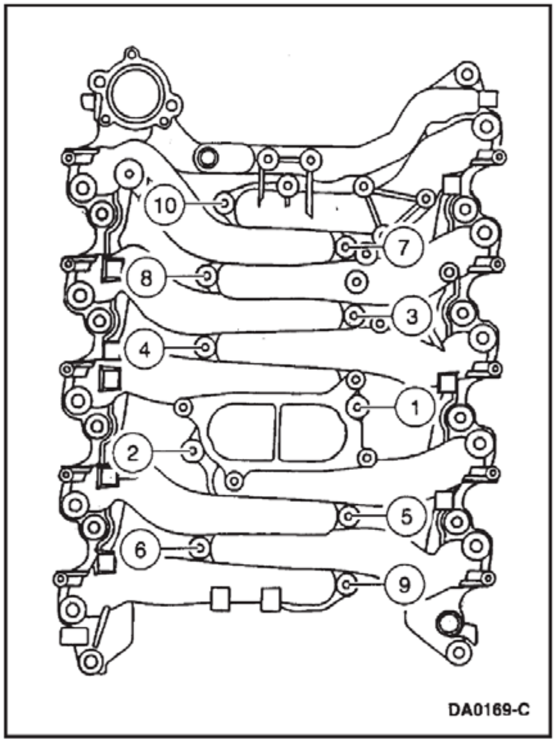
    - Remove the ten bolts.
    - Discard the intake manifold gasket.

15. Clean all mating surfaces.

Intake Manifold – Variable Resonance Induction System (VRIS) - Installation

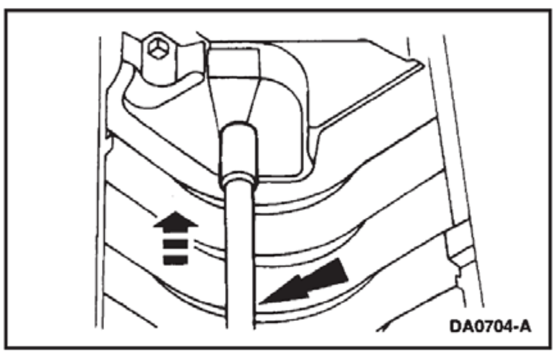


1. Position the lower intake manifold gasket (9461) and the upper intake manifold on the intake manifold and loosely install the ten bolts.

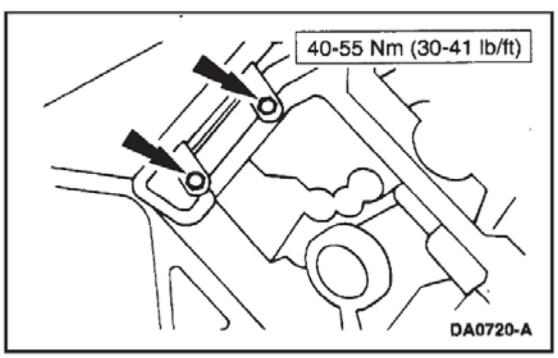


2. **NOTE:** Tighten the bolts in two stages.

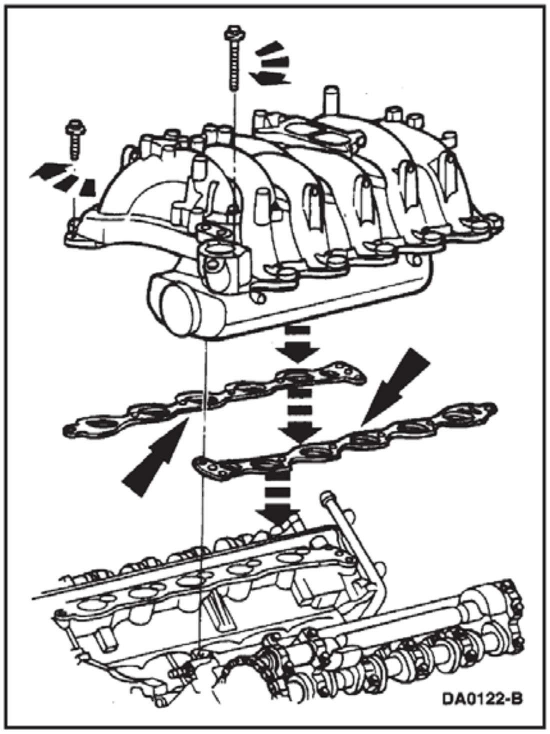
Tighten the bolts in the sequence shown.
- Stage 1: Tighten to 2 Nm (18 lb/in).
- Stage 2: Tighten to 8-12 Nm (71-106 lb/in).



3. Position the water return tube as shown.

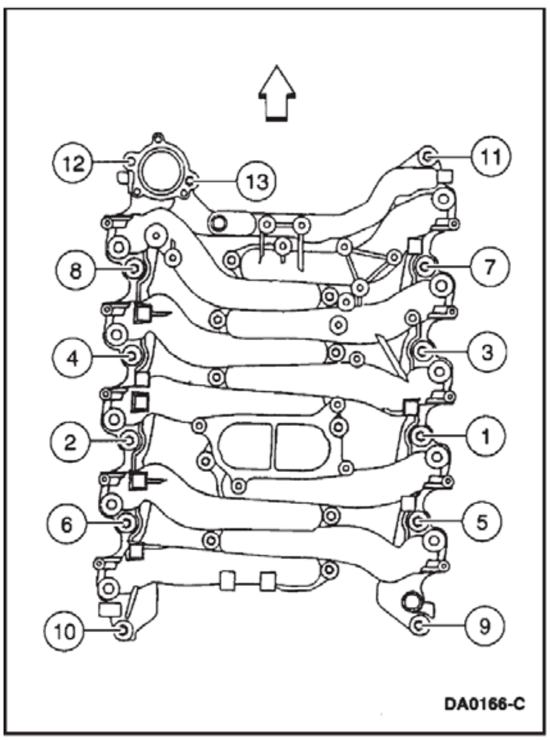


4. Install the heater water return tube studs.



5. Install the upper intake manifold.

   - Position the upper intake manifold gaskets and the intake manifold, and loosely install the bolts.

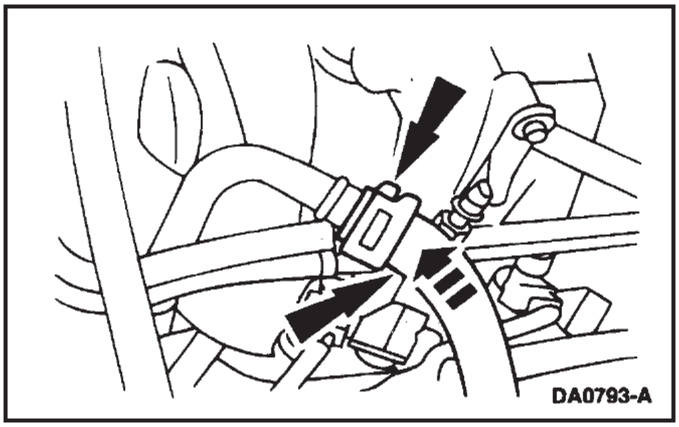


6. Install the thermostat, gasket and the thermostat housing and loosely install the bolts.

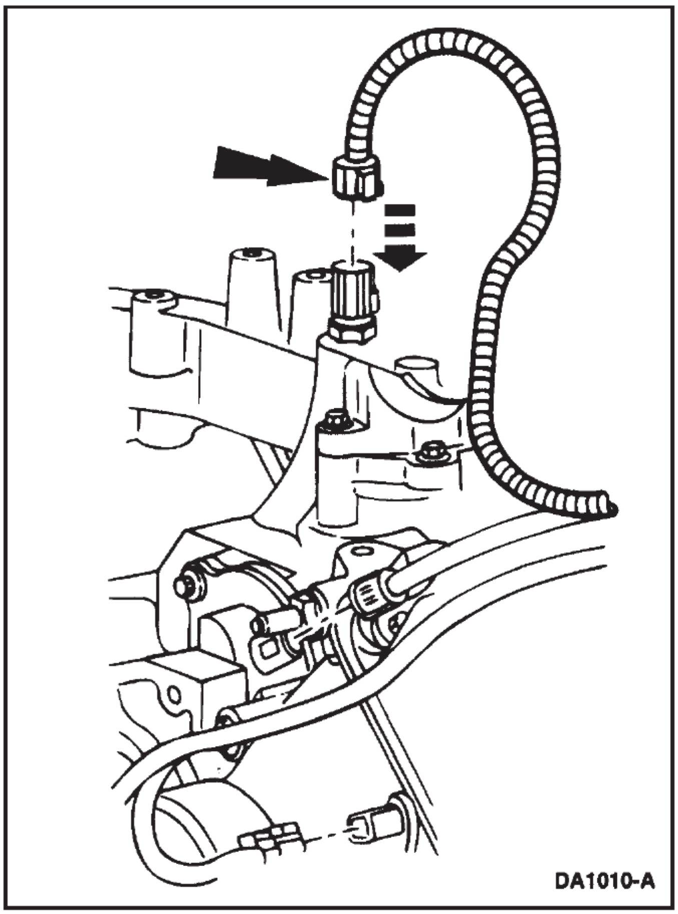
7. **NOTE:** Be sure to tighten the bolts in two stages.

   Tighten the bolts in the sequence shown.

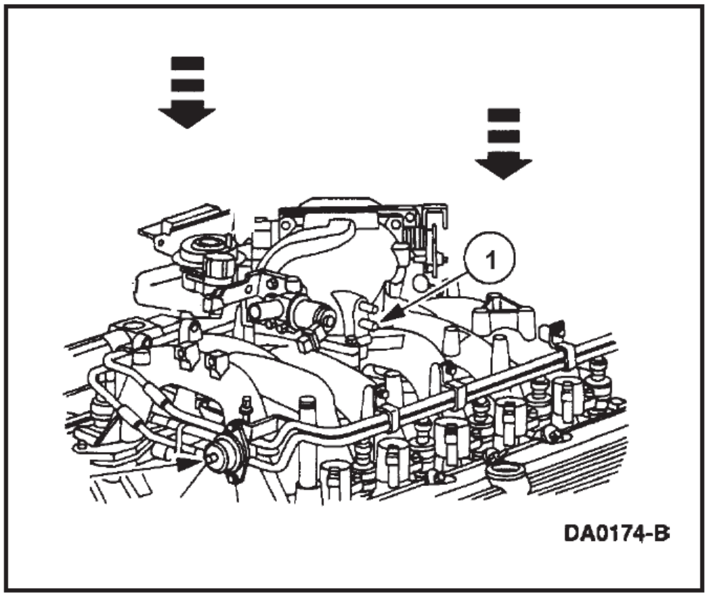
   - Stage 1: Tighten to 2 Nm (18 lb/in).
   - Stage 2: Tighten to 20-30 Nm (15-22 lb/ft).



8. Install the heater water hose and position the clamp.



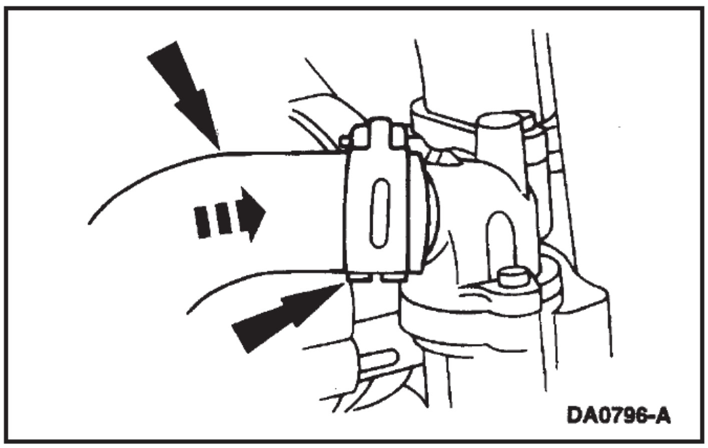
9. Connect the water temperature indicator sending unit electrical connector.
10. Install the generator.
11. Install the drive belt
12. Install the ignition coils.



13. Connect the engine vacuum hoses.

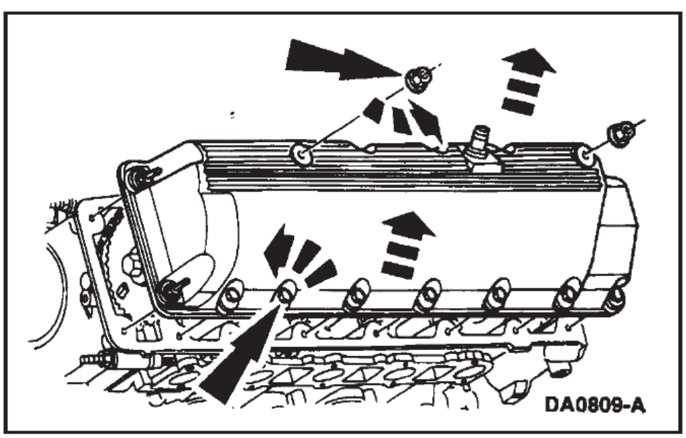
- Vacuum source.

14. Connect the engine water outlet hose and position the hose clamp.



15. Install the air cleaner outlet tube (9B659).
16. Fill the cooling system; refer to Section 05.
17. Install the engine cover.
18. Connect the battery ground cable.

Valve Cover – Left - Removal



1. **NOTE:** The bolts are a part of the valve cover (6582) and are not to be removed.

   Fully loosen the valve cover.

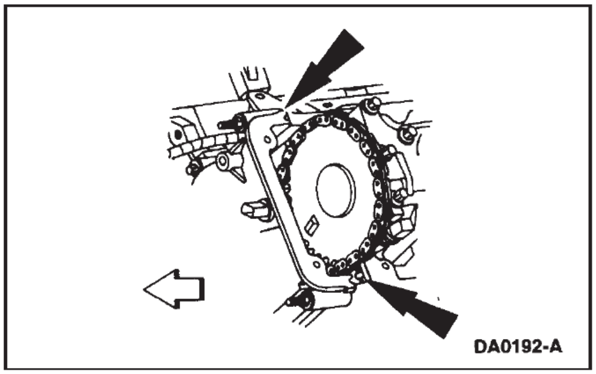
- Remove the two nuts and the sixteen bolts, and remove the valve cover and the valve cover gasket (6584).

Valve Cover – Left - Installation

1. **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

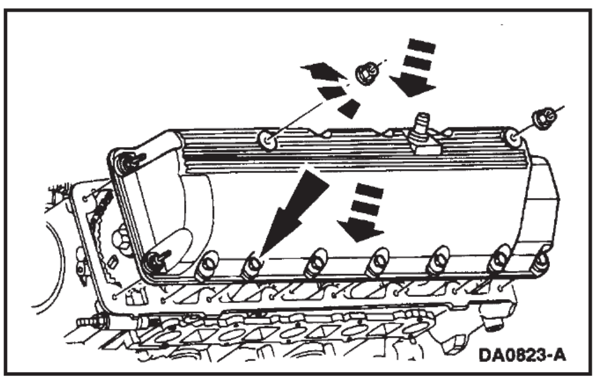


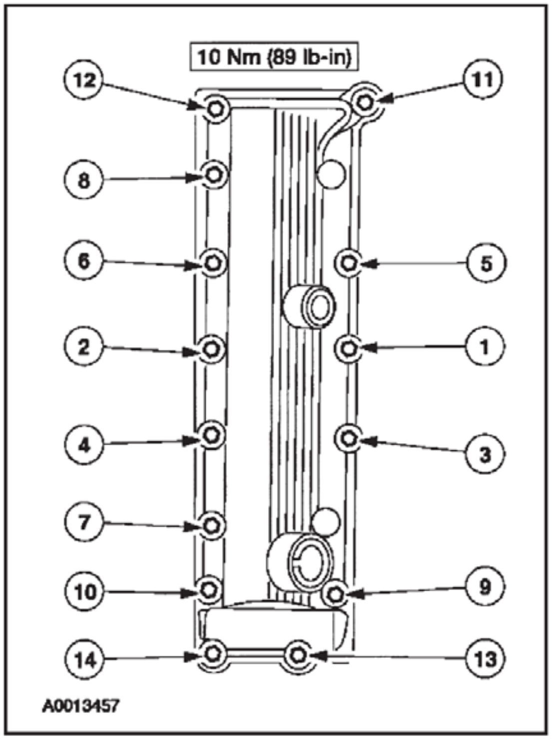
- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

2. Apply silicone in two places where the engine front cover (6019) meets the cylinder head.

- Use Silicone Gasket and Sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

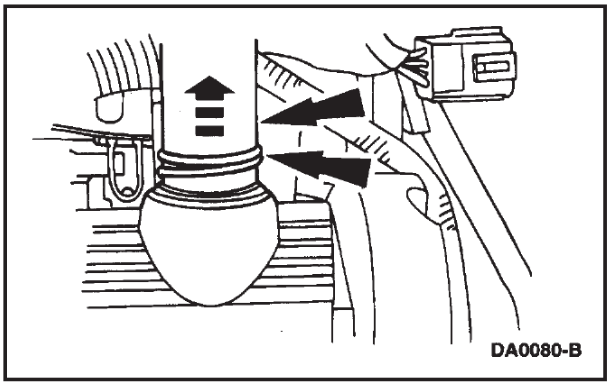
3. Position the valve cover and the valve cover gasket on the cylinder head and loosely install the bolts and nuts.

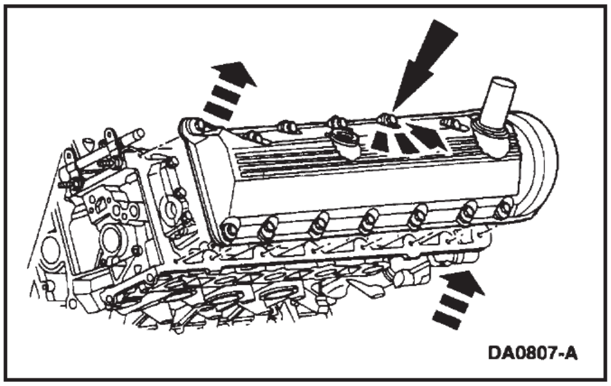




4. Tighten the nuts and bolts in the sequence shown.

Valve Cover – Right - Removal





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

2. **NOTE:** The bolts are a part of the valve cover and are not to be removed.

   Fully loosen the bolts, and remove the valve cover and the valve cover gasket (6584).

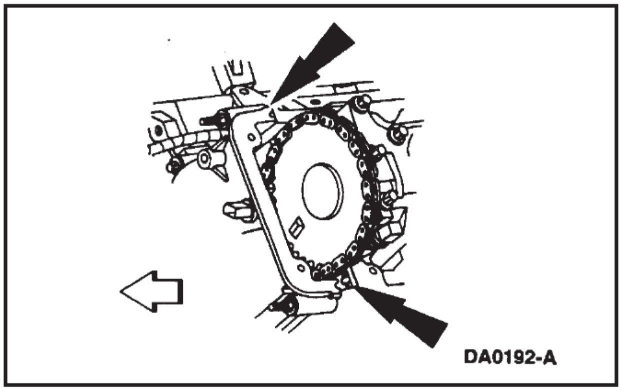
Valve Cover – Right - Installation

1. Remove the PCV valve.

   CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.

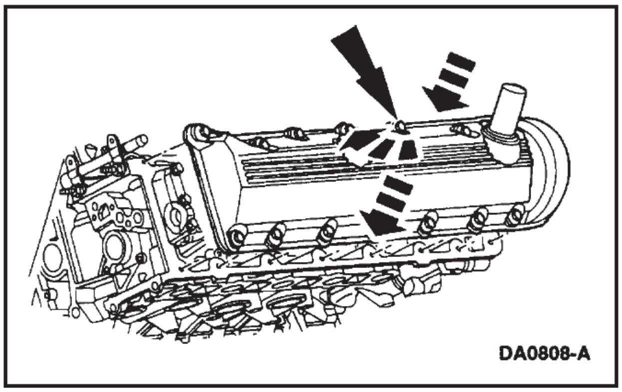
- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323- A6.

NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

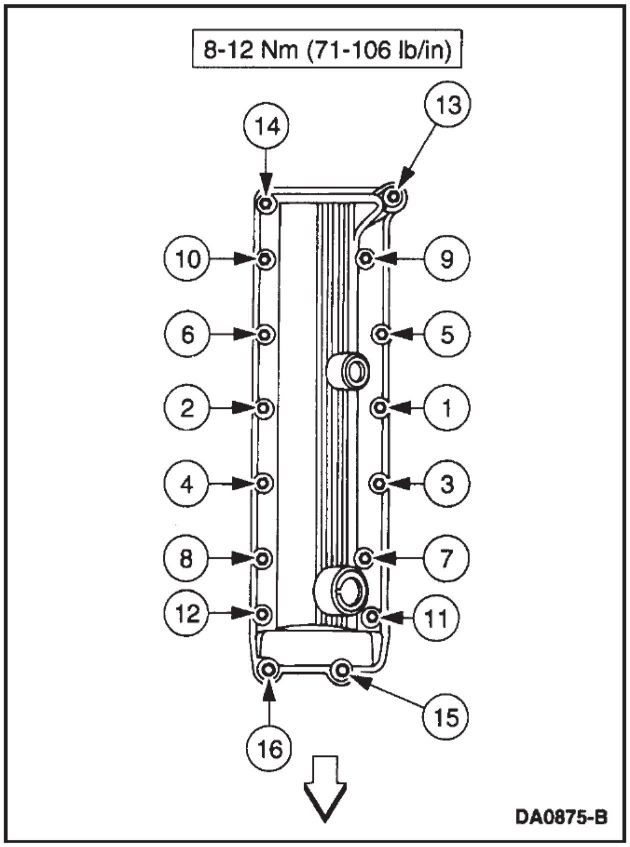


- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSE-M5B292-A.

2. Apply silicone in two places where the engine front cover (6019) meets the cylinder head (6049).



3. Position the valve cover on the cylinder head and loosely install the bolts.

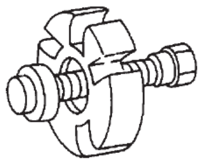
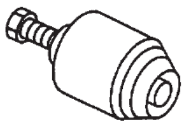


4. Tighten the bolts in the sequence shown.

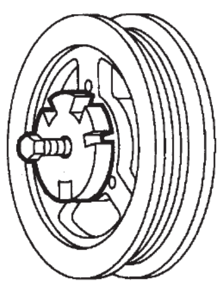
5. Reinstall the PCV valve.

Crankshaft Pulley - Removal

Special Tool(s)

 ST1286-A	Crankshaft Damper Remover 303-009 (T58P-6316-D)
 ST1288-A	Front Cover Seal Remover 303-107 (T74P-6700-A)

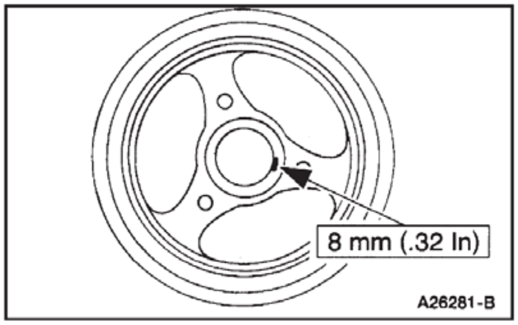
Special Service Tools called for by the procedures can be obtained by calling:
1-800-ROTUNDA (1-800-768-8632).



DA0524-A

1. Remove the engine cooling fan and fan shroud (8146).
2. Remove the drive belt (8620).
3. Remove the crankshaft pulley bolt (6A340).
4. Using the Crankshaft Damper Remover, remove the crankshaft pulley (6312).

Crankshaft Pulley - Installation

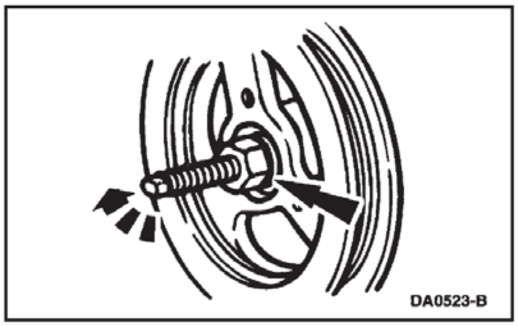


CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.

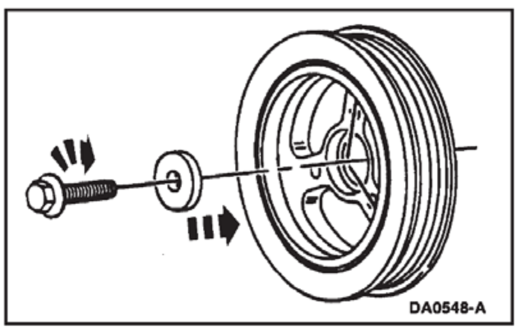
- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSE-M4G323-A6.

  NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSE-M5B292-A.



1. Use the Crankshaft Damper Replacer to install the crankshaft pulley.



2. Tighten the crankshaft pulley bolt in four stages.
- Stage 1: Tighten to 90 Nm (66 lb/ft).
- Stage 2: Loosen 360 degrees.
- Stage 3: Tighten to 47-53 Nm (35-39 lb/ft).
- Stage 4: Tighten an additional 85-95 degrees.

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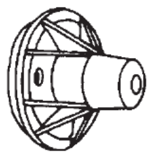
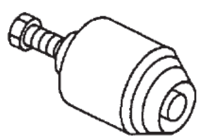
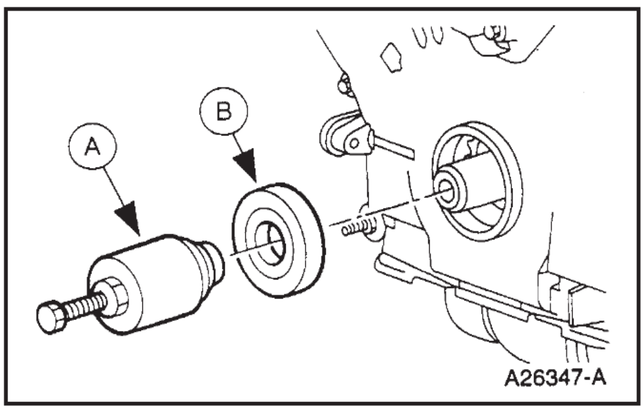
Crankshaft Front Oil Seal - Removal

Special Tool(s)

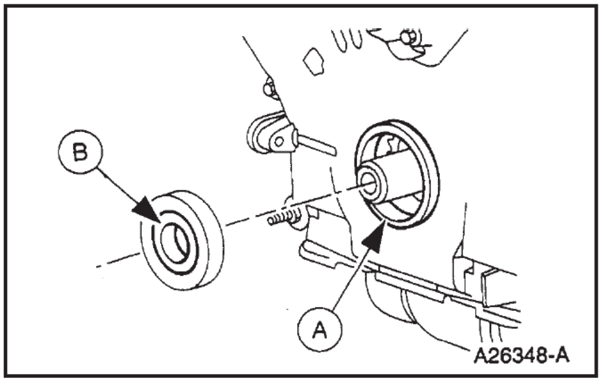
 ST1506-A	Crankshaft Rear Seal Replacer T88T-6701-B1
 ST1288-A	Front Cover Seal Remover 303-107 (T74P-6700-A)

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



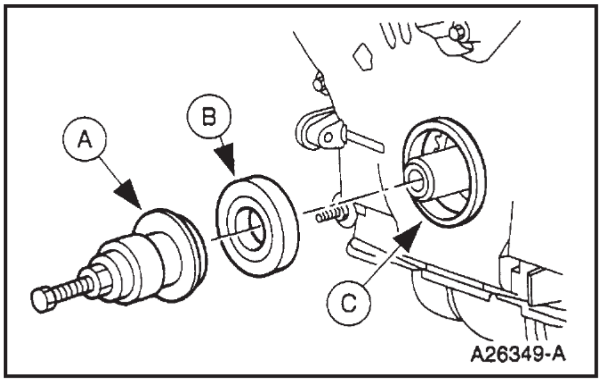
1. Remove the crankshaft pulley (6312); refer to this section.
2. Using the (a) Front Cover Seal Remover, remove the (B) crankshaft front seal (6700).

Crankshaft Front Oil Seal - Installation



1. Lubricate the (A) engine front cover (6019) and the (B) crankshaft front seal inner lip.

- Use Super Premium SAE 5W30 Motor Oil XO-5W30-QSP or equivalent meeting Ford specification WSS-M2C153-G.



2. Use the (A) Crankshaft Seal Replacer to install the (B) crankshaft front seal into the (C) engine front cover.

3. Install crankshaft pulley; refer to Crankshaft Pulley in this section.

Front Engine Cover - Removal

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

   Disconnect the battery ground cable (14301).

2. Remove the valve covers (6582); refer to Valve Cover in this section.

3. Remove the radiator (8005).

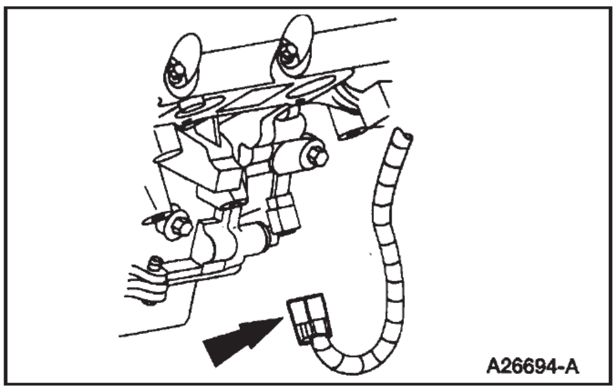
4. Disconnect the camshaft position sensor (CMP sensor) (6B288).

5. Remove the drive belt (8620).

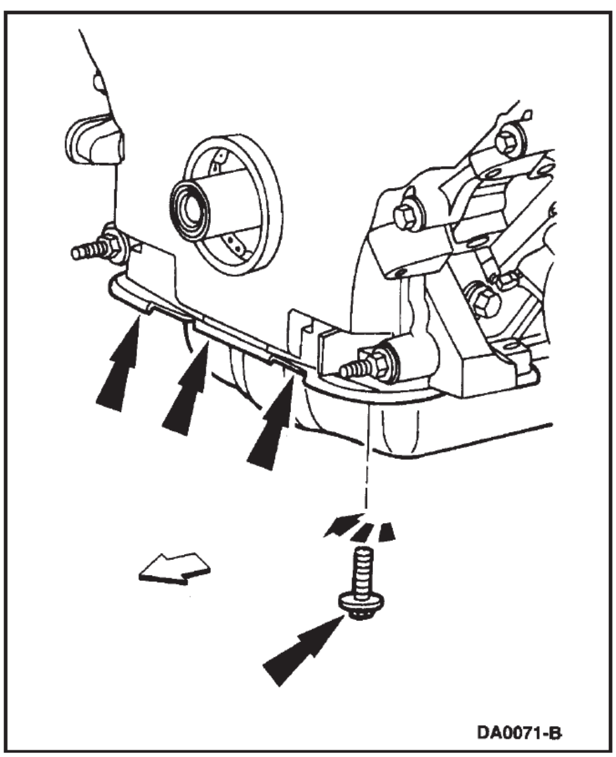
6. Disconnect the crankshaft position (CKP) sensor electrical connector.

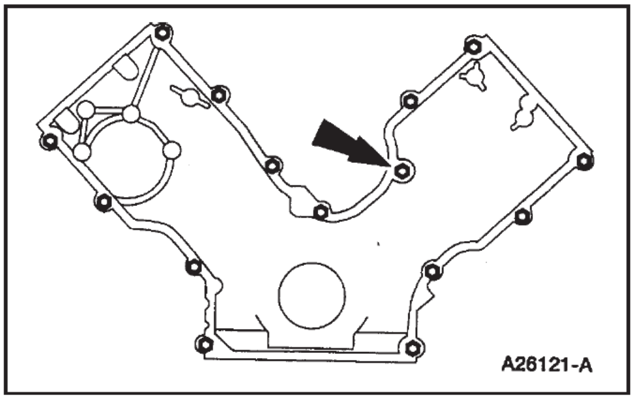
7. Remove the drain plug and drain the engine oil.

8. Remove the crankshaft front seal (6700); refer to Crankshaft Front Oil Seal in this section.

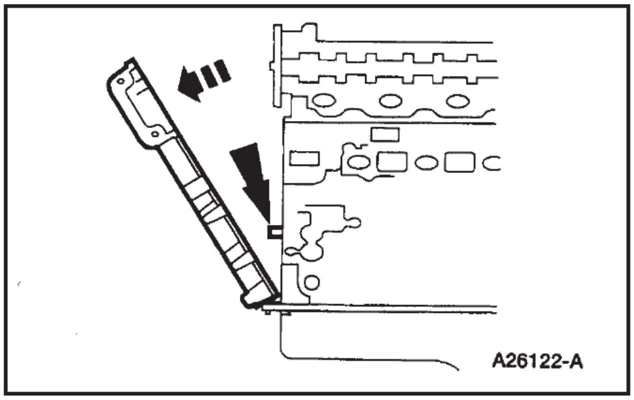


9. Remove the bolts from the front of the oil pan that hold the front cover.



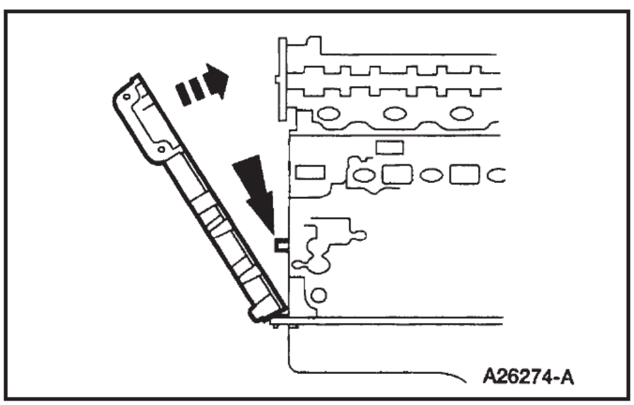


10. Remove the engine front cover fasteners.



11. Remove the engine front cover (6019) from the front cover to cylinder block dowels (6C002).

Front Engine Cover - Installation



1. Install a new engine front cover gasket (6020) on the engine front cover, then position the engine front cover on the front cover to cylinder block dowels.

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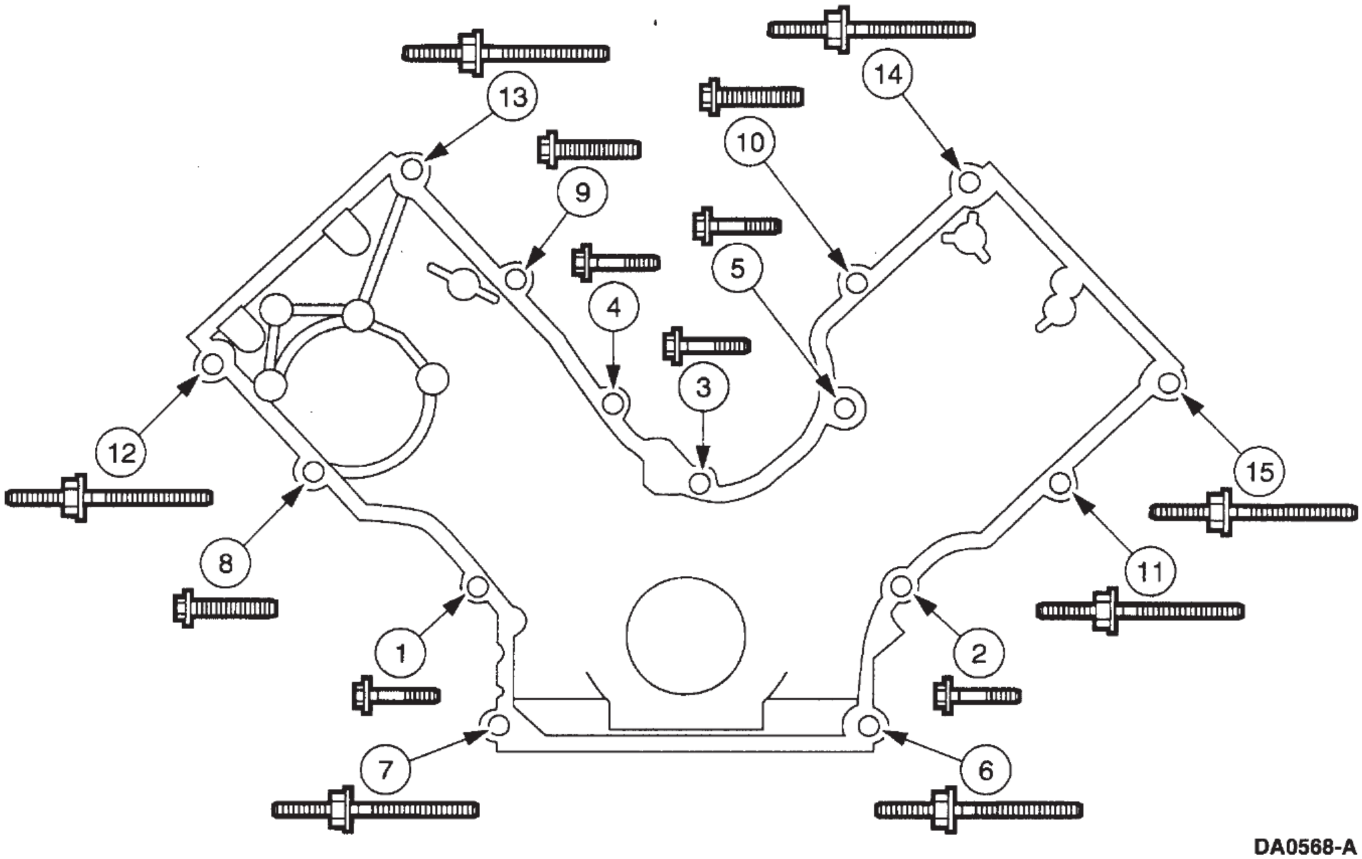
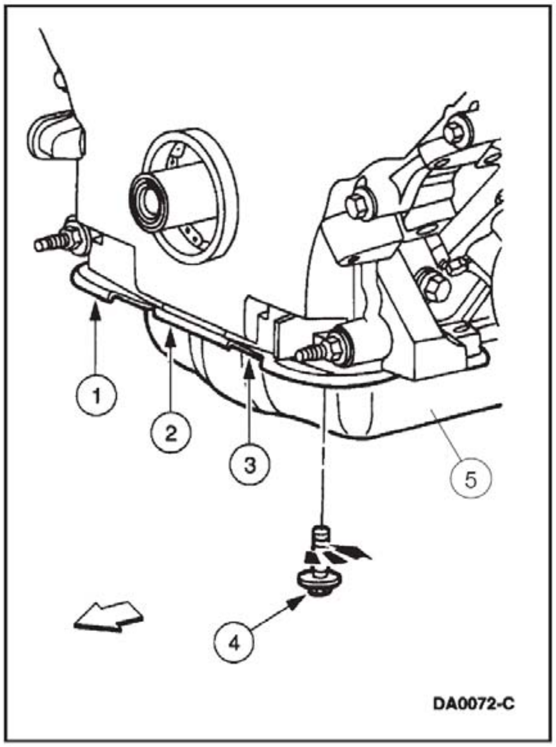


Item	Part Number	Description
1	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
2	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
3	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
4	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
5	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
6	N808529	Stud, Hex-Head Pilot, M10 x 1.5 x 1.5 x 103.1
7	N808529	Stud, Hex-Head Pilot, M10 x 1.5 x 1.5 x 103.1
8	N808142	Screw and Washer, Hex Pilot, M10 x 1.5 x 57.5

Item	Part Number	Description
9	N808142	Screw and Washer, Hex Pilot, M10 x 1.5 x 57.5
10	N808142	Screw and Washer, Hex Pilot, M10 x 1.5 x 57.5
11	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
12	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
13	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
14	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
15	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6

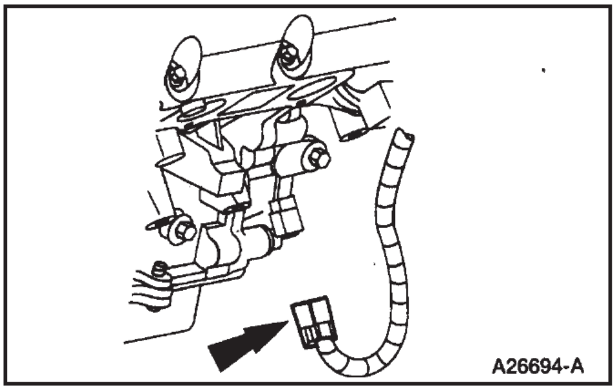


2. Tighten the fasteners in two stages following the sequence shown.

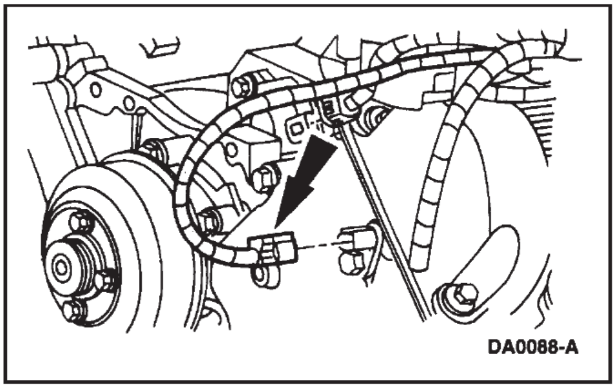
- Stage 1: Tighten fasteners 1 through 5 to 20-30 Nm (15-22 lb/ft).
- Stage 2: Tighten fasteners 6 through 15 to 40-55 Nm (30-41 lb/ft).

3. **NOTE:** Be sure to tighten the bolts through the front of the oil pan 5 in two stages.

- Stage 1: Tighten to 20 Nm (15 lb/ft).
- Stage 2: Tighten an additional 60 degrees.



4. Connect the CKP sensor electrical connector.
5. Install the water pump pulley.

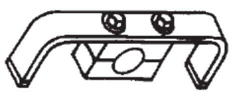


6. Connect the CMP electrical connector.
7. Install a new crankshaft front seal and the crankshaft pulley (6312); refer to Crankshaft Pulley in this section.
8. Install the drive belt (8620).
9. Install the valve covers; refer to Valve Cover in this section.
10. Fill the engine (6007) with oil.

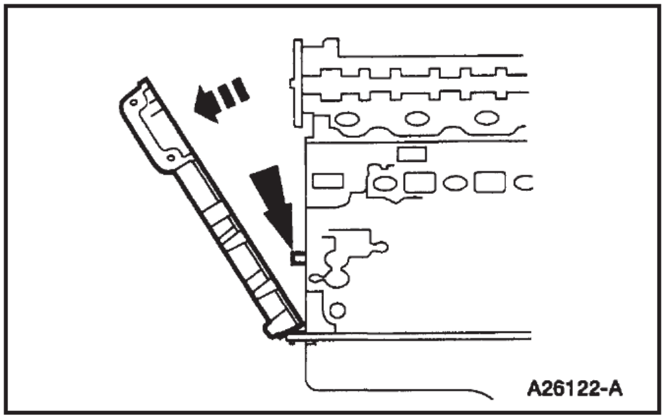
- Use engine oil meeting Ford specification D9AZ-19579A.

Timing Drive Components - Removal

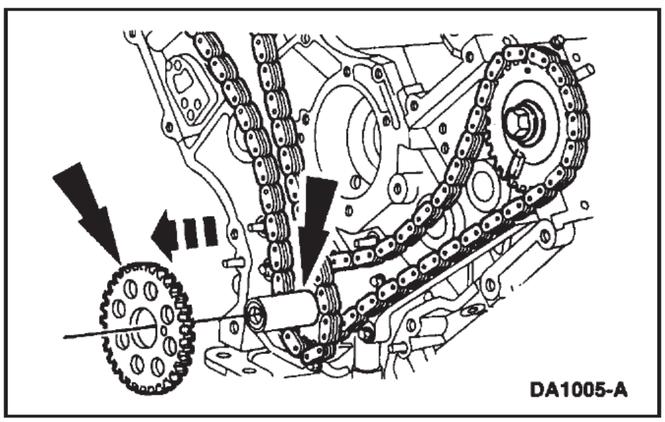
Special Tool(s)

	Camshaft Holding Tool 303-557 (T96T-6256-B) (2 Req'd)

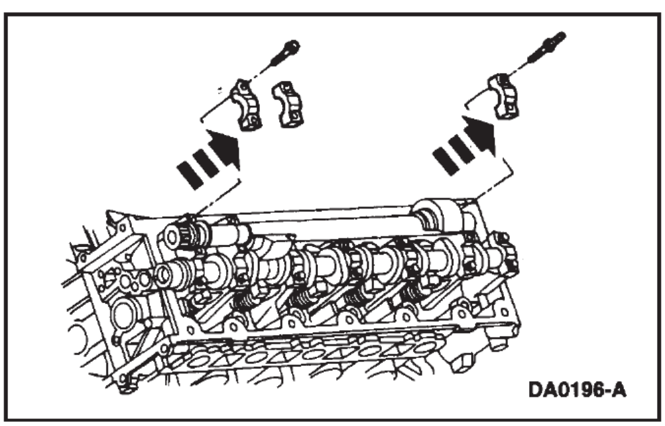
Special Service Tools called for by the procedures can be obtained by calling:
1-800-ROTUNDA (1-800-768-8632).



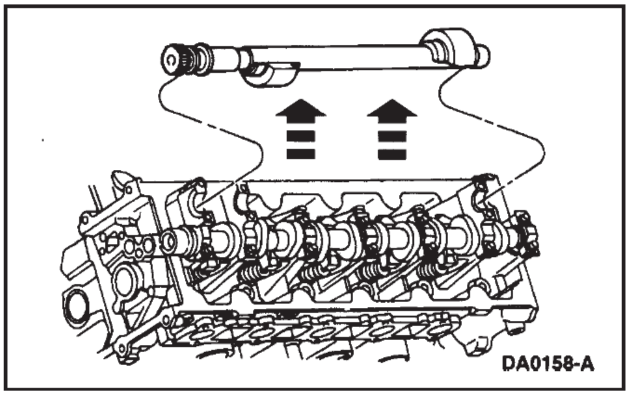
1. Remove the engine front cover (6019); refer to Engine Front Cover in this section.



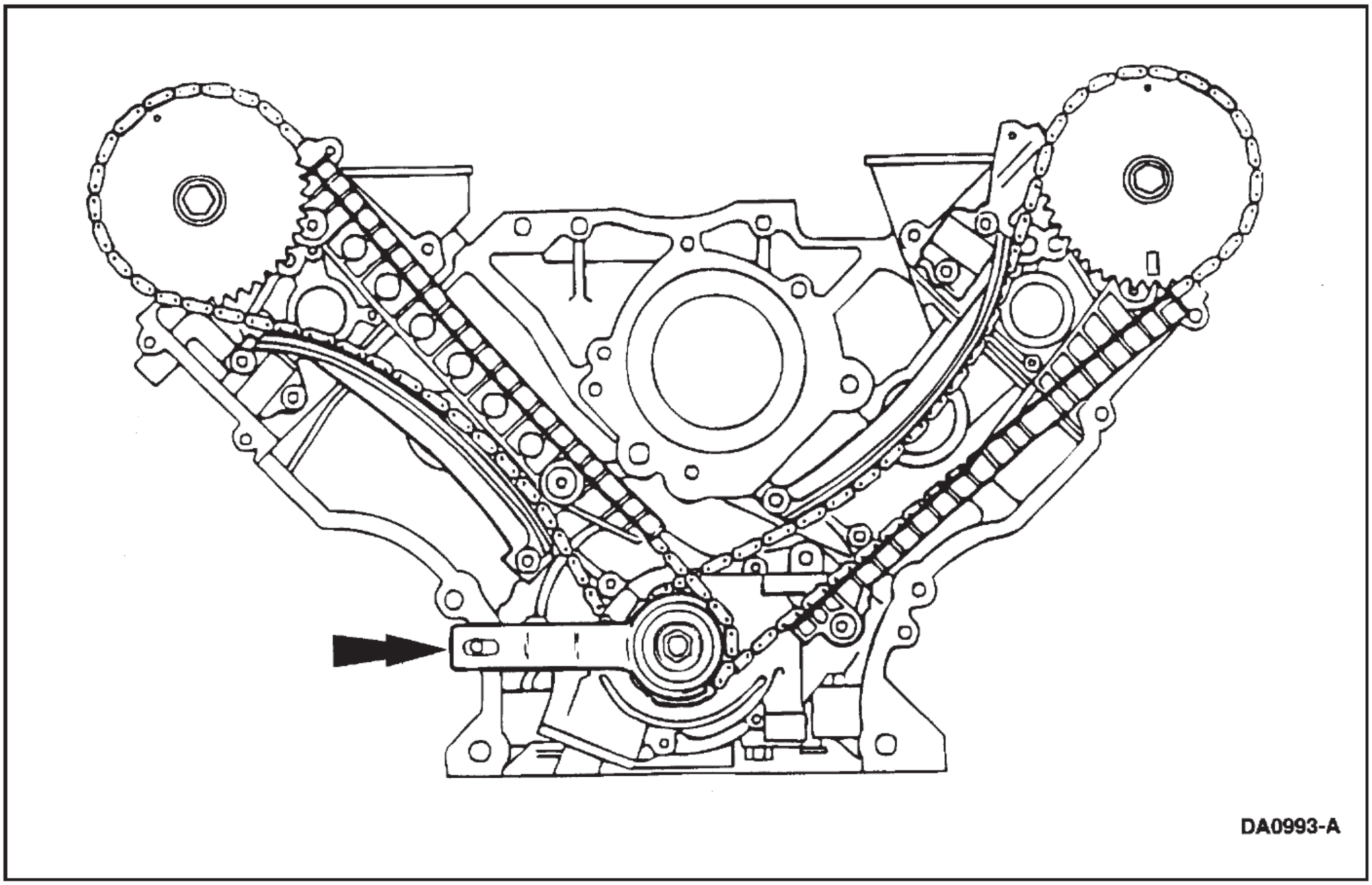
2. Remove the crankshaft sensor ring from the crankshaft (6303).



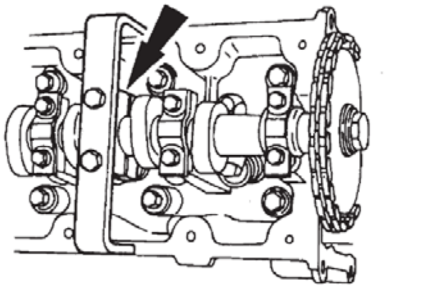
3. Remove the six bolts and remove the balance shaft bearing caps.



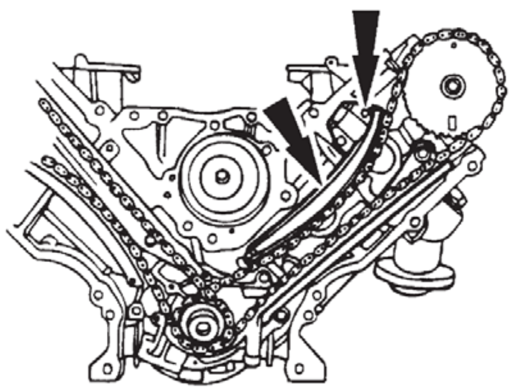
4. Remove the balance shaft.



5. **CAUTION: Unless otherwise instructed, at no time when the timing chains (6268) are removed and the cylinder heads (6049) are installed may the crankshaft or camshaft (6250) be rotated. Severe piston (6108) and valve damage could occur.**
Use the Crankshaft Holding Tool to position the crankshaft as shown.


DA1006-A

6. Install the Camshaft Holding Tools on the camshafts.


DA1000-A

7. Remove the bolts and the timing chain tensioners (6L266). Remove the timing chain tensioner arms (6L253) from the dowel pins.

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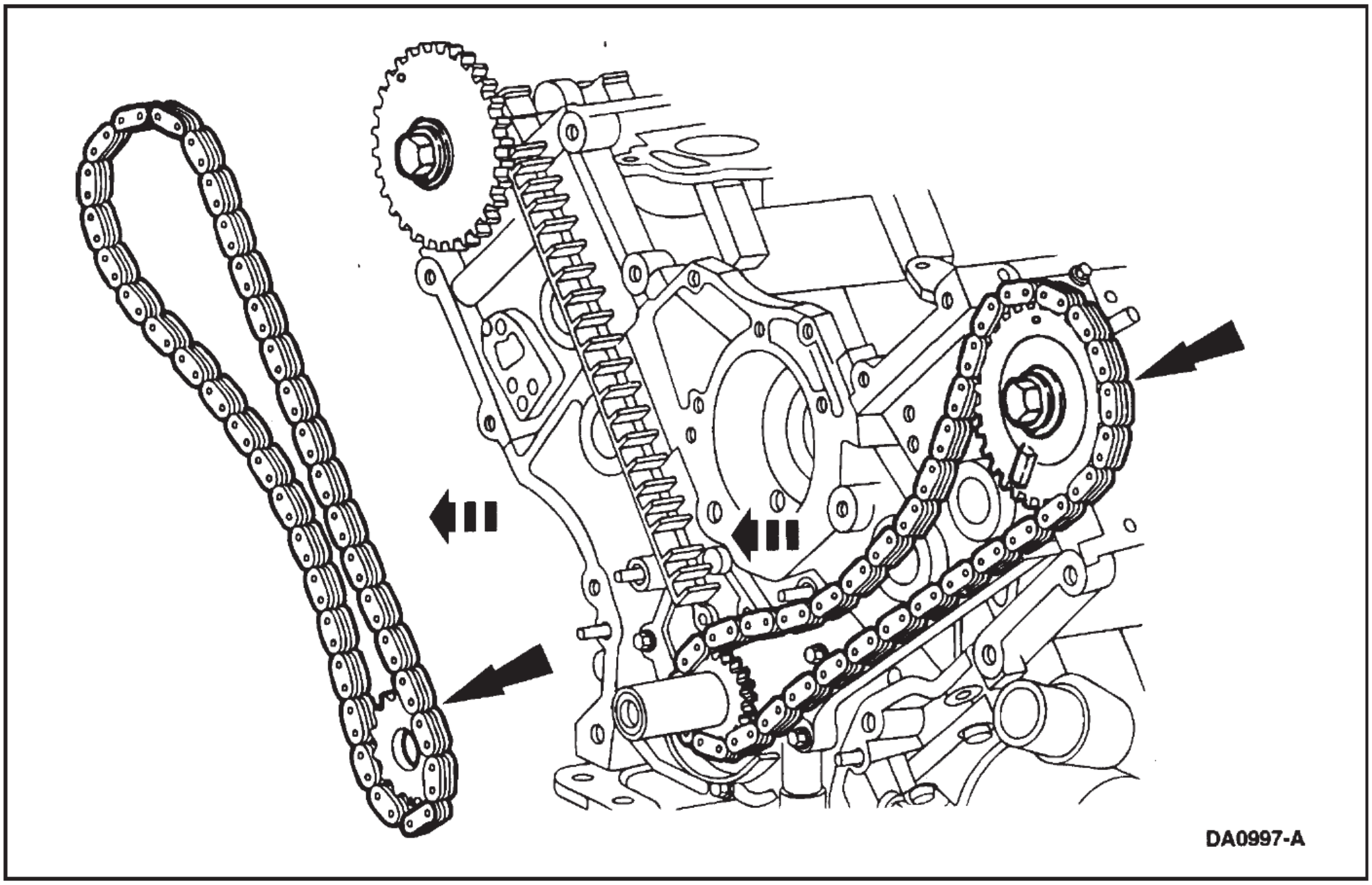
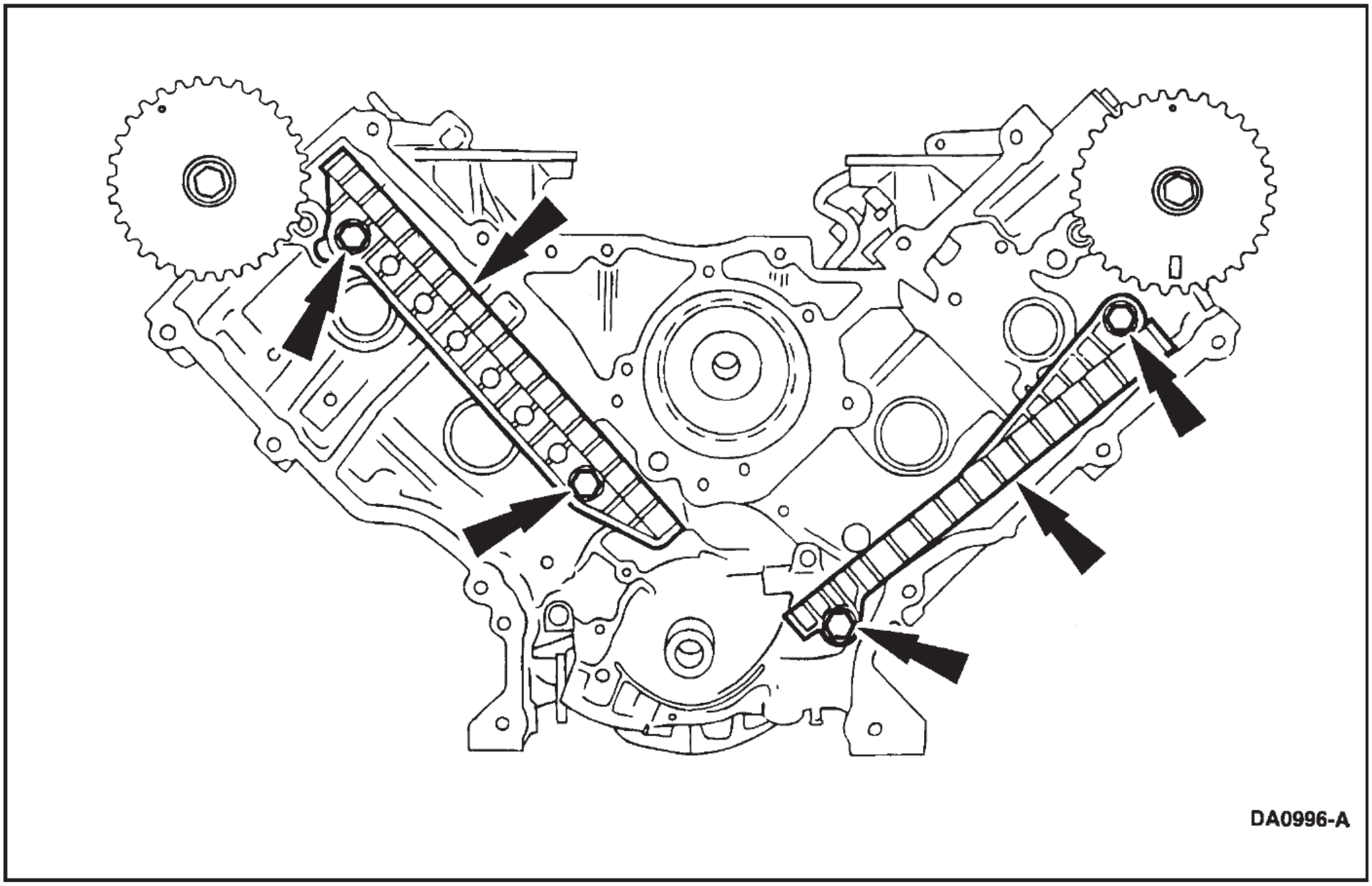


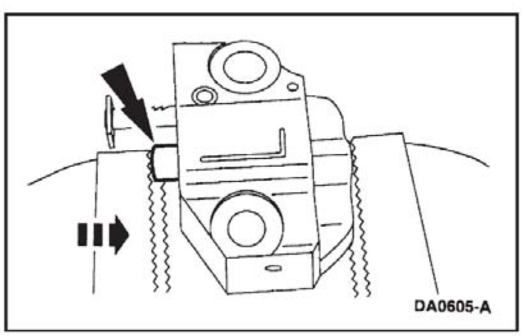
8. Remove the LH and RH timing chain and the crankshaft sprockets (6306).

1. Remove the RH timing chain from the camshaft sprocket (6256).
2. Remove the RH timing chain and outer crankshaft sprocket from the crankshaft.
3. Repeat for the LH timing chain and crankshaft sprocket.



9. Remove the timing chain guides (6K297).
- Remove the bolts.
- Remove the timing chain guides.

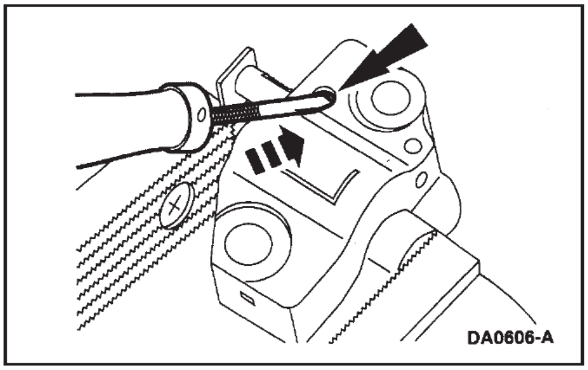
Timing Drive Components - Installation



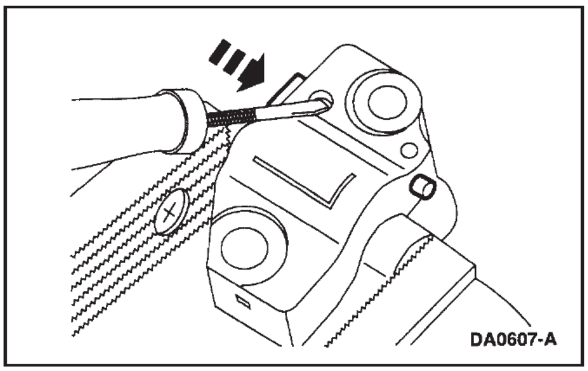
1. **CAUTION: Timing chain procedures must be followed exactly or damage to valves and pistons will result.**

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

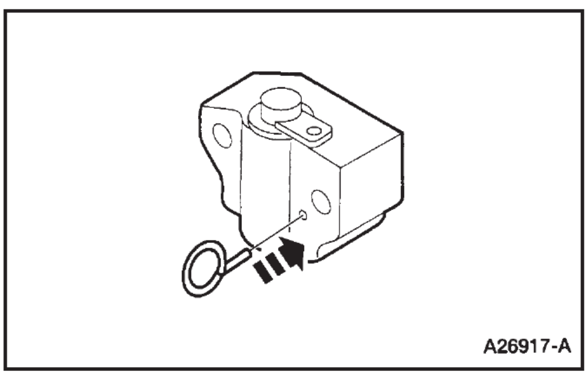
   Compress the tensioner plunger, using an edge of a vise.



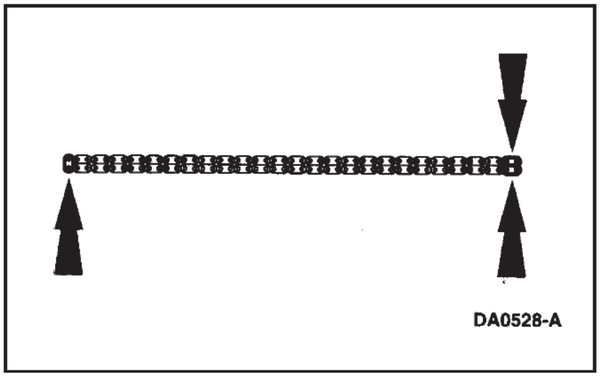
2. Using a small screwdriver or pick, push back and hold the ratchet mechanism.



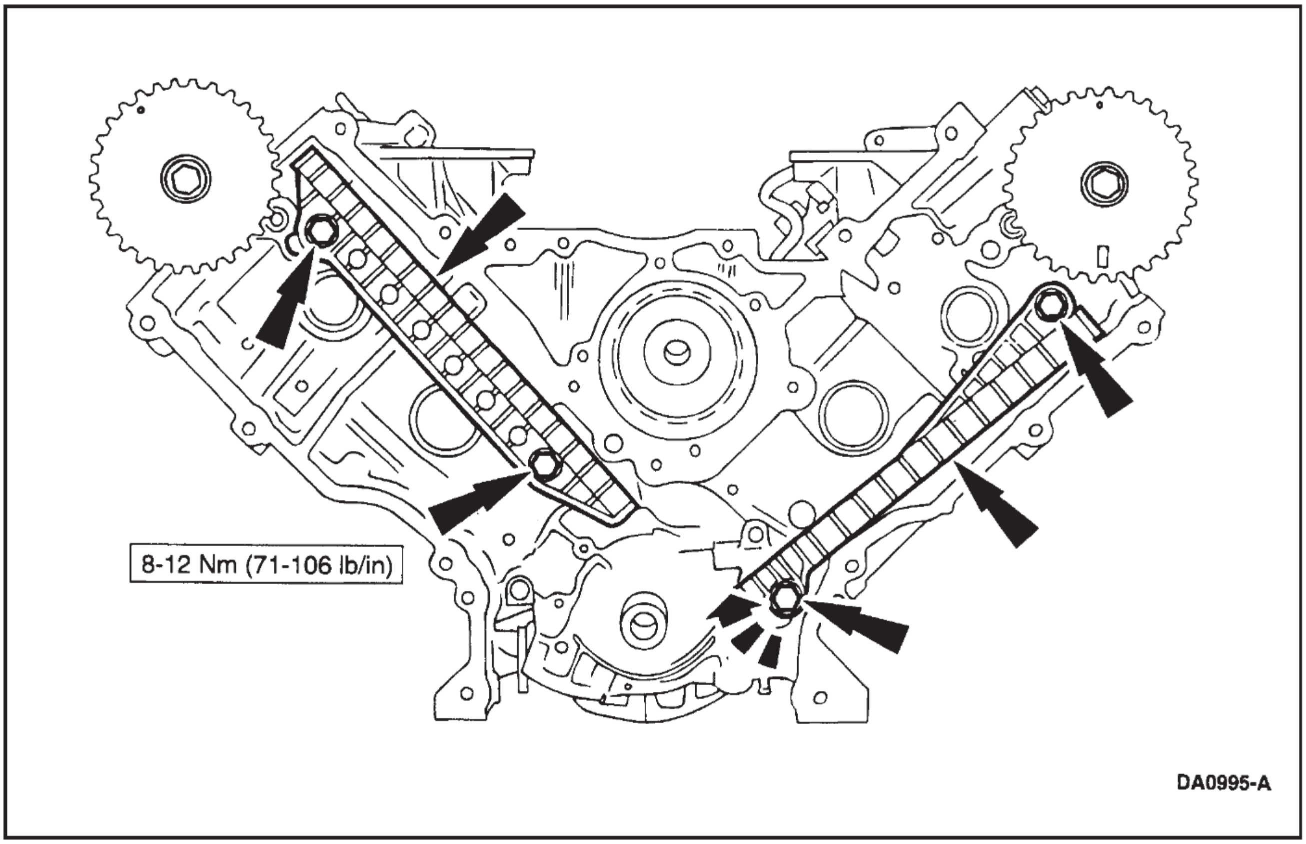
3. While holding the ratchet mechanism, push the ratchet arm back into the tensioner housing.



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

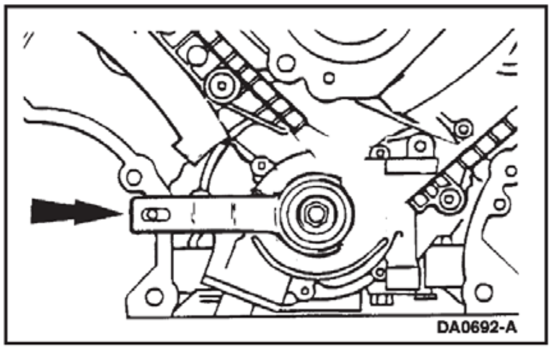


5. If copper links are not visible, mark two links on one end and one link on the other end, and use as timing marks.

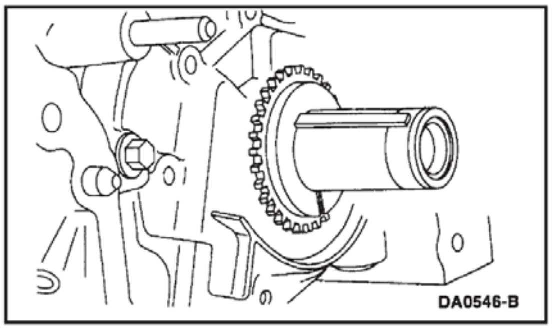


6. Install the timing chain guides.

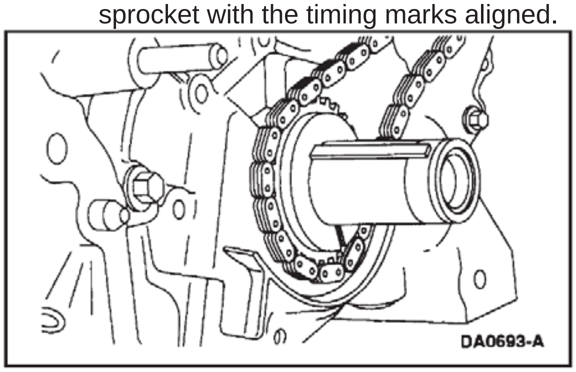
7. Remove the Crankshaft Holding Tool



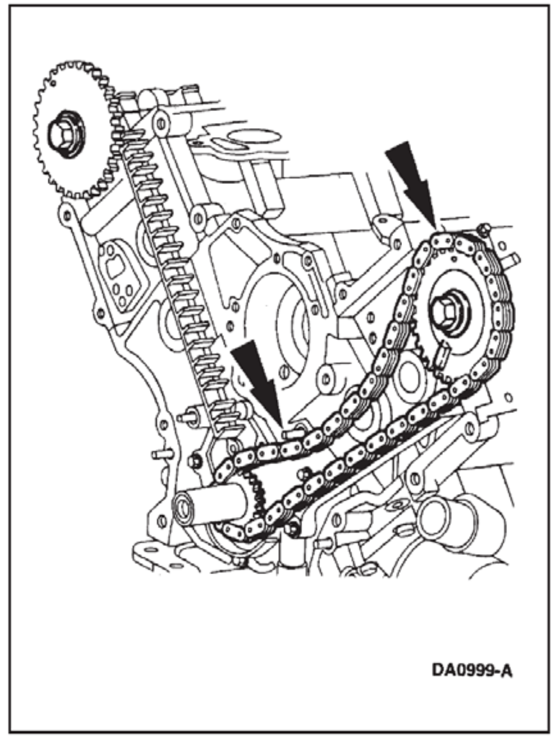
8. Install the inner crankshaft sprocket with the long hub facing outward.

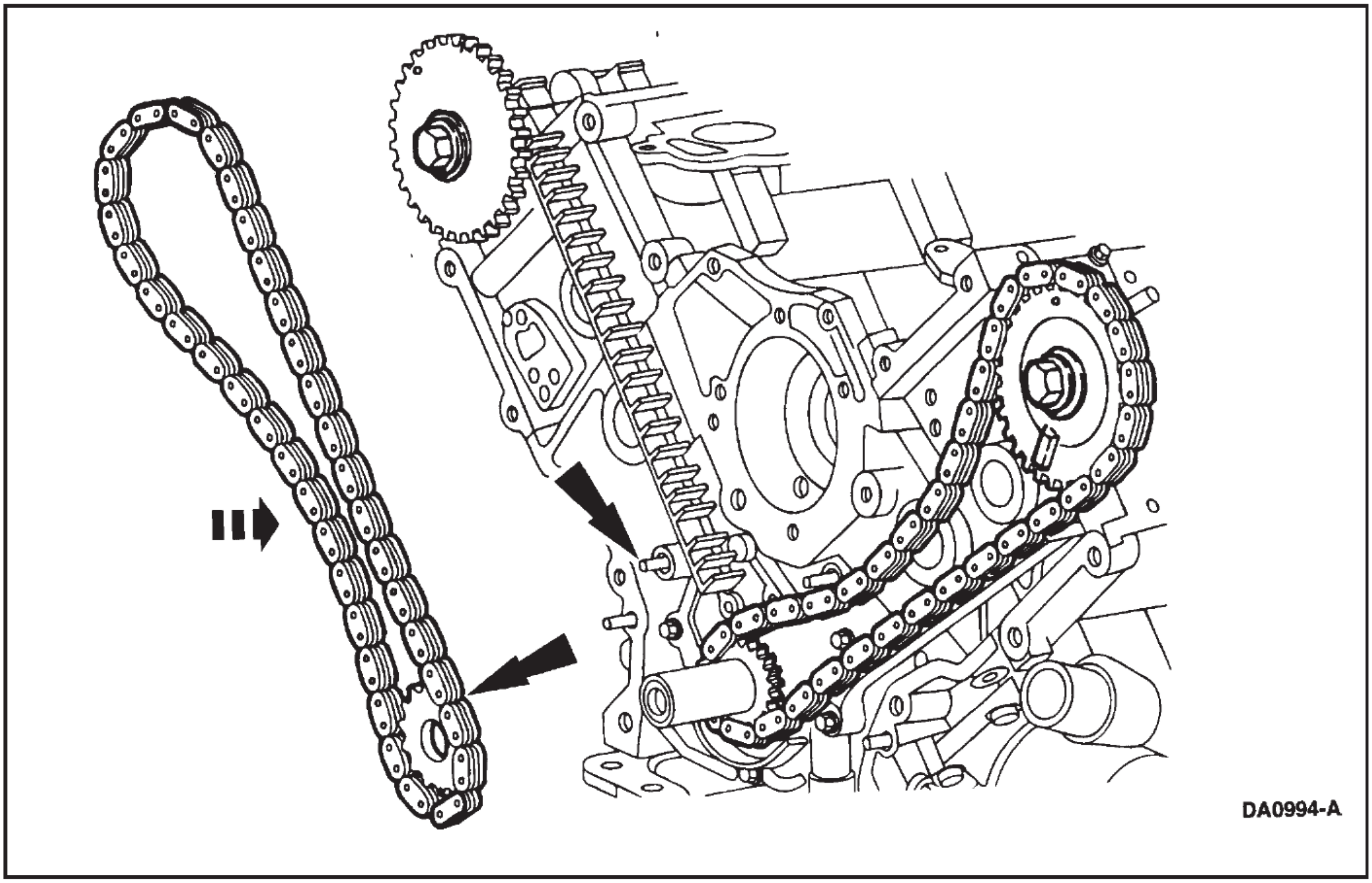


9. Install the inner timing chain on the crankshaft sprocket with the timing marks aligned.



10. **NOTE:** Be sure the upper half of the timing chain is below the tensioner





11. ⚠ **CAUTION: The camshaft sprocket can jump time if the Camshaft Holding Tool is not secured.**

    NOTE: Be sure the chain link and crankshaft sprocket timing marks are aligned.

    NOTE: The lower half of the timing chain must be positioned above the dowel.

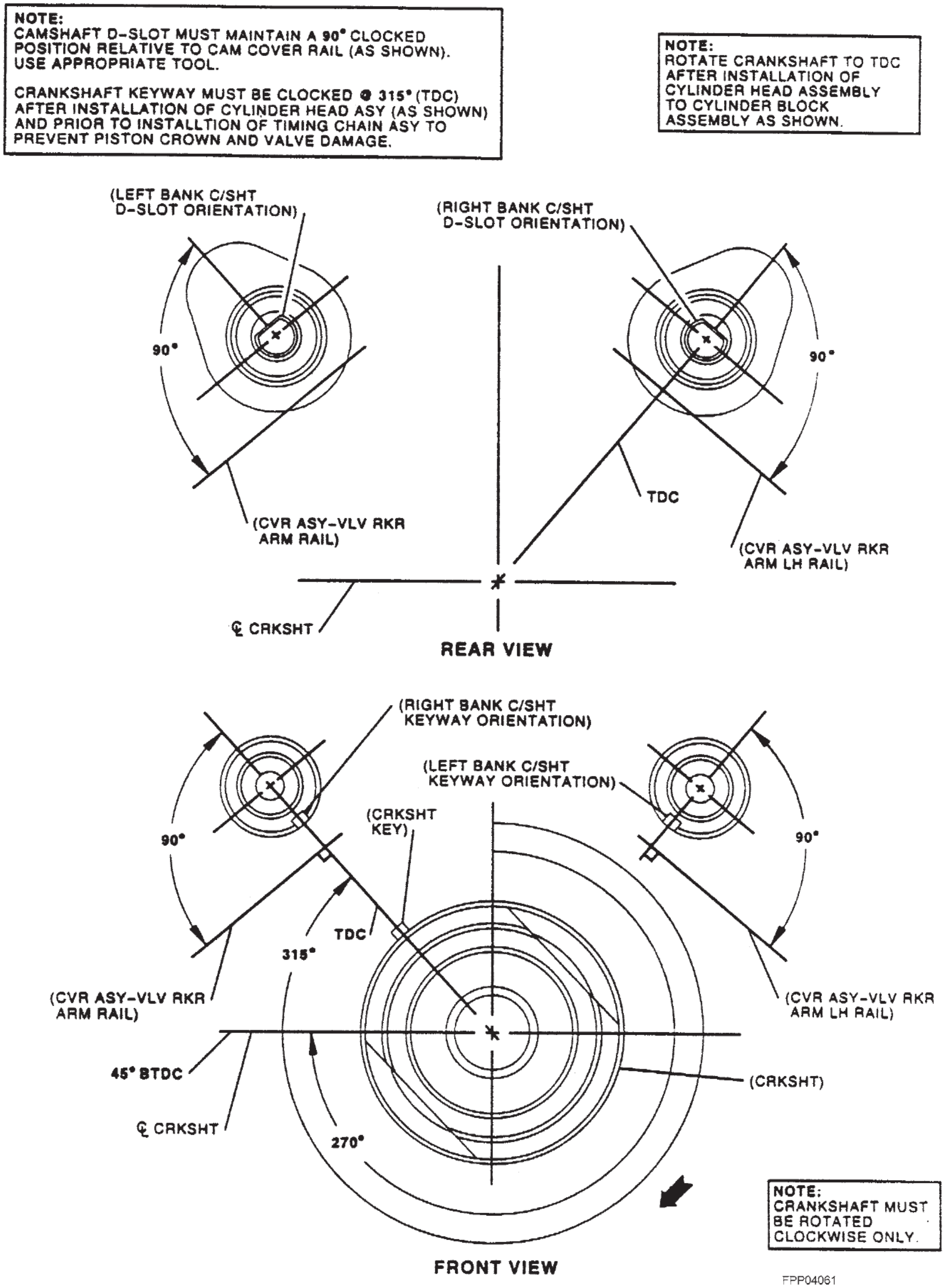
    Install the outer crankshaft sprocket and timing chain belt with the long hub of the crankshaft sprocket facing inward.

12. Position the timing chain on the camshaft sprocket. Make sure the two copper-colored links align with the camshaft sprocket timing mark.

13. Check for proper alignment of all timing marks.

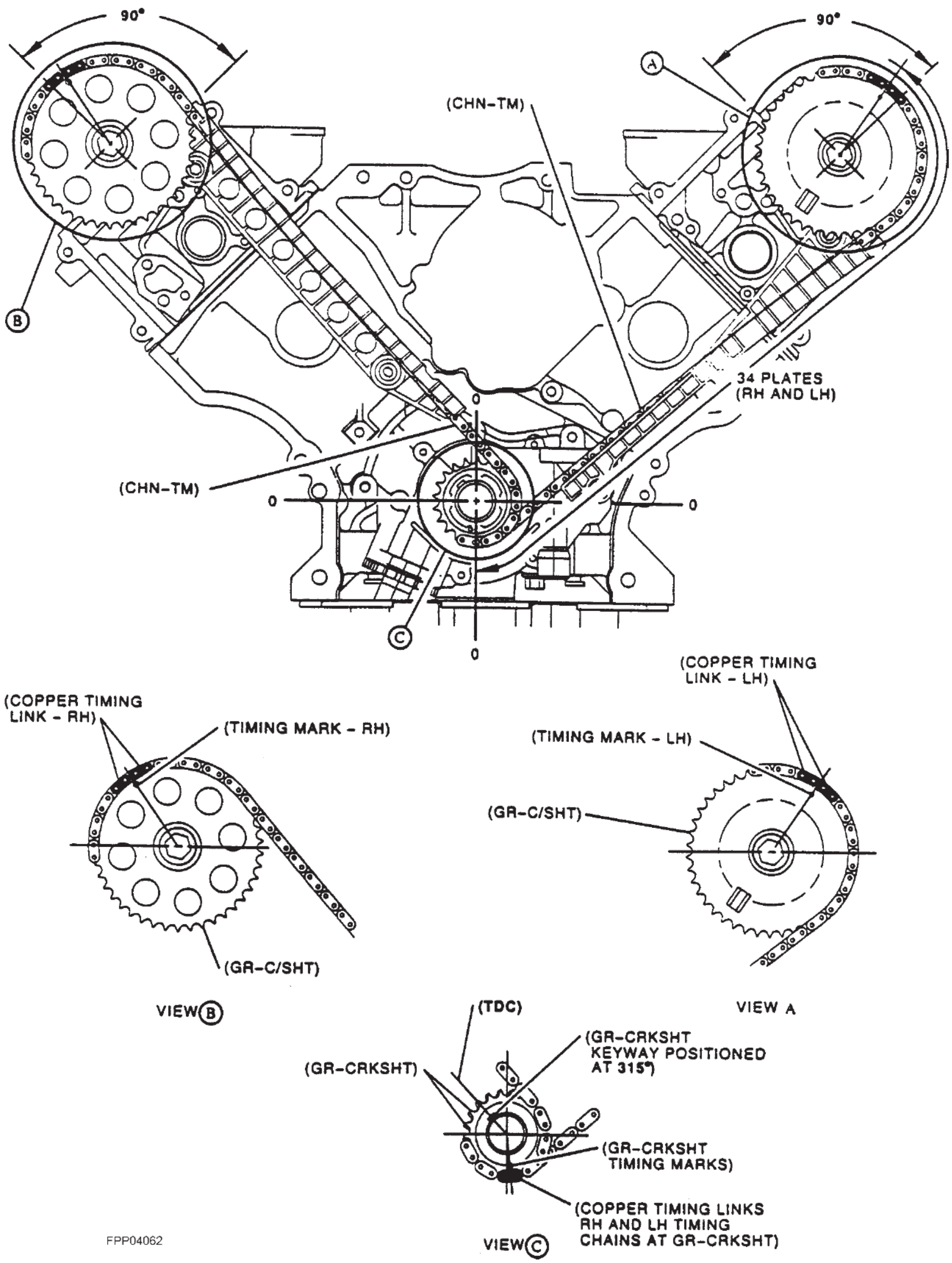
WSG-1068 ENGINE

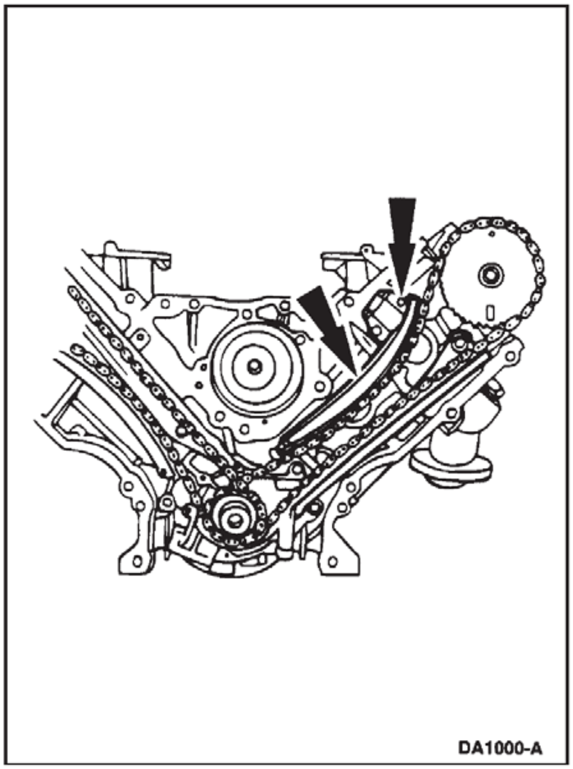
Camshaft Assembly Timing Mark Alignment



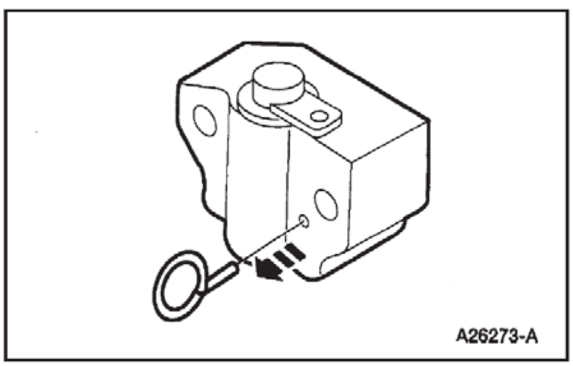
WSG-1068 ENGINE

Timing Chains, Camshaft Gears and Crankshaft Gears Alignment

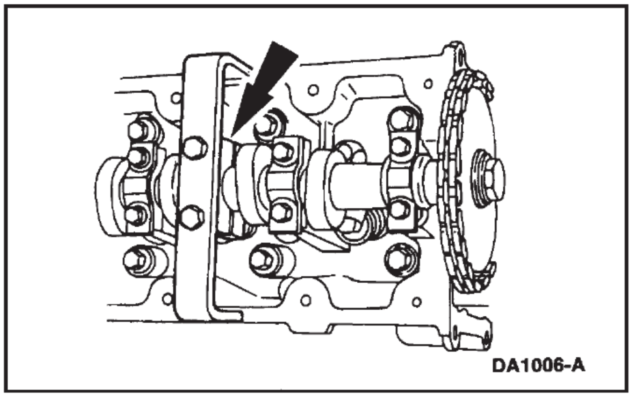




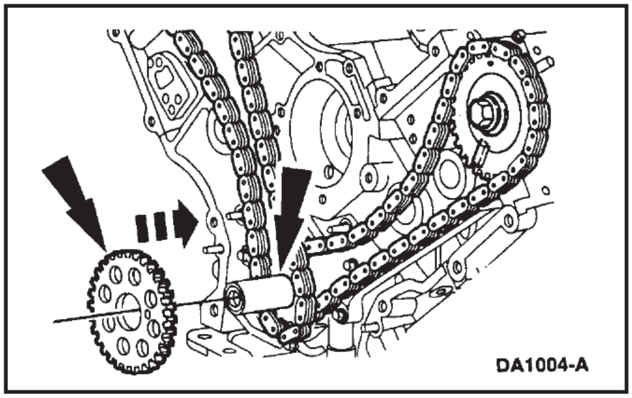
14. Position the LH and RH timing chain tensioner arms on the dowel pins. Position the timing chain tensioners and install the bolts.



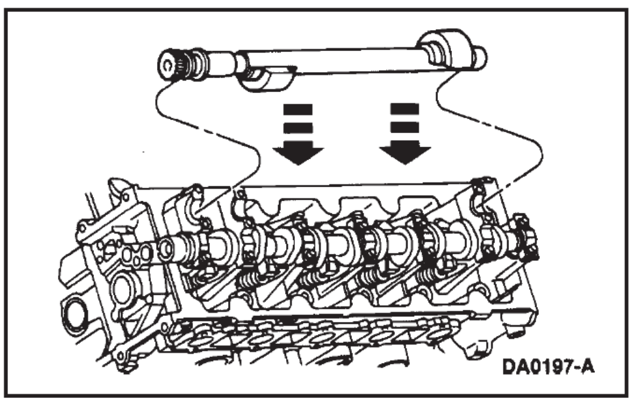
15. Remove the retaining pins from the RH and LH timing chain tensioners.



16. Remove the Camshaft Holding Tools from the camshafts.

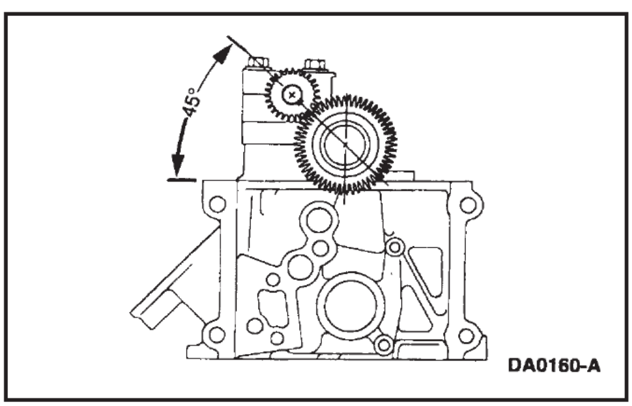


17. Install the crankshaft sensor ring on the crankshaft.

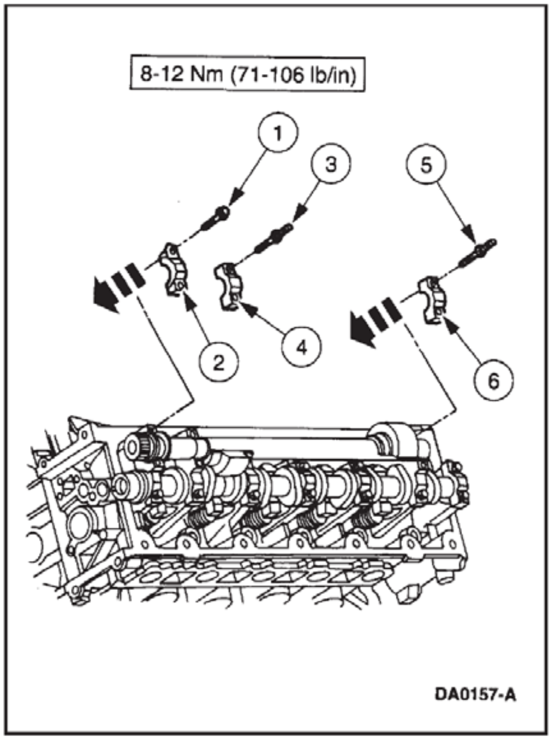


18. Lubricate the balance shaft journals with engine oil.
    - Use Super Premium SAE 5W30 Motor Oil XO-5W30-QSP or equivalent meeting Ford specification WSS-M2C153-G.

19. Position the balance shaft on the journals.

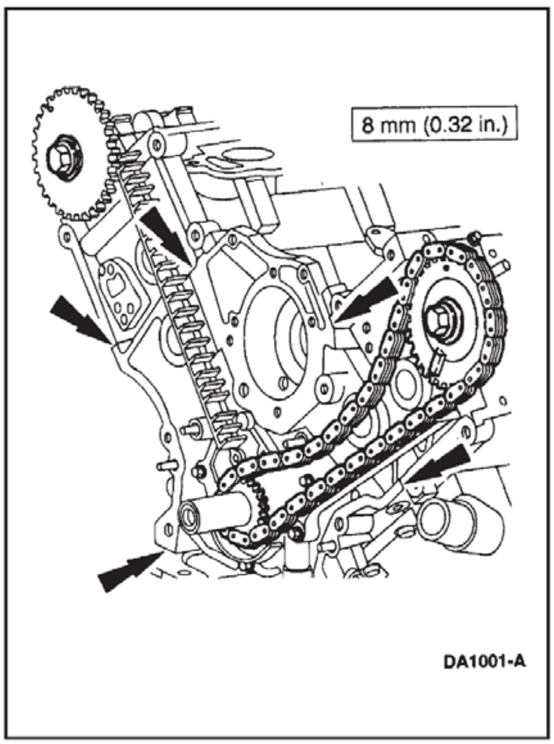


20. Align the balance shaft timing marks as shown.



21. Lubricate the bearing caps with engine oil.
    - Use Super Premium SAE 5W30 Motor Oil XO- 5W30-QSP or equivalent meeting Ford specification WSS-M2C153-G.

22. Install the bearing caps, the bolts and tighten the bolts in the sequence shown.



23. **NOTE:** The timing chain is removed for clarity.

CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSE-M4G323-A6.

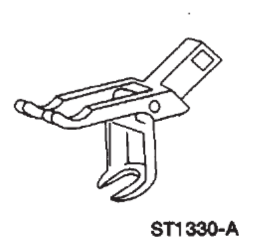
NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSE-M5B292-A.

24. Install engine front cover; refer to Engine Front Cover in this section.

Camshaft - Removal

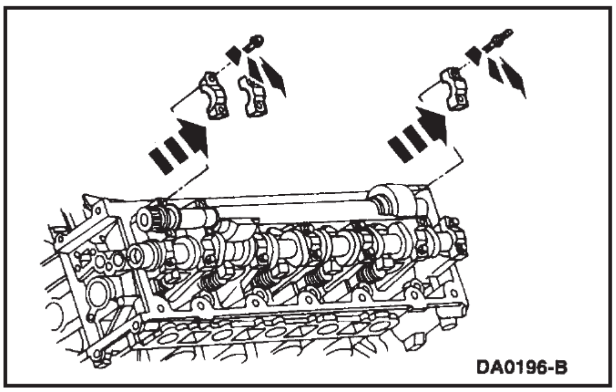
Special Tool(s)

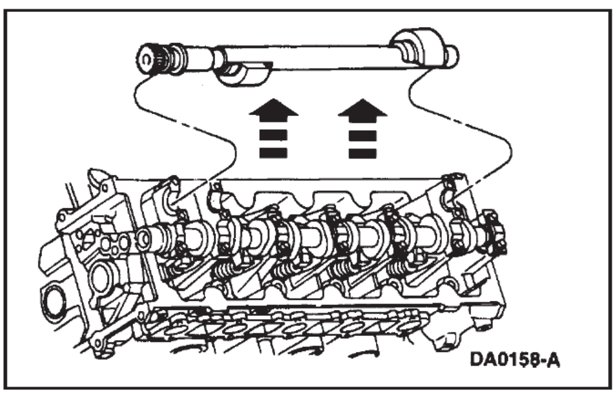


Valve Spring Compressor
303-381 (T91P-6565-A)

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

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

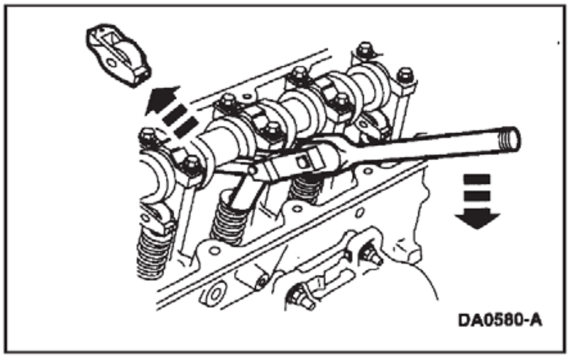




1. Disconnect the battery ground cable (14301).
2. Remove the intake manifold (9424); refer to Intake Manifold – Variable Resonance Induction System (VRIS) in this section.
3. Remove the timing chains (6268); refer to Timing Drive Components in this section.

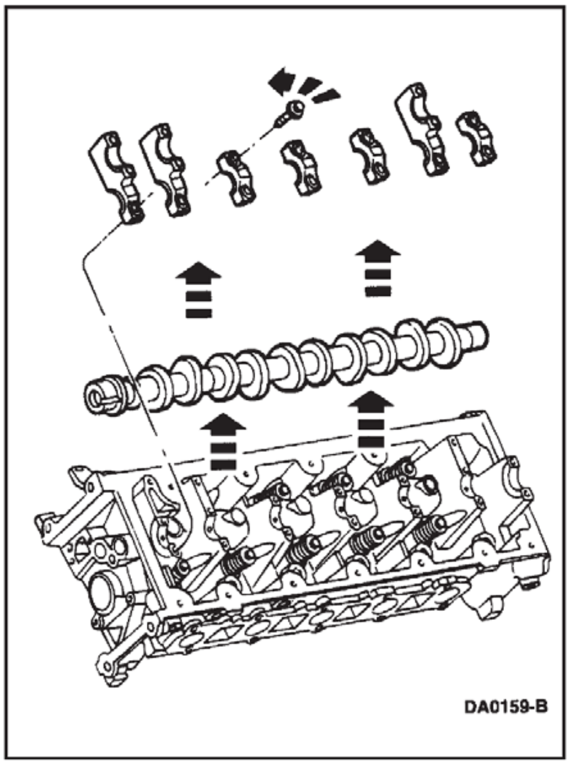
CAUTION: The caps must be marked for installation in their original location or damage to the engine may occur.

4. Remove the six bolts retaining the balance shaft bearing caps and remove the bearing caps.
5. Remove the balance shaft.



6. Use the Valve Spring Compressor to compress the valve springs (6513) and remove the camshaft roller followers.

CAUTION: The caps must be marked for installation in their original location or damage to the engine may occur.

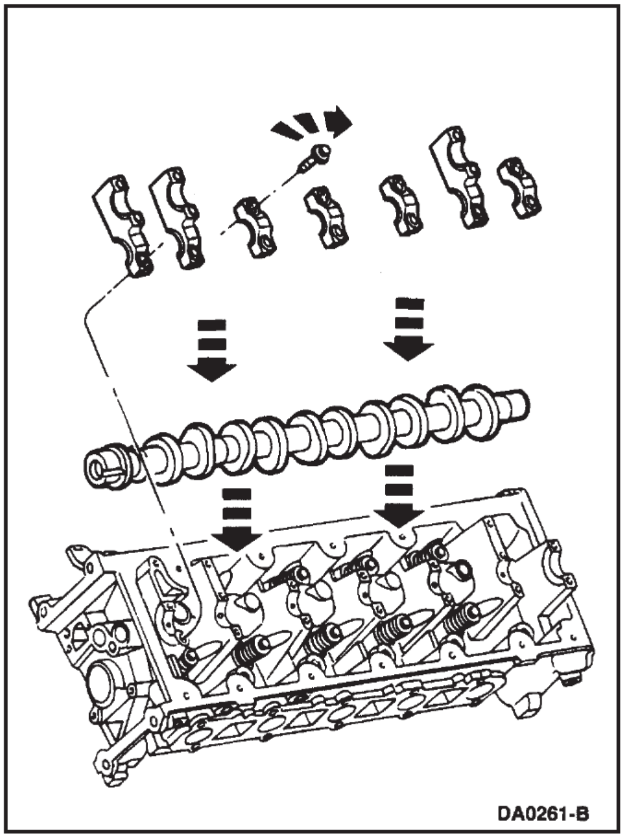


7. Remove the bolts, the camshaft bearing caps (6B280) and the camshaft (6250) from the cylinder block (6010).

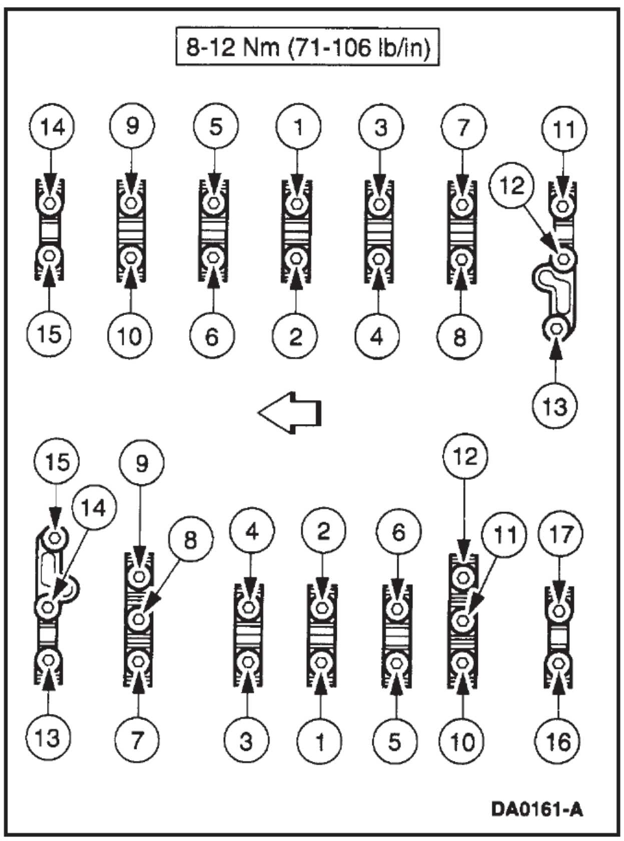
Camshaft - Installation

1. Lubricate the camshaft journals and bearing caps.

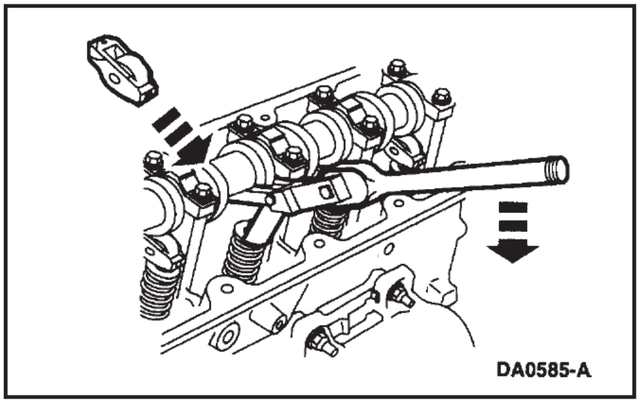
- Use Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-G.



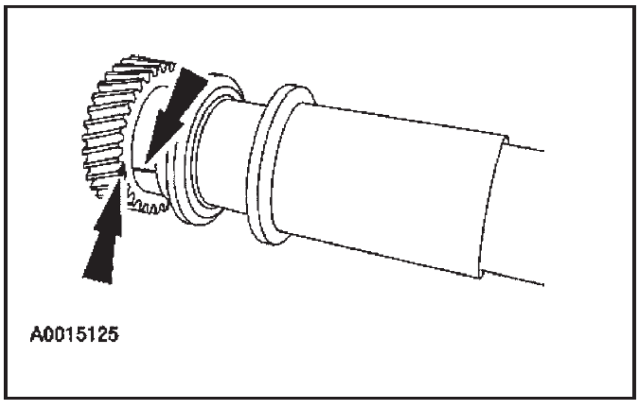
2. Install the bearing caps in their original locations and the bolts.



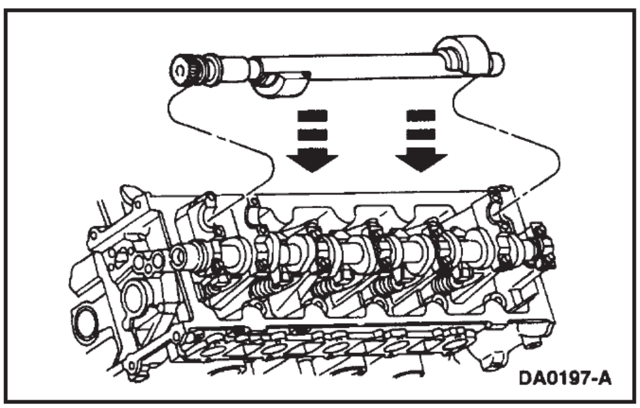
3. Tighten the bolts in the sequence shown.



4. Use the Valve Spring Compressor to compress the valve springs and install the camshaft roller followers.

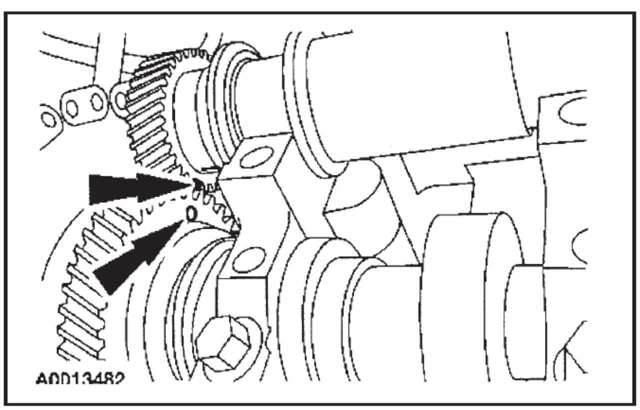


5. Lubricate the balance shaft journals with engine oil.
   - Use Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-G.

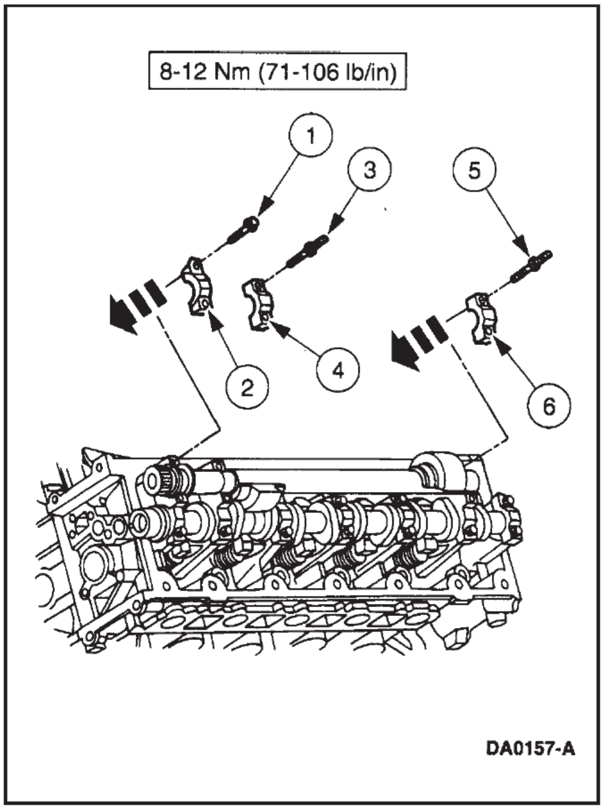


6. Using the index mark on the balance shaft, mark the corresponding teeth on the gear with chalk.

7. Position the balance shaft on the journals.



8. Align the balance shaft timing marks as shown. Align the chalk mark on the balance shaft with the camshaft timing mark as shown.



9. Lubricate the balance shaft journals with engine oil.

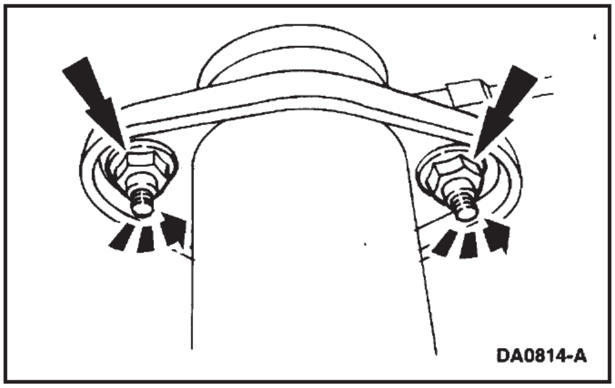
- Use Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-G.

10. Position the bearing caps in their original locations and the bolts. Tighten the bolts in the sequence shown.

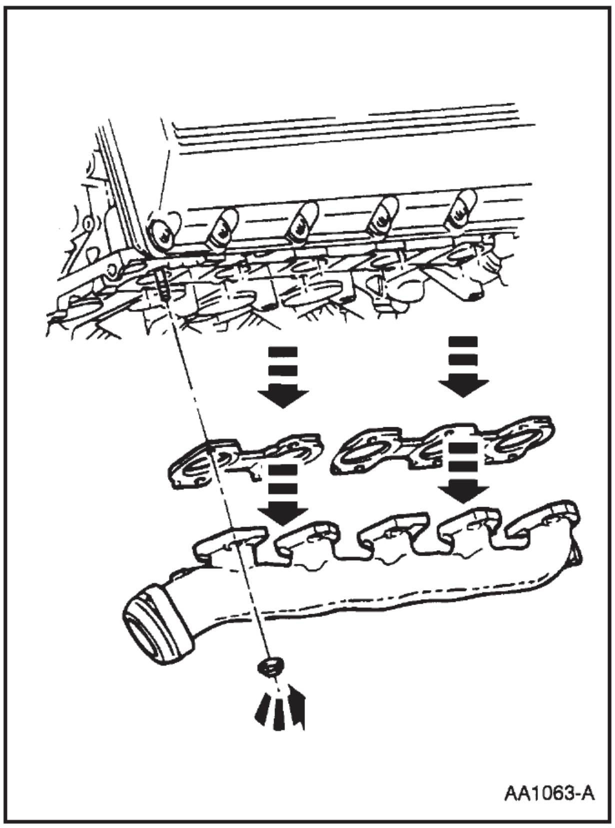
11. Install the intake manifold; refer to Intake Manifold – Variable Resonance Induction System (VRIS) in this section.

12. Install the timing chains; refer to Timing Drive Components in this section.

Exhaust Manifold – RH - Removal



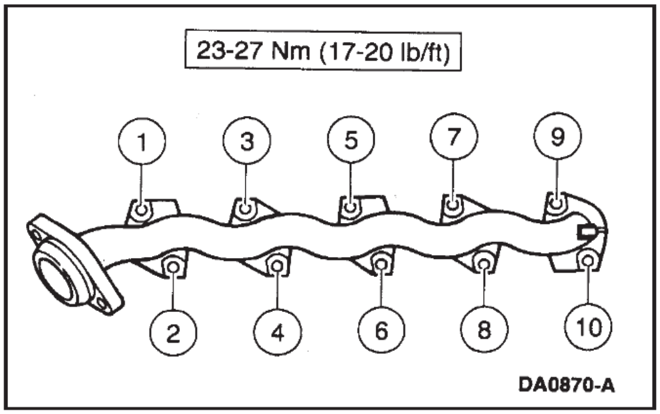
1. Remove the nuts from exhaust pipe and remove exhaust pipe.

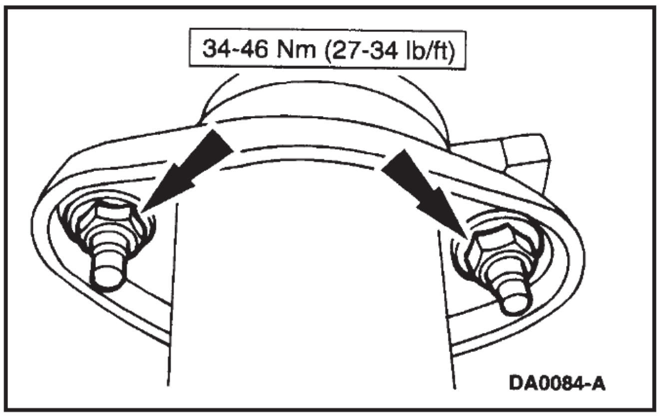


2. Remove the ten nuts and the exhaust manifold (9430) and exhaust manifold gasket (9448). Discard the exhaust manifold gasket.

3. Clean and inspect the exhaust manifold; refer to Section 01.

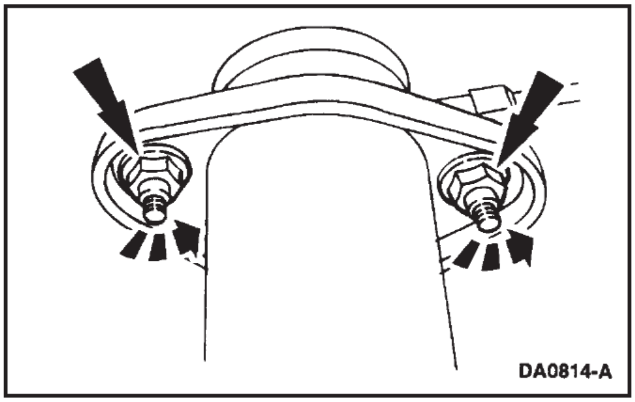
Exhaust Manifold - RH - Installation



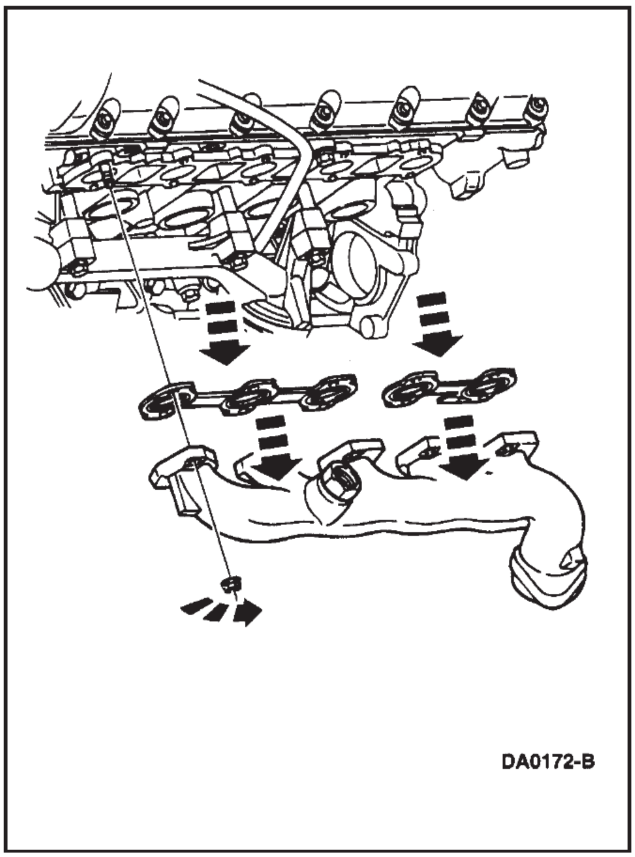


1. Follow the removal procedure in reverse order.

Exhaust Manifold – LH - Removal



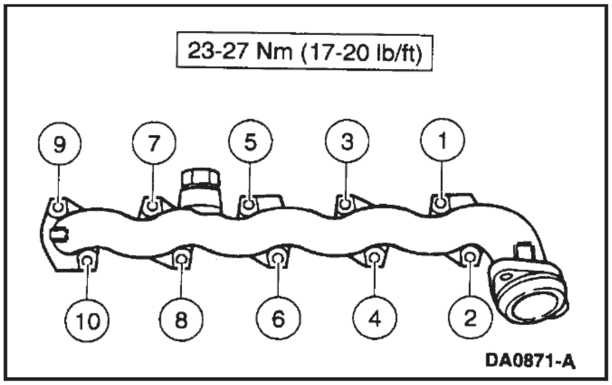
1. Remove the nuts from the exhaust pipe and remove pipe.

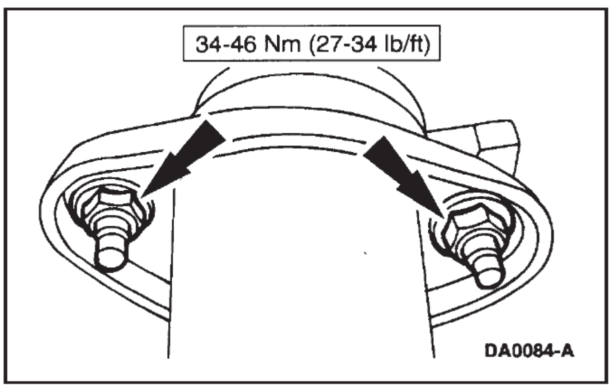


2. Remove the exhaust manifold nuts and the exhaust manifold (9430). Discard the exhaust manifold gaskets (9448).

3. Clean and inspect the exhaust manifold; refer to Section 01.

Exhaust Manifold – LH - Installation

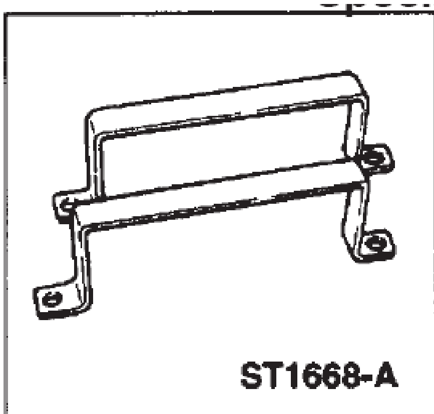




1. Follow the removal procedure in reverse order.

Cylinder Head - Removal

Special Tool(s)

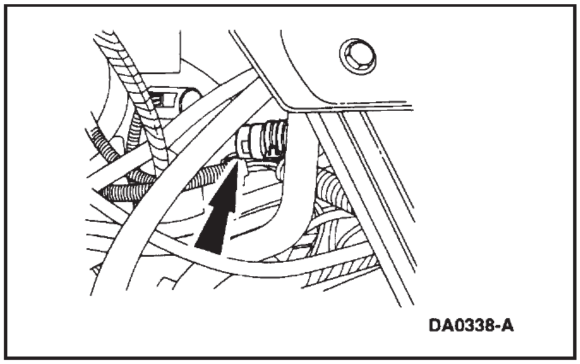


Lifting Handles
303-572 (T97T-6000-A)

Special Service Tools called for by the procedures can be obtained by calling:

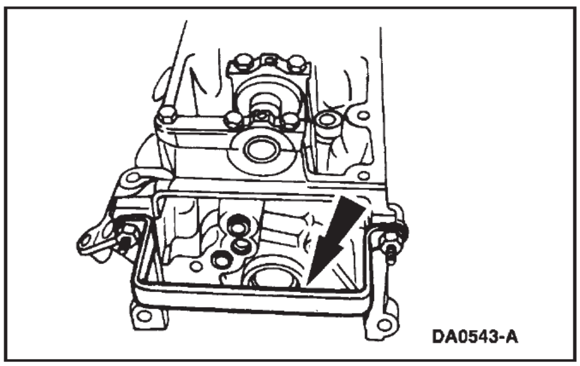
1-800-ROTUNDA (1-800-768-8632).

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



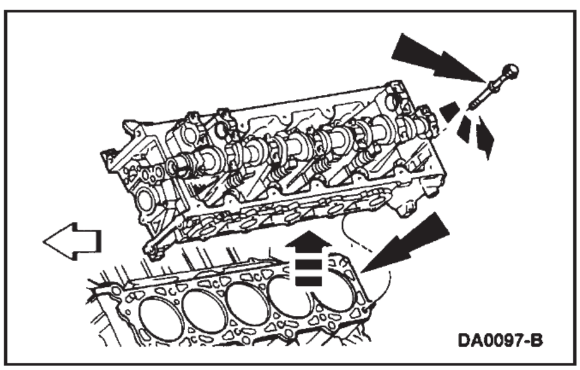
DA0338-A

2. Remove the intake manifold (9424); refer to Intake Manifold – Variable Resonance Induction System (VRIS) in this section.
3. Remove the timing chains (6268); refer to Timing Drive Components in this section.
4. Compress and slide the hose clamp back and remove the evaporation water hose (18472) if so equipped.



DA0543-A

5. Install the Lifting Handles.



DA0097-B

6. ⚠ CAUTION: These bolts must be replaced with new bolts. They are tighten-to-yield designed and cannot be reused.

Remove the bolts and the cylinder head (6049).

- Discard the head gasket (6051), the cylinder head bolts (6049) and clean the engine block surface.
- The LH is shown. The RH is similar.

7. **NOTE:** Sealant must be removed and area cleaned with solvent.

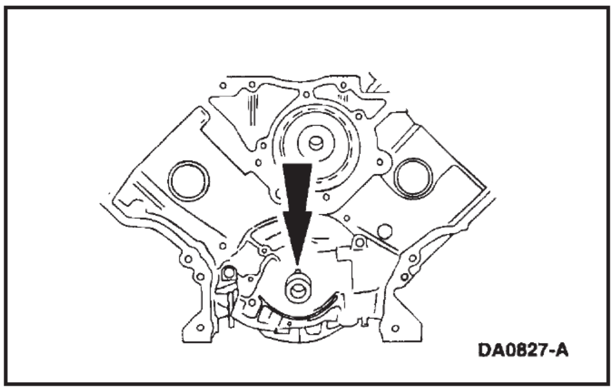
CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSE-M4G323-A6.

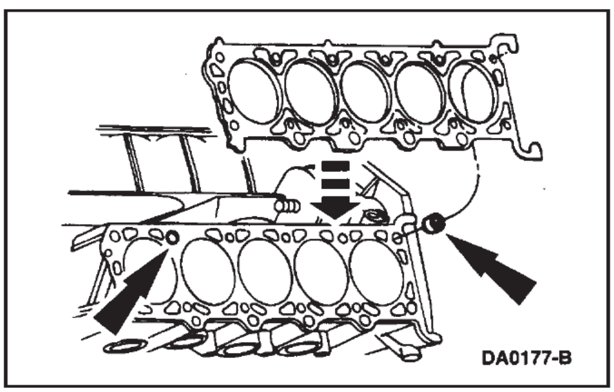
  NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSE-M5B292-A.

Cylinder Head - Installation

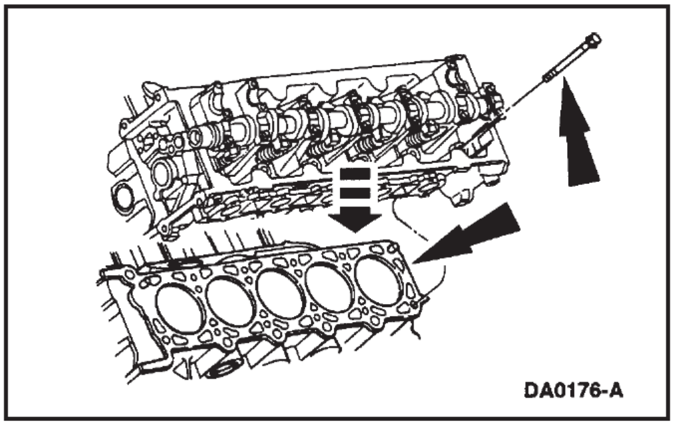


1. Rotate the crankshaft (6303) to position the keyway at 12 o'clock.



2. **NOTE:** Do not turn the crankshaft until otherwise instructed.

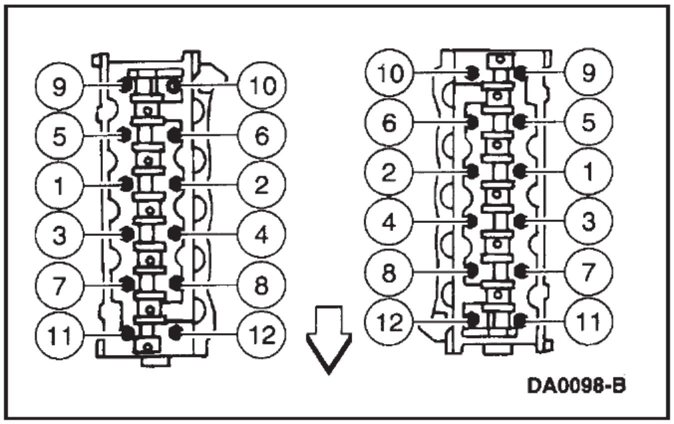
   Install the head gasket over the dowel pins.



3. **NOTE:** Head bolts are torque to yield and must be replaced whenever cylinder head is removed.

   Install the cylinder head on the head gasket and loosely install new bolts.

- The LH is shown; the RH is similar.

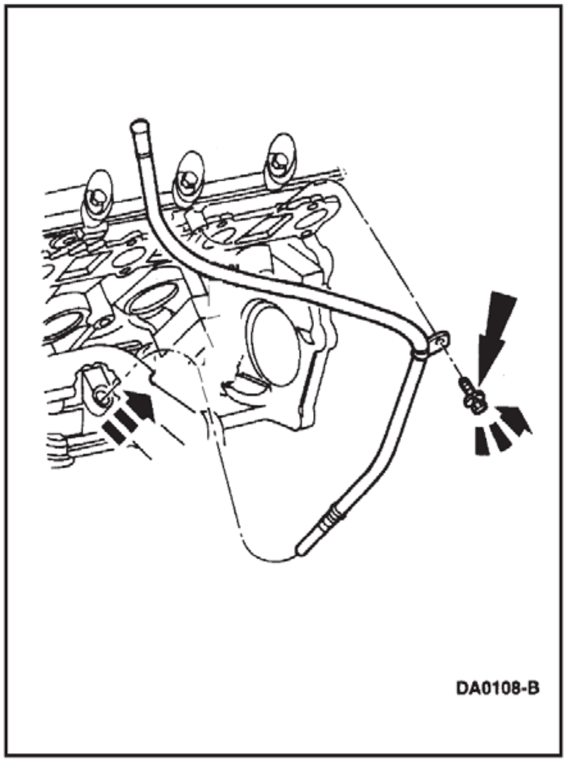


4. **NOTE:** Be sure to tighten the bolts in three stages.

- Stage 1: Tighten to 37-43 Nm (27-32 lb/ft).
- Stage 2: Tighten an additional 85 degrees to 95 degrees.
- Stage 3: Tighten an additional 85 degrees to 95 degrees.

5. Install the timing chains; refer to Drive Components in this section.
6. Install the intake manifold; refer to Intake Manifold – Variable Resonance Induction System (VRIS) in this section.

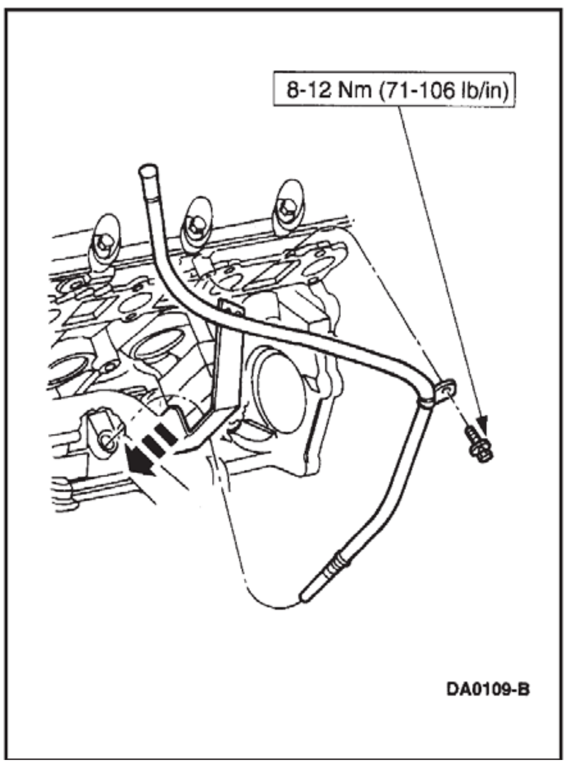
Oil Level Indicator Tube - Removal



1. Remove the bolt and remove the oil level indicator tube (6754).

2. Inspect the oil level indicator tube for damage.

Oil Level Indicator Tube - Installation

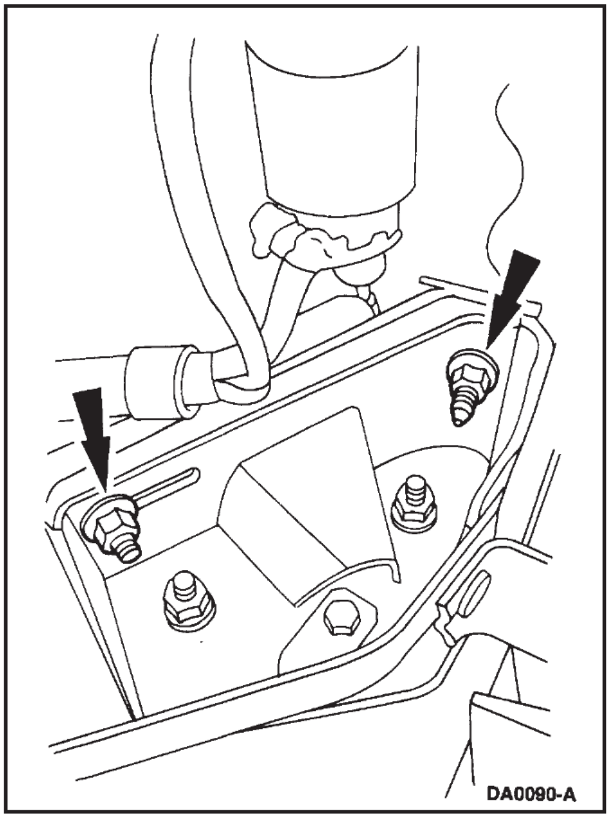


1. Follow the removal procedure in reverse order.

2. Replace and lubricate the O-rings with Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-G.

3. Replace oil level indicator (oil dipstick).

Oil Pan - Removal

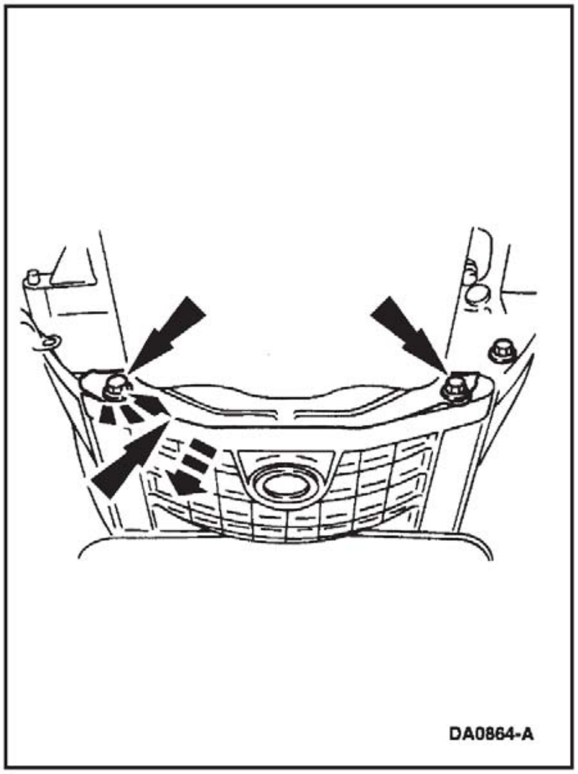


1. Disconnect the battery ground cable (14301).

2. Partially drain the radiator (8005) and disconnect the upper radiator hose (8260) at the radiator.

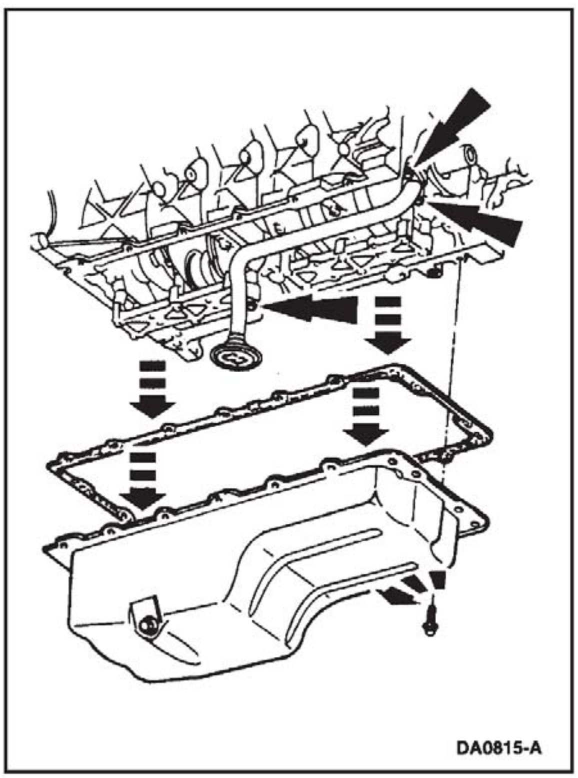
3. Drain the engine oil and remove the oil bypass filter (6714).

4. Remove the nuts retaining the front engine support insulator (6038) to the front engine support bracket (6028). The RH is shown, the LH is typical.



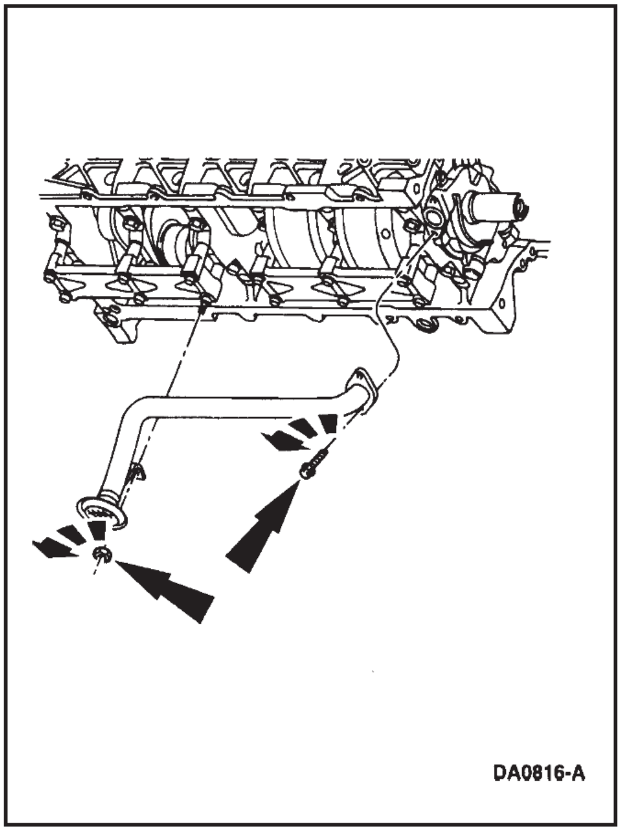
DA0864-A

5. Remove the flywheel inspection plate.



DA0815-A

6. Remove the bolts and partially lower the oil pan (6675).

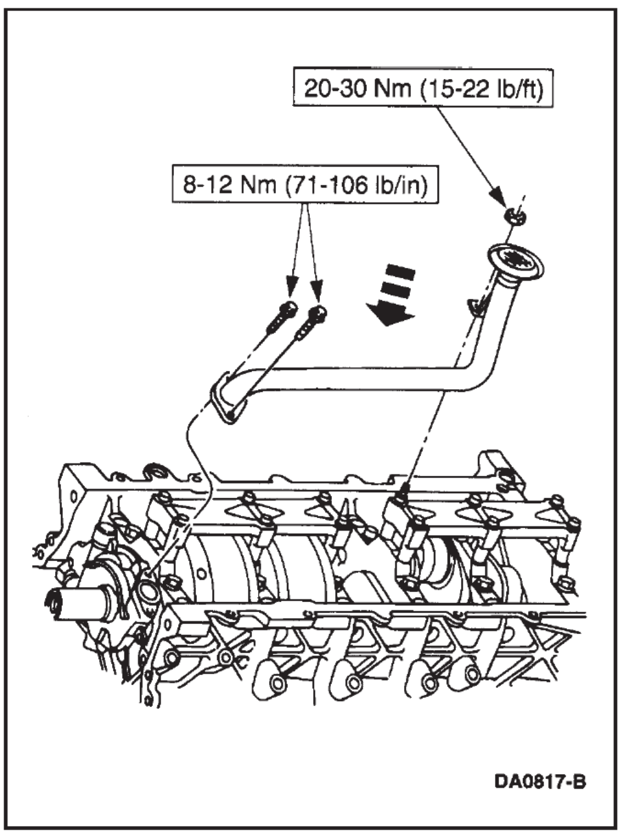


7. Remove the two bolts and the nut retaining the oil pump screen cover and tube (6622) and let them drop into the oil pan.

8. Remove the oil pan and oil pan gasket (6710) from the rear of the engine.

9. Clean the mating surfaces and thoroughly clean the oil pan.

Oil Pan - Installation



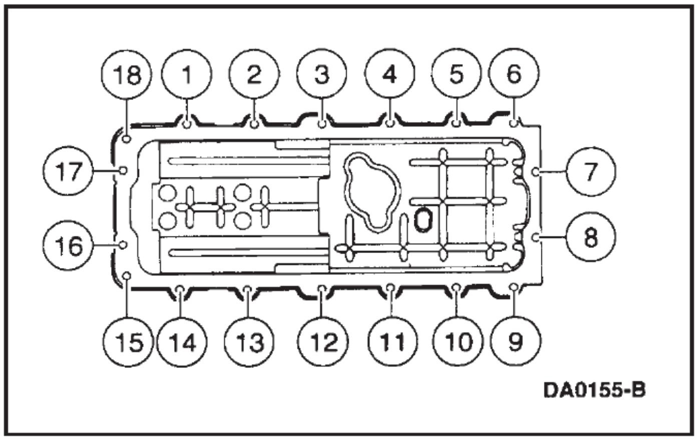
1. Install the oil pump screen cover and tube.

2. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSE-M4G323-A6.

  NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSE-M5B292-A.



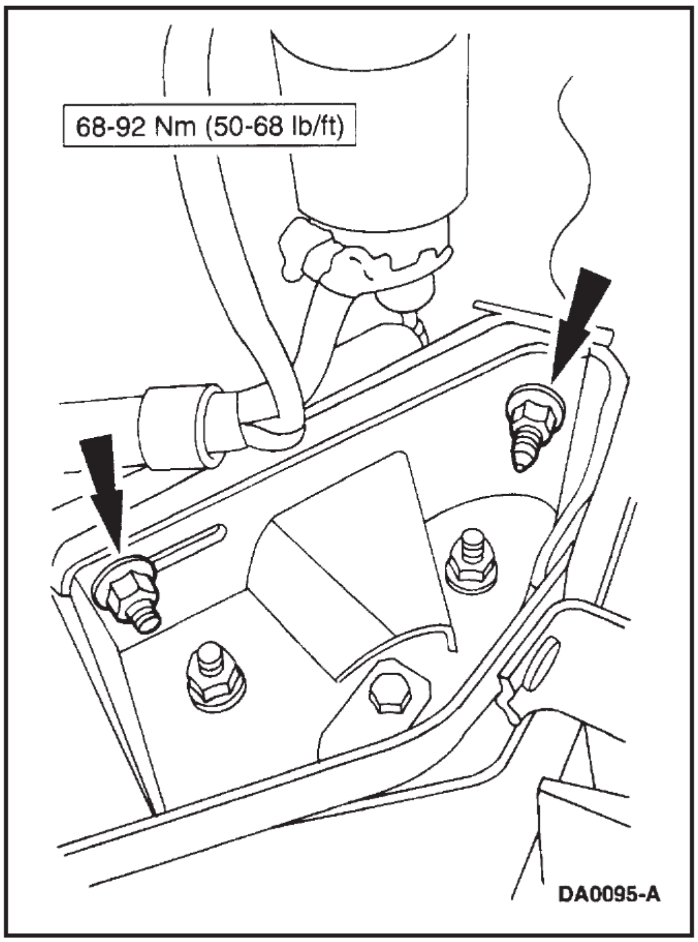
3. **NOTE:** Be sure to tighten the bolts in three stages.

   Replace oil pan and bolts.

   Tighten the bolts in the sequence shown.

- Stage 1: Tighten to 2 Nm (18 lb/in).
- Stage 2: Tighten to 20 Nm (15 lb/ft).
- Stage 3: Tighten an additional 60 degrees.

4. Install oil drain plug 11-16 Nm (98-143 lb/in).



5. Tighten the front engine support insulators.
6. Connect the battery ground cable.
7. Fill the engine with oil.

- Use Motorcraft Engine Oil XO-5W30-QSP or equivalent meeting Ford specification WSSM2C153-G.

8. Fill the cooling system.

Oil Pump - Removal

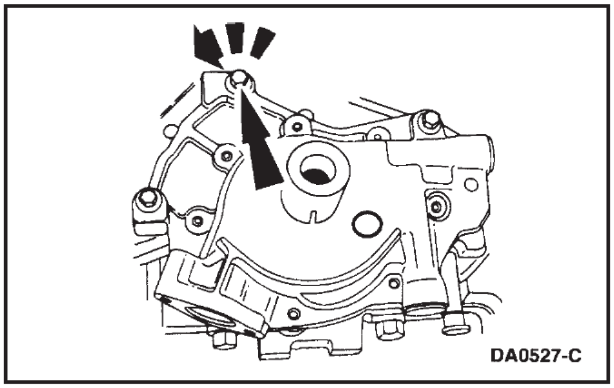
1. Disconnect the battery ground cable (14301).

2. Remove the engine front cover (6019) and crankshaft sprockets (6306); refer to Engine Front Cover in this section.

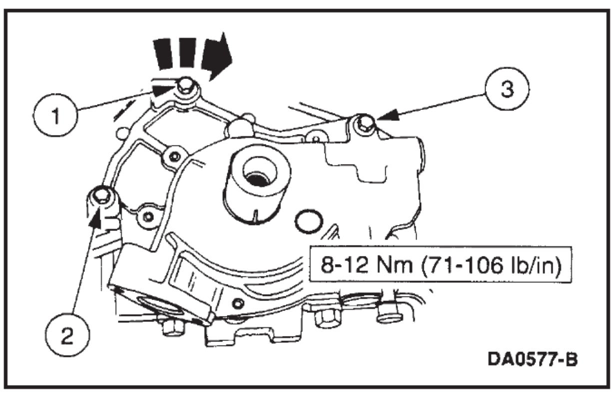
3. Remove the oil pan (6675); refer to Oil Pan in this section.

4. Remove the oil pump (6600).

- Remove the bolts.
- Remove the oil pump



Oil Pump - Installation



1. Clean and inspect the mating surfaces.

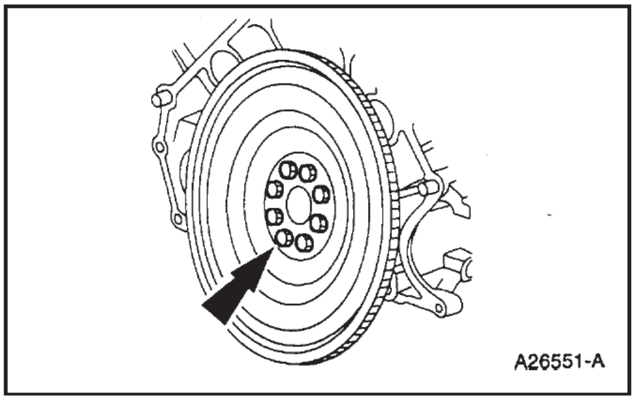
2. Position the oil pump and loosely install the bolts. Tighten the bolts in the sequence shown.

3. Install the oil pan; refer to Oil Pan in this section.

4. Install the timing chain (6268); refer to Timing Drive Components in this section.

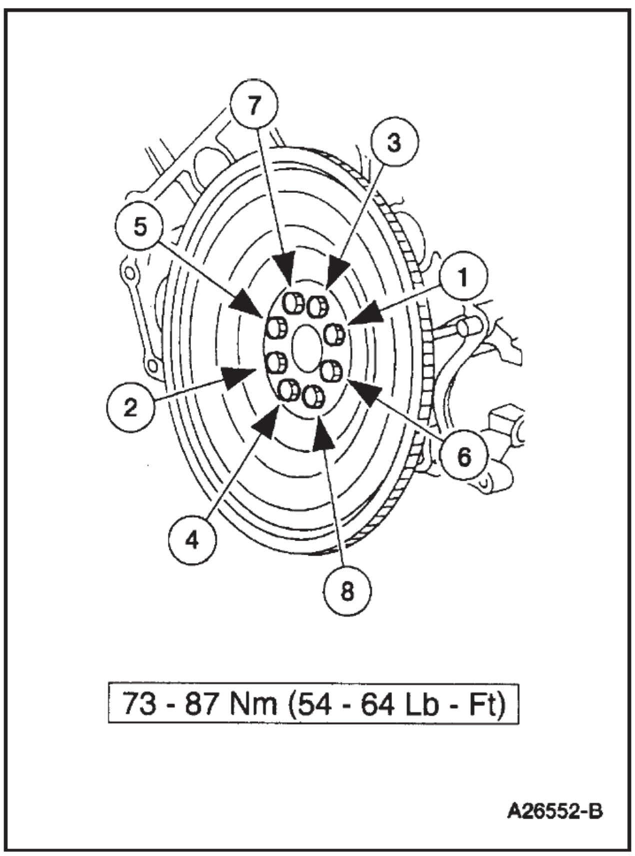
5. Connect the battery ground cable.

Flywheel - Removal



1. Disconnect the battery ground cable (14301).
2. Remove generator from bell housing.
3. Remove bell housing.
4. Remove the bolts and the flywheel (6375).

Flywheel - Installation

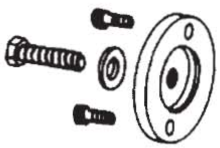
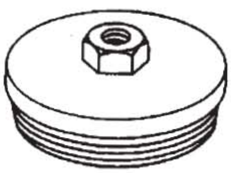
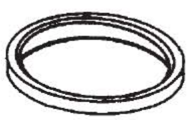


1. Follow the removal procedure in reverse order.

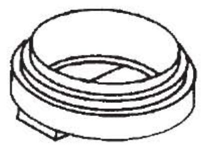
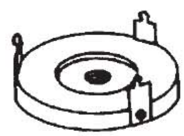
WSG-1068 ENGINE

Crankshaft Rear Oil Seal - Removal

Special Tool(s)

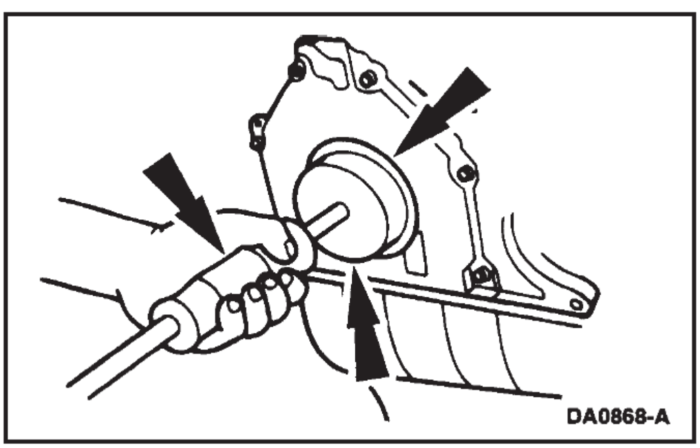
 ST1480-A	Rear Crankshaft Seal Adapter 303-518 (T95P-6701-DH)
 ST1382-A	Rear Crankshaft Seal Remover 303-519 (T95P-6701-EH)
 ST1482-A	Rear Crankshaft Slinger Replacer 303-517 (T95P-6701-CH)

Special Tool(s)

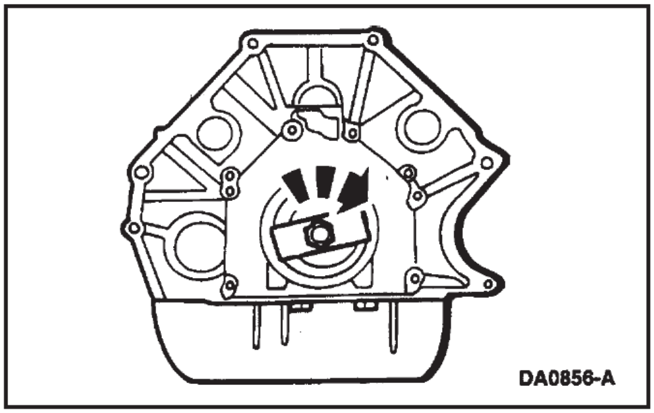
 ST1479-A	Rear Crankshaft Seal Replacer 303-516 (T95P-6701-BH)
 ST1481-A	Rear Crankshaft Slinger Remover 303-514 (T95P-6701-AH)
 ST1185-A	Slide Hammer 100-001 (T50T-100-A)

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

1. Disconnect the battery ground cable (14301).
2. Remove the flywheel (6375); refer to Flywheel in this section.
3. Use the Rear Crankshaft Slinger Remover and the Slide Hammer to remove the crankshaft oil slinger (6310).
4. Use the Rear Crankshaft Seal Remover and the Impact Slide Hammer to remove the crankshaft rear oil seal (6701).



Crankshaft Rear Oil Seal - Installation



1. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

  NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

2. Using the Rear Crankshaft Seal Replacer and the Rear Crankshaft Seal Adapter, install the crankshaft rear oil seal.

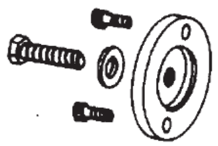
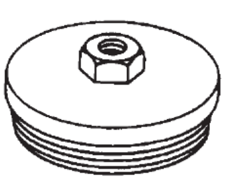
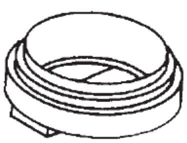
3. With the Rear Crankshaft Seal Adapter still installed, use the Rear Crankshaft Slinger Replacer and the Rear Crankshaft Seal Replacer to install the rear main seal slinger.

4. Install the flywheel; refer to Flywheel in this section.

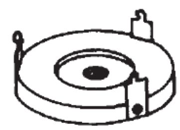
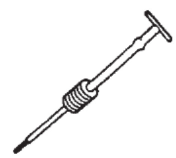
5. Connect the battery ground cable.

Crankshaft Rear Oil Seal (with retainer plate) - Removal

Special Tool(s)

 ST1480-A	Rear Crankshaft Seal Adapter 303-518 (T95P-6701-DH)
 ST1382-A	Rear Crankshaft Seal Remover 303-519 (T95P-6701-EH)
 ST1479-A	Rear Crankshaft Seal Replacer 303-516 (T95P-6701-BH)

Special Tool(s)

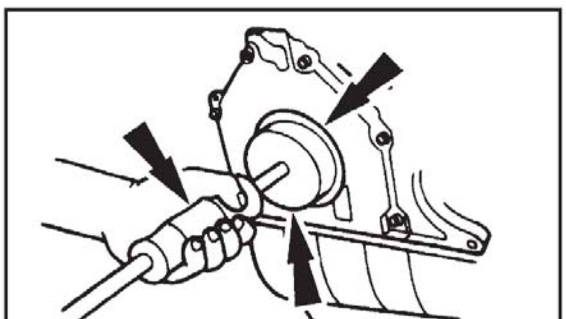
 ST1481-A	Rear Crankshaft Slinger Remover 303-514 (T95P-6701-AH)
 ST1482-A	Rear Crankshaft Slinger Replacer 303-517 (T95P-6701-CH)
 ST1185-A	Slide Hammer 100-001 (T50T-100-A)

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

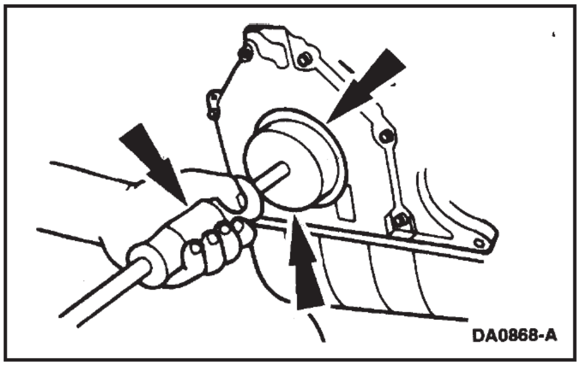
1. Disconnect the battery ground cable (14301).

   Remove the flywheel (6375); refer to Flywheel in this section.

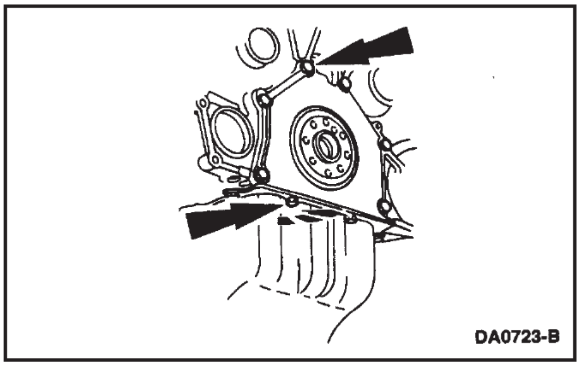
2. Use the Rear Crankshaft Slinger Remover and the Impact Slide Hammer to remove the crankshaft oil slinger (6310).



DA0868-A



3. Use the Rear Crankshaft Seal Remover and the Impact Slide Hammer to remove the crankshaft rear oil seal (6701).



4. Remove the oil pan; refer to Oil Pan in this section.
5. Remove the crankcase bolts and the crankshaft rear oil seal retainer plate.

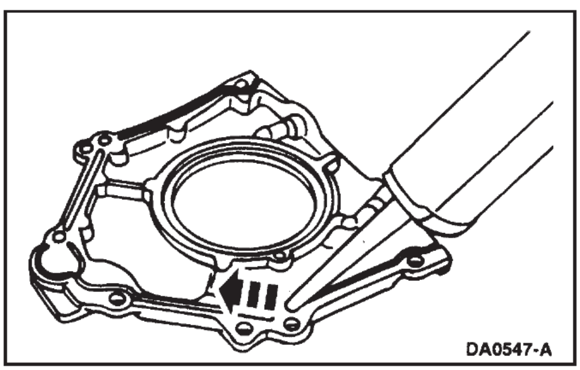
Crankshaft Rear Oil Seal (with retainer plate) - Installation

1. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

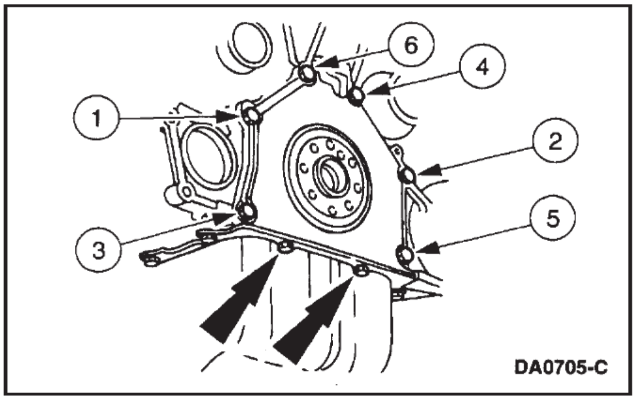
NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.



2. Apply a bead of silicone around the rear oil seal retainer sealing surface.

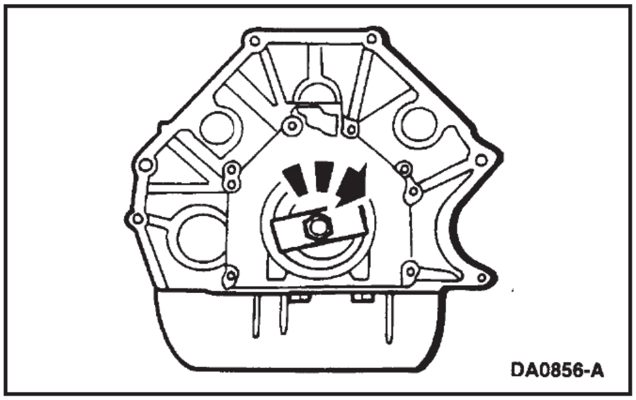
- Use Silicone Gasket and Sealant F6AZ-19562-A or equivalent meeting Ford specification WSEM4G323-A6.



3. **NOTE:** If the rear main oil seal is still in place and being reinstalled, be sure the lip is not folded over or wrinkled during the retainer plate installation. The seal lip must start squarely on the crankshaft journal.

   Position the crankshaft rear oil seal and retainer (6K301), install the bolts. Then install the oil pan and the two bolts. Tighten in two stages.

- Stage 1: Tighten retainer plate bolts to 8-12 Nm (71-107 lb/in).
- Stage 2: Tighten oil pan bolts to 14-20 Nm 10-15 lb/ft) then tighten an additional 90°.

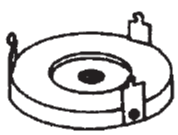


4. Use the Rear Crankshaft Seal Replacer and Rear Crankshaft Seal Adapter to install the crankshaft rear oil seal.
5. With the Rear Crankshaft Seal Adapter still installed, use the Rear Crankshaft Slinger Replacer and Rear Crankshaft Seal Replacer to install the crankshaft oil slinger.
6. Install the flywheel; refer to Flywheel in this section.
7. Connect the battery ground cable.

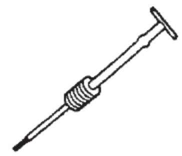
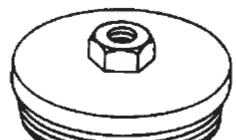
WSG-1068 ENGINE

Engine - Removal

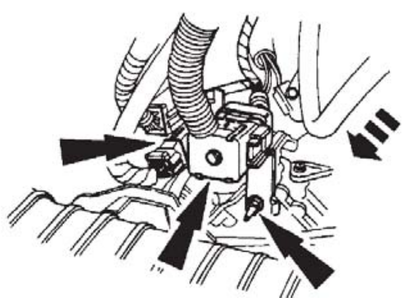
Special Tool(s)

 ST1377-A	Modular Lifting Bar 303-F047 (014-00073) or Equivalent
 ST1481-A	Rear Crankshaft Slinger Remover T95P-6701-AA

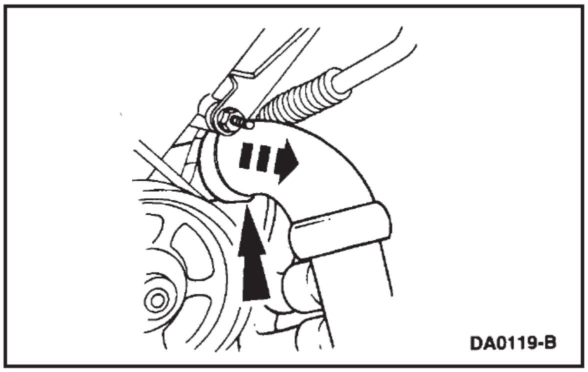
Special Tool(s)

 ST1185-A	Impact Slide Hammer 100-001 (T50T-100-A)
 ST1382-A	Rear Crankshaft Seal Remover 303-519 (T95P-6701-EH)

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

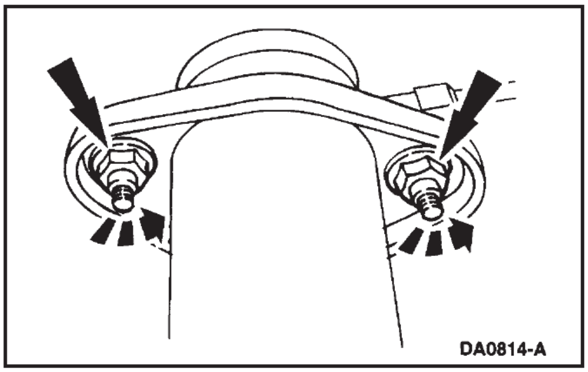

DA0724-B

1. Disconnect the battery ground cable (14301).
2. Remove the intake manifold (9424); refer to Intake Manifold – Variable Resonance Induction System (VRIS) in this section.
3. Remove the radiator upper and lower radiator supports (16138).
4. Remove the radiator (8005), fan shroud (8146) and engine cooling fan.
5. Remove the drive belt (8620); refer to Section 05.



6. At the oil cooler water inlet, disconnect and set aside the lower radiator hose (8286).

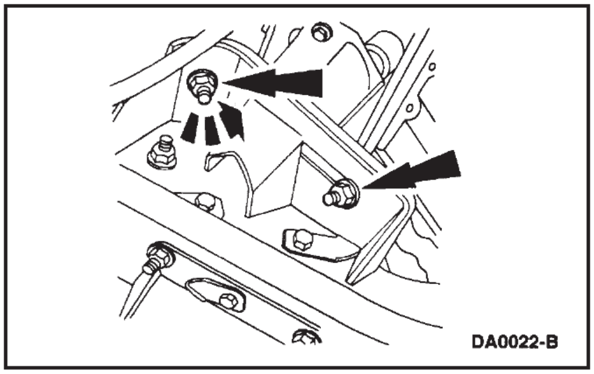
7. Disconnect the engine harness.



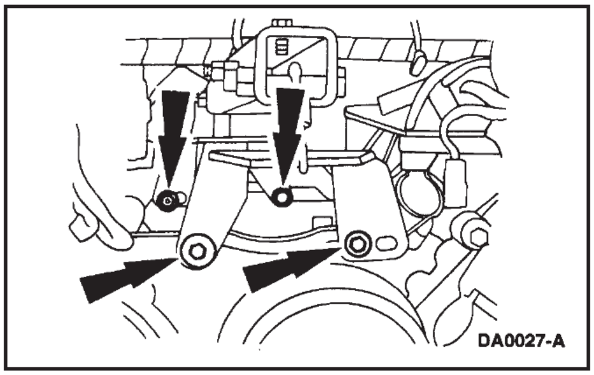
8. Remove exhaust pipe nuts.

9. Drain engine oil and remove the oil bypass filter (6714).

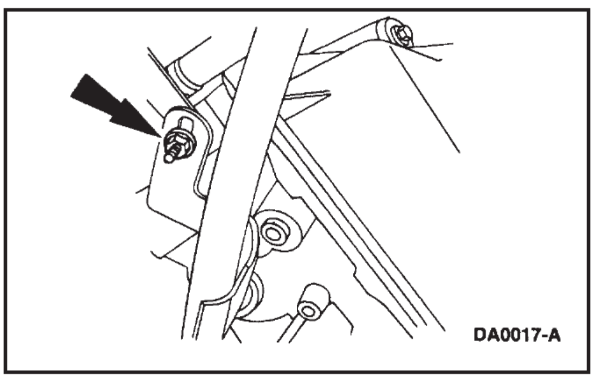
10. Remove the starter motor (11002); refer to Section 07.



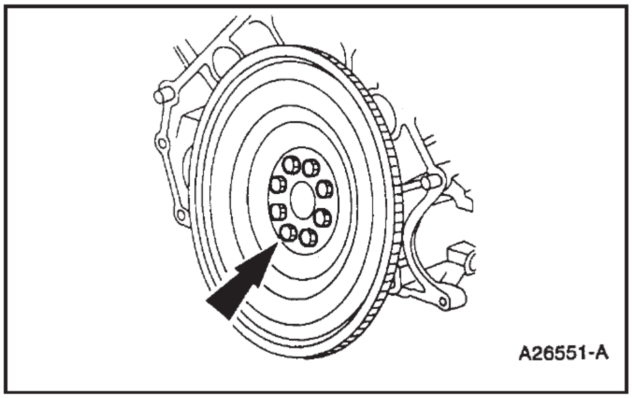
11. Remove the engine support insulator nuts.



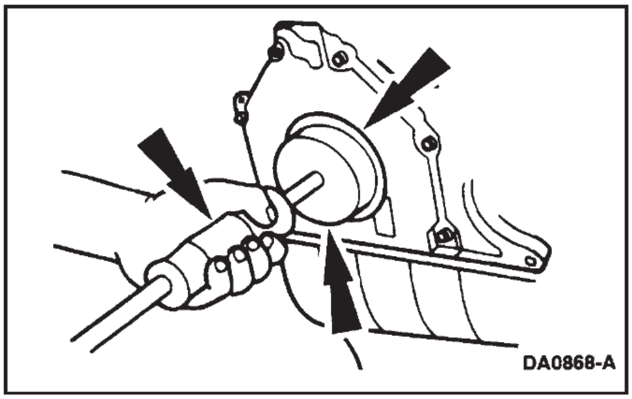
12. Install the Modular Lifting Bar.



13. Remove the engine from the equipment.

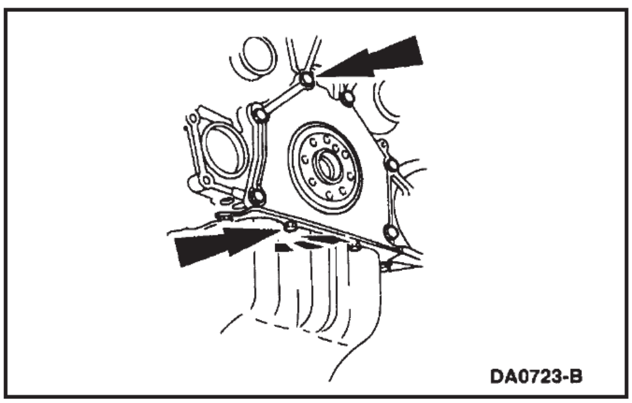


14. Remove the bolts, and remove the flywheel.



15. Use the Rear Crankshaft Slinger Remover and the Impact Slide Hammer to remove the crankshaft oil slinger (6310).

16. Use the Rear Crankshaft Seal Remover and the Impact Slide Hammer to remove the crankshaft rear oil seal (6701).



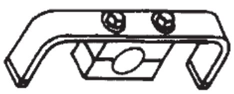
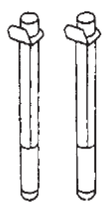
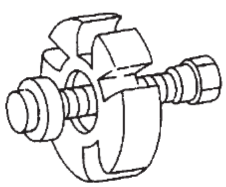
17. Remove the bolts and remove the crankshaft rear oil seal retainer plate.

18. Mount the engine on an engine stand.

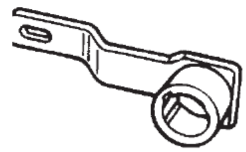
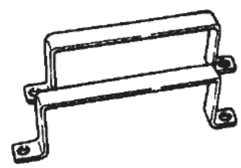
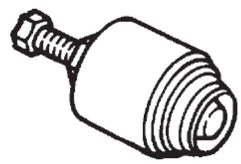
19. Remove the Modular Lifting Bar.

Engine - Disassembly

Special Tool(s)

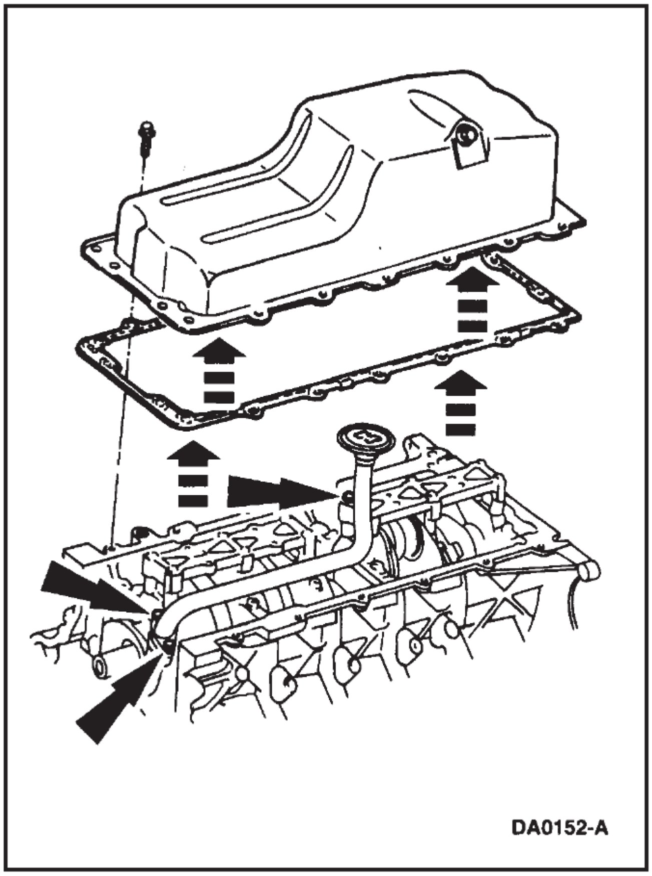
	Camshaft Holding Tool (2 Required) 303-557 (T96T-6256-B)
 ST1337-A	Connecting Rod Guide Tool 303-442 (T93P-6136-A)
 ST1286-A	Crankshaft Damper Remover 303-009 (T58P-6316-D)

Special Tool(s)

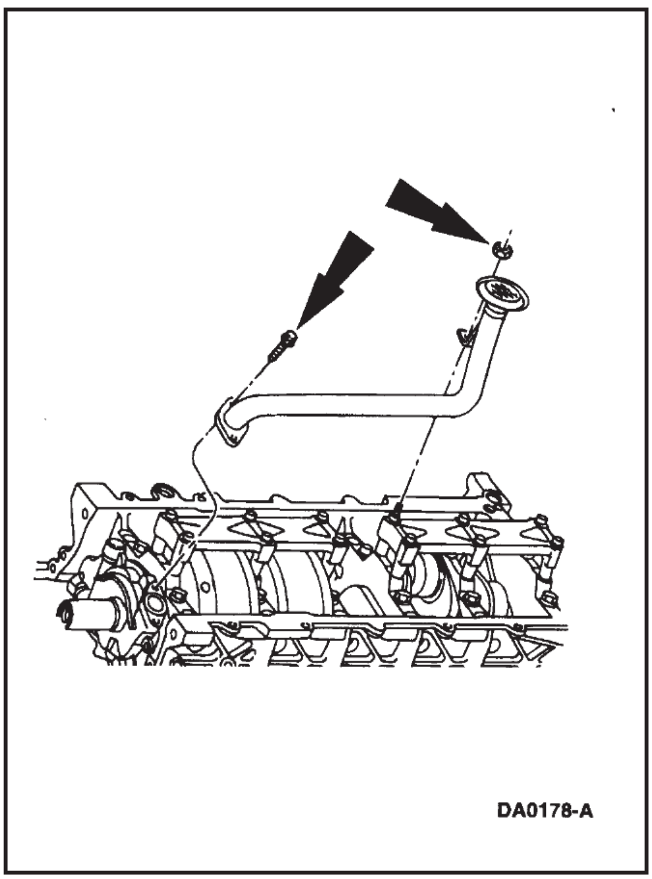
 ST1335-A	Crankshaft Holding Tool 303-448 (T93P-6303-A)
 ST1668-A	Lifting Handles (2 Sets Required) 303-572 (T97T-6000-A)
 ST1730-A	Front Cover Seal Remover 303-107 (T74P-6700-A)

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

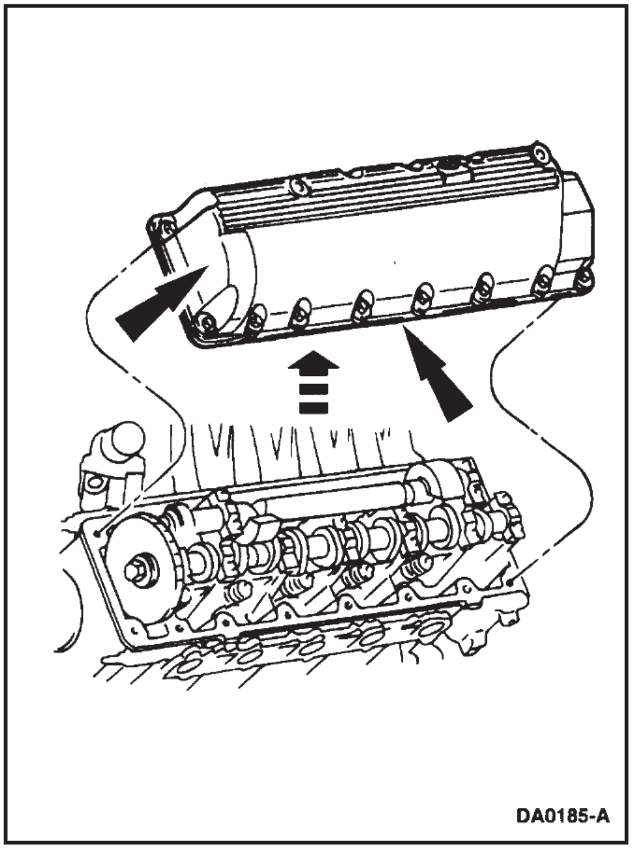
1. With the engine on the engine stand, remove the engine wiring harness.



2. Remove the bolts, the oil pan (6675), and the oil pan gasket (6710).



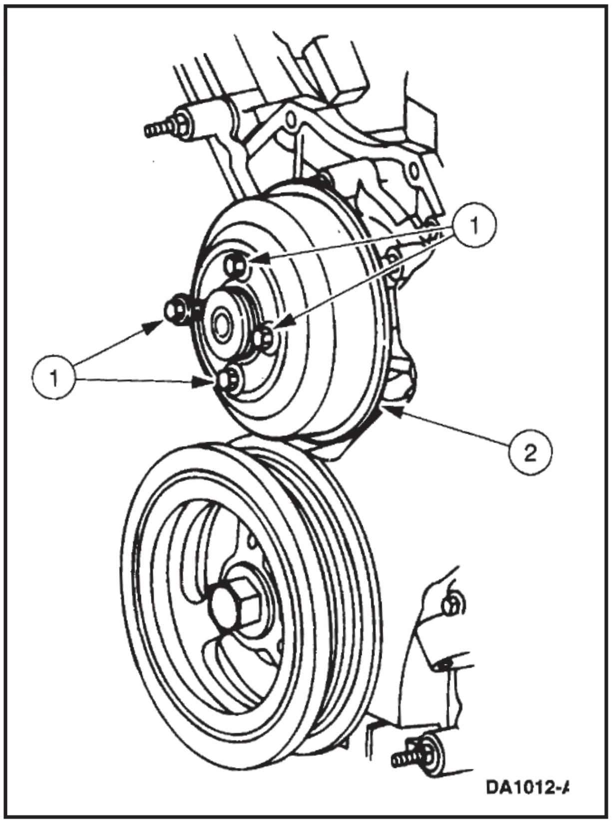
3. Remove the two bolts and nut retaining the oil pump screen cover and tube (6622) and remove the oil pump screen cover and tube.



4. **NOTE:** The bolts are a part of the valve cover (6582) and are not to be removed.

   LH is shown; RH is similar.

   - Fully loosen the sixteen bolts, and remove the valve cover gasket (6584).

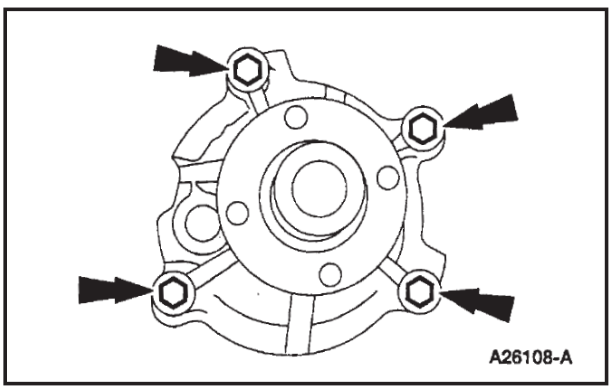


5. Remove the drive belt.

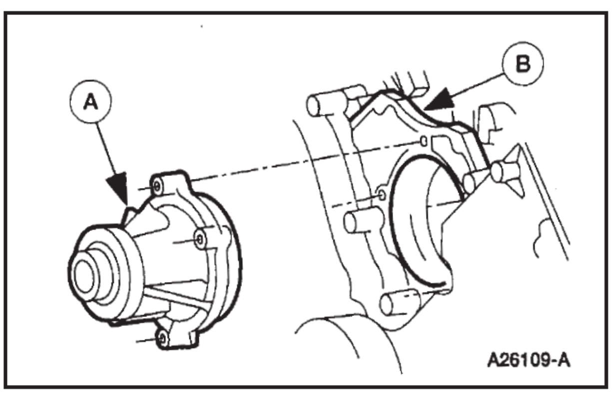
6. Remove the water pump pulley (8509).

    1. Remove the four bolts.

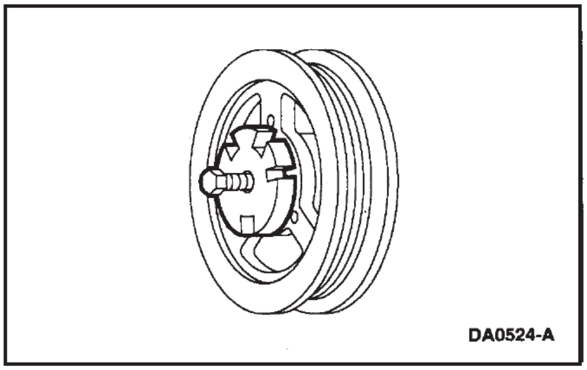
    2. Remove the water pump pulley.



7. Remove the four bolts from the water pump.

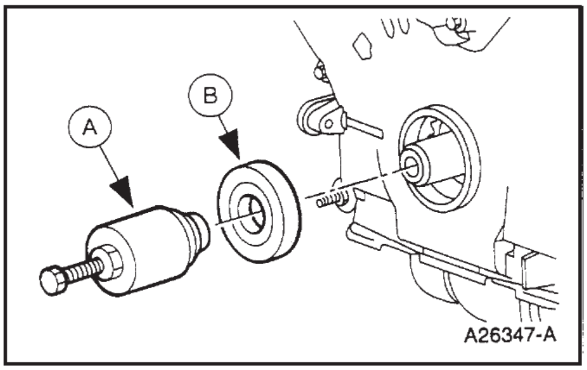


8. Remove the (A) water pump (8501) from the (B) cylinder block (6010).

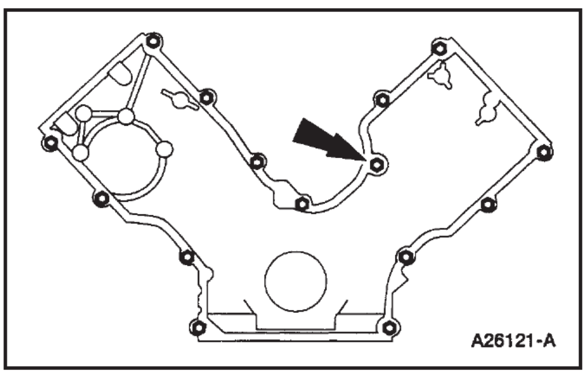


9. Remove the crankshaft pulley bolt (6A340).

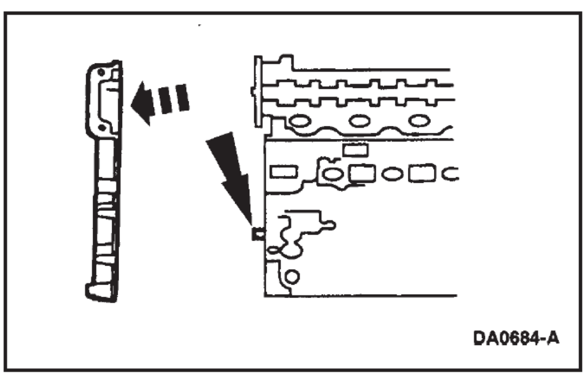
   Use the Crankshaft Damper Remover to remove the crankshaft pulley (6312).



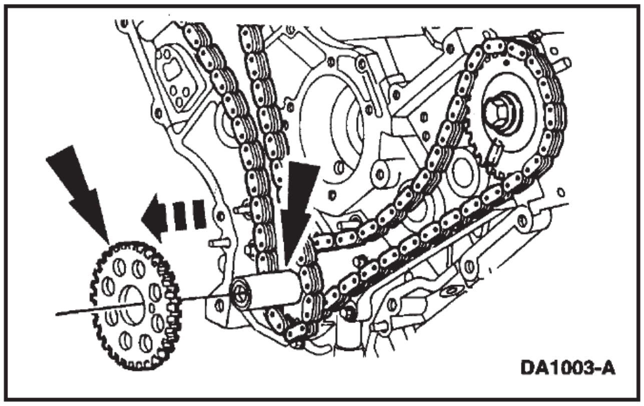
10. Use the (A) Front Cover Seal Remover to remove the (B) crankshaft front seal (6700).



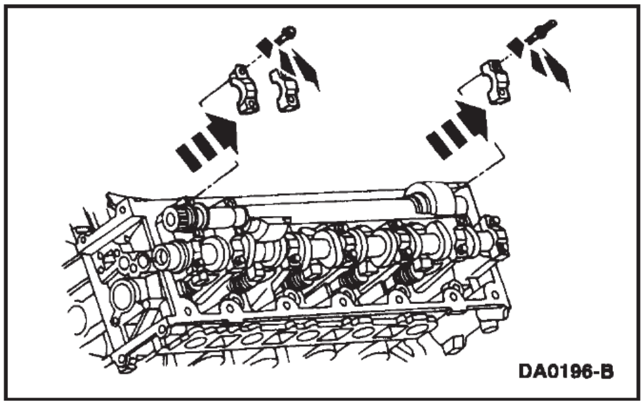
11. Remove the engine front cover fasteners.



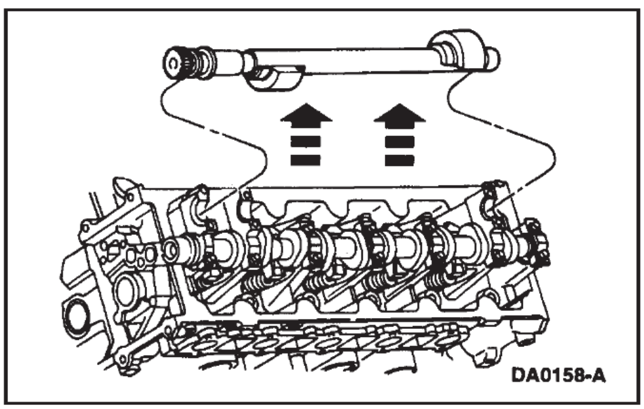
12. Remove the engine front cover (6019) from the front cover to cylinder block dowels (6C002).



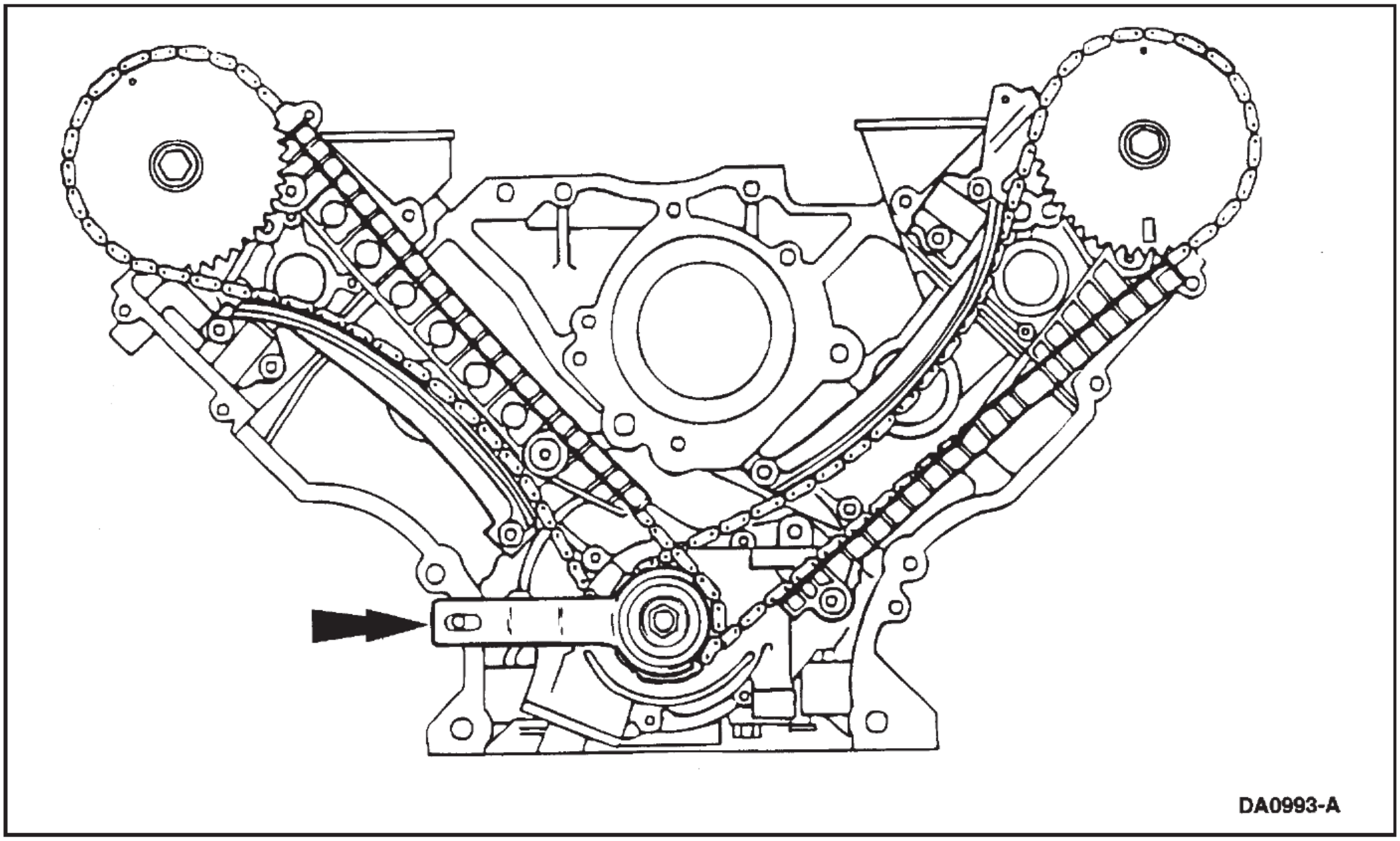
13. Remove the crankshaft sensor ring from the crankshaft (6303).

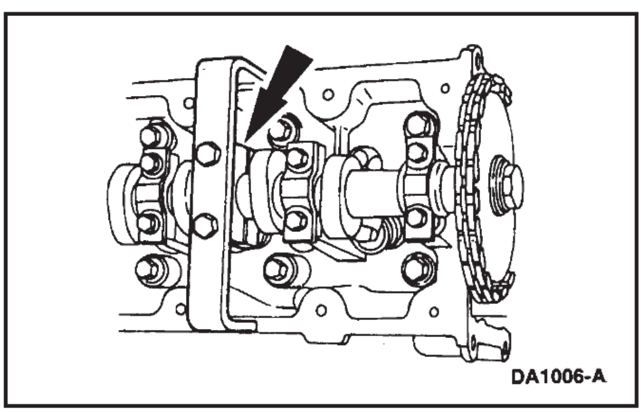


14. Remove the balancing shaft bearing caps.



15. Remove balancing shaft.

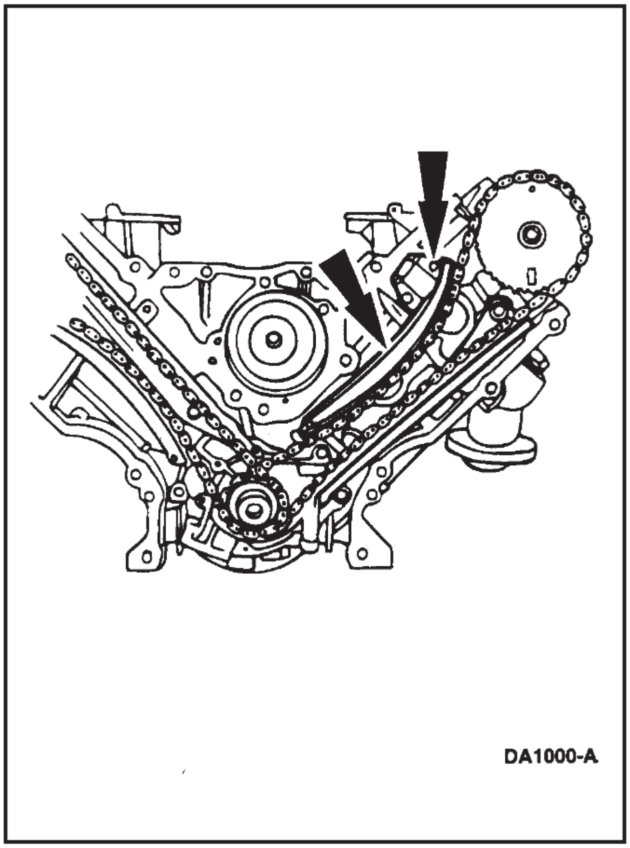




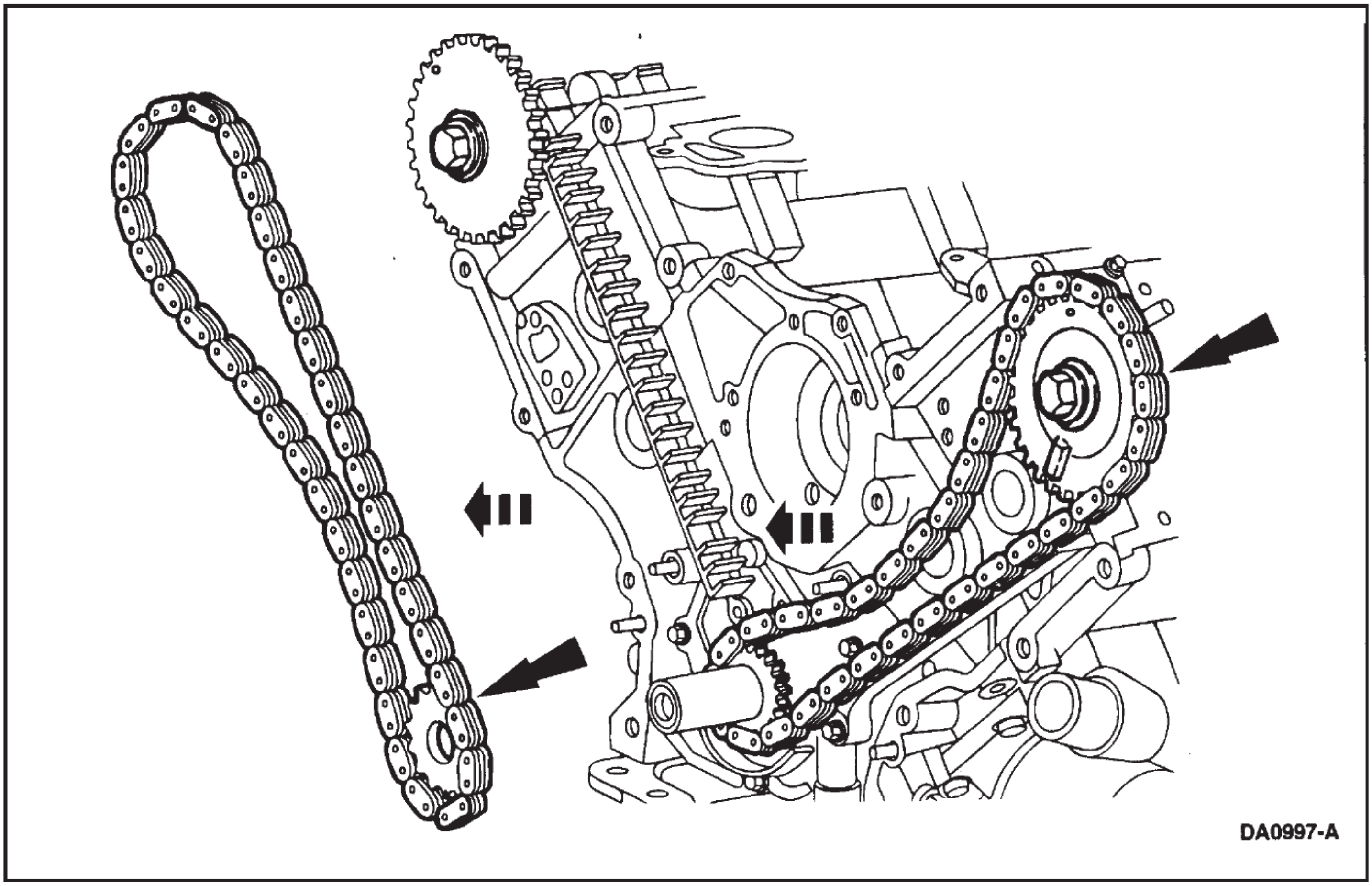
16. **CAUTION: Unless otherwise instructed, at no time when the timing chains (6268) are removed and the cylinder heads (6049) are installed is the crankshaft or camshaft (6250) to be rotated. Severe piston (6108) and valve damage will occur.**

    Position the crankshaft with the Crankshaft Holding Tool as shown.

17. Install the Camshaft Holding Tools on the camshafts (2).



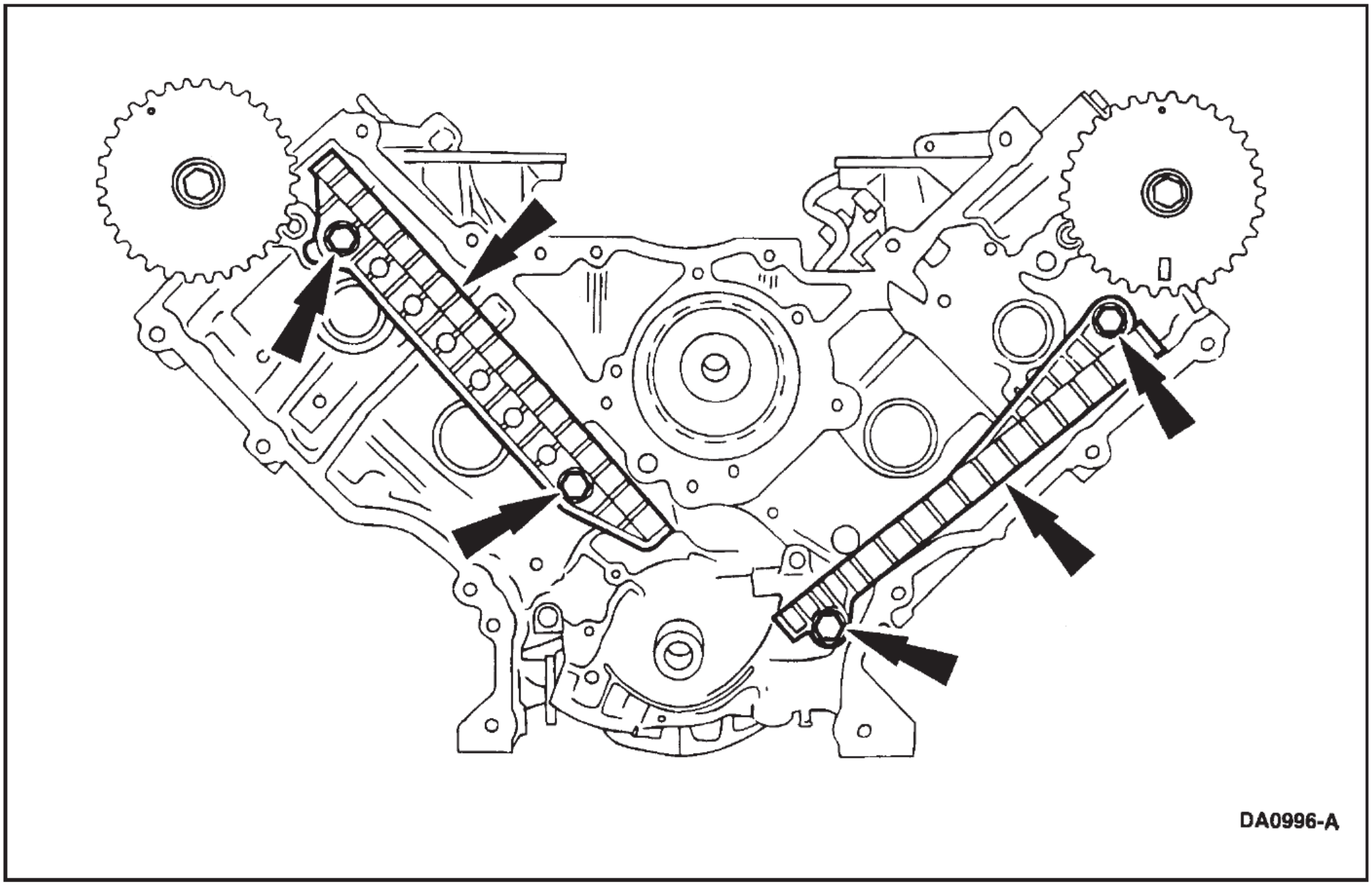
18. Remove the bolts and the timing chain tensioners (6L266). Remove the timing chain tensioner arms (6L253) from the dowel pins.



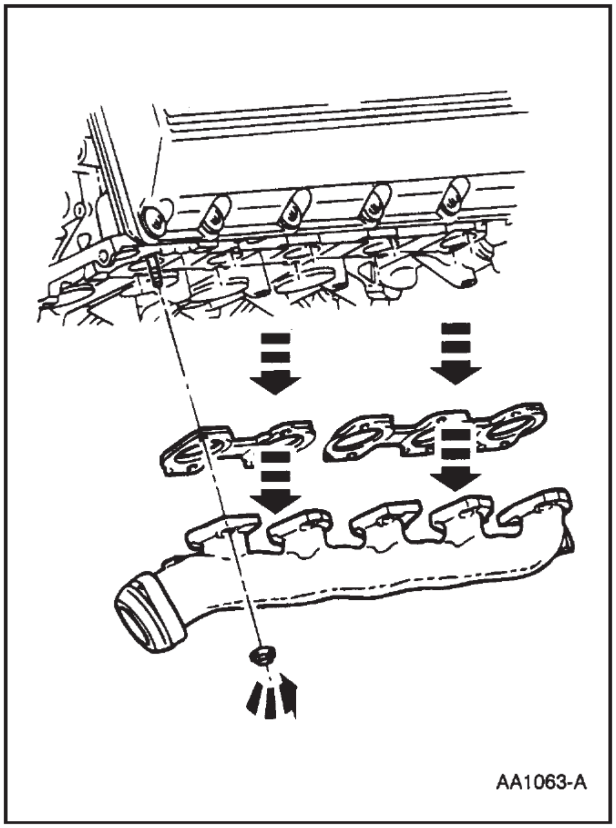
19. **CAUTION: Unless otherwise instructed, at no time when the timing chain are removed and the cylinder heads are installed is the crankshaft or camshaft to be rotated. Severe piston and valve damage will occur.**

- Remove the Crankshaft Holding Tool.

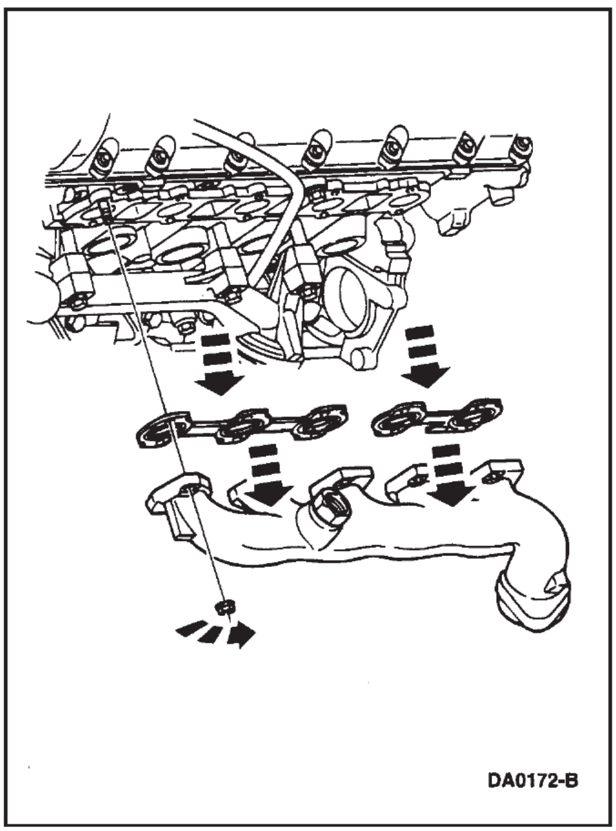
- Remove the RH timing chain from the camshaft sprocket (6256).
- Remove the RH timing chain and outer crankshaft sprocket from the crankshaft.
- Repeat for the LH timing chain and crankshaft sprocket.



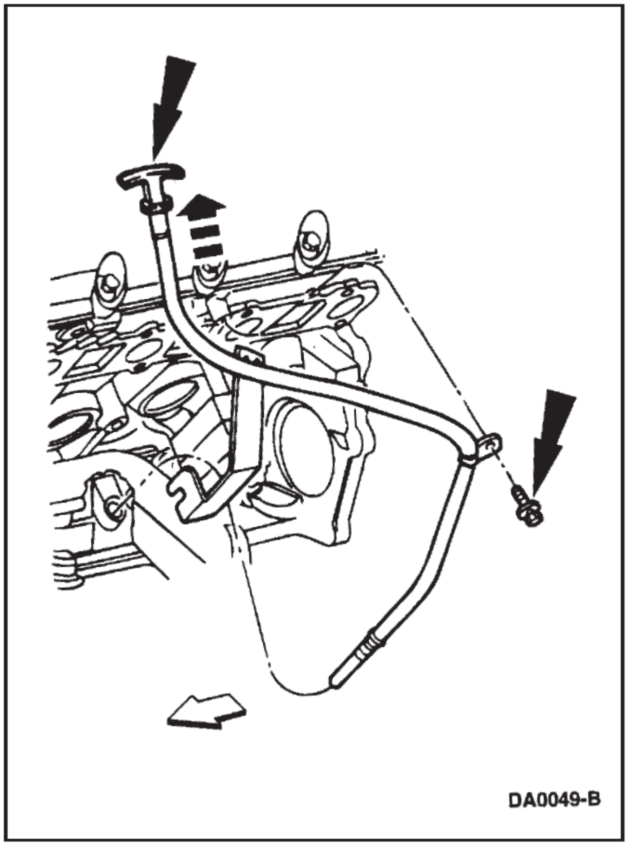
20. Remove the timing chain guides (6K297).
- Remove the bolts.
- Remove the timing chain guides.



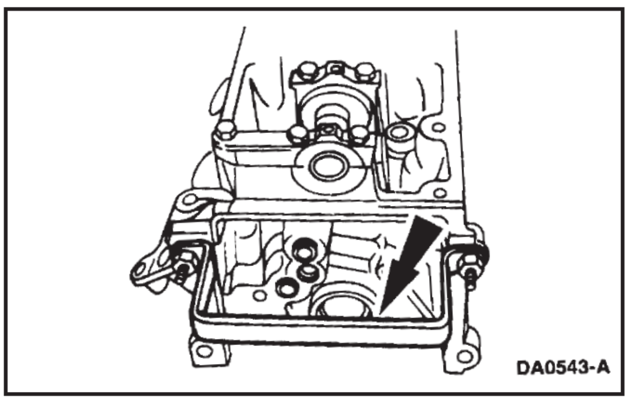
21. Remove the ten nuts and the RH exhaust manifold (9430) and exhaust manifold gasket (9448). Discard the exhaust manifold gasket.



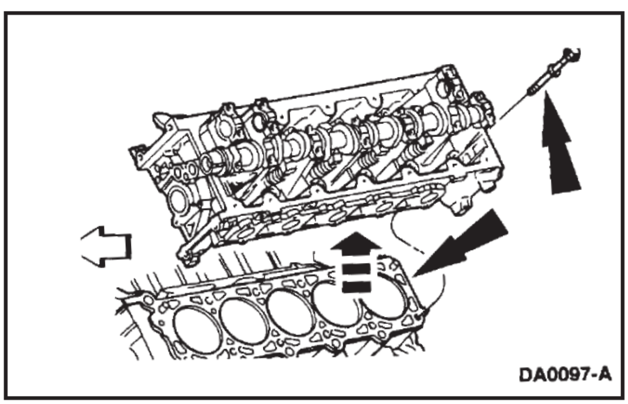
22. Remove the ten nuts, the LH exhaust manifold and the exhaust manifold gaskets. Discard the exhaust manifold gasket.



23. Remove the oil level dipstick, the bolt and the oil level indicator tube (6754).



24. Install the Lifting Handles on both ends of the cylinder head.



25. ⚠ **CAUTION: These bolts must be replaced with new bolts. They are tighten-to-yield designed and cannot be reused.**

Remove the bolts, cylinder head, and head gasket.

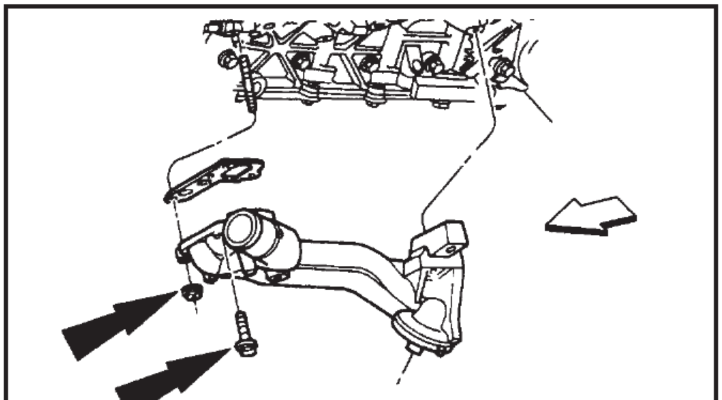
- Discard the head gasket (6051), cylinder head bolts and clean the engine block surface.
- LH is shown; RH is similar.

26. Use silicone gasket and sealant F6AZ-19562-AA equivalent meeting Ford specification WSE-M4G323-A6.

    NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

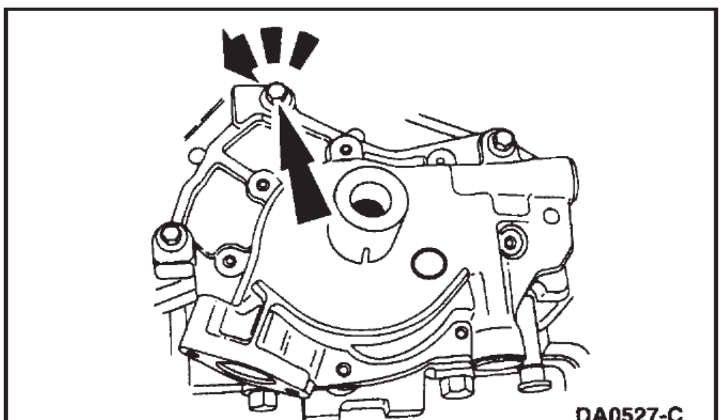
- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

27. Remove the bolts and remove the engine mounts.



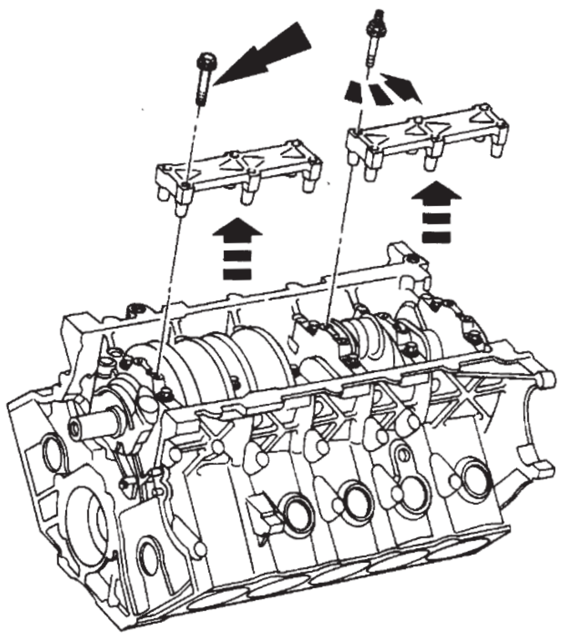
DA0065-A

28. Remove the bolts and nut retaining the oil filter adapter (6881) to the cylinder block. Remove the oil filter adapter and clean the gasket surface.



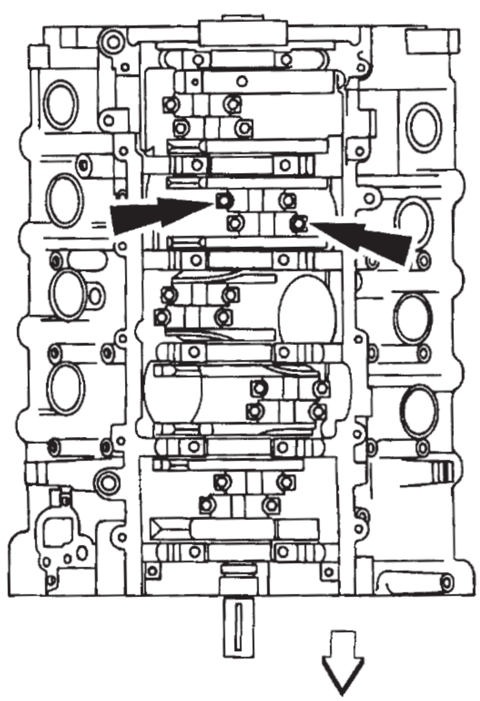
DA0527-C

29. Remove the bolts and the oil pump (6600).



DA0271-B

30. Remove the twelve bolts and the two lower crankshaft bearing supports.

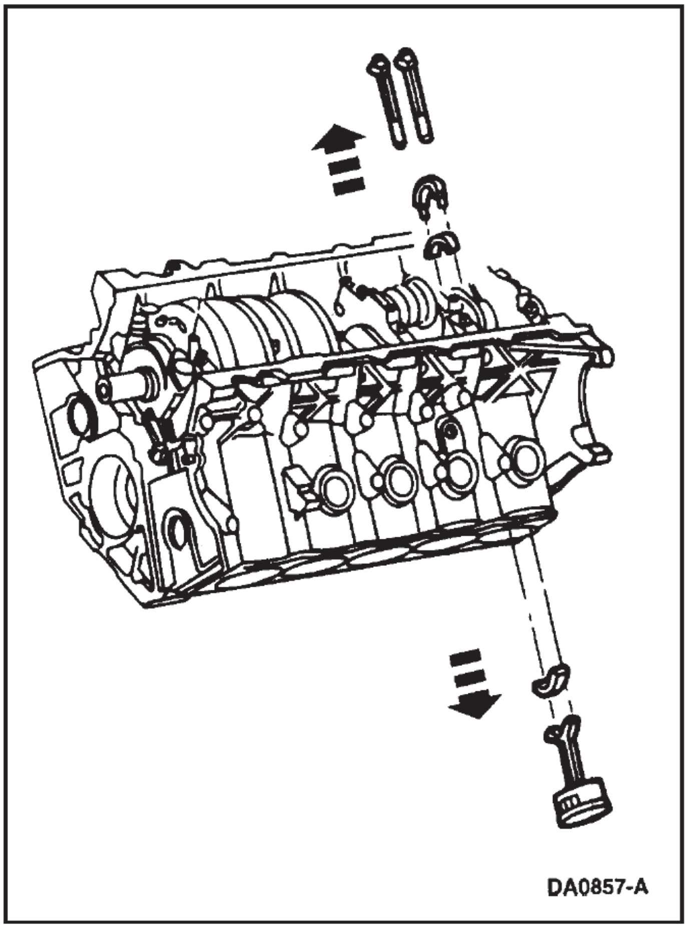


DA0272-A

31. ⚠ **CAUTION: Make sure connecting rods (6200) and rod caps are numbered, to keep in proper orientation.**

Remove the bolts and the connecting rod caps.

- Rotate the crankshaft so that the connecting rod is at bottom dead center.
- Remove the bolts and discard them.

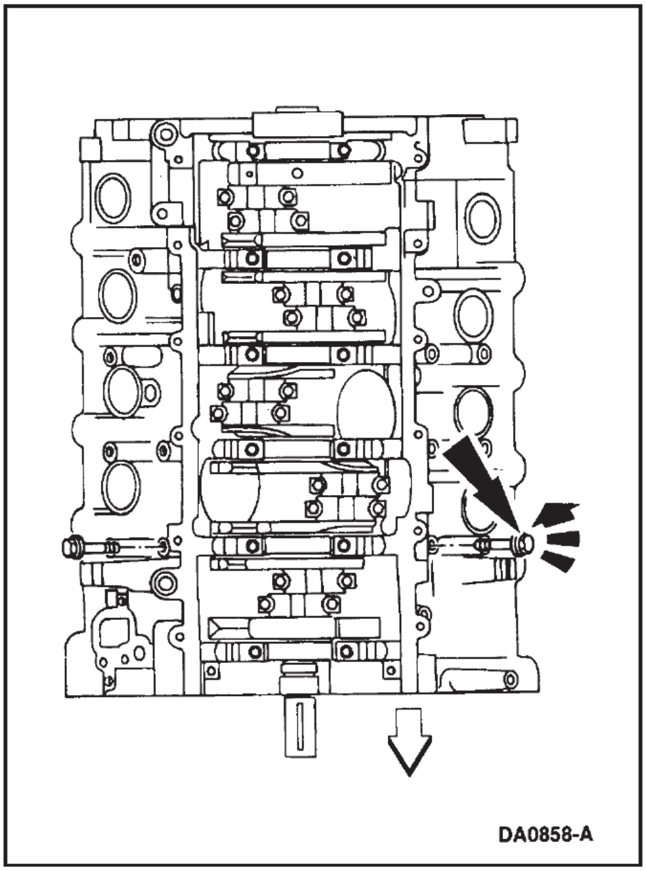


32. ⚠**CAUTION: Do not scratch the cylinder walls or the crankshaft journals with the connecting rod.**

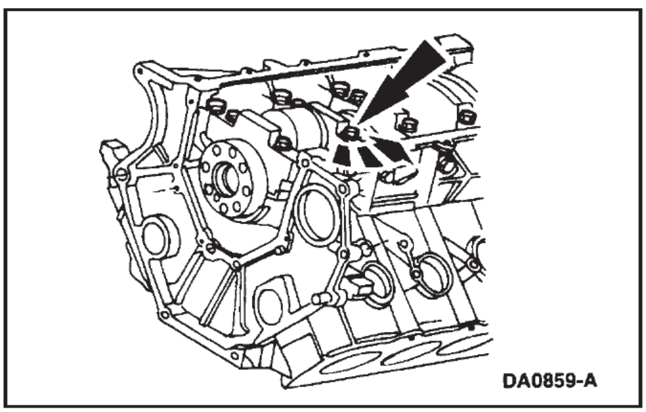
Remove the piston and rod assembly.

- Use the Connecting Rod Guide Tools to guide the
  piston and rod assembly out of the cylinder.

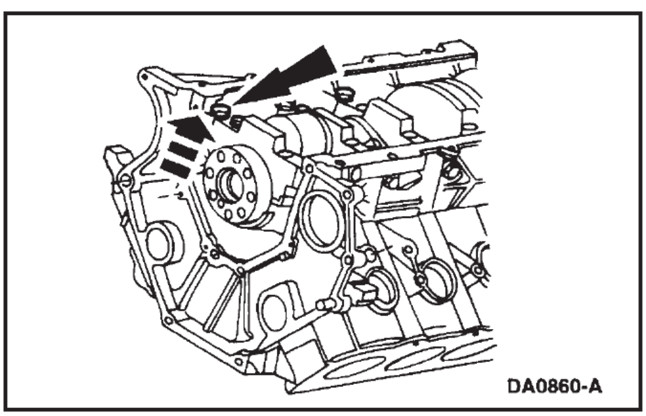
33. Repeat the previous steps until all ten piston and rod assemblies have been removed from the cylinder block.



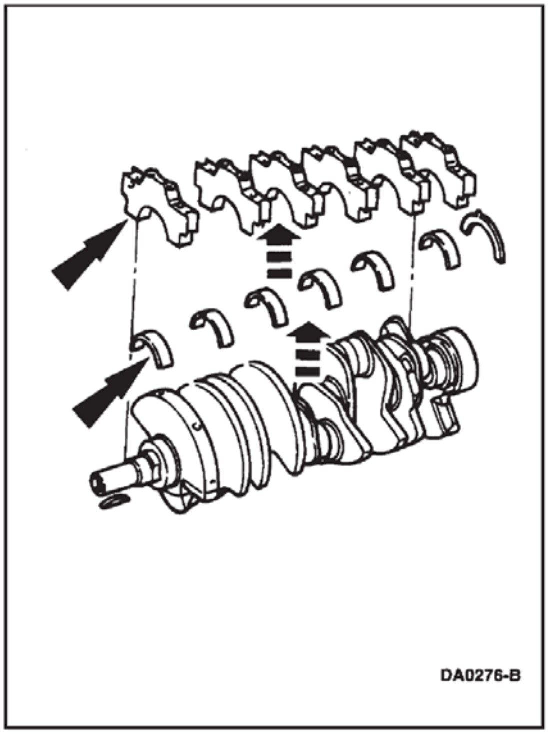
34. Remove and discard the twelve cross-mounted bolts.



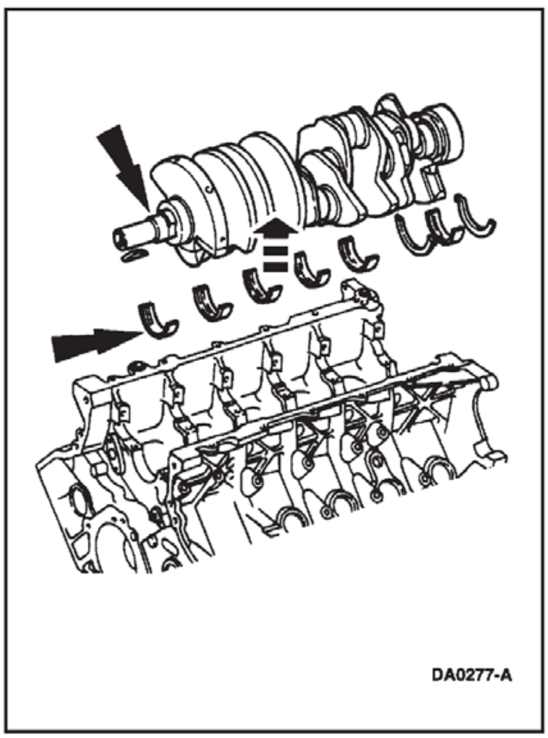
35. Remove the main bearing bolts and discard the bolts.



36. Remove the main bearing cap dowel pins.



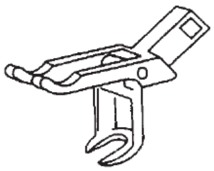
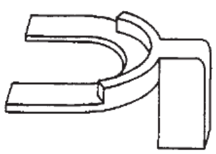
37. Remove the main bearing caps, the lower crankshaft main bearings (6333) and the thrust washer.



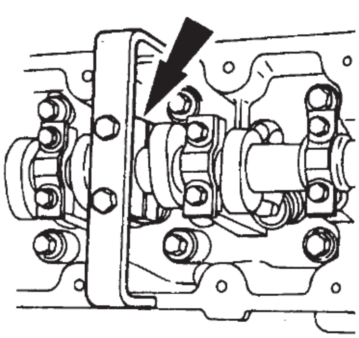
38. Remove the crankshaft and the crankshaft main bearings from the cylinder block.

Cylinder Head - Disassembly

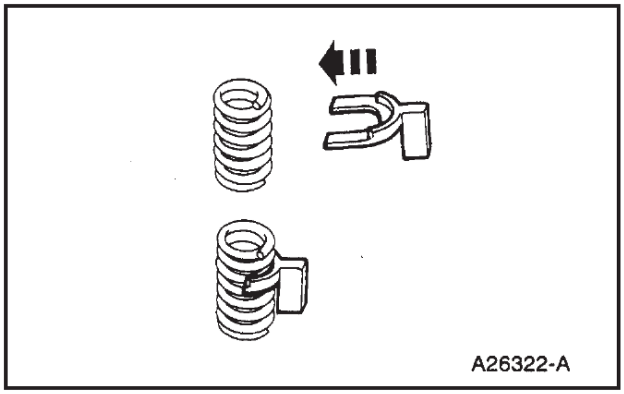
Special Tool(s)

 ST1330-A	Valve Spring Compressor 303-381 (T91P-6565-A)
 ST1331-A	Valve Spring Spacer 303-382 (T91P-6565-AH)
 ST1332-A	Valve Stem Seal Replacer 303-383 (T91P-6571-A)

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


DA1006-A

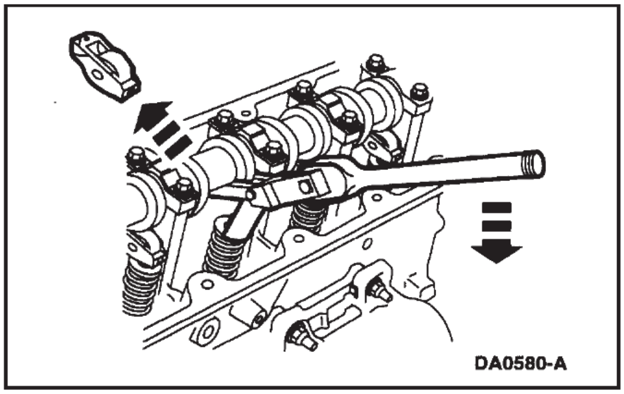
1. Remove the Camshaft Holding Tool from the camshaft(6250).



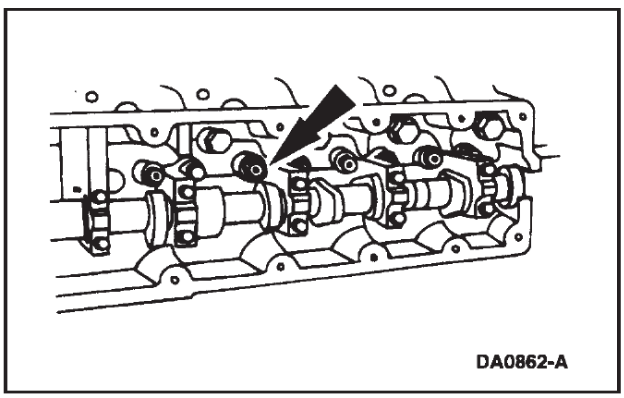
2. ⚠ **CAUTION: Do not remove the camshaft before removing the roller followers.**

   ⚠ **CAUTION: Place the cylinder head on a cardboard or wood surface to prevent damage to the joint face.**

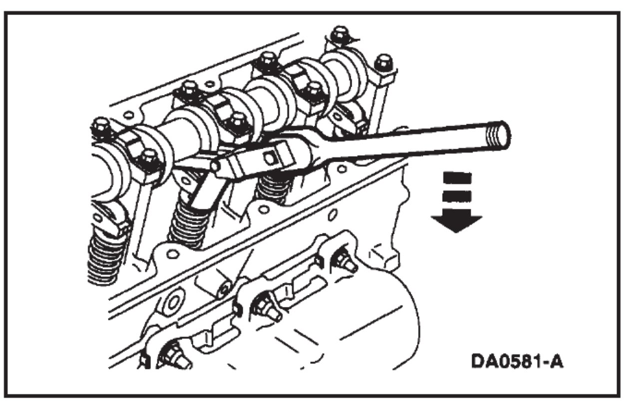
   Install the Valve Spring Spacer between the valve spring coils to prevent valve stem seal damage.



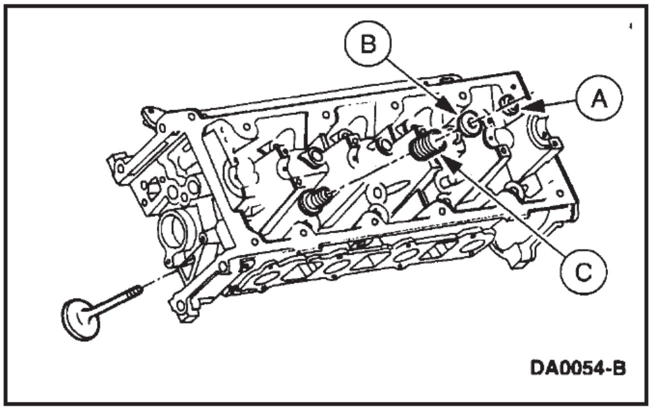
3. Use the Valve Spring Compressor to compress the valve springs (6513), and remove the roller followers.



4. Remove the hydraulic lash adjusters.



5. Use the Valve Spring Compressor to compress the valve springs.

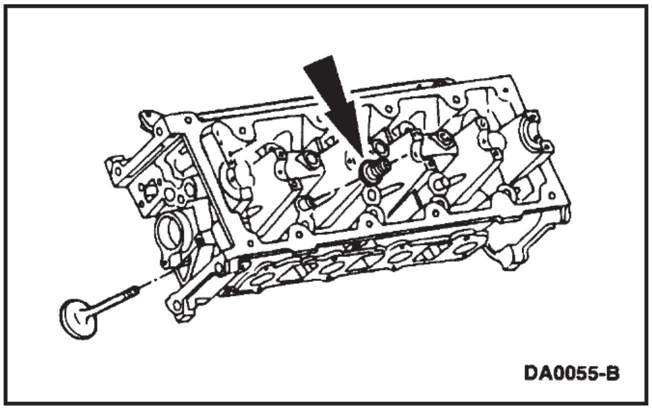


6. ⚠ **CAUTION: Keep the valves and the valve spring retainer keys (6518) in order so they can be installed in the same positions.**

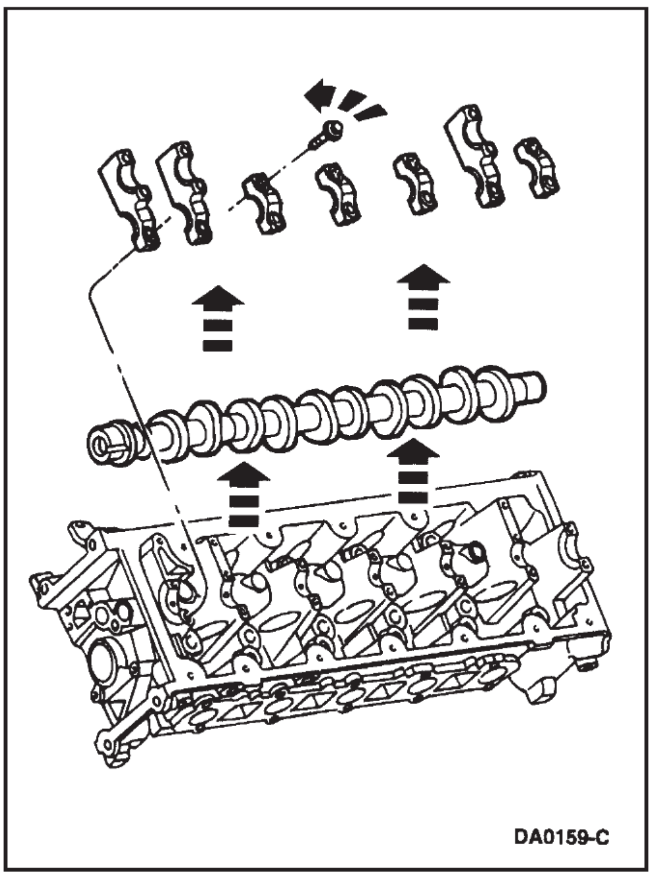
   NOTE: The 8-cylinder is shown. The 10-cylinder is similar.

   NOTE: Shown without camshaft for clarity.

   Remove the (A) valve spring retainer keys, the (B) valve spring retainers (6514), the (C) valve springs, and the valves.



7. Remove the valve stem seals (6571).



8. ⚠ **CAUTION: The caps must be marked for installation in their original location or damage to the engine may occur.**

   Remove the bolts, the bearing caps and the camshaft.

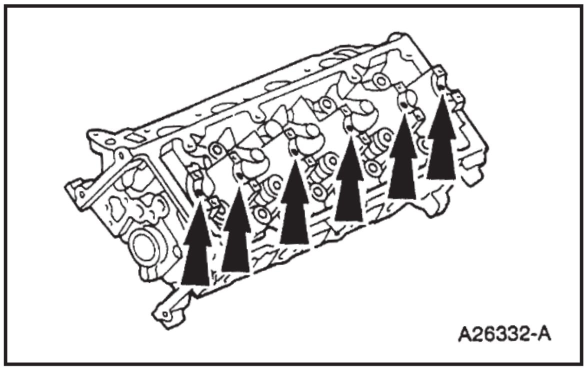
Cylinder Head - Assembly

1. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

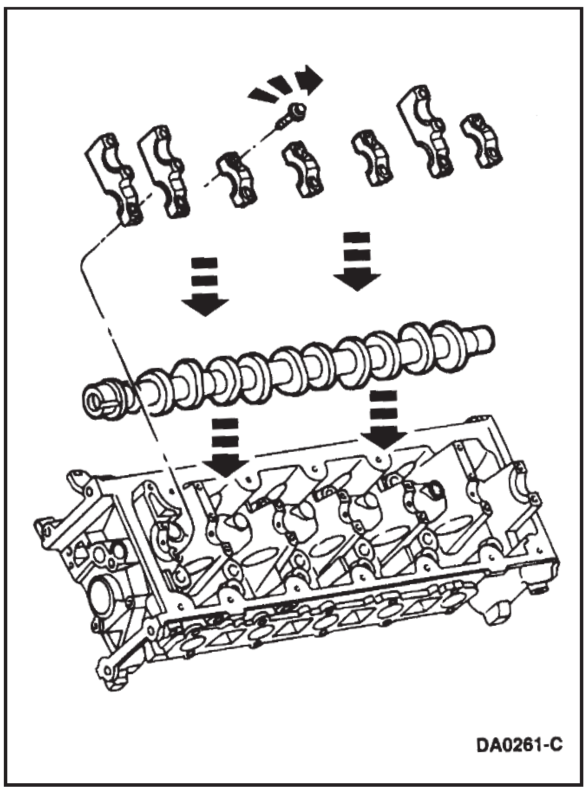
NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.



2. Lubricate the camshaft journals.

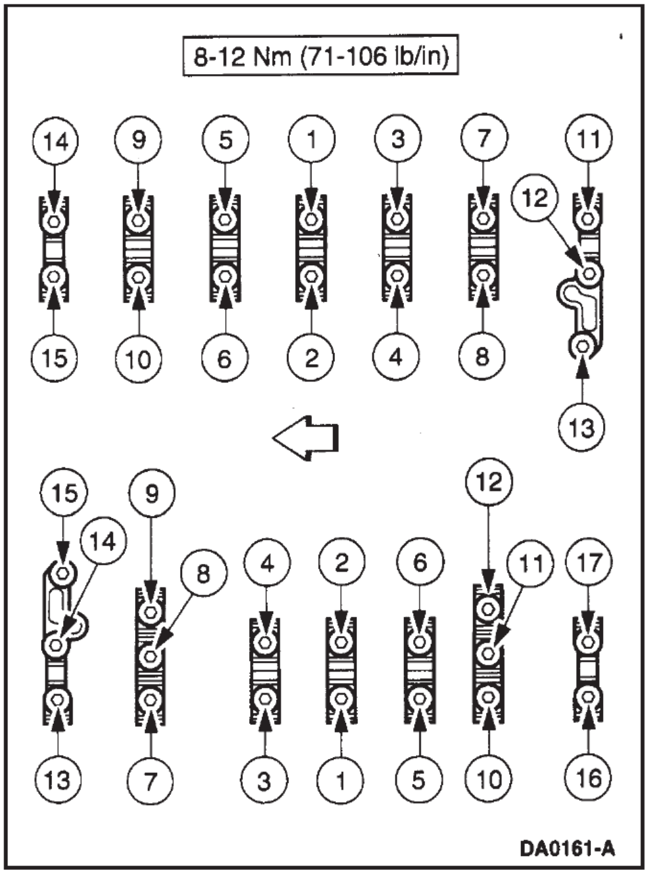
- Use Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-C.



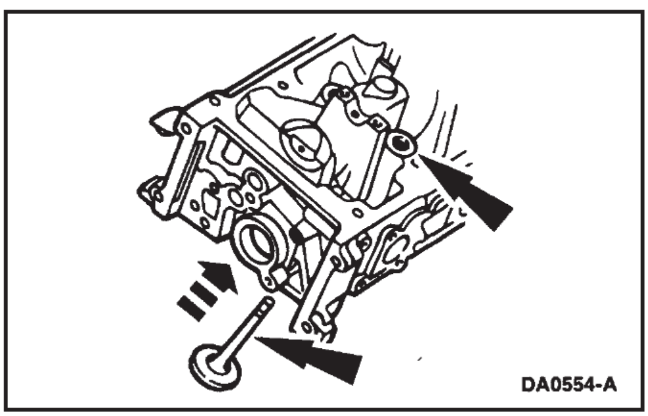
3. Install the camshaft and the camshaft bearing caps in their original location and the bolts.

- Lubricate and position the camshaft bearing caps.

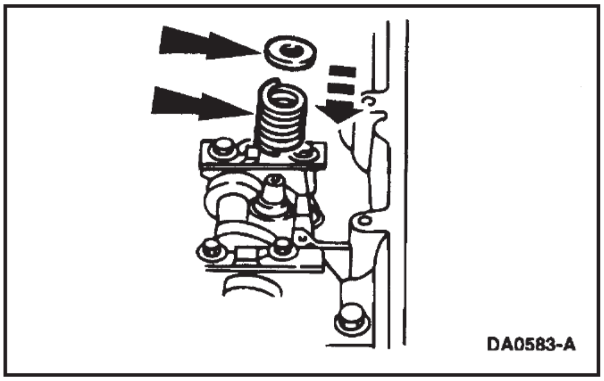
  --Use Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-G.



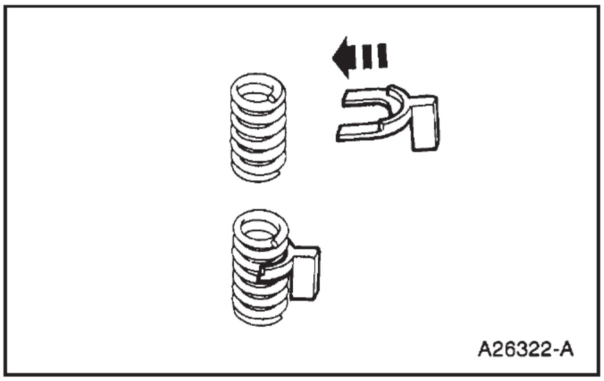
4. Tighten the bolts in the sequence shown.



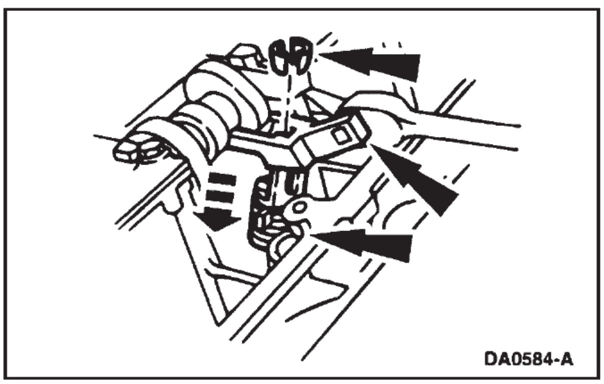
5. Install the valves in the valve guides located in the cylinder block (6010).



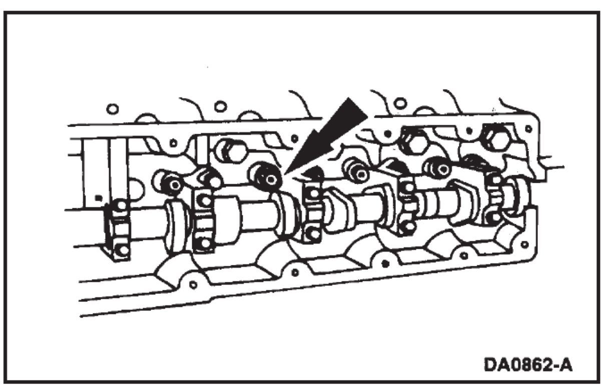
6. Install the valve spring and the valve spring retainer onto the valve.



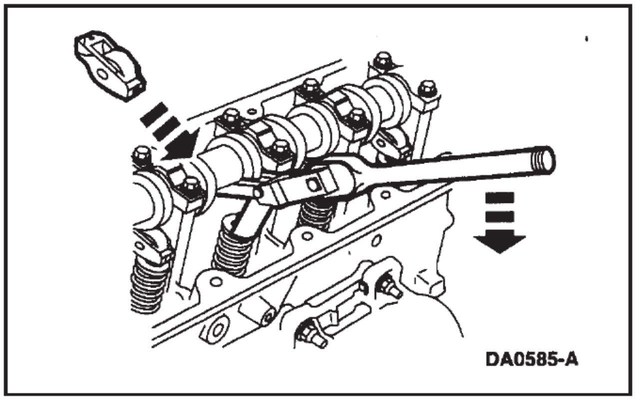
7. Install the valve spring spacer between the valve spring coils to prevent valve stem seal damage.



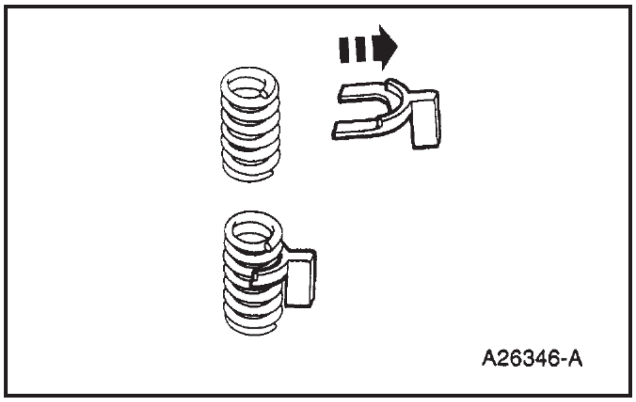
8. Use the Valve Spring Compressor to compress the valve spring, and install the valve spring retainer keys.



9. Install the hydraulic lash adjusters.



10. Install the roller followers.

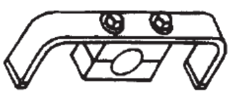
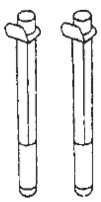
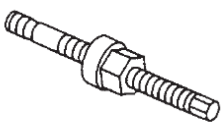
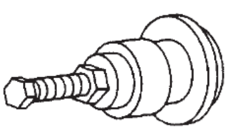


11. Remove the Valve Spring Spacer.

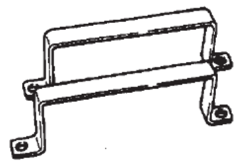
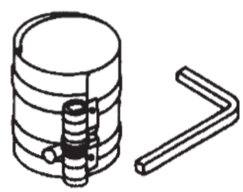
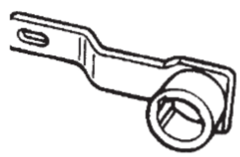
WSG-1068 ENGINE

Engine - Assembly

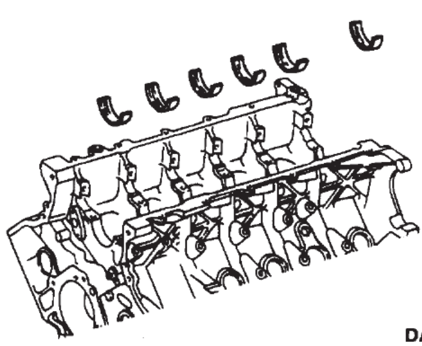
Special Tool(s)

	Camshaft Holding Tool 303-557 (T96T-6256-B) (2 Req'd)
 ST1337-A	Connecting Rod Guide Tool 303-442 (T93P-6136-A)
 ST1287-A	Crankshaft Damper Replacer 303-102 (T74P-6316-B)
 ST1328-A	Crankshaft Seal Replacer/Aligner 303-335 (T88T-6701-A)

Special Tool(s)

 ST1668-A	Lifting Handles (2 Sets Required) 303-572 (T97T-6000-A)
	Piston Ring Compressor 303-D032 (D81L-6002-C) or Equivalent
 ST1335-A	Crankshaft Holding Tool 303-448 (T93P-6303-A)

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

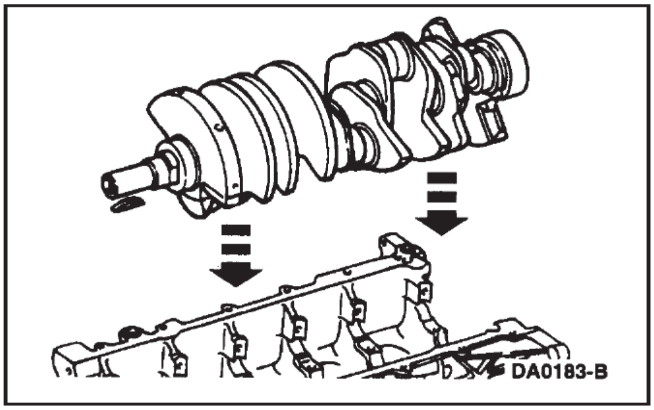


DA0876-A

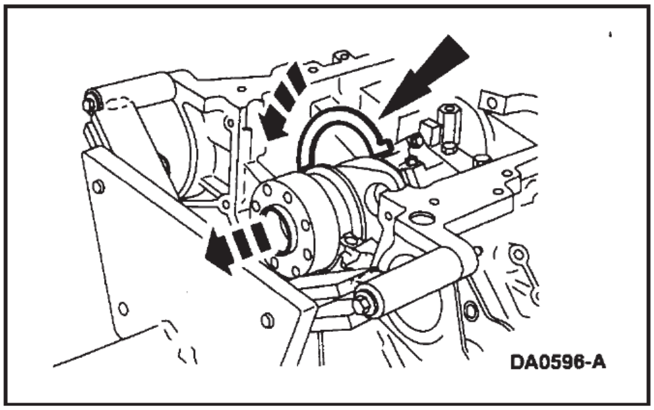
1. **NOTE:** Before assembling the cylinder block (6010), all seating surfaces must be free of chips, dirt, paint and foreign material. Also, make sure the coolant and oil passages are clear.

   Lubricate and install the crankshaft upper main bearings into the cylinder block.

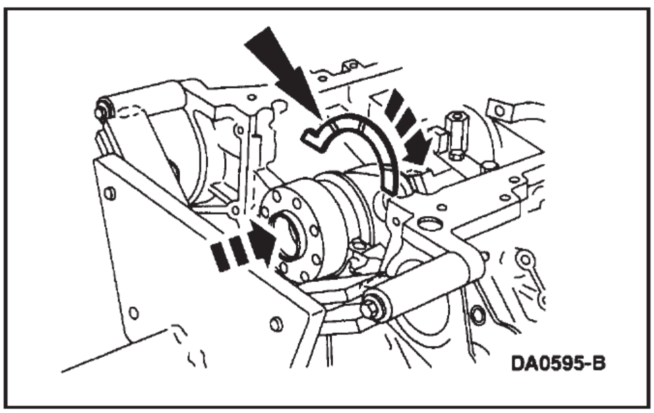
   - Use Super Premium SAE 5W30 Motor Oil D9AZ-19579-A or equivalent meeting Ford specification WSS-M2C153-G.



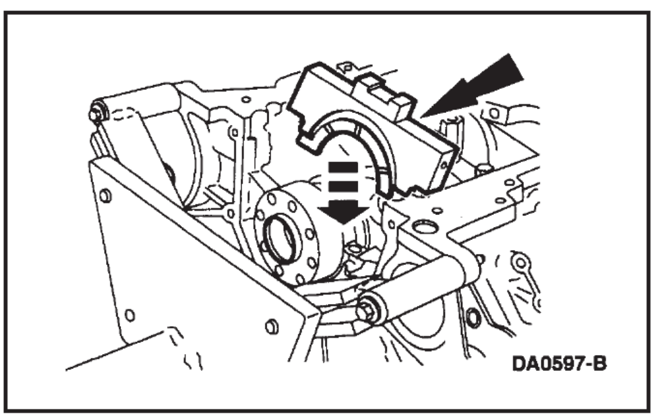
2. Install the crankshaft (6303) into the cylinder block and onto the upper crankshaft main bearings (6333).



3. Push the crankshaft rearward and install the rear lower crankshaft thrust washer (6334) at the back of the No. 6 main boss.

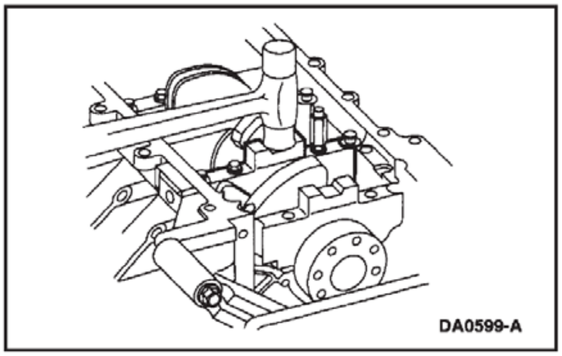


4. Push the crankshaft forward and install the front lower crankshaft thrust washer at the front of the No. 6 main boss.

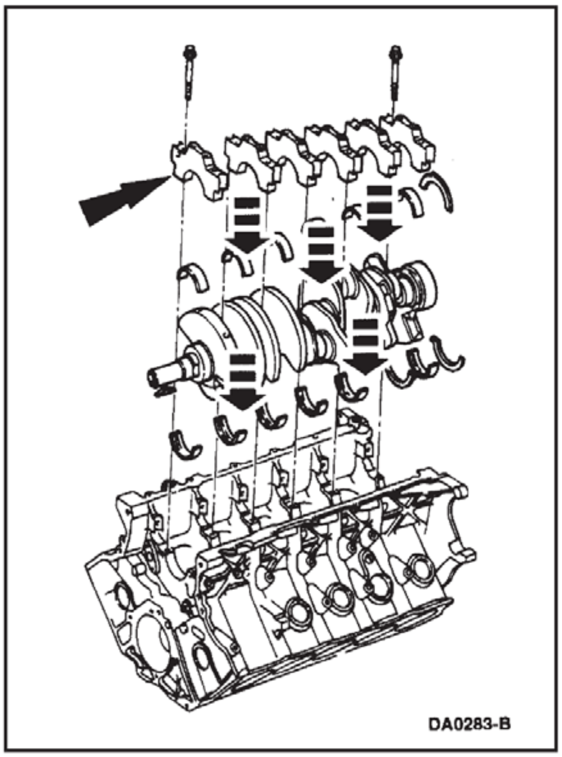


5. **NOTE:** To aid in assembly, apply petroleum jelly to the back of the crankshaft thrust washer.

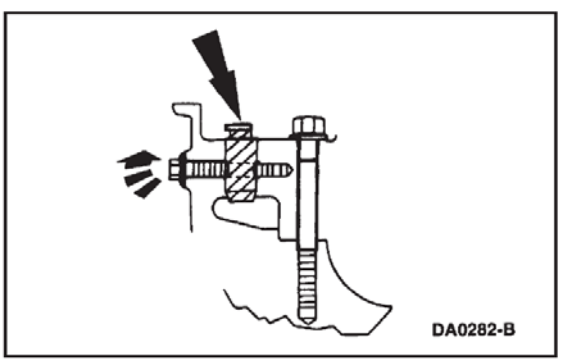
   Install the upper crankshaft thrust washer to the back side of the No. 6 main bearing cap, with oil grooves facing the crankshaft surface, and install the No. 6 rear main bearing cap.



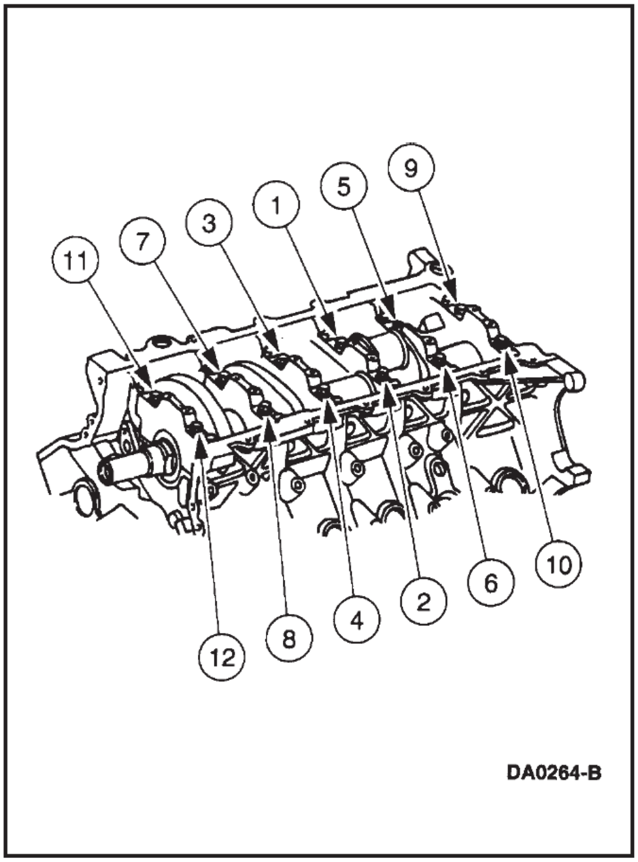
6. Install the No. 1 through No. 5 crankshaft lower main bearings into the main bearing caps. Locate the main bearing caps on the cylinder block and tap into place using a plastic or dead-blow hammer.



7. Install new main cap bearing bolts.

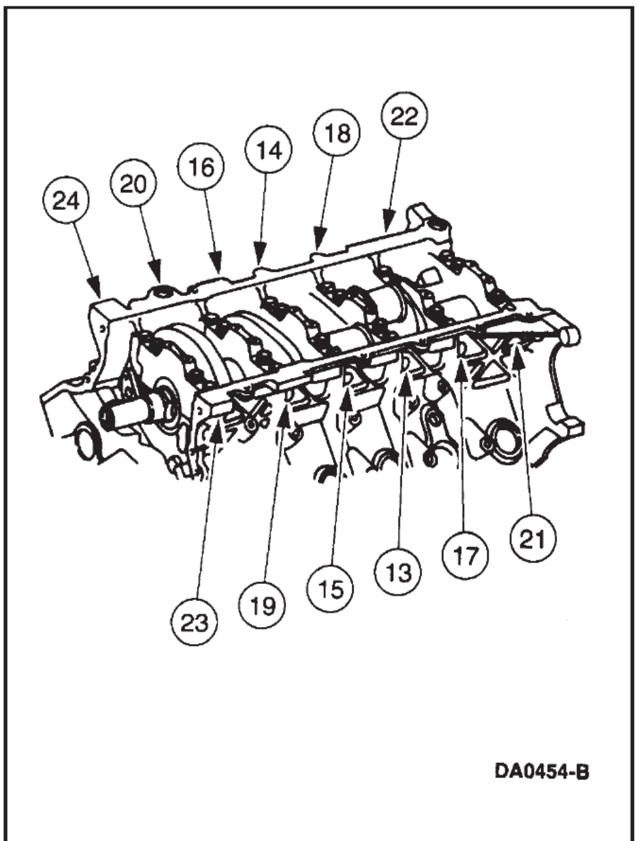


8. Install the ten dowel pins so that the flat sides face the crankshaft. Install the cross-mounted bolts.



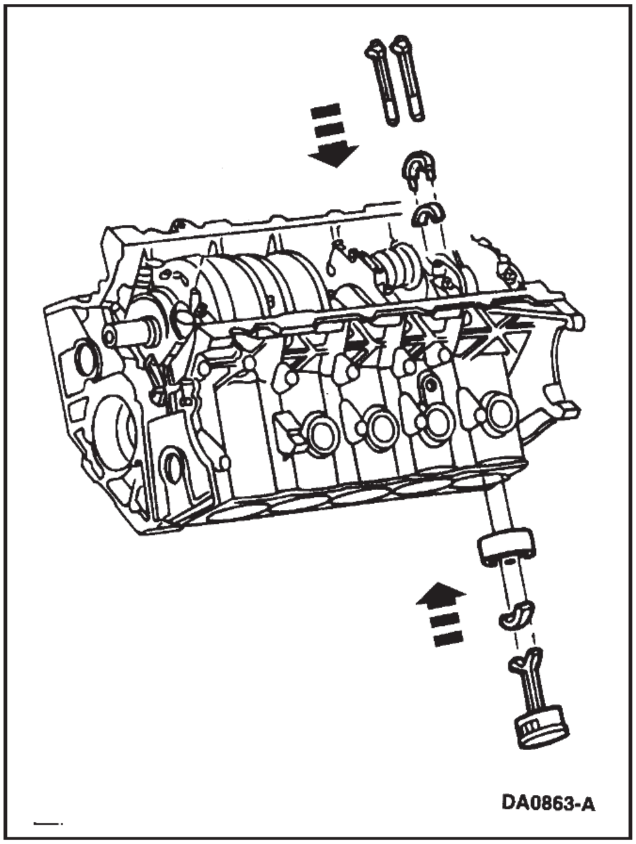
9. Tighten fasteners 1 through 12 in two stages in the sequence shown.

- Stage 1: Tighten to 37-43 Nm (22-32 lb/ft).
- Stage 2: Tighten an additional 85 degrees to 95 degrees.



10. Tighten fasteners 13 through 24 in two stages in the sequence shown.

- Stage 1: Tighten to 27-33 Nm (20-26 lb/ft).
- Stage 2: Tighten an additional 85 degrees to 95 degrees.



11. Use the Connecting Rod Guide Tool and Piston Ring Compressor to install the piston and connecting rod assembly.

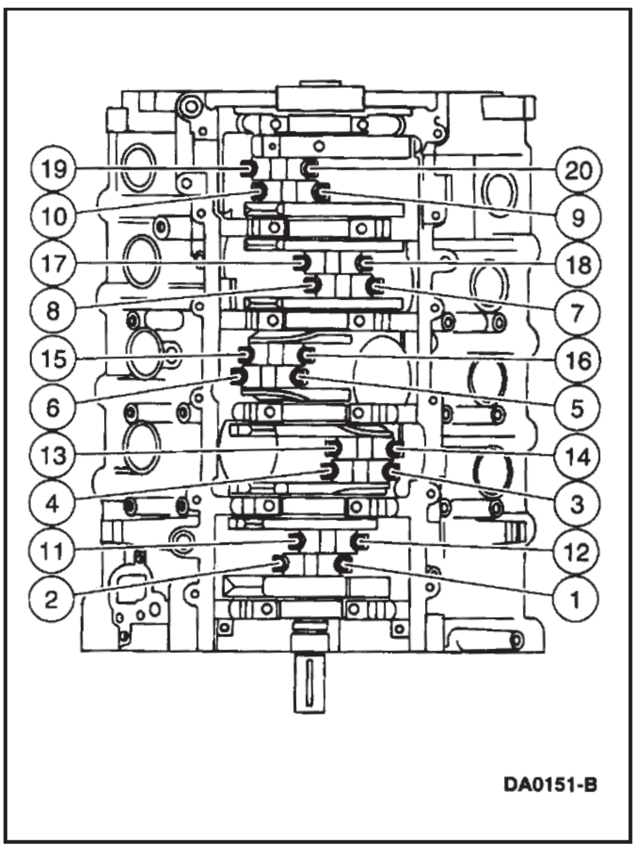
12. ⚠ **CAUTION: Do not scratch the cylinder walls or crankshaft journals with the connecting rod (6200).**

    Once the connecting rod is seated on the crankshaft journal, remove the connecting rod guide tools.

13. ⚠ **CAUTION: The rod cap installation must keep the same orientation as marked during disassembly.**

    NOTE: The connecting rod caps are of the “cracked’’ design and must mate with the connecting rod ends. Excessive bearing clearance will result if not mated properly.

    Install the connecting rod bearings, position the connecting rod cap and loosely install the two new bolts.

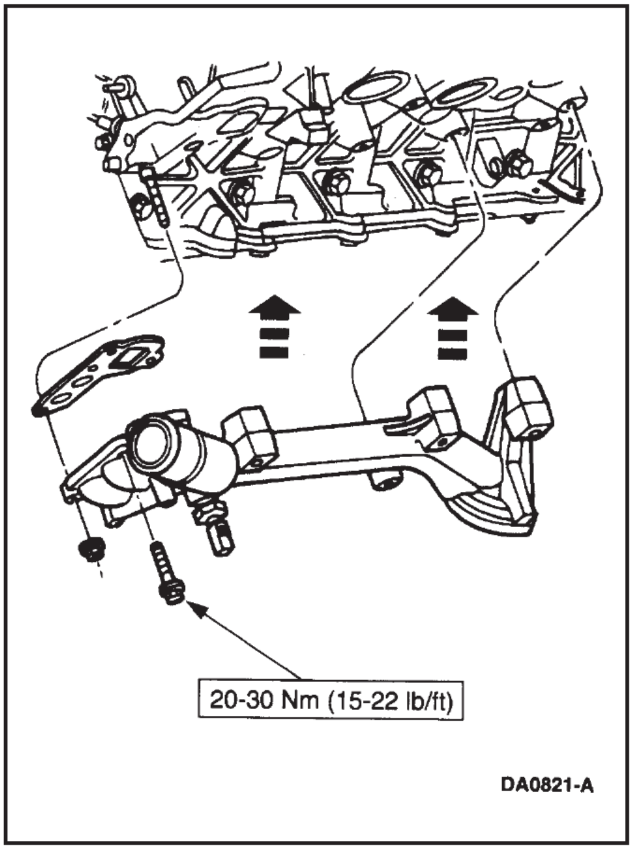


14. **NOTE:** Be sure to tighten the bolts in two stages.

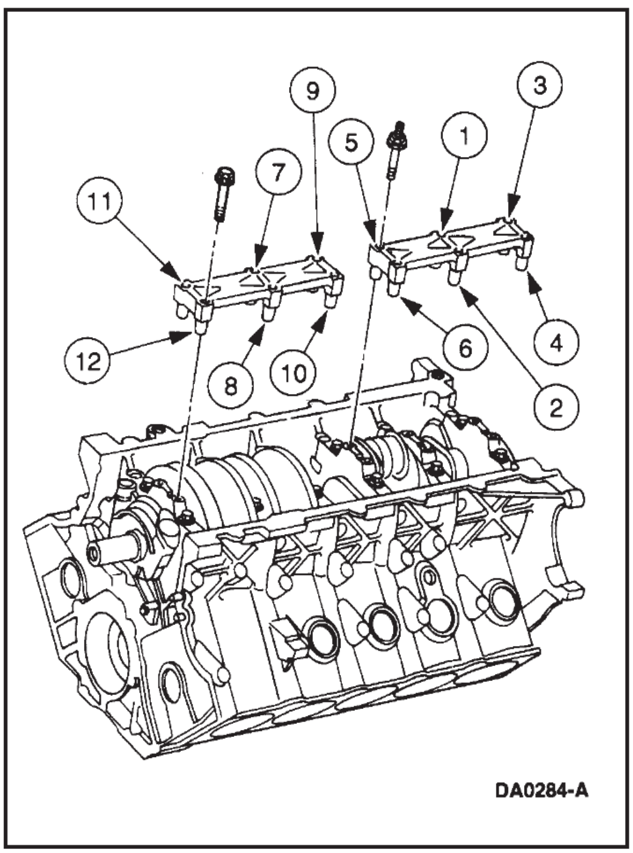
    Tighten the connecting rod bolts in the sequence shown.

- Stage 1: Tighten to 40-45 Nm (30-33 lb/ft).
- Stage 2: Tighten an additional 90 degrees to 120 degrees.

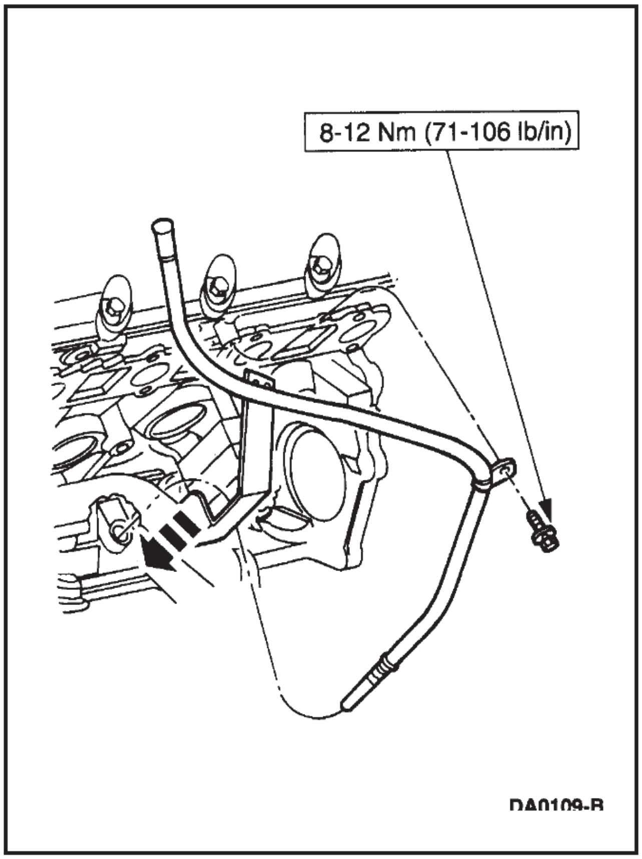
15. Rotate the crankshaft and repeat the procedure to position each connecting rod at bottom dead center until all bolts are tightened to specification.



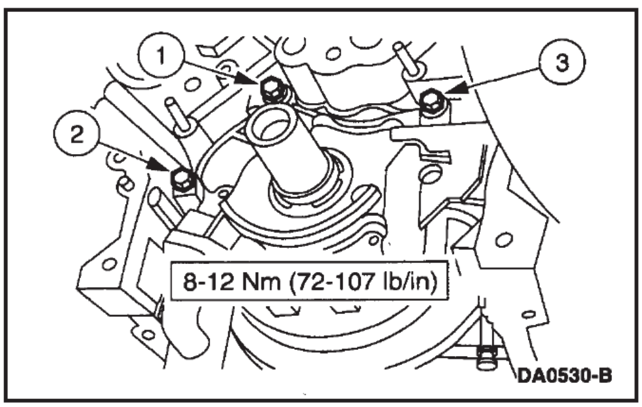
16. Install the oil filter adapter (6881).
17. Install the front engine support insulators (6038).



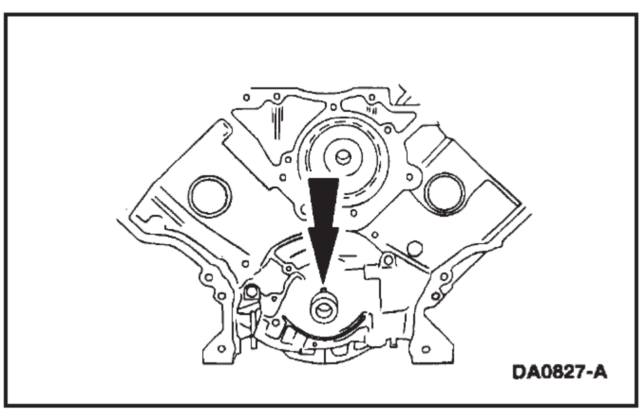
18. Install the lower crankshaft bearing supports and tighten fasteners in the sequence shown.



19. Install the oil level indicator tube (6754).

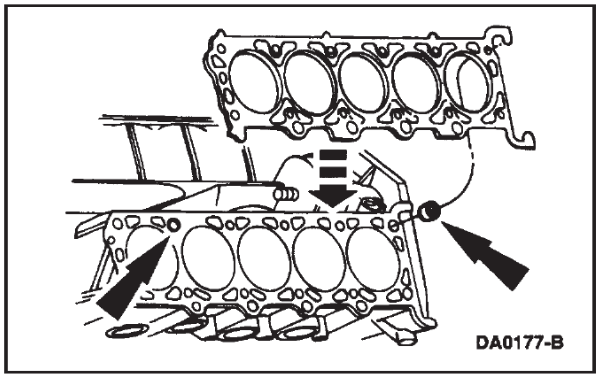


20. Position the oil pump (6600) and install the bolts loosely. Tighten the bolts in the sequence shown.

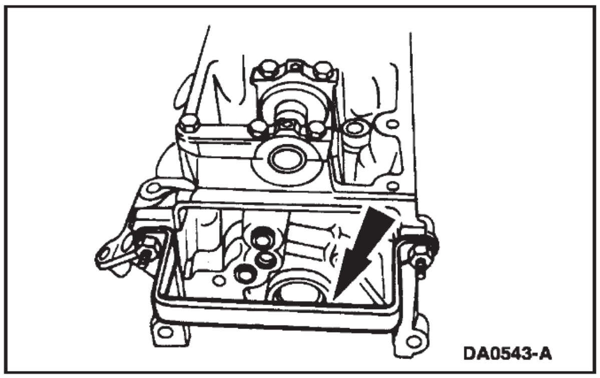


21. Rotate the crankshaft to position the keyway at 12 o'clock.

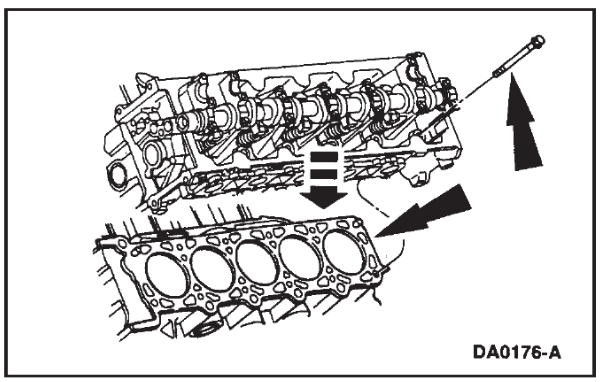
    NOTE: After crankshaft has been positioned, do not turn the crankshaft until instructed to do so.



22. Install the head gasket (6051) over the dowel pins.
23. Install the Camshaft Holding Tools.

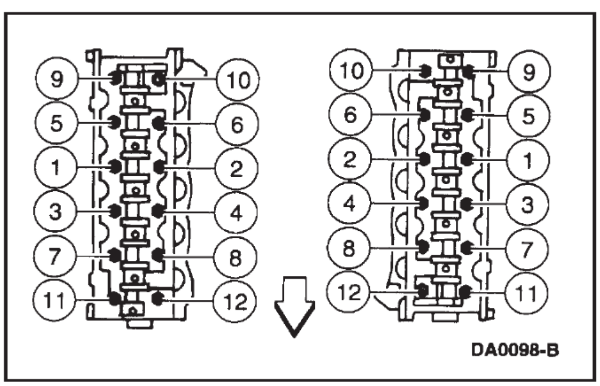


24. Install the Lifting Handles.



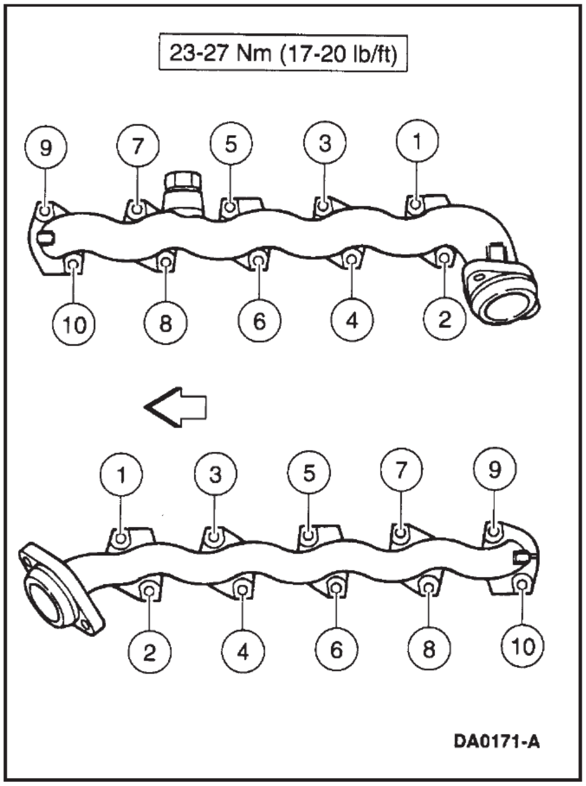
25. Install the cylinder head (6049) on the head gasket and loosely install new bolts.

- The LH is shown; the RH is similar.

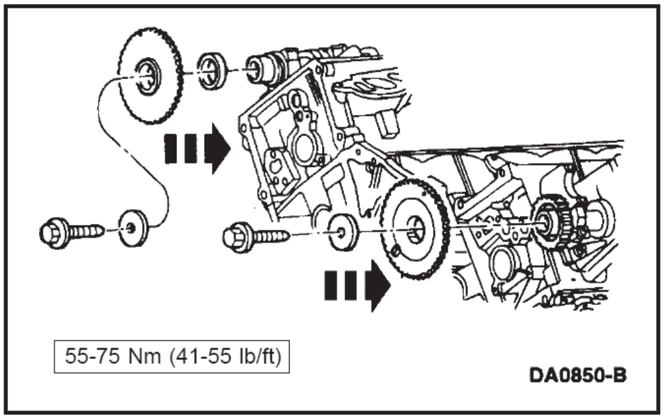


26. **NOTE:** Be sure to tighten the new bolts in three stages.

- Stage 1: Tighten to 37-43 Nm (27-32 lb/ft).
- Stage 2: Tighten an additional 85 degrees to 95 degrees.
- Stage 3: Tighten an additional 85 degrees to 95 degrees.

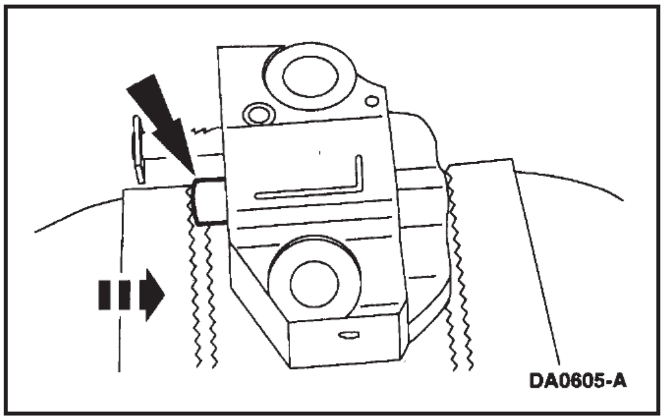


27. Install the left and right exhaust manifold gaskets (9448) and exhaust manifolds (9430). Loosely install the nuts. Tighten the nuts in the sequence shown.



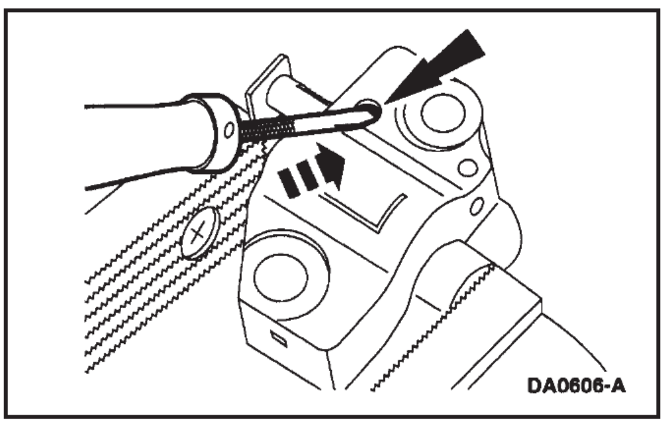
28. ⚠ **CAUTION: Timing chain procedures must be followed exactly or damage to valves and pistons (6108) will result.**

If removed, install the left and right camshaft sprockets (6256).

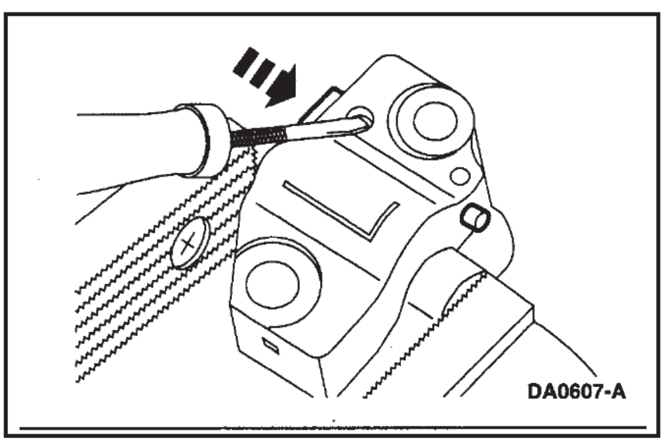


29. ⚠ **CAUTION: Do not compress the ratchet assembly. This will damage the ratchet assembly.**

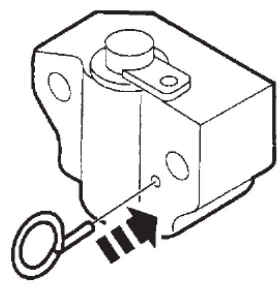
Compress the tensioner plunger, using an edge of a vise.



30. Using a small screwdriver or pick, push back and hold the ratchet mechanism.

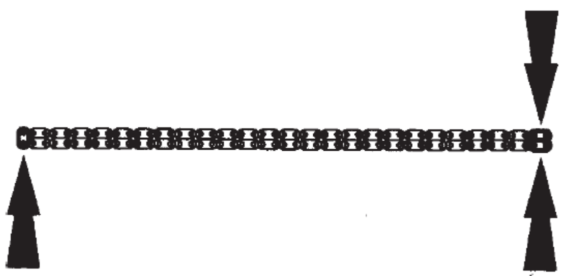


31. While holding the ratchet mechanism, push the ratchet arm back into the tensioner housing.



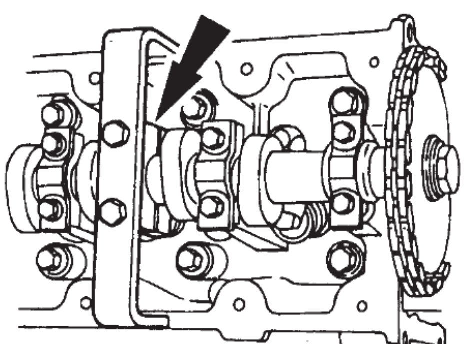
A26917-A

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



DA0528-A

33. If the copper links are not visible, mark two links on one end and one link on the other end to use as timing marks.



DA1006-A

34. Loosen the Camshaft Holding Tools on both camshafts (6250).

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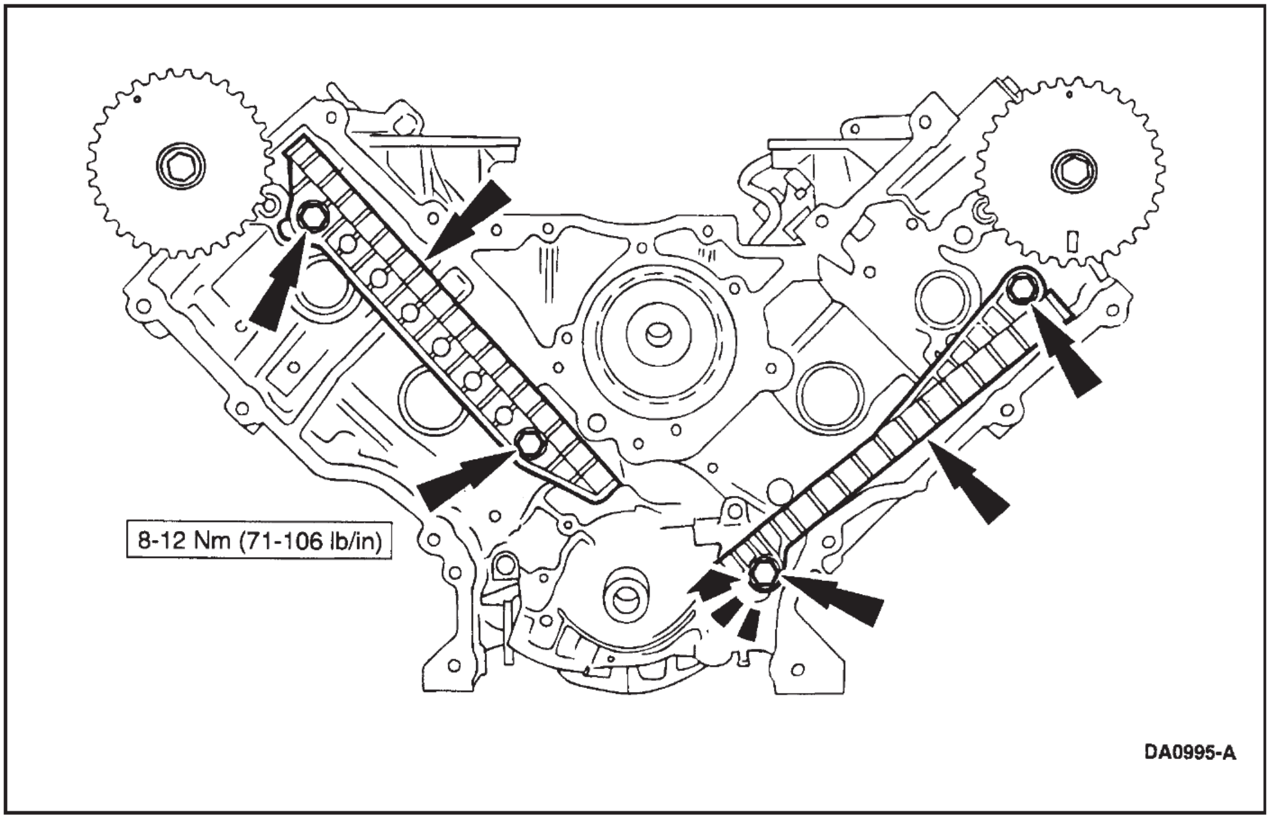
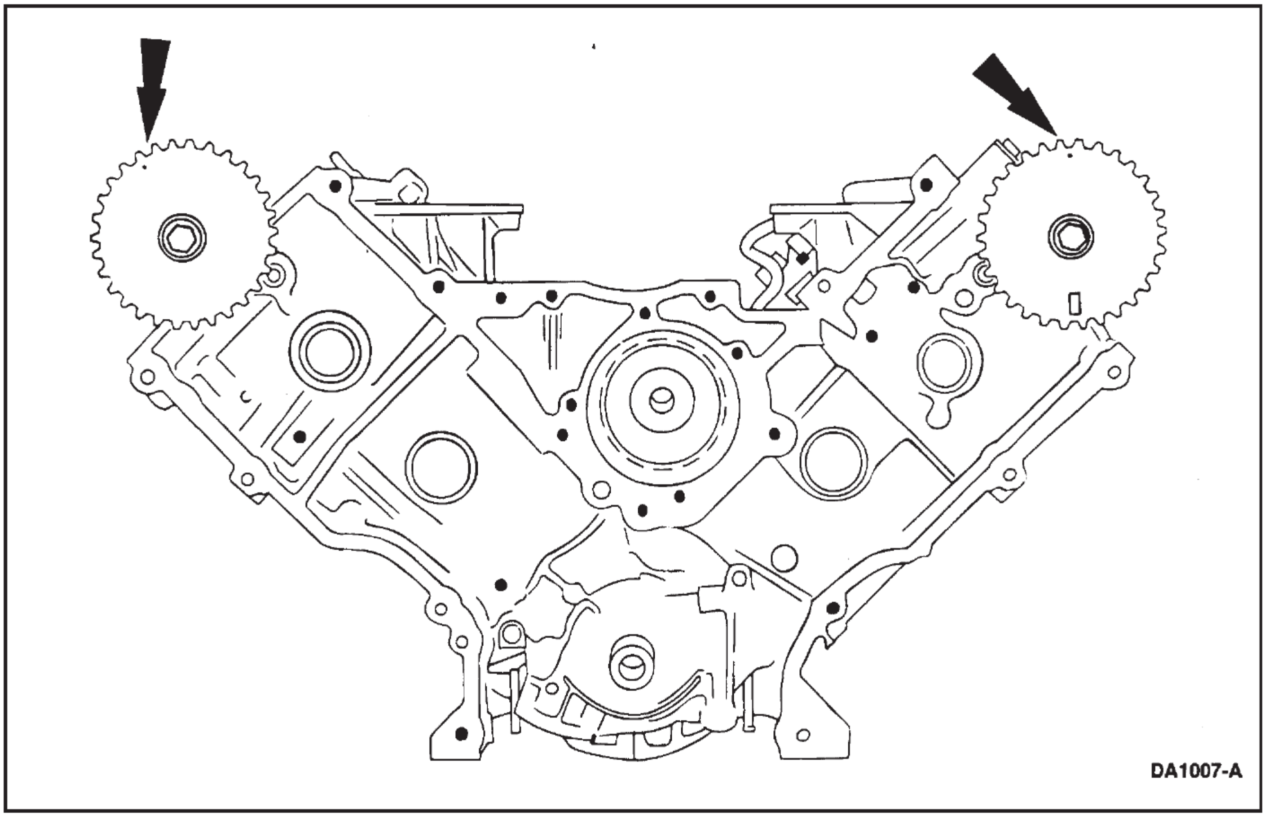
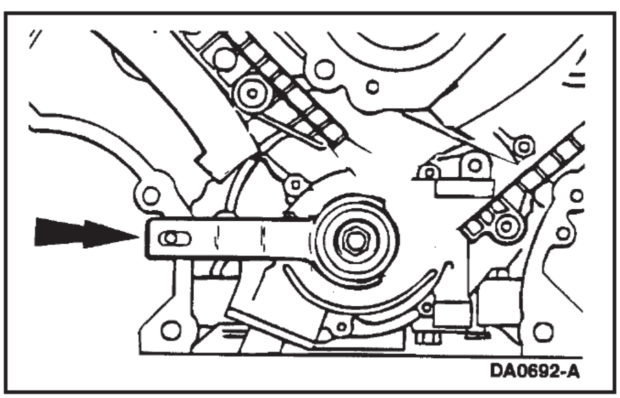


35. Install the timing chain guides (6K297).

36. Rotate the LH camshaft sprocket until the timing mark is approximately at 12 o'clock.

Rotate the RH camshaft until the timing mark is approximately at 11 o'clock. Tighten the Camshaft Holding Tools to maintain camshaft pre-positioning.



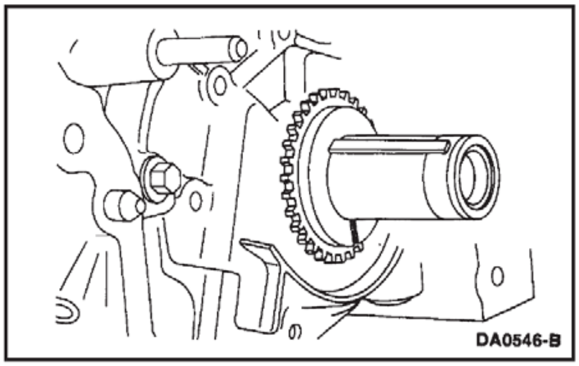


37. **CAUTION: Unless otherwise instructed, at no time when the timing chains (6268) are removed and the cylinder heads are installed is the crankshaft or camshaft to be rotated. Severe piston and valve damage will occur.**

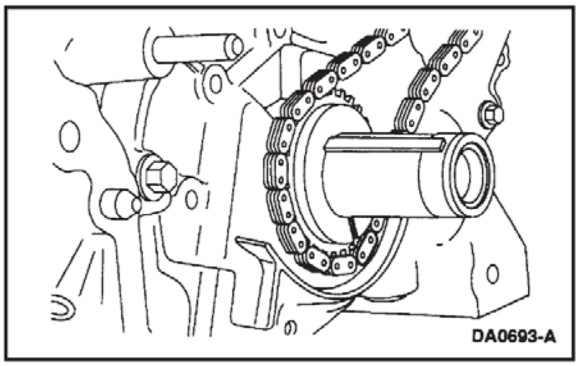
    CAUTION: Rotate the crankshaft counterclockwise only. Do not rotate past the position shown or severe piston or valve damage can occur.

    Position the crankshaft with the Crankshaft Holding Tool.

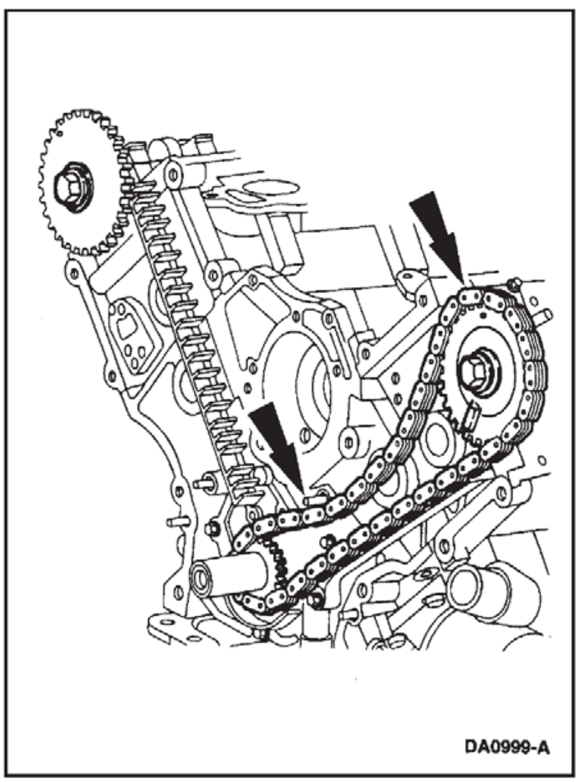
38. Remove the Crankshaft Holding Tool.



39. Position the inner crankshaft sprocket (6306) with the long hub facing outward.



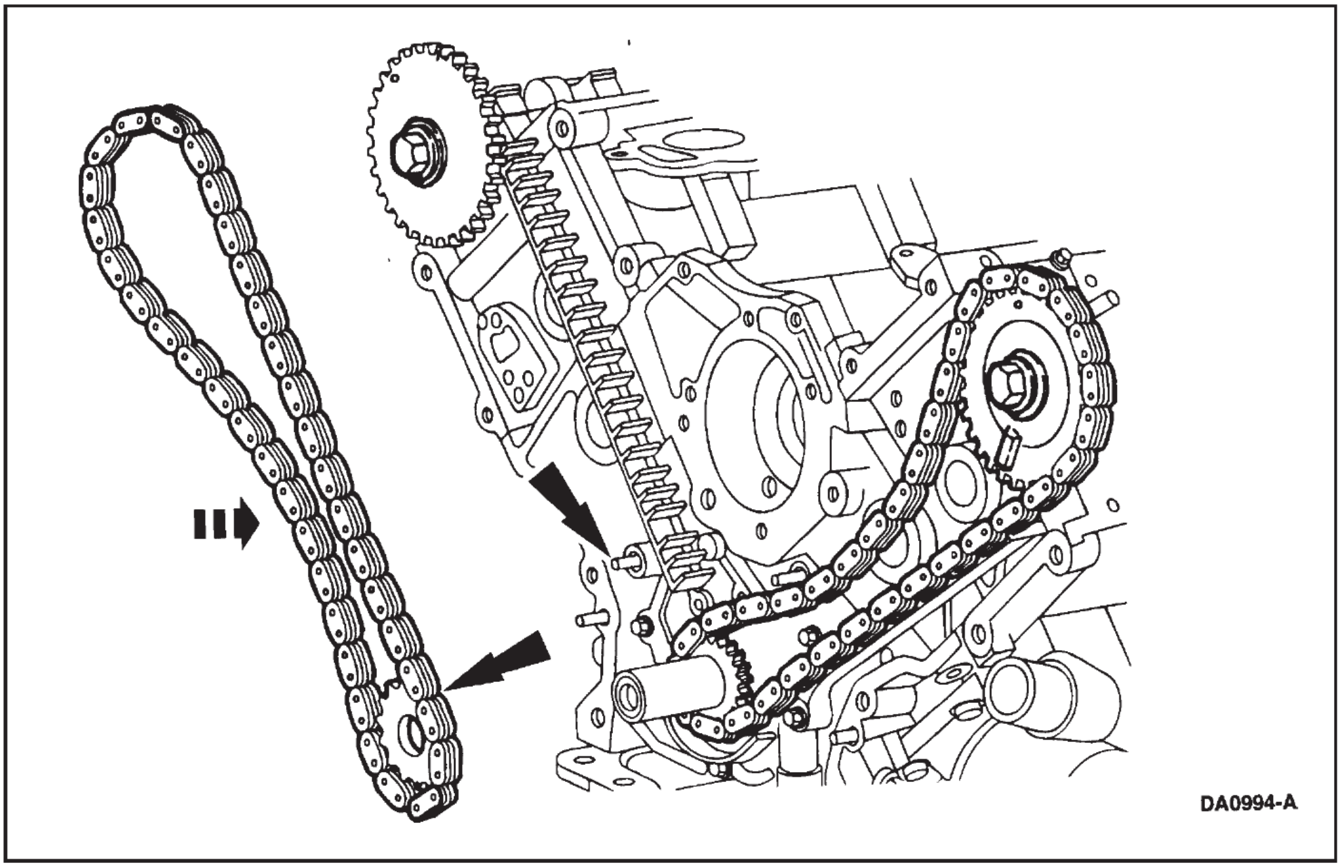
40. Install the LH timing chain/belt onto the crankshaft sprocket, aligning the one copper link on the timing chain with the slot on the crankshaft sprocket.



41. **NOTE:** Make sure the upper half of the timing chain is below the tensioner guide dowel. If necessary, use the Camshaft Holding Tool to adjust.

NOTE: If necessary, adjust the camshaft sprocket slightly to obtain timing mark alignment.

Position the timing chain on the camshaft sprocket with the two copper chain links and the camshaft sprocket timing mark aligned.



42. **CAUTION: The camshaft sprocket can jump time if the Camshaft Holding Tool is not secured.**

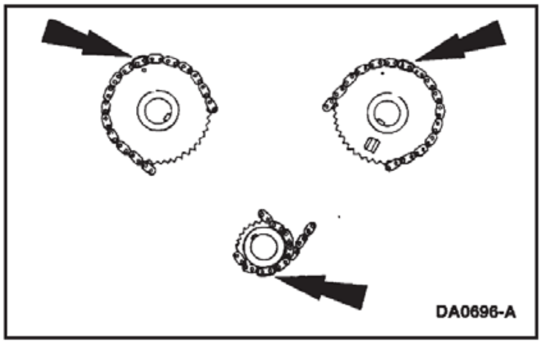
    NOTE: Be sure the copper chain link and the crankshaft sprocket timing mark are aligned.

    NOTE: The lower half of the timing chain must be positioned above the dowel.

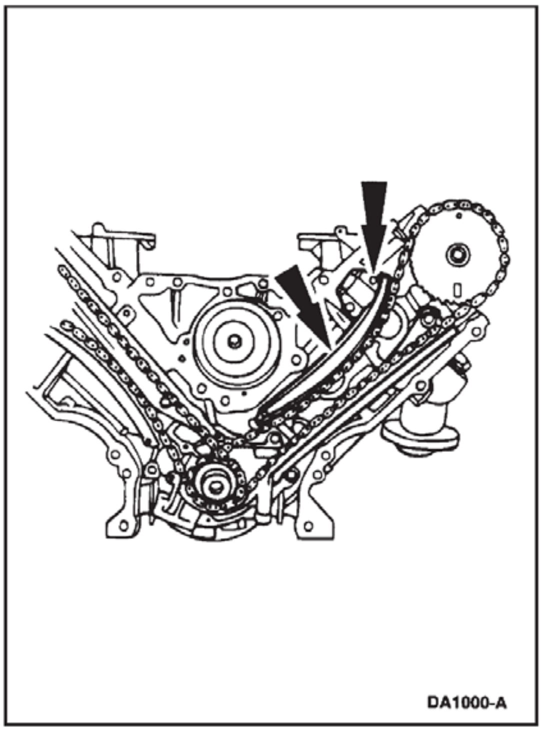
    Position the outer camshaft sprocket and the RH timing chain with the long hub of the camshaft sprocket facing inward.

43. **NOTE:** If necessary, adjust the camshaft sprocket slightly to obtain timing mark alignment.

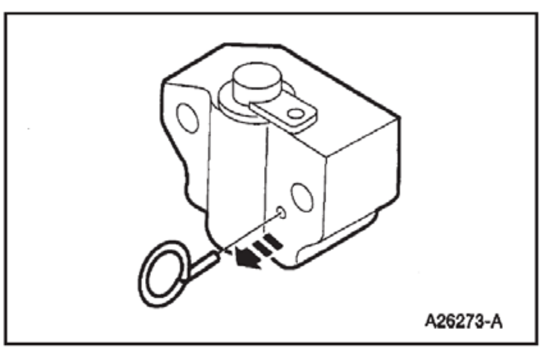
    Position the RH timing chain on the camshaft sprocket. Make sure the two copper-colored links align with the camshaft sprocket timing mark.



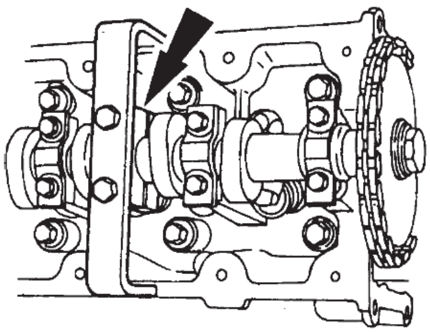
44. As a post-check, verify timing mark alignment.



45. Position the LH and RH timing chain tensioner arm (6L253) on the dowel pins. Position the timing chain tensioners (6L266), and install the bolts.



46. Remove both the RH and LH retaining pins from the timing chain tensioner assembly.

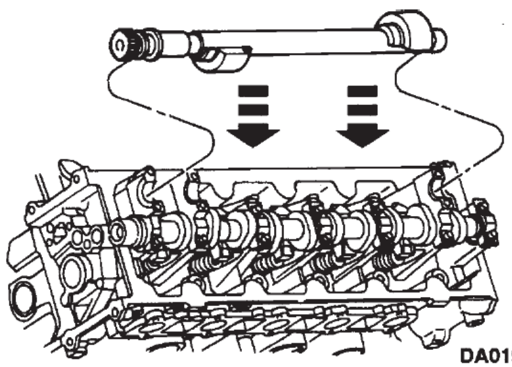


DA1006-A

47. Remove the Camshaft Holding Tools from the camshafts.

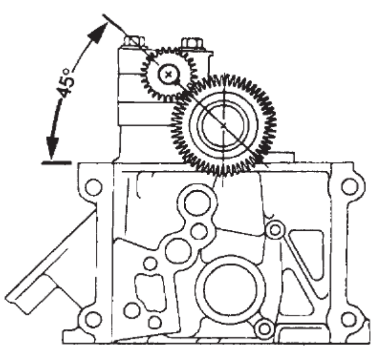
48. Lubricate the balance shaft journals with engine oil.

- Use Super Premium SAE 5W30 Motor Oil XO-5W30-QSP or equivalent meeting Ford specification WSS-M2C153-G.



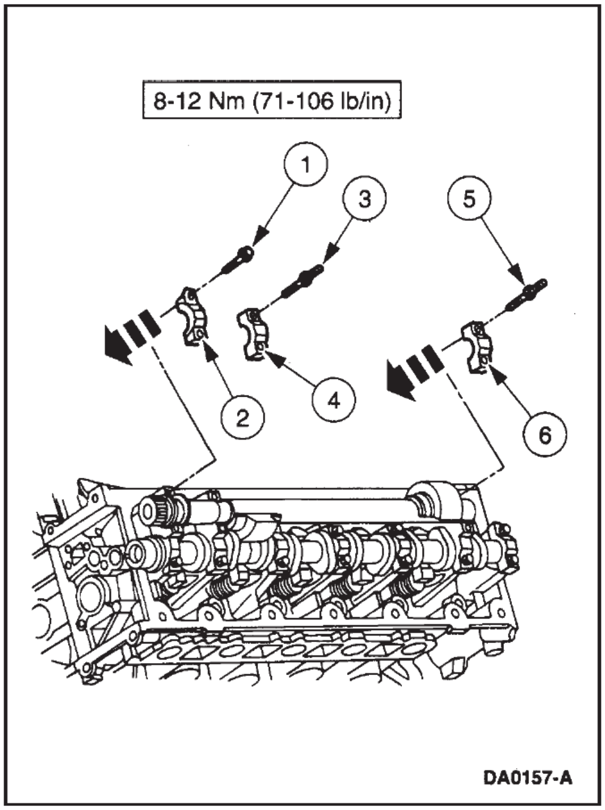
DA0197-A

49. Position the balance shaft on the journals.



DA0160-A

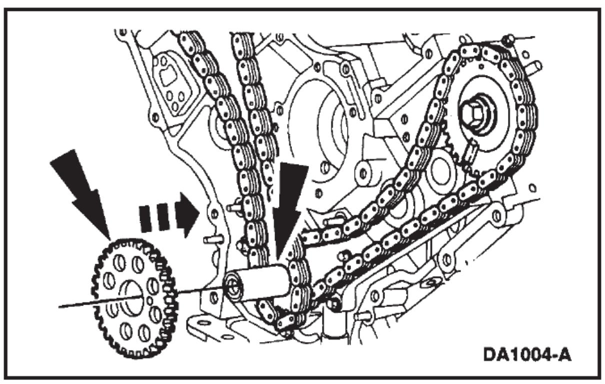
50. Align the balance shaft timing marks as shown.



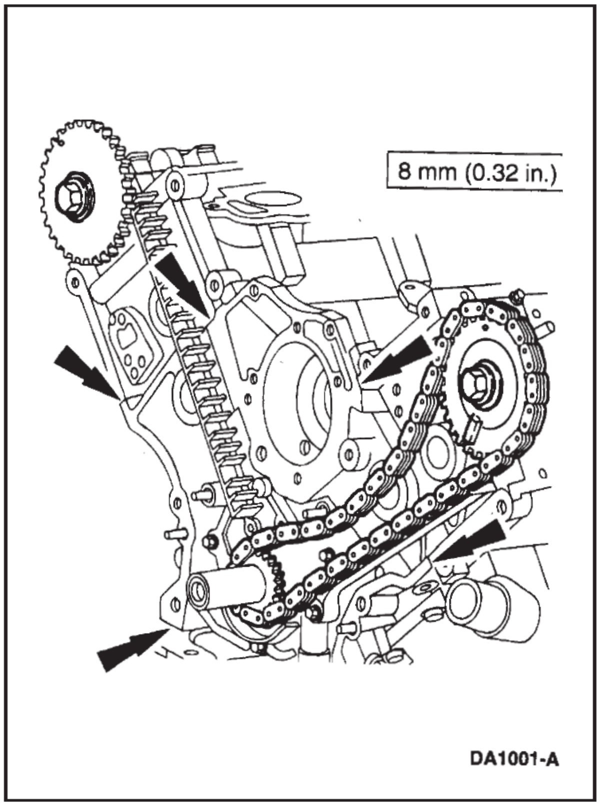
51. Lubricate the balance shaft journals with engine oil.

- Use Super Premium SAE 5W30 Motor Oil XO-5W30-QSP or equivalent meeting Ford specification WSS-M2C153-G.

52. Install the bearing caps and the bolts. Tighten the bolts in the sequence shown.



53. Position the crankshaft sensor ring.



54. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

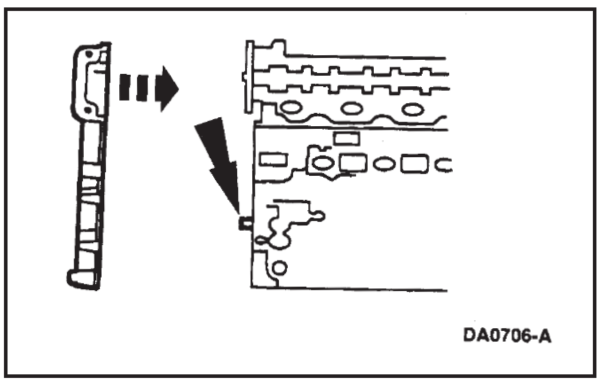
- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

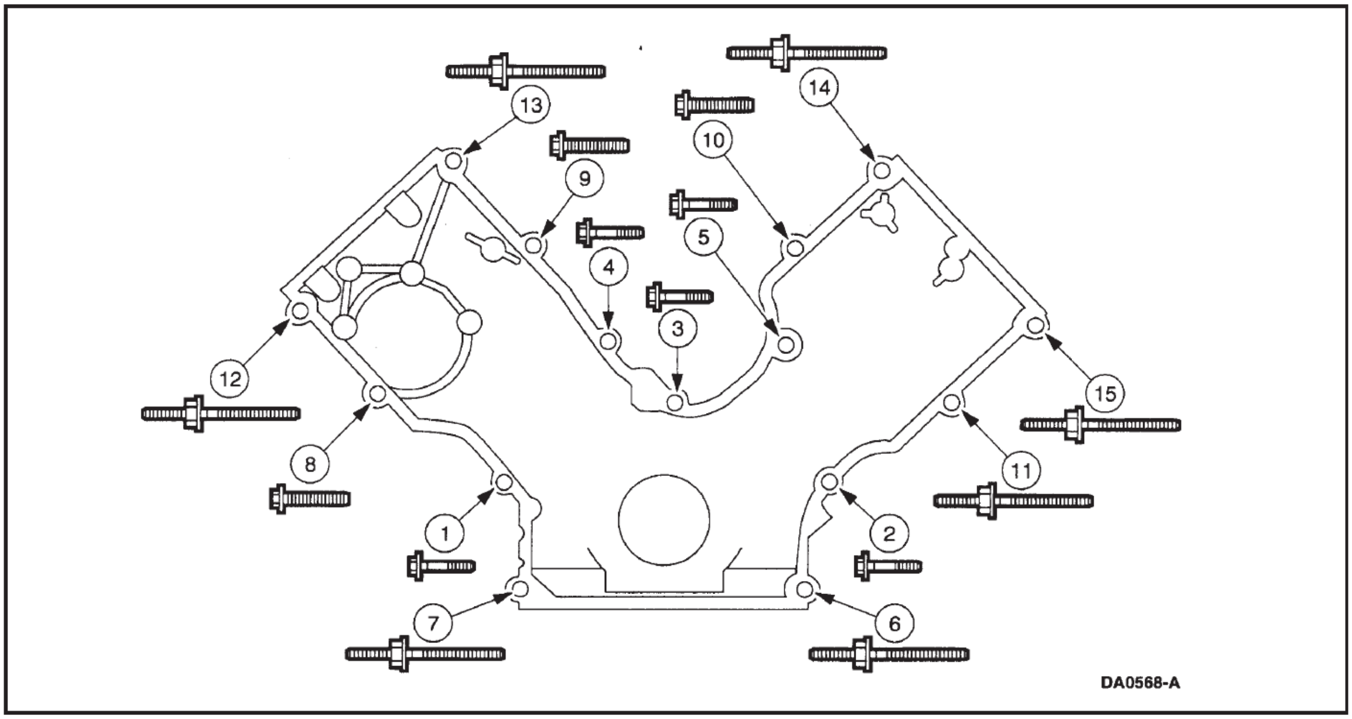
- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

NOTE: The RH timing chain is removed for clarity.

- Apply a bead of silicone along the cylinder headto-block surface and the oil pan-to-cylinder block surface as specified.



55. Install a new engine front cover gasket (6020) onto the engine front cover (6019), then position the engine front cover on the front cover to cylinder block dowel (6C002).



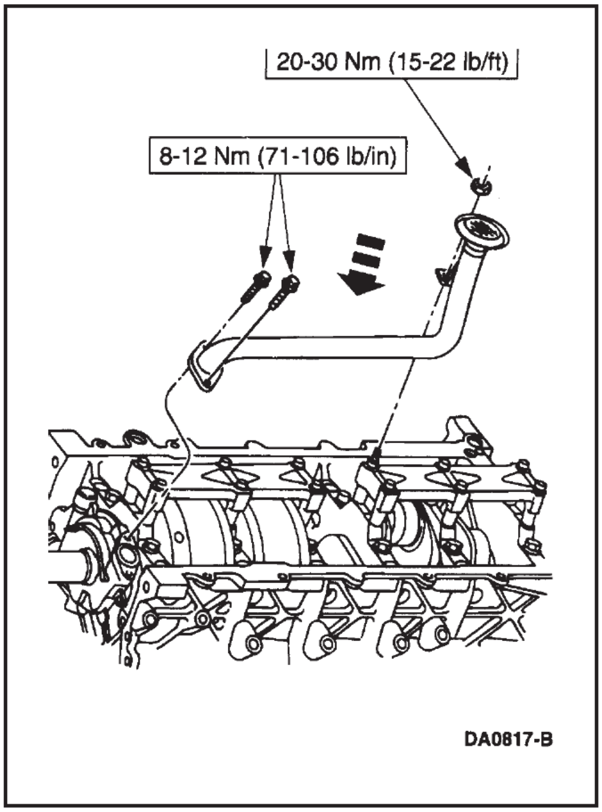
56. Loosely install the fasteners.

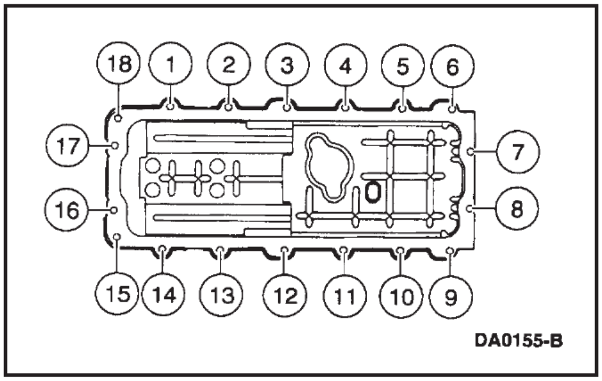
Item	Part Number	Description
1	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
2	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
3	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
4	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
5	N806177	Bolt, Hex Flange Head Pilot, M8 x 1.25 x 53
6	N808529	Stud, Hex-Head Pilot, M10 x 1.5 x 1.5 x 103.1
7	N808529	Stud, Hex-Head Pilot, M10 x 1.5 x 1.5 x 103.1
8	N808142	Screw and Washer, Hex Pilot, M10 x 1.5 x 57.5

Item	Part Number	Description
9	N808142	Screw and Washer, Hex Pilot, M10 x 1.5 x 57.5
10	N808142	Screw and Washer, Hex Pilot, M10 x 1.5 x 57.5
11	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
12	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
13	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
14	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6
15	N808140	Stud and Washer, Hex-Head Pilot, M10 x 1.5 x M8 x 1.25 x 109.6

57. Tighten the fasteners in two stages; refer to the preceding illustration.

- Stage 1: Tighten fasteners 1 through 5 to 20-30 Nm (15-22 lb/ft).
- Stage 2: Tighten fasteners 6 through 15 to 40-55 Nm (30-41 lb/ft).





58. Position the oil pump screen cover and tube (6622) and install the bolts and nut.

59. **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

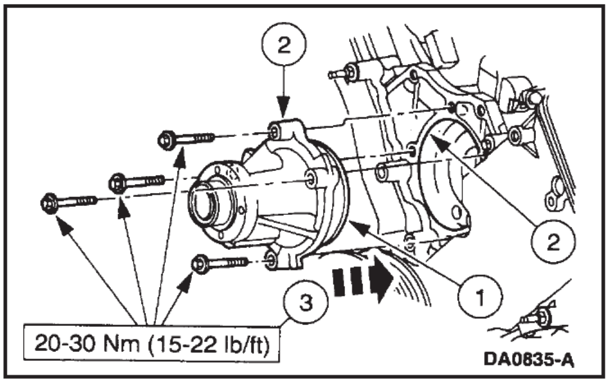
NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.
- Apply a bead of silicone where the rear crankshaft seal retainer plate and the front cover meets the cylinder block.
- Use Silicone Gasket and Sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

60. **NOTE:** Be sure to tighten the bolts in three stages. Install the oil pan (6675). Tighten the bolts in the sequence shown.

- Stage 1: Tighten to 2 Nm (18 lb/in).
- Stage 2: Tighten to 20 Nm (15 lb/ft).
- Stage 3: Tighten an additional 60 degrees.

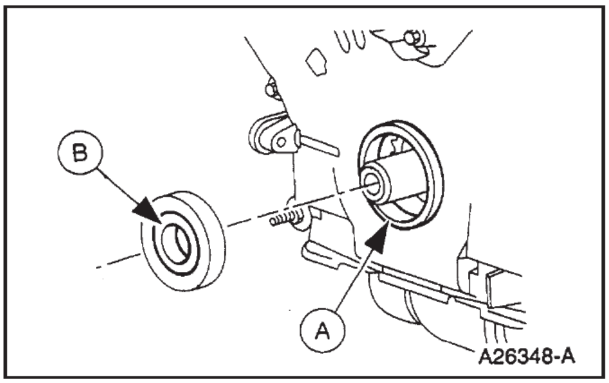
61. Install the oil drain plug. 11-16 Nm (98-143 lb/in).



62. **CAUTION: Do not rotate the water pump housing once the water pump (8501) has been positioned in the cylinder block. Damage to the O-ring seal will occur.**

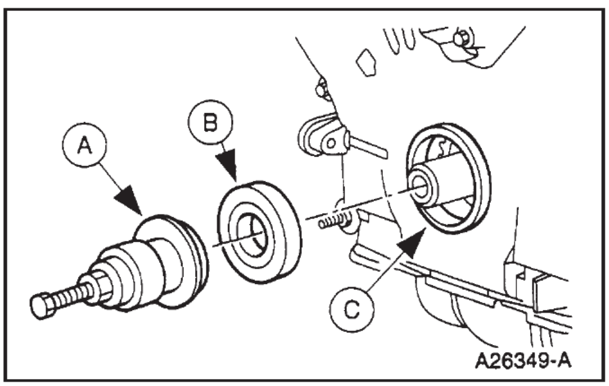
Install the water pump.

1. Lubricate the new O-ring seal using Premium Cooling Fluid E2FZ-19549-AA or equivalent meeting Ford specification ESE-M97B44-A and install the O-ring seal onto the water pump.
2. Position the water pump into the cylinder block.
3. Install the water pump retaining bolts.

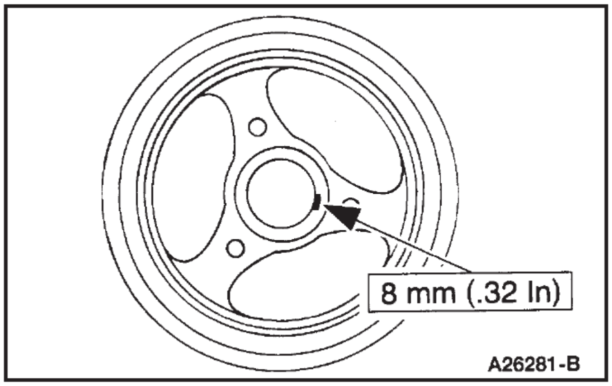


63. Lubricate the (A) engine front cover and the (B) front oil seal inner lip.

- Use Super Premium SAE 5W30 Motor Oil XO-5W30-QSP or equivalent meeting Ford specification WSS-M2C153-G.



64. Use the (A) Crankshaft Seal Replacer/Aligner to install the (B) crankshaft front seal (6700) into the (C) engine front cover.



65. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

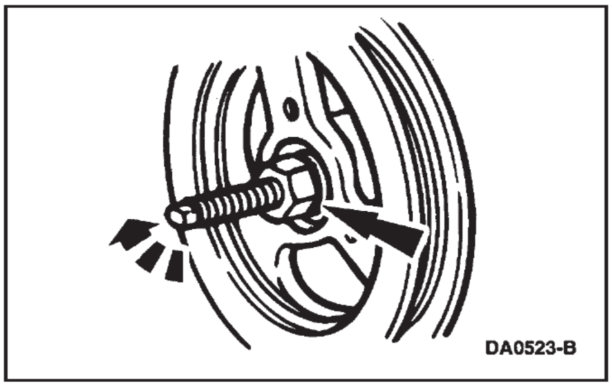
- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

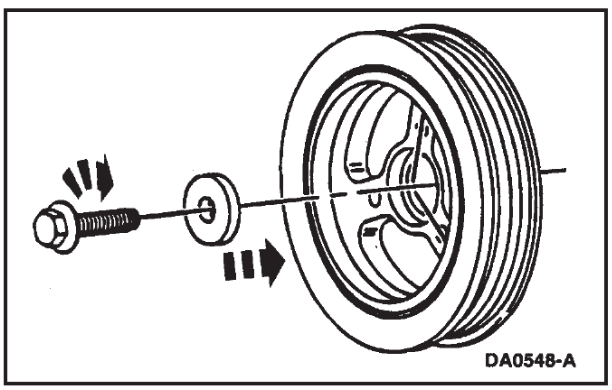
- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

Apply silicone to the Woodruff key slot on the crankshaft pulley (6312).

- Use Silicone Gasket and Sealant F6AZ-19562-A or equivalent meeting Ford specification WSEM4G323-A6.

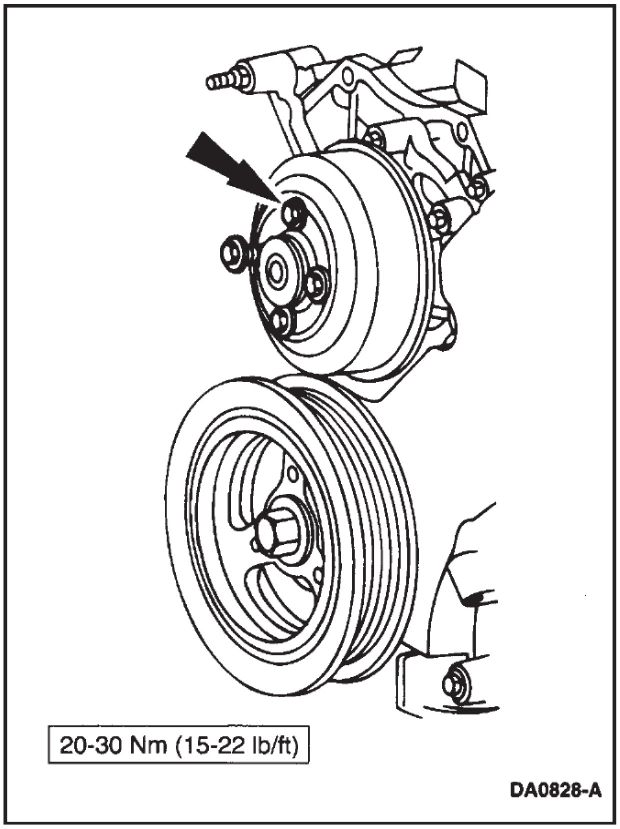


66. Use the Crankshaft Damper Replacer to install the crankshaft pulley.

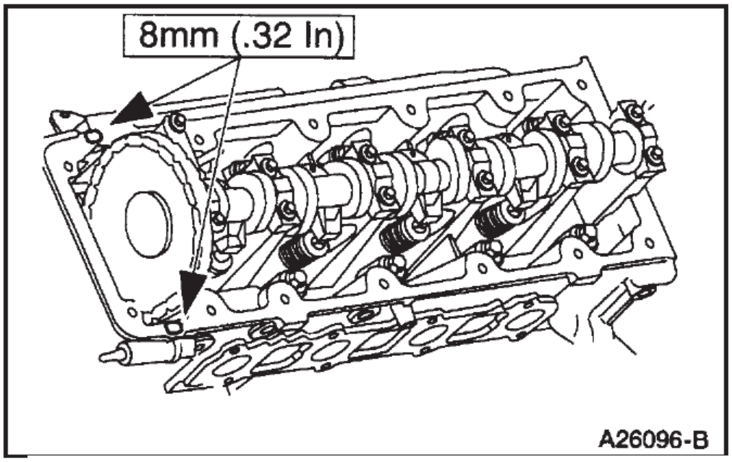


67. Tighten the crankshaft pulley bolt (6A340) in four stages.

- Stage 1: Tighten to 90 Nm (66 lb/ft).
- Stage 2: Loosen 360 degrees.
- Stage 3: Tighten to 47-53 Nm (35-39 lb/ft).
- Stage 4: Tighten an additional 85-90 degrees.



68. Position the water pump pulley (8509) on the water pump and install the bolts.



69. **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

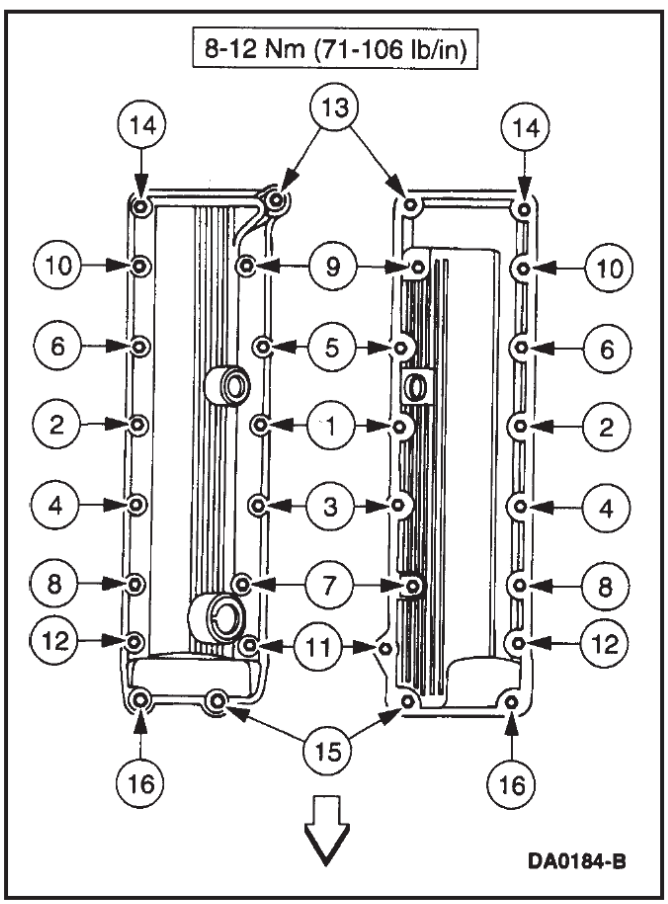
Apply silicone in two places where the engine front cover meets the cylinder head.

- Use Silicone Gasket and Sealant F6AZ-19562- AA or equivalent meeting Ford specification WSEM4G323-A6.

70. Position the valve covers (6582).

71. Tighten the bolts in the sequence shown.

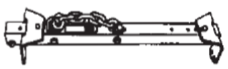
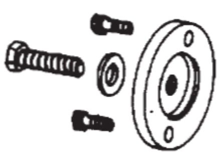
72. Install the engine control wire harness.



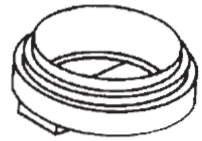
WSG-1068 ENGINE

Engine - Installation

Special Tool(s)

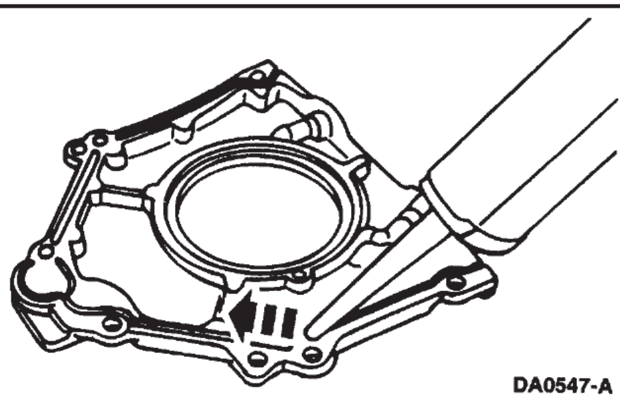
 ST1377-A	Modular Lifting Bar 303-F047 (014-00073) or equivalent
 ST1480-A	Rear Crankshaft Seal Adapter 303-518 (T95P-6701-DH)

Special Tool(s)

 ST1479-A	Rear Crankshaft Seal Replacer 303-516 (T95P-6701-BH)
 ST1482-A	Rear Crankshaft Slinger Replacer 303-517 (T95P-6701-CH)

Special Service Tools called for by the procedures can be obtained by calling:

1-800-ROTUNDA (1-800-768-8632).



DA0547-A

1. Attach the Modular Lifting Bar.

2. Remove the engine from the engine stand.

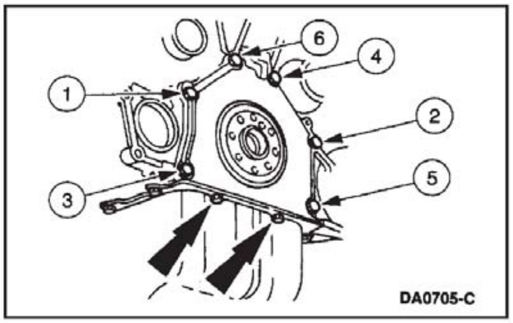
3. ⚠ **CAUTION: Mating parts must make contact to each other within 4 minutes and connecting bolts must be torqued within 15 minutes after applying sealant. Failure to follow this procedure can cause future oil leakage.**

- Use silicone gasket and sealant F6AZ-19562-AA or equivalent meeting Ford specification WSEM4G323-A6.

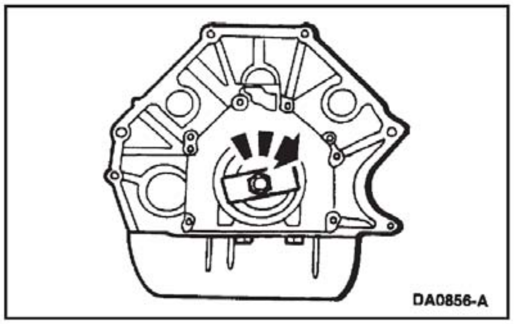
NOTE: Sealant must be removed and area cleaned with solvent if above instructions are not followed.

- Use metal surface cleaner F4AZ-19A536-RA or equivalent meeting Ford specification WSEM5B292-A.

4. Apply a bead of silicone around the rear oil seal retainer sealing surface.

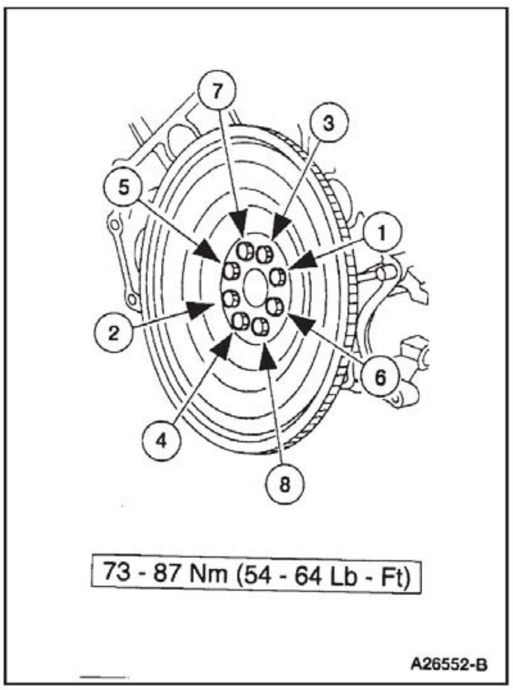


5. Install the retainer plate. Tighten the bolts to 8-12 Nm (71-107 lb/in).



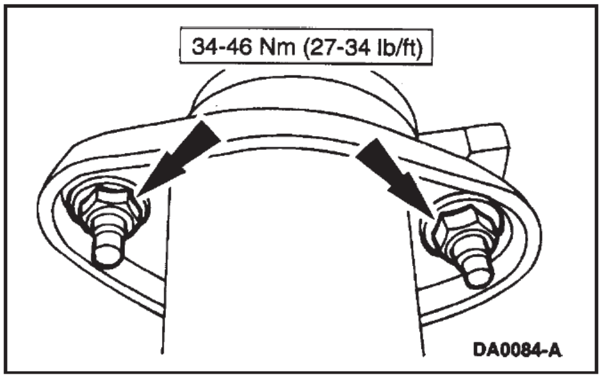
6. Use the Rear Crankshaft Seal Replacer and Rear Crankshaft Seal Adapter to install the crankshaft rear oil seal (6701).

7. With the Rear Crankshaft Seal Adapter still installed, use the Rear Crankshaft Slinger Replacer to install the crankshaft oil slinger.



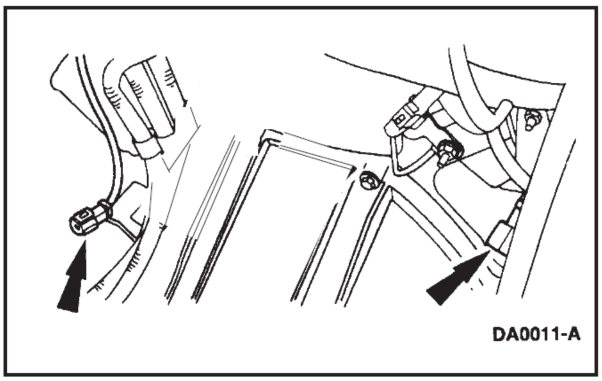
8. Install the flywheel (6375).

9. Install the starter motor (11002).



10. Connect the left and right exhaust pipes and install and tighten the nuts.

    NOTE: Apply a light coat of anti-sieze compound F6AZ-9L494-AA or equivalent meeting Ford specification ESE-M12A4-A to the threads of the exhaust manifold studs.



11. Connect the LH and RH heated exhaust gas oxygen sensor connector if equipped.
12. Install the intake manifold (9424); refer to Intake Manifold – Variable Resonance Induction System (VRIS) in this section.
13. Install vacuum hoses.
14. Install the drive belt (8620).
15. Install the upper and lower radiator supports (16138).
16. Install the radiator (8005).
17. Install the engine air cleaner (ACL) (9600) and the air cleaner outlet tube (9B659).
18. Fill all fluids to the proper levels.
19. Connect the battery ground cable (14301).
20. Start the engine and check for leaks. Stop the engine and recheck the fluid levels.

WSG-1068 ENGINE

SPECIFICATIONS

Torque Specifications

Description	Nm	Lb/Ft	Lb/In
Bolt Hex Flanged (Front of Engine)	20-30	15-22	–
Camshaft Bearing Cap Bolts	8-12	–	71-106
Camshaft Sprocket Bolts	55-75	41-55	–
CKP/CID Bolt	8-12	–	71-106
Coil Pack Bracket Bolts	20-30	15-22	–
Connecting Rod Bolts	(1)(2)	(1)(2)	(1)(2)
Crankshaft Pulley Bolt	(1)	(1)	(1)
Engine Support Insulator Bolts	80	59	–
Engine Support Insulator Nuts	90	66	–
Exhaust Manifold Nuts	23-27	17-20	–
Exhaust System to Exhaust Manifold Nuts	34-46	27-34	–
Flywheel Bolts	73-87	54-64	–
Front Engine Support Insulator	68-92	50-68	–
Head Bolts (LH) (RH) (1)	(1)(2)	(1)(2)	(1)(2)
Heater Water Return Tube Studs	40-55	30-41	–
Idler Pulley Bolt	20-30	15-22	–
Jack Screws	(1)	(1)	(1)
Lower Crankshaft Bearing Bolts and Stud Bolts	20-30	15-22	–
Lower Power Steering Bolts	20-30	15-20	–
Main Bearing Cap Bolts	(1)(2)	(1)(2)	(1)(2)
Main Cap Side Bolts	(1)(2)	(1)(2)	(1)(2)
Motor Mount Pivot Bolt	68-92	50-68	–
Motor Mount to Engine Bolts	52-71	38-52	–
Oil Cooler to Adapter	55-60	–	41-44
Oil Filter	14-17	–	125-151.6
Oil Filter Adapter Assembly Bolts	20-30	15-22	–
Oil Level Indicator Bracket Nut	20-30	15-22	–
Oil Level Indicator Tube Bolt	8-12	–	71-106
Oil Pan Bolts	(1)	(1)	(1)
Oil Pan Drain Plug	11-16	-	98-143
Oil Pump Bolts	8-12	–	71-107
Oil Pump Screen Cover and Tube Bolts	8-12	–	71-106
Oil Pump Screen and Cover Assembly Spacer	20-30	15-22	–
Oil Pump Screen Cover and Tube Nut	20-30	15-22	–
Power Steering Pump Bolts	20-30	15-22	–
Rear Oil Seal Bolts	8-12	–	71-106
Screw and Washer (Front of Engine)	40-55	29-40	–
Stud and Washer (Front of Engine)	40-55	29-40	–
Timing Chain Guide Bolts	8-12	–	71-106
Torque Converter Nuts	34-46	25-34	–

(Continued)

Torque Specifications (Continued)

Description	Nm	Lb/Ft	Lb/In
Flywheel Housing to Engine Bolts	41-54	30-40	–
Upper Intake Manifold Bolts	(1)	(1)	(1)
Upper Intake Manifold to Cylinder Head Bolts	(1)	(1)	(1)
Upper Power Steering Bolts	20-30	15-20	–
Valve Cover Bolts	8-12	–	71-106
Water Pump Bolts	20-30	15-22	–
Water Pump Pulley Bolts	20-30	15-22	–

(1) Refer to this section for tightening procedure and sequence.

(2) Torque to yield bolts must be discarded and replaced with new bolts.

General Specifications

Item	Specification
Displacement (CID)	6.8L (415)
No. Cylinder	10
Bore/Stroke	90.215/105.8 mm
Fire Order	1-6-5-10-2-7-3-8-4-9
Oil Capacity (With oil filter – 6.5)	6.0 qts. 6.5 qts.
Oil Pressure 93.33°C (200°F) at Cylinder Block	18 psi @ 650 rpm 100 psi @ 4,000 rpm
Cylinder Head/Valve Train	
Combustion Chamber Volume	52.6 - 51.6 cc
Valve Seat Width – Intake	2.1-1.9 mm
Valve Seat Width – Exhaust	2.1-1.9 mm
Valve Seat Angle	45.00-44.50 degrees
Valve Seat Runout (T.I.R.)	0.025 mm
Valve Arrangement (Front to Rear)	
Valve Stem Guide Clearance: Intake	0.069-0.020 mm
Exhaust	0.095-0-045 mm
Valve Head Diameter: Intake	44.63-44.37 mm
Exhaust	34.12-33.88 mm
Valve Face Runout (Limit)	0.05 mm
Valve Face Angle	45.75-45.25 degrees
Valve Stem Diameter: Intake	6.995-6.975 mm
Exhaust	6.970-6.949 mm
Valve Stem Diameter (List Oversizes): Intake	N/A
Exhaust	N/A
Valve Spring Compression Pressure: Intake (N @ Spec. Length)	667.3 N @ 28.02 mm
Exhaust (N @ Spec. Length)	667.3 N @ 28.02 mm

(Continued)

General Specifications (Continued)

Item	Specification
Valve Spring Free Length: Intake	50.2 mm
Exhaust	50.2 mm
Valve Spring Installed Pressure N @ Spec. Length: Intake	289.1 N @ 40.01 mm
Exhaust	289.1 N @ 40.01 mm
Valve Springs Installed Pressure N @ Spec. Length – Service Limit: Intake	274.6 mm @ 40.01 mm
Exhaust	274.6 mm @ 40.01 mm
Valve Springs – Out of Square Limit: Intake	2.5 degrees
Exhaust	2.5 degrees
Valve Guide Inside Diameter	7.044-7.015 mm
Camshaft	
Lobe Lift: Intake	6.58077 mm
Exhaust	6.58551 mm
Lobe Lift – Allowable Lift Loss	0
Valve Lift @ Zero Lash: Intake	12.00 mm
Exhaust	12.00 mm
Camshaft End Play	0.25-0.188 mm
End Play Service Limit	0.025-0.188 mm
Journal to Bearing Clearance	0.076-0.025 mm
Clearance Service Limit	–
Journal Diameters	26.962-26.936 mm
Journal Inside Diameter (Cap Assembled)	27.012-26.987 mm
Camshaft Runout: Full Indicator Measurement on all journals when supported on front and rear journals Engine	0.09 mm (5 Places)
Cylinder Bore Diameter: Grade 1	90.200-90.210 mm
Grade 2	90.210-90.220 mm
Grade 3	90.220-90.230 mm
Piston	
Piston Diameter (Grade 2) at Right Angle to Pin Bore	90.180 ± 0.005 mm
Piston to Bore Clearance	(-0.005) to +0.025 mm
Pin Bore Diameter (Piston)	22.008-22.014 mm
Pin Diameter	22.0005-22.0030 mm
Clearance (Neg. or Pos.)	0.01395-0.005 mm
Pin Bore Diameter (Rod)	22.012-22.024 mm
Clearance	0.009-0.0235 mm
Ring Groove Width: Top	1.503-1.505 mm
Intermediate	1.502-1.504 mm

General Specifications (Continued)

Item	Specification
Oil Control	3.030-3.050 mm
Piston Ring Gap: Top	0.13-0.28 mm
Intermediate	0.25-0.40 mm
Oil Control	0.15-0.65 mm
Crankshaft	
Main Bearing Journal Diameter	27-482-67.504
Maximum Out-of-Round	0.0075 mm Between Cross Sections
Maximum Taper (Straightness)	0.004 mm
Runout: FIM of center journals when located on front and rear journal	TBD
Clearance – Crankshaft Journal to Main Bearing Clearance	0.048-0.024 mm
Connecting Rod Journal Diameter	53.003-52.983 mm
Maximum Out-of-Round	0.0075 mm Between Cross Sections
Maximum Taper	0.004 mm
Crankshaft End Play	0.075-0.377
Connecting Rod	
Big End Journal Inside Diameter with Assembled Liners	53.049-53.027 mm
Rod Bearing to Journal Clearance	0.064-0.026 mm
Pin Bore Diameter (Rod)	22.024-22.012 mm
Balance Shaft System	
Balance Shaft Journal Diameter	26.962-26.936 mm
Clearance – Balance Shaft Journal to Cylinder Head	0.076-0.025 mm
Cylinder Head B/S Journal Diameter	27.012-26.987 mm
Gear Backlash	0.0076-0.1295 mm
Balance Shaft End Play	0.04-0.18 mm
Rod Length (Centerline Bore-to-Bore)	169.1 mm
Alignment: Bore-to-Bore Max. Twist	± 0.05 mm
Bore-to-Bore Max. Bend	± 0.038 mm
Side Play (As Assembled to Crank): Standard Play	0.410 ± 0.26 mm
Max Play	0.670 mm

(Continued)

General Specifications (Continued)

Item	Specification
Sealant and Lubricants	
Silicone Gasket and Sealant F6AZ-19562-AA (in Canada CXC-8-B) (in Oregon F5FZ-19549-CC)	ESE-M97B44-A
Super Premium Engine Oil SAE 5W30	D9AZ-19579A
Petroleum Jelly	WSD-M1C226-A
Metal Surface Cleaner F4AZ-19A536-RA	WSE-M5B392-A
Anti-seize Compound F6AZ-9L494-AA	ESE-M12A4-A

WSG-1068 IGNITION SYSTEM

03

INDEX

Subject **Page**

WSG-1068 IGNITION SYSTEM

GENERAL INFORMATION

Color Abbreviations

BL	Blue	N	Natural
BK	Black	O	Orange
BR	Brown	PK	Pink
DB	Dark Blue	P	Purple
DG	Dark Green	R	Red
GN	Green	T	Tan
GY	Gray	W	White
LB	Light Blue	Y	Yellow
LG	Light Green		

NOTE: Whenever a wire is labeled with two colors, the first color listed is the basic color of the wire, and the second color listed is the stripe marking of the wire.

How to Find Electrical Concerns

Troubleshooting Steps
These six steps present an orderly method of troubleshooting.

Step 1: Verify the concern.

- Operate the complete system to check the accuracy and completeness of the customer's complaint.

Step 2: Narrow the concern.

- Using a DVOM, narrow down the possible causes and locations of the concern to pinpoint the exact cause.
- Read the description about the components and study the wiring schematic. You should then know enough about the circuit operation to determine where to check for the trouble.

Step 3: Test the cause.

- Use electrical test procedures to find the specific cause of the symptoms.

Step 4: Verify the cause.

- Confirm that you have found the correct cause by connecting jumper wires and/or temporarily installing a known good component and operating the circuit.

Step 5: Make the repair.

- Repair or replace the inoperative component.

Step 6: Verify the repair.

- Operate the system as in Step 1 and check that your repair has removed all symptoms without creating and new symptoms.

Troubleshooting Tools

Jumper Wire

This is a test lead used to connect two points of a circuit. A Jumper Wire can bypass an open in a wire to complete
a circuit.

**WARNING: NEVER USE A JUMPER WIRE ACROSS LOADS (MOTORS, ETC.) CONNECTED BETWEEN HOT AND GROUND. THIS DIRECT BATTERY
SHORT MAY CAUSE INJURY OR FIRE.**

Voltmeter

A DC Voltmeter measures circuit voltage. Connect negative
(- or black) lead to ground, and positive (+ or red) lead to voltage measuring point.

Ohmmeter

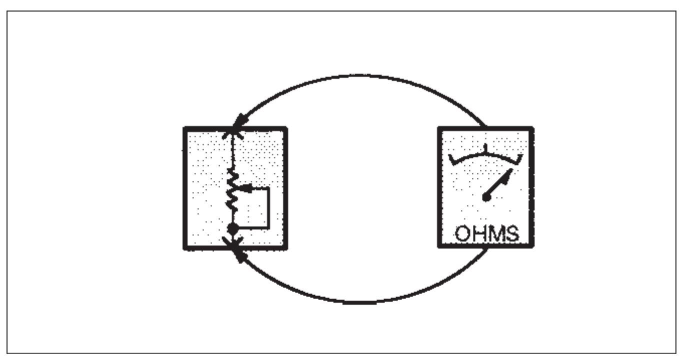


Figure 1 – Resistance Check

An Ohmmeter shows the resistance between two connected points (Figure 1).

Test Lamp

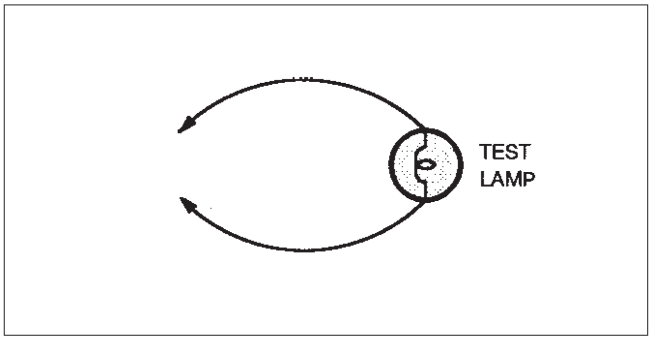


Figure 2 – Test Lamp

A Test Light is a 12-volt bulb with two test leads (Figure 2).

Uses: Voltage Check, Short Check.

Self-Powered Test Lamp

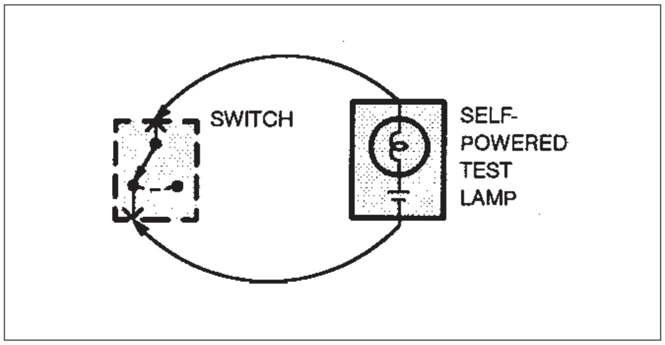


Figure 3 – Continuity Check

The Self-Powered Test Lamp is a bulb, battery and set of test leads wired in series (Figure 3). When connected to two points of a continuous circuit, the bulb glows.

Uses: Continuity Check, Ground Check.

CAUTION: When using a self-powered test lamp or ohmmeter, be sure power is off in circuit during testing. Hot circuits can cause equipment damage and false readings.

Switch Circuit Check & Voltage Check

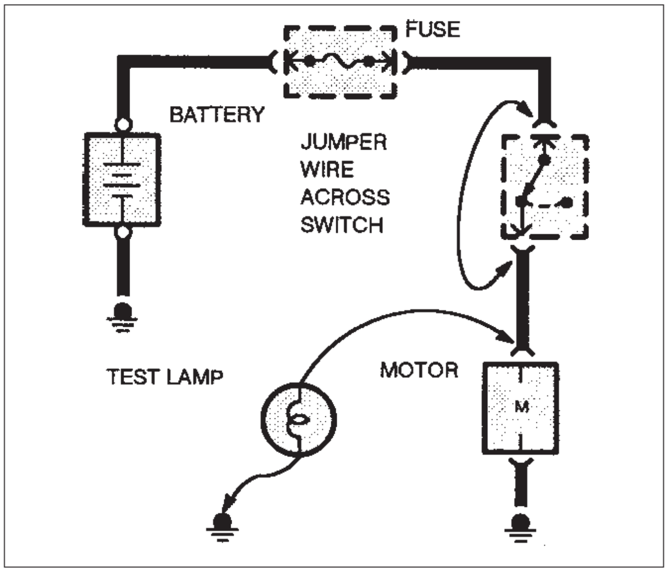


Figure 4 – Switch Circuit Check and Voltage Check

In an inoperative circuit with a switch in series with the load, jumper the terminals of the switch to power the load. If jumpering the terminals powers the circuit, the switch is inoperative (Figure 4).

Continuity Check (Locating open circuits)

Connect one lead of test lamp to a known good ground or the negative (-) battery terminal. Test for voltage by touching the other lead to the test point. The bulb goes on when the test point has voltage (Figure 4).

Short Check

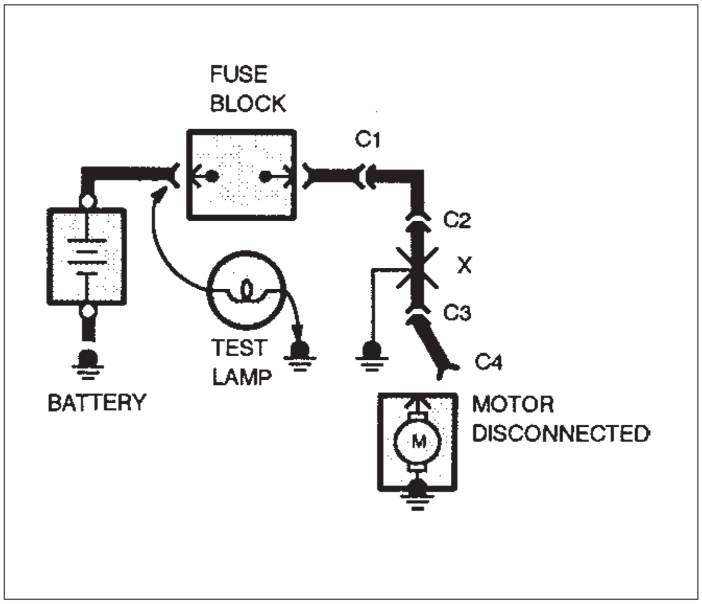


Figure 5 – Short Check

A fuse that repeatedly blows is usually caused by a short to ground. It's important to be able to locate such a short quickly (Figure 5).

1. Turn off everything powered through the fuse.

2. Disconnect other loads powered through the fuse:
   - Motors: disconnect motor connector (Connector C4 in Figure 5).
   - Lights; remove bulbs.

3. Turn the Ignition Switch to RUN (if necessary) to power fuse.

4. Connect one Test Lamp lead to the hot end of the blown fuse. Connect the other lead to ground. The bulb should glow, showing power to fuse. *(This step is just a check to be sure you have power to the circuit).*

5. Disconnect the test lamp lead that is connected to ground, and reconnect it to the load side of the fuse at the connector of the disconnected component. (In Figure 5, connect the test lamp lead to connector C4).
   - If the Test Lamp is off, the short is in the disconnected component.
   - If the Test Lamp goes on, the short is in the wiring.You must find the short by disconnecting the circuit connectors, one at a time, until the Test Lamp goes out. For example, in Figure 5 with a ground at X, the bulb goes out when C1 or C2 is

disconnected, but not after disconnecting C3. This means the short is between C2 and C3.

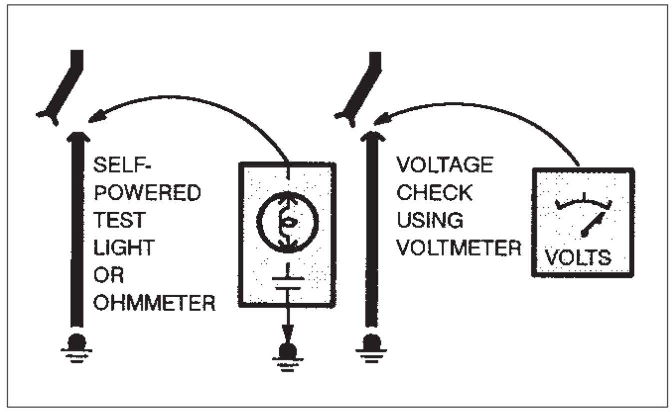


Figure 6 – Ground Check

Ground Check

Turn on power to the circuit. Perform a Voltage Check between the suspected inoperative ground and the frame. Any indicated voltage means that the ground is inoperative (Figure 6).

Turn off power to the circuit. Connect one lead of a Self-Powered Test Lamp or Ohmmeter to the wire in question and the other lead to a known ground. If the bulb glows, the circuit ground is OK (Figure 6).

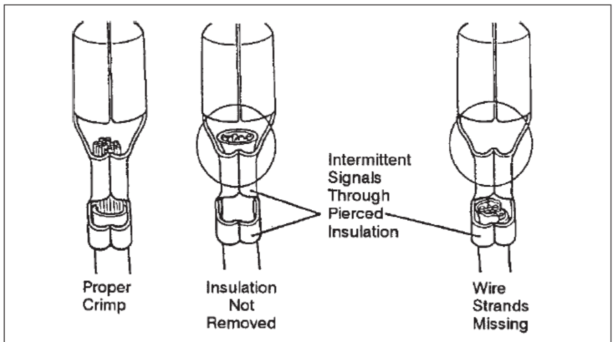
The circuit schematics in this manual make it easy to identify common points in circuits. This knowledge can help narrow the concern to a specific area. For example, if several circuits fail at the same time, check for a common power or ground connection. If part of a circuit fails, check the connections between the part that works and the part that doesn't work.

For example, if the low beam headlamps work, but the high beams and the indicator lamp don't work, then the power and ground paths must be good. Since the dimmer switch is the component that switches this power to the high beam lights and the indicator, it is most likely the cause of failure.

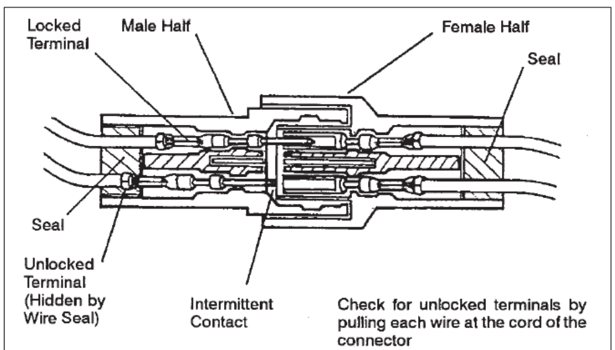
Troubleshooting Wiring Harness and Connector Hidden Concerns

The following illustrations are known examples of wiring harness, splices and connectors that will create intermittent electrical concerns. The concerns are hidden and can only be discovered by a physical evaluation as shown in each illustration.

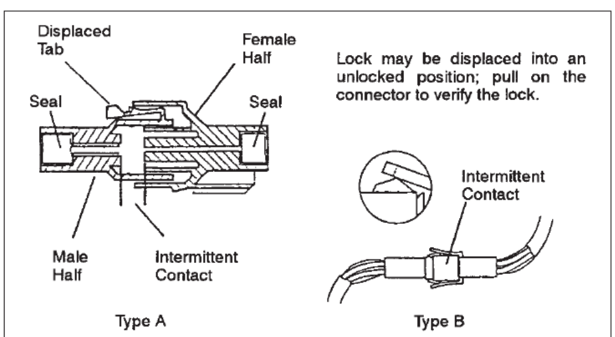
NOTE: When servicing gold plated terminals in a connector, only replace with gold plated terminals designed for that connector.



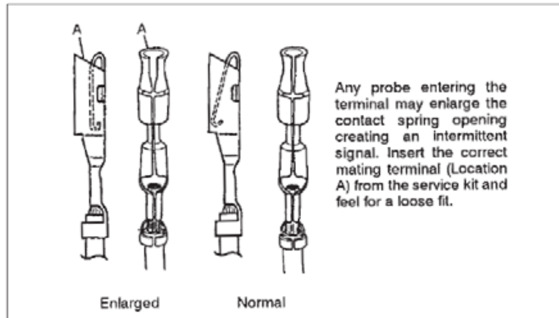
DEFECTIVE INSULATION STRIPPING



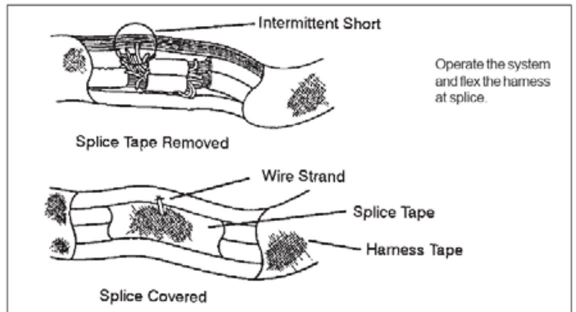
TERMINAL NOT PROPERLY SEATED



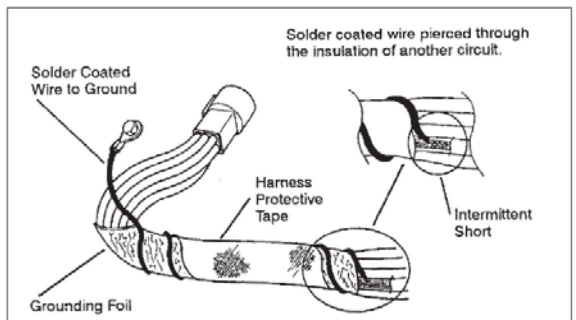
PARTIALLY MATED CONNECTORS



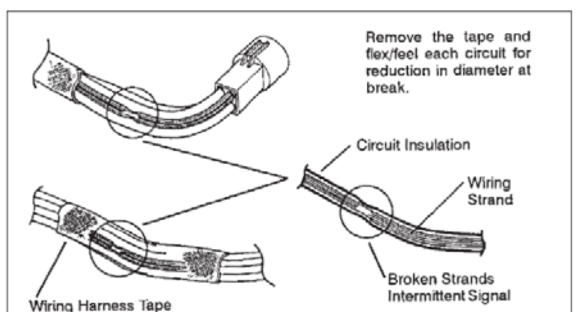
DEFORMED (ENLARGED) FEMALE TERMINALS



ELECTRICAL SHORT WITHIN THE HARNESS



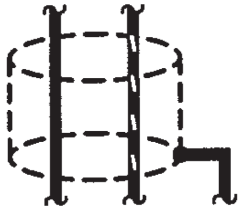
ELECTRICAL SHORT INSIDE THE HARNESS



BROKEN WIRE STRANDS IN HARNESS

WSG-1068 IGNITION SYSTEM

Electrical Symbols



SHIELD
WIRES ARE COVERED BY A SHIELD

FIELD COIL

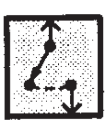
MOTOR

HEATING ELEMENT

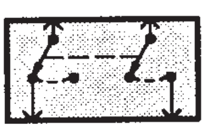
THERMISTOR

RHEOSTAT OR POTENTIOMETER

SOLENOID



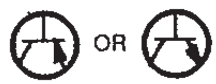
SWITCH



GANGED SWITCHES
CONTACTS MOVE AT THE SAME TIME

DIODES
CURRENT FLOWS IN DIRECTION OF ARROW ONLY

CAPACITOR



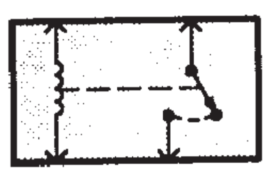
TRANSISTOR

GAUGE

LIGHT EMITTING DIODE (LED)

LIGHT BULB

DUAL FILAMENT LIGHT BULB



RELAY
CONTACTS CHANGE POSITION WITH CURRENT THROUGH COIL

WSG-1068 IGNITION SYSTEM

WARNING: WHEN CARRYING OUT SERVICE OPERATIONS ON AN ENGINE EQUIPPED WITH DISTRIBUTORLESS IGNITION. FOLLOW ALL THE USUAL SAFETY MEASURES TO PREVENT THE POSSIBILITY OF ELECTRIC SHOCKS SHOULD BE FOLLOWED.

NOTE: High tension voltage produced by a distributorless ignition system is higher than for a conventional ignition system. It is in excess of 55,000 Volts.

Description

The WSG-1068 engine uses a Coil On Plug Ignition System to ignite the fuel/air mixture at the correct time and sequence based upon the input it receives. The brain of this system is a Global Control Platform (GCP). The GCP has the capability at the OEM option to protect the engine from over heating and low oil pressure. Inputs are sensors or switches that feed the GCP information.

- Engine Cylinder Head Temperature Sensor (CHT) Input.
- Camshaft Position Sensor (CMP) Input.
- Crankshaft Position Sensor (CKP) Input.
- Fuel Select Switch.

From these inputs, the GCP computes spark strategy (spark advance) and fuel mixture (air/fuel) to obtain optimum engine performance for correct load conditions.

Operation

The ignition control module needs the following information to calibrate the engine properly:

- Crankshaft position.
- Engine RPM.
- Engine temperature.
- Engine load and altitude.
- Fuel select switch.

The camshaft position sensor (CMP sensor):

- Sends the Ignition Control Module a signal indicating camshaft position used for fuel synchronization.

The crankshaft position sensor (CKP sensor):

- Sends the Ignition Control Module a signal indicating crankshaft position.
- Is essential for calculating spark timing.

The intake air temperature sensor (IAT sensor):

- Sends the ignition control module a signal indicating the temperature of the air entering the engine, but is not used on this engine.
- Resistance decreases as temperature increases.

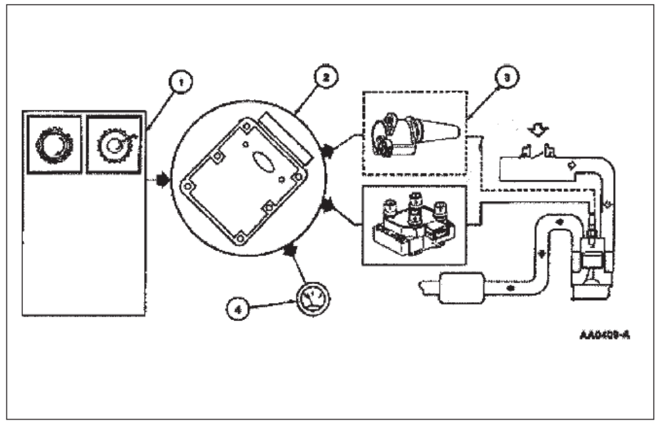
The cylinder heat temperature (CHT sensor):

- Sends a signal to the Ignition Control Module indicating the cylinder head temperature.

WSG-1068 IGNITION SYSTEM

Overview

The Ignition System is designed to ignite the compressed air/fuel mixture in an internal combustion engine by a high voltage spark from an ignition coil. The ignition system also provides engine timing information to the GCP for proper engine operation and misfire detection.



Electronic Ignition System

The Coil On Plug (COP) EI System uses a separate coil per spark plug and each coil is mounted directly onto the plug. The COP EI System eliminates the need for spark plug wires but does require input from the camshaft position (CMP) sensor. Operation of the components are as follows:

1. **Note:** Electronic Ignition engine timing is entirely controlled by the GCP. Electronic Ignition engine timing is NOT adjustable. Do not attempt to check base timing. You will receive false readings.

2. The GCP uses the CMP sensor not shown on COP EI Systems to identify top dead center of compression of cylinder 1 to synchronize the firing of the individual coils.

3. The GCP acts as an electronic switch to ground in the coil primary circuit. When the switch is closed, battery positive voltage (B+) applied to the coil primary circuit builds a magnetic field around the primary coil. When the switch opens, the power is interrupted and the primary field collapses inducing the high voltage in the secondary coil windings and the spark plug is fired. A kickback voltage spike occurs when the primary field collapses.

4. The GCP processes the CKP signal and uses it to drive the tachometer as the Clean Tach Out (CTO) signal.

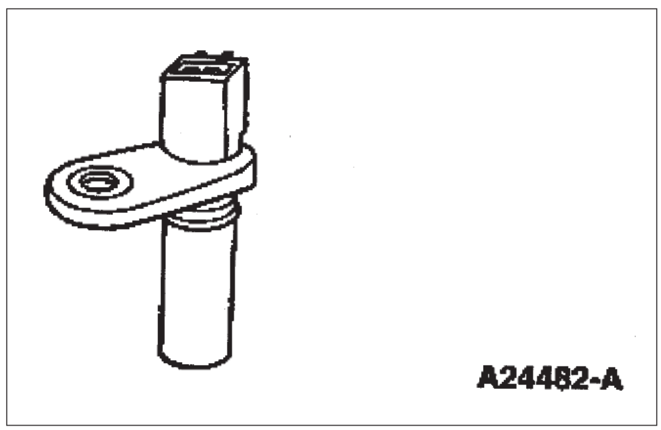
Starting RPM

The program strategy requires the engine to obtain a minimum of 100-140 RPM before the GCP will allow ignition spark to be generated. Any failure with an auxiliary system can cause excessive engine crank (load) force, which may cause the engine too not reach the required starting RPM. Perform a thorough inspection of all auxiliary systems and components, inspect for binding hydraulic pumps and misalignment of drive systems.

Camshaft Position Sensor

The Camshaft Position (CMP) Sensor detects the position of the camshaft. The CMP Sensor identifies when piston #1 is on its compression stroke.

The CMP Sensor is a magnetic transducer mounted on the engine front cover adjacent to the camshaft. By monitoring a target on the camshaft sprocket, the CMP sensor identifies cylinder one to the GCP. The COP EI system uses this information to synchronize the firing of the individual coils.



WSG-1068 IGNITION SYSTEM

The Fuel Select Switch

In the event that the engine is operated on alternate fuels such as natural gas, compressed natural gas (CNG), or liquefied petroleum gas (LPG), timing can be modified with a Fuel Select Switch.

NOTE: Fuel select switch is supplied by the customer.

- Sends a signal to the GCP to adjust base timing for alternate fuel
- Is manually controlled.

With this system, the GCP monitors the engine load, speed, operating temperature, air intake 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 settings in case of component failure. Particular attention has been given to spark optimization for excellent fuel economy and power 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 but little of the coil energy is lost.

Run Mode

The GCP interprets engine speed above100 RPM as Run Mode.

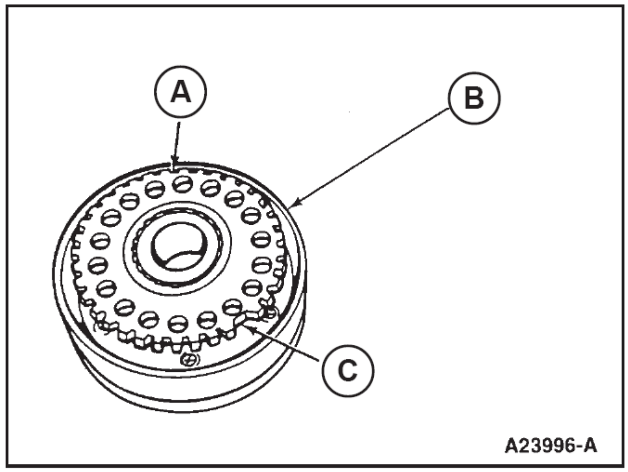
The Base Spark Advance (BSA) is calculated by the (GCP) module processing the engine speed and load plus sensors mentioned in operation of this section and Fuel Select Switch.

Inputs to the GCP Effecting the Ignition

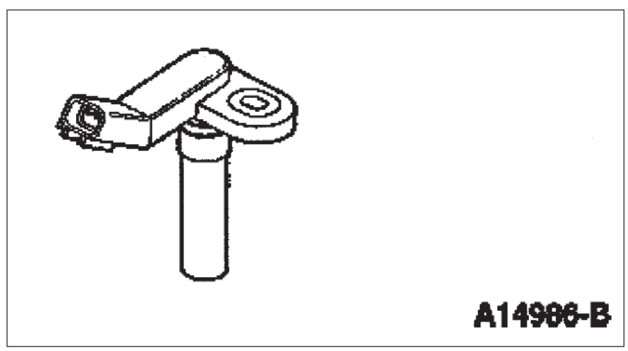
The spark strategy is based on sensors and manifold vacuum input to the GCP module, which include the following inputs:

Crankshaft Position Sensor (CKP Sensor)

The CKP sensor is a magnetic transducer mounted on the engine block adjacent to a pulse wheel located on the crankshaft. By monitoring the crankshaft mounted pulse wheel **A** , the CKP is the primary sensor for ignition information to the GCP. The pulse wheel located behind the crankshaft pulley **B** , has a total of 39 teeth spaced 9 degrees apart with one empty space **C** for a missing tooth. An A/C voltage signal is generated which increases with engine rpm and provides engine speed and crankshaft position information to the GCP. By monitoring the pulse wheel, the CKP sensor signal indicates crankshaft position and speed information to the GCP. The CKP sensor is also able to identify piston travel in order to synchronize the ignition system and provide a way of tracking the angular position of the crankshaft relative to a fixed reference for the CKP sensor configuration. GCP also uses the CKP signal to determine if a misfire has occurred by measuring rapid decelerations between teeth.



A	**Pulse Wheel (Part Crankshaft Pulley).**
B	**Crankshaft Damper (Face Down) 6312.**
C	**Gap in Teeth (Provides position reference for number one piston**

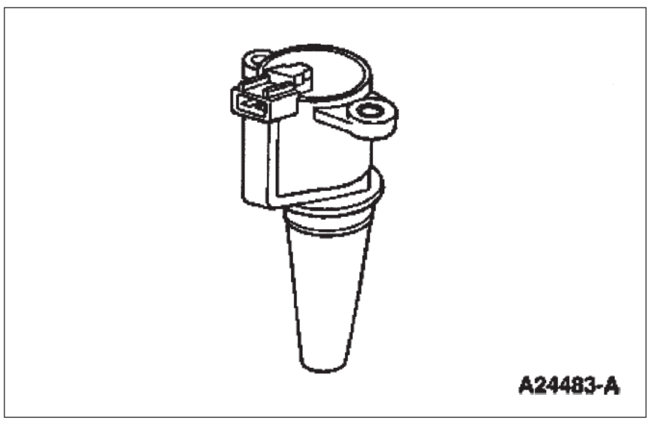


WSG-1068 IGNITION SYSTEM

Coil On Plug
The coil on plug (COP) ignition operates similar to standard coil pack ignition except each plug has one coil per plug. COP has three different modes of operation: engine crank, engine running and CMP Failure Mode Effects Management (FMEM).

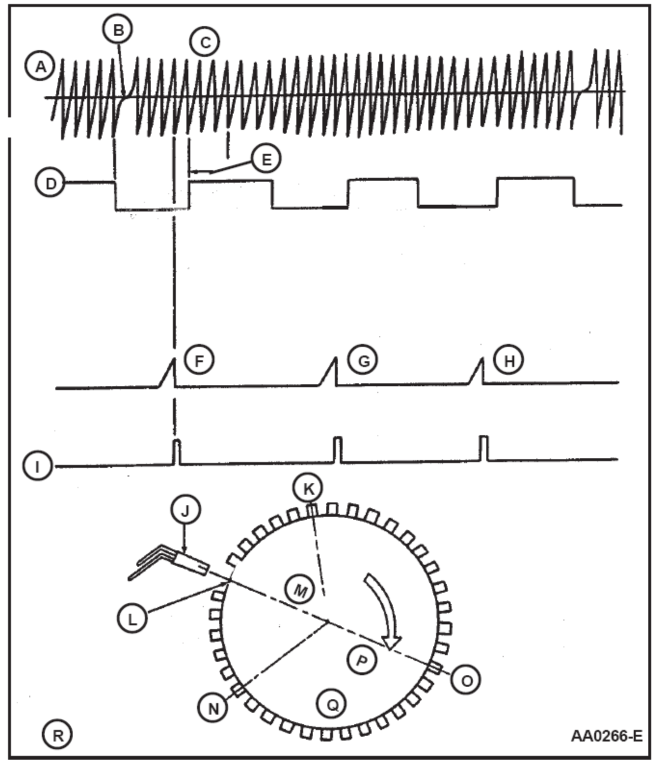
Engine Crank/Engine Running
During engine crank the GCP will fire two spark plugs simultaneously. Of the two plugs simultaneously fired one will be under compression the other will be on the exhaust stroke. Both plugs will fire until camshaft position is identified by a successful camshaft position sensor signal. Once camshaft position is identified only the cylinder under compression will be fired.

CMP FMEM
During CMP FMEM the COP ignition works the same as during engine crank. This allows the engine to operate without the GCP knowing if cylinder one is under compression or exhaust.



Cranking Mode
Cranking mode is the area of engine operating speed within which the ignition timing is at a static position. The static spark advance is fixed at 10 degrees BTDC up to 250 RPM.

Transient Mode
This function is to provide a limp in mode whenever certain components fail. The engine will run but at a set timing and batch fuel delivery. This mode will stay in effect until problem is corrected or ignition turned off and back on if an intermittent problem.



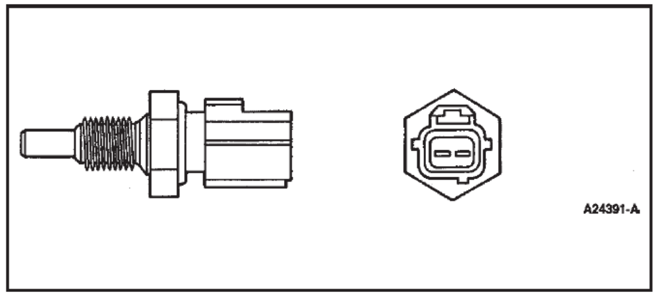
- A CKP Sensor
- B Missing Tooth 60° BTDC
- C TDC
- D Spark
- E 10° BTDC
- F Coil 1
- G Coil 2
- H Coil 3
- I IDM
- J CKP Sensor
- K TDC 2 and 6
- L Missing Tooth
- M 60° BTDC
- N TDC 1 and 5
- O TDC 3 and 4
- P 1 and 5
- Q Crankshaft Wheel
- R **Note:** This diagram does not correlate to any timing marks that may be on the engine front cover or dampener.

Overspeed Mode
Over-speed protection is available on certain GCP modules that have set RPM limits. Refer to the GCP Replacement chart. When the module senses the engine RPM is at the preset limit, grounding of the Coil on Plugs is removed stalling the engine. The ignition must cycle from on to off and to start in order to restart the engine. Note: this strategy must be compatible with governor controllers.

Electronic Engine Controls

Refer to Section 08 of this manual.

Cylinder Head Temperature Sensor (CHT Sensor)



Cylinder Head Temperature (CHT) Sensor.

The cylinder head temperature (CHT) sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as temperature increases, and increases as temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the GCP corresponding to temperature.

Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow.

Voltage that is dropped across a fixed resistor in series with the sensor resistor determines the voltage signal at the GCP. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The CHT sensor is installed in the aluminum cylinder head and measures the metal temperature. The CHT sensor communicates an overheating condition to the GCP. The GCP would then initiate a cooling strategy based on information from the CHT sensor. A cooling system failure such as low coolant or coolant loss could cause an overheating condition. As a result, damage to major engine components could occur. Using a CHT sensor and cooling strategy would prevent damage by allowing air cooling of the engine and limp home capability.

WSG-1068 IGNITION SYSTEM

Starting Mode

Module enters start mode at first application of power. No spark is applied for first turn of crankshaft. Timing is fixed at 10 degrees BTDC. Dwell is fixed at 10 degrees of crankshaft rotation. Start mode remains in effect until 10 turns of the crankshaft @ 500 rpm. If drops below 500 rpm at any time, turn counter is reset. Once 10 turns are made @ 100 rpm or greater, module is set to run mode. In transitioning to run mode, calculated timing values are ramped into system during approximately 3.5 revolutions to ensure transition. Dwell is determined with a base value plus a correction factor based on system voltage.

CHT Effects

Cylinder Head Temperature (CHT) is monitored and a correction factor is applied to engine timing based on one of three 1 X 8 tables. OCT1 selects which timing table will be used for correction.

IAT Effects (Not Used)

Intake Air Temperature (IAT) is monitored and a correction factor is applied to engine timing based on one of three 1 X 8 tables. OCT1 selects which timing table will be used for correction.

Overspeed Protection

The GCP module contains an RPM limit that is set at 3200 RPM. Reaction is the module will be shut off, stalling the engine. Key must cycle from run to off to start in order to restart engine. Note: this strategy must be compatible with governor controllers.

Engine Protection

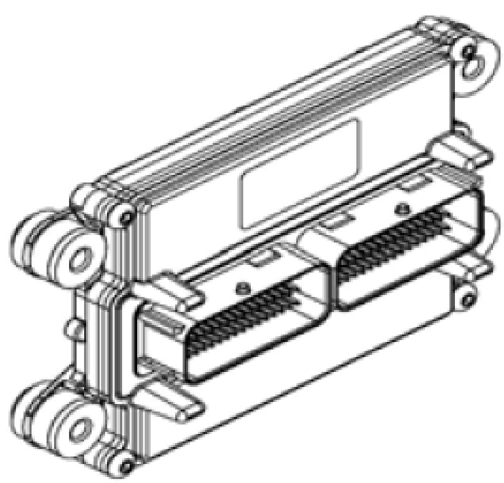
Reaction for overtemp (based on CHT input) and low oil pressure (based on oil pressure switch input) the module will be shut off, stalling the engine. Key must cycle from run to off to start in order to restart engine. Engine protection becomes active after 240 crankshaft revolutions and when 800 rpm is exceeded. The purpose of having to meet these conditions provides an opportunity for the engine to restart if the failure still exists which caused the engine to stall. Over temperature reaction is experienced when temperature reaches 250°F. Low oil pressure reaction is experienced when oil pressure drops below 6 psi +/- 1.5 psi. Oil pressure switch position is normally open when engine is off.

Starter Lockout

Starter lockout relay control open drain (GCP switch to ground). Activated once engine is in the run mode and has reached 600 RPM. Will not allow start until ignition voltage to GCP module is switched off and back on.

Tachometer Output

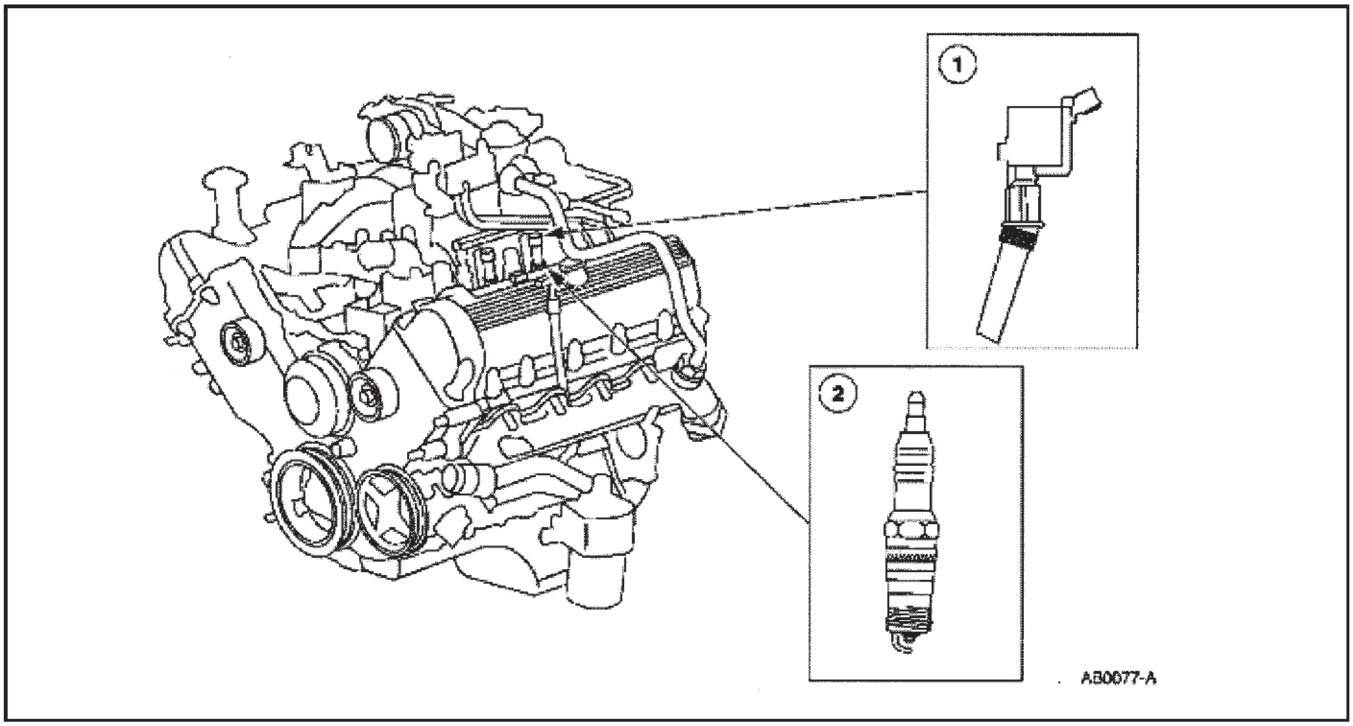
Tachometer output will be from Pin #2 of the 42 pin harness. The pulses per revolution will be determined by the number of cylinders the GCP will control. The four cylinder GCP will output 2 pulses per revolution, the six cylinder GCP output 3 pulses per revolution, the eight cylinder output 4 pulses per revolution, and the ten cylinder 5 pulses per revolution. The intention of this is to allow for use of a conventional tachometer from this output.



Global Control Platform (GCP)

WSG-1068 IGNITION SYSTEM

Ignition System - Components Location



1 Ignition Coil (12029)   2 Spark Plug (12405)

The 6.8L engine is equipped with a coil on plug ignition system. This system has a separate ignition coil mounted on each spark plug. Operation of the coils is controlled by global control platform (GCP), which computes ignition timing based on inputs from the electronic engine control system sensors. For additional information on sensor inputs related to ignition control; refer to Section 08.

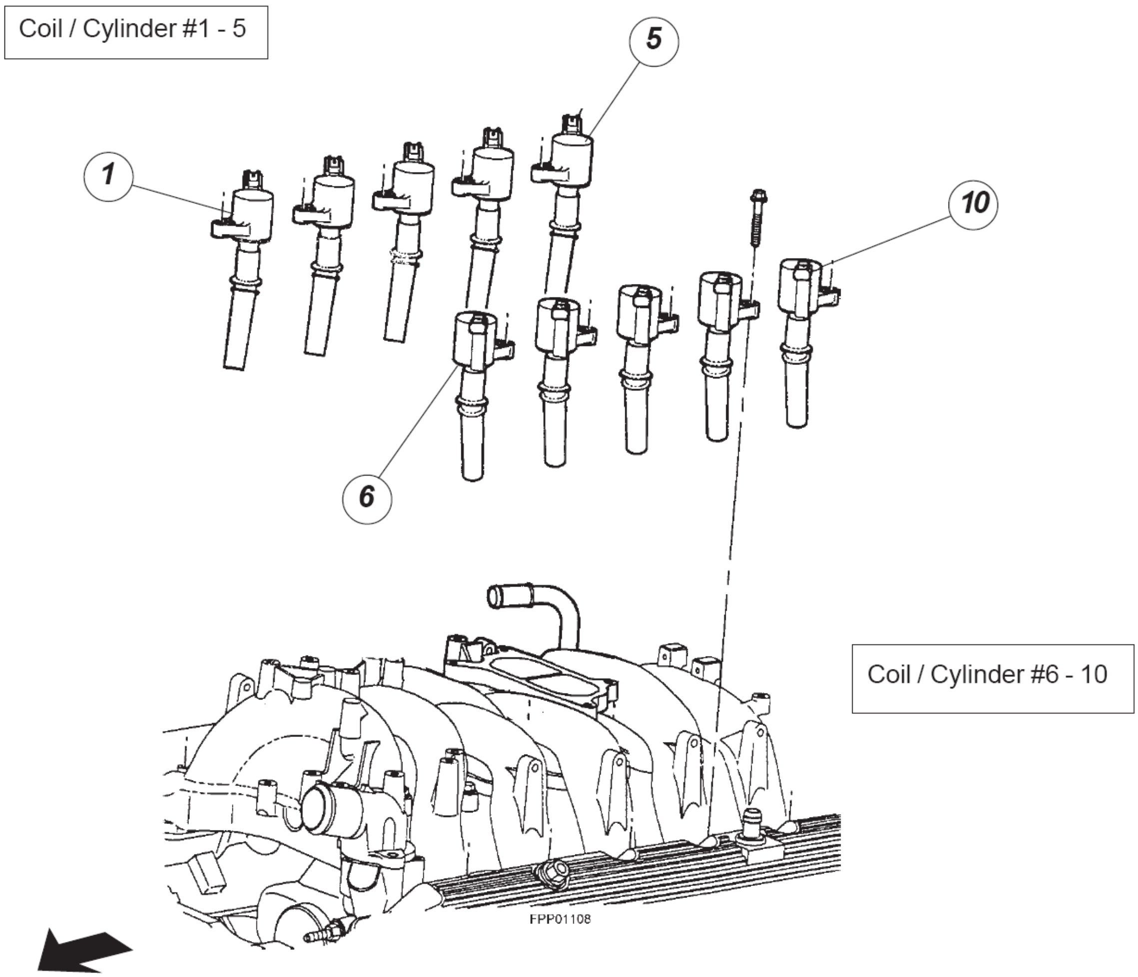
The ignition coils change a supplied low voltage signal into high voltage pulses to the spark plugs. The ignition control module controls the low side of each coil.

The ignition system is set for base timing at 10 degrees before top dead center (BTDC) and is not adjustable.

Refer to Specifications for firing order.

WSG-1068 IGNITION SYSTEM

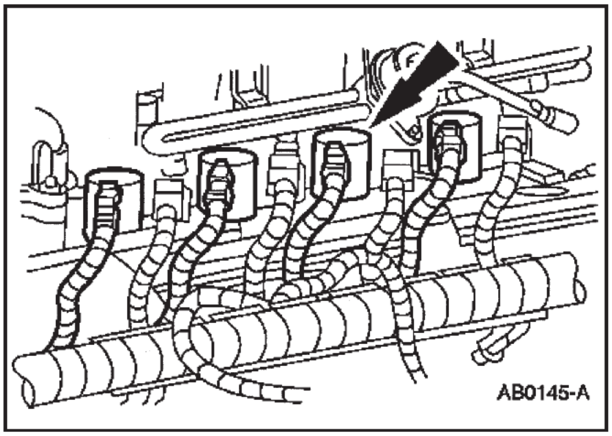
Firing Order



WSG-1068 IGNITION SYSTEM

Ignition Coil-On Plug - Removal

1. Disconnect the wiring at the coil.



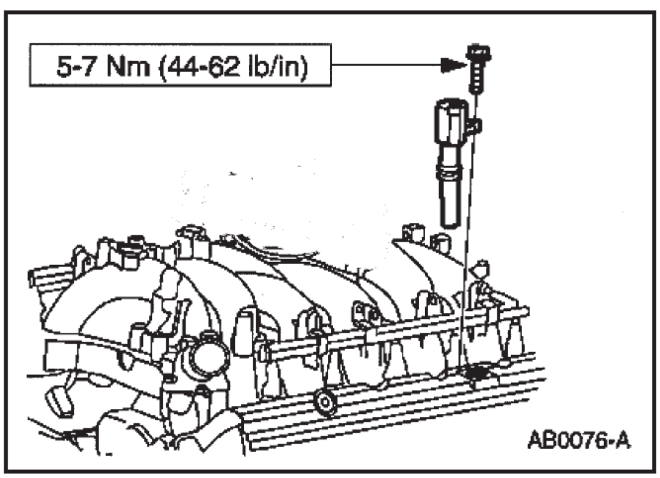
2. Remove the bolt and the coil.

Ignition Coil-On Plug - Installation

WARNING: ALWAYS WEAR SAFETY GLASSES TO PROTECT EYES FROM FLYING FOREIGN MATERIAL.

1. NOTE: Remove any foreign material from spark plug wells with compressed air.

2. Insert a small amount of dielectric grease into each boot using Motorcraft Silicone Brake Caliper Grease and Dielectric Compound XG-3 or equivalent meeting Ford specification ESE-M1C171-A.



To install, reverse the removal procedure.

WSG-1068 IGNITION SYSTEM

Harness Connector Pinout Description

GCP *Connector (10 Pin) Terminals*			
I/O	***Conn***	***Pin***	***Description***
I	*Main*	1	*Coil #1*
I	*Main*	5	*Coil #7*
I	*Main*	3	*Coil #6*
I	*Main*	7	*Coil #3*
I	*Main*	6	*Coil #5*
I	*Main*	11	*Coil #8*
I	*Main*	10	*Coil #10*
I	*Main*	9	*Coil #4*
I	*Main*	2	*Coil #2*
I	*Main*	63	*Coil #9*

I / O = Input / Output

WSG-1068 IGNITION SYSTEM

Fuel Select Operation

Fuel Select is Used to select ignition table for fuel type. The user has several options for this which is all dependent on whether pin 7 of the 42 pin connector is Open, grounded or has 12 volts. The configurations are listed below.

Fuel Select Configuration

1	GND = LP, Open = Gsln , +V = NG
2	Gnd = NG, Open = Gsln, +V = LP
3	Gnd/Open = Gsln, +V = LP
4	Gnd/Open = Gsln, +V = NG
5	Gasoline Only
6	LP Only
7	NG Only
8	Gnd/Open = LP, +V = NG
9	Gnd/Open = NG, +V = LP
10	Gnd = LP, Open = NG, +V = Gsln

WSG-1068 IGNITION SYSTEM

DIAGN0SIS AND TESTING

Service Adjustments And Checks

1. Each 400 hours of engine operation remove the spark plugs and clean and adjust the electrode.

2. Clean and visually check each coil-on plug connectors, check for secure fit.

Diagnostic Equipment

To accurately diagnose Coil on Plug (COP), certain diagnostic equipment and tools are required. In addition, the suggested diagnostic equipment may make the job easier and more convenient.

Prior to diagnosing COP, obtain the following test equipment or equivalent.

- Spark tester, neon bulb type (Champion CT-436).

- Spark tester, gap type (special service tool D81P-6666-A).

Connect this gap type spark tester between any COP and engine ground to instantly determine if spark is being provided to the plug. A spark plug with a broken side electrode is not sufficient to check for spark and may lead to incorrect results.

- Volt-ohmmeter (Rotunda 73111 Automotive Meter 105- R005 7 or equivalent).

A volt-ohmmeter is essential for gathering system operating data during diagnosis, testing, and engine servicing procedures. This digital volt ohmmeter (DVOM) can also be used for general purpose electrical troubleshooting on conventional starting and charging systems.

CAUTION: There should be no wires spliced to the main wire harness for source of power or RPM signal unless pre-approved by Ford Power Products. Otherwise, any alteration will void the warranty. Altering of wire harness may cause lack of power, no start, or erratic running.

NOTE: When using the spark plug firing indicator, place the grooved end as close as possible to the plug boot. Very weak or no flashing may be caused by a fouled plug.

NOTE: Do not use an incandescent test lamp to check CKPS- or CKPS+ circuits. The lamp will prevent the circuit from operating.

WSG-1068 IGNITION SYSTEM

Preliminary Checks

Before using this section verify the customer complaint and refer to the appropriate symptom chart. Perform the procedure included in the symptom chart.

Basic Circuit Checks

Basic circuit checks help to minimize pinpoint test steps by providing a procedure to diagnose harness faults associated with the Electronic Engine Control (EC) System. The following techniques provide helpful reminders for diagnosing open circuits (continuity), shorts to ground and shorts to power.
NOTE:

- The suspect circuit must be isolated before testing.
- When disconnecting any harness connector, always inspect for damaged or pushed out pins, corrosion and loose wires. Repair as necessary.
- The digital multimeter must be set to the correct scale.
- The techniques do not apply in all situations, therefore, it is necessary to follow each pinpoint test step accurately and completely.
- General resistance and voltage values are specified below. Always use the pinpoint test values if they differ.
- Always turn the key to the OFF position unless directed otherwise by the pinpoint test.

Each of the following procedures will require the Global Control Platform (GCP) and component to be disconnected to isolate the harness.

Open Circuit (Continuity)

Disconnect GCP. Measure the harness resistance between the suspect circuit at the harness connector and the appropriate GCP harness connector pin. The resistance must be less than 5.0 ohms.

Shorts to Ground

Measure the harness resistance between the suspect circuit at the harness connector and a reliable ground (B+, chassis ground or PWR GND). The resistance must be greater than 10,000 ohms.

Shorts to Power

Key ON to power up circuit. Measure voltage between the suspect circuit at the harness connector and a reliable ground. The voltage must be less than 1.0 volt.

Visual/Physical Check

Several of the symptom procedures call for a careful visual/ physical check. This can often lead to repairing a problem without performing unnecessary steps. Use the following guidelines when performing a visual/physical check:

Inspect unit for modifications or aftermarket equipment that can contribute to 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 all wires and harnesses for proper connections and routing, bent or broken connector pins, burned, chafed, or pinched wires, corrosion, and verify harness grounds are clean and tight.
- Inspect GCP, sensors and actuators for physical damage.
- Inspect fuel system for adequate fuel level, and fuel quality (concerns such as proper fuel pressure and contamination).
- Inspect intake air system and air filter for restrictions.

Intermittent Problems

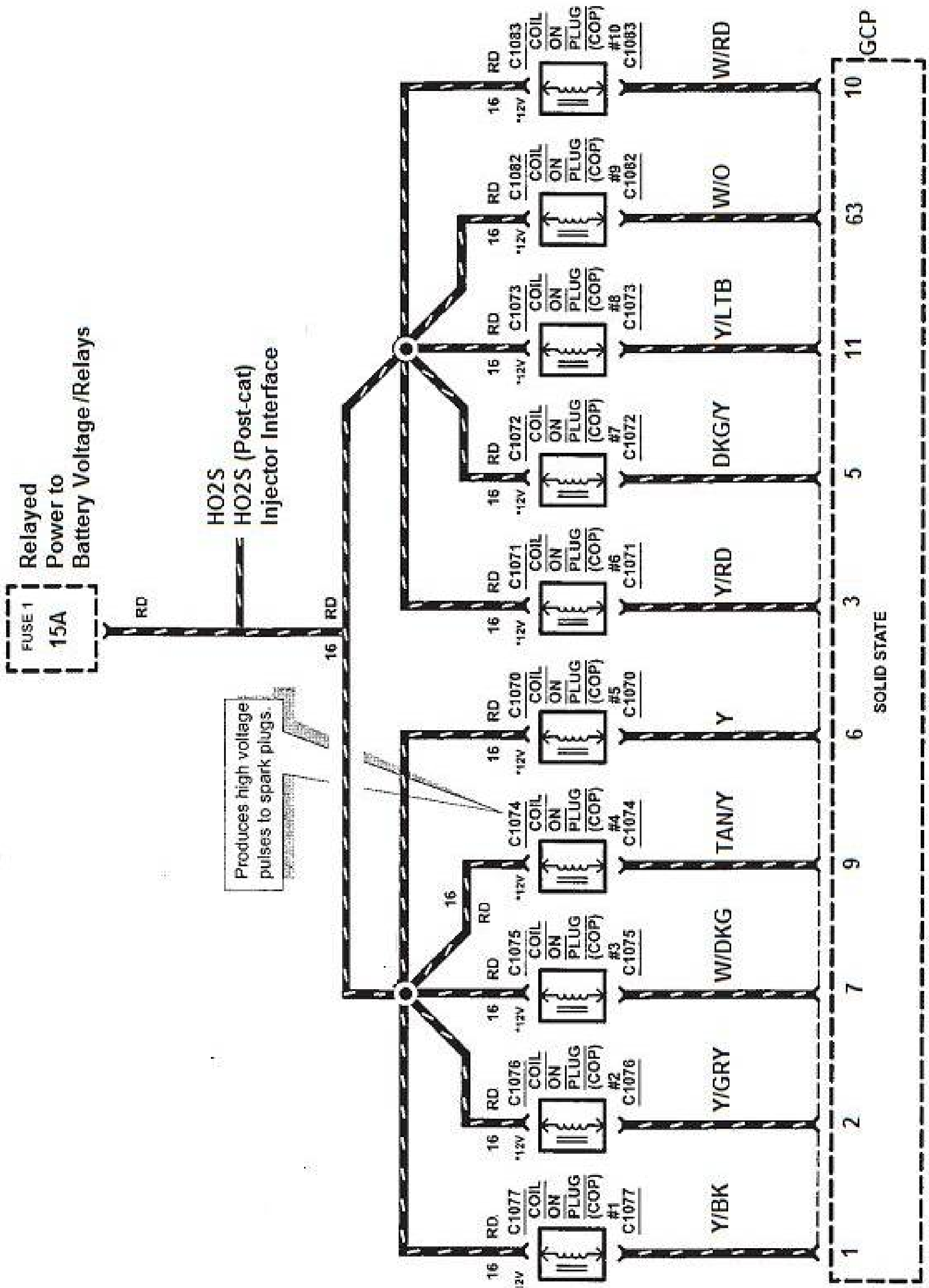
Most intermittent problems are caused by faulty electrical connections or wiring. Perform a careful visual/physical check for the following conditions:

- 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

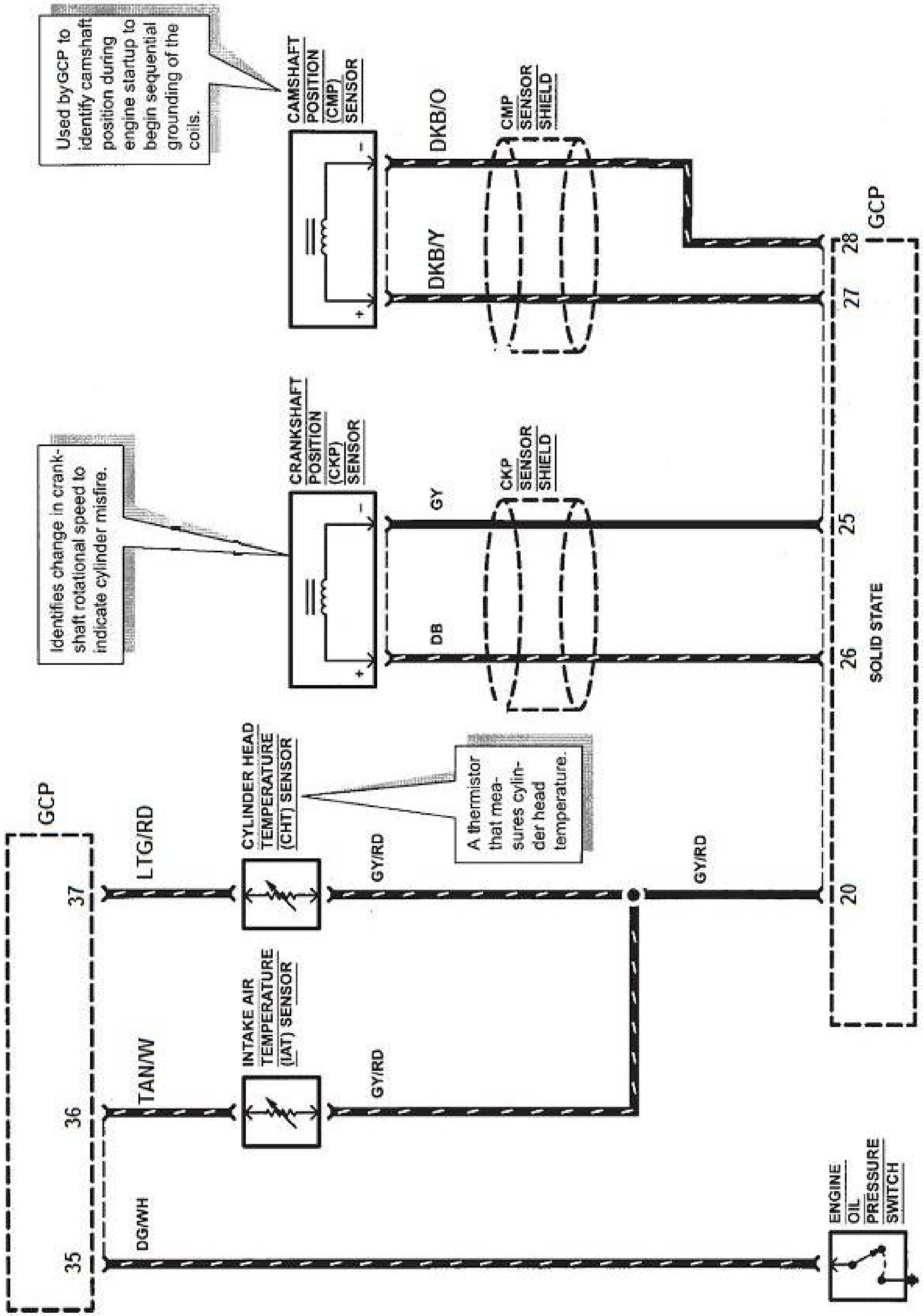
WSG-1068 IGNITION SYSTEM

Engine Controls



WSG-1068 IGNITION SYSTEM

Engine Sensors (part of SK2U1L-12A200-BA)



WSG-1068 IGNITION SYSTEM

42 Pin Engine Harness Connectors

F8JL-14324-AC & F8JL-14324-BA	SH 4/5/06	
42 pin engine to frame harness (6.8L)		
GCP Engine to Frame Harness Pinout (Harness Part # F8JL-14324-AC or BA)		
Pin #	**Wire Color**	**Description**
1	Red/Light Green	+12 V switched
2	Tan/Yellow	Tachometer output
3	Pink / Light Blue	RS232 Rx / Self Test Input
4	Not populated	Brake input
5	Pink/Black	To fuel pump positive
6	Pink/Light Green	To MIL
7	Y / Bk or BR / W	Fuel select
8	Yellow	Not used
9	Yellow	Not used
10	Not populated	Aux. Analog PUD1
11	Tan / Orange	RS232 Tx
12	Not populated	FPP2
13	Red/Light Blue	Not used
14	Light Blue/Black	FPP1
15	Dark Blue	To start switch "S" terminal
16	Red/White	Aux. PWM 4
17	Not populated	Not used
18	White / Purple	To fuel pump negative
19	Not populated	Autocrank start
20	Not populated	Not used
21	Not populated	Aux. PWM 5
22	Purple	Not used
23	Not populated	GVS 2
24	Tan/Light Blue	GVS 1
25	Black/Yellow	IVS
26	Dark Green/White	Oil pressure
27	Not populated	Aux. Out 2
28	Not populated	CAN +
29	Not populated	CAN -
30	Not populated	Not used
31	Brown/White	+5v ref
32	Not populated	Aux. Analog PD1
33	Gray/Red	Analog return
34	Black/White	Not used
35	Not populated	Roadspeed +
36	Not populated	Roadspeed -
37	Dark Green / Orange	Analog aux. PUD2

WSG-1068 IGNITION SYSTEM

90 Pin GCP Connector

Pinout

Pin	Function	Limits	Pin	Function	Limits	Pin	Function	Limits
1	SPK_COIL1a	0-12v, Primary Coil = 10A Max.	31	5V_ext2	4.5 V, 1mA	61	EGOH_2	3.0 A LS to GND
2	SPK_COIL1b	0-12v, Primary Coil = 10A Max.	32	5V_rtn2	GND, 1mA	62	EGOH_1	3.0 A LS to GND
3	SPK_COIL2a	0-12v, Primary Coil = 10A Max.	33	PULSE_in	10Ω Imp., Rise-3.0v, Fall-2.5v	63	SPK_COIL4c	0-12v, Primary Coil = 10A Max.
4	SPK_GND	GND, 10A	34	GOV1	0-28 V, 12.0KΩ MP to +2.7V	64	INJ1_LS	2.0 A LS to GND
5	SPK_COIL2b	0-12v, Primary Coil = 10A Max.	35	OILP	0-5 V, 22.1KΩ PU to +5V	65	INJ2_LS	2.0 A LS to GND
6	SPK_COIL3a	0-12v, Primary Coil = 10A Max.	36	IAT	0-5 V, 2.21KΩ PU to +5V	66	INJ3_LS	2.0 A LS to GND
7	SPK_COIL3b	0-12v, Primary Coil = 10A Max.	37	ECT	0-5 V, 22.1KΩ PU to +5V	67	INJ4_LS	2.0 A LS to GND
8	EGO_3	0-1.2 V	38	AUX_ana_PU1 (FRT)	0-5 V, 2.21KΩ PU to +5V	68	INJ5_LS	2.0 A LS to GND
9	SPK_COIL3c	0-12v, Primary Coil = 10A Max.	39	AUX_ana_PU2 (GFT)	0-5 V, 2.21KΩ PU to +5V	69	Ground	GND, 14 A
10	SPK_COIL4a	0-12v, Primary Coil = 10A Max.	40	AUX_ana_PU3 (IVS)	0-5 V, 2.21KΩ PU to +5V	70	INJ6_LS	2.0 A LS to GND
11	SPK_COIL4b	0-12v, Primary Coil = 10A Max.	41	AUX_DIG3 (Brake Status)	0-28 V, 12.0KΩ MP to +2.7V	71	AUX_PWM8 (Inj 8)	2.0 A LS to GND
12	AUX_ana_PD1	0-5 V, 100KΩ PD to GND	42	AUX_DIG4 (Gov 2)	0-28 V, 12.0KΩ MP to +2.7V	72	STARTER	0.5 A LS to GND
13	AUX_ana_PD2 (FRP)	0-5 V, 100KΩ PD to GND	43	TACH	0.5 A LS to GND	73	RELAY	0.5 A LS to GND
14	CAN1+	Pulled to 2.5V, Driven to 5.0V	44	Vswitch	6-18V, 14A	74	MIL	0.5 A LS to GND
15	CAN1-	Pulled to 2.5V, Driven to 5.0V	45	AUX_ana_PUD2	0-5 V, 2.21KΩ PU to +5V	75	EGOH_3	3.0 A LS to GND
16			46	AUX_ana_PUD1	0-5 V, 100KΩ PD to GND	76	AUX_PWM7 (Inj 7)	2.0 A LS to GND
17			47	TPS1	0-5 V, 100KΩ PD to GND	77	LOCKOFF	3.0 A LS to GND
18	AUX_ana_PD3	0-5 V, 100KΩ PD to GND	48	TPS2	0-5 V, 100KΩ PD to GND	78	AUX_PWM6	0.5 A LS to GND
19	5V_ext1	5.0 V, 200mA	49	AUX_DIG1 (Fuel Type)	0-28 V, 12.0KΩ MP to +2.7V	79	Vbat	6-18V, 14A
20	5V_rtn1	GND, 200mA	50	AUX_DIG2	0-28 V, 12.0KΩ MP to +2.7V	80	DBW+	± 6.0 A H-Bridge
21	EGO_1	0-1.2 V	51	KNK1+	Wide-band (High Gain)	81	Ground	GND, 14 A
22	EGO_2	0-1.2 V	52	KNK1-	Wide-band (High Gain)	82	DBW-	± 6.0 A H-Bridge
23	MAP	0-5 V, 100KΩ PD to GND	53	FPP1	0-5 V, 100KΩ PD to GND	83		
24	AUX_ana_PUD3	0-5 V, 100KΩ PD to GND	54	FPP2-IVS	0-5 V, 22.1KΩ PU to +5V	84	AUX_PWM5 (Inj 10)	2.0 A LS to GND
25	CRK_POS	10KΩ Impedance, 200 V p-p	55	PC_Tx	RS-232	85	AUX_PWM1	0.5 A LS to GND
26	CRK_NEG	10KΩ Impedance, 200 V p-p	56	PC_Rx	RS-232	86	AUX_PWM4 (Inj 9)	2.0 A LS to GND
27	CAM_POS	10KΩ Impedance, 200 V p-p	57	KNK2+	Wide-band (High Gain)	87	AUX_PWM2	0.5 A LS to GND
28	CAM_NEG	10KΩ Impedance, 200 V p-p	58	KNK2-	Wide-band (High Gain)	88		
29	SPD_POS	10KΩ Impedance, 200 V p-p	59	Vbat_prot	6-18V, 6A	89	AUX_PWM3_Rec	Recirculation Diode
30	SPD_NEG	10KΩ Impedance, 200 V p-p	60	Vbat	6-18V, 14A	90	AUX_PWM3	7.0 A LS to GND

WSG-1068 IGNITION SYSTEM

Pinpoint Test A - Ignition Check

The ignition system check will verify the required inputs and outputs recommended by Engine Distributors Inc. Always locate and inspect all power, ground and terminal connections prior to the start of this test, as failures and corrosion associated with these areas can adversely affect the engine to start properly.

Inspection and Verification

1. Visually inspect for obvious signs of mechanical and electrical damage.
2. Visually inspect for and note auxiliary system connections not shown on the **recommended wiring schematic**.

Step	Action	Values	Yes	No
1	1. Key Off, Engine Off. 2. Inspect the battery for clean and tight battery positive and negative connections. 3. Using an ohmmeter, measure the voltage across the battery posts. Is the voltage within the specified value?	12.53 Volts	GO to Step 2	Recharge the battery. TEST the system for normal operation.
2	1. Disconnect the Battery Positive cable from the battery and the starter B+ post. 2. Using an ohmmeter, measure the resistance between the terminal ends of the cable. Is the resistance within the specified value?	Less than 5 Ohms	GO to Step 3	Replace the Battery Positive Cable and RETEST
3	1. Disconnect the Battery Negative cable from the battery. 2. Using an ohmmeter, measure the resistance between the terminal ends of the cable. Is the resistance within the specified value?	Less than 5 Ohms	GO to Step 4	Replace the Battery Negative Cable and RETEST
4	1. Key Off, Engine Off. 2. Inspect the starter B+ terminal for a clean and tight connection. 3. Using an ohmmeter, measure the voltage at the starter B+ terminal Is the voltage within the specified value?	Battery Voltage	GO to Step 5	REPAIR the circuit(s) in question. TEST the system for normal operation.
5	1. KOEO. 2. Using an ohmmeter, measure the voltage at the ignition switch B terminal. Is the voltage within the specified value?	Battery Voltage	GO to Step 6	Inspect or Replace the 30A fuse. REPAIR the circuit(s) in question. TEST the system for normal operation.
6	1. KOEO. 2. Using an ohmmeter, measure the voltage at the ignition switch I terminal. Is the voltage within the specified value?	Battery Voltage	GO to Step 7	Remove and Replace the Ignition Switch And Retest

WSG-1068 IGNITION SYSTEM

Step	Action	Values	Yes	No
7	1. Inspect the throttle plate. 2. Verify that the throttle plate is moving during crank. Is the throttle plate moving?		Return to Symptom Chart	Refer to the Fuel Systems Manufacturing Information and Test

WSG-1068 FUEL SYSTEM

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NOTE: For further information on Servicing the fuel system, refer to Manufacturer's Service Information.

WSG-1068 FUEL SYSTEM

GENERAL INFORMATION

System Operation - LPG

WARNING:

WHEN INSTALLING ANY LIQUID PETROLEUM GAS/FUEL SYSTEMS, FOLLOW ALL COUNTRY AND LOCAL CODES.

IN THE USA FOLLOW ALL REGULATIONS AND STANDARDS MANDATED BY THE NATIONAL FIRE PROTECTION ASSOCIATION, INC. INCLUDING NEPA 37, NFPA 52, AND NFPA 58, PLUS ANY OTHER STANDARDS. YOU CAN OBTAIN COPIES FROM YOUR LOCAL FIRE DEPARTMENT.

FOR CANADIAN CODES SEE NATIONAL STANDARDS OF CANADA.

IN THE UNITED KINGDOM FOLLOW THE CODE OF PRACTICE ELEVEN PRODUCED BY THE LPG/NG ASSOCIATION.

High pressure liquefied Petroleum Gas passes through a solenoid operated fuel shut-off valve into an engine coolant heated vaporizer/regulator unit where it is converted into a low pressure gas. This gas is then fed into the carburetor body/mixer where a vacuum operated gas metering valve ensures that the correct air-to-fuel ratio is maintained.

When the engine is switched off, the electrical supply to the fuel shut-off solenoid is disconnected and the valve closes, cutting off the high pressure fuel supply to the vaporizer/regulator. The electrical supply to fuel shut-off valve passes through a vacuum operated safety switch. Should the engine stall, the vacuum switch opens and cuts off the electrical supply to the fuel shut-off valve. When starting the engine, there is sufficient vacuum present, even at cranking speed, to close the safety switch.

FUEL SYSTEMS – FIELD CALIBRATIONS/GENERAL
When performing field calibrations on LPG & NG systems, it should be noted that improper fuel calibrations and/or improper hardware installation may result in decreased durability/life of the cylinder head valve train. Validation testing on the valve train was conducted in a controlled laboratory environment with proper air-fuel distribution and proper air-fuel ratios which fall within acceptable ranges.

WSG-1068 FUEL SYSTEM

System Operation – Natural Gas

WARNING:

WHEN INSTALLING ANY NATURAL GAS/FUEL SYSTEMS, FOLLOW ALL COUNTRY AND LOCAL CODES.

IN THE USA FOLLOW ALL REGULATIONS AND STANDARDS MANDATED BY THE NATIONAL FIRE PROTECTION ASSOCIATION, INC. INCLUDING NEPA 37, NFPA 52, AND NFPA 58, PLUS ANY OTHER STANDARDS. YOU CAN OBTAIN COPIES FROM YOUR LOCAL FIRE DEPARTMENT.

FOR CANADIAN CODES SEE NATIONAL STANDARDS OF CANADA.

IN THE UNITED KINGDOM FOLLOW THE CODE OF PRACTICE ELEVEN PRODUCED BY THE LPG/NG ASSOCIATION.

Natural gas passes through a vacuum operated fuel shutoff valve into a regulator unit where it is converted into a low pressure gas. This gas is then fed into the mixer where a vacuum operated gas metering valve ensures that the correct air-to-fuel ratio is maintained.

When the engine is switched off, vacuum supply to the fuel shut-off vacuum is disconnected and the valve closes, cutting off the fuel supply to the regulator.

Should the engine stall, the loss of vacuum will close the fuel shut-off valve. When starting the engine, there is sufficient vacuum present, even at cranking speed, to open the fuel shut-off valve.

The system is similar to the LPG system, except a convertor (vaporizer) is not used, and the coolan connections are also not needed. A regulator is required and must be supplied by the OEM to suit the mains gas supply pressure.

WSG-1068 FUEL SYSTEM

DIAGNOSIS AND TESTING

Pinpoint Test A - Fuel Pressure Check

Inspection and Verification

1. Visually inspect for obvious signs of mechanical and electrical damage.
2. Visually inspect for and note auxiliary system connections not shown on the **Recommended Customer Connections Wiring Schematic**.

Normal Operation

Fuel pressure is customer supplied. The following test is a generalized procedure, which should be completed prior to all test.

Step	Action	Values	Yes	No
1	1. Key Off, Engine Off 2. Check the fuel supply line and shut-off valve for proper operation. Is the fuel supply line in the open position and the shut-off valve operating properly?		GO to Step 2	Repair or replace any inoperative component and Retest
2	1. Check the fuel system pressure. Is the fuel supply pressure within the specified value?	LPG: System Pressure NG: 11"of water column	GO to Step 3	Correct fuel pressure and Retest
3	1. Note: This test may require an assistant depending on the application. 2. Key Off. 3. Hold the fuel lockout device. 4. Key On. 5. Vacuum controlled fuel lockout units require the engine to be cranked. Does the fuel lockout unit open?		GO to Step 7	For electric lockout units GO to Step 4 For Vacuum controlled units GO to Step 6
4	1. Disconnect the fuel lockout unit connector. 2. KOEO 3. Check for battery voltage. Is battery voltage present?		GO to Step 5	REPAIR the circuit(s) in question. TEST the system for normal operation.
5	1. Key Off 2. Check the other side of the fuel lockout connector pin for continuity to a known good ground. Is the resistance less than 5 ohms?		Check for fuel line blockage Refer to the Fuel Systems Manufacturing Information and Test	Is the resistance less than 5 Ohms?
6	1. Key Off 2. Inspect all vacuum hoses for damage. 3. Disconnect the vacuum hose to the fuel lockout unit. 4. Using a manual vacuum tester, connect to the lockout unit. 5. While holding the lockout device apply vacuum to the fuel lockout unit. Does the lockout device hold vacuum and is fuel present?		Go to Step 7	Refer to the Fuel Systems Manufacturing Information and Test

Step	Action	Values	Yes	No
7	1. Inspect the throttle plate. 2. Verify that the throttle plate is moving during crank. Is the throttle plate moving?		Return to Symptom Chart	Refer to the Fuel Systems Manufacturing Information and Test

WSG-1068 COOLING SYSTEM

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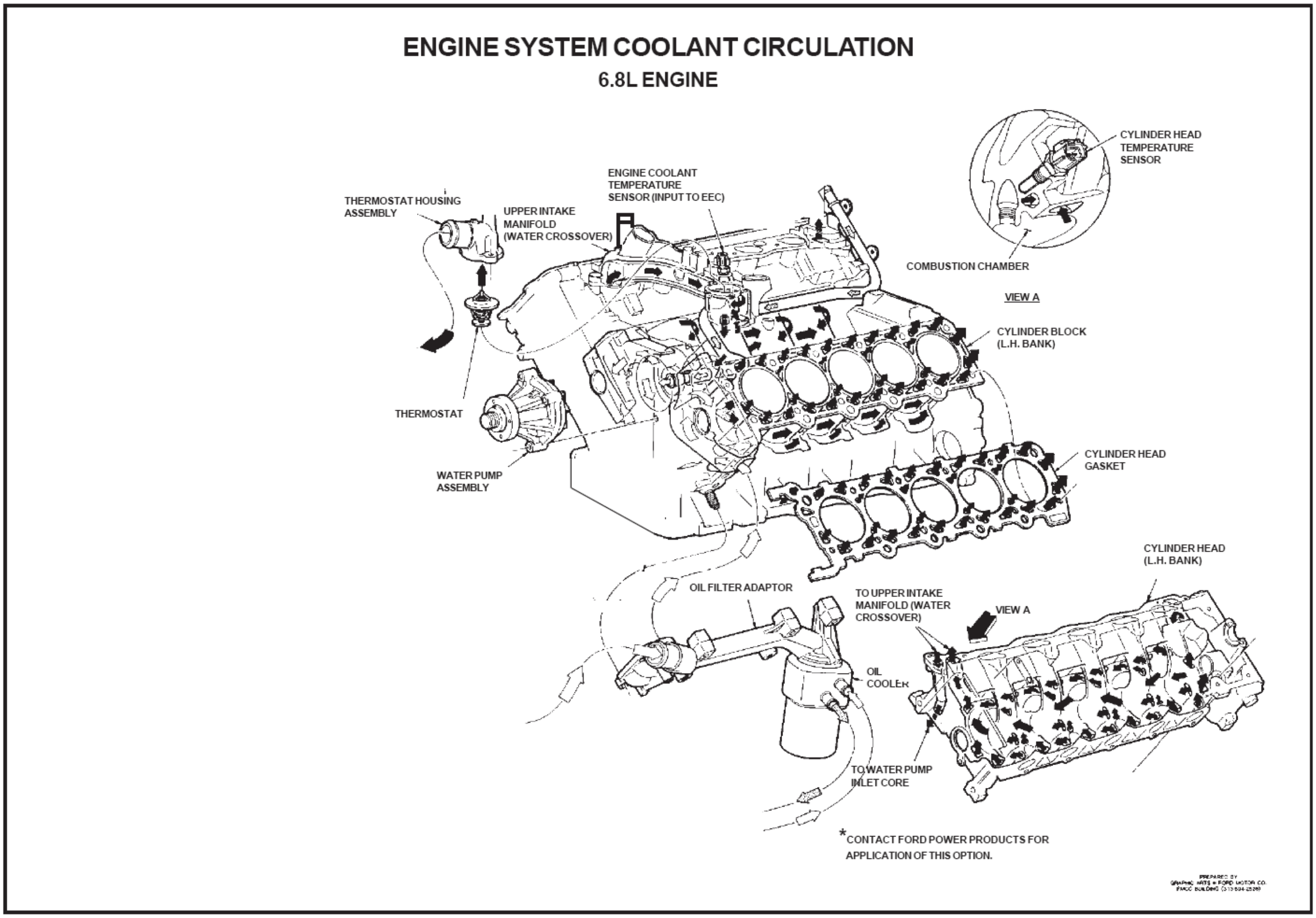
WSG-1068 COOLING SYSTEM

GENERAL INFORMATION



Engine Cooling

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 cooling system components are:

- Cylinder head temperature sensor (CHT sensor).
- Water thermostat and gasket assembly.
- Water pump assembly.

WSG-1068 COOLING SYSTEM

Coolant Flow is as follows:

- The water pump (8501) circulates the coolant.
- From the water pump to the engine block and the cylinder heads (6049) to the thermostat.
  – Thermostat closed, the coolant returns to the water pump through bypass hose.

  – Thermostat open, the coolant flows back to the radiator.

  – To the radiator for heat rejection then back to the lower radiator hose.

  – From the lower radiator hose (8286) to the water pump.

⚠ CAUTION: Alkaline brine solutions will cause serious engine cooling system damage.

⚠ CAUTION: Do not use. 100,000 mile, red in color antifreeze, it is not compatible with copper radiators.

Coolant:

- Use a 50/50 mix of Ethylene Glycol Permanent Antifreeze and water. This mixture is to be used year round with temperatures above -30°F.

Recycled Coolant:

- Use recycled engine coolant produced by Ford approved processes. Not all coolant recycling processes produce coolant which meets Ford specification ESE-M97B44- A or WSS-M97B44-D, and use of such a coolant may harm engine and cooling system components.

Unsatisfactory Coolant Material:

- Alcohol-type antifreeze does not provide adequate water pump lubrication.

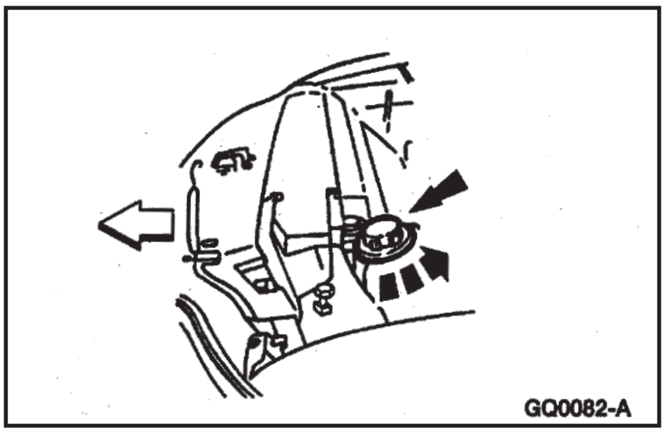
  – Has a lower boiling point.

  – Provides reduced antifreeze protection.

WSG-1068 COOLING SYSTEM

GENERAL SERVICE PROCEDURES

Cooling System Draining



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 AVOID 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 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.

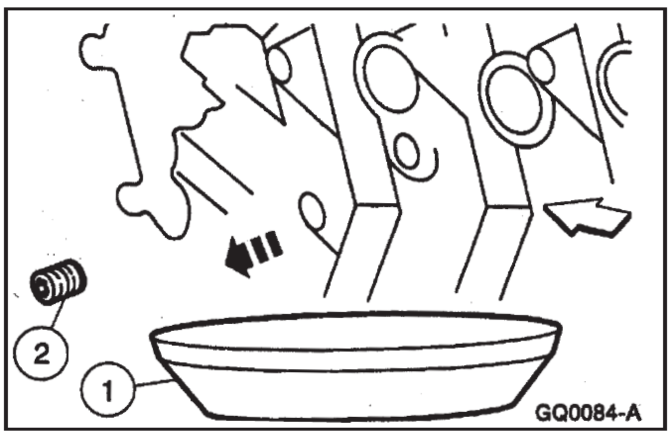
2. When you are sure all the pressure has been released, (still with a cloth) turn the pressure relief cap counterclockwise and remove.

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 properly.

NOTE: About 80% of coolant capacity can be recovered with the engine in the vehicle. Dirty, rusty or contaminated coolant requires replacement.

3. Place a suitable container below the radiator draincock (8115). If equipped, disconnect the coolant return hose at the fluid cooler.

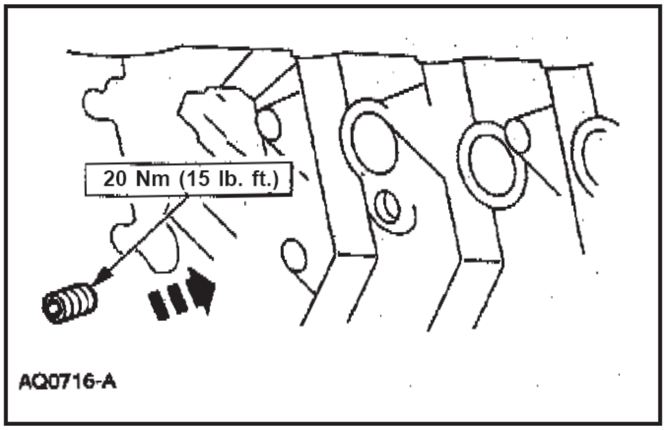
4. Open the radiator draincock.



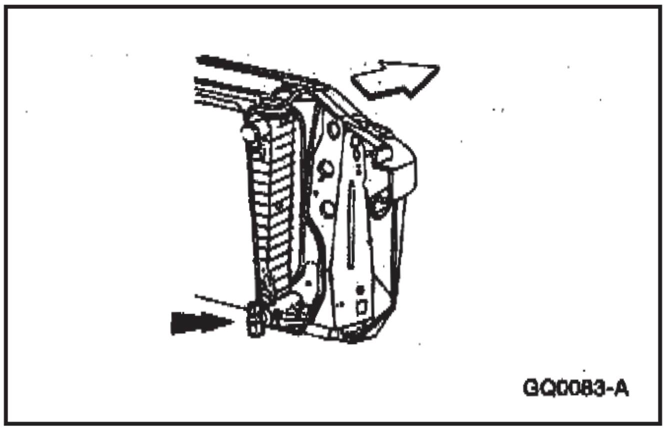
5. Remove the cylinder drain plug, if equipped, to drain the coolant from the cylinder block (6010).

   1. Place a drain pan below the cylinder block.

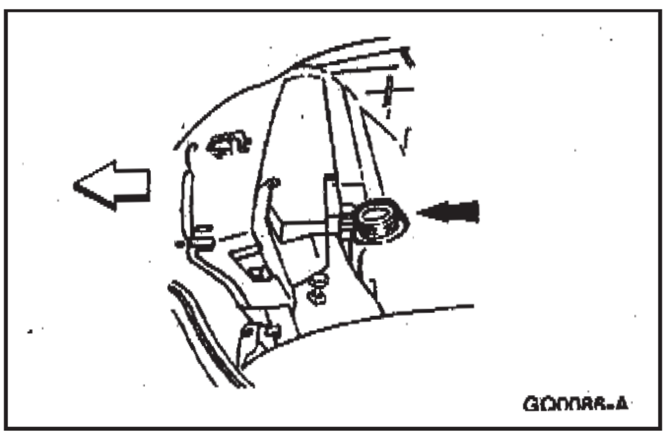
   2. Remove the drain plugs.



6. When the coolant is drained, make sure drain plugs are installed and tight.



7. Close the radiator draincock when finished.



Cooling System Filling

1. Add the proper engine coolant mixture to the degas bottle or radiator.

2. Move the temperature blend selector to the full warm position when equipped.

3. Run the engine until it reaches operating temperature.

4. Add the proper engine coolant mixture to the degas bottle or radiator until the coolant level is between the “COOLANT FILL LEVEL’’ marks.

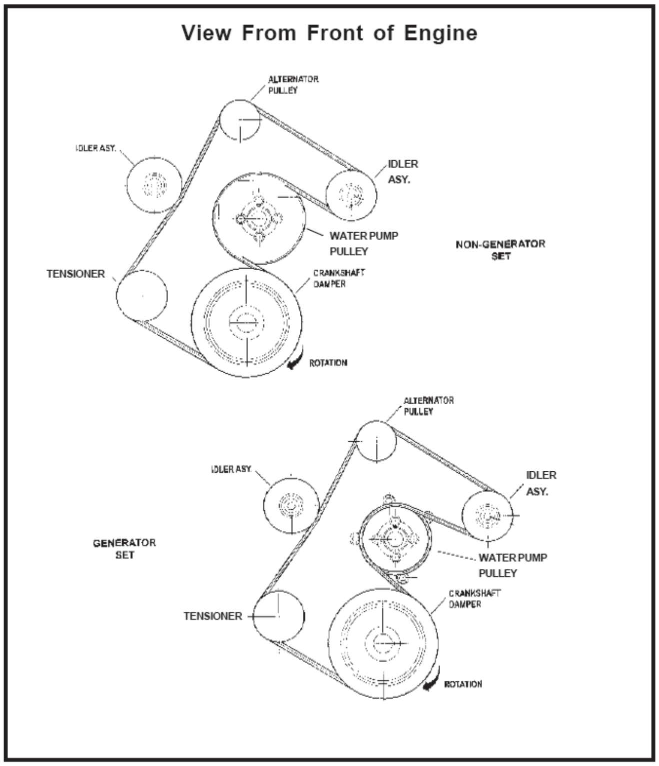
   NOTE: Systems without degas bottle fill radiator up to 1 inch below the filler neck.

5. Turn off the engine and allow the cooling system to cool.

6. Repeat Steps 1 through 5 until the radiator level is OK.

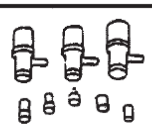
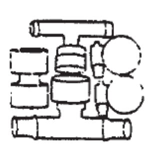
WSG-1068 COOLING SYSTEM

Drive Belt Routing



Cooling System Flushing

Special Tool(s)

 ST1166-A	Coolant System Drain/Flush/ Fill. 164-R3673
 ST1167-A	Flush Kit Hardware Package 164-R3658 or equivalent
 ST1168-A	Drain Kit 164-R3662 or equivalent

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

WSG-1068 COOLING SYSTEM

REMOVAL AND INSTALLATION

Radiator Hose - Removal

Radiator hoses should be replaced whenever they become cracked, rotted or have a tendency to collapse.

Drain the radiator into appropriate container then loosen the clamps at each end of the hose to be removed. Slide the hose off the radiator connection and the engine water outlet connection (upper hose) or the water pump connection (lower hose).

Radiator Hose - Installation

Position the clamps at least 1/8 inch from each end of the hose. Coat the connection areas with an approved water-resistant sealer and slide the hose on the connection. Make sure the clamps are beyond the bead and placed in the center of the clamping surface of the connections. Tighten the clamps. Fill the radiator with the recommended permanent antifreeze and water 50/50 mixture. Operate the engine for several minutes, then check the hoses and connections for leaks.

Thermostat - Removal

WARNING: AVOID INJURY FROM HOT COOLANT WHEN ENGINE IS HOT.

1. Partially drain the cooling system. For additional information, refer to Cooling System Draining, Filling and Flushing in this section.

2. Disconnect the upper radiator hose.

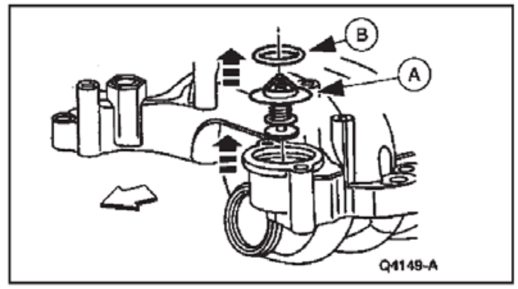
3. Remove the water outlet connection.

   - Remove the bolts.

   - Remove the water outlet connection.

4. Remove the (**B**) O-ring seal and the (**A**) water thermostat (8575).

   - Discard the (**B**) O-ring seal.

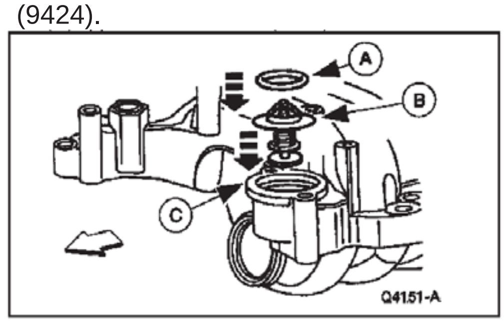


(A) Thermostat (B) O-ring Seal

Thermostat - Installation

NOTE: Thermostat must be installed as illustrated.

1. Install the (B) water thermostat and use a new (**A**) Oring seal to position the (**B**) water thermostat in the (**C**) upper intake manifold (9424).

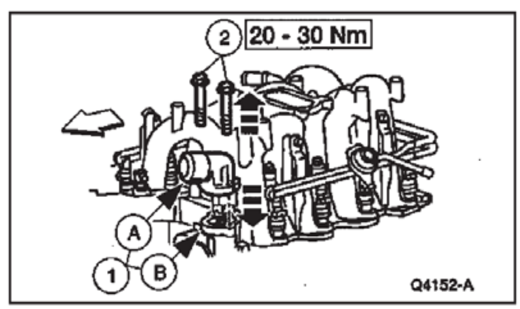


(A) O-ring Seal (B) Thermostat (C) Intake Manifold

2. Install the water outlet connection.

   1. Position the (**A**) water outlet connection on the (**B**) upper intake manifold.

   2. Install the bolts.



3. Connect the upper radiator hose.

4. Fill the cooling system. For additional information, refer to Cooling System Draining, Filling and Flushing in this section.

With or Without Dry Fuel Evaporator Plumbing

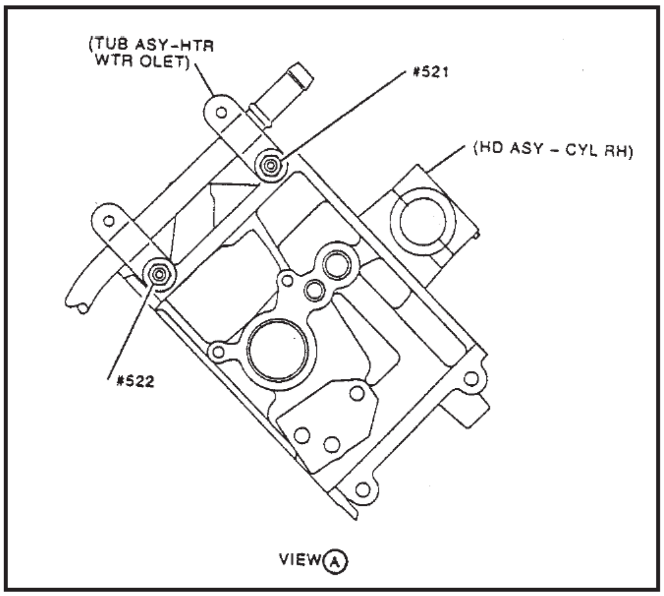
Removal of Heater Water Inlet Tube (18663)

1. Drain the cooling system.

2. Remove the upper and lower intake manifold together. Refer to Section 01 for details.

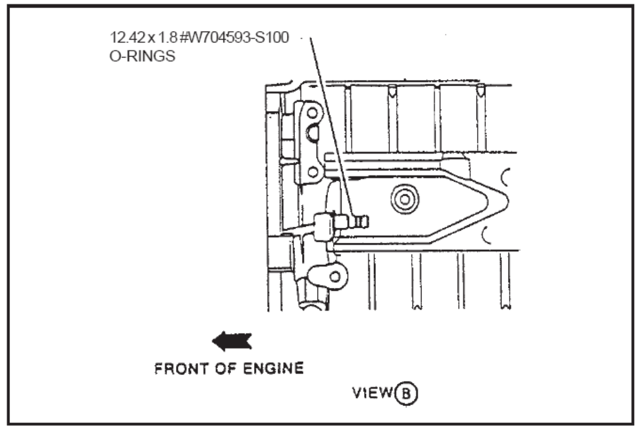
3. Remove the two studs securing the tube to the rear of the right side cylinder head and remove the tube.

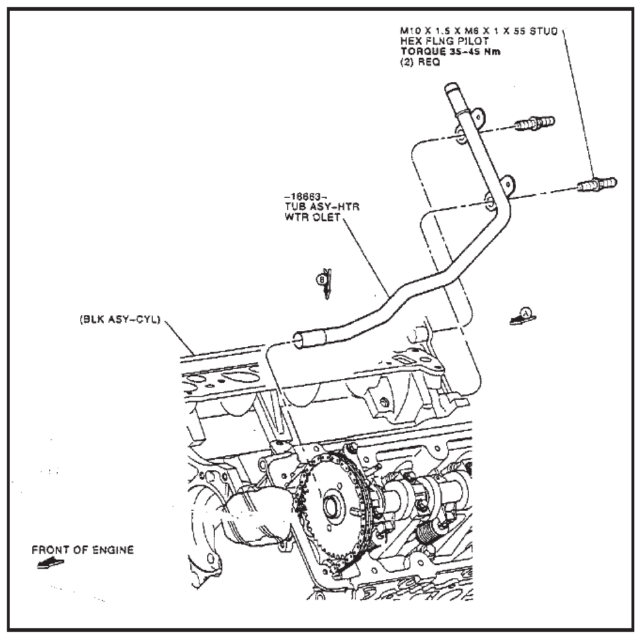
4. Inspect the water pump tube assembly o-rings for damage.



Installation of Water Heater Return Tube Assembly with by-pass Hose

1. Lightly lubricate the o-rings prior to installing the water outlet tube.





2. Install the heater water outlet tube.

3. Install the water tube-mounting studs.

4. Install the lower and upper intake manifold. (Refer to Section 01.

5. Install rubber cap and clamp on outlet tube if not using LPG or cab heater.

6. Refill the cooling system.

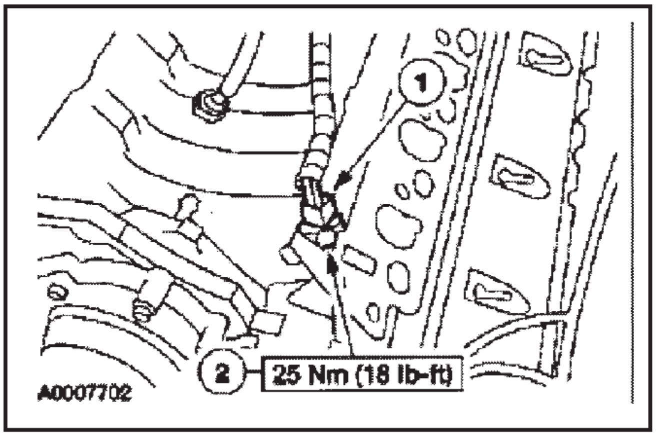
Cylinder Head Temperature (CHT) Sensor - Replacement

1. Remove the upper and lower intake manifold together. For additional information, refer to Section 01.

2. Remove the cylinder head temperature (CHT) sensor.

   1. Disconnect the electrical connector.

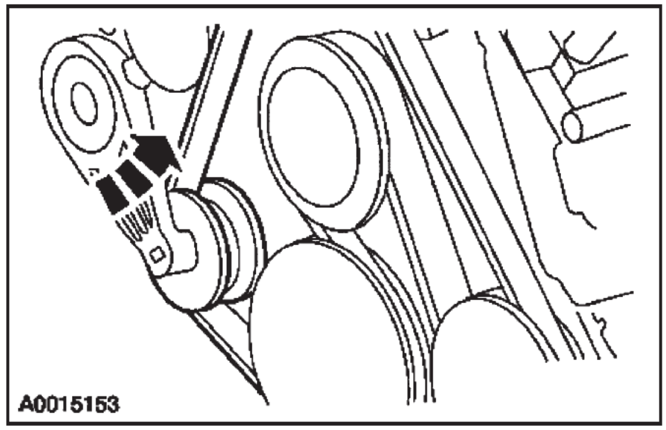
   2. Remove the CHT sensor.



3. To install, reverse the removal procedure.

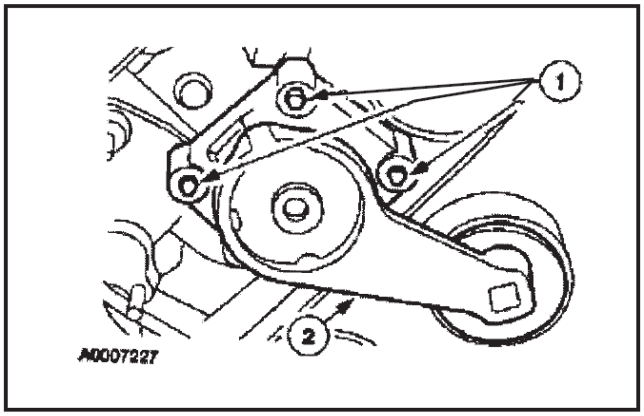
CAUTION: Do not over torque. May damage sensor.

Fan Drive Belt - Removal and Installation



1. Rotate the drive belt tensioner counterclockwise and remove the drive belt.

2. **NOTE**: Refer to 05-9 for correct drive belt routing. To install, reverse the removal procedure.



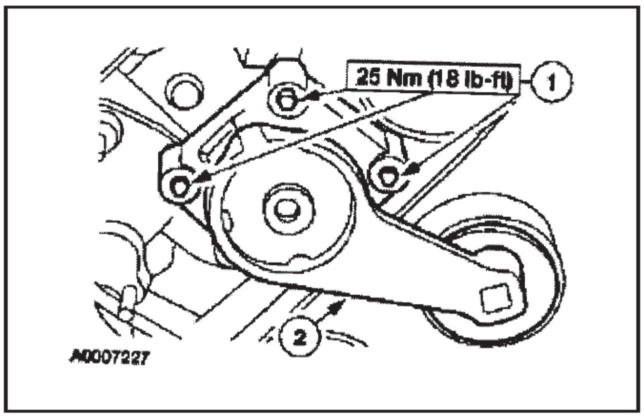
Belt Tensioner - Removal

1. Remove the drive belt (8620). For additional information, refer to Fan Drive Belt page 05-12.

2. Remove the belt tensioner.

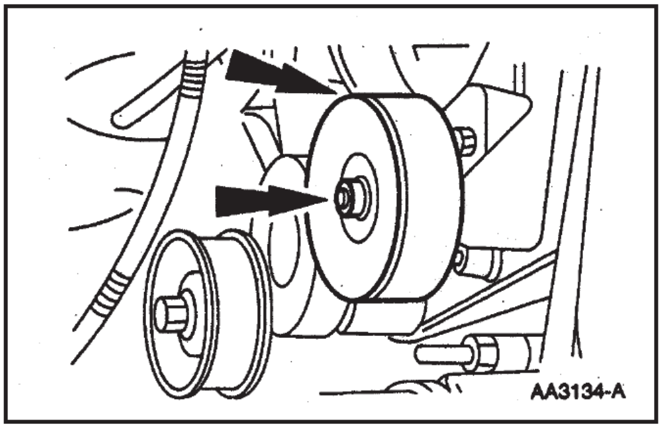
   1. Remove the bolts.

   2. Remove the belt tensioner.



Belt Tensioner - Installation

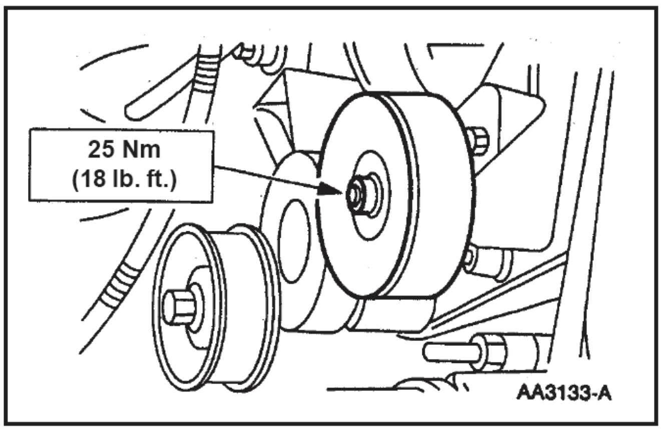
1. To install, reverse the removal procedure.



Belt Idler Pulley - Removal

1. Remove the fan drive belt (8620) off of the belt idler pulley (8678). For additional information, refer to Fan Drive Belt page 05-12.

2. Remove the bolt and the belt idler pulley.



Belt Idler Pulley - Installation

1. To install, reverse the removal procedure.

Water Pump - Removal

Material

Item	Specification
Motorcraft Premium Engine Coolant VC-4-A	ESE-M97B44-A

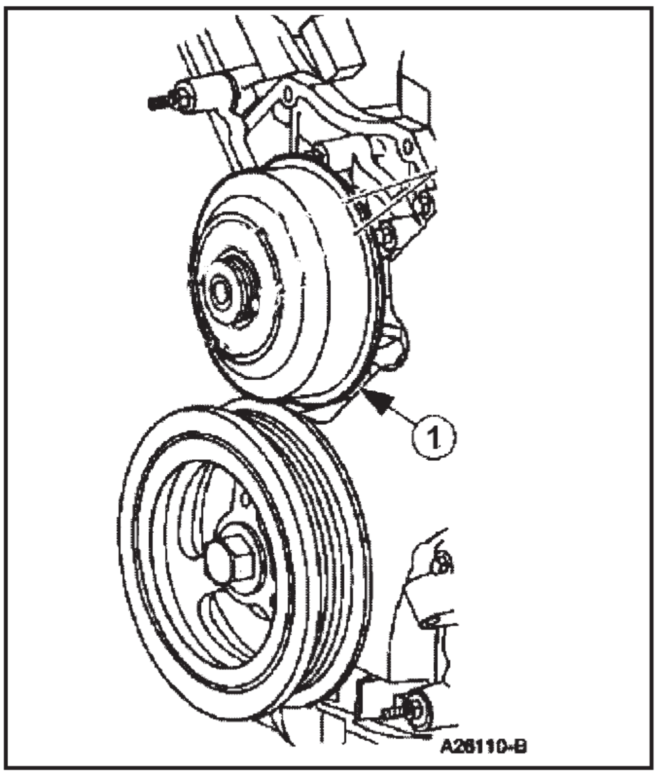
1. Drain the cooling system. For additional information, refer to Cooling System Draining, Filling and Flushing page 05-05.

2. Remove the engine cooling fan.

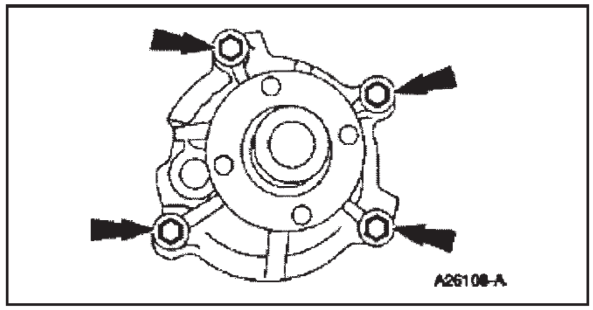
3. Remove the drive belt. For additional information, refer to Fan Drive Belt page 05-12.

4. Remove the water pump pulley (8509).

   - Remove the water pump pulley.

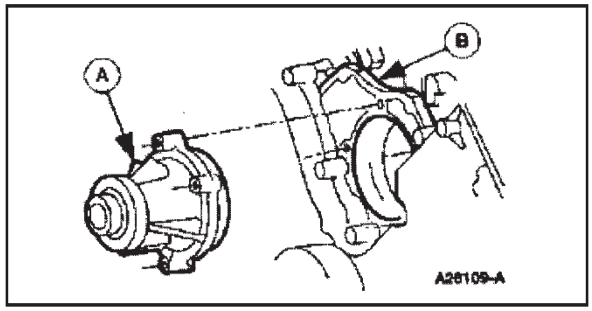


5. Remove the water pump bolts.



6. Remove the (A) water pump from the (B) cylinder block.

   - Clean and inspect the mating surfaces.



Water Pump - Installation

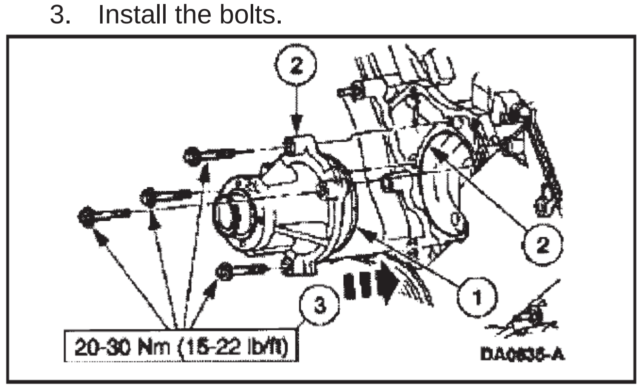
1. **CAUTION: Cooling systems are recommended to be filled with Motorcraft Premium Engine Coolant VC-4-A meeting Ford specification ESE-M97B44-A (green color). Do not mix coolant types.**

Install the water pump:

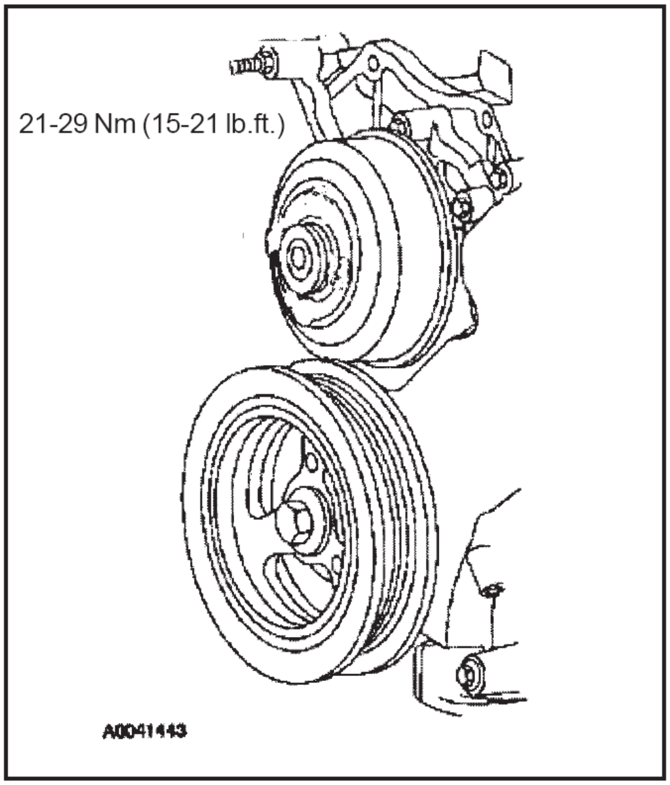
1. Lubricate the new O-ring seal using engine coolant and install the O-ring seal onto the water pump.

2. Position the water pump into the engine block and heater water outlet tube.

3. Install the bolts.



2. Position the pulley onto the water pump.



3. Install the fan spacer and fan.

4. Install the drive belt.

5. Refill the cooling system. For additional information, refer to Cooling System Draining, Filling and Flushing in this section.

WSG-1068 COOLING SYSTEM

DIAGNOSING AND TESTING

Refer to the following Diagnosis Chart for cooling system problems, their possible cause and recommended correction. Refer to the pertinent part for testing and repair.

The most frequent cooling system complaints are leakage and overheating. Either of these problems will soon render the vehicle inoperable.

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

Most vehicles 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.

CONDITION	POSSIBLE SOURCE	ACTION
• Loss of coolant.	• Pressure cap and gasket. • Leakage. • Internal leakage.	• Inspect, washer 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, water pump. 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 cylinder block.
• Engine overheats.	• Low coolant level. • Faulty drive belt tensioner. • Pressure cap. • Radiator obstruction. • Closed thermostat. • Fan. • Ignition. • Temp. gauge. • Engine. • Coolant mixture.	• Fill as required. Check for coolant loss. • Replace belt or tensioner as required. • Test. replace if necessary. • Remove bugs, leaves, etc. • Test, replace if necessary. • Test, replace if necessary. • Check electrical circuits and repair as required. • Check water pump and block for blockage. • 1/2 water and 1/2 permanent antifreeze mixture.
• Engine fails to reach normal operating temperature.	• Open thermostat. • Temperature gauge.	• Test, replace if necessary. • Check electrical circuits and repair as required.

Visual Inspection

Check for leakage at:

1. All hoses and hose connections.
2. Radiator seams, radiator core, and radiator drain petcock.
3. All block core plugs and drain plugs.
4. Edges of all cooling system gaskets.
5. Water pump shaft and bushing.

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

Examine oil dipstick for evidence of coolant contaminated engine oil (white milky appearance).

WSG-1068 COOLING SYSTEM

Cooling System Visual Test

Special Tool(s)

 ST1720-A	Battery/Anti-Freeze Tester 014-R1060 or equivalent

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

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 AVOID 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 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.

   CAUTION: If there is engine coolant in the engine oil the cause must be corrected and the oil changed or engine damage may occur.

   NOTE: Check the engine coolant in the degas bottle and radiator (8005) when vehicle has been allowed to reach normal operating temperature. This will make sure sufficient engine coolant exchange has occurred.

3. Inspect the coolant in both the radiator and the degas bottle for coolant color:
   - Clear, light green or blue indicates higher water
   content than required
   - Dark brown indicates unauthorized stop leak may have been used. Use cooling system Stop Leak Powder E6AZ-19558-A or equivalent meeting Ford specification ESE-M99B170-A only.
   - A light or reddish-brown color indicates rust in the cooling system. Flush the system and refill with the correct mixture of water and Premium Engine Coolant (green in color), E2FZ-19549-AA or equivalent meeting Ford specification ESEM97B44-A.
   - An irridescent sheen on top of the coolant indicates a trace of oil is entering the cooling system.
   - A milky-brown color indicates that oil is entering the cooling system.
   - The causes of the leak might be:

     – A blown head gasket (6051).

     – A cracked or warped cylinder head (6049).

     – A crack in the engine oil gallery and the cooling passageways.
   - If engine coolant is present in the engine oil, the cause of the leak might be:

     – A blown head gasket.

     – A cracked or warped cylinder head.

     – A crack in the engine oil gallery and cooling passageways.

4. If the engine coolant appearance is good, test the engine coolant range with the battery and antifreeze tester:
   - Maximum ratio is 60/40.
   - Minimum ratio is 45/55.
5. Check the engine coolant system conditions:
   - If the engine cooling fluid is low, add specified coolant mixture only.
   - If the engine coolant fluid tests weak, add straight engine coolant until the readings are within acceptable levels.
   - If the engine coolant tests strong, remove some of the engine coolant and add water until readings are within acceptable levels.
6. Check for electrical charge in coolant. Using a DVOM, insert the (+) probe into coolant without touching radiator. Hold the (-) probe to radiator shell or a good ground and read the volts.:
   - Less then 1.5 volts is good.
   - If voltage is above 1.5 volts - drain, flush and replace coolant with a 50/50 mixture.

NOTE: Above 3 volts may indicate a bad head gasket.

Thermostat Test – Thermostat Removed

WARNING: USE CAUTION WORKING WITH HOT BOILING WATER AND WEAR APPROPRIATE PROTECTIVE GEAR. MAY CAUSE BODILY HARM.

Remove the thermostat and immerse it in boiling water. Replace the thermostat if it does not open at least 0.230" after one minute at 212°F.

If the problem being investigated is the inability of the cooling system to reach normal operating temperature, the thermostat should be checked for leakage. This may be done by holding the thermostat up to a lighted background. Leakage of light all around the thermostat valve (thermostat at room temperature) indicates that the thermostat is unacceptable and should be replaced. It is possible, on some thermostats, that a slight leakage of light at one or two locations on the perimeter of the valve may be detected. This should be considered normal.

Radiator Leak Test, Removed From Vehicle

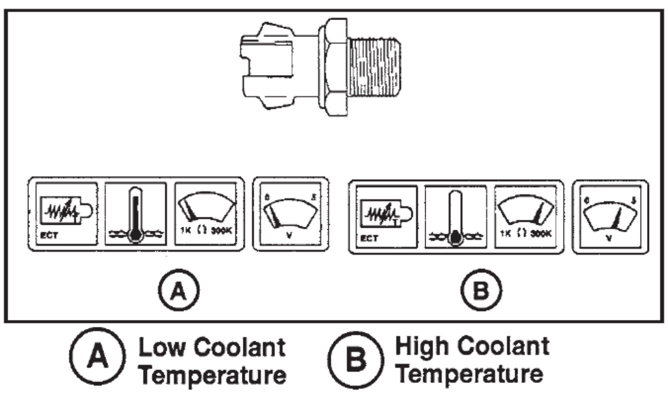
CAUTION: Never leak test an aluminum radiator in the same water that copper/brass radiators are tested in. Flux and caustic cleaners may be present in the cleaning tank and they will damage aluminum radiators.

1. Always install plugs in the oil cooler fittings before leak-testing or cleaning any radiator.

2. Clean the radiator before leak-testing to avoid contamination of the tank.

3. Leak-test the radiator in clean water with 138 kPa (20 psi) air pressure.

Engine Cylinder Head Temp. (CHT) Sensor



Circuit Description

The engine cylinder head temperature (CHT) sensor is a thermistor which measures the temperature of the engine cylinder head. The GCP supplies a ground (Gray/Red) from the sensor and monitors voltage signal (Lt Green / Red) to the sensor. When the engine coolant is cold, the sensor resistance is high and the GCP will monitor a high signal voltage at the CHT signal circuit. If the engine cylinder head is warm, the sensor resistance is lower, causing the GCP to monitor a lower voltage.

- Engine cylinder head temperature (CHT) sensor is a type of thermistor that converts engine temperature to an electrical voltage signal.
- The electrical resistance of the (CHT) sensor changes with temperature. As engine coolant temperature increases, the (CHT) resistance decreases.
- Output is a variable voltage signal which typically ranges from 0.3 volt to 4.5 volts.
- At -40°F (CHT) resistance is approximately 925K ohms.
- At 77°F (CHT) resistance is approximately 30K ohms.
- At 248°F (CHT) resistance is approximately 1.2K ohms.

  NOTE: Complete list of temperature sensor characteristics can be found on page 05-21 of this section.

Diagnostic Aids

The (CHT) sensor shares the same ground with other sensors. Check the ground circuit 359 (Gray) if other shared components.

NOTE: Refer to Section 08 for further diagnostics.

Inspect the harness connectors for backed-out terminals, improper mating, broken locks, improperly formed or damaged terminals, and poor terminal-to-wire connections. Inspect the wiring harness for damage. If the harness appears to be OK, back probe the CHT sensor connector with a digital voltmeter and observe the voltage while moving connectors and wiring harnesses related to the CHT sensor. A change in the voltmeter display will indicate the location of the fault.

WSG-1068 COOLING SYSTEM

CHT Sensor Data

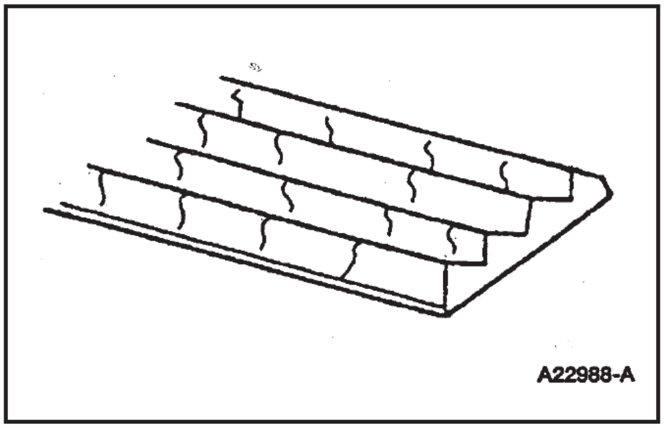
Temperature Sensor Characteristics

TEMPERATURE (C)	(F)	NOM R, (OHMS)	NOM E_{OUT} (VOLTS)
-40	-40	925,021	4.54
-35	-31	673,787	4.50
-30	-22	496,051	4.46
-25	-13	368,896	4.41
-20	-4	276,959	4.34
-15	5	209,816	4.25
-10	14	160,313	4.15
-5	23	123,485	4.02
0	32	95,851	3.88
5	41	74,914	3.71
10	50	58,987	3.52
15	59	46,774	3.32
20	68	37,340	3.09
25	77	30,000	2.86
30	86	24,253	2.62
35	95	19,716	2.39
40	104	16,113	2.15
45	113	13,236	1.93
50	122	10,926	1.72
55	131	9,061	1.52
60	140	7,548	1.34
65	149	6,332	1.18
70	158	5,335	1.04
75	167	4,515	.91
80	176	3,837	.79
85	185	3,274	.70
90	194	2,804	.61
95	203	2,411	.53
100	212	2,080	.47
105	221	1,801	.41
110	230	1,564	.36
115	239	1,363	.32
120	248	1,191	.28
125	257	1,044	.25
130	266	918	.22
135	275	809	.19
140	284	715	.17
145	293	633	.15
150	302	563	.14

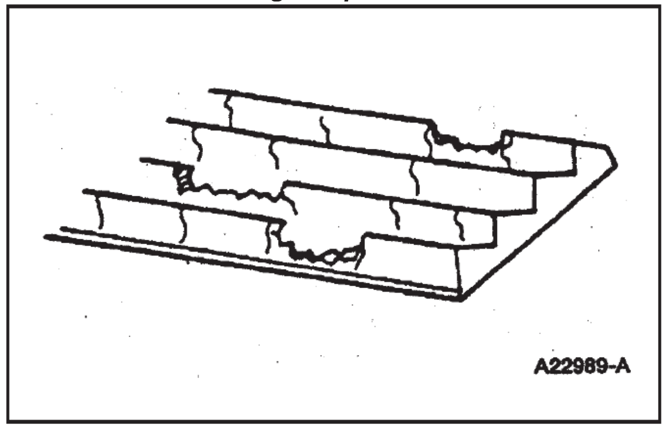
Voltage values calculated for VREF=5 volts (may vary 15% due to sensor and VREF variations).

V-Ribbed Serpentine Drive Belt

Cracks Across Ribs - Normal



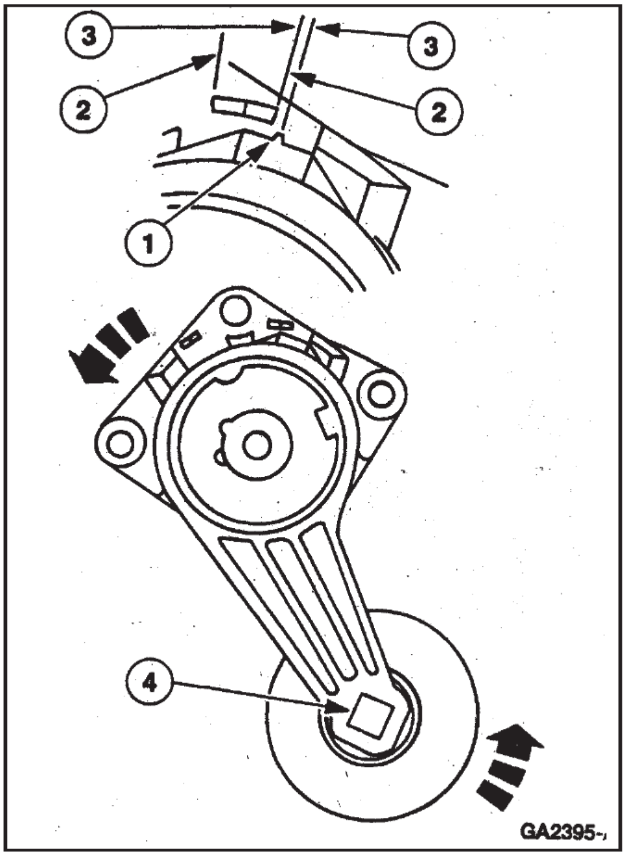
Chunks of Rib Missing - Replace Belt



Drive Belt Symptom Chart

Condition	Possible Source	Action
• Drive belt cracking • Drive belt chunking.	• Worn out. • Overheated • Chemical or oil spilled on belt.	• REPLACE the drive belt; Refer to Belt in this section.
• Drive belt noise or squeal.	• Pulley misalignment. • Excessive pulley groove runout. • Damaged drive belt tensioner (6B209). • Fluid or contamination on the drive belt.	• DETERMINE from which pulley the noise originates. CHECK that area with a straightedge and LOOK for for accessory pulley to be out of position in the fore/aft direction or at an angle to the straightedge. REPLACE the pulley or the component; • Replace belt tensioner. • CLEAN or REPLACE the drive belt; Refer to Fan Drive Belt this section.

Drive Tensioner/Belt Length Indicator



Item	Part Number	Description
1	–	Belt Length Indicator
2	–	Acceptable Belt Installation and Wear Range
3	–	Belt Replacement Range
4	–	Belt Tension Relief Point (Use 1/2 Inch Ratchet)

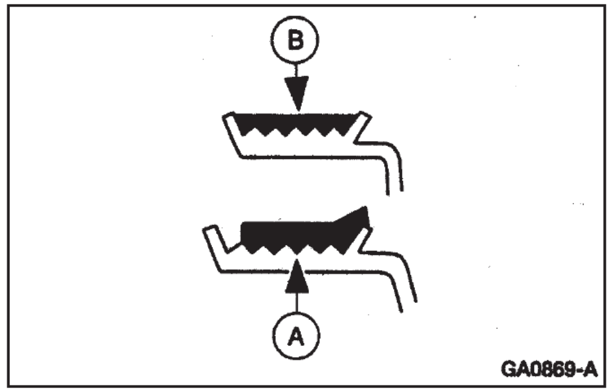
Automatic tensioners are calibrated at the factory to provide the correct amount of tension to the belt. Unless a spring within the tensioner assembly breaks or some other mechanical part of the tensioner fails, there is no need to check tensioners for proper tension.

The only mechanical check that need be made, if you have any doubt about the tensioner function, would be to remove the belt in the area of the tensioner, to avoid belt contact, then using the proper tool, rotate the tensioner from its relaxed position through its full stroke and back to the relaxed position to assure that there is no “stick, grab, bind,” and to assure that there is tension on the spring. It is a normal condition for the tensioner to be moving, under certain conditions, when the engine is running. If the tensioner meets this criteria, it should be assumed to be a good tensioner.

Drive Belt Misalignment

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

Non-standard replacement drive belts may track differently or improperly. If a replacement drive belt tracks improperly, replace it with an original equipment drive belt to avoid performance failure or loss of belt.



With the engine running, check drive belt tracking. If the **A** edge of the drive belt rides beyond the edge of the pulleys, noise and premature wear may occur. Make sure the **B** drive belt rides correctly on the pulley. If a drive belt tracking condition exists, proceed with the following:

Visually check the drive belt tensioner for damage, especially the mounting pad surface. If the drive belt tensioner is not installed correctly, the mounting surface pad will be out of position. This will result in a chirp or squeal noises.

- With the engine running, visually observe the grooves in the pulleys (not the pulley flanges or pulley front surfaces) for excessive wobble. Replace components as required.

- Check all accessories, mounting brackets and the drive belt tensioner for any interference that would prevent the component from mounting properly. Correct any interference condition and recheck belt tracking.

- Tighten all accessories, mounting brackets, and drive belt tensioner retaining hardware to specification.
  Recheck the drive belt tracking.

WSG-1068 COOLING SYSTEM

Visual Inspection Chart

Special Tool(s)

 ST1474-A	Radiator/Heater Core Pressure Tester 014-R1072 or equivalent
 ST1137-A	Rotunda 73 Digital Multimeter 105-R0051 or equivalent

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

Inspection and Verification

1. Verify the customer's concern by operating the engine to duplicate the condition.

2. Inspect to determine if any of the following mechanical or electrical concerns apply.

Inspection and Verification

Mechanical	Electrical
• Leaks • Damaged hoses • Loose/damaged hose clamps • Damaged water thermostat gasket • Damaged head gaskets • Damaged intake manifold gasket • Damaged water pump • Damaged radiator • Damaged degas bottle • Damaged fan/fan clutch	• Damaged engine coolant temperature sensor • Damaged wiring

3. If the inspection reveals an obvious concern that can be readily identified, repair as necessary.

4. If the concern remains after the inspection, determine the symptom(s) and go to the Symptom Chart.

Symptom Chart

Condition	Possible Source	Action
• Loss of Coolant	• Radiator. • Water pump seal. • Radiator hoses. • Heater hoses/tubes. • Heater core (if equipped). • Engine gaskets. • Degas bottle.	• GO to Pinpoint Test A.
• The Engine Overheats	• Water thermostat. • Water pump. • Internal engine coolant leak. • Radiator. • Cooling fan. • Pressure relief cap.	• GO to Pinpoint Test B.
• The Engine Does Not Reach Normal Operating Temperature	• Water thermostat.	• GO to Pinpoint Test C.

WSG-1068 COOLING SYSTEM

PINPOINT TEST A: LOSS OF COOLANT

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
1 CHECK THE ENGINE COOLANT LEVEL	
NOTE: Allow the engine to cool before checking the engine coolant level.	
	1 Visually check the engine coolant level at the degas bottle (if equipped). • Is the engine coolant level within specification? ▶ **Yes** GO to **2.** ▶ **No** REFILL the engine coolant as necessary. GO to **6.**
2 CHECK THE PRESSURE RELIEF CAP	
	1 Perform the Pressure Relief Cap Test. For additional information, refer to Component Tests, Cap-Pressure Relief in this section. • Is pressure relief cap OK? ▶ **Yes** GO to **3.** ▶ **No** INSTALL a new pressure relief cap. TEST the system for normal operation.
3 CHECK THE ENGINE COOLANT FOR INTERNAL LEAK	
	1 Inspect the engine coolant in degas bottle for signs of engine oil. • Is oil evident in coolant? ▶ **Yes** If engine oil is evident, GO to Section 01. ▶ **No** GO to **4**. (Continued)

PINPOINT TEST A: LOSS OF COOLANT (Continued)

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
4 CHECK THE ENGINE BLOCK FOR COOLANT	
	1 Remove the oil level dipsticks (6750) from the engine. • Is coolant evident in oil? ▶ **Yes** If coolant is in engine, GO to Section 01. ▶ **No** GO to **5.**
5 CHECK THE COOLANT RECOVERY SYSTEM	
	1 ⚠ **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 AVOID 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 110°F.** 2 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. 3 When you are sure all the pressure has been released, (still with a cloth) turn counterclockwise and remove the pressure relief cap. 4 Inspect the pressure relief cap for foreign material between the sealing gasket and the diaphragm. • Is the pressure relief cap OK? ▶ **Yes** GO to **6.** ▶ **No** CLEAN or INSTALL a new pressure relief cap. TEST the system for normal operation. GO to **1**.

PINPOINT TEST B: THE ENGINE OVERHEATS

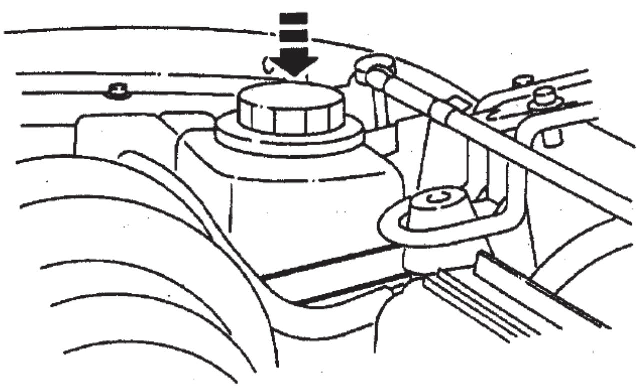
PINPOINT TEST A: LOSS OF COOLANT (Continued)

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
6 CHECK THE DEGAS BOTTLE	
	1 **NOTE:** The engine must be cool when coolant is added to the degas bottle. Add coolant to the degas bottle until fluid is between the coolant fill level marks. • Does the degas bottle leak? ▶ **Yes** INSTALL a new degas bottle. TEST the system for normal operation. ▶ **No** PERFORM the cooling system pressure test. For additional information, refer to Component Tests and Pressure Test in this section. REPAIR as necessary. TEST the system for normal operation.

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
1 CHECK THE ENGINE COOLANT LEVEL	
NOTE: If the engine is hot, allow the engine to cool before proceeding.	
	1 ⚠ **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 AVOID 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 110°F.** 2 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. 3 When you are sure all the pressure has been released, (still with a cloth) turn counterclockwise and remove the pressure relief cap. 4 Check the engine coolant level at the degas bottle. • Is the engine coolant OK? ▶ **Yes** GO to **2.** ▶ **No** REFILL the engine coolant at the degas bottle. GO to Pinpoint Test A.

(Continued)

PINPOINT TEST B: THE ENGINE OVERHEATS (Continued)

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
2 CHECK THE COOLANT CONDITION	
	1 Check the coolant for contaminants such as rust, corrosion, or discoloration. • Is the coolant condition OK? ► **Yes** GO to **3.** ► **No** FLUSH the engine cooling system. For additional information, refer to Flushing – Engine and Radiator in this section. TEST the system for normal operation.
3 CHECK FOR AN AIRFLOW OBSTRUCTION	
	1 Inspect the radiator for obstructions such as leaves or dirt. • Is there an obstruction? ► **Yes** REMOVE the obstruction. CLEAN the radiator. TEST the system for normal operation. ► **No** GO to **4.**
4 CHECK THE HEATER CORE (IF EQUIPPED) OPERATION AND/OR LPG EVAPORATOR	
 Q4194-B	1 Install the pressure relief cap.

(Continued)

PINPOINT TEST B: THE ENGINE OVERHEATS (Continued)

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
4 CHECK THE LPG EVAPORATOR OPERATION (Continued)	
	2 As the engine starts to heat up, feel the inlet and outlet heater water hoses (18472). They should feel approximately the same after three or four minutes. • Is the LPG evaporation hose approximately the same temperature as the inlet heater water hose? ▶ **Yes** GO to **5.** ▶ **No** TURN the engine off. REPAIR or INSTALL a new heater core or clear the LPG evaporation coolant passage way. TEST the system for normal operation.
5 CHECK THE WATER THERMOSTAT OPERATION	
	1 Start the engine and allow the engine to run for ten minutes. 2 Feel the inlet and outlet heater water hoses and the underside of the upper radiator hose (8260). • Are the upper radiator hose and the heater water hoses cold? ▶ **Yes** INSTALL a new water thermostat. TEST the system for normal operation. ▶ **No** Go to **6.**
6 CHECK THE COOLING FAN OPERATION	
	1 Perform the cooling fan component tests. For additional information, refer to the Component Tests in this section. • Is the cooling fan operation OK? ▶ **Yes** GO to Section 01 for diagnosis and testing of the engine. ▶ **No** INSTALL a new component determined to be faulty. For additional information, refer to Fan – Blade, and Shroud in this section. TEST the system for normal operation.

(Continued)

PINPOINT TEST C: THE ENGINE DOES NOT REACH NORMAL OPERATING TEMPERATURE

TEST CONDITIONS	TEST DETAILS/RESULTS/ACTIONS
1 CHECK THE ENGINE TEMPERATURE	
	1 Start the engine and allow the engine to idle for ten minutes. Feel the inlet and heater water hoses and the underside of the upper radiator hose. • Are the upper radiator hose and the heater water hoses cold? ► **Yes** INSTALL a new water thermostat. ► **No** Test and diagnose the engine coolant temperature gauge.

SPECIFICATIONS

General Specifications

Item	Specification
Drive Belt	6 Ribs
Capacity 4.2L[1] (qts)	16.4 (17.3)
Coolant Mixture With Water	50%[2]
Radiator Pressure Test	138 kPa (20 psi)
Water Pump Pulley Ratio	1.2
Water Thermostat Start To Open Temperature C (F)	83-87°C (181-188.6°F)
Water Thermostat Full Open Temperature C (F)	97.7-100°C (206-213°F)
Lubrication & Sealants	
Ford Premium Cooling System Flush F1AZ-19A503-A	ESR-M14P7-A
Pipe Sealant with Teflon® D8AZ-19554-A	WSK-M2G350-A2
Premium Long Life Grease XG-1-C	ESA-M1C75-B
Stop Leak Powder E6AZ-19558-A	ESE-M99B170

[1] Includes radiator coolant recovery reservoir fluid level between the "COOLANT FILL LEVEL" lines.

[2] Ford Premium Engine Coolant (green in color) ESE-M97B44-A or -B (Canada: Motorcraft CXC-10-B, Oregon: VC-5) Recycled Coolant or equivalent meeting Ford specification ESE-M97B44-A.

NOTE: Bolt information on installation page this section.

Torque Specifications

Description	Nm	Lb-Ft
Belt Idler Pulley Bolt	55	40
Drive Belt Tensioner Bolt	55	40

Description	Nm	Lb-Ft	Lb-In
Cylinder Head Temperature Sensor	9-11	–	80-95
Pulley to water pump	21-29	15-21	
Fan Assembly To Water Pump	55	41	–
Fan Shroud Bolts	9	–	80
Radiator Draincock	0.7-1.4	–	6-12
Radiator Support Bracket Bolts	30	22	–
Water Inlet and Outlet Connection Clamps	9	–	80
Water Pump Bolts	25	18	–
Water Outlet Tube Mounting Bolt	35-45	26-33	–

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WSG-1068 CHARGING SYSTEM

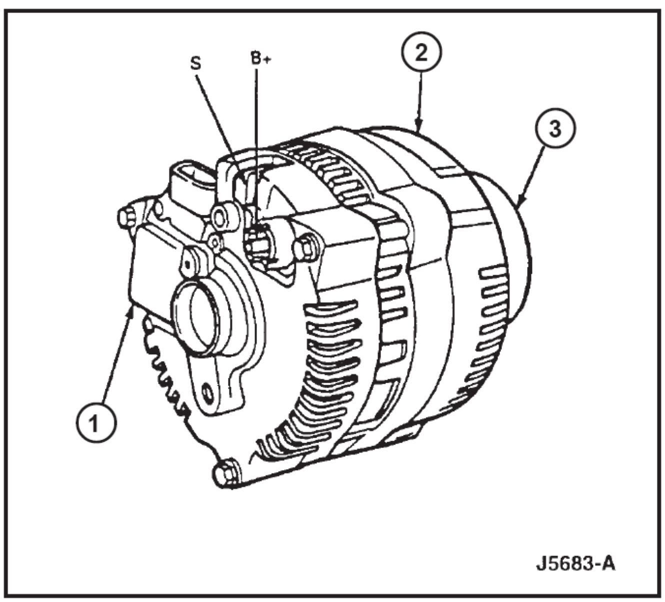
GENERAL INFORMATION

Generator

With the key in the RUN position, voltage is applied through the charge indicator lamp “I” circuit to the voltage regulator. This turns the voltage regulator on allowing current to flow from the battery sense “A” circuit to the generator field coil. When the engine (6007) is started, the generator (10346) begins to generate alternating (AC) current which is converted to direct (DC) current by the rectifier internal to the generator. This current is then supplied to the electrical system through the Battery Positive voltage (B+) terminal located on the rear of the generator.

Once the generator begins generating current, a voltage signal is taken from the stator and fed back to the voltage regulator “S” circuit, turning off the charge indicator/lamp.

With the system functioning normally, the generator output current is determined by the voltage at the “A” circuit. This voltage is compared to a set voltage internal to the voltage regulator, and the voltage regulator controls the generator field current to maintain proper generator output. The set voltage will vary with temperature and is typically higher in the winter than in the summer, allowing for better battery recharge.



1. Generator Regulator 10316
2. Generator 10346
3. Generator Pulley 10344

Battery Positive Voltage (B+) Output

The generator output circuit 38 (BK/O) is supplied through the battery positive voltage (B+) output connection to the battery and electrical system. The B+ circuit is hot at all times. This circuit is protected by a 12 gage fuse link.

“I” Circuit

The “I” circuit, or ignition switch (11572), (R/Tan) is used to turn on the voltage regulator. This circuit is closed with the ignition switch in the RUN position. This circuit is also used to turn the charge indicator lamp on if there is a fault in the charging system operation or associated wiring circuits.

“A” Circuit

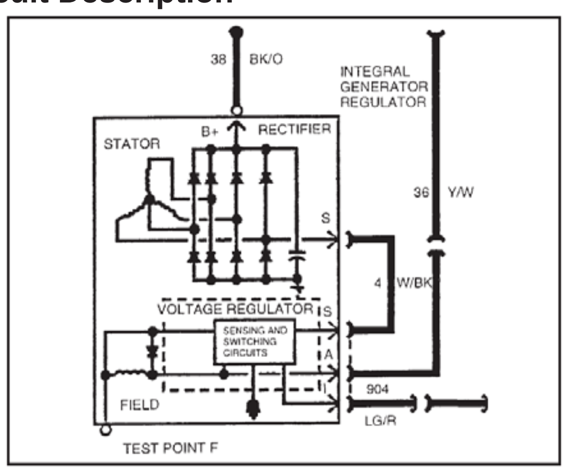
NOTE: The “A” circuit is electrically hot at all times.

The “A” circuit, or battery sense circuit, (Red) is used to sense the battery voltage. This voltage is used by the voltage regulator to determine the output. This circuit is also used to supply power to the field coil. This circuit is recommended to be protected by a 10 amp fuse or a fuse link.

“S” Circuit

The “S” circuit, or stator circuit is used to feed back a voltage signal from the generator to the voltage regulator. This voltage, typically 1/2 battery voltage when the generator is operating, is used by the voltage regulator to turn off the charge indicator lamp.
Not used with this system.

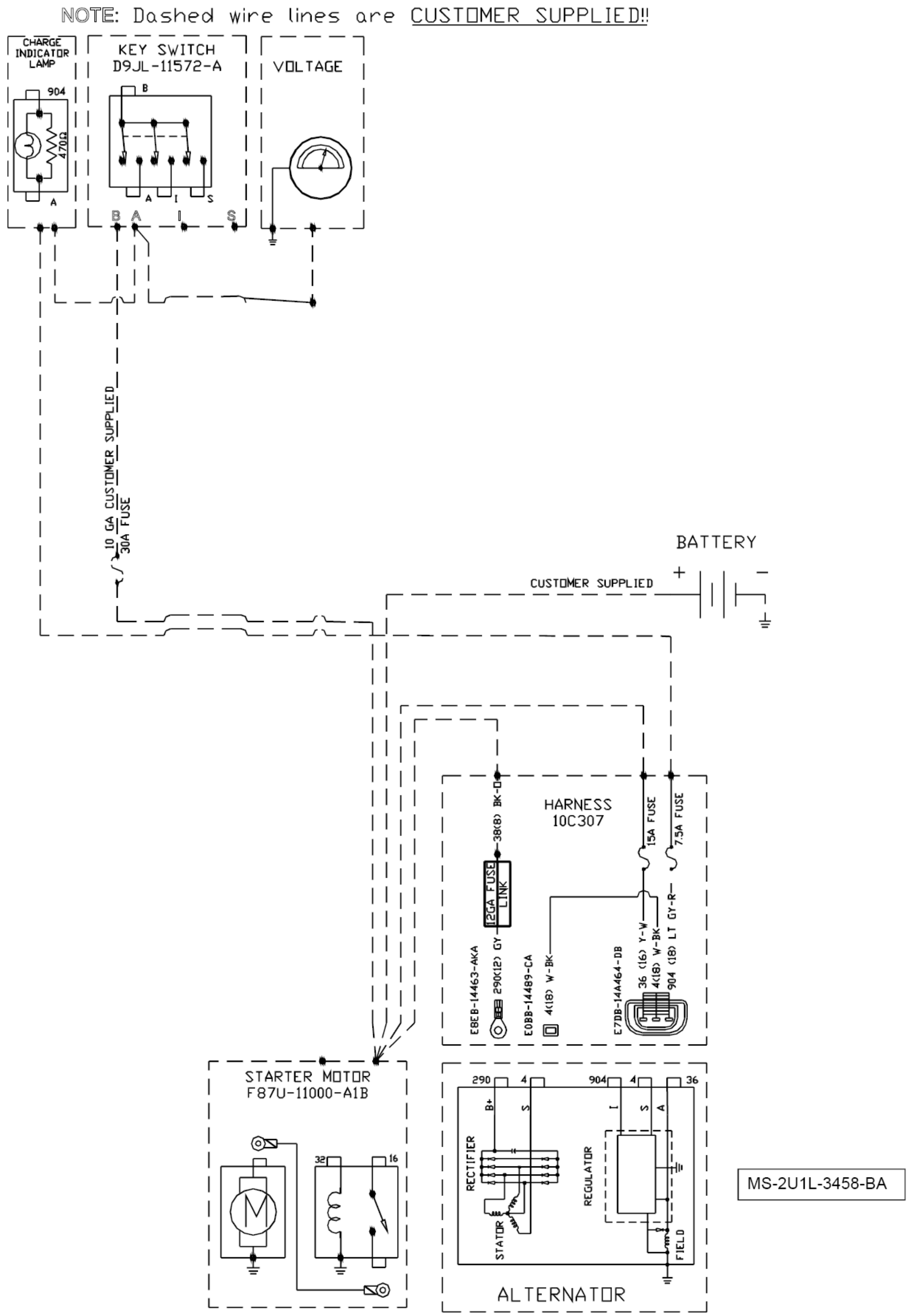
Circuit Description



WSG-1068 CHARGING SYSTEM

DIAGNOSIS AND TESTING

Recommended Accessory Wiring



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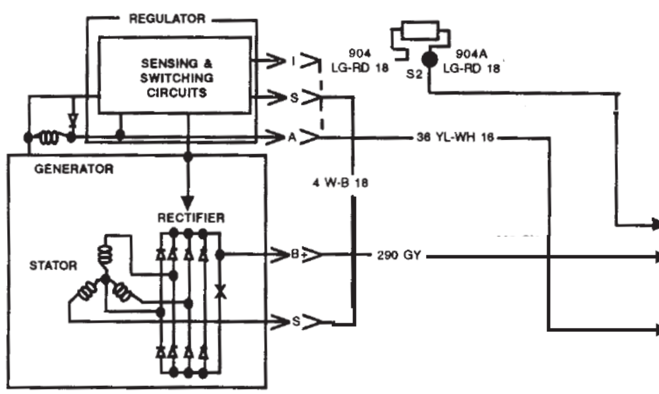
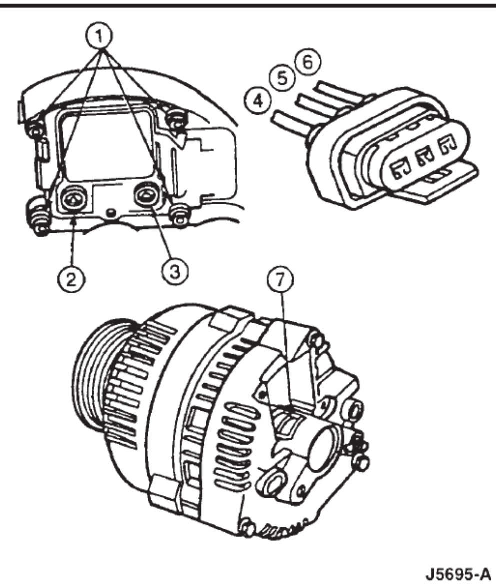
Recommended Generator Wiring



Circuit Item	Color	Description
904	LT GR-RD	Gen. reg. “I” to resistor
290	GY	Fuse link to splice w/38
36	YL-WH	“A” Battery Sense

Before performing generator tests on the unit, note conditions such as: slow cranking, dead battery, charge indicator lamp stays on with engine running, etc. This information will aid in isolating the part of the system causing the symptom.



Voltage Regulator and Back of Governor

Item	Part Number	Description
1	–	Mounting Screws (Ground Connection) (4 req’d). Tighten to 1.7-2.8 Nm (15-25 In-Lb) (Part of 10316).
2	–	Brush Holder Screw (Test Point “F”) (Part of 10316).
3	–	Brush Holder Screw (Test Point “A”) (Part of 10316).
4	–	I Circuit 904 (Part of 14305).
5	–	S Circuit 4 (part of 14305).
6	–	A Circuit 36 (Part of 14305).
7	10328	Rotor Slip Ring.

WSG-1068 CHARGING SYSTEM

Visual Inspection

Preliminary checks to the charging system should be made regardless of the fault condition. These checks include:

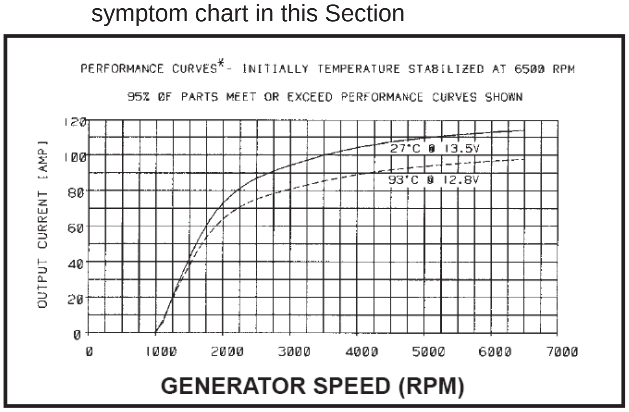
1. Check battery posts and cable terminals for clean and tight connections. Clean the posts and the cables to ensure good electrical contact.
2. Check for secure connections at the generator output, regulator, and engine ground. Also check the connection at the load distribution point (starter relay).
3. Check the fuses/fuse links and wiring to the generator to ensure that they are not burned or damaged. This condition, resulting in an open circuit or high resistance, can cause erratic or intermittent charging system concerns.
4. Check the battery voltage. If the voltage is less than 12.3 volts with the engine and all accessories off, charge battery before proceeding.

In order to check the generator, the use of Rotunda Starting and Charging System Tester 078-00005 (VAT-40) [Rotunda Tools (1-800-578-7375)] or equivalent, is recommended.

Generator Output Test

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

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+ output lead Circuit 38 (BK/O) (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 graph below. If not, refer to symptom chart in this Section



Generator Voltage Test

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.

   NOTE: If voltage is **not** within specifications, refer to symptom chart.

Battery — Drain 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 the engine or operate accessories that draw more than 10A.

NOTE: No accessory system should have more than a 50 mA (0.050 amp) draw.

NOTE: Many modules draw 10 mA (0.010 amp) or more continuously.

NOTE: Use an in-line ammeter between the battery positive or negative post and its respective cable.

NOTE: Typically, a drain of approximately one amp can be attributed to a lamp staying on continually. Other component failures or wiring shorts may be located by selectively pulling fuses to pinpoint the location of the current drain. When the current drain is found, the meter reading will fall to an acceptable level. If the drain is still not located after checking all the fuses, it may be due to the generator.

NOTE: To accurately test the drain on a battery, an in-line digital ammeter must be used. Use of a test lamp or voltmeter is not an accurate method.

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Check for current drains on the battery in excess of 50 milliamps (0.050 amp) with all the electrical accessories off and the engine off. Current drains can be tested with the following procedure:

1. Make sure the junction box/fuse panels are accessible without turning on auxiliary components.

2. Operate the engine at least five minutes and exercise systems.

3. Allow the engine to sit with the key OFF for at least 40 minutes to allow modules to time out/power down.

4. Connect a fused jumper wire between the negative battery cable and the negative battery post to prevent modules from resetting and to catch capacitive drains.

5. Disconnect the negative battery cable from the post without breaking the connection of the jumper wire.

   NOTE: It is very important that continuity is not broken between the battery and the negative battery cable when connecting the meter. If this happens, the entire procedure must be repeated. Connect the tester between the negative battery cable and the post. The meter must be capable of reading milliamps and should have a 10amp capability.

NOTE: If 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.

6. Remove the jumper wire.

NOTE: Amperage draw will vary from engine to engine depending on the equipment package. Compare to a similar engine for reference.

NOTE: No engine application should have more than a 50 mA (0.050 amp) draw.

7. If the draw is found to be excessive, pull fuses or disconnect suspected draws one at a time and note the current drop. Do not reinstall the fuses or connections until you are finished testing.

8. Check the wiring for any auxiliary circuits that run from the battery. Disconnect these circuits if the draw is still excessive.

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Symptom Chart

SYMPTOM	POSSIBILE CAUSE	ACTION
Batter is discharged (battery voltage less than 8 volts)	• Corroded terminal(s). • Loose connection(s). • High key-off current drain(s). • Battery. • Generator.	Go to Pinpoint Test A
The charge system warning indicator is on with the engine running (the system voltage does not increase)	• Circuitry. • Voltage regulator. • Generator.	Go to Pinpoint Test C
The system overcharges (battery voltage greater than 15 volts)	• Circuitry. • Voltage regulator. • Generator.	Go to Pinpoint Test B
The charging system warning indicator flickers or is intermittent	• Corroded terminal(s). • Circuitry. • Voltage regulator. Generator. • Fuse(s).	Go to Pinpoint Test A
The generator is noisy	• Bolts or brackets. • Drive belt. • Generator or pulley.	Inspect accessory drive components

WSG-1068 CHARGING SYSTEM

Pinpoint Test A: Generator Output Voltage

Inspection and Verification

1. Visually inspect for obvious signs of terminal corrosion and electrical harness damage.
2. Inspect fusible links and generator connector for bent or backed-out connector pins, or damage to wiring.
3. Visually inspect for and note auxiliary system connections not shown on the **Recommended Customer Connections Wiring Schematic**.

Normal Operation

With voltage applied to the generator I circuit, the regulator is activated, allowing current to flow from the sense A circuit to generator field coil. The generator then generates an internal AC current, which is converted to a DC output by the rectifier assembly internal to the generator, and is supplied to the battery through the B+ terminal. The S (stator) circuit is used to feed back a voltage signal from the generator to the regulator. This voltage (typically half battery voltage) is used by the regulator to turn off the charge indicator.

Step	Action	Values	Yes	No
1	1. Determine if the battery can hold a charge and is OK for use. Is the battery OK?	12.53-15.2 volts	GO to Step 2	Install a new battery and RETEST the system for normal operation.
2	1. Measure the voltage at the B+ terminal on the back of the generator. Is the voltage at B+ terminal equal to battery voltage?		GO to Step 3	Check the fusible links and replace if required. If OK inspect for open circuits.
3	1. Measure voltage at test point A on the voltage regulator. Is the voltage at test point A equal to battery voltage?		GO to Step 4	Check the fusible links and replace if required. If OK inspect for open circuits.
4	1. Measure voltage at test point F. Is the voltage at test point A equal to battery voltage?		GO to Step 5	GO to Step 11
5	1. KOEO. 2. Note: Voltage regulator must be connected to wiring harness for this test. Measure the voltage at wiring harness I terminal circuit 904. Is the voltage greater than 1 volt?		GO to Step 6	REPAIR the circuit(s) in question. TEST the system

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Step	Action	Values	Yes	No
6	1. Measure the voltage drop between test point A on the voltage regulator and the positive (+) battery post. Is the voltage drop less than 0.25 volts?		Go to Step 7	Inspect auxiliary wiring connections for an excessive current draw. Check the fusible links and replace if required. REPAIR the circuit(s) in question. TEST the system
7	1. Measure the voltage at test point F on the voltage regulator. Is the voltage at test point F less than 2 volts?		Go to Step 8	Refer to the Fuel Systems Manufacturing Information and Test
8	1. Remove the one-pin S connector from the generator. 2. Measure for voltage between the S terminal on the back of the generator and ground. Is the voltage reading greater than 1 volt?		**Replace the generator**.	Go to Step 9
9	1. Install the S connector. 2. Start the engine. 3. Turn on any accessory. 4. With the engine running at 2000 RPM, measure the voltage drop between the B+ terminal on the back of the generator and the positive (+) battery post. Is the voltage drop greater than 0.5 volts?		Go to Step 10	Inspect wiring for auxiliary connections for an excessive current draw. REPAIR the circuit(s) in question. TEST the system
10	1. Connect a jumper wire from test point A on the voltage regulator to the battery negative post 2. Perform the Generator Output Test. Is generator output greater than the minimum output specified?		**Replace the Voltage Regulator**	**Replace the Generator**
11	1. Remove the generator. 2. Remove the voltage regulator. 3. Measure the resistance between the generator slip rings. Is the resistance greater than 10 ohms or less than 1 ohm?		**Replace the Generator**	Check for worn brushes (less than 8mm long) or open brush leads and replace if required

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Pinpoint Test B: Voltage Output High

Inspection and Verification

1. Visually inspect for obvious signs of terminal corrosion and electrical harness damage.
2. Inspect for poor ground connections or backed-out connector pins, or damage to wiring.
3. Visually inspect for and note auxiliary system connections not shown on the **Recommended Customer Connections Wiring Schematic.**

Step	Action	Values	Yes	No
1	1. KOEO. 2. Measure the voltage drop between test point A on the voltage regulator and the positive (+) battery post. Is the voltage drop less than 0.25 volt?		GO to Step 2	Inspect auxiliary wiring connections for an excessive current draw. Check the fusible links and replace if required. REPAIR the circuit(s) in question. TEST the system
2	1. NOTE: Voltage regulator must be connected to wiring harness for this test. 2. Measure the voltage at wiring harness I terminal Red/Tan Is the voltage greater than 1volt?		GO to Step 3	Inspect auxiliary wiring connections for an excessive current draw. Check the fusible links and replace if required. REPAIR the circuit(s) in question. TEST the system
3	1. Check for poor ground connections between voltage regulator and the generator. 2. Check for poor ground connection between the engine and battery. Are all ground connections clean and tight?		GO to Step 4	CLEAN or REPAIR grounds as required
4	1. Key OFF 2. Measure voltage at test point F on the voltage regulator. Is the voltage at test point F equal to battery voltage?		Generator is OK, Replace the voltage regulator	GO to Step 5
5	1. Remove the generator. 2. Remove the voltage regulator. 3. Measure the resistance between each generator slip ring to the generator housing. Is the resistance between each ring and the generator housing less than 200 ohms?		If grease or dirt has accumulated near the slip rings, CLEAN the slip rings and RECHECK resistance. If still less than 200 ohms, Replace the generator.	Replace the voltage regulator

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Pinpoint Test C: Indicator Lamp ON, Engine Running

Inspection and Verification

1. Visually inspect for obvious signs of terminal corrosion and electrical harness damage or a bulb failure.
2. Inspect fusible links and generator connector for bent or backed-out connector pins, or damage to wiring.
3. Visually inspect for and note auxiliary system connections not shown on the **Recommended Customer Connections Wiring Schematic**.

Normal Operation

With voltage applied the high side of a charge warning indicator lamp, the generator will momentarily will pull the warning lamp to ground and illuminate the indicator until the regulator is activated. The S (stator) circuit **NOT USED**, is used to feed back a voltage signal from the generator to the regulator. This voltage (typically half battery voltage) is used by the regulator to turn off the charge indicator.

Step	Action	Values	Yes	No
1	1. Disconnect the three-pin generator connector. 2. KOEO Is the charge indicator ON?		Inspect the auxiliary wiring for a short to ground. REPAIR the circuit(s) in question. TEST the system	GO to Step 2
2	1. KOEO 2. Jumper the generator harness connector I terminal, circuit 904 LT GY/RD to ground. Does the charge indicator illuminate?		GO to Step 3	Inspect the warning bulb and circuit 904 for an open circuit. REPAIR the circuit(s) in question. TEST the system
3	1. Reconnect the three-pin generator connector. 2. Remove the one-pin S connector. 3. Jumper the S terminal circuit 4 WH/BK to battery voltage. Is the charge indicator ON?		Remove the jumper wire. GO to Step 4	Remove the jumper wire. GO to Step 5
4	1. Key Off. 2. Disconnect the three-pin generator connector. 3. Measure the resistance between the one-pin S connector and the S (center) pin of the voltage regulator connector. Is the resistance greater than 1 ohm?		Repair open or excess resistance in circuit 4 WH/BK. TEST the system	CHECK for a loose or bent pin in the voltage regulator or connector. If OK, replace the voltage regulator.
5	1. Reconnect the one-pin S connector. 2. Start the engine. 3. Measure the voltage at the one-pin S connector. Is the voltage at least ½ of the battery voltage?		GO to Step 6	GO to Pinpoint Test A to find the cause of low generator output.

REMOVAL AND INSTALLATION

Generator - Removal

1. Disconnect battery ground cable (14301).
2. Remove snow/ice shield.
3. Disconnect the generator voltage regulator wiring (14305) to the voltage regulator.
4. Remove wiring connector bracket.
5. Relieve the tension of the drive belt tensioner (613209) and remove the drive belt.
6. Remove the bolts holding the generator to the generator bracket (10A313).
7. Remove the generator from the generator bracket.

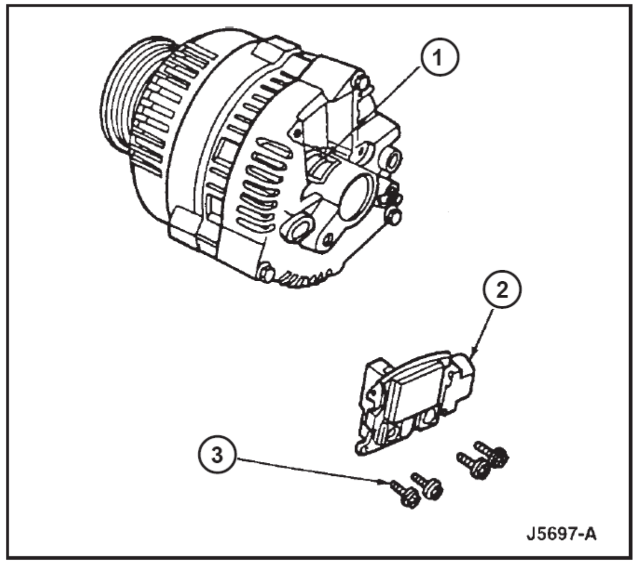
Generator - Installation

1. Position the generator on the generator bracket.
2. Install the bolts and tighten to 40-55 Nm (30 -40 ftlb).
3. Install the drive belt over the generator pulley.
4. Relieve the tension of the drive belt tensioner and install the drive belt over tensioner.
5. Connect generator voltage regulator wiring to the voltage regulator. Tighten generator Battery Positive Voltage (B+) wire attaching nut to 9-12 Nm (6.5-9 ftlb).
6. Install wiring connector bracket.
7. Install snow/ice shield.
8. Connect battery ground cable.

Regulator - Removal

1. **NOTE:** for ease or removal and installation of regulator, remove the generator from engine as described above.

   Remove the four screws (T20 Torx type head) attaching the voltage regulator to the generator housing. Remove the voltage regulator with generator brush holder (10351) attached, from the generator.



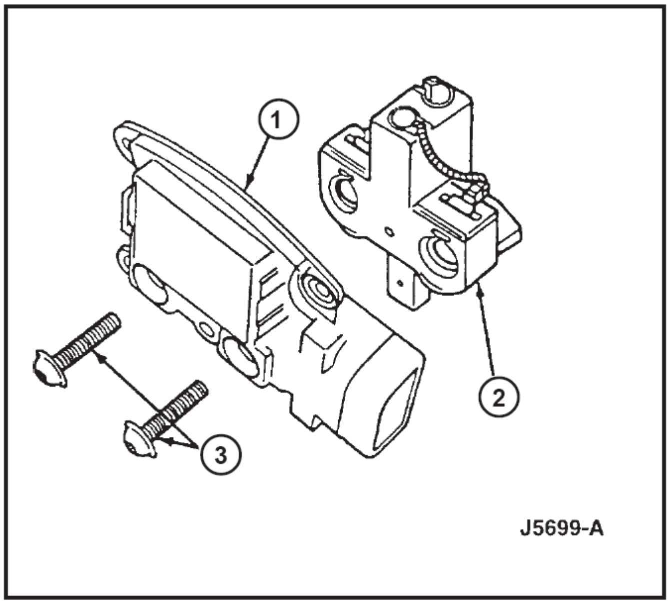
1 Slip Rings 10328

2 Regulator 10316 and Brush Holder Assembly 10347

3 Screw 4 Req'd. Tighten to 2.3-3.4 Nm (20-30 In-Lb)

2. Hold the voltage regulator in one hand and pry off the cap covering the “A” screw head with a screwdriver.

3. Remove two screws (T20 Torx type head) attaching the regulator to the generator brush holder. Separate the regulator from generator brush holder. 06-15



(1) Voltage Regulator 10316

(2) Generator Brush Holder 10347

(3) Screw (2 Req’d) Tighten to 2.8-4.0 Nm (25-35 In-Lb)

Regulator - Installation

1. Replace generator brush holder to voltage regulator and install attaching screws.

2. Replace cap on the head of the “A” terminal screw.

3. Depress the generator brushes in the generator brush holder.

   - Hold the generator brushes in position by inserting a standard size paper clip (or equivalent) through both the location hole in the voltage regulator and through the holes in the generator brush holders.

4. Install the voltage regulator and generator brush holder to the generator with attaching screws.

   - Remove paper clip (or equivalent) from the regulator.

5. Install generator following installation in this section.

   NOTE: Only the regulator, brush holder and generator pulley are serviceable. If the generator needs further service, it must be replaced as an assembly.

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SPECIFICATIONS

Torque Specifications

Description	N m	Lb-Ft	Lb-In
Mounting Bracket Bolts	40-55	30-40	
Regulator Ground Screw	1.7-2.8	15.25	
Wire Attaching Nut	9-12	6.5-9	
Voltage Reg. Hold Down Bolts	2.8-4.0		25-35

Generator Parts Cross-Reference

Base Part #	Part Name	Old Part Name
6007	Engine	
6B209	Drive Belt Tensioner	
8620	Drive Belt	
10A313	Generator Bracket	Alternator Mounting Parts
10344	Generator Pulley	Alternator Pulley
10346	Generator	Alternator
10351	Generator Brush Holder	
14305	Generator Voltage Regulator Wiring	

Special Tools

Rotunda Equipment

Tool Number	Description
105-R0057	73111 Automotive Meter

WSG-1068 STARTER SYSTEM

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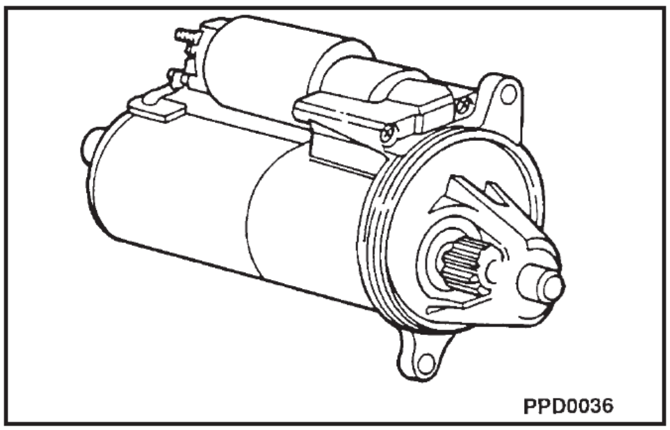
WSG-1068 STARTER SYSTEM

GENERAL INFORMATION

The function of the starting system is to crank the engine at a speed fast enough to permit the engine to start. Heavy cables, connectors, and switches are used in the starting system because of the large current required by the starter while it is cranking the engine. The amount of resistance in the starting circuit must be kept to an absolute minimum to provide maximum current for starter operation. A discharged or damaged battery, loose or corroded connections, or partially broken cables will result in slower than normal cranking speeds, and may even prevent the starter from cranking the engine.

The starting system includes the permanent magnet gearreduction starter motor with a solenoid-actuated drive, the battery, a remote control starter switch (part of the ignition switch), the starter relay, the heavy circuit wiring, and may include starter lock-out, controlled by the GCP through a starter lockout relay.

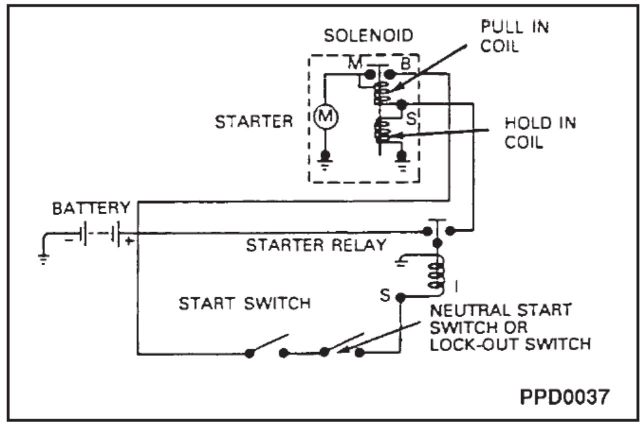
Field Service



Starter Motor Assy 11001

Sequence Of Operation

1. The ignition switch is turned to the START position.
2. A remote starter relay is energized, which provides voltage to the starter solenoid. The starter solenoid is energized, creating a magnetic field in the solenoid coil.
3. The iron plunger core is drawn into the solenoid coil.
4. A lever connected to the drive assembly engages the drive pinion gear to the flywheel ring rear.
5. When the iron plunger core is all the way into the coil, its contact disc closes the circuit between the battery and the motor terminals.
6. The current flows to the motor, and the drive pinion gear drives the flywheel and the engine crankshaft.
7. As current flows to the motor, the solenoid pull in coil is bypassed.
8. The hold-in coil keeps the drive pinion gear engaged with the flywheel.
9. The gear remains engaged until the ignition switch is released from the START position.



NOTE: The GCP is programmed to lock the starter out when the engine is operating over 600 rpm and the following sequence takes place:

Starter Lockout Relay

See page 07-6 for further details.

1. During start up with key in the on position 12V (B+) is applied to relay PIN 72 of the GCP (Lt Gn/ Pr).
2. With ignition switch turned to the crank position, current flows from ignition switch to relay circuit 87A (LB/Pink) 16G through relay and out circuit 30 (LB/Pink) 16G to starter solenoid.
3. The starter than should respond as in steps 2 through 9. The GCP keeps the starter relay closed until it reads 400+ engine rpm. Over 600 rpm the GCP grounds circuit causing the relay to open. This will prevent starter engagement while engine is running.

NOTE: An overrunning clutch in the drive assembly protects the starter from the excessive speeds during the brief period before the driver releases the ignition switch from the START position (as the engine starts).

WSG-1068 STARTER SYSTEM

For cases of a starter that cranks the engine very slowly, connect a 12-volt booster battery to the system.

NOTE: Engine may not start if crank sensor reads less than 140 RPM.

Jump Starting

To avoid damage to the vehicle or 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 vehicle to be started. Disconnecting the battery could damage the vehicle's electronic system.

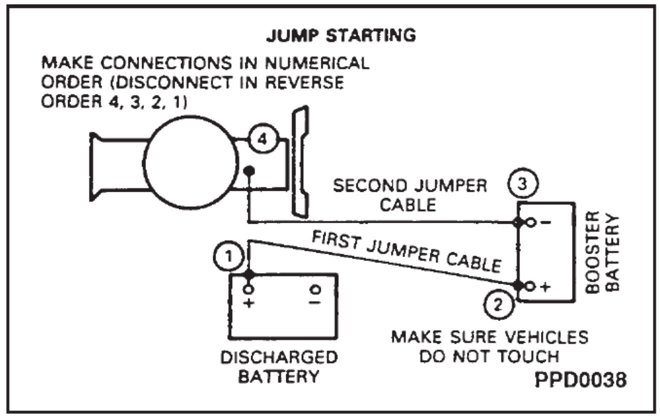
Negative Grounded Battery

WARNING:TO AVOID INJURY, USE PARTICULAR CARE WHEN CONNECTING A BOOSTER BATTERY TO A DISCHARGED BATTERY.

1. Position vehicles or equipment so jumper cables will reach, being careful that vehicles do not touch.

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.



NOTE: Be sure to disconnect battery negative cable before servicing starter.

2. Make jumper cable connections.

   a) Connect one end of first jumper cable to positive (+) **1** terminal of discharged battery and other end of positive (+) **2** terminal of booster battery.
   b) Connect one end of second jumper cable to negative (-) **3** terminal of booster battery. Connect other end to an engine bolthead or good metallic contact spot on engine **4** of equipment to be started. NOT TO NEGATIVE (-) BATTERY TERMINAL.
   c) Make sure jumper cables are not in way of moving engine parts.
   d) Start engine of vehicle with good battery. Run engine at a moderate speed.
   e) Start engine of vehicle with discharged battery. Follow starting instructions in the Owner Guide.
3. Completely discharged batteries may require an electrical load to initialize charging.

4. Remove cables in exact REVERSE sequence. Begin by removing negative (-) cable from engine of vehicle

If the starter does not turn the engine over, even with the booster battery attached, refer to On Vehicle Testing.

WSG-1068 STARTER SYSTEM

DIAGNOSIS AND TESTING

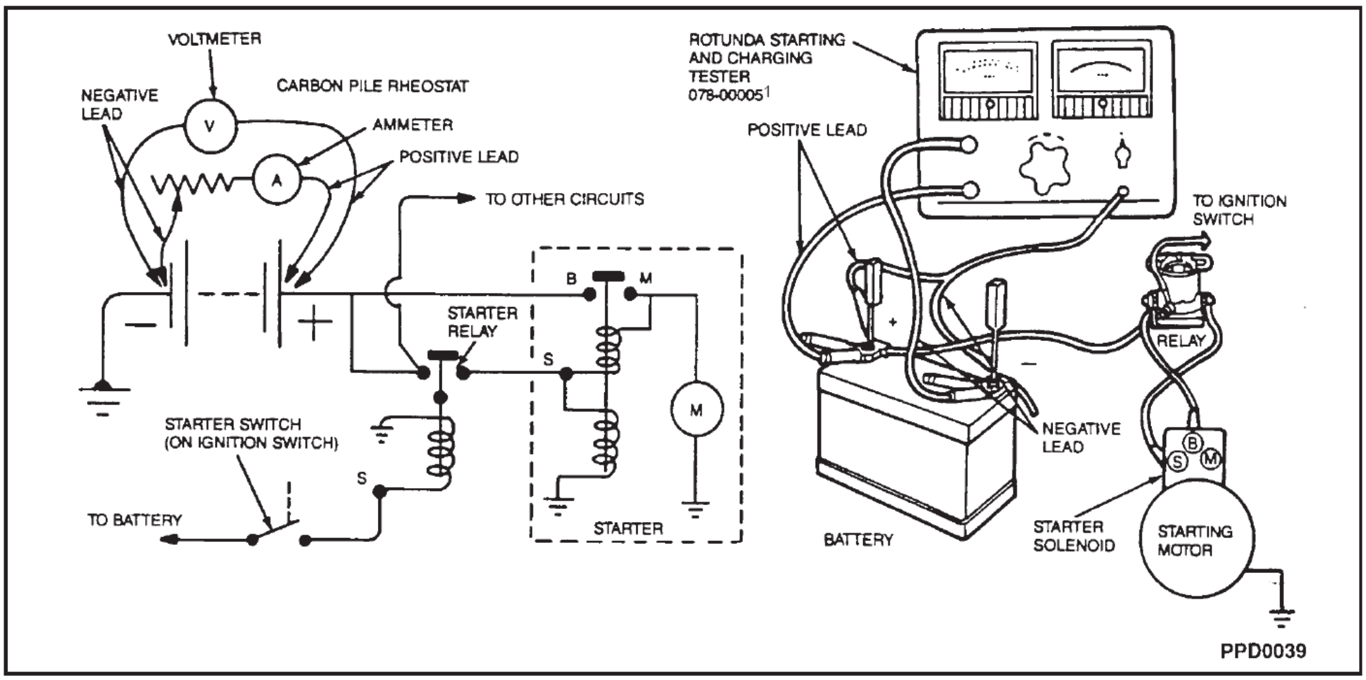
Starter Load Test

Conduct this test if the starter cranks slowly and it is desired to compare current to specifications.

1. Connect Rotunda Starting and Charging Tester 078-00005 or equivalent. Make sure that current is not flowing through ammeter and heavy-duty carbon pile rheostat portion of circuit (rheostat at maximum counterclockwise position).

2. Disconnect load from engine. Place transmission in NEUTRAL. Crank engine with ignition off, and determine exact reading on voltmeter. This test is accomplished by disconnecting push-on connector “S’’ at starter relay and by connecting a remote control starter switch from positive battery terminal to “S’’ terminal starter relay.

3. Stop cranking engine and reduce resistance of carbon pile until voltmeter indicates same reading as that obtained while starter cranked the engine. The ammeter will indicate starter current draw under load. Check this with value listed in Specifications on page 07-19.



Bench Tests

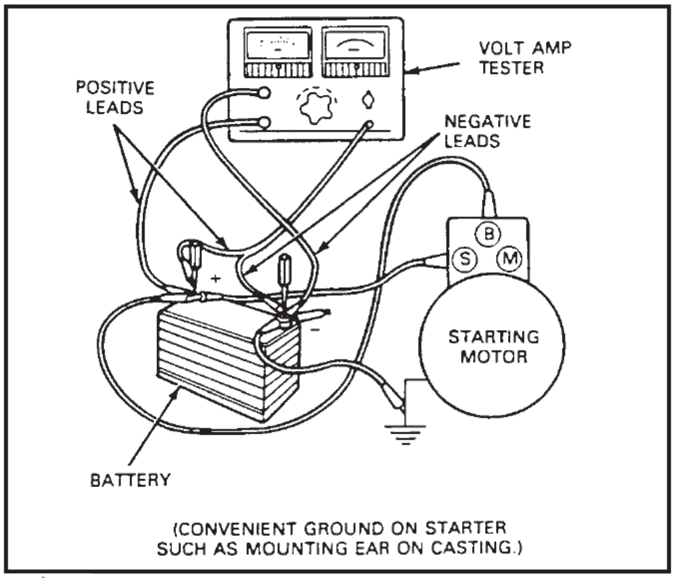
⚠ **CAUTION: Make sure that the starter is securely mounted in bench vise while energizing, as starter will move or jump.**

1. Connect a fully charged battery, Rotunda Starting and Charging Tester 078-00005, or equivalent. Make sure that the battery and starter motor are grounded.
2. Engage the remote starter switch.
3. The starter motor should eject the starter drive and run smoothly. If the starter motor does not run smoothly, replace it.
4. While the starter motor is running, check the voltmeter and ammeter.
5. If the voltage is lower than the 11.0 volts, or the amperage is higher than 70 amps, replace the starter motor.

NOTE: Service parts for rebuilding permanent magnet starter are not available from Ford Power Products.
[1]Rotunda 1-800-578-7375

WSG-1068 STARTER SYSTEM

Starter No-Load Test



CAUTION: Make sure that the starter is securely mounted in bench vise while energizing, as starter will move or jump.

Wire Color	Relay Terminal	Circuit Description
Lt Bl / Pink	30	Voltage to Starter
Red / Lt Gn	86	Relay Coil Power
Lt Gn / Pr	85	To GCP
Lt Bl / Pink	87A	Ignition Feed
W / Pink	87	Auxiliary Run Output

NOTE: All readings are made with connector attached to relay and back probing connector using a paper clip and fully charged battery.

WSG-1068 STARTER SYSTEM

System Inspection and Verification

CAUTION: When disconnecting the plastic hardshell connector at the solenoid “S” terminal, grasp the plastic connector and pull lead off. DO NOT pull separately on lead wire.

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.

NOTE: Be sure to disconnect battery negative cable before servicing starter.

1. Inspect starting system for loose connections.
2. If system does not operate properly, note condition and continue diagnosis using the symptom chart.

WARNING: WHEN WORKING IN AREA OF THE STARTER, BE CAREFUL TO AVOID TOUCHING HOT EXHAUST COMPONENTS.

SYMPTOM CHART

CONDITION	POSSIBLE SOURCE	ACTION
Starter solenoid does not pull in and starter does not crank (audible click may or may not be heard).	• Low battery. • Defective remote relay. • Open circuit or high resistance in external feed circuit to starter solenoid.	• Charge battery and retest. • Go to Test A. • Go to Test A.
Unusual starter noise during starter overrun.	• Starter not mounted flush (cocked). • Noise from other components. • Ring gear tooth damage or excessive ring gear runout. • Defective Starter.	• Realign starter on transmission bell housing or SAE housing. • Investigate other powertrain accessory noise contributors. • Replace flywheel ring gear. • Replace starter. See removal and installation procedure this section.
Starter cranks but engine does not start.	• Problem in fuel delivery system. • Problem in ignition system. • Engine-related problem. • Engine does not exceed 100 RPM.	• Refer to manufacture installed fuel system information. • Refer to ignition 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. • Auxiliary Drive binding.	• Charge or replace battery. • Check that all connections are secure. • Replace ring gear. • Check starter load. • Inspect auxiliary drives and components.
Starter remains engaged and runs with engine.	• Shorted ignition switch. • Battery cable touching solenoid “S” terminal (defective or mispositioned cable). • Defective Starter.	• Go to Section 03. • Replace or relocate cable. • Replace starter. See removal and installation procedure this section.
Starter clicks and engages but engine will not crank.	• Low battery power. • Seized auxiliary component. • Hydrolocked cylinder. • Seized main or rod bearing.	• Check battery. • Inspect auxiliary components. • Remove all plugs one at a time while checking for fluid in cylinders. • Repair as needed. Refer to Section 01.

WSG-1068 STARTER SYSTEM

Pinpoint Test A - Starter Lockout Relay Check

Inspection and Verification

1. Visually inspect for obvious signs of mechanical and electrical damage.
2. Visually inspect for and note auxiliary system connections not shown on the **recommended wiring schematic**.
3. >= Greater than
4. < = Less than

Normal Operation

Terminals 30 and 87A of the starter lockout relay are normally closed while the ignition switch is in the start/crank position and the engine rpm is less than 600. When the engine has reached 600 rpm or greater the GCP will ground the relay terminal 85 and open terminals 30 & 87A which will not allow the starter to be engaged while the engine is operating above 600 rpm.

Step	Action	Values	Yes	No
1	1. Check Fuse 1 for an open 10A fuse Is the fuse open?		Go to Section 03	GO to Step 2
2	1. Disconnect the starter lockout relay. 2. Key Off 3. Using an ohmmeter, measure for battery voltage on Term 86 RD/LG at the starter lockout relay connector. 4. KOEO. Is the voltage within the specified value?	Battery Voltage	GO to Step 3	Repair Rd / Lt Gn circuit for open and Retest
3	1. Disconnect the starter lockout relay. 2. Key Off 3. Using an ohmmeter. measure the resistance of Lt Gn/ Purple to GND. 4. KOEO. Is the resistance less than 5.0 ohms?	>5ohms	GO to Step 4	GO to Step 5
4	1. Disconnect the GCP Connector 2. Disconnect the starter lockout relay. 3. Using an ohmmeter, measure the resistance of PIN 72 of GCP connector Lt Gn / Purple circuit to GND Is the resistance less than 5.0 ohms?	>5ohms	Repair Lt Gn/Purple for a short to gnd and Retest	Replace the GCP and retest
5	1. Key Off. 2. Disconnect the starter lockout relay. 3. Refer to the pin numbers molded on the Starter Lockout Relay. 4. Apply 12 volts to Starter Lockout relay terminal 30. 5. Apply ground to Starter Lockout relay terminal 85. 6. Measure the resistances between pin 30 and 87A. Is the resistance less than 5.0 ohms?		REPLACE the Starter Lockout Relay and retest.	

WSG-1068 STARTER SYSTEM

Pinpoint Test B - Starter Does Not Crank

Inspection and Verification

1. Visually inspect for obvious signs of mechanical and electrical damage.
2. Visually inspect for and note auxiliary system connections not shown on the **Recommended Customer Connections Wiring Schematic**.

Normal Operation

Terminals 30 and 87A of the starter lockout relay are normally closed while the ignition switch is in the start/crank position and the engine rpm is less than 600. Battery voltage flows to the starter solenoid engaging the starter. When the engine has reached 600 rpm or greater the GCP will ground the relay terminal 85 and open terminals 30 & 87A which will not allow the starter to be engaged while the engine is operating above 600 rpm. Once the relay is energized it will not reset until the GCP is turned off and then back on.

Step	Action	Values	Yes	No
1	Have you preformed Pin Point Test E Ignition Check?		GO to Step 2	Go to Section 03 Pin Point Test A
2	1. Note: This test may require an assistant depending on the application. 2. Turn and hold the Ignition switch in the START position. 3. Using an ohmmeter, measure for battery voltage at the starter solenoid START terminal. Is the voltage within the specified value?	Battery Voltage	GO to Section 0 7	GO to Step 3
3	1. Disconnect the starter lockout relay. 2. Turn and hold the Ignition switch in the START position. 3. Using an ohmmeter, measure for battery voltage on Circuit 87A Lt Bl/Pink at the starter lockout relay connector Is the voltage within the specified value?	Battery Voltage	GO to Step 4	Repair Circuit 87A between the starter lockout relay and the ignition switch S terminal for OPEN circuit and RETEST
4	1. Key OFF 2. Using an ohmmeter, measure resistance between Circuit 30 Lt Bl/Pink at the starter lockout relay connector and the starter ignition start terminal. Is the resistance less than 5 Ohms?		GO to Step 5	Repair Circuit 30 between the starter lockout relay and the starter solenoid ignition start terminal for OPEN circuit and RETEST
5	1. Disconnect the starter lockout relay. 2. KOEO 3. Turn and hold the Ignition switch in the START position. 4. Using an ohmmeter, measure resistance between Circuit 85 Lt Gn/Purp at the starter lockout relay connector and known good ground. Is the resistance greater than 5 Ohms?		GO to Step 7	GO to Step 6

WSG-1068 STARTER SYSTEM

Step	Action	Values	Yes	No
6	1. Key Off. 2. Disconnect the starter lockout relay. 5. Using an ohmmeter, measure resistance between the Starter Lockout Relay terminals 30 and 87A. Is the resistance less than 5 Ohms?		GO to Step 7	REPLACE The Starter Relay and RETEST
7	1. Key OFF. 2. Disconnect the GCP connector 3. Disconnect the starter lockout relay. 4. Using an ohmmeter, measure resistance between Circuit 85 Lt Gn/Purp at the starter lockout relay connector and known good ground. Is the resistance less than 5 Ohms?		REPLACE the GCP and retest.	REPAIR the circuit(s) in question. TEST the system for normal operation.

Component Tests

Starter Motor - Voltage Drop Test

WARNING: WHEN REPAIRING THE STARTER MOTOR OR PERFORMING OTHER UNDERHOOD WORK IN THE VICINITY OF THE STARTER MOTOR, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES. WHEN SHORTED TO GROUND, MAY CAUSE PERSONAL INJURY.

CAUTION: A protective cap or boot is provided over the battery input terminal on all vehicle lines and must be replaced after repairing. Failure to replace protective cap could cause electrical short that may damage electrical system. Be sure to disconnect the battery ground cable before repiaring the starter motor.

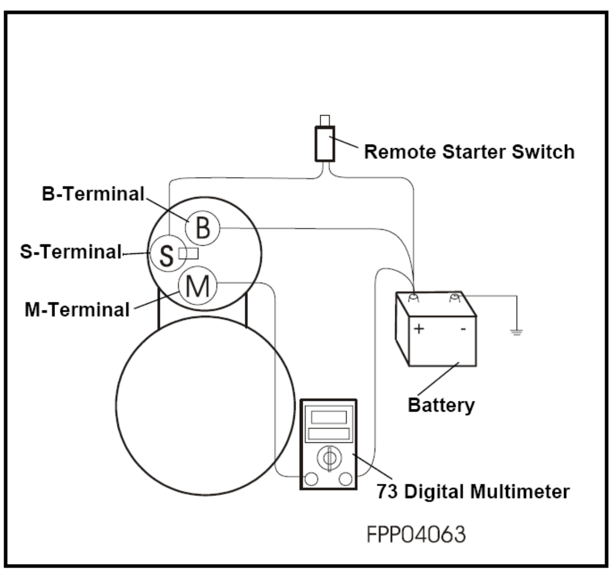
NOTE: Always connect the 73 Digital Multimeter at the component terminal rather than at the wiring end connector. Making a connection at the wiring end connector could result in false readings because the meter will not pick up a high resistance between the wiring connector and the component.

Starter Motor - Motor Feed Circuit

1. Make sure the battery is fully charged.

2. Connect a remote starter switch between the starter motor solenoid S-terminal and the battery positive (+) terminal.

3. Connect the 73 Digital Multimeter positive lead to the battery positive (+) post. Connect negative lead to the starter motor solenoid M-terminal.

4. 

gage the remote starter switch. Read and record the voltage. The voltage reading should be 0.5 volts or less.

5. If the voltage reading is 0.5 volts or less -- Refer to"Starter Motor - Motor Ground Circuit" on page 14.

6. If the voltage reading is greater than 0.5 volts, indicating excessive resistance, move the 73 Digital Multimeter negative lead to the starter motor B-terminal and repeat the test. If the voltage reading at the B-terminal is lower than 0.5 volts, the concern is either in the connections at the starter motor solenoid or in the starter motor solenoid contacts.

7. Remove the cables from the starter motor solenoid B-, S- and M-terminals. Clean the cables and connections and reinstall the cables to the proper terminals. Repeat Steps 3 through 6. If the voltage drop reading is still greater than 0.5 volts when checked at the M-terminal or less than 0.5 volts when checked at the B-terminal, the concern is in the solenoid contacts. Replace the starter motor.

8. If the voltage reading taken at the starter motor solenoid B-terminal is still greater than 0.5 volts after cleaning the cables and connections at the solenoid, the concern is either in the positive (+) battery cable connection or in the positive battery cable itself.

9. By moving the 73 Digital Multimeter negative 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. Repair or replace this connection as required.

WSG-1068 STARTER SYSTEM

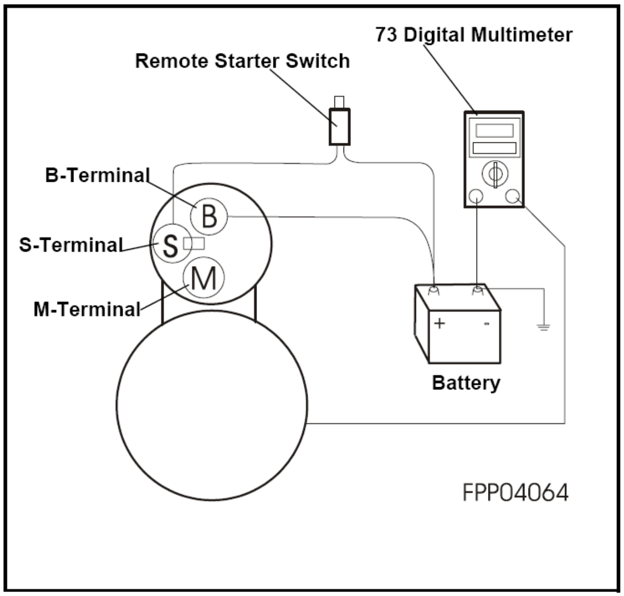
Starter Motor - Motor Ground Circuit

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. Disconnect the inertia fuel shutoff switch (on road vehicle only).

2. Connect a remote starter switch between the starter motor solenoid S-terminal and the battery positive (+) terminal.

3. Connect the 73 Digital Multimeter positive lead to the starter motor housing (the connection must be clean and free of rust or grease). Connect the negative lead to the negative (-) battery terminal.



4. Engage the remote starter switch and crank the engine. Read and record the voltage reading. The reading should be 0.5 volts or less.

5. If the voltage drop is more than 0.5 volts, clean the negative cable connections at the battery and body connections, and retest.

6. If the voltage drop is greater than 0.5 volts, determine which way the current is flowing in the cable. Connect the 73 Digital Multimeter positive lead to the end of the cable nearest battery positive.

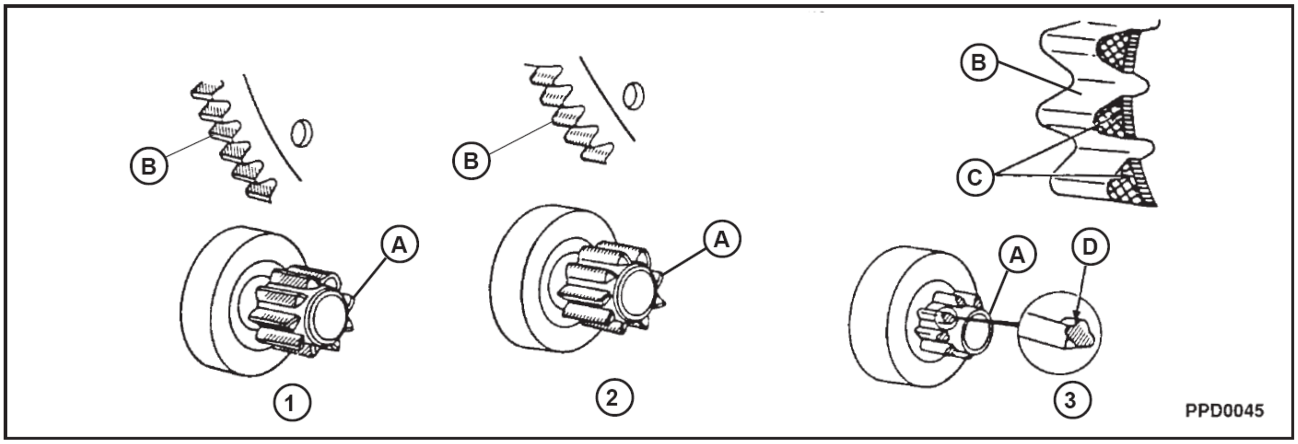
7. Connect the multimeter negative lead to the terminal at the other end of the cable.

8. Crank the engine and observe the voltage reading. The voltage reading should be 0.5 volts or lower. If the voltage drop is too high, clean the terminal ends. Retest, and if still high, replace the cable. If the voltage reading is less than 0.5 volts and the engine still cranks slowly, replace the starter motor.

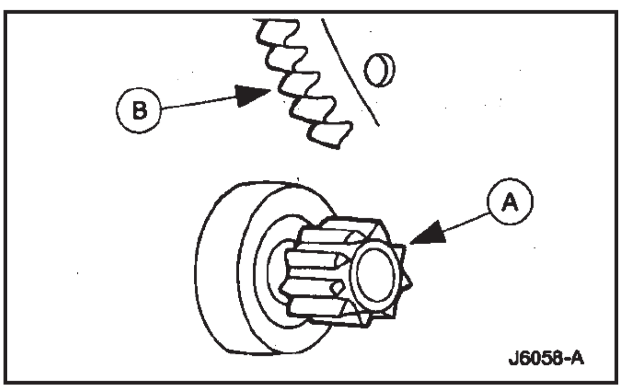
WSG-1068 STARTER SYSTEM

Starter Drive and Flywheel Ring Gear Inspection

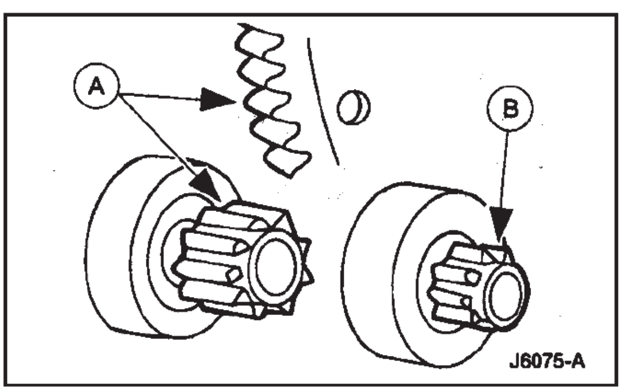
Pinion and Ring Gear Wear Patterns



1 **NORMAL WEAR PATTERN**	2 **SMALL WEAR PATTERN**	3 **MILLED GEARS**
A Armature Gear	A Armature Gear	A Armature Gear
B Flywheel Gear	B Flywheel Gear	B Flywheel Gear
		C Milled Condition Excessive Wear on 3 or 3 Teeth
		D Milled Tooth Metal Build-up Will Not Permit Engagement



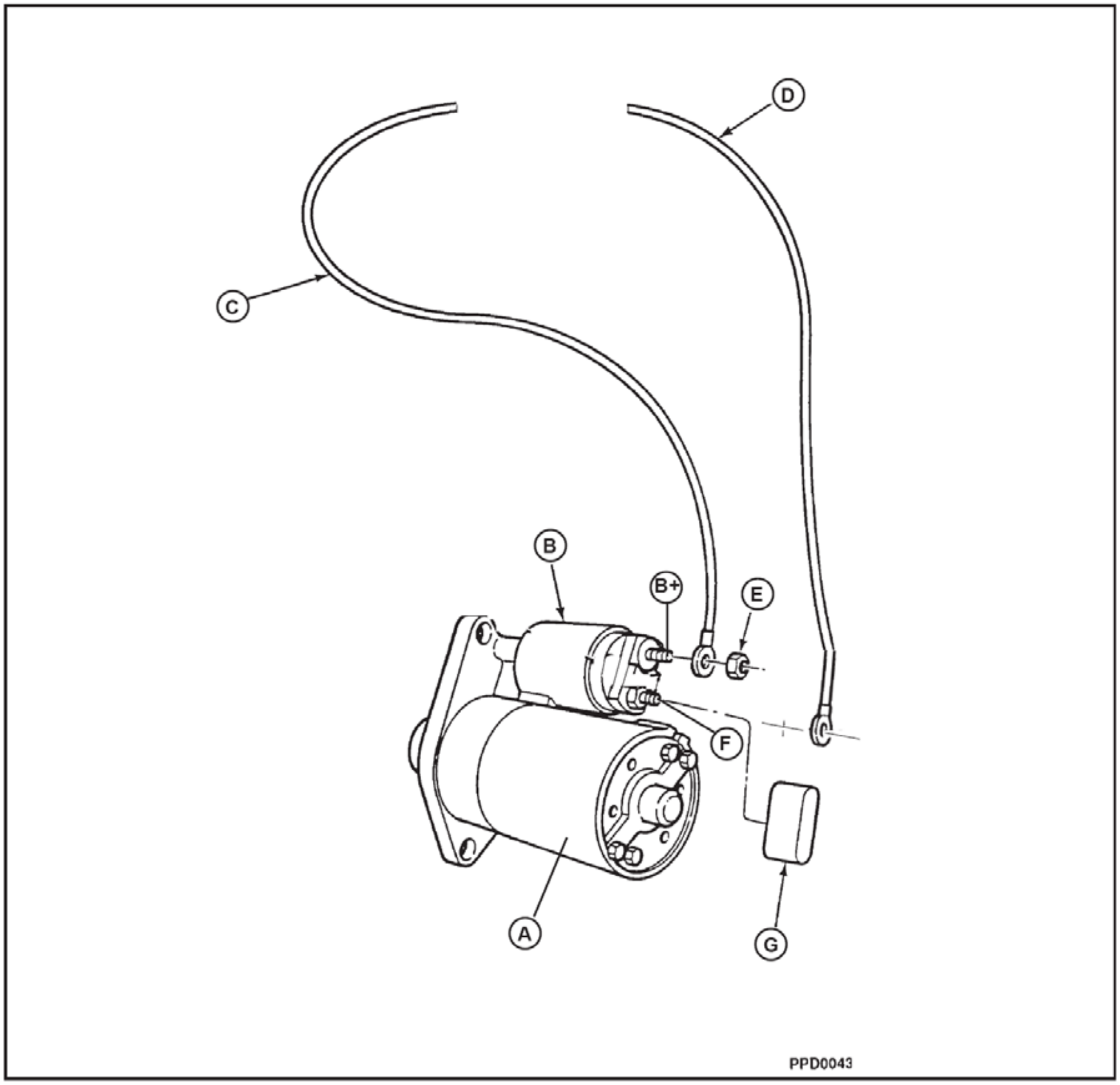
1. Check the wear patterns on the (A) starter drive (11350) and the (B) flywheel ring gear. If the wear pattern is normal, install the starter motor; refer to Starter Motor - Installation on page 07-18.



2. If the (A) starter drive gear and the flywheel ring gear are not fully meshing or the gears are (B) milled or damaged, replace the starter motor; refer to Starter Motor - Installation on page 07-18. Replace the flywheel ring gear.

WSG-1068 STARTER SYSTEM

REMOVAL AND INSTALLATION



CAUTION: A jumper wire must not be installed between the large round electrical terminal and the solenoid blade terminal at the starter. If done, voltage is generated to the solenoid by the spinning starter after release of the start key or button, causing the starter to remain engaged, resulting in failure.

A	Permanent Magnet Starter
B	Starter Motor Solenoid
B+	12 Volt Battery Supply Terminal
C	Starter Cable
D	B+ when relay is energized from ignition switch in crank position to "S" Terminal
E	Nut
F	Starter Solenoid Ignition Feed
G	Terminal Cover

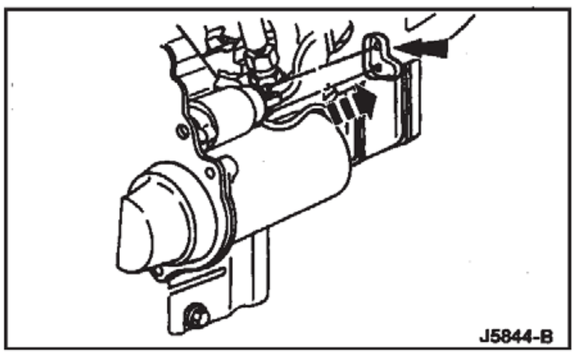
WSG-1068 STARTER SYSTEM

Starter Motor - Removal

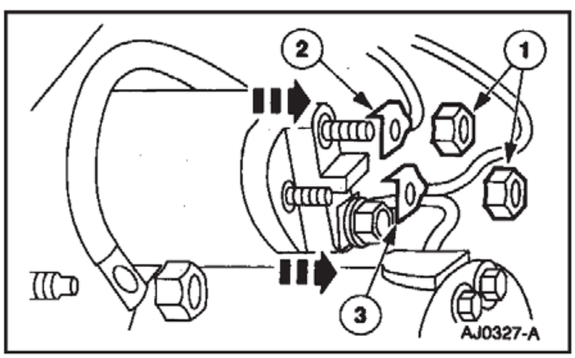
WARNING: WHEN CARRYING OUT MAINTENANCE ON THE STARTER SYSTEM BE AWARE THAT HEAVY GAUGE LEADS OR CONNECTED DIRECTLY TO THE BATTERY. MAKE SURE PROTECTIVE CAPS ARE IN PLACE WHEN MAINTENANCE IS COMPLETE. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

1. Disconnect the battery ground cable.

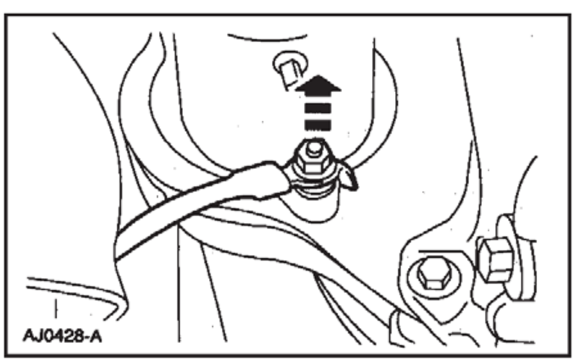
2. Raise and support the vehicle or equipment.



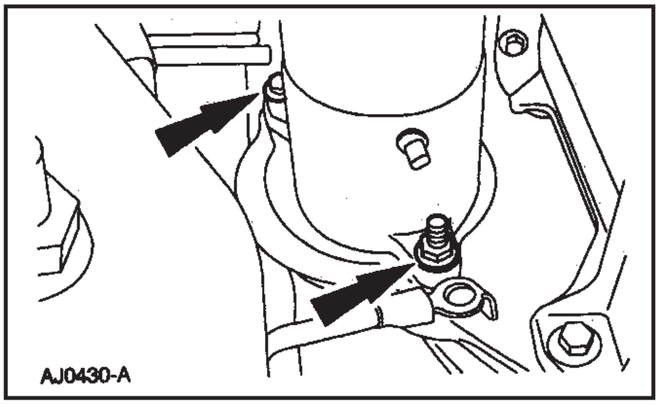
3. Remove the starter motor solenoid terminal cover (11N087).



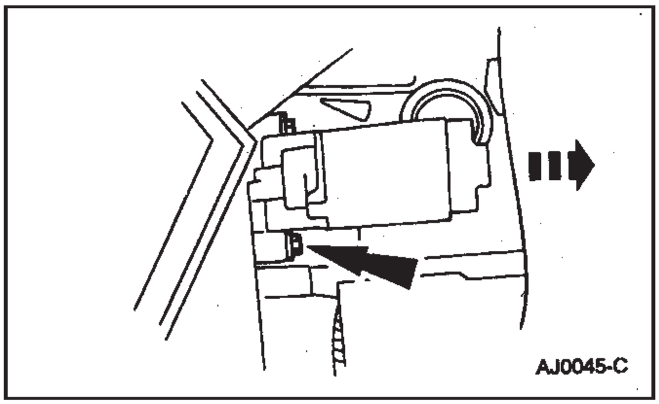
4. Disconnect the starter motor electrical connections.
    1. Remove the two nuts.
    2. Remove the battery cable.
    3. Remove the starter solenoid wire.



5. Remove the nut and the starter motor ground cable when equipped.



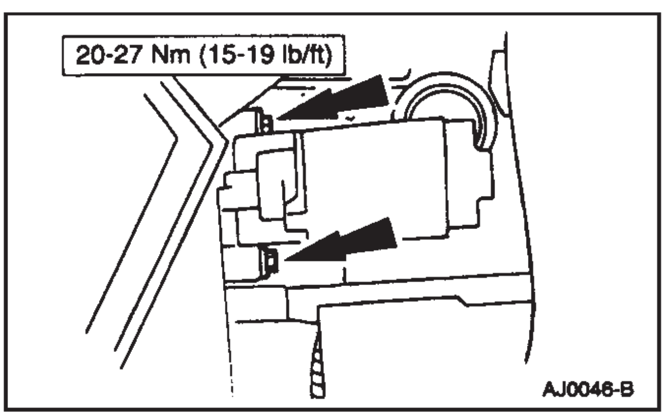
6. Remove the bolt and nut.



7. Remove the starter motor.

Starter Motor - Installation

WARNING: WHEN CARRYING OUT MAINTENANCE ON THE STARTER SYSTEM BE AWARE THAT HEAVY GAUGE LEADS ARE CONNECTED DIRECTLY TO THE BATTERY. MAKE SURE PROTECTIVE CAPS ARE IN PLACE WHEN MAINTENANCE IS COMPLETE. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

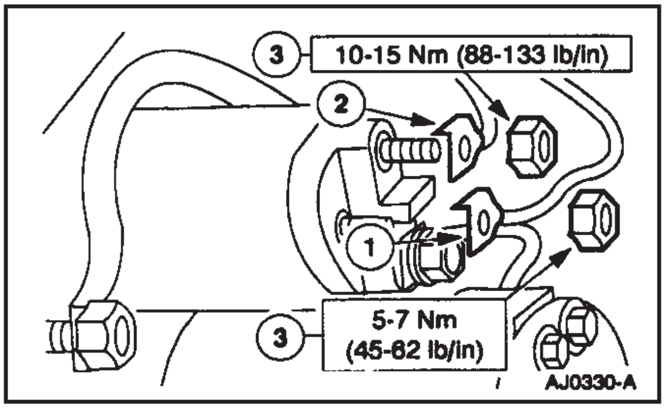


NOTE: It is recommended that wiring service kit F2PZ-11K162-A be used, which includes a 70 inch long #12 gauge wire, a terminal nut, a terminal cover, four tie wraps and insulation instructions.

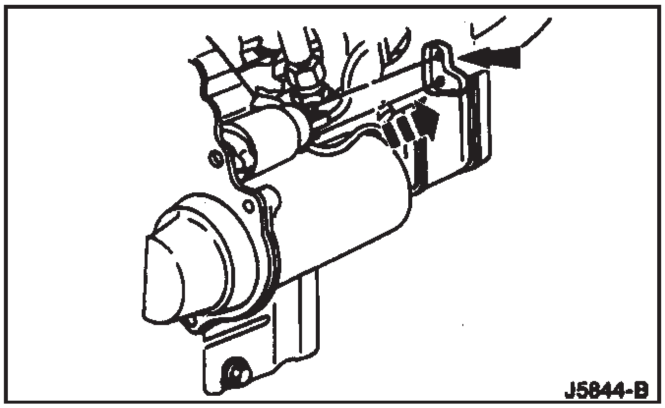
1. Install the starter motor.

   1. Position the starter motor.

   2. Install the bolts.



2. Connect the starter motor electrical connections.
    1. Position the starter solenoid wire.
    2. Position the battery cable.
    3. Install the nuts.



3. Install the starter motor solenoid terminal cover.
4. Connect the battery ground cable.

WSG-1068 STARTER SYSTEM

SPECIFICATIONS

Torque Specifications

Description	Nm	Lb-In
Brush Plate Screw	2.3-3.4	20-30
Mounting Bolt	20.3-27	15-20 (Lb-Ft)
Solenoid Bolt	5.1-9.6	45-85
Starting Circuit Max. Voltage Drop (Engine Temp. Normal) Volts		0.5
Terminal Nut "S"	10-14	84-120
Terminal Nut "B"	10-14	84-120
Through-Bolt	5.0-9.5	45-84

Electrical Specifications

Voltage Drop	
Starting circuit maximum voltage drop (engine temp. normal)	0.5 volts

General Specifications

Starter Motor						Max. Load	No Load	Starter Brushes			
Motor Diameter		Current Draw Under Normal Load	Normal Engine Cranking Speed *	Min. Stall Torque @ 5 Volts				Mfg. Length		Spring Tension	
mm	Inches	Amps	RPM	Nm	Lb-Ft	Amps	Amps	mm	Inches	N	oz.
108	4	130-220	140-220	14.7	11.0	800	70 ± 10	16.8	0.66	18	64

Maximum commutator runout is 0.12mm (0.005 inch). Maximum starting circuit voltage drop (battery positive terminal to starter terminal) at normal engine temperature is 0.5 volt.

*NOTE: Engine may not start if cranking speed is below 140 RPM.

Special Tools

Rotunda Equipment

Tool Number	Description
105-R0057	Digital Volt/Ohm Meter (DVOM)

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

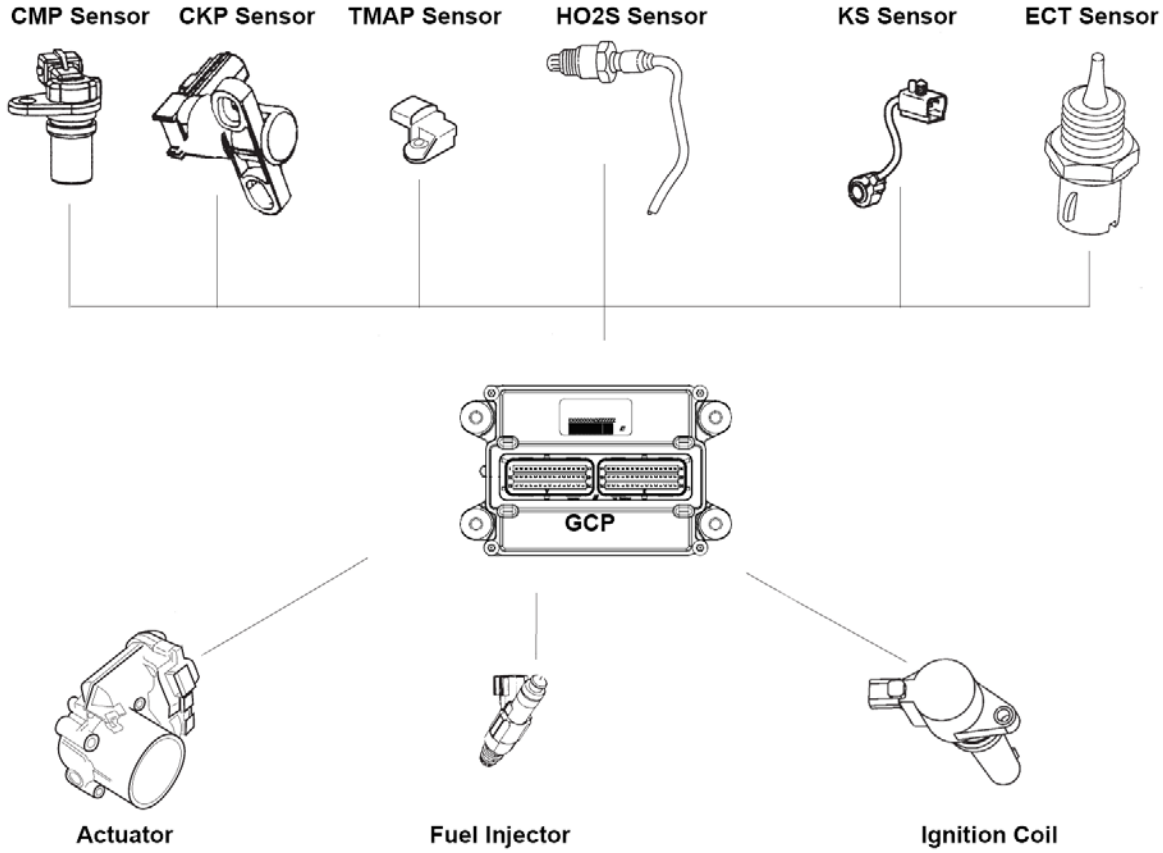
WSG-1068 ENGINE CONTROLS

08

WSG-1068 ENGINE CONTROLS

GENERAL INFORMATION

GCP and Sensors



Engine Control Module (GCP)

The Engine Control Module (GCP) has the following features:

- Programmable four speed electronic governing,
- 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.
- Starter lockout.
- Auto crank
- Programmable overspeed protection.
- Diagnostic software allows viewing of historical and active faults with on-demand diagnostics to throttle-by-wire or variable speed control governing.
- Programmable emergency warning/shut-down feature for high water temperature, low oil pressure, etc
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. And if you only want to view engine parameters and fault codes, all you need is a Personal Digital Assistant (PDA) and our easy to load software and a communications cable.

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
- Electronic Throttle Control
- Electric Fuel Pump
- Diagnostics - Malfunction Indicator Lamp (check engine lamp)
- Diagnostics - Data Link Connector (DLC)

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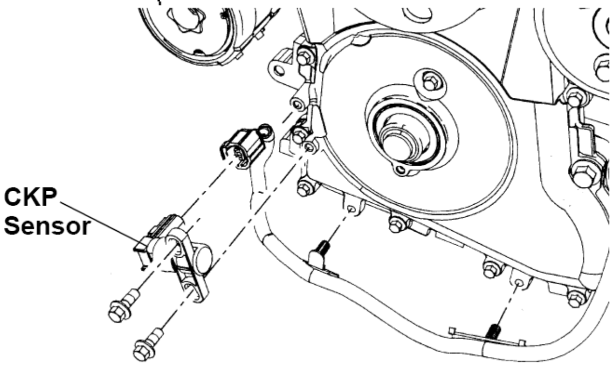
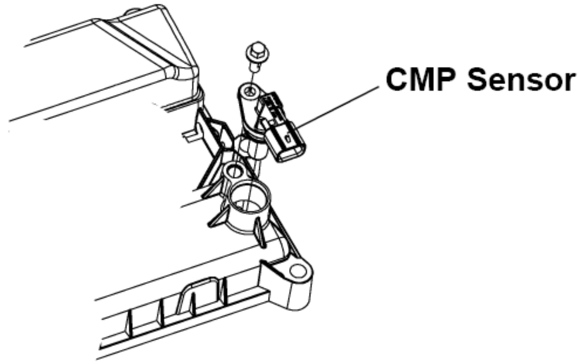
Crankshaft Position (CKP) Sensor

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

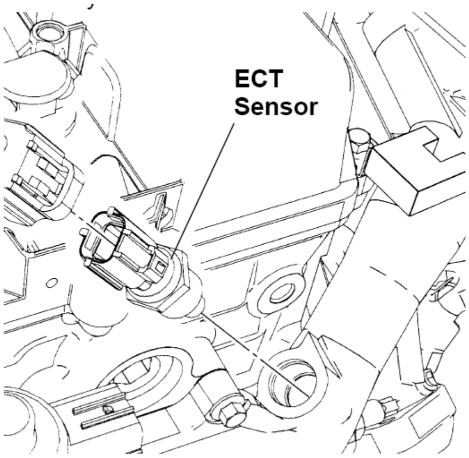
The Camshaft Position (CMP) Sensor uses a variable reluctor sensor to detect camshaft position. The CMP signal is created as piston #1 is a pre-determined number of degrees after top dead center on the power stroke.

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 245 will set.

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 244) 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.

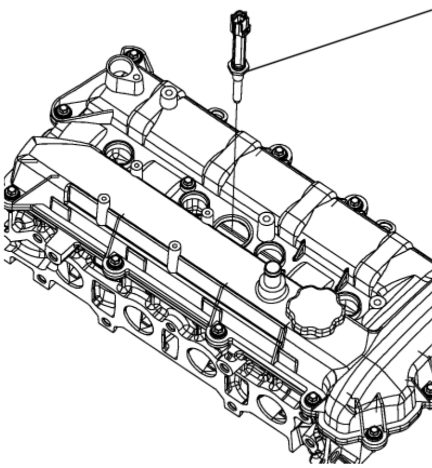


After engine start-up, the temperature should rise steadily to about 85°C (185°F). It then stabilizes when the thermostat opens. If the engine has not been run for several hours (overnight), the engine coolant temperature and intake air temperature displays should be close to each other. A fault in the engine coolant sensor circuit will set a DTC 221 or DTC 222.

TEMP. C°	TEMP. F°	NOM Rt, (OHMS)	NOM E_{OUT} (VOLTS)
-40	-40	925,021	4.54
-35	-31	673,787	4.50
-30	-22	496,051	4.46
-25	-13	368,896	4.41
-20	-4	276,959	4.34
-15	5	209,816	4.25
-10	14	160,313	4.15
-5	23	123,485	4.02
0	32	95,851	3.88
5	41	74,914	3.71
10	50	58,987	3.52
15	59	46,774	3.32
20	68	37,340	3.09
25	77	30,000	2.86
30	86	24,253	2.62
35	95	19,716	2.39
40	104	16,113	2.15
45	113	13,236	1.93
50	122	10,926	1.72
55	131	9,061	1.52
60	140	7,548	1.34
65	149	6,332	1.18
70	158	5,335	1.04
75	167	4,515	.91
80	176	3,837	.79
85	185	3,274	.70
90	194	2,804	.61
95	203	2,411	.53
100	212	2,080	.47
105	221	1,801	.41
110	230	1,564	.36
115	239	1,363	.32
120	248	1,191	.28
125	257	1,044	.25
130	266	918	.22
135	275	809	.19
140	284	715	.17
145	293	633	.15
150	302	563	.14
Voltage values calculated for VREF = 5 volts (may vary ± 15% due to sensor and VREF variations)			

Cylinder Head Temperature (CHT) Sensor

The Cylinder Head Temperature (CHT) Sensor is a thermistor which changes its resistance based on the temperature of cylinder head. Low 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 sensor through a resistor in the GCP and monitors the signal voltage. The signal voltage will be high when the cylinder head is cold and low when the cylinder head is hot. By measuring the voltage, the GCP calculates the cylinder head temperature. The CHT sensor signal is used to adjust spark timing according to the incoming air density.



Heated Oxygen Sensor (HO2S)

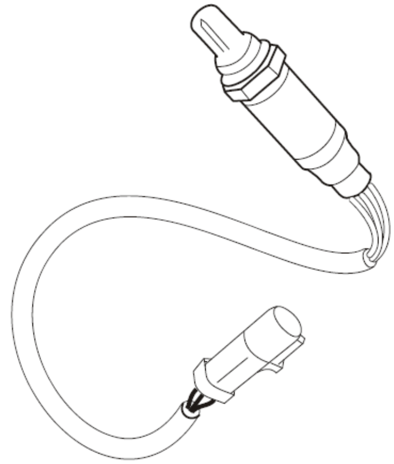
The Heated Oxygen Sensor (HO2S) is mounted in the exhaust stream where it can monitor the oxygen content of the exhaust gas. The oxygen present in the exhaust gas reacts with the sensor to produce a voltage output. This voltage should constantly fluctuate from approximately 100mV to 900 mV, when the 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)

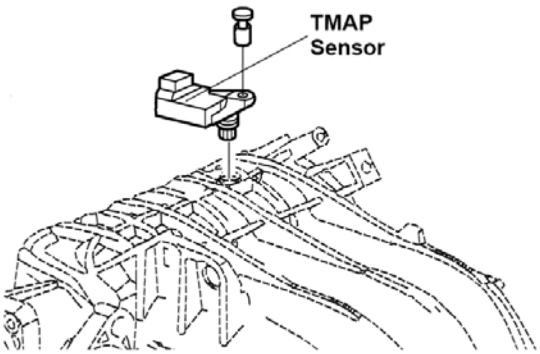
Temperature Manifold Absolute Pressure (TMAP) Sensor

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:

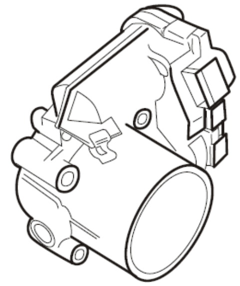
- Range of Measurement: 1.7 - 15.2 psi.
- Measurement Accuracy: ± 0.2 psi
- Sensor Response Time: 3-15 msec.
- Resolution: 0.02 psi

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 531 or DTC 533. A hard failure with the TP sensor ground circuit for more than two consecutive seconds may set DTC 532. 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
- The fuel rail
- The fuel filter
- The GCP
- The Crankshaft Position (CKP) Sensor
- The Camshaft Position (CMP) Sensor
- The fuel pump
- The fuel pump relay
- 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.

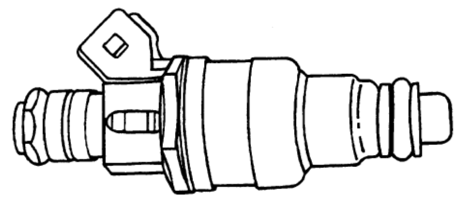
The fuel metering system starts with the fuel in the fuel tank. The fuel is drawn up to the fuel pump through a pre-filter. The electric fuel pump then delivers the fuel to the fuel rail through an in-line fuel filter. The pump is designed to provide fuel at a pressure above the pressure needed by the injectors. A fuel pressure regulator in the fuel filter assembly keeps fuel available to the fuel injectors at a constant pressure. ?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.

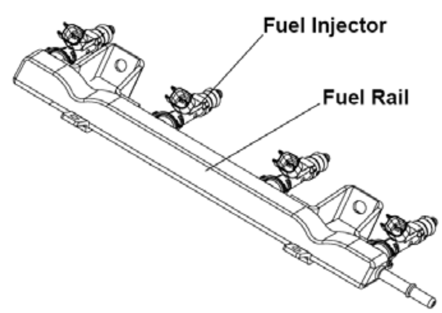


The fuel is injected under pressure in a conical spray pattern at the opening of the intake valve. Excess fuel not used by the injectors passes through the fuel pressure regulator before being returned to the fuel tank.

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.

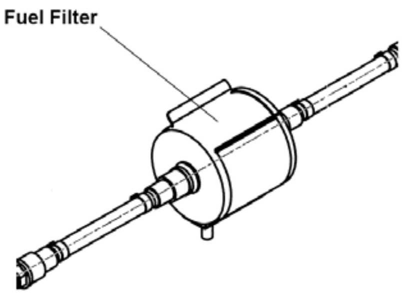
Fuel Rail

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

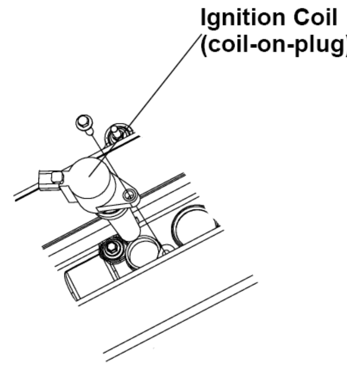
When the key is first turned "ON", the GCP energizes the fuel pump relay for two seconds to build up the fuel pressure quickly. If the engine is not started within two seconds, the GCP shuts the fuel pump off and waits until the engine is cranked. When the engine is cranked and crankshaft position signal 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.

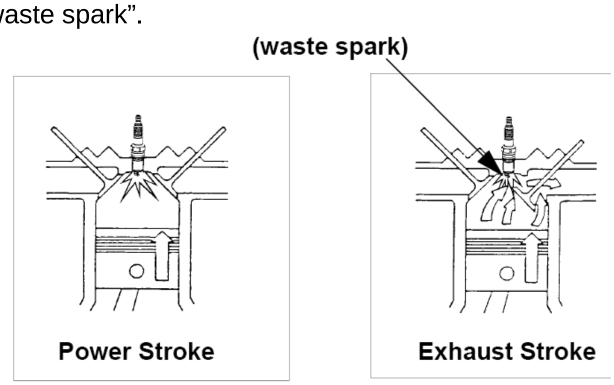
Coil-on-plug Ignition

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 cooldown 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 95°F (35°C).
- 15 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

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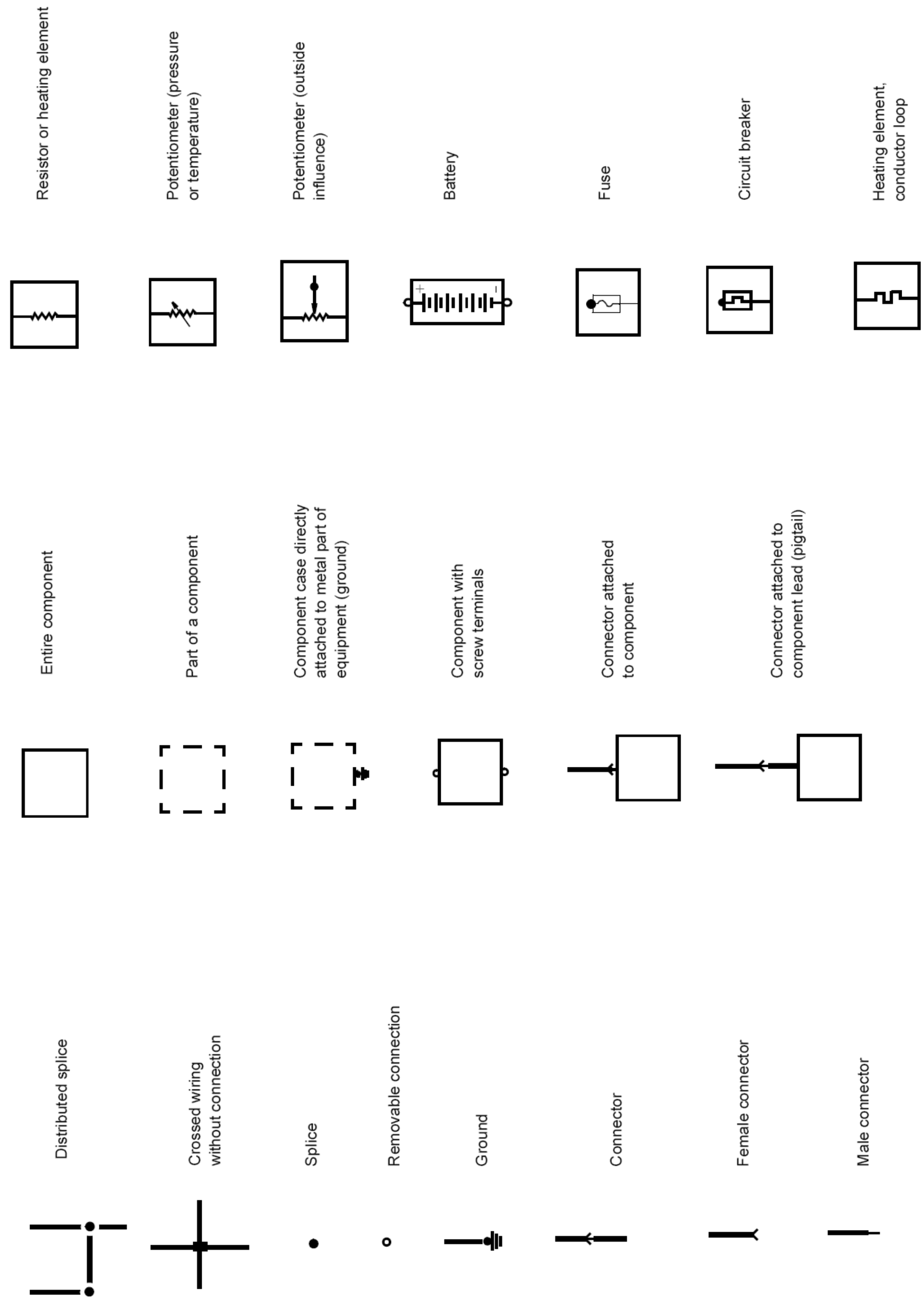
Diagrams and Schematics

Symbols



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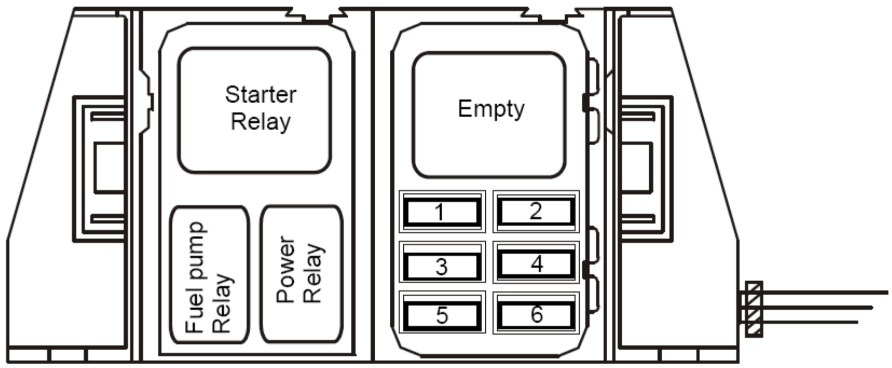
GCP - Power Distribution Box

Part of -5250010- 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	-	Not used

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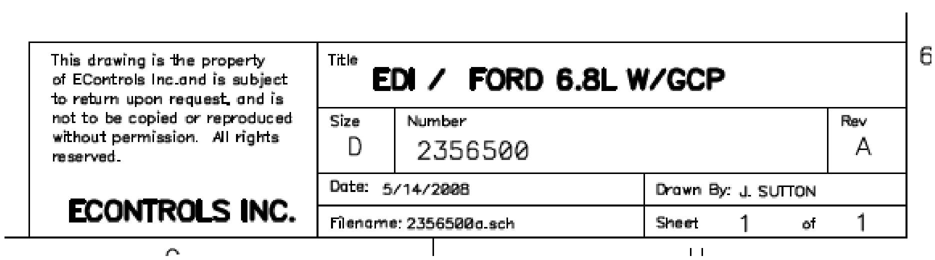
Wire Colors

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:



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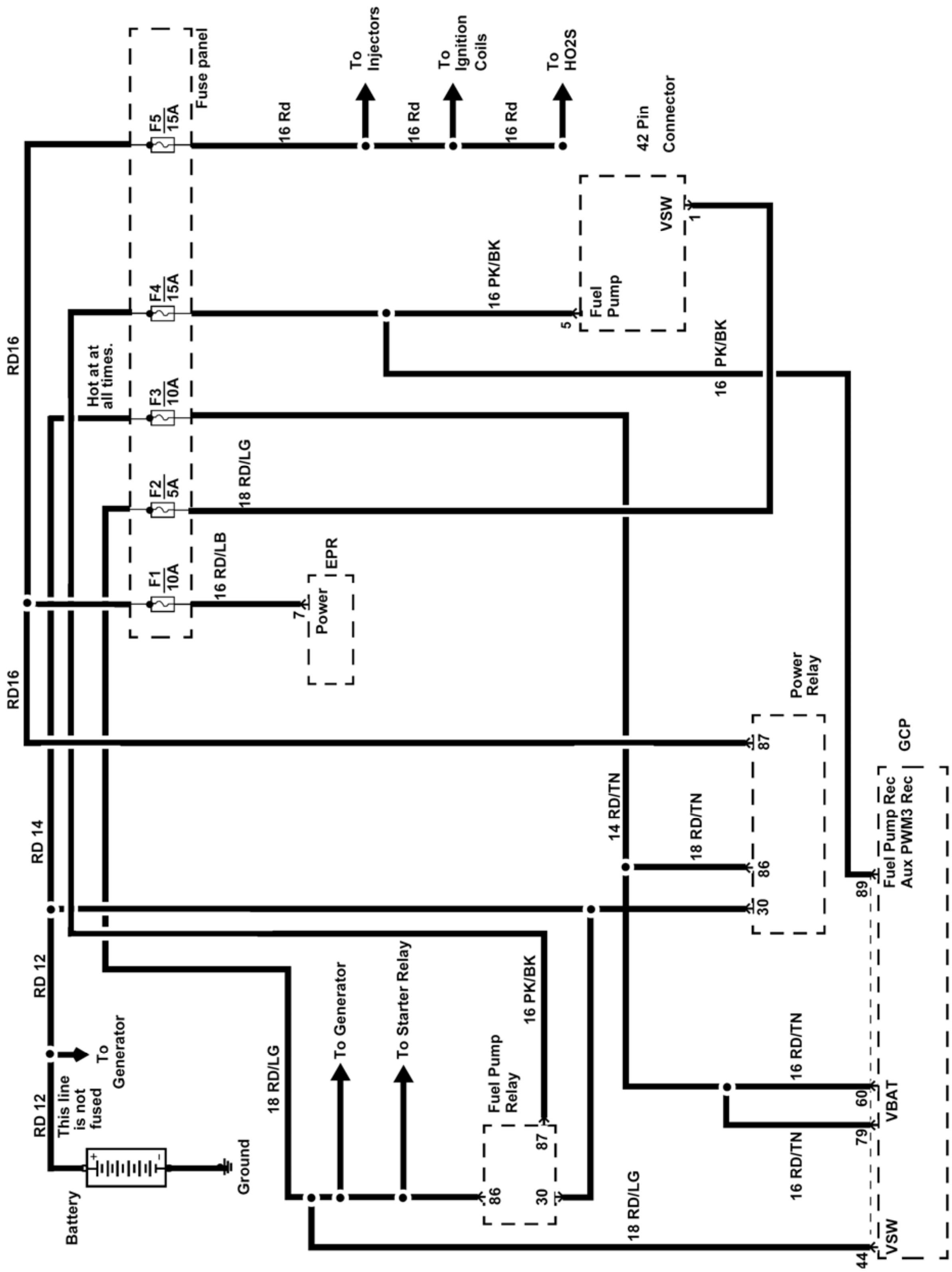
Power Distribution



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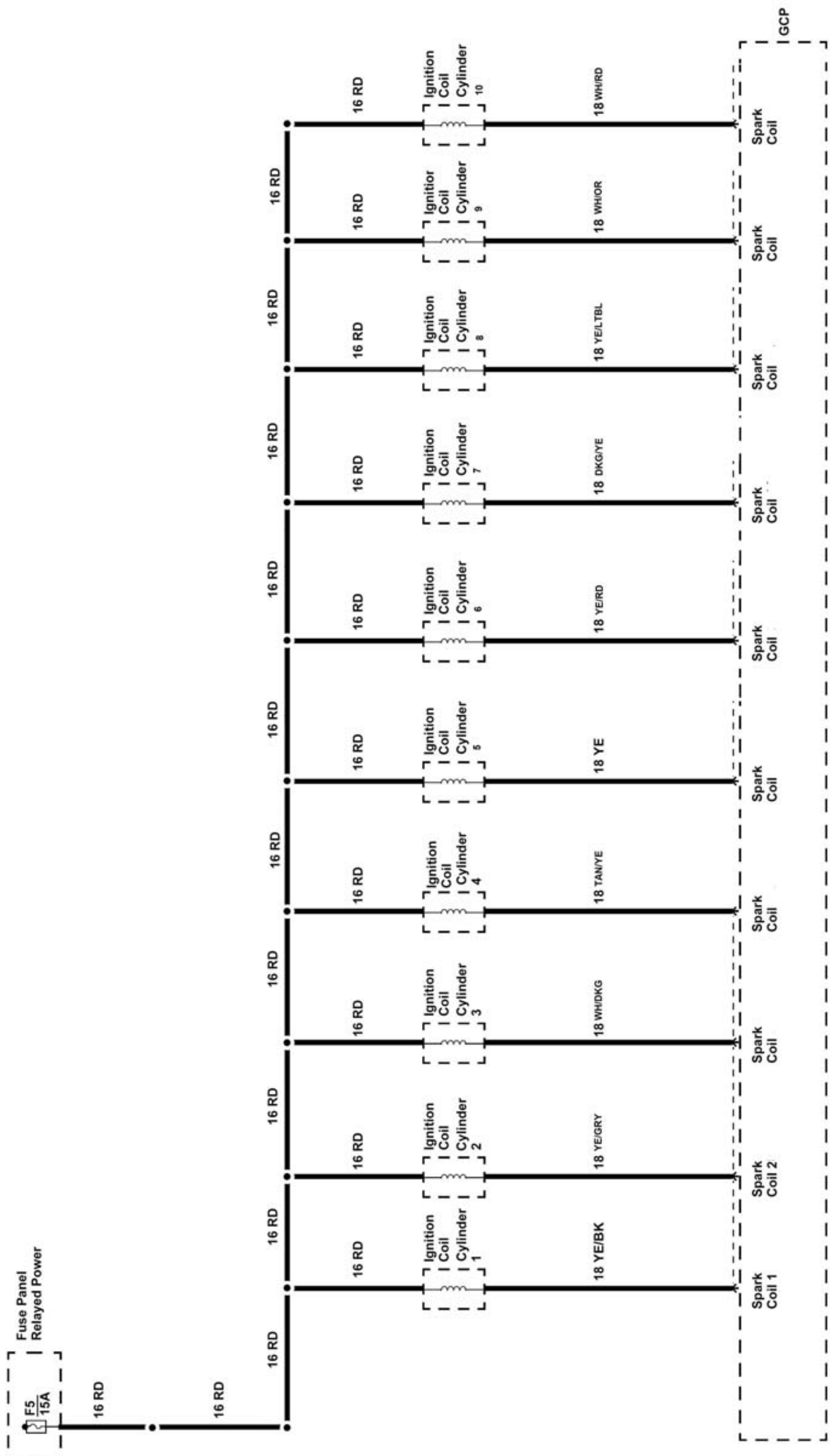
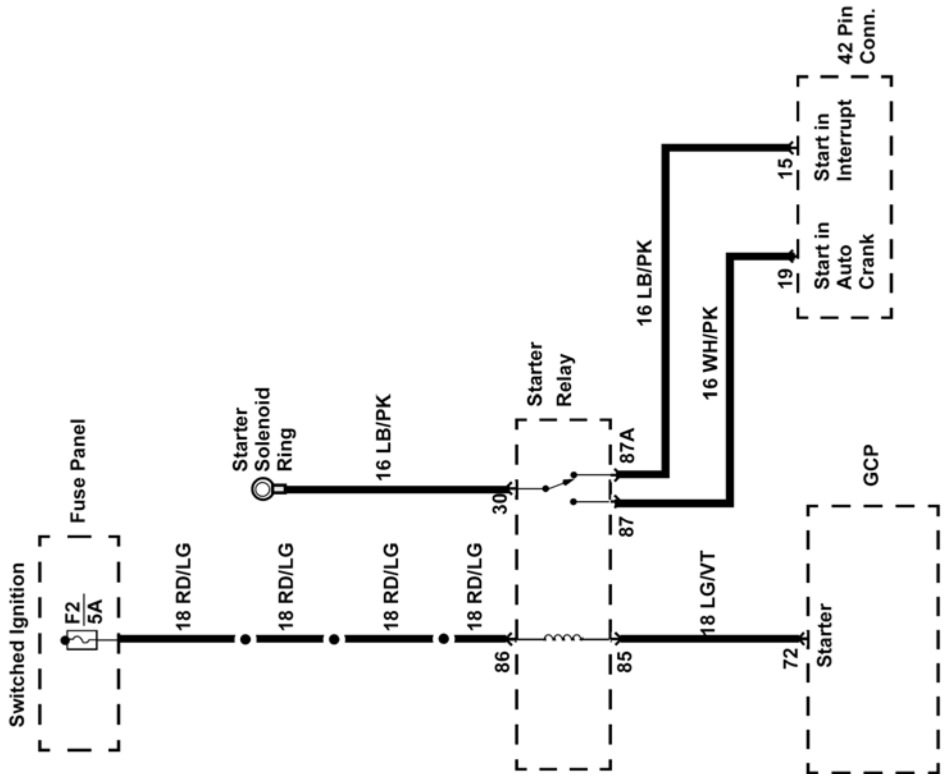
Ignition System



Starting System



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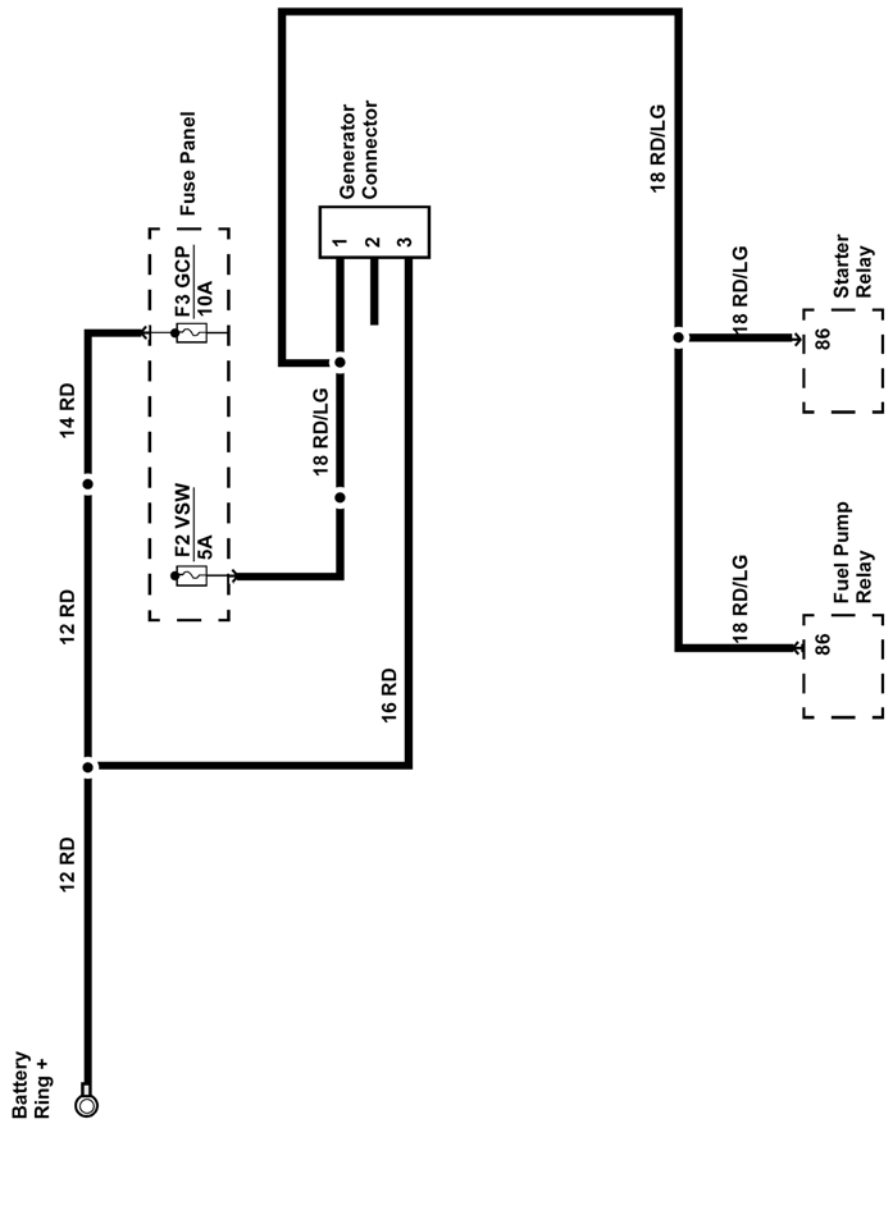
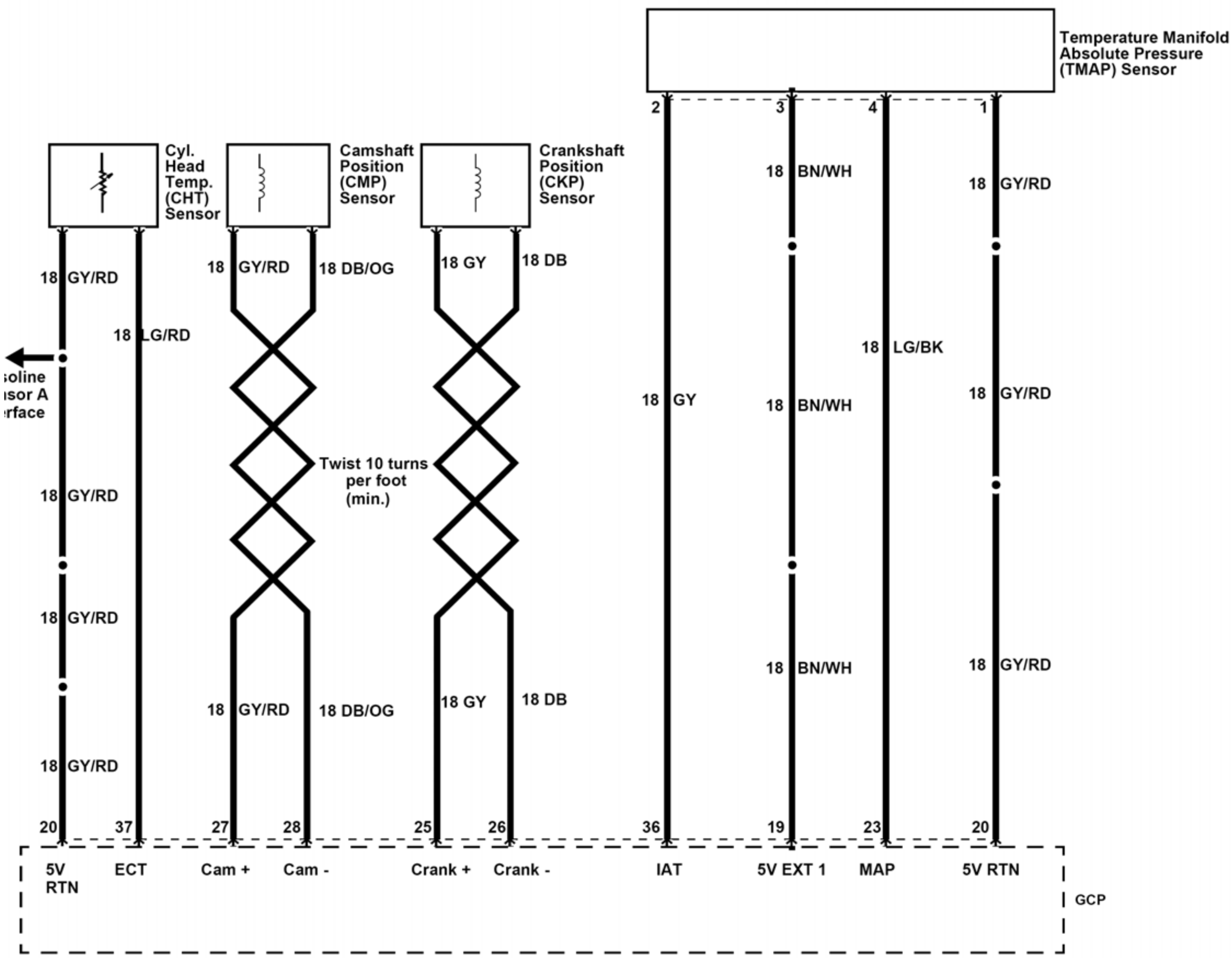
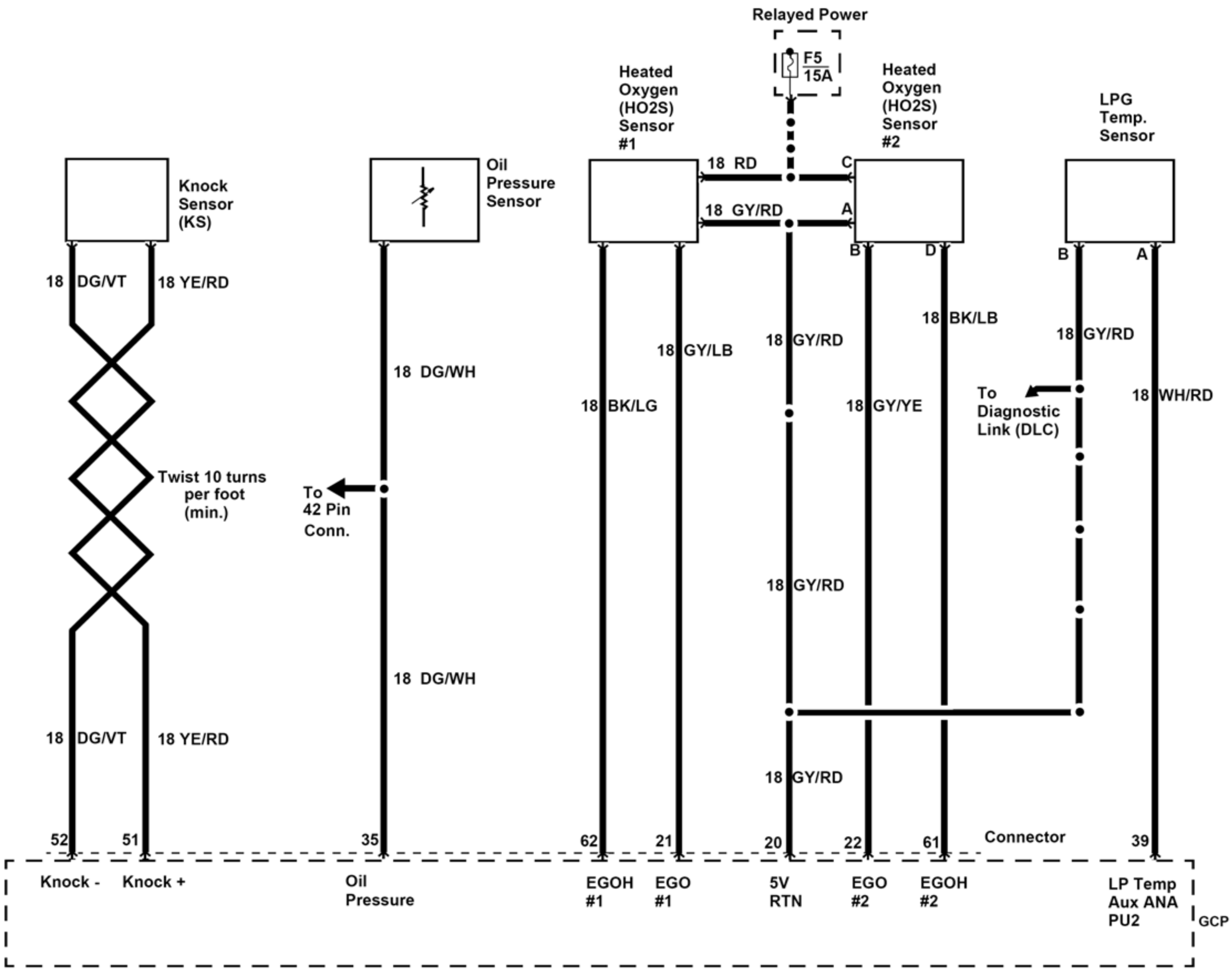
Charging System



Engine Controls - Sensors (1 of 2)



Engine Controls - Sensors (2 of 2)



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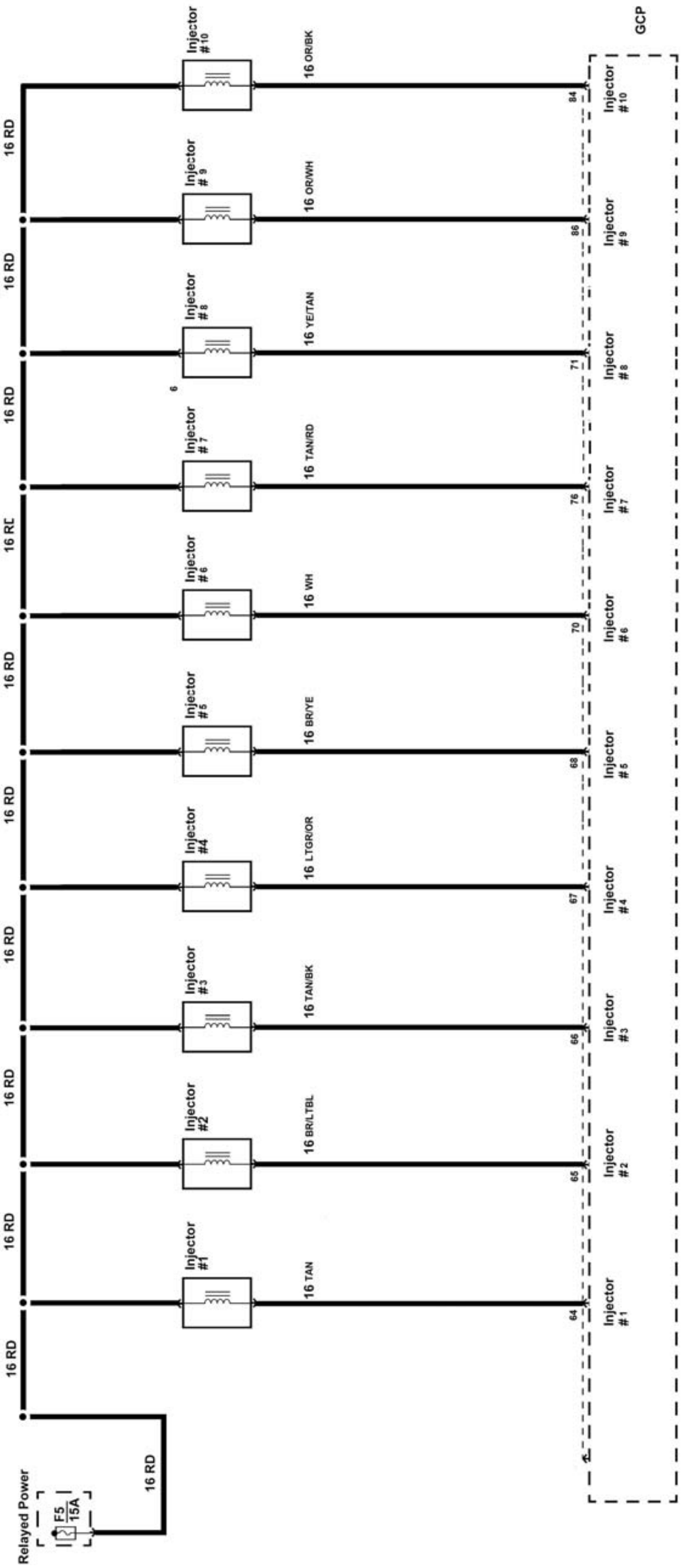
Fuel Injectors



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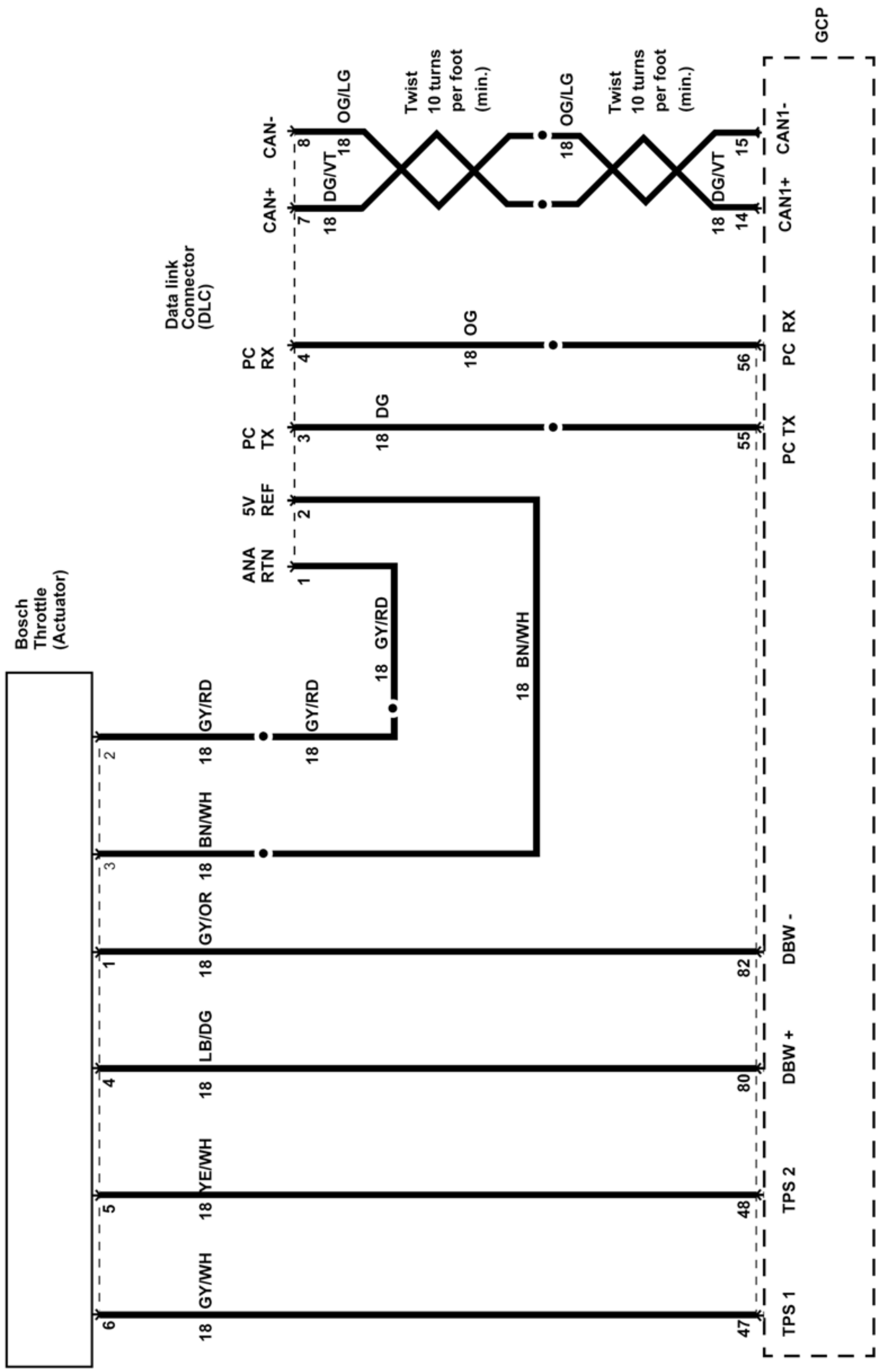
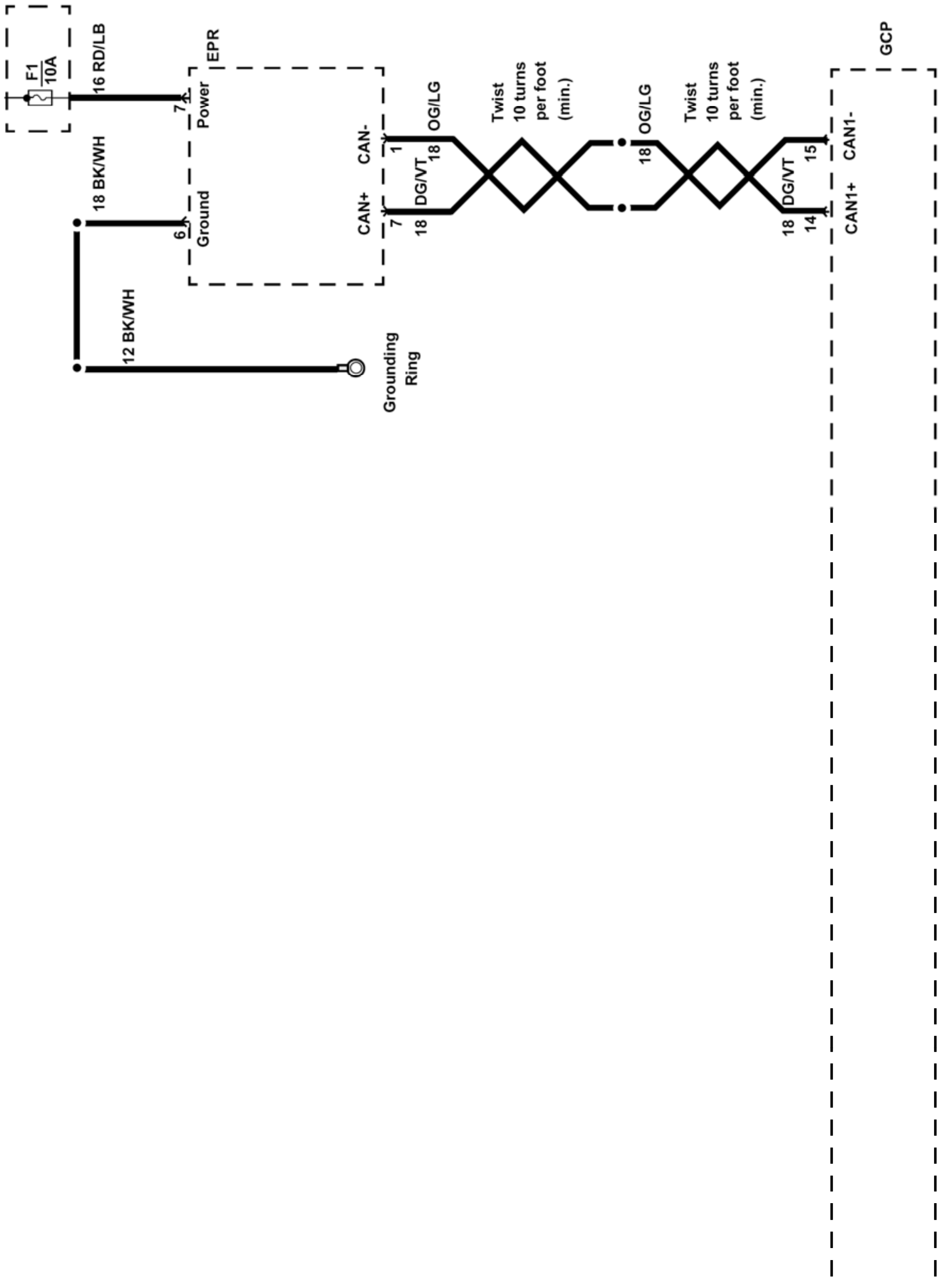
Engine Controls - Actuator / Data Link Connector (DLC)



Engine Controls - Dry Fuel EPR



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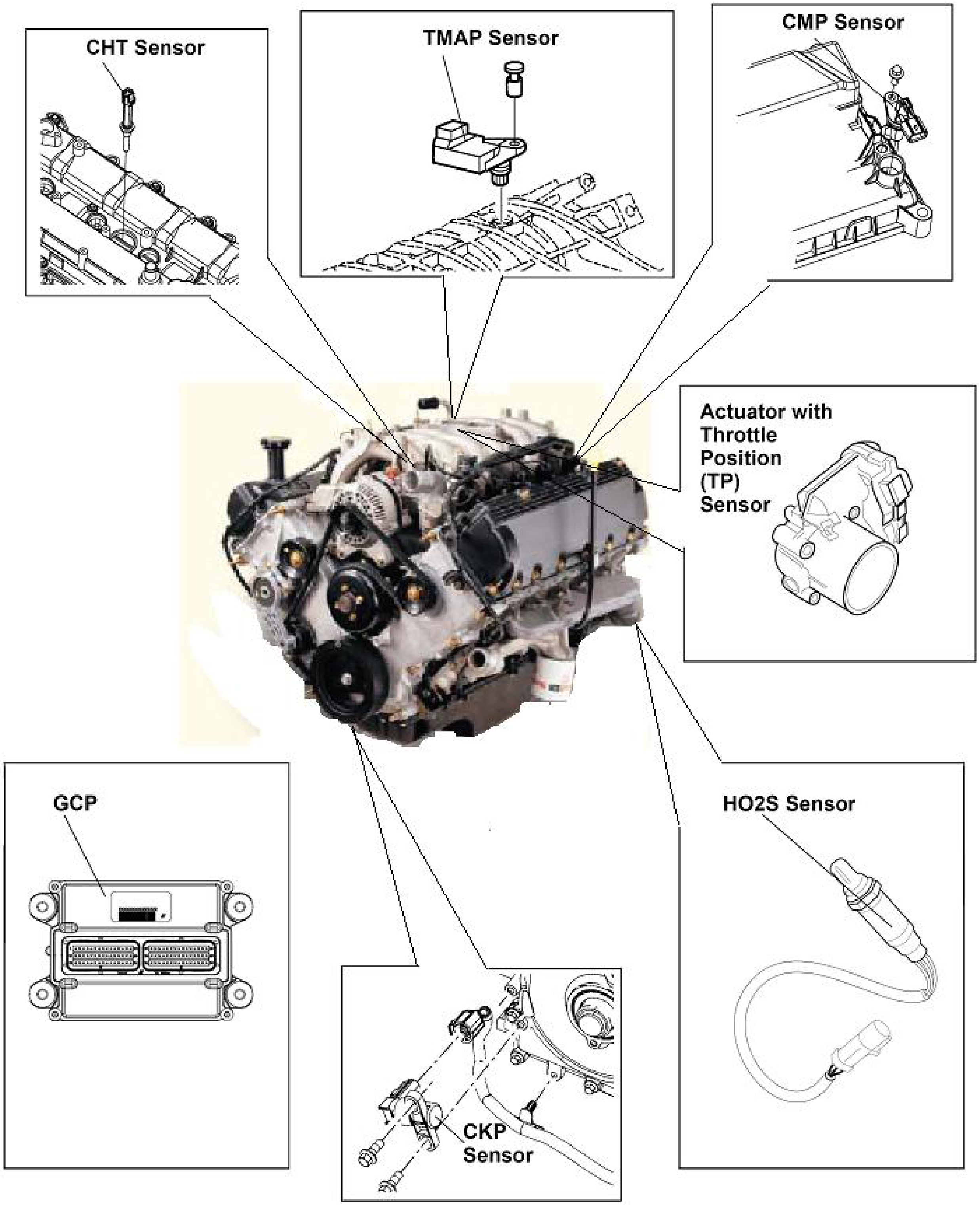
Engine Component Locator View



WSG-1068 ENGINE CONTROLS

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 (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 igniti n 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.

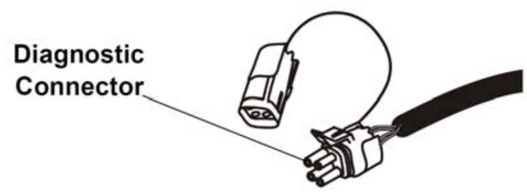
Intermittent MIL

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. Contact an EDI customer service representative at (**1 800 220 2700**) for more information.

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 or hand held Palm Pilot® using the optional serial interface available. 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. The STI white/purple wire branches off to terminal "A" of the 4 pin diagnostic connector. If no DTC is stored with key on/engine off (KOEO), a DTC 123 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 123), 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 serial port) or personal digital assistant (PDA) and a communications cable/interface cable kit:

- Kit for laptop part #: PN 5080050

The required software is available from your local EDI distributor or you can download it from: web.fpp.ford.com

Laptop Requirements:

- USB Port
- 800 x 600 dpi screen
- Windows 95 or newer operating system
- No speed minimum
- 32 MB of RAM

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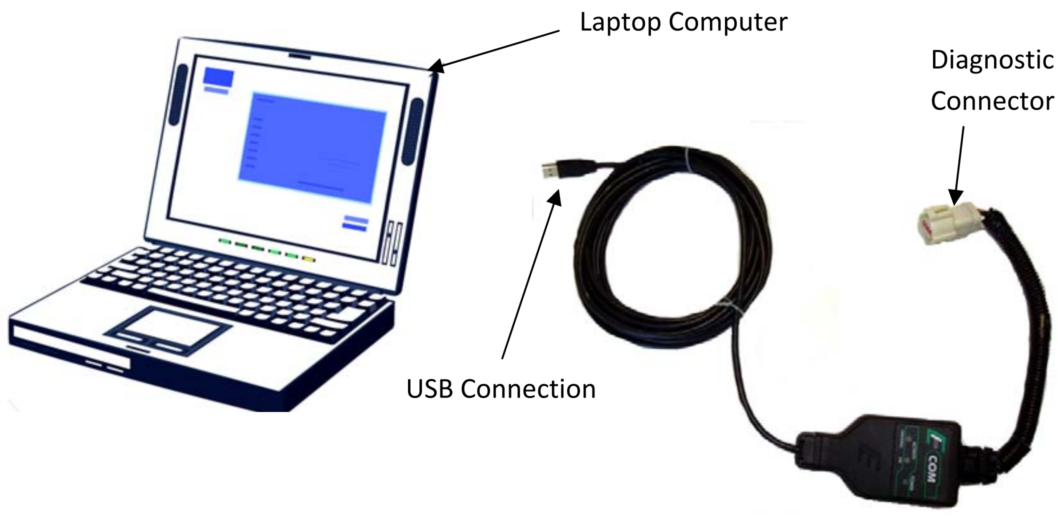
Interface Hook-up

For connection to a laptop, use kit PN 5080050. Connect USB port on the back of the laptop computer. Connect interface cable to the to the diagnostic connector on the engine harness.



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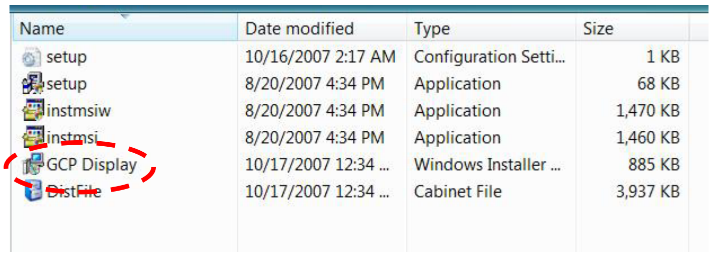
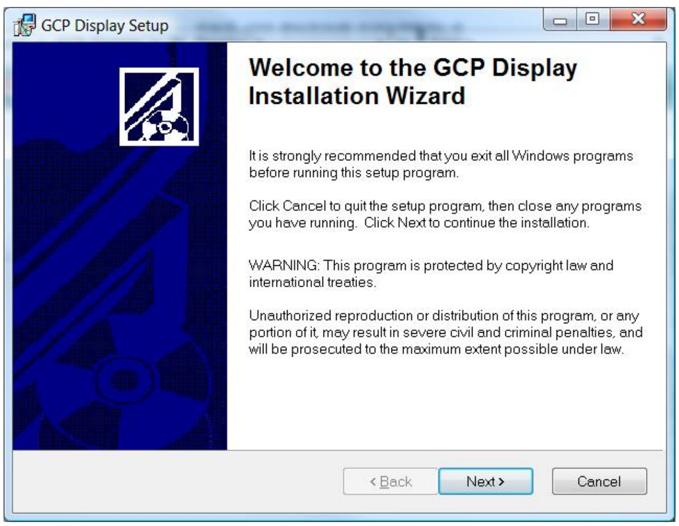
GCP Software Installation

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.

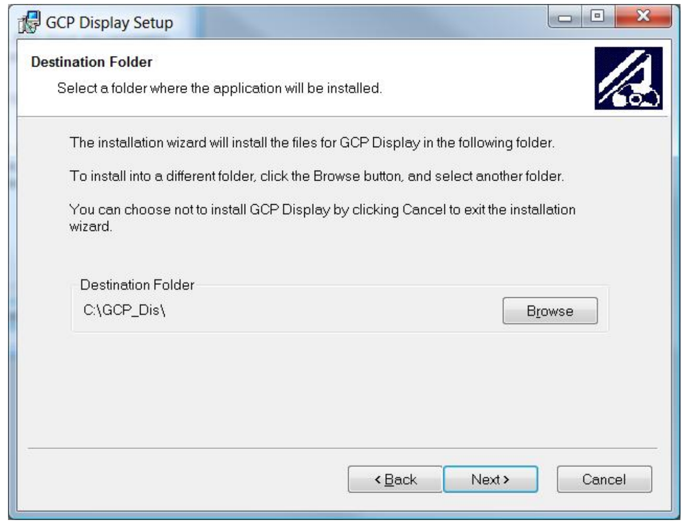


Double click FPP Display icon.
You will now see a welcome screen.



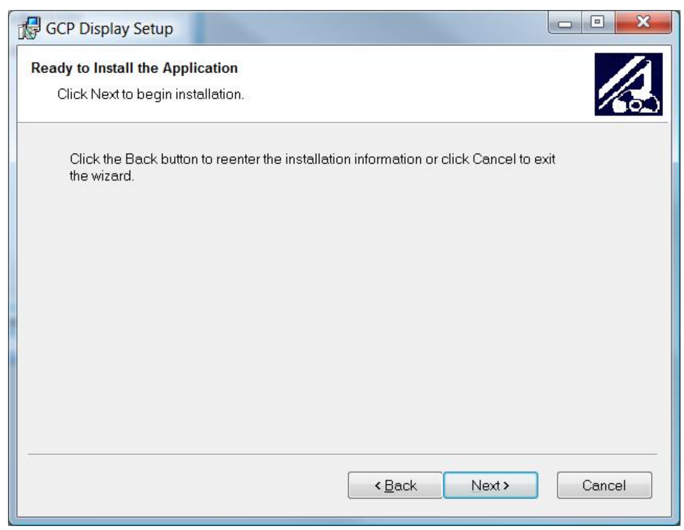
Click next.

A screen will pop up telling you the name of the destination folder.



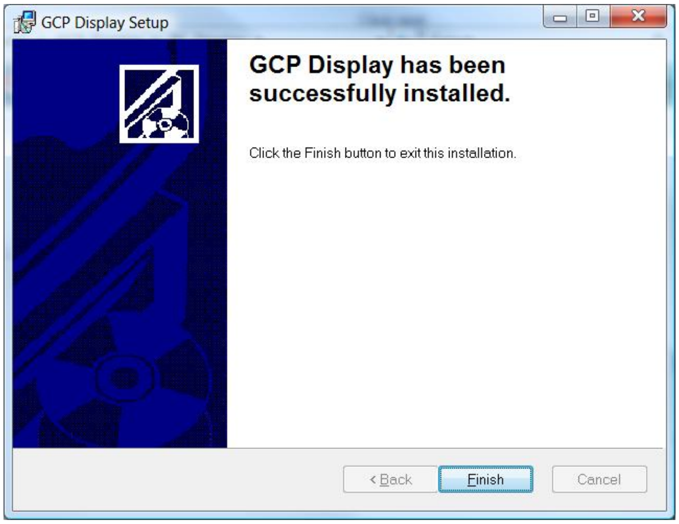
Click next.

You will now see a screen telling you it is ready to install the software.



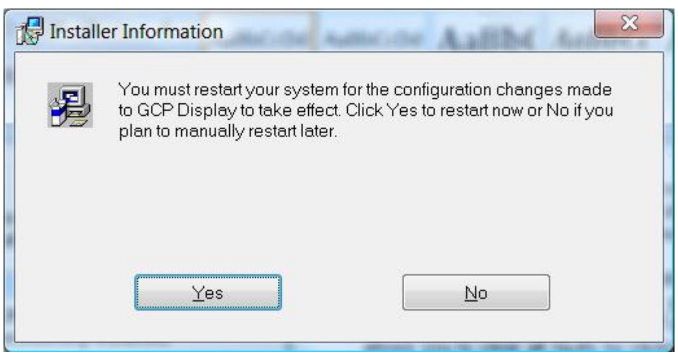
Click next.

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.



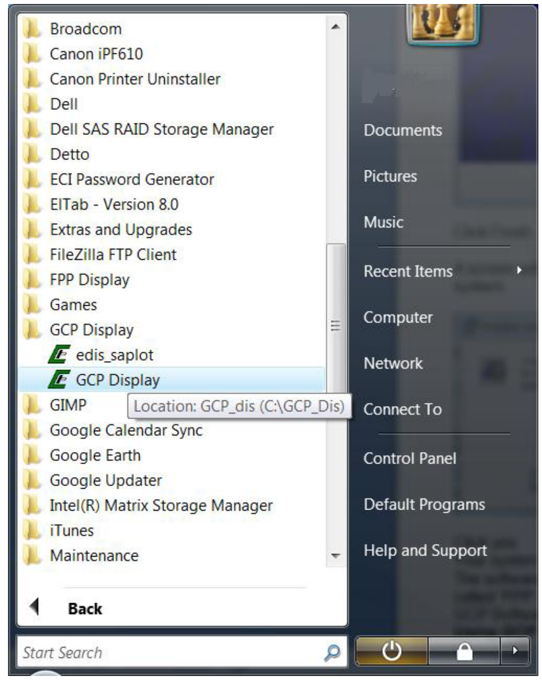
Click yes.

Your system will shut down and reboot.

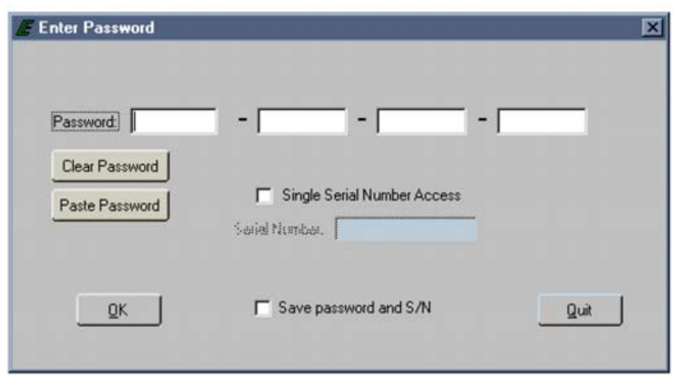
The software is now installed on your system in a folder called "FPP Display". Refer now to "Using Technicians GCP Software" in this Section.

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 on the label of the CD-ROM.



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".

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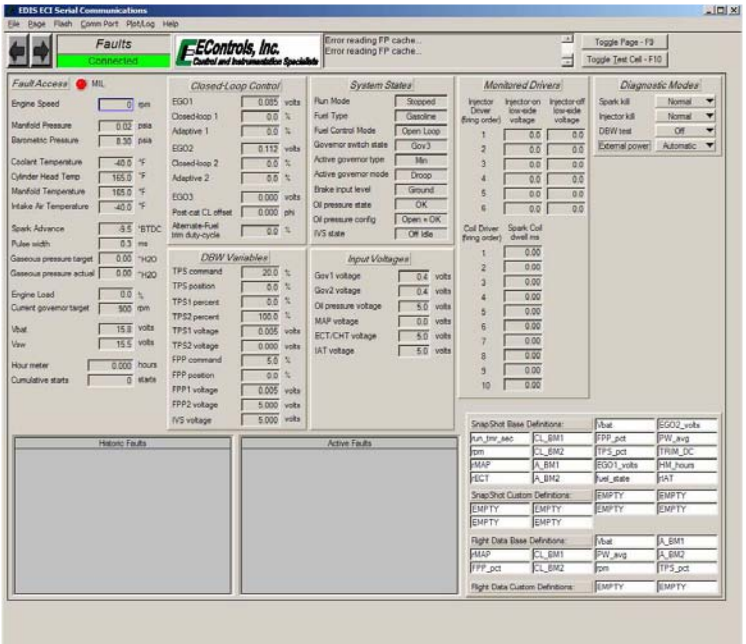
Diagnostic Trouble Codes

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 FORD 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

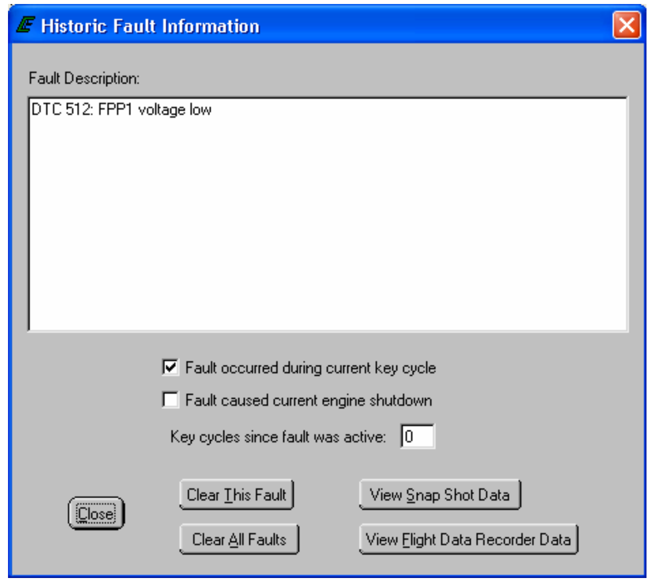
To open a DTC, click on the DTC in the Historic Faults column. A DTC Dialog Box will pop up on the screen. The DTC Dialog Box contains the following useful information:

- 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.

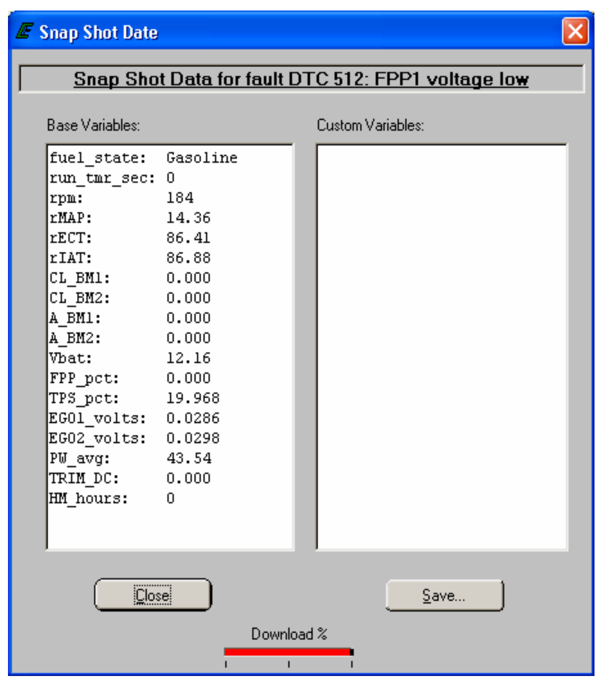
NOTE: Record faults before clearing them. This will aid in diagnosis.

Hear is an example of a DTC Dialogue Box.



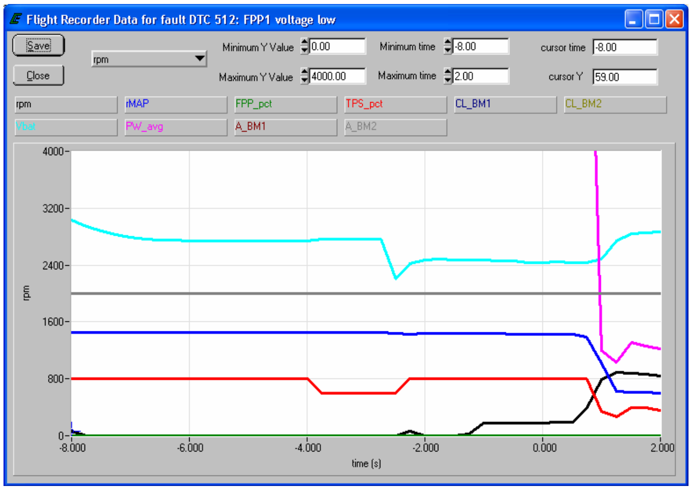
Snap Shot Data

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. Here is an example of a flight Data Recorder Data window.



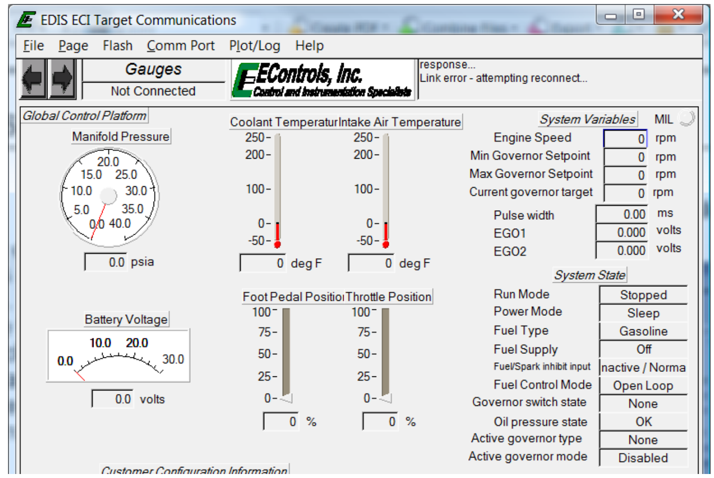
The FAULTS screen shows the following:

- 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.

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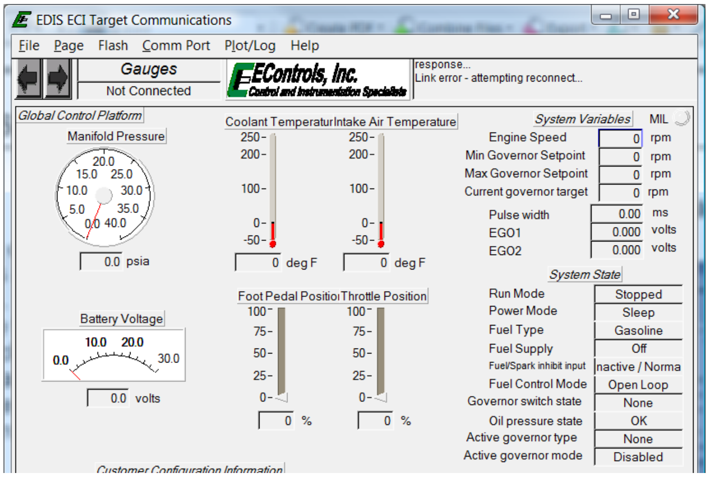
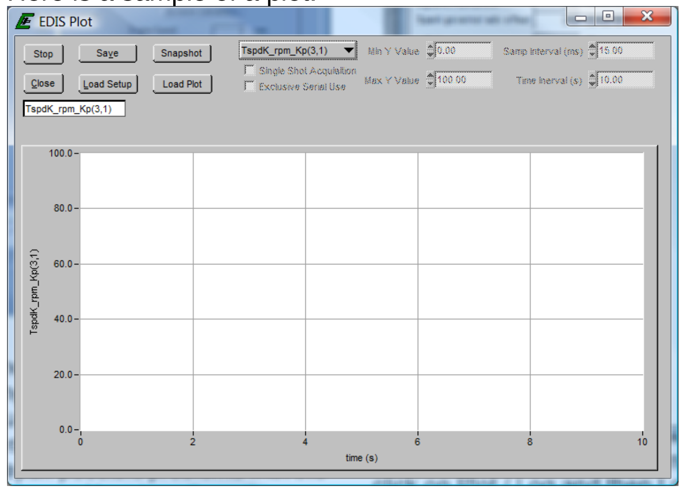
Plotting and Data Logging



Here is a sample of a plot.



Recording the values and voltages can be a very useful tool while diagnosing engine problems. The FORD diagnostic software includes real time **plotting** and real time **logging** capabilities. These features enhance the ability to diagnose and repair possible problems with the FORD system. Both plotting and logging allows the user to record, in real time, any variable that can be seen in the FPP_Dis software. In order to record variables, the FPP_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".

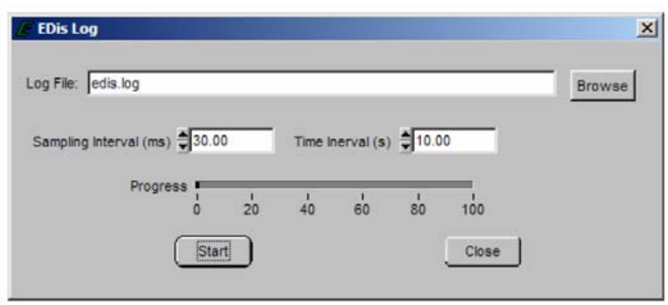
Next, press the "P" key or click the Plot/Log button and then click the Plot Tags button to invoke the plotting feature. This begins the plot function and you can observe the plotted variables. The plot sweeps from right to left. To stop the plotting feature, simply click the "STOP" button. To restart the plotter, click on the "START" 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 the "SAVE" button. 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 FPP_Dis folder, or the data can be viewed in Notepad or Excel.

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 FPP_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 and during a log file.



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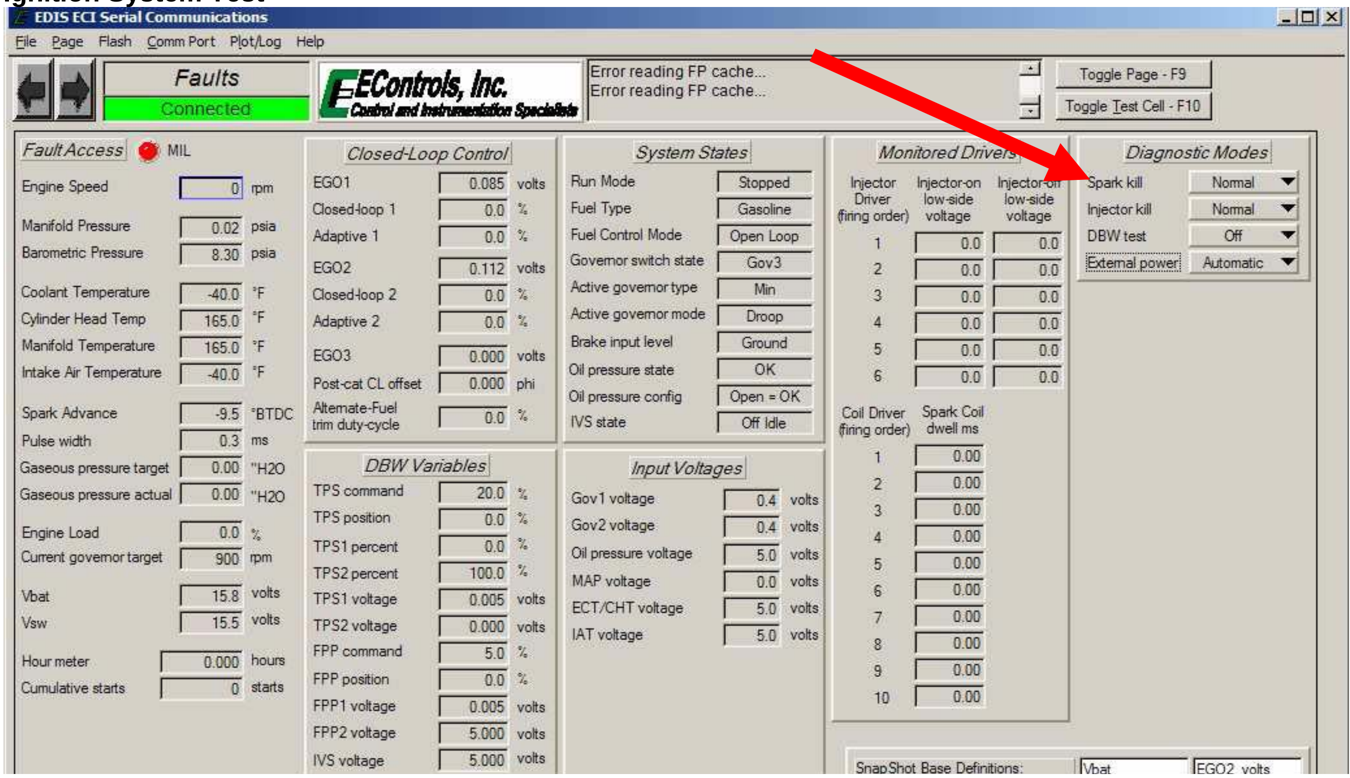
Ignition System Test



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.

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 minutes. 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.

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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 and TPS related faults.

FPP 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.

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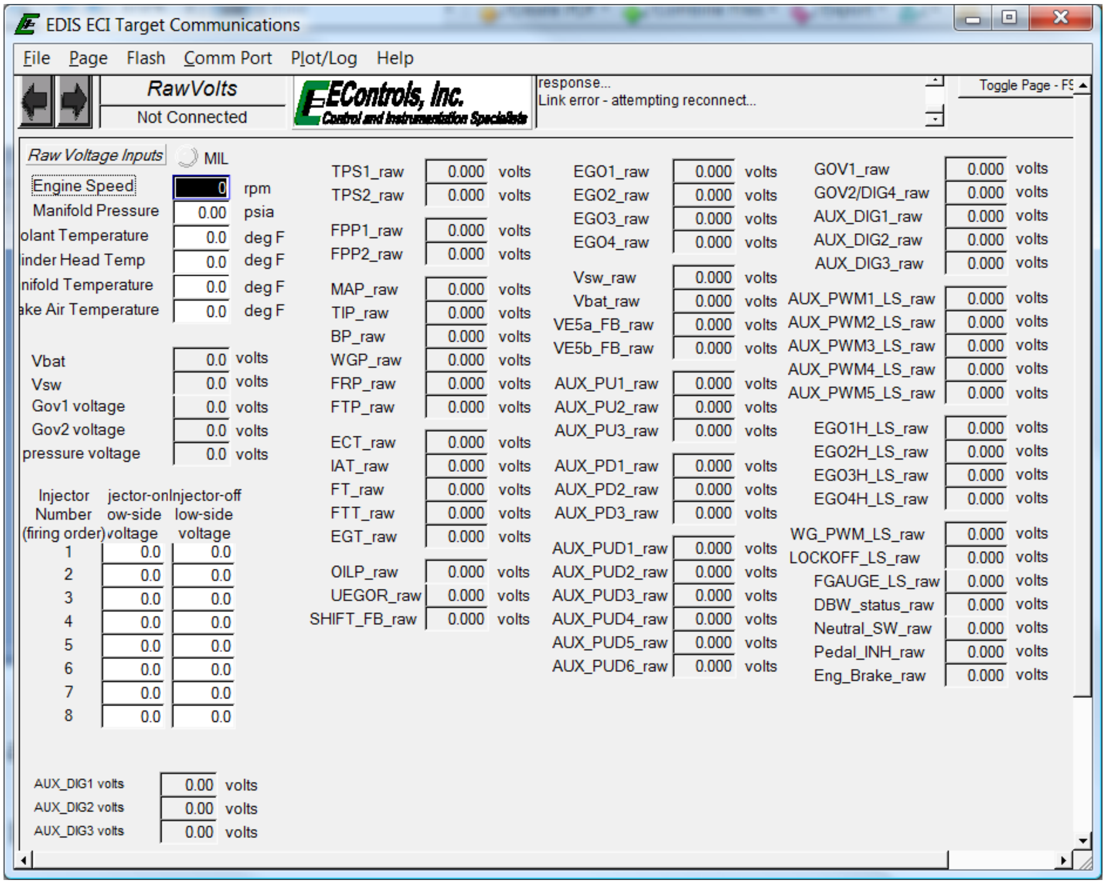
RAW VOLTS Screen



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.

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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.

WSG-1068 ENGINE CONTROLS

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.

NOTE: Items listed in the possible cause column generally do not set a diagnostic trouble code (DTC) orilluminate 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.

Engine Performance - No Load

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

WSG-1068 ENGINE CONTROLS

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

WSG-1068 ENGINE CONTROLS

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	• Ignition System • Fuel Delivery System • Sticking Fuel Injector • High Fuel Pressure
- Blue Smoke	• 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

WSG-1068 ENGINE CONTROLS

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:

- 123 will flash 3 times to indicate the beginning of the flash code display sequence.
- Any active DTC's will flash 3 times each.
- 123 will flash 3 times indicating the end of the code display sequence.

If code 123 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 corresponding DTC chart. Begin with the lowest number code first.

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.

WSG-1068 ENGINE CONTROLS

Diagnostic Trouble Code	
11	Intake cam / distributor position
16	Never crank synced at start
24	Exhaust cam position
91	FP low voltage
92	FP high voltage
107	MAP Low Voltage
108	MAP High Pressure
111	IAT higher than expected 1
112	IAT low voltage
113	IAT high voltage
116	ECT higher than expected 1
117	ECT/CHT Low Voltage
118	ECT/CHT High Voltage
121	TPS1 lower than TPS2
122	TPS1 low voltage
123	TPS1 high voltage
127	IAT higher than expected 2
129	BP low pressure
134	EGO open/lazy pre-cat 1
140	EGO open/lazy post-cat 1
154	EGO open/lazy pre-cat 2/post-cat 1
160	EGO open/lazy post-cat 2
171	AL high gasoline bank1
172	AL low gasoline bank1
174	AL high gasoline bank2
175	AL low gasoline bank2
182	FT Gasoline Low Voltage
183	FT Gasoline High Voltage
187	FT Gaseaous fuel low voltage
188	FT Gaseaous fuel high voltage
217	ECT higher than expected 2
219	Max govern speed override
221	TPS1 higher than TPS2
222	TPS2 low voltage
223	TPS2 high voltage
236	TIP Active
237	TIP Low Voltage
238	TIP High Voltage
261	Injector Loop Open or Low-side short to Ground
262	Injector Coil Shorted
264	Injector Loop Open or Low-side short to Ground

265	Injector Coil Shorted
267	Injector Loop Open or Low-side short to Ground
268	Injector Coil Shorted
270	Injector Loop Open or Low-side short to Ground
271	Injector Coil Shorted
273	Injector Loop Open or Low-side short to Ground
274	Injector Coil Shorted
276	Injector Loop Open or Low-side short to Ground
277	Injector Coil Shorted
279	Injector Loop Open or Low-side short to Ground
280	Injector Coil Shorted
282	Injector Loop Open or Low-side short to Ground
283	Injector Coil Shorted
285	Injector Loop Open or Low-side short to Ground
286	Injector Coil Shorted
288	Injector Loop Open or Low-side short to Ground
289	Injector Coil Shorted
301	Emissions/catalyst damaging misfire
302	Emissions/catalyst damaging misfire
303	Emissions/catalyst damaging misfire
304	Emissions/catalyst damaging misfire
305	Emissions/catalyst damaging misfire
306	Emissions/catalyst damaging misfire
307	Emissions/catalyst damaging misfire
308	Emissions/catalyst damaging misfire
326	Knock 1 Excessive Signal
327	Knock 1 sensor Open
331	Knock 2 Excessive Signal
332	Knock 2 sensor Open
336	Crank sync noise
337	Crank loss
341	Cam sync noise
342	Cam loss
420	Gasoline cat monitor
430	Gasoline cat monitor
524	Oil pressure low
562	Battery Voltage Low
563	Battery Voltage High
601	Flash checksum invalid
604	RAM failure
606	COP failure
615	Start relay coil open

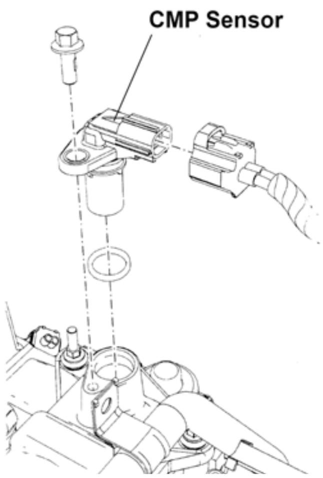
616	Start relay control ground short
617	Start relay coil short to power
627	Fpump relay coil open
628	Fpump relay control ground short
628	FPump motor loop open or high-side shorted to ground
629	Fpump relay coil short to power
629	FPump motor high-side shorted to power
642	5VE1 low voltage
643	5VE1 high voltage
650	MIL open
652	5VE2 low voltage
653	5VE2 high voltage
685	Relay Coil Open
686	Relay Control ground short
687	Relay coil short to power
1111	Fuel rev limit
1112	Spark rev limit
1121	FPP1/2 simultaneous voltages out of range
1122	FPP1/2 do not match each other or the IVS
1151	CL high LPG
1152	CL low LPG
1153	CL high NG
1154	CL low NG
1155	CL high gasoline bank1
1156	CL low gasoline bank1
1157	CL high gasoline bank2
1158	CL low gasoline bank2
1161	AL high LPG
1162	AL low LPG
1163	AL high NG
1164	AL low NG
1165	LPG cat monitor
1166	NG cat monitor
1171	Megajector delivery pressure higher than expected
1172	Megajector delivery pressure lower than expected
1173	Megajector comm lost
1174	Megajector voltage supply high
1175	Megajector voltage supply low
1176	Megajector internal actuator fault detection
1177	Megajector internal circuitry fault detection
1178	Megajector internal comm fault detection
1181	Fuel run-out longer than expected
1182	Fuel impurity level high

1183	Megajector autozero / lockoff failed
1311	Misfire detected
1312	Misfire detected
1313	Misfire detected
1314	Misfire detected
1315	Misfire detected
1316	Misfire detected
1317	Misfire detected
1318	Misfire detected
1511	AUX analog PU1 high
1512	AUX analog PU1 low
1513	AUX analog PU2 high
1514	AUX analog PU2 low
1515	AUX analog PD1 high
1516	AUX analog PD1 low
1517	AUX analog PU3 high
1518	AUX analog PU3 low
1521	CHT higher than expected 1
1522	CHT higher than expected 2
1531	IVS/Brake/Trans-Park interlock failure
1541	AUX analog PUD1 high
1542	AUX analog PUD1 low
1543	AUX analog PUD2 high
1544	AUX analog PUD2 low
1545	AUX analog PUD3 high
1546	AUX analog PUD3 low
1547	AUX analog PUD4 high
1548	AUX analog PUD4 low
1551	AUX DIG1 high
1552	AUX DIG1 low
1553	AUX DIG2 high
1554	AUX DIG2 low
1555	AUX DIG3 high
1556	AUX DIG3 low
1561	AUX analog PD2 high
1562	AUX analog PD2 low
1563	AUX analog PD3 high
1564	AUX analog PD3 low
1611	5VE 1/2 simultaneous out-of-range
1612	RTI 1 loss
1613	RTI 2 loss
1614	RTI 3 loss
1615	A/D loss
1616	Invalid interrupt

1621	Rx Inactive
1622	Rx Noise
1623	Invalid Packet Format
1626	CAN Tx failure
1627	CAN Rx failure
1628	CAN addresss conflict failure
1629	J1939 TSC1 message receipt lost
1630	J1939 ETC message receipt lost
1631	PWM1-Gauge1 open / ground short
1632	PWM1-Gauge1 short to power
1633	PWM2-Gauge2 open /ground short
1634	PWM2-Gauge2 short to power
1635	PWM3-Gauge3 open / ground short
1636	PWM3-Gauge3 short to power
1637	PWM4 open / ground short
1638	PWM4 short to power
1639	PWM5 open / ground short
1640	PWM5 short to power
1641	Buzzer control ground short
1642	Buzzer open
1643	Buzzer control short to power
1644	MIL control ground short
1645	MIL control short to power
1661	PWM6 open / ground short
1662	PWM6 short to power
1663	PWM7 open / ground short
1664	PWM7 short to power
1665	PWM8 open / ground short
1666	PWM8 short to power
1669	PWM9 open / ground short
1670	PWM9 short to power
2111	Unable to reach lower TPS
2112	Unable to reach higher TPS
2115	FPP1 higher than IVS limit
2116	FPP2 higher than IVS limit
2120	FPP1 invalid voltage and FPP2 disagrees with IVS
2121	FPP1 lower than FPP2
2122	FPP1 high voltage
2123	FPP1 low voltage
2125	FPP2 invalid voltage and FPP1 disagrees with IVS
2126	FPP1 higher than FPP2
2127	FPP2 low voltage
2128	FPP2 high voltage
2130	IVS stuck at-idle, FPP1/2 match
2131	IVS stuck off-idle, FPP1/2 match
2135	TPS1/2 simultaneous voltages out of range
2139	FPP1 lower than IVS limit
2140	FPP2 lower than IVS limit
2229	BP high pressure
2300	Primary Loop Open or Low-side Short to Ground
2301	Primary Coil Shorted
2303	Primary Loop Open or Low-side Short to Ground
2304	Primary Coil Shorted
2306	Primary Loop Open or Low-side Short to Ground
2307	Primary Coil Shorted
2309	Primary Loop Open or Low-side Short to Ground
2310	Primary Coil Shorted
2312	Primary Loop Open or Low-side Short to Ground
2313	Primary Coil Shorted
2315	Primary Loop Open or Low-side Short to Ground
2316	Primary Coil Shorted
2318	Primary Loop Open or Low-side Short to Ground
2319	Primary Coil Shorted
2321	Primary Loop Open or Low-side Short to Ground
2322	Primary Coil Shorted
2324	Primary Loop Open or Low-side Short to Ground
2325	Primary Coil Shorted
2327	Primary Loop Open or Low-side Short to Ground
2328	Primary Coil Shorted
2618	Tach output ground short
2619	Tach output short to power
1624/1625	Shutdown Request

REMOVAL AND INSTALLATION

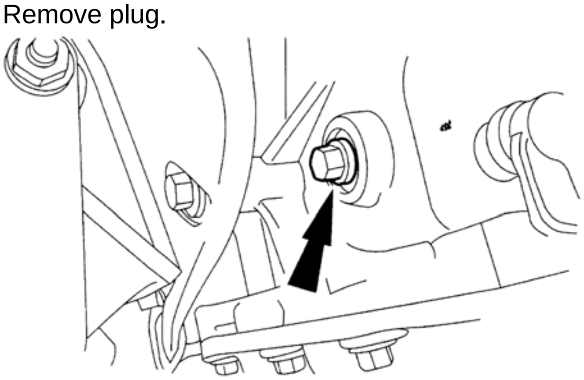
Camshaft Position (CMP) Sensor - Replacement



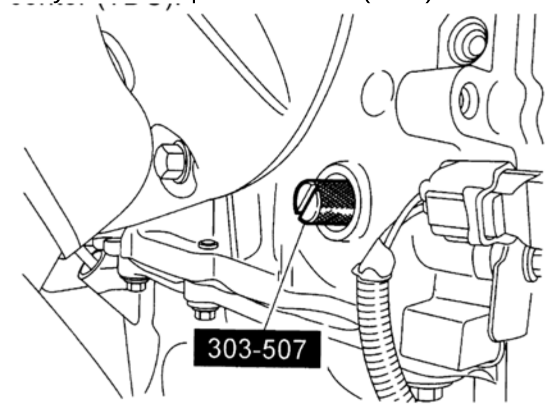
1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CMP Sensor.
3. Disconnect CMP electrical connector.
4. Remove bolt and CMP Sensor.
5. Reverse procedure to install:
   - Use a new o-ring seal
   - Lubricate o-ring with clean engine oil prior to installation
   - Tighten bolt to 7 Nm (62 lb-in).

Crankshaft Position (CKP) Sensor - Removal

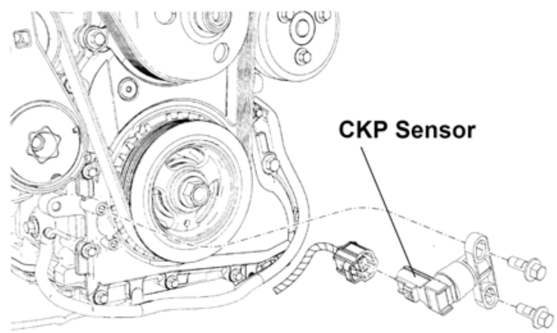
1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CKP Sensor.
3. Disconnect CKP electrical connector.
4. Remove plug.



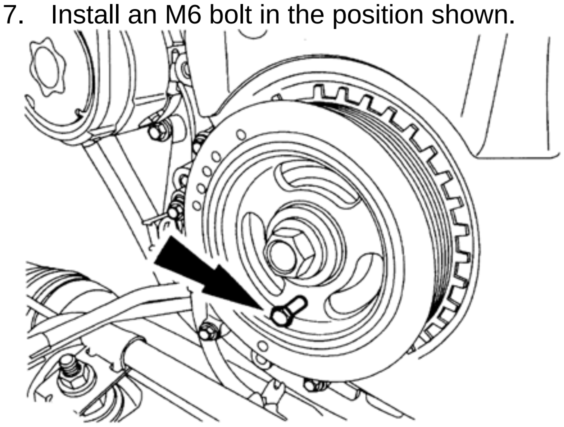
5. Install special tool 303-507 and turn the crankshaft pulley bolt to position the No. 1 cylinder at top dead center (TDC).



6. Remove 2 bolts and CKP sensor.



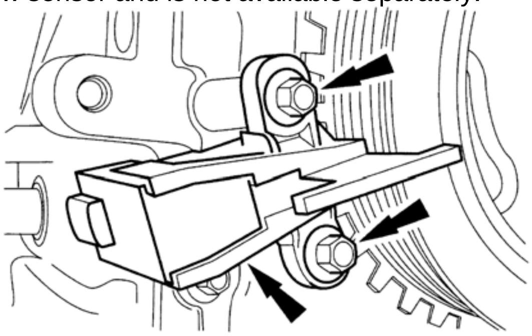
7. Install an M6 bolt in the position shown.



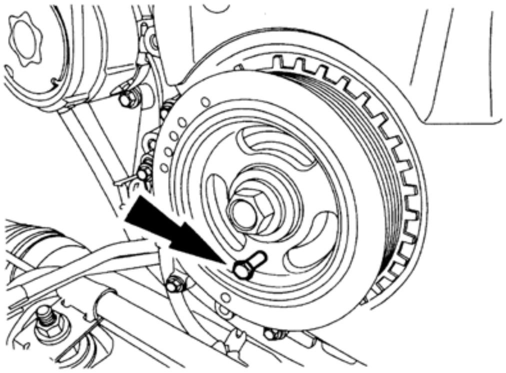
Crankshaft Position (CKP) Sensor - Installation

1. Position CKP sensor and loosely install the 2 bolts.

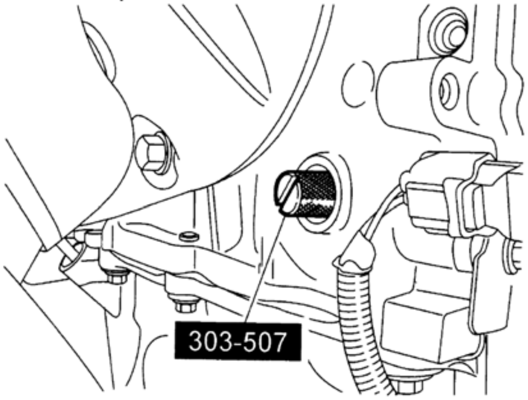
NOTE: The CKP sensor alignment tool is supplied with the new sensor and is not available separately.



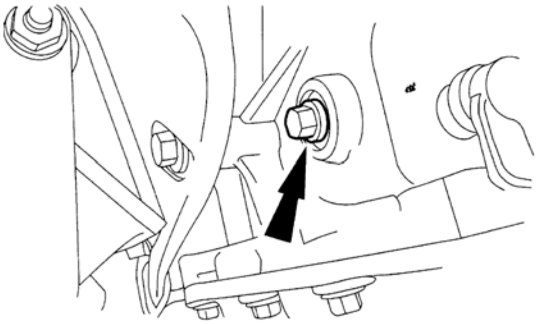
2. Adjust the CKP sensor with the alignment tool and tighten 2 bolts.
   - Tighten to 7 Nm (62 lb-in).
3. Connect CKP sensor electrical connector
4. Remove the M6 bolt.



5. Remove special tool 303-507.

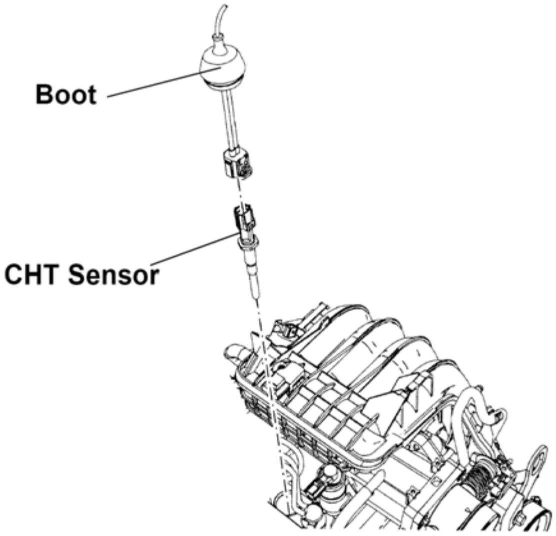


6. Install the plug:
   - Tighten to 10 Nm (89 lb-in)



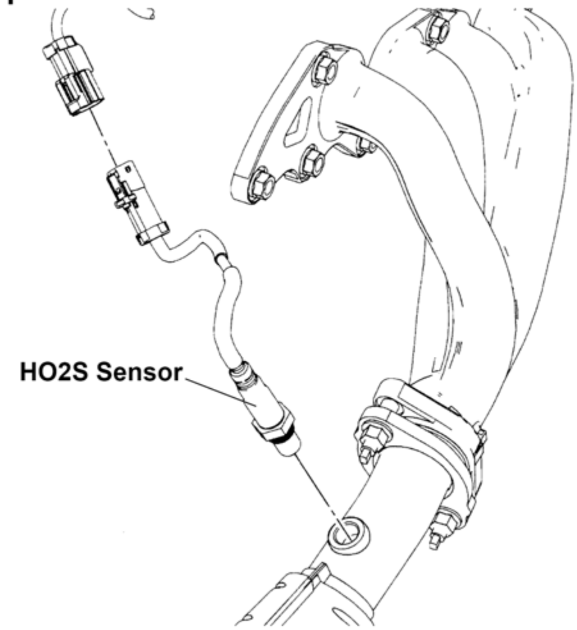
7. Reconnect or install any other component that was removed.
8. Reconnect battery cable -- refer to section 6.

Cylinder Head Temperature (CHT) Sensor - Replacement

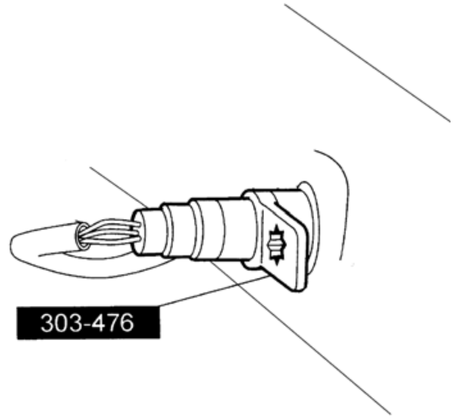


1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CHT Sensor.
3. Pull back the CHT sensor cover and disconnect electrical connector.
4. Remove the CHT Sensor.
5. Reverse procedure to install:
   - Tighten CHT sensor to 12 Nm (9 lb-ft).

Heated Oxygen Sensor (HO2S) - Replacement

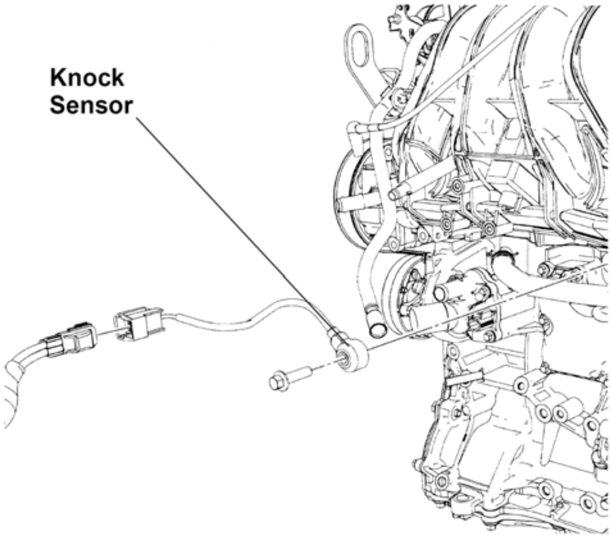


1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the HO2S Sensor.
3. Disconnect HO2S electrical connector.
   NOTE: Use penetrating oil to assist in removal.
4. Remove HO2S sensor using special tool 303-476.



5. 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.

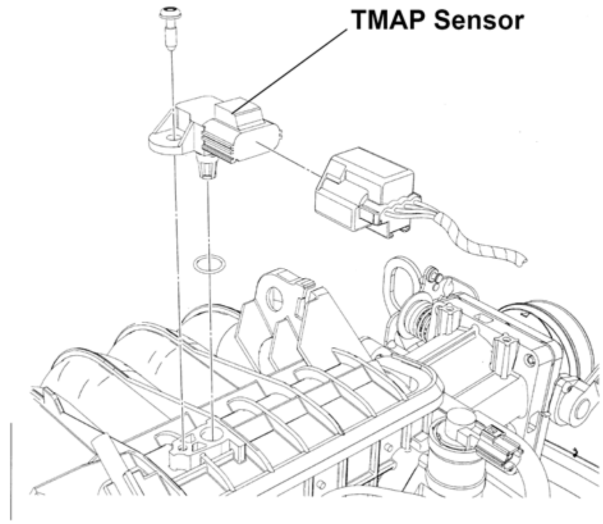
2. Remove or disconnect any component to allow access and removal of the knock sensor.

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:
   - Use a new o-ring seal
   - Tighten bolt to ?? Nm (?? lb-??).

WSG-1068 ENGINE CONTROLS

SPECIFICATIONS

TORQUE SPECIFICATIONS			
Description	Nm	lb.ft.	lb.in.
CHT Sensor	12		9
CMP Sensor	7		62
CKP Sensor	7		62
ECT Sensor			
HO2S Sensor	40	30	
Knock Sensor	20	15	
TMAP Sensor			

SPECIAL TOOLS	
HO2S Removal Tool	303-476

WSG-1068 METRICS

INDEX

WSG-1068 METRICS

INTRODUCTION

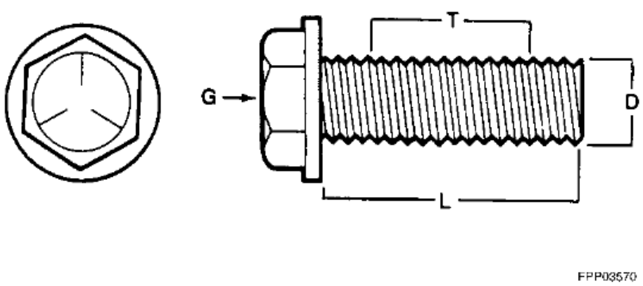
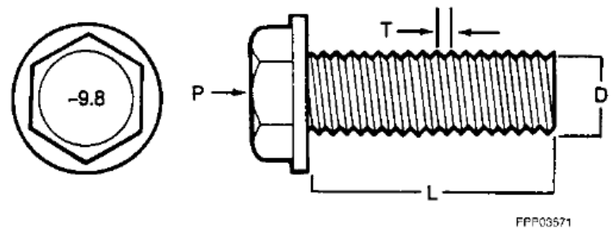
Most threaded fasteners are covered by specifications that define required mechanical properties, such as tensile strength, yield strength, proof load and hardness. These specifications are carefully considered in initial selection of fasteners for a given application. To ensure continued satisfactory 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

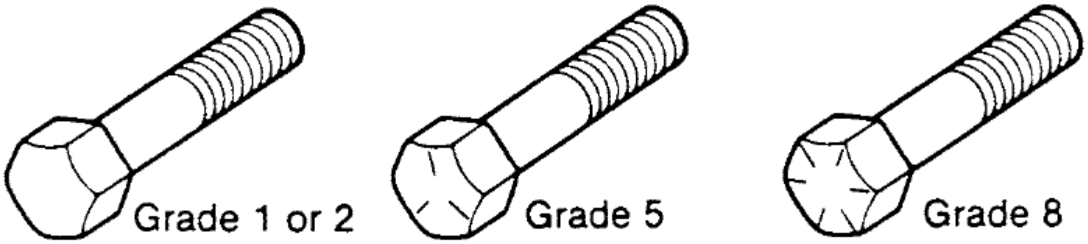
English System Bolt, 1/2 - 13 x 1	Metric System Bolt, M12 - 1.75 x 25
	
G = Grade Marking (bolt strength) L = Length (inches) ** T = Thread Pitch (thread/inch) D = Nominal Diameter (inches)	P = Property Class (bolt strength) * L = Length (millimeters) ** T = Thread Pitch (thread width crest to crest 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.

WSG-1068 METRICS

BOLT STRENGTH IDENTIFICATION

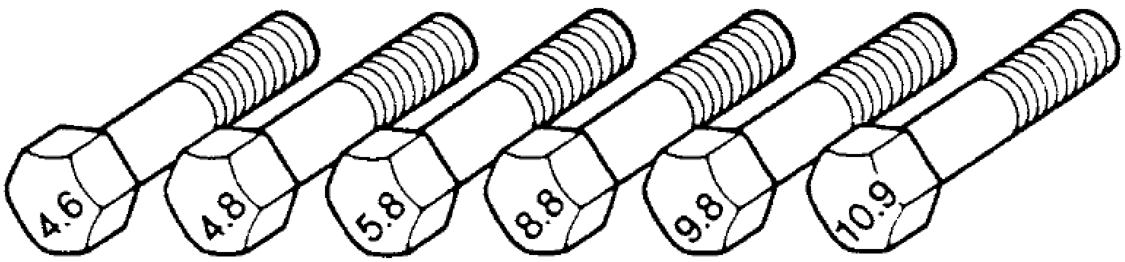
English System



FPP03572

English (inch) bolts: Identification marks correspond to bolt strength, increasing number of slashes represent increasing strength.

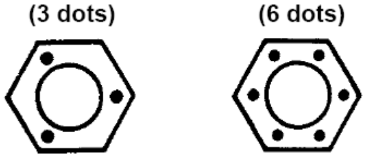
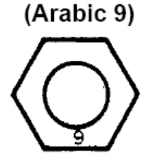
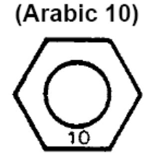
Metric System



FPP03573

Metric (mm) bolts: Identification class numbers correspond to bolt strength, increasing numbers represent increasing strength. Common metric fastener bolt strength property are 9.8 and 10.9 with the class identification embossed on the bolt head.

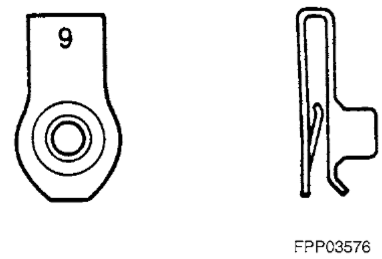
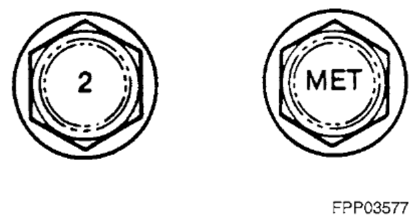
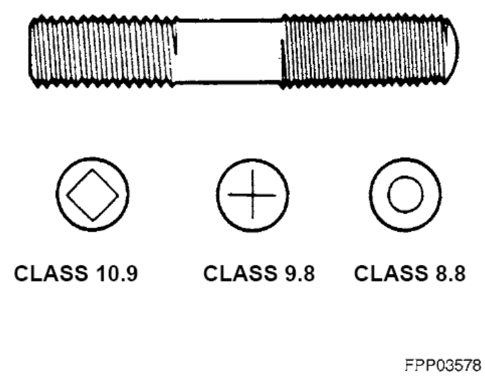
HEX NUT STRENGTH IDENTIFICATION

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.

WSG-1068 METRICS

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	
Tapping, thread forming and certain other case hardened screws	
Studs, Large studs may carry the property class number. Smaller studs use a geometric code on the end.	

WSG-1068 METRICS

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/m^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
lb/ft	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

WSG-1068 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	.53125	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

WSG-1068 METRICS

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)

WSG-1068 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)

WSG-1068 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

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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)

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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)

WSG-1068 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)

WSG-1068 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)

WSG-1068 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)

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