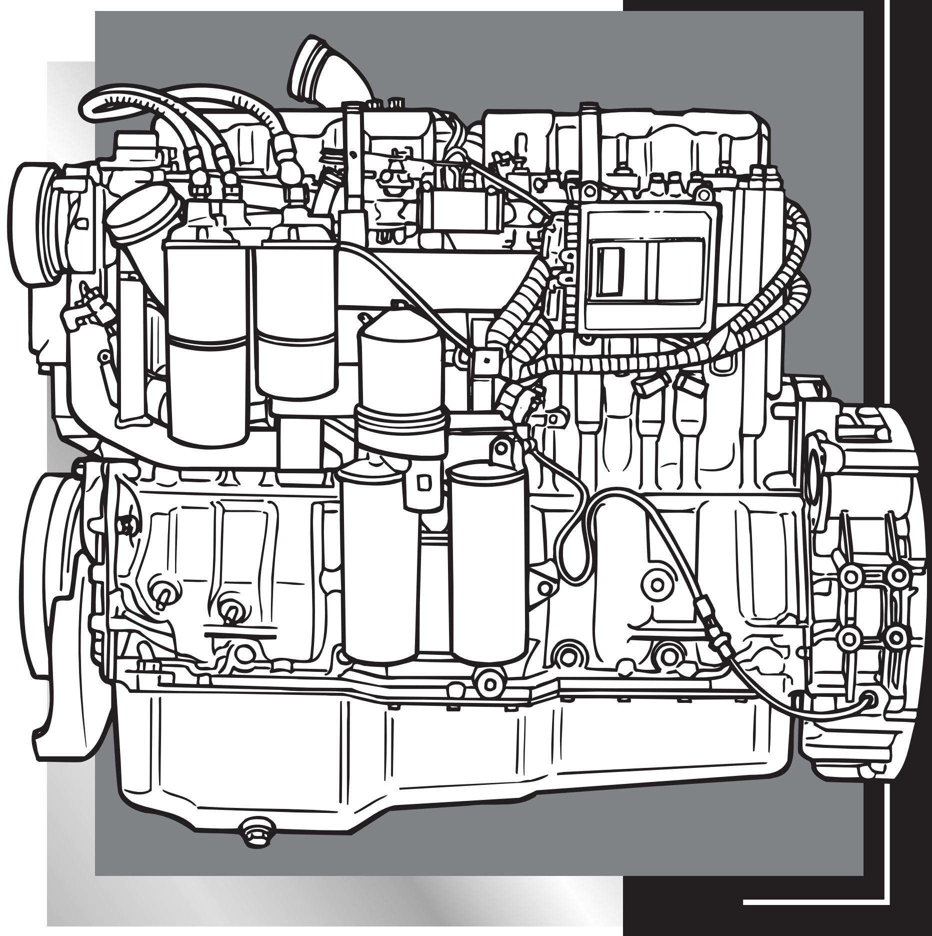

E-TECH™ ENGINE

SERVICE MANUAL

(Includes Left-Side Redesign)

OCTOBER 2000
(REVISED)
5-106

front.fm Page -ii Friday, August 4, 2000 11:16 AM newknow.fm Page 1 Thursday, May 21, 1998 2:23 PM

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Crankshaft Center Main Bearing Specification Update

Effective January 2006, Mack Powertrain Engineering has widened the crankshaft center main bearing runout specification. The maximum allowable crankshaft runout specification was changed from 0.005 in. (0.127 mm) to 0.007 in. (0.178 mm). The manuals listed below are affected by this change.

Reference: **Engine Manuals**

5-101 E7

5-106 E-Tech™

5-107 E7G

5-110 ASET™ AI/AMI

5-111 ASET™ AC

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SERVICE BULLETIN

NUMBER: SB-210-034
DATE: 5/14/02
MODEL: E-Tech™

(Also applies to Mack Trucks Australia)

MISCELLANEOUS FASTENER CHANGES — E-TECH™ ENGINES

The following fastener changes were made on E-Tech™ engines:

- **Injection Nozzle Hold-Down Screws —** Beginning 3/00, the injection nozzle hold-down screws having the 15 mm external hex head have been changed to a new screw (part No. 421GC2116M) that has a 16 mm internal hex head.
- **Rocker Shaft Mounting Bracket Bolts —** Beginning 4/00, the bolts and washers used to secure the rocker shaft mounting brackets to the cylinder head have been changed to a flange-head bolt (part No. 65AM5010). Tightening torque value for this new fastener remains the same at 40 lb-ft (50 N•m).
- **Air Compressor Mounting Screw —** Beginning 8/00, the original hex-head screw has been changed to a flange-head screw (part No. 27AM16). This change was made so that the mounting screw clamp load is distributed over a wider area of the flat washer.
- **Camshaft Thrust Washer —** Beginning 10/00, the two screws and washers used to secure the camshaft thrust washer to the block were changed to a flange-head screw (part No. 66AM44). Tightening torque value for this fastener remains the same at 15 lb-ft (20 N•m).
- **Cylinder Head Capscrews —** Beginning 6/01, the cylinder head capscrews and the separate hardened flat washer were replaced in production with capscrews having captured washers (part number series 400GC317M). This change was implemented to prevent the possibility of omitting or installing more than one washer during assembly. Additionally, the outside diameter of the captured washer was reduced slightly (approximately 0.030″) to accommodate the redesigned cylinder head cover that was phased into production 7/01. Cylinder head capscrew torque remains the same at 205 lb-ft (278 N•m).
- **Flywheel-to-crankshaft mounting bolts —** Beginning 9/01, bolts having captured washers (part Nos. 419GC31M and 419GC31M2) were released into production to replace the previously used bolts and separate hardened flat washer used to secure the flywheel to the crankshaft. Flywheel-to-crankshaft mounting bolt torque remains the same at 185 lb-ft (250 N•m).
- **Electronic Unit Pump (EUP) hold-down screws —** Beginning 11/01, new hold-down screws (part No. 421GC2123M) were released into production for the electronic unit pumps. These screws are dimensionally the same as the previously used screws, but conform to a more stringent specification that controls minor surface forming defects to a greater degree than for common fasteners.Torque of the EUP hold-down bolts has been changed from 42 lb-ft (57 N·m) to 60 lb-ft (81 N·m).
- **Turbocharger Mounting Nuts —** Beginning 5/02, new turbocharger mounting nuts were released into production. These nuts (part No. 142GC247M) are composed of silver-plated stainless steel to provide greater resistance to heat than the previous nuts. Additionally, these nuts have the Spiralock™ self-locking thread feature to prevent loosening in service.

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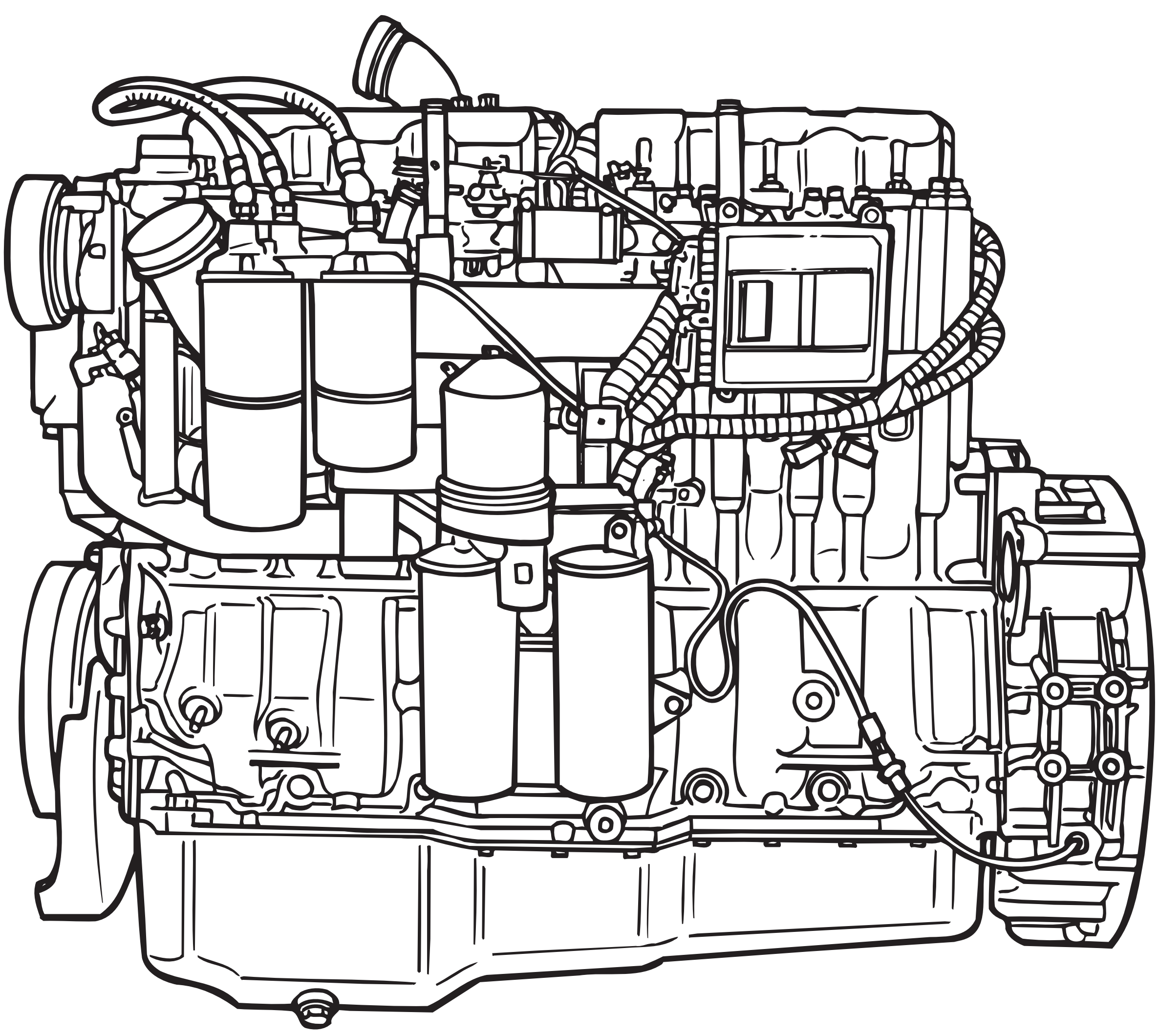
E-TECH™ ENGINE SERVICE MANUAL

(Includes Left-Side Redesign)



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ATTENTION

The information in this manual is not all inclusive and cannot take into account all unique situations. Note that some illustrations are typical and may not reflect the exact arrangement of every component installed on a specific chassis.

The information, specifications, and illustrations in this publication are based on information that was current at the time of publication.

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

front.fm Page vi Friday, August 4, 2000 11:16 AM

TABLE OF CONTENTS

TABLE OF CONTENTS

front.fm Page viii Friday, August 4, 2000 11:16 AM

TABLE OF CONTENTS

TABLE OF CONTENTS

NOTES

5_106_00.bk Page 1 Friday, August 4, 2000 11:17 AM

INTRODUCTION

SAFETY INFORMATION

Advisory Labels

Cautionary *signal words* (Danger-Warning-Caution) may appear in various locations throughout this manual. Information accented by one of these signal words must be observed to minimize the risk of personal injury to service personnel, or the possibility of improper service methods which may damage the vehicle or cause it to be unsafe. Additional Notes and Service Hints are used to emphasize areas of procedural importance and provide suggestions for ease of repair. The following definitions indicate the use of these advisory labels as they appear throughout the manual:

DANGER

Activities associated with **Danger** ***indicate that death or serious personal injury may result from failing to heed the advisory. Serious personal injury may be equated to career-ending injury.***

WARNING

Activities associated with *Warning* indicate that personal injury may result from failing to heed the advisory. In this case, personal injury is not equated to career-ending injury, but results in possible change in quality of life.

CAUTION

Activities associated with ***Caution*** *indicate that product damage may result from failing to heed the advisory. Caution is not used for personal injury.*

NOTE

A procedure, practice, or condition that is essential to emphasize.

SERVICE HINT

A helpful suggestion that will make it quicker and/or easier to perform a procedure, while possibly reducing service cost.

INTRODUCTION

Service Procedures and Tool Usage

Anyone using a service procedure or tool not recommended in this manual must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects. Individuals deviating in any manner from the instructions provided assume all risks of consequential personal injury or damage to equipment involved.

Also note that particular service procedures may require the use of a special tool(s) designed for a specific purpose. These special tools must be used in the manner described, whenever specified in the instructions.

WARNING

1. **Before starting a vehicle, always be seated in the driver's seat, place the transmission in neutral, be sure that parking brakes are set, and disengage the clutch.**
2. **Before working on a vehicle, place the transmission in neutral, set the parking brakes, and block the wheels.**
3. **Before towing the vehicle, place the transmission in neutral and lift the rear wheels off the ground, or disconnect the driveline to avoid damage to the transmission during towing.**

DANGER

Engine-driven components such as Power Take-Off (PTO) units, fans and fan belts, driveshafts and other related rotating assemblies, can be very dangerous. Do not work on or service engine-driven components unless the engine is shut down. Always keep body parts and loose clothing out of range of these powerful components to prevent serious personal injury. Be aware of PTO engagement or nonengagement status. Always disengage the PTO when not in use.

REMEMBER,
SAFETY . . . IS NO ACCIDENT!

INTRODUCTION

Mack Trucks, Inc. cannot anticipate every possible occurrence that may involve a potential hazard. Accidents can be avoided by recognizing potentially hazardous situations and taking necessary precautions. Performing service procedures correctly is critical to technician safety and safe, reliable vehicle operation.

The following list of general shop safety practices can help technicians avoid potentially hazardous situations and reduce the risk of personal injury. DO NOT perform any services, maintenance procedures or lubrications until this manual has been read and understood.

- Perform all service work on a flat, level surface. Block wheels to prevent vehicle from rolling.
- DO NOT wear loose-fitting or torn clothing. Remove any jewelry before servicing vehicle.
- ALWAYS wear safety glasses and protective shoes. Avoid injury by being aware of sharp corners and jagged edges.
- Use hoists or jacks to lift or move heavy objects.
- NEVER run engine indoors unless exhaust fumes are adequately vented to the outside.
- Be aware of hot surfaces. Allow engine to cool sufficiently before performing any service or tests in the vicinity of the engine.
- Keep work area clean and orderly. Clean up any spilled oil, grease, fuel, hydraulic fluid, etc.
- Only use tools that are in good condition, and always use accurately calibrated torque wrenches to tighten all fasteners to specified torques. In instances where procedures require the use of special tools which are designed for a specific purpose, use only in the manner described in the instructions.
- Do not store natural gas powered vehicles indoors for an extended period of time (overnight) without first removing the fuel.
- Never smoke around a natural gas powered vehicle.

5_106_00.bk Page 5 Friday, August 4, 2000 11:17 AM

EXPLANATION OF NUMERICAL CODE

The organization of MACK service manuals has been upgraded to standardize manual content according to a reference system based on component identification. The new reference system will help link the information contained in this publication with related information included in other MACK service/warranty publications, such as associated service bulletins, warranty manuals, and MACK Service Labor Time Standards.

The system is based on a numerical code, the first **digit** of which identifies the general component grouping as listed here:

GROUP **0**00 — GENERAL DATA

GROUP **1**00 — CHASSIS

GROUP **2**00 — ENGINE

GROUP **3**00 — CLUTCH, TRANSMISSION, TRANSFER CASE AND PTO

GROUP **4**00 — STEERING, AXLES, WHEELS AND TIRES, DRIVELINE

GROUP **5**00 — BRAKES, AUXILIARY SYSTEMS

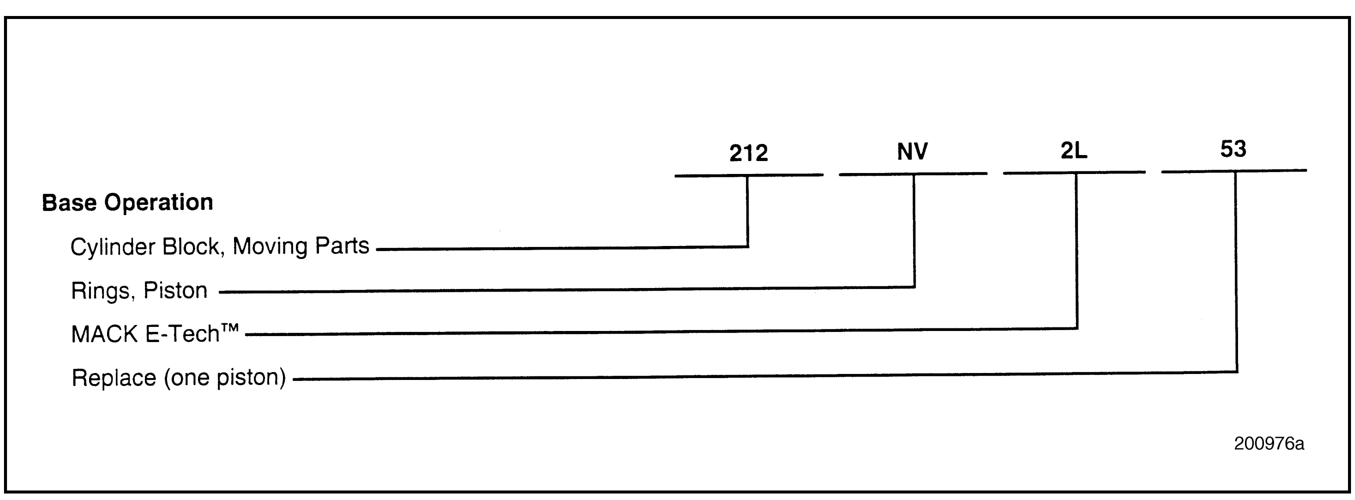
GROUP **6**00 — CAB, TRUCK BODY

GROUP **7**00 — ELECTRICAL

The second two digits of the three-digit code are used to identify the **system, assembly** or **subassembly**, as appropriate, within each of the groupings. The codes applicable to this publication are shown at the beginning of each procedure, as necessary, to guide you to specific component information.

Additionally, a two-character alpha code (i.e., [NV] RINGS, PISTON) may be referenced with each procedure. This alpha code, in combination with the three-digit Group number, identifies the specific assembly, sub-assembly or part, and directly relates to the first five positions of the operation code listed in MACK Service Labor Time Standards.

Examples:



Numerical Code

ABOUT THIS MANUAL

Changes from the Existing E-Tech™ Service Procedures Manual

Mack Trucks, Inc. has made many major improvements to this E-Tech™ Service Procedures Manual, with changes to both content and organization. This is a complete manual, describing engine features and the operation of major systems as well as providing comprehensive overhaul procedures, specifications and adjustments.

All specifications and torque values are given in English and metric measurements. Critical torque values are also included in the text, eliminating the need to refer to SPECIFICATIONS section each time a specified torque value is required. The Special Tools list has been revised to include all special tools required for a complete overhaul. Warnings, cautions, notes and service hints help the technician service the engine safely and efficiently.

The engine disassembly procedures show how to remove components in an order that requires the least amount of handling. Where appropriate, it includes general information needed to properly service that component.

Various component bench procedures guide the technician in disassembly, cleaning, inspection and assembly of each component. Each bench procedure helps in determining if the part is serviceable or should be replaced.

The engine reassembly procedure includes step-by-step instructions for reassembling the engine. This helps to ensure proper installation and longer service life.

Under Engine Setup and Adjustments, the latest setup information is provided for adjusting all E-Tech™ engine models. Engines perform best and conserve fuel most efficiently when adjusted properly.

Two additional procedures are included as guides for removing and reinstalling the engine. Both sections are generic in nature since E-Tech™ engine installation procedures vary from one vehicle style to another. As such, the procedures are intended as a checklist to remind the technician of all necessary tasks.

While troubleshooting procedures are similar for most diesel engines, this manual includes only those that pertain to the E-Tech™ engine. The TROUBLESHOOTING section contains symptom-related questions as well as tests to help the technician consider all possible problem sources.

This service manual also includes applicable information from active service bulletins and service letters since publication of the E-Tech™ Service Procedures Manual dated July 1999.

ABOUT THE E-TECH™ ENGINE AND ITS SERVICE

This publication is intended to provide technicians with a working knowledge of the E-Tech™ engine, including both early-production and current-production versions.

The E-Tech™ engine has undergone a left-side redesign. Changes include a new plate-type oil cooler and a new oil filter mounting arrangement. This new oil filter arrangement includes a new centrifugal oil filter assembly, where the centrifugal filter assembly is now mounted upside down, and the external oil drain is eliminated. This new centrifugal oil filter is called Centri-Max® PLUS.

The engine electronic control unit (EECU) has been relocated to the left side of the engine and is mounted on a new one-piece inlet manifold. Relocating the EECU has eliminated the need for the EECU cooling plate, and has also brought about a design change to the unit pump front outboard heat shield. Additionally, with the change to the one-piece inlet manifold, the fuel filter mounting adapter is new and is located slightly forward of the previous location.

Descriptions of these design changes and the other features are provided in the DESCRIPTION & OPERATION section. Additionally, the service effects of these changes on removal, installation, disassembly, assembly, setup and adjustment procedures, etc., are included in the respective sections of this publication.

Development of the E-Tech™ engine has been driven by three basic requirements. It was designed to:

- Meet projected exhaust and noise emissions regulations.
- Meet customer demands for improved fuel economy, driveability and engine braking.
- Compete in a world market.

Although the drive to reduce emissions and noise levels is primarily the result of government mandates, the E-Tech™ engine is designed to provide customers with an improved engine over the existing E7 engine it replaces. Specific improvements include:

- Improved fuel economy.
- Increased throttle response (time to 90 percent torque is faster with the E-Tech™).
- More retarding horsepower through a newly designed J-Tech™ Engine Brake from Jacobs.

Mack Trucks, Inc. is looking beyond the borders of North America to increase its market and bring the quality, toughness and technology associated with the MACK name to a worldwide audience. The current environment of global regulations concerning exhaust emissions, noise and other factors has leveled the playing field on an international basis. This means that the improvements made to meet the North American environmental regulations can now be applied worldwide.

The E-Tech™ engine is used in MACK trucks and European Renault VI trucks.

5_106_00.bk Page 8 Friday, August 4, 2000 11:17 AM

NOTES

5_106_00.bk Page 9 Friday, August 4, 2000 11:17 AM

IDENTIFICATION

5_106_00.bk Page 10 Friday, August 4, 2000 11:17 AM

ENGINE MODEL IDENTIFICATION

Engine Information Plate

The E-Tech™ engine information plate is located on the top of the front cylinder head cover (back cover for LE and MR chassis). This plate includes information concerning:

- Engine model, serial number and 11GBA part number.
- Advertised horsepower at rated speed rpm.
- Emissions regulations to which the engine conforms and other pertinent information required by emissions regulations.
- Inlet and exhaust valve lash settings and engine brake slave piston lash setting.

The following explanations are provided to aid in interpreting some of the key information found on the engine information plate.

Block 1 — U.S. EPA Regulations

- An “X” in block one means the engine meets United States EPA regulations for the year stamped in block four.
- Two dashes in block one indicate the engine does not meet United States EPA regulations for the year stamped in block four. This is only permissible with certain export engines. All domestic engines will have an “X” in block one.

Block 2 — California Regulations

- An “X” in block two indicates the engine meets California emissions regulations for the year stamped in block four. This engine is referred to as a “50-state” engine and can be sold in any state throughout the U.S.
- Two dashes stamped in block two mean the engine does not meet California emissions regulations. If an engine has an “X” in block one and two dashes in block two, it is referred to as a “49-state” engine, meaning it is not certified for sale in California.

Block 3 — ADR Regulations

- An “X” in block three means the engine has been certified to meet Australian emissions regulations.
- Two dashes in block three mean the engine does not meet Australian emissions regulations.

Block 4 — Model Year

- The four-digit number stamped in block four represents the year in which the engine was certified.

Block 5 — Federal Family

- A 12-digit number stamped in block five denotes the Federal Family to which the engine belongs for emissions certification purposes.
- All domestic engines will have a 12-digit Federal Family number in block five.

Block 6 — California Family

- If the engine meets California emissions regulations, the same 12-digit number stamped in the Federal Family block is stamped in block six.
- If the engine does not meet California emissions regulations, there will be two dashes in block six.

Block 7 — Initial Injection Timing

- E-Tech™ engines do not have an initial injection timing, as this is controlled electronically.
- E-Tech™ engines will have “NA” stamped in block seven.

Block 8 — Engine Brake

- This block is only used when the engine is equipped with an engine brake. The stamping in this block indicates the engine brake slave-piston lash setting.

Figure 1 illustrates the location of the information plate and Figure 2 illustrates its content.

5_106_00.bk Page 11 Friday, August 4, 2000 11:17 AM

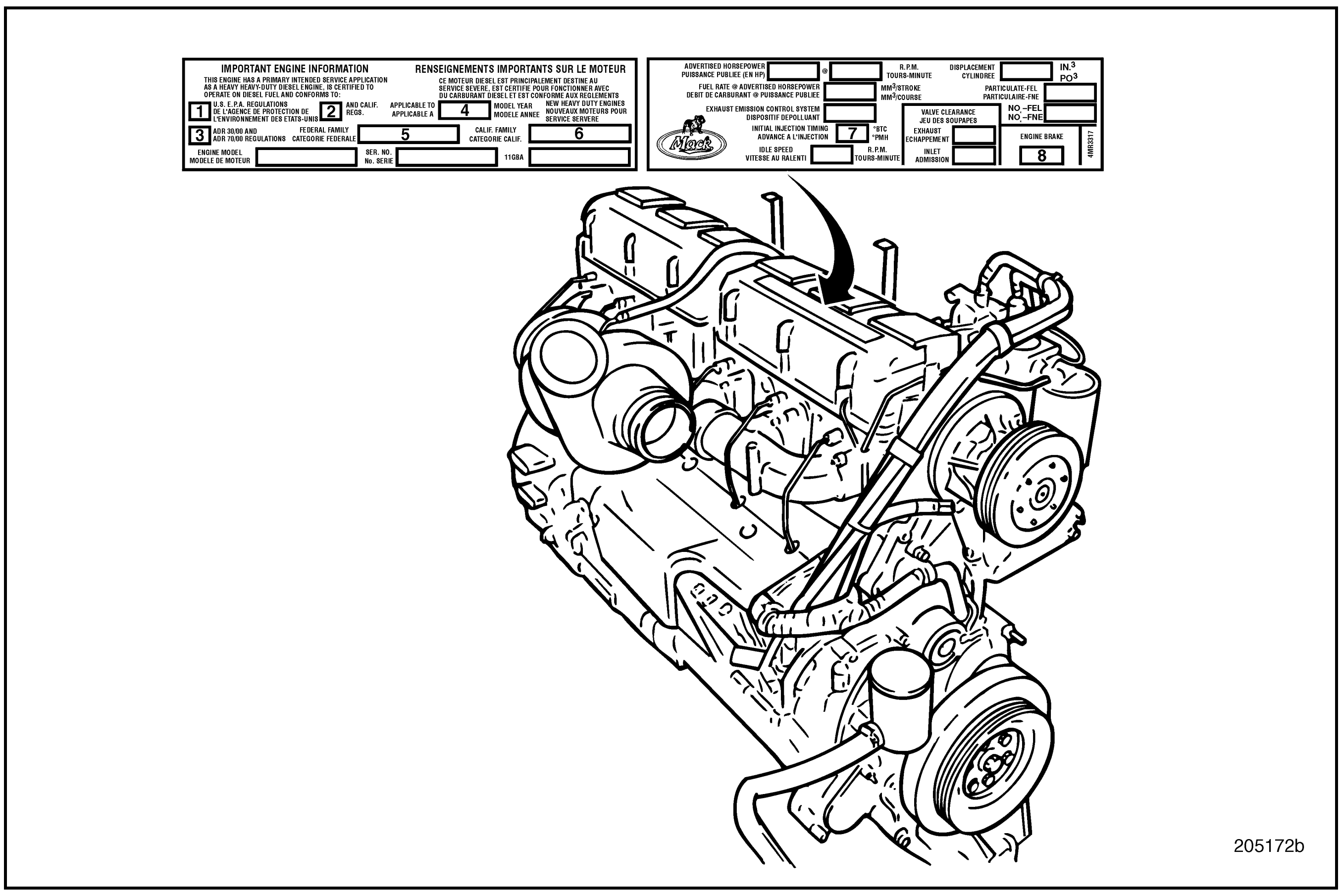


Figure 1 — Engine Information Plate Location

5_106_00.bk Page 12 Friday, August 4, 2000 11:17 AM

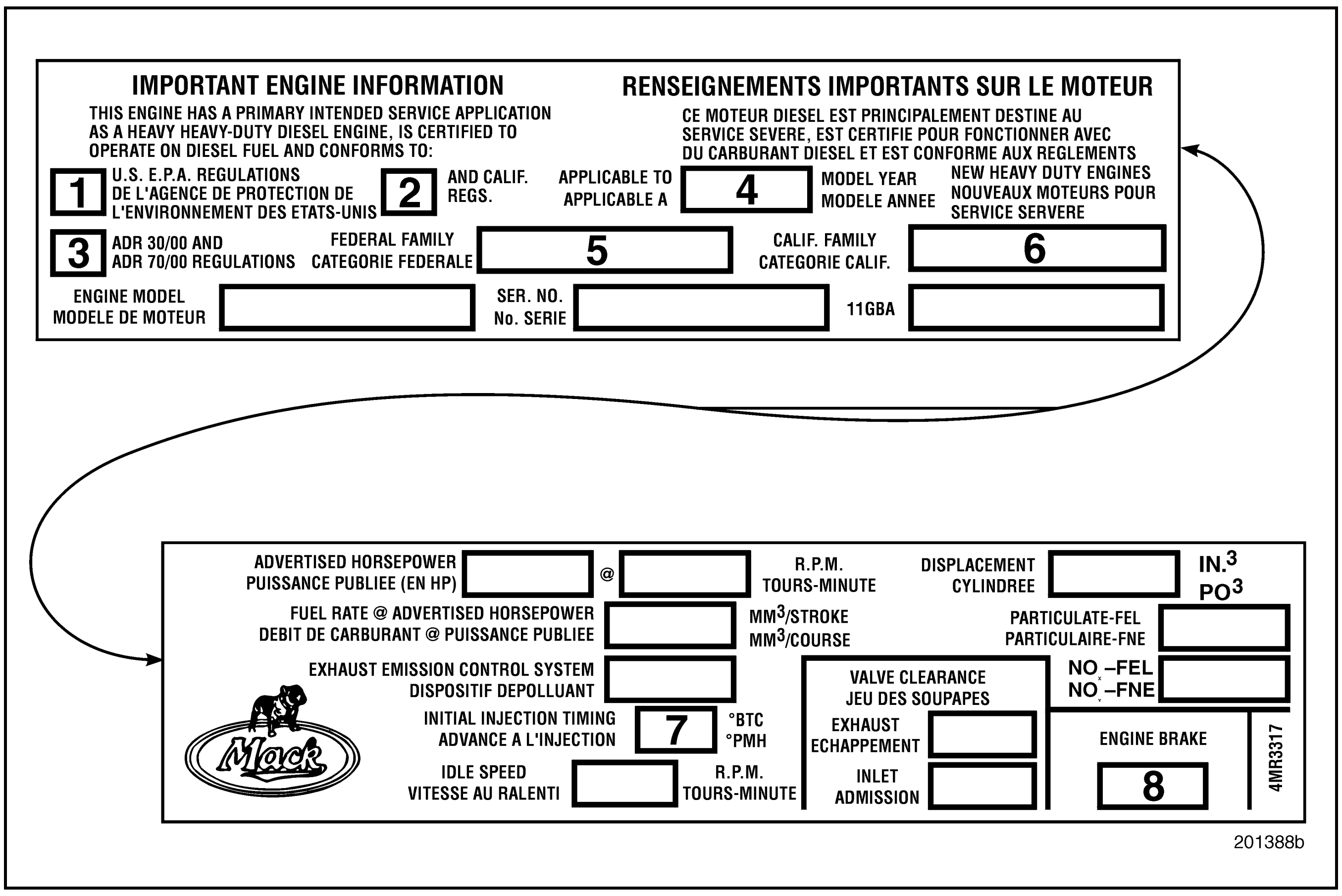


Figure 2 — Engine Information Plate

Engine Serial Number Identification

In addition to the engine information plate on the front cylinder head cover, the engine is also identified by the engine serial number stamped into the cylinder block. This serial number is located on the block right side just below the turbo oil drain tube flange as shown in Figure 3.

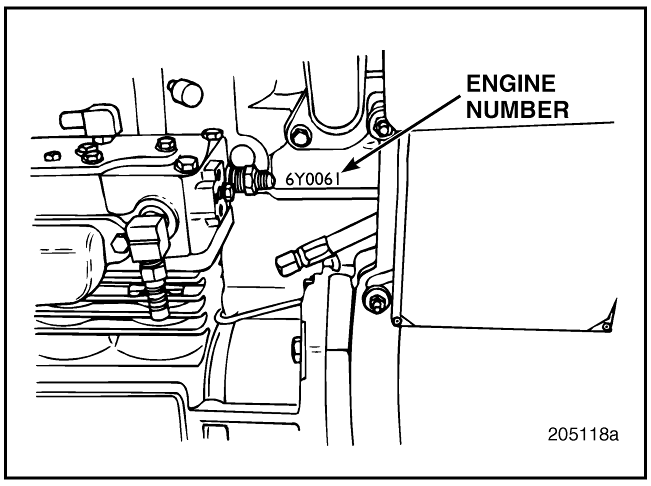


Figure 3 — Engine Serial Number

5_106_00.bk Page 13 Friday, August 4, 2000 11:17 AM

DESCRIPTION & OPERATION

5_106_00.bk Page 14 Friday, August 4, 2000 11:17 AM

E-TECH™ ENGINE DESIGN FEATURES

The E-Tech™ engine evolved from the E7 PLN (commonly referred to as the E7). The four primary design features that differentiate the E-Tech™ engine from the E7 engine are as follows:

- Electronic Unit Pump (EUP) fuel injection system
- V-MAC® III electronic control system
- Poly-v belt drive system
- J-Tech™ engine brake system from Jacobs

These major changes resulted in subsequent improvements and redesign of related components within the engine.

Electronic Unit Pumps

Electronic Unit Pump (EUP) technology, which has been utilized in the heavy-duty industry for many years, has been adapted for the E-Tech™ engine to achieve:

- Optimum performance
- Lower emissions
- Simplified service
- More effective pump/engine diagnostics (individual cylinders can be isolated)

An EUP is a single-plunger fuel-injection pump, one per cylinder, driven by a third lobe on the engine camshaft. The pump roller follower (tappet) is in contact with the engine cam lobe.

The EUP is very similar to a unit injector. The primary difference is that the EUP delivers fuel through a fuel injection line to a conventional-style nozzle-holder assembly, whereas a unit injector has a nozzle mounted directly on it.

The EUP is capable of providing very high fuel-injection pressures. The pump is controlled by a high-speed solenoid valve (see Figure 4) responding to electronic signals from the V-MAC III engine control module. This electronic control provides a greater timing range. The combination of higher pressures and greater timing control improves the combustion process and optimizes engine performance. This enables the E-Tech™ engine to conform to more stringent emissions regulations while providing performance and fuel economy improvements.

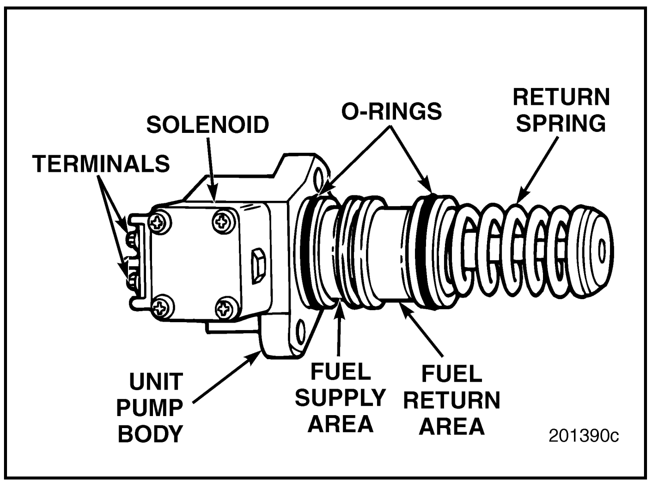


Figure 4 — EUP Components

NOTE

Electronic unit pumps for engines produced through approximately late 3rd quarter 2000 were fitted with three O-rings on the pump housings. Pumps on engines produced later than 3rd quarter 2000 are fitted with two O-rings in the top and bottom grooves. The O-ring in the center groove has been eliminated.

5_106_00.bk Page 15 Friday, August 4, 2000 11:17 AM

The EUP design does not include a helix on the pump plunger. Fuel delivery is controlled entirely by the solenoid valve. To start fuel delivery, the V-MAC III control system allows current to flow to the solenoid, closing the solenoid valve and trapping fuel in the pump. As the plunger moves upward, fuel is delivered through the high-pressure line to the fuel-injector nozzle assembly. When current flow to the solenoid is stopped, the solenoid valve opens and fuel in the pump then flows to the cylinder block fuel return gallery. Refer to Figure 5.

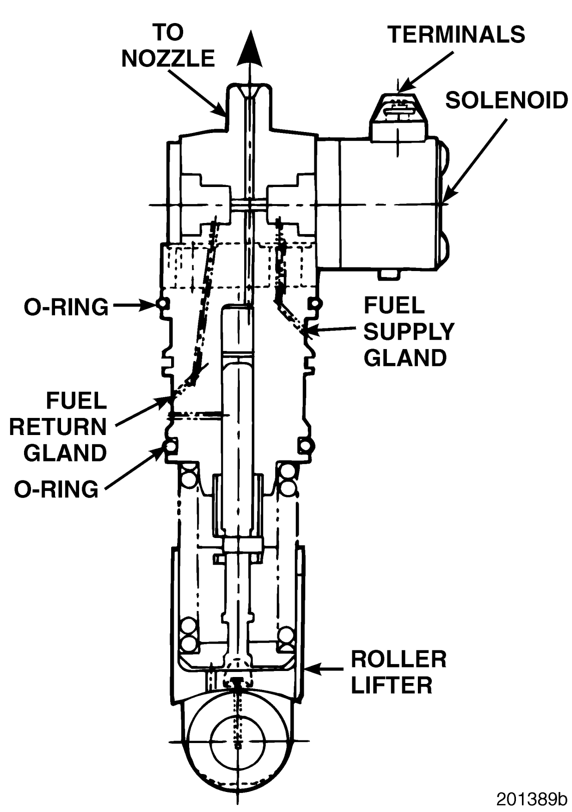


Figure 5 — Electronic Unit Pump

NOTE

Current production E-Tech™ engines contain EUPs with three O-rings. On future production engines the center O-ring will be eliminated. Present EUP service kits available through MACK service parts do not contain the center (brown) O-ring.

The EUP system, using proven industry technology, is well adapted to troubleshooting. When required, an individual EUP can be replaced with a minimum of downtime.

Because the unit pumps are located in close proximity to the exhaust manifold, heat shields have been added to prevent excessive heat from reaching the EUP components.

CAUTION

The right-side heat shields on an E-Tech™ engine are a mandatory part of the engine (Figure 6). The heat shields must be reinstalled if they are removed for maintenance or repair. Failure to do so will result in damage to the sensitive electronic components.

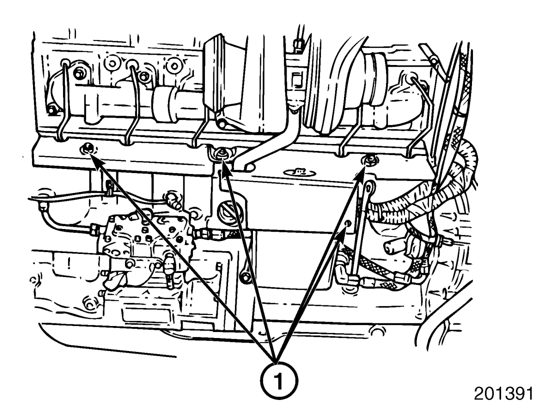


Figure 6 — Heat Shields (with Right-Side Mounted EECU)

1. Heat Shield Attachment Points

5_106_00.bk Page 16 Friday, August 4, 2000 11:17 AM

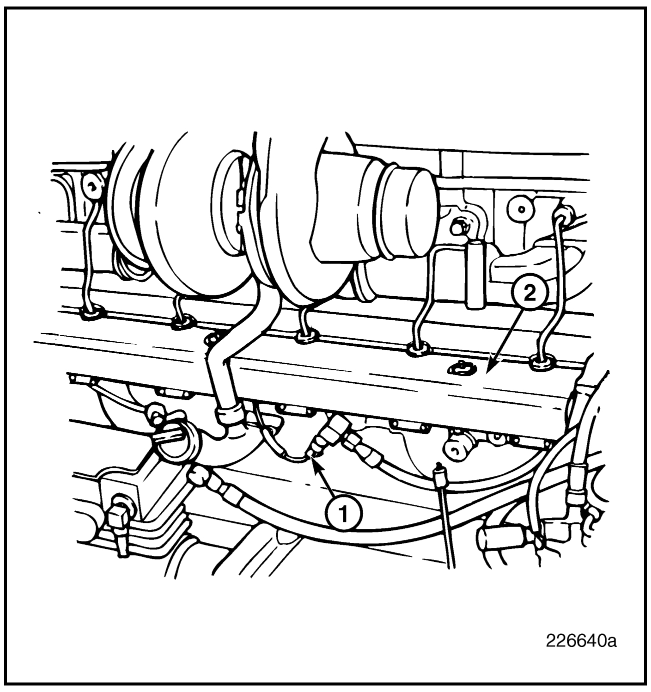


Figure 7 — Heat Shields (with Left-Side Mounted EECU)

1. Fuel Temperature Sensor	2. Redesigned Heat Shield

V-MAC III

The V-MAC III engine control system has been developed specifically for the E-Tech™ engine. Features include electronic drivers and diagnostics for unit pumps, separate engine and vehicle control units, and a revised wiring harness. These features make V-MAC III applicable only to the E-Tech™ engine.

V-MAC III ELECTRONIC CONTROL UNITS

The Engine Electronic Control Unit (EECU) is located on the right side of the engine (Figure 8) in early-production engines. Characteristics of the engine design, such as heat shields, vibration isolation, and running low-pressure fuel through the EECU mounting plate (to cool it), permit the EECU to be mounted directly on the engine in the right-side location.

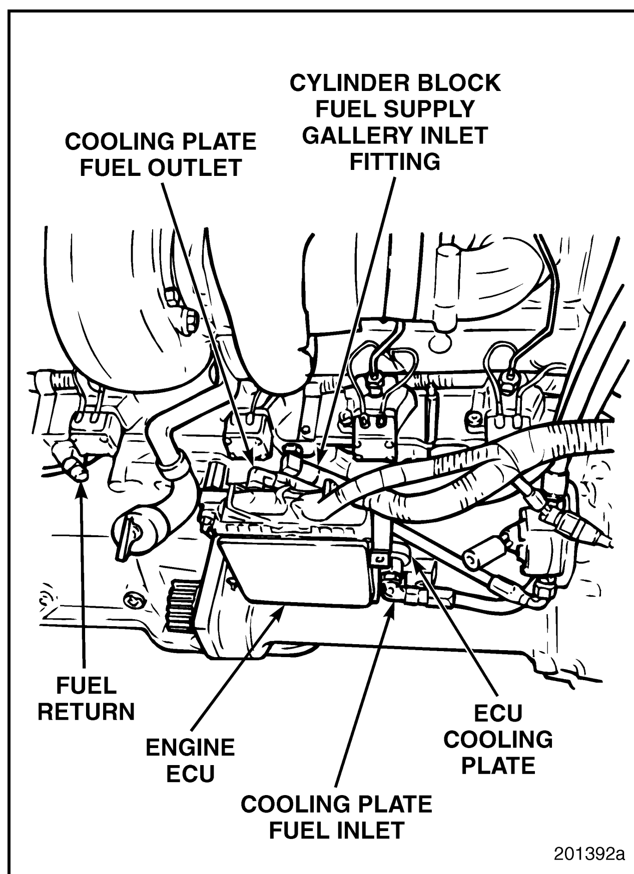


Figure 8 — V-MAC III Engine EECU (Right-Side Mounted)

5_106_00.bk Page 17 Friday, August 4, 2000 11:17 AM

For current-production engines, the EECU is relocated to the left side of the engine (Figure 9) and mounted on a new one-piece air inlet manifold (Figure 13). With this relocation, the fuel-cooled backing plate is no longer necessary and has been eliminated. The new harness is routed around the rear of the engine, and the module and harness connections are mounted vertically at the forward end of the module. This provides an improved environment and less chance for water infiltration at the harness connectors.

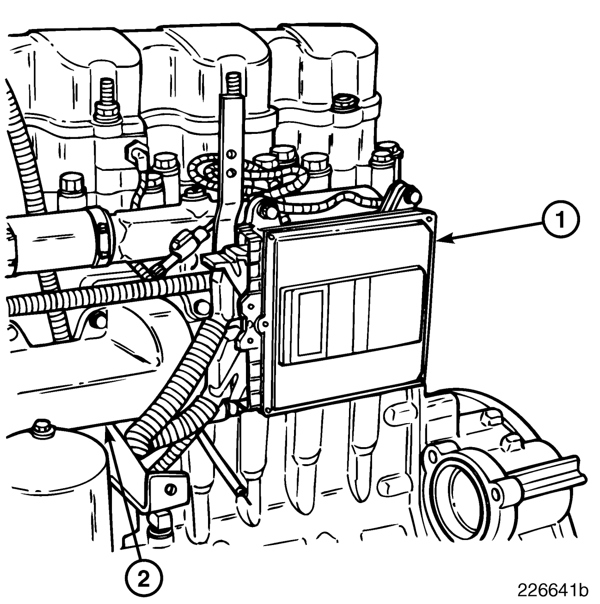


Figure 9 — EECU (Left-Side Mounted)

1. Engine ECU	2. Air Inlet Manifold

The cab-mounted Vehicle Electronic Control Unit (VECU) provides a base for future development, such as “total vehicle” systems and wireless communication.

For enhanced quality, an engine-mounted EECU allows the complete engine system (EECU, harness and sensors) to be assembled at the engine manufacturing/assembly plant, then tested and verified on site. The entire engine electronic package can be left undisturbed during the vehicle assembly process.

With the two-module design, a more efficient and reliable electronic communication network, known as multiplexing, can be used. Multiplexing essentially means that inputs and outputs to and from one control unit are “batched” and sent as a package to the other control unit via a single, high-speed communication line. Inherent to this system is a significant reduction in the length and number of wires, specifically those which must pass through the bulkhead, as well as the related connections.

V-MAC III SYSTEM SENSORS

There are a total of eight engine-mounted sensors and one vehicle-mounted sensor. Seven of the sensors provide input for the operation of the V-MAC III engine control system, while the remaining two sensors provide input for the dash gauges. The dash gauge oil temperature sensor is optional.

The following list and Figure 10 through Figure 19 identify the nine sensors and the features and location of each. Three of the V-MAC III sensors will be described in detail. These are the fuel temperature sensor and the engine speed and engine position sensors. The engine speed and engine position sensors are functionally similar to the E7 RPM/TDC and TEM sensors, but are later designs, quite different from the E7 sensors.

- Engine Speed Sensor
- Fuel Temperature Sensor
- Oil Pressure Sensor
- Ambient Air Temperature Sensor (see Note)
- Boost Air Temperature Sensor
- Dash Gauge Coolant Temperature Sensor
- V-MAC III Coolant Temperature Sensor
- Engine Position Sensor
- Dash Gauge Oil Temperature Sensor (optional)

5_106_00.bk Page 18 Friday, August 4, 2000 11:17 AM

NOTE

The chassis-mounted ambient air temperature sensor was not available with early-production engines. It was phased into production beginning approximately mid-July 1999 for CX model chassis, mid-September 1999 for CH, CL, RD8, MR, DM and DMM model chassis and early November 1999 for RD6, RB and LE model chassis. The sensor is mounted off-engine and supplies temperature input to the engine electronic control unit (EECU), so that the V-MAC system can determine a more accurate indication of inlet air temperature.

Location of the sensor depends upon chassis model, but in general, it is located at the front of the chassis mounted either on the front crossmember behind the bumper, on a hood hinge, hood hinge bracket, body, spring bracket, or grille guard assembly.

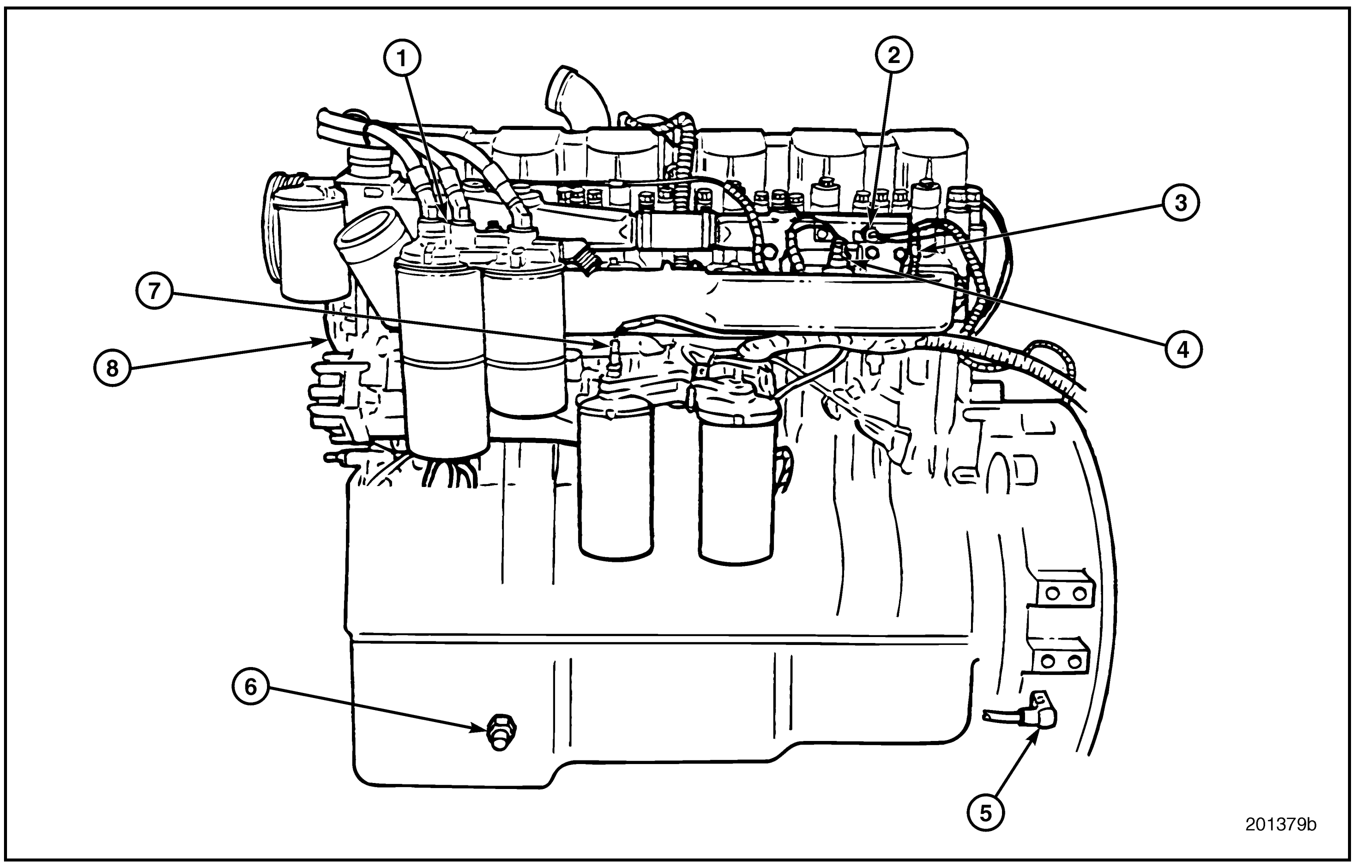


Figure 10 — V-MAC III Engine-Mounted Sensor Locations (Pre-Left-Side Redesign)

1. Fuel Temperature Sensor (Behind Fittings) 2. Dash Gauge Coolant Temperature Sensor 3. V-MAC III Coolant Temperature Sensor 4. Boost Air Temperature Sensor 5. Engine Speed Sensor (on Left Side of Flywheel Housing)	6. Dash Gauge Oil Temperature Sensor (on Left Side of Oil Pan) 7. Oil Pressure Sensor 8. Engine Position Sensor (on Engine Front Cover)

5_106_00.bk Page 19 Friday, August 4, 2000 11:17 AM

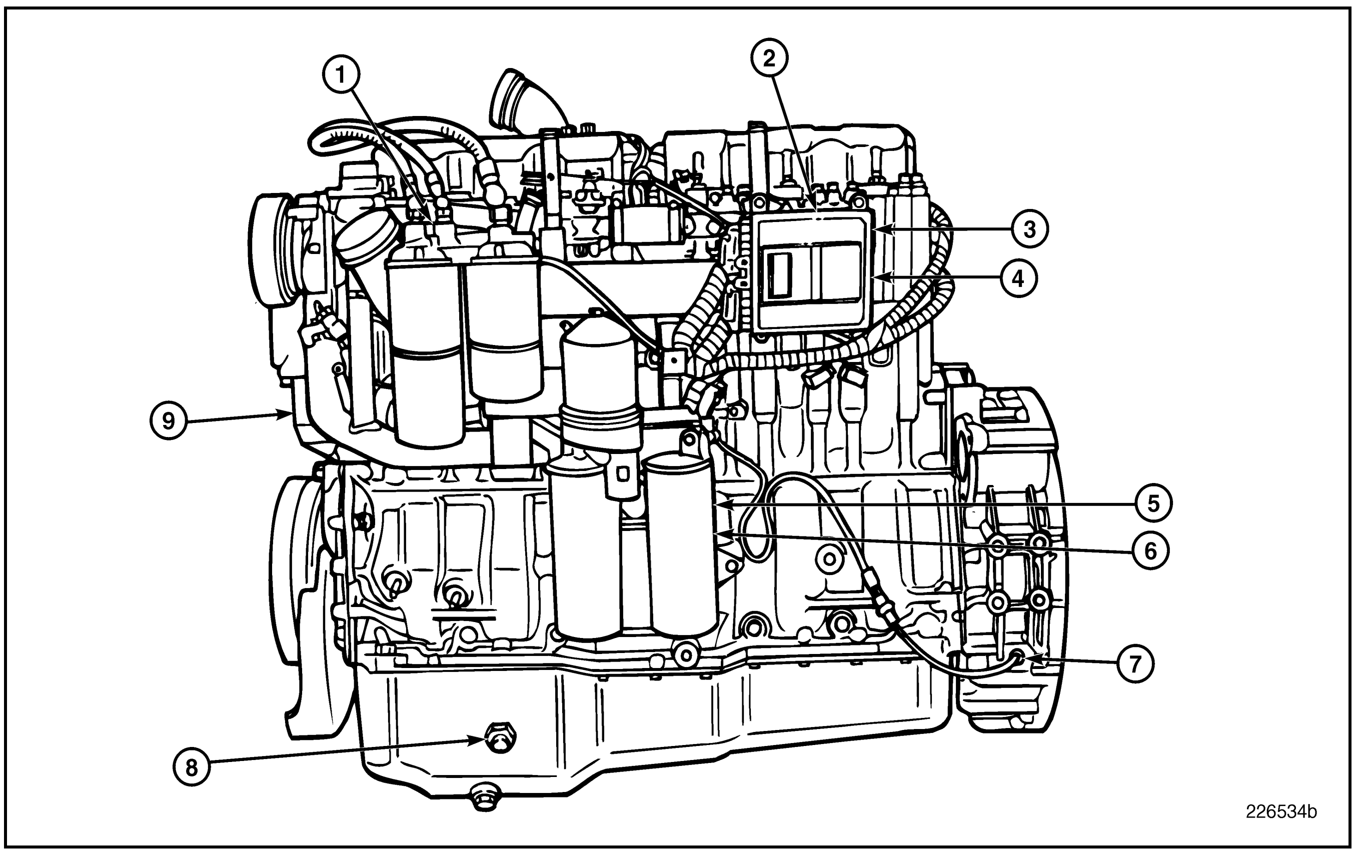


Figure 11 — V-MAC III Engine-Mounted Sensor Locations (with Left-Side Mounted EECU)

1. Fuel Temperature Sensor (Behind Fittings) 2. Dash Gauge Coolant Temperature Sensor (on Side of Coolant Manifold) 3. V-MAC III Coolant Temperature Sensor (on End of Coolant Manifold) 4. Boost Temperature Sensor (on Top of Air Inlet Manifold)	5. Oil Temperature Sensor (on Filter Mounting Bracket) 6. Oil Pressure Sensor (on Filter Mounting Bracket) 7. Engine Speed Sensor 8. Dash Gauge Oil Temperature Sensor 9. Engine Position Sensor (on Engine Front Cover)

On current-production engines with the left-side mounted EECU, there are three harness connectors adjacent to the oil pressure sensor. One connector, the oil pressure sensor connector, is always used. The other two connectors are for an optional oil temperature sensor. One connector (color-coded black) is for the oil temperature sensor used with the standard dashboard, and the other connector (color-coded gray) is for the oil temperature sensor used with the electronic dash. Oil temperature sensor part No. 64MT2116 is used with the standard dashboard and sensor part No. 64MT2103 is used with the electronic dashboard.

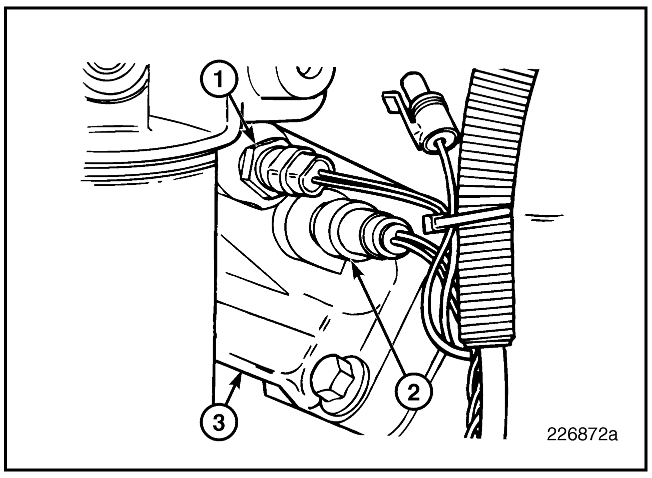


Figure 12 — V-MAC III Sensor Locations at Filter Mounting Bracket (with Left-Side Mounted EECU)

1. Oil Temperature Sensor 2. Oil Pressure Sensor	3. Filter Mounting Bracket

On current-production engines with the left-side mounted EECU, the boost temperature sensor port has been moved to the manifold inlet area (depending upon chassis model, the manifold inlet is at the front, or the center). There is a large boss at the rear of the manifold for boost air supply to the air compressor and boost pressure access ports.

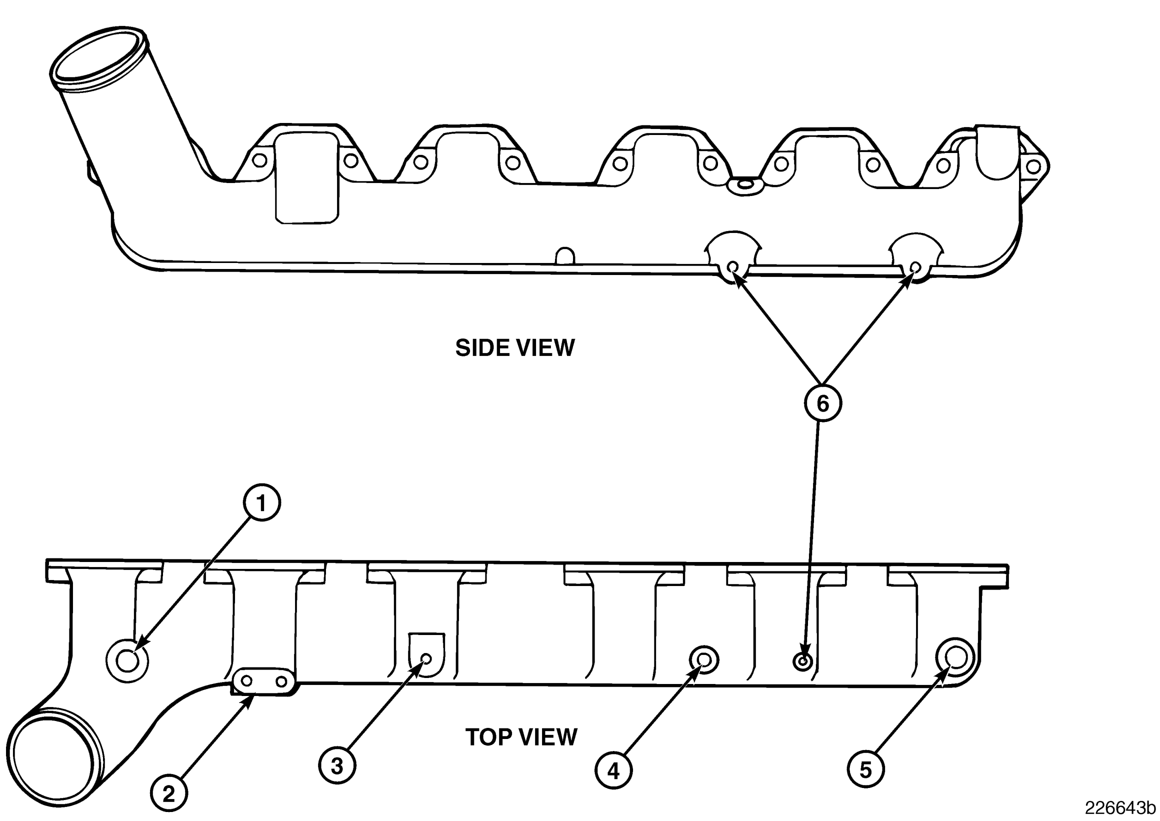


Figure 13 — V-MAC III Sensor Locations with Front Air Inlet Manifold (Left-Side Mounted EECU)

1. Boost Temperature Sensor 2. Fuel Filter Mounting Bracket Boss 3. Port for Boost Pressure Test Gauge 4. Boost Pressure Port for Line-to-Dash Gauge or Boost Pressure Sensor	5. Boost Air Supply to Air Compressor 6. Engine Electronic Control Unit Isolator Mounting Stud, Threaded Bosses

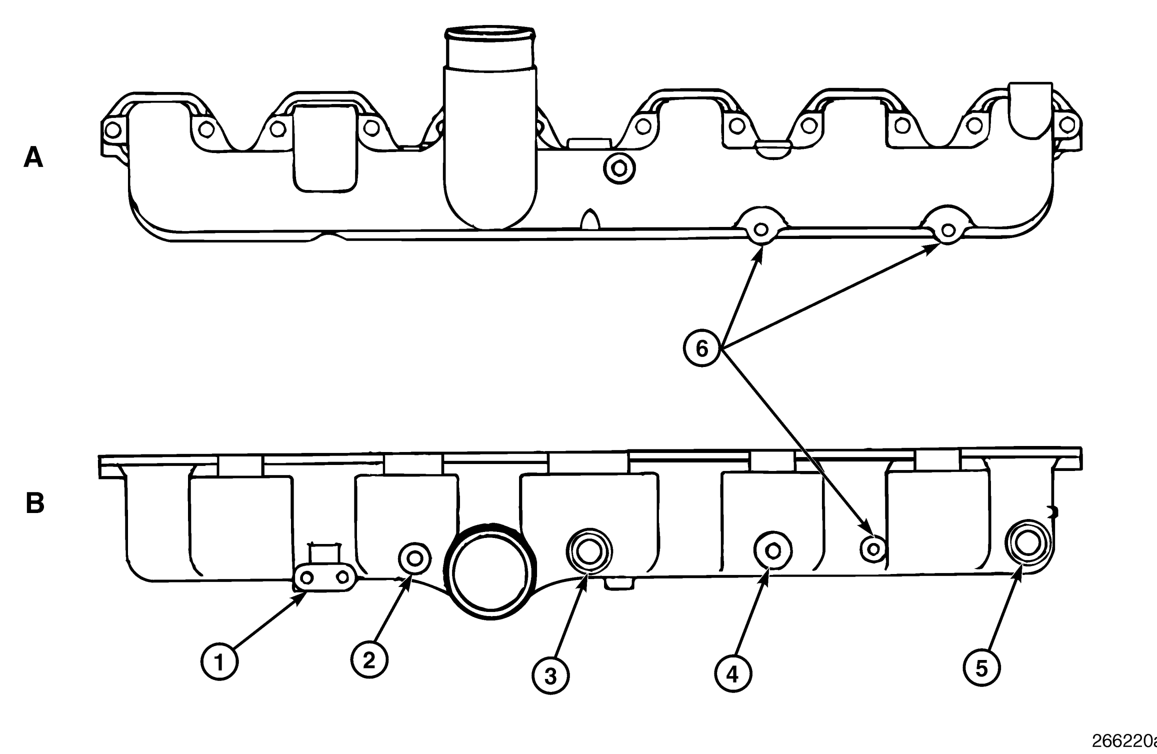


Figure 14 — V-MAC Sensor Locations with Center Air Inlet Manifold (Left-Side Mounted EECU)

A. Side View B. Top View 1. Fuel Filter Mounting Bracket Boss 2. Port for Boost Pressure Test Gauge 3. Boost Temperature Sensor	4. Boost Pressure Port for Line-to-Dash Gauge or Boost Pressure Sensor 5. Boost Air Supply to Air Compressor 6. Engine Electronic Control Unit Isolator Mounting Stud, Threaded Bosses

NOTE

An interim version front manifold was used on engines with the new oil cooler/filter arrangement, but without the engine ECU relocation.

The V-MAC III sensors have different mounting methods, or mounting threads, compared to the similar V-MAC® II sensors:

- V-MAC III engine speed and engine position sensors are flange-mounted with a mounting screw.
- V-MAC III oil pressure, boost temperature, fuel temperature and coolant temperature sensors have English pipe threads.
- Dash gauge sensors for coolant and oil temperatures are threaded sensors with English pipe threads, the same as the E7 with V-MAC II.

5_106_00.bk Page 22 Friday, August 4, 2000 11:17 AM

Fuel Temperature Sensor

On early-production engines with a right-side mounted EECU, a fuel temperature sensor is provided at the top of the secondary fuel filter mounting adapter (Figure 15) installed in a boss adjacent to the outlet fitting. The V-MAC III system monitors fuel temperature at the secondary fuel filter outlet, as fuel is being supplied to the cylinder block fuel gallery inlet. This fuel temperature data improves accuracy of the mpg fuel consumption information shown on the Co-Pilot® display.

The fuel temperature sensor is the same as the coolant temperature sensor used at the rear of the water manifold location. The illustration that follows shows a CH/CL/DM engine-mounted, fuel filter adapter. The RD/MR/LE chassis-mounted secondary fuel filter mounting adapter has a similar sensor mounting boss. In either case, if the fuel temperature sensor is not used, the boss should not be drilled and tapped.

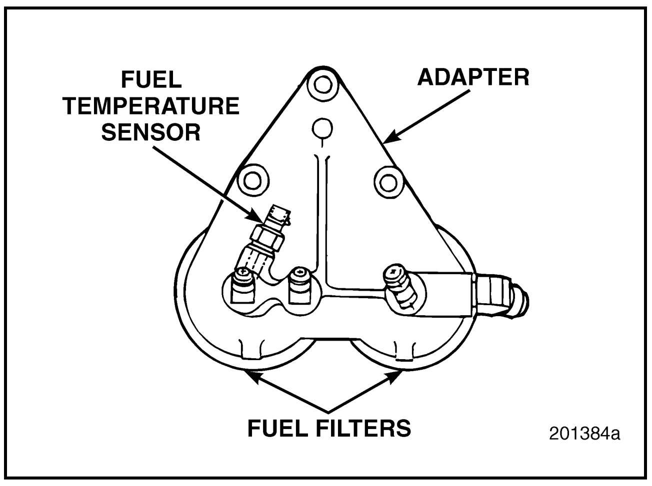


Figure 15 — Fuel Temperature Sensor (Engine with Right-Side Mounted EECU)

On current-production engines with the left-side mounted EECU, the fuel temperature sensor is located at the fuel cylinder block fuel gallery inlet (Figure 16). This location is standardized for all fuel filter arrangements, simplifying and improving the line routing.

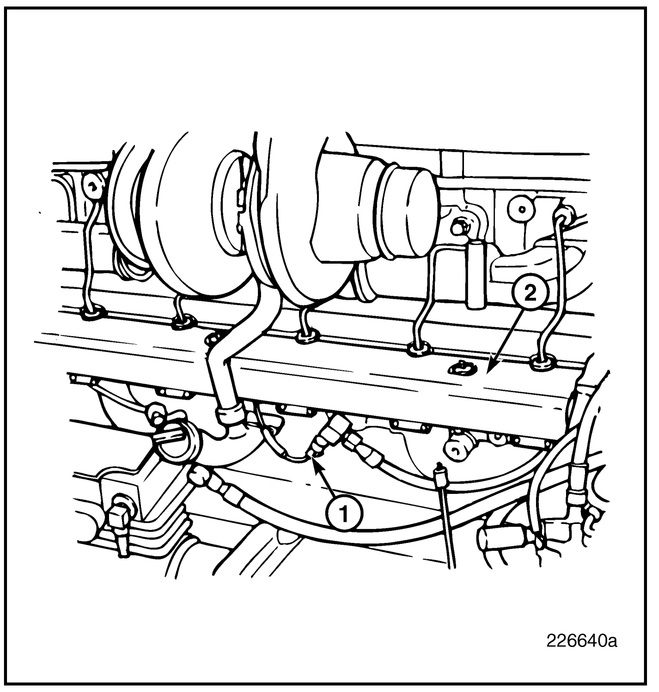


Figure 16 — Fuel Temperature Sensor (Engine with Left-Side Mounted EECU)

1. Fuel Temperature Sensor	2. EUP Heat Shield

Engine Speed Sensor

This sensor is located at the left side of the engine flywheel housing (Figure 17). It is flange-mounted and held in place by a retaining screw. **The engine speed sensor is the same part number as the engine position sensor, located on the engine front cover.**

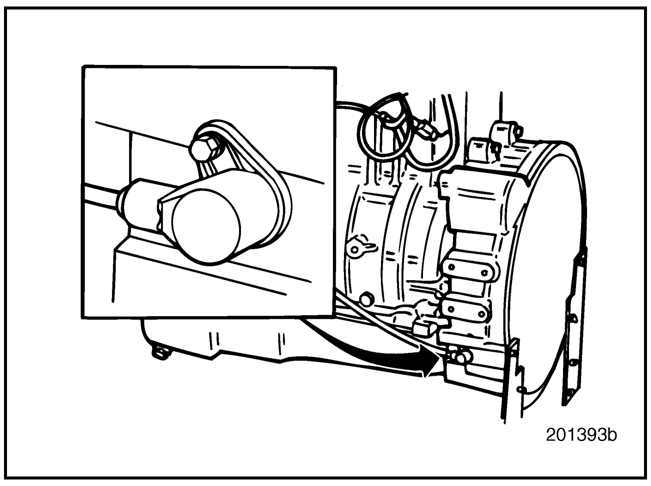


Figure 17 — Engine Speed Sensor

The E-Tech™ flywheel has 117 teeth (one less tooth than the E7 engine flywheel) and has two adjacent teeth with part of their width (1/4 inch) machined off. These two teeth on the E-Tech™ flywheel allow the sensor to determine top dead center (TDC) of cylinder Nos. 1 and 6, whereas sensing notches are used on the front face of the E7 flywheel. Because of this feature, ring gear-to-flywheel indexing must be maintained.

Engine Position Sensor

The engine position sensor is located on the engine front cover (Figure 18) and is retained in the same manner as the engine speed sensor. This sensor is designed to monitor the passage of holes which are in the front face of the camshaft timing gear. This sensor performs a function similar to the TEM sensor in the Bosch Injection Pump RE30 governor on the E7 engine.

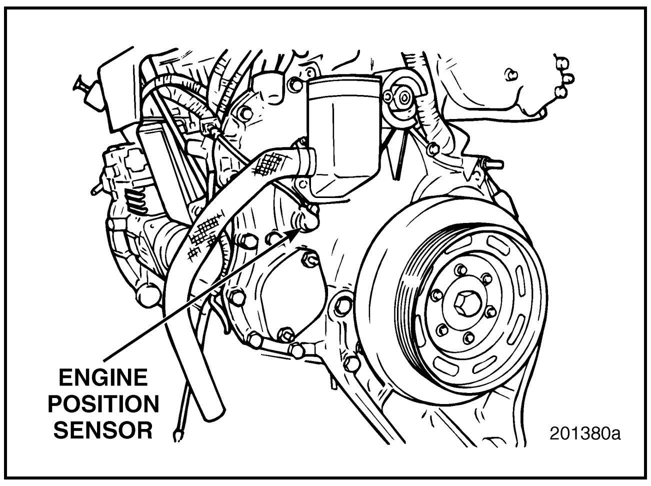


Figure 18 — Engine Position Sensor

Boost Temperature Sensor and Boost Pressure Diagnostic Ports

A V-MAC III boost temperature sensor is located on the top of the rear inlet manifold (Figure 19). There is no boost pressure sensor because, as with all V-MAC systems, V-MAC III uses ECU programming for transient smoke control.

There are two boost pressure gauge ports just forward of the boost temperature sensor. The forward port is used for the dash boost pressure gauge when chassis is so equipped. The port adjacent to the boost temperature sensor can be used to install a boost pressure gauge for diagnostic purposes if the need arises.

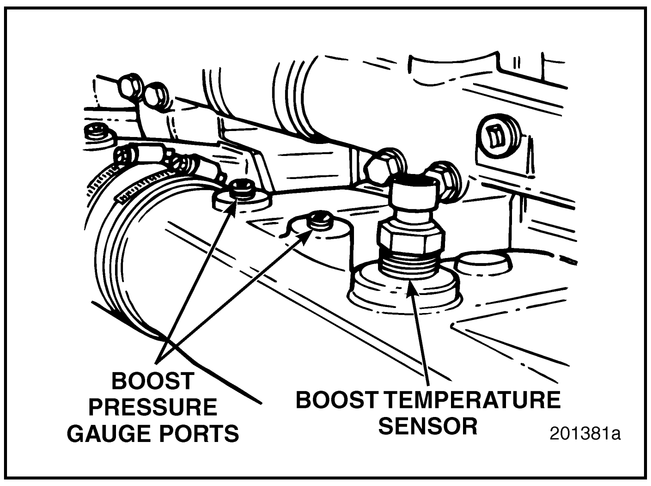


Figure 19 — Boost Temperature Sensor and Boost Pressure Gauge Ports

Belt Drive System

The belt drive system uses a single 10-rib poly-v belt to drive the alternator, water pump, and fan drive (Figure 20). A separate single-v belt, running off the water pump pulley, drives the refrigerant compressor. The service life of the poly-v belt is considerably improved over other systems and allows the use of higher horsepower cooling fans.

Both manually tensioned and automatically tensioned systems are used. Whether an engine has the manually tensioned or automatically tensioned system depends on the specific engine configuration and application.

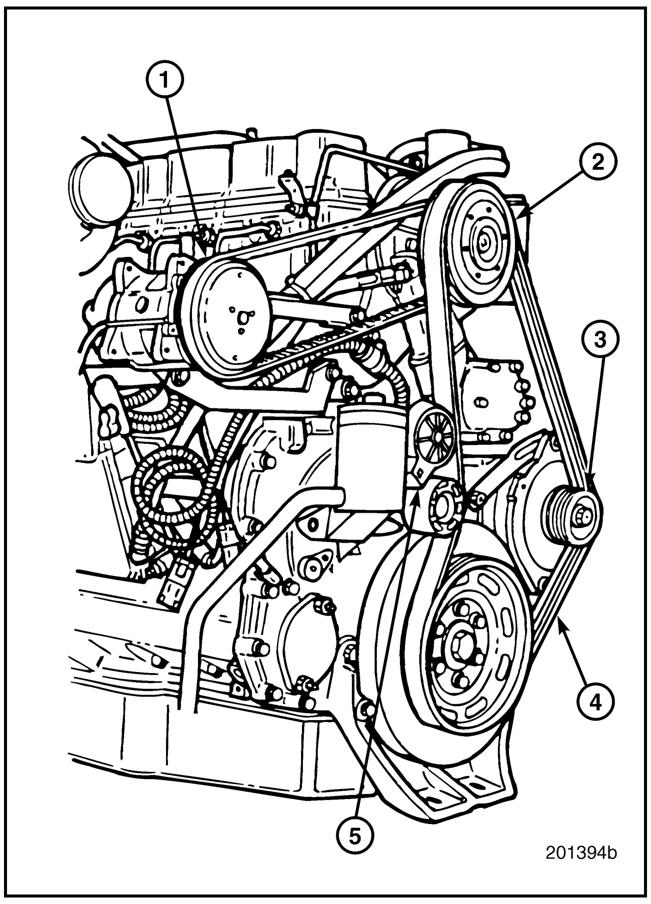


Figure 20 — Belt Drive

1. Air Conditioner Compressor 2. Water Pump	3. Alternator 4. Poly-V Belt 5. Tensioning Device

J-Tech™ Engine Brake

The J-Tech™ engine brake is a vehicle-slowing device that allows the engine to act as an air compressor, producing retarding horsepower that helps slow the vehicle. The braking action is accomplished through hydraulics using a master-slave piston arrangement similar to a hydraulic jack. When the engine brake is operated, a single exhaust valve opens near top dead center of the compression stroke, releasing high-pressure air out the exhaust. Opening one exhaust valve, instead of two, significantly reduces load to the engine brake and the valve train without adversely affecting braking power. Releasing compressed air to the exhaust prevents the return of energy to the engine piston on the expansion stroke. The result is a net power loss from the engine, or retarding horsepower, used to slow the vehicle.

With the J-Tech™ engine brake unit, the master piston of a given cylinder activates the slave piston of that same cylinder, providing optimum timing of the compression release. The E-Tech™ engine uses the same engine brake unit on the front and rear cylinder head.

5_106_00.bk Page 25 Friday, August 4, 2000 11:17 AM

ENGINE BRAKE FEATURES

Refer to Figure 22.

There are major valve train changes relative to engine brake implementation on the E-Tech™ engine. The most evident changes include:

- A significantly larger brake unit with a different appearance and operating concept than the E7.
- Standard E-Tech™ valve yokes are used at all positions. The special Jacobs exhaust yokes on the E7 engine are not used. Note that the E-Tech™ engine uses a different valve yoke from the E7 engine. The E7 and E-Tech™ yokes are not interchangeable.
- A hollow yoke adjusting screw with a floating pin in the screw is used in the exhaust yokes. The screw opens only the exhaust valve directly beneath it when the J-Tech™ engine brake is activated.
- Unique exhaust rocker arm adjusting screws and nuts (Figure 21).

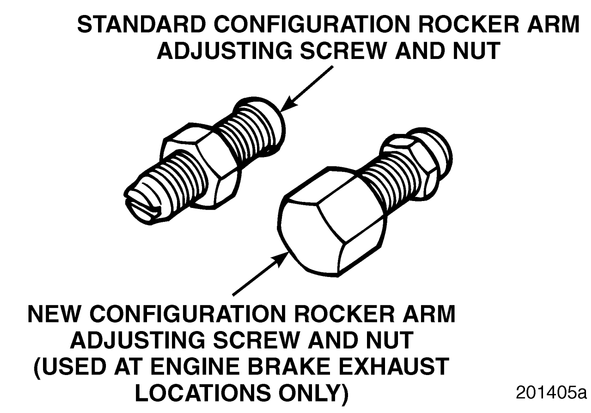


Figure 21 — Rocker Arm Adjusting Screws and Nuts

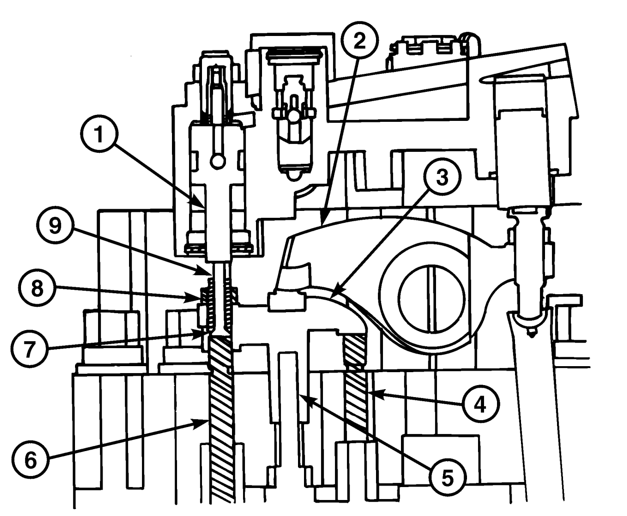


Figure 22 — J-Tech™ Brake Valve Yoke Hollow Adjusting Screw Arrangement

5_106_00.bk Page 26 Friday, August 4, 2000 11:17 AM

ENGINE BRAKE OPERATION

Refer to Figure 23.

The J-Tech™ brake functions in the following manner:

- Under powered operation, a large lash in the valve train “skips” the 0.100-inch brake bump on the camshaft.
- During engine brake operation, the solenoid valve is energized, allowing engine oil to fill the J-Tech™ brake housing oil passages.
- Oil overcomes the control valve spring and drives the control valve up in its bore. Oil passes through the ball check inside the control valve and exits through the port in the side, filling the master/slave piston circuit.
- Oil pressure causes the master piston and rocker arm to move down, removing the large lash from the cam side of the valve train. The result is a corresponding lash increase on the exhaust valve side.
- The brake bump on the exhaust cam forces the master piston upward and directs high-pressure oil to the slave piston. The check valve in the control valve prevents high-pressure oil from escaping.
- High-pressure oil causes the slave piston to move down, opening the outboard exhaust valve via a valve-actuating pin which passes through the center of the yoke adjusting screw. Activation occurs near top dead center and releases compressed air into the exhaust manifold.
- At stroke bottom, the slave piston separates from the reset valve, allowing oil to flow into the accumulator. This action reduces pressure in the high-pressure circuit, permitting the slave piston to retract and the exhaust valve to close in preparation for normal exhaust cycle. Oil in the accumulator ensures the hydraulic circuit is fully charged for the next cycle.

NOTE

To help prevent breaking or dislodging of the control valve snap ring, the J-Tech™ control valve components have been redesigned to incorporate a new-style collar (which replaces the old-style valve stop spacer) and outer spring and a retaining washer. With this change, the part number of the engine brake housing assembly was changed from 757GB58B to 757GB58C (beginning with housing assembly Serial No. D69006001), and was phased into E-Tech™ engine production June 30, 1999 (beginning with engine serial number 9M4395).

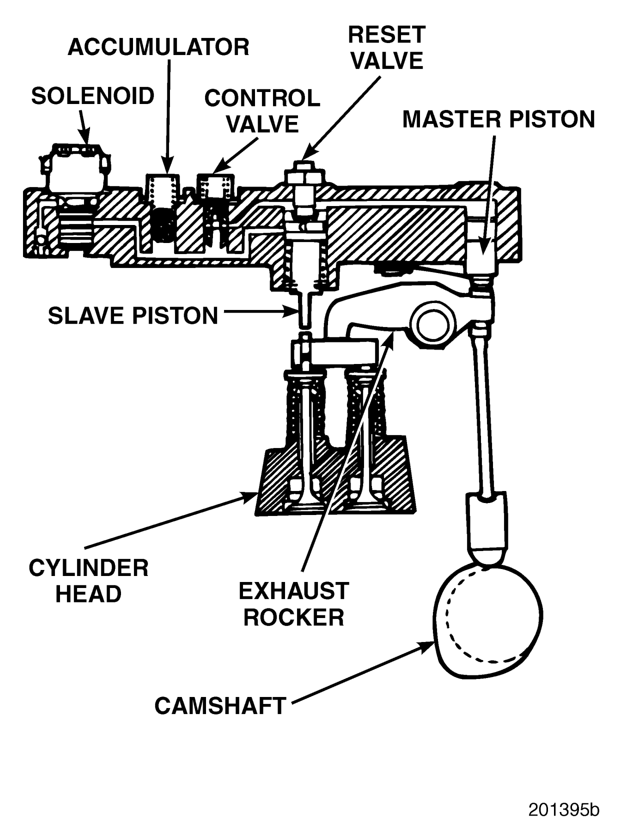


Figure 23 — J-Tech™ Brake

Camshaft

The large diameter of the camshaft (Figure 24) provides the strength necessary for actuating the unit pumps. In addition to the inlet and exhaust valve lobes, lobes have been added to drive the unit pumps. The camshaft also has more aggressive intake and exhaust cam profiles for improved fuel economy and emissions. A bump in the exhaust cam profile provides timing for engine brake operation.

The camshaft has induction-hardened journals and lobes. This process produces a pronounced heat discoloration mark approximately 3/8-inch wide, around the front and rear faces of each journal and lobe.

As an additional aid in reducing cam bushing temperature, a groove has been added to the No. 4 journal of current-production camshafts. This groove was not included on early-production units. Adding the groove to the camshaft journal has not resulted in a change to the camshaft part number.

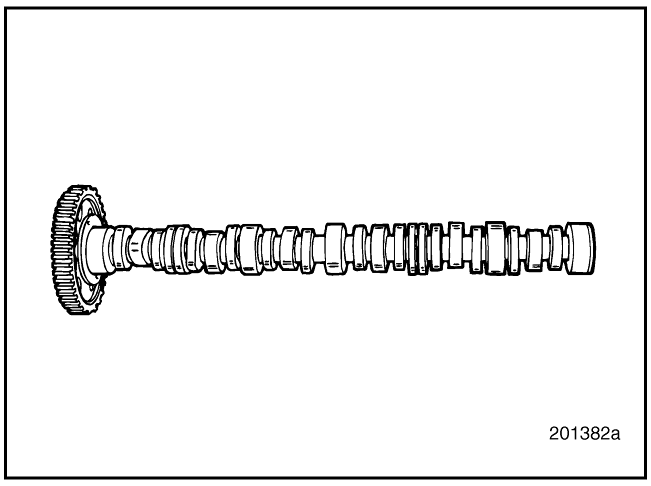


Figure 24 — Camshaft

Valve Train

The valve train accommodates the aggressive cam profiles. Roller lifters and roller followers or “tappets” (Figure 25) are used to actuate the valves and unit pumps, respectively. The roller lifters handle aggressive cam profiles better and have increased load-carrying capability.

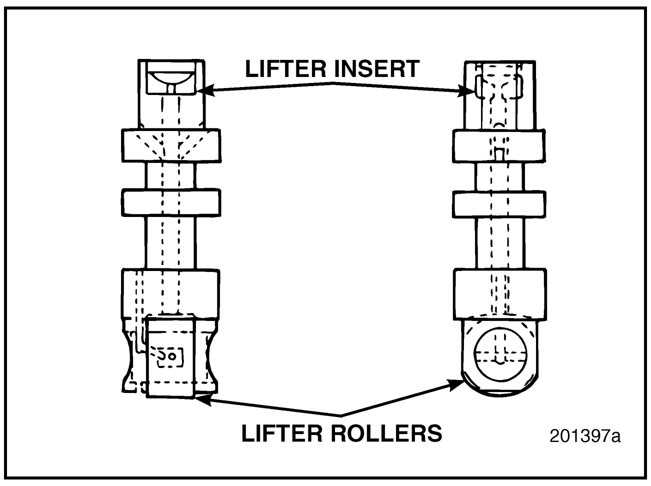


Figure 25 — Roller Lifters

VALVES

The stem tip of the valve has grooves to identify the valve as intake or exhaust. The exhaust seat face is 30 degrees, whereas the inlet valve seat is 20 degrees.

VALVE SEALS

The engines are produced with a valve stem seal that features a multi-lip upper section, combined with a second lip to significantly reduce crankcase blow-by. This seal can easily be identified by the steel retainer band around the top of the seal lip.

To improve seal-to-guide retention, the guides have three sharp ridges machined into the upper outside diameter surface. Refer to Figure 26.

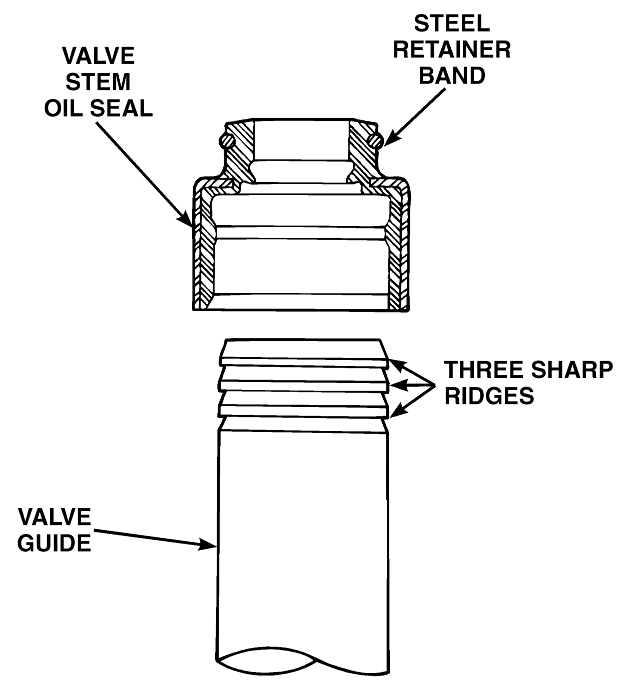


Figure 26 — Valve Seal

VALVE SPRINGS, ROTATORS AND PUSH RODS

E-Tech™ valve springs and rotators have heavier spring tension (pressure) than the E7 to accommodate the more aggressive cam profiles. Push rod design also incorporates a larger diameter to handle the increased loads.

YOKES

Pin-Type Yokes

During February of 1999, the welded wear pad-style yoke was supplemented in production with a headed pin ("button") type yoke. The material of the pin-type yoke remains ductile iron.

Both the new configuration and the previous configuration valve yokes are being used in current E-Tech™ engine production, but the yokes will not be intermixed on the same engine.

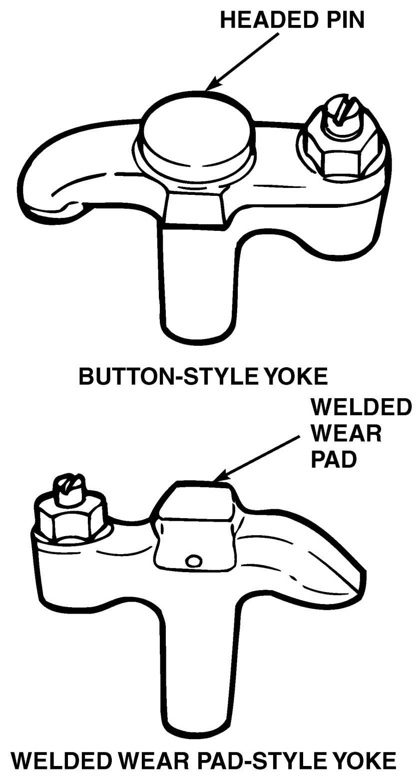


Figure 27 — Current Valve Yokes

NOTE

For service purposes, it is acceptable to intermix the different configuration yokes on the same engine.

5_106_00.bk Page 29 Friday, August 4, 2000 11:17 AM

On E-Tech™ and E7 engines, the valve yokes are very similar. However, it extremely critical that the correct valve yokes are used with the correct engine. The previous configuration yokes were identified with the letter “M” or “E” cast into the top of the yoke next to the slipper pad wear area. The letter “M” signifies the valve yoke is used in E7 engines, and the letter “E” signifies that the yoke is used in E-Tech™ engines. On the new “button-head” style valve yoke, however, the letters “M” and “E” have been eliminated. Additionally, the yokes no longer have part numbers stamped on them. Installation of the correct new button-head style valve yokes on the correct engine is still critical. Therefore, a means of positively differentiating between E-Tech™ and E7 is provided in the following information and illustrations.

The most positive means of identification are by looking at the nose of the valve yoke. The E-Tech™ yoke has the nose end of the slipper pad area ground flat as shown in Figure 28.

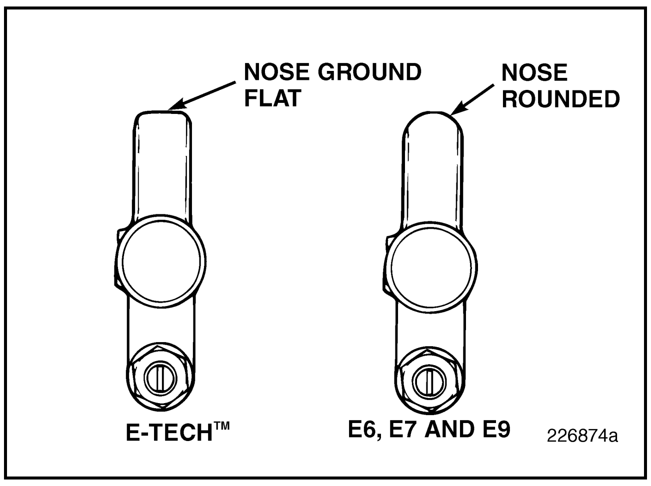


Figure 28 — E-Tech™, E6, E7 and E9 Valve Yokes (Top View)

A second method of identifying the “button-head” yoke is to look at the side view. On the yoke used for the E-Tech™ engine, the top surface of the adjusting screw end is on the same plane as the bottom surface of the “button-head.” On the E6, E7 and E9 valve yokes, the top surface of the adjusting screw area is 0.145 inch below the bottom surface of the “button-head.” Refer to Figure 29 for an illustration of these differences.

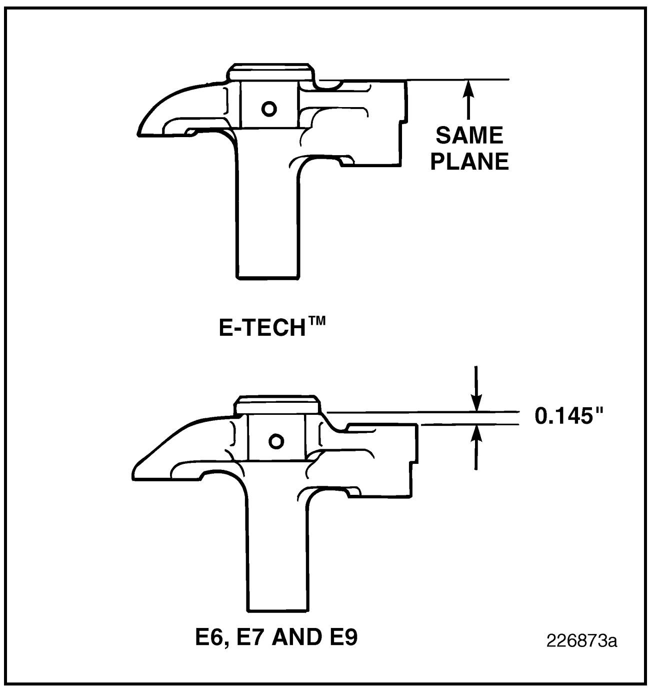


Figure 29 — Valve Yoke Side View

The yokes used on the E-Tech™ engine have a deeper engagement at yoke screw end than E7 because of the longer valve (Figure 30). E7 and E-Tech™ yokes are very similar in appearance, but should not be interchanged.

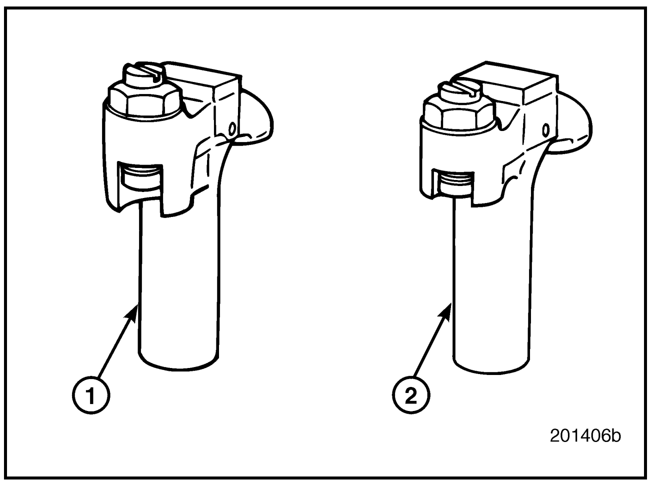


Figure 30 — Valve Yokes

1. E-Tech™	2. E7

5_106_00.bk Page 30 Friday, August 4, 2000 11:17 AM

CAUTION

Do not interchange yokes. If an E-Tech™ yoke is used on an earlier E7 engine, the valve keepers will become dislodged and cause a dropped valve. This will cause severe engine damage. If the E7 yoke is used on an exhaust location of a J-Tech™ brake-equipped E-Tech™ engine, the yoke will disengage from the valve stem tip during engine brake operation. See Figure 31.

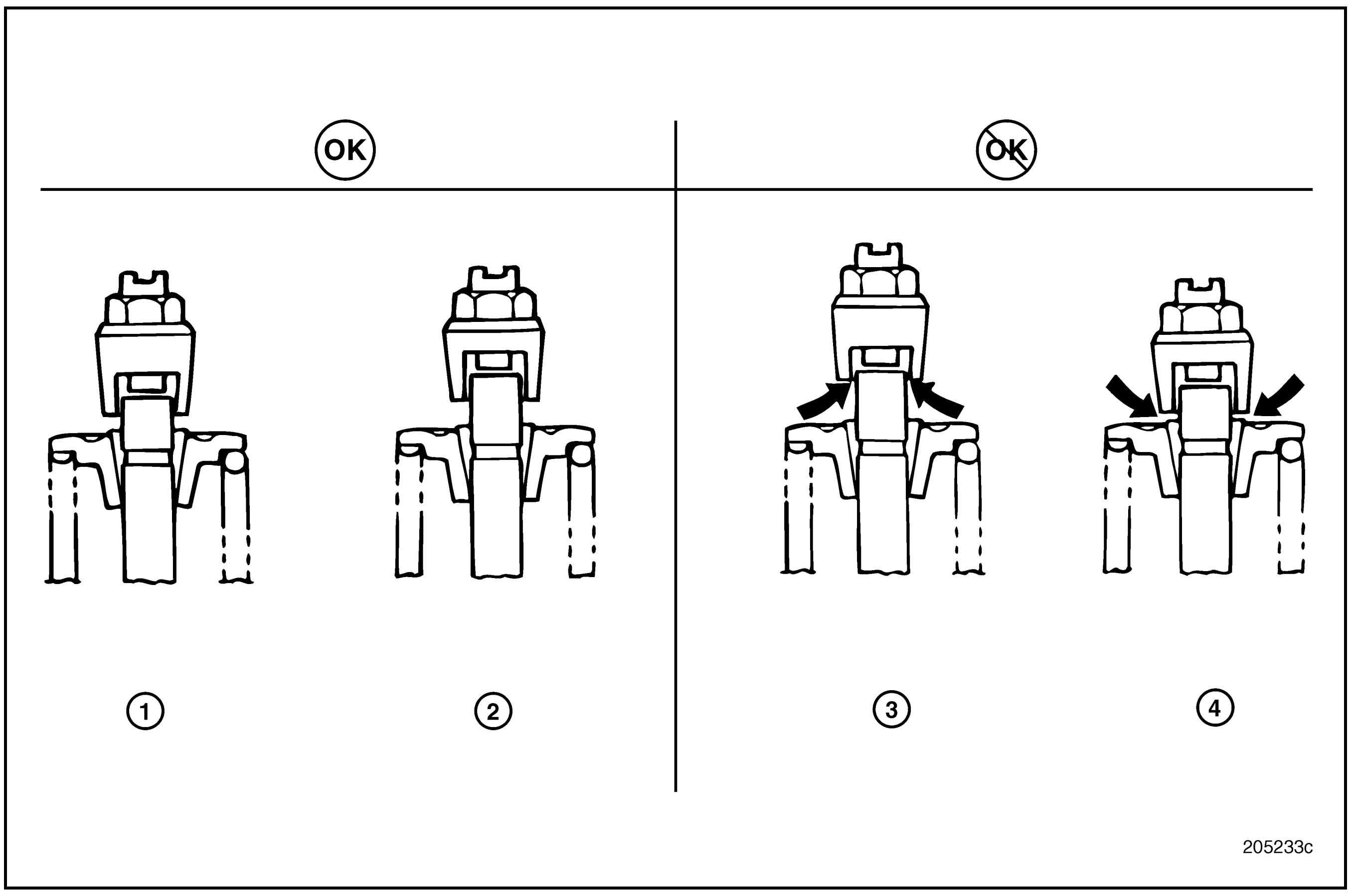


Figure 31 — Yoke/Valve Combinations

1. Correct E7 Yoke/Valve Combination 2. Correct E-Tech™ Yoke/Valve Combination 3. E7 Yoke with E-Tech™ Valve	4. E-Tech™ Yoke with E7 Valve Note: Arrows identify problem areas.

Pinless Valve Yokes — Inlet Valve Locations

Beginning on March 2, 2000 (engine serial No. 0D0120), pinless valve yokes were implemented into production on all E-Tech™ engines. The pinless yokes are used for the inlet valve only. This change also affects the cylinder heads which no longer have yoke guide pins at the inlet valve locations.

The pinless yoke is self-leveling in operation and does not have a yoke leveling adjustment screw. Inlet valve lash adjustments are performed in the normal manner with the rocker arm adjusting screw. For the exhaust valves, it is still necessary to adjust the valve yoke first, then the rocker arm lash.

The bottom of the valve yoke that bridges the two inlet valves has a round hole and an elongated hole that fit over the valve stems. The nose of the yoke with the elongated hole has two notches in the casting. When installing the pinless yokes, it is important that the end of the yoke with the two notches faces away from the valve rocker shaft. If the yoke is installed incorrectly, the yoke will contact the rocker arm.

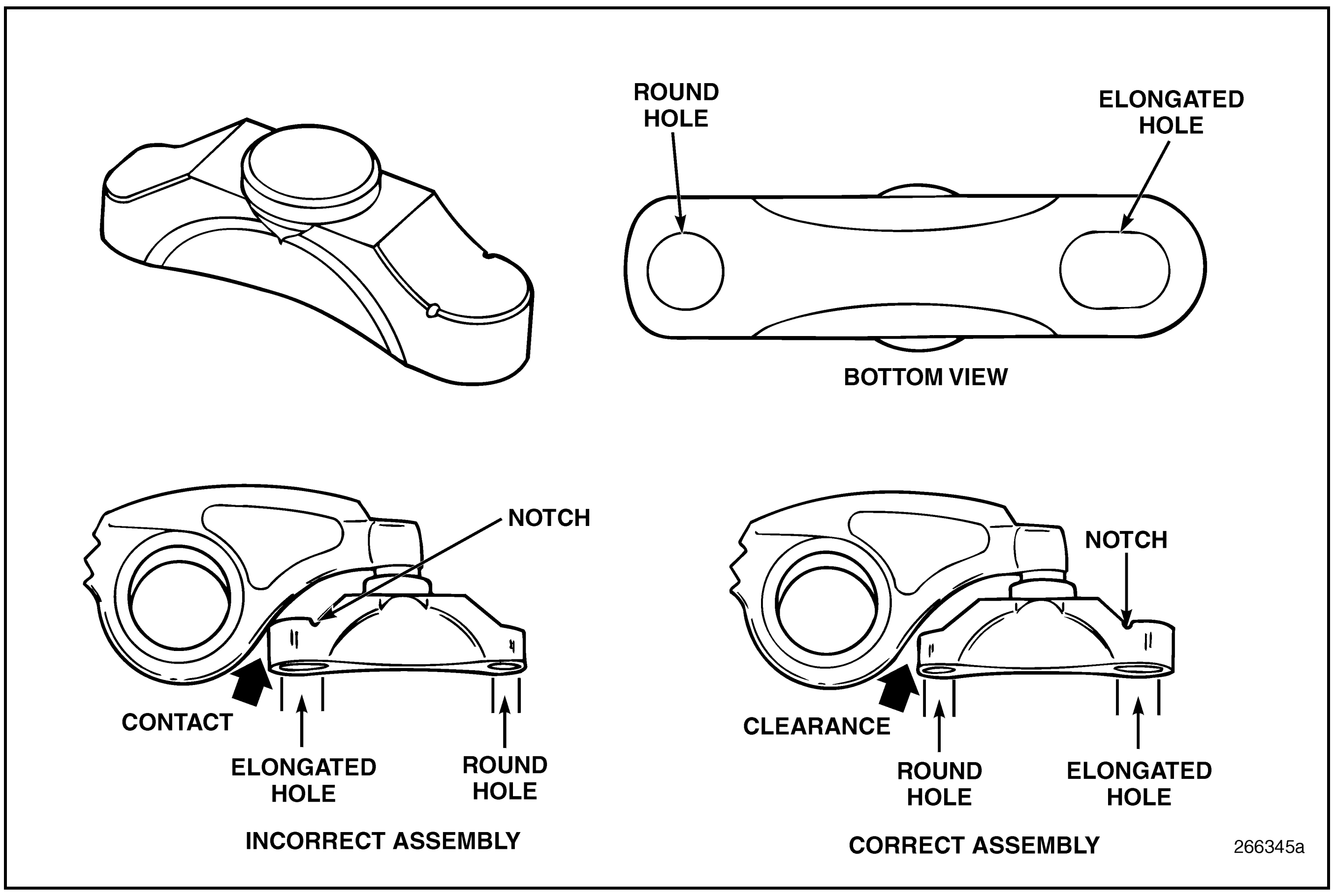


Figure 32 — Proper Assembly of the Pinless Valve Yoke

ROCKER ARMS

Early-production E-Tech™ used the older-style E7 rocker arms. Effective second quarter 1997, a newly designed rocker arm (Figure 33) on which the slipper-end wear surface is a hardened, headed pin pressed into the rocker arm, was introduced and is currently used.

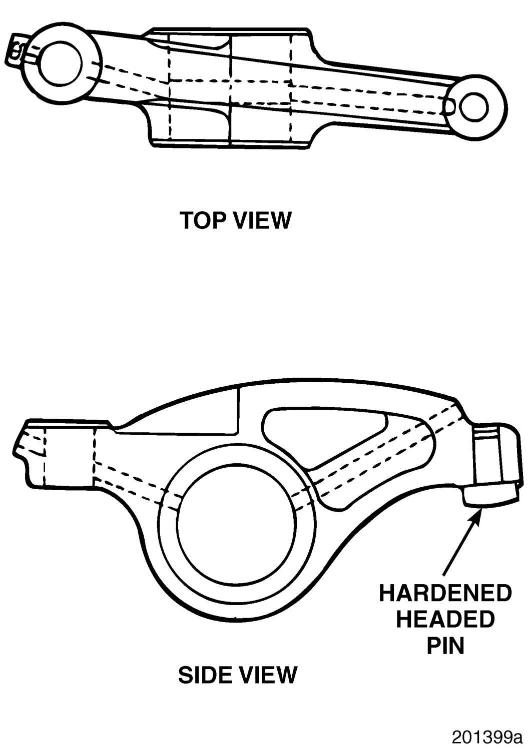


Figure 33 — New-Style Rocker Arm

ROCKER ARM/SHAFT ASSEMBLY

Improved features of the E-Tech™ rocker arm/ shaft assemblies include:

- No coil springs between rocker arms
- C-clips used to retain rocker arms
- Longer shaft lengths
- Cup plugs in shaft ends
- Improved centering of rocker arm slipper feet over yoke pads

Low-Pressure Fuel System

The flow of fuel through the low-pressure side of the fuel system is essentially the same as that in the E7 engine for current-production engines with the left-side mounted EECU. However, on early-production engines with the right-side mounted EECU, a cooling plate was added to the circuit (Figure 34).

Fuel flows from the fuel tank to the primary filter, the EECU cooling plate (if equipped), the supply pump, the secondary filter and the unit pumps. Unused fuel is collected in the fuel return gallery in the cylinder block and returned to the fuel tank by a fuel return line.

To decrease restriction in the low-pressure fuel system, hoses and fittings with larger inside diameters are used for all suction lines in the E-Tech™ system.

To meet unit pump demands, the supply pump provides a 100 gph fuel flow at 70 psi pressure. This high level of flow and pressure is needed to cool the unit pumps and EECU, and keep the fuel supply gallery filled. A check valve fitting, located on the fuel return gallery outlet on the cylinder block right side, maintains fuel gallery pressure and prevents the system from bleeding down when the engine is not operating.

NOTE

On current-production engines, a new fuel gallery pressure regulating valve with a 70 psi spring setting is used to reduce fuel gallery pressure and fuel dilution.

The gear-type supply pump is located on the rear side of the right-front flange of the cylinder block. It is driven by the engine camshaft gear. A hand primer pump is mounted on the supply pump.

5_106_00.bk Page 33 Friday, August 4, 2000 11:17 AM

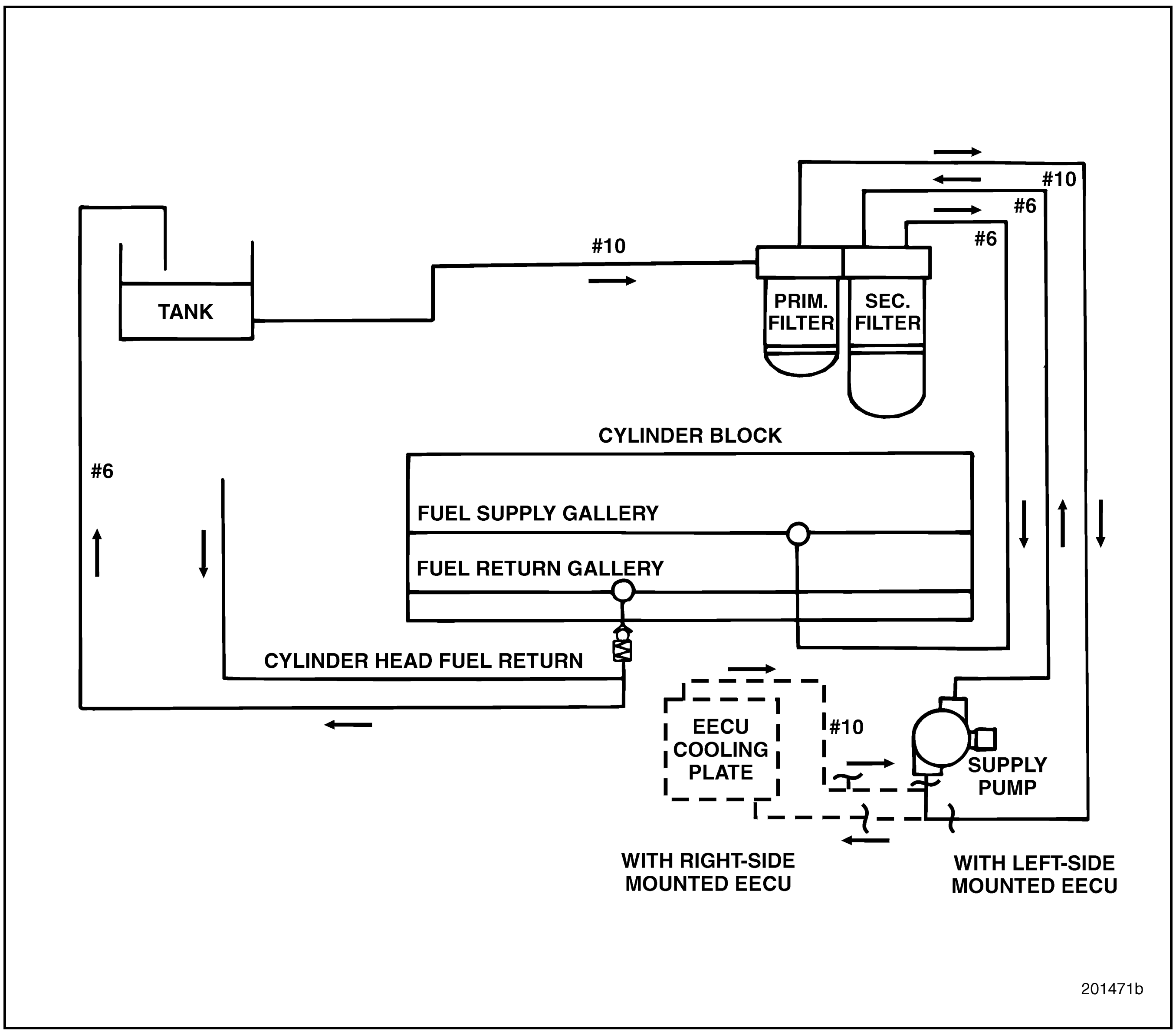


Figure 34 — Low-Pressure Fuel System

Fuel Filtration System

To build up the extremely high pressures required for improved combustion, unit pumps must have an unrestricted supply of clean fuel. The E-Tech™ filtration system, which utilizes a primary and secondary filter element, was designed to provide optimum balance between filtration efficiency (micron size) and filter change interval (restriction).

The main design features of the E-Tech™ filtration system include:

- Fine micron media
- Large diameter seal surface on both filters, as well as different primary and secondary thread sizes (to avoid mix-up with E7 filters)
- Unique identification system (a red primary filter and green secondary filter with black logo and lettering, and two 1/4-inch black bands, four inches from top of filter). Refer to Figure 35.

CAUTION

It is mandatory to use these improved fuel filters on E-Tech™ engines to protect the unit pumps from contaminant damage to the very close-toleranced internal components.

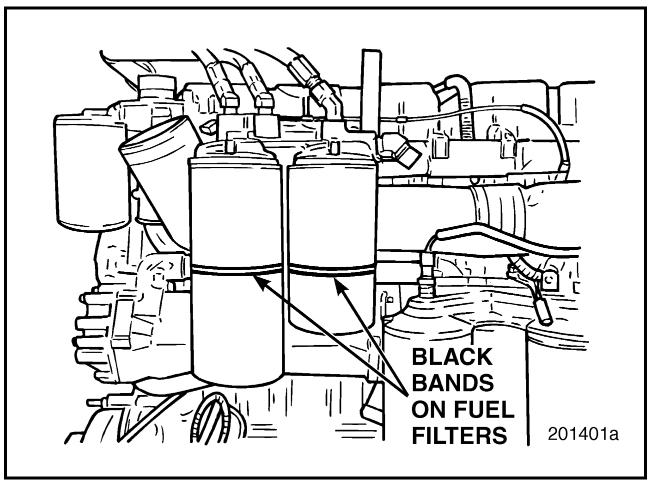


Figure 35 — Fuel Filters

The fuel filter mounting adapter is made from a casting, on which the primary and secondary mounting flanges are the same large size (Figure 36). The adapter has metric thread spuds for mounting the fuel filters. As has always been the practice, primary and secondary spuds are different sizes, so only the correct filter can be installed at the proper location.

CAUTION

The correct fuel filter mounting adapter must be used on the proper engine (E-Tech™ or E7) to ensure the correct filters are used.

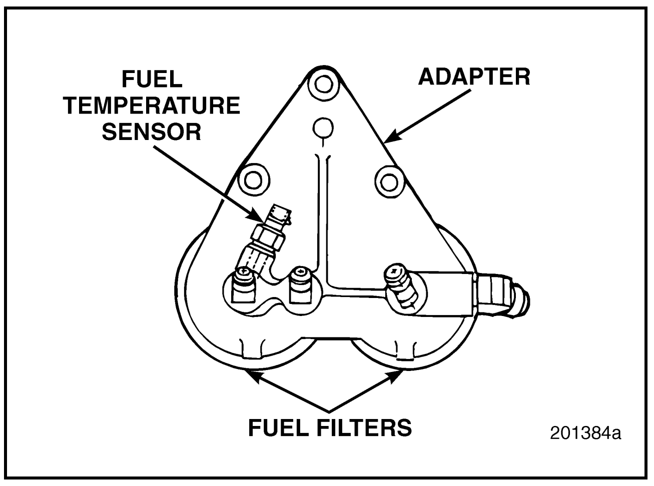


Figure 36 — Fuel Filter Mounting Adapter (with Right-Side Mounted EECU)

V-MAC III monitors fuel temperature at the secondary fuel filter outlet which supplies fuel to the gallery feeding the unit pumps (early production), or at the cylinder block fuel gallery inlet (current production). This fuel temperature data is used by the system to adjust fuel delivery for optimized power and to provide accurate mpg fuel consumption information shown on the Co-Pilot display.

5_106_00.bk Page 35 Friday, August 4, 2000 11:17 AM

High-Pressure Fuel System

The high-pressure fuel system (Figure 37) is designed to provide fuel to the combustion chamber under high pressure. In this system, unit pumps (one per cylinder) replace the previously used fuel injection pump. The unit pump operating pressures are 26,000 psi, more than 50 percent greater than the peak injection pressures of the E7 engine. These higher pressures, along with an extended timing range and optimized timing control, provide performance improvements.

Fuel is supplied to each of the unit pumps by the fuel supply gallery in the cylinder block. The high pressure required for fuel injection is generated by a pump plunger (10 mm diameter, 18 mm stroke), which is actuated by a roller cam follower (tappet) driven by the engine camshaft. The volume of fuel delivered to each cylinder is precisely metered by a solenoid mounted on each of the unit pumps, which responds to signals from the V-MAC III EECU. The pressurized fuel is delivered to the injector nozzles by individual fuel injector lines, which are the same for all cylinders and all E-Tech™ engine models.

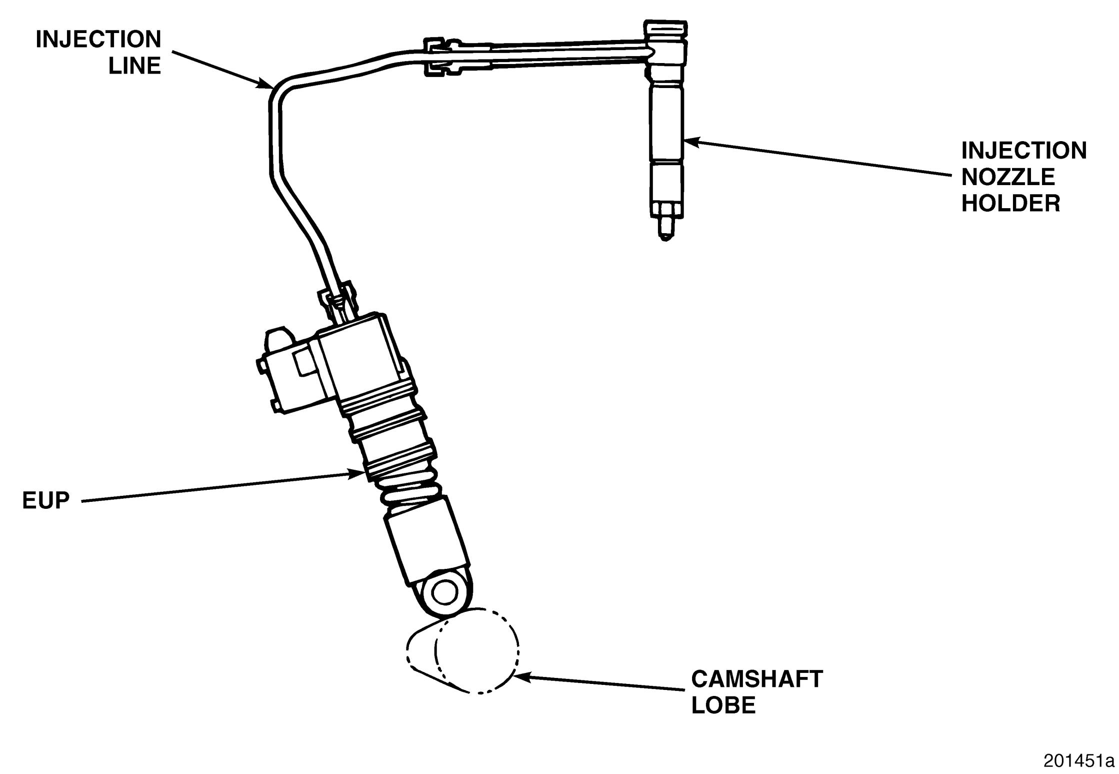


Figure 37 — High-Pressure Fuel System

High-Pressure Fuel Injection Lines

High-pressure fuel lines for each cylinder (Figure 38) are short (17 inches) and have the same bends and the strength to withstand the high fuel pressure generated by electronic unit pumps. The same part number is used for all cylinders and all engine models. Also, there are no clamps used on these lines.

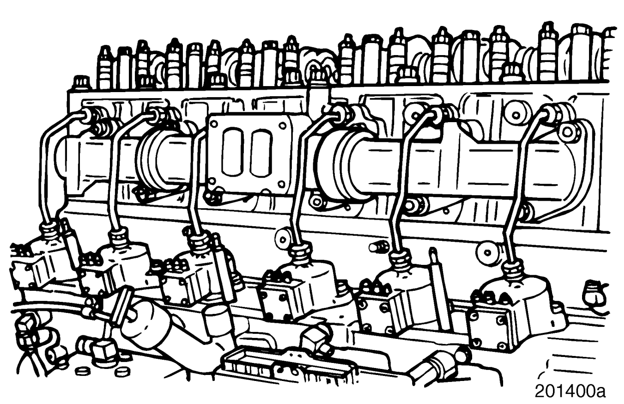


Figure 38 — Fuel Injection Lines

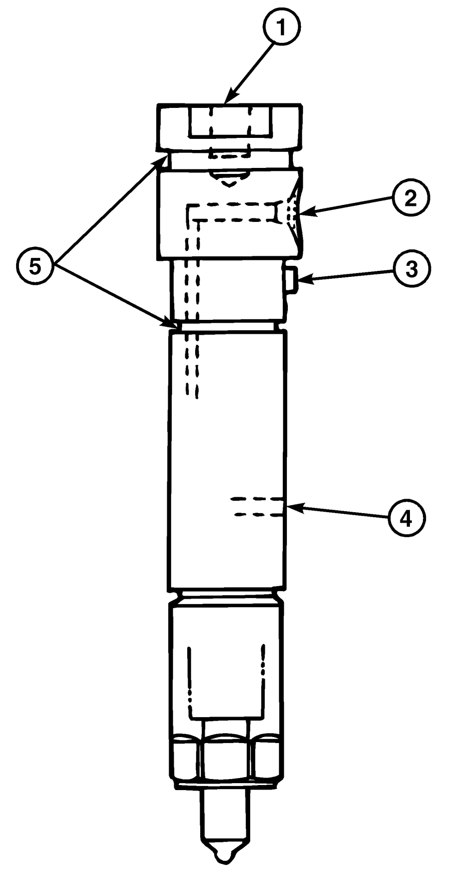
Fuel Injector Assemblies

Injector nozzles in the E-Tech™ differ from those used in the E7 in that they have increased material strength, a larger 22-mm diameter and a higher pressure capability. These features are essentially due to the higher operating pressures generated by the unit pumps.

In the E-Tech™ engine, a pin on the nozzle holder locates the nozzle in the cylinder head. The locating pin is on the same side as the nozzle holder fuel inlet port. Refer to Figure 39.

NOTE

A check valve is incorporated in the nozzle holders on current-production engines.



1. 5/16 INCH-24 THREADS FOR REMOVING NOZZLE FROM CYLINDER HEAD
2. NOZZLE FUEL INLET (HIGH PRESSURE FUEL LINE CONNECTION)
3. NOZZLE-TO-CYLINDER HEAD INDEXING PIN
4. NOZZLE FUEL RETURN DUCT OUTLET
5. O-RING GROOVES

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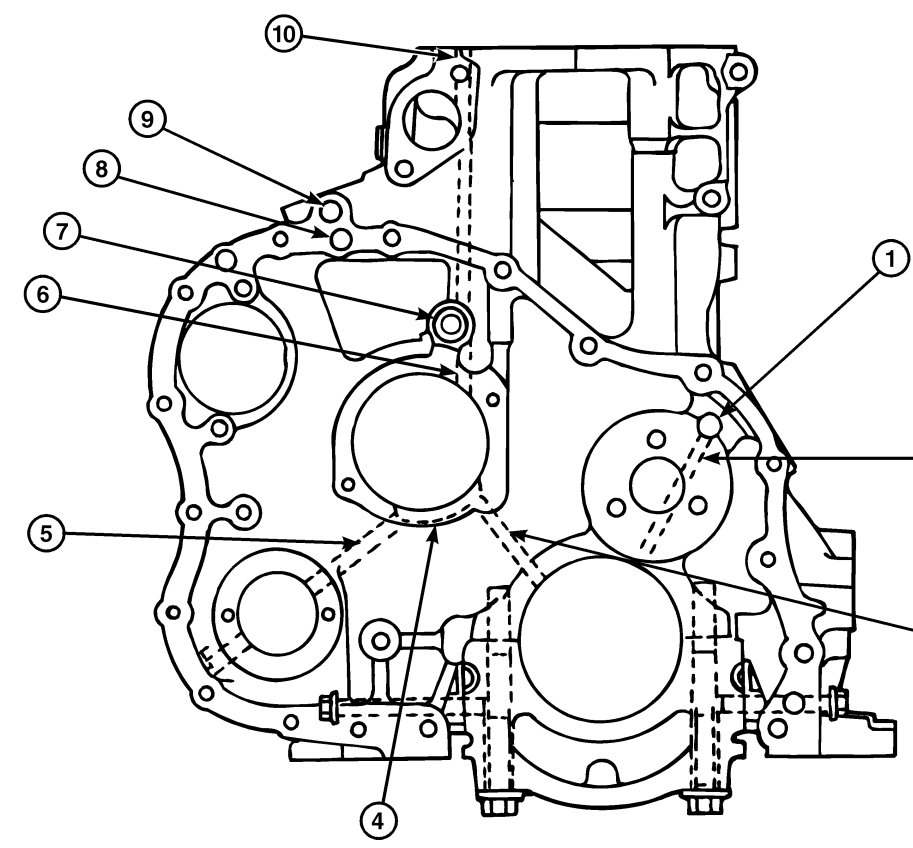
Figure 39 — Fuel Injector Nozzle Holder

5_106_00.bk Page 37 Friday, August 4, 2000 11:17 AM

Cylinder Block

The cylinder block is a single-piece design made of high-strength alloyed gray cast iron. The deep skirt extends well below the crankshaft center line and incorporates seven main bearings. The bearing caps are made of ductile iron and use buttress screws at the intermediate locations. Replaceable wet-dry sleeves line the cylinder bore.

Due to the large camshaft diameter, the cam bore position is shifted up and outboard to operate the unit pumps and provide cam-to-crank clearance (Figure 40). To accommodate this change in cam position, the push rod holes are angled four degrees and the air compressor angled outboard. The crank and cam timing gears do not mesh directly, but power transmission occurs through an idler gear mounted in an idler gear bore in the front face of the cylinder block. The right-front flange on the cylinder block provides a mounting surface for the fuel supply pump.



1. MAIN OIL GALLERY
2. MAIN GALLERY TO MAIN BEARING BORE OIL PASSAGE
3. MAIN BEARING BORE TO CAM BORE OIL PASSAGE
4. FRONT CAM BUSHING BORE TO FRONT AUX. BUSHING OIL SUPPLY ANNULUS
5. FRONT CAM BUSHING BORE TO FRONT AUXILIARY BUSHING OIL PASSAGE
6. NO. 2 AND NO. 5 CAM BUSHING BORE OIL SUPPLY TO RIGHT SIDE OIL GALLERY AND CYLINDER HEADS
7. VALVE LIFTER/EUP OIL GALLERY
8. FUEL RETURN GALLERY
9. FUEL SUPPLY GALLERY
10. OIL PASSAGES FROM NO. 2 AND NO. 5 CAM BORES TO CYLINDER HEADS

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Figure 40 — Cylinder Block

The main oil gallery runs along the left side of the block. A second oil gallery — the valve lifter/EUP oil supply gallery — runs along the right side of the block. The valve lifter bores directly intersect this right-side gallery, while oil is supplied to the EUP by six passages drilled from the block's right side, through the EUP bore and into the adjacent valve lifter bore. The six holes along the block's right side are closed off with pipe plugs.

Both the left- and right-side oil galleries are drilled from the front and the rear, but do not meet at the center. Oil is supplied to the valve lifter/EUP oil gallery through drilled passages from the No. 2 and No. 5 cam bushings. An annulus in No. 2 and No. 5 main bearing bores, as well as the groove in the upper bearing inserts, ensures a high volume of oil to the lifter/EUP gallery.

Internal fuel supply and return galleries for the unit pumps are gun-drilled axially, the full length of the block's right side just below the unit pump mounting flange surface.

Current-production cylinder blocks were changed to accommodate a redesigned oil cooler/filter mounting arrangement. Early-production engines used an externally drained Centri-Max® filter. This arrangement has been replaced by the internally drained Centri-Max PLUS filter on current-production engines. The major change to the cylinder block is in the four-bolt oil filter pedestal mounting pad located at the center left-hand side of the block. With the elimination of the externally drained Centri-Max® filter, two internal drain holes are now cast into this mounting pad. These drain holes allow the Centri-Max® PLUS drain oil to pass directly into the crankcase. The two 3/4-inch “as-cast” holes are visible inside the crankcase on either side of the No. 4 main bearing bulkhead, between Nos. 3 and 4 piston cooling nozzles. The external oil drain port in the cylinder block used for the externally drained Centri-Max® filter is covered with a block-off plate.

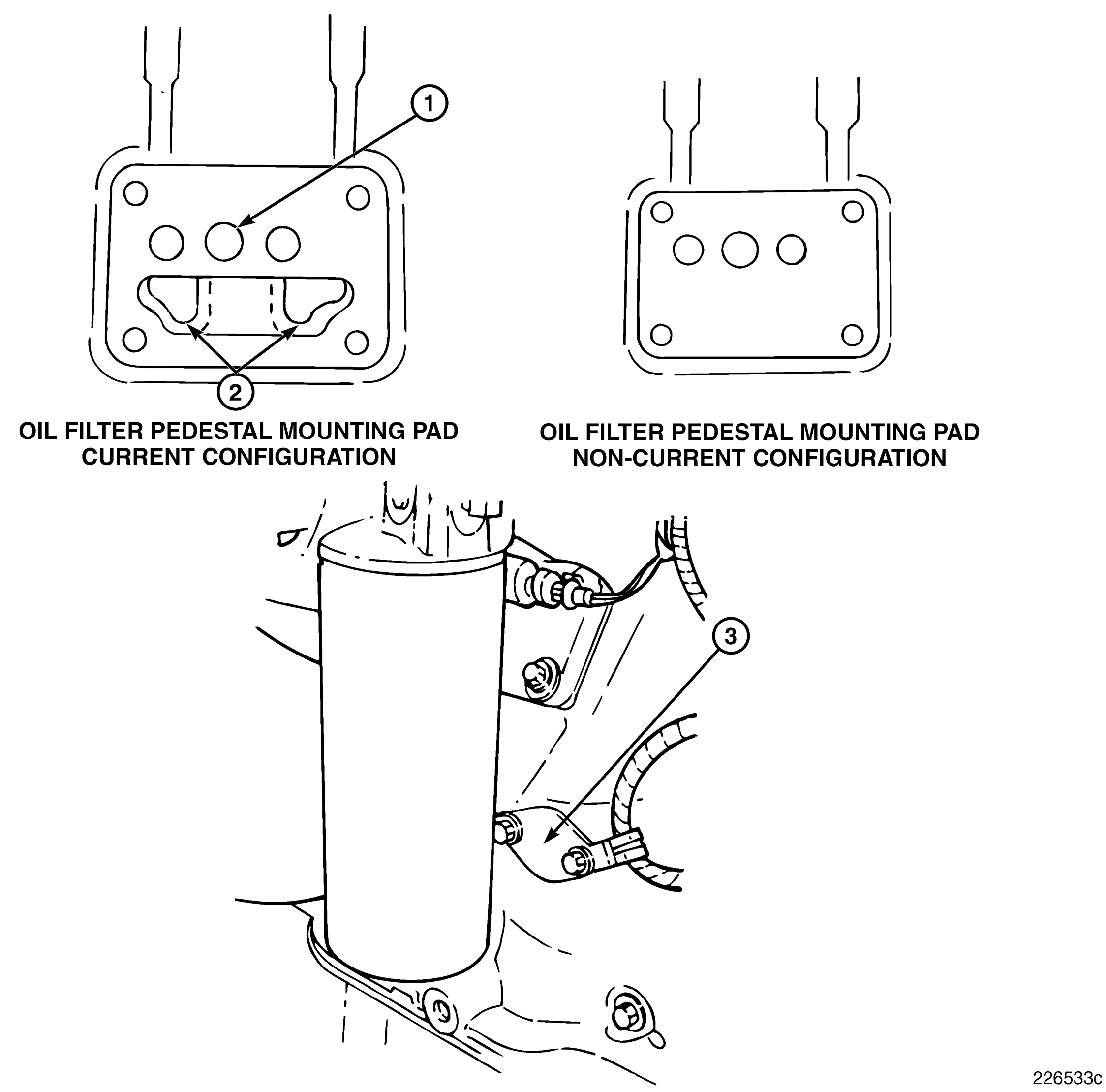


Figure 41 — Oil Filter Pedestal Mounting Pad and External Oil Drain Block-Off Plate

1. Oil Passage — Oil Pump-to-Oil Cooler and Filters 2. Internal Drain Holes	3. External Oil Drain Block-Off Plate

The new internally drained Centri-Max® PLUS filter requires the two internal drain cavities in the cylinder block. The same cylinder blocks, however, are used to service engines having either the externally drained Centri-Max®, or the internally drained Centri-Max® PLUS filter assemblies. When a block is used for an engine equipped with the externally drained Centri-Max filter, the oil drain cavities are not functional.

Crankshaft

The crankshaft is fully counterbalanced and has induction hardened journals. There are seven main bearings with thrust washers located at the center main bearing (position No. 4) to absorb fore and aft end thrust. Crankshaft extension at the forward end carries the main drive gear, vibration damper and accessory drive pulleys. The main drive gear has a shrink fit and the vibration damper hub has a press fit. The main drive gear is keyed to the crankshaft for proper assembly and engine timing. The flywheel is mounted to a flange at the rear of the crankshaft. Two seals, one at the front and one at the rear, prevent engine lubricating oil from leaking around the ends of the crankshaft.

Bearing caps are furnished with the crankcase and support the crankshaft in true alignment. Webs integral to the crankcase provide the upper half of the main bearing supports. Removable caps provide the lower support and are held in position with capscrews. The bearing caps are not interchangeable and each has a number stamped on it which signifies its correct location and alignment in the crankcase. The caps are numbered 1 through 7, with the No. 1 main bearing cap at the front of the engine. The bearing inserts are precision-designed, and are positioned between the crankshaft and crankcase, and between the crankshaft and the bearing caps. Thrust flanges to support the thrust washers are located at the center main bearing (No. 4).

Block Heater for Front (Water Pump) Location

The engine accepts a straight element unit in the rear location. Front installations require a curved-element heater (Figure 42). This curved element is located inside the lower part of the water pump housing, which has been revised to accommodate it. With factory installations, CH/CL models use the rear location, while RD, MR and other Macungie-built models use the front location.

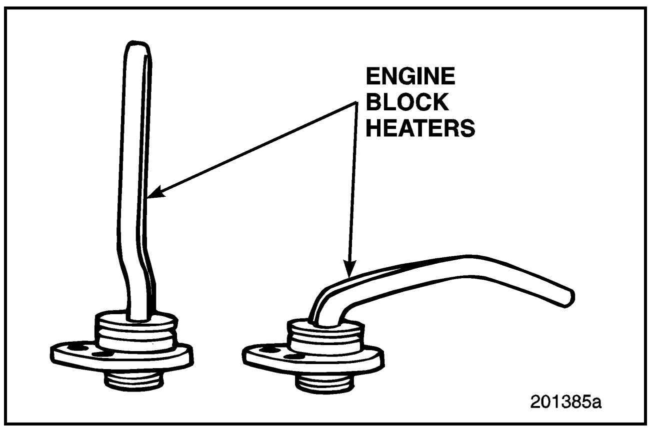


Figure 42 — Straight and Curved Block Heaters

5_106_00.bk Page 41 Friday, August 4, 2000 11:17 AM

Cylinder Head

The cast iron cylinder head (Figure 43) is constructed using a special iron alloy. The head contains cored inlet, exhaust and coolant passages, drilled oil passages, replaceable inlet and exhaust guides and seats, various drilled passages and tapped holes. Each cylinder head covers three cylinders and has two inlet and two exhaust valves per cylinder. Circular grooves correspond with the fire ring bead on the cylinder sleeves. This design sets the fire ring over the liner. With the cylinder head installed and the bolts tightened to specification, the liner coining bead extrudes the fire ring into the cylinder head groove, providing a positive combustion pressure seal.

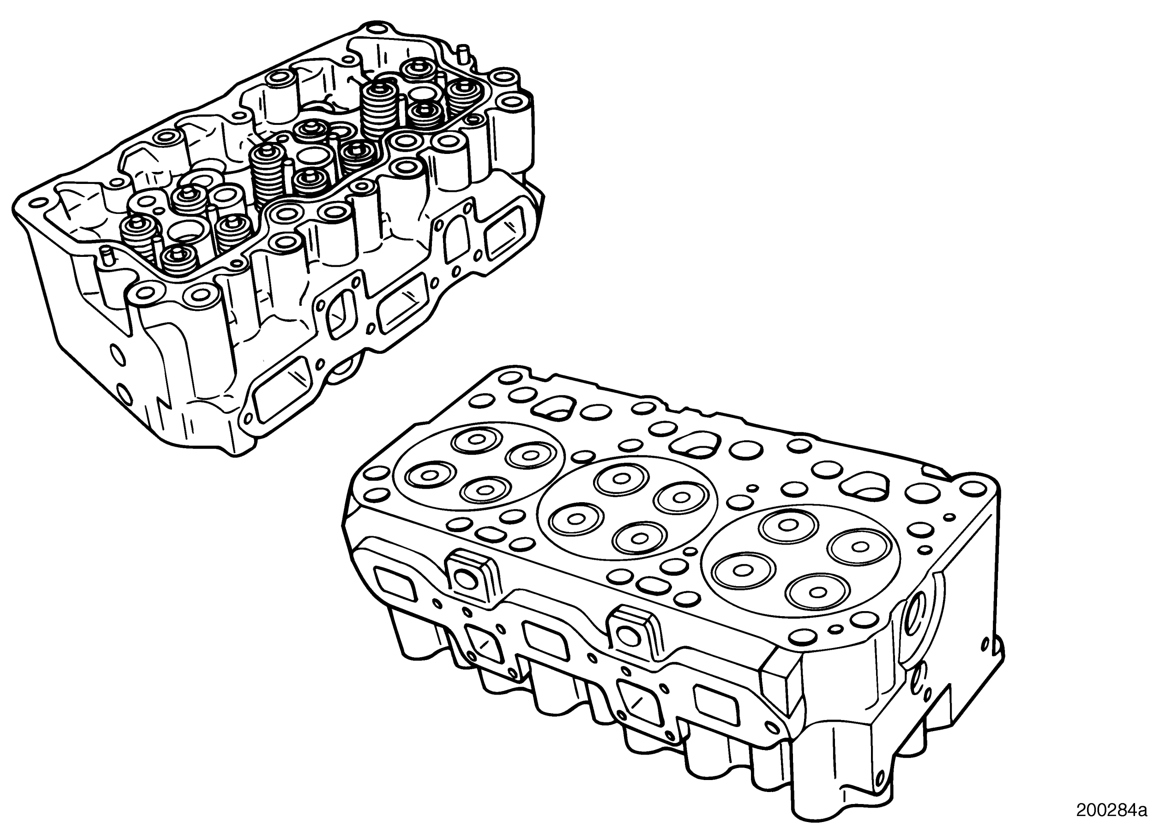


Figure 43 — E-Tech™ Cylinder Head

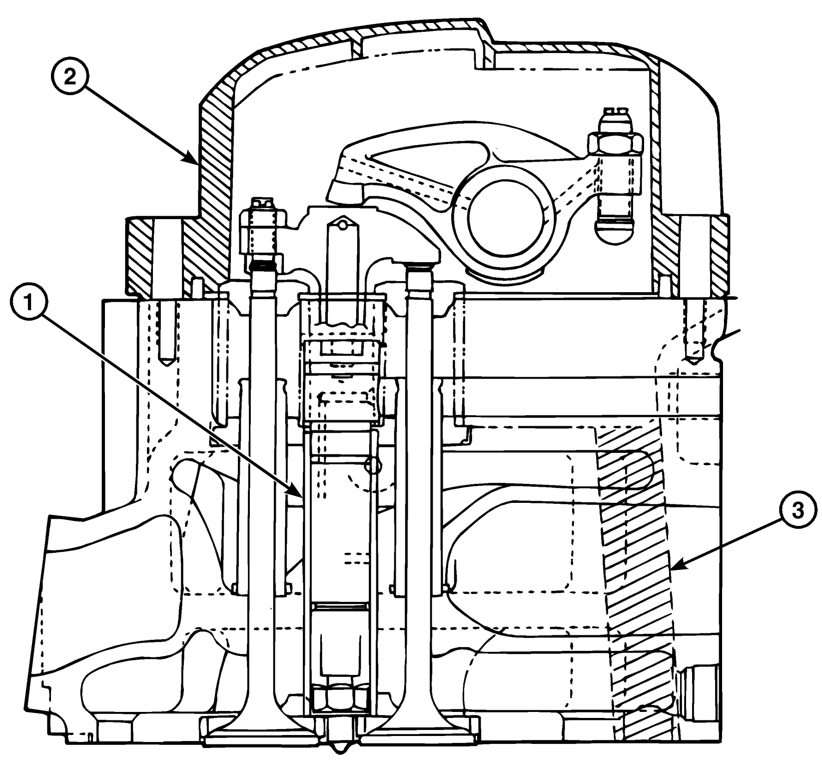
DESCRIPTION & OPERATION

Some characteristics of the E-Tech™ cylinder head are not visually evident, but are still significant (Figure 44). They include the following listed items:

- Push rod holes are angled at four degrees due to outboard location of camshaft.
- Large nozzle sleeve diameter to accommodate 22-mm nozzle holder assembly.
- Water-jacket casting designed to improve coolant flow.
- Lower exhaust stud holes intersect with push rod holes; upper exhaust holes may intersect as well. This requires that all exhaust studs be sealed at installation to prevent oil weepage.

NOTE

E-Tech™ and E7 cylinder heads cannot be interchanged because of the differences in the machining.



1. LARGE DIAMETER NOZZLE SLEEVE TO ACCOMMODATE 22 MM NOZZLE
2. E7 EUP CYLINDER HEAD COVER
3. PUSH ROD HOLE ANGLED AT FOUR DEGREES

Figure 44 — Cylinder Head and Cover

5_106_00.bk Page 43 Friday, August 4, 2000 11:17 AM

Cylinder Head Gasket

E7 and E-Tech™ engines use the same fire ring, but a different cylinder head gasket. The gaskets are identical except for obvious differences at the right-side push rod cutout areas. The right-side edge of the E7 gasket is straight, except for protrusions at the four right-side head bolt holes. The E-Tech™ gasket has these protruded areas as well, but also has six larger protrusions at the push rod hole cutouts (Figure 45). Care must be exercised to use the proper gasket only on the engine for which it is designed.

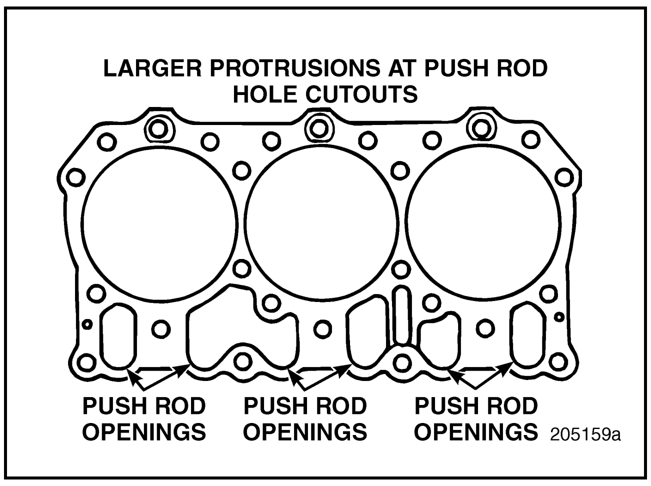


Figure 45 — E-Tech™ Head Gasket

Gear Train

The gear train of the E-Tech™ engine (Figure 46) is designed to accommodate the large diameter camshaft and the addition of electronic unit pumps. The major changes include all new gears, an added idler gear, and camshaft and auxiliary gears that rotate in opposite directions than the E7. In addition, the power steering pump and air compressor rotate in opposite directions and the oil pump drive gear helix has been reversed to maintain pumping direction.

The larger camshaft on the E-Tech™ had to be relocated upward and outward from the original E7 location in order for the engine camshaft to drive the unit pumps. This placed the camshaft further away from the crankshaft and, as a result, larger timing gears are required. An idler gear is used between the crank and cam gears. This keeps the gear sizes from becoming too large and keeps the engine timing gear flange and timing gear cover from requiring enlargement.

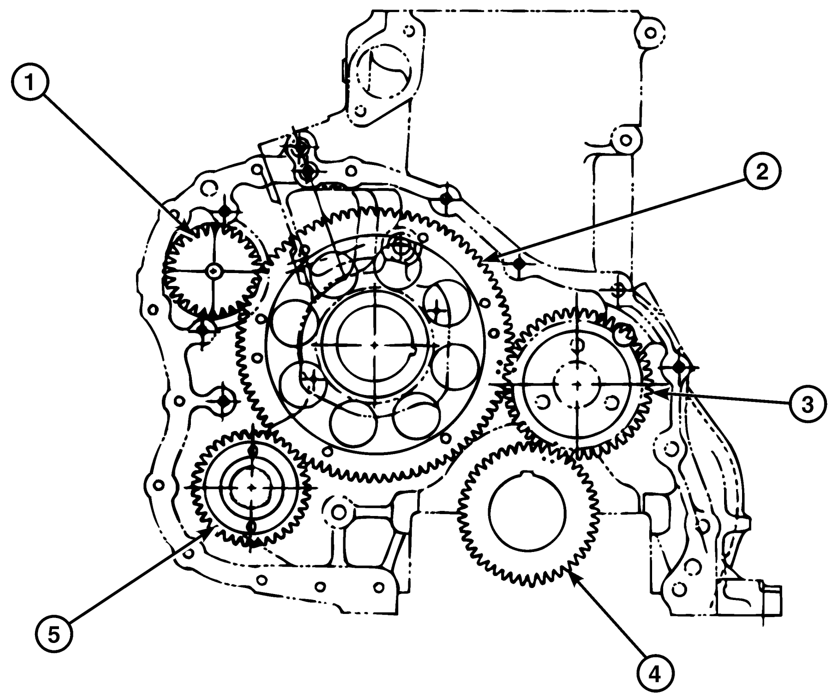


Figure 46 — E-Tech™ Gear Train

1. Fuel Pump Gear 2. Camshaft Gear 3. Idler Gear	4. Crankshaft Gear 5. Auxiliary Shaft Gear

NOTE

There are 45 gear teeth on the crankshaft gear, 90 teeth on the camshaft gear and 48 on the idler gear. Because the idler gear has 3 more teeth than the crankshaft gear, the timing marks (Figure 47) align only once every 16 revolutions of the crankshaft. This is called a “hunting tooth” system.

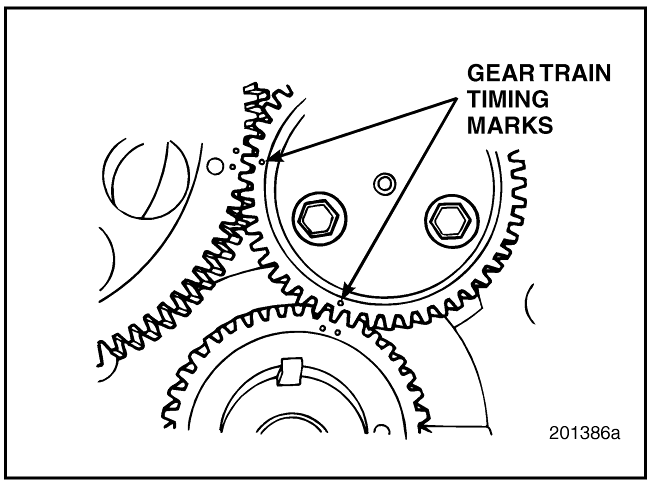


Figure 47 — Timing Marks

Because of the addition of an idler gear, the E-Tech™ engine camshaft rotates in the opposite direction of the camshaft in the E7 engine. The additional gearing also changes rotation direction for the air compressor and the power steering pump. However, the oil pump drive gear helix has been changed to keep the same oil pump direction of rotation.

Air Compressor

E7 and E-Tech™ air compressors have the same internal components, as the air compressor functions equally well with either direction of rotation. There are, however, some external differences between the engines and air compressors, which prevent the compressors from being interchangeable between the two engines.

The E-Tech™ air compressor benefits from the 22% faster auxiliary shaft speed with quicker pump-up times, faster air-system recovery and less operating time under load.

Power Steering Pump

E7 and E-Tech™ engines have the capability of driving a power steering pump from either the front or rear of the auxiliary shaft. Naturally, the direction of rotation of a front power steering pump is opposite that of a rear power steering pump. For example, the E-Tech™ auxiliary shaft has a direction of rotation opposite that of the E7, while an E7 front-mounted, power steering pump has the same direction of rotation as an E-Tech™ rear-mounted, power steering pump.

CAUTION

Always refer to part number specification information when installing a power steering pump to ensure that the correct part with the correct direction of rotation is being used. Installing a power steering pump with the wrong direction of rotation will result in pump failure and inoperative power steering.

Vibration Damper Hub

Because the E-Tech™ engine timing gears are wider than those used in the E7, the E-Tech™ vibration damper hub is 3/8 inch shorter than the E7 hub (Figure 48). The hubs look the same, but are different lengths. Always make sure the correct vibration damper is used for the correct engine model.

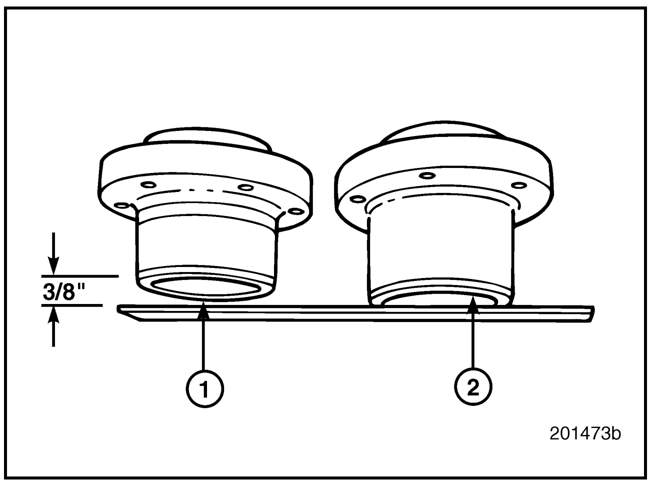


Figure 48 — Vibration Damper Hub

1. E-Tech™ Hub	2. E7 Hub

Front Cover

Refer to Figure 49.

The front cover has been designed with a boss for the automatic belt tensioner, room for the idler gear, a mounting for the crankcase breather, and a boss for the engine position sensor.

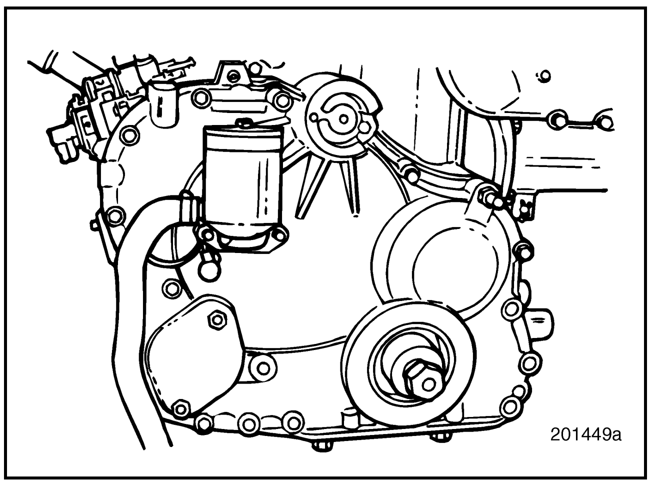


Figure 49 — Front Cover

CRANKCASE BREATHER

A noticeable feature of the front cover is the crankcase ventilation assembly. The E-Tech™ engine has a crankcase breather filter assembly which mounts on the engine front timing gear cover. This system traps, collects and returns oil to the engine crankcase that would otherwise be lost with blow-by gases (Figure 50).

During operation, blow-by gases from the engine pass upward through the filter element, then down and out through the center standpipe, which exits from the canister lower-outboard side. When blow-by gases pass through the filter element, oil collects on element surfaces and then drains back into the crankcase.

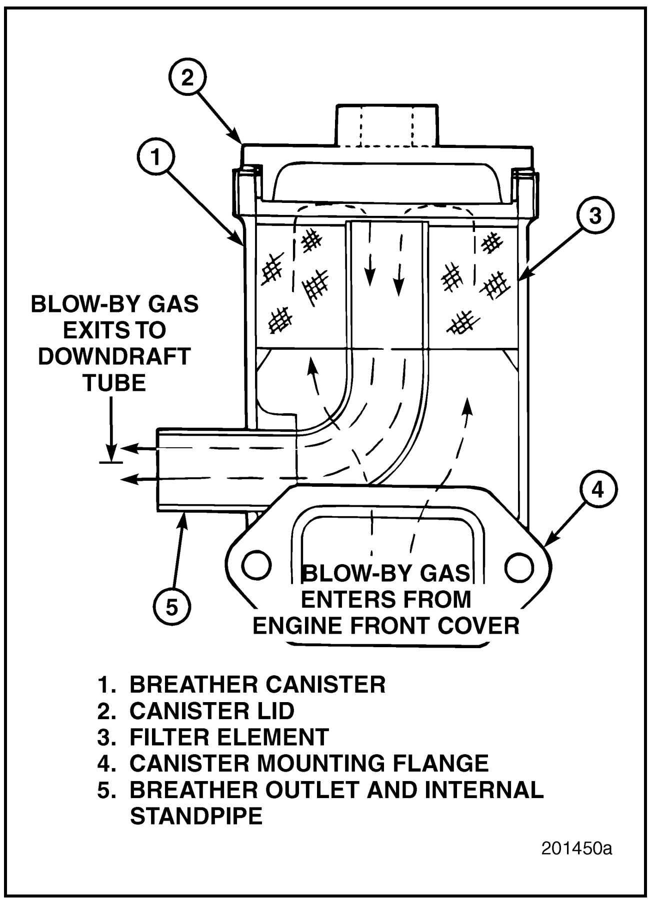


Figure 50 — Crankcase Breather Operation (Cast-Aluminum Housing Shown)

NOTE

Early-production engines are equipped with a cast-aluminum crankcase breather housing, whereas, current-production engines are equipped with a housing made of fiberglass-reinforced nylon (Figure 51). The breather element, housing mounting gasket and O-rings are NOT interchangeable between the two housing designs.

The canister lid and element are removable to allow element cleaning.

5_106_00.bk Page 47 Friday, August 4, 2000 11:17 AM

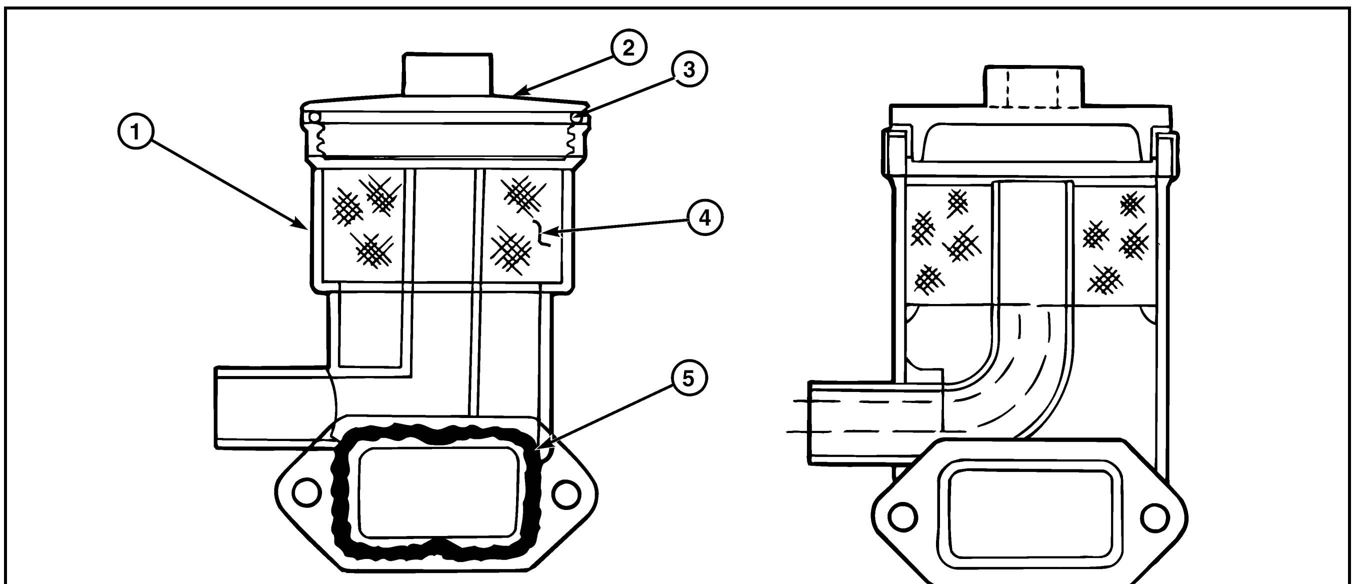


Figure 51 — Crankcase Breather (Current Production)

1. Fiberglass-Reinforced Nylon Housing 2. Cover 3. Cover O-Ring	4. Filter Element 5. Assembly Mounting O-Ring/Gasket

Centri-Max® Oil Filter Breather Vent

The oil filter vent line between the cylinder head cover and the filter mounting adapter on the E7 engine is not used on the E-Tech™ engine. The vent line is replaced by a vent-to-atmosphere fitting on the filter mounting adapter.

Lubrication System

There are several changes to the lubrication system of the E-Tech™ engine, as compared to the E7. The major changes are:

- A second oil gallery along the engine right side that provides oil to the valve roller followers and EUPs
- An oil pump that has a drive gear helix opposite that of the E7

Since its introduction, the E-Tech™ engine has evolved with changes to the oil cooler and oil filter mounting arrangement. These changes are also described in this section.

MAIN OIL GALLERY

The main oil gallery on the E-Tech™ is the same as the E7 oil gallery with these exceptions:
On early-production engines, a special cross-drilled plug was used at the front to facilitate oil flow to the idler gear bore and No. 1 main bearing bore. This special plug was factory-installed in the cylinder blocks and should not be removed. For current production, the block is machined to accept a 3/4-inch cup plug in place of the special cross-drilled plug (Figure 52).

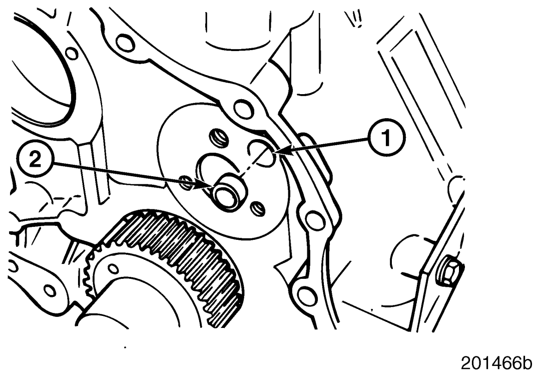


Figure 52 — Cross-Drilled Plug

1. Main Oil Gallery	2. Cup Plug, 3/4-Inch

5_106_00.bk Page 48 Friday, August 4, 2000 11:17 AM

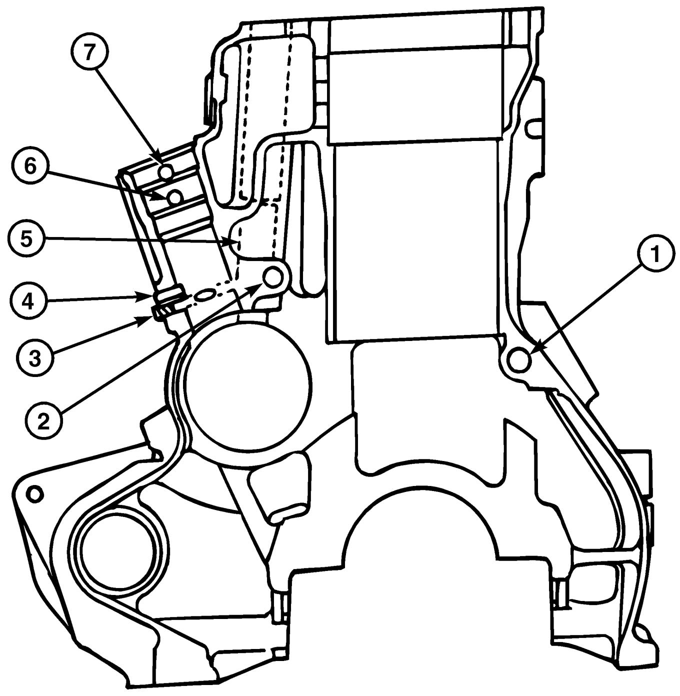
VALVE LIFTER/EUP OIL GALLERY

Refer to Figure 53.

A second oil gallery, located above the camshaft, supplies oil to the valve lifter bores and EUP bores. Oil is fed to this gallery by drilled passages from the No. 2 and No. 5 cam bores which also feed oil to the cylinder head rocker arm shaft and engine brake assemblies. The No. 2 and No. 5 main bearing bores are grooved to satisfy the additional oil flow required by this second oil gallery. The tappet guide pins in the EUP bores are factory-installed in all cylinder blocks and should not be removed.

OIL PASSAGES

- The passage from the main oil gallery to the No. 1 main bearing bore intersects the idler gear hub bore to provide lubrication to the idler gear bushing.
- There are two oil annulus passages in the No. 2 and No. 5 main bearing bores. These passages, together with the groove in the upper bearing inserts, ensure a high volume of oil to the right-side oil gallery.
- Valve lifter (roller follower) bores intersect the right-side oil gallery.
- Passages drilled through each EUP bore and into the adjacent valve lifter bore provide oil feed to each EUP.



1. MAIN OIL GALLERY
2 VALVE LIFTER/EUP OIL GALLERY
3. VALVE LIFTER BORE TO EUP BORE OIL SUPPLY PASSAGE (CLOSED WITH PIPE PLUG)
4. EUP BORE TAPPET GUIDE PIN
5. VALVE ROLLER FOLLOWER BORE
6. FUEL RETURN GALLERY
7. FUEL SUPPLY GALLERY

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Figure 53 — Sectioned View, Front of E-Tech™ Engine Block

OIL PUMP

Due to the addition of an idler gear, the auxiliary shaft on the E-Tech™ engine turns the opposite direction of the E7 auxiliary shaft. In order for the E-Tech™ oil pump to turn the same direction as the E7 pump, the gear set helixes are different.

On the E-Tech™, driving thrust load of the shaft pumping gears is toward the pump housing and not toward the pump cover, as with the E7 engine. Refer to Figure 54.

NOTE

- An improper drive gear on the oil pump will prevent oil pump installation, assuming a correct gear is on the auxiliary shaft.
- If an oil pump and an auxiliary shaft assembly were replaced, two improper gears could be installed, and engine failure would result.
- In replacing any of these critical parts, always refer to part number information in the MACK Parts System to ensure the correct component is being used.

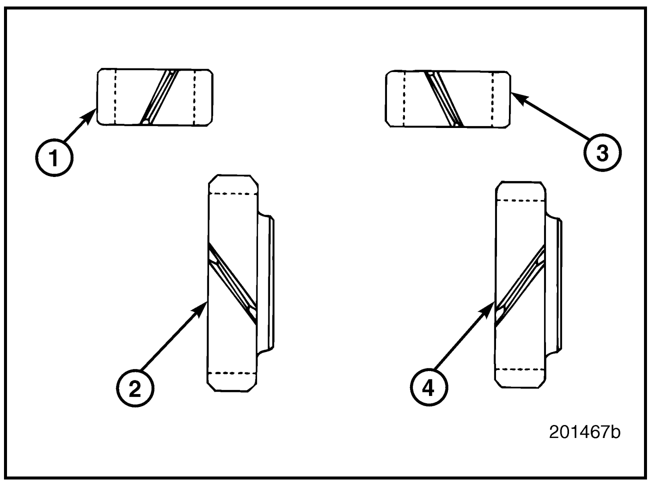


Figure 54 — Oil Pump Drive Gears

1. E7 Oil Pump Gear (12 Teeth) 2. E7 Aux. Pump Gear (18 Teeth)	3. E-Tech™ Oil Pump Gear (13 Teeth) 4. E-Tech™ Aux. Shaft Gear (17 Teeth)

The E-Tech™ auxiliary shaft speed or rpm is 22% faster than that of the E7. As a result, the E-Tech™ oil pump (which has slower ratio oil pump gears) turns 6% faster than the E7. This provides increased lubricating capacity. Also, the auxiliary shaft used on the E-Tech™ engine (Figure 55) is through-drilled to carry oil to the rear auxiliary shaft bushing. This is different from the E7 engine, which provides oil to the rear bushing through a cylinder block oil passage.

NOTE

The E-Tech™ auxiliary shaft is identified by three painted stripes (early production) or three machined circumferential cuts (later production) in front of the stamped part number.

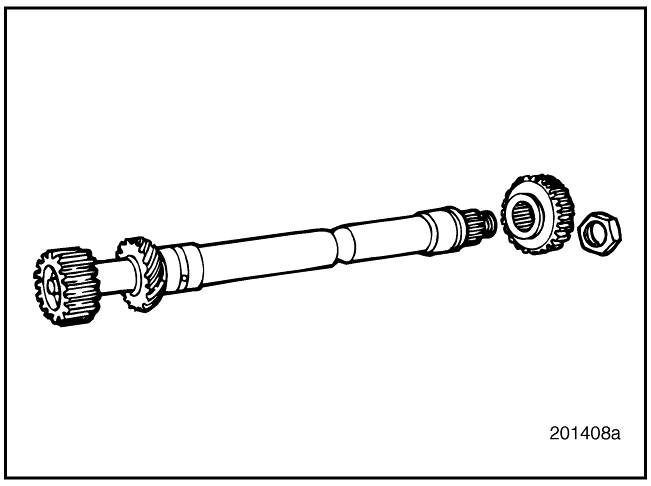


Figure 55 — Auxiliary Shaft

OIL COOLER AND FILTER MOUNTING BRACKET

Early-production E-Tech™ engines retained the same removable bundle-type oil cooler and filter arrangement as the E7. Current-production engines, however, have a plate-type oil cooler and a redesigned oil filter mounting arrangement. The arrangement includes a new centrifugal oil filter assembly, called Centri-Max® PLUS, that is inverted and mounted on top of the bracket. Also, with this arrangement, the external oil drain is eliminated.

On current-production engines, the main member to which the oil cooler and oil filters are mounted is a new one-piece aluminum casting which bolts to the four-bolt pad on the cylinder block. An oil drain passage within the casting allows the oil from the Centri-Max® PLUS filter to drain back to the crankcase.

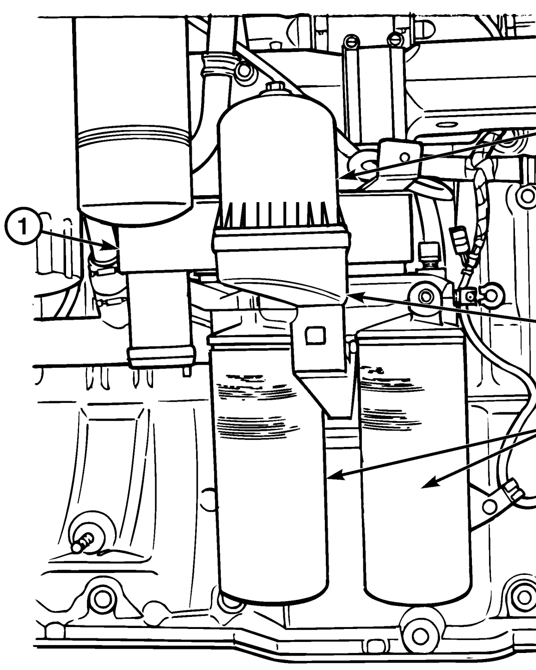


Figure 56 — Oil Cooler/Filter Mounting Bracket

1. Oil Cooler 2. Centri-Max® PLUS Oil Filter	3. Oil Filter Mounting Bracket 4. Spin-On, Full-Flow Oil Filters

5_106_00.bk Page 51 Friday, August 4, 2000 11:17 AM

Ports for the V-MAC III oil pressure and oil temperature sensors are located on this mounting assembly. Remote oil supply ports are provided for the turbocharger, and also to supply oil pressure for other items such as a turbo-unloader, REPTO, a mechanical oil pressure gauge or a remote-mounted centrifugal oil filter.

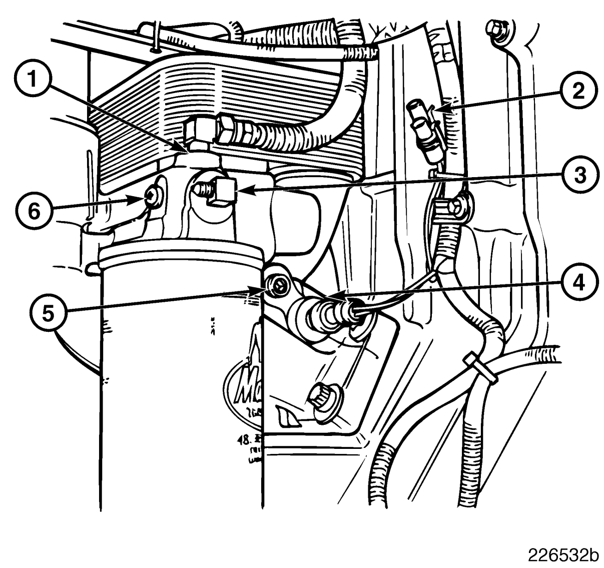


Figure 57 — Oil Supply Ports

1. Turbocharger Oil Supply Port 2. Oil Temperature Sensor Harness Connectors 3. Oil Supply Port for REPTO, Turbo Unloader, Remote-Mounted Oil Filter	4. Oil Pressure Sensor 5. Oil Temperature Sensor Port 6. Oil Supply Port for Mechanical Oil Pressure Dashboard Gauge

5_106_00.bk Page 52 Friday, August 4, 2000 11:17 AM

OIL FILTERS

The oil filters on the E-Tech™ are the same as those used on the E7 engine. However, the Centri-Max® vent line is not used on the E-Tech™ engine; a breather vent fitting is used in its place.

CENTRI-MAX® PLUS OIL FILTER ASSEMBLY

The Centri-Max® PLUS oil filter assembly on current-production engines is mounted at the top of the oil filter mounting bracket assembly, between, and outboard of the two full-flow spin-on filters. It is mounted in an inverted position, opposite the way in which the externally drained Centri-Max® filter is mounted on early-production engines.

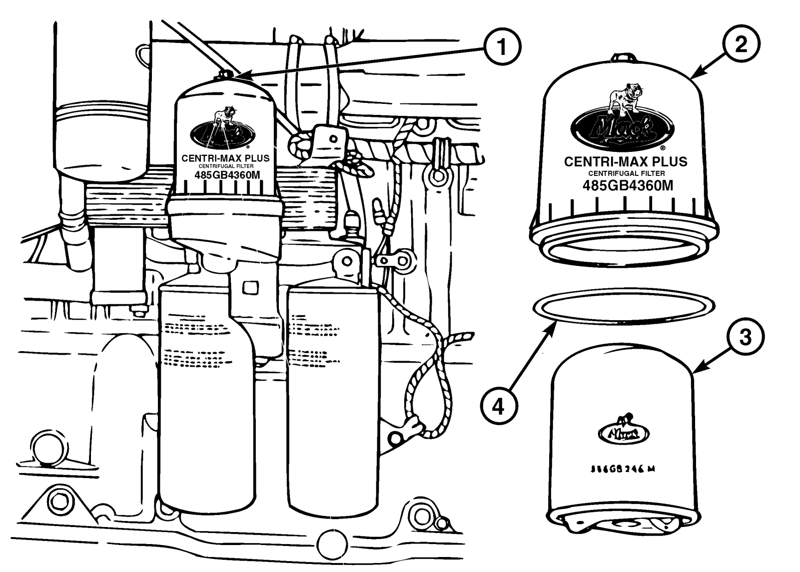


Figure 58 — Centri-Max® PLUS Oil Filter Assembly

1. Cover Bolt 2. Centri-Max® PLUS Cover Assembly	3. Centri-Max® PLUS Rotor (Part No. 236GB245M) 4. O-Ring

OIL COOLER

The removable bundle-type oil cooler used on early-production engines has been replaced by a single-piece, plate-type design on current-production engines. The plate-type oil cooler has a stainless steel housing and integral water inlet and outlet tubes. The cooler bolts directly to the aluminum oil filter mounting bracket with two bolts at each one of the oil ports.

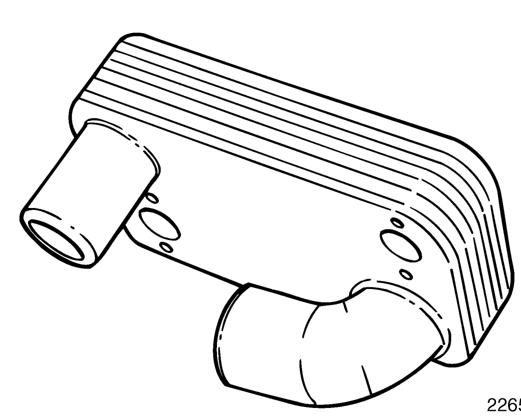


Figure 59 — Plate-Type Oil Cooler Assembly

A 2-1/4-inch diameter steel coolant tube connects the oil cooler water outlet to the water pump inlet. The tube connects to the water pump with a flange, and a gasket is used at the joint between the water pump and tube flange. On earlier engines, the coolant tube connects to the oil cooler water outlet by an O-ring connection. On later engines, the O-ring connection was replaced by a hose connection. The most commonly used tube has two smaller tubes attached to the main tube (one tube for the thermostat bypass and the other for the water line to the surge tank). Other chassis models use variations of this tube assembly.

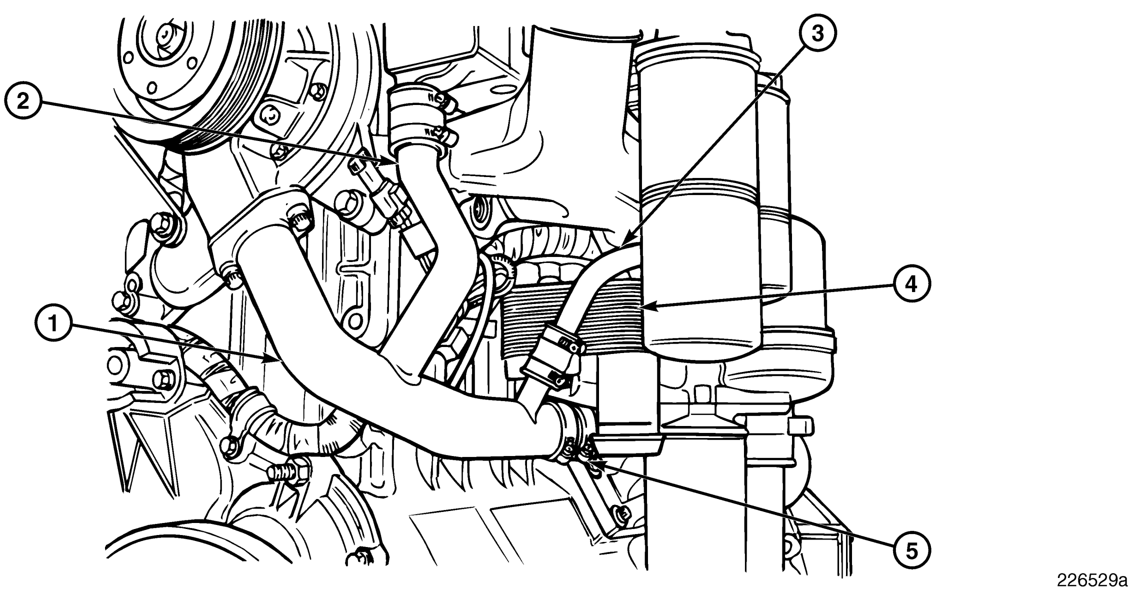


Figure 60 — Oil Cooler-to-Water Pump Inlet Line

1. Oil Cooler-to-Water Pump Coolant Tube 2. Thermostat Bypass Tube 3. Coolant Line to Surge Tank	4. Oil Cooler 5. Hose Connection

5_106_00.bk Page 54 Friday, August 4, 2000 11:17 AM

OIL COOLER DE-AERATION LINE

To vent air which may otherwise become trapped in the plate-type oil cooler when filling the cooling system with coolant, a de-aeration line has been added. This line is routed from the oil cooler top left-front corner to the top front of the water manifold. CH model chassis have an additional vent line from the top of the water pump to the top of the thermostat housing. This replaces the steel line used on CH model chassis with the removable bundle-type oil cooler. The de-aeration line is made from 1/4-inch inside diameter (1/2-inch outside diameter) silicone heater hose, and is protected from rubbing and chafing by length of convoluted tubing.

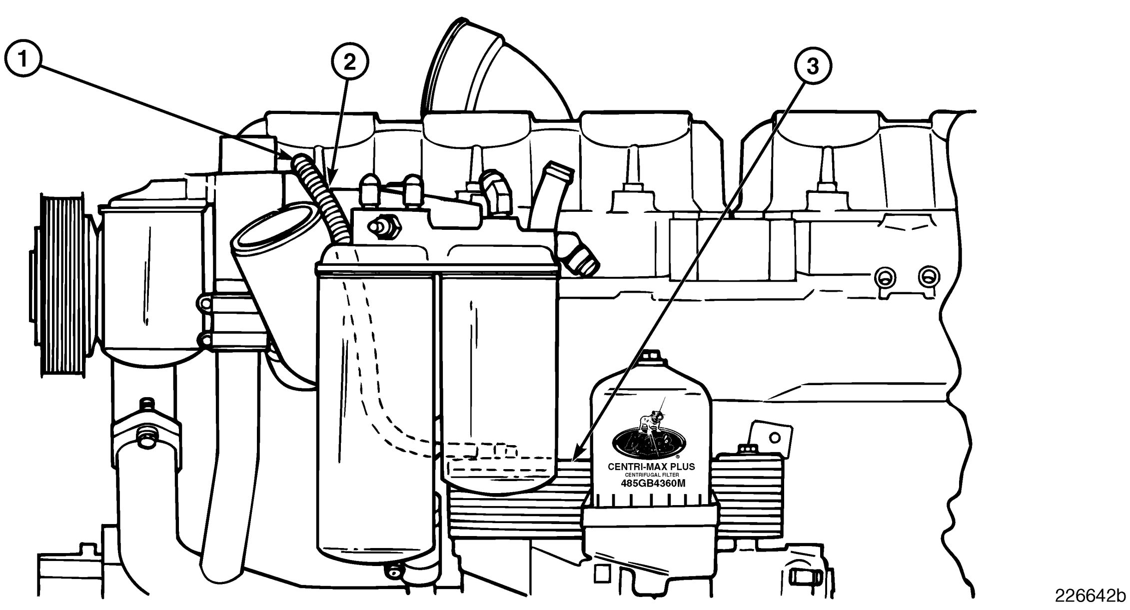


Figure 61 — Oil Cooler De-Aeration Line

1. De-Aeration Line 2. Convoluted Tubing	3. Oil Cooler

GLOSSARY OF TERMS

Breather Canister

A canister through which blow-by gases are filtered to remove engine oil for return of oil to the crankcase. The canister is mounted on the engine front cover.

Breather Filter

A meshed metal filtration element inside the breather canister. The element can be removed, cleaned and reinstalled in the canister.

Electronic Unit Pump (EUP)

An electronically controlled fuel injection pump, one for each cylinder of an engine. The electronic unit pumps are actuated by roller followers and lobes on the engine camshaft.

Engine Electronic Control Unit (EECU)

A microprocessor-based controller, sometimes referred to as a module, mounted on the right or left side of the E-Tech™ engine. With the MACK V-MAC III system, the EECU primarily controls fuel timing and delivery, fan operation, engine protection functions and engine brake operation.

H-Ring

A type of guide ring used to prevent axial rotation of the valve roller follower. On the E-Tech™ engine, a ring is press-fit into each valve lifter bore.

Idler Gear

A timing gear positioned between the crankshaft and camshaft gears in the front gear train of the E-Tech™ engine.

Idler Tensioner

An automatic belt tensioning device designed to maintain optimum tension under varying engine speeds and load. The idler tensioner is optional on the E-Tech™ engine.

Poly-V Belt

A multi-ribbed belt design which is incorporated into a single drive belt and pulley system at the front of the E-Tech™ engine.

Pump Line Nozzles (PLN)

A fuel injection system using a single multi-plunger fuel injection pump supplying fuel to individual nozzles at each cylinder. (This system applies to the E7 engine only and not the E-Tech™.)

Roller Follower

A type of lifter with an axle-mounted roller that rides on (or follows) a camshaft lobe. The rolling motion of this design provides increased load capacity with less friction than the flat-faced lifter design. Roller followers are used to provide the lifting action for the electronic unit pumps and the intake and exhaust valves on the E-Tech™ engine.

Tappet Guide Pin

A pin used to prevent axial rotation of an EUP tappet. The pin is pressed into the cylinder block EUP tappet bore wall and fits into a slot in the tappet.

Vehicle Control Unit (VECU)

A microprocessor-based controller, sometimes referred to as a module, mounted in the cab, inside the passenger-side dash panel. With the MACK V-MAC III system, the VECU controls engine speed, cruise control, accessory relay controls, idle shutdown, and trip recorder functions.

5_106_00.bk Page 56 Friday, August 4, 2000 11:17 AM

NOTES

5_106_00.bk Page 57 Friday, August 4, 2000 11:17 AM

TROUBLESHOOTING

5_106_00.bk Page 58 Friday, August 4, 2000 11:17 AM

ENGINE SYMPTOM DIAGNOSIS

V-MAC III Diagnostics

NOTE

When operating in cold weather, fuel waxing can cause many of the problems described below. Also, water in the fuel can damage unit pumps and nozzles. Be sure to check for water in the fuel and/or fuel congealing before proceeding to troubleshoot a problem.

Also, refer to the V-MAC III service manual, 8-211, for applicable blink code information.

ENGINE WILL NOT CRANK

Possible Cause	Correction
1. Batteries have low output.	1. Check the batteries. Charge or replace as required.
2. Loose or corroded battery or ground connections.	2. Clean and tighten battery and ground connections.
3. Broken or corroded wires.	3. Check voltage at the following connections: — Switch to starter — Battery to starter Replace as required.
4. Faulty starter or starter solenoid.	4. Check operation of starter and solenoid. Repair as required.
5. Faulty key switch.	5. Replace key switch.
6. Internal seizure.	6. Bar the engine over one complete revolution. If the engine cannot be turned, internal damage is indicated. Disassemble engine and repair as required.

ENGINE CRANKS — WILL NOT START

Possible Cause	Correction
1. Slow cranking speed.	1. Check corrections listed in preceding chart, ENGINE WILL NOT CRANK.
2. Code(s) present.	2. Correct cause of code(s). Refer to ENGINE MISFIRES — CODE(S) PRESENT chart.
3. No fuel to engine.	3. Check for fuel in the fuel tank. Check for plugged fuel tank connections, restricted or kinked fuel suction lines, fuel transfer pump failure or clogged fuel filters.
4. Defective fuel transfer pump.	4. Check transfer pump for minimum output pressure. Change fuel filters if low. Look for air leaks and recheck pressure. If still below minimum, replace transfer pump.
5. Poor quality fuel, or water in fuel.	5. Drain fuel from tank. Replace fuel filters and fill fuel tank with MACK-specified diesel fuel.
6. Incorrect engine oil viscosity.	6. Drain oil. Replace oil filters and fill crankcase with recommended grade oil.
7. Low compression.	7. Check cylinder compression. If low, refer to LOW COMPRESSION chart.
8. Faulty EUP fuel-return check valve.	8. Check for free poppet movement.
9. Faulty electrical connections.	9. Check electrical connections at ECU, engine position and engine-speed sensor connections.

ENGINE MISFIRES — CODE(S) PRESENT

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s). Check harness, battery and ground connections. If code(s) remains, replace ECU. If code is still present after replacing ECU, reinstall original ECU and refer to item 7 in ENGINE MISFIRES — NO CODE(S) chart.

ENGINE MISFIRES — NO CODE(S)

Possible Cause	Correction
1. Broken or leaking high-pressure fuel lines.	1. Check for fuel leaks. Repair as necessary.
2. Poor quality fuel, or water or dirt in fuel.	2. Drain fuel from tanks. Replace fuel filters and fill tank with MACK-specified diesel fuel.
3. Air in fuel system.	3. Check fuel system for air leaks. Repair as necessary. (Air generally gets into the fuel system on suction side of the fuel pump.)
4. Low fuel supply pressure.	4. Check to be sure there is fuel in the fuel tank. Check for sharp bends or kinks in the fuel line between the fuel tank and the fuel transfer pump. Also, check for clogged suction pipe (in the fuel tank) or a plugged fuel suction hose. Check for air in the fuel system, and check the fuel pressure. If the pressure is lower than specified, replace the fuel filters. Inspect fuel return check valve for free-moving poppet. If still low, replace the transfer pump.
5. Improper valve lash adjustment.	5. Check adjustment. Correct as necessary.
6. Worn camshaft lobe.	6. With valve lash properly adjusted, check rocker arm movement. If not within specifications, replace worn parts.
7. Valves not seating properly.	7. Remove heads, recondition valves as required, and reinstall heads.
8. Defective fuel injection nozzles or unit pump.	8. **Note:** The following test will register a fault in the ECU which may be cleared after test is completed. Make sure all EUP terminal wires are connected and tight. With the engine operating at low idle (625–675 rpm), connect a jumper wire across the EUP terminals one cylinder at a time. If the cylinder is firing correctly, the engine sound will change. If a cylinder does not change the engine sound, that cylinder is not firing correctly. If a cylinder is not firing correctly, determine if a fuel pulse is present in the high-pressure injection line by touching the line firmly with a screwdriver about one inch from the EUP. **Note:** When it is difficult to determine if the problem is the EUP or the nozzle, first switch the EUP with that of an adjacent cylinder and recheck for a pulse in both affected cylinders. If the problem follows with the EUP, then the EUP is at fault. If the problem remains with the original cylinder, then the nozzle may be at fault. Compare the pulse felt with the EUP shorted vs. not shorted. If a normal pulse is detected when the EUP is not shorted, the problem may be in the injection nozzle or the engine valve adjustment. First check engine valve adjustment. If OK, repair or replace the nozzle. If no pulse is detected, replace the unit pump for that cylinder. **Note:** A tachometer that senses injection-line pressure can also be used to check if pulse is present (use J 39638 Tech Tach or equivalent). If an engine rpm is recorded on the tachometer, the problem may be in the injection nozzle or the engine valve adjustment. If no reading is obtained, replace the unit pump for that cylinder.
9. Cylinder head gasket leakage.	9. Check for visible signs of leakage, coolant in the oil, or traces of oil in the coolant. Use a compression tester to check each cylinder. Replace cylinder head gasket if necessary.

ENGINE STALLS AT LOW SPEEDS

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. Cylinder cutting out.	2. Isolate cylinder and determine cause of cutting out. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
3. Idle speed set too low.	3. Check idle setting. Adjust as necessary.
4. High parasitic load.	4. Check for excessive loading due to engaged auxiliary attachments.
5. Fuel tank vent clogged or partially clogged.	5. Check fuel tank vents. Repair as necessary.
6. Low fuel supply.	6. Check for sufficient fuel in the fuel tank. Check fuel filters, replace if necessary. Check fuel supply lines for restrictions or air in the system. Check fuel return check valve for free-moving poppet. Check fuel pressure and repair or replace supply pump as required.
7. Defective fuel injection nozzle.	7. Isolate defective nozzle and replace. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
8. Defective unit pump.	8. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.

ERRATIC ENGINE SPEED

Possible Cause	Correction
1. Air leaks in fuel suction line.	1. Check for air leaks. Repair as necessary.

LOW POWER

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. Intercooler cracked or leaking.	2. Inspect intercooler, pressure-test, and repair or replace as required.
3. Plugged fuel tank vents.	3. Clean the fuel tank vents.
4. Restrictions in the air intake system such as clogged air filter(s).	4. Check for restrictions in the air intake system. Check the air pressure in the air intake manifold. Replace the air filter and make necessary repairs to the air intake system.
5. Poor quality fuel.	5. Drain fuel tank(s), clean system and replace fuel filters. Fill tank with MACK-specified diesel fuel. Bleed system.
6. Low fuel pressure.	6. Check for sufficient fuel in the fuel tank. Check fuel filters, replace if necessary. Check fuel supply lines for restrictions or air in the system. Check fuel return check valve for free-moving poppet. Check fuel pressure and repair or replace supply pump as required.
7. Improper valve lash adjustment.	7. Adjust valve lash to specified clearance.
8. Fuel-injection nozzle failure.	8. Repair or replace defective nozzle. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
9. Turbocharger dirty or malfunctioning.	9. Inspect turbocharger. Clean, repair or replace as required.
10. Exhaust restriction.	10. Check for restrictions in the exhaust system.
11. Low compression.	11. Check items listed under LOW COMPRESSION.
12. Restrictions in intercooler.	12. Perform restriction pressure test. Clean any restrictions.
13. Restrictions in intercooler inlet/outlet tubes.	13. Disconnect tubing and clean restrictions.

5_106_00.bk Page 61 Friday, August 4, 2000 11:17 AM

NOTE

Low power complaints may result from many factors other than an engine problem. Be sure to check the chassis and trailer for dragging brakes and assess the drivetrain combination for driveability and application (engine-rated bhp, transmission and rear-axle ratios, tire sizes, etc.).

ENGINE WILL NOT ACHIEVE NO-LOAD GOVERNED RPM

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).

EXCESSIVE BLACK OR GRAY SMOKE

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. Intercooler core leakage.	2. Pressure-test intercooler. If test results are unsatisfactory, remove, repair or replace intercooler as needed.
3. Intercooler core fin obstructions.	3. Clean intercooler fins.
4. Insufficient air for combustion.	4. Check air cleaner for restrictions. Check inlet manifold pressure, and inspect the turbocharger for proper operation. Repair or replace as required.
5. Excessive exhaust back pressure.	5. Check for faulty exhaust piping or restrictions in the muffler. Repair or replace as required.
6. Improper grade of fuel.	6. Drain fuel from tank(s). Replace fuel filters and fill tank(s) with MACK-specified diesel fuel.
7. Defective fuel injection nozzle or unit pump.	7. Isolate defective nozzle and replace. Refer to item 8 under ENGINE MISFIRES — NO CODE(S) chart.
8. Improper engine valve adjustment.	8. Reset valve adjustment.
9. Malfunctioning exhaust/intake valve.	9. Repair cylinder head/valve train.

EXCESSIVE BLUE OR WHITE SMOKE

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. No code(s) present, faulty cylinder.	2. Isolate faulty cylinder and repair as required.
3. Low fuel pressure.	3. Check fuel lines and filters for blockage.
4. Engine lubricating oil level too high.	4. Drain excess lubricating oil. If the oil is contaminated with either fuel or coolant, completely drain the oil pan. Change the oil filters. Locate the source of the leak and correct. Fill with MACK-specified engine oil. Check the oil level with the dipstick. DO NOT overfill.
5. Turbocharger passing oil.	5. Check for oil in the inlet manifold. Check for air inlet restriction (clogged air filter). Repair or replace turbocharger as required.
6. Worn piston rings.	6. Determine and correct the root cause, and repair engine as required.
7. Engine misfiring or running rough.	7. Check items as outlined in ENGINE MISFIRES — NO CODE(S) chart.

EXCESSIVE FUEL CONSUMPTION

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. Restrictions in the air induction system.	2. Inspect system. Remove restrictions and replace defective parts as required.
3. External fuel system leakage.	3. Check external piping on fuel system for signs of fuel leakage. Repair as required.
4. Defective injection nozzle assembly.	4. Isolate defective nozzle assembly. Repair and replace as required. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
5. Internal engine wear.	5. Determine and correct the root cause, and repair engine as required.

EXCESSIVE OIL CONSUMPTION

Possible Cause	Correction
1. External oil leaks.	1. Check engine for visible signs of oil leakage. Look for loose or stripped oil drain plugs, broken gaskets (cylinder head cover, etc.), and front and rear oil seal leakage.
2. Turbocharger passing oil.	2. Check for oil in the inlet manifold. Check for excessive inlet restriction (such as a dirty air filter). Repair/replace air filter or turbocharger as required.
3. Air compressor passing oil.	3. Repair or replace air compressor.
4. Clogged crankcase breather pipe.	4. Remove obstructions.
5. Excessive exhaust back pressure.	5. Check exhaust pressure. Repair as required.
6. Worn valve stem seals.	6. Replace valve stem seals.
7. Worn valve guides.	7. Check for valve guide wear and replace guides as required.
8. Internal engine wear.	8. Determine and correct the root cause, and repair engine as required.

ENGINE OVERHEATS

Possible Cause	Correction
1. Coolant level low.	1. Locate cause. Look for leaking gaskets or loose or leaking hoses. Repair, replace or tighten as required. Replenish coolant.
2. Loose or worn fan belts.	2. Adjust belt tension or replace belts as required.
3. Restricted airflow through radiator.	3. Remove any restrictions from the outer surface of the radiator.
4. Plugged radiator core.	4. Remove, repair or replace radiator as required.
5. Defective radiator pressure cap.	5. Test pressure of the radiator cap. Replace cap if required.
6. Defective coolant thermostat or temperature gauge.	6. Check opening temperature of thermostat. Check for correct installation. Check temperature gauge and sending unit. Replace if defective.
7. Viscous (or ON/OFF) fan drive not operating properly, or fan improperly positioned.	7. Check fan operation. Repair as required.
8. Combustion gases in coolant.	8. Determine point where gases are entering the cooling system. Repair or replace parts as required.
9. Defective water pump.	9. Remove, repair and reinstall water pump as required.
10. Plugged oil cooler.	10. Remove oil cooler. Disassemble, remove restrictions/replace parts as required. Reinstall.
11. Winterfront (if equipped) not opened.	11. Open or remove winterfront at specified ambient temperatures.
12. Shutters not opening properly (for chassis equipped with shutters).	12. Check shutter operation. Repair as required.

HIGH EXHAUST TEMPERATURE

Possible Cause	Correction
1. Operating chassis in wrong gear ratio for load, grade and/or altitude.	1. Instruct operator on correct gear selection for load and grade conditions.
2. Restrictions in the air induction system.	2. Inspect air induction system. Remove restrictions and/or replace defective parts.
3. Air leaks in the air induction system.	3. Check pressure in the air intake manifold. Look for leaking piping and/or loose clamps. Make necessary repairs.
4. Leaks in the exhaust system (before the turbocharger).	4. Check exhaust system for leaks. Make necessary repairs.
5. Restrictions in the exhaust system.	5. Inspect system. Make necessary repairs.
6. Improper valve lash adjustment.	6. Adjust valve lash setting to specified clearance.
7. Defective fuel injection nozzle assembly.	7. Isolate defective nozzle. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
High Pyrometer — Normal Boost	
8. Loose ducting.	8. Repair loose connections.
9. Intercooler core fin obstructions.	9. Clean intercooler fins.
High Pyrometer — Low Boost	
10. Intercooler core leakage.	10. Pressure-test intercooler. Remove, repair or replace intercooler if test results are unsatisfactory.
11. Dirty turbocharger.	11. Remove turbocharger and clean.
12. Leaks in the pressurized side of the air induction system.	12. Check for leaks. Repair as required.
13. Blockage in ducting between the air cleaner and the turbocharger.	13. Check for blockage and repair.

LOW ENGINE OIL PRESSURE

Possible Cause	Correction
1. Oil level insufficient. Oil leaking from oil line, gasket, etc.	1. Check engine oil level. Add oil if necessary. Check for oil leaks. Repair as required.
2. Incorrect oil viscosity.	2. Drain oil, change oil filters, and fill with the proper grade oil meeting MACK specifications.
3. Defective oil pressure gauge.	3. Check the operation of the oil pressure gauge. If defective, replace.
4. Clogged oil filter(s).	4. Replace oil filters. Clean or replace oil cooler. Drain oil and refill with oil meeting MACK specifications.
5. Engine oil diluted with diesel fuel.	5. Check fuel system for leaks. Make necessary repairs. Drain diluted oil, change oil filters, and refill with oil meeting MACK specifications.
6. Defective oil pump.	6. Remove oil pressure relief valve and check condition of seat. Check that relief valve spring is not sticking, and check for proper spring tension. Check internal thrust washer. Check cap. Check assembly parts. Using the incorrect parts will result in incorrect oil pressure. Make any necessary repairs or install a new relief valve.
7. Oil pump gears not meshing properly.	7. Check mounting arrangement. If the engine has been rebuilt, check that the gear ratio of the oil pump drive and driven gears are correct. Incorrect gear combinations will result in immediate gear failure and possible engine damage.
8. Incorrect oil filter mounting pad gasket.	8. Check for correct oil pad gasket.
9. Excessive clearance between crankshaft and bearings.	9. Overhaul the engine. Replace any worn/defective parts.

OIL IN THE COOLING SYSTEM

Possible Cause	Correction
1. Defective oil cooler core.	1. Disassemble and repair or replace oil cooler core.
2. Blown head gasket.	2. Replace head gasket.
3. Cylinder head porosity.	3. Replace cylinder head.

COOLANT IN ENGINE OIL

Possible Cause	Correction
1. Defective oil cooler core.	1. Disassemble and repair or replace oil cooler core.
2. Cylinder head pipe plug leaking.	2. Repair leak.
3. Cylinder head gasket failure.	3. Pressure-test cooling system and repair as required.
4. Cylinder sleeve seat leaking.	4. Pressure-test cooling system and repair as required.
5. Cracked cylinder head.	5. Pressure-test cooling system and repair as required.

LOW COMPRESSION

Possible Cause	Correction
1. Improper valve lash adjustment.	1. Adjust valve lash to specified clearance.
2. Blown head gasket.	2. Replace head gasket.
3. Broken or weak valve springs.	3. Check and replace defective parts as required.
4. Valves not seating properly.	4. Remove, recondition and reinstall heads.
5. Piston rings stuck, worn, broken or improperly seated.	5. Determine and correct root cause and repair engine as required.
6. Camshaft or valve lifters worn.	6. Replace camshaft and/or valve lifters and perform any other necessary repairs as required.

FUEL IN LUBE OIL

Possible Cause	Correction
1. Excessive idling, especially in cold weather.	1. Minimize idling time and use all recommended cold weather accessories.
2. Injector nozzle malfunctioning.	2. Remove and pop-test nozzles. Clean or replace nozzles as required.
3. Unit pump O-ring leaking.	3. Replace O-rings.

5_106_00.bk Page 66 Friday, August 4, 2000 11:17 AM

CAMSHAFT TIMING AND LOBE LIFT CHECKS [213 CH]

Camshaft Timing Check

Correct camshaft timing is essential for proper engine performance. Incorrect camshaft timing may be suspected if soon after engine overhaul, lack of performance, unusual noise or excessive smoke is reported.

NOTE

On the E-Tech™ engine, timing marks are stamped on the flywheel just as they are on the E7 engine. The E-Tech™ engine, however, does not have a timing pointer since setting injection pump-to-engine timing is not necessary. The flywheel timing marks can be used to check the camshaft-to-crankshaft timing by looking up through the hole where the timing pointer would be located and viewing the timing marks. A pencil point may be inserted through the timing pointer hole to easily pinpoint the timing marks on the scale.

NOTE

Camshaft timing can be checked using either the cylinder No. 3 or No. 4 inlet valve. For example purposes, the No. 3 cylinder will be used in the steps below.

1. Remove the cylinder head cover over cylinder No. 3.
2. Locate the inlet valves for No. 3 cylinder (the sixth valve set from the front of engine). Bar the engine to position the No. 3 piston at top dead center (TDC) of the compression stroke.
3. Loosen (back off) the inlet valve rocker adjusting screw jam nut. Ensure that the valve yoke is correctly adjusted. Adjust the inlet valve to zero lash.
4. Position a dial indicator (magnetic-base type) probe on the valve spring retainer. Preload the indicator to 1/2 indicator plunger travel.
5. Bar the engine in the direction of normal rotation and carefully observe the direction in which the indicator needle travels. Use the dial indicator to determine when the inlet valve is fully open.
6. Stop rotating the engine when travel of the dial indicator needle stops. If the dial indicator needle reverses direction, the full-open position is passed. Repeat the procedure if this occurs.
7. Remove the timing hole cover from the flywheel housing so that the flywheel timing marks can be viewed. Engine timing should be approximately 26 degrees. A difference of approximately 10 degrees indicates that the crankshaft-to-camshaft timing gears may be mismatched one tooth.

Camshaft Lobe Lift Check

When diagnosing potential lifter or camshaft failures, 0.030 inch (0.76 mm) less than the lift of a new camshaft is considered the minimum acceptable camshaft lobe lift for used components. Intake lobe lift differs depending on the camshaft part number. Camshaft lobe lift is measured by using a dial indicator at the push rod with the rocker arm adjusted to zero lash.

CHASSIS-MOUNTED CHARGE AIR COOLING TESTS [233 FA]

General Information

The Chassis-Mounted Charge Air Cooling (CMCAC) system cools hot turbocharged air before it enters the engine intake manifold. The CMCAC system uses ambient air as a cooling medium by allowing it to pass through a core equipped with heat-exchanging fins.

Hot turbocharged air, varying in pressure from 0.0–25 psi (0.0–172 kPa), passes through core tubes where heat is transferred to the ambient air by heat-exchanging fins.

Front-section core construction consists of a series of cold bars, cold fins and tube plates. Side-section core construction consists of a series of hot bars and hot fins.

Special Tool Required

- Charge Air Cooler Pressure Fixture J 41473

CMCAC Troubleshooting

Symptom	Probable Cause	Remedy
Normal Boost — High Pyrometer	1. Core fin obstructions.	1. Clean core fins.
Low Boost — High Pyrometer	1. Restriction in ducting between air cleaner and turbo.	1. Check for blockage and clean.
	2. Dirty turbocharger.	2. Clean turbocharger.
	3. Leaks in the pressurized side of the induction system.	3. Check for and repair leaks.
	4. Inlet manifold leak.	4. Check for loose or missing fittings, plugs, and/or damaged manifold-to-cylinder head gaskets. Replace missing parts, and repair loose connections.
	5. Open petcock (if equipped).	5. Close petcock.
	6. Core leakage.	6. Pressure-test core. Remove, repair or replace core if test results are not satisfactory.
Low Power	1. Restrictions in cooler.	1. Perform restriction pressure test. Clean out restriction.
	2. Restrictions in cooler inlet and outlet tubes.	2. Disconnect and clean obstructions.

CMCAC Pressure Test

Refer to Figure 62.

1. Remove the air ducting from core.
2. Plug the core inlet opening.
3. Insert a plug with an air line adapter in the core outlet opening.

NOTE

Charged air cooler pressure fixture J 41473 can be used on coolers with flange connections.

4. Connect a safety chain or cable to both plugs.

WARNING

Stand clear of the plug area when system is pressurized.

5. When plugs are secured, attach an air line (fitted to a pressure regulator and gauge) to the air line adapter in the core outlet opening.
6. Pressurize the system to 30 psi (207 kPa).
7. Shut off the air source. Pressure should not drop more than 5 psi (35 kPa) within 15 seconds. Repair or replace the core if pressure drop exceeds specification.
8. Carefully release pressure from the system.
9. After repairing or replacing the core, reconnect ducting. Tighten clamp nuts until clamp spring is fully compressed.

NOTE

When the spring is fully compressed, the torque applied on the nut is generally between 40–55 lb-in (4.5–6.2 N•m).

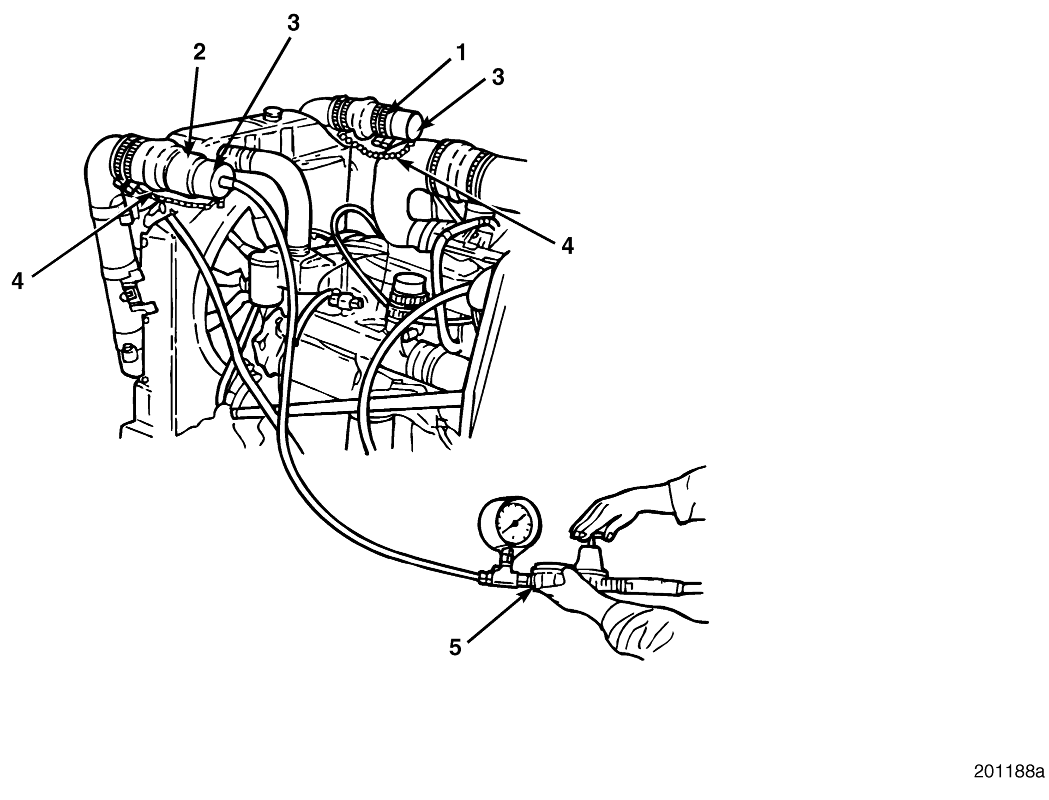


Figure 62 — CMCAC Pressure Test

1. Core Inlet 2. Core Outlet 3. Plug (Part of J 41473)	4. Safety Chain 5. Air Pressure Regulator and Gauge (J 41473)

5_106_00.bk Page 69 Friday, August 4, 2000 11:17 AM

Restriction Pressure Test

SERVICE HINT

Perform the restriction pressure test at maximum full-load condition.

A restriction in the internal portion of the cooler may interfere with proper airflow and can result in excessively high pyrometer readings. To perform a restriction pressure test, use the following procedure:

1. Install pressure gauge lines at both the inlet and outlet tubes of the charge air cooler.

NOTE

Some units are equipped with connection ports on the inward sides of the inlet and outlet charge cooler tubes. If so equipped, the plugs can be removed from these ports and the gauge lines connected. If not, adapters with gauge ports must be installed in the cooler inlet and outlet tubes.

2. Install the appropriate pressure gauge(s) to the cooler inlet and outlet tubes.
3. Start the engine and while operating it at full-load condition, read the pressure drop across the cooler.
   - If the pressure drop is higher than 2 psi (13.79 kPa) at full-load condition, the cooler has internal restrictions.
   - If the pressure drop is lower than 2 psi (13.79 kPa), the cooler is OK and can remain in service.

NOTE

If using manometers for this test, the difference between readings should not exceed 4 in-Hg (13.5 kPa).

4. Stop the engine.
5. If the pressure drop is higher than the specified amount, remove the cooler from the vehicle and flush the inside. Follow the procedure covered under CMCAC Preventive Maintenance to remove any deposits that may be present. Reinstall the cooler and then pressure-test the cooler.
6. If the cooler passes the restriction and pressure tests, remove the test equipment, reinstall inlet and outlet tubes, hoses and clamps. Reinstall the gauge-port plugs on systems so equipped. Tighten the clamps to 38 lb-in (4.3 N•m).

CAUTION

The clamp springs must always be located on the underside of the tube to avoid damaging the hood when closed.

Core Inspection

GUIDELINES

With the exception of straightening minor bends in the cold fins, the CMCAC core is not repairable and should be replaced when more extensive damage is encountered. To ensure that the CMCAC system will function properly after repair or replacement, a pressure/leak test is recommended.

Damage	Core Failures	Recommended Repair Procedure	System Check
Repairable	Bent cold fins	Straighten with small screwdriver or pair of small needlenose pliers.	Perform pressure/leak test.
Nonrepairable	All header tank-to-core separations	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	All header tank cracks	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Internal fins damaged and separated from tube plate	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Tube blockage	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Tube/plate cracks or welds, cold bar separations or openings	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Excessive cold fin damage (original shape of fins distorted beyond repair)	No repair procedure is recommended — replace unit.	Perform pressure/leak test.

INSPECTION

1. Carefully inspect the entire system to determine the exact location and extent of damage.
2. Inspect the cold fins and cold bars that run horizontally in the cooler.
3. Inspect all brazed or welded joints in the header tank.

CMCAC Preventive Maintenance

In case of engine and/or turbocharger failure, the charge air cooler should be flushed to make sure the cooler is free of debris.

FLUSHING PROCEDURE

1. Remove the chassis-mounted cooler and flush the inside with a safety solvent to remove oil and other foreign debris.
2. Shake cooler to remove large pieces.
3. Wash with hot, soapy water. Rinse with clean water and blow dry with compressed air in the reverse direction of flow.
4. Carefully inspect cooler to ensure cleanliness.

CAUTION

Do not use caustic cleaners when flushing the cooler. Be extremely careful when handling the cooler so as not to damage the core.

CYLINDER HEAD AND CYLINDER BLOCK LEAK TEST PROCEDURE

Verify suspected leaks in the cylinder heads or cylinder block by pressure testing before deciding to replace the cylinder head or block. Do not use magnaflux inspections alone as replacement criteria.

Before proceeding with the tests, look for coolant stains around the 3/4-inch NPT plugs on the tops of the cylinder heads. Check that the plugs are torqued to 55 lb-ft (75 N•m).

NOTE

Cylinder head pipe plugs used on engines manufactured April 1, 1999 or later (beginning with engine serial number series 9F) have encapsulated epoxy sealant applied to the threads. These pipe plugs are tightened to 55 lb-ft (75 N•m) at assembly, and the epoxy locks them in place. These plugs will not turn when an attempt is made to tighten them. If a coolant leak at an epoxy-sealed pipe plug is suspected, the plug may be removed by heating it to 400°F (205°C) with a torch. Before reinstalling the plug, the epoxy sealant must be thoroughly cleaned from the pipe plug threads, and the threads in the cylinder head. The plug and the cylinder head threads must then be cleaned with Loctite® Primer T and resealed with Loctite® 277. Reinstall the plug and torque to 55 lb-ft (75 N•m).

Also, make sure leakage is not caused by the oil cooler or air compressor. Perform the simpler checks first to prevent unnecessary engine disassembly. While performing the following tests, watch for indications of minor leaks, such as small bubbles, that can develop into more severe leaks during engine operation.

Cylinder Head and Head Gasket Check — In Chassis

1. Look for coolant stains around the 3/4-inch NPT pipe plugs on top of the cylinder heads. Check plug torque. The plug torque specification is 55 lb-ft (75 N•m). Refer to Figure 63.

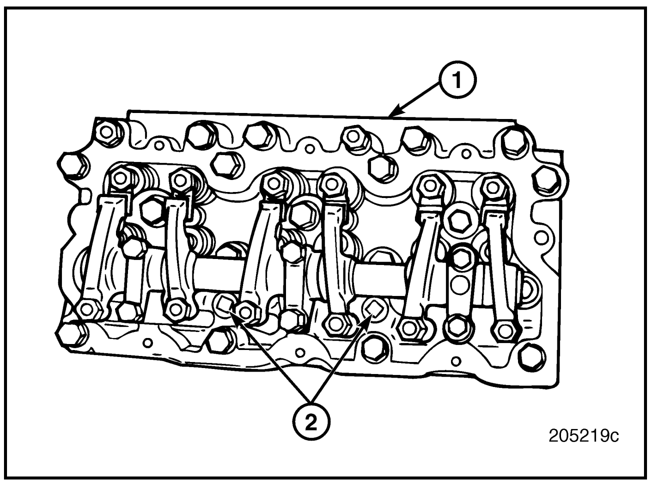


Figure 63 — Cylinder Head Pipe Plugs (3/4-Inch NPT)

1. Cylinder Head	2. Pipe Plugs

2. Before removing the thermostat, drain coolant from the cooling system until the coolant level is below the thermostat housing.
3. Remove the thermostat and leave the thermostat housing open. Install a short section of hose, approximately 6–8 inches (152–203 mm) long, on the thermostat housing and add enough coolant to fill the housing.
4. Remove the fan belt from the water pump.
5. Start the engine and run at 1000 rpm.
6. Observe coolant in the thermostat housing for air bubbles. This can indicate combustion pressurization of the cooling system and possible cylinder head gasket failure. Also, watch for traces of oil which would indicate possible cylinder head gasket or oil passage leakage.

NOTE

It is normal for some air bubbles to form in the cooling system as a result of the engine warming up to operating temperature.

The occurrence of large “gulp-type” movements of coolant indicates a partially blocked oil cooler inlet screen (bundle-type oil cooler only).

7. Apply a soap-and-water solution between two cylinder heads to check for external combustion leakage.

Cylinder Head Fuel Passages Leak Check — In Chassis

NOTE

The symptoms of coolant-in-fuel are a loss of coolant with no apparent external leak, together with one or more of the following: coolant in fuel tank, coolant in fuel filter or yellow fuel out of fuel return line.

1. Disconnect the return fuel interconnecting tube between the front and rear cylinder heads. Run a line from each cylinder head into a container.
2. Pressurize the cooling system with a maximum of 15 psi (103 kPa) air pressure and look for coolant coming out of a fuel return line.
3. An alternate method is to disconnect the fuel return line at the front of the front cylinder head. Introduce a maximum air pressure of 25 psi (172 kPa) to the fitting in the cylinder head. Then look for air bubbles in the coolant.
4. After determining which cylinder head is suspected of leaking, remove the nozzles from that cylinder head and pressurize the cooling system with a maximum of 15 psi (103 kPa). Look into each nozzle sleeve bore for signs of coolant leakage.
5. A cracked or leaking nozzle sleeve should be replaced as an on-engine repair using the procedures described under Engine Disassembly procedures in the REPAIR INSTRUCTIONS section. If after replacing the nozzle sleeve(s) the re-pressure test shows that the problem still exists, the cylinder head(s) should be replaced.

Cylinder Block/Cylinder Head Coolant Passages Leak Check — In Chassis

Refer to Figure 64.

1. Drain coolant from the engine.
2. Remove the engine oil pan and cylinder head valve covers.
3. Remove the water pump assembly and use a suitable plate and gasket to seal the opening.
4. Remove the upper and lower hoses from the thermostat housing. Remove the thermostat housing and thermostat.
5. Secure a suitable plate and gasket over the thermostat housing opening in the coolant manifold.
6. Install an air fitting into one of the pipe plug holes in the coolant manifold.
7. Reinforce the hose connecting the coolant manifold sections by installing a hose clamp around the center of the hose to prevent it from rupturing during testing.
8. Remove one of the large pipe plugs from the water manifold and add hot water to fill the cooling system. Increase cylinder block temperature to 150°F (66°C). Loosen one of the pipe plugs near the top of the cylinder block to bleed air from the water jacket while filling. Also open the block drain to allow water to flow out. This will help warm the cylinder block. Tighten the loosened pipe plug after all of the trapped air has escaped.
9. After the cylinder block is sufficiently heated, close the block drain and apply approximately 50 psi (345 kPa) air pressure to the air connection.

CAUTION

Do not exceed 50 psi (345 kPa) air pressure. Damage to seals or cup plugs may result.

10. Check for coolant leaks at the bottom of each cylinder bore.
    - Coolant leaking between the cylinder sleeve outside diameter and cylinder block indicates a leaking cylinder sleeve seat.
    - Coolant leaking down the inside diameter of the cylinder sleeve indicates a leaking head gasket.

NOTE

Water leaking from the No. 2 or No. 5 cam bushings or from the No. 2 or No. 5 main bearings can indicate a breakthrough between the rocker arm feed passage and the water jacket (cylinder head).

Refer to the repair procedures in this manual to correct leaks.

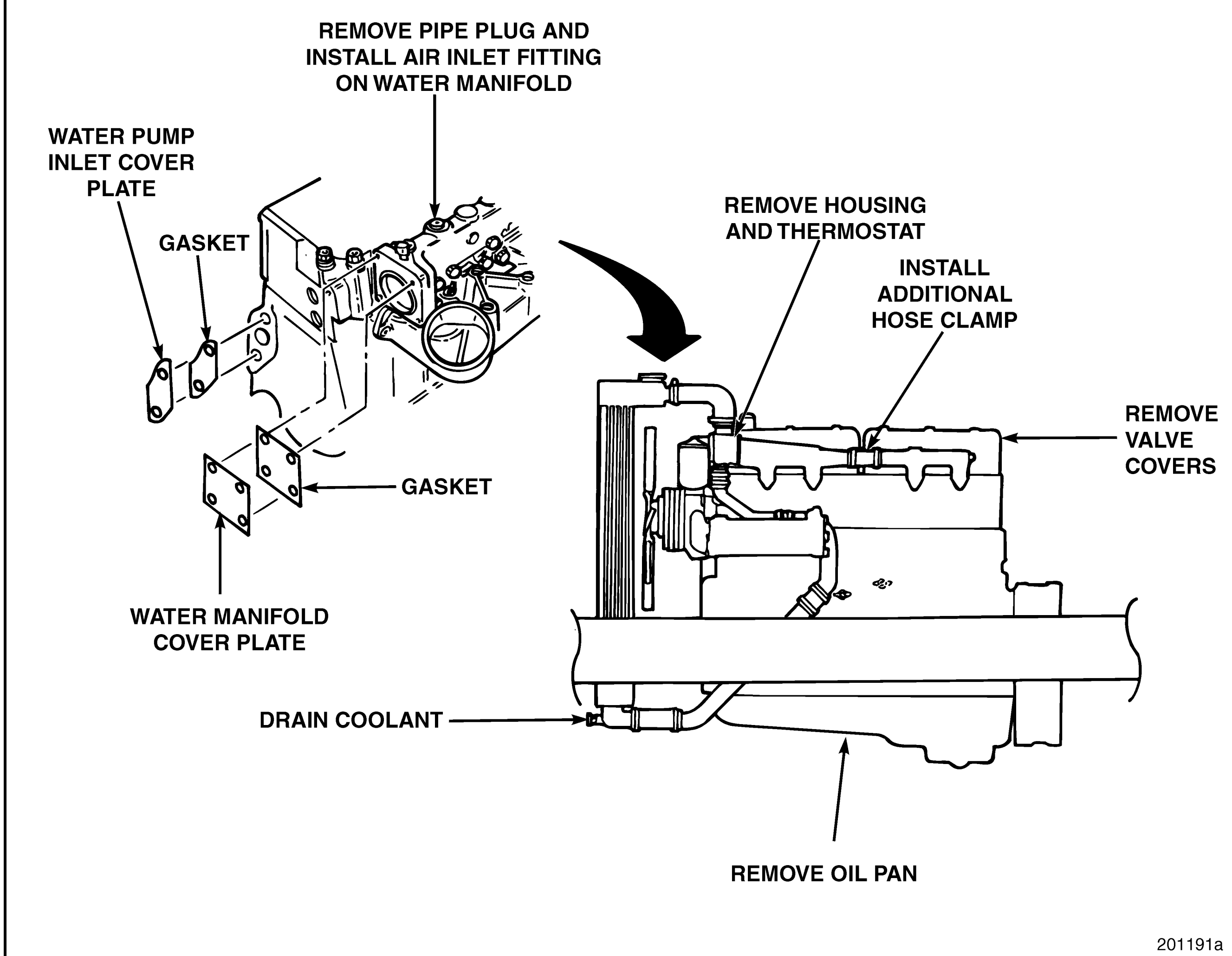


Figure 64 — Cylinder Block/Cylinder Head Leak Check (In Chassis)

5_106_00.bk Page 74 Friday, August 4, 2000 11:17 AM

Cylinder Head Oil Passage Leak Check — Out of Chassis

Refer to Figure 65.

1. Remove the cylinder head from the engine.
2. Install a suitable plug to seal the rocker arm oil passage at deck side of the head. There are two ways to plug the hole:
   - Drill and tap the oil passage to accept a pipe plug.
   - Insert a suitable rubber plug and clamp the plug in position with a C-clamp.
3. Install an air fitting in the rocker arm passage in the top of the head. Use a discarded rocker arm bracket with an oil feed passage. Cut the bracket through the rocker arm shaft bore parallel to the mounting base surface. Drill and tap the oil supply passage to accept an air fitting.
4. Bolt the modified bracket with air fitting to the cylinder head over the oil supply passage.
5. Immerse the cylinder head in water. Heat the water and cylinder head to 150°F (66°C).
6. Apply up to 50 psi (345 kPa) air pressure to the air fitting adapter installed in the rocker arm oil passage. Check for air bubbles. The formation of air bubbles indicates internal leakage between the cylinder head oil passage and the water jacket.

CAUTION

Do not exceed 50 psi (345 kPa). Damage to seals or cup plugs may result.

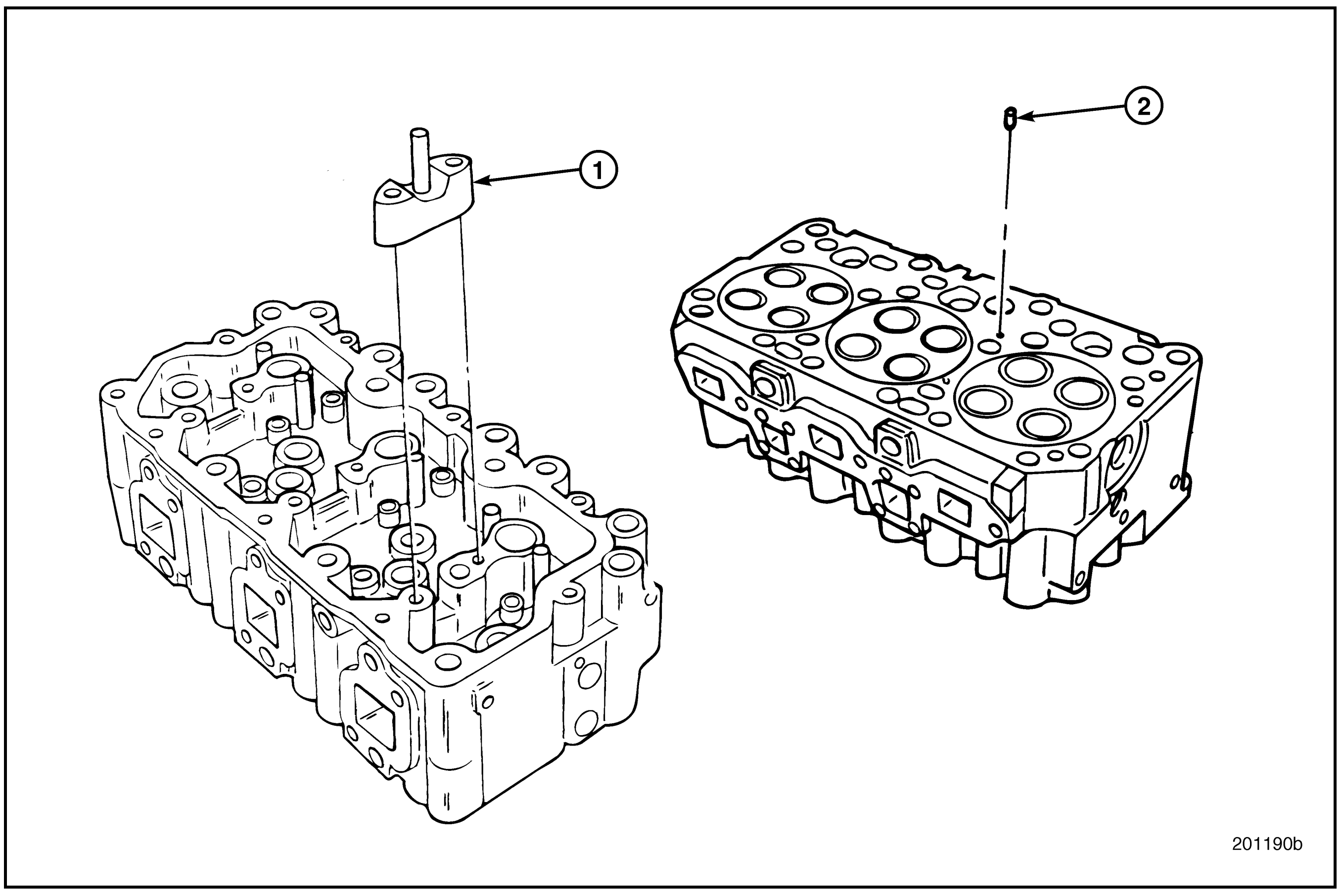


Figure 65 — Cylinder Head Oil Passage Leak Check (Out of Chassis)

1. Modified Bracket with Air Fitting	2. Plug (Pipe or Rubber)

Cylinder Head Coolant Passage Leak Check — Out of Chassis

Refer to Figure 66.

1. Remove cylinder head from the engine.
2. Fabricate a suitable 3/4-inch thick (19.1 mm) steel plate and a 1/4-inch (6.4 mm) rubber gasket. The plate must have cutouts for the entire combustion chamber. Position plate and gasket assembly on the underside of head and secure with C-clamps, or with head bolts if the plate has been drilled for bolts.
3. Use suitable plate and gasket to seal the water manifold openings. Install an air fitting onto the plate.
4. Immerse the cylinder head in water. Heat the water and head to 150°F (66°C).
5. Apply up to 50 psi (345 kPa) air pressure to the fitting installed in the plate covering the water manifold opening. Check for air bubbles. The formation of air bubbles indicates that the cylinder head coolant passages may be leaking.

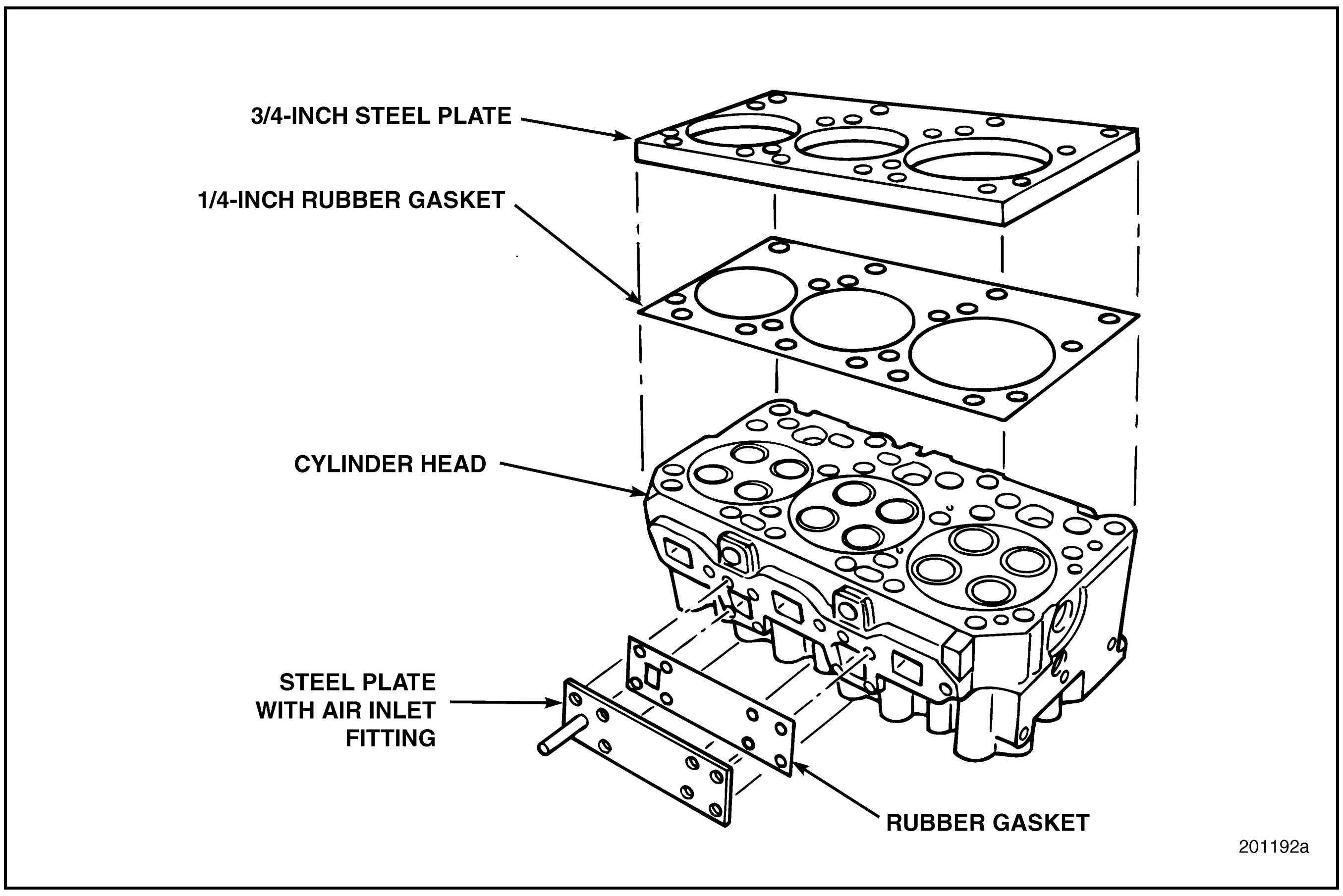


Figure 66 — Cylinder Head Coolant Passage Leak Check (Out of Chassis)

Cylinder Block Coolant Passage Leak Check — Out of Chassis

Refer to Figure 67.

1. Fabricate two 3/4-inch thick (19.1 mm) steel plates to simulate cylinder heads. The plates must have cutouts for the head capscrews and liners. Use a 1/4-inch (6.4 mm) thick rubber gasket as a seal. Install the plates onto the cylinder block.

NOTE

As an alternative to step 1, conduct the test using two known leak-free cylinder heads complete with gaskets and fire rings in place of the steel plates. With this alternative, a water manifold (with the outlet end sealed) can be used to seal off the cylinder head coolant ports. Fittings can be installed on the water manifold to introduce the heated water and air pressure needed for the test.

2. Remove the water pump assembly and seal the opening with a suitable plate and rubber gasket. The plate must be fabricated with adapters so that water heated to 150°F (66°C) and pressurized to 50 psi (345 kPa) can be introduced into the system.
3. Apply approximately 50 psi (345 kPa) air pressure into the cooling system. Visually inspect the cylinder block for signs of air and water leaks.

CAUTION

Do not exceed 50 psi (345 kPa). Damage to seals or cup plugs may result.

5_106_00.bk Page 77 Friday, August 4, 2000 11:17 AM

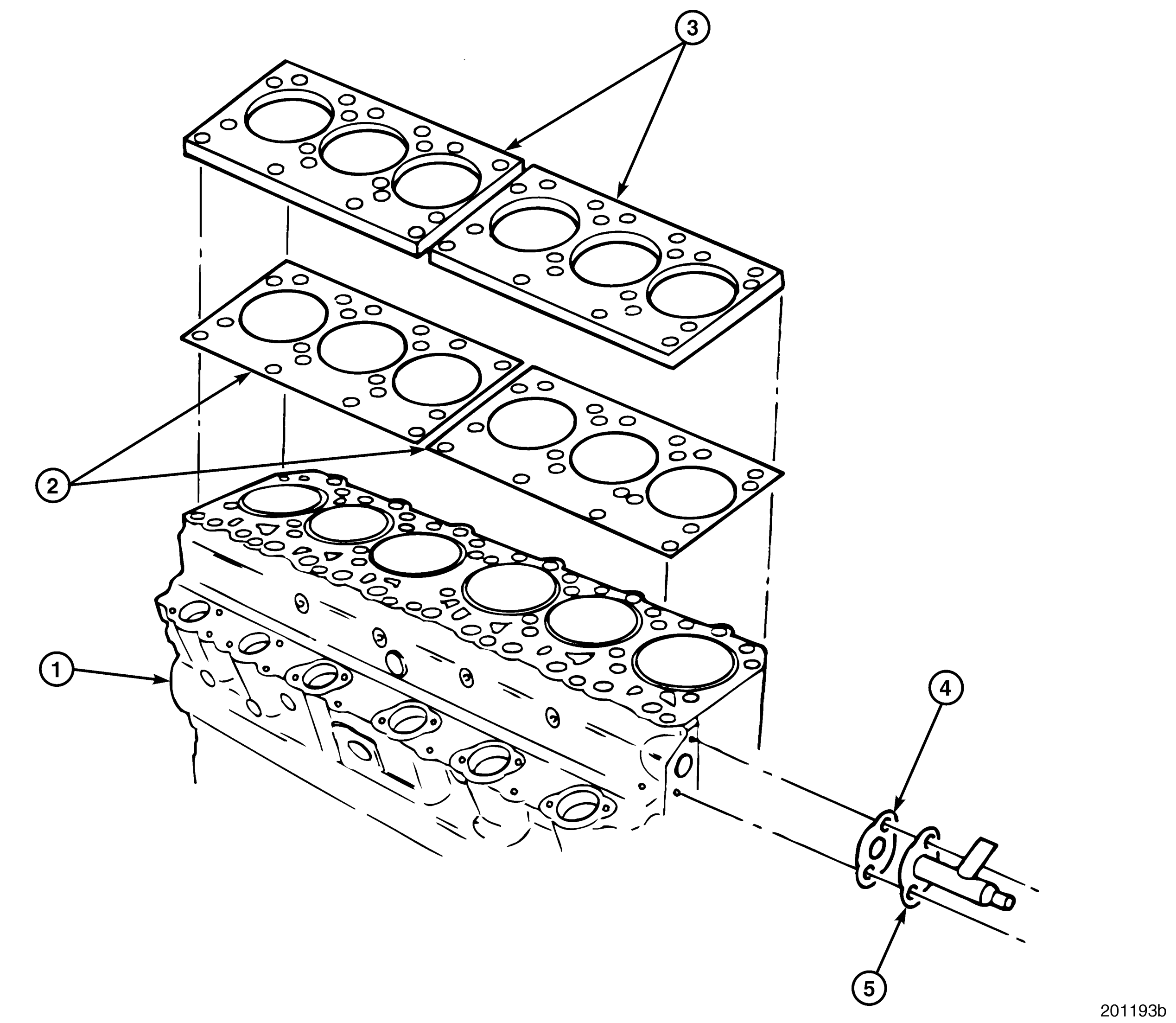


Figure 67 — Cylinder Block Coolant Passage Leak Check (Out of Chassis)

1. Cylinder Block 2. 1/4-inch Rubber Gaskets 3. 3/4-inch Steel Plates	4. Rubber Gasket 5. Plate with Air/Water Inlet Fittings

5_106_00.bk Page 78 Friday, August 4, 2000 11:17 AM

ENGINE BRAKE TESTS (MACK E-TECH™ ENGINE WITH J-TECH™ ENGINE BRAKE)

Operational Tests

Before beginning the troubleshooting procedures, try to determine the exact nature of the problem. Talk to the driver, owner and/or mechanic to pinpoint the complaint or problem. The following checks may be helpful in trying to determine the nature of the problem.

BEFORE STARTING THE ENGINE

If there is a report of engine or engine brake noise, remove the engine covers to determine the cause.

1. Check for broken or loose parts.
2. Check valve and engine brake lash settings.
3. Check for possible bent valves or push rods. Possible causes of bent valves or push rods could be:

   Engine overspeeding — Usually several valves are affected.

   One bent exhaust valve or push rod — This indicates a possible problem with a stuck master or slave piston, damaged slave piston adjusting screw (reset screw) or excessive oil pressure. See the Table on page 81 for oil pressure requirements.

   A bent exhaust valve may be caused by the valve stem stuck in its guide, bad yoke adjustment, or broken or weak valve springs.

TEST DRIVE

1. Test drive the vehicle and measure intake manifold boost pressure while operating the engine brake. Refer to the Table on page 78 for boost pressures.

RETARDING BOOST PRESSURES (PSI)

MACK E7 300A E-Tech™ Engine (Schwitzer S-300 Pre-12/99 — S-400S Post 12/99 Turbo)
2100 rpm — 18 psi Boost
1900 rpm — 17 psi Boost
1700 rpm — 16 psi Boost
1500 rpm — 14 psi Boost
1300 rpm — 10 psi Boost
1100 rpm — 8 psi Boost
MACK EM7 275, 300 and E7 310/330 E-Tech™ Engines (Schwitzer S-300 Pre-12/99 — S-400S Post 12/99 Turbo)
2100 rpm — 19 psi Boost
1900 rpm — 18 psi Boost
1700 rpm — 18 psi Boost
1500 rpm — 16 psi Boost
1300 rpm — 11 psi Boost
1100 rpm — 8 psi Boost
MACK E7 300, 330/350, 350, 355/380, 400 E-Tech™ Engines (Schwitzer S-300 Pre-12/99 — S-400S Post 12/99 Turbo)
2100 rpm — 18 psi Boost
1900 rpm — 18 psi Boost
1700 rpm — 17 psi Boost
1500 rpm — 14 psi Boost
1300 rpm — 10 psi Boost
1100 rpm — 8 psi Boost
MACK E7 427, 460 E-Tech™ Engines (Schwitzer S-400 Pre-12/99 — S-400S Post 12/99 Turbo)
2100 rpm — 17 psi Boost
1900 rpm — 15 psi Boost
1700 rpm — 14 psi Boost
1500 rpm — 11 psi Boost
1300 rpm — 8 psi Boost
1100 rpm — 6 psi Boost

NOTE

If the vehicle does not have a boost pressure gauge, one must be installed. A pipe plug is located in the air inlet manifold for this purpose.

2. It is best to conduct the test with a loaded vehicle, engine at maximum rated rpm and the engine brake ON. Downhill operation is desirable to stabilize rpm.
3. Record the maximum boost pressure with both housings (HI position).
4. Record the boost pressure with the switch in the LO position.

NOTE

LO position may be either front or rear housing.

5. Disconnect the LO position harness to the solenoid and rerun the test with the switch in the HI position. Record the results.

NOTE

The individual housing readings will not be half of the maximum boost pressure reading due to the effect of the turbocharger. The individual boost pressure readings, however, should be approximately the same.

6. A significantly lower reading in one housing indicates a possible problem with the housing. Compare the maximum boost pressure with the boost pressures in the Table on page 78. A low reading indicates a possible problem. Readings within 3 psi of the values shown indicate proper operation of the engine brake.

Electrical Troubleshooting

The J-Tech™ engine brake is activated by the V-MAC® system. When the ignition switch is turned ON, the engine brake solenoids are supplied a constant 12-volt direct current with current flow increasing whenever the engine brake is activated. To properly diagnose electrical problems with the brake, an ammeter may be required.

If insufficient electrical power is reaching the engine brake, perform the preliminary checks outlined below. For more information, see the V-MAC® III Service Manual, 8-211.

NO ENGINE BRAKE OPERATION

1. Check for a blown fuse or circuit breaker.
2. With electrical power OFF, check the control system for a short to ground. Check systems separately to isolate where the short is occurring. If the control system is OK up to the engine brake spacer connection, measure the resistance to the solenoid valve. High resistance means an open circuit in the solenoid or solenoid wire.

ONLY ONE HOUSING OPERATING

1. Determine which housing is not operating by closing all the switches and checking the power at the wires leading to the solenoid valves (front and rear).
2. Remove the wire to the solenoid valve at the spacer and check for resistance (the Table on page 80). No reading indicates an open circuit in the wire or solenoid coil. A low resistance reading indicates a short to ground in the solenoid wire or solenoid coil.

SERVICE HINT

A constant 12-volt low amperage signal is supplied to the engine brake solenoids by the V-MAC III module when the ignition switch is turned on. During an engine braking event, V-MAC increases the current to the solenoids to activate the engine brake. The most accurate method of checking electrical functionality of the engine brake solenoids circuit is by using an ammeter to measure current at the solenoids when the engine brake is activated. When the engine brake is activated, current should be approximately 1.59 amps. For additional information, consult the V-MAC® III Service Manual, 8-211.

3. Test the solenoid by checking for current draw and pull-in voltage per specifications listed in the Table on page 80.

5_106_00.bk Page 80 Friday, August 4, 2000 11:17 AM

SOLENOID SPECIFICATIONS

12-Volt Solenoid:	
	Resistance — 8.7 to 10.0 ohms
	Current Draw — 0.9 to 1.6 amps
	Pull In Voltage — 9 volts DC minimum
24-Volt Solenoid:	
	Resistance — 32.6 to 39.8 ohms
	Current Draw — 0.46 to 0.75 amps
	Pull In Voltage — 18 volts DC minimum

INTERMITTENT BRAKING

Inspect all wiring for loose connections and all switches for proper adjustment.

POOR PERFORMANCE

Connect a volt/ohmmeter (multimeter) to the electrical connector on the spacer. Verify that a steady voltage signal is present when the engine brake is active. If not, check for loose connections or faulty switches. Repeat for all spacer terminals.

Hydraulic/Mechanical Troubleshooting

SPECIAL TOOL REQUIRED

- Jacobs Oil Pressure Test Kit 4559-18280

Remove the covers to begin inspecting the brake housings and attendant hardware.

GENERAL INSPECTION AND ADJUSTMENT VERIFICATION

1. Visually inspect the brake units for obvious damage or missing parts. Replace as necessary.
2. Check the slave piston-to-actuator pin for proper clearance as shown in the Table on page 80. Also check the intake and exhaust valve clearance. Readjust if necessary.

NOTE

Valve clearance must be checked with the timing pointer hole on the flywheel housing aligned with the proper valve setting mark on the flywheel for the cylinder being checked. This ensures that the valve lifter is on the camshaft base circle and not on the brake ramp portion of the lobe.

WARNING

Wear eye protection and do not expose your face over the engine area. Keep hands away from moving parts. Take precautions to prevent oil leakage down onto the engine.

Whenever engine is running and the cylinder head covers are removed, oil splashing in the engine brake area could cause personal injury.

Never remove any engine brake component with the engine running. Personal injury may result.

NOTE

Slave piston clearance settings must be made with the engine stopped and cold and with the exhaust valves closed.

SLAVE PISTON CLEARANCE SETTINGS

E-Tech™ Engine with J-Tech™ Engine Brake
Adjustment — 0.015 inches (0.381 mm)
Slave piston adjusting tool — standard feeler gauge
Adjust following the firing order — 1, 5, 3, 6, 2, 4

DETERMINING ENGINE OIL PRESSURE AND OIL PRESSURE AT THE ENGINE BRAKE UNITS

The engine brake requires a minimum oil pressure to operate. To determine the oil pressure at the engine brake housing solenoid valves, use the Jacobs oil pressure test kit (part No. 4559-18280) and follow the instructions included in the kit. See the Table on page 81 for oil pressure requirements.

NOTE

The engine oil temperature must be within normal operating range when the test is performed.

If the oil pressure remains low, correct the engine problem as described under OIL PRESSURE DROPPING BELOW MINIMUM REQUIRED FOR ENGINE BRAKE OPERATION in the Troubleshooting Guide included in this section.

OIL PRESSURE REQUIREMENTS

E-Tech™ Engine with J-Tech™ Engine Brake
Engine rpm 2100 — 40 psi (2.8 bar)
Engine rpm 1700 — 35 psi (2.4 bar)*
Engine rpm 1500 — 30 psi (2.0 bar)*
Engine rpm 1300 — 30 psi (2.0 bar)*
Engine rpm 1100 — 30 psi (2.0 bar)*
* Specified pressures with engine at normal operating temperatures

INSPECTION OF ENGINE BRAKE COMPONENTS

If oil pressure at the brake housings is sufficient for brake operation, then inspect the engine brake components for excess wear, damage or malfunctioning conditions described in this section.

1. Start the engine and allow it to idle for a few minutes. Check for oil leakage at the oil supply screw, solenoid valve and housing pipe plugs. Oil leakage can result in weak, intermittent or no braking. If leakage is found, shut down the engine and replace seals or repair as needed.

   When the engine is shut down for several minutes, the oil in the brake housings will bleed down. To refill the brake housings for immediate operation, depress the solenoid cap (pin) several times to fill the housing with engine oil.

2. With the engine brake on, observe that the master pistons are moving out of the housing and making contact with the exhaust rocker spherical nuts. They should move in and out freely. If they do not, shut down the engine and check the control valves and control valve springs for those cylinders.

WARNING

Remove control valve retaining components carefully to avoid personal injury. Control valve retaining components are under load from the control valve springs.

3. The control valve must move freely in the bore. If not, remove it and replace with a **new** control valve.

NOTE

If the bore is damaged (scored), use a light crocus cloth to smooth the bore. Clean the bore and install a **new** control valve. If severe damage to the bore is found, replace the housing.

4. Replace any broken springs.
5. If the control valves and springs are OK and the master and slave pistons were observed not to be operating, remove the housings for inspection.

   Visually inspect the following:

   Master piston springs — If broken or worn, replace the springs.

   Master pistons — Pistons must move freely in the bore. Check the hard facing on the master piston for damage; this is the area that contacts the spherical nut.

   Spherical nut rocker adjusting screw — Check the spherical nut for excessive wear. If a depression of 0.005 inch or deeper is found in the top of the spherical nut or if the pattern of wipe extends beyond the edge of the nut, replace the spherical nut. Also, replace the companion master piston. The spherical end of the rocker adjusting screw should be checked for proper contour and smooth appearance. Replace if necessary.

   Internal check valve components — If the housing contains internal check valve components and a hollow oil supply screw, remove the check valve components (ball, spring, retaining ring and washer) from the housing and replace the hollow oil supply screw with the current-production screw containing an integral check valve.

   Oil supply screws — Check for damage and replace if necessary.

5_106_00.bk Page 82 Friday, August 4, 2000 11:17 AM

6. Check the screw and pin assembly to ensure that the pin is not bent or damaged. The pin should not stick in the screw at any point in its travel. There should be no signs of mushrooming or other damage where the slave piston contacts the screw. Check to ensure that the retainer is in place on the top of the pin, making the pin captive in the screw. Replace the screw and pin assembly as a unit, if necessary.
7. Remove and inspect the reset screw. A spring-loaded plunger located at the bottom of the screw seals the hole in the slave piston to provide proper master/slave operation. A stuck plunger or any debris will cause the hole in the slave piston to be uncovered prematurely, dumping oil pressure and shutting down the circuit. The reset screw prevents overtravel of the slave piston and exhaust valve to engine piston contact.

NOTE

Reset screw assemblies are not field serviceable.

8. Remove the slave pistons, using the following procedure.

WARNING

Wear safety glasses.

The slave piston is retained by springs that are under heavy compression. If the following instructions are not followed and proper tools not used, the springs will be discharged with enough force to cause personal injury.

SLAVE PISTON REMOVAL

1. Remove the locknut on the slave piston adjusting screw. Back out the adjusting screw until the slave piston is fully retracted (screw is loose).
2. Place the hole in the slave piston clamp fixture over the slave piston adjusting screw. Replace locknut. Finger-tighten to hold fixture securely.
3. While holding the fixture in position, screw the holder down over the slave piston until the spring retainer is contacted.
4. Turn the handle slowly until the retainer is depressed to about 1/32 inch (1 mm), relieving pressure against the retaining ring.
5. Remove the retaining ring using retaining ring pliers. Back out the holder until the springs are loose, and remove the fixture. Remove all components, ensuring that there is no binding or burrs. Clean in an approved cleaning solvent. Inspect parts and replace as necessary.
6. A shiny, smooth contact surface on the reset screw plunger and slave piston is normal. If a rough surface exists on the plunger and/or slave piston, replace the parts. There should be a light spring force on the plunger and it should move freely. If not, replace the reset screw assembly.
7. Use the clamp fixture to reinstall the piston and springs. Be sure the retaining rings are placed on the retainer before screwing the clamp holder down.
8. Compress the slave piston springs down until the retainer is about 1/32 inch (1 mm) below the retaining ring groove. Reinstall the retaining ring. Be sure the retaining ring is fully seated in the groove.
9. Remove the clamp fixture slowly to ensure proper seating of retaining ring.

Final Test

Follow the instructions in the installation manual to reassemble the housings. Install a **new** oil supply seal ring.

1. Install the housings on the engine and adjust the slave piston clearance to the proper settings shown in the Table on page 80.
2. Before installing the engine covers, start the engine and allow it to warm up for a few minutes.
3. Depress the solenoid valve several times to fill the housing with engine oil.

NOTE

Engine brakes require a minimum oil pressure for operation. If there is less than minimum at idle, run the engine at higher rpm (800–900) when making checks. See the Table on page 81 for oil pressure requirements.

5_106_00.bk Page 83 Friday, August 4, 2000 11:17 AM

4. Check for oil leaks at the oil supply screw, solenoid valve and housing pipe plugs. If leakage is noticed, shut down the engine and repair the leaks.

NOTE

Some leakage will be seen at the master piston, slave piston and control valves. This is normal. Excessive leakage must be investigated (see Hydraulic/Mechanical Troubleshooting).

5. After final inspection and necessary repair, shut down the engine and replace the gaskets and covers.
6. Test drive the vehicle following the Test Drive procedures (covered earlier) to verify corrective action.

Troubleshooting Guide

Following is a listing of problem conditions showing the probable causes and subsequent corrections.

ENGINE FAILS TO START

- **Solenoid valve stuck in ON position** — Ensure that electrical current is off to the engine brake units. If the solenoid valve remains on (cap down) with current off, replace the solenoid valve.

ENGINE BRAKE WILL NOT OPERATE

- **Blown fuse, open electrical leads** — Look for a short circuit in the wiring. Replace any broken, brittle or chafed wires. Check solenoid tab for signs of shorting and replace if necessary. Replace 10 amp fuse.
- **On/Off switch, clutch switch or multi-position switch out of adjustment or defective** — Use a volt/ohm meter to make certain that there is electrical voltage available at both terminals of each switch. Readjust if needed or replace if voltage will not pass through switch.

WARNING

Do not touch electrical connection when system is energized.

- **Incorrect electrical power source** — Check that the supply voltage is the appropriate voltage. Recommended power source is from the key switch ON position. Ensure that power is not taken from a source with an additional on/off switch, i.e., light switch. See solenoid specifications in the Table on page 80. Make sure wiring is in accordance with MACK wiring instructions.
- **Low engine oil pressure** — Determine oil pressure at engine brakes (solenoid valve and control valve); see oil pressure requirements in the Table on page 80. If oil pressure is below specification, the engine should be repaired in accordance with MACK procedures.
- **Slave lash not properly adjusted** — The model 690 engine brake is very sensitive to adjustment. Incorrect adjustment may hold the valves open during positive power, leading to engine failure, or may cause the engine brake to work poorly or not at all. Confirm that the engine brake is properly adjusted in accordance with the Table on page 80.

ENGINE BRAKE DOES NOT OPERATE AT LOW ENGINE RPM

- **Inlet check valve leaking** — Early-production engine brake housings contained a check valve (with ball, spring, retaining ring and washer) assembled into the housing. In June 2000, the housing's internal check valve components and hollow oil supply screw were replaced by a new oil supply screw containing an integral check valve. If the housing contains the early-production internal check valve components and a hollow oil supply screw, remove the check valve components (ball, spring, retaining ring and washer) from the housing and replace the hollow oil supply screw with the current-production screw containing an integral check valve.

ENGINE BRAKE ACTIVATES WITH SWITCHES OPEN (OFF)

- **Solenoid valve seal center ring damaged** — Remove solenoid and replace all three seal rings.
- **Engine brake improperly wired** — Check wiring in accordance with MACK wiring diagrams.

ENGINE BRAKE SLOW TO OPERATE OR WEAK IN EFFECT

- **Lube oil cold and thick** — Allow engine to warm before operating brakes.
- **Improper slave piston adjustment or slave piston sticking in bore** — Readjust in accordance with the Table on page 80. Ensure that the slave piston responds smoothly to the reset screw by loosening the jam nut and turning the screw through its full travel for full slave piston motion. Make sure piston travels the full range without binding or sticking.

WARNING

Remove the slave piston carefully when disassembly is necessary. Use Jacobs slave piston tool part No. 4559-25084. Slave piston springs are under heavy compression.

- **Reset screw not properly sealing** — Remove reset screw and check for debris on the plunger or surface of the slave piston. Check to ensure that plunger moves freely with light pressure. Tip of plunger should be smooth and free of nicks or scratches. Replace reset screw if necessary.
- **Lower solenoid seal damaged allowing oil to exit the housing** — Remove solenoid valve and replace all seal rings.
- **Solenoid screen clogged stopping supply of oil to brake** — Remove solenoid valve and clean screen.
- **Master piston not moving in bore** — Inspect master piston and bore for scoring or burrs. If any are present, clean the surface with crocus cloth. If unable to remove burrs, replace piston or housing. Inspect lube oil for signs of contaminants. If any are present, replace oil and filter and correct cause of contamination.
- **Control valves binding in housing bore** — Remove control valve. If body is scored, replace the control valve. Check for contaminants in lube oil. Clean housing and control valve. If binding continues, replace housing.
- **Control valve defective** — Remove control valve. Make sure check ball is seated in bore and can be moved off seat. Make sure there is spring pressure against the ball. Flush in cleaning solvent. Replace if necessary.
- **Switch operation sluggish** — Check dash switches, clutch switch, or other control switches. Readjust or replace as required. Check clutch return springs for proper operation. Check all controls for correct operation and replace as required.
- **Solenoid valve operation erratic** — Check solenoid valve using electrical specifications presented in the Table on page 80. Disconnect the solenoid lead and provide 12 volts directly to the solenoid. Ensure that the solenoid cap depresses.

WARNING

Do not touch electrical connection when system is energized.

OIL PRESSURE DROPPING BELOW MINIMUM REQUIRED FOR ENGINE BRAKE OPERATION

- **Upper solenoid seal ring damaged** — Remove solenoid. Inspect seal ring and replace all seal rings.
- **Aeration of lubricating oil** — Check for aeration of the oil. Activate, then deactivate engine brake and observe escape oil coming from control valve cover. If oil has bubbles or is foamy, air is present in system. Aeration can be caused by an overfilled or underfilled crankcase, or a crack or other leak in the oil pickup tube. Correct in accordance with MACK procedures.
- **Lubricating oil being diluted by fuel oil** — Have an oil analysis of lube oil to determine if fuel is present. Correct per MACK procedures.
- **Low engine oil level** — Consult engine manual for specifications. Add oil or recalibrate dipstick as required.

5_106_00.bk Page 85 Friday, August 4, 2000 11:17 AM

- **Worn rocker arm bores or shaft journals** — Inspect rocker arm bores and shaft journals. Repair as required.
- **Worn crankshaft bearings or camshaft bushings** — Replace bearings and bushings in accordance with MACK overhaul procedures.

ONE OR MORE CYLINDERS FAIL TO STOP BRAKING OR ENGINE STALLS

- **Control valve inner spring broken** — Replace inner spring.
- **One or more control valves stuck in ON or UP position** — Check control valves for binding. Remove and clean, or replace if necessary. Inspect lube oil for contaminates.
- **Solenoid valve sticking in ON position** — If solenoid valve cap remains down with no electric current being supplied, replace the solenoid valve.
- **Center solenoid seal ring damaged (allows oil to enter brake with solenoid valve closed)** — Remove solenoid and replace all seal rings.
- **Solenoid valve exhaust plugged** — Remove any restrictions at exhaust (bottom) of solenoid valve.
- **Clutch switch stuck in ON position or out of adjustment** — Check for proper operation. Readjust or replace as needed.

ENGINE MISSES OR LOSES POWER

- **Slave piston adjustment too tight** — Readjust slave piston clearance in accordance with the Table on page 80.

SUDDEN DROP IN ENGINE LUBE OIL PRESSURE

- **Upper solenoid valve seal missing or damaged** — Remove solenoid and replace upper seal ring.

5_106_00.bk Page 86 Friday, August 4, 2000 11:17 AM

NOTES

5_106_00.bk Page 87 Friday, August 4, 2000 11:17 AM

MAINTENANCE

BELT DRIVE SYSTEM TENSIONING [216]

The belt drive system uses a single, 10-rib poly-v belt to drive the alternator, water pump, and fan drive. A separate single-v belt, running off the water pump pulley, drives the refrigerant compressor. The service life of the poly-v belt is considerably improved over other systems and allows the use of higher horsepower cooling fans. Refer to Figure 68.

Both manually tensioned and automatically tensioned systems are used. Whether an engine has the manually tensioned or automatically tensioned system depends on the specific engine configuration and application. The following service information covers both systems.

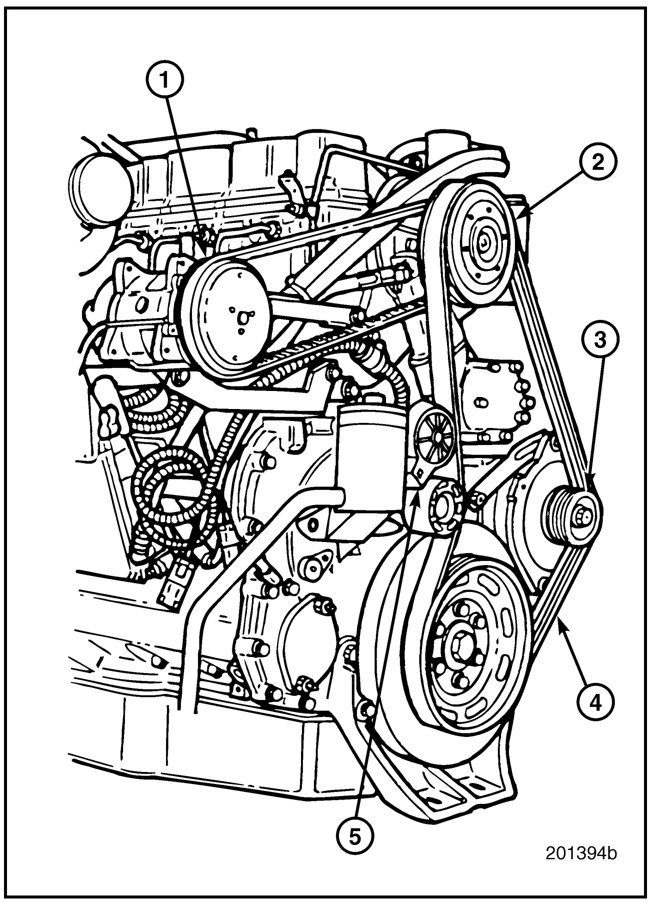


Figure 68 — Belt Drive

1. A/C Compressor 2. Water Pump 3. Alternator	4. Poly-V Belt 5. Tensioning Device

Manually Tensioned System

INSTALLATION

Loosen the alternator mounting bolts and pivot the alternator inboard, far enough to allow the belt to be placed over the pulleys without force. Do not pry the belt over a pulley.

TENSIONING

Using a belt tension gauge, such as J 41251-B from Kent-Moore, check the belt tension at the widest span between pulleys. Adjust belt tension according to the following specifications:

- New belt: 270 lbs. ± 10 lbs.
- Used belt: 230 lbs. ± 10 lbs.
- Minimum allowable tension (before retension is required): 150 lbs.

MAINTENANCE

The belt tension and condition of the belt should be checked when performing preventive maintenance inspections A, B, C and D as outlined in the *Maintenance and Lubrication* manual, TS494. Belts should be tightened when needed, using the procedures described in this manual.

Automatically Tensioned System

INSTALLATION

Swing the tensioner to the fully sprung position and, without force, place the belt over the pulleys. Do not allow the tensioner to snap against its stops. Do not pry the belt over a pulley.

TENSIONING

No tensioning adjustment is required. Once the tensioner is released against the belt, the belt is tightened to optimum tension automatically at all speeds and loads.

MAINTENANCE

The condition of the belt and tensioner should be checked when performing preventive maintenance inspections A, B, C and D as outlined in the *Maintenance and Lubrication* manual, TS494. Belt tension level need not be checked as long as tensioner is in good condition and there is no evidence of a loose belt.

5_106_00.bk Page 89 Friday, August 4, 2000 11:17 AM

FILTER ELEMENT REPLACEMENT

General Information

The engine may be equipped with either a cast aluminum or fiberglass-reinforced nylon crankcase breather filter canister as shown in Figure 69. Regardless of the canister style, the breather filter element can be cleaned if it has become plugged following the procedure in this section.

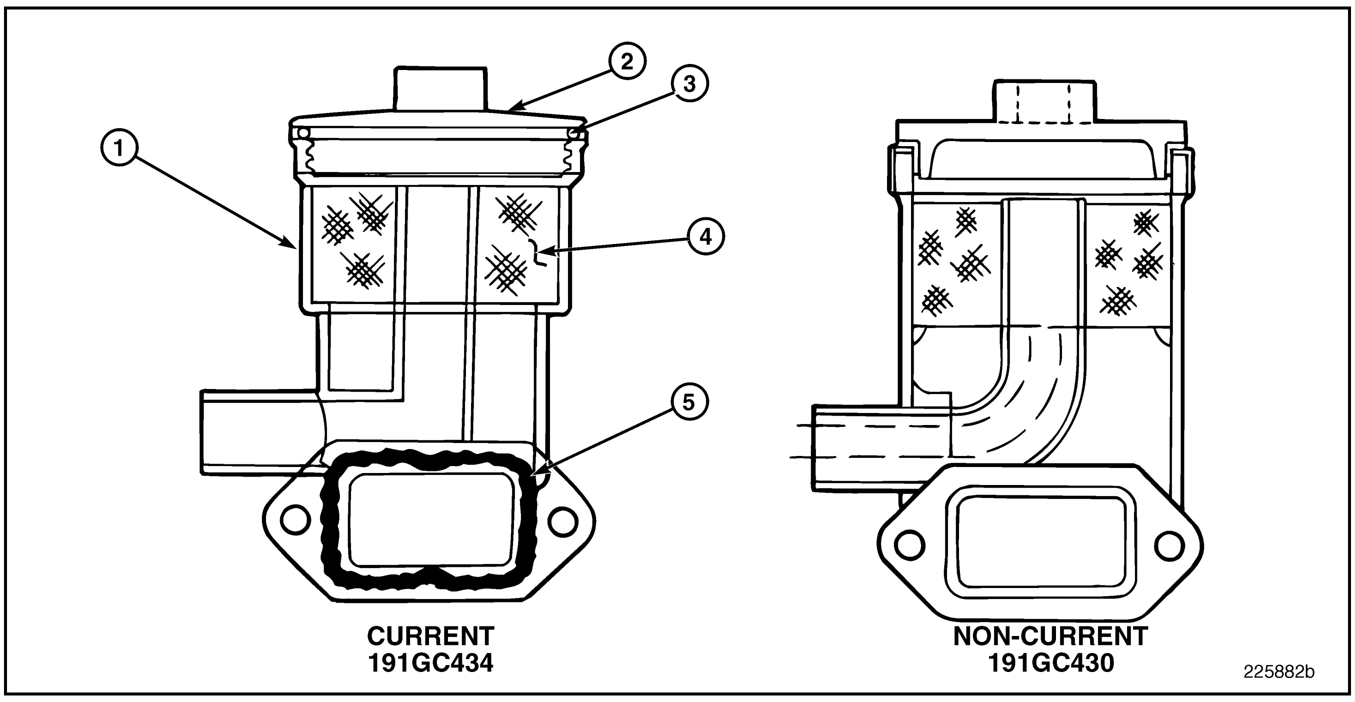


Figure 69 — Canister Housings

1. Fiberglass-Reinforced Nylon Housing 2. Breather Cover 3. Cover O-Ring	4. Filter Element 5. Housing Mount O-Ring/Gasket

Crankcase Breather Filter Cleaning [219 ER]

1. Remove the canister cover by unthreading it from the housing.
2. Place a thin-blade screwdriver between the outside diameter of the element and the canister housing (Figure 70). Then, remove the element by rotating the screwdriver and element while exerting upward pressure.
3. Wash the element in shop solvent and blow dry with shop air.
4. Reinstall the element in the canister housing.
5. Install and tighten the canister cover.

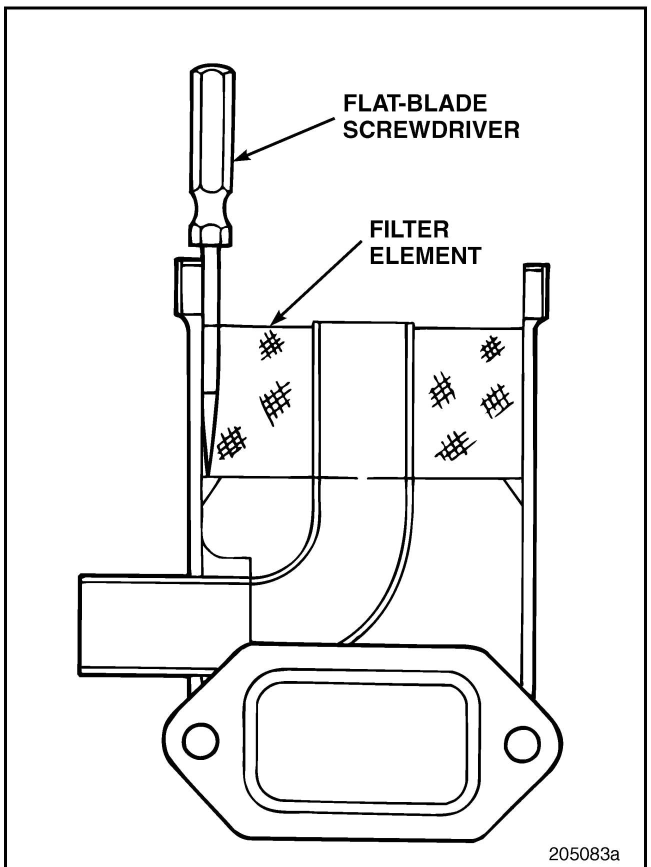


Figure 70 — Breather Filter Element Removal (Cast Aluminum Housing Shown)

Oil Filter Element Replacement [219 EV]

SPECIAL TOOLS REQUIRED

- Fuel and Oil Filter Wrench J 24783
- Oil Filter Wrench J 29927

GENERAL INFORMATION

Two different oil filter mounting adapter designs are used, one for engines with the removable bundle-type oil cooler and another for engines with the plate-type cooler.

Engines with removable bundle-type oil coolers — The plunger-style oil filter bypass relief valve used in early production oil filter mounting adapters was replaced with a poppet-style valve in November 1997 (beginning with engine serial number series 7V). With this change, the oil filter mounting adapter was redesigned to accommodate the poppet-style relief valve and to eliminate the section that contained the plunger-style valve. When performing an oil and filter change, it is suggested that functionality of the poppet-style relief valve be checked by pushing against the viton disk to verify spring tension.

Engines with plate-type oil coolers — The oil filter mounting adapters on these engines are also fitted with the poppet-style valve. Again, the functionality of the poppet-style relief valve can be checked by pushing against the viton disk to verify spring tension each time the oil and filters are replaced.

Centri-Max® filter assemblies — There are different style rotors used in both the externally drained and internally drained Centri-Max® assemblies. As such, it is important that the proper rotor be used in the Centri-Max® unit for which it was designed.

From the inception of the Centri-Max® filter assembly (externally drained), the rounded end of the original rotor (part No. 236GB244A) had several straight ribs radiating from the center of the rotor, like spokes of a wheel.

Effective September 1998, a more efficient "swept" rotor (part No. 236GB244B) was implemented into production. The swept rotor is easily identified by the ribs on the rounded end, which are now curved rather than straight.

The Centri-Max® PLUS (internally drained) unit also uses the swept rotor design, but the bushings in each end of the rotor are of a smaller inside diameter to fit over the smaller diameter spindle used with the internally drained configuration. This rotor (part No. 236GB245M) must be used with the Centri-Max® PLUS filter. If either of the other two rotor part numbers are used, they will be loose on the spindle and will not rotate. If the rotor does not rotate, the centrifugal filter will not function. The Centri-Max® PLUS canister carries the warning to use only rotor No. 236GB245M. No other rotor will work.

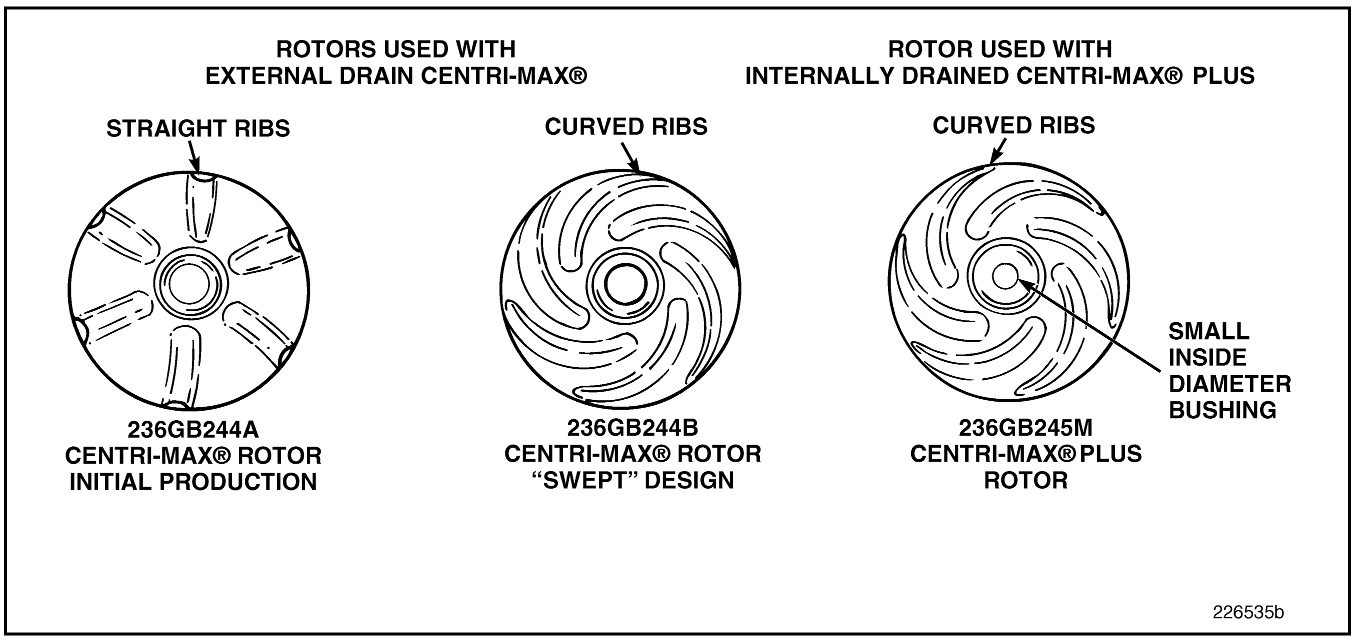


Figure 71 — Centri-Max® Rotors

DISPOSABLE SPIN-ON OIL FILTER REPLACEMENT

Change oil and replace oil filters using the following procedure:

1. Run the engine until normal operating temperature is reached. Then, shut off the engine and drain the oil before the engine cools.
2. Thoroughly clean the area around the filters before removing.
3. Using tool J 24783, remove both spin-on filters and wipe the filter mounting base clean.
4. Prefill each filter with 2 quarts (1.9 liters) of the specified engine oil. DO NOT allow any contaminants to enter the filters while prefilling.
5. Apply a film of clean engine oil to the sealing gasket on each new filter.
6. Install the filters and tighten 3/4 to 1 turn after the gasket contacts the base.
7. Fill the crankcase with the recommended engine oil. If the engine is equipped with a REPTO unit, add one additional quart.
8. Start the engine and check for leaks. Run the engine for approximately five minutes, then shut it off and recheck the oil level. Add oil if necessary.

NOTE

Use of anything other than genuine MACK filters may cause damage and void the engine warranty. Change filters according to the recommended maintenance schedule.

CENTRI-MAX® FILTER REPLACEMENT

(Externally Drained Filter)

1. Clean the area around the centrifugal filter before removing the drain hose.
2. Loosen the hose clamp at the bottom of the filter housing and disconnect the drain hose.
3. Loosen the hose clamp at the cylinder block drain and rotate the hose out of the way.
4. Using tool J 24783, remove the centrifugal oil filter housing.

CAUTION

Be sure to apply the filter removal tool on the filter housing at the point marked "WRENCH HERE."

5. Remove and discard the filter seal and rotor. Clean the filter housing.
6. Install a **new** filter seal and rotor in the filter housing.
7. Apply a thin film of engine oil to the sealing gasket. Install the centrifugal filter housing and tighten the housing an additional 3/4 turn BY HAND after the gasket contacts the base.
8. Install the drain hose on the base of the filter housing and tighten the hose clamps at the cylinder block and filter housing.
9. Start the engine and check for leaks.

CENTRI-MAX® PLUS FILTER REPLACEMENT

(Internally Drained Filter)

1. To prevent contamination from entering the engine, thoroughly clean the area around the centrifugal oil filter (Figure 72) before removing the cover assembly.
2. Loosen the nut at the top of the cover assembly, then remove the cover.
3. Remove and discard the rotor.
4. Clean the inside of the cover assembly.
5. Install a **new** rotor over the spindle.

CAUTION

Use only the rotor designed for use with the Centri-Max® PLUS centrifugal filter assembly. Any other rotor will not work.

6. Remove and discard the seal from the cover assembly.
7. Install a **new** seal.
8. Apply a thin film of clean engine oil to the seal.
9. Install the cover assembly.
10. Tighten the cover assembly nut to 15 lb-ft (20 N•m).
11. Start the engine and check for leaks.

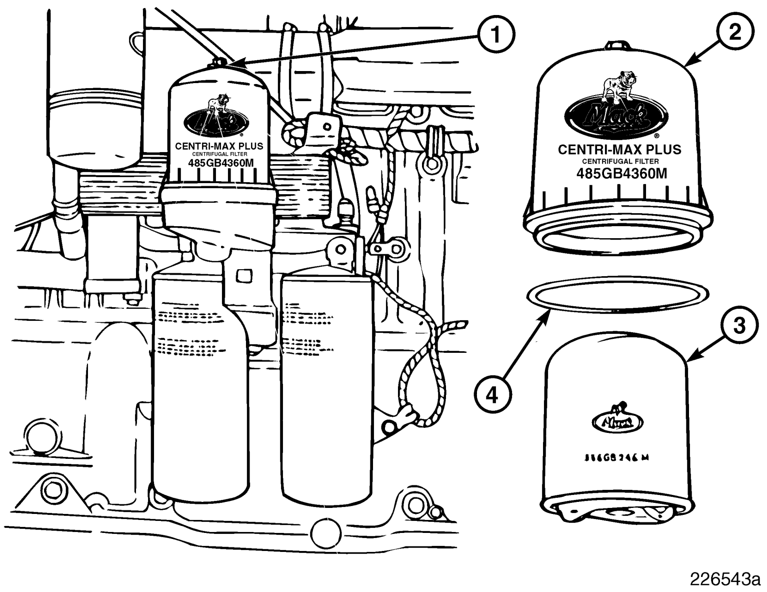


Figure 72 — Centri-Max® PLUS Oil Filter Assembly

1. Cover Bolt 2. Centri-Max® PLUS Cover Assembly	3. Centri-Max® PLUS Rotor (Part No. 236GB245M) 4. O-Ring

CENTRI-MAX® PLUS SPINDLE REPLACEMENT

[219 EV]

Normally, it should never be necessary to replace the Centri-Max® PLUS rotor spindle. However, if the spindle is damaged in any way, replacement procedures are as follows:

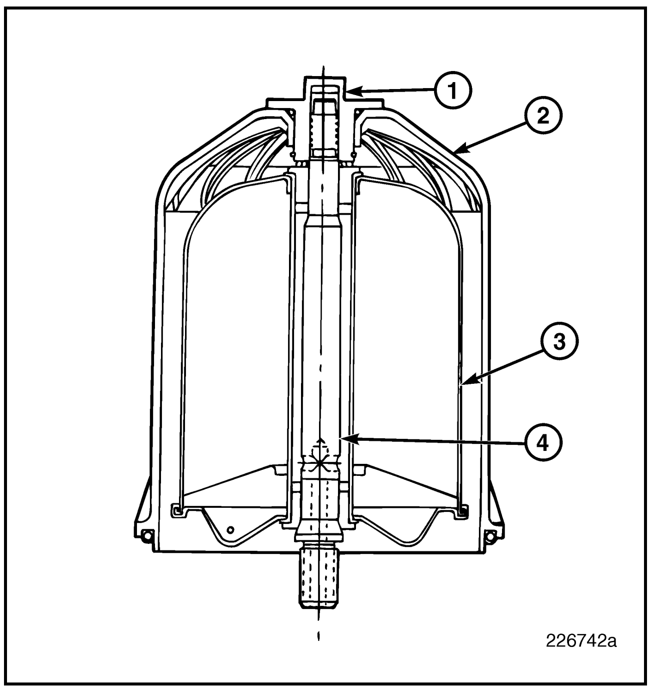


Figure 73 — Centri-Max® PLUS Rotor Spindle Replacement

1. Cover Bolt (Tighten to 15 lb-ft [20 N•m]) 2. Rotor Cover	3. Rotor 4. Spindle (Tighten to 15–20 lb-ft [20–27 N•m])

1. Remove the existing rotor spindle.
2. Using Loctite® Primer T, thoroughly clean the threads of the new spindle, along with the threads inside the oil filter mounting bracket where the spindle will be installed.
3. Apply Loctite® 271 to the threads of the new spindle.
4. Assemble the spindle to the oil filter mounting bracket and tighten to 15–20 lb-ft (20–27 N•m).
5. Allow the Loctite to cure for 24 hours before starting the engine.

Fuel Filter Replacement

[224 KP, 231 PV]

GENERAL INFORMATION

Special high filtration fuel filters have been developed for the E-Tech™ engine. These filters have metric mounting threads and can be identified by the two 1/4-inch wide bands around the circumference of the filter. Figure 74 shows the fuel filters required for the E-Tech™ engine.

NOTE

Attempting to install E7 filters with English threads on an E-Tech™ engine (that has metric threaded spuds) will cause the following to occur:

Primary Filter — The diameters of the filter threads and the threaded spud are close in size. Although the filter can be started on the spud threads using force, the threads will be damaged.

Secondary Filter — The diameter of the filter threads is smaller than the diameter of the threaded spud. Consequently, the filter cannot be installed.

Attempting to install E-Tech™ filters (with metric threads) on an E7 engine with English threads would not result in damage to the threads. The diameters of the filter threads are large enough to prevent installation of the filters.

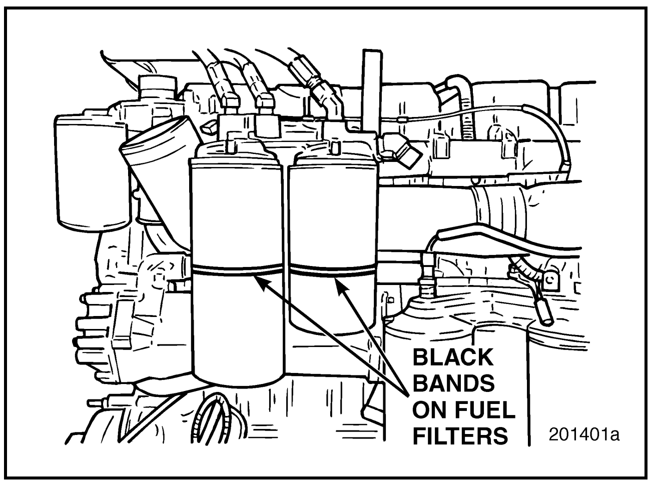


Figure 74 — Fuel Filters

5_106_00.bk Page 94 Friday, August 4, 2000 11:17 AM

REPLACEMENT PROCEDURE

Install fuel filters using the following procedure.

1. Wipe the filter mounting base clean.
2. Apply a film of clean engine oil to the sealing gasket.
3. Fill the filter with clean fuel.
4. Install the filter and tighten 3/4 to 1 turn after gasket contacts the base.
5. Start the engine and check for leaks.

NOTE

Use of anything other than genuine MACK filters may cause damage and void the engine warranty. Change filters according to the recommended maintenance schedule.

NOTE

If the engine fails to start after installing new fuel filters, refer to Priming the Fuel System under Engine Final Preparation and Operational Check.

Coolant Conditioner Replacement [125 LD]

If the engine is equipped with the optional coolant conditioner, the conditioner element is replaced as follows:

1. Place a suitable container below the coolant filter area to catch any spilled coolant.
2. Using a suitable filter wrench (J 29927, or equivalent), remove the coolant conditioner filter element and discard.
3. Apply a light film of oil on the face of the new filter element gasket seal.
4. Install the filter element on the coolant conditioner base assembly. Using tool J 24783, tighten the filter element one full turn after gasket contacts the base.

5_106_00.bk Page 95 Friday, August 4, 2000 11:17 AM

REPAIR INSTRUCTIONS

ENGINE REMOVAL

General Instructions

Details of the engine removal procedure vary from one vehicle to another. This section provides general guidelines for removing the engine from the vehicle.

NOTE

Before beginning engine removal, make sure all equipment is available for use and has been inspected for safety.

NOTE

It is good practice to steam clean the engine to remove road grime, grease and oil before starting work. Steam cleaning the engine and engine area allows more detailed inspection and improved workmanship.

Care must be used to keep moisture from entering the air intake system. If moisture does enter the system, make sure it is removed (dried out) before the engine is reinstalled.

1. Position vehicle on a flat and level surface in an area with ample work space in and around the vehicle. Ensure that a suitable lifting device is available.
2. Apply the parking brake and block the vehicle wheels to prevent vehicle from moving. Observe all safety precautions.
3. Disconnect the battery negative (ground) cable.
4. Drain the air tanks.

Removal from Vehicle

1. Remove the hood (if so equipped) and position it away from the work area to prevent accidents or hood damage to conventional models. On cab over engine models, tilt cab forward.
2. Place a suitable container beneath the engine and drain the engine oil and coolant. Open the coolant drain valves in the block, if applicable.
3. Using an appropriated filter wrench, remove the oil filters, fuel filters and coolant conditioner.
4. Loosen clamps that secure the air intake tube to the turbocharger and air filter. Remove the intake tube.
5. If vehicle is equipped with air conditioning:
   a. Recover the refrigerant using A/C refrigerant recovery and recycling equipment.
   b. Disconnect the A/C compressor discharge hose at the connection near the radiator support.
   c. Disconnect the A/C line at the receiver/dryer.
   d. Locate and disengage the electrical connector from the binary pressure switch on the receiver/dryer.
   e. Locate and disengage the electrical connector from the low-pressure cutout switch in the A/C refrigerant line.
6. Disconnect the upper radiator hose from the engine coolant outlet fitting.
7. Disconnect the lower radiator hose from the coolant inlet of the oil cooler assembly.
8. Remove the clamps that retain the coolant overflow tank and then remove the tank.

9. Disconnect the chassis-mounted charge air cooler inlet hose at the cooler.
10. Disconnect the chassis-mounted charge air cooler outlet hose at the cooler.
11. Locate the engine coolant temperature sensor and disengage the electrical connector, if applicable. Remove the sensor harness from the radiator support.
12. Remove fastener from the bracket that secures the radiator fan clutch air solenoid valve to the radiator support, if so equipped. Set the solenoid valve aside.
13. Remove the fan assembly as follows:
    a. Loosen the eight fan assembly mounting nuts (2) and capscrews (1). Refer to Figure 75.
    b. While supporting the fan assembly (3), remove the nuts (2) from the capscrews (1) and remove the fan assembly.
    c. If the fan assembly is equipped with a viscous drive, be sure to store the assembly either horizontally, with the fan face down (hub flange up), or vertically, as shown in Figure 76. This will prevent fluid leaking from the assembly.

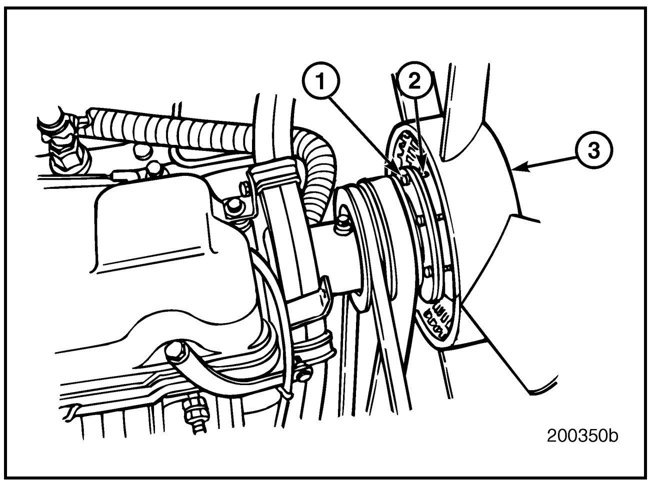


Figure 75 — Fan Assembly Removal

1. Capscrew 2. Nut	3. Fan Assembly

CAUTION

Do not store the assembly horizontally with the fan face up (hub flange down). Fluid in the viscous drive reservoir can leak out.

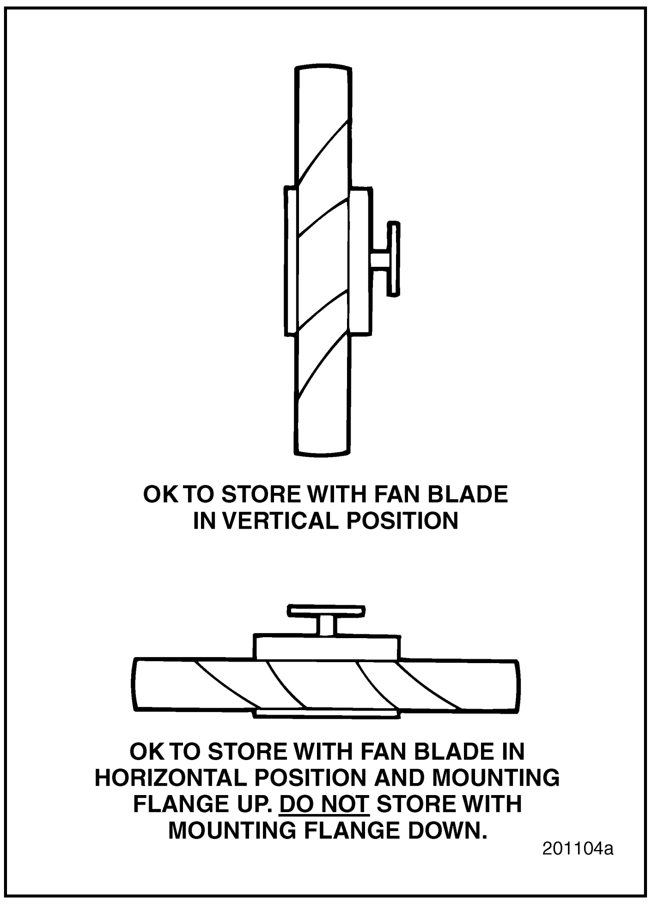


Figure 76 — Viscous Fan Drive Assembly Storage

14. Obtain a lifting device (chain fall or engine hoist) and support the radiator.
15. Remove the retaining bolts from the radiator support mounts.
16. Remove the radiator from the vehicle, using the lifting device and an assistant, if required.
17. Disconnect the heater hoses and A/C refrigerant lines, if applicable, from connections at the lower dash panel behind the engine.
18. Disconnect the tube connecting the turbocharger to the air cleaner assembly.

5_106_00.bk Page 98 Friday, August 4, 2000 11:17 AM

19. Remove all coolant tubes, ground straps, air lines, fuel lines, hydraulic hoses or tubes, throttle linkage and electrical wiring harnesses that are attached to the engine and would prevent its removal.
20. Remove the air cleaner assembly, if required.
21. Remove the exhaust bracket from the clutch, torque converter or flywheel housing and remove exhaust clamp at the turbocharger.
22. Remove power steering hoses and the reservoir, if applicable.
23. Disconnect any electrical cables or wires still connected to the starter. Remove three mounting capscrews from the mounting flange and remove the starter.
24. Support the transmission with an appropriate transmission jack.
25. Remove the retaining bolts that secure the transmission bell housing to the flywheel housing.
26. Remove the hood rest crossmember(s), if applicable.
27. Obtain the appropriate lifting equipment (bar or chain) and attach to the proper lift points on the engine.
28. Position and attach the engine hoist to the lift bar or chain and, using the hoist, place tension on the bar or chain.
29. If the vehicle is equipped with a manual transmission, remove the clutch linkage and bracket retaining bolts.
30. If the vehicle is equipped with an automatic transmission, remove the torque converter access panel and remove the capscrews that secure the torque converter to the flywheel.
31. Remove the retaining bolts that secure the engine mounts to the engine.
32. With the help of an assistant, remove the engine from the vehicle. Watch for obstructions that may interfere with its removal such as engine or chassis components, brackets, clamps or other parts still attached to the engine.
33. Refer to Engine Disassembly procedures for mounting the engine on an engine stand.

ENGINE DISASSEMBLY

General Instructions

This section includes step-by-step procedures for the complete disassembly of the MACK E-Tech™ engine upon removal from the vehicle. Major components are removed as assemblies and overhauled in the respective bench procedures sections.

CAUTION

Failure to follow the sequence of operations listed in this section may result in damage to the components or personal injury.

Filter Element Removal

[219 EV]

The fuel and oil filter elements, as well as the Centri-Max® or Centri-Max® PLUS assembly, must be removed before mounting the adapter plate to the engine. If not already removed, remove the filters following the procedure below.

Refer to Figure 77.

1. Place a suitable container below the filter element area to catch any spilled fluids.
2. Using a suitable filter wrench, remove the fuel and oil filter elements. Do not reuse filter elements. Discard used elements in a responsible, environmentally safe manner.
3. If equipped with the current top-mounted Centri-Max® PLUS oil filter (Figure 77):
   a. Loosen and remove the retaining bolt (1) at the top of the filter cover (2).
   b. Remove the cover, element and rotor (3). Discard the seal (4).

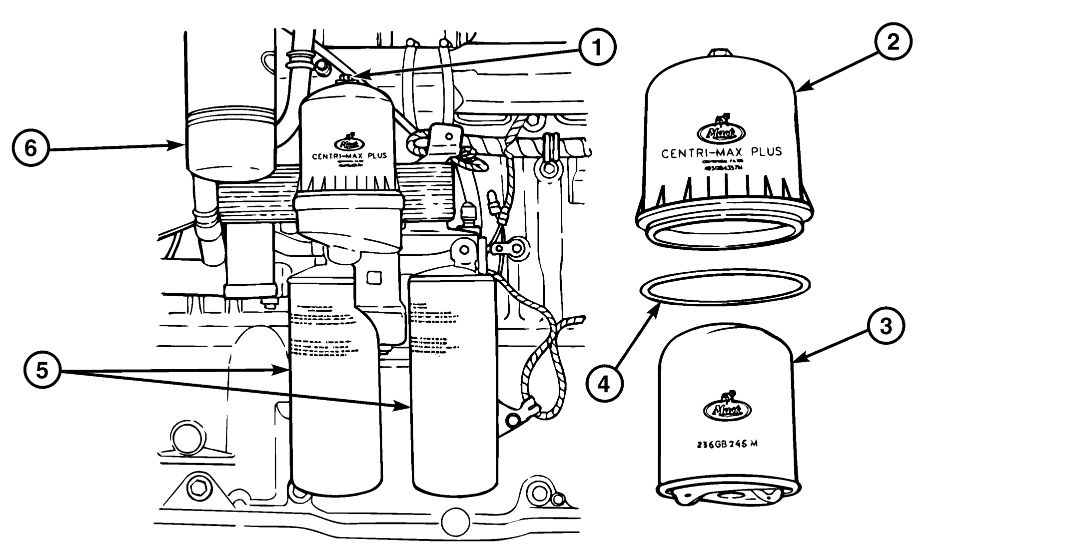


Figure 77 — Centri-Max® PLUS Housing

1. Filter Mounting Bolt	4. Seal
2. Centri-Max® PLUS Filter Cover	5. Spin-On Full-Flow Oil Filters
3. Element and Rotor	6. Fuel Filter

4. If equipped with the earlier Centri-Max® design oil filter (Figure 78):
   a. Loosen drain hose assembly (4) from the Centri-Max® filter housing assembly by loosening hose clamp (3) at the Centri-Max® housing.
   b. Remove two nuts (6) and two washers (5) from studs (1) securing hose adapter (7) at the cylinder block. Discard O-ring (8).
   c. Remove drain hose assembly (4).
   d. Using tool J 24783, remove the centrifugal oil filter housing (9).

CAUTION

Apply the filter wrench to area labeled “WRENCH HERE” on the Centri-Max® filter housing. Application outside of the labeled area will result in damage to the Centri-Max® housing.

   e. Remove and discard the filter seal (2) and the centrifugal cartridge (10). Clean the filter housing.

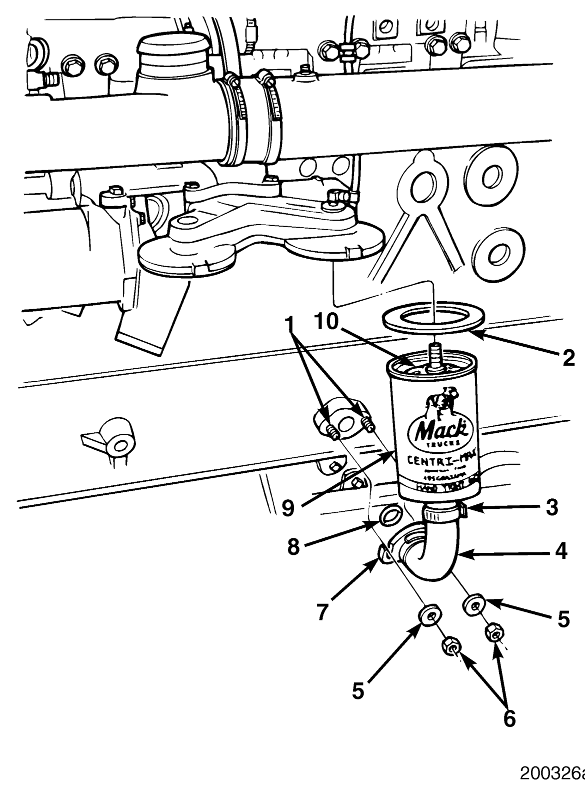


Figure 78 — Centri-Max® Housing

1. Studs	6. Nuts
2. Seal Ring	7. Adapter
3. Clamp	8. O-Ring
4. Drain Hose Assembly	9. Centri-Max® Housing
5. Washers	10. Centri-Max® Element

Oil Cooler and Oil Filter Mounting Bracket Assembly Removal

[215 DW, 219 EP]

If the engine is equipped with the plate-type oil cooler, the cooler and oil filter mounting bracket must be removed before mounting the engine in the stand. The configuration of the housing assembly protrudes into the area required for the engine mounting adapter plate. The removable bundle-type oil cooler and oil filter mounting bracket does not protrude into the mounting area and can remain on until after the engine is mounted in the stand if desired.

PLATE-TYPE OIL COOLER AND OIL FILTER MOUNTING BRACKET WITH INVERTED TOP-MOUNTED CENTRI-MAX® PLUS

(Current Production)

Refer to Figure 79 and remove the assembly as follows:

1. Disconnect the harness from the oil pressure and oil temperature sensors (6 and 5) on the filter mounting bracket (9).
2. Disconnect the turbocharger lubrication supply line (2) from the mounting bracket.
3. Loosen the hose clamps at the cooler-to-water pipe connection, and slide the hose away from the cooler and further onto the tube.
4. While supporting the oil cooler and oil filter mounting bracket assembly with one hand, remove the four capscrews (7) attaching the oil cooler and oil filter mounting bracket to the cylinder block (8).
5. Lift the oil cooler and oil filter mounting bracket assembly off the block surface and place on a clean work surface.

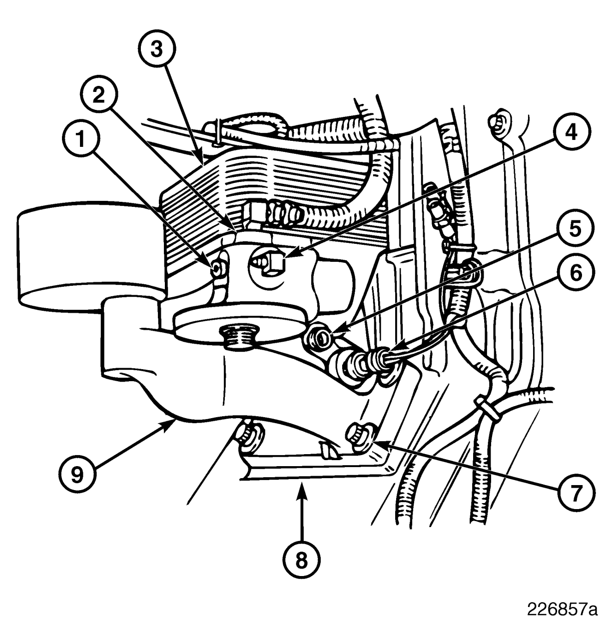


Figure 79 — Plate-Type Oil Cooler and Oil Filter Mounting Bracket Removal

1. Oil Supply Port (for Mechanical Dashboard Gauge) 2. Turbocharger Lubrication Supply Line 3. Oil Cooler 4. Oil Supply Port (for REPTO), Turbo Unloader and Remote-Mounted Oil Filter	5. Oil Temperature Sensor Port 6. Oil Pressure Sensor 7. Mounting Bracket Capscrews (Four) 8. Cylinder Block 9. Oil Filter Mounting Bracket

5_106_00.bk Page 102 Friday, August 4, 2000 11:17 AM

REMOVABLE BUNDLE-TYPE OIL COOLER AND OIL FILTER MOUNTING BRACKET WITH EXTERNALLY DRAINED CENTRI-MAX®

(Early Production)

Refer to Figure 80.

1. Disconnect the turbocharger lubrication supply line (6) from the oil filter/cooler assembly (5) and turbocharger, and remove hose.
2. Disconnect feed line (2) from the centrifugal filter housing fitting. Tag and cap line and fitting.
3. Remove four capscrews (3) securing oil filter feed assembly (4) to engine block.

NOTE

Unless it is necessary to repair any portion of the oil cooler or oil filter mounting bracket, remove the units as an assembly. The assembly can be disassembled later, if necessary. Refer to “Oil Cooler Disassembly” under Lubrication System Components Bench Procedures in the REPAIR INSTRUCTIONS section.

Later-production filter adapters are redesigned to use a poppet-type pressure relief valve in place of the plunger-type valve.

NOTE

The S300 and S400 model turbochargers use a stainless steel braided line connected directly to the threaded oil inlet port at the turbocharger.

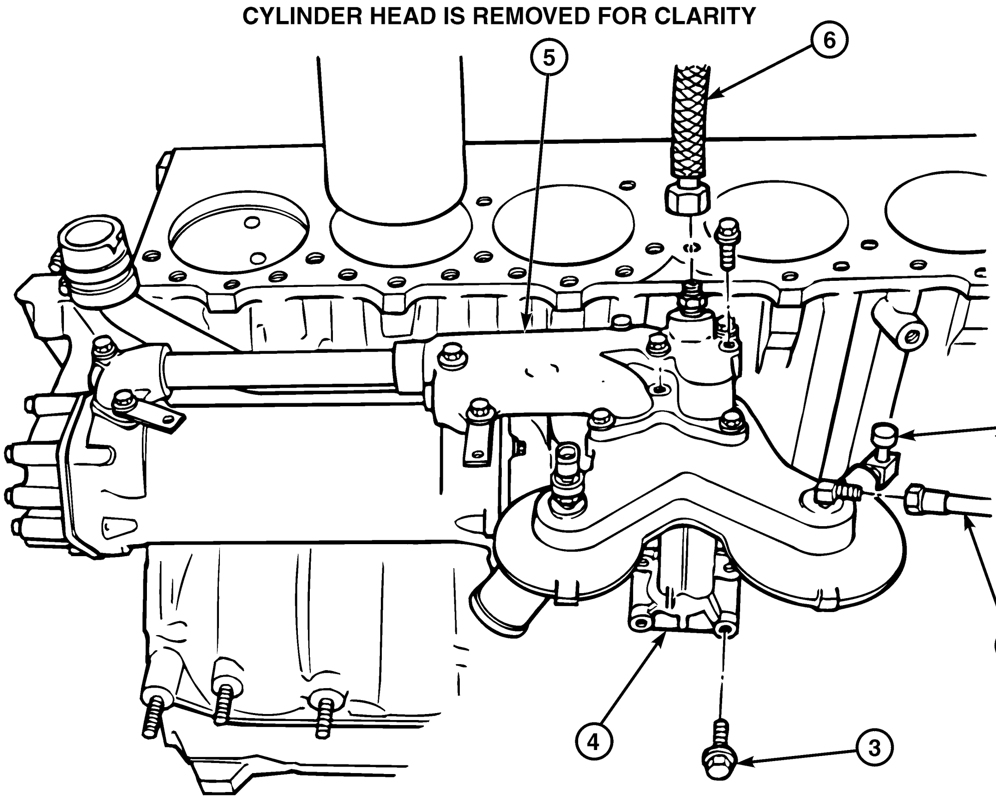


Figure 80 — Removable Bundle Oil Cooler and Oil Filter Mounting Bracket Removal

1. Vent Fitting 2. Feed Line 3. Capscrew	4. Oil Filter Feed Assembly 5. Oil Filter/Cooler Assembly 6. Turbocharger Lubrication Supply Line

Mounting Engine in Stand

WARNING

The engine weighs approximately 2,300 lbs. (1043 kg) wet. Stay out from under the engine when it is being lifted. Failure of the lifting device could result in serious injury or death. Make sure to use lifting equipment that is rated at a capacity greater than the weight of the engine.

CAUTION

Engine stand, Kent-Moore tool number J 29109, and adapter plate J 38048, are recommended to safely support the engine during disassembly and assembly procedures.

Avoid using an engine stand that supports the engine on the oil pan rail while the oil pan is still installed. Damage to the oil pan, pan gasket or the isolators may result. If this type of stand must be used and the oil pan is to remain installed, support the engine on the pads provided at each corner of the cylinder block as shown in Figure 81.

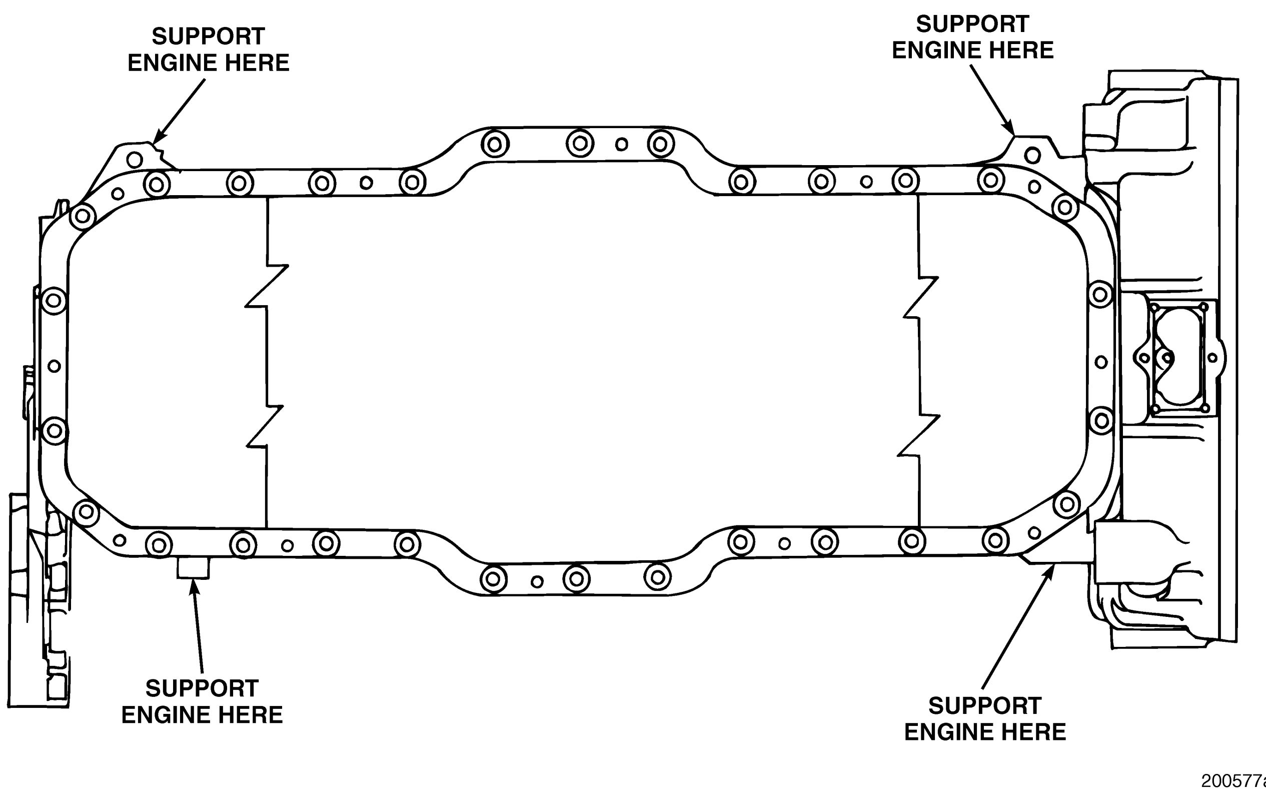


Figure 81 — Engine Support Pads

SPECIAL TOOLS REQUIRED

- Engine Stand J 29109
- Adapter Plate J 38048

PROCEDURE

Refer to Figure 82.

1. Using three mounting capscrews (2), secure adapter plate J 38048 (1) to the left side of the engine.
2. Secure adapter plate (1) to engine stand J 29109 (3) with six mounting capscrews (4).
3. Remove lifting device from the engine.

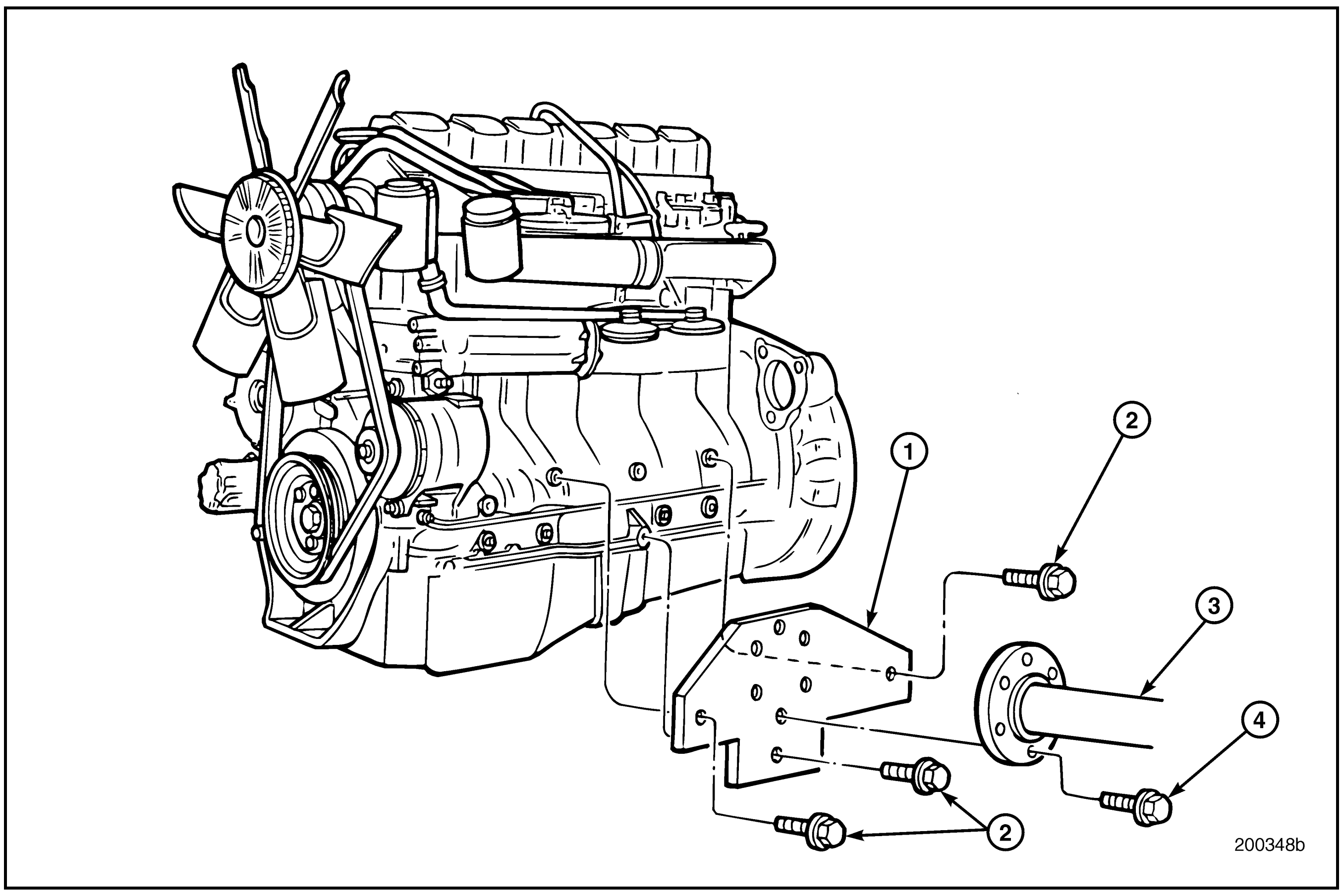


Figure 82 — Engine Mounting in Stand

1. Adapter Plate J 38048 2. Capscrews	3. Engine Stand J 29109 4. Capscrew

Alternator Removal

[271 CB]

Refer to Figure 83.

1. Loosen adjusting capscrew (1) and mounting capscrews (2).
2. Remove the poly-v drive belt.
3. Disconnect and tag electrical wires.
4. Remove mounting nuts, washers and capscrews (2), and remove alternator (3).
5. Remove mounting hardware and remove alternator plate.

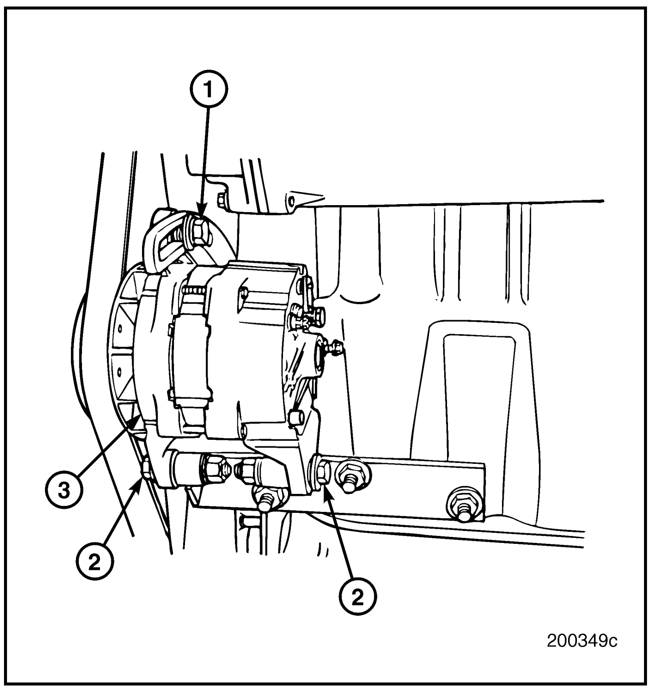


Figure 83 — Alternator Removal

1. Adjusting Capscrew 2. Mounting Capscrews	3. Alternator

Engine Electronic Control Unit (EECU) Removal

[230 EA]

Left-Side Mounted Assembly

NOTE

The following procedure applies for an EECU mounted on the left side of the engine. The procedure for a right-side mounted unit with cooling plate is covered later in this section.

1. Thoroughly clean the area around the ECU harness connector to make sure the terminals remain clean for reassembly.
2. Disconnect the wiring harness to the EECU (Figure 84).

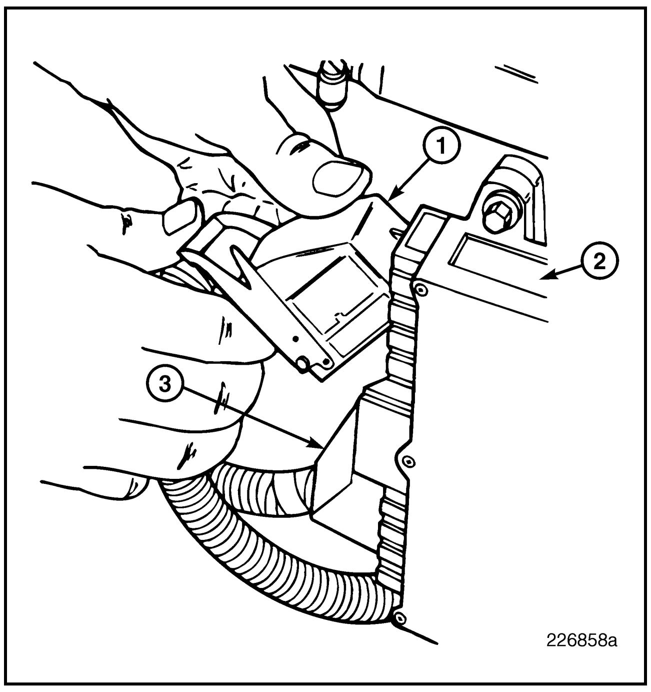


Figure 84 — EECU Connector Removal

1. Upper Connector 2. EECU	3. Lower Connector

5_106_00.bk Page 106 Friday, August 4, 2000 11:17 AM

3. Remove the two top retaining nuts and isolating washers that secure the EECU to the EECU mounting bracket (Figure 85). Then, remove the two bottom retaining nuts and isolating washers that secure the EECU to the of the air inlet manifold.
4. Carefully remove the EECU from the inlet manifold. The bracket can remain attached to the inlet manifold providing the manifold is not being replaced.

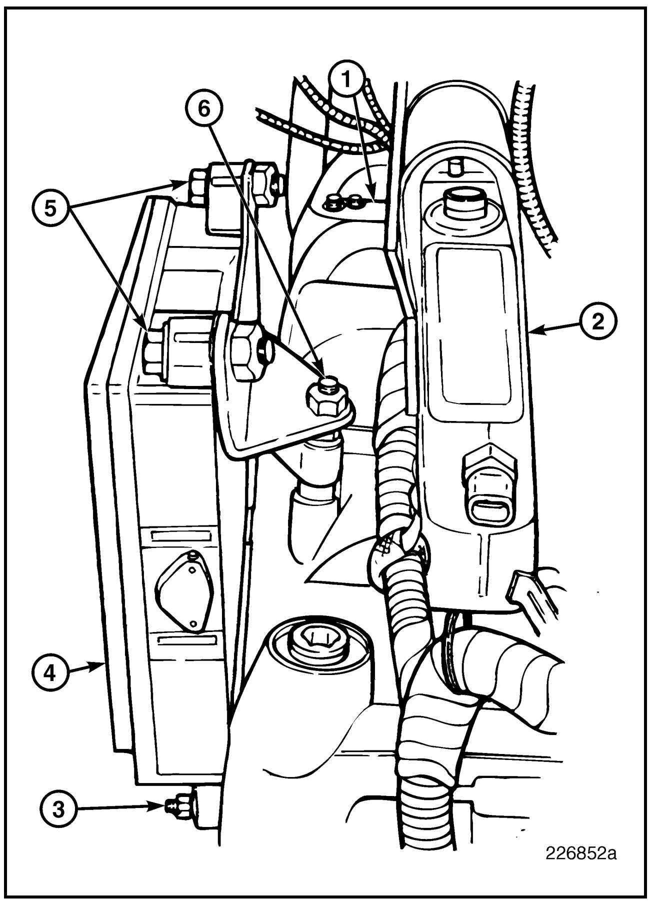


Figure 85 — EECU Removal (Left-Side Mounted Unit)

1. Air Inlet Manifold 2. Coolant Manifold 3. Lower Mounting Bolts (Two)	4. EECU 5. Upper Mounting Bolts (Two) 6. Mounting Stud

Fuel Filter Adapter Assembly Removal

[231 PB]

Refer to Figure 86 and Figure 87.

1. Disconnect wiring harness connector at the fuel temperature sensor on top of the fuel filter adapter assembly, if so equipped (1).
2. Disconnect fuel lines from fittings (2, 3 and 5) on the adapter. Tag and cap all lines.
3. Remove three capscrews (4) from the top of the fuel filter adapter assembly.
4. Remove fuel filter adapter assembly from the air inlet manifold (7).
5. Remove fuel supply hose stand-off bracket from head bolt/water pump support bracket and remove supply hose.

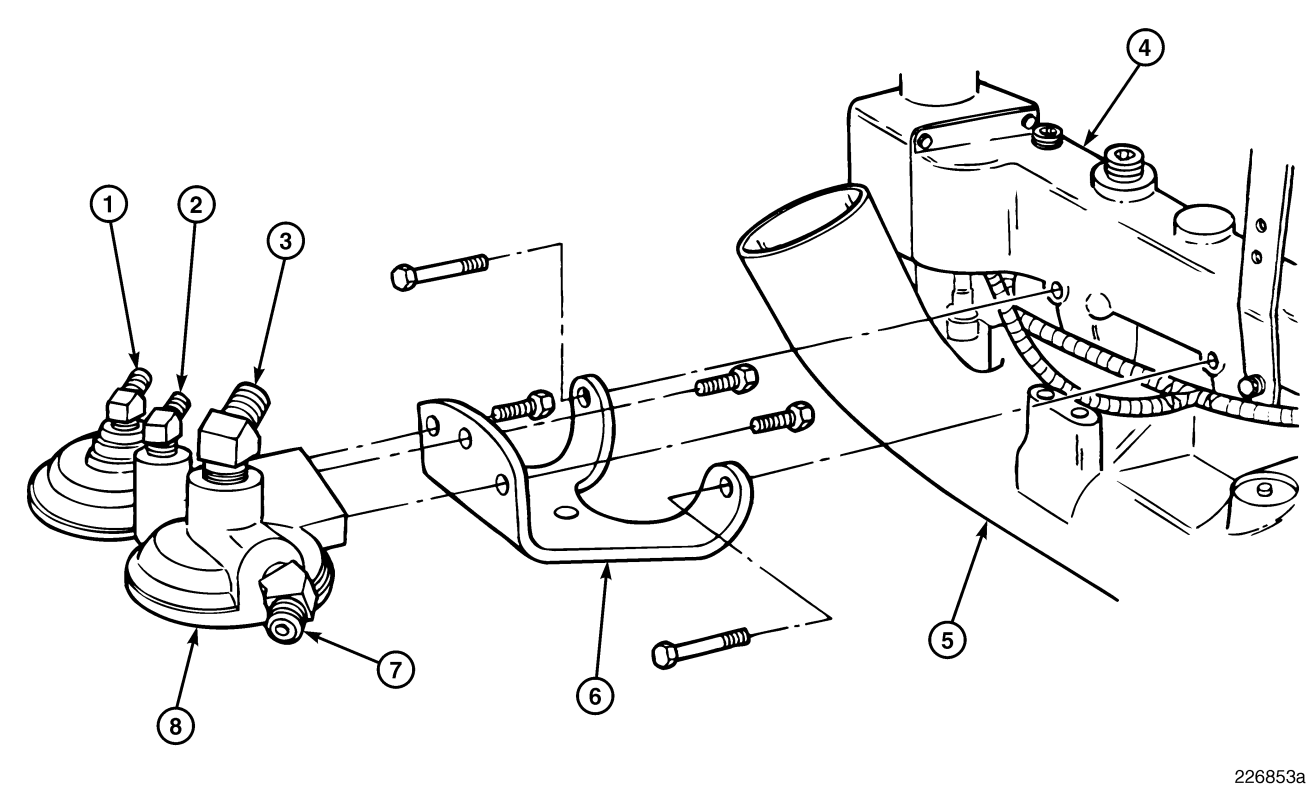


Figure 86 — Fuel Filter Adapter Assembly Removal (Current Production)

1. Secondary Filter Fitting (Out)	5. Air Inlet Manifold
2. Secondary Filter Fitting (In)	6. Mounting Bracket
3. Primary Filter Fitting (Out)	7. Primary Filter Fitting (In)
4. Coolant Manifold	8. Fuel Filter Adapter

5_106_00.bk Page 108 Friday, August 4, 2000 11:17 AM

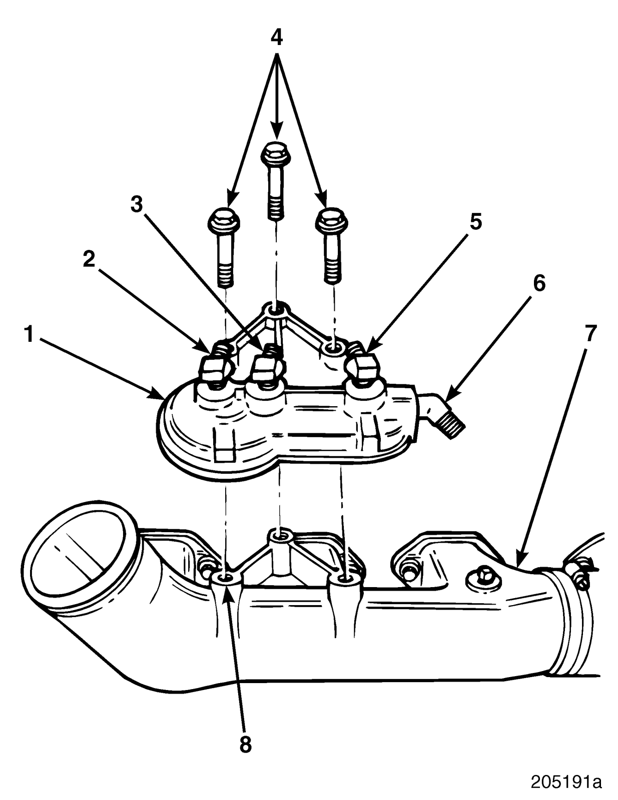


Figure 87 — Fuel Filter Adapter Assembly (Early Production)

1. Fuel Filter Adapter Assembly 2. Secondary Filter Fitting (Out) 3. Secondary Filter Fitting (In)	4. Capscrews 5. Primary Filter Fitting (Out) 6. Primary Filter Fitting (In) 7. Air Inlet Manifold 8. Mounting Flange

Coolant Conditioner Element Removal

[215 LD]

NOTE

The following procedure applies for engines equipped with a coolant conditioner. The coolant conditioner is available as an option on current-production engines.

Refer to Figure 88 and Figure 90.

1. Disconnect wiring harness leads at the coolant temperature sensor on the coolant manifold and the boost air temperature sensor on the air inlet manifold. Position leads out of way.
2. Disconnect fittings (3) from both ends of the coolant conditioner supply tube. Remove tube (2).

NOTE

Remove only the supply tube. Do not remove the brass elbow fittings at the manifold and the cylinder block.

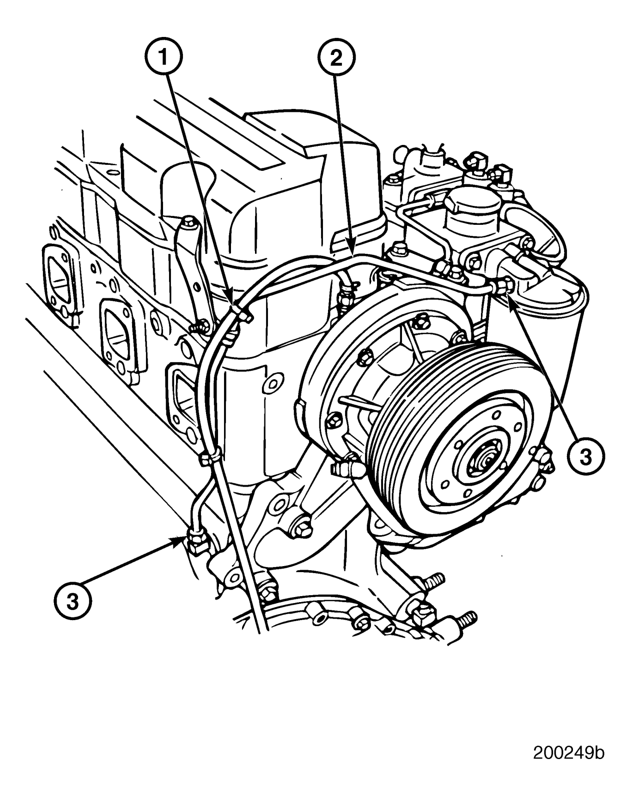


Figure 88 — Coolant Conditioner Supply Tube Removal

1. Plastic Tie Wrap 2. Coolant Conditioner Supply Tube	3. Fittings

5_106_00.bk Page 109 Friday, August 4, 2000 11:17 AM

3. Place a suitable container below the coolant filter area to catch any spilled coolant.
4. Using a suitable filter wrench (J 29927, or equivalent), remove the coolant conditioner filter element (14). Discard element.
5. Remove coolant conditioner head assembly (2) from thermostat housing (5) by removing mounting capscrews (1).
6. Remove and discard O-ring (4).
7. Carefully remove and examine the check valve assembly (3). Examine check valve assembly by depressing the check ball. If it resists movement and does not return to its seat freely, the check valve assembly must be replaced.

Oil Cooler-to-Water Pump Inlet Line Removal

If the engine is equipped with the plate-type oil cooler, remove the oil cooler-to-water pump inlet line (Figure 89) as follows:

1. Remove the two clamps and flexible coupling between the inlet line and the coolant manifold.
2. Support the line and remove the two capscrews securing the inlet line to the water pump and remove the line.

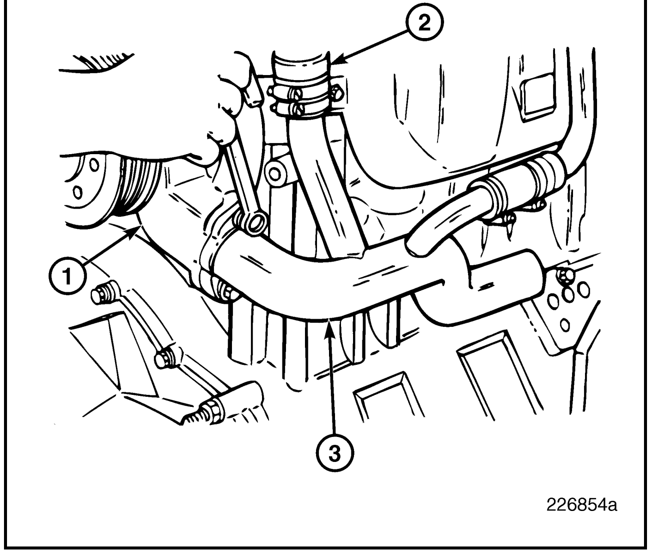


Figure 89 — Oil Cooler-to-Water Pump Inlet Line Removal

1. Water Pump 2. Coupling	3. Inlet Pipe

Thermostat Removal

[215 NU]

Refer to Figure 90.

1. With the coolant conditioner element (if equipped) removed, remove two capscrews (13) that secure the thermostat housing (5) to coolant manifold (9).
2. Loosen two hose clamps (10) on the coupling (12) that connect the oil cooler supply tube (11) to the thermostat housing.
3. Taking care to prevent the thermostat (7) from falling, remove the thermostat housing (5) and thermostat. Discard gasket (8).

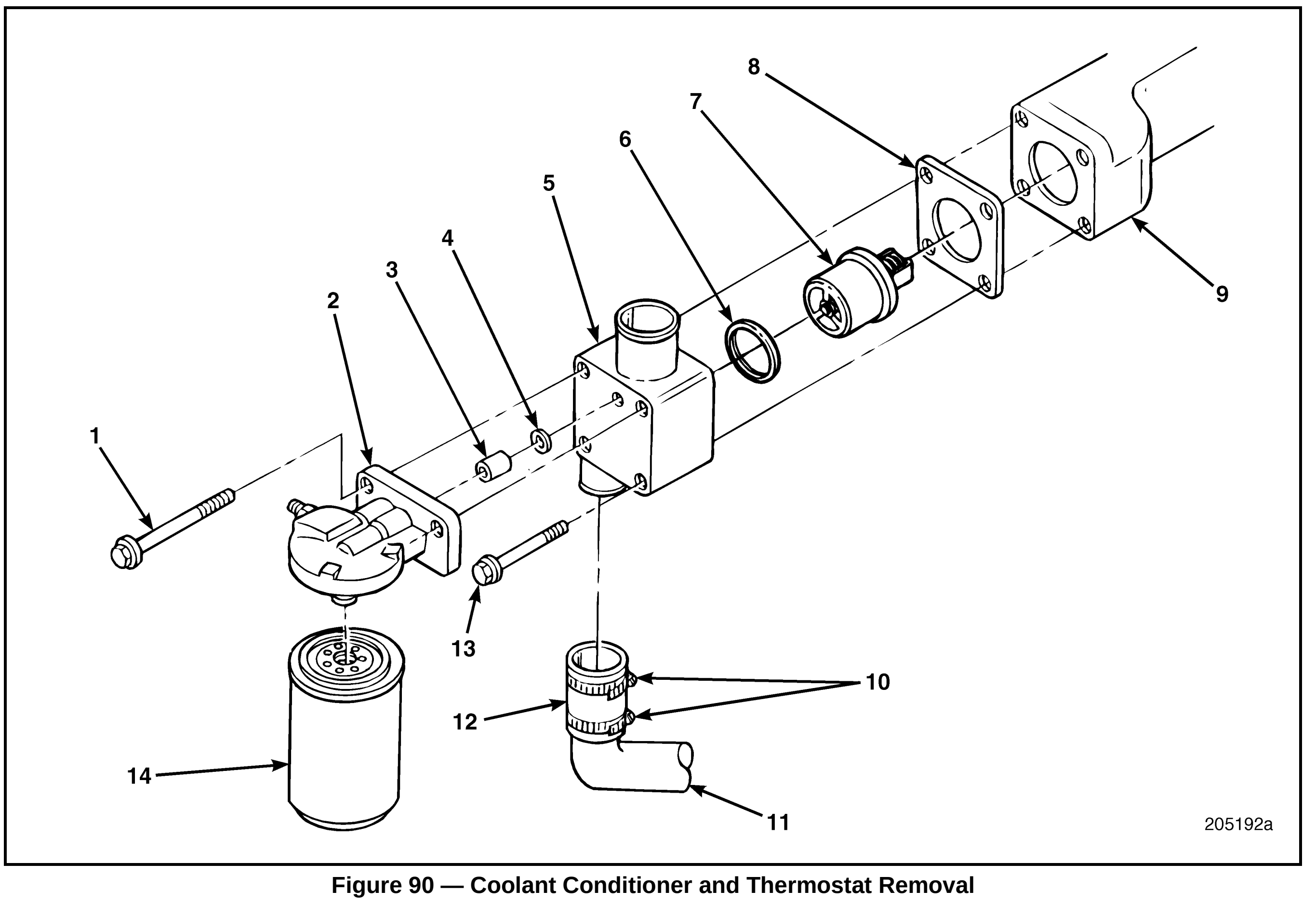


Figure 90 — Coolant Conditioner and Thermostat Removal

1. Capscrew 2. Coolant Conditioner Head Assembly (If Equipped) 3. Check Valve Assembly (Only with Coolant Conditioner) 4. O-Ring (Only with Coolant Conditioner) 5. Thermostat Housing 6. Thermostat Seal 7. Thermostat	8. Gasket 9. Coolant Manifold 10. Clamps 11. Oil Cooler Supply (Bypass) Tube 12. Coupling Hose 13. Capscrew 14. Coolant Conditioner Filter Element (If Equipped)

Coolant Manifold Removal

[215 NK]

Refer to Figure 91.

1. Disconnect wires to dash gauge and V-MAC III coolant temperature sensors, and boost air temperature sensor. Position wires out of way.
2. Disconnect and remove line between coolant manifold and water pump.
3. Support the coolant manifold sections and remove 12 capscrews (5) retaining the manifold sections (1 and 4) to the cylinder heads.

NOTE

The hex-head capscrews and washers used to attach the manifold on early-production engines are replaced by flangehead capscrews in later production.

4. Remove manifold assembly. It may be necessary to pry or tap lightly with a soft mallet on the housing sections to break the seal.
5. If necessary, separate the two coolant manifold sections (1 and 4) by loosening two clamps (3) and removing the coupling (2).
6. If the coolant manifold is to be replaced, remove sensor located on the manifold (4).

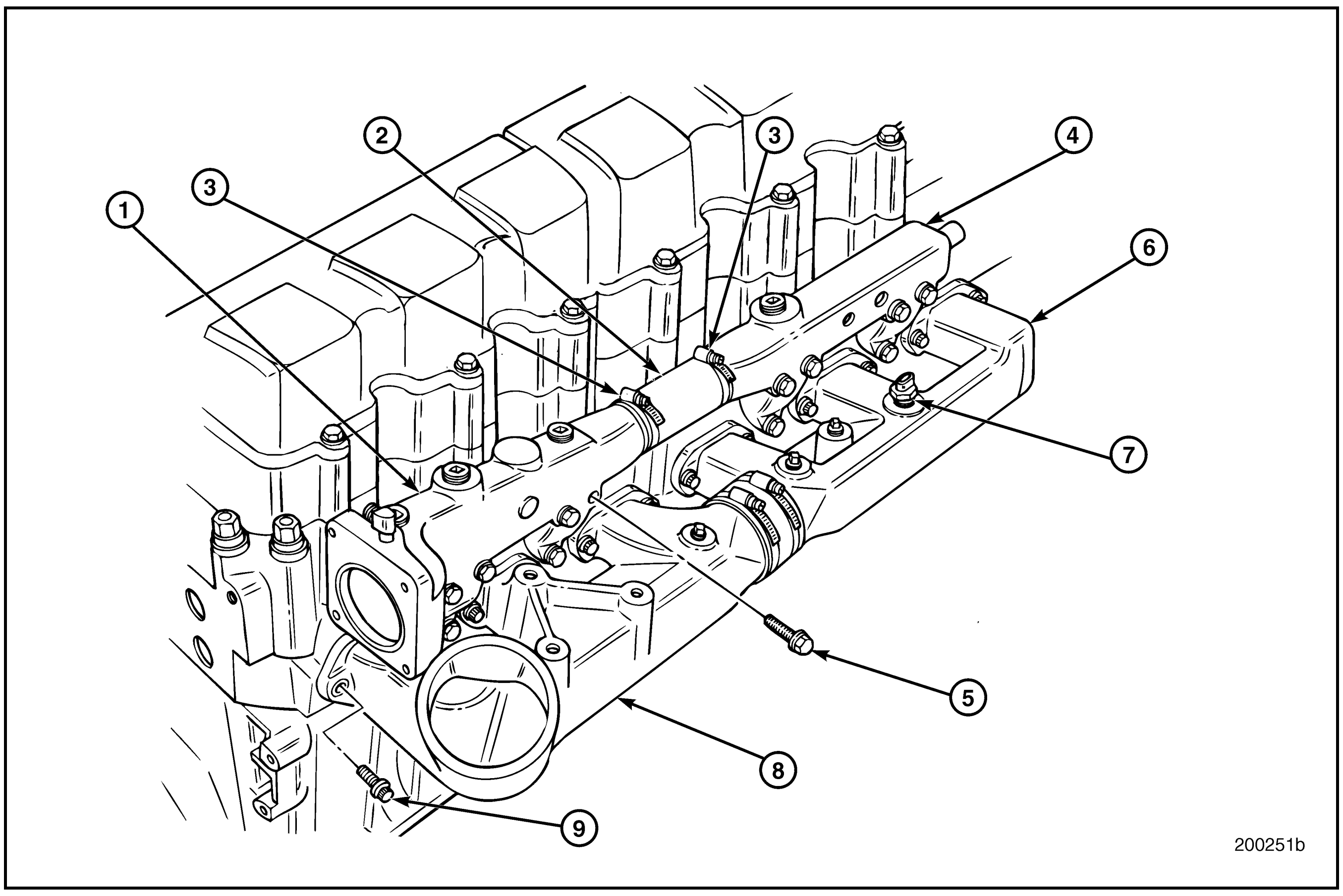


Figure 91 — Air Inlet/Coolant Manifold Removal (Shown with Two-Piece Air Inlet Manifold, Typical)

1. Coolant Manifold, Front Section 2. Coupling Hose 3. Clamp 4. Coolant Manifold, Rear Section 5. Capscrew	6. Air Inlet Manifold, Rear Section 7. Sensor 8. Air Inlet Manifold, Front Section 9. Capscrew, 12-Point

Air Inlet Manifold Removal

[214 HD]

The following procedure applies for both the early-production engines (right-side mounted EECU) equipped with a two-piece air inlet manifold and current-production engines (left-side mounted EECU) equipped with a one-piece manifold.

Refer to Figure 91 and Figure 92.

1. Support the air inlet manifold and remove 12 capscrews (9) that secure the manifold (6 and 8) to the cylinder heads.
2. Remove air inlet manifold. It may be necessary to gently pry or tap the manifold lightly with a soft mallet to break the seal.
3. If the air inlet manifold is to be replaced, remove sensor (7) located on the inlet manifold (6), if installed.

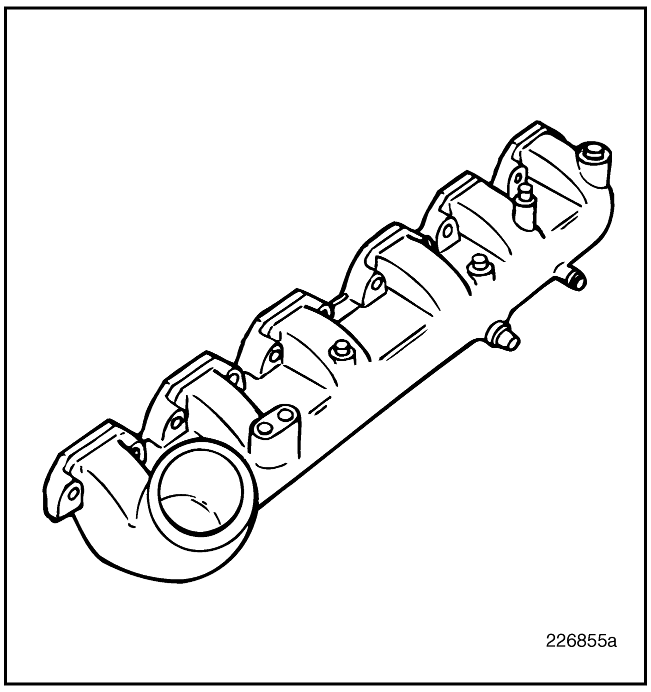


Figure 92 — One-Piece Air Inlet Manifold

Water Pump Removal

[215 SW]

Refer to Figure 93.

1. Disconnect coolant return hose to air compressor (1) at fitting on water pump.
2. Remove three mounting capscrews (3) and remove water pump (2).

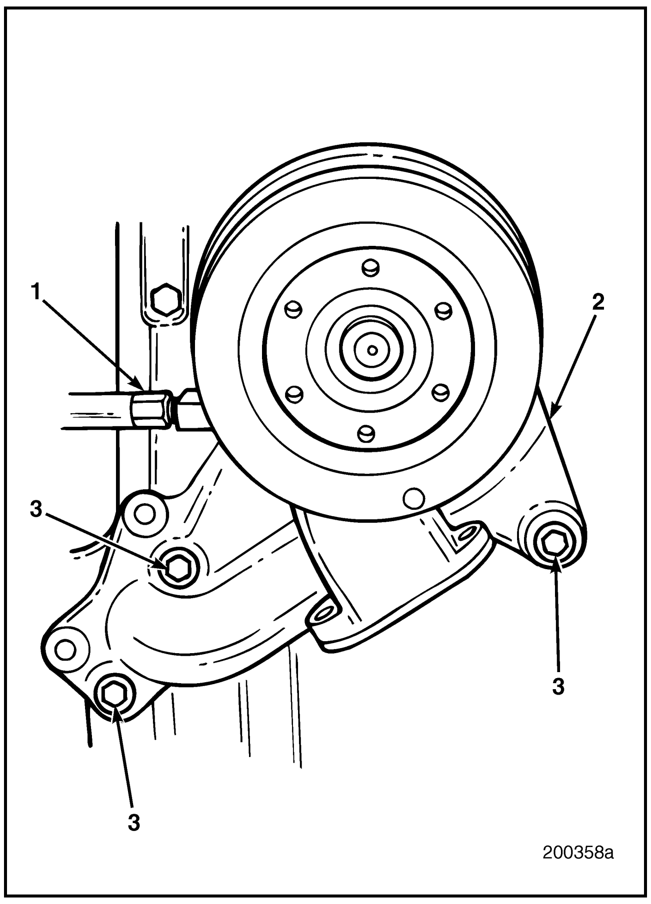


Figure 93 — Water Pump Removal

1. Air Compressor Coolant Return Line	2. Water Pump 3. Capscrew

5_106_00.bk Page 113 Friday, August 4, 2000 11:17 AM

Turbocharger Removal

[214 SD]

Refer to Figure 94.

1. Remove two capscrews (3) securing turbocharger lubrication drain tube (4) to turbocharger (1).
2. Remove drain tube (4) from cylinder block.
3. Loosen four turbocharger mounting nuts (5) and remove turbocharger (1).

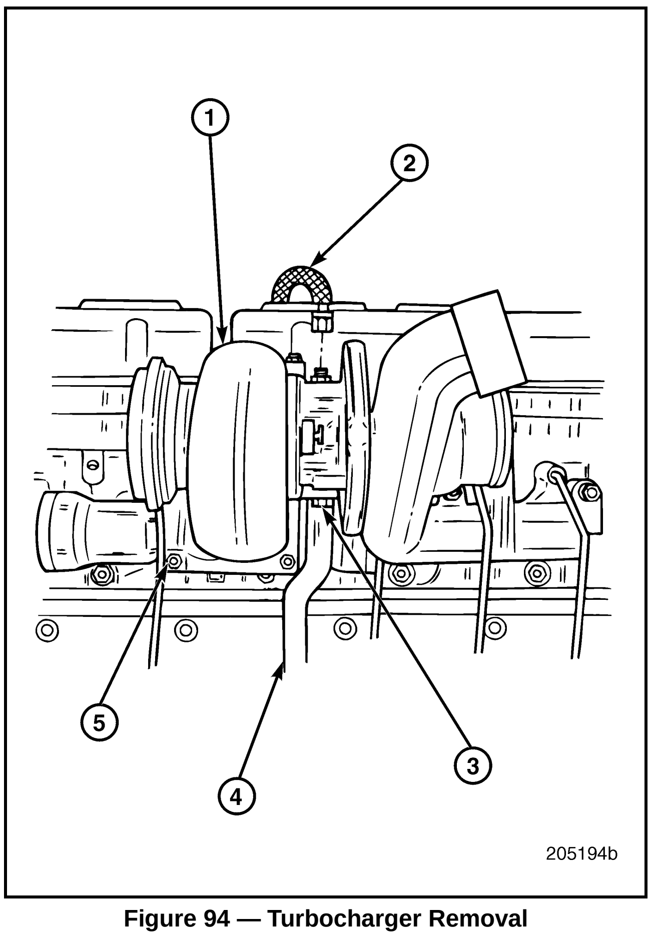


Figure 94 — Turbocharger Removal

1. Turbocharger 2. Lubrication Supply Line 3. Capscrew	4. Lubrication Drain Tube 5. Mounting Nut

Fuel Nozzle Inlet Tube Assembly Removal

[222 KD]

Refer to Figure 95.

1. Remove the four retaining nuts securing the three-section heat shield to the cylinder block and remove shield.
2. Loosen the tube sleeve nut (1) at the unit pump for the No. 1 cylinder. Be careful to avoid twisting the line while loosening the nut.
3. Loosen tube sleeve nut (2) and tube clamping screw at the cylinder head and remove the tube assembly. Cap the line and fittings to prevent contaminants from entering the system.

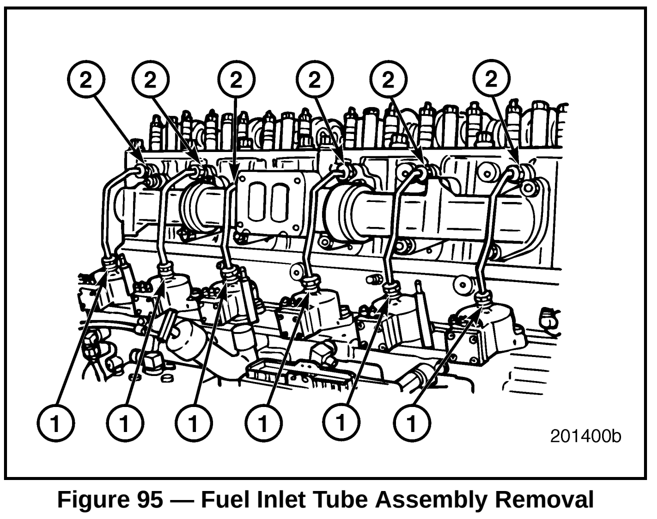


Figure 95 — Fuel Inlet Tube Assembly Removal

1. EUP Sleeve Nut	2. Fuel Inlet Tube Clamping Screw and Sleeve Nut

4. Repeat this procedure for the five remaining cylinders.

5_106_00.bk Page 114 Friday, August 4, 2000 11:17 AM

Exhaust Manifold Removal

[214 EG]

1. Support the exhaust manifold and remove 12 mounting nuts (Figure 96) securing the manifold to cylinder heads.
2. Remove the exhaust manifold.
3. Discard gaskets.

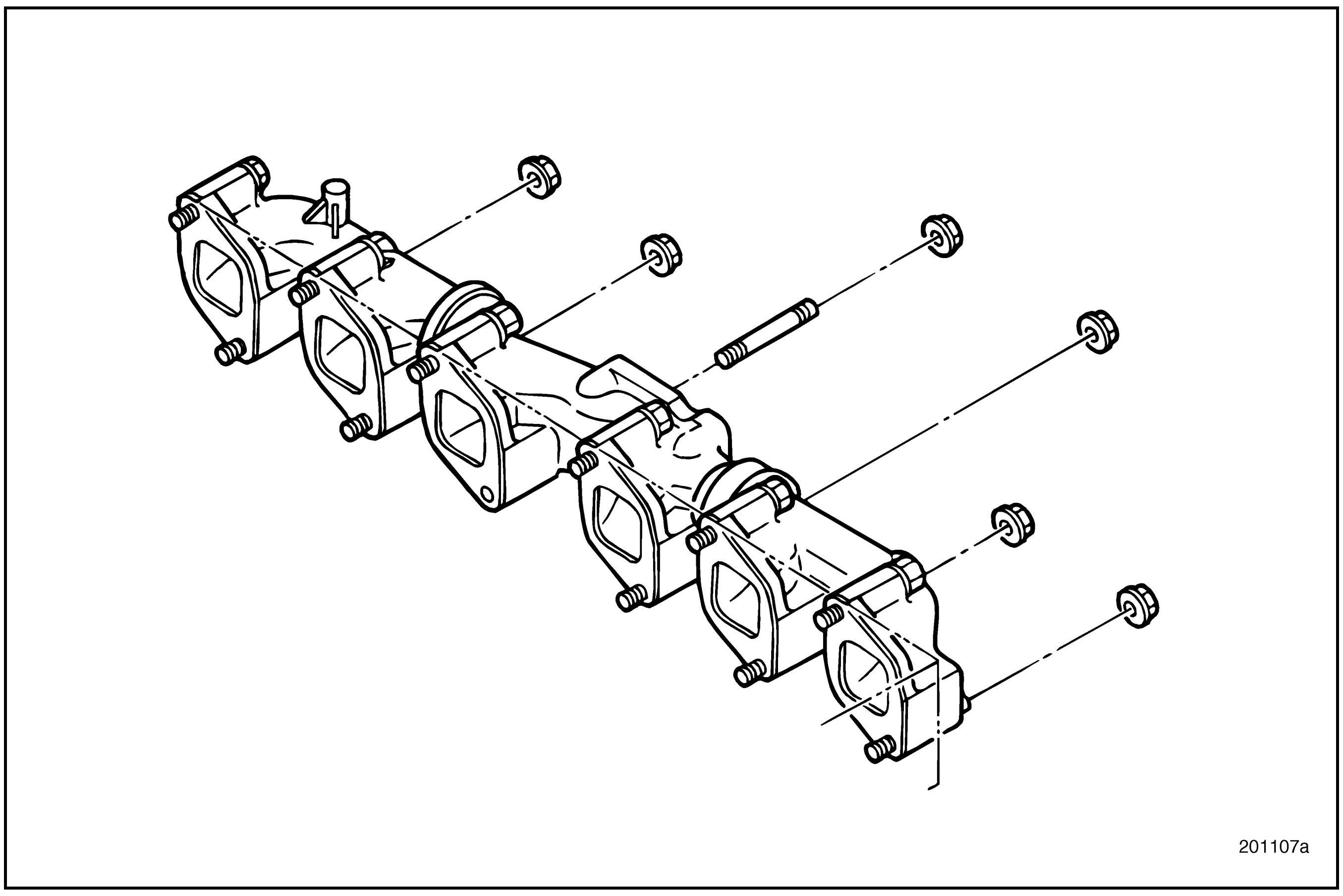


Figure 96 — Exhaust Manifold Removal

Engine Wiring Harness Removal

1. Disconnect the harness at each of the EUP terminals.
2. Disconnect the harness at the EECU.
3. Disconnect the harness at the engine speed and position sensors and any remaining sensor locations not previously disconnected.
4. Remove the harness attaching hardware and remove harness from the engine.

Engine Electronic Control Unit (EECU) and Cooling Plate Removal

[230 EA]

Right-Side Mounted Assembly

Refer to Figure 97.

1. Thoroughly clean the area around the EECU harness connector to make sure the terminals remain clean for reassembly.
2. Disconnect the wiring harness and coolant inlet and outlet lines to the EECU cooling plate if not already done.
3. Remove the five retaining nuts and isolating washers that secure the EECU and cooling plate to the cylinder block.
4. Carefully remove the EECU and cooling plate from the block.

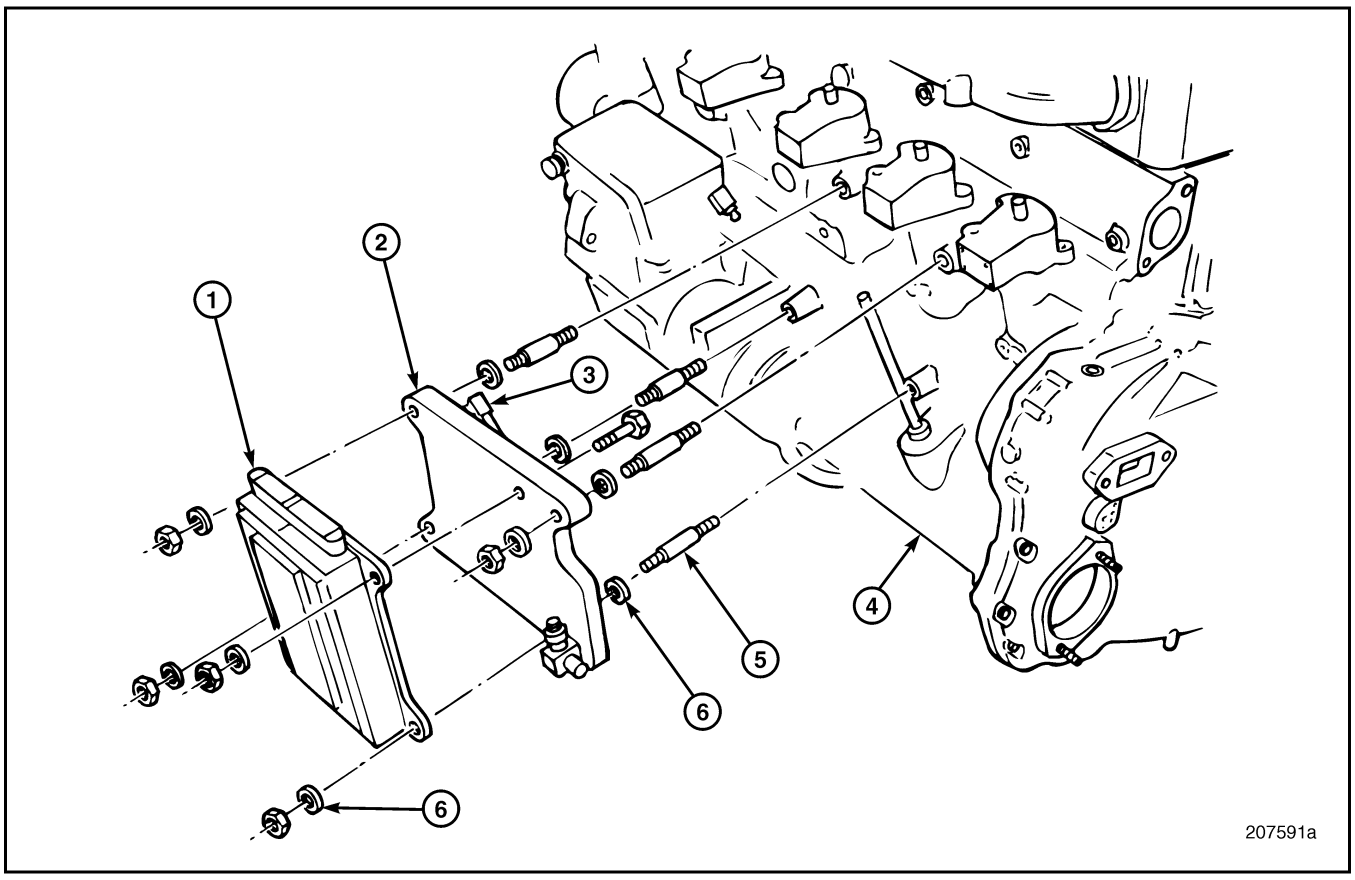


Figure 97 — EECU and Cooling Plate Removal

1. Engine Electronic Control Unit (EECU) 2. EECU Cooling Plate 3. Coolant Fitting	4. Cylinder Block 5. Mounting Stud 6. Isolating Washers

5_106_00.bk Page 116 Friday, August 4, 2000 11:17 AM

Electronic Unit Pump (EUP) Removal

[221 GP]

NOTE

EUPs must be paint marked with the cylinder number, and reinstalled at their original locations. This will eliminate any need to reprogram EUP information. If a **new** EUP is installed, reprogramming must be performed.

1. Place a drain pan beneath the right side of the engine. Remove the fuel-outlet fitting from the cylinder block fuel-return gallery above the air compressor. This allows fuel to drain from the internal passages.

WARNING

The EUP spring may be preloaded with significant spring tension, depending upon cam lobe position. To avoid injury from the EUP springing outward, steps 2 through 4 must be followed.

2. Remove the inboard EUP screw completely.
3. Loosen outboard EUP screw and back it out 1/2 inch.
4. Insert screwdrivers under the bolt bosses (front and rear) and pry until the EUP comes out against the screw head. (The EUP may spring out against the screw head.)

NOTE

The rapid upward movement of the EUP may result in the tappet spring retainer becoming dislodged from the plunger foot. If this occurs, simply reinstall the retainer. This situation does not indicate any problem with the parts and should not occur if the above procedures are followed.

5. Remove outboard EUP screw completely and remove EUP from the cylinder block. Refer to Figure 98. Place the EUP in a clean area and cover it to prevent entry of dirt and other contaminants.

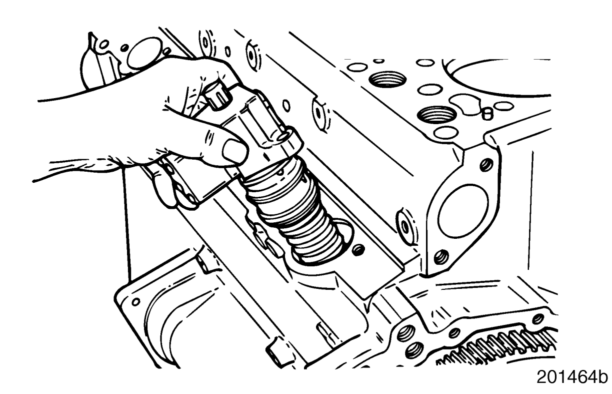


Figure 98 — EUP Removal

6. Remove roller tappet from the EUP bore by hand (Figure 99). Do not use a tool, as it could damage the bore. Place the roller tappet in a clean area and cover it to prevent the entry of dirt and other contaminants.

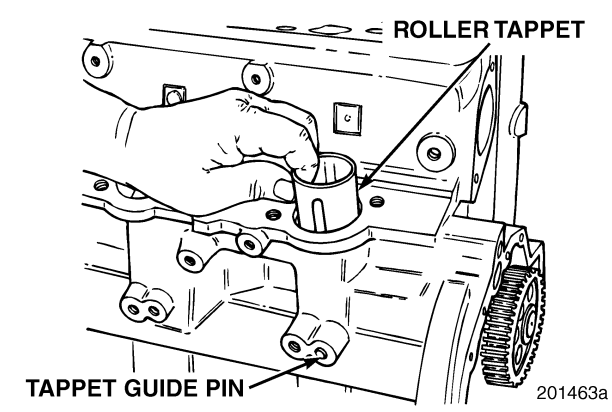


Figure 99 — Tappet Removal

Oil Fill Tube Removal

Remove capscrews securing oil filler feed tube to cylinder block. Remove tube.

5_106_00.bk Page 117 Friday, August 4, 2000 11:17 AM

Air Compressor Removal

[261 CK]

Refer to Figure 100.

Disconnect two coolant lines (1 and 3) from the air compressor head (2) at the fittings. Tag and cap lines.

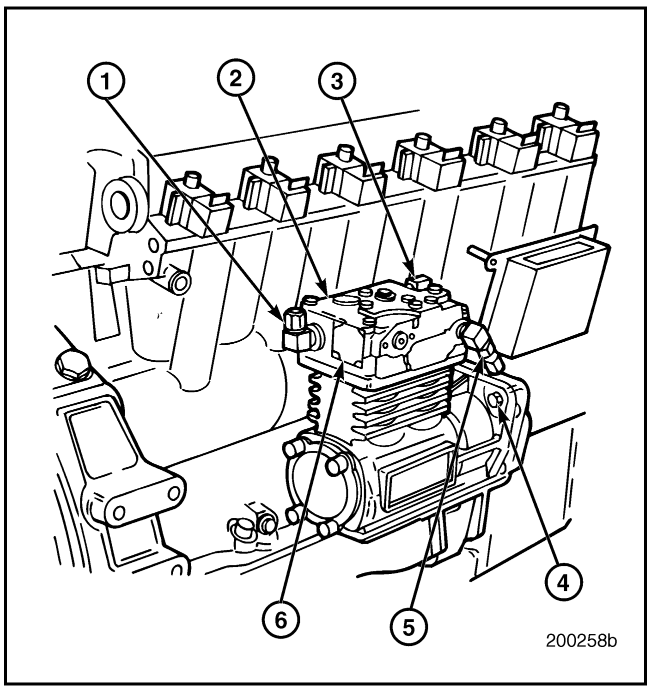


Figure 100 — Air Compressor Connections

1. Coolant Supply Line 2. Air Compressor Head 3. Coolant Return Line 4. Capscrew	5. Drain Fitting 6. Air Governor Mounting Flange

WARNING

The air compressor is heavy. Lifting the air compressor may require the help of an assistant or suitable lifting device. Attempting to lift the compressor without such assistance may result in severe personal injury.

Refer to Figure 101.

1. Remove three mounting capscrews (5) securing air compressor (1) to auxiliary shaft housing.
2. Taking care not to damage or lose the lubrication oil supply tube (2), remove the air compressor by pulling it rearward out of the mounting flange. Discard gasket.

NOTE

If the oil supply tube is lost and not reinstalled, the air compressor will fail from lack of lubrication.

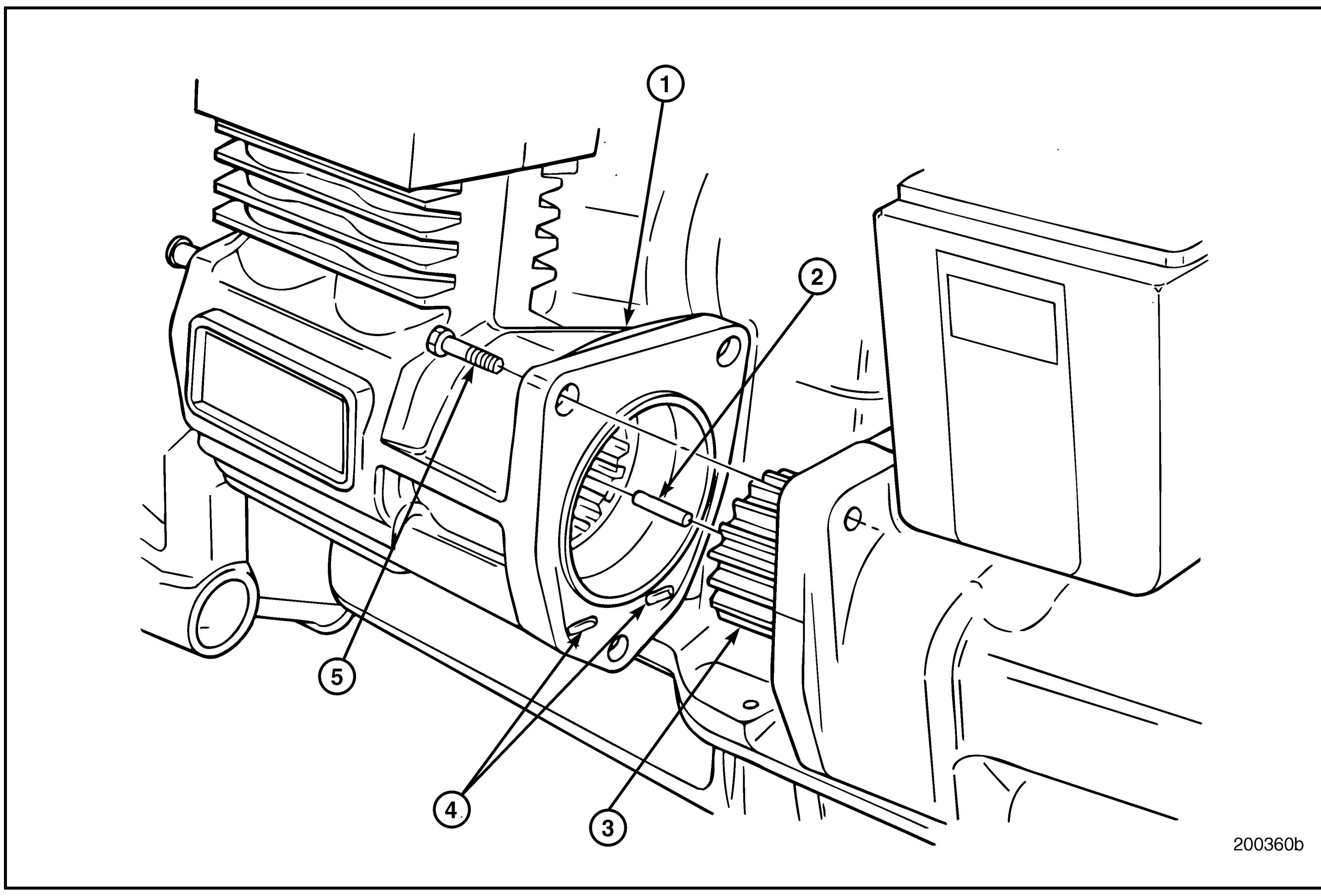


Figure 101 — Air Compressor Removal

1. Air Compressor 2. Oil Supply Tube 3. Auxiliary Shaft	4. Oil Drain Openings 5. Capscrew

Valve Cover and Spacer Removal

[213 JB]

NOTE

If engine is equipped with an engine brake, a spacer is installed under the valve cover. Longer capscrews are used to secure the valve cover and spacer to the cylinder head.

Refer to Figure 102 for disassembled view.

1. Remove valve covers (1) by removing six retaining capscrews (2) from each cover.
2. Discard seals.
3. If an engine brake is installed, perform the following:
   a. Remove control wire (3) from left side of each riser housing (4).
   b. Disconnect wires at the actuator solenoid connector.
   c. Remove spacers. Discard seals.

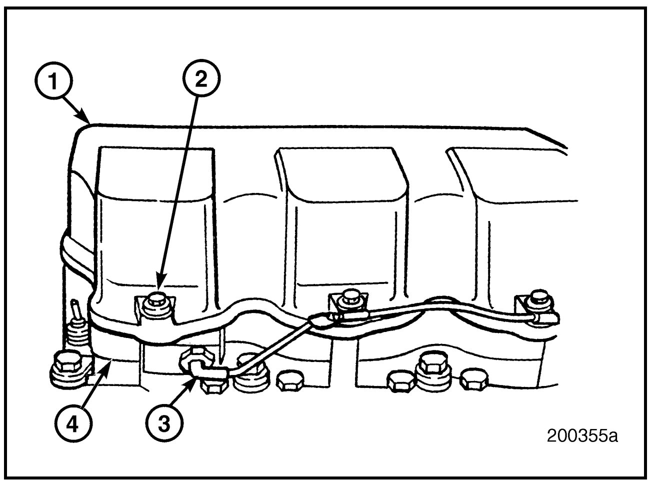


Figure 102 — Control Wire Removal

1. Valve Cover 2. Capscrew	3. Control Wire 4. Spacer Housing

Rocker Arm, Valve Yoke and Push Rod Removal

[213 LP, NV & LH]

Refer to Figure 104.

1. If equipped with an engine brake, remove the six capscrews (3) and washers retaining the brake actuator assembly (13) and rocker arm assembly (10) to each cylinder head.
2. Remove the brake actuator and rocker arm assemblies from each cylinder head (one actuator and rocker arm assembly per head).

NOTE

If an engine brake was not installed, there will be six shorter capscrews retaining the rocker arm assembly to the cylinder head.

3. Remove valve yokes from each pair of valves by lifting straight up on each yoke. Tag yokes for reassembly.
4. Remove valve push rods and tag rods for reassembly.

CAUTION

The valve roller follower has an insert in the top end to provide a hardened wear surface for contact with the push rod (Figure 103). The insert is staked in place during manufacture of the lifter (later production is press fit). However, with very early version roller lifters, insert movement can take place during engine operation, resulting in the insert no longer being retained by the staking.

As each push rod is removed, immediately inspect the lower end to see if a lifter insert is stuck to the push rod ball end. If an insert is present, carefully place the push rod back into its installed position, and by feel, attempt to engage the insert into its bore in the lifter top. Once fully engaged, remove push rod with a twisting/side-load motion, so the insert will remain in place in the lifter bore.

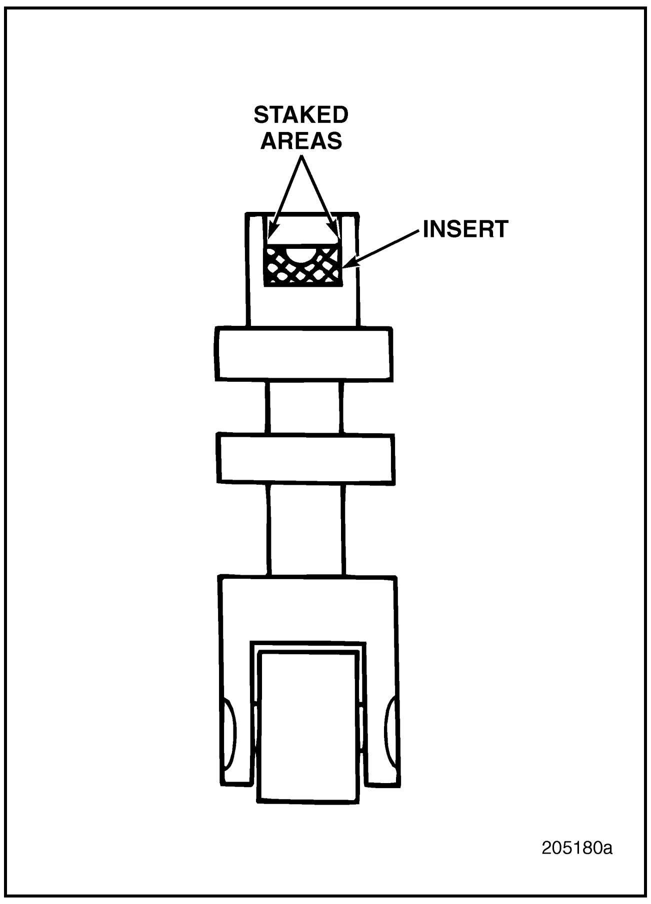


Figure 103 — Valve Lifter Insert

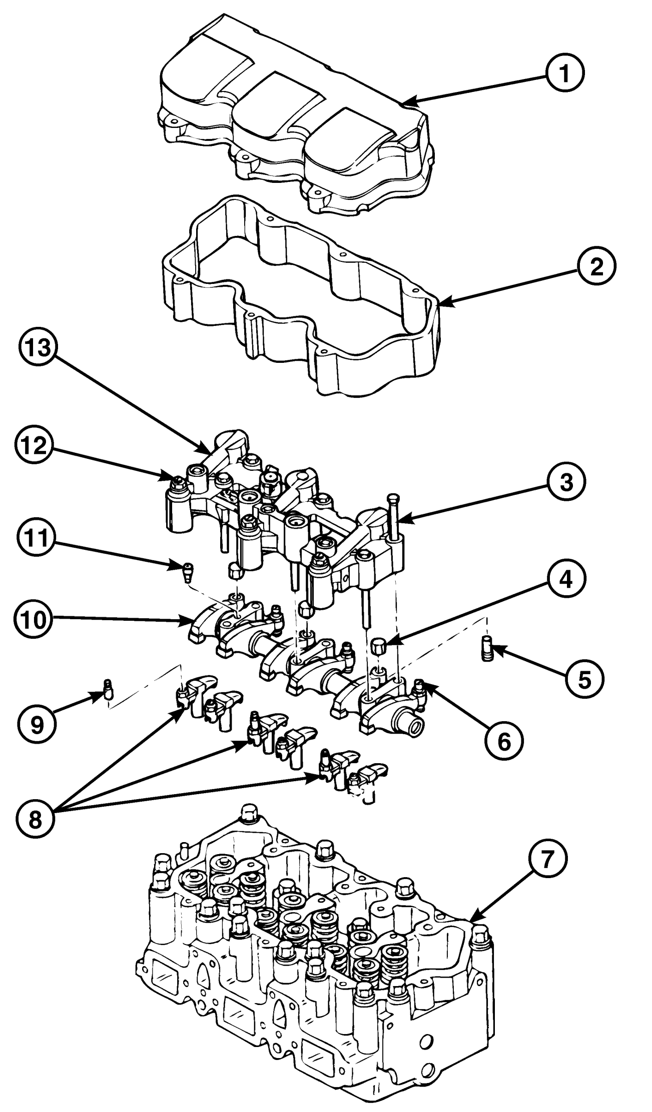


Figure 104 — Rocker Arm Shaft and Engine Brake Assembly

1. Valve Cover 2. Spacer 3. Capscrew 4. Spherical Jam Nut 5. Exhaust Adjusting Screw 6. Standard Adjusting Screw and Jam Nut (Inlet Valves) 7. Cylinder Head	8. Exhaust Valve Yokes 9. Actuator Pin Assembly 10. Rocker Arm Shaft Assembly 11. Engine Brake Oil Supply Screw 12. Slave Piston Adjusting Screw 13. Engine Brake Assembly

Nozzle Holder Removal

[222 KG]

SPECIAL TOOL REQUIRED

- Injection Nozzle Puller J 37093

SERVICE HINT

After removing the nozzles, it is a good practice to label or tag them for reinstallation into the same cylinders. After removal, place nozzles on a clean surface.

Refer to Figure 105.

1. Remove nozzle holder retainer (2).
2. Assemble injection nozzle puller J 37093 as follows:
   a. Attach nut (12), bearing (11), spacer (10) and rubber washer (9) to tool handle (1).
   b. Screw handle (1) in threaded hole of nozzle holder (5) until rubber washer (9) is slightly compressed.
3. With tool in position, turn nut (12) clockwise to draw nozzle holder from cylinder head nozzle mounting hole (8).
4. Continue turning nut until nozzle holder is free of insert. Remove nozzle holder and puller tool as an assembly.
5. Remove nozzle holder gasket (7). The gasket is manufactured from a special iron material 0.060-inch (1.524 mm) thick.
6. Remove remaining nozzle holders in the same manner.

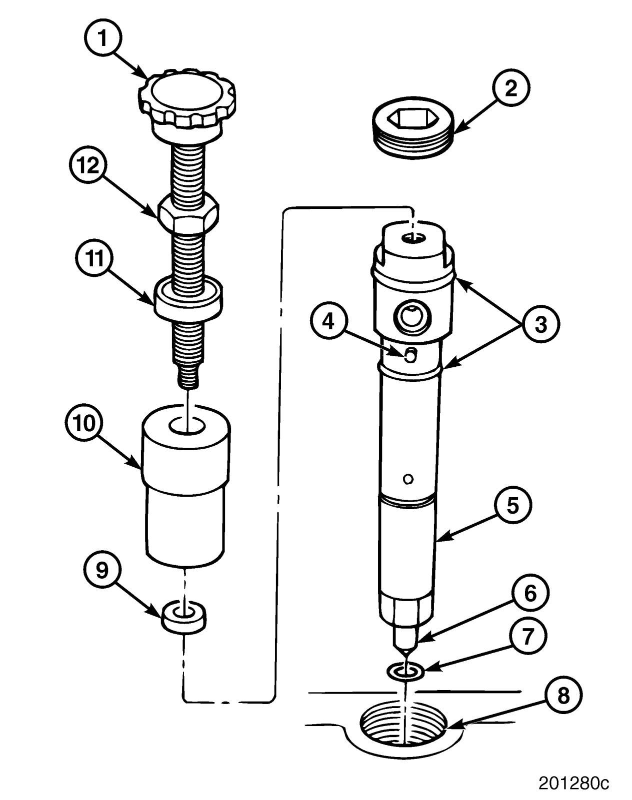


Figure 105 — Nozzle Holder Removal

1. Handle	7. Gasket
2. Nozzle Holder Retainer	8. Nozzle Mounting Hole
3. O-Rings	9. Rubber Washer
4. Alignment Pin	10. Spacer
5. Nozzle Holder	11. Bearing
6. Nozzle	12. Nut

Cylinder Head Assembly Removal [213 EV]

Refer to Figure 106.

1. Remove fuel return tube (2) from between the cylinder head assemblies (4) by loosening the tube sleeve nuts from each end.
2. Remove fuel return line (3) at the rear of the rearward cylinder head, if not already removed.
3. Remove cylinder head bolts (1 and 5). Refer to cylinder head bolt torque sequence chart under Cylinder Head Installation in Engine Reassembly, for location of bolts, if necessary.

WARNING

Cylinder head assemblies are heavy. Lifting a cylinder head requires the help of an assistant or suitable lifting device. Attempting to lift a cylinder head without assistance may result in severe personal injury.

4. Using a suitable lifting device, remove heads from the cylinder block.
5. Remove gaskets and six fire rings. Discard gaskets and fire rings.

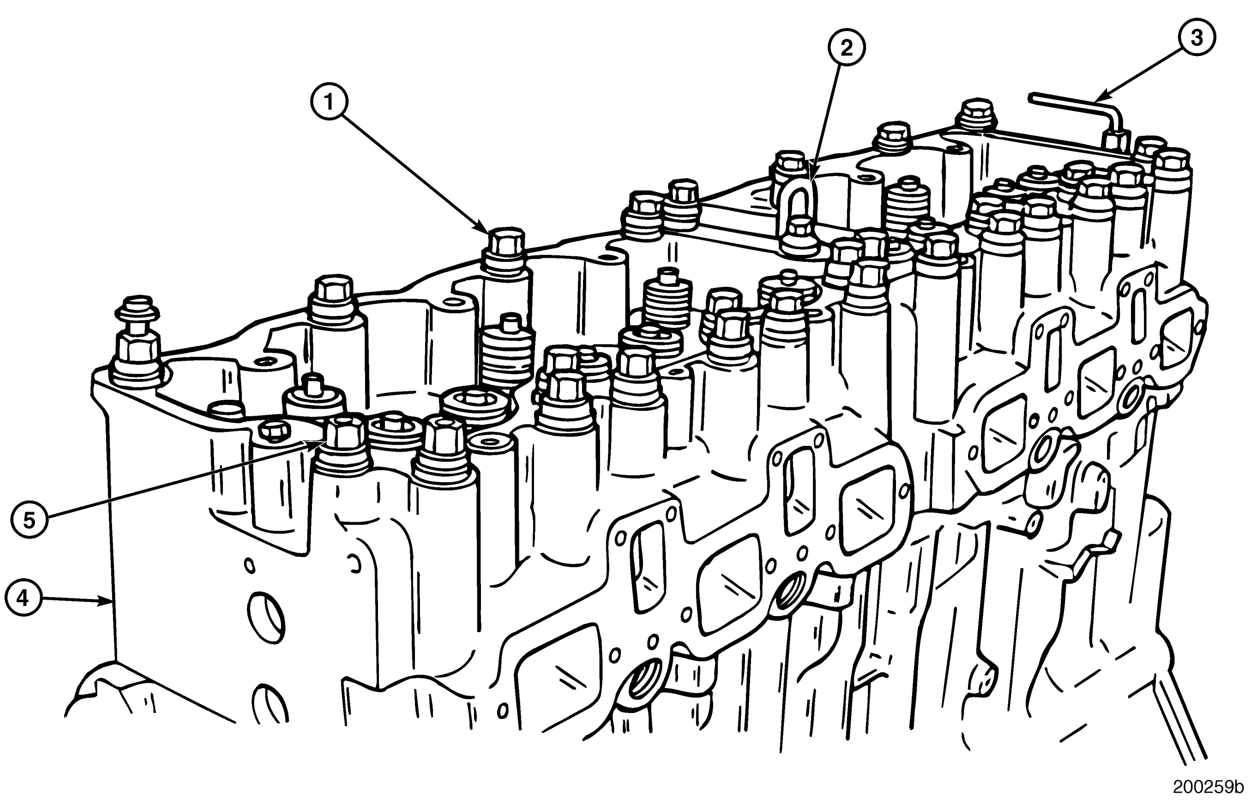


Figure 106 — Cylinder Heads

1. Bolt 2. Fuel Return Tube 3. Fuel Return Line	4. Cylinder Head 5. Bolt (with Bracket Mounting Capscrew Hole in Head)

Vibration Damper and Crankshaft Hub Removal

[212 RB, RH]

1. Remove six mounting capscrews (3). Refer to Figure 107.

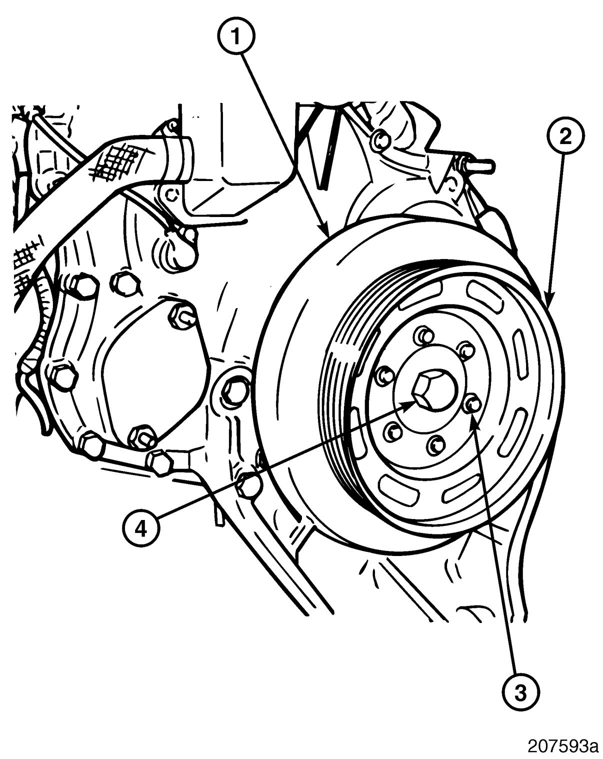


Figure 107 — Vibration Damper Removal

1. Vibration Damper 2. Pulley	3. Mounting Capscrews 4. Hub Capscrew

2. Remove vibration damper (1) and fan belt drive pulley (2) together.
3. Using a suitable wrench, remove crankshaft hub capscrew (4).
4. Using a suitable puller such as J 24420-C, remove the crankshaft hub. Refer to Figure 108.

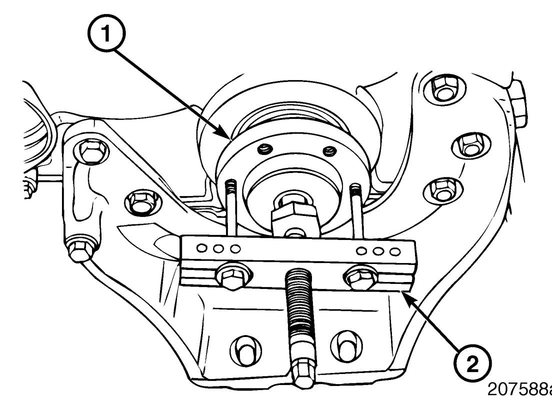


Figure 108 — Crankshaft Hub Removal

1. Crankshaft Hub	2. Puller

Oil Pan Removal

[211 NB]

WARNING

Make sure all loose components are secured to, or removed from, the engine before rotating engine on the stand. Failure to do so may result in damage to components or severe personal injury.

Refer to Figure 109.

1. Remove the nuts from the two studs (early production) or shouldered bolts (current production) securing the oil pan to the front cover.
2. Remove the nuts from the two studs (early production) or shouldered bolts (current production) securing the oil pan to the flywheel housing.
3. Remove the remaining integral hex-head shoulder studs and shouldered bolts securing the oil pan to the pan rails and remove the oil pan.

5_106_00.bk Page 124 Friday, August 4, 2000 11:17 AM

NOTE

Oil pans with isolating gaskets are secured with a combination of shouldered bolts and shouldered studs with separate nuts (two piece) or integral hex-head shoulder studs (one piece) along the pan rails. Some early engine versions used an additional washer between the nut and the isolator.

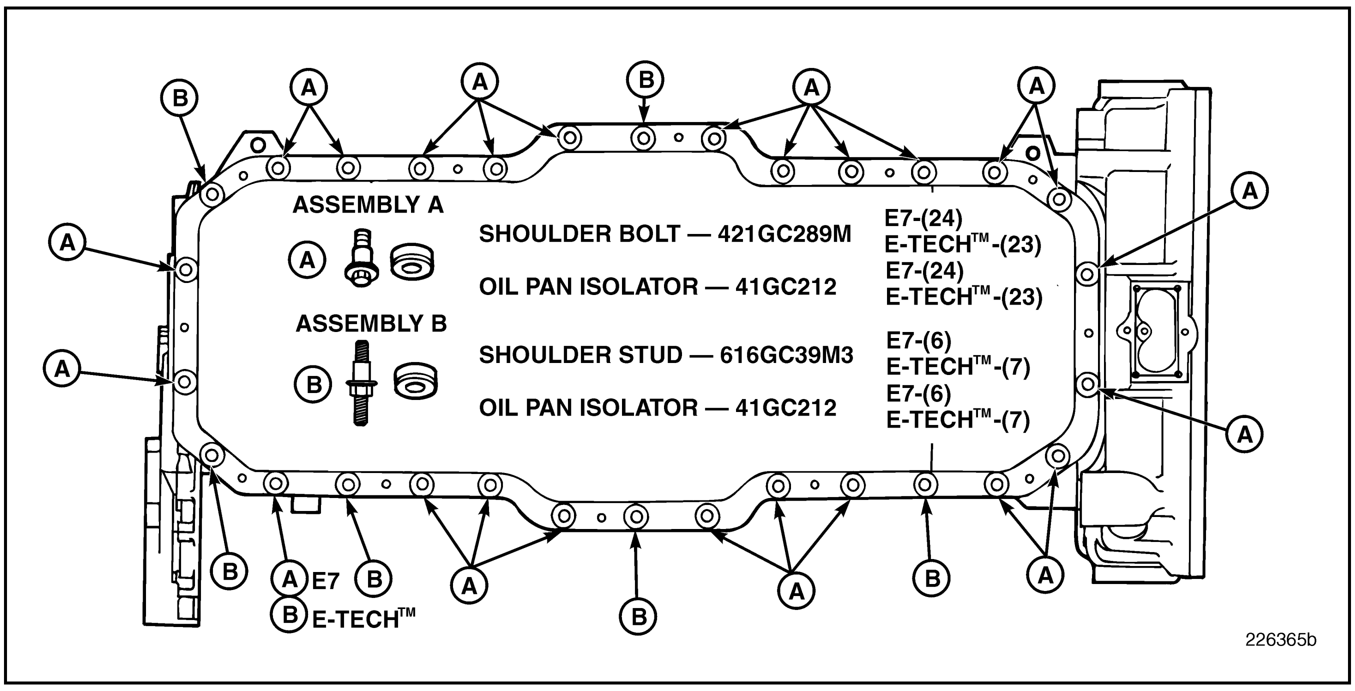


Figure 109 — Isolating Oil Pan Hex-Head Shoulder Bolt (A) and Shoulder Stud (B) Locations

Oil Pump Removal

[219 MU]

Refer to Figure 110.

SERVICE HINT

If the oil pump must be disassembled for any reason, it will be easier to loosen the housing cover retaining capscrews, the screen, the oil inlet tube capscrews, the cover plate capscrews, and the relief valve cap while the pump is still secured in position. Do so before loosening the three retaining capscrews.

The E-Tech™ screen for the oil inlet tube is held in place by a steel retainer ring.

Remove the oil pump as a unit by removing three retaining capscrews (1).

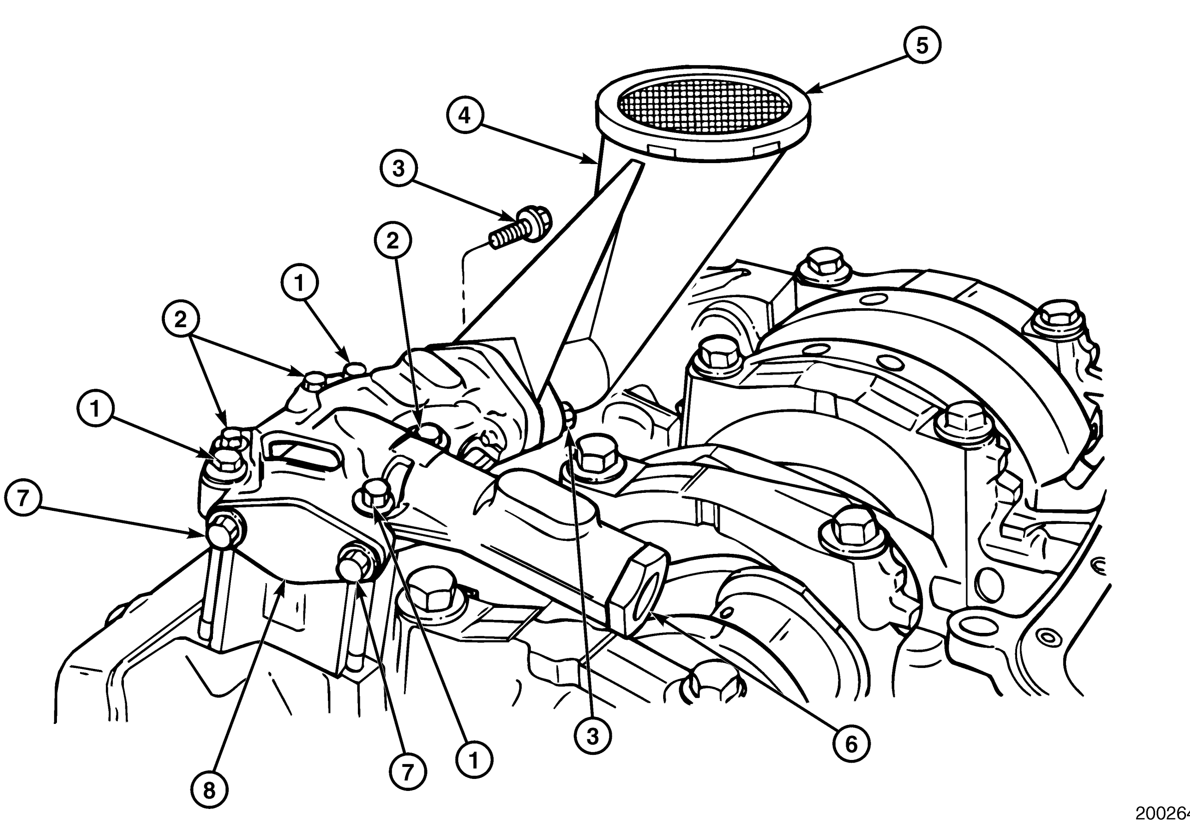


Figure 110 — Lubrication Oil Pump

1. Pump Mounting Capscrews	5. Screen
2. Capscrews	6. Relief Valve Cap
3. Capscrews, 12-Point	7. Capscrews
4. Oil Inlet (Pickup) Tube	8. Plate

Front Cover Removal

[211 RP]

CAUTION

For early-production engines equipped with studs, it is not recommended to remove the front cover without first removing the oil pan. Doing so may result in damage to the isolating oil pan gasket. Current-production engines use shoulder bolts in the front cover positions making removal of the oil pan not necessary.

Refer to Figure 111.

1. Remove front engine mount pedestal (2) by removing six retaining capscrews (3 and 4).
2. Remove remaining mounting capscrews from front cover (1).
3. Remove front cover. It will be necessary to pry the cover from the engine block. Be careful not to damage cover or block while using sharp tools around machined surfaces.

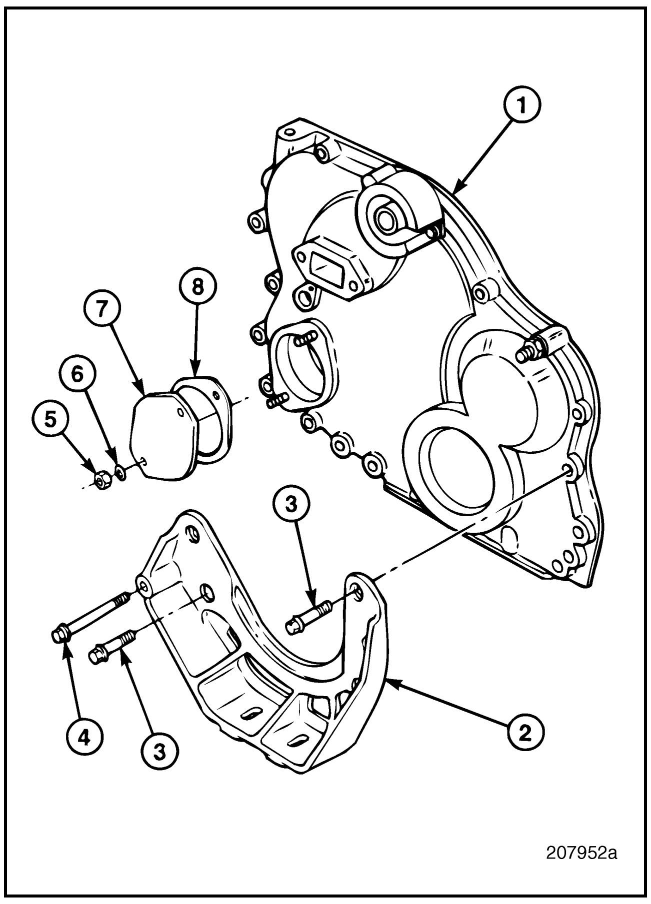


Figure 111 — Front Cover Removal

1. Front Cover	5. Nut
2. Pedestal	6. Washer
3. Capscrew (Short)	7. Cover
4. Capscrew (Long)	8. Gasket

5_106_00.bk Page 127 Friday, August 4, 2000 11:17 AM

Auxiliary Shaft Removal

[212 CV]

Refer to Figure 112.

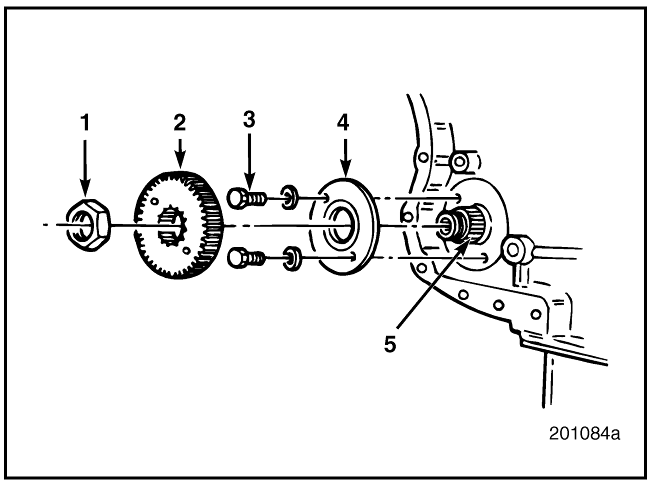


Figure 112 — Auxiliary Shaft Gear

1. Nut 2. Auxiliary Shaft Gear 3. Capscrew	4. Captured Thrust Washer 5. Shaft Splines

1. Remove auxiliary shaft gear retaining nut (1).
2. Using a suitable puller such as J 4558-01, remove auxiliary shaft gear (2) from the splines (5) on the end of shaft (Figure 113).

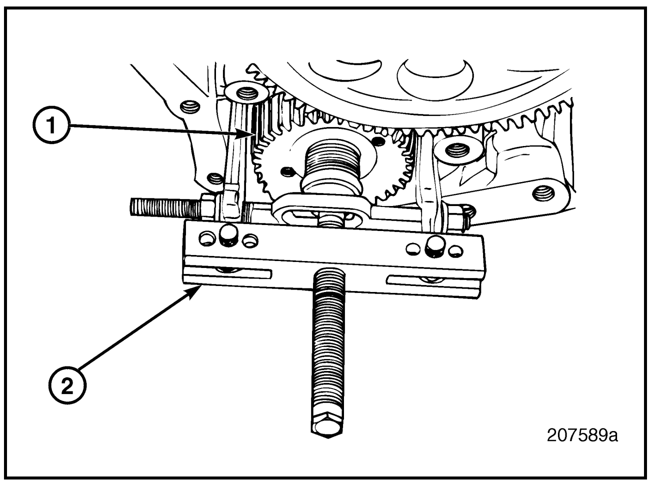


Figure 113 — Auxiliary Shaft Gear Removal

1. Auxiliary Shaft Gear	2. Puller

3. Remove two retaining capscrews from auxiliary shaft captured thrust washer. Remove washer.

Refer to Figure 114.

CAUTION

Be very careful to avoid damaging the auxiliary shaft bushings or journals while removing the shaft.

4. Remove the auxiliary shaft (3) by pulling it rearward out of the air compressor mounting flange opening. With engine oil pump in position, a rotating motion may be necessary to clear the engine oil pump drive gear (5).

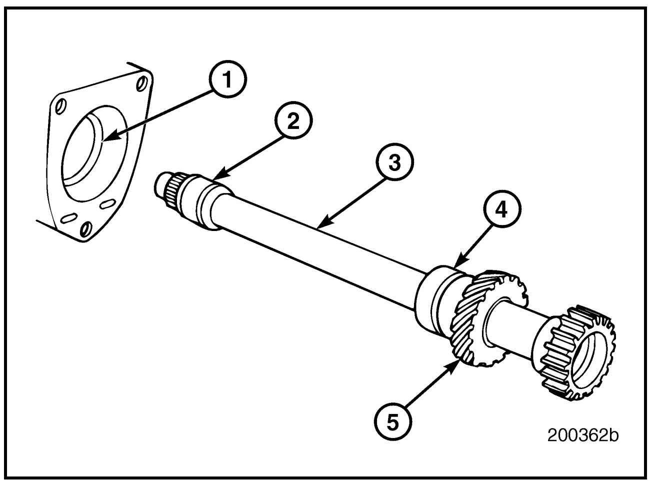


Figure 114 — Auxiliary Shaft Removal

1. Rear Bushing 2. Front Journal 3. Auxiliary Shaft	4. Rear Journal 5. Oil Pump Drive Gear

Camshaft Removal

[213 CH]

WARNING

Make sure all loose components are secured to, or removed from, the engine before rotating engine on the stand. Failure to do so may result in damage to components or severe personal injury.

1. Rotate engine so that the oil pan rail is upward (engine inverted).

NOTE

When engine is rotated, the roller valve lifters will fall downward into the push rod holes and rest against the H-rings. They will be out of the way for camshaft removal.

2. Remove the two 12-point capscrews (3) that retain camshaft thrust washer (1). Camshaft may have to be rotated slightly to make the capscrews accessible through openings (2) in the camshaft drive gear (4). Refer to Figure 115.

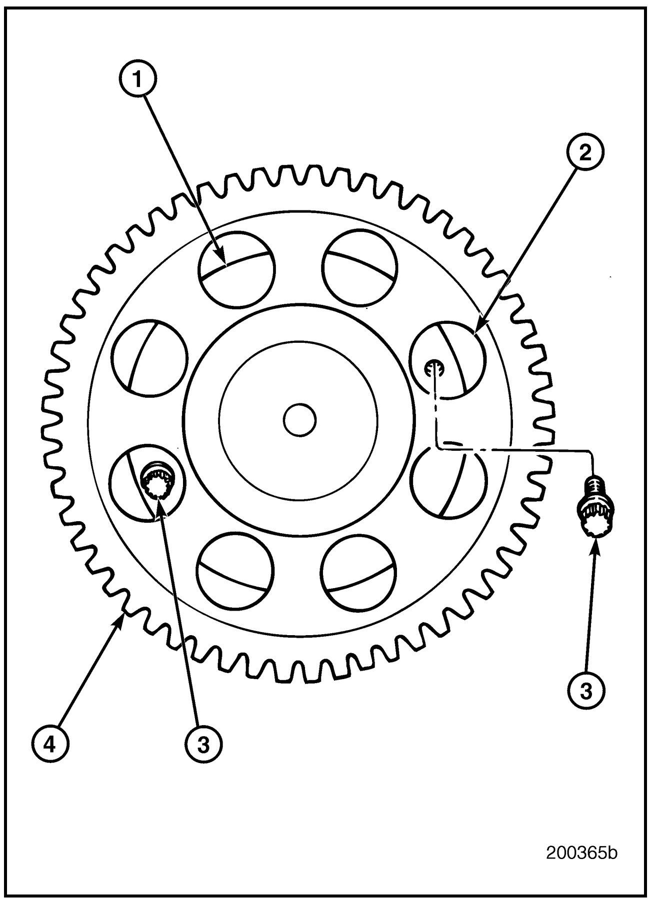


Figure 115 — Camshaft Thrust Washer Capscrews

1. Thrust Washer 2. Openings	3. Capscrew, 12-Point 4. Camshaft Drive Gear

3. Install the camshaft removal/installation tool J 41682 (Figure 116) in position on the rear segment of the camshaft, securing it with the clip to the shaft.

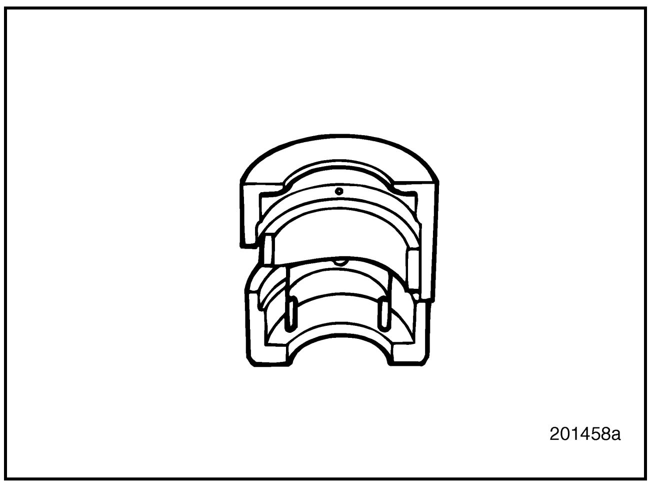


Figure 116 — Camshaft Installation Guide

4. Taking care not to damage camshaft or bushings, pull camshaft out of the front of the engine (Figure 117). Carefully guide rear of shaft through the journals. If shaft does not come out freely, ensure all valve lifters are clear of camshaft cams and journals.

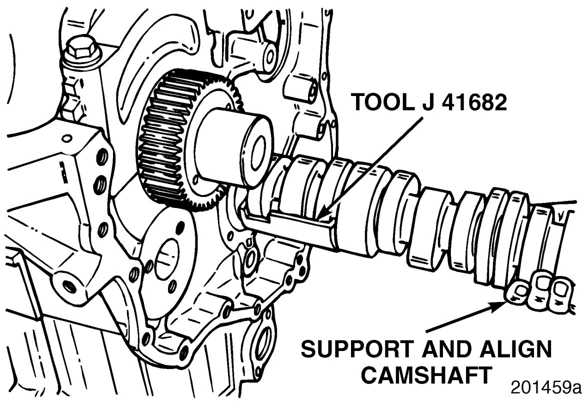


Figure 117 — Camshaft Removal

5. Remove valve lifters.

SERVICE HINT

Valve lifters have established wear patterns and should be reinstalled in same locations. Label each valve lifter upon removal and place on a clean work surface.

Piston and Connecting Rod Assembly Removal

[212 NP, LQ]

WARNING

The crankshaft and related components are heavy, have sharp edges and many possible pinch points. Always be careful while working in this area to avoid serious personal injury.

NOTE

Before removing pistons, connecting rods and rod caps, ensure they are marked so they can be reinstalled in the same cylinders from which they were removed.

Remove connecting rod and piston assemblies in companion cylinder sets: 1 and 6, 2 and 5, and 3 and 4.

1. Rotate engine stand 90 degrees so that pistons lie horizontally in the block with top of pistons and connecting rods accessible.
2. Rotate crankshaft so that pistons 1 and 6 are lowered in the cylinder at least 2 inches (51 mm) to allow adequate room to remove carbon from upper edge of sleeves.

   Refer to Figure 118.
3. Using a sharp knife, carefully remove any carbon at the top of the sleeves. Remove any remaining carbon using crocus cloth or fine sandpaper. Then wipe inside of sleeves with a clean cloth.

CAUTION

Use care not to damage the cylinder sleeve when removing carbon buildup.

5_106_00.bk Page 130 Friday, August 4, 2000 11:17 AM

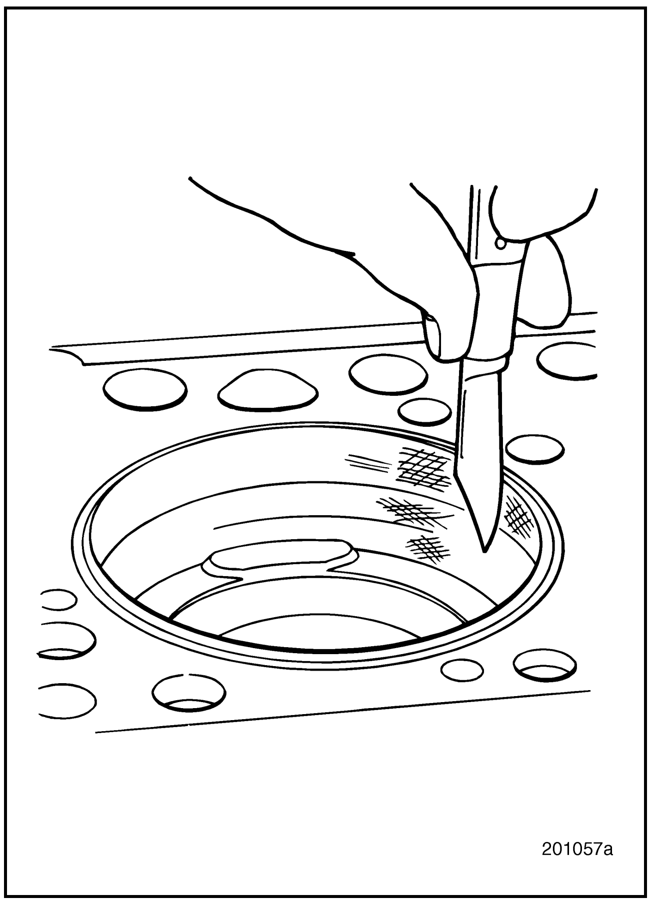


Figure 118 — Carbon Removal from Cylinder Sleeves

Refer to Figure 119.

4. Rotate crankshaft so that pistons 1 and 6 are at bottom dead center. Remove connecting rod capscrews and rod bearing caps.

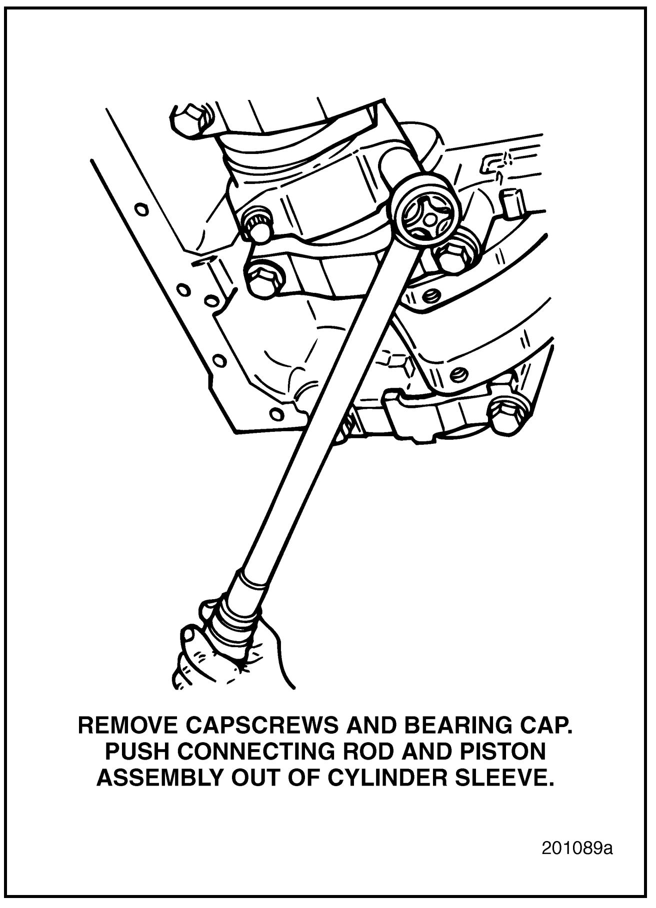


Figure 119 — Piston and Connecting Rod Assembly Removal

5. Using a hammer handle, push piston 1 from the cylinder bore. Remove piston 6 in the same manner.
6. After removing pistons 1 and 6, rotate crankshaft so that next set of pistons (2 and 5) is at bottom dead center.
7. Repeat steps 2 through 6 for removing piston sets 2 and 5, and 3 and 4.

Flywheel Removal

[212 UC]

Refer to Figure 120.

1. With engine stand rotated so that engine is inverted (crankshaft horizontal), loosen all six flywheel retaining capscrews.

NOTE

On vehicles equipped with an automatic transmission, it may be necessary to remove additional components to gain access to the flywheel retaining capscrews. Refer to Automatic Transmission Drive Arrangement Assembly Instructions manual 5-902 for instructions regarding these arrangements.

2. Remove two of the flywheel retaining capscrews that are opposite each other. Install two longer capscrews or studs to allow flywheel to be safely removed from the crankshaft.
3. Remove remaining capscrews.
4. Carefully tap flywheel by alternating from side to side to work it off the aligning dowel pins.

WARNING

The flywheel is heavy. Lifting the flywheel will require the help of an assistant or the use of a suitable lifting device (J 25026-A or equivalent). Attempting to lift a flywheel without such assistance may result in severe personal injury.

NOTE

Remove flywheel timing pointer, if present, to avoid damaging the pointer during flywheel removal.

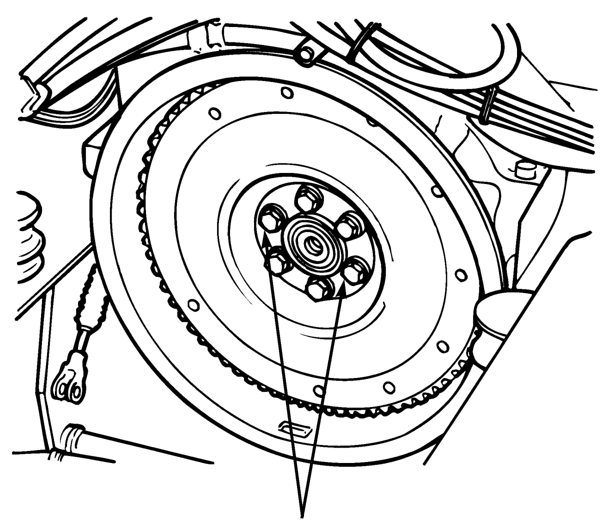


Figure 120 — Flywheel Removal

5. Support the flywheel and remove two guide capscrews.
6. Using a suitable lifting device such as J 25026-A, or adequate assistance, remove flywheel.

Flywheel Housing Removal

[211 HD]

Refer to Figure 121.

1. Remove eight mounting capscrews (3) from flywheel housing (2).
2. Remove flywheel housing. It may be necessary to tap lightly on the housing with a soft mallet to separate housing from engine block.

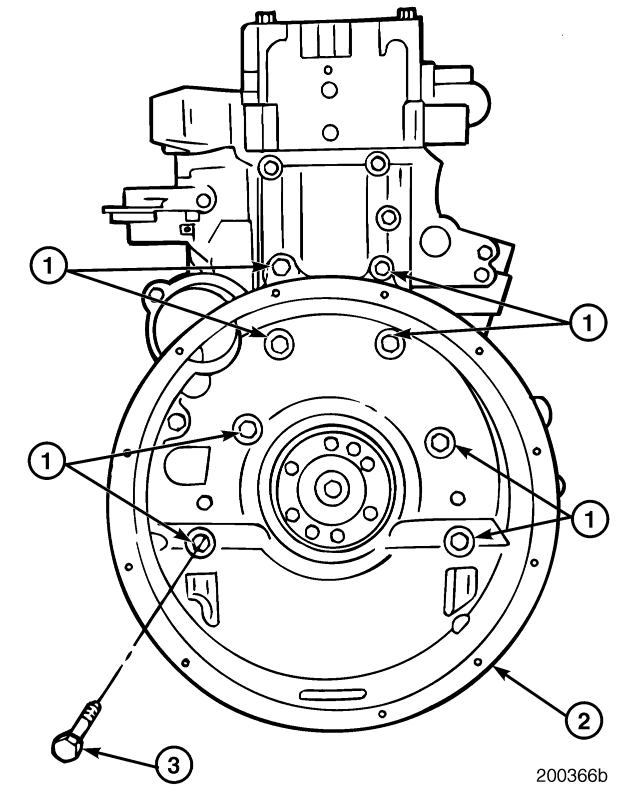


Figure 121 — Flywheel Housing Removal

1. Capscrew Locations 2. Flywheel Housing	3. Capscrew

5_106_00.bk Page 133 Friday, August 4, 2000 11:17 AM

Main Bearing Cap Removal

[211 JA]

NOTE

Before removing main bearing caps, ensure they are marked so they can be reinstalled on the same journals. Keep the bearings with the same cap and tag, or mark them to identify the cam side of the bearings.

Refer to Figure 122.

1. Remove eight buttress capscrews (2 and 3).
2. Remove main bearing capscrews (1) from each of the seven bearing caps (4 and 5). The center main bearing cap (5) houses the thrust washers.
3. Position a lady-foot pry bar under the tabs provided on bearing caps and pry bearing caps upward. To work them loose, it may be necessary to tap the bearing caps alternately from side to side with a soft mallet.

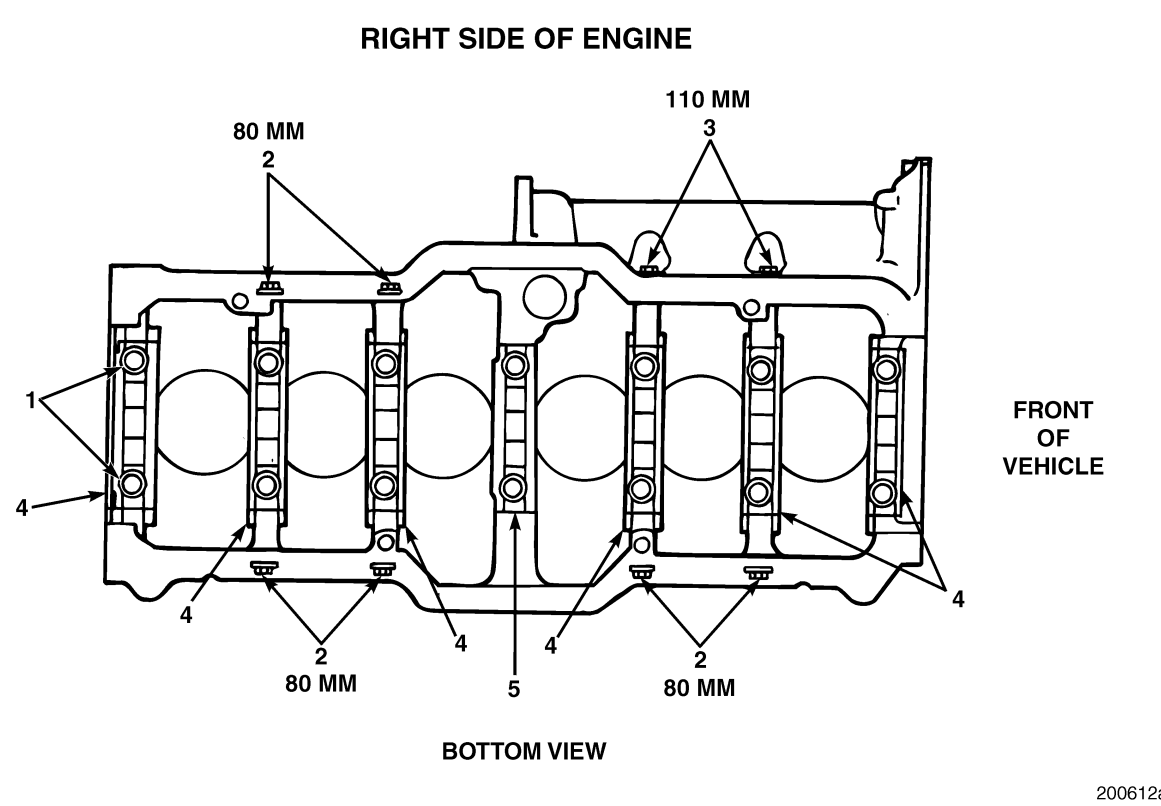


Figure 122 — Buttress Capscrew Installation

1. Main Bearing Cap Capscrews 2. Buttress Capscrews, 80 mm 3. Buttress Capscrews, 110 mm	4. Main Bearing Caps 5. Center Main Bearing Cap

5_106_00.bk Page 134 Friday, August 4, 2000 11:17 AM

Crankshaft Removal

[212 HP]

Refer to Figure 123.

1. Using a suitable lifting device, secure a sling or crankshaft support tool around the crankshaft and lifting device hook. Ensure crankshaft is evenly balanced when lifted from the engine block.
2. Lift crankshaft from engine block and store in a secured stand, or horizontally on V-blocks.

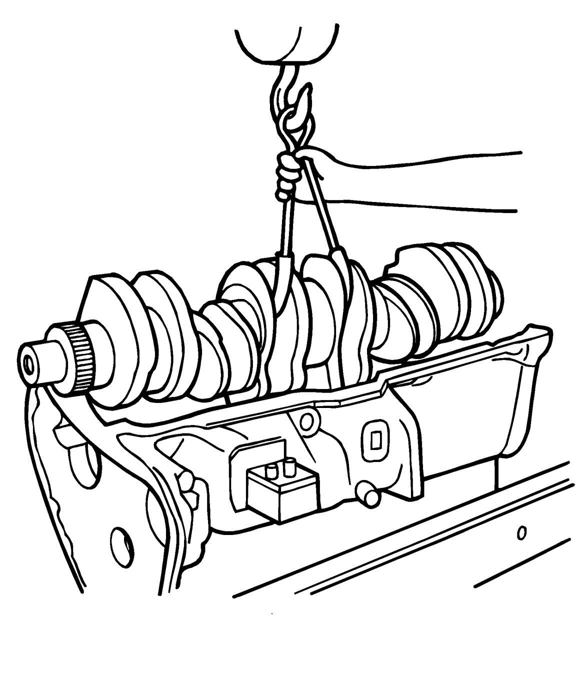


Figure 123 — Crankshaft Removal

3. Remove the main journal bearing inserts from the cylinder block and tag for inspection.

CYLINDER BLOCK RECONDITIONING [211 DB]

Special Tools Required

- Camshaft Bushing Installation/Removal Kit J 42377
- Camshaft Bushing Remover/Installer J 21428-01
- Counterbore Tool PT2210
- Counterbore Cutter Plate PT2210-3A
- Hex Key Wrench PT2210-14
- Universal Dial Depth Gauge PT5025
- 3-Inch Stylus Extension PT5025-11

Piston Cooling Spray Nozzle Removal

[219 RV]

CAUTION

To avoid damaging the spray nozzles, remove them before removing the sleeves.

SERVICE HINT

It is best to use a 10-mm, 6-point socket on a 12-inch extension to remove the nozzle retaining capscrews.

Refer to Figure 124.

1. Remove the piston cooling spray nozzle (2) by removing the retaining capscrew (3).
2. Carefully pull outward on the spray nozzle to remove it from the block.
3. Remove and discard the elastomer seal (1).
4. Repeat steps 1 through 3 to remove the remaining spray nozzles.

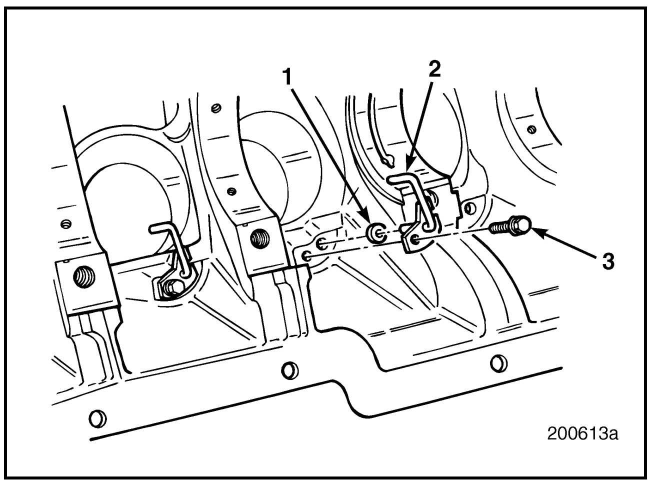


Figure 124 — Spray Nozzle Removal

1. Elastomer Seal 2. Spray Nozzle	3. Capscrew

Cylinder Sleeve Removal

[212 NC]

SPECIAL TOOL REQUIRED

- Cylinder Liner/Sleeve Puller PT6435

NOTE

With early engine production, a crevice seal, similar to an O-ring, was installed in the groove located in the outside diameter of the cylinder sleeve, near the sleeve top. It has been determined, however, that the crevice seal is not necessary. Therefore, effective approximately December 1998, the crevice seal is no longer used in production engines. Additionally, effective January 1999, the crevice seal groove in the cylinder sleeve has been eliminated.

Effective with these production changes, cylinder sleeve part Nos. 509GC463 and 509GC466 for service use will not have the crevice seal groove, and it is recommended that use of the crevice seal be discontinued in all engine repairs or rebuilds, whether or not the liner has a crevice seal groove.

Refer to Figure 125 and Figure 126.

1. Rotate the engine in the stand so that it is upright (deck surface upward).
2. Use puller PT6435, or equivalent, to remove the cylinder sleeve (1) from the cylinder block (4).
3. Position the puller above the sleeve and guide the puller shaft through the sleeve.

CAUTION

Extreme care must be taken to make sure the puller shoe is properly aligned in the bottom of the sleeve to prevent damage to the block.

4. Position the puller shoe so that it catches the lower lip of the sleeve. Ensure that it does not extend beyond the outside edges of the sleeve so it will not come into contact with the cylinder block as the sleeve is removed.
5. Tighten screw on the puller until the sleeve comes free from the cylinder block bore. Remove shims (2), if any are installed.

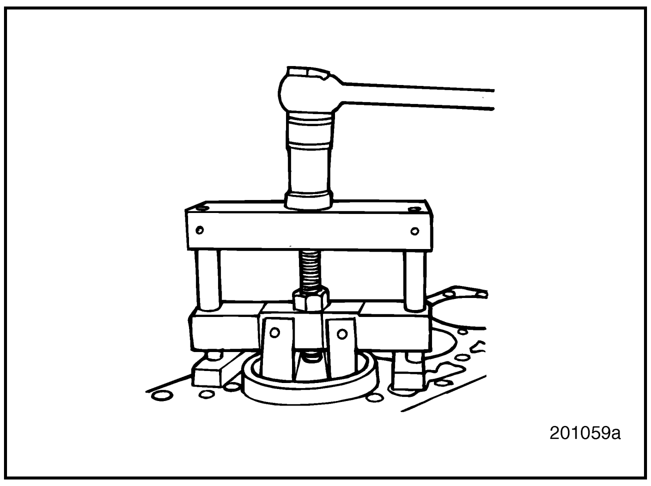


Figure 125 — Cylinder Liner/Sleeve Puller PT6435

6. Remove the puller from the sleeve.
7. Remove the crevice seal from the sleeve, if so equipped.
8. Repeat steps 2 through 7 to remove the remaining cylinder sleeves.

5_106_00.bk Page 136 Friday, August 4, 2000 11:17 AM

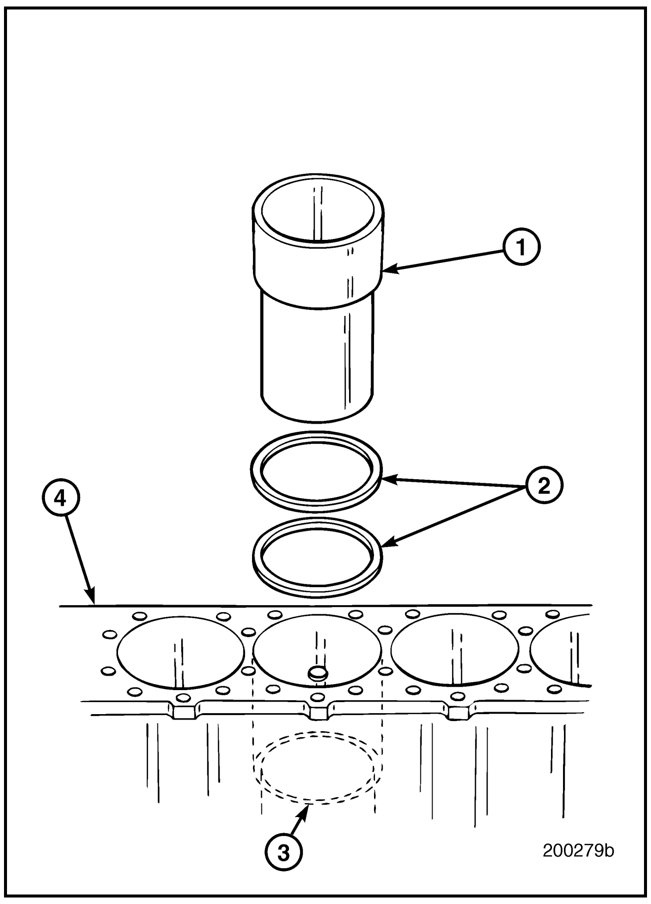


Figure 126 — Cylinder Sleeve Removal

1. Cylinder Sleeve 2. Shims	3. Counterbore Ledge 4. Cylinder Block

Cleaning and Inspection

The engine should have been thoroughly steam cleaned prior to component removal. If heavy accumulations of dirt and grease are still present, steam clean the block as thoroughly as possible before attempting to clean with solvents.

WARNING

Cleaning solvent is flammable and toxic to the eyes, skin and respiratory tract. Skin and eye protection is required. Avoid repeated or prolonged contact. Use only in well-ventilated area.

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes or irritate the skin. Pressure must not exceed 30 psi (207 kPa). Eye protection is required. Use only with effective chip guarding and personal protective equipment (goggles/shield, gloves, etc.).

NOTE

Cleaning the cylinder block is important. While cleaning the cylinder block, carefully inspect the areas around the cup plugs and the coolant jacket. If cup plugs or pipe plugs show signs of leaking, they should be replaced.

Cleaning the cylinder block is a good time to inspect it for cracks or other possible defects that may be reason for rejection. Refer to the TROUBLESHOOTING section of this manual for information on testing for leaks in the cylinder head and cylinder block. If damage is not found until after the engine is assembled, the engine must be disassembled and rebuilt again.

SOLVENT TANK CLEANING

NOTE

Use a cleaning tank large enough to accommodate the largest component to be cleaned. Fill the tank with a suitable solvent and always use caution while cleaning parts. Parts may be dried with compressed air.

1. Scrape any remaining gasket material from the block.
2. Using a wire brush or rotary wheel, remove any rust, corrosion or other debris from the block.
3. Clean all other block surfaces with mineral spirits or other suitable solvent.
4. Using due care and caution, clean and dry the block with compressed air.

5_106_00.bk Page 137 Friday, August 4, 2000 11:17 AM

INSPECTION

NOTE

A complete discussion of the proper methods of precision measuring and inspection is outside the scope of this manual. However, every shop should be equipped with standard gauges, such as bore gauges, dial indicators, outside and inside micrometers, thickness gauges and straightedges.

Check the cylinder block for indications of cracking or coolant leakage. If any damage is suspected, use a standard dye penetrant or magnaflux procedure to determine if cracks exist. A cracked engine block must be replaced and never reused.

Refer to Figure 127.

Using a straightedge (PT5027 or equivalent) and thickness gauges, check the cylinder head mounting surfaces for flatness. The cylinder block mounting surface on a service block should be flat within 0.004 inch (0.102 mm).

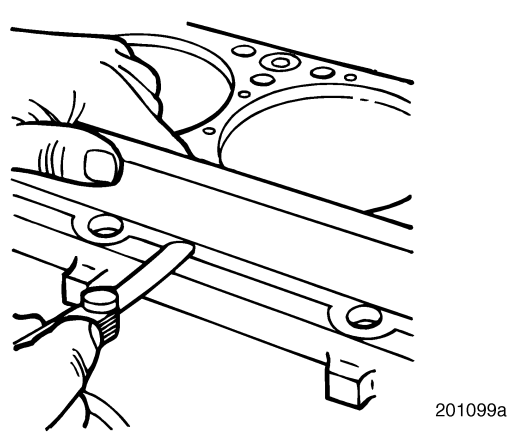


Figure 127 — Checking Flatness of Cylinder Block Deck

SERVICE HINT

If the cylinder block is determined to be serviceable after thorough cleaning and inspection, reassemble the engine. Use replacement or original parts, as determined during component inspection.

Cylinder Sleeve Counterbore [211 DB]

INSPECTION AND REPAIR

If the cylinder block deck is resurfaced, the cylinder sleeve counterbore depth must be recut to specification. If the cylinder block deck was not resurfaced but cylinder sleeve counterbore surface shows excessive pitting or erosion, recut the counterbore as required.

Use shims to re-establish the correct liner flange height. Shims are available in the following thicknesses: 0.002, 0.003, 0.004, 0.008, 0.010, 0.012 and 0.014 inch.

To resurface the cylinder sleeve counterbore area of the cylinder block, use counterbore tool PT2210 with counterbore cutter plate PT2210-3A.

NOTE

This procedure can be performed either in or out of the chassis. If performing the procedure in the chassis, be sure to cover the crankshaft and any holes in the block to prevent contamination from machining chips.

CAUTION

Do not cut seats deeper than 4.034 inches (102.464 mm).

1. Make sure that the top of the deck is clean and free of burrs. Use a finish mill file and crocus cloth, if necessary, to create a smooth, flat surface for positioning the tool.
2. Using compressed air, thoroughly remove all debris.

NOTE

Universal dial depth gauge PT5025, with a three-inch stylus extension PT5052-11, is recommended for measuring the counterbore.

3. Measure and record the counterbore in four places, 90 degrees apart. Using a depth gauge with a three-inch extension, mark the shallowest point. Subtract the lowest number from the highest number. This is the minimum amount to be machined for cleanup.

SETTING UP COUNTERBORE TOOL PT2210 WITH CUTTER PLATE PT2210-3A

Refer to Figure 128.

1. Loosen the two cutter bit hold-down capscrews (9). Install cutter bit (11) into cutter plate PT2210-3A (13) by turning the cutter bit adjuster (10) counterclockwise. Cutter bit face must be facing a clockwise rotation cut.

CAUTION

Do not tighten the cutter bit hold-down cap (12).

The cutter point should not extend beyond the outer edge of the cutter plate. If the cutter bit does stick out, damage to the bit will occur when installing counterbore tool onto cylinder block.

2. Install the cutter plate on the main shaft (15). Use the large end of hex key wrench PT2210-14 (18) to hold the cutter plate and tighten securely. The hole in the side of the cutter plate accepts the large end of the tool.

CAUTION

Do not allow the cutter bit (11) to touch the cylinder sleeve bore wall.

SERVICE HINT

When the entire block must be counterbored, cut the deepest bores first. This way, the tool can be adjusted to the lowest depth and used for all cylinders, ensuring uniform depth on all cylinder counterbores.

3. Position the tool in the cylinder bore by backing off the depth-set collars (5 and 16) and lowering the cutter plate (13) into the counterbore to center the tool.
4. Secure the cutter plate to the cylinder block with four M16 x 2 x 90 hex-head capscrews (3) and special washers (4) from the counterbore tool kit PT2210.
5. Cross-torque the capscrews to 30 lb-ft (41 N•m) using torque wrench J 24406 or equivalent.

NOTE

Lift T-handle (2) slightly (so cutter plate is not in contact with the counterbore) and rotate the mainshaft (15) counterclockwise to ensure cutter plate turns freely without binding. If necessary, loosen the capscrews and relocate the tool.

6. Using the counterbore tool T-handle (2), raise the cutter plate approximately 1/2 inch (12.7 mm) from the counterbore ledge.
7. Using hex key wrench PT2210-14 (18), turn the cutter bit adjusting screw (10) clockwise until the cutter bit contacts the counterbore ledge. Do not touch the counterbore wall.
8. Back off the lower depth-set collar (16) and lower the cutter plate until the cutter rests on the ledge.
9. Rotate the lower depth-set collar down until the collar contacts the main housing.
10. Rotate the collar an additional five increments totaling 0.005 inch (0.127 mm). Each graduation of the collar is one-thousandth (0.001) of an inch (0.025 mm). This will lift the cutter bit 0.005 inch (0.127 mm) off the counterbore ledge, allowing an accurate setting of the cutter bit.

NOTE

It may be necessary to use a flashlight to see the cutter bit adjusting screw.

11. Using hex key wrench PT2210-14 (18), turn the cutter bit adjusting screw clockwise until the cutter bit rests on the counterbore ledge.
12. If the cutter bit will not adjust, adjust the lower depth-set collar (16) 0.005 inch (0.127 mm) more and recheck cutter bit hold-down screws for looseness.
13. Zero the depth-set collars:
    a. Back off the lower depth-set collar (16) and carefully lower the cutter plate (13) into the bore and allow the cutter to rest on the counterbore ledge.
    b. Rotate both depth-set collars (5 and 16) down until the bottom collar contacts the main housing (8).

CAUTION

Do not force the collar beyond this point, as it will lift the cutter plate and prevent an accurate zero reading.

14. Set the depth of the cut. Determine the final depth of the cut and back off the top depth-set collar accordingly. Each increment on the depth-set collar increases the depth of the cut by one-thousandth (0.001) of an inch (0.025 mm). Tighten the thumbscrew (17) on the upper collar (5) securely.

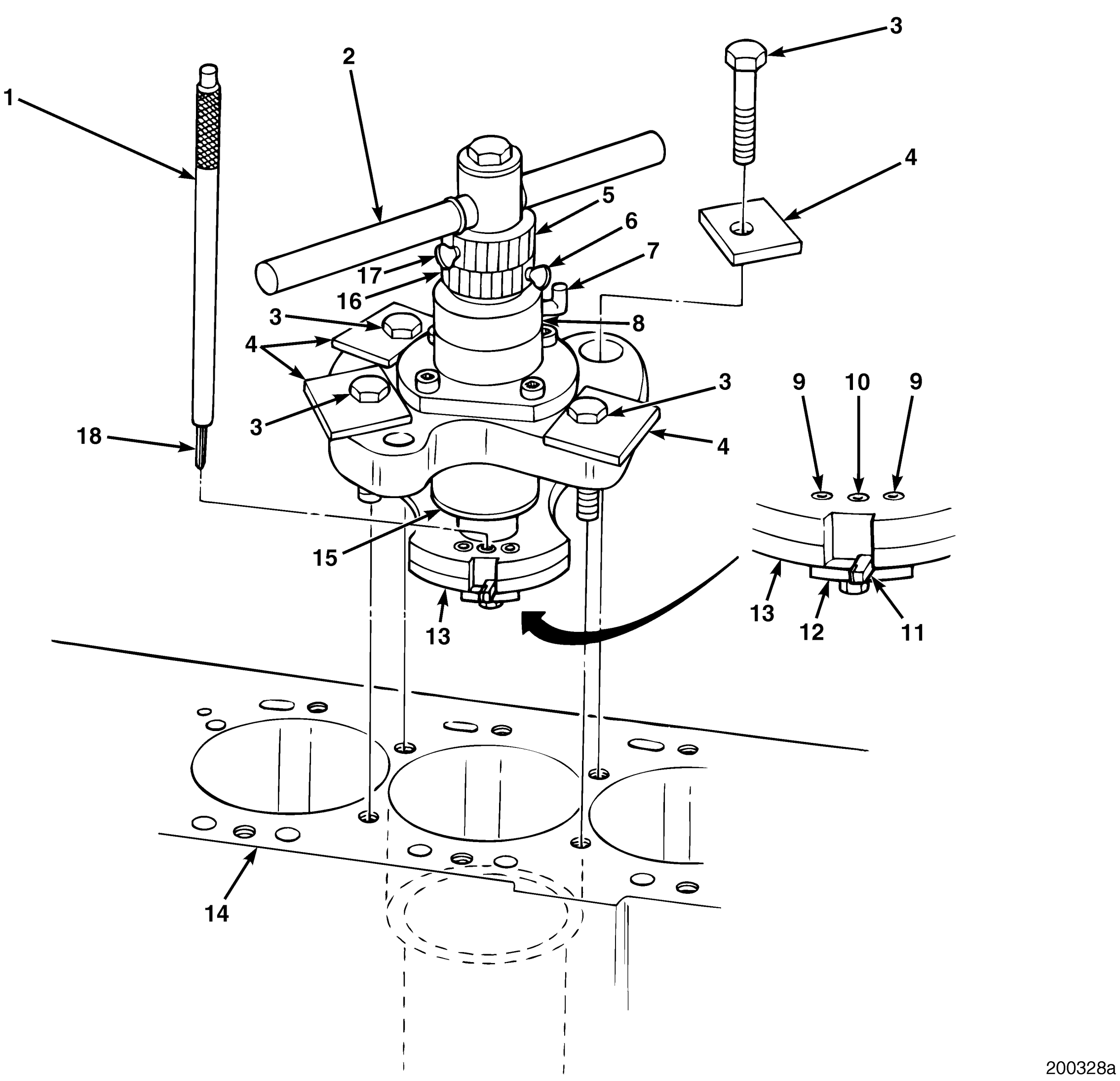


Figure 128 — Counterbore Ledge Tool Installation

1. Cutter Plate Holder 2. T-Handle 3. Capscrews, M16 x 2 x 90 4. Special Washers 5. Upper Depth-Set Collar 6. Lower Thumbscrew 7. Oil Fill Tube 8. Main Housing 9. Hold-Down Capscrews	10. Cutter Bit Adjuster 11. Cutter Bit 12. Hold-Down Cap 13. Cutter Plate 14. Cylinder Block 15. Main Shaft 16. Lower Depth-Set Collar 17. Upper Thumbscrew 18. Hex Key Wrench

CUTTING THE COUNTERBORE

Refer back to Figure 128.

1. Fill the oil fill tube (7) with 30W nondetergent oil to maintain lubrication during use.
2. Back off the lower depth-set collar (16) two increments or less, and tighten the thumbscrew (6) securely.
3. Cut the counterbore by turning the T-handle clockwise while maintaining constant downward pressure on the tool. Stop the handle in a different position to avoid creating a ridge in the counterbore.
4. Continue backing off the lower depth-set collar, no more than two graduations per cut. Check the depth measurement between each adjustment. Plan to remove 0.001 inch (0.025 mm) on the final cut to meet the final predetermined counterbore depth. This ensures achieving a very fine machined finish.
5. Remove the tool from the cylinder bore.
   a. Loosen the two cutter bit hold-down capscrews (9) and rotate the cutter bit adjusting screw (10) counterclockwise until the cutter bit is retracted into the cutter plate (13).
   b. Remove the four machine hold-down bolts (3) and special washers (4).
   c. Remove the tool from the cylinder bore.
6. Follow steps 1 through 5 for the remaining cylinders.

COUNTERBORE DEPTH MEASUREMENT

Measure the counterbore depth (Figure 129) and calculate the number of shims (part Nos. 505GC26P2, P3, P4, P10, P12 and P14) needed to obtain proper cylinder sleeve flange height. The shim "P" number signifies shim thickness, i.e., P14 is 0.014-inch thick. When installing shims, always use the thickest shims and the least amount of shims as possible to obtain the proper sleeve flange height.

NOTE

The standard production counterbore depth has been changed from 4.000–4.004 inches to 3.998–4.002 inches.

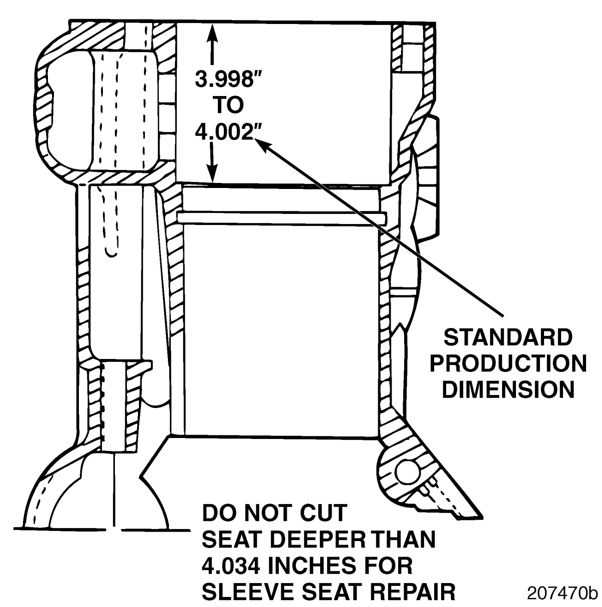


Figure 129 — Counterbore Depth Measurement

Cup Plug Replacement

REMOVAL

Refer to Figure 130.

1. Using a hammer and punch, drive one edge of the plug inward. The plug should rotate causing the opposite edge to move outward. When the edge moves out far enough, grab it with a pair of pliers and pull it out.

CAUTION

If, after several taps with a hammer, the plug does not rotate and is being driven inward, stop tapping. Drill a hole approximately 1/8 inch (3.2 mm) in diameter in the center of the plug. Insert a sheet-metal screw in the hole. Leave enough of the screw protruding from the plug to allow a pry bar to be inserted under the head of the screw and pry the plug out.

2. Clean the plug hole(s) with a wire brush or wire wheel. After cleaning, visually check the surface for cracks.

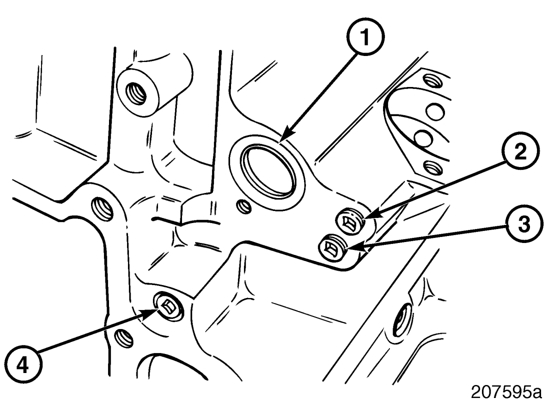


Figure 130 — Cylinder Block Plugs

1. Coolant Passage Cup Plug	3. Lower Fuel Gallery Pipe Plug
2. Upper Fuel Gallery Pipe Plug	4. Oil Gallery Pipe Plug

INSTALLATION

1. After cleaning the plug hole, apply a thin coat of Loctite® 277 to both the surface of the hole and the outer edge of the plug.
2. Using a proper driver, align the plug in the hole and drive it inward until the outer lip of the plug is flush with the cylinder block. Refer to Figure 131.

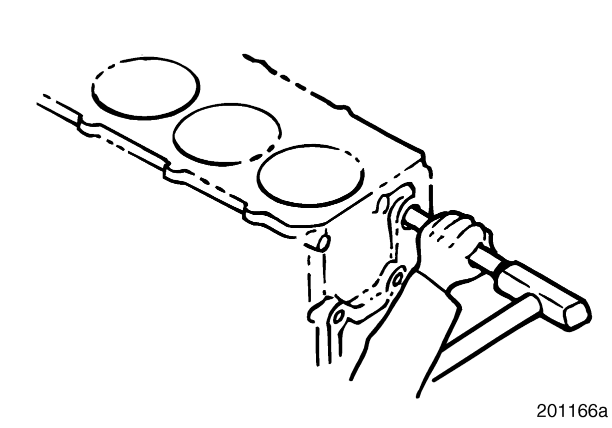


Figure 131 — Cylinder Block Cup Plug Installation

Pipe Plug Replacement

NOTE

Any rust around a pipe plug is an indication of a leak and the plug should be replaced.

REMOVAL

1. Using an appropriate wrench, remove the plug.
2. Clean the threads in the block by running a tap into the hole, just far enough to remove any rust on the threads without expanding the diameter of the hole. Use compressed air to remove any chips from the block.

NOTE

It is best to replace a leaking pipe plug. However, if reusing the same plug, clean thoroughly, paying special attention to the threads.

3. Using a wire wheel, clean the threads of the plug. Visually check the thread surfaces for burrs or damage. Then clean and check the remaining surfaces.

INSTALLATION

Apply an appropriate Teflon® thread sealant to the threads and install the plug. Tighten the plug to specification. Refer to the torque chart in the SPECIFICATIONS section of this manual.

NOTE

New plugs may already have a sealer applied to the threads. Applying a Teflon® sealer to the threads will not adversely affect the precoating.

H-Ring Replacement

[213 LD]

H-rings are placed in the lifter bores to prevent the lifters from turning, and performing the same function as the roller tappet guide pins used with electronic unit pumps. The H-rings have an interference fit with the lifter bores in which they are installed and, under normal circumstances, are never removed.

If an unusual failure situation results in an H-ring being dislodged, it can be reinstalled or replaced with a **new** part, as required, using the following procedure:

1. Remove the affected H-ring, using remover tool J 42426 in combination with slide hammer J 6125-1B. Refer to Figure 132.

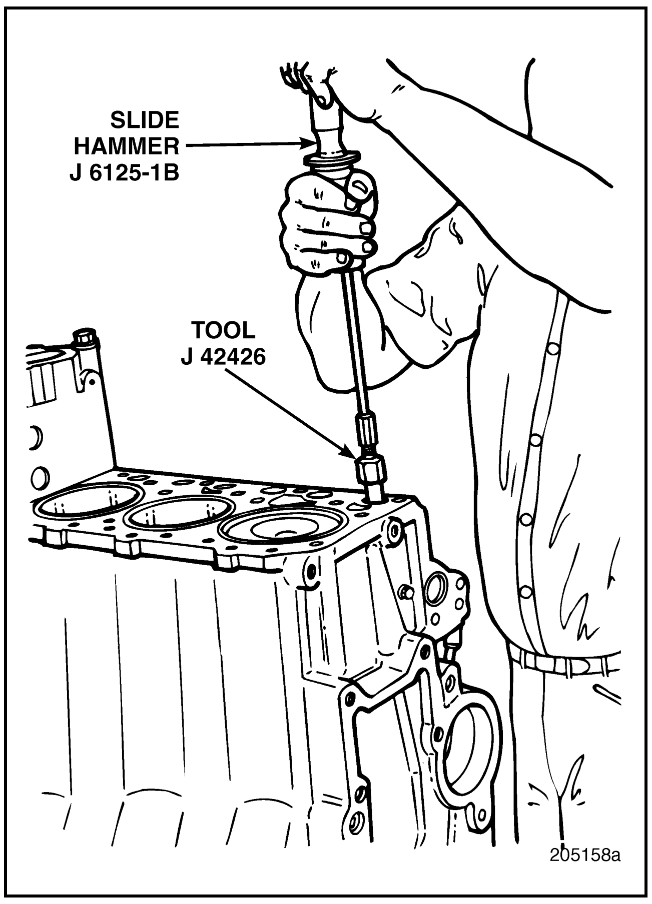


Figure 132 — H-Ring Removal

5_106_00.bk Page 144 Friday, August 4, 2000 11:17 AM

NOTE

In some cases, the H-ring remover tool may not position the collet far enough into the H-ring to provide proper engagement for removal. If this situation occurs, remove 0.375 inches (9.5 mm) of the threads by grinding or cutting them down; remove any burrs. This will allow the tool to be positioned further into the lifter bore.

2. Inspect the cylinder block lifter bore and place a **new** H-ring into the top of the bore. If a **new** H-ring is a slip-fit in the bore, the bore is oversize.
3. If the lifter bore appears OK (will support the interference fit of the H-ring), clean the bore and dislodged H-ring (or **new** H-ring, if required) with Loctite® Primer T. Then apply Loctite® RC/609 to the bore and to the H-ring outside surface.
4. Use service tool J 41683 to install the H-ring. This tool pilots into two lifter bores at the same time to properly align and install the H-ring. If the proper interference fit has been maintained, resistance should be felt as the H-ring is driven into the bore. Refer to Figure 133 and Figure 134.

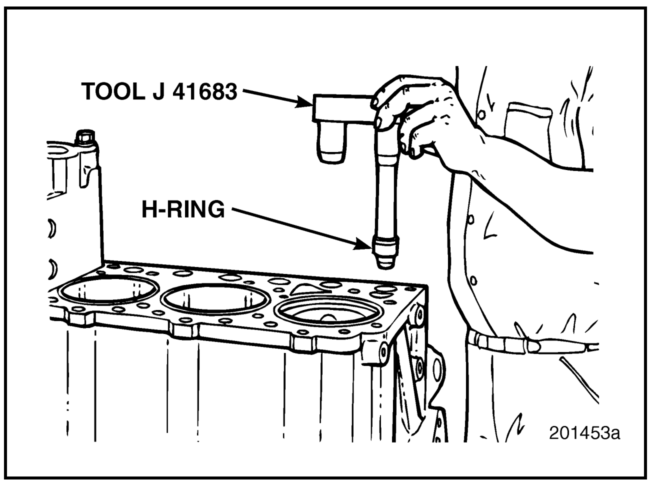


Figure 133 — H-Ring Installation Tool

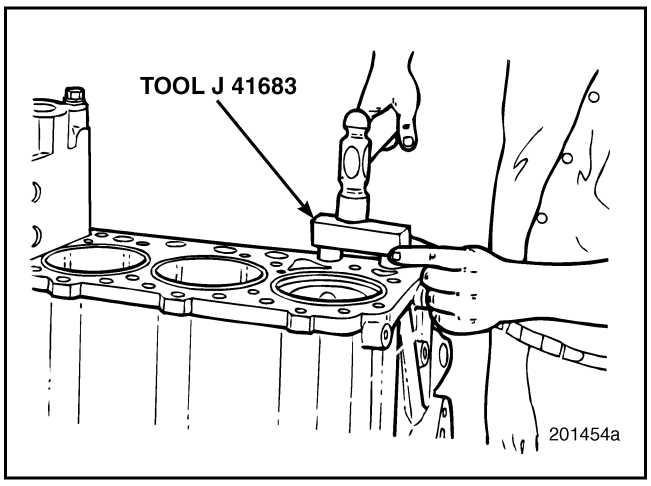


Figure 134 — H-Ring Installation

NOTE

Be sure the H-ring is installed with grooved side toward the bottom. Refer to Figure 135.

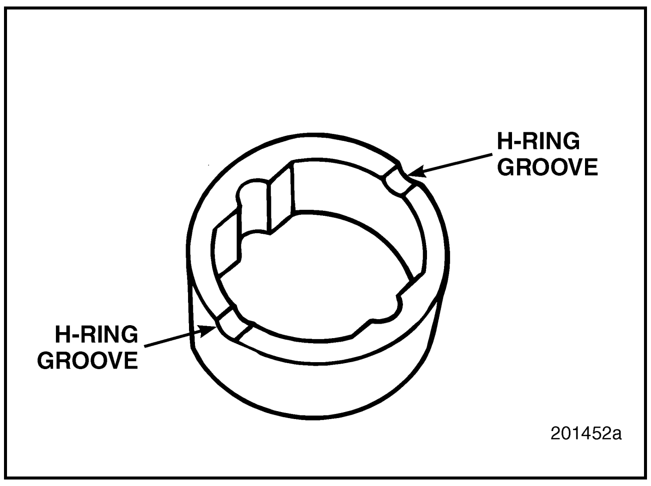


Figure 135 — H-Ring

Camshaft Bushing Replacement

[213 CC]

Typically, camshaft bushings have an extremely long service life and need not be replaced unless they are obviously damaged or worn beyond normal wear limits. However, It is good policy to replace the camshaft bushings when overhauling the engine out of chassis, even if the bushings are within acceptable wear tolerances.

REMOVAL

NOTE

Camshaft bushings are identified in sequence, 1 to 7, starting from the front of the engine.

1. Using camshaft bushing remover/installer J 42377 (with J 21428-01 Cam Bushing Installer Set) and a hammer, remove the No. 1 camshaft bushing from the cylinder block. Refer to Figure 136.

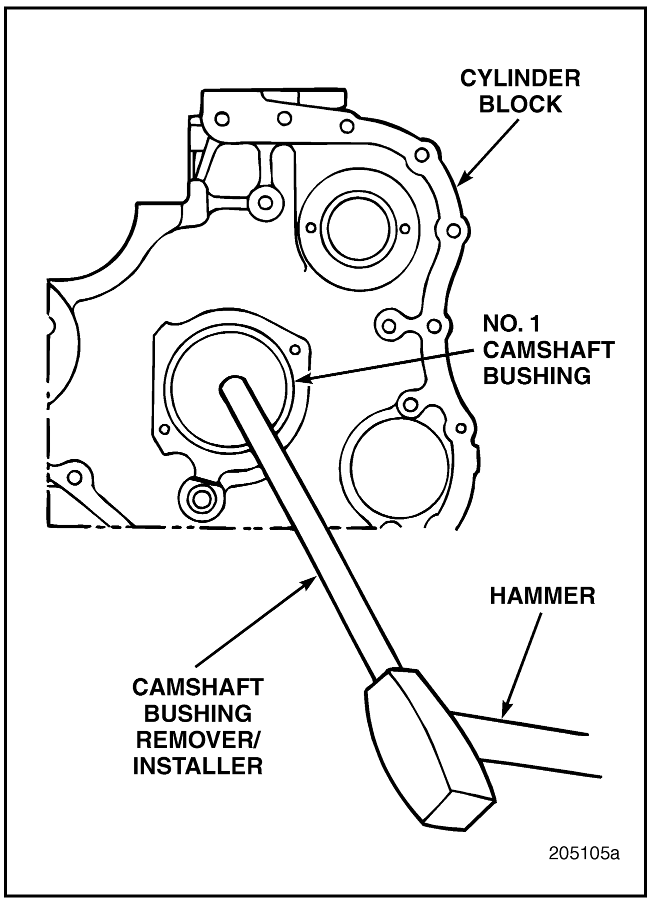


Figure 136 — Camshaft Bushing Removal

2. Remove the remaining six bushings in sequence.
3. Check the bushing bore diameters and finish in the block, using a telescoping gauge or inside micrometer.

CAMSHAFT BUSHING ALIGNMENT

Each camshaft bushing is located at set distances from the thrust washer mounting surface to the forward edge of the bushing. Refer to Figure 137.

When installed to the proper dimensions, the intermediate bushings (locations 2, 3, 5 and 6) are approximately centered in their bores, in the front-to-rear direction. The front, center and rear bushings, however, are not centered. The offsets are described as follows:

- No. 1 bushing — Installed with the front of the bushing flush, to 0.030 inch behind the front face of the bore. There is approximately 1/8-inch of the bore visible on the rear side of the bushing.
- No. 4 bushing — When installed correctly, there is approximately 0.400 inch (10 mm) of bore visible at the front face of the bushing, and approximately 0.040 inch (1 mm) of bushing protrusion from the rear of the bore.
- No. 7 bushing — When installed correctly, there is an approximate 1/8-inch wide section of bore visible at the front face of the bushing.

Installing the cam bushings to the correct dimensions optimizes bushing-to-cylinder block oil hole alignment. Even when installed to the proper dimensions, however, the No. 1 and No. 4 bushings have only approximately 1/2-to-2/3 of the oil hole in alignment with the oil hole in the bore, as 100 percent oil hole alignment is not attainable or required.

NOTE

Beginning approximately mid-December 1999, a groove, 360 degrees around the inside diameter, has been added to the camshaft bushings (part No. 57GB37). The grooved bushings can be used with either the grooved or non-grooved camshaft journals, and the camshaft with grooved journals can be used with either grooved or non-grooved bushings. Parts can be intermixed in an engine.

5_106_00.bk Page 146 Friday, August 4, 2000 11:17 AM

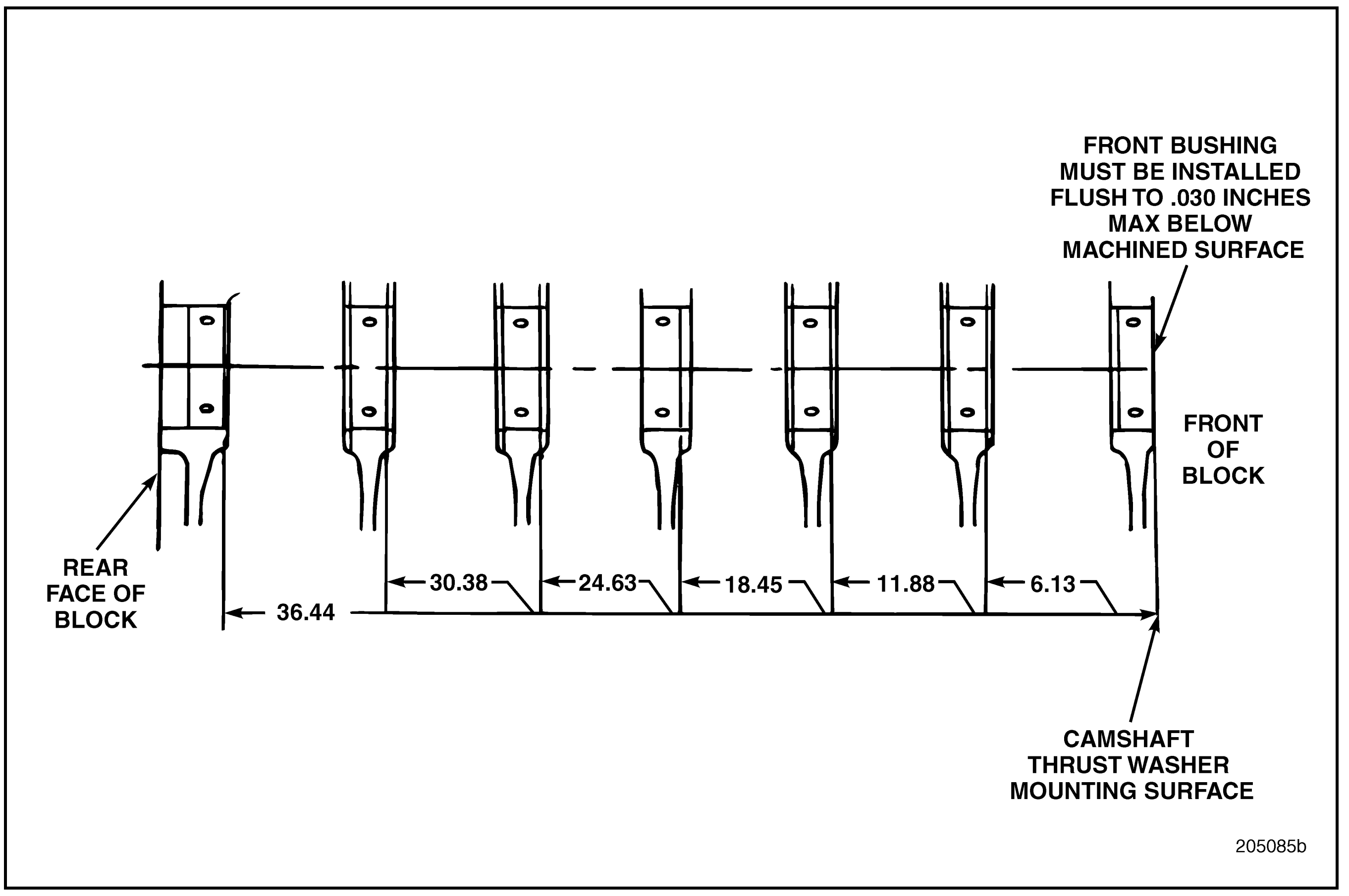


Figure 137 — Camshaft Bushing Locations

BUSHING INSTALLATION

1. Clean the surfaces of the bushing and the bore. Dry both surfaces with compressed air.
2. Using a dark-colored felt-tip marker, mark the block and bushing with a line to facilitate correct alignment at installation. Refer to Figure 138.

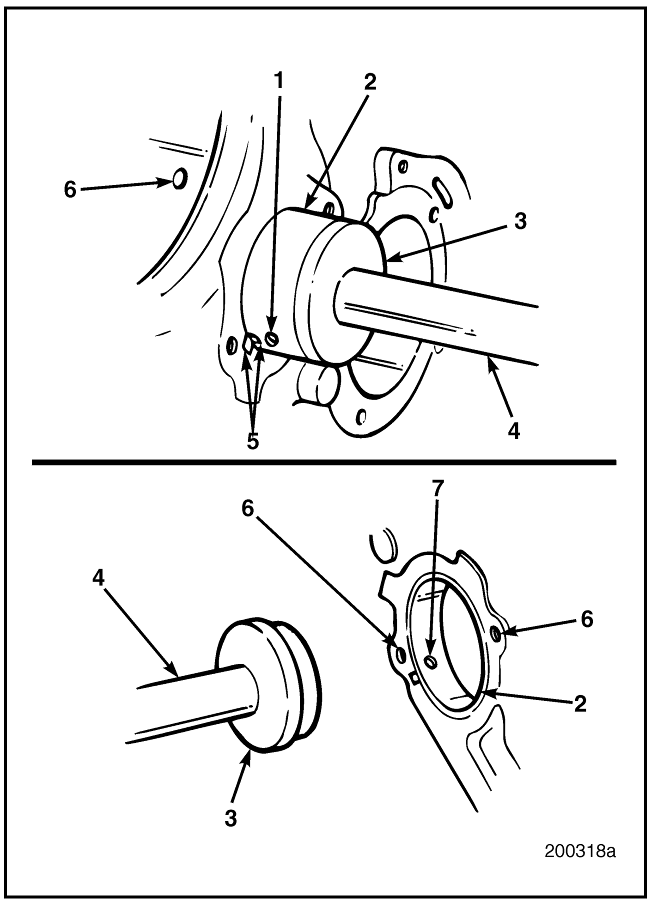


Figure 138 — Camshaft Bushing Installation

1. Bushing Oil Hole 2. Bushing 3. Pilot Adapter (J 42377) 4. Bushing Remover/ Installer (J 21428-01 Kit)	5. Alignment Mark 6. Mounting Hole 7. Block Oil Passage

3. Position the replacement bushing (2) against the side of the block at the No. 7 (rear) bushing bore. Align the oil hole in the bushing (1) with the oil passage (7) in the block.
4. Using bushing remover/installer J 42377 (with J 21428-01 Cam Bushing Installer Set), install the bushing.

CAUTION

Correct installation of each camshaft bushing is very important. If a bushing is not properly aligned with both its oil supply and oil feed passages in the cylinder block, either the camshaft bushing will fail or the components lubricated by the bushing feed will fail from inadequate lubrication.

5. Install the camshaft bushings in sequence, starting at the back of the cylinder block with No. 7 and finishing with No. 1.
6. After all the bushings are in place, measure the ID of each to ensure that they are not undersize because of burrs on the OD caused by installation (Figure 139). Refer to the Fits and Limits charts in the SPECIFICATIONS section for the correct bushing ID dimensions.

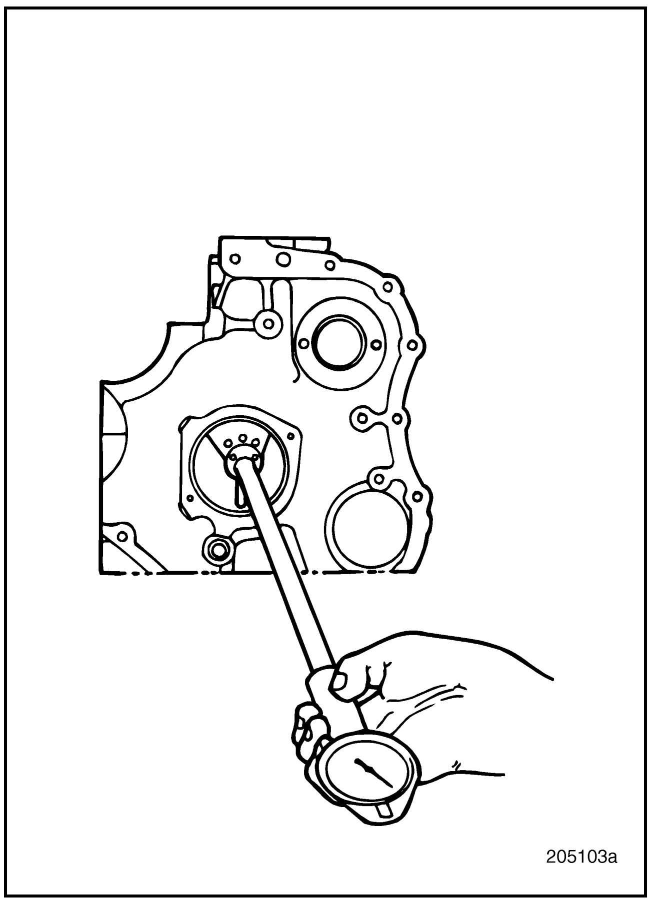


Figure 139 — Camshaft Bushing ID Check

5_106_00.bk Page 148 Friday, August 4, 2000 11:17 AM

Auxiliary Shaft Bushing Replacement

[212 CB]

The front and rear auxiliary shaft bushings are identical. Procedures for inspection and replacement are as follow:

INSPECTION

1. Using a telescope gauge or inside micrometer, measure the auxiliary bushing bores. Take two readings, perpendicular to each other, in each bore. Record the readings. Refer to Figure 140.
2. Compare the readings with tolerances listed under Fits and Limits in the SPECIFICATIONS section.

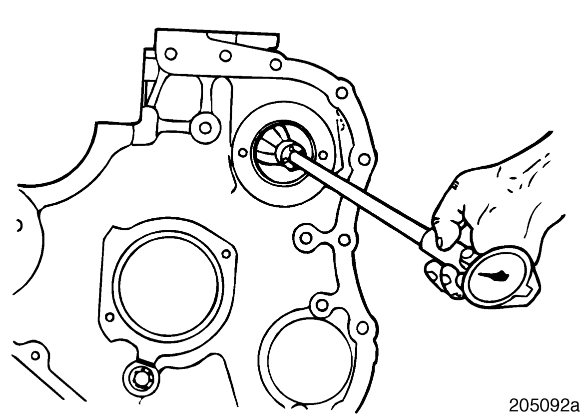


Figure 140 — Auxiliary Shaft Bushing ID Check

BUSHING REMOVAL

Use J 21428-01 to remove the bushings. If there is any indication that a bushing has turned in the block, check the bushing bore diameter with a telescoping gauge or inside micrometer.

BUSHING INSTALLATION

CAUTION

Correct installation of the auxiliary shaft bushings is very important. If the front bushing is misaligned, lubrication oil flow to the front bushing and journal will be blocked. The rear bushing does not have any cylinder block oil passage to align with the holes in the bushing. However, the oil holes in the bushing and the oil groove between those oil holes are in the most desirable location when the bushing is installed with indexing notches at the 5:30 and 10 o'clock positions.

Use care not to lose the short oil feed tube, 1.25 inches (32 mm) in length, which connects the oil feed hole in the rear of the auxiliary shaft to the oil feed hole in the front of the air compressor crankshaft. If it is accidentally lost during air compressor or auxiliary shaft service work and not reinstalled, the compressor will fail from oil starvation. Also, the loss of oil pressure resulting from the missing tube can cause damage and problems in other components and parts.

5_106_00.bk Page 149 Friday, August 4, 2000 11:17 AM

Oil hole alignment of the front bushing-to-cylinder block oil holes must be checked prior to, and at the completion of, installation. The cylinder block rear bushing bore has no oil holes to align with the bushing oil holes, so simply install the bushings with the indexing notches at the 5:30 and 10 o'clock positions. Refer to Figure 141 and Figure 142.

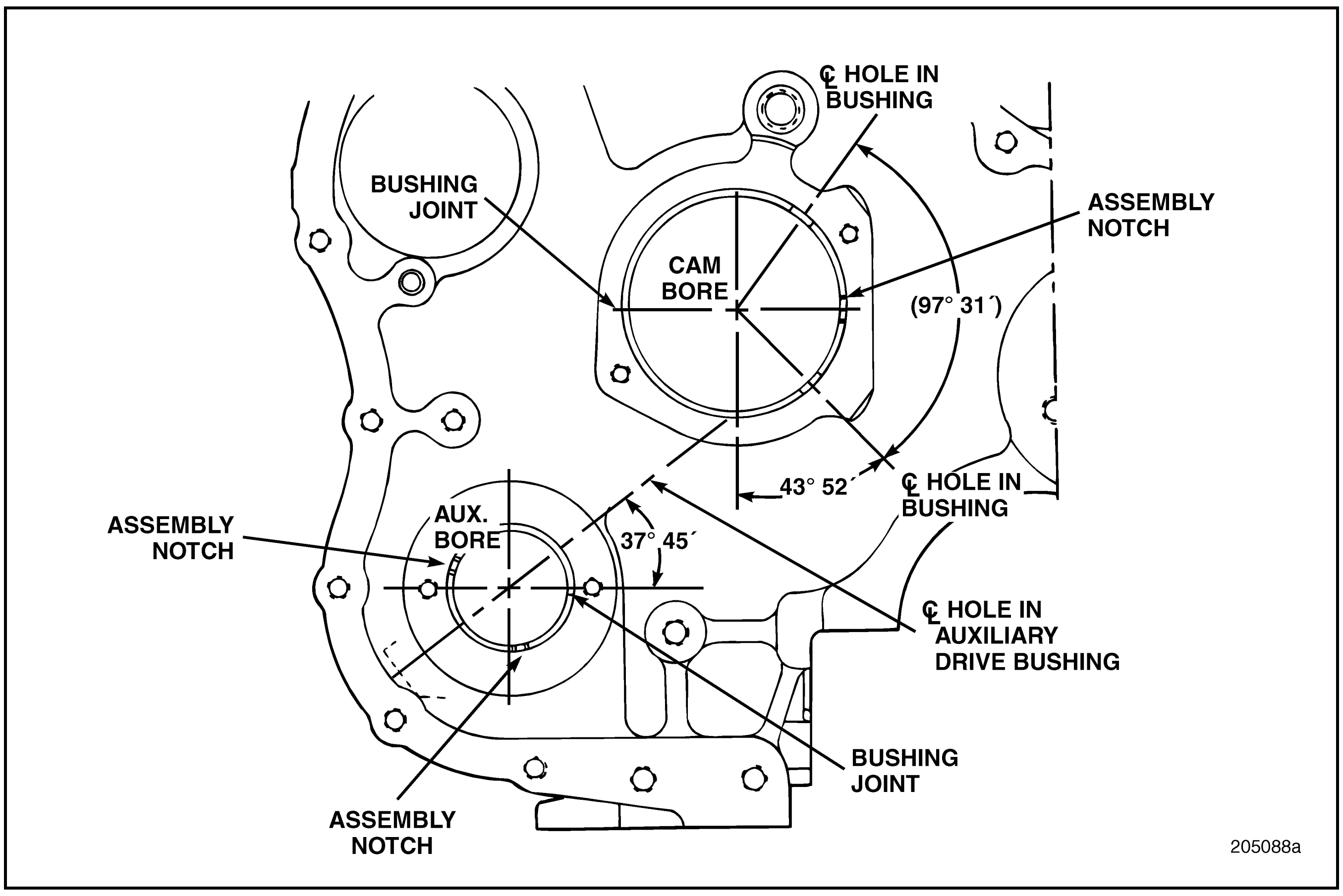


Figure 141 — Front Camshaft and Auxiliary Shaft Assembly Notch Locations

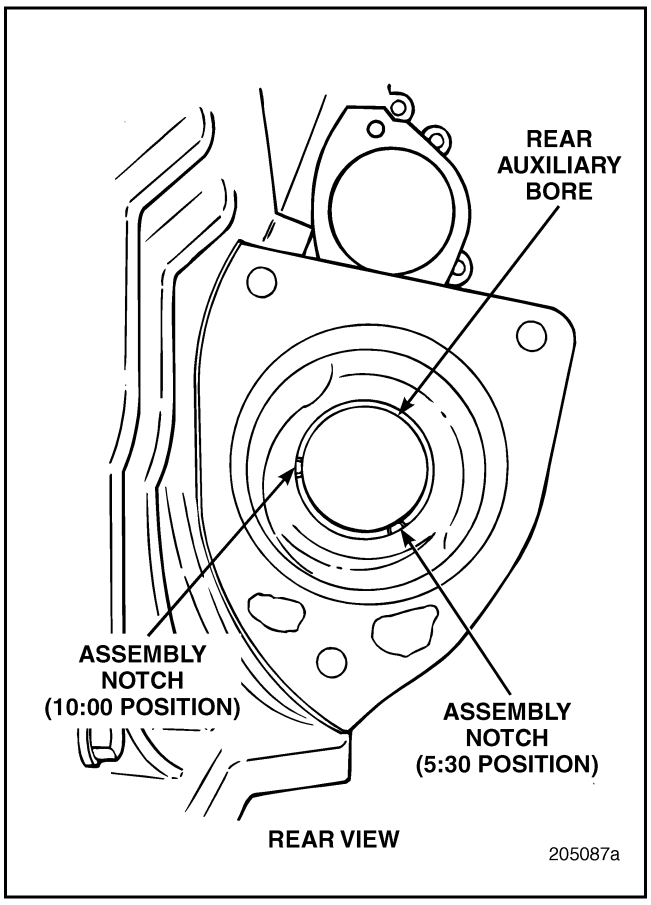


Figure 142 — Rear Auxiliary Bushing Alignment

1. Clean the surfaces of the bushing and the bore. Dry both surfaces with compressed air.
2. Using a dark-colored felt-tip marker, mark the block and the bushing with a line (1) to facilitate correct alignment during installation. Refer to Figure 143.
3. Position the replacement bushing (2) against the front face of the block at the front bushing bore. Align the oil hole in the bushing with the hole in the block.

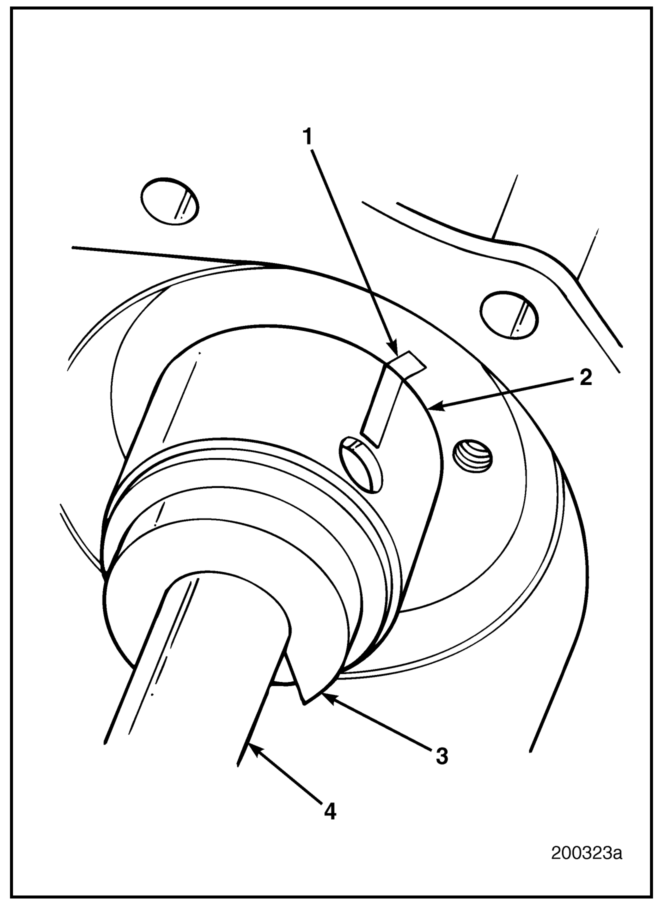


Figure 143 — Auxiliary Shaft Bushing Alignment

1. Alignment Mark 2. Bushing 3. Pilot Adapter J 37713	4. Camshaft Bushing Remover/Installer (J 21428-01 Kit)

4. Using camshaft bushing removal/installation tool J 21428-01 (4) and the appropriate pilot adapter (3), install the bushing.
5. Check the bushing surface for burrs caused by installation.
6. After the bushing is in place, measure the ID to ensure that the bushing is not undersize because of burrs on the OD caused by installation. Refer to the Fits and Limits chart in the SPECIFICATIONS section in this manual for the bushing ID dimensions.

7. Working from the front of the cylinder block, repeat steps 1 through 6 to install the front bushing.
8. Bushings must be installed to the depths described in Figure 144.

CAUTION

The front auxiliary shaft bushing must be flush or recessed within 0.030 inch (0.763 mm) of the machined front surface of the cylinder block. Incorrect recess will cause misalignment of the oil supply hole, resulting in insufficient lubrication of the journal. Also, any bushing protrusion will allow the thrust washer to seat on the bushing and result in the thrust washer mounting screws coming loose.

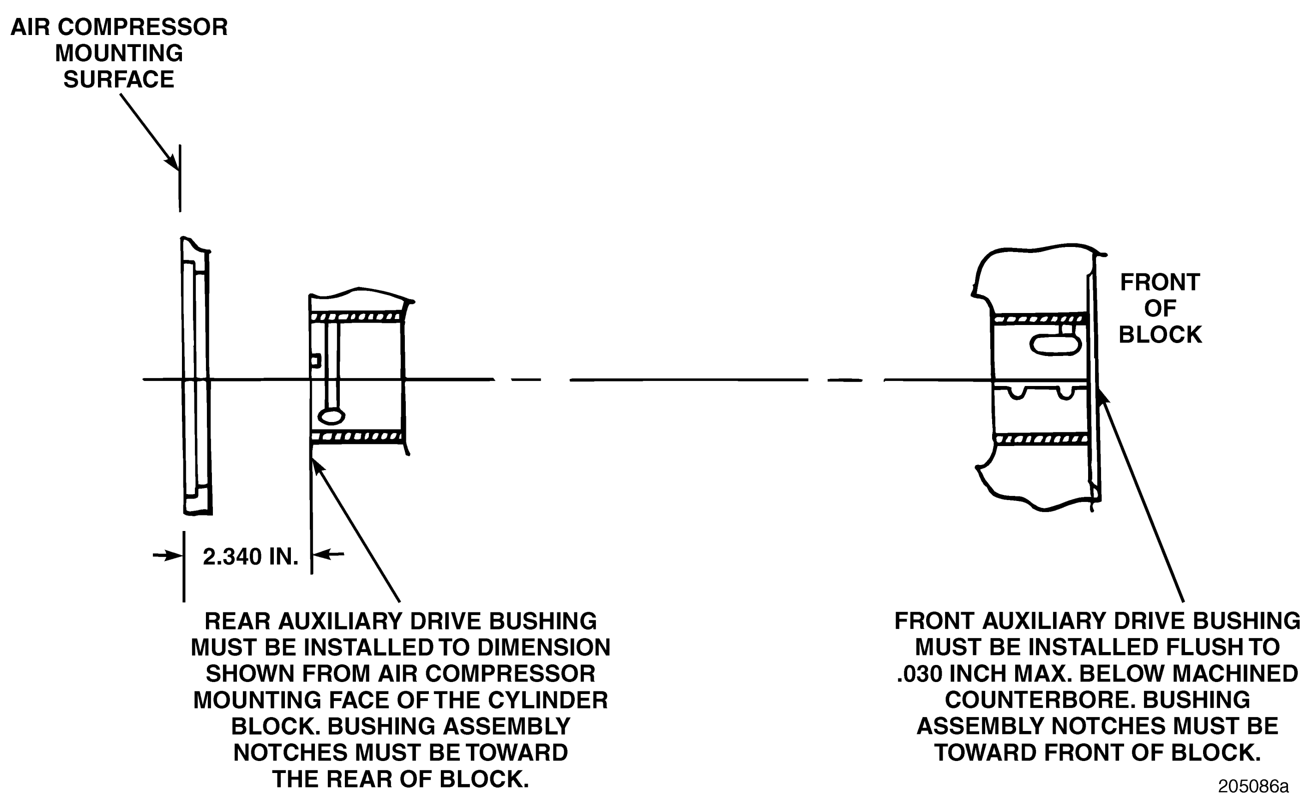


Figure 144 — Auxiliary Bushing Installation Dimensions

9. Install the thrust washer and tighten the retaining screws to the specified torque, 15 lb-ft (20 N•m).

Cylinder Sleeve Installation

[212 NC]

GENERAL INFORMATION

The cylinder sleeves are a wet-dry design made of centrifugally cast alloyed iron. Working with the pistons, piston rings, cylinder heads and cylinder head gaskets, the sleeves provide a seal against combustion pressure. The sleeves also transfer combustion heat to the engine coolant and guide piston travel. Correct extension of the sleeve flange above the top deck and uniform cylinder block counterbore are essential for satisfactory sleeve service life and head gasket seal.

NOTE

With early engine production, a crevice seal, similar to an O-ring, was installed in the groove located in the outside diameter of the cylinder sleeve, near the sleeve top. It has been determined, however, that the crevice seal is not necessary. Therefore, effective approximately December 1998, the crevice seal is no longer used in production engines. Additionally, effective January 1999, the crevice seal groove in the cylinder sleeve has been eliminated.

Effective with these production changes, cylinder sleeve part Nos. 509GC463 and 509GC466 for service use will not have the crevice seal groove, and it is recommended that use of the crevice seal be discontinued in all engine repairs or rebuilds whether or not the liner has a crevice seal groove.

SPECIAL TOOLS REQUIRED

- Depth Gauge J 26948
- Dial Bore Gauge J 5347-B
- Cylinder Hone and Glaze Breaker J 5902-01

INSTALLATION PROCEDURE

Refer to Figure 145.

1. Thoroughly clean and dry the prepared cylinder block (4), counterbore ledge (3) and cylinder sleeves (1). Refer to the cylinder block cleaning and inspection procedures in this section.
2. If the counterbore ledge (3) has been cut, place the shims (2) on the cylinder block counterbore ledge. Use the fewest number of shims required to achieve the proper cylinder sleeve flange height. Always place the thickest shim on the bottom.

NOTE

If shims are used, apply RTV silicone on top of the shims only. If RTV is applied under the shims, the shims may be displaced when the sleeve is installed

3. Apply approximately a 0.120–0.160-inch (3.048–4.064-mm) bead of RTV silicone (MACK Silastic® 342SX32, Dow Corning Silastic® RTV732 or General Electric RTV130) on the cylinder block sleeve seat and completely around the cylinder wall as shown in Figure 145. Do not use excessive amounts of RTV. Do not apply more than a 0.160-inch bead.

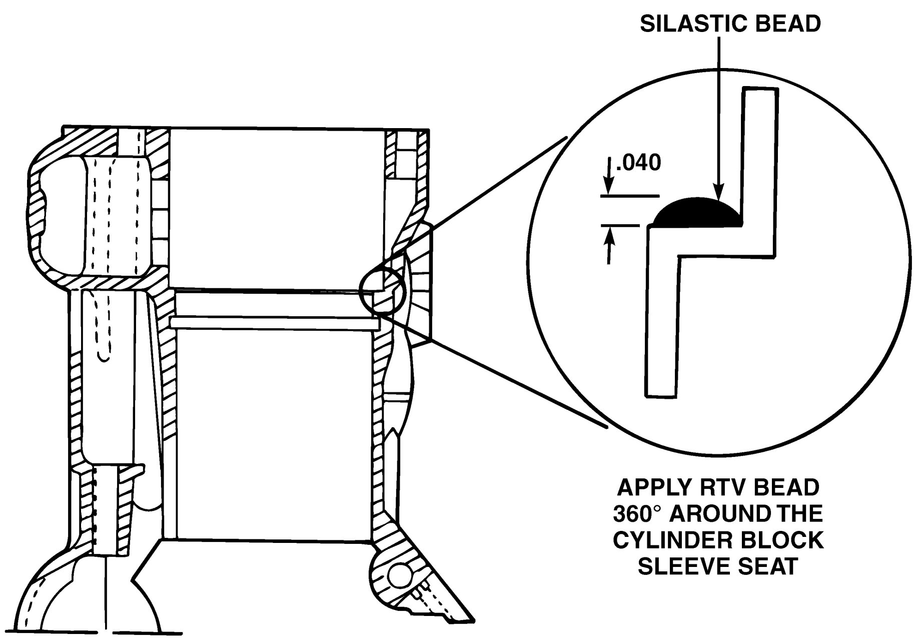


Figure 145 — Cylinder Block Sleeve Seat

NOTE

Applying a Silastic® bead is now standard assembly procedure whenever cylinder sleeves are installed.

To prevent partial curing and questionable sealing and bonding, apply Silastic® just before installing the sleeves.

CAUTION

The cylinder block counterbore ledge and the cylinder sleeve must be kept clean and free of any oil residue to ensure that the Silastic® bead seals and bonds properly.

4. Position the cylinder sleeve (1) in the cylinder bore.
5. With the palms of the hands placed on the upper end of the cylinder sleeve 180 degrees apart, push downward with a quick, even pressure. Then, using a large plastic-faced hammer, tap the sleeve close to the inside diameter to fully seat the sleeve. Tap alternately from one side to the other, gradually working around the entire circumference of the sleeve.

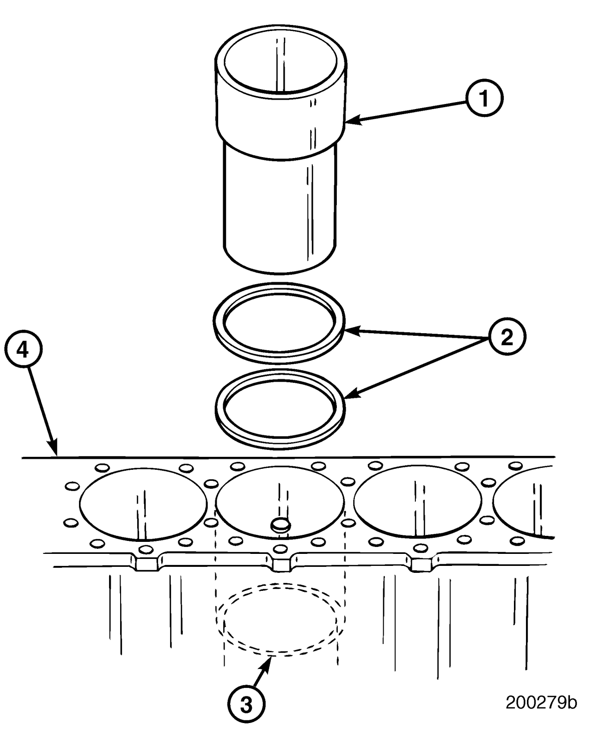


Figure 146 — Sleeve Installation

1. Sleeve 2. Shims (as Required)	3. Counterbore Ledge 4. Cylinder Block

NOTE

Clean any RTV from around the bottom of the cylinder sleeve and the block which may have been pressed out from the sealing surfaces of the block and sleeve during installation.

6. After the cylinder sleeve is fully seated, use depth gauge J 26948, or equivalent, to check the flange height-above-deck dimensions. The specified dimension is 0.023–0.029 inch (0.584–0.737 mm). The measurement should be taken in the channel between the sleeve top lip (fire dam) and the coining bead. Refer to Figure 147.

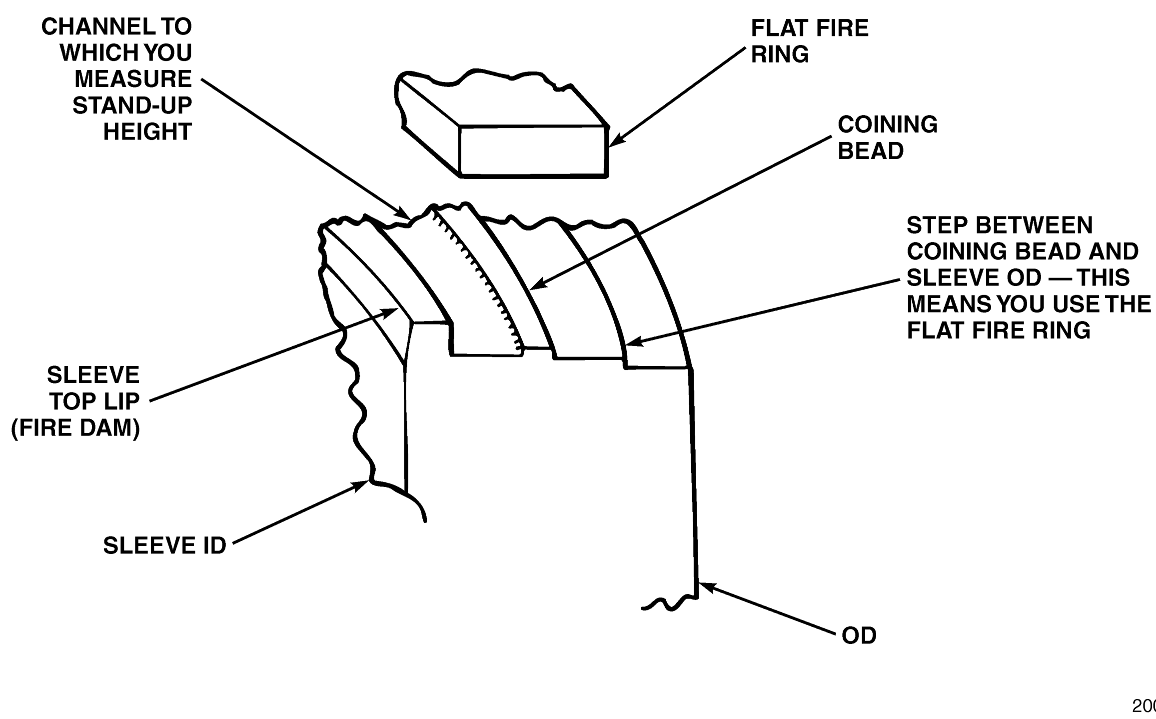


Figure 147 — Cylinder Sleeve/Fire Ring Configuration

NOTE

The height of the cylinder sleeves above the cylinder block deck (under the same cylinder head) can vary as long as all are within the 0.023–0.029-inch (0.584–0.737-mm) specification.

7. Using dial bore gauge J 5347-B, or equivalent, check the cylinder sleeve for out-of-round and taper limit (Figure 148). Take readings in two directions, 90 degrees apart, at each of three levels.

   Cylinder sleeve ID maximum: 4.877 inches (123.876 mm).

   Cylinder sleeve ID minimum: 4.875 inches (123.825 mm). The cylinder sleeve ID may be a minimum 4.872 inches (123.749 mm) due to close-in from press fit.

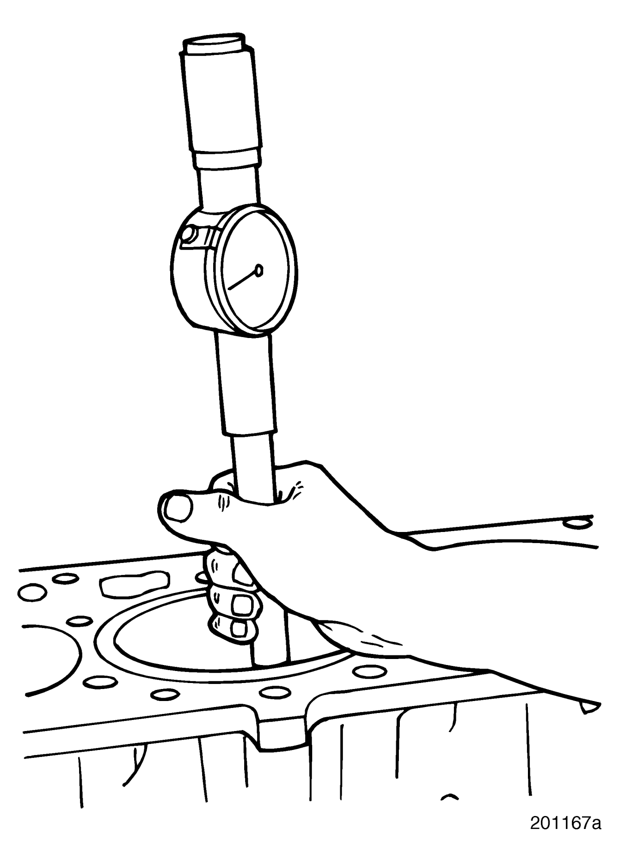


Figure 148 — Checking Cylinder Sleeve for Out-of-Round or Taper

HONING THE CYLINDER SLEEVE BORE

CAUTION

All MACK engines currently produced have fine precision-finished cylinder sleeves. Because of the precision finish, honing is NOT recommended. Particles from the honing process which become wedged in the pattern are impossible to completely remove and can cause further damage.

5_106_00.bk Page 157 Friday, August 4, 2000 11:17 AM

Piston Cooling Spray Nozzle Installation

[219 RV]

SPECIAL TOOL REQUIRED

- Two-Piece Piston Cooling Nozzle Aimer
  J 39045

INSTALLATION PROCEDURE

Refer to Figure 149.

1. Using a liberal amount of lubricant, install the elastomer sleeve (7) on the locator tube (6).
2. Install a retaining screw (4) in the spray nozzle bracket (3).
3. Position the spray nozzle locator tube (6) in the cylinder block oil passage (2) and using torque wrench J 24406, or equivalent, tighten the retaining screw to the specified torque, 15 lb-ft (20 N•m).

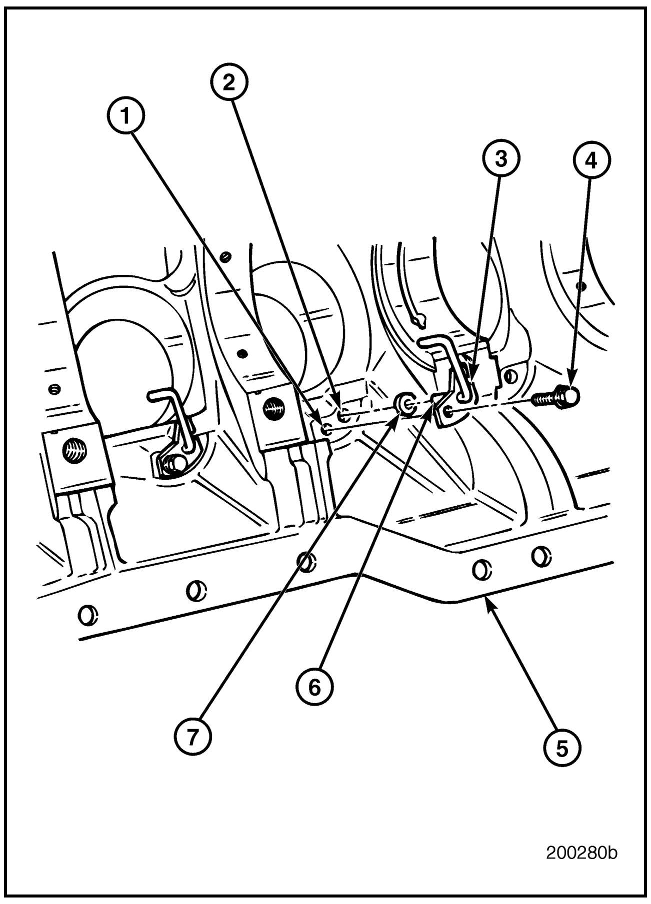


Figure 149 — Spray Nozzle Installation

1. Threaded Hole	5. Cylinder Block
2. Oil Passage	6. Locator Tube
3. Spray Nozzle Bracket	7. Elastomer Sleeve
4. Retaining Screw	

5_106_00.bk Page 158 Friday, August 4, 2000 11:17 AM

PISTON COOLING NOZZLE SPRAY POSITIONING

Refer to Figure 150.

The piston cooling oil spray target location on the underside of the piston is important. It ensures adequate dissipation of heat from the piston. Correct positioning of the nozzles also ensures that the crankshaft counterweights do not strike the nozzles.

SERVICE HINT

For ease of installation and to reduce the amount of crankshaft rotation needed to facilitate access to the spray nozzles, install the spray nozzles in the following set order: cylinders 1 and 6, 5 and 2, 3 and 4.

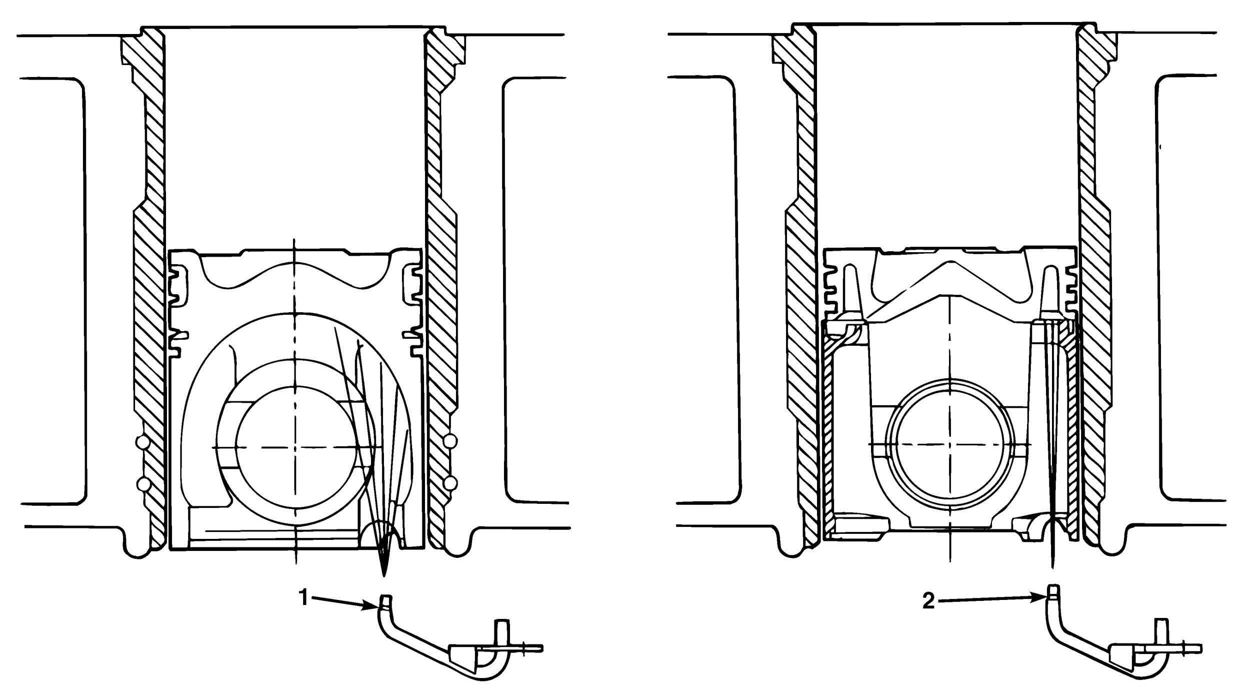


Figure 150 — Spray Nozzle Patterns

1. Old Pattern (E7 Engine with Aluminum Pistons, Prior to 1991)	2. New Pattern (E-Tech™ and E7 Engines with Two-Piece Pistons, 1991 and Later)

Using piston cooling nozzle spray position set J 39045 (1991 and later), check the direction of the spray from the nozzles. Refer to Figure 151.

1. Position rod (6) in the end of the spray nozzle (7).
2. Place the applicable plastic target (1) on the cylinder block (2) over the cylinder to be tested.
3. Install a cylinder head bolt through the target alignment hole (3) and into the cylinder block capscrew hole (4) to align the target.

4. The rod (6) should now be aligned in the target area (5). If the rod is at the edge of the target area, center the rod in the target area as follows:
   a. Loosen the nozzle setscrew. A slight adjustment can then be made to center the rod within the target area.
   b. Following adjustment, tighten the setscrew to the specified torque, 15 lb-ft (20 N•m).

CAUTION

Always replace a badly deformed spray nozzle. Do not attempt to realign it. Precise targeting is necessary to adequately cool the piston crown.

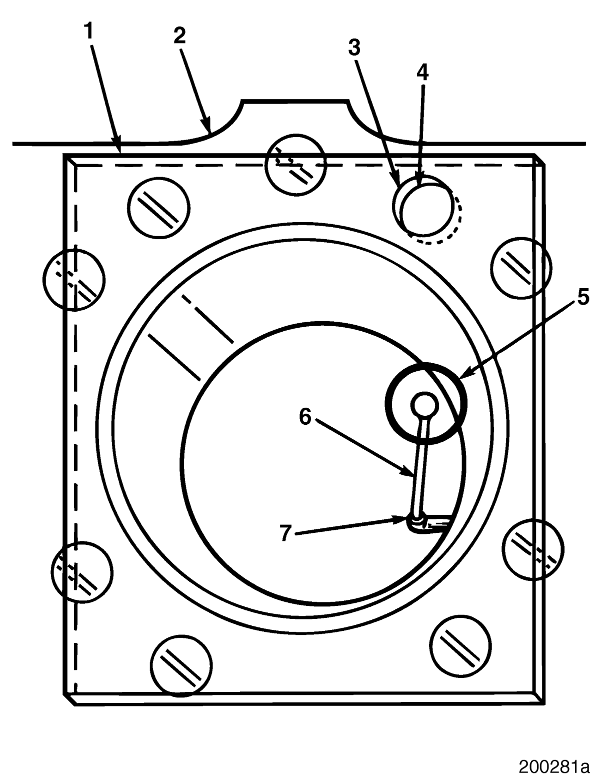


Figure 151 — Spray Nozzle Targeting

1. Plastic Target 2. Cylinder Block 3. Alignment Hole 4. Cylinder Block Hole	5. Target Area 6. Rod 7. Spray Nozzle

Cylinder Block Dowel Pin Replacement

[211 HA]

GENERAL INFORMATION

The E-Tech™ engine uses precision-made round-type and blade-type locating dowel pins for alignment of the front cover and flywheel housing. A blade-type pin is used for alignment of the flywheel.

SPECIAL TOOL REQUIRED

- Flywheel Housing/Timing (Front) Cover Locating Pin Driver J 37712

REMOVAL

If it is necessary to remove the front cover or flywheel housing locating dowel pins, do so as follows:

1. Securely clamp the pin with a pair of locking pliers.
2. While exerting an outward force, rotate the pin back and forth until the pin works free from the hole.

INSTALLATION

Two dowel pins are used to locate the flywheel housing to the cylinder block. One dowel is round, the other is a blade type. One end of the blade-type pin is also round and is the end installed in cylinder block.

NOTE

The dowels used for the front cover installation are similar except for the size. The smaller dowels are used for the front cover. The larger dowels are used for the flywheel housing.

ROUND DOWEL PIN INSTALLATION

Refer to Figure 152.

1. Insert the round dowel pin (2) into the flywheel housing/front cover locating pin driver J 37712 (1). The pin must be positioned in the driver with the tapered end of the dowel facing outward.
2. Position the exposed end of the dowel into the left dowel pin hole (4) in the cylinder block (3).
3. Using a hammer, drive the pin into the block until the driver contacts the cylinder block. When the driver has made contact with the block, the dowel pin will be at the correct dimension above the block surface.

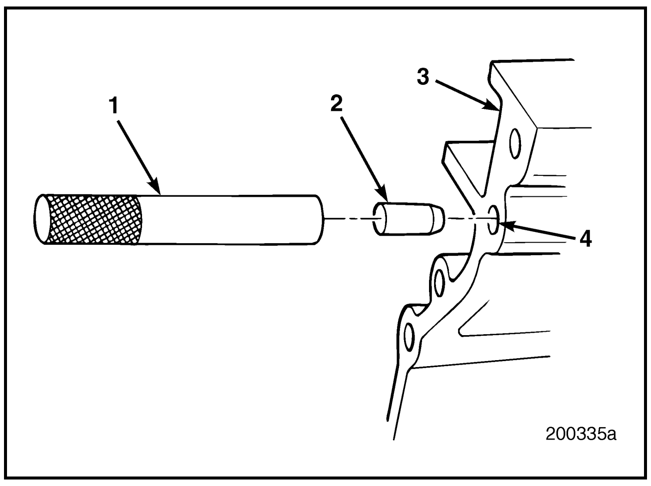


Figure 152 — Round Dowel Pin Installation

1. Locating Pin Driver 2. Round Dowel Pin	3. Cylinder Block 4. Dowel Pin Hole

BLADE-TYPE DOWEL PIN INSTALLATION

1. Position the round end of the blade-type dowel pin into the dowel pin hole in the cylinder block. The blade end must be aligned vertically (up and down) with the block.
2. Using a hammer, drive the dowel pin into the block until the shoulder of the pin is flush with the cylinder block surface.

CRANKSHAFT AND FLYWHEEL BENCH PROCEDURES

General Information

Initially, flywheels used with E-Tech™ engines have six timing grooves milled into the face surface for standardization with the E7 PLN engines. However, the grooves are not required for E-Tech™ engines and are eliminated on current-production flywheels.

Crankshaft Inspection

[212 HP]

GENERAL INSTRUCTIONS

NOTE

All bearing surfaces must be free of grit and burrs. Small particles of dust and dirt left between the crankshaft and bearings will cause rapid wear and scoring of the crankshaft journal and inserts. Any foreign material left between the crankshaft bearing inserts and caps will cause distortion of the insert and a reduction in operating clearance at that point. The resulting frictional heat at the point of distortion will cause the bearing material to melt away from steel backing of the bearing. Such melted material will create further hot spots until complete bearing failure occurs. Anything that interferes with the operating clearance of any bearing and proper heat dissipation affects bearing life. Cleanliness cannot be overstressed.

INSPECTION

1. Inspect the crankshaft journals for out of round, taper and poor surface finish.
2. Visually check the crankshaft for any apparent cracks, worn journals and damage to threads, dowel pin or main drive gear.
3. Magnaflux the crankshaft to check further for cracks. This process requires special equipment and application methods.
4. Using standard machinists’ inspection practice, check the crankshaft to ensure it is straight.
5. Measure the crankshaft journals with a micrometer. Measure each journal in two locations, 90 degrees apart, and record the measurements.
6. Check the measurements against specifications listed under Fits and Limits in the SPECIFICATIONS section.
7. If the crankshaft journals are worn, out of round, or tapered, replace the crankshaft. New or exchange crankshafts are available from MACK Parts Distribution Centers.

CAUTION

Crankshaft regrinding by anyone other than Mack Trucks, Inc. is NOT recommended due to the tight control required on maintaining geometrical tolerances, and the hardened characteristics of crankshaft journals and journal fillets.

If crankshaft main journals or connecting rod journals are not a standard size, be sure to use properly sized bearing inserts when reassembling the engine. Bearing insert sizing is identified with a “P” following the part number, and is stamped on the back side of the bearing insert. For example, if a journal is 0.010 inch (0.254 mm) undersize, a 0.010-inch undersize bearing is required and will be stamped “P10.”

CAUTION

Some crankshafts may have journals which are 0.002 inch (0.0508 mm) undersize. These crankshafts are marked by a streak of white paint adjacent to the journal. Always check the journals to ensure using bearing inserts of the proper size.

Crankshaft Dowel Pin Replacement [212 HA]

All E-Tech™ engine crankshafts are equipped with a blade-type flywheel-to-crankshaft dowel pin installed in the rear flange directly opposite the manufacturing locator hole. Hole sizes are as follows:

Manufacturing locator hole — approximately 1/2 inch (12.7 mm) in diameter and 3/8 inch (9.52 mm) deep; used in the manufacturing process

Flywheel dowel pin hole — approximately 9/16 inch (14.29 mm) in diameter by 7/8 inch (22.23 mm) deep

All **new** service replacement crankshafts, short blocks or basic engines will have a dowel pin in the crankshaft rear flange. In nearly all cases, the flywheel will already have a hole in it to accept the dowel pin. If an earlier version flywheel or torque converter drive flange without a dowel pin hole is used for replacement, it must be reworked.

If it is necessary to rework the flywheel or torque converter drive flange, two holes must be added using a 19/32-inch drill bit. One hole is for the dowel pin and another directly opposite the first hole is to maintain balance of the flywheel/torque converter drive flange.

Refer to Figure 153.

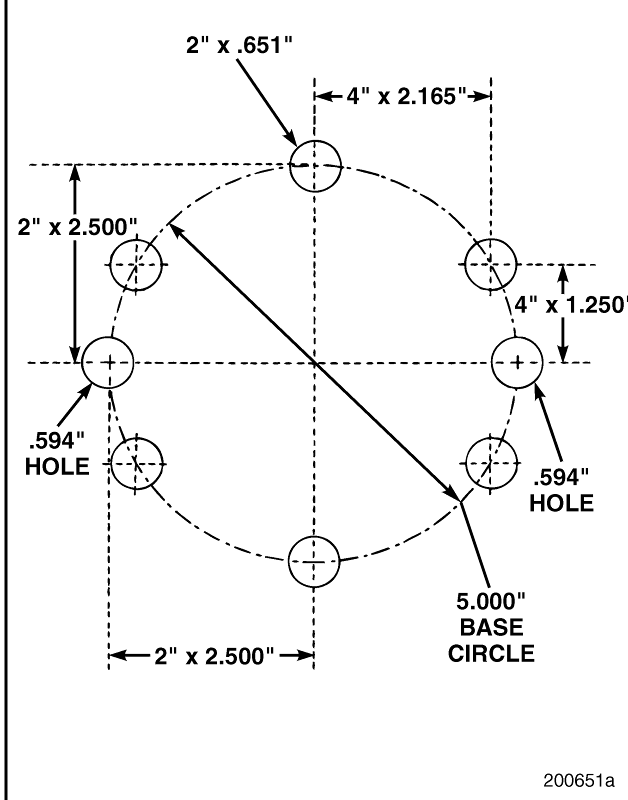


Figure 153 — Dowel Pin Hole Dimensions (Flywheel or Torque Converter Drive Flange)

DOWEL PIN REMOVAL

To remove the crankshaft dowel pin:

1. Securely grip the dowel pin with locking pliers.
2. Rotate the dowel pin back and forth while exerting outward pressure until the pin is removed.

DOWEL PIN INSTALLATION

To install a replacement crankshaft dowel pin:

1. Position the dowel pin in a 0.5562-inch (14.1275-mm) diameter unthreaded hole in the rear flange of the crankshaft. The pin must be installed with the flat surface aligned parallel to the center of the crankshaft as shown in Figure 154.
2. Use a soft metal hammer and punch to drive the pin into the hole. The pin must be firmly seated and protrude 0.77 inch (19.56 mm) from the crankshaft.

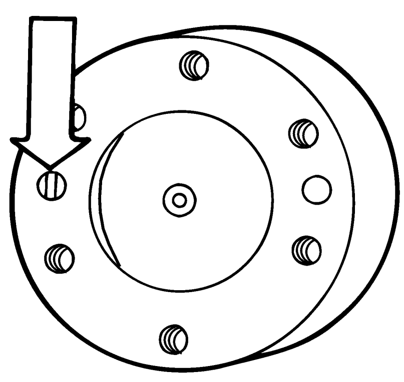


Figure 154 — Dowel Pin Alignment

Crankshaft Gear Replacement [212 HV]

INSPECTION

After inspecting the crankshaft and determining that it is within specification, inspect the crankshaft gear for cracks and broken, worn or chipped teeth. If the gear is defective, it must be replaced.

REPLACEMENT

Refer to Figure 155.

1. Using a suitable puller, such as J 21834-4A, or equivalent, remove the gear and key.

NOTE

The threads in the end of the crankshaft are M8 x 1.25.

2. Clean the gear mounting surface. It should be free of grooves, scratches and burrs. Use a file, sandpaper or crocus cloth, as required.

CAUTION

Take care not to damage the key slot while installing the key.

3. Insert the key (4) into the key slot (3). Lightly tap the key with a soft metal hammer to seat it in the slot.
4. Heat the replacement gear (1) to approximately 250°F (121°C) in a temperature-controlled oven or on a hot plate.

CAUTION

Wear protective gloves when handling the heated crankshaft gear to prevent burns or personal injury.

CAUTION

Take care not to damage the gear teeth while seating the gear.

5_106_00.bk Page 164 Friday, August 4, 2000 11:17 AM

5. Position the gear over the end of the crankshaft (2) with the timing mark facing outward, the chamfer (6) toward the rear of the shaft, and the key slot aligned with key in the shaft.
6. In one rapid motion, push the heated gear against the flange (5). With the gear properly positioned, immediately and carefully tap the gear to help seat it against the flange.

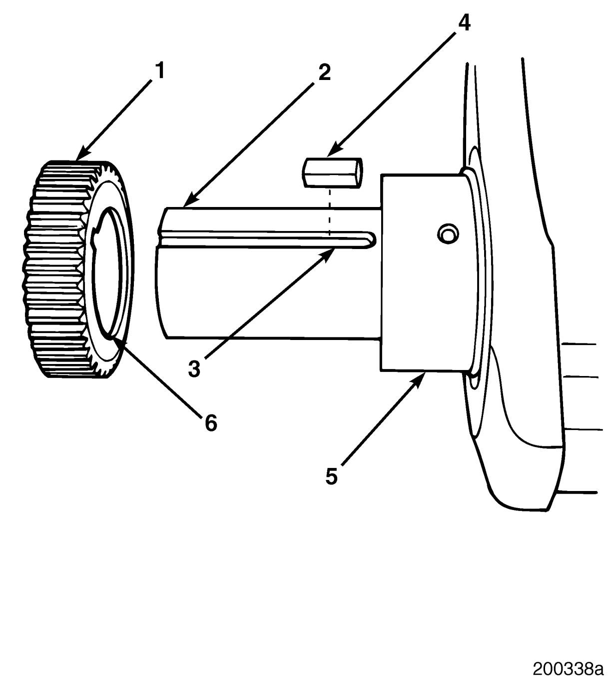


Figure 155 — Drive Gear Installation

1. Gear 2. Shaft 3. Key Slot	4. Key 5. Flange 6. Chamfer

Crankshaft Wear Ring Installation [212 JH]

When the service oil seal is to be replaced and the crankshaft flange is worn, the crankshaft can be salvaged by installing a crankshaft wear ring. An oil seal with a larger inside diameter is used with this wear ring.

SPECIAL TOOLS REQUIRED

- Crankshaft Rear Seal Installer J 37716-A
- Wear Ring Installer J 38880
- Universal Driver Handle J 8092

REMOVAL

CAUTION

A limited number of crankshafts were manufactured with a repair sleeve installed on the flange. The repair sleeve is usually not noticeable and is finish ground to standard flange size. If the repair sleeve is damaged or becomes loose, the crankshaft must be replaced.

Special care must be taken not to damage the crankshaft flange during wear ring removal.

Refer to Figure 156.

1. The wear ring can be removed by carefully applying heat, using a ball-peen hammer to expand the diameter, or by using a chisel to split the wear ring. Use extreme care not to damage the crankshaft flange.

CAUTION

Place the chisel face squarely on the wear ring and carefully strike the chisel with a hammer to cut part-way through the ring. The wear ring will loosen enough to be removed without cutting completely through it. The goal is to carefully remove the wear ring in this manner and not cut, nick or damage the crankshaft flange.

5_106_00.bk Page 165 Friday, August 4, 2000 11:17 AM

2. Thoroughly clean the flange area of the crankshaft. Check for nicks or scratches and repair any damaged areas with crocus cloth as necessary.

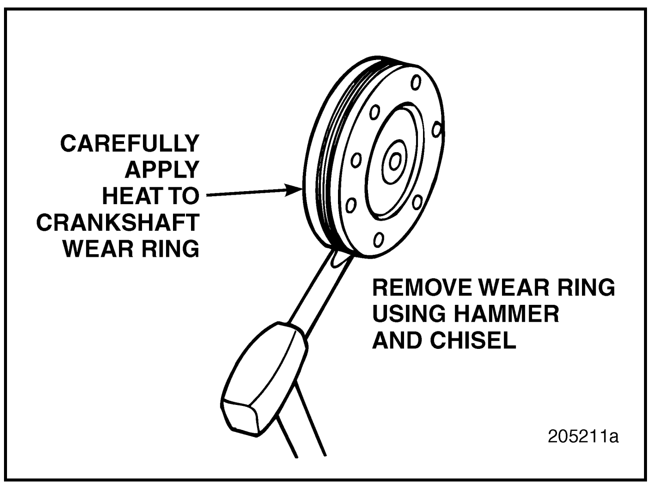


Figure 156 — Crankshaft Wear Ring Removal

INSTALLATION

Refer to Figure 157.

⚠ CAUTION

On some wear rings it may be difficult to determine the direction of the arrow on the inside diameter. In this case, ensure proper installation by installing the wear ring with the chamfer on the inside diameter toward the engine. The chamfer on the outside diameter of the wear ring must face away from the engine.

NOTE

The crankshaft wear ring is a shrink fit on the crankshaft flange. Use wear ring installer J 38880 and universal driver handle J 8092 to install the ring to the proper depth.

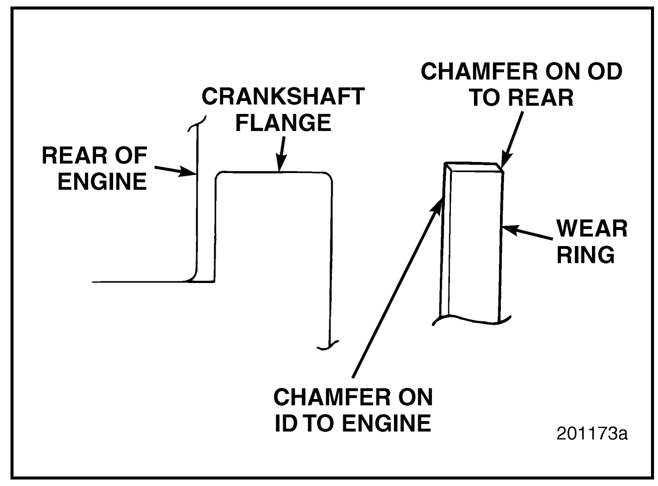


Figure 157 — Proper Crankshaft Wear Ring Installation

1. Position the wear ring in the spring clips of the wear ring installer J 38880 with the arrow pointing away from the installer tool. Refer to Figure 158.

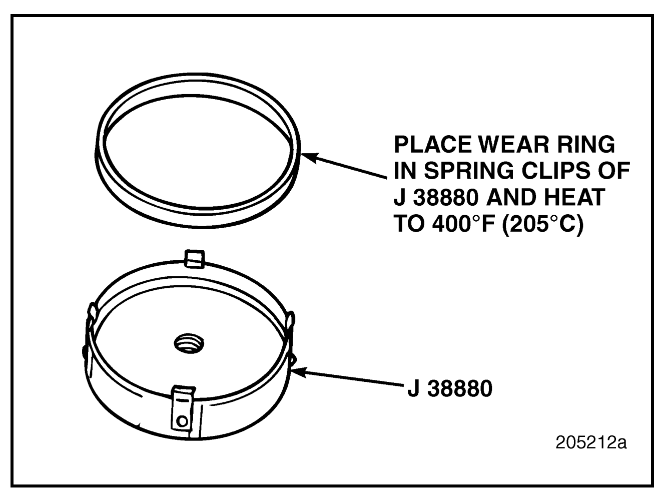


Figure 158 — Crankshaft Wear Ring Installation

2. Heat the wear ring and wear ring installer together in a temperature-controlled oven or on a hotplate, with the wear ring on the bottom and installed in the spring clips of the installer. Work as close as possible to the engine to avoid heat loss after heating the ring. Heat to 400°F (205°C). Do not install the driver handle at this time. This allows the wear ring to maintain sufficient heat until it is fully installed on the flange.

CAUTION

Do not heat the wear ring with a torch. This type of heat source will not heat the ring evenly.

3. Thoroughly clean and dry the crankshaft oil seal mounting flange.
4. After the wear ring is sufficiently heated, use heat-resistant gloves to install the universal driver handle J 8092 into the threaded hole in the center of the installation tool.
5. Remove the wear ring and installation tool from the oven or hot plate and immediately place in position on the crankshaft flange. Push the wear ring onto the flange until the installation tool is fully seated against the end of the flange. As the wear ring cools, it will shrink-fit onto the crankshaft flange.
6. Allow the wear ring to cool completely. Then remove the installation tool.

WEAR RING WITH DOUBLE-LIP TEFLON® SEAL (AUTOMATIC TRANSMISSION)

The oversize inside diameter lip seal and wear ring are shipped as an assembly with the seal installed on the wear ring. For this combination, the seal and the wear ring are installed as an assembly. Refer to the crankshaft rear oil seal installation procedures under Engine Reassembly in the REPAIR INSTRUCTIONS section.

5_106_00.bk Page 167 Friday, August 4, 2000 11:17 AM

Flywheel Inspection and Resurfacing

[212 UB]

The flywheel is a design with an integral, non-replaceable ring gear. If the ring gear teeth are in good condition, the flywheel surface should be checked as follows:

1. Inspect the flywheel to determine if it requires resurfacing. The wear areas should be measured using a straightedge across the friction face and a thickness gauge. If the wear measurement is 0.020 inch (0.508 mm) or less, the flywheel does NOT need to be machined when operated against ceramic clutch facings.
2. Resurface the flywheel as required. To ensure satisfactory service life, the maximum amount of material that may be removed from the flywheel surface is 0.070 inch (1.78 mm).

NOTE

When resurfacing a flat-style flywheel, it is very important that the machine shop NOT leave a step on the friction face outer diameter adjacent to the clutch locating pilot. There is an undercut relief in the corner between the friction face and the clutch locating pilot, and resurfacing must go up to this relief. If resurfacing is done to a depth which would eliminate the relief, a new relief must be cut. Refer to Figure 159.

When attempting to resurface as close to the clutch locating pilot as possible, keep in mind that the pilot must not be altered. The pilot controls the location of the clutch. If the locating pilot is altered, an imbalance will result.

Some machine shop operations may not have the tooling and locating equipment necessary for resurfacing a flat-style flywheel.

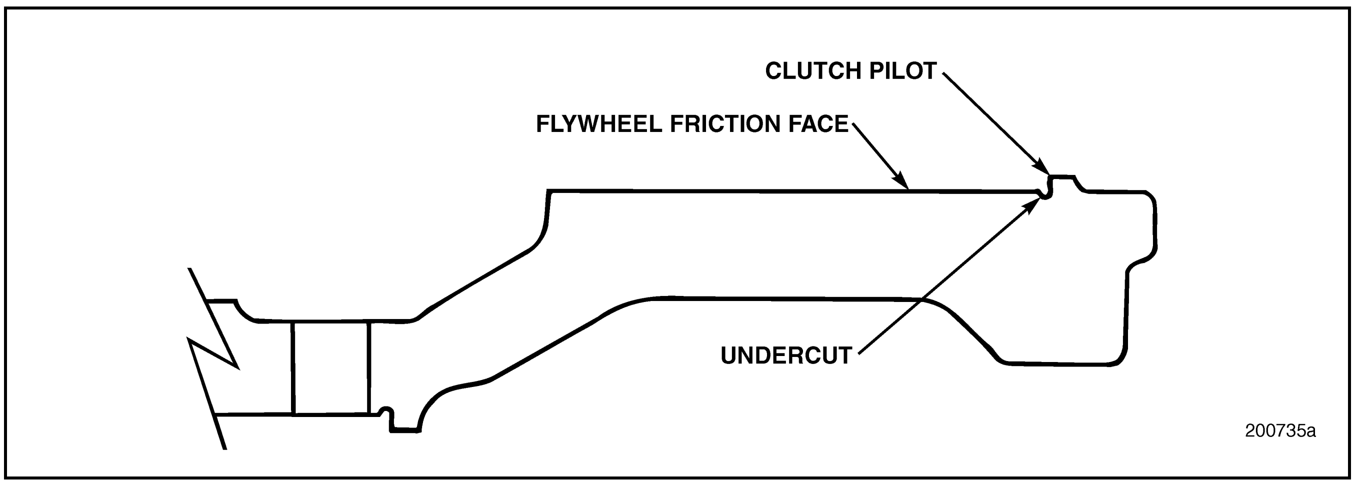


Figure 159 — Flywheel Resurfacing

AUXILIARY SHAFT AND CAMSHAFT BENCH PROCEDURES

Auxiliary Shaft Inspection

[212 CV]

The E-Tech™ auxiliary shaft is identified by three painted stripes (early production) or three machined circumferential cuts (later production) in front of the stamped part number.

INSPECTION

Refer to Figure 160.

1. Thoroughly clean the auxiliary shaft.
2. Inspect the auxiliary shaft journals and splines, and gear teeth and splines for evidence of cracks, pitting, scoring or severe wear. If any of these conditions exist, replace the auxiliary shaft.
3. Make sure the orificed cup plug is in place in the internal passage at the front of the auxiliary shaft.

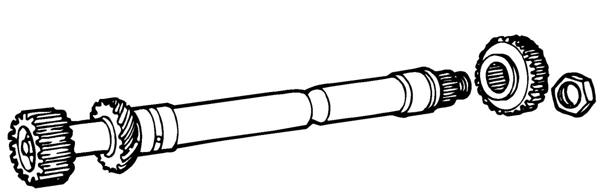


Figure 160 — Auxiliary Shaft

Camshaft Inspection

[213 CH]

GENERAL INSTRUCTIONS

To optimize camshaft timing for certain engine models, an offset-type camshaft key (P/N 54GC29) is used. The offset key is color-coded (with one end of the key painted white and the other end painted red) and is installed with the offset either to the right (cam timing retarded) or to the left (cam timing advanced). Correct camshaft key offset installation is dependent upon engine horsepower ratings.

NOTE

Some late-production high-horsepower engines use the offset key, P/N 54GC31.

Make sure that the correct camshaft key and positioning is used for the applicable engine model. Engine timing will be adversely affected if the incorrect key or positioning is used. When utilizing the offset key, it must be installed with the proper color facing front as follows:

- **Straight Key P/N 43AX9** — Used with EM7-300 (1750 rpm), E7-310/330, E7-330/350, E7-355/380, E7-350 (1800 rpm), E7-400 (1800 rpm), E7-454
- **Red Offset Key P/N 54GC29** — Used with RED facing front for EM7-275 (1750 rpm) and E7-300 (1700/1800/1950 rpm) effective January 1998 with engine serial number series 8A. Also used with RED facing front for EM7-300 (1750 rpm) and E7-310/330 effective December 8, 1999 with engine serial number 9Y0870 and implementation of Step 7 software.
- **White Offset Key P/N 54GC29** — Used with WHITE facing front for E7-427 (effective June 1997, with engine serial number 7M1305) and E7-460 (effective June 1997, with engine serial number 7M3166).

Prior to the offset key tie-ins to the engine serial numbers listed above, all engine models used the straight key.

CAMSHAFT GEAR REMOVAL

An extremely tight interference fit holds the cam gear on the camshaft. Typically, 10 tons of force is required to remove the gear. When cam gear removal or installation is required, use the following procedures.

DANGER

A considerable amount of force may be necessary to remove damaged or spun gears. DO NOT apply more than 25 tons (22.7 metric tons) of force to gears. Doing so may shatter the gears and result in severe personal injury.

Refer to Figure 161.

1. Position two adequate steel plates on the press to support the camshaft gear. The plates should have a 4-inch (101.6-mm) hole cut out in the center when placed side-by-side, or similar size v-grooves, to allow clearance for the shaft journals and greater support for the gear.
2. Set camshaft, supported by the gear, into the press.
3. Using a suitable arbor, press the camshaft out of the camshaft gear.

NOTE

Some engines use a straight key while others use an offset key positioned to the right or left depending on the engine model. If an offset key is used, be sure to note the positioning of the key so that it can be reinstalled in the same position.

CAUTION

Make sure there is enough clearance between the end of the camshaft and the floor while removing the gear. Do not let the camshaft fall or strike the floor when pressed from the gear. The camshaft can be bent easily, and may go unnoticed. Installing a bent camshaft in the engine could result in cam bushing failure.

4. Remove the thrust washer.

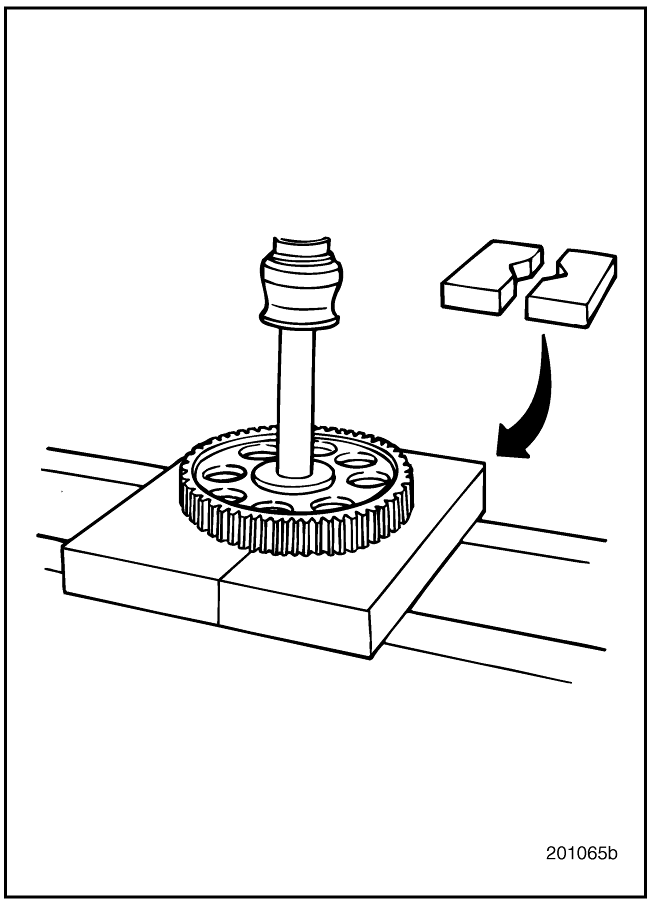


Figure 161 — Camshaft Gear Removal

INSPECTION

Refer to Figure 162.

1. Thoroughly clean the camshaft (3).

NOTE

Use magnaflux (PT7190) inspection procedure to detect cracks.

2. Inspect the camshaft lobes and journals for evidence of cracks, pitting, scoring or severe wear. If any of these conditions exist, replace the camshaft.
3. Inspect the camshaft gear (1) and camshaft captured thrust washer (2) for cracks, pitting, scoring or adverse wear.
4. Visually inspect the key (4) for signs of distortion or breakage.

CAMSHAFT GEAR INSTALLATION

The camshaft gear is shrink-fit onto the camshaft. To install the gear, it must be heated in an oven to 425°F (204°C). Do not attempt to heat the gear with a welding torch as this method will not provide even heating and could cause weakening of the metal.

An oven is the preferred method for heating the camshaft gear. However, an industrial grade hot plate can be used as an alternative to the oven. When using a hot plate, temperature sticks or a thermocouple must be used to determine gear temperature. The hot plate, temperature sticks and thermocouple are available through any industrial supply company.

NOTE

The camshaft gear is a “long-life” part that should be reused providing it is not damaged.

When installing the camshaft gear, use only the heat method procedure below for both new or used parts. Do not use a press to install the gear.

HEAT METHOD — CAMSHAFT GEAR INSTALLATION

Refer to Figure 162.

1. Using a suitable contact-type cleaner that dries rapidly and leaves no residue, thoroughly clean the camshaft and gear.

NOTE

The camshaft and gear must be grease- and oil-free to ensure a good shrink-fit.

2. Install the key (4) into the camshaft keyway. It may be necessary to tap the key with a soft metal hammer to ensure proper seating of the key.

NOTE

Some engines use a straight key while others use an offset key positioned to the right or left depending on the engine model. If an offset key is used, be sure the key is properly positioned for the engine model. Refer to the appropriate MACK Engine Tune-up Specifications for the correct key offset.

3. Install a **new** camshaft captured thrust washer (2) on the camshaft.

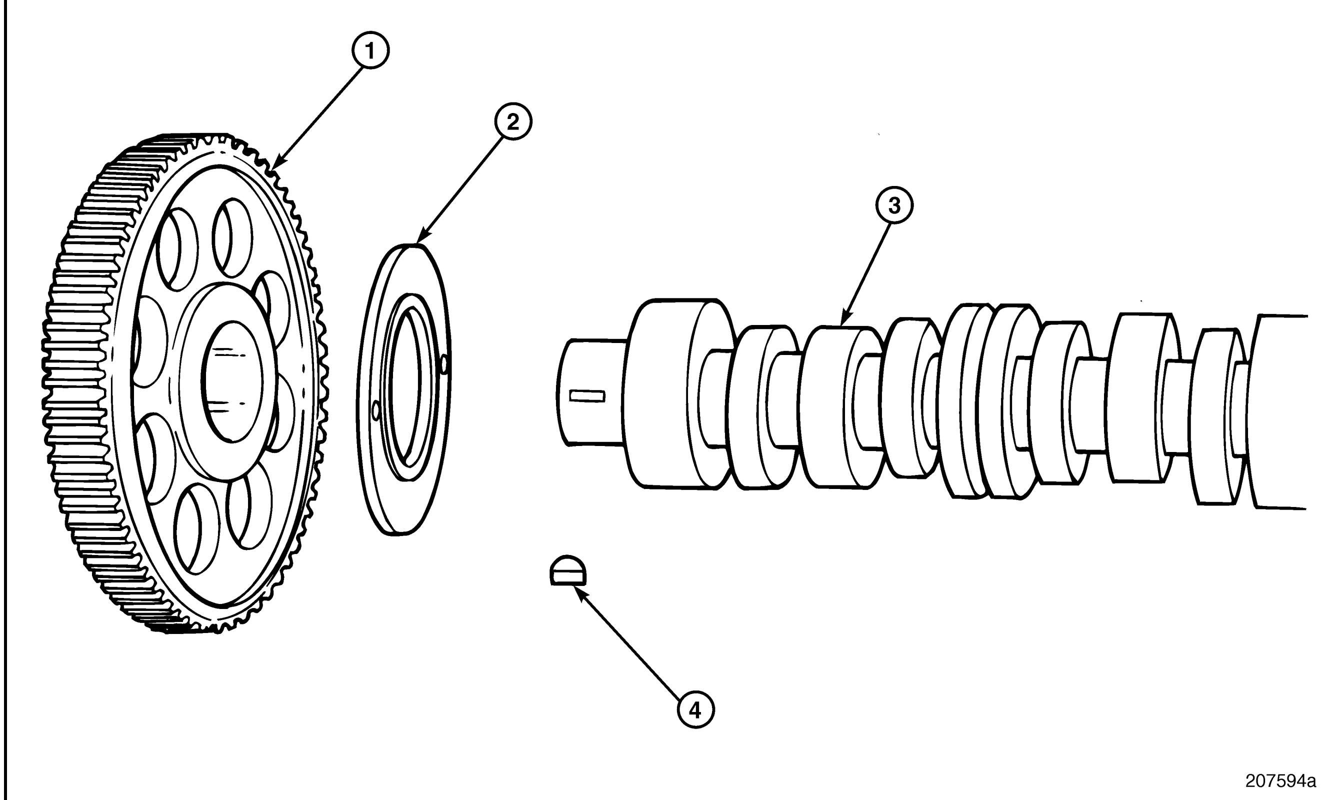


Figure 162 — Camshaft Assembly Components

1. Camshaft Gear 2. Camshaft Captured Thrust Washer	3. Camshaft 4. Key

5_106_00.bk Page 172 Friday, August 4, 2000 11:17 AM

4. Set the camshaft close to the oven in which the camshaft gear will be heated. It should be set vertically on the floor with the front of the shaft up. Secure the shaft so it cannot wobble or fall over as the gear is being installed.
5. Heat the camshaft gear to 425°F (204°C) in an oven (preferred — an old kitchen oven is sufficient) or on an industrial grade hot plate used in combination with temperature-sensing equipment described earlier. Adequate heating will require one to two hours. Do not heat the gear for more than two hours nor exceed 425°F (204°C) as heat treatment may be affected.

NOTE

DO NOT attempt to heat the gear with a torch. This method will only provide localized heating, will not permit proper expansion and may affect heat treatment of the gear.

6. Remove the gear from the oven and position it on the camshaft with the keyway aligned with the key and the timing marks facing up (Figure 163).

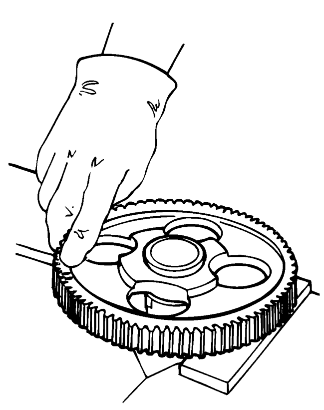


Figure 163 — Camshaft Gear Installation, Heat Method

DANGER

Wear protective gloves when handling the heated gear.

7. Using a quick, steady motion, push downward on the gear until the gear is fully seated against the cam shoulder surface.

CAUTION

The heat-expanded gear bore will begin to transfer heat to the camshaft as soon as contact between the gear and shaft is made. Therefore, it is absolutely necessary that the gear be installed in one rapid motion to the fully seated position.

If the gear is allowed to stop on the camshaft before it is fully seated, it will become immovable. If this occurs, DO NOT press gear onto the camshaft. Instead, remove gear with a press and thoroughly inspect the gear bore, camshaft journal and key. If there is no scoring, galling or tearing, repeat the installation procedure using the removed components. If damage is minimal, the components can and must be repaired and then reinstalled. If the damage is significant, the components must be replaced.

8. Allow the gear to cool.
9. When the gear is fully seated, there should be 0.003–0.012 inch (0.076–0.31 mm) clearance between the rear face of the gear and the thrust washer when measured with a feeler gauge.

CONNECTING ROD AND PISTON BENCH PROCEDURES

Connecting Rod Inspection and Reconditioning

[212 LP]

GENERAL INSTRUCTIONS

The connecting rod and cap design incorporates alignment sleeves. The caps can be identified by the flat, machined bottom shown in Figure 164. The connecting rod part number is forged into the I-beam of the rod.

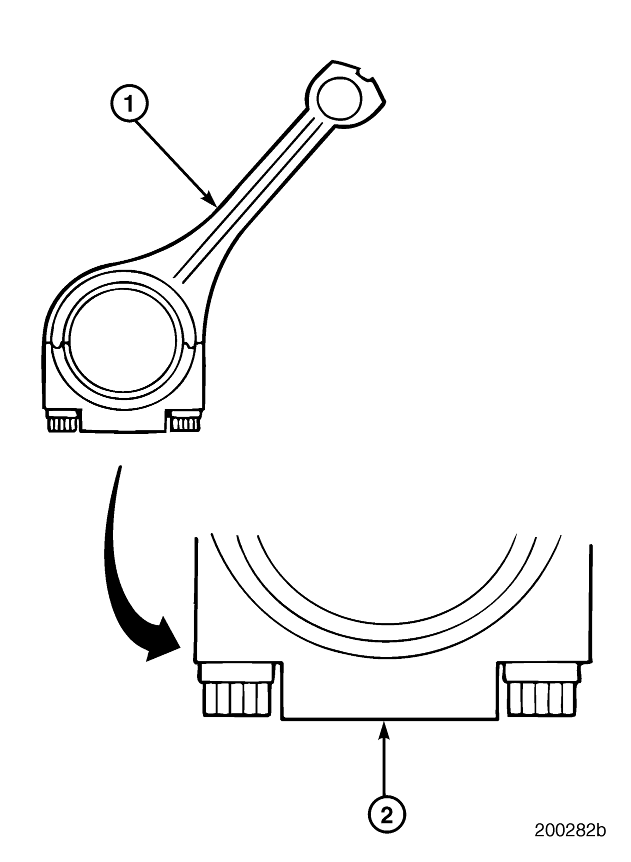


Figure 164 — Connecting Rod Identification

1. Connecting Rod	2. Rod Cap Machined Surface

Refer to Figure 165.

Each connecting rod assembly has two alignment sleeves (3), one sleeve in each capscrew hole of the rod cap (1) to locate and align the cap and rod thrust faces. These sleeves provide the best alignment when sleeve gaps are positioned at a location approximately 90 degrees to the tongue or groove (2). The sleeve gaps must not be in line with the tongue or groove.

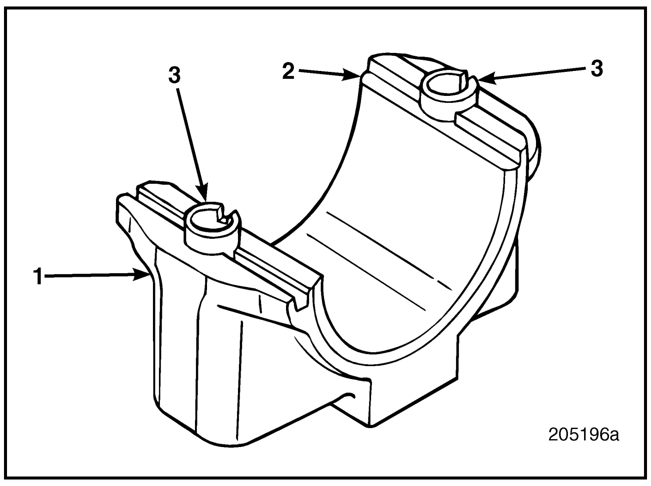


Figure 165 — Connecting Rod with Alignment Sleeves

1. Rod Cap 2. Bearing Insert	3. Alignment Sleeve

NOTE

It is essential to closely control the weight of reciprocating parts. Connecting rods fall into two weight classes, M1 or M2. Initially, the classes were identified by the respective “M” number (M1 or M2) stamped onto the connecting rod bearing cap. Now, however, only the M1 rod carries the weight class identification stamped on the rod cap. The M2 connecting rod is no longer stamped with the weight class identifier.

When installing a single rod, or less than a full set, examine the removed rod for part number and M number. Installing parts with the same weight class is preferred.

Connecting rods can be weighed to ensure using the proper weight class. Connecting rod weights for each engine, within each weight class, should not vary by more than 0.46 ounce (13.04 grams). The maximum weight difference between the heaviest possible M2 rod and the lightest possible M1 rod is 0.83 ounce (23.53 grams).

SPECIAL TOOLS REQUIRED

- Piston Pin Bushing Remover/Installer J 37717
- Piston Pin Burnishing Broach J 37718
- Connecting Rod Fixture 945-6041

INSPECTION

- Inspect the connecting rods for nicks, cracks, signs of overheating, or bends or twisting that can cause rod failure.
- Inspect bolt holes for elongation or pulled threads.
- Check mating surfaces between the rod and cap for correct fit.
- Inspect the crankshaft journal bearing surface and wrist pin bushing.

If any of the above parts are suspected of being faulty, replace the connecting rod.

SERVICE HINT

If it is determined that the condition of any part or component is questionable or is at the limit of tolerance, replace it. If the questionable part or component is reused, it may fail or become out of tolerance after a short time in operation. It is cost-efficient to replace components when rebuilding.

Use genuine MACK replacement parts.

WRIST PIN BUSHING REPLACEMENT

If the wrist pin bushing is found to be out of tolerance, it should be replaced.

Refer to Figure 166.

To replace the bushing:

1. Position the rod in a press with the piston pin bushing remover/installer J 37717 inserted into the wrist pin bushing.
2. Press the bushing out of the rod.

CAUTION

Use care not to twist or bend the connecting rod while pressing the bushing.

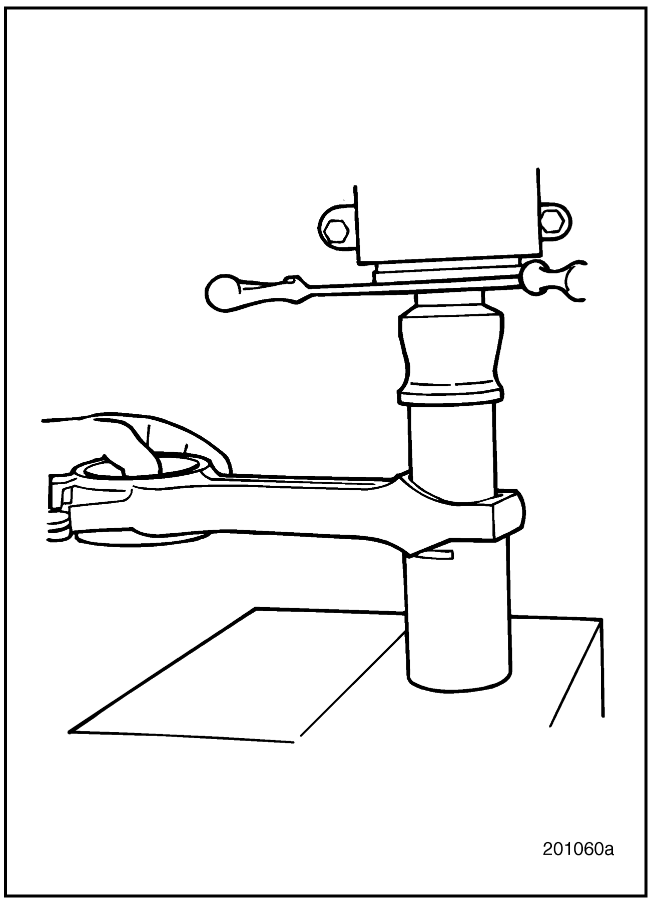


Figure 166 — Wrist Pin Bushing Removal

Wrist Pin Bushing Installation

CAUTION

The wrist pin bushing has a lubrication hole through it. This hole MUST be aligned with the rifle-drilled hole in the rod to allow oil flow to the wrist pin. If the holes are not aligned, wrist pin, piston, and connecting rod failure will result.

1. Position the rod and wrist pin bushing remover/installer J 37717 in a press, and press the **new** bushing into the rod.
2. Align the hole in the bushing with the rifle-drilled hole in the rod.

   Refer to Figure 167.
3. Position the rod assembly in a press with wrist pin bushing burnishing broach J 37718.

5_106_00.bk Page 175 Friday, August 4, 2000 11:17 AM

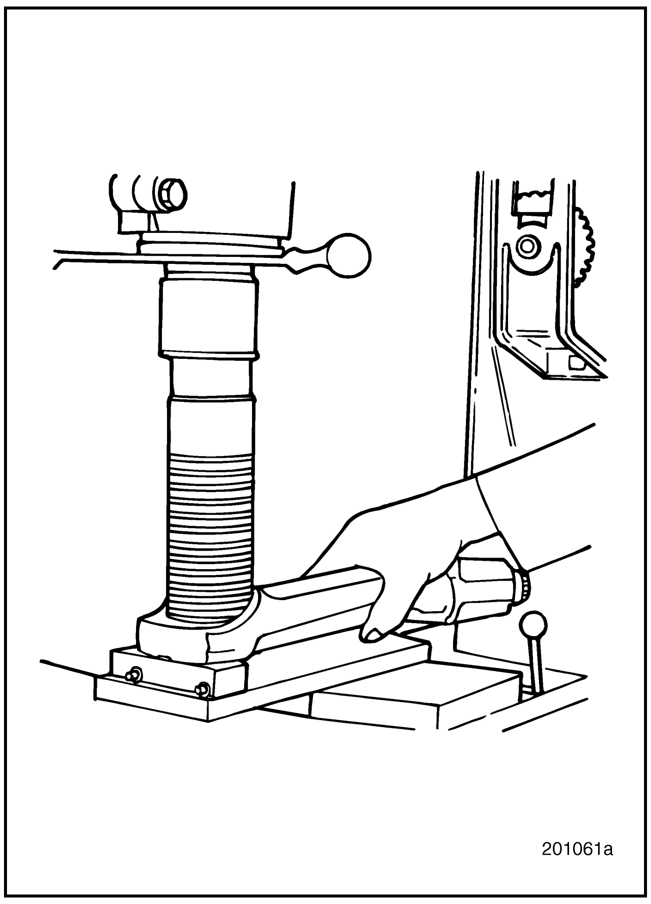


Figure 167 — Burnishing Wrist Pin Bushing

4. Using a suitable lubricant, press the broach through the bushing to expand the bushing.

   Refer to Figure 168.

CAUTION

Make certain that the bushing is fully expanded for a tight fit in the connecting rod bore or it will loosen, rotate and fail.

Use care not to twist or bend the connecting rod while pressing the broach through the bushing.

5. Clean all shavings from the rifle-drilled hole in the rod.
6. Check the alignment of the connecting rod for twist or bend.

CONNECTING ROD ALIGNMENT CHECK

1. Position the connecting rod in a connecting rod fixture, Sweeney 945-6041, or equivalent. Use the appropriate mandrel and plunger extension for the engine.

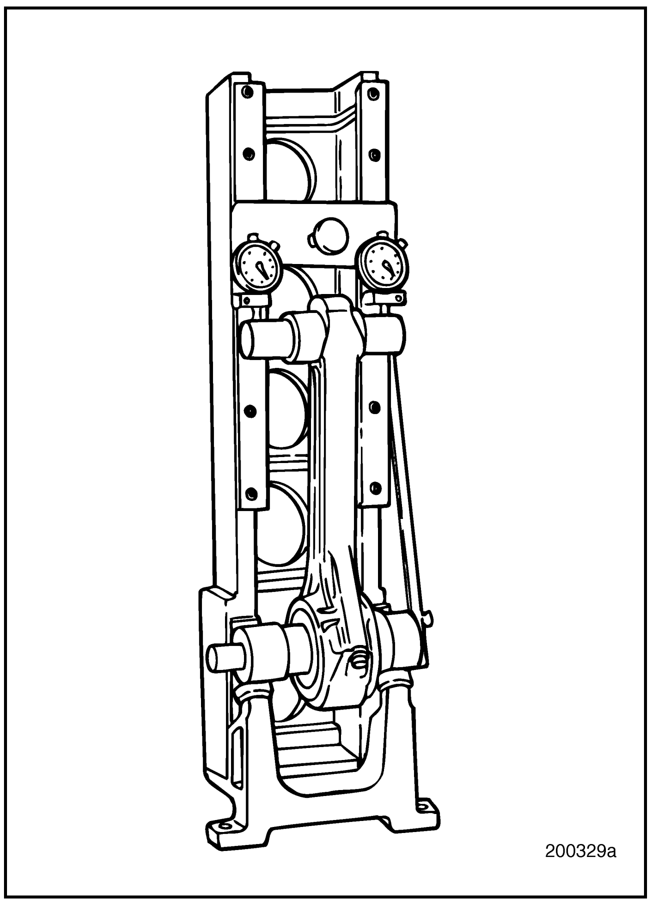


Figure 168 — Connecting Rod Fixture

2. Check the rod for twist or bend exceeding the following specifications. Specified distances are center-to-center.
   - Maximum twist of the connecting rod within 12 inches (30.5 cm) is 0.010 inch (0.254 mm).
   - Maximum bend of the connecting rod within 12 inches (30.5 cm) is 0.004 inch (0.102 mm).

Piston Inspection and Cleaning [212 NP]

GENERAL INFORMATION

The E-Tech™ engine uses a two-piece piston design with the crown made from forged steel and the skirt from cast aluminum. The forged steel crown incorporates two compression ring grooves and one oil ring groove. An oil accumulator relief is machined into the lower half of the third ring land face, 360 degrees around the piston circumference.

A plasma-faced, keystone-type compression ring is used in the top groove of the crown and a tapered chrome, rectangular-type compression ring is used in the second groove. The oil control ring is located in the third groove, nearest the wrist pin bore.

Early-production piston crowns were fitted with steel-backed bronze bushings in the wrist pin bores. A redesign of the piston crown for current production eliminates the bushings from the bores. This change was phased into production beginning July 1999.

The wrist pin bore pedestal of the crown and the piston skirt are stamped FRONT, and must be installed facing the front of engine.

CAUTION

A radius is cut in the lower edge of the piston skirt to provide clearance for the piston cooling nozzle. The piston must be installed with the word FRONT facing the front of engine.

SPECIAL TOOLS REQUIRED

- Piston Ring Expander PT6587
- Keystone Ring Groove Gauge J 29510

DISASSEMBLY

Refer to Figure 169.

1. Using piston ring expander PT6587, remove the piston rings.

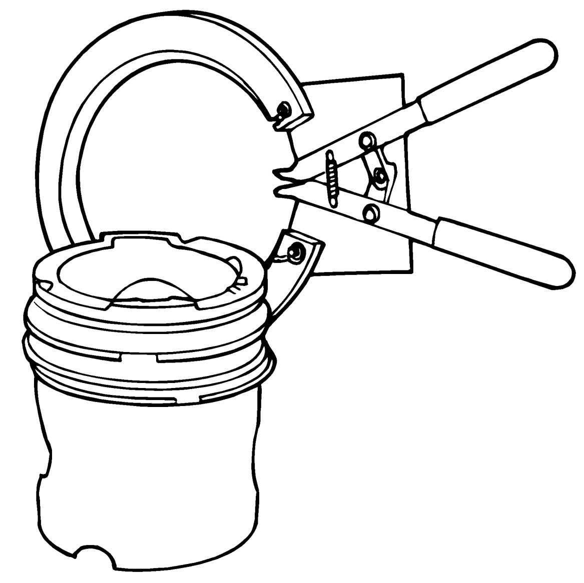


Figure 169 — Piston Ring Removal

2. Thoroughly clean the piston ring grooves, combustion bowl area and snap ring grooves. All carbon must be removed. Carbon left in the piston ring grooves will reduce ring clearance and prevent replacement rings from seating properly.

CAUTION

Be sure that the cleaning solvent is approved for steel and aluminum. Incompatible solvents may cause damage to the pistons or skirts.

3. Clean the pistons with the approved solution and a brass brush. Take care to avoid damaging the pistons while cleaning.

INSPECTION

Inspect the piston ring grooves, lands, piston skirt and combustion bowl for wear, scuffing, cracks or blow-by. Pistons are NOT repairable. Discard the piston if it is damaged.

CAUTION

Do not stamp or engrave on TOP of the piston. Doing so will reduce piston life.

To ensure that pistons are reinstalled in the same cylinders, the pistons must be tagged with the corresponding cylinder number when removed during disassembly.

Piston Ring Replacement

[212 NV]

NOTE

Before installing piston rings, check the keystone ring groove wear and ring end gap.

1. Place a piston ring in the cylinder sleeve. Push it down into the sleeve with an inverted piston to ensure that it is positioned squarely in the sleeve.
2. Using thickness gauges, check the ring end gap. Refer to Fits and Limits in the SPECIFICATIONS section for end gap tolerance. All rings to be used should be checked in this manner.

CAUTION

Do not file or grind chrome-plated piston rings. This may cause the chrome to flake, resulting in ring failure.

KEYSTONE RING GROOVE CHECK

Refer to Figure 170.

Keystone piston-ring groove gauge J 29510 consists of two 0.120-inch (3.048 mm) diameter pins (1) connected at the ends by two springs (2).

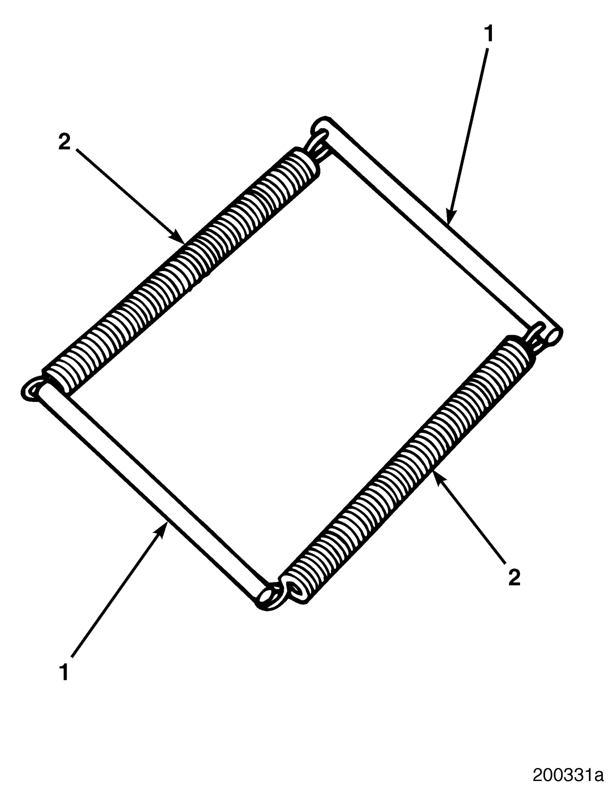


Figure 170 — Ring Groove Gauge

1. Pins	2. Springs

1. Place the pins of the keystone piston ring groove gauge J 29510 opposite each other in the groove to be measured. The pins will be held in position by the springs.

   Refer to Figure 171.

2. Using a four- to five-inch micrometer, measure the distance between the outer edges of the two parallel pins. Check each compression ring groove in two locations: parallel and perpendicular to the wrist pin bore. Record both measurements.
3. Compare readings with the tolerances listed under Fits and Limits in the SPECIFICATIONS section.

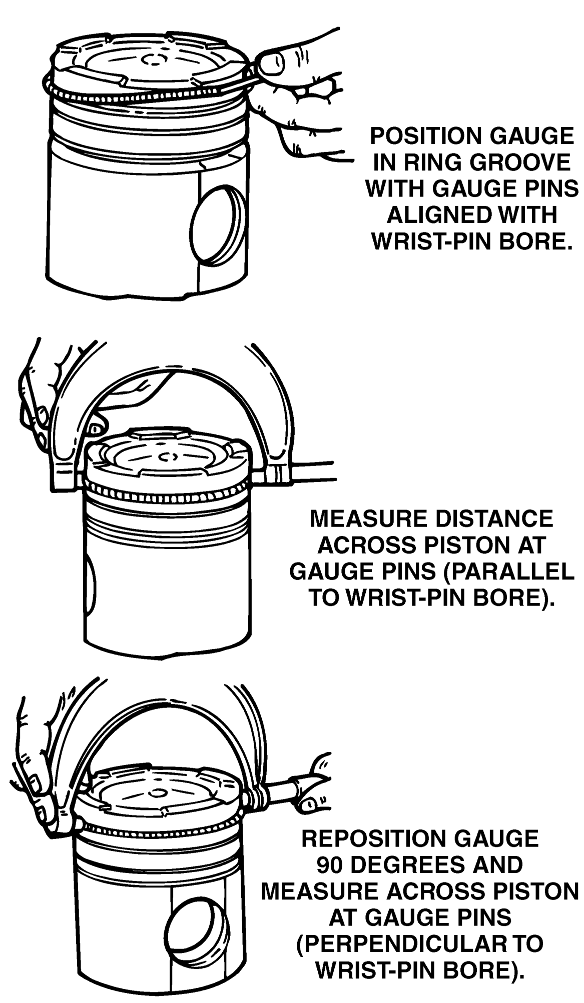


Figure 171 — Ring Groove Wear Measurement

4. Perform steps 1, 2 and 3 on each piston.

   Refer to Figure 172.

5. Check the oil control ring as follows:
   a. Using a thickness gauge, check for excessive wear of the oil control ring groove side clearance (1). Position a **new** oil control ring in the groove and insert a thickness gauge between the ring and upper land of the groove.
   b. Record the measurement and compare the reading with the tolerance listed under Fits and Limits in the SPECIFICATIONS section.

NOTE

For a **new** ring and piston, the oil ring side clearance is 0.0016–0.0030 inch (0.0406–0.0762 mm). For an old ring and piston, the clearance should NOT exceed 0.0045 inch (0.1143 mm).

6. Perform step 5 on each piston.

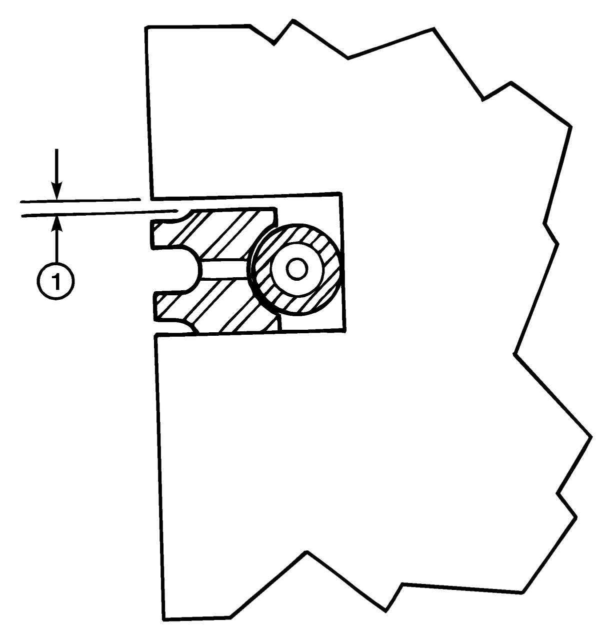


Figure 172 — Side Clearance Measurement

1. Ring Groove Side Clearance

RING INSTALLATION

NOTE

Identification markings on the rings should face the piston top. The keystone ring goes in the top ring groove.

Follow the directions on each piston ring packet.

Refer to Figure 173.

1. To prevent distortion, use the proper size piston ring expander (PT6587) to place rings in the piston grooves.

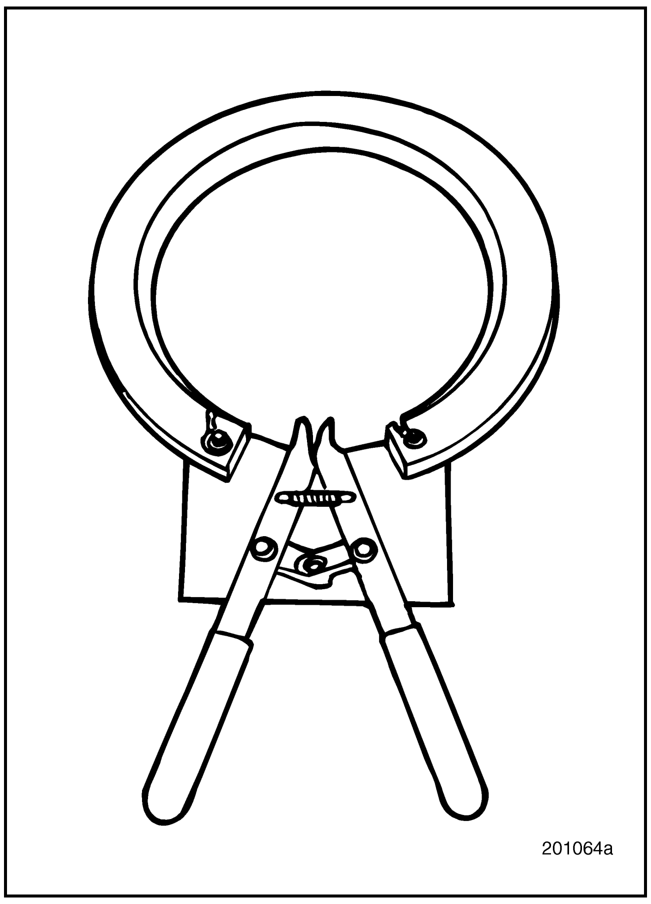


Figure 173 — Piston Ring Expander PT6587

2. Stagger the piston rings so that no ring gap is directly over the wrist pin bore, and no ring end gaps are aligned over each other (Figure 174).

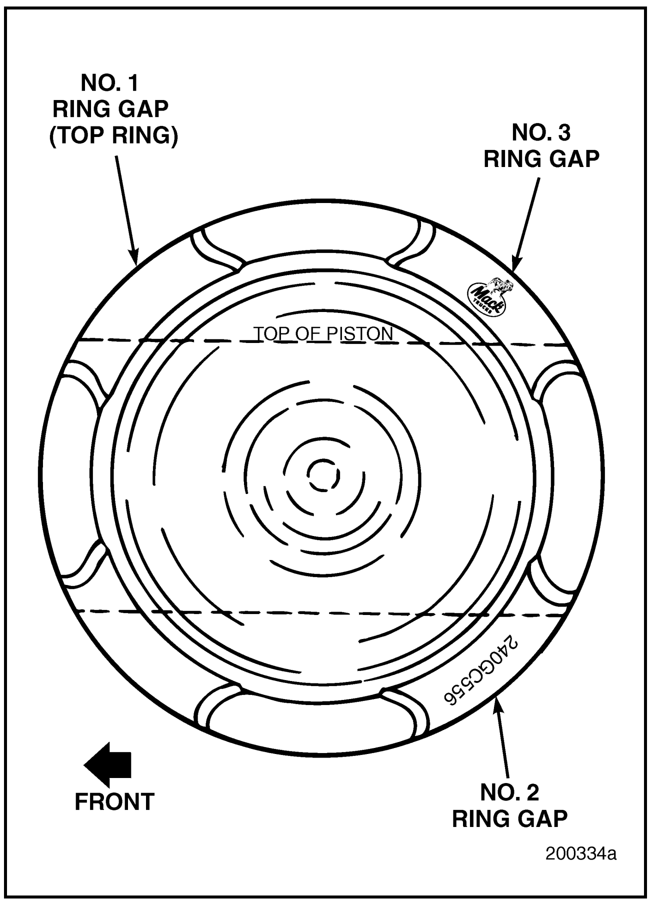


Figure 174 — Ring Gap Locations

Assembling Connecting Rod to Piston

[212 LP & NP]

Refer to Figure 175.

1. Install a retaining snap ring in one of the wrist pin retaining grooves.
2. Position the connecting rod in the piston assembly. Make sure that the side of the rod marked FRONT is properly aligned with the FRONT markings on the piston crown and skirt.

NOTE

The current piston skirt, part No. 240GC590BM, is symmetrical in design, having piston cooling nozzle clearance cutouts on both the right and left sides. Although the word “FRONT” still appears at the bottom, the symmetrical design allows the skirt to be assembled to the piston crown in either direction.

CAUTION

Be sure that the piston and rod assemblies are clearly marked with the cylinder location. They must be returned to same cylinder from which they were removed.

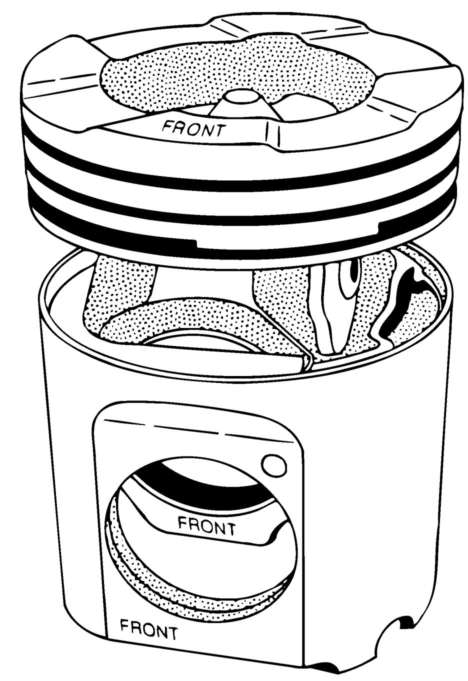


Figure 175 — Piston Markings

3. Using a generous amount of clean engine oil, push the piston wrist pin into the wrist pin bore, aligning the two piston sections and the connecting rod.

NOTE

Early-production piston crowns were fitted with steel-backed bronze bushings in the wrist pin bores. A redesign of the piston crown for current production eliminates the bushings from the bores. This change was phased into production beginning July 1999.

4. Secure the pin in position by inserting a snap ring in the remaining piston snap ring groove.
5. Place the assembled piston in a clean location until it is needed for installation into the engine cylinder sleeve.
6. Perform steps 1 through 5 on the remaining pistons.

CYLINDER HEAD OVERHAUL [213 EV]

Special Tools Required

- Valve Spring Compressor J 43887 (for valves with tip-end rotators)
- Valve Spring Compressor J 29294-B (for valves with bottom rotators)
- Fire Ring Groove Cutter J 29600-C
- E7 Cutter Head J 37719
- Depth Gauge J 26948
- Valve Guide Remover J 37482
- Valve Guide Installer J 37809
- Valve Guide Reamer J 37481
- Valve Seat Extractor Kit PT6391
- Collet PT6390-4
- Valve Seat Insert Counterbore HT77136
- Valve Insert Installer Set J 38586
- Driver Handle J 8092
- Prussian Blue
- Model MST 50 Universal Spring Tester J 22738-02
- Injection Nozzle Sleeve Extractor J 29880
- Basic Heavy-Duty Dowelout Kit PT6575
- Dowelout, Extractor (7/16 inch) PT6570-11
- Torque Wrench J 24407
- Slide Hammer J 2619-01
- Valve Yoke Guide Pin Installer J 29296
- Injection Nozzle Sleeve Installer J 29297
- Cylinder Head Core Plug Installer (13/16-inch cup plugs) J 34684
- Cylinder Head Core Plug Installer (1-1/16 inch cup plugs) J 34687
- Valve Seal Installer J 42453
- Valve Stem Seal Remover J 39460

Inlet and Exhaust Valve Removal [213 NB]

GENERAL INFORMATION

Current-production engines use a tip-end valve rotator (P/N 722GC314) as shown in Figure 176. The tip-end rotator is installed at the top of the valve spring, and replaces the bottom rotator which was used on early-production engines. With the tip-end valve rotators, there is a greater amount of valve key protrusion above the rotator when compared with the key protrusion above the valve spring retainer washers on early-production engines. The top of the valve keys are practically flush with the top of the valve retainer washers. The tip-end rotator, however, has an undercut on top, so the top of the key protrudes approximately 3/32-inch as shown in Figure 177.

NOTE

Do not clean either type (bottom or tip-end) of rotators in a hot tank or use any type of cleaning method which could introduce contaminants to the rotator internal parts or damage the tip-end rotator insert.

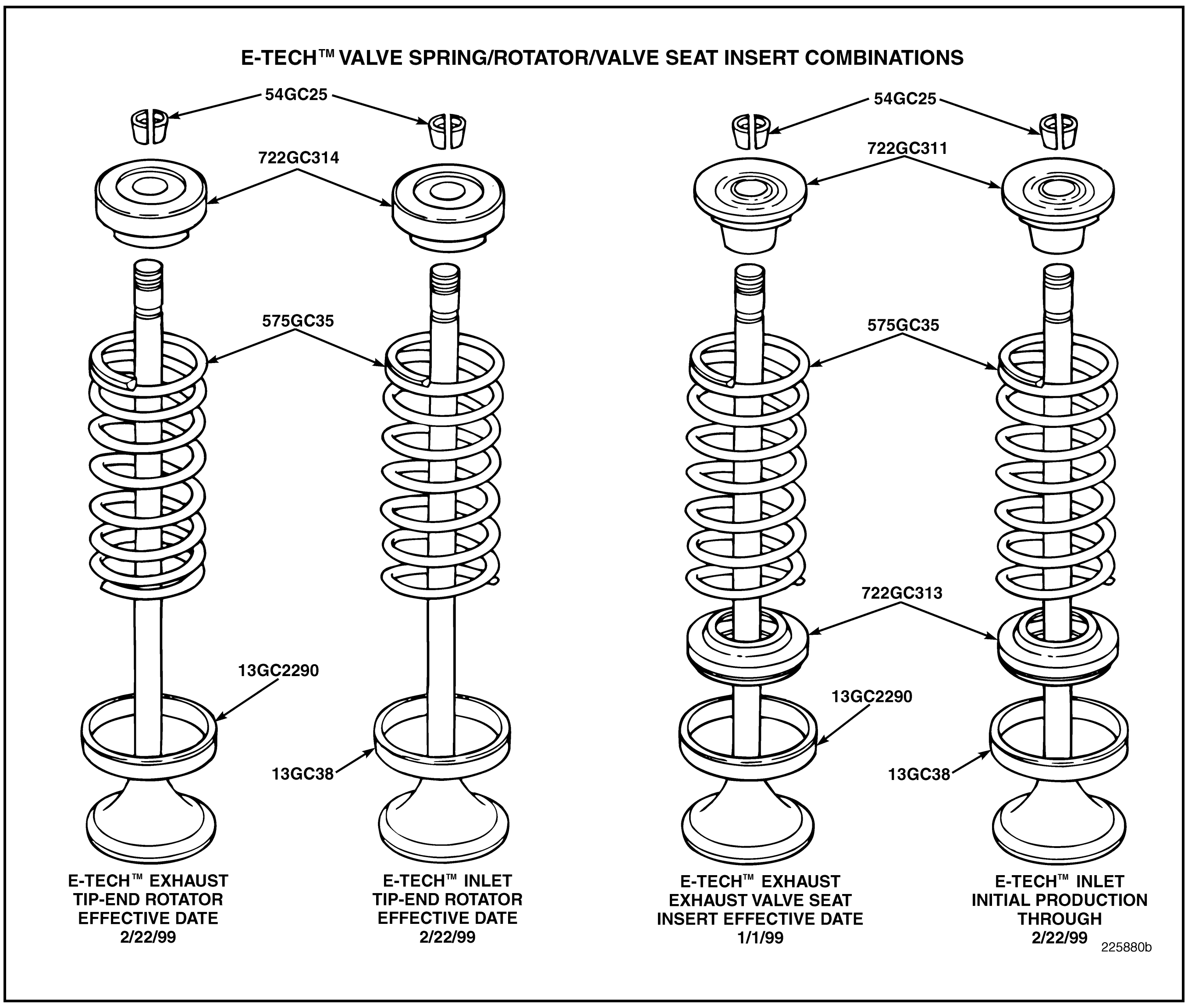


Figure 176 — Valve Spring, Rotator and Valve Seat Insert Combinations

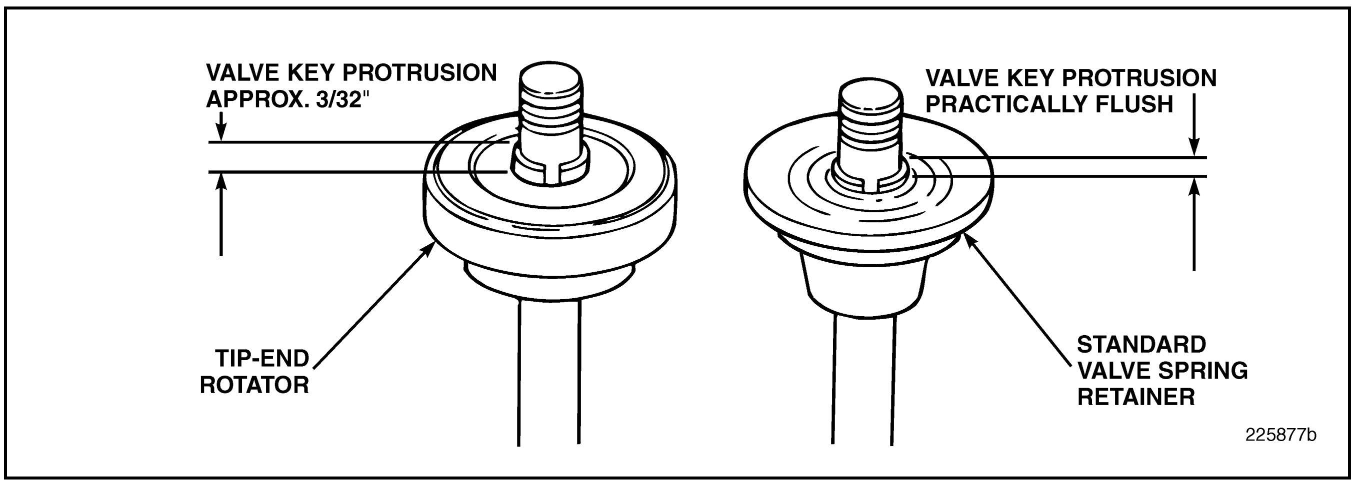


Figure 177 — Valve Key Protrusion

REMOVAL PROCEDURE

Refer to Figure 178.

1. Attach the valve spring compressor to the cylinder head. Use spring compressor J 43887 for valves with tip-end rotators or J 29294-B for valves with bottom rotators.
2. Rest tool compression forks (4) on top of the upper washer (3) and center the forks above the valve.
3. Depress the tool handle until the valve spring is compressed. Remove the valve spring washer keys (2) using a magnet (1).

   Valve Stem Seals — The E-Tech™ engine valve stem seals are easily identified by the steel retainer band around the top of the seal lip. The guides have three sharp ridges machined into the upper outside diameter surface (refer to Figure 179) for excellent seal-to-guide retention. The following part numbers apply:

   - Valve stem seal — P/N 446GC328
   - Valve guide — P/N 714GB3103

NOTE

Valve spring compressor, J 43887 or J 29294-B, must be repositioned for each series of valves (two inlet and two exhaust per cylinder). Drilled and tapped holes are provided for each cylinder.

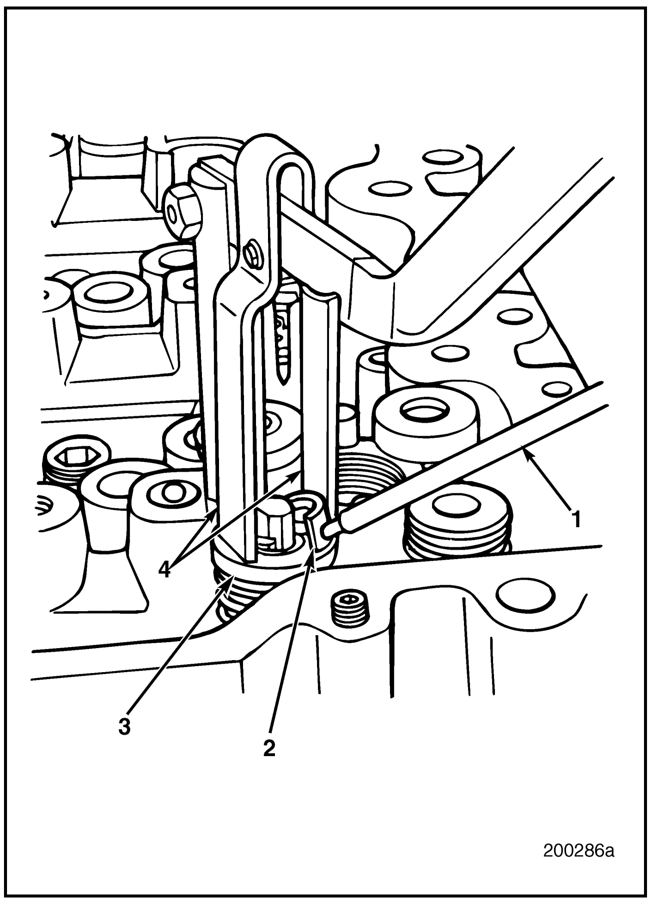


Figure 178 — Valve Spring Keeper Removal

1. Magnet 2. Valve Spring Washer Keys	3. Upper Washer 4. Tool Compression Forks

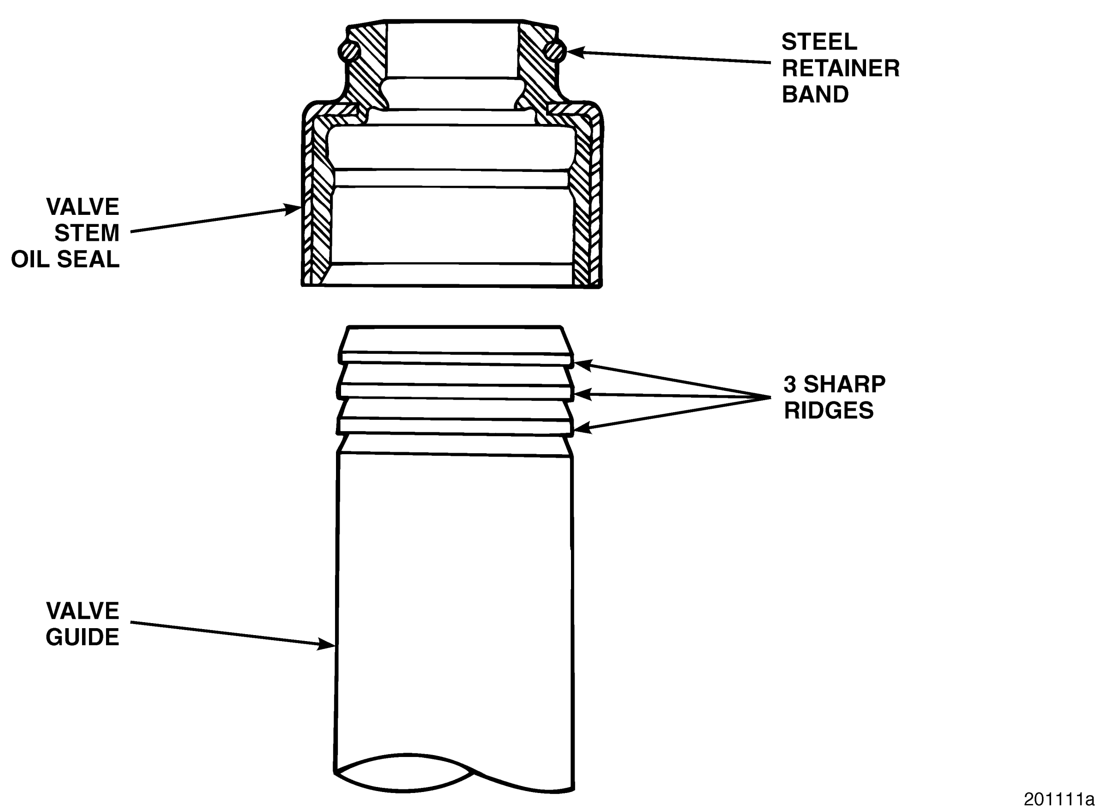


Figure 179 — Valve Stem Seal

4. With the valve spring keepers removed, remove the upper washer or tip-end rotator, valve spring, oil seal, lower washer (Roto-Coil) if so equipped, and valve. Refer to Figure 176.

NOTE

After removing the valve springs, removal of the existing valve stem seals can be accomplished easily and quickly by using the J 39460 Valve Stem Seal Removal tool. Failure to use this tool could make seal removal more difficult, and could result in damage to the outside diameter of the valve guides.

Cylinder Head Inspection

NOTE

Pressure Test — It is recommended that cylinder heads be pressurized and checked for internal cracks and leaks. Refer to Cylinder Head and Cylinder Block Leak Test procedures in the TROUBLESHOOTING section.

Check the cylinder head deck surface for warping, pitting or other imperfections. Deck surface flatness must not vary more than 0.0015 inch (0.0381 mm) over 18 inches (45.7 cm) of surface area. Resurface or replace as necessary.

When resurfacing, remove a minimum amount of material from the deck to obtain a flat, uniform surface. Standard head height is 6.397–6.391 inches (162.483–162.310 mm). A maximum of 0.010 inch (0.254 mm) of material may be removed, making the minimum height of a resurfaced head 6.381 inches (162.077 mm).

NOTE

When the deck is resurfaced, fire ring groove and valve seat insert dimensions must be re-established following the procedure in Fire Ring Groove Cutting.

Fire Ring Groove Cutting

GENERAL INFORMATION

Fire ring grooves are located in the machined flat surface (deck) of the cylinder head that mates with the engine block. This design provides a locking groove for the fire ring to seat, as well as a positive-combustion pressure seal.

After resurfacing the cylinder head deck, it is necessary to re-establish the fire ring groove depth using the fire ring groove cutter J 29600-C. Refer to Figure 180.

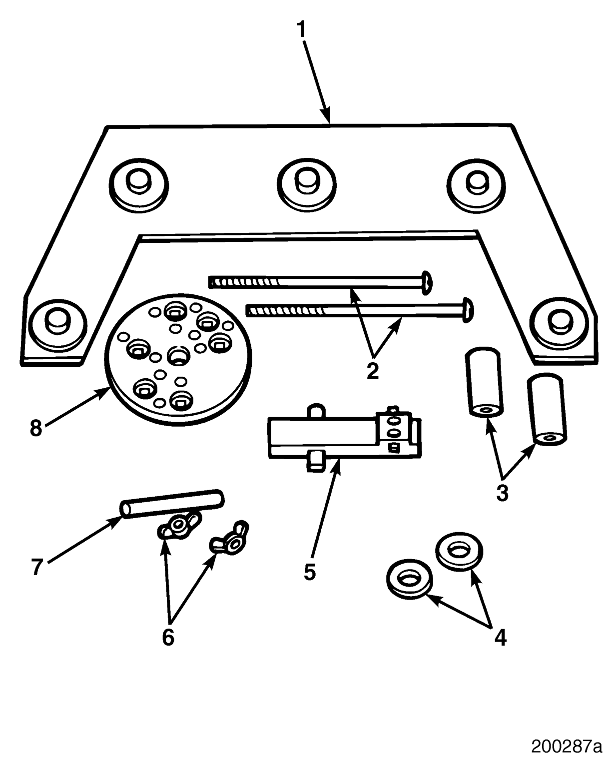


Figure 180 — Fire Ring Groove Cutter J 29600-C

1. Alignment Fixture 2. Hold-Down Capscrews 3. Spacers 4. Washers	5. Cutter Head (J 37719) 6. Wing Nuts 7. Thickness Gauges 8. Cutter Base

5_106_00.bk Page 186 Friday, August 4, 2000 11:17 AM

GROOVE CUTTING PROCEDURE

1. Place the cutter base on the cylinder head. Insert the hold-down capscrews into the appropriate mounting holes (per application) until the hold-down capscrews bottom out in the mounting holes. Refer to Figure 181.

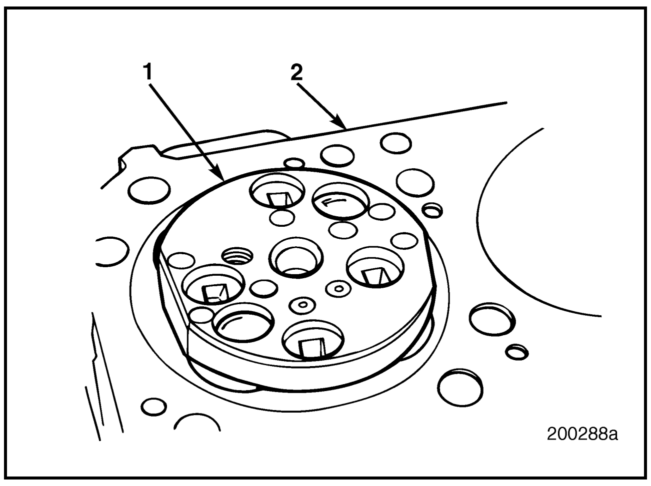


Figure 181 — Cutter Base Alignment

1. Cutter Base	2. Cylinder Head

2. Position the cylinder head so the threaded section of the hold-down capscrews can be reached as shown in Figure 182. Install the spacer, washer and wing nut. Lightly tighten the wing nut.

NOTE

The cutter base must be free to move.

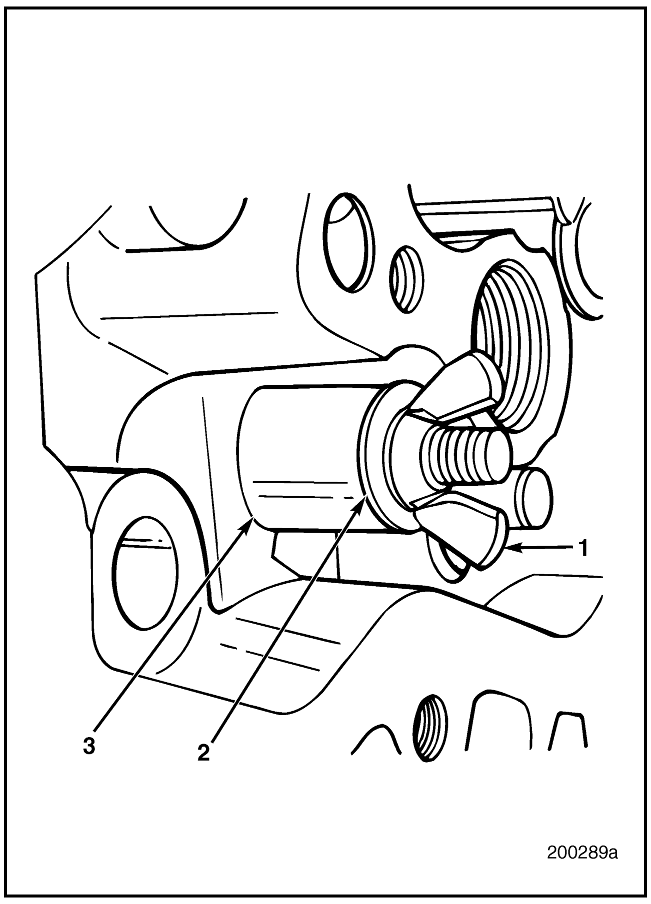


Figure 182 — Fastening Cutter Base

1. Wing Nut 2. Washer	3. Spacer

3. Place the alignment fixture over the cutter base as shown in Figure 183 to ensure proper positioning. With the fixture in place, tighten wing nuts on the hold-down capscrews. Remove the alignment fixture.

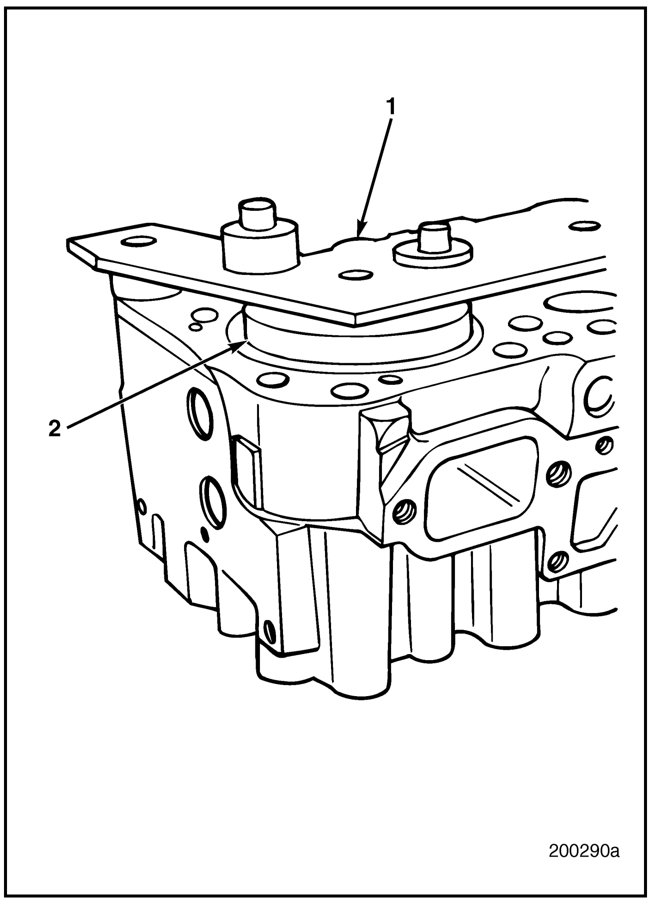


Figure 183 — Alignment Fixture Placement

1. Alignment Fixture	2. Cutter Base

NOTE

The desired finished fire ring groove depth is 0.008 inch (0.203 mm).

4. Install the cutter head J 37719 (1) on the cutter base (4) as shown in Figure 184.
   a. If a fire ring groove (3) is visible, check the existing fire ring groove depth dimension with depth gauge J 26948. The difference between 0.008 inch and the actual remaining depth of fire ring groove is the amount to cut. Insert two appropriate thickness gauges (2) between the cutter head (1) and base (4).
   b. If a fire ring groove (3) is not visible, insert two 0.008-inch thickness gauges (2) between the cutter head (1) and base (4).

5. Adjust the cutter head J 37719 until it bottoms out on the deck surface of the existing fire ring groove. Tighten the cutter head in this position and remove the two thickness gauges.

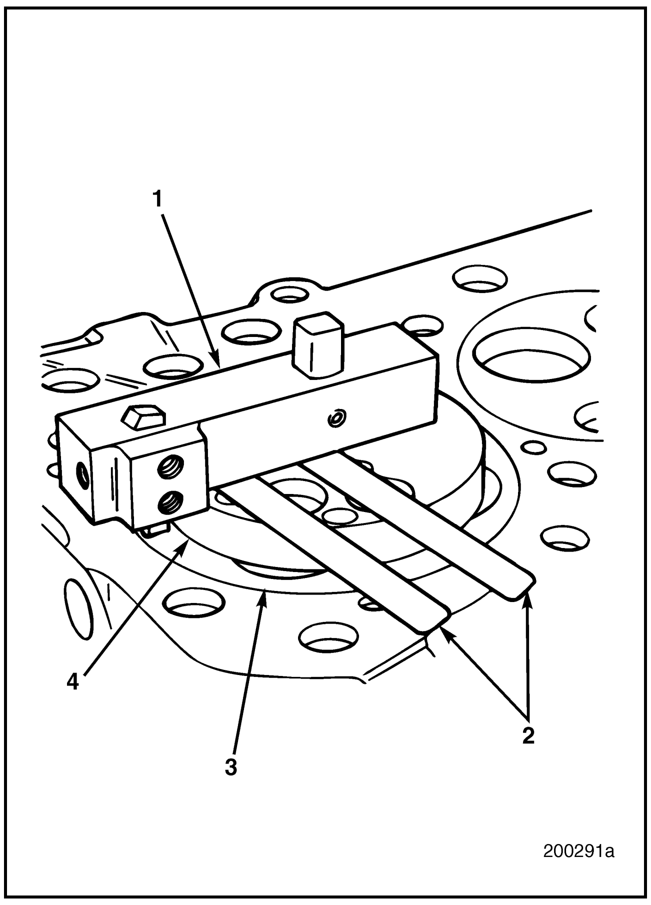


Figure 184 — Setting Cutter Depth

1. Cutter Head (J 37719) 2. Thickness Gauges	3. Fire Ring Groove 4. Cutter Base

6. Install a socket (1) and T-handle (2) on the cutter head (3) as shown in Figure 185. Using the T-handle, rotate the cutter head in a clockwise direction only, applying an even downward pressure to cut the fire ring groove.

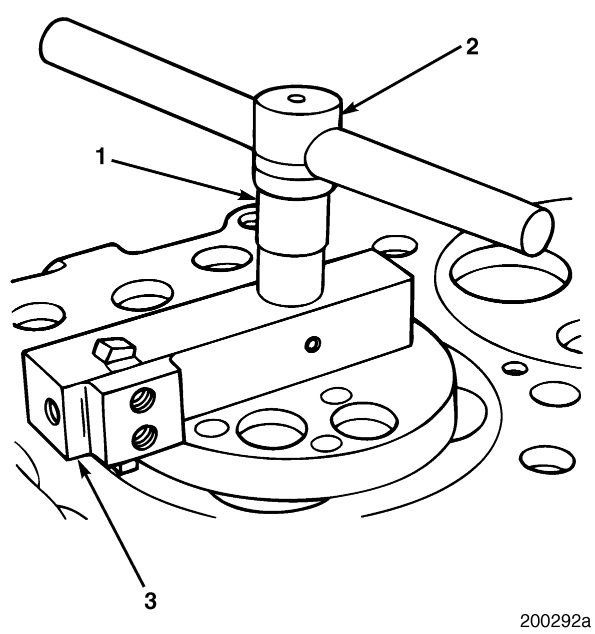


Figure 185 — Cutting Ring Groove

1. Socket 2. T-Handle	3. Cutter Head (J 37719)

7. After the groove is cut, remove the cutter head and base from the cylinder head.
8. Use a honing stone to remove any burrs around the fire ring groove.
9. Check the fire ring groove depth with depth gauge J 26948 to verify that the groove depth meets specification. If the groove depth does not meet specification, recut as necessary.
10. Repeat the above procedure to cut each fire ring groove.

NOTE

To ensure proper groove depth, always adjust the cutting tool height when cutting the next groove.

Valve Guide Replacement

[213 EP]

INLET AND EXHAUST VALVE GUIDE DIMENSIONS

Refer to Figure 186.

- Valve guide ID (3) — 3/8 inch (9.53 mm)
- Top end of guide to valve spring seat (4) — 0.959 ± 0.040 inch (24.36 ± 1.02 mm)
- Valve guide extension, fire deck to top of guide (5) — 5.24 ± 0.03 inch (133.10 ± 0.76 mm)
- Valve guide bore in head (6) — 0.687–0.686 inch (17.450–17.424 mm)
- Valve guide OD (7) — 0.6886–0.6881 inch (17.4904–17.4777 mm)

5_106_00.bk Page 189 Friday, August 4, 2000 11:17 AM

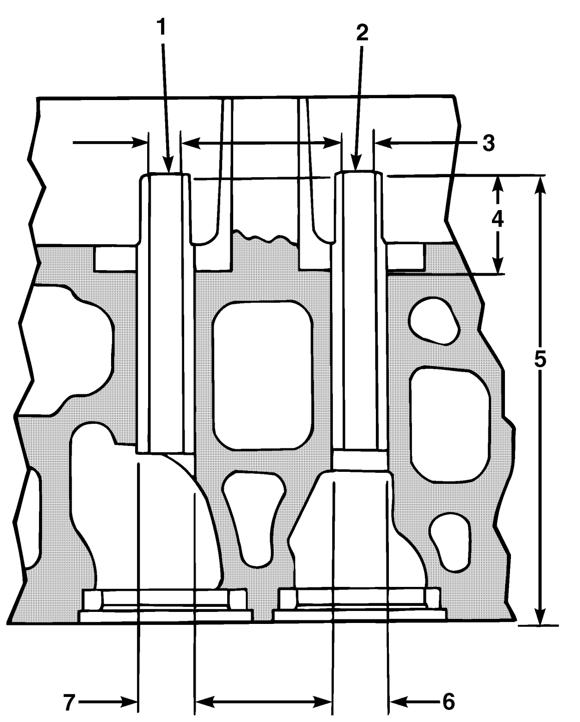


Figure 186 — Valve Guide Dimensions

1. Exhaust Valve Guide 2. Inlet Valve Guide 3. Valve Guide ID 4. Top End of Guide to Valve Spring Seat	5. Valve Guide Extension, Fire Deck to Top of Guide 6. Valve Guide Bore in Head 7. Valve Guide OD

INSPECTION

NOTE

Worn valve guides may result in poor valve-to-seat contact, valve damage or oil consumption.

1. Inspect the valve guides for wear, damage, cracks and looseness. Use a small bore gauge (1) to obtain an accurate valve guide bore (2) measurement. Refer to Figure 187.

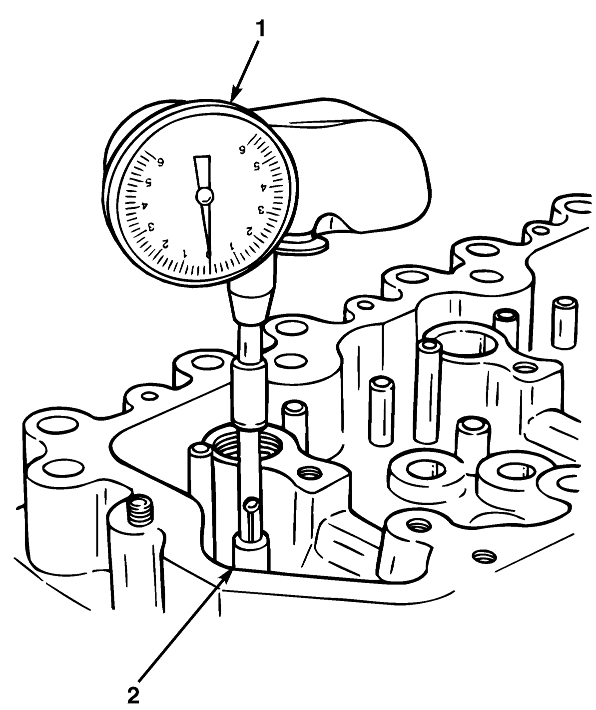


Figure 187 — Measuring Valve Guide Bore

1. Bore Gauge	2. Valve Guide Bore

2. Use a depth gauge to check valve guide extension. Refer to Figure 188.

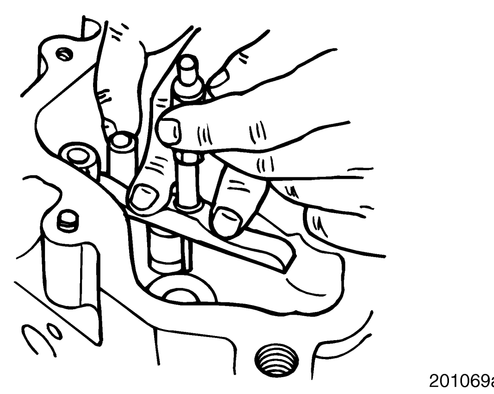


Figure 188 — Checking Valve Guide Extension

5_106_00.bk Page 190 Friday, August 4, 2000 11:17 AM

NOTE

When reconditioning the cylinder head, it is recommended that all valve guides be replaced.

VALVE GUIDE REMOVAL

SERVICE HINT

Clean the exhaust valve guide OD (shoulder) before removal. With the guide removed, use a rotary brush to clean the exhaust valve guide bore and prevent scoring.

Refer to Figure 189.

1. Insert valve guide remover J 37482 (1) into the valve guide from the deck side of the cylinder head (2).

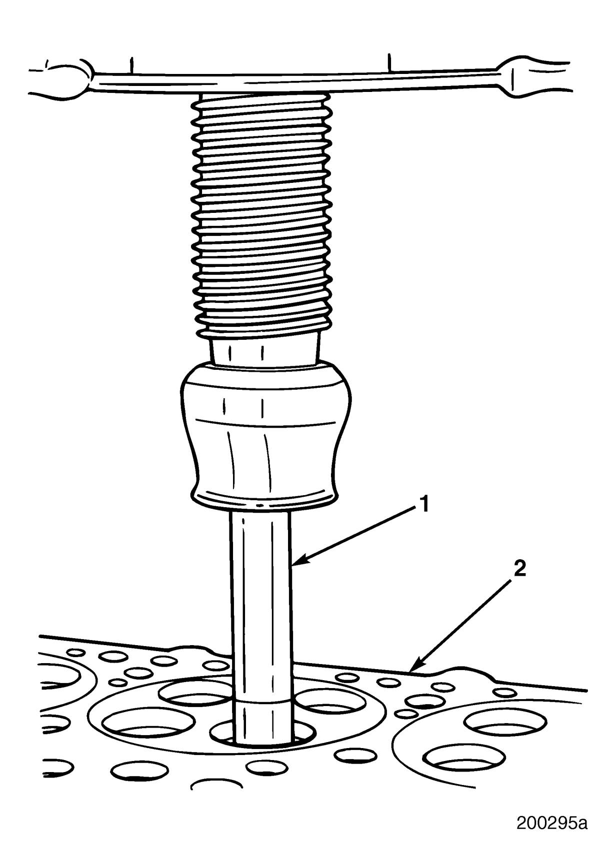


Figure 189 — Valve Guide Remover J 37482

1. Valve Guide Remover J 37482	2. Cylinder Head

2. Press out the old valve guides from the cylinder head.
3. Check the valve guide bore in the cylinder head for wear, cracks or other damage. Clean the surfaces thoroughly and check the ID measurement.

VALVE GUIDE INSTALLATION

1. Insert a **new** valve guide into the valve guide installer J 37809.
2. Oil the OD of the guide before installation.
3. Using tool J 37809, press the guide into the top of the cylinder head.
4. Using the depth gauge, check the extension of the guide from the valve spring seat to the top end of the guide. Refer back to Figure 188.
5. Using valve guide reamer J 37481 (1), ream the valve guide (2) to dimension as shown in Figure 190.

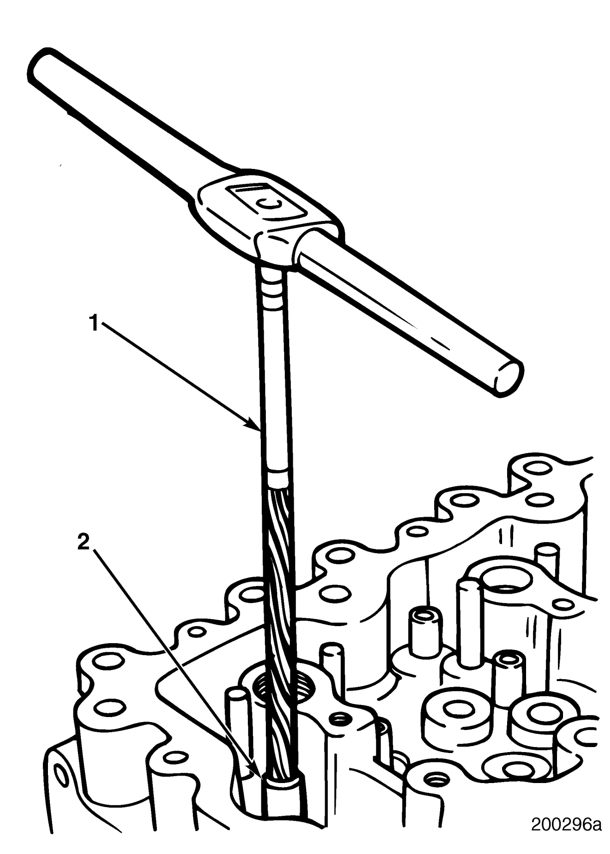


Figure 190 — Reaming Valve Guide

1. Valve Guide Reamer J 37481	2. Valve Guide

5_106_00.bk Page 191 Friday, August 4, 2000 11:17 AM

6. Repeat steps 1 through 5 to install the remaining valve guides.
7. Thoroughly clean all metal debris from the valve guides and the surrounding area.
8. Install the valves in the cylinder head and check for binding, looseness and other conditions that may result in premature valve or valve guide failure.

Valve Seat Insert Replacement

[213 FB]

INLET AND EXHAUST VALVE SEAT INSERT DIMENSIONS

Refer to Figure 191.

- Valve seat (3) insert face angle (1)
  - — Inlet: 20° 30′ ± 15′
  - — Exhaust: 30° – 0′/+ 30′
- Valve seat insert diameter (2)
  - — Inlet: 1.832–1.831 inches (46.533–46.507 mm)
  - — Exhaust: 1.693–1.691 inches (43.002–42.951 mm)
- Valve seat width (4) — 0.066 ± 0.015 inch (1.676 ± 0.381 mm)

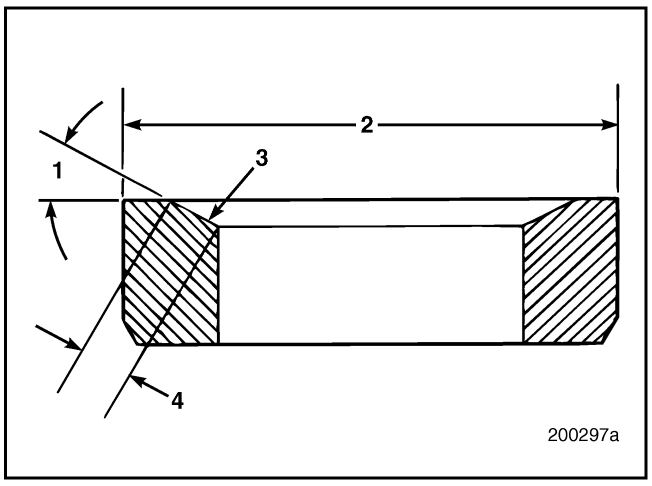


Figure 191 — Valve Seat Insert Dimensions

1. Valve Seat Insert Face Angle 2. Valve Seat Insert Diameter	3. Valve Seat 4. Valve Seat Width

INSPECTION

Visually inspect the valve seat inserts for looseness, cracks or other conditions that may result in improper operation. Replace seats as necessary.

VALVE SEAT INSERT REMOVAL

Valve seat extractor kit PT6391 and collet PT6390-4 are used to remove the inlet and exhaust seat inserts. Refer to Figure 192.

NOTE

Collet PT6390-4 is not included in the basic kit PT6391.

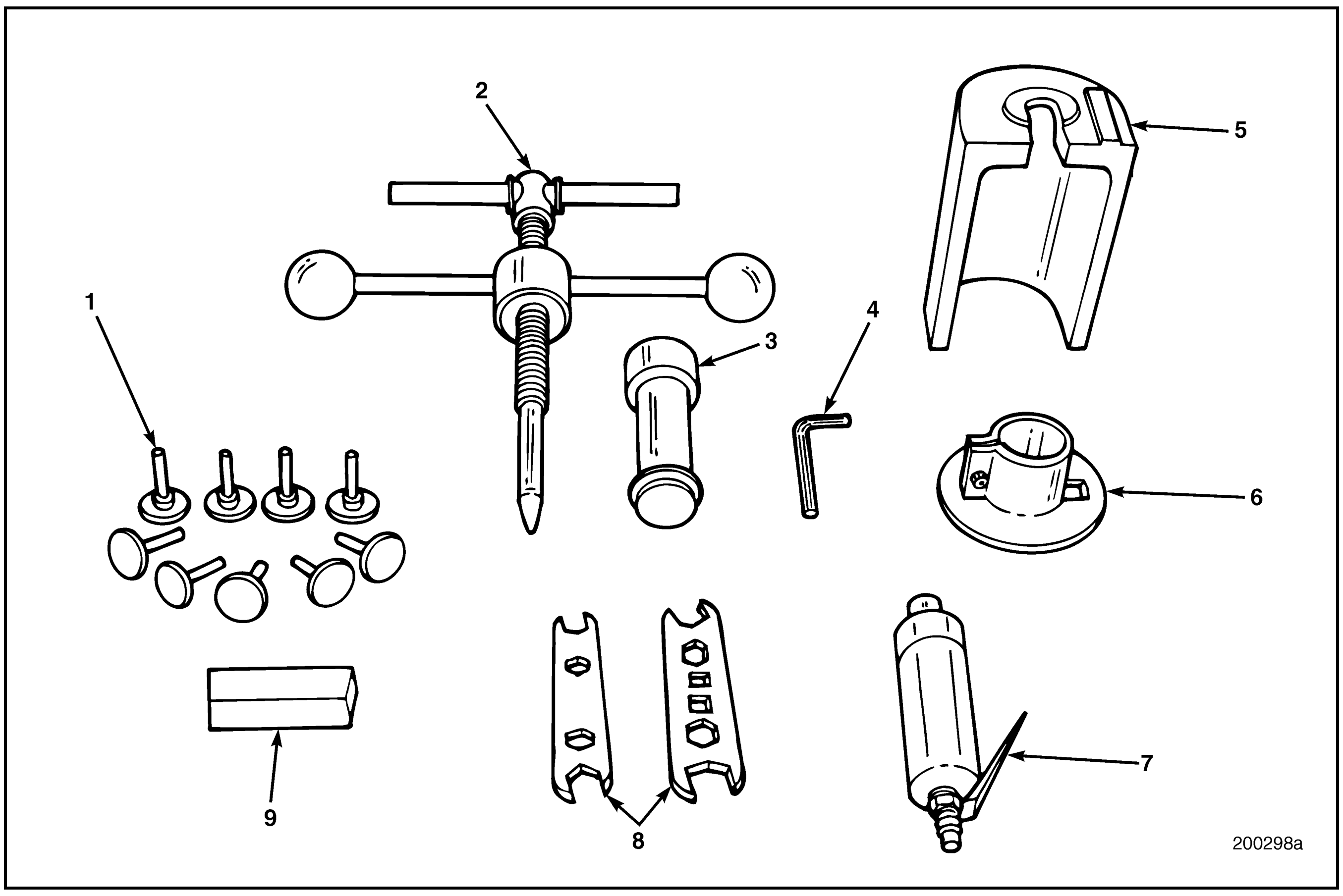


Figure 192 — Valve Seat Extractor Kit PT6391

1. Grinding Wheels 2. T-Handle and Shaft Assembly 3. Collet 4. Allen Wrench 5. Lifting Bridge	6. Grinder Base 7. Grinder 8. Wrenches 9. Dressing Stone

1. Using depth measurement tool (1), measure the distance from the cylinder head surface (2) to the point on insert where the groove will be ground as shown in Figure 193.

NOTE

This point should be approximately 0.060 inch (1.524 mm) below any angular face on the valve seat insert.

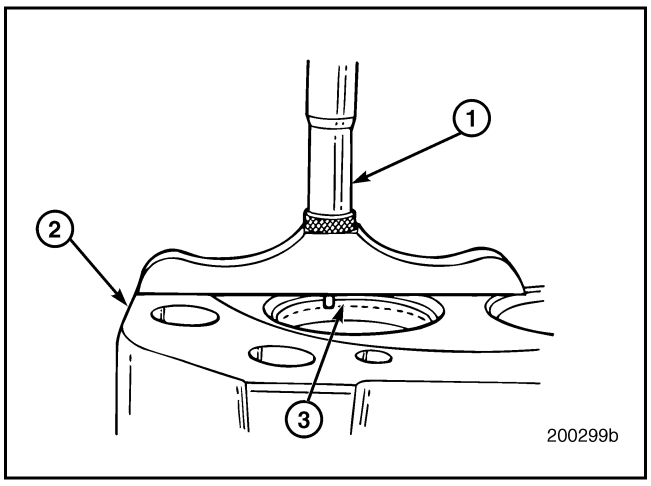


Figure 193 — Valve Insert Depth Measurement

1. Depth Measurement Tool 2. Cylinder Head	3. Groove

2. Install grinding wheel (2) into the grinder (4) and set depth of the grinder base (1) to the dimension found in the preceding step. Refer to Figure 194.
3. Secure the base to grinder by tightening the hex-head screw (3).

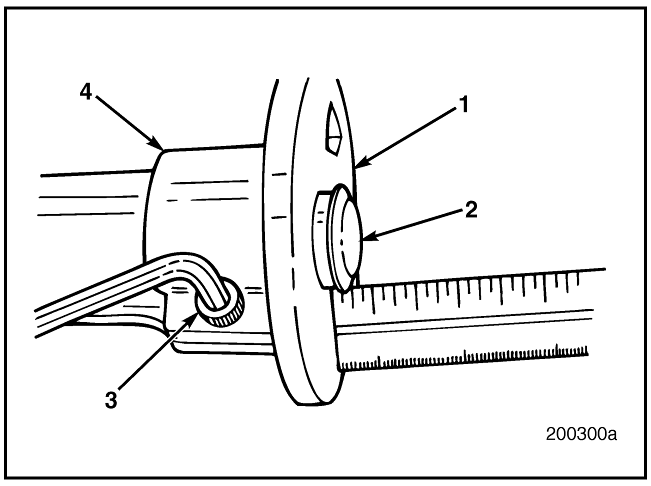


Figure 194 — Setting Depth of Grinder

1. Grinder Base 2. Grinding Wheel	3. Hex-Head Screw 4. Grinder

4. Grind a groove around the inside circumference of the valve seat insert. This groove should be approximately 0.030 inch (0.762 mm) deep.

CAUTION

Use care not to damage any machined surface of the cylinder head.

5. Attach the collet to the T-handle and shaft assembly.
6. Position the collet in the valve seat insert so ridge of the collet will be inside the groove. Turn the T-handle to fully expand the collet.
7. Position lifting bridge (3) under the crank handle (2) as shown in Figure 195. Turn the crank handle clockwise to remove the insert.
8. Release insert from the collet (4) by slightly turning the T-handle (1).

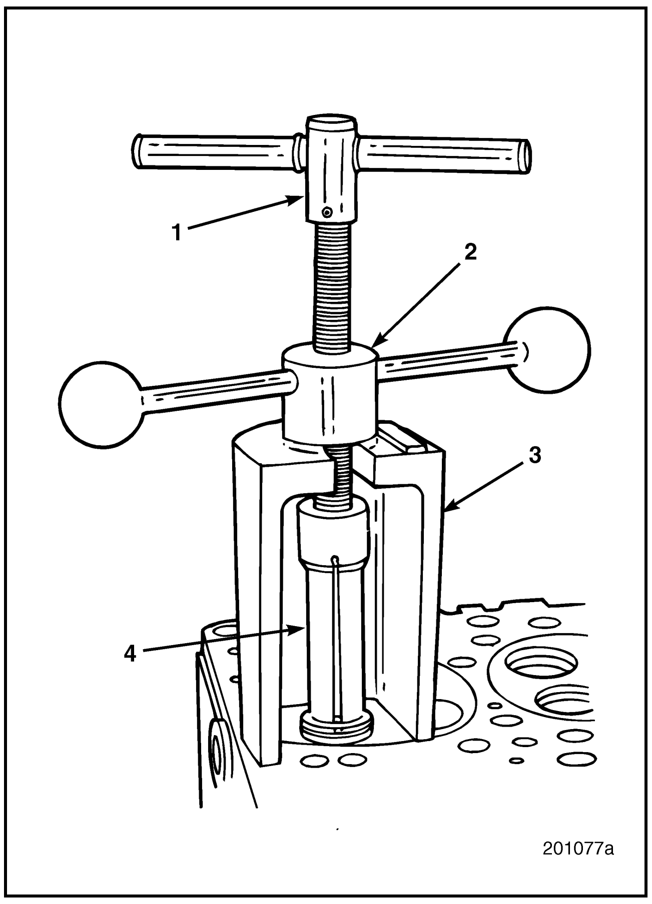


Figure 195 — Removing Valve Insert

1. T-Handle 2. Crank Handle	3. Lifting Bridge 4. Collet

5_106_00.bk Page 194 Friday, August 4, 2000 11:17 AM

VALVE SEAT INSERT COUNTERBORE

Refer to Figure 196.

- Valve seat counterbore depth (3):
  - — Exhaust: 0.376–0.372 inch (9.55–9.449 mm)
  - — Inlet: 0.364–0.360 inch (9.246–9.144 mm)
- Inlet valve seat insert counterbore diameter (4): 1.8295–1.8285 inches (46.4693–46.4439 mm)
- Exhaust valve seat counterbore diameter (5): 1.6885–1.6875 inches (42.8879–42.8625 mm)

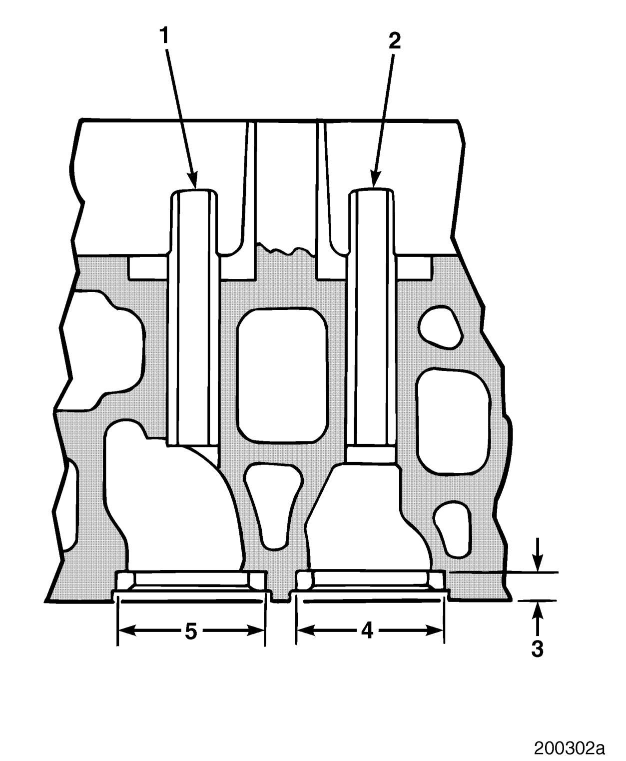


Figure 196 — Valve Seat Insert Counterbore Dimensions

1. Exhaust Valve Guide 2. Inlet Valve Guide 3. Valve Seat Counterbore Depth	4. Inlet Valve Seat Insert Counterbore Diameter 5. Exhaust Valve Seat Counterbore Diameter

INSPECTION

1. With the valve seat insert removed from the cylinder head, clean the surface thoroughly with a wire brush.
2. Check the surface finish for smoothness. Check the counterbore diameter (Figure 197) with an inside diameter micrometer. Compare to specification.

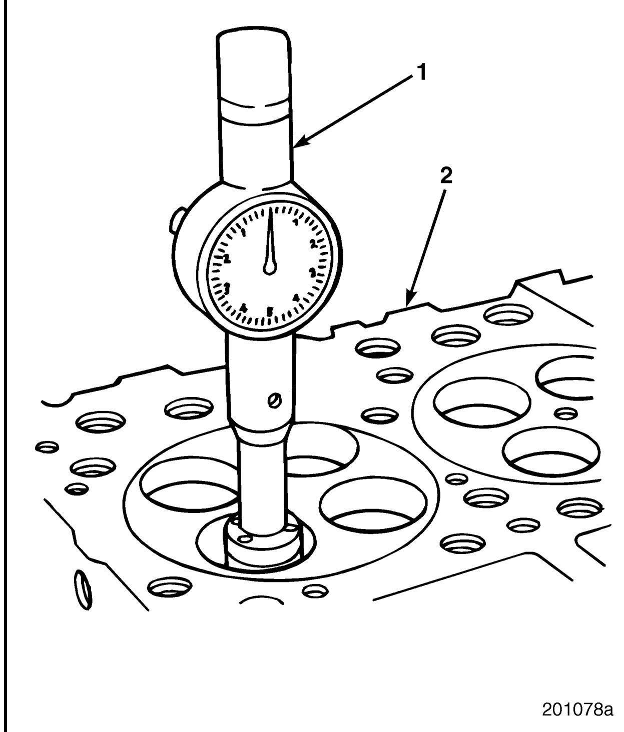


Figure 197 — Checking Counterbore Dimensions

1. Inside Diameter Micrometer	2. Cylinder Head

5_106_00.bk Page 195 Friday, August 4, 2000 11:17 AM

VALVE SEAT INSERT INSTALLATION

NOTE

Oversize inlet and exhaust valve seat inserts are available in 0.005, 0.015, 0.031, 0.047 and 0.062 inch sizes if the counterbore requires machining.

1. If required, machine the inlet and exhaust valve seat insert counterbores using tool HT77136.
2. Position the valve seat insert (1) over the corresponding counterbore as shown in Figure 198. Install the inserts using valve seat insert installation set J 38586 (2). Use driver handle J 8092 (3) to drive the valve seat insert into the counterbore.

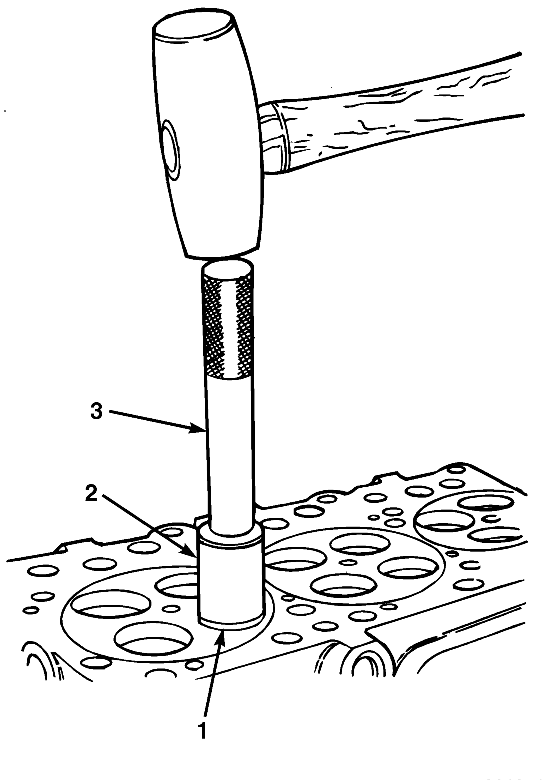


Figure 198 — Valve Seat Insert Installation

1. Valve Seat Insert 2. J 38586	3. J 8092

3. Grind the inlet/exhaust valve seat inserts to specification.
   - Inlet valve inserts: 20° 30′ ± 15′ angle
   - Exhaust valve inserts: 30° –0′/+30′

CAUTION

Always use 30-degree valves with 30-degree valve inserts and 20-degree valves with 20-degree valve inserts. Excessive wear and possible failure will result if 30-degree parts are matched with 20-degree parts.

NOTE

If valve seat insert widths exceed specifications when grinding the inserts, use a 15-degree angle grinding stone to obtain the correct width.

4. After grinding, thoroughly clean the valve seat insert.
5. Determine the concentricity of each valve seat insert relative to the valve guide. Valve seat runout is to be held within 0.002 inch (0.051 mm) FIM (Full Indicator Movement), with finished valve guide ID measurements made from snug-fitting arbor (1) and through-mounted into finished valve guides (2) as shown in Figure 199.

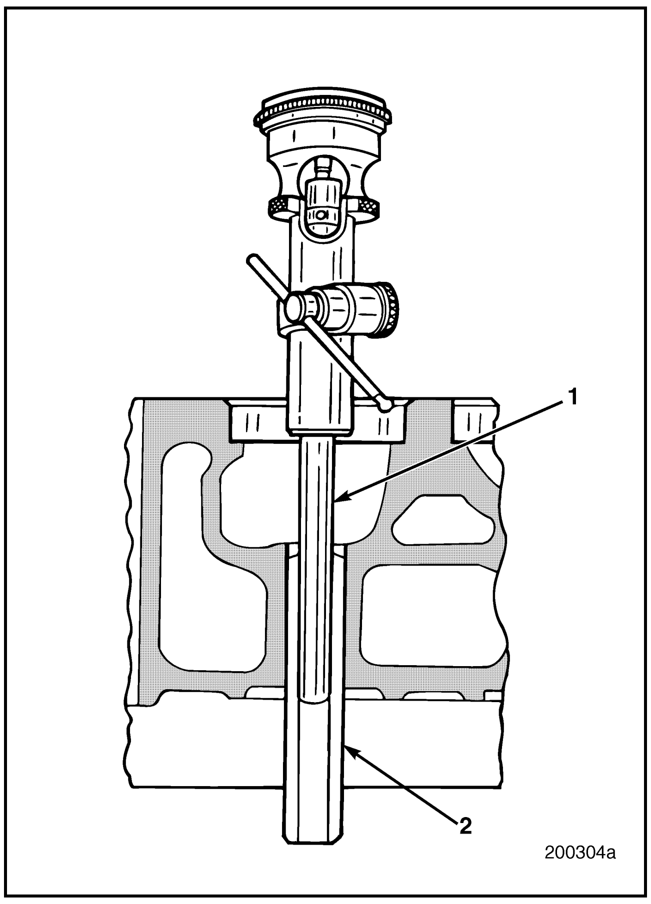


Figure 199 — Checking Valve Seat Runout

1. Arbor	2. Valve Guides

6. After checking runout, determine the position of contact between the valve and valve seat insert. Apply a dab of Prussian Blue to the valve face at four points, 90 degrees apart.
7. Lower stem of the valve into the valve guide and allow the valve face to rest on the seat insert. Rotate the valve 90 degrees on the insert. Carefully remove the valve without making contact with the valve face. Properly ground inserts should show a full pattern of contact on the insert.

NOTE

Thoroughly clean the cylinder head after checking the valve seat inserts and before installing the valves.

Valve Spring Inspection

[213 MB]

1. Visually inspect the inside surfaces of the spring coils. Also, feel the inside surfaces of each spring for any indication of roughness or grooving. If either of these conditions exist, replace the spring.
2. Check springs on the universal spring tester J 22738-02 as shown in Figure 200. With springs compressed to 1.5 inches (38.1 mm), the pressure should be within specification, 190–210 lb (86.2–95.3 kg).

NOTE

If spring pressure does not meet specification, replace the spring.

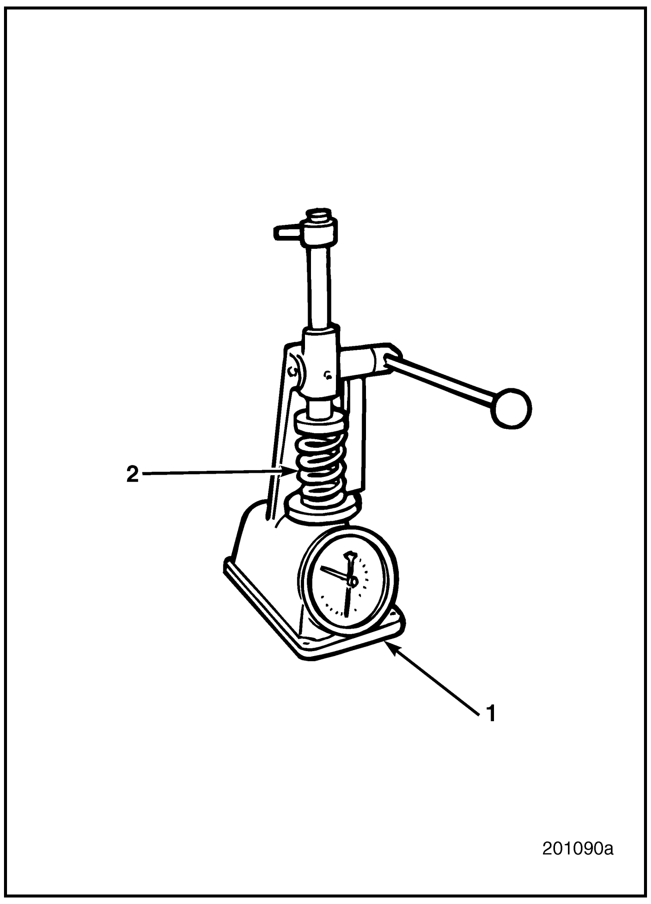


Figure 200 — Checking Valve Spring Pressure

1. Spring Tester J 22738-02	2. Valve Spring

5_106_00.bk Page 197 Friday, August 4, 2000 11:17 AM

Injection Nozzle Holder Insert Replacement

[213 GB]

The injection nozzle holder insert is machined to provide a press-fit in the cylinder head.

REMOVAL PROCEDURE

1. To remove the injection nozzle holder insert, tap the ID with a 24 mm -3 tap to a depth of approximately 1-1/2 inches.
2. Install nozzle sleeve (insert) puller J 42678 (2) to slide hammer J 2619-01 (1) or equivalent as shown in Figure 201.
3. Thread the puller into the end of the nozzle holder insert and use the slide hammer to remove the insert.

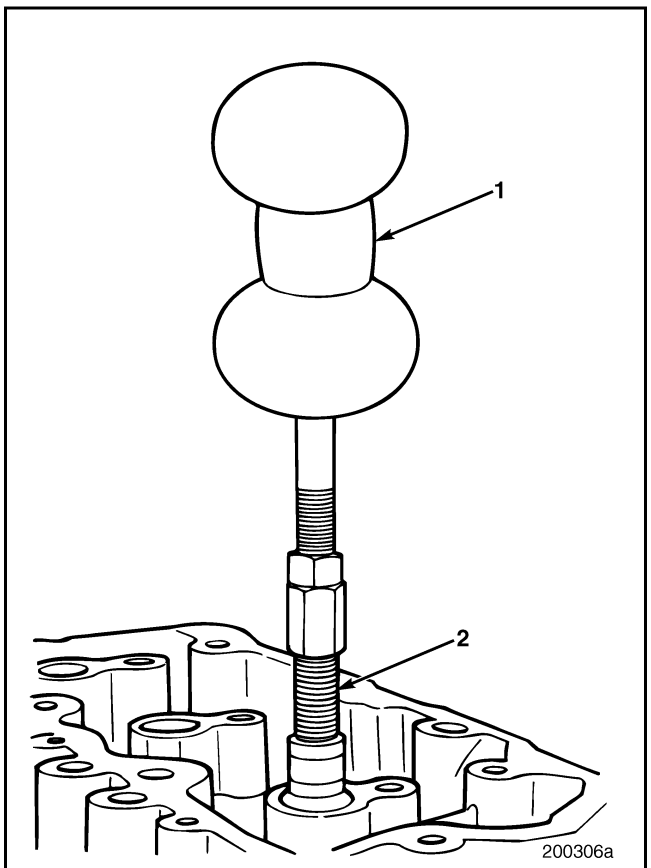


Figure 201 — Removing Injection Nozzle Holder Insert

1. Slide Hammer J 2619-01	2. Sleeve Puller J 42678

INSTALLATION PROCEDURE

1. Clean the nozzle insert bore in the cylinder head and the contact surfaces with Loctite® Primer T.
2. Apply Loctite® 620 to the cylinder head and insert surfaces. Refer to Figure 202.

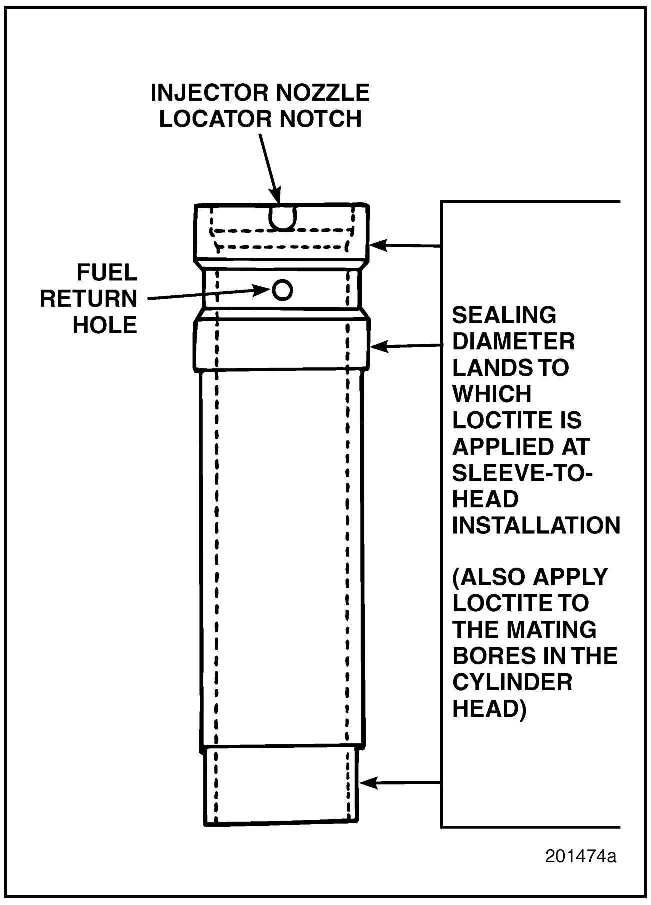


Figure 202 — Fuel-Injection Nozzle Insert

3. Install the insert in the cylinder head with the indexing notch aligned in direction of the high-pressure fuel line hole in the head.
4. Install the alignment pin and using nozzle insert installer J 42595, drive the insert into the cylinder head until it bottoms on the lower counterbore face. Refer to Figure 203 and Figure 204.

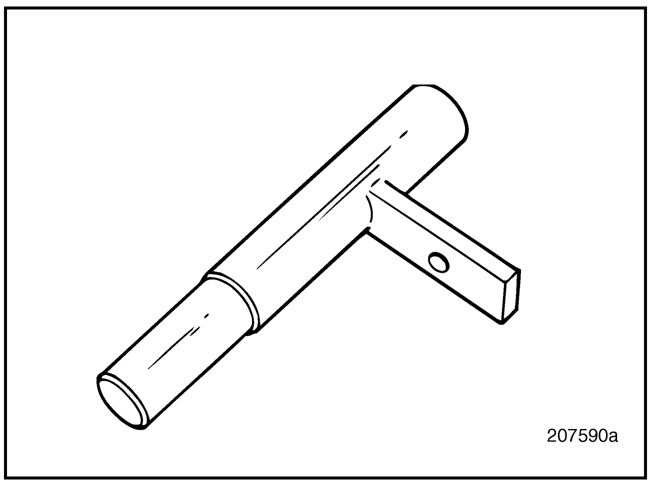


Figure 203 — Nozzle Sleeve (Insert) Installer

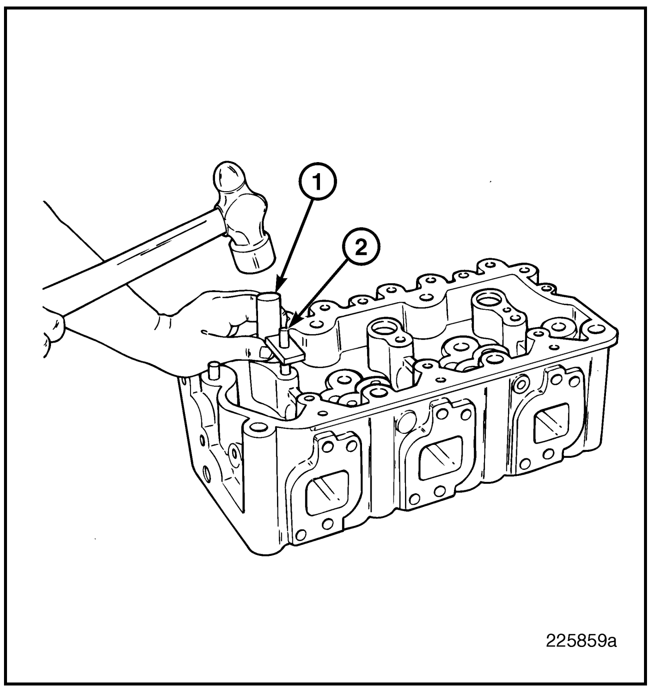


Figure 204 — Injection Nozzle Holder Insert Installation

1. Nozzle Sleeve Installer J 42595	2. Alignment Pin

Valve Yoke Guide Pin Replacement [213 FH]

Valve yoke guide pins are located between each set of inlet and exhaust valve guides on engines produced before March 2, 2000. Beginning with March 2, 2000 production (engine serial No. 0D0120), valve yoke guide pins are located only between each set of exhaust valve guides since these engines use pinless valve yokes to actuate the inlet valves.

INSPECTION

Inspect the valve yoke guide pin surface for cracks or other damage. Also check the pin diameter and installed height.

REMOVAL PROCEDURE

Remove a broken pin as follows:

NOTE

Due to the hardness of the valve yoke guide pins, drilling and tapping must be done slowly with sharp tools and with plenty of lubrication.

1. Center punch the broken section of the pin in the cylinder head prior to drilling.

NOTE

The punch mark must be close to the center of the broken pin to control the drilling operation.

2. Using a drill press, drill a 13/64-inch pilot hole completely through the broken section of the yoke pin.

NOTE

A drill press is strongly recommended to keep the drilled hole straight with the yoke pin hole in the cylinder head. Use care when drilling to “feel” when the drill bit passes through the yoke pin and contacts the cylinder head. Stop drilling at that point to avoid drilling through the head and into the water jacket.

3. Drill a 5/16-inch hole completely through the broken section of the yoke pin.

4. Tap the broken yoke pin as deep as possible using a 3/8-inch NC starter tap and cutting oil. Clean out the cutting chips using compressed air.
5. Repeat the above step using a 3/8-inch NC bottom tap. Again, clean out the cutting chips using compressed air.
6. Using a slide hammer fitted with a 3/8-inch NC extractor, remove the broken yoke pin from the cylinder head (Figure 205).

NOTE

Thread the slide-hammer extractor as deep as possible into the threaded yoke pin. Failure to install the extractor deep enough will cause the yoke pin to break again.

7. Clean out any remaining chips with compressed air and inspect the yoke pin hole in the cylinder head for drilling or tapping damage.

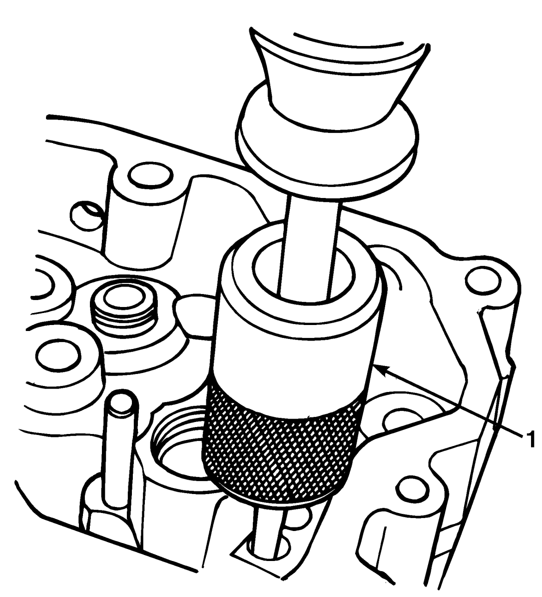


Figure 205 — Valve Yoke Guide Pin Removal

1. Extractor Lock (Part of PT6570-11)

INSTALLATION PROCEDURE

If a **new** valve yoke guide pin is required, apply Loctite® 635 to the pin and use guide pin installer J 29296 to drive the pin into the cylinder head. The guide pin will be at the correct height when tool bottoms on the cylinder head. Refer to Figure 206.

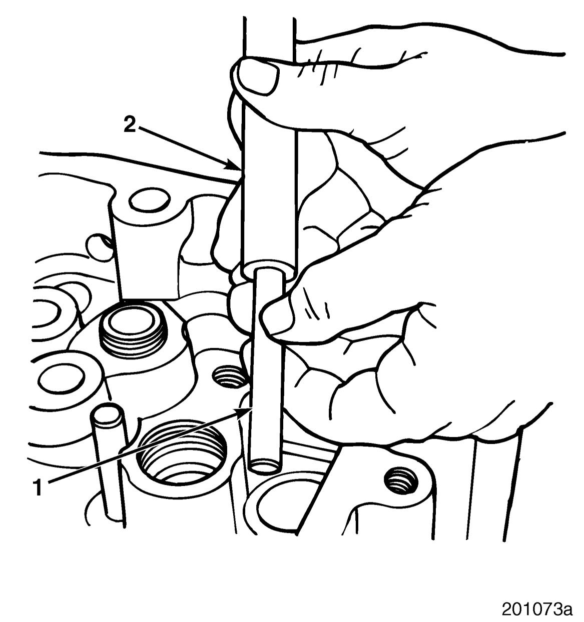


Figure 206 — Valve Yoke Guide Pin Installation

1. Valve Yoke Guide Pin	2. J 29296

Cylinder Head Cup Plug Replacement

[213 FP]

The cylinder head has two different size cup plugs. Both sizes are installed using the following procedure:

1. Clean the cup bore thoroughly.
2. Using Loctite® 277 sealer, or equivalent, apply the sealer to the cup plug and plug bore in the head.

3. Install cup plugs in the cylinder head, using the appropriate cylinder head core plug installer, J 34684 for 13/16-inch (20.64 mm) cup plugs, and J 34687 for 1-1/16 inch (26.99 mm) cup plugs. Refer to Figure 207.

NOTE

Cup plug should be installed flush with the cylinder head machined surface to 0.020 inch (0.508 mm) below the surface.

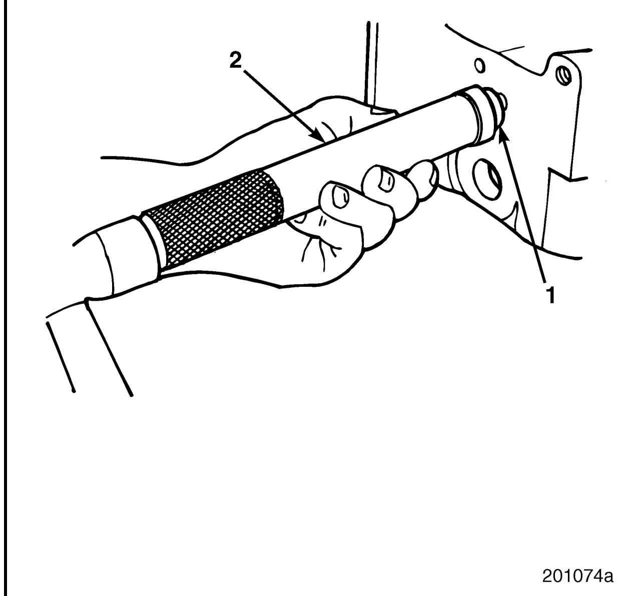


Figure 207 — Cylinder Head Cup Plug Installation

1. Cup Plug	2. Cup Plug Installer

Cylinder Head Pipe Plug Replacement

GENERAL INFORMATION

The 3/4-inch cylinder head pipe plugs sealed with a teflon-based thread sealer may loosen and result in a coolant leak after initial installation. Beginning April 1, 1999 (engine serial number series 9F), 3/4-inch pipe plugs having a preapplied encapsulated epoxy sealant were phased into engine production. With the epoxy sealer, the pipe plugs are locked into place, making them immovable when normal loosening/tightening methods are used. Should it become necessary to remove a pipe plug, the following procedure should be used.

NOTE

If a cylinder head has been placed in a hot chemical tank for cleaning and degreasing, the pipe plugs must be checked for looseness. If a plug is found to be loose, the epoxy seal has been broken, making it necessary to remove the plug, clean the plug and cylinder head threads with Loctite® Primer T and reseal the threads with Loctite® 277.

If coolant leaks at the cylinder head pipe plugs are encountered on engines manufactured prior to engine serial number series 9F, the pipe plugs must be removed, cleaned and reinstalled following the procedures below.

REPLACEMENT (3/4-INCH PLUGS)

Refer to Figure 208.

1. Heat the pipe plug to 400°F (205°C) with a torch.
2. With the pipe plug heated sufficiently, remove the plug from the cylinder head.
3. Remove the epoxy sealant from the threads on both the plug and in the cylinder head.
4. Clean the plug and cylinder head threads with Loctite® Primer T.
5. Apply Loctite® 277 sealant to the plug and cylinder head threads.
6. Install the plugs and tighten to the specified torque, 55 lb-ft (68 N•m).

REPLACEMENT (1/8-, 1/16-INCH PLUGS)

1. If reusing a pipe plug, the threads on the plug and in the cylinder head must be thoroughly cleaned and dried.
2. Apply dry pipe thread sealant to the pipe plug and plug bore in the cylinder head.
3. Install a 1/8-inch NPT pipe plug in the fuel passage at the top front location of the front cylinder head. Tighten the plug to the specified torque, 6 lb-ft (8 N•m).
4. Install a 1/16-inch NPT pipe plug in each end of the cylinder head. Tighten the plugs to the specification.

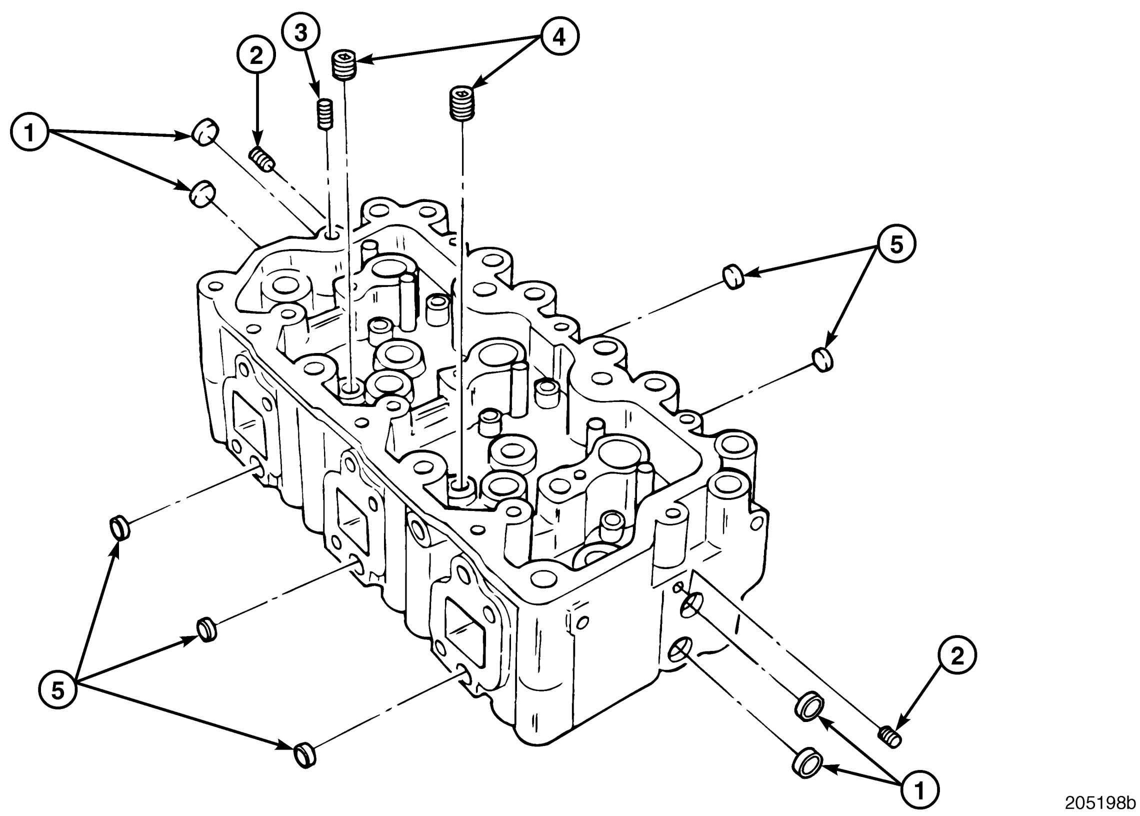


Figure 208 — Cylinder Head Pipe Plug Locations

1. 1-1/16-inch Cup Plug 2. 1/16-inch NPT Plug 3. 1/8-inch NPT Plug	4. 3/4-inch NPT Plug 5. 13/16-inch Cup Plug

5_106_00.bk Page 202 Friday, August 4, 2000 11:17 AM

Valve Replacement

[213 NB]

INSPECTION

Refer to Figure 209.

Visually inspect valves for cracks, pits or other conditions that may cause improper operation. Check valve seat angle. Also check stem length, diameter and condition.

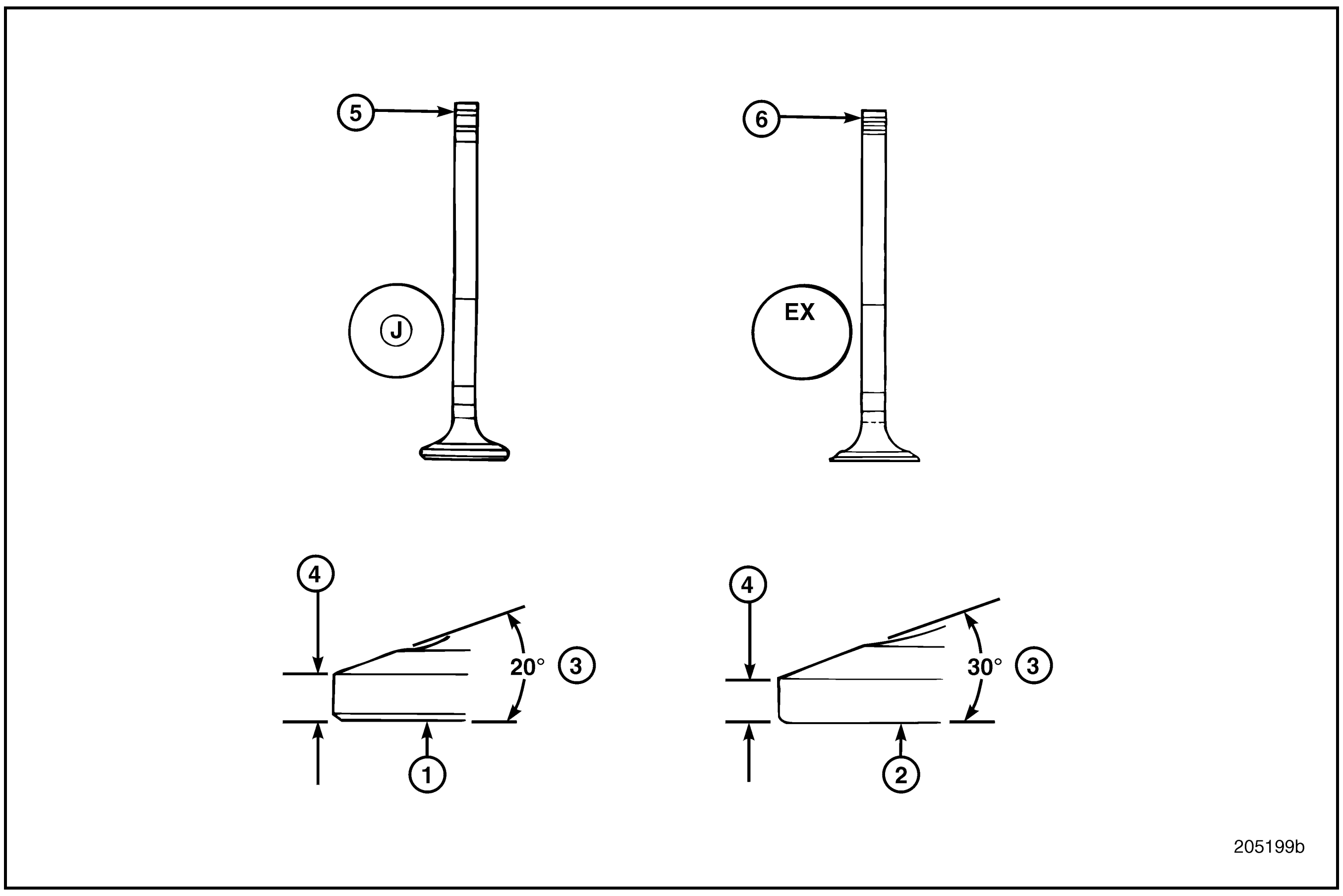


Figure 209 — Valve Dimensions

1. Inlet Valve 2. Pyromet Exhaust Valve 3. Seat Angle: 20° Inlet, 30° Exhaust	4. Minimum After Grinding: 0.130 inch (Inlet), 0.100 inch (Exhaust) 5. One Stem Groove 6. Two Stem Grooves

INLET AND EXHAUST VALVE IDENTIFICATION

To permit positive identification, exhaust valve has two stem grooves and inlet valve has one stem groove in addition to the valve spring keeper groove.

The valves are also identified by the letter "J" (20-degree inlet), and letters "EX" (exhaust), on the bottom face of the valve head. Refer to Figure 210 for an illustration of the inlet valve identification.

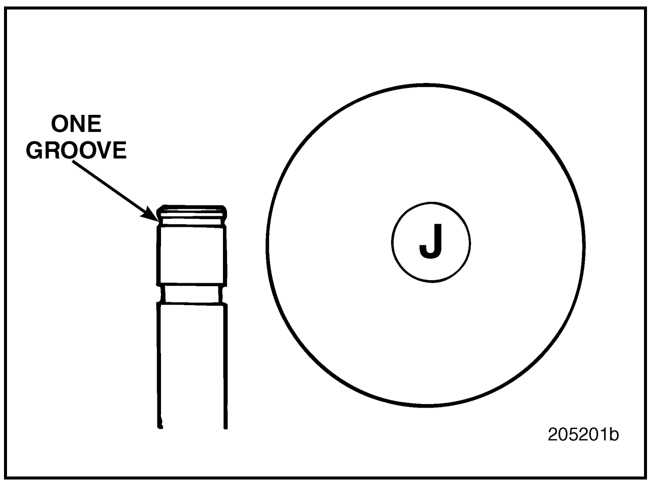


Figure 210 — 20-Degree Intake Valve Identification

VALVE INSTALLATION

CAUTION

The inlet and exhaust valve head diameters are nearly the same size. It is important, therefore, that extra care be taken when installing these valves.

NOTE

With the new, more effective valve stem seals (P/N 446GC328), pre-lubing the seals and valve stems during installation is extremely important. Perform the following:

- Valve Stem-to-Guide — If valves are removed, lubricate the inside diameter of the valve guides by using a "bottle brush" coated with Dow Corning® BR2 Plus multipurpose grease. This is particularly important when both the valves and the valve guides are new. With an on-engine seal replacement, pre-lube the valve stems with clean engine oil while moving the valve up and down, prior to installation of the valve spring.
- Valve Stem-to-Seal Lip — The inside diameter of the seal lip and outside diameter of the valve stem should be well-lubricated with clean engine oil when installing the seal over the valve stem.

It is essential that the J 42453 Valve Stem Seal Installation tool be used to install the seals. This tool bottoms on the cylinder head rocker arm mounting bracket surface when the seal is installed to the proper depth on the valve guide. Using any non-bottoming type seal driver (such as a socket) may result in distorting the top surface of the seal casing which permanently distorts the seal lip and prevents proper sealing. It can also result in the top rubber portion of the seal being cut off.

1. Lubricate the valve guides and valve stems with clean engine oil prior to installation.
2. Install the valve spring lower washer (Roto-Coil) over the valve guide.

NOTE

Before installing the valve stem seals, be sure the rotator has been installed. The rotator will not fit over the valve stem seal.

3. Lubricate the valve stem seals with engine oil and install the seals using valve seal installer J 42453.
4. Install the valve in the cylinder head.
5. Check the valve stem tip for nicks or burrs that may damage valve seal upon installation.
6. Install the valve spring, upper washer and keepers. Use tool J 29294-B to install the keepers.
7. After the valves are installed, check each inlet valve for head height above the cylinder deck. The protrusion dimension for inlet valves should be 0.0425 +0.009/–0.007 inch (1.0795 +0.229/–0.178 mm). Refer to Figure 211 and Figure 212.

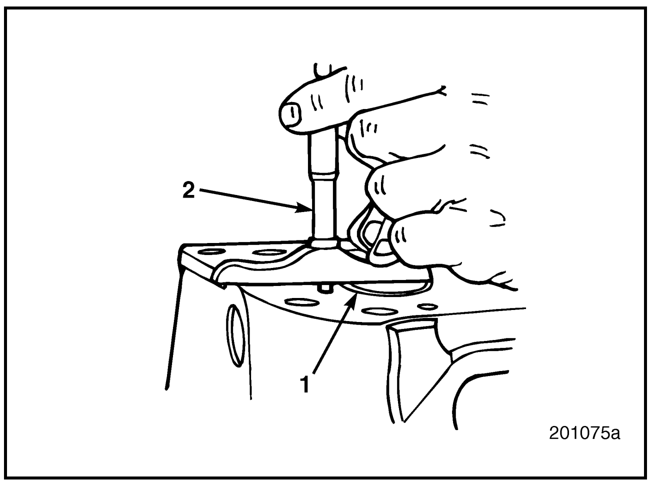


Figure 211 — Checking Valve Assembly Height

1. Inlet Valve	2. Depth/Height Measurement Tool

8. Check each exhaust valve for head depth below the cylinder deck. The depth dimension for the exhaust valve should be 0.021 +0.009/–0.007 inch (0.553 +0.229/–0.178 mm).

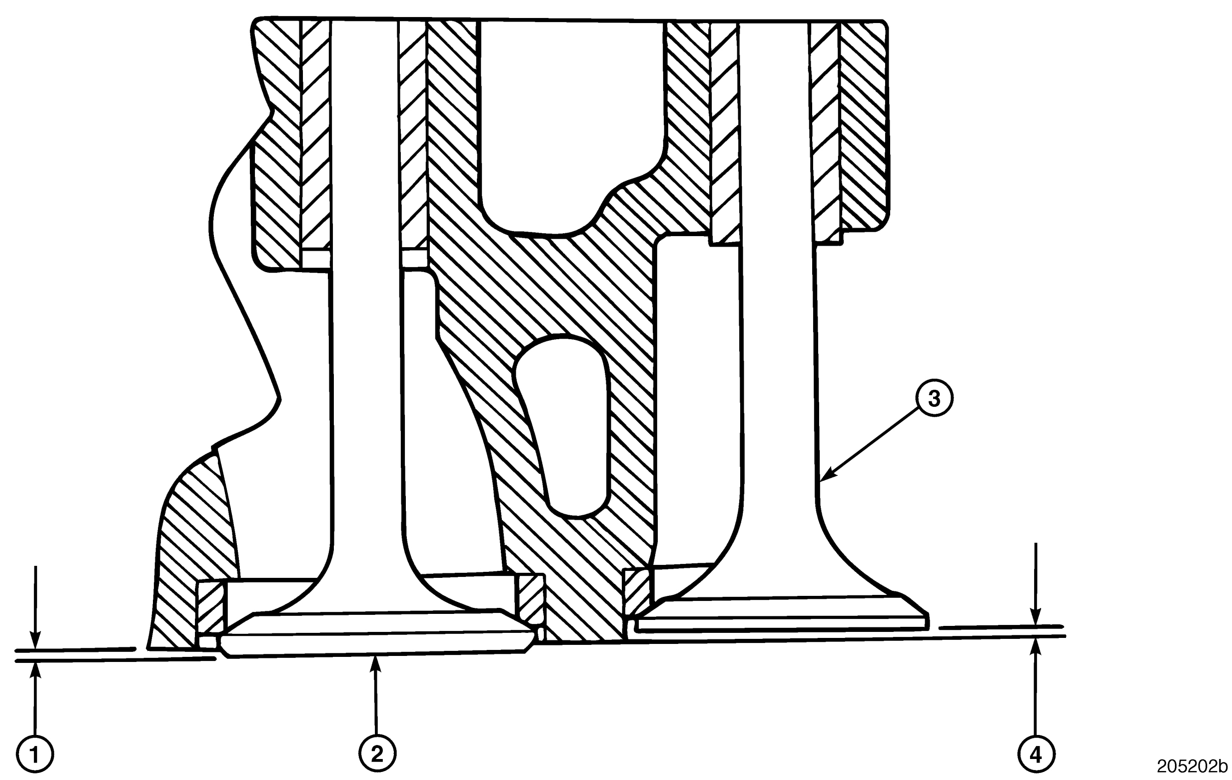


Figure 212 — Inlet/Exhaust Valve Head Depth Measurement

1. Inlet Protrusion Above Deck: 0.0425 inch +0.009/–0.007 inch (1.0795 +0.229/–0.178 mm) 2. Inlet Valve	3. Exhaust Valve 4. Exhaust Valve Depth Below Deck: 0.021 inch +0.009/–0.007 inch (0.553 +0.229/–0.178 mm)

NOTE

If the dimensions are not within specification, machine the valve seat insert and/or valve face as necessary. Refer back to the Valve Seat Insert Installation procedure in this section.

5_106_00.bk Page 206 Friday, August 4, 2000 11:17 AM

VALVE ROCKER ARM SHAFT BENCH PROCEDURES [213 LP]

Rocker Arms

Early-production E-Tech™ engines used the older style rocker arms of the E7 engine. Effective second quarter 1997, both models use a newly designed rocker arm (Figure 213) where the slipper end wear surface is a hardened, headed pin, pressed into the rocker arm.

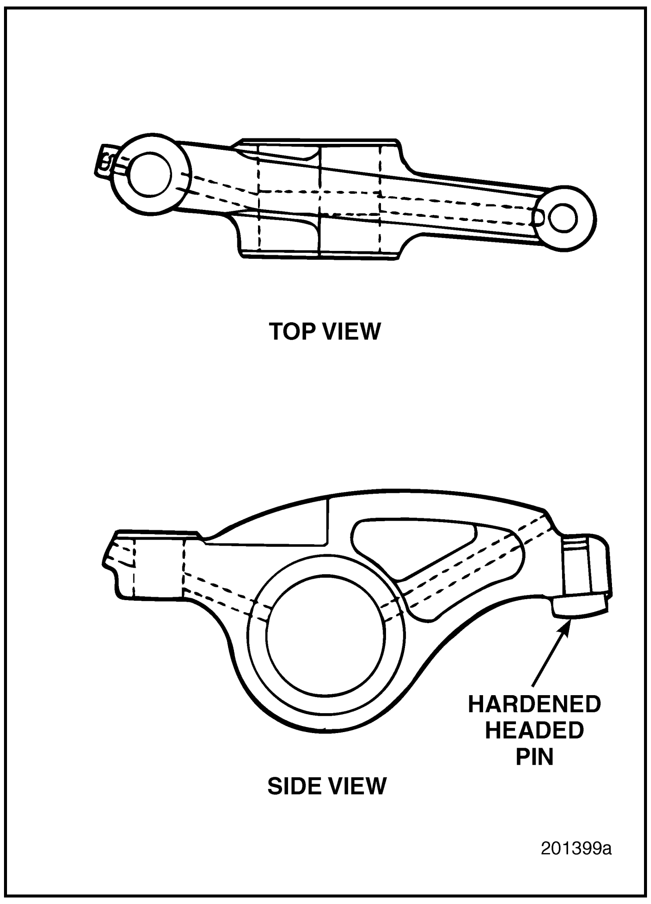


Figure 213 — New-Style Rocker Arm

Valve Rocker Arm Shaft Disassembly (without/with Engine Brake)

NOTE

For early-production engines, six C-clips are used to retain the rocker arms in position. For later-production, the four inboard C-clips and washers are replaced with two spacer tubes to properly position the rocker arms.

Refer to Figure 214 and Figure 215. The shaft assembly is disassembled as follows:

1. Remove the C-clip and flat washer from one end of the shaft.
2. Remove the outer rocker arm and spring washer.
3. Press the mounting bracket from the shaft. Use care not to drop the assembly as the bracket is removed.
4. Remove the second spring washer, rocker arm, flat washer and C-clip or spacer tube, if so equipped.
5. Repeat steps 1 through 4 to remove the two remaining rocker arm sets from the shaft.
6. Remove the adjusting screws and jam nuts from the rocker arms.

Inspection

Inspect all components of the rocker arm and bracket assembly for evidence of damage or wear. Replace as necessary.

Valve Rocker Arm Shaft Reassembly (without Engine Brake)

NOTE

There is a shouldered rocker arm mounting capscrew at one end of each rocker arm assembly to ensure proper alignment.

Refer to Figure 214.

The assembly procedure for the rocker arm shaft is described below. The arrangement includes valve rocker arms (with lash adjusters) and mounting brackets mounted on the shaft. The bracket mounting dimensions are the same for both non-brake and brake assemblies.

1. Lubricate the six adjusting screws and jam nuts (4), and install one in each of the rocker arms. The adjusting screws are identical for both inlet and exhaust rocker arms.
2. Position the shaft (8) so that the screw locating hole is in line with the bracket locating screw hole.
3. The offset side of the bracket must be positioned toward the right side of the engine.
4. Assemble bracket (6) on a press table. Press the shaft into the bracket until the oil hole in the shaft is aligned with the hole in the bracket. Install the locating screw and lock washer (3) to secure the bracket on the shaft.
5. Lubricate the spring washers (2) and install the washers on the shaft, one on each side of the mounting bracket.
6. Lubricate the exhaust rocker arm (5) and install it on the shaft.
7. Install a flat washer and C-clip (1) on the shaft to retain the exhaust rocker arm.
8. Lubricate the inlet rocker arm (7) and install it on the shaft.
9. Install a flat washer and C-clip (1) on the shaft to retain the inlet rocker arm.
10. Install a flat washer and C-clip, if so equipped, on the shaft to position and retain the exhaust rocker arm at the center position of the shaft.
11. Lubricate the exhaust rocker arm and install on the shaft.
12. Lubricate a spring washer, install it on the shaft next to the exhaust rocker arm and press the center mounting bracket onto the shaft. This bracket does not have a threaded hole on top or an oil hole at bottom surface. Align the mounting surface and offset of the bracket with the bracket already installed.
13. Lubricate a spring washer and install it on the shaft next to the center bracket.
14. Lubricate and install the inlet rocker arm on the shaft.
15. Install a flat washer and C-clip (1) on the shaft to retain the center inlet rocker arm.
16. Follow steps 10 through 15 to install the remaining set of rocker arms and mounting bracket.

SERVICE HINT

At this point, a used or scrapped cylinder head can be used as a template for proper bracket alignment and to ensure mounting surfaces of each bracket are parallel.

17. Check for proper bracket alignment. Ensure that mounting surfaces of each bracket are parallel.

5_106_00.bk Page 208 Friday, August 4, 2000 11:17 AM

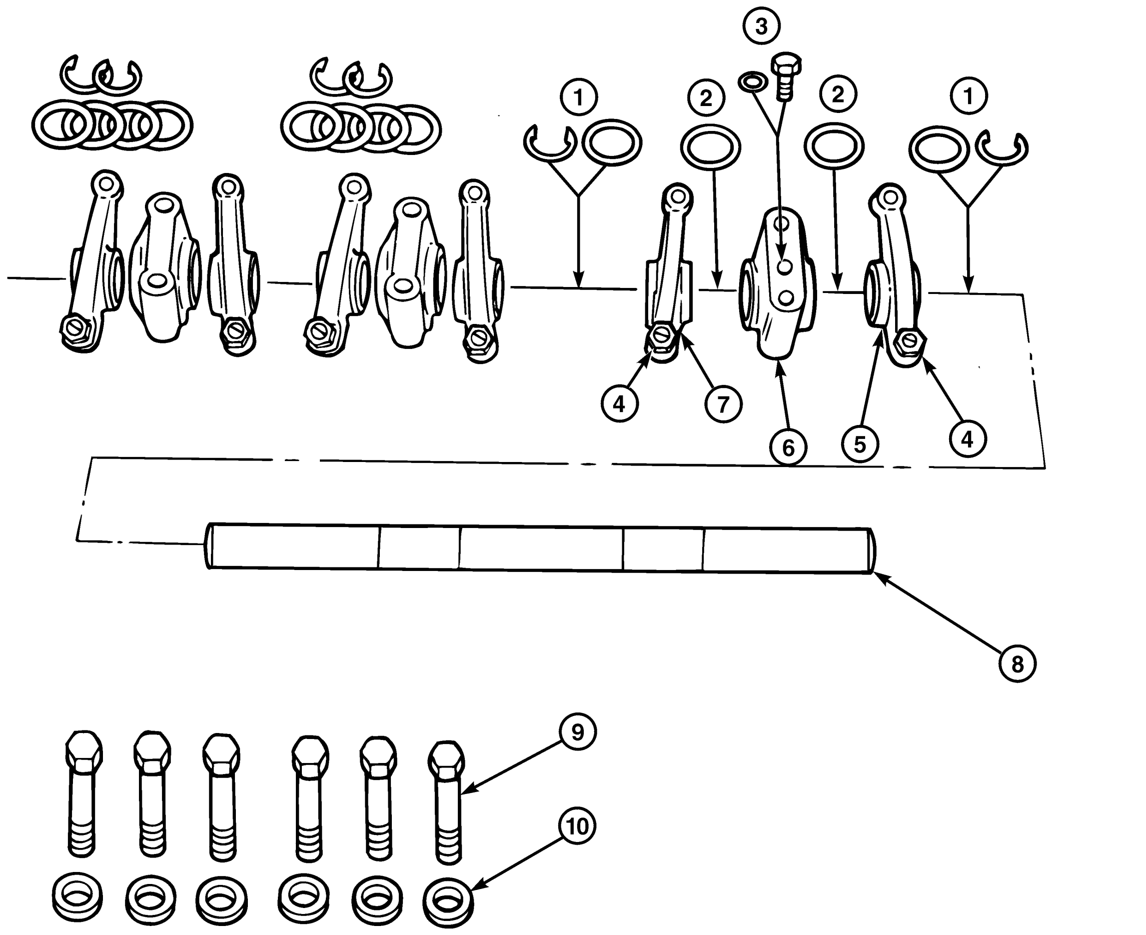


Figure 214 — Valve Rocker Arm Shaft Assembly (without Engine Brake)

1. Flat Washer and C-Clip 2. Spring Washer 3. Locating Screw and Lock Washer 4. Standard Adjusting Screws and Jam Nuts 5. Exhaust Rocker Arm	6. Mounting Bracket 7. Inlet Rocker Arm 8. Shaft 9. Capscrews (Short) 10. Washers (not used if equipped with flangehead bolts)

Valve Rocker Arm Shaft Reassembly (with J-Tech™ Engine Brake)

NOTE

There is a shouldered rocker arm mounting capscrew at one end of each rocker arm assembly to ensure proper alignment.

Refer to Figure 215.

The assembly procedure for the rocker arm shaft of a J-Tech™ brake-equipped engine is nearly identical to that of the non-brake engine with the following differences:

- An oil supply screw (3) replaces the locating screw and lock washer.
- A spherical jam nut and adjusting screw (4) replaces the standard jam nut and adjusting screw on the exhaust rocker arms.

The installation procedure is as follows:

1. Lubricate the three adjusting screws and jam nuts (8) for the **inlet rocker arms**, and install one in each of the arms.
2. Lubricate the three adjusting screws and spherical jam nuts (4) for the **exhaust rocker arms**, and install one in each of the arms.
3. Position the shaft (9) so that the screw locating hole is in line with the bracket locating screw hole.
4. The offset side of the bracket must be positioned toward the right side of the engine.
5. Assemble bracket (6) on a press table. Press the shaft into the bracket until the oil hole in the shaft is aligned with the hole in the bracket. Install the oil supply screw (3) to secure the bracket on the shaft and tighten the screw to specification, 5 lb-ft (7 N•m).
6. Lubricate the spring washers (2) and install the washers on the shaft, one on each side of the mounting bracket.
7. Lubricate the exhaust rocker arm (5) and install it on the shaft.
8. Install a flat washer and C-clip (1) on the shaft to retain the exhaust rocker arm.
9. Lubricate the inlet rocker arm (7) and install it on the shaft.
10. Install a flat washer and C-clip (1) on the shaft to retain the inlet rocker arm.
11. Install a flat washer and C-clip on the shaft to position and retain the exhaust rocker arm at the center position of the shaft.
12. Lubricate the exhaust rocker arm and install on the shaft.
13. Lubricate a spring washer, install it on the shaft next to the exhaust rocker arm and press the center mounting bracket onto the shaft. This bracket does not have a threaded hole on top or an oil hole at bottom surface. Align the mounting surface and offset of the bracket with the bracket already installed.
14. Lubricate a spring washer and install it on the shaft next to the center bracket.
15. Lubricate and install the inlet rocker arm on the shaft.
16. Install a flat washer and C-clip (1) on the shaft to retain the center inlet rocker arm.
17. Follow steps 11 through 16 to install the remaining set of rocker arms and mounting bracket.

SERVICE HINT

At this point, a used or scrapped cylinder head can be used as a template for proper bracket alignment and to ensure mounting surfaces of each bracket are parallel.

18. Check for proper bracket alignment. Ensure that mounting surfaces of each bracket are parallel.

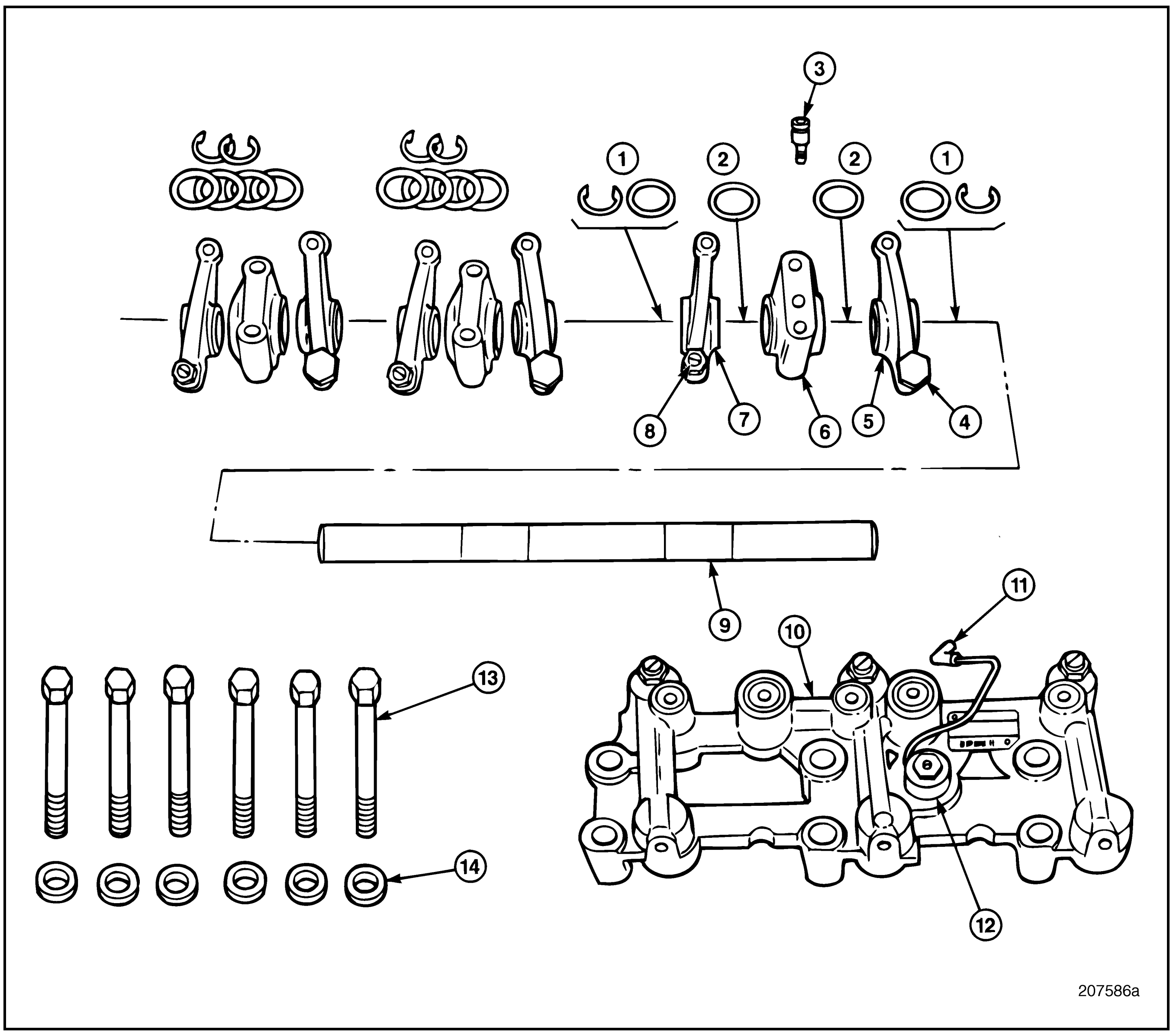


Figure 215 — Valve Rocker Arm Shaft Assembly (with J-Tech™ Engine Brake)

1. Flat Washer and C-Clip 2. Spring Washer 3. Oil Supply Screw (New Style Design with Integral Check Valve)* 4. Adjusting Screw and Spherical Jam Nut 5. Exhaust Rocker Arm 6. Mounting Bracket 7. Inlet Rocker Arm	8. Standard Adjusting Screw and Jam Nut 9. Shaft 10. Engine Brake Actuator Assembly 11. Electrical Connector 12. Solenoid 13. Capscrews (Long) 14. Washers (not used if equipped with flangehead bolts)

* A new oil supply screw assembly has been released for the J-Tech™ engine brake. This new screw incorporates an oil supply check valve, eliminating the need for the oil supply check valve components in the engine brake housing.

LUBRICATION SYSTEM BENCH PROCEDURES

Oil Cooler Assembly Reconditioning

[215 DW]

See Cooling System Components Bench Procedures in the REPAIR INSTRUCTIONS section.

Oil Pump Reconditioning

[219 MU]

Because of differences in the E-Tech™ and E7 gear set helixes, it is important that the correct replacement parts are used in making the repair.

- An improper drive gear on the oil pump will prevent oil pump installation, assuming a correct gear is on the auxiliary shaft.
- If an oil pump and an auxiliary shaft assembly were replaced, two improper gears could be installed, and engine failure would result.
- In replacing any of these critical parts, always refer to part number information in the MACK Parts System to ensure the correct component/part is being used.

DISASSEMBLY

Refer to Figure 216.

1. For ease of disassembly, reinstall the oil pump in the cylinder block or in a suitable holding fixture.
2. Remove the oil inlet (pickup) tube and screen assembly (not shown).

NOTE

Before inlet tube removal, note the orientation of tube for reassembly purposes. Inlet tubes are positioned differently for front or rear sump applications. Caution must be used to ensure that the correct mounting holes are used for the proper sump application.

3. Remove the oil pressure relief valve cap (13).
4. Remove the oil pressure relief valve spring (12) and plunger (11).
5. Remove the oil pump housing cover (7) from the oil pump housing (4).
6. Slide the oil pump idler gear (14) off the shaft.
7. Remove the oil pump from the cylinder block or other suitable holding fixture.
8. Turn the oil pump upside down and remove the oil pump shaft nut (1) and washer (2).
9. Using a press, remove the driven gear (3) and key (5) from the pump gear and shaft assembly (6).
10. Remove the pumping gear/shaft assembly and thrust washer from the housing.
11. Remove the oil pump inlet flange plate (9) and gasket (8) from the housing by removing the capscrews (10).

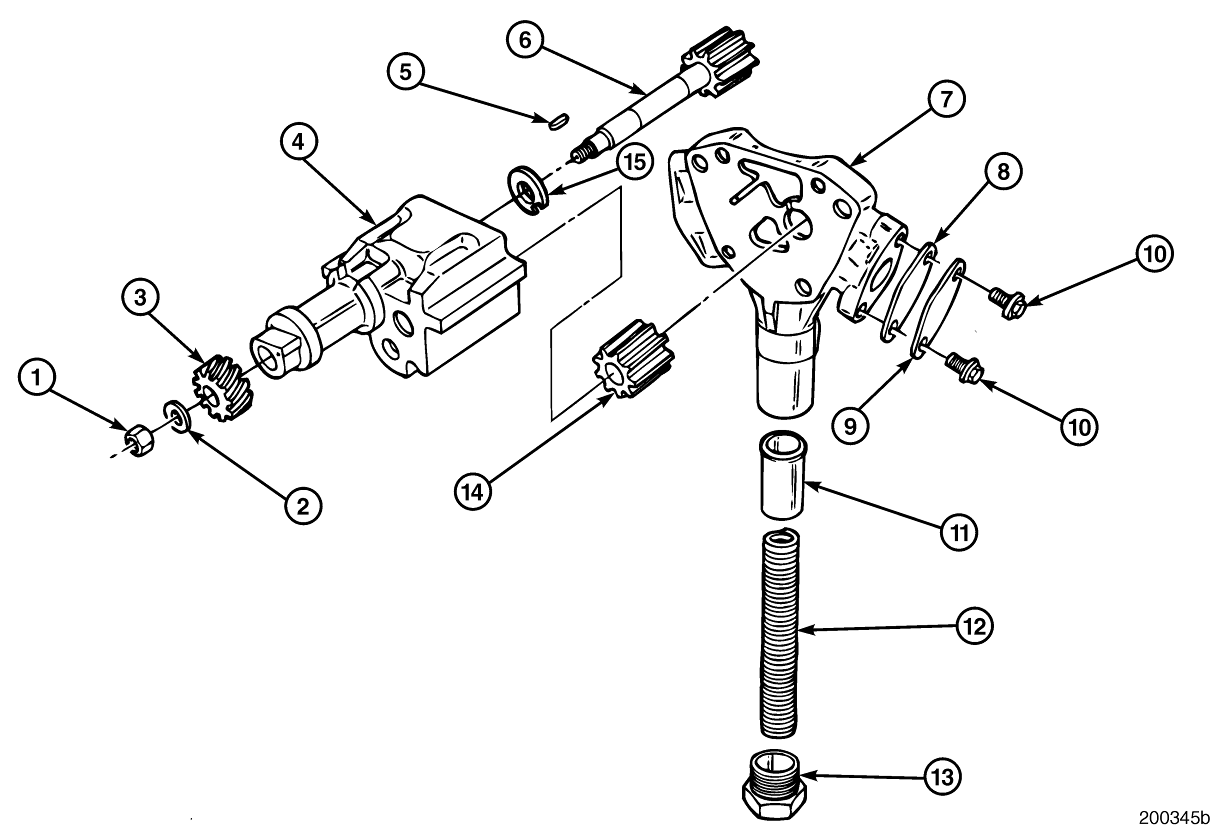


Figure 216 — Lubrication Oil Pump

1. Self-Locking Nut 2. Washer 3. Driven Gear 4. Housing 5. Key 6. Pump Gear and Shaft 7. Oil Pump Housing Cover 8. Gasket	9. Inlet Flange Plate 10. Capscrews 11. Plunger 12. Relief Valve Spring 13. Relief Valve Cap 14. Idler Gear 15. Thrust Washer

INSPECTION AND CLEARANCE CHECKS

Refer to Figure 216.

1. Clean and inspect the oil pump housing (4) for scoring, cracks or other damage. If any of these conditions exist, replace the oil pump.
2. Check the bushings in the pump housing for burrs, nicks or cracks.

NOTE

The bushings are an integral part of the oil pump housing. If the bushings are damaged, replace the oil pump housing.

3. Clean and inspect the relief valve spring (12) for breaks. Replace as necessary.
4. Clean and inspect the plunger (11) outer diameter for galling and scoring. If galling and scoring are present, replace the plunger.
5. Inspect the plunger seating surface for burrs or nicks. If the seating surface contains burrs or nicks, repair the seat as follows:
   a. Place valve lapping compound on the plunger seat.
   b. Insert plunger in the relief valve housing and rotate plunger against the seat to smooth seat.
   c. Remove the plunger and clean it.
6. Check the pump idler gear (14) for free play by spinning it on its shaft. If any binding occurs, check the housing bore and gear teeth for burrs, nicks or other damage. Replace as necessary.
7. Insert the pump gear and shaft, and thrust washer in the housing; check for free play by spinning the gear. If any binding occurs, check the housing and gear teeth for burrs, nicks or other damage. Replace as necessary. (The E-Tech™ engine oil pump utilizes a one-piece shaft with integral pumping gear.)

NOTE

Before proceeding with assembly of the pump, insert the pump gear and idler gear in the housing. Check end clearance, side clearance and backlash of the gears as follows.

End Clearance Check

Refer to Figure 217. With the pump gear and idler gear in place, position a straightedge across the housing and the face of the gears. Check end clearance as follows:

- Low Limit — Run a 0.003-inch (0.076-mm) thickness gauge between the straightedge and the gears. The gauge should move freely without binding. If binding occurs, check the gears for nicks or burrs. Replace as necessary.
- High Limit — Run a 0.007-inch (0.178-mm) thickness gauge between the straightedge and the gears. The gauge should be very tight. If the gauge moves freely, replace the gears.

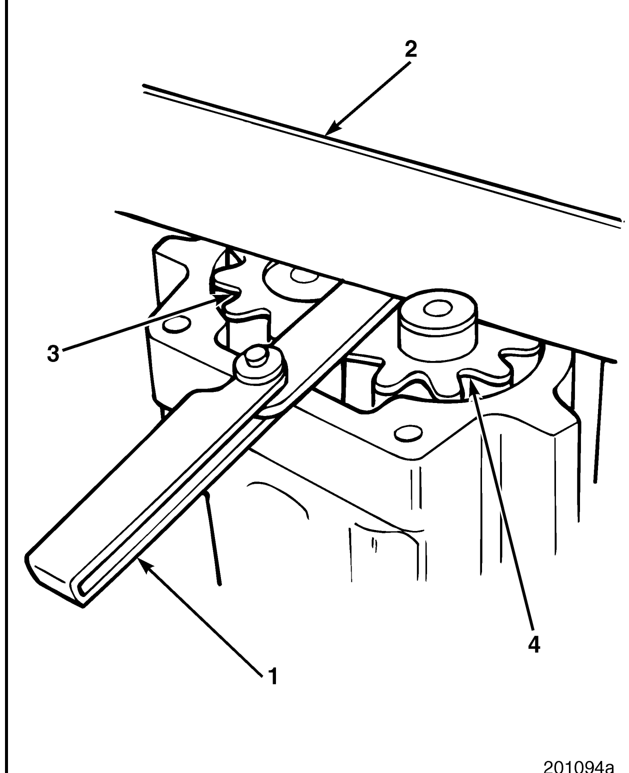


Figure 217 — Oil Pump Driving/Idler Gear Assembly End Clearance Check

1. Thickness Gauge	3. Pump Gear
2. Straightedge	4. Pump Idler Gear

Side Clearance Check

Refer to Figure 218. With the straightedge positioned across the housing and the face of the gears, check side clearance as follows:

- Low Limit — Insert a 0.002-inch (0.051-mm) thickness gauge between side of the gears and housing. The gauge should pass between gears and housing without drag. If it drags, check the housing and gears for nicks or burrs. Replace as necessary.
- High Limit — Insert a 0.006-inch (0.152-mm) thickness gauge between gears and housing. The gauge should not pass through. If the gauge passes through, replace the housing.

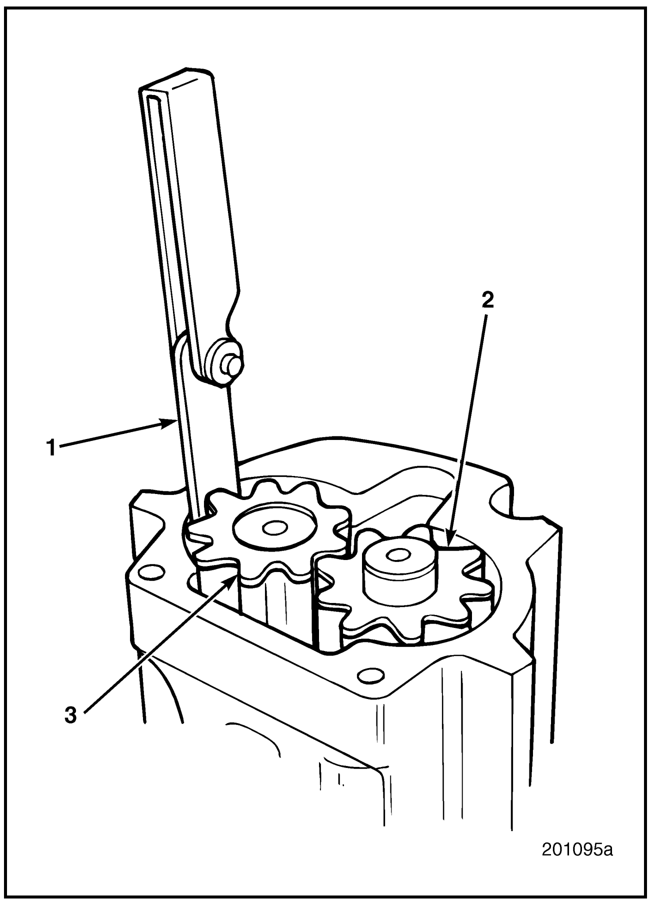


Figure 218 — Oil Pump Driving/Idler Gear Assembly Side Clearance Check

1. Thickness Gauge 2. Pump Idler Gear	3. Pump Gear

Backlash Check

Refer to Figure 219.

Check backlash between the pump gear (3) and idler gear (2) with a thickness gauge (1).

- Low Limit — Insert a 0.013-inch (0.33-mm) thickness gauge between the pump idler gear and pump gear. The gauge should pass between gears without binding. If binding occurs, check for nicks or burrs. Replace as necessary.
- High Limit — Insert a 0.028-inch (0.711-mm) thickness gauge between the pump idler gear and pump gear. The gauge should not pass through. If the gauge passes through, replace the gears.

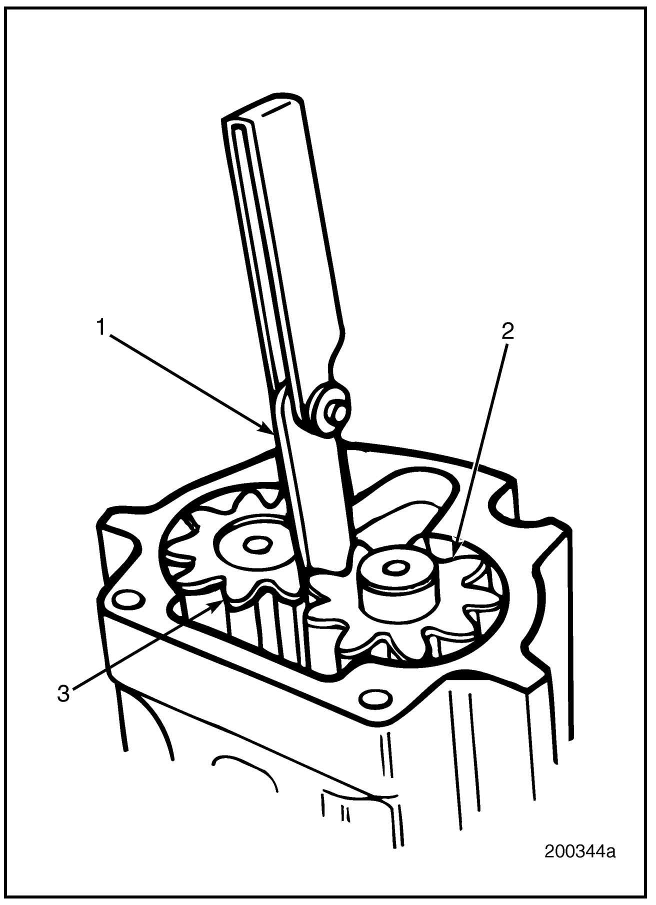


Figure 219 — Checking Oil Pump Gear Backlash

1. Thickness Gauge 2. Pump Idler Gear	3. Pump Gear

REASSEMBLY

Refer back to Figure 216.

1. Install the one-piece pump gear/shaft (6) and thrust washer (15) in the housing and check for free spin.
2. Install key (5) in the pump gear shaft (6).
3. Place gear (3) on the shaft, aligning the slot with the shaft key. Press the driven gear on the shaft.
4. Install washer (2) and self-locking nut (1) on the shaft. Tighten the nut to specification, 60 lb-ft (81 N•m), using torque wrench J 24407, or equivalent.
5. Install the idler gear (14) on the housing shaft.
6. Install cover (7) on the pump and secure the cover with capscrews. Tighten the capscrews to specification, 15 lb-ft (20 N•m).

NOTE

Apply Loctite® 271 to all capscrews used to assemble the oil pump.

7. Install the oil pressure relief valve plunger (11) in the relief valve housing (4).

CAUTION

To maintain correct oil pressure for the various oil system arrangements, the proper oil pressure relief valve spring and cap combination must be used. Using incorrect components may result in either high or low oil pressure, and contribute to premature engine damage.

8. Install the oil pressure relief valve spring (12) in the relief valve housing.
9. Clean the relief valve cap (13) and install it in the relief valve housing.
10. Install the pump inlet flange plate (9) and gasket (8) on the housing. Secure the plate with capscrews (10).
11. Install the oil inlet (pickup) tube and screen assembly.

NOTE

Because the inlet tube must be in a vertical position when installed in the engine, the mounting flange bolt pattern is off-set to the same degree as the oil pump-to-cylinder block mounting angle. The mounting flange of the inlet tube has four bolt holes marked with an F or R to distinguish which two holes are used for the front sump, and which two holes are used for rear sump applications. Caution must be used to ensure that the correct mounting holes are used for the proper sump applications.

COOLING SYSTEM COMPONENTS BENCH PROCEDURES

Oil Cooler Reconditioning

[215 DW]

Early-production engines with the right-side mounted EECU are equipped with a removable bundle-type oil cooler that can be disassembled, inspected and tested, and the bundle replaced if necessary. The plate-type oil cooler (Figure 220) on current-production engines with the left-side mounted EECU cannot be disassembled. Should it fail, it is replaced as an assembly.

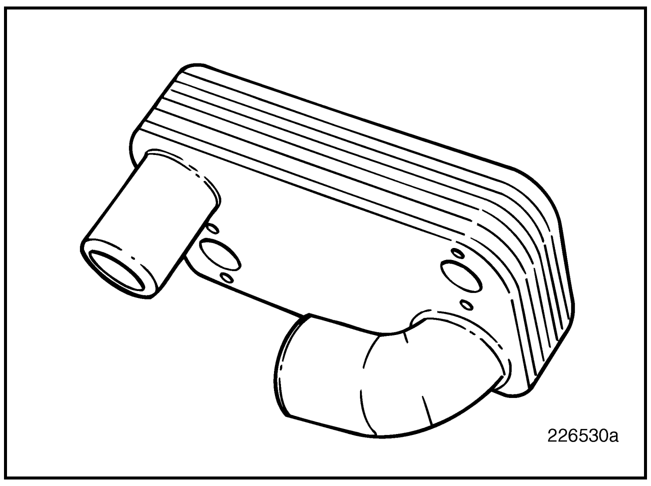


Figure 220 — Plate-Type Oil Cooler Assembly

The following disassembly and assembly procedures apply only for the removable bundle-type oil cooler.

REPAIR INSTRUCTIONS

GENERAL INSTRUCTIONS

Refer to Figure 221.

Periodic visual inspection of the oil cooler will indicate condition of gaskets and O-rings. If a problem exists, components of the assembly can be serviced separately.

NOTE

The presence of engine oil in the engine coolant may indicate internal engine problems or worn, loosened or damaged parts within the oil cooler. Continued operation under these conditions may result in severe engine damage.

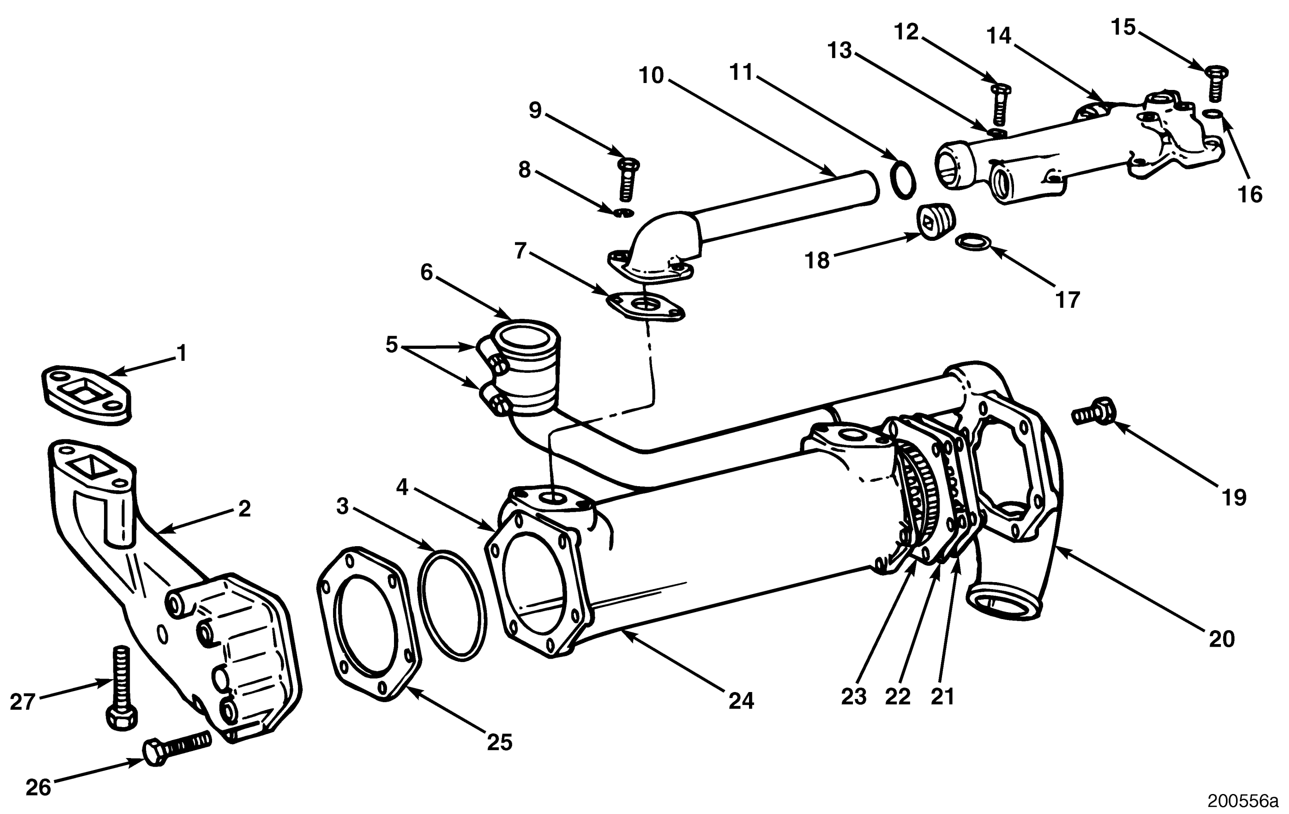


Figure 221 — Removable Bundle-Type Oil Cooler Assembly

1. Gasket	15. Capscrew
2. Coolant Outlet End Cap	16. Washer
3. O-Ring	17. O-Ring
4. Mounting Flange	18. Pipe Plug
5. Clamps	19. Capscrew
6. Coupler	20. Coolant Inlet Cap
7. Gasket or O-Ring	21. Gasket
8. Washer	22. Bundle
9. Capscrew	23. Gasket
10. Oil Outlet Tube	24. Housing
11. O-Ring	25. Gasket
12. Capscrew	26. Capscrew
13. Washer	27. Capscrew
14. Oil Supply Head	

5_106_00.bk Page 217 Friday, August 4, 2000 11:17 AM

DISASSEMBLY

Refer to Figure 221.

1. Remove the coolant inlet end cap (20) by removing six capscrews (19).
2. Remove the coolant outlet end cap (2) by removing six capscrews (26).
3. Remove the bundle (22) from the coolant inlet end of the housing (24).
4. Remove the O-ring (3) from the coolant outlet end of the housing.
5. Clean gasket material from all surfaces.

INSPECTION

1. Visually inspect the housing for cracks which may cause a leak. Replace the housing if damaged.
2. Pressure check the oil cooler for leaks by installing a test plate with an air fitting as follows:
   a. Position a rubber gasket (5) and test plate (4) on the mounting flange (1) and secure the plate with mounting capscrews (2) as shown in Figure 222.
   b. Install a steel plate (2) with a rubber gasket on the oil outlet opening. Secure the plate to the housing (1) with two capscrews (3) as shown in Figure 223.
   c. Connect an air line and pressurize the assembly to 80 psi (552 kPa). Submerge the assembly in water to check for leaks.

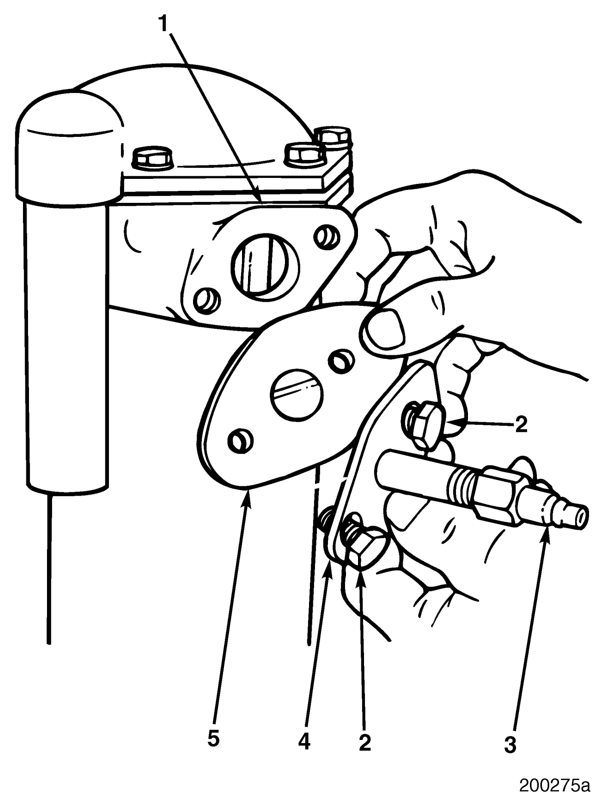


Figure 222 — Installing Test Plate

1. Mounting Flange 2. Capscrews 3. Air Fitting	4. Test Plate 5. Rubber Gasket

NOTE

When pressure testing the complete oil cooler assembly using an in-line pressure regulator, first apply pressure at 2–5 psi (14–34 kPa) maximum and check for leaks. Then gradually increase the pressure, checking for leaks until 80 psi (552 kPa) is reached.

5_106_00.bk Page 218 Friday, August 4, 2000 11:17 AM

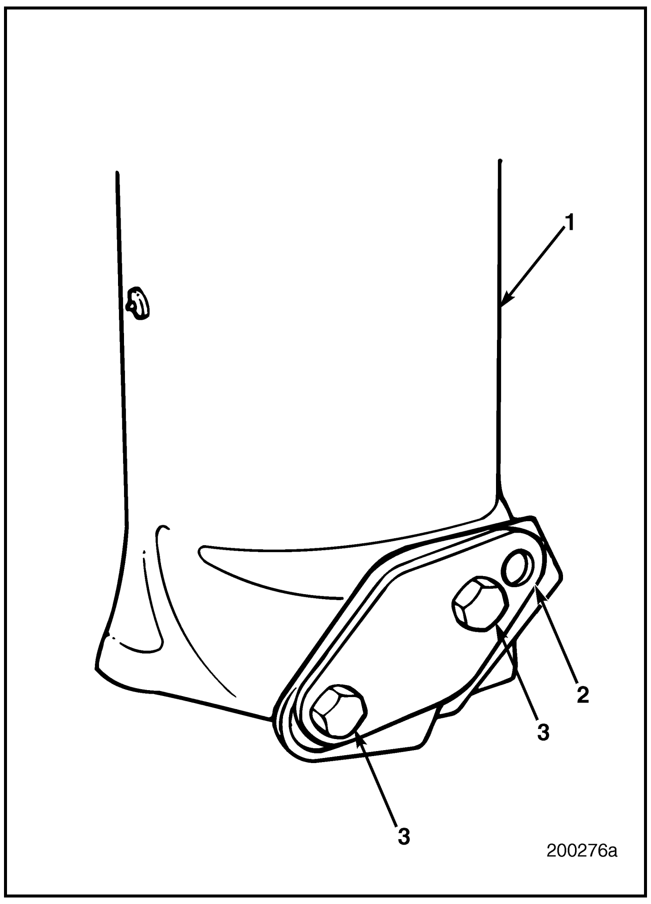


Figure 223 — Sealing Oil Outlet

1. Housing 2. Plate	3. Capscrews

3. If a leak is detected in the bundle after a pressure check of the oil cooler, replace the bundle.

ASSEMBLY

Refer to Figure 221.

Lubricate and install O-ring (3) in the groove at the coolant outlet end of the oil cooler housing (24).

1. Apply Permatex® gasket sealer on the coolant inlet flange before installing the gasket (23).
2. Install the gasket (23) on the coolant inlet end of the housing (24).
3. Apply Permatex® gasket sealer on top of the gasket.
4. Install the bundle (22). If necessary, tap the bundle with a soft-faced hammer to seat the bundle past the O-ring (3).

NOTE

The alignment notch in the bundle end flange must be positioned at the top for proper installation.

5. Apply Permatex® gasket sealer on the bundle end.
6. Place the gasket (21) on the bundle end.
7. Apply Permatex® gasket sealer on top of the gasket (21) before installing the inlet cap (20).
8. Install the coolant inlet end cap and secure the cap with six capscrews (19).
9. Tighten the coolant inlet end-cap capscrews to the specified torque, 20 lb-ft (27 N•m), using torque wrench J 24405, or equivalent.
10. Apply Permatex® sealant to both sides of the gasket (25) and install the gasket on the mounting flange (4) of the housing.
11. Install the coolant outlet end cap (2) with six capscrews (26).
12. Tighten the coolant outlet end-cap capscrews to the specified torque, 20 lb-ft (27 N•m), using torque wrench J 24406, or equivalent.

Water Pump Reconditioning

[215 SW]

The water pump is not a field-rebuildable unit. If a pump failure occurs, exchange it for a new or remanufactured unit available through the MACK Parts System.

5_106_00.bk Page 219 Friday, August 4, 2000 11:17 AM

FUEL SYSTEM COMPONENTS BENCH PROCEDURES

Electronic Unit Pump (EUP) Inspection

[221 GP]

Refer to Figure 224.

Visually inspect each electronic unit pump assembly and O-rings for signs of wear or damage. Replace the O-rings as required. If a pump is damaged or not operating properly, replace the pump; it is not repairable.

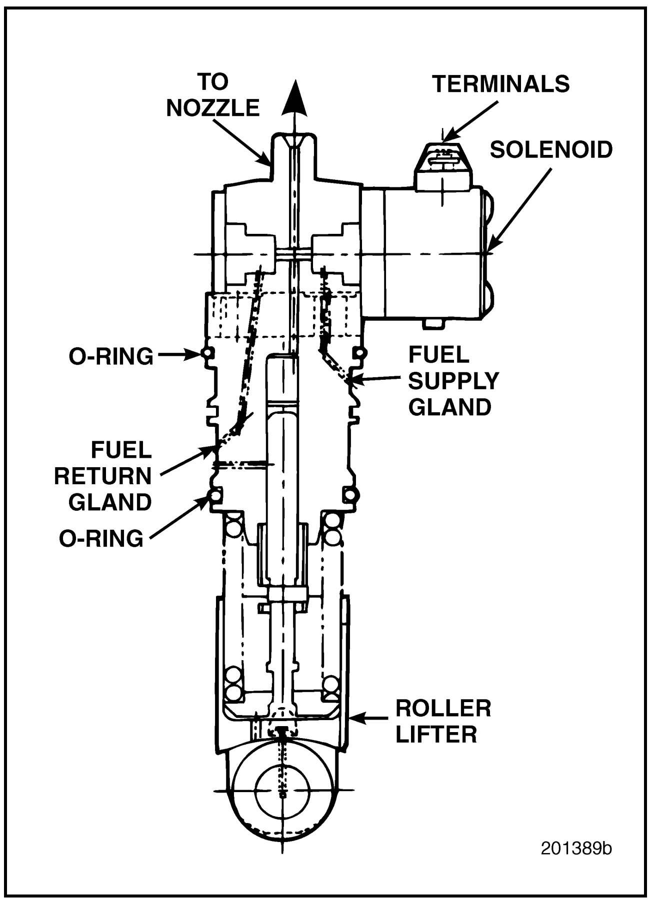


Figure 224 — Electronic Unit Pump Assembly

Installation of Electronic Unit Pump Plunger Spring and Seat

Improper removal of an electronic unit pump (EUP) from an engine, or certain failures such as broken EUP hold-down bolts, will result in a rapid pop-up of the pump from the bore. Should this occur, the unit pump tappet spring seat can dislodge from the plunger foot. The plunger, however, is retained by a retaining clip, so it will remain in place. Should a spring seat dislodge, no damage occurs to any of the parts involved, and the unit pump may be reassembled as described below.

NOTE

When servicing a unit pump, take care not to damage any machined or threaded surfaces. Work should be performed on a clean, non-metallic surface.

1. Remove the plunger retaining clip.

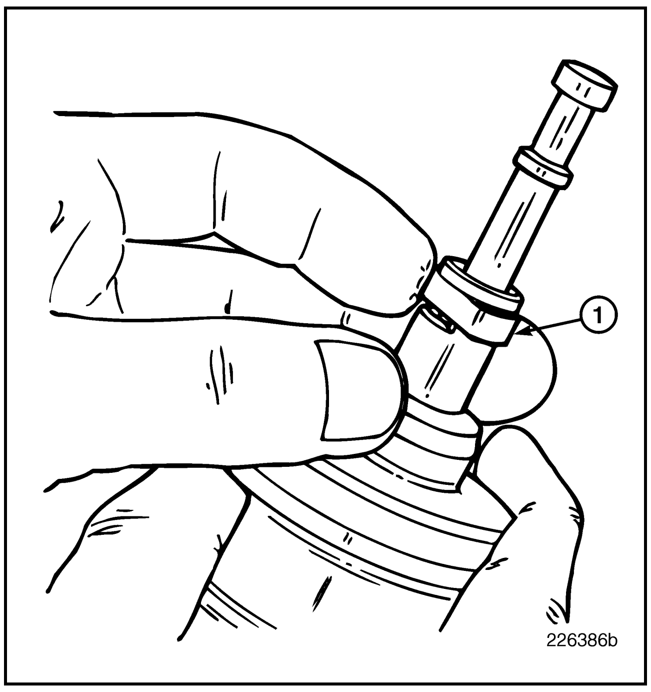


Figure 225 — Plunger Retaining Clip Removal

1. Retaining Clip

5_106_00.bk Page 220 Friday, August 4, 2000 11:17 AM

2. Pull the plunger out of the unit pump bore until the gold portion of the plunger is visible through the retaining clip slot. The shoulder of the plunger (where the silver-colored and gold-colored areas meet), will just align with the bottom of the unit pump housing.

NOTE

To avoid possible contamination or damage to the plunger, do not remove the plunger completely from the unit pump. If the plunger is inadvertently removed, dip it in clean fuel, carefully reinstall into the unit pump bore, then check for smooth, free movement in the unit pump bore.

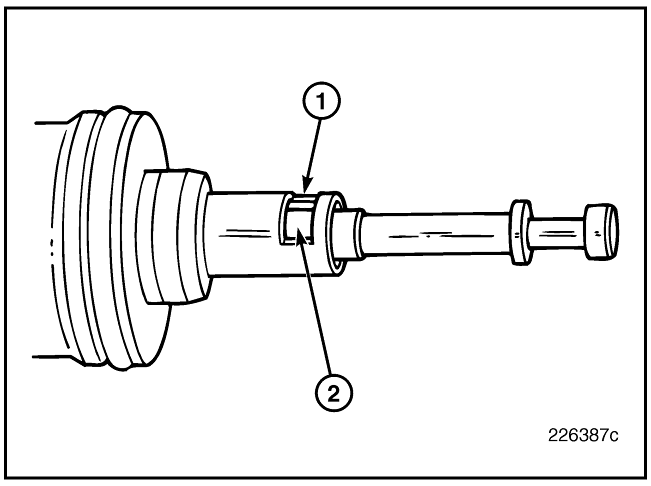


Figure 226 — Gold-Colored Plunger Surface, Behind Retaining Clip Slot

1. Retaining Clip Slot	2. Gold-Colored Surface

3. With the plunger pulled from the unit pump bore as described in step 2, slide the retaining clip into place. The flat side of the clip goes into the retaining clip slot.

NOTE

The plunger must be positioned as described in step 2 when the clip is installed, or reassembling the unit pump spring and spring seat will be difficult, if not impossible.

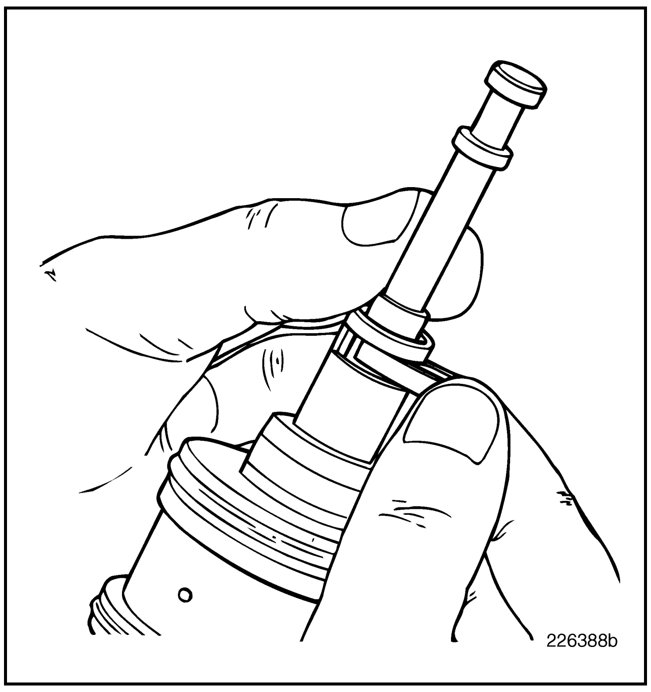


Figure 227 — Plunger Retaining Clip Installation

4. Place the spring onto the unit pump body.

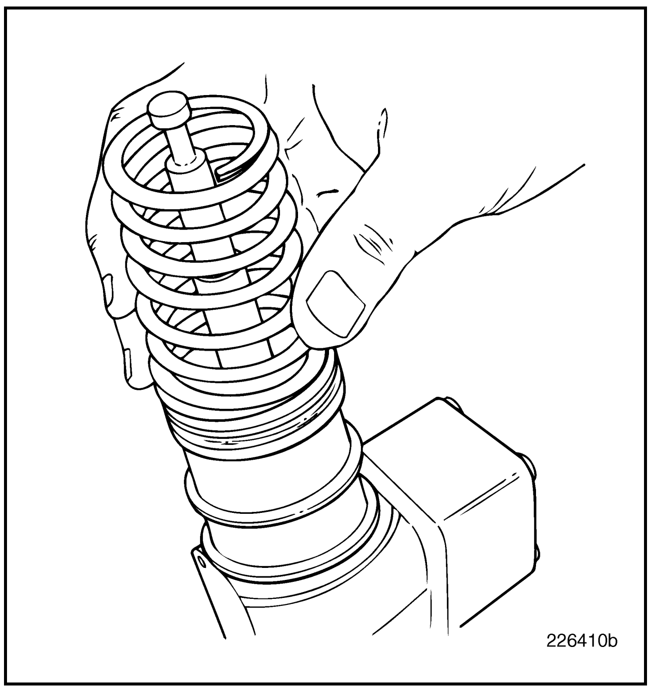


Figure 228 — Plunger Spring Installation

5. Install the spring seat (flat side against the spring) with the larger hole of the spring seat keyhole opening over the plunger foot.
6. Slide the spring seat so that the plunger foot goes into the smaller, center hole of the keyhole slot.

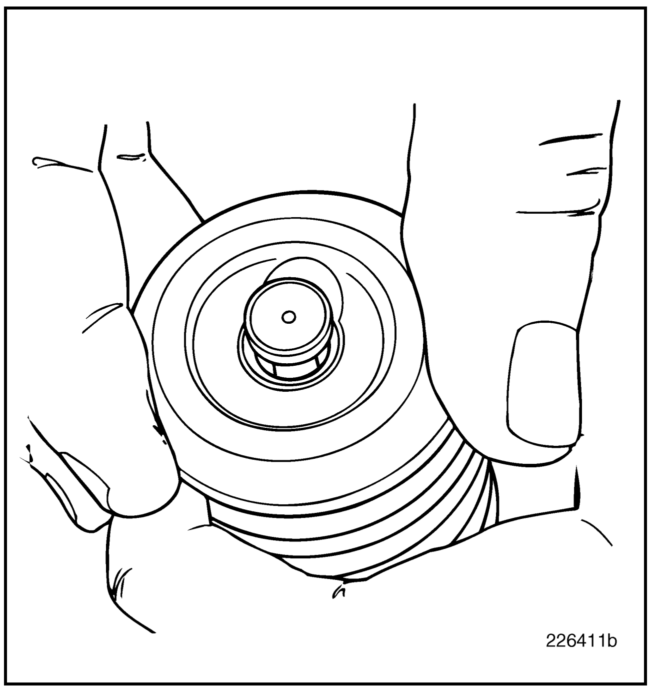


Figure 229 — Spring Seat Installation

7. Using the heel of the hand, press down on the plunger and spring seat until a click is heard. The click indicates that the plunger has been pushed down, and the retaining clip has seated to hold the plunger, spring and spring seat in place.

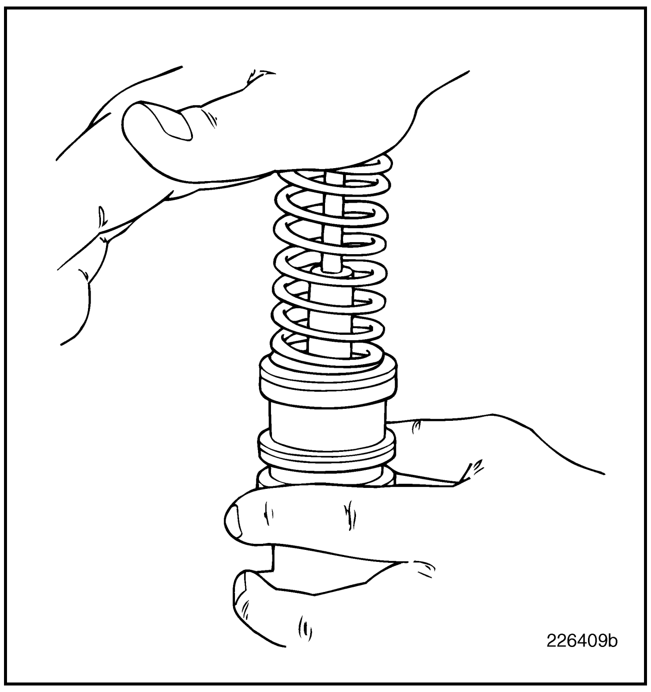


Figure 230 — Plunger and Spring Seat Seating

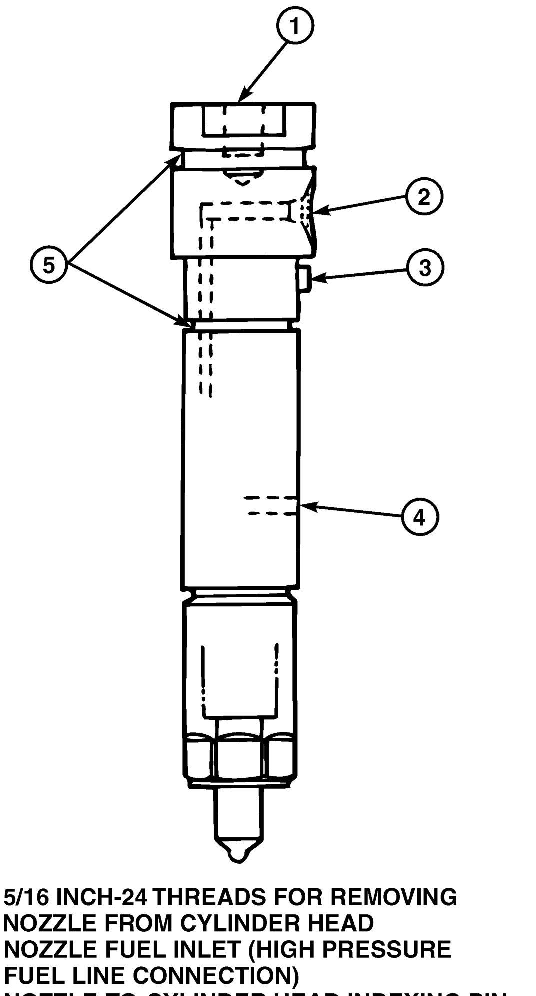
8. Install **new** O-rings and lubricate with clean engine oil.

9. Reinstall the unit pump into the engine using the procedures as outlined under Engine Reassembly in the REPAIR INSTRUCTIONS section.

Fuel Injector Nozzle Cleaning [222 KG]

Refer to Figure 231.

When servicing the nozzle holder assemblies, cleaning of the nozzle tips may be necessary. Special care must be taken when cleaning the nozzle tips to avoid damaging the nozzle spray holes.



1. 5/16 INCH-24 THREADS FOR REMOVING NOZZLE FROM CYLINDER HEAD
2. NOZZLE FUEL INLET (HIGH PRESSURE FUEL LINE CONNECTION)
3. NOZZLE-TO-CYLINDER HEAD INDEXING PIN
4. NOZZLE FUEL RETURN DUCT OUTLET
5. O-RING GROOVES

201402a

Figure 231 — Fuel Injection Nozzle Holder Assembly

ULTRASONIC CLEANING METHOD

Ultrasonic cleaning is the **preferred method** for cleaning the fuel injector nozzles. Ultrasonic cleaning units, such as J 29653-A, use sound waves or mechanical vibrations approximately 55,000 cycles per second above human hearing range. The sound waves are generated by the transducer, which changes high-frequency electrical energy into mechanical energy.

BRASS BRUSH/WIRE WHEEL METHOD

Cleaning the fuel injector nozzles with a brass brush or wire wheel may be acceptable under some conditions, but it is **not recommended**. The nozzles will be damaged if a steel wire wheel is used for cleaning. Damage can also occur if an improper size brass-wire wheel and/or improper speed is used.

ENGINE REASSEMBLY

General Instructions

This section includes step-by-step procedures for complete reassembly of the MACK E-Tech™ engine. Major components that were inspected and overhauled or replaced under the respective bench procedure sections of this manual are reinstalled here as assemblies.

CAUTION

Failure to follow the sequence of operations listed may result in damage to components or personal injury.

NOTE

After cleaning the components, properly store them where they will remain clean until needed for reassembly.

When required for installing components, be sure to use clean engine oil of the approved type.

Crankshaft Installation

[212 HP]

1. Be sure that the crankshaft and the crankcase area of the cylinder block are clean.
2. Thoroughly clean each main bearing bore and the back of each bearing insert before installation. The inserts must be installed dry.

CAUTION

The hole in the insert must line up with the drilled hole in the block or the bearing will fail due to lack of lubrication. The upper bearing insert is stamped on the back with the word “UPPER.”

3. Place the upper half of the bearing insert (2) in the cylinder block main bearing bore, making sure that the locating tab (1) fits into the notch in the bore (Figure 232).

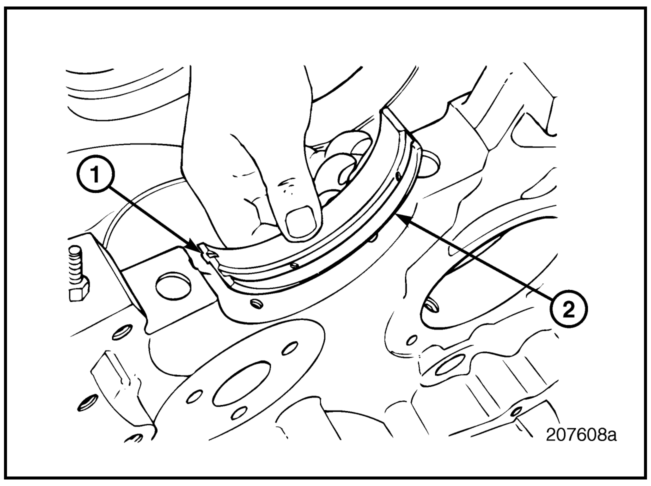


Figure 232 — Main Bearing Insert (Upper)

1. Locating Tab	2. Bearing Insert

4. Repeat the previous step to install the remaining upper inserts. Refer to Figure 233 for the part number and location of each bearing insert.

CAUTION

A bearing insert installed at the wrong location can cause engine failure.

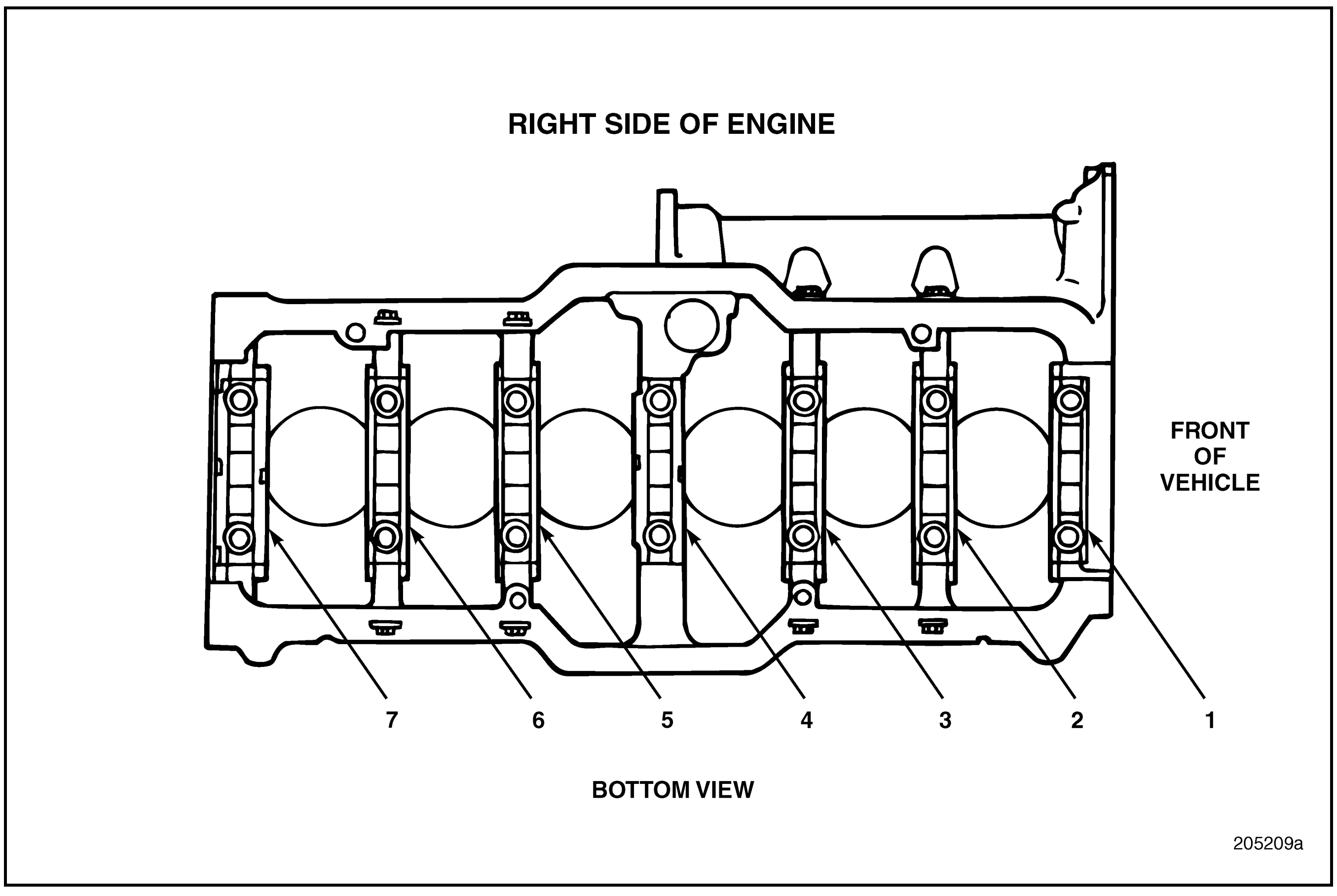


Figure 233 — Main Bearing Insert Part Numbers and Locations

1. Upper Insert — 646B348; Lower Insert — 646B343 2. Upper Insert — 646B345; Lower Insert — 646B343 3. Upper Insert — 646B345; Lower Insert — 646B343 4. Upper Insert — 646B349; Lower Insert — 646B344	5. Upper Insert — 646B345; Lower Insert — 646B343 6. Upper Insert — 646B345; Lower Insert — 646B343 7. Upper Insert — 646B350; Lower Insert — 646B344

5_106_00.bk Page 224 Friday, August 4, 2000 11:17 AM

5. Apply a light coat of clean engine oil on the insert surfaces and on the crankshaft main bearing journals.

WARNING

Due to the considerable weight of the crankshaft, extreme care must be observed during installation. No nicks, scratches, burrs, or any other kinds of distress are acceptable on the main bearing and/or crankshaft journals and fillets.

6. Using a suitable lifting device, position the crankshaft in the cylinder block.

Main Bearing Cap Installation

[212 HH]

NOTE

Unfinished main bearing caps are available for servicing of E-Tech™ engines. These are undersize bore bearing caps for service rebore:

- Cap, Intermediate and Front Main Bearing (Semi-Finished), No. 223GB2131M
- Cap, Rear and Center Main Bearing (Semi-Finished), No. 223GB2132

SPECIAL TOOL REQUIRED

- Magnetic Base Indicator Tool J 7872

INSTALLATION PROCEDURE

1. Clean the bore in the bearing cap and back of the lower bearing insert.
2. Install the bearing insert in the bearing cap bore (Figure 234). The insert must be installed dry.

NOTE

The lower bearing inserts do not have a hole or a groove. They are stamped with the word “LOWER.”

CAUTION

Do not mix the caps or inserts. The caps are numbered from 1 through 7, front to rear.

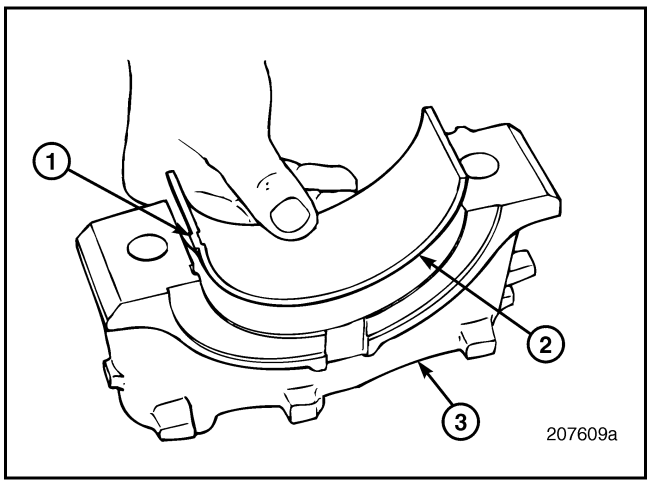


Figure 234 — Main Bearing Installation (Lower)

1. Locating Tab 2. Bearing Insert	3. Bearing Cap

3. Lubricate the threads of the bearing capscrews with clean engine oil and place capscrews in the cap holes.
4. Position the No. 1 bearing cap over the No. 1 crankshaft journal and start the screws in the threaded holes in the cylinder block.
5. Using a plastic-faced mallet, tap the bearing cap down until it contacts the machined mounting surface.
6. Tighten the screws until they contact the bearing cap. At this time, tighten them only finger-tight.
7. Repeat the above steps for the bearing cap Nos. 2, 3, 5, 6 and 7. The center bearing cap, No. 4, is installed later.
8. Tighten the bearing cap capscrews to specification, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.

9. Place the upper thrust washer sections in position in the cylinder block at the center bearing, No. 4, location as shown in Figure 236. The steel side of the thrust washer goes toward the block, the copper or aluminum-faced side goes toward the crankshaft (this applies to upper and lower thrust washer sections). Oil reservoir grooves are cut into the aluminum-faced side, as well as tip-face reliefs.

NOTE

Use standard thickness thrust washers initially.

SERVICE HINT

Beginning October 1996, a new style thrust washer was phased into production for E-Tech™ engines. These thrust washers are steel backed with an aluminum facing material on the side installed against the crankshaft. The obvious color difference of the previously used bronze/ steel washers is no longer present making it difficult to determine which side of the washer is meant to be installed against the crankshaft. Care should be taken when installing these aluminum faced thrust washers as the steel side is nearly the same color as the aluminum surface. Locate the oil the reservoir grooves and the tip reliefs cut into the aluminum, and install those sides against the crankshaft.

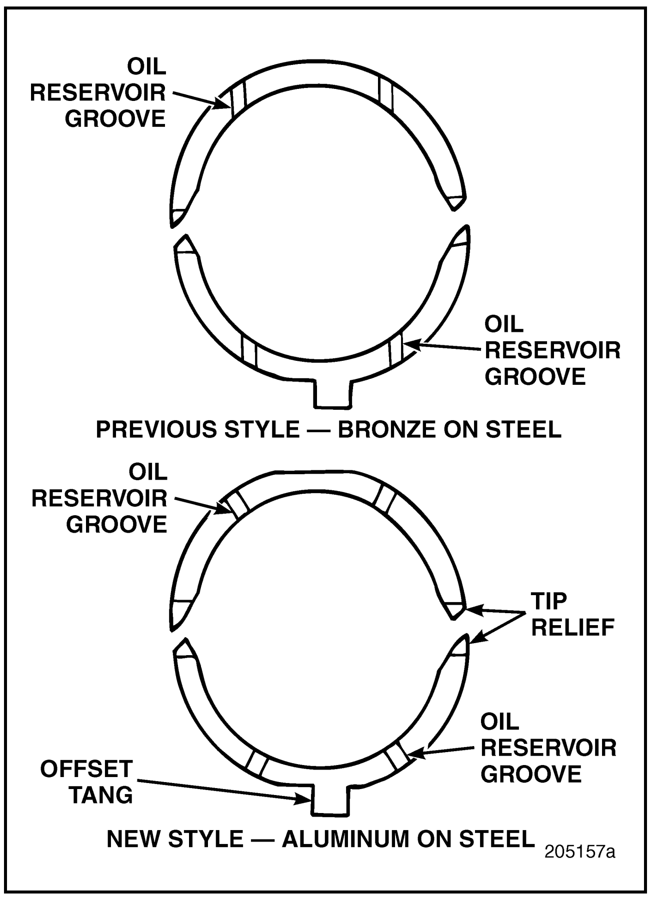


Figure 235 — Thrust Washer Styles

CAUTION

To prevent damage, ensure the thrust washers are installed in the correct position when assembling an engine. Failure to install the thrust washer properly will result in rapid wear of the area where the crankshaft contacts the thrust washer.

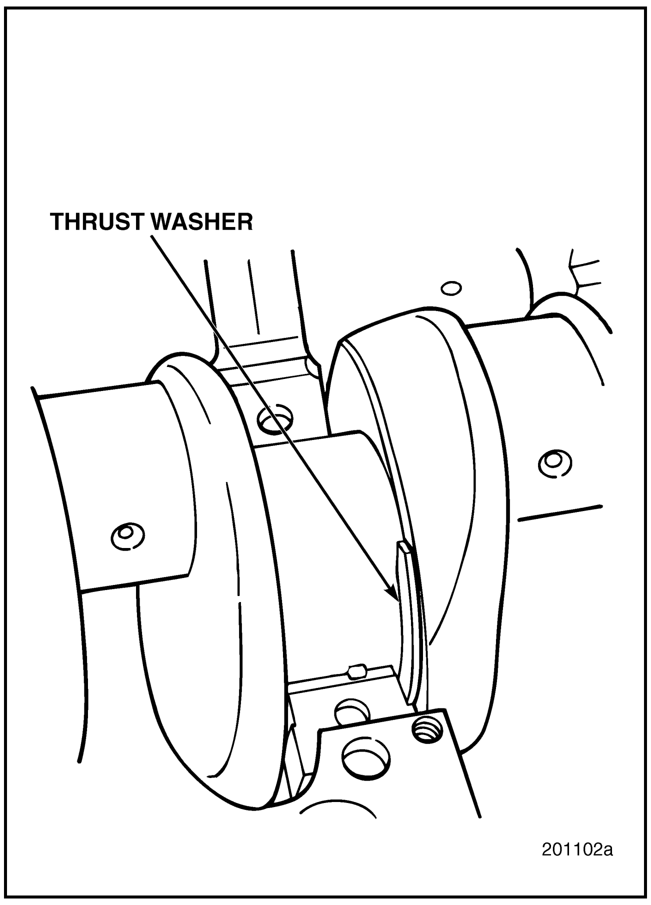


Figure 236 — Crankshaft Thrust Washer Installation

10. Position the lower thrust washer sections on the center bearing cap (aluminum-faced side toward crankshaft) and install the cap (Figure 237). Torque the capscrews to specification, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.

5_106_00.bk Page 227 Friday, August 4, 2000 11:17 AM

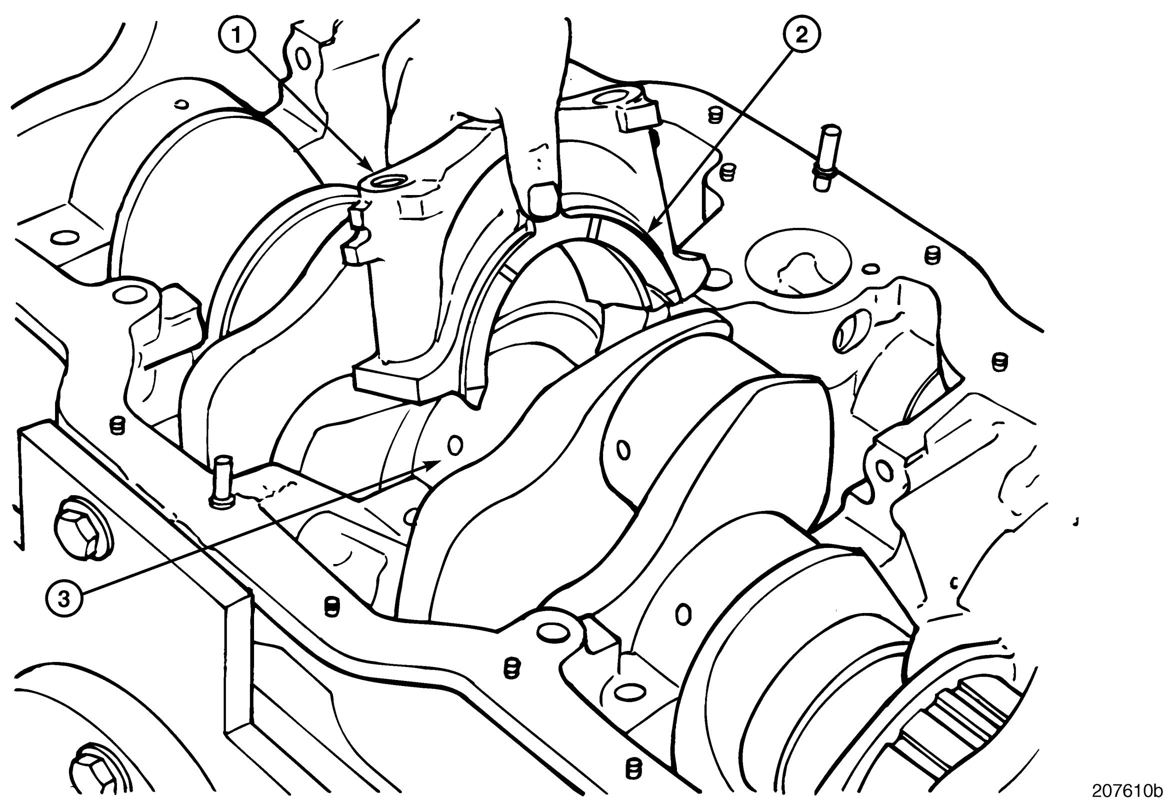


Figure 237 — Main Bearing Cap/Thrust Washer Installation

1. Bearing Cap 2. Thrust Washer	3. No. 4 Journal

11. Install a magnetic base indicator tool, J 7872, or equivalent, on the block with the plunger against a crankshaft counterweight to check crankshaft end play.
12. Using a suitable pry bar, move the crankshaft either forward or rearward until it stops. Tap the end of the crankshaft with a plastic-faced hammer to seat the thrust washer.
13. Using the pry bar, move the crankshaft in the opposite direction. Tap the end of the crankshaft with a plastic-faced hammer to seat the other thrust washer.
14. Set the dial on the indicator to zero.
15. Using the pry bar, move the crankshaft in the opposite direction and read the dial indicator. Refer to the allowable tolerances under Fits and Limits in the SPECIFICATIONS section.
16. If the end play is out of specification, remove the thrust washers and install properly sized thrust washers, as required, to bring the end play into specification.

CAUTION

The thickness of the thrust washers used in the bearing cap must match the thickness of the thrust washers in the block. Be sure to put the aluminum-faced bearing surface of the thrust washer against the crankshaft when installing the thrust washers.

17. Install the center main bearing cap, with bearing insert and the correct thrust washer sections in place, and torque the bearing capscrews to specification.
18. Recheck the end play to ensure the thrust washers have been installed correctly and that end play is within specification. Rotate the crankshaft to ensure there is no binding.

CHECKING RUNNING CLEARANCE

CAUTION

When using the Plastigage method of checking running clearance, do not turn the crankshaft. Doing so will destroy the Plastigage.

NOTE

If checking the main bearing clearance with the engine in the upright position (such as in the chassis), the weight of the crankshaft must be removed from the lower half of the bearing being checked. To do this, place cardboard under the crankshaft journal in the main caps adjacent to the journal to be checked and tighten the adjacent caps until the journal to be checked seats against the upper bearing. Do not fully torque screws. Capscrews on the bearing being checked should be torqued to specification after Plastigage strip has been positioned on the bearing shell and the cap reinstalled. Support the crankshaft at Nos. 1, 4 and 7 main journals, while checking Nos. 2, 3, 5 and 6 bearings. Support the crankshaft at the Nos. 3 and 5 journals, while checking the Nos. 1, 4 and 7 bearings.

ENGINE OUT OF CHASSIS AND INVERTED

1. Use Plastigage to check the main bearing clearance. Check each bearing, one at a time, by placing a piece of Plastigage on the journal and tightening the cap in place. The bearing clearance is determined by measuring the width of the crushed Plastigage with the supplied gauge.
2. Place a section of Plastigage (2) on the journal to be checked and assemble the main bearing cap (1) to the cylinder block as shown in Figure 238.
3. Apply a light coat of oil on the threads of the bearing cap capscrews and secure the cap.
4. Tighten the capscrews to the specified torque, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent. The Plastigage strip will be crushed between the bearing insert (3) and the crankshaft journal (4).

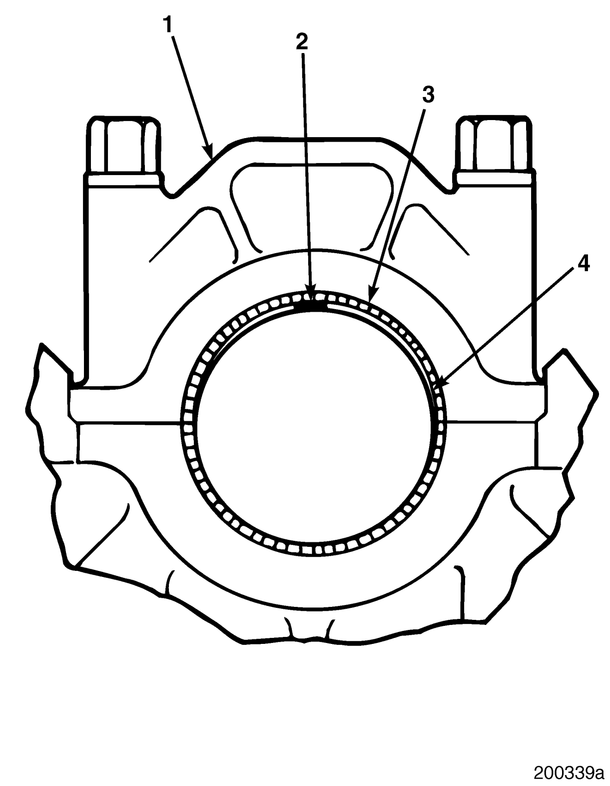


Figure 238 — Checking Running Clearance with Plastigage

1. Main Bearing Cap 2. Plastigage	3. Bearing Insert 4. Crankshaft Journal

5. Remove the capscrews and cap, and check the bearing running clearance.
6. Check the width of the Plastigage using a Plastigage width chart. After measuring width, remove the Plastigage from the bearing.
7. If the clearance is not within specification, correct the clearance as required. Be sure to use the proper size bearing(s).
   - If the clearance is less than specified, check behind the bearing for dirt, chips or burrs which would prevent the bearing from seating properly.
   - If the bearing bores and inserts are clean and undamaged, replace the inserts with inserts sized to provide the specified clearance.

8. Reposition the cap on the journal. Lubricate the capscrews with clean engine oil of the proper specification. Lubricate and install the bearing cap buttress capscrews as required, finger-tight. Install the bearing cap capscrews and tighten to the specified torque value, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.

   Refer to Figure 239.

NOTE

There are two buttress capscrew dimensions:

- LH side 2, 3, 5, 6 and RH side 5 and 6 (6 total) are 80 mm long (1).
- RH side FRT 2 and 3 (2 total) are 110 mm long (2).

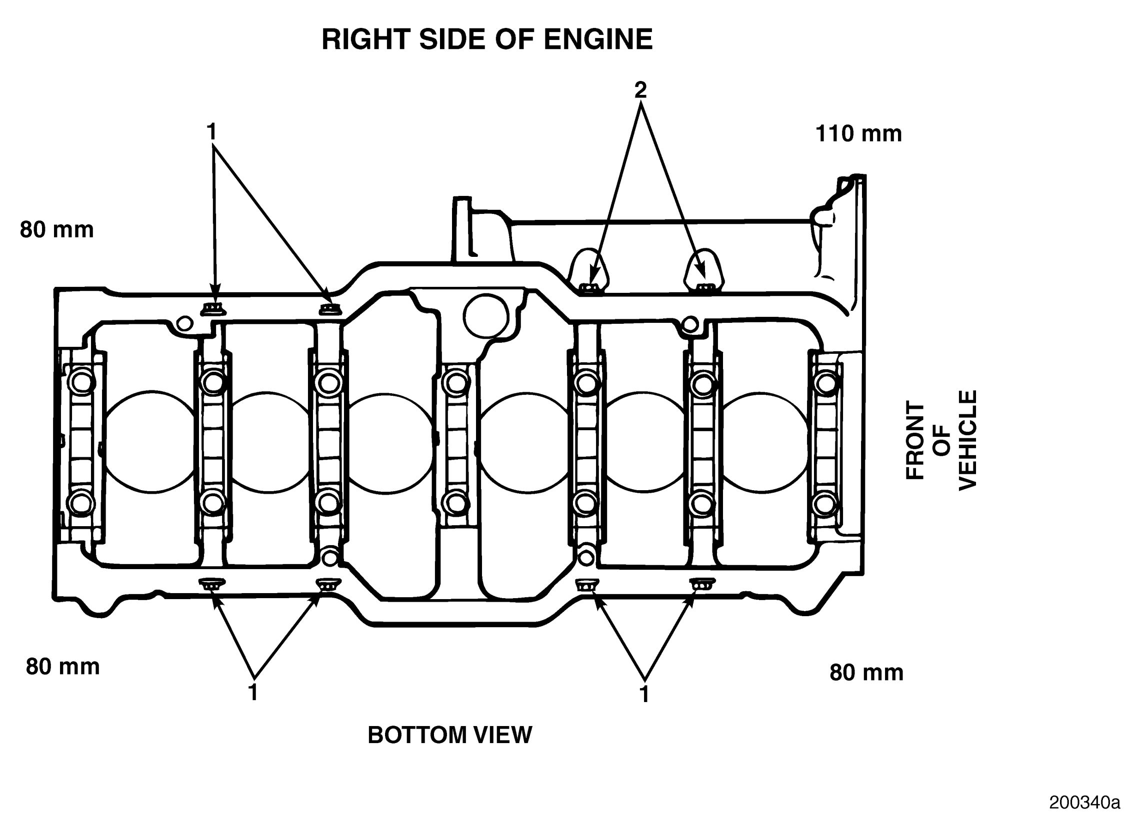


Figure 239 — Buttress Capscrew Locations

1. 80-mm Buttress Capscrews	2. 110-mm Buttress Capscrews

9. After obtaining the proper main bearing clearance at all seven journal locations, check the torque of the main bearing capscrews, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.

10. Tighten the buttress capscrews to the specified torque, 90 lb-ft (122 N•m), using torque wrench J 24407, or equivalent.

5_106_00.bk Page 230 Friday, August 4, 2000 11:17 AM

Piston and Connecting Rod Installation

[212 NP and 212 LP]

SPECIAL TOOL REQUIRED

- Piston Ring Compressor J 23442 or Piston Ring Compressor PT7070-A
- BT 91104 – Torque Angle Gauge

INSTALLATION PROCEDURE

1. Rotate the crankshaft so that the journals for the No. 1 and No. 6 cylinders are at bottom dead center (BDC) (Figure 240).

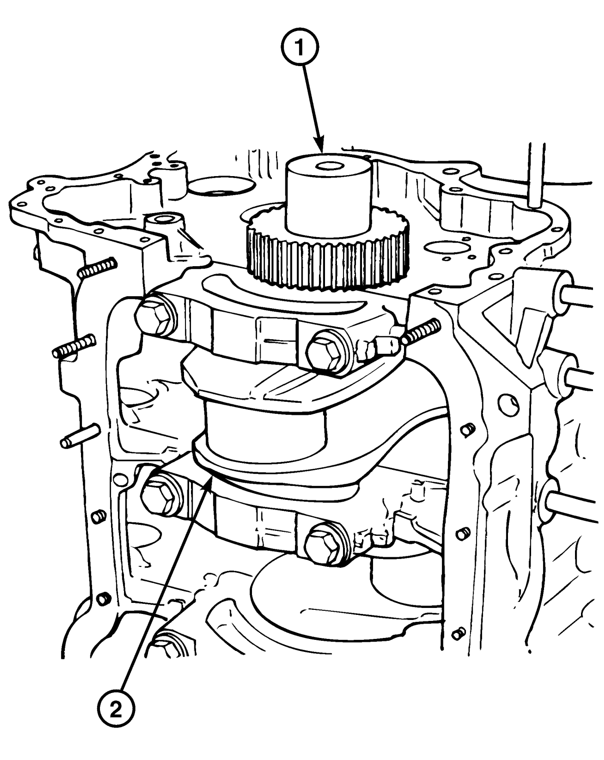


Figure 240 — No. 1 Cylinder (Crankshaft at BDC)

1. Crankshaft	2. No. 1 Journal

2. Place the piston marked No. 1 on a clean, flat surface. Rest the piston and rod assembly on the piston crown with the rod upward.
3. Apply a light coat of clean engine oil to the piston and rings.
4. Apply a light coat of clean engine oil to the inside surface of the piston ring compressor, J 23442, PT7070-A, or equivalent.
5. Install the ring compressor by slipping it over the rod and down over the piston skirt. Continue to slide the tool downward, carefully guiding the rings into the ring grooves until the tool contacts the surface on which the piston crown is resting.
6. Position the upper bearing insert into the connecting rod. Align the tab in the bearing insert with the notch in the rod. Be sure that the hole in the bearing aligns with the oil passage in the rod.

CAUTION

The hole in the upper connecting rod bearing must be aligned with the oil passage in the connecting rod. Otherwise, damage to the bearing, rod and crankshaft journal will result.

7. Apply a light coat of clean engine oil to the bearing surface.
8. Apply a light coat of clean engine oil to the inside surface of the No. 1 cylinder sleeve.
9. With the ring compressor (2) in place, position the piston and rod assembly (1) into the No. 1 cylinder as shown in Figure 241 until the compressor contacts the top of the sleeve. The arrow and word FRONT on both the piston crown and the connecting rod must be facing the front of the engine.

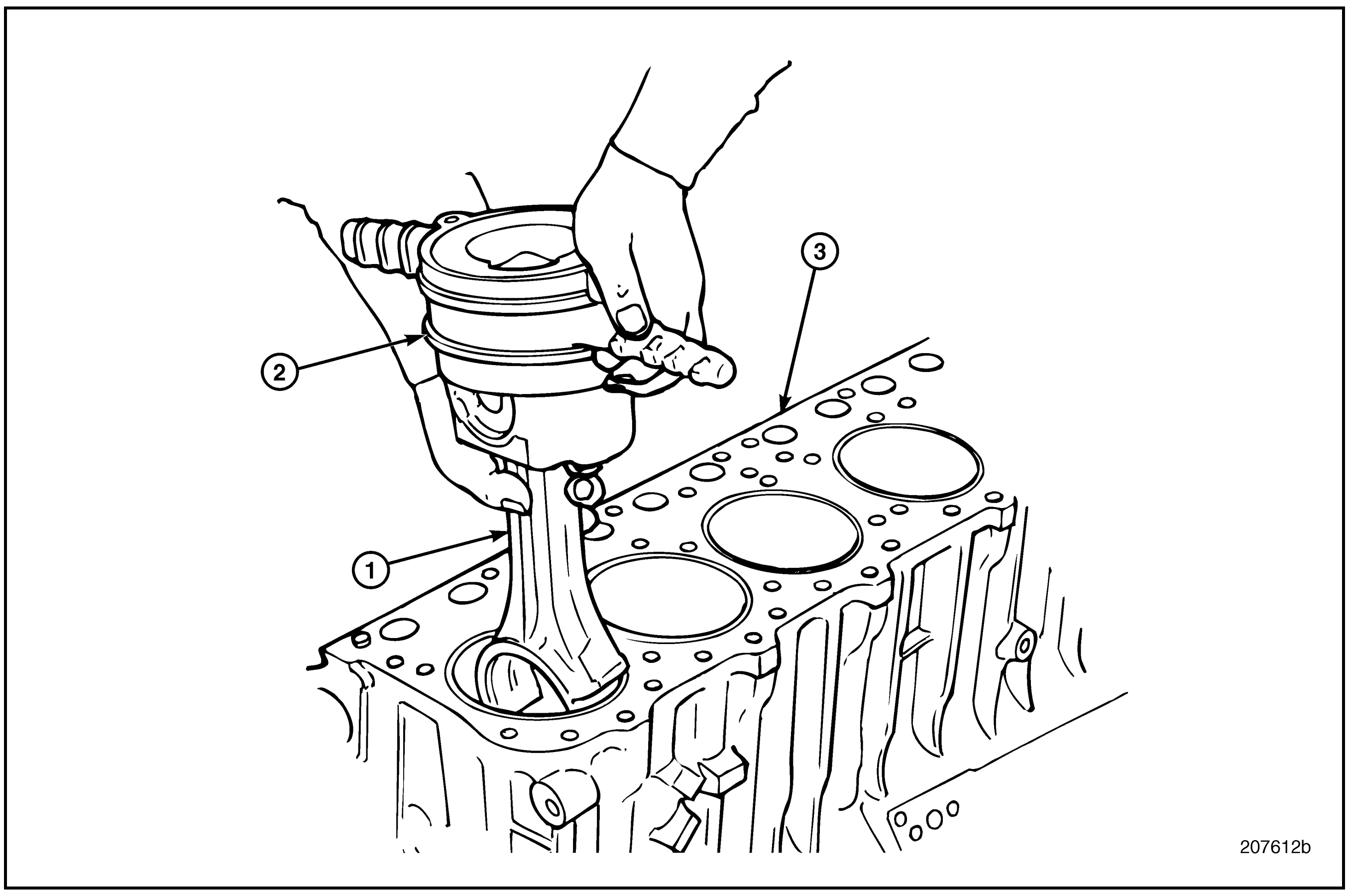


Figure 241 — Piston and Connecting Rod Installation

1. Connecting Rod Assembly 2. Piston Ring Compressor Tool	3. Cylinder Block

10. Make sure the connecting rod is aligned with the crankshaft journal.

11. While applying downward pressure to the ring compression tool (1) to keep it in contact with the cylinder sleeve as shown in Figure 242, use a hammer handle to push the piston (2) through the tool. Continue pushing on the piston until the top ring has passed into the cylinder sleeve.

5_106_00.bk Page 232 Friday, August 4, 2000 11:17 AM

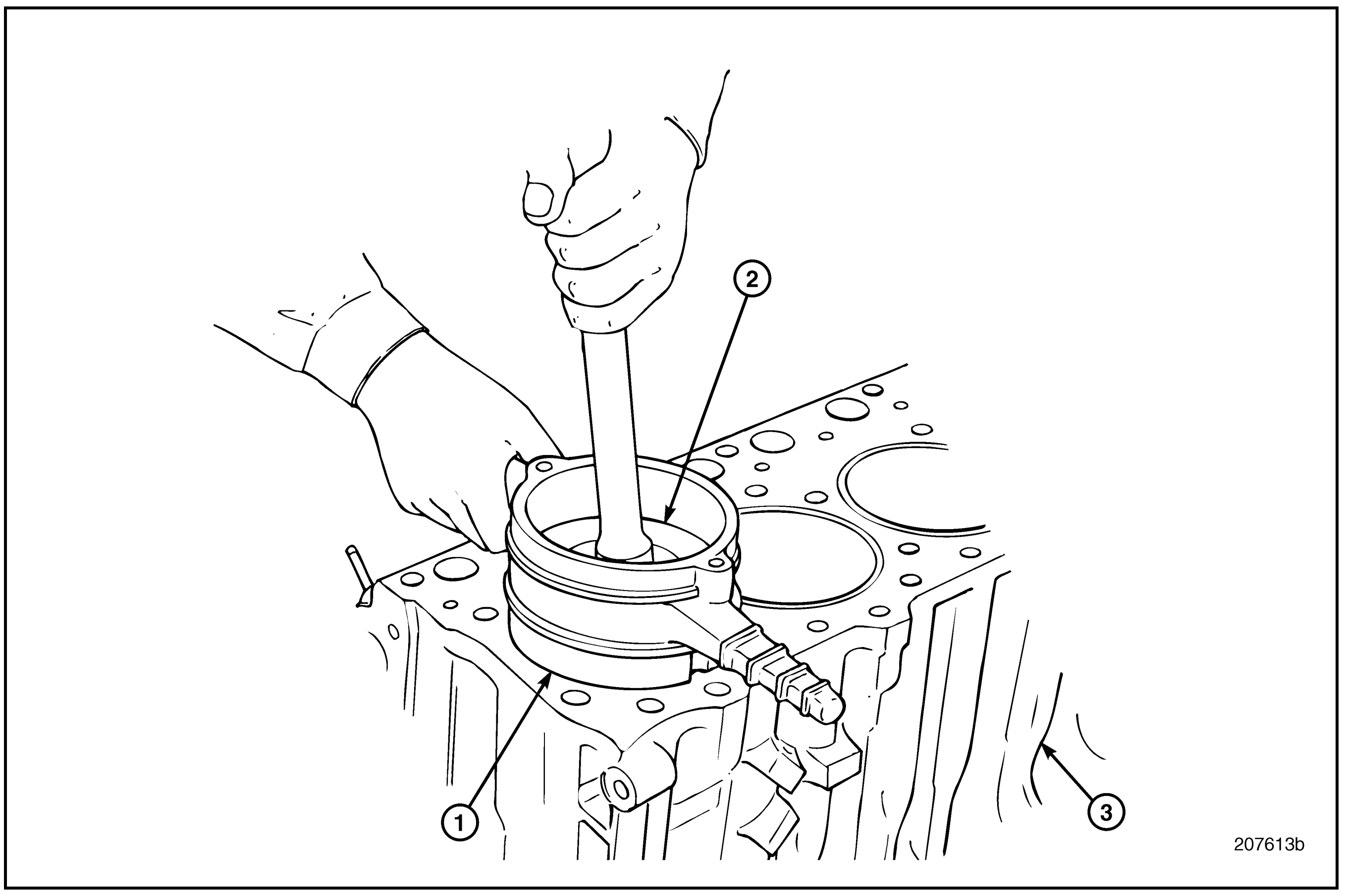


Figure 242 — Pushing Piston into Cylinder Sleeve

1. Piston Ring Compressor Tool 2. Piston	3. Cylinder Block

CAUTION

Do not force the piston. This indicates an incorrectly aligned ring. Remove the piston assembly, correct the problem, and then reinstall it. Make sure the compressor tool remains in contact with the cylinder sleeve until the piston clears the tool. If contact is not maintained, damage to the rings may result.

Before pushing the piston all the way down in the sleeve, check to see if piston cooling nozzle (1) is aligned with the nozzle clearance notch (2) provided in the lower end of the piston skirt as shown in Figure 243. Damage to piston or spray nozzle may result if it is not aligned.

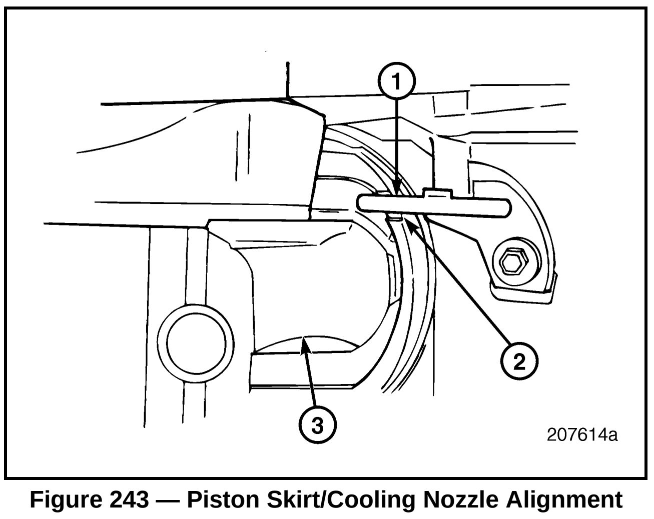


Figure 243 — Piston Skirt/Cooling Nozzle Alignment

1. Cooling Nozzle 2. Clearance Notch	3. Connecting Rod

5_106_00.bk Page 233 Friday, August 4, 2000 11:17 AM

12. Align the rod with the crankshaft journal and continue pushing the piston into the sleeve while guiding the rod end to clear the piston cooling nozzle and seat properly on the crankshaft journal.
13. Ensure that the correct rod bearing lower insert (matched to upper insert) and the alignment sleeves are positioned in the bearing cap.
14. Begin by installing the bearing cap at the No. 1 connecting rod journal (Figure 244) and check **Running Clearance** following the procedure later in this section. Repeat the running clearance check following the installation of each of the remaining five pistons.

CAUTION

*Running clearance must be checked after installing **each** piston. Damage to engine may result if clearance is not within specification.*

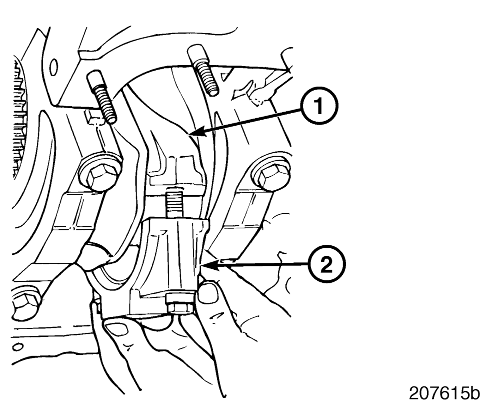


Figure 244 — Connecting Rod Cap Installation

1. Connecting Rod	2. Bearing Cap

15. Repeat the above steps to install the No. 6 piston.
16. Rotate the crankshaft so that the journals for the No. 2 and No. 5 cylinders are at bottom dead center and install the No. 2 and No. 5 pistons following the above steps.
17. Rotate the crankshaft so that the journals for the No. 3 and No. 4 cylinders are at bottom dead center and install the No. 3 and No. 4 pistons, again following the above steps.

RUNNING CLEARANCE CHECK

1. Place a section of Plastigage on the rod cap bearing and assemble cap to the rod.
2. Apply a light coat of oil on the threads of the rod cap capscrews and secure the cap.
3. Angle torque the capscrews to 30 lb-ft (41 N•m) plus 90 degrees using torque angle gauge set BT 91104, or equivalent.

NOTE

The angle-torque method applies for 14-mm capscrew part Nos. 396GC211M and 396GC212M with partial and full threaded shanks, respectively. Intermixing the partial and full threaded 14-mm capscrews on the same connecting rod is permissible.

4. Remove the capscrews and cap.
5. Check the width of the Plastigage on the removed cap using a Plastigage width chart. After measuring width, remove the Plastigage from the bearing.
6. If the clearance is not within specification, correct the clearance as required:
   - If the clearance is less than specified, check behind the bearing for dirt, chips or burrs which would prevent the bearing from seating properly.
   - If the bearing bores and inserts are clean and undamaged, replace the inserts with inserts sized to provide the specified clearance.
7. Reposition the cap on the journal. Lubricate capscrews with clean engine oil, install the capscrews and tighten to the specified torque, 30 lb-ft (41 N•m) plus 90 degrees using torque angle gauge set BT 91104, or equivalent.

CAUTION

If the cap and rod are not properly aligned, bearing and rod damage may result.

8. Check the rod side clearance (Figure 245) by installing a thickness gauge between the rod and the side of the journal. Check along the entire parting line area.

5_106_00.bk Page 234 Friday, August 4, 2000 11:17 AM

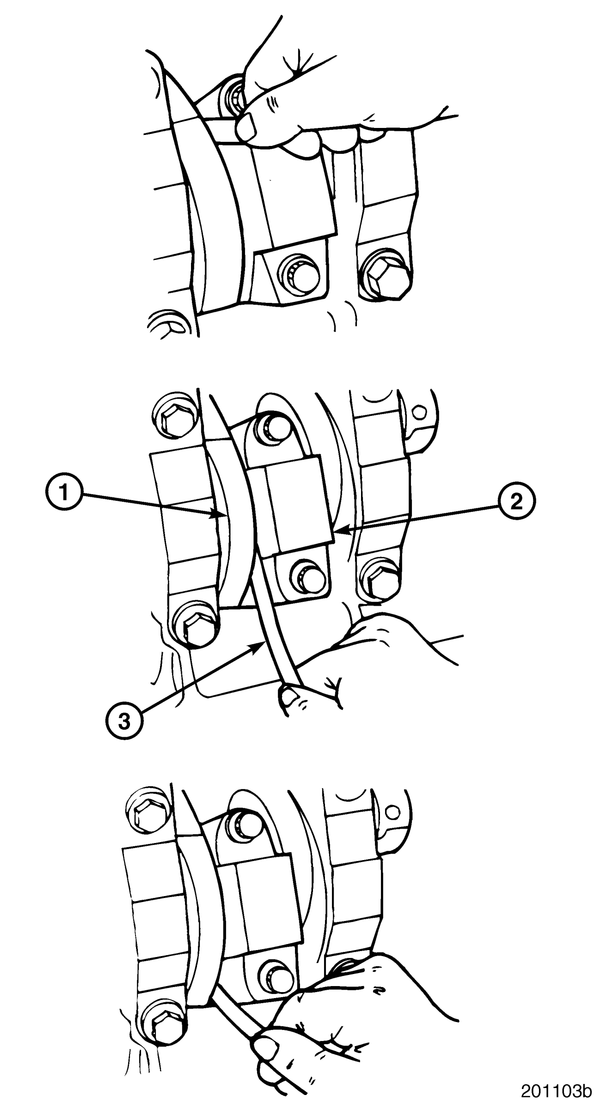


Figure 245 — Connecting Rod Side Clearance Check

1. Crankshaft Journal 2. Rod Bearing Cap	3. Thickness Gauge

9. The clearance must be within specification listed under Fits and Limits in the SPECIFICATIONS section. If not, recheck for proper cap and rod alignment.

Flywheel Housing Installation

[211 HD]

NOTE

Production phase-in of a redesigned die-cast aluminum housing began approximately mid-November 1998. The noticeable design differences of the new die-cast aluminum housing compared with the permanent mold cast aluminum housing include a smaller diameter starter drive gear mounting housing with two large strengthening ribs along the top, and other structural ribs around the housing.

INSPECTION

Inspect the flywheel housing machined surfaces, capscrews, holes and dowel locations for cracks or wear. Replace if cracks are evident.

CAUTION

Before installing the flywheel housing, examine the crankshaft flange for any cracks, surface damage or presence of foreign particles. This type of damage could ruin the sealing capabilities of the new seal and lead to oil leakage.

DOWEL PINS

A combination of round- and blade-style locating dowel pins are used to install the front cover and flywheel housing. A blade-style pin is used for the flywheel. When installing the blade-style pins, make sure the blade is properly positioned:

Vertically (pointing up and down) — for the front cover and flywheel housing

Parallel to crankshaft center line — for the flywheel

CAPSCREWS (FLYWHEEL HOUSING)

Refer to Figure 246.

NOTE

The E-Tech™ flywheel housing castings are manufactured to use standardized housing mounting hardware as follows:

- Two upper external mounting location capscrews — M3 (3 inches long)
- Six internal mounting location capscrews — M (2 inches long)
- Eight washers used with aluminum housing — part No. 35AX1489
- Eight washers used with ductile iron housing — part No. 271AM5008

CAUTION

Service replacement flywheel housings are the standardized flywheel housing. The new appropriate mounting hardware comes with the new-style flywheel housing supplied by the MACK Truck Parts System.

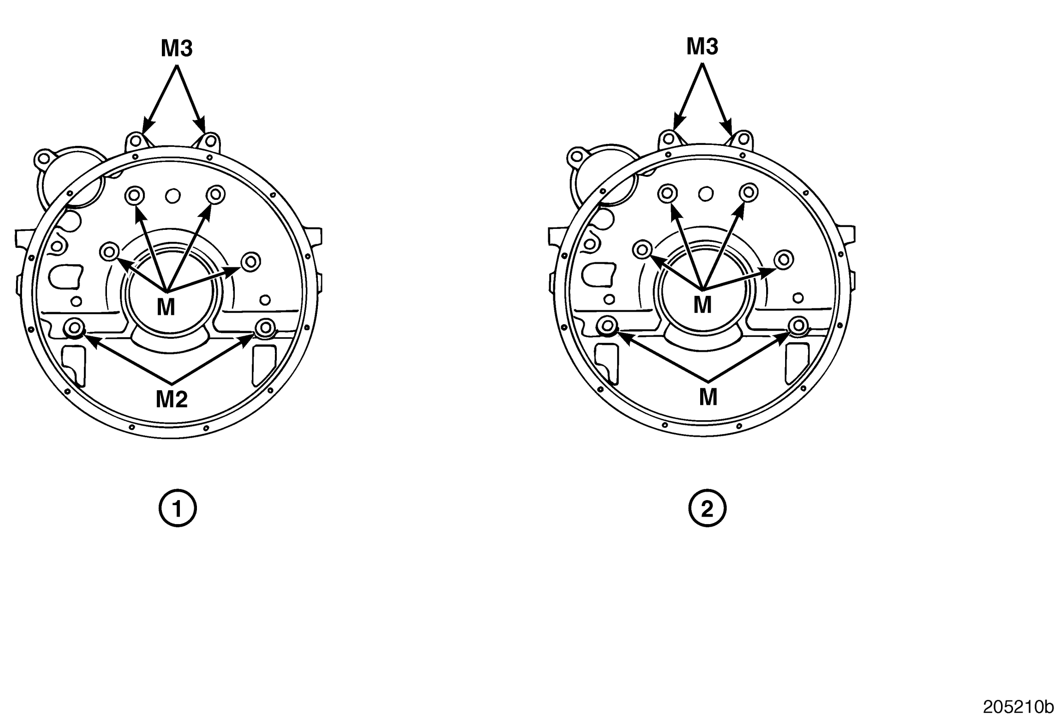


Figure 246 — Flywheel Housing Bolts

1. Old-Style Aluminum Flywheel Housing (No Longer Used)	2. Standardized Flywheel Housing (Aluminum or Ductile Iron)

INSTALLATION

1. Remove the rear crankshaft oil seal from the flywheel housing by drilling two 3-mm holes, 180 degrees apart, into the outer edge of the seal. Remove the seal with a slide hammer fitted with a No. 10 sheet metal screw. Thread it into each of the holes alternately and work the seal free.
2. Using standard shop cleaning procedures for aluminum, clean the seal mounting surface.
3. Insert the two dowel pins in the cylinder block if they were removed. Refer to Figure 247.

NOTE

The flywheel housing dowels maintain the alignment of the flywheel housing on the engine. This is necessary to center the transmission with respect to the engine flywheel and crankshaft.

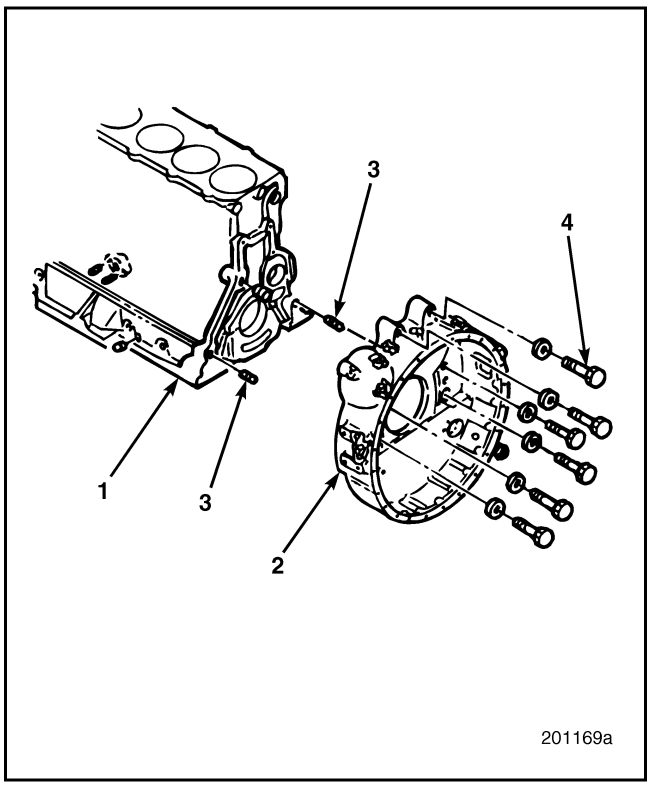


Figure 247 — Flywheel Housing Installation

1. Cylinder Block	3. Dowel Pin
2. Flywheel Housing	4. Capscrews

4. Apply an even coat of Silastic® (approximately a 1/16-inch [2 mm] bead) to the flywheel housing mounting surface of the cylinder block. Refer to Figure 248.

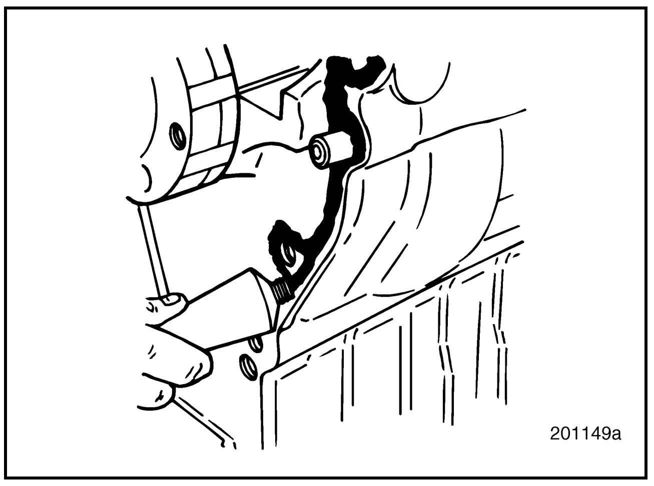


Figure 248 — Applying Sealant

5. Align the flywheel housing on the dowels and position it flush against the cylinder block surface. Refer to Figure 249.

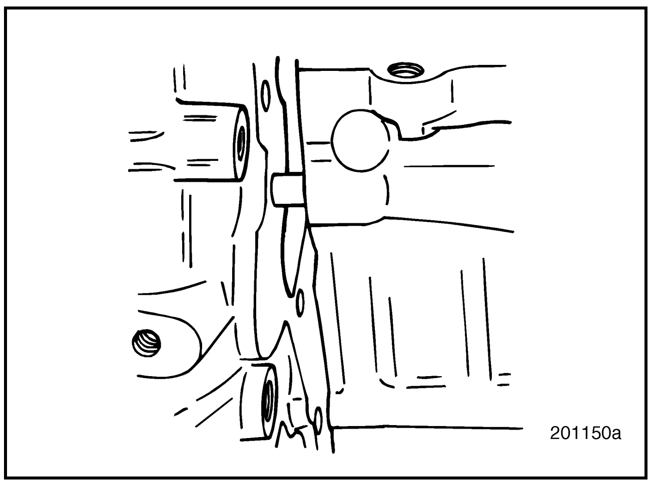


Figure 249 — Positioning Flywheel Housing

6. Install the flywheel housing mounting capscrews and tighten them finger-tight.
7. Tighten all flywheel housing capscrews to the specified torque, 170 lb-ft (231 N•m), using torque wrench J 24407, or equivalent.

RUNOUT

With the machined dowel method of installation, flywheel housing runout is well within the old service specification of 0.010 inch (0.254 mm) Total Indicated Runout (TIR), when checked with an alignment bar through the cylinder block main bearing bores. However, when checking flywheel runout using a dial indicator on the crankshaft rear flange or the flywheel, results may exceed 0.010 inch (0.254 mm) due to factors such as crankshaft movement within the bearing clearances and other variables.

NOTE

The dial indicator is the only method which can be used at this stage of assembly (with crankshaft in place). The machined dowel method requires that crankshaft and piston assemblies be removed.

Flywheel housing runout specifications are as follows:

- Runout checked with an alignment bar installed through the cylinder block main bearing bores: 0.010 inch (0.254 mm) TIR maximum. Refer to Figure 250.
- Runout checked with a dial indicator (PT5035 with Z adapter PT5035-1) mounted on the crankshaft rear flange or flywheel as shown in Figure 251 is: 0.020 inch (0.508 mm) TIR maximum. This way, the runout may appear to be excessive due to crankshaft movement within bearings and other variables.

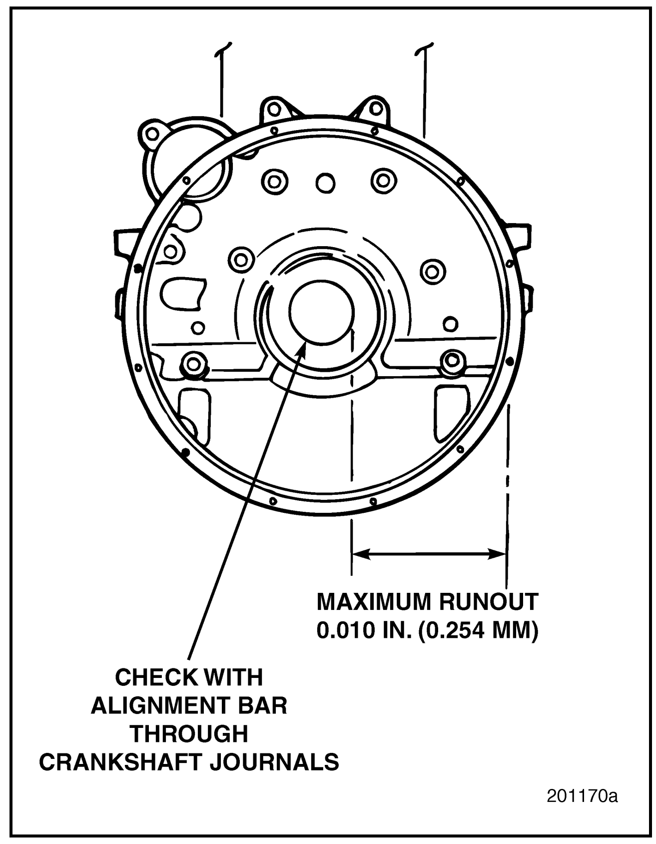


Figure 250 — Flywheel Housing Runout Check with Alignment Bar

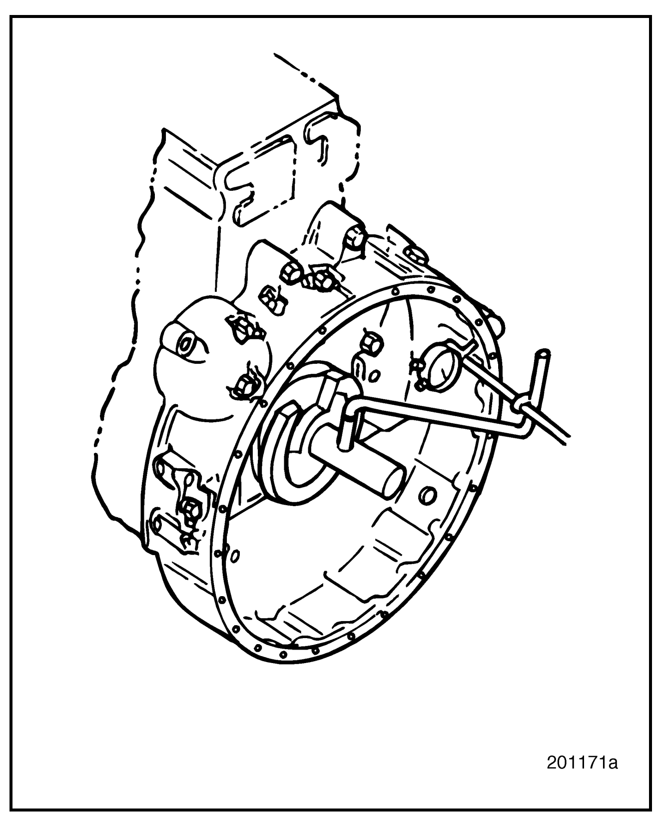


Figure 251 — Flywheel Housing Runout Check with Dial Indicator

5_106_00.bk Page 238 Friday, August 4, 2000 11:17 AM

Crankshaft Rear Oil Seal Installation

[212 JH]

MACK E-Tech™ engines are produced with Teflon® oil seals. Engines with dry flywheel housings (standard transmission) use single-lip seals, while those with wet flywheel housings (automatic transmission) use double-lip seals. Single-lip replacement seals are available in Viton or Teflon®; double-lip replacement seals are available in Teflon® only. Viton seals are available with an oversized inside diameter and the corresponding wear ring.

INSTALLATION — SINGLE-LIP SEAL

Crankshaft design allows the single-lip seal to be installed at the production depth of 0.344 inch ± 0.005 inch (8.74 mm ± 0.127 mm), or a service depth of 0.250 inch ± 0.005 inch (6.35 mm ± 0.127 mm) from the rear outer edge of the crankshaft flange.

NOTE

Special handling precautions must be taken while installing Teflon® seals. Do not lubricate the lips of a Teflon seal before installation. Teflon® seals function most effectively when installed dry.

Standard-size Teflon® seals are shipped on a plastic installation sleeve. Do not remove the seal from the sleeve before installation. The installation sleeve provides a smooth surface for the seal as it moves from the tool to the crankshaft flange.

1. Thoroughly clean the surface of the crankshaft flange.
2. Position the oil seal (2) and installation sleeve (3) onto the recessed side of J 37716-B oil seal installation tool adapter plate (1) as shown in Figure 252. The single-lip seal must be installed with the lip toward the engine.

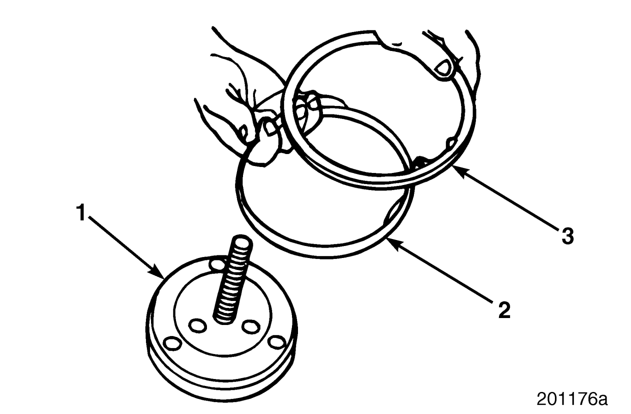


Figure 252 — Crankshaft Rear Oil Seal Installation

1. J 37716-B 2. Oil Seal	3. Installation Sleeve

3. Using the three guide pins, attach the adapter plate to the crankshaft flange. Refer to Figure 253.

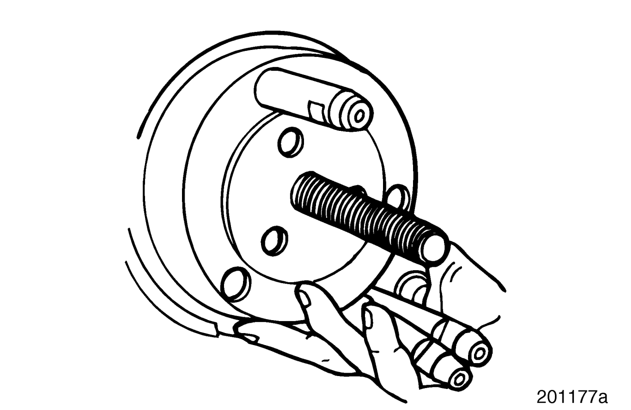


Figure 253 — Adapter Plate J 37716-B Installation

4. Determine the seal and wear ring installation depth:
   - **New** seal on a **new** crankshaft or service crankshaft with a **new** wear ring — Install to the initial production depth of 0.339–0.349 inch (8.611–8.865 mm).
   - **New** seal on a service crankshaft with/without a used wear ring — Install to the service depth of 0.245–0.255 inch (6.223–6.477 mm).
   - Wear ring installation depth — 0.15–0.220 inch (5.461–5.588 mm).

   Refer to Figure 254.

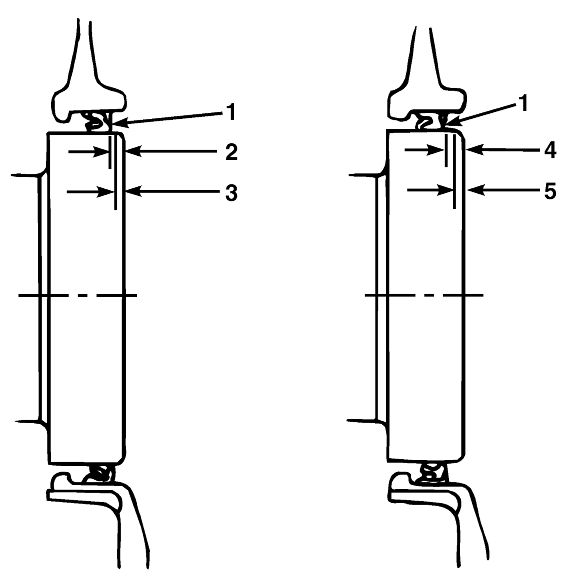


Figure 254 — Crankshaft Rear Oil Seal

1. Crankshaft Rear Oil Seal 2. Production Seal Installation Depth 3. Service Seal Installation Depth	4. Service Seal Installation Depth with Wear Ring 5. Wear Ring Installation Depth

5. The two installation depths are stamped above two of the guide pin bores on the installation tool press plate. To install the seal to the desired depth, position the press plate so that the guide pins go through the bore stamped with the desired depth.
6. Install the press plate driver hex nut and continue tightening until a positive stop is felt. At this point, the seal is installed to the proper depth.
7. Remove the installation tool.

INSTALLATION — WEAR RING WITH DOUBLE-LIP TEFLON® SEAL

(WET-TYPE FLYWHEEL HOUSING)

The oversize inside diameter lip seal and wear ring are shipped as an assembly, with the seal installed on the wear ring. Do not remove the seal from the wear ring prior to installation. The wear ring and seal installer J 35529 is required for installation. This tool presses both the wear ring and the oil seal onto the crankshaft flange.

SPECIAL TOOL REQUIRED

- Wear Ring and Seal Installer J 35529

Refer to Figure 255.

1. Remove existing wear ring from crankshaft before installing **new** wear ring.
2. Thoroughly clean and dry the crankshaft flange.
3. Apply a thin, even layer of Loctite® 609 to the circumference of the crankshaft flange.

NOTE

Do not lubricate the lips of a Teflon® seal before installation. Teflon® seals function most effectively when installed dry.

4. The lip of one side of the seal is yellow. Install the oil seal with the yellow lip toward the transmission. Position the oil seal and wear ring assembly onto the recessed side of the installation tool adapter plate with the yellow lip facing away from the direction of installation (toward the transmission).
5. Using the three guide pins, attach the oil seal installation tool adapter plate to the crankshaft flange.
6. Install the press cup over the guide pins. Then install the press cup driver hex nut.
7. Tighten the hex nut until a positive stop is felt. At that point, the oil seal and wear ring are properly installed on the crankshaft flange. The double-lip seal is properly installed to a depth of 0.250 inch ± 0.005 inch (6.35 mm ± 0.127 mm).
8. Remove the installation tool.

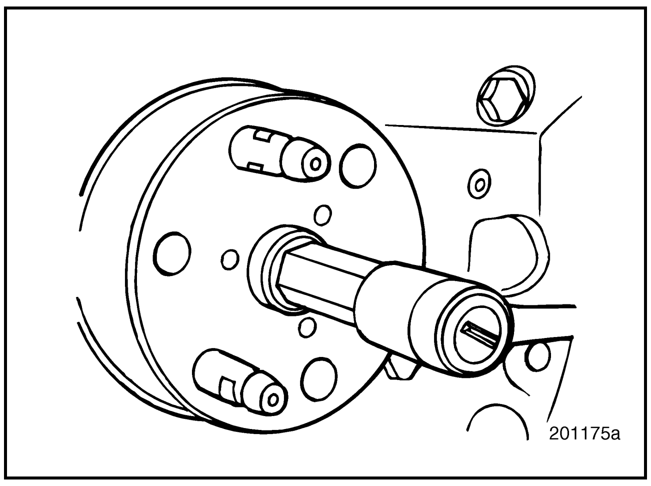


Figure 255 — Crankshaft Wear Ring (with Double-Lip Teflon® Seal) Installation

Flywheel Installation

[212 VC]

TIMING SCALE

The flywheel has a stamped timing scale of top center (TC) to 45 degrees of engine travel (engine timing) and three stamped locations, 120 degrees apart, for valve settings as shown in Figure 256. The flywheel still has pump timing marks to accommodate application to both E-Tech™ and E7 engines; the marks are not needed for the E-Tech™ engine.

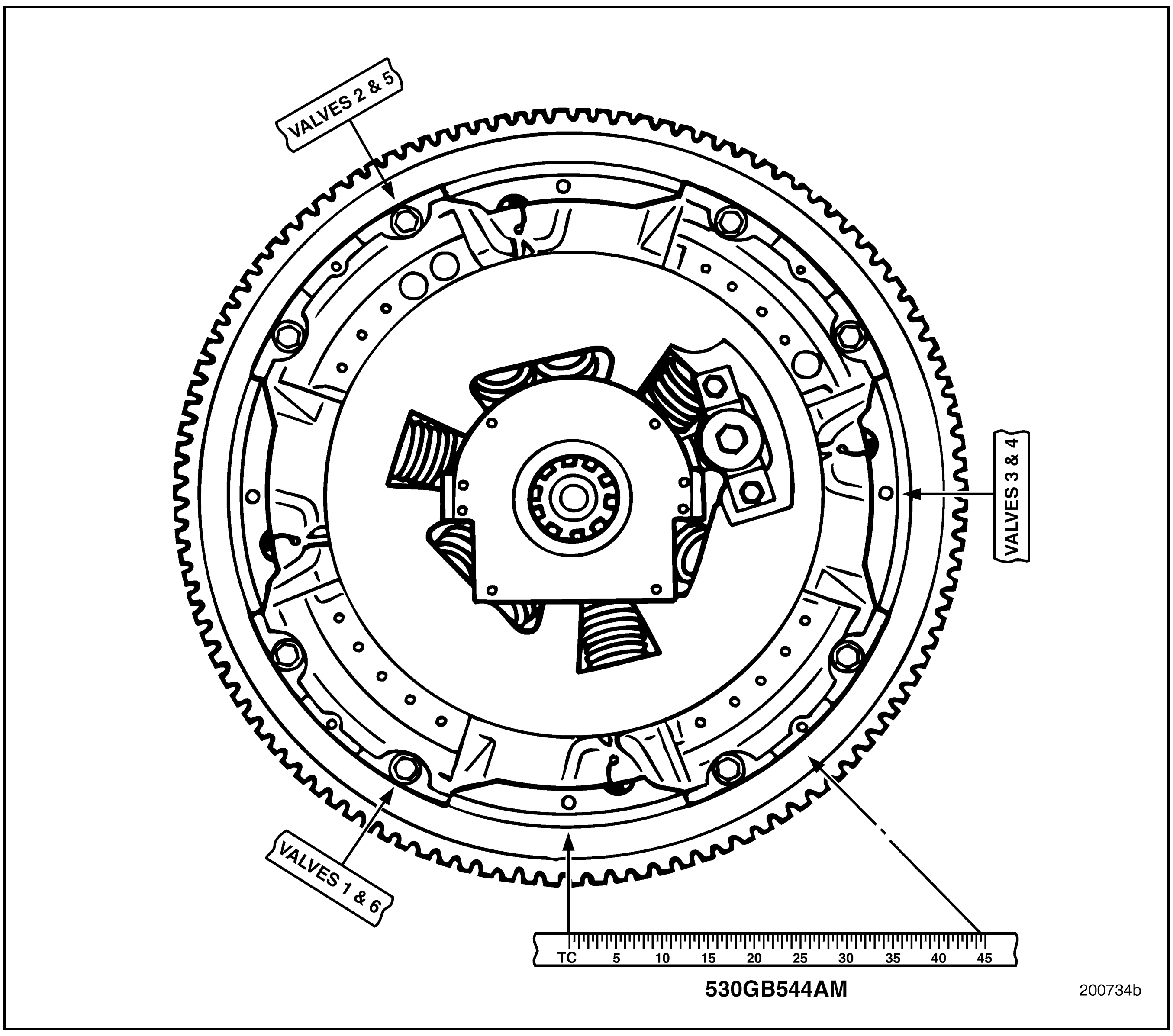


Figure 256 — Flywheel Markings

INSTALLATION PROCEDURE

CAUTION

After resurfacing, any flywheel with drilled balance holes on the clutch side requires rebalancing by a machine shop.

NOTE

On vehicles equipped with an automatic transmission, it may be necessary to install different components to the flywheel retaining capscrews. Refer to Automatic Transmission Drive Arrangement Assembly Instructions manual, 5-902, for installation instructions regarding these arrangements.

SERVICE HINT

When installing the flywheel, insert two alignment studs into the flywheel mounting holes to aid in installation.

Refer to Figure 257.

1. Position the flywheel over the dowel pin and alignment studs on the flywheel mounting surface at the rear of the crankshaft.
2. Install the flywheel mounting capscrews in the exposed mounting holes. At this time, tighten the capscrews finger-tight only.
3. Remove the two alignment studs and insert the remaining mounting capscrews.

CAUTION

Do not torque capscrews adjacent to each other in sequence. Doing so may result in uneven flywheel alignment. Capscrews on opposite sides of the flywheel should be alternately tightened to the specified torque.

4. Tighten the capscrews to the specified torque, 185 lb-ft (251 N•m), alternating from opposite sides to apply even pressure to the flywheel (use torque wrench J 24407, or equivalent).

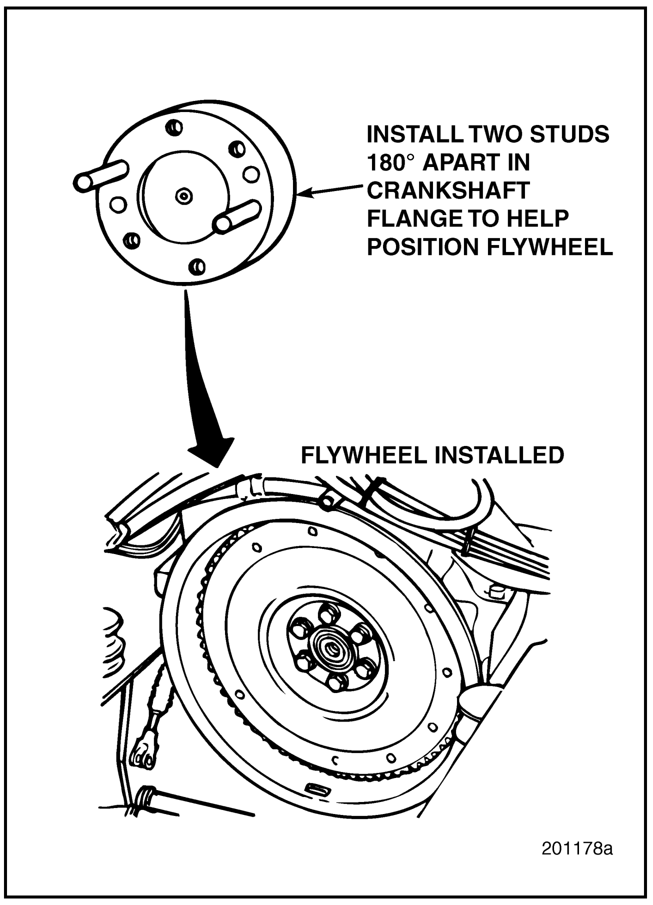


Figure 257 — Flywheel Installation

Valve Lifter Installation

[213 LB]

1. Rotate the engine 180 degrees, so bottom of the engine is facing up.
2. Apply a generous coating of clean engine oil to the lifters.
3. Install the lifters into the cylinder block lifter bores as shown in Figure 258.

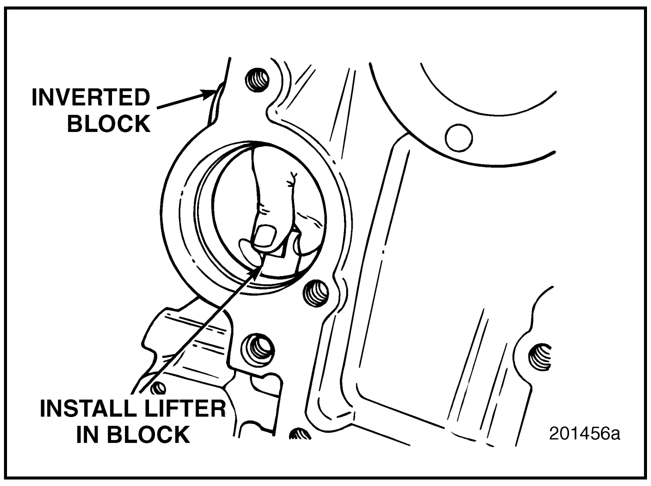


Figure 258 — Valve Lifter Installation

4. Make sure that the lifter flats are aligned with the H-ring flats (Figure 259) and that the lifters are fully seated against the H-rings. Once installed, it should be possible to rotate lifters slightly from left to right.

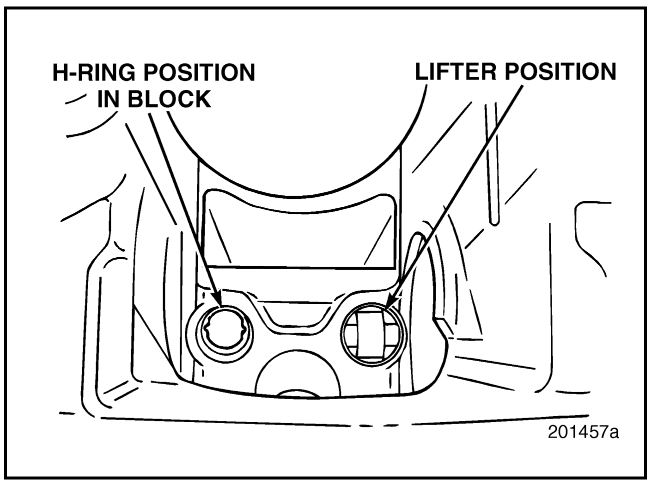


Figure 259 — Installed Valve Lifter

Camshaft Installation

[213 CH]

Before installing a camshaft in any engine, ensure that cam is clean, undamaged and well-lubricated with clean engine oil. Refer to the Auxiliary Shaft and Camshaft Bench Procedures in the REPAIR INSTRUCTIONS section.

SERVICE HINT

When installing the camshaft, it is easier to remove the camshaft guide from the camshaft (after installation) when the idler gear is removed and alignment of the timing marks is not being attempted at the same time. The final step in the process is to reinstall the idler gear.

NOTE

Use camshaft guide tool J 41682 to ease installation of the camshaft and avoid damage to the camshaft bushings.

Install the camshaft as follows:

1. Apply a generous coating of clean engine oil to the camshaft bushings.
2. Clean the camshaft with a suitable solvent.
3. Install the camshaft installation guide over the large flat of the injector lobe, between the last two cam journals (journals at the back of shaft). Refer to Figure 260.

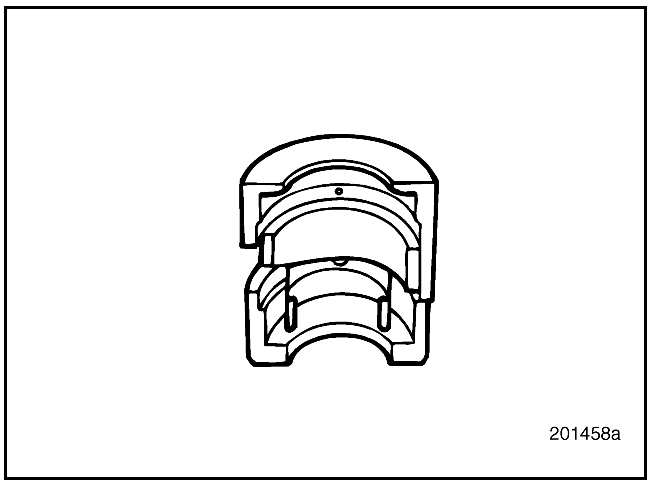


Figure 260 — Camshaft Installation Guide

5_106_00.bk Page 243 Friday, August 4, 2000 11:17 AM

4. Apply clean engine oil to the installation guide.

NOTE

The camshaft is heavy, approximately 90 pounds with the gear. The installation guide allows the camshaft to slide from one cam bushing to the next without allowing the cam to drop when one journal clears the bushing bore.

5. With the engine still rotated 180 degrees (crankcase facing up, head deck facing down), position the camshaft in the block with the cam installation guide facing down toward the floor as shown in Figure 261.
6. Slide the cam all the way into the block.

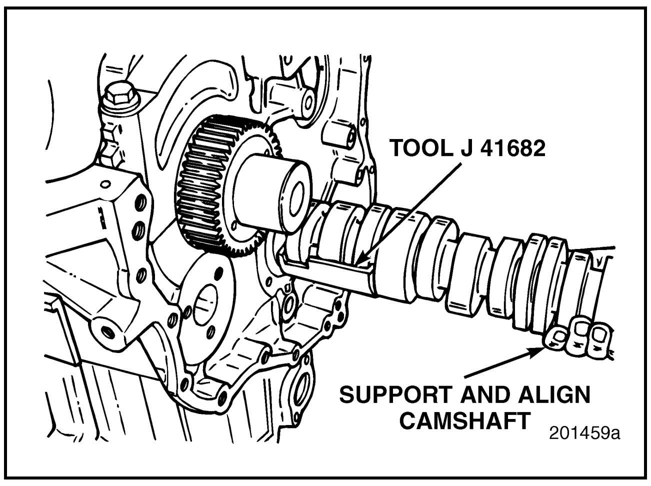


Figure 261 — Camshaft Installation

7. After the camshaft is fully installed, install the thrust washer screws and tighten to specification, 15 lb-ft (20 N•m).
8. Rotate crankshaft and camshaft to facilitate installation guide removal. The camshaft must be rotated so that the installation guide faces up toward the cylinder block pan rail. The crankshaft must be rotated so the No. 6 connecting rod journal faces down toward the cylinder block top deck (piston at TDC).
9. Remove the installation guide tool J 41682.

Camshaft Core Plug Installation [213]

After the camshaft is installed, install the core plug.

1. Position the core plug onto the core plug installation tool J 42490 (used with J 8092 driver handle). Refer to Figure 262.

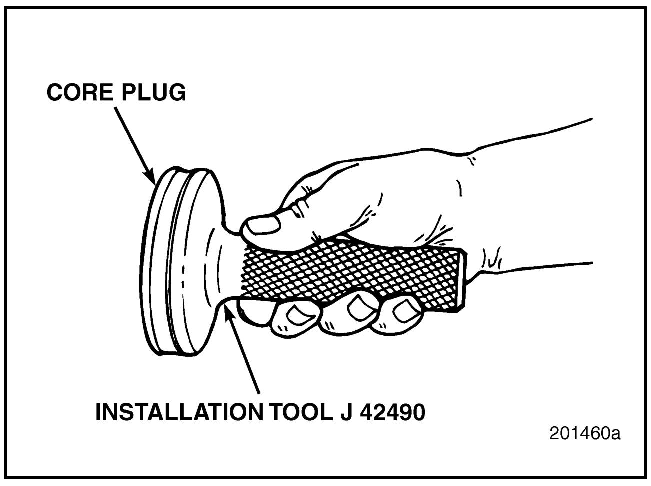


Figure 262 — Camshaft Core Plug Installation Tool

2. Position the core plug in the cylinder block.
3. Drive the core plug into place by striking the installation tool with a hammer (Figure 263) until the core plug is seated. Core plug is fully seated when the step in the installation tool bottoms against the block.

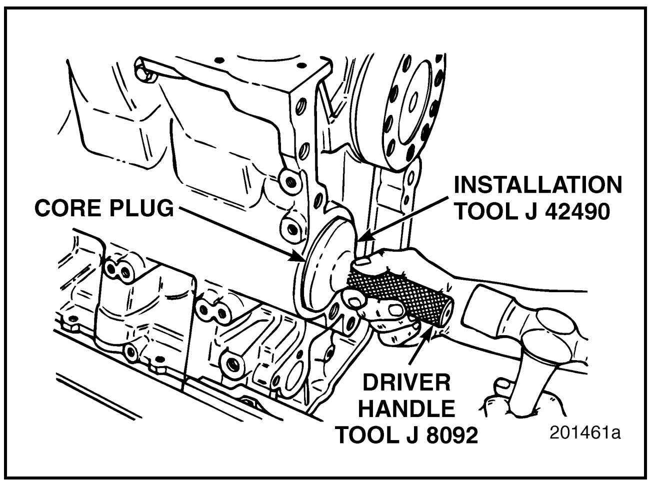


Figure 263 — Camshaft Core Plug Installation

Camshaft Idler Gear Installation

[213 DE]

Before installing the idler gear/hub assembly, determine which is the top mounting hole on the hub.

The idler gear is held in place by a flanged hub mounted to the cylinder block by three bolts. Although the bolt-mounting pattern may *appear* symmetrical, it is not. The non-symmetrical mounting pattern ensures that oil feed passages in the hub will be properly aligned with the oil feed passage in the cylinder block, which lubricates the idler gear hub bushing.

To aid in aligning the hub to the mounting holes in the cylinder block, at the 12-o'clock position (engine upright), the hub mounting bolt hole is identified by the word "UP" steel-stamped just below the mounting hole.

1. With the engine in an upright position and the hub correctly aligned with the mounting bolt holes, place idler hub against the block and verify good mounting hole alignment (Figure 264).

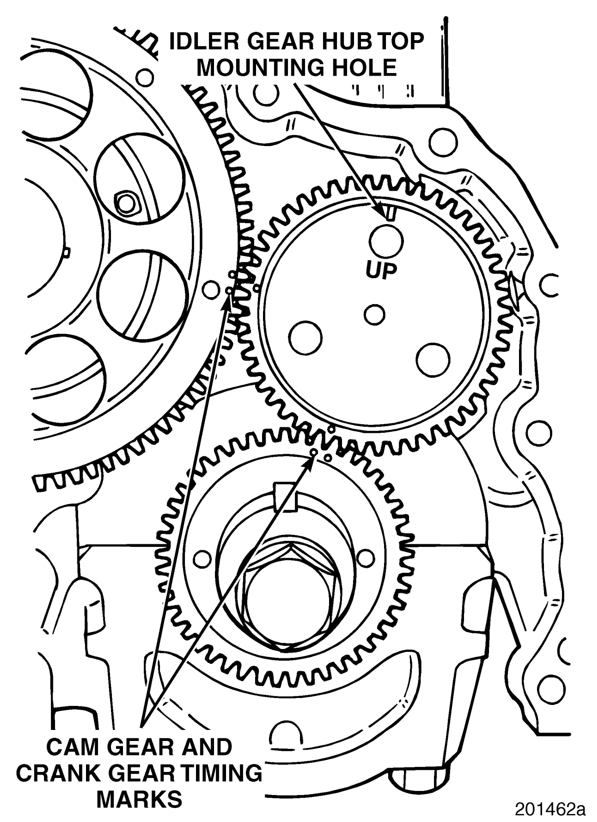


Figure 264 — Hub Correctly Positioned on Block

2. Align the timing marks. First look at the timing marks on both the camshaft and crankshaft gears. Note that two teeth are marked (side by side) on each gear. These two timing marks must align with the single timing marks on the idler gear. When properly installed, the two single timing marks on the idler gear will fall between the two timing marks on the camshaft and crankshaft gears. To attain correct alignment, rotate the crankshaft and camshaft gears until the camshaft timing marks are in approximately the 3:30 position, and the crankshaft gear timing marks are in approximately the 1 o'clock position (with engine in the upright position and viewed from the front).

NOTE

There are 45 gear teeth on the crankshaft gear, 90 teeth on the camshaft gear and 48 on the idler gear. Because the idler gear has 3 more teeth than the crankshaft gear, the timing marks align only once every 16 revolutions of the crankshaft. This is called a “hunting tooth” system.

3. Slide the idler gear onto the hub assembly with timing marks facing out.
4. Position the idler gear timing marks so they align (Figure 265) with the crankshaft and camshaft gear timing marks. Then slide the idler gear/hub assembly into position on the cylinder block.

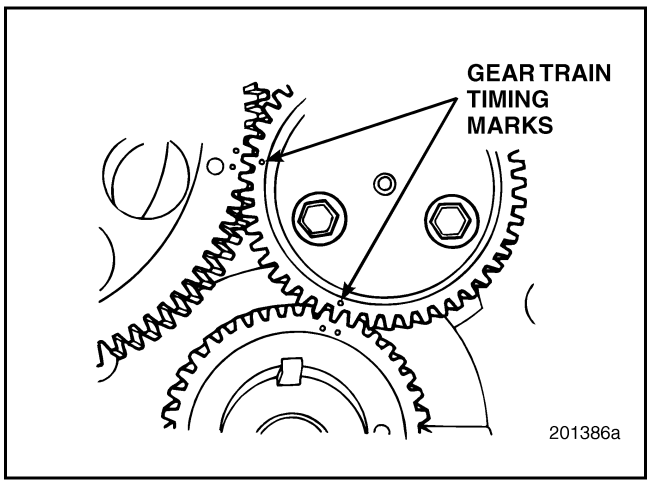


Figure 265 — Timing Marks Properly Aligned

5. Oil the bolts with clean engine oil. Start the bolts a few turns.
6. Tap the hub portion of the assembly with a brass hammer to seat the components.
7. Tighten the bolts evenly to specification. Do not use an impact wrench or other air tool to tighten bolts.

Auxiliary Shaft Installation

[212 CV]

Before installing the auxiliary shaft in the engine, ensure that the shaft is clean, undamaged and well-lubricated with clean engine oil. Refer to the Auxiliary Shaft and Camshaft Bench Procedures in the REPAIR INSTRUCTIONS section.

Refer to Figure 266.

CAUTION

Replace the auxiliary shaft as an assembly only. Do not try to dismantle or rework the shaft since doing so may result in damage to the engine.

1. Lubricate the front auxiliary shaft journal (2), rear auxiliary shaft journal (4) and shaft bearings (in cylinder block) with clean engine oil.

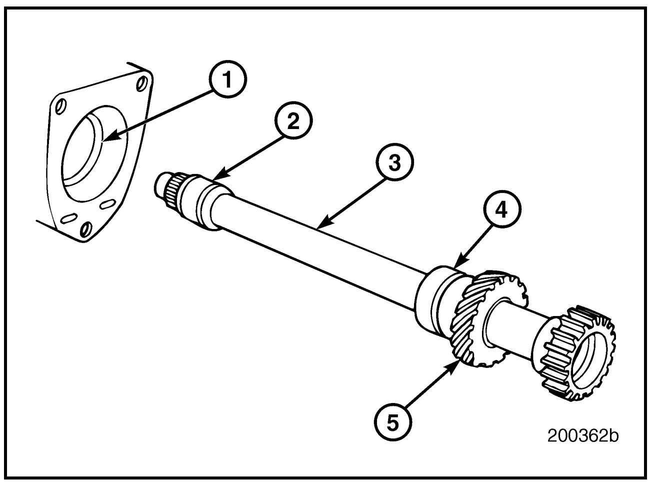


Figure 266 — Auxiliary Shaft Installation

1. Rear Bearing 2. Auxiliary Shaft Front Journal 3. Shaft	4. Auxiliary Shaft Rear Journal 5. Oil Pump Drive Gear

2. Install shaft (3) into the rear of the auxiliary shaft housing. Use care when aligning the shaft through the rear bearing (1).

   Refer to Figure 267.
3. Install the thrust washer (4) and secure it in position with the patch-lock capscrews (3) and hardened washers.
4. Tighten the thrust washer retaining patch-lock capscrews to the specified torque, 15 lb-ft (20 N•m), using torque wrench J 24406, or equivalent.
5. Install the auxiliary shaft gear (2) on the shaft splines (5).

NOTE

The auxiliary shaft and nut threads must be clean and dry before assembly. Clean the threads thoroughly with Brakleen® or electrical contact cleaner. Apply Loctite® 271 or 277 to the threads and install the nut.

6. Install the auxiliary shaft nut (1) and tighten to the specified torque, 300 lb-ft (407 N•m), using torque wrench J 23775-01, or equivalent.

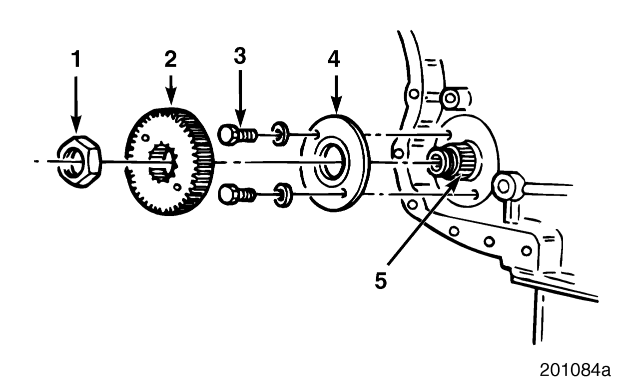


Figure 267 — Auxiliary Shaft Gear Installation

1. Nut 2. Auxiliary Shaft Gear 3. Capscrew	4. Thrust Washer 5. Shaft Splines

Oil Pump Installation

[219 MU]

Make sure the oil pump is in satisfactory condition as covered under Lubrication System Components Bench Procedures in the REPAIR INSTRUCTIONS section.

NOTE

Because of differences in the E-Tech™ and E7 gear set helixes, it is important that the correct component/parts are installed.

- An improper drive gear on the oil pump will prevent oil pump installation, assuming a correct gear is on the auxiliary shaft.
- If an oil pump and an auxiliary shaft assembly were replaced, two improper gears could be installed, and engine failure would result.
- In replacing any of these critical parts, always refer to part number information in the MACK Parts System to ensure the correct component/part is being used.

1. Position the oil pump (1) on the cylinder block (3). Refer to Figure 268.
2. Secure the pump in position using the mounting capscrews (2). Tighten the mounting capscrews to the specified torque, 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.

CAUTION

Apply Loctite® 271 to all capscrews used to install the oil pump.

5_106_00.bk Page 247 Friday, August 4, 2000 11:17 AM

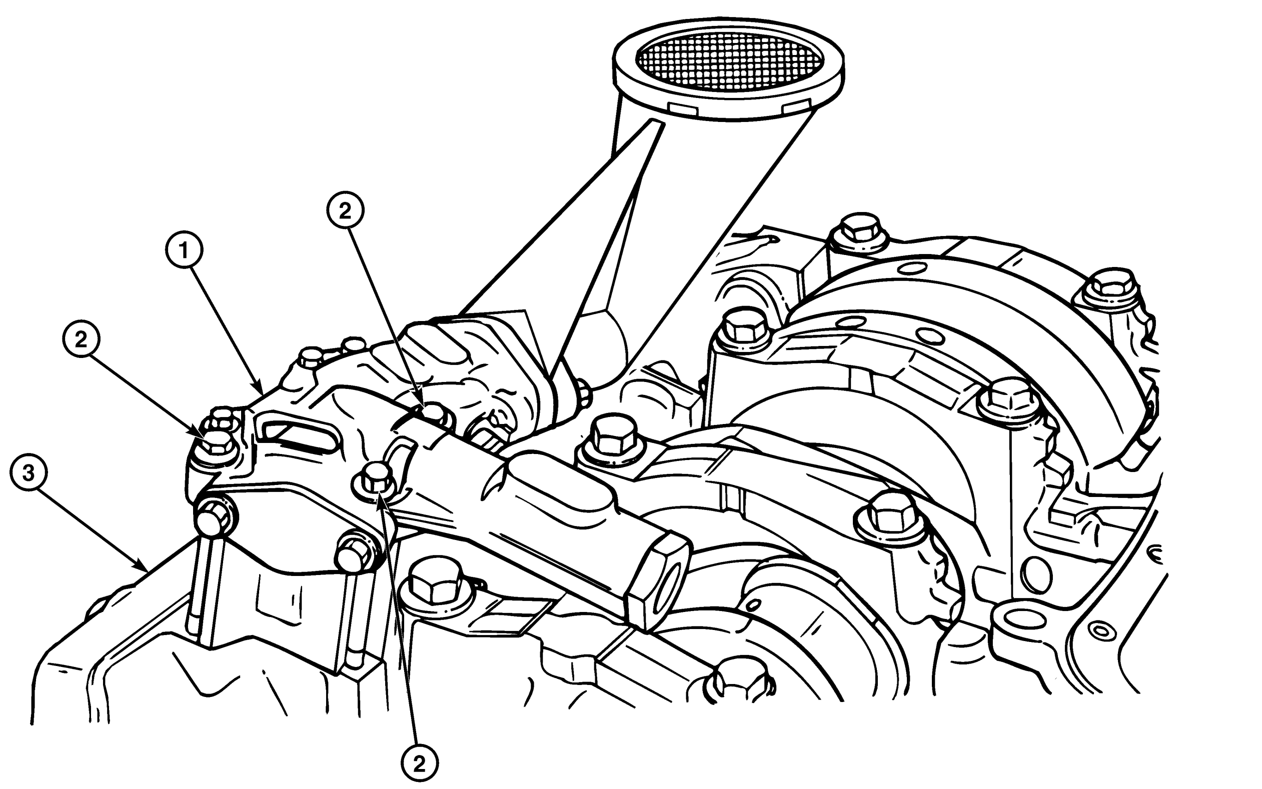


Figure 268 — Oil Pump Installation

1. Lubrication Oil Pump 2. Mounting Capscrews	3. Cylinder Block

CAUTION

After the oil pump has been installed, check the backlash between the auxiliary shaft gear and the oil pump driven gear.

3. Check the auxiliary shaft gear to oil pump driven gear backlash, 0.0072–0.0138 inch (0.1829–0.3505 mm), using a thickness gauge between the auxiliary shaft gear and the oil pump driven gear.

Front Cover Installation

[211 RP]

With the crankshaft, camshaft and auxiliary shaft in place, install the front cover.

1. Apply a light coat of Silastic® to the timing cover mounting surface.
2. Position the timing cover on the cylinder block mounting surface.
3. Secure the timing cover to the cylinder block using the mounting capscrews. Torque the capscrews to 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.
4. Position the front pedestal mount on the timing cover and secure with the mounting hardware. Torque the pedestal mounting capscrews to 70 lb-ft (95 N•m), using torque wrench J 24407, or equivalent.

Crankshaft Front Seal Installation

[211 JB]

SPECIAL TOOLS REQUIRED

- Crankshaft Front Seal Installer J 37715-A
- Crankshaft Front Seal Adapter J 37715-2

INSTALLATION PROCEDURE

NOTE

Installation depth of the E-Tech™ engine front crankshaft seal, relative to the front crankshaft stem, is controlled by the installation tool adapter. Ensure that the correct adapter, J 37715-2, is used.

Refer to Figure 269.

1. Position the lip-type seal on the seal installer (J 37715-2 adapter in combination with J 37715-A), with the solid portion of the seal outward (toward the tool).
2. Position the tool over hub and into the seal opening.

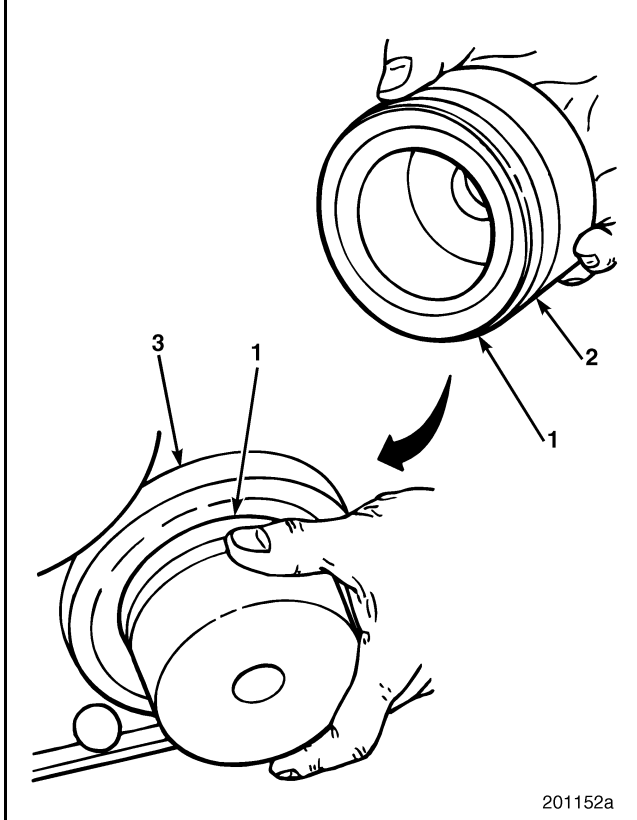


Figure 269 — Crankshaft Front Seal Installation

1. Front Cover Seal 2. Seal Installer J 37715-A	3. Front Cover

3. Insert the hub capscrew into the hole in the seal installation tool and draw the seal in until the tool bottoms out on the face of the crankshaft.
4. Remove the tool and check the seal to ensure it has been evenly installed.

Crankshaft Hub Installation

[212 RH]

INSPECTION

Inspect the crankshaft hub for scoring and condition of the flange and threaded holes.

CAUTION

Replace the hub if the removed seal shows signs of wear. Mack Trucks, Inc. does not recommend the use of a service sleeve to repair the crankshaft hub when there is hub damage. When there is damage to the hub, replace it.

INSTALLATION PROCEDURE

Refer to Figure 270.

1. Using a suitable grease-type lubricant, coat the working surface of the seal in preparation for the crankshaft hub installation.

NOTE

Teflon®-type seals do not require greasing the working surface of the seal.

2. Heat the hub to approximately 250°F (121°C) prior to installation.
3. Using heat-resistant gloves, position the hub on the crankshaft.

NOTE

While the crankshaft has a keyway slot, the crankshaft hub does not. For the E-Tech™ engine, timing is set in relation to the flywheel position and not the crankshaft hub, eliminating the need for a hub key and precise alignment.

4. In a quick, even motion, push the hub onto the crankshaft.
5. Install the hub washer and capscrew. Tighten the capscrew to the specified torque, 330 lb-ft (447 N•m), using torque wrench J 23775-01, or equivalent.

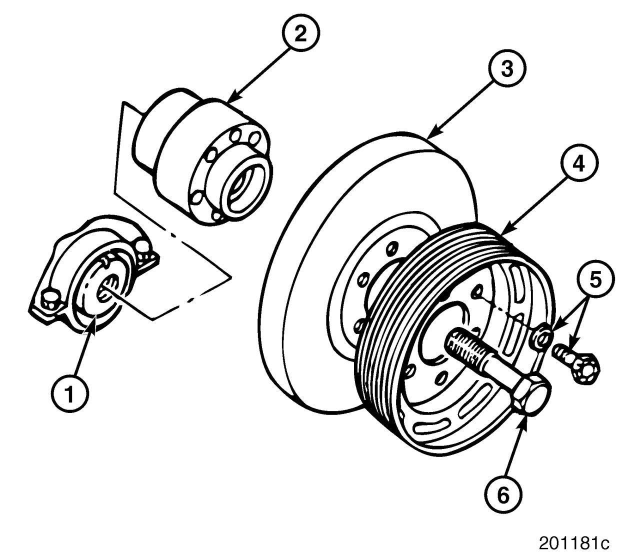


Figure 270 — Crankshaft Hub/Vibration Damper

1. Crankshaft 2. Crankshaft Hub 3. Vibration Damper 4. Pulley	5. Damper/Puller Capscrews and Washers 6. Hub Capscrew

Vibration Damper Installation

[212 RB]

INSPECTION

CAUTION

When removing or handling the vibration damper, be careful not to damage the housing. Any dents in the outer housing may render the damper ineffective and result in cracks in the crankshaft. The vibration damper cannot be repaired.

Inspect the vibration damper for dents, nicks or fluid leaks in the outer housing. If any of the above are evident, the vibration damper must be replaced. Due to the close clearances between the damper housing and its internal flywheel, dents or nicks may cause contact between the two components. Fluid loss will deteriorate the dampening effect of the damper.

INSTALLATION PROCEDURE

1. Position the vibration damper and drive pulley on the crankshaft hub.
2. Install the six mounting capscrews. Tighten the capscrews to the specified torque, 45 lb-ft (61 N•m).

Oil Pan Installation

[211 NB]

GENERAL INFORMATION

With the isolating oil pan gasket arrangement, 8-mm mounting holes are tapped into the cylinder block, front cover and flywheel housing. Figure 271 shows the production arrangement.

NOTE

Through late August 1999, the isolated oil pan gasket mounting arrangement used shoulder studs to secure the oil pan to the front timing cover, flywheel housing and at certain locations along the oil pan sides. Beginning approximately late August 1999, the shoulder studs at the timing cover and flywheel housing were changed to shoulder capscrews (part No. 421GC289M), and, approximately fourth quarter 1999, the shoulder studs with a separate nut used at locations on the sides of the oil pan were changed to a one-piece integral hex-head shoulder stud assembly (part No. 616GC39M3).

Prior to the fourth quarter 1999 introduction of the one-piece integral hex-head shoulder stud assembly, flat washers (part No. 37AX68) were added to the shoulder studs (part No. 616GC239M) to compensate for the gap between the nut and the shoulder stud and to ensure sufficient clamp load to the gasket. This change went into effect February 22, 1999, beginning with engine serial No. 9C2735.

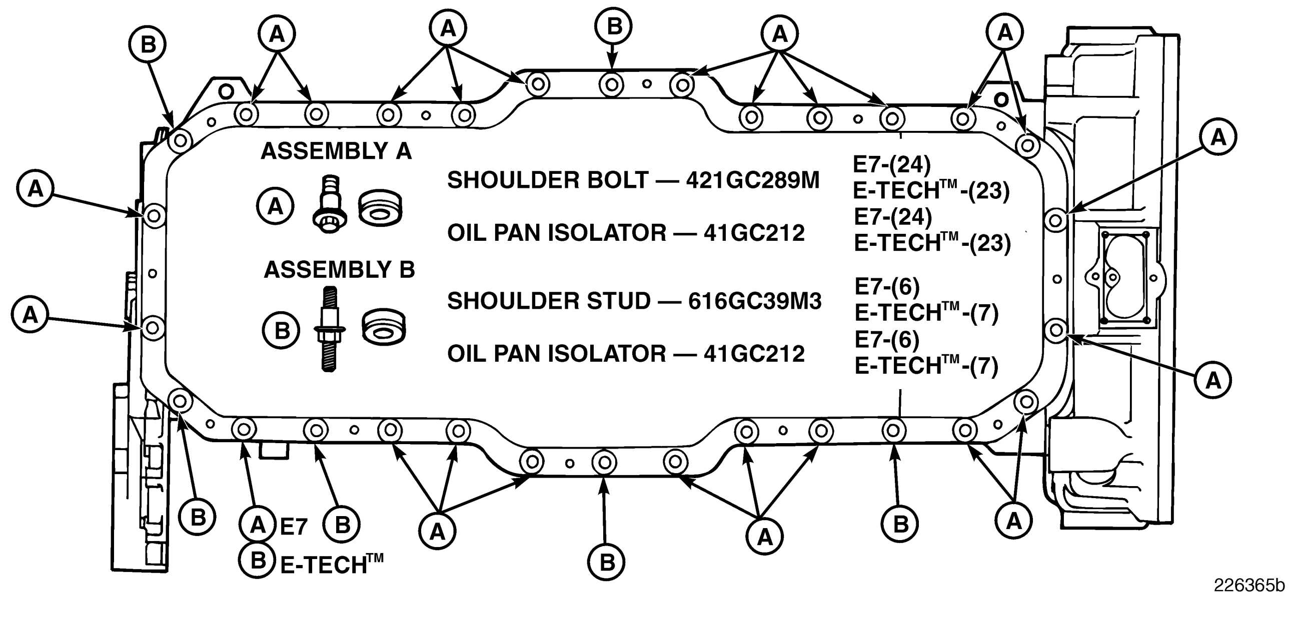


Figure 271 — Oil Pan Stud Identification

5_106_00.bk Page 251 Friday, August 4, 2000 11:17 AM

The isolating oil pan gasket contains 12 integral locating/retaining cones which lock into holes drilled through the oil pan rails, and two large rectangular tabs located directly across from each other on the inner perimeter of the gasket. The cones keep the gasket properly located during oil pan installation, and the rectangular tabs serve as a starting point for locating the gasket on the oil pan rail.

INSTALLATION PROCEDURE

1. Clean any oil from the cylinder block mounting surface and the oil pan rail. The oil pan must be installed dry.

CAUTION

Oil on the surface of the gasket or the rails of the cylinder block and oil pan during the oil pan installation can cause the gasket to bulge out between any two bolts, particularly those at the mid-section corners. This condition may not occur immediately, but can do so at any time after installation. To avoid this occurrence, wipe any oil from the inner walls of the cylinder block crankcase and then clean the rails of the cylinder block and oil pan with a suitable non-flammable solvent. Dry the cleaned surfaces completely.

2. Position the isolating oil pan gasket on the oil pan rails with the ribbed side facing up.
3. Beginning at the center of the pan at one of the rectangular tabs, align the rubber locating cones with corresponding holes in the pan rails (Figure 272).

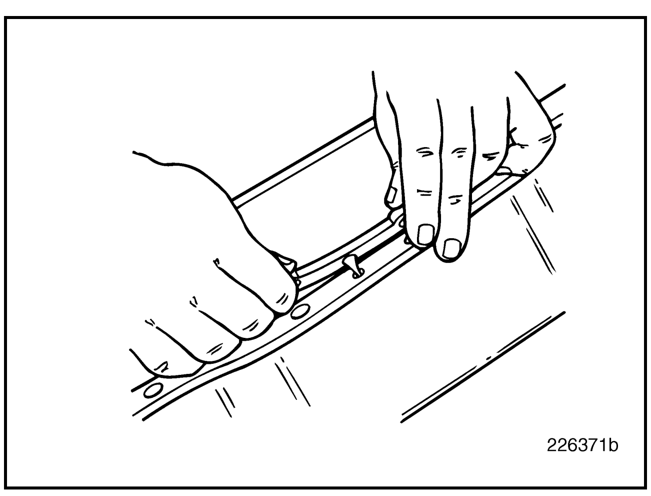


Figure 272 — Locating Cone Alignment

4. In one motion, firmly press down on the gasket with one hand while carefully pulling the rubber cone through the hole with the other hand until seated (Figure 273). Continue this procedure for the remaining locating cones.

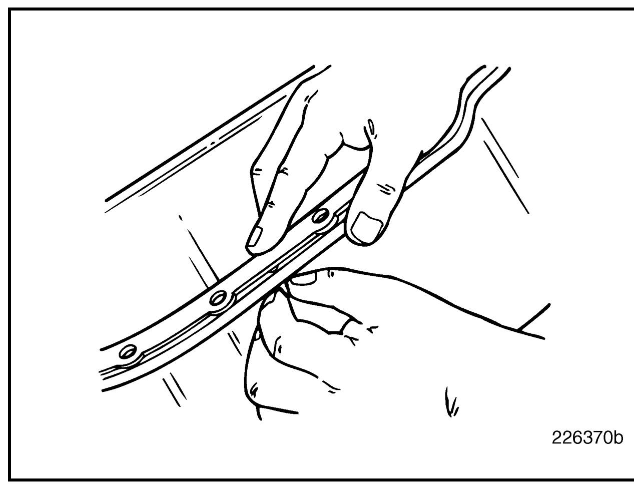


Figure 273 — Locating Cone Installation

5. Visually check the underside of the pan rail to ensure that all locating cones are properly seated.

NOTE

During removal of the isolating oil pan from the engine, the studs may have backed out while loosening the stud nuts. Be sure they are fully seated prior to installing the oil pan.

6. When installing the oil pan on the engine, center the pan before tightening the fasteners so that the edges of the metal isolator washers do not touch the pan. Refer to Figure 274.

NOTE

On engines manufactured prior to fourth quarter 1999 (having a separate nut), install the flat washer (part No. 37AX68) with the shoulder studs. These flat washers are not necessary, and should not be used with the one-piece integral hex-head shoulder studs.

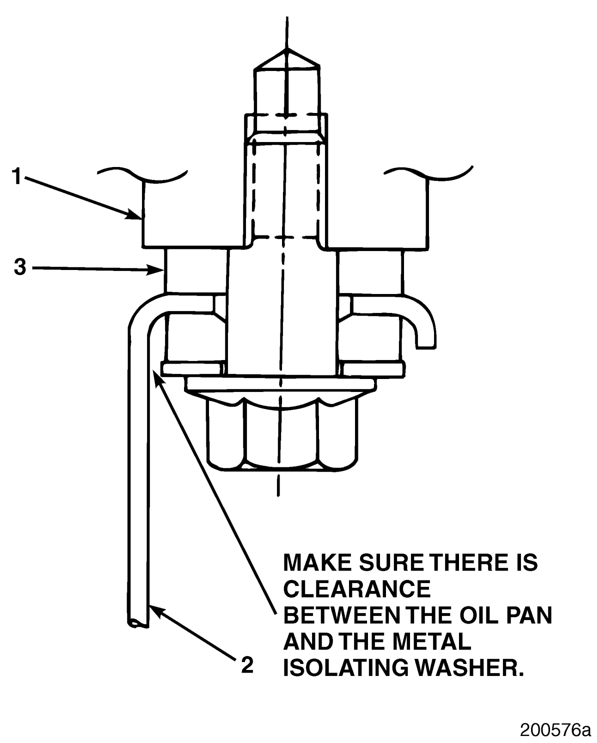


Figure 274 — Checking Clearance

1. Cylinder Block 2. Oil Pan	3. Rubber Gasket

Cylinder Head Installation

[213 EV]

Ensure that the cylinder heads are in acceptable condition. Refer to the cylinder head inspection procedures under Cylinder Head Reconditioning in the REPAIR INSTRUCTIONS section.

NOTE

All MACK head gaskets are precoated and do not require any type of additional sealing compound.

Refer to Figure 275.

1. Place the head gaskets in position on the locating pins in the cylinder block deck.
2. Place a fire ring carefully in position on top of each cylinder sleeve.

CAUTION

Check that the design of the fire ring used is the correct match for the cylinder sleeves installed.

3. Position the partially assembled cylinder heads (valves, nozzle holder sleeves, core/ pipe plugs installed) on the cylinder block. Locate the heads into the guide pins in the cylinder block.

NOTE

Two of the head mounting capscrews have threaded holes drilled in the heads for bracket-mounting purposes. The drilled capscrews must be located in the correct positions for proper bracket installation.

5_106_00.bk Page 253 Friday, August 4, 2000 11:17 AM

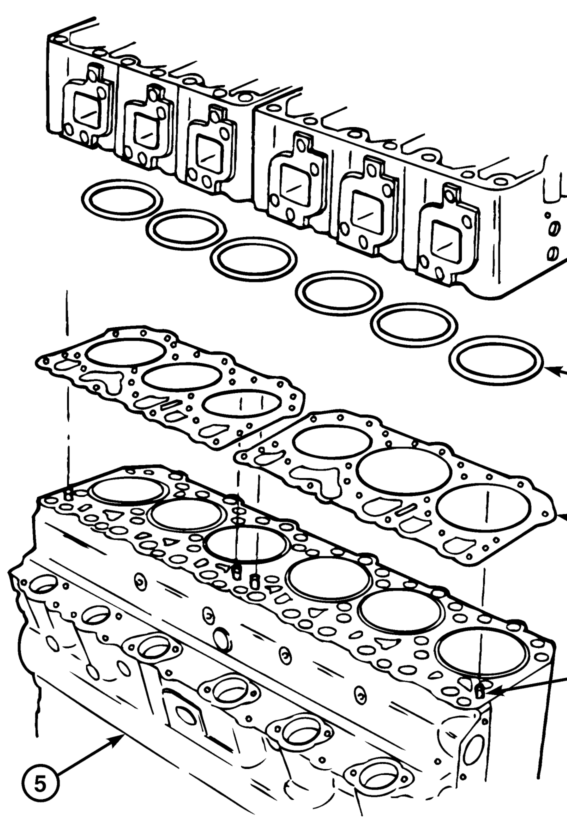


Figure 275 — Cylinder Head Gasket and Fire Ring Positioning

1. Cylinder Head 2. Fire Rings 3. Gasket	4. Guide Pins 5. Cylinder Block

4. Check the condition of the capscrews and lubricate the capscrew heads (underside), threads and washers with clean engine oil.

NOTE

Do not install painted capscrews at locations that are under the valve cover.

5. Insert the capscrews in the mounting holes. Tighten all cylinder head capscrews finger-tight. (There are two cylinder head capscrew lengths: 198.0 mm and 225.0 mm.)

6. Check the alignment of the cylinder heads by placing a straightedge against the exhaust manifold mounting surfaces (Figure 276). Using a feeler gauge, measure any gaps between the straightedge and manifold mounting surfaces. The heads should be in alignment within 0.005 inch (0.127 mm). If not, reposition the heads to achieve the specified alignment.

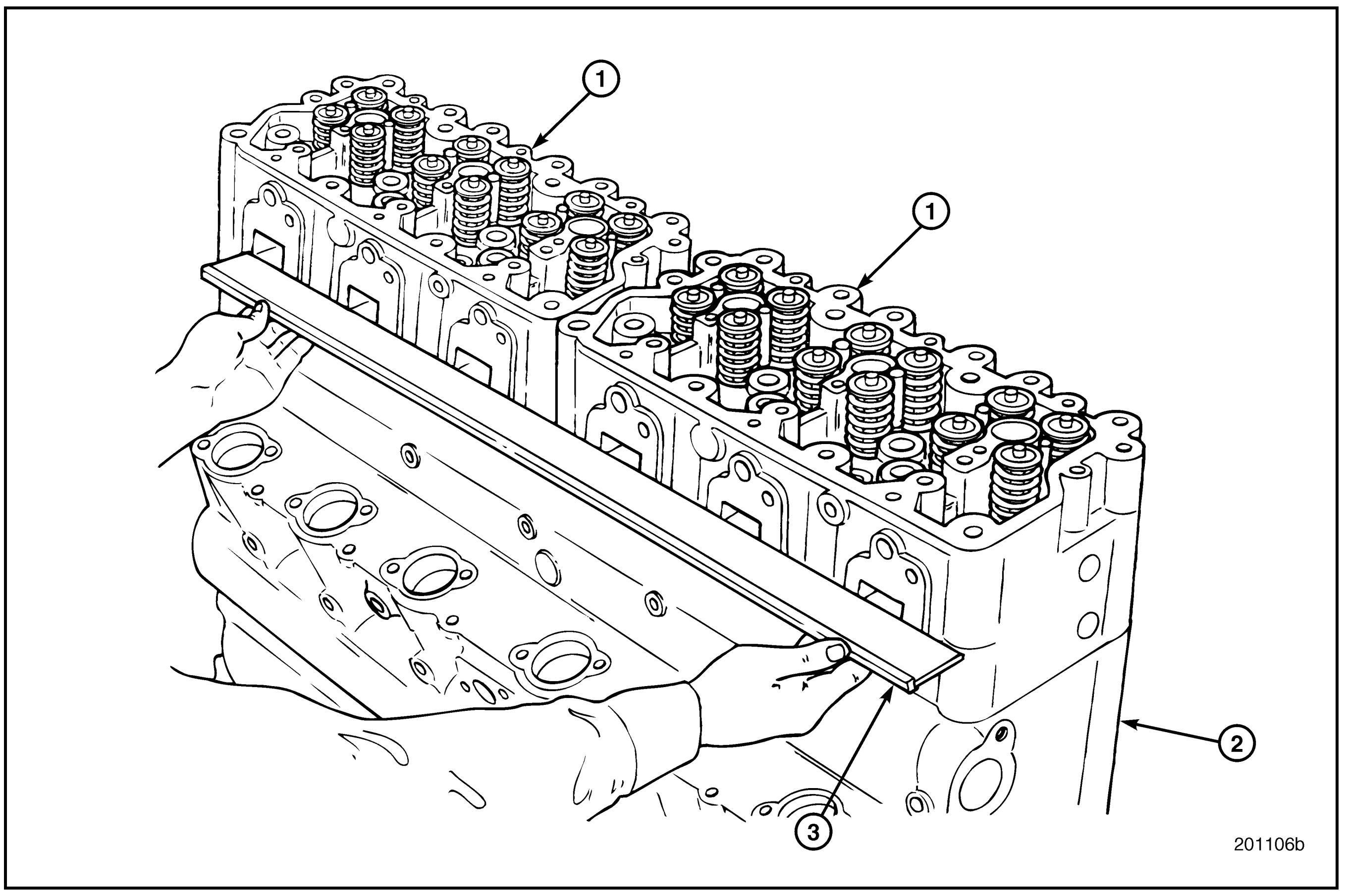


Figure 276 — Cylinder Head Alignment

1. Cylinder Heads 2. Cylinder Block	3. Straightedge

5_106_00.bk Page 255 Friday, August 4, 2000 11:17 AM

7. Oil all cylinder head capscrew bosses, capscrew threads and washers with engine oil prior to assembly. Do not oil threads in cylinder block. Using torque wrench J 24407, or equivalent, tighten all cylinder head mounting capscrews to specification in three stages as listed below. Refer to Figure 277 for the tightening sequence.
   a. Tighten all capscrews in sequence to 50 lb-ft (68 N•m).
   b. Tighten all capscrews in sequence to 125 lb-ft (170 N•m).
   c. Tighten all capscrews in sequence to the final specified torque value of 205 lb-ft (278 N•m).

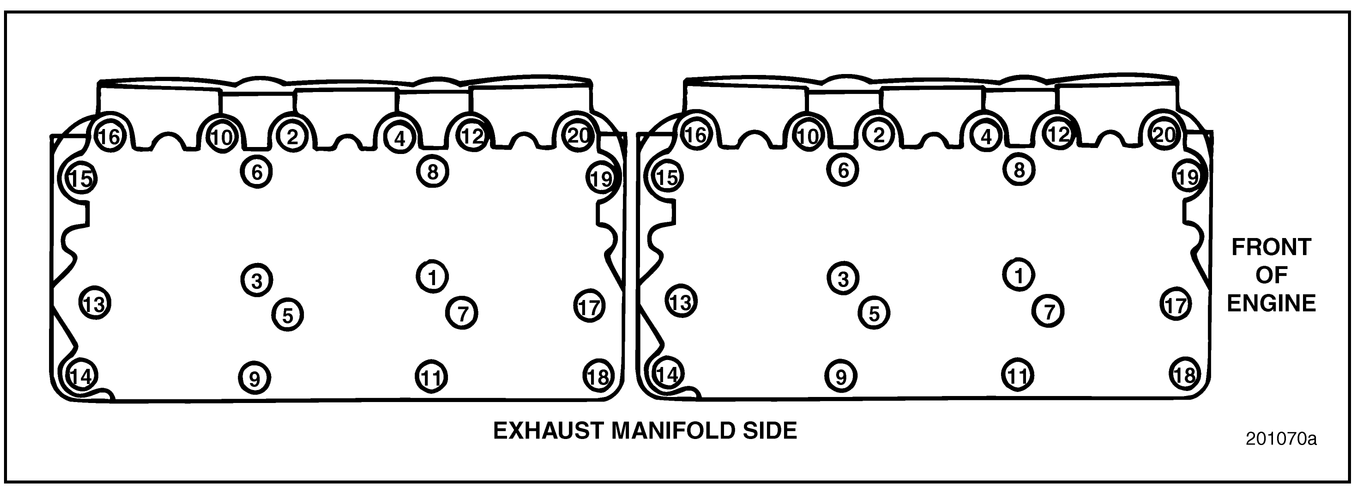


Figure 277 — Head Bolt Torque Sequence Chart

Exhaust Manifold Installation

[214 EG]

MANIFOLD STUD INSTALLATION

Apply Loctite® 272 to the cylinder head engagement threads of all exhaust studs, prior to installation.

⚠ CAUTION

Lower exhaust stud holes intersect with the push rod holes; upper exhaust holes may intersect as well. This requires that all exhaust studs be sealed at installation to prevent oil leakage.

On some E-Tech™ engines, the lower exhaust manifold-to-cylinder head stud hole may be drilled deep enough to allow the stud to enter the push rod bore. In these instances, the 20 lb-ft (27 N•m) of torque may not be reached until the stud contacts the push rod. In all cases, a stud protrusion of 1.75 inch (44.45 mm) must be maintained. Refer to Figure 278.

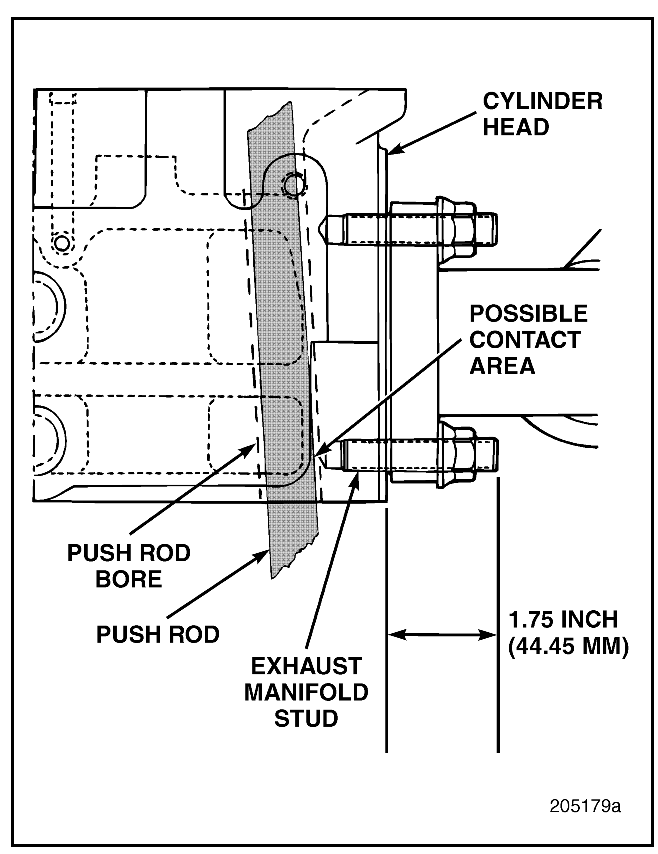


Figure 278 — Exhaust Stud Protrusion

MANIFOLD INSTALLATION

Refer to Figure 279.

1. Install the 12 studs in position on the cylinder head.
2. Position six manifold gaskets on the studs.

NOTE

Exhaust manifold nuts must be installed dry (no lubrication).

3. Position the exhaust manifold on the mounting studs and secure with nuts. Tighten the nuts to the specified torque:
   - 55 lb-ft (75 N•m) for 10-mm nuts
   - 65 lb-ft (88 N•m) for 12-mm nuts

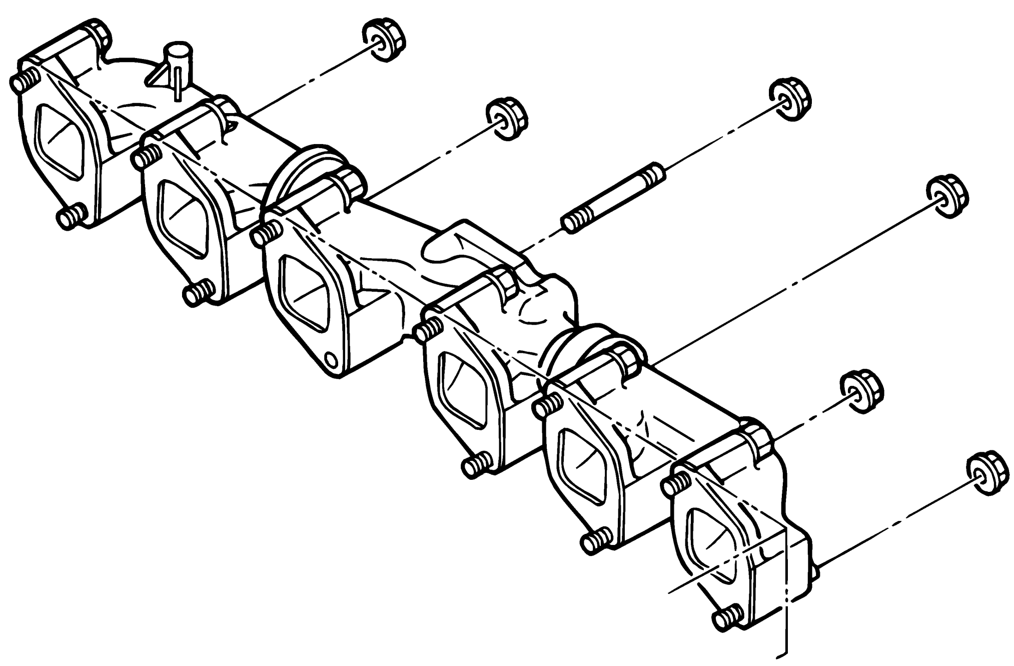


Figure 279 — Typical Exhaust Manifold Installation

Nozzle Holder Assembly Installation [222 KG]

GENERAL INFORMATION

The nozzle holder is positioned vertically in the cylinder head and centered in the cylinder between the four valves. The nozzle fuel inlet tube is inserted through the side of the cylinder head and the tapered end of the inlet tube seals the area between the tube and the nozzle holder. The tube is secured in position with a sleeve nut.

SPECIAL TOOL REQUIRED

- Injection Nozzle Puller J 37093

INSTALLATION PROCEDURE

1. Install the washer-type gasket in place on the bottom of the nozzle, using a small dab of grease to hold it in place.

NOTE

An alternate method is to drop the washer in the nozzle holder sleeve bore as shown in Figure 280. Make sure the washer-type gasket is centered and lying flat in the bottom of the nozzle holder sleeve bore.

CAUTION

Care must be taken with either method of installation to NOT misposition the gasket. If mis-positioned, the washer may be damaged and result in severe combustion leakage.

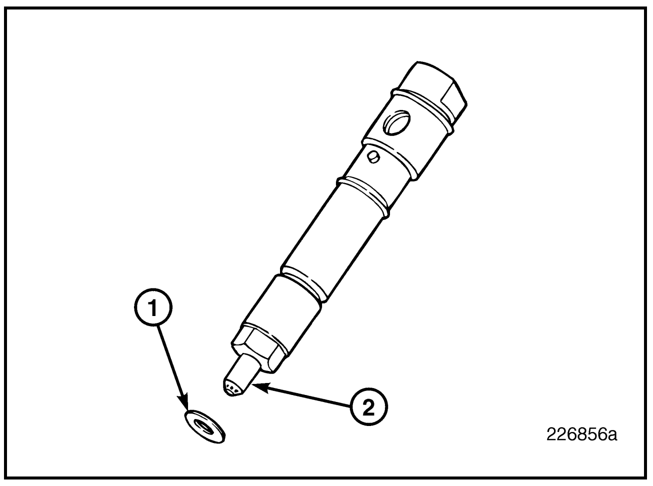


Figure 280 — Nozzle Holder Gasket Installation

1. Washer	2. Nozzle

2. Lubricate the surface of the nozzle holder with clean engine oil and install the two O-rings on the holder.
3. Thread injection nozzle puller J 37093 into the top of nozzle holder as shown in Figure 281.

5_106_00.bk Page 258 Friday, August 4, 2000 11:17 AM

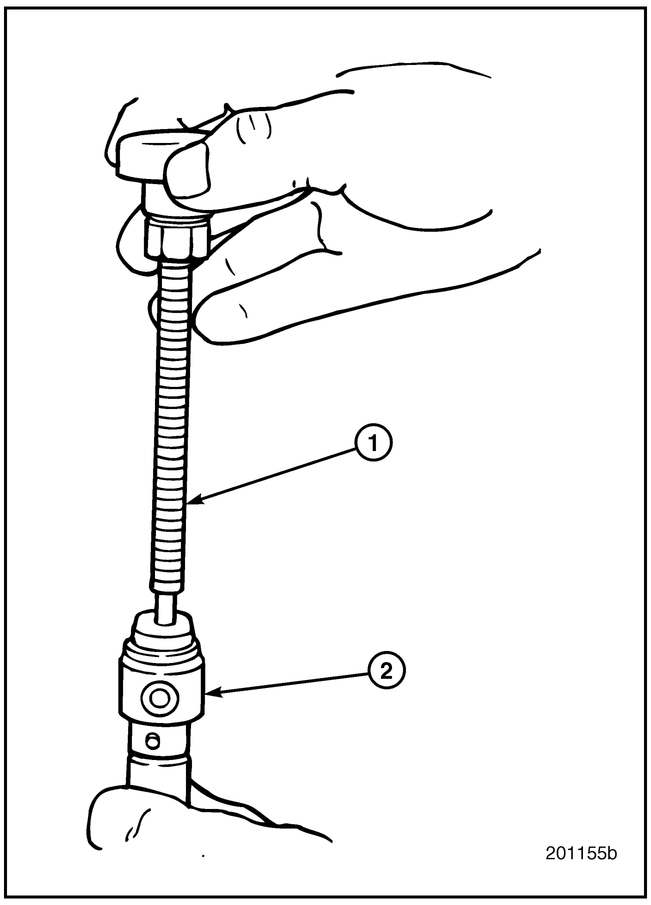


Figure 281 — Puller Application

1. Nozzle Holder Puller J 37093	2. Nozzle Holder

4. Insert the nozzle holder in the nozzle holder sleeve. Be sure to align the locator pin in the nozzle holder with the notch in the nozzle holder sleeve to ensure inlet tube alignment. Refer to Figure 282.

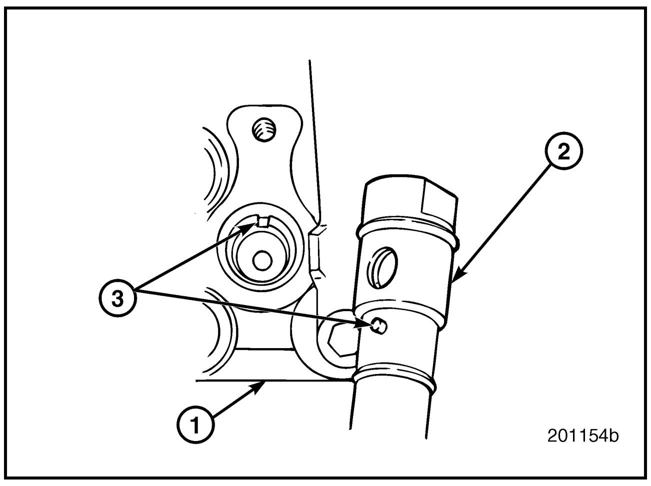


Figure 282 — Nozzle Holder Alignment

1. Cylinder Head 2. Nozzle Holder	3. Locator Pin and Sleeve Notch Must Align.

5. After ensuring that the nozzle holder locator pin is properly aligned with the alignment notch in the nozzle holder sleeve, push downward on the handle of the installation tool driving the nozzle holder into position. Refer to Figure 283.

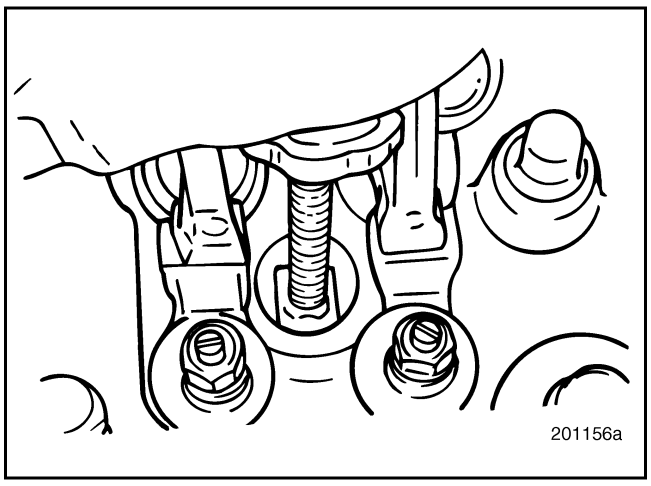


Figure 283 — Nozzle Holder Installation

6. Remove the tool from the nozzle holder and insert the gauge block on the end of the tool handle.

5_106_00.bk Page 259 Friday, August 4, 2000 11:17 AM

7. Insert the gauge block into the nozzle holder sleeve bore. The gauge block should be flush with the top surface of the cylinder head nozzle sleeve bore. Refer to Figure 284.
   - If the gauge block is below the surface, it may indicate that the gasket was omitted.
   - If the gauge block is too high, it may indicate that there are two gaskets installed under the nozzle holder, or the nozzle holder has not been fully inserted.
   - If a gauge block is not available, measure the distance from the top surface of the cylinder head sleeve bore to the top of the nozzle holder. The nominal measurement should be 0.564 inch (14.326 mm).

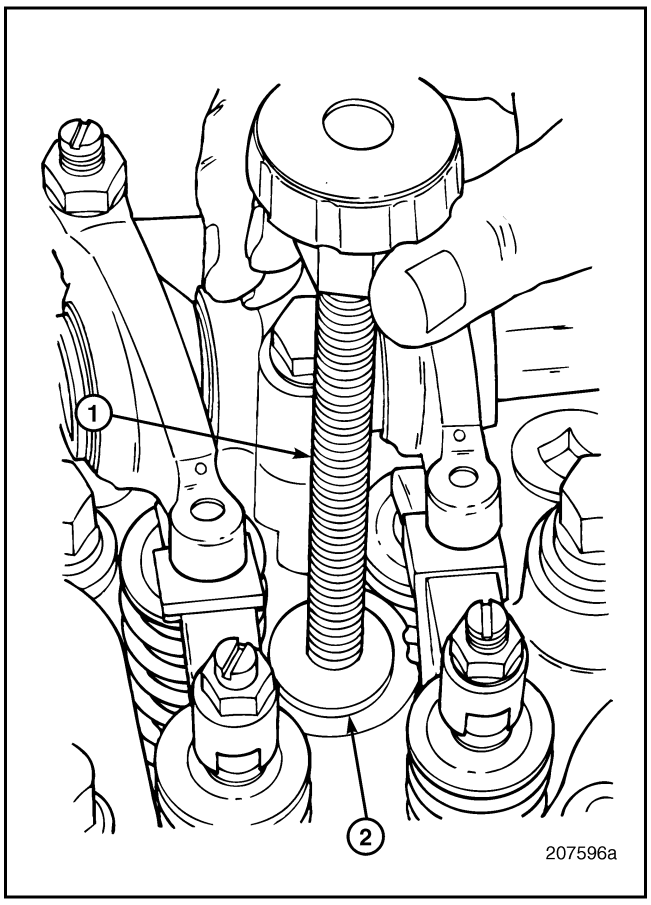


Figure 284 — Nozzle Holder Installation Check

1. Nozzle Holder Puller J 37093	2. Gauge Block

8. Lubricate the threads of the retaining plug and install it as shown in Figure 285. Tighten the plug to the specified torque, 45 lb-ft (61 N•m), using torque wrench J 24407, or equivalent.

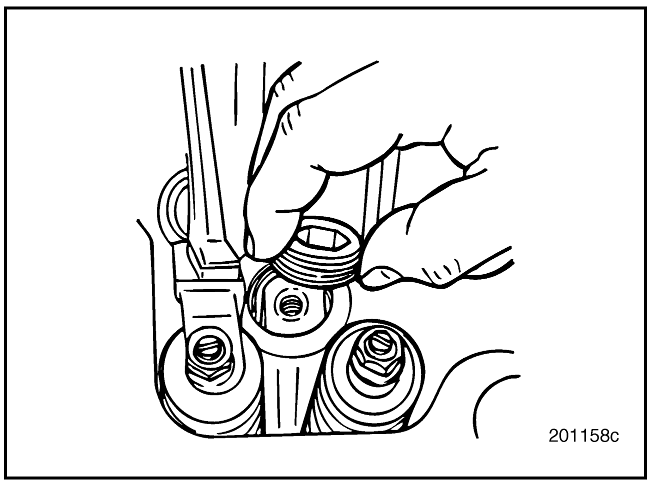


Figure 285 — Retaining Plug Installation

Push Rod Installation

[213 LH]

Check the condition of the push rods before installing them. Replace any rods that have loose ends, are bent, or show signs of excessive wear.

NOTE

Used push rods have established wear patterns. Push rods being returned to service should be installed in the same position from which they were removed.

When installing **new push rods**, make sure that the correct replacement rods are used. There are differences in the rods used for engines with or without an engine brake.

1. Apply lubricating oil to the spherical end of the push rod and insert it into the respective lifter opening. Ensure that it has engaged the lifter by lifting it slightly. If the lifter has been properly contacted, some resistance will be felt in the rod as the lifter is raised.
2. Repeat step 1 until all 12 push rods are in position.

Valve Yoke Installation

[213 NV]

(Non-Brake and J-Tech™ Brake Equipped)

There are two exhaust valves and two inlet valves for each cylinder. Each rocker arm, in conjunction with the valve yoke, operates both valves together as a set (exhaust or inlet). The E-Tech™ engine yokes are no longer identified with a raised letter “E” cast into the surface. E-Tech™ yokes must now be identified by shape only. Two ways of identifying shape are by looking at the nose end of the valve yoke. The E-Tech™ yoke has the nose end of the slipper pad area ground flat as shown in Figure 28.

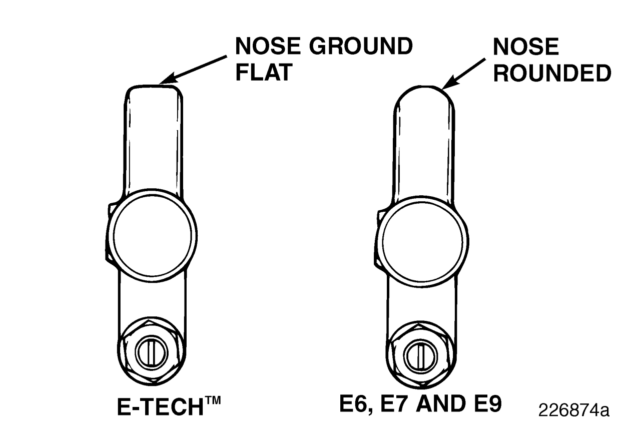


Figure 286 — E-Tech™, E6, E7 and E9 Valve Yokes (Top View)

The second method of identifying the E-Tech™ valve yoke is by viewing the yoke from the side, the top surface of the adjusting screw end will appear on the same plane as the bottom surface of the “button-head.” On the E6, E7 and E9 valve yoke, the top surface of the adjusting screw area is 0.145″ below the bottom surface of the “button-head.” Refer to Figure 287 for an illustration of these differences.

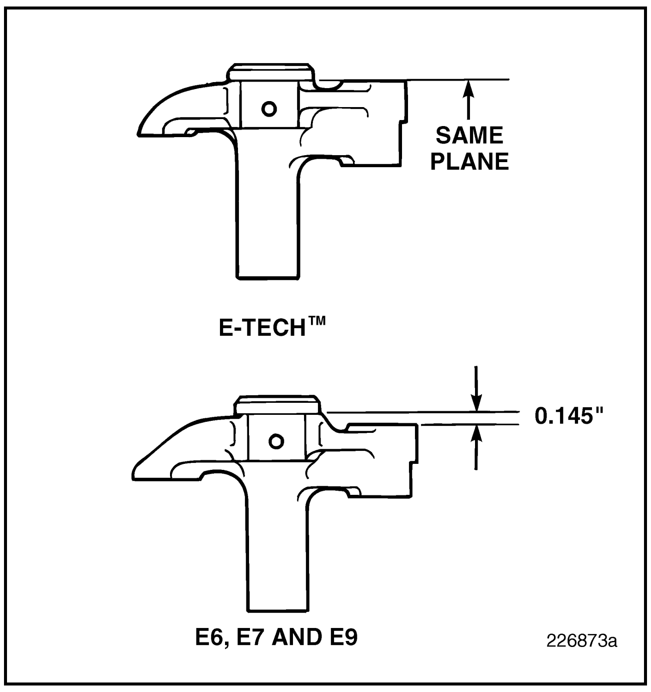


Figure 287 — Valve Yoke Side View

CAUTION

Do not interchange yokes. If an E-Tech™ valve yoke is used on an E7 engine, the valve keepers will dislodge and cause a dropped valve, resulting in severe engine damage. If an E7 valve yoke is used on a J-Tech™ equipped E-Tech™ engine, the yoke will disengage from the valve stem tip during engine brake operation.

NOTE

Used yokes have established wear patterns. Yokes being returned to service should be installed in the same position from which they were removed.

Refer to Figure 288. The valve yoke installation procedure for both non-brake and brake-equipped engines follows.

1. Lubricate the yoke guide pins (6) (if equipped) with clean engine oil.

5_106_00.bk Page 261 Friday, August 4, 2000 11:17 AM

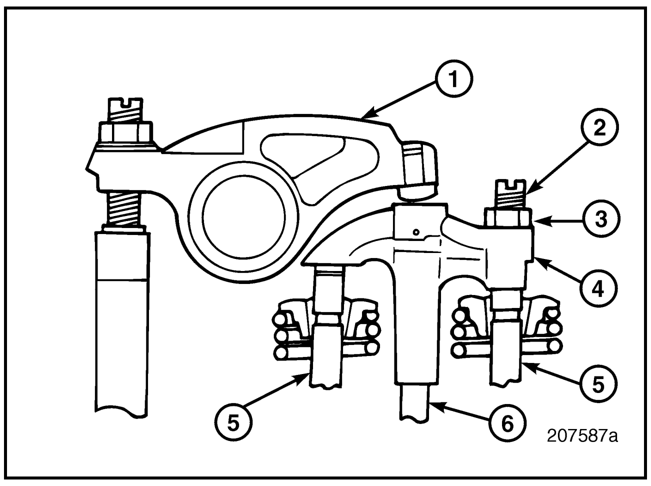


Figure 288 — Valve Yoke

1. Rocker Arm	4. Valve Yoke
2. Yoke Adjusting Screw	5. Valve Stem
3. Jam Nut	6. Yoke Guide Pin

2. Place the valve yokes (4) on the yoke guide pins from which they were removed for both inlet and exhaust (early production) or exhaust only (engine serial No. 0D0120 or later). Current-production engines use a pinless yoke at the inlet positions. The pinless yokes are installed over two inlet valves with the notch and the elongated hole facing away from the rocker arm as shown in Figure 289.

CAUTION

When installing pinless yokes, the end of the yoke with the two notches must face away from the valve rocker shaft. If the yoke is installed incorrectly, it will contact the rocker arm. See Figure 289.

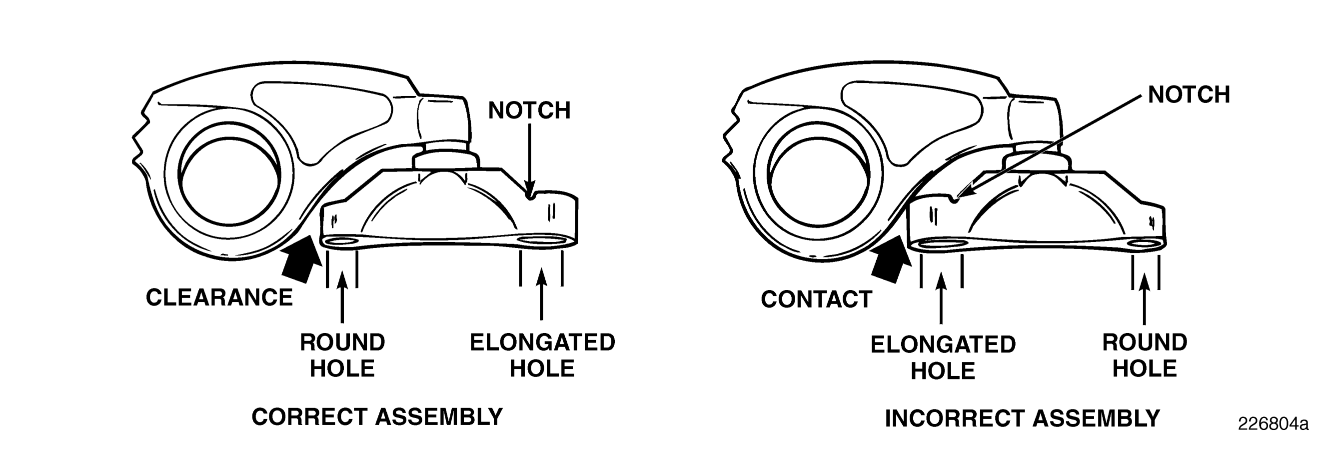


Figure 289 — Proper Assembly of the Pinless Valve Yoke

3. Slightly rock the yokes from side-to-side to be sure they are seated on the valve stems.

CAUTION

The exhaust valve yokes on engines equipped with the J-Tech™ engine brake use an actuator pin assembly, part No. 421GC41M, in place of the standard yoke adjusting screw. Ensure that the yokes with actuator pin assemblies are in position over the exhaust valves.

Rocker Arm and Engine Brake Installation

[213 LP]

The valve rocker arm assemblies are nearly identical on non-brake and brake-equipped engines. There are two differences, however, on engines equipped with the J-Tech™ engine brake:

- Revised adjusting screws with spherical jam nuts replace the standard adjusting screws and jam nuts on the exhaust rocker arms.
- An oil supply screw replaces the locating screw and lock washer on the rocker arm mounting bracket.

INSTALLATION (NON-BRAKE EQUIPPED ENGINES)

1. Make sure the locating screw and lock washer are in position on the rocker arm mounting bracket for each cylinder head.
2. Make sure that all 12 push rods are properly seated in the respective lifter sockets.
3. Position the rocker arm assemblies on the cylinder heads.
4. Ensure that the ball end of the rocker arm adjusting screws (inlet and exhaust) are in position in the push rod sockets, and line up the rocker bracket mounting holes with the holes in the cylinder head. Be careful not to disengage any of the push rods from the lifters.

CAUTION

Make sure that adjusting screws are retracted upward in the rocker arms. If extended far below the rocker arm, the push rods can be bent when tightening the rocker arm assembly brackets.

5. Lubricate the threads of the rocker arm mounting capscrews with clean engine oil. Install the capscrews and tighten to the specified torque, 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent. Refer to Figure 290.
6. Adjust the valve lash to the specified settings. Refer to Valve Yoke and Valve Lash Adjustments in the ENGINE SETUP AND ADJUSTMENTS section.

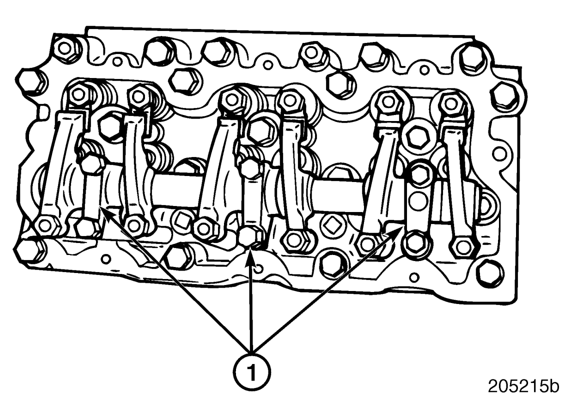


Figure 290 — Valve Rocker Arm Installation

1. Rocker Arm Mounting Brackets

INSTALLATION (J-TECH™ BRAKE-EQUIPPED ENGINES)

Refer to Figure 291.

1. Make sure the oil supply screw is in position on the rocker arm mounting bracket for each cylinder head and tightened to specification, 5 lb-ft (6.8 N•m).
2. Make sure that all 12 push rods are properly seated in the respective lifter sockets.
3. Position the rocker arm assemblies on the cylinder heads.
4. Ensure that the ball end of the rocker arm adjusting screws are in position in the push rod sockets, and line up the rocker bracket mounting holes with the holes in the cylinder head. Be careful not to disengage any of the push rods from the lifters.

CAUTION

Make sure that adjusting screws (inlet and exhaust) are fully retracted upward in the rocker arms. If extended far below the rocker arm, the push rods can be bent when tightening the rocker arm assembly brackets.

5. Loosen the three slave piston adjusting screw jam nuts on each brake assembly and back out the adjusting screws so that the slave pistons are fully retracted into the housings.
6. Carefully place each housing on the appropriate rocker arm shaft assembly so the oil supply screw engages the locating hole in the brake housing.
7. Lubricate the threads of the brake housing mounting bolts with clean engine oil and install the bolts in the housing mounting bolt holes. Ensure that the correct mounting bolts are used:

   Bolt P/N 416GC22M — use with housing P/N 757GB58.

   Bolt P/N 421GC314M — use with housing P/Ns 757GB58A and 757GB58B.

8. Starting with the center pair of mounting bolts, tighten all six bolts on each housing just enough to seat the housing on the rocker shaft brackets. Make sure the brake housings come down level to avoid possible damage to the rocker shaft brackets. Also, make sure that all of the push rods remain properly engaged at both ends.
9. After each brake housing is seated on the cylinder head, tighten the mounting bolts to specification, 45 lb-ft (61 N•m).
10. Adjust the valve lash to the specified settings. Refer to Valve Yoke, Valve Lash and Slave Piston Adjustments in the ENGINE SETUP AND ADJUSTMENTS section.

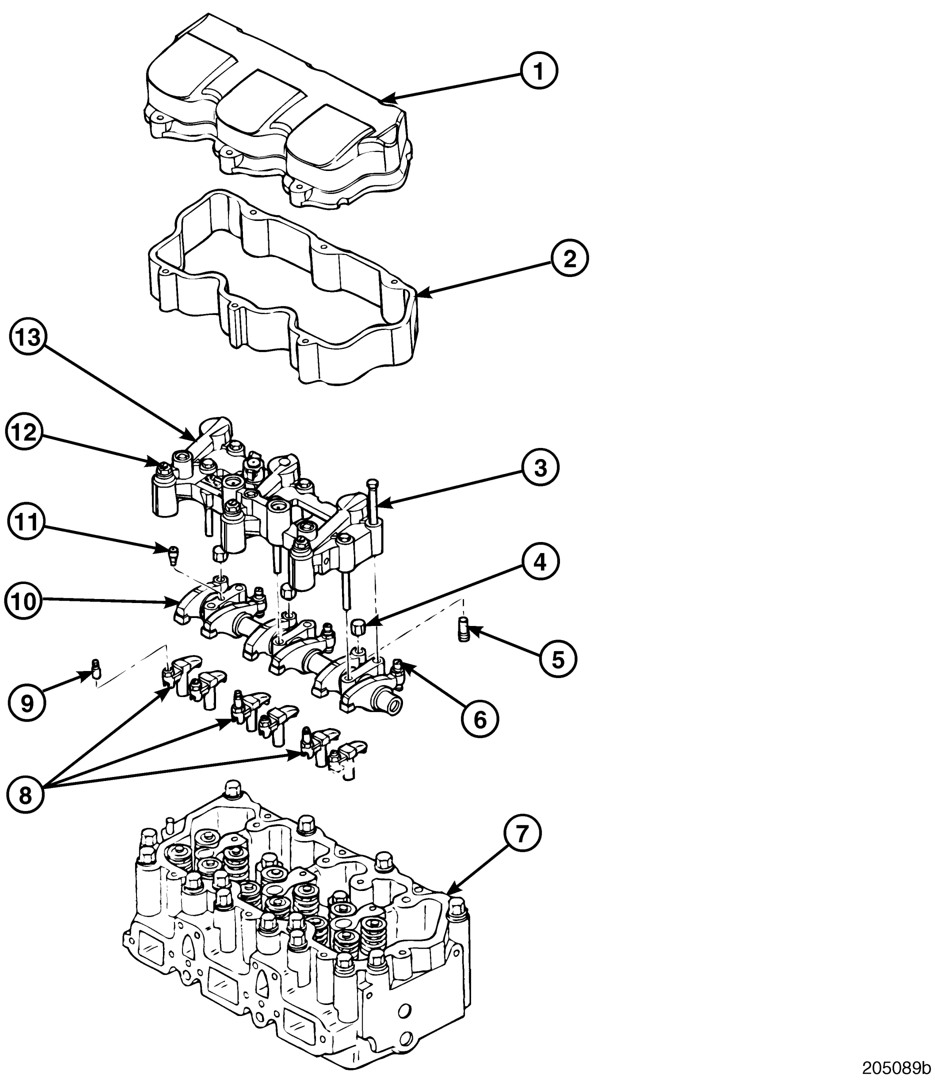


Figure 291 — Rocker Arm Shaft and J-Tech™ Engine Brake Components

1. Valve Cover	8. Exhaust Valve Yokes
2. Spacer	9. Actuator Pin Assembly
3. Long Capscrew	10. Rocker Arm Shaft Assembly
4. Spherical Jam Nut	11. Oil Supply Screw (New Style Design with Integral Check Valve)*
5. Exhaust Adjusting Screw	12. Slave Piston Adjusting Screw
6. Standard Adjusting Screw And Jam Nut (Inlet Valves)	13. Engine Brake Assembly
7. Cylinder Head	

* A new oil supply screw assembly has been released for the J-Tech™ engine brake. This new screw incorporates an oil supply check valve, eliminating the need for the oil supply check valve components in the engine brake housing.

Valve Cover and Spacer Installation [213 JB]

GENERAL INFORMATION

NOTE

The valve cover (and spacer, if equipped with an engine brake) requires a strip-type seal valve cover gasket, 51 inches (130 cm) in length.

Sealing compounds are not necessary.

Early-production engines (before October 1998) were built with non-isolating cover-mounting hardware. Valve covers for this mounting arrangement had cutouts at three corners of the cover flange. October 1998 and later-production engines are built with isolating-type valve cover mounting hardware to reduce noise. The valve covers on these later-production engines have only one cutout in the flange.

INSTALLATION

Refer back to Figure 292.

NOTE

Installation procedures for the spacer and valve cover seal are identical.

1. Install a seal strip (2) in the seal grooves (3) of the spacers.
   a. Thoroughly clean the gasket contact surface.
   b. Install one end of the spacer gasket into the seal groove (inboard side) approximately 1/4 inch (6.4 mm) from the end of the groove.
   c. Guide the seal strip into the groove around the circumference of the spacer. Complete the installation with an overlap at the starting point, approximately 1/4 inch (6.4 mm) from the end of the groove.

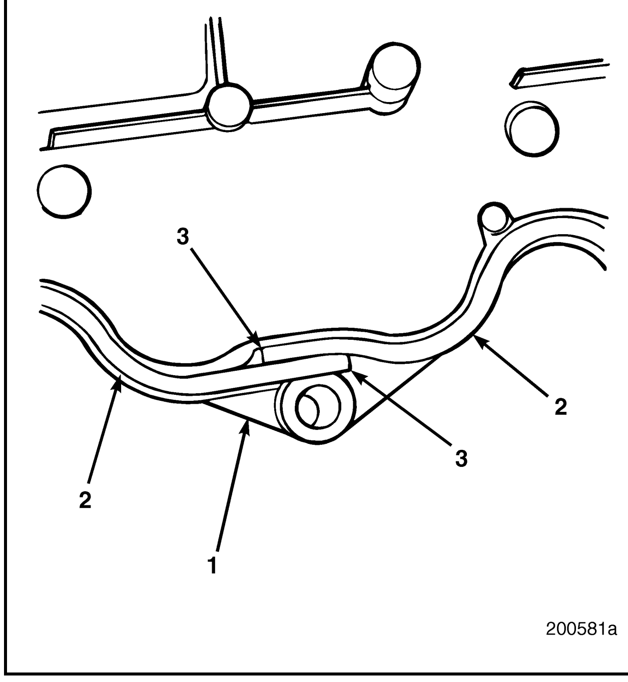


Figure 292 — Gasket Installation

1. Valve Cover 2. Seal Strip	3. Seal Groove

2. Position the spacers on the cylinder heads.
3. Connect the actuator wire to the actuator.
4. Install a seal strip in the valve cover seal groove of the valve covers.
   a. Thoroughly clean the gasket contact surface.
   b. Install one end of the valve cover gasket into the seal groove (inboard side) approximately 1/4 inch (6.4 mm) from the end of the groove.
   c. Guide the seal strip into the groove around the circumference of the valve cover. Complete the installation with an overlap at the starting point, approximately 1/4 inch (6.4 mm) from the end of the groove.

5. Position the valve covers (1) on the cylinder heads or on the spacers (4), if so equipped, as shown in Figure 293.
6. Lubricate the threads of the capscrews (2) and secure the valve covers with the lubricated capscrews. Tighten the capscrews to the specified torque, 16 lb-ft (22 N•m).

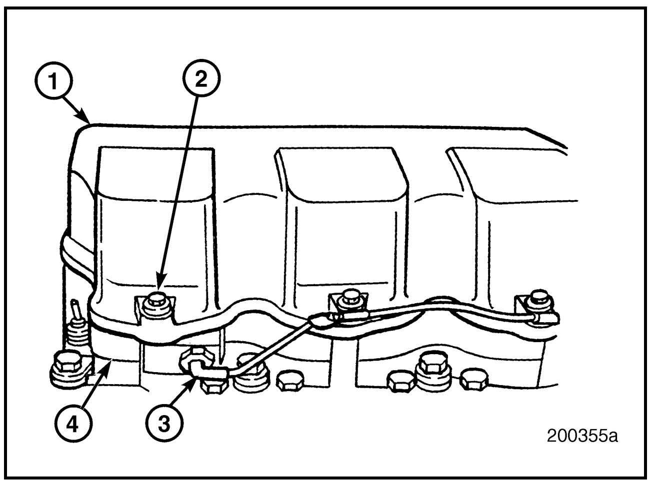


Figure 293 — Valve Cover Installation

1. Valve Cover 2. Capscrew	3. Actuator 4. Spacer

Oil Fill Tube Installation

1. Add a bead of RTV sealant on the mounting flange around the fill tube opening.
2. Position the fill tube on the cylinder block and install the capscrews.
3. Tighten the capscrews to specification, 15 lb-ft (20 N•m).

Engine ECU/Cooling Plate Installation

[230 EA]

(Right-Side Mounted Assembly)

NOTE

The following procedure applies for an EECU with cooling plate mounted on the right side of the engine. The procedure for the left-side mounted unit is covered later in this section.

Refer to Figure 294.

1. Install the four mounting studs in the cylinder block.
2. Install the four isolating washers on the studs and install the cooling plate.
3. Position the EECU on the cooling plate, and install the isolating washers and fasteners. Tighten fasteners to specification.

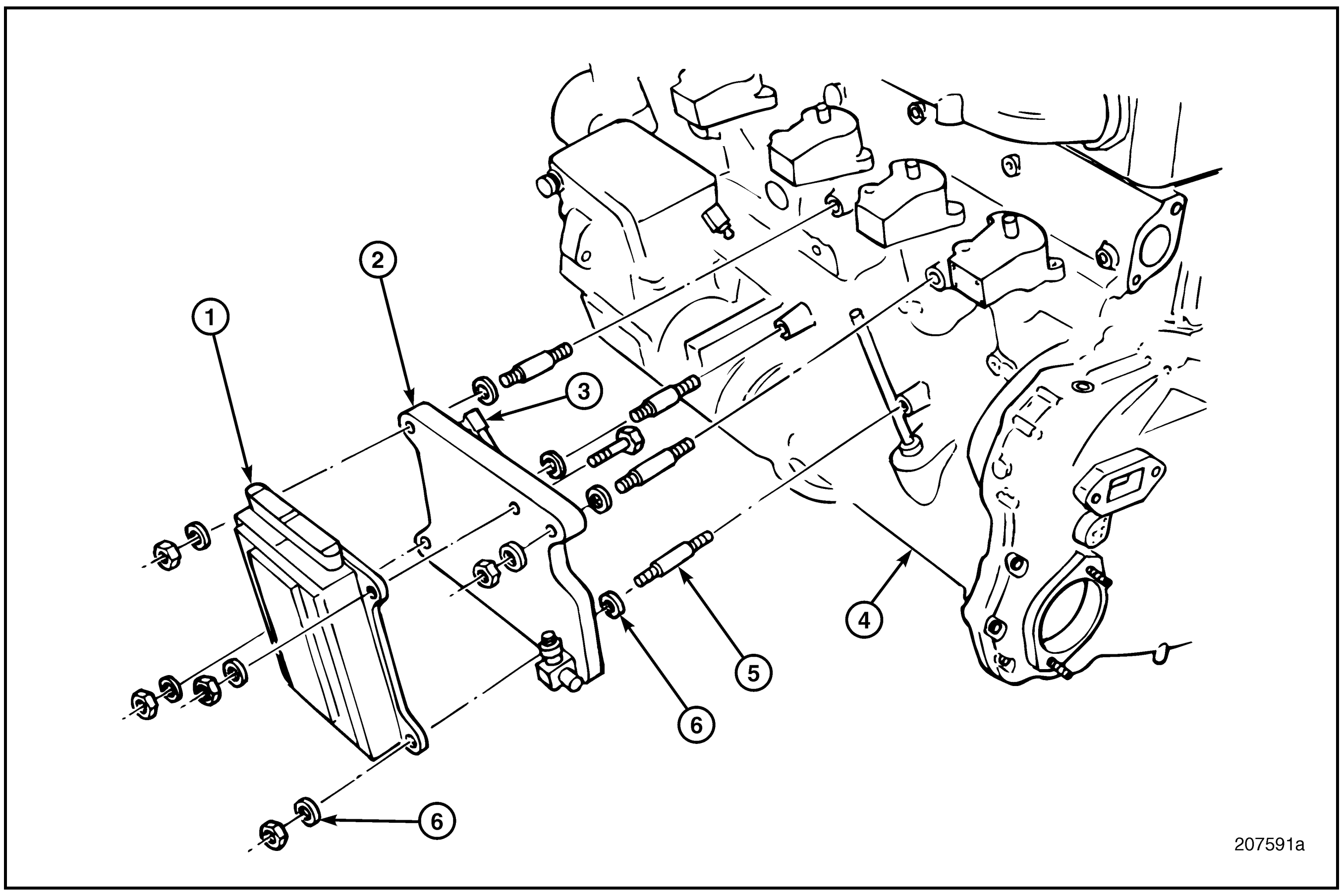


Figure 294 — Engine ECU/Cooling Plate Installation (Right-Side Mounted Unit)

1. Engine Electronic Control Unit (EECU)	4. Cylinder Block
2. EECU Cooling Plate	5. Mounting Studs
3. Coolant Fitting	6. Isolating Washers

5_106_00.bk Page 267 Friday, August 4, 2000 11:17 AM

Air Compressor Installation

[261 CK]

Refer to Figure 295.

NOTE

If the compressor drive coupling has been removed or a replacement compressor is being installed, air compressor coupling holder tool J 41071 will be required to hold the compressor shaft while the coupling nut is being torqued. Torque coupling nut to 60 lb-ft (81 N•m). Do not use air impact wrench (air gun), use an accurately calibrated torque wrench such as J 24406, or equivalent.

1. Install a **new** gasket on the air compressor mounting flange.
2. Check to ensure that the lubrication oil supply tube (2) is in place and position the air compressor (1) on the mounting flange.

CAUTION

If the oil supply tube is lost, the air compressor will fail from lack of oil.

3. Install the three mounting capscrews (5) and tighten to the specified torque, 70 lb-ft (95 N•m), using torque wrench J 24407, or equivalent.
4. Reconnect the coolant lines to the air compressor cylinder head.

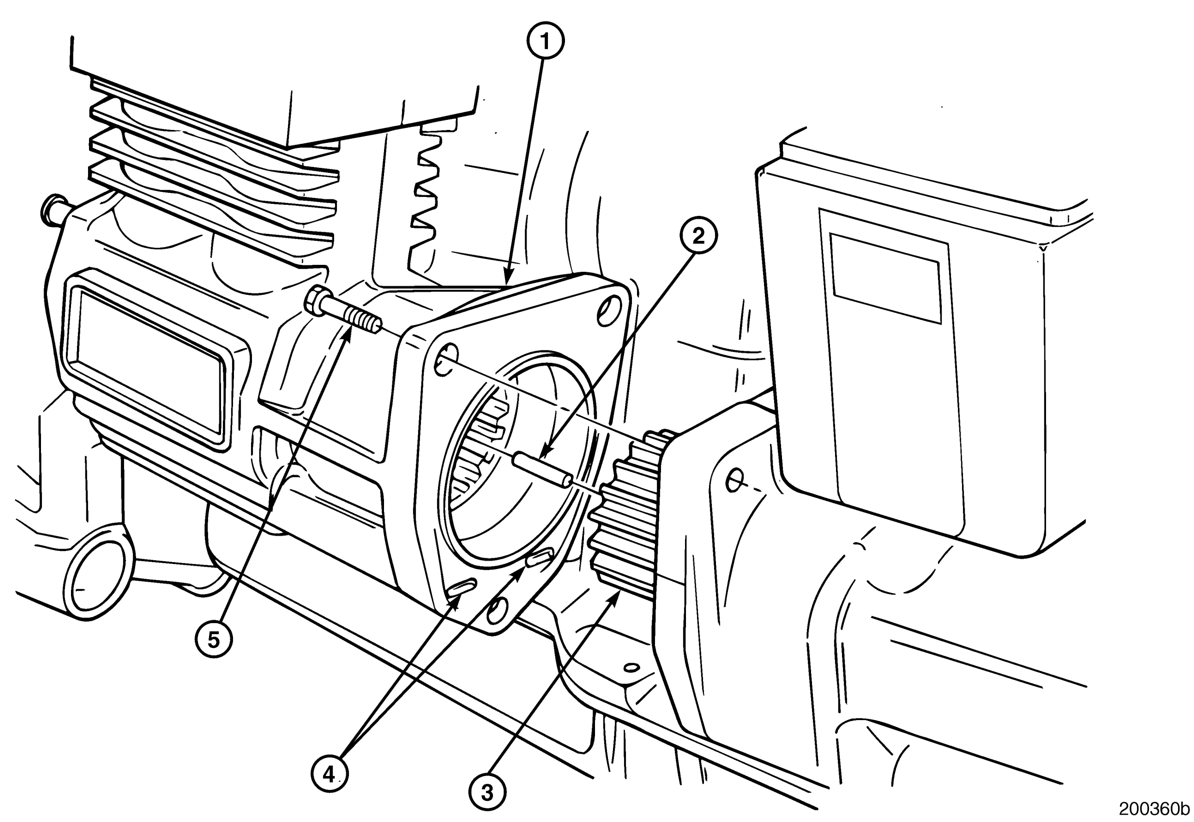


Figure 295 — Air Compressor Installation

1. Air Compressor 2. Oil Supply Tube 3. Auxiliary Shaft	4. Oil Drain Openings 5. Capscrew

Electronic Unit Pump Installation [221 GP]

TAPPET INSTALLATION

1. Clean the cylinder block at the mounting surface and bore, if required.

NOTE

Use only a soft rag and solvent to clean the cylinder block. Minor fretting at the EUP mounting surface is acceptable.

2. Generously lubricate the roller tappet with clean engine oil and carefully install it into the bore, pushing it down until it contacts the camshaft lobe. The slot in the roller tappet MUST be oriented outward to align with the pin in the bore. Once installed, the roller tappet should slide freely in the bore.

CAUTION

The tappet guide pins in the EUP bores are factory-installed in all cylinder blocks and should not be removed.

PUMP INSTALLATION

1. Install **new** O-rings on each of the EUP assemblies.
2. Generously lubricate the EUP O-rings with clean engine oil and install the No. 1 EUP into the cylinder block (Figure 296).

SERVICE HINT

Minimize oil above the top O-ring to avoid weepage of excess oil (trapped above the top O-ring) onto the cylinder block.

CAUTION

To avoid O-ring damage, the cam lobe must be positioned with the base circle up prior to installation of each EUP. Do not use the starter to rotate the engine; instead, use the flywheel barring tool.

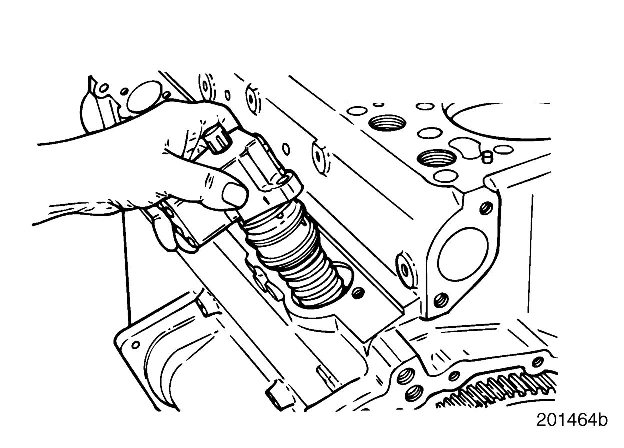


Figure 296 — Unit Pump Installation

3. Reinstall the EUP screws and tighten evenly to draw the EUP into the cylinder block (Figure 297). Tighten the screws to the specified torque, 42 lb-ft (57 N•m).

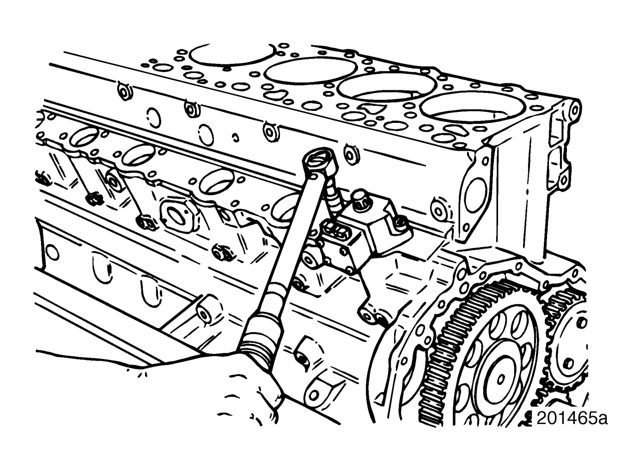


Figure 297 — Tightening Unit Pump Fasteners

4. Repeat steps 1 and 2 to install the five remaining EUP assemblies.

NOTE

If an EUP has been replaced with a **new** unit, the **new** unit must be calibrated as described under Engine Setup and Adjustments in the REPAIR INSTRUCTIONS section.

Engine Wiring Harness Installation

1. Position the wiring harness on the engine and secure it with the attaching hardware.
2. Connect the harness at each of the EUP terminals.
3. Connect the harness at the EECU. Make sure the locking tabs are in place.
4. Connect the harness to any sensors now installed or as reassembly progresses.

Fuel Nozzle Inlet Tube Assembly Installation

[222 KD]

Refer to Figure 298.

1. Lubricate the nozzle inlet tube clamping screw threads for each assembly before installing.
2. Install the fuel nozzle inlet tube assembly for the No. 1 cylinder into the cylinder head until light contact is made with the nozzle holder. Lightly tighten the clamping screw and then lightly tighten the fuel inlet tube sleeve nut (2).

NOTE

The fuel nozzle inlet tube assemblies are identical for all six cylinders.

3. Connect the line (1) at the No. 1 unit pump. Tighten the clamping screw and sleeve nuts to the specified torque, using torque wrench J 24407, or equivalent.
   - Line clamping screw at cylinder head: 35 lb-ft (47 N•m)
   - Line nut at cylinder head clamping screw: 25 lb-ft (34 N•m)
   - Line nut at EUP: 25 lb-ft (34 N•m)

NOTE

An open-ended “crow’s foot” adapter is required with the torque wrench for installation of nozzle fuel inlet tube assemblies. Avoid twisting the lines when tightening the sleeve nuts.

4. Repeat steps 1 through 3 for the five remaining fuel nozzle inlet tube assemblies.

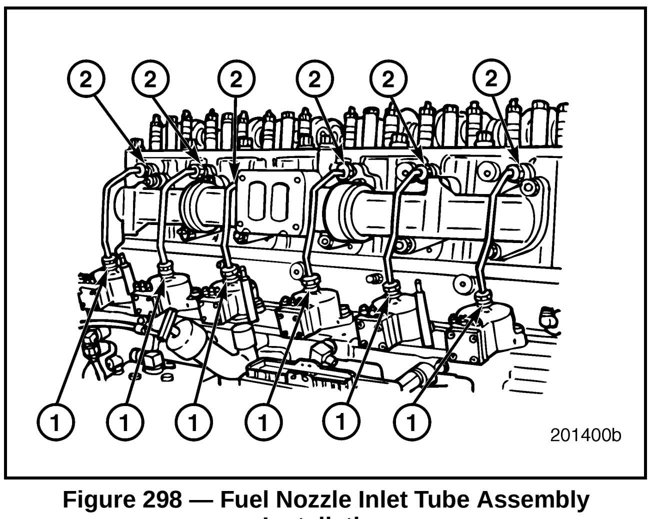


Figure 298 — Fuel Nozzle Inlet Tube Assembly Installation

1. EUP Sleeve Nut	2. Fuel Inlet Tube Clamping Screw and Sleeve Nut

Turbocharger Installation

[214 SC]

(Includes Pre-Lubing Procedures)

Refer to Figure 299.

1. Inspect the intake and exhaust systems leading to and from the turbocharger to ensure absence of foreign material, including burrs and loose lining fragments.

NOTE

A thorough inspection is required as even small particles can cause severe rotor damage if inducted during high-speed operation.

2. Use **new** and approved gaskets at the various air, oil and exhaust connections to the turbocharger. Avoid the use of sealing or jointing compounds at all flanged connections.
3. Use a high-temperature, anti-seize compound (such as Fel Pro C5A) on all threaded fasteners connected to the turbocharger.
4. Position the turbocharger (1) over the mounting studs on the exhaust manifold.
5. Install the four mounting nuts (5) and tighten to the specified torque, 40 lb-ft (54 N•m), using torque wrench J 24406, or equivalent.
6. Fill the oil inlet port to overflowing with clean engine oil before connecting the oil feed hose to the turbocharger.
7. Install the lubrication feed hose (2).
8. If the clamp plates or V-bands are loosened for angular orientation of the compressor cover or turbine housing, ensure that the mating flanges are tightly seated and that the fasteners are snug but will still allow cover orientation.

   Complete the orientation of the cover and housing before making any rigid connections to the compressor inlet or to the turbine outlet. Tighten the clamp plate capscrews (used on Schwitzer model S300 turbocharger only) to the specified torque, 140 lb-in (16 N•m), if equipped, and V-band retaining nuts, 90 lb-in (10 N•m), using torque wrench J 5853-C, or equivalent. Then make certain that all ducting aligns closely with the turbocharger. This minimizes external stresses acting on the unit.
9. Before connecting the drain hose, crank the engine without firing until a steady stream of oil flows from the drain port.
10. Install the lubrication drain tube (4) and tighten the capscrews (3) to the specified torque, 15 lb-ft (20 N•m), using torque wrench J 24406, or equivalent.
11. Install the clamp securing the lubrication drain tube to the oil fill tube.
12. Operate the engine at low idle for at least three minutes after completing the installation of the turbocharger.

5_106_00.bk Page 271 Friday, August 4, 2000 11:17 AM

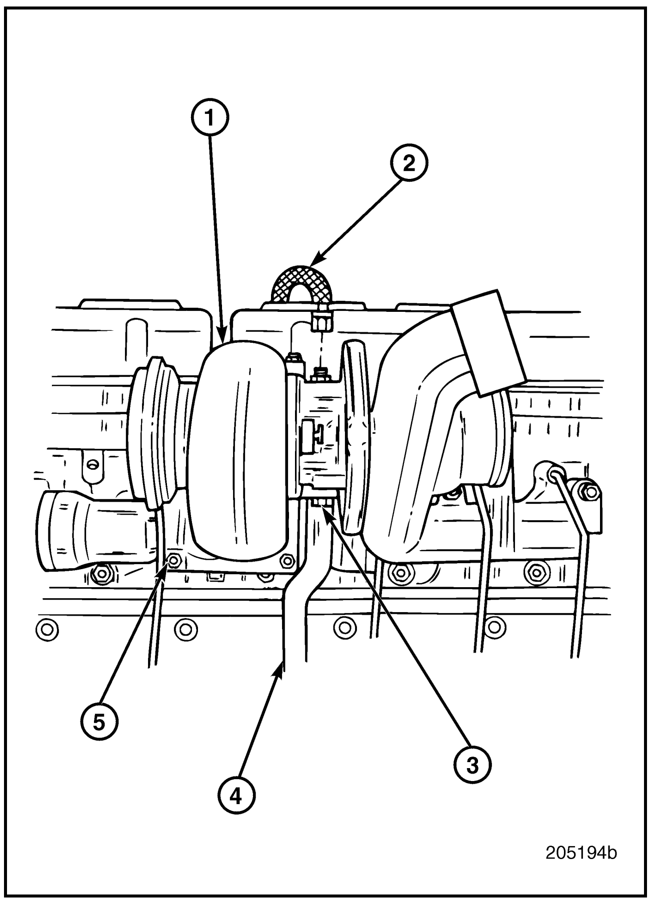


Figure 299 — Turbocharger Installation

1. Turbocharger 2. Lubrication Supply Hose 3. Capscrew	4. Lubrication Drain Tube 5. Mounting Nut

Water Pump Installation

[215 SW]

Refer to Figure 300.

⚠ CAUTION

The water pump-to-housing mounting capscrews should not be lubricated before installation. Instead, apply thread sealing compound to all water pump-to-water pump housing capscrews. Also apply thread sealing compound to the water pump housing (pump outlet) to cylinder block capscrews.

1. Position a gasket on the water pump mounting flange.
2. Position the pump on the cylinder block and install the three mounting capscrews (3).
3. Install the refrigerant compressor support bracket, if required, on the front of the cylinder head with the appropriate mounting hardware. (Insert a spacer if the refrigerant compressor support bracket and fan ring arrangement are not used.)

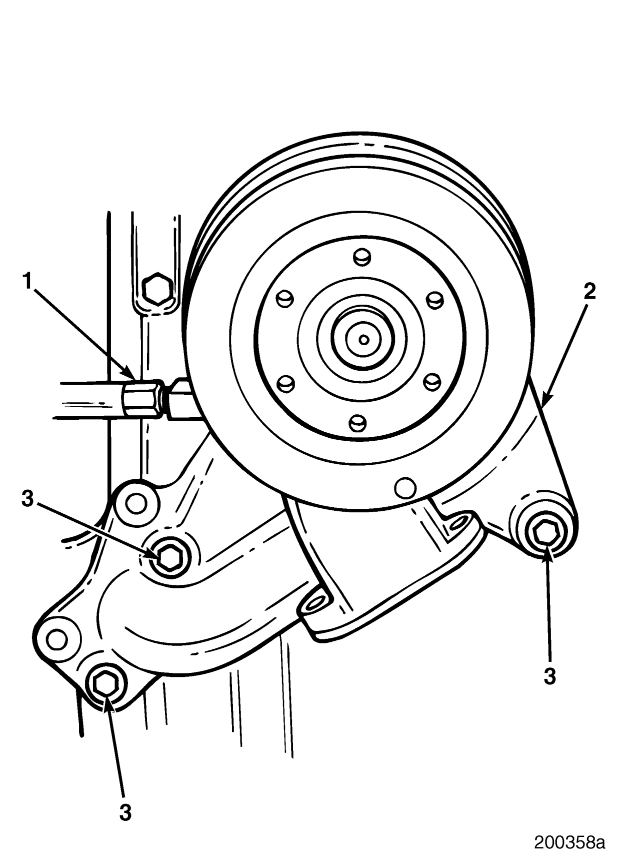


Figure 300 — Water Pump Installation

1. Air Compressor Line 2. Water Pump	3. Capscrew

Oil Cooler and Oil Filter Mounting Bracket Installation

[215 DW and 219 EP]

PLATE-TYPE OIL COOLER AND OIL FILTER MOUNTING BRACKET WITH CENTRI-MAX® PLUS (INTERNALLY DRAINED)

(Current Production)

If the engine is equipped with the current-production plate-type oil cooler, the oil cooler and oil filter mounting bracket assembly cannot be installed until after the engine has been removed from the repair stand. The procedure for this configuration is covered as the last item in this section.

REMOVABLE BUNDLE-TYPE OIL COOLER AND OIL FILTER MOUNTING BRACKET WITH CENTRI-MAX® (EXTERNALLY DRAINED)

(Early Production)

If the engine is equipped with the early production removable bundle-type oil cooler, the oil cooler and oil filter mounting bracket assembly can be installed at this point of reassembly using the procedures that follow.

ASSEMBLING A NEW OIL FILTER ADAPTER (IF REPLACED)

A new oil filter mounting bracket does not come as a complete assembly. If the adapter on an oil filter mounting bracket is being replaced, the fittings, nipples, spuds, etc., must be installed before installing the filter mounting bracket on the engine. Perform the following procedures before installing the threaded spuds into the filter adapter.

Refer to Figure 301.

1. Apply a continuous bead of Loctite® 609 or 271 around the circumference of the spud, between the second and fifth threads from the upper end.
2. Screw the spuds into the filter adapter until they protrude 0.703 inch (17.856 mm) when measured from the bottom of the spud to the sealing surface of the oil filter head assembly. To ensure that the spuds are secure in the adapter housing, they may be “staked” by using a small punch to make a small indentation between the threads of the spud and the adapter.
3. Apply a continuous bead of Loctite® 609 or 271 around the circumference of the fitting between the second and fifth threads of the upper end of the Centri-Max® fitting. Install the fitting and tighten to the specified torque, 135–165 lb-ft (183–224 N•m), using torque wrench J 24407, or equivalent. DO NOT stake the Centri-Max® fitting.

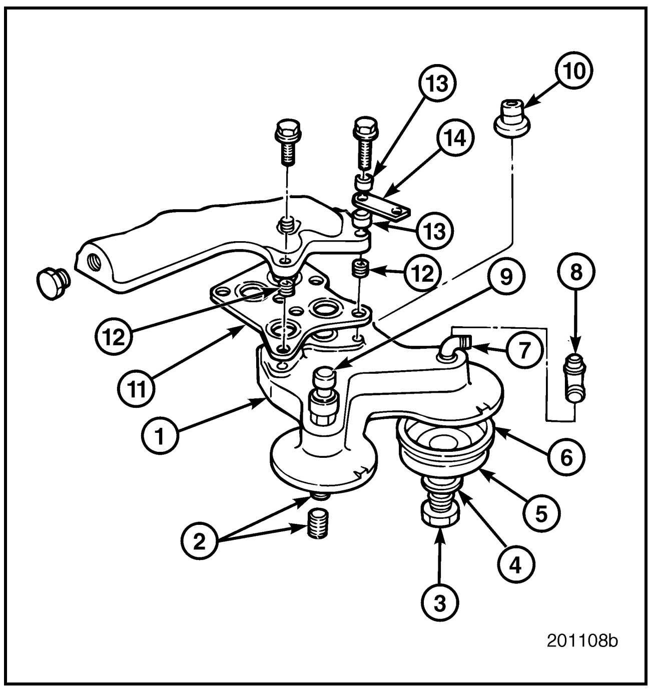


Figure 301 — Oil Filter Adapter Assembly

1. Adapter Housing	8. Vent Fitting
2. Filter Adapter Fitting	9. Oil Pressure Sensor
3. Filter Adapter Fitting (Centri-Max®)	10. Oil Filter Bypass Valve Plunger Assembly
4. Pilot Ring Washer	11. Adapter Gasket
5. Pilot Ring	12. Insert
6. Gasket	13. Spacer
7. Gauge Connector Elbow	14. Wiring Harness Bracket

SERVICE HINT

The oil cooler and oil filter mounting bracket assembly can be installed separately, but assembling them together on a bench is easier and reduces the possibility of damaging the O-ring seals.

INSTALLATION PROCEDURE

Refer to Figure 302.

1. Lubricate the oil cooler supply tube (5) with Vaseline®, or equivalent.
2. Position the coupling (4) over the lubricated tube.
3. Place two clamps (3) over the coupling.
4. Place a gasket on the oil supply mounting flange (11).
5. Position the oil cooler and oil filter mounting adapter assembly on the engine. Slide the coupling (4) over the thermostat housing flange. Lubricate the threads of the capscrews (10) and insert the capscrews into the mounting flange. Do not tighten the capscrews at this time.
6. Place a gasket on the water pump mounting flange (2).
7. Lubricate the threads of the two mounting capscrews (1) and insert the capscrews to secure the oil cooler flange (2) to the water pump. Tighten the capscrews to the specified torque, 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.
8. Tighten the oil supply housing capscrews (10) to the torque, 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.
9. Tighten the clamps (3) to the specified torque, 38 lb-in (4.3 N•m).
10. Connect the oil hose (8) to the fitting (9).
11. Coat the threads of the oil sending unit (12) with sealing compound and install the unit in the oil filter adapter assembly (13).

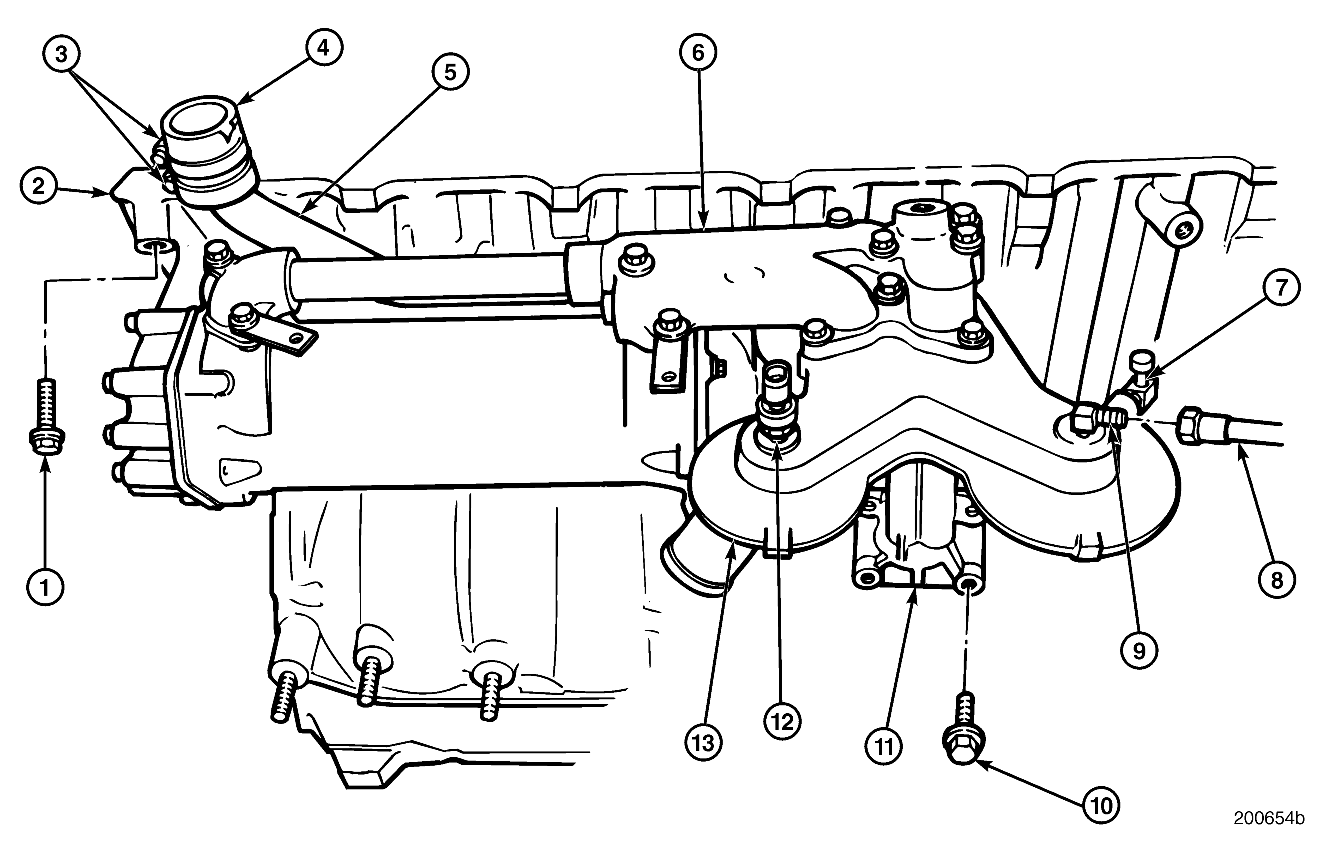


Figure 302 — Removable Bundle-Type Oil Cooler and Oil Filter Mounting Bracket Assembly Installation

1. Capscrew	8. Oil Hose
2. Water Pump Mounting Flange	9. Fitting
3. Clamps	10. Capscrew
4. Coupling	11. Oil Supply Mounting Flange
5. Oil Cooler Supply Tube (Water Bypass Tube)	12. Sending Unit
6. Oil Filter/Cooler Assembly	13. Oil Filter Mounting Bracket Assembly
7. Vent Fitting	

Coolant Manifold Installation

[215 NK]

INSPECTION

Check the coolant manifold sections for restrictions, cracks and flange wear. The manifold cannot be repaired. Replace if any signs of damage are present.

INSTALLATION PROCEDURE

Refer to Figure 303.

1. Ensure that the front coolant manifold section (1) is clean. Position a coolant/air inlet manifold gasket on the mounting surface.
2. Lubricate threads of the capscrews (5) with clean engine oil and secure the front coolant manifold section in place with the mounting capscrews.

NOTE

Early-production engines use hex-head capscrews and washers; later-production engines use flangehead capscrews.

3. Place couple (2) in position on the couple mounting flange. Place two clamps (3) over the couple.
4. Insert the rear manifold section (4) in the couple.
5. Place a gasket between the mounting surfaces of the rear manifold section and the cylinder head.
6. Lubricate threads of the mounting capscrews (5) and secure the rear manifold section with the mounting capscrews.
7. Tighten all mounting capscrews to the specified torque, 25 lb-ft (34 N•m), using torque wrench J 24406, or equivalent.
8. Ensure that the couple is properly installed and secure it in position with the clamps. Tighten the clamps to the specified torque, 38 lb-in (4.3 N•m).

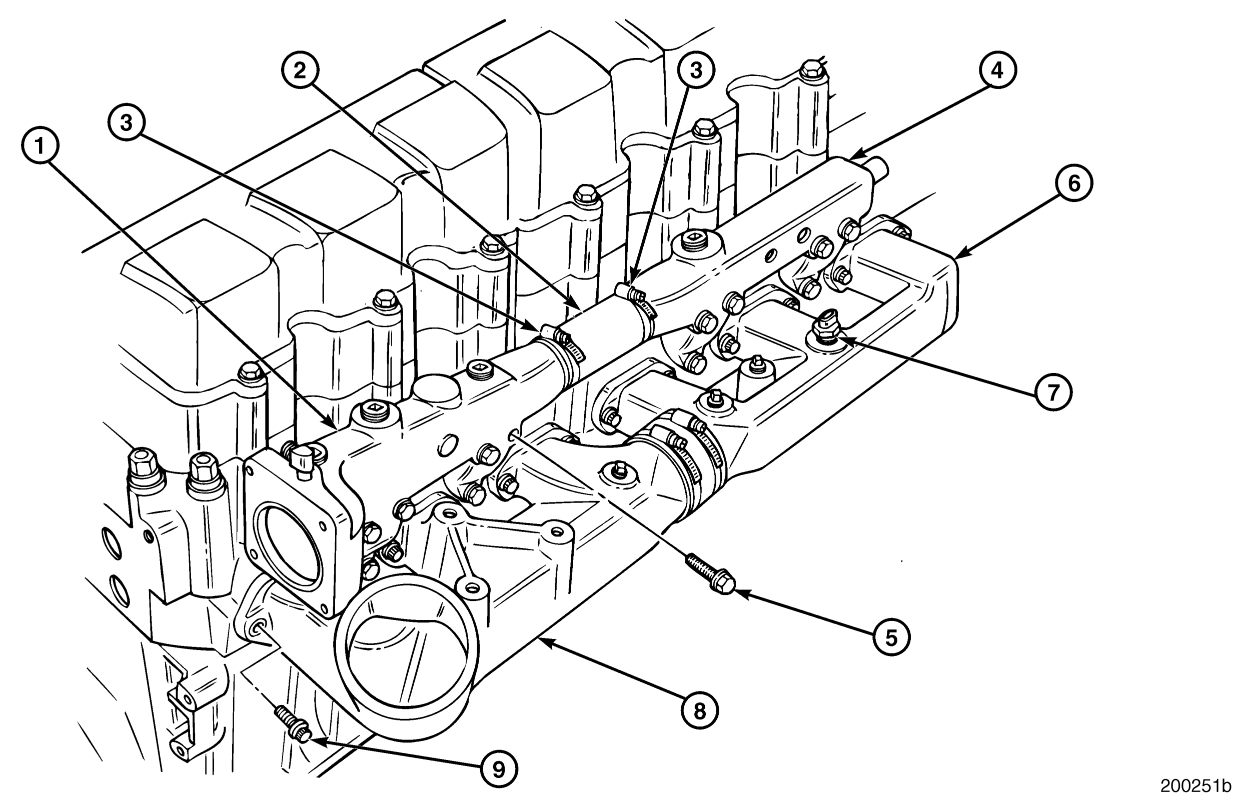


Figure 303 — Coolant Manifold and Air Inlet Manifold Installation (Shown with Two-Piece Air Inlet Manifold)

1. Coolant Manifold, Front Section	6. Air Inlet Manifold, Rear Section
2. Couple	7. Inlet Air Temperature Sensor (Sending Unit)
3. Clamp	8. Air Inlet Manifold, Front Section
4. Coolant Manifold, Rear Section	9. Capscrew, 12-Point
5. Capscrew	

Air Inlet Manifold Installation

[214 HD]

Refer to Figure 303 and Figure 304.

1. For two-piece manifolds place the front air inlet manifold section (8) into position on the cylinder head and insert the 12-point capscrews (9) and washers. Current production one-piece manifolds are positioned on the cylinder heads with all the retaining 12-point capscrews inserted.
2. Torque capscrews to 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.
3. For two-piece manifolds, place the coupling on the rear of the front air inlet section (8). Assemble two clamps on the coupling and install the rear air inlet section (6).
4. Continue assembling the two-piece manifold by inserting the 12-point capscrews and torque to 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.
5. Tighten the clamps on the coupling and torque to 38 lb-in (4.3 N•m).

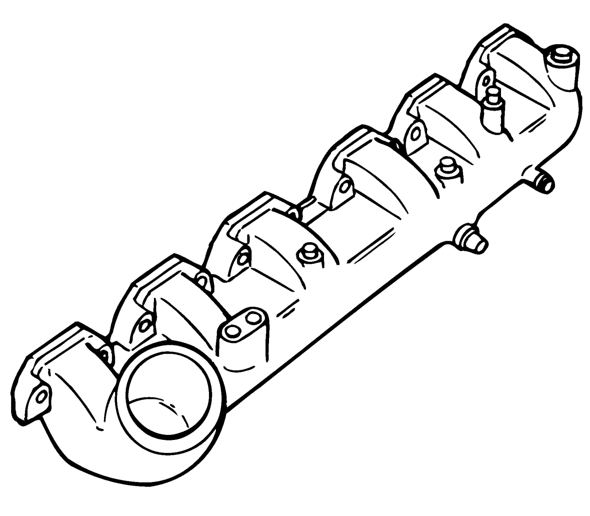


Figure 304 — One-Piece Air Inlet Manifold (Current Production)

Thermostat, Housing and Seal Installation

[215 NU, NG & LD]

Refer to Figure 305.

1. When replacing a seal for any reason, examine the surface of the thermostat sleeve, the bore area and the seal to prevent premature failure of the new seal. A sealing lip that has been turned back, cut or otherwise damaged will leak and must be replaced. The lip faces the front of the engine.
2. Remove any surface nicks, burrs, sharp edges and tool marks from the thermostat sleeve and housing bore area using crocus cloth.
3. Check to see that the replacement seals are free from any contaminants such as chips, grit, dust or any other debris that would prevent the seal from properly seating in the thermostat housing.
4. Press the seal into the housing bore with smooth, uniform pressure, using seal installation tool J 26637-A and driver handle J 8092.

NOTE

Tool J 26637-A is designed to regulate the thermostat seal installation depth. The shoulder on the tool bottoms on the thermostat bore of the housing to prevent the seal from being installed too far.

NOTE

Wherever possible, an arbor press should be used to apply assembly pressure. The use of a hammer is not recommended since uneven pressure would be applied directly to seal surfaces. Precautions should be taken against cocking the seal throughout the installation operation. Make sure the seal is not cocked when installed.

5. Position the thermostat (7) in the housing (5) with the jiggle pin or caged ball up.
6. Install a gasket (8) on the housing mounting surface.
7. Position the housing assembly on the coolant manifold (9) mounting surface.
8. Secure in position with two lower mounting capscrews (13).

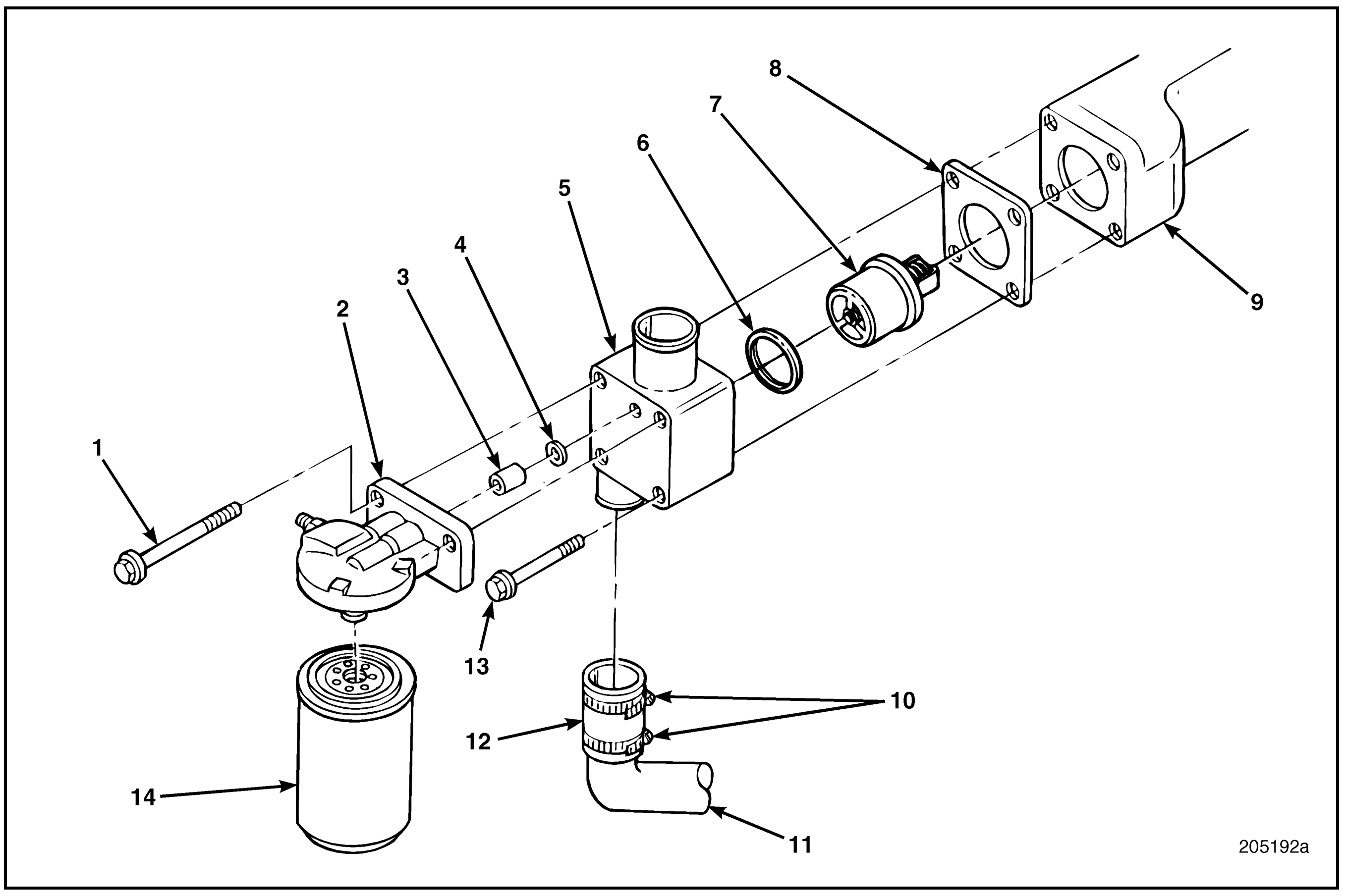


Figure 305 — Thermostat Housing Installation

1. Capscrew	8. Gasket
2. Coolant Conditioner Adapter Assembly (if Equipped)	9. Coolant Manifold
3. Check Valve (if Equipped)	10. Clamps
4. O-Ring	11. Oil Cooler Supply (Bypass) Tube
5. Thermostat Housing	12. Coupling (Hose)
6. Thermostat Seal	13. Capscrew
7. Thermostat	14. Coolant Conditioner Filter Element (if Equipped)

5_106_00.bk Page 278 Friday, August 4, 2000 11:17 AM

Coolant Conditioner Installation

Refer to Figure 305.

1. Position a check valve assembly (3) in the coolant conditioner head assembly (2). The ball end of the check valve must be inserted first.
2. Position an O-ring (4) in the O-ring recess of the head assembly.
3. Install the head assembly (2) on the thermostat housing (5) and secure with capscrews (1).
4. Tighten the capscrews to the specified torque, 15 lb-ft (20 N•m), using torque wrench J 24406, or equivalent.
5. Apply a light film of engine coolant on the face of the coolant conditioner filter gasket seal.
6. Install the coolant conditioner filter element (14). Turn the coolant conditioner filter one full turn after the gasket contacts base. Use tool J 24783 to tighten.

Fuel Filter Adapter Assembly Installation

[231 PB]

Refer to Figure 306 and Figure 307.

1. Install the fuel filter adapter (1) to the air inlet manifold (7).
2. Install the three capscrews (4) and tighten to the specified torque, 35 lb-ft (48 N•m).
3. Install the three fuel lines to the fittings (2, 3 and 5) and tighten to the specified torque, 25 lb-ft (34 N•m).

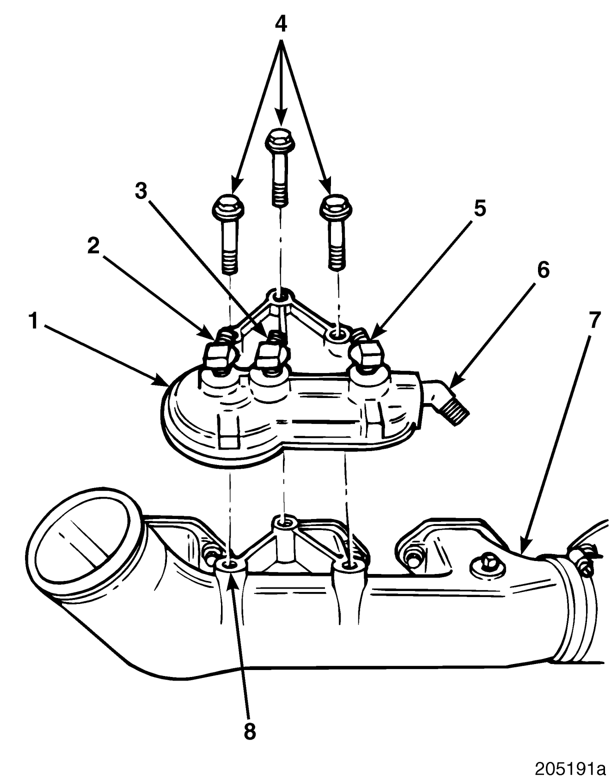


Figure 306 — Fuel Filter Adapter Assembly Installation with Two-Piece Air Inlet Manifold

1. Fuel Filter Adapter Assembly	5. Primary Filter Fitting (Out)
2. Secondary Filter Fitting (Out)	6. Primary Filter Fitting (In)
3. Secondary Filter Fitting (In)	7. Air Inlet Manifold
4. Capscrews	8. Mounting Flange

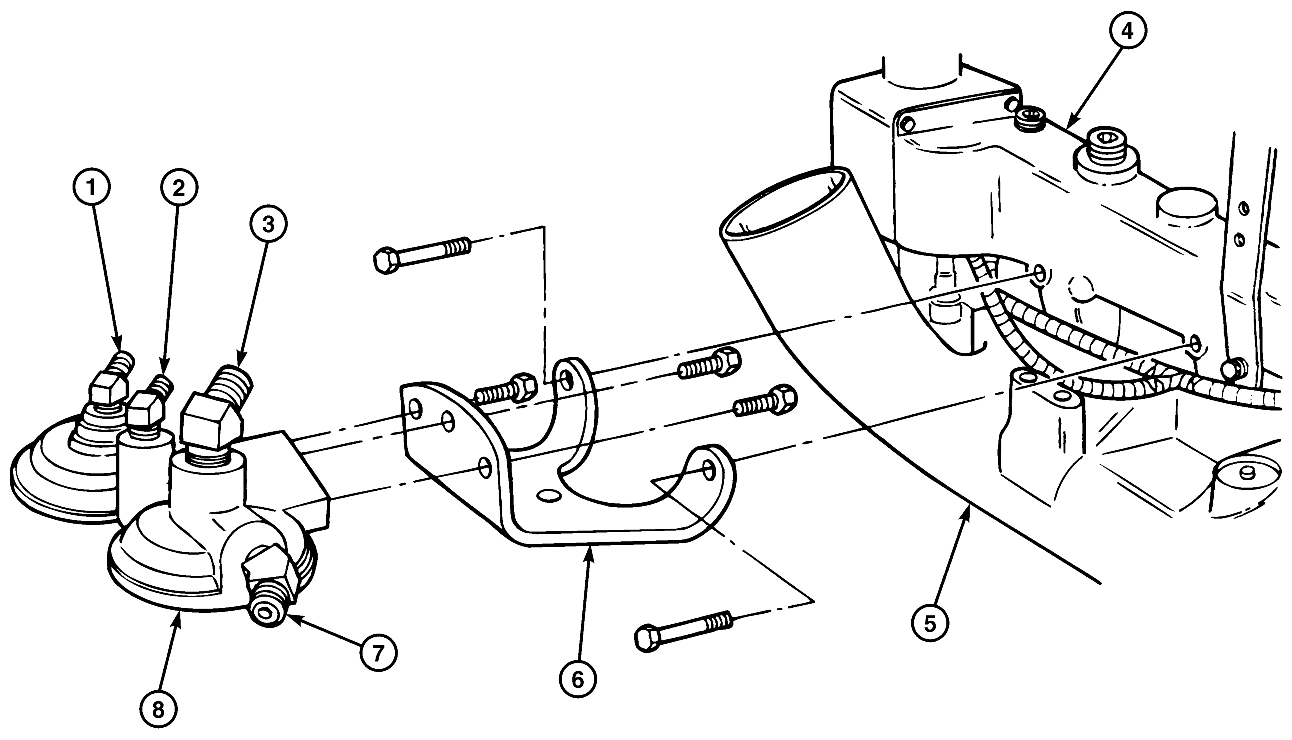


Figure 307 — Fuel Filter Adapter Installation with One-Piece Inlet Manifold

1. Secondary Filter Fitting (Out) 2. Secondary Filter Fitting (In) 3. Primary Filter Fitting (Out) 4. Coolant Manifold	5. Air Inlet Manifold 6. Mounting Bracket 7. Primary Filter Fitting (In) 8. Fuel Filter Adapter

Engine ECU Installation

[230 EA]

Left-Side Mounted Assembly

1. Position the EECU and bracket assembly on the air inlet manifold and install the isolating washers and three mounting capscrews (Figure 308). Tighten the capscrews to specification, 15 lb-ft (20 N•m).
2. Connect the wiring harness to the EECU.

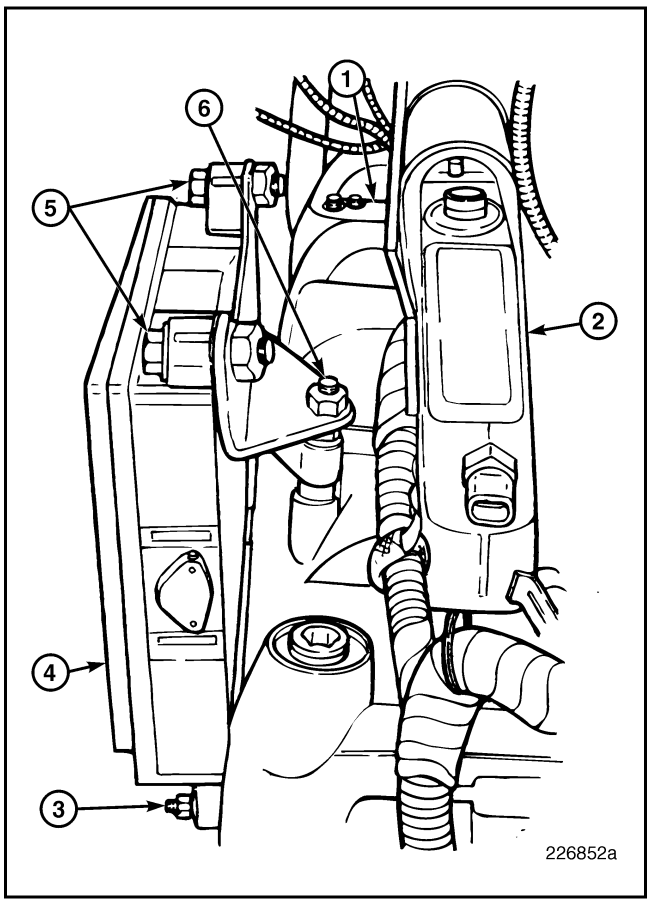


Figure 308 — Engine ECU Installation (Left-Side Mounted Unit)

1. Air Inlet Manifold 2. Coolant Manifold 3. Lower Mounting Bolts (Two)	4. EECU 5. Upper Mounting Bolts (Two) 6. Mounting Stud

Oil Cooler-to-Water Pump Inlet Line Installation

If the engine is equipped with the plate-type oil cooler, install the oil cooler-to-water pump inlet line (Figure 309) as follows:

1. Place the inlet line in position on the engine and loosely install the capscrews attaching the line to the water pump.
2. Install the flexible hose coupling and two clamps between the inlet line and the coolant manifold.
3. Tighten the two capscrews securing the inlet line to the water pump to specification, 60 lb-ft (81 N•m).

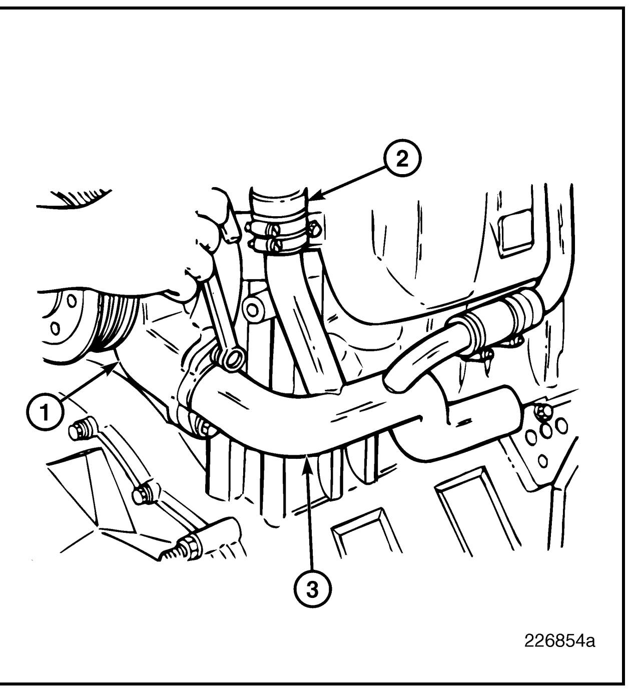


Figure 309 — Oil Cooler-to-Water Pump Inlet Line Installation

1. Water Pump 2. Thermostat By-Pass Hose Connection	3. Water Pump Inlet Pipe

Alternator Installation

[271 CB]

Refer to Figure 310.

1. Install the alternator plate and mounting hardware.
2. Position the alternator on the plate and install the capscrews (2), washers and mounting nuts.
3. Connect the electrical wires as tagged during disassembly.
4. Install the poly-V drive belt (1).
5. Adjust the drive belt tension to specification as described under Belt Drive System procedures in the MAINTENANCE section.

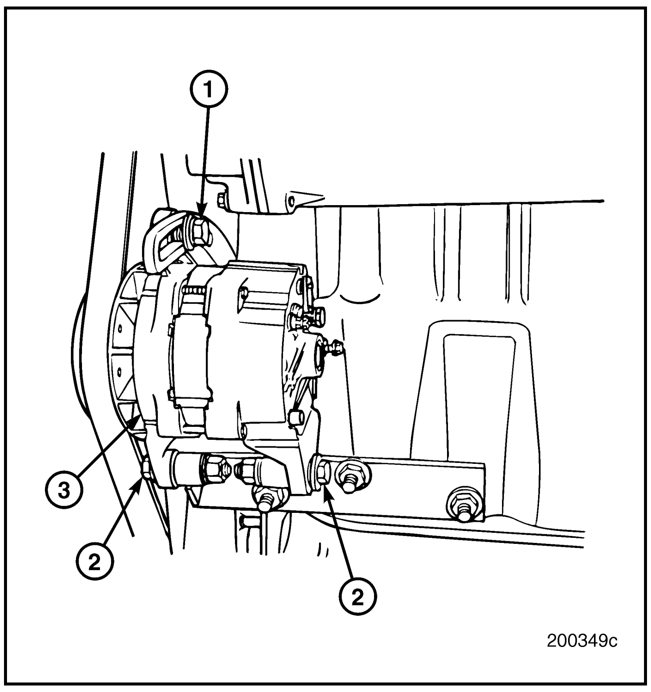


Figure 310 — Alternator Installation

1. Adjusting Capscrew 2. Mounting Capscrews	3. Alternator

Removing Engine from Engine Stand

[200 EA]

1. Attach a suitable lifting device to lifting points on the engine.
2. Position and attach an engine hoist to the lifting device; operate the hoist to place tension on the lifting device.
3. With the lifting device now supporting the engine weight, remove the mounting capscrews from the engine stand.
4. Using the lifting device, place the engine in a suitable support rack or install the engine in the vehicle (see Engine Installation in the REPAIR INSTRUCTIONS section).

5_106_00.bk Page 282 Friday, August 4, 2000 11:17 AM

Plate-Type Oil Cooler and Oil Filter Mounting Bracket Assembly Installation

[215 DW, 219 EP]

When the engine is equipped with the current-production plate-type oil cooler, the cooler and oil filter mounting bracket cannot be installed until the engine is removed from the repair stand.

Refer to Figure 312 and install the assembly as follows:

1. Install an alternator mounting stud (part No. 107AM5009) or stud of the same thread into the upper right-hand corner of the oil filter pedestal mounting pad. Only one stud can be installed due to the close proximity of the oil cooler to the inlet manifold.
2. Apply a small amount of grease to the back of the oil filter mounting bracket pedestal gasket around the area of the mounting hole on the left-hand side of the gasket as shown in Figure 311. This will hold the gasket in place as the oil cooler and filter assembly is installed.

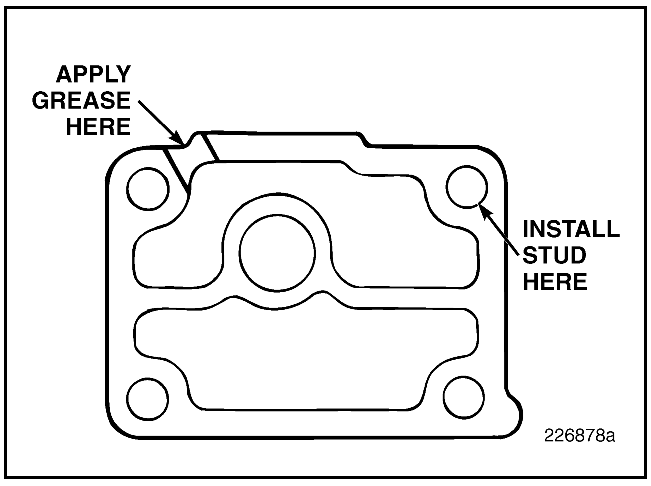


Figure 311 — Gasket Grease Application

3. Apply the gasket onto the block over the previously installed alternator stud.
4. If not previously done, install the cooler-to-water pipe hose onto the water pump inlet pipe and slide completely onto the pipe to allow installation of the oil cooler. Also loosely install both the hose clamps.
5. Install the filter assembly pedestal onto the stud with the forward end of the assembly tilted downward approximately 1 inch (to allow clearance with the inlet manifold). Once the assembly is mounted on the stud, pivot the assembly clockwise to align the remaining three mounting holes of the pedestal, while making sure the gasket remains in the proper position.
6. With the mounting holes of the pedestal aligned, install the bolt in the upper front mounting hole position. Then install the remaining two bolts in the lower mounting holes.
7. Remove the stud from the upper right mounting hole, then install the mounting bolt.
8. Snug all bolts (7) in a criss-cross pattern, then tighten to 60 lb-ft (81 N•m).
9. Slide the cooler-to-water pipe hose from its previously positioned location on the pipe to be centered between the cooler and the water pipe.
10. Properly position the two hose clamps and tighten in position.
11. Install the turbocharger lubrication supply line (2).
12. Connect the harness to the oil pressure and oil temperature sensors (6 and 5) on the filter mounting bracket (9).

5_106_00.bk Page 283 Friday, August 4, 2000 11:17 AM

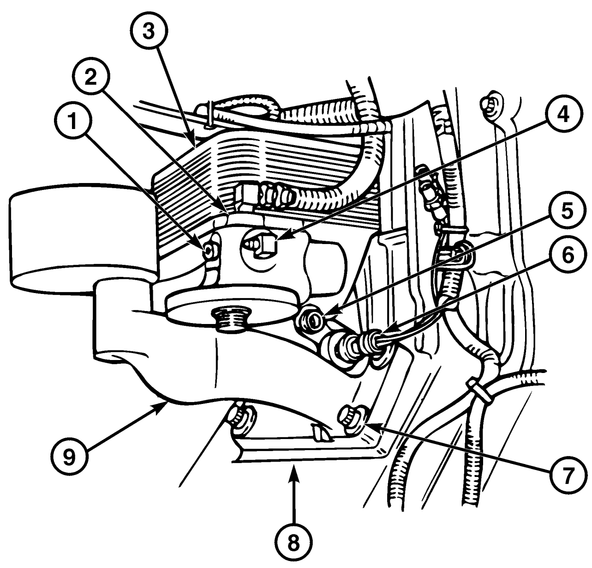


Figure 312 — Plate-Type Oil Cooler and Oil Filter Mounting Bracket Installation

1. Oil Supply Port for Mechanical Oil Pressure Dashboard Gauge 2. Turbocharger Lubrication Supply Port 3. Oil Cooler 4. Oil Supply Port for REPTO, Turbo Unloader and Remote-Mounted Oil Filter	5. Oil Temperature Sensor Port 6. Oil Pressure Sensor 7. Mounting Capscrews 8. Cylinder Block 9. Oil Filter Mounting Bracket

ENGINE INSTALLATION

General Instructions

Engine installation details vary from vehicle to vehicle. The following procedure provides general installation guidelines for MACK E-Tech™ engines.

Before beginning, make sure all equipment has been inspected for safety and is available for use. Place the vehicle on a flat, level surface. Make sure the area has ample work space.

NOTE

Torsional idler-gear assemblies are available for servicing both 1:1 and 0.7:1 ratio Flywheel Power Take-Off (FWPTO) units in E-Tech™ engines equipped with a T200 series transmission and FWPTO. These assemblies feature a two-piece idler gear and torsion spring.

The torsional idler-gear assembly reduces spline wear on the FWPTO input (drive) gear. If the unit is removed for any reason:

- Inspect the input gear splines for excessive wear.
- If the splines show excessive wear, disassemble the FWPTO far enough to gain access to the idler-gear assembly. Refer to MACK Service Manual 10-901, *Flywheel Power Take-Off*.

Engine Installation into Vehicle

NOTE

Obtain assistance when installing the engine. Be sure to watch for obstructions such as engine or chassis components, brackets, clamps or other components that may interfere with engine installation.

1. Align engine with the torque converter or clutch (as applicable) and install the transmission bell housing-to-flywheel housing capscrews. Tighten the capscrews to specification.
2. Install engine mount capscrews to secure the engine to the engine mounts. Tighten the capscrews to specification.
3. Remove transmission jack from under transmission.
4. Install the clutch linkage and bracket-retaining capscrews.
5. Install power steering hoses and reservoir, if applicable.
6. Install the hood rest crossmember(s), if applicable.
7. Install the exhaust bracket to the flywheel housing and install exhaust clamp at the turbocharger.
8. Install the starter. Connect wiring and cables.
9. Install the air cleaner housing, if required.
10. Install all coolant tubes, ground straps, air lines, fuel lines, hydraulic hoses or tubes, throttle linkage and electrical wiring harnesses that were removed from the engine during removal.

NOTE

On some engine models, the machined V-band was replaced with a 3.5-inch push-on turbocharger discharge connection that is angled forward. The remaining models use a 3-inch push-on connection directed 90 degrees outward from the center line of the turbocharger. You will need to know which turbocharger type is used on the engine when ordering replacement parts.

11. Connect the air inlet tube between the turbocharger and air cleaner assembly.
12. Connect the heater hoses and A/C refrigerant lines, if applicable, where attached at the lower dash panel behind the engine.
13. Install the fan and fan clutch assembly.
14. Install the accessory drive belts and adjust the belts to specification.
15. Using a lifting device, place the radiator in position at the front of the engine.
16. Install the retaining capscrews to the lower radiator support mounts.

17. Install the retaining capscrews to the radiator support rods.
18. Position the fan clutch air solenoid valve, if so equipped, on the radiator support and install the retaining fastener.
19. Locate the engine coolant temperature sensor, if applicable, and connect it to the wiring harness. Fasten the sensor harness to the radiator support.
20. Connect the chassis-mounted charge air cooler (CMCAC) outlet hose at the cooler.
21. Connect the CMCAC inlet hose at the cooler.
22. Place the coolant overflow tank in position and install the retaining clamps.
23. Connect the lower radiator hose to the coolant inlet of the oil cooler assembly.
24. Connect the upper radiator hose to the coolant outlet fitting on the engine.
25. If the vehicle is equipped with air conditioning:
    a. Connect the A/C refrigerant low-pressure cutout switch to the wiring harness connector.
    b. Connect the binary (cycling clutch) pressure switch on the receiver/dryer to the wiring harness connector.
    c. Connect the A/C line at the receiver/dryer.
    d. Connect the A/C compressor discharge hose to the system at the connection point near the radiator support.
    e. Recharge the A/C system with refrigerant using refrigerant recovery and recycling equipment (J 38750-A for R12 or J 39500-B for R134A).
26. Place the air intake tube in position and tighten the clamps securing the intake tube to the turbocharger and air filter.
27. Install the hood. Refer to the Hood Installation procedures in the appropriate vehicle manual.

IN-CHASSIS PART/ COMPONENT PROCEDURES

This section presents four standalone replacement operations which can be done in-chassis and not involve a full engine overhaul. These operations include Electronic Unit Pump Replacement, Camshaft Replacement, Engine Brake Control Valve Replacement and Valve Lifter H-Ring Installation Check.

Electronic Unit Pump (EUP) Replacement

[221 GP]

To properly service the electronic unit pumps (EUPs), it is essential to understand unit pump removal, pin and tappet installation, and unit pump installation. Each of these procedures is covered individually.

UNIT PUMP REMOVAL

NOTE

When it is necessary to remove more than one EUP, the removed EUPs must be paint-marked with the cylinder number, and reinstalled at their original locations. This will eliminate any need to reprogram EUP information. If a new or remanufactured EUP is installed, reprogramming must be performed as described at the conclusion of the EUP installation section.

1. Remove the heat shields.
2. Clean the EUP and cylinder block around the EUP to ensure that no debris enters the engine during EUP removal.

CAUTION

To avoid engine damage due to debris entering EUP bores of the cylinder block, step 2 MUST be followed.

3. On chassis with inlet manifold-mounted fuel filters, remove both the inlet and outlet fuel hoses from the secondary fuel filter. This allows additional fuel to drain from the hose, through the cylinder block, and out of the internal passages.

   On chassis with remote-mounted fuel filters, remove the fuel hose from the cylinder block fuel-inlet fitting, which is behind the EECU at the top. This allows additional fuel to drain through the cylinder block and out of the internal passages.
4. Place a drain pan beneath the right side of the engine. Remove the fuel-outlet fitting from the cylinder block fuel return gallery above the air compressor. This allows fuel to drain from the internal passages.

CAUTION

To ensure that minimal fuel enters crankcase oil during EUP removal, steps 3 and 4 MUST be followed. To avoid fuel spillage, do not crank the engine with the starter at any time during EUP removal or replacement.

5. Remove the injection tube.
6. Remove wire terminals from the EUP.
7. Remove the inboard EUP screw completely.
8. Loosen outboard EUP screw and back it out 1/2 inch.
9. Insert screwdrivers under the bolt bosses (front and rear) and pry until the EUP comes out against the screw head. (The EUP may spring out against the screw head.)

WARNING

The EUP spring may be preloaded with significant spring tension, depending upon cam lobe position. To avoid injury from the EUP springing outward, steps 7–9 must be followed.

10. Remove outboard EUP screw completely and remove EUP from the cylinder block. Place the EUP in a clean area and cover it to prevent entry of dirt and other contaminants.

11. Remove roller tappet from the EUP bore by hand. Do not use a tool as it could damage the bore. Place the roller tappet in a clean area and cover it to prevent the entry of dirt and other contaminants.

TAPPET GUIDE PIN INSPECTION

1. Visually inspect the EUP bore in the cylinder block for protrusion of the guide pin into the bore. If the pin protrudes approximately 2 mm into the bore and is not damaged, it is OK and no further action is required.
2. If the guide pin end is damaged or does not protrude approximately 2 mm into the bore, replace it as follows:
   a. Using a 1/4-inch diameter punch from outside of the cylinder block, drive the guide pin from its bore.
   b. Clean the pin bore in the block and a **new** pin, part No. 183GC252, with Loctite® primer "T." Then, coat bore and pin with Loctite® 609, or equivalent.
   c. Drive the pin into the bore until it is flush with the cylinder block outer surface as shown in Figure 313.

NOTE

Occasionally, a failure will result in severe wear and breakage of the roller and roller axle, causing these parts to separate from the lifter body. Subsequently, the lifter legs (which had retained the axle in the lifter body) are bent outward and driven up into the lifter bore by the cam lobe. This action damages the bottom 1/4 to 3/8 inch of the bore, preventing installation of a new lifter.

The damaged bore area must be cleaned up with a file, stone, or emery paper before the new lifter can be installed. Use care when removing raised metal so not to enlarge the bore diameter. Any remaining nicks or scores will not inhibit proper function of the parts and cause no problem.

NOTE

A small amount of scuffing or foreign particle scoring in a lifter bore can inhibit static-free movement of a lifter. While this will not cause a lifter to hang-up during engine operation, it is sometimes noticed during lifter removal or installation. If this condition is encountered, use a brake hone to lightly finish the bottom area of the lifter bore. Trial-fit the lifter until the high spots have been removed and free-movement is re-established.

TAPPET INSTALLATION

1. Clean the cylinder block at the mounting surface and bore, if required.

NOTE

Use only a soft rag and solvent to clean the cylinder block. Minor fretting at the EUP mounting surface is acceptable.

2. Generously lubricate the roller tappet with clean engine oil and carefully install it into the bore using a finger. Refer to Figure 313.

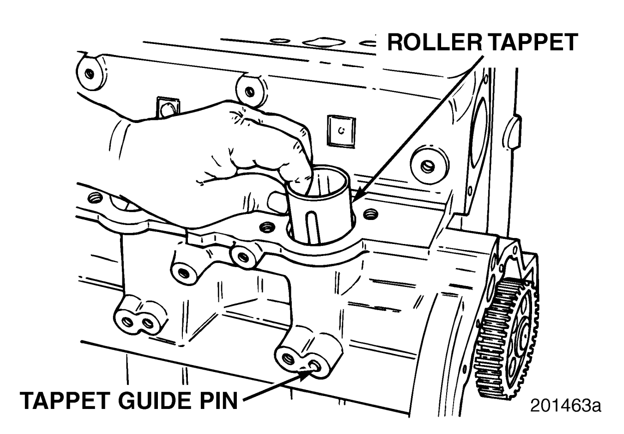


Figure 313 — Positioning Tappet

NOTE

The slot in the roller tappet MUST be oriented outward to align with the pin in the bore. The roller tappet should slide freely in the bore.

5_106_00.bk Page 288 Friday, August 4, 2000 11:17 AM

UNIT PUMP INSTALLATION

1. Install two **new** O-rings on the replacement EUP in the upper and lower O-ring grooves.
2. Generously lubricate EUP O-rings with clean engine oil and install the EUP into the cylinder block (Figure 314).

SERVICE HINT

Minimize oil above top O-ring to avoid weepage of excess oil (trapped above the top O-ring) onto the cylinder block.

CAUTION

To avoid O-ring damage, the cam lobe must be positioned with the base circle up prior to installation of each EUP. Do not use the starter to rotate the engine; instead, use the flywheel barring tool.

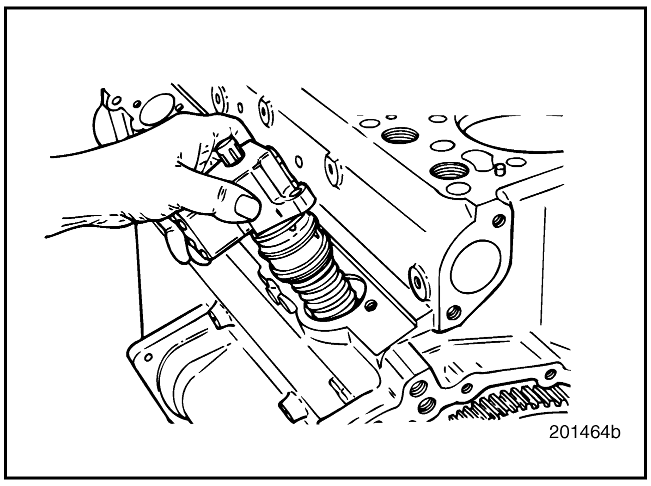


Figure 314 — Unit Pump Installation

3. Reinstall the EUP screws and tighten evenly to draw the EUP into the cylinder block. Tighten screws to 42 lb-ft (57 N•m).
4. Reinstall the injection line and torque to specification as follows:
   - Line clamp screw at cylinder head: 35 lb-ft (47 N•m)
   - Line nut at cylinder head clamp screw: 25 lb-ft (34 N•m)
   - Line nut at EUP: 25 lb-ft (34 N•m)
5. Reinstall the wire terminals and tighten to specification, 9 lb-in (1 N•m). Do not bend wire terminals down after installation.

NOTE

If an EUP has been replaced with a new or remanufactured unit, the replacement unit must be calibrated as described under Electronic Pump Calibration in the Engine Setup and Adjustments section. This will ensure optimum engine performance.

6. Reinstall the heat shields.

Camshaft Replacement (Engine in Chassis)

[213 CH]

The preliminary steps for replacing the camshaft will vary depending on the chassis configuration and engine model. As such, these steps are general in nature. Begin the operation by disconnecting the battery and draining all fluids from the engine. Then, remove the hood and fender assembly, radiator, engine accessories/ drives, ducts, valve covers, engine brake assemblies (if equipped), rocker shaft assemblies, push rods, oil pan and front cover, etc. The cylinder heads will remain installed.

CAMSHAFT REMOVAL

SERVICE HINT

When removing or installing the camshaft, first remove the idler gear and hub. It is easier to remove the camshaft guide from the camshaft (after installation) when the idler gear has been removed and alignment of the timing marks is not being attempted at the same time. The final step in the process is to reinstall the idler gear.

CAUTION

With the engine in the chassis, the valve lifters must be held in the UP position, using tappet holders J 37720-C in combination with J 42425.

1. Insert the tappet holder in the lifter bore so that the magnetic head of the tool holds the lifter in position. Check to see if the tool has captured the valve lifter by drawing upward on the tool. A resistance will be felt that cannot be felt if the magnet has contacted something other than a valve lifter.
2. Secure the lifter in the UP position with grommets provided with the tappet holders. The holding tool shafts of two adjacent valve lifters can be prevented from dropping by wrapping a rubber band around the two shafts. This draws the shafts together and holds them in position. Refer to Figure 315.

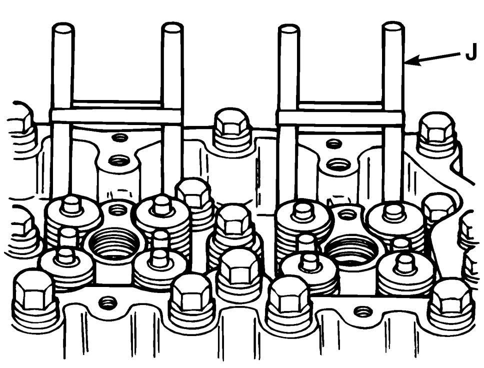


Figure 315 — Valve Lifter (Tappet) Holder Tool J 37720-C

3. Remove the two 12-point capscrews (3) that retain camshaft thrust washer (1). Camshaft may have to be rotated slightly to make the capscrews accessible through openings (2) in the camshaft drive gear (4). Refer to Figure 316.

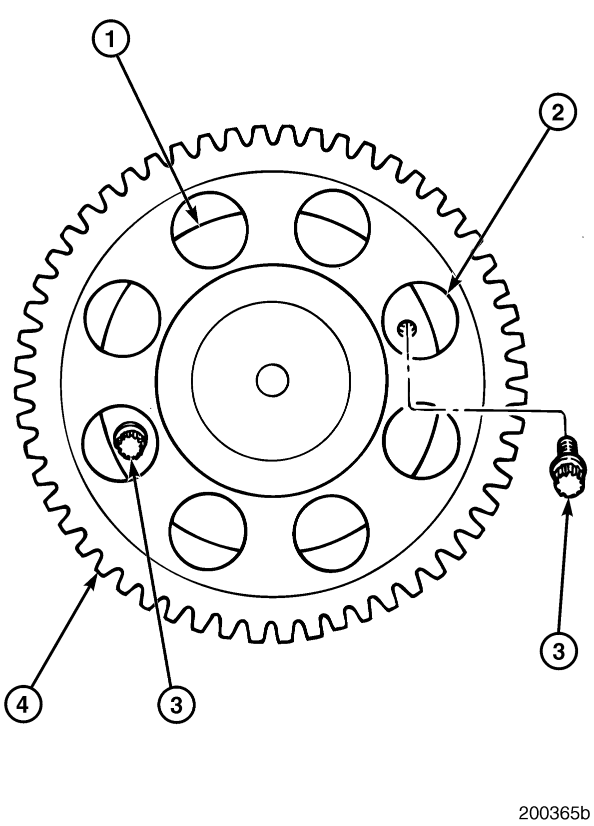


Figure 316 — Camshaft Thrust Washer Capscrews

1. Thrust Washer 2. Openings (8, Current Production)	3. Capscrew, 12-Point 4. Camshaft Drive Gear

4. Install the camshaft removal/installation tool J 41682 (Figure 317) in position on the rear segment of the camshaft, securing it with the clip to the shaft.

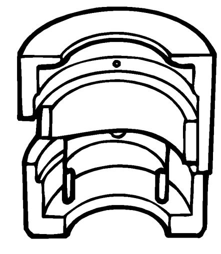


Figure 317 — Camshaft Removal/Installation Tool

5_106_00.bk Page 290 Friday, August 4, 2000 11:17 AM

5. Taking care not to damage camshaft or bushings, pull the camshaft out of the front of the engine. Carefully guide rear of the shaft through the journals. If the shaft does not come out freely, ensure that all valve lifters are clear of the camshaft cams and journals.
6. Remove and inspect the valve lifters.

SERVICE HINT

Valve lifters have established wear patterns and should be reinstalled in same locations. Label each valve lifter upon removal and place on a clean work surface.

CAMSHAFT INSTALLATION

General Instructions

Before installing a camshaft in any engine, ensure that cam is clean. Parts that are free of dirt/contamination and are well-lubricated with clean engine oil are essential for initial start-up and run-in. If necessary, wash and brush the camshaft in solvent and blow-dry with compressed air. Also, check the camshaft for possible handling burrs on the edges of journals and lobes. Any minor burrs can be removed with a fine stone.

NOTE

Use camshaft guide tool J 41682 to ease installation of the camshaft and avoid damage to the camshaft bushings.

Procedure

Install the camshaft as follows:

NOTE

In order to use the valve lifter tool to hold the valve lifters in position, the cylinder heads must be installed on the engine.

Arrange valve lifters in order identified so that they can be reinstalled back into the same hole.

1. Apply a generous coating of clean engine oil to the valve lifters.
2. Install a lifter into the lifter bore by aligning the lifter flats with the H-ring flats. As the lifter is seated, it should be possible to rotate it slightly from left to right.

CAUTION

With the engine in the chassis, the valve lifters must be held in the UP position, using tappet holders J 37720-C in combination with J 42425.

3. As the lifter is installed, it must be held in position by inserting a tappet holder into the opening through the top of the cylinder head and block. The tappet holder must be positioned so that the magnetic head of the tool holds the lifter in position. Check to see if the tool has captured the valve lifter by drawing upward on the tool. A resistance will be felt that cannot be felt if the magnet has contacted something other than a valve lifter.
4. Secure the lifter in the UP position with grommets provided with the tappet holders. The holding tool shafts of two adjacent valve lifters can be prevented from dropping by wrapping a rubber band around the two shafts. This draws the shafts together and holds them in position. Refer to Figure 315.
5. Repeat steps 2 through 4 to install each of the remaining valve lifters.
6. Apply a generous coating of clean engine oil to camshaft bushings.
7. Clean camshaft with a suitable solvent.

CAUTION

Make sure the captured thrust washer and camshaft gear are properly installed on the camshaft.

8. Install the camshaft installation guide tool over the large flat of the injector lobe, between the last two cam journals (journals at back of shaft).
9. Apply clean engine oil to the installation guide.

N O T E

The camshaft is heavy, approximately 90 pounds with the gear. The installation guide allows the camshaft to slide from one cam bushing to the next without allowing the cam to drop when one journal clears the bushing bore.

10. Slide the camshaft into the block with the cam installation guide facing down toward the floor. Refer to Figure 318.
11. Slide the cam all the way into the block.

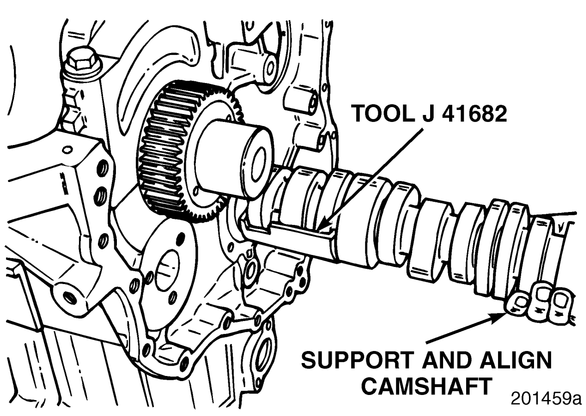


Figure 318 — Camshaft Installation

12. After the camshaft is fully installed, install the thrust washer screws and tighten to specification.
13. Rotate the crankshaft and camshaft to facilitate installation guide removal. The camshaft must be rotated so that the installation guide faces the cylinder block pan rail. The crankshaft must be rotated so the No. 6 connecting rod journal faces the cylinder block top deck (piston at TDC).
14. Remove the installation guide tool J 41682.

[213] CAMSHAFT IDLER GEAR INSTALLATION

Before installing the idler gear/hub assembly, determine which is the top mounting hole on the hub.

The idler gear is held in place by a flanged hub mounted to the cylinder block by three bolts. Although the bolt-mounting pattern may *appear* symmetrical, it is not. The non-symmetrical mounting pattern ensures that oil feed passages in the hub will be properly aligned with the oil feed passage in the cylinder block, which lubricates the idler gear hub bushing.

To aid in aligning the hub to the mounting holes in the cylinder block, the hub mounting-bolt hole at the 12 o'clock position (engine upright) is identified by the word "UP" steel-stamped just below the mounting hole. Refer to Figure 319.

1. With the engine in an upright position and the hub correctly aligned with the mounting bolt holes, place the idler hub against the block and verify good mounting-hole alignment.

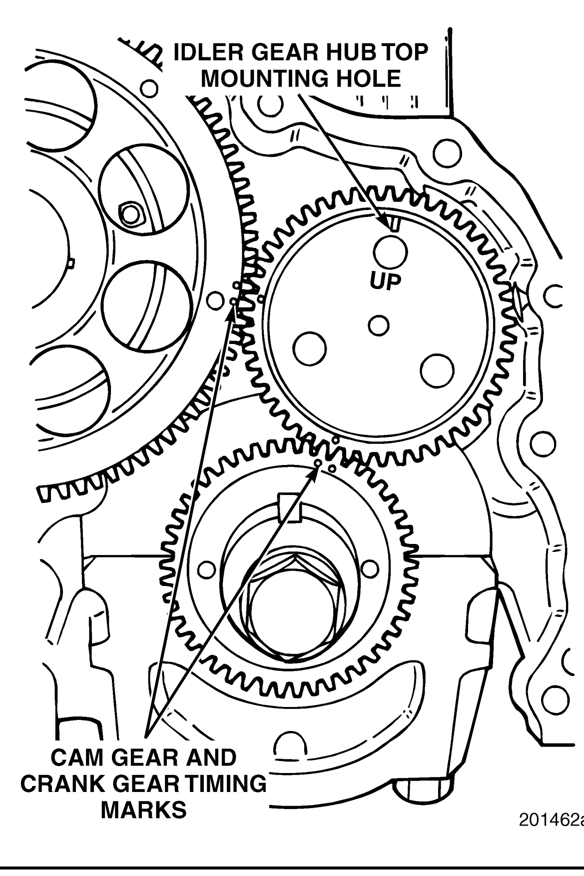


Figure 319 — Hub Correctly Positioned on Block

5_106_00.bk Page 292 Friday, August 4, 2000 11:17 AM

2. Align the timing marks. First look at the timing marks on both the camshaft and crankshaft gears. Note that two teeth are marked (side-by-side) on each gear. These two timing marks must align with the single timing marks on the idler gear. When properly installed, the two single timing marks on the idler gear will fall between the two timing marks on the camshaft and crankshaft gears. To attain correct alignment, rotate the crankshaft and camshaft gears until the camshaft timing marks are in approximately the 3:30 position, and the crankshaft gear timing marks are in approximately the 1 o'clock position (with engine in upright position and viewed from the front).

NOTE

There are 45 gear teeth on the crankshaft gear, 90 teeth on the camshaft gear and 48 on the idler gear. Because the idler gear has 3 more teeth than the crankshaft gear, the timing marks align only once every 16 revolutions of the crankshaft. This is called a "hunting tooth" system.

3. Slide the idler gear onto the hub assembly with timing marks facing out.
4. Position idler gear timing marks so they align with the crankshaft and camshaft gear timing marks. Then slide the idler gear/hub assembly into position on the engine block.
5. Oil the bolts with clean engine oil. Start bolts a few turns.
6. Tap the hub portion of the assembly with a brass hammer to seat components.
7. Tighten the bolts evenly to specification. Do not use an impact wrench or other air tool to tighten bolts.

Final Assembly

Complete the reassembly of the engine by installing the front cover, seals, oil pan, push rods, rocker shaft assemblies, engine brake assemblies (if equipped), valve covers, other engine accessories/drives, radiator, hood and fender assembly, etc.

Once the engine reassembly has been accomplished, follow the procedures under Engine Setup and Adjustments, and Final Preparation and Operational Check in the REPAIR INSTRUCTIONS section to complete the camshaft replacement.

Engine Brake Control Valve Replacement

(J-Tech™ Engine Brake)

GENERAL INFORMATION

With J-Tech™ engine brake units built prior to June 1999, the possibility exists that the snap ring securing the control valve in the J-Tech™ brake units may break or dislodge, allowing oil pressure to push the control valve components from the housing bore. This results in loss of oil pressure and a poor performing or non-functioning engine brake unit. In most instances, however, this condition will go unnoticed until the cylinder head covers are removed. A broken or dislodged control valve retaining snap ring will not cause any damage to the engine.

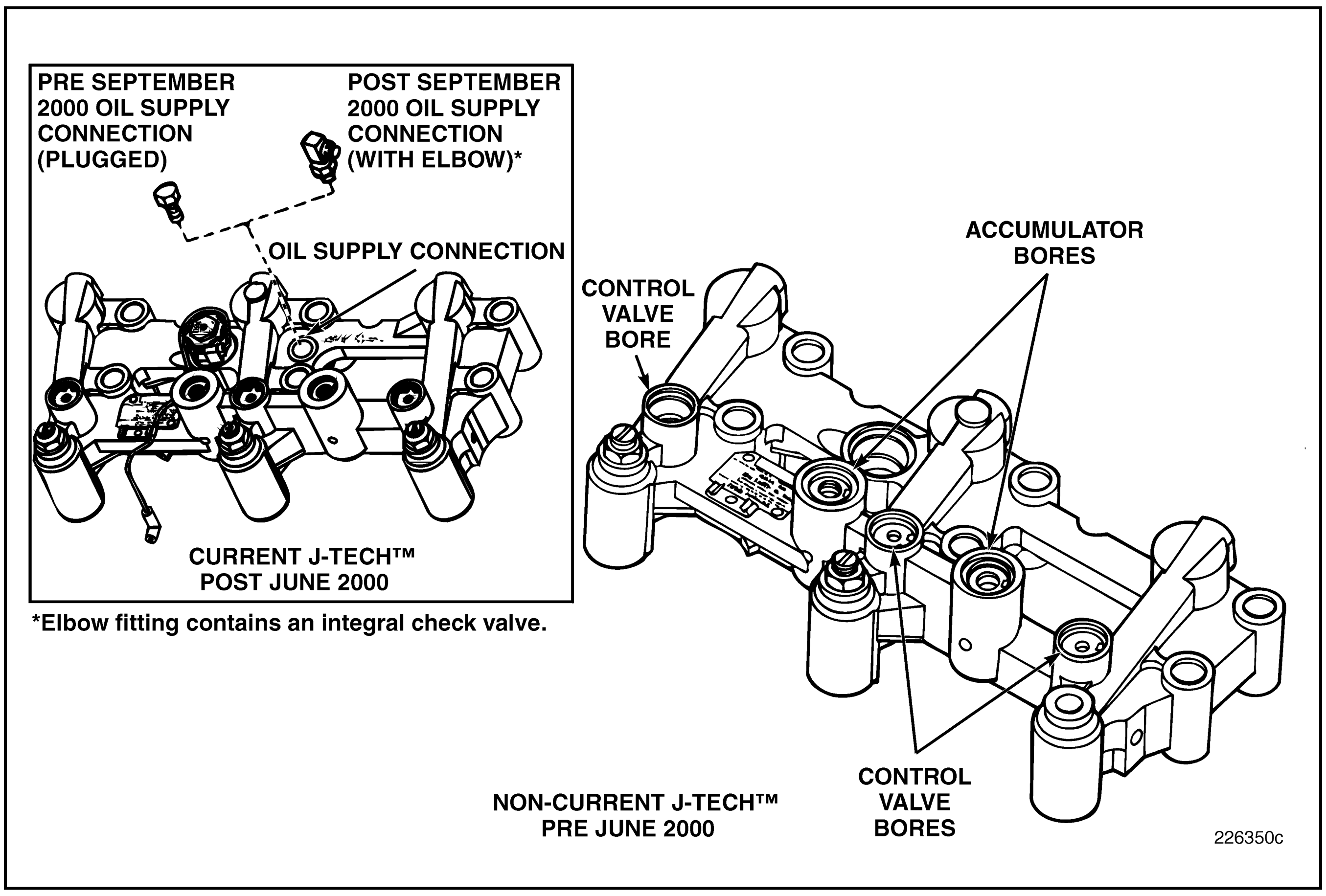


Figure 320 — Engine Brake Housing Assembly

To prevent breaking or dislodging of the control valve snap ring, the J-Tech™ control valve components have been redesigned to incorporate a new-style collar (which replaces the old-style valve stop spacer), an outer spring and a retaining washer (Figure 321). With this change, the part No. of the engine brake housing assembly was changed from 757GB58B to 757GB58C (beginning with housing assembly serial No. D690060001), and was phased into E-Tech™ engine production June 30, 1999 (beginning with engine serial number 9M4395).

A control valve update kit (part No. 4559-28190) for Jacobs 690 (J-Tech™) engine brake is available through the MACK Parts System. The kit includes all the necessary components to replace all six control valves on the engine.

NOTE

The control valve stop spacer used with the previous (non-current) control valve assembly has been terminated and is no longer available. Additionally, the new-style collar and outer spring are not compatible with the non-current control valves. Use of the collar and outer spring with the old-style control valve will result in no braking function.

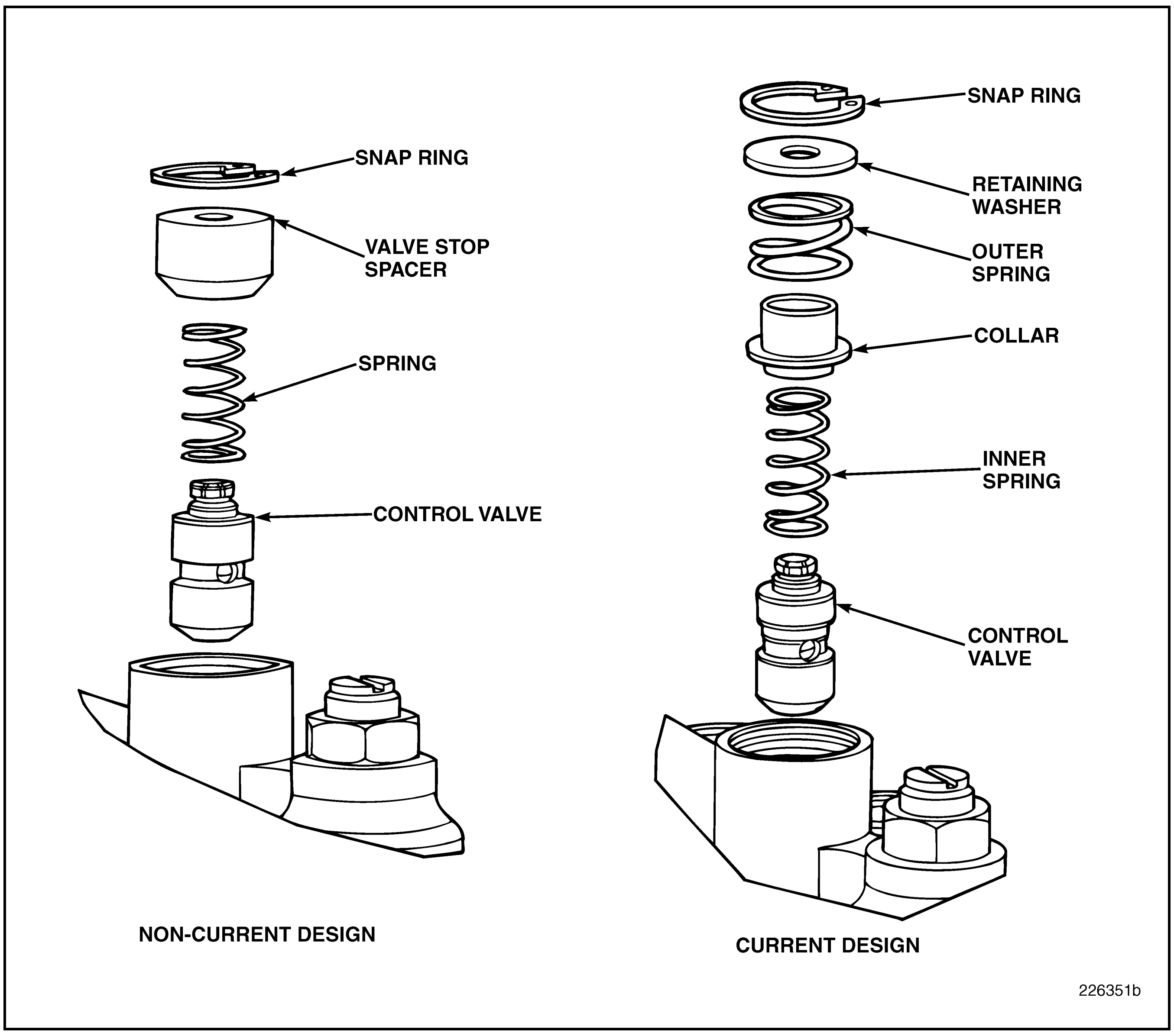


Figure 321 — J-Tech™ Control Valve Components

INSPECTION AND REPAIR

Remove the cylinder head valve covers and check the control valve bores in each J-Tech™ assembly (Figure 320) for a dislodged or broken snap ring(s). Should a broken or dislodged control valve snap ring be encountered, it is recommended that the control valve components for all six control valves on the engine be replaced with these new components. After installing the new-style control valve components, the letter "C" should be stamped on the Jake brake housing identification plate, as shown in Figure 322 to identify that they have the updated components.

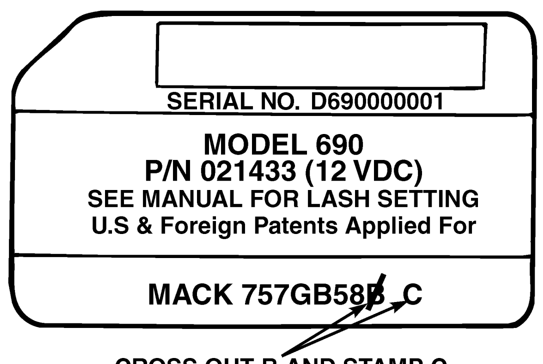


Figure 322 — J-Tech™ Housing Identification Plate

Valve Lifter H-Ring Installation Check

CAUTION

Any valve train failure which results in excessive valve lash can result in the valve lifter H-ring being dislodged or partially dislodged. If an engine has had such a failure, the affected cylinder must be checked for proper positioning of the H-ring.

Dislodging of the H-ring from its bore results from valve lifter inertia forcing the H-ring upward. When the H-ring at a failure cylinder is higher than that of an adjacent cylinder, the appropriate action must be taken depending upon how much the H-ring has been pushed upward. Measure the installation depth of the H-ring as follows:

1. Remove the push rod and look down the push rod hole, observing the top of the lifter and the top of the H-ring.
2. Place an approximate 15-inch length of welding rod on the top of the H-ring, at the outboard side. Refer to Figure 323.

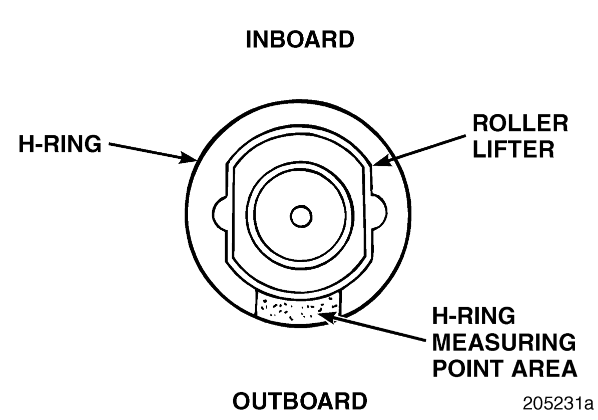


Figure 323 — H-Ring Measuring Point

3. Place a straightedge on the cylinder head top rail surface, in contact with the welding rod.
4. Mark the welding rod at the straightedge contact point.
5. Perform the same check at an adjacent cylinder and mark this location on the welding rod. Compare measurements with the original mark made at the suspect cylinder.
   - If the H-ring at the failure cylinder is the same height to 1/16 inch (1.574 mm) higher as compared to that of an adjacent cylinder, it is concluded that no partial dislodging of the H-ring has occurred. No further action is required.
   - If the H-ring at the failure cylinder is 1/16–1/4 inch (1.574–3.175 mm) higher than that of an adjacent cylinder, only partial dislodging has taken place, but H-ring to lifter engagement was maintained. Proceed to step 6 for repositioning of the H-ring.
   - If the H-ring is more than 1/4 inch (3.175 mm) higher than that of an adjacent cylinder, it is very likely that lifter and camshaft lobe damage has taken place. The lobe must be inspected and the camshaft and lifter replaced as necessary. Proceed to step 6 for repositioning of the H-ring.
6. Place a long screwdriver or long piece of drill rod on the H-ring top surface and using a cross-alternating pattern as shown in Figure 324, carefully tap the H-ring back into place. The depth should match that of the adjacent unaffected cylinder as marked previously on the welding rod.

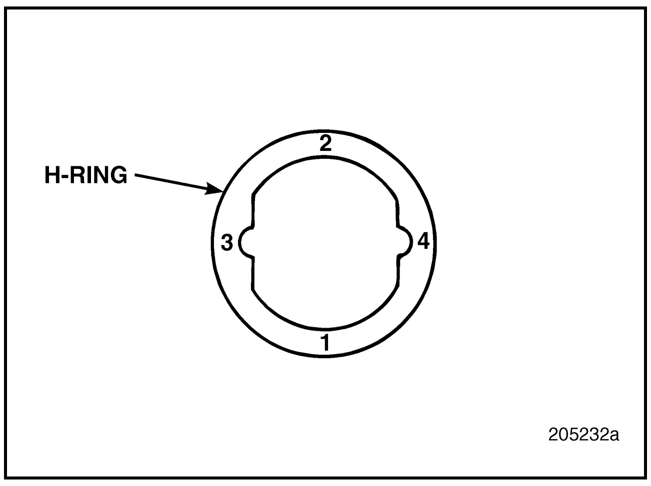


Figure 324 — Alternating Pattern for H-Ring

ENGINE SETUP AND ADJUSTMENTS

Fuel Injection Timing

There is no longer a need to set injection pump-to-engine timing. Consequently, the timing pointer on the engine front cover is eliminated. In place of the timing procedure, unit pump-to-engine timing is programmed into and controlled by the EECU. However, the flywheel still has pump timing marks to accommodate application to both E-Tech™ and E7 engines; the marks are not needed for the E-Tech™ engine.

Valve Yoke, Valve Lash and Engine Brake Adjustments

[213 NB]

GENERAL INSTRUCTIONS

NOTE

The pinless type inlet valve yoke is self-leveling and does not have a yoke leveling adjustment screw. Inlet valve lash adjustments are performed in the normal manner with the rocker arm adjusting screw.

Yoke and valve adjustments are done in two stages. Adjust the pin-type yoke clearance FIRST, and then adjust the valve lash. Make sure both adjustments are done in firing order sequence. Manually rotate the engine in normal rotation direction until the center of the timing pointer hole in the flywheel housing aligns with the valves 1 and 6 mark on the flywheel and the No. 1 piston is on the compression stroke. The flywheel has three stamped locations at 120-degree intervals for valve settings.

NOTE

Yoke and valve adjustments must be made under static conditions with coolant temperature below 100°F (37°C).

NOTE

Engine firing order is 1-5-3-6-2-4.

SPECIAL TOOL REQUIRED

- Engine Barring Socket J 38587-A

LOCATING AND MARKING FLYWHEEL VALVE ADJUSTMENT MARKINGS

NOTE

Some engines may be equipped with flywheels that have missing or illegible valve adjustment markings. If this problem is encountered, a typical flywheel can be marked while the engine is in the chassis.

TYPICAL FLYWHEELS

On a typical flywheel, the top center (TC) markings, and the valve adjustment markings, are directly in line with the clutch mounting bolt/bolt holes. To determine if the engine is equipped with a typical flywheel, view the flywheel through the timing access hole in the flywheel housing. Align the TC markings with the timing pointer. If the flywheel is typical, there should be a clutch mounting bolt/bolt hole directly in line with the TC marking. In this case, the valve adjustment markings should be in line with a clutch mounting bolt at three locations. Refer to Figure 325.

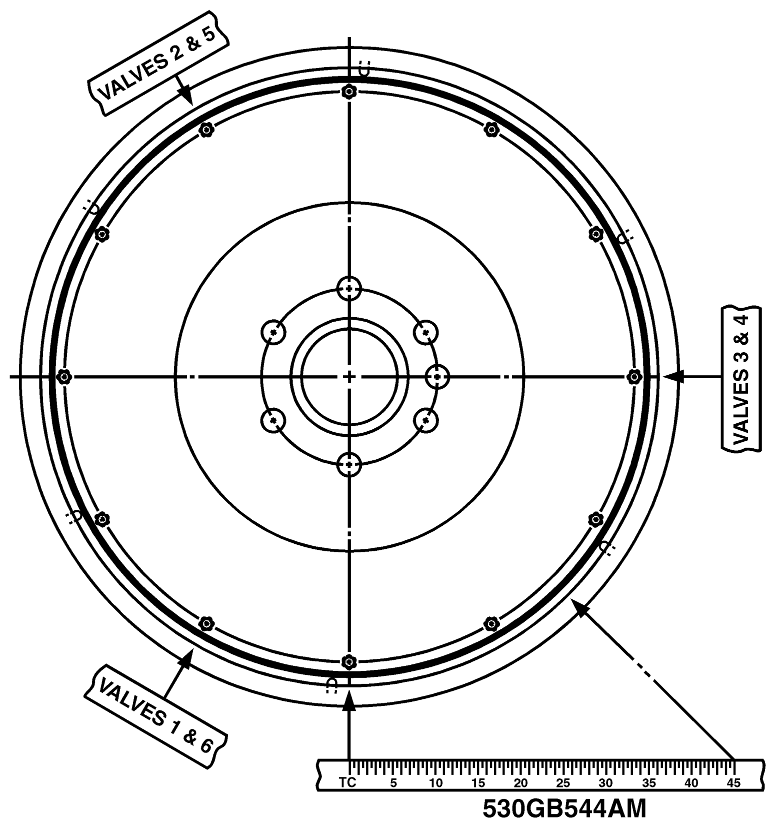


Figure 325 — Flywheel Marks

There are 12 clutch mounting bolt holes in the flywheel, but only 8 of these holes are used to mount the clutch. Every third bolt hole, for a total of four, is not used. These holes are in an open area between the clutch mounting flanges. The unused holes are easy to see through the timing access hole in the flywheel housing. The bolt holes where there are clutch mounting bolts are more difficult to see because the clutch mounting bolt head is somewhat rearward of the timing access opening. To aid in counting the clutch mounting bolt/bolt holes, keep in mind that there is slightly over four inches between one bolt hole and the next. Locating the clutch mounting bolts may be made easier by removing the bell housing inspection cover and viewing or feeling for the bolts through the access hole.

After verifying that there is a clutch mounting bolt/bolt hole in line with the TC mark, the next step is to find the three locations where the valve adjustment marks should be. Put a temporary mark (chalk, grease pencil, paint, etc.) at each of the three locations. Proceed as follows:

1. Beginning with the TC mark aligned with the timing pointer, rotate the engine in the direction of normal rotation (counterclockwise, viewed from rear) to the next clutch mounting bolt/bolt hole. Temporarily mark this location for cylinders 1 and 6.
2. Continue rotating the engine in the normal direction and count the clutch mounting bolt/bolt holes as they pass the timing access opening. At the fourth mounting bolt/bolt hole, make a temporary mark on the flywheel for cylinders 2 and 5.
3. Rotate the engine another four mounting bolt/bolt holes and make a temporary mark on the flywheel for cylinders 3 and 4.
4. Rotate the engine another three clutch mounting bolt/bolt holes and verify that the flywheel is at the TC mark. Then, rotate the engine one more bolt/bolt hole and verify that the flywheel is at the temporary mark made for cylinders 1 and 6.

5. Permanently mark the flywheel at this location for cylinders 1 and 6. To gain access, rotate the engine slightly so that the area to be marked is either to the right or left side of the timing pointer. Place a chisel mark directly in line with the clutch mounting bolt/bolt hole. Then, stamp or electric-etch the cylinder numbers on either side of the chisel mark.
6. Rotate the engine to the remaining locations and make sure to count the clutch mounting bolt/bolt holes to verify the locations of the temporary markings. Once verified, permanently mark each location as described.

NON-TYPICAL FLYWHEELS

If the engine is equipped with a non-typical flywheel, the TC markings will be halfway between two clutch mounting bolts. If this type of flywheel has no valve adjustment markings, it should be replaced.

VALVE YOKE ADJUSTMENT

Beginning March 2, 2000 (engine serial No. 0D0120), pinless valve yokes were implemented into production on all E-Tech™ engines. The pinless yokes are used for the inlet valves only. The cylinder heads no longer have yoke guide pins at the inlet valve locations.

The pinless yoke is self-leveling in operation and does not have a leveling adjustment screw. Inlet valve adjustments are performed in the normal manner with the rocker arm adjusting screw. For the exhaust valves, it is still necessary to adjust the valve yoke first, then the rocker arm lash.

CAUTION

Make sure that adjusting screws are retracted upward in the rocker arms. If they extend too far below the rocker arm, the push rods can be bent when tightening the rocker arm assembly brackets.

Verify that the slave piston adjusting screws are fully retracted and that all the spherical jam nuts are turned down snug against the rocker arms before rotating the engine crankshaft for valve lash adjustment. Rotating the engine crankshaft with the spherical jam nuts loose, or the slave piston adjusting screws not fully retracted, could damage the brake master pistons.

Refer to Figure 326 and Figure 327.

1. Using engine barring socket J 38587-A, manually rotate engine in normal rotation direction until pointer in flywheel housing aligns with the valves 1 and 6 mark on the flywheel and the No. 1 piston is on the compression stroke.

NOTE

Valve lash must be set using the valve adjustment marks on the engine flywheel, which are at 30 degrees ATC. This ensures that the lifter is on the camshaft base circle and not on the brake ramp portion of the lobe.

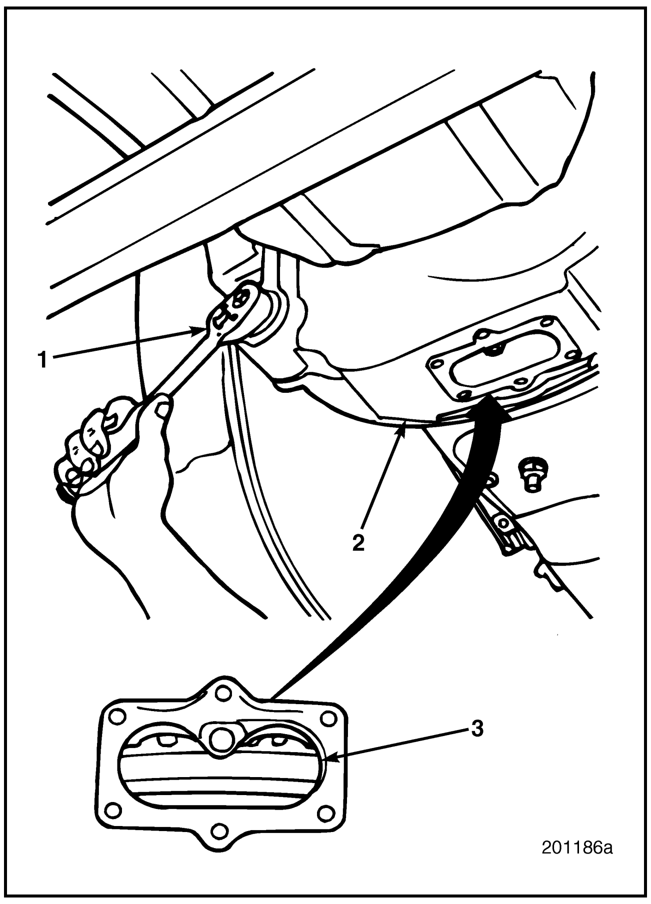


Figure 326 — Engine Crankshaft Rotation

1. Barring Socket J 38587-A 2. Flywheel Housing	3. Flywheel

2. Back off the valve rocker adjusting screws.
3. Loosen the No. 1 cylinder yoke adjusting screw jam nuts for the inlet and exhaust valves.
4. Exert moderate force on the yoke by pressing on the rocker arm slipper end. Turn down the yoke adjusting screw until it makes solid contact with the outboard valve stem tip, as sensed by a light drag on the adjusting screw.

CAUTION

If the engine is equipped with an engine brake, the exhaust yoke will be equipped with an actuator pin adjusting screw.

Do not allow anything to press down on the actuating pin during adjustment. The pin must be fully extended, approximately 1/4 inch (6.350 mm) above the top of the hollow adjusting screw. If the pin is held down and not fully extended, an improper adjustment and engine failure will result.

5. Turn adjusting screw an additional 1/6 turn (60 degrees) clockwise.

SERVICE HINT

A 1/6 turn is equal to one flat on the adjusting screw locknut.

6. Hold the yoke adjusting screw in this position while tightening the adjusting screw jam nut to the specified torque, 33 lb-ft (45 N•m), using torque wrench J 24407, or equivalent.

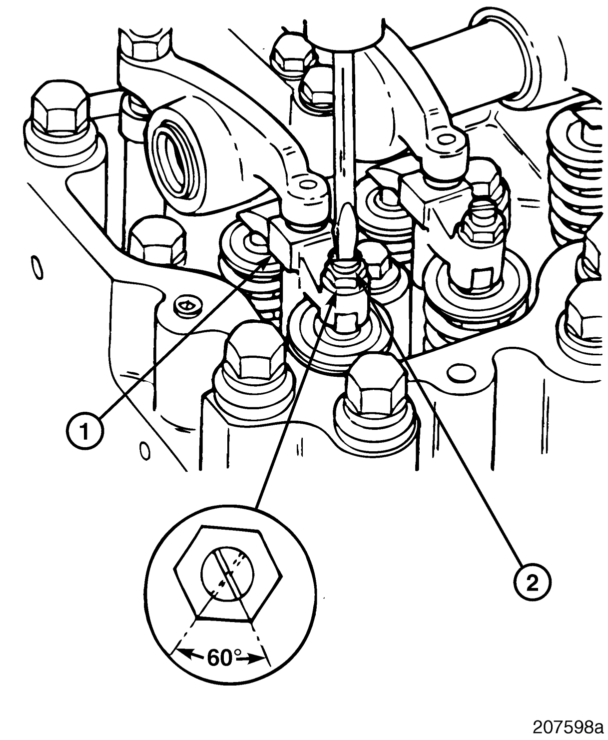


Figure 327 — Yoke Adjusting Screw and Jam Nut

1. Valve Yoke	2. Adjusting Screw

7. Check yoke adjustment as follows:
   a. Insert a 0.010-inch (0.254-mm) thickness gauge between the yoke and valve stem, at both the inboard and outboard locations.
   b. Exert moderate force on the yoke by pressing on the rocker arm slipper end as shown in Figure 328. An equal drag should be felt on both thickness gauges. If drag is unequal, readjust the yoke adjusting screw, as required.

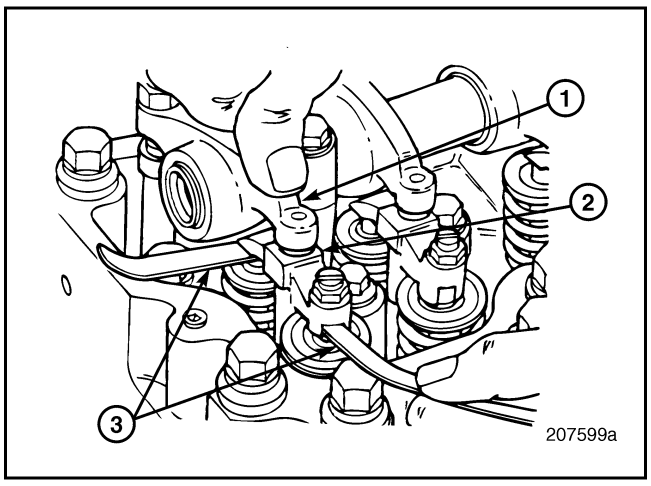


Figure 328 — Checking Yoke Adjustment

1. Rocker Arm 2. Valve Yoke	3. Thickness Gauges

INLET VALVE ADJUSTMENT

Refer to Figure 329.

Inlet valve lash clearance is 0.016 inch (0.406 mm).

NOTE

When checking the inlet valve adjustment as part of a troubleshooting routine, the acceptable range is 0.012–0.020 inch (0.305–0.508 mm). Do NOT readjust the lash clearance unless it is outside of this range.

1. Place a 0.016-inch (0.406-mm) thickness gauge between the rocker arm and yoke on the No. 1 cylinder.
2. Turn the adjusting screw until a light drag is felt on the thickness gauge.
3. After setting adjustment screw, tighten jam nut to specification, 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.

NOTE

Do not allow the adjustment screw to turn.

4. After tightening jam nut, recheck valve lash clearance. Readjust as necessary.

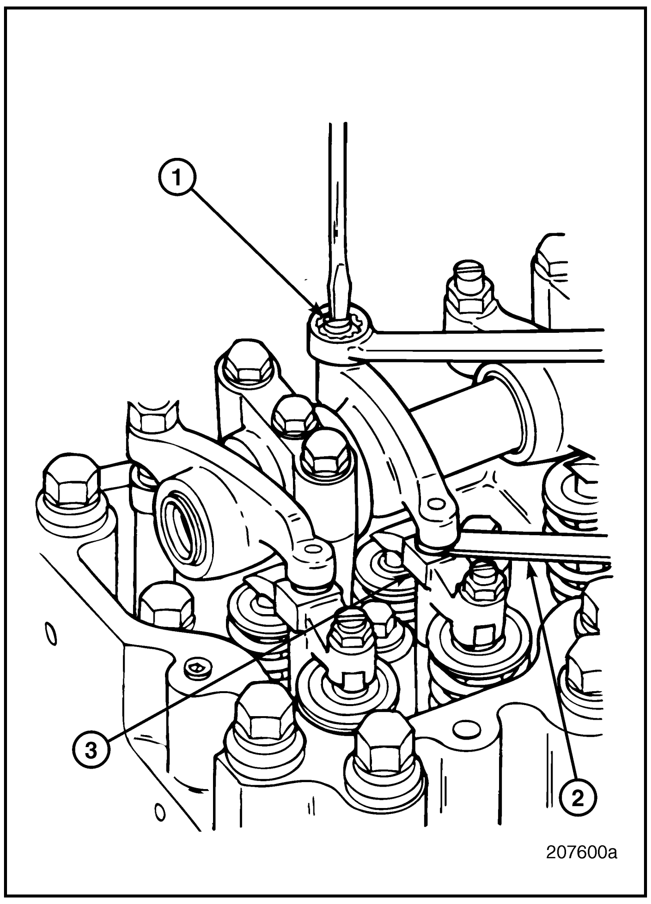


Figure 329 — Inlet Valve Adjustment

1. Adjusting Screw 2. Thickness Gauge	3. Valve Yoke

5_106_00.bk Page 302 Friday, August 4, 2000 11:17 AM

EXHAUST VALVE ADJUSTMENT

Refer to Figure 330.

Exhaust valve clearance is 0.024 inch (0.610 mm).

NOTE

When checking the exhaust valve adjustment as part of a troubleshooting routine, the acceptable range is 0.020–0.028 inch (0.508–0.711 mm). Do NOT readjust the lash clearance unless it is outside of this range.

1. Place a 0.024-inch (0.610-mm) thickness gauge between the rocker arm and yoke on the No. 1 cylinder.
2. Turn the adjusting screw until a light drag is felt on the thickness gauge.
3. After adjustment is complete, tighten jam nut to specification, 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.

NOTE

Do not allow the adjustment screw to turn.

CAUTION

The J-Tech™ exhaust rocker arm adjusting screw spherical jam nut is a through-hardened nut. When tightening these nuts, be aware of the following:

- *Always use the proper 20-mm size wrench. Using an improper size wrench to tighten the jam nuts can lead to jam nut breakage.*
- *Overtightening the jam nut when adjusting valves may result in jam nut breakage. If there is too much or too little drag on the thickness gauge, loosen the jam nut and reading valve lash.*

4. Recheck valve lash clearance after tightening jam nut. Readjust as necessary.

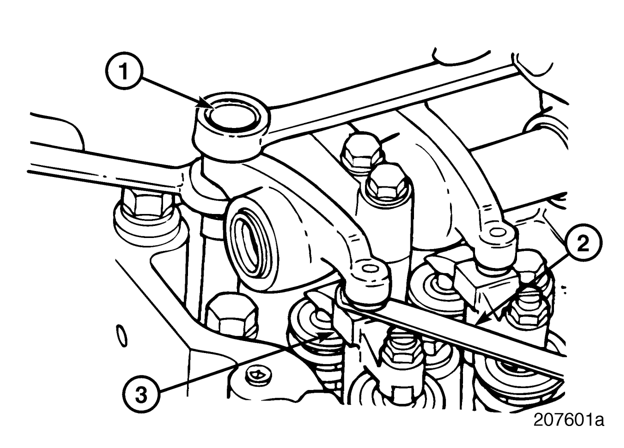


Figure 330 — Exhaust Valve Adjustment

1. Spherical Jam Nut 2. Thickness Gauge	3. Valve Yoke

ENGINE BRAKE ADJUSTMENT (IF EQUIPPED)

[213]

Refer to Figure 331.

1. Place a 0.015-inch (0.381-mm) thickness gauge between the slave piston stem and the actuator pin in the yoke adjusting screw.
2. Turn the slave piston adjusting screw to set the lash.

NOTE

It may be necessary to back off the adjusting screw slightly to remove the thickness gauge. However, be sure to return the adjusting screw to the proper position.

3. Tighten the jam nut to specification, 25 lb-ft (34 N•m).

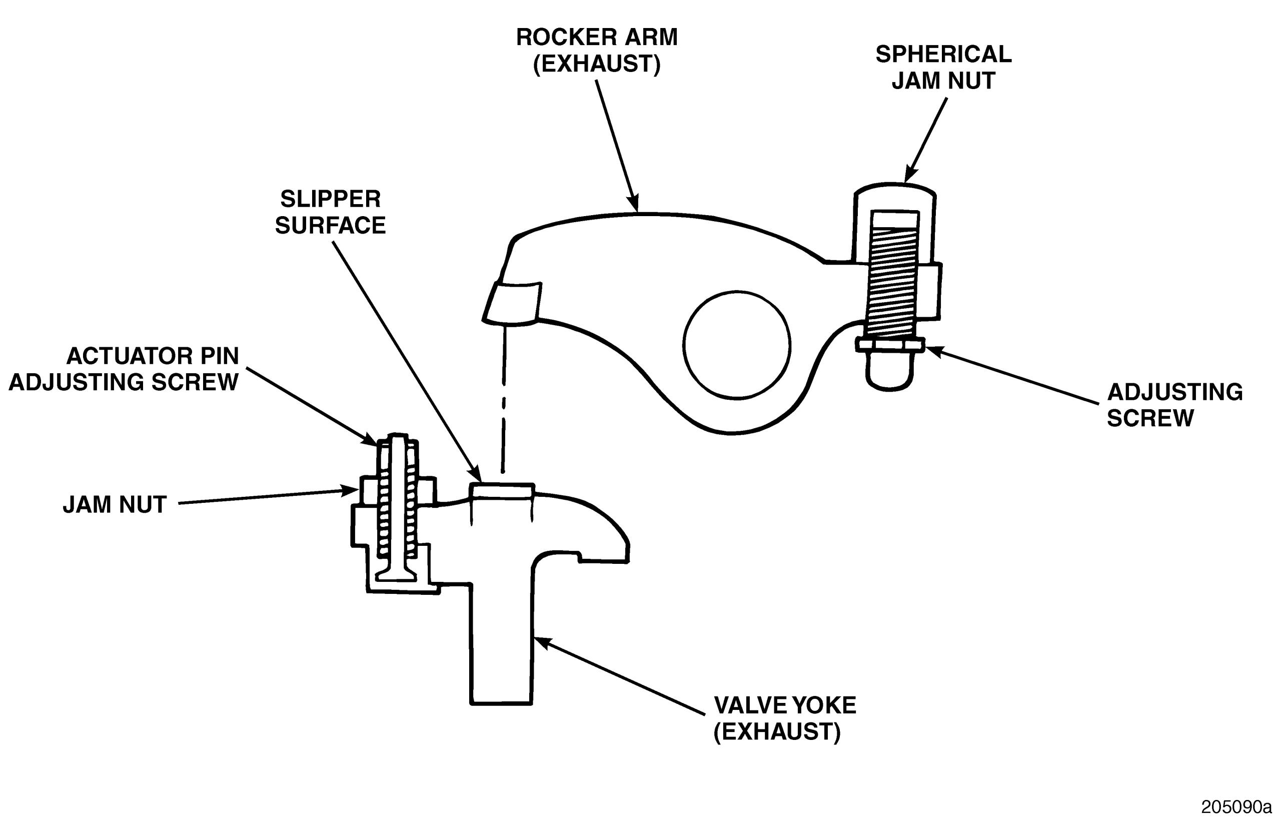


Figure 331 — J-Tech™ Exhaust Valve Rocker Arm and Yoke

CONTINUATION OF ADJUSTMENTS FOR REMAINING CYLINDERS

1. Using the barring socket, manually rotate the engine crankshaft (Figure 332) in normal rotation direction 120 degrees until the center of the timing pointer hole in flywheel housing aligns with the “2 & 5” mark on the flywheel and the No. 5 piston is on the compression stroke.

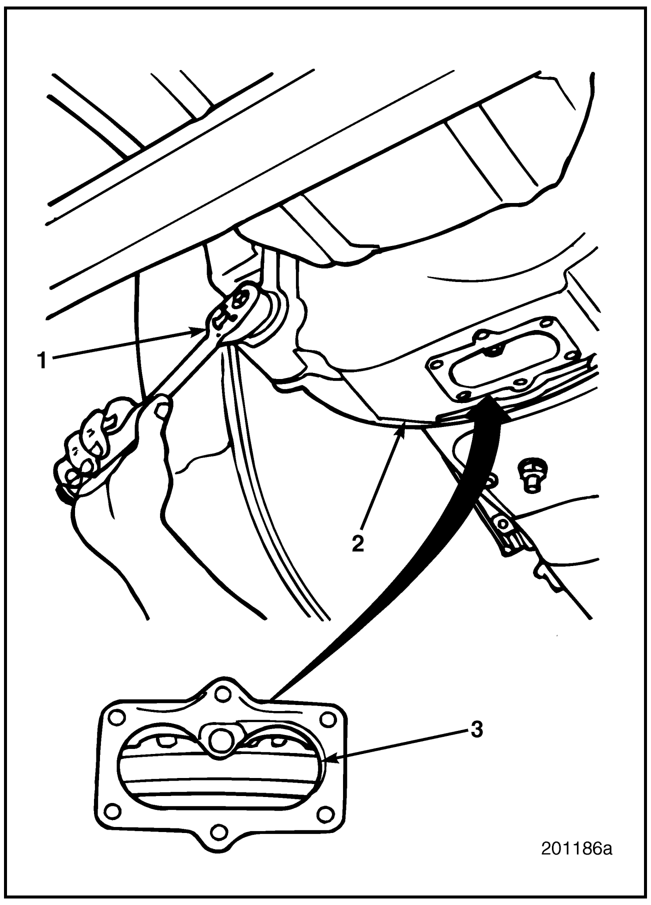


Figure 332 — Engine Crankshaft Rotation

1. Barring Socket J 38587-A 2. Flywheel Housing	3. Flywheel

2. Adjust the final intake and exhaust valve lash, and engine brake slave piston lash for cylinder No. 5 as described in the procedure for cylinder No. 1. (Continue this process for each of the remaining cylinders, following the engine firing order sequence, 1-5-3-6-2-4.)
3. Make sure that the Jacobs electrical connector, MACK part No. 4559-17366, is installed in each of the engine brake cylinder head cover spacers. Install one valve cover gasket in each spacer and position the spacers on the cylinder heads.
4. Connect the solenoid wires to the inside terminal of the electrical connectors on the spacers. Connect the brake lead wires from the engine harness to the outside terminals.
5. Install the gaskets in the cylinder head valve covers and position the covers on the spacers.
6. Install six mounting bolts in each of the cylinder head covers/spacers and tighten the bolts to 20 lb-ft (27 N•m).

Engine Speed and Position Sensors Installation and Adjustment

ENGINE SPEED SENSOR

Because the engine speed sensor (Figure 333) is controlled by the measurement and selection of proper mounting shims, the installation procedure is as follows:

1. Using a depth micrometer or vernier caliper, measure from the sensor mounting surface on the flywheel housing to the OD of a flywheel ring tooth.

NOTE

Measurement must be made to the tooth OD or an inaccurate measurement will result.

2. Select and install a shim on the sensor mounting flange. Refer to following chart for shim selection.

SHIM SELECTION CHART FOR ENGINE SPEED AND ENGINE POSITION SENSORS

Depth as Measured	Use the Following P/N 505GC28 Shims
Less than/equal to 1.328	(2) P30
1.329 through 1.343	(1) P15 + (1) P30
1.344 through 1.358	(1) P30
1.359 through 1.373	(1) P15
Equal to/greater than 1.374	None

3. Install the sensor with the appropriate shim. Tighten the capscrew retaining the sensor to proper specification.

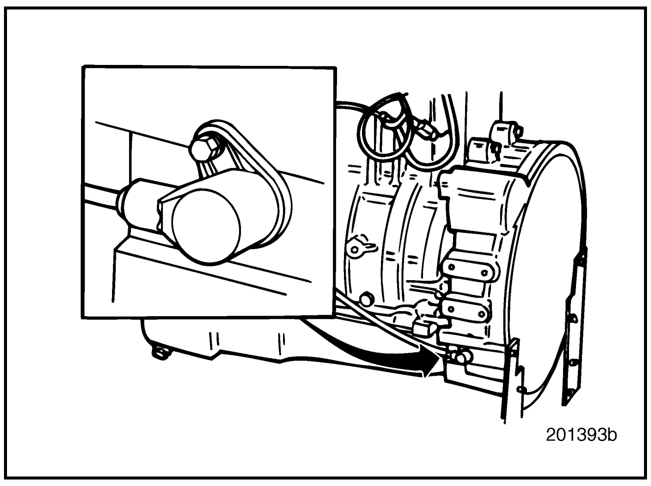


Figure 333 — Engine Speed Sensor

ENGINE POSITION SENSOR

Installation of this sensor (Figure 334) is the same as that for the engine speed sensor except for the first step. When installing the engine position sensor, make the shim calculation measurement from the sensor mounting surface on the front timing gear cover to the face of the camshaft gear.

NOTE

Do not measure into one of the sensing holes in the gear face or an inaccurate measurement will result.

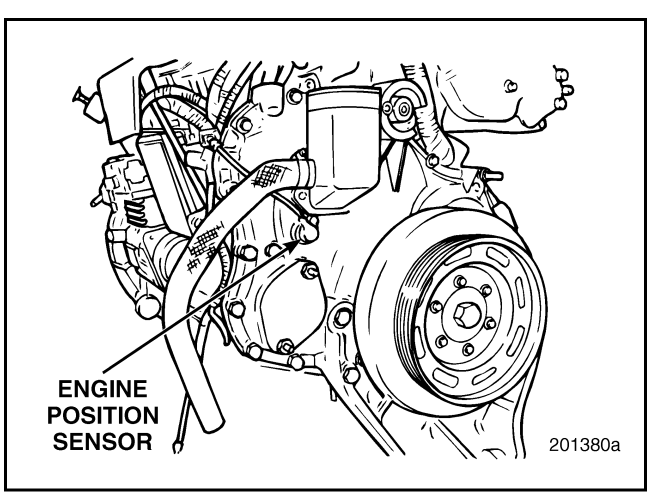


Figure 334 — Engine Position Sensor

OTHER ENGINE-MOUNTED SENSORS

The remaining engine-mounted sensors are thread-mounted and are not adjustable. These include the Fuel Temperature, Boost Air Temperature, Boost Pressure Sensor, Coolant Temperature, Oil Temperature and Oil Pressure sensors. Refer to the Torque Specifications for Engine-Mounted Sensors in the SPECIFICATIONS section for thread sizes and torque specifications.

CAUTION

Do not use an E7 English pipe-thread sensor in place of a metric straight-thread sensor (or vice versa). Doing so will result in thread damage to both the sensor and the tapped hole into which the sensor is installed.

Electronic Unit Pump (EUP) Calibration

[221 GP]

Whenever an electronic unit pump(s) is replaced in an engine, it is necessary to recalibrate the pump(s) by entering the calibration code into the engine electronic control unit (EECU). The calibration code is a four-digit number that can be found on the data plate of each individual unit pump. This calibration code is then entered by using a personal computer that is running the V-MAC® Service Support Software or the Pro-Link® 9000.

The four-digit calibration code can be found on the EUP data plate, shown after the letters “CAL” for early production EUPs. For later-production EUPs, the calibration code is still found in the same location on the data plate (next to the word MACK), only the identification letters “CAL” have been eliminated to provide room for larger bar codes.

ENGINE FINAL PREPARATION AND OPERATIONAL CHECK

Filter Element Installation

CAUTION

All filters and coolant conditioners must meet MACK specifications. Prime oil filters before installation using the correct specification engine oil.

1. Install a **new** air filter in the air filter housing.
2. Install the applicable Centri-Max® (externally drained) or Centri-Max® PLUS (internally drained) filter assembly. Be sure to use a **new** rotor element and O-ring.

CAUTION

There are different rotor assemblies for the standard Centri-Max® (externally drained) and Centri-Max® PLUS (internally drained) filter assemblies. Take care to use the correct rotor for the applicable configuration. While either of the two rotors available for the externally drained configuration will slide on the spindle of the internally drained configuration, they will be loose and not rotate, causing the unit to not function.

3. Using an appropriate filter wrench such as J 29927, install the two full-flow oil filter elements and coolant conditioner element.

NOTE

Prime the fuel filter elements before installation. Use only clean, MACK-specified, Grade 2D diesel fuel.

4. Prime the PRIMARY fuel filter element (red) by filling with clean No. 2 fuel oil. Do not fill the filter through the center hole; it must be filled using the outer holes. Lubricate the gasket with oil and install the filter.
5. Prime the SECONDARY fuel filter element (green) by filling with clean No. 2 fuel oil. Do not fill the filter through the center hole; it must be filled using the outer holes. Lubricate the gasket with oil and install the filter.

Engine Lubrication System

GENERAL INSTRUCTIONS

A lubricating oil film coats rotating parts and bearings of an overhauled engine, but this may not provide sufficient lubrication when the engine is started for the first time. The following briefly describes the recommended procedure for ensuring proper lubrication.

CAUTION

Do not mix brands or types of lubricants. Chemical additives may be incompatible and may contribute to the formation of sludge, acid or hardening.

SERVICE HINT

Usually there are various points on the engine where a pressure line may be tapped into, but if no other is apparent, the oil gauge line may be disconnected and a pressure tank applied at that point.

PRIMING THE LUBRICATION SYSTEM

1. Fill the engine crankcase to the specified capacity with the recommended MACK-specified EO-M engine oil.
2. Fill a pressure prelubricator (J 39258-A) with the recommended oil and connect the pressure prelubricator to main oil gallery. Prime the engine lubrication system with sufficient oil.
3. Remove the oil level dipstick and check the crankcase level. Add sufficient oil, if necessary, to bring it to the FULL mark on the dipstick. Do not overfill.

Turbocharger

1. Disconnect the turbocharger oil inlet line and pour approximately one pint (473 ml) of clean engine oil into the line. This ensures that the bearings are properly lubricated for initial start-up.
2. Reconnect the oil line.

Cooling System

1. Check the cooling system. Make sure all plugs are installed and tight. Make sure the thermostat is installed.
2. Fill the system with the recommended coolant.

NOTE

To ensure that all air is purged from the cooling system, remove a plug from the top (or end) of the coolant manifold during filling. This will eliminate any air that is trapped as a result of rapid filling.

3. Install a **new** coolant conditioner and fill with the recommended coolant mixture.
4. Check that all plugs and thermostat(s) are installed.

Fuel System

GENERAL INSTRUCTIONS

1. Check the fuel system to ensure that all connections are tight.
2. Remove any trapped air by operating the manual priming pump located on the side of the fuel supply pump, using the following procedure.

NOTE

Prime the fuel system with clean, Grade 2D diesel fuel (DF-A).

PRIMING THE FUEL SYSTEM

Using a hand-priming pump is usually only necessary when the fuel system has run dry. If the hand-priming pump is needed, use the following procedure for priming a dry fuel system.

1. Fill the primary and secondary fuel filters.
2. Disconnect the inlet hose at the secondary fuel filter. (This is the center fitting on the CH/CL fuel filter mounting adapter.)
3. Hand-prime until fuel is seen at the inlet hose fitting. This should take approximately 50 hand pumps.

SERVICE HINT

Excessive hand-priming after fuel is seen at the fitting may make the engine difficult to start.

4. Reconnect the inlet hose to the secondary fuel filter and start the engine.

SERVICE HINT

If the engine does not start, refill both filters and repeat the priming procedure outlined in steps 2, 3 and 4.

NOTE

Do not crank the engine continuously for more than 30 seconds without allowing the starter to cool for 2 minutes between cranks.

⚠ CAUTION

The only acceptable method of priming the fuel system is the hand primer pump. The application of air pressure to the fuel tank or the use of an auxiliary pump to prime the fuel system is PROHIBITED. These priming techniques may result in severe engine damage caused by leakage of fuel past the supply pump seal and into the crankcase.

Engine Operational Check

1. Remove all tools from the engine compartment.
2. Connect the battery cables (negative cable last).
3. Clear the work area of debris and personnel.
4. Start the engine. Check for leaks and monitor gauges for satisfactory oil pressure, etc.
5. After several minutes, shut the engine down. Check the fluid levels and fill to capacity before restarting the engine.
6. Refer to the Rebuilt Engine Run-In Procedures in this section for testing procedures.

REBUILT ENGINE RUN-IN PROCEDURES

General Instructions

The durability and service life of a rebuilt engine is directly related to its initial run-in following overhaul. After a complete overhaul or any major repair job involving installation of piston rings, pistons, cylinder sleeves or bearings, the engine must be run-in prior to release for service.

Run-in procedures vary depending on method used (i.e., engine dynamometer, chassis dynamometer or highway run-in). Regardless of method, however, always properly prepare the engine before starting it for the first time.

Run-In Check

NOTE

Install any additional instrumentation needed for the run-in method selected.

The operator should be familiar with the correct, established procedure for checking chassis power *before* using chassis dynamometer method for run-in (refer to applicable chassis dynamometer operation procedures).

The operator must be observant throughout the entire run-in procedure, in order to detect any problems that develop. Constantly monitor the instrumentation displaying functions of the engine and support systems, and record all readings.

If, during run-in, the engine develops any of the following abnormal running characteristics, shut it down immediately. Investigate and correct the problem before continuing the run-in procedure.

Always investigate the following conditions:

- Unusual noises such as knocking, scraping, etc.
- A significant drop in engine oil pressure
- A significant rise in coolant temperature, exceeding 240°F (116°C)
- A significant rise in oil temperature that exceeds 240°F (116°C)
- An exhaust temperature that exceeds maximum acceptable limits for the specific engine involved, as measured by a pyrometer (if applicable)
- Any oil, coolant or air inlet system leaks

CYLINDER HEAD RETORQUING

After run-in procedure, in sequence, back off each cylinder head capscrew individually until free. Then retorque same capscrew to 205 lb-ft (278 N•m).

5_106_00.bk Page 309 Friday, August 4, 2000 11:17 AM

SPECIFICATIONS

E-TECH™ ENGINE MECHANICAL SPECIFICATIONS

Performance Specifications

NOTE

Retarding power specifications apply only for engines equipped with the optional J-Tech™ engine brake.

EM7-275 E-TECH™

Power at Governed Speed — 275 hp (205 kW) at 1750 rpm

Peak Power — 285 hp (212 kW) at 1500 rpm

Maximum Torque — 1,305 lb-ft (1 769 N•m) at 1020 rpm

Torque Rise — 58 percent

Engine Brake Retarding Power — 330 hp (230 kW) at 2100 rpm

EM7-300 E-TECH™

Power at Governed Speed — 300 hp (224 kW) at 1750 rpm

Peak Power — 310 hp (231 kW) at 1500 rpm

Maximum Torque — 1,425 lb-ft (1 932 N•m) at 1020 rpm

Torque Rise — 58 percent

Engine Brake Retarding Power — 330 hp (230 kW) at 2100 rpm

E7-300 E-TECH™

Power at Governed Speed — 300 hp (224 kW) at 1800 rpm

Maximum Torque — 1,160 lb-ft (1 572 N•m) at 1200 rpm

Torque Rise — 33 percent

Engine Brake Retarding Power — 335 hp (234 kW) at 2100 rpm

E7-310/330 E-TECH™

Power at Governed Speed — 310 hp (231 kW) at 1800 rpm

Peak Power — 330 hp (246 kW) at 1500 rpm

Maximum Torque — 1,360 lb-ft (1 844 N•m) at 1100 rpm

Torque Rise — 50 percent

Engine Brake Retarding Power — 335 hp (234 kW) at 2100 rpm

E7-330/350 E-TECH™

Power at Governed Speed — 330 hp (246 kW) at 1800 rpm

Peak Power — 350 hp (261 kW) at 1500 rpm

Maximum Torque — 1,460 lb-ft (1 979 N•m) at 1100 rpm

Torque Rise — 52 percent

Engine Brake Retarding Power — 335 hp (234 kW) at 2100 rpm

E7-350 E-TECH™

Power at Governed Speed — 350 hp (261 kW) at 1800 rpm

Maximum Torque — 1,360 lb-ft (1 844 N•m) at 1200 rpm

Torque Rise — 33 percent

Engine Brake Retarding Power — 335 hp (234 kW) at 2100 rpm

E7-355/380 E-TECH™

Power at Governed Speed — 355 hp (265 kW) at 1800 rpm

Peak Power — 380 hp (284 kW) at 1500 rpm

Maximum Torque — 1,560 lb-ft (2 115 N•m) at 1100 rpm

Torque Rise — 51 percent

Engine Brake Retarding Power — 335 hp (234 kW) at 2100 rpm

SPECIFICATIONS

E7-400 E-TECH™

Power at Governed Speed — 400 hp (298 kW) at 1800 rpm

Maximum Torque — 1,460 lb-ft (1 979 N•m) at 1200 rpm

Torque Rise — 25 percent

Engine Brake Retarding Power — 335 hp (234 kW) at 2100 rpm

E7-427 E-TECH™

Power at Governed Speed — 427 hp (318 kW) at 1800 rpm

Maximum Torque — 1,560 lb-ft (2 115 N•m) at 1200 rpm

Torque Rise — 25 percent

Engine Brake Retarding Power — 360 hp (251 kW) at 2100 rpm

E7-460 E-TECH™

Power at Governed Speed — 460 hp (342 kW) at 1850 rpm

Peak Power — 487 (363 kW) at 1600–1700 rpm

Maximum Torque — 1,660 lb-ft (2 251 N•m) at 1200 rpm

Torque Rise — 25 percent

Engine Brake Retarding Power — 360 hp (251 kW) at 2100 rpm

Material and Dimensional Data

WEIGHTS AND DIMENSIONS

Item	Specification
Weight (wet) — includes oil and coolant	2340 lbs. (1062 kg)
Weight (dry)	2290 lbs. (1039 kg)
Displacement	728 cu. in. (12 L)
Bore and stroke	4-7/8 in. x 6-1/2 in. (124 mm x 165 mm)
Coolant capacity	13 qts. (12.3 L)
Sleeve design	Wet/dry
Compression ratio	16.1:1
Fasteners and threads	Metric
Flywheel housing — standard	Aluminum
Flywheel housing — optional	Ductile iron

COMPONENT FEATURES AND MATERIALS

Item	Description
Cylinder block	Alloyed gray cast iron
Main bearing caps	Ductile iron, intermediates supported with buttress screws
Flywheel housing	Aluminum, standard SAE No. 1, precision-doweled
Engine front cover (timing gear cover)	Die-cast aluminum, precision-doweled
Cylinder sleeve	Wet/dry, replaceable, centrifugally cast, alloyed cast iron
Cylinder sleeve crevice seal	Teflon®-coated AFLAS/EPDM, intolerant of oil; use glycol for installation lubricant
Cylinder heads	Alloyed gray cast iron, two per engine; four valves per cylinder
Cylinder head gaskets — body	Nonasbestos material with steel core, two per engine
Cylinder head gaskets — fire ring	Steel, keyed, six per engine

SPECIFICATIONS

Item	Description
Pistons	Two-piece articulated, steel crown with three rings, aluminum alloy skirt, pin bushings (early production), bushingless (current production). The crown of bushingless pistons is manganese-phosphate coated.
Piston rings — compression	Keystone, plasma-faced top ring. Rectangular, chrome, tapered-face second ring
Piston ring — oil	Dual chrome-faced rails, conformable with coil spring expander
Piston pin	Full-floating, 2.25-inch (57-mm) diameter, full-pressure lubrication through rifle-drilled holes in connecting rod
Connecting rods	Forged steel, I-beam type with tapered pin end, 35-degree cap angle, 10.4 inches (264 mm) center-to-center length
Crankshaft	Drop-forged, medium carbon steel, elotherm-hardened journals and fillets, eight integral counterweights, 3.25-inch (83-mm) pin journal diameter, 4.5-inch (114-mm) main journal diameter
Bearings — main	Steel back, cast copper-lead intermediate layer, lead-tin overlay
Bearings — connecting rod	Steel back, cast copper-lead intermediate layer, lead-tin overlay, deltawall
Vibration damper	Constructed with internal metal inertia ring, viscous fluid filled
Camshaft	Carbon steel with induction-hardened journals and lobes, gear driven
Valves — inlet	Poppet type with positive rotators, 20-degree seat, two per cylinder
Valves — exhaust	Poppet type with positive rotators, 30-degree seat, two per cylinder
Valve lifters	Roller follower type
Oil filters	Two spin-on disposable; one Centri-Max®
Air compressor	Flange-mounted, gear driven, oil-lubricated and water-cooled from engine; Bendix, Holset or Meritor WABCO
Turbocharger	Radial-flow type, exhaust gas driven, oil lubricated from engine; Schwitzer
Lubrication system	Full pressure, wet sump, 28-quart (26.5 L) capacity, 25,000-mile (40 000-km) highway/300-hour stop-and-go change interval; MACK-approved EO-M oil. If application meets Line Haul 1 requirements, it qualifies for extended service interval with MACK-approved EO-M Plus oil.
Valve seat inserts	Pressed-in head, replaceable
Manifold — air inlet	Two piece, six port
Manifold — exhaust	Three piece, six port
Manifold — water	Two piece, four port
Fuel injection pumps	Electronic unit pumps, Bosch
Fuel supply pump	Gear type, Bosch
Fuel injection nozzles	8-hole, 140-degree spray angle, Bosch
Fuel filters	Spin-on disposal type with metric mounting threads
Water pump	Centrifugal-rotor type, belt driven
Thermostat	180-degree opening with rubber-seated flange seal and stainless steel caged check-ball vent
Coolant conditioner (optional)	Spin-on type, disposable

SPECIFICATIONS

FITS AND LIMITS

The specifications as listed are for new parts, and therefore, maximum wear must be established by good judgment, experience and sound shop practice.

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
AUXILIARY SHAFT		
Shaft End Play	0.003–0.012 in.	0.076–0.305 mm
Shaft Journal Clearance	0.0020–0.0072 in.	0.051–0.183 mm
Shaft Bushing, Presized ID (front and rear)	2.064–2.068 in.	52.426–52.527 mm
Shaft Bushing, Presized OD (front and rear)	2.3140–2.3155 in.	58.7756–58.8137 mm
Shaft Bushing, Bore in Block (front and rear)	2.311–2.312 in.	58.699–58.725 mm
Shaft Bushing, Press-Fit in Bore (front and rear)	0.002–0.0045 in.	0.0518–0.1143 mm
Shaft Journal to Bushing (front and rear)	0.0020–0.0072 in.	0.0508–0.1829 mm
Shaft Journal Diameter OD (front and rear)	2.061–2.062 in.	52.349–52.375 mm
Oil Pump Driving Gear ID (press-fit)	1.6255–1.6250 in.	41.2877–41.2750 mm
Auxiliary Shaft Oil Pump Drive Journal	1.6278–1.6272 in.	41.3461–41.3309 mm
Air Compressor Drive Sprocket (press-fit)	1.1250–1.242 in.	28.575–31.547 mm
Auxiliary Shaft Air Compressor Sprocket Journal	1.1272–1.1268 in.	28.6309–28.6207 mm
CAMSHAFT		
Bushing Free OD	4.0045–4.0065 in.	101.714–101.765 mm
Bushing Bore in Cylinder Block	3.9995–4.0005 in.	101.587–101.613 mm
Bushing Press-Fit in Bore	0.004–0.007 in.	0.102–0.178 mm
Bushing ID (Installed)	3.8188–3.8213 in.	96.998–97.061 mm
Cam Journal Diameter	3.8150–3.8160 in.	96.901–96.926 mm
Journal-to-Bushing Clearance	0.0028–0.0063 in.	0.071–0.160 mm
Cam Gear Journal OD on Camshaft	2.50205–2.50255 in.	63.552–63.565 mm
Cam Gear Bore ID	2.4983–2.4993 in.	63.457–63.482 mm
Cam Gear-to-Journal Press-Fit	0.00275–0.00425 in.	0.070–0.108 mm
Inlet Valve Lobe Nominal Lift	0.320 in.	8.128 mm
Exhaust Valve Lobe Nominal Lift	0.334 in.	8.484 mm
EUP Lobe Nominal Lift	0.704 in.	17.882 mm
Camshaft End Play	0.003–0.012 in.	0.076–0.305 mm
CONNECTING ROD		
Connecting Rod Journal to Bearing Clearance	0.0012–0.0054 in.	0.030–0.137 mm
Side Clearance	0.007–0.014 in.	0.178–0.355 mm
Length between Centers	10.4375 in.	26.5113 cm
Cap Angle	35 degrees	
Bore for Bushing	2.4355–2.4345 in.	61.8617–61.8363 mm
Burnish Bushing to:	2.2305–2.2275 in.	56.6547–56.5785 mm
Finish Bore to:	2.2504–2.2500 in.	57.1602–57.1500 mm
Crankpin Bore Diameter (as bored)	3.4305–3.4297 in.	87.1347–87.1144 mm
Crankpin Bore Diameter (reassembled)	3.4309–3.4294 in.	87.1449–87.1068 mm

SPECIFICATIONS

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Bearing ID (in place)	2.9993–3.0013 in.	76.1822–76.2330 mm
Twist (within 12 in./30.48 cm)	0.010 in.	0.254 mm
Bend (within 12 in./30.48 cm)	0.004 in.	0.1016 mm
CRANKSHAFT		
End Play	0.004–0.013 in.	0.102–0.330 mm
Crankpin Journal OD	3.248–3.247 in.	82.4992–82.4738 mm
Main Journal OD	4.4974–4.4964 in.	114.2340–114.2086 mm
Journal Out-of-Round or Taper (maximum diameter)	0.00035 in.	0.00889 mm
Max. Runout at No. 4 Journal (shaft supported on No. 1 and No. 7)	0.005 in.	0.127 mm
Front Oil Seal Installation Depth		
Production	0.125 in.	3.175 mm
Service Replacement	0.219 in.	5.563 mm
Main Journal to Bearing Clearance	0.0022–0.0056 in.	0.056–142 mm
Front and Rear Oil Seals Square to Crankshaft (Must Be Held Relative to Main Bearing Bores)	0.010 in.	0.254 mm
Rear Oil Seal Installation Depth		
Production	0.344 in.	8.738 mm
Service Replacement	0.250 in.	6.350 mm
CYLINDER BLOCK		
Deck Flatness	0.002 in.	0.0508 mm
Dowel Pin Holes (flywheel housing to block mounting)	0.6237–0.6247 in.	15.8420–15.8674 mm
Cylinder Bore in Block (upper)	5.501–5.500 in.	139.725–139.970 mm
Cylinder Bore in Block (lower)	5.1266–5.1250 in.	130.2156–130.1750 mm
Cylinder Bore Out-of-Round or Taper (on diameter) (During manufacturing the cylinder bores are honed with a torque-plate [simulated cylinder head] installed).	0.004 in. max., without torque plate installed	0.1016 mm
Sleeve OD (at upper pilot diameter)	5.5040–5.5030 in.	139.8016–139.7762 mm
Sleeve Bead for Fire Ring (protrusion above sleeve channel)	0.0067–0.010 in.	0.1702–0.2540 mm
Sleeve in Bore (upper press-fit)	0.004–0.002 in.	0.1016–0.0508 mm
Sleeve in Bore (lower loose fit)	0.0029–0.0003 in.	0.0737–0.0076 mm
Main Bearing Bore in Block	4.818–4.817 in.	122.3772–122.3518 mm
Main Bearing-to-Crankshaft Journal Clearance	0.0022–0.0056 in.	0.0559–0.1422 mm
Main Bearing ID (in place)	4.502–4.4996 in.	104.3508–114.2898 mm
Note: Extension of the cylinder sleeve above the cylinder block deck can vary under the same head, as long as all are within the 0.023–0.029 inch (0.584–0.737 mm) specification.		
Cyl. Sleeve Flange Channel to Block Deck (Do Not Measure from Top of Bead)	0.023–0.029 in.	0.584–0.737 mm
Cyl. Sleeve ID (Installed, See “NOTE 8 — CYLINDER SLEEVE ID” on page 328.)	4.8755–4.877 in.	123.838–123.876 mm
EUP Tappet Bore	1.7320–1.7336 in.	43.993–44.033 mm
EUP Tappet OD	1.7299–1.7307 in.	43.939–43.960 mm
EUP Tappet-to-Bore Clearance	0.0013–0.0037 in.	0.033–0.094 mm

5_106_00.bk Page 315 Friday, August 4, 2000 11:17 AM

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Valve Roller Follower Bore	1.1245–1.1255 in.	28.562–28.588 mm
Valve Roller Follower OD	1.122–1.123 in.	28.499–28.524 mm
Valve Roller Follower-to-Bore Clearance	0.0015–0.0035 in.	0.038–0.089 mm
Valve Roller Follower H-Ring Bore	1.1245–1.1255 in.	28.562–28.588 mm
Valve Roller Follower H-Ring OD	1.1261–1.1265 in.	28.603–28.613 mm
Valve Roller Follower H-Ring-to-Bore Press Fit	0.0006–0.0020 in.	0.015–0.051 mm
CYLINDER HEAD		
Alignment Across Exhaust Ports	0.005 in.	0.127 mm
Deck Flatness (over 18 in./45.72 cm)	0.0015 in.	0.0381 mm
Overall Height	6.391–6.397 in.	162.331–162.484 mm
Fire Ring Groove (width)	0.030–0.036 in.	0.762–0.914 mm
Fire Ring Groove (depth)	0.005–0.013 in.	0.127–0.330 mm
Fire Ring Groove (ID)	5.137–5.139 in.	130.479–130.531 mm
Valve Guide OD	0.6886–0.6881 in.	17.4904–17.4777 mm
Valve Guide Ream ID (after installation, inlet and exhaust, used with 3/8 valve stem)	0.3745–0.3755 in.	9.5123–9.5377 mm
Top End of Valve Guide to Valve Spring Seat	0.959 ± 0.040 in.	24.359 ± 1.016 mm
Valve Guide Bore in Head	0.686–0.687 in.	17.424–17.450 mm
Valve Guide to Bore (press-fit)	0.0011–0.0026 in.	0.0279–0.0660 mm
Valve Guide Extension (fire deck to top of guide)	5.24 ± 0.03 in.	113.096 ± 0.762 mm
Yoke Guide Pin OD	0.4389–0.4392 in.	11.1481–11.1557 mm
Yoke Guide Pin Installed Height	1.848–1.918 in.	46.939–48.717 mm
Valve Seat Width (inlet and exhaust)	0.051–0.081 or 1/16 ± 1/64 in.	1.295–2.057 or 1.588 ± 0.397 mm
Valve Seat Insert Face Angle (inlet)	20° 30′ ± 15′	
Valve Seat Insert Face Angle (exhaust)	30° –0′/+30′	
Valve Seat-to-Guide Runout	0.002 in. F.I.M.	0.0508 mm
Valve Seat Insert Counterbore Diameter (inlet)	1.8285–1.8295 in.	46.4439–46.4693 mm
Valve Seat Insert Counterbore Diameter (exhaust)	1.6875–1.6885 in.	42.8625–42.8879 mm
Valve Seat OD (inlet)	1.831–1.832 in.	46.507–46.533 mm
Valve Seat OD (exhaust)	1.692–1.693 in.	42.977–43.002 mm
Valve Seat Insert (inlet, press-fit in head)	0.0015–0.0035 in.	0.0381–0.0889 mm
Valve Seat Insert (exhaust, press-fit in head)	0.0035–0.0055 in.	0.0889–0.1397 mm
Valve Seat Counterbore Depth (inlet)	0.360–0.364 in.	9.144–9.246 mm
Valve Seat Counterbore Depth (exhaust)	0.372–0.376 in.	9.449–9.550 mm
Injection Nozzle Holder Insert Bore		
Upper and 2nd Bore	1.0740–1.0754 in.	27.280–27.315 mm
Lower Bore	1.058–1.060 in.	26.873–26.924 mm
Lobing (Max. per 30-degree Segment)	0.0004 in.	0.010 mm
Injection Nozzle Holder Insert OD		
Upper and 2nd Sealing Diameters	1.0773–1.0781 in.	27.363–27.384 mm
Lower Sealing Diameter	1.06145–1.06225 in.	26.961–26.981 mm

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
FLYWHEEL AND HOUSING		
Dowel Pin Hole, Flywheel Housing (round pin, LH)	0.6259–0.6263 in.	15.8979–15.9080 mm
Dowel Pin Hole, Flywheel Housing (blade pin, RH)	0.6831–0.6835 in.	17.3507–17.3609 mm
Dowel Pin Diameter (round pin, LH)	0.6251–0.6253 in.	15.8775–15.8826 mm
Dowel Pin Diameter (blade pin, RH)	0.6251–0.6253 in.	15.8775–15.8826 mm
Cylinder Block End	0.6251–0.6253 in.	15.8775–15.8826 mm
Flywheel Housing End	0.6820–0.6825 in.	17.3228–17.3355 mm
Crankshaft Seal Mounting Bore	6.748–6.752 in.	171.3992–171.5008 mm
Starter Motor Mounting Bore	3.625–3.629 in.	92.075–92.117 mm
Transmission Mounting Face Axial Runout	0.008 in. TIR (Max)*	0.203 mm TIR (Max)*
Transmission Pilot Bore Radial Runout	0.010 in. TIR (Max)*	0.254 mm TIR (Max)*
Rear Seal Bore Radial Runout (See “NOTE 9 — REAR SEAL BORE RADIAL RUNOUT” on page 328.)	0.009 in. TIR (Max)*	0.2329 mm TIR (Max)*
* Note: Must be held relative to main bearing bores. Check runout with an alignment bar installed through the cylinder block main bearing bores.		
FUEL SUPPLY PUMP		
Pump Gear End Play (steel gear)	0.008 in. (Max)	0.203 mm (Max)
Pump Gear End Play (plastic gear)	0.019 in. (Max)	0.483 mm (Max)
IDLER GEAR		
Gear Journal Clearance	0.0022–0.0045 in.	0.056–0.114 mm
Gear End Play	0.003–0.009 in.	0.076–0.228 mm
JACOBS ENGINE BRAKE		
Slave Piston Lash Adjustment	0.015 in.	0.381 mm
OIL PUMP		
Gear to Cover End Clearance	0.0035–0.0060 in.	0.089–0.152 mm
Oil Pump OD to Cavity Clearance	0.003–0.0045 in.	0.076–0.114 mm
Oil Pump Gear Backlash (Inside Pump)	0.018–0.035 in.	0.457–0.889 mm
Oil Pump Drive Gear to Driven Gear Backlash	0.008–0.016 in.	0.203–0.406 mm
Relief Valve Spring (free length)	6.4 in.	162.6 mm
Relief Valve Spring Pressure (compressed to 5.56 in./14.12 cm)	63 lbs.	28.6 kg
Relief Valve Opening Pressure	90–115 psi	621–793 kPa
PISTON		
Top Extension Above/Below Cyl. Block Deck at TDC	+0.020 to –0.002 in.	+0.508 to –0.051 mm
Wrist Pin Bore	2.2501–2.2509 in.	57.153–57.173 mm
Wrist Pin Length	3.820–3.825 in.	97.028–97.155 mm
Wrist Pin-to-Piston/Bore Clearance (The 2-piece piston crown had bushings prior to mid-1999, and no bushings after that date. Both versions have the same clearance specifications.)	0.0012–0.0021 in.	0.0297–0.0547 mm
Wrist Pin OD	2.24875–2.24895 in.	57.11825–57.12333 mm
Piston-to-Liner Clearance (2-piece piston, 90 degrees from pin axis)	0.0030–0.0050 in.	0.0762–0.1270 mm

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Ring Groove Service Limit, Top (over 0.120 in./3.048 mm pins)	4.912 in.	124.765 mm
PISTON RINGS		
Compression Ring End Gap (No. 349GC3101)	0.016–0.028 in.	0.406–0.711 mm
Compression Ring End Gap (No. 349GC3102)	0.013–0.025 in.	0.330–0.635 mm
Oil Control Ring End Gap (No. 350GC340)	0.013–0.028 in.	0.330–0.711 mm
Piston Ring Side Clearance (new)	0.0016–0.0030 in.	0.0406–0.0762 mm
Piston Ring Side Clearance (used)	Maximum 0.0045 in.	Maximum 0.1143 mm
Note: End gap checked in 4.875 gauge diameter. For every 0.001-inch (0.0254-mm) increase in gauge diameter, ring gap will increase by 0.003 inch (0.076 mm). Refer to a MACK branch or dealer for specifications for piston ring part numbers not listed above.		
ROCKER ARM		
Rocker Arm Ratio	1.5:1	
Rocker Arm Hole ID	1.1306–1.1326 in.	28.7172–28.7680 mm
Rocker Arm Hole-to-Shaft Clearance	0.004–0.0015 in.	0.1016–0.0381 mm
Rocker Arm Shaft OD	1.1286–1.1291 in.	28.6664–28.6791 mm
Push Rod Overall Length (from ball end, 0.560 in./14.224 mm ball placed in cup)	14.108–14.170 in.	358.343–359.918 mm
TIMING GEAR AND FRONT COVER		
Idler Gear to Camshaft Gear Backlash	0.001–0.008 in.	0.025–0.203 mm
Camshaft Gear to Auxiliary Shaft Gear Backlash	0.001–0.009 in.	0.025–0.229 mm
Camshaft Gear to Fuel Supply Pump Gear Backlash	0.001–0.008 in.	0.025–0.203 mm
Crankshaft Gear to Idler Gear Backlash	0.001–0.008 in.	0.025–0.203 mm
Dowel Pin Holes (both, in cylinder block)	0.4987–0.4997 in.	12.6670–12.6924 mm
Dowel Pin Hole (round pin, in front cover, RH)	0.5005–0.5012 in.	12.7127–12.7305 mm
Dowel Pin Hole (blade pin, in front cover, LH)	0.5577–0.5584 in.	14.1656–14.1834 mm
Dowel Pin OD (round pin, RH)	0.5001–0.5003 in.	12.7025–12.7076 mm
Dowel Pin OD (blade pin, in cylinder block, LH)	0.5001–0.5003 in.	12.7025–12.7076 mm
Dowel Pin OD (blade pin, in front cover, LH)	0.5570–0.5575 in.	14.1478–14.1605 mm
Crankshaft Seal Mounting Bore	3.9995–4.0025 in.	101.5873–101.6635 mm
Timing Gear Cover Seal Mounting Bore to Crankshaft Runout	0.015 in. TIR (Max)	0.381 mm TIR (Max)
Timing Gear Cover Seal Square to Crankshaft	0.010 in. (Max)	0.254 mm (Max)
Hydraulic Steering Pump Mounting Bore	3.2525–3.2545 in.	82.6135–82.6643 mm
Note: Must be held relative to main bearing bores. Check runout with an alignment bar installed through the cylinder block main bearing bores.		
TURBOCHARGER		
Shaft End Play (models S300, S400)	0.003–0.006 in.	0.0762–0.1524 mm
Bearing Radial Check (measured at bearings)	0.018–0.029 in.	0.4572–0.7366 mm
VALVES		
Lash Setting (Rocker Arm to Valve Guide Yoke Clearance) Cold*		
Inlet (adjustment at scheduled intervals)	0.016 in.	0.406 mm

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Inlet (acceptable range for interim checks)	0.012–0.020 in.	0.305–0.508 mm
Exhaust (adjustment at scheduled intervals)	0.024 in.	0.601 mm
Exhaust (acceptable range for interim checks)	0.020–0.028 in.	0.508–0.711 mm
* ‘Note: Valve Yoke Setting must be completed at each location with the respective piston at TDC firing position prior to setting the (cold static) rocker arm lash. (See procedure in this manual for engines with J-Tech™ Brake.)		
Valve Face to Deck (inlet)	+0.0425 ± 0.007 in.	+1.0795 ± 0.1778 mm
Valve Face to Deck (exhaust)	–0.021 ± 0.007 in.	–1.5334 ± 0.1778 mm
Valve Stem-to-Guide (inlet)	0.0015–0.0035 in.	0.0381–0.0889 mm
Valve Stem-to-Guide (exhaust)	0.0025–0.0045 in.	0.0635–0.1143 mm
Valve Stem OD (inlet, 3/8 in.)	0.373–0.372 in.	9.474–9.449 mm
Valve Stem OD (exhaust, 3/8 in.)	0.3720–0.3710 in.	9.4488–9.4234 mm
VALVE SEAT ANGLE		
Exhaust	30° + 0´/– 30´	
Inlet	20° 30´ ± 15´	
VALVE SPRINGS		
Free length	2.830 in.	71.882 mm
Spring pressure — when compressed to 1.5 in. (38.1 mm)	190–210 lbs	86.184–95.256 kg

E-Tech™ Component Torque Specifications

NOTE

All components are to be clean and free from foreign material or corrosion. Assemblies are to be made using suitable tools and procedures so that no permanent damage will occur as a result of the assembly.

Threads, washer and underhead of screw or washer face of nuts should be lubricated with engine oil, unless otherwise specified.

The following listed fasteners require the use of a calibrated manual torque wrench.

Fasteners noted by a star * require retorque after engine run-in.

TORQUE SPECIFICATIONS FOR CRITICAL FASTENERS

CRITICAL FASTENERS

Fastener Name	Torque	
	Lb-Ft	**N•m**
AIR COMPRESSOR		
Air Compr. Coupling to Air Compr. Retaining Nut	60	81
Air Compr. to Cyl. Block Mounting Screw	80 (Dry)	108 (Dry)
AUXILIARY DRIVE		
Aux. Shaft Gear Retaining Nut (See “NOTE 1 — AUXILIARY SHAFT GEAR RETAINING NUT INSTALLATION” on page 328.)	300 (Dry)	405 (Dry)
Aux. Shaft Thrust Washer to Block Screw	15	20
Aux. Shaft Hole Cover Stud Nut	40	55
BRAKE COMPONENTS — JACOBS		
Oil Supply Screw	4-6	5-8
Jake Brake Housing Hold-Down Screw	45	61
Rocker Arm Adjusting Screw Jam Nut	40	55
Cyl. Head Cover Mounting Screw	16	22
Slave Piston Adjusting Screw Jam Nut	25	34
Yoke Adjusting Screw Nut (locknut on actuator pin screw)	33	44
CAMSHAFT		
Camshaft Thrust Washer to Cyl. Block Screw	15	20
CONNECTING ROD		
Connecting Rod Screw Angle Torque (Rods utilizing M14 threads, and cap-to-rod alignment sleeves)	30 + 90°	41 + 90°
Connecting Rod Screw (Rod utilizing M16 threads, and **no** cap-to-rod alignment sleeves)	150	203

SPECIFICATIONS

Fastener Name	Torque	
	Lb-Ft	**N•m**
CRANKSHAFT		
Vibration Damper Hub to Crank Screw	360	490
Vibration Damper to Hub Screw	45	61
CYLINDER BLOCK		
Main Bearing Capscrew (See “NOTE 2 — MAIN BEARING CAP INSTALLATION” on page 328.)	210	285
Cylinder Block Main Brg. Cap Buttress Screw (See “NOTE 2 — MAIN BEARING CAP INSTALLATION” on page 328.)	95	128
CYLINDER HEAD		
Cylinder Head Capscrew* (See “NOTE 3 — CYLINDER HEAD TORQUING” on page 328.)	205	278
Cylinder Head Cover Screw*	16	22
Inlet Manifold to Cyl. Head Screw	40	55
ELECTRONIC UNITS		
EECU to Cyl. Block Mtg. Screw	31	42
EECU Isolating Studs	18	24
EECU Mounting Nuts	15	20
EECU Cooling Plate Screw	12	16
Electronic Unit Pump Terminal Screw	13 lb-in ± 2 lb-in	1.5 ± 0.2
Electronic Unit Pump to Cyl. Block Screw	42	57
FAN DRIVE		
Fan Drive Pulley to Hub Screw	25	34
Poly-V Belt Tensioner Mounting Screw	40	55
FLYWHEEL, FLYWHEEL HOUSING AND CLUTCH		
Flywheel Hsg. to Cylinder Block Screw	170	230
Flywheel to Crankshaft Screw	185	250
Clutch to Flywheel Mounting Screw	40	55
Transmission to Flywheel Hsg. Screw	40	55
FUEL SYSTEM		
Fuel Filter Brkt. to Inlet Mfld. Screw	35	47
Fuel Supply Gallery Fitting Locknut	27	37
Fuel Return Gallery Ftg. (Check Valve) Locknut	27	37
Fuel Supply Pump to Cyl. Block Screw	40	55
INJECTOR NOZZLE AND NOZZLE FUEL INLET TUBE		
Inj. Nozzle Holder Hold-Down Screw	45	61
Noz. Fuel Inlet Tube Clamp Screw to Cyl. Head	35	47
Noz. Fuel Inlet Tube Nut at Cylinder Head	25	34
Noz. Fuel Inlet Tube Nut at EUP	25	34
OIL COOLER – Bundle-Type		
Oil Cooler Fitting to Water Pump Mounting Screw	60	81
Oil Cooler Oil Inlet and Outlet Tube Flange Mounting Screw	40	55
Oil Cooler/Oil Filter Fitting to Oil Filter Mounting Adapter Screw	40	55

SPECIFICATIONS

Fastener Name	Torque	
	Lb-Ft	N•m
Oil Cooler Water Inlet and Water Outlet Ftg. to Oil Cooler Screw	20	27
OIL COOLER – Plate-Type		
Oil Cooler Tube to Water Pump (MR Model Stud)	20	27
Oil Cooler Tube to Water Pump	40	55
Oil Cooler to Brkt.	20	27
Oil Cooler/Oil Filter Brkt. Fittings 1/4 NPT (Turbo, REPTO)	12	16
Oil Cooler/Oil Filter Brkt. to Cylinder Block	40	55
OIL FILTER		
Centrifugal Oil Filter Drain Fitting Stud Nut	40	55
Centrifugal Oil Filter Mounting Adapter	150	203
Centri-Max Plus Spindle (LSR)	15	20
Centri-Max Plus Cover (LSR)	15	20
Oil Filter Pedestal to Cyl. Block Screw	60	81
Oil Filter Relief Valve Plunger Spring Cap	100	135
Oil Filter Adapter to Oil Cooler Brkt. Screw	40	55
OIL PAN		
Oil Pan Drain Plug	55	75
Oil Pan to Cyl. Block Fastener (8 mm Screw)	23	31
Oil Pan to Cyl. Block Shoulder Bolt/Stud	15	20
OIL PUMP		
Oil Pump Cover to Housing Screw	15	20
Oil Pump to Cyl. Block Mtg. Screw	40	55
Oil Pump Shaft Driven Gear Retaining Nut	60	81
Oil Pump Inlet Ftg. to Oil Pump Hsg. Screw	35	47
Oil Pump Pressure Relief Valve Cap	80	108
PISTON COOLING		
Piston Cooling Nozzle to Cyl. Block Screw	15	20
SENSORS (FOR DASH DISPLAY)		
Coolant Temp. (1/2 NPT, Side Mount on Water Manifold)	23	31
Oil Temp. (1/4 NPT, Mount on Oil Filter Pedestal	18	24
Oil Temp. (1/2 NPT, Side Mount on Oil Pan)	23	31
SENSORS (V-MAC III)		
Ambient Air Temperature (1/2 NPT)	23	31
Boost Air Temperature (M16 x 2)	28	38
Coolant Temperature (3/8 NPT, Rear Mount on Water Manifold)	23	31
Fuel Temperature (3/8 NPT)	23	31
Oil Pressure (M10 x 1.5)	12	16
Engine Speed & Position (Flywheel Hsg. and Engine Front Cover)	7	10
TIMING GEAR COVER (ENGINE FRONT COVER)		
Breather Mounting Screws	15	20
Timing Cover and Frt. Support Brkt. to Cyl. Block Screw	70	95

SPECIFICATIONS

Fastener Name	Torque Lb-Ft	Torque N•m
Timing Cover to Cyl. Block Screw	40	55
TURBO AND EXHAUST MANIFOLD		
Turbo to Exhaust Manifold Stud Nut	40	55
Turbo Oil Inlet Tube to Turbo Screw	15	20
Turbo Oil Drain Tube to Turbo Screw	15	20
Exh. Mfld. to Cyl. Head Stud (Install with Loctite® 272. See "NOTE 4 — EXHAUST MANIFOLD TORQUING" on page 328.)	20 (Dry)	27 (Dry)
Exh. Mfld. to Cyl. Head Stud Nut (12 mm Full Threaded Stud, See "NOTE 4 — EXHAUST MANIFOLD TORQUING" on page 328)	80	109
Oil Fill/Turbo Drain to Block Screw	40	55
VALVE ROCKER ARM		
Valve Rocker Arm Bracket to Cylinder Head Screw	40	55
Valve Rocker Arm Adjusting Screw Jam Nut	40	55
Valve Yoke Adjusting Screw Jam Nut (See "NOTE 5 — VALVE YOKE SETTING" on page 328.)	33	45
Valve Rocker Arm Shaft Locating Screw	23	31
WATER MANIFOLD AND WATER PUMP		
Water Pump Shaft Locknut	80	108
Water Manifold to Cylinder Head Screw	33	44
Water Pump Housing to Cylinder Block Screw	60	81
Water Pump Cover to Water Pump Hsg. Screw	15	20
MISCELLANEOUS		
Alternator Mtg. Stud Nut	70	95
Coolant Conditioner Adapter/Thermostat Housing Mounting Screw	15	20
Heat Shield-to-Cylinder Block Mounting Studs	15	20
Heat Shield Mounting Nuts	15	20
Heat Shield Standoff Studs	18	24
Hydraulic Steering Pump to Engine Front Cover Stud Nut	40	55
Idler Gear Hub to Cyl. Block Screw	70	95
Oil Dipstick Guide Tube Compression Nut	24	33

TORQUE SPECIFICATIONS FOR HOSE CLAMPS

HOSE CLAMPS (SEE “NOTE 6 — HOSE CLAMP INSTALLATION POSITIONING INFORMATION” ON PAGE 328)

Fastener Name	Torque	
	Lb-In	N•m
For Standard SAE J536 Type F Hose Clamps		
Air Inlet Systems	38	4
Oil Drain Systems	28	3
Water or Coolant Systems	28	3
Hi-Torque Heavy-Duty Worm Clamp	80	9
T-Bolt Type Hose Clamp	50	6

TORQUE SPECIFICATIONS FOR PIPE PLUGS

PIPE PLUGS (SEE “NOTE 7 — PIPE PLUG SEALING” ON PAGE 328)

Pipe Plug Size	Torque	
	Lb-Ft	N•m
1/8 NPT	6	8
1/4 NPT	18	24
3/8 NPT	23	31
1/2 NPT	23	31
3/4 NPT — Cylinder Head 3/4 NPT — Other	55 35–65	68 48–88
1 NPT	43	58
1-1/4 NPT	75	101

5_106_00.bk Page 324 Friday, August 4, 2000 11:17 AM

TORQUE SPECIFICATIONS FOR ENGINE-MOUNTED SENSORS

E-TECH™ ENGINE-MOUNTED SENSORS

Description	Sensor and Sensor Mounting Hardware	Sensor Threads	Mounting Torque
V-MAC III Engine Speed Sensor	64MT348M sensor and 505GC28 P15 and P30 shims, as required. Sensor is retained by one 66AM3 capscrew with M6 x 1.0 metric threads.	None	7 lb-ft (10 N•m)
V-MAC III Fuel Temperature Sensor	64MT2103 sensor only	3/8-inch NPT English pipe threads	23 lb-ft (31 N•m)
V-MAC III Oil Pressure Sensor	64MT2114 sensor only	1/8-inch NPT English pipe threads	12 lb-ft (16 N•m)
V-MAC III Boost Air Temperature Sensor	64MT2102 sensor only (no washer required; replaces sensor P/N 64MT2111M sensor and washer P/N 57AM5)	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
V-MAC III Boost Pressure Sensor (Optional and Electronic Dash)	46MT2101	1/4-inch NPT	18 lb-ft (24 N•m)
Ambient Air Temperature Sensor (Mounted on front of chassis)	64MT2118M	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
Dash Gauge Coolant Temperature Sensor	64MT2112M sensor only	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
V-MAC III Coolant Temperature Sensor	64MT2103 sensor only	3/8-inch NPT English pipe threads	23 lb-ft (31 N•m)
V-MAC III Engine Position Sensor	64MT348M sensor and 505GC28 P15 and P30 shims, as required. Sensor is retained by one 66AM3 capscrew with M6 x 1.0 metric threads.	None	7 lb-ft (10 N•m)
Dash Gauge Oil Temperature Sensor (Standard Dash) **Non-Current**	64MT2112M (Sensor mounts in oil pan)	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
Dash Gauge Oil Temperature Sensor (Electronic Dash) **Non-Current**	64MT2113M (Sensor mounts in oil pan)	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
Dash Gauge Oil Temperature Sensor (Standard Dash) **Current Production**	64T2116 (Sensor mounts in oil filter pedestal)	3/8-inch NPT English pipe threads	20 lb-ft (27 N•m)
Dash Gauge Oil Temperature Sensor (Electronic Dash) **Current Production**	64MT2103 (Sensor mounts in oil filter pedestal)	3/8-inch NPT English pipe threads	20 lb-ft (27 N•m)

CAUTION

Overtorquing a sensor or sensor mounting screw can result in sensor breakage or thread damage.

5_106_00.bk Page 325 Friday, August 4, 2000 11:17 AM

TORQUE SPECIFICATIONS FOR NON-CRITICAL FASTENERS

PROPERTY CLASS 8.8

Size (mm)	Pitch	Tightening Torques	
		Lb-Ft	N•m
6	0.75	6	8
6	1.00	6	8
8	1.00	15	20
8	1.25	14	19
10	1.25	30	41
10	1.50	28	38
12	1.25	55	75
12	1.75	50	68
14	1.50	86	117
14	2.00	80	109
16	1.50	133	180
16	2.00	124	168
18	1.50	193	262
18	2.50	172	233
20	1.50	270	366
20	2.50	244	331
22	1.50	365	495
22	2.50	332	450
24	2.00	459	622
24	3.00	421	571
27	2.00	666	903
27	3.00	618	838
30	2.00	928	1258
30	3.50	838	1136
33	2.00	1250	1695
33	3.50	1140	1546
36	3.00	1551	2103
36	4.00	1465	1986

PROPERTY CLASS 9.8

Size (mm)	Pitch	Tightening Torques	
		Lb-Ft	N•m
6	0.75	7	10
6	1.00	6	8
8	1.00	16	22
8	1.25	15	20
10	1.25	33	45
10	1.50	31	42
12	1.25	59	80
12	1.75	54	73
14	1.50	94	127
14	2.00	87	118
16	1.50	144	195
16	2.00	135	183
18	1.50	210	285
18	2.50	187	254
20	1.50	293	397
20	2.50	264	358
22	1.50	395	536
22	2.50	360	488
24	2.00	498	675
24	3.00	456	618
27	2.00	722	979
27	3.00	669	907
30	2.00	1005	1363
30	3.50	908	1231
33	2.00	1355	1837
33	3.50	1235	1674
36	3.00	1681	2279
36	4.00	1587	2152

PROPERTY CLASS 10.9

Size (mm)	Pitch	Tightening Torques Lb-Ft	Tightening Torques N•m
6	0.75	9	12
6	1.00	8	11
8	1.00	21	29
8	1.25	20	27
10	1.25	42	57
10	1.50	40	54
12	1.25	76	103
12	1.75	69	94
14	1.50	120	163
14	2.00	111	151
16	1.50	184	250
16	2.00	172	233
18	1.50	268	363
18	2.50	239	324
20	1.50	374	507
20	2.50	337	457
22	1.50	505	685
22	2.50	460	624
24	2.00	636	862
24	3.00	583	790
27	2.00	922	1250
27	3.00	855	1159
30	2.00	1284	1741
30	3.50	1159	1571
33	2.00	1730	2346
33	3.50	1578	2140
36	3.00	2146	2910
36	4.00	2027	2748

5_106_00.bk Page 328 Friday, August 4, 2000 11:17 AM

SPECIFICATION FOOTNOTES

NOTE 1 — AUXILIARY SHAFT GEAR RETAINING NUT INSTALLATION

- A new nut has pre-applied thread locker. No degreasing of a new nut is recommended. However, degrease shaft threads thoroughly with Loctite® Primer-T, or equivalent, prior to nut installation.
- It is acceptable to reuse an auxiliary drive gear retaining nut. If reusing a nut, the nut threads, as well as the shaft threads, must also be thoroughly cleaned with Loctite® Primer-T, or equivalent, and Loctite® 277 used on the nut and shaft threads.

NOTE 2 — MAIN BEARING CAP INSTALLATION

Main bearing cap assembly shall be performed in the following steps:

1. Buttress screws installed finger-tight in order to align the hole in the block and the hole in the main bearing cap.
2. Main bearing capscrews torqued.
3. Buttress screws torqued.

NOTE 3 — CYLINDER HEAD TORQUING

Cylinder head assembly and torquing is to be performed as follows:

1. Oil all cylinder head capscrew bosses, capscrew threads and washers with engine oil prior to assembly. Do not oil threads in cylinder block. Using torque wrench J 24407, or equivalent, tighten capscrews to specification in three stages on any one head in the proper sequence, as shown in the Engine Reassembly procedures section.
   a. Initially, torque all capscrews in sequence to 50 lb-ft (68 N•m).
   b. Tighten all capscrews in sequence to 125 lb-ft (170 N•m).
   c. Tighten all capscrews in sequence to the final torque value of 205 lb-ft (278 N•m).
2. After run-in procedure, in sequence, back off each capscrew individually until free. Then retorque same capscrew to 205 lb-ft (278 N•m).

NOTE 4 — EXHAUST MANIFOLD TORQUING

Torque exhaust manifold nuts to 35 lb-ft (47 N•m) in a top-to-bottom sequence. Retorque to 80 lb-ft (109 N•m) following the same top-to-bottom sequence.

NOTE

On some E-Tech™ engines, the exhaust manifold-to-cylinder head stud hole may be drilled deep enough to allow the stud to enter the push rod bore. In these instances, the 20 lb-ft (27 N•m) torque may not be reached until the stud contacts the push rod. In all cases, a stud protrusion of 1.75 inch (44.45 mm) must be maintained.

NOTE 5 — VALVE YOKE SETTING

1. Push down on the slipper face of yoke. Turn down yoke adjusting screw until it contacts outboard valve stem tip, as sensed by light drag on adjusting screw.
2. Turn adjusting screw an additional 60 degrees (1/6 turn) clockwise.
3. Holding yoke adjusting screw in this position, lock jam nut.

NOTE 6 — HOSE CLAMP INSTALLATION POSITIONING INFORMATION

The band of any hose clamp in all installations should be a minimum of 0.090 inch (2.3 mm) from the end of the hose and must be clear of tube bead.

NOTE 7 — PIPE PLUG SEALING

All pipe plugs must be sealed using Loctite® PST pipe thread sealant with Teflon®, or equivalent.

NOTE 8 — CYLINDER SLEEVE ID

Cylinder sleeve ID may be 4.872 inch (123.749 mm) minimum at top of sleeve due to close-in from press fit.

NOTE 9 — REAR SEAL BORE RADIAL RUNOUT

Runout is to be checked with an alignment bar installed through the cylinder block main bearing bores.

E-TECH™ ENGINE LUBRICANT AND SEALANT SPECIFICATIONS

Use only the following recommended sealing compounds and lubricants.

NOTE

All genuine MACK cylinder head gaskets are precoated and do not require any type of sealing compound. Before installing **new** gaskets, degrease both gasket sealing surfaces to avoid leaks.

Location	Sealant or Lubricant
Camshaft gear assembly	Loctite® 609
Cup plugs/threaded plugs	Loctite® 277 or equivalent/Teflon® thread sealer
Injection nozzle holder inserts (upper and lower end)	Loctite® 620
Chassis-mounted charge air cooling system (core sealing)	Dow Corning® No. 1200 primer, Dow Corning® RTV 734 adhesive (clear), and naphtha solvent or equivalent
Cylinder sleeve seat	MACK Silastic (RTV Silicone Adhesive Sealant) part No. 342SX32
Oil filter sealing gasket	Clean engine oil
Holding metal parts in place	MACK MG-C grease or petroleum jelly (Vaseline®)
Valve stems and guides	Dow Corning® BR2 Plus Multi-Purpose Grease
Engine front cover (timing gear cover)	MACK Silastic (RTV Silicone Adhesive Sealant) part No. 342SX32
Engine parts, fasteners (sides and threads), and washers	Clean engine oil
Exhaust manifold studs	Loctite® 272 high temperature thread sealer
Oil cooler assembly	Permatex® gasket sealer
Oil cooler assembly O-ring	Drydene® No. 4000
O-rings (except as noted)	MACK O-ring lubricant part No. 243SX41
Sensor, engine oil pressure	Sealing compound on threads
Sensor, intake manifold temperature	
Sensor, coolant temperature	
Sensor, coolant level	
Crankshaft flange and wear ring	Loctite® 609
Turbocharger mounting nuts	Fel Pro C5A
Centri-Max® PLUS Spindle Threads	Loctite® 271

FASTENER TORQUE

Fastener Selection and Installation

Selection and correct installation of threaded fasteners are essential parts of any assembly or rebuild procedure. Fasteners hold much of a vehicle together. If a fastener fails to do its job properly, it can cause a minor problem such as a loose mirror, or a large problem, such as loss of steering control.

Because there are so many styles of fasteners, in various sizes and quality grades, a mechanic must have a working familiarity with the fasteners commonly used in vehicles. Only in this way can the correct selection and installation of the proper fastener be ensured. Each fastener is intended to do a particular job, and is selected by the vehicle manufacturer for its suitability for that job.

Proper installation is as important as the selection of the correct fastener. Improperly installing a correct fastener is just as bad as using an incorrect one. Undertightening and overtightening both result in an improperly installed fastener. When threaded fasteners are tightened, a slight stretching of the fastener occurs, and it is this stretching that binds the assembly together. If too little tightening occurs, the slight stretching does not happen, and the joint is not clamped securely. If too much tightening occurs, the fastener will be excessively stretched, causing narrowing of the fastener and possibly breaking. Correct and consistent use of a torque wrench ensures the fasteners are properly tightened, and clamping the pieces of the assembly together.

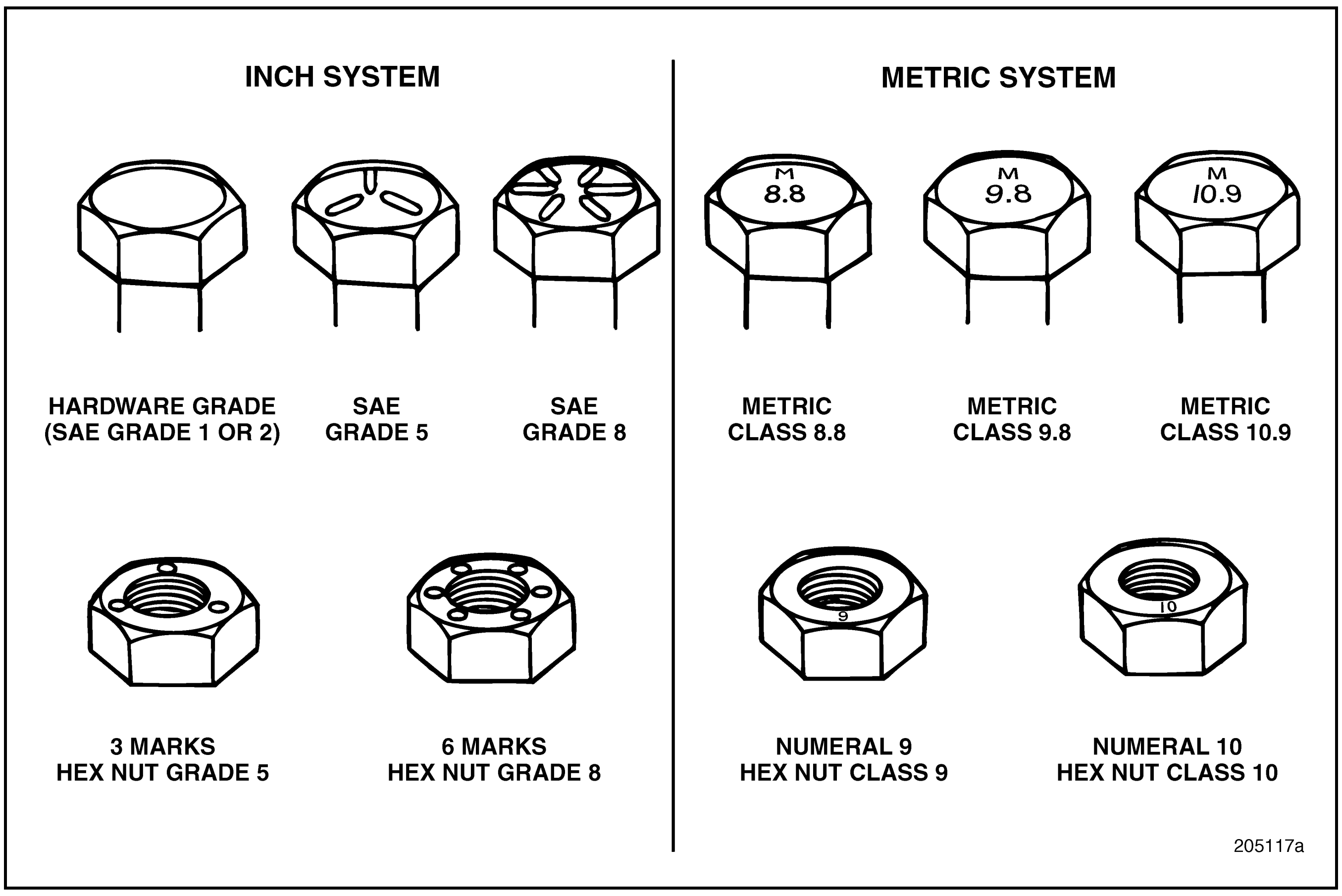


Figure 335 — Fastener Grading System

5_106_00.bk Page 331 Friday, August 4, 2000 11:17 AM

Fastener Sizes and Types

The first and most important fact that the mechanic must know about a fastener is whether it is a U.S. (Inch System) or a metric thread. Next, the size of the fastener, which is usually determined by the diameter of the shank, the length of the fastener, which is usually measured from the bottom of the head to the end of the thread, and the pitch of the threads.

The pitch of U.S. (Inch System) fasteners is measured by determining the number of threads per inch. The two pitches commonly used in vehicles are coarse thread, officially called Unified National Coarse (UNC), and fine thread, officially called Unified National Fine (UNF).

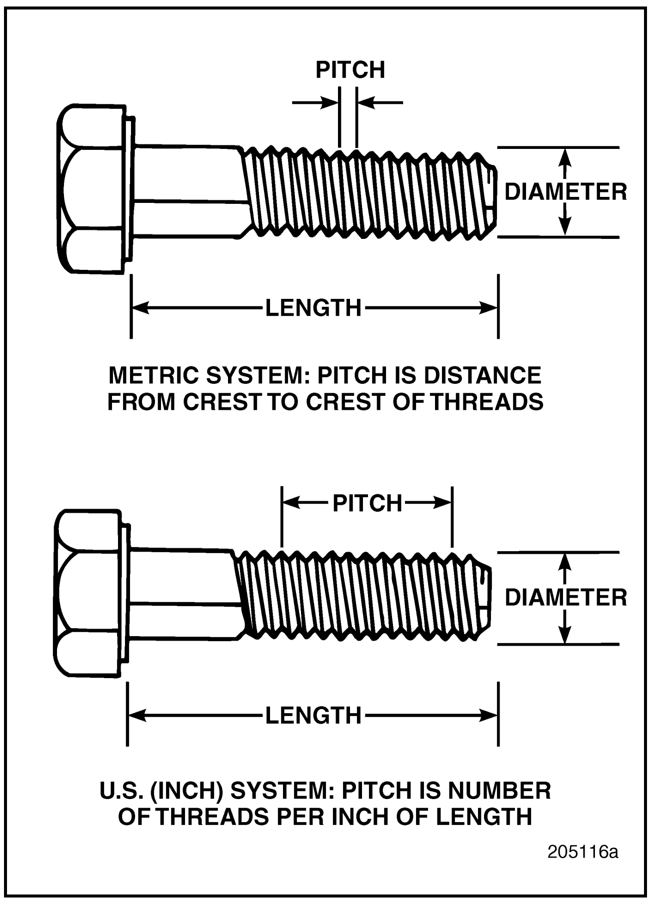


Figure 336 — Fastener Dimensions

The pitch of metric fasteners is measured by determining the millimeters per thread. For example, a bolt with 0.8 pitch would have 125 complete threads in a 100-millimeter section (100 mm divided by 125 threads equals 0.8), and a bolt with 1.0 pitch would have 100 threads in a 100-millimeter section. Pitch may be measured directly, using a ruler and counting the threads. Also, thread pitch gauges are available for both U.S. and metric threads, which make it easy to check the pitch of a fastener.

In the U.S. system, a typical designation would be: 7/16-20 x 1. This describes a bolt that is 7/16 inch in diameter, has 20 threads per inch, and is one inch long. The metric system is similar. A typical metric designation would be: 10 x 0.8 x 25 mm. This describes a bolt that is 10 mm in diameter, has a thread pitch of 0.8 (0.8 mm per thread), and is 25 mm long.

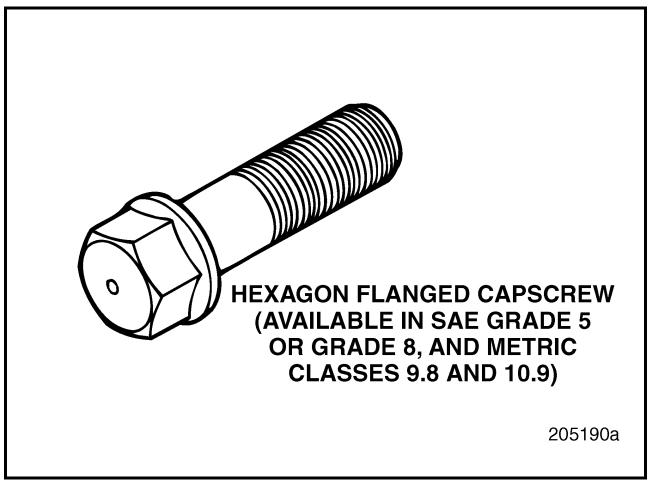


Figure 337 — Flanged Capscrew

5_106_00.bk Page 332 Friday, August 4, 2000 11:17 AM

NOTES

5_106_00.bk Page 333 Friday, August 4, 2000 11:17 AM

SCHEMATICS & DIAGRAMS

ENGINE SYSTEM SCHEMATICS (FLUIDS FLOW)

Cooling System Flow Diagram

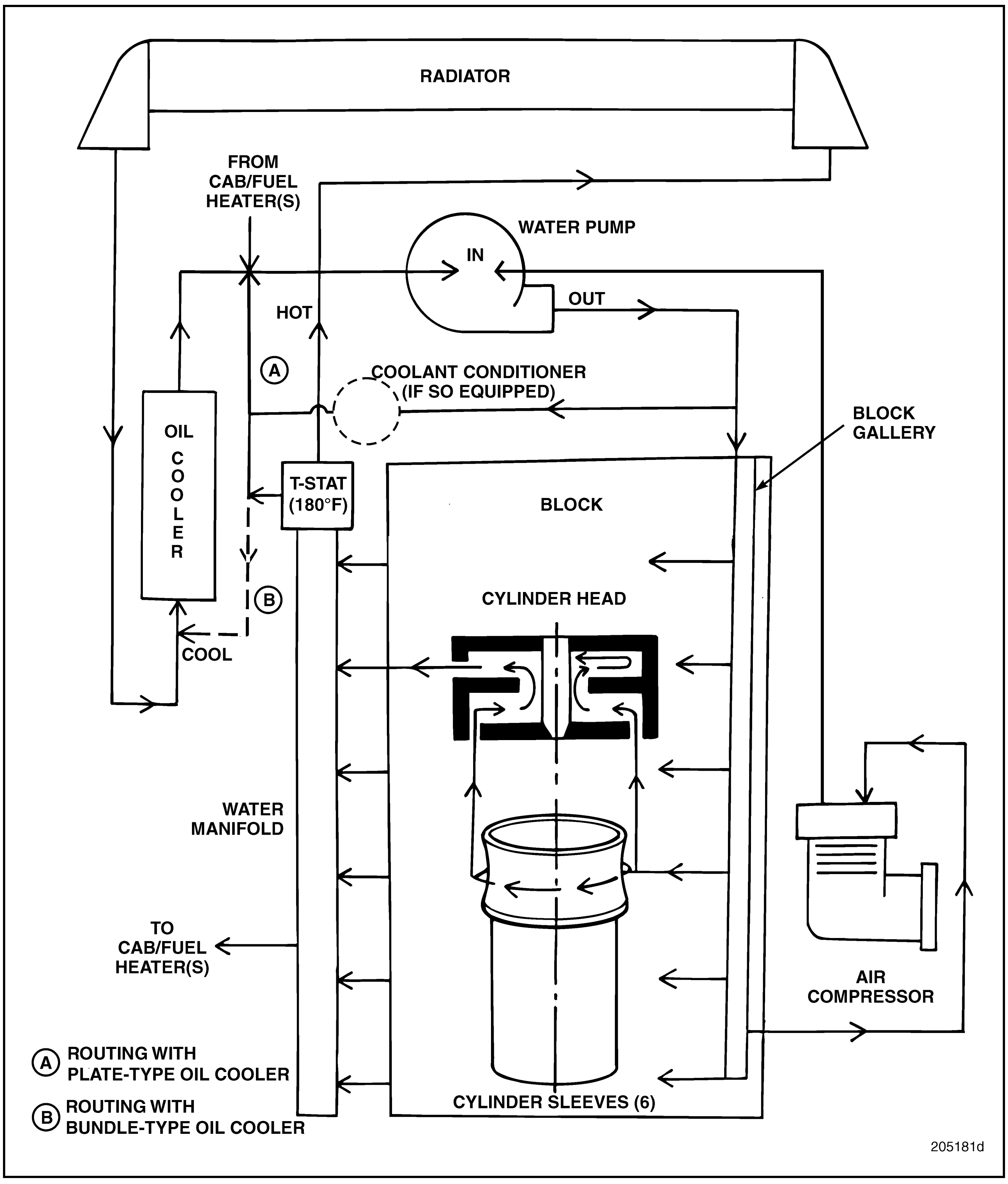


Figure 338 — E-Tech™ Cooling Circuit

Lubrication System Flow Diagram

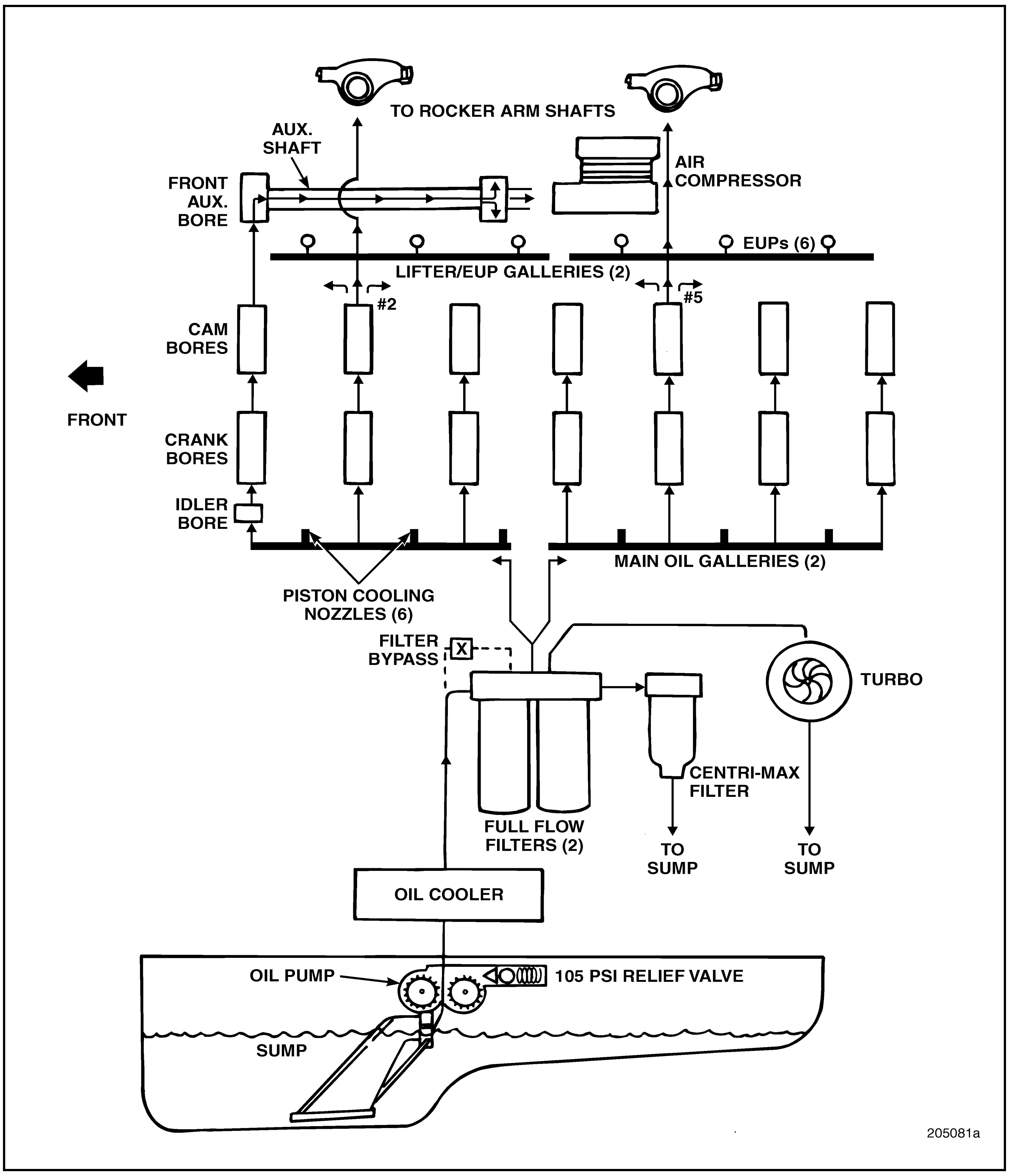


Figure 339 — E-Tech™ Oil Flow Schematic

5_106_00.bk Page 336 Friday, August 4, 2000 11:17 AM

Fuel System Flow Diagram

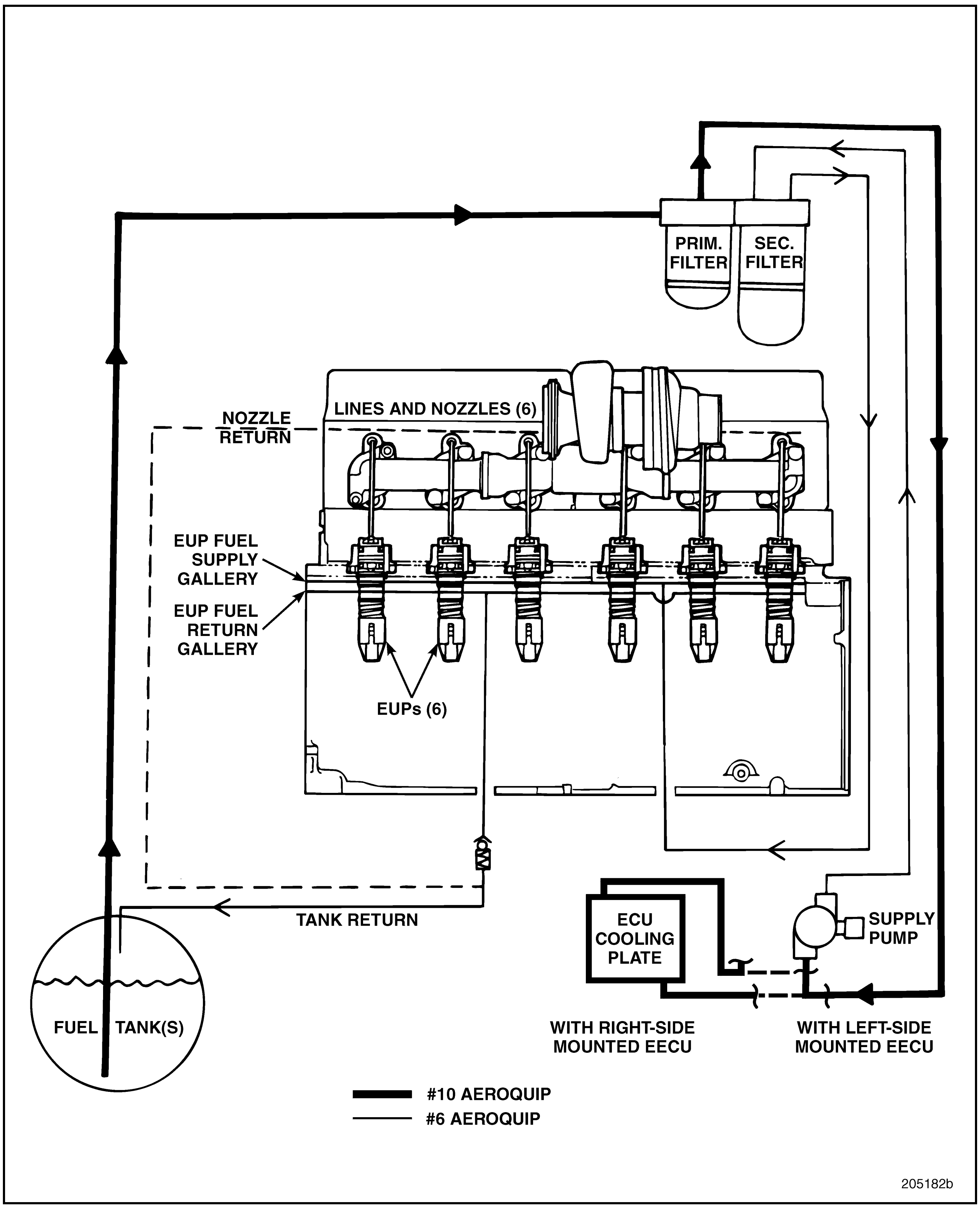


Figure 340 — E-Tech™ Fuel System

5_106_00.bk Page 337 Friday, August 4, 2000 11:17 AM

SPECIAL TOOLS & EQUIPMENT

E-TECH™ ENGINE SPECIAL TOOLS

Special Tools for Engine Overhaul

Tool No.	Description
814	Midget Seal Tool
00-18238	Jacobs Slave Piston Tool
014177	Jacobs Thickness Gauge, 0.085 inch (2.16 mm)
018781	Jacobs Thickness Gauge, 0.080 inch (2.03 mm)
021327	Jacobs Thickness Gauge, 0.100 inch (2.54 mm)
022001	Jacobs Thickness Gauge, 0.060 inch (1.52 mm)
945-6041	Connecting Rod Fixture (Sweeney)
HT77136	Valve Seat Insert Counterbore
J 2619-01	Slide Hammer
J 4558-O1	Flywheel Remover
J 5347-B	Dial Bore Gauge
J 5853-C	Torque Wrench (3/8 DR, 0-600 IN)
J 5902-01	Cylinder Hone and Glaze Breaker
J 6125-1B	Slide Hammer (5/16-18 thread with 3/8-16 adapter)
J 6692-B	Cylinder Compression Gauge
J 7872	Magnetic Base Indicator Tool
J 8092	Universal Driver Handle (threaded 3/4-10)
J 21428-01	Camshaft Bushing Remover and Installer Set
J 21588	Injector Gasket Retriever
J 21834-4A	Two Jaw Adjustable Puller
J 22738-02	Universal Spring Tester, Model MST 50
J 23442	Piston Ring Compressor
J 23775-01	Torque Wrench (100–600 lb-ft)
J 24406	Torque Wrench (15–100 lb-ft)
J 24407	Torque Wrench (30–250 lb-ft)
J 24783	Fuel/Oil Filter Wrench (spin-on)
J 25026-A	Flywheel Lifting Sling
J 26589	Nozzle Insert Carbon Reamer
J 26637-A	Thermostat Seal Installer
J 26948	Depth Gauge
J 29075-B	Fuel Injection Nozzle Tester (use with J 42639 Adapter Set)
J 29109	Engine Stand
J 29294-B	Valve Spring Keeper Remover
J 29296	Valve Yoke Guide Pin Installer
J 29297	Nozzle Sleeve Installer
J 29510	Keystone Piston Ring Groove Gauge
J 29539-15	Top Dead Center Indicator Metric Adapter
J 29539-A	Top Dead Center (TDC) Indicator

5_106_00.bk Page 339 Friday, August 4, 2000 11:17 AM

Tool No.	Description
J 29600-C	Fire Ring Groove Cutter
J 29653-A	Ultrasonic Nozzle Cleaner
J 29880	Nozzle Sleeve Extractor
J 34046-A	Compression Gauge Adapter Set
J 34046-5	Compression Tester Metric Adapter (used with J 34046-A)
J 34684	Cylinder Head Core Plug Installer (13/16 inch)
J 34687	Cylinder Head Core Plug Installer (1-1/16 inch)
J 35529	Wear Ring and Seal Installer
J 37077	Position Sensor
J 37093	Injection Nozzle Puller
J 37481	Valve Guide Reamer (3/8-inch diameter)
J 37482	Valve Guide Remover (3/8 inch)
J 37712	Flywheel Housing/Timing Cover Locating Pin Driver
J 37713	Camshaft Bushing Installation Removal Kit (use with J 21428-01 Kit)
J 37715-A	Crankshaft Front Seal Installer
J 37715-2	Crankshaft Front Seal Installation Spacer (use with J 37715-A Front Seal Installer)
J 37716-A	Rear Seal Installer
J 37716-B	Crankshaft Rear Seal Installer
J 37717	Connecting Rod Bushing Remover/Installer
J 37718	Piston Pin Burnishing Broach
J 37719	Fire Ring Groove Cutter
J 37720-C	Tappet Holders
J 37721-A	Piston Cooling Nozzle Spray Position Set (for 1989/1990 production)
J 37809	Valve Guide Installer (3/8 inch)
J 38048	Engine Stand Adapter Plate
J 38586	Valve Seat Installation Set
J 38587-A	Engine Barring Socket
J 38880	Wear Ring Installer
J 39045	Two-Piece Piston Cooling Nozzle Aimer (for 1991 and later production)
J 39258-A	Engine Pre-Luber
J 39460	Valve Stem Seal Removal Tool (3/8 in.)
J 39500-B	A/C Recovery & Recycling Unit (R-134a)
J 41071	Air Compressor Coupling Holding Wrench
J 41251-B	Belt Tension Gauge
J 41461	Camshaft Removal/Installation Tool
J 41473	Charge Air Cooler Tester
J 41682	Camshaft Removal/Installation Guide
J 41683	Valve Roller Follower H-Ring Installer
J 42185	Belt Tension Gauge
J 42377	Camshaft Bushing Remover/Installer (use with J 21428-01 Cam Bushing Remover/Installer Set)
J 42425	Valve Lifter/Roller Follower Magnetic Retainers (use with top rods from J 37720-B Tappet Holder Kit)

Tool No.	Description
J 42426	Valve Roller Follower H-Ring Remover (use with J 6125-1B Slide Hammer)
J 42453	Valve Seal Installer
J 42490	Camshaft Cup Plug Installer (use with J 8092 Driver Handle)
J 42595	Fuel Injection Nozzle Sleeve Installer
J 42639	Fuel Injection Nozzle Tester Adapter Set (use with J 29075-B, Nozzle Tester)
J 42678	Fuel Injection Nozzle Sleeve Puller (use with J 2619-01 Slide Hammer)
J 42680	Fuel Injection Nozzle Combustion Gasket Seat Carbon Reamer
J 43887	Valve Spring Compressor
PT2210	Counterbore Tool
PT2210-14	Hex Key Wrench
PT2210-3A	Counterbore Cutter Plate
PT5025	Universal Dial Depth Gauge
PT5025-11	3-inch Stylus Extension
PT 5027	Cylinder Head/Block Straightedge (36 in.)
PT5035	Flywheel Housing Dial Indicator Set
PT5035-1	Flywheel Housing Indicator Extension
PT6390	Valve Seat Extractor Kit (complete with collets)
PT6390-4	Collet
PT6391	Valve Seat Extractor Kit (basic)
PT6435	Cylinder Liner/Sleeve Puller (lubricate with extreme pressure lubricant J 23444-A)
PT6570-11	Dowelout, Extractor (7/16 inch)
PT6575	Basic Heavy-Duty Dowelout Kit
PT6587	Piston Ring Expander
PT7070-A	Piston Ring Compressor

V-MAC III Special Tools

Tool No.	Description
J 37490	Diesel Electronic Connector Replacement Kit
J 38351-B	Serial Link Adapter Assembly
J 38480	Portable Printer (use with J 38500-1)
J 38500-1	Pro-Link Diagnostic Scan Tool
J 38500-60A	Pro-Link Cable (to vehicle), 6-Pin Deutsch
J 38500-61	PC Interface Cable
J 38500-63	Serial Link Jumper (Deutsch-to-Deutsch)
J 38500-630A	Pro-Link V-MAC III Diagnostic Cartridge
J 38500-1500C	Pro-Link Multi-Protocol Cartridge
J 38581	Connector, Test Adapter Kit
J 38582	Terminal Crimping and Removal Tool Kit
J 38675B	Pro-Link® 9000 Analyzer with V-MAC III Diagnostic Cartridge
J 38740	V-MAC Hub Barring Tool
J 38748	V-MAC Test Lead, Seven-Pin Connector
J 39200	Fluke Model 87 Digital Multi-Meter

5_106_00.bk Page 342 Friday, August 4, 2000 11:17 AM

NOTES

Index.fm Page 343 Friday, August 4, 2000 11:16 AM

INDEX

INDEX

INDEX

Index.fm Page 346 Friday, August 4, 2000 11:16 AM

Index.fm Page 347 Friday, August 4, 2000 11:16 AM

Index.fm Page 348 Friday, August 4, 2000 11:16 AM

NOTES

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SERVICE MANUAL
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