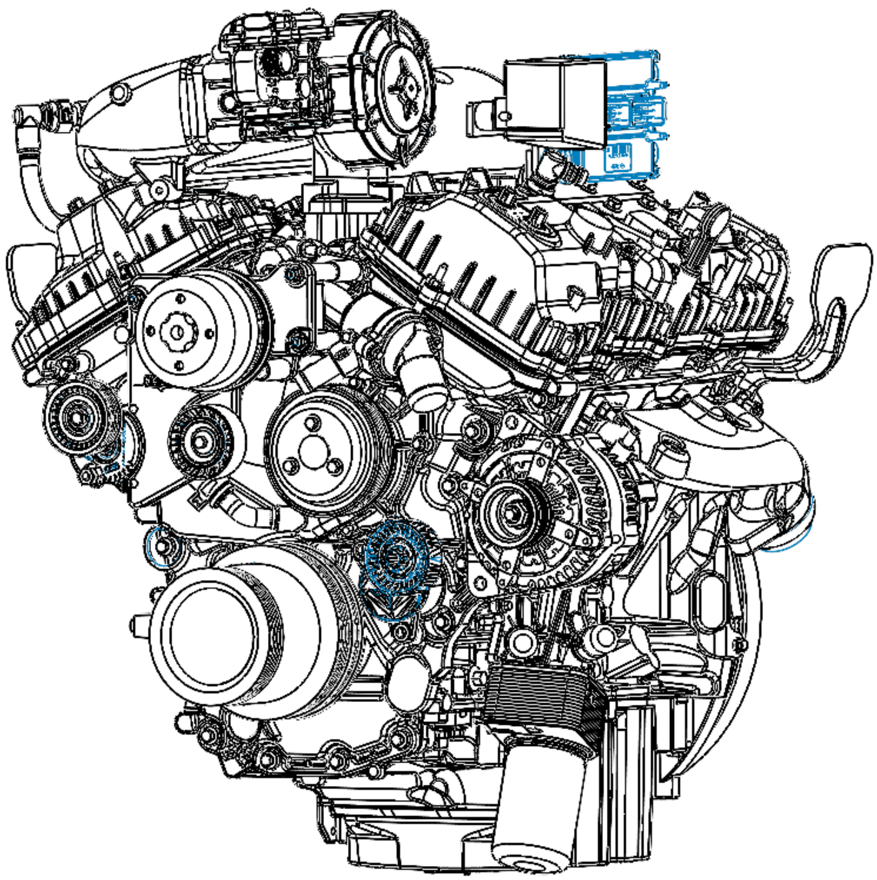
LSG-635
3.5 LITER

INDUSTRIAL ENGINE SERVICE MANUAL



Powertrain Assemblies
& Components Provided
By Ford Component Sales

POWERED BY Ford

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Section

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Engine Distributors Inc (EDI)

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HEALTH & SAFETY

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

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

The following recommendations are for general guidance:

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

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

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

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

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

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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General Service Procedures **Page**

GENERAL INFORMATION

Introduction

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

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

This engine incorporates a closed-type crankcase ventilation system.

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

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

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

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

Engine Distributors Inc. (EDI) does not recommend using abrasive grinding discs to remove engine gasket material. Use manual gasket scrapers for removing gasket material from the engine sealing surfaces. Take added care to prevent scratching or gouging aluminum sealing surfaces.

Safety Notice

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

Notes, Cautions, and Warnings

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

GENERAL WARNINGS:
TO HELP AVOID INJURY:

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

Battery Handling and Charging

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

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

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.

LSG-635 GENERAL INFORMATION

Forward

This book contains service information for the engine(s) listed on the title page.

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

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

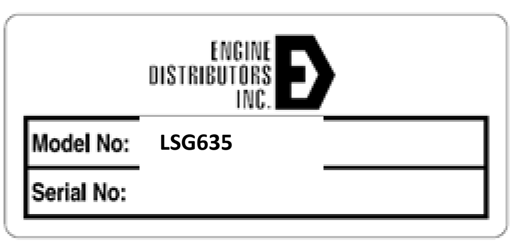
Where the terms "Right" or "Left" occur in this publication, they refer to the respective sides of the engine when viewed from the rear or flywheel end.

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

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

Engine Identification

Because Ford Power Products markets such a wide range of industrial gasoline and diesel engines - manufactured both in the U.S. and overseas - it is important that you have as complete identification of the engine as possible in order to provide the correct replacement parts. Review the list in the back of this book, for an EDI distributor in your area. You can obtain a standard parts listing describing the parts. It remains a distributor function to identify the part number.



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

Parts and Service

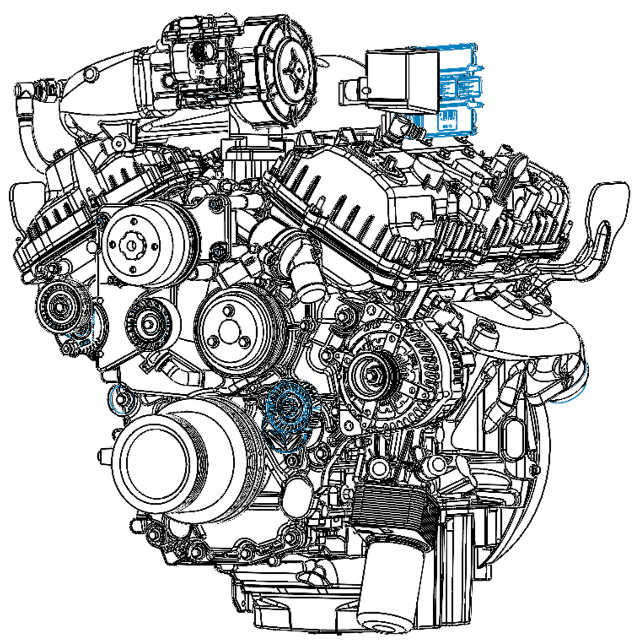
Replacement parts can be obtained through your local EDI Distributor listed in the back portion of this manual. They also may be found in the yellow pages under "Engines" or contact EDI directly at **1 800 220 2700**.

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

Description and Operation

Section 01 of this manual covers general procedures and diagnosis of the engine system, including base engine repair procedures that would be common to most engines. Refer to Section 02 for more specific service information on the LSG635 engine.

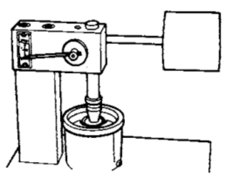
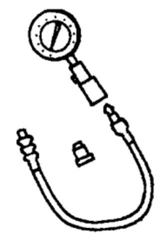
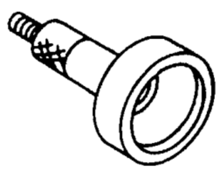
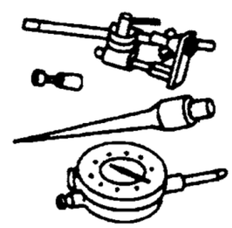
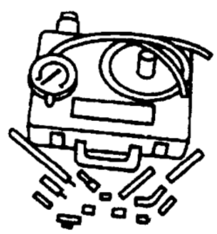
The LSG635 engine incorporates a closed positive crankcase ventilation system and an exhaust emission control system.



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

DIAGNOSIS AND TESTING

Special Tools

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

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

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

Inspection and Verification

1. Verify the customer concern by operating the engine to duplicate the condition.

2. Visually inspect for obvious signs of mechanical and electrical damage:
   - Engine coolant leaks.
   - Engine oil leaks.
   - Fuel leaks.
   - Damaged or severely worn pads.
   - Loose mounting bolts, studs, and nuts.

3. If the inspection reveals obvious concerns that can be readily identified, repair as required.

4. If the concerns remain after the inspection, determine the symptoms and go to the symptom chart.

Symptom Chart

Condition	Possible Source	Action
Difficult Starting	Damaged starting system.	Refer to Section 07.
	Damaged charging system/battery.	Refer to Section 06.
	Burnt valve.	Replace valve.
	Worn piston.	Replace piston and pin.
	Worn piston rings or worn cylinder.	Repair or replace cylinder blocks.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Damaged fuel system.	Refer to Section 04.
	Damaged ignition system.	Refer to Section 03.
	Spark plugs gapped incorrectly.	Check plug gap.
	Damaged hydraulic tappet or hydraulic lash adjuster.	Replace tappet or lash adjuster.
Poor Idling	Damaged hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Improper valve-to-valve seat contact.	Replace valve or valve seat.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Malfunctioning or damaged fuel system.	Refer to Section 04 of this manual*.
	Malfunctioning or damaged ignition system.	Refer to Section 03 of this manual*.
	Spark plugs gapped incorrectly.	Check plug gap.
	Malfunctioning or damaged IAC motor or system.	Refer to Section 03 of this manual.
Abnormal combustion	Damaged hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Burnt or sticking valve.	Repair or replace valve.
	Weak or broken valve spring	Replace valve spring
	Carbon accumulation in combustion chamber.	Eliminate carbon buildup.
	Malfunctioning or damaged fuel system	Refer to Section 04 of this manual*.
	Malfunctioning or damaged ignition system.	Refer to Section 03 of this manual*.

Condition	Possible Source	Action
Excessive Oil Consumption	Worn piston ring groove.	Replace piston and pin.
	Sticking piston rings.	Repair or replace piston rings.
	Worn piston or cylinders.	Repair or replace piston or cylinder blocks.
	Worn valve stem seal.	Replace valve stem seal.
	Worn valve stem or valve guide.	Replace valve stem and guide.
	Leaking oil.	Repair oil leakage.
	Worn piston rings.	Replace piston rings.
	Plugged PCV system.	Service PCV system.

LSG-635 GENERAL INFORMATION

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

PCV System Malfunction

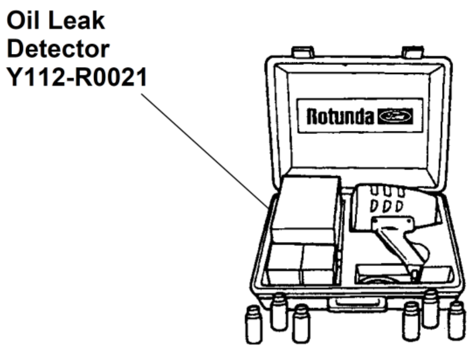
A malfunctioning Positive Crankcase Ventilation System (closed type) may be indicated by loping or rough engine idle. Do not attempt to compensate for this idle condition by disconnecting the PCV system and making an air bypass or idle speed adjustment.

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

Engine Oil Leaks

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

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



Fluorescent Oil Additive Method

Use a 12 Volt Master UV Diagnostic Inspection Kit, such as the Rotunda Oil Leak Detector Y112-R0021 or equivalent, to perform the following procedure for oil leak diagnosis.

1. Clean the engine with a suitable solvent to remove all traces of oil.
2. Drain engine oil crankcase and refill with recommended oil, premixed with Diesel Engine Oil Dye 164-R3705 meeting Ford specification ESEM9C103- B1 or equivalent. Use a minimum 14.8 ml (0.5 ounce) to a maximum 29.6 ml (1 ounce) of fluorescent additive to all engines. If the oil is not premixed, fluorescent additive must first be added to crankcase.
3. Run the engine for 15 minutes. Stop the engine and inspect all seal and gasket areas for leaks using the 12 Volt Master UV diagnostic Inspection Kit. A clear bright yellow or orange area will identify the leak. For extremely small leaks, several hours may be required for the leak to appear.
4. If necessary, pressurize the main oil gallery system to locate leaks due to improperly sealed, loose or cocked plugs.
5. Repair all leaks as required.

Pressure Method

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

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

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

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

Testing Procedure

- Open the air supply valve until the pressure gauge maintains 20 kPa (3 psi).
- Inspect sealed or gasketed areas for leaks by applying a solution of liquid detergent and water over areas for formation of bubbles which indicates leakage.

Leakage Points - Above Engine

Examine the following areas for oil leakage.

- valve cover gaskets
- intake manifold gaskets
- cylinder head gaskets
- oil filter
- oil pump (if external)
- oil level indicator tube connection
- oil pressure sensor

Leakage Points - Under Engine

- oil pan gaskets
- oil pan sealer
- oil pan rear seal
- engine front cover gasket

- crankshaft front seal
- crankshaft rear oil seal

Leakage Points - with Flywheel Removed

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

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

- rear main bearing cap and seals
- flywheel mounting bolt holes (with flywheel installed)
- camshaft rear bearing covers or pipe plugs at the end of oil passages (except for overhead cam)

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

Compression Tests

Compression Gauge Check

1. Make sure the oil in the crankcase is of the correct viscosity and at the proper level and that the battery is properly charged. Operate until the engine is at normal operating temperature. Turn the ignition switch to the OFF position, then remove all the spark plugs.
2. Set the throttle plates in the wide-open position.
3. Install a Compression Tester such as Rotunda Compression Tester 059-R0009, or equivalent, in the No. 1 cylinder.
4. Install an auxiliary starter switch in the starting circuit. With the ignition switch in the OFF position, and using the auxiliary starter switch, crank the engine a minimum of five compression strokes and record the highest reading. Note the approximate number of compression strokes required to obtain the highest reading.
5. Repeat the test on each cylinder, cranking the engine approximately the same number of compression strokes.

Test Results

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

If one or more cylinders read low, squirt approximately one tablespoon of clean engine oil meeting Ford specification WSS-M2C960-A1 on top of the pistons in the low-reading cylinders. Repeat the compression pressure check on these cylinders.

Example Readings

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

Compression Pressure Limit Chart

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

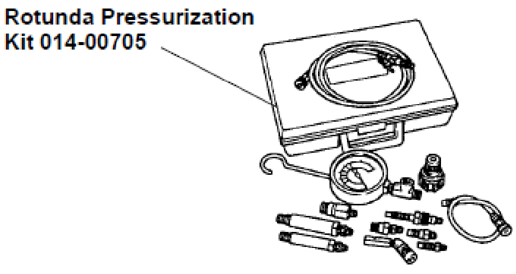
Interpreting Compression Readings

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

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

Cylinder Leakage Detection

When a cylinder produces a low reading, use of the Engine Cylinder Leak Detection/Air Pressurization Kit, such as the Rotunda Pressurization Kit 014-00705, or equivalent, will be helpful in pinpointing the exact cause.



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

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

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

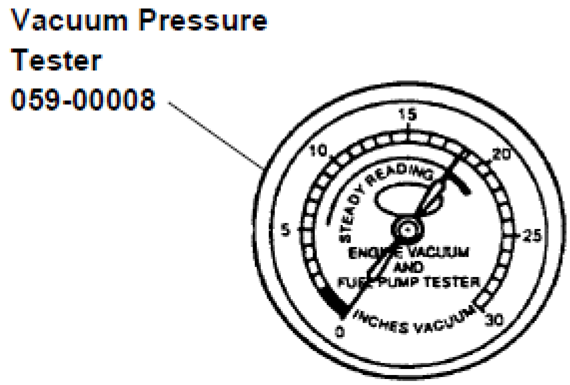
Oil Leak and Valve Stem Seal Test

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

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

Intake Manifold Vacuum Test

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



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

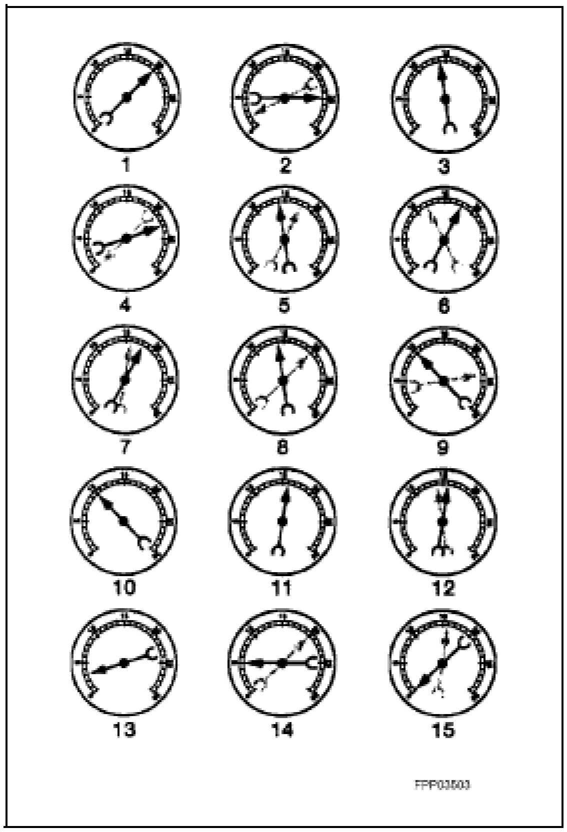
The reading should be quite steady. If necessary, adjust the gauge damper control (where used) if the needle is fluttering rapidly. Adjust the damper until the needle moves easily without excessive flutter.

Interpreting Vacuum Gauge Readings

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

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

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



1. NORMAL READING: Needle between 51-74 kPa (15-22 in-Hg) and holding steady.
2. NORMAL READING DURING RAPID ACCELERATION AND DEACCELERATION: When the engine is rapidly accelerated (dotted needle), the needle will drop to a low reading (not to zero). When the throttle is suddenly released, the needle will snap back up to a higher than normal figure.
3. NORMAL FOR HIGH-LIFT CAMSHAFT WITH LARGE OVERLAP: The needle will register as low as 51 kPa (15 in-Hg) but will be relatively steady. Some oscillation is normal.
4. WORN RINGS OR DILUTED OIL: When the engine is accelerated (dotted needle), the needle drops to 0 kPa (0 in-Hg). Upon deceleration, the needle runs slightly above 74 kPa (22 in-Hg).
5. STICKING VALVES: When the needle (dotted) remains steady at a normal vacuum but occasionally flicks (sharp, fast movement) down and back about 13 kPa (4 in-Hg), one or more valves may be sticking.
6. BURNED OR WARPED VALVES: A regular, evenly spaced, downscale flicking of the needle indicates one or more burned or warped valves. Insufficient hydraulic lash adjuster or hydraulic lash adjuster (HLA) clearance will also cause this reaction.
7. POOR VALVE SEATING: A small but regular downscale flicking can mean one or more valves are not seating.
8. WORN VALVE GUIDES: When the needle oscillates (swings back and forth) over about a 13 kPa (4 in- Hg) range at idle speed, the valve guides could be worn. As engine speed increases, the needle will become steady if guides are responsible.
9. WEAK VALVE SPRINGS: When the needle oscillation becomes more violent as engine rpm is increased, weak valve springs are indicated. The reading at idle could be relatively steady.
10. LATE VALVE TIMING: A steady but low reading could be caused by late valve timing.
11. IGNITION TIMING RETARDING: Retarded ignition timing will produce a steady but somewhat low reading.
12. INSUFFICIENT SPARK PLUG GAP: When spark plugs are gapped too close, a regular, small pulsation of the needle can occur.
13. INTAKE LEAK: A low, steady reading can be caused by an intake manifold or throttle body gasket leak.
14. BLOWN HEAD GASKET: A regular drop of approx. 33-50 kPa (10-15 in-Hg) can be caused by a blown head gasket or warped cylinder head-to-cylinder block surface.
15. RESTRICTED EXHAUST SYSTEM: When the engine is first started and is idled, the reading may be normal, but as the engine rpm is increased, the back pressure caused by a clogged muffler, kinked tail pipe or other concerns will cause the needle to slowly drop to 0 kPa (0 in-Hg). The needle then may slowly rise. Excessive exhaust clogging will cause the needle to drop to a low point even if the engine is only idling.

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

Excessive Engine Oil Consumption

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

- severe loading applications
- sustained high speed operation

Engines need oil to lubricate the following internal components:

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

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

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

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

Operating under varying conditions can frequently be misleading. An engine that has been run for short hours or in below-freezing ambient temperatures may have consumed a “normal” amount of oil.

However, when checking engine oil level, it may measure up to the full mark on the oil level dipstick due to dilution (condensation and fuel) in the engine crankcase. The engine might then be run at high speeds where the condensation and fuel boil off. The next time the engine oil is checked, it may appear that a liter (quart) of oil was used in about 3 to 3-1/2 hours.

This perceived 3 to 3-1/2 hours per liter (quart) oil consumption rate causes customer concern even though the actual overall oil consumption rate is about 50 hours per liter (quart).

Make sure the selected engine oil meets Ford specification WSS-M2C960-A1 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 workloads and other considerations.
2. Verify that the engine has no external oil leak as described under Engine Oil Leaks in the Diagnosis and Testing portion of this section.
3. Verify that the engine has the correct oil level dipstick.
4. Verify that the engine is not being run in an overfilled condition. Check the oil level at least five minutes after a hot shutdown with the engine/vehicle parked on a level surface. In no case should the level be above the top of the cross-hatched area and the letter F in FULL. If significantly overfilled, perform= steps 5 through 9. If not proceed to step 10.
5. Drain the engine oil, remove and replace the oil filter and refill with one quart less than the recommended amount.
6. Run the engine for three minutes (10 minutes if cold), and allow the oil to drain back for at least five minutes with the engine/vehicle on a level surface.
7. Remove oil level dipstick and wipe clean.

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

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

10. Record the vehicle mileage or hours.

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

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

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

Oil Pressure Test

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

Valve Train Analysis – Static

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

Rocker Arm

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

Camshaft Roller Followers and Hydraulic Lash Adjusters

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

Camshaft

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

Push Rods (if equipped)

- Check for bent push rods and restricted oil passage.

Valve Springs

- Check for broken or damaged parts.

Valve Spring Retainer and Valve Spring Retainer Keys

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

Valve Spring Retainer Keys

- Check for proper seating on the valve stem.

Valves and Cylinder Head

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

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

Valve Train Analysis – Dynamic

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

Rocker Arm

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

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

Push Rods (if equipped)

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

Positive Rotator and Valve Spring Retainer Keys

- Check for proper operation of positive rotator.

Valves and Cylinder Head

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

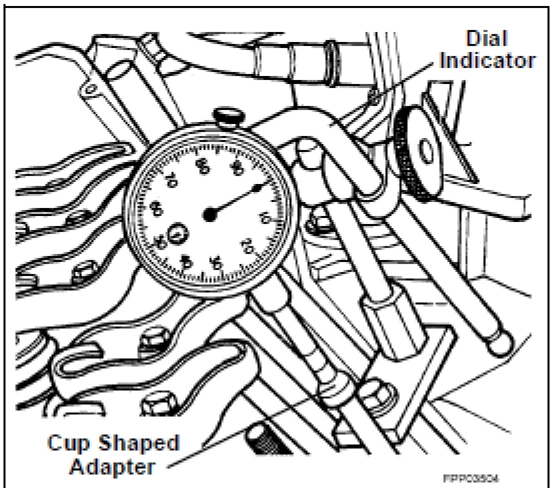
If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1200 rpm with the PTO in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and camshaft roller followers are well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

Camshaft Lobe Lift

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

1. Remove the valve covers.

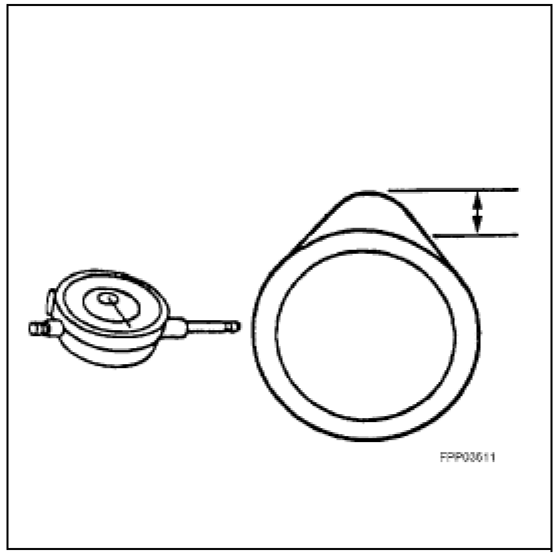
2. Remove the rocker arm seat bolts, rocker arm seat and rocker arms (if equipped).



Typical Engine with Push Rods

3. Make sure the lash adjuster is seated against camshaft. Install the dial Indicator with Bracketry so the ball socket adapter of the indicator is on top of the hydraulic lash adjuster or the Cup Shaped Adapter is on top of the push rod and in the same plane as the lash adjuster push rod movement.

4. On engines with overhead cam, install the dial Indicator with Bracketry so the plunger is on top of the camshaft lobe and in the same plane as the camshaft lobe movement.



5. Remove the spark plugs.

6. Connect an auxiliary starter switch in the starting circuit. Crank the engine with the ignition switch in the OFF position. Bump the crankshaft over until the indicator is measuring on the base circle of the camshaft lobe (in its lowest position). If checking during engine assembly, turn the crankshaft using socket or ratchet.

7. Zero the dial indicator. Continue to rotate the crankshaft slowly until the camshaft lobe is in the fully-raised position (highest indicator reading).

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

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

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

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

11. Reinstall components as necessary.

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

Hydraulic Valve Lash Adjuster

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

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

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

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

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

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

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

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

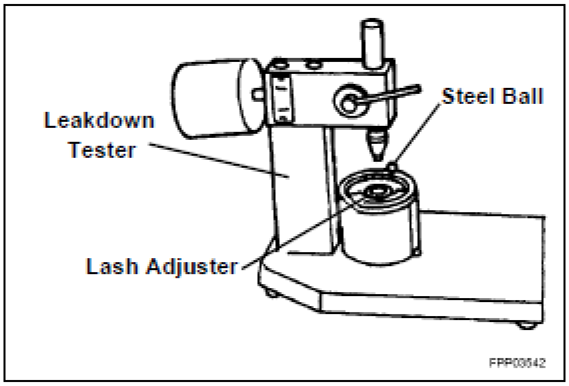
Leak down Testing

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

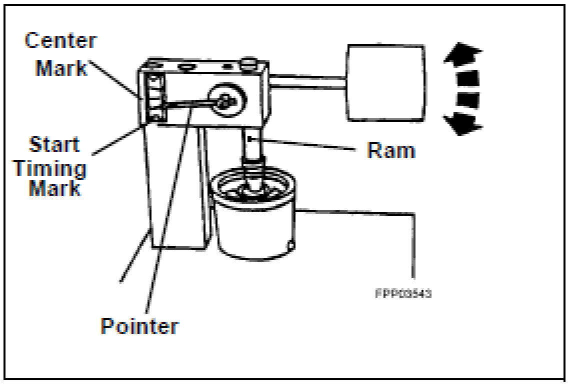
1. Clean the lash adjuster to remove all traces of engine oil.

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

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



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



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

GENERAL SERVICE PROCEDURES

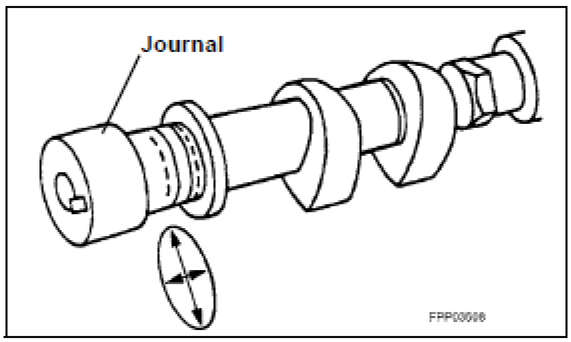
WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT, DO NOT OPERATE THE ENGINE UNTIL THE FAN BLADE HAS BEEN EXAMINED FOR POSSIBLE CRACKS AND SEPARATION.

NOTE: Illustrations are typical and may not reflect your particular engine. Specifications show the expected minimum or maximum condition.

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

Camshaft Journal Diameter

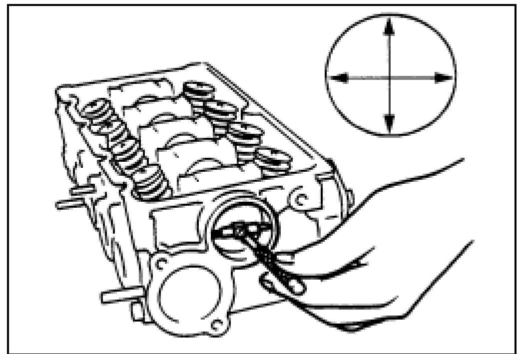
- Measure each camshaft journal diameter in two directions.
- If it is out of specification, replace as necessary.

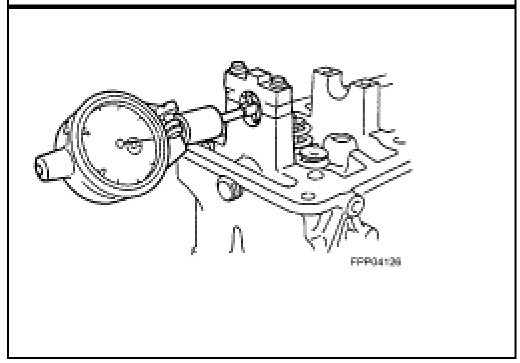


Camshaft Journal Clearance

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

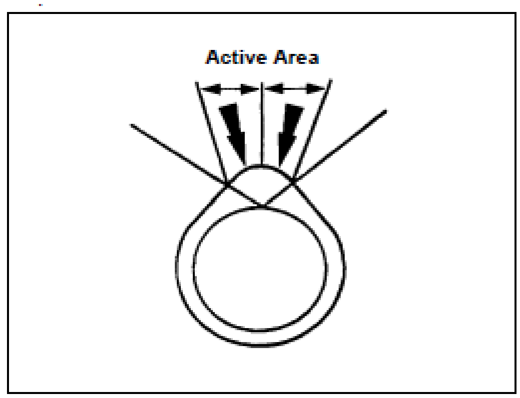
- Measure each camshaft bearing in two directions.
- Subtract the camshaft journal diameter from the camshaft bearing diameter





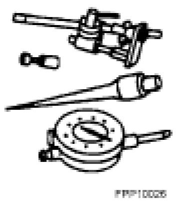
Camshaft Lobe Surface

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

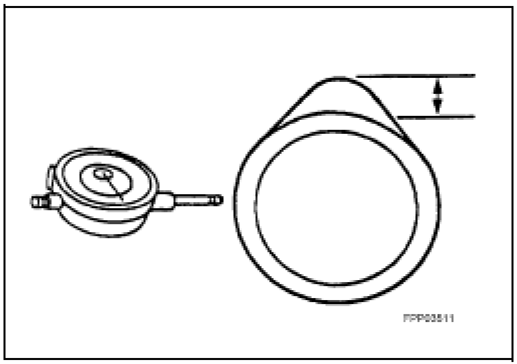


Camshaft Lobe Lift

Special Tool(s)

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

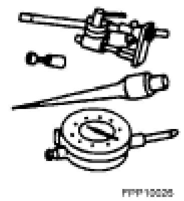
1. Use the Dial Indicator with Bracketry to measure camshaft intake lobe lift.



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

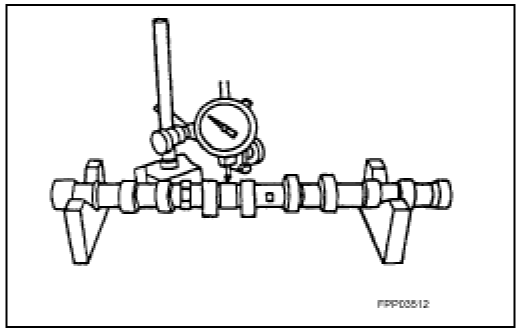
Camshaft Runout

Special Tool(s)

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

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

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



Camshaft End Play

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

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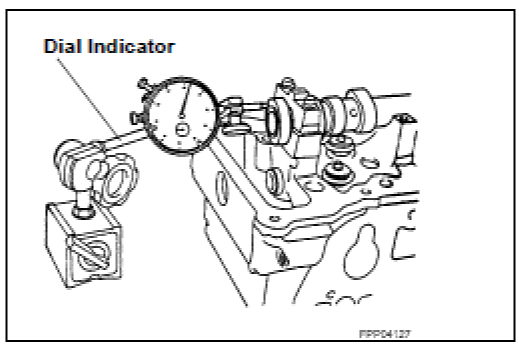
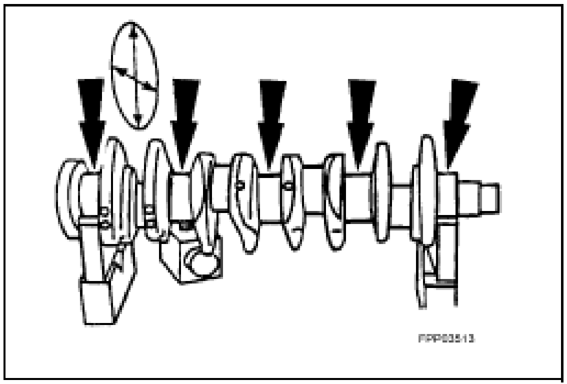


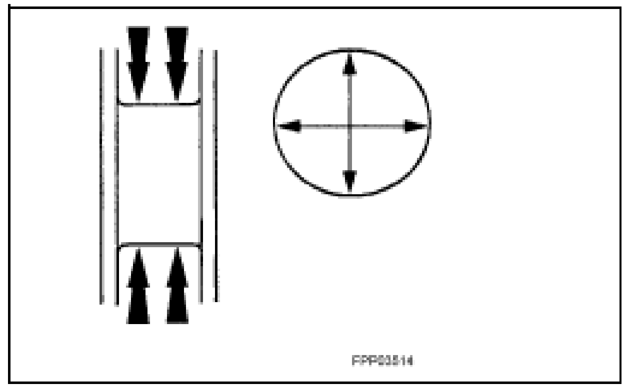
Crankshaft Main Bearing Journal Diameter

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



Crankshaft Main Bearing Journal Taper

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



Crankshaft Main Bearing Journal Clearance

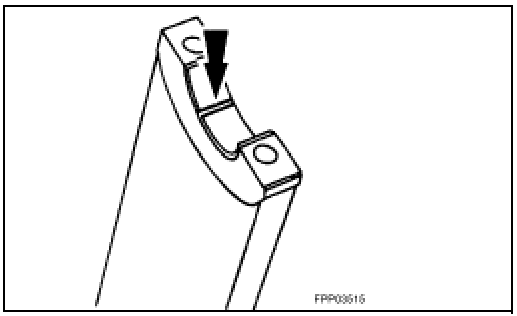
Special Tool(s)

 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)

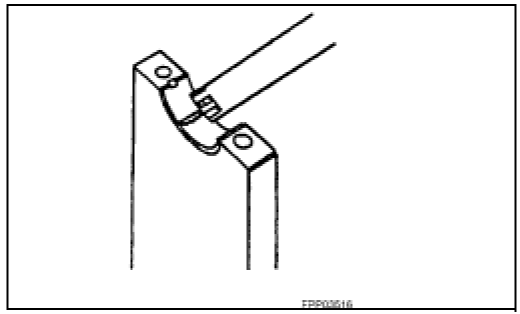
NOTE: Crankshaft main bearing journals must be within specifications before checking journal clearance.

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

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



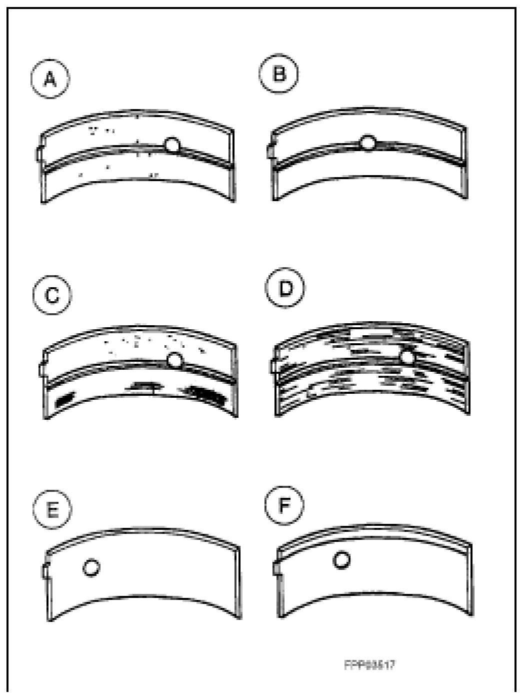
3. Install and remove the crankshaft main bearing cap.
4. Verify the crankshaft journal clearance.
   - If it is out of specification, replace as necessary



Bearing Inspection

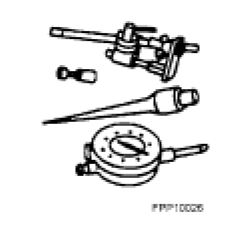
Inspect bearings for the following defects. Possible causes are shown:

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

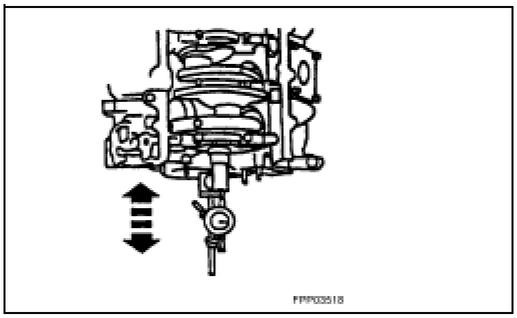


Crankshaft End Play

Special Tool(s)

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

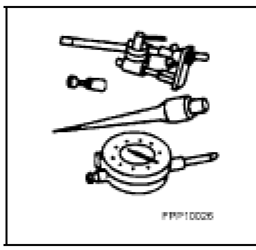
1. Measure the crankshaft end play. Use the Dial Indicator with Bracketry to measure crankshaft end play.
2. Position the crankshaft to the rear of the cylinder block.
3. Zero the Dial Indicator with Bracketry.



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

‘’Crankshaft Runout

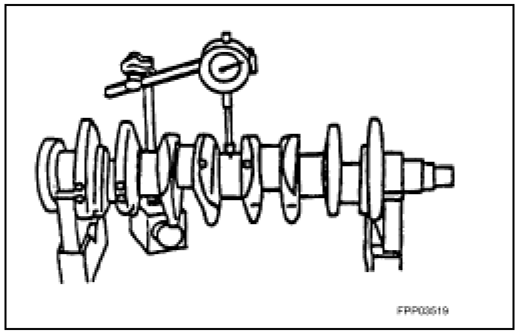
Special Tool(s)

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

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

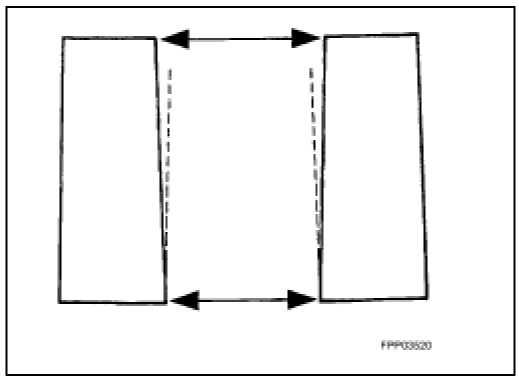
Use the Dial Indicator with Bracketry to measure the crankshaft runout.

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



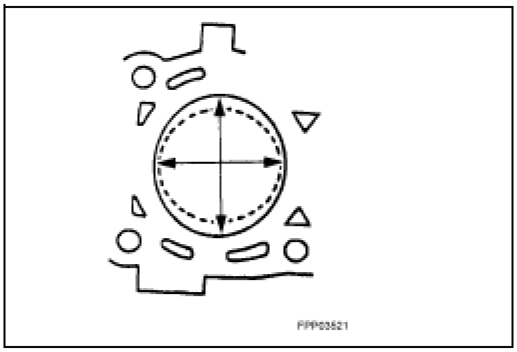
Cylinder Bore Taper

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



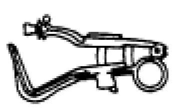
Cylinder Bore Out-of-Round

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



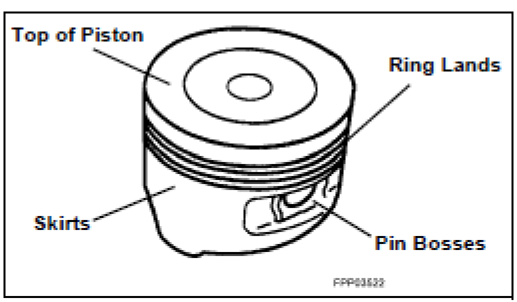
Piston Inspection

Special Tool(s)

 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)

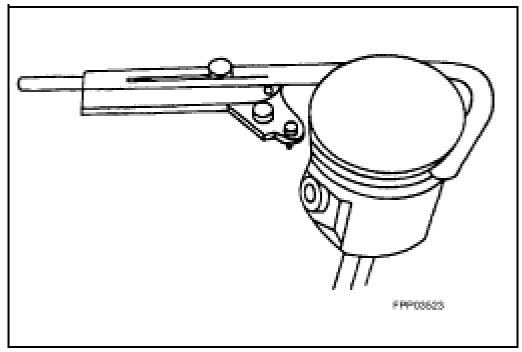
CAUTION: Do not use a caustic cleaning solution or a wire brush to clean the pistons or possible damage can occur.

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.



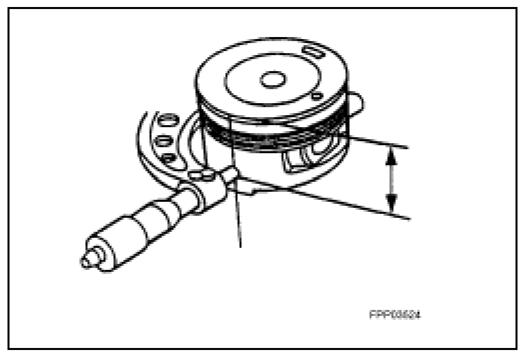
2. Use the Piston Ring Groove Cleaner to clean the piston ring grooves.

- Make sure the oil ring holes are clean.



Piston Diameter

- Measure the piston skirt diameter.



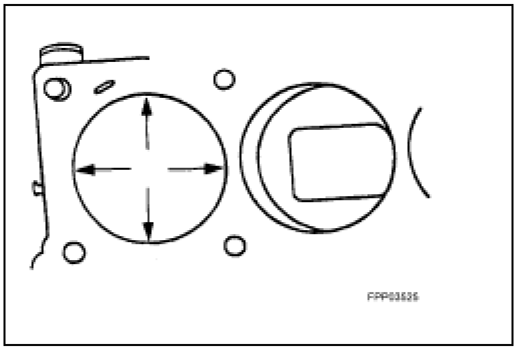
Piston to Cylinder Bore Clearance

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

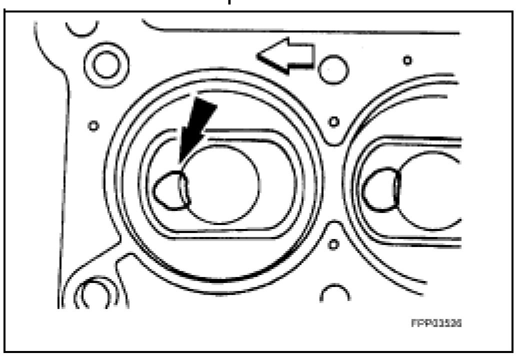
Piston Selection

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

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



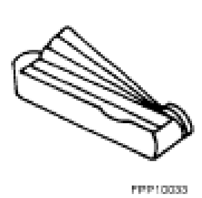
NOTE: For precision fit, new pistons are divided into three categories within each size range based on their relative position within the range. A paint spot on the new pistons indicates the position within the size range.



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

Piston Ring End Gap

Special Tool(s)

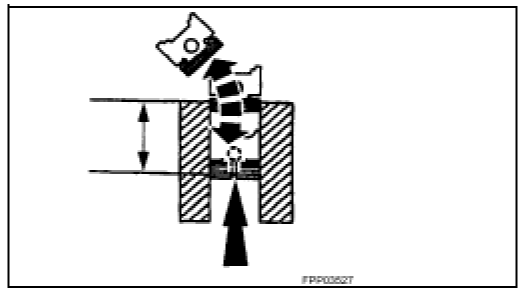
	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

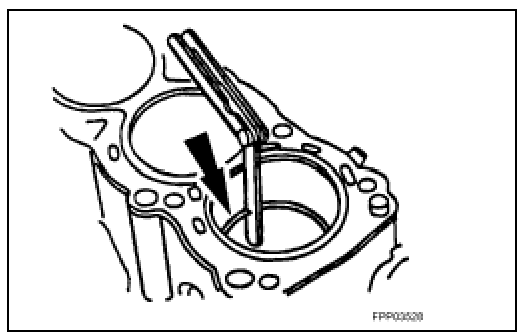
CAUTION: Piston rings should not be transferred from one piston to another to prevent damage to cylinder worn or piston.

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

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

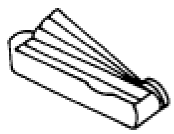


2. Use a feeler gauge to measure the top piston ring end gap and the second piston ring end gap.

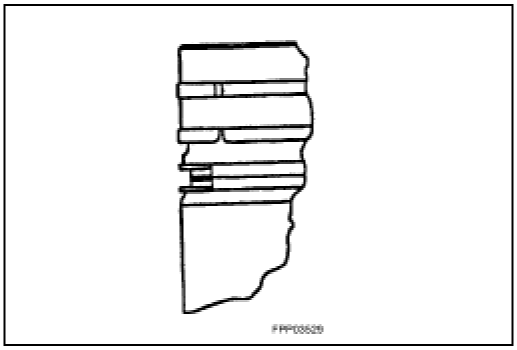


Piston Ring-to-Groove Clearance

Special Tool(s)

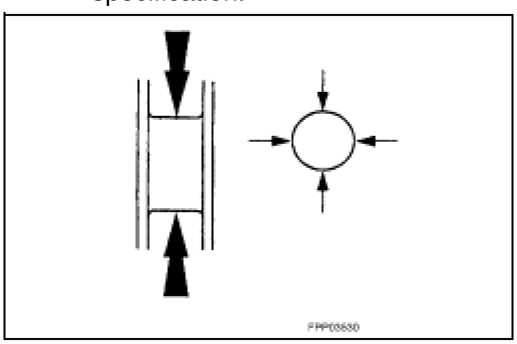
	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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



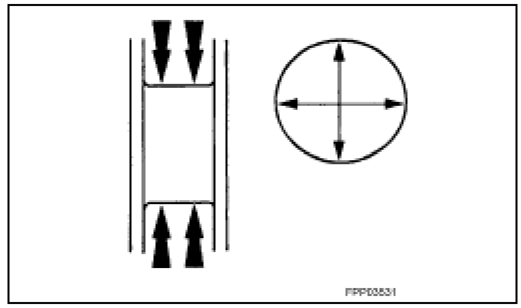
Crankshaft Connecting Rod Journal Diameter

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



Crankshaft Connecting Rod Journal Taper

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

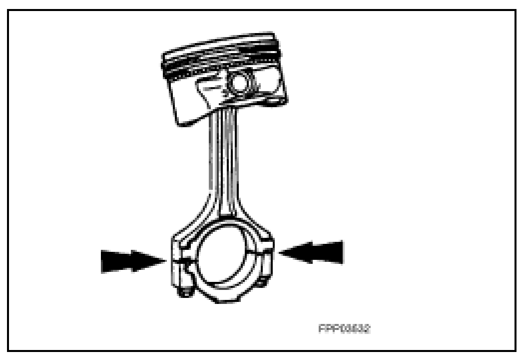


Connecting Rod Cleaning

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

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

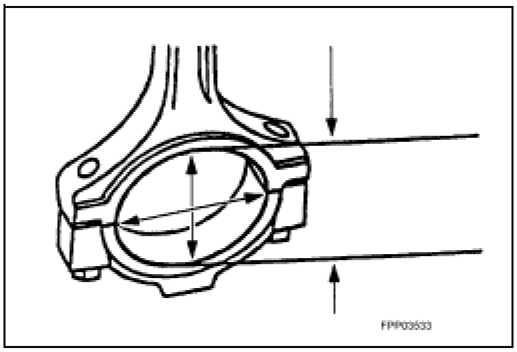
- Mark and separate the parts and clean with solvent. Clean the oil passages



Connecting Rod Larger End Bore

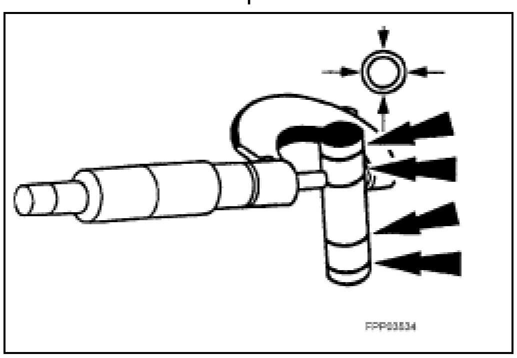
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

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



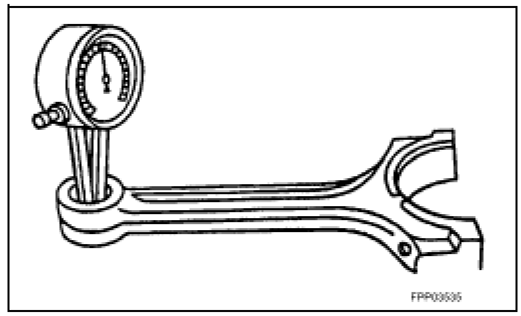
Piston Pin Diameter

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



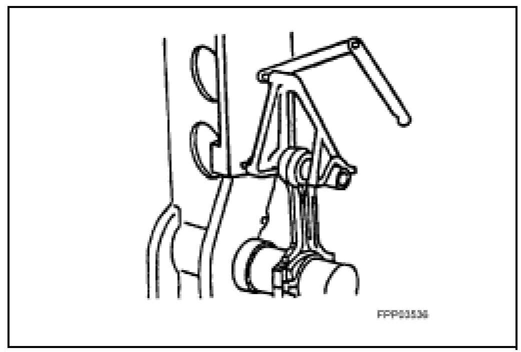
Connecting Rod Bushing Diameter

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



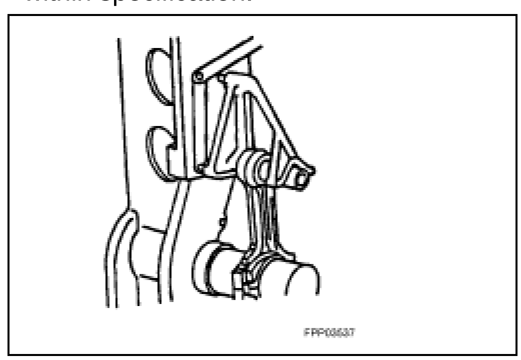
Connecting Rod Bend

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



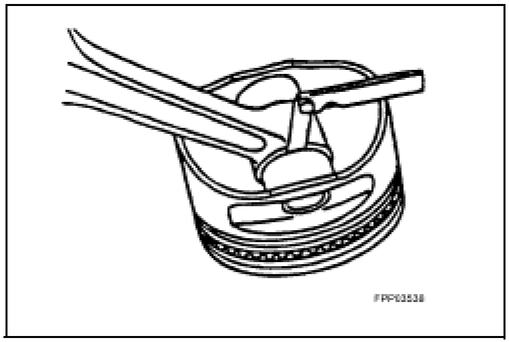
Connecting Rod Twist

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



Connecting Rod Piston Pin Side Clearance

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



Connecting Rod Journal Clearance

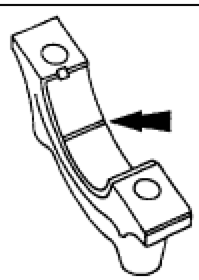
Special Tool(s)

 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.

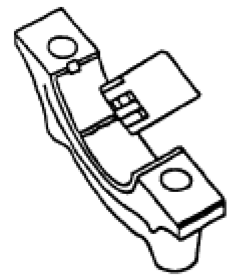
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

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



NOTE: Do not turn the crankshaft during this step.

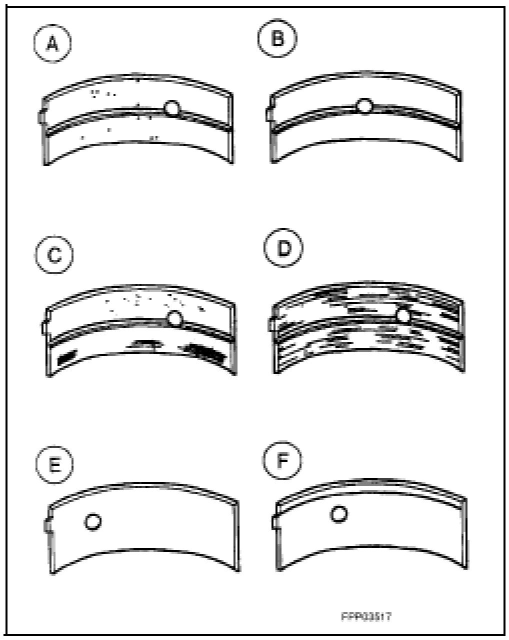
4. Install and torque to specifications, then remove the connecting rod bearing cap.
5. Measure the Plastigage® to get the connecting rod bearing journal clearance. The Plastigage® should be smooth and flat. A change width indicates a tapered or damaged connecting rod bearing or connecting rod.



Bearing Inspection

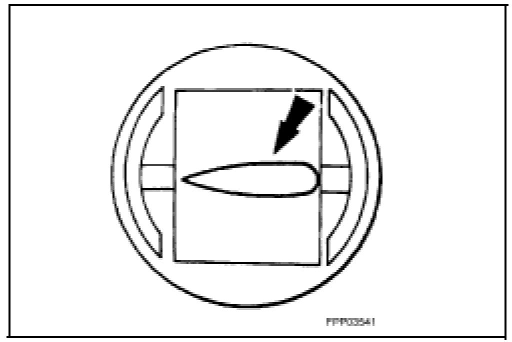
Inspect bearings for the following defects. Possible causes are shown:

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



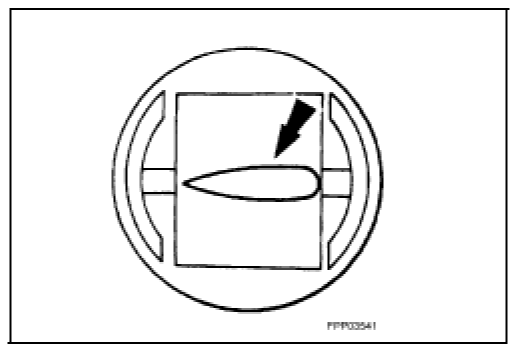
Roller Follower Inspection

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



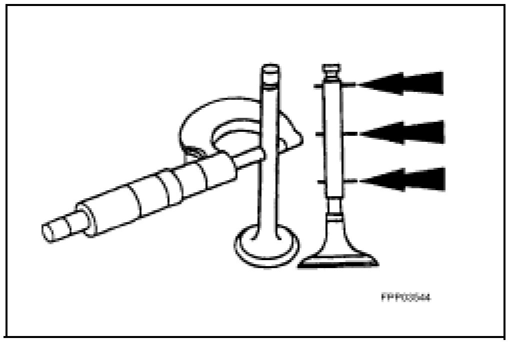
Hydraulic Lash Adjuster Inspection

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



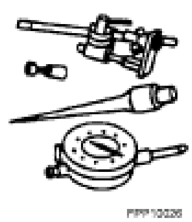
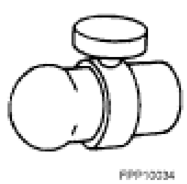
Valve Stem Diameter

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



Valve Stem-to-Valve Guide Clearance

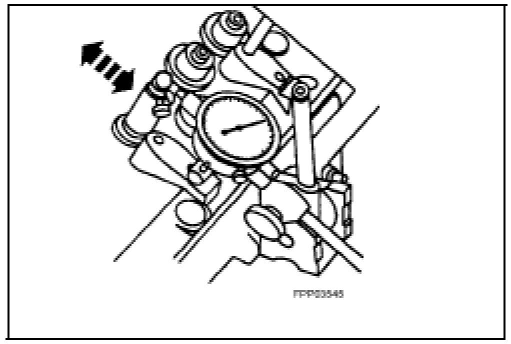
Special Tool(s)

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

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

NOTE: If necessary, use a magnetic base.

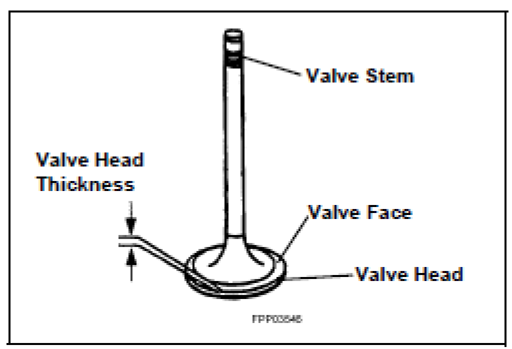
1. Install the Valve Stem Clearance Tool on the valve stem and install the Dial Indicator with Bracketry. Lower the valve until the Valve Stem Clearance Tool contacts the upper surface of the valve guide.
2. Move the Valve Stem Clearance Tool toward the Dial Indicator and zero the Dial Indicator. Move the Valve Stem Clearance Tool away from the Dial Indicator and note the reading. The reading will be double the valve stem-to-valve guide clearance. Valves with oversize stems will need to be installed if out of specification.



Valve Inspection

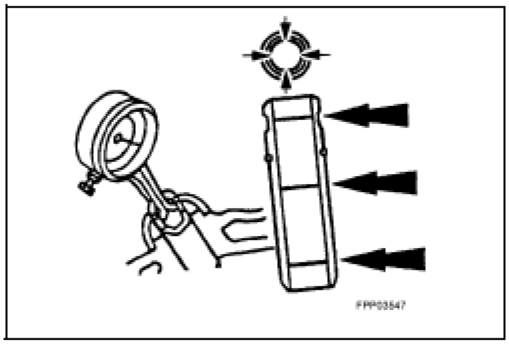
Inspect the following valve areas:

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



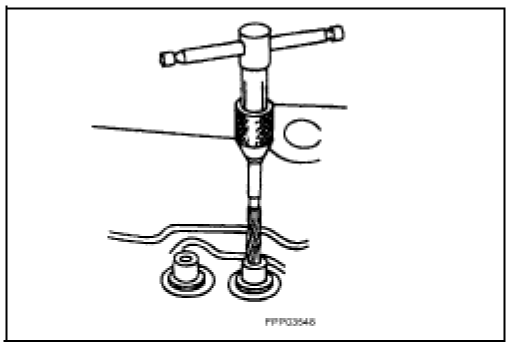
Valve Guide Inner Diameter

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



Valve Guide Reaming

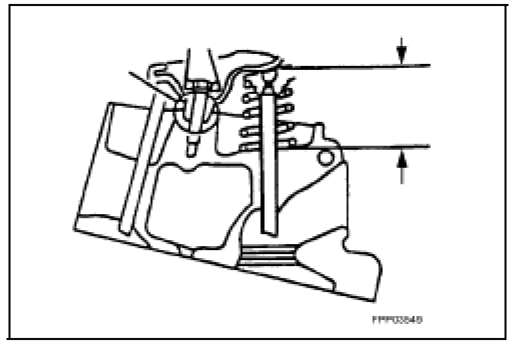
1. Use a hand-reaming kit to ream the valve guide.



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

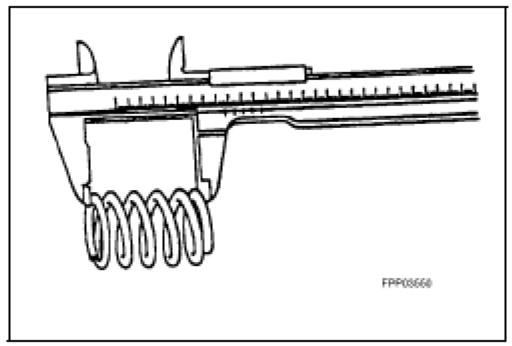
Valve Spring Installed Length

- Measure the installed length of each valve spring.



Valve Spring Free Length

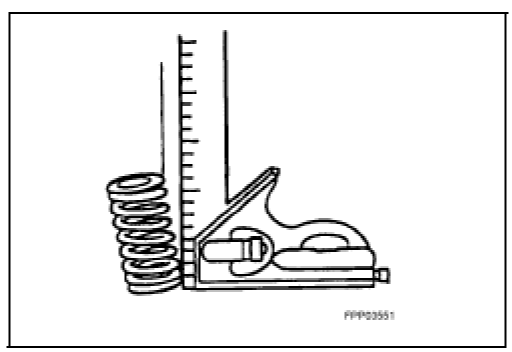
- Measure the free length of each valve spring.



Valve Spring Out-of-Square

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

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

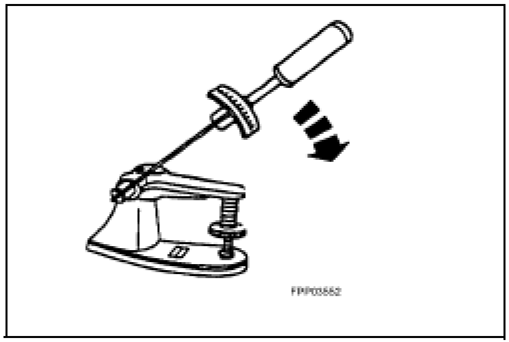


Valve Spring Compression Pressure

Special Tool(s)

	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)

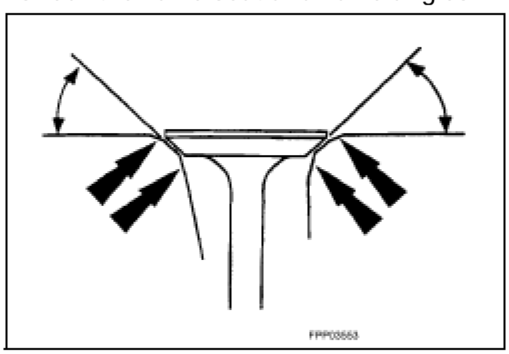
- Use the Valve/Clutch Spring Tester to check the valve springs for proper strength at the specified valve spring length.



Valve and Seat Refacing Measurements

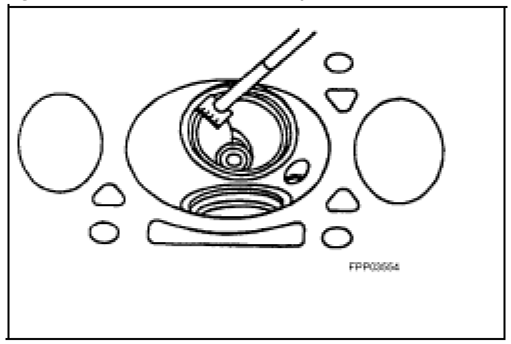
NOTE: After grinding valves or valve seats, check valve clearance.

- Check the valve seat and valve angles.



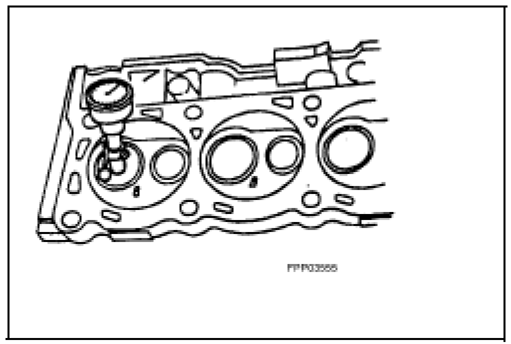
Valve Seat Width

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



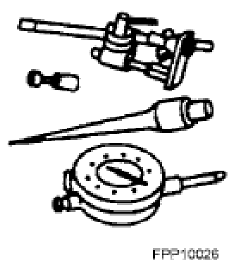
Valve Seat Runout

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

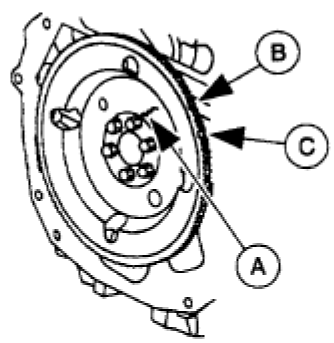


Flywheel Inspection

Special Tool(s)

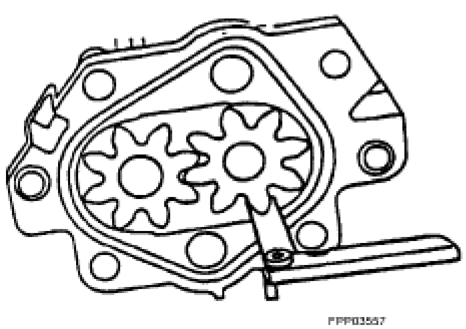
	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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



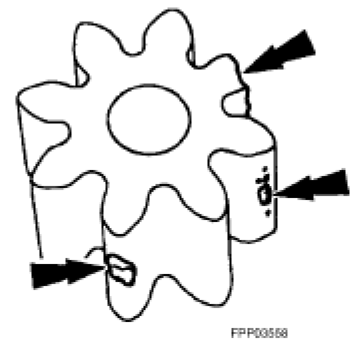
Oil Pump Gear Radial Clearance

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



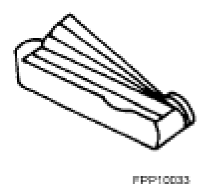
Oil Pump Rotor Inspection

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

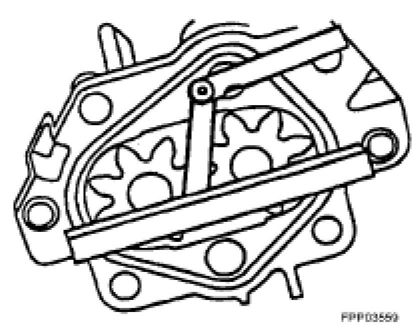


Oil Pump Side Clearance

Special Tool(s)

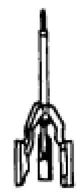
	Feeler Gauge D81L-4201-A or Equivalent
	Straight Edge D83L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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



Cylinder Bore Honing

Special Tool(s)

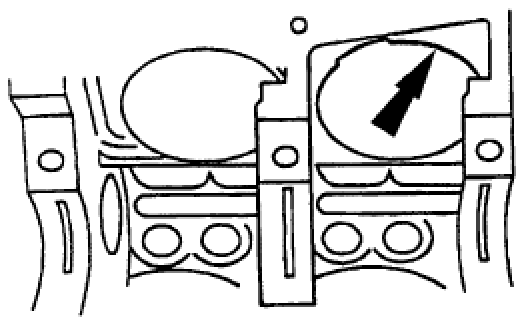
 FPP10037	Engine Cylinder Hone Set T73L-6011-A Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

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

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

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



FPP03560

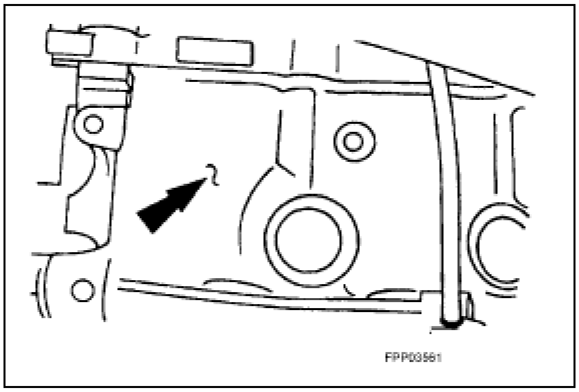
Cylinder Bore Cleaning

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-5W20-Q1SP or -DSP or equivalent meeting Ford specification WSS-M2C960-A1.

Cylinder Block Repair - Cast Iron Porosity Defects

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

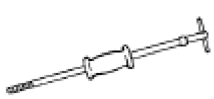


Repair porosity defects with an epoxy sealer meeting Ford specification M3D35-A (E).

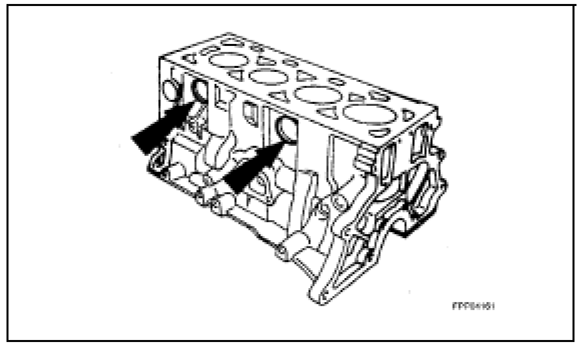
1. Clean the surface to be repaired to a bright, oil-free metal surface.
2. Chamfer or undercut the repair area to a greater depth than the rest of the cleaned surface. Solid metal must surround the area to be repaired.
3. Apply the epoxy sealer and heat-cure with a 250- watt lamp placed 254 mm (10 inches)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

Cylinder Block Core Plug Replacement

Special Tool(s)

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

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



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

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

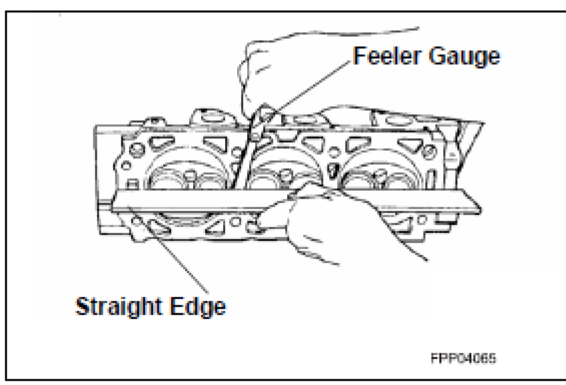
3. Coat the cylinder block core plug and bore lightly with Threadlock® 262 E2FZ-19554-B or equivalent meeting Ford specification WSK-M2G351-A6 and install the cylinder block core plug.

Cylinder Head – Distortion

Special Tool(s)

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

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

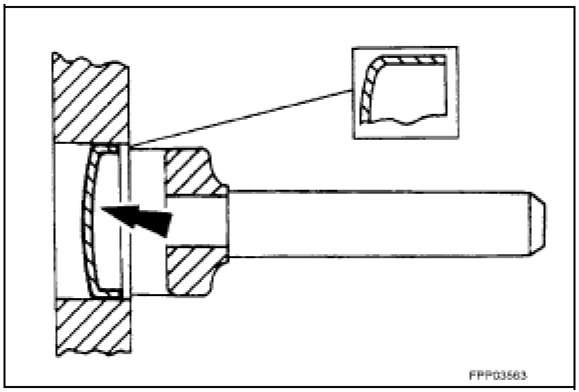


Cylinder Block Core Plug – Cup-Type

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

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

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



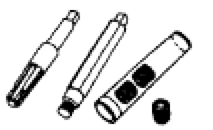
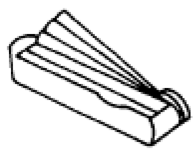
Cylinder Block Core Plug – Expansion-Type

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

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

Spark Plug Thread Repair

Special Tool(s)

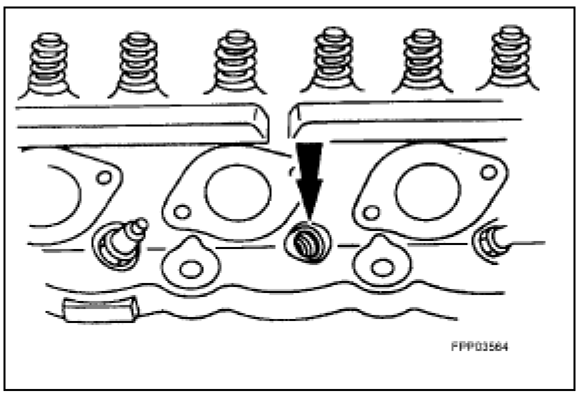
	Tapersert Installation Kit 107-R0921 or Equivalent
	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

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

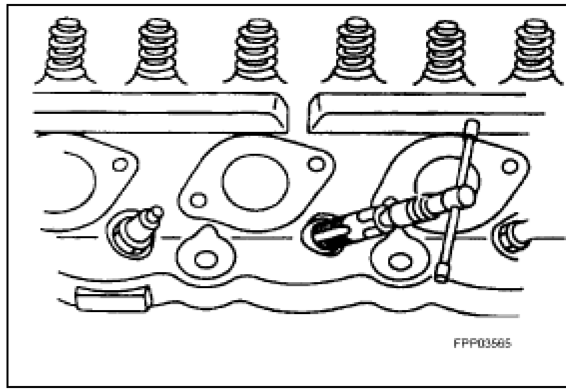
CAUTION: Do not use power or air-driven tools for finishing taperserts.

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

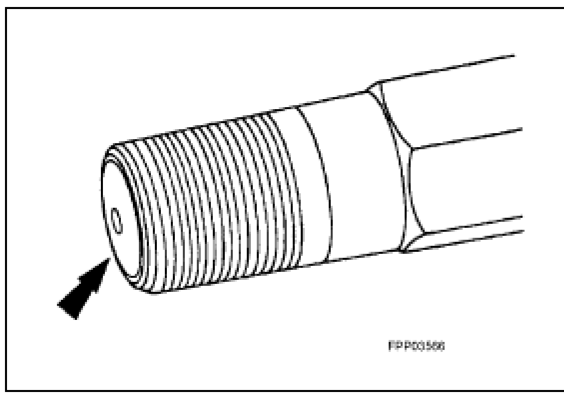
1. Clean the spark plug seat and threads.



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

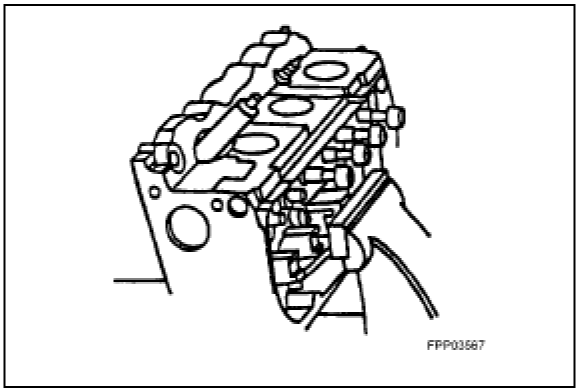


3. Continue cutting the threads and applying oil until the stop ring bottoms against the spark plug seat.
4. Remove the tap and metal chips.
5. Coat the threads of the mandrel with cutting oil. Thread the tapersert onto the mandrel until one thread of the mandrel extends beyond the tapersert.

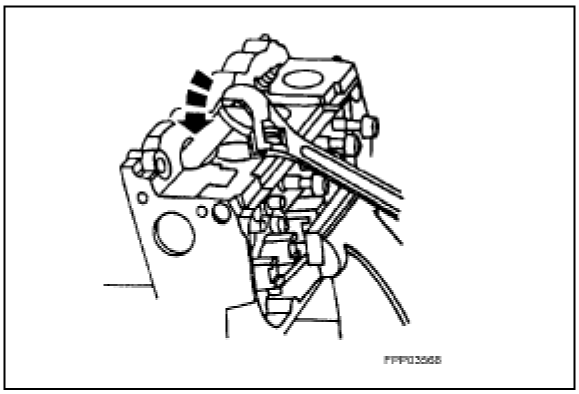


NOTE: A properly installed tapersert will be either flush with or 1.0 mm (0.039 inch) below the spark plug gasket seat.

6. Tighten the tapersert into the spark plug hole.



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



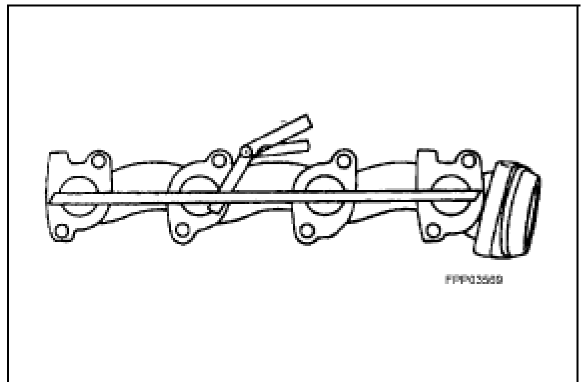
Exhaust Manifold Straightness

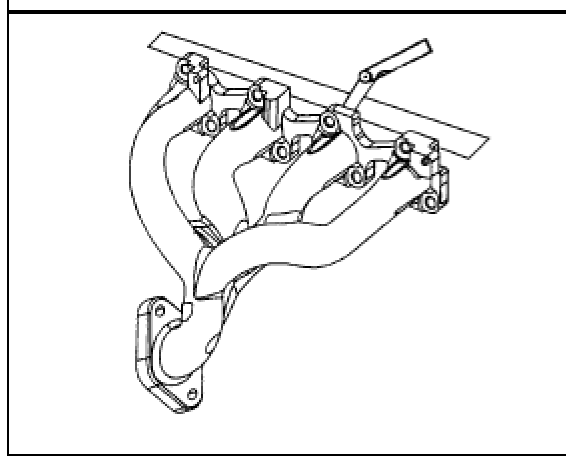
Special Tool(s)

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

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

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





LSG-635 GENERAL INFORMATION

SPECIFICATIONS

General Specifications		
ITEM	**SPECIFICATION**	**FILL CAPACITY with Filter**
Motorcraft Silicone Gasket and Sealant	**WSE-M4G323-A6**	
Motorcraft Threadlock	**WSK-M2G351-A6**	
Motorcraft 5W-20/5W-30 Synthetic Motor Oil	**WSS-M2C960-A1/WSS-M2C961-A1**	TLL00339 and prior = 6.0 qt (5.68L) TLL00340 and later = 12 qt (11.36L)

NOTE: Ford engines are designed to perform with engine oils that are licensed by the American Petroleum Institute (API), and oils carrying the most current API Classification SP or greater must be used.

LSG-635 ENGINE

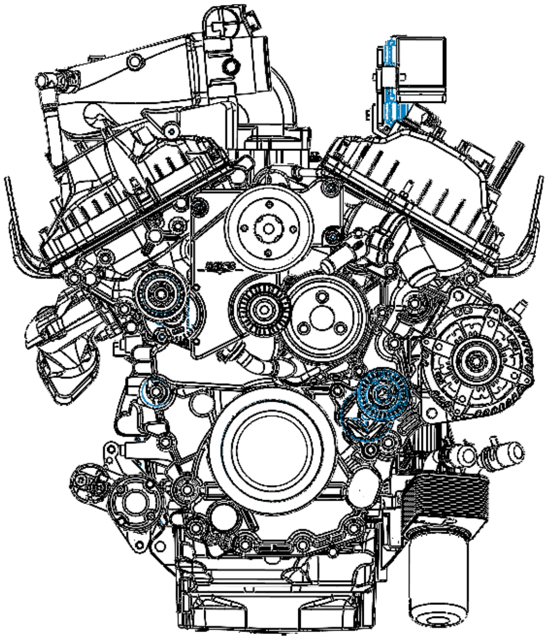
INDEX

Subject

INDEX (CONT.)

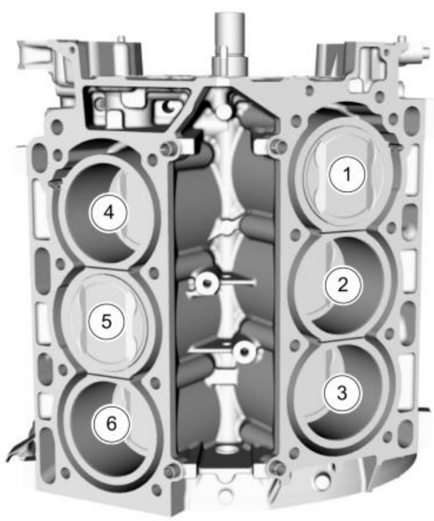
Subject

GENERAL INFORMATION



Engine

The LSG635 is a 4 valve per cylinder, dual overhead cam engine. The engine block is cast aluminum with iron cylinder liners. Connecting rods are made of sintered metal; the crankshaft is nodular iron with five main bearings. The cam cover, oil pan and front cover are also made of aluminum.



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

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

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

NOTE: A set of metric wrenches are required to service the LSG635 engine.

⚠

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

Positive Crankcase Ventilation System

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

Engine Cooling System

The 3.5L engine is liquid cooled, using an engine mounted coolant pump and external radiator. This is a full flow system regulated by a thermostat, located behind the water outlet connection. The thermostat controls and maintains engine temperature.

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

Valves and Seats

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

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

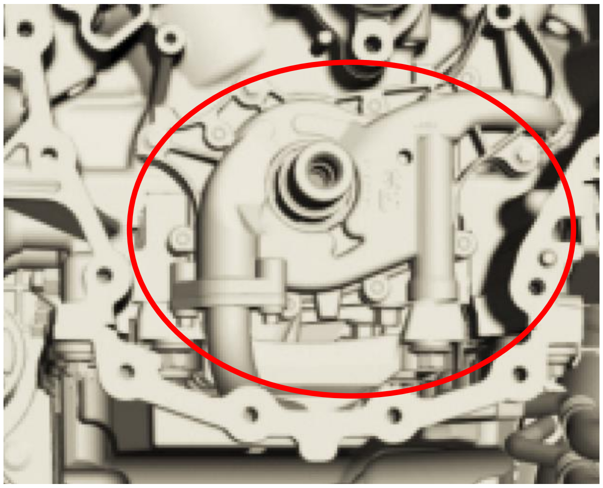
Lubrication System

The engine lubrication system consists of:

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

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

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



Variable camshaft timing (VCT)

This system is an electronically controlled camshaft adjuster that allows variable timing for the inlet camshaft. Note only the inside (intake side) VCT solenoids are utilized.

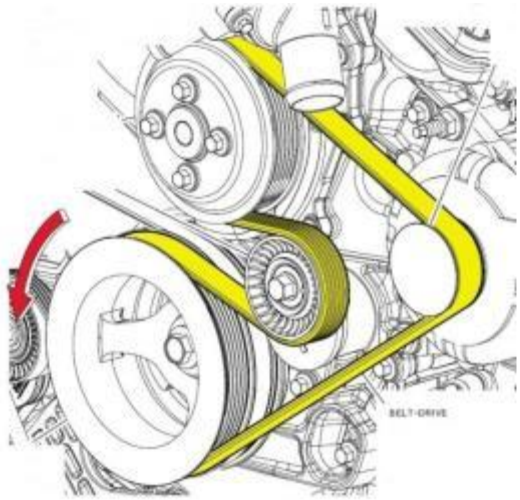
The valves are driven by a timing chain which drives the inlet camshaft timing control unit. This unit drives the associated camshafts. The timing chain is tensioned using a conventional timing chain tensioner.

Advantages of variable camshaft timing (VCT).

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

Drive Belt System

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



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

Ignition System

The ignition used on the 3.5L engine is an Electronic Distributorless Ignition System (EDIS). Individual ignition coils are located directly above each spark plug and are used to ignite the fuel in the cylinders.

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

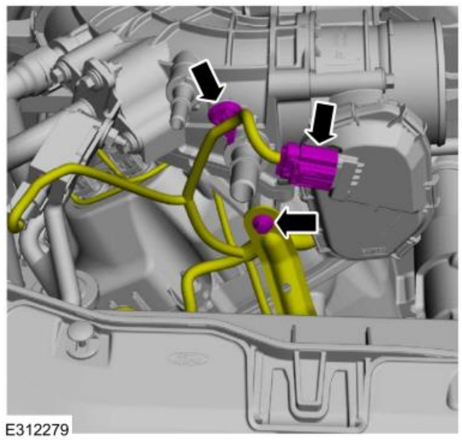
Fuel System

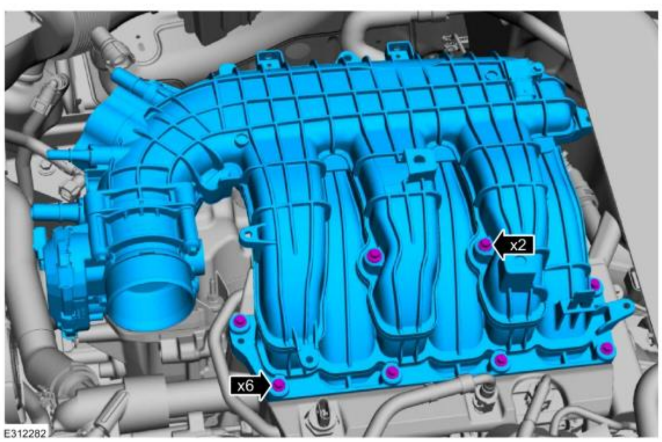
The fuel system includes a remote mounted electric fuel pump. The pump regulates and maintains fuel flow, through an in-line fuel filter to the electronic actuator mounted on the intake manifold.

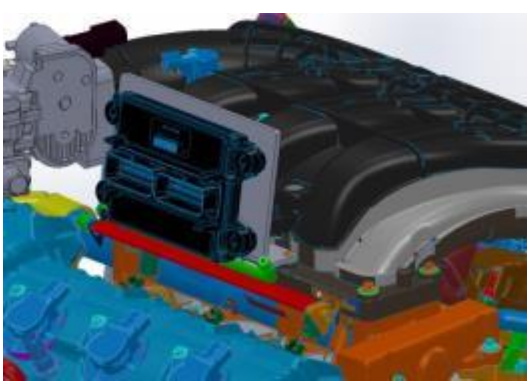
The engine can be adapted for dry fuel use. Refer to Section 04 of this manual for more information on the fuel system.

REMOVAL & INSTALLATION
Intake Manifold - Removal

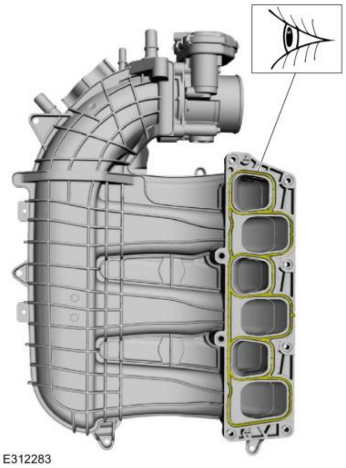
1. Remove and/or disconnect components to allow access and removal of the intake manifold. Label if necessary to allow for correct reinstallation. This includes the ECU and mounting bracket.







2. Remove 2 Upper bolts and 6 bolts on base of intake manifold



3. Clean and inspect all sealing surfaces of the upper and lower intake manifold.

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

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

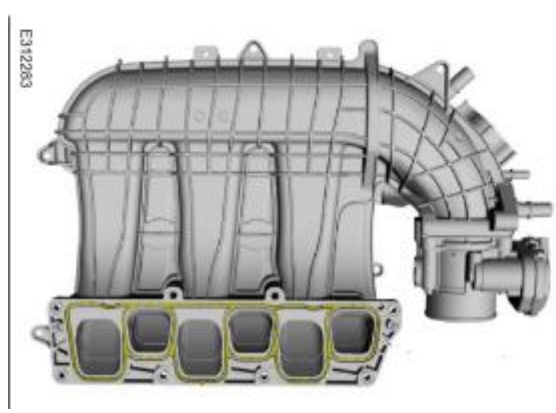
WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND META SURFACE PREP.

Visually inspect the upper intake manifold gaskets for nicks, cuts and abrasions. If these conditions are not present, the gaskets may be re-used.

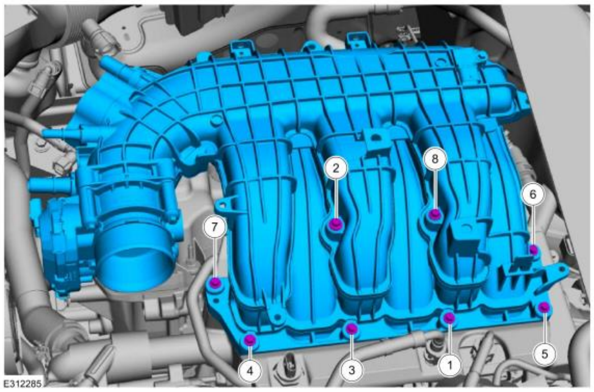
5. Remove and discard intake manifold gaskets.

Intake Manifold - Installation

1. Install new intake gaskets



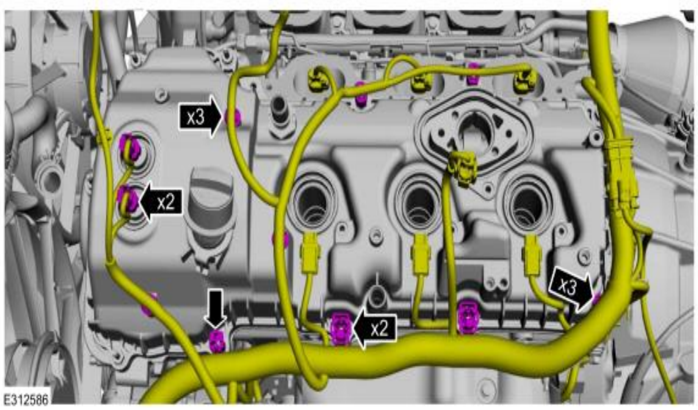
2. Position intake manifold and install 8 bolts.
    - Tighten to 10 Nm (89 lb-in).
    - Additional 45º



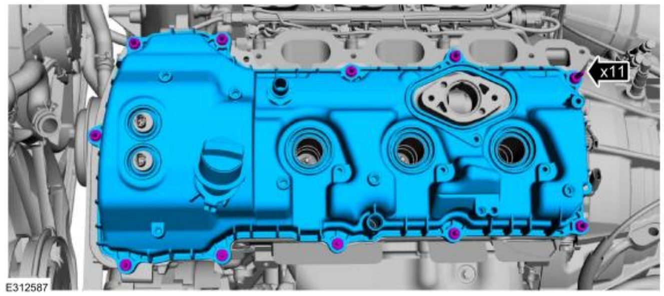
3. Reinstall or connect any components that were removed or disconnected.

LH Camshaft Cover - Removal

1. Disconnect negative battery cable -- refer to Section 6.
2. Remove and/or disconnect components to allow access and removal of the camshaft cover. Label if necessary to allow for correct reinstallation.



3. Disconnect VCT connector
4. Disconnect ignition coil connectors.
5. Disconnect crankcase ventilation tube quick connect coupling.
6. Remove bolts and camshaft cover.



7. Remove and discard main valve cover gasket.

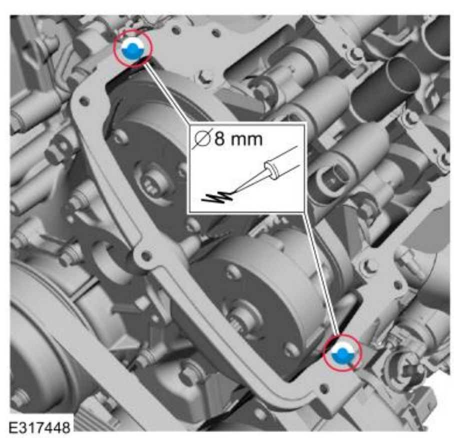
CAUTION: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges which make leak paths. Use a plastic scraping tool to remove all traces of old sealant.

8. Clean the sealing surface of the cylinder head with silicone gasket remover and metal surface prep. Inspect the VCT oil control solenoid seals and spark plug tube seals, remove and discard any damaged seals.
9. If damaged remove the VCT solenoid seal with special tool, 205-153 and 205-142.
10. If damaged remove the spark plug seals with 205-153 and 303-1247.

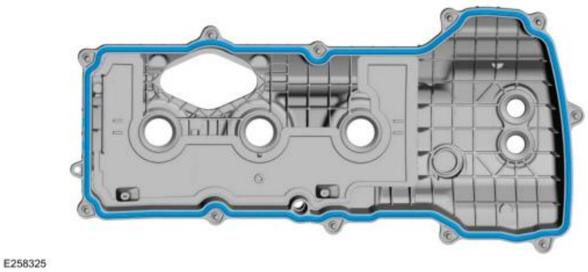
WARNING: OBSERVE ALL WARNINGS AND CAUTIONS AND FOLLOW ALL APPLICATION DIRECTIONS CONTAINED ON THE PACKAGING OF THE SILICONE GASKET REMOVER AND METAL SURFACE PREP.

LH Camshaft Cover - Installation

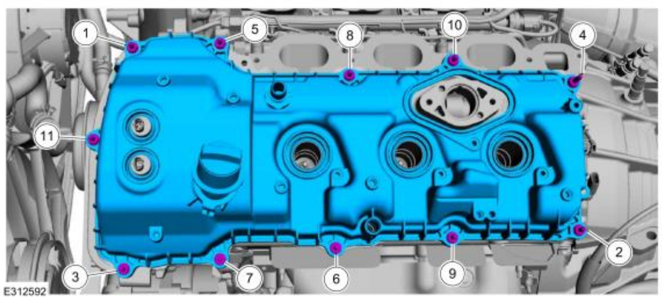
1. Apply an 8 mm (0.31 in) bead of Motorcraft® High Performance Engine RTV Silicone to the engine front cover-to-cylinder head joints. *Material* : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



2. Install new valve cover gasket



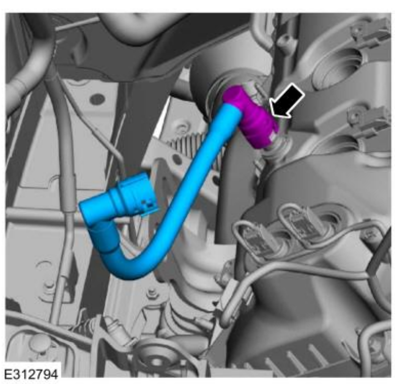
3. Position camshaft cover and install bolts in sequence shown
   - Tighten to 10 Nm (89 lb-in)



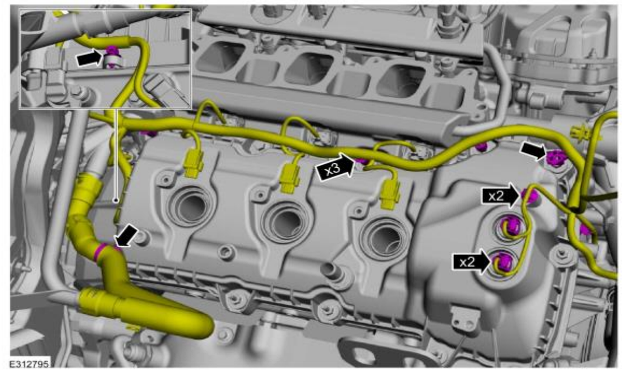
4. Reconnect crankcase ventilation tube.
5. Reinstall or connect any other components that were removed or disconnected
   - Dipstick and tube, coil packs, VCT solenoid
6. Reconnect negative battery cable -- refer to Section 6.

RH Camshaft Cover - Removal

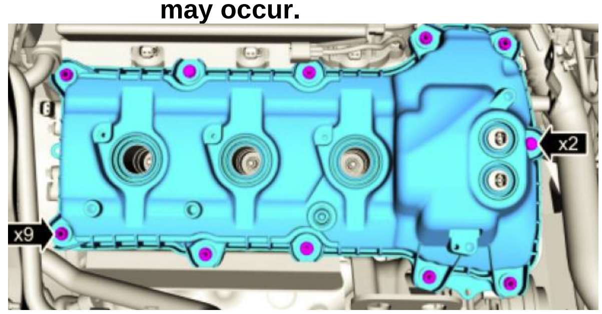
1. Disconnect negative battery cable -- refer to Section 6.
2. Remove and/or disconnect components to allow access and removal of the camshaft cover. Label if necessary to allow for correct reinstallation.
3. Remove intake manifold (refer to page 2-5)
4. Remove RH ignition coils
5. Remove the PCV Tube



6. Disconnect the VCT oil control solenoid electrical connector then detach all wiring harness retainers.



7. Loosen the bolts and remove the valve cover
   a. **While removing the valve cover do not apply excessive force to the VCT oil control solenoid or damage may occur. If the VCT oil control solenoid sticks to the VCT seal, carefully wiggle the valve cover until the bond breaks free or damage to the VCT seal and VCT oil control solenoid may occur.**



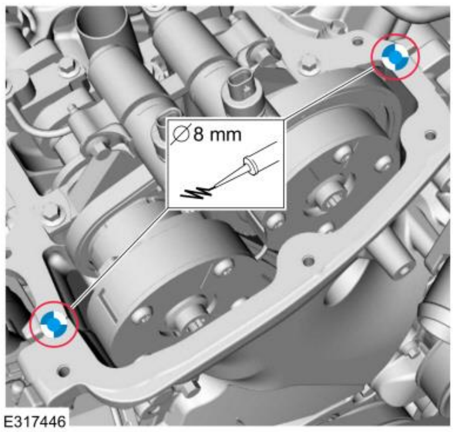
8. Remove and discard the valve cover gasket.

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

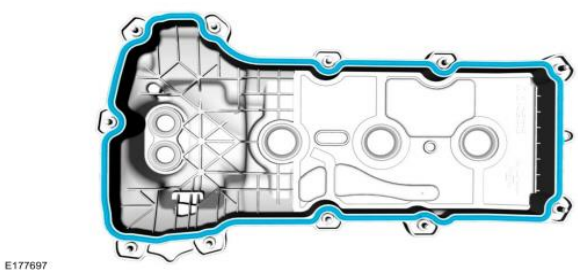
9. Clean the sealing surface of the cylinder head with silicone gasket remover and metal surface prep. Inspect the VCT oil control solenoid seals and spark plug tube seals, remove and discard any damaged seals.
10. If damaged remove the VCT solenoid seal with special tool, 205-153 and 205-142. Use the same tools to reinstall.
11. If damaged remove the spark plug seals with 205-153 and 303-1247. Use the same tools to reinstall.

RH Camshaft Cover - Installation

1. Apply an 8 mm (0.31 in) bead of Motorcraft® High Performance Engine RTV Silicone to the engine front cover-to-cylinder head joints.
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)

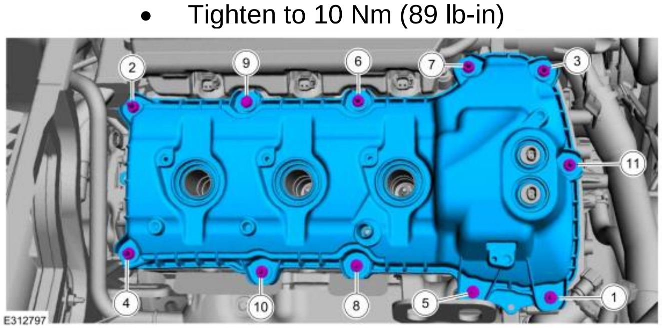


2. Install the new valve cover gasket.



3. Position camshaft cover and install bolts in sequence shown

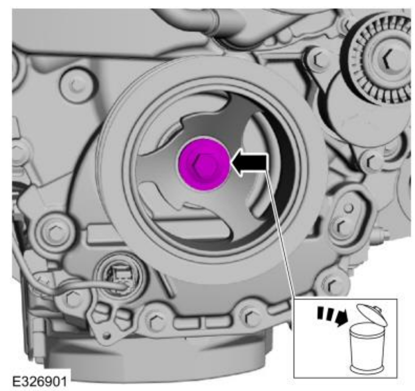
   - Tighten to 10 Nm (89 lb-in)



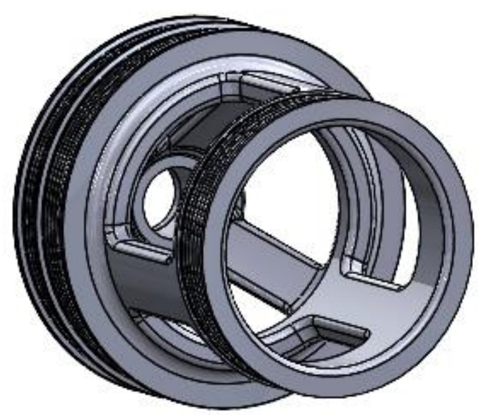
4. Make sure the VCT seals in the valve cover are below the top of the VCT oil control solenoid electrical connector or the VCT seal may leak oil.
5. Install the PCV tube, coils and electrical connectors.
6. Install the intake manifold (refer to page 2-5)

Crankshaft Pulley / Front Seal - Removal

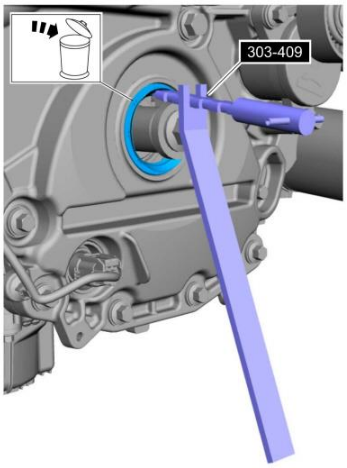
1. Remove and/or disconnect components to allow access and removal of the crankshaft pulley. Label if necessary to allow for correct reinstallation.
2. Remove the drive belt -- refer to Section 6.
3. Remove the crankshaft bolt and washer.
   a. Discard the bolt



4. Using a three leg puller, OTC 6667 or Rotunda equivalent, remove the crankshaft pulley.



5. Using the special tool, remove and discard the crankshaft front seal. Use special service tool: 303-409, crankshaft seal remover.

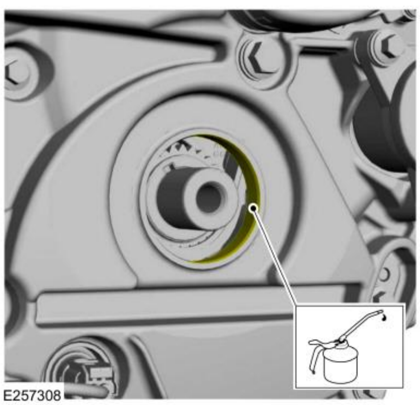


E257306

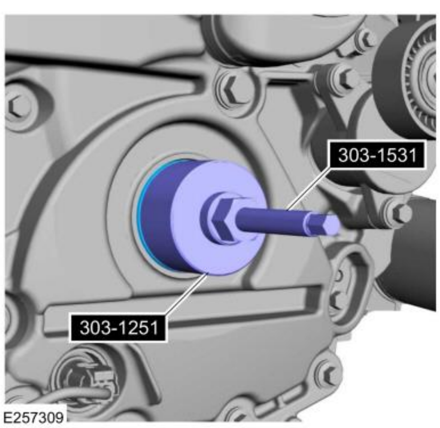
Crankshaft Pulley / Front Seal-Installation

CAUTION: Do not reuse the crankshaft pulley bolt.

1. Apply clean engine oil on the crankshaft front seal bore.


E257308

2. Using the special tools, install the crankshaft front seal. Special tool 303-1531 and 303-1251, front seal installer.

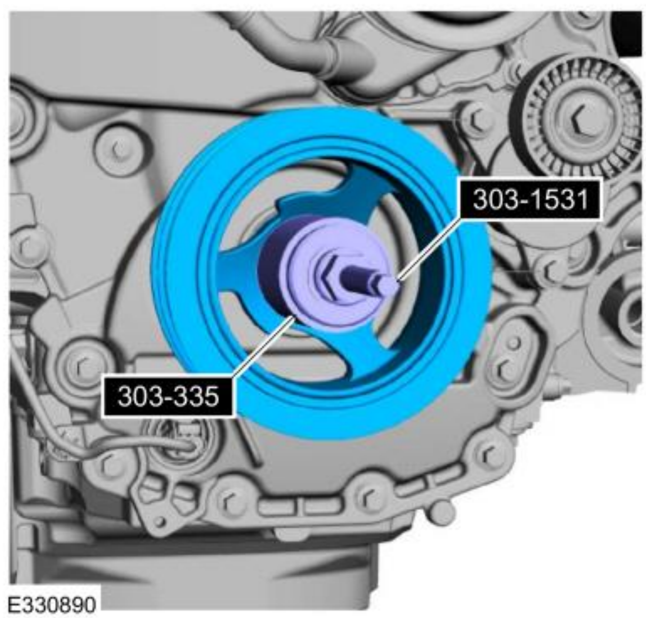


E257309

3. Lubricate the crankshaft front seal and the crankshaft pulley with clean engine oil.


E323749

4. Using the special tools, installed the crankshaft pulley, special tool 303-335 and 303-1531.



E330890

5. Using a universal pulley holder (such as an OTC 4754, or equivalent), install the new crankshaft bolt and washer and tighten in three stages.
   - Stage 1: 37 lb.ft (50 Nm)
   - Stage 2: 90°
   - Stage 3: 60°

6. Reinstall all components that were removed to gain access to the crankshaft front pulley.

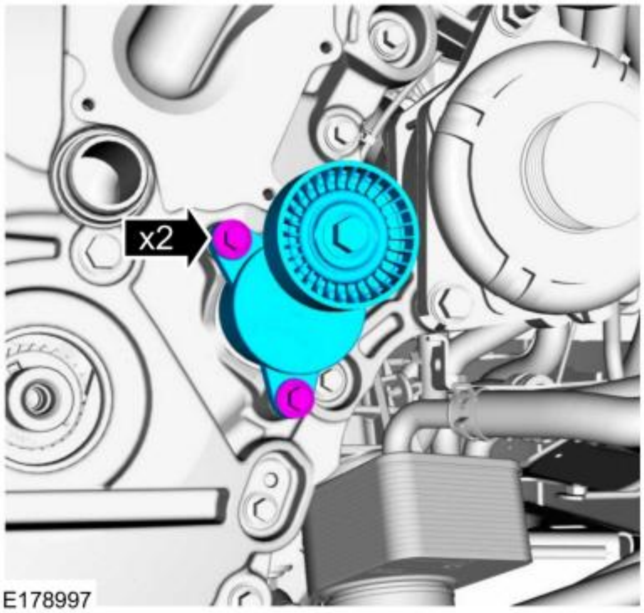
Engine Front Cover - Removal

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

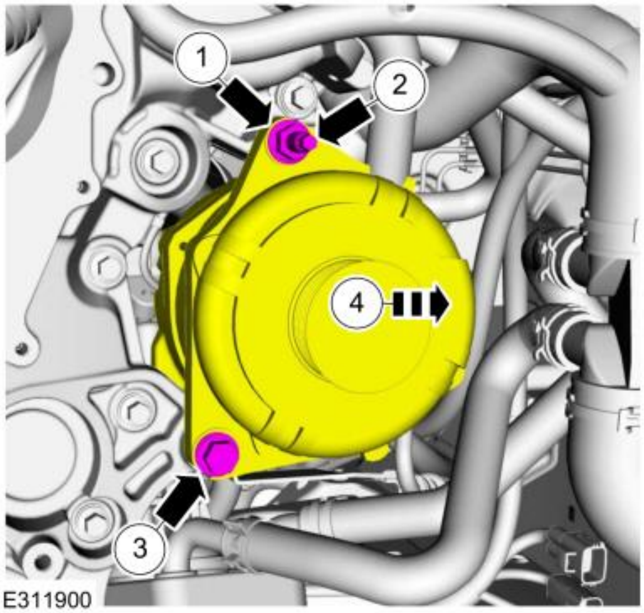
2. Remove the following items:

    a. Valve Cover LH – Page 2-6
    b. Valve Cover RH – Page 2-7
    c. Crankshaft front seal – Page 2-8
    d. Coolant Pump – Section 5

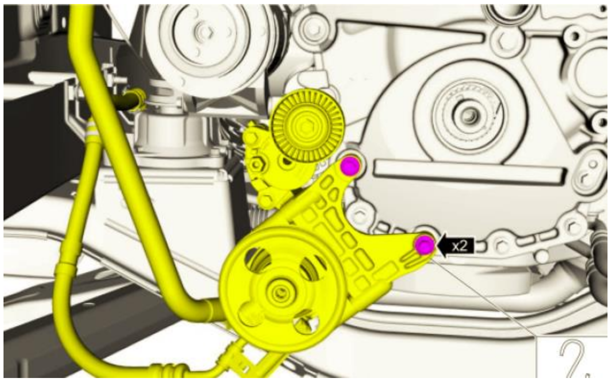
3. Remove the bolts and the accessory drive belt tensioner.



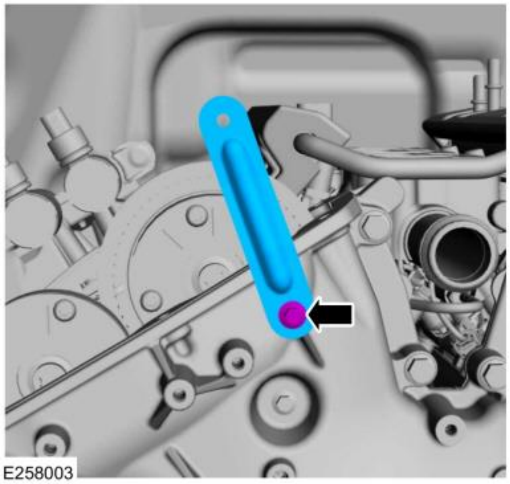
4. Remove the alternator



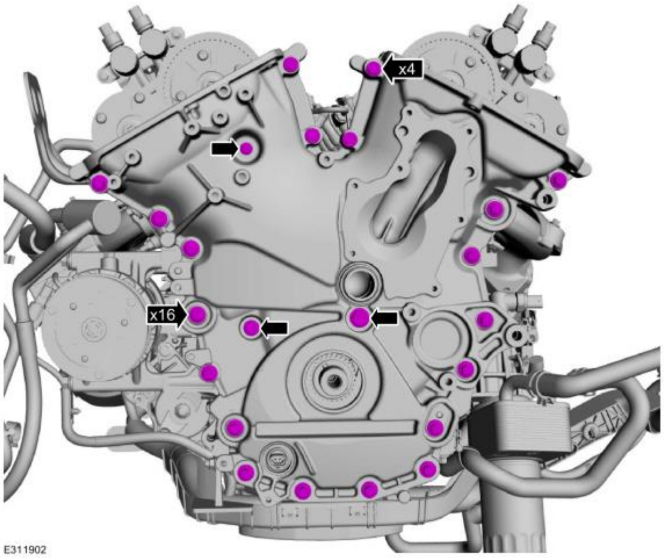
5. Remove the power steering pump bolt and secondary tensioner if equipped.



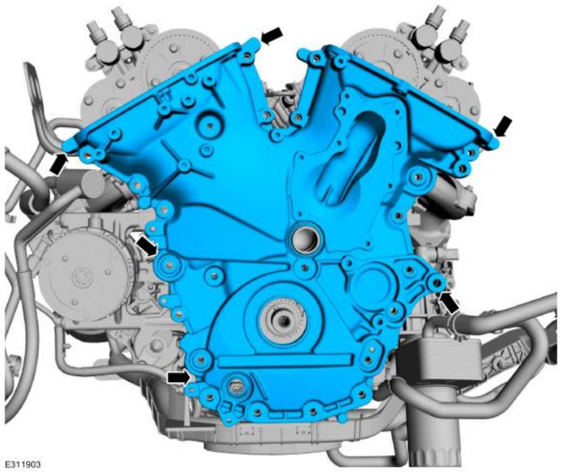
6. Remove the bolt and the upper intake manifold support bracket.



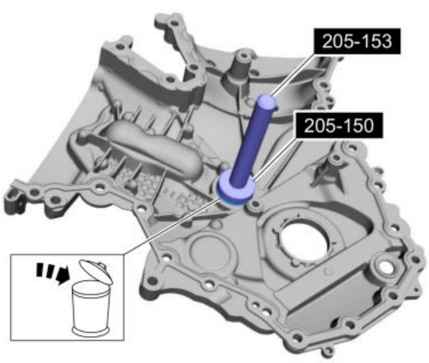
7. Remove the engine front cover bolts.



8. Using a pry tool, locate the pry pads shown and pry the engine front cover loose and remove.

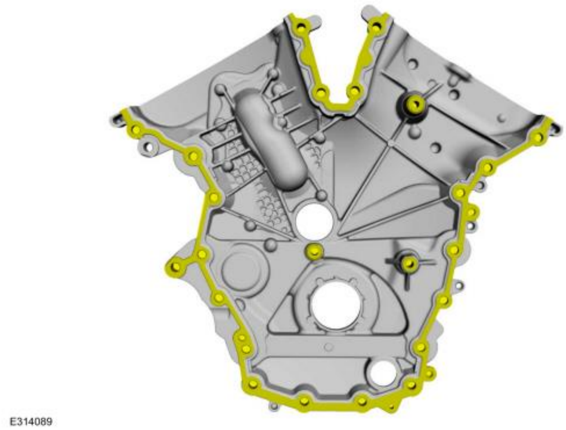


9. With the cover removed, remove the front cover to coolant pipe seal using special tool 205-150 and 205-153.



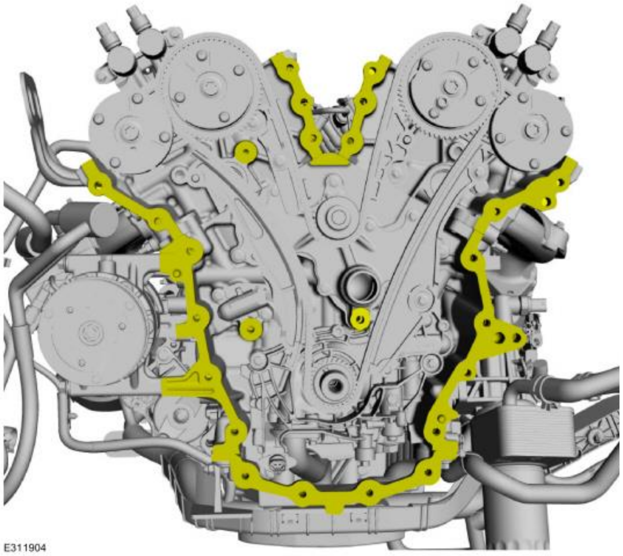
E258006

10. **NOTICE: Only use a 3M™ Roloc® Bristle Disk (2-in white, part number 07528) in a suitable tool turning at the recommended speed of 15,000 rpm, to clean the engine front cover. Do not use metal scrapers, wire brushes or any other power abrasive disk to clean front cover.**
    - **a.** Make sure that the mating faces of the front cover are clean and free of foreign material.
    - **b.** Refer to: RTV Sealing Surface Cleaning and Preparation (303-00 Engine System – General Information, General Procedures).
    - **c.** *Material* : Motorcraft® Silicone Gasket Remover / ZC-30-A
    - **d.** *Material* : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
    - **e.** *Material* : Motorcraft® Metal Surface Prep / ZC-31-B
    - **f.** Thoroughly wash the engine front cover to remove any foreign material, including any abrasive particles created during the cleaning process.



11. **NOTICE: Place clean, lint-free shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**
    NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white part number 07528) to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. They also cause contamination that will cause premature engine failure. Remove all traces of the gasket.

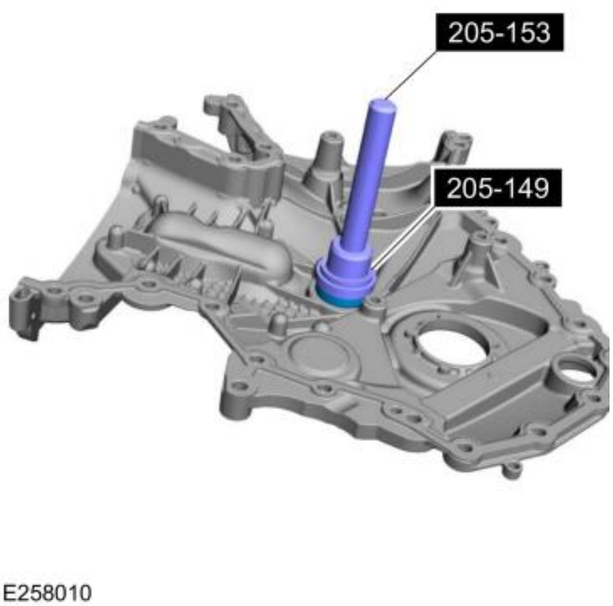
    Make sure that the mating faces of the engine block and oil pan are clean and free of foreign material.
    Refer to: RTV Sealing Surface Cleaning and Preparation (303-00 Engine System - General Information, General Procedures).
    Use the General Equipment: Plastic Scraper
    Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
    Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
    Material : Motorcraft® Metal Surface Prep / ZC-31-B



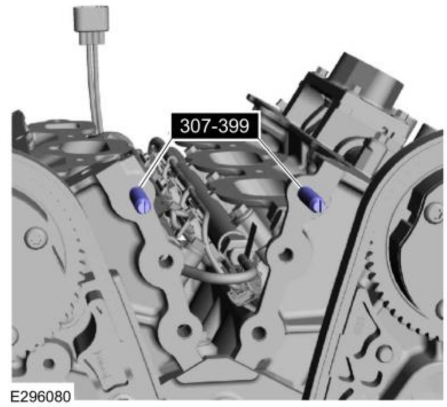
Engine Front Cover - Installation

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

1. Using the special tools, install the engine front cover to coolant pipe seal. *Use Special Service Tool* : 205-149 (T80T-4000-R) Installer, Spindle Bearing , 205-153 (T80T-4000-W) Handle



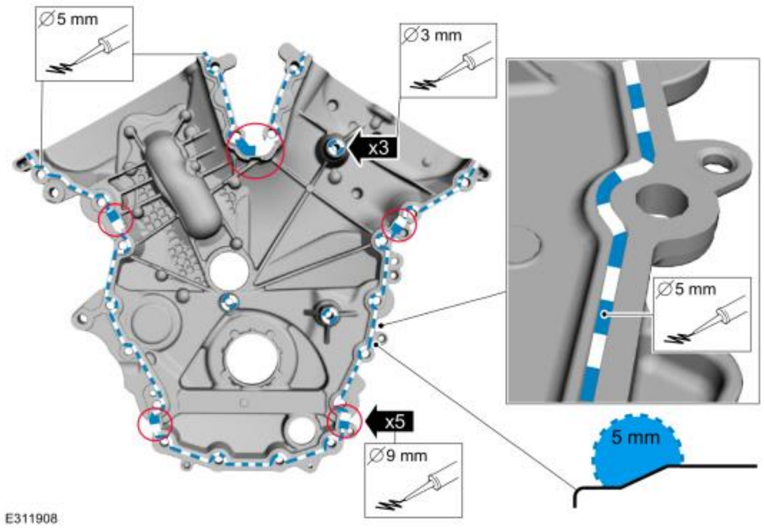
2. *Install Special Service Tool* : 307-399 Alignment Pins, Transmission Fluid Pump



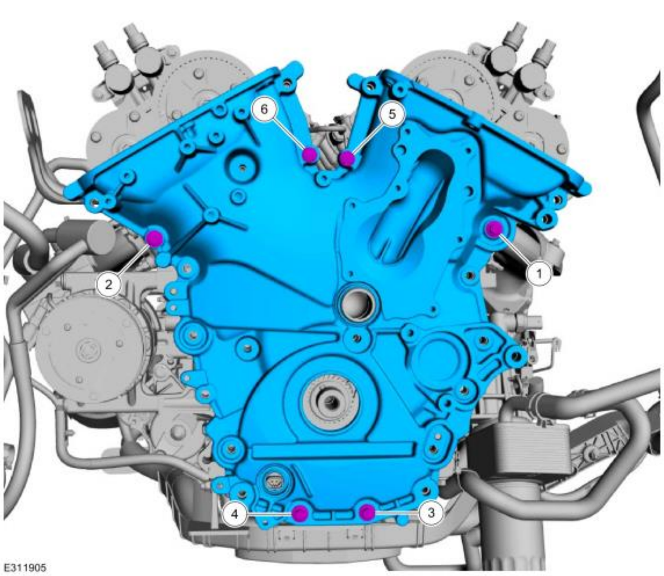
3. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**

   NOTE: *The engine front cover and the 6 bolts must be installed within 4 minutes of the initial sealant application. The remainder of the engine front cover bolts must be installed and tightened within 35 minutes of the initial sealant application. If the time limits are exceeded, the sealant must be removed, the sealing area cleaned and sealant reapplied. Failure to follow this procedure can cause future oil leakage.*

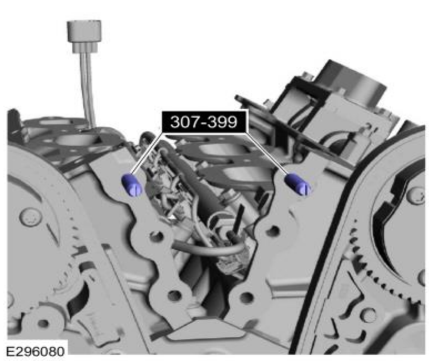
   Apply a 3 mm (0.12 in) bead of Motorcraft® High Performance Engine RTV Silicone to the engine front cover sealing surfaces including the inner bolt bosses.
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)
   Apply a 5 mm (0.19 in) bead of Motorcraft® High Performance Engine RTV Silicone on the chamfer, as shown
   Material: Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)
   Apply a 9 mm (0.35 in) bead of Motorcraft® High Performance Engine RTV Silicone to the oil pan-to-cylinder block joint and the cylinder head-to-cylinder block joint areas of the engine front cover in places as indicated.
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



4. **NOTE:** *Make sure the 2 locating dowel pins are seated correctly in the cylinder block.*
    1. Install the engine front cover and the bolts. *Torque* : 27 lb.in (3 Nm)



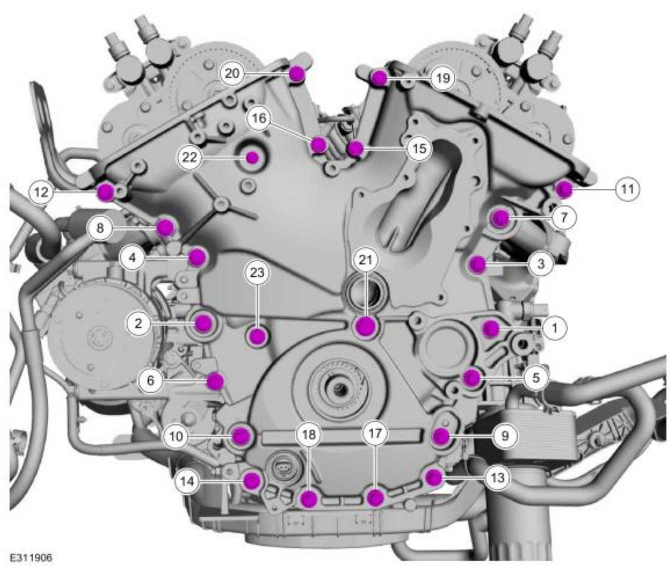
5. *Remove Special Service Tool* : 307-399 Alignment Pins, Transmission Fluid Pump



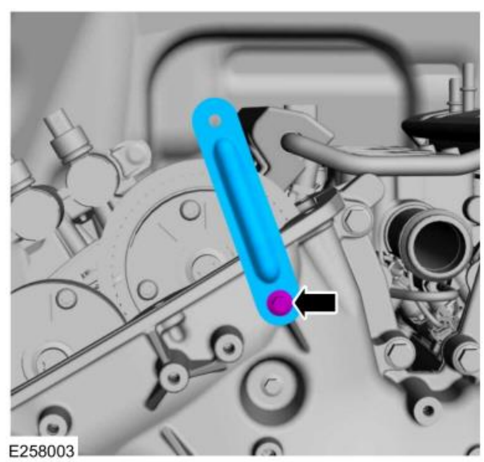
6. **NOTE:** *Install 2 W503297 (10mm Hex) M8 x 1.25 x 35 bolt and washer in bolt holes 10 and 18. After the tightening sequence is completed, bolts 10 and 18 will be removed in the next step to accommodate installation of the power steering pump assembly and bolts.*
    Install the remaining engine front cover bolts.

Torque :

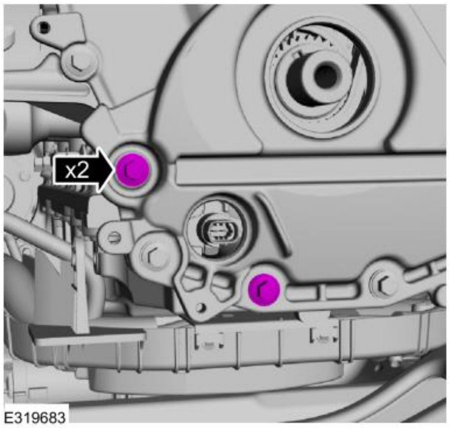
- Stage 1: Tighten bolts 1 thru 21 to: 89 lb.in (10 Nm)
- Stage 2: Tighten bolts 1 thru 20 and 23 to: 177 lb.in (20 Nm)
- Stage 3: Tighten bolts 1 thru 20 and 23 an additional: 45°
- Stage 4: Tighten bolt 21 to: 177 lb.in (20 Nm)
- Stage 5: Tighten bolt 21 an additional: 90°
- Stage 6: Tighten bolt 22 to: 89 lb.in (10 Nm)
- Stage 7: Tighten bolt 22 an additional: 45°



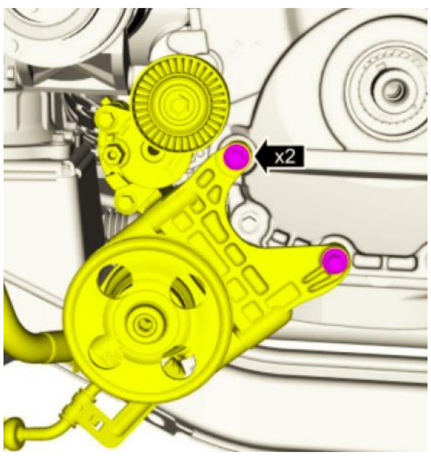
7. Install the upper intake manifold support bracket and the bolt finger-tight.



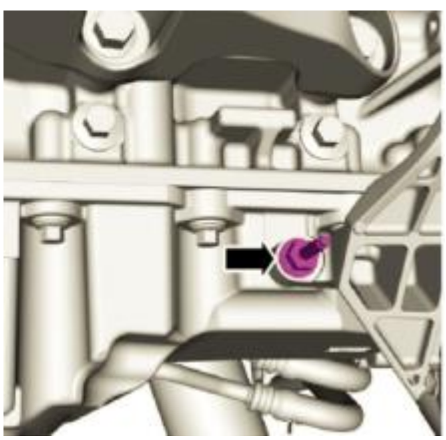
8. If equipped with a power steering pump, remove these two bolts.



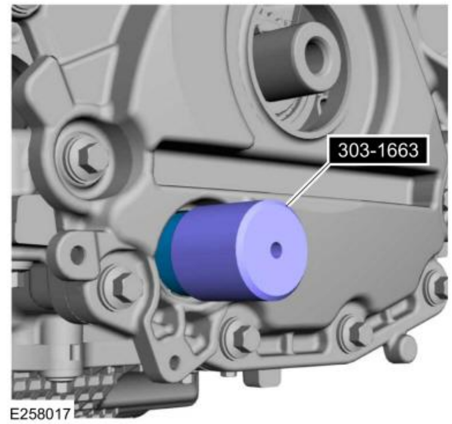
9. **NOTE:** *Do not tighten the bolts at this time.* Position the power steering pump and hoses and install the bolts by hand. If equipped with power steering pump.



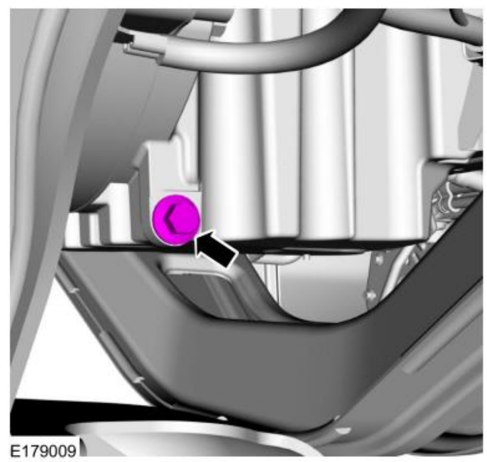
10. Install the power steering pump bracket stud bolt. *Torque* : 27 lb.in (3 Nm)



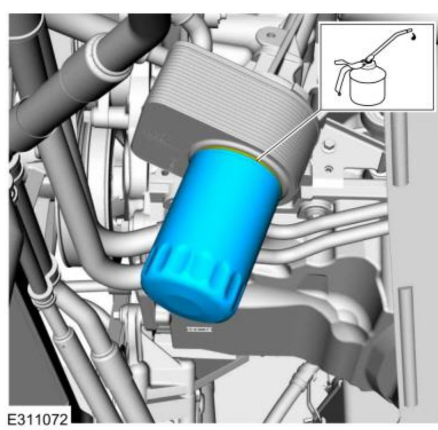
11. Tighten the two front power steering bolts 26 ft-lb (35Nm) and rear stud 19ft-lb (26Nm).
12. If no power steering, use special service tool 303-1663 and a hammer to install the oil pump electrical connector seal.



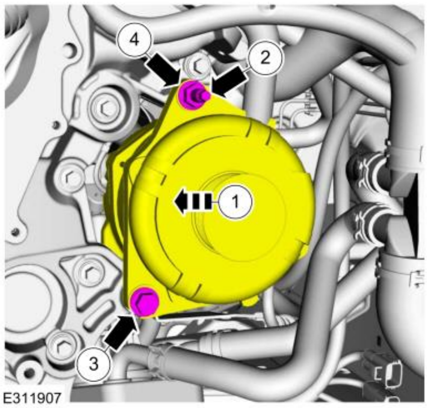
13. Remove the oil pan drain plug and drain the engine oil.
    1. Install the drain plug
        i. *Torque* : 19 lb.ft (26 Nm)



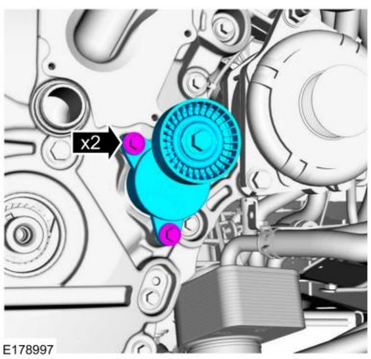
14. Remove and discard the engine oil filter. Lubricate the oil filter seal with clean engine oil and install and tighten in 2 stages
    1. Stage 1: Install to initial gasket contact.
    2. Stage 2: Tighten ¾ to 1 turn.



15. Install the alternator
    1. Install the stud bolt
        i. *Torque* : 71 lb.in (8 Nm)
    2. Install the generator.
    3. Install the bolt.
        i. *Torque* : 35 lb.ft (47 Nm)
    4. Install the nut.
        i. *Torque* : 35 lb.ft (47 Nm)



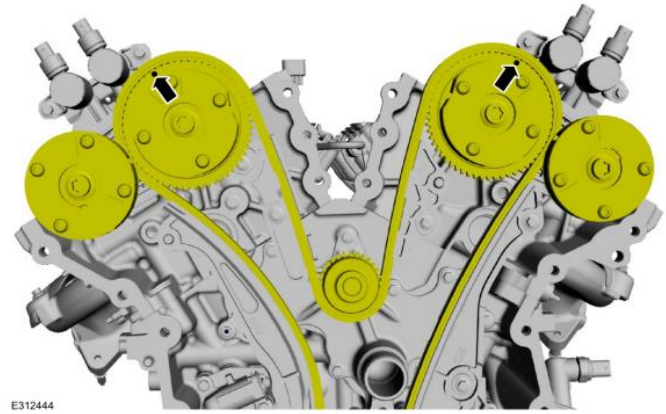
16. Install the accessory drive belt tensioner and the bolts. *Torque* : 18 lb.ft (25 Nm)



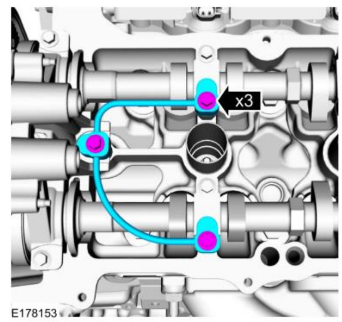
17. Install the following items.
    1. Valve Cover LH – Page 2-6
    2. Valve Cover RH – Page 2-8
    3. Crankshaft front seal – Page 2-9
    4. Coolant Pump – Section 5
18. Tighten the bolt for the upper intake manifold support bracket. *Torque* : 89 lb.in (10 Nm)
19. Fill with clean engine oil.

Timing Chain Removal

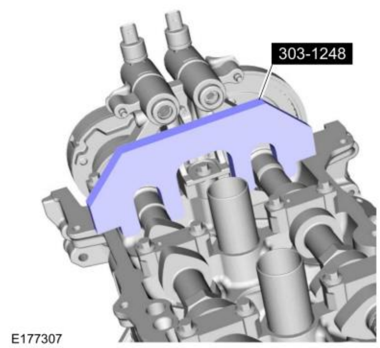
1. Remove engine front cover – refer to page 2-10
2. Install the original crankshaft pulley bolt and washer.
3. Note: rotate the crankshaft in the a clockwise direction only.
    a. Rotate the crankshaft clockwise and align the timing marks on the intake VCT units as shown.



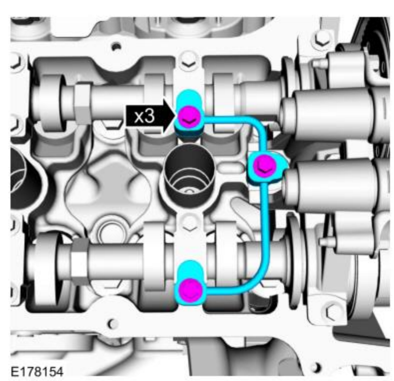
4. Remove the bolts and the LH oil tube.



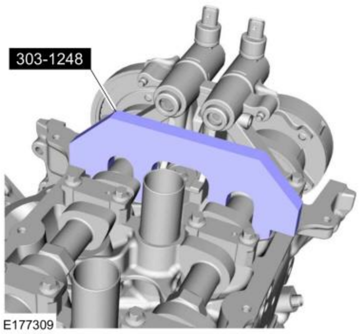
5. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position. Install Special Service Tool* : 303-1248 Camshaft holding tools



6. Remove the bolts and the RH oil tube



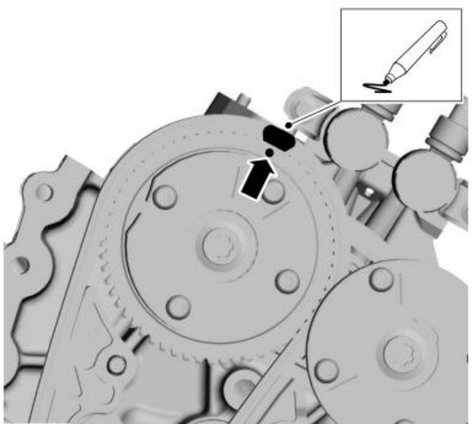
7. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position. Install Special Service Tool* : 303-1248 Camshaft holding tools.



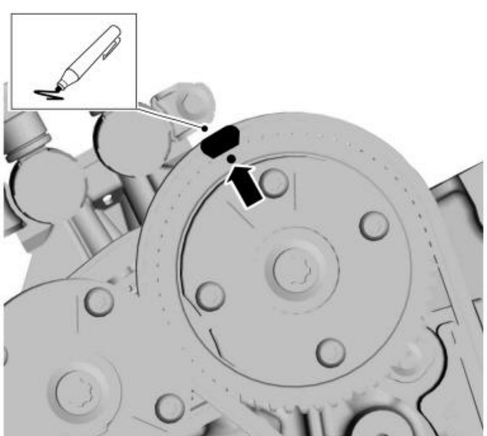
E177309

NOTE: ***The following 3 steps are for timing chains that the colored links are not visible.***

8. Mark the timing chain link that aligns with the timing mark on the LH intake VCT unit as shown.

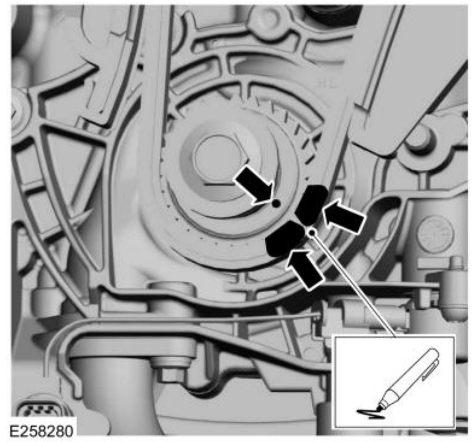

E312445

9. Mark the timing chain link that aligns with the timing mark on the RH intake VCT unit as shown.

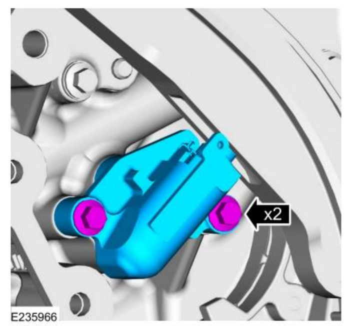

E312446

10. **NOTE:** *The crankshaft sprocket timing mark should be between the colored links.*

    Mark the timing chain links that aligns with the timing mark on the crankshaft sprocket as shown.


E258280

11. Remove the bolts and the timing chain tensioner.

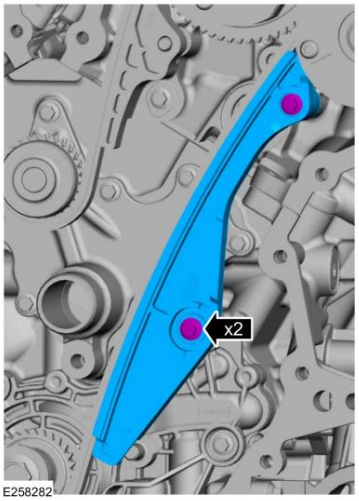


E235966

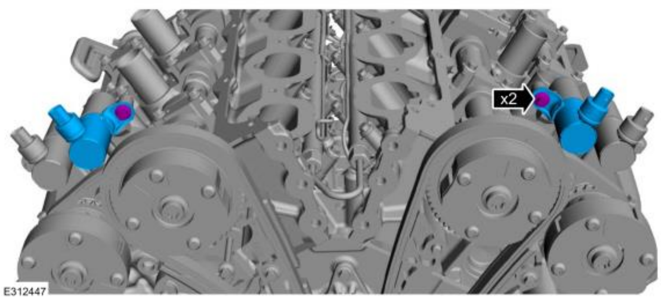
12. Remove the timing chain tensioner arm.


E258281

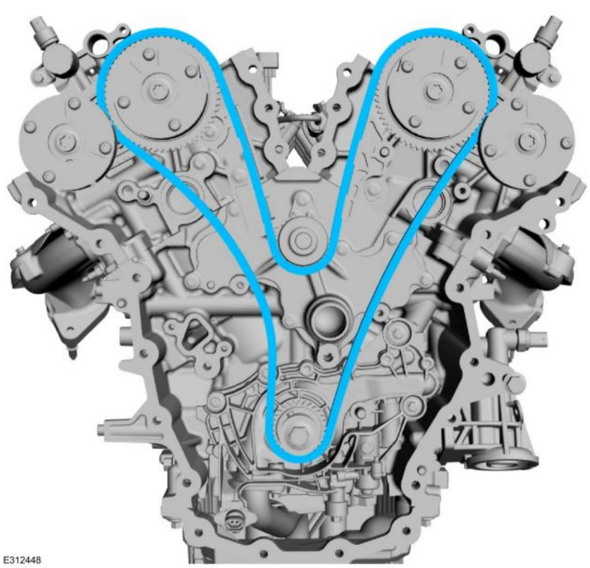
13. Remove the bolts and the lower LH timing chain guide.



14. **NOTE:** *Removal of the VCT oil control solenoid will aid in the removal of the timing chain.*
    NOTE: *A slight twisting motion will aid in the removal of the VCT oil control solenoids.*
    NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.*
    Remove the bolts and the VCT oil control solenoids

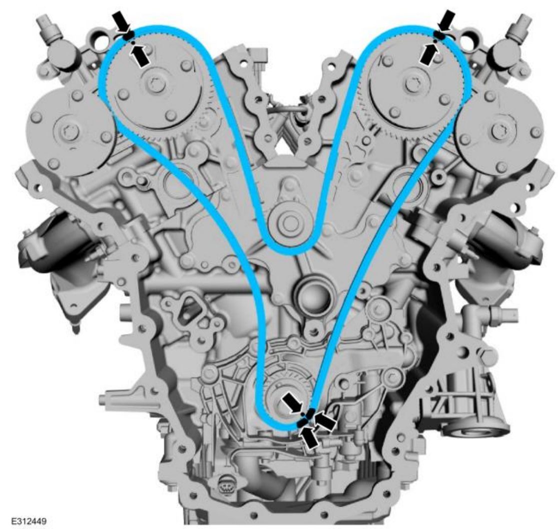


14. Remove the timing chain

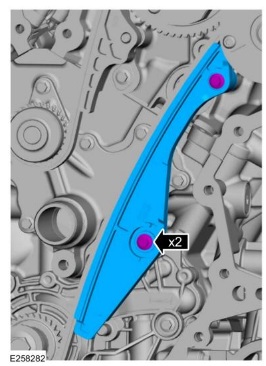


Timing Chain Installation

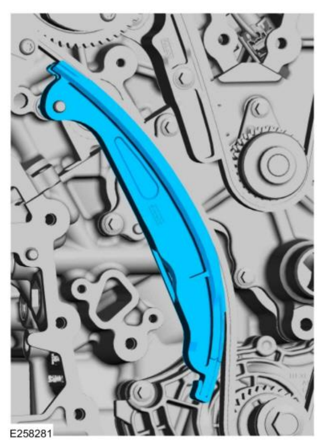
1. **NOTE:** *It may be necessary to rotate the camshafts slightly, to align the timing marks.* Install the timing chain with the colored links aligned with the timing marks on the VCT units and the crankshaft sprocket.



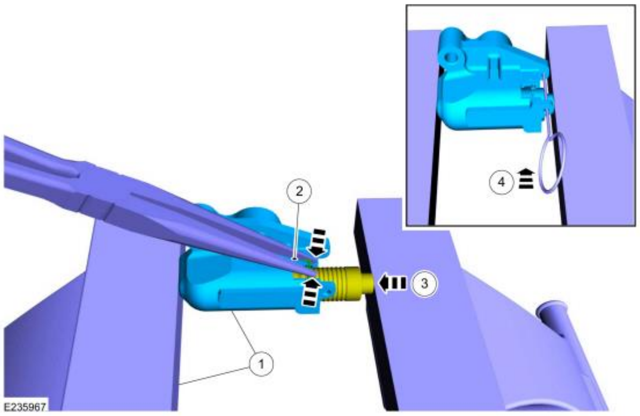
2. Install the lower LH timing chain guide and the bolts. *Torque* : 89 lb.in (10 Nm)



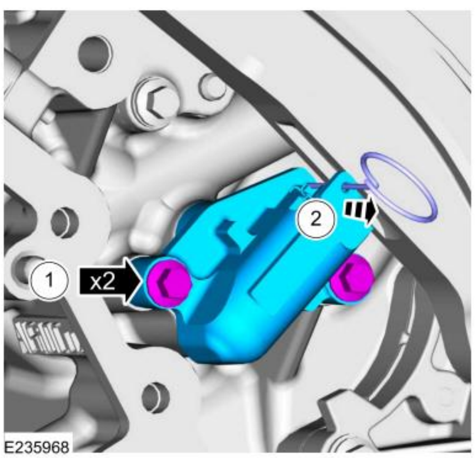
3. Install the timing chain and tensioner arm.



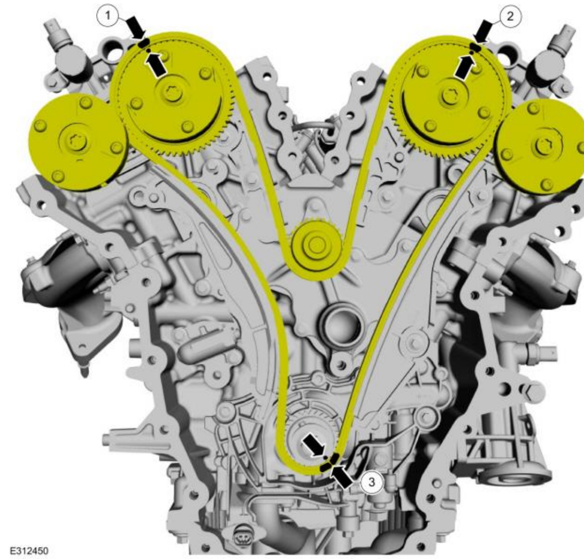
4. Position the tensioner in a soft-jawed vise. Using pliers, squeeze the ends of the ratchet wire clip together. Using the soft-jawed vise, compress the plunger to the reset position. Install a locking pin in the 2 holes of the tensioner body to hold the plunger in place.



5. **NOTE:** *It may be necessary to rotate the camshafts slightly to remove slack from the timing chain to install the tensioner.* Install the timing chain tensioner and the bolts.
   a. *Torque* : 89 lb.in (10 Nm)
   b. Remove the lockpin.

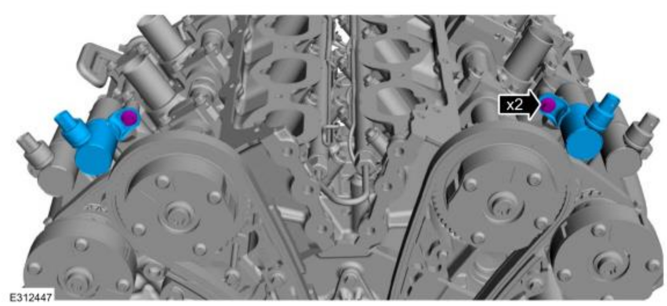


6. As a post-check, verify correct alignment of all timing marks.
   a. There are 48 links in between the RH intake VCT unit colored link (1) and the LH intake VCT unit colored link (2)
   b. There are 35 links in between LH intake VCT unit colored link (2) and the 2 crankshaft sprocket links (3).

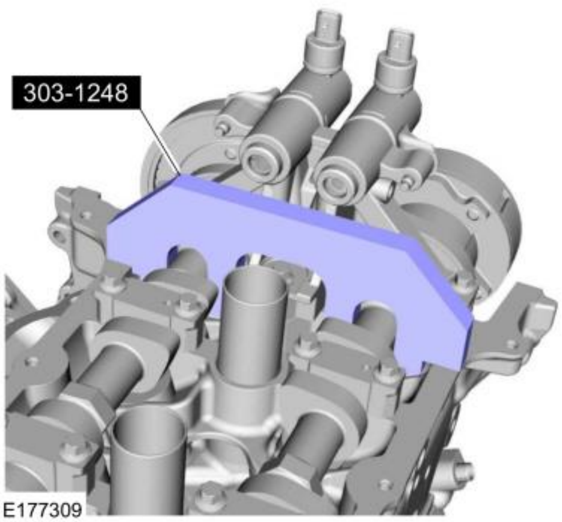


7. **NOTICE: Do not use excessive force when installing the VCT oil control solenoid. Damage to the mega cap could cause the cylinder head to be inoperable. If difficult to install the VCT oil control solenoid, inspect the bore and VCT oil control solenoid to ensure there are no burrs, sharp edges or contaminants present on the mating surface. Only clean the external surfaces as necessary.**

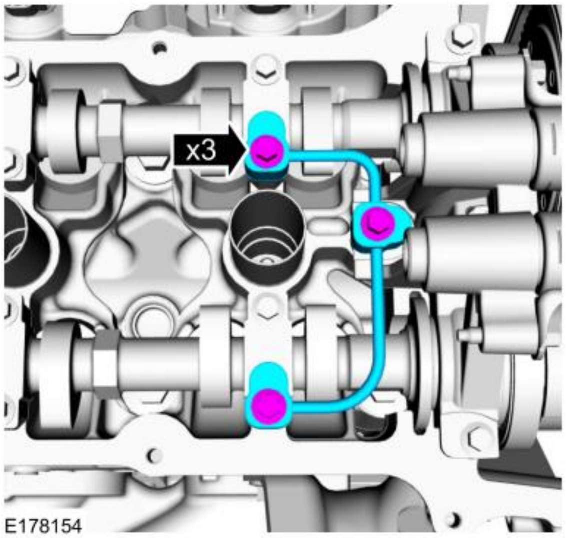
   NOTE: *A slight twisting motion will aid in the installation of the VCT oil control solenoid.*
   NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.* Install the VCT oil control solenoids and the bolts.
   Torque :
   Stage 1: 71 lb.in (8 Nm)
   Stage 2: 20°



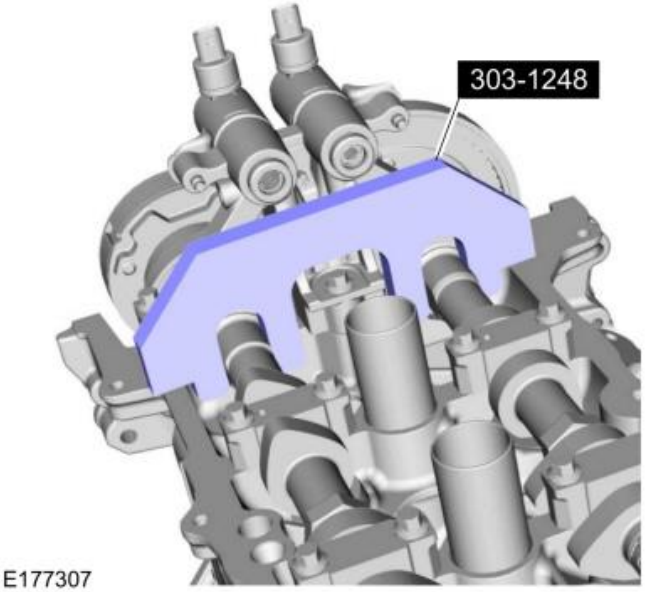
8. *Remove Special Service Tool* : 303-1248
   Camshaft holding tools



9. Install the RH oil tube and the bolts.
   Torque :
   Stage 1: 71 lb.in (8 Nm)
   Stage 2: 60°

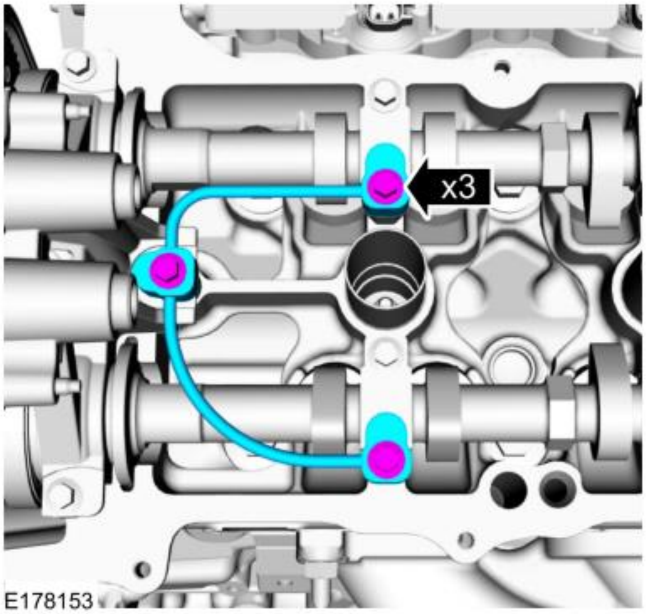


10. *Remove Special Service Tool* : 303-1248
    Camshaft holding tools



11. Install the LH oil tube and the bolts.

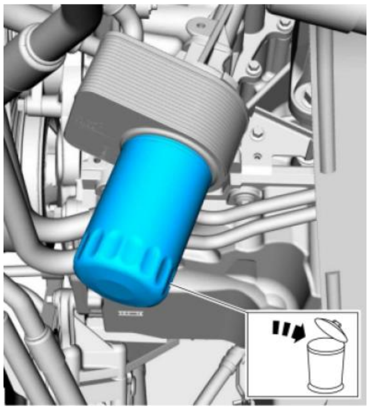
    Torque :
    Stage 1: 71 lb.in (8 Nm)
    Stage 2: 60°



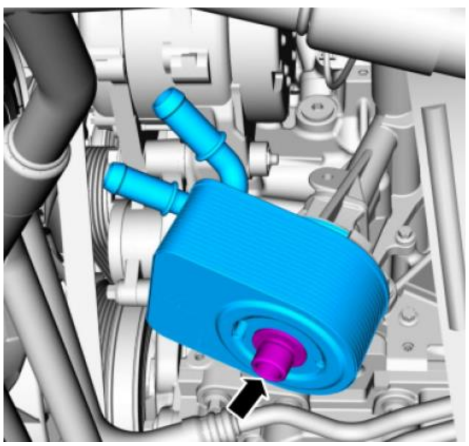
12. Remove and discard the original crankshaft pulley bolt.
13. Install the engine front cover.
    Refer to: Engine Front Cover page 2-12

Oil Cooler Removal and Installation

1. Remove and discard the engine oil filter. Use the General Equipment: Oil Drain Equipment



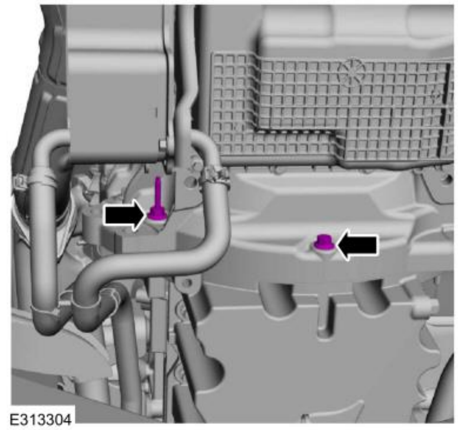
2. Remove the bolt and the oil cooler.

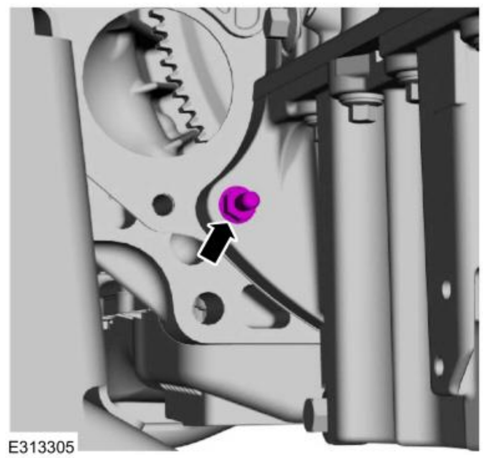


3. To Reinstall make sure the oil cooler-to-oil filter adapter is aligned.
    a. Install the oil cooler and the bolt.
    b. *Torque* : 43 lb.ft (58 Nm)
4. Install a new engine oil filter
5. Inspect and adjust the oil level as necessary.

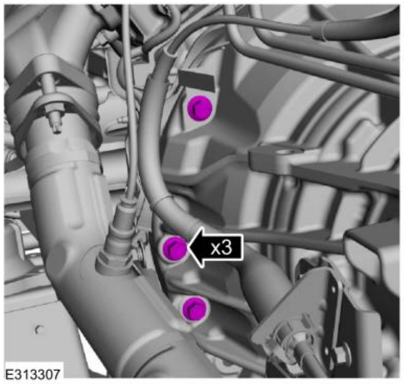
Oil Pan Removal

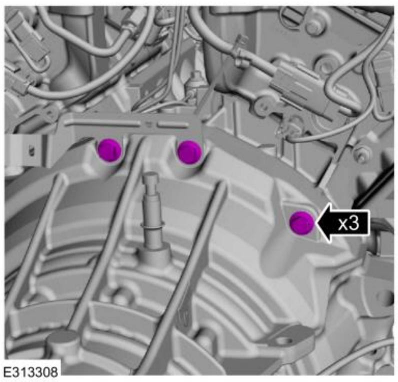
1. Remove the power steering pump if equipped.
2. Remove the oil pan bolt and stud bolt.



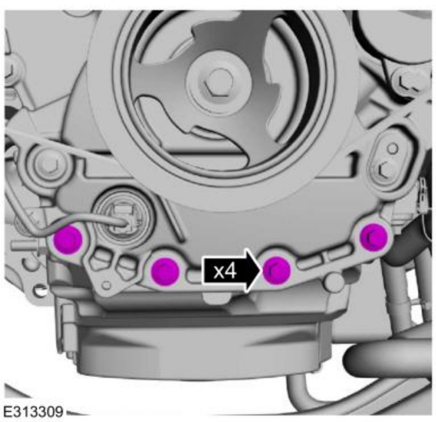


3. Loosen the flywheel/bellhousing bolts.

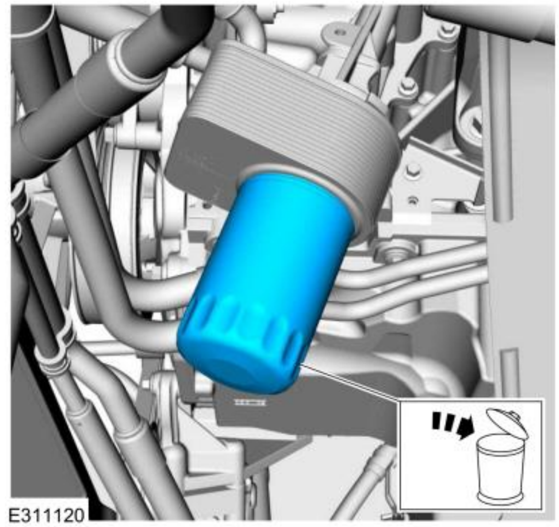




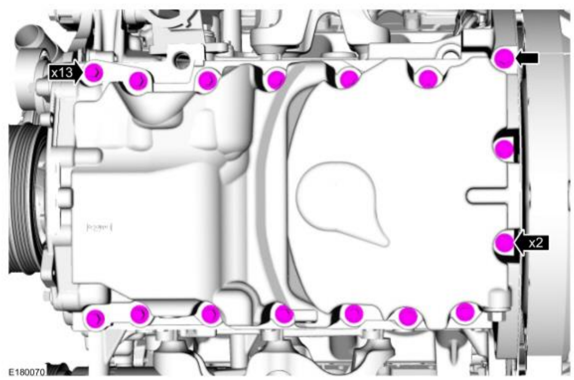
4. Remove the front cover bolts



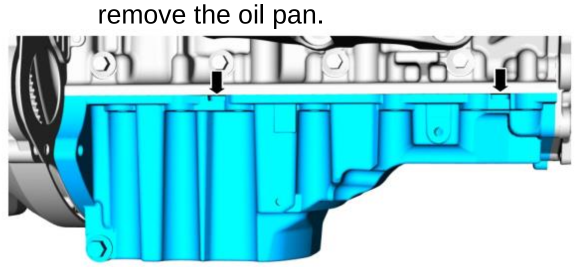
5. Remove the oil pan plug and drain the engine oil. Use the General Equipment: Oil Drain Equipment
    a. Install the oil pan drain plug.
    b. *Torque* : 19 lb.ft (26 Nm)
6. *Remove and discard the engine oil filter*



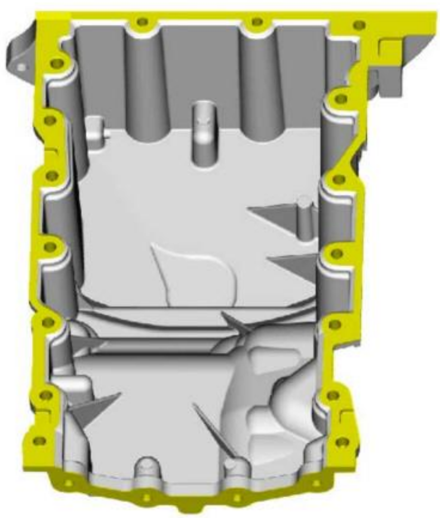
7. Remove the oil filter housing retainer and set aside.
8. Separate the flywheel housing from the engine.
9. Remove the oil pan bolts.



10. Using a pry tool on the pry pads shown, remove the oil pan.

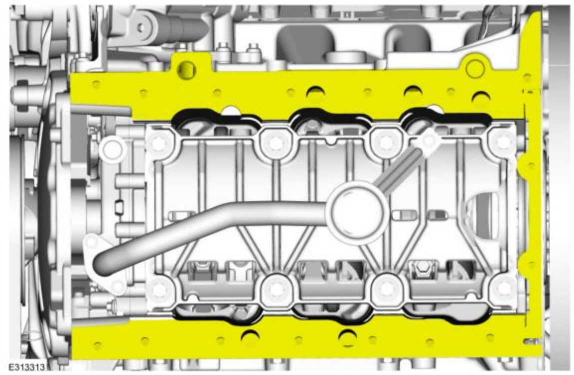


11. **NOTICE: Only use a 3M™ Roloc® Bristle Disk (2-in white, part number 07528) in a suitable tool turning at the recommended speed of 15,000 rpm, to clean the oil pan. Do not use metal scrapers, wire brushes or any other power abrasive disk to clean. These tools cause scratches and gouges that make leak paths.**
    - **a.** Make sure that the mating faces of the oil pan are clean and free of foreign material
    - **b.** *Material* : Motorcraft® Silicone Gasket Remover / ZC-30-A *Material* : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.) *Material* : Motorcraft® Metal Surface Prep / ZC-31-B. Thoroughly wash the oil pan to remove any foreign material, including any abrasive particles created during the cleaning process.



E314090

12. **NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the sealing surfaces of the engine block. These tools cause scratches and gouges that make leak paths. They also cause contamination that causes premature engine failure. Remove all traces of the gasket.**
    - **a.** Make sure that the mating faces of the engine block are clean and free of foreign material.



13. **NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the sealing surfaces of the engine block. These tools cause scratches and gouges that make leak paths. They also cause contamination that causes premature engine failure. Remove all traces of the gasket.**
    - **a.** Make sure that the mating faces of the engine front cover are clean and free of foreign material.

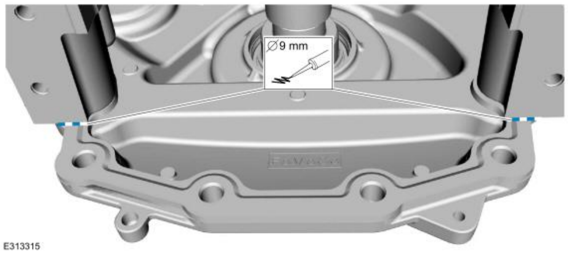
E313314

Oil Pan installation

NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.

1. Apply a 9 mm (0.35 in) bead of Motorcraft® High Performance Engine RTV Silicone to the 2 crankshaft engine front cover-to-cylinder block joint areas.

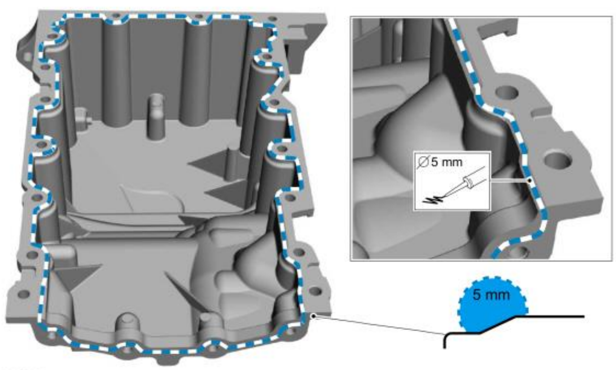
Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



E313315

2. Apply a 5 mm (0.2 in) bead of Motorcraft® High Performance Engine RTV Silicone on the chamfer, as shown.

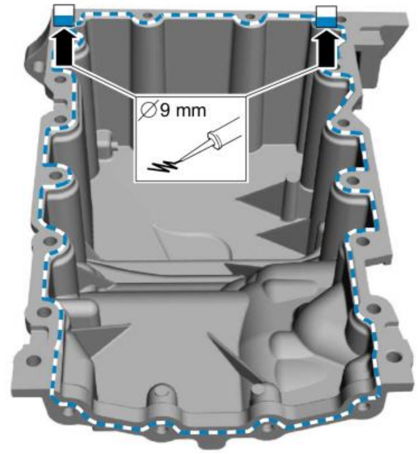
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



E313316

NOTE: *The oil pan and the specified bolts must be installed and the oil pan aligned to the cylinder block within 4 minutes of sealant application. Final tightening of the oil pan bolts must be carried out within 60 minutes of sealant application.*

3. Apply a 9 mm (0.21 in) bead of Motorcraft® High Performance Engine RTV Silicone to the 2 crankshaft seal retainer plate-to-cylinder block joint areas on the sealing surface of the oil pan.
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)

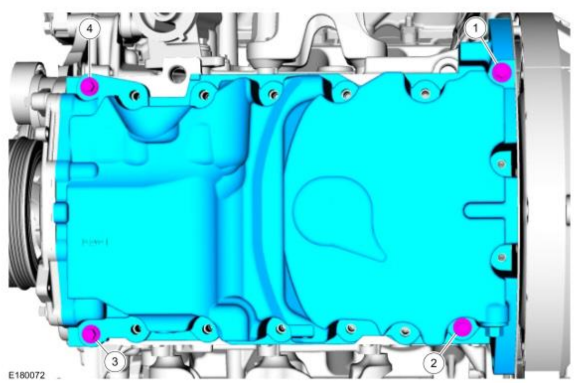


E313317

4. **NOTE:** *The oil pan and the specified bolts must be installed within 4 minutes of the start of sealant application.*

   NOTE: *Keep the oil pan as close as possible to the transmission while installing, then slide forward towards the engine front cover to prevent wiping off of the sealant.*

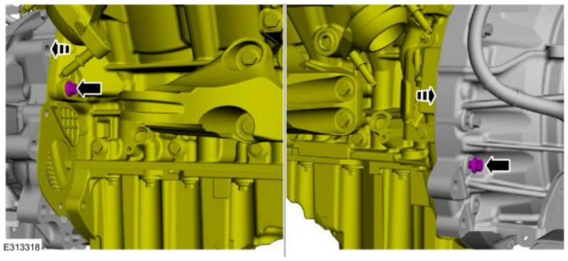
   Install the bolts finger tight.



E180072

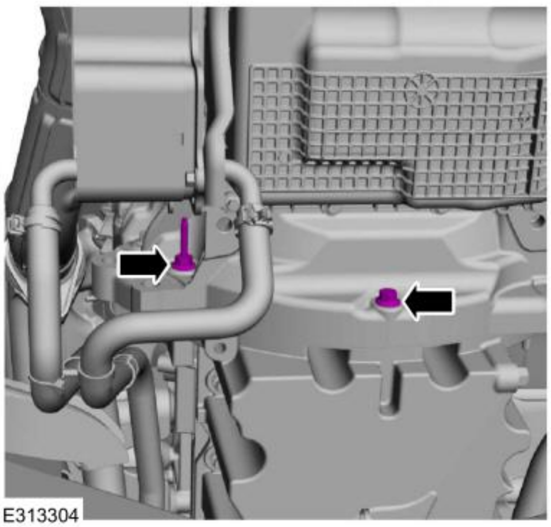
5. **NOTE:** *Do not torque at this time.*

   Draw the flywheel housing and engien together using the bolts.



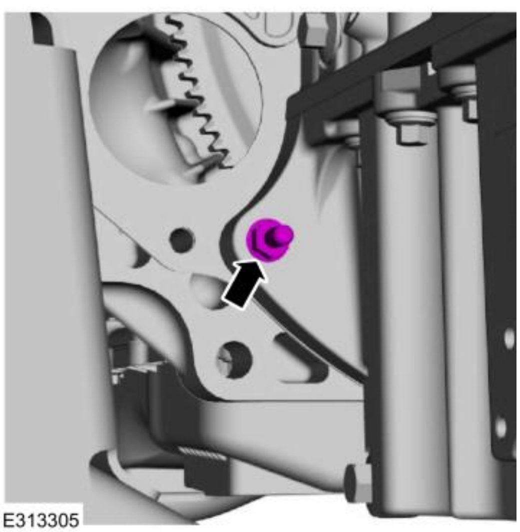
6. **NOTE:** *Do not torque at this time.*

   Install the oil pan bolt and stud bolt.

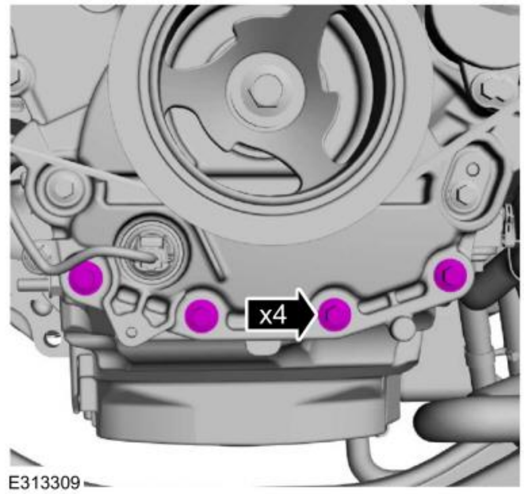


7. **NOTE:** *Do not torque at this time.*

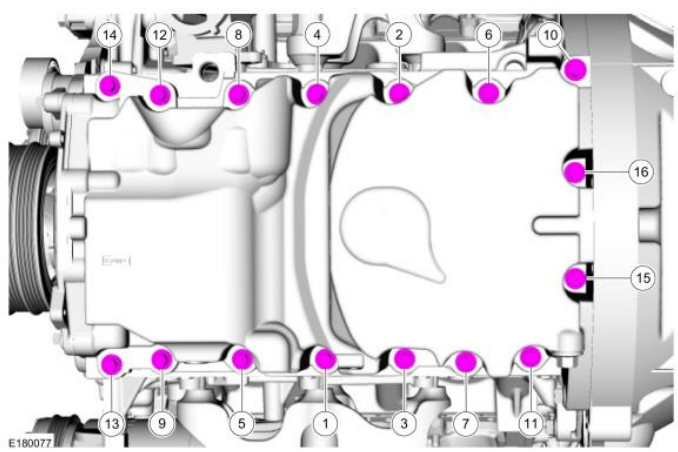
   Install the oil pan stud bolt.



8. Install the engine front cover bolts finger tight.



9. Install the remaining oil pan bolts and tighten in sequence.
   Torque :
   Stage 1: Tighten bolts 1-9 and 11-14 to: 177 lb.in (20 Nm)
   Stage 2: Tighten bolts 1-9 and 11-14 an additional: 45°
   Stage 3: Tighten bolt 10 to: 177 lb.in (20 Nm)
   Stage 4: Tighten bolt 10 to an additional: 90°
   Stage 5: Tighten bolts 15 and 16 to: 89 lb.in (10 Nm)
   Stage 6: Tighten bolts 15 and 16 an additional: 45°

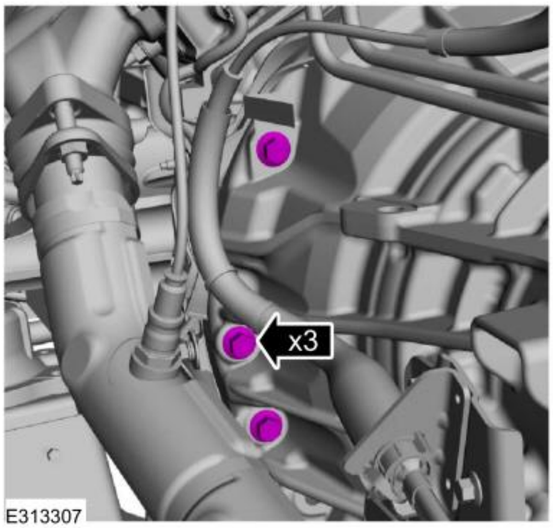


10. **NOTE:** *After the tightening sequence is completed, the W503297 (10mm Hex)*

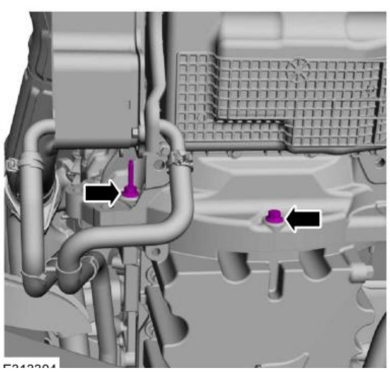
M8 x 1.25 x 35 bolt and washer will be removed to accommodate installation of the power steering pump assembly bolt.

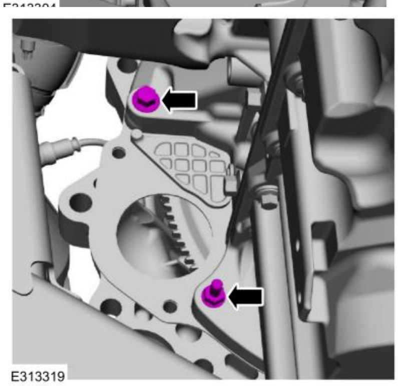
Tighten the engine front cover bolts.
Torque : 18 lb.ft (24 Nm)

11. Tighten the oil pan and bellhousing bolts.
Torque : 35 lb.ft (48 Nm)

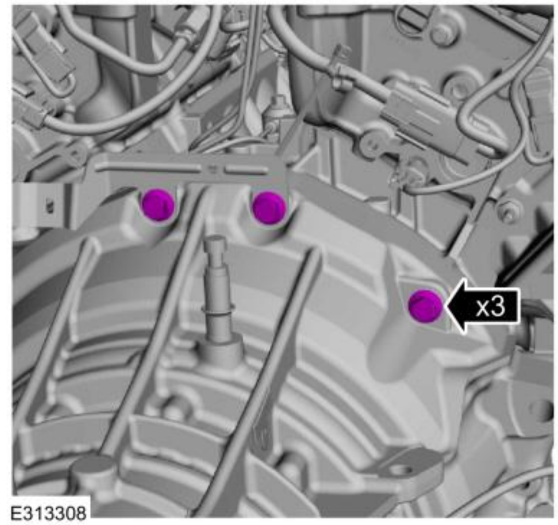


12. Tighten the oil pan and bellhousing bolts.
Torque : 35 lb.ft (48 Nm)





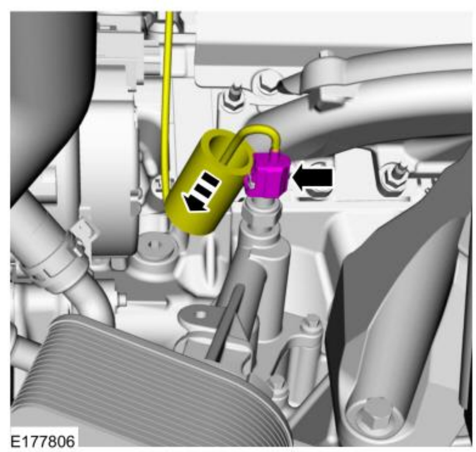
13. Tighten the bellhousing bolts.
Torque : 35 lb.ft (48 Nm)



14. Reinstall all other components that were taken off during the removal stage.

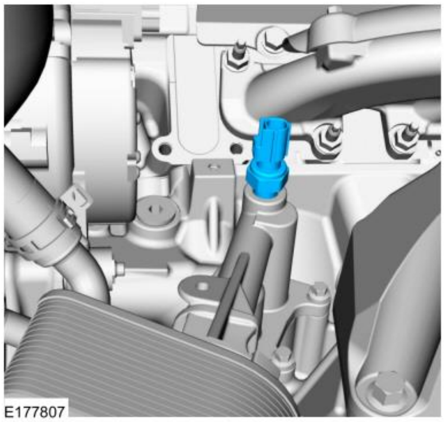
Oil Pressure Switch Removal and Install

1. Slide the insulator off and disconnect oil pressure switch electrical connector.



2. Remove the oil pressure switch.

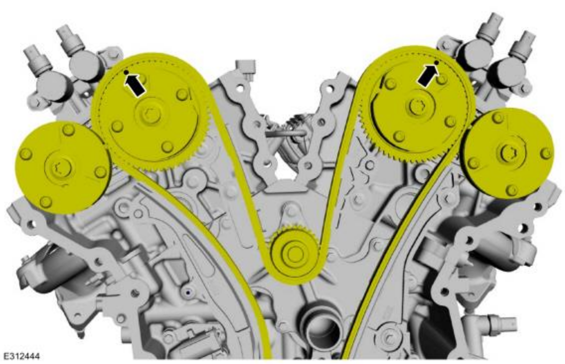
3. **NOTE:** *If the oil pressure switch is to be reused, apply thread sealant.*
Install the oil pressure switch.
Material : Thread Sealant with PTFE / TA-24-B (WSK-M2G350-A2)
    - *Torque* : 159 lb.in (18 Nm)



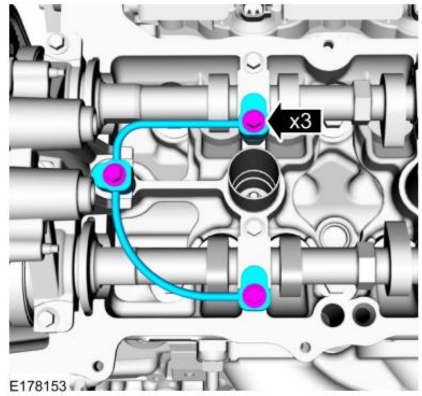
4. Connect the oil pressure switch electrical connector and slide the insulator on.

Oil Pump Removal

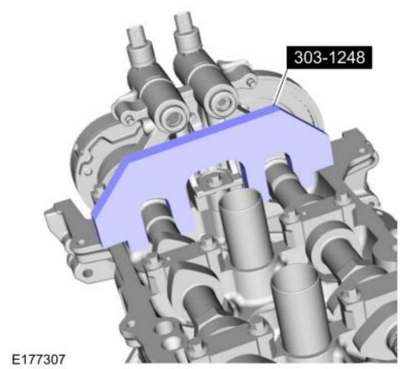
1. Remove engine from equipment
2. Remove engine front cover, page 2-10.
3. Rotate the engine in a clockwise direction only.
    a. Align the timing marks.



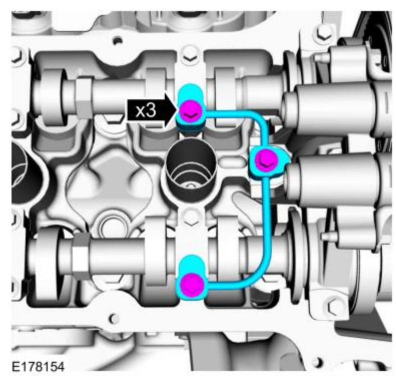
4. Remove the bolts and the LH oil tube.



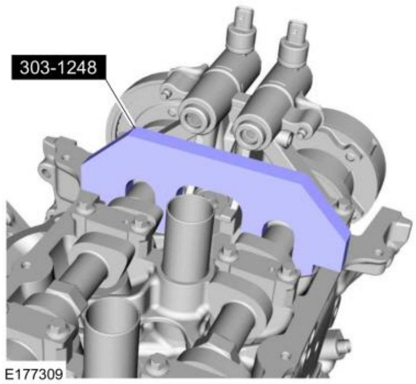
5. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position Install Special Service Tool* : 303-1248 Camshaft holding tools



6. Remove the bolts and the RH oil tube.

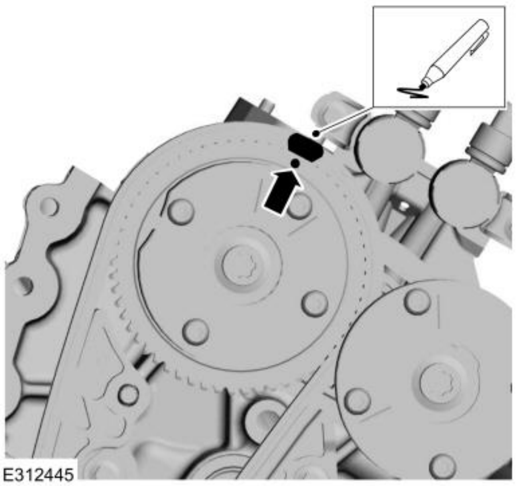


7. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position. Install Special Service Tool* : 303-1248 Camshaft holding tools.

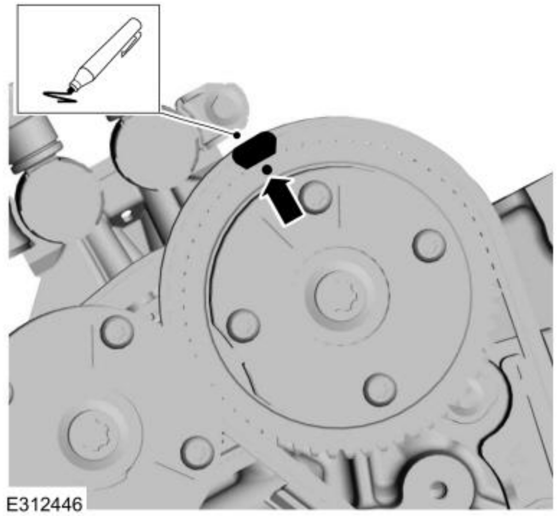


NOTE: ***The following 3 steps are for primary timing chains that the colored links are not visible.***

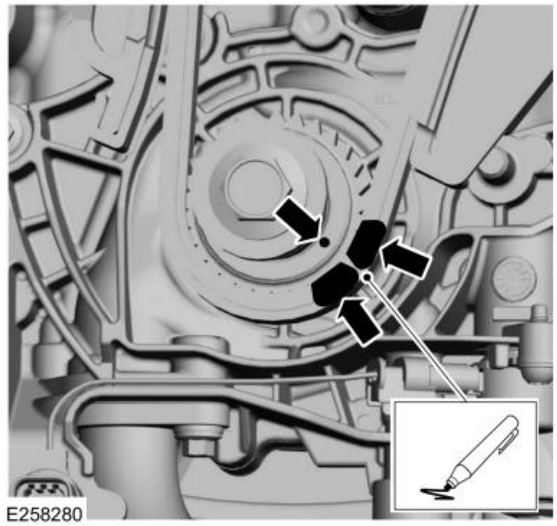
8. Mark the timing chain link that aligns with the timing mark on the LH intake VCT unit as shown.



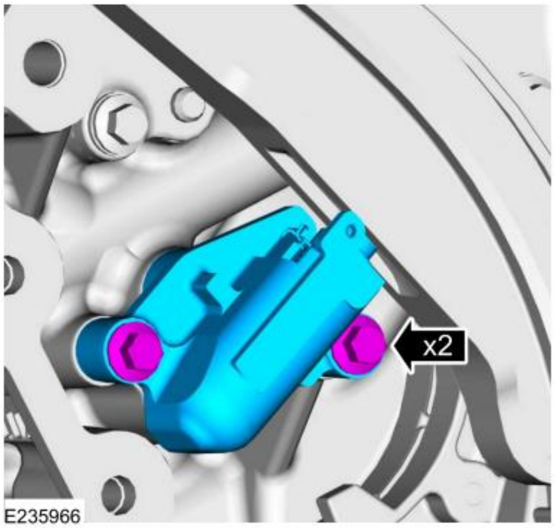
9. Mark the timing chain link that aligns with the timing mark on the RH intake VCT unit as shown.



10. **NOTE:** *The crankshaft sprocket timing mark should be between the 2 colored links.*
    Mark the timing chain links that aligns with the timing mark on the crankshaft sprocket as shown.

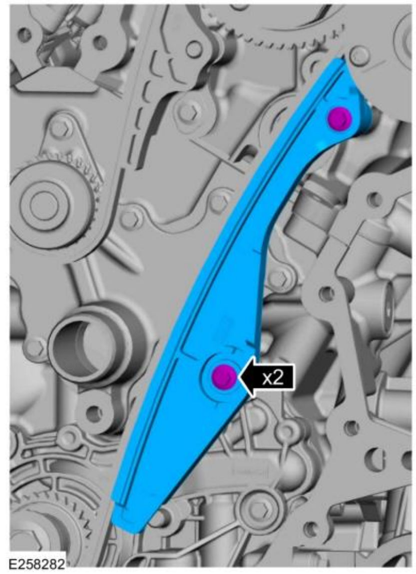


11. Remove the bolts and the timing chain tensioner.

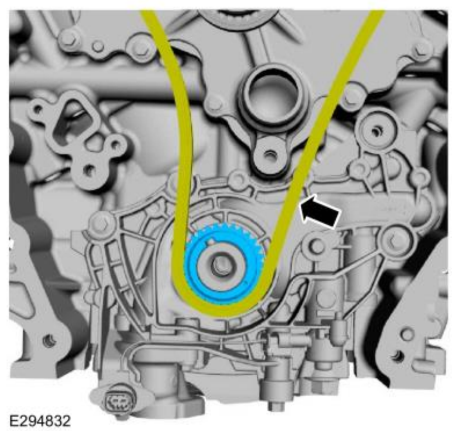


12. Remove the timing chain tensioner arm.

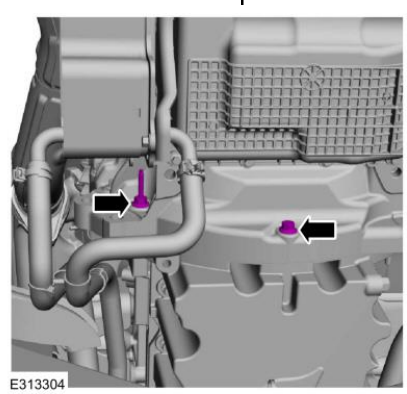
13. Remove the bolts and the lower LH timing chain guide.

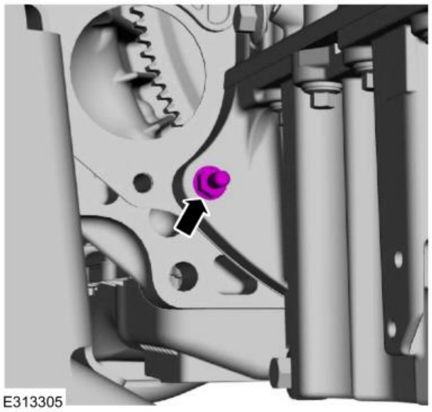


14. Position the timing chain aside and remove the crankshaft sprocket.

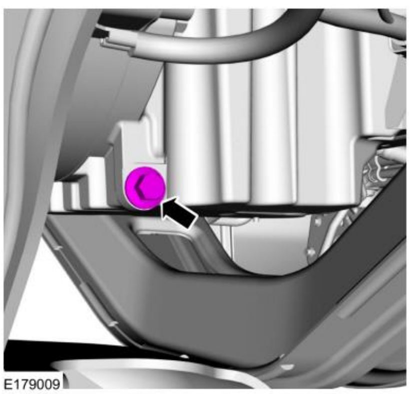


15. Remove the rear oil pan bolts.

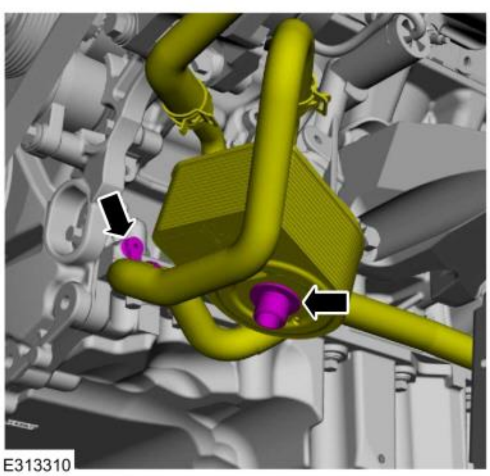



E313305

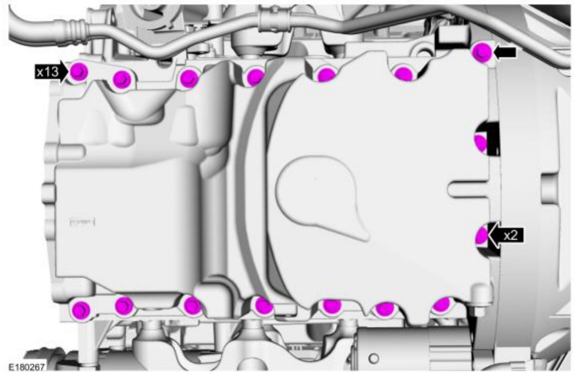
16. Remove the oil pan plug and drain the engine oil.
    a. Use the General Equipment: Oil Drain Equipment
    b. Install the oil pan drain plug.
    c. *Torque* : 19 lb.ft (26 Nm)


E179009

17. Remove and discard the engine oil filter.
18. Remove the retainer and position the oil cooler aside.

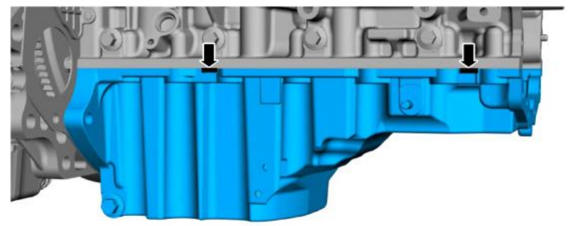

E313310

19. Remove the oil pan bolts.



E180267

20. Using a pry tool on the pry pads shown, remove the oil pan.

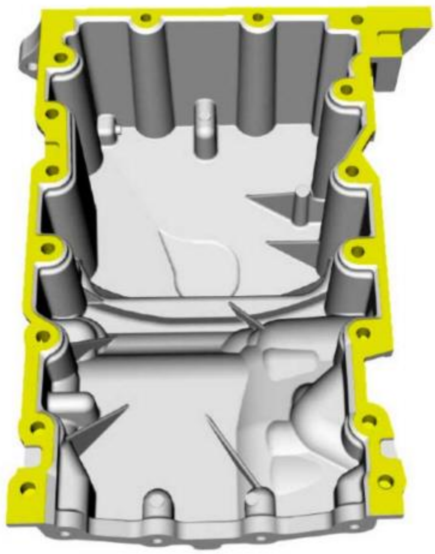

E313446

21. **NOTICE: Only use a 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the oil pan and engine front cover. Do not use metal scrapers, wire brushes or any other power abrasive disk to clean. These tools cause scratches and gouges that make leak paths.**

    Make sure that the mating faces of the oil pan are clean and free of foreign material.

    Procedures).*Material* : Motorcraft® Silicone Gasket Remover / ZC-30-A *Material* : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.) *Material* : Motorcraft® Metal Surface Prep / ZC-31-A

    Thoroughly wash the oil pan to remove any foreign material, including any abrasive particles created during the cleaning process.

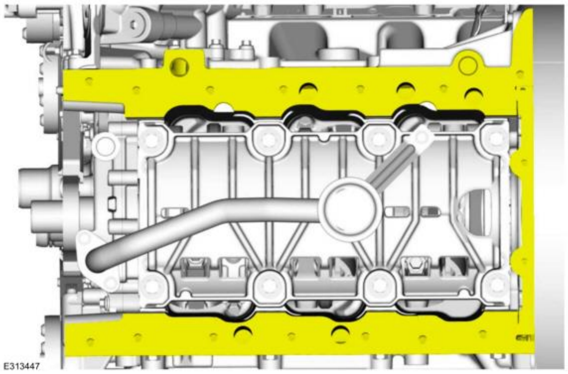


E314091

22. **NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the sealing surfaces of the engine block. These tools cause scratches and gouges that make leak paths. They also cause contamination that causes premature engine failure. Remove all traces of the gasket.**

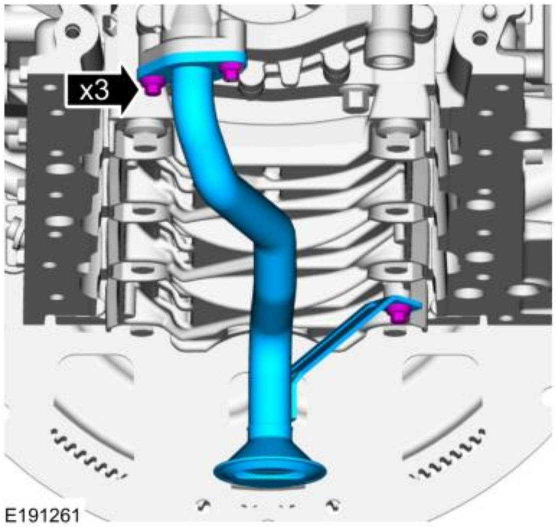
Make sure that the mating faces of the engine block are clean and free of foreign material.

Use the General Equipment: Plastic Scraper
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-A



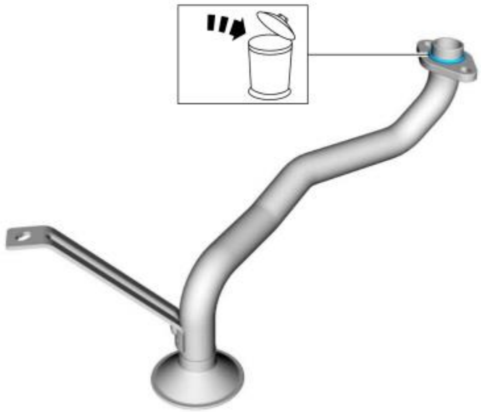
E313447

23. Remove the bolts and oil pump screen and pickup tube.



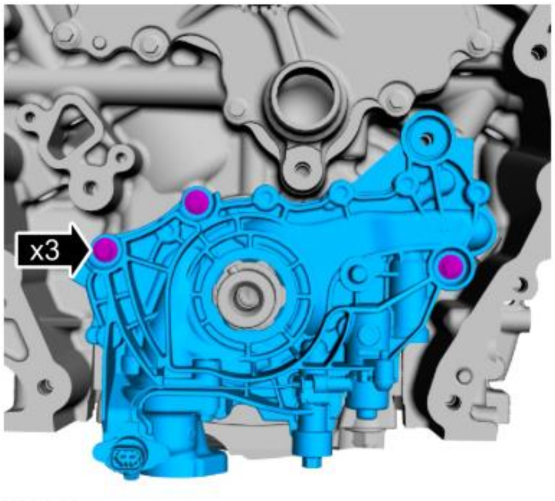
E191261

24. Remove and discard the oil pump screen and pickup tube O-ring seal.



E177322

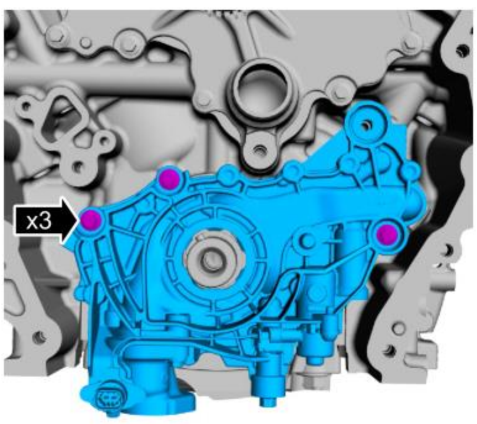
25. Remove the bolts and oil pump.



E294833

Oil Pump Installation

1. Install the oil pump and the bolts.
   a. *Torque* : 89 lb.in (10 Nm)

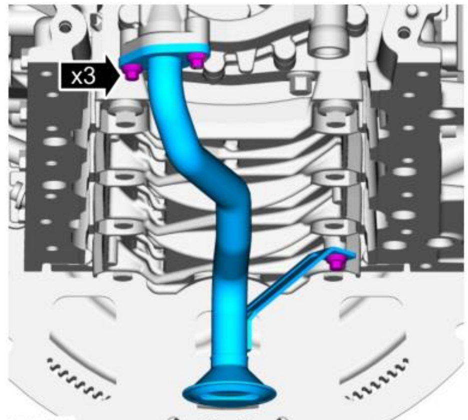


E294833

2. Install a new oil pump screen and pickup tube O-ring seal.

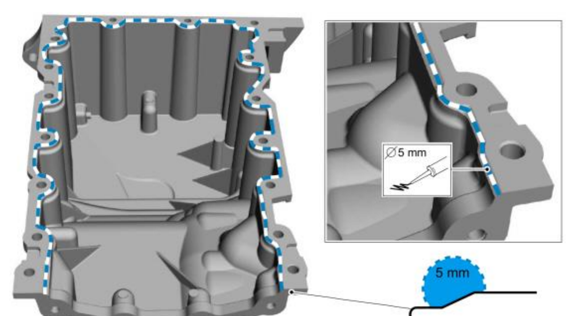

E242196

3. Install the oil pump screen and pickup tube and the bolts.
   Torque : 89 lb.in (10 Nm)



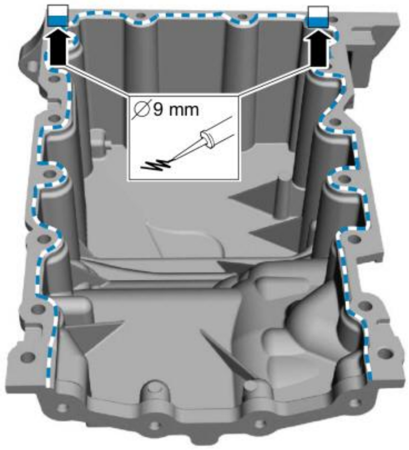
E191261

4. **NOTE:** *The oil pan and the specified bolts must be installed and the oil pan aligned to the cylinder block within 4 minutes of sealant application. Final tightening of the oil pan bolts must be carried out within 60 minutes of sealant application.*
   Apply a 5 mm (0.2 in) bead of Motorcraft® High Performance Engine RTV Silicone on the chamfer, as shown.
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



E313448

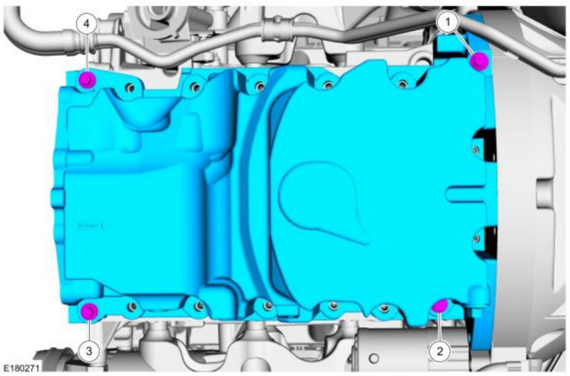
5. Apply a 9 mm (0.35 in) bead of Motorcraft® High Performance Engine RTV Silicone to the 2 crankshaft seal retainer plate-to-cylinder block joint areas on the sealing surface of the oil pan. *Material* : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



E313449

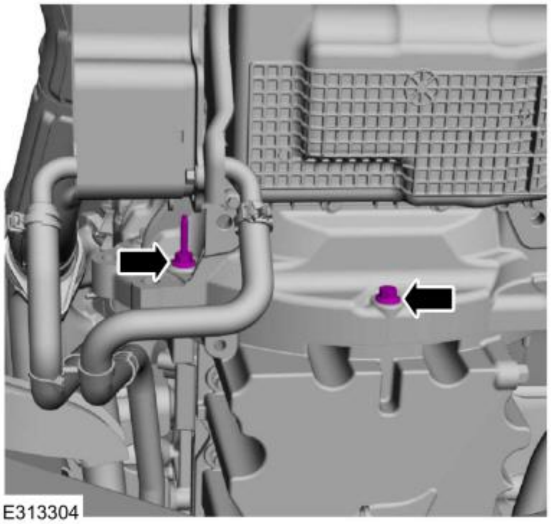
6. **NOTE:** *The oil pan and the specified bolts must be installed within 4 minutes of the start of sealant application.*

   NOTE: *Keep the oil pan as close as possible to the transmission while installing, then slide forward towards the engine front cover to prevent wiping off of the sealant.*
   Install the bolts finger tight.



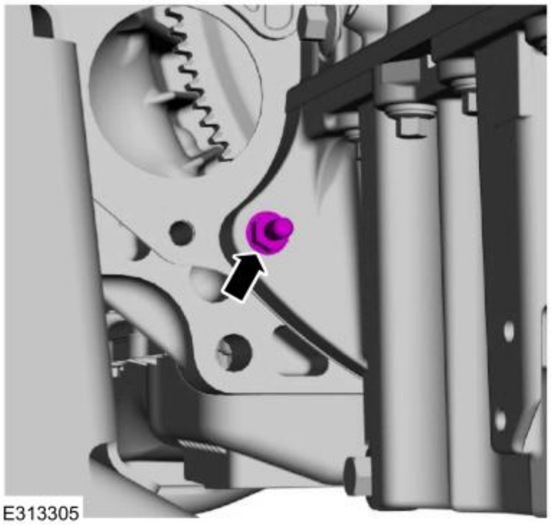
E180271

7. **NOTE:** *Do not torque at this time.*
   Install the oil pan bolt and stud bolt.



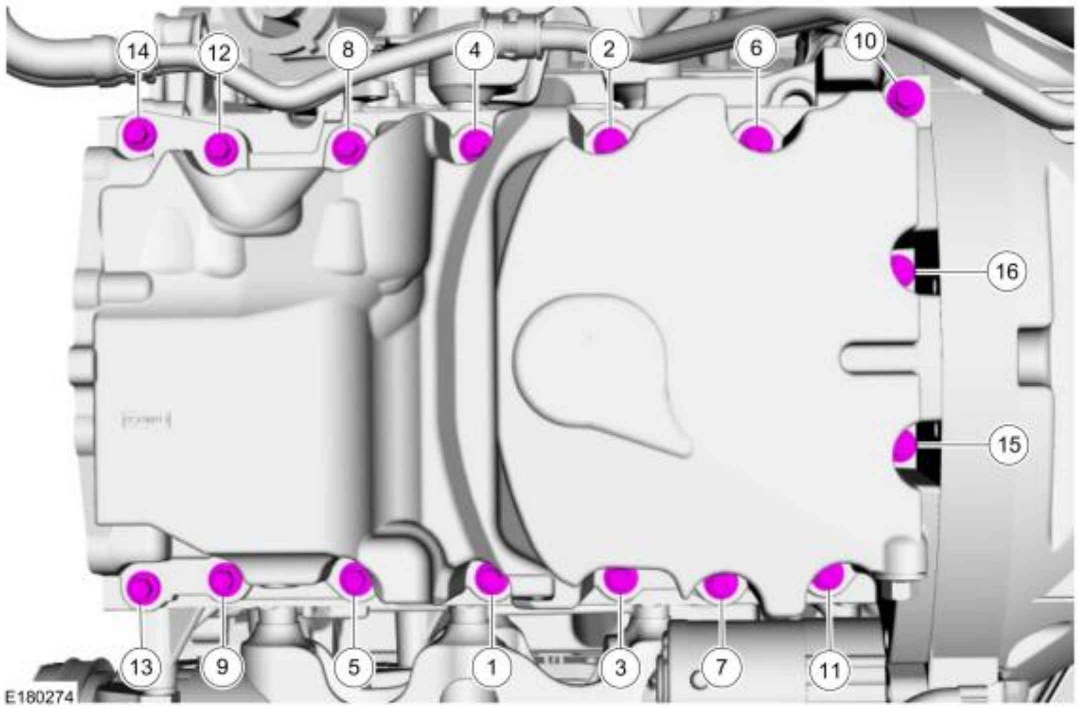
E313304

8. Install the oil pan stud bolt.



E313305

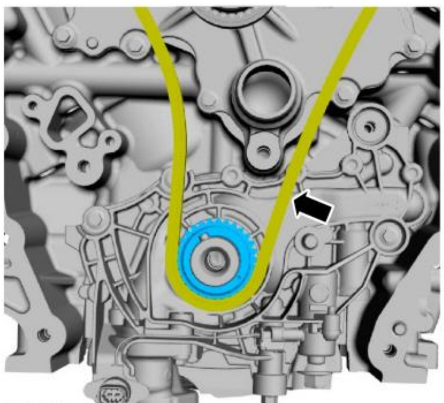
9. Install the remaining oil pan bolts and tighten in sequence.
   Torque :
   Stage 1: Tighten bolts 1-9 and 11-14 to: 177 lb.in (20 Nm)
   Stage 2: Tighten bolts 1-9 and 11-14 an additional: 45°
   Stage 3: Tighten bolt 10 to: 177 lb.in (20 Nm)
   Stage 4: Tighten bolt 10 an additional: 90°
   Stage 5: Tighten bolts 15 and 16 to: 89 lb.in (10 Nm)
   Stage 6: Tighten bolts 15 and 16 an additional: 45°



10. Tighten the oil pan bolt and stud bolt.
    a. *Torque:* 35 lb.ft (48Nm)

11. Tighten the oil pan stud bolt.
    a. *Torque:* 35 lb.ft (48Nm)
12. Install new oil filter.
    a. *Torque:*
    Stage 1: Install to initial gasket contact
    Stage 2: Tighten ¾ to 1 turn.

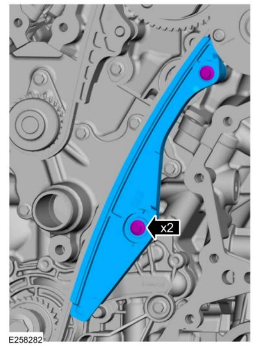
13. Install the crankshaft sprocket with the timing dot mark out.



E294832

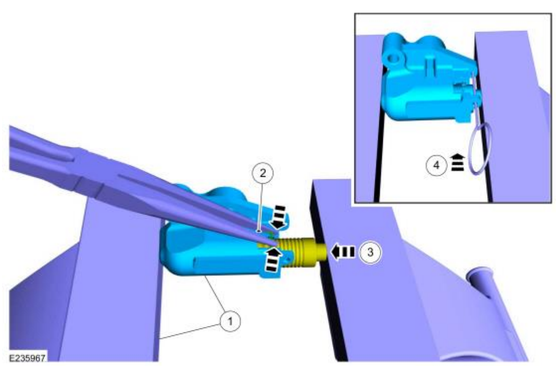
14. **NOTE:** *It may be necessary to rotate the camshafts slightly, to align the timing marks.*
    Install the timing chain with the colored links aligned with the timing marks on the VCT units and the crankshaft sprocket.

15. Install the lower LH timing chain guide and the bolts.
    Torque : 89 lb.in (10 Nm)



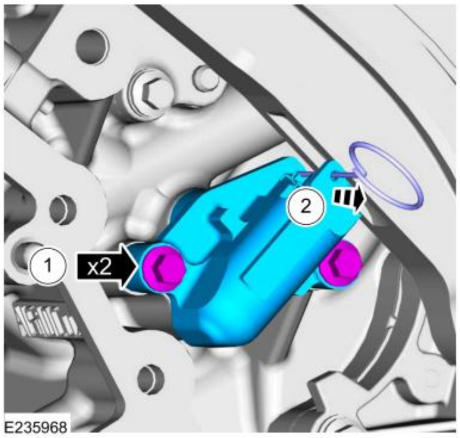
16. Install the timing chain tensioner arm.

17. Position the tensioner in a soft-jawed vise. Using pliers, squeeze the ends of the ratchet wire clip together. Using the soft-jawed vise, compress the plunger to the reset position. Install a locking pin in the 2 holes of the tensioner body to hold the plunger in place.

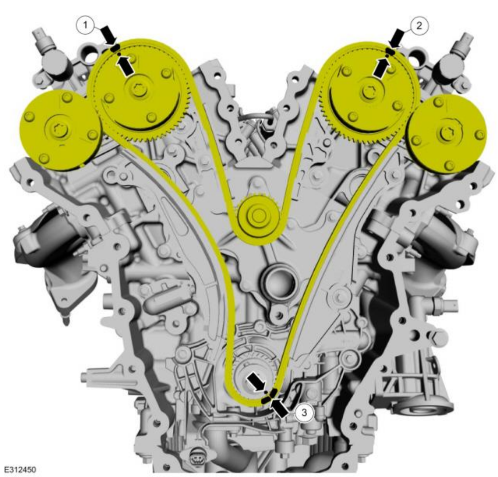


18. **NOTE:** *It may be necessary to rotate the camshafts slightly to remove slack from the timing chain to install the tensioner.*
    Install the timing chain tensioner and the bolts.

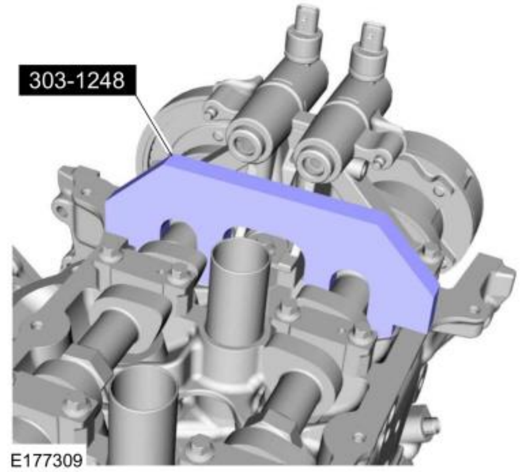
Torque : 89 lb.in (10 Nm)
Remove the lockpin.



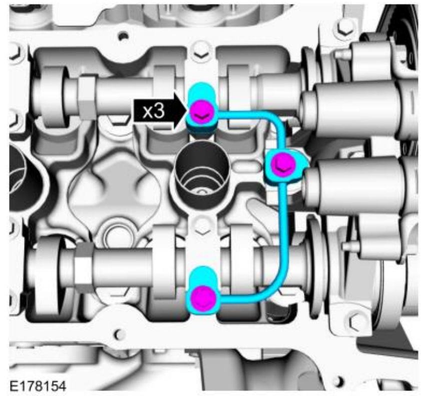
19. As a post-check, verify correct alignment of all timing marks.
    a. There are 48 links in between the RH intake VVT unit colored link (1) and the LH intake VVT unit colored link (2).
    b. There are 35 links in between LH intake VVT unit colored link (2) and the crankshaft sprocket links (3).



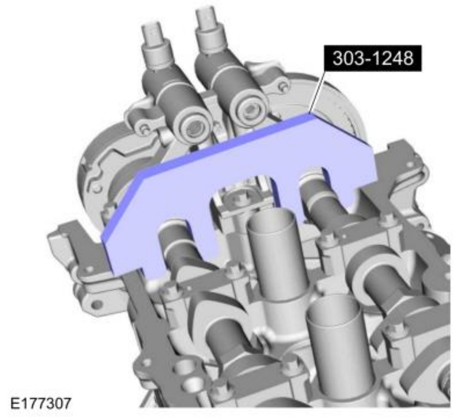
20. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



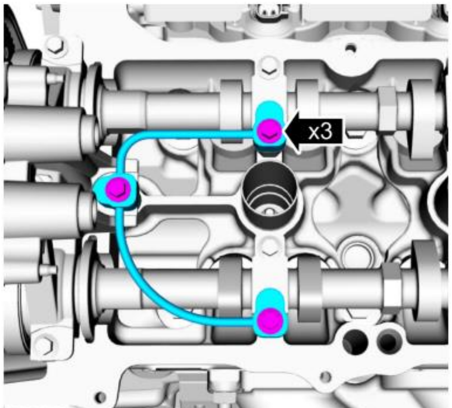
21. Install the RH oil tube and the bolts.
    Torque :
    Stage 1: 71 lb.in (8 Nm)
    Stage 2: 60°



22. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



23. Install the LH oil tube and the bolts.
    Torque :
    Stage 1: 71 lb.in (8 Nm)
    Stage 2: 60°

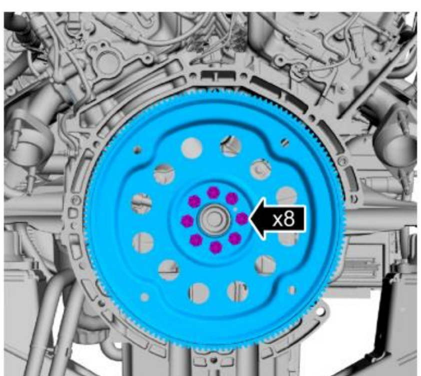


E178153

24. Install the engine front cover.
    Refer to: Engine Front Cover Installation page, 2 – 12
25. Reinstall the engine into the piece of equipment and connect all electrical connections that were unplugged during the removal.
26. Fill with engine oil. SAE 5W-20, 6 quarts.

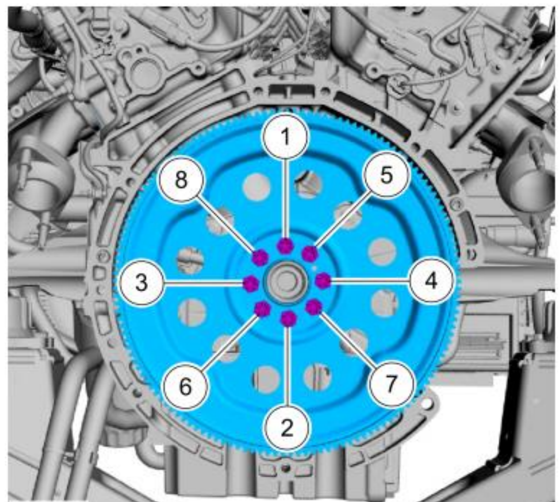
Flexplate / Flywheel Removal and Installation

1. Remove the transmission or flywheel housing.
2. Remove the bolts and flexplate/flywheel



E312155

3. **NOTE:** *One of the 8 flexplate holes are offset so the flexplate can only be installed in one position.*
    - Install the flexplate alighning it with the offset hole and hand start bolts 5, 6, 7, and 8.
    - Tighten the bolts 5, 6, 7, and 8 in sequence one turn at a time until the flexplate is snug against the rear face of the crankshaft.
    - Torque the bolts 5, 6, 7, and 8 in sequence
        - *Torque:* 59 lb.ft (80 Nm)
    - Install the bolts 1, 2, 3, and 4 finger tight.
    - Torque the bolts 1, 2, 3, and 4 in sequence.
        - *Torque:* 59 lb.ft (80 Nm)



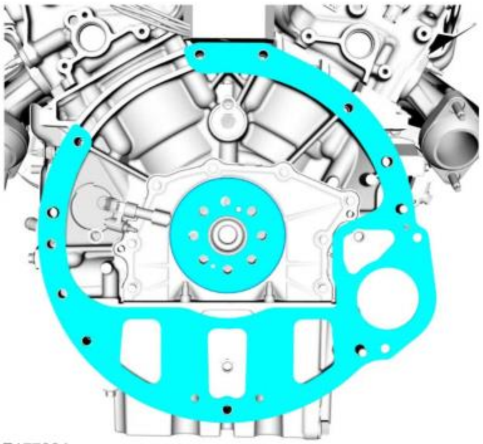
E312156

4. Install the transmission or the flywheel housing

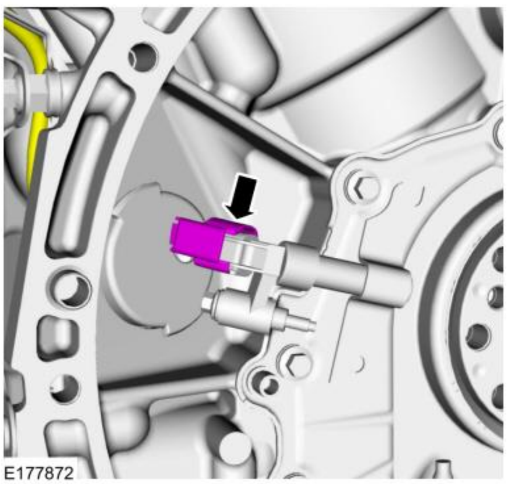
Crank Rear Seal Removal

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

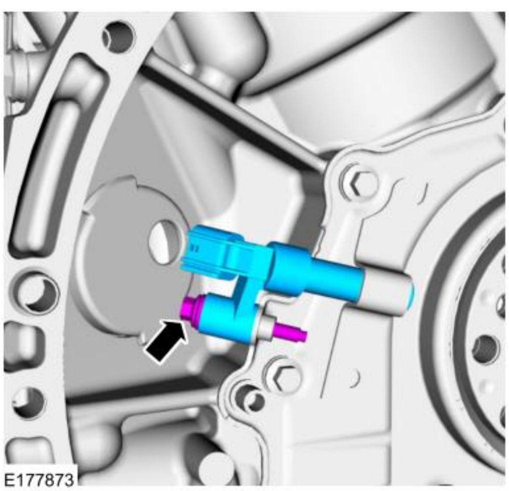
1. Remove the flexplate or flywheel, refer to previous section.
2. Remove the crankshaft sensor ring and the engine-to-transmission spacer plate.


E177224

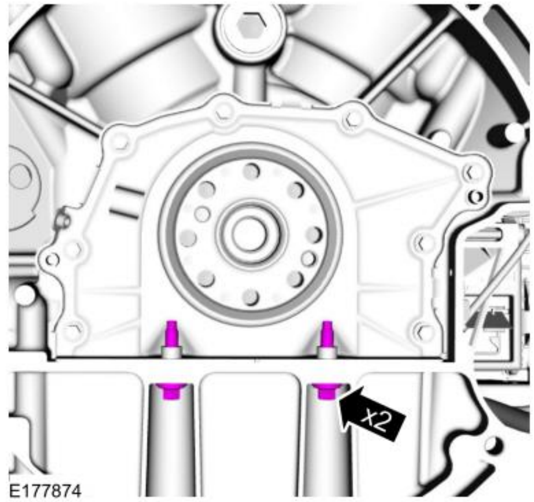
3. Disconnect the CKP sensor electrical connector.


E177872

4. Remove the bolt and the CKP sensor.

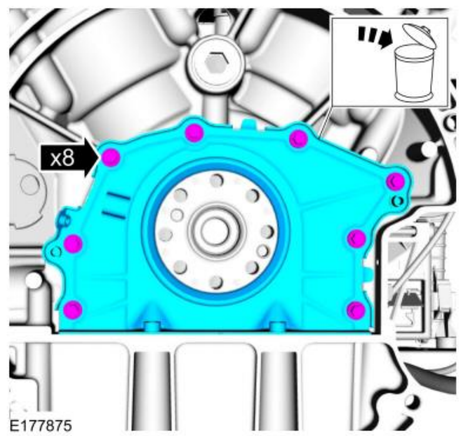

E177873

5. Remove oil pan-to-crankshaft rear seal bolts.



E177874

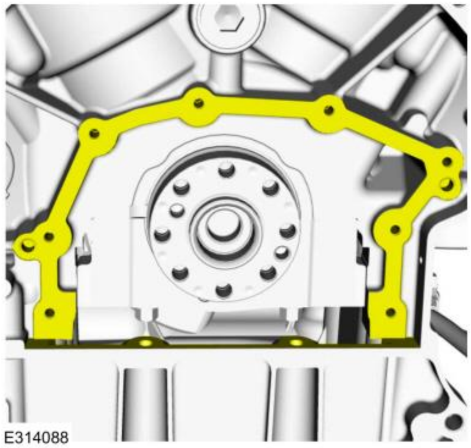
6. Remove the bolts and the crankshaft rear seal and discard the seal.



E177875

7. **NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the sealing surfaces of the engine block. These tools cause scratches and gouges that make leak paths. They also cause contamination that causes premature engine failure. Remove all traces of the gasket.**
   Make sure that the mating faces are clean and free of foreign material. Information, General Procedures).
   Use the General Equipment: Plastic Scraper
   Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
   Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)

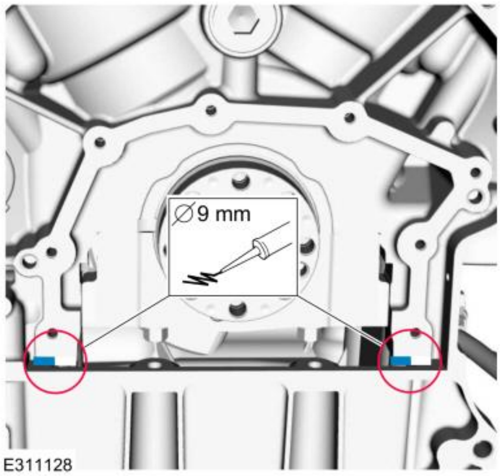
Material : Motorcraft® Metal Surface Prep / ZC-31-B



Crank Rear Seal Installation

1. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**
   NOTE: *The crankshaft rear seal retainer must be installed and the bolts tightened within 10 minutes of sealant application.*

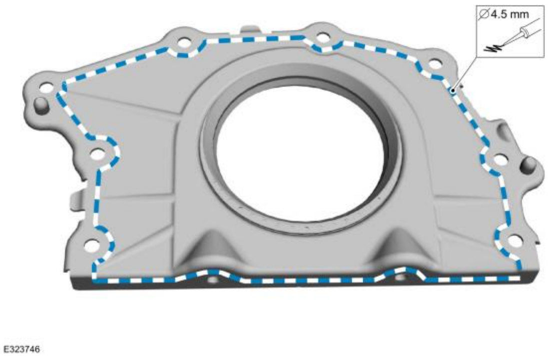
   Apply 9 mm (0.354 in) bead of silicone sealant at the T-joints.
   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



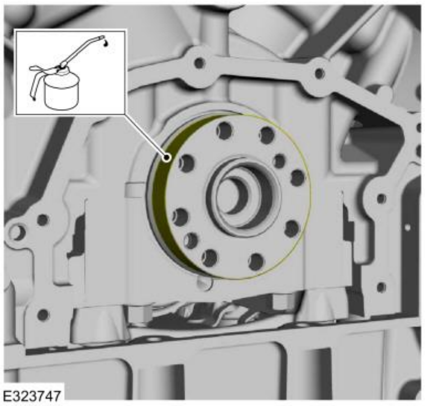
2. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**
   NOTE: *The crankshaft rear seal retainer must be installed and the bolts tightened within 10 minutes of sealant application.*

   Apply 4.5 mm (0.177 in) bead of silicone sealant

   Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)

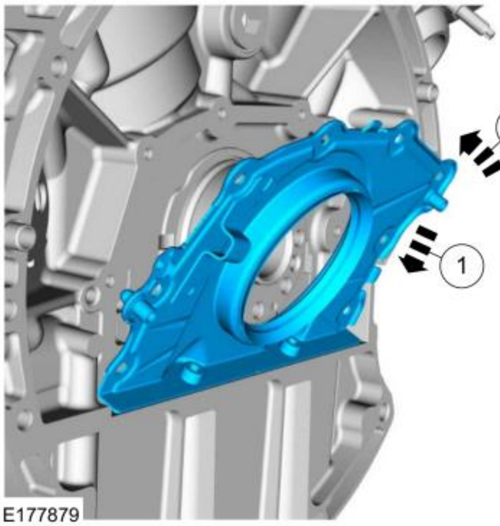


3. Lubricate the crankshaft rear seal with clean engine oil.
   Material : Motorcraft® SAE 5W-20 Premium Synthetic Blend Motor Oil (U.S.) / XO-5W20-QSP (U.S.) (WSS-M2C945-A)

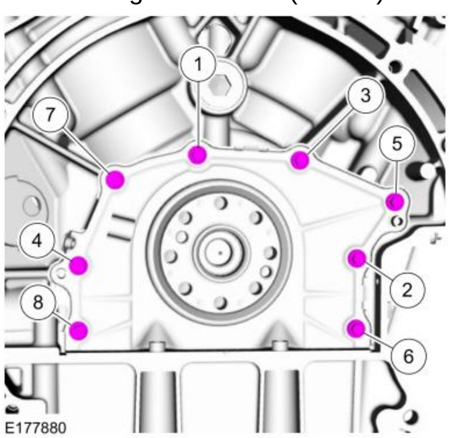


4. Installing the rear retainer
   a. Install the crankshaft rear seal retainer at an angle above the oil pan flange to avoid scraping off the sealer

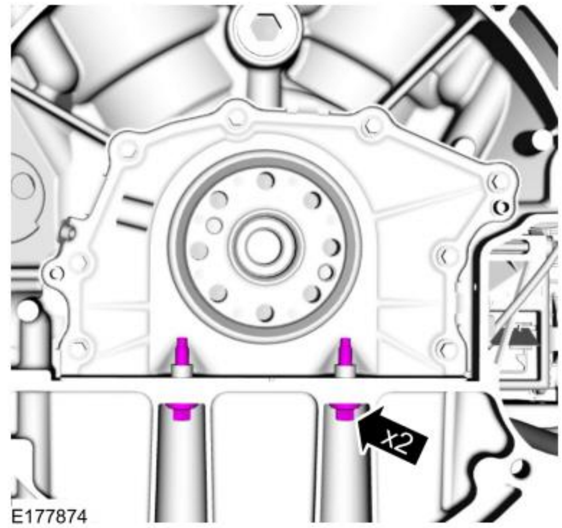
b. Tilt the seal retainer up and onto the rear of the cylinder block.



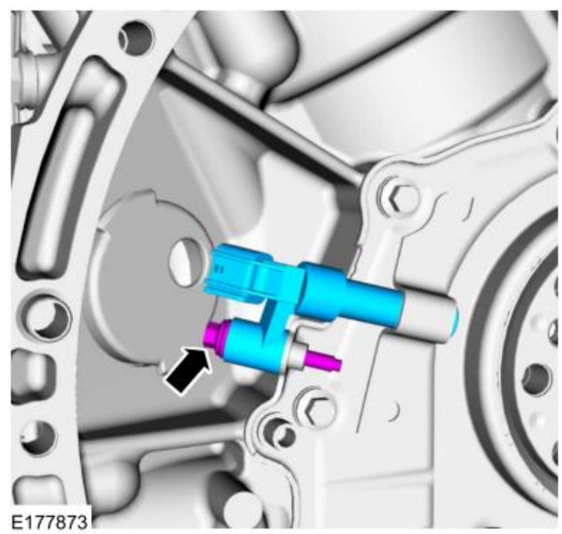
5. Install the bolts and tighten in sequence shown.
Torque :
Stage 1: 89 lb.in (10 Nm)



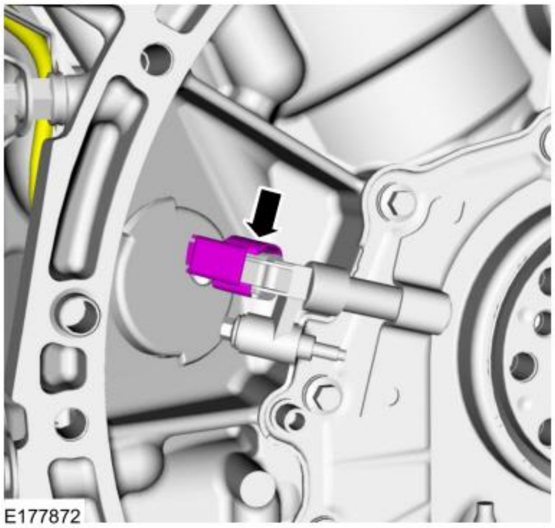
6. Install oil pan-to-crankshaft rear seal bolts.
Torque :
Stage 1: 89 lb.in (10 Nm)
Stage 2: 45°



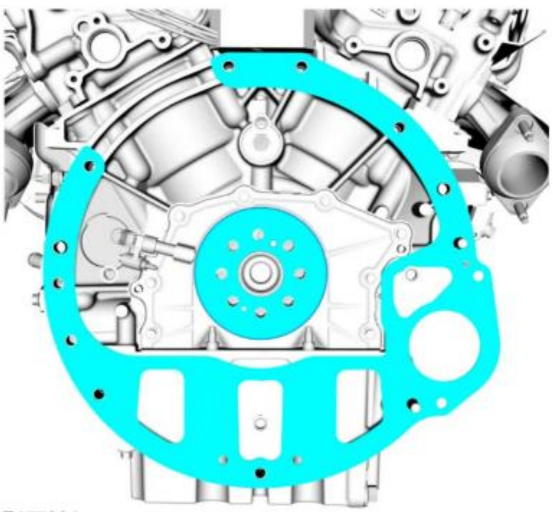
7. Install the CKP sensor and bolt.
Torque: 53 lb.in (6 Nm)



8. Connect the CKP sensor electrical connector.


E177872

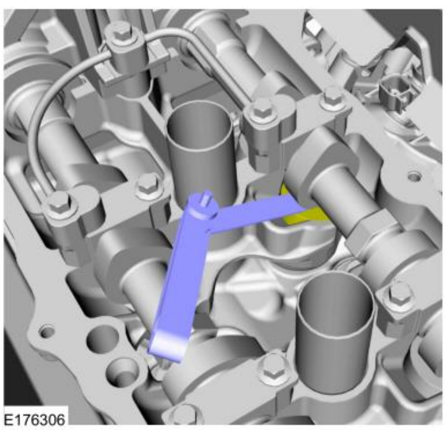
9. Install the engine-to-transmission spacer plate and the crankshaft sensor ring.


E177224

10. Install the flexplate / flywheel, see page 2- 36.

Valve Clearance Adjustment

1. Refer to valve cover LH removal and installation or valve cover RH removal and installation.
2. **NOTE:** *Engine must be at room temperature before measuring. The valve clearance must be measured with the camshaft at base circle. The engine will have to be rotated with the crankshaft pulley bolt to bring each valve to base circle.*
   a. Measure the clearance of each valve and record its location. A midrange clearance is the most desirable: Use the General Equipment: Feeler Gaug
   b. RH Intake: 0.15-0.25 mm (0.0059-0.0098 in)
   c. LH Intake: 0.18-0.28 mm (0.0071-0.110 in)
   d. Exhaust: 0.360-0.460 mm (0.01-0.02 in)



3. **NOTE:** *The number on the valve tappet reflects the thickness of the valve tappet. For example, a tappet with the number 3.310 has the thickness of 3.31 mm (0.13 in).* If any of the valve clearances are out of specification, select new tappets using this formula: tappet thickness = measured clearance + the base tappet thickness - most desirable thickness. Select the tappets and mark the installation location.
4. **NOTE:** *The following step is only necessary if adjustment is required.* Refer to: Camshafts removal and installation, next two sections.

CAMSHAFTS Removal

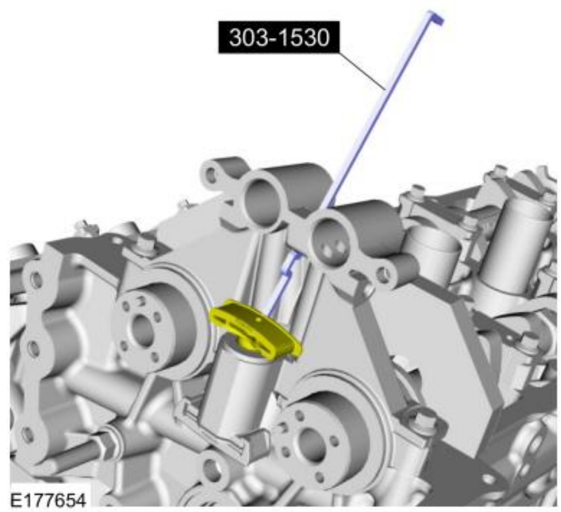
NOTICE: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces that enters the oil passages, coolant passages or the oil pan, may cause engine failure.

All camshafts

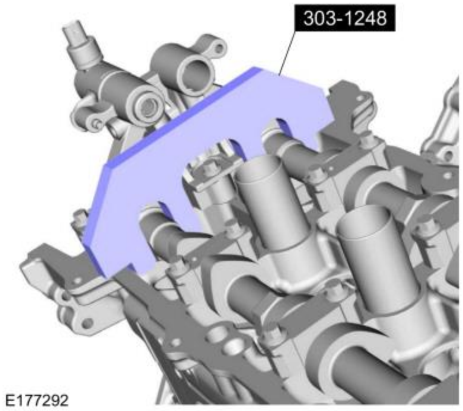
1. Remove the LH or RH VCT unit. Refer to: Variable Camshaft Timing (VCT) page 2-48.

LH camshafts

2. **NOTE:** *The VCT oil control solenoids are removed for clarity.* *Remove Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



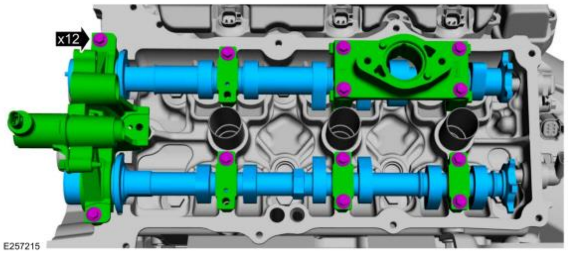
3. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



4. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in their original positions.*

   NOTE: *Mark the exhaust and intake camshafts for installation into their original locations.*

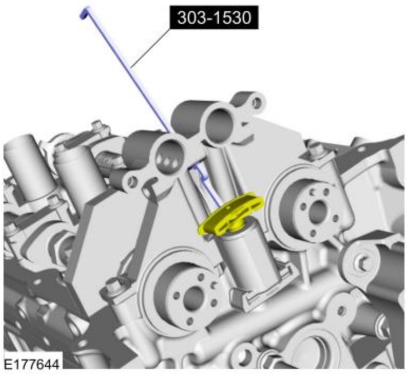
   Remove the bolts, camshaft caps and the camshafts.



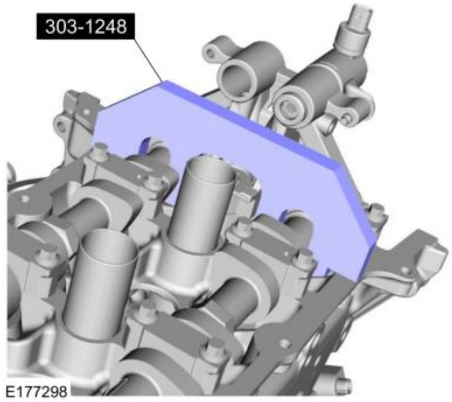
RH CAMSHAFTS

5. **NOTE:** *The VCT oil control solenoids are removed for clarity.*

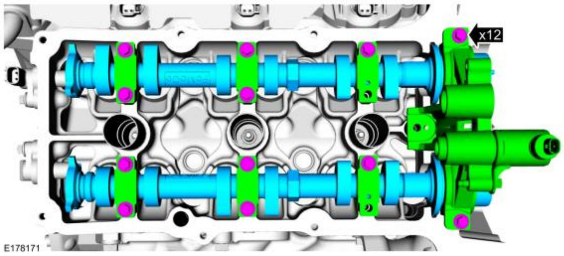
   Remove Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



6. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



7. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in theiroriginal positions.*
   NOTE: *Mark the exhaust and intake camshafts for installation into their original locations.*
   Remove the bolts, camshaft caps and the camshafts.

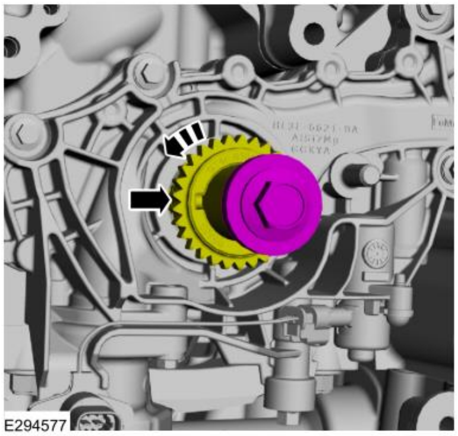


CAMSHAFT Installation

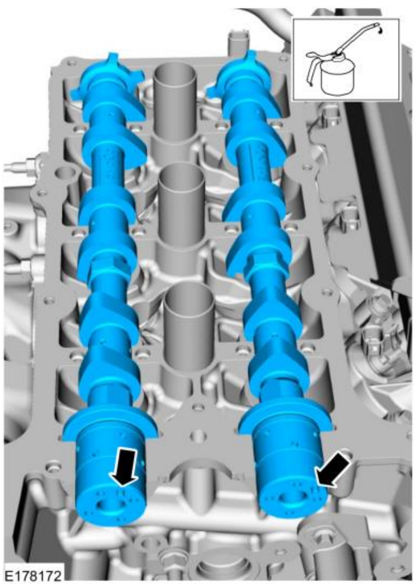
RH camshafts

1. **NOTICE: The crankshaft must remain in the freewheeling position (crankshaft dowel pin at 9 o'clock) until after the camshafts are installed and the valve clearance is checked/adjusted. Do not turn the crankshaft until instructed to do so. Failure to follow this process will result in severe engine damage.**

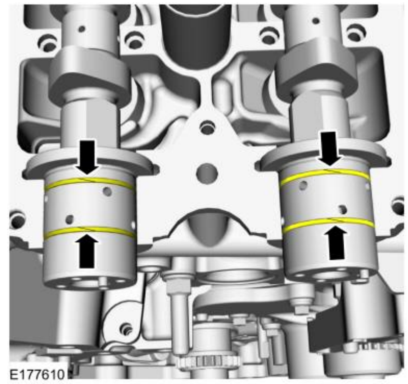
   Rotate counterclockwise to the 9 o'clock position.


E294577

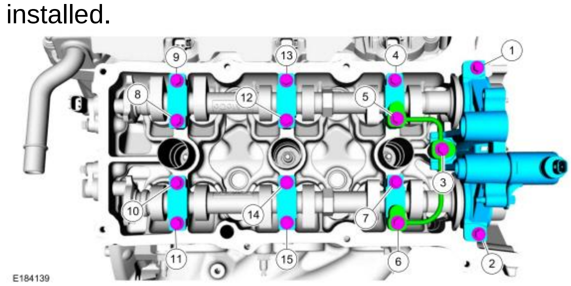
2. Lubricate the camshafts with clean engine oil and position the camshafts onto the RH cylinder head in the neutral position as shown. *Material* : Motorcraft® SAE 5W-20


E178172

3. **NOTICE: The camshaft seal gaps must be at the 12 o'clock position or damage to the engine may occur.** Position the camshaft seals gaps at 12 o'clock.

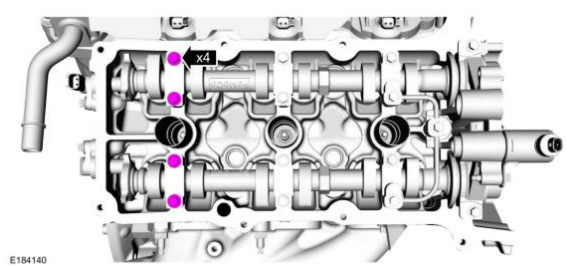

E177610

4. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in their original positions.*
Install the camshaft caps, oil tube and the bolts.
Torque :
Stage 1: Tighten bolts 1, 2, 4, 5, 6 and 7 to: 71 lb.in (8 Nm)
Stage 2: Tighten bolts 1, 2, 4, 5, 6 and 7 an additional: 45°
Stage 3: Tighten bolts 8, 9, 10, and 11 to: 71 lb.in (8 Nm)
Stage 4: Tighten bolts 12, 13, 14, and 15 to: 71 lb.in (8 Nm)
Stage 5: Tighten bolts 12, 13, 14, and 15 and additional: 45°
The camshaft torque sequence (bolt 3) will be finished after the timing chain is installed.



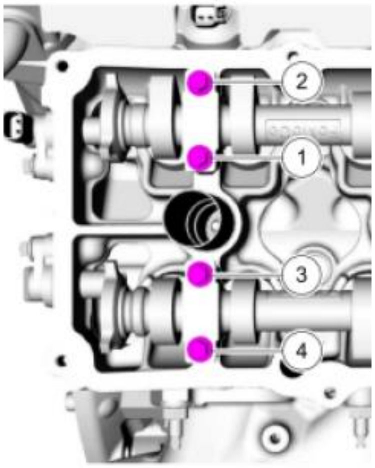
E184139

5. Loosen the camshaft cap bolts.



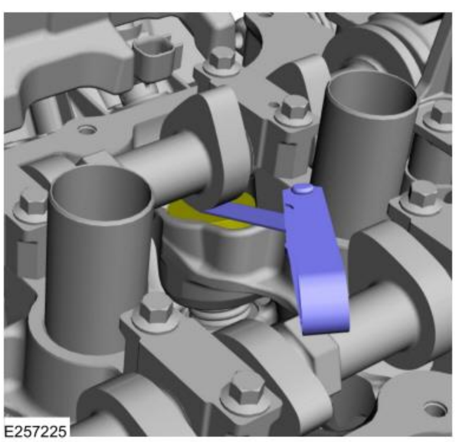
E184140

6. Tighten the camshaft cap bolts.
   Torque :
   Stage 1: 71 lb.in (8 Nm)
   Stage 2: 60°

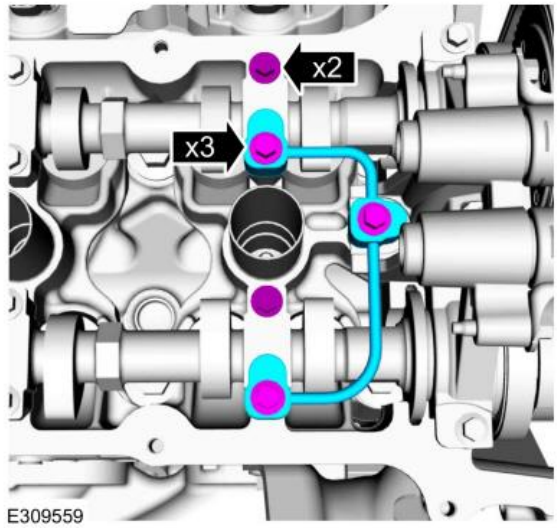


7. **NOTICE: If any components are installed new, the engine valve clearance must be checked/adjusted or engine damage may occur.**
   NOTE: *Use a camshaft sprocket bolt to turn the camshafts.*
   Confirm that the valve tappet clearances are within specification. If valve tappet clearances are not within specification, the clearance must be adjusted by installing new valve tappet(s) of the correct size.
   Refer to: Valve Clearance Adjustment (page 2-41)

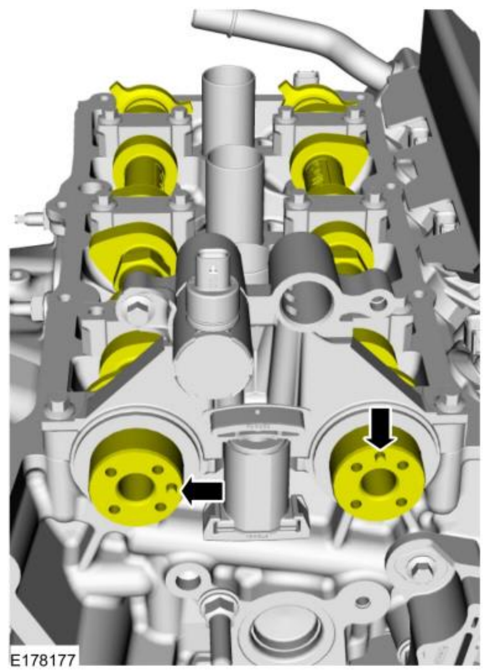
   Use the General Equipment: Feeler Gauge



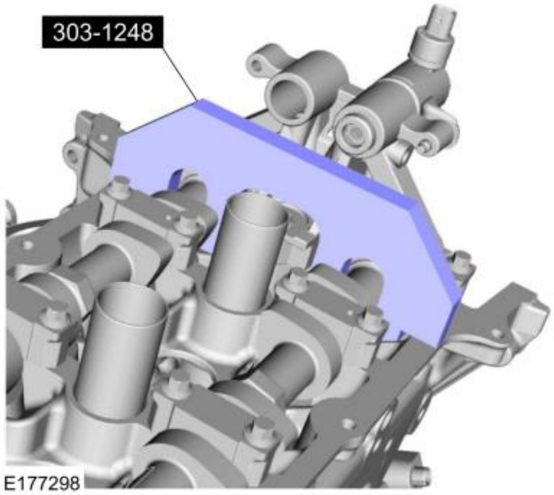
8. Remove the bolts and the RH oil tube. Loosen the 2 bolts.



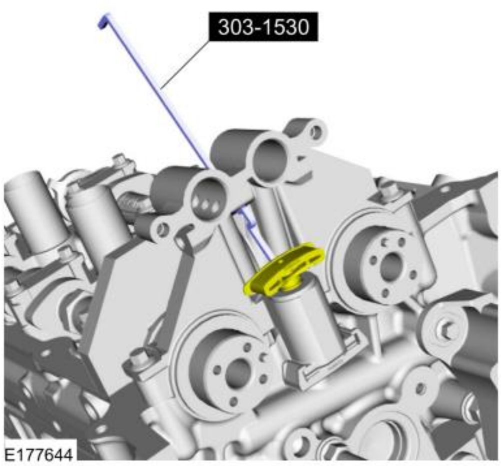
9. Rotate the RH camshafts to the TDC .



10. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position.*
    Install Special Service Tool : 303-1248 Camshaft holding tools

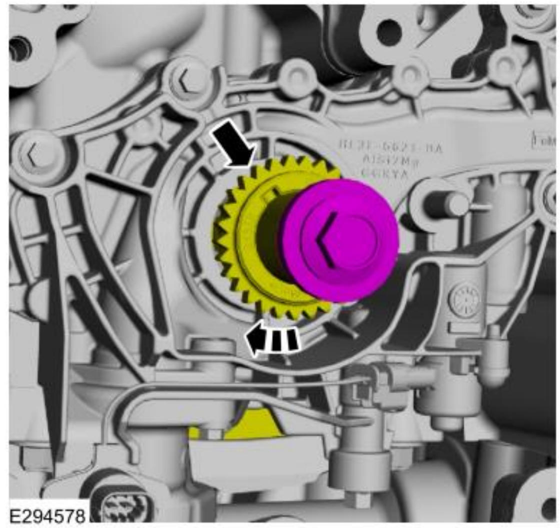


11. **NOTE:** *The VCT oil control solenoids are removed for clarity.*
    Install Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down

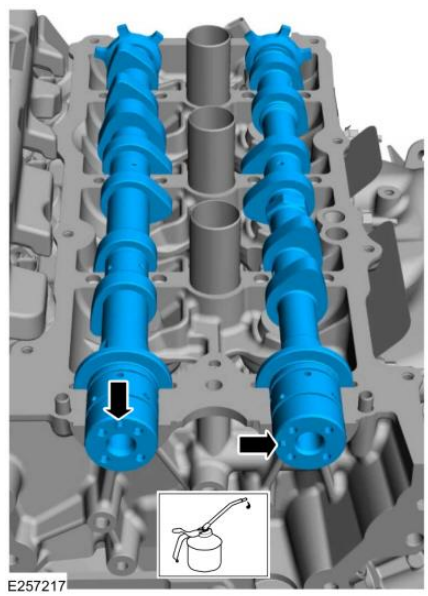


LH CAMSHAFTS

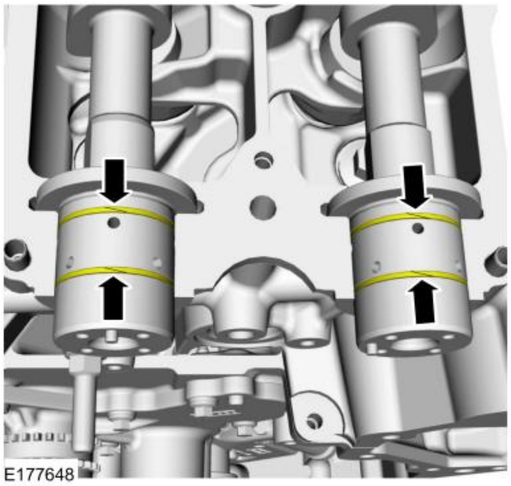
12. **NOTICE: The crankshaft must remain in the freewheeling position (crankshaft dowel pin at 9 o'clock) until after the camshafts are installed and the valve clearance is checked/adjusted. Do not turn the crankshaft until instructed to do so. Failure to follow this process will result in severe engine damage.**
    Rotate counterclockwise to the 9 o'clock position.



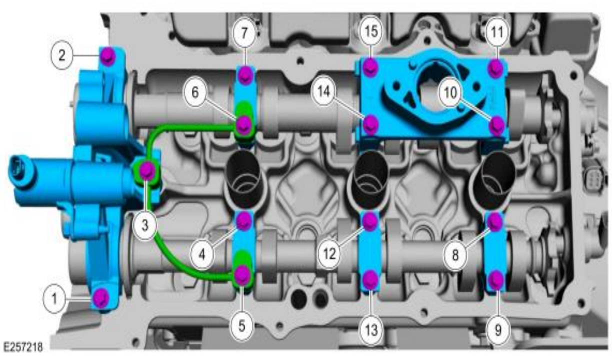
13. Lubricate the camshafts with clean engine oil and position the camshafts onto the LH cylinder head in the neutral position as shown. *Material* : Motorcraft® SAE 5W-20 Premium Synthetic Blend Motor Oil (U.S.) / XO-5W20-QSP (U.S.) (WSS-M2C960-A1)



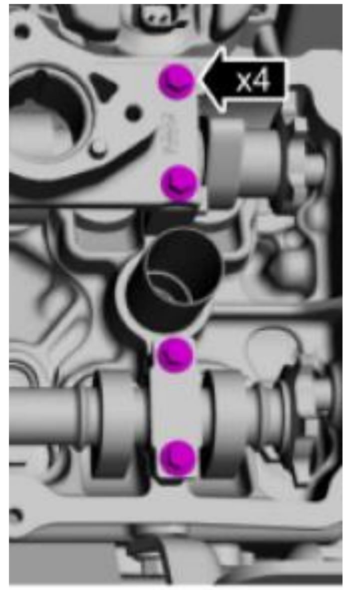
14. **NOTICE: The camshaft seal gaps must be at the 12 o'clock position or damage to the engine may occur.**
    Position the camshaft seals gaps at 12 o'clock.



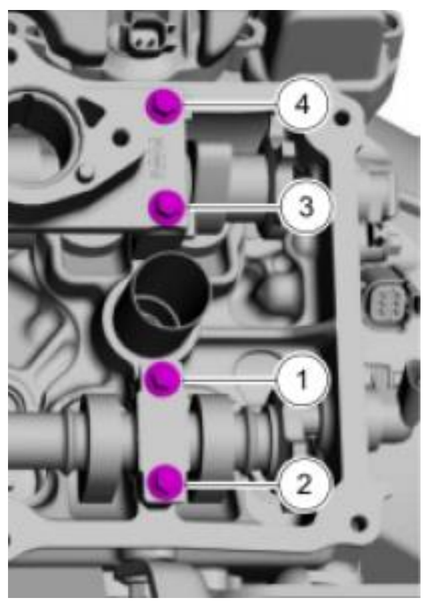
15. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in their original positions.*
Install the camshaft caps, oil tube and the bolts.
Torque:
Stage 1: Tighten bolts 1, 2, 4, 5, 6 and 7 to: 71 lb.in (8 Nm)
Stage 2: Tighten bolts 1, 2, 4, 5, 6 and 7 an additional: 45°
Stage 3: Tighten bolts 8, 9, 10 and 11 to: 71 lb.in (8 Nm)
Stage 4: Tighten bolts 12, 13, 14 and 15 to: 71 lb.in (8 Nm)
Stage 5: Tighten bolts 12, 13, 14 and 15 an additional: 45°
The camshaft torque sequence (bolt 3) will be finished after the timing chain is installed



16. Loosen the camshaft cap bolts.



17. Tighten the camshaft cap bolts in the sequence shown.
Torque :
Stage 1: 71 lb.in (8 Nm)
Stage 2: 60°

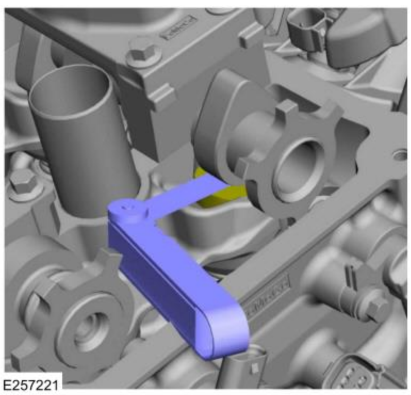


18. **NOTICE: If any components are installed new, the engine valve clearance must be checked/adjusted or engine damage may occur.**
NOTE: *Use a camshaft sprocket bolt to turn the camshafts.*

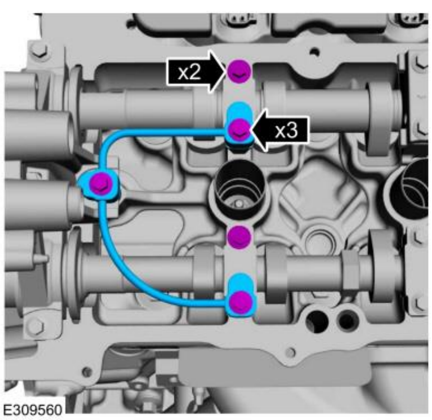
Confirm that the valve tappet clearances are within specification. If valve tappet clearances are not within specification, the clearance must be adjusted by installing new valve tappet(s) of the correct size.

Refer to: Valve Clearance Adjustment page 2-41

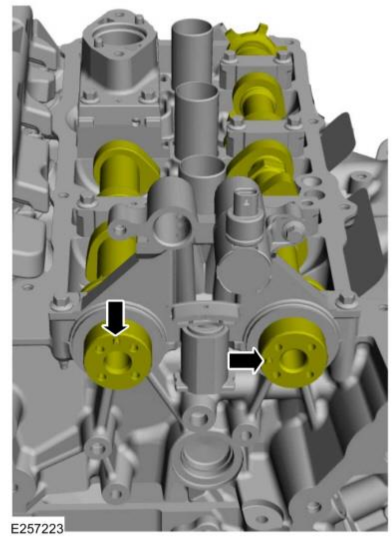
Use the General Equipment: Feeler Gauge



19. Remove bolts and the LH oil tube. Loosen the 2 bolts.

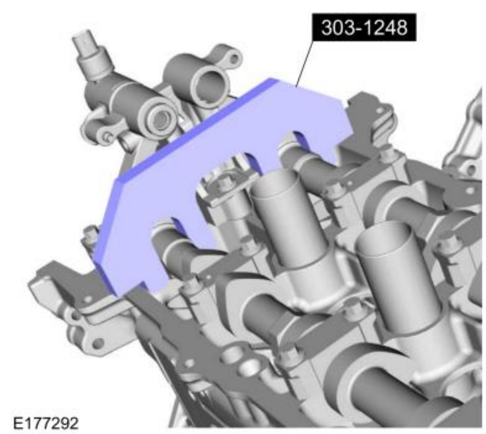


20. Rotate the LH camshafts to the TDC.

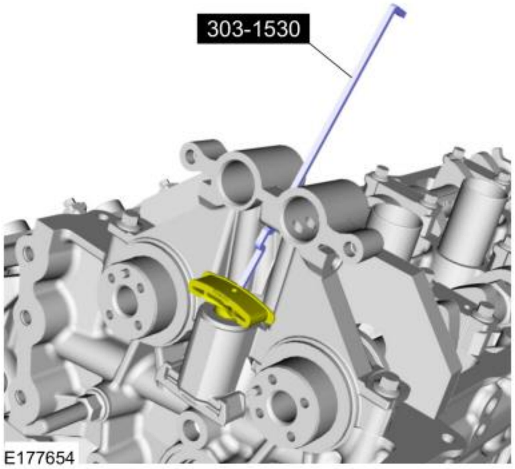


21. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position.*

    Install Special Service Tool : 303-1248 Camshaft holding tools

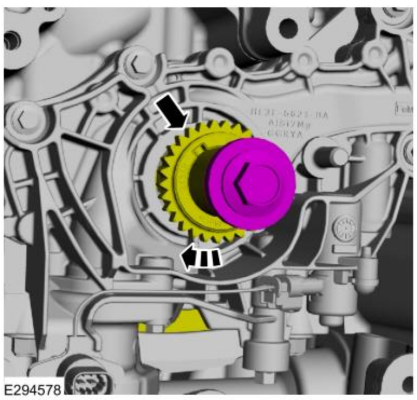


22. **NOTE:** *The VCT oil control solenoids are removed for clarity. Install Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



All camshafts

23. Rotate the crankshaft clockwise 60 degrees to the TDC position (crankshaft dowel pin at 11 o'clock).



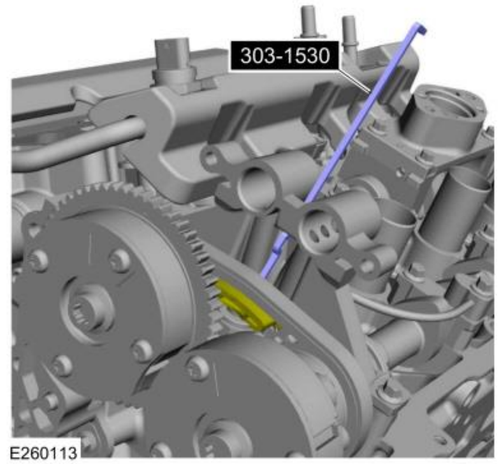
24. Install the LH or RH VCT unit. Refer to: Variable Camshaft Timing (VCT) Unit, page 2-48

Variable Camshaft Timing Solenoid (VCT/VVT) Removal

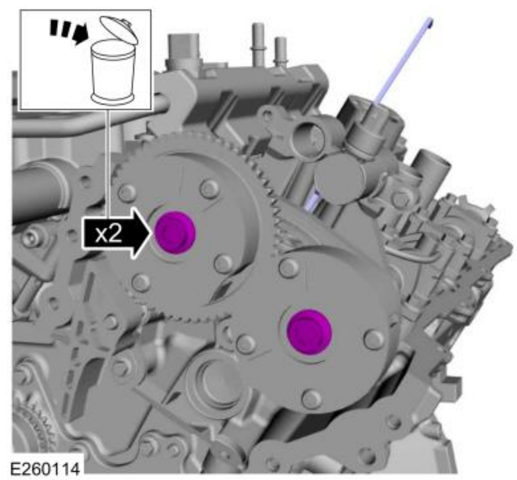
NOTICE: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces, that enters the oil passages, coolant passages or the oil pan may cause engine failure.

1. Remove the timing chain. Refer to: Timing Chain page 2-15.
2. Note: The VCT oil control solenoids are removed for clarity.

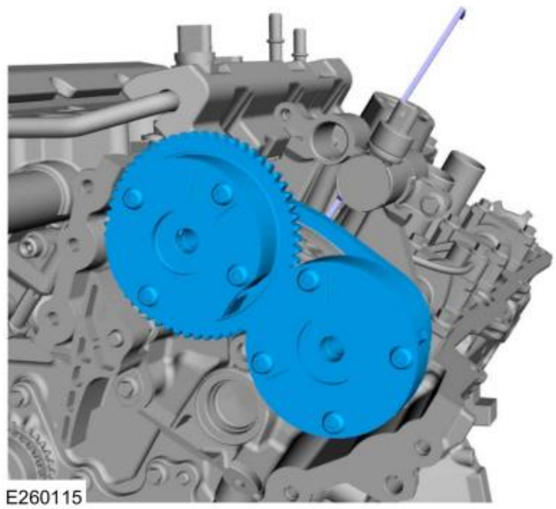
Compress the LH secondary timing chain tensioner and install the special tool in the hole on the rear of the secondary timing chain tensioner guide and let it hold against the mega cap to retain the tensioner in the collapsed position.*Use Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



3. Remove and discard the LH VCT unit bolts.



4. Remove the LH VCT units.

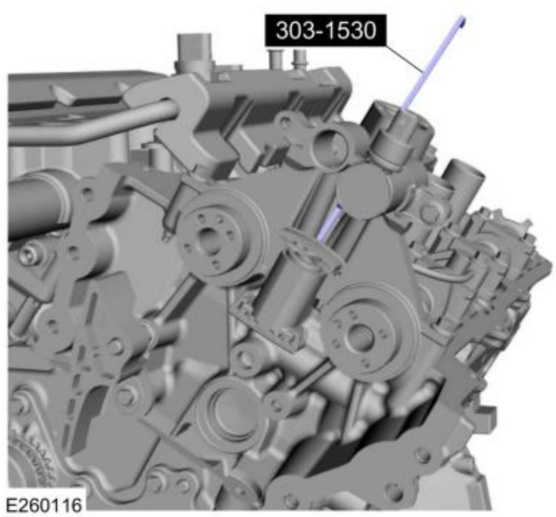


Replacement of the LH secondary timing chain tensioner

NOTICE: The following 4 steps are only for the replacement of the secondary timing chain tensioner.

Do not reuse the secondary timing chain tensioner if removed, or damage to the engine may occur.

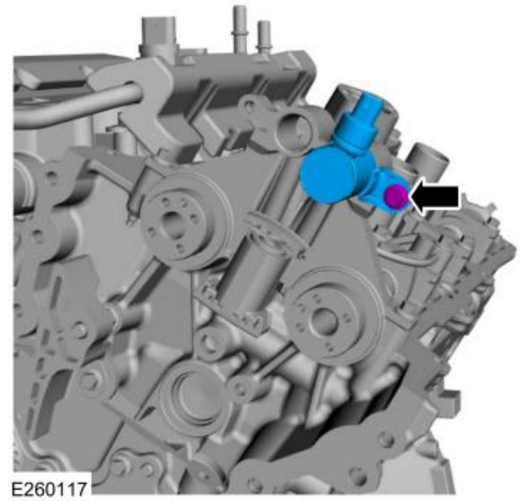
5. *Remove Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



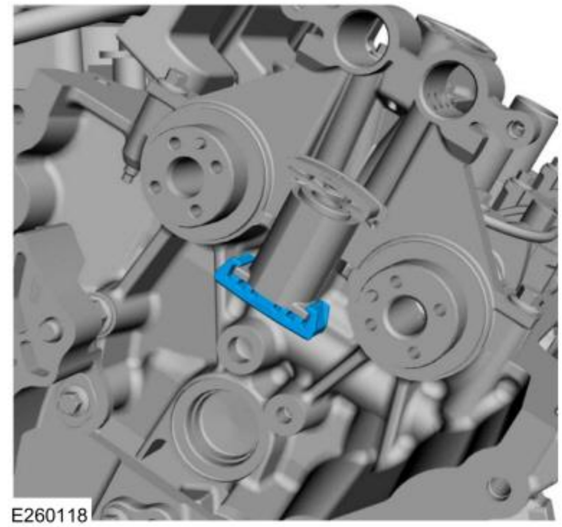
6. **NOTE:** *A slight twisting motion will aid in the removal of the VCT oil control solenoid.*

   NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.*

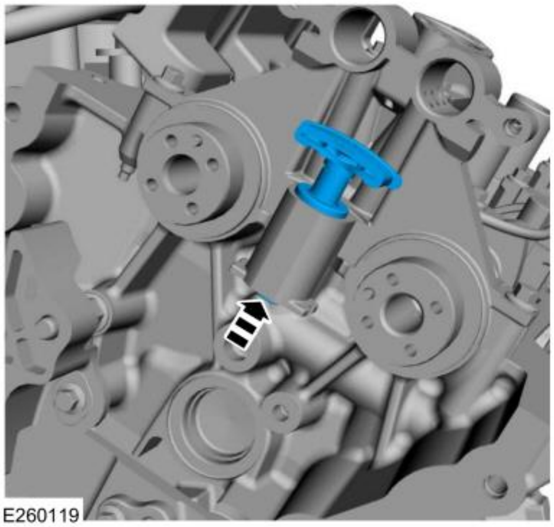
   Remove the bolt and the exhaust VCT oil control solenoid.



7. Remove the LH secondary timing chain tensioner shoe.



8. Remove the LH secondary timing chain tensioner by pushing up from the bottom.

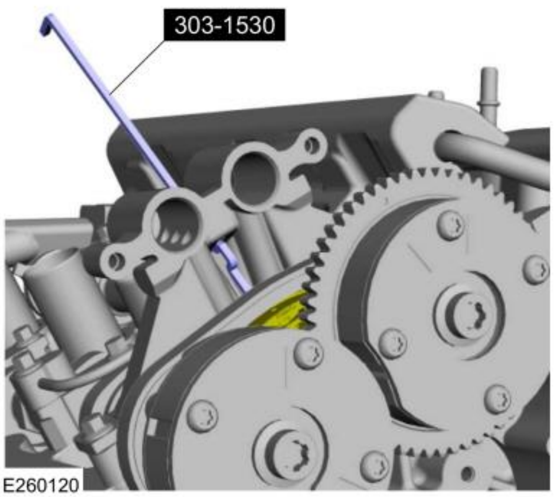


RH variable camshaft timing (VCT) unit

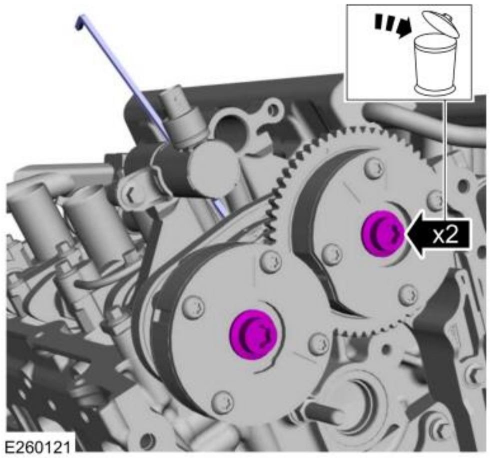
9. **NOTE:** *The VCT oil control solenoids are removed for clarity.*

   Compress the RH secondary timing chain tensioner and install the special tool in the hole on the rear of the secondary timing chain tensioner guide and let it hold against the mega cap to retain the tensioner in the collapsed position.

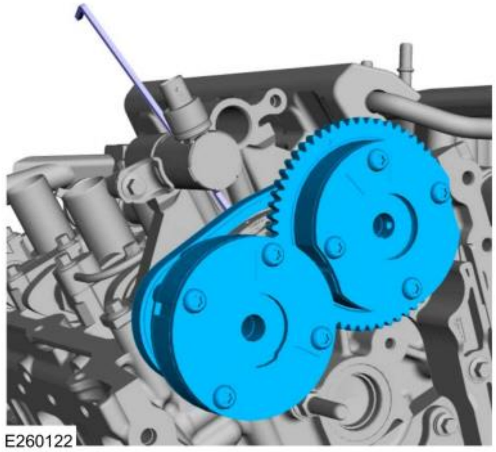
   Use Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



10. Remove and discard the RH VCT unit bolts.



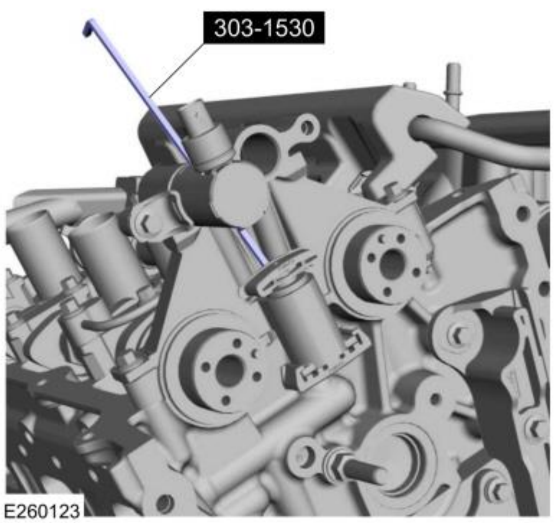
11. Remove the RH VCT units.



Replacement of the RH secondary timing chain tensioner

NOTICE: The following 4 steps are only for the replacement of the secondary timing chain tensioners. Do not reuse the secondary timing chain tensioners if removed, or damage to the engine may occur.

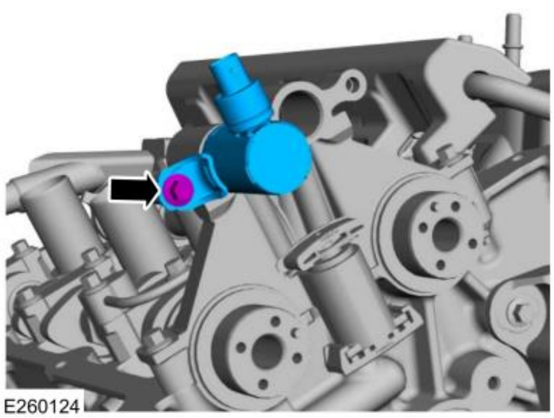
12. *Remove Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



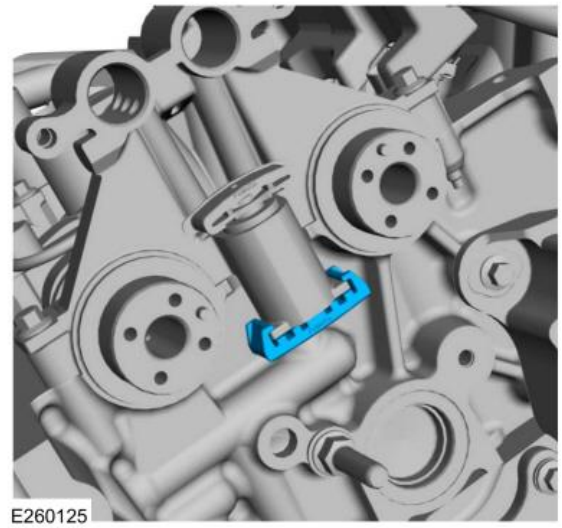
13. **NOTE:** *A slight twisting motion will aid in the removal of the VCT oil control solenoid.*

    NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.*

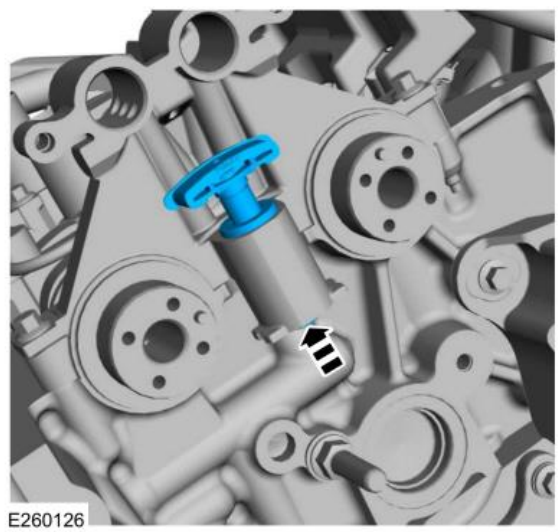
    Remove the bolt and the exhaust VCT oil control solenoid.



14. Remove the RH secondary timing chain tensioner shoe.



15. Remove the RH secondary timing chain tensioner by pushing up from the bottom.

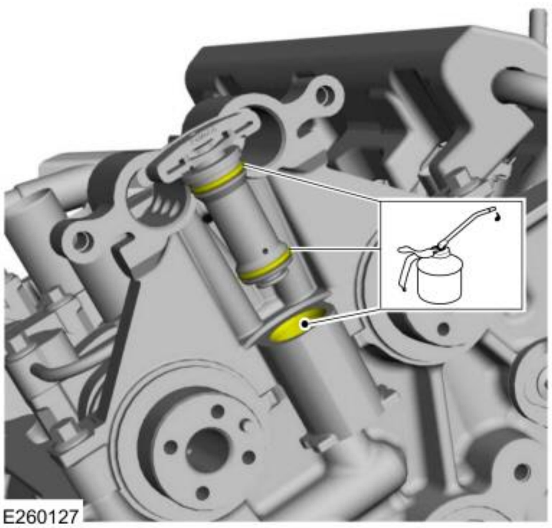


Variable Camshaft Timing Solenoid (VCT/VVT) Installation

Installation of the RH secondary timing chain tensioner

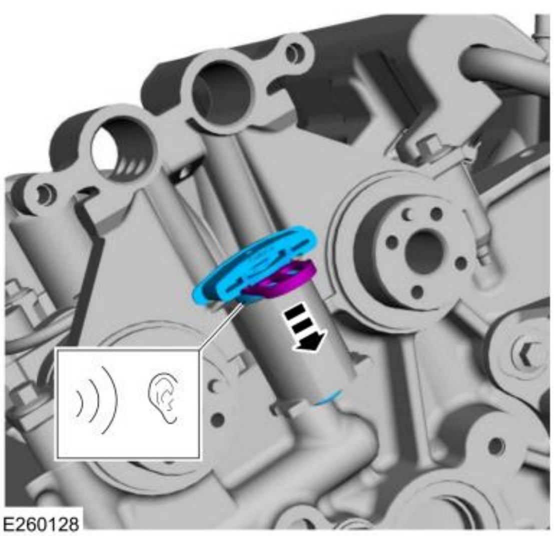
NOTICE: The following 10 steps are only for the installation of the RH secondary timing chain tensioners. Do not reuse the secondary timing chain tensioners if removed, or damage to the engine may occur.

1. **NOTE:** *Do not remove the secondary timing chain tensioner shipping clip, until instructed to do so.*
   Apply clean engine oil to the secondary timing chain tensioner O-ring seals and mega cap bore. *Material* : Motorcraft® SAE 5W-20

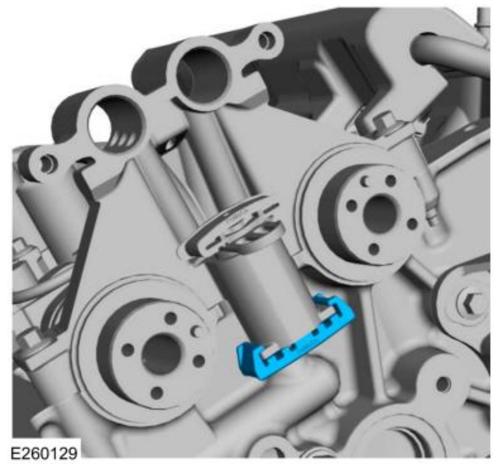


2. **NOTE:** *Do not remove the secondary timing chain tensioner shipping clip, until instructed to do so.*

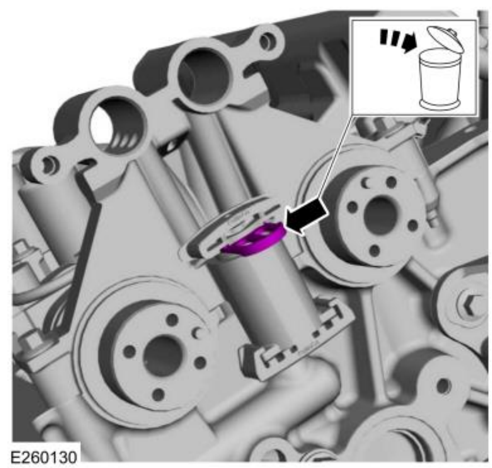
   Install the RH secondary timing chain tensioner by pushing it down all the way until a snap is heard and the tensioner is seated all the way down the mega cap bore.



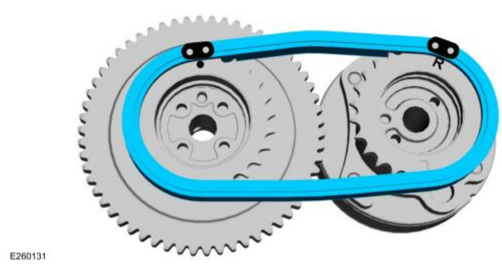
3. Install the RH secondary timing chain tensioner shoe.



4. Remove and discard the RH secondary timing chain tensioner shipping clip.

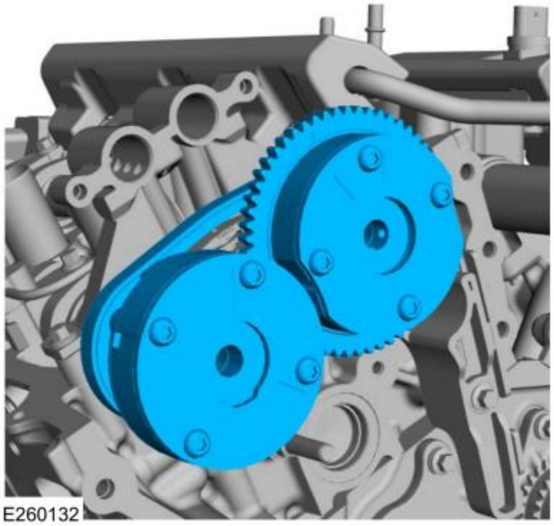


5. Align the colored links with the timing marks and assemble the RH VCT units.

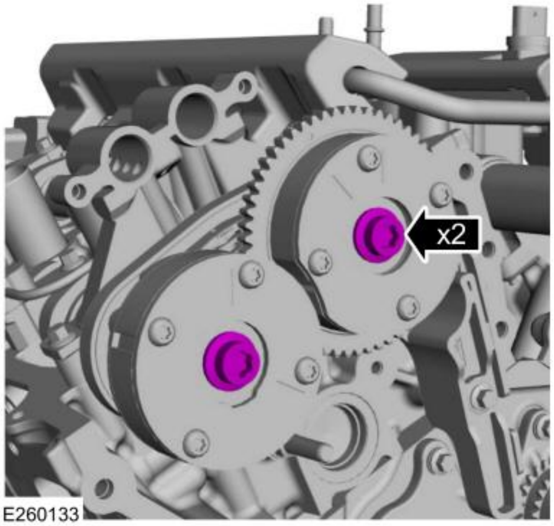


6. **NOTE:** *It may be necessary to rotate the camshafts slightly, to install the RH secondary timing assembly.*

Position the RH VCT units and secondary timing chain onto the camshafts by aligning the holes in the VCT units with the dowel pins in the camshafts.

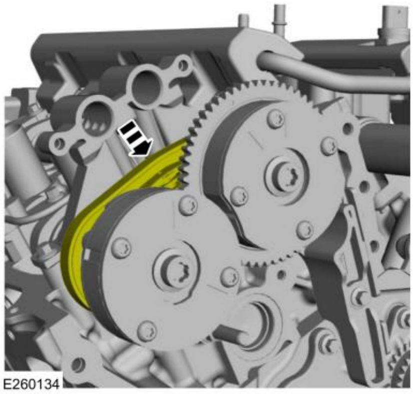

E260132

7. Install the new RH VCT unit bolts and tighten in 4 stages.
   Torque :
   Stage 1: 30 lb.ft (40 Nm)
   Stage 2: Loosen:: 1 turn(s)
   Stage 3: 18 lb.ft (25 Nm)
   Stage 4: 180°



E260133

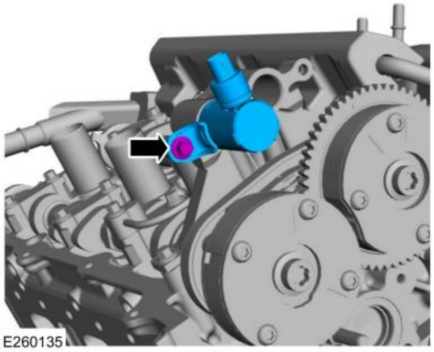
8. Activate the RH secondary timing chain tensioner by pressing down on the secondary timing chain and tensioner top shoe until it bottoms out, let go of the tensioner and it will spring up putting tension on the chain.


E260134

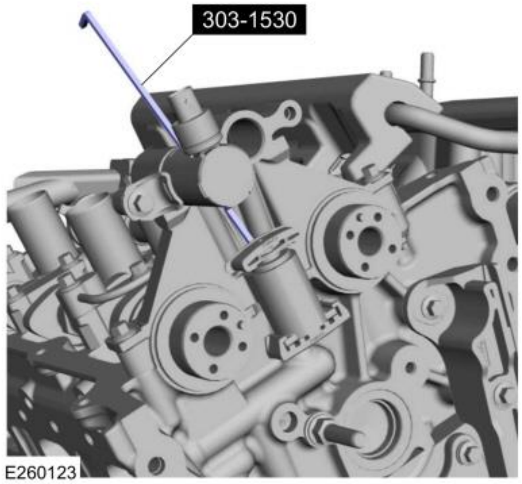
9. **NOTICE: Do not use excessive force when installing the VCT oil control solenoid. Damage to the mega cap could cause the cylinder head to be inoperable. If difficult to install the VCT oil control solenoid, inspect the bore and VCT oil control solenoid to ensure there are no burrs, sharp edges or contaminants present on the mating surface. Only clean the external surfaces as necessary.**

   NOTE: *A slight twisting motion will aid in the installation of the VCT oil control solenoid*

   NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.*Install the RH exhaust VCT oil control solenoid and the bolt.
   Torque :
   Stage 1: 71 lb.in (8 Nm)
   Stage 2: 20°

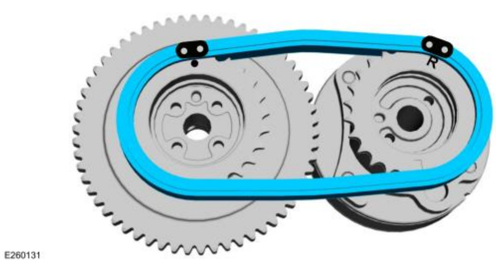

E260135

10. *Install Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down

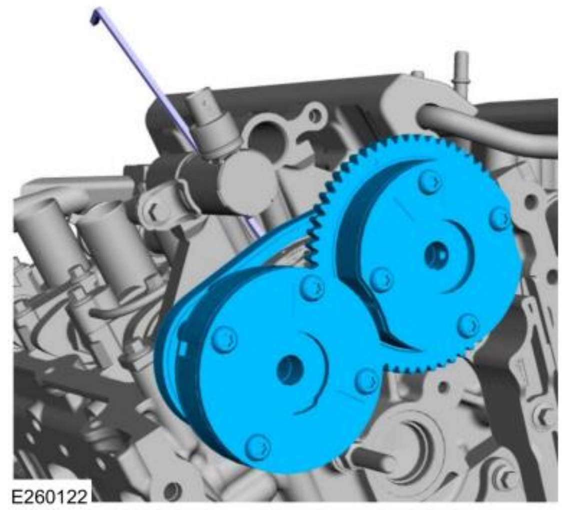


RH variable camshaft timing (VCT) unit

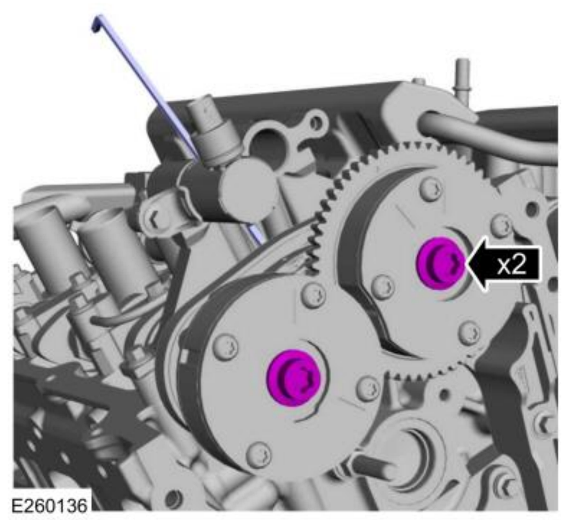
11. Align the colored links with the timing marks and assemble the RH VCT units.



12. **NOTE:** *It may be necessary to rotate the camshafts slightly, to install the RH VCT units.*
    Position the RH VCT units and secondary timing chain onto the camshafts by aligning the holes in the VCT units with the dowel pins in the camshafts.



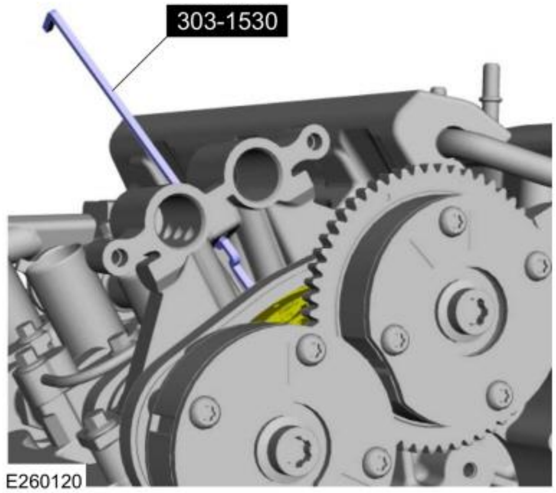
13. Install the new RH VCT unit bolts and tighten in 4 stages.
    Torque :
    Stage 1: 30 lb.ft (40 Nm)
    Stage 2: Loosen:: 1 turn(s)
    Stage 3: 18 lb.ft (25 Nm)
    Stage 4: 180°



14. **NOTE:** *Make sure the secondary timing chain is centered on the timing chain tensioner guides.*

    NOTE: *The VCT oil control solenoids are removed for clarity.*

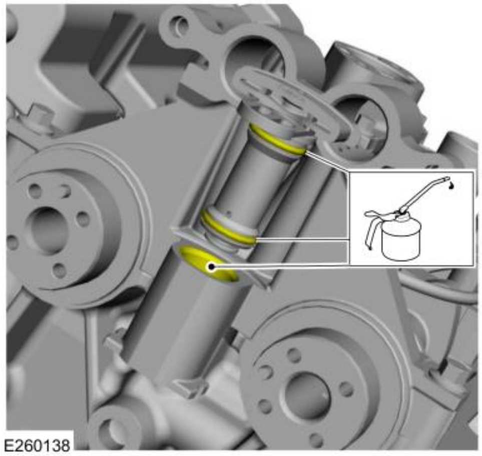
    Remove Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



Installation of the LH secondary timing chain tensioner

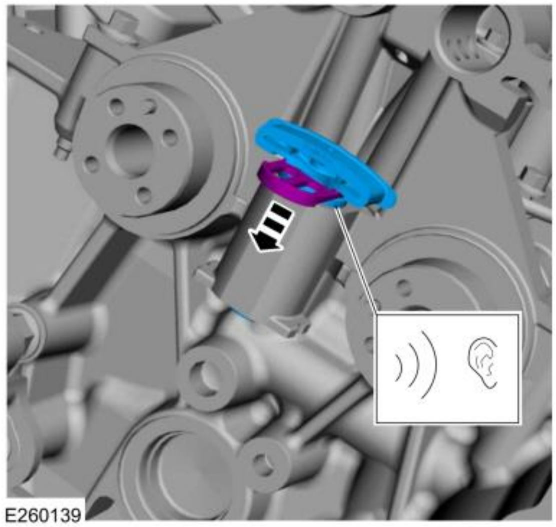
NOTICE: The following 10 steps are only for the replacement of the secondary timing chain tensioners. Do not reuse the secondary timing chain tensioners if removed, or damage to the engine may occur.

15. **NOTE:** *Do not remove the secondary timing chain tensioner shipping clip, until instructed to do so.* Apply clean engine oil to the secondary timing chain tensioner O-ring seals and mega cap bore. *Material* : Motorcraft® SAE 5W-20

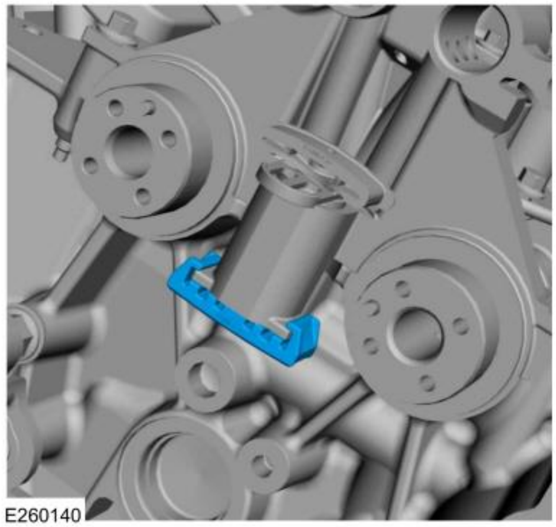


16. **NOTE:** *Do not remove the secondary timing chain tensioner shipping clip, until instructed to do so.*

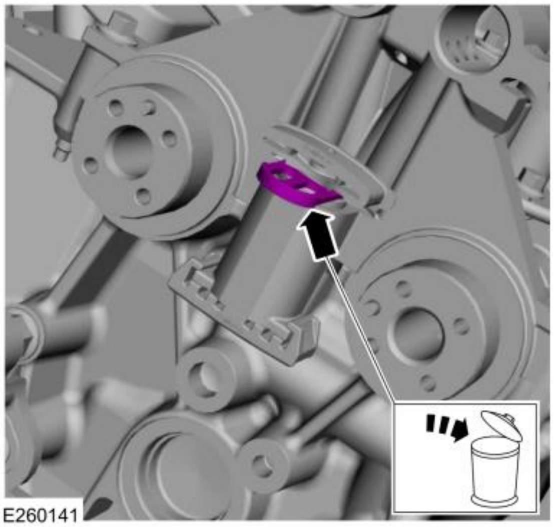
Install the LH secondary timing chain tensioner by pushing it down all the way until a snap is heard and the tensioner is seated all the way down the mega cap bore.



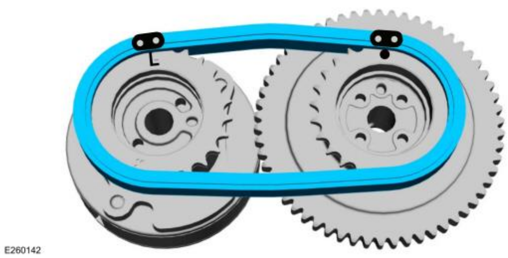
17. Install the LH secondary timing chain tensioner shoe.



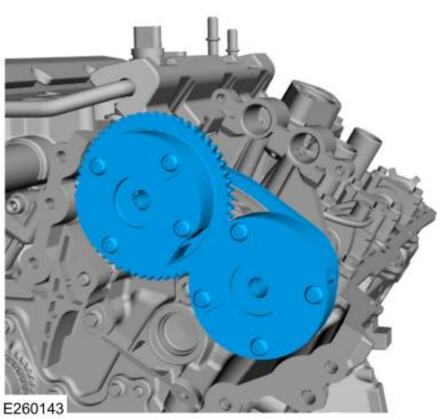
18. Remove and discard the LH secondary timing chain tensioner shipping clip.



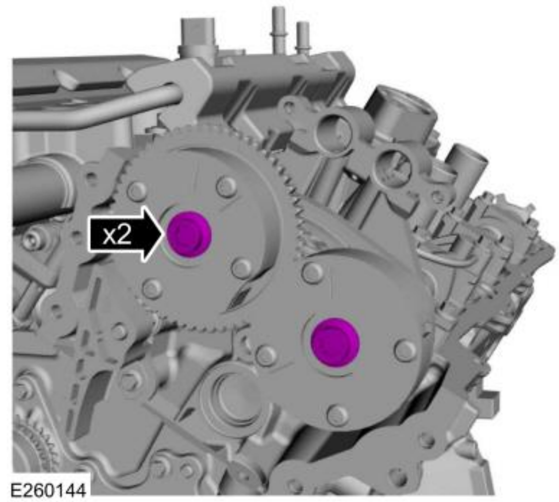
19. Align the colored links with the timing marks and assemble the LH VCT units.



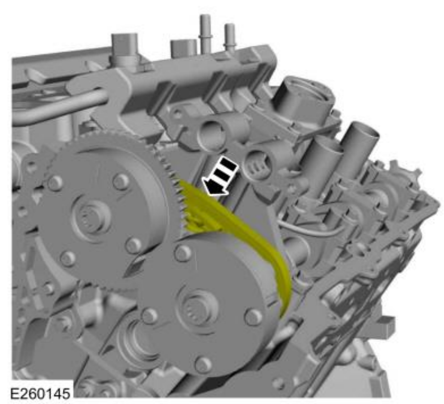
20. Position the LH VCT units and secondary timing chain onto the camshafts by aligning the holes in the VCT units with the dowel pins in the camshafts.



21. Install the new LH VCT unit bolts and tighten in 4 stages.
    Torque :
    Stage 1: 30 lb.ft (40 Nm)
    Stage 2: Loosen:: 1 turn(s)
    Stage 3: 18 lb.ft (25 Nm)
    Stage 4: 180°



22. Activate the LH secondary timing chain tensioner by pressing down on the secondary timing chain and tensioner top shoe until it bottoms out, let go of the tensioner and it will spring up putting tension on the chain.



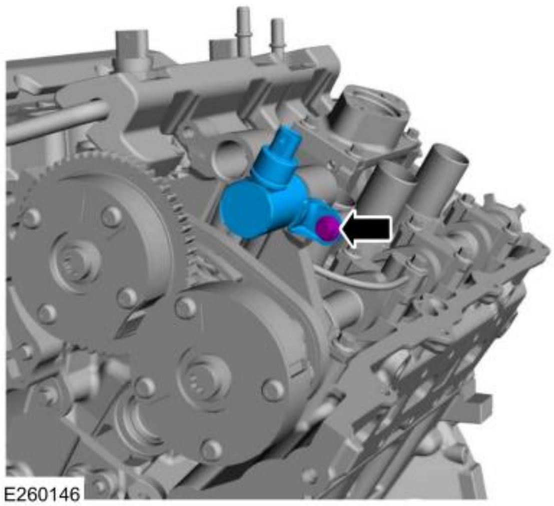
23. **NOTICE: Do not use excessive force when installing the VCT oil control solenoid. Damage to the mega cap could cause the cylinder head to be inoperable. If difficult to install the VCT oil control solenoid, inspect the bore and VCT oil control solenoid to**

ensure there are no burrs, sharp edges or contaminants present on the mating surface. Only clean the external surfaces as necessary.

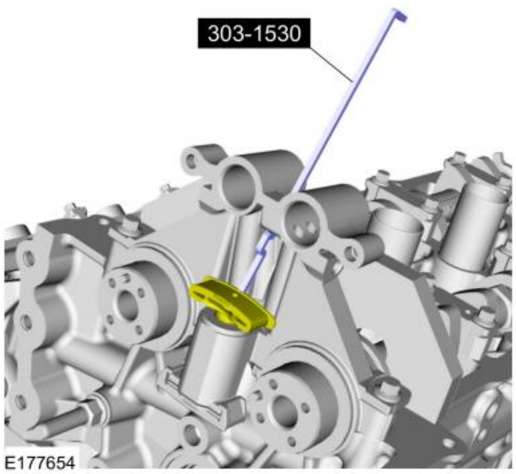
NOTE: *A slight twisting motion will aid in the installation of the VCT oil control solenoid*

NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.*

Install the LH exhaust VCT oil control solenoid and the bolt.

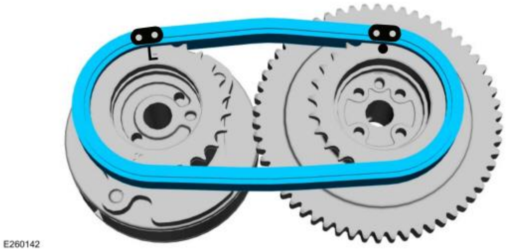


24. *Install Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



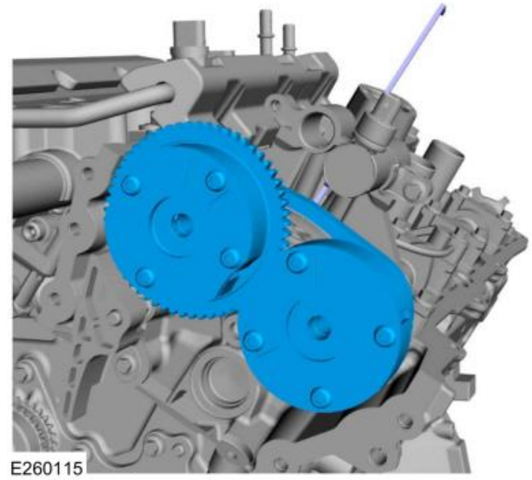
LH variable camshaft timing (VCT) unit

25. Align the colored links with the timing marks on the LH VCT units.

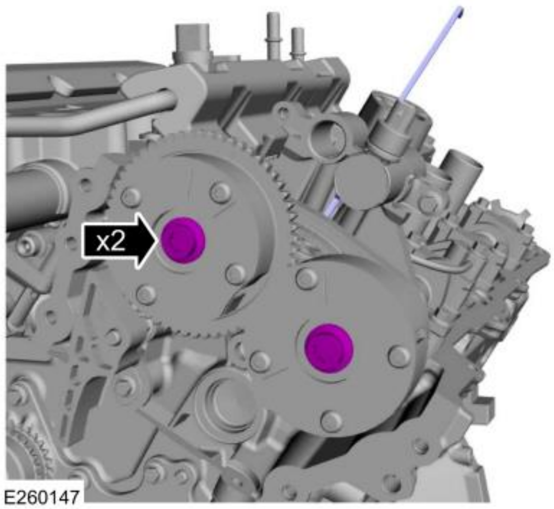


26. **NOTE:** *It may be necessary to rotate the camshafts slightly, to install the LH secondary timing assembly.*

    Position the LH VCT units and secondary timing chain onto the camshafts by aligning the holes in the VCT units with the dowel pins in the camshafts.



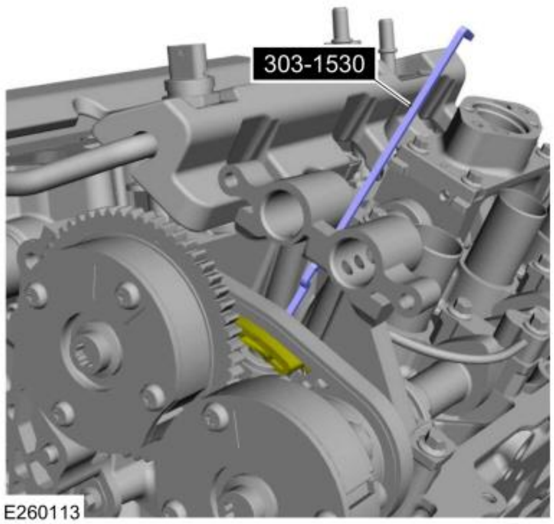
27. Install the new LH VCT unit bolts and tighten in 4 stages.
    Torque :
    Stage 1: 30 lb.ft (40 Nm)
    Stage 2: Loosen:: 1 turn(s)
    Stage 3: 18 lb.ft (25 Nm)
    Stage 4: 180°



28. ***NOTE:** Make sure the secondary timing chain is centered on the timing chain tensioner guides.*

    ***NOTE:** The VCT oil control solenoids are removed for clarity.*

    Remove Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



All variable camshaft timing (VCT) unit

29. Install the timing chain.
    Refer to: Timing Chain install page 2-17

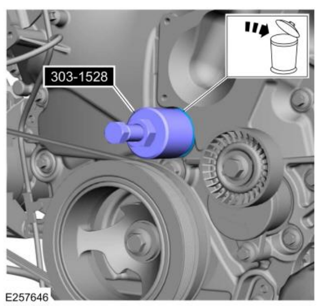
Front Cover to Coolant Seal Pipe Removal

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

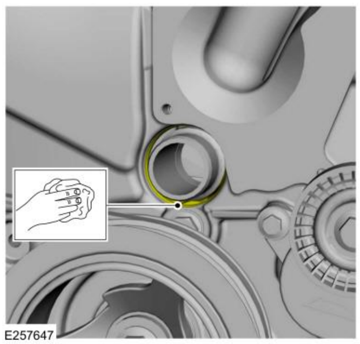
1. Remove the coolant pump, section 5.

2. Using the special tool, remove the front cover to coolant pipe seal.

   Use Special Service Tool : 303-1528 Remover/Installer, Water Tube Seal
   Reset the special tool center bolt to its retracted position.
   Screw the special tool onto the front cover to coolant pipe seal until it bottoms out.
   Using a brass hammer, give the special tool a slight tap inward to break front cover radial seal lose.
   Turn the special tool center bolt clockwise and remove the front cover to coolant pipe seal.

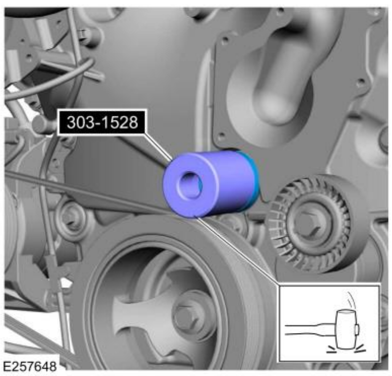


3. Clean the engine front cover to coolant pipe seal area.

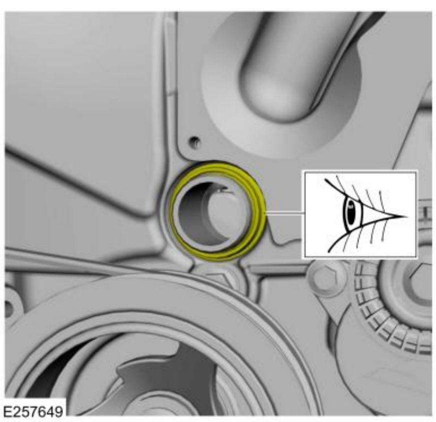


Front Cover to Coolant Seal Pipe Installation

1. Using the special tool, install the front cover to coolant pipe seal.
   Use Special Service Tool : 303-1528 Remover/Installer, Water Tube Seal
   Position the front cover to coolant pipe seal on the special tool.
   Position the special tool into the engine front cover.
   Using a brass hammer, tap the special tool until the front cover to coolant pipe seal bottoms out.



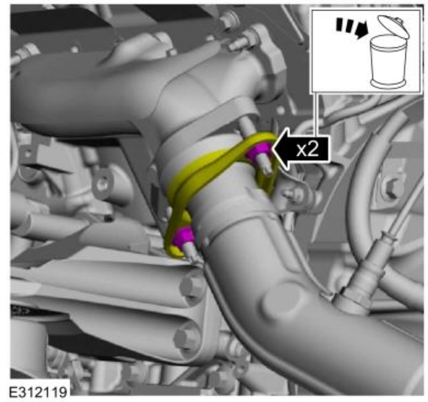
2. Inspect the front cover to coolant pipe seal for proper installation or damage.



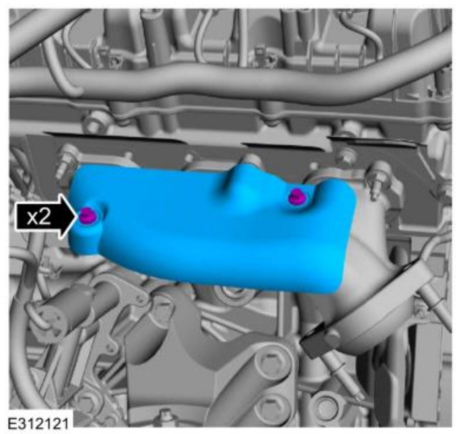
3. Install the coolant pump, refer to section 5.

Exhaust Manifold LH Removal

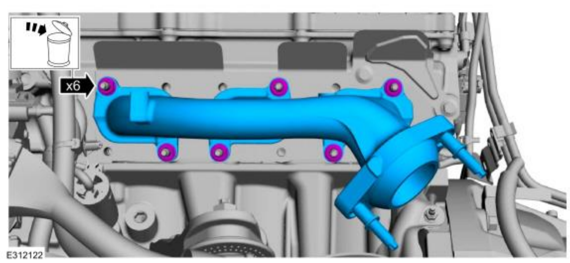
1. Discard and remove the LH exhaust pipe flange nuts.



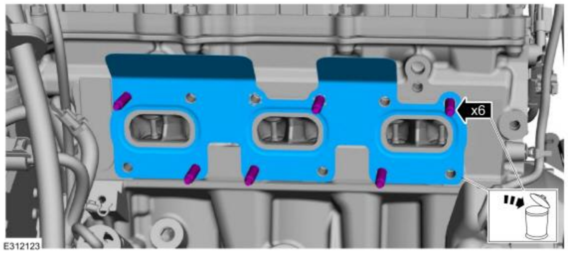
2. Remove the bolts and the exhaust manifold heat shield. (if equipped)



3. Remove the nuts and the exhaust manifold.
   Discard the nuts.



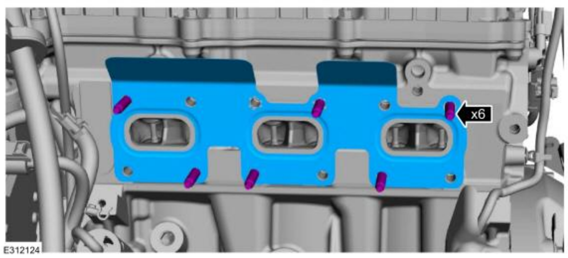
4. Remove and discard the exhaust manifold gasket.
   Remove and discard the exhaust manifold studs



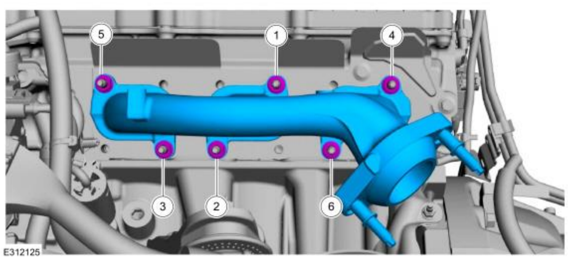
5. Clean and inspect the exhaust manifold.

Exhaust Manifold LH Installation

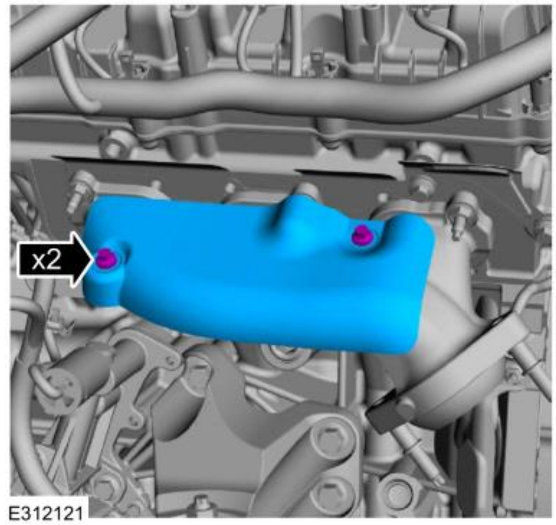
1. Install the new exhaust manifold studs.
   Torque : 106 lb.in (12 Nm)
   Install the new exhaust manifold gasket.



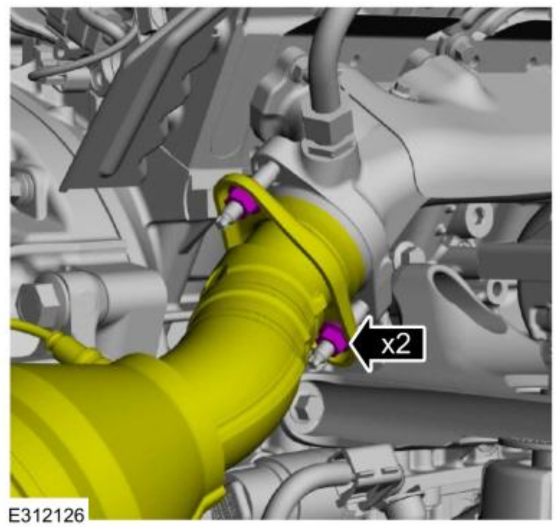
2. Install the exhaust manifold and the new nuts.
   Torque :
   Stage 1: 168 lb.in (19 Nm)
   Stage 2: 18 lb.ft (25 Nm)



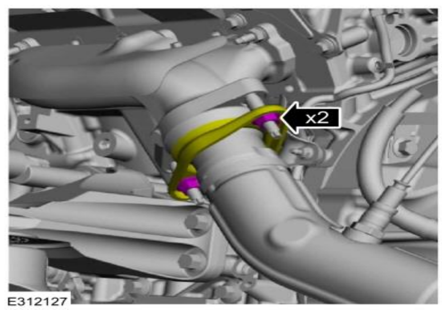
3. Install the exhaust manifold heat shield and the bolts.
   Torque : 106 lb.in (12 Nm)



4. Position the RH catalytic converter and install new flange nuts.
   Torque : 30 lb.ft (40 Nm)

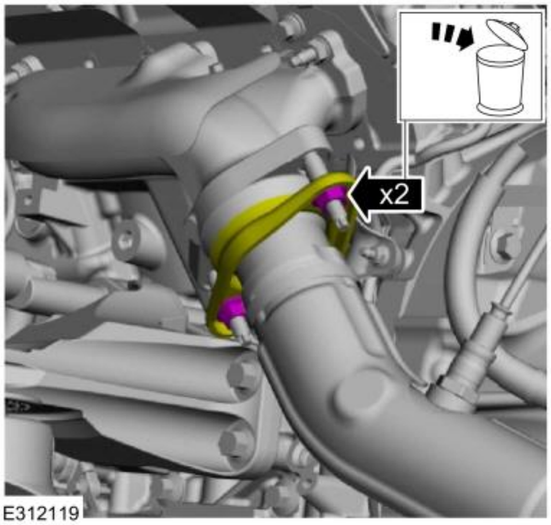


5. Install the LH flange and new nuts.
   Torque : 30 lb.ft (40 Nm)

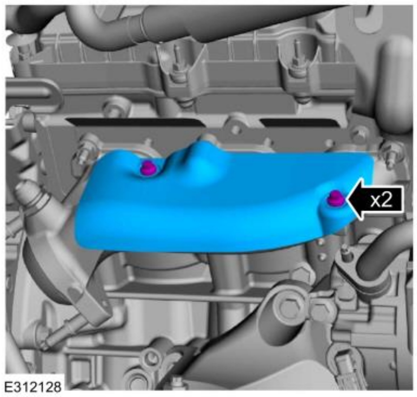


Exhaust Manifold RH Removal

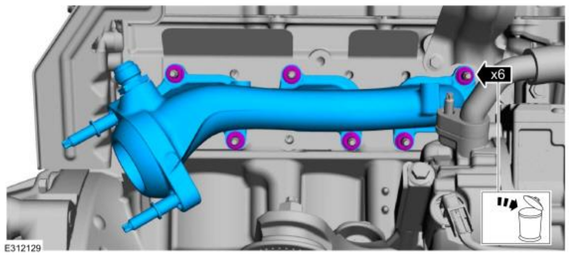
1. Discard and remove the RH exhaust pipe flange nuts.



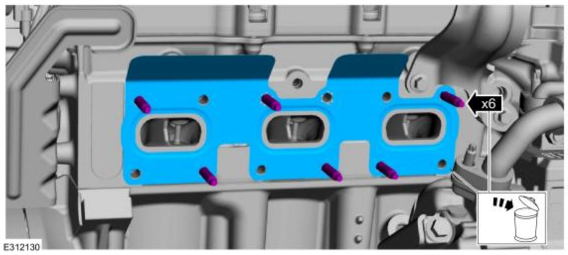
2. Remove the bolts and the exhaust manifold heat shield.



3. Remove the nuts and the exhaust manifold.
   Discard the nuts.



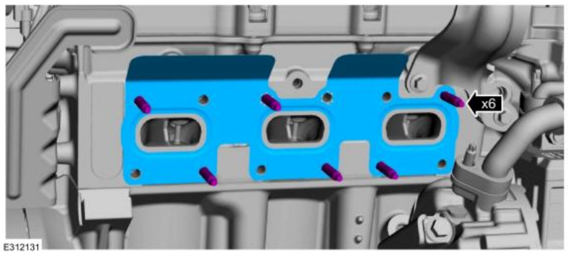
4. Remove and discard the exhaust manifold gasket.
   Remove and discard the exhaust manifold studs.



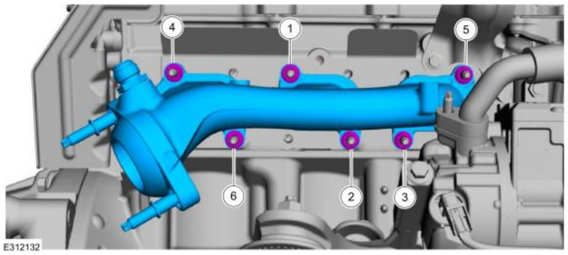
5. Clean and inspect the exhaust manifold.

Exhaust Manifold RH Installation

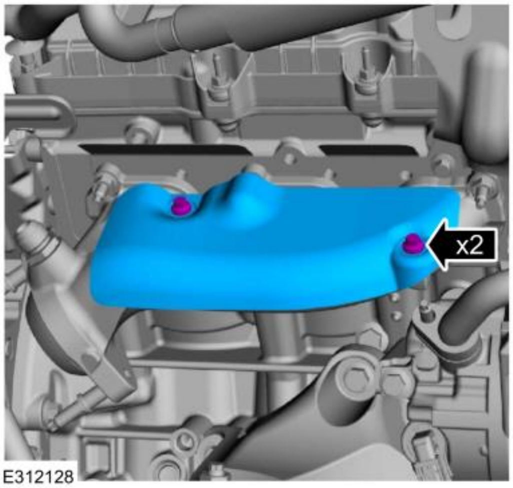
1. Install the new exhaust manifold studs.
   Torque : 106 lb.in (12 Nm)
   Install the new exhaust manifold gasket.



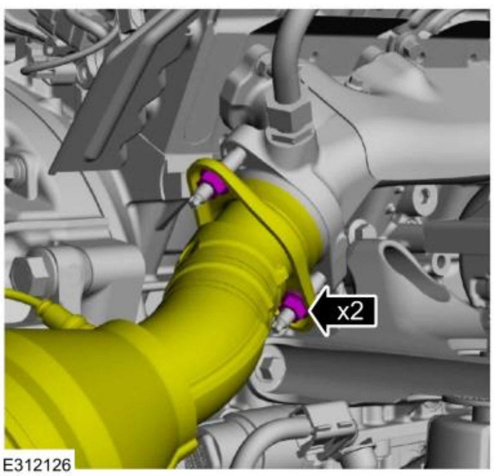
2. Install the exhaust manifold and the new nuts.
   Torque :
   Stage 1: 168 lb.in (19 Nm)
   Stage 2: 18 lb.ft (25 Nm)



3. Install the exhaust manifold heat shield and the bolts.
   Torque : 106 lb.in (12 Nm)

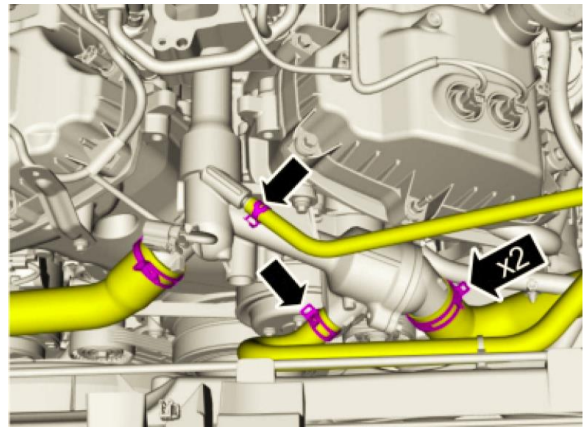


4. Position the RH catalytic converter and install new flange nuts.
   Torque : 30 lb.ft (40 Nm)

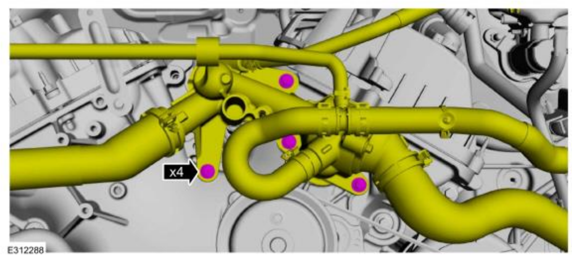


Lower Intake Manifold Removal

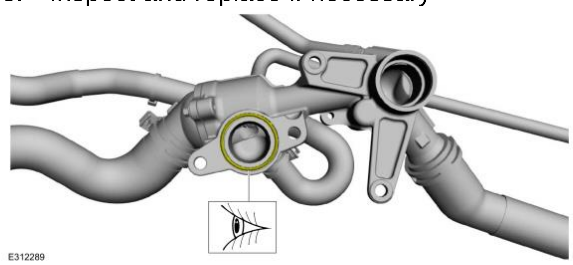
1. Release fuel system pressure
2. Disconnect battery ground cable
3. Drain the cooling system
4. Remove the upper intake manifold, page 2-5.
5. Remove the fuel line quick disconnect from the fuel rail
6. Disconnect the coolant hoses.
   Use the General Equipment: Hose Clamp Remover/Installer



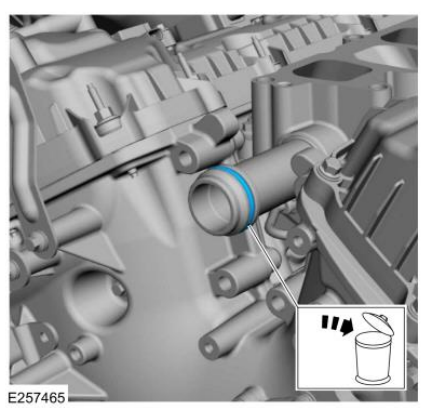
7. Remove the bolts and the thermostat housing.



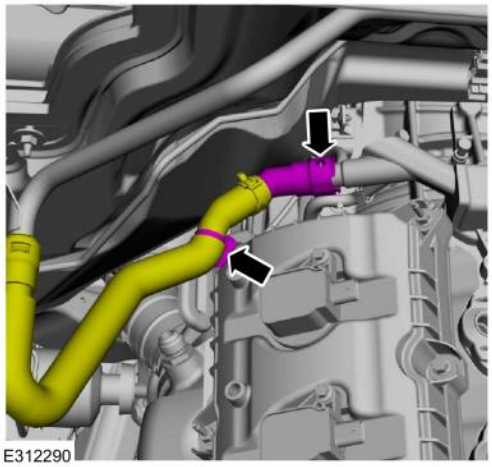
8. Inspect and replace if necessary



9. Remove and discard thermostat housing O-ring seal.

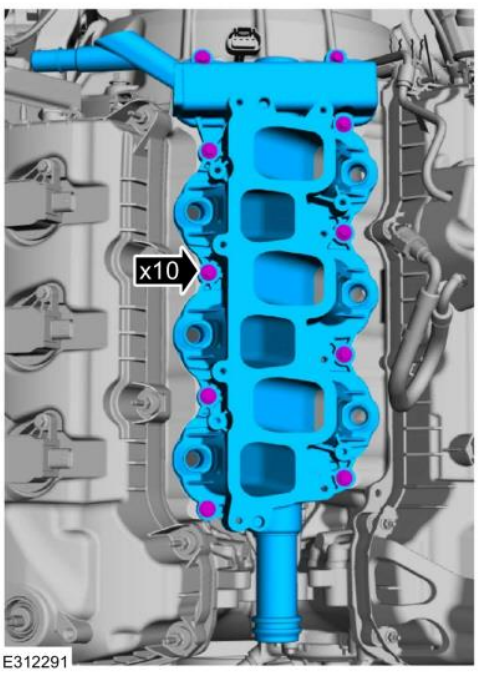


10. Disconnect the fuel injector electrical connectors.
    Disconnect the coolant tube from the lower intake manifold.



E312290

11. Remove the bolts and the lower intake manifold.



E312291

12. Remove and discard the lower intake manifold gaskets.

E308783

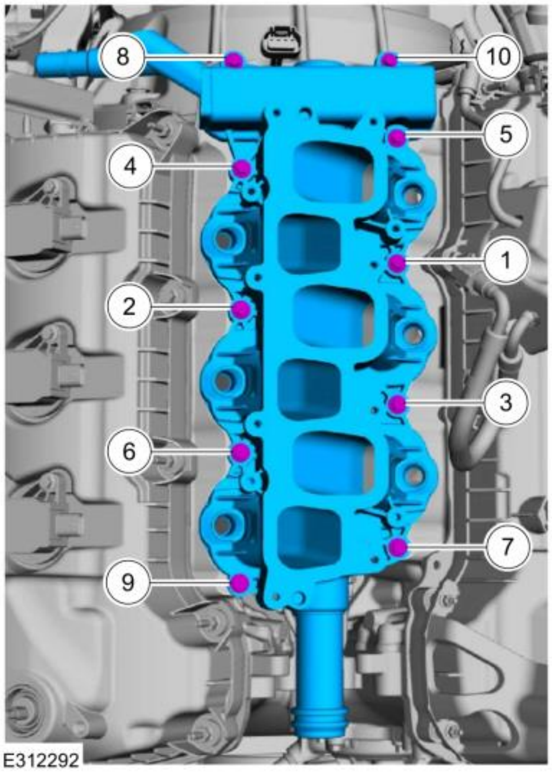
13. Clean and inspect all sealing surfaces.

Lower Intake Manifold Installation

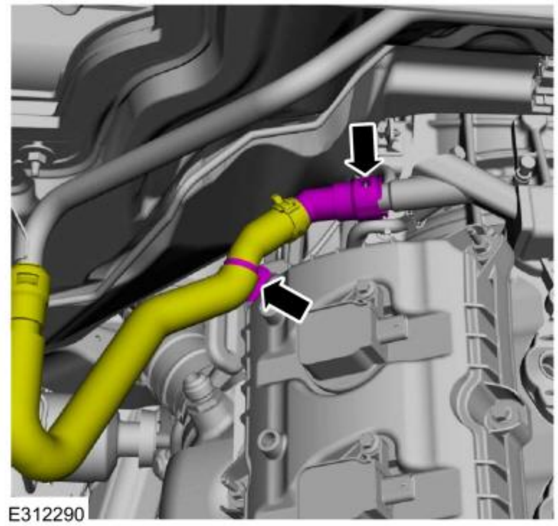
NOTICE: If the engine is repaired or replaced because of upper engine failure, typically including valve or piston damage, check the intake manifold for metal debris. If metal debris is found, install a new intake manifold. Failure to follow these instructions can result in engine damage.

1. Install the new lower intake manifold gaskets.

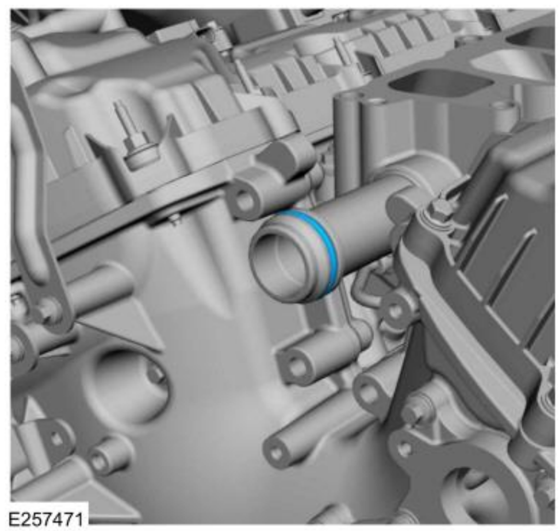
2. Install the lower intake manifold and the bolts.
   Torque : 89 lb.in (10 Nm)



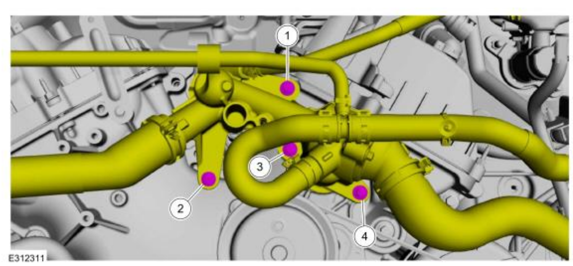
3. Connect the coolant tube to the lower intake manifold.
   Connect the fuel injector electrical connectors.
   Attach the coolant tube retainer to the valve cover stud bolt.



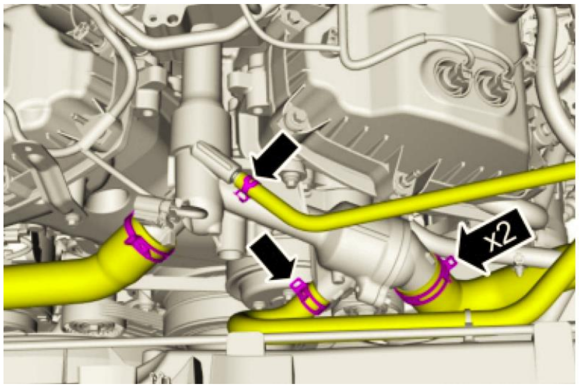
4. Install a new thermostat housing O-ring seal.



5. Install the thermostat housing and the bolts.
   Torque :
   Stage 1: 71 lb.in (8 Nm)
   Stage 2: 45°



6. Connect the coolant hoses.
   Use the General Equipment: Hose Clamp Remover/Installer



7. Connect the fuel tube quick release coupling.

8. Install the upper intake manifold, page 2-5

9. Connect the battery ground

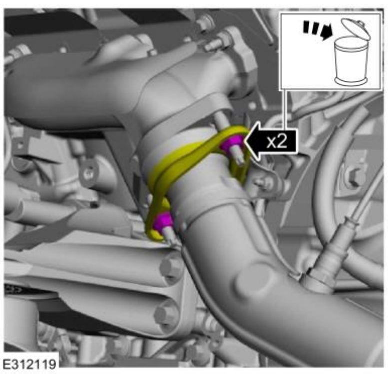
10. Fill the cooling system.

LH Cylinder Head Removal

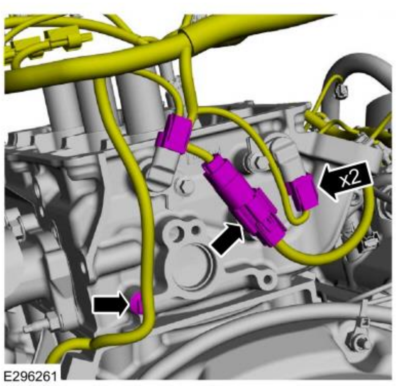
NOTICE: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces that enters the oil passages, coolant passages or the oil pan, can cause engine failure.

NOTE: *If the cylinder head is replaced, a new secondary timing chain tensioner will need to be installed.*
Refer to VCT unit.

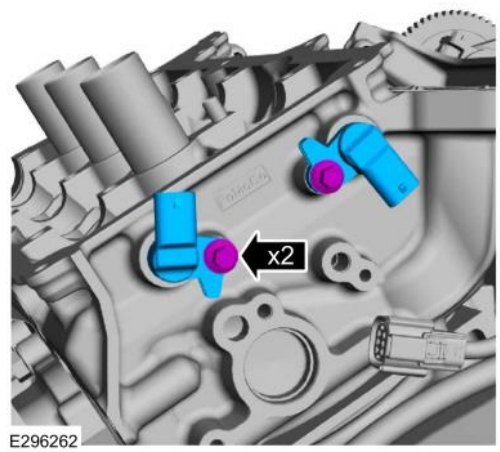
1. Release the fuel system pressure.
2. Disconnect the battery ground cable.
3. Drain the cooling system.
4. Remove and discard the LH exhaust flange nuts.



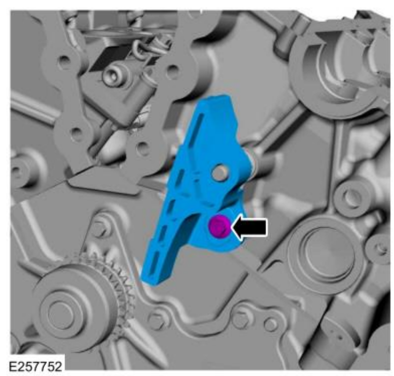
5. Remove the LH CAMSHAFTS. Page 2-41.
6. Loosen the fuel rail to fuel high-pressure fuel tube flare nuts and remove. Discard the fuel rail to fuel rail high-pressure fuel



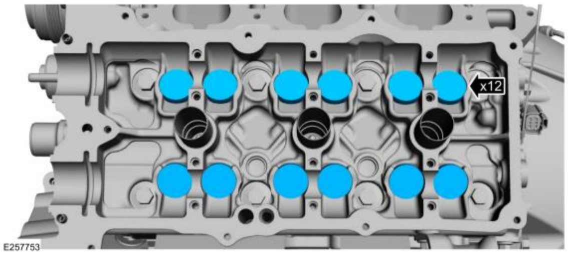
7. Disconnect the CMP sensor electrical connectors.
8. Remove the bolts and the CMP sensors.



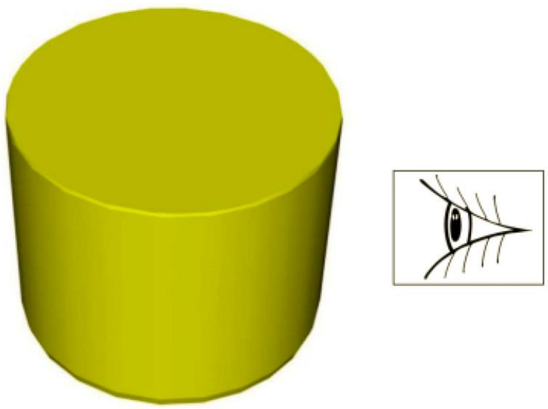
9. **NOTICE: Do not use power tools to remove the bolt or damage to the upper LH timing chain guide may occur.**
   Remove the bolt and the upper LH timing chain guide.



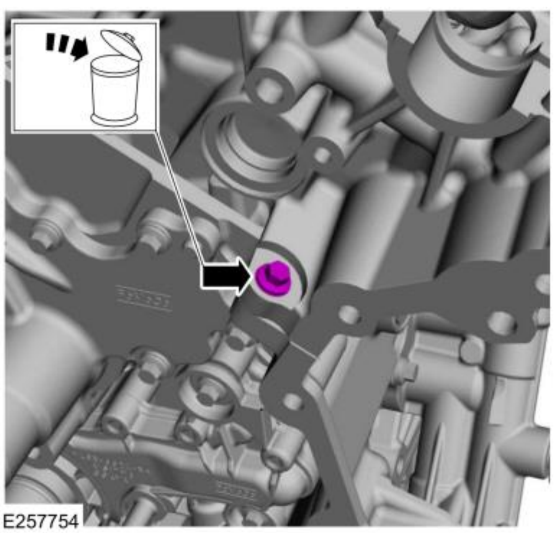
10. **NOTE:** *If the components are to be reinstalled, they must be installed in the same positions. Mark the components for installation into their original locations.*
    Remove the valve tappets.



11. Inspect and install new components as necessary.

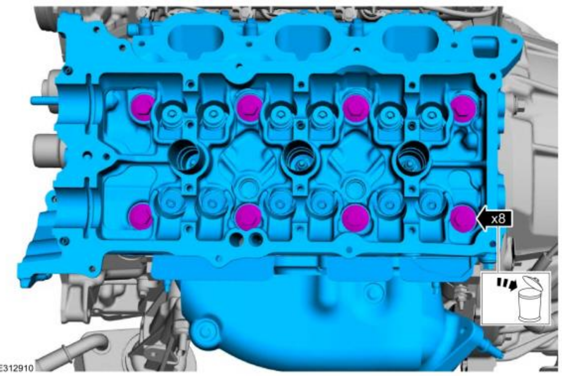


12. Remove and discard the M6 bolt.



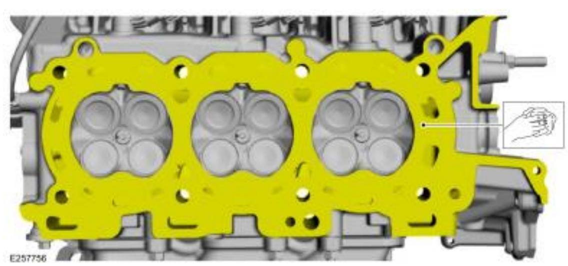
13. **NOTICE: Place clean shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**
NOTICE: Aluminum surfaces are soft and can be scratched easily. Never place the cylinder head gasket surface, unprotected, on a bench surface
NOTE: *The cylinder head bolts must be discarded and new bolts must be installed. They are tightento-yield designed and cannot be reused.*

Remove and discard the bolts.
Remove the cylinder head.

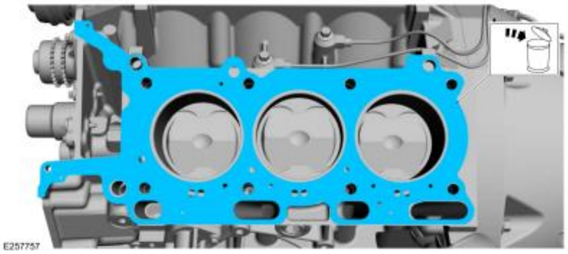


14. **NOTICE: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. Use a plastic scraping tool to remove all traces of the head gasket.**

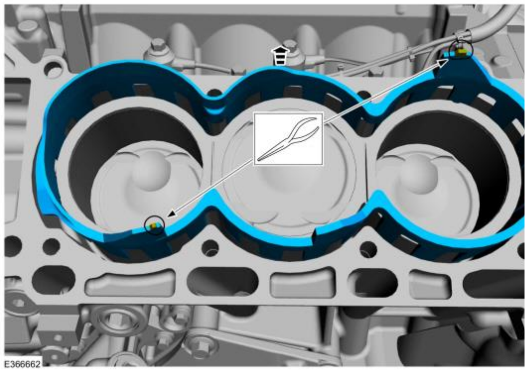
Make sure that the mating faces of the cylinder head are clean and free of foreign material.



15. Remove and discard the cylinder head gasket.



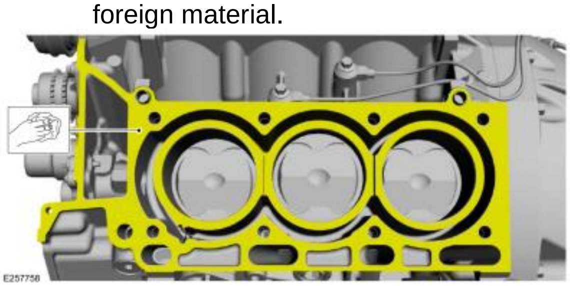
16. Remove the water jacket spacer. Use the General Equipment: Long Nose Pliers



17. **NOTICE: Place clean, lint-free shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**

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

    Make sure that the mating faces of the engine block are clean and free of foreign material.

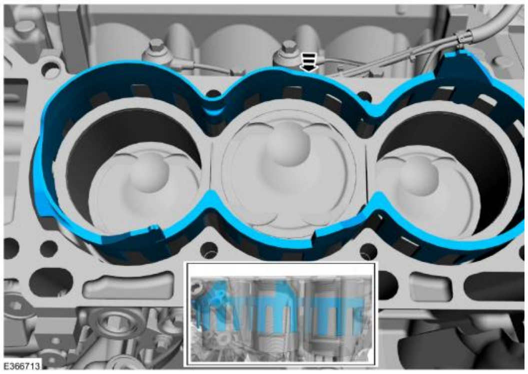


18. Support the cylinder head on a bench with the head gasket side up. Check the cylinder head distortion and the cylinder block distortion. Refer to: Cylinder Head Distortion (Engine System - General Information, General Procedures, section 01).

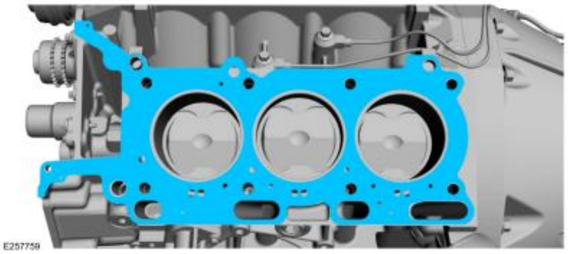
    Refer to: Cylinder Block Distortion (Engine System - General Information, General Procedures section 01).

LH Cylinder Head Installation

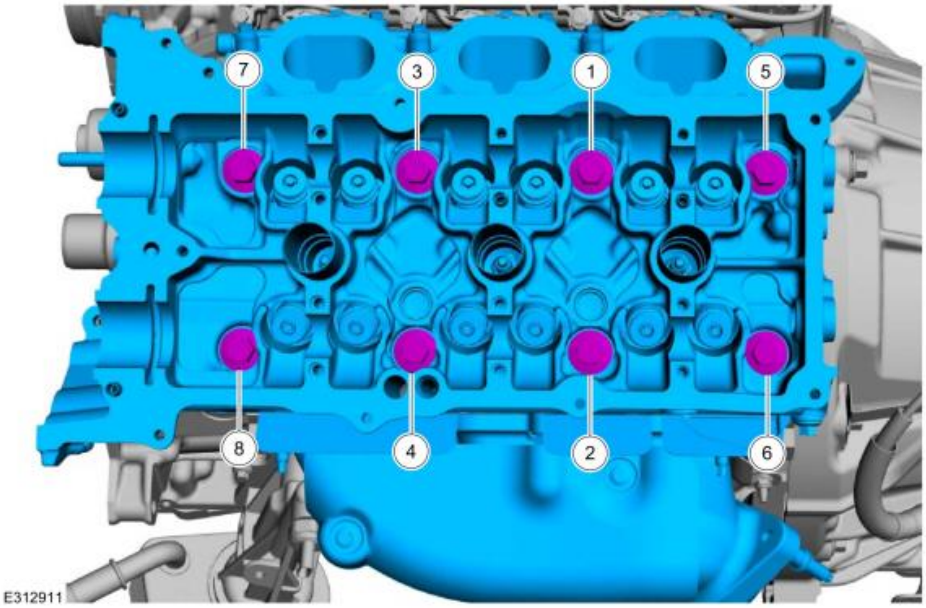
1. Install the water jacket flush with the bottom of the block.



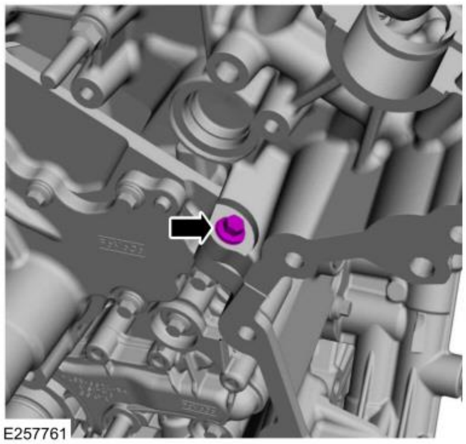
2. Install the cylinder head gasket.



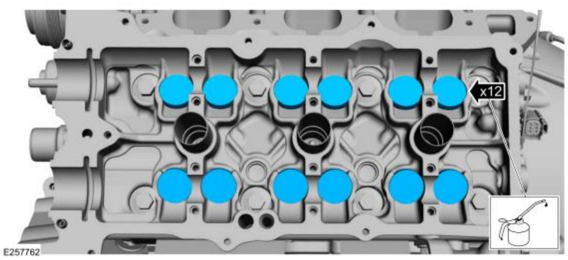
3. **NOTE:** *If the cylinder head is replaced, a new secondary timing chain tensioner will need to be installed.*
   NOTE: *Install new cylinder head bolts.*
   Install the cylinder head and the new bolts.
   Torque :
   Stage 1: 177 lb.in (20 Nm)
   Stage 2: 26 lb.ft (35 Nm)
   Stage 3: 90°
   Stage 4: 90°
   Stage 5: 45°



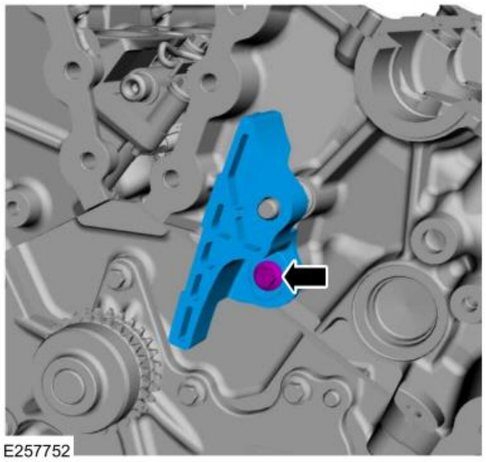
4. Install the M6 bolt.
   Torque : 89 lb.in (10 Nm)



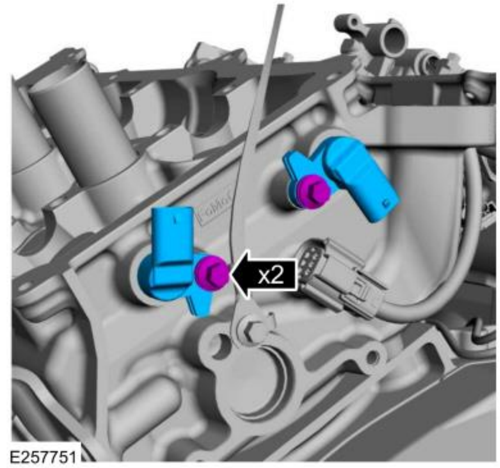
5. **NOTE:** *The valve tappets must be installed in their original positions.*
   Lubricate the valve tappets with clean engine oil and install. *Material* : Motorcraft® SAE 5W-20



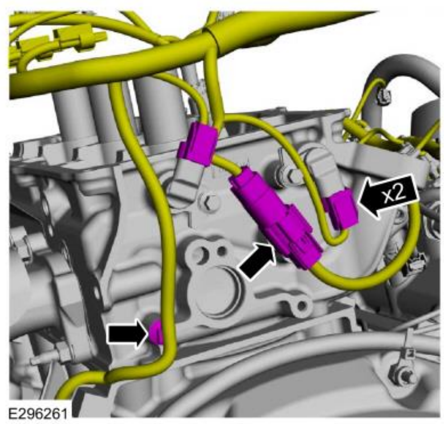
6. **NOTICE: Do not use power tools to install the bolt or damage to the upper LH timing chain guide may occur.**
   Install the upper LH timing chain guide and the bolt. *Torque* : 89 lb.in (10 Nm)



7. **NOTE:** *Lubricate the O-ring seals with clean engine oil.*
   Install the CMP sensors and the bolts.
   Torque: 89 lb.in (10 Nm)



8. Connect the CMP sensors electrical connectors.



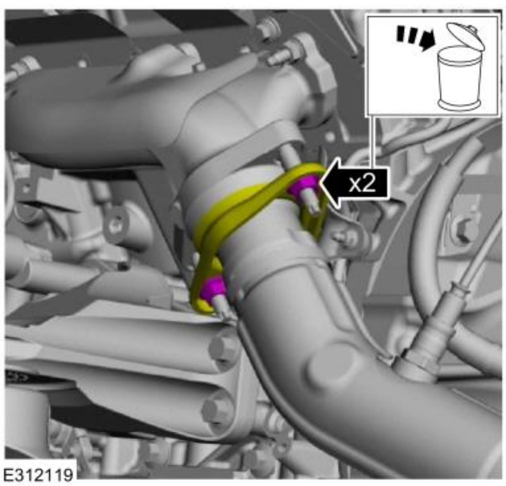
9. Install the LH camshafts, page 2-42.
10. Install new exhaust pipe flange nuts, torque 30lb.ft. (40 Nm)
11. Perform an oil change and clean with fresh oil.
    a. Drain plug torque, 20 lb.ft (27 Nm)
    b. Oil filter torque
       i. Stage 1: Install to initial gasket contact
       ii. Stage 2: Tighten to ¾ to 1 turn.
12. Reconnect battery grounds.

RH Cylinder Head Removal

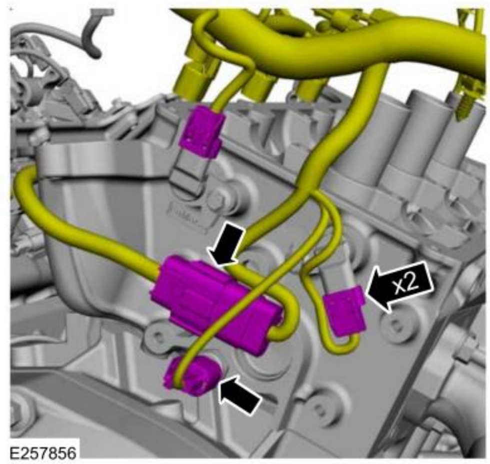
NOTICE: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces that enters the oil passages, coolant passages or the oil pan, can cause engine failure.

NOTE: *If the cylinder head is replaced, a new secondary timing chain tensioner will need to be installed.*
Refer to VCT unit.

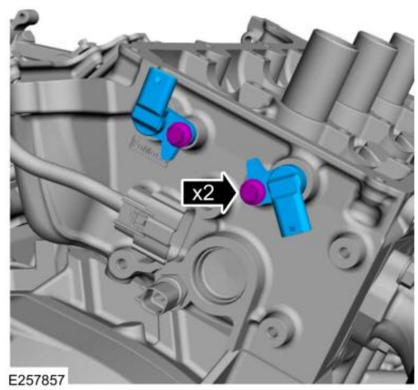
1. Release the fuel system pressure.
2. Disconnect the battery ground cable.
3. Remove and discard the LH exhaust flange nuts.



4. Remove the RH CAMSHAFTS. Page 2-41.
5. Disconnect the CMP sensor electrical connectors and the CHT sensor electrical connector.



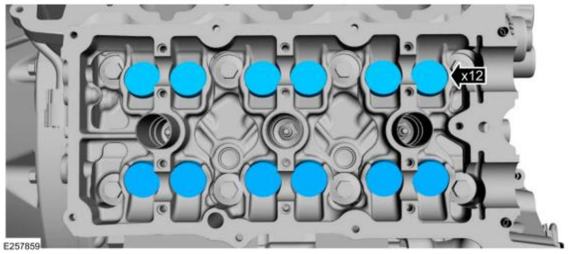
6. Remove the bolts and the CMP sensors.



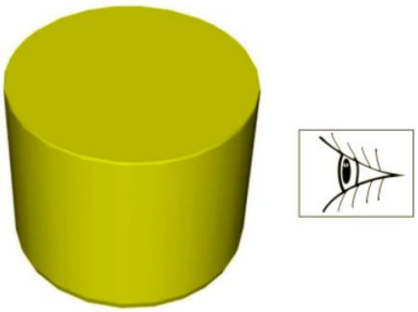
7. **NOTICE: Do not use power tools to remove the bolt or damage to the upper RH timing chain guide may occur.**
   Remove the bolt and the RH timing chain guide.

8. **NOTE:** *If the components are to be reinstalled, they must be installed in the same positions. Mark the components*

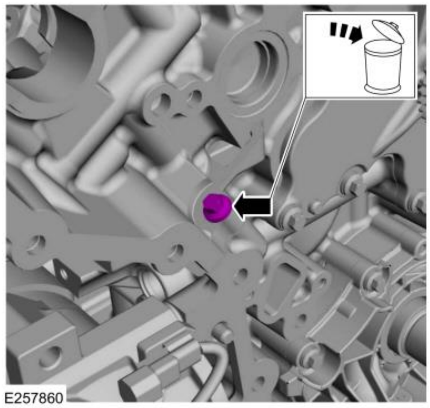
for installation into their original locations.
Remove the valve tappets.



9. Inspect and install new components as necessary.

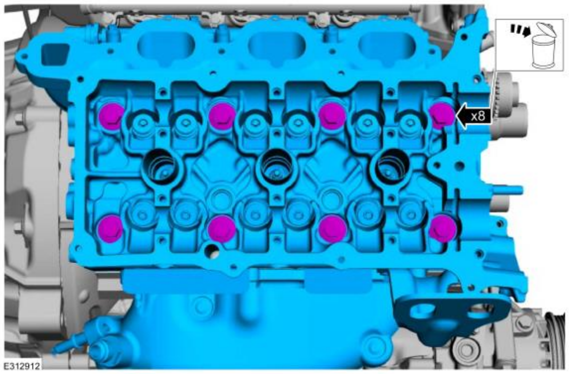


10. Remove and discard the M6 bolt.



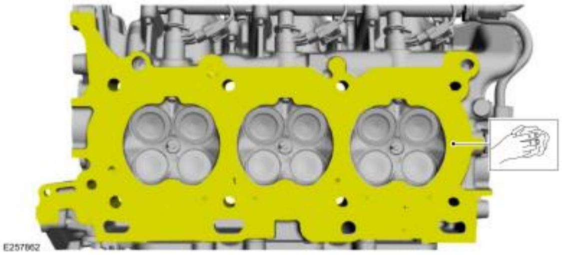
11. **NOTICE: Place clean shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**
NOTICE: Aluminum surfaces are soft and can be scratched easily. Never place the cylinder head gasket surface, unprotected, on a bench surface
NOTE: *The cylinder head bolts must be discarded and new bolts must be installed. They are tighten-to-yield designed and cannot be reused.*

Remove and discard the bolts.
Remove the cylinder head.



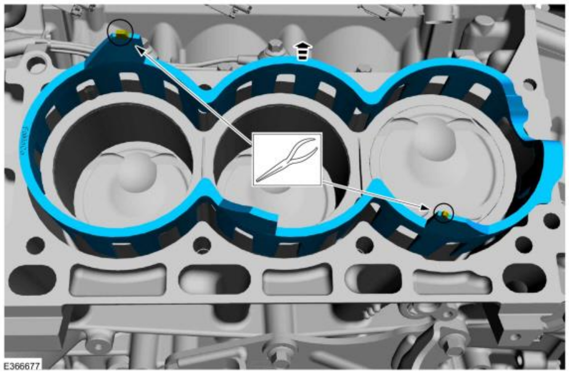
12. **NOTICE: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. Use a plastic scraping tool to remove all traces of the head gasket.**

Make sure that the mating faces of the cylinder head are clean and free of foreign material.



13. Remove and discard the cylinder head gasket.

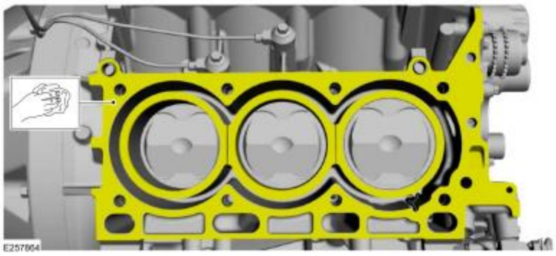
14. Remove the water jacket spacer. Use the General Equipment: Long Nose Pliers.



15. **NOTICE: Place clean, lint-free shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**

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

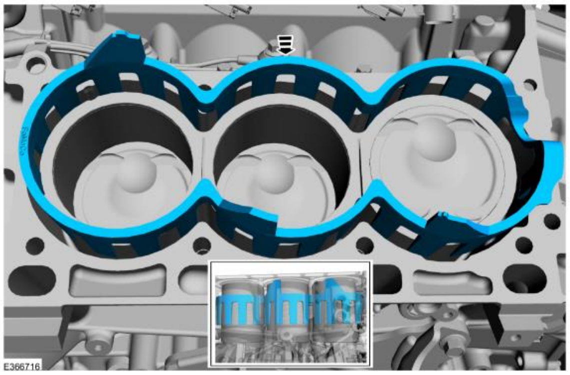
    Make sure that the mating faces of the engine block are clean and free of foreign material.



16. Support the cylinder head on a bench with the head gasket side up. Check the cylinder head distortion and the cylinder block distortion. Refer to: Cylinder Head Distortion (Section 01 Engine System - General Information, General Procedures). Refer to: Cylinder Block Distortion (Section 01 Engine System - General Information, General Procedures).

RH Cylinder Head Installation

1. Install the water jacket flush with the bottom of the block.

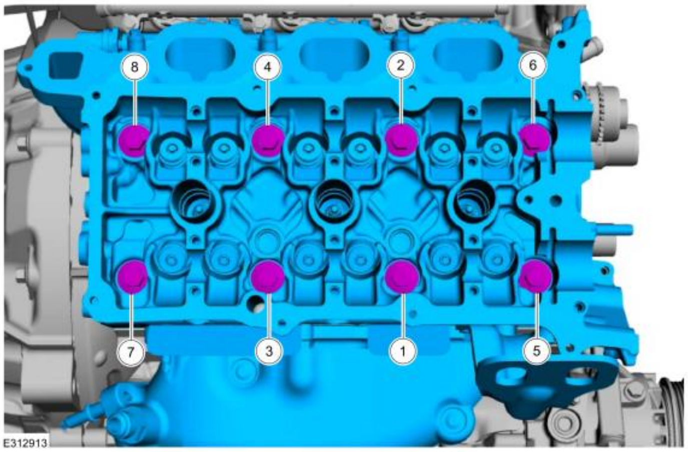


2. Install the cylinder head gasket.

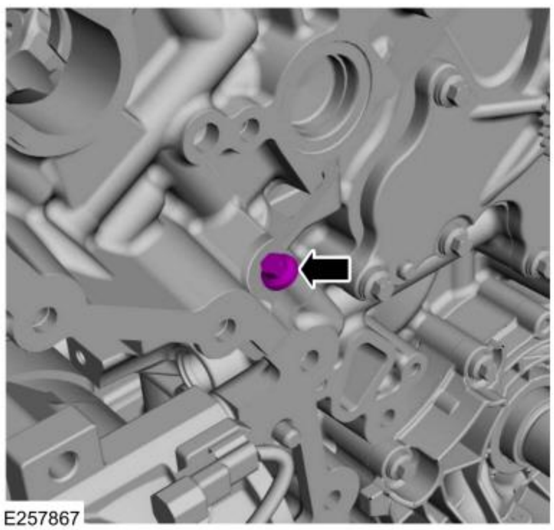
3. **NOTE:** *If the cylinder head is replaced, a new secondary timing chain tensioner will need to be installed.*

   NOTE: *Install new cylinder head bolts.*

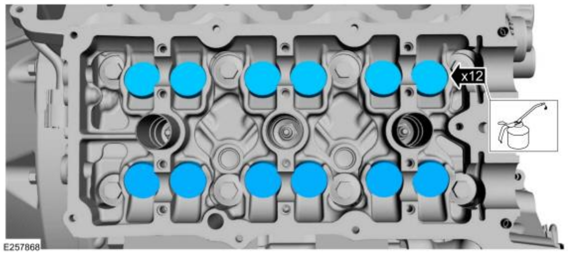
   Install the cylinder head and the new bolts.
   Torque :
   Stage 1: 177 lb.in (20 Nm)
   Stage 2: 26 lb.ft (35 Nm)
   Stage 3: 90°
   Stage 4: 90°
   Stage 5: 45°



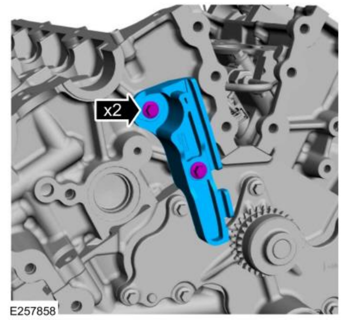
4. Install the M6 bolt.
   Torque : 89 lb.in (10 Nm)



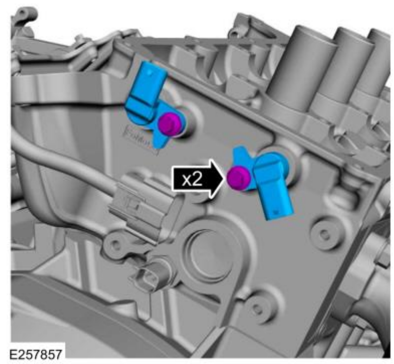
5. **NOTE:** *The valve tappets must be installed in their original positions.* Lubricate the valve tappets with clean engine oil and install. *Material* : Motorcraft® SAE 5W-20



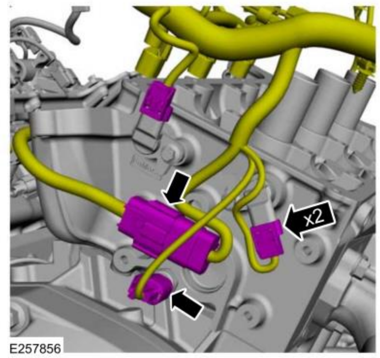
6. **NOTICE: Do not use power tools to remove the bolt or damage to the upper RH timing chain guide may occur.** Install the RH timing chain guide and the bolt.
   Torque : 89 lb.in (10 Nm)



7. **NOTE:** *Lubricate the O-ring seals with clean engine oil.* Install the CMP sensors and the bolts. *Material* : Motorcraft® SAE 5W-20
   Torque : 89 lb.in (10 Nm)



8. Connect the RH CMP sensor electrical connectors and the CHT sensor electrical connect.



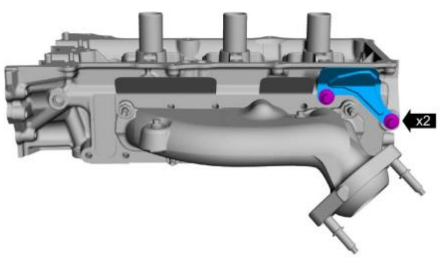
9. Install the RH camshafts, page 2-42.
10. Install new exhaust pipe flange nuts, torque 30lb.ft. (40 Nm)
11. Perform an oil change and clean with fresh oil.
    a. Drain plug torque, 20 lb.ft (27 Nm)
    b. Oil filter torque
        i. Stage 1: Install to initial gasket contact.
        ii. Stage 2: Tighten to ¾ to 1 turn.
12. Reconnect battery grounds.

Cylinder Head Disassembly

NOTICE: If replacing the cylinder head, do not reuse the secondary timing chain tensioners, they must be replaced or damage to the engine may occur. Refer to Variable Camshaft Timing (VCT) Unit.

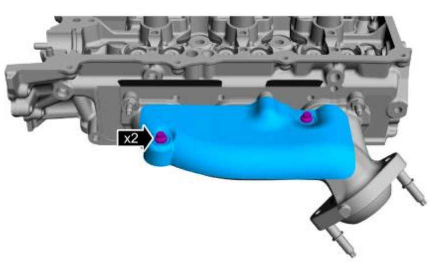
LH cylinder head

1. Remove the bolts and the exhaust manifold shield.



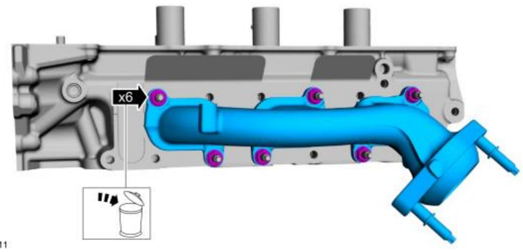
E313809

2. Remove the bolts and the exhaust manifold heat shield.



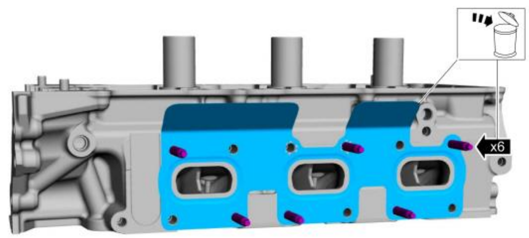
E313810

3. Remove the nuts and the exhaust manifold.
   Discard the nuts.



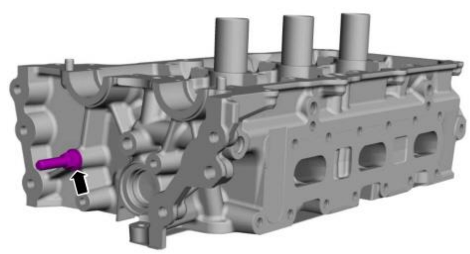
E313811

4. Remove and discard the studs and the exhaust manifold gasket.



E313812

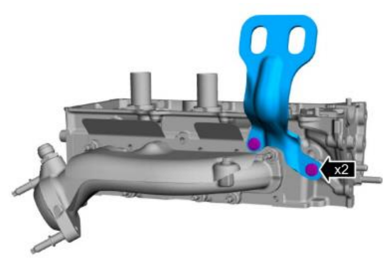
5. Remove the timing chain guide pin.



E259199

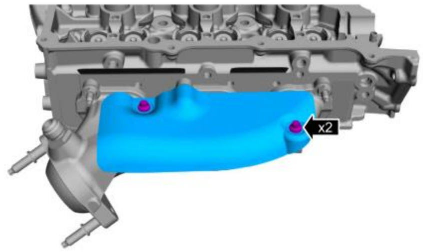
RH cylinder head

6. Remove the bolts and the engine lift eye.



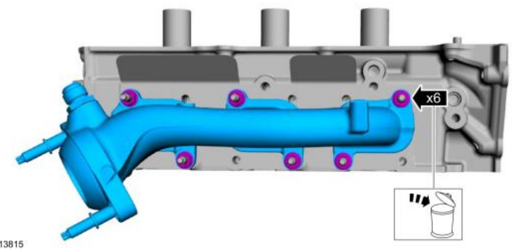
E313813

7. Remove the bolts and the exhaust manifold shield.



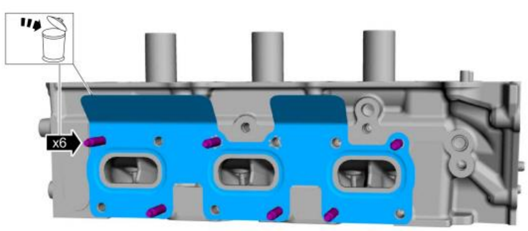
E313814

8. Remove the nuts and the exhaust manifold.
   Discard the nuts.



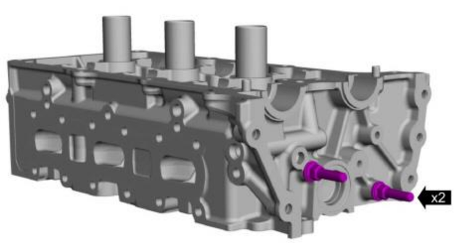
E313815

9. Remove and discard the studs and the exhaust manifold gasket



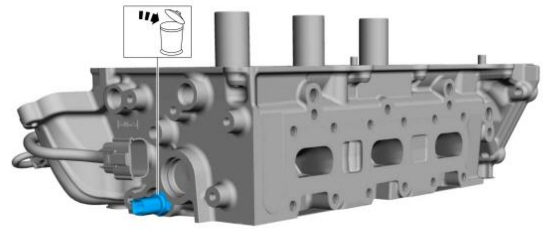
E313816

10. Remove the timing chain tensioner arm and timing chain guide pins.



E313817

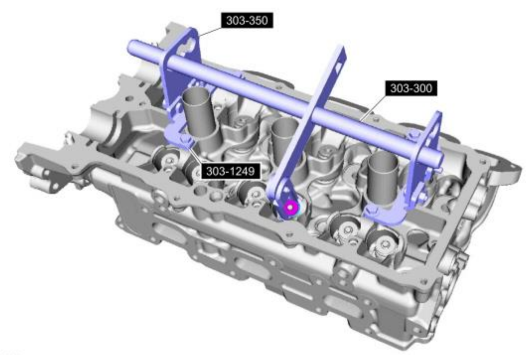
11. Remove and discard the CHT sensor.


E259207

All cylinder heads

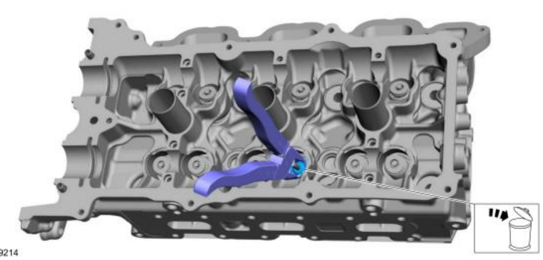
12. Remove the spark plugs, refer to section 03.

13. **NOTE:** *If the components are to be reinstalled, they must be installed in the same positions. Mark the components for installation into their original locations.*
    Using the special tools, remove the valve collet, valve spring retainer and the valve spring.
    Use Special Service Tool : 303-300 (T87C-6565-A) Set, Valve Spring Compressor , 303-350 (T89P-6565-A) Compressor, Valve Spring , 303-1249 Valve Spring Compressor

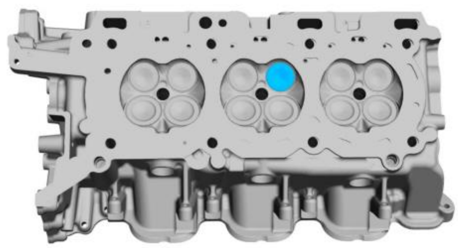


E151602

14. Remove the valve stem seal. Use valve stem seal pliers (such as BeTooll HW0107 or equivalent).


E259214

15. Remove the valve



E259215

16. Repeat the previous 3 steps for each valve.

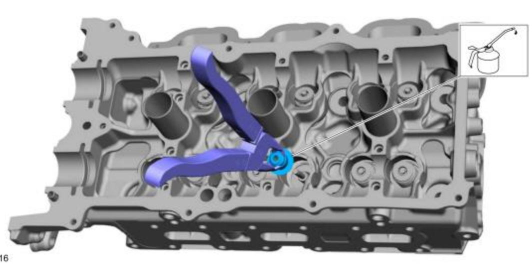
Cylinder Head Installation

All cylinder heads

1. Install the valve.

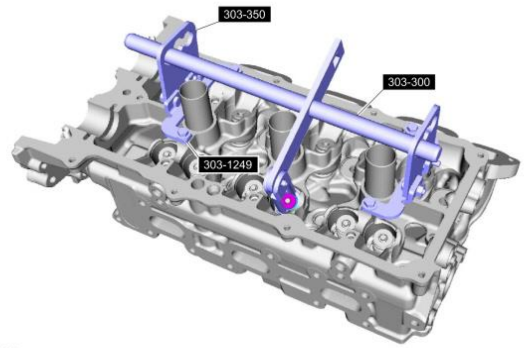
E259215

2. Lubricate with clean engine oil and use commercially available valve stem seal pliers to install the valve stem seal.
   Material : Motorcraft® SAE 5W-20



E259216

3. Using the special tools, install the valve spring, valve spring retainer and the valve collet. *Use Special Service Tool* : 303-300 (T87C-6565-A) Set, Valve Spring Compressor , 303-350 (T89P-6565-A) Compressor, Valve Spring , 303-1249 Valve Spring Compressor

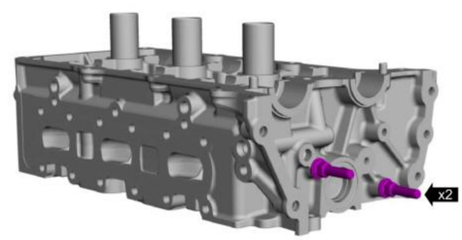


E151602

4. Repeat the previous 3 steps for each valve.
5. Install the spark plugs. Refer to section 03.

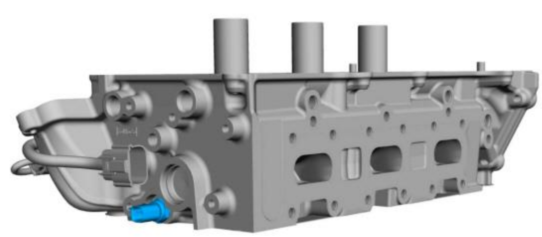
RH cylinder head

6. Install the timing chain tensioner arm and timing chain guide pins.
   a. *Torque* : Stage 1: 177 lb.in (20 Nm)
   b. Stage 2: 60º



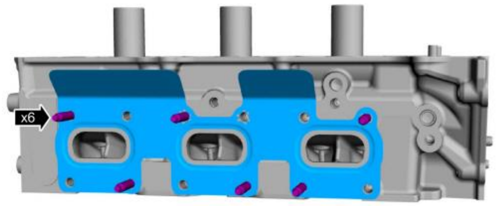
E313817

7. Install a new CHT sensor.
   Torque : 89 lb.in (10 Nm)



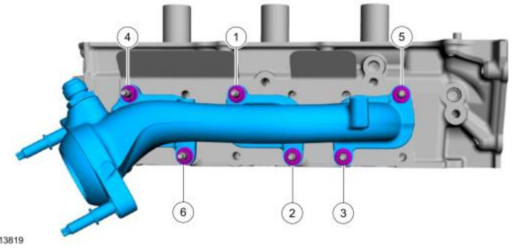
E259219

8. Install the new the studs and the exhaust manifold gasket.
   Torque : 106 lb.in (12 Nm)



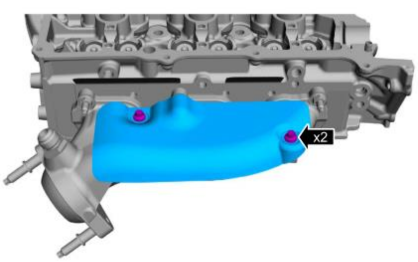
E313818

9. Install the exhaust manifold and the new nuts.
   Torque :
   Stage 1: 168 lb.in (19 Nm)
   Stage 2: 18 lb.ft (25 Nm)



E313819

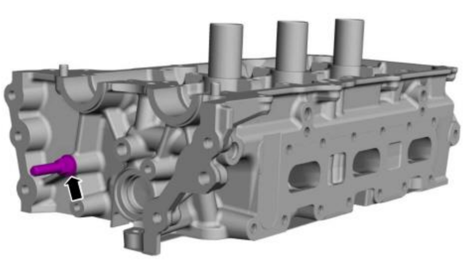
10. Install the exhaust manifold heat shield and the bolts.
    Torque : 106 lb.in (12 Nm)



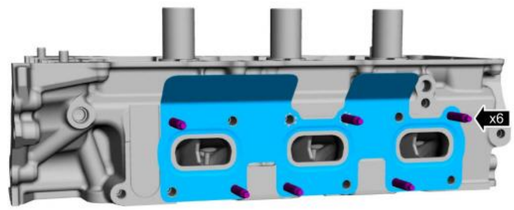
E313814

LH cylinder head

11. Install the timing chain guide pin.
    Torque : Stage 1: 177 lb.in (20 Nm)
    Stage 2: 60º

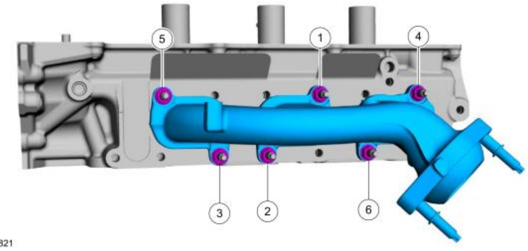

E259199

12. Install the new the studs and the exhaust manifold gasket.
    Torque : 106 lb.in (12 Nm)



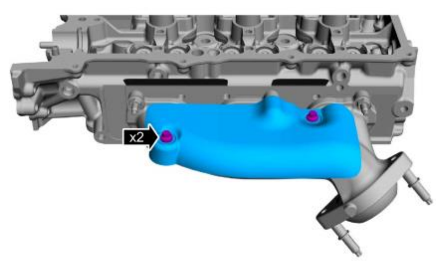
E313820

13. Install the exhaust manifold and the new nuts.
    Torque :
    Stage 1: 168 lb.in (19 Nm)
    Stage 2: 18 lb.ft (25 Nm)



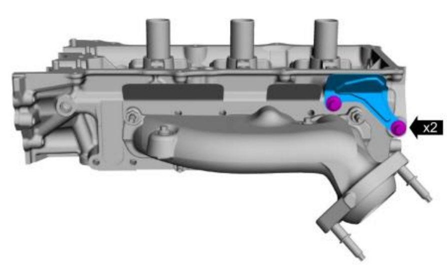
E313821

14. Install the exhaust manifold heat shield and the bolts.
    Torque : 106 lb.in (12 Nm)



E313810

15. Install the exhaust manifold shield and the bolts.
    Torque : 177 lb.in (20 Nm)



E313809

Piston Disassembly/ASSEMBLY

1. Remove the piston rings and discard

E178665

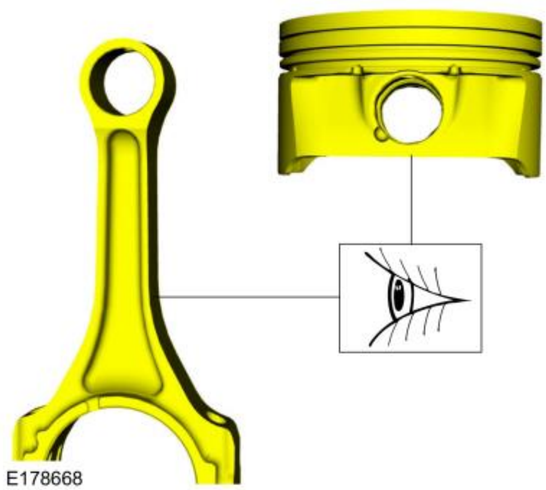
2. Remove the piston pin retainers and discard.
   Remove the piston pin.

E178666

3. **NOTE:** *If the piston and connecting rod are to be reinstalled, they must be assembled in the same orientation. Mark the piston orientation to the connecting rod for reassembly.*
   Remove the piston from the connecting rod.

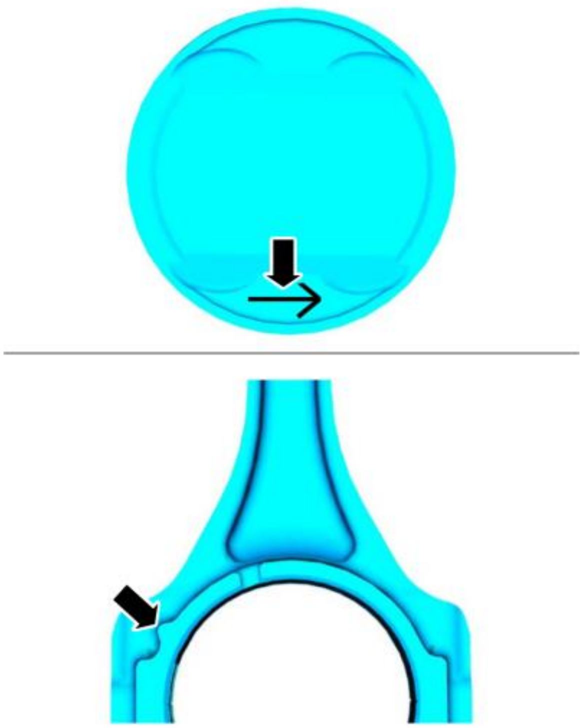
E178667

4. Inspect the piston and connecting rod.
   Refer to: Piston Inspection (Section 01 Engine System - General Information, General Procedures).



E178668

5. If the piston and/or connecting rod are being installed new, the piston rod orientation marks and the arrow on the top of the dome of the piston should be facing toward the front of the engine block.



E178669

6. Install the piston to the connecting rod.

E178670

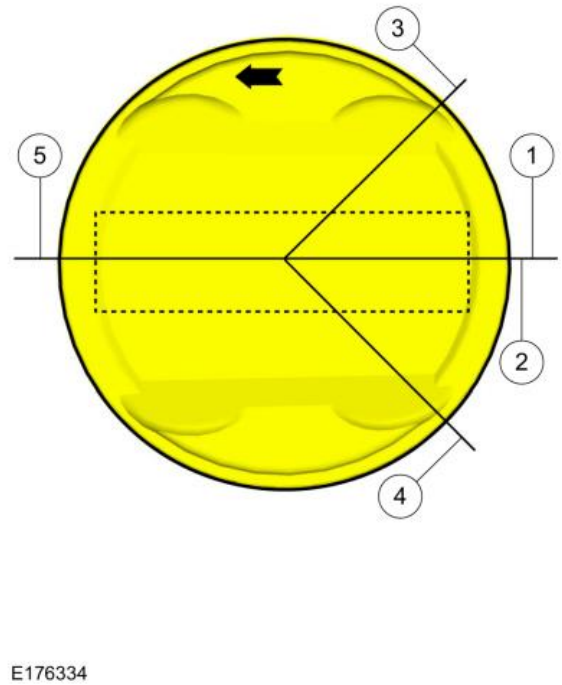
7. Lubricate with clean engine oil and install the piston pin. *Material* : Motorcraft® SAE 5W-20

E178671

8. **NOTE:** *The piston pin retaining clip gap orientation must be toward the top or dome of piston.*
   Install the piston pin retainers.

E178672

9. Lubricate with clean engine oil and install the piston rings. *Material* : Motorcraft® SAE 5W-20



10. **NOTE:** *The piston compression upper and lower ring should be installed with the "O" mark on the ring face pointing up toward the top of the piston.*
NOTE: *The arrow on the top of the piston indicates the front of the engine*

.

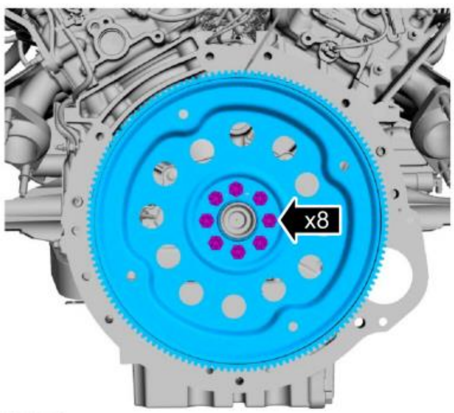
1. Center line of the piston parallel to the wrist pin bore.
2. Upper compression ring gap location.
3. Upper oil control segment ring gap location.
4. Lower oil control segment ring gap location.
5. Expander ring and lower compression ring gap location.

Engine Disassembly

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

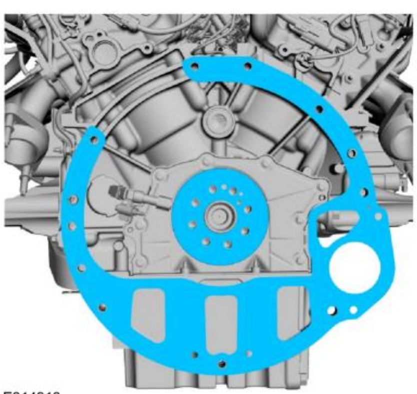
NOTE: *If the cylinder head(s) is replaced, a new secondary timing chain tensioner will need to be installed.*
NOTE: *Refer to the exploded view under the Engine Component View in the Description and Operation.*

1. Remove the bolts and the flexplate.



E314912

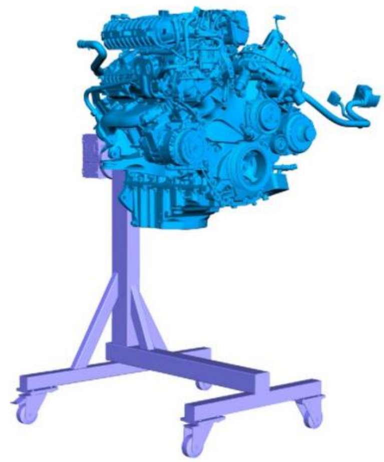
2. Remove the crankshaft sensor ring and the engine-to-transmission spacer plate (if equipped).



E314913

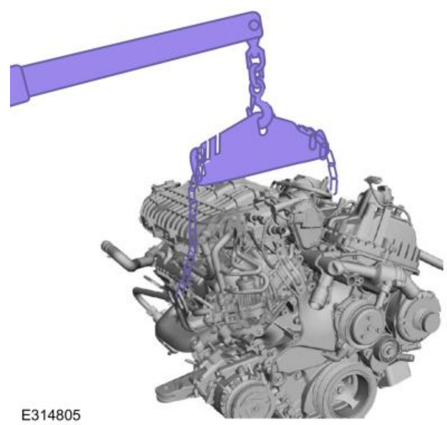
3. **NOTE:** *Install the engine stand bolts into the cylinder block only. Do not install the bolts into the oil pan.*

   Mount the engine to the mounting stand. Use the General Equipment: Mounting Stand



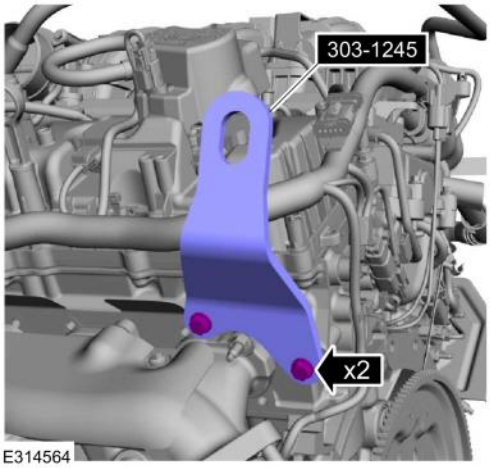
E314914

4. Remove the floor crane.
   Use the General Equipment: Floor Crane

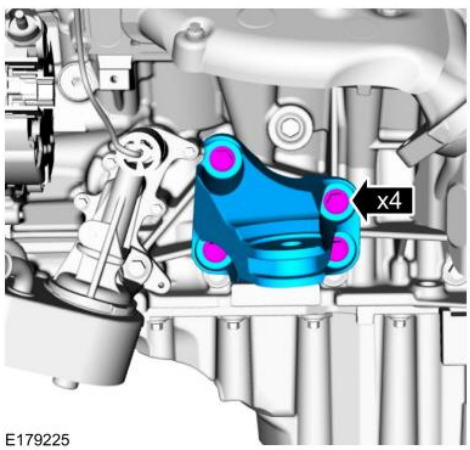


E314805

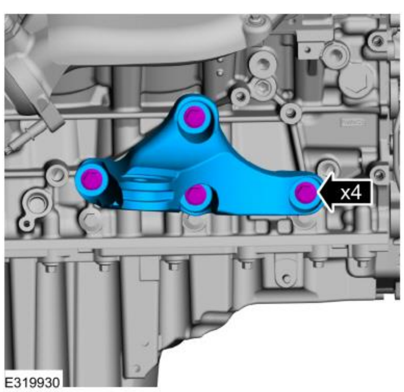
5. Remove the LH engine lift eye.
   Use Special Service Tool : 303-1245 Engine Lift Eye



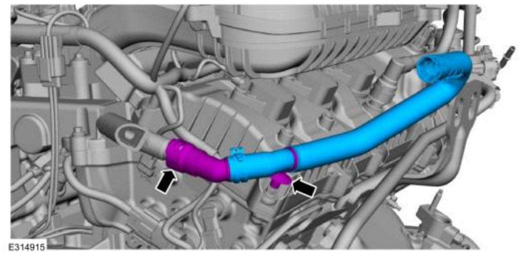
6. Remove the bolts and the LH engine mount bracket.



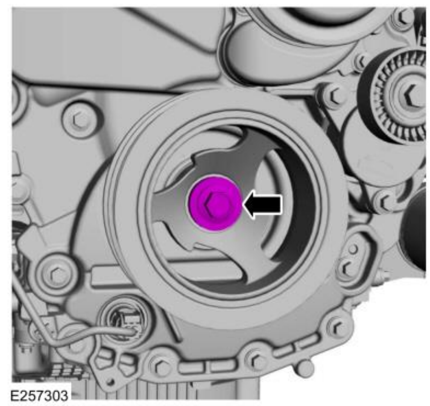
7. Remove the bolts and the RH engine mount bracket.



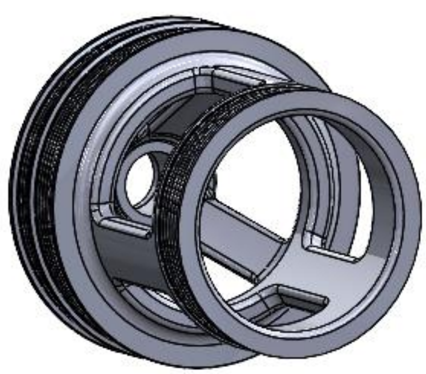
8. Disconnect the quick release connector, retainer and remove the coolant tube.



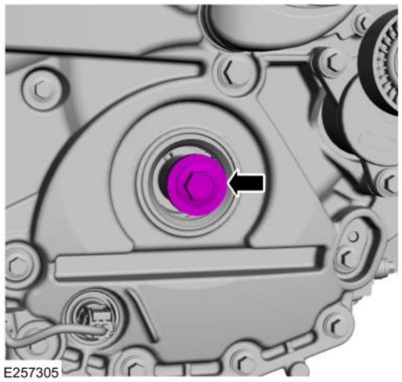
9. Remove the crankshaft pulley bolt and washer.
   Discard the bolt.



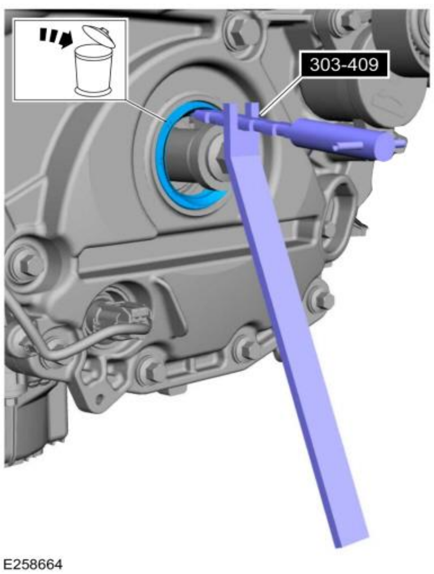
10. Using a three leg puller, remove the crankshaft pulley.
    Use the General Equipment: Three Leg Puller, OTC 6667, or Rotunda equivalent.



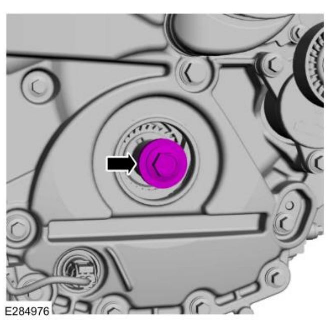
11. Install the original crankshaft pulley bolt and washer.



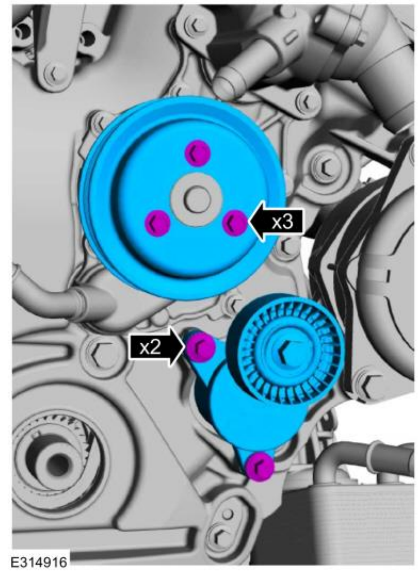
12. Using the special tool, remove and discard the crankshaft front seal.
    Use Special Service Tool : 303-409 (T92C-6700-CH) Remover, Crankshaft Seal



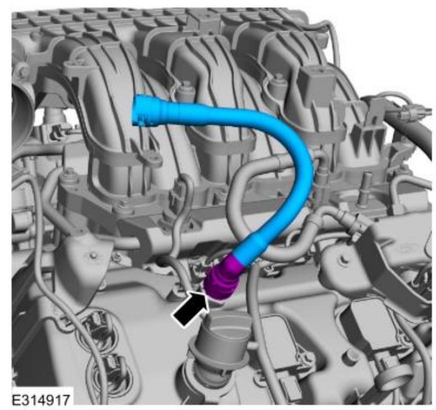
13. Remove the original crankshaft pulley bolt and washer.



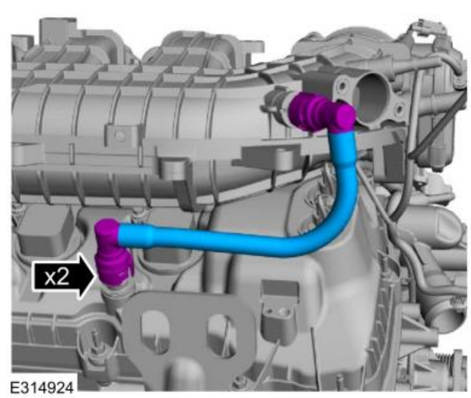
14. Remove the bolts, coolant pump pulley and the accessory drive belt tensioner.



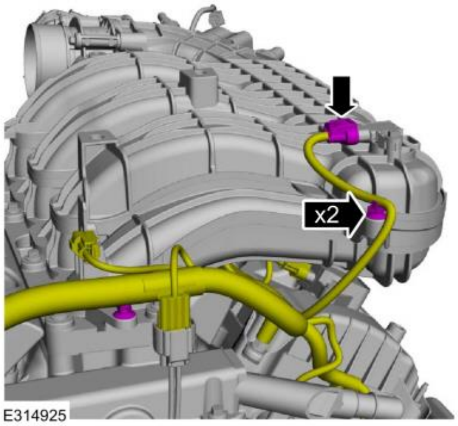
15. Remove the crankcase vent tube.



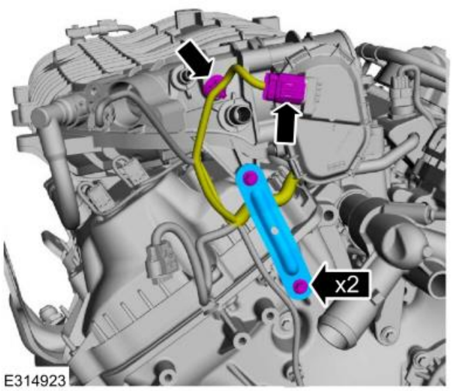
16. Remove the PCV tube.



17. Disconnect the MAP sensor electrical connector and wiring harness retainers.

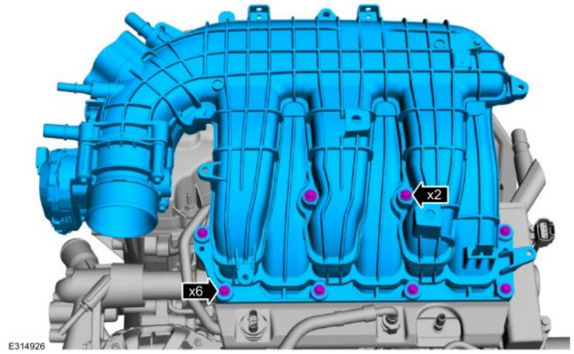


18. Remove the bolts and the upper intake manifold support bracket.

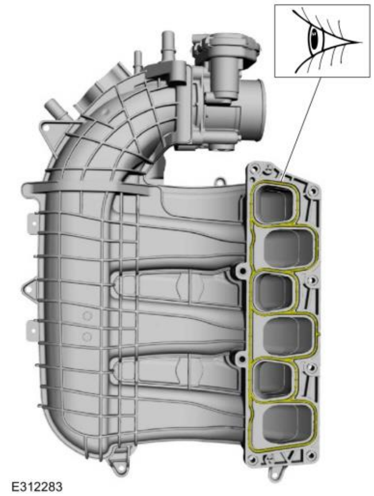


NOTICE: If the engine is repaired or replaced because of upper engine failure, typically including valve or piston damage, check the intake manifold for metal debris. If metal debris is found, install a new intake manifold. Failure to follow these instructions can result in engine damage.

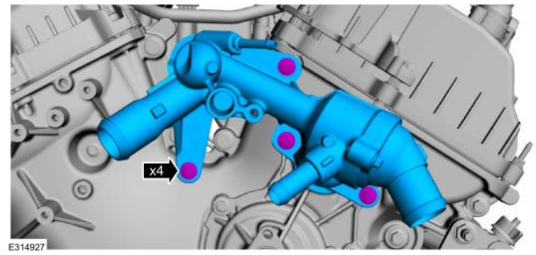
Remove the bolts and the upper intake manifold.



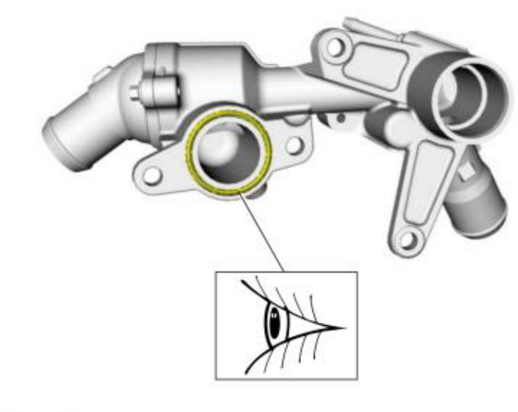
19. Visually inspect the upper intake manifold gaskets for nicks, cuts, and abrasions. If these conditions are not present, the gaskets may be re-used.



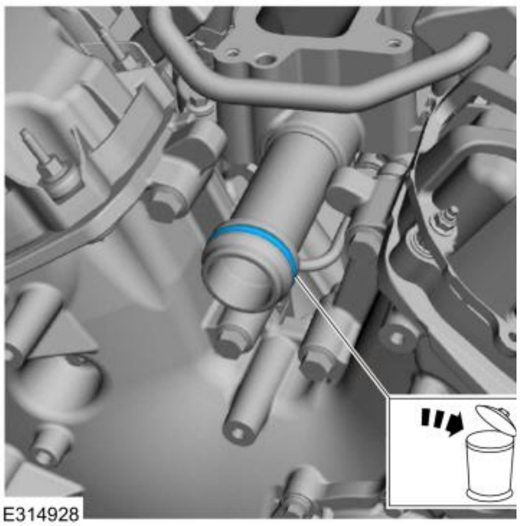
20. Remove the bolts and the thermostat housing.



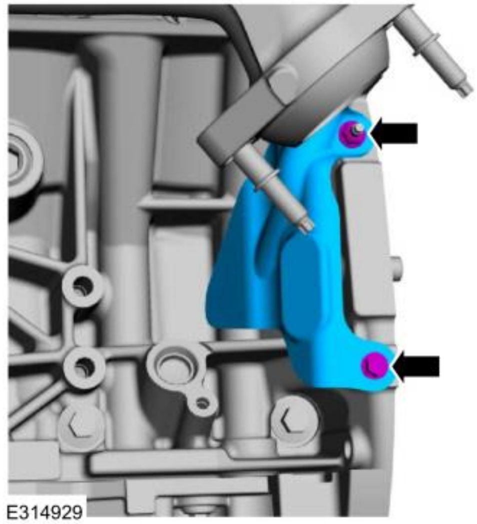
21. Inspect and replace if necessary.


E177269

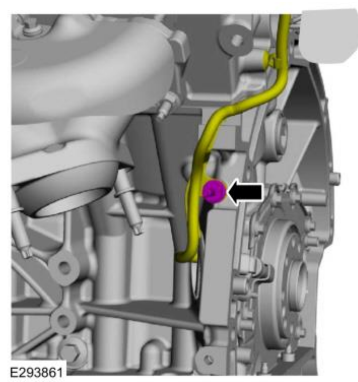
22. Remove and discard the thermostat housing O-ring seal.


E314928

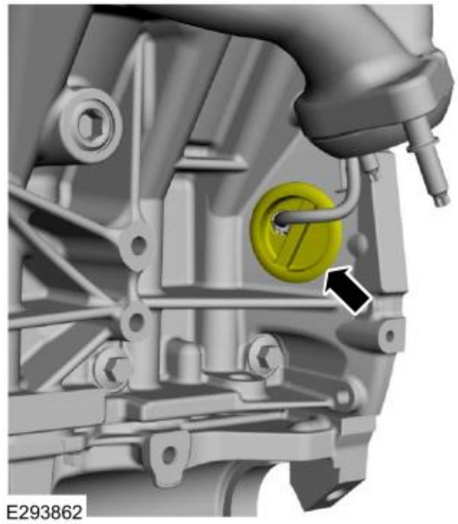
23. Remove the nut, bolt and the heat shield.


E314929

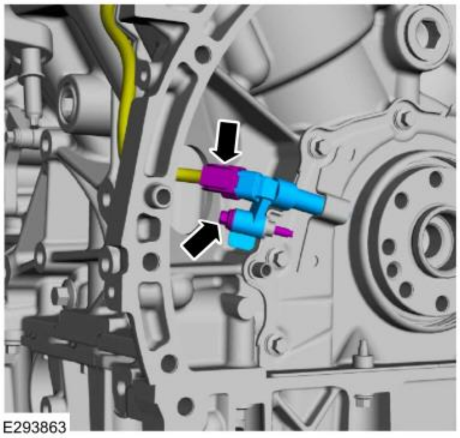
24. Remove the wiring harness retainer stud bolt.


E293861

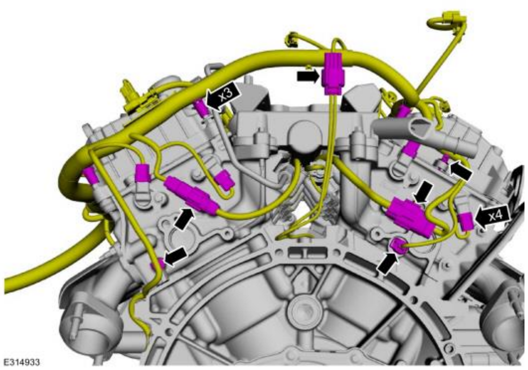
25. Remove the wiring harness grommet.


E293862

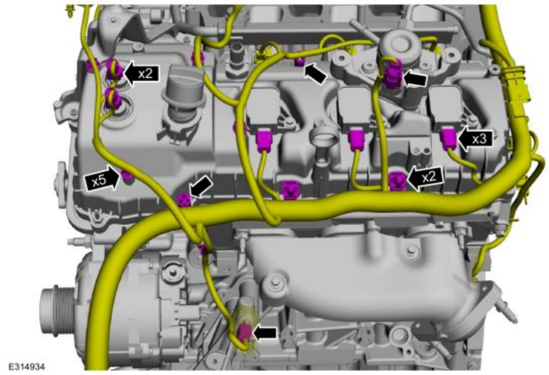
26. Disconnect the CKP sensor electrical connector.
    Remove the bolt and the CKP sensor.



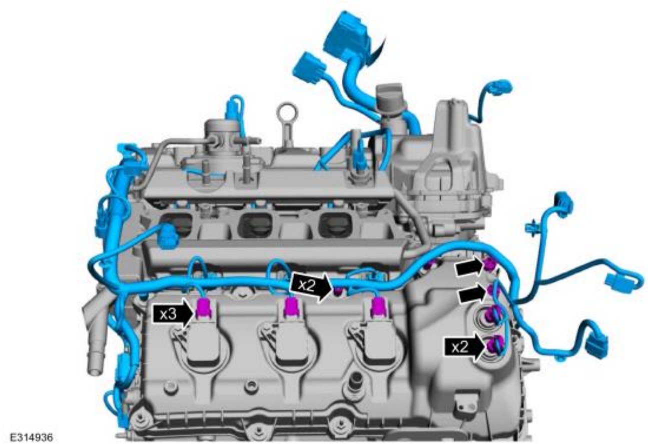
27. Disconnect the KS and CHT sensor electrical connectors.
    Disconnect the CMP sensor electrical connectors.
    Detach the wiring harness retainers.



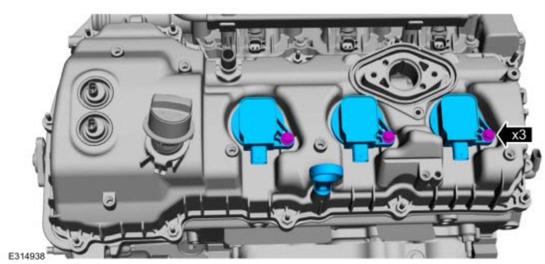
28. Disconnect the VCT oil control solenoids electrical connectors. Disconnect the ignition coil-on-plug electrical connectors. Disconnect the wiring harness electrical connectors.
    Detach the wiring harness retainers.



29. Disconnect the wiring harness electrical connectors.
    Detach the wiring harness retainers and remove the engine wiring harness.



30. **NOTE:** *When removing the ignition coil-on-plugs, a slight twisting motion will break the seal and ease removal.*
    Remove the bolts and the ignition coil on-plugs.
    Remove the oil level indicator.



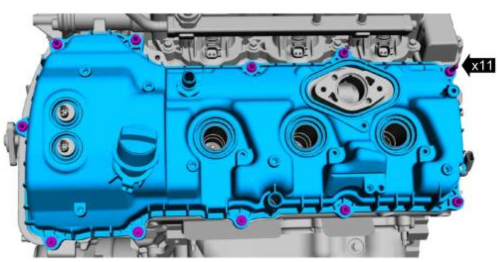
31. Inspect the coil seals for rips, nicks or tears.

E258684

32. **NOTICE: While removing the valve cover do not apply excessive force to the VCT oil control solenoid or damage may occur.**

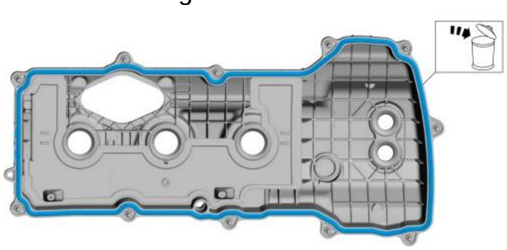
    NOTICE: If the VCT oil control solenoid sticks to the VCT seal, carefully wiggle the valve cover until the bond breaks free or damage to the VCT seal and VCT oil control solenoid may occur.

    Loosen the bolts and the valve cover.



E314939

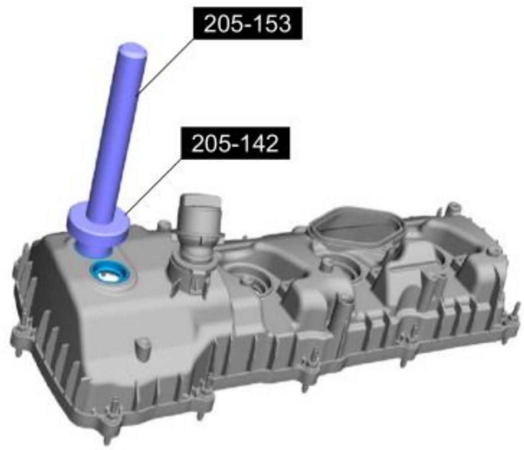
33. Discard the gasket



E258318

34. **NOTE:** *Inspect the VCT solenoid seals. Remove any damaged seals.*

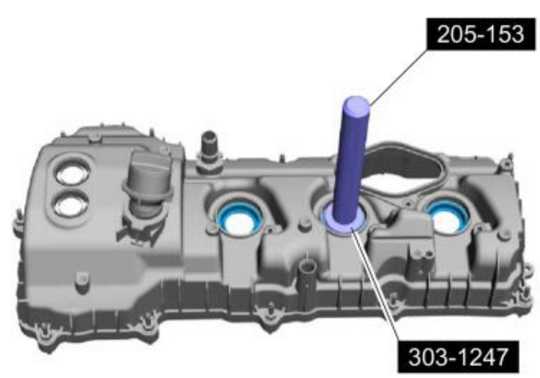
    Using the special tools, remove and discard the seal(s).
    Use Special Service Tool : 205-142 (T80T-4000-J) Installer, Differential Bearing Cone , 205-153 (T80T-4000-W) Handle



E312588

35. **NOTE:** *Inspect the spark plug tube seals. Remove any damaged seals.*

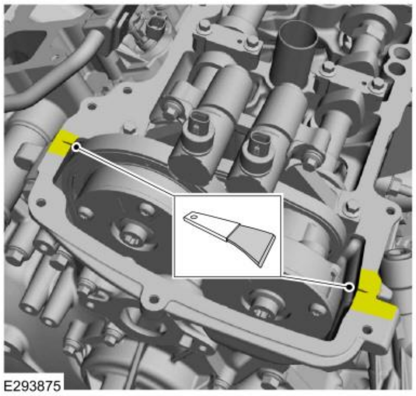
    Using the special tools, remove and discard the seal(s). *Use Special Service Tool* : 205-153 (T80T-4000-W) Handle , 303-1247 VCT Spark Plug Tube Seal Remover and Installer



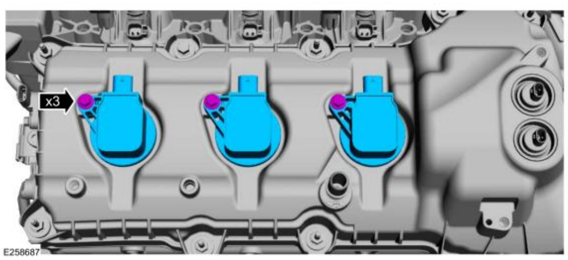
E312589

36. Make sure that the mating faces are clean and free of foreign material. Refer to: RTV Sealing Surface Cleaning and Preparation (section 01 Engine

System – General Information, General Procedures). Use the General Equipment: Plastic Scraper
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-B


E293875

37. **NOTE:** *When removing the ignition coil-on-plugs, a slight twisting motion will break the seal and ease removal.*
Remove the bolts and the ignition coil-on-plugs.



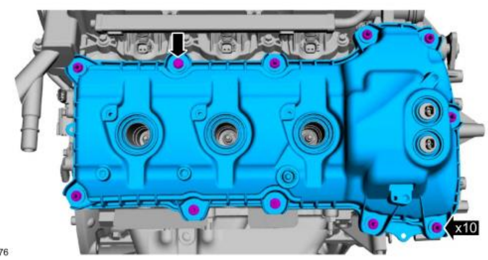
E258687

38. Inspect the coil seals for rips, nicks or tears.


E258684

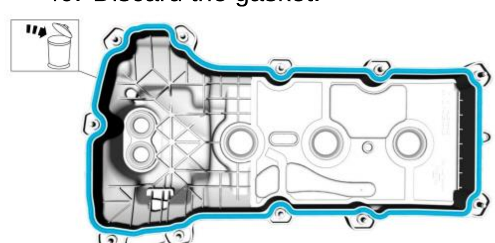
39. **NOTICE: While removing the valve cover do not apply excessive force to the VCT oil control solenoid or damage may occur.**
NOTICE: If the VCT oil control solenoid sticks to the VCT seal, carefully wiggle the valve cover until the bond breaks free or damage to the VCT seal and VCT oil control solenoid may occur.

Loosen the bolts and remove the valve cover.



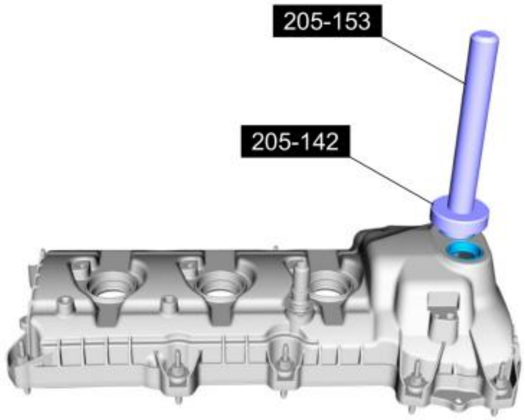
E293876

40. Discard the gasket.


E177250

41. **NOTE:** *Inspect the VCT solenoid seals. Remove any damaged seals.*

Using the special tools, remove and discard the seal(s).
Use Special Service Tool : 205-142 (T80T-4000-J) Installer, Differential Bearing Cone , 205-153 (T80T-4000-W) Handle

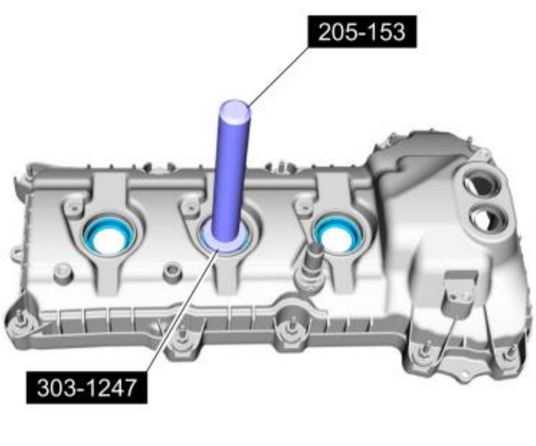


E177340

42. **NOTE:** *Inspect the spark plug tube seals. Remove any damaged seals.*

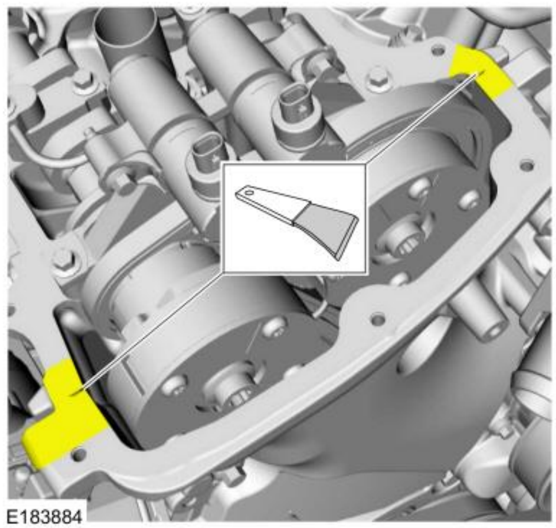
    Using the special tools, remove and discard the seal(s). *Use Special Service Tool* : 205-153 (T80T-4000-W) Handle , 303-1247 VCT Spark Plug Tube Seal

    Remover and Installer



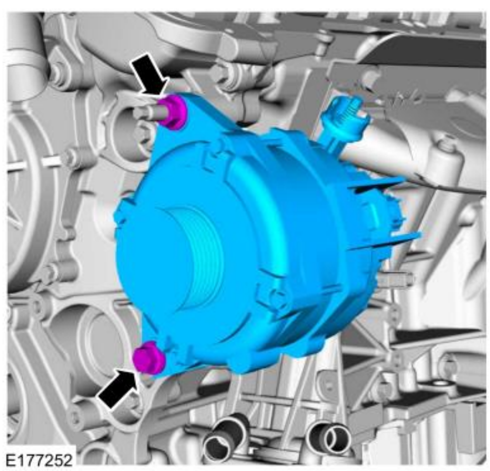
E177341

43. Make sure that the mating faces are clean and free of foreign material. Refer to: RTV Sealing Surface Cleaning and Preparation (section 01 Engine System – General Information, General Procedures). Use the General Equipment: Plastic Scraper
    Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
    Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
    Material : Motorcraft® Metal Surface Prep / ZC-31-B



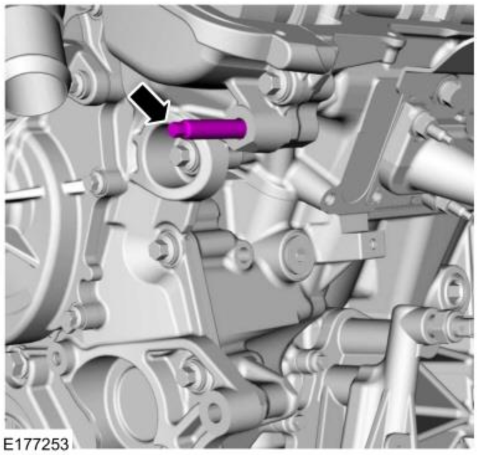
E183884

44. Remove the bolts and the generator.

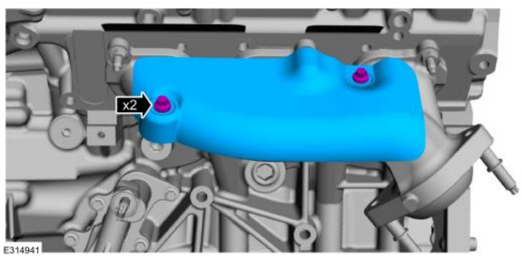


E177252

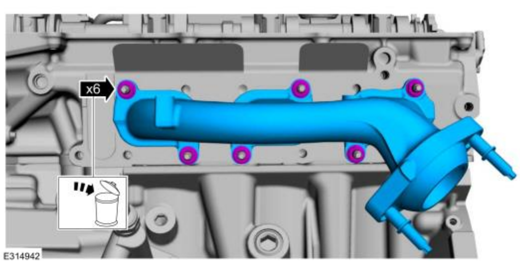
45. Remove the generator stud bolt.



46. Remove the bolts and the LH exhaust manifold heat shield.

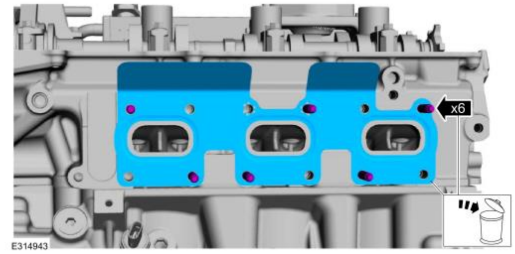


47. Remove the nuts and the LH exhaust manifold.
Discard the nuts.

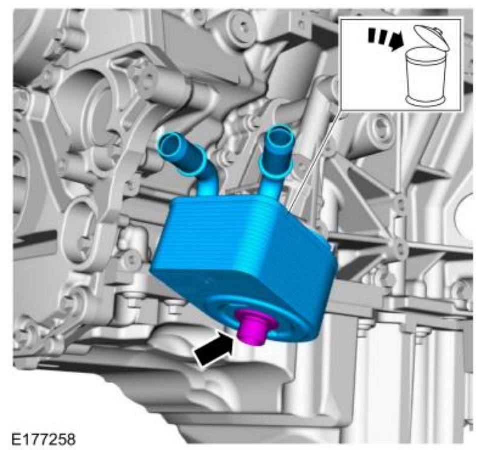


48. Clean and inspect the catalytic converter flange.
Refer to: Exhaust Manifold Cleaning and Inspection (Section 01 Engine System - General Information, General Procedures)

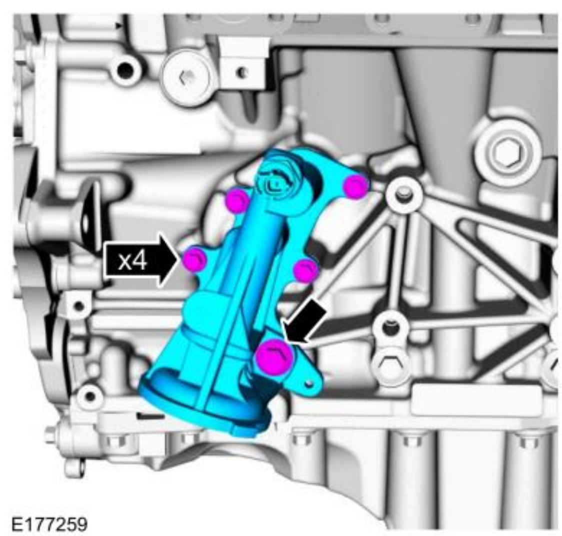
49. Remove and discard the LH exhaust manifold gasket and studs.



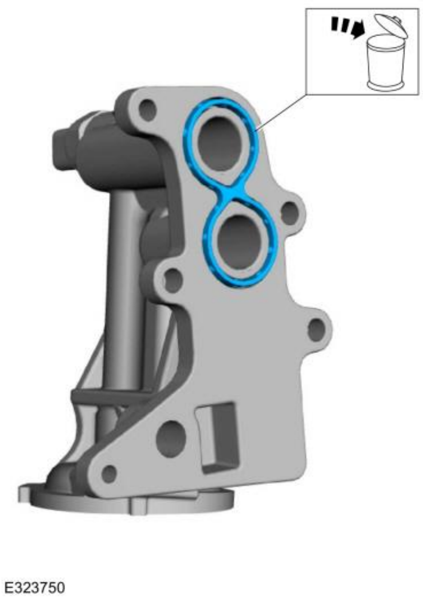
50. **NOTICE: If metal or aluminum material is present in the oil cooler, mechanical concerns exist. Failure to correct these concerns may cause engine failure.**
Remove the bolt and the oil cooler.
Discard the oil cooler..



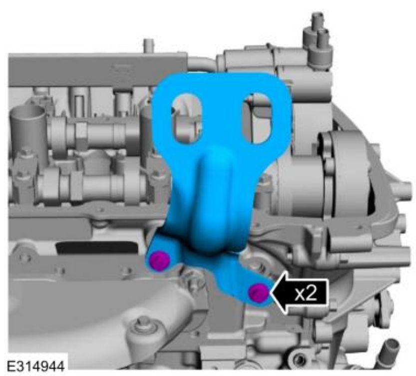
51. Remove the bolts and the oil filter adapter.



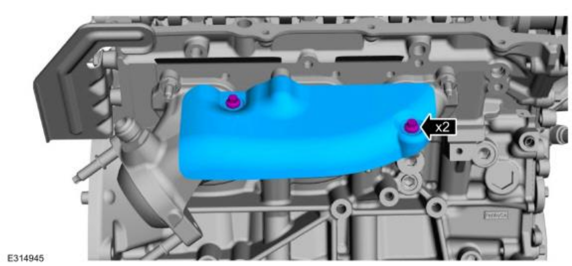
52. Inspect and replace if necessary.



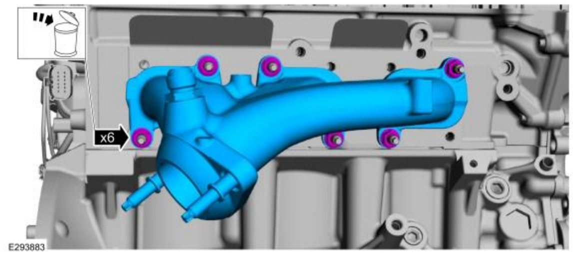
53. Remove the bolts and the RH lift eye.



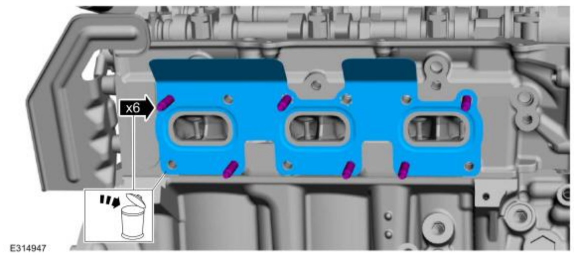
54. Remove the bolts and the RH exhaust manifold heat shield.



55. Remove the nuts and the RH exhaust manifold.
    Discard the nuts.

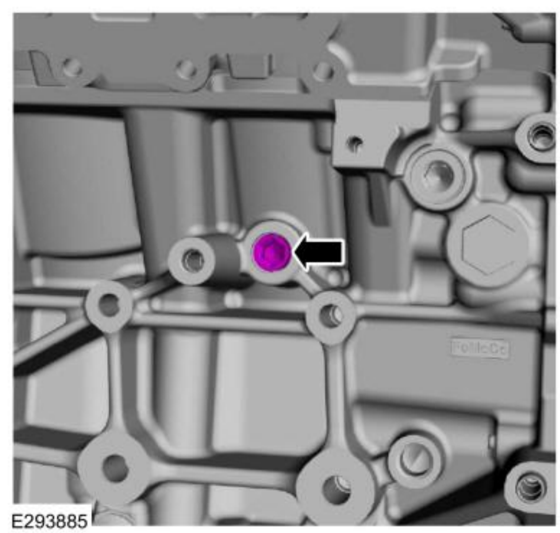


56. Remove and discard the RH exhaust manifold gasket and studs.

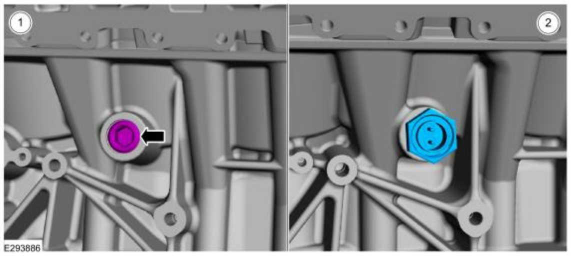


57. Clean and inspect the catalytic converter flange.
    Refer to: Exhaust Manifold Cleaning and Inspection (Section 01 Engine System - General Information, General Procedures).

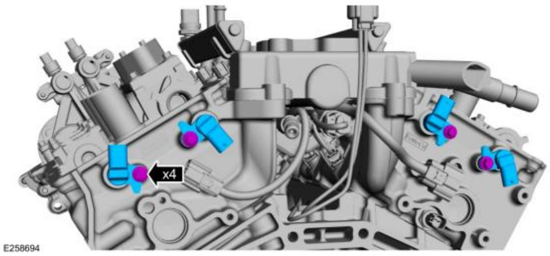
58. Remove the RH block coolant drain plug and allow coolant to drain from the cylinder block.



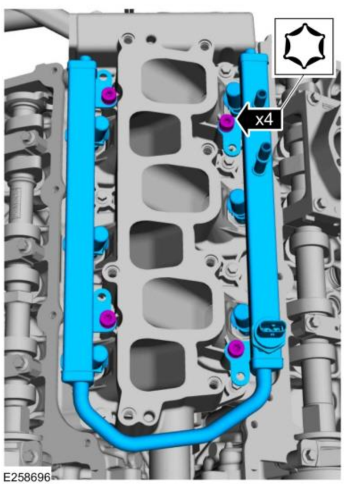
59. Remove the LH block coolant drain plug and allow coolant to drain from the cylinder block.



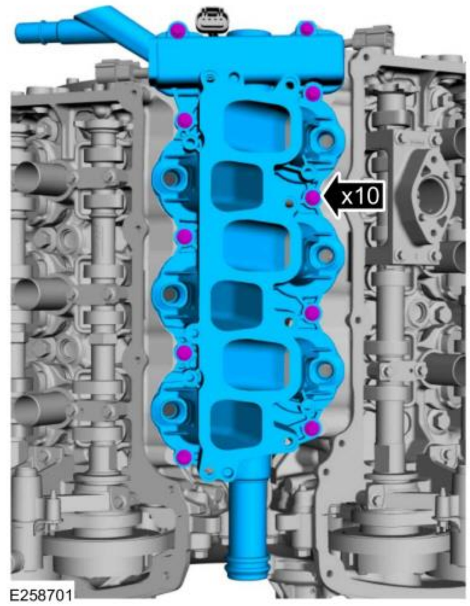
60. Remove the bolts and the CMP sensors.



61. Remove the bolts and the fuel rail.

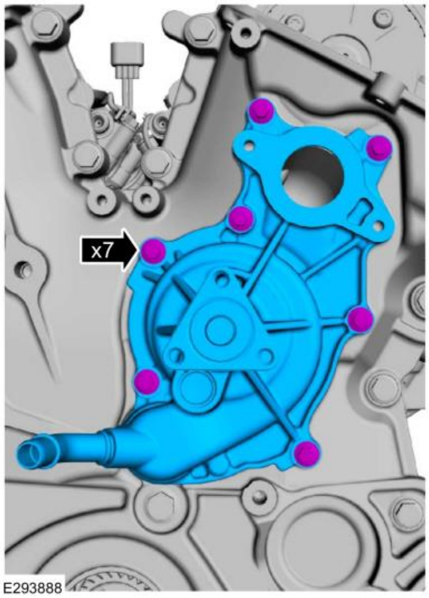


62. Remove the bolts and the lower intake manifold.



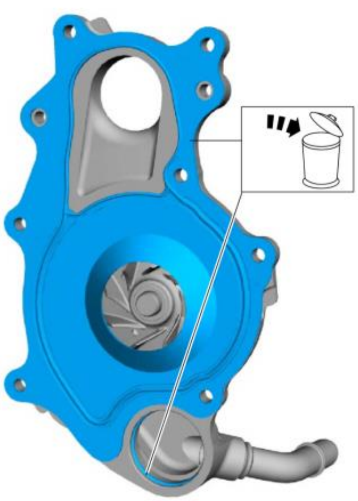
63. Visually inspect the lower intake manifold gaskets for nicks, cuts, and abrasions. If these conditions are not present, the gaskets may be re-used.

64. Remove the bolts and the coolant pump.



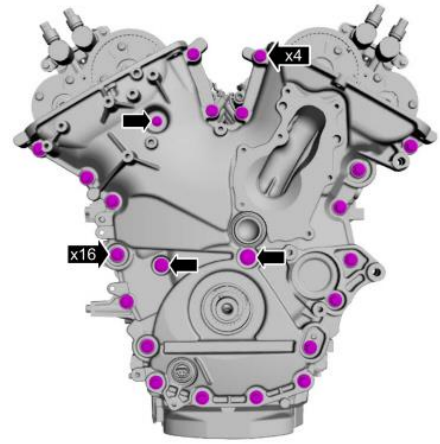
E293888

65. Remove and discard the coolant pump gasket and O-ring seal.



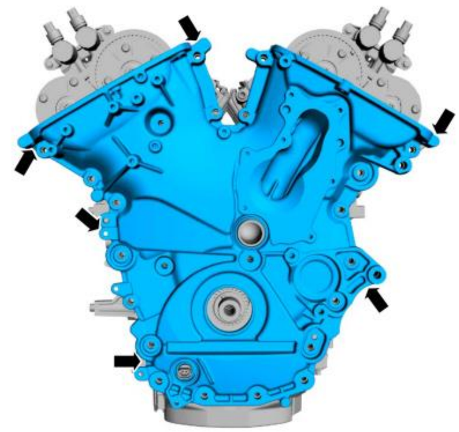
E293889

66. Remove the engine front cover bolts.



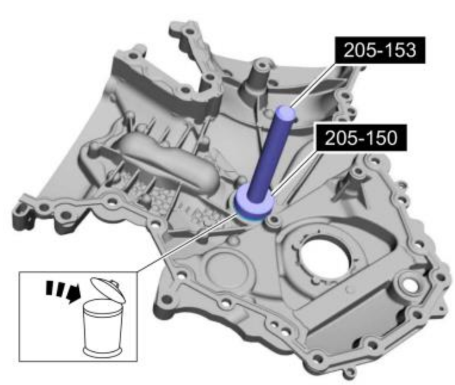
E314949

67. Using a pry tool, locate the 6 pry pads shown and pry the engine front cover loose and remove.



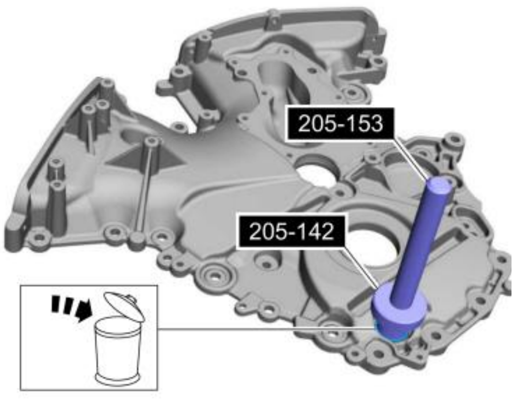
E314950

68. Using the special tools, remove the engine front cover to coolant pipe seal. *Use Special Service Tool* : 205-150 (T80T-4000-S) Installer, Spindle Bearing , 205-153 (T80T-4000-W) Handle



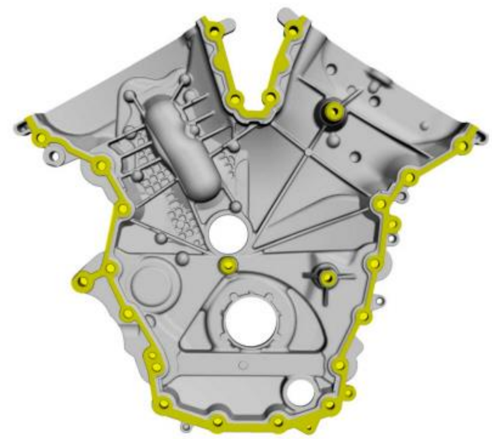
E258006

69. Using the special tools, remove and discard the oil pump electrical connector seal. *Use Special Service Tool* : 205-150 (T80T-4000-S) Installer, Spindle Bearing , 205-153 (T80T-4000-W) Handle

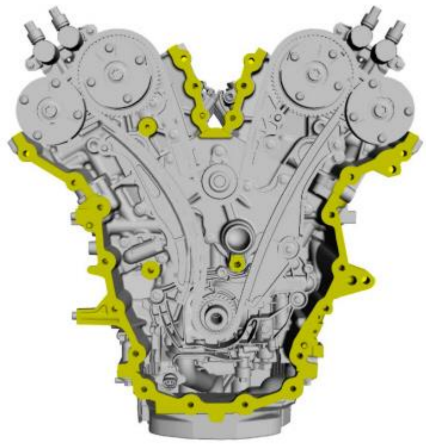


E258007

70. **NOTICE: Only use a 3M™ Roloc® Bristle Disk (2-in white, part number 07528) in a suitable tool turning at the recommended speed of 15,000 rpm, to clean the engine front cover. Do not use metal scrapers, wire brushes or any other power abrasive disk to clean front cover.**
Make sure that the mating faces of the front cover are clean and free of foreign material.
Refer to: RTV Sealing Surface Cleaning and Preparation (Section 01 Engine System – General Information, General Procedures).
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-B
Thoroughly wash the engine front cover to remove any foreign material, including any abrasive particles created during the cleaning process.

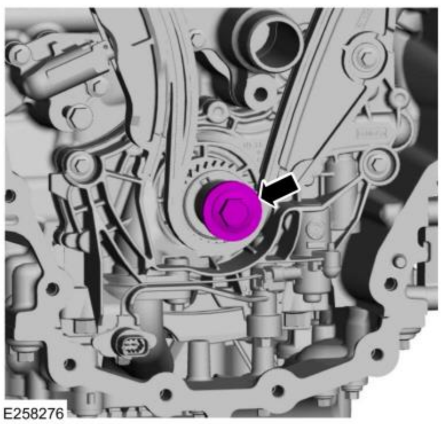

E314089

71. **NOTICE: Place clean, lint-free shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**
NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white part number 07528) to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. They also cause contamination that will cause premature engine failure.
Remove all traces of the gasket.
Make sure that the mating faces of the engine block and oil pan are clean and free of foreign material.
Refer to: RTV Sealing Surface Cleaning and Preparation (Section 01 Engine System – General Information, General Procedures). Use the General Equipment: Plastic Scraper
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-B



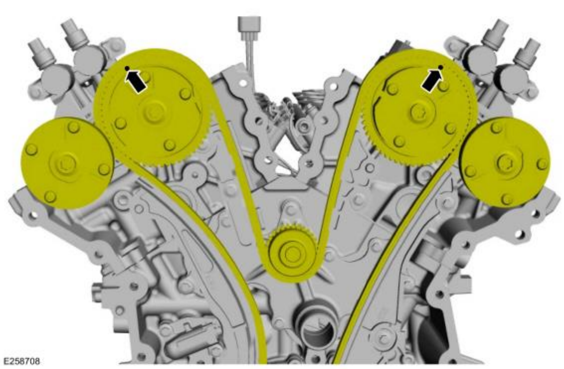
E314951

72. Install the original crankshaft pulley bolt and washer.



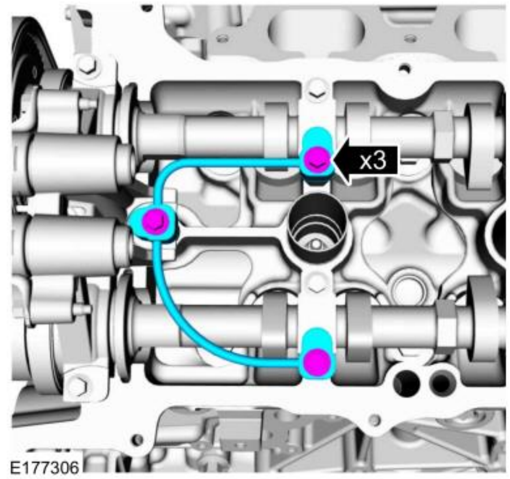
E258276

73. **NOTE:** *Rotate the crankshaft in a clockwise direction only.*
Rotate the crankshaft clockwise and align the timing marks on the intake VCT units as shown.



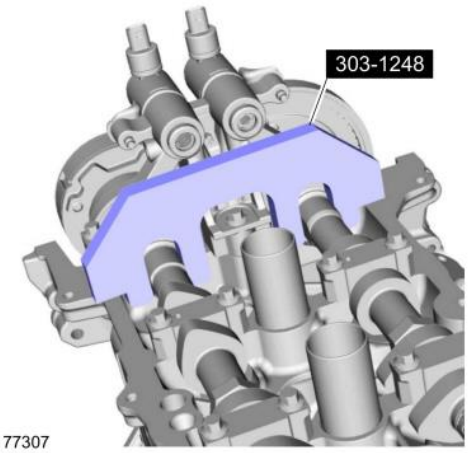
E258708

74. Remove the bolts and the LH oil tube.



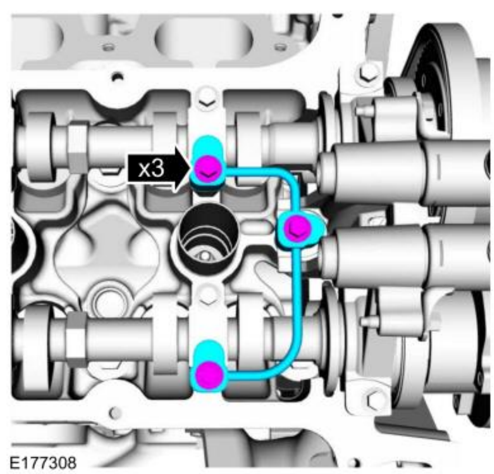
E177306

75. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position.*
Install Special Service Tool : 303-1248 Camshaft holding tools



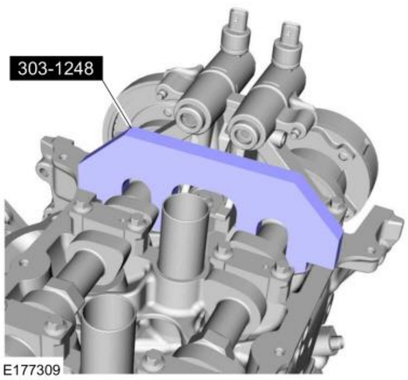
E177307

76. Remove the bolts and the RH oil tube.

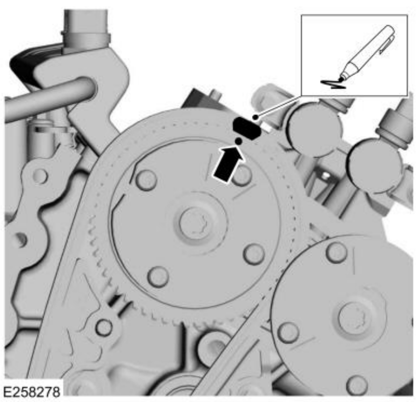


E177308

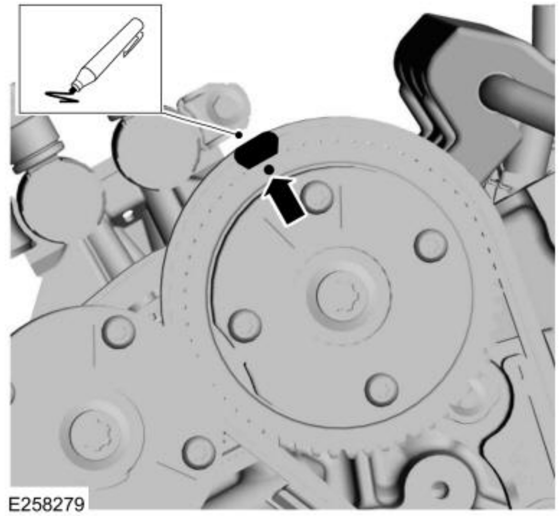
77. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position.*
    Install Special Service Tool : 303-1248 Camshaft holding tools



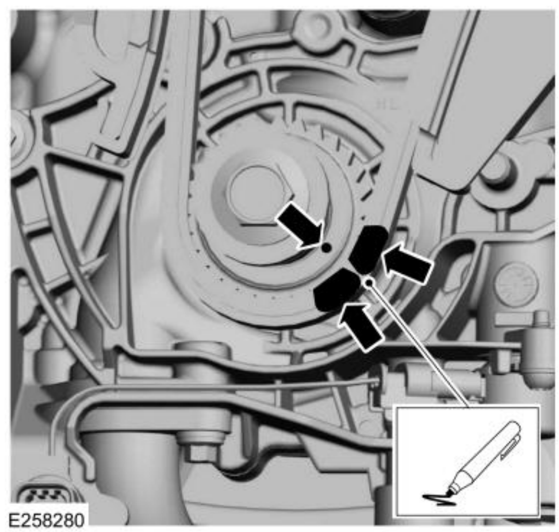
78. **NOTE:** ***The following 3 steps are for primary timing chains that the colored links are not visible.***
    Mark the timing chain link that aligns with the timing mark on the LH intake VCT unit as shown.



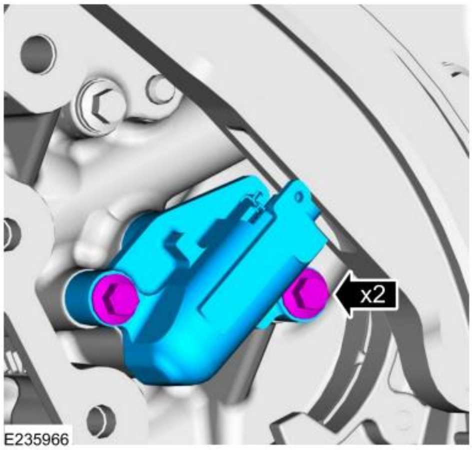
79. Mark the timing chain link that aligns with the timing mark on the RH intake VCT unit as shown.



80. **NOTE:** *The crankshaft sprocket timing mark should be between the colored links.*
    Mark the timing chain links that aligns with the timing mark on the crankshaft sprocket as shown.

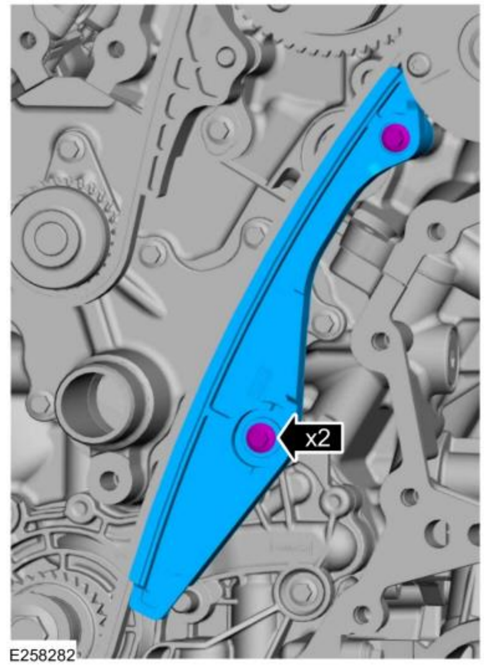


81. Remove the bolts and the timing chain tensioner.



82. Remove the timing chain tensioner arm.

83. Remove the bolts and the lower LH timing chain guide.



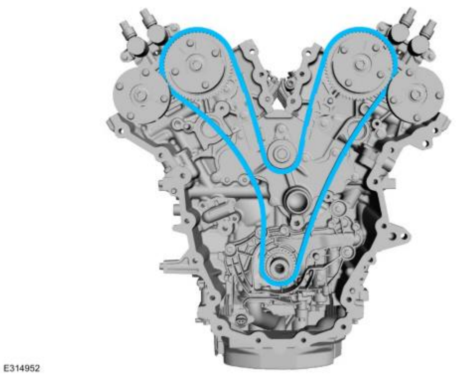
84. **NOTE:** *Removal of the VCT oil control solenoid will aid in the removal of the timing chain.*

    NOTE: *A slight twisting motion will aid in the removal of the VCT oil control solenoids.*

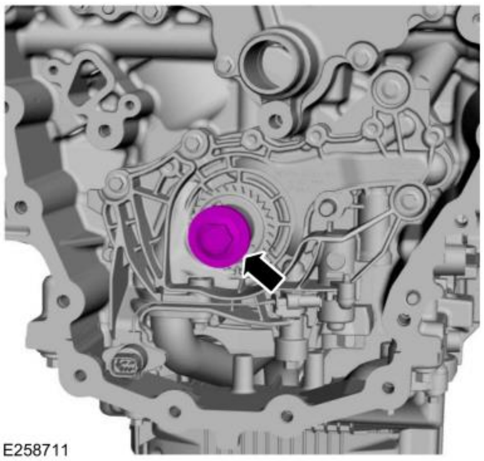
    NOTE: *Keep the VCT oil control solenoid clean of dirt and debris.*

    Remove the bolts and the VCT oil control solenoids.

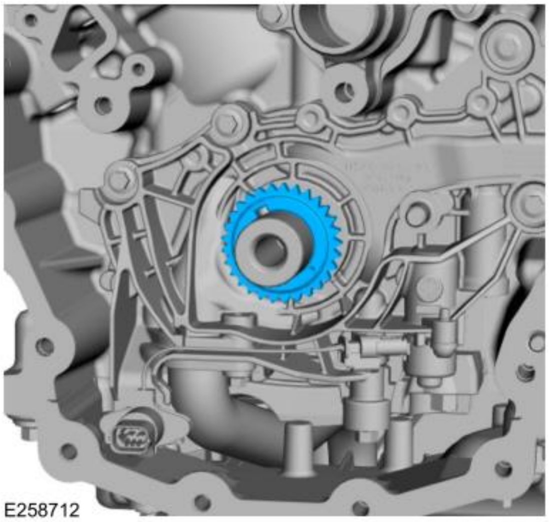
85. Remove the timing chain.



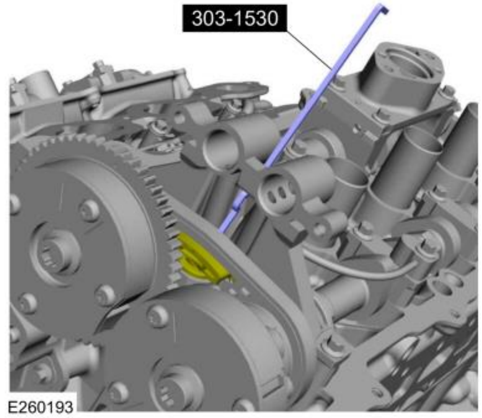
86. Remove the crankshaft pulley bolt and washer.



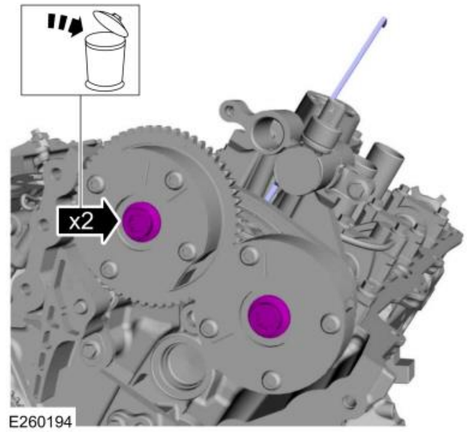
87. Remove the crankshaft sprocket.



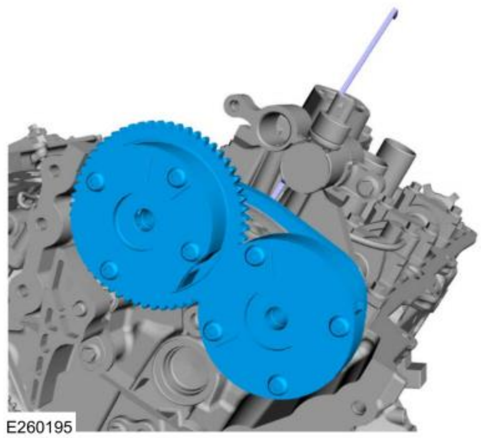
88. **NOTE:** *The VCT oil control solenoids are removed for clarity.*
Install Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



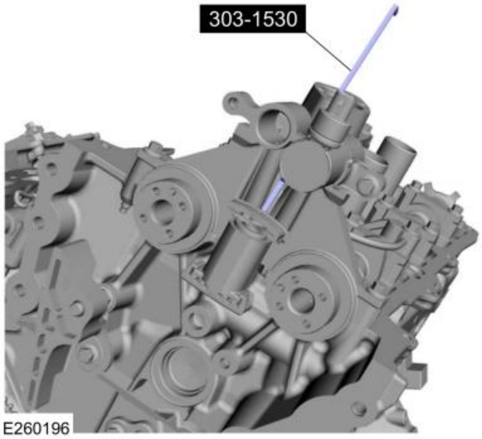
89. Remove and discard the LH VCT unit bolts.



90. Remove the LH VCT units and secondary timing chain.

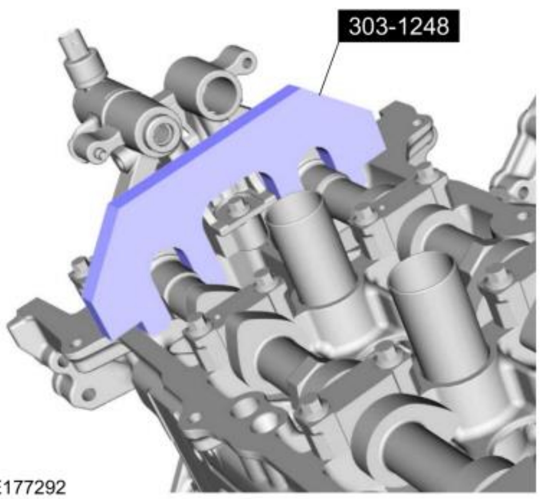


91. *Remove Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



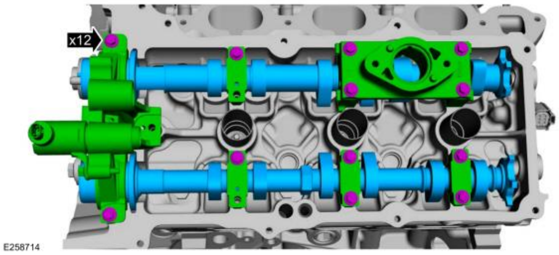
E260196

92. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



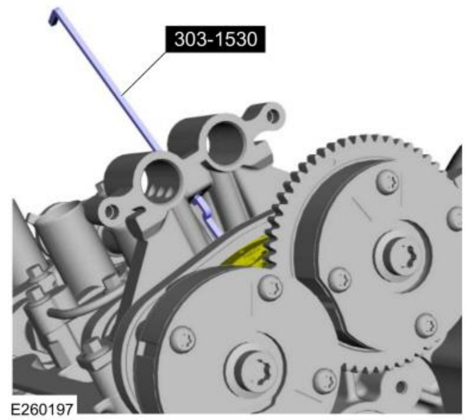
E177292

93. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in their original positions.*
NOTE: *Mark the exhaust and intake camshafts for installation into their original locations.*
Remove the bolts, camshaft caps and the camshafts.



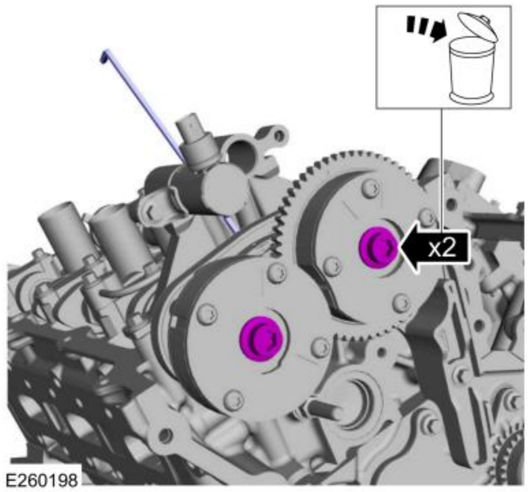
E258714

94. **NOTE:** *The VCT oil control solenoids are removed for clarity.*
Install Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



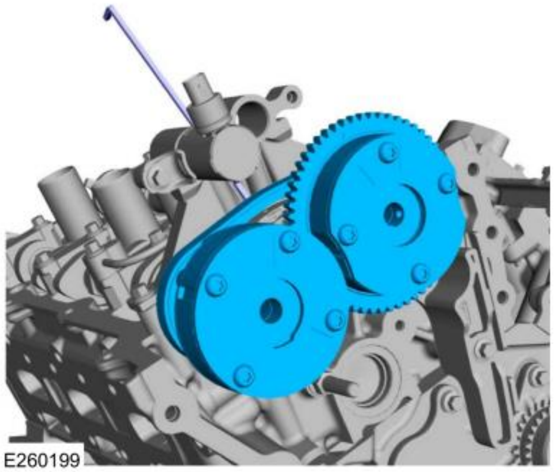
E260197

95. Remove and discard the RH VCT unit bolts.

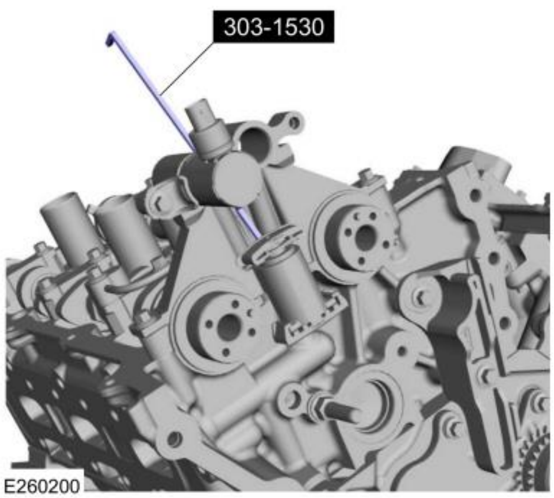


E260198

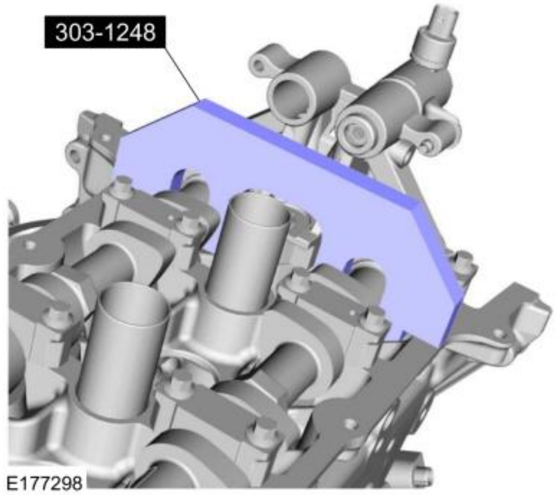
96. Remove the RH VCT units and secondary timing chain.



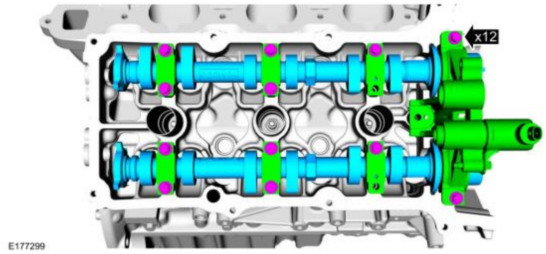
97. *Remove Special Service Tool* : 303-1530 Tool, Chain Tensioner Hold Down



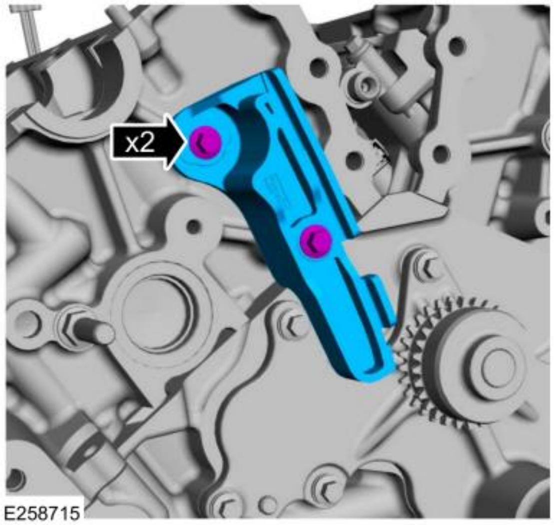
98. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



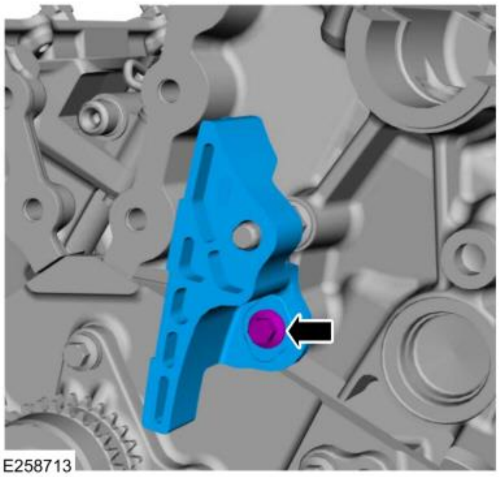
99. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in their original positions.*
NOTE: *Mark the exhaust and intake camshafts for installation into their original locations.*
Remove the bolts, camshaft caps and the camshafts.



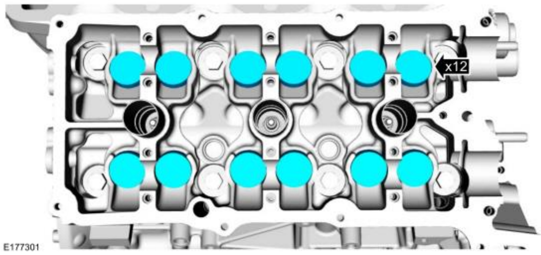
100. **NOTICE: Do not use power tools to remove the bolt or damage to the RH primary timing chain guide may occur.**
Remove the bolt and the RH timing chain guide.



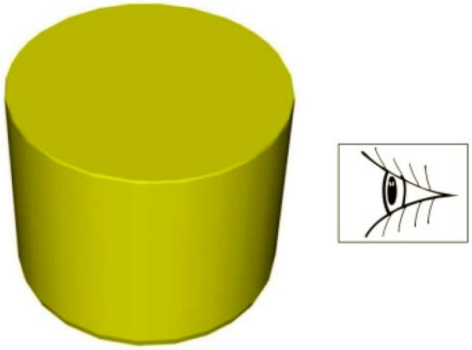
101. **NOTICE: Do not use power tools to remove the bolt or damage to the LH primary timing chain guide may occur.**
Remove the bolt and the LH timing chain guide.



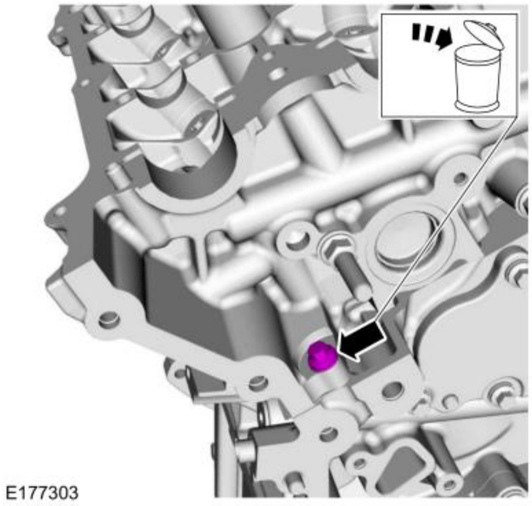
102. **NOTE:** *If the components are to be reinstalled, they must be installed in the same positions. Mark the components for installation into their original locations.*
NOTE: *RH shown, LH similar.*
Remove the valve tappets from the cylinder heads.



103. Inspect and install new components as necessary.



104. Remove and discard the M6 bolt.



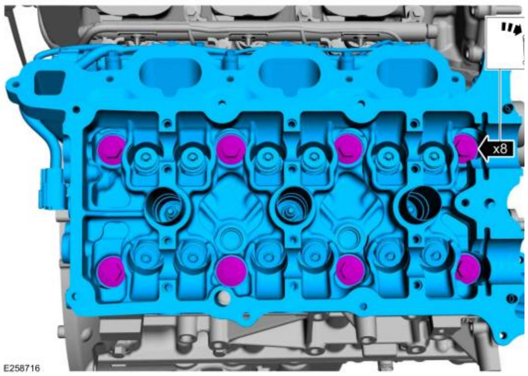
105. **NOTICE: Place clean shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**
NOTICE: Aluminum surfaces are soft and can be scratched easily. Never

place the cylinder head gasket surface, unprotected, on a bench surface

NOTE: *The cylinder head bolts must be discarded and new bolts must be installed. They are tightento- yield designed and cannot be reused.*

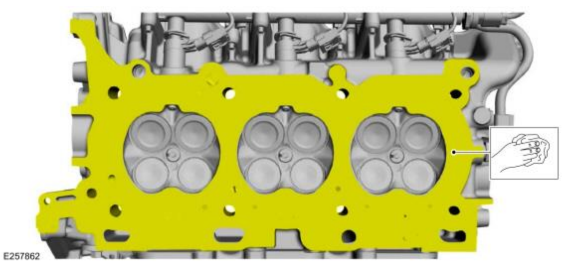
Remove and discard the bolts from the cylinder head.

Remove the cylinder head.

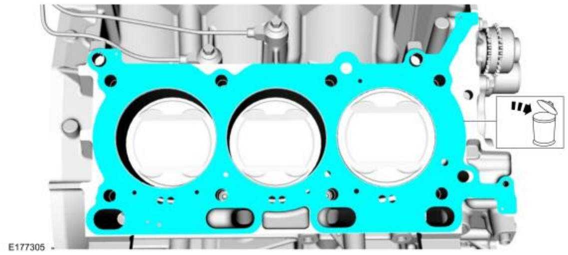


106. **NOTICE: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. Use a plastic scraping tool to remove all traces of the head gasket.**

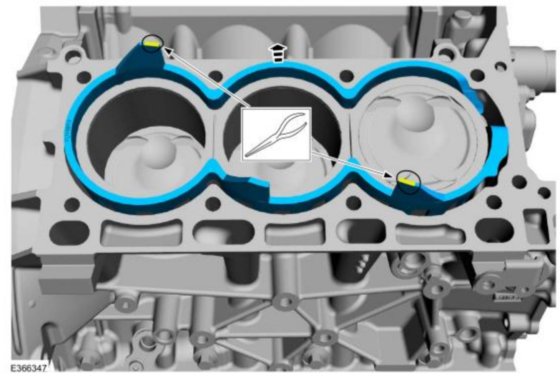
Make sure that the mating faces of the cylinder head are clean and free of foreign material.



107. Remove and discard the cylinder head gasket.



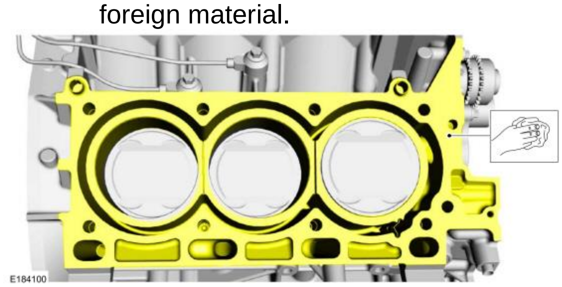
108. Remove the RH water jacket spacer. Use the General Equipment: Long Nose Pliers



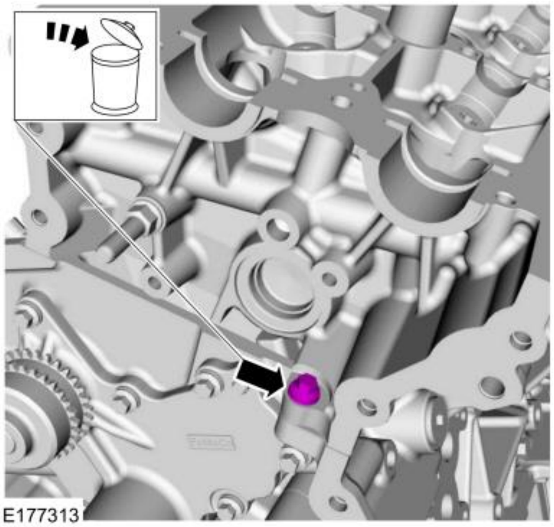
109. **NOTICE: Place clean, lint-free shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**

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

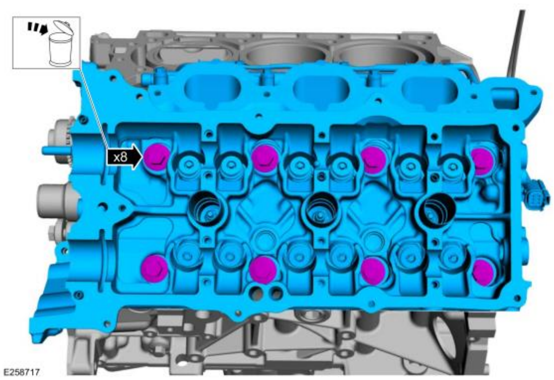
Make sure that the mating faces of the engine block are clean and free of foreign material.



110. Remove and discard the M6 bolt.



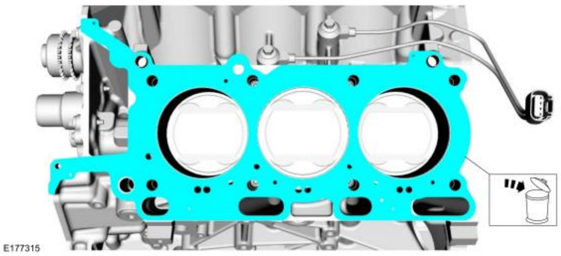
111. **NOTICE: Place clean shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material (including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.**
NOTICE: Aluminum surfaces are soft and can be scratched easily. Never place the cylinder head gasket surface, unprotected, on a bench surface
NOTE: *The cylinder head bolts must be discarded and new bolts must be installed. They are tightento- yield designed and cannot be reused.*
Remove and discard the bolts from the cylinder head.
Remove the cylinder head.



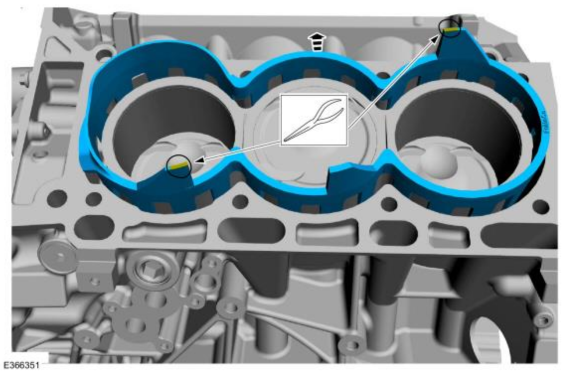
112. **NOTICE: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. Use a plastic scraping tool to remove all traces of the head gasket.**

Make sure that the mating faces of the cylinder head are clean and free of foreign material.

113. Remove and discard the cylinder head gasket.



114. Remove the LH water jacket spacer. Use the General Equipment: Long Nose Pliers



115. **NOTICE: Place clean, lint-free shop towels over exposed engine cavities. Carefully remove the towels so foreign material is not dropped into the engine. Any foreign material**

(including any material created while cleaning gasket surfaces) that enters the oil passages or the oil pan, may cause engine failure.

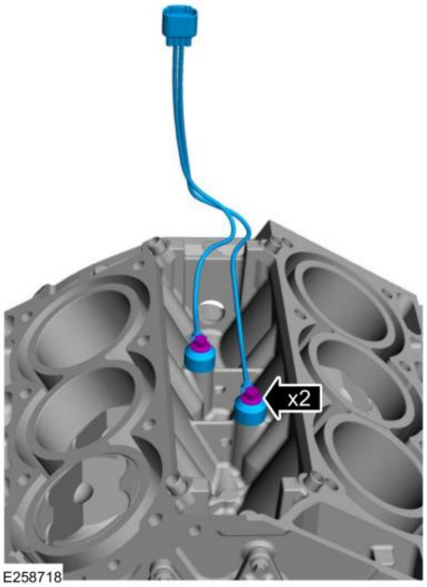
NOTICE: Do not use metal scrapers, wire brushes, power abrasive discs or other abrasive means to clean the sealing surfaces. These tools cause scratches and gouges that make leak paths. Use a plastic scraping tool to remove all traces of the head gasket.

Make sure that the mating faces of the engine block are clean and free of foreign material.

E184102

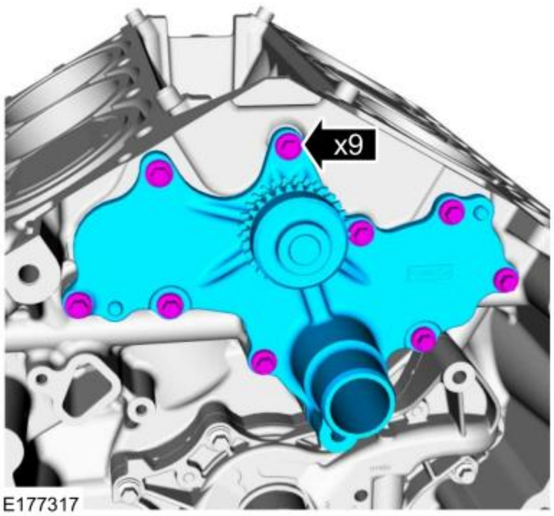
116. Support the cylinder head on a bench with the head gasket side up. Check the cylinder head distortion. Refer to: Cylinder Head Distortion (Section 01 Engine System - General Information, General Procedures).

117. Remove the bolts and the KS .



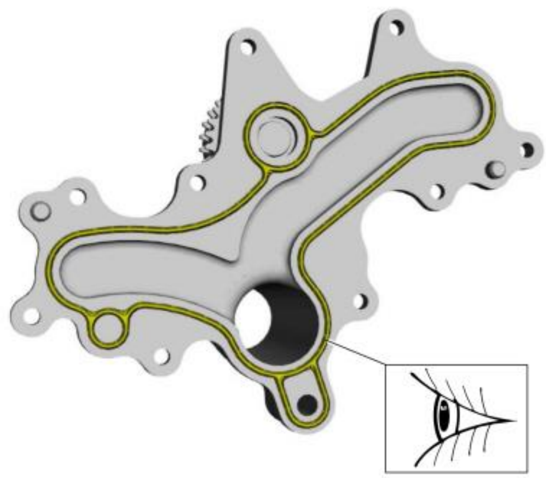
E258718

118. Remove the bolts and the channel cover plate.



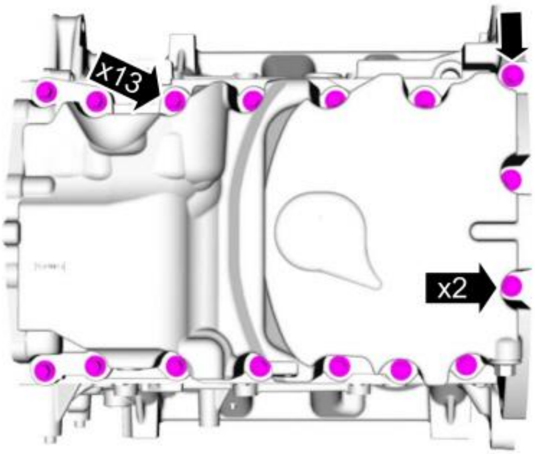
E177317

119. Inspect and replace if necessary.



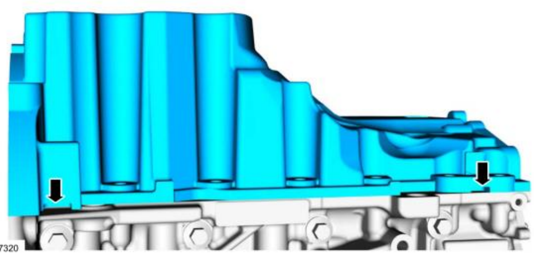
E258719

120. Remove the oil pan bolts.



E177319

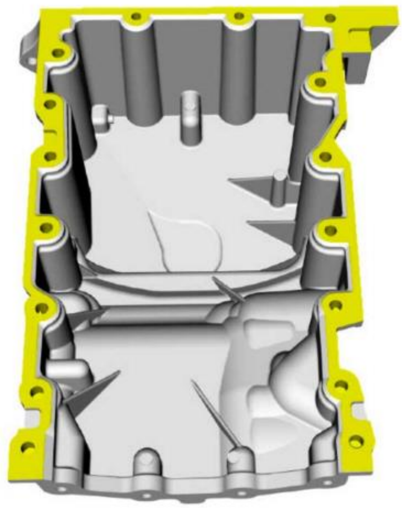
121. Using a pry tool, locate the pry pads at the LH and RH side of the oil pan and pry the oil pan loose and remove.



E177320

122. **NOTICE: Only use a 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the oil pan and engine front cover. Do not use metal scrapers, wire brushes or any other power abrasive disk to clean. These tools cause scratches and gouges that make leak paths.**
Make sure that the mating faces of the oil pan are clean and free of foreign material.
Refer to: RTV Sealing Surface Cleaning and Preparation (Section 01 Engine System – General Information, General Procedures).
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-B

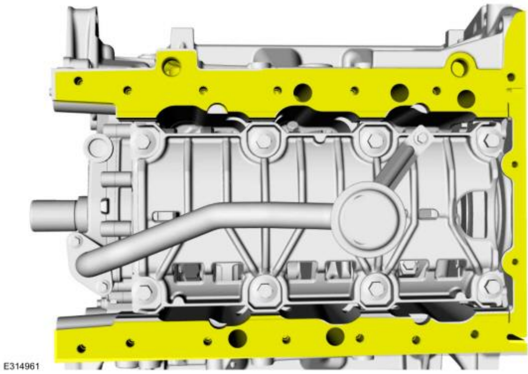
Thoroughly wash the oil pan to remove any foreign material, including any abrasive particles created during the cleaning process.



E314091

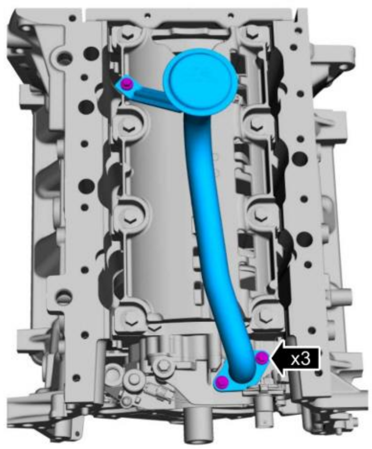
123. **NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the sealing surfaces of the engine block. These tools cause scratches and gouges that make leak paths. They also cause contamination that causes premature engine failure. Remove all traces of the gasket.**

Make sure that the mating faces of the engine block are clean and free of foreign material.
Refer to: RTV Sealing Surface Cleaning and Preparation (Section 01 Engine System – General Information, General Procedures).
Use the General Equipment: Plastic Scraper
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-B



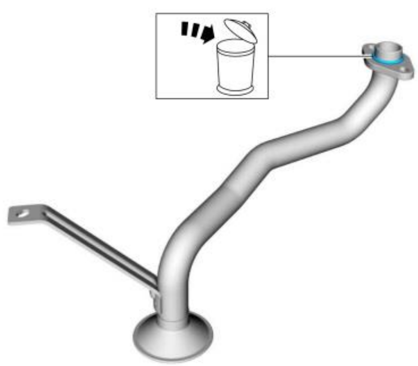
E314961

124. Remove the bolts and the oil pump screen and the pickup tube.



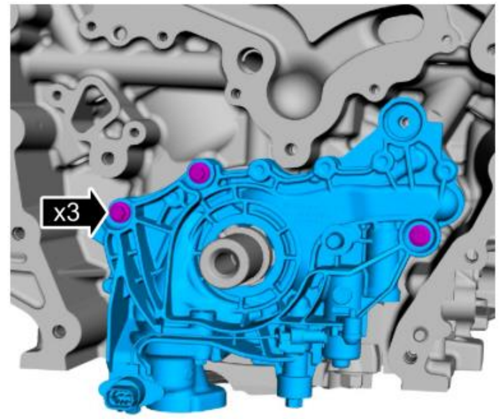
E258727

125. Remove and discard the oil pump screen and the pickup tube O-ring seal.



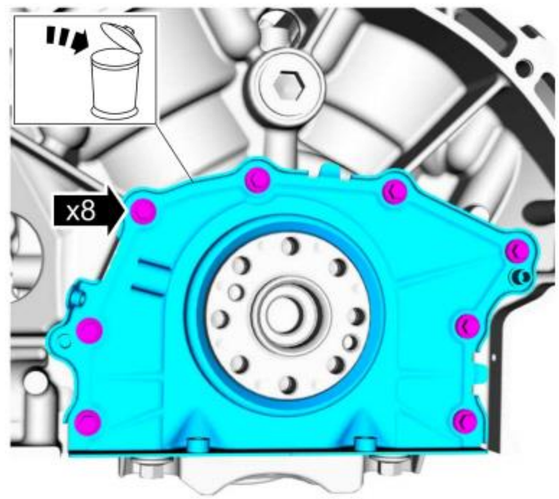
E177322

126. Remove the bolts and the oil pump.



E293904

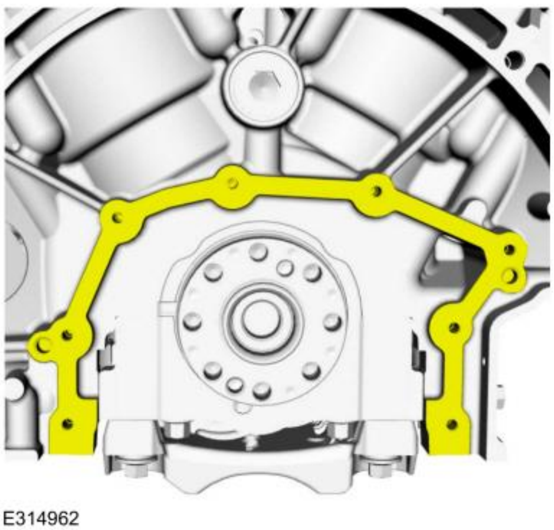
127. Remove the bolts and the crankshaft rear seal.
Discard the crankshaft rear seal.



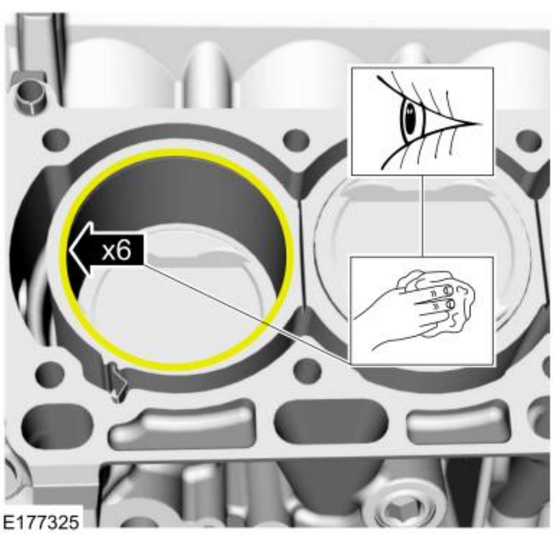
E177324

128. **NOTICE: Do not use wire brushes, power abrasive discs or 3M™ Roloc® Bristle Disk (2-in white, part number 07528) to clean the sealing surfaces of the engine block. These tools cause scratches and gouges that make leak paths. They also cause contamination that causes premature engine failure. Remove all traces of the gasket.**
Make sure that the mating faces is clean and free of foreign material.
Refer to: RTV Sealing Surface Cleaning and Preparation (Section 01 Engine

System – General Information, General Procedures).
Use the General Equipment: Plastic Scraper
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Metal Brake Parts Cleaner (U.S.) / PM-4-A, PM-4-B (U.S.)
Material : Motorcraft® Metal Surface Prep / ZC-31-B

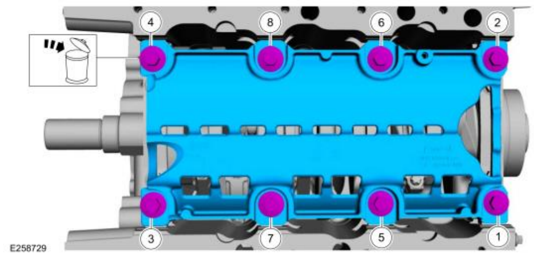


129. Inspect and clean the specified component with a abrasive pad.



130. Remove and discard the bolts in the sequence shown.

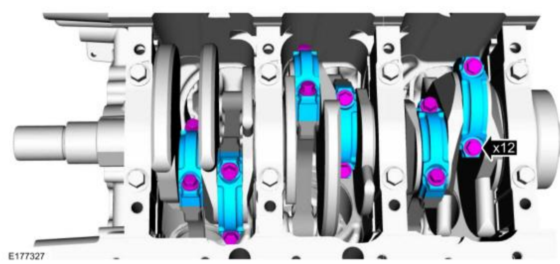
Remove the main bearing cap support brace.



131. **NOTE:** *The connecting rod cap bolts are a torque-to-yield design. The original connecting rod cap bolts will be used when measuring the connecting rod large end bore during assembly. The connecting rod cap bolts will be discarded after measurement.*

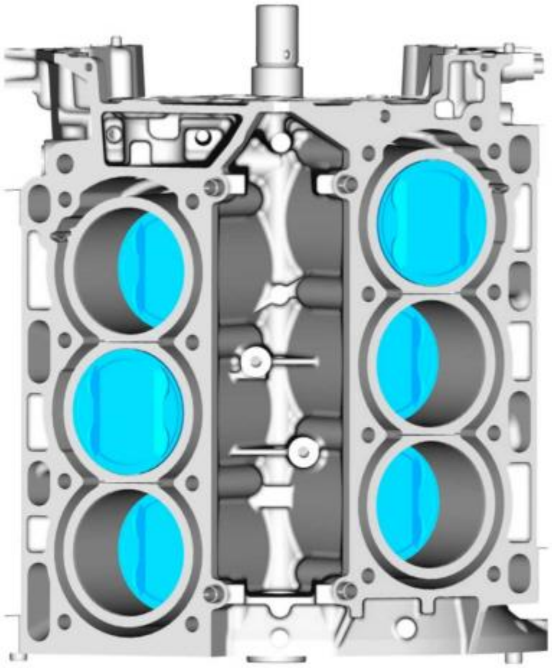
NOTE: *Clearly mark the position and orientation of the connecting rods, connecting rod caps and connecting rod bearings for reassembly.*

Remove the connecting rod cap bolts and caps.



132. **NOTICE: Do not scratch the cylinder walls or crankshaft journals with the connecting rod while removing the pistons.**

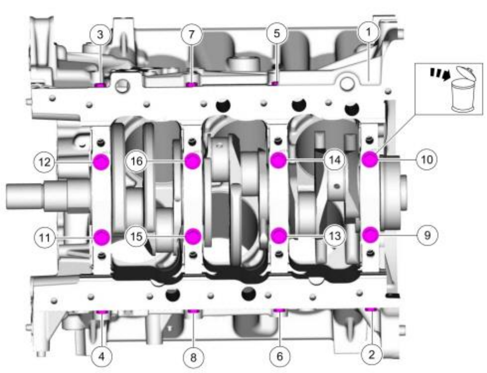
Remove the piston/rod assembly from the engine block.



E177328

133. Inspect the pistons.
Refer to: Piston Inspection (303-00 Engine System - General Information, General Procedures).

134. **NOTE:** *Clearly mark the position and orientation of the main bearing caps for reassembly.* Remove and discard the bolts in the sequence shown.

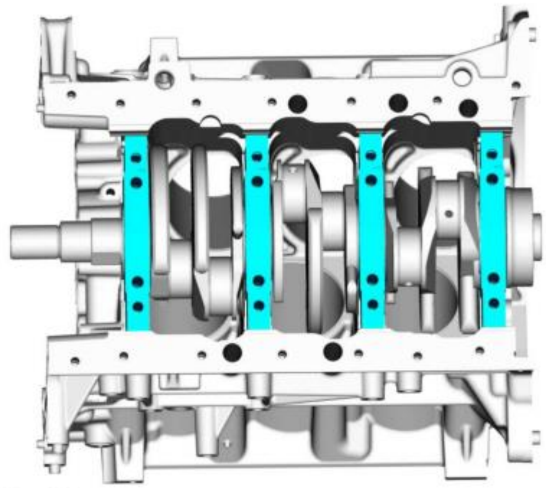


E177329

135. **NOTE:** *If the main bearings are being reused, mark them for correct position and orientation for reassembly.*

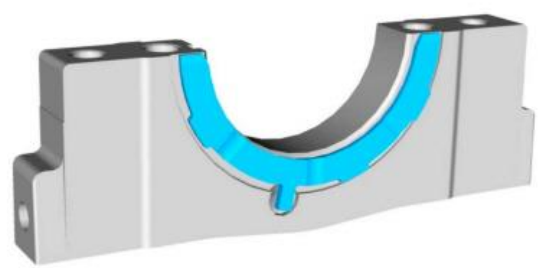
NOTE: *Note the position of the thrust washer on the outside of the No. 4 rear main bearing cap.*

Remove the main bearing caps.



E177330

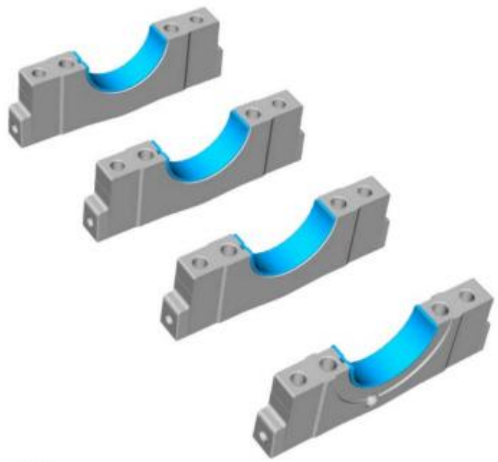
136. Remove the lower crankshaft thrust washer from the back side of the No. 4 rear main bearing cap.



E177331

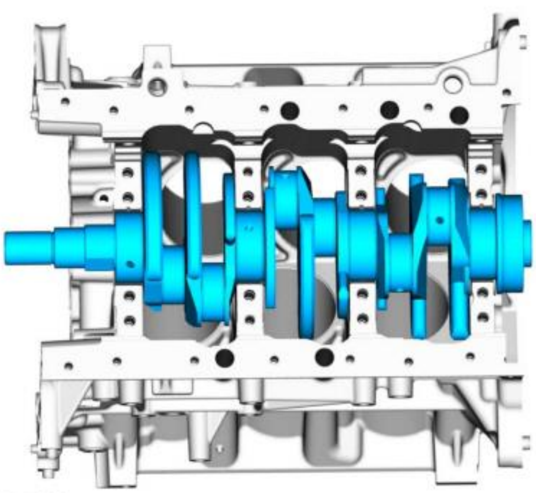
137. **NOTE:** *If the main bearings are being reused, mark them for correct position and orientation for reassembly.*

Remove the crankshaft main bearings from the main bearing caps.

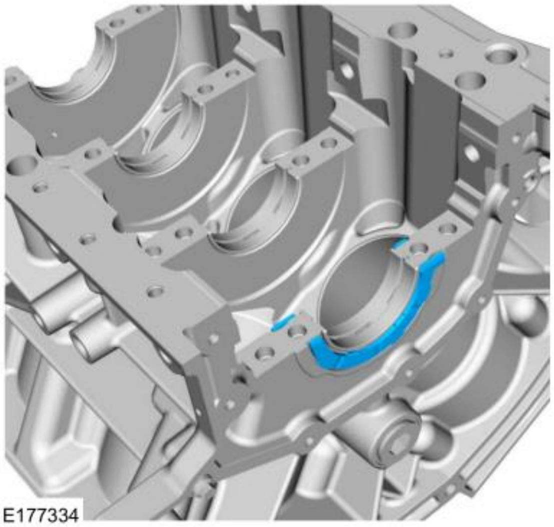

E177332

138. **NOTE:** *Note the position of the 2 thrust washers on the inside and outside of the rear main bearing bulkhead.*

Remove the crankshaft.

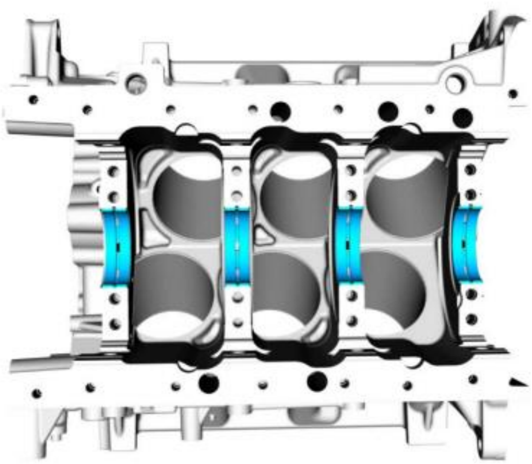

E177333

139. Remove the crankshaft thrust bearings from the rear main bearing bulkhead.

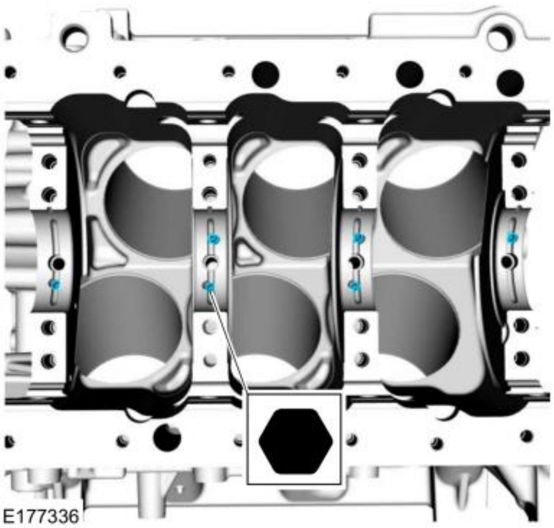

E177334

140. **NOTE:** *If the main bearings are being reused, mark them for correct position and orientation for reassembly.*

Remove the crankshaft main bearings from the cylinder block.


E177335

141. Using a hexagonal screwdriver, remove the piston oil cool valves.



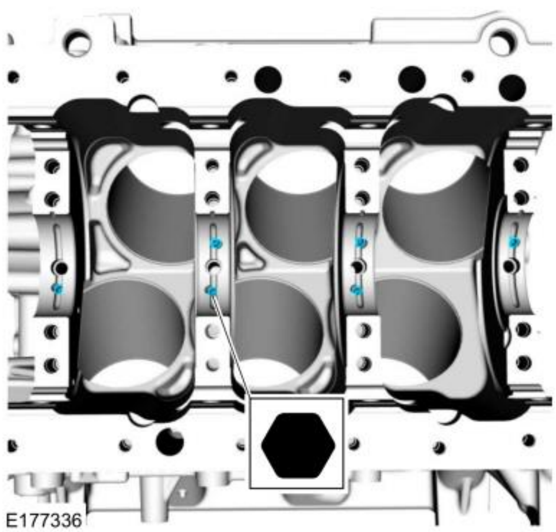
142. Inspect the cylinder block distortion.
Refer to: Cylinder Block Distortion (Section 01 Engine System - General Information, General Procedures).

Engine Assembly

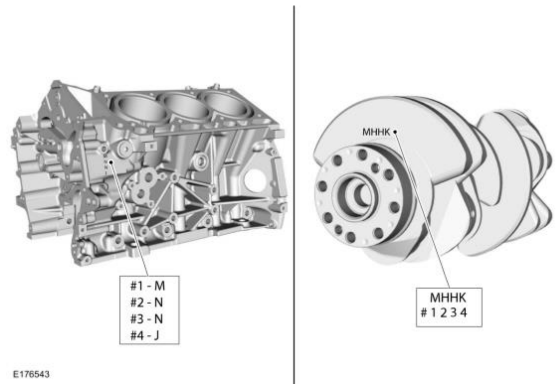
NOTICE: During engine repair procedures, cleanliness is extremely important. Any foreign material, including any material created while cleaning gasket surfaces that enters the oil passages, coolant passages or the oil pan, may cause engine failure.

NOTE: *Assembly of the engine requires various inspections/measurements of the engine components. These inspections/measurements will aid in determining if the engine components will require replacement. Refer to Section 01*
NOTE: *If the cylinder head(s) is replaced, a new secondary timing chain tensioner will need to be installed. Refer to VCT unit.*

1. Using a hexagonal screwdriver, install the piston oil cool valves.
   Torque : 35 lb.in (4 Nm)



2. **NOTE:** *This step is for selecting the correct main bearings.*
   NOTE: *The #1 main bearing is at the front of the engine block.*
   - Select the crankshaft main bearings for each crankshaft journal.
   - Record the code that is on the cylinder block face.
   - Record the code that is on the crankshaft flange.
   - The first letter is for main No. 1 and the next letters are for mains 2, 3 and 4.



3. **NOTE:** *This chart is for selecting main bearings 1 and 4 only, the remaining bearings will be selected using a different chart in the next step.*
   - Using the data recorded earlier and the Bearing Select Fit Chart, Standard Bearings, determine the required bearing grade for main bearings 1 and 4.
   - Read the first letter of the engine block main bearing code and the first letter of the crankshaft main bearing code.
   - Read down the column below the engine block main bearing code letter and across the row next to the crankshaft main bearing code letter, until the 2 intersect. This is the required bearing grade(s) for the No. 1 crankshaft main bearing.
   - As an example, if the engine block code letter is "M" and the crankshaft code letter is "M", the correct bearing grade for this main bearing is a "2" for the upper bearing and a "2" for the lower bearing.
   - Repeat the above steps using the fourth letter of the block and crankshaft codes to select the No. 4 bearing.

MAIN HOUSING BORE DIAMETER

CRANKSHAFT DIAMETER

		A 1 72.400	B 2 72.401	C 3 72.402	D 4 72.403	E 5 72.404	F 6 72.405	G 7 72.406	H 8 72.407	I 9 72.408	J 10 72.409	K 11 72.410	L 12 72.411	M 13 72.412	N 14 72.413	O 15 72.414	P 16 72.415	Q 17 72.416	R 18 72.417	S 19 72.418	T 20 72.419	U 21 72.420	V 22 72.421	W 23 72.422	X 24 72.423	Y 25 72.424
U	67.503	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3
T	67.502	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3
S	67.501	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3
R	67.500	1 / 1	1 / 1	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3
Q	67.499	1 / 1	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3
P	67.498	1 / 1	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3
O	67.497	1 / 1	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3
N	67.496	1 / 1	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3
M	67.495	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3
L	67.494	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3
K	67.493	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
J	67.492	1 / 2	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
I	67.491	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
H	67.490	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
G	67.489	1 / 2	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
F	67.488	1 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
E	67.487	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
D	67.486	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
C	67.485	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
B	67.484	2 / 2	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3
A	67.483	2 / 2	2 / 2	2 / 2	2 / 2	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	2 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3	3 / 3

FOR MAINS #1 AND #4 ONLY

UPPER MAIN GRADE (BLOCK SIDE) / LOWER MAIN GRADE (CAP SIDE)

4. **NOTE:** *This chart is for selecting main bearings 2 and 3 only.*
   - Using the data recorded earlier and the Bearing Select Fit Chart, Standard Bearings, determine the required bearing grade for main bearings 2 and 3.
   - Read the second letter of the engine block main bearing code and the second letter of the crankshaft main bearing code.
   - Read down the column below the engine block main bearing code letter and across the row next to the crankshaft main bearing code letter, until the 2 intersect. This is the required bearing grade for the No. 2 crankshaft main bearing.
   - As an example, if the engine block code letter is "N" and the crankshaft code letter is "H", the correct bearing grade for this main bearing is "2"
   - Repeat the above steps using the third letter of the block and crankshaft codes to select the No. 3.

MAIN HOUSING BORE DIAMETER

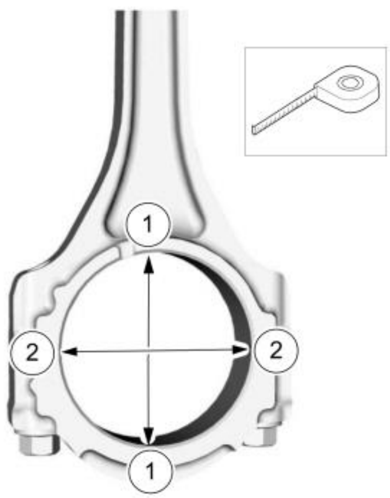
CRANKSHAFT DIAMETER	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
U	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2
T	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
R	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
Q	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
P	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
O	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
N	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
M	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3
L	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3
K	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3
J	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3
I	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3
H	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
G	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3
F	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3
E	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3
D	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
C	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
B	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3
A	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

FOR MAINS #2 AND #3 ONLY

5. **NOTICE: The rod cap installation must keep the same orientation as marked during disassembly or engine damage may occur.**
   Using the original connecting rod cap bolts, install the connecting rod caps and bolts.
   Torque :
   Stage 1: 17 lb.ft (23 Nm)
   Stage 2: 32 lb.ft (43 Nm)
   Stage 3: 105°

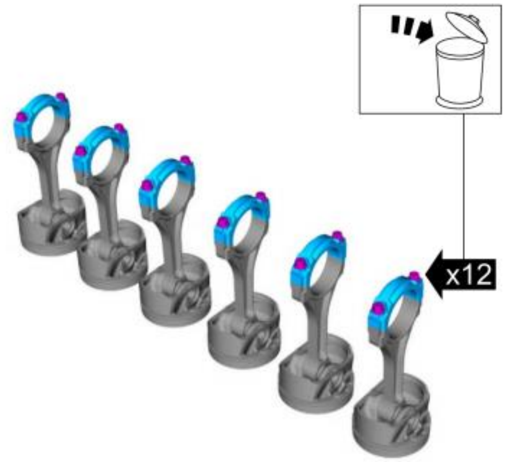
E177202

6. Measure the connecting rod large end bore in 2 directions.



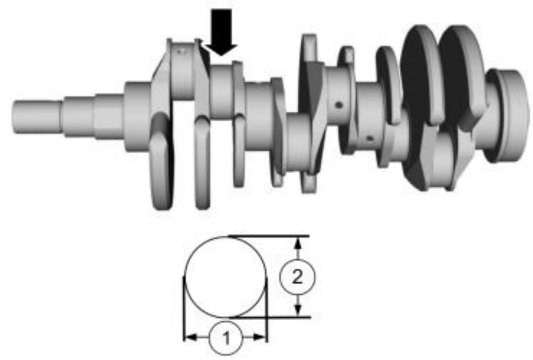
E177203

7. Remove the bolts and the rod cap. Discard the bolts.



E177204

8. Measure each of the crankshaft connecting rod bearing journal diameters in at least 2 directions.



E177205

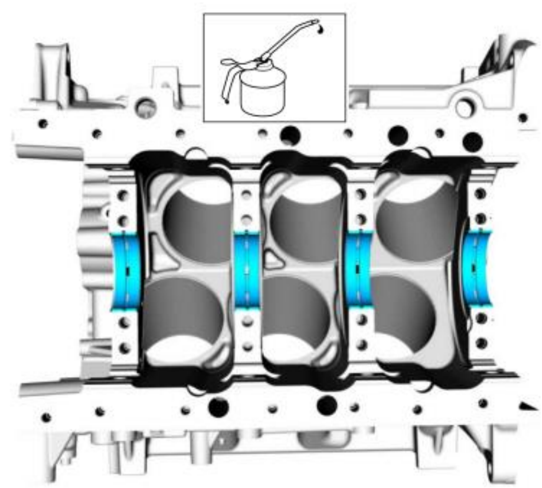
9. Using the chart, select the correct connecting rod bearings for each crankshaft connecting rod journal.

LSG-635 ENGINE

		CONNECTING ROD LARGE END BORE (59.XXX)																				
		1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
		.866	.867	.868	.869	.870	.871	.872	.873	.874	.875	.876	.877	.878	.879	.880	.881	.882	.883	.884	.885	.886
CRANK JOURNAL	56.003	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	56.002	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	56.001	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	56.000	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.999	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.998	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.998	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.998	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.995	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.994	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.993	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.992	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.991	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.990	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.989	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.988	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.987	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.986	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.985	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.984	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	55.983	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3

		MINIMUM	MAXIMUM	NOMINAL
WALL GRADES	1	1.918 mm	1.924 mm	1.921 mm
	2	1.921 mm	1.927 mm	1.924 mm
	3	1.925 mm	1.931 mm	1.928 mm

10. **NOTE:** *Before assembling the cylinder block, all sealing surfaces must be free of chips, dirt, paint and foreign material. Also, make sure the coolant and oil passages are clear.*
   Lubricate the upper crankshaft main bearings with clean engine oil and install in the cylinder block.
   Material : Motorcraft® SAE 5W-20

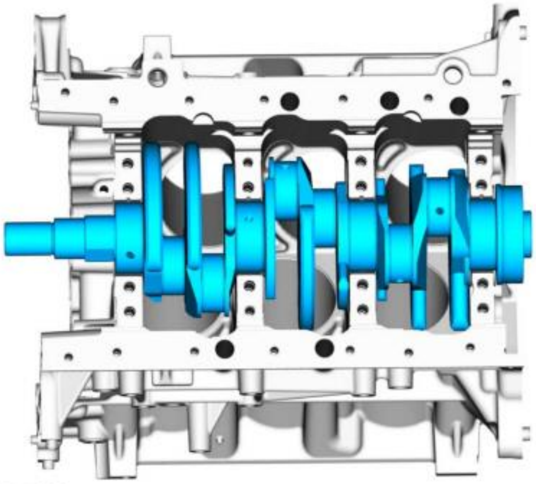


E177206

11. **NOTE:** *Do not install the upper thrust bearings until the crankshaft is installed.*

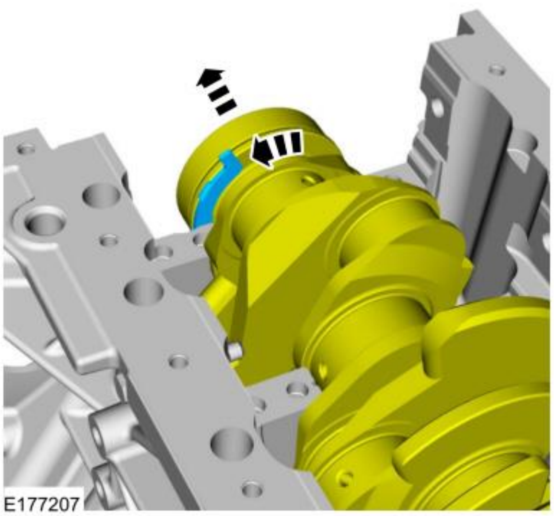
NOTE: *Lubricate the thrust surfaces of the crankshaft with clean engine oil.*

Install the crankshaft.
Material : Motorcraft® SAE 5W-20



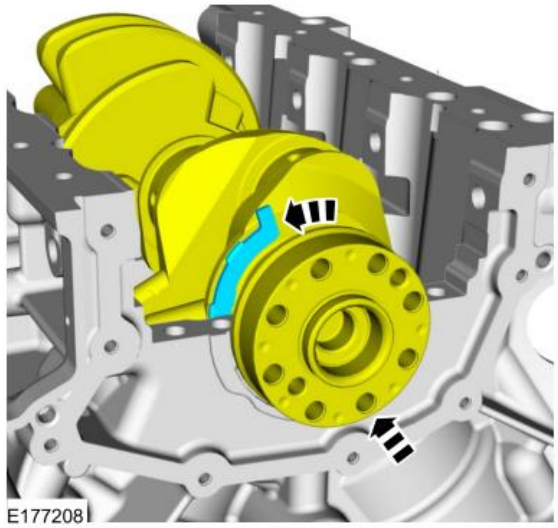
E177333

12. **NOTE:** *Make sure the side of the thrust washer, with the wide oil grooves, faces the crankshaft thrust surface.*
   Push the crankshaft rearward and install the rear crankshaft upper thrust washer at the back of the No. 4 rear bulkhead.



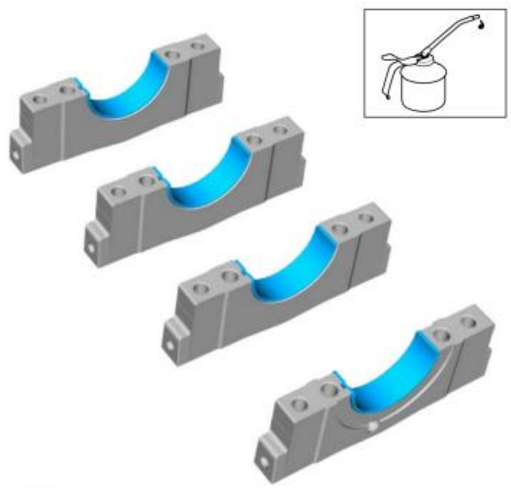
E177207

13. **NOTE:** *Make sure the side of the thrust washer, with the wide oil grooves, faces the crankshaft thrust surface.*
   Push the crankshaft rearward and install the rear crankshaft upper thrust washer at the back of the No. 4 rear bulkhead.



E177208

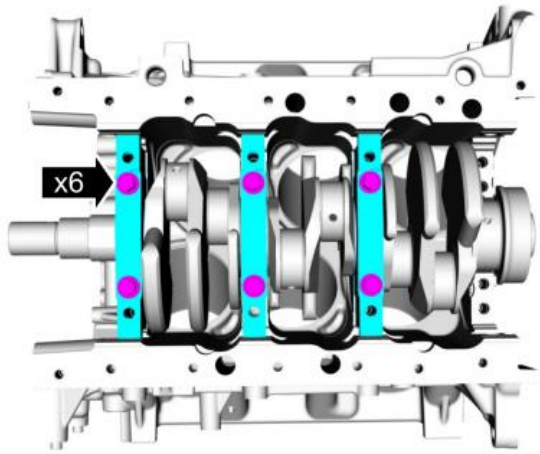
14. Lubricate the crankshaft lower main bearings with clean engine oil and install them into the main bearing caps. Check seating and squareness of the bearings to make sure of proper seating in caps. *Material* : Motorcraft® SAE 5W-20



E177209

15. Position the No. 1, No. 2 and No. 3 main bearing caps on the cylinder block and, keeping the caps as square as possible, alternately draw the caps

down evenly using the new bolts until the main bearing caps are seated.

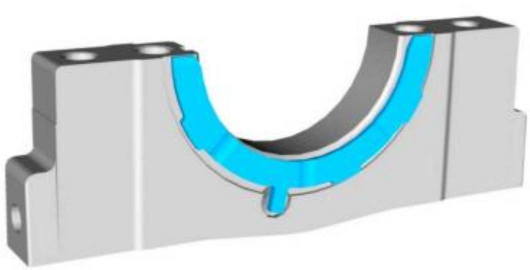


E177210

16. **NOTE:** *Make sure the side of the thrust washer, with the wide oil grooves, faces the crankshaft thrust surface.*

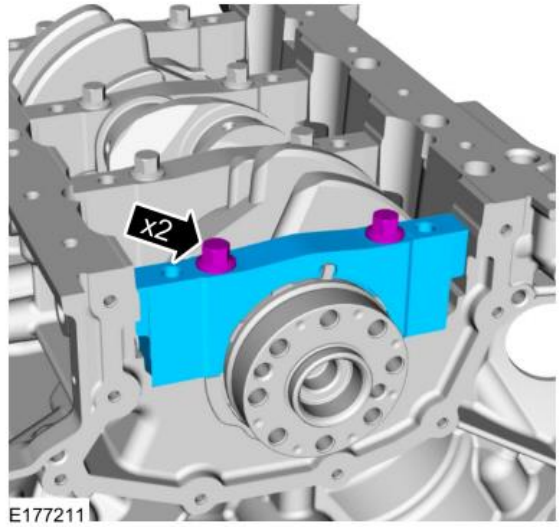
    NOTE: *To aid in assembly, apply petroleum jelly to the back of the crankshaft thrust washer.*

    Install the lower crankshaft thrust washer to the back side of the No. 4 rear main bearing cap, with the tab aligned with the cutout in the main bearing cap.



E177331

17. Position main bearing cap No. 4 on the cylinder block and keeping the cap as square as possible, alternately draw the cap down evenly using the new bolts until the main bearing cap is seated.

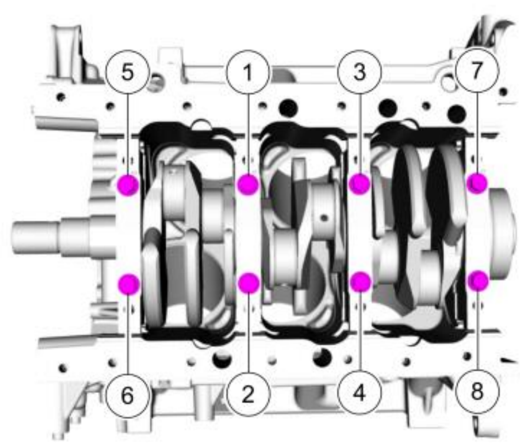


E177211

18. **NOTE:** *While tightening the main bearing vertical bolts, push the crankshaft forward and the No. 4 main bearing cap rearward to seat the crankshaft thrust washers.* Tighten the main bearing bolts.

    Torque :

    Stage 1: 20 lb.ft (27 Nm)
    Stage 2: 180°

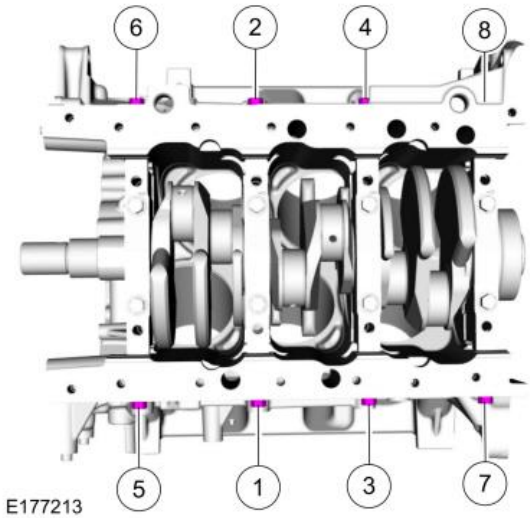


E177212

19. Install the new main bearing cap side bolts.

    Torque:

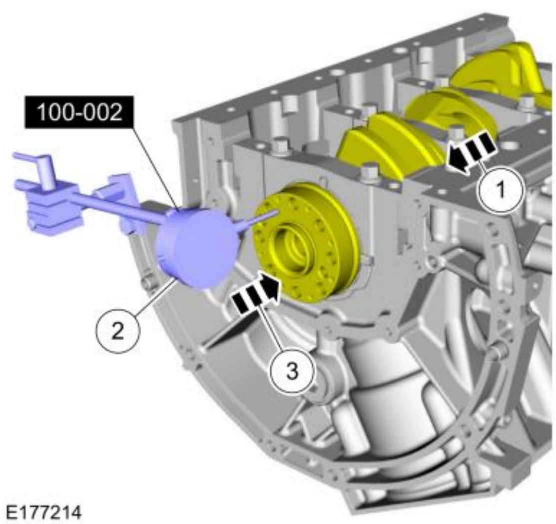
    Stage 1: 33 lb.ft (45 Nm)
    Stage 2: 90°



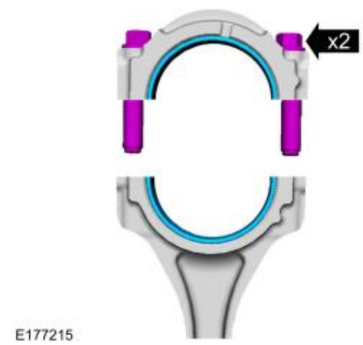
20. Position the crankshaft to the rear of the cylinder block. *Use Special Service Tool* : 100-002 (TOOL-4201-C) Holding Fixture with Dial Indicator Gauge

    Zero the Dial Indicator Gauge.

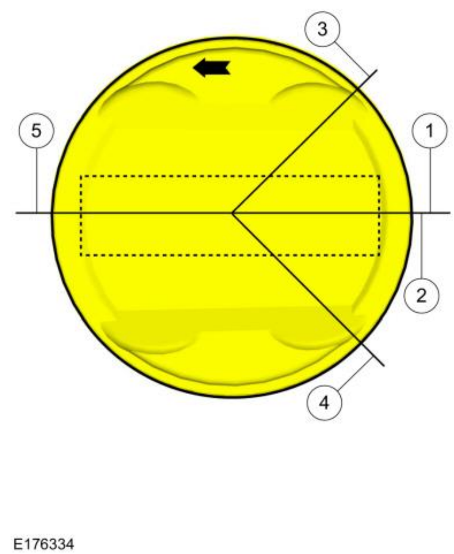
    Move the crankshaft to the front of the cylinder block. Measure and record the crankshaft end play.



21. **NOTICE: The rod cap installation must keep the same orientation as marked during disassembly or engine damage may occur.**
    Prepare the connecting rod and cap
    Insert the new bolts in the rod cap.
    Insert the upper and lower rod bearings into the rod and cap.



22. **NOTE:** *The piston compression upper and lower ring should be installed with the "O" mark on the ring face pointing up toward the top of the piston.*
    NOTE: *The arrow on the top of the piston indicates the front of the engine.*
    1. Center line of the piston parallel to the wrist pin bore.
    2. Upper compression ring gap location.
    3. Upper oil control segment ring gap location.
    4. Lower oil control segment ring gap location.
    5. Expander ring and lower compression ring gap location



23. **NOTICE: Be sure not to scratch the cylinder wall or crankshaft journal with the connecting rod. Push the**

piston down until the connecting rod bearing seats on the crankshaft journal.

NOTE: *Lubricate the pistons, piston rings, connecting rod bearings and the entire cylinder bores with clean engine oil.*

NOTE: *Make sure the piston rings are positioned to specifications for installation. Refer to Piston in this section.*

NOTE: *If the piston and or connecting rod are being installed new, the piston rod orientation marks and the arrow on the top of the dome of the piston should be facing toward the front of the engine block.*

NOTE: *If the piston and connecting rod are to be reinstalled, they must be installed in the same orientation as disassembled.*

Using the Piston Ring Compressor, install the piston and connecting rod assemblies. Repeat until all 6 piston assemblies are installed.

Use the General Equipment: Piston Ring Compressor.

E177217

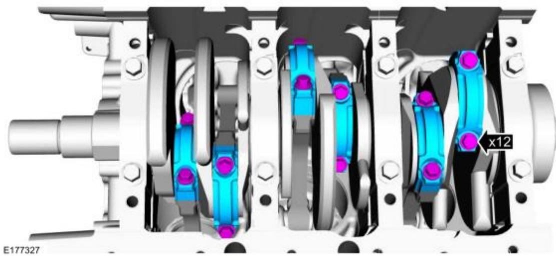
24. **NOTICE: The rod cap installation must keep the same orientation as marked during disassembly or engine damage may occur.**

NOTE: *After installation of each piston, connecting rod, rod cap and bolts, rotate the crankshaft to verify smooth operation.*

Install the connecting rod cap and the new bolts.

Torque :

Stage 1: 17 lb.ft (23 Nm)
Stage 2: 32 lb.ft (43 Nm)
Stage 3: 105°

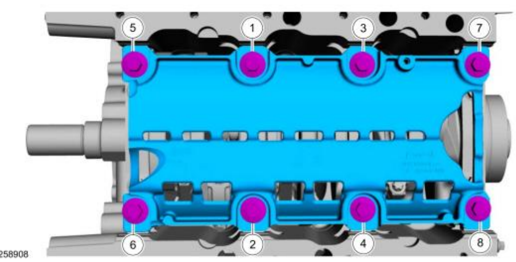


E177327

25. Install the main bearing cap support brace and the new bolts.

Torque :

Stage 1: 20 lb.ft (27 Nm)
Stage 2: 225°

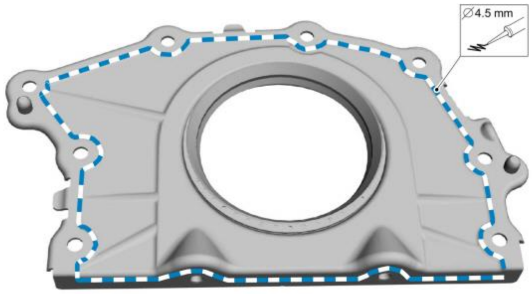


E258908

26. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**

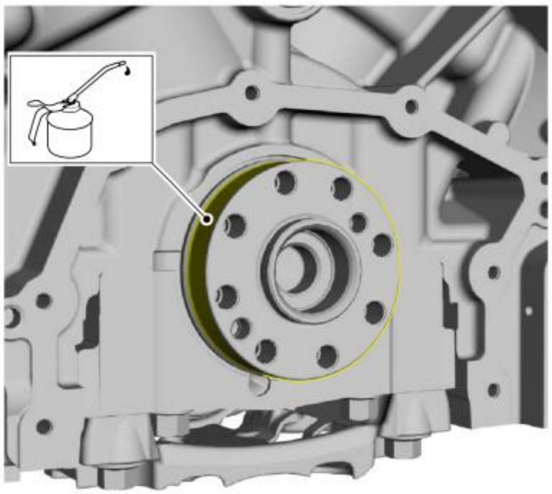
NOTE: *The crankshaft rear seal retainer must be installed and the bolts tightened within 4 minutes of sealant application.*

Apply a 4.5 mm (0.177 in) bead of Motorcraft® High Performance Engine RTV Silicone to the sealing surface of the crankshaft rear seal retainer.



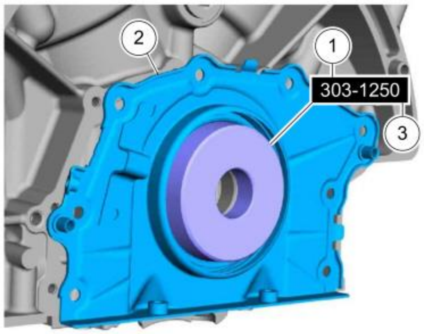
E323746

27. Lubricate the crankshaft rear seal with clean engine oil.
    Material : Motorcraft® SAE 5W-20



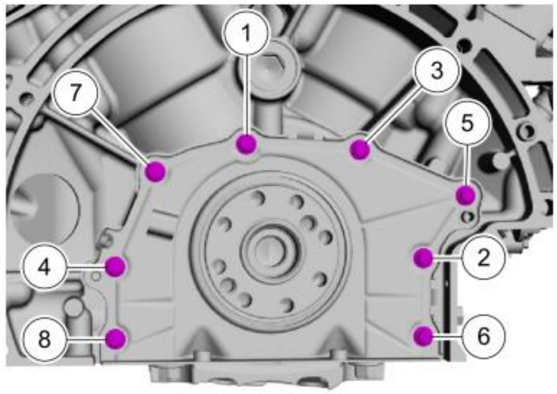
E323748

28. Install the crankshaft rear seal and the bolts using Special Service Tool: 303-1250 Seal Installer, Rear Main.
    Torque : 89 lb.in (10 Nm)



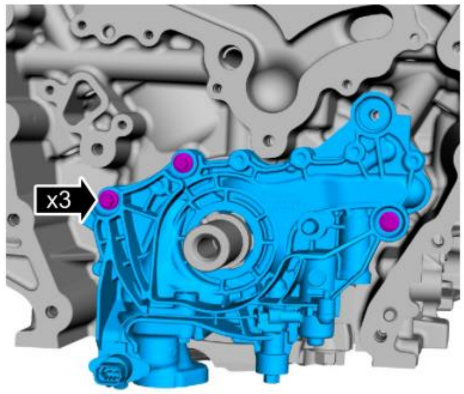
E309487

The crankshaft rear seal retainer must be installed and the bolts tightened within 10 minutes of sealant application.



E309488

29. Install the oil pump and the bolts.
    Torque : 89 lb.in (10 Nm)

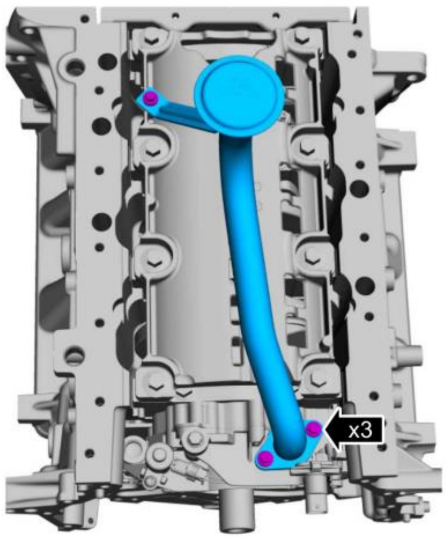


E293904

30. Install a new oil pump screen and the pickup tube O-ring seal.

E242196

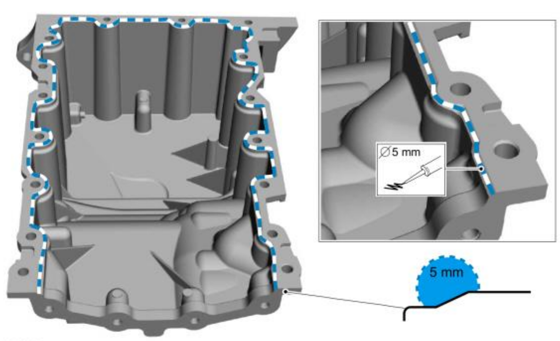
31. Install the oil pump screen and the pickup tube and the bolts.
Torque : 89 lb.in (10 Nm)



E258727

32. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**

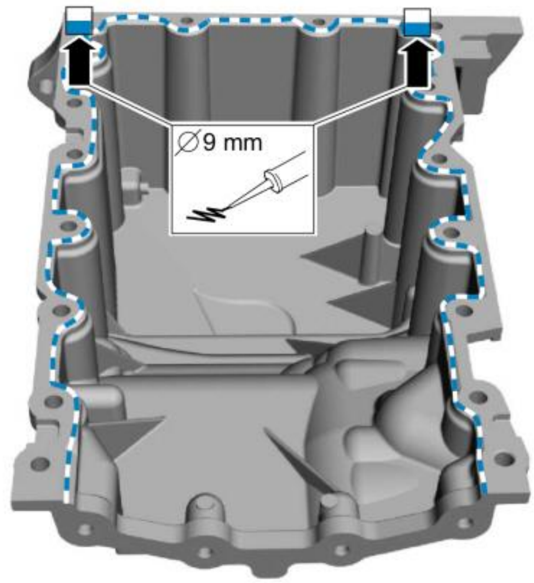
Apply a 5 mm (0.2 in) bead of Motorcraft® High Performance Engine RTV Silicone on the chamfer, as shown.



E313448

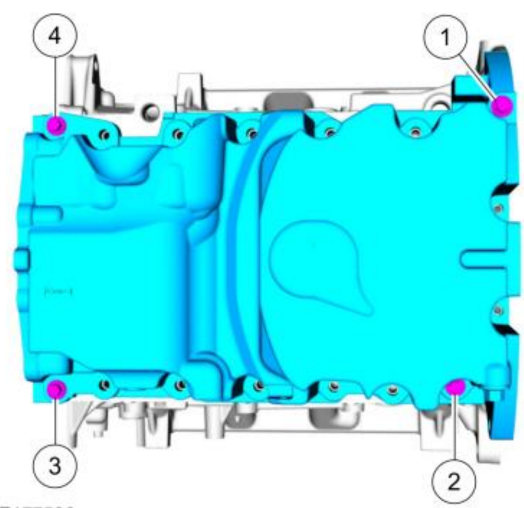
33. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**

Apply a 9 mm (0.35 in) bead of Motorcraft® High Performance Engine RTV Silicone to the 2 crankshaft seal retainer plate-to-cylinder block joint areas on the sealing surface of the oil pan.



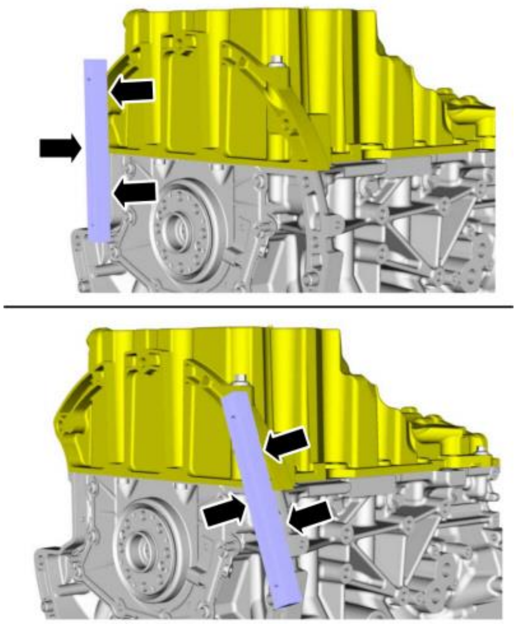
E313449

34. Install the oil pan and bolts.
Torque :
Stage 1: 27 lb.in (3 Nm)
Stage 2: Loosen:: 180°



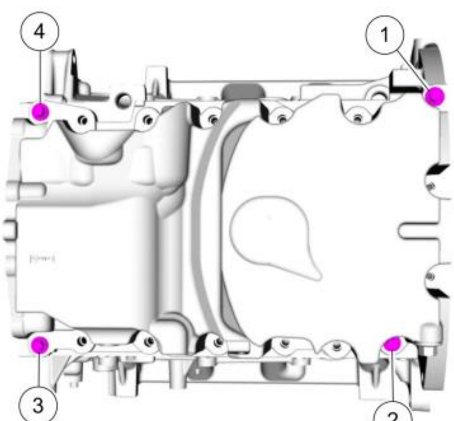
E177596

35. Using a straight edge, align the oil pan flush with the rear of the cylinder block at the 2 areas shown.
    Use the General Equipment: Round-Ended Steel Rule



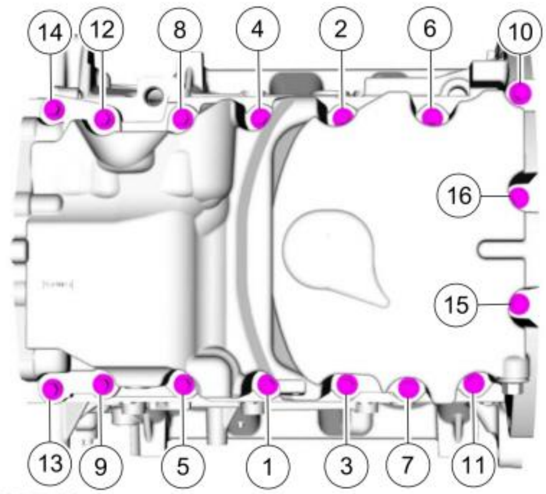
E177597

36. Tighten the bolts in the sequence,
    Torque : 27 lb.in (3 Nm)



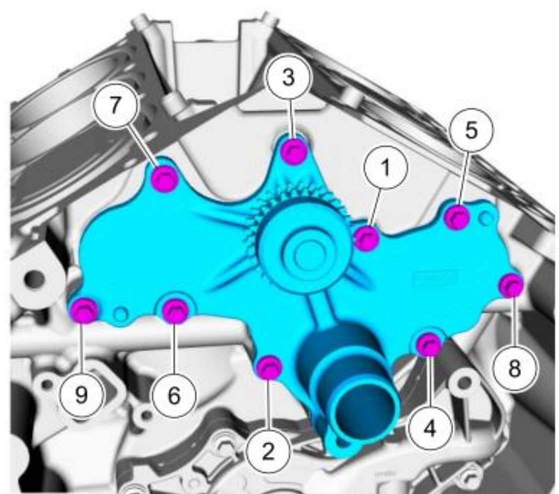
E177598

37. Install the remaining oil pan bolts.
    Torque :
    Stage 1: Tighten bolts 1-9 and 11-14 to: 177 lb.in (20 Nm)
    Stage 2: Tighten bolts 1-9 and 11-14 an additional: 45°
    Stage 3: Tighten bolt 10 to: 177 lb.in (20 Nm)
    Stage 4: Tighten bolt 10 to an additional: 90°
    Stage 5: Tighten bolts 15 and 16 to: 89 lb.in (10 Nm)
    Stage 6: Tighten bolts 15 and 16 an additional: 45°



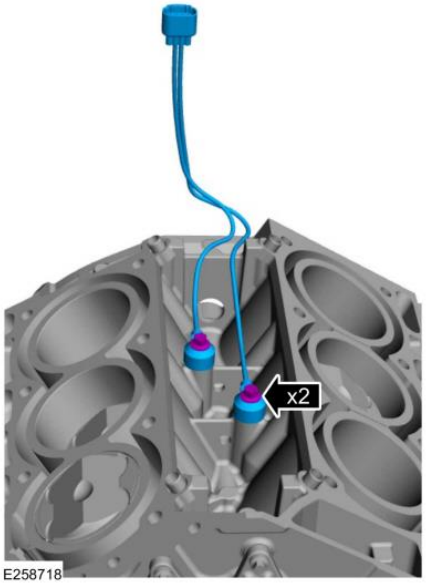
E177599

38. Install the channel cover plate and the bolts.
    Torque :
    Stage 1: 89 lb.in (10 Nm)
    Stage 2: 45°

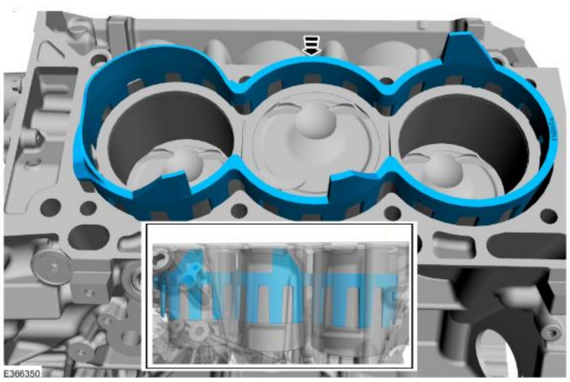


E177600

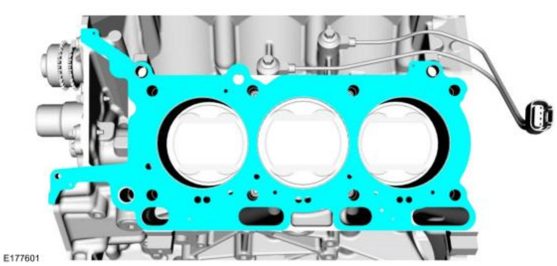
39. Install the KS and the bolts.
    Torque : 177 lb.in (20 Nm)



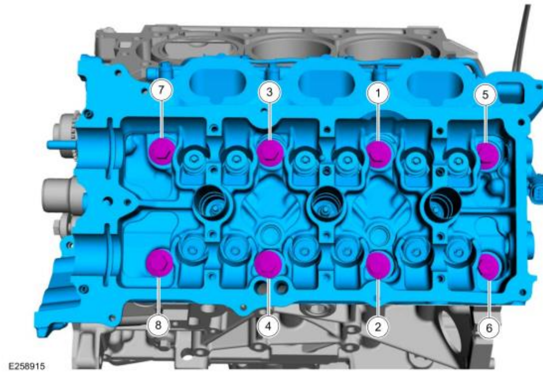
40. Install the LH water jacket flush with the bottom of the block.



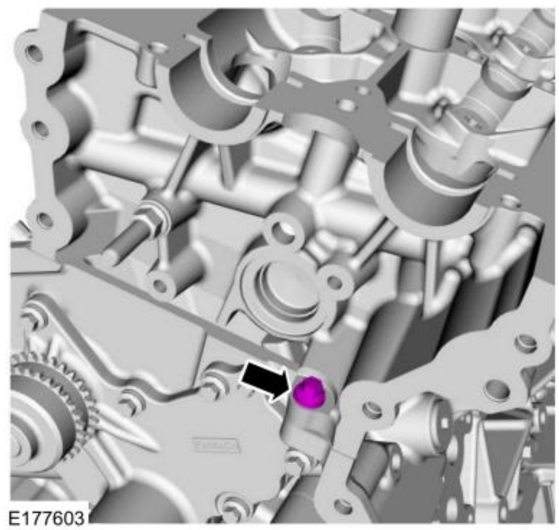
41. Install the LH cylinder head gasket.



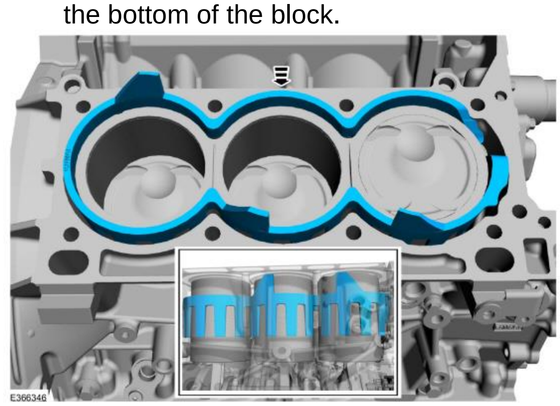
42. **NOTE:** *If the cylinder head is replaced, a new secondary timing chain tensioner will need to be installed.*
 Install the cylinder head and the new bolts.
 Torque :
 Stage 1: 177 lb.in (20 Nm)
 Stage 2: 26 lb.ft (35 Nm)
 Stage 3: 90°
 Stage 4: 90°
 Stage 5: 45°



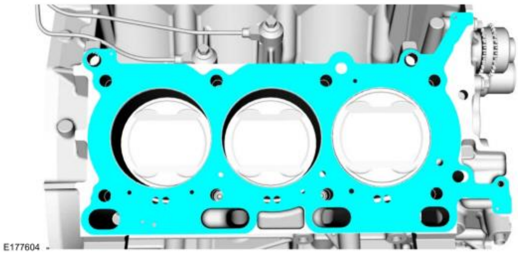
43. Install the M6 bolt.
 Torque : 89 lb.in (10 Nm)



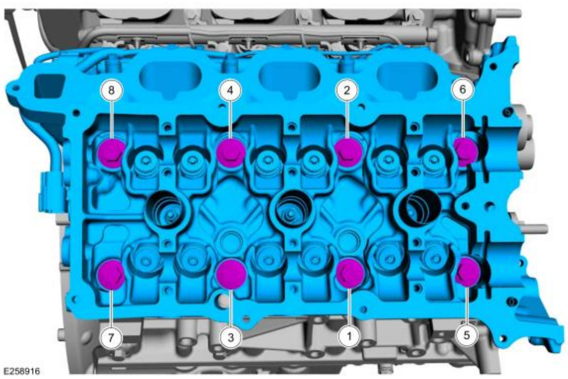
44. Install the RH water jacket flush with the bottom of the block.



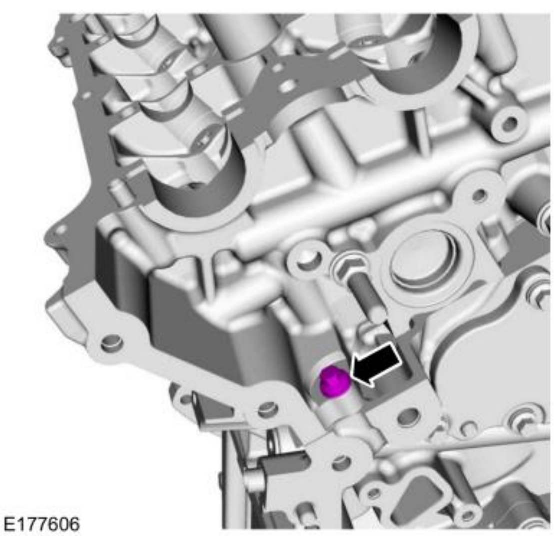
45. Install the RH cylinder head gasket.



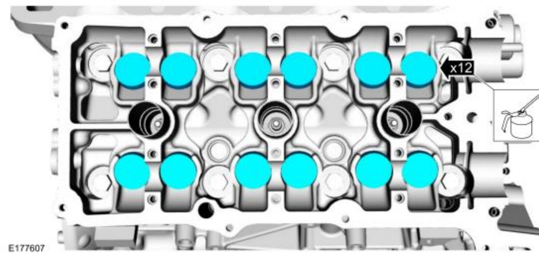
46. **NOTE:** *If the cylinder head is replaced, a new secondary timing chain tensioner will need to be installed.*
    Install the cylinder head and the new bolts.
    Torque :
    - Stage 1: 177 lb.in (20 Nm)
    - Stage 2: 26 lb.ft (35 Nm)
    - Stage 3: 90°
    - Stage 4: 90°
    - Stage 5: 45°



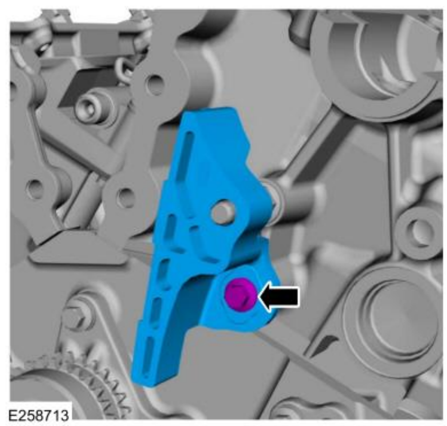
47. Install the M6 bolt.
    Torque : 89 lb.in (10 Nm)



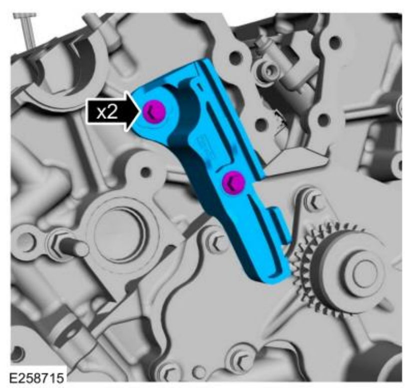
48. **NOTE:** *The valve tappets must be installed in their original positions.*
    NOTE: *Coat the valve tappets with clean engine oil prior to installation.*
    NOTE: *RH shown, LH similar.*
    Install the valve tappets.
    Material : Motorcraft® SAE 5W-20



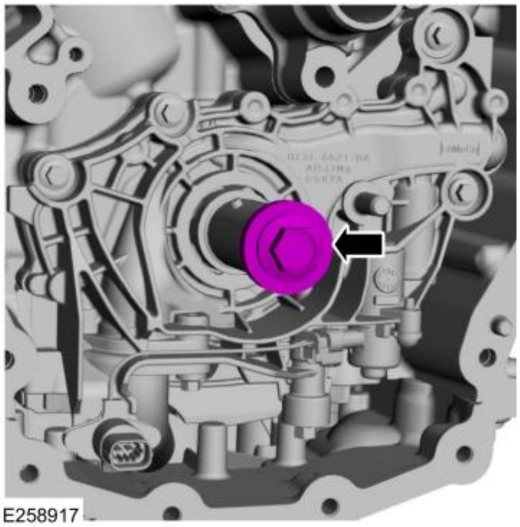
49. Install the LH primary timing chain guide and the bolt.



50. Install the RH primary timing chain guide and the bolts.
    Torque : 89 lb.in (10 Nm)

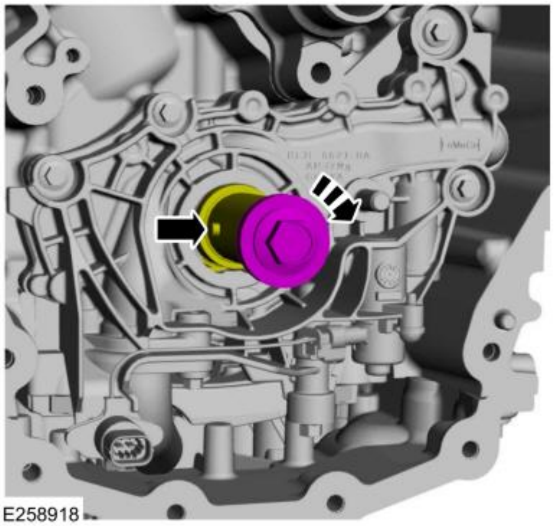


51. Install the original crankshaft bolt and washer.


E258917

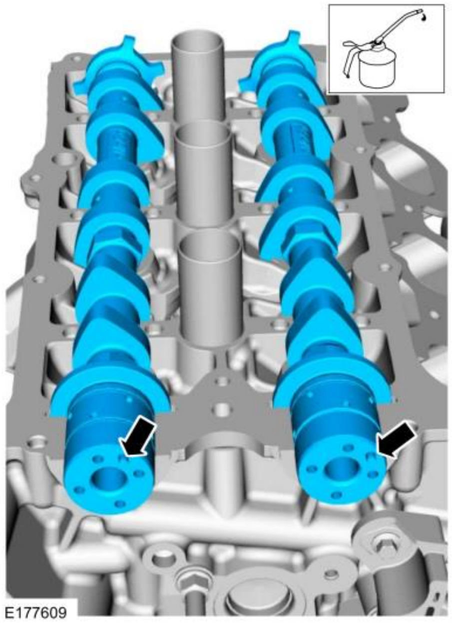
52. **NOTICE: The crankshaft must remain in the freewheeling position (crankshaft dowel pin at 9 o'clock) until after the camshafts are installed and the valve clearance is checked/adjusted. Do not turn the crankshaft until instructed to do so. Failure to follow this process will result in severe engine damage.**

Position the crankshaft dowel pin in the 9 o'clock position.


E258918

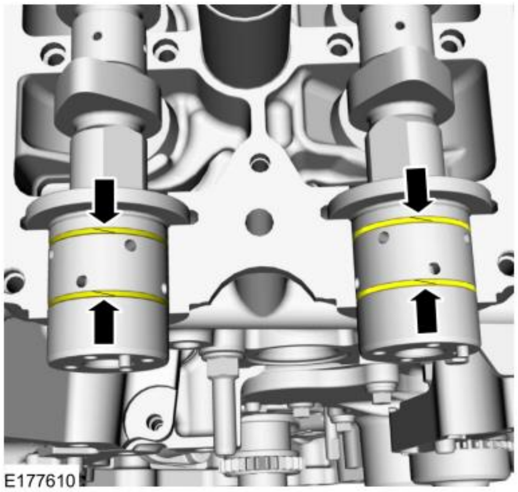
53. **NOTE:** *Coat the camshafts with clean engine oil prior to installation.*

Lubricate the camshafts with clean engine oil and position the camshafts onto the RH cylinder head in the neutral position as shown.
Material : Motorcraft® SAE 5W-20


E177609

54. **NOTICE: The camshaft seal gaps must be at the 12 o'clock position or damage to the engine may occur.**

Position the RH camshaft seals gaps as shown.


E177610

55. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they*

are assembled in their original positions.

Install the camshaft caps, oil tube and the bolts.

Torque :

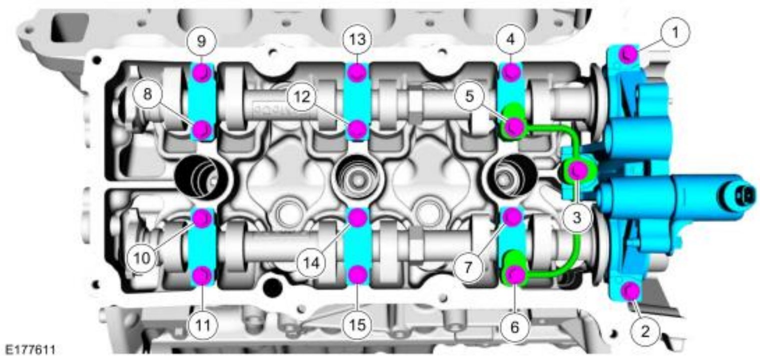
Stage 1: Tighten bolts 1, 2, 4, 5, 6, and 7 to: 71 lb.in (8 Nm)

Stage 2: Tighten bolts 1, 2, 4, 5, 6, and 7 an additional: 45°

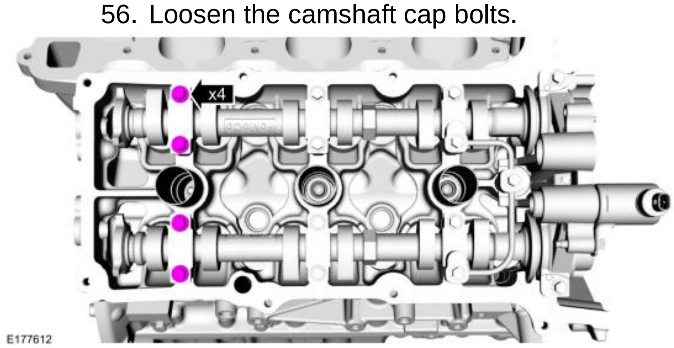
Stage 3: Tighten bolts 8, 9, 10 and 11 to: 71 lb.in (8 Nm)

Stage 4: Tighten bolts 12, 13, 14 and 15 to 71 lb.in (8 Nm)

Stage 5: Tighten bolts 12, 13, 14 and 15 an additional: 45°



56. Loosen the camshaft cap bolts.

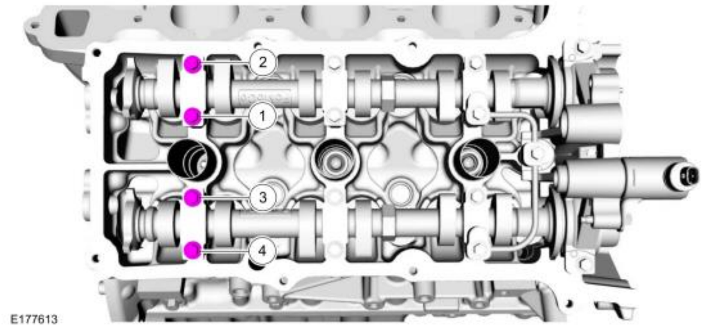


57. Tighten the camshaft cap bolts.

Torque :

Stage 1: 71 lb.in (8 Nm)

Stage 2: 45°



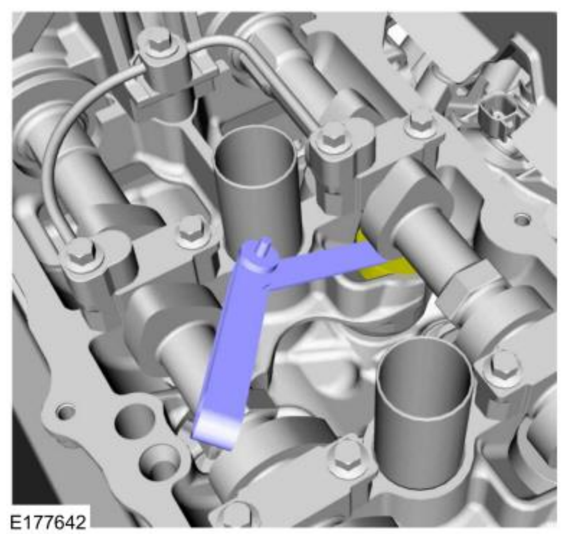
58. **NOTICE: If any components are installed new, the engine valve clearance must be checked/adjusted or engine damage may occur.**

NOTE: *Use a camshaft sprocket bolt to turn the camshafts.*

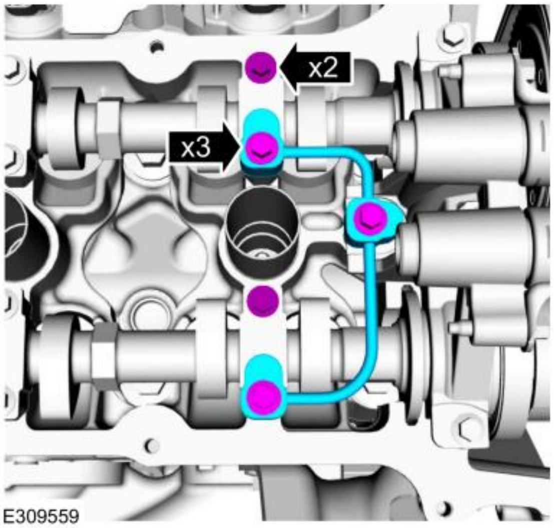
Confirm that the valve tappet clearances are within specification. If valve tappet clearances are not within specification, the clearance must be adjusted by installing new valve tappet(s) of the correct size.

Refer to: Valve Clearance Adjustment Page 2-41.

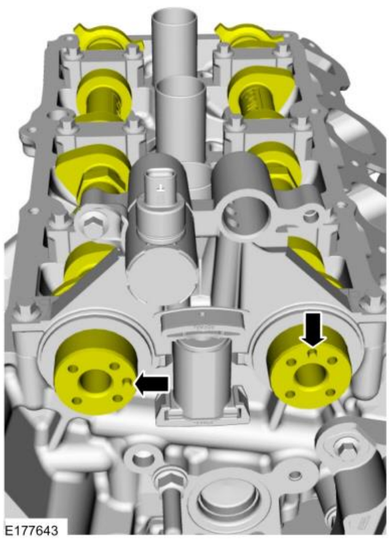
Use the General Equipment: Feeler Gauge



59. Remove the bolts and the RH oil tube. Loosen the 2 bolts.

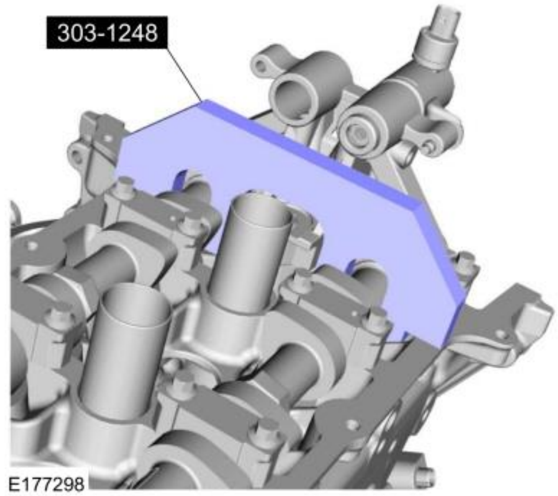


60. Rotate the RH camshafts to TDC.



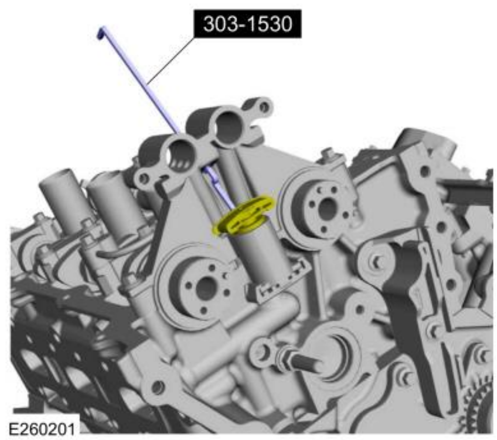
61. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position.*

    Install Special Service Tool : 303-1248 Camshaft holding tools

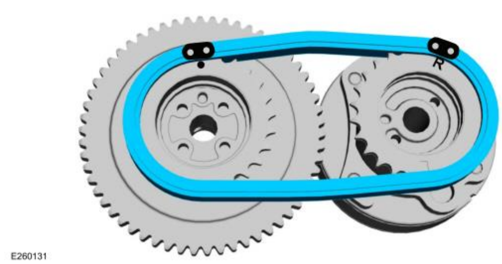


62. **NOTE:** *The VCT oil control solenoids are removed for clarity.*

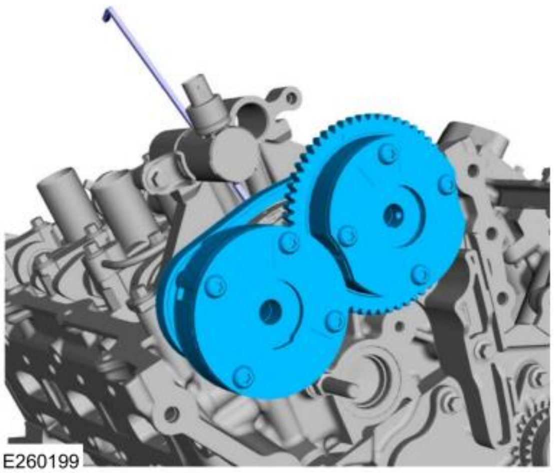
    Install Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



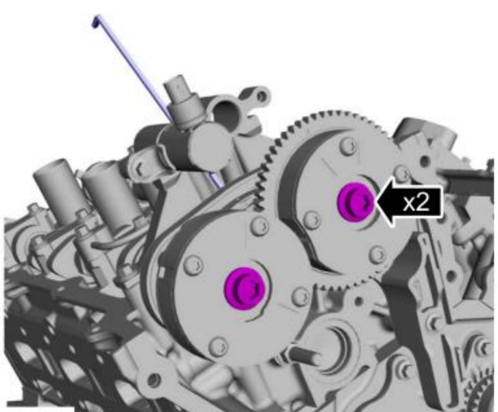
63. Align the colored links with the timing marks and assemble the RH VCT units.



64. **NOTE:** *It may be necessary to rotate the camshafts slightly, to install the RH secondary timing assembly.*
    Position the RH VCT units and secondary timing chain onto the camshafts by aligning the holes in the VCT units with the dowel pins in the camshafts.

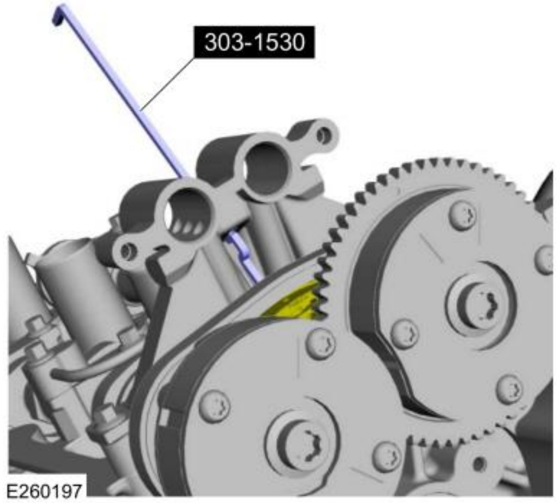

E260199

65. Install the new RH VCT unit bolts.
    Torque :
    Stage 1: 30 lb.ft (40 Nm)
    Stage 2: Loosen:: 1 turn(s)
    Stage 3: 18 lb.ft (25 Nm)
    Stage 4: 180°



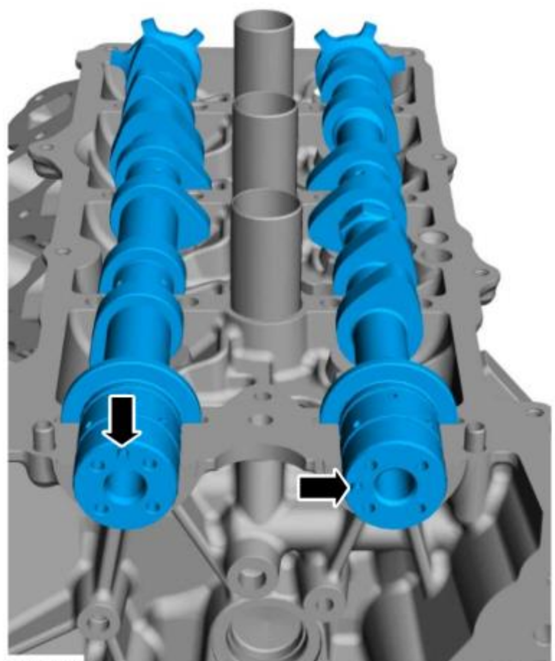
E260202

66. **NOTE:** *Make sure the secondary timing chain is centered on the timing chain tensioner guides.*
    NOTE: *The VCT oil control solenoids are removed for clarity.*
    Remove Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down

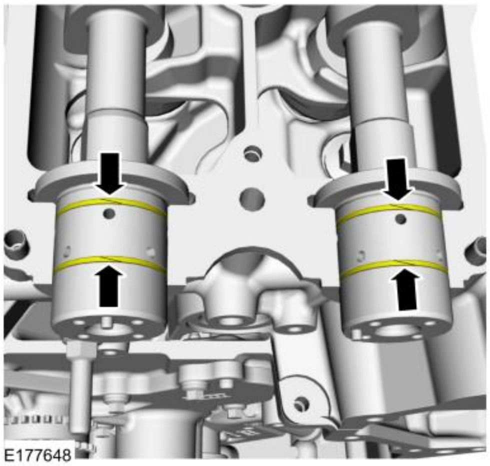


E260197

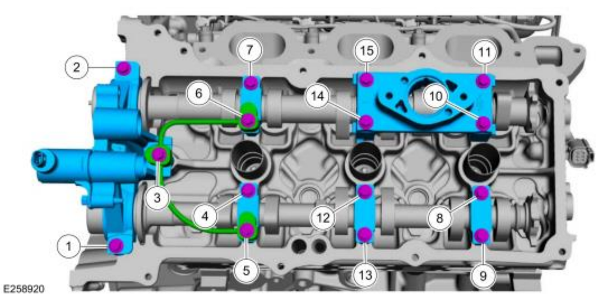
67. **NOTE:** *Coat the camshafts with clean engine oil prior to installation.*
    Lubricate the camshafts with clean engine oil and position the camshafts onto the LH cylinder head in the neutral position as shown.
    Material : Motorcraft® SAE 5W-20


E259031

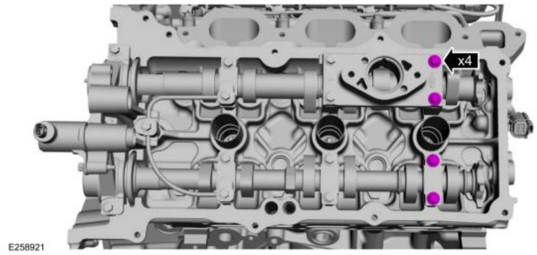
68. **NOTICE: The camshaft seal gaps must be at the 12 o'clock position or damage to the engine may occur.**
   Position the LH camshaft seals gaps as shown.



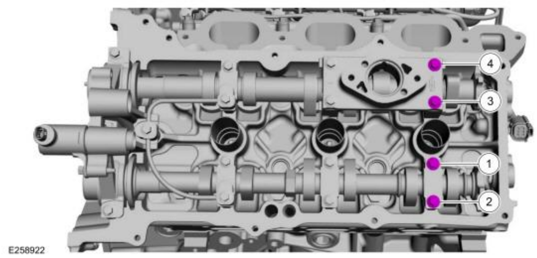
69. **NOTE:** *Cylinder head camshaft bearing caps are numbered to verify that they are assembled in their original positions.*
   Install the camshaft caps, oil tube and the bolts.
   Torque :
   Stage 1: Tighten bolts 1, 2, 4, 5, 6 and 7 to: 71 lb.in (8Nm)
   Stage 2: Tighten bolts 1, 2, 4, 5, 6 and 7 an additional: 45°
   Stage 3: Tighten bolts 8, 9, 10 and 11 to: 71 lb.in (8Nm)
   Stage 4: Tighten bolts 12, 13, 14 and 15 to: 71 lb.in (8Nm)
   Stage 5: Tighten bolts 12, 13, 14 and 15 an additional: 45°



70. Loosen the camshaft cap bolts.

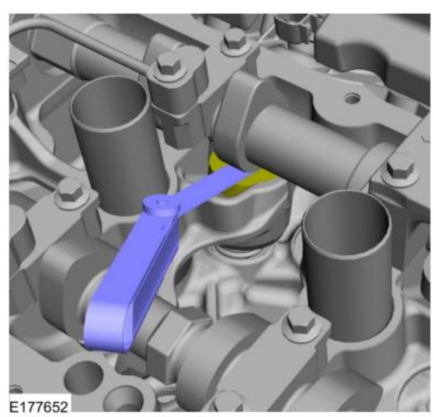


71. Tighten the camshaft cap bolts.
   Torque :
   Stage 1: 71 lb.in (8 Nm)
   Stage 2: 60°

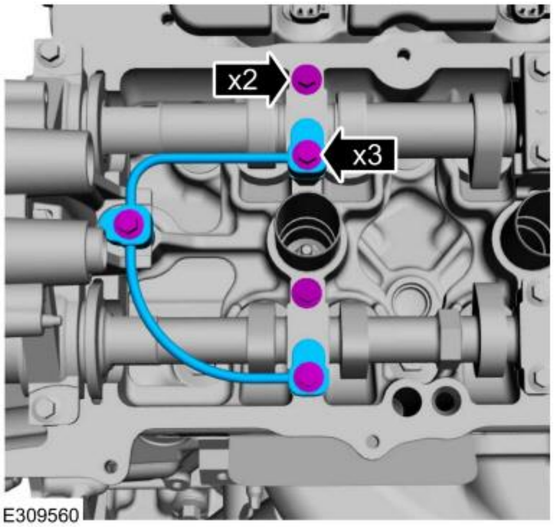


72. **NOTICE: If any components are installed new, the engine valve clearance must be checked/adjusted or engine damage may occur.**
   NOTE: *Use a camshaft sprocket bolt to turn the camshafts.*
   Confirm that the valve tappet clearances are within specification. If valve tappet clearances are not within specification, the clearance must be adjusted by installing new valve tappet(s) of the correct size.

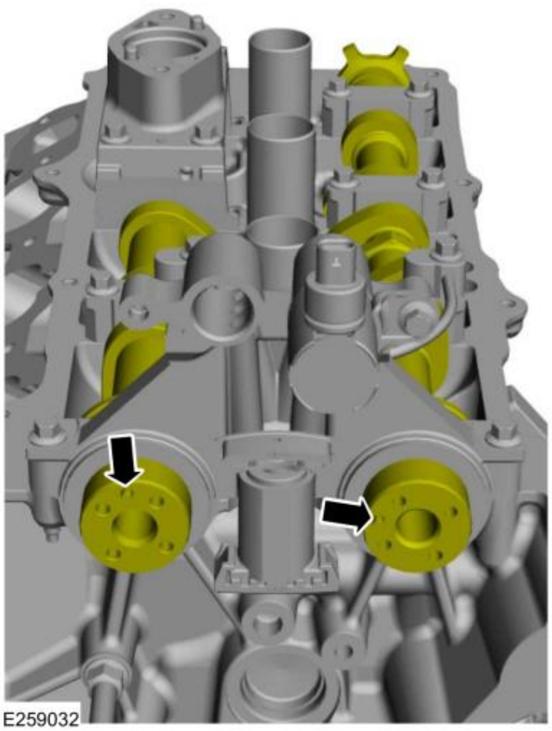
   Refer to: Valve Clearance Adjustment Page 2-41.
   Use the General Equipment: Feeler Gauge



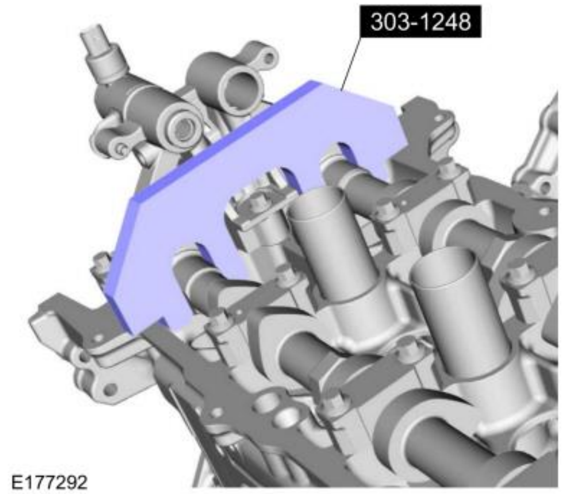
73. Remove bolts and the LH oil tube.
    Loosen the 2 bolts.



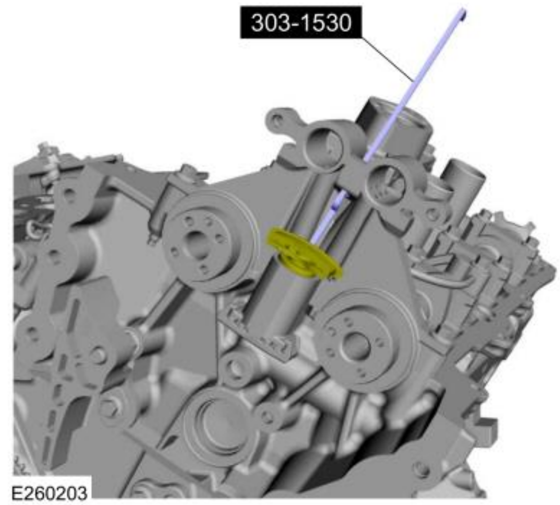
74. Rotate the LH camshafts to TDC.



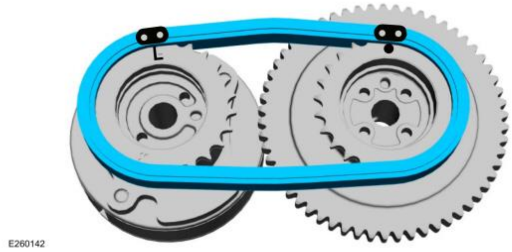
75. **NOTE:** *The Camshaft Holding Tool will hold the camshafts in the TDC position.*
    Install Special Service Tool : 303-1248 Camshaft holding tools



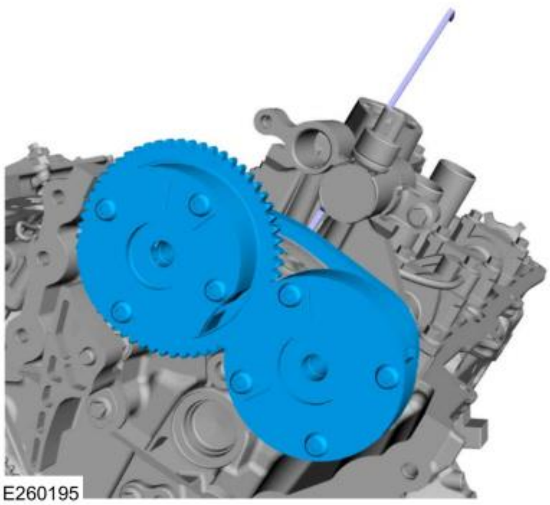
76. **NOTE:** *The VCT oil control solenoids are removed for clarity.*
    Install Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



77. Align the colored links with the timing marks and assemble the LH VCT units.

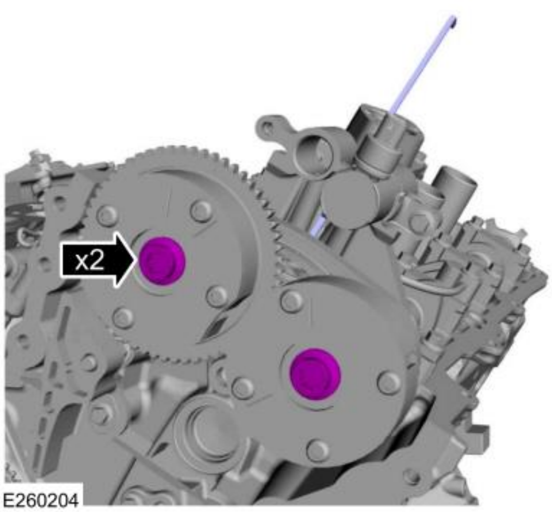


78. **NOTE:** *It may be necessary to rotate the camshafts slightly, to install the LH secondary timing assembly.*
   Position the LH VCT units and secondary timing chain onto the camshafts by aligning the holes in the VCT units with the dowel pins in the camshafts.



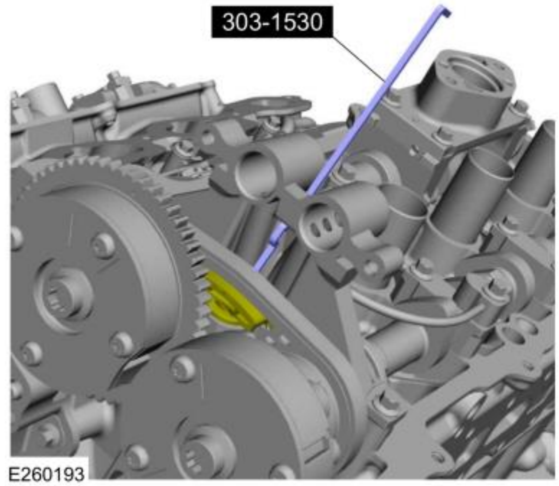
E260195

79. Install the new LH VCT unit bolts.
   Torque :
   Stage 1: 30 lb.ft (40 Nm)
   Stage 2: Loosen:: 1 turn(s)
   Stage 3: 18 lb.ft (25 Nm)
   Stage 4: 180°



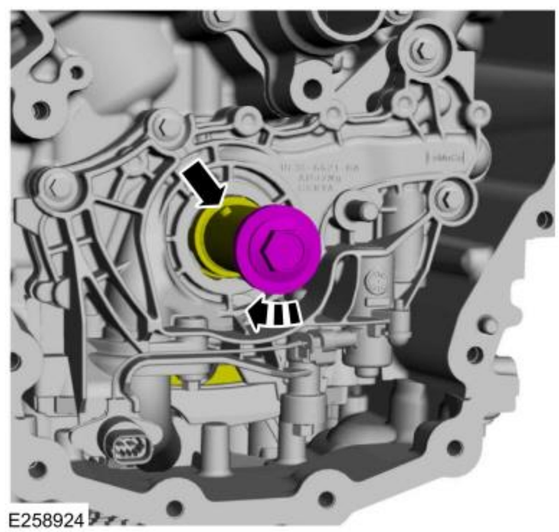
E260204

80. **NOTE:** *Make sure the secondary timing chain is centered on the timing chain tensioner guides.*
   NOTE: *The VCT oil control solenoids are removed for clarity.*
   Remove Special Service Tool : 303-1530 Tool, Chain Tensioner Hold Down



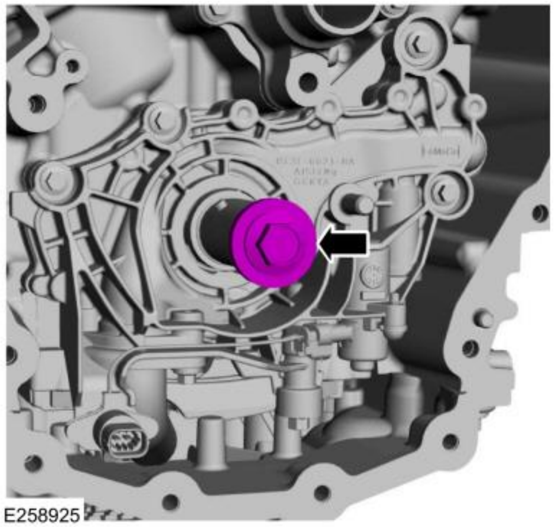
E260193

81. Using the crankshaft bolt, rotate the crankshaft clockwise 60 degrees to the TDC position (crankshaft dowel pin at 11 o'clock).

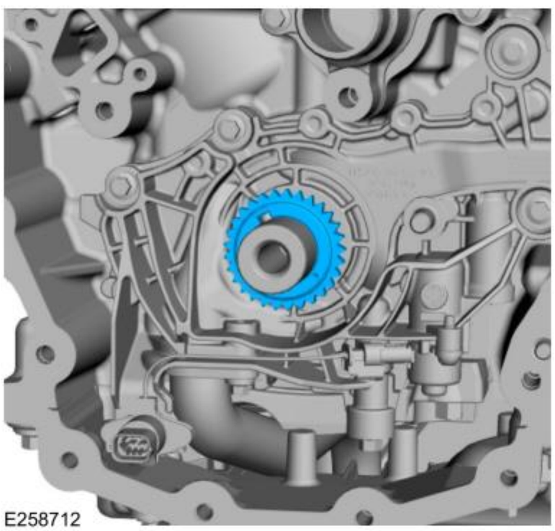


E258924

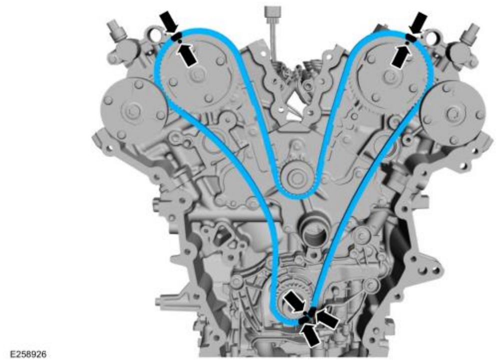
82. Remove the crankshaft pulley bolt.



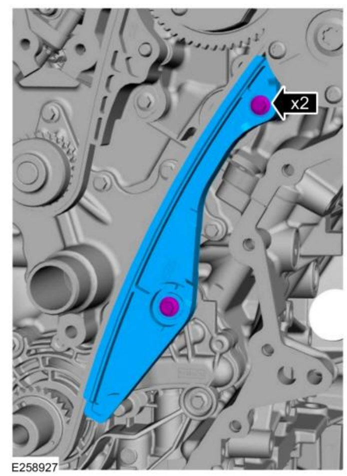
83. Install the crankshaft sprocket.



84. **NOTE:** *It may be necessary to rotate the camshafts slightly, to align the timing marks.*
    Install the timing chain with the colored links aligned with the timing marks on the VCT units and the crankshaft sprocket.

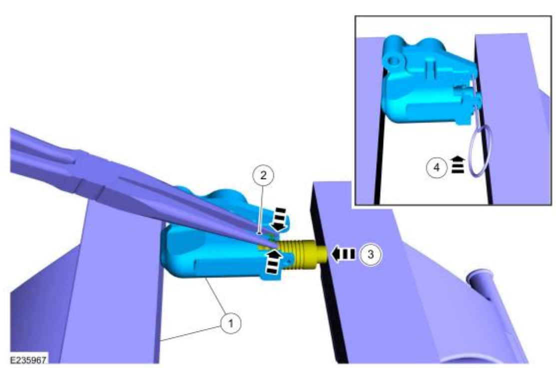


85. Install the lower LH timing chain guide and the bolts.
    Torque : 89 lb.in (10 Nm)

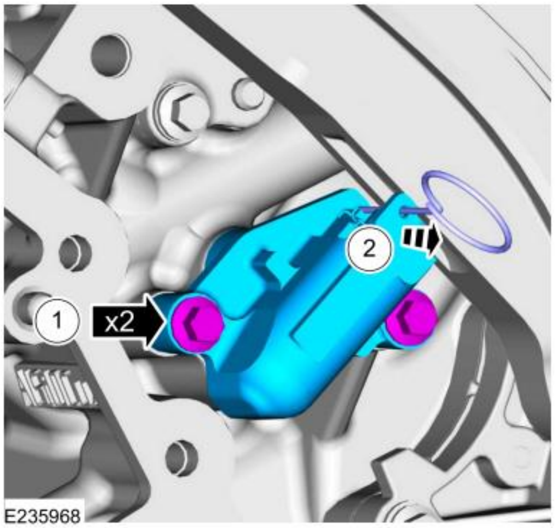


86. Install the timing chain tensioner arm.

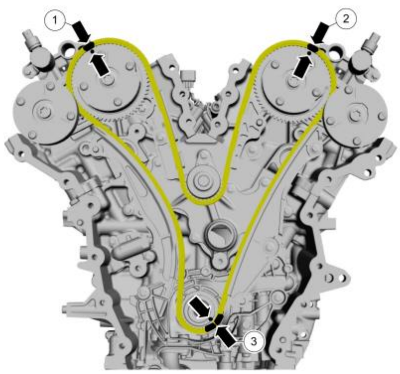
87. Position the tensioner in a soft-jawed vise. Using pliers, squeeze the ends of the ratchet wire clip together. Using the soft-jawed vise, compress the plunger to the reset position. Install a locking pin in the 2 holes of the tensioner body to hold the plunger in place.



88. **NOTE:** *It may be necessary to rotate the camshafts slightly to remove slack from the timing chain to install the tensioner.*
Install the timing chain tensioner and the bolts
Torque : 89 lb.in (10 Nm)
Remove the lockpin.

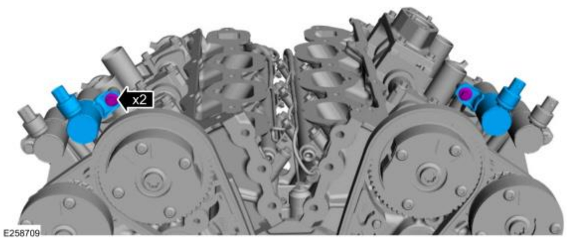


89. As a post-check, verify correct alignment of all timing marks.
There are 48 links in between the RH intake VCT unit colored link (1) and the LH intake VCT unit colored link (2).
There are 35 links in between LH intake VCT unit colored link (2) and the 2 crankshaft sprocket links (3).

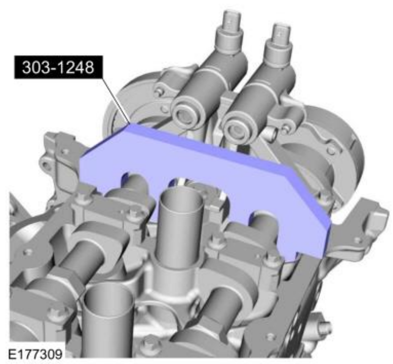


E258929

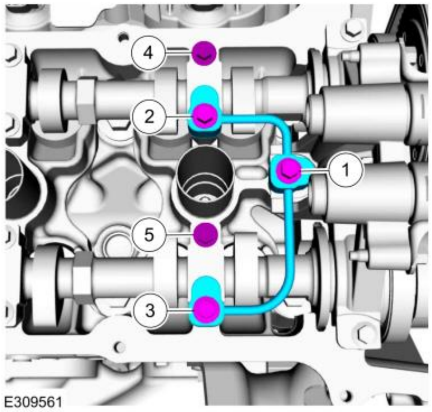
90. **NOTICE: Do not use excessive force when installing the VCT oil control solenoid. Damage to the mega cap could cause the cylinder head to be inoperable. If difficult to install the VCT oil control solenoid, inspect the bore and VCT oil control solenoid to ensure there are no burrs, sharp edges or contaminants present on the mating surface. Only clean the external surfaces as necessary.**
Install the VCT oil control solenoids and the bolts.
Torque :
Stage 1: 71 lb.in (8 Nm)
Stage 2: 20°



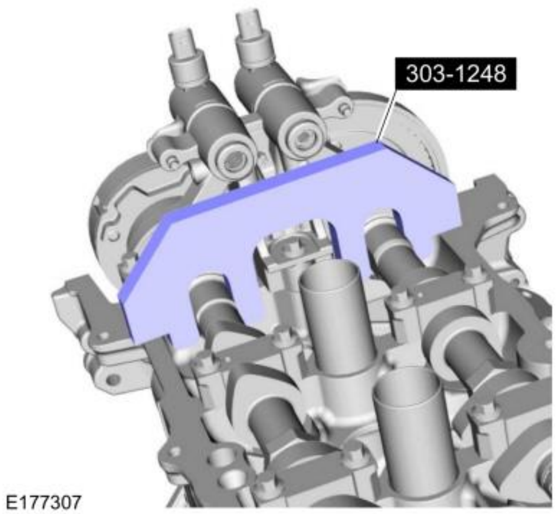
91. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



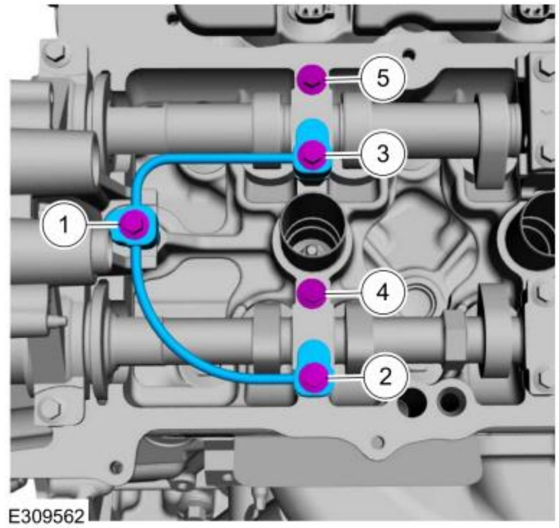
92. Install the RH oil tube and the bolts.
Torque :
Stage 1: Tighten bolts 1, 2 and 3 to: 71 lb.in (8 Nm)
Stage 2: Tighten bolts 1, 2 and 3 an additional: 60°
Stage 3: Tighten bolts 4 and 5 to: 71 lb.in (8 Nm)
Stage 4: Tighten bolts 4 and 5 an additional: 45°



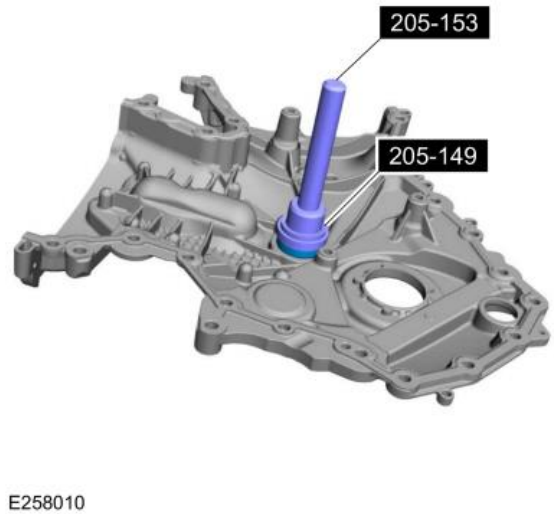
93. *Remove Special Service Tool* : 303-1248 Camshaft holding tools



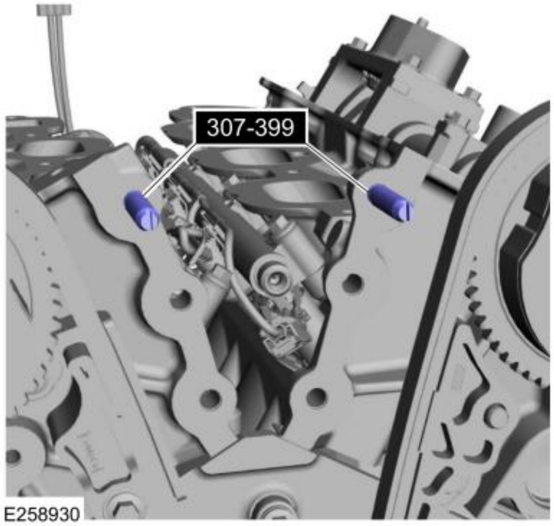
94. Install the LH oil tube and the bolts.
Torque :
Stage 1: Tighten bolts 1, 2 and 3 to: 71 lb.in (8 Nm)
Stage 2: Tighten bolts 1, 2 and 3 an additional: 60°
Stage 3: Tighten bolts 4 and 5 to: 71 lb.in (8 Nm)
Stage 4: Tighten bolts 4 and 5 an additional: 45°



95. Using the special tools, install the front cover to coolant pipe seal. *Use Special Service Tool* : 205-149 (T80T-4000-S) Installer, Spindle Bearing , 205-153 (T80T-4000-W) Handle



96. *Install Special Service Tool* : 307-399 Alignment Pins, Transmission Fluid Pump

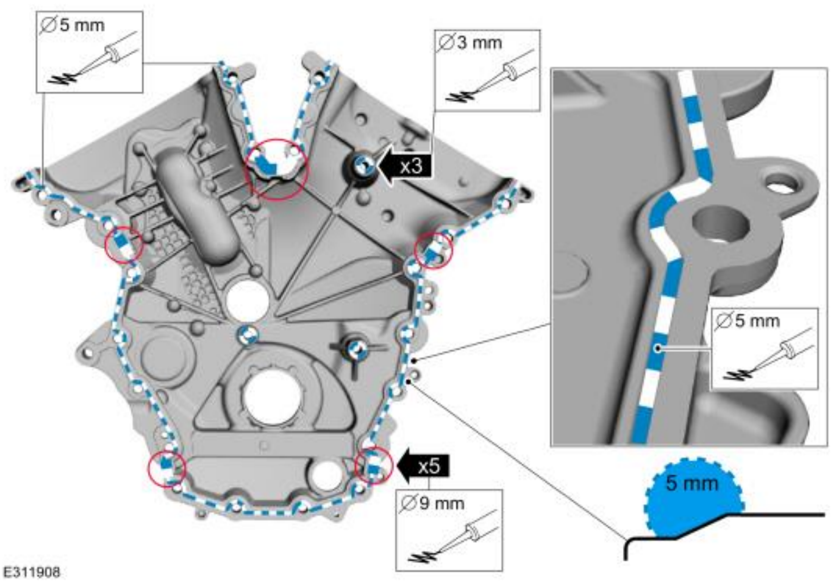


Apply a 5 mm (0.19 in) bead of Motorcraft® High Performance Engine RTV Silicone to the oil pan-to-cylinder block joint and the cylinder head-to-cylinder block joint areas of the engine front cover in places as indicated.
Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)

Apply a 9 mm (0.35 in) bead of Motorcraft® High Performance Engine RTV Silicone to the oil pan-to-cylinder block joint and the cylinder head-to-cylinder block joint areas of the engine front cover in places as indicated.
Material: Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)

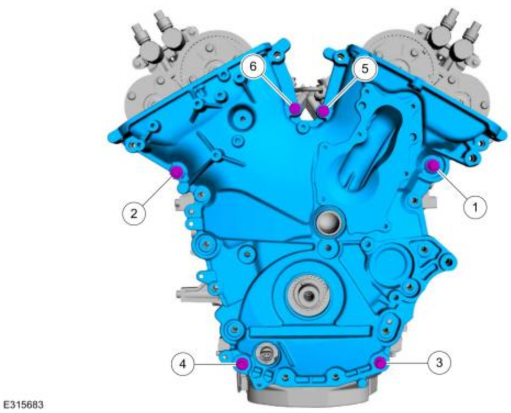
97. **NOTICE: Failure to use Motorcraft® High Performance Engine RTV Silicone may cause the engine oil to foam excessively and result in serious engine damage.**

NOTE: *The engine front cover and 6 bolts must be installed within 4 minutes of the initial sealant application. The remainder of the engine front cover bolts must be installed and tightened within 35 minutes of the initial sealant application. If the time limits are exceeded, the sealant must be removed, the sealing area cleaned and sealant reapplied. To clean the sealing area, use silicone gasket remover and metal surface prep. Failure to follow this procedure can cause future oil leakage.*

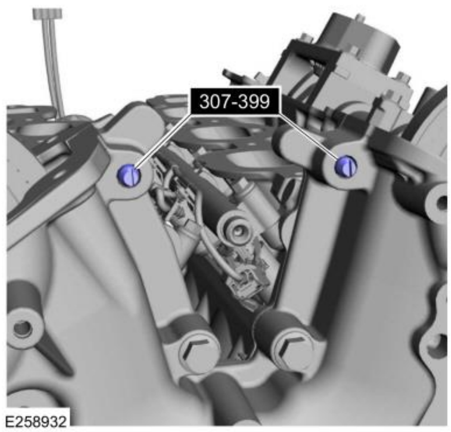


Apply a 3.0 mm (0.12 in) bead of Motorcraft® High Performance Engine RTV Silicone to the engine front cover sealing surfaces including the inner bolt bosses.*Material* : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)

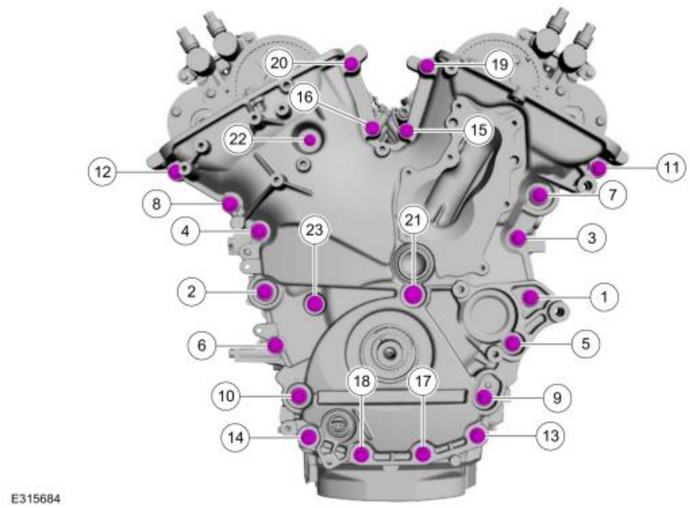
98. **NOTE:** *It will be necessary to obtain 2 W503297 (10mm Hex) M8 x 1.25 x 35 bolts and washers to replace the power steering pump bracket bolts during the front cover tightening process.*
NOTE: *Make sure the locating dowel pins are seated correctly in the cylinder block.* Install the engine front cover and the bolts.
Torque : 27 lb.in (3 Nm)



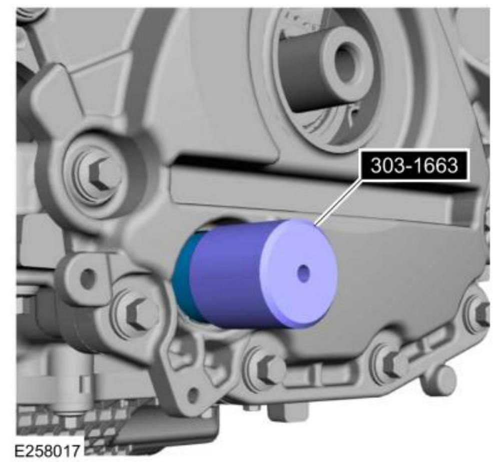
99. *Remove Special Service Tool* : 307-399 Alignment Pins, Transmission Fluid Pump



100. **NOTE:** *After the tightening sequence is completed, bolts 10 and 18 will be removed in the next step to accommodate installation of the power steering pump assembly and bolts.* Install the remaining engine front cover bolts.
Torque :
Stage 1: Tighten bolts 1 through 21 to: 89 lb.in (10 Nm)
Stage 2: Tighten bolts 1 through 20 and 23 to: 177 lb.in (20Nm)
Stage 3: Tighten bolts 1 through 20 and 23 an additional: 45°
Stage 4: Tighten bolt 21 to: 177 lb.in (20 Nm)
Stage 5: Tighten bolt 21 an additional: 90°
Stage 6: Tighten bolt 22 to: 89 lb.in (10 Nm)
Stage 7: Tighten bolt 22 an additional: 45°



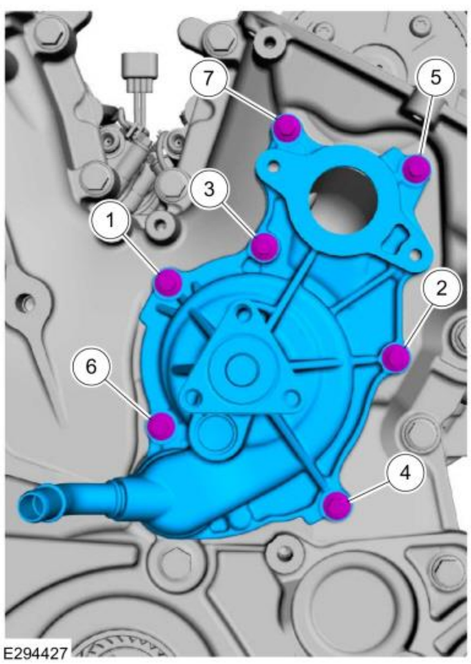
101. Using the special tool and a hammer, install the oil pump electrical connector seal. Use Special Service Tool: 303-1663 Installer, VDOP Seal.
Make sure the oil pump electrical connector seal is below the top of the oil pump electrical connector or the oil pump electrical connector seal may leak oil.



102. Install a new coolant pump gasket and O-ring seal.

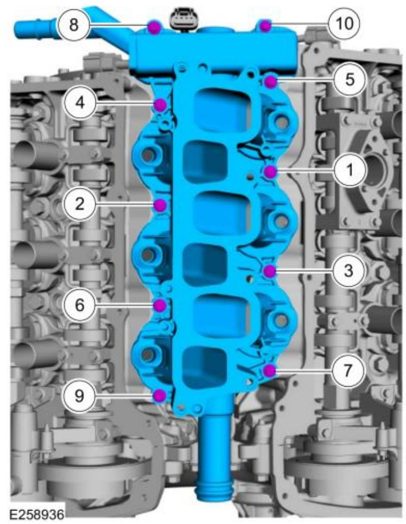
E294426

103. Install the coolant pump and the bolts.
Torque :
Stage 1: 89 lb.in (10 Nm)
Stage 2: 45°

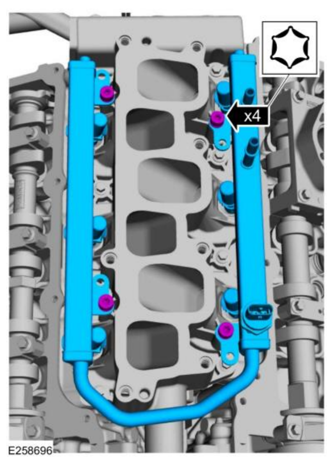


104. **NOTICE: If the engine is repaired or replaced because of upper engine failure, typically including valve or piston damage, check the intake manifold for metal debris. If metal debris is found, install a new intake manifold. Failure to follow these instructions can result in engine damage.**

Install the lower intake manifold and the bolts.
Torque : 89 lb.in (10 Nm)



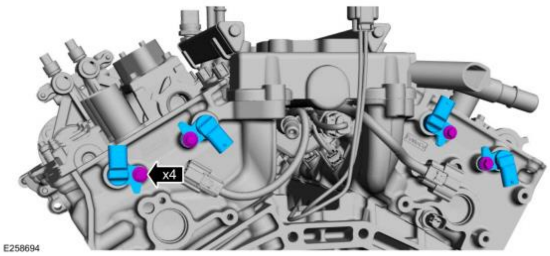
105. Install the fuel rail and the bolts.
Torque: 89 lb.in (10 Nm)



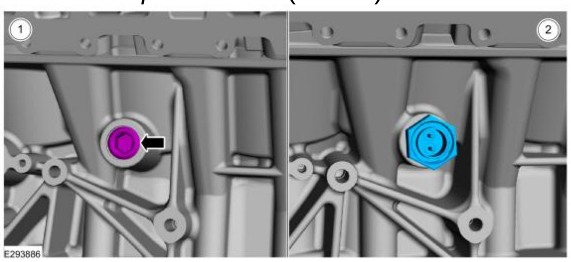
106. **NOTE:** *Apply clean engine oil to the CMP sensor O-ring seals.*

Install the CMP sensors and the bolts.
Material : Motorcraft® SAE 5W-20

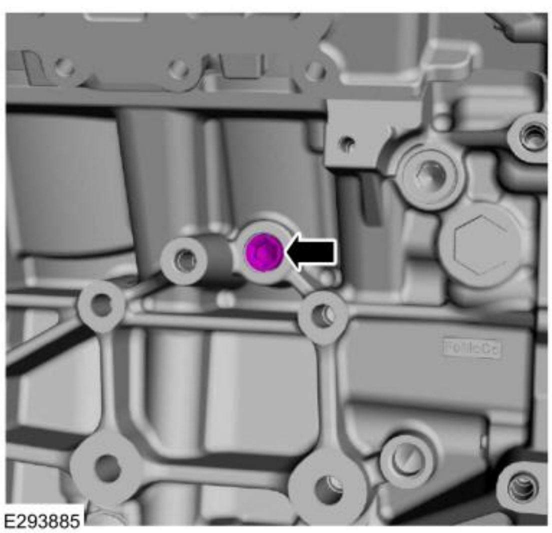
Torque : 89 lb.in (10 Nm)



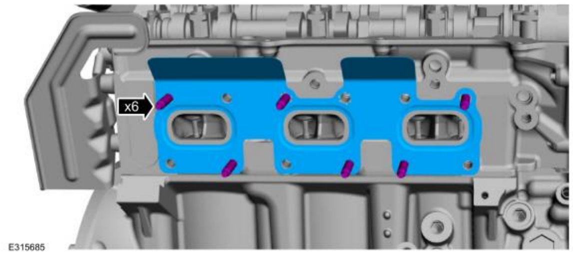
107. Install the LH block coolant drain plug.
Torque : 30 lb.ft (40 Nm)



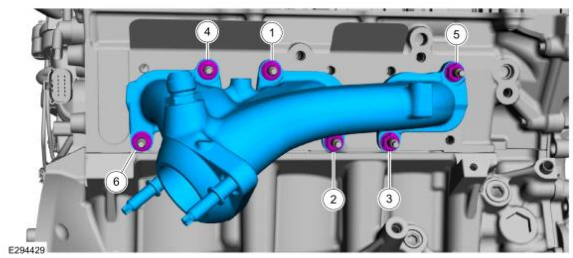
108. Install the LH block coolant drain plug.
Torque : Stage 1: 142 lb.in (16 Nm)
Stage 2: 180°



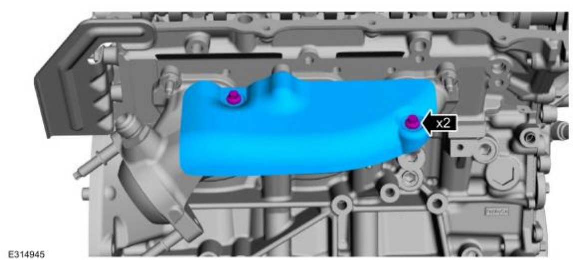
109. Install the exhaust manifold studs
Torque : 106 lb.in (12 Nm)
Install the exhaust manifold gasket.



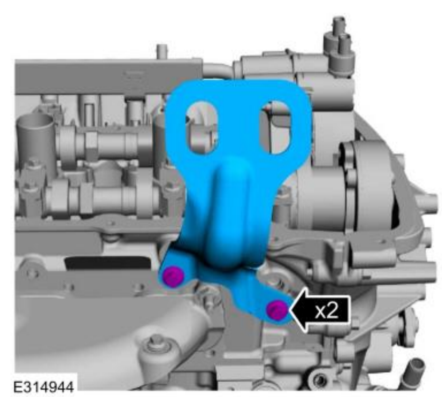
110. Install the exhaust manifold and the new nuts.
Torque :
Stage 1: 168 lb.in (19 Nm)
Stage 2: 18 lb.ft (25 Nm)



111. Install the RH exhaust manifold heat shield and the bolts.
Torque : 106 lb.in (12 Nm)



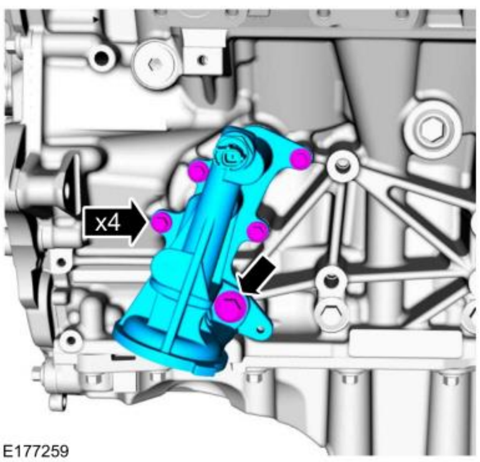
112. Install the RH lift eye and the bolts. *Torque:* 18 lb.ft (24 Nm)



113. Install a new oil filter adapter gasket.

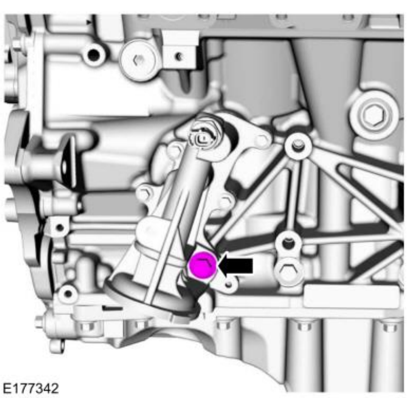
E323751

114. Install the oil filter adapter and the bolts finger-tight.



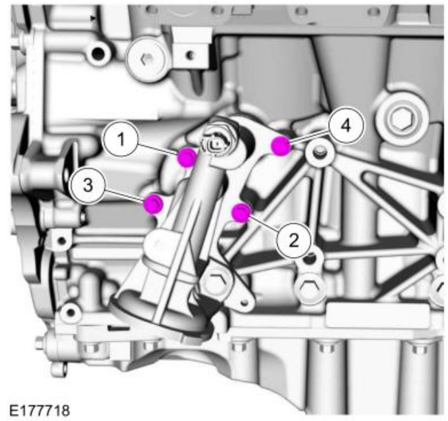
E177259

115. Tighten the bolt.
Torque : 31 lb.ft (42 Nm)



E177342

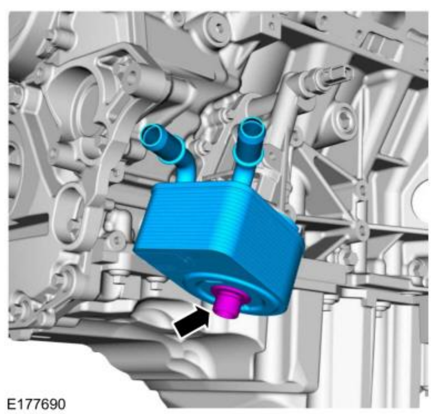
116. Tighten the bolts in sequence shown.
Torque :
Stage 1: 89 lb.in (10 Nm)
Stage 2: 45°



E177718

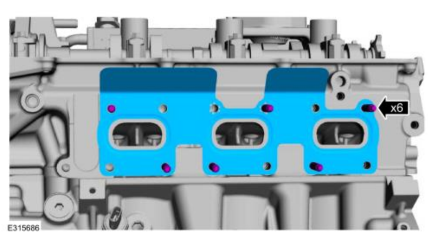
117. **NOTICE: A new oil cooler must be installed or severe damage to the engine can occur.**

Install the new oil cooler and the bolt.
Torque : 43 lb.ft (58 Nm)



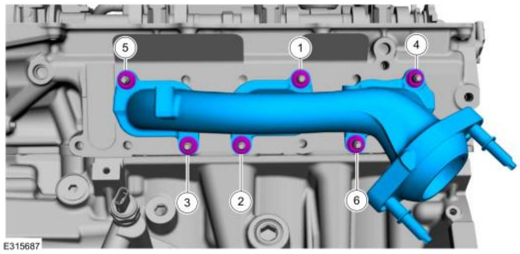
E177690

118. Install the exhaust manifold studs.
Torque : 106 lb.in (12 Nm)
Install the exhaust manifold gasket.

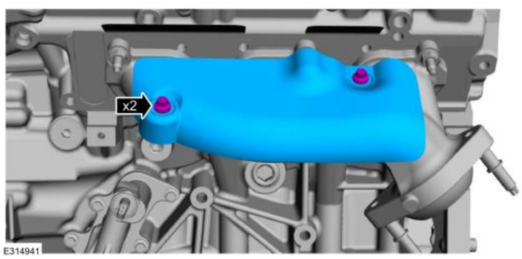


E315686

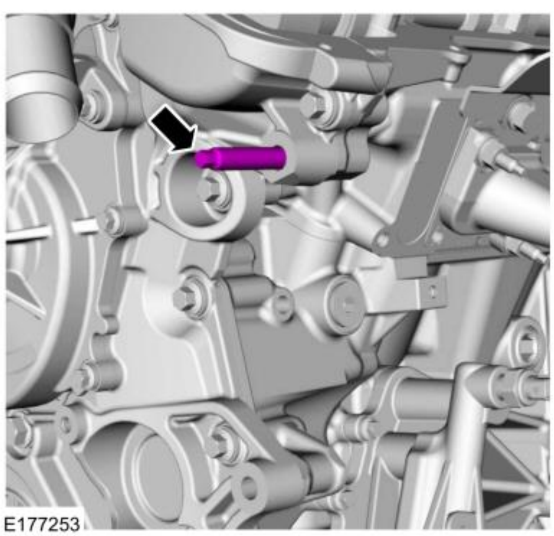
119. Install the exhaust manifold and the new nuts.
Torque :
Stage 1: 168 lb.in (19 Nm)
Stage 2: 18 lb.ft (25 Nm)



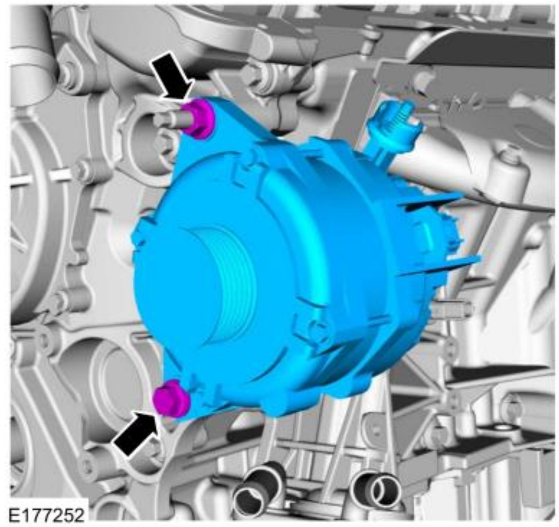
120. Install the exhaust manifold heat shield and the bolts.
Torque : 106 lb.in (12 Nm)



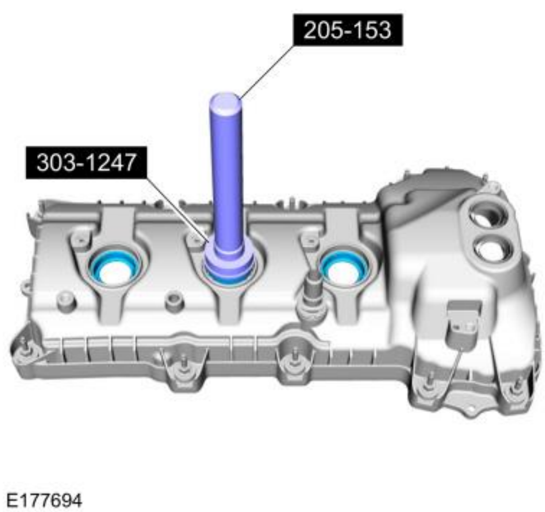
121. Install the generator stud bolt.
Torque : 71 lb.in (8 Nm)



122. Install the generator, nut and bolt.
Torque : 35 lb.ft (47 Nm)

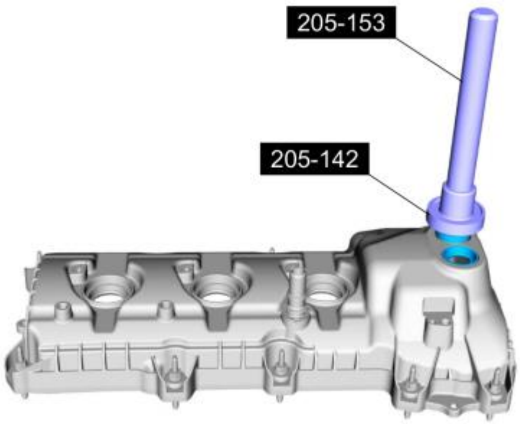


123. **NOTE:** *Installation of new seals is only required if damaged seals were removed.*
If removed, using the special tools, install the spark plug tube seals.
Use Special Service Tool : 303-1247 VCT Spark Plug Tube Seal Remover and Installer , 205-153 (T80T-4000-W) Handle



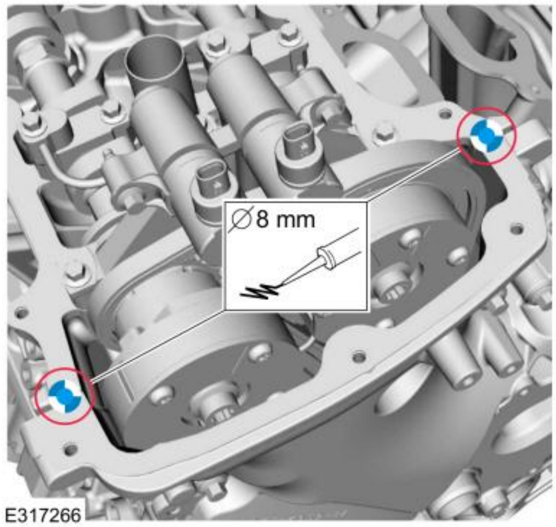
124. **NOTE:** *Installation of new seals is only required if damaged seals were removed.*
If removed, using the special tools, install the VCT oil control solenoid seals.

Use Special Service Tool : 205-142 (T80T-4000-J) Installer, Differential Bearing Cone , 205-153 (T80T-4000-W) Handle



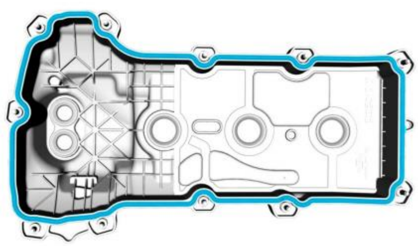
E177695

125. **NOTE:** *If the valve cover is not installed and the fasteners tightened within 4 minutes, the sealant must be removed and the sealing area cleaned. To clean the sealing area, use silicone gasket remover and metal surface prep. Failure to follow this procedure can cause future oil leakage.*
Apply an 8 mm (0.31 in) bead of Motorcraft® High Performance Engine RTV Silicone to the engine front cover-to-cylinder head joints.
Material : Motorcraft® Metal Surface Prep / ZC-31-B
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



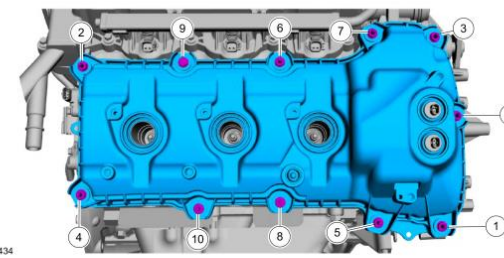
E317266

126. Install a new valve cover gasket.



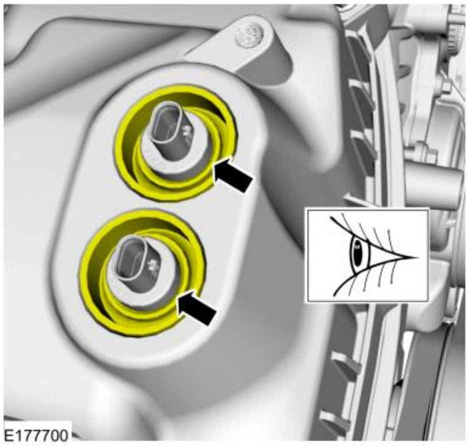
E177697

127. Install the valve cover and tighten the bolts.
Torque : 89 lb.in (10 Nm)



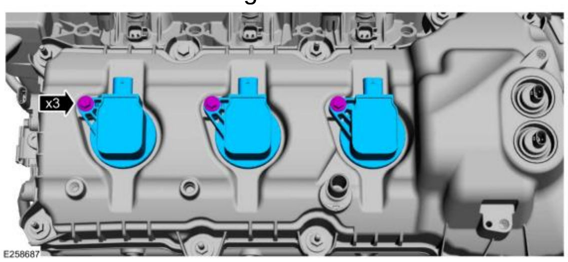
E294434

128. Make sure the VCT seals in the valve cover are below the top of the VCT oil control solenoid electrical connector or the VCT seal may leak oil.



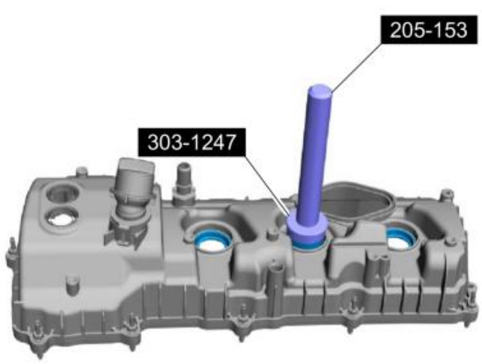
129. Install the RH coil-on-plugs and the bolts.

Torque : Stage 1: 62 lb.in (7 Nm)
Stage 2: 50º



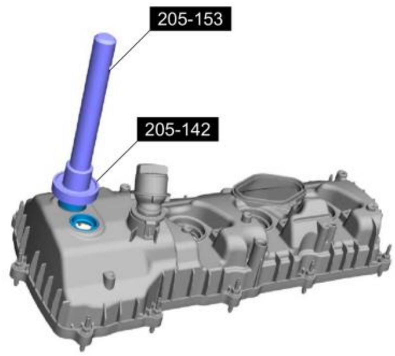
130. **NOTE:** *Installation of new seals is only required if damaged seals were removed.*

If removed, using the special tools, install the spark plug tube seals.
Use Special Service Tool : 303-1247 VCT Spark Plug Tube Seal Remover and Installer , 205-153 (T80T-4000-W) Handle



E312590

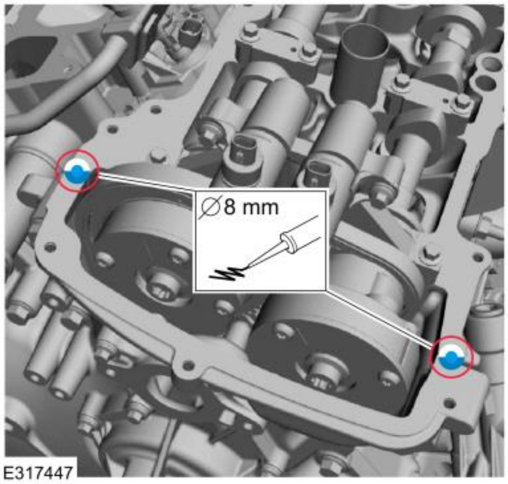
131. **NOTE:** *Installation of new seals is only required if damaged seals were removed.* If removed, using the special tools, install the VCT oil control solenoid seals. *Use Special Service Tool* : 205-142 (T80T-4000-J) Installer, Differential Bearing Cone , 205-153 (T80T-4000-W) Handle



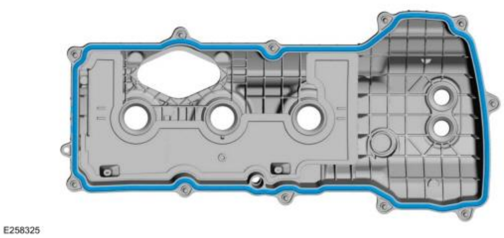
E312591

132. **NOTE:** *If the valve cover is not installed and the fasteners tightened within 4 minutes, the sealant must be removed and the sealing area cleaned. To clean the sealing area, use silicone gasket remover and metal surface prep. Failure to follow this procedure can cause future oil leakage.*

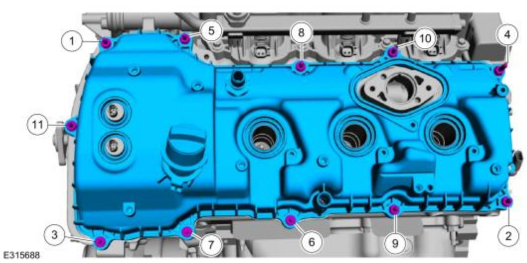
Apply an 8 mm (0.31 in) bead of Motorcraft® High Performance Engine RTV Silicone to the engine front cover-to-cylinder head joints.
Material : Motorcraft® Metal Surface Prep / ZC-31-B
Material : Motorcraft® Silicone Gasket Remover / ZC-30-A
Material : Motorcraft® High Performance Engine RTV Silicone / TA-357 (WSE-M4G323-A6)



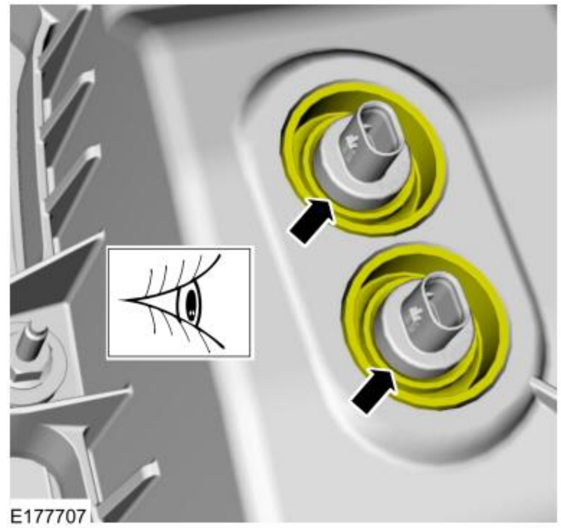
133. Install a new valve cover gasket.



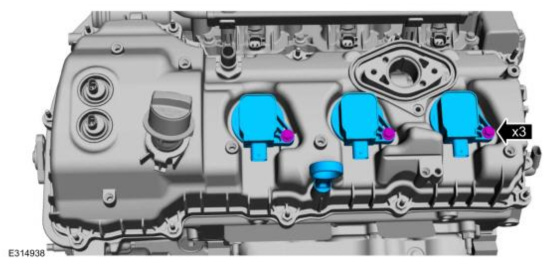
134. Install the valve cover and tighten the bolts.
Torque : 89 lb.in (10 Nm)



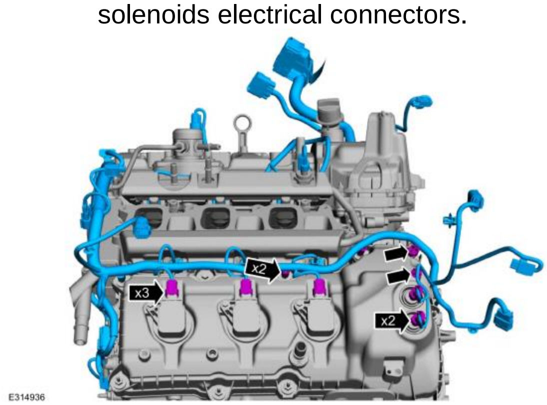
135. Make sure the VCT seals in the valve cover are below the top of the VCT oil control solenoid electrical connector or the VCT seal may leak oil.



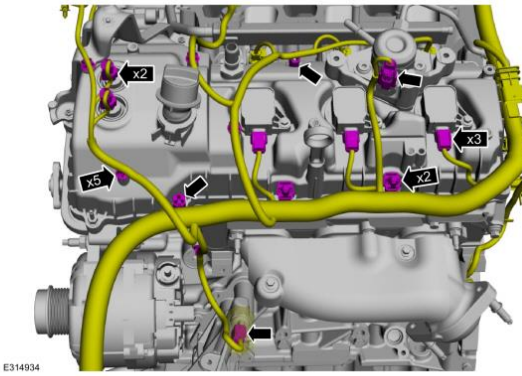
136. Install the LH coil-on-plugs and the bolts.
Torque : Stage 1: 62 lb.in (7 Nm)
Stage 2: 50º
Install the oil level indicator.



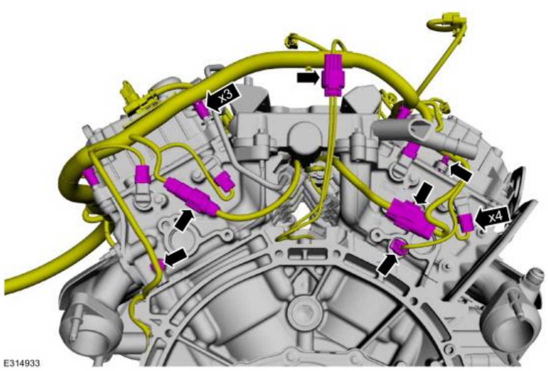
137. Install the engine wiring harness and attach the wiring harness retainers. Connect the wiring harness electrical connectors. Connect the VCT oil control solenoids electrical connectors.



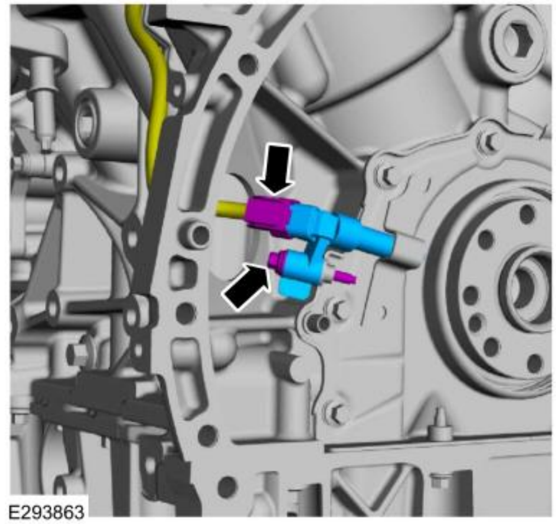
138. Attach the wiring harness retainers
Connect the wiring harness electrical connectors.
Slide the insulator on the oil pressure switch.



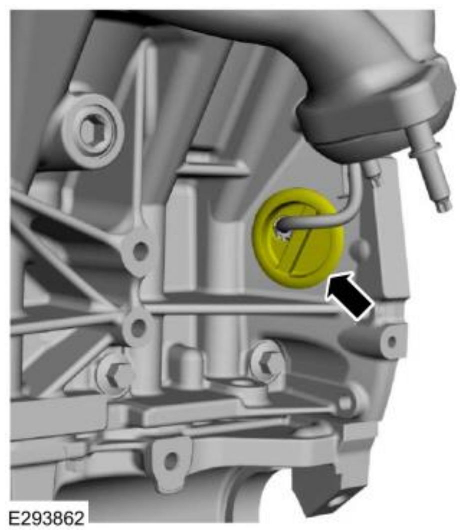
139. Attach the wiring harness retainers.
Connect the CMP sensor electrical connectors.
Connect the KS sensor electrical connector.



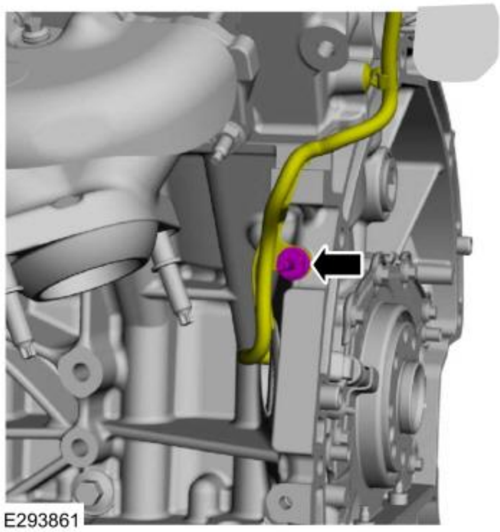
140. Install the CKP sensor and the bolt.
Torque : 53 lb.in (6 Nm)
Connect the CKP sensor electrical connector.



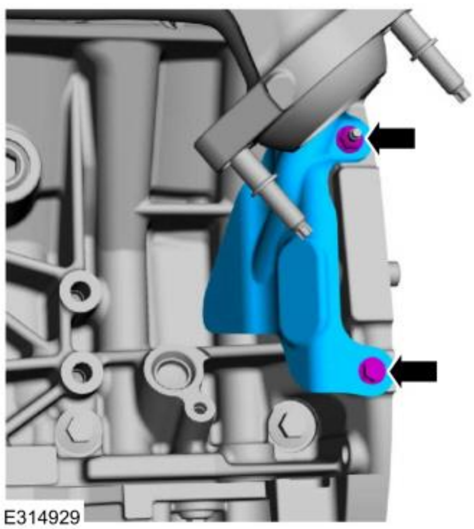
141. Install the wiring harness grommet.



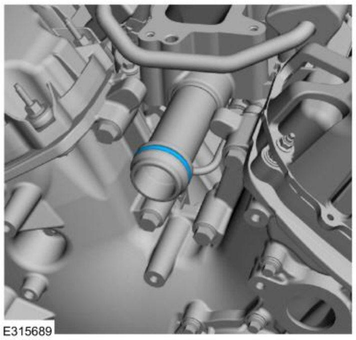
142. Install the wiring harness retainer stud bolt.
Torque : 89 lb.in (10 Nm)



143. Install the heat shield, nut and bolt.
Torque : 89 lb.in (10 Nm)



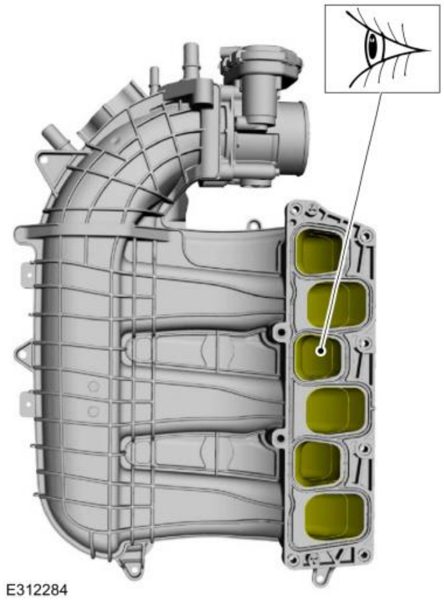
144. Install a new thermostat housing O-ring seal.



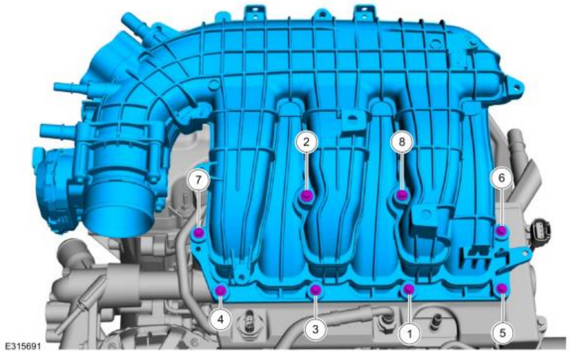
145. Install the thermostat housing and the bolts.
Torque: Stage 1: 71 lb.in (8 Nm)
Stage 2: 45º

NOTICE: If the engine is repaired or replaced because of upper engine failure, typically including valve or piston damage, check the intake manifold for metal debris. If metal debris is found, install a new intake manifold. Failure to follow these instructions can result in engine damage.

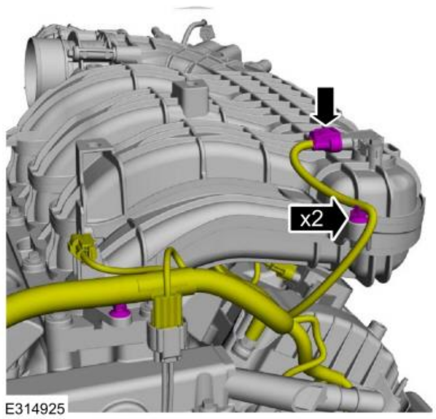
146. Inspect the intake manifold for damage or metal debris.



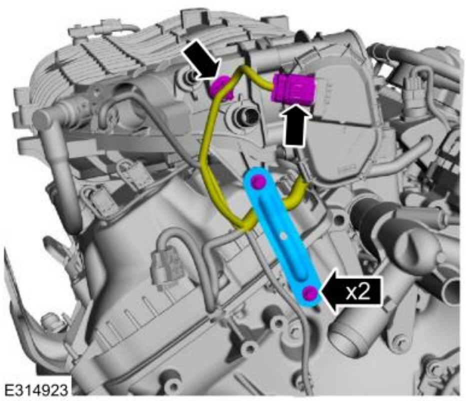
147. Install the upper intake manifold and the bolts.
Torque: Stage 1: 89 lb.in (10 Nm)
Stage 2: 45º



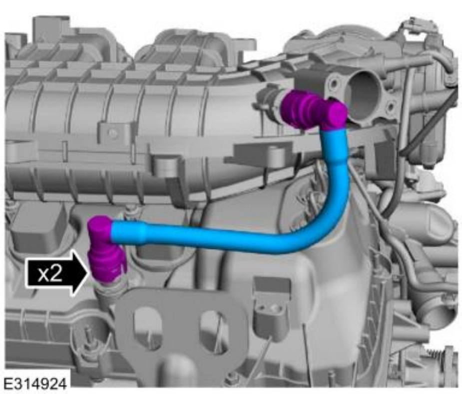
148. Connect the MAP sensor electrical connector and wiring harness retainers.



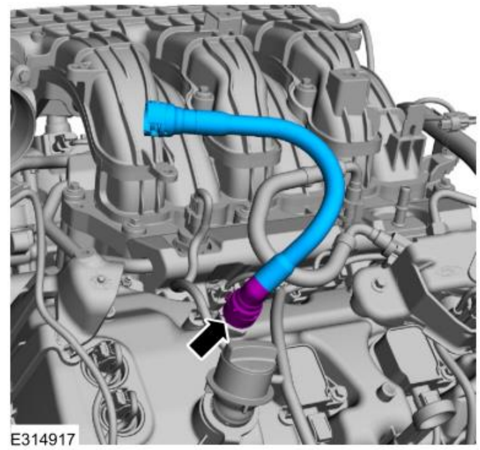
149. Install the upper intake manifold support bracket and the bolt.
Torque : 89 lb.in (10 Nm)



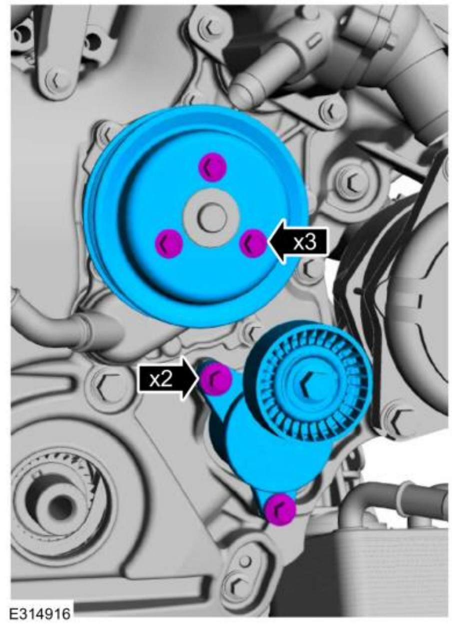
150. Install the PCV tube.



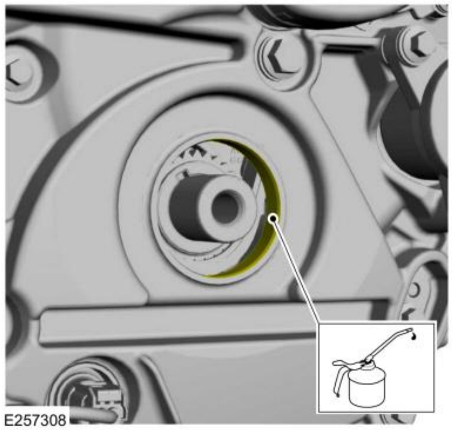
151. Install the crankcase vent tube.



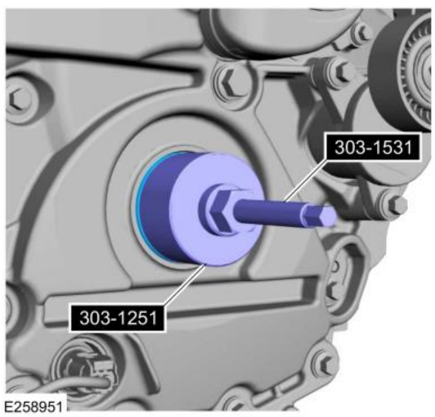
152. 1. Install the coolant pump pulley and the bolts.
Torque : 18 lb.ft (24 Nm)
2. Install the accessory drive belt tensioner and the bolts.
Torque: 18 lb.ft (24 Nm)



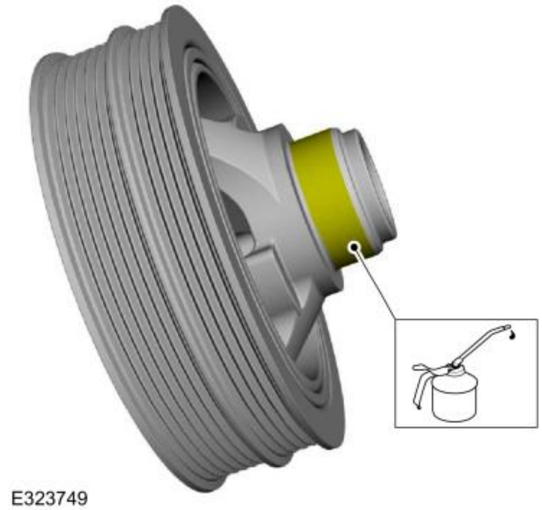
153. Lubricate the crankshaft front seal bore with clean engine oil.
Material : Motorcraft® SAE 5W-20



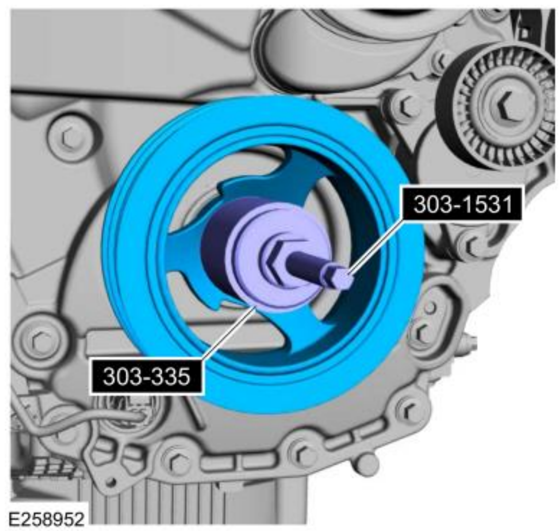
154. Using the special tools, install the crankshaft front seal.
Use Special Service Tool : 303-102 Installer, Crankshaft Pulley , 303-1251 Installer, Front Seal



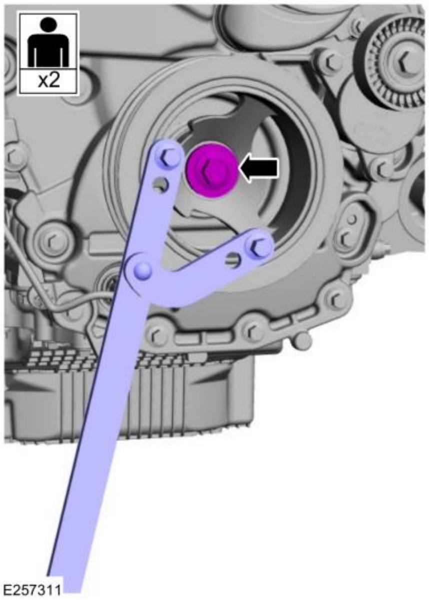
155. Lubricate the crankshaft front seal and the crankshaft pulley with clean engine oil. *Material* : Motorcraft® SAE 5W-20



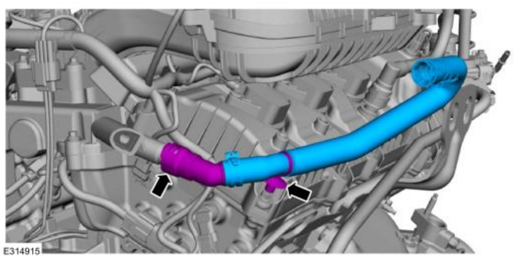
156. Using the special tools, install the crankshaft pulley. *Use Special Service Tool* : 303-102 Installer, Crankshaft Pulley , 303-335 (T88T-6701-A) Installer, Front Cover Oil Seal



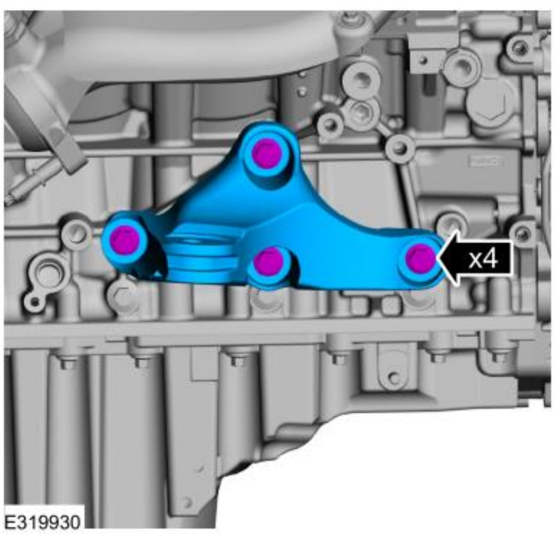
157. With the aid of an assistant, install the new crankshaft bolt and the washer. Use a universal pulley holder.
Torque :
Stage 1: 37 lb.ft (50 Nm)
Stage 2: 90°
Stage 3: 60°



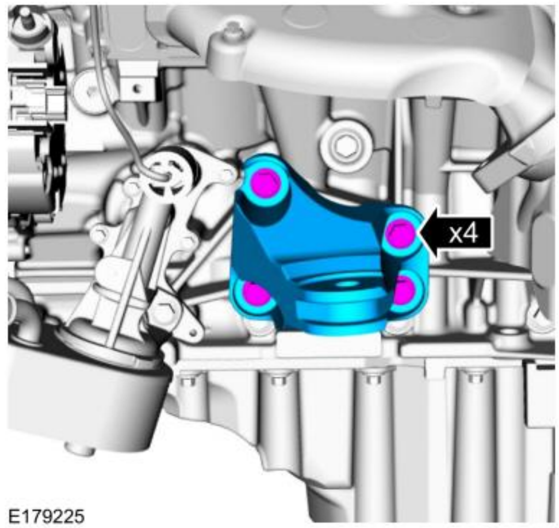
158. Install the coolant tube and retainer



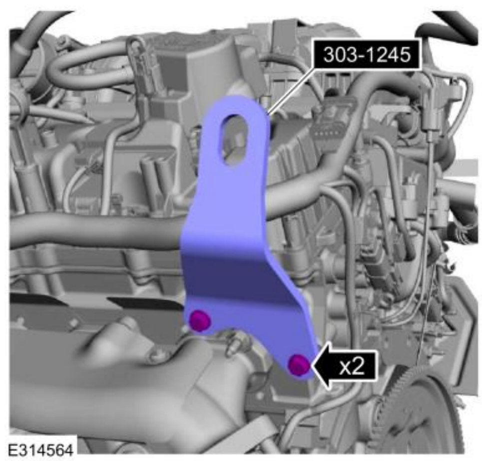
159. Install the RH engine mount bracket and the bolts.
Torque : 46 lb.ft (63 Nm)



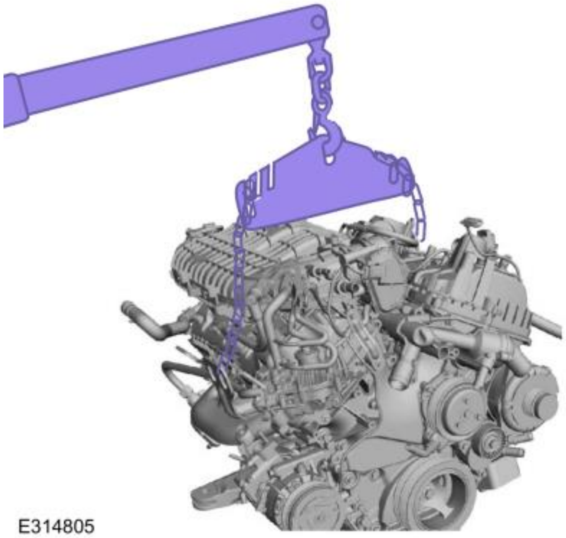
160. Install the LH engine mount bracket and the bolts.
Torque : 46 lb.ft (63 Nm)



161. Install the LH engine lift eye.
Use Special Service Tool : 303-1245 Engine Lift Eye

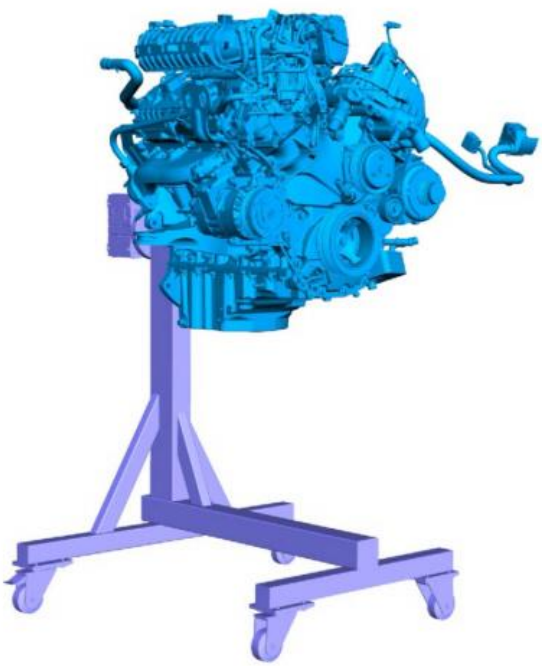


162. Install the floor crane.
Use the General Equipment: Floor Crane



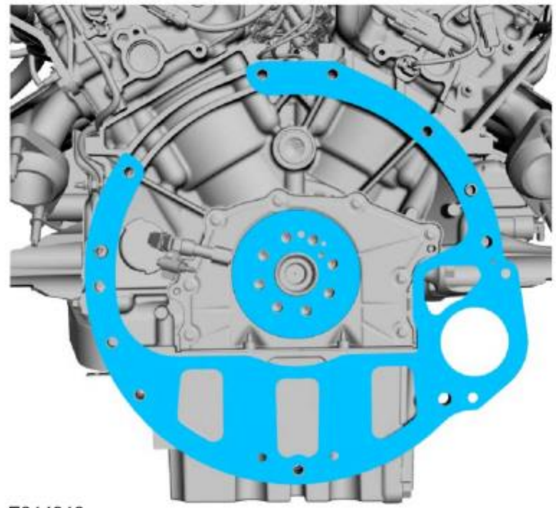
E314805

163. Remove the engine from the mounting stand. Use the General Equipment: Mounting Stand



E314914

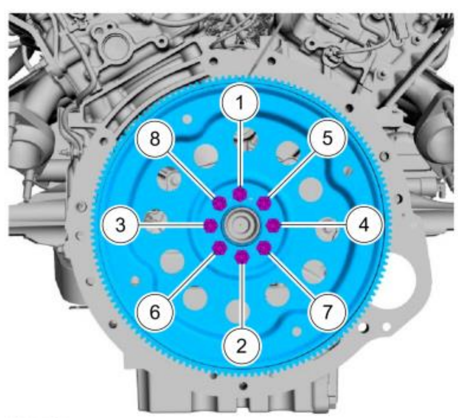
164. Install the crankshaft sensor ring and the engine-to-transmission spacer plate.



E314913

165. **NOTE:** *One of the 8 flexplate holes are offset so the flexplate can only be installed in one position*

Install the flexplate aligning it with the offset hole and hand start bolts 5, 6, 7 and 8.
Tighten the bolts 5, 6, 7 and 8 in sequence one turn at a time until the flexplate is snug against the rear face of the crankshaft.
Torque the bolts 5, 6, 7 and 8 in sequence. *Torque*: 59 lb.ft (80 Nm)
Install the bolts 1, 2, 3 and 4 finger tight.
Torque the bolts 1, 2, 3 and 4 in sequence. *Torque*: 59 lb.ft (80 Nm)



E315701

LSG-635 ENGINE

Specifications

Engine

Item	Specification
Displacement	3.5L (4V) (2214 CID)
No. of cylinders	6
Bore/stroke	92.5/86.7 mm (3.641/3.413 in)
Firing order	1-4-2-5-3-6
Spark plug	12405
Spark plug gap	1.25-1.35 mm (0.049-0.053 in)
Compression ratio	11.8:1
Engine weight (without accessory drive components)	390.2 lb (177 kg)

Lubricants

Item	Specification
Motorcraft® SAE 5W-20 Premium Synthetic Blend Motor Oil	XO-5W20-QSP1 (WSS-M2C960-A1)

Engine Oil Capacity

Item	Specification
Service fill including oil filter	TLL00339 and prior = 6.0 qt (5.68L) TLL00340 and later = 12 qt (11.36L)

Oil Pressure

Item	Specification
Oil pressure @ 1,500 rpm with engine at normal operating temperature	21.8 psi (150 kPa)

LSG-635 ENGINE

Cylinder Head and Valve Train

Item	Specification
Cylinder head gasket surface flatness	Flatness within 50 microns on any 150 mm (5.9 in) x 150 mm (5.9 in)and 25 microns on any 25 mm (1.0 in) x 25 mm (1.0 in).
Valve tappet clearance – RH intake	0.0059 –0.0098 in (.15 –.25 mm)
Valve tappet clearance – LH intake	0.0071 –0.0110 in (.18 –.46 mm)
Valve tappet clearance – exhaust – Engine must be at room temperature before measuring	0.0142 -0.0181 in (.36 -.46 mm)
Valve guide bore inner diameter	0.217 -0.218 in (5.519 -5.549 mm)
Valve stem diameter – intake	0.2157 –0.2164 in (5.479 –5.497 mm)
Valve stem diameter - exhaust	0.2152 –0.2159 in (5.466 –5.484 mm)
Valve stem-to-guide clearance - intake	0.0009 –0.0028 in (.022 –.07 mm)
Valve stem-to-guide clearance - exhaust	0.0014 –0.0033 in (.035 –.083 mm)
Valve head diameter - intake	1.46 in (37 mm)
Valve head diameter - exhaust	1.22 in (31 mm)
Valve face runout	0.002 in (.05 mm)
Valve face angle	45.25 –45.75 °
Valve seat width - intake	0.051 –0.063 in (1.3 –1.6 mm)
Valve seat width - exhaust	0.067 –0.079 in (1.7 –2 mm)
Valve seat runout	0.002 in (.04 mm)
Valve seat angle	44.5 –45.5 °
Valve spring free length (approx.)	1.890 in (48 mm)
Valve spring compression pressure (N @ spec. length)	525 N @ 27.0 mm (114.7 lb @ 1.06 in)
Valve spring installed height	1.457 in (37 mm)
Valve spring installed height pressure (N @ spec. length)	235 N @ 37.0 mm (53 lb @ 1.45 in)
Valve spring installed pressure — service limit	5% force loss @ specified height

Camshaft

Item	Specification
Theoretical valve lift (intake) @ 0 lash	0.394 in (10 mm)
Theoretical valve lift (exhaust) @ 0 lash	0.39 in (10 mm)
Lobe lift - intake	0.394 in (10 mm)
Lobe lift - exhaust	0.39 in (10 mm)
Allowable lobe lift loss	0.0024 in (.062 mm)
Camshaft journal bore inside diameter — 1st journal	1.537 –1.538 in (39.0375 –39.0625 mm)
Camshaft journal bore inside diameter — intermediate journals	1.023 –1.024 in (25.9875 –26.0125 mm)
Camshaft bearing outside diameter — 1st journal	1.535 –1.536 in (38.99 –39.01 mm)
Camshaft bearing outside diameter — intermediate journals	1.021 –1.022 in (25.937 –25.963 mm)
Camshaft journal-to-bearing clearance, 1st journal — service limit	0.0029 in (.0725 mm)
Camshaft journal-to-bearing clearance, intermediate journals — service limit	0.0030 in (.0755 mm)
Runout	0.0016 in (.04 mm)
End play - standard	0.0030 –0.0065 in (.075 –.165 mm)
End play - service limit	0.0075 in (.19 mm)

Cylinder Block

Item	Specification
Cylinder bore diameter	3.642 –3.761 in (92.5 –95.52 mm)
Cylinder bore roundness	0.0005 in (.013 mm)
Cylinder bore taper	0.0004 in (.01 mm)
Block main bore roundness	0.0003 in (.008 mm)
Main bearing bore inside diameter	2.850 –2.851 in (72.4 –72.424 mm)
Head gasket surface flatness	Flat within 0.150 mm (0.005 in) overall 0.050 mm (0.001 in) per 150 mm (5.905 in) x 150 mm (5.905 in) 0.025 mm (0.0009 in) per 25mm (0.98 in) x 25 mm (0.98 in)

Crankshaft

Item	Specification
Main bearing journal diameter	2.657 in (67.5 mm)
Main bearing journal maximum taper	0.1575 in (.004 m)
Main bearing journal maximum out-of-round	0.0002 in (.006 mm)
Main bearing journal-to-main bearing clearance	0.0004 –0.0001 in (.011 –.0022 mm)
Connecting rod journal diameter	2.204 –2.205 in (55.983 –56.003 mm)
Connecting rod journal maximum taper	0.0002 in (.004 mm)

Connecting rod journal maximum out-of-round	0.0002 in (.006 mm)
Crankshaft end play	0.0002 –0.0005 in (.0041 –.0124 mm)

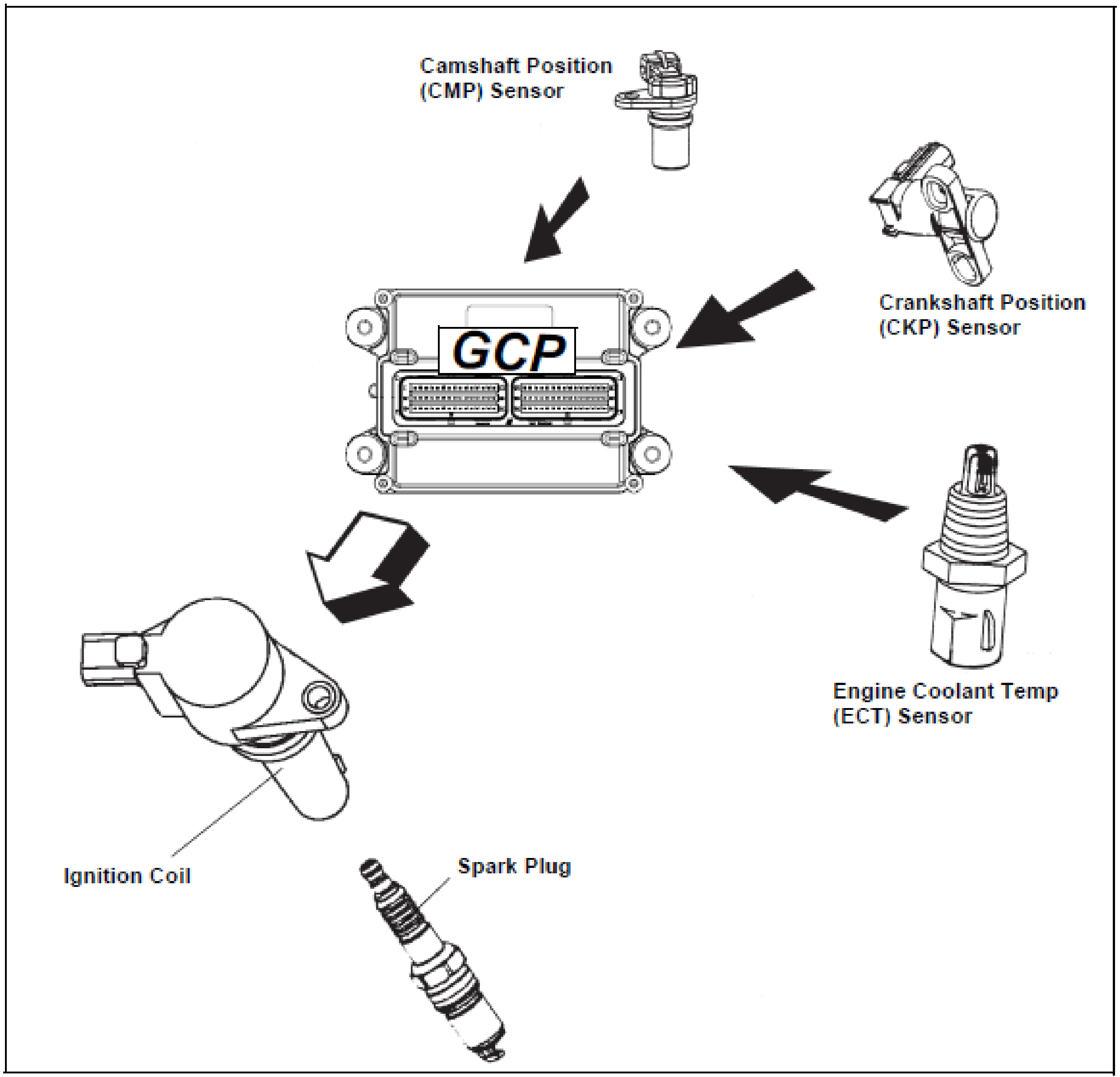
Piston and Connection Rod

Item	Specification
Piston diameter - single grade	3.6396 –3.6402 in (92.446 –92.46 mm)
Piston-to-cylinder bore clearance	0.0016 –0.0029 in (.04 –.074 mm)
Piston ring end gap - compression (top, gauge diameter)	0.0091 –0.0130 in (.23 –.33 mm)
Piston ring end gap - compression (bottom, gauge diameter)	0.0157 –0.0236 in (.4 –.6 mm)
Piston ring end gap — oil ring (steel rail, gauge diameter)	0.0079 -0.0276 in (.2 -.7 mm)
Piston ring groove width - compression (top)	0.0406 -0.0413 in (1.03 -1.05 mm)
Piston ring groove width — compression (bottom)	0.0406 -0.0413 in (1.03 -1.05 mm)
Piston ring groove width - oil ring	0.0799 –0.0807 in (2.03 –2.05 mm)
Piston ring width - upper compression ring	0.0382 –0.0390 in (.97 –.99 mm)
Piston ring width - lower compression ring	0.0382 –0.0390 in (.97 –.99 mm)
Piston ring-to-groove clearance (upper and lower compression rings)	0.0016 –0.0031 in (.04 –.08 mm)
Piston pin bore diameter	0.9057 –0.9059 in (23.004 –23.009 mm)
Piston pin diameter	0.9054 –0.9055 in (22.997 –23 mm)
Piston pin length	2.1654 -2.1770 in (55 -55.3 mm)
Piston pin-to-piston fit	0.0002 –0.0005 in (.004 –.012 mm)
Piston-to-connecting rod clearance	0.1 in (2.7 mm)
Connecting rod-to-pin clearance - standard	0.0001 –0.0007 in (.003 –.018 mm)
Connecting rod pin bore diameter	0.9056 –0.9061 in (23.003 –23.015 mm)
Connecting rod length (center-to-center)	6.01 in (152.68 mm)
Connecting rod maximum allowed bend	0.0015 in (.038 mm)
Connecting rod maximum allowed twist	0.0020 in (.05 mm)
Connecting rod bearing bore diameter – single grade	2.3570 –2.3576 in (59.869 –59.883 mm)
Connecting rod bearing-to-crankshaft clearance	0.0008 –0.0021 in (.02 –.054 mm)
Connecting rod side clearance (assembled to crank) - standard	0.0069 –0.0167 in (.175 –.425 mm)
Connecting rod side clearance (assembled to crank) - service limit	0.0069 –0.0167 in (.175 –.425 mm)

LSG-635 IGNITION SYSTEM

INDEX

GENERAL INFORMATION



Description

The LSG635 engine is equipped with an individual coil on plug electronic ignition system. The brain of this system is the Electronic Engine Control (4G) Module which receives inputs from the following:

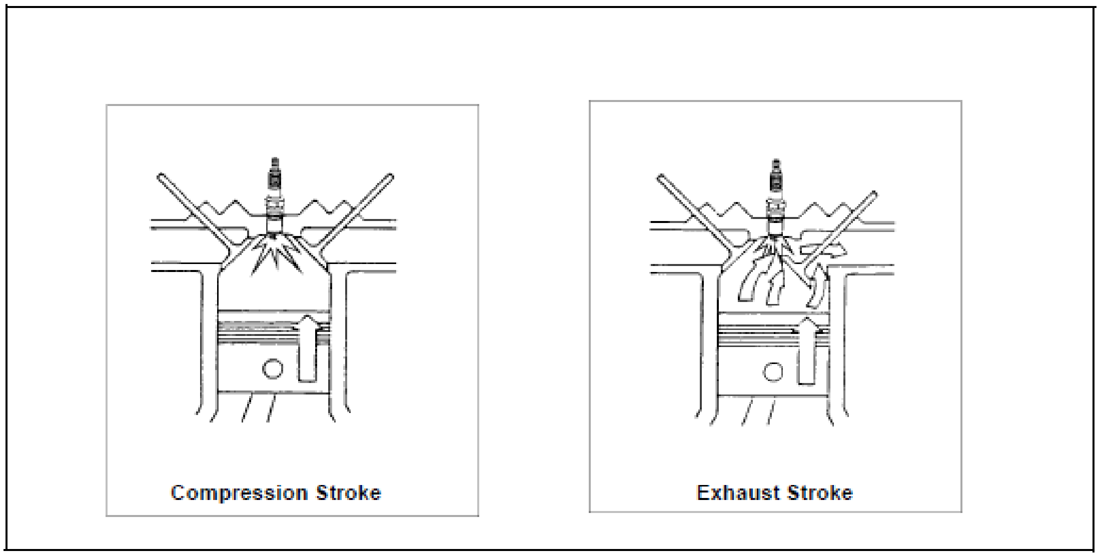
- Crankshaft Position (CKP) Sensor
- Camshaft Position (CMP) Sensor
- Engine Temperature Sensor

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

- Ignition Coils
- Spark Plugs.

⚠

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



Operation

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

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

Engine Speed and Crankshaft Position

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

Engine Temperature

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

Fuel Octane Level Adjustment

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

Ignition Coil Driver

The ECU switches 6 individual ignition coils on and off at the correct times to give the desired spark advance. Ignition timing is adjusted constantly by the ECU. Many factors including all the sensor inputs, affect the final ignition setting.

Run Mode

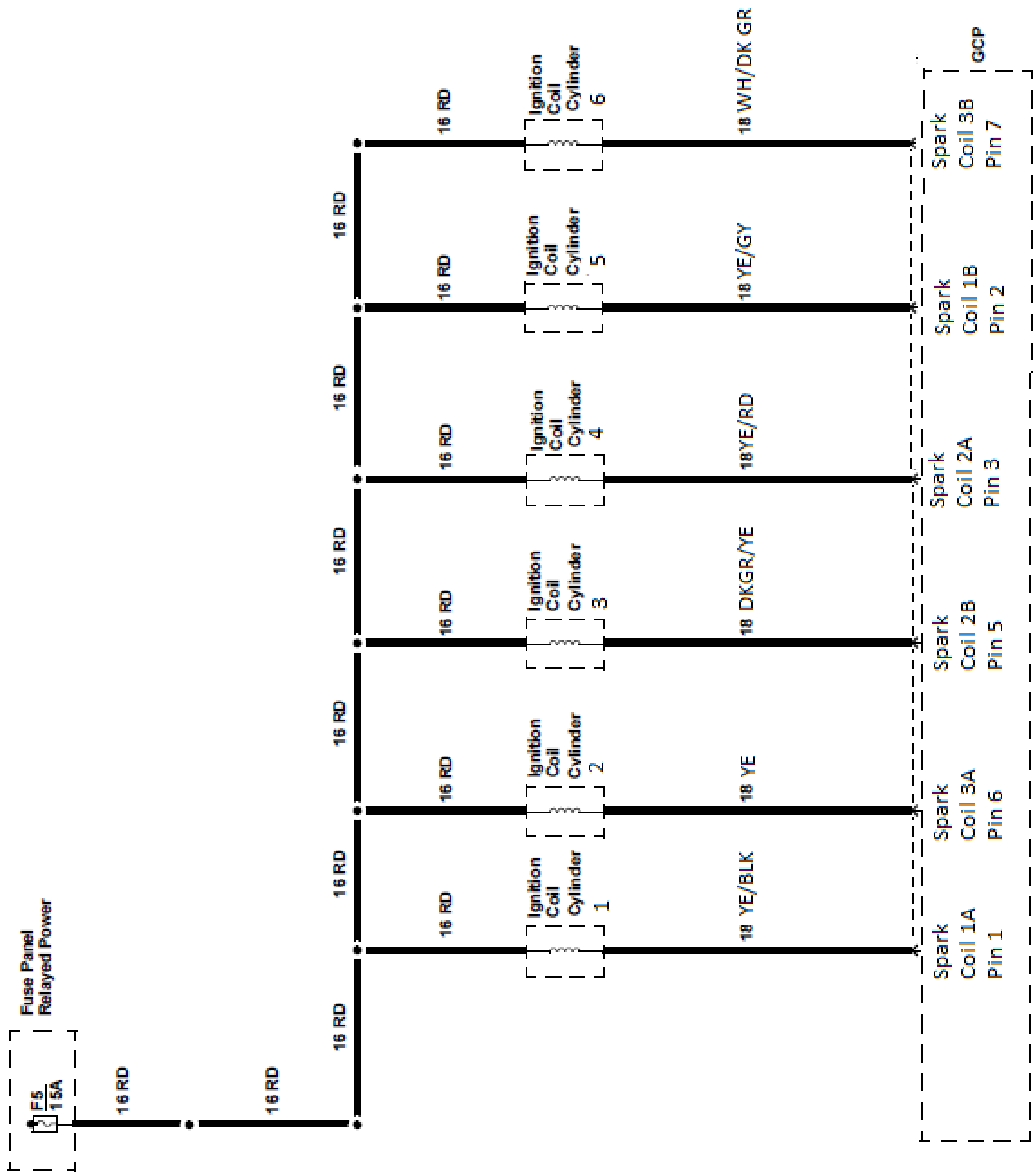
The ECU interprets engine speed above 400 rpm as Run Mode. The Base Spark advance (BSA) is calculated by the ECU processing the engine speed input.

Transient Mode

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

LSG-635 IGNITION SYSTEM

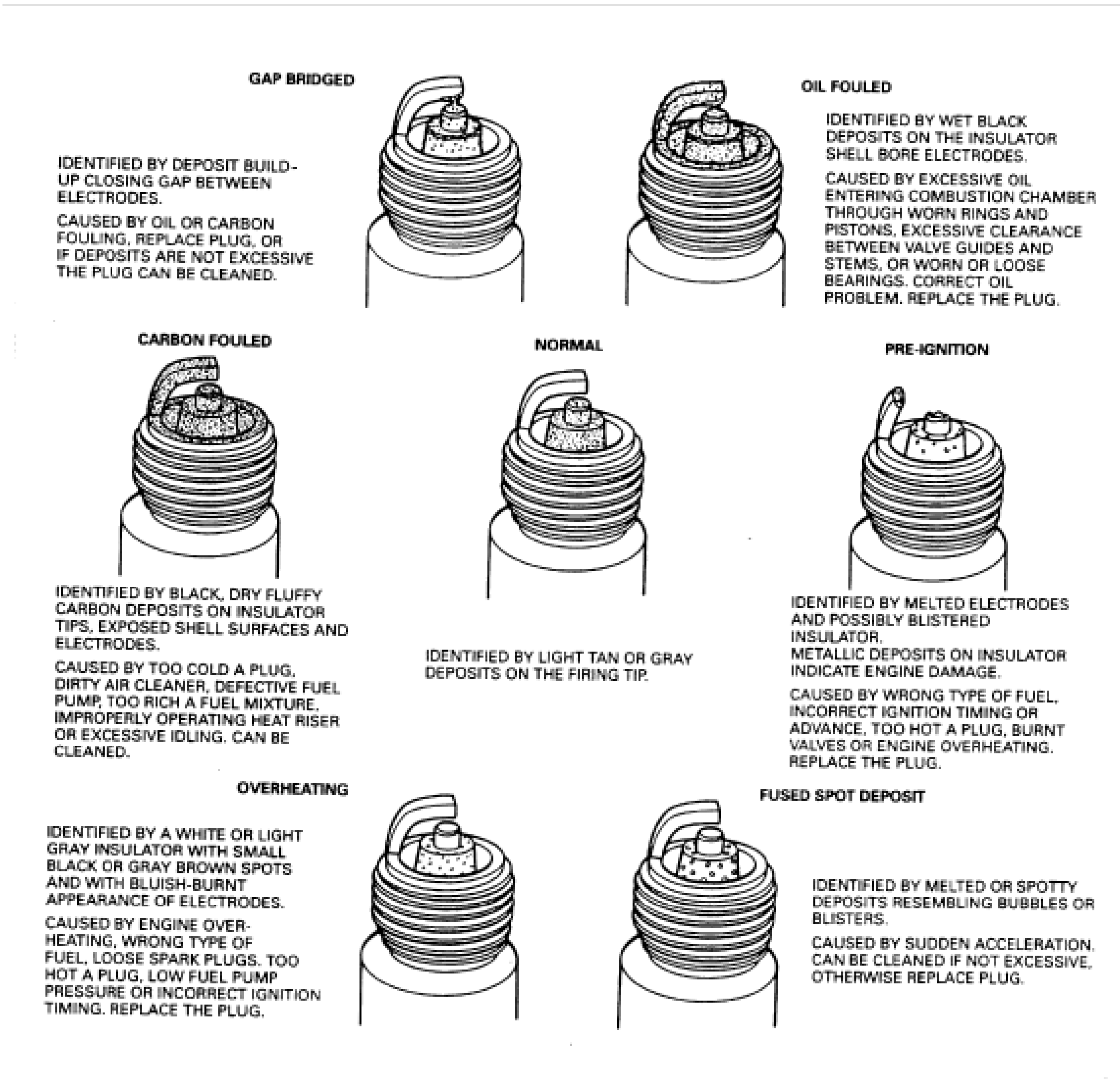
Wiring Diagram

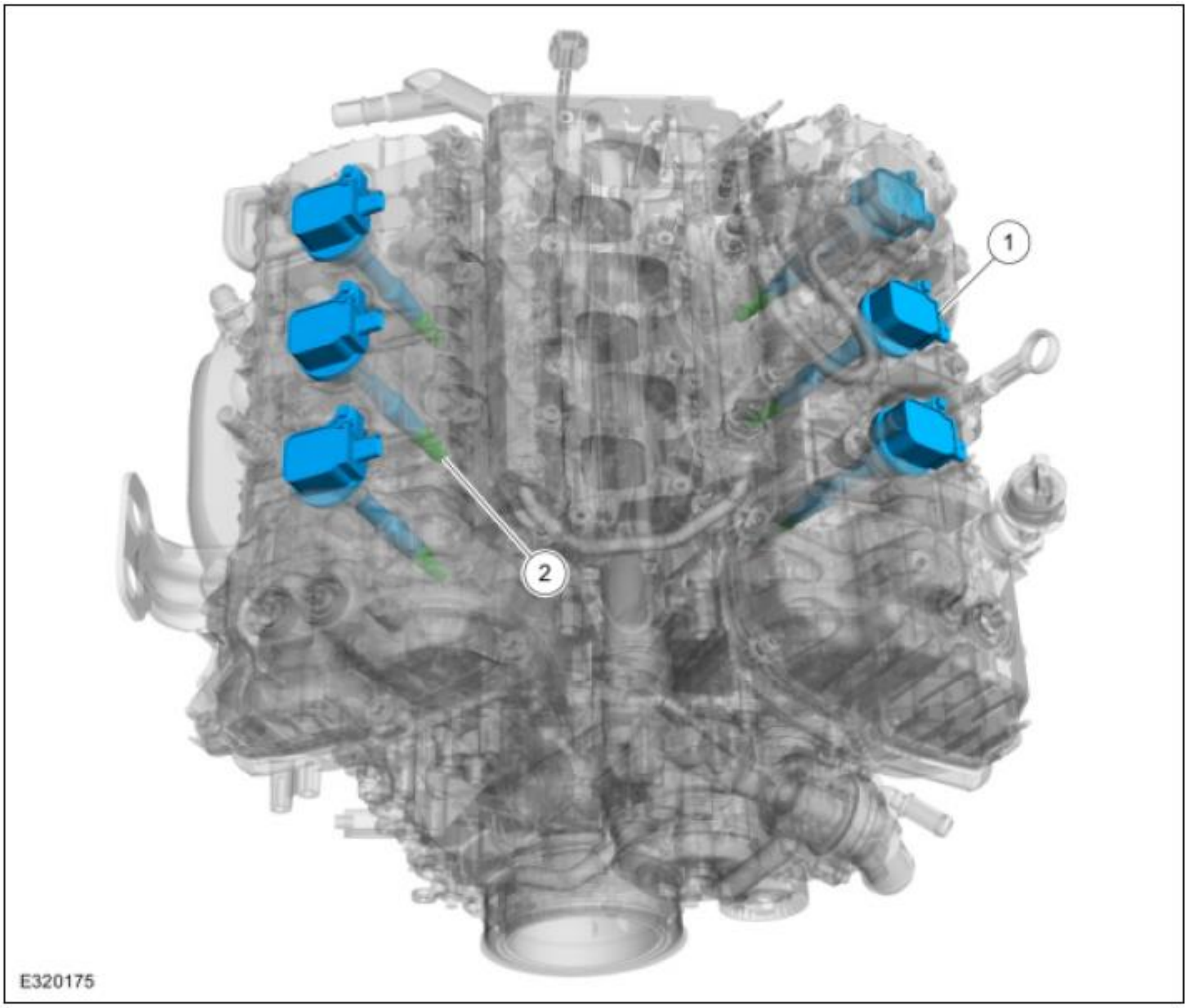


DIAGNOSIS AND TESTING

Spark Plug Inspection

Inspect the spark plug tip as in the chart below:

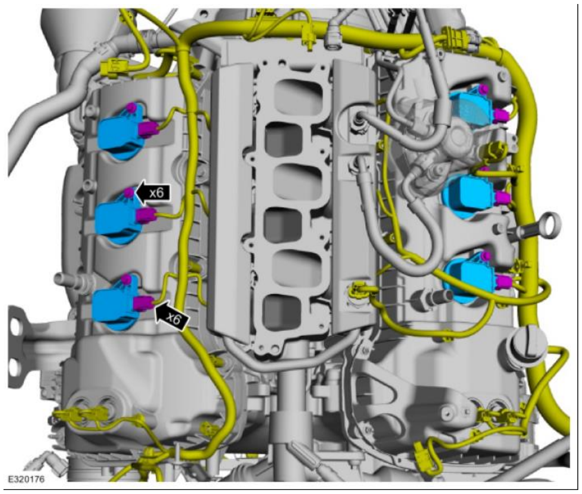




Item	Description
1	Ignition coil-on-plug(s)
2	Spark plug(s)

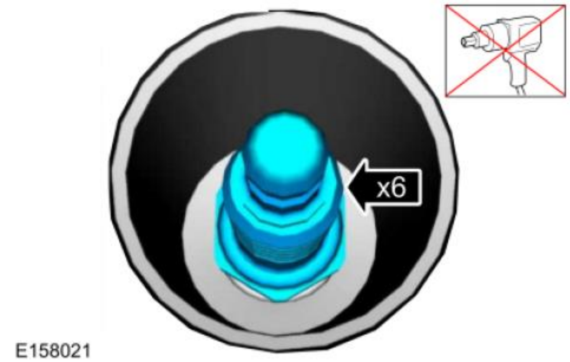
REMOVAL AND INSTALLATION

Ignition Coil – Replacement

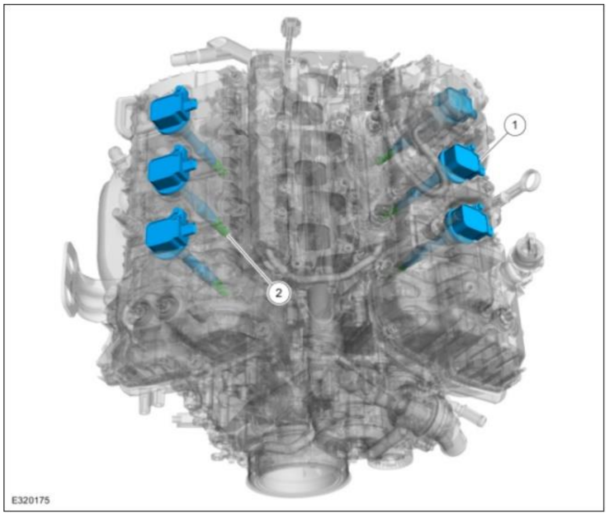


1. Disconnect the ignition wires and remove intake manifold – Refer to Upper Intake Manifold Engine, Removal and Installation in the Engine Section
2. Disconnect the coil-on-plug electrical connectors
3. Remove the coil-on-plug bolts
    - To install, tighten to 7 Nm (62 lb-in), Stage 2: 50º
4. Remove the ignition coils
    - NOTE: a slight twisting motion will make removal easier
5. To install, reverse the procedure

Spark Plug – Removal



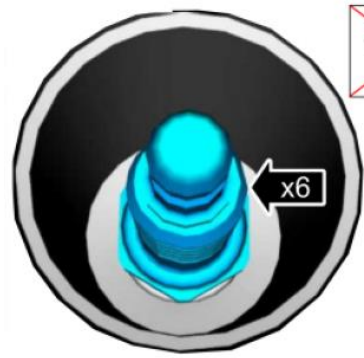
1. Remove ignition coil -- Refer to “Ignition Coil - Replacement” on page 7 of this section.
2. Loosen spark plugs and remove any dirt or foreign material from spark plug areas of cylinder head with compressed air.
3. Remove spark plugs and mark location using a piece of masking tape.
4. Inspect condition of spark plug -- Refer to “Spark Plug Inspection” on page 5 of this section.



Spark Plug - Installation

1. Apply a few drops of engine oil to spark plug threads near tip.

2. Adjust spark plug gap to: 1.3 mm (0.051in.).



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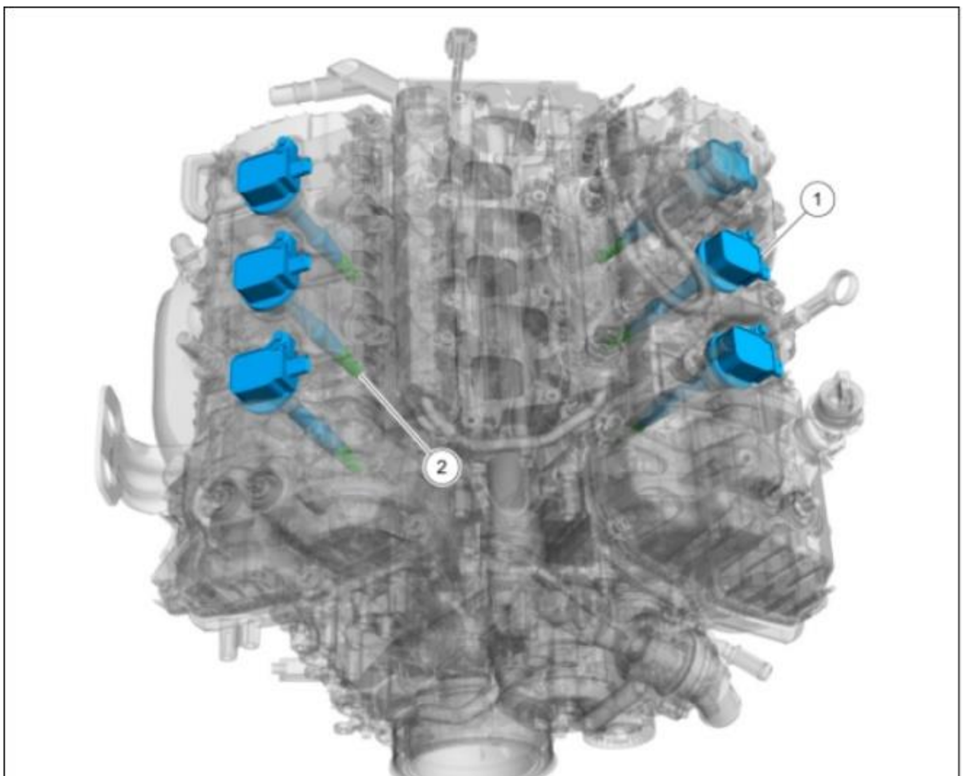
3. Install spark plugs (to original locations) and tighten to 11 lb-ft. (15 Nm).

4. Install coil -- Refer to "Ignition Coil - Replacement" on page 7 of this section.

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Firing Order	1-4-2-5-3-6
Spark Plug	Type: 12405 Gap: 1.3 (0.051 in.)

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Spark Plugs	15	11	133
Coil bolts	7(stage1) 50°(stage2)	5.1(stage1) 50°(stage2)	62(stage1) 50°(stage2)



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LSG-635 FUEL SYSTEM

INDEX

Subject **Page**

CAUTIONS & WARNINGS

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

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

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

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

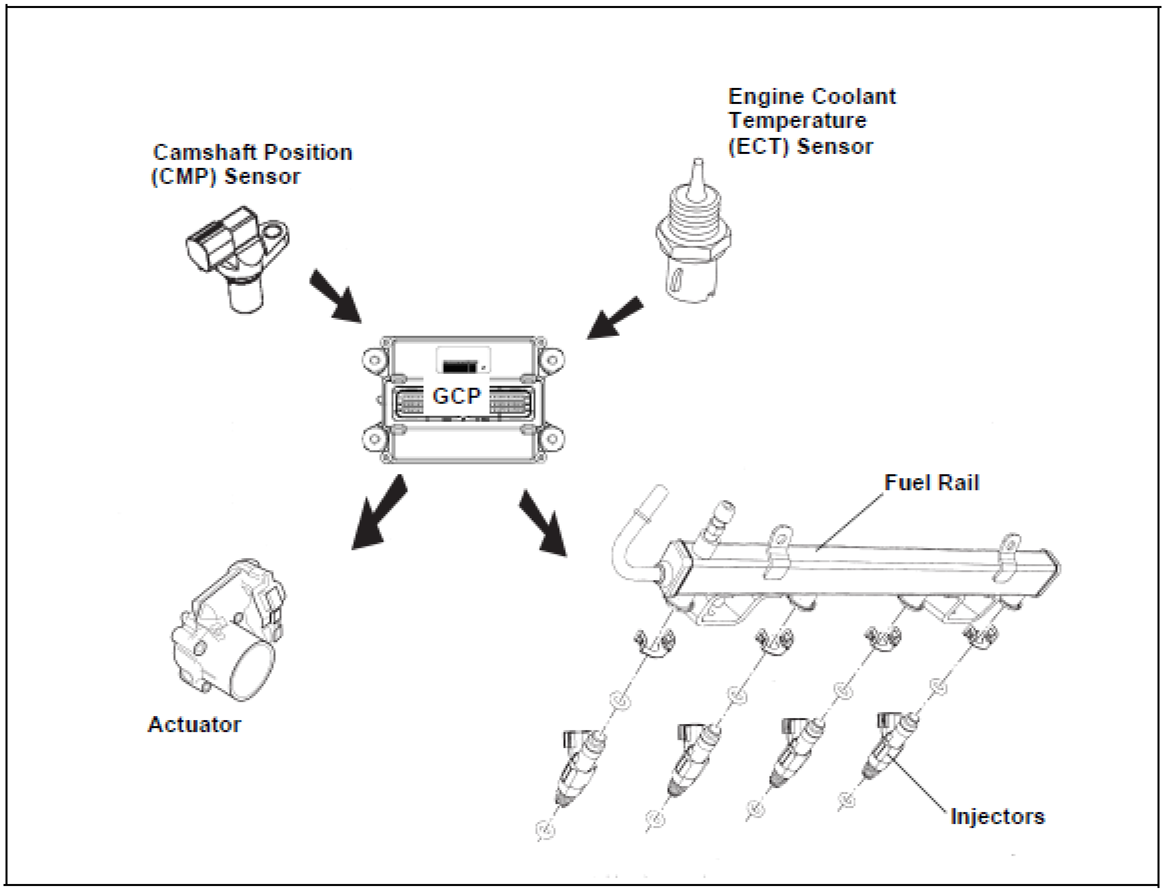
CAUTION: If the liquid or vapor tube is damaged (torn, holes or delaminated), a new tube assembly must be installed. Do not use aftermarket sleeving. Do not re-adhere loose sleeving material.

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

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

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

GENERAL INFORMATION - GASOLINE



Description

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

Fuel Rail

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

Fuel Injector

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

Camshaft Position (CMP) Sensor

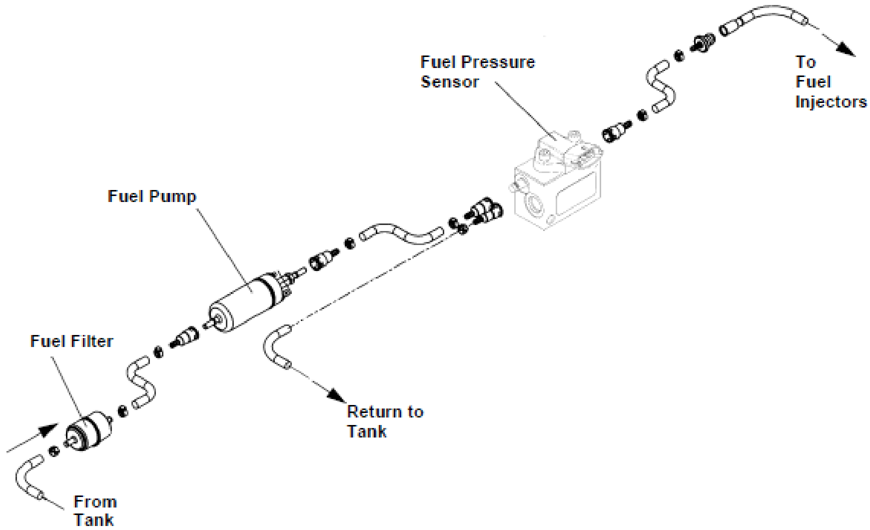
The Camshaft Position (CMP) Sensor is mounted in the camshaft cover. This signal is sent to the GCP which uses it to indicate the position of the #1 piston during its power stroke. The GCP uses the CMP signal as a “sync pulse” to trigger the injectors in the proper sequence. This allows the GCP to calculate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

Engine Coolant Temperature (ECT) Sensor

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

Actuator

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



Operation

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

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

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

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

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

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

Fuel System Requirements

Fuel Tanks

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

Wet Fuels

The following fuels must all be unleaded and clean:

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

Fuel Pump

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

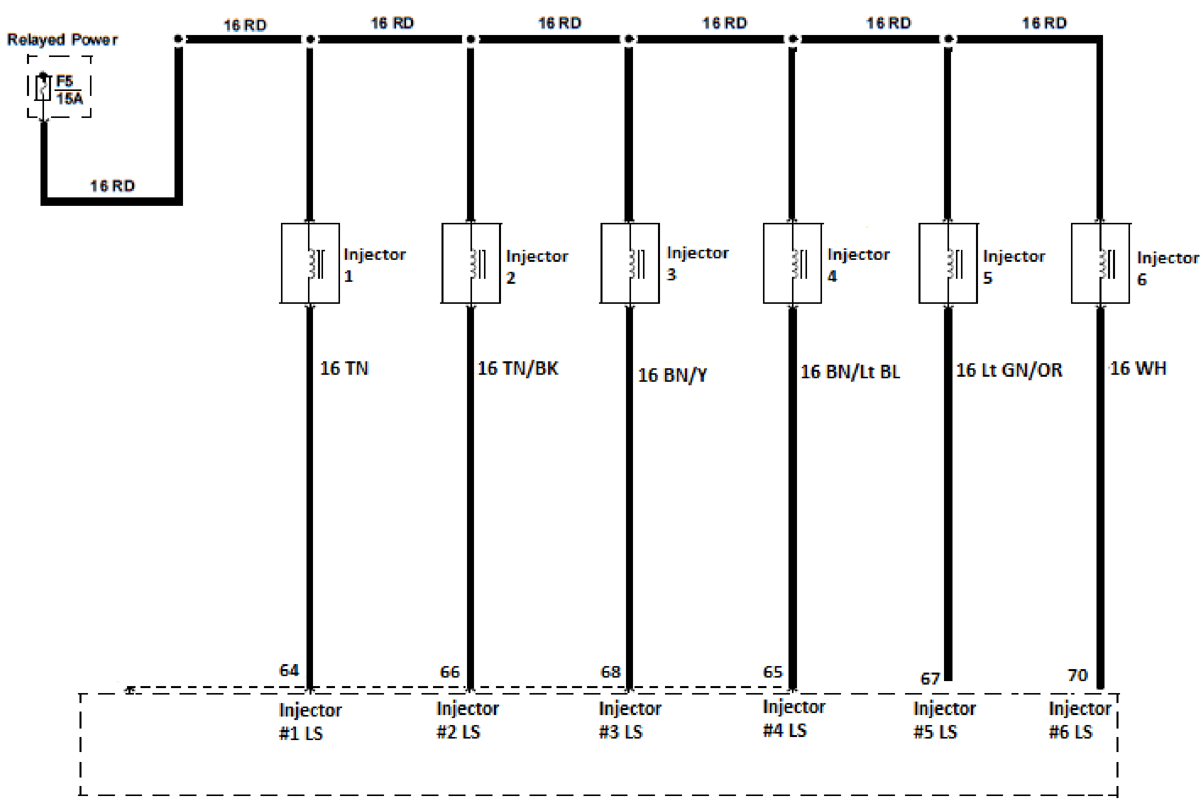
CAUTION: The electric fuel pump MUST NOT be mounted directly on the engine assembly, as engine vibration will shorten the life of the pump.

Wiring Diagrams

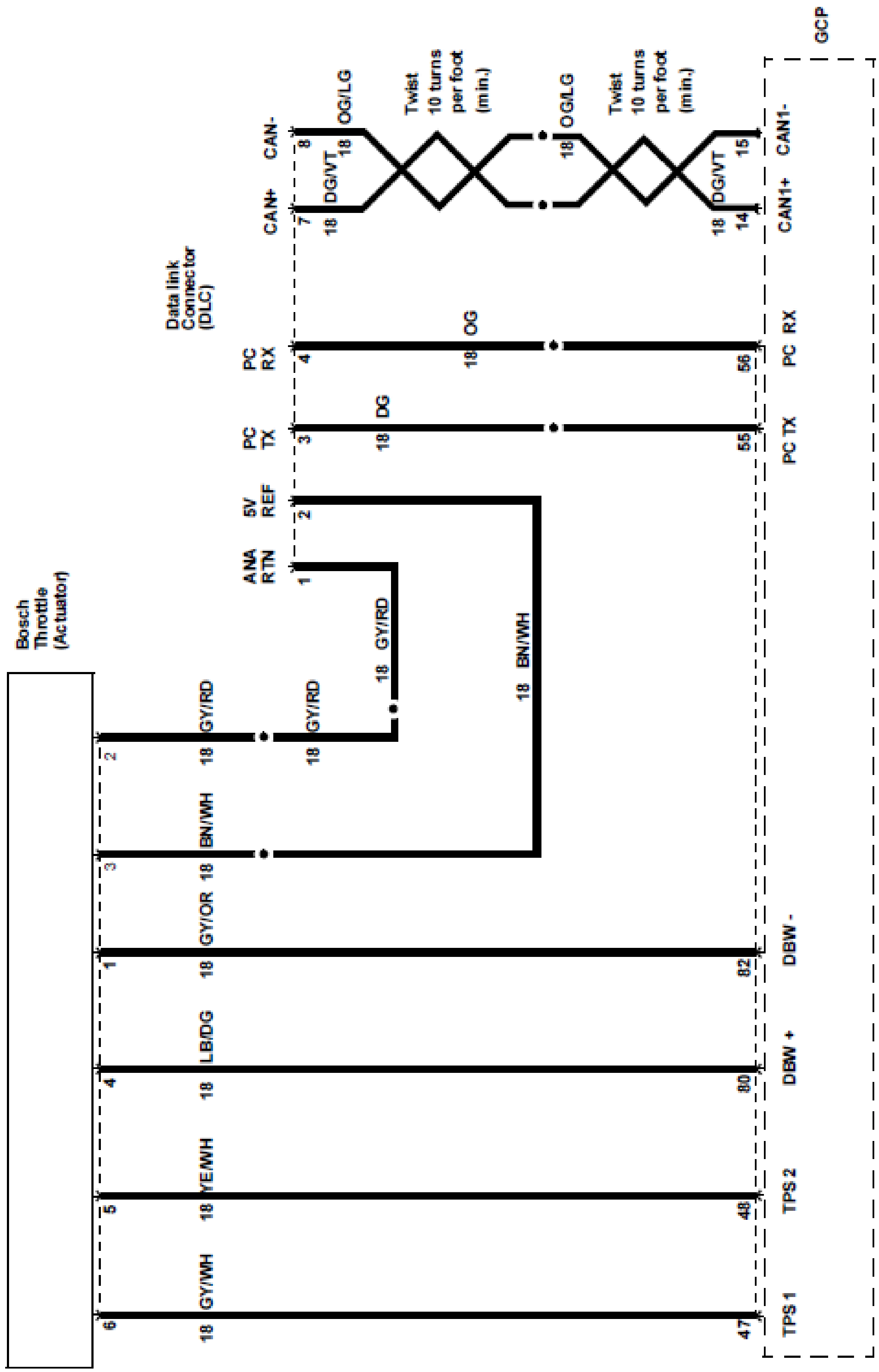
Revision Level
The following wiring schematics are taken from the wiring diagram listed below.

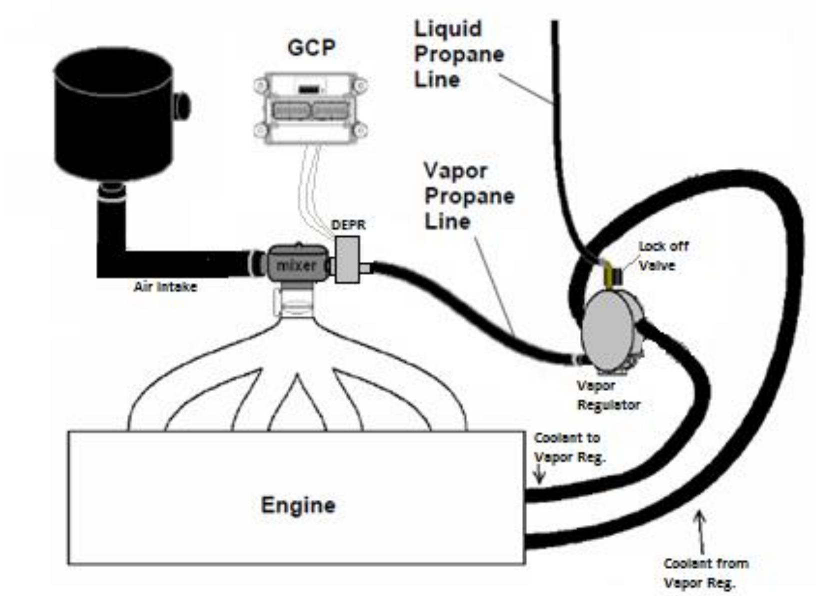
Title EDI / FORD 3.5L Bi–Fuel		
Size D	Number 5210130	Rev 2
Date: 10/10/2020	Drawn By: J. SUTTON	
Filename: FORD_35L_BIFUELr2.sch	Sheet 1 of 1	

Fuel Injectors



Actuator / Data Link Connector (DLC)





DRY FUEL

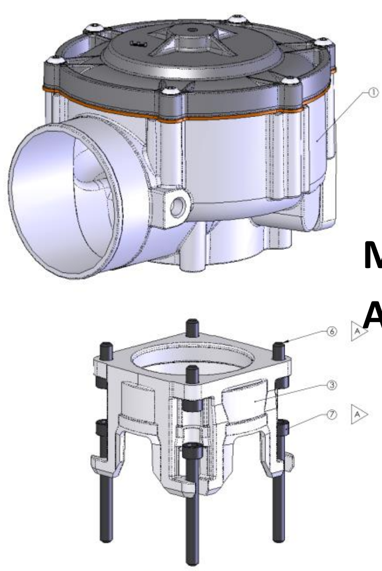
Description

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

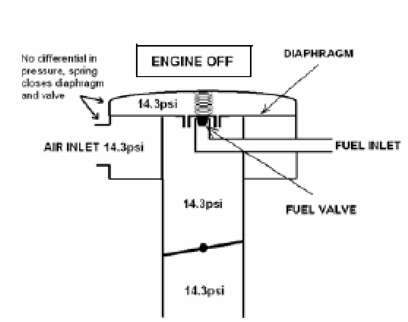
Vapor Carburetor. Pressure is regulated by a Direct Electronic Pressure Regulator (DEPR) which is controlled by the GCP. Coolant is circulated through the DEPR.

Operation

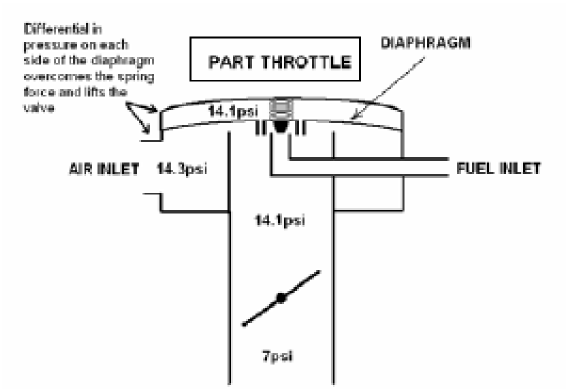
The dry fuel vapor carburetor is a device by which fuel can be added to passing air flow. The amount of fuel added is related to the amount of air passing through the carburetor.



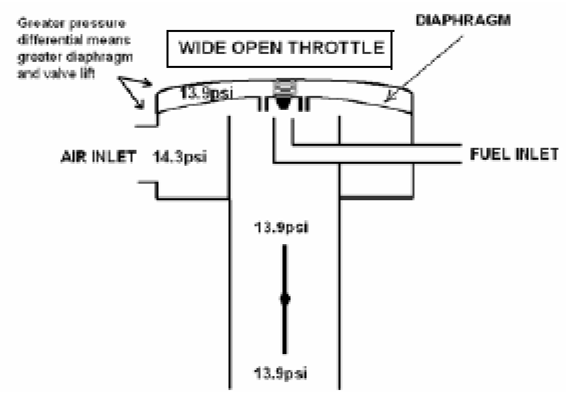
Mixer Assembly



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

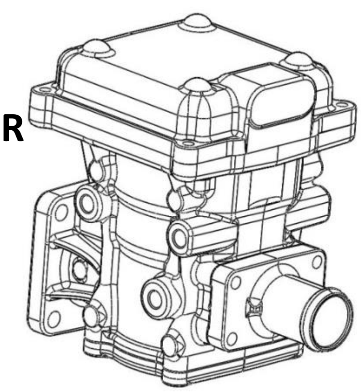


The greater the airflow into the engine, the greater the pressure drop across the diaphragm and the more lift occurs on the fuel valve. This allows more fuel to be drawn into the engine.

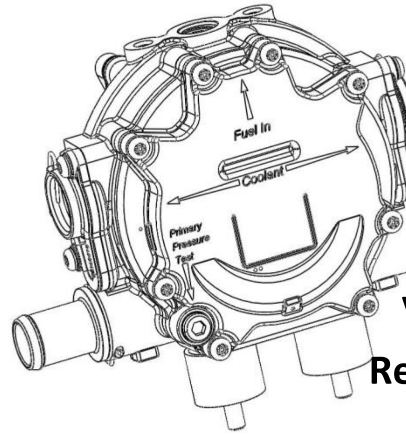


While the carburetor is designed to mix the fuel and air and adjust fuel to match the speed and load of the engine, it has only “ballpark” accuracy. This accuracy is not fine enough to achieve emissions targets. To achieve accurate fueling, the air inlet pressure to the carburetor is controlled by a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

DEPR



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



Vapor Regulator

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

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

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

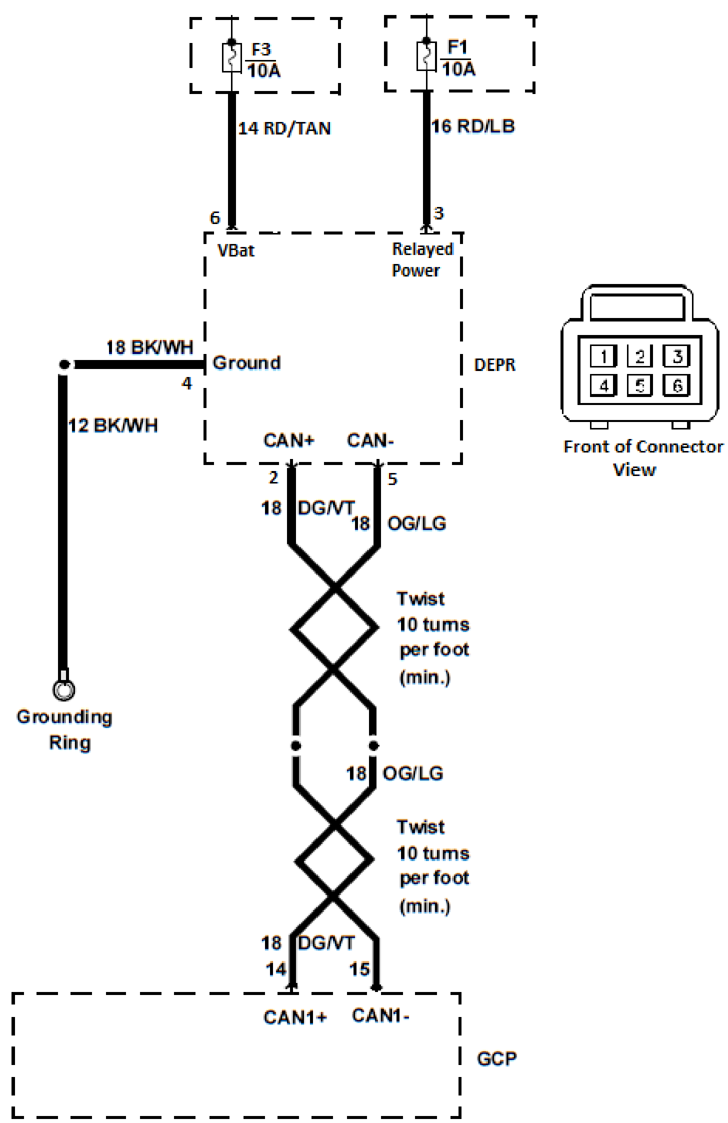
Wiring Diagrams

Revision Level

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

Title	EDI / FORD 3.5L Bi-Fuel		
Size: D	Number: 5210130		Rev: 2
Date: 10/10/2020		Drawn By: J. SUTTON	
Filename: FORD_35L_BIFUELr2.sch		Sheet 1 of 1	

Engine Controls – Dry Fuel DEPR



DIAGNOSIS AND TESTING - LPG
Symptom Chart

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

Preliminary Test

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

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

Diagnostic Charts

Perform the preliminary test before proceeding.

Engine Cranking but Will Not Start

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

Diagnostic Aids

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

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

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

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

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

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

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

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

Diagnostic Aids

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

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

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

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

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

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

Engine Backfires

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

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

Emission Failure - Rich Mixture

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

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

Emission Failure - Lean Mixture

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

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

Engine Overheats

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

Diagnostic Aids

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

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

Engine Stops Running (Dies)

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

Diagnostic Aids

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

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

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

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

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

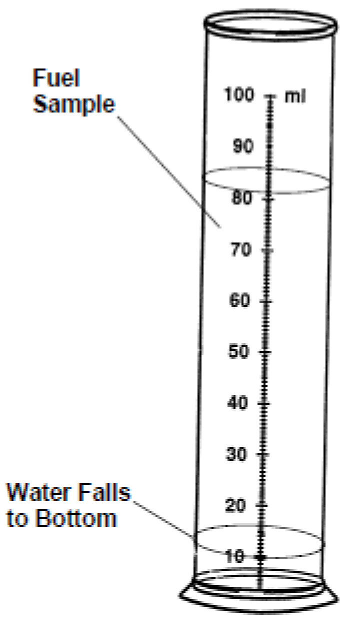
DIAGNOSIS AND TESTING – GASOLINE

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

Visual Inspection

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

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



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

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

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

Fuel Pressure Check

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

1. Connect to the GCP display
2. Put the key in the on position.
3. On the faults page check the fuel pressure by cycling the keyswitch.
4. Fuel pressure should be as follows:
    a. Key on, Engine off (first 50 seconds): 69psia
    b. Engine running:69psia

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

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

- Fuel pressure should be as follows:
    - Key on, Engine off (first 50 seconds): 55psig
    - Engine running: 55psig

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

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

Fuel Pump Check

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

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

Fuel Block Check

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

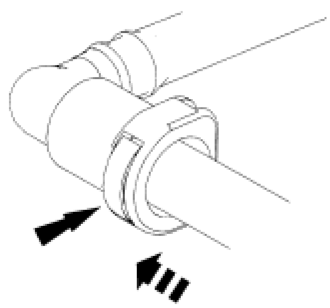
- Check wiring from the fuel block to the main engine harness
- If damaged replace the fuel block jumper harness
- Bad or diesel fuel can damage this component. Replace if known fuel contamination.
- Grounding out the fuel pump can cause the fuel pump to output ~120psia. If this is done and the GCP display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

Quick Connect Coupling - Type I - Disconnect

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

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

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



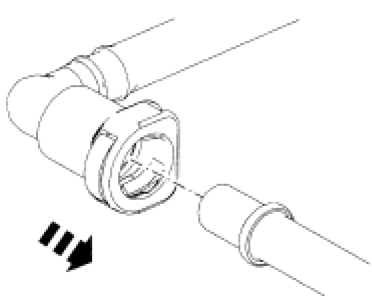
Quick Connect Coupling - Type I - Connect

1. Inspect for damage and clean fittings.

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

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

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



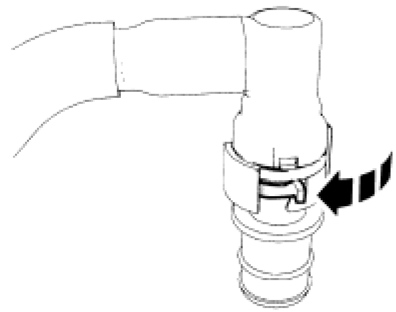
4. Pull on the fitting to make sure it is fully engaged.

Quick Connect Coupling - Type II - Disconnect

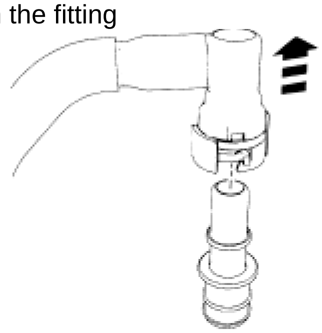
WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

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

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



3. Separate the quick connect coupling from the fitting

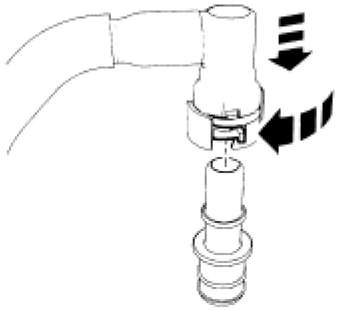


Quick Connect Coupling - Type II – Connect

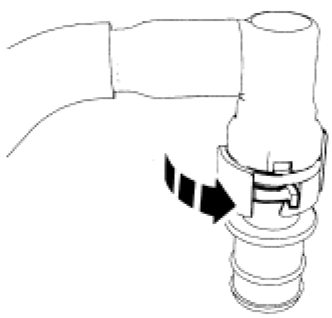
1. Inspect for damage and clean fittings.

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

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



4. Position the locking tab into the latched position.



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

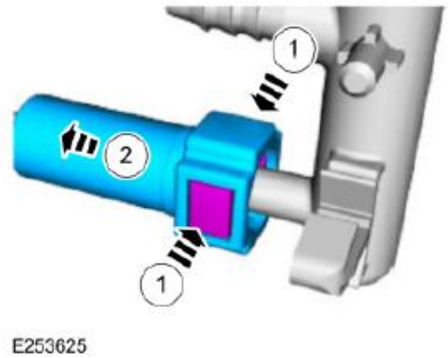
Quick Connect Coupling - Type III - Disconnect

⚠

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

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

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

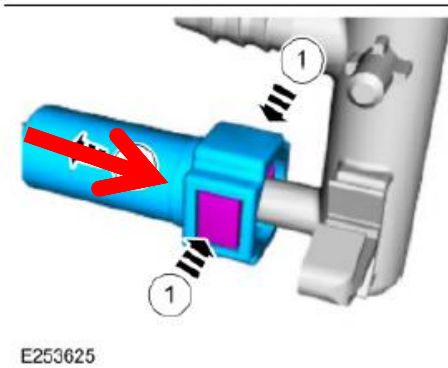


Quick Connect Coupling - Type III – Connect

1. Inspect for damage and clean fittings.

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

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



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

REMOVAL AND INSTALLATION

Fuel Rail & Injectors - Replacement

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

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

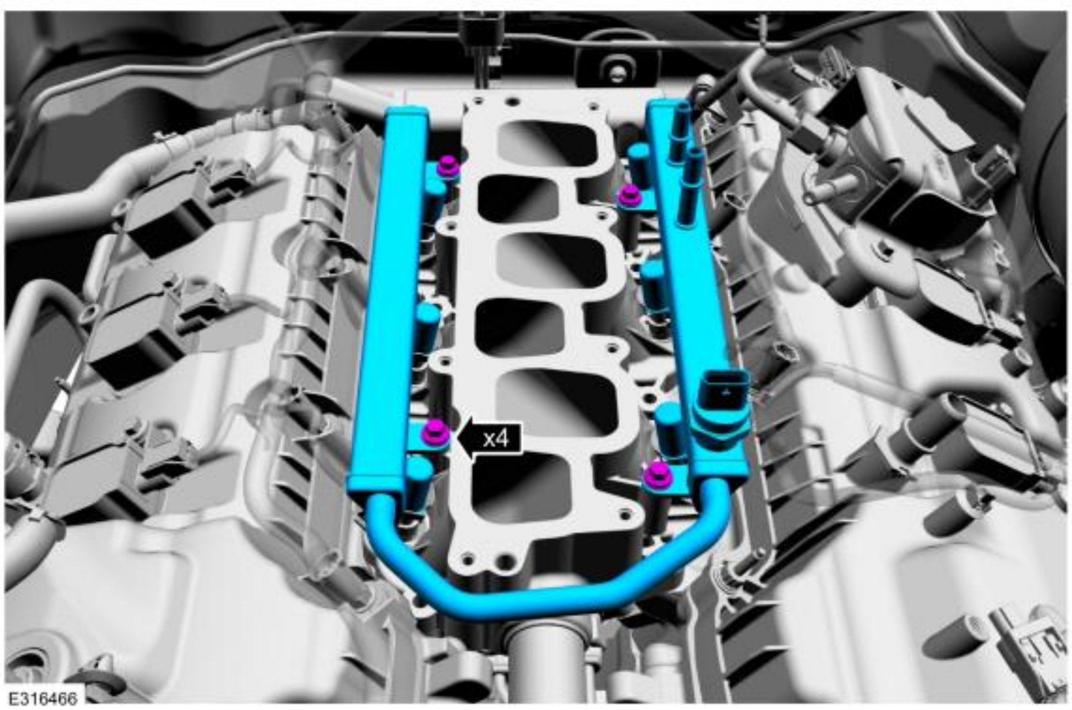
1. Disconnect the battery ground cable.
2. Remove and/or disconnect components to allow access and removal of the fuel rail & injectors. Label if necessary to allow for correct reinstallation.

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

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

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

8. Reverse procedure to install:
   - Lubricate new o-rings with clean engine oil
   - Tighten fuel rail bolts to 10 Nm (89 lb-in) then an additional 45 degrees.

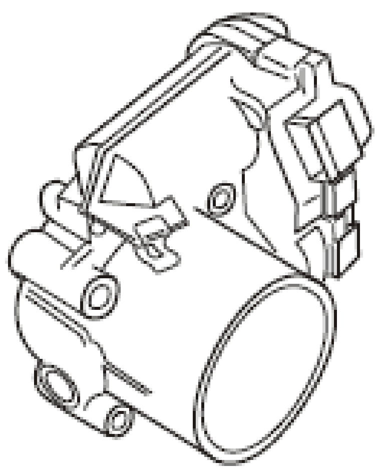


Actuator - Removal

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

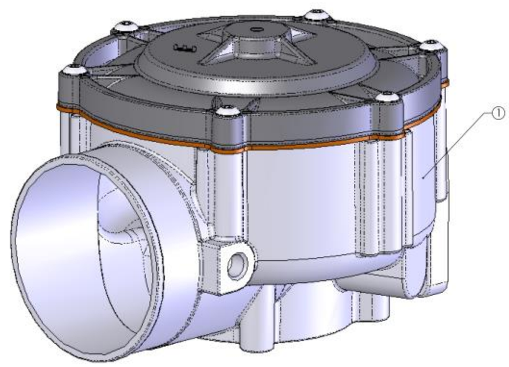
Actuator - Installation

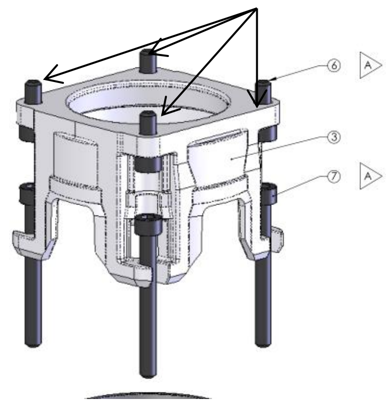
1. Inspect gasket and install a new one if necessary.
2. Position actuator onto studs.
3. Install nuts
    - Tighten to 8 ft-lb
4. Reconnect electrical connectors.
5. Reconnect accelerator cable.
6. Reconnect air cleaner components to actuator.
7. Install or connect any other component removed or disconnected.



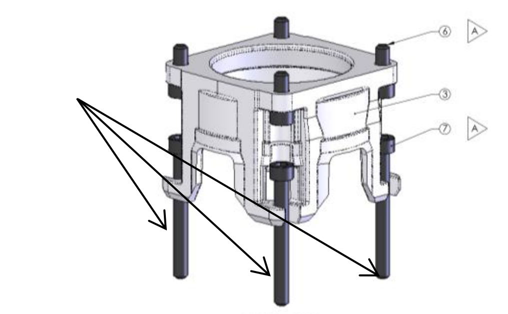
Mixer - Removal

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





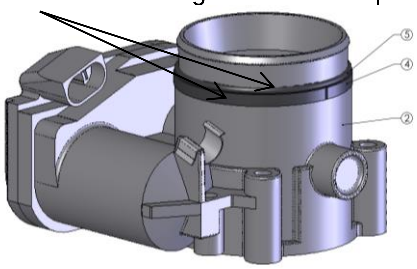
2. To Remove the Mixer adapter, unscrew the four bolts. This will also unmount the actuator



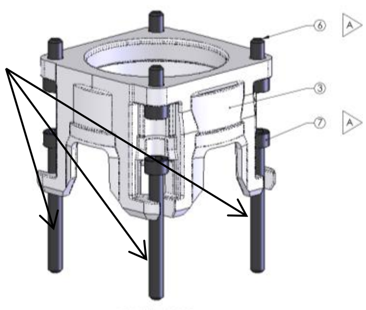
3. The DEPR can also be disconnected from the mixer via the four mounting bolts.

Mixer - Installation

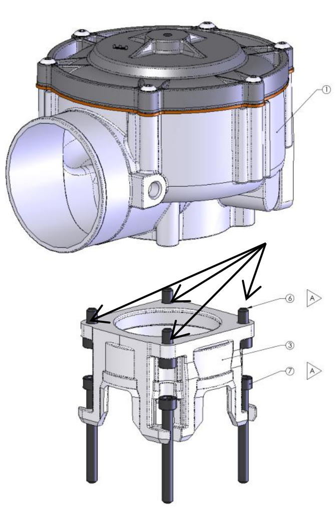
1. Reverse the removal procedure. Ensure to install the two gaskets on the actuator before installing the mixer adapter.



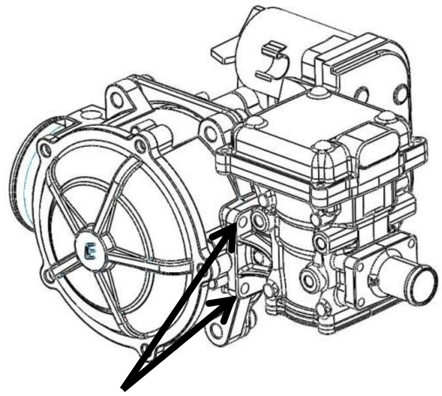
2. Mount the actuator with the mixer adapter using the four 55mm long M6x1.0 bolts. Ensure the gasket for the actuator is not damaged.
   - Tighten to 6 lb-ft



3. Mount the mixer to the mixer adapter using the four short M6x1.0x16 bolts. Ensure the gasket on the mixer is not damaged.
   - Tighten to 6 lb-ft



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



Specifications

GENERAL SPECIFICATIONS	
Fuel Pressure	276 kPA (40psig)
Motorcraft SAE 5W-20/5W30 Super Premium	WSS-M2C960-A1/WSS-M2C961-A1

Torque Specifications			
Description	Nm	Lb.ft.	Lb.in
Fuel Rail Bolts	10	---	89

LSG-635 COOLING SYSTEM

INDEX

Subject

CAUTIONS & WARNINGS

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

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

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

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

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

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

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

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

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

CAUTION: Only this antifreeze, or proprietary antifreeze meeting Ford specification WSS-M97B57-A1 should be used when topping-up or re-filling the cooling system. Do not mix coolant types.

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

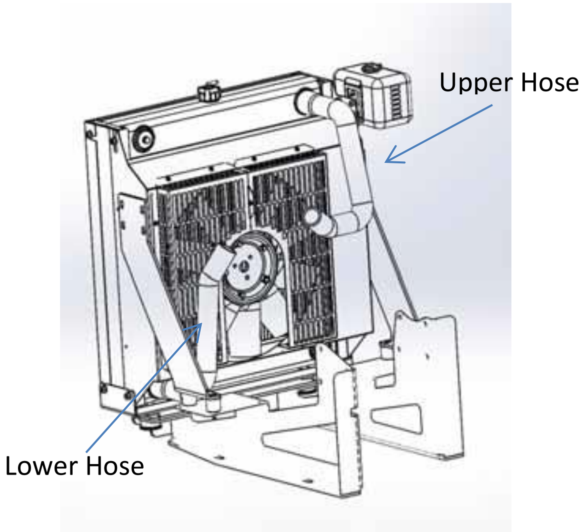
CAUTION: If there is engine coolant in the engine oil or transmission fluid, the cause must be corrected and oil/fluid changed or major component damage can occur.

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

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

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

GENERAL INFORMATION



Description

The cooling system consists of the following:

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

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

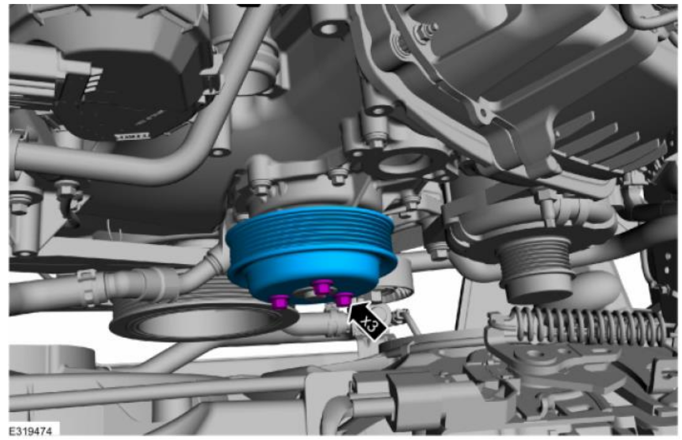
The ECT Sensor is used by the GCP to obtain coolant temperature information. Refer to Section 8 for further information on this sensor.

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

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

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

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



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

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

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

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

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

DIAGNOSIS AND TESTING

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

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

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

Visual Inspection

Check for leaks or damage at:

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

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

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

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

Coolant Inspection

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

Check level and condition of coolant:

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

Coolant Range Check

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

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

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

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

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

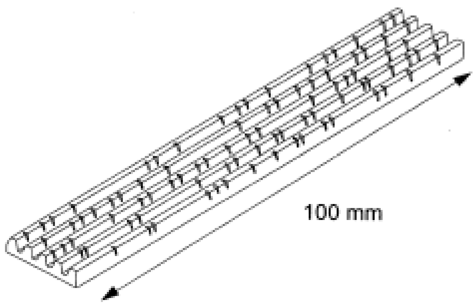
Drive Belt Inspection

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

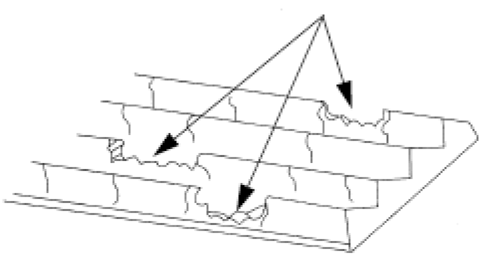
With engine running, observe the belt movement. It should respond when engine is accelerated rapidly. If tensioner moves excessively without rapid acceleration, install a new belt. If excessive movement still exists, install a new tensioner.

Visually inspect the belt for obvious signs of damage.

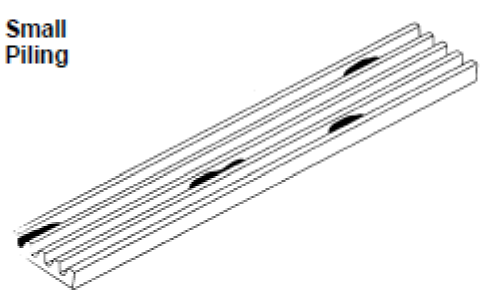
- Up to 15 cracks in a rib over a distance of 100 mm (4.0 in) can be considered acceptable.



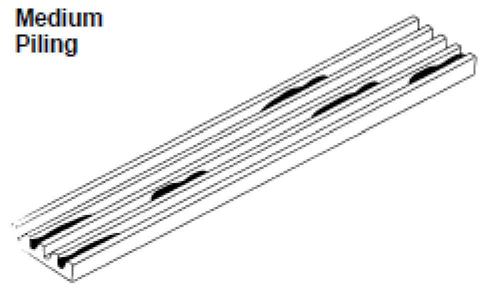
- If cracks are beyond acceptable or, any chunks are found to be missing from the ribs, a new belt must be installed.



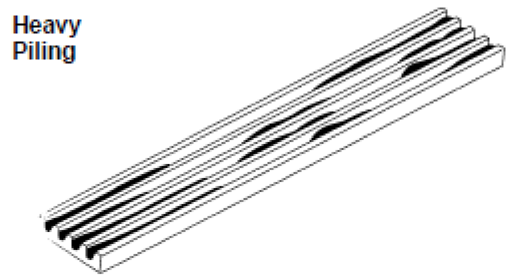
- Small scatted deposits of rubber material (known as piling) are not a concern.



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

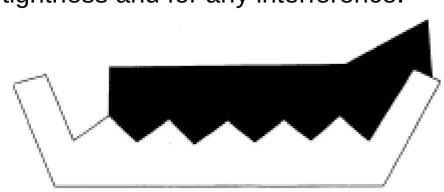


- If heavy deposits are apparent, resulting in noise and belt instability, install a new belt.



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

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



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

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

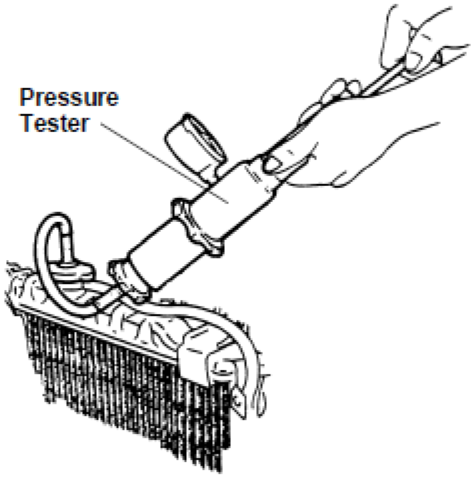
CAUTION: Incorrect drive belt installation will cause excessive drive belt wear and can cause the belt to come off the pulleys.

Symptom Chart

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

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

Cooling System Pressure Test



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

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

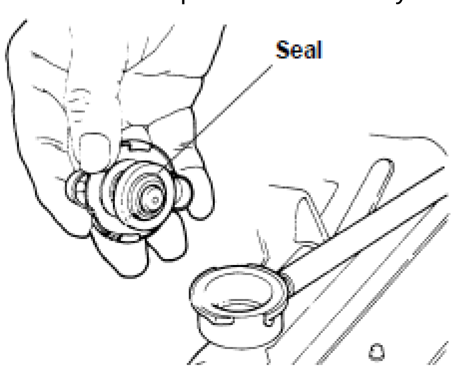
CAUTION: Do not pressurize the cooling system beyond 138 kPa (20 psi).

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

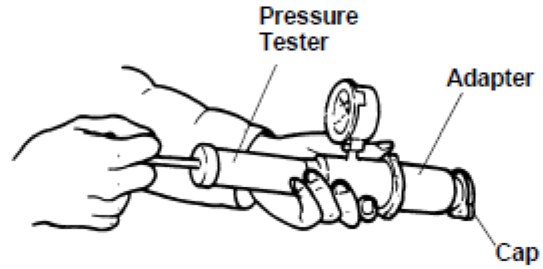
Radiator Cap Pressure Test

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

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



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



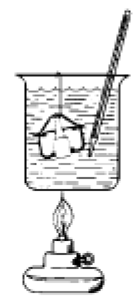
NOTE: If the plunger of the pressure tester is depressed too fast, an incorrect pressure reading will result.

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

4. Release the pressure and repeat the test.

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

Thermostat Operational Check



1. Hold thermostat up to the light.

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

3. Place the thermostat and a thermometer in water.

4. Gradually increase the water temperature

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

GENERAL SERVICE PROCEDURES

Draining the Cooling System

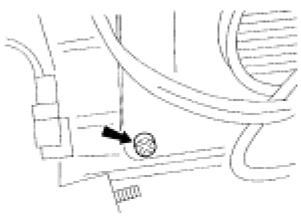
WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Remove radiator cap.

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

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

Radiator Drain Cock



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

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

Flushing the Cooling System

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

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

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

Filling the Cooling System

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

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

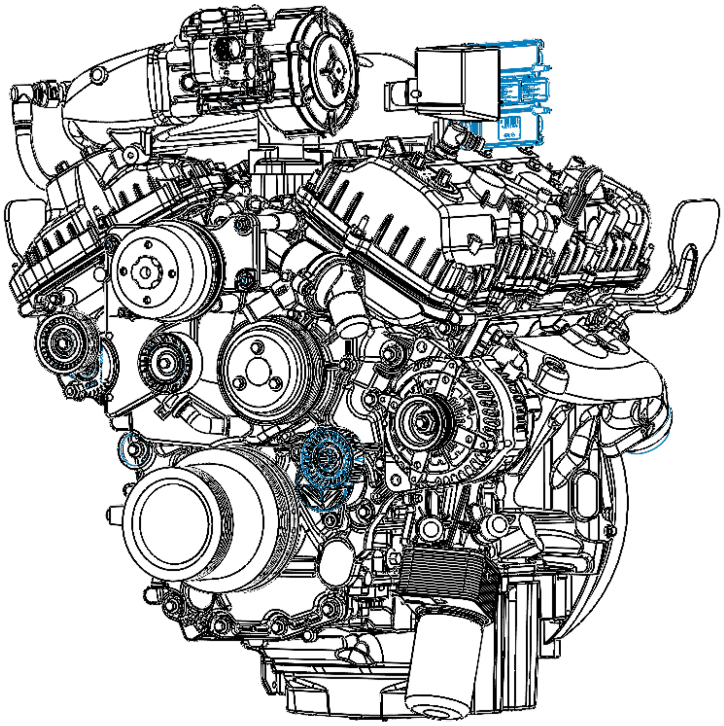
CAUTION: Not all coolant recycling processes produce coolant which meets Ford specification ESEM97B44- A or WSS-M97B44-D. Use of coolant that does not meet specifications may harm engine and cooling system components.

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

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

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

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



REMOVAL AND INSTALLATION

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

Fan Belt – Removal

NOTE: Note belt routing for installation purposes.

1. Rotate tensioner clockwise to relieve belt tension.
2. Remove belt
3. Inspect belt and pulleys – Refer to "Visual Inspection" of this section.

Drive Belt - Removal

NOTE: Note belt routing for installation purposes.

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

Drive Belt - Installation

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

Fan Belt – Installation

1. Place belt around extended crank pulley and fan pulley.
2. Route belt correctly and release tensioner onto belt.
3. Recheck belt routing and groove alignment.

Belt Tensioner – Replacement

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

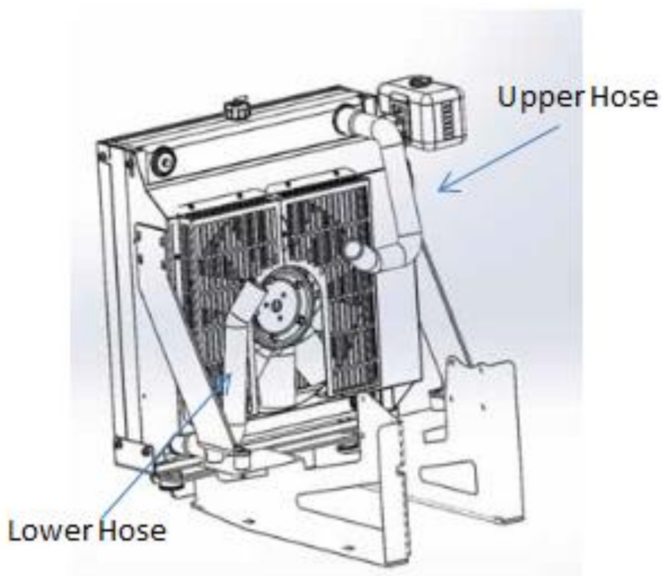
Idler Pulley - Replacement

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

Radiator Hose - Removal

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

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



Radiator Hose - Installation

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

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

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

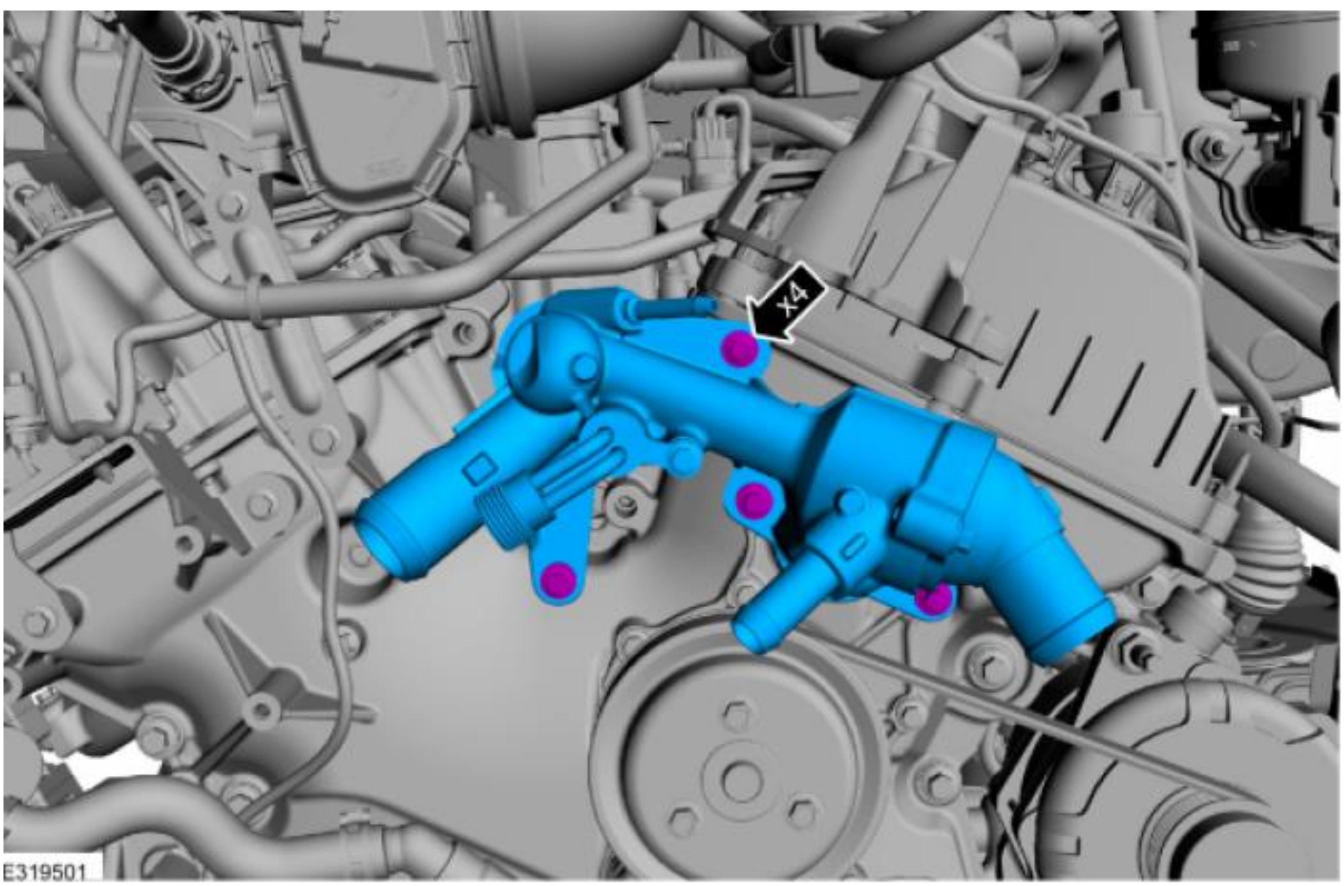
Thermostat & Housing – Replacement

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

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

NOTE: General thermostat and housing shown

1. Allow the engine to cool down until the coolant has lowered in temperature to below 110°F.
2. Drain the radiator so coolant level is below the thermostat -- Refer to "Draining the Cooling System" of this section.
3. Remove or disconnect components as necessary to gain access to the thermostat housing.
4. Disconnect the lower radiator hose.
5. Remove bolts and thermostat housing.
6. Reverse procedure to install
    - Clean and inspect gasket, install a new gasket if necessary.
    - Tighten bolts to 8 Nm (71 lb-in). than an additional 45°

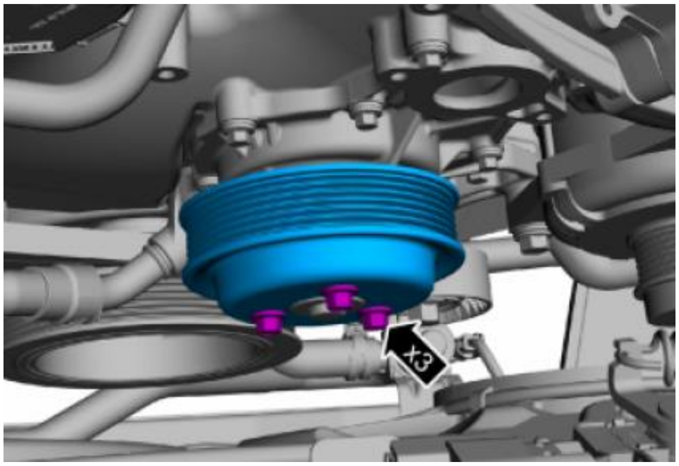


Coolant Pump - Replacement

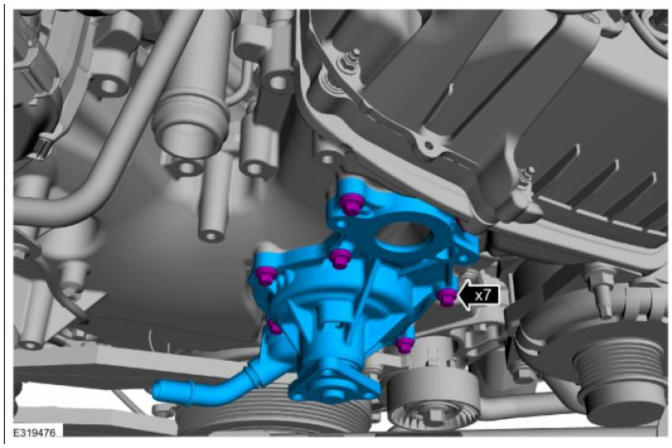
⚠

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

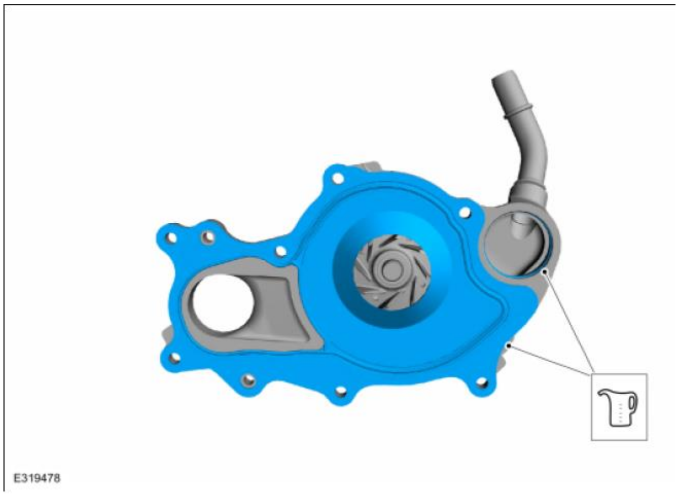
1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Remove or disconnect components as necessary to gain access to the coolant pump.
3. Remove the fan belt – Refer to “Fan Belt – Removal” of this section.
4. Remove the drive belt – Refer to “Drive Belt – Removal” of this section.
5. Remove 3 bolts and coolant pump pulley.



6. Remove 7 bolts and coolant pump.



7. Reverse procedure to install:
   - Replace both the coolant pump gasket and O-ring seal when installing new pump. Lubricate it with clean engine coolant.



   - Tighten coolant pump bolts to
     1. Stage 1: 10 Nm (89 lb-in)
     2. Stage 2: 45^{o}
   - Tighten pulley(fan) bolts to
     1. 24 Nm (18 lb-ft)

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Coolant/Water Mixture	50/50
Pressure Relief Cap Opening Pressure kPa (psi)	120 – 150 kPa (17.4 – 21.7 psi)
Radiator Pressure Test	138 kPa (20 psi)
Thermostat start to open temperature	83.9°C – 87.8°C (183°F-190°F)
Thermostat full open temperature	98.9°C (206°F)
Coolant Specification WSS-M97B57-A1	Motorcraft Premium Gold Engine Coolant

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Coolant pump pulley bolts	24	18	
Coolant pump to block bolts	10 + 45°	---	89 + 45°
Draincock	2	---	18
Thermostat housing bolts	8 45°	---	71 45°

LSG-635 CHARGING SYSTEM

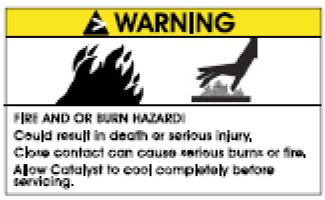
INDEX

Subject

Cautions & Warnings

Typical Battery Labeling

The handling and correct use of lead acid batteries is not as hazardous provided that sensible precautions are observed and that operatives have been trained in their use and are adequately supervised. It is important that all labeling on the battery is carefully read, understood and complied with. The format of the following symbols and labels is common to most brands of lead acid battery.



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

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

⚠

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

⚠

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

⚠

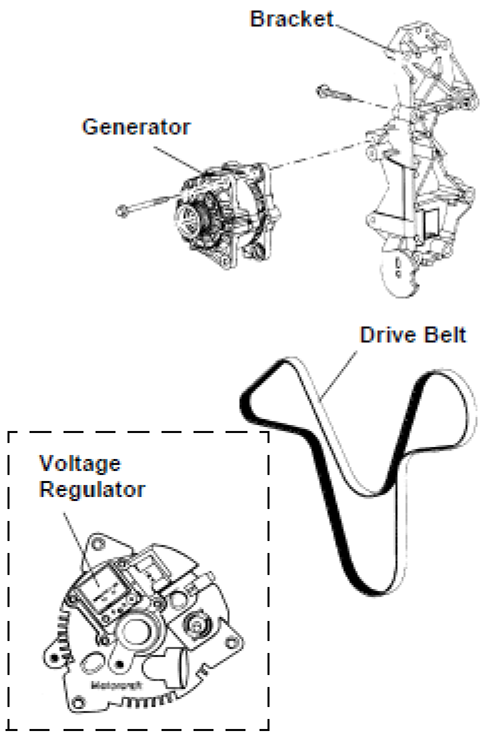
WARNING: KEEP BATTERIES OUT OF THE REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH THE SKIN OR EYES, FLUSH IMMEDIATELY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

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

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

LSG-635 CHARGING SYSTEM

GENERAL INFORMATION



Description

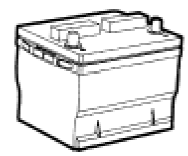
WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

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

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

Battery power

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



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

Operation

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

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

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

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

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

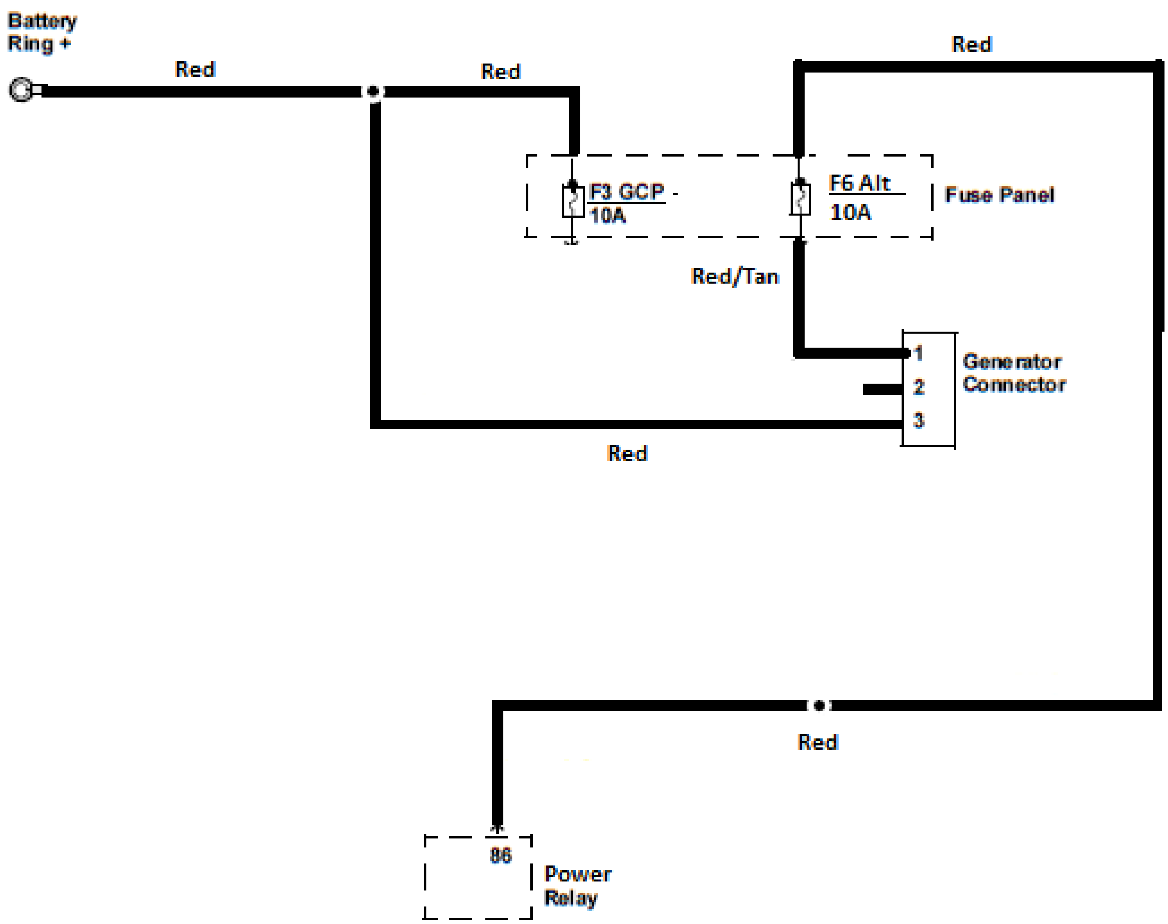
Wiring Diagram

Revision Level

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

Title EDI / FORD 3.5L Bi-Fuel		
Size D	Number 5210130	Rev 2
Date: 10/10/2020	Drawn By: J. SUTTON	
Filename: FORD_35L_BIFUELr2.sch	Sheet 1 of 1	

Charging System



DIAGNOSIS AND TESTING

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

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

Preliminary Checks

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

Perform the following checks before any testing:

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

Warning Indicator Check

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

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

Symptom Chart

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

Battery Drain Test

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

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

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

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

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

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

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

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

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

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

Battery Load Test

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

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

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

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

Generator Output Test

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

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

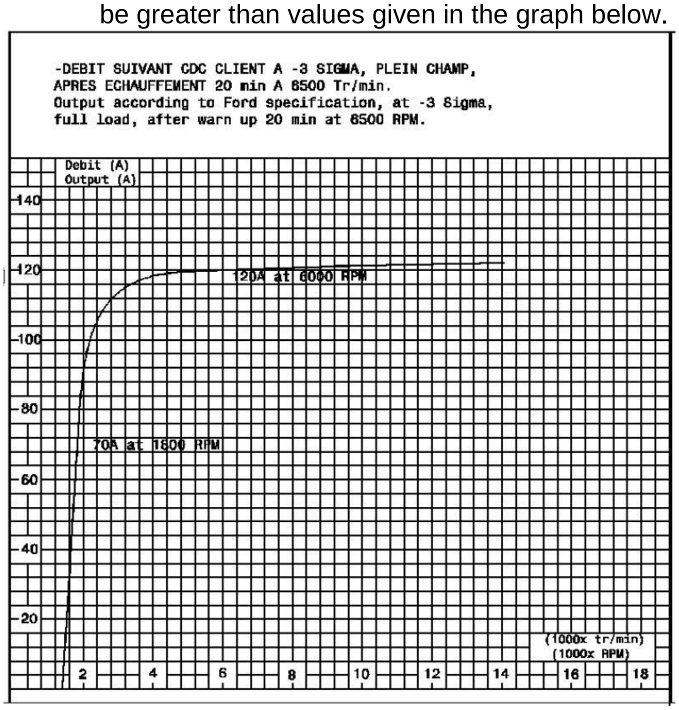
CAUTION: Do not allow any metal object to come in contact with the housing and the internal diode cooling fins with the ignition on or off. A short circuit may result and burn out the diodes.

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

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

NOTE: Turn off all lamps and accessories.

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



Generator Voltage Test

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

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

GENERAL SERVICE PROCEDURES

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

Battery Cleaning and Inspection

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

Battery Tools

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

Clamp Puller

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

Battery Clamp Spreader

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

Terminal Cleaning Brush

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

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

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

Battery Charging

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

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

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

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

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

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

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

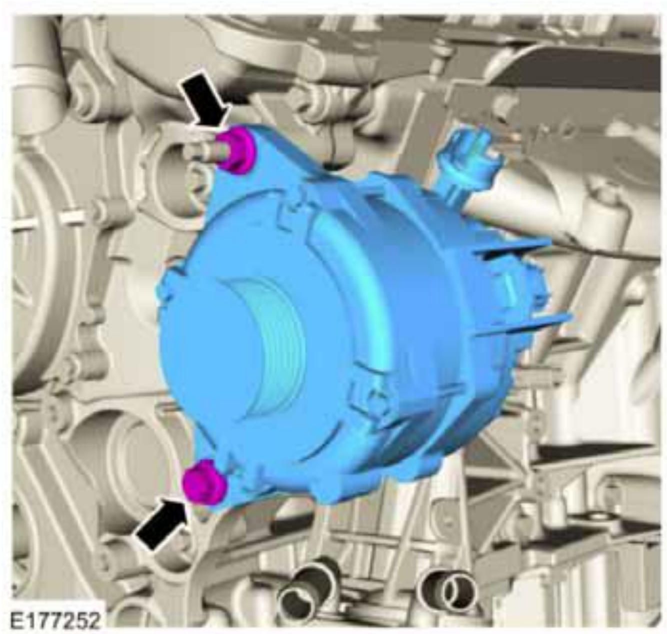
After releasing switch and with charger still on, measure battery voltage. If it shows 12 volts or higher, the battery is accepting a charge and is capable of being recharged. However, it may require up to two hours of charging with batteries colder than 5°C (41°F) before charging rate is high enough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

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

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

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

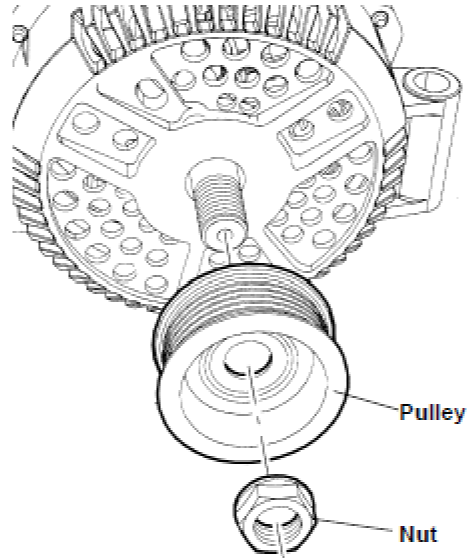
REMOVAL AND INSTALLATION
Generator – Replacement



1. Disconnect battery negative cable -- Refer to "Battery Cleaning and Inspection" on page 9 of this section.
2. Remove or disconnect any component to allow access and removal of generator.
3. Remove drive belt -- refer to cooling system section.
4. Remove 2 bolts on the right hand side and one bolt on the front and position the generator aside.
5. Disconnect electrical connector.
6. Remove generator.
7. Reverse procedure to install:
    - Tighten generator bolts to 47 Nm (35 lb-ft).
    - Tighten B+ terminal to 15 Nm (133 lb-in).

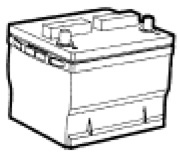
Generator Pulley - Replacement

1. Remove generator assembly -- Refer to "Generator - Replacement" of this section.
2. Remove nut.



3. Remove pulley.
4. Reverse procedure to install:
    - Tighten nut to 109 Nm (80 lb-ft).

Battery - Removal



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

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES, OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION.
IN CASE OF ACID CONTACT WITH SKIN OR EYES, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES AND GET PROMPT MEDICAL ATTENTION. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

CAUTION: Care should be taken when removing or replacing the cable clamp bolts so that the battery terminal is not subjected to any excessive lateral or twisting forces. Such forces could cause major damage to the internal components of the battery, and leakage at the terminals.

1. Remove battery cables from battery terminals (battery ground cable first).
2. Remove battery hold down components.

CAUTION: When lifting a plastic-cased battery, excessive pressure on the end walls could cause acid to spew through the vent caps, resulting in personal injury, damage to the equipment or battery. Lift with a battery carrier or with your hands on opposite corners.

3. Remove battery from equipment.

Battery - Installation

1. Clean cable terminals and battery hold down clamp with a wire brush. Replace all cables or parts that are worn or frayed.
2. Clean battery tray with a wire brush and scraper.
3. Place battery in battery tray with positive and negative cables in same position as when removed.
4. Assemble and tighten battery hold down clamp so battery is secure. Do not tighten excessively.
5. Secure cables to proper terminals. Tighten to 6 Nm (53 lb-in). Apply petroleum jelly to terminals.

Ford Motor Company strongly recommends that lead acid batteries be returned to an authorized recycling facility for disposal.

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Generator Output	150 max. amps @ 1800 – 6000 generator rpm (approx. 500 – 2000 engine rpm)
Battery	12 volt 750 CCA
Battery charging voltage	13 – 15.5 volts

TORQUE SPECIFICATIONS			
Description	**Nm**	**Lb-ft**	**Lb-in**
Generator Mounting bolts	47	35	---
Regulator attachment screws	3	---	27
Battery cable nuts	15	---	133
Generator pulley nut	109	80	---
Generator wiring nuts	8	---	71

SPECIAL TOOLS	
VAT-40 Starting/charging Tester	078-00005

LSG-635 STARTER SYSTEM

INDEX

CAUTIONS & WARNINGS

WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: WHEN WORKING IN THE AREA OF THE STARTER MOTOR, BE CAREFUL TO AVOID TOUCHING HOT EXHAUST COMPONENTS. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

CAUTION: A protective cap or boot is provided over the battery input terminal and must be reinstalled after removal.

CAUTION: Be sure to disconnect the battery ground cable before repairing the starter motor.

WARNING: HYDROGEN AND OXYGEN GASES ARE PRODUCED DURING NORMAL BATTERY OPERATION. THIS GAS MIXTURE CAN EXPLODE IF FLAMES, SPARKS OR LIGHTED TOBACCO ARE BROUGHT NEAR THE BATTERY. WHEN CHARGING OR USING A BATTERY IN AN ENCLOSED SPACE, ALWAYS PROVIDE VENTILATION AND SHIELD YOUR EYES.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

WARNING: TO AVOID INJURY, USE PARTICULAR CARE WHEN CONNECTING A BOOSTER BATTERY TO A DISCHARGED BATTERY.

GENERAL INFORMATION

Description

The starter motor provides the rotation of the engine crankshaft, through the flywheel, that is needed to start the engine.

The starter system consists of:

- starter motor
- starter solenoid
- starter relay
- battery.

The starter motor is a permanent magnet, gear reduction type. It runs on 12 volts DC current.

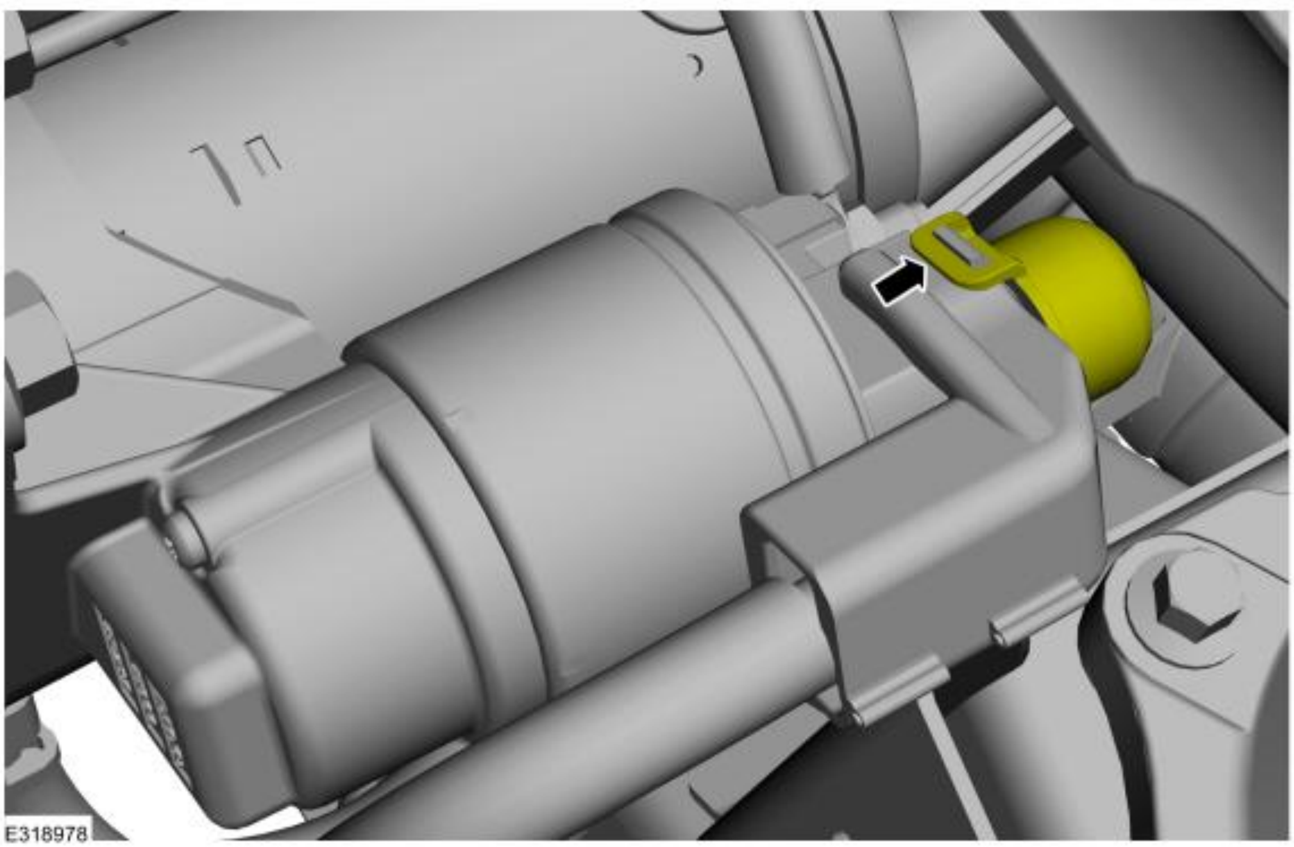
The starter solenoid is integral to the motor and a relay is also used. Refer to the charging section for information on the battery.

Operation

When the ignition is turned to the start position, the starter relay switches power to the starter solenoid, causing the starter motor to engage (transmission must be in PARK or NEUTRAL).

Battery power is always present at the starter motor B+ terminal. The starter motor relay, when energized, sends current to the starter motor “S” terminal, which causes the motor’s shaft to rotate. When the starter switch is released, a spring returns the solenoid to the released position.

The starter relay is grounded through the GCP and the power to trigger the starter is from the OEMs keyswitch. When both conditions are present the relay closes and engages the starter.

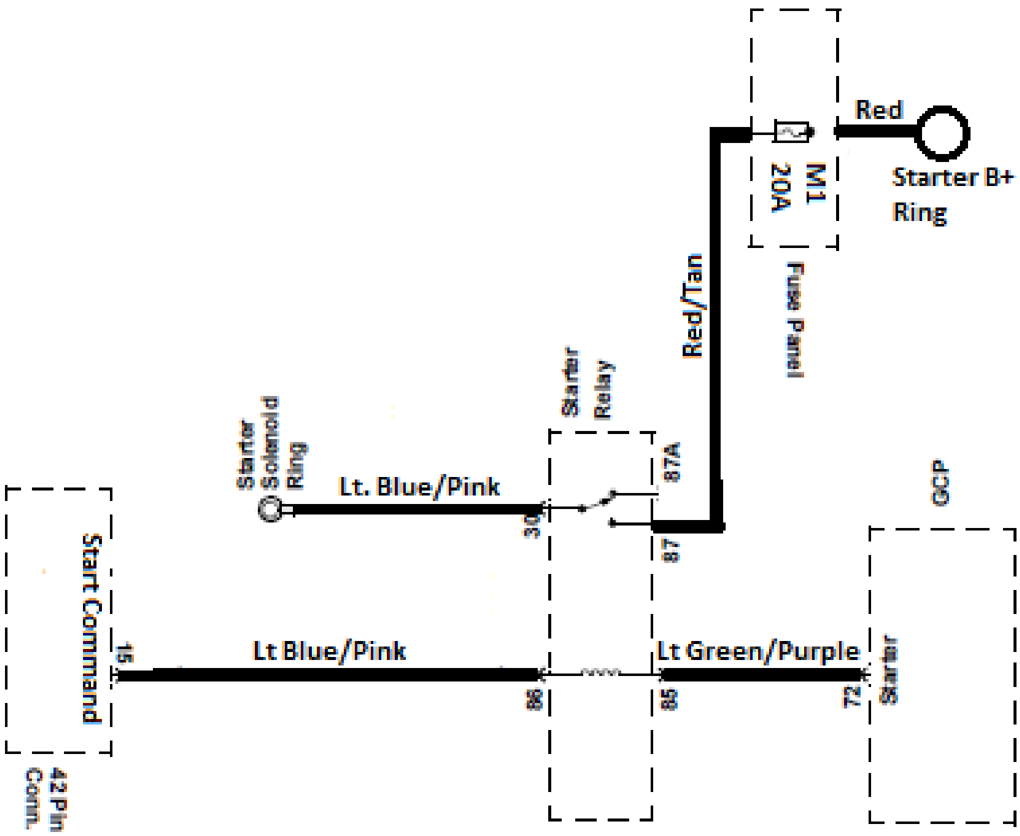


Wiring Diagram

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

Title EDI / FORD 3.5L Bi–Fuel		
Size D	Number 5210130	Rev 2
Date: 10/10/2020	Drawn By: J. SUTTON	
Filename: FORD_35L_BIFUELr2.sch	Sheet 1 of 1	

Starting System



DIAGNOSIS AND TESTING

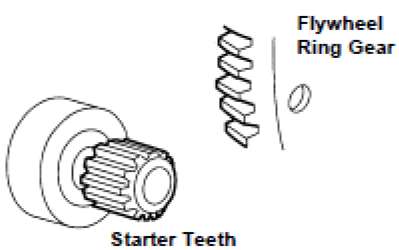
WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: When testing with a meter, always make connections with the component terminal rather than at the wiring end connector. Making connection with the wiring end connector can result in a false reading, because the meter will not pick up any high resistance between the wiring connector and the component.

Visual Inspection

CAUTION: Be sure to disconnect battery negative cable before servicing starter.

- Verify the concern by operating the starting system to duplicate the conditions.
- Inspect starting system for loose connections.
- Check the wear patterns on the starter drive and the flywheel ring gear. If the starter drive gear and the flywheel ring gear are not fully meshing or the gears are milled or damaged, replace the starter motor and if necessary, replace flywheel ring gear.



If the inspection reveals an obvious concern that can be readily identified, repair as necessary.

If the concern remains after the inspection, note condition and continue diagnosis using the symptom chart.

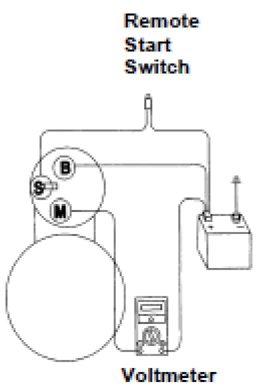
Symptom Chart

CONDITION	POSSIBLE SOURCE	ACTION
Starter does not crank (audible click may or may not be heard)	• Open fuse • Low Battery • Defective remote relay • Open circuit or high resistance in external feed circuit to starter solenoid • Defective starter • Defective neutral park switch	• Check fuse continually • Refer to battery diagnosis in charging section • Check relay • Check starter wiring • Rplace starter motor • Replace switch
Unusual starter noise	• Starter note mounted flush (cocked) • Noise from other components • Ring gear tooth damage or excessive ring gear runout • Defective starter	• Realign starter or transmission bell housing or SAE housing • Investigate other powertrain accessory noise • Replace flywheel ring gear • Replace Starter motor
Starter spins but the engine does not crank	• Starter note mounted flush (cocked) • Ring gear tooth damage	• Realign starter or transmission bell housing or SAE housing • Replace flywheel ring gear
Starter cranks but engine does not start	• Problem in fuel system • Engine related problem	• Refer to fuel system section • Refer to section 01, diagnosis and testing
Starter cranks slowly	• Low Battery • High resistance or loose connections in starter solenoid battery feed or ground circuit • Ring gear runout excessive • Defective Starter	• Charge or replace battery • Check that all connections are secure • Replace ring gear • Replace starter motor
Starter remains engaged and runs with engine	• Shorted ignition switch • Battery cable touching solenoid "S" terminal • Defective starter	• Replace ignition switch • Replace or relocate cable • Replace starter motor
Starter clicks and engages but engine will not crank	• Hydrolocked cylinder • Seized main or rod bearing	• Remove all plugs one at a time while checking for fluid in cylinders • Repair as needed – refer to sections 01

Motor Feed Circuit - Voltage Drop Test

Slow cranking is often caused by high resistance in the battery cables or connections, especially in cold weather. After all batteries check good and terminals are clean and tight, check the starter motor feed circuit:

1. Connect a remote starter switch between the starter "S" terminal and the battery positive (+) terminal.
2. Connect a digital multimeter positive lead to the battery positive (+) post. Connect negative lead to the starter solenoid "M" terminal.

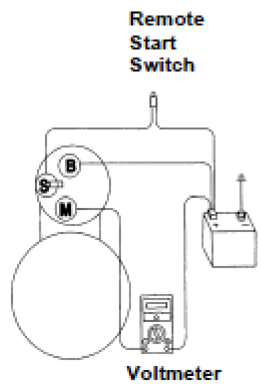


3. Engage the remote starter switch. Read and record the voltage. The voltage reading should be 0.5 volt or less.
   - If 0.5 volt or less -- refer to starter motor ground circuit test.
   - If greater than 0.5 volt, indicating excessive resistance, move the negative lead to the "B" terminal as shown and repeat the test. If voltage reading at the "B" terminal is lower than 0.5 volt, the concern is either in the connections at the starter solenoid or in the solenoid contacts. By moving the lead toward the battery and checking each mechanical connection point, the excessive voltage drop can be located. When the high reading disappears, the last mechanical point that was checked is the concern. Clean or repair as necessary.

Starter Motor - Ground Circuit Check

A slow cranking condition can be caused by resistance in the ground or return portion of the cranking circuit. Check the voltage drop in the ground circuit as follows:

1. Connect a remote starter switch between the starter solenoid "S" terminal and the battery positive (+) post.



2. Connect a digital multimeter positive (+) lead to the starter motor housing (the connection must be clean and free of rust or grease).
3. Connect the negative (-) lead of the voltmeter to the negative (-) battery terminal.
4. Engage the remote starter switch and crank the engine. Read and record the voltage reading.
   a. A reading of 0.2 volt or less indicates a good ground connection.
   b. If reading is more than 0.2 volts, clean all ground connections and retest. If still too high replace battery negative cable.

NOTE: If the voltage reading is less than 0.2 volt and the engine still cranks slowly, install a new starter motor.

GENERAL SERVICE PROCEDURES

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

Jump Starting

For cases of a starter that cranks the engine very slowly, connect a 12 volt booster battery to the system. To avoid damage to the equipment and battery or the possibility of personal injury, follow these instructions and precautions:

WARNING: HYDROGEN AND OXYGEN GASES ARE PRODUCED DURING NORMAL BATTERY OPERATION. THIS GAS MIXTURE CAN EXPLODE IF FLAMES, SPARKS OR LIGHTED TOBACCO ARE BROUGHT NEAR THE BATTERY. WHEN CHARGING OR USING A BATTERY IN AN ENCLOSED SPACE, ALWAYS PROVIDE VENTILATION AND SHIELD YOUR EYES.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO,
SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

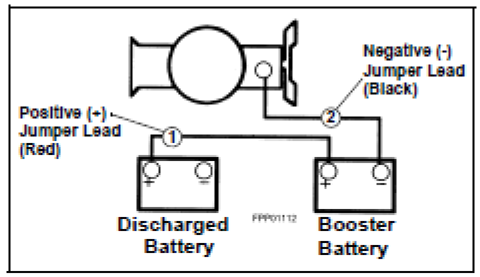
CAUTION: Do not disconnect the battery of the engine to be started. Disconnecting the battery could damage the equipment's electronic system.

WARNING: MAKING THE FINAL CABLE CONNECTION COULD CAUSE AN ELECTRICAL SPARK NEAR THE BATTERY AND COULD CAUSE AN EXPLOSION. REFER TO WARNING AT THE BEGINNING OF THE JUMP STARTING PROCEDURE.

WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER UNDERHOOD WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS "ELECTRICALLY HOT" AT ALL TIMES.

WARNING: TO AVOID INJURY, USE PARTICULAR CARE WHEN CONNECTING A BOOSTER BATTERY TO A DISCHARGED BATTERY.

1. Position equipment so jumper cables will reach, being careful that equipment does not touch each other.



NOTE: Be sure to disconnect battery negative cable before servicing starter.

2. Connect one end of positive red jumper cable (+) 1 to positive terminal of discharged battery and other end to positive terminal of booster battery.

3. Connect one end of negative black jumper cable (-) 3 to negative terminal of booster battery. Connect other end to an engine bolthead or good metallic contact spot on engine of equipment to be started. NOT TO NEGATIVE (-) BATTERY TERMINAL.
4. Make sure jumper cables are not in way of moving engine parts.
5. Start engine with good battery. Run engine at a moderate speed.
6. Start engine with discharged battery. Follow starting instructions in the Operator handbook.
7. Completely discharged batteries may require an electrical load to initialize charging.
8. Remove cables in exact REVERSE sequence. Begin by removing negative cable from engine that had discharged battery.

If the starter does not turn the engine over, even with the booster battery attached, refer to Diagnosis.

REMOVAL AND INSTALLATION

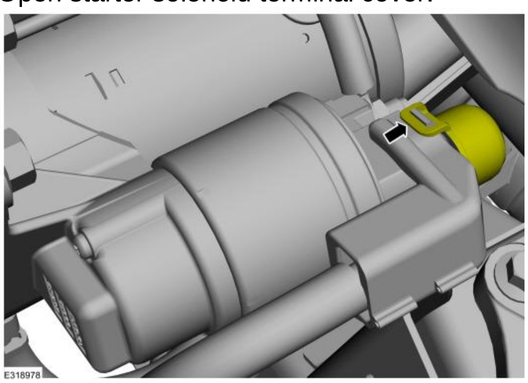
WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

Starter Motor – Replacement

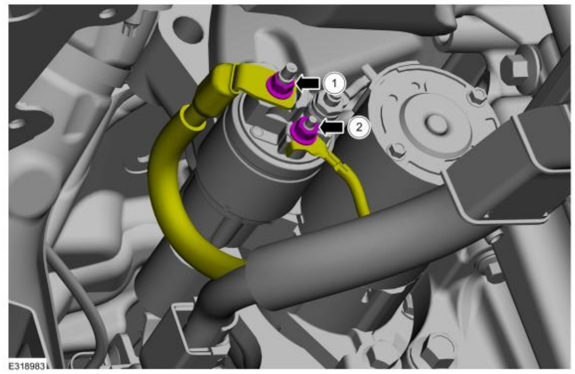
WARNING: WHEN SERVICING STARTER OR PERFORMING OTHER WORK IN THE VICINITY OF THE STARTER, BE AWARE THAT THE HEAVY GAUGE BATTERY INPUT LEAD AT THE STARTER SOLENOID IS “ELECTRICALLY HOT” AT ALL TIMES.

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

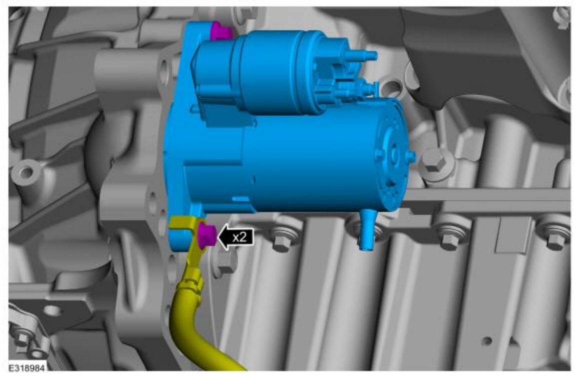
1. Disconnect negative battery cable.
2. Remove any component to allow access and removal of the starter motor.
3. Open starter solenoid terminal cover.



4. Remove the starter solenoid terminal nuts
    - 1) To install, tighten to 12 Nm (106 lb-in)
    - 2) To install, tighten to 6 Nm (53 lb-in)



5. Remove the starter motor mounting bolts and the starter motor and position ground wire aside.



    - To install, position the starter motor and loosely install the bolts
    - To install, tighten to 35 Nm (26 lb-ft)
6. Reverse procedure to install.

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Current draw NO Load	100-150 amps
Current Draw Max Load	750 amps
Cranking Speed	200-245 RPM

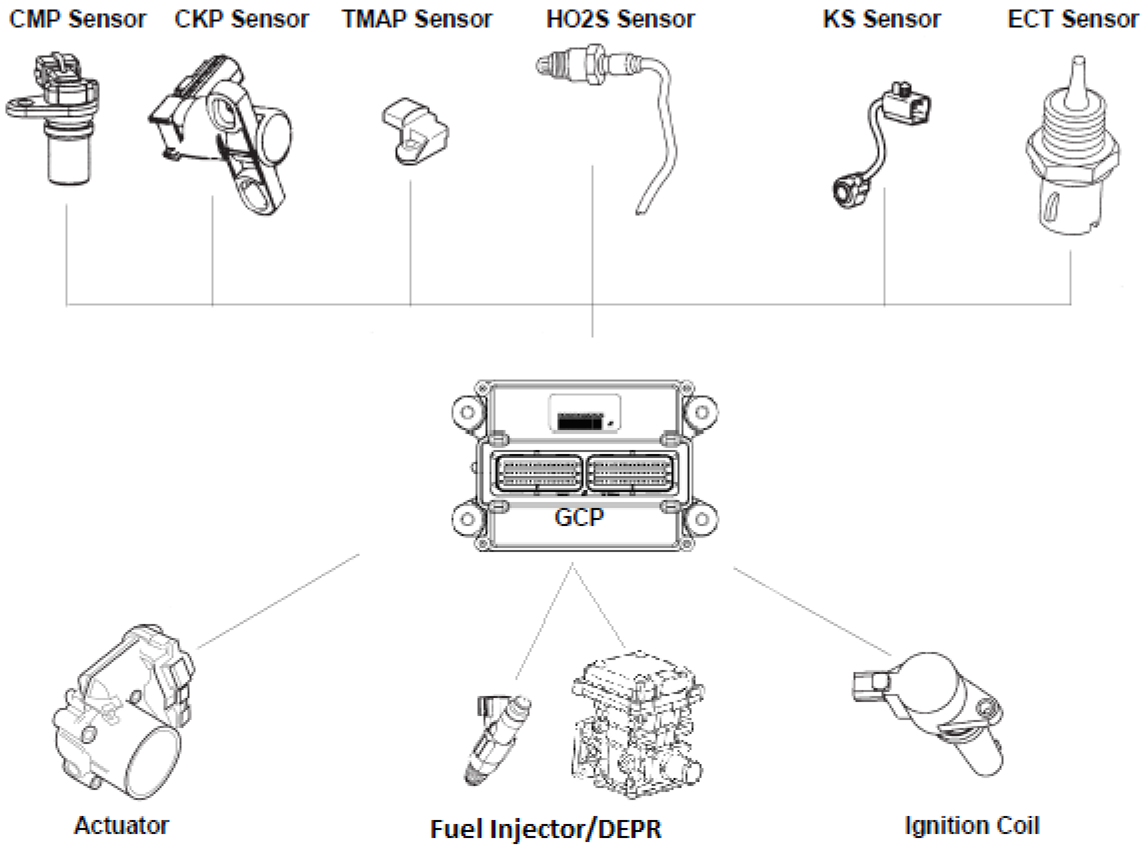
TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Mounting bolts/nuts/studs	35	26	---
Battery Cable nuts	6	--	53
Solenoid Terminal nut	6	---	53
Solenoid terminal B+ nut	12	106	---

SPECIAL TOOLS	
VAT-40 Starting/Charging Tester	078-00005

LSG-635 Engine Controls

INDEX

GENERAL INFORMATION
GCP and Sensors



Engine Control Module (GCP)

The Engine Control Module (GCP) has the following features:

- Programmable four speed electronic governing, throttle-by-wire or variable speed control governing.
- Programmable emergency warning/shut-down feature for high water temperature, low oil pressure, etc.
- Starter lockout.
- Auto crank
- Programmable overspeed protection
- Automatic altitude compensation.
- Sequential port fuel injection (gasoline) with pressure regulator to precisely control fuel delivery.
- Dry fuel lockout controlled by the GCP produces a reliable transition when switching fuels.
- Certified closed loop dry fuel control.
- Configurable inputs available based on customer requirements.
- Configurable outputs available based on ECT, RPM or MAP signals and customer requirements.
- Diagnostic software allows viewing of historical and active faults with on-demand diagnostics to assist technicians and reduce equipment downtime.

The Engine Control Module (GCP) engine control system is a complete engine control system for Ford industrial engines running on gasoline, propane or natural gas. Each module can be set up to run an engine on any two of the three fuels in certified closed loop control, with virtually transparent on-the-fly fuel switching.

Each module can also be set up to run on a variety of electronic governing:

- It can be programmed to provide up to four specific speeds with use of a matching toggle switch
- It can be programmed to provide an infinite variety of speeds (with customer-specified minimum and maximum) based on a variable signal input.
- It can be an electronic replacement for a throttle cable with maximum speed governing (throttle-bywire).
- Or it can switch between throttle-by-wire and a second fixed or variable input based on a neutral/ parking brake signal.

With the GCP system, a laptop and a communications cable, diagnosis becomes simpler. The technician can either view engine data with a real time graphing program, or store that data into a numeric data file.

Every time a fault is set, the laptop will give you detailed information about the fault, including:

- when it happened
- if the fault still exists
- a list of essential engine data from the time of the fault.

It can also display a 10 second graph of critical engine data, from 8 seconds before the fault occurred to two seconds after.

With many OEMs using control modules to control their machinery, the GCP has the ability to communicate engine data to and receive commands from other control modules through a Controller Area Network (CAN) link, with messages written in the J1939 protocol.

This allows large amounts of data to move throughout the machine through only two wires, and can be used to run some module based gauge packages.

The GCP also carries auxiliary features that can be programmed to control OEM devices, allowing the OEM to eliminate components from their machinery.

The GCP is also equipped with multiple safety and protection devices that protect the user and engine from hazards such as:

- over speed
- over temperature
- over voltage
- low oil pressure
- unauthorized tampering
- over cranking starter motor.

The GCP controls the following:

- Fuel metering system
- Ignition timing
- On-board diagnostics for engine functions

The GCP constantly observes the information from various sensors. The GCP controls the systems that affect engine performance. The GCP performs the diagnostic function of the system. It can recognize operational problems, alert the operator through the Malfunction Indicator Lamp (MIL), and store diagnostic trouble codes (DTC's). DTC's identify the problem areas to aid the technician in making repairs.

The GCP supplies either 5 or 12 volts to power various sensors or switches. The power is supplied through resistances in the GCP which are so high in value that a test light will not light when connected to the circuit. In some cases, even an ordinary shop voltmeter will not give an accurate reading because its resistance is too low. Therefore, a digital voltmeter with at least 10 megohms input impedance is required to ensure accurate voltage readings. The GCP controls output circuits such as the fuel injectors, electronic governor, etc., by controlling the ground or the power feed circuit through transistors or other solid state devices.

The GCP is designed to maintain exhaust emission levels to government mandated standards while providing excellent operation and fuel efficiency. The GCP monitors numerous engine functions via electronic sensors such as the throttle position (TP) sensor and the heated oxygen sensor (HO2S).

GCP Inputs (operating conditions read)

- Engine Coolant Temperature
- Crankshaft Position
- Exhaust Oxygen Content
- Manifold Absolute Pressure
- Battery Voltage
- Throttle Position / Electronic Actuator
- Fuel Pump Voltage

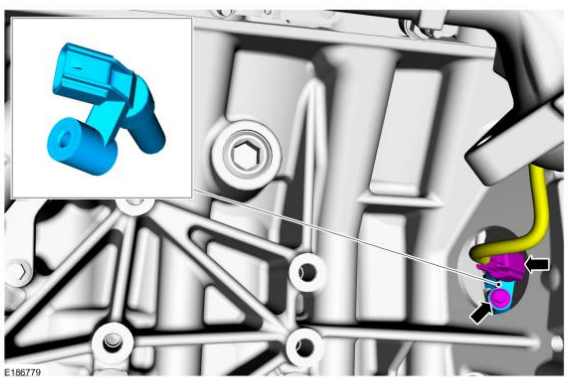
- Intake Air Temperature
- Camshaft Position

ECU Outputs (systems controlled)

- Fuel control (Injectors/DEPR)
- Electronic Throttle Control
- Electric Fuel Pump (gasoline)
- Diagnostics - Malfunction Indicator Lamp (check engine lamp)
- Diagnostics - Data Link Connector (DLC)
- Variable valve timing (VVT)

Crankshaft Position (CKP) Sensor

The Crankshaft Position (CKP) Sensor provides a signal used by the Engine Control Module (GCP) to calculate the ignition sequence. The sensor initiates the reference pulses which the GCP uses to calculate RPM and crankshaft position.

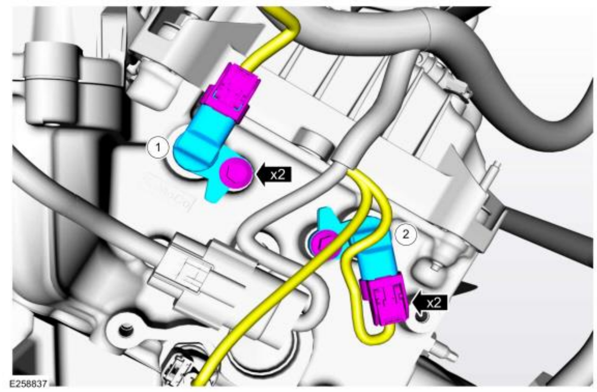


Camshaft Position (CMP) Sensor

The Camshaft Position (CMP) Sensor uses a variable reluctor sensor to detect camshaft position. The CMP signal is created as piston #1 is a pre-determined number of degrees after top dead center on the power stroke.

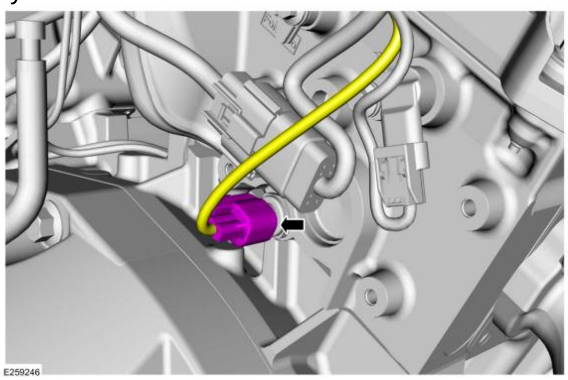
The Camshaft Position (CMP) Sensor sends a CMP signal to the GCP. The GCP uses this signal as a “sync pulse” to trigger the injectors in the proper sequence.
The GCP uses the CMP signal to indicate the position of the #1 piston during its power stroke. The CMP uses a Hall Effect sensor to measure piston position. This allows the GCP to calculate true sequential fuel injection (SFI) mode of operation. If the GCP detects an incorrect CMP signal while the engine is running, DTC 341 will set (CAM sync noise).

If the CMP signal is lost while the engine is running, the fuel injection system will shift to a calculated sequential fuel injection mode based on the last fuel injection pulse, and the engine will continue to run. As long as the fault (DTC 342, CAM loss) is present, the engine can be restarted. It will run in the previously established injection sequence.



Engine Cylinder Head Temp (CHT) Sensor

The Cylinder Head Temperature (CHT) 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 CHT 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 93°C (200°F). It then stabilizes when the thermostat opens. If the engine has not been run for several hours (overnight), the engine coolant temperature and intake air temperature displays should be close to each other. A fault in the engine coolant sensor circuit will set a DTC 117 or DTC 118 (Low/High Voltage).

OPERATING RANGE	MIN	NOMINAL	MAX
OPERATING VOLTAGE (V)	.5v	3.00v	4.98
OPERATING CURRENT (mA)	0.005mA	0.100	2.57mA
CURRENT IN-RUSH (A)	N/A	N/A	N/A
DESIGN RESISTANCE (Ω)	992Ω	30K	1017KΩ
DESIGN INDUCTANCE (H)	N/A	N/A	N/A
OPERATING TEMPERATURE (°C)	-40	25	125

Heated Oxygen Sensor (HO2S)

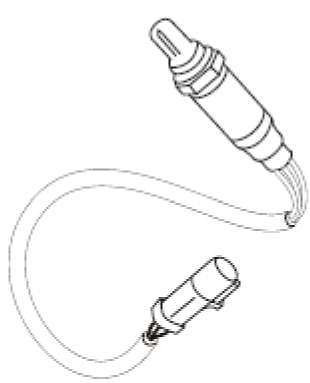
The Heated Oxygen Sensor (HO2S) is mounted in the exhaust stream where it can monitor the oxygen content of the exhaust gas. The oxygen present in the exhaust gas reacts with the sensor to produce a voltage output. This voltage should constantly fluctuate from approximately 100mV to 900 mV, when the engine is running in closed loop fuel control.

The Heated Oxygen Sensor (HO2S) voltage can be monitored on an IBM PC compatible computer with diagnostic software. By monitoring the voltage output of the oxygen sensor, the GCP calculates the pulse width command for the injectors to produce the proper combustion chamber mixture.

The 4-wire HO2S indicates whether the air/fuel ratio is rich or lean with respect to stoichiometry. The signal from this sensor contains valid air/fuel ratio information only when the sensor element has reached its normal operating temperature. The 4-wire HO2S also has an isolated case ground which goes to Signal Return (SIGRTN) either in the processor (as a dedicated HO2S ground) or as a jumper to SIGRTN in the wiring harness.

Low HO2S voltage indicates a lean mixture which will result in a rich command to compensate.

High HO2S voltage indicates a rich mixture which will result in a lean command to compensate.



Specifications

- Accuracy of measurement: ±1.5%
- Operating Temp. Range: 350°C to 850°C (sensor tip)
- Sensor Response Time: 300-1500 msec.
- Heater Current Draw: 1 A steady state
- Voltage Output:
    - 0 - 450 mV (lean exhaust gas)
    - 450 - 1000 mV (rich exhaust gas)

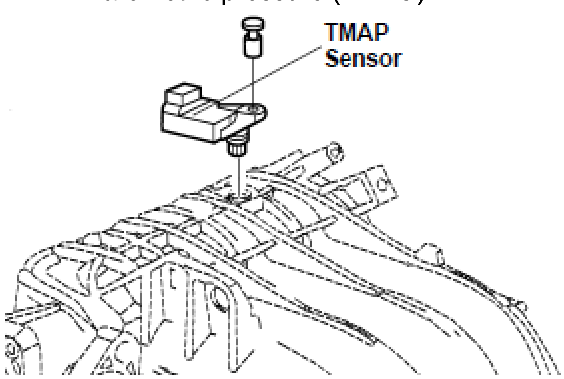
Temperature Manifold Absolute Pressure (TMAP) Sensor

The Temperature Manifold Absolute Pressure (TMAP) Sensor responds to changes in intake manifold pressure (vacuum). The TMAP sensor signal voltage to the GCP varies from below 2 volts at idle (high vacuum) to above 4 volts with the ignition ON, engine not running or at wide-open throttle (low vacuum).

The TMAP sensor consists of a pressure sensing element (capacitor) and signal conditioning electronics. The capacitor has a vacuum/pressure reference which results in one surface (diaphragm) of the capacitor being partially deflected. Further changes in pressure produce corresponding changes in the deflection of the diaphragm and therefore a change in capacitance. This capacitance change is converted to a frequency by the conditioning electronics.

The TMAP sensor is used to determine the following:

- Engine vacuum level for engine control purposes.
- Barometric pressure (BARO).



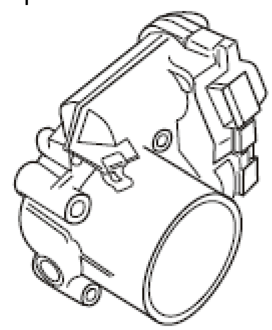
Specifications:

- Range of Measurement: 1.7 - 15.2 psi.
- Measurement Accuracy: ± 0.2 psi
- Sensor Response Time: 3-15 msec.
- Resolution: 0.02 psi

Present design: Silicon Capacitive Absolute Pressure (SCAP) sensor with a maximum operating temperature of 100°C. The output is a 50% duty cycle wave form whose frequency is proportional to the pressure input.

Throttle Position (TP) Sensor / Electronic Actuator

The Throttle Position (TP) Sensor is a dual track rotary potentiometer that uses a variable resistive element which is packaged inside a plastic housing. The resistive element varies linearly and is directly proportional to the throttle plate angle. The GCP applies reference voltage and ground to the sensor and monitors the sensor's ratio metric output voltage to determine precise throttle position. The electronic actuator has two TP outputs that the GCP monitors.



The Electronic Actuator consists of a throttle body, an electronically-actuated throttle plate, and a built-in throttle position (TP) Sensor. The Electronic Actuator also acts as an idle air control (IAC) valve. Changes in engine load are detected by the GCP by comparing manifold absolute pressure (TMAP) with throttle position. When the GCP detects a change in engine load, it can adjust idle speed by changing the PWM signal to the actuator.

As the throttle valve opens, the output increases so that at wide open throttle (WOT), the output voltage should be above 4 volts.

The GCP calculates fuel delivery based on throttle valve angle (operator demand). A hard failure in the TP sensor 5 volt reference or signal circuits for greater than 2 consecutive seconds will set a DTC 123 or DTC 223. A hard failure with the TP sensor ground circuit for more than two consecutive seconds may set DTC 222. If any (TP) DTC is set the GCP will shut down the engine immediately.

Specifications:

- Range of Measurement: 0-85° (angular)
- Measurement Accuracy: ±2% of VREF
- Resolution: 0.5° max.

Fuel System Components - Gasoline

The fuel metering system is made up of the following parts:

- The fuel injectors (gasoline)
- The fuel rail (gasoline)
- The fuel filter (gasoline)
- The GCP
- The Crankshaft Position (CKP) Sensor
- The Camshaft Position (CMP) Sensor
- The fuel pump (gasoline)
- The fuel pump relay (gasoline)
- The Direct Electronic Pressure Regulator (Gaseous Fuels)
- The Fuel Lock Off Solenoid (Gaseous Fuels)
- The Mixer (Gaseous Fuels)
- The Vapor Regulator (LPG/CNG)
- Heated Oxygen (HO2S) Sensor
- Temp/Manifold Absolute Pressure (TMAP) Sensor

The basic function of the air/fuel metering system is to control the air/fuel delivery to the engine. Fuel is delivered to the engine by individual fuel injectors mounted in the intake manifold near each intake valve.

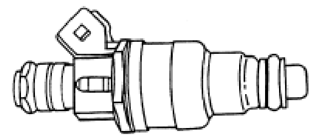
The fuel metering system starts with the fuel in the fuel tank. The fuel is drawn up to the fuel pump through a pre-filter. The electric fuel pump then delivers the fuel to the fuel rail through an in-line fuel filter. The pump is designed to provide fuel at a pressure above the pressure needed by the injectors. A fuel pressure regulator in the fuel filter assembly keeps fuel available to the fuel injectors at a constant pressure of 45psig. A return line delivers unused fuel back to the tank.

The main control sensor is the heated oxygen sensor (HO2S) located in the exhaust system. The HO2S tells the GCP how much oxygen is in the exhaust gas. The GCP changes the air/fuel ratio to the engine by controlling the amount of time that the fuel injector is “ON”. The best mixture to minimize exhaust emissions is 14.7 parts of air to 1 part of gasoline by weight, which provides the most efficient combustion. Because of the constant measuring and adjusting of the air/fuel ratio, the fuel injection system is called a “closed loop” system.

The GCP monitors signals from several sensors in order to determine the fuel needs of the engine. Fuel is delivered under one of several conditions called “modes”. All modes are controlled by the GCP. Refer to “Open Loop and Closed Loop Operation” for more information.

Fuel Injector

The Electronic Fuel Injection (EFI) fuel injector is a solenoid operated device controlled by the GCP. The GCP energizes the solenoid, which opens a valve to allow fuel delivery.

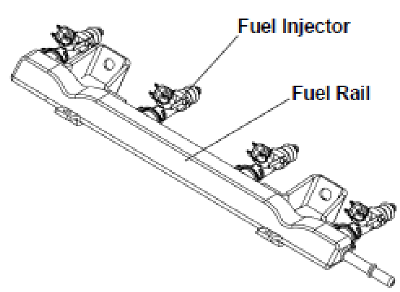


The fuel is injected under pressure in a conical spray pattern at the opening of the intake valve. Excess fuel not used by the injectors passes through the fuel pressure regulator before being returned to the fuel tank.

A fuel injector which is stuck partly open will cause a loss of fuel pressure after the engine is shut down, causing long crank times.

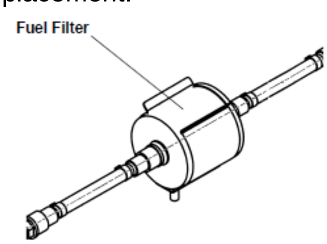
Fuel Rail

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



Fuel Filter

The fuel filter is an inline filter assembly. Refer to Section 4 for information on relieving fuel pressure, disconnecting fuel lines and fuel filter replacement.



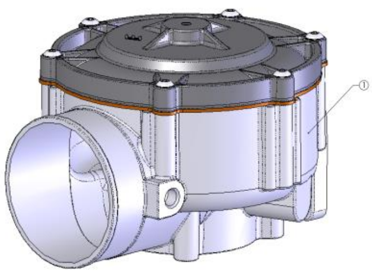
Fuel Pump Electrical Circuit

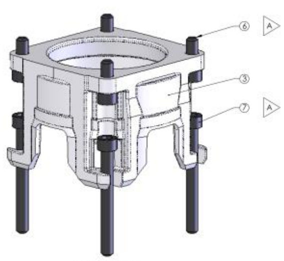
When the key is first turned "ON", the GCP energizes the fuel pump relay for two seconds to build up the fuel pressure quickly. If the engine is not started within two seconds, the GCP shuts the fuel pump off and waits until the engine is cranked. When the engine is cranked and crankshaft position signal has been detected by the GCP, the GCP supplies 12 volts to the fuel pump relay to energize the electric fuel pump.

An inoperative fuel pump will cause a "no-start" condition. A fuel pump which does not provide enough pressure will result in poor performance.

Mixer (Gaseous Fuels)

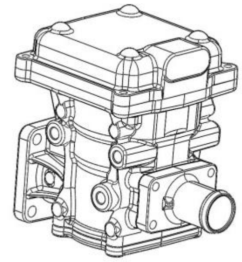
The Mixer allows air and fuel to mix together before entering the engine. Based on pressure differentials the diaphragm in the mixer will actuate allowing the proper amount of air and fuel to mixer together. This pressure differential is based on the vacuum in the intake manifold of the engine which is directly related to load.





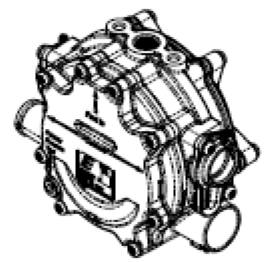
DEPR (Direct Electronic Pressure Regulator)

The DEPR controls the fuel trim to the engine on dry fuels based on inputs to the GCP (HO2 sensor, MAP sensor, crank and cam sensors). Nominal pressure input to the DEPR is ~ 11" WC and outputs ~ 4 – 5" WC. It is mounted directly to the mixer.



Vapor Regulator

The vapor regulator is used with LPG and CNG fuels. It converts LPG from a liquid state to a gaseous state. Nominal pressure output is ~11" of WC to the DEPR.



Coolant is run through the DEPR to prevent freezing of the regulator which could result in a lean fuel condition.

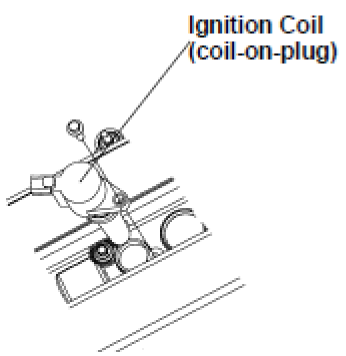
Fuel Lock Off Valve

The fuel lock off valve is located before the DEPR and/or the vapor regulator. It is only open during cranking and running. This prevents the intake manifold from filling with gaseous fuel which could result in a backfire. The power is constant and supplied by the power relay. The ground of the solenoid is controlled by the GCP.

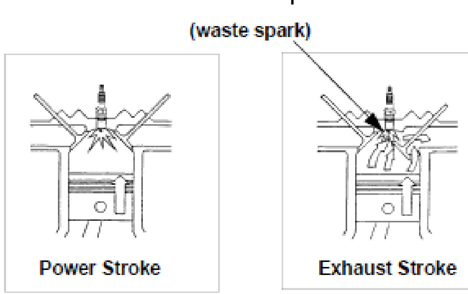
Coil-on-plug Ignition

The coil-on-plug ignition system controls fuel combustion by providing a spark to ignite the compressed air/fuel mixture at the correct time. To provide optimum engine performance, fuel economy, and control of exhaust emissions, the GCP controls the spark advance of the ignition system. Coil-on-plug ignition has the following advantages over a mechanical distributor system:

- No moving parts
- Less maintenance
- Remote mounting capability
- No mechanical load on the engine
- More coil cool down time between firing events
- Elimination of mechanical timing adjustments
- Increased available ignition coil saturation time
- Elimination of high tension wires



The coil-on-plug design has individual coils mounted directly over each spark plug. Each cylinder is paired with its opposing cylinder in the firing order, so that one cylinder on compression fires simultaneously with the opposing cylinder on exhaust. The spark that occurs in the cylinder on the exhaust stroke is referred to as a "waste spark".



The primary coils in the coil pack are triggered by the "ignition coil feed#1" and ignition coil feed #2" signals from the GCP.

Open Loop and Closed Loop Operation

NOTE: No DTC will be set unless engine has operated in closed loop status for more than 6 seconds.

The GCP will operate in the following two modes:

- Open loop
- Closed loop

When the engine is first started, the system is in "open loop" operation. In open loop, the GCP ignores the signal from the Heated Oxygen Sensor (HO2S). It uses a pre-programmed routine to calculate the air/fuel ratio based on inputs from the TP, ECT, TMAP & CKP sensors.

The system remains in open loop until the following conditions are met:

- The ECT has reached 75°F (24°C).
- 50 seconds has elapsed since starting the engine.

After these conditions are met, the engine is said to be operating in "closed loop". In closed loop, the GCP continuously adjusts the air/fuel ratio by responding to signals from the HO2S (except at wide-open throttle). When the HO2S reports a lean condition (low sensor signal voltage), the GCP responds by increasing the "on" time of the fuel injectors, thus enriching the mixture. When the HO2S reports a rich condition (high sensor signal voltage), the GCP responds by reducing the "on" time of the fuel injectors, thus leaning out the mixture.

Adaptive Learn
Adaptive Learn is a fuel correction coefficient that is derived from the closed loop correction and is stored in the GCP's memory.

The normal purpose of the Adaptive Learn is to compensate fuel flow for the following:

- Fuel composition variance
- Engine wear
- Component variation
- Component degradation

The GCP system will operate in closed loop plus adaptive learn when the ECT reaches 165°F.

NOTE: The adaptive learn coefficient will get erased if battery power falls below 9.5 volts.

GCP Service Precautions
The GCP is designed to withstand normal current draws associated with engine operation. When servicing the GCP, observe the following guidelines:

- Do not overload any circuit.
- When testing for opens and shorts, do not ground or apply voltage to any of the GCP's circuits unless instructed to do so.
- When measuring voltages, use only a digital voltmeter with an input impedance of at least 10 megohms.
- Do not employ any non-standard practices such as charging the battery with an arc welder.
- Take proper precautions to avoid static damage to the GCP. Refer to "electrostatic Discharge Damage" for more information.

Use of Circuit Testing Tools
Do not use a test light to diagnose the engine electrical systems unless specifically instructed by the diagnostic procedures. A test light can put an excessive load on a GCP circuit and result in component damage. For voltage measurements, use only a digital voltmeter with an input impedance of at least 10 megaohms.

Electrostatic Discharge Damage
Electronic components used in the GCP are often designed to carry very low voltage. Electronic components are susceptible to damage caused by electrostatic discharge. Less than 100 volts of static electricity can cause damage to some electronic components. By comparison, it takes as much as 4000 volts for a person to feel the spark of a static discharge.

There are several ways for a person to become statically charged. The most common methods of charging are by friction and induction.

An example of charging by friction is a person sliding across a seat.

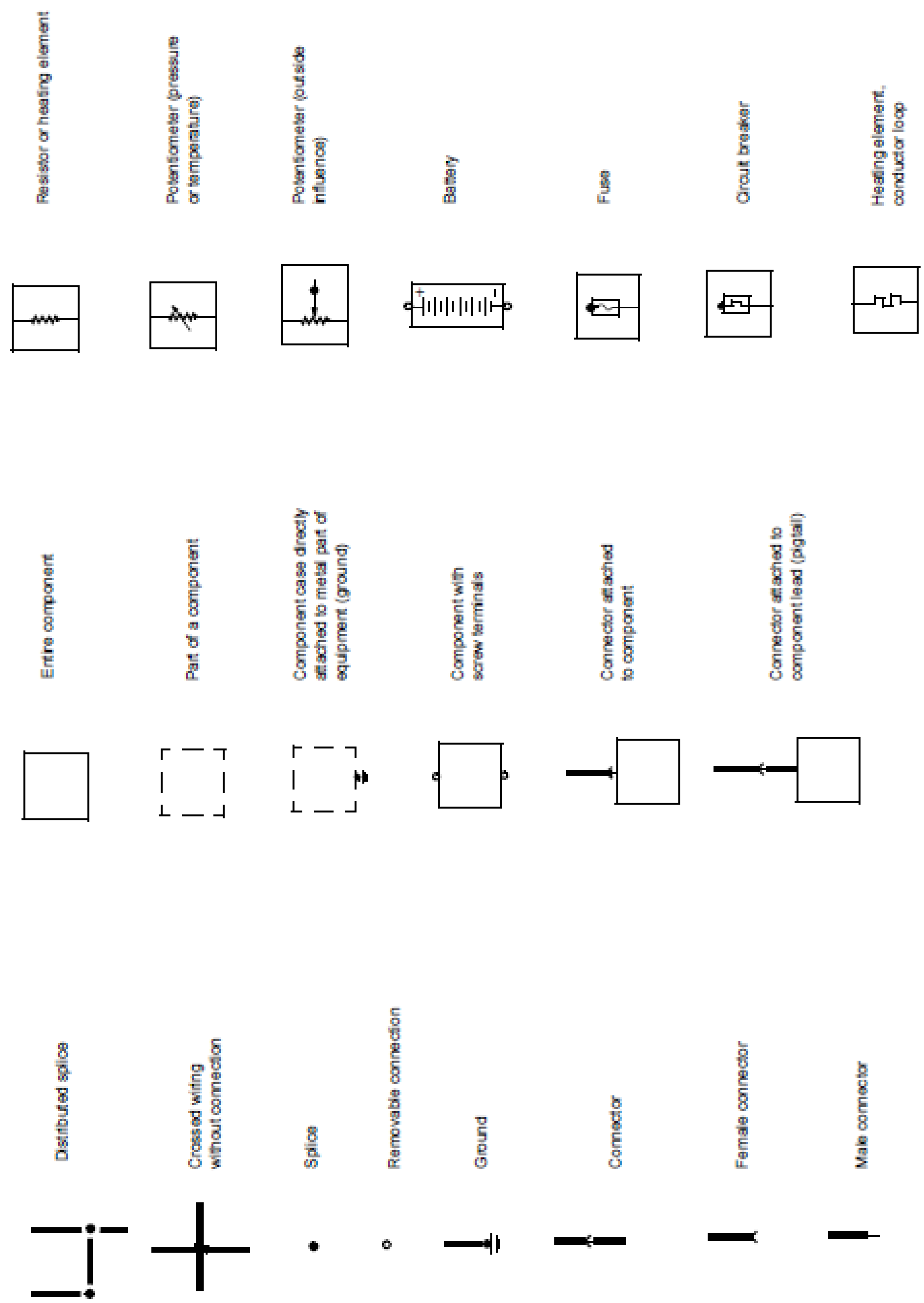
Charge by induction occurs when a person with well insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off, leaving the person highly charged with the opposite polarity. Static charges can cause damage, therefore it is important to use care when handling and testing electronic components.

CAUTION: To prevent possible electrostatic discharge damage, follow these guidelines:

- Do not touch the GCP connector pins or soldered components on the GCP board.
- Do not open the replacement part package until the part is ready to be installed.
- Before removing the part from the package, ground the package to a known good ground on the equipment.
- If the part has been handled while sliding across a seat, while sitting down from a standing position, or while walking a distance, touch a known good ground before installing the part.

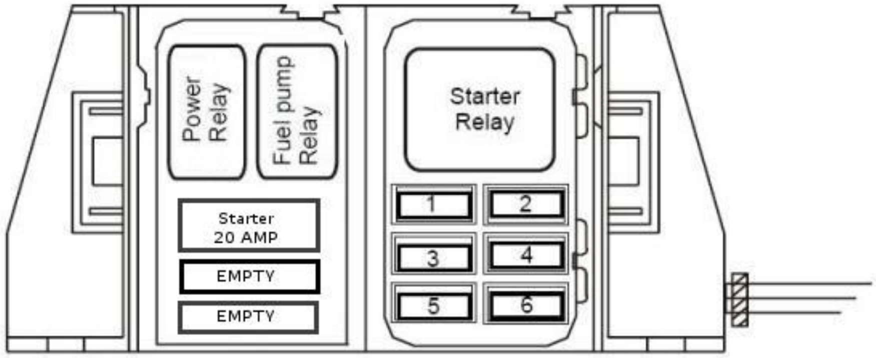
Diagrams and Schematics

Symbols



GCP - Power Distribution Box

Part of -5210130- Engine Wiring Harness



Fuse	Amps	Circuits protected
1	10	Battery Voltage to EPR
2	5	Ignition Voltage to GCP and Relays
3	10	Battery Voltage to GCP
4	15	Fuel pump
5	15	Battery Voltage out of Power Relay
6	10	Alternator

Wire Colors

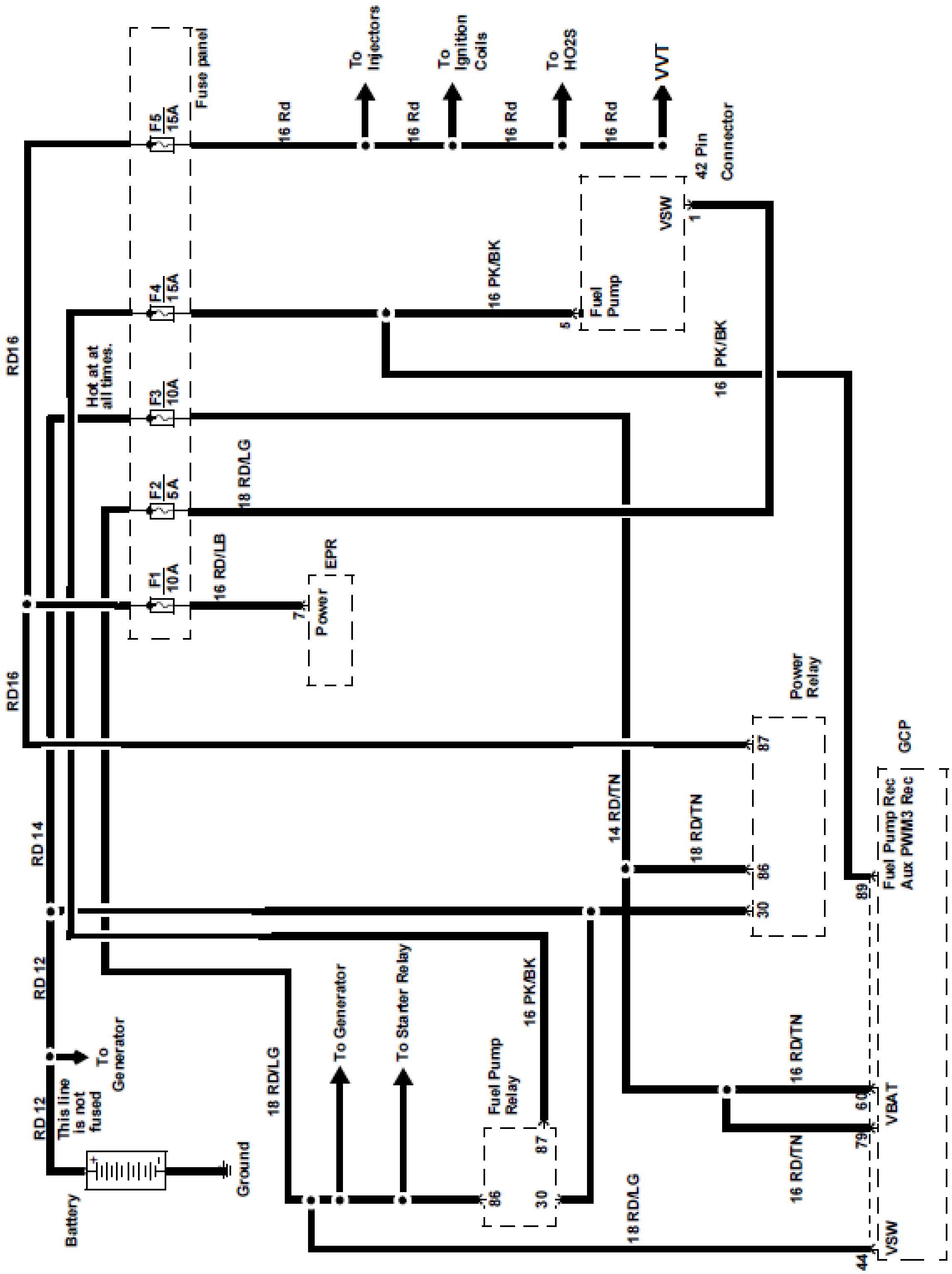
Symbol	Color
BK	BLACK
BN	BROWN
BU	BLUE
DB	DARK BLUE
DG	DARK GREEN
GN	GREEN
GY	GRAY
LB	LIGHT BLUE
LG	LIGHT GREEN
NA	NATURAL
OG	ORANGE
PK	PINK
RD	RED
SR	SILVER
TN	TAN
VT	VIOLET
WH	WHITE
YE	YELLOW

Revision Level

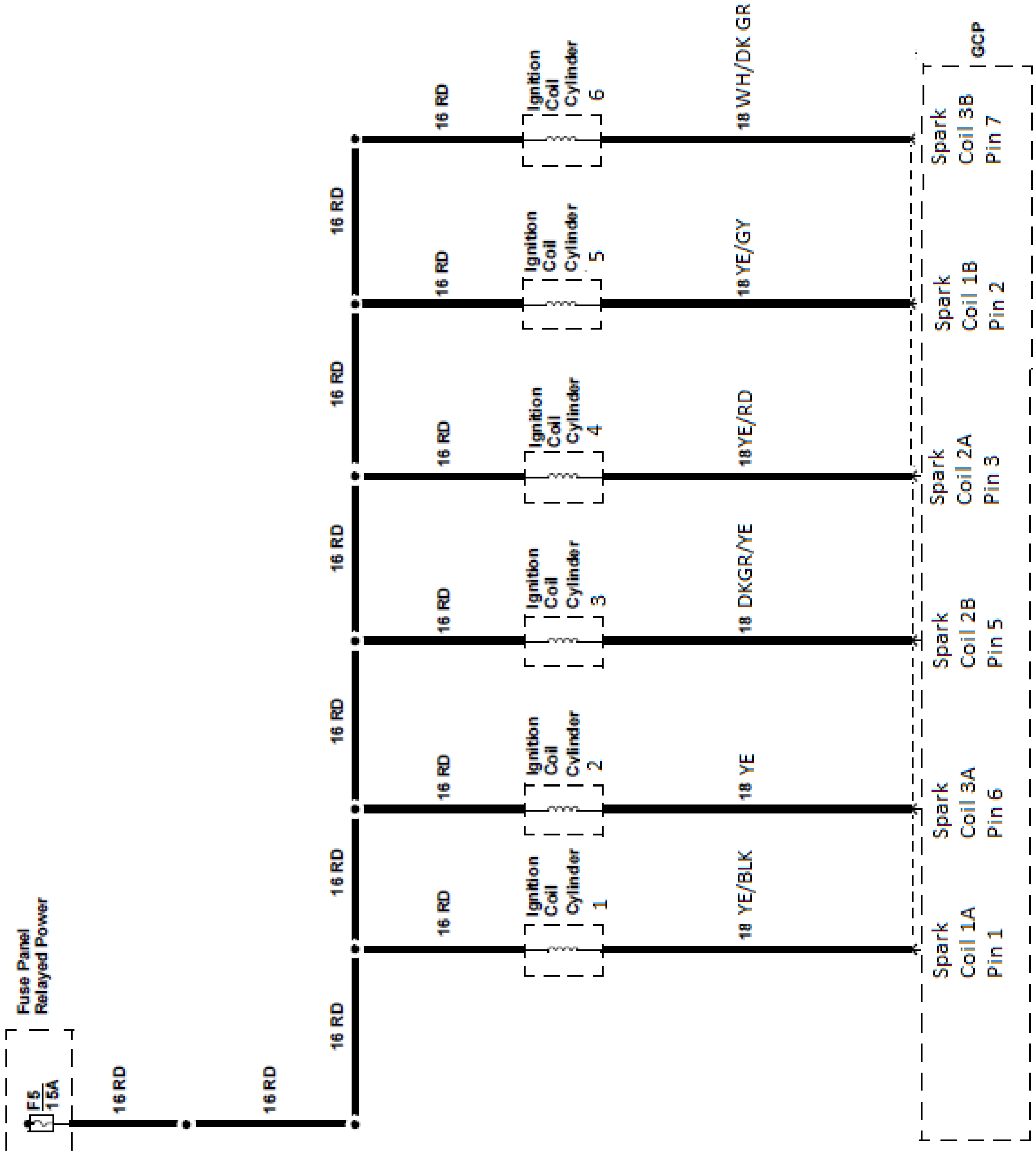
The following wiring schematics are taken from the wiring diagram labeled below:

Title: EDI / FORD 3.5L Bi–Fuel		
Size: D	Number: 5210130	Rev: 2
Date: 10/10/2020	Drawn By: J. SUTTON	
Filename: FORD_35L_BIFUELr2.sch	Sheet 1 of 1	

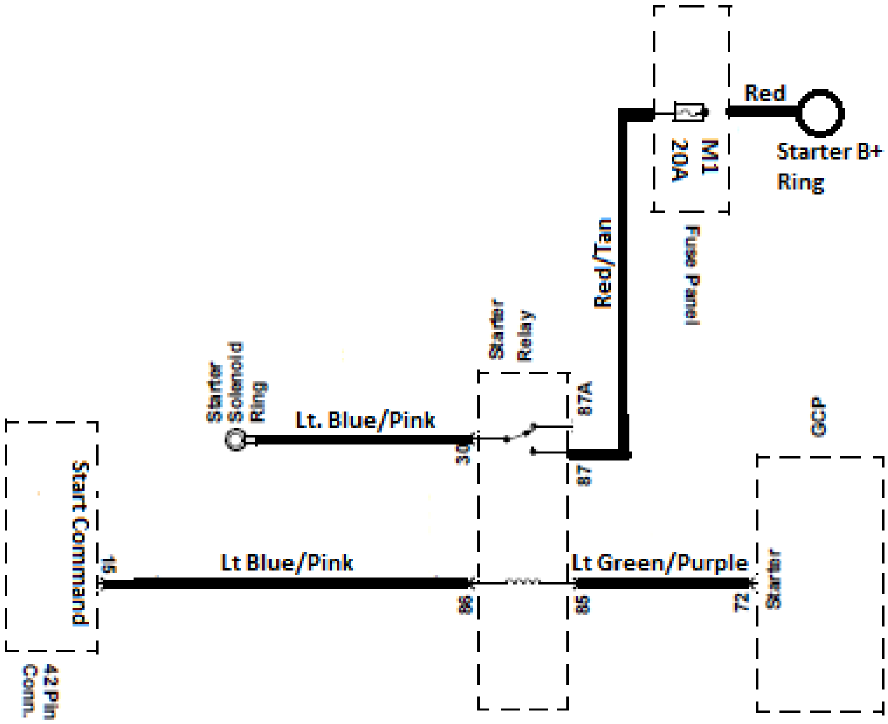
Power Distribution



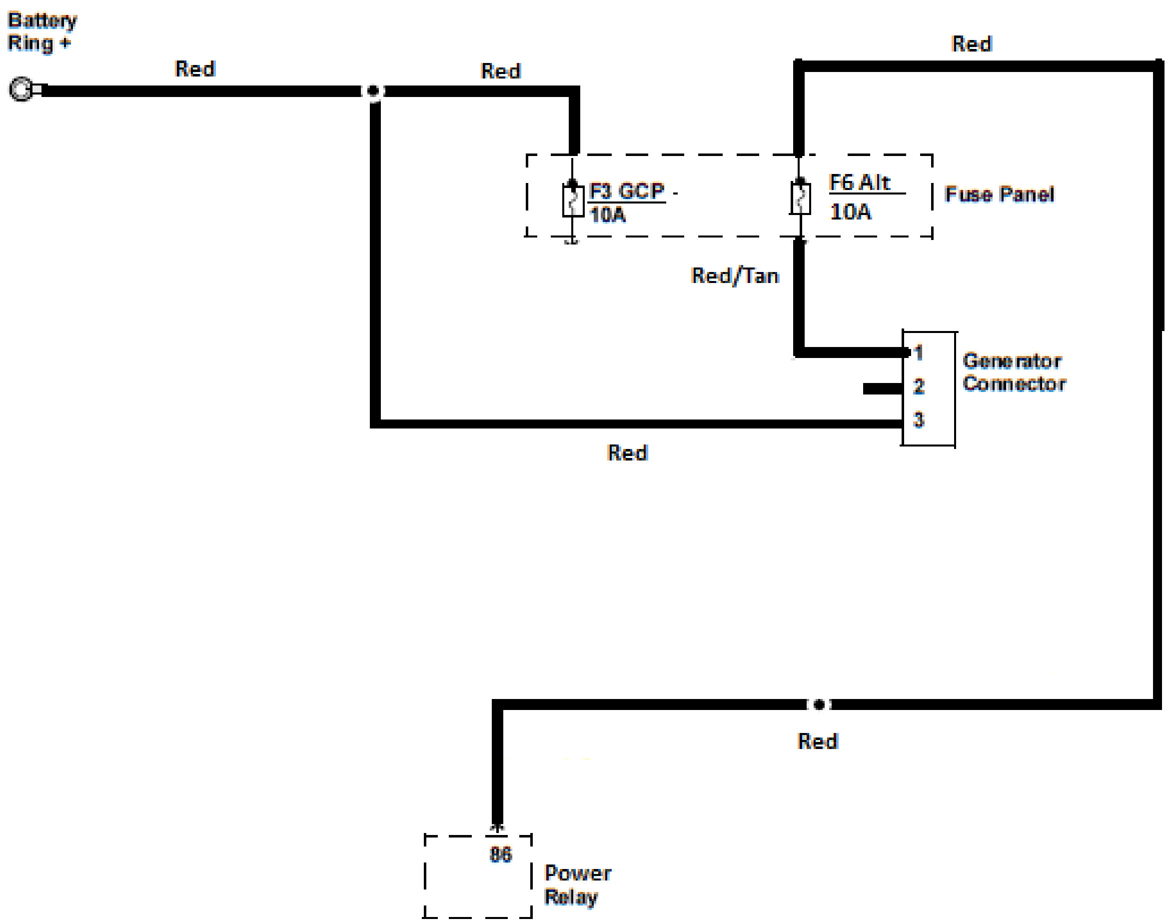
Ignition System



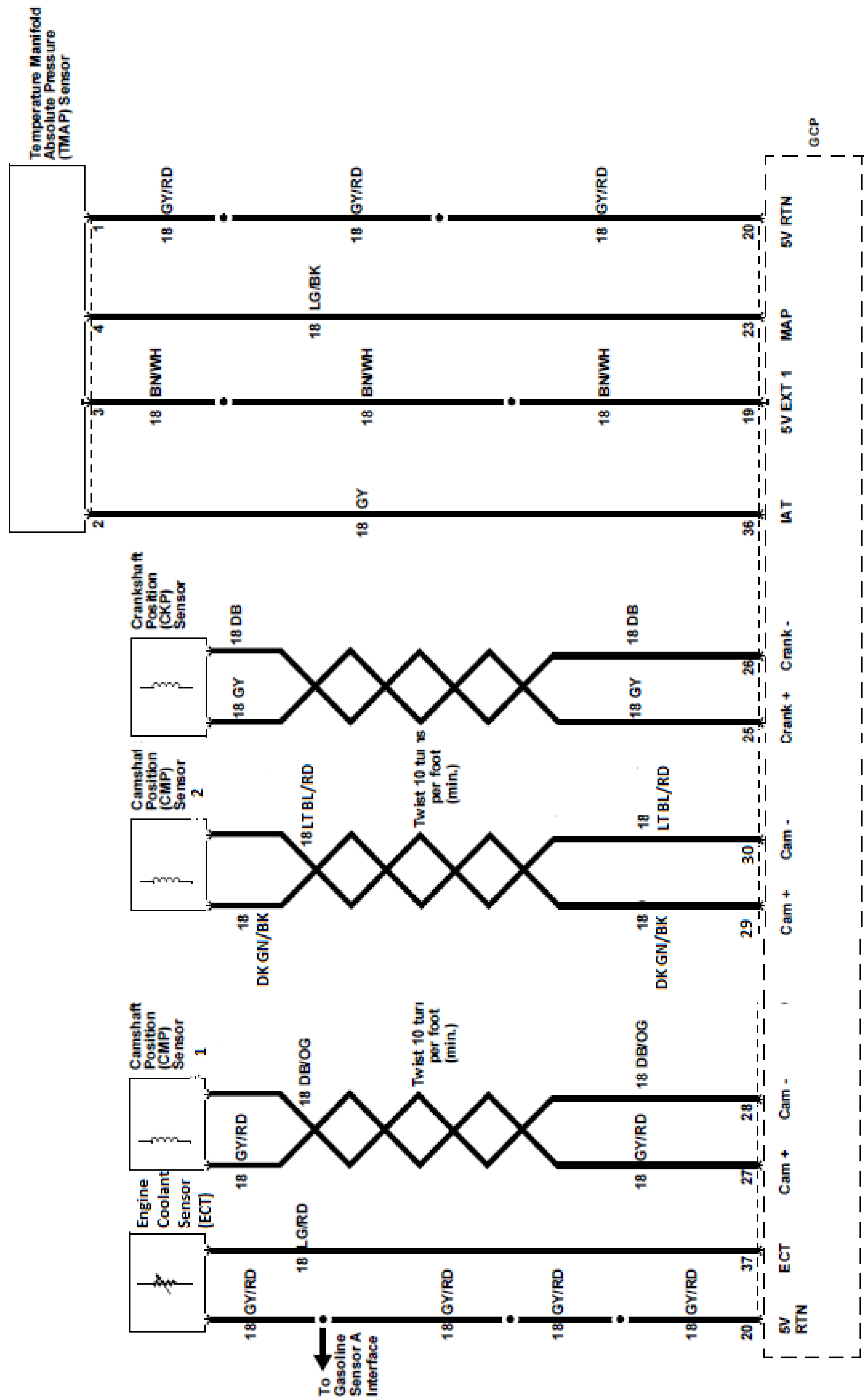
Starting System



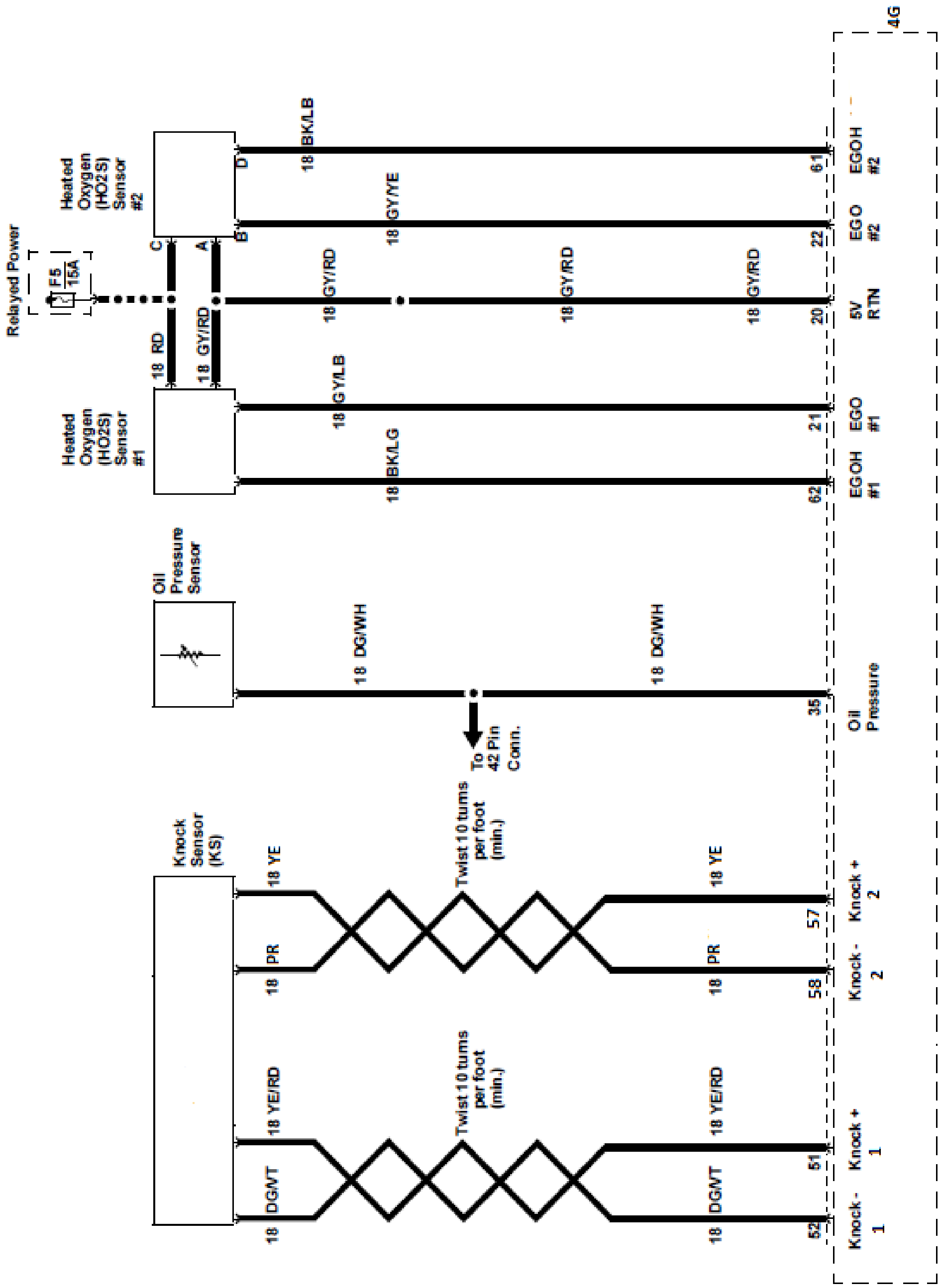
Charging System



Engine Controls - Sensors (1 of 2)



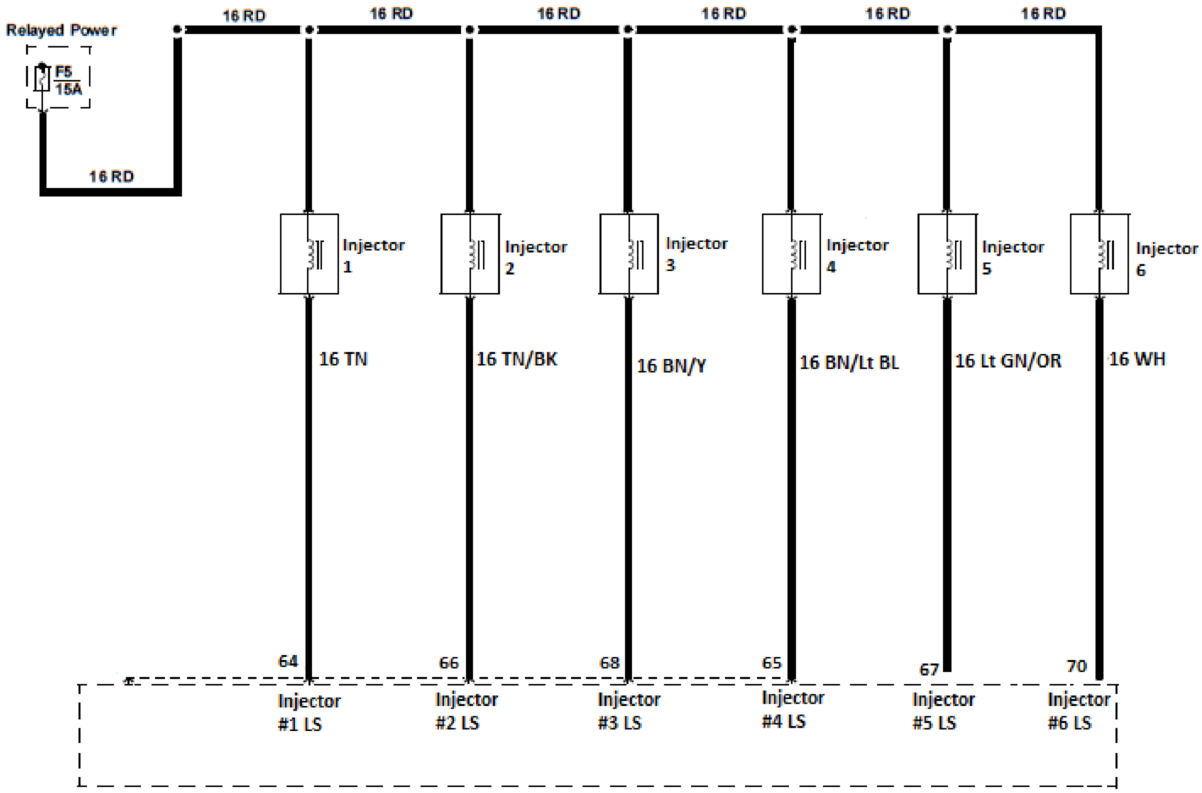
Engine Controls - Sensors (2 of 2)



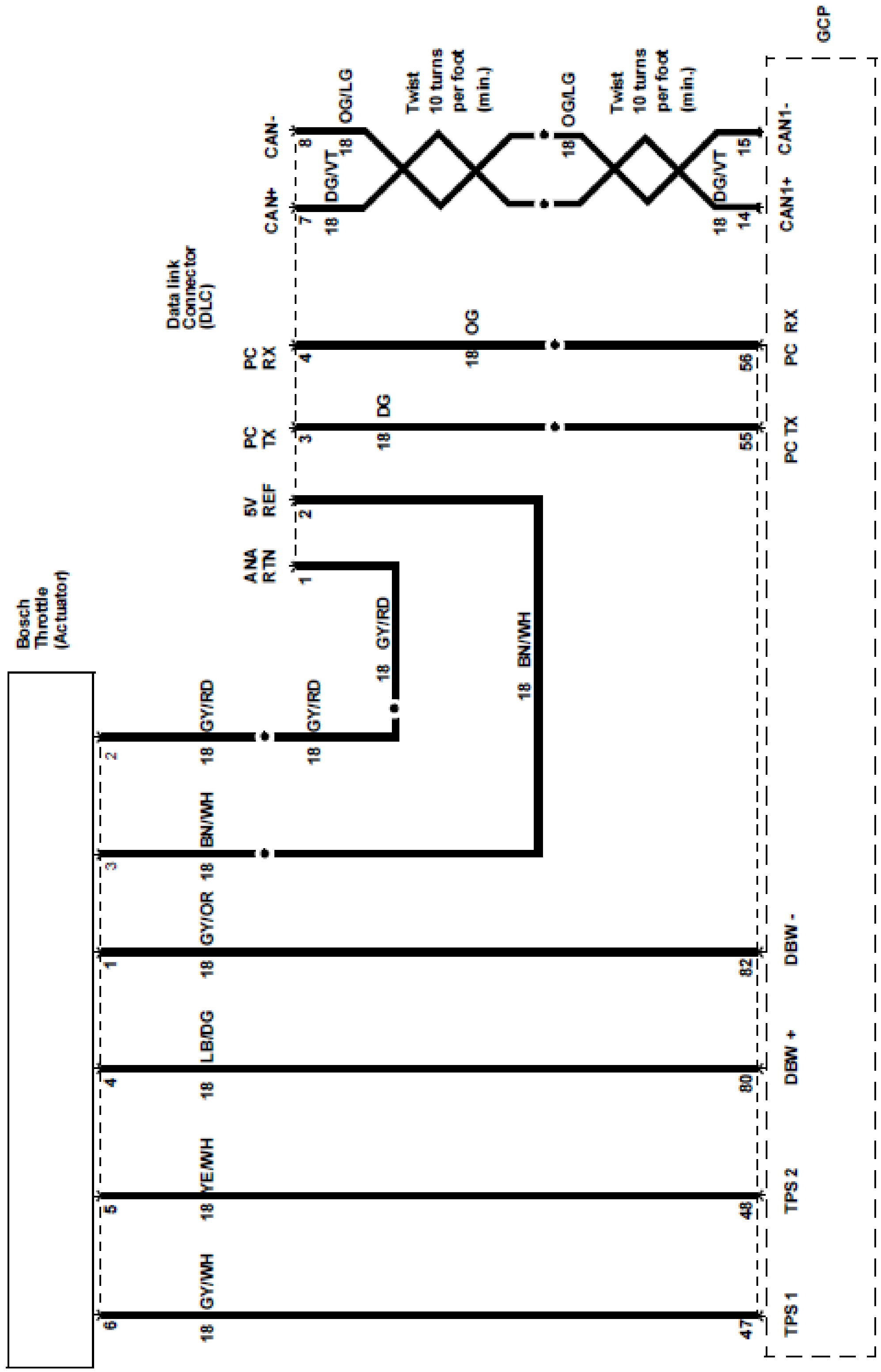
Fuel

Injectors

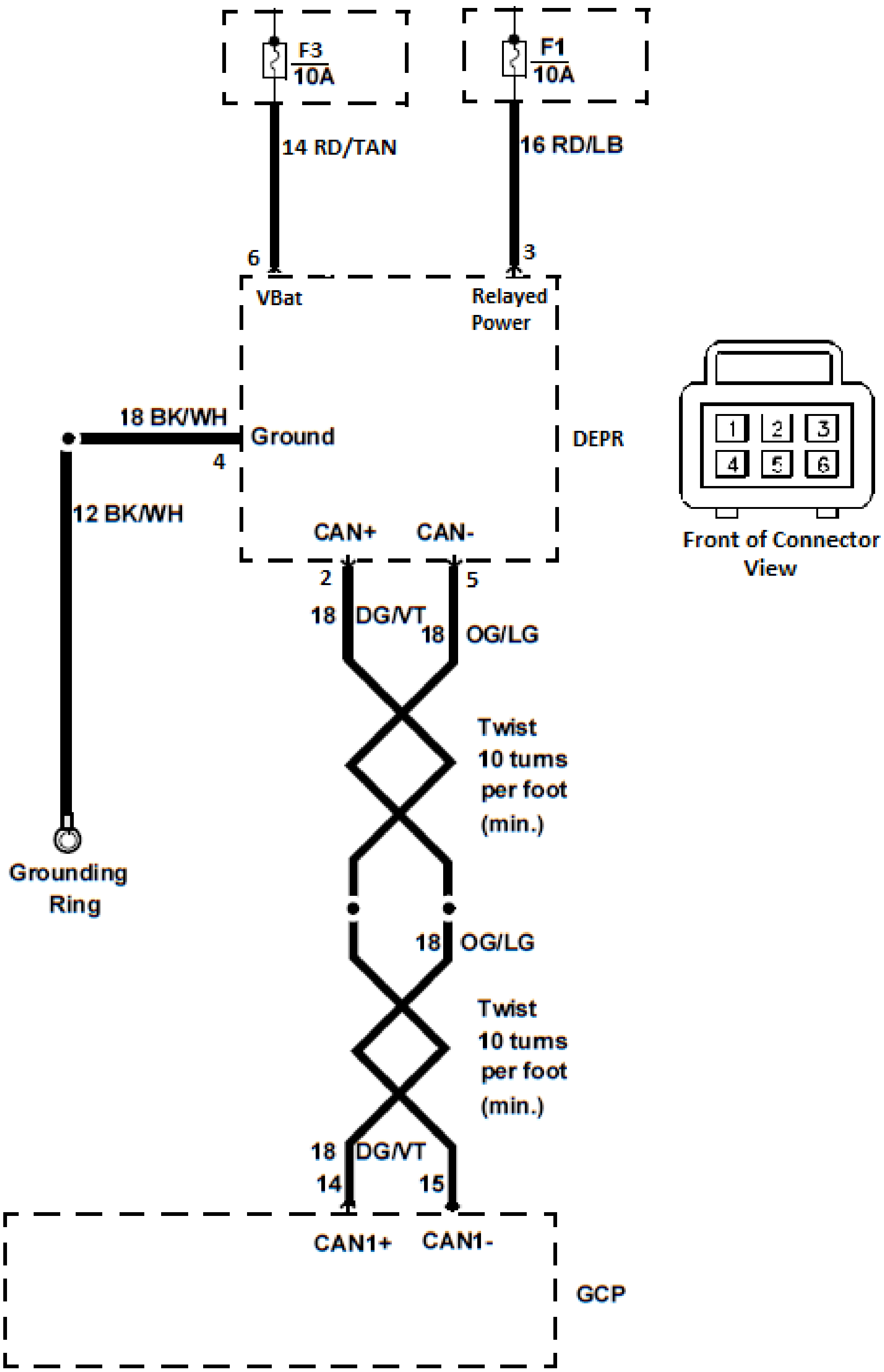
Engine Controls – Fuel Injectors



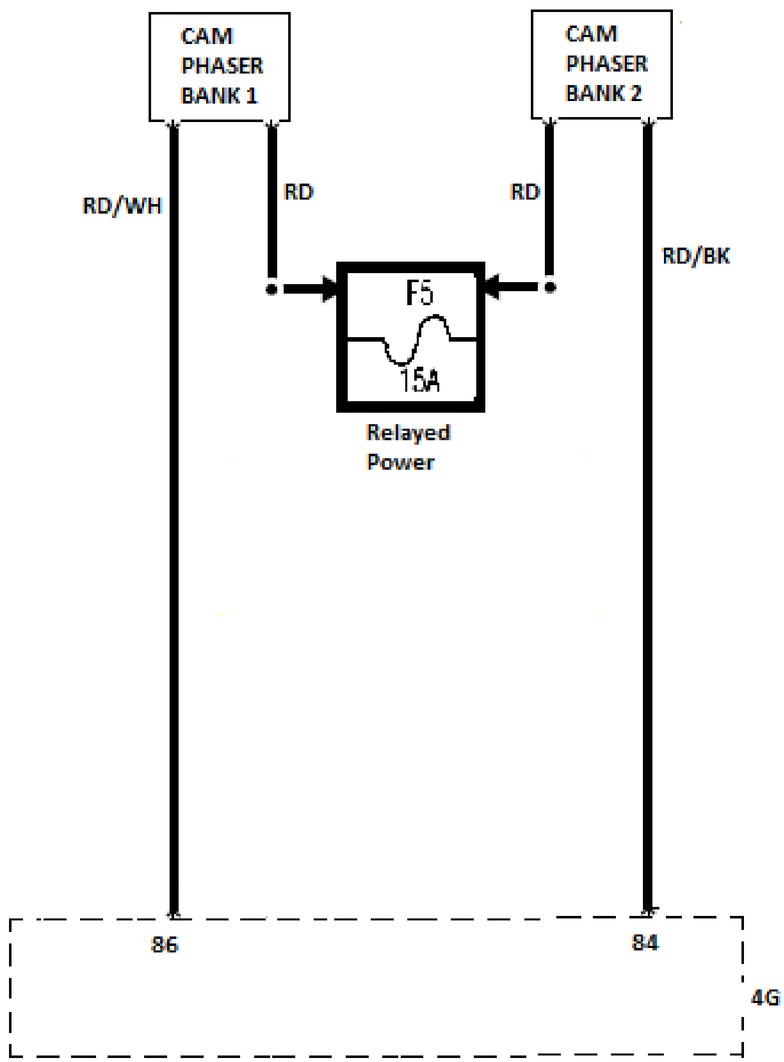
Engine Controls - Actuator / Data Link Connector (DLC)



Engine Controls - Dry Fuel DEPR



Cam Phasors


CAM
PHASER
BANK 1
CAM
PHASER
BANK 2
RD/WH
RD
RD
RD/BK
F5
15A
Relayed
Power
86
84
4G

DIAGNOSIS AND TESTING

Diagnostic Approach

Use the following step by step approach when diagnosing an engine performance problem:

1. Verify the concern and determine if it is a deviation from normal operation.
2. Once the concern has been verified, preliminary checks can be done. Conduct a thorough visual inspection, be alert for unusual sounds or odors, and gather diagnostic trouble code (DTC) information.
3. If a diagnostic trouble code (DTC) is stored, follow the designated DTC chart exactly to make an effective repair.
4. If no DTC is stored, select the symptom from the symptom charts and follow the suggestions to complete the repair.
5. If no matching symptom is available, analyze the complaint and develop a plan for diagnostics utilizing the wiring diagrams, technical assistance and repair history.
6. Some diagnostic charts contain diagnostic aids which give additional information about a system. Be sure to use all of the information that is available to you.

GCP Diagnostic Overview

FORD Diagnostic Trouble Codes are set when the FORD system GCP runs a diagnostic self-test and the test fails. When a DTC is set, the FORD system GCP will illuminate the Malfunction Indicator Lamp (MIL) on the instrument panel and save the code in memory.

The FORD system GCP will continue to run the self-test unless the DTC is an oxygen sensor lean, oxygen sensor rich, or a GCP related DTC. If the system continues to fail the test, the lamp will stay illuminated and the DTC is current (ACTIVE). All DTC's are stored as historical faults until they are cleared. All DTC's except the GCP related DTC's will automatically clear from memory if the DTC does not reset within 50 consecutive engine run cycles.

While a Diagnostic Trouble Code is current for a sensor, the FORD system GCP may assign a default limp home value and use that value in its control algorithms. All of the FORD system diagnostic self-tests run continuously during normal engine operation.

The Diagnostic Trouble Codes can be read by using either the Malfunction Indicator Lamp (MIL) or a Laptop computer. Refer to Using a Laptop Computer to Diagnose the FORD System and Using a Diagnostic Jumper to Diagnose the FORD System, located in this section. Diagnostic Trouble Codes can be cleared from memory with a laptop computer or by turning the ignition key to the OFF position and removing the FORD system main power fuse (F3) for 15 seconds.

If more than one DTC is detected, begin with the lowest number DTC and diagnose each problem to correction unless directed to do otherwise by the fault tree. The DTC's are numbered in order of importance. Having DTC 112 and DTC 122, both concerning the oxygen sensor, is possible. By repairing DTC 112 first, the problem causing the DTC 122 may also be corrected.

On-Board Diagnostics - GCP

The diagnostic tests and circuit charts are designed to assist the technician to locate a faulty circuit or component through a process of logical decisions. The tests and charts are prepared with the requirement that the engine functioned correctly at the time of assembly and that there were not multiple faults present.

There is a continuous self-diagnosis on certain control functions. This diagnostic capability is complimented by the diagnostic procedures contained in this section. The language for communicating the source of the malfunction is a system of diagnostic trouble codes.

When a malfunction is detected by the Engine Control Module (GCP), a Diagnostic Trouble Code (DTC) is set and the Malfunction Indicator (MIL) lamp will be illuminated (refer to MIL DTC Retrieval Procedure for process description) -- Refer to "Diagnosis Using a Personal Computer" on page 26 or Palm Pilot Diagnosis, for information regarding performing GCP and engine control system diagnosis.

Engine Control Module (GCP) Limp Home Mode Strategy

The GCP has four settings for limp home mode. Depending on what Diagnostic Trouble Code (DTC) is set, one or more of the limp home modes will be in effect.

The four limp home modes are as follows:

Power Derate 1

The actuator is limited to a maximum opening of 50%. If "Power Derate 1" is active, it will remain active until the active DTC goes away.

The following DTC's will cause Power Derate 1 to take affect:

- DTC 1521: CHT/ECT higher than expected 1. (CHT/ ECT is greater than 240 °F).
- DTC 111: IAT higher than expected 1. (IAT is greater than 200°F).
- DTC 327: Knock sensor open. (1.6L and 4.2L only)
- DTC 326: Excessive knock signal. (1.6L and 4.2L only)
- DTC 2122: FPP1 high voltage.
- DTC 2123 FPP1 low voltage.
- DTC 2128: FPP2 high voltage.
- DTC 2127: FPP2 low voltage.
- DTC 1531: IVS/Brake interlock failure.

Power Derate 2

The actuator is limited to a maximum opening of 20%. If "Power Derate 2" is active, it will remain active until the active DTC goes away and the ignition input to the GCP (usually the ignition switch) is cycled.

- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.
- DTC 1171: MegaJector delivery pressure higher than expected.
- DTC 1172: MegaJector delivery pressure lower than expected.
- DTC 1173: MegaJector communication lost.
- DTC 1176: MegaJector internal actuator fault detection.
- DTC 1177: MegaJector internal circuitry fault detection.
- DTC 1178 MegaJector internal communication fault detection.
- DTC 606: COP failure (Internal GCP failure).
- DTC 1612: RTI 1 loss (internal GCP failure).
- DTC 1613: RTI 2 loss (internal GCP failure).
- DTC 1614: RTI 3 loss (internal GCP failure).
- DTC 1615: A/D loss (internal GCP failure).
- DTC 1616: Invalid interrupt (internal GCP failure).
- DTC 601: Flash checksum invalid (internal GCP failure).
- DTC 604: RAM failure (internal GCP failure).

Fault Low Rev Limit

The engine RPM will be limited to a maximum of 1600 RPM. If the "Fault Low Rev Limit" is active, it will remain active until the active DTC goes away and the ignition input to the GCP (usually the ignition switch) is cycled.

- DTC 2122: FPP1 high voltage.
- DTC 2123: FPP1 low voltage.
- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.
- DTC 1531: IVS/Brake interlock failure.

Force to Idle

The engine RPM will be limited to a maximum of 800 RPM. If the "Force to Idle" is active, it will remain active until the active DTC goes away.

- DTC 2122: FPP1 high voltage.
- DTC 2123: FPP1 low voltage.
- DTC 2128: FPP2 high voltage.
- DTC 2127: FPP2 low voltage.
- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.

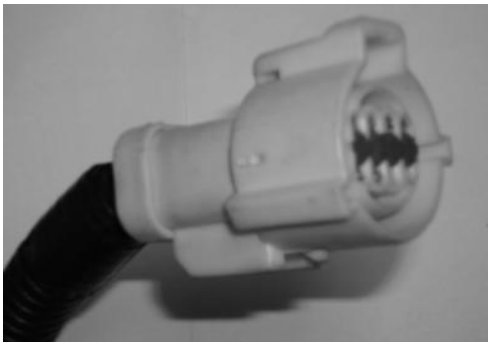
Intermittent MIL

Conditions that are only present from time to time are called intermittents. To resolve intermittents, perform the following steps:

1. Evaluate the history of DTC's observed with this particular engine.
2. Evaluate the symptoms and conditions described by the customer.
3. Use strategy-based diagnosis, especially where it relates to the elimination of bad connectors and wiring.
4. When using a personal computer with Ford software, data-capturing capabilities are available that can assist in detecting intermittents. Review the user manual pdf document that is included on the software CD.

Malfunction Indicator Lamp (MIL) DTC Retrieval Procedure

NOTE: DTC's can be retrieved from the engine control module (GCP) by using either the MIL or an IBM compatible personal computer with a USB port. Refer to Equipment Setup for information about using a personal computer to assist with unit diagnosis.



DTC's can be retrieved by shorting the Self-Test Input (STI) connector to ground. The STI circuit is a white/ purple wire exiting pin 3 of the 42 pin connector. 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 1654 is flashed, indicating that all systems are OK.

During key on/engine running (KOER) operation, with no DTCs stored, the MIL is not illuminated. If during

KOER operation a DTC is stored, the MIL will illuminate and remain on steady if the code is active.

MIL Bulb Test

The MIL bulb test occurs KOEO with the STI connector not grounded. The MIL bulb will stay on and remain on if no DTCs are present. If DTCs are present (except DTC 1654), the MIL bulb will blink. If the MIL bulb does not illuminate when bulb test is performed, access diagnostic software and view the fault indicator on screen. If the screen fault indicator is illuminated and the MIL light is not, inspect the bulb and replace it if damaged. If bulb is OK or does not illuminate after replacement, refer to MIL circuit test procedure. Once MIL bulb illumination has been verified or established, DTCs can be extracted from the MIL as follows:

DTC Extraction

- KOEO, short the STI circuit to a known good ground. There will be a 5 second delay before DTCs begin flashing.

When extracting DTCs via the MIL the following apply:

- The flashing MIL is on for 0.4 second and off for 0.4 second.
- The MIL is off for 1.2 seconds between digits of three digit DTCs.
- The MIL is off for 2.4 seconds between DTCs.
- Each DTC repeats 3 times before the next stored DTC begins flashing
- Up to 6 DTCs can be stored.
- Once all stored DTCs are flashed, the process repeats with the first stored DTC.
- DTCs are flashed in the order in which they were set.

Once the DTC(s) is retrieved, refer to the appropriate DTC chart for explanation of what caused the DTC to set. Perform component and circuit test as required to conduct repair.

Diagnosis Using a Personal Computer

Equipment Requirements

You will need a laptop computer with a USB Port and CD drive.

- Kit for laptop part #: 5080050
  - ECOM Cable
  - Software CD

The required software is included with the kit via a CD.

Laptop Requirements:

• USB port
• 800 x 600 dpi screen
• Windows 95 or newer operating system
• No speed minimum
• 32 MB of RAM

Interface Hook-Up
For a connection to a laptop, use the below ECOM cable (5080050).

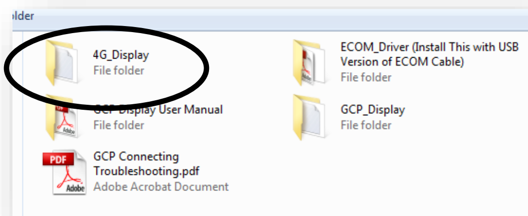
4G Display Software Installation

Insert CD into CD-ROM drive.

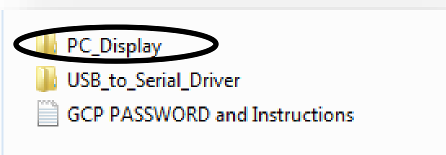
Double click “My Computer” Icon.

Double Click CD-ROM drive letter

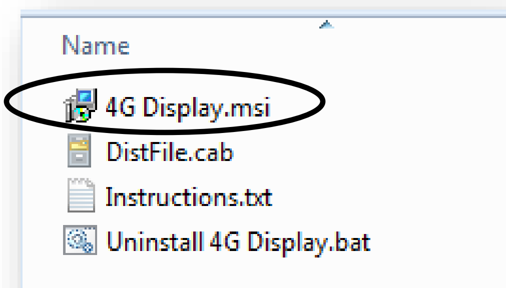
This will display the contents of the CD as shown.



Double click GCP_Display folder.



Double click the PC_Display folder.

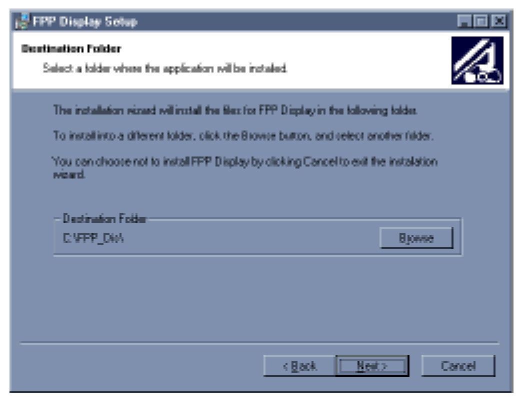


Double click the 4G Display icon.

You will now see a welcome screen.

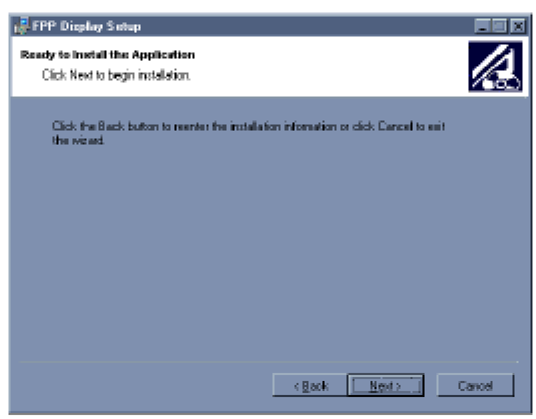
Click next.

A screen will pop up telling you the name of the destination folder.



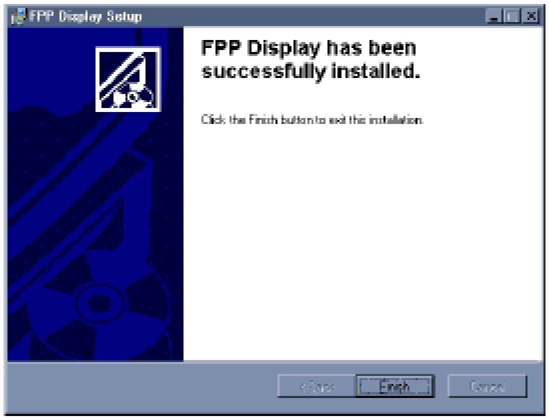
Click next.

You will now see a screen telling you it is ready to install the software.



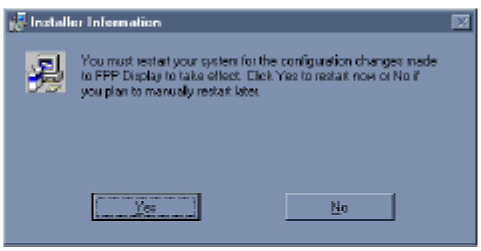
Click next.

You will see an Installation Success" screen when the software is finished installing.



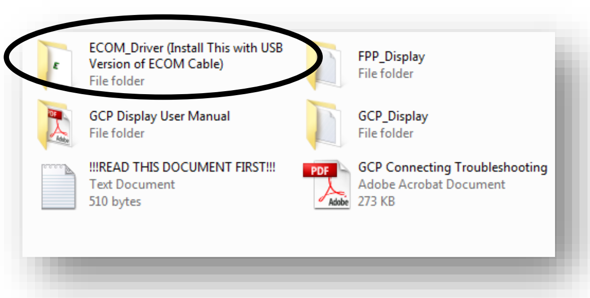
Click Finish.

A screen will pop up asking if it is ok to reboot your system.

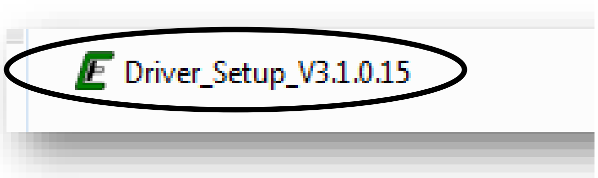


Click No.

Go back to the main CD folder.



Double click the ECOM driver folder.



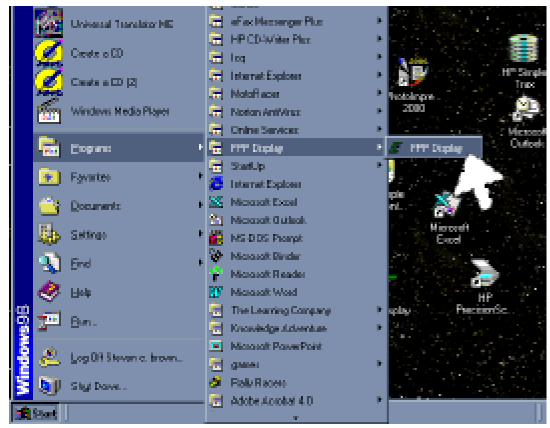
Double click the Driver Setup icon.

Follow those install instructions. Once successfully installed reboot your system.

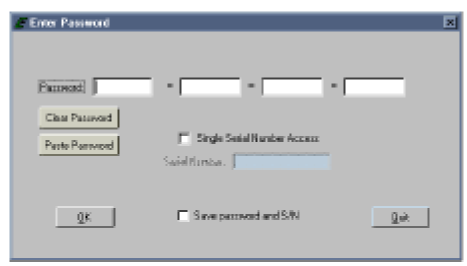
The software is now installed on your system in a folder called "GCP Display". Refer now to "Using Technicians GCP Software" in this Section.

Using GCP Software - Menu Functions

You can begin using the technicians GCP software after installation, by clicking Start - Programs - GCP Display - GCP Display as shown.



Type in the Password which can be found in the text file on the CD in the GCP Display folder.

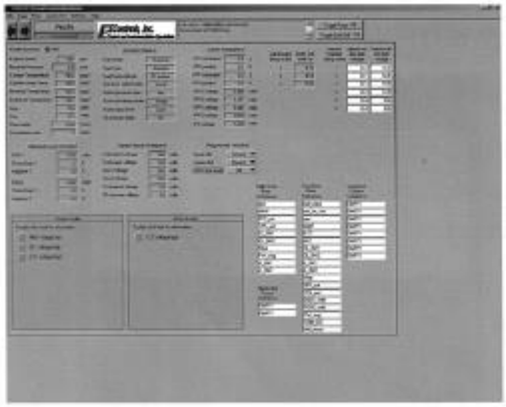


Place the ignition key in the ON position.

The GCP system Gauge screen should now appear and a green banner in the upper left hand corner will read "Connected".

Diagnostic Trouble Codes

The System Fault screen is used to view and clear DTC's, which have been set.



Checking Diagnostic Trouble Codes

The System Fault screen contains a listing of all of the Historic and Active DTC's set within the GCP system. If a DTC is stored in memory, the screen will display that fault in the Historic Faults column. If the fault condition currently exists, the DTC will also show up in the Active Faults column.

Opening Diagnostic Trouble Codes

To open a DTC, click on the DTC in the Historic Faults column. A DTC Dialog Box will pop up on the screen. The DTC Dialog Box contains the following useful information:

- If the fault occurred during the current key cycle.
- If the fault caused current engine shutdown.
- How many key cycles since the fault was active.
- Snapshot Data (explained later).
- Flight Data Recorder (explained later).

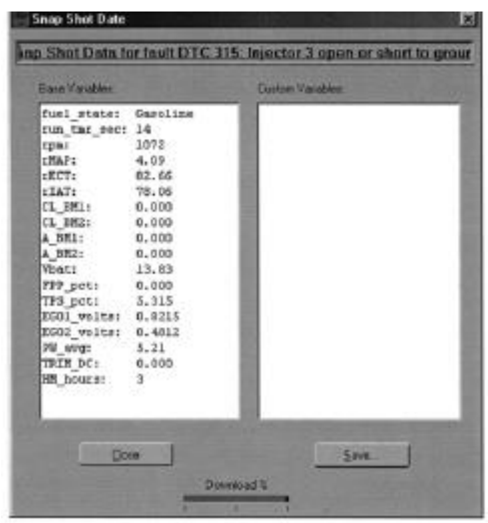
The DTC Dialogue Box also allows you to clear a single fault by clicking on the "Clear This Fault" button and it allows you to clear all faults by clicking on the "Click All Faults" button.

NOTE: Record faults before clearing them. This will aid in diagnosis.

Below is an example of a DTC Dialogue Box.

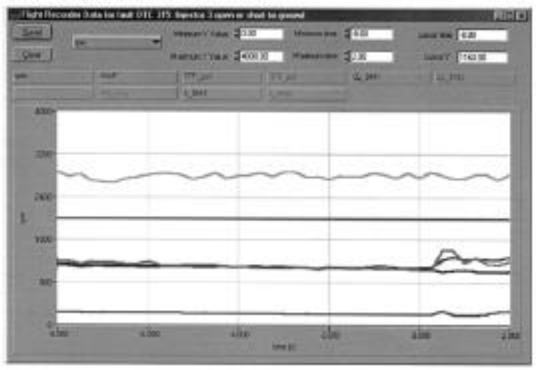
Snap Shot Data

The Snap Shot Data is a listing of specific engine system variables. These variables are recorded by the GCP at the instant the DTC sets. By clicking on the "View Snap Shot Data" button, a new window will pop up and you will be able to view these variables. Here is an example of a Snap Shot Data window.



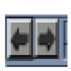
Flight Data Recorder
The Flight Data Recorder is also a listing of specific engine system variables. These variables are recorded by the GCP for an interval of 10 seconds. The 10 second interval includes 8 seconds before the DTC sets and 2 seconds after the DTC sets. By clicking on the “View Flight Data Recorder Data” button, a new window will pop up and you will be able to view these variables.

Below is an example of a flight Data Recorder Data window.



The FAULTS screen shows the following:

- Fault Access
- System States
- DBW Variables
- Closed Loop Control
- Digital Input Voltages
- Diagnostic Modes
- Historic Faults
- Active Faults

Use the  keys at the upper left corner or the “page” command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

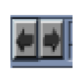
Data Stream - Reading Sensor & Actuator Values

Most applicable sensor and actuator values are displayed on the Gauges Screen. The display shows the voltage the FORD system GCP is reading and, for sensors, the sensor value in engineering units.

This is one of three main screens (GAUGES, FAULTS AND RAW VOLTS).

The GAUGES screen shows the following:

- Manifold Absolute Pressure (MAP)
- Engine Coolant Temperature (ECT)
- Intake Air Temperature (IAT)
- Throttle Position (TP)
- Foot Pedal Position (FPP)
- Battery Voltage
- Engine speed (RPM)
- Exhaust Gas Oxygen (HO2S)
- Hour meter
- Number of continuous starts
- Run mode, power mode and fuel type

Use the  keys at the upper left corner or the “page” command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

NOTE: If a DTC for a sensor is current, the engineering value for that sensor may be a default, limp home value and the voltage value will be the actual sensor voltage. Use the voltage value when performing diagnostics unless directed to do otherwise by the diagnostic trouble tree.

Plotting and Data Logging

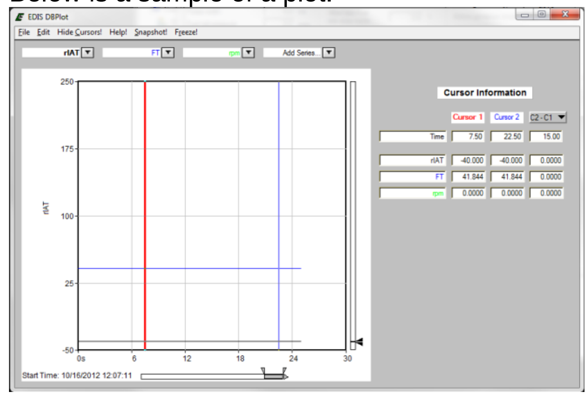
Recording the values and voltages can be a very useful tool while diagnosing engine problems. The GCP diagnostic software includes real time **plotting** and real time **logging** capabilities. These features enhance the ability to diagnose and repair possible problems with the GCP system. Both plotting and logging allows the user to record, in real time, any variable that can be seen in the GCP_Dis software. In order to record variables, the GCP_Dis software must be “Connected” to the GCP.

Plotting

To plot a variable, you must first “TAG” the variable. To do this, use the mouse to right click on the variable. The variable will highlight in green to let you know it is “TAGGED”.
Next, press the “P” key or click the Plot/Log button and then click the Plot Tags button to invoke the plotting feature. This begins the plot function and you can observe the plotted variables. The plot sweeps from right to left. To stop the plotting feature, simply click the “Freeze”. To restart the plotter, click on the “Resume” button. The maximum number of variables that can be plotted at one time is 10. The range of the selected variables will be shown on the Y-axis and the time will be shown on the x-axis. You may change the desired time interval and sample interval for the plot by stopping the plot and typing in a new intervals.

The plot can be saved to the PC by stopping the plot and clicking “File” then “SAVE”. When saving a plot, you will have to type in a filename. Plot files can later be viewed with the edis_saplot software located in the Windows Start Programs GCP_Dis folder, or the data can be viewed in Notepad or Excel.

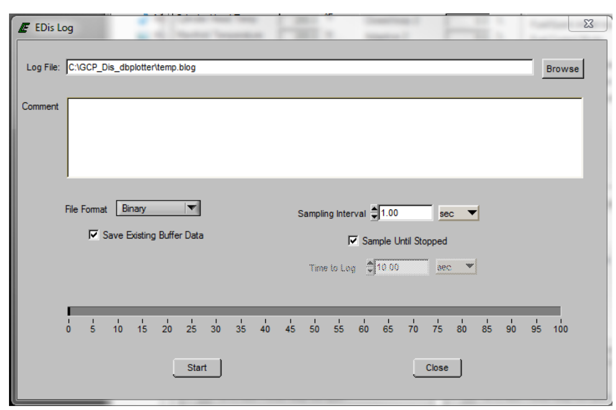
Below is a sample of a plot.



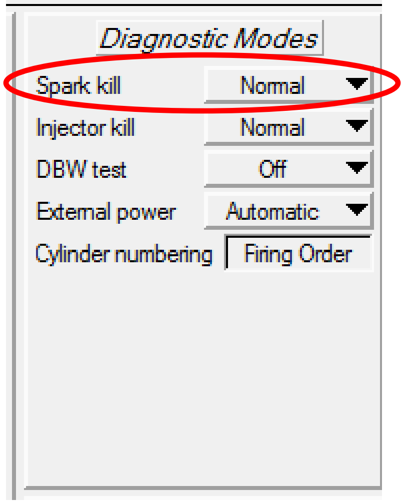
Logging

Logging variables means the variables are stored to the PC. During logging, there is no plot shown on the screen. To log variables you must first “TAG” the variables by right clicking them (same as plotting). Next, click on Plot / Log and then Log Tags. An “Edis Log” window will pop up. You can type in a custom log File name or select a custom folder to save the log file to. The default filename is “edis.log” and the default folder is GCP_Dis. The sample interval and time interval can also be changed from the default. To start logging, click on the “START” button. You will see the progress bar moving from 0 to 100%. When the logging is complete, you can close the Edis Log box or start another log file. If you start another log file, you must change the Log File name or the first log file will be overwritten. To view the contents of a saved log file, you can use Notepad or Excel.

The following are examples showing the Edis Log box before starting a log file, when running the log file the progress bar will move.



Ignition System Test



The Spark Kill diagnostic mode allows the technician to disable the ignition on individual cylinders. If the Spark Kill diagnostic mode is selected with the engine running below 1000 RPM, the minimum throttle command will lock into the position it was in when the test mode was entered. If the Spark System Test mode is selected with the engine running above 1000 RPM, the throttle will continue to operate normally.

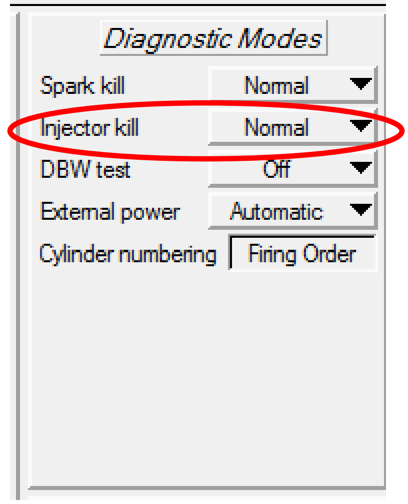
Spark kill is only available on gasoline, NOT on gaseous fuels.These diagnostic modes are found on the faults page.

Disabling Ignition Ouputs

To disable the ignition system for an individual cylinder, use the mouse to highlight the “Spark Kill” button and select the desired coil. The spark output can be re-enabled by using the mouse to highlight the “Spark Kill” button and selecting “Normal”. If the engine is running below 1000 RPM, the spark output will stay disabled for 15 seconds and then re-set. If the engine is running above 1000 RPM, the spark output will stay disabled for 5 seconds and then reset.
This test mode has a timeout of 10 seconds. Record the rpm drop related to each spark output disabled.

The Spark outputs are arranged in the order which the engine fires, not by cylinder number.

Injector Test

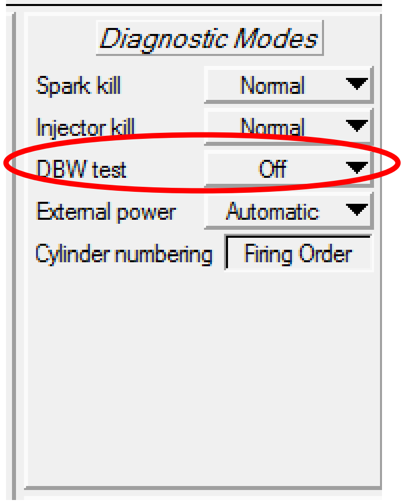


The Injector Kill mode is used to disable individual fuel injectors. If the Injector Kill mode is selected with the engine running below 1000 RPM, the minimum throttle **command** will lock into the position it was in when the test mode was entered. If the Injector Kill mode is selected with the engine running above 1000 RPM, the throttle will continue to operate normally.

Disabling Injectors

To disable an injector, use the mouse to select the desired injector. The word “Normal” will change to the Injector you have selected. The injector driver can be re-enabled by selecting again. If the engine is running below 1000 RPM, the injector driver will stay disabled for 15 seconds and then re-set. If the engine is running above 1000 RPM, the injector driver will stay disabled for 5 seconds and then re-set. Record the change in rpm or closed loop multiplier while each driver is disabled.

Throttle Test



To select this test mode the engine must be off, but the key must be in the ON position.

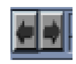
The DBW Test mode allows the technician to control the throttle directly (without the engine running) with the foot pedal or entering a number into the “TPS Command” box. It is used during the diagnostic routines specified for FPP (foot pedal position) and TPS (throttle position sensor) related faults.

FP position displays the current position of the foot pedal as a percentage. FPP volts display the voltage that the GCP is reading from the FPP sensor.

TPS Command displays the commanded throttle position expressed as a percentage, which is being sent to the throttle. TPS Position is the actual percent of throttle opening being sent to the GCP from the throttle. TPS volts display the actual TPS signal voltage the GCP is receiving from the throttle.

RAW VOLTS Screen

The RAW VOLTS screen shows actual voltage readings from various circuits.

Use the  keys at the upper left corner or the “page” command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

Visual Inspection

Perform a careful visual and physical engine inspection before performing any diagnostic procedure. Perform all necessary repairs before proceeding with additional diagnosis, this can often lead to repairing a problem without performing unnecessary steps. Use the following guidelines when performing a visual/physical inspection check:

- Inspect engine for modifications or aftermarket equipment that can contribute to the symptom; verify that all electrical and mechanical loads or accessory equipment is “OFF” or disconnected before performing diagnosis.
- Inspect engine fluids for correct levels and evidence of leaks.
- Inspect vacuum hoses for damage, leaks, cracks, kinks and improper routing, inspect intake manifold sealing surface for a possible vacuum leak.
- Inspect PCV valve for proper installation and operation.
- Inspect all wires and harnesses for proper connections and routing; bent or

broken connector pins; burned, chafed, or pinched wires; and corrosion. Verify that harness grounds are clean and tight.

- Inspect GCP, sensors and actuators for physical damage.
- Inspect GCP grounds for cleanliness, tightness, and proper location.
- Inspect fuel system for adequate fuel level, and fuel quality (concerns such as proper octane, contamination, winter/summer blend).
- Inspect intake air system and air filter for restrictions.
- Inspect battery condition and starter current draw.

If no evidence of a problem is found after visual inspection has been performed, proceed to "Diagnostic System Check"

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.

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.

Symptom Charts

NOTE: If you have a symptom of the pedal not working, and no DTC is set, go to the voltage screen and check pedal voltage. If pedal voltage is.75-1.25 volts, and idle validation switch says you're at idle - replace the pedal.

Engine Performance - No Load

NOTE: Items listed in the possible cause column generally do not set a diagnostic trouble code (DTC) or illuminate the MIL light.

NOTE: EDI engines are used in many different applications and equipment. When performing any system diagnosis be aware of any OEM inputs or equipment monitoring devices that may have an effect on the engine's performance or any of the engine's operating systems.

SYMPTOM	POSSIBLE CAUSE
Engine Runs Briefly and Shuts Down	• Loss of Spark • Frozen Fuel Regulator (Dry Fuel) • Low Fuel Pressure • Air Inlet Restriction • Wiring Failure • GCP Failure
Engine Cranks But No Start	• Faulty OEM Drivers Safety Shut-Off Seat Switch • Coil Power Loss • GCP Ground Loss • GCP Power Loss • Severe Vacuum Leak (Dry Fuel) • Air Inlet Restriction • Air Inlet Leak (Dry Fuel) • Fuel Lock-Off Inoperative (Dry Fuel) • Wiring Failure • Low Fuel Pressure • Ancillary Components Binding
Engine Runs Poorly	• High Fuel Pressure • Low Fuel Pressure • Contaminated Fuel • Incorrect Fuel Select Table Selected • Wrong GCP Installed • Actuator Air Blockage • Map Sensor Leak • Fuel Contaminated • Noise Suppression Capacitor Failure • Improper PCV Routing • Valve Timing • Low Cylinder Compression
Engine Cranks Slowly	• Excessive Engine Load (Hydraulic Pump Failing, Binding Ancillary Drive Components)\ • Low Battery Voltage • Incorrect Battery Specifications • Incorrect Battery Cable Size • Starter Relay • Starter Failure (Excessive Drain)
Engine Does Not Crank	• Dead Battery • Ground Loss • Ancillary Components Binding or Seized • OEM Shutdown - Oil Level Safety • Starter Lockout Relay Failure • Ignition Switch Failure • Bad Starter • Crank Control Wire Failure • Loose Connection or Corrosion

Engine Performance - While Under Load

SYMPTOM	POSSIBLE CAUSE
Engine Stalls/Quits	• Faulty OEM Drivers Safety Shut-off Seat Switch • Low Battery Voltage • Low Fuel Pressure • OEM Safety Shutdowns • Bad MAP Sensor • Air Restriction • Coil Failure • Fuel Mixer Binding (Dry Fuel)
Runs Rough	• Ground Loss • Misrouted Spark Plug Wires • Fuel System Failure • Vacuum Leak • Wiring Failure • Low Fuel Pressure • Spark Plugs Fouled • Incorrect Valve Timing
Misses	• Fuel System Failure • Misrouted Spark Plug Wires • Spark Plug Gap Too High • Spark Plugs Fouled • Cracked Spark Plug Insulator • Incorrect Valve Timing • Compression Loss
Hesitation/Stumble	• Low Fuel Pressure • Spark Plugs Fouled • MAP Sensor Vacuum Signal Loss
Surge	• Low Fuel Pressure • Map Sensor Failure • Application or Ancillary System Momentarily Binding During Load or Unload
Backfires	• Faulty OEM Drivers Safety Shut-off Seat Switch • Fouled Spark Plugs • Spark Plug Wire Broke • GCP Momentary Ground Loss • Excess Lean Condition • Fuel Lock-Off Leaking (Dry Fuel) • Intake Manifold Leak • Bad Intake Valve
Lack of Power	• Ancillary Components Binding • Intake Air Restriction • Crossed Spark Plug Wires • Spark Plugs Fouled • Fuel System Failure • Low Fuel Pressure • Low Cylinder Compression
Spark Knock	• Poor Quality or Contaminated Fuel • Carbon Build-up • Wrong Spark Plugs (Too High Heat Range) • Fuel Delivery System • PCV System • Fuel Selection Timing • Cylinder Hot Spots

Engine Concerns

SYMPTOM	POSSIBLE CAUSE
Oil System Concerns **- High Oil Consumption**	• Positive Crankcase Ventilation (PCV) System • Oil Viscosity • External Leaks • Improper Oil Dipstick • Valve Seals • Cylinder Wall Taper Excessive • Worn Piston Rings
Cooling System Concerns	• Trapped Air • Worn Drive Belt • Worn Water Pump • Stuck Thermostat • Plugged Radiator (Internal & External) • Dry Fuel System Running Rich
Exhaust System Concerns (visible smoke) **- Black Smoke** **- Blue Smoke**	• Ignition System • Fuel Delivery System • Sticking Fuel Injector • High Fuel Pressure • PCV System • Worn Piston Rings • Worn valve guides
Fuel System Concerns	• Leaky Lines • Contaminated Fuel • Excessive Alcohol in Fuel • Incorrect Octane Rating
Engine Noise	• Low Oil Pressure • Oil Filter Restriction

Engine Control Module (GCP) – Diagnostic Trouble Codes

CAUTION: When checking codes with the diagnostic software, the DTC terminal can NOT be grounded.

CAUTION: Removing battery power before accessing diagnostic program will erase all codes recorded.

This section contains circuit description information and troubleshooting charts on all the DTC's obtained by diagnostic software or a Malfunction Indicator Lamp (MIL). When diagnostic trouble codes are obtained by a Malfunction Indicator Lamp (MIL), the following sequence will be flashed:

- 1654 will flash 3 times to indicate the beginning of the flash code display sequence.
- Any active DTC's will flash 3 times each.
- 1654 will flash 3 times indicating the end of the code display sequence.

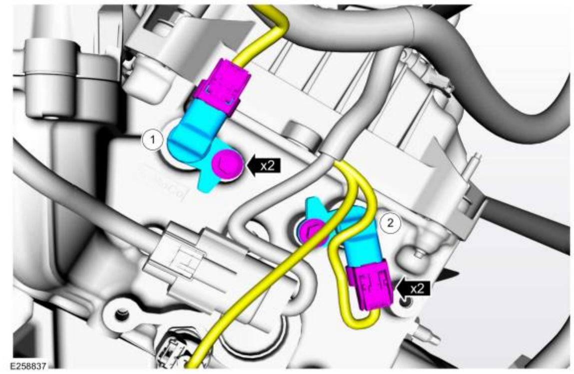
If code 1654 is the only code present, the system does not have any active codes - all systems are working fine.

If an active DTC is present, refer to the GCP diagnostic manual for code description and troubleshooting.

NOTE: If you have a symptom of the pedal not working, and no DTC is set, go to the voltage screen and check pedal voltage. If pedal voltage is .75 - 1.25 volts, and idle validation switch says you're at idle – replace the pedal.

REMOVAL AND INSTALLATION

Camshaft Position (CMP) Sensor - Replacement

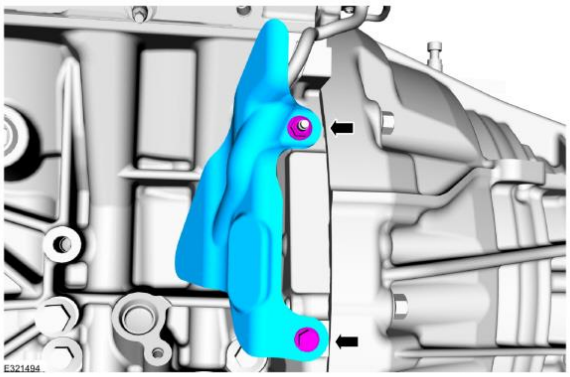


NOTE: Sensor is located at the back of the engine on both sides

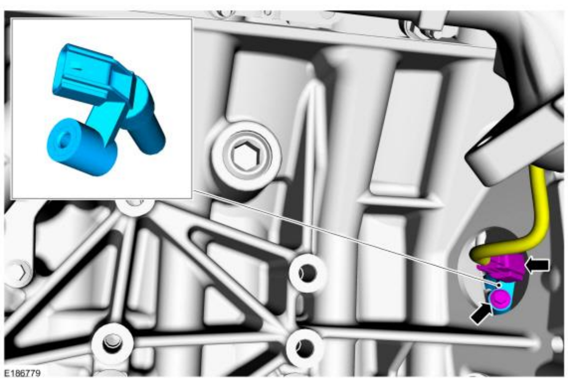
1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CMP Sensor.
3. Disconnect CMP electrical connector.
4. Remove bolt and CMP Sensor.
5. Reverse procedure to install:
   - Use a new o-ring seal
   - Lubricate o-ring with clean engine oil prior to installation
   - Tighten bolt to 10 Nm (89 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. Remove the nut, bolt, and heat shield
    - Torque: 10 Nm (89 lb-in)



4. Disconnect CKP electrical connector underneath rubber protector.
5. Remove bolt and CKP sensor.
    - Torque: 6 Nm (53 lb-in)



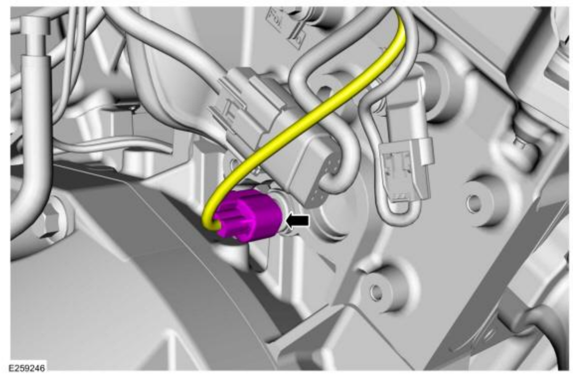
Crankshaft Position (CKP) Sensor - Installation

1. To install, reverse the removal process.

Cylinder Head Temperature (CHT) Sensor- Replacement

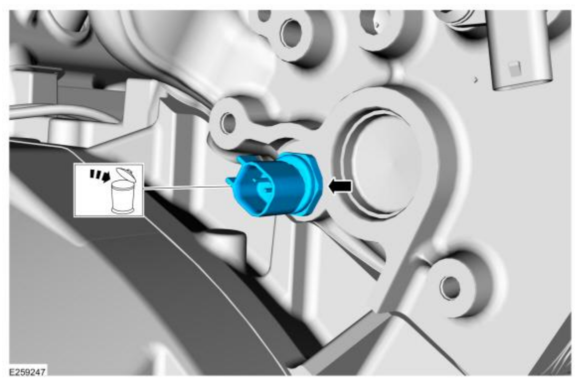
NOTE: Removal steps in this procedure may contain installation details.

1. Disconnect battery ground cable -- refer to section 6
2. Disconnect the CHT sensor.



NOTE: Do not reuse the CHT sensor, install a new sensor.

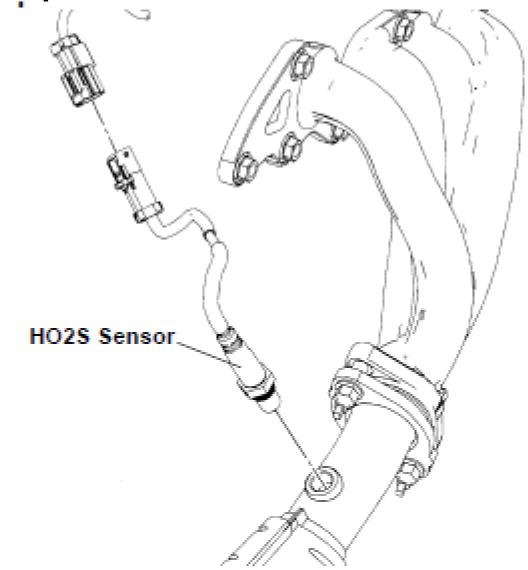
3. Remove and discard the CHT sensor
    - Torque: 11 Nm (97 lb-in)



Installation

1. To install, reverse the removal procedure.

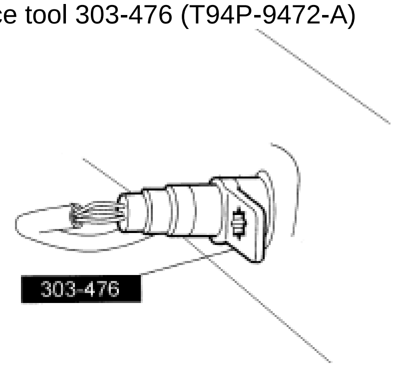
Heated Oxygen Sensor (HO2S) - Replacement



4. Disconnect battery ground cable -- refer to section 6
5. Remove or disconnect any component to allow access and removal of the HO2S Sensor.
6. Disconnect HO2S electrical connector.

NOTE: Use penetrating oil to assist in removal.

7. Remove HO2S sensor using special service tool 303-476 (T94P-9472-A)

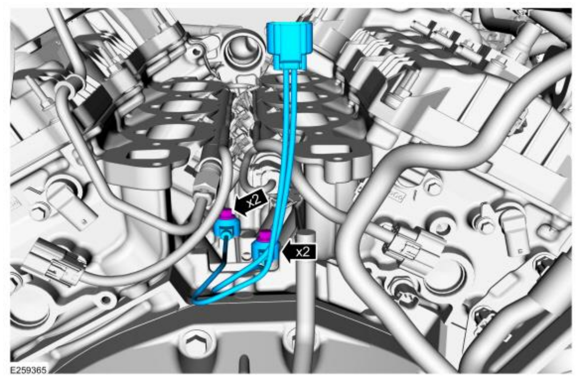


8. Reverse procedure to install:
   - Apply a light coat of anti-seize lubricant to the threads of the sensor.
   - Tighten sensor to 48 Nm (35 lb-ft).

Knock Sensor (KS) – Replacement

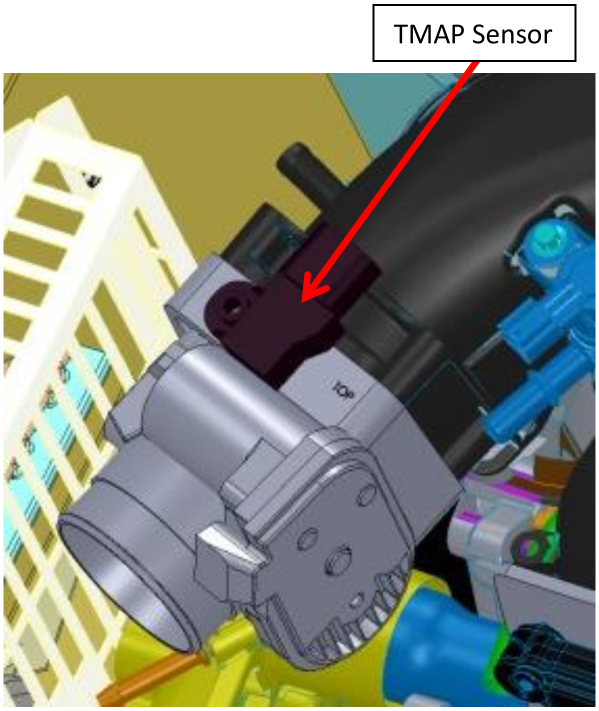
NOTE: The sensor is located below the intake manifold

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. Remove the Lower Intake Manifold – refer to *Lower Intake Manifold Removal* in section 2.
4. Disconnect KS sensor electrical connector.



NOTE: The KS sensor is a one-time use item and a new KS sensor must be installed.

5. Remove bolt and KS sensor and discard sensor.
6. Reverse procedure to install:
   - Install a new KS sensor
   - Tighten bolt to 20 Nm (177lb-in).



Temperature Manifold Absolute Pressure (TMAP) Sensor – Replacement

1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the TMAP sensor.
3. Disconnect TMAP electrical connector.
4. Remove bolt and TMAP Sensor.
5. Reverse procedure to install:
    a. Use a new o-ring seal
    b. Tighten bolt to 3 Nm (2.2 lb-ft).

Actuator/Throttle Position (TP) Sensor - Replacement

Removal

NOTE: Removal steps in this procedure may contain installation details.

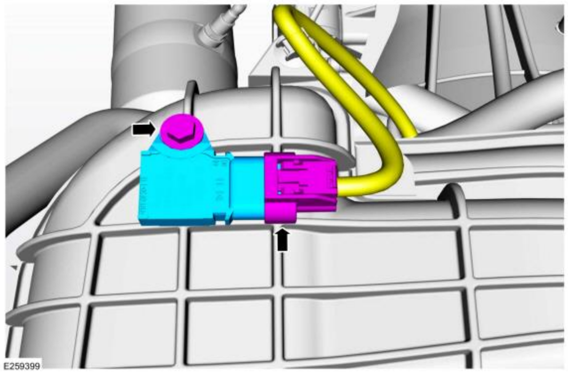
1. Disconnect battery ground cable -- refer to section 6
2. Disconnect the connector from the throttle
3. Remove the bolts from the throttle to the plate
4. Remove the bolts from the plate to the intake manifold
5. **NOTE:** The gasket is to be reused unless damaged.

Installation

1. To install, reverse the removal procedure.
    - Torque bolts to 10 Nm
2. The gasket between the throttle and plate is to be reused unless damaged.

Manifold Absolute Pressure (MAP) Sensor – Replacement

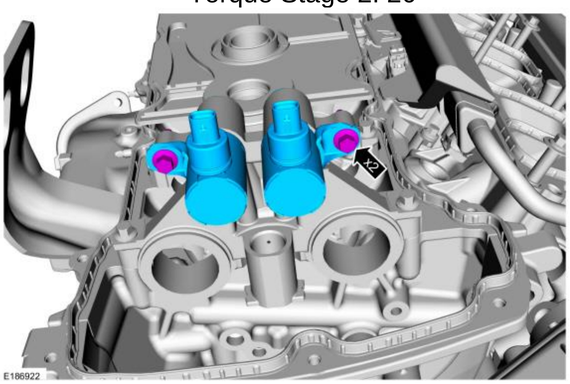
Removal
1. Disconnect battery ground cable – refer to section 6.
2. Disconnect the electrical connector and remove the MAP sensor.
    - Torque: 7 Nm (62lb-in)



Installation
1. To install, reverse the removal process.

Variable Camshaft Timing (VCT) Oil Control Solenoid – Replacement

NOTE: Removal steps in this procedure may contain installation details.
1. Disconnect battery ground cable – refer to section 6.
2. Remove the valve covers.
    - Refer to section 2 for valve cover removal procedures
3. Remove the bolts and the VCT control solenoids.
4. Reinstall new VCTs and bolts.
    - Torque Stage 1: 8 Nm (71 lb-in)
    - Torque Stage 2: 20º



LSG-635 METRICS

INDEX

INTRODUCTION

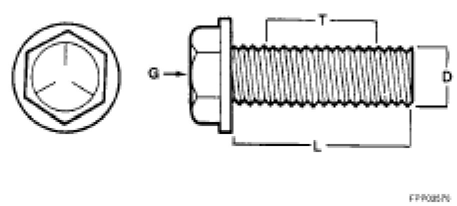
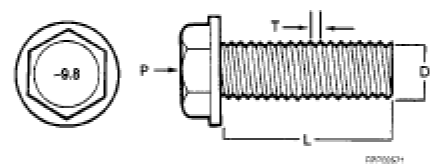
Most threaded fasteners are covered by specifications that define required mechanical properties, such as tensile strength, yield strength, proof load and hardness. These specifications are carefully considered in initial selection of fasteners for a given application. To ensure continued satisfactory 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.

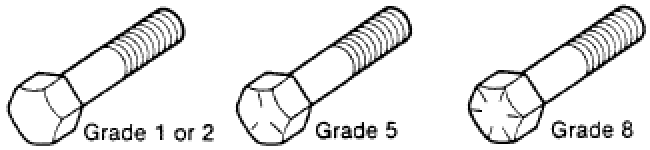
NOMENCLATURE FOR BOLTS

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.

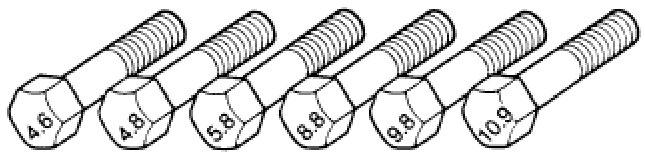
BOLT STRENGTH IDENTIFICATION

English System



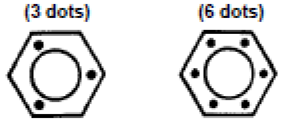
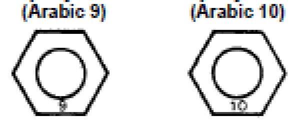
English (inch) bolts: Identification marks correspond to bolt strength, increasing number of slashes represent increasing strength.

Metric System



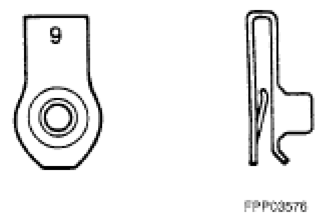
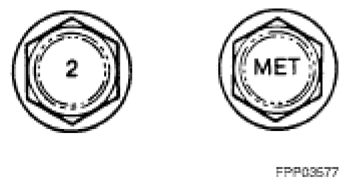
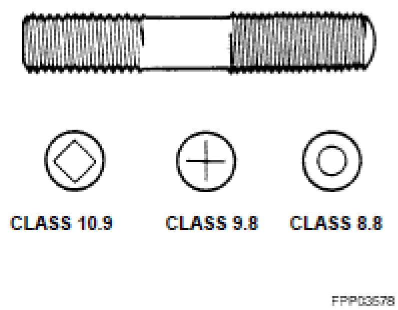
Metric (mm) bolts: Identification class numbers correspond to bolt strength, increasing numbers represent increasing strength. Common metric fastener bolt strength properties are 9.8 and 10.9 with the class identification embossed on the bolt head.

HEX NUT STRENGTH IDENTIFICATION

English System - Grade Identification	Metric System - Class Identification
HEX NUT Grade 5 (3 dots) — HEX NUT Grade 8 (6 dots)  FPP03574	HEX NUT Property Class 9 (Arabic 9) — HEX NUT Property Class 10 (Arabic 10)  FPP03575
Increasing dots represent increasing strength.	May also have blue finish or paint daub on hex flat. Increasing numbers represent increasing strength.

OTHER TYPES OF PARTS

Metric identification schemes vary by type of part, most often a variation of that used of bolts and nuts. Note that many types of English and Metric fasteners carry no special identification if they are otherwise unique.

Stamped U-Nuts	
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.	

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

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

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)

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)

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

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)

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)

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)

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)

New Term	New Acronym	Old Terms (Acronyms)
Torque Converter Clutch Relay	TCC Relay	Lock Up Relay
Torque Converter Clutch Solenoid Valve	TCC Solenoid Valve	Lock Up Solenoid Valve (LUS)
Transmission Control Module	TCM	Transmission Control Module
Transmission Range	TR	- Park, Reverse, Neutral, Drive, Low (PRNDL) - Selection Lever Position (SLP) - Transmission Range Selection (TRS)
Transmission Range Sensor	TR Sensor	Manual Lever Position Sensor (MLP Sensor)
Transmission Range Switch	TR Switch	- Manual Range Position Switch (MRPS) - Transmission Position Switch - Transmission Range Selection Switch (TRSS)
Turbocharger	TC	Turbo
Vehicle Speed Sensor	VSS	- Distance Sensor - Pulse Generator (PG)
Voltage Regulator	VR	voltage Regulator (VR)
Volume Air Flow	VAF	- Air Flow Control (AFC) - Air Flow Meter - Vane Air Flow
Volume Air Flow Sensor	VAF Sensor	- Air Flow Meter - Air Flow Sensor (AFS)
Warm Up Oxidation Catalytic Converter	WU-OC	Light Off Catalyst
Warm Up Three Way Catalytic Converter	WU-TWC	Light Off Catalyst
Wide Open Throttle	WOT	Full Throttle
Wide Open Throttle Switch	WOT Switch	Wide Open Throttle Switch (WOTS)

EDI Ford Industrial Engine Distributor List

7/27/2020

AUSTRALIA

	Deutz Australia		+61 (0)3 9549 8400

EUROPE

GERMANY	Sauer & Sohn Sauer Motive Systems	Gross Zimmerner Strasse 51 D-64807 Dieburg Germany	49-6071-206-330 49-6071-206-219
GREAT BRITAIN	Hendy Power	School Lane Chandlers Ford Industrial Estate, Eastleigh, Hampshire SO53 4DG England	44-2380-579-800 44-2380-271-471
GREAT BRITAIN	Power Torque Engineering	Herald Way, Binly, Conventry Warwichshire CV3 2RQ England	44-2476-635-757 44-2476-635-878
ITALY	Compagnia Technica Motori S.p.A.	Via Magellano 1, I-20090 Cesano Boscone, (Milano) Italy	39-02-450-581 39-02-450-582(60/62)
NETHERLANDS	My Power Products	Houtzaagmolen 41 MIJDRECHT Netherlands NL 364	03-129-758-1555

MEXICO

	Equipos y Motores Ind.	Ave. Cuitlahuac No. 700 Col. Popotla 11400 Mexico, D.F.	52-55-5341-9066

ASIA

China & Taiwan	Project Engineering, Inc.	700 Envoy Circle, Suite 704 Louisville, KY 40299, USA	01-(502)-491-9030 peiusa@aol.com
	GuangQing (Anhui) Gas Technologies Co. Ltd.	Room 1608, Xinke Building, No. 58, Feixi Road, Hefei, Anhui, 230022 China	86-(0551)-6363-6167 www.impcochina.com

NORTH AMERICA - UNITED STATES

ALABAMA	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
ALASKA	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
ARIZONA	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
ARKANSAS	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
CALIFORNIA	Smith Power Products Inc.	8 Glendale Avenue Sparks, NV 89431	P: 775-359-1713 F: 775-359-6579
COLORADA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
CONNECTICUT	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
DELAWARE	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
FLORIDA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
	Engine Distributors Inc.	2917 S. W. Second Ave. Fort Lauderdale, FL 33315	1-800-220-2700
GEORGIA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
HAWAII	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
IDAHO	Smith Power Products Inc.	4045 Transport Street Boise, ID 83705	P: 208-345-1500 F: 208-345-1619
ILLINOIS	Crosspoint	3621 West Morris St. Indianapolis, IN 46241	1-800-426-7693; 317-240-1965
INDIANA	Crosspoint	3621 West Morris St. Indianapolis, IN 46241	1-800-426-7693; 317-240-1965
IOWA	Anderson Industrial Engines Co.	5532 Center Street Ohmaha, NE 68106	402-558-8700
KENTUCKY	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
KANSAS	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700

NORTH AMERICA - UNITED STATES

LOUISIANA	Engines , Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
MAINE	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
MARYLAND	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
MASSACHUSETTS	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2701
MICHIGAN	Michigan CAT	24800 Novi Rd. Novi, MI 48375	248-349-7050
MINNESOTA	Michigan CAT	24800 Novi Rd. Novi, MI 48375	248-349-7050
MISSISSIPPI	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
MISSOURI	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
MONTANA	Smith Power Products Inc.	4045 Transport Street Boise, ID 83705	P: 208-345-1500 F: 208-345-1619
NEBRASKA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
NEVADA	Smith Power Products Inc.	8 Glendale Avenue Sparks, NV 89431	P: 775-359-1713 F: 775-359-6579
		4900 East Idaho Street Elko, NV 89801	P: 775-738-7154 F: 775-738-9325
NEW HAMPSHIRE	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
NEW JERSERY	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
NEW YORK	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
NEW MEXICO	Smith Power Products Inc.	2101 Pepsi Way Aztec, NM 87410	P: 505-333-7343
NORTH DAKOTA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
NORTH CAROLINA	Engine Distributors Inc.	303 Interstate Dr. Archdale, NC 27263	1-800-220-2700
OHIO	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
OKLAHOMA	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
OREGON	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700

NORTH AMERICA - UNITED STATES

EASTERN PENNSYLVANIA	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
WESTERN PENNSYLVANIA	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
RHODE ISLAND	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
SOUTH CAROLINA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
SOUTH DAKOTA	Anderson Industrial Engines Co.	5532 Center Street Omaha, NE 68106	402-558-8700
TENNESSEE	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
TEXAS	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
UTAH	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
WASHINGTON	Smith Power Products Inc.	3065 W. California Ave. Salt Lake City, UT 84104	P: 800-658-5352 F: 801-415-5700
WEST VIRGINIA	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
WISCONSIN	Michigan CAT	24800 Novi Rd. Novi, MI 48375	248-349-7050
WYOMING	Smith Power Products Inc.	4 Layos Drive Rock Springs, WY 82901 855 South 1500 East Vernal, UT 84078	P: 307-382-4330 F: 307-382-4354 P: 435-789-1860 F: 435-789-3259
VERMONT	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
VIRGINIA	Engine Distributors Inc.	303 Interstate Dr. Archdale, NC 27263	1-800-220-2700

NORTH AMERICA - CANADA

ALBERTA, SASKATCHEWAN	Industrial Engines Ltd.	14355 120th Ave. Edmonton, Alberta Canada, T5L 2R8	780-484-6213
ALBERTA, SASKATCHEWAN	Simson Maxwell	8750-58th Avenue, Edmonton,AB Canada T6E 6G6	1-800-374-6766
ALBERTA, SASKATCHEWAN	Simson Maxwell	467 Exploration Ave, SE Calgary, Alberta T3S 0B4	403-252-8131
BRITISH COLUMBIA	Simson Maxwell	1605 Kebet Way Port C, BC Canada V3C 5W9	1-800-374-6766
	Simson Maxwell	#12-4131 Mostar Road, Nanaimo BC, Canada V9T 5P8	1-800-374-6766
	Simson Maxwell	1846 Quinn Street, Prince George, BC Canada V2L 3H4	1-800-374-6766
MONTREAL	MARINDUSTRIAL	8550 Delmeade Montreal, QUEBEC Canada, H4T 1L7	514-342-2748
NEW BRUNSWICK, NOVA SCOTIA, NEWFOUNDLAND	DAC Industrial Engines, Inc.	10 Akerley Blvd., Unit 61 Dartmouth, NS, B3B 1J4	902-468-3765 877-468-3765
ONTARIO	MARINDUSTRIAL	3495 Laird Rd. Unit 22-23 Mississauga, ON, L5L 5S5	905-829-3004