6.5 Liter V8
Turbo Diesel Engine

STG
GM Service Technology Group

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6.5L V8 Turbo Diesel Engine
Student Workbook

Foreword

While this booklet will serve as an excellent review of the extensive program presented in the training center session, it is not intended to substitute for the various service manuals normally used on the job. The range of specifications and variations in procedures between divisions requires that the division service publications be referred to, as necessary, when performing these operations.

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1. General Information

EGR

6.2 - LD - LH6 UP TO 8500

6.2 HD - LL4 PAST 8600

NO EGR

6.5 HD - L65

Application

In the 1992 model year, General Motors introduces the 6.5L V8 turbocharged diesel engine (Figure 1-1) in light-duty trucks with a Gross Vehicle Weight Rating (GVWR) between 8,500 and 15,000 pounds. Specific vehicles include the following models:

- C-series and K-series pick-up
- C-series chassis cab

The engine is manufactured at the Moraine Engine Plant in Dayton, Ohio. It is the result of engineering performed at the Romulus Engineering Center in Michigan.

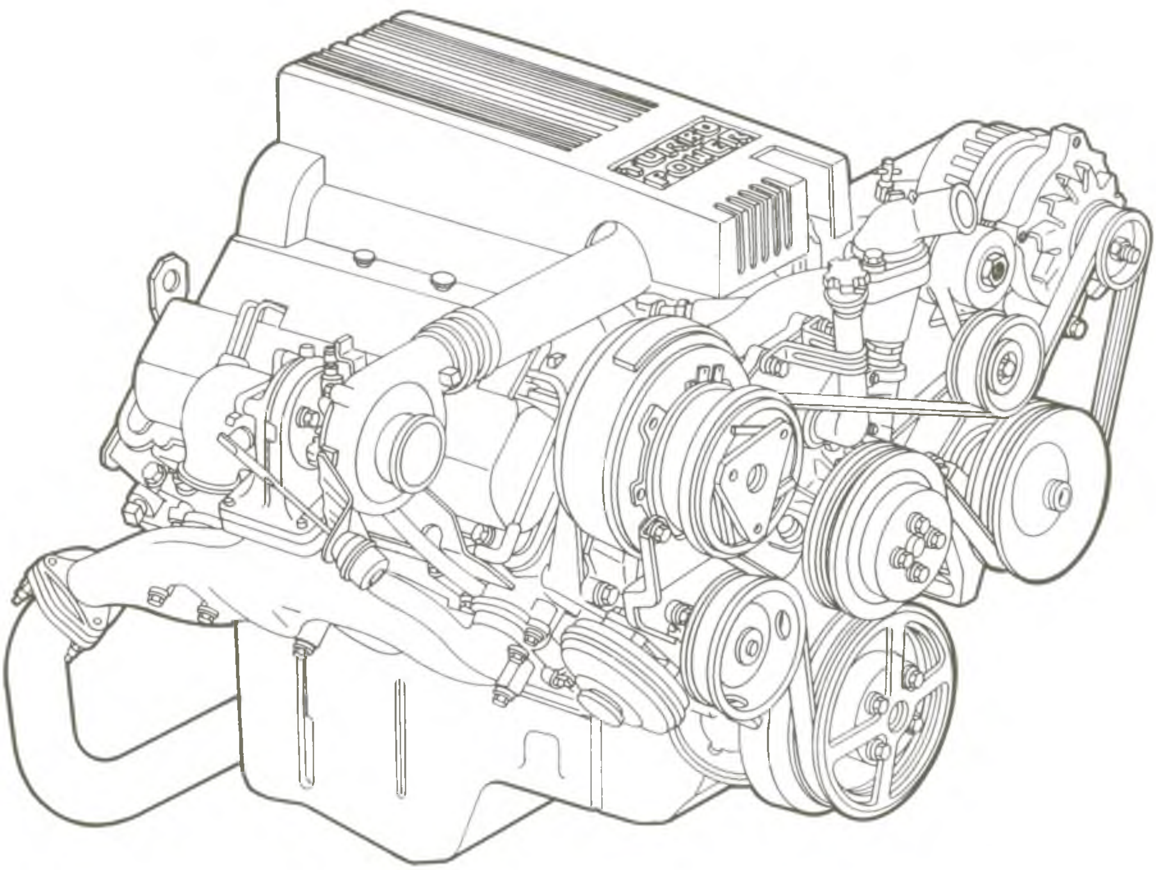


Figure 1-1, 6.5L V8 Turbo Diesel Engine – View of Right Side

Identification

6.5 VIN F

The 6.5L V8 turbo diesel engine has an identification number stamped on an upper surface of the cylinder case near the #1 cylinder intake manifold runner (see Figure 1-2). The stamping shows the following information:

- Broadcast code (engine configuration), using the first three characters:
  - Model year (1st letter)
  - Engine size and application (2nd and 3rd letters)
- Month of manufacture, using two digits (01 to 12)
- Day of manufacture, using two digits (01 to 31)

The fuel injection pump has a metal identification plate riveted to the left side of its housing. The model and serial numbers are stamped on the plate.

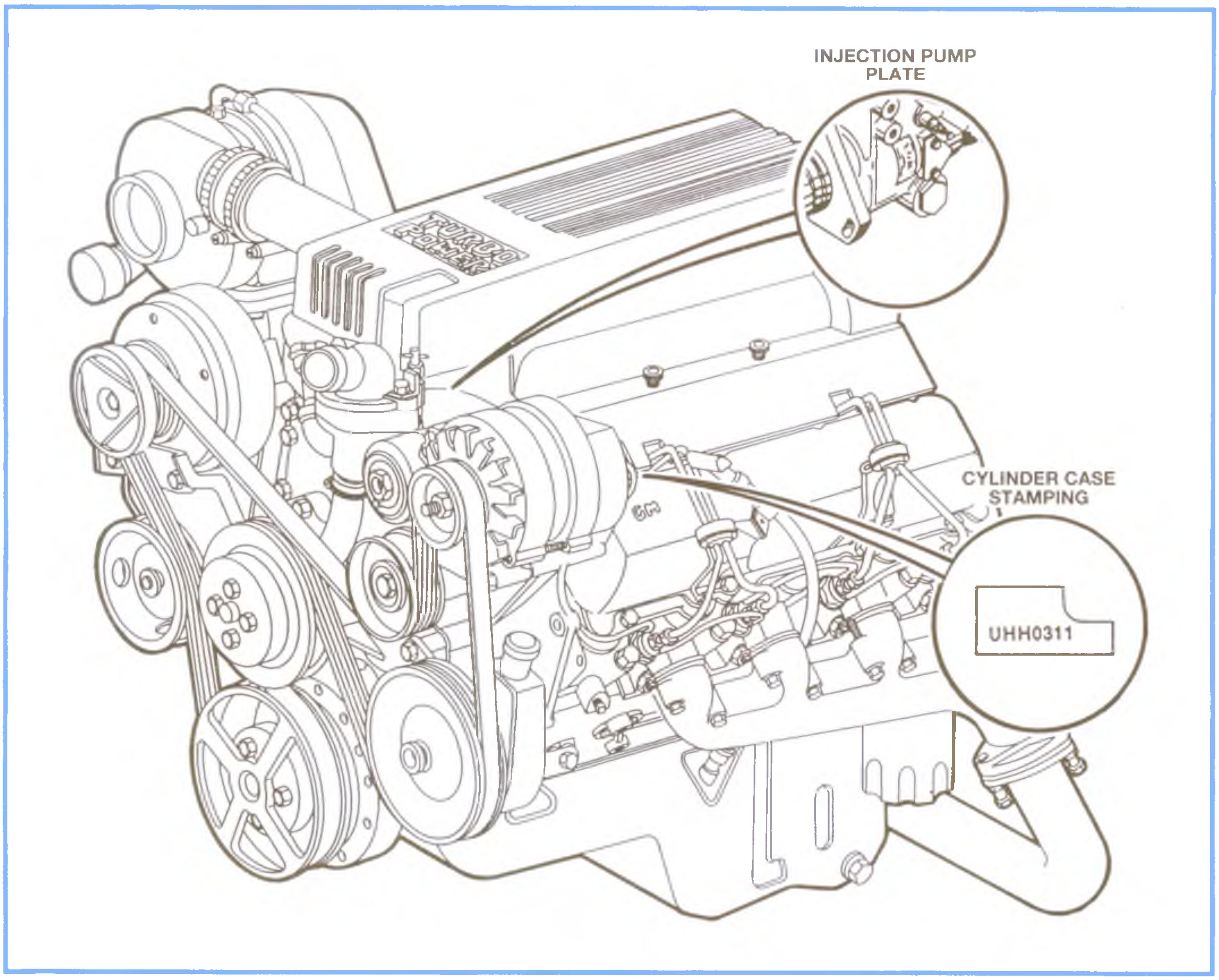


Figure 1-2, **Engine Identification Number**

Design Features

The 6.5L V8 turbo diesel engine has the following design features (refer to Figure 1-3):

- It has the Regular Production Option (RPO) code L65.
- Its eight cylinders have a bore diameter of 103mm (4.055 in.).
- Its crankshaft provides a 97mm (3.818-in.) stroke for each of the eight pistons.
- It operates with a four-stroke cycle.
- It has a compression ratio of 21.0 to 1.
- Each cylinder has a high-swirl pre-combustion chamber to mix fuel and air efficiently, resulting in low exhaust emissions.
- It produces 190 horsepower at 3400 rpm, and 380 lb-ft of torque at 1700 rpm (SAE net).
- Using the turbocharger, the engine has a maximum air intake pressure of 5 psi.

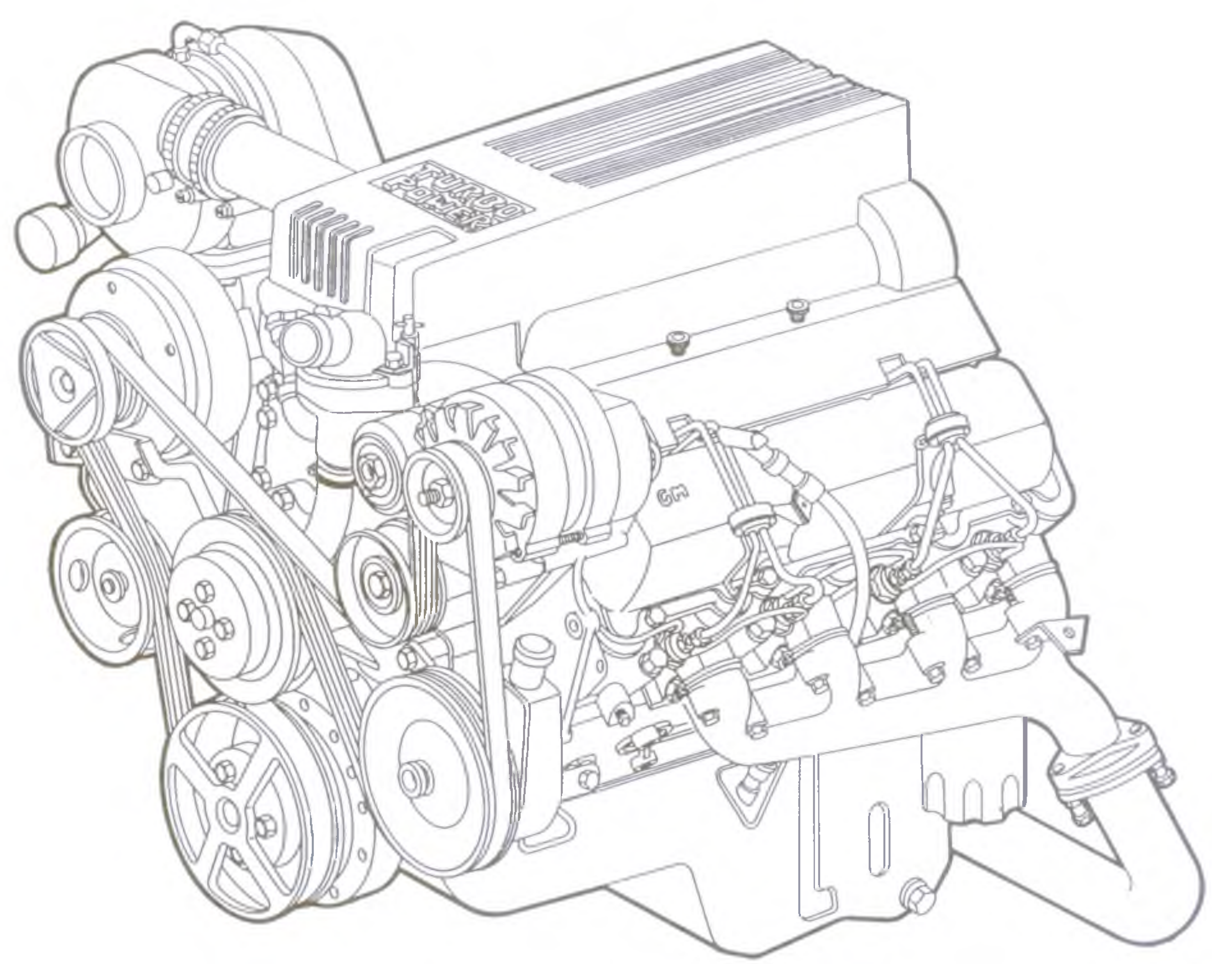


Figure 1-3, 6.5L V8 Turbo Diesel Engine - View of Left Side

Major Component Groups

The 6.5L V8 turbo diesel engine has the following major groups of parts (refer to Figure 1-4):

- Mechanical system
- Lubrication system
- Cooling system
- Accessory drive system
- Air induction/exhaust systems
- Fuel system
- Electrical systems

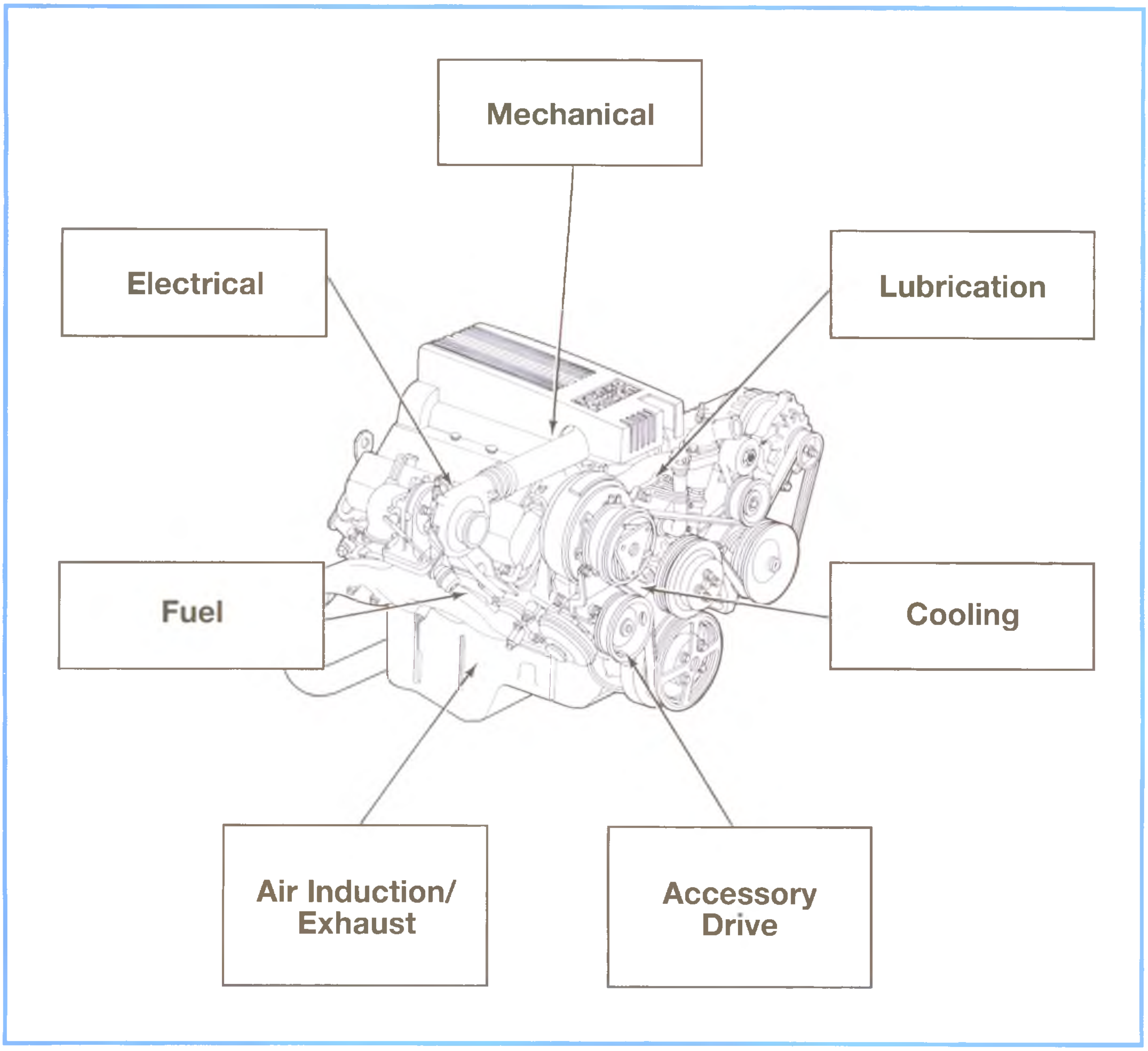


Figure 1-4, 6.5L V8 Turbo Diesel Engine Component Systems

Basic Operation

Intake Stroke

The following events occur during the intake stroke for any of the cylinders of the 6.5L V8 turbo diesel engine (refer to Figure 1-5):

- At the end of the exhaust stroke, the rotating crankshaft also rotates the camshaft and the intake lobe for the cylinder pushes a hydraulic roller lifter upward.
- The lifter operates a rocker arm, using a hollow push rod, which pushes open the intake valve.
- As the crankshaft rotates, it pulls the connecting rod/piston for the cylinder in a downward direction.
- The action of the piston and the turbocharger causes the air induction system to allow air (and crankcase gases) to move into the combustion area of the cylinder.

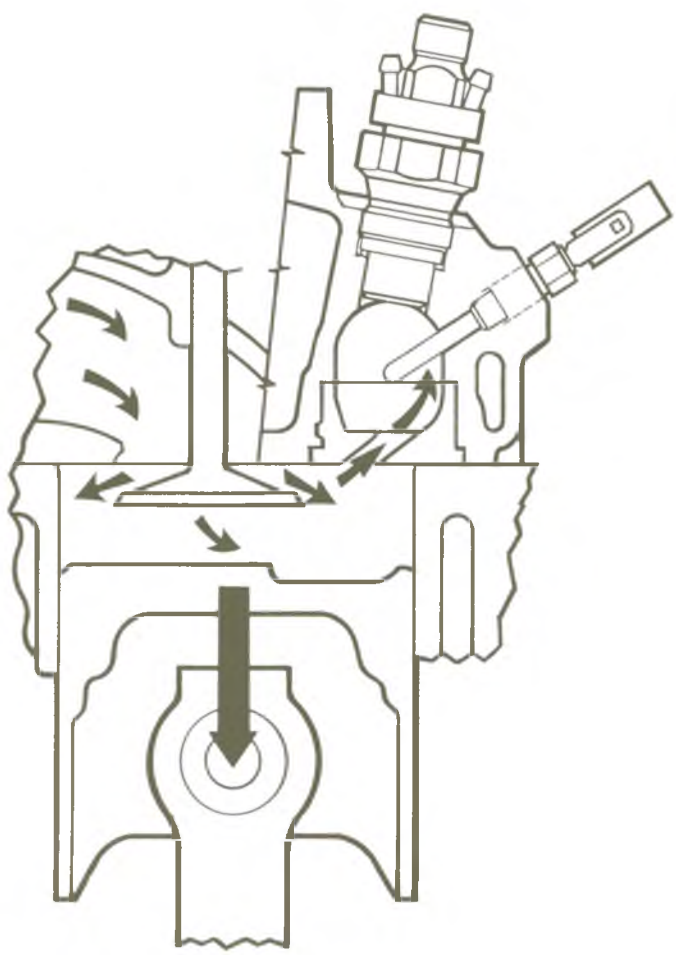


Figure 1-5, **Intake Stroke Operation**

Compression Stroke

The following events occur during the compression stroke for any of the cylinders of the 6.5L V8 turbo diesel engine (refer to Figure 1-6):

- At the end of the intake stroke, the rotating crankshaft also rotates the camshaft, and the intake lobe for the cylinder allows downward movement of a hydraulic roller lifter.
- Intake valve spring pressure pushes the intake valve closed and also operates the rocker arm, moving the push rod and lifter downward.
- As the crankshaft rotates, it pushes the connecting rod/piston for the cylinder in an upward direction.
- The action of the piston causes the air (and crankcase gases) in the combustion area of the cylinder to be greatly compressed and heated.

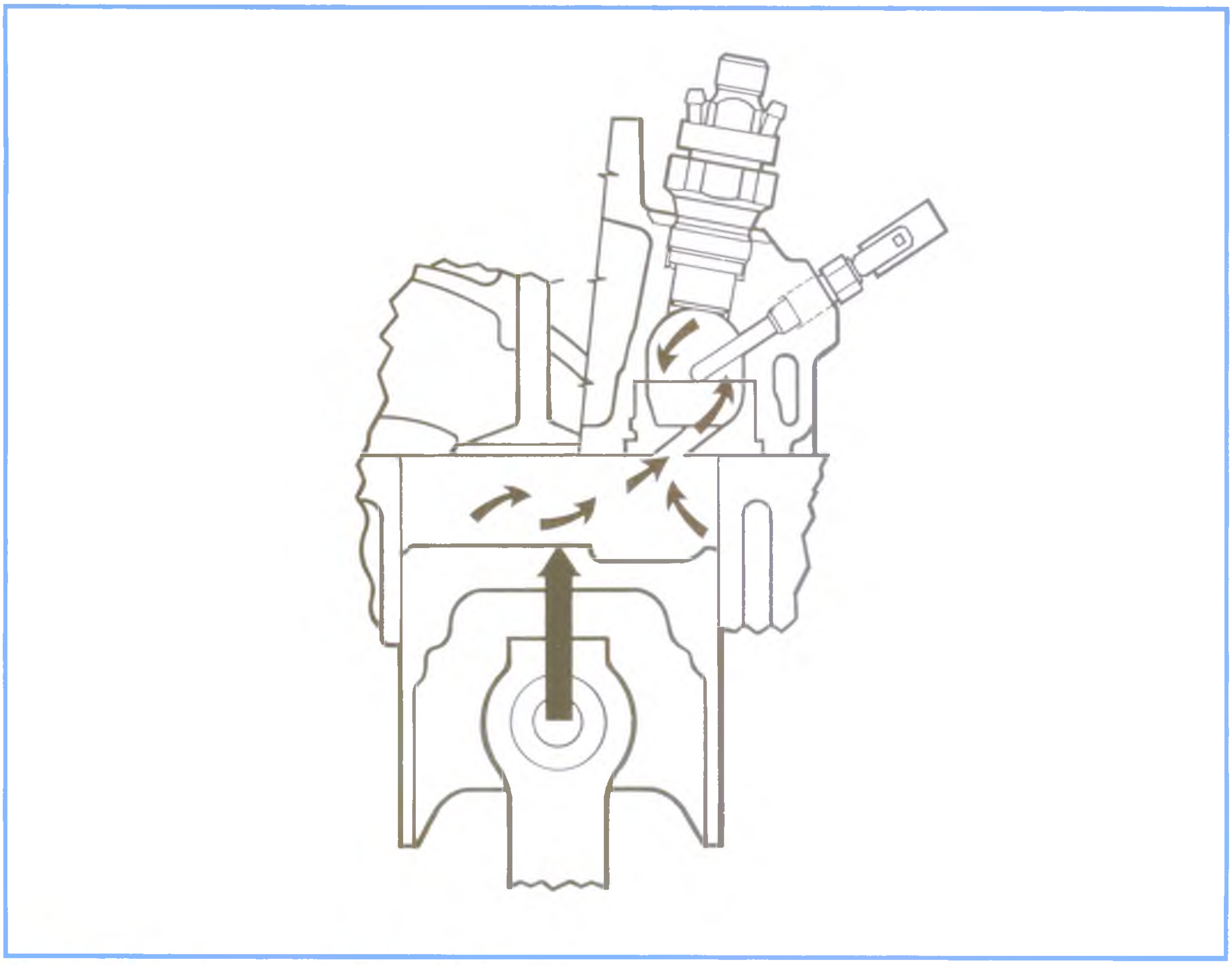


Figure 1-6, Compression Stroke Operation

Power Stroke

The following events occur during the power stroke for any of the cylinders of the 6.5L V8 turbo diesel engine (refer to Figure 1-7):

- At the end of the compression stroke, the fuel injection pump (operated at camshaft speed by a gearset) delivers fuel through a pipe to a nozzle positioned in the combustion area of the cylinder.
- The nozzle opens, spraying fuel into the hot, swirling air in the pre-combustion chamber.
- The heated air/fuel mixture achieves combustion, and expanding gases push the connecting rod/piston for the cylinder in a downward direction.
- The connecting rod/piston provides rotating force for the crankshaft.

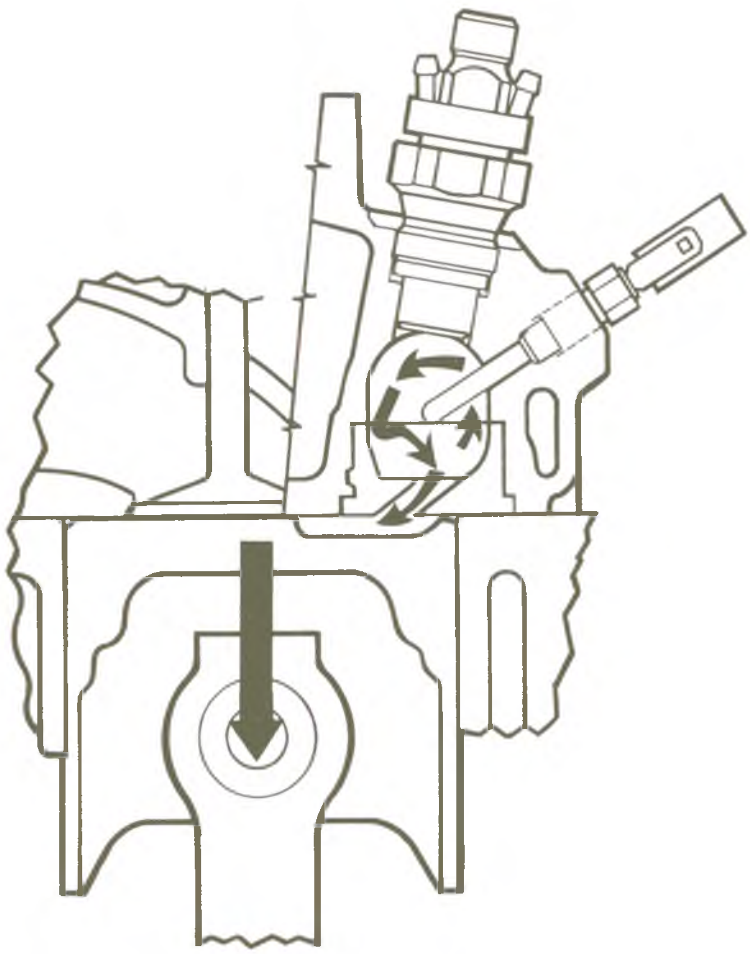


Figure 1-7, Power Stroke Operation

Exhaust Stroke

The following events occur during the exhaust stroke for any of the cylinders of the 6.5L V8 turbo diesel engine (refer to Figure 1-8):

- At the end of the power stroke, the rotating crankshaft also rotates the camshaft and the exhaust lobe for the cylinder pushes a hydraulic roller lifter upward.
- The lifter operates a rocker arm, using a hollow push rod, which pushes open the exhaust valve.
- As the crankshaft rotates, it pushes the connecting rod/piston for the cylinder in an upward direction.
- The action of the piston pushes post-combustion gases out of the cylinder combustion area through the exhaust system (incuding the turbocharger).
- At the end of the exhaust stroke, the rotating crankshaft also rotates the camshaft, and the exhaust lobe for the cylinder allows downward movement of a hydraulic roller lifter.
- Exhaust valve spring pressure pushes the exhaust valve closed and also operates the rocker arm, moving the push rod and lifter downward.

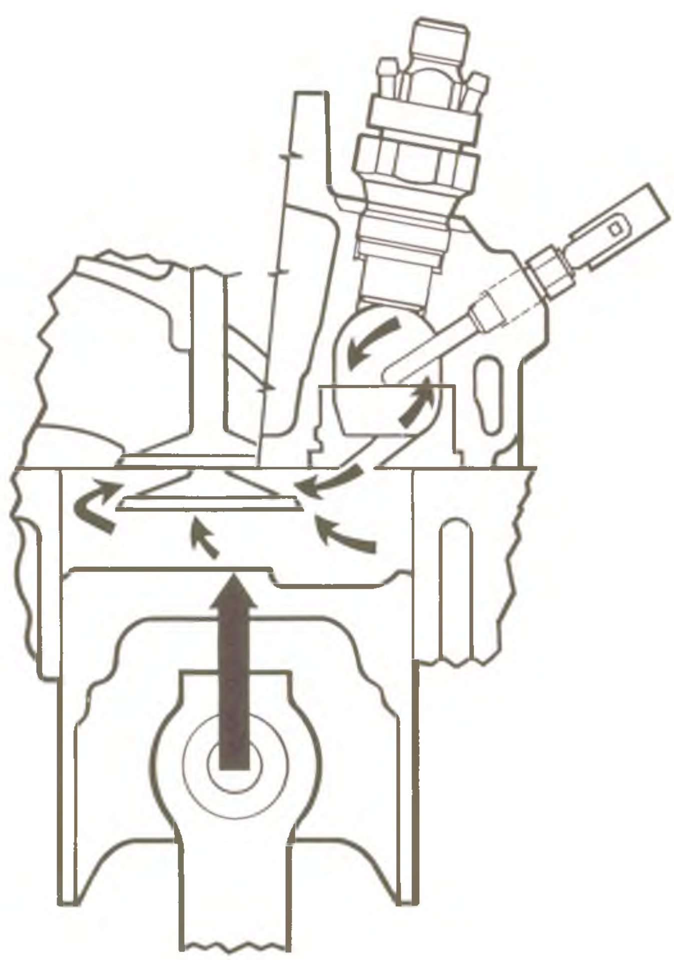


Figure 1-8, **Exhaust Stroke Operation**

Maintenance

Engine Oil Change

The 6.5L V8 turbo diesel engine uses lubricating oil that meets the SG/CE quality standards of the American Petroleum Institute (API).

The recommended oil viscosity to use depends on the ambient operating temperature (see Figure 1-9). Ratings are based on standards set by the Society of Automotive Engineers (SAE).

The factory fill of oil has an SAE viscosity rating of SAE 15W-40, which is preferred. Oil with a viscosity rating of 10W-40 is not recommended for this engine.

When consistently hot ambient temperatures are expected, a straight-weight SAE 30 oil is recommended. When consistently cold ambient temperatures are to be encountered, a multi-viscosity SAE 10W-30 oil should be used.

Proper cold-weather starting depends on a number of things, including a fast cranking speed provided by using the correct oil viscosity and the use of the block heater.

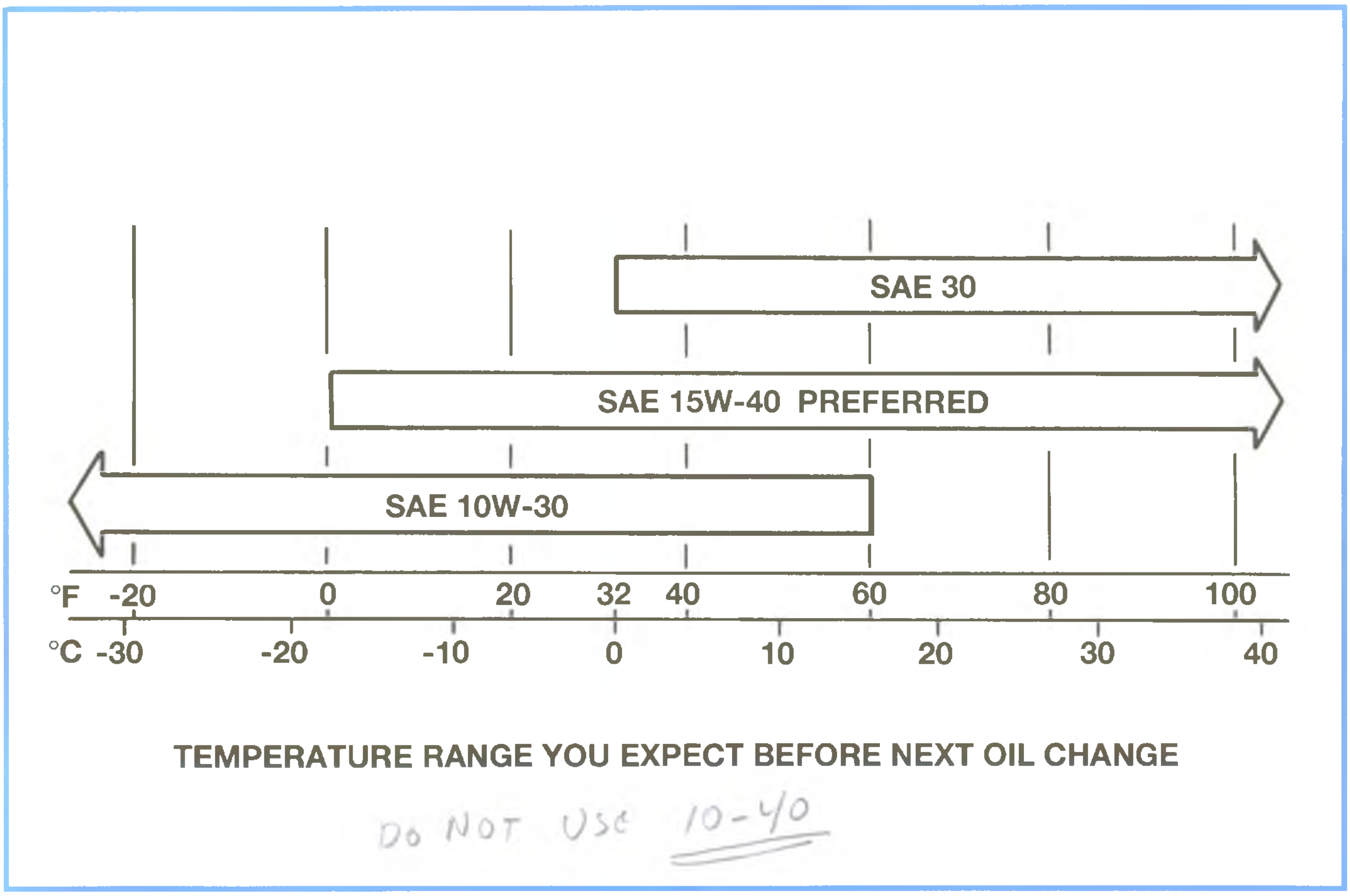


Figure 1-9, Engine Oil Recommendation Chart

1. General Information

Oil change maintenance includes the following directions:

- Perform at intervals of every 2,500 miles (or 3 months) when vehicle usage includes any of the following conditions:
  - Most trips are less than 4 miles (6 kilometers) in length.
  - Most trips are less than 10 miles (16 kilometers) in length and the outside temperature is below freezing.
  - The engine is at low speed most of the time (as in stop-and-go traffic, door-to-door delivery or other commercial uses). IDLING
  - Operation is in dusty areas or under off-road use.
  - Operation includes trailer towing.
- Perform at intervals of every 5,000 miles if none of the above conditions applies.
- Include a filter replacement (use AC P/N PF35).
- Refill with a crankcase capacity of 6.5 liters (7 quarts).

Idle Speed Adjustment

The 6.5L V8 turbo diesel engine has an idle speed control screw on the left side of the injection pump (see Figure 1-10). Also, a fast idle solenoid in the same location controls engine speed during warm-up.

As part of maintenance, the idle speed should be adjusted at 5,000 miles, then at 30,000 miles, 60,000 miles, etc. A magnetic-type engine tachometer or a Tech 1 diagnostic tool should be used to indicate engine speed when performing this procedure (see page 7-17 for more information). Refer to page 7-87 of this book for the idle speed adjustment procedure.

Figure 1-10, Idle Speed Screw Location

Cooling System Service

The 6.5L V8 turbo diesel engine uses a 50/50 mixture of ethylene glycol-based coolant and water in its cooling system. The coolant must meet the GM 1899-M or 6038-M engineering specifications.

At intervals of every 30,000 miles (or 24 months), the cooling system should be drained, flushed and refilled. The system capacity is 26.5 liters (28 quarts), with or without A/C.

Air Filter Replacement

The 6.5L V8 turbo diesel engine uses an air filter specially designed for it (see Figure 1-11). The maintenance schedule requires air filter replacement every 30,000 miles. Operating conditions may require a more frequent air filter change.

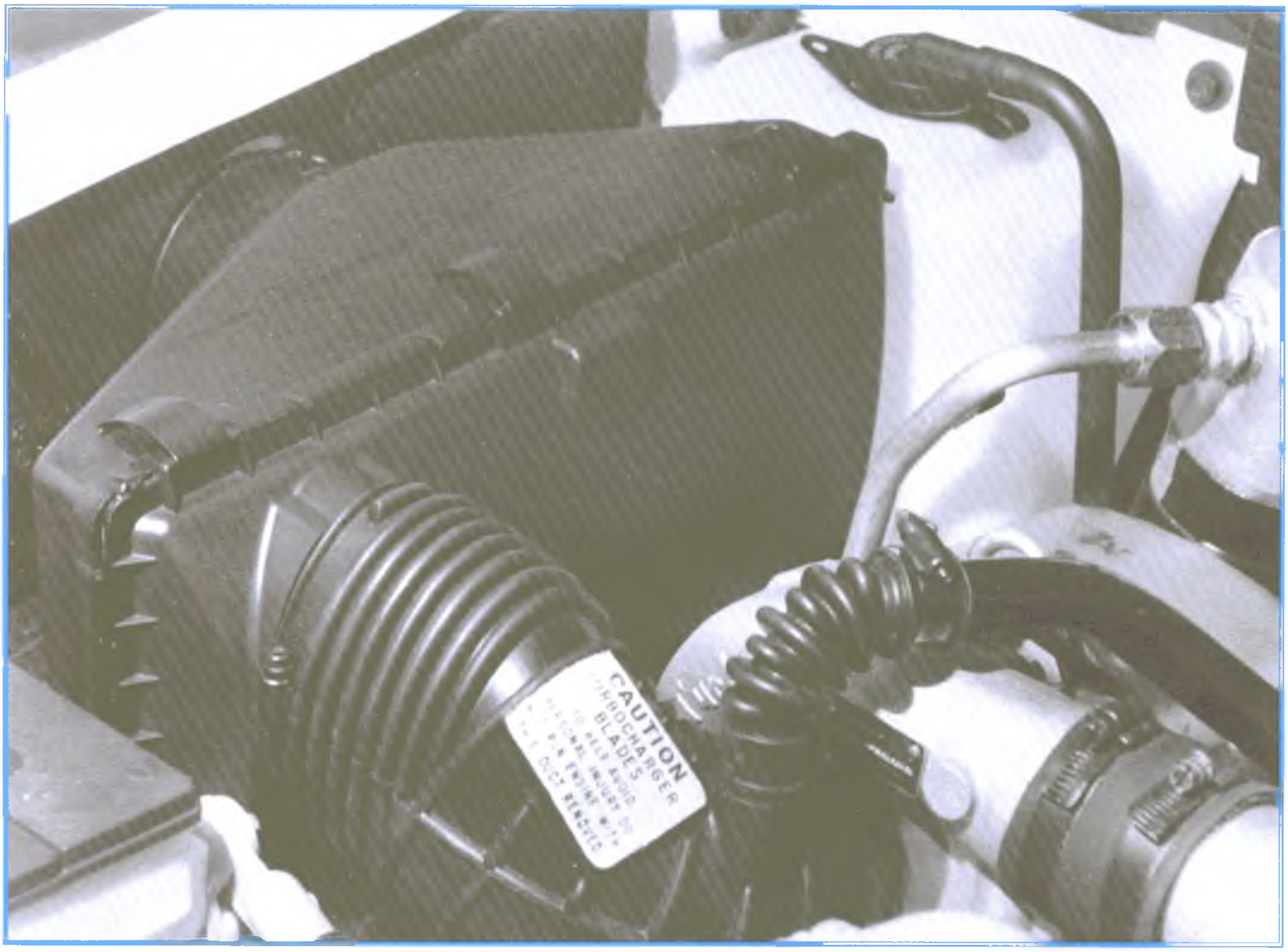


Figure 1-11, Air Filter Location

Air Intake System Inspection

The condition of the air intake system for the 6.5L V8 turbo diesel is very important to the life of both the engine and its turbocharger (see Figure 1-12). At intervals of every 10,000 miles, the ducts, fasteners and clamps of the air intake system should be inspected for wear or damage.

Crankcase Depression Regulator Valve (CDRV) Inspection

The 6.5L V8 turbo diesel engine has a Crankcase Depression Regulator Valve (CDRV) that controls the amount of crankcase gases mixing with intake air. At intervals of every 60,000 miles, the valve should be checked for proper operation.

A fault in the CDRV may be the cause of an external engine oil leak. See page 6-24 of this book for the crankcase pressure checking procedure.

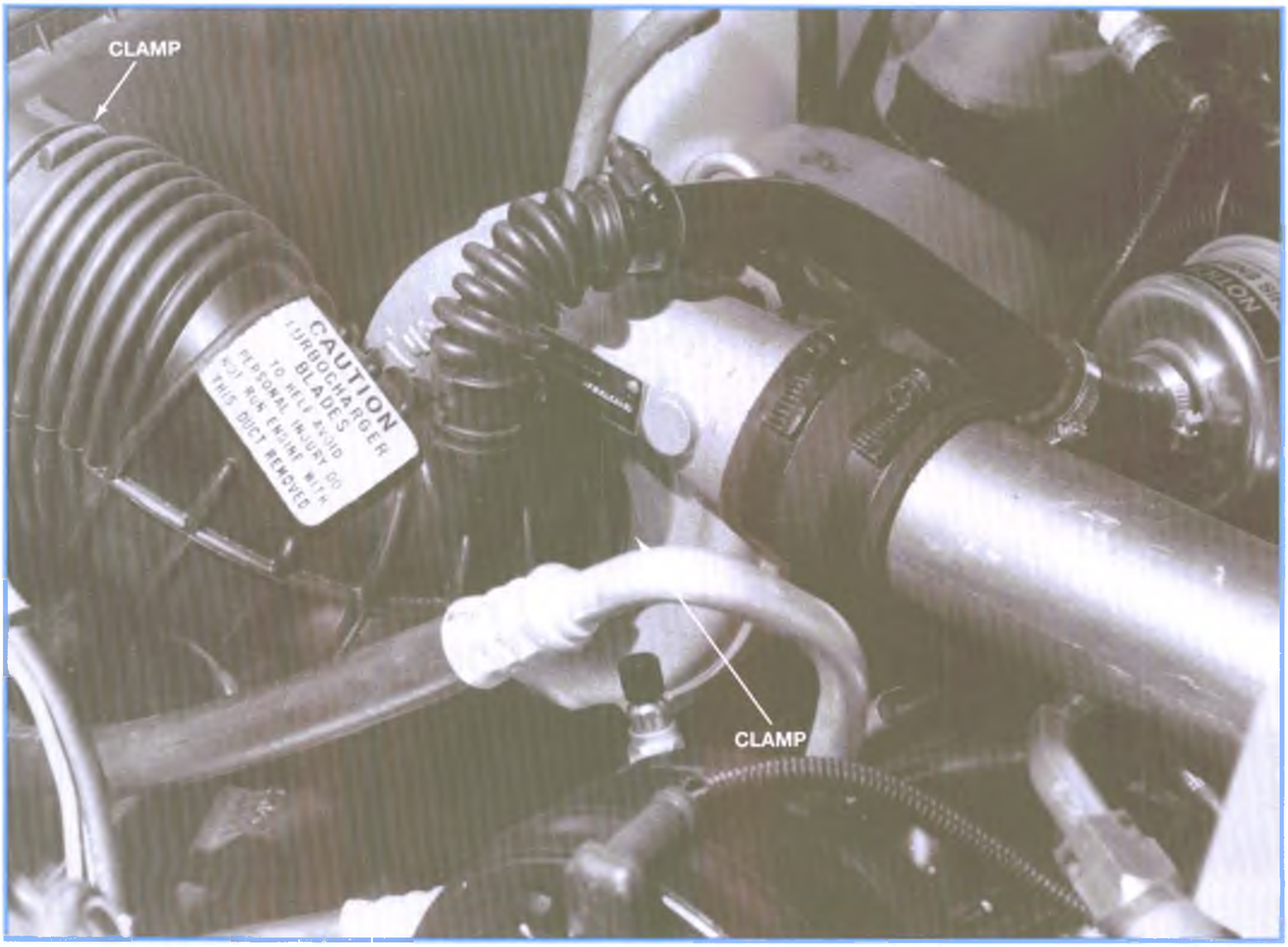


Figure 1-12, **Air Intake Duct Location**

Fuel Filter Replacement

The 6.5L V8 turbo diesel engine has one two-stage filter for its fuel system, mounted on the rear of the intake manifold (see Figure 1-13). The maintenance schedule calls for fuel filter replacement every 30,000 miles.

Operating conditions may require a more frequent fuel filter change. A restricted fuel filter may be the cause of a loss of engine power.

Drive Belt Inspection

The 6.5L V8 turbo diesel engine has one poly-V serpentine accessory drive belt under a tension by spring-loaded idler pulley. At intervals of every 60,000 miles, the drive belt should be inspected for damage, wear or excessive stretching.

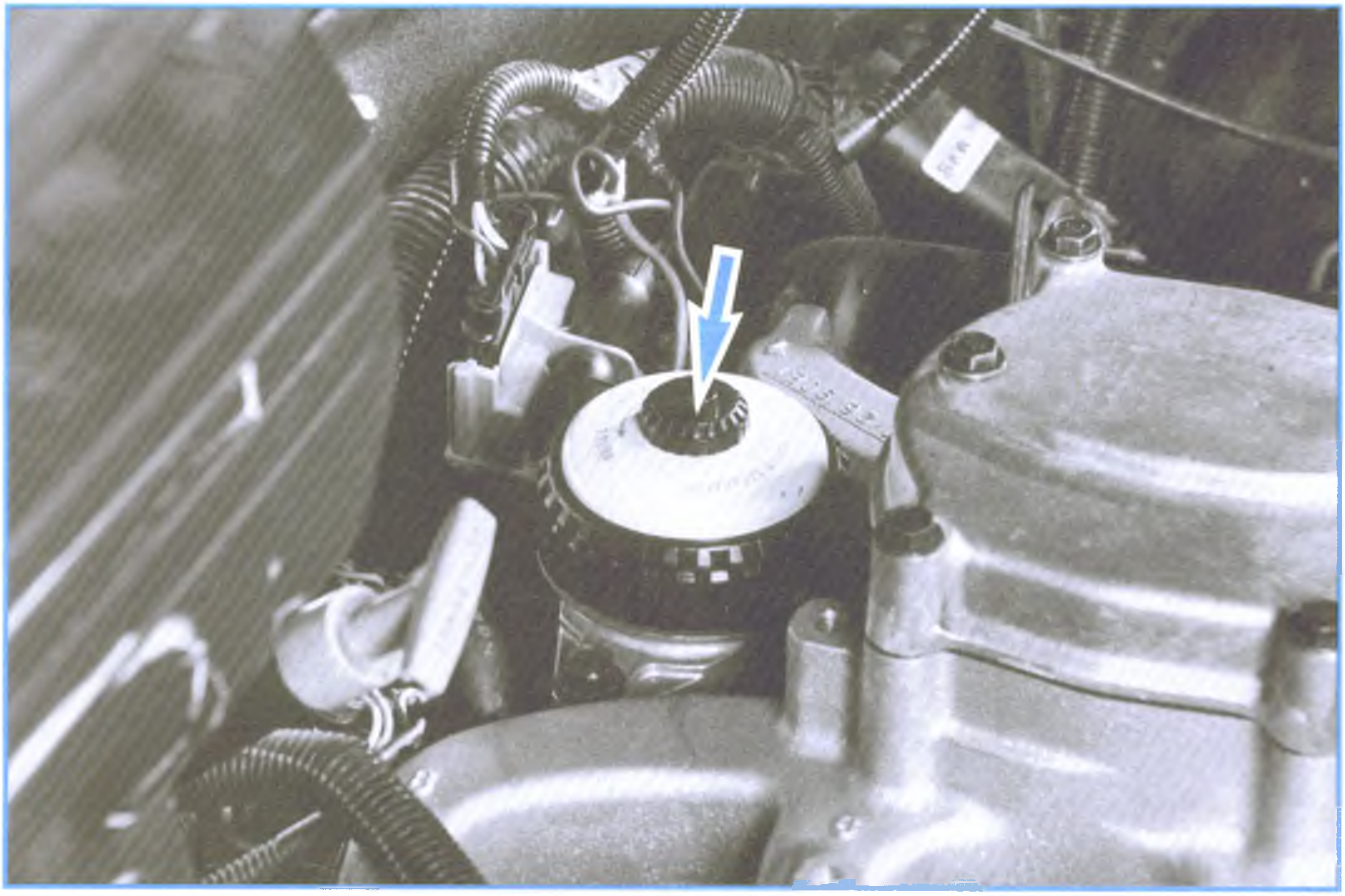


Figure 1-13, Fuel Filter Location

Shields and Underhood Insulation Inspection

The 6.5L V8 turbo diesel engine uses a heat shield to protect parts near the turbocharger turbine housing (see Figure 1-14). Shields also protect the glow plug wiring for cylinders #4 and #6 and cranking motor solenoid from excessive heat.

In addition to the heat shields, a sound insulator cover is installed over the intake manifold. According to the maintenance schedule, these components and the hood insulator should be checked for damage every 10,000 miles.

Thermostatically Controlled Engine Cooling Fan Inspection

The 6.5L V8 turbo diesel engine cooling system uses a fan rotated by the accessory drive belt. This fan has a clutch that is applied when underhood temperature reaches a given point.

According to the maintenance schedule, the release and apply of the fan clutch should be checked every 12 months or 10,000 miles. The inspection also involves checking the fan blades for damage. See page 4-15 of this book for the cooling fan clutch checking procedure.

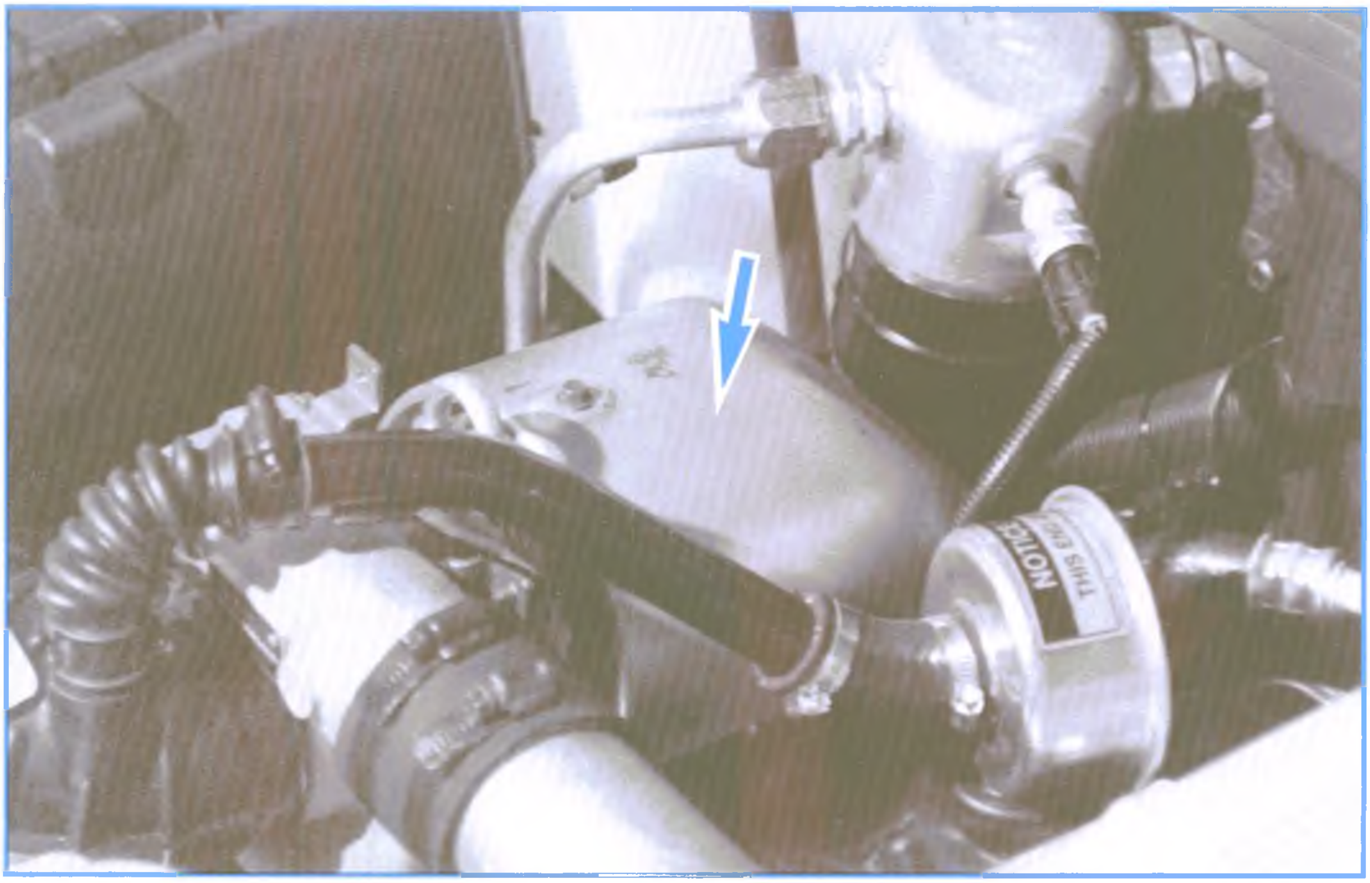


Figure 1-14, **Turbocharger Heat Shield Location**

Operating Procedures

Preparing for Cold Weather Starting

To perform the correct cranking procedure speed, do the following things:

- Use oil with the correct viscosity.
- Use the block heater system, following these directions:
  - Open the hood.
  - Unwrap the electrical cord for the block heater, located in the vehicle engine compartment.
  - Plug the cord into a 120 VAC electrical outlet, using a heavy-duty extension cord if necessary.
  - Follow the usage chart shown in Figure 1-15.
- Before starting the engine, disconnect the electrical cord and re-wrap it properly in the engine compartment.

To assure engine operation at ambient temperatures below 20° F (-7° C), prevent #2-D fuel from waxing and plugging the fuel filter by using #1-D fuel or a winterized blend of #1-D and #2-D fuels. A symptom of this condition may be when the engine starts, stalls after a short period of time and does not restart. Do not winterize diesel fuel by blending it with gasoline.

Emergency Jump Starting

Although the 6.5L V8 turbo diesel engine has a dual-battery electrical system, the jump starting procedure is the same as with vehicles that have a single battery. Jumper cable connection to either battery is acceptable, but use of the right battery (closest to the cranking motor) is preferred.

Viscosity Grade Oil	32° to 0°F (0° to -18°C)	Below 0°F (Below -18°C)
30	2 HOURS MINIMUM*	8 HOURS MINIMUM
15W-40	NOT REQUIRED	8 HOURS MINIMUM
10W-30	NOT REQUIRED	8 HOURS MINIMUM

*The times listed are minimum times. It will not harm either the block heater or the vehicle to leave it plugged in longer than the times stated.

Figure 1-15, **Block Heater Usage Chart**

1. General Information

Starting

The 6.5L V8 turbo diesel engine starts differently than a gasoline engine, using the following steps:

1. Have all passengers fasten their seat belts.
2. Apply the parking brake.
3. For automatic transmissions, do the following things:
   - Shift the transmission to P range (vehicle not moving) or N range (vehicle moving).

   For manual transmissions, do the following things:
   - Shift the transmission to Neutral.
   - Press the clutch pedal fully.
4. Turn the ignition switch to the RUN position and wait until the GLOW PLUGS lamp in the instrument panel is OFF.

Note: Do not use starting aids such as ether.

5. Press the accelerator pedal fully and release it.
6. Turn the ignition switch to the CRANK position until the engine starts or 15 seconds elapse.

Note: Do not leave the vehicle while the engine is running.

7. Turn the ignition switch to RUN and do the following things:
   - If the engine runs, press the brake pedal and shift the transmission into gear.
   - If the engine does not run, wait 15 seconds and repeat step 4.
8. Wait a few seconds before moving the vehicle, especially in cold weather.

Note: During cold weather starting, the engine may temporarily run with a slight increase in noise and exhaust smoke.

9. Release the parking brake and move the vehicle.

Note: If the engine fails to start, do the following things:

- Do not use starting aids such as ether.
- Check the state of charge for the batteries.
- Check for proper operation of the glow plug system:
  - The GLOW PLUGS lamp should be ON for several seconds, then OFF for several seconds.
  - Cycling of the GLOW PLUGS lamp should continue (ON for a few seconds, OFF for several seconds) for a total of 25 seconds.
  - During cranking, the GLOW PLUGS lamp may be ON.
  - After cranking, cycling of the GLOW PLUGS lamp should continue (ON for a few seconds, OFF for several seconds) for a total of 25 seconds.
- If the above items check good, perform further diagnosis.

2. Mechanical System

Overview

The mechanical system of the 6.5L V8 turbo diesel engine includes the following groups of parts (refer to Figure 2-1):

- Cylinder case assembly
- Cylinder head assemblies
- Valve train
- Front cover
- Injection pump drive
- Intake manifold
- Exhaust manifolds

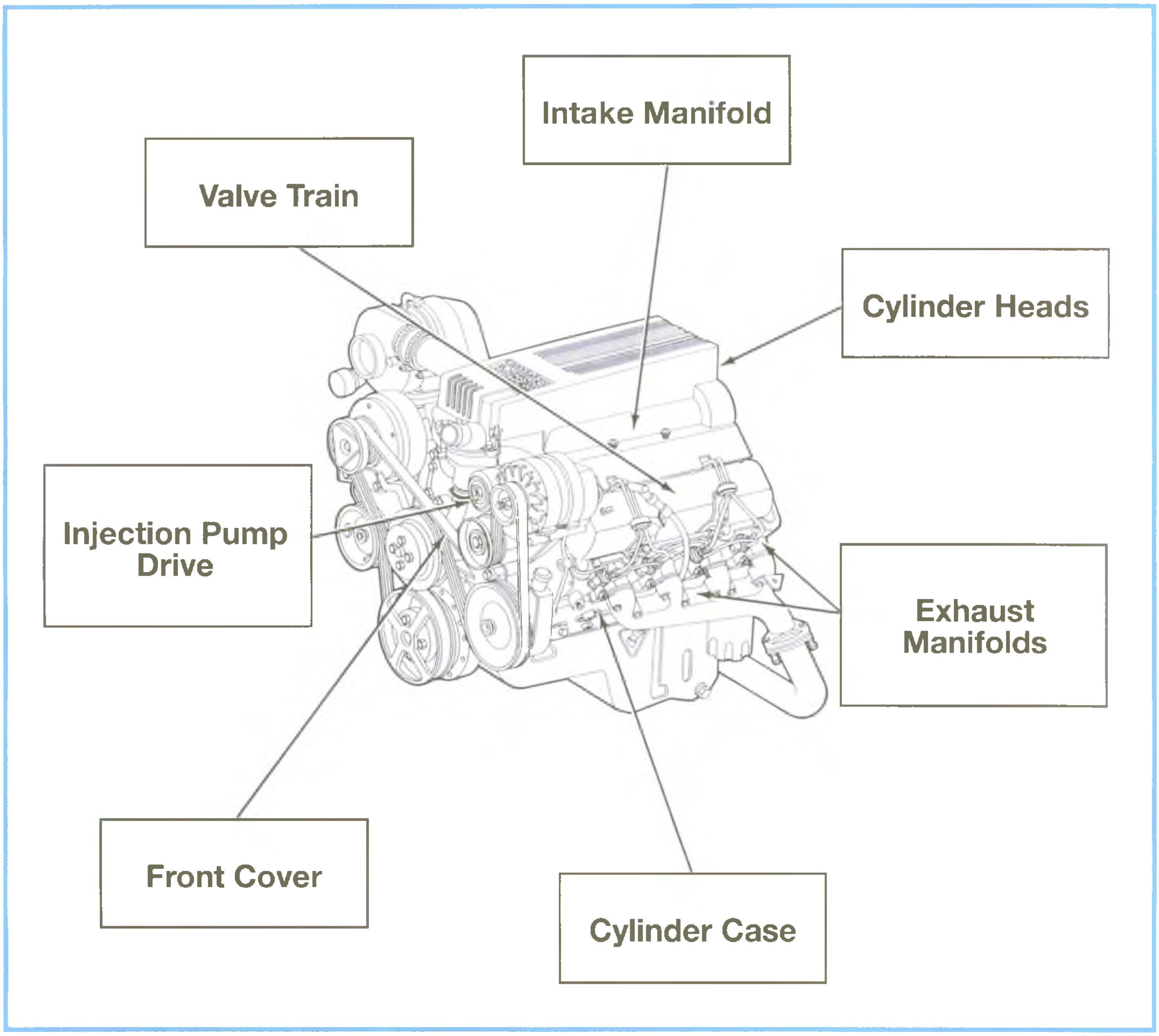


Figure 2-1, Mechanical System Part Groups

Cylinder Case Assembly

Cylinder Case Features

The one-piece cylinder case is made from cast iron and has the following features (refer to Figures 2-2 and 2-3):

- Support for the crankshaft
- Support for the camshaft and hydraulic lifters
- Cylinder bores for the piston/connecting rod assemblies
- Mounting surfaces for cylinder heads
- Mounting surfaces for the front cover and oil pan
- Lubrication and cooling system passages
- Surfaces for powertrain mounts

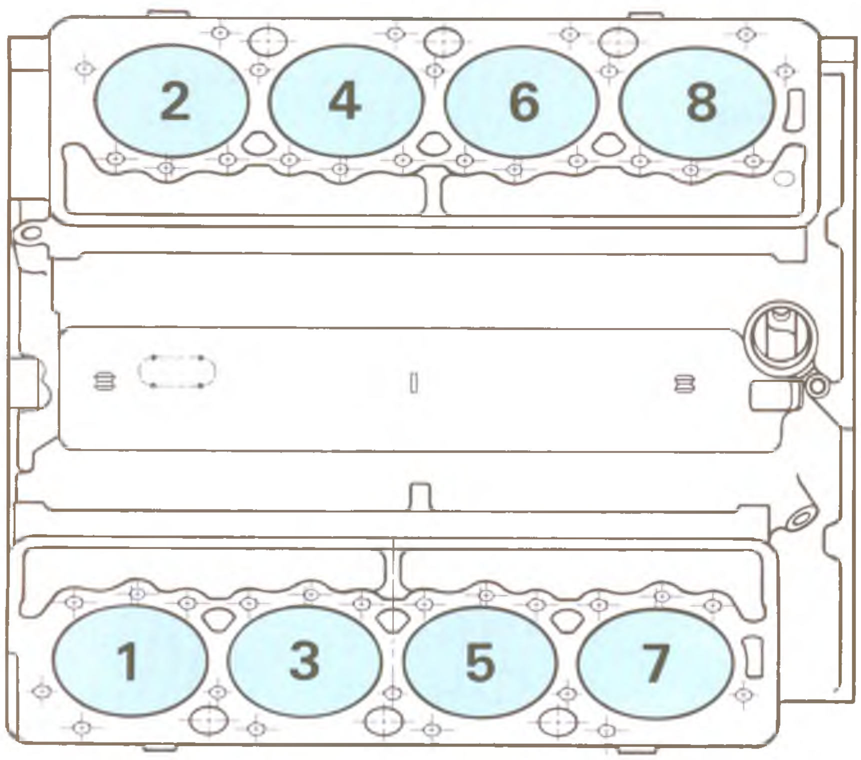


Figure 2-2, Cylinder Case Assembly (1)

Service of the cylinder case includes the following repairs:

- No machining of these surfaces:
  - Crankshaft bearing bores
  - Camshaft bearing bores
  - Hydraulic lifter bores
  - Cylinder head decks
- Machining of the cylinder bores to accommodate 0.50mm (0.020-in.) oversize service pistons

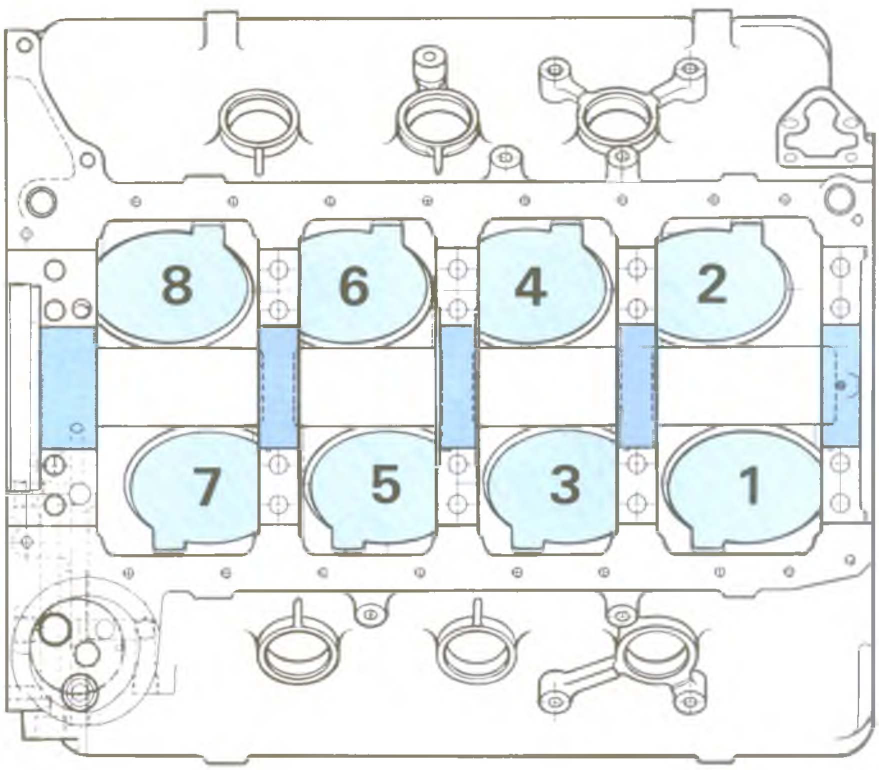


Figure 2-3, **Cylinder Case Assembly (2)**

Crankshaft Support

The cylinder case has five split bores to support the crankshaft (see Figure 2-4). Four bolts retain each bearing cap to the cylinder case. Each bore uses a two-piece sleeve bearing insert providing an oil clearance for the crankshaft. The #3 bore has a bearing insert with thrust flanges to control crankshaft end-play.

During engine manufacture, a combination of three bearing insert sizes is used at each of the five bores and is based on crankshaft journal measurements (refer to Figure 2-5). Upper insert halves have an oil groove, and lower insert halves have no groove.

The crankshaft installation procedure requires the following steps:

- Seat all main bearing caps with a mallet and initially tighten both the inner and outer bolts for each main bearing cap.
- Thrust the crankshaft rearward and forward, using a mallet.
- Insert a soft wedge between the crankshaft and a bearing cap to keep the crankshaft in its forward position.
- Tighten the two inner bolts for each main bearing cap to 104-118 ~~N·m~~ FL (141-160 ~~lb-ft~~ N·M) torque.
- Tighten the two outer bolts for each main bearing cap to 126-145 N·m (93-107 lb-ft) torque.

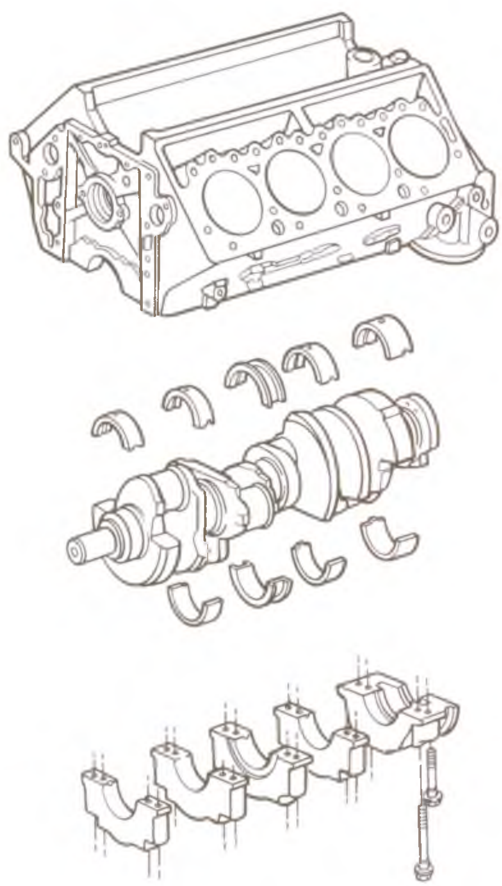


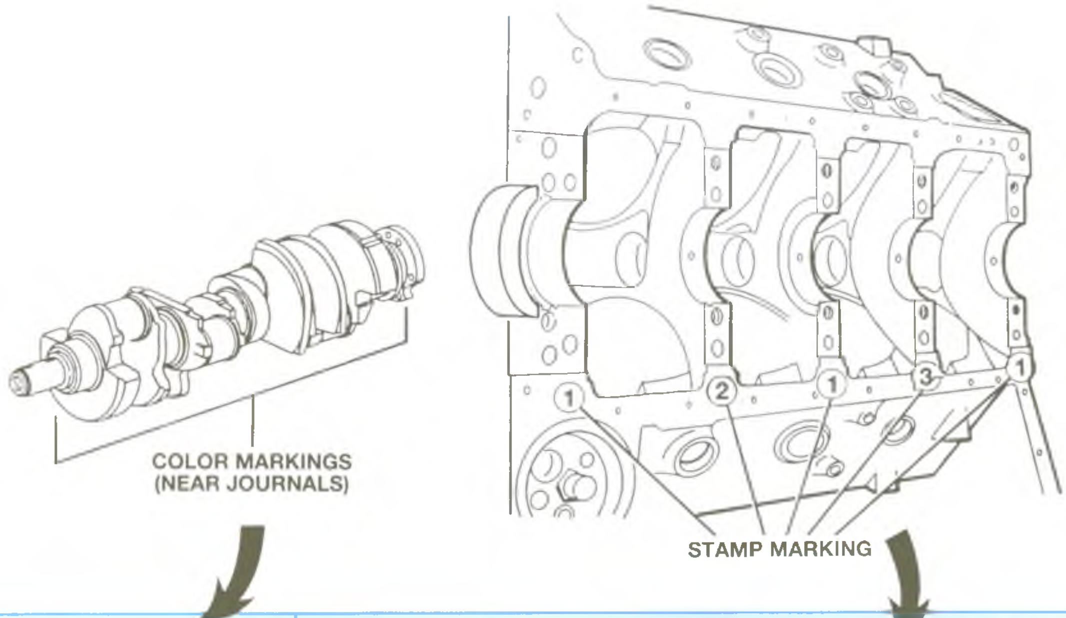
Figure 2-4, **Crankshaft Support**

For service purposes, bearing size combinations provide the following oil clearance, as measured with the plastigage procedure:

- Bearing #1, #2, #3 and #4: 0.045 to 0.083 mm (0.0018 to 0.0033 in.)
- Bearing #5: 0.055 to 0.093 mm (0.0022 to 0.0037 in.)

Three sizes of main bearing inserts are available for service:

- Standard
- 0.013 mm (0.0005 in.) U.S. (Undersize)
- 0.026 mm (0.001 in.) U.S. (Undersize)



CRANKSHAFT MAIN JOURNAL DIAMETER		CYLINDER & CASE MAIN BEARING BORE DIAMETER		
#1 TO #4	**#5**	**79.850 79.842 STAMP 3**	**79.842 79.834 STAMP 2**	**79.834 79.826 STAMP 1**
74.917 74.925 BLUE	74.912 74.920 BLUE	1-.026 U.S. IN CASE 1-.026 U.S. IN CAP	1-.013 U.S. IN CASE 1-.026 U.S. IN CAP	1-STD IN CASE 1-.026 U.S. IN CAP
74.925 74.933 ORANGE	74.920 74.928 ORANGE	1-.026 U.S. IN CASE 1-.013 U.S. IN CAP	1-.013 U.S. IN CASE 1-.013 U.S. IN CAP	1-STD IN CASE 1-.013 U.S. IN CAP
74.933 74.942 WHITE	74.928 74.936 WHITE	1-.026 U.S. IN CASE 1-STD IN CAP	1-.013 U.S. IN CASE 1-STD IN CAP	1-STD IN CASE 1-STD IN CAP

Figure 2-5, **Crankshaft Main Bearing Selection Chart**

Crankshaft Features

The crankshaft is made of cast iron and has integral counterweights (see Figure 2-6). The main bearing and crankpin journals are machined with deep, rolled fillets for added strength. No machining of the crankshaft during service is allowed, since the fillets may be disturbed.

The front of the crankshaft has a shoulder and key for the mounting of a double-row roller chain sprocket to drive the camshaft. Timing of the crankshaft with the camshaft is performed with the crankshaft sprocket mark in a 12 o'clock position and the camshaft sprocket mark in a 6 o'clock position.

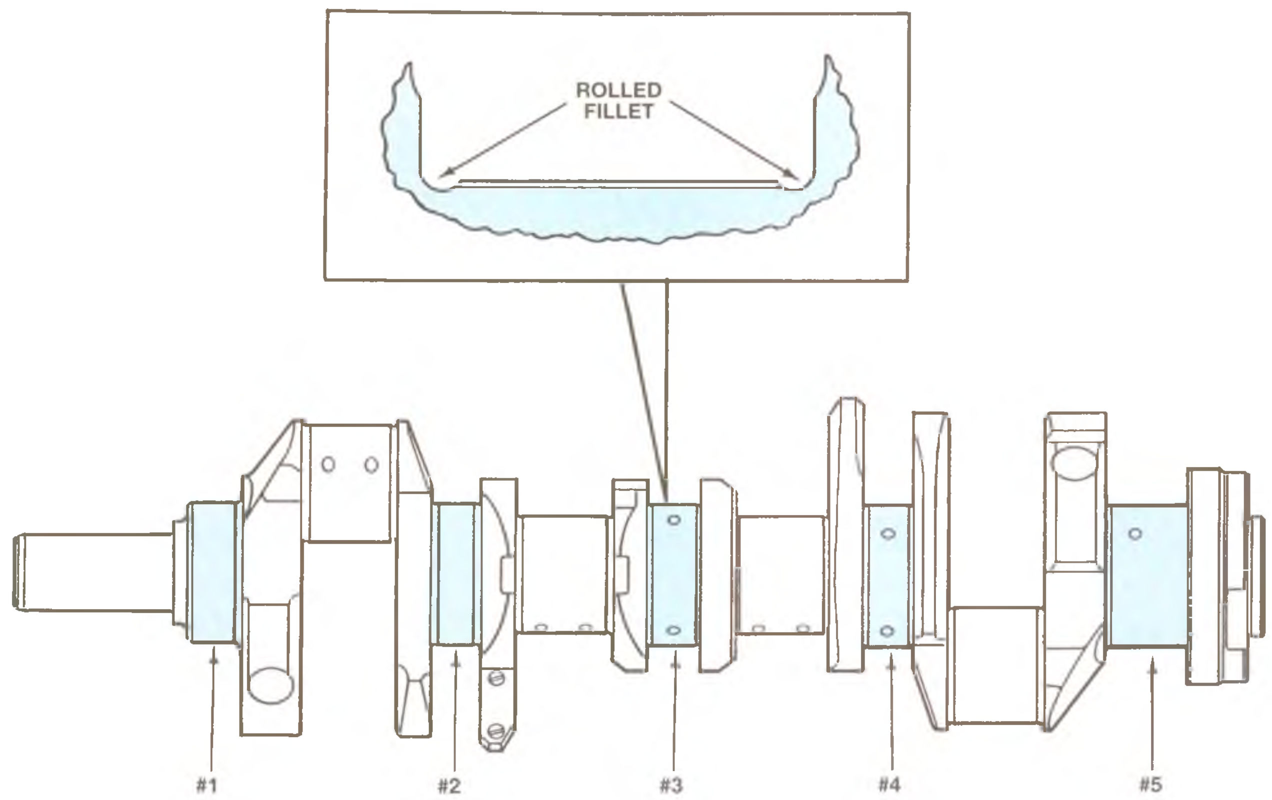


Figure 2-6, **Crankshaft Features**

The crankshaft uses the mass of the flexplate and torque converter to smooth its power pulses to the transmission (see Figure 2-7, view A). During engine manufacture, minor dynamic imbalance may be corrected at the rear by either welding weights or drilling holes in the flexplate.

A torsional damper mounted on the front of the crankshaft absorbs the twisting energy from multiple-cylinder power pulses (see Figure 2-7, view B). The damper is an assembly of a hub/inner ring and an outer ring held together by vulcanized rubber. During engine manufacture, dynamic imbalance may be corrected at the front by installing pin weights in one or more of twelve holes in the torsional damper outer ring.

During service, the torsional damper and crankshaft for each particular engine should be kept together to prevent mismatching. If a crankshaft has been broken, the torsional damper should be inspected as a possible cause for the damage.

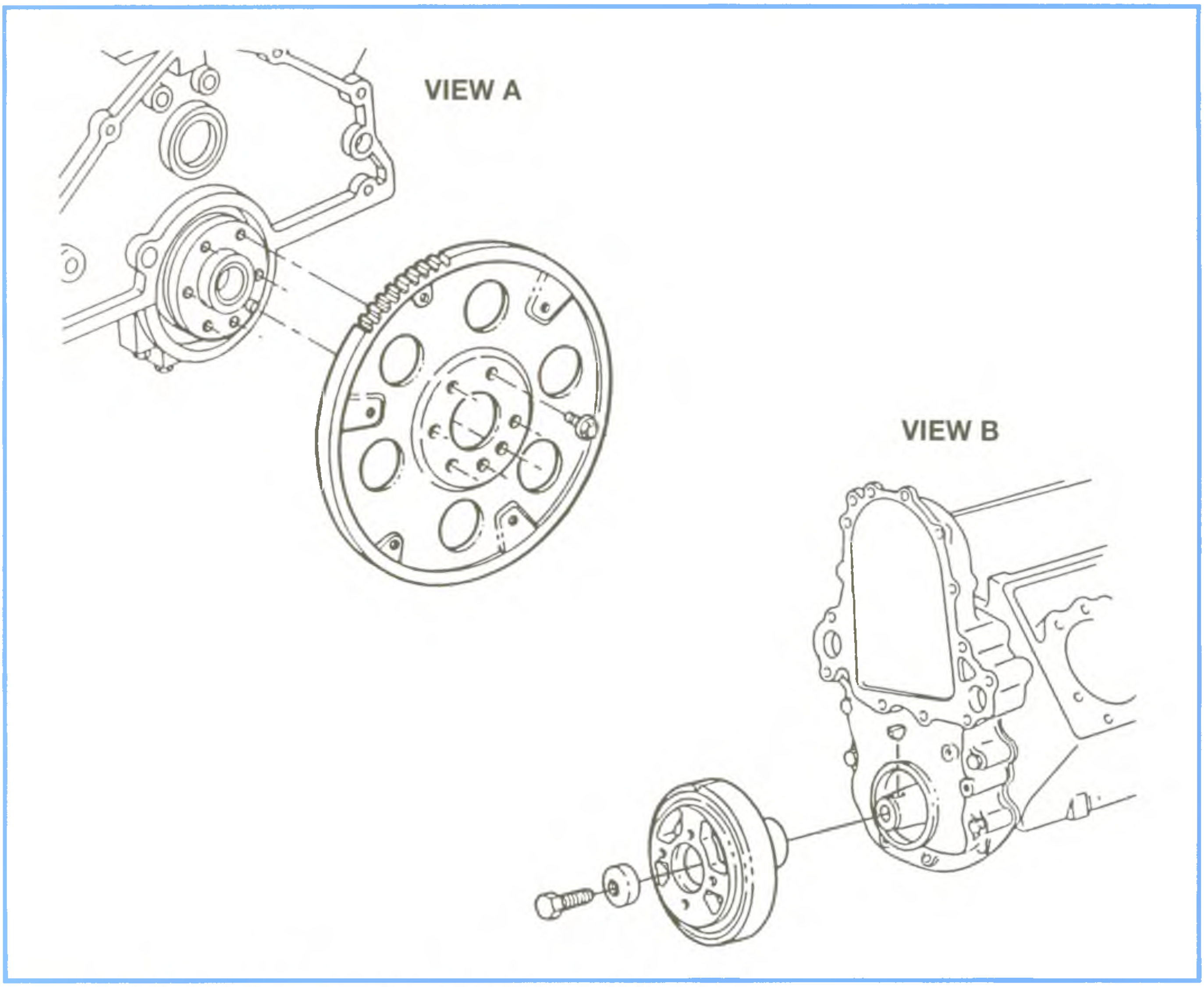


Figure 2-7, Crankshaft Flexplate and Torsional Damper

Camshaft Support

The cylinder case has five bores to support the camshaft. The bores use one-piece sleeve bearings of different sizes, with bores #1 to #4 having a larger inside diameter than bore #5.

A thrust plate mounted at the front of the cylinder case controls the camshaft end-play (see Figure 2-8, view A). A spacer positioned between the camshaft and thrust washer is installed with a chamfer on its inner diameter facing the camshaft.

A cup plug at the rear of the cylinder case seals camshaft bore #5 (see Figure 2-8, view B). A sealant is used on the outside diameter of the plug, which is installed flush with its bore.

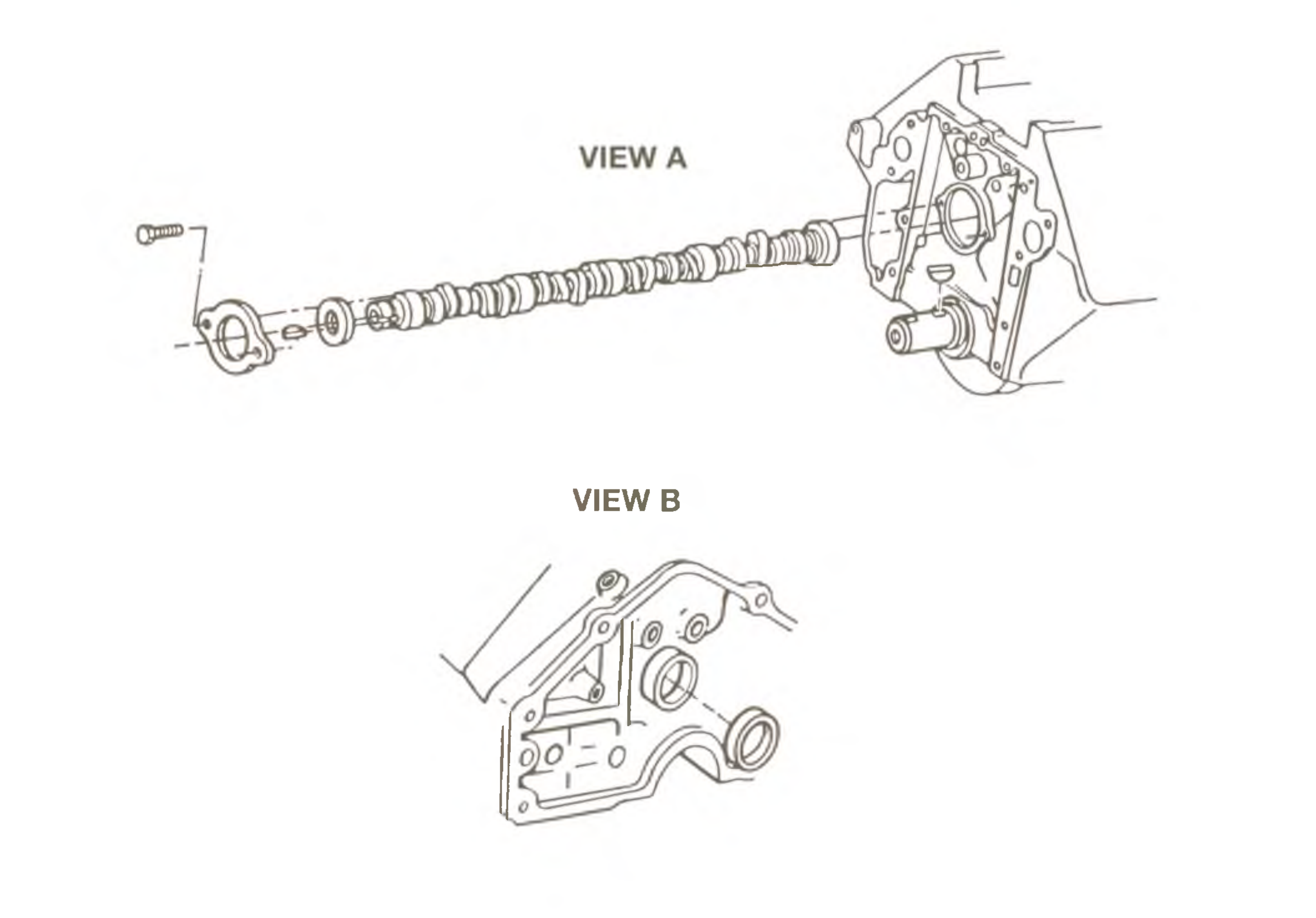


Figure 2-8, Camshaft Support Features

During service, camshaft bearings #1 and #5 may be removed and installed by using a special driver (see Figure 2-9, view A). The removal and installation of bearings #2, #3 and #4 require the use of a special pulling tool (see Figure 2-9, view B).

To assure proper oiling and support for camshaft loads during engine operation, the camshaft bearings installed during service must have the following alignment features:

- An oil supply hole of each bearing must be in the 4 o'clock position (when viewed from the front of the engine).
- The seam of each bearing must face the upper part of the engine.
- The #1 bearing has a notch that faces the front of the engine, as well as another oil hole positioned in the 12 o'clock position.

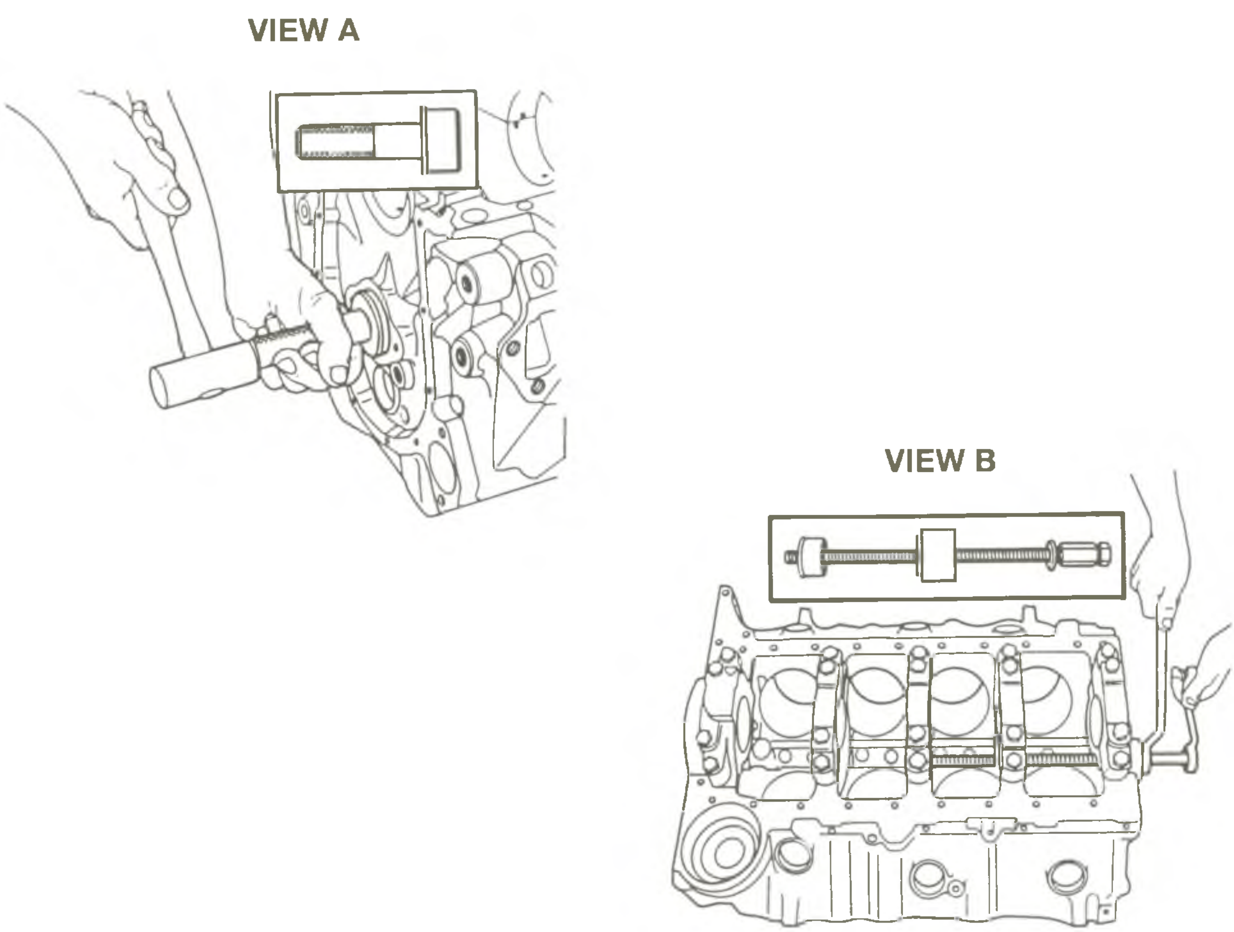


Figure 2-9, **Camshaft Bearing Service**

Camshaft Features

The camshaft is made of forged steel and has sixteen lobes to operate hydraulic roller lifters for eight intake and eight exhaust valves (see Figure 2-10). A helical gear at the rear of the camshaft rotates the oil pump drive/engine speed sensor assembly. No machining of the camshaft journals or lobes is allowed during service.

During installation of the camshaft, all journals and lobes are coated with engine oil. The gear teeth that operate the oil pump drive/engine speed sensor assembly are coated with a special grease.

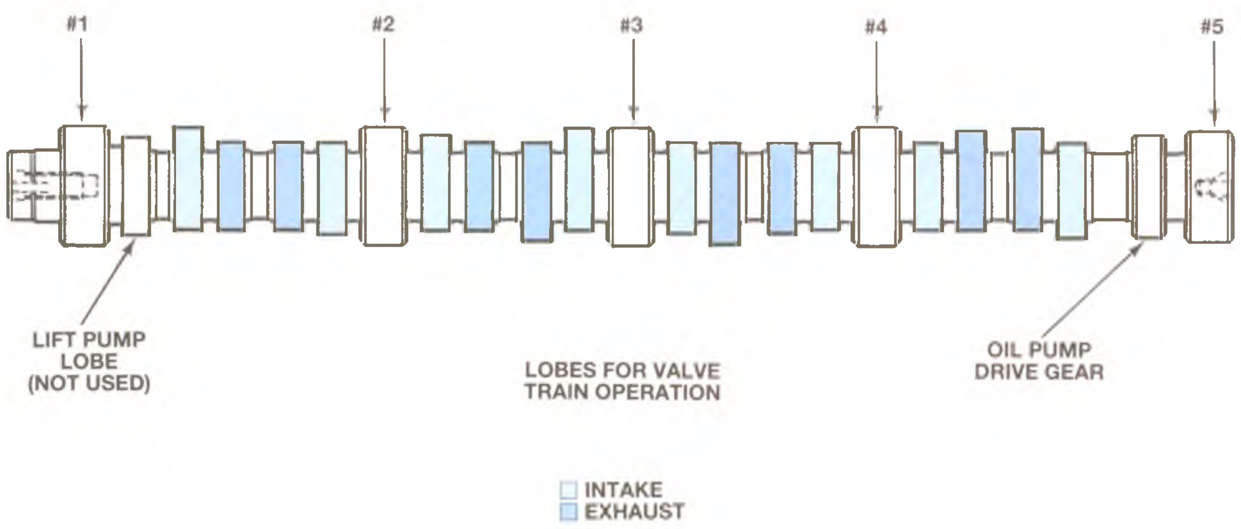


Figure 2-10, Camshaft Features

The camshaft has a driven sprocket mounted on its front end, using a key. A drive gear for the fuel injection pump also mounts on the front of the camshaft, and a bolt holds both the sprocket and the gear in place.

The timing chain between the crankshaft and camshaft is of the open roller, double-row design (see Figure 2-11). Timing is performed when the alignment mark of the camshaft sprocket is in the 6 o'clock position, facing the crankshaft sprocket alignment mark.

For inspection during service, the timing chain has a procedure to check the maximum amount of deflection. A dial indicator is used to measure total travel as the chain is moved from its full outward to full inward position. The specification for timing chain deflection is 12.7 mm (0.500 in.) for a new chain and 20.3 mm (0.800 in.) for a used chain.

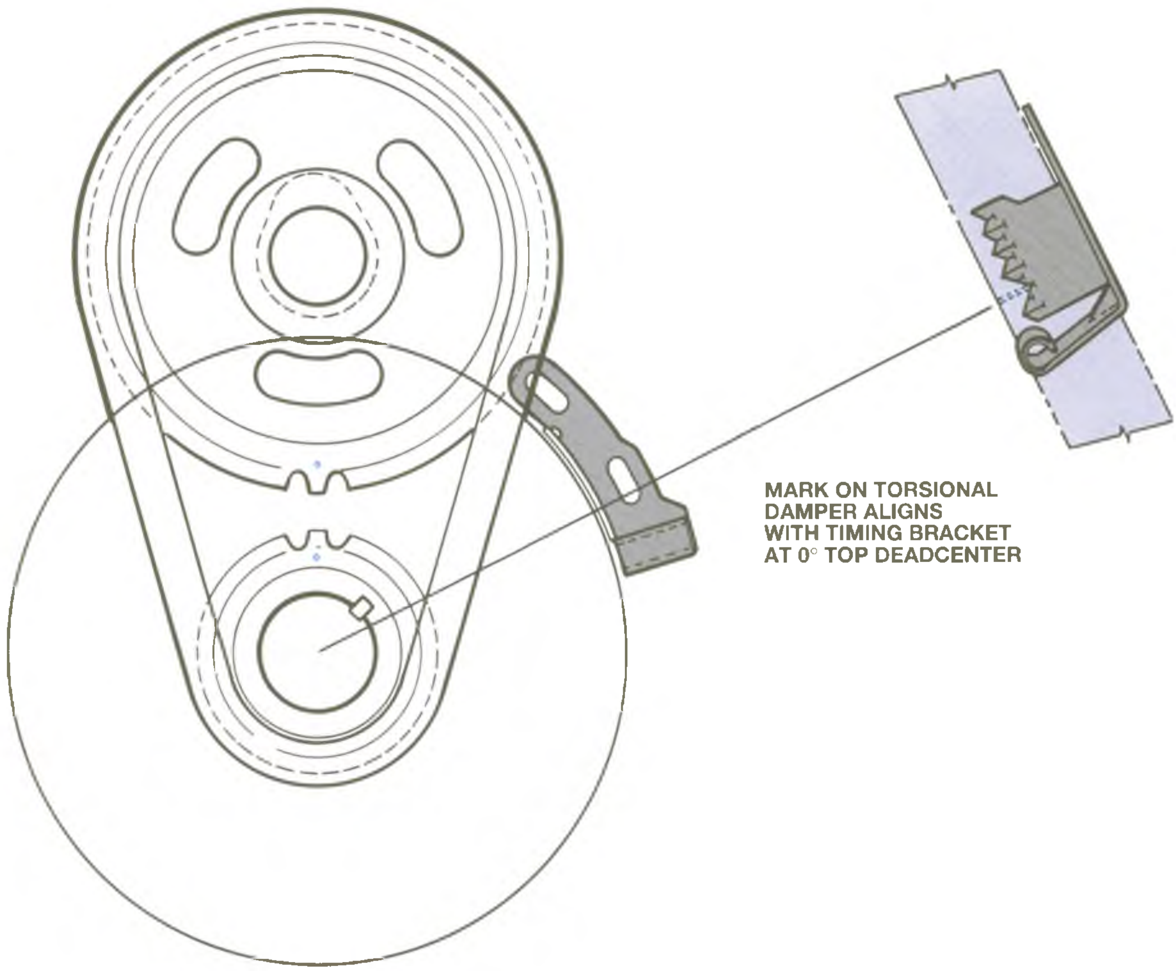


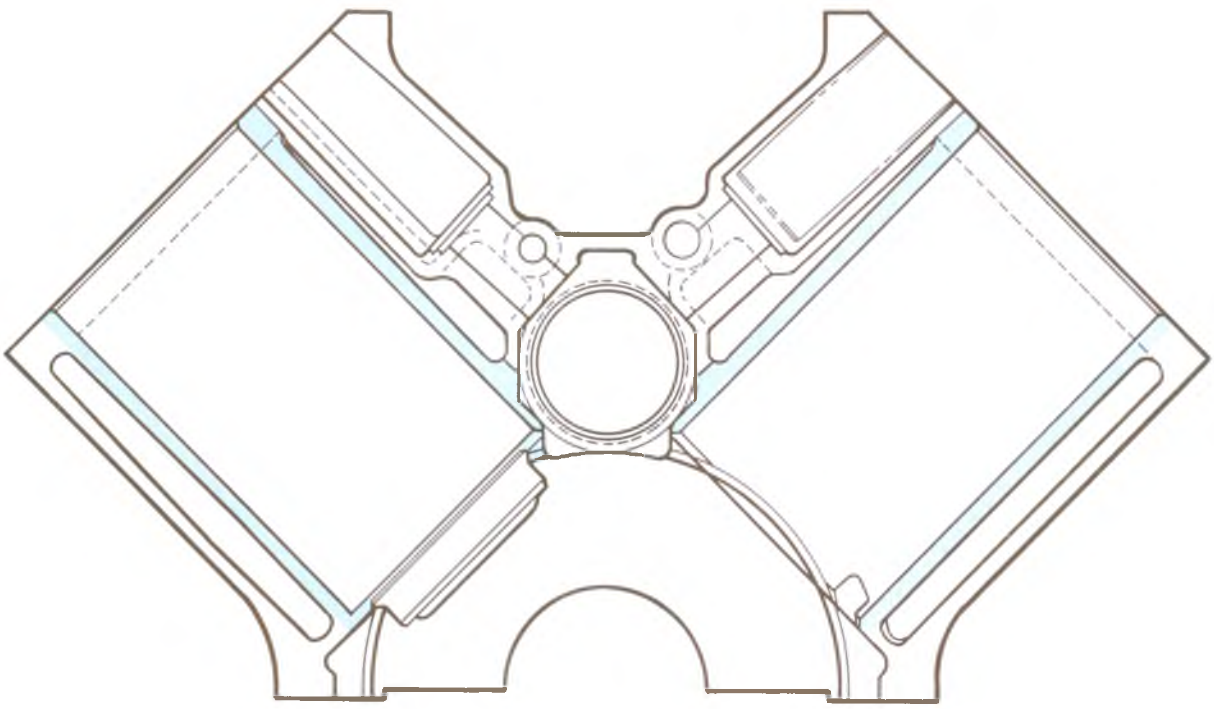
Figure 2-11, **Camshaft Timing Chain**

Cylinder Bores

The cylinder case has eight machined cylinder bores to support the piston/connecting rod assemblies (see Figure 2-12). The bores have different diameter sizes, with cylinders #7 and #8 slightly larger than cylinders #1 to #6. The difference in bore size allows for more piston expansion in the rear two cylinders.

During engine manufacture, one of two piston sizes (labeled J and K) is used at each of the eight cylinders and is based on cylinder bore size and recommended clearance. Each piston has ~~a~~ NO size identification mark on its face and piston pin boss surfaces.

The cylinder case pan rail has a piston size identification marking for each bore (see Figure 2-13). These are matched with the piston sizes during the assembly process.



CYLINDER BORE DIAMETER FOR JT PISTON:
102.974 TO 102.987 mm (4.05409 TO 4.05461 IN.)

CYLINDER BORE DIAMETER FOR KT PISTON:
102.987 TO 103.000 mm (4.05461 TO 4.05512 IN.)

Figure 2-12, Cylinder Bores

Piston-to-bore clearance specifications used in manufacturing are as follows:

- Bores #1 to #6: 0.094 to 0.120 mm (0.0037 to 0.0047 in.)
- Bores #7 and #8: 0.107 to 0.133 mm (0.0042 to 0.0052 in.)

For service purposes, three sizes of pistons are available as follows:

- Service Standard (labeled JT)
- Service – High Limit (labeled GT)
- Service – 0.50 mm O.S. (labeled as 0.50 OST)

The JT piston size has a skirt diameter of 102.867 to 102.880 mm (4.0499 to 4.0504 in.) and fits in a cylinder with a bore diameter of 102.947 to 102.987 mm (4.05409 to 4.05461 in.).

The GT piston size has a skirt diameter of 102.906 to 102.919 mm (4.0514 to 4.0519 in.) and fits in a cylinder with a bore diameter of 103.013 to 103.026 mm (4.05563 to 4.05614 in.).

The 0.50 OST piston has a skirt diameter of 103.401 to 103.414 mm (4.0709 to 4.0714 in.) and fits in a cylinder with a bore diameter of 103.508 to 103.521 mm (4.07512 to 4.07563 in.).

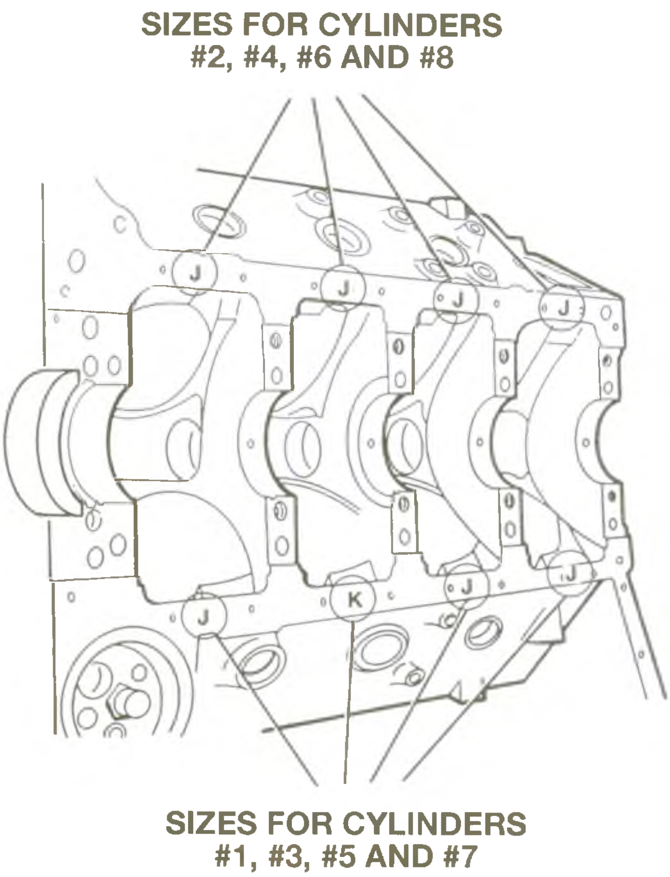


Figure 2-13, Cylinder Bore Identification

Piston Features

Each piston is made of cast aluminum and has the following features (refer to Figure 2-14):

- A face with a special combustion chamber indentation
- A cast-in insert for a top compression ring with a keystone-shaped cross section
- A machined groove for a 2nd compression ring
- A machined groove for a two-piece oil control ring
- Bores for a full-floating piston pin, secured at each end by a round wire retaining ring
- A machined outer diameter with a specially shaped skirt area

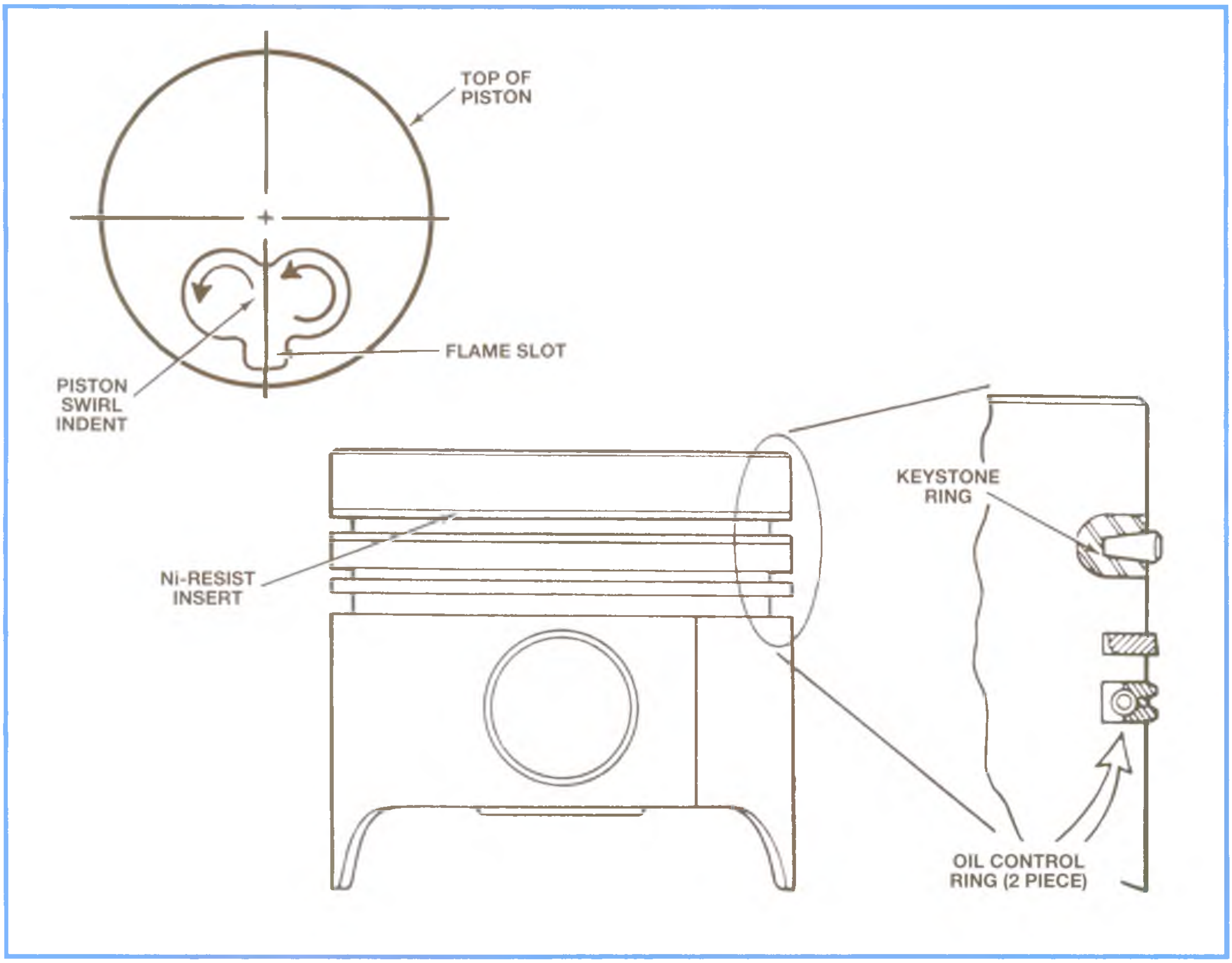


Figure 2-14, Piston Design Features

During service, several critical piston installation procedures are followed:

- Each piston ring is checked for correct end gap clearance before it is installed.
- Each piston ring groove is cleaned without removing metal.
- The compression rings are installed with identification markings facing upward.
- Installed piston rings are checked for free movement in their grooves.
- Each piston ring gap must be aligned (refer to Figure 2-15).
- Before installation into the cylinder bore, the piston and rings should be coated with engine oil.
- During installation, the combustion area on the face of the piston must face toward the outside of the cylinder case.

Installation of each piston pin retaining ring requires the use of special tool J 29134-A. After installation, each ring is checked for proper installation in its groove. The opening in a retaining ring that has been installed should face downward (toward the crankshaft).

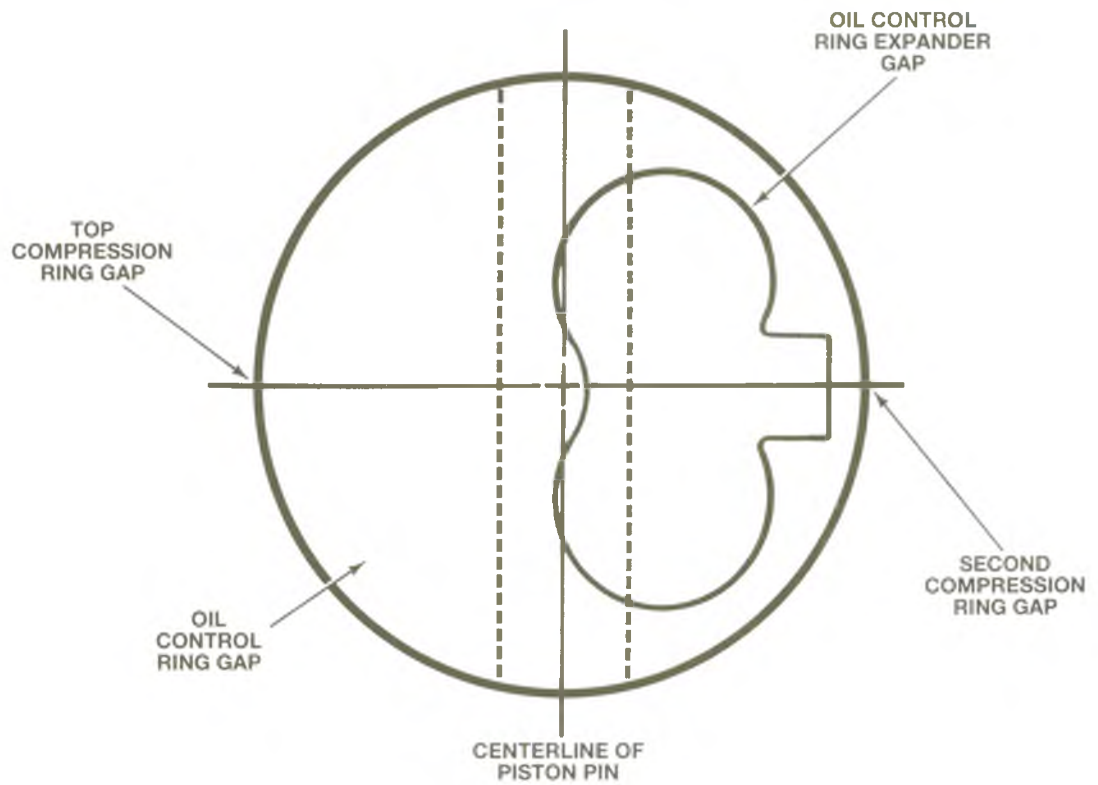


Figure 2-15, Piston Service Features

Connecting Rod Features

Each connecting rod is made of forged steel and has a precision-machined bronze bushing in its piston pin bore (refer to Figure 2-16). The crankpin bore of each connecting rod is split and holds a two-piece sleeve bearing insert. Studs and nuts retain the rod caps.

Each connecting rod is carefully balanced, and no repair procedures (such as straightening, bushing replacement or crankpin bore enlargement) are allowed. Clearance between the piston pin and connecting rod bushing must not exceed 0.030 mm (0.0012 in.).

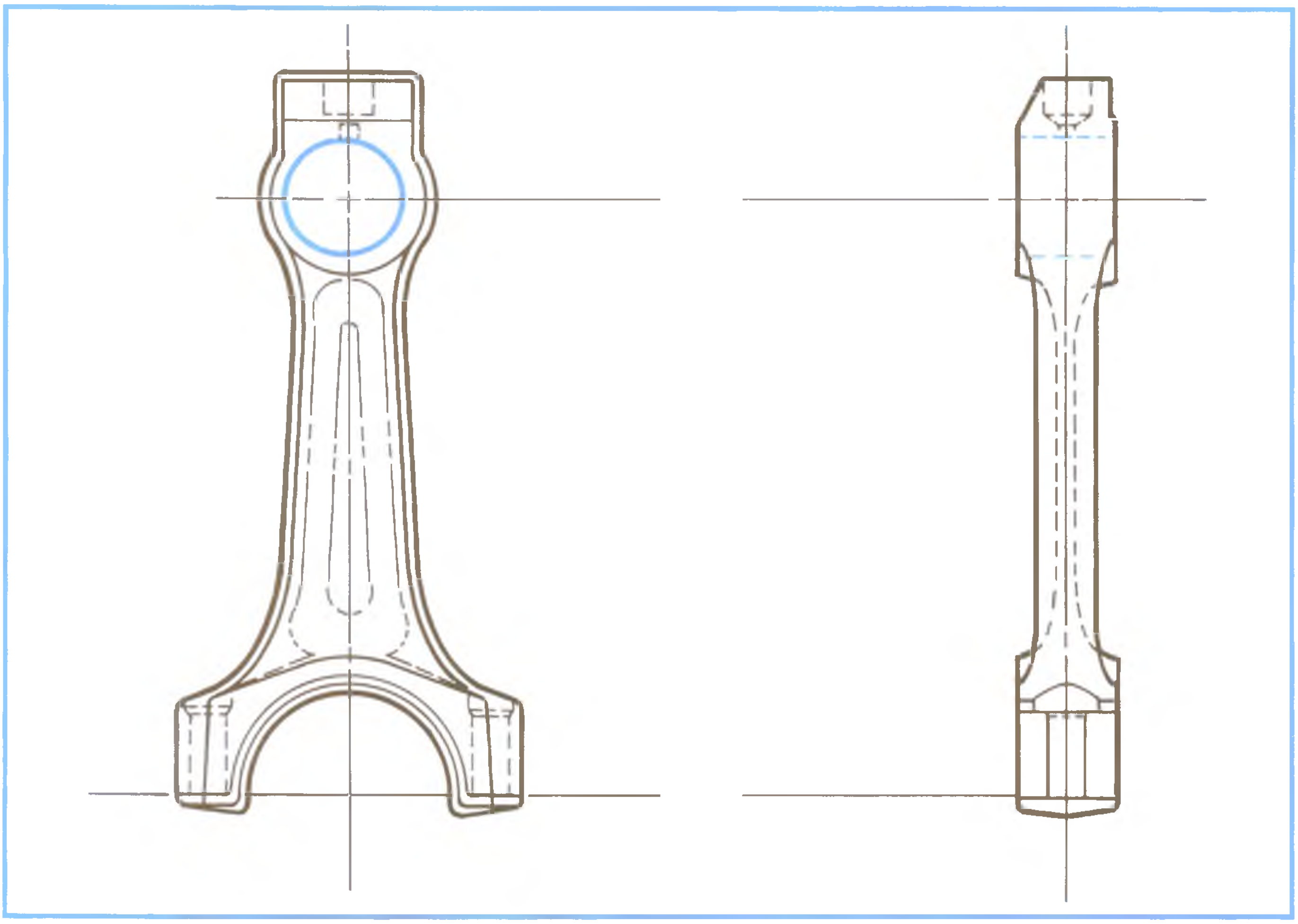


Figure 2-16, Connecting Rod Design Features

Connecting rods are fitted to pistons so that the bearing tang slots of both the rod and its matched cap face away from the camshaft. During engine manufacture, a combination of two bearing insert sizes is used at each of the eight connecting rod bores and is based on crankpin journal measurements (refer to Figure 2-17).

For service purposes, bearing size combinations provide an oil clearance of 0.045 to 0.100 mm (0.0018 to 0.0039 inch), as measured with the plastigage procedure.

Two sizes of crankpin bearing inserts are available for service:

- Standard (yellow color identification)
- 0.026mm (0.001 in.) U.S. (green color identification)

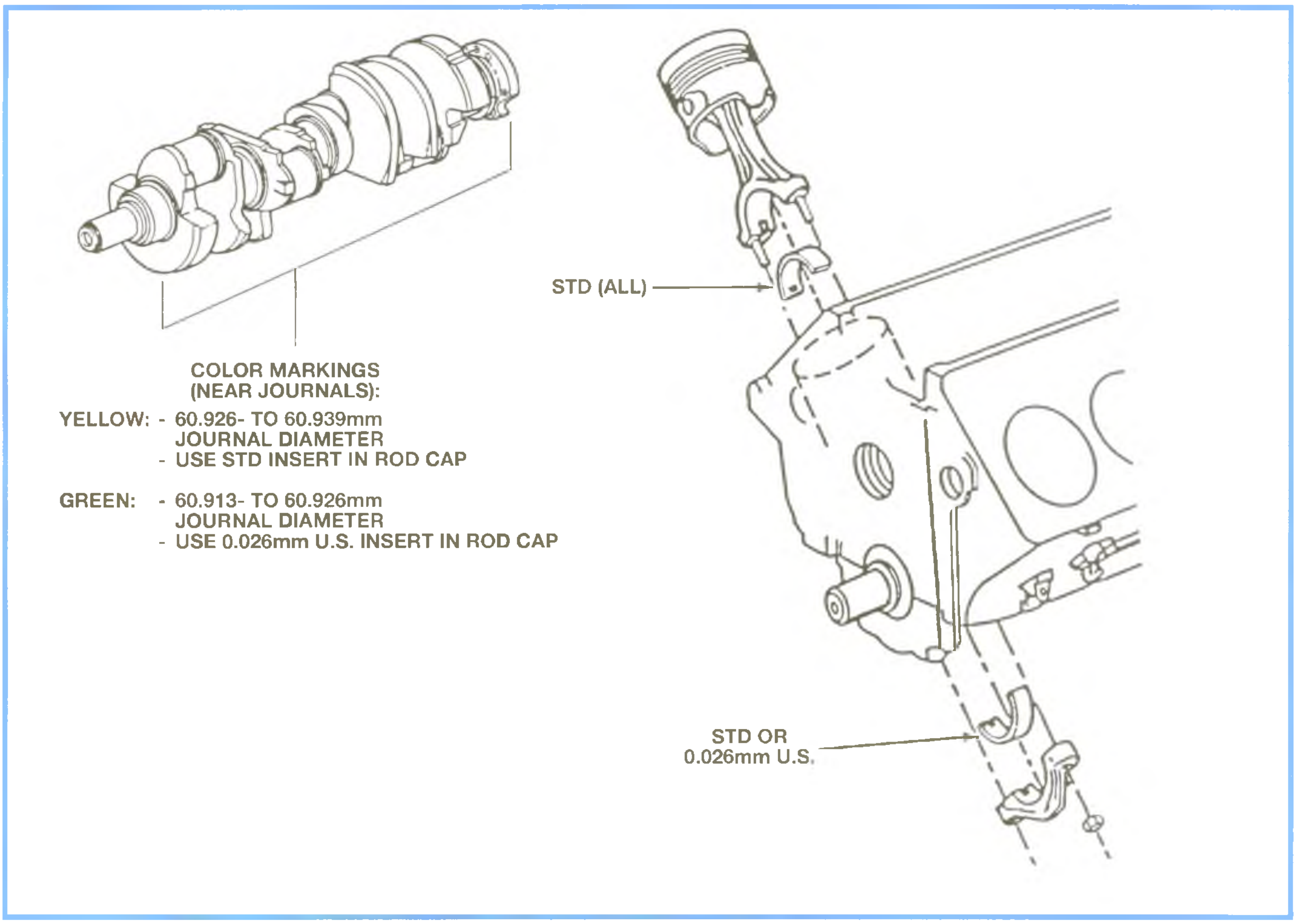


Figure 2-17, **Connecting Rod Bearing Selection Chart**

Cylinder Head Assemblies

The cylinder case provides mounting surfaces for two cylinder heads that are identical except for external hardware. Each one-piece cylinder head is made from cast iron and has the following features (refer to Figure 2-18):

- One pre-combustion chamber per cylinder, partially formed with a specially made cup insert
- Mounting surfaces for one injection nozzle and glow plug to project into each pre-combustion chamber
- Intake and exhaust ports with poppet-type valve assemblies
- A 17-bolt cylinder case mounting, providing 5-bolt clamping around each cylinder bore
- Cylinder bore and passage sealing with a special one-piece gasket (graphite coated)
- Cooling system passages
- Lubrication system oil drain-back passages
- Mounting surfaces for accessories and engine lift brackets

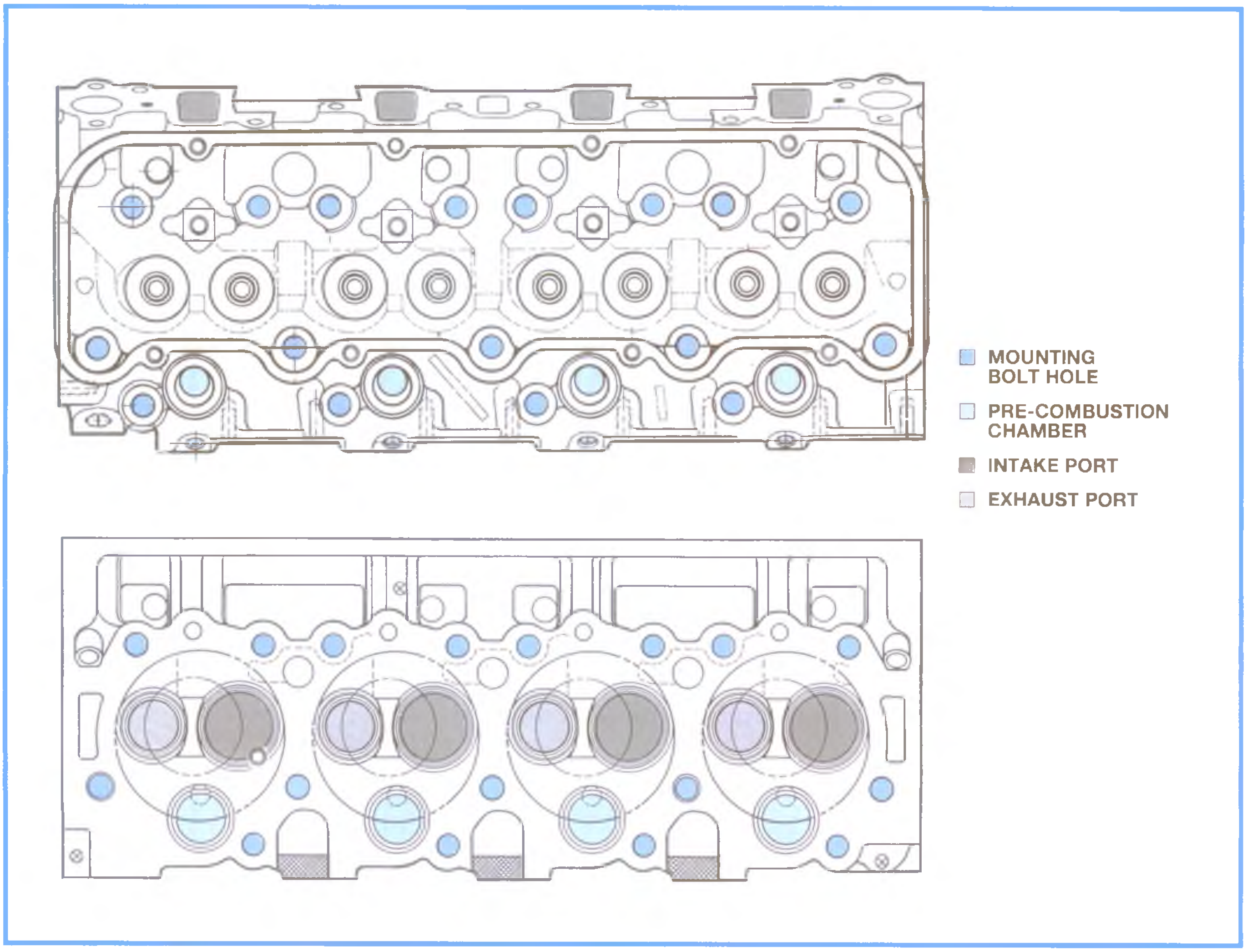


Figure 2-18, Cylinder Head Assembly

Each cylinder has a pre-combustion chamber to mix fuel and air efficiently, resulting in low exhaust emissions. An insert made of stainless steel forms one half of the pre-combustion chamber, while the casting of the cylinder head forms the other half. The shape and size of the inside of the insert is specific to the 6.5L V8 turbo diesel engine and should not be confused with inserts for other diesel engines.

Each pre-combustion chamber insert has a notch that aligns with a matching groove in the cylinder head (see Figure 2-19, view A). Insert identification markings for the 6.5L V8 turbo diesel application include two dots and the letter T.

During service, each pre-combustion chamber insert may be removed with a brass punch and hammer after the nozzle and glow plug are removed. Inspection of the insert includes a check for excessive heat cracks in the area of the flame slot exit (see Figure 2-19, view B). After installation, the insert must have a specified height (relative to the cylinder head surface) of 0 to 0.051 mm (0 to 0.002 in.).

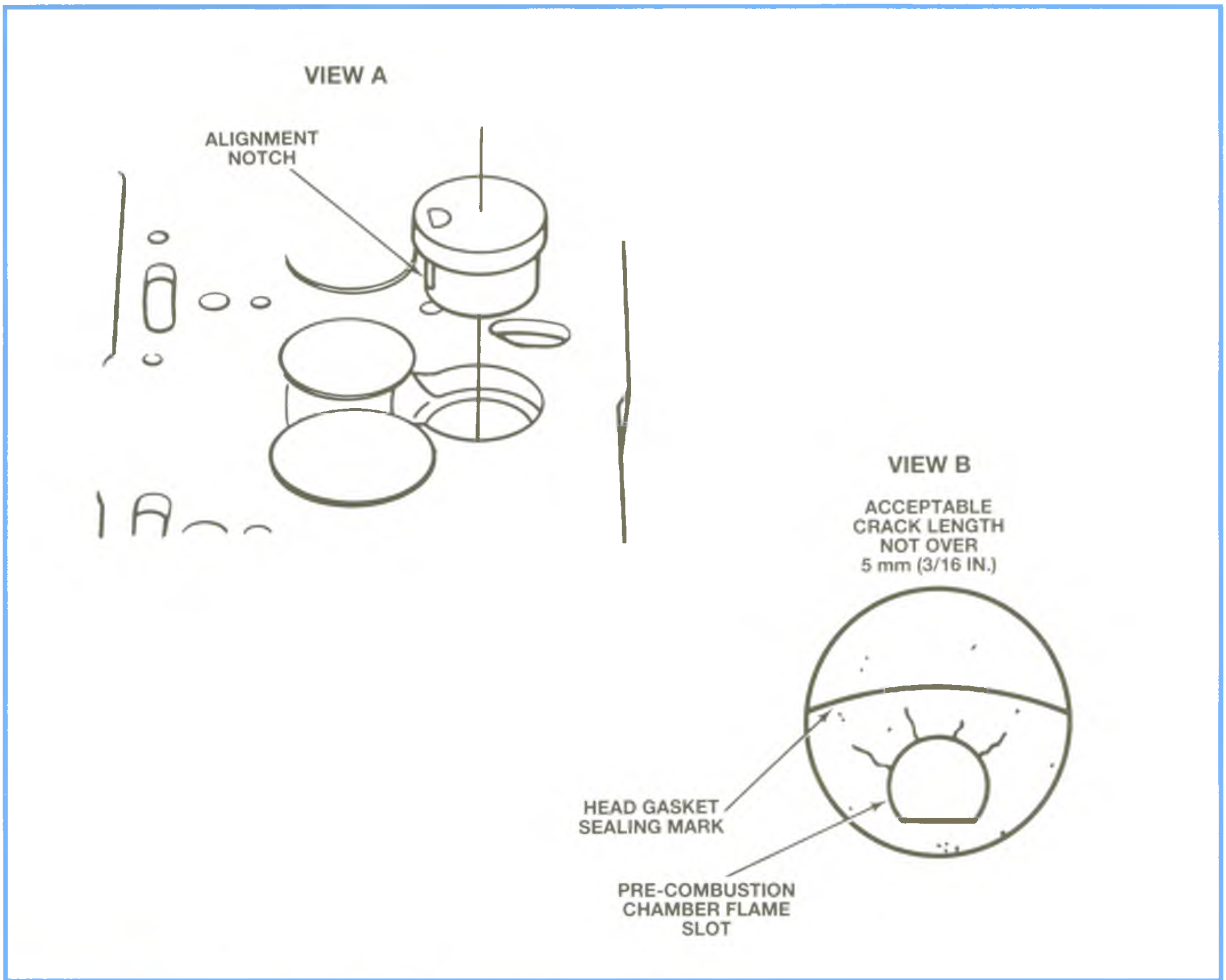


Figure 2-19, **Pre-Combustion Chamber Insert Features**

During service, the procedure for installing a cylinder head gasket has the following critical steps:

1. Clean all cylinder head bolts and bolt holes to remove old sealant.
2. Check the cylinder case and head surface for excessive warpage:
   - Limit of 0.15mm (0.006-in.) warpage across the length
   - Limit of 0.075mm (0.003-in.) warpage across the width
   - No damage in sealing ring or coolant passage areas
3. Check that each pre-combustion chamber is flush with the cylinder head surface (limit is 0.05 mm [0.002 in.] above surface).
4. Check that the alignment dowels allow the cylinder head to rest on the cylinder case.
5. Clean the cylinder case and head sealing surfaces.
6. Install a new head gasket.
7. Install the cylinder head assembly without scuffing the gasket.
8. Coat each cylinder head bolt with pipe thread sealant with TEFLON® on the threads and under the head.
9. Follow this tightening sequence (refer to Figure 2-20):
   - Hand tighten all bolts.
   - Tighten bolts in the specified sequence to 25 N·m (20 lb-ft).
   - Tighten bolts in the specified sequence to 65 N·m (50 lb-ft).
   - Tighten bolts in the specified sequence an additional 90 degrees of rotation.

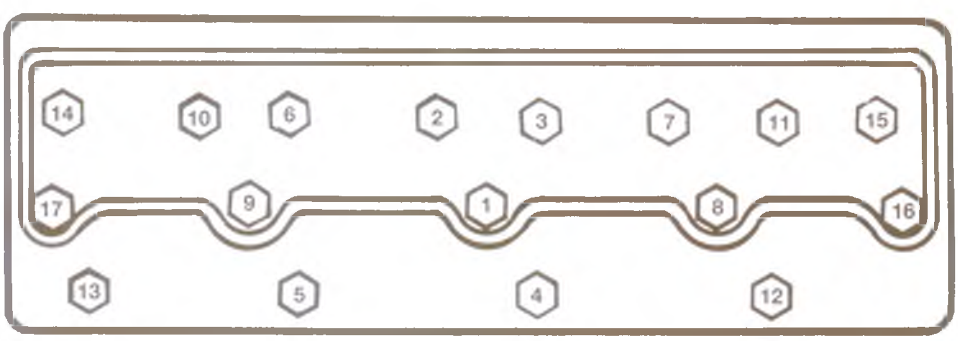


Figure 2-20, Cylinder Head Bolt Tightening Sequence

Valve Train

The valve train includes the following parts (refer to Figure 2-21):

- Sixteen hydraulic roller lifters, positioned in cylinder case bores by guide plates and clamps
- A push rod for each lifter that provides mechanical movement and the transfer of lubricating oil to a rocker arm
- Four rocker arm assemblies, each containing a shaft with an intake and exhaust valve rocker arm for two cylinders
- Eight intake valve assemblies, each including an oil seal, return spring, two-piece stem retainer and a spring retainer
- Eight exhaust valve assemblies, each including two oil seals, a return spring, a two-piece stem retainer and a spring retainer/rotator

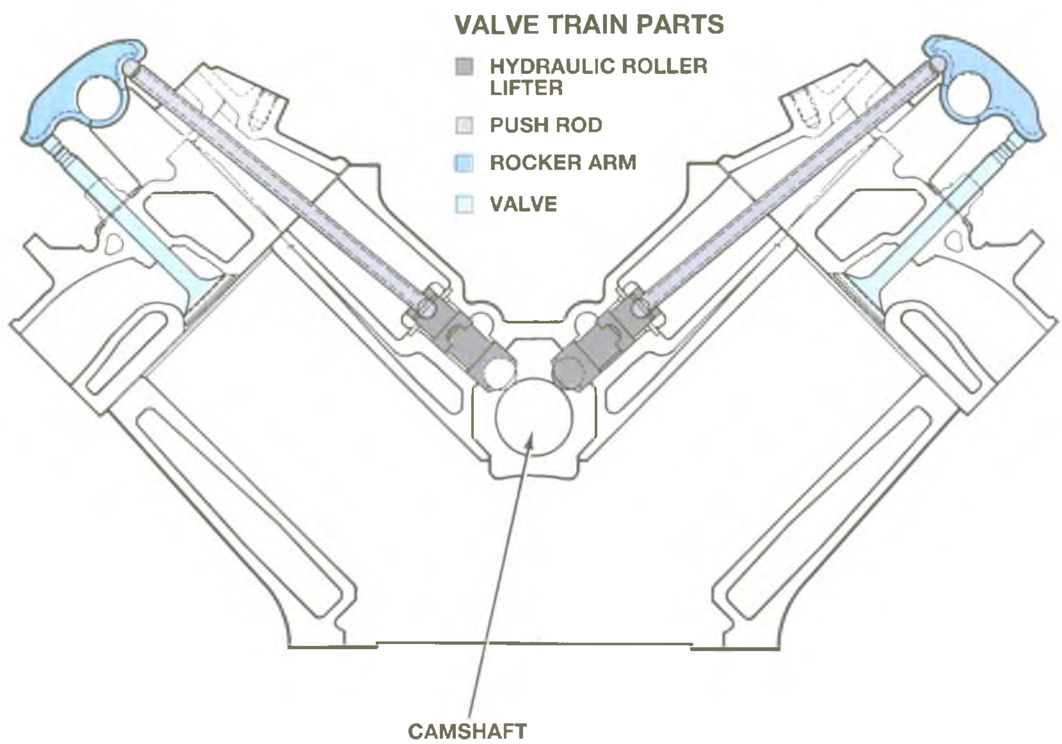


Figure 2-21, Valve Train Design Features

Each hydraulic roller lifter is an assembly of parts (see Figure 2-22, view A). Lifter operation transfers rotary camshaft motion to the upward and downward motion of the push rod, providing a hydraulic cushion (see Figure 2-22, views B and C).

When the camshaft lobe is not pushing upward, the lifter allows oil under lubrication system pressure to move through an internal plunger and past a check ball. As the camshaft lobe pushes the lifter body upward, oil is trapped under the plunger by the check ball, transferring force from the lifter body to the plunger and push rod seat. During its operation, each lifter pumps oil through its mating push rod, giving lubrication to the rocker arm and upper cylinder head parts.

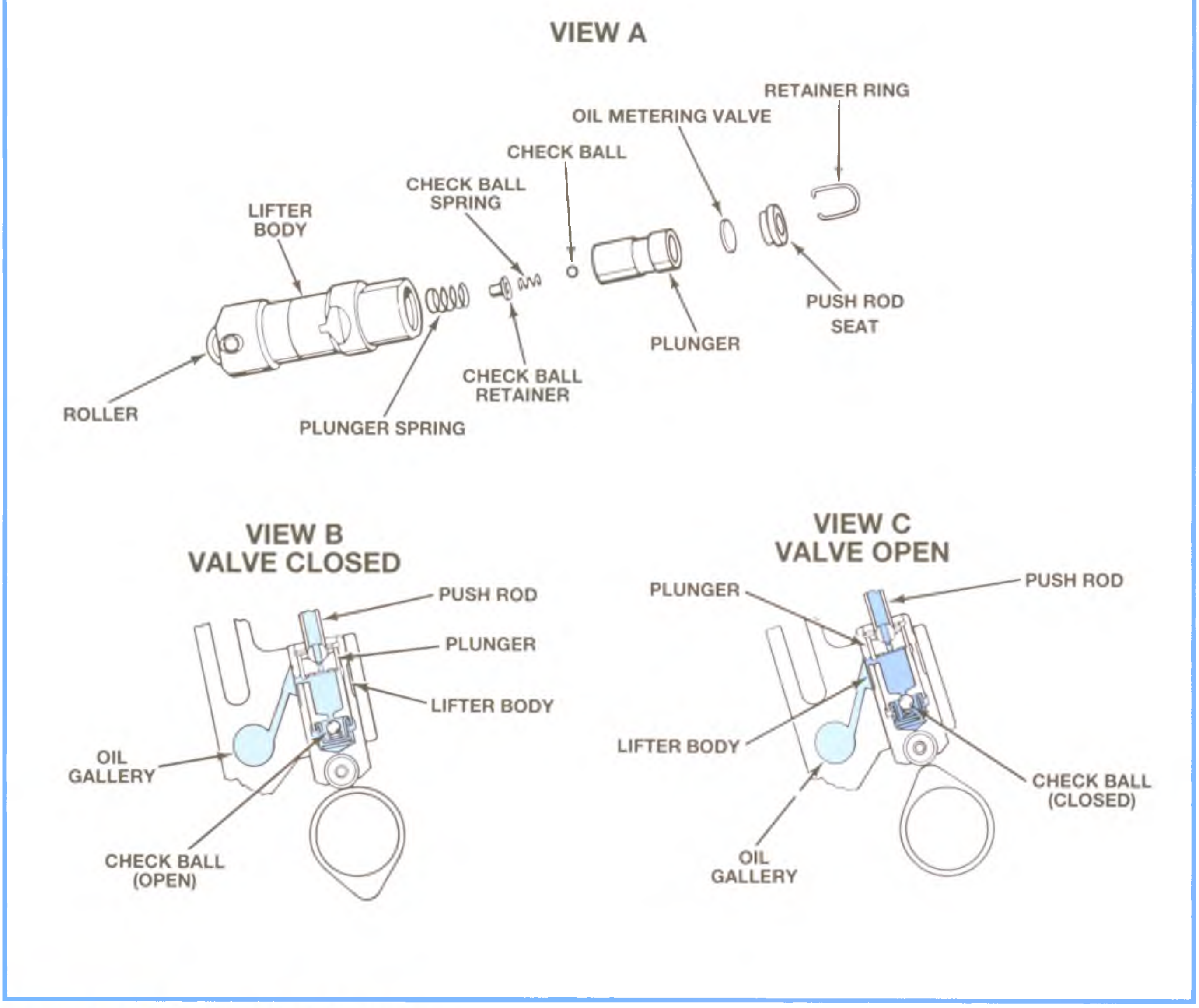


Figure 2-22, Valve Lifter Features

The hydraulic lifters use guides to keep them from rotating (see Figure 2-23). Each guide positions two lifters, and a bolt-in clamp holds each pair of guides in place. For the entire engine, eight guides and four clamps are used.

The lifter installation procedure has the following critical steps:

1. Coat the roller (and its bearing) of each lifter with a special extreme-pressure lubricant (GM P/N 1052365).
2. Install each lifter in its bore in the cylinder case.
3. Install each guide, rotating the lifters to align with it.
4. Install each clamp, aligning its ends with the center holes of each guide.
5. Tighten each clamp bolt to 26 N·m (19 lb-ft) torque.
6. Manually rotate the crankshaft two complete revolutions (720 degrees of rotation) to check for binding.

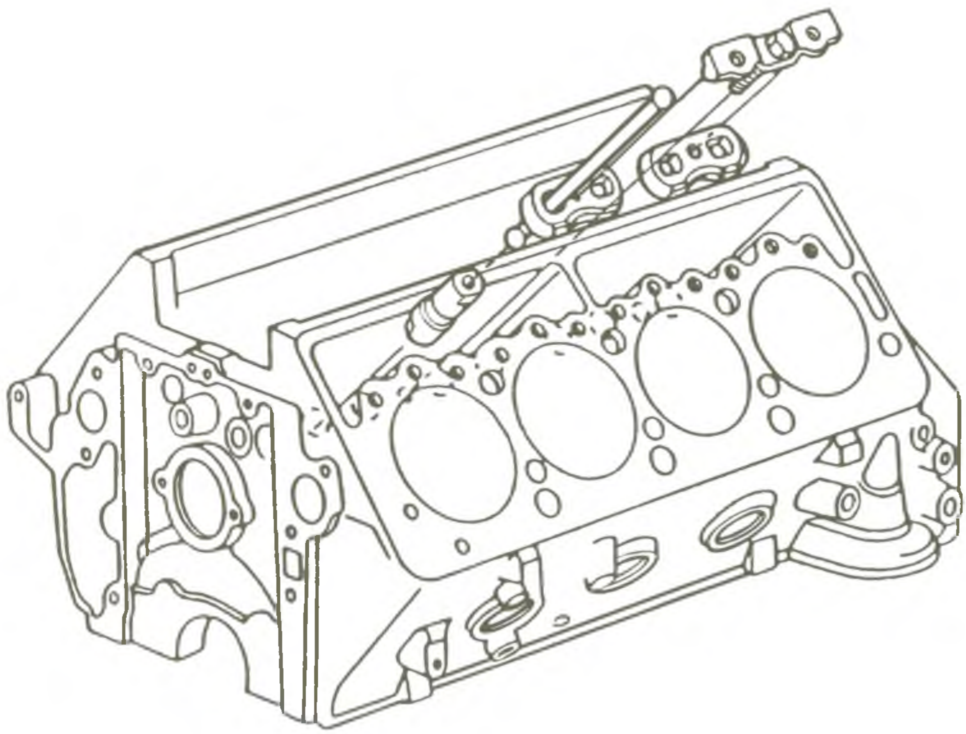


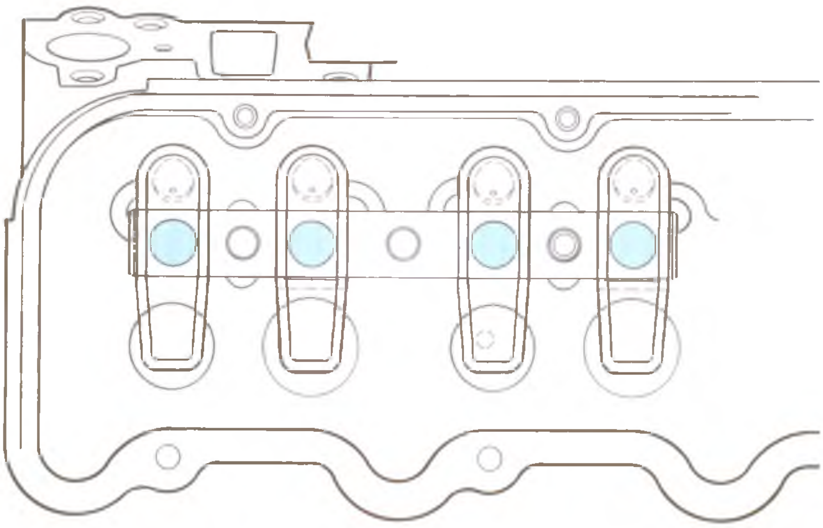
Figure 2-23, **Valve Lifter Guides and Clamps**

Each push rod is a hollow steel tube with hollow metal balls welded to each end. One push rod ball end has greater hardness (identified by a paint stripe on the tube) and contacts a rocker arm. The other ball end rests in a seat of the hydraulic roller lifter.

Four stamped steel rocker arms are assembled to a hollow steel shaft and are located by press-in nylon buttons (see Figure 2-24). Rocker arms are identical for either the intake or exhaust valve position for each cylinder.

Two bolts hold each rocker arm assembly to the cylinder head, using specially shaped washers. Each cylinder head has two rocker arm assemblies.

TOP VIEW



SIDE VIEW

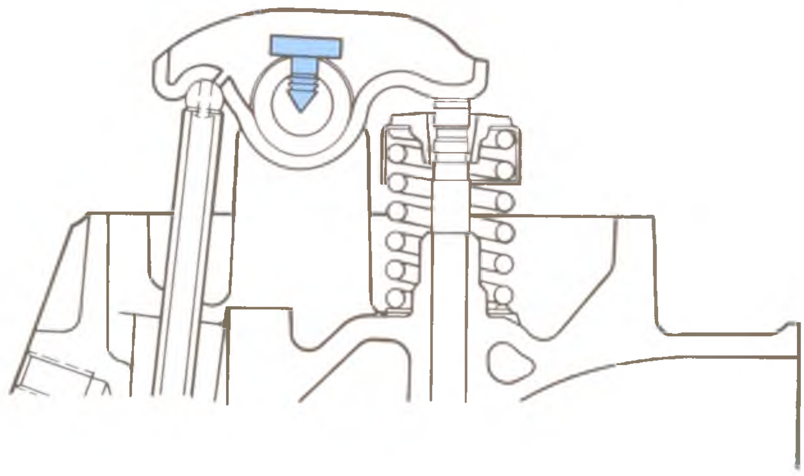


Figure 2-24, Rocker Arm Assembly Features

The positions of the pistons must not be close to the valves during rocker arm installation. If any of the hydraulic lifters are full of oil, installing a rocker arm assembly may cause the lifter to push its valve into the face of a piston unless certain precautions are taken.

The procedure for installing a rocker arm assembly has these steps:

1. Rotate the crankshaft so that the torsional damper mark aligns with the TDC mark of the timing bracket on the front cover.
2. Rotate the crankshaft in a counterclockwise direction so that the torsional damper mark moves a distance of $3^1/_2$ in. (see Figure 2-25).
3. Evenly tighten the two mounting bolts for each rocker arm assembly.
4. Tighten the rocker arm mounting bolts to 55 N·m (40 lb-ft) torque.

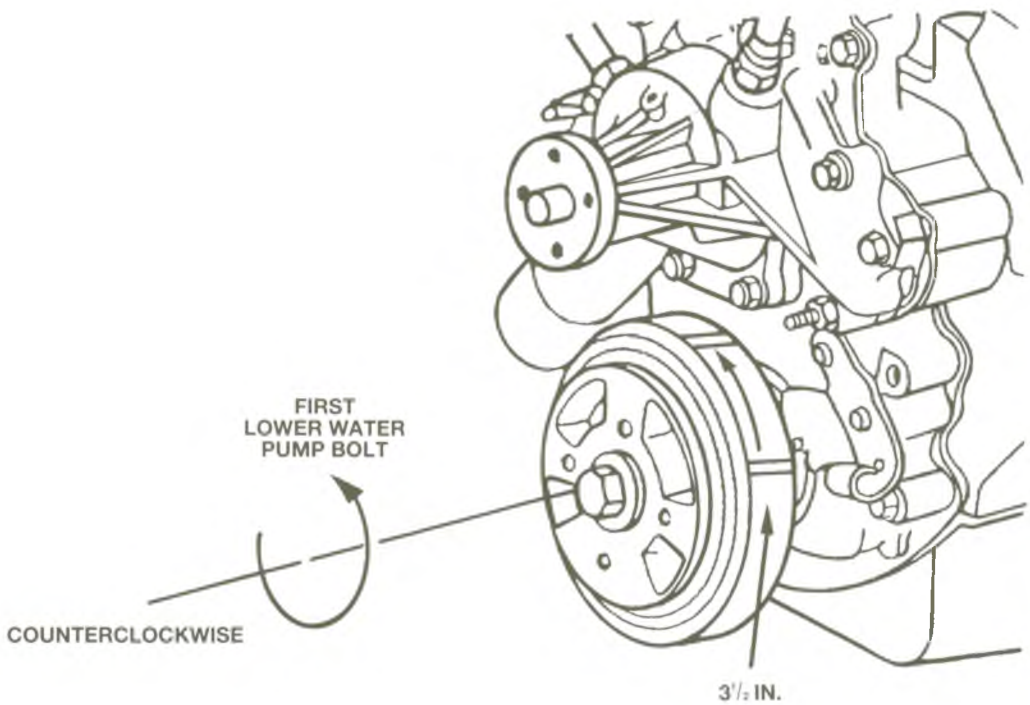


Figure 2-25, Crankshaft Position During Rocker Arm Installation

The intake and exhaust valve assemblies have the parts shown in Figures 2-26 and 2-27. Each intake and exhaust valve slides in a guide bore machined in the cylinder head. Its valve face contacts a seat surface of the cylinder head that has been hardened by electric induction heating.

Both intake and exhaust valves use the same return spring assemblies, consisting of inner and outer coils designed to dampen vibration caused by high-speed valve operation. A metal washer positioned under each return spring prevents cylinder head surface wear.

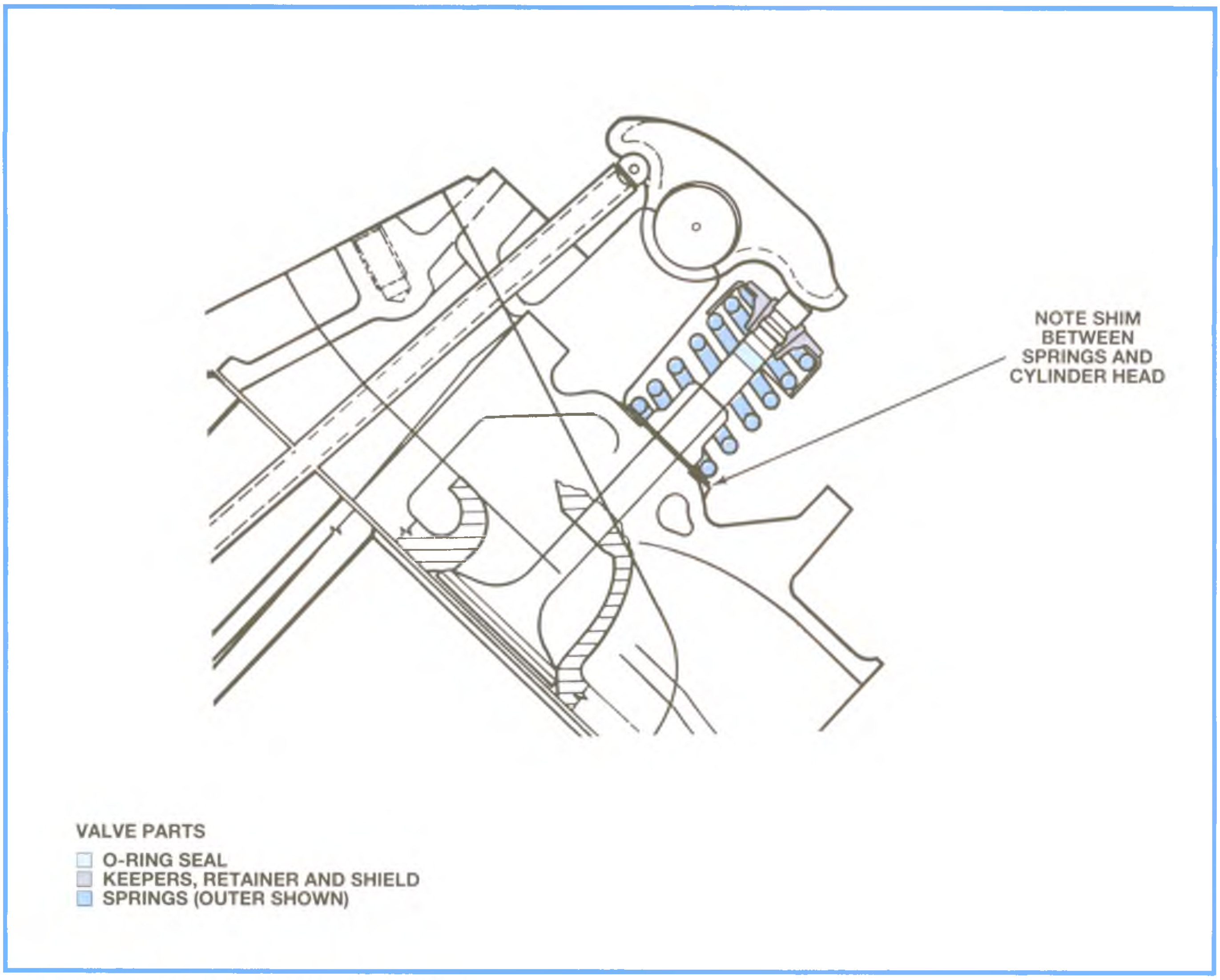


Figure 2-26, Intake Valve Assembly

Each intake and exhaust valve stem has a square-cut seal ring, and the exhaust valve also uses a lip-type seal mounted on the upper end of the valve guide. An intake valve uses a spring retainer with two valve stem keepers, while an exhaust valve has a rotator with its two keepers.

Valve service includes procedures for minor machining of the valve face and seat surfaces. Valve guide repair involves reaming guides to an oversize bore dimension and using new valves with an oversize stem diameter.

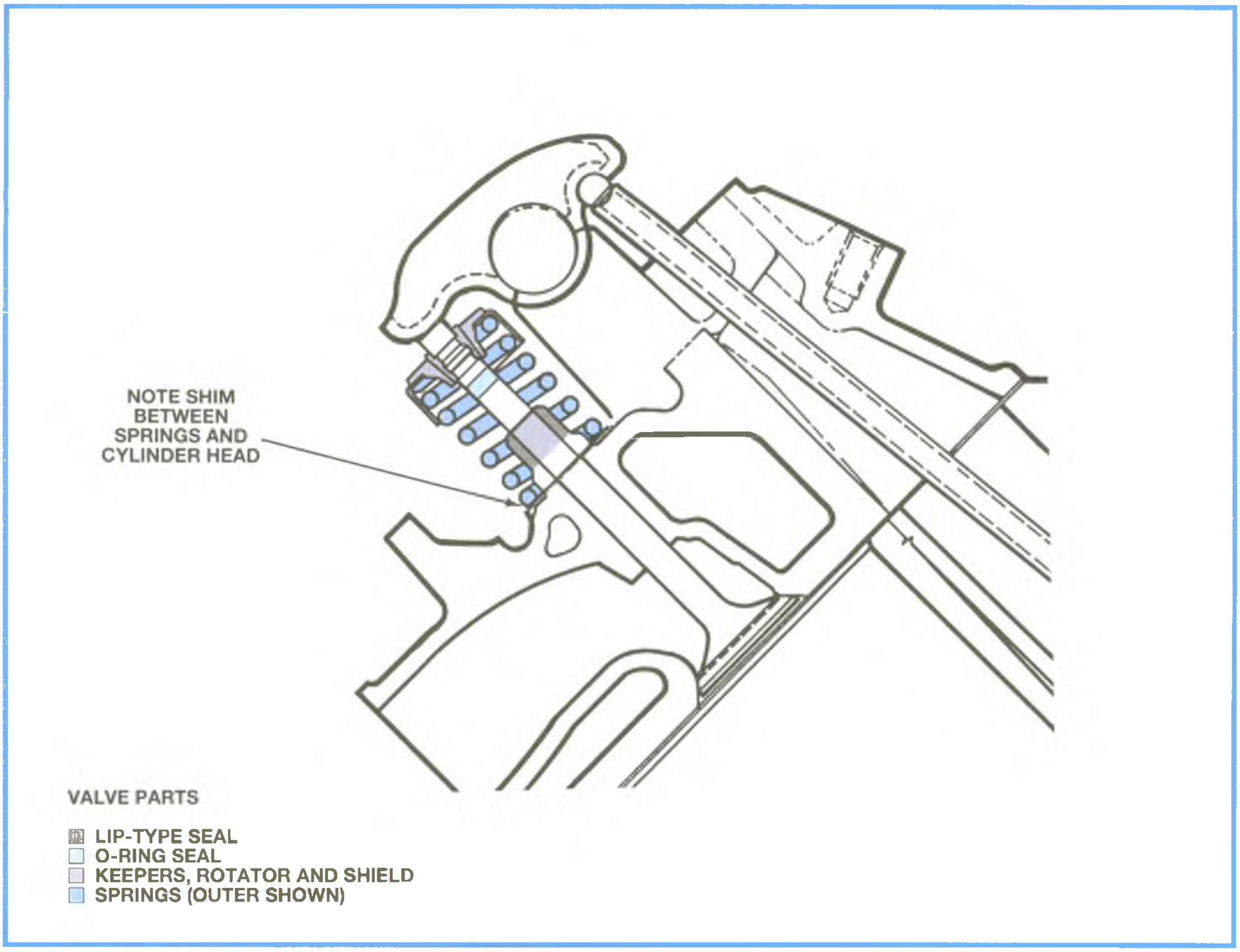


Figure 2-27, Exhaust Valve Assembly

Valve train operation relates to the following diagnosis hints:

Condition #1: Momentary noise after engine is started
Cause: Oil drains from the lifters that are holding valves open when the engine is not running
Correction: None, since the condition is normal.

Condition #2: Intermittent noise at engine idle speed (disappearing when engine speed is increased)
Cause: Check ball inside one or more lifters is pitted or dirty
Correction: Clean or replace suspect lifter(s) - refer to Figure 2-28.

Condition #3: Noise at slow idle or with hot engine oil (quiet when engine speed is increased or with ~~hot~~ COLD engine oil)
Cause: One or more lifters has a high leakdown rate
Correction: Replace suspect lifter(s).

Condition #4: Noise at high engine speed (quiet when engine speed is low)
Cause:
A. High engine oil level (causing oil foaming)
B. Low engine oil level (causing oil aeration)
C. Oil pan bent or oil pump pick-up damaged
Correction:
A. Drain engine oil to correct level.
B. Fill engine oil to correct level.
C. Repair or replace oil pan or oil pump.

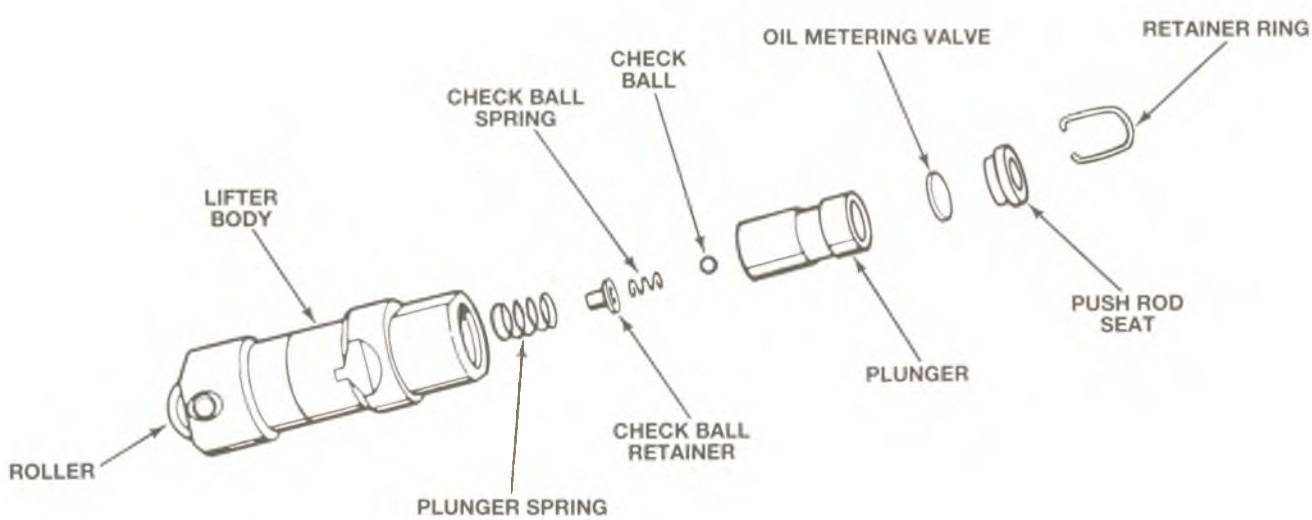


Figure 2-28, **Valve Lifter Parts**

Condition #5: Noise at engine idle speed (increasing in level as engine speed increases to 1500 rpm)
Cause:
A. Badly worn or scuffed valve tip/rocker arm
B. Excessive valve stem-to-guide clearance
C. Excessive valve seat run-out
D. Valve spring that is off-square
E. Excessive valve face run-out
F. Valve spring clicking on rotator

Correction:
A. Replace suspect parts.
B. Check and correct valve stem-to-guide clearance.
C. Machine valve seat(s) or replace cylinder head.
D. Check and replace suspect valve spring(s) - refer to Figure 2-29.
E. Machine or replace valve(s).
F. Rotate valve spring.

Condition #6: Noise at all engine speeds
Cause:
A. Foreign particles in one or more valve lifters
B. Excessive valve lash

Correction:
A. Clean suspect valve train part(s).
B. Check the following valve train parts for wear:
- Push rods (check lubrication)
- Rocker arms/shafts (check lubrication)
- Lifters (sticking plungers or internal wear)

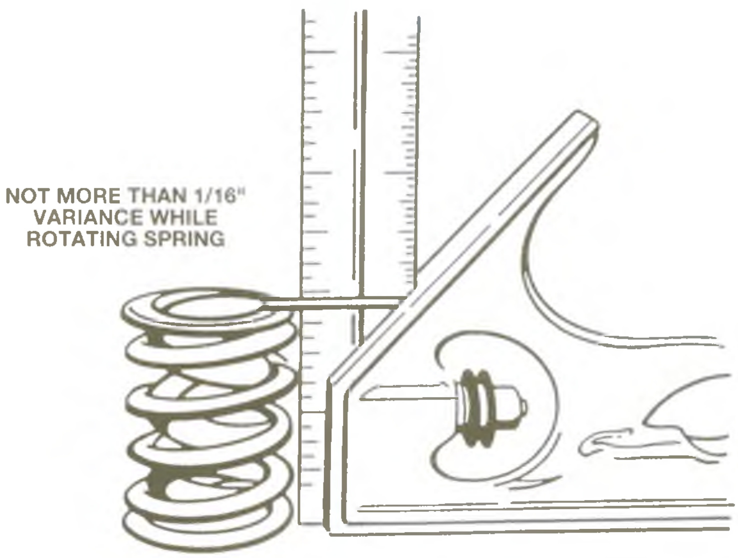


Figure 2-29, **Valve Spring Squareness Check**

Front Cover

The front cover is made of cast aluminum and has several features (refer to Figure 2-30):

- Mounting surfaces for the crankshaft front seal, water pump assembly, injection pump and accessory supports
- Sealing surfaces at the cylinder case and oil pan
- Cooling system passages
- A timing bracket for service purposes

During engine manufacture, the timing bracket is installed after the #1 piston is moved to its TDC position. This process involves balancing the positions of the #3 and #5 pistons in their bores. When the crankshaft is at the #1 TDC position, the timing bracket is aligned with the torsional damper mark and bolted in place.

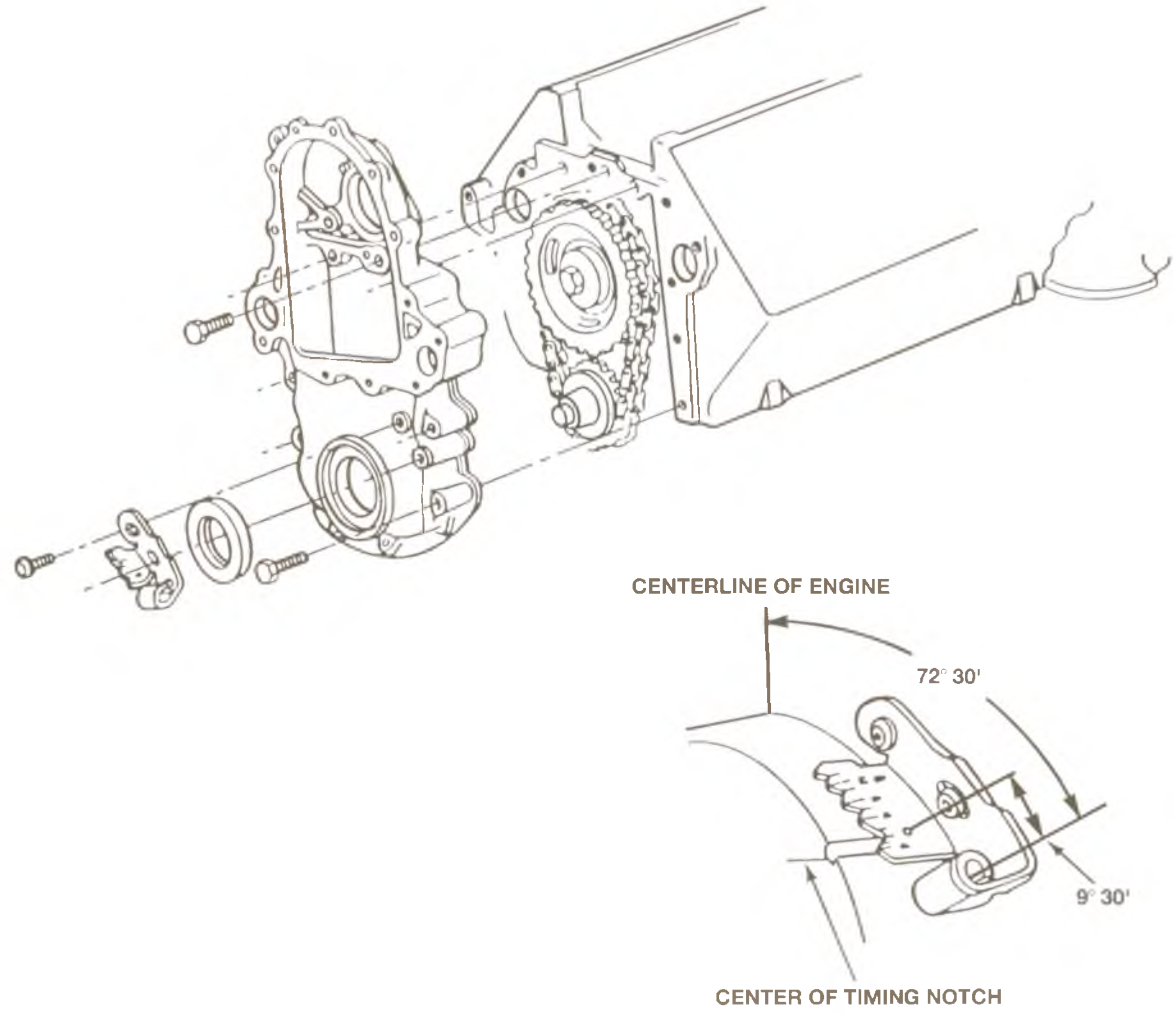


Figure 2-30, Front Cover Features

The installation of the front cover has two parts. During the first part, the front cover itself has three upper and four lower bolts installed (see Figure 2-31, view A). These bolts have threads lightly coated with engine oil.

During the second part of front cover installation, the injection pump driven gear is aligned with the drive gear on the camshaft and mounted to the pump drive shaft with bolts. Then the water pump assembly is installed, using the following fasteners (see Figure 2-31, view B):

- Two studs and six bolts (lightly coated with engine oil), holding the water pump assembly to the front cover
- Three studs and two bolts (coated with GM P/N 1052080 sealant), holding both the water pump and front cover to the cylinder case

Note the proper installation of the two bolts used to hold the water pump and front cover to the cylinder case, since one is slightly shorter than the other one.

Refer to page 3-13 for information about the removal and installation of the crankshaft front seal.

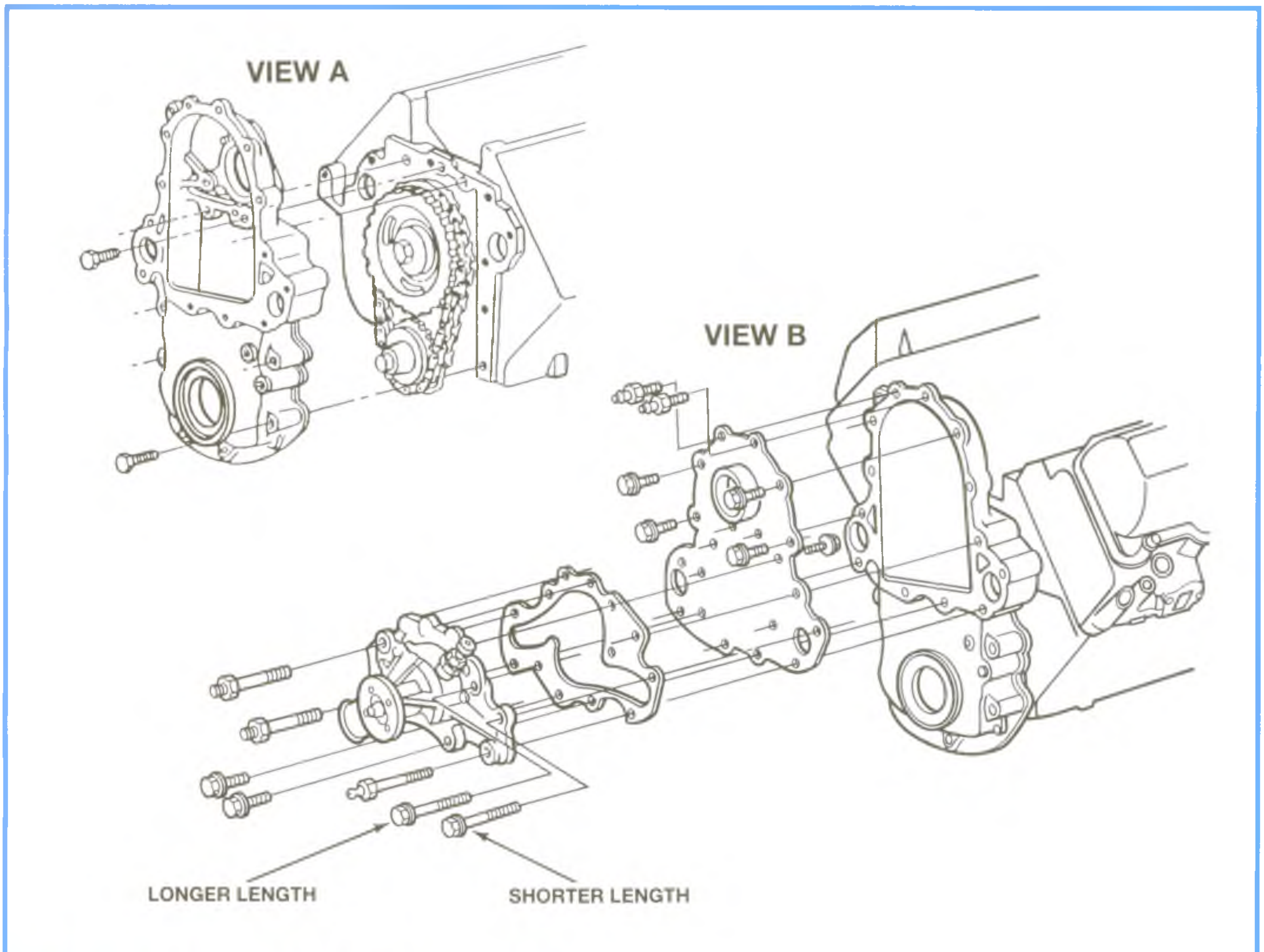


Figure 2-31, **Front Cover Installation**

Injection Pump Drive

The operation of the injection pump is performed by gears inside the front cover (see Figure 2-32). The injection pump drive gear mounts on the front of the camshaft and rotates at one-half the rotating speed of the crankshaft. The front cover-mounted injection pump supports the driven gear, which mounts to the injection pump drive shaft with three bolts. Alignment marks on the front cover and the injection pump provide a static timing of fuel injection.

A roller bearing inside the injection pump is used for injection pump drive shaft support and is lubricated by engine oil splashed inside the front cover. A spring-loaded button on the front of the injection pump drive shaft rests against a metal finger on the back of the water pump plate inside the front cover.

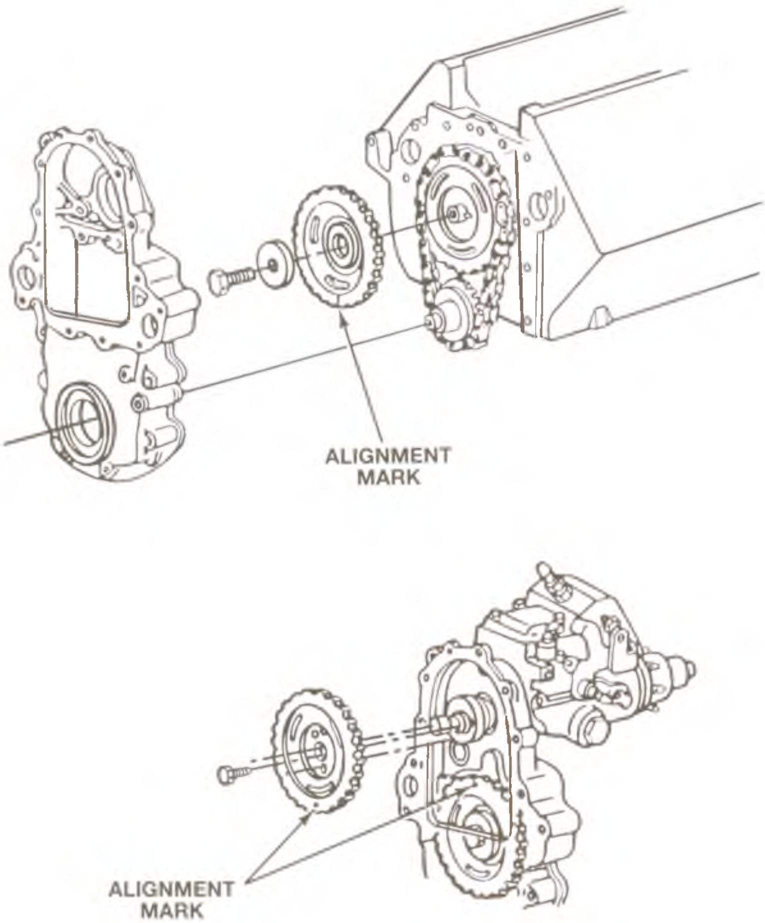


Figure 2-32, **Injection Pump Drive**

As part of installing a new front cover, the static timing mark must be made for alignment with the injection pump. The steps are as follows:

1. With the injection pump removed, rotate the engine to the TDC position for the #1 piston so that the slot in the injection pump driven gear is in the 6 o'clock position (see Figure 2-33, view A).
2. Install the special timing fixture (J 33042) to the injection pump driven gear, using the bolt provided with the tool.
3. Retain the special timing fixture against the front cover, using the top injection pump mounting stud and nut (finger tighten).
4. Rotate the special tool toward the engine left cylinder head with 48 N·m (35 lb-ft) torque, and strike the scribe of the tool with a mallet (see Figure 2-33, view B).
5. Complete the front cover installation steps.

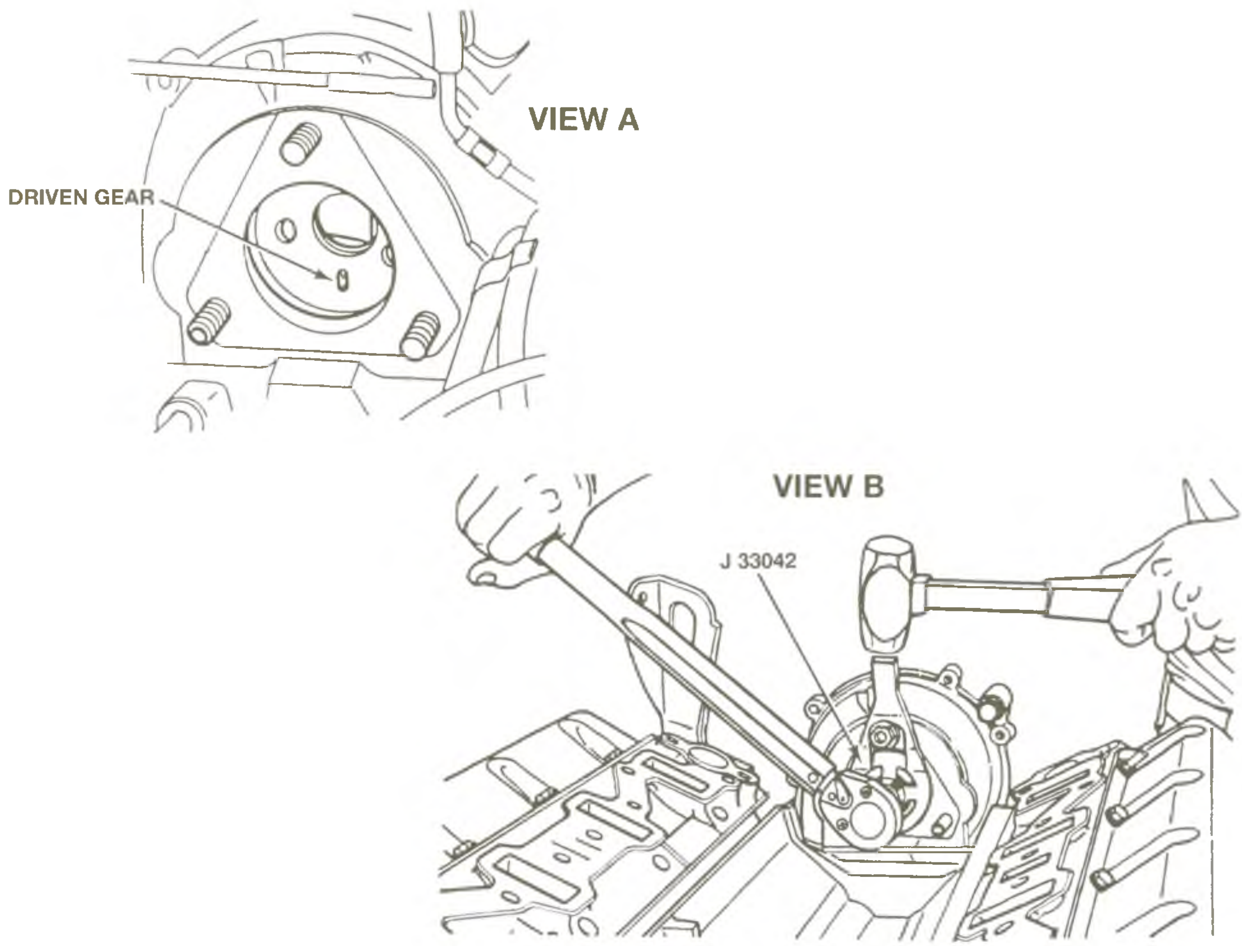


Figure 2-33, **Static Timing Mark Installation**

Intake Manifold

The intake manifold is cast aluminum and connects the air induction system inlet duct to the intake ports of each cylinder head (see Figure 2-35). Features of the intake manifold include the following items:

- Mounting to the air inlet duct with bolts and a paper gasket
- Mounting to each cylinder head with bolts and studs, as well as a special composite gasket
- Support for eight injection lines, using brackets and rubber isolators
- Support for the turbocharger oil supply line, using a bracket
- Support for the fuel filter assembly

The installation of the intake manifold requires a variety of bolts and studs that are tightened in a specific sequence (see Figure 2-34). The torque specification for the intake manifold mounting bolts and studs is 34-50 N·m (25-37 lb-ft).

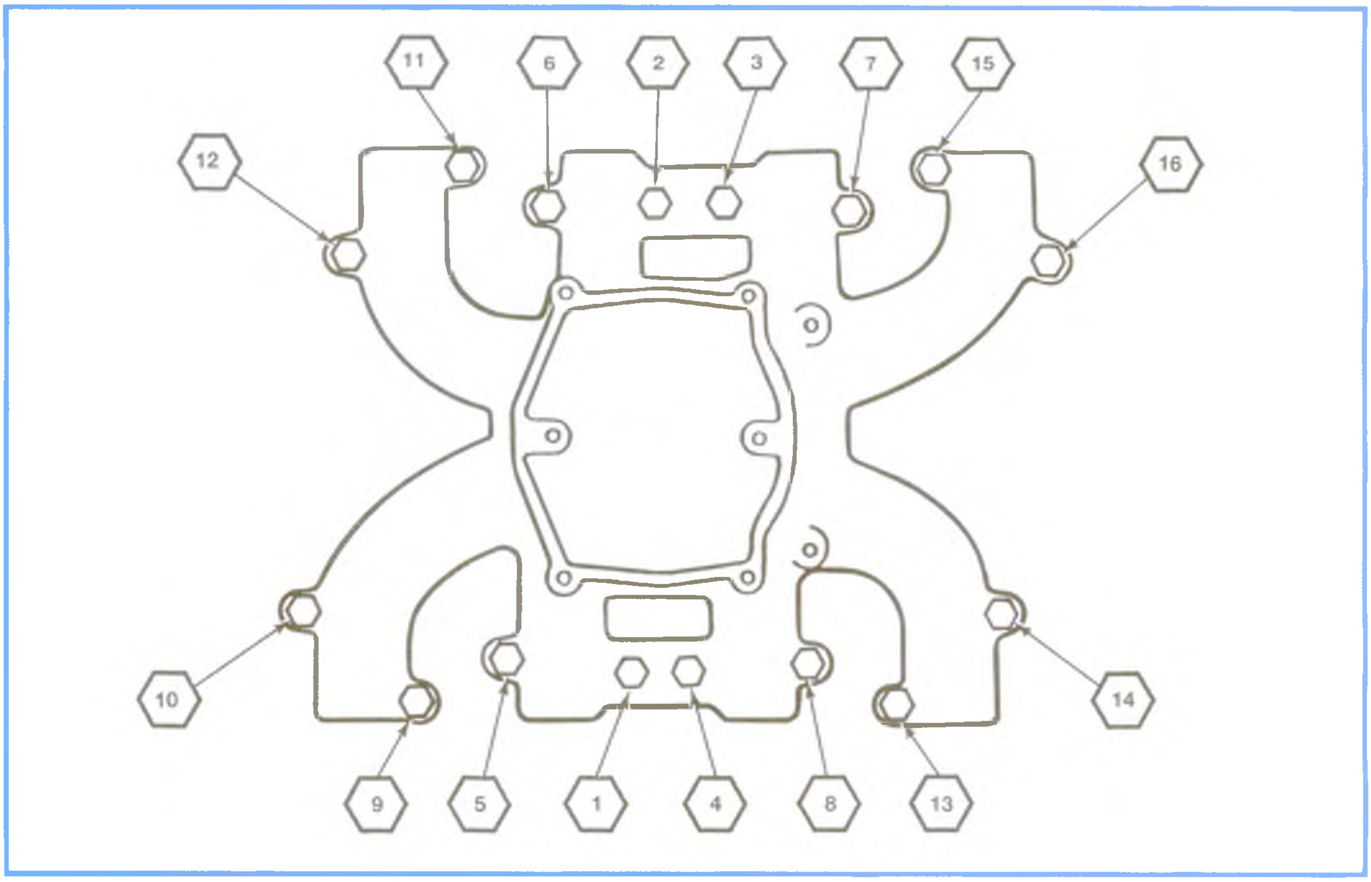


Figure 2-34, Intake Manifold Bolt Tightening Sequence

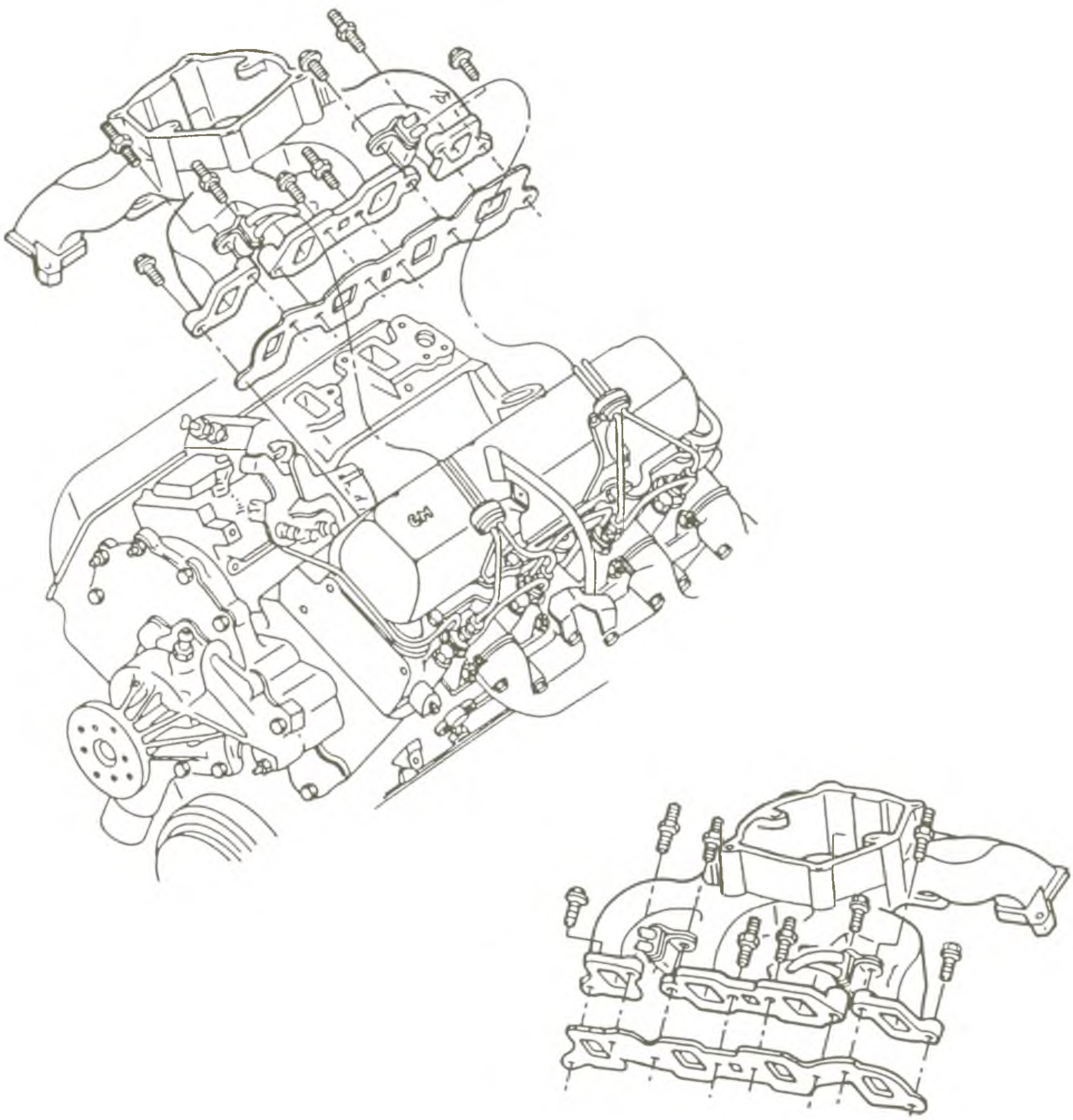


Figure 2-35, Intake Manifold Mounting

Exhaust Manifolds

The left and right exhaust manifolds are cast iron and have different functions. Each exhaust manifold mounts to a cylinder head with bolts and studs, using no gasket (see Figure 2-36).

The left exhaust manifold connects the left cylinder head to the right exhaust manifold, using a tubular steel crossover pipe and flared flange joints.

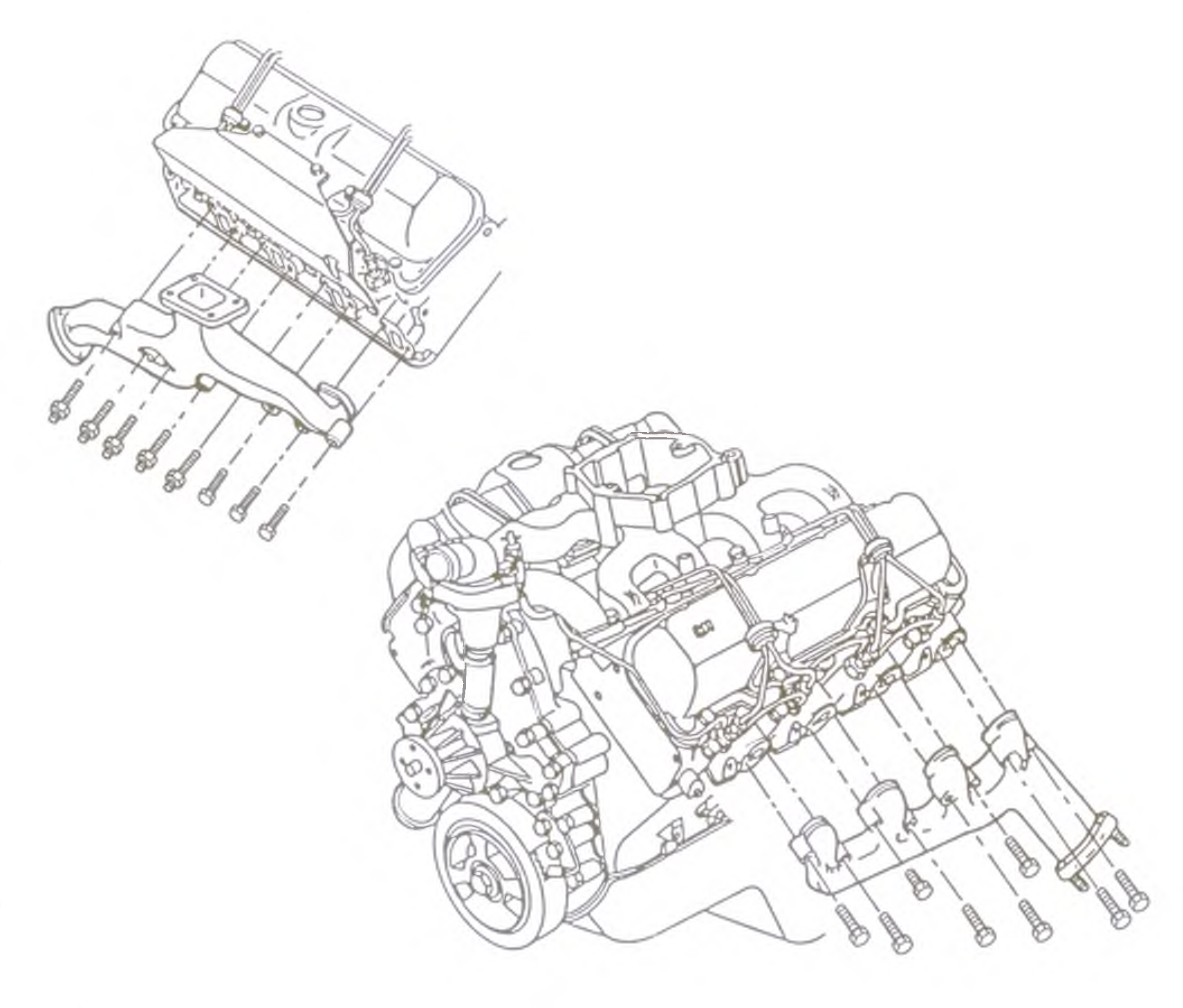


Figure 2-36, Left Exhaust Manifold

The right exhaust manifold (see Figure 2-37) directs the combined exhaust from both cylinder heads to the turbine housing of the turbocharger, which is bolted at a flange joint (see Figure 2-38 on next page). The outlet of the turbine housing connects to the exhaust pipe and muffler.

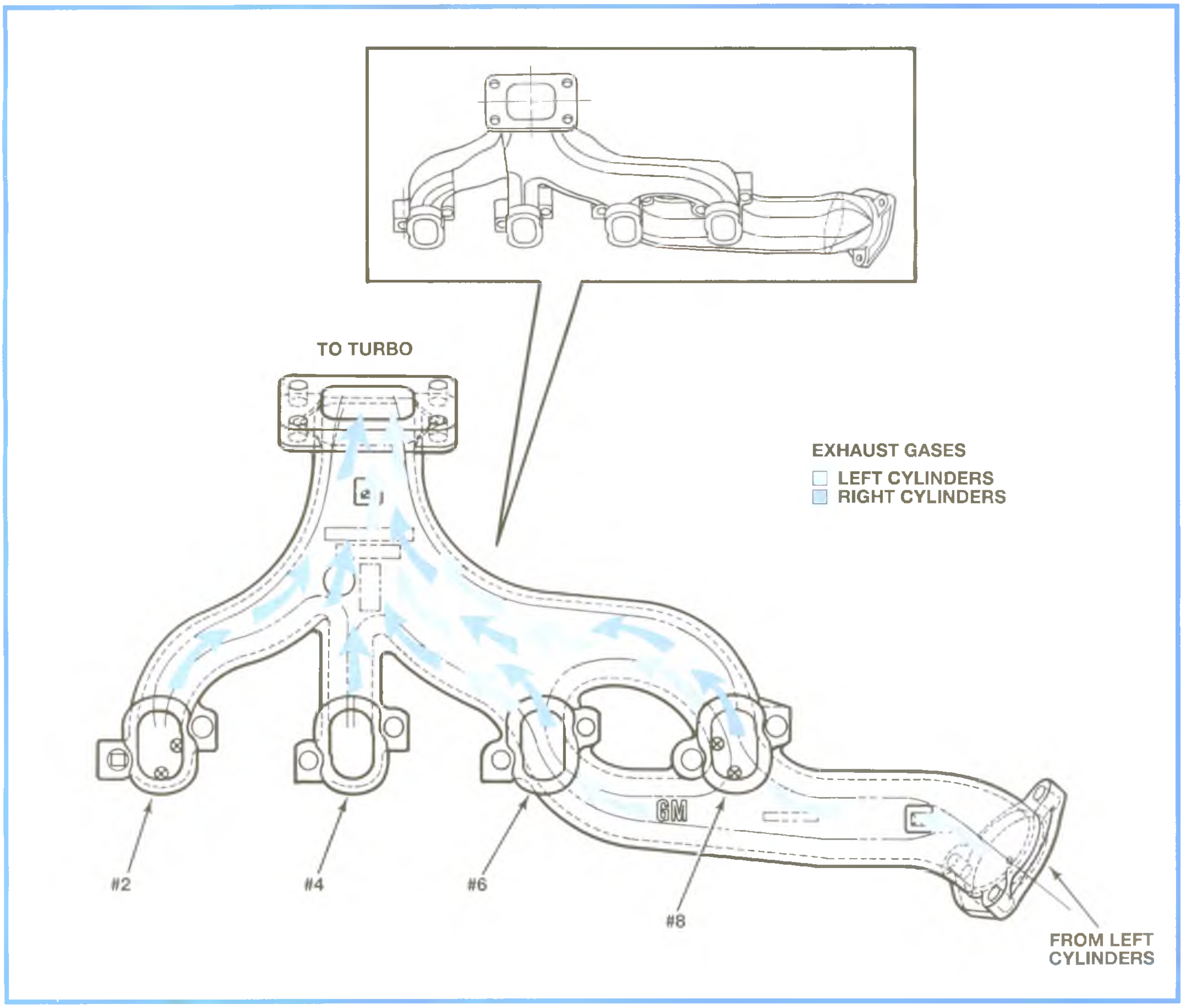


Figure 2-37, Right Exhaust Manifold

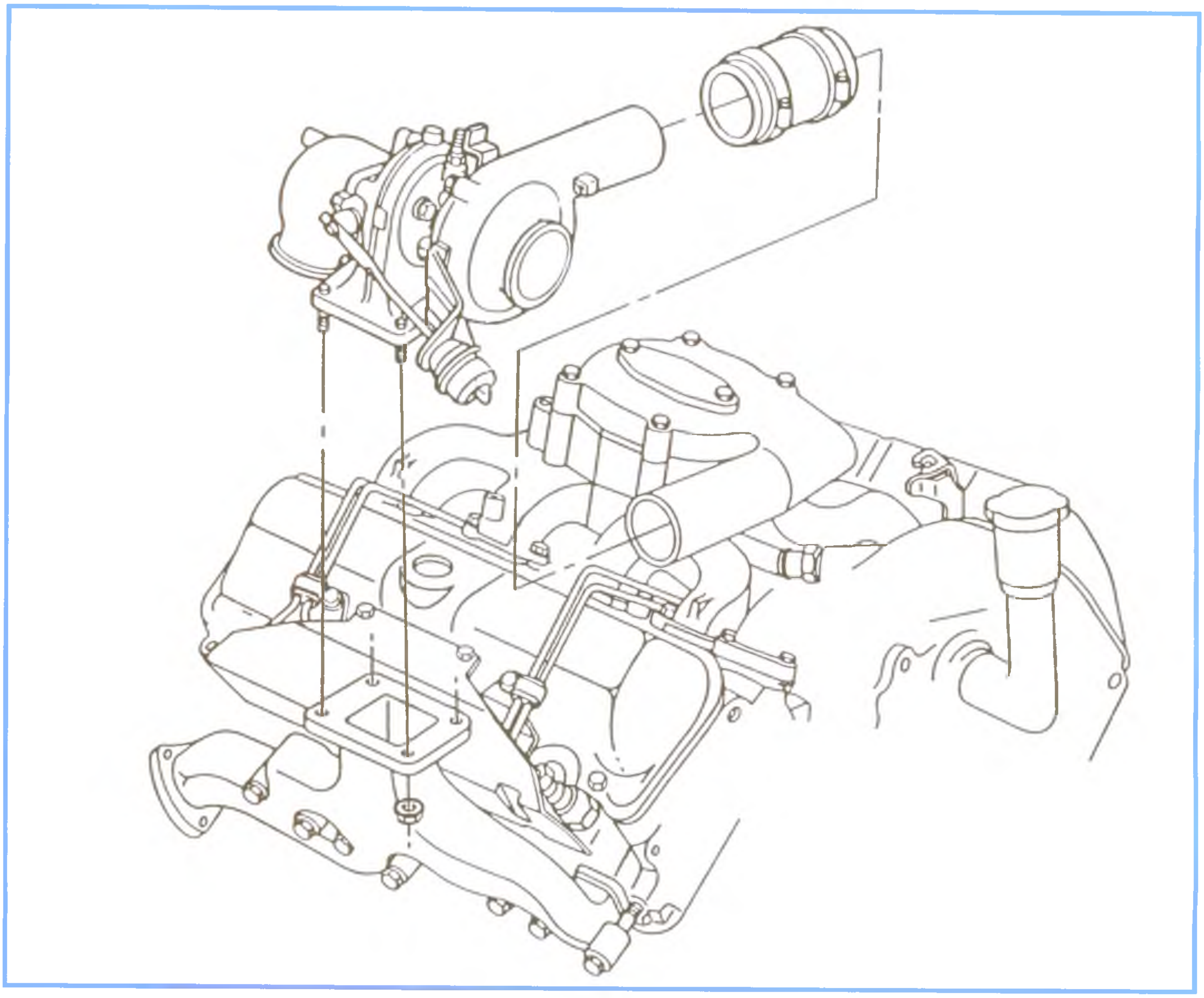


Figure 2-38, Turbocharger Mounting

Related Diagnosis/Service Procedures

Compression Test

1. Bring the engine to operating temperature, with batteries fully charged.
2. Remove the B+ wire from the fuel shut-off solenoid wire on the injection pump.
3. Remove the glow plugs for all cylinders (use tool J 39084 to remove the glow plug wires for cylinders #4 and #6).
4. Install compression gauge adapter J 26999-10 into the glow plug hole of the first cylinder to be tested (see Figure 2-39, view A).
5. Connect compression gauge J 26999-12 to the adapter (see Figure 2-39, view B).
6. Crank the engine for six "puffs," observing the following
   - Rate of pressure increase with each "puff"
   - Final pressure reading
7. Install the compression gauge and adapter in the next cylinder to be tested.

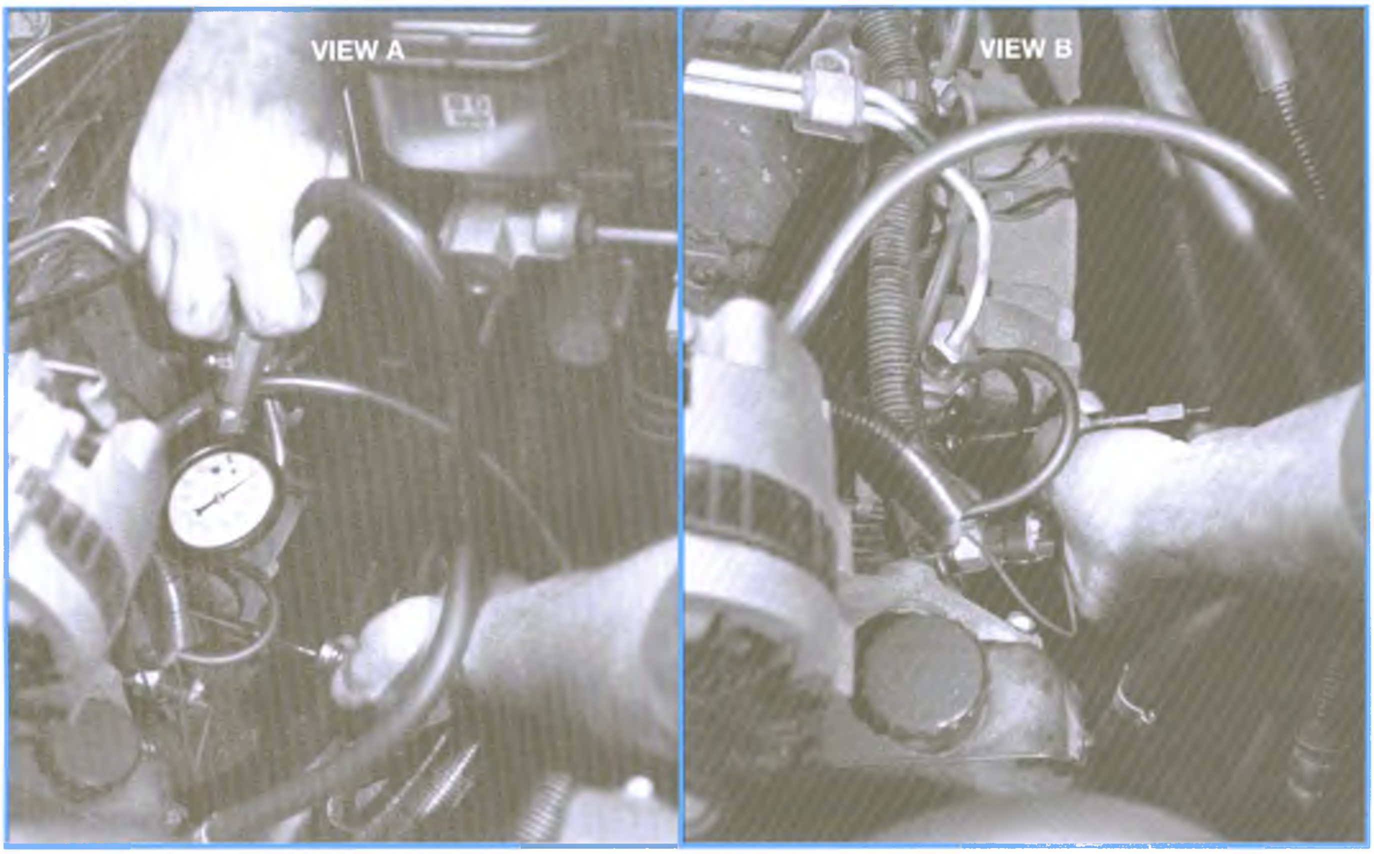


Figure 2-39, Compression Gauge Installation

8. Test each cylinder, noting the pressure readings.
9. Analyze the test results:
   - Pressure should build rapidly and evenly to a minimum of 2625 to 2760 kPa (380 to 400 psi).
   - No cylinder should read less than 2625 kPa (380 psi).
   - The lowest-reading cylinder should not be less than 80 percent of the highest-reading cylinder.

Note: Do not add oil to perform a "wet" test on any cylinder, as immediate engine damage will result.

10. Install the glow plugs (tighten to 11 to 16 N·m [8 to 12 lb-ft] torque).
11. Connect the B+ wire for the injection pump fuel shut-off solenoid.
12. Check the engine operation and charge the batteries.

Unsticking Piston Rings

If the results of a compression test or crankcase pressure check indicate that carbon accumulation may cause the piston rings to stick in their grooves, the following procedure may be performed:

1. Bring the engine to operating temperature.
2. Disconnect the batteries to prevent the engine from cranking.
3. Remove the glow plugs from all cylinders.
4. Obtain one can of top engine cleaner (GM P/N 1050002) and squirt equal amounts of it into the eight cylinders through the glow plug holes.
5. Allow the top engine cleaner to work for at least 24 hours.
6. Move the vehicle to a well-ventilated area.
7. Connect the batteries.
8. Cover the glow plug holes with shop towels.
9. Crank the engine to expel the top engine cleaner through the glow plug holes.
10. Clean any spillage of top engine cleaner on engine and vehicle parts to prevent finish damage.
11. Install the glow plugs.
12. Start the engine and bring it to operating temperature.
13. Repeat the compression test or crankcase pressure check to verify that the piston rings are unstuck.

Camshaft Lobe Lift Check

1. Remove the rocker arm cover and rocker arm shaft assemblies for the cylinders to be checked.
2. Rotate the crankshaft so that one push rod for the cylinder being checked is at its minimum height (valve closed).
3. Install a dial indicator so that its button rests on the top of the push rod for the first valve of the cylinder being checked (see Figure 2-40, view A).
4. Make sure that the dial indicator stem is parallel to the push rod and that the indicator needle points to zero.
5. Rotate the crankshaft until the push rod is at its maximum height (valve fully open).
6. Observe the amount of dial indicator travel (see Figure 2-40, view B):
   - If travel is more than 7.063 mm (0.278 in.), see step 7.
   - If travel is less than 7.063 mm (0.278 in.), replace the camshaft and lifters.
7. Perform steps 2 through 6 for the other valve for the cylinder being checked.
8. When all cylinders are checked, remove the dial indicator and install the rocker arm shaft assemblies and rocker arm covers (if repairs are not required).

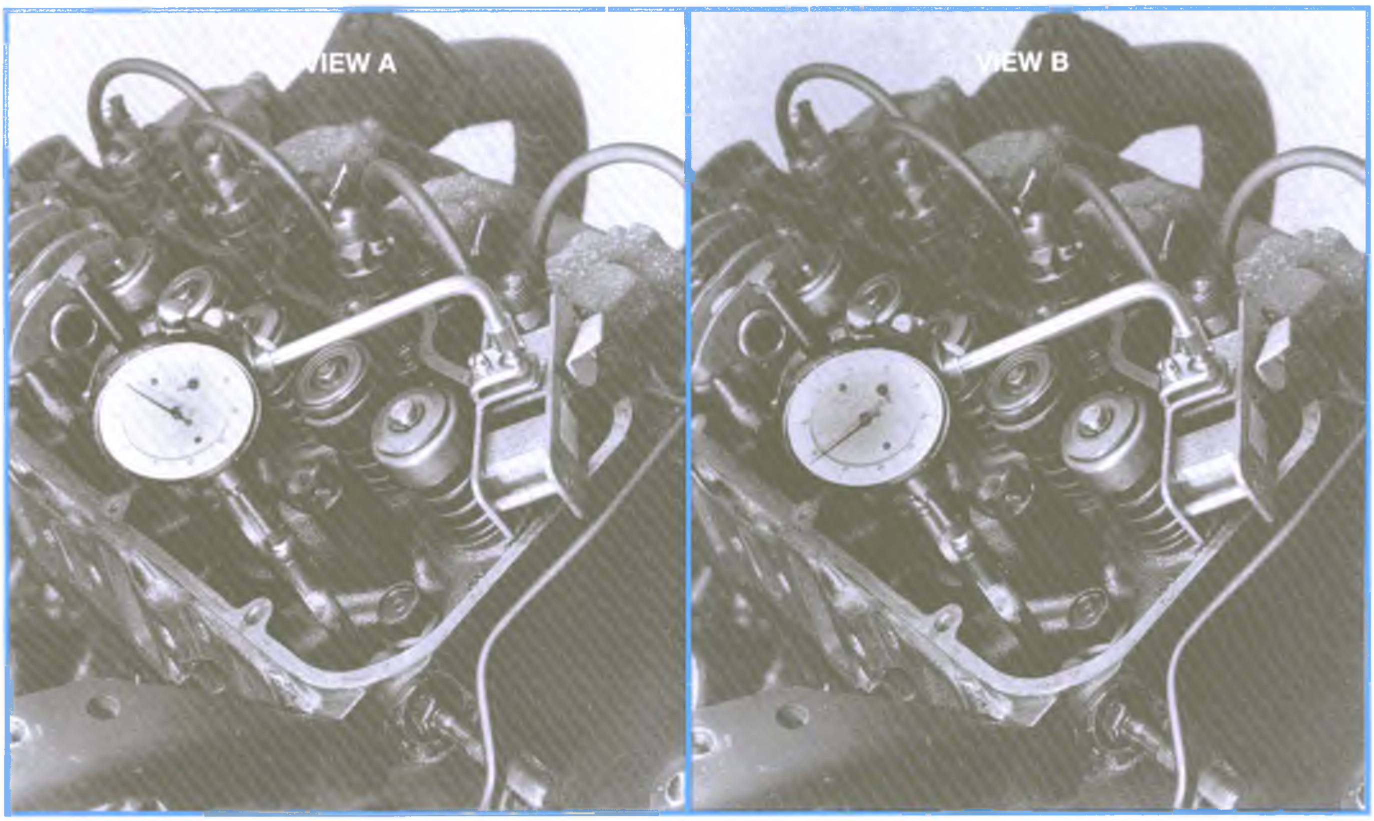


Figure 2-40, Camshaft Lobe Lift Check

Camshaft and Injection Pump Timing Check

1. Rotate the crankshaft to the 0 degrees TDC position.
2. Remove the oil fill pipe and grommet.
3. Inspect the position on the injection pump driven gear:
   - If the alignment slot is at the 6 o'clock position, go to step 4.
   - If the alignment slot is at the 12 o'clock position, rotate the crankshaft one revolution and go to step 4.
4. Remove the water pump assembly.
5. Inspect that the alignment marks of the injection pump drive and driven gears are next to each other (see Figure 2-41, view A).
6. Remove the injection pump driven gear from the drive shaft of the injection pump.
7. Rotate the crankshaft one revolution (in a clockwise direction) to the 0 degrees TDC position and remove the torsional damper and front cover.
8. Remove the injection pump drive gear from the front of the camshaft.

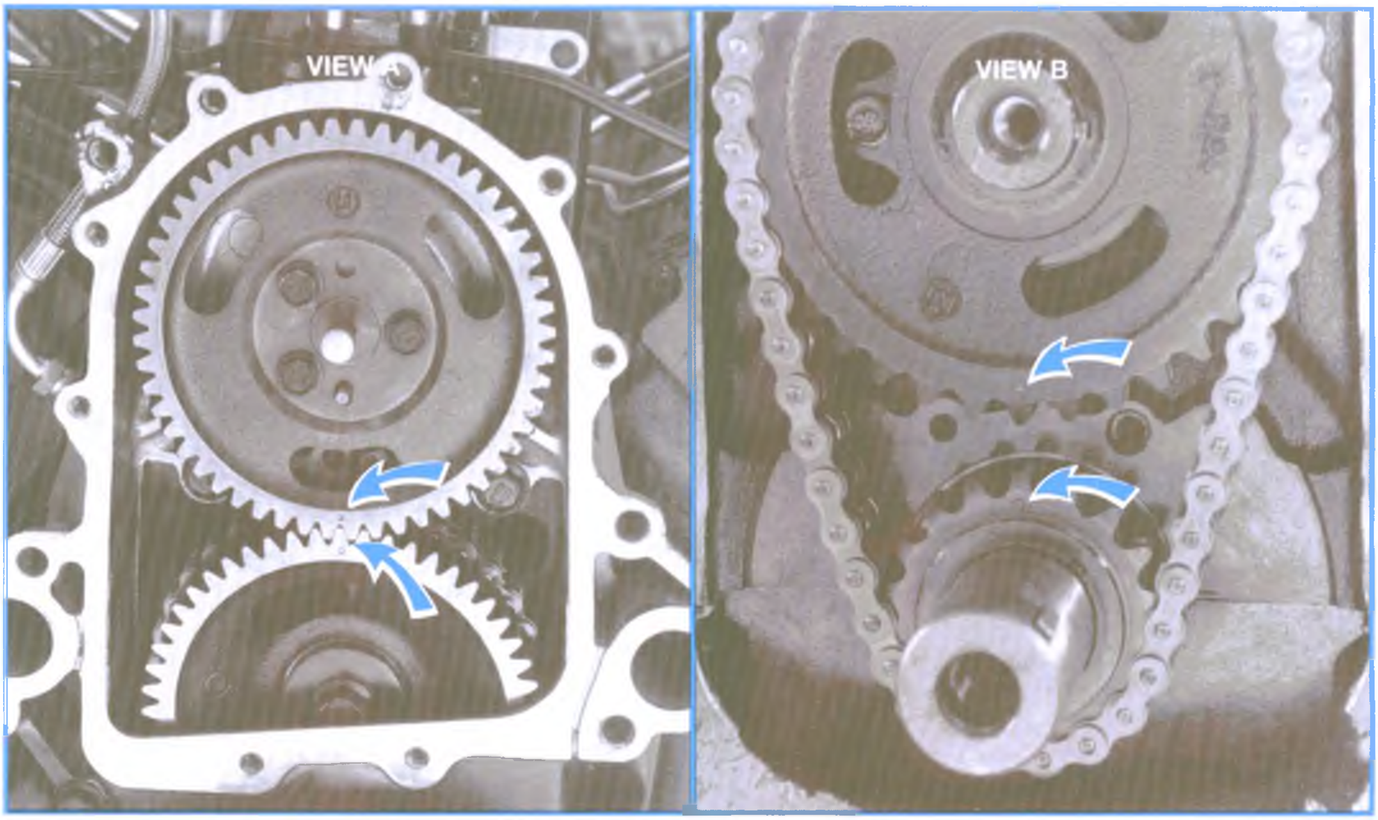


Figure 2-41, Injection Pump and Camshaft Timing Check

9. Inspect that the alignment marks of the crankshaft and camshaft sprockets are next to each other (see Figure 2-41, view B).
10. Check the tension of the timing chain:
    - Install a dial indicator so that its plunger tip contacts the outside of the timing chain at a midpoint between the crankshaft and camshaft sprockets on the right side of the engine.
    - At the location of the dial indicator plunger contact, move the timing chain toward the center of the engine and align the dial indicator needle with zero (see Figure 2-42, view A).
    - Move the timing chain away from the center of the engine and observe the total dial indicator needle travel (see Figure 2-42, view B):
        - If measured travel is within the following specifications, go to step 10:
        - Less than 12.7 mm (0.500 in.) for a new chain
        - Less than 20.3 mm (0.800 in.) for a used chain
        - If measured travel is not within the specifications, replace the timing chain and sprockets.

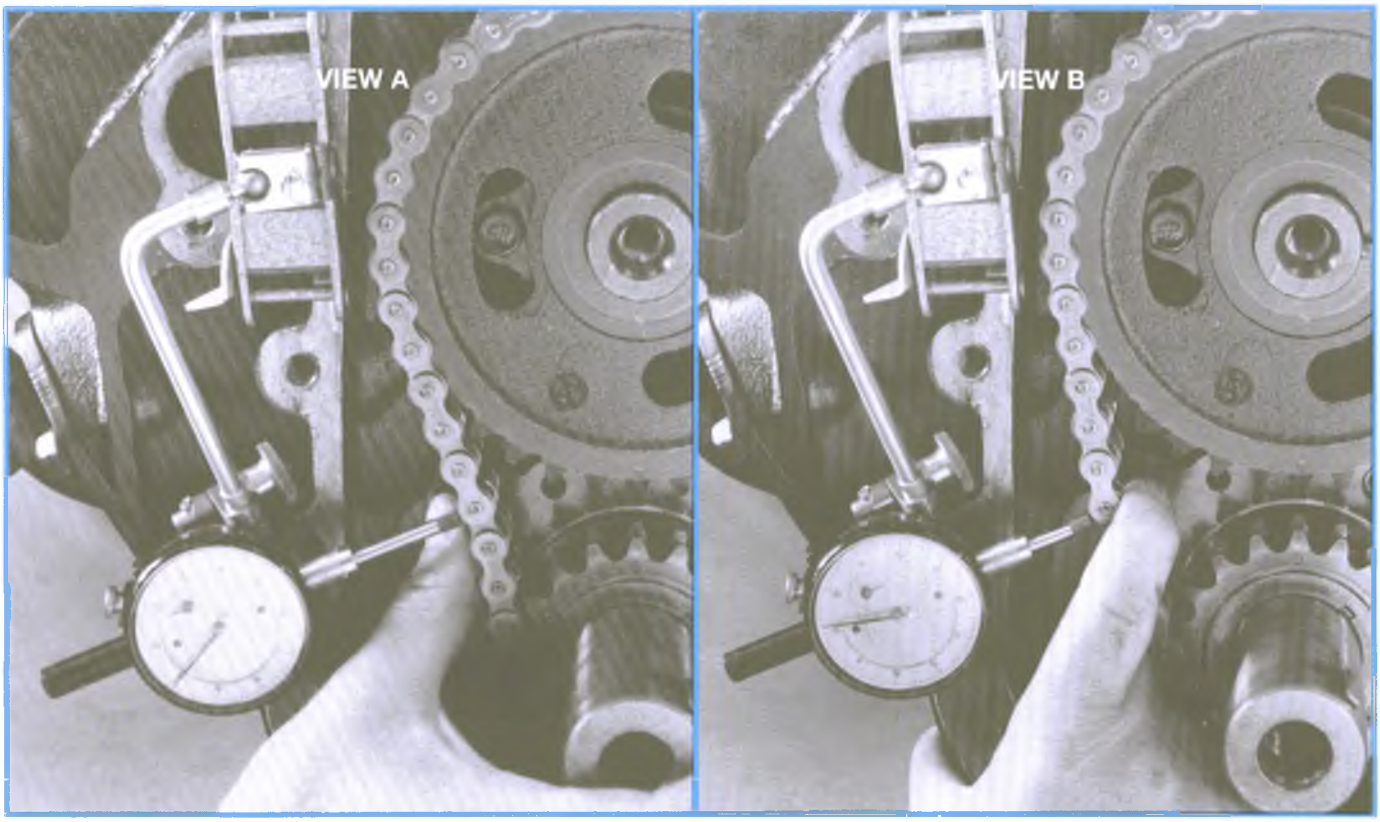


Figure 2-42, Timing Chain Wear Check

11. Remove the timing chain and sprockets, check the following items and make any necessary corrections:
    - Alignment mark on the crankshaft sprocket in the 12 o'clock position
    - Key and keyway of the crankshaft with no damage
    - Alignment mark on the camshaft sprocket in the 6 o'clock position
    - Alignment dowel of the camshaft with no damage
12. Install the timing chain and sprockets and rotate the crankshaft one revolution (in a clockwise direction) to the 0 degrees TDC position.
13. Install the injection pump drive and driven gears with aligned marks.
14. Install the front cover, torsional damper, water pump assembly and oil fill pipe.

3. Lubrication System

Overview

The lubrication system of the 6.5L V8 turbo diesel engine includes the following groups of parts (refer to Figure 3-1):

- Oil pump assembly
- Oil cooler system
- Oil filter
- Cylinder case and crankshaft passages
- Crankshaft seals
- Sealing surfaces

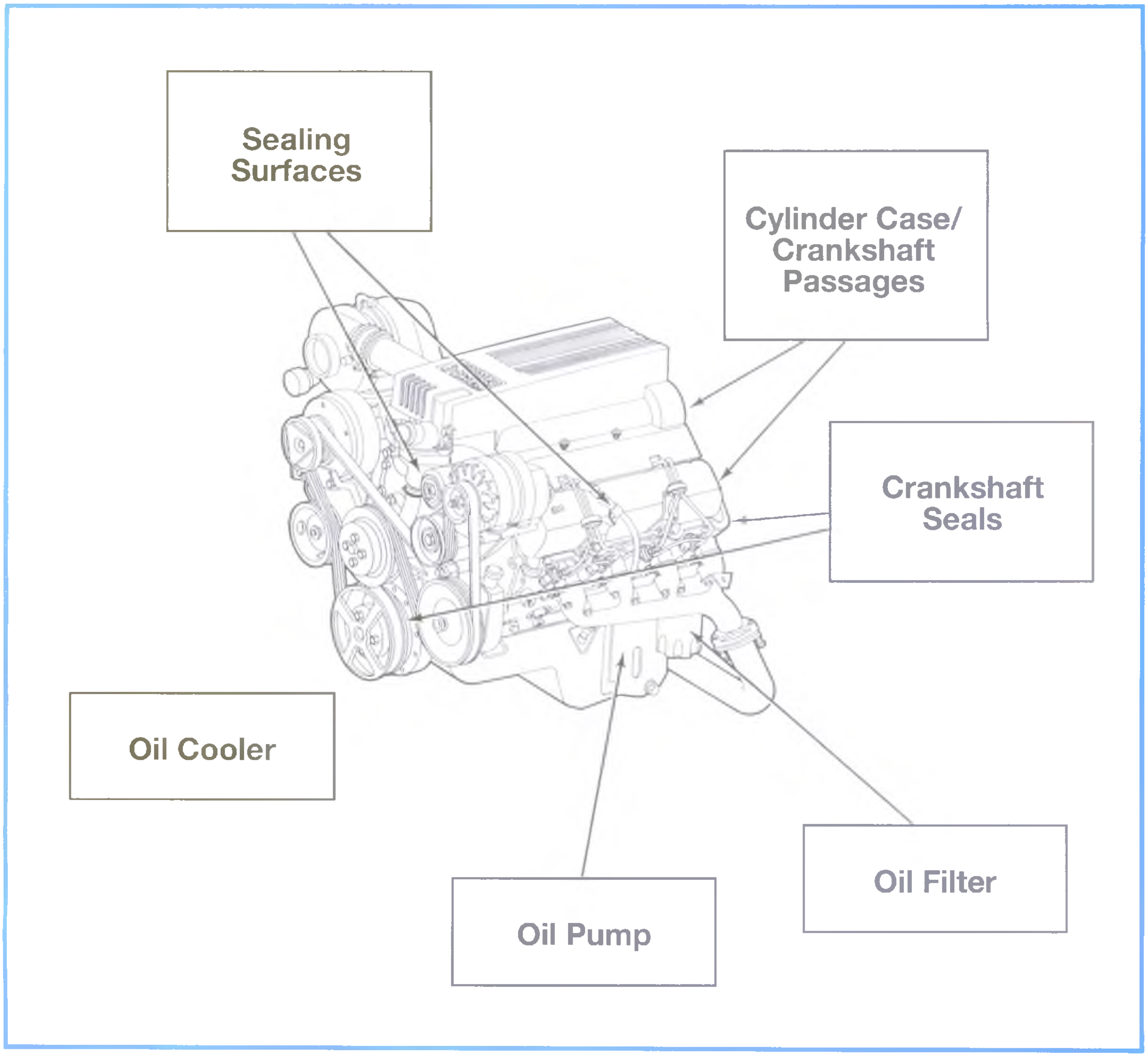


Figure 3-1, Lubrication System

Oil Pump Assembly

The oil pump assembly mounts on the crankshaft main bearing cap #5, using a bolt and alignment dowels (see Figure 3-2). It uses drive and driven gears to move oil under pressure to the various parts of the engine. The engine must never be run with the oil pump drive/engine speed sensor removed.

The camshaft has a helical gear that rotates a mating gear of the oil pump drive/engine speed sensor assembly. The oil pump drive uses a six-sided rod to connect to the oil pump drive gear.

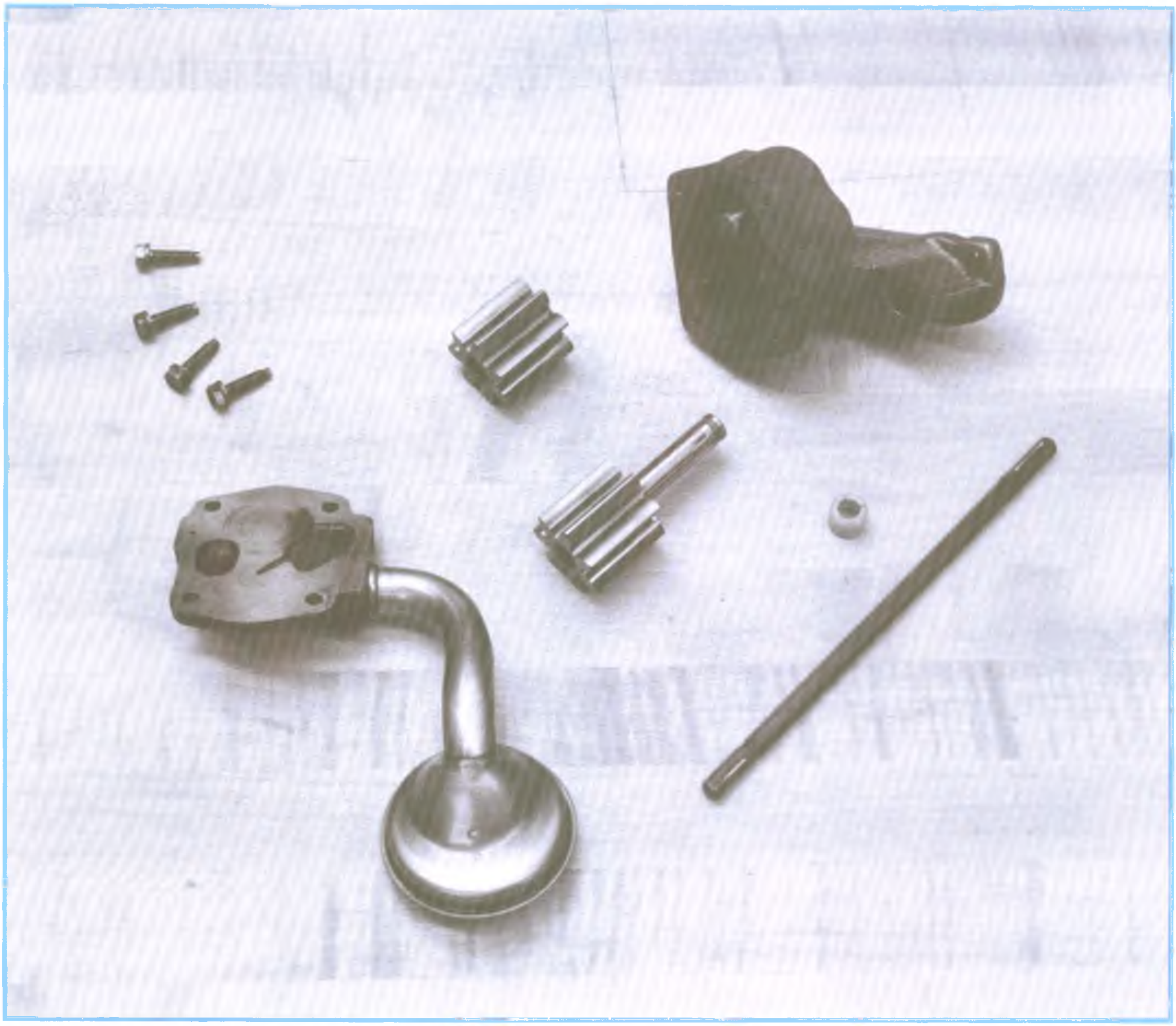


Figure 3-2, **Oil Pump Assembly**

As the pump gears rotate, oil in the sump of the oil pan is drawn in through a suction screen and tube. The action of the gears moves oil into the lubrication system under pressure, and a regulator valve in the pump housing limits the maximum pressure to 80 psi.

Oil from the pump moves through the #5 bearing cap and cylinder case passages to a plug, which directs it to the oil cooler system (see Figure 3-3).

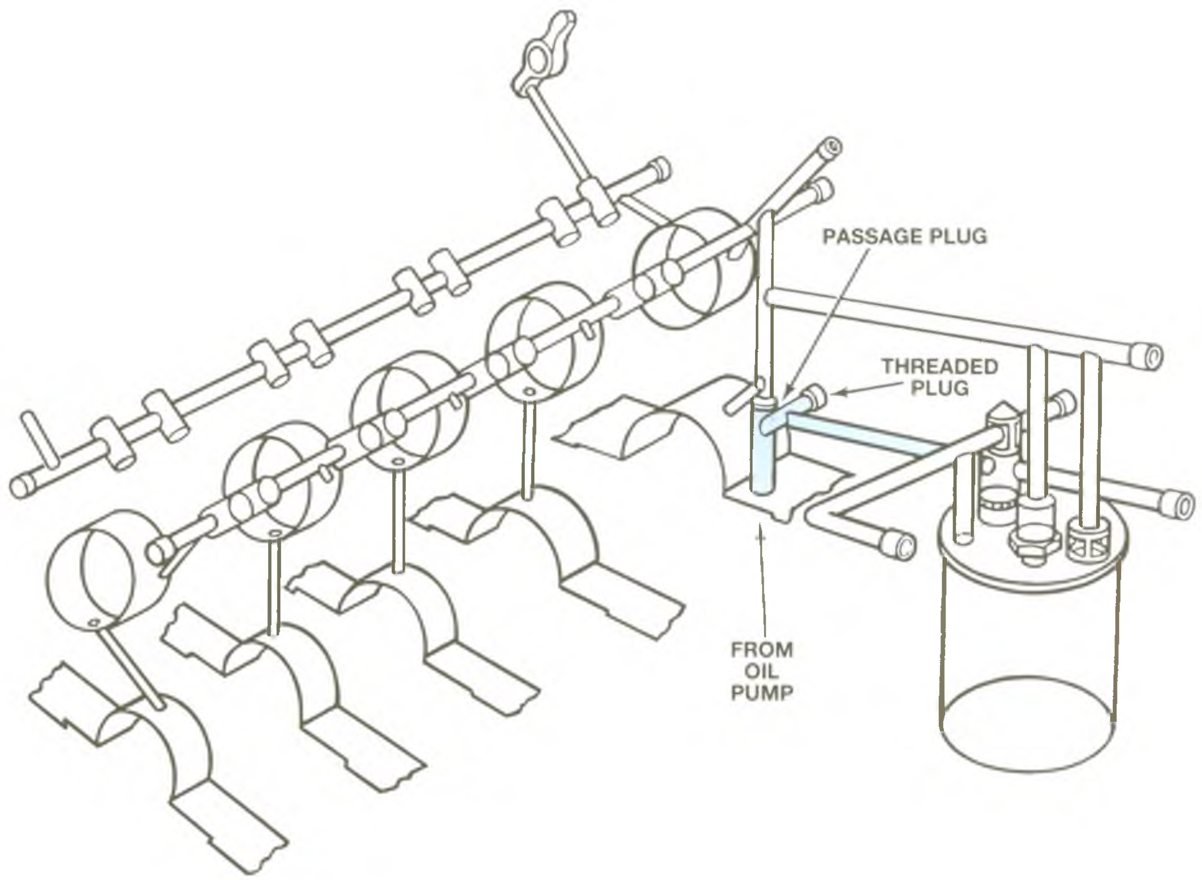


Figure 3-3, **Lubrication System Diagram – Oil Pump Flow**

Oil Cooler System

Passages in the cylinder case allow oil under pressure from the pump to move through a pipe/hose assembly to a cooler in the cooling system radiator (see Figure 3-4). The oil returns from the cooler through another pipe/hose assembly and enters the cylinder case again (see Figure 3-5).

If the difference in pressure between the oil entering and exiting the cooler system is greater than 9-11 psi, a valve in the cylinder case opens to allow oil to bypass the cooler system. This may occur during cold temperature operation when oil viscosity is high, or when a restriction exists in the cooler system.

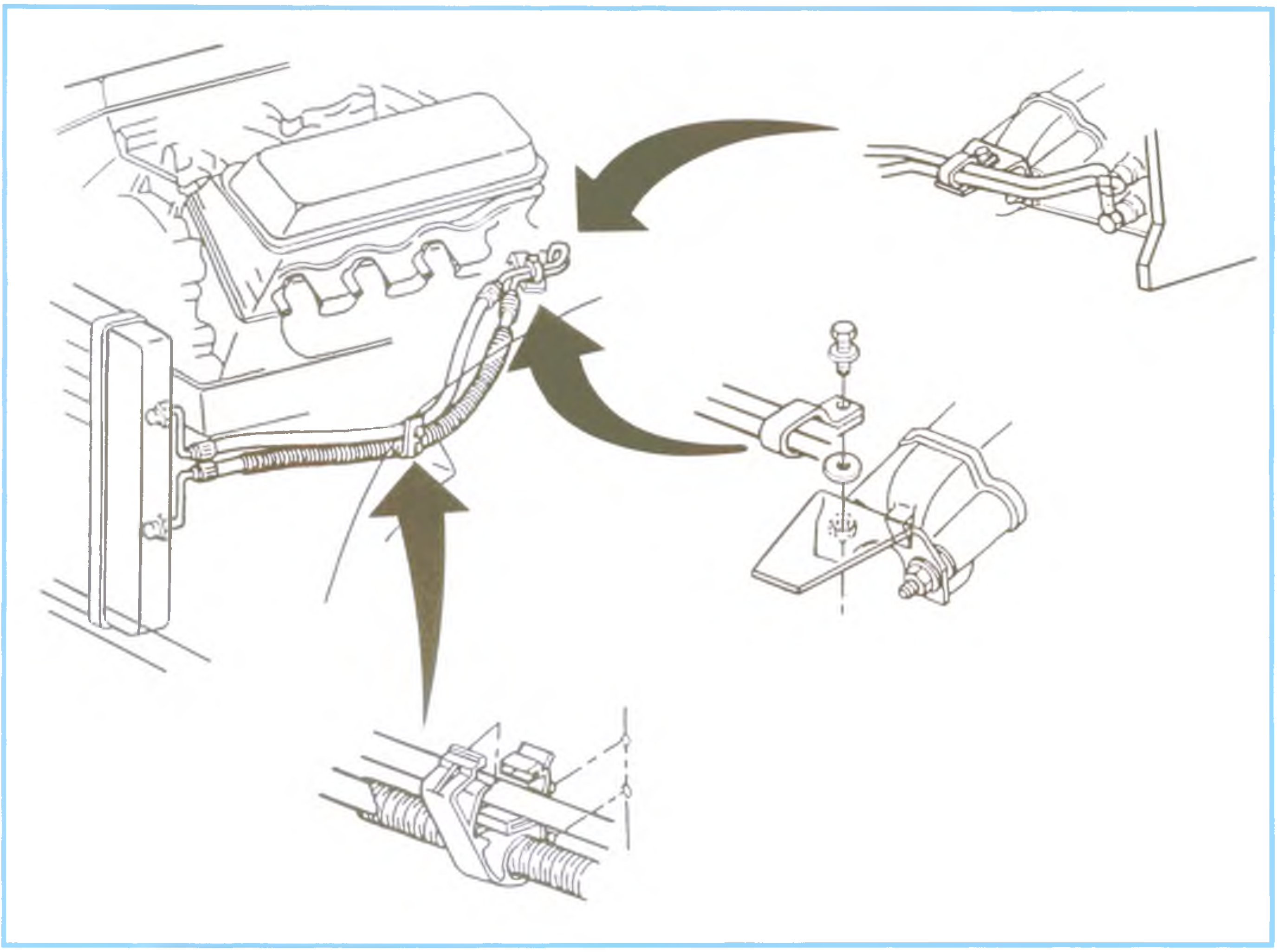


Figure 3-4, Oil Cooler System

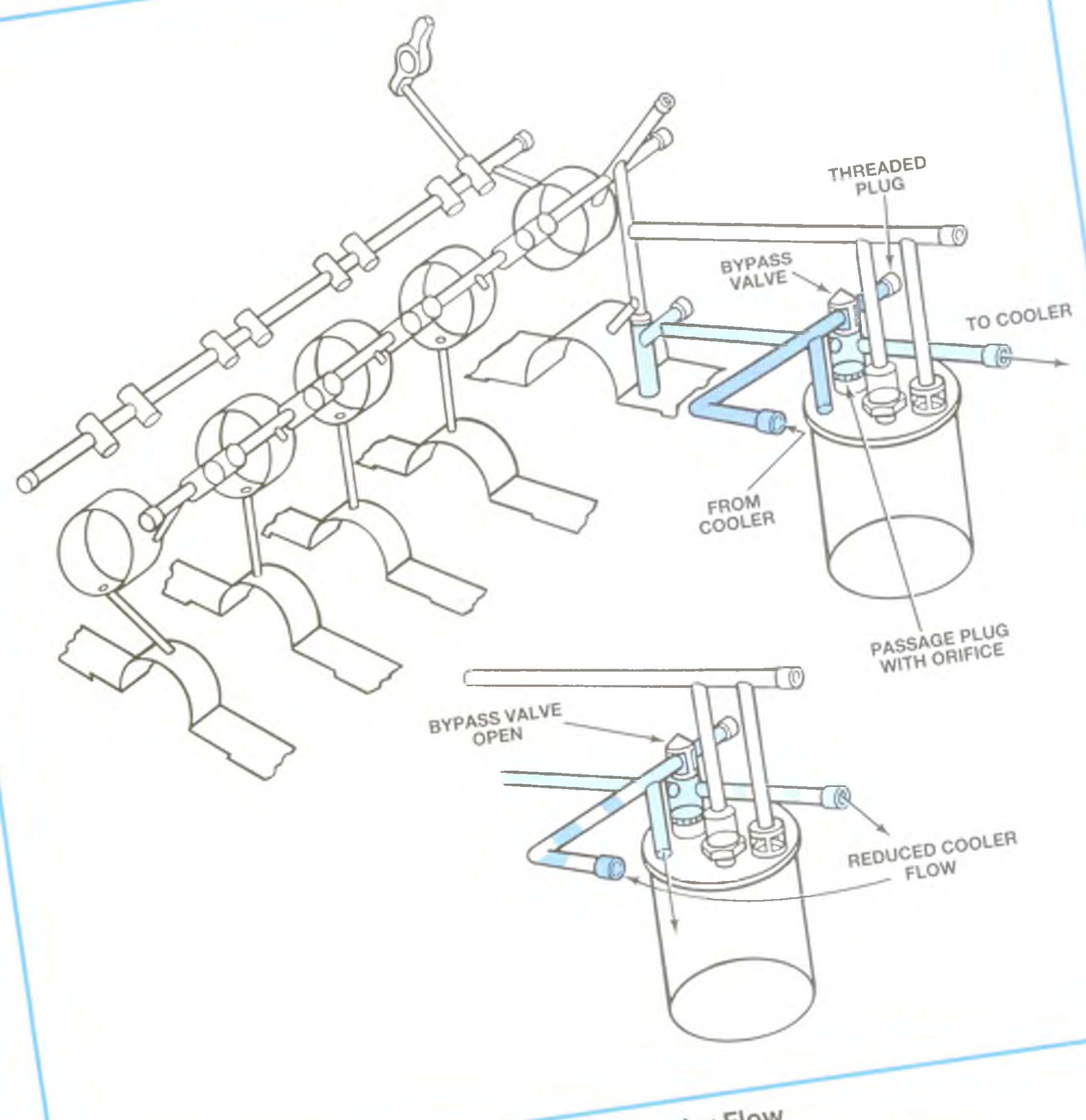


Figure 3-5, **Lubrication System Diagram – Oil Cooler Flow**

Oil Filter

Oil returning from the cooler system travels in a cylinder case passage to the oil filter, which is a spin-on replaceable cartridge. The oil filter mounts on a hollow threaded fitting and uses a soft ring to seal against the cylinder case flange (see Figure 3-6).

The oil filter is of the full-flow design, since all oil from the pump and cooler system must pass through it. A valve mounted in the cylinder case allows oil to bypass the filter when the difference in pressure between the inlet and outlet exceeds 16-19 psi. The bypass valve provides lubrication to the engine if the filter becomes extremely restricted.

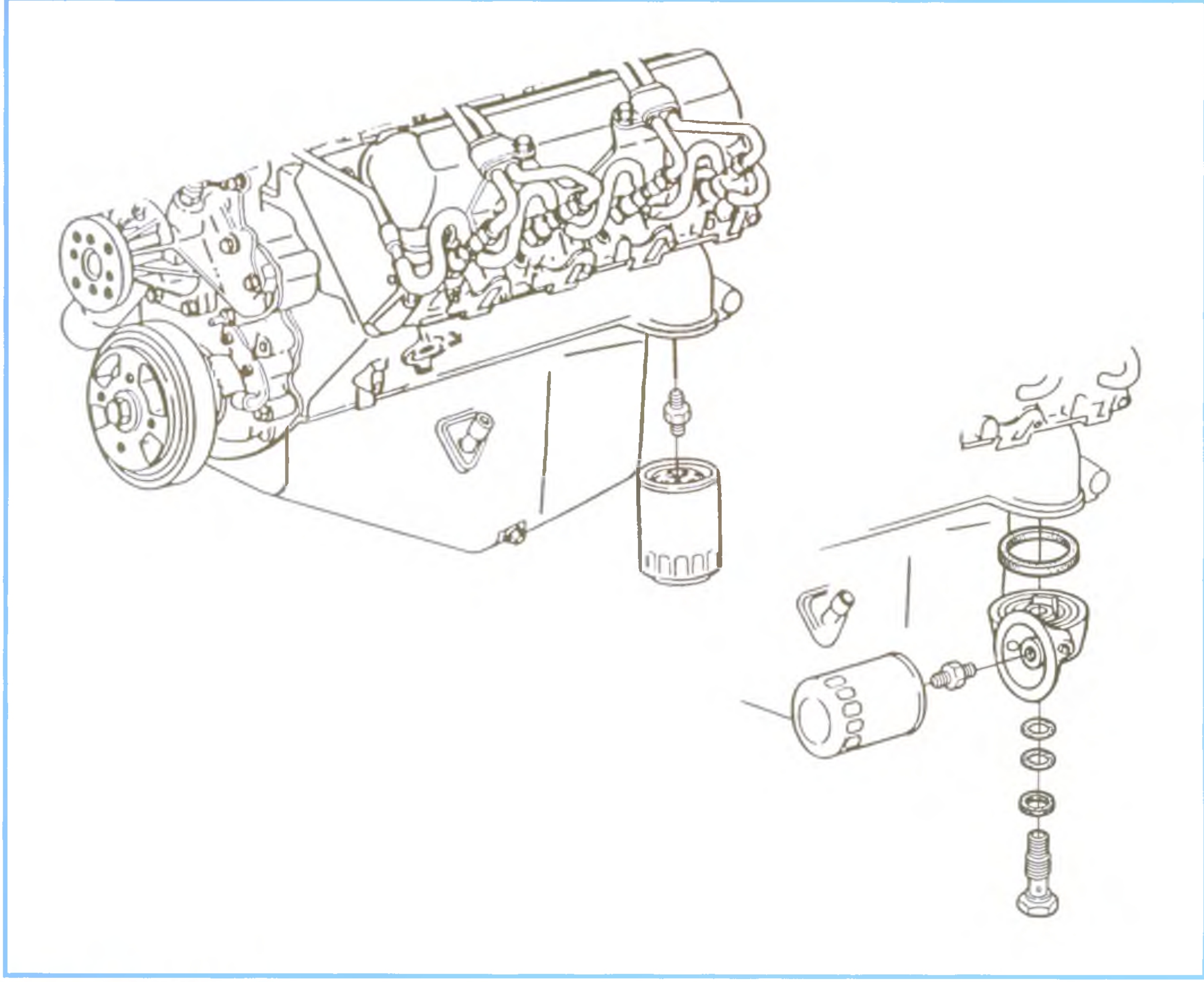


Figure 3-6, Oil Filter

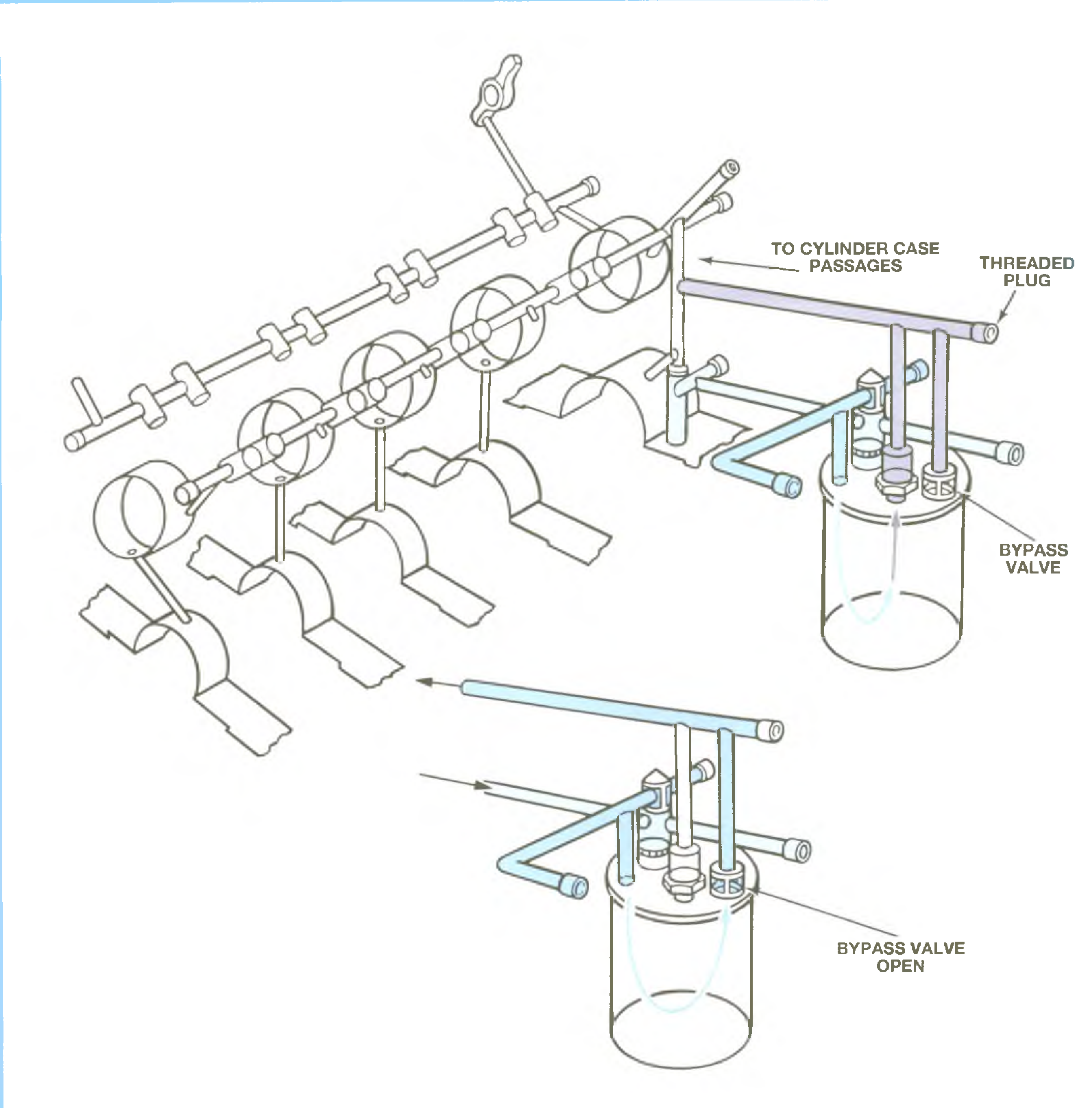


Figure 3-7, Lubrication System Diagram – Oil Filter Flow

Cylinder Case and Crankshaft Passages

Oil leaving the filter travels through the cylinder case in several directions (refer to Figure 3-8). It flows to the #5 crankshaft main bearing and moves up a vertical passage at the rear of the cylinder case.

At the top of the vertical passage, oil flow moves to the oil pressure switch or gauge sending unit. During service, oil pressure is checked at the switch/sending unit fitting. Oil also travels to the left bank of hydraulic roller lifters, where it then travels to the camshaft bearings.

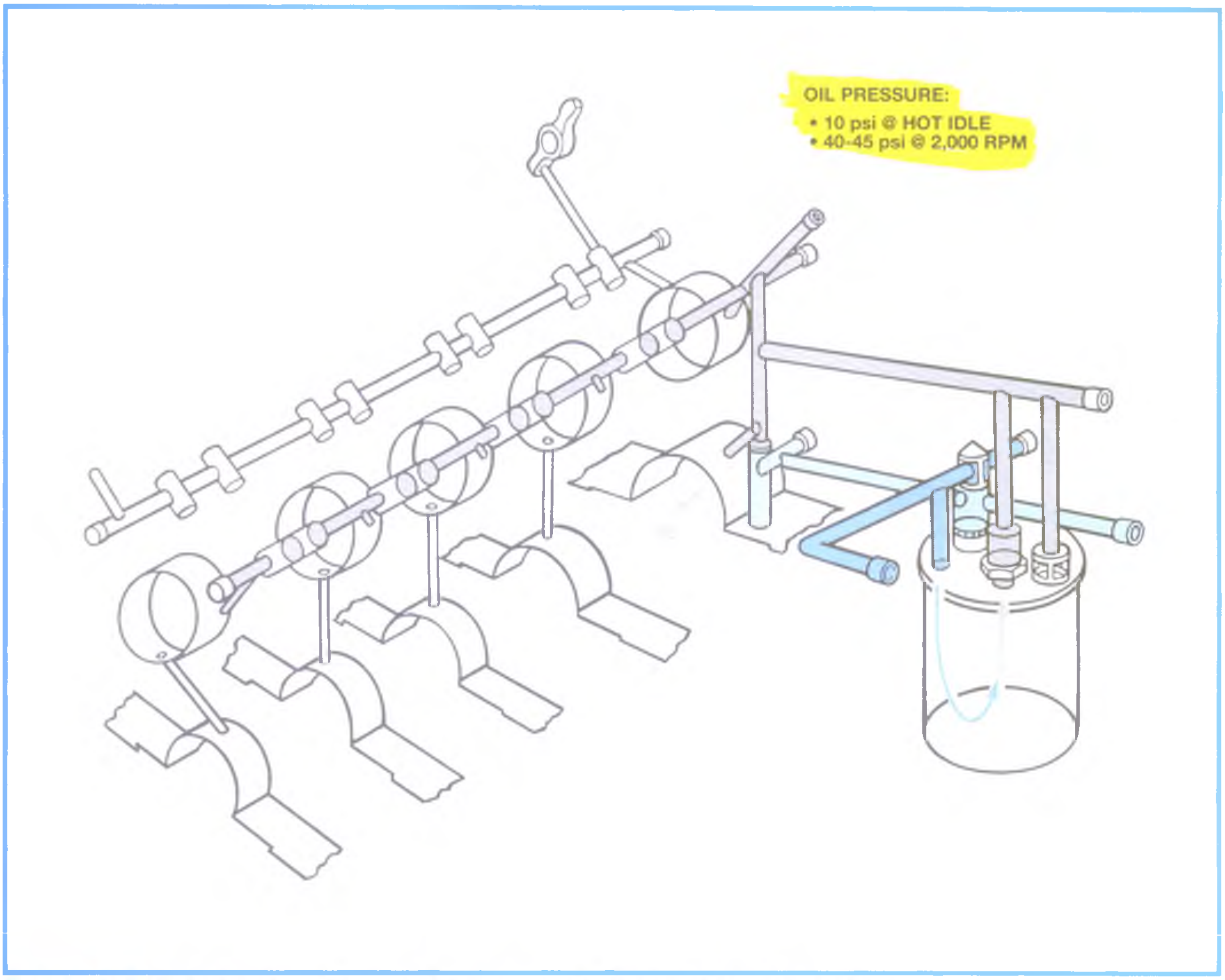


Figure 3-8, Lubrication System Diagram – Cylinder Case Flow (1)

At camshaft bearing #5, oil travels in a circular passage around the bearing insert to a passage connected to the right bank of hydraulic roller lifters (see Figure 3-9). At the front end of this passage in the cylinder case, a fitting and special hose provide supply oil to the turbocharger. Due to the design of the turbocharger oil passages, engine operation does not require a cool-down idling procedure before shut-down to prevent coking.

At camshaft bearings #4, #3, #2 and #1, oil travels in circular passages around the bearing inserts to passages connected to the crankshaft main bearings.

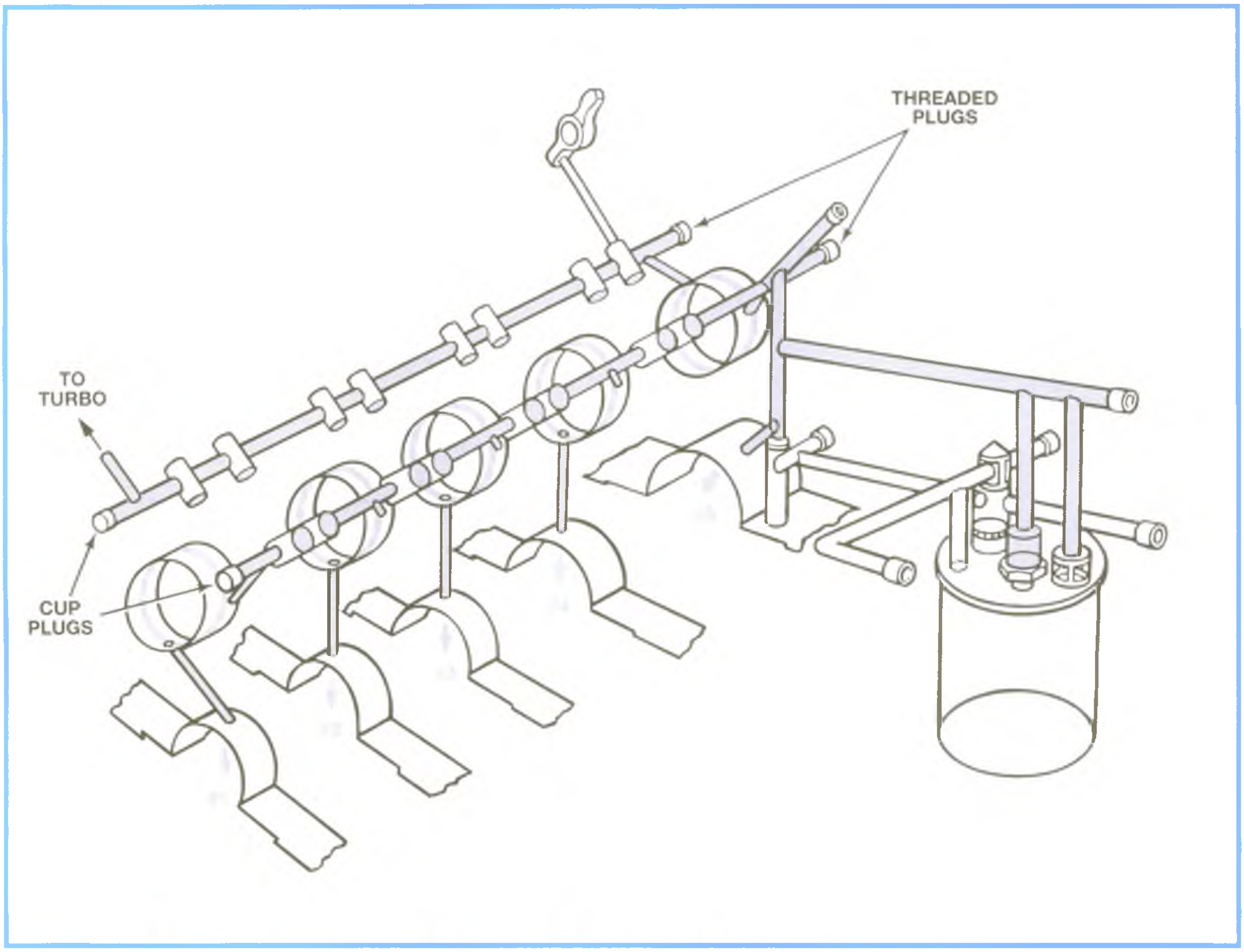


Figure 3-9, **Lubrication System Diagram – Cylinder Case Flow (2)**

3. Lubrication System

During operation of the hydraulic roller lifters, some of the oil is squirted upward through the hollow push rods to the rocker arms. Some of the oil flow at the crankshaft #1 main bearing and camshaft #1 bearing splashes on the timing chain and sprockets, as well as the injection pump drive and driven gears.

Some of the lubricating oil flow at the crankshaft main bearings travels through passages connected with the crankpin journals (see Figure 3-10). During crankshaft rotation, some of the oil that exits from the sides of the connecting rod bearings is thrown upward to lubricate the piston pins and cool the undersides of the piston faces.

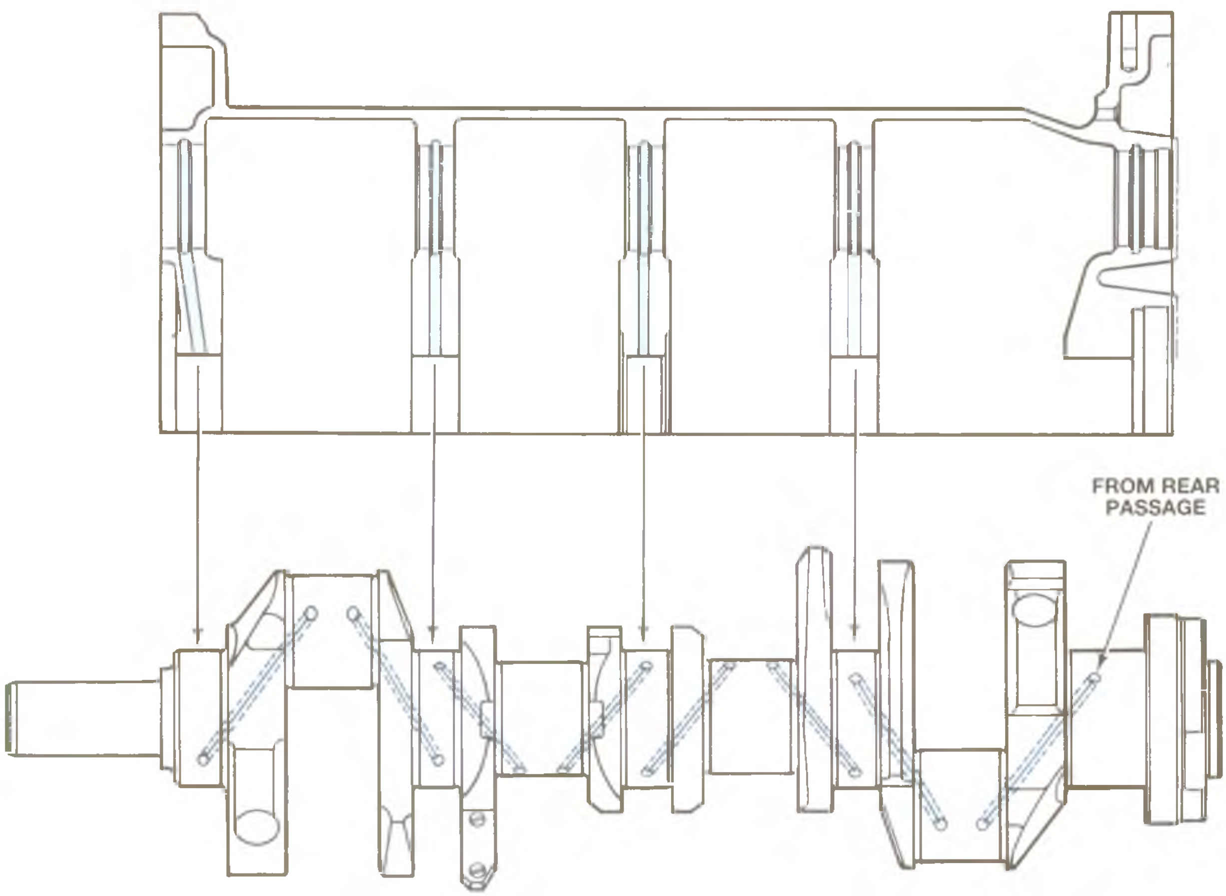


Figure 3-10, **Crankshaft Oil Passages**

Once the oil from the pump reaches all its destinations, it drains back to the sump in the oil pan through open areas in the cylinder heads, cylinder case and front cover. The turbocharger has a special drain pipe/hose that connects to a metal flange on the lower right side of the cylinder case (see Figure 3-11).

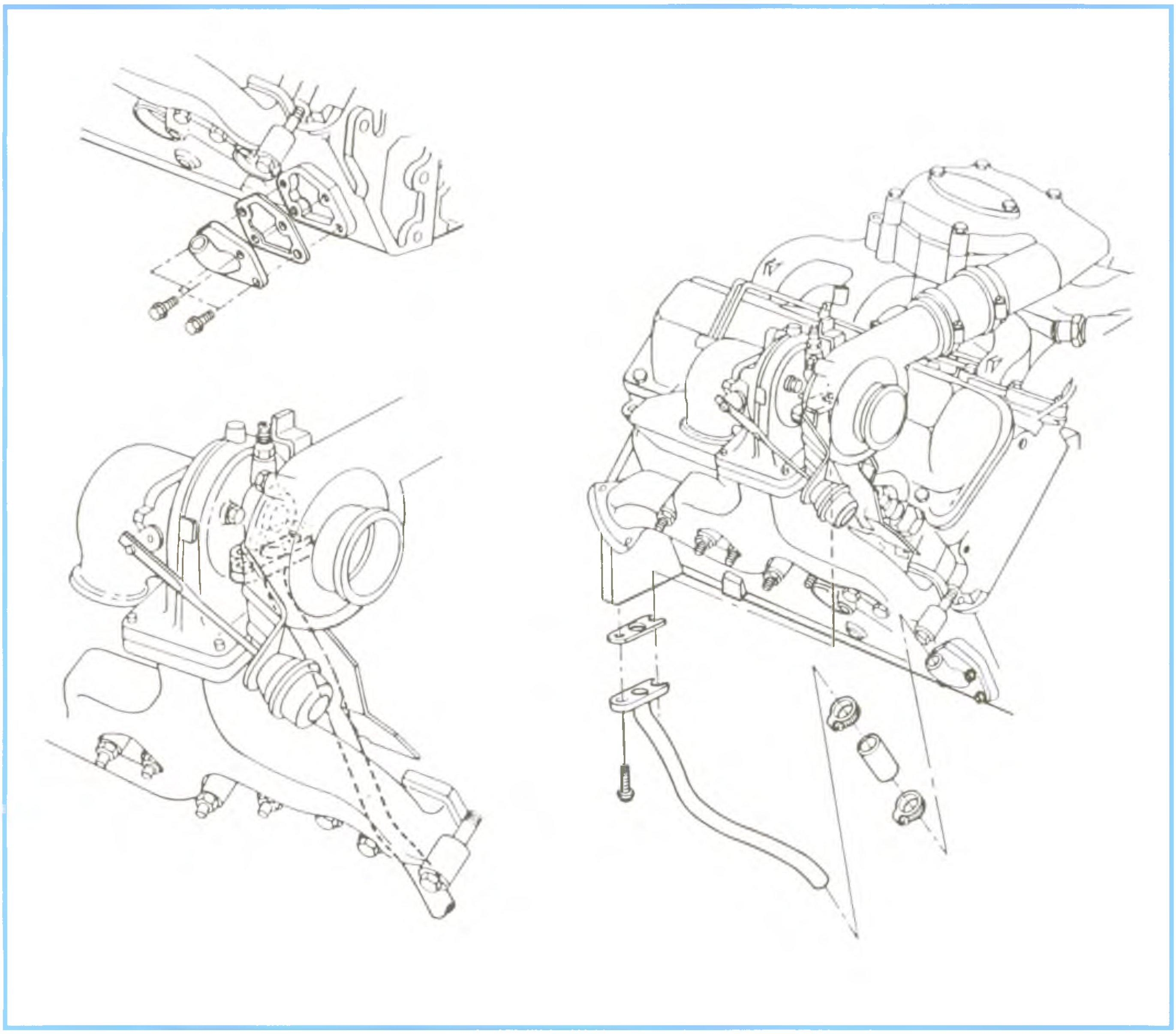


Figure 3-11, **Turbocharger Drain Tube/Hose**

Crankshaft Seals

The front cover has a single-piece lip-type seal that rides on the torsional damper at the front of the crankshaft (see Figure 3-12, view A). The cylinder case and crankshaft #5 main bearing cap together form a mounting surface for the rear crankshaft seal (see Figure 3-12, view B). Like the crankshaft front seal, the rear seal is of a single-piece lip-type design.

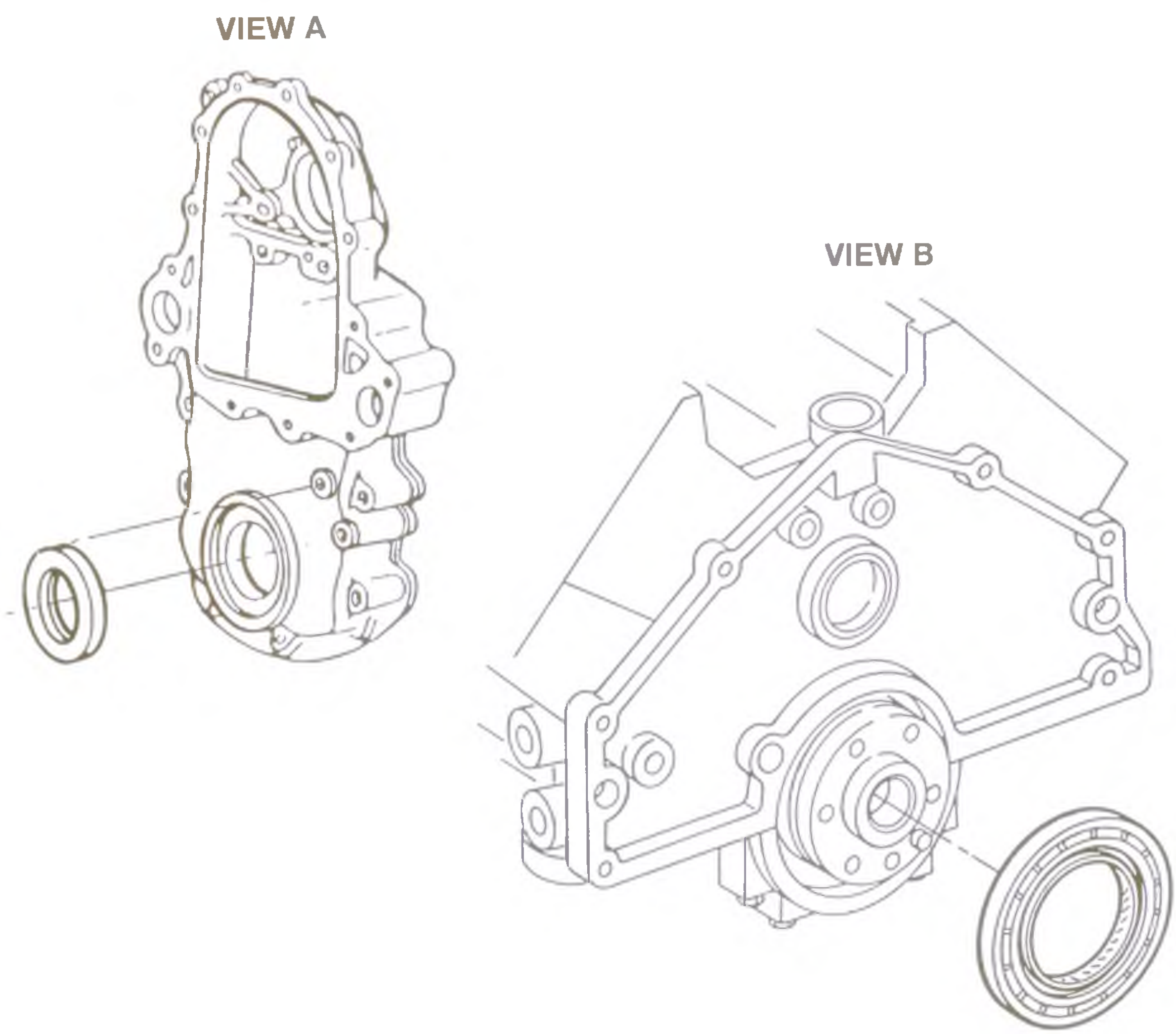


Figure 3-12, Crankshaft Seals

During the service replacement procedure, the crankshaft front seal may be removed by using a slide hammer and hook-type adapter. The crankshaft rear seal may be removed by careful prying.

The front seal requires a special driving tool for its installation (see Figure 3-13, view A). The rear seal has a special pushing tool to be used during its installation that repositions the seal for a different contact with the crankshaft flange (see Figure 3-13, view B).

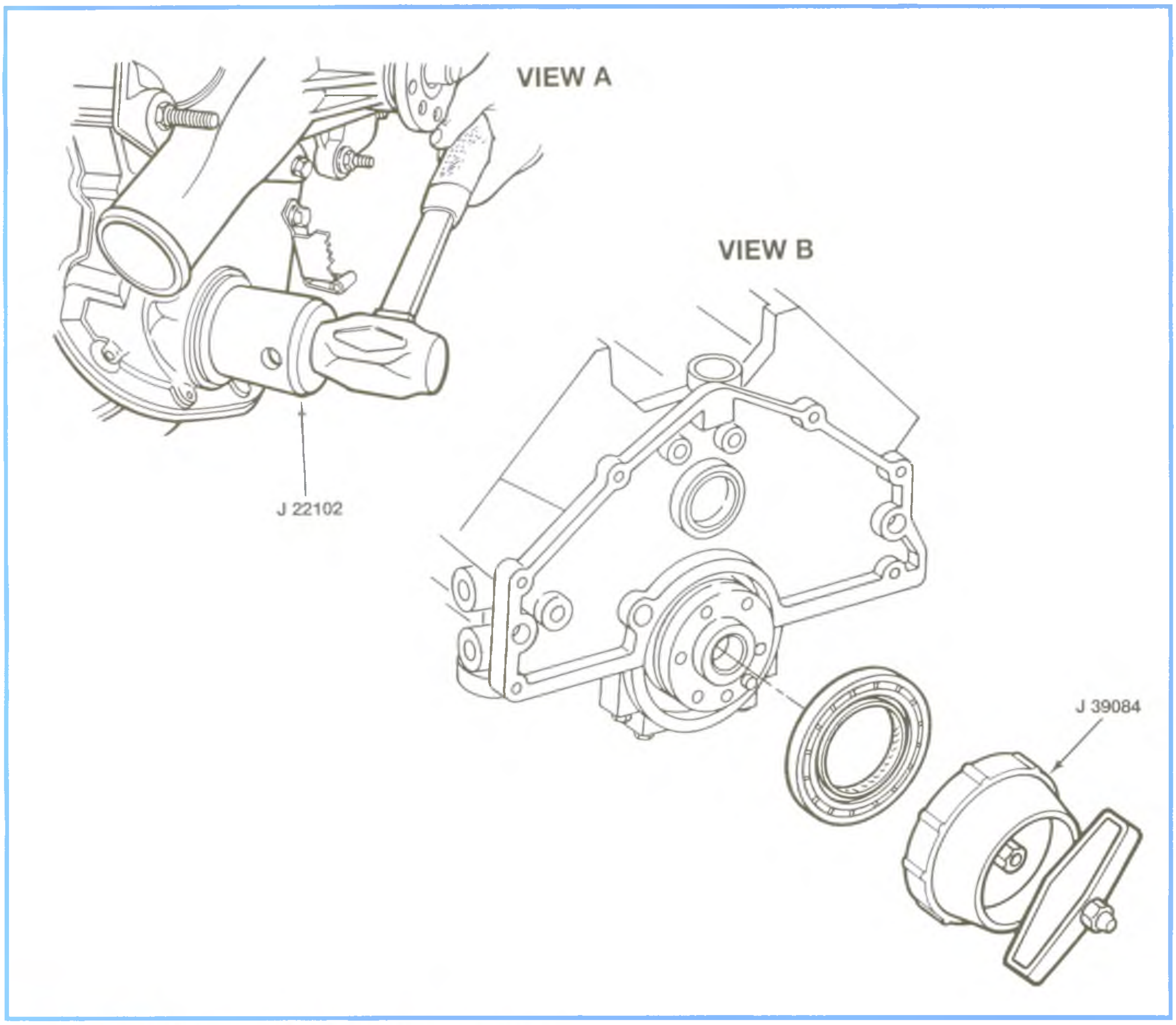


Figure 3-13, **Crankshaft Seal Installation**

Sealing Surfaces

The front cover uses an anaerobic sealant (GM P/N 1052942) at its surfaces that contact the cylinder case and water pump assembly (see Figure 3-14). This type of sealant is soft and pliable when exposed to air and cures to a hard film when parts are joined.

The water pump assembly also uses anaerobic sealant at its contact surface with the front cover (see Figure 3-15, view A). Other front cover sealing areas include the oil fill pipe grommet (see Figure 3-15, view B) and the injection pump gasket (see Figure 3-15, view C).

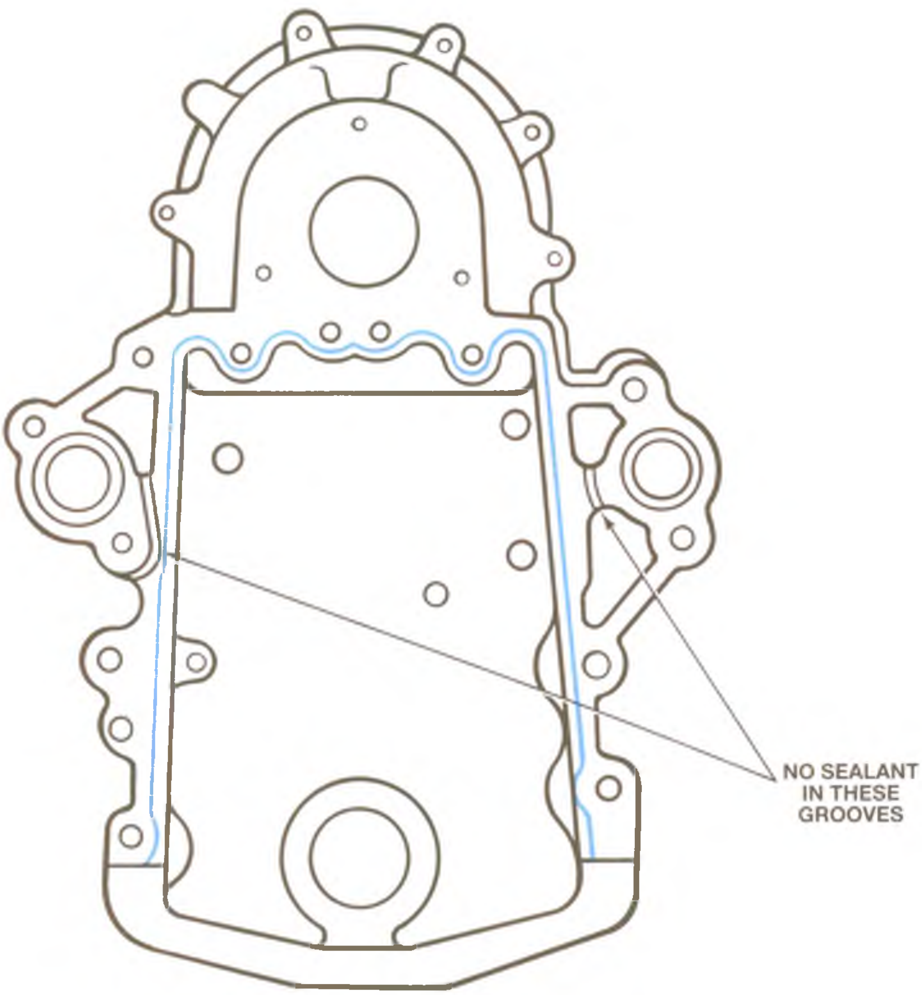


Figure 3-14, **Front Cover Sealing Surfaces (1)**

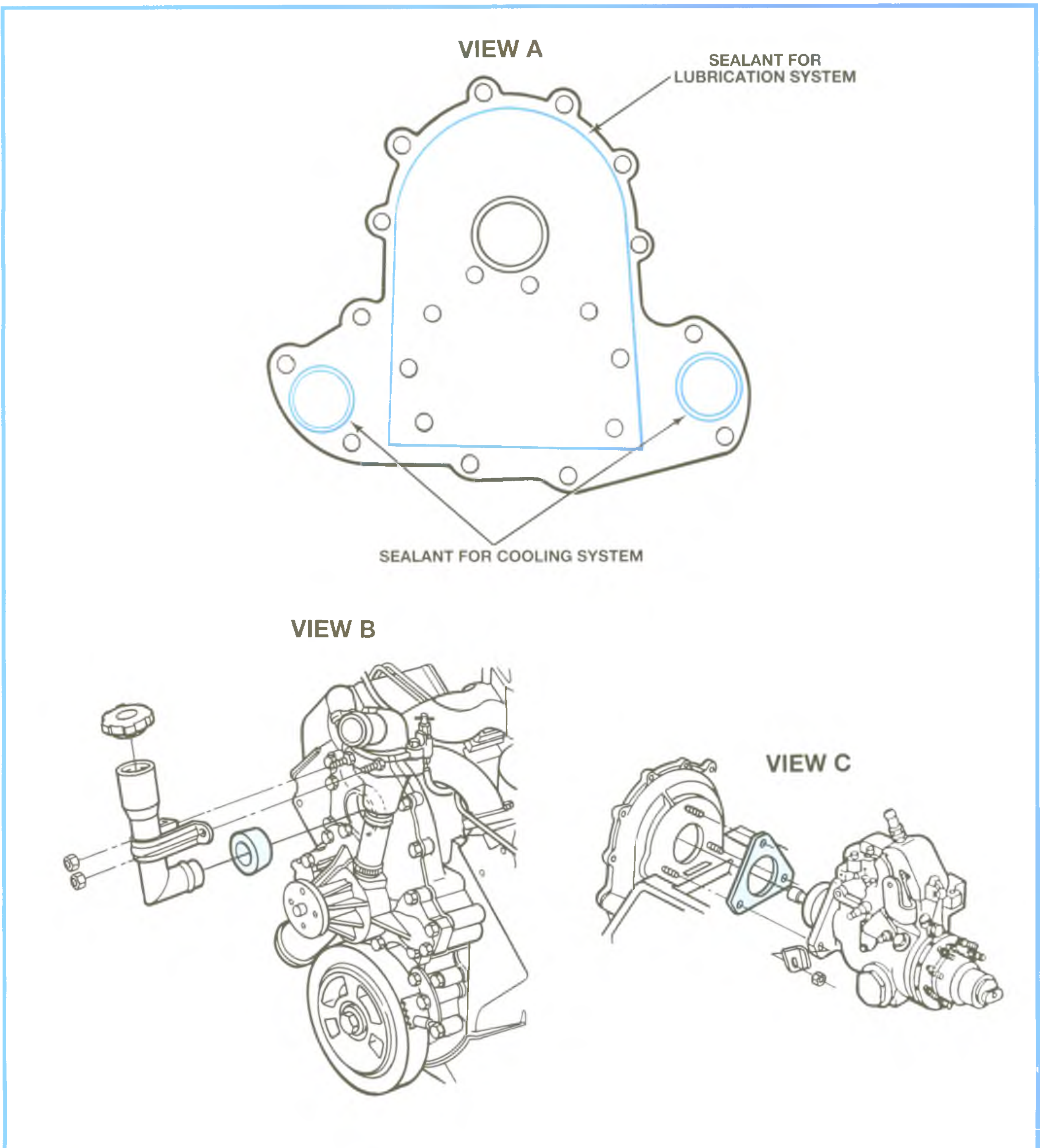


Figure 3-15, Front Cover Sealing Surfaces (2)

Each rocker arm cover uses an RTV (Room Temperature Vulcanizing) sealant (GM P/N 1052915) on its flange that contacts the cylinder head (see Figure 3-16, view A). The right rocker arm cover also has a grommet at the Crankcase Depression Regulator Valve (CDRV) fitting.

The oil pan also uses RTV sealant on its cylinder case and front cover sealing flanges, as well as a rubber seal at the crankshaft #5 main bearing cap (see Figure 3-16, view B). The oil dipstick tube has an O-ring seal at its mounting in the left side of the oil pan.

The cylinder case has lubrication system passage plugs that use thread sealant (GM P/N 1052080). The oil pump drive uses an O-ring seal at its mounting bore in the cylinder case.

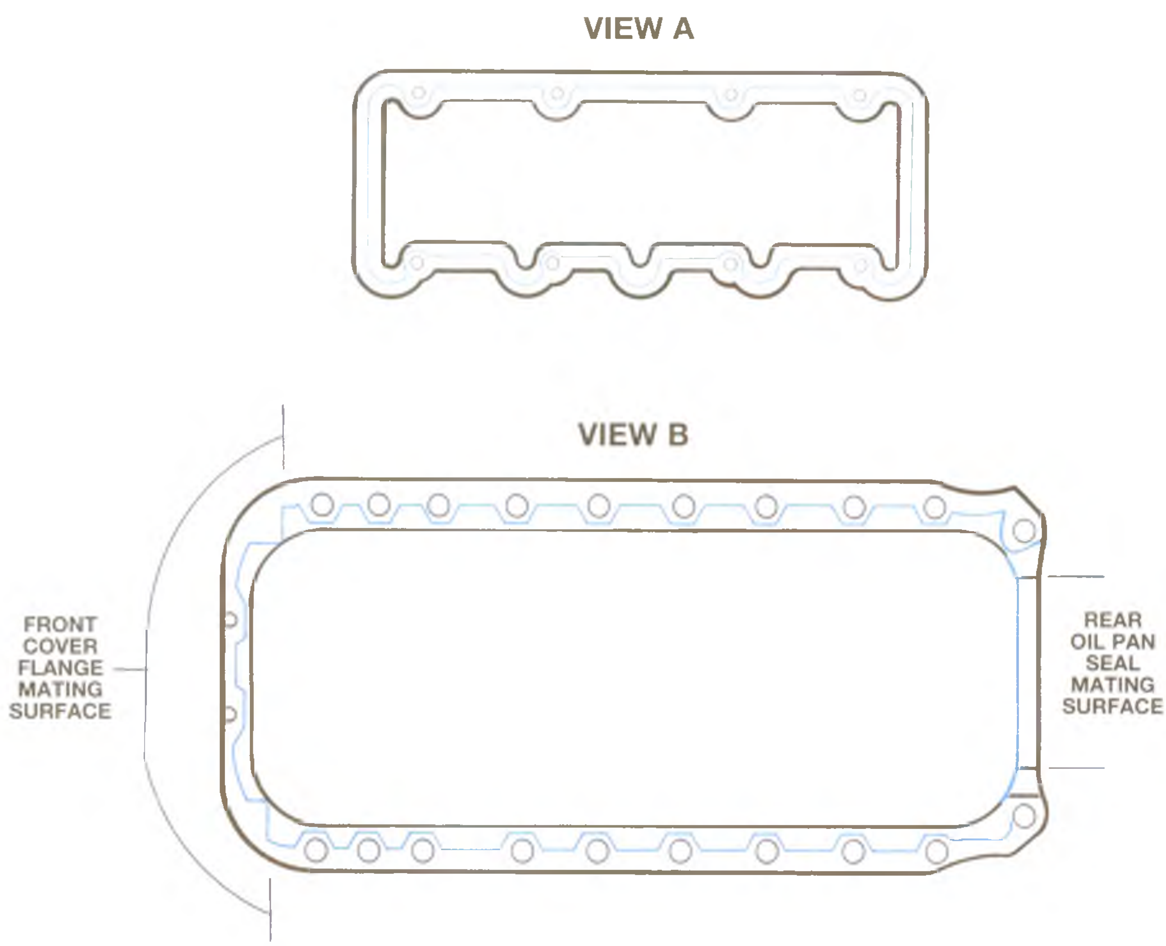


Figure 3-16, Rocker Arm Cover and Oil Pan Sealing Surfaces

Related Diagnosis/Service Procedures

Oil Pressure Check

1. Bring the engine to operating temperature.
2. Remove the oil pressure switch/sending unit.
3. Install a tee adaptor between the oil pressure switch/sending unit and cylinder case passage fitting.
4. Connect a pressure gauge that reads from 0 to 1034 kPa (0 to 150 psi) to the tee adaptor (see Figure 3-17).
5. Start and run the engine, observing the gauge reading:
   - If the gauge reading at idle speed is lower than 69 kPa (10 psi), go to step 6.
   - If the gauge reading at 2,000 rpm is lower than 276 to 310 kPa (40 to 45 psi), go to step 6.
   - If the gauge reading at any engine speed is higher than 552 kPa (80 psi), go to step 7.

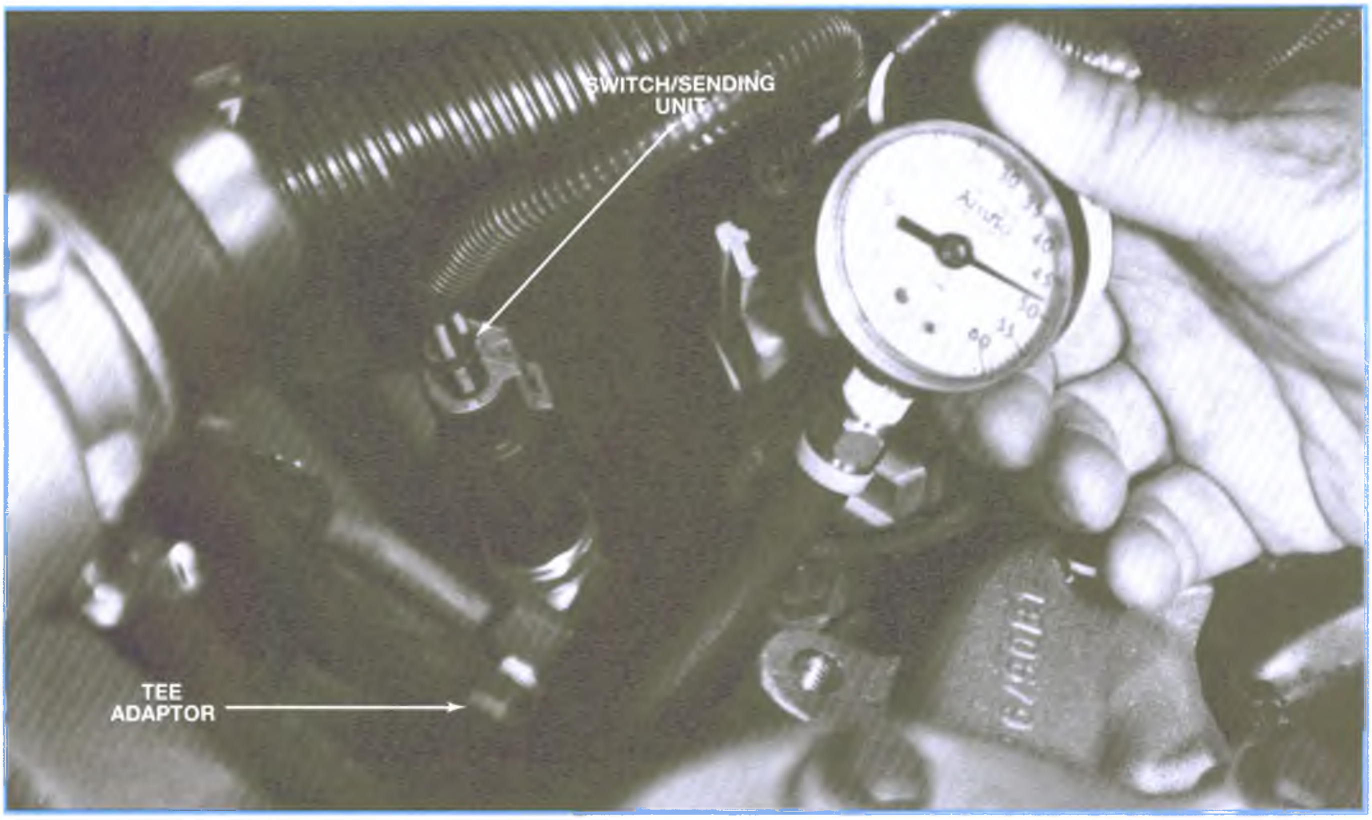


Figure 3-17, **Oil Pressure Check (1)**

6. Remove the pressure gauge and tee adaptor and install the oil pressure switch/sending unit.
7. Check the oil pressure between the pump and the filter, using tool J 25087-C (see Figure 3-18):
   - If the gauge reading at idle speed or 2,000 rpm is lower than the specification, inspect the following parts:
     - Oil pump and pressure regulator valve
     - Crankshaft bearings for excessive clearance
     - Camshaft bearings for excessive clearance
     - Hydraulic lifters for excessive bore clearance
     - Cylinder case passages for internal leaks
   - If the gauge reading at idle speed or 2,000 rpm meets the specification, inspect the following parts for restriction:
     - Oil cooler and bypass valve
     - Oil filter and bypass valve
     - Cylinder case passages
8. Remove the oil pump and inspect the pressure regulator valve for binding related to excessively high oil pressure (replace the oil pump, if needed).

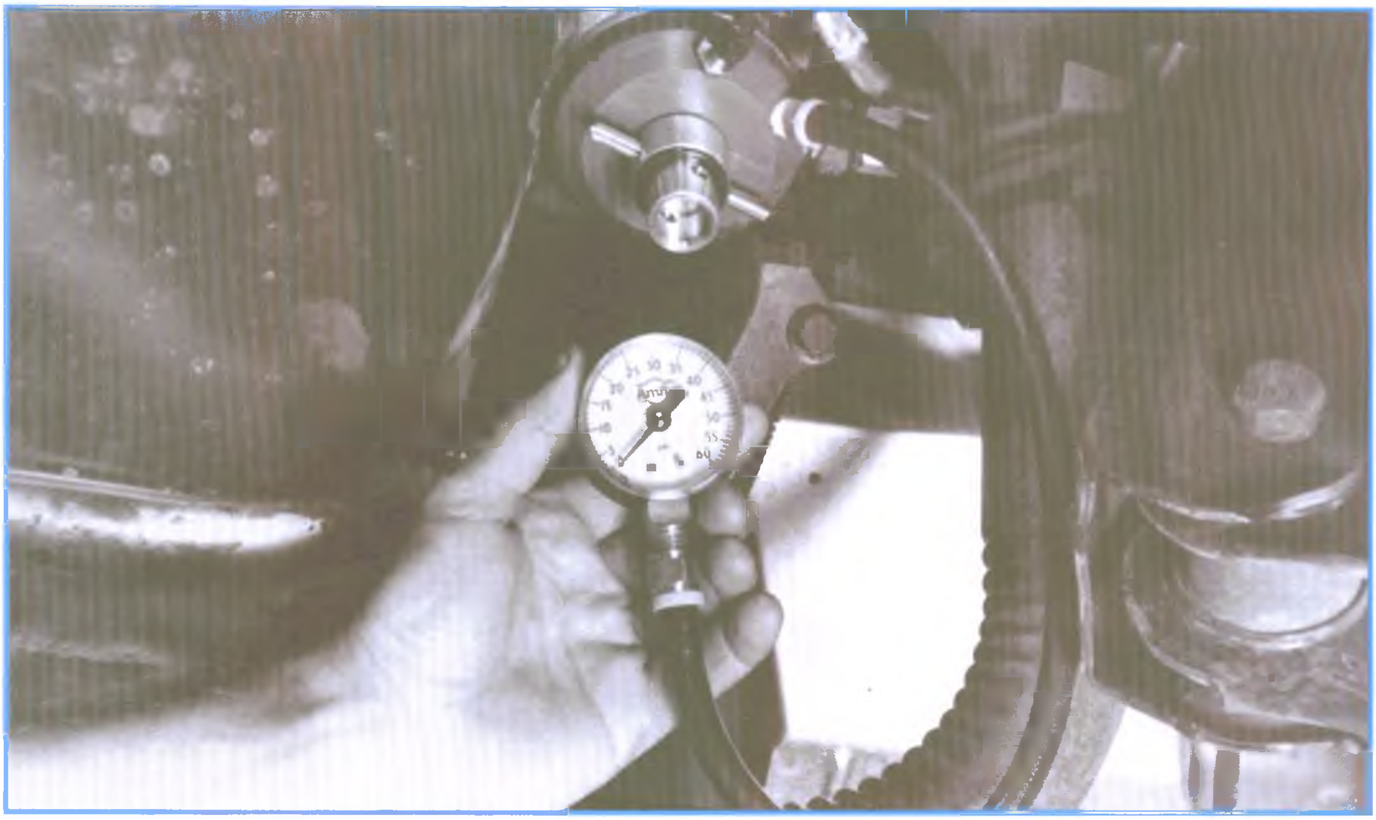


Figure 3-18, Oil Pressure Check (2)

4. Cooling System

Overview

The cooling system of the 6.5L V8 turbo diesel engine includes the following groups of parts (refer to Figure 4-1):

- Water pump assembly
- Cylinder case and head passages
- Water crossover and thermostat
- Heater core system
- Radiator system
- Cooling fan assembly

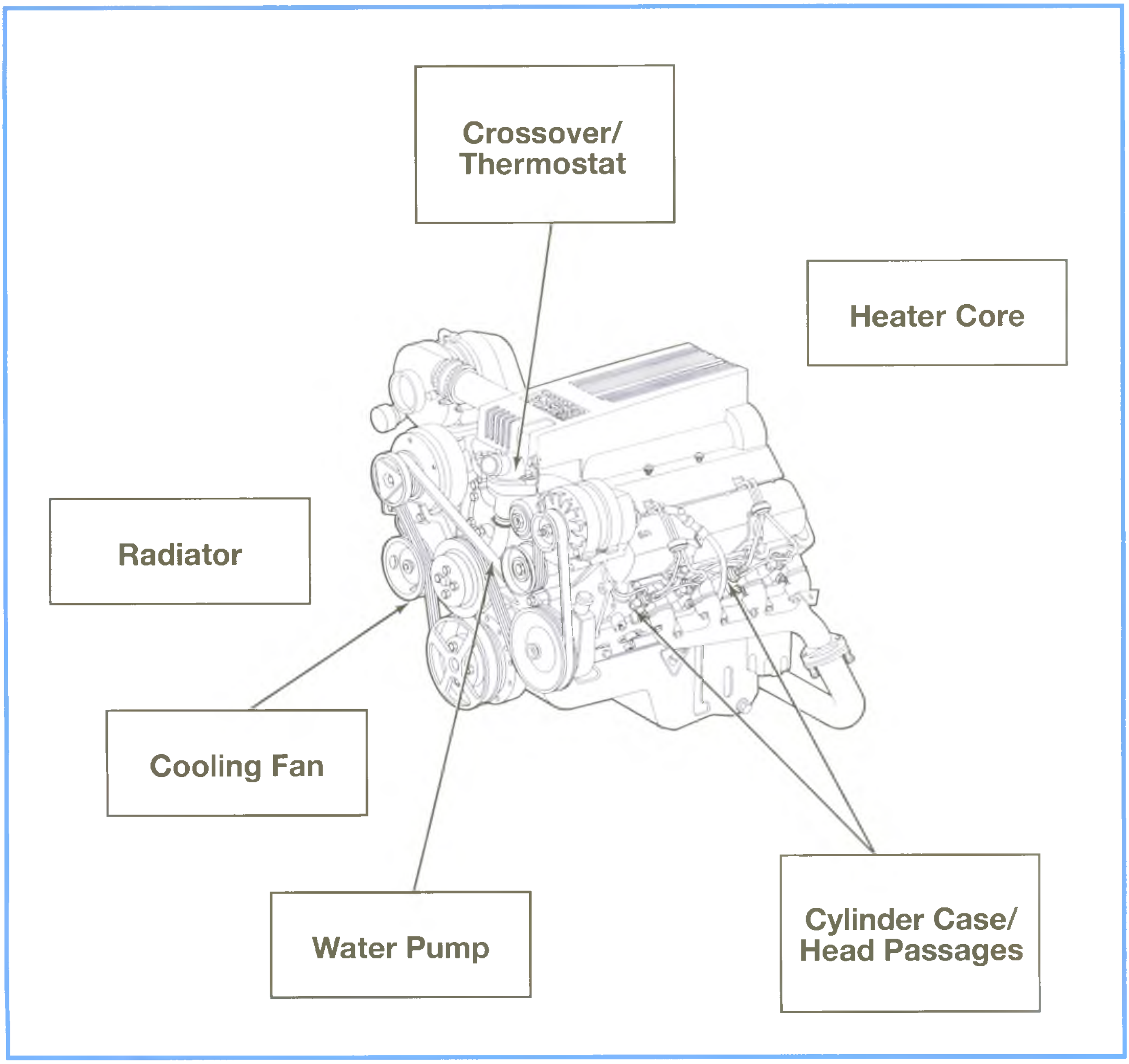


Figure 4-1, **Cooling System Part Groups**

Water Pump Assembly

The water pump assembly consists of the pump itself, as well as a plate. Bolts attach the pump to the plate (see Figure 4-2, view A), and a gasket seals the surface between the two parts (see Figure 4-2, view B).

The water pump assembly mounts on the front cover, using a variety of fasteners and anaerobic sealant (see pages 2-30 and 3-14 for more information).

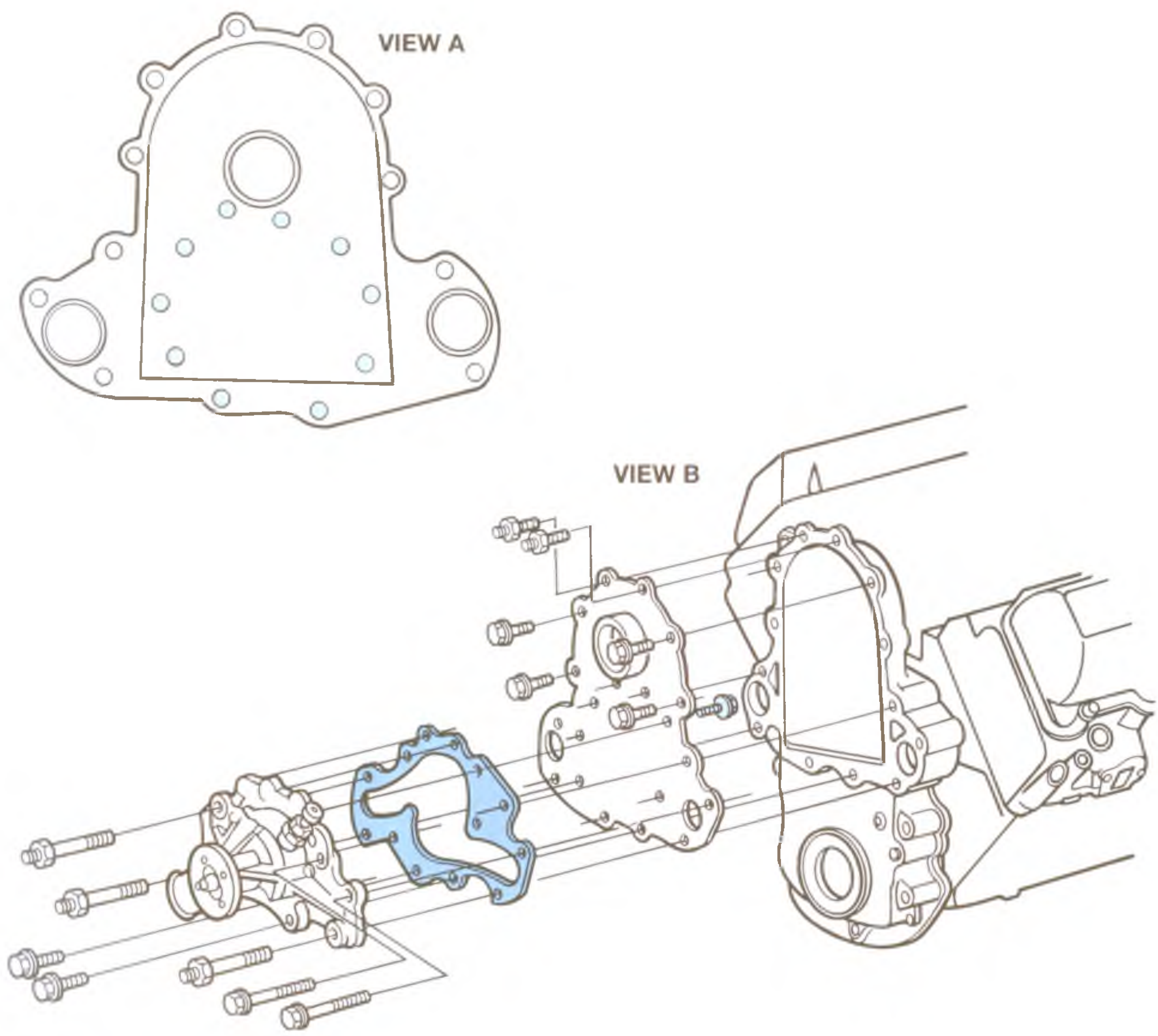


Figure 4-2, **Water Pump Assembly**

The accessory drive belt allows the crankshaft to rotate the pump shaft and impeller in a counterclockwise direction, using a pulley held in place by the mounting of the cooling fan assembly to the pump shaft flange. As the impeller rotates, coolant in the radiator is drawn into the pump through a hose connected to the inlet fitting (see Figure 4-3).

The action of the impeller increases coolant pressure, and fluid is pushed through two front cover passages into each side of the cylinder case.

During service, a replacement water pump must match the 6.5L V8 turbo diesel application in capacity and impeller rotation. An incorrect replacement part may cause engine overheating.

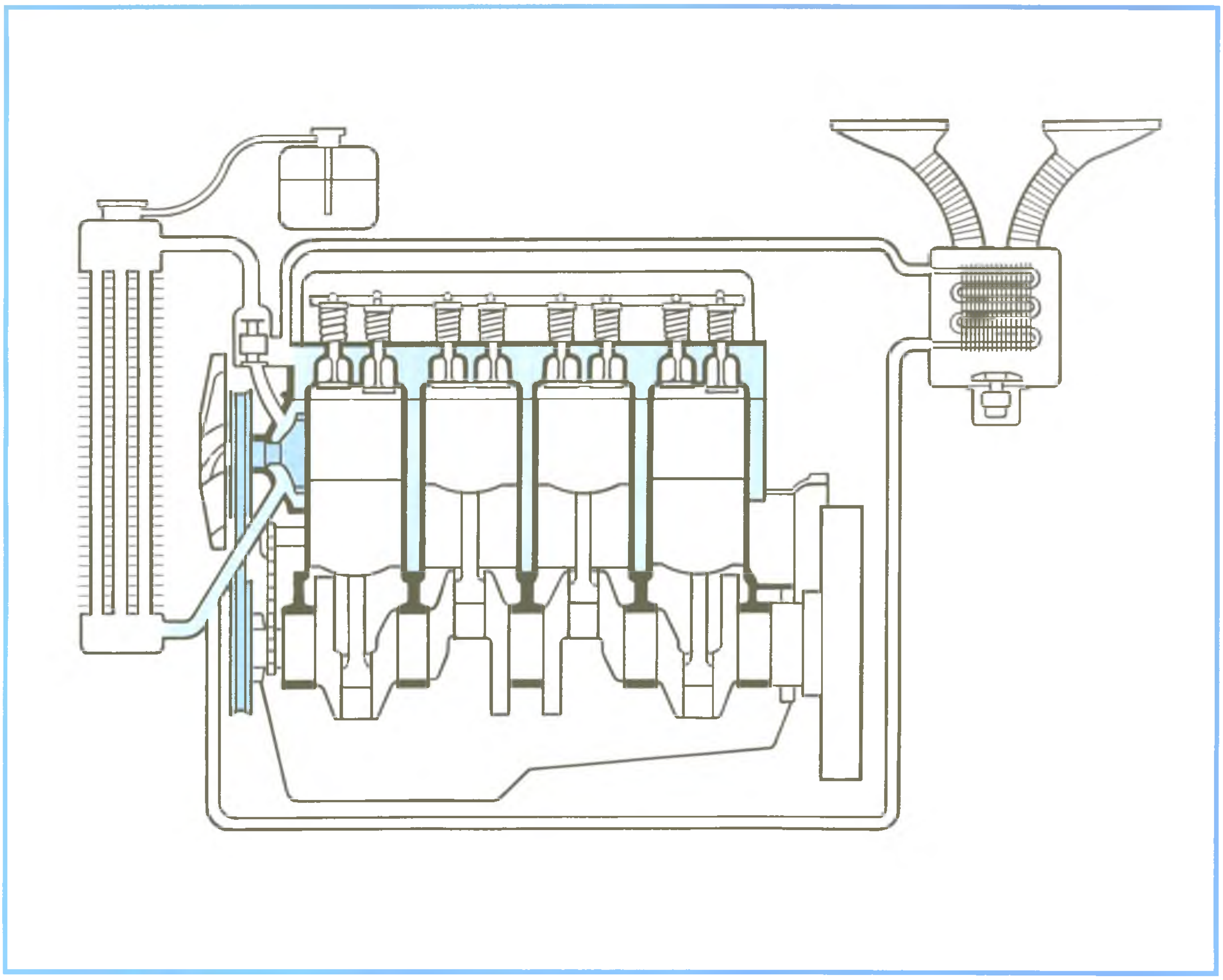


Figure 4-3, **Cooling System Diagram – Water Pump Flow**

Cylinder Case and Head Passages

The path of coolant moving from the water pump includes cylinder case passages surrounding each of the cylinder bores and cylinder head passages surrounding the combustion chamber and valve port areas. Each cylinder head gasket has restrictions to control the flow of coolant from the cylinder case into the cylinder head passages.

Cup plugs seal five of the six cooling system passage openings in the cylinder case (see Figure 4-4). The sixth passage opening has a special plug with an integral heating element that is used for warming the engine for starting in extremely cold temperatures (see page 8-2 for more information).

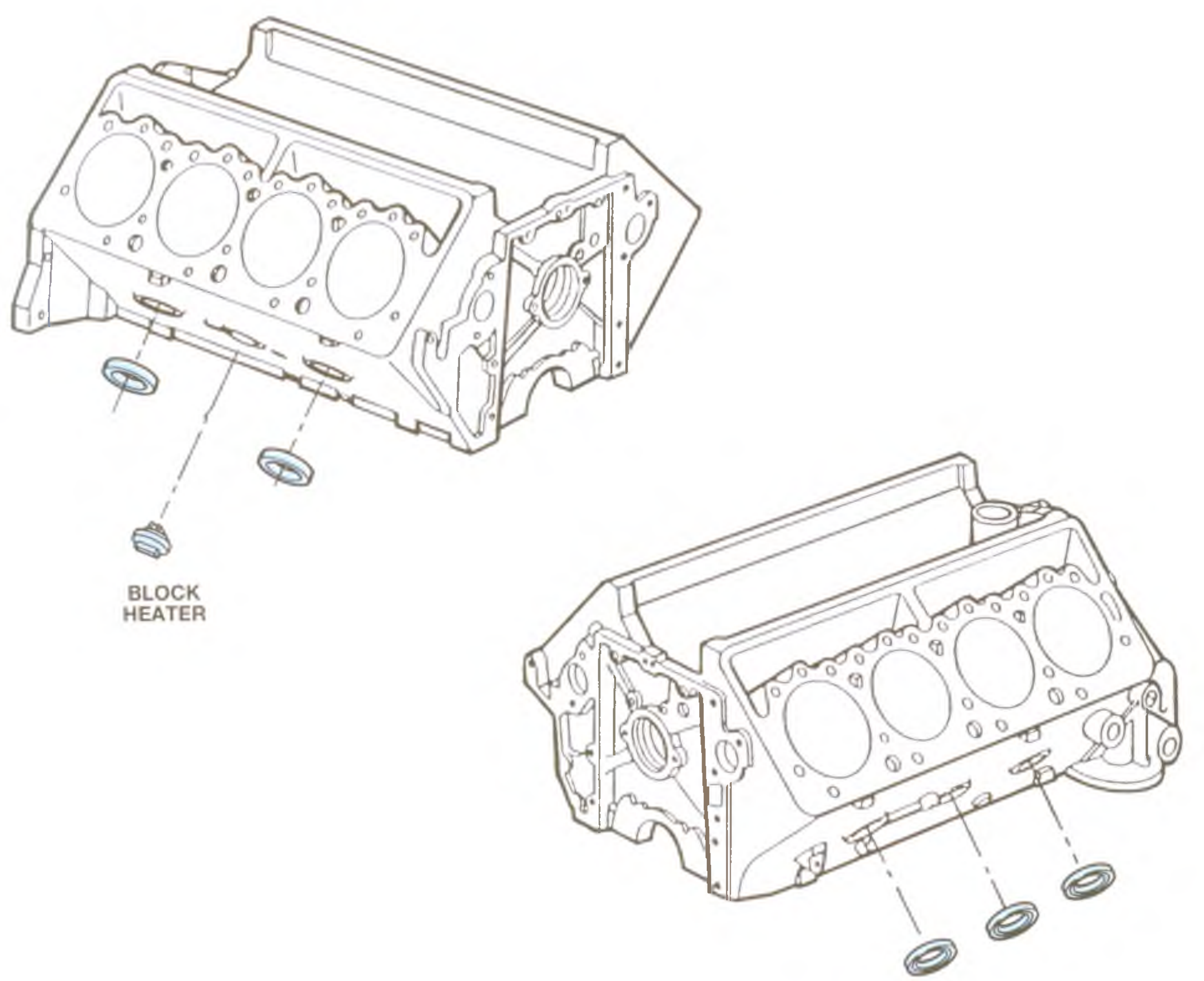


Figure 4-4, Cylinder Case Plugs

Each cylinder head has a plate retained with bolts and a gasket to seal a rear cooling system passage (see Figure 4-5, view A). The right cylinder head has a threaded plug at its outer rear corner to seal cooling system passages. Both cylinder heads also have four small cup plugs beneath the intake ports.

The left cylinder head uses a switch (for an engine temperature warning lamp circuit) or sending unit (for a gauge circuit) threaded into the outer front corner location (see Figure 4-5, view B). The engine temperature warning lamp will light when the cooling system temperature at the left cylinder head switch location is above 258° F (126° C) (see page 8-36 for more information).

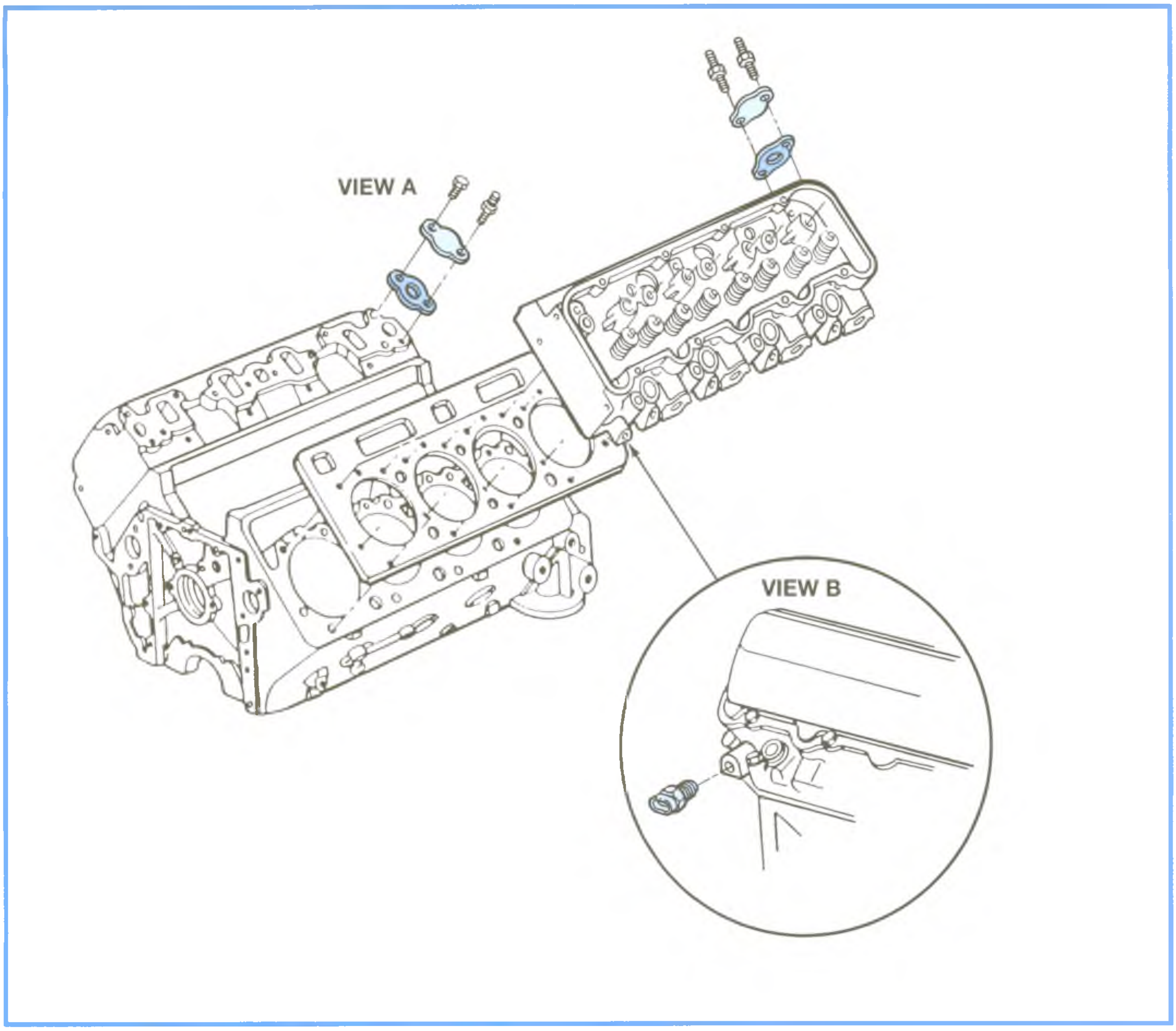


Figure 4-5, Cylinder Head Cooling System Features

Water Crossover and Thermostat

Coolant exiting each cylinder head moves through the water crossover mounted to a common outlet. The water crossover uses a bolt and stud to retain it to each cylinder head, and a gasket provides sealing (see Figure 4-6, view A).

The water crossover contains a thermostat that sends coolant to the water pump through a hose during engine warm-up operation. A bolt and stud hold the thermostat housing to the water crossover, and a gasket seals the flange (see Figure 4-6, view B).

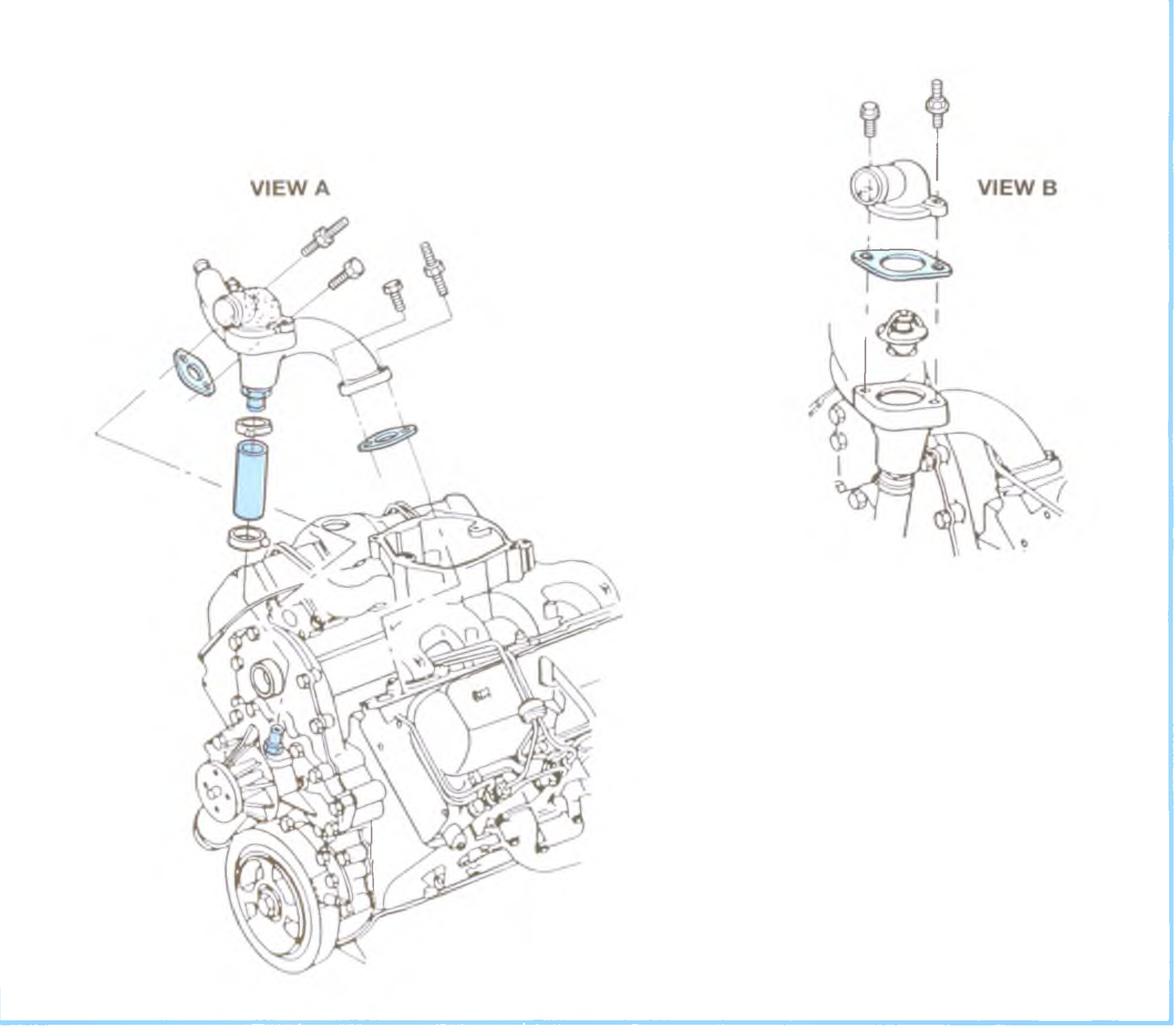


Figure 4-6, **Water Crossover and Thermostat**

When the coolant reaches a temperature of 190° F (88° C), the thermostat begins to close a bypass passage to the water pump and open a passage through a hose to the radiator (see Figure 4-7). At 215° F (102° C), the bypass passage is fully closed and full flow is allowed from the engine to the radiator. The full-blocking function of the thermostat is required to provide maximum cooling system efficiency.

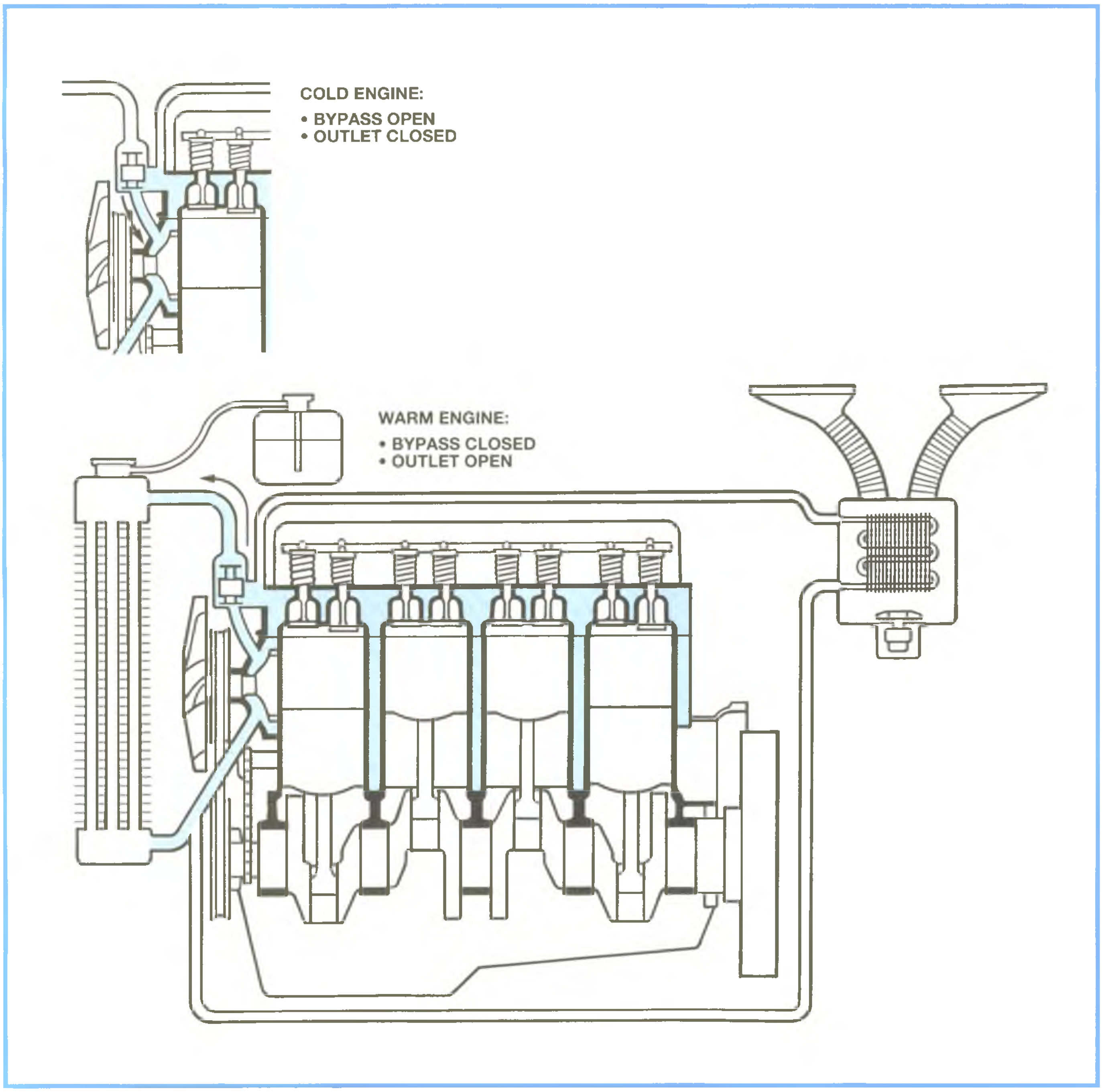


Figure 4-7, **Cooling System Diagram – Thermostat Flow**

Heater Core System

The water crossover has a fitting connected to the inlet hose of a heater core in the passenger compartment (refer to Figure 4-8). The heater core is a heat exchanger assembly of finned metal tubing connected to end tanks. Airflow caused by the operation of the heating system blower motor removes heat from the coolant flowing through the heater core.

The heater core has a steady flow of coolant heated by the engine at all times, since no restrictor or control valve is used (see Figure 4-9). The outlet of the heater core connects to a hose and fitting on one end tank of the radiator.

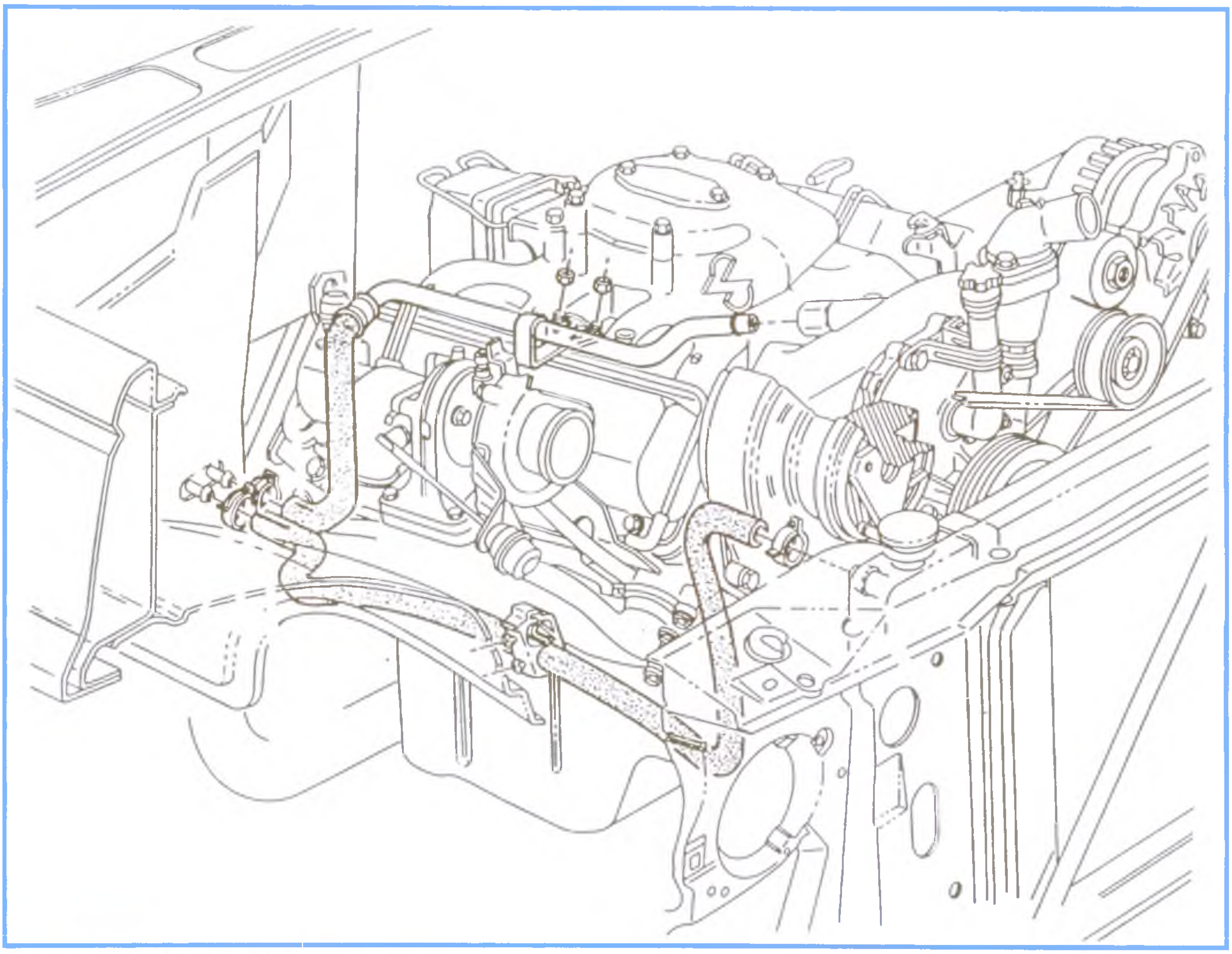


Figure 4-8, Heater Core System

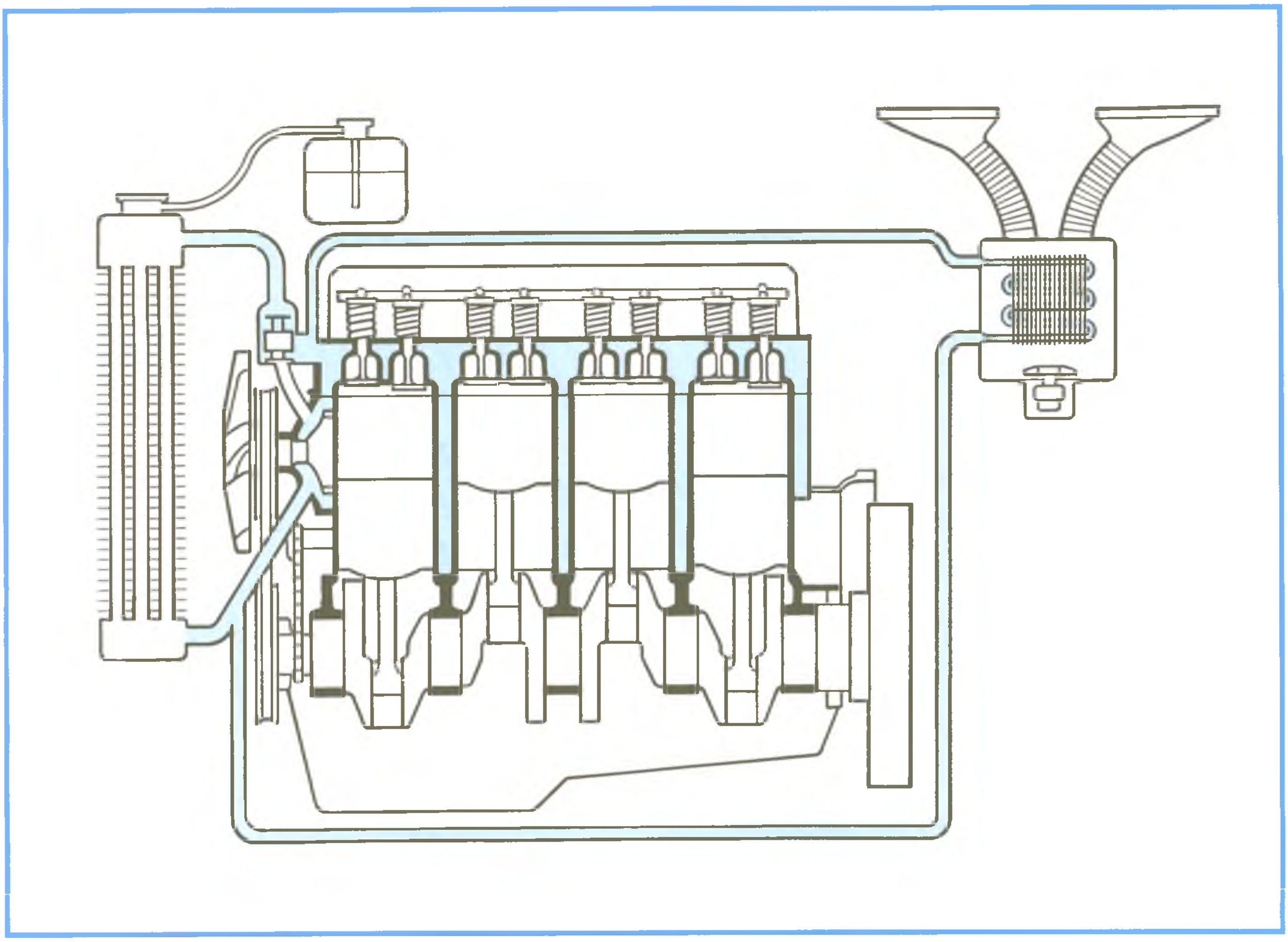


Figure 4-9, Cooling System Diagram – Heater Core Flow

Radiator System

The radiator is a heat exchanger assembly of finned metal tubing connected to end tanks and is mounted in front of the cooling fan assembly (see Figure 4-10). One of the radiator end tanks has the engine oil cooler mounted inside it, and the other end tank contains the automatic transmission oil cooler.

Airflow caused by vehicle movement and the operation of the cooling fan removes heat from the coolant flowing through the radiator. The radiator has a steady flow of coolant from the engine through the heater core system at all times, and also has direct flow from the engine through the water crossover when the thermostat is above 190° F (88° C).

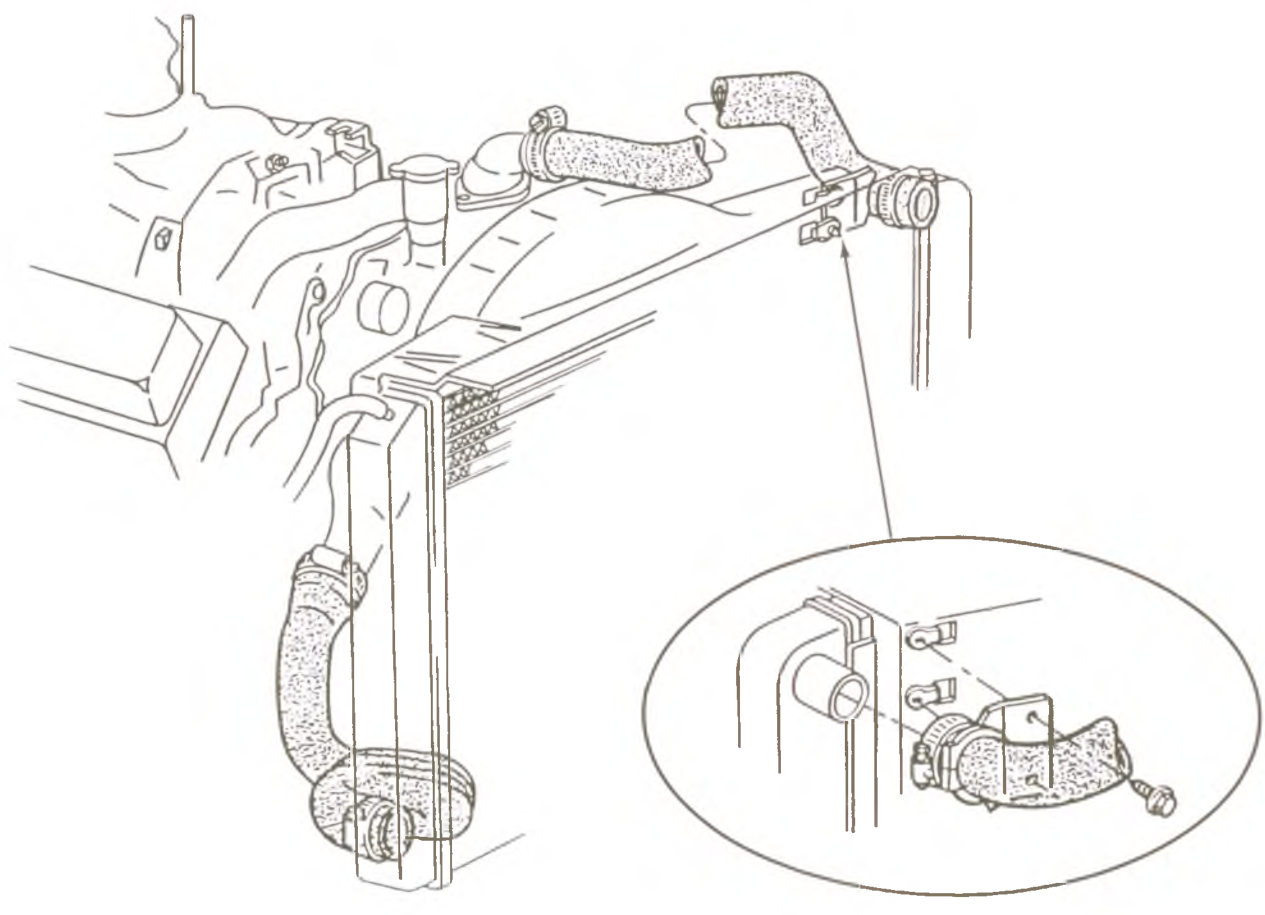


Figure 4-10, Radiator System

The radiator has a pressure/vacuum relief valve in its fill cap, and the cap fitting has connection to a remote reservoir. The radiator cap limits cooling system pressure to a maximum of 15 psi.

When the pressure valve of the radiator cap opens, excess pressure and coolant are exhausted to the reservoir (see Figure 4-11). When the vacuum valve of the radiator cap opens, coolant travels from the reservoir into the radiator.

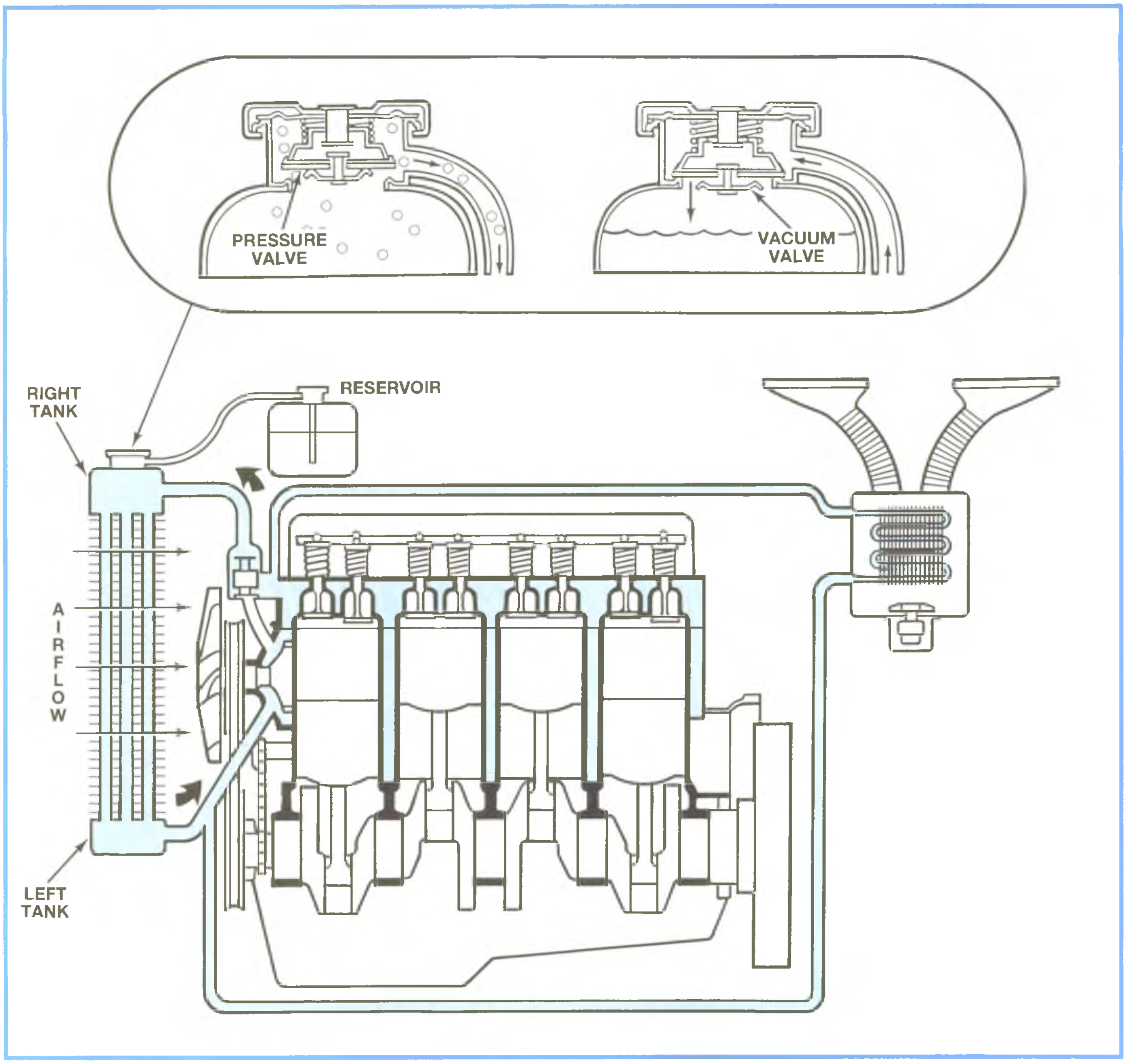


Figure 4-11, Cooling System Diagram – Radiator Flow

4. Cooling System

One of the end tanks has a fitting for the probe used in a low coolant warning lamp circuit (see Figure 4-12). The monitoring circuit is located in a module mounted behind the instrument cluster.

The low coolant circuit has the ability to detect the absence of liquid in the radiator tank at the probe location and complete the LOW COOLANT warning lamp circuit to alert the vehicle driver (see page 8-37 for more information).

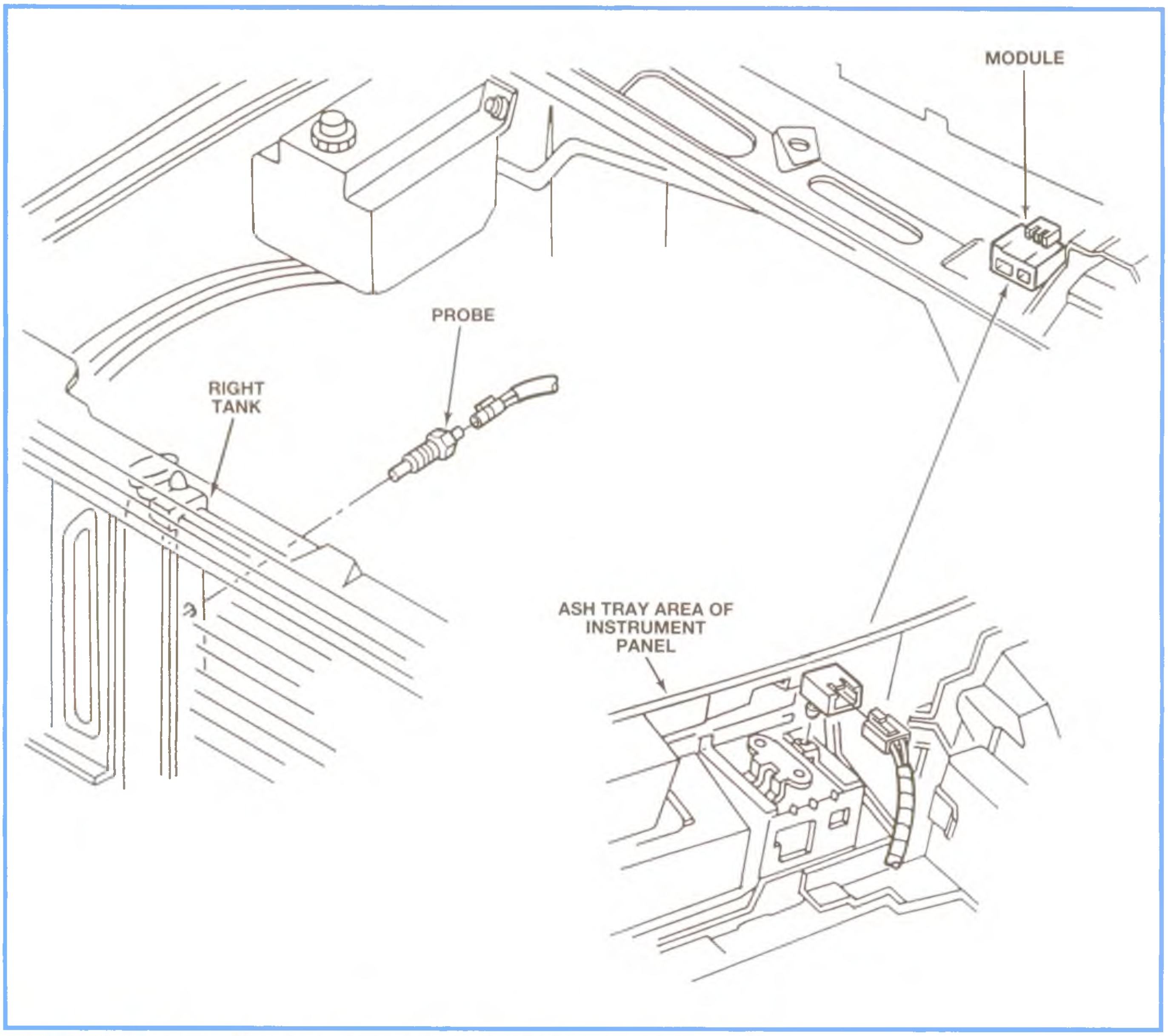


Figure 4-12, **Low Coolant Warning Lamp Circuit Components**

Cooling Fan Assembly

The cooling fan assembly, along with the water pump pulley, mounts to the water pump with studs and nuts. The accessory drive belt operation of the water pump also rotates the shaft and driving member of the fan clutch at all times. An aluminum housing has the fan blade assembly bolted to it and is the driven member of the fan clutch.

The operation of the fan occurs when the driving and driven members of the clutch are held together hydraulically by silicone fluid (see Figure 4-13, view A). A bimetallic coil controls the flow of silicone fluid from a reservoir (through a pump plate) to the area between the driving and driven members of the fan clutch (see Figure 4-13, view B). As the two members attempt to shear the silicone fluid, a coupling action takes place.

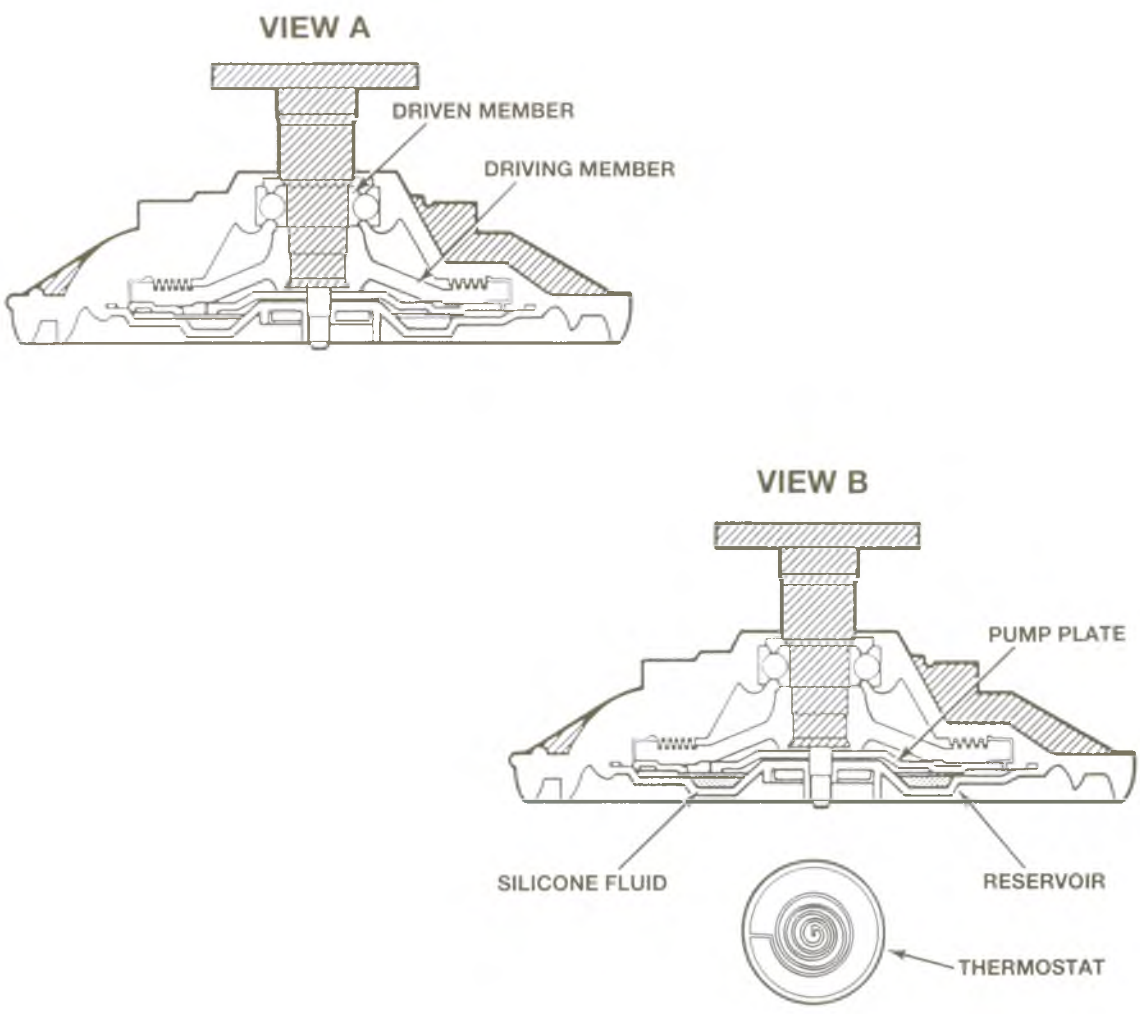


Figure 4-13, Cooling Fan Clutch Parts

When the temperature of the air flowing through the radiator is below 165° F (74° C), the bimetallic coil operation of the pump plate prevents the silicone fluid from moving to the area between the drive and driven members of the fan clutch (see Figure 4-14, view A). Even though the accessory drive belt is rotating, it is not rotating the fan blades with force.

When the temperature of the air flowing through the radiator is above 165° F (74° C), the bimetallic coil operation of the pump plate allows the silicone fluid to move into the area between the drive and driven members of the fan clutch (see Figure 4-14, view B). Now the accessory drive belt rotates the fan blades with force.

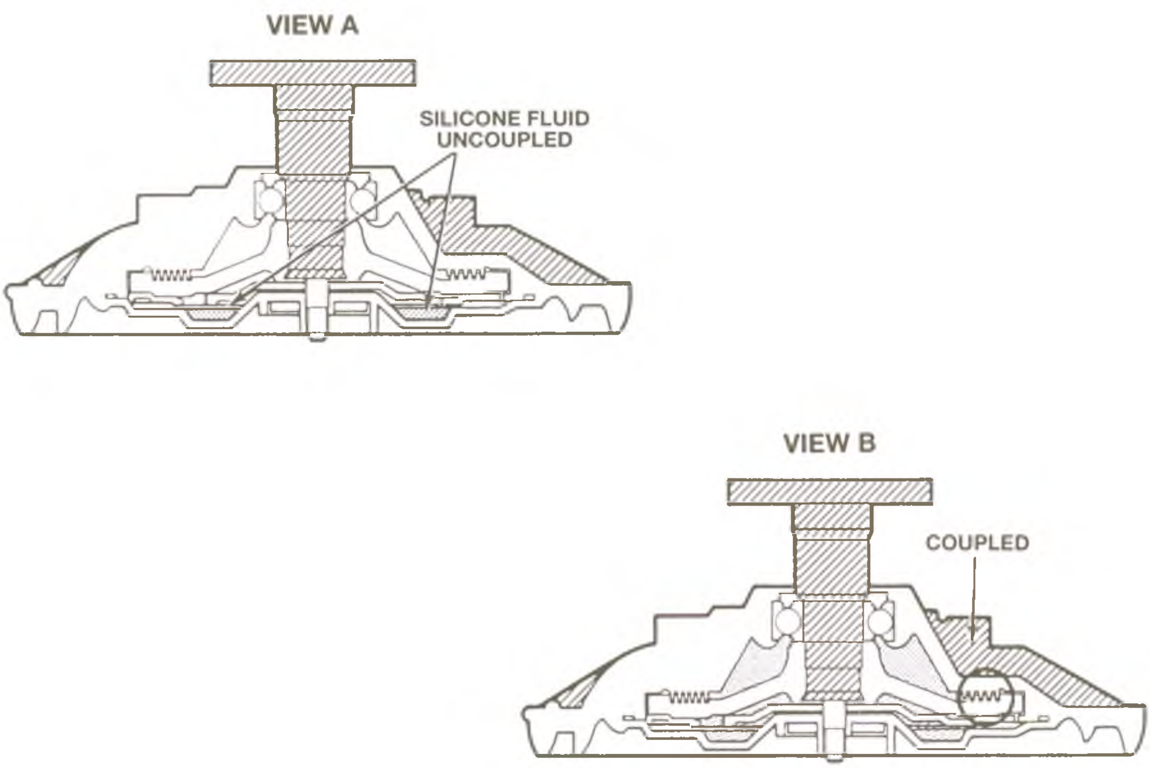


Figure 4-14, **Cooling Fan Clutch Operation**

The following diagnosis hints relate to cooling fan operation:

Condition #1: Noise

Cause: A. Clutch distributing silicone fluid immediately after engine start-up

B. Clutch fully applied to provide maximum cooling

Correction: A and B. None, since the conditions are normal.

Condition #2: Looseness

Cause: Approximately 1/4-inch lateral movement at the fan blade tip (related to the fan clutch bearing design)

Correction: None, since the condition is normal.

Condition #3: Leakage

Cause: Small silicone fluid leakage in the bearing area

Correction: None, since the condition is normal.

Condition #4: Engine overheating

Cause: Incorrect fan clutch operation

Correction: Follow this diagnostic sequence:

1. Allow the engine to cool for complete fan clutch release.
2. Spin the fan/clutch assembly to check for slight drag.
   - Replace the fan clutch if it spins for more than five revolutions.
   - Replace the fan blade assembly if any blades are bent.
3. Mount a thermometer in the airflow path (on the fan shroud) between the radiator and fan.
4. Start the engine and operate it at 2,000 rpm (A/C on) with the radiator grille covered.
5. Observe the thermometer reading when the fan clutch applies.
   - Noise indicates fan clutch apply, as well as a temperature drop of 5° to 15° F (3° to 9° C).
   - Replace the fan clutch if no clutch apply occurs.
   - Replace the fan clutch if the temperature of clutch apply is not 150° to 195° F (66° to 91° C).
6. Uncover the radiator grille and run the engine at 1,500 rpm for cooling.
7. After several minutes of engine operation, check that the fan clutch releases.
   - Replace the fan clutch if no clutch relase occurs.

Cooling System Diagnostic Hints

The causes for problems not requiring disassembly of the cooling system include the following items:

- Large obstructions in the airflow path of the radiator:
  - An add-on auxiliary oil cooler
    - Remove or relocate.
  - Additional license plates
    - Remove or relocate.
  - Grille-mounted spare tire
    - Remove or relocate.
  - Ice, snow or mud in grille
    - Remove.
  - Fog or driving lights mounted in bumper cut-outs.
    - Remove or relocate.

- Engine oil level too high
  - Check and drain to proper level.

- Wrong radiator for application
  - Install correct radiator.

- Loose, damaged or missing air baffle and seals
  - Repair or replace parts.

- Incorrect fuel injection timing
  - Adjust timing to correct specification.

The causes for problems requiring disassembly of the cooling system include the following items:

- Incorrect or damaged cooling fan
  - Replace with new part.

- Incorrect cooling system pressure
  - Check and repair or replace parts.

- Defective water pump (impeller vanes, bearing or seal)
  - Replace with new part.

- Plugged radiator tubes
  - Remove for flow check and repair.

- Internal engine coolant leaks (cylinder case/cylinder heads/front cover)
  - Disassemble, inspect and replace damaged parts.

- Plugged cylinder head coolant passages
  - Disassemble, inspect and replace cylinder head.

Related Diagnosis/Service Procedures

Cooling System Diagnosis – Overheating

1. Check the coolant level in the following steps:
   A. Observe the level in the coolant reservoir:
      - If the level is low, go to step B.
      - If the level is correct, check the drive belt.

   B. Remove the radiator cap (engine cool) and observe the coolant level:
      - If the level is low, go to step C.
      - If the level is correct, check the drive belt.

   C. Check for external leakage:
      - If no leakage is visible, go to step D.
      - If leakage is visible, make repairs and re-check the cooling system operation.

   D. Check cooling system pressure
      - If the system maintains pressure, go to step E.
      - If the system loses pressure, locate the source of the leakage, make repairs and check the cooling system operation.

   E. Check the coolant mixture concentration:
      - If the coolant mixture is correct, check the drive belt.
      - If the mixture concentration is incorrect, change it and check the cooling system operation.

2. Check the drive belt in the following steps:
   A. Check drive belt tension and condition (see Figure 4-16):
      - If the tension and condition are good, check the condition of the hoses.
      - If the tension is low, go to step B.
      - If the condition is poor, replace the drive belt and check the cooling system operation.

   B. Check the drive belt tensioner operation:
      - If the tensioner checks good, replace the drive belt and check the cooling system operation.
      - If the tensioner checks bad, replace it and check the cooling system operation.

3. Check the condition of the hoses:
   - If all hoses check good, check the thermostat operation.
   - If any hose is collapsed, replace it and check the cooling system operation.

4. Check the thermostat opening temperature (refer to page 4-18):
   - If the opening temperature is correct, check the radiator.
   - If the opening temperature is high, replace the thermostat and check the cooling system operation.

5. Check the radiator in the following steps:
   A. Check the airflow through the radiator:
      - If the airflow is unrestricted, check the coolant flow.
      - If the airflow is restricted, repair and check the cooling system operation.
   B. Check the coolant flow through the radiator:
      - If the coolant flow is unrestricted, check the cylinder case and head passages for restrictions.
      - If the coolant flow is restricted, repair the radiator and check the cooling system operation.

6. Check the cylinder case and head passages in the following steps (see Figure 4-15):
   A. Check the coolant flow:
      - If the coolant flow is unrestricted, check for combustion gas flow into the cooling system.
      - If the coolant flow is restricted, replace the faulty component and check the cooling system operation.
   B. Check combustion gas flow:
      - If no combustion gas flow into the cooling system exists, check the water pump.
      - If combustion gas flow into the cooling system is evident, replace the faulty component and check the cooling system operation.

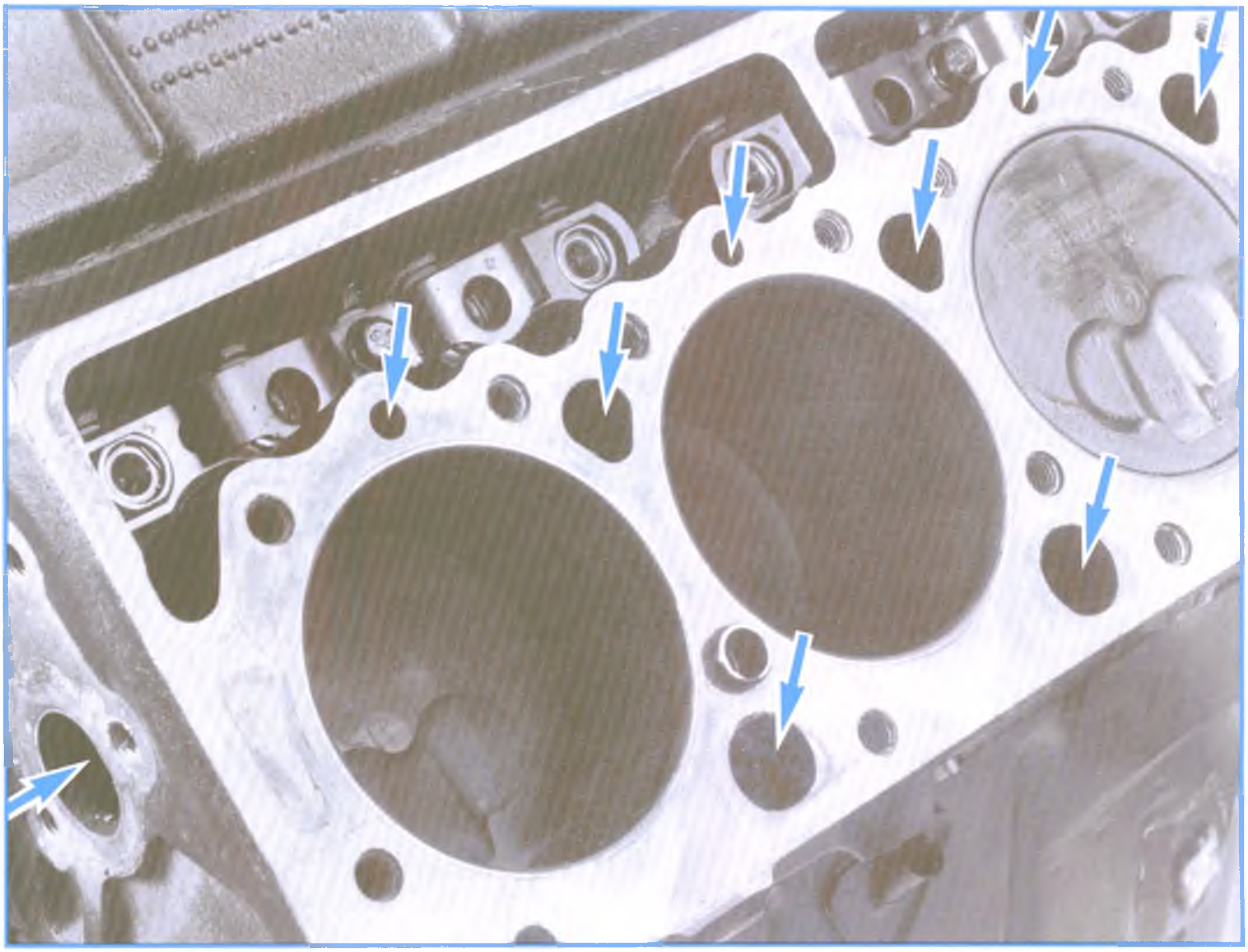


Figure 4-15, Coolant Passage Inspection

7. Remove and check the water pump operation (see Figure 4-16):
   - If the condition of the impeller and passages is good, check other factors.
8. Check the fan clutch operation (refer to the diagnostic hints on page 4-15):
   - If the fan clutch applies, refer to other factors.
   - If the fan clutch does not apply, replace it and check the cooling system operation.
9. Check other factors for overheating:
   - Operation of the vehicle under heavy loads
   - Air conditioning system operation
   - High oil level
   - Restriction in airflow to the radiator
   - Extremely high ambient temperature

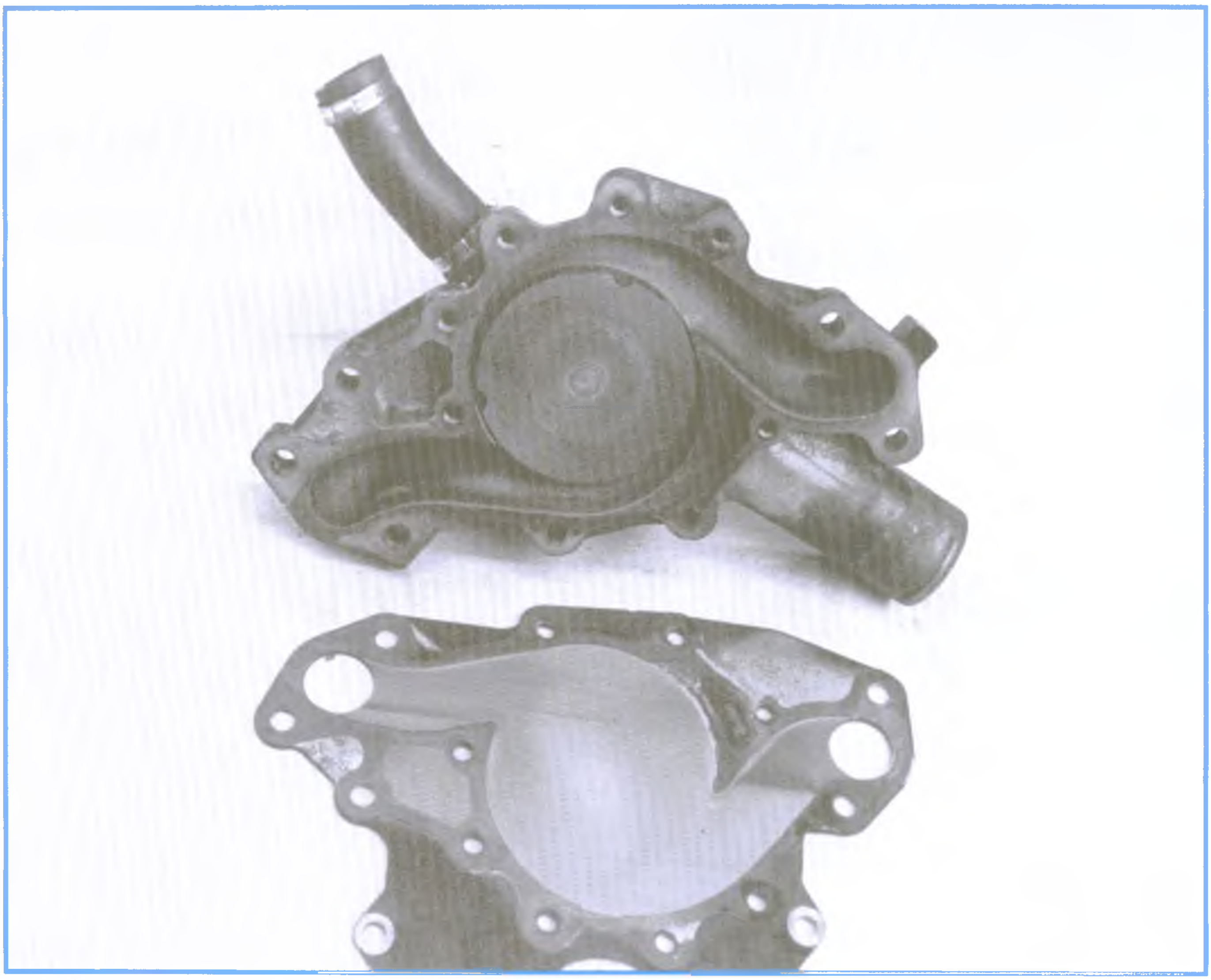


Figure 4-16, Water Pump Inspection

Cooling System Thermostat Diagnosis

1. Check for low opening temperature in the following steps:
   A. Remove the radiator cap (cool engine).
   B. Rub a 188° F (86.6° C) temperature crayon on the thermostat housing (see Figure 4-17). J-24731-
   C. Start and run the engine at a fast idle speed.
   D. Watch for coolant flow in the radiator before the temperature crayon begins to melt:
      - If coolant does not flow before the temperature crayon mark melts, check for other causes.
      - If coolant flows before the temperature crayon mark melts, replace the thermostat and check the cooling system operation.

2. Check for high opening temperature in the following steps:
   A. Remove the radiator cap (cool engine).
   B. Rub a 206° F (96.6° C) temperature crayon on the thermostat housing.
   C. Start and run the engine at a fast idle speed.
   D. Watch for coolant flow in the radiator before the temperature crayon begins to melt:
      - If coolant flows before the temperature crayon mark melts, check for other causes.
      - If coolant does not flow before the temperature crayon mark melts, replace the thermostat and check the cooling system operation.

Figure 4-17, Cooling System Thermostat Diagnosis

5. Accessory Drive System

Overview

The accessory drive system of the 6.5L V8 turbo diesel engine includes the parts shown in Figures 5-1 (this page) and 5-2 (next page).

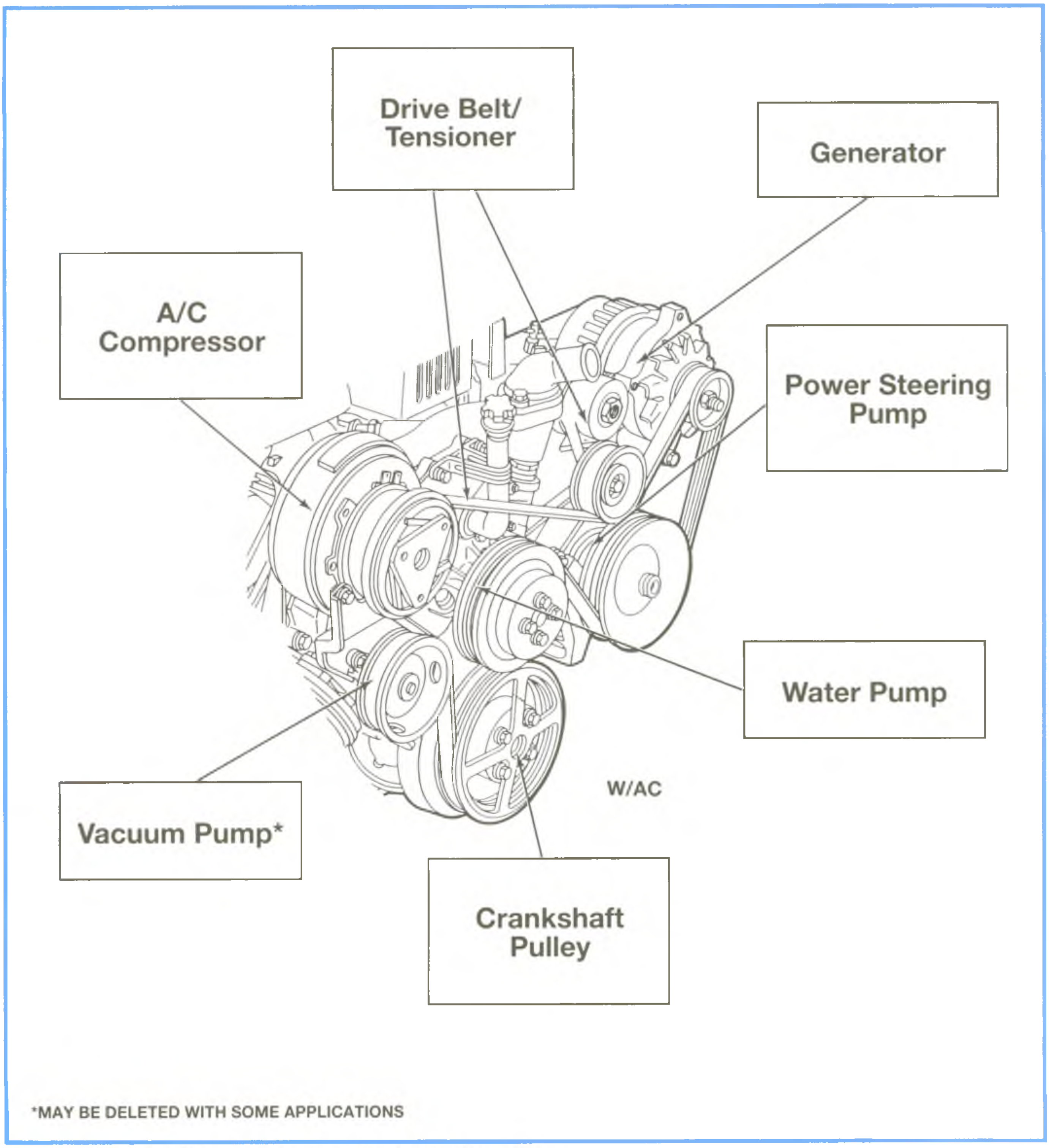


Figure 5-1, **Engine Accessory Drive System (1)**

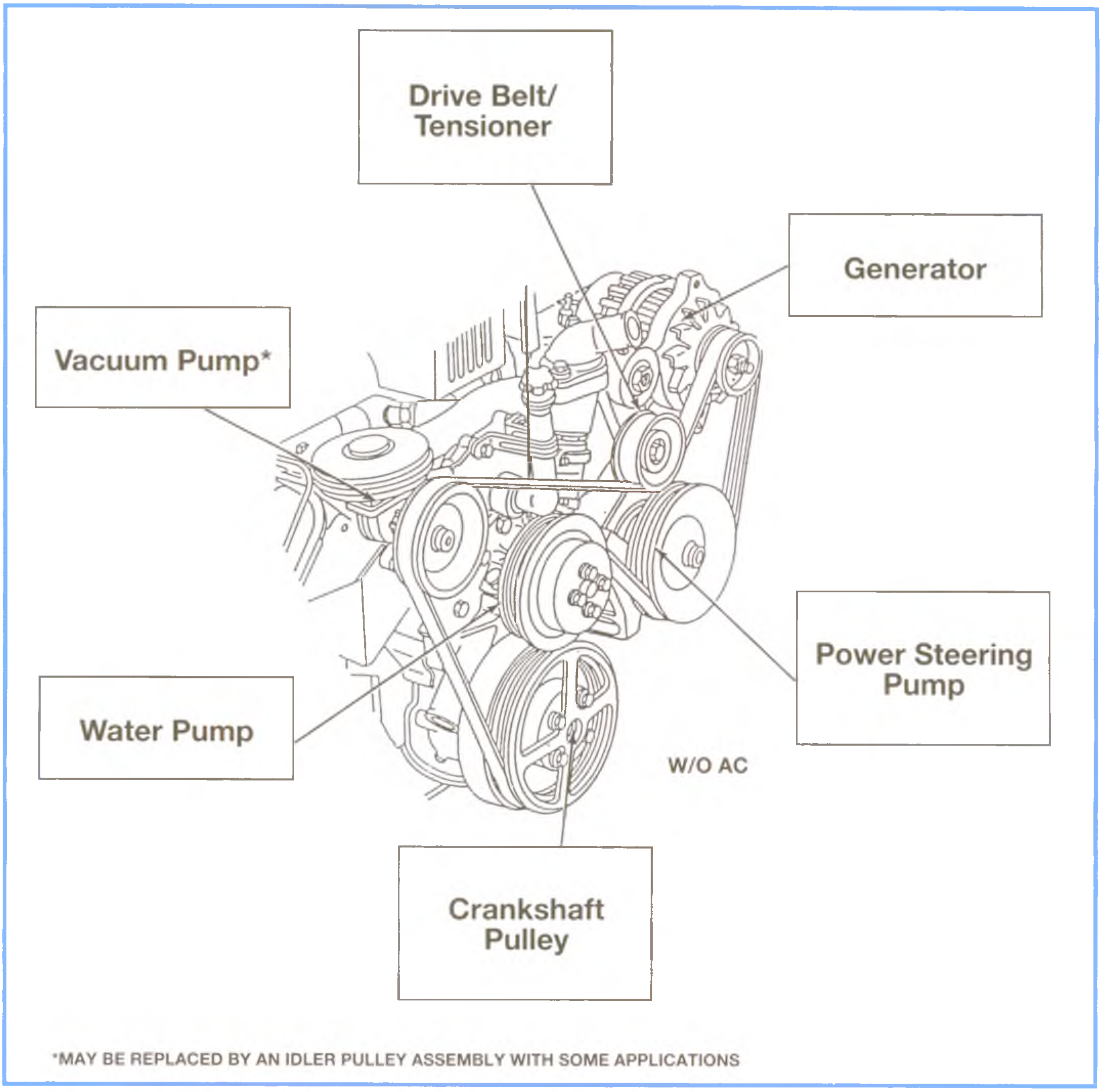


Figure 5-2, Engine Accessory Drive System (2)

Crankshaft Pulley Assembly

The crankshaft pulley assembly for the accessory drive system mounts on the torsional damper, using four bolts (refer to Figure 5-3). The pulley assembly has an inner hub (fastened to the crankshaft) and an outer pulley (connected to the inner hub with vulcanized rubber and ball bearing).

The ball bearing and rubber mounting allow the outer pulley to rotate slightly in relation to the inner hub. This occurs briefly when changes in crankshaft speed during acceleration and deceleration vary slightly with the rotating speed of the drive belt and its accessory loads.

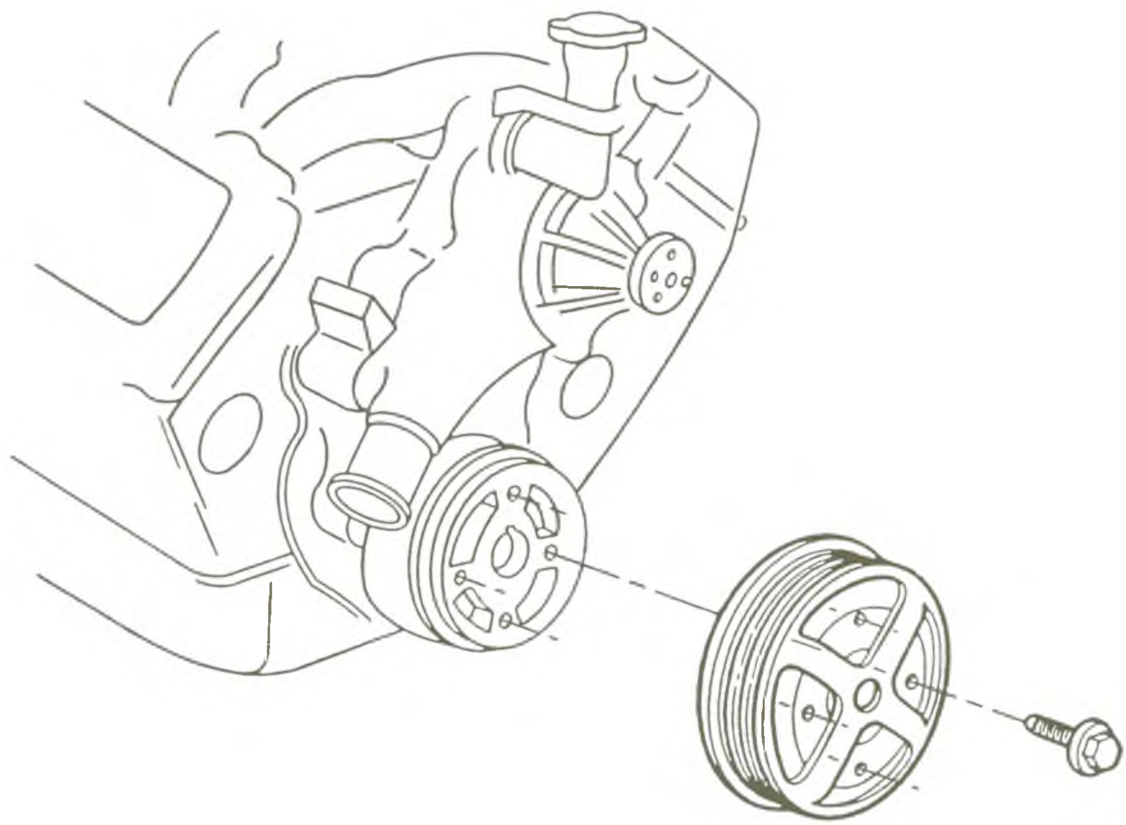


Figure 5-3, **Crankshaft Pulley Assembly**

Drive Belt and Tensioner

The crankshaft pulley assembly uses a drive belt that is flat on one side and has poly-V construction on the other side (refer to Figure 5-4). The path of the belt allows it to drive the water pump with its flat side and drive the power steering pump, generator and A/C compressor with its poly-V side. The vacuum pump is driven with either the flat side (with A/C) or poly-V side (without A/C).

The drive belt has a tensioner located on the accessory support mounted to the left cylinder head. The tensioner uses a spring to constantly apply force to the flat side of the drive belt, using a rotating idler pulley. For service purposes, the tensioner has a built-in gauge to indicate the amount of drive belt stretch and related tension.

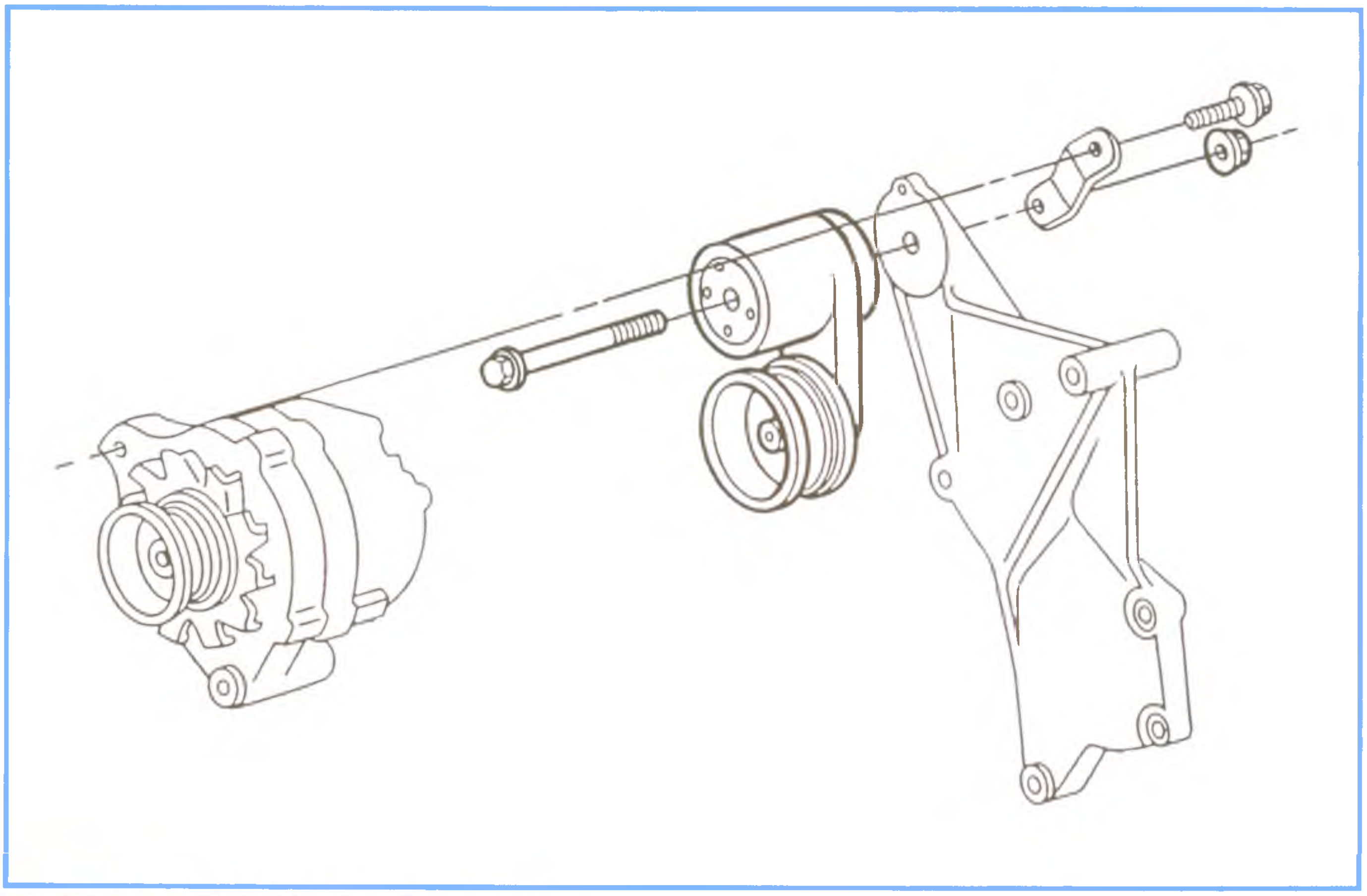


Figure 5-4, Drive Belt and Tensioner

Engine Accessories

Water Pump

The crankshaft rotates the water pump/cooling fan assembly in a counterclockwise direction, using the flat side of the drive belt (see Figure 5-5). The water pump assembly mounts on the engine front cover, and mounting studs on the water pump for the cooling fan assembly secure the driven pulley.

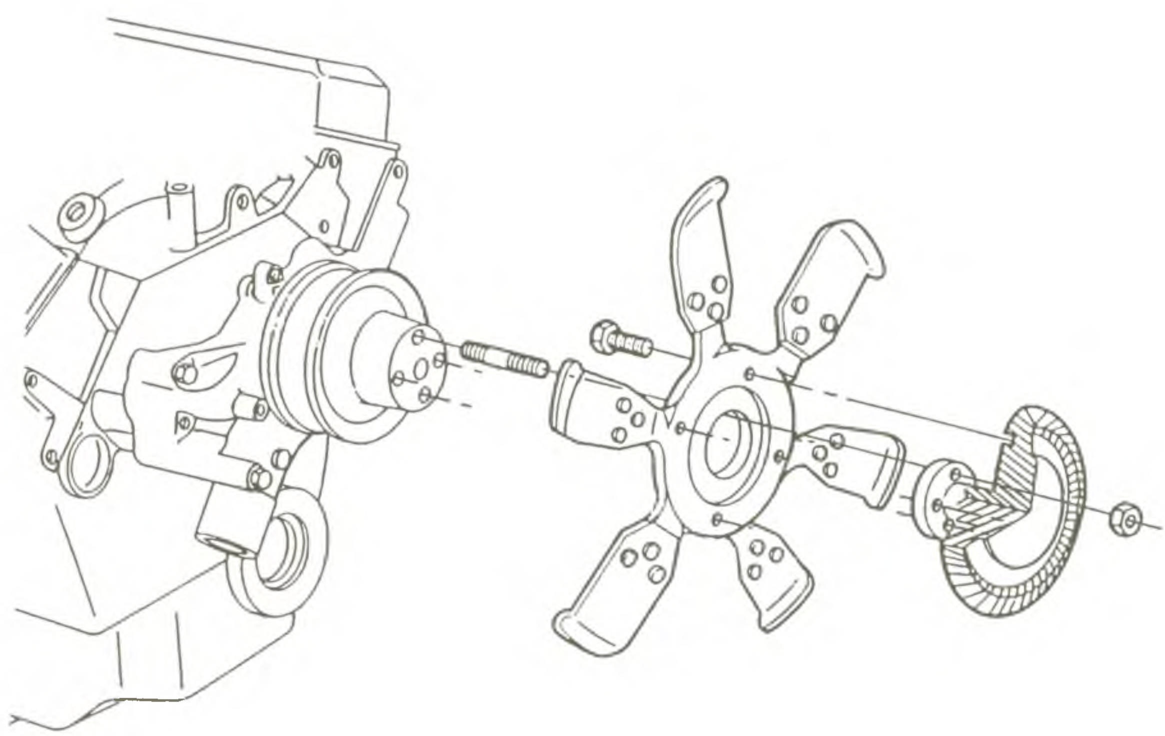


Figure 5-5, **Water Pump**

Power Steering Pump

The crankshaft rotates the shaft of the power steering pump in a clockwise direction, using the poly-V side of the drive belt. The power steering pump mounts on the lower part of the left cylinder head accessory support and has a brace that connects to both the cylinder case and front cover (see Figure 5-6).

The power steering pump uses a pulley that is pressed on its shaft. During replacement, a special tool is required to remove and install the pulley.

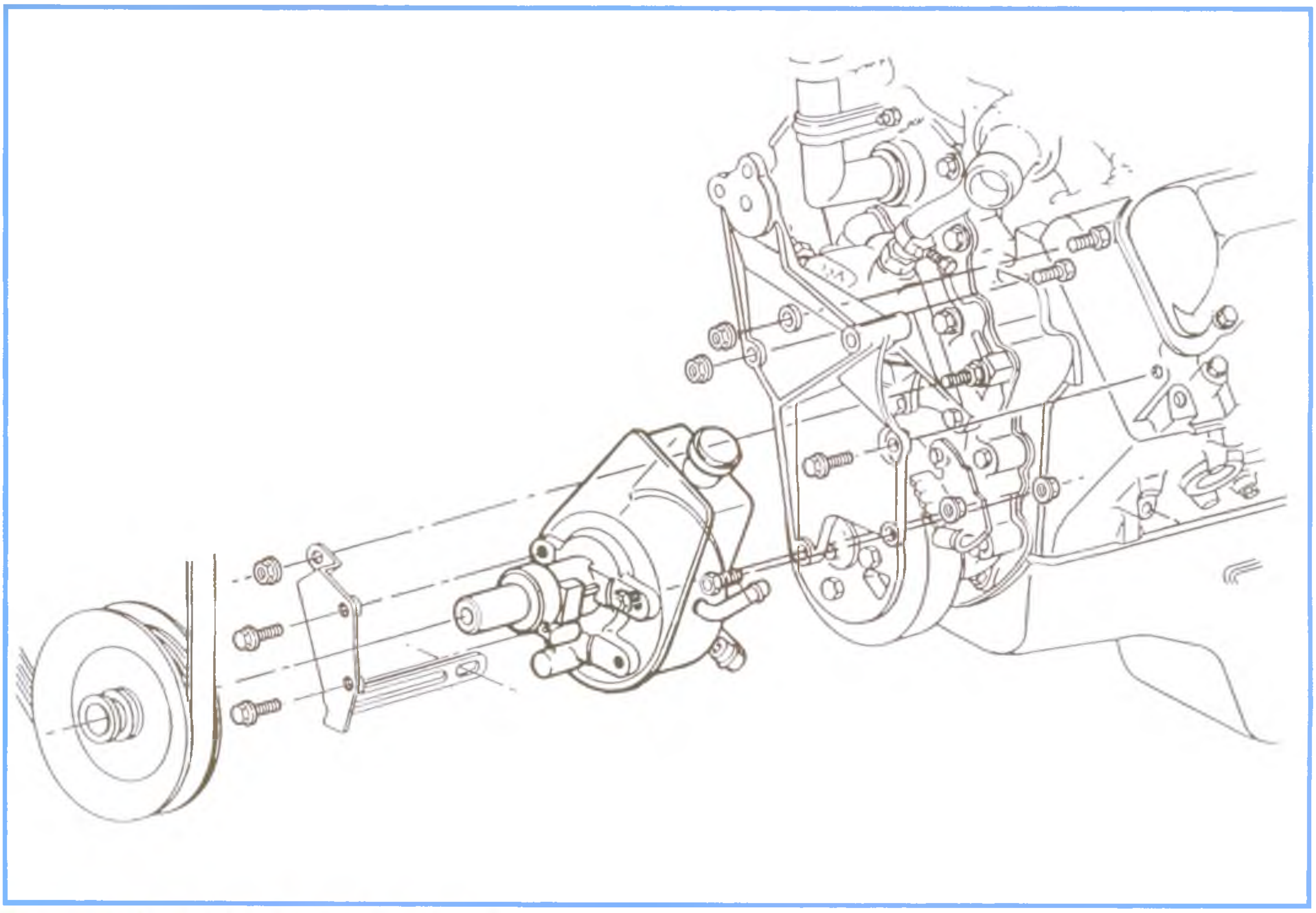


Figure 5-6, **Power Steering Pump**

Generator

The crankshaft rotates the rotor of the generator in a clockwise direction, using the poly-V side of the drive belt. The generator mounts on the upper part of the left cylinder head accessory support (see Figure 5-7). It has a rear brace that connects to the left cylinder head and an upper brace that connects to the front cover.

The generator uses a pulley that is secured by a large nut threaded on the front of the rotor. Disassembly of the generator is not required for the replacement of the pulley.

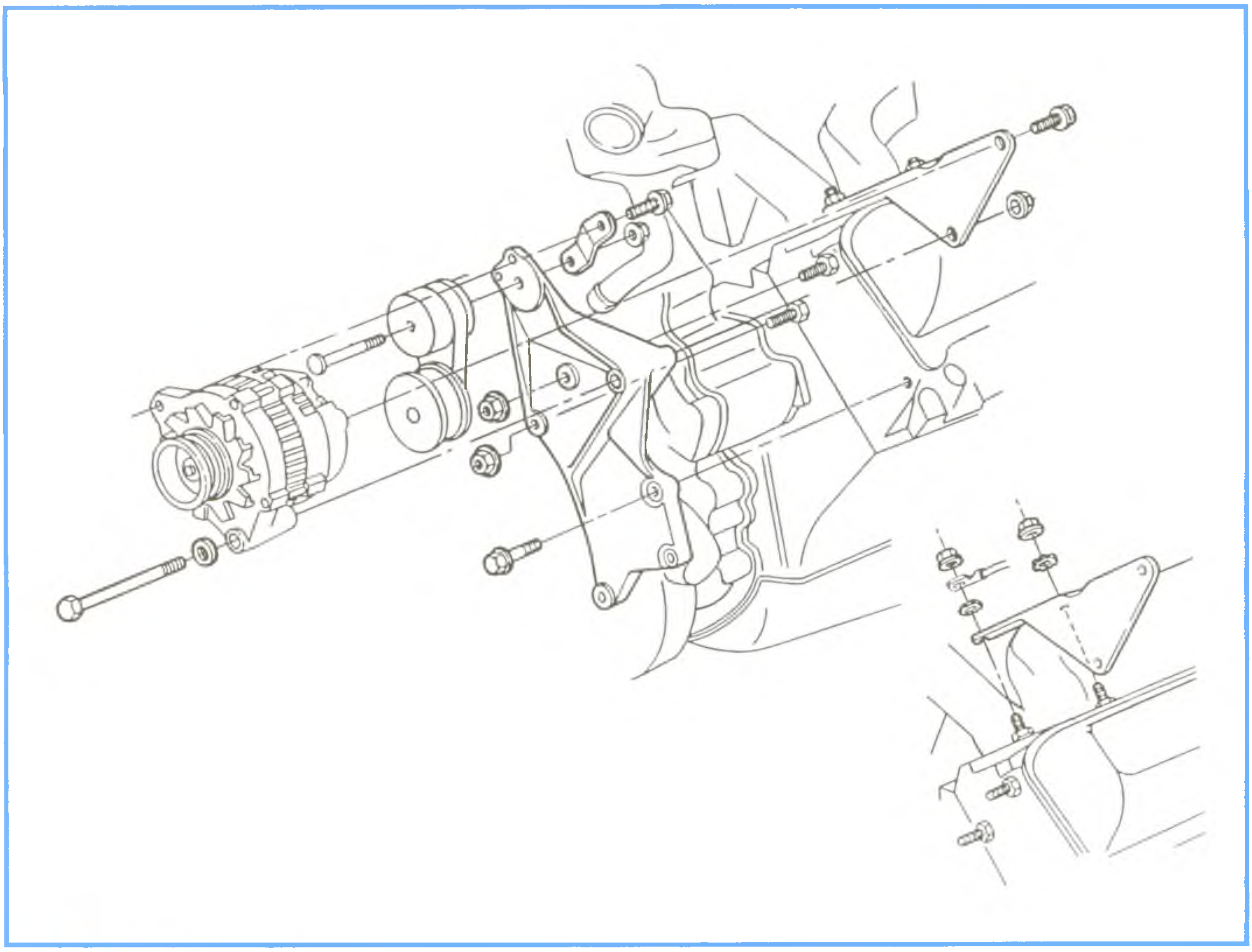


Figure 5-7, Generator

A/C Compressor

The crankshaft rotates the shaft of the A/C compressor in a clockwise direction, using the poly-V side of the drive belt. The A/C compressor mounts on a support bolted to the right cylinder head (see Figure 5-8). It has a front bracket that connects to the engine front cover.

The A/C compressor uses a pulley/bearing assembly that mounts on the compressor housing with a snap ring and press fit. Replacement of the pulley/bearing assembly requires special tools and the removal of the compressor shaft drive plate.

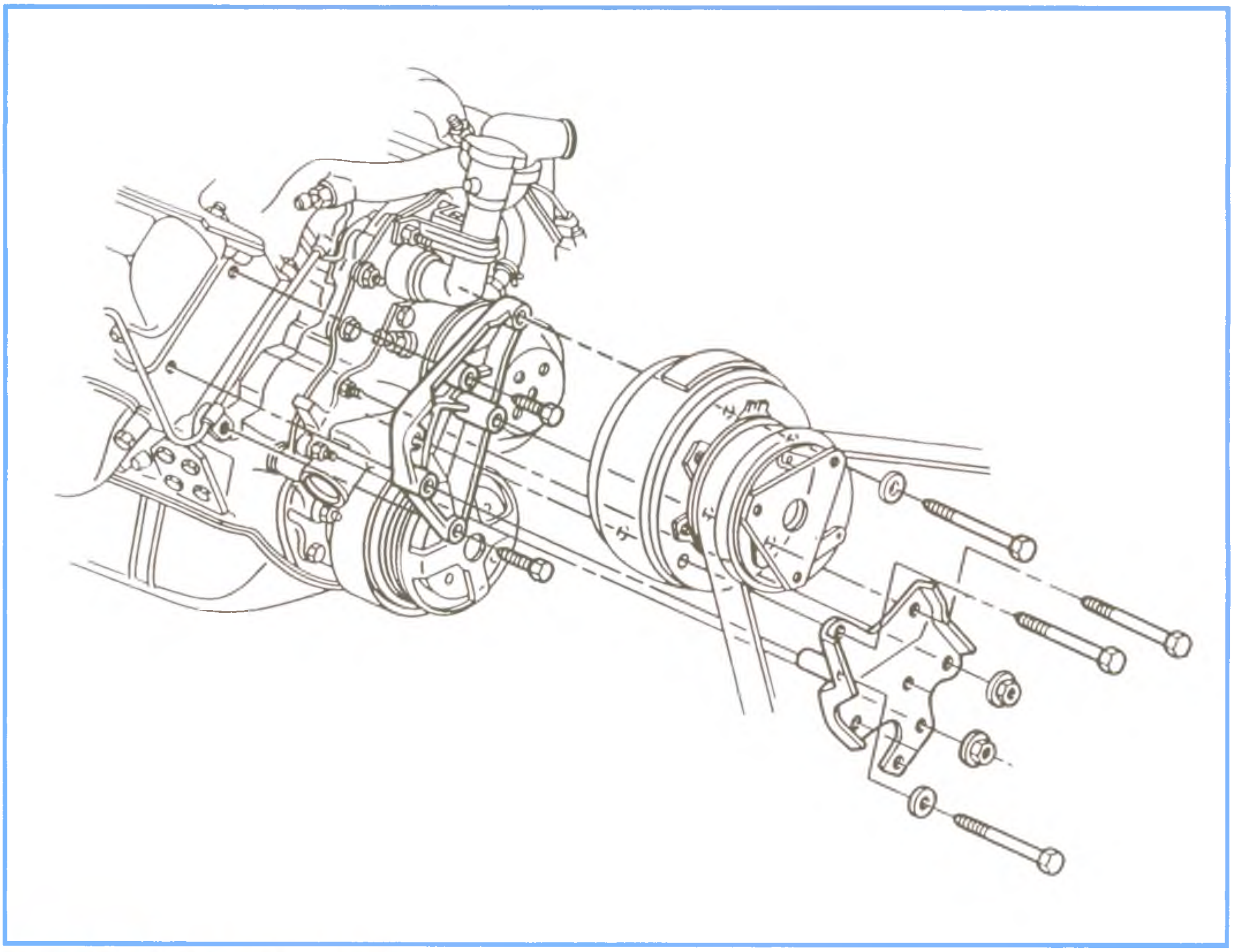


Figure 5-8, **A/C Compressor**

Vacuum Pump

When the vehicle is not equipped with A/C, the crankshaft rotates the shaft of a vacuum pump or idler pulley assembly in a clockwise direction, using the poly-V side of the drive belt. In this application, either a vacuum pump or idler pulley assembly mounts on a bracket bolted to the right cylinder head and front cover (refer to Figure 5-9).

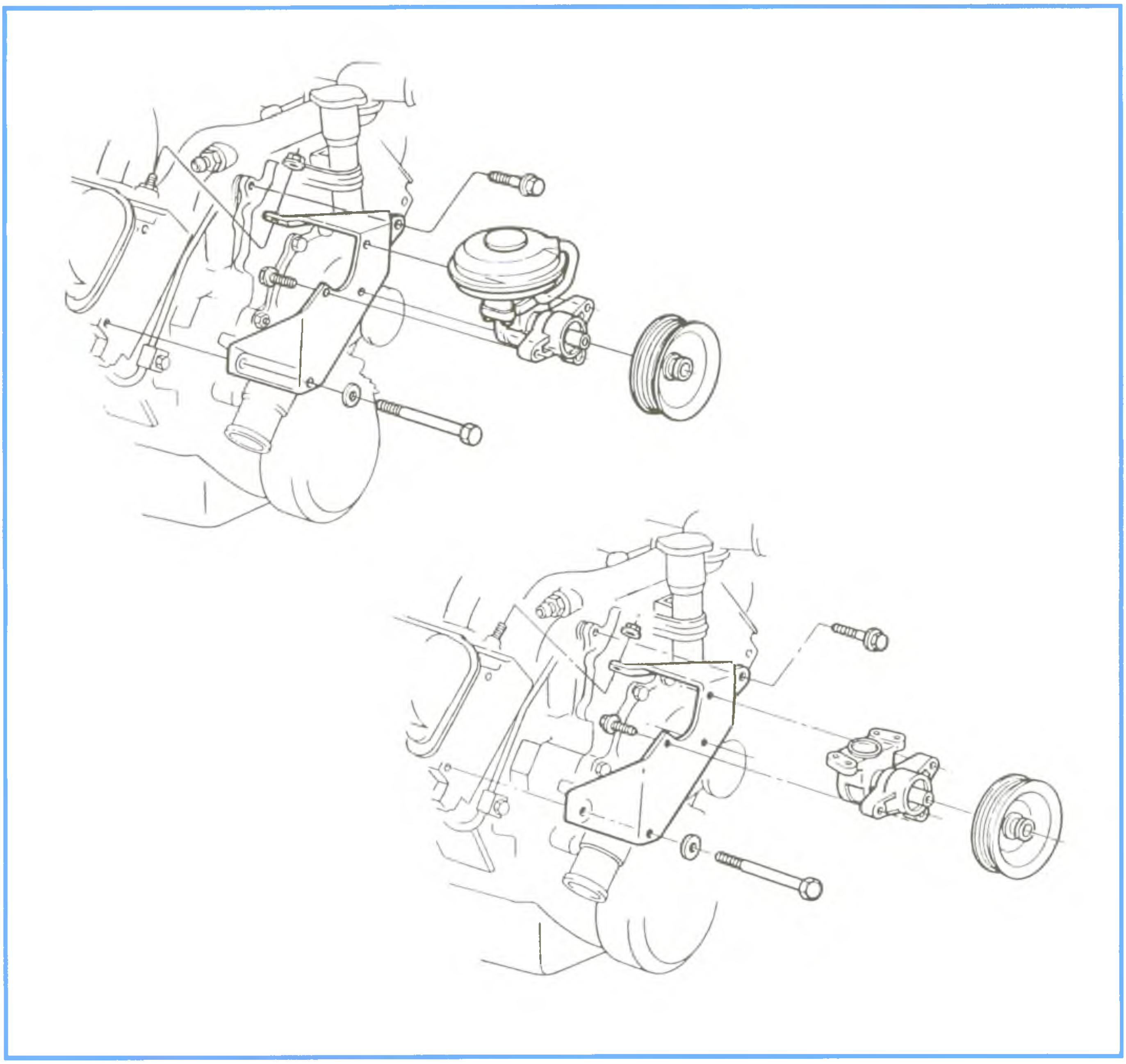


Figure 5-9, **Vacuum Pump (1)**

When the vehicle has A/C, the crankshaft rotates the shaft of a vacuum pump in a counterclockwise direction, using the flat side of the drive belt. In this application, a vacuum pump mounts on the front bracket supporting the A/C compressor, which is bolted to the engine front cover (refer to Figure 5-10). Some vehicle applications may delete the use of a vacuum pump.

Like the power steering pump, the vacuum pump uses a pulley that is pressed on its shaft. During replacement, a special tool is required to remove and install the pulley.

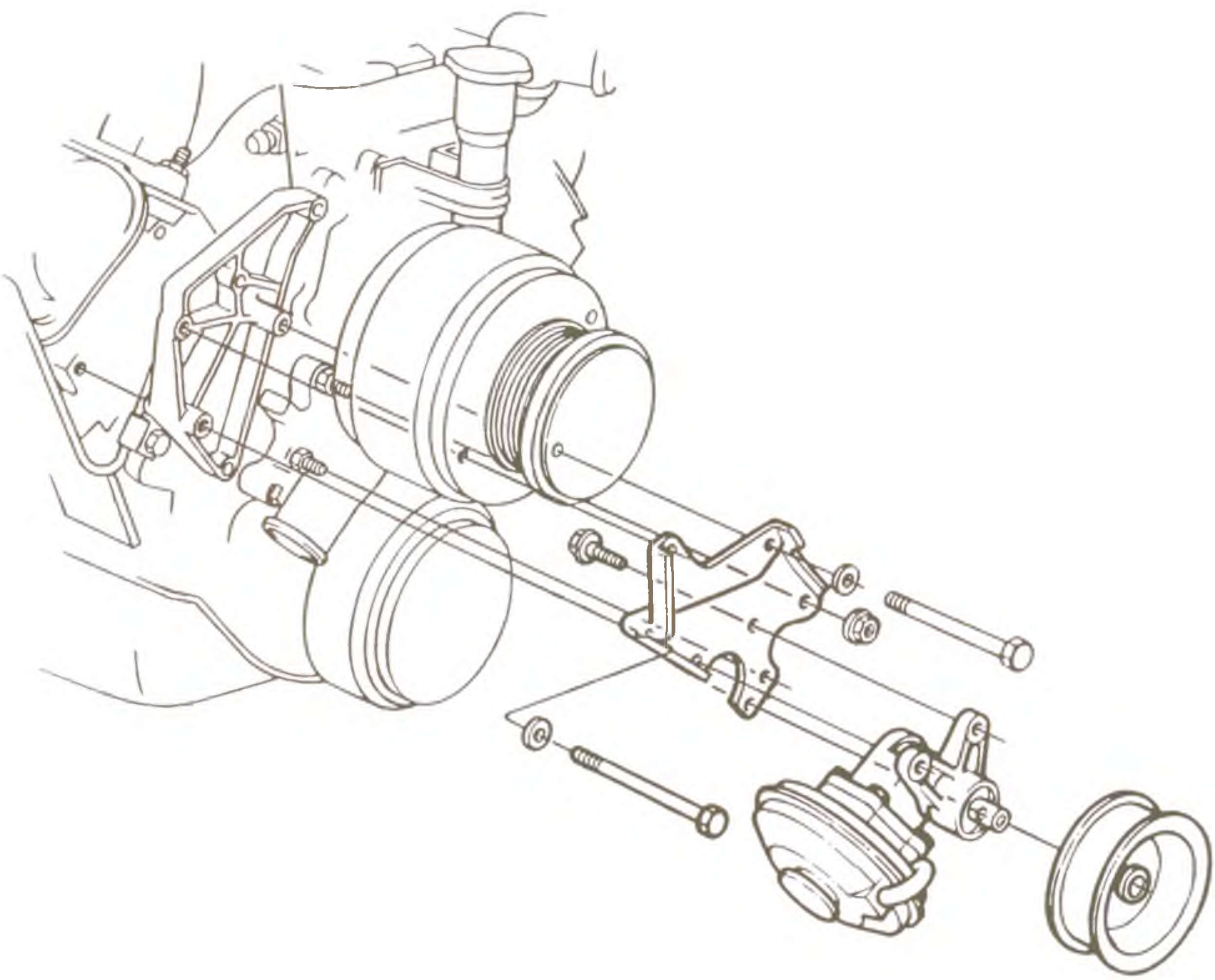


Figure 5-10, Vacuum Pump (2)

Related Diagnosis/Service Procedures

Drive Belt Diagnosis

1. Observe the operation of the drive belt:
   - If the belt has wear or faulty operation, go to step 2.
   - If the belt makes excessive noise, go to step 3.

2. Check the drive belt system for faulty operation in the following steps:
   A. Observe if the drive belt stays aligned with the pulleys during engine operation (see Figure 5-11):
      - If the drive belt stays aligned with the pulleys, go to step B.
      - If the drive belt becomes misaligned, check for the following conditions and make necessary repairs:
        - Misaligned crankshaft or accessory pulleys
        - Mispositioned or loose accessory support brackets
        - Belt damage
        - Faulty tensioner
        - Worn idler or tensioner pulley bearings

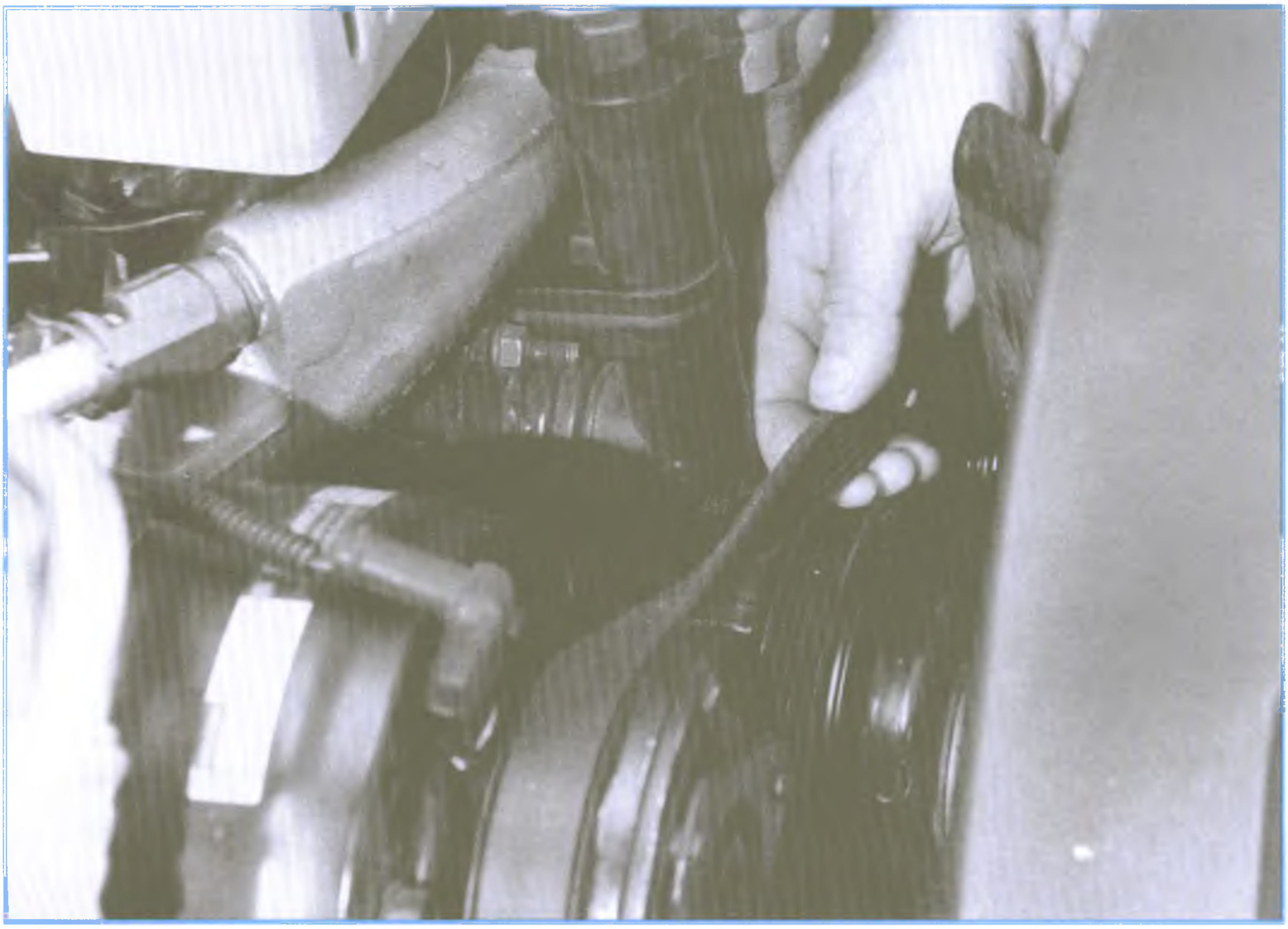


Figure 5-11, Drive Belt System Inspection

B. Observe if the drive belt system causes excessive vibration during engine operation:
- If excessive vibration does not exist, go to step C.
- If excessive vibration exists, check for the following conditions and make necessary repairs:
  - Bent or cracked pulleys
  - Cracked, mispositioned or loose accessory support brackets
  - Damaged cooling fan blades
  - Worn or damaged water pump or cooling fan clutch

C. Check the drive belt for pilling (a random accumulation of rubber dust in the pulley grooves):
- If pilling fills the pulley grooves to a depth of less than 1/3, consider the amount of wear as normal and go to step D.
- If pilling fills the pulley grooves to a depth of more than 1/3, check the operation of the drive belt tensioner.

D. Check the drive belt for excessive wear on either outside rib:
- If no excessive wear exists, check the drive belt system for noisy operation.
- If excessive wear exists, replace the drive belt and check the match of the belt ribs to the pulley grooves.

3. Check the drive belt system for noisy operation in the following steps:

A. Listen for chirping (a high-pitched noise usually heard once per revolution of the belt or pulley):
- If no chirping noise exists, go to step B.
- If a chirping noise exists, check for the following conditions and make necessary repairs:
  - Misaligned crankshaft or accessory pulleys
  - Bent or cracked pulleys
  - Mispositioned or loose accessory support brackets
  - Belt damage

B. Listen for squealing (a loud screeching noise that is usually caused by a slipping belt, especially when the accessory load on the belt changes):
- If no squealing noise exists, go to step C.
- If a squealing noise exists, check for the following conditions and make necessary repairs:
  - Seizing bearings in accessory components
  - Low drive belt tension
  - Excessive belt length (stretch)

C. Listen for whining (a high-pitched noise that is continuous):
- If no whining noise exists, go to step D.
- If a whining noise exists, check for the following conditions and make necessary repairs:
  - Worn bearings in accessory components
  - Bearing wear in the tensioner pulley or idler pulley

D. Listen for a faint, cycling, rumbling noise:
- If no noise is present, the drive belt system is working correctly.
- If the noise is present, clean pilling accumulation from pulley grooves and replace the drive belt.

6. Air Induction/Exhaust Systems

Overview

The air induction and exhaust systems of the 6.5L V8 turbo diesel engine include the following parts (refer to Figure 6-1):

- Outside air intake duct and air filter assembly
- Turbocharger assembly
- Air inlet duct
- Crankcase ventilation system
- Exhaust pipes and muffler

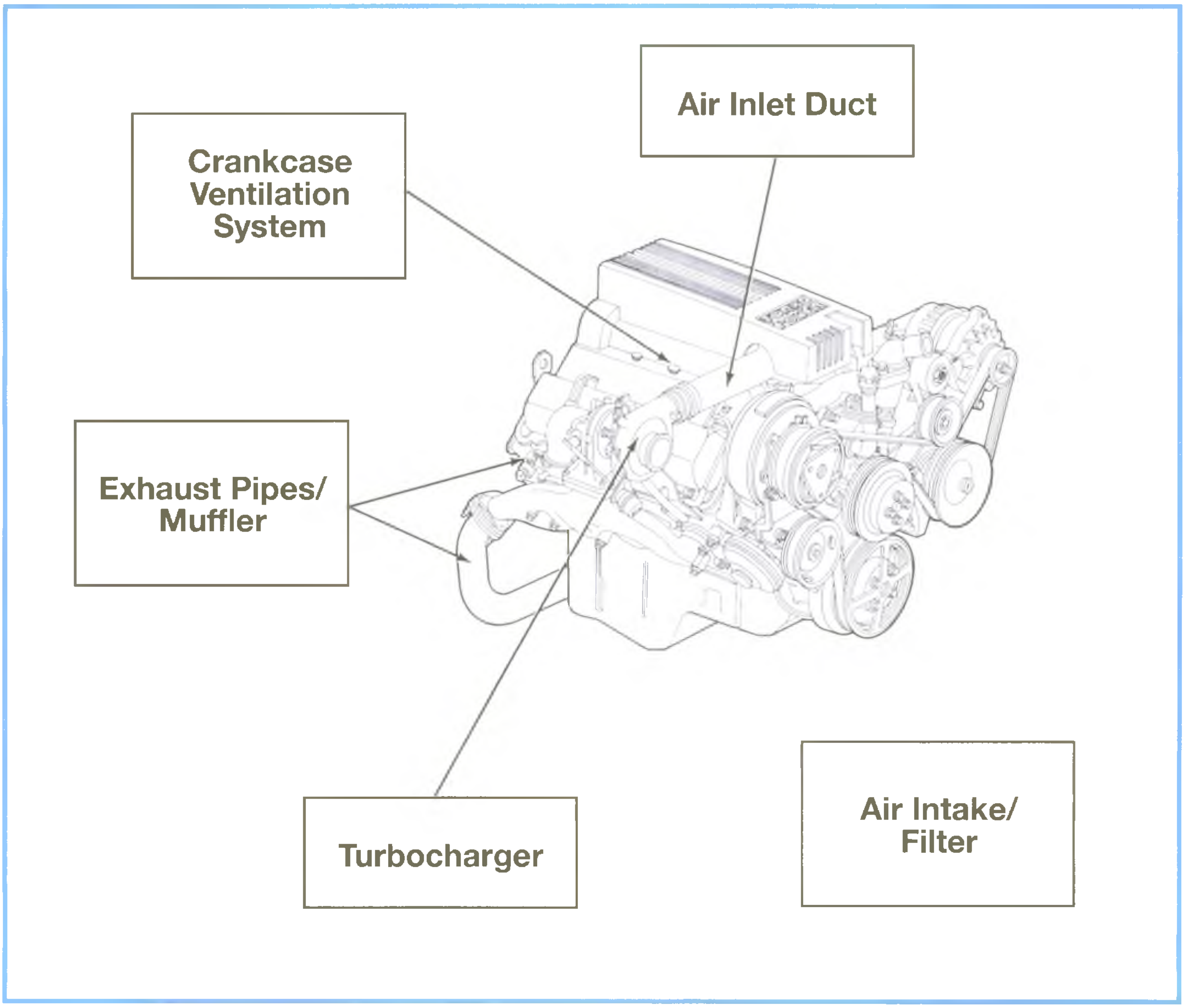


Figure 6-1, **Air Induction and Exhaust System Parts**

Outside Air Intake Duct and Air Filter Assembly

Outside air enters the induction system at a duct located between the right front inner and outer fenders (refer to Figure 6-2). It flows into the air filter assembly, which contains a replaceable filter element located inside a two-piece housing made of composite material. The air filter housing mounts to the right inner fender with a bracket and bolts. It has a moisture drain positioned on its bottom side.

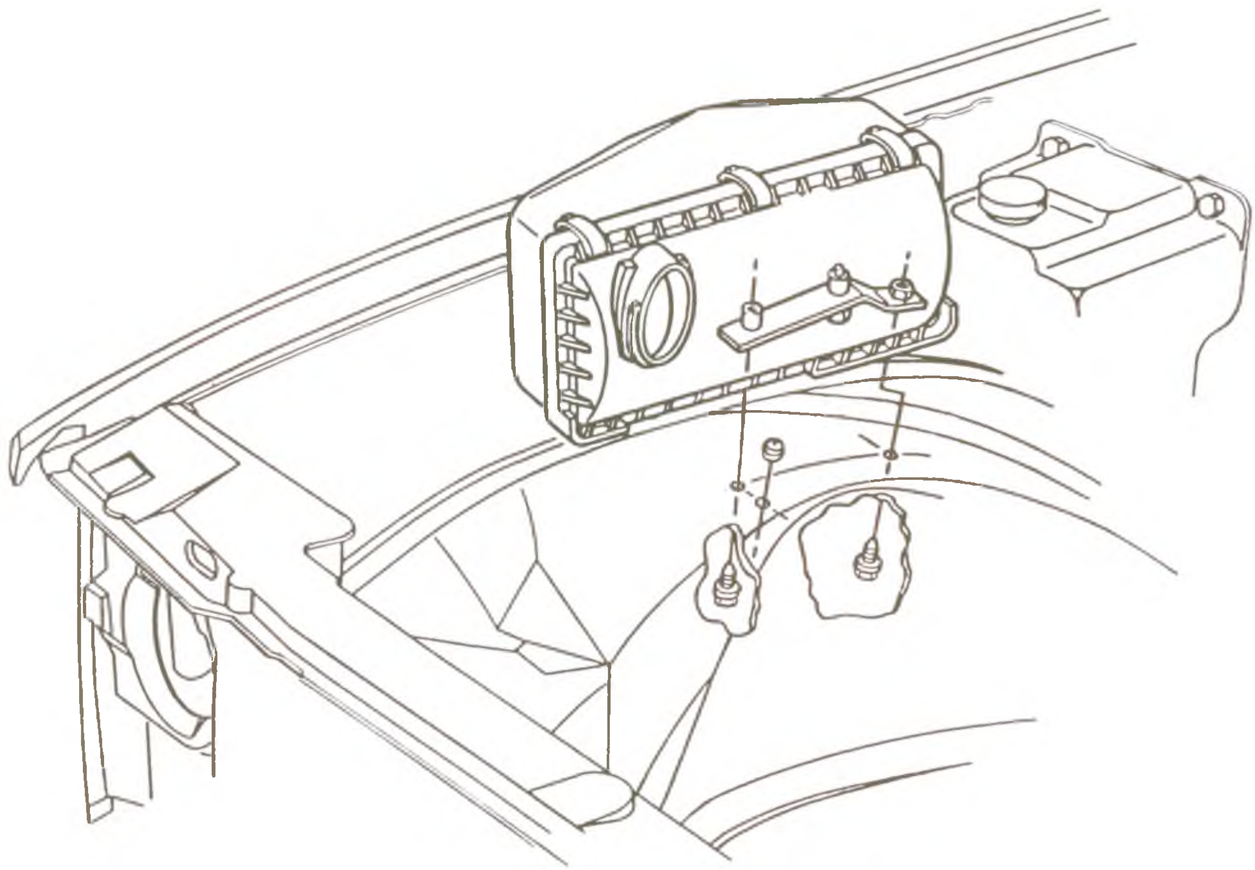


Figure 6-2, **Air Filter Assembly**

The outlet of the air filter connects to the turbocharger inlet with a reinforced flexible duct, using screw-type clamps (see Figure 6-3). The sealing of this duct is very important in protecting the turbocharger compressor wheel from damage by unfiltered particles.

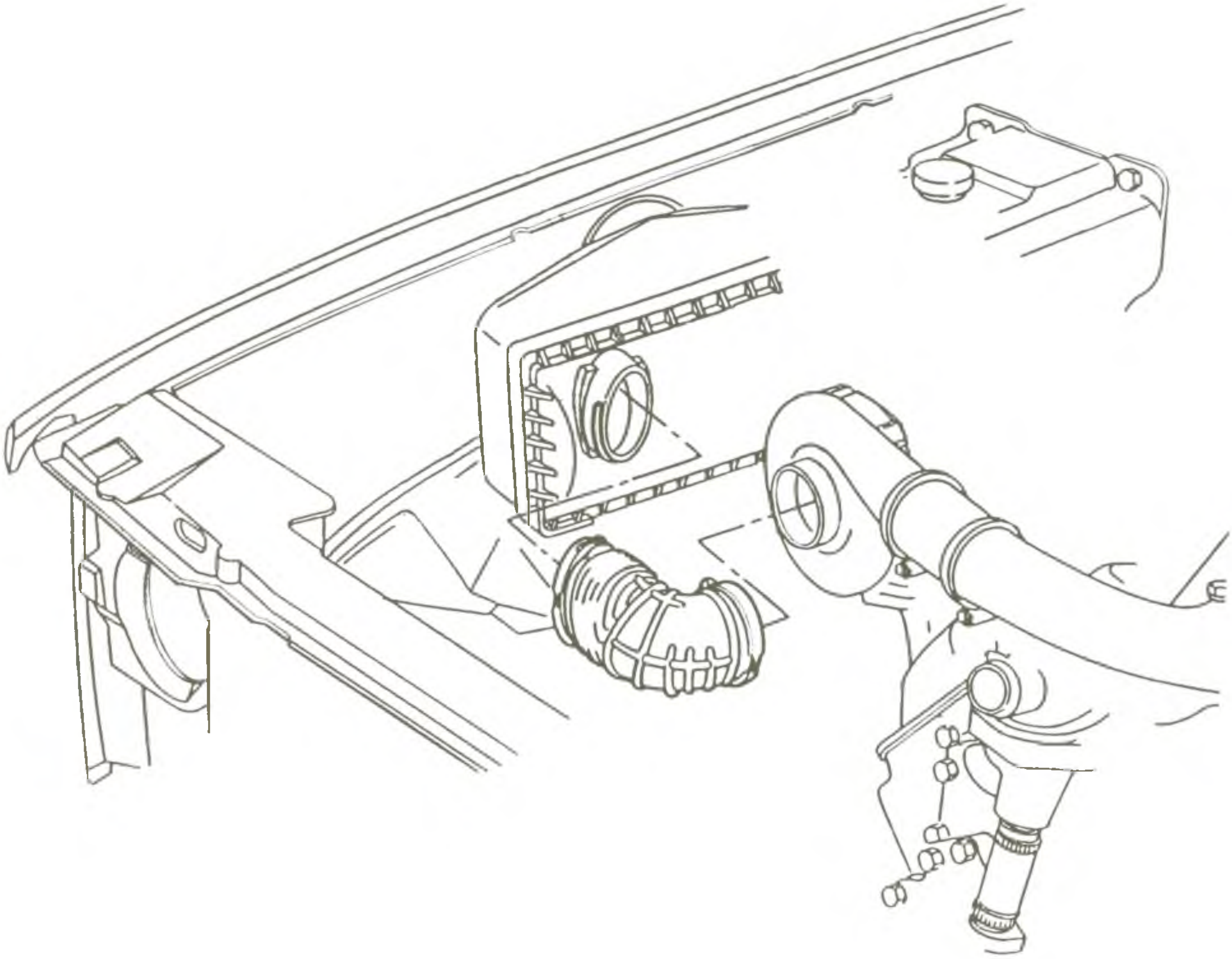
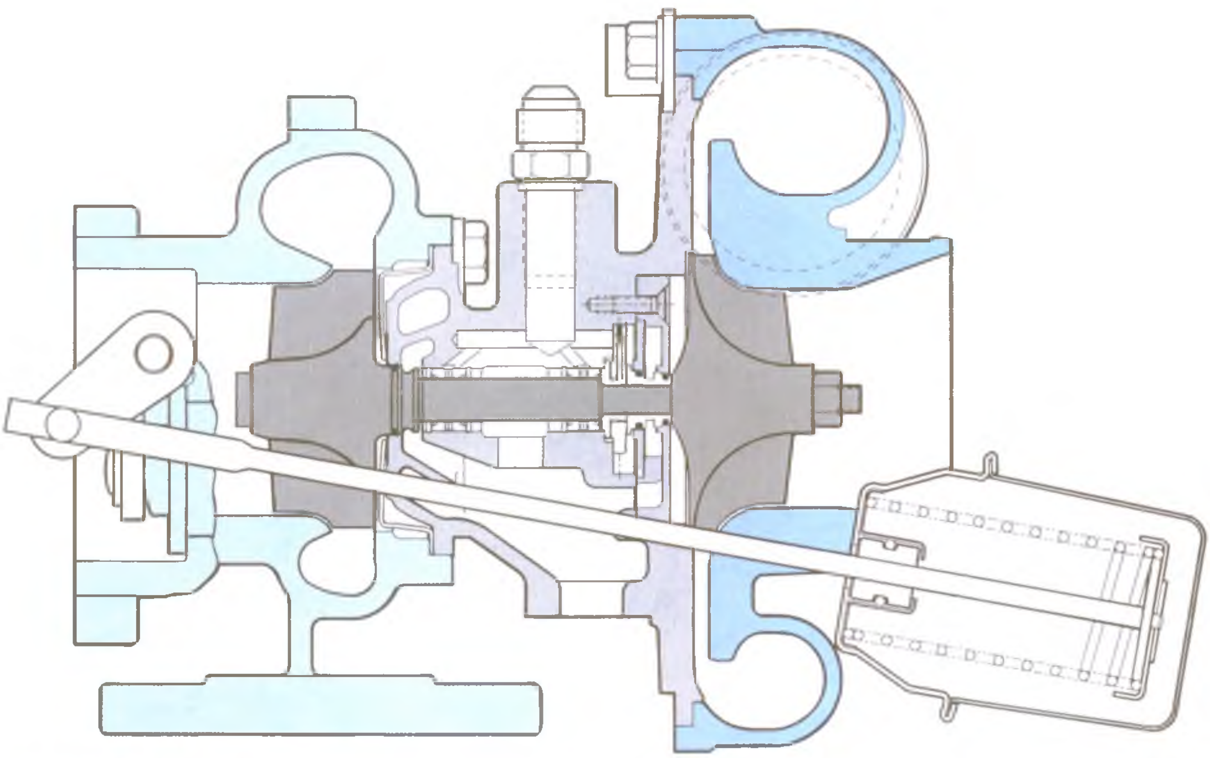


Figure 6-3, Turbocharger Inlet Duct

Turbocharger Assembly

Basic Construction and Operation

The turbocharger assembly has a turbine housing, a compressor housing and a bearing housing (refer to Figure 6-4). A turbine wheel/shaft connects to a compressor wheel, and the assembly rotates inside the housings.



TURBINE HOUSING
BEARING HOUSING
COMPRESSOR HOUSING
TURBINE WHEEL/SHAFT AND COMPRESSOR WHEEL

Figure 6-4, Turbocharger Major Components

Basic turbocharger operation starts with exhaust gases entering the turbine housing, causing the turbine wheel/shaft to rotate (see Figure 6-5). As the exhaust gases spin the turbine wheel/shaft, the compressor wheel spins. The action of the compressor wheel increases the pressure and flow of the air intake charge and is dependent on exhaust gas flow.

The power of the engine provides exhaust gas pressure needed to take air under atmospheric pressure and provide air under boost pressure in the engine intake manifold. Since exhaust gas pressure varies with engine speed, the amount of boost also varies.

15,000 - 80,000 rpm

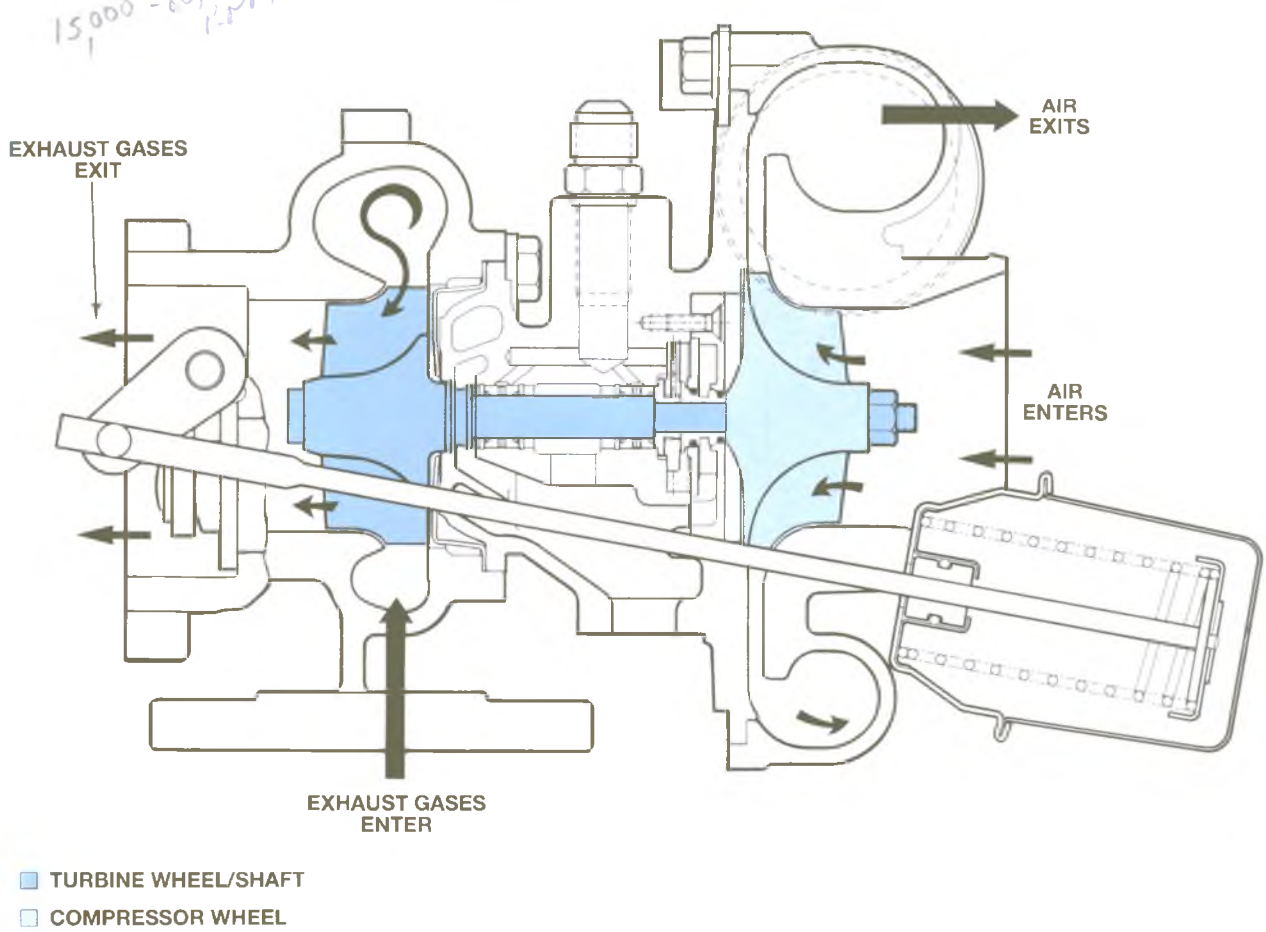


Figure 6-5, **Basic Turbocharger Operation**

Turbocharger Mounting

The engine supports the turbocharger, using the right exhaust manifold, and studs and nuts secure it (see Figure 6-6). Exhaust gases from both the left and right cylinder heads flow into the turbine housing and the gases exit the turbine housing into the exhaust pipe and muffler.

The compressor housing of the turbocharger has an inlet connected to the air filter assembly. All intake air to the engine flows into and out of the compressor housing.

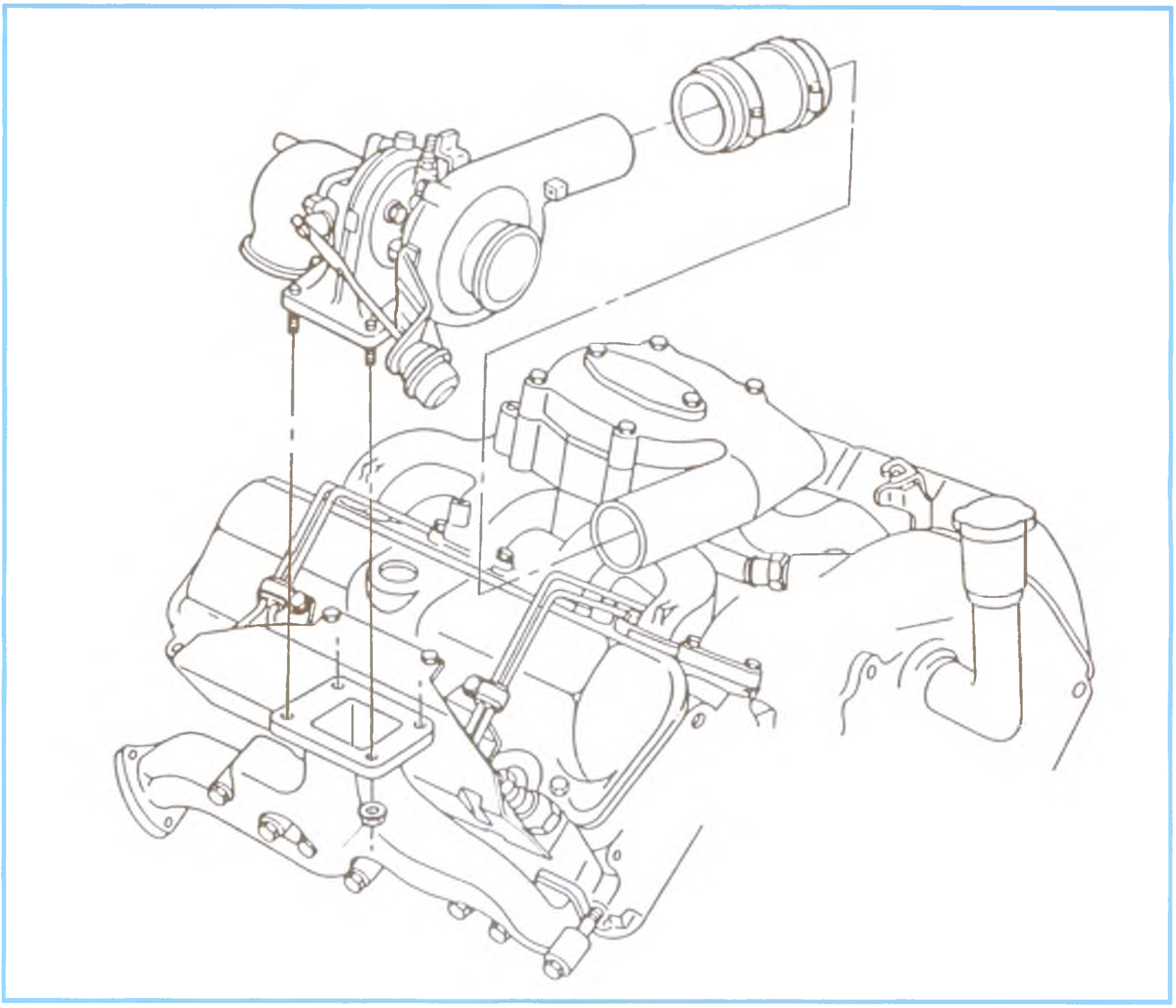


Figure 6-6, **Turbocharger Exhaust System Mounting**

The turbocharger bearing housing has an oil inlet connected to a supply hose from the engine lubrication system (see Figure 6-7). The oil outlet from the bearing housing has a pipe/hose connecting it to the crankcase part of the cylinder case (see page 3-11 for more information).

A shield mounted on a bracket at the right rocker cover prevents heat produced by the turbocharger from affecting the operation of the fuel injection nozzles for cylinders #4 and #6. The heat shield is secured by slot alignment and two bolts.

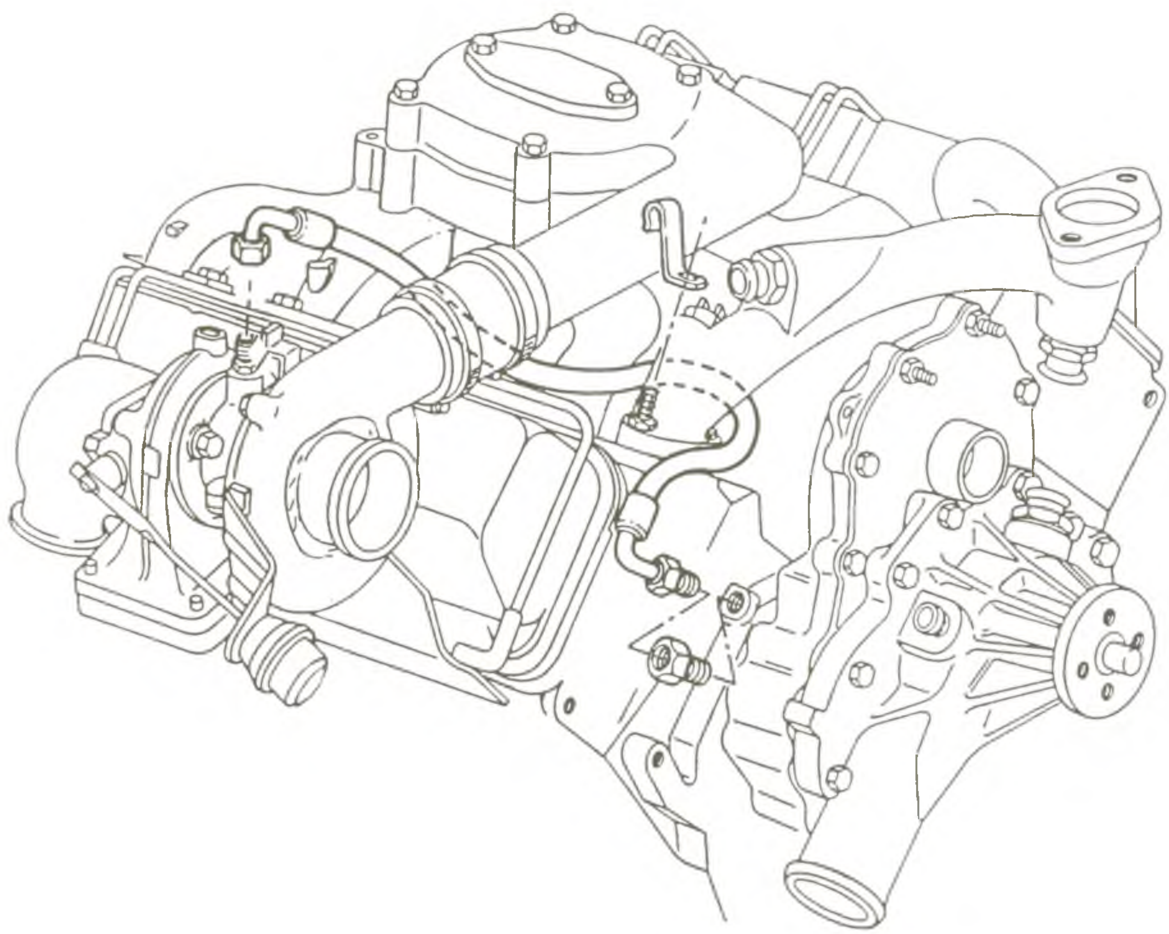


Figure 6-7, **Turbocharger Oil Supply Hose**

Turbocharger Lubrication

Oil entering the bearing housing of the turbocharger travels to two sleeve-type bearings (refer to Figure 6-8). The bearings have clearance in the housing and float in oil during turbocharger operation. The turbine wheel/shaft also floats in oil between it and the bearings.

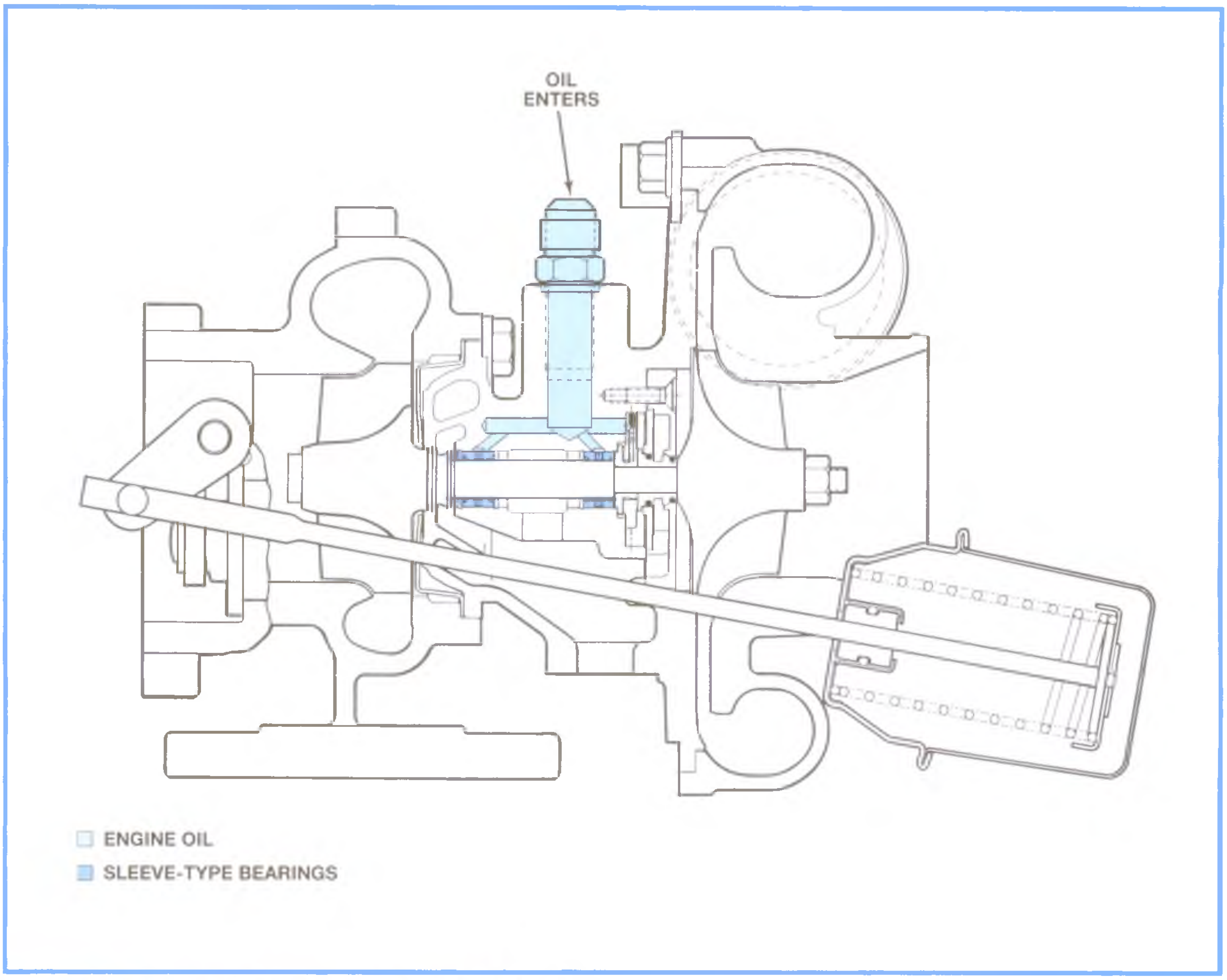


Figure 6-8, Turbocharger Lubrication (1)

As oil moves past the bearings and shaft, it travels in a special passage inside the bearing housing near the turbine wheel to cool nearby parts (see Figure 6-9). The oil then exits the bearing housing at an outlet port and travels to the crankcase part of the cylinder case through a drain pipe/hose.

A shield between the turbine and bearing housings reduces the transfer of heat to the lubricating oil. The use of the special cooling passage and heat shield greatly reduces the possibility of oil in the turbocharger overheating and forming carbon deposits (known as coking). No special turbocharger cool-down procedure to prevent coking is required after running the engine.

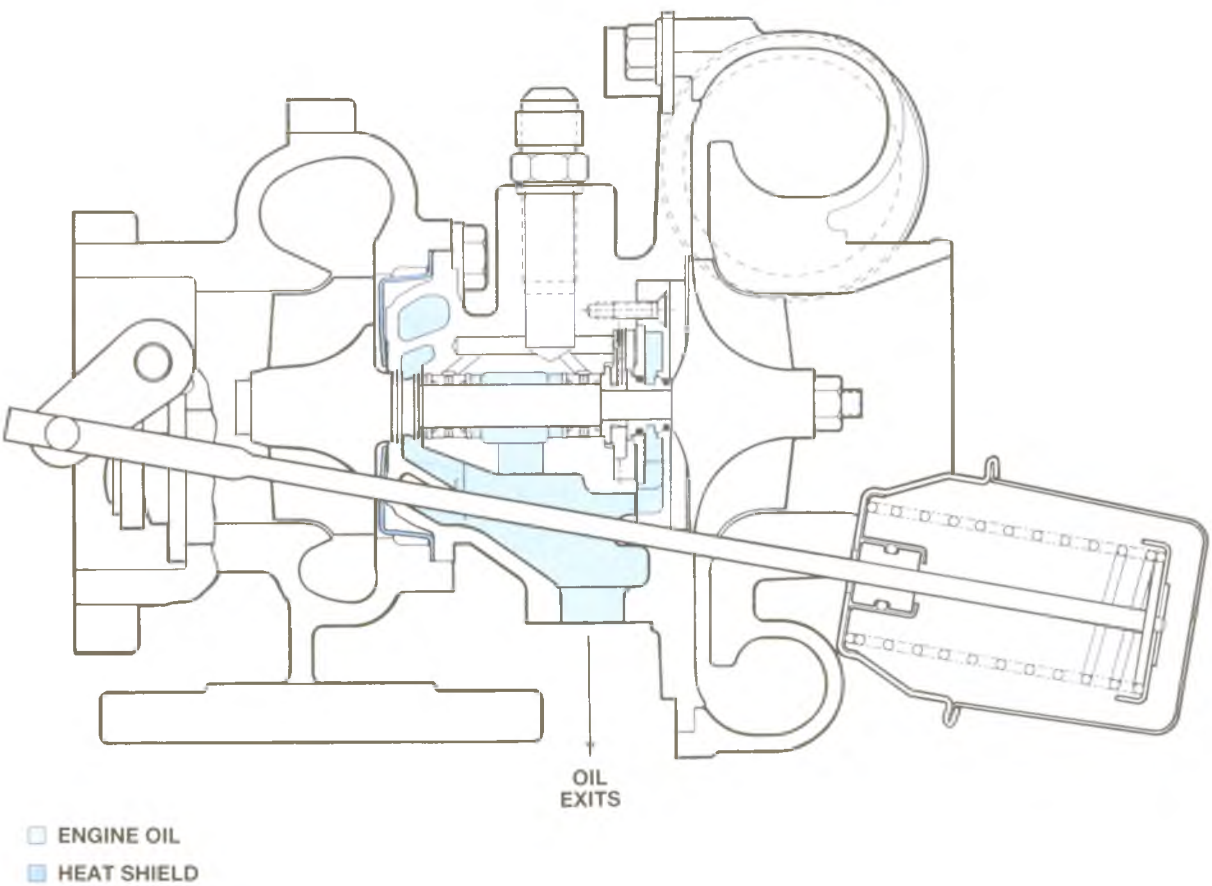


Figure 6-9, **Turbocharger Lubrication (2)**

Turbocharger Bearings and Seals

The sleeve-type bearing at the turbine wheel end of the bearing housing has two retaining rings to keep it in position (refer to Figure 6-10). The sleeve-type bearing at the compressor wheel end of the bearing housing is positioned by a retaining ring and the thrust bushing.

The turbocharger uses a thrust bushing and bearing at the compressor wheel end of the turbine wheel/shaft to control end-play.

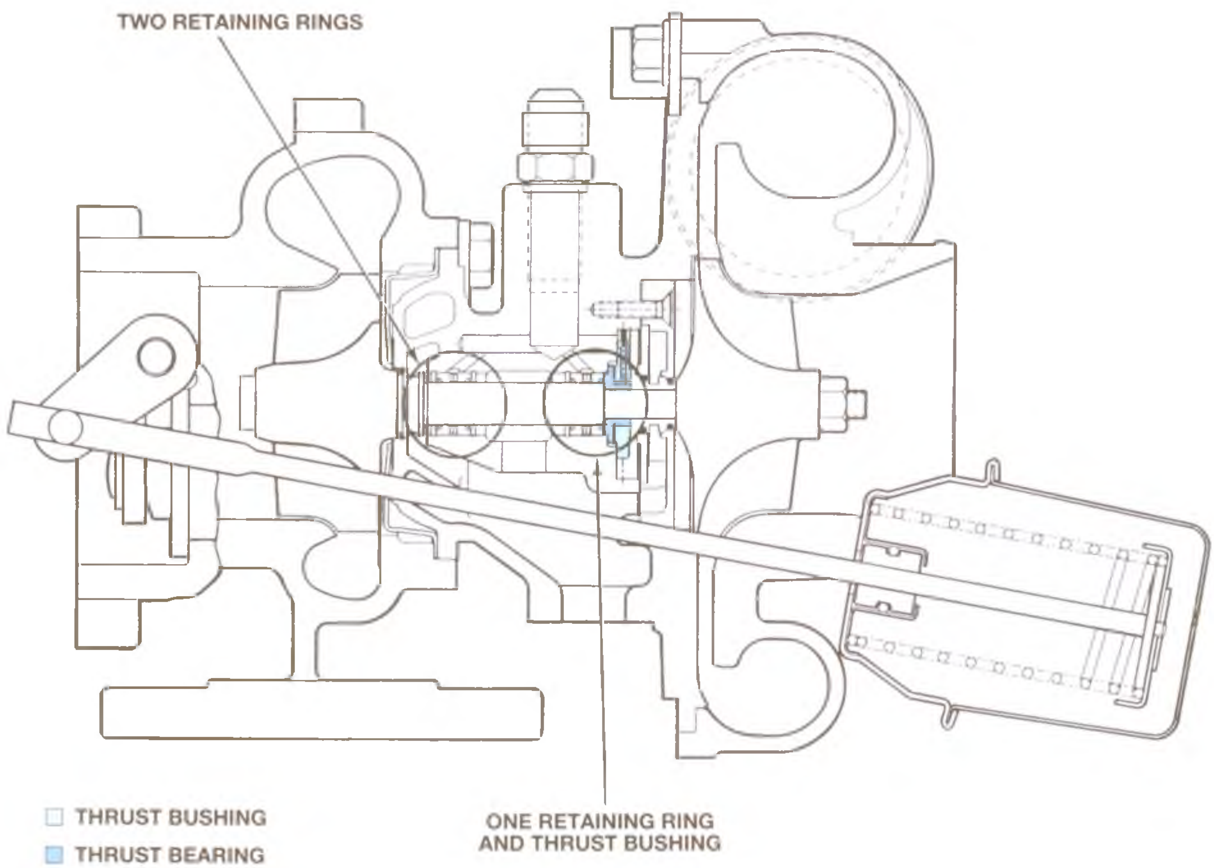


Figure 6-10, Turbocharger Bearings

Two metal seal rings on the turbine wheel/shaft contact a seal plate assembly to prevent oil from entering the compressor housing (see Figure 6-11). One metal seal ring on the other end of the turbine wheel/shaft contacts the bearing housing bore to prevent oil from entering the turbine housing.

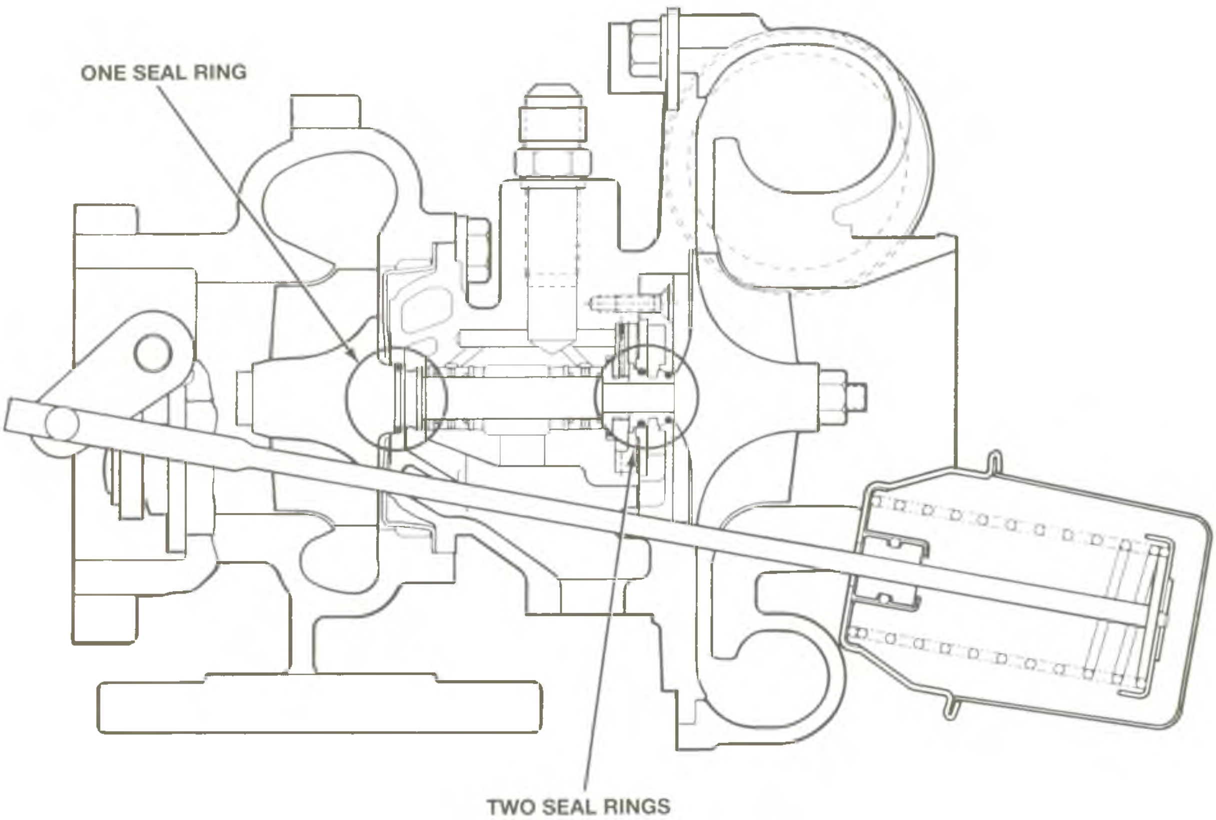


Figure 6-11, **Turbocharger Seals**

Turbocharger Wastegate Valve and Actuator Assembly

The turbocharger turbine housing has a mechanically operated wastegate valve that allows exhaust gases to bypass the turbine wheel and directly enter the exhaust pipe/muffler (see Figure 6-12). The wastegate valve operates at higher exhaust gas pressures to limit engine power. It acts like a turbine wheel speed governor to limit the maximum amount of boost pressure to 5 psi.

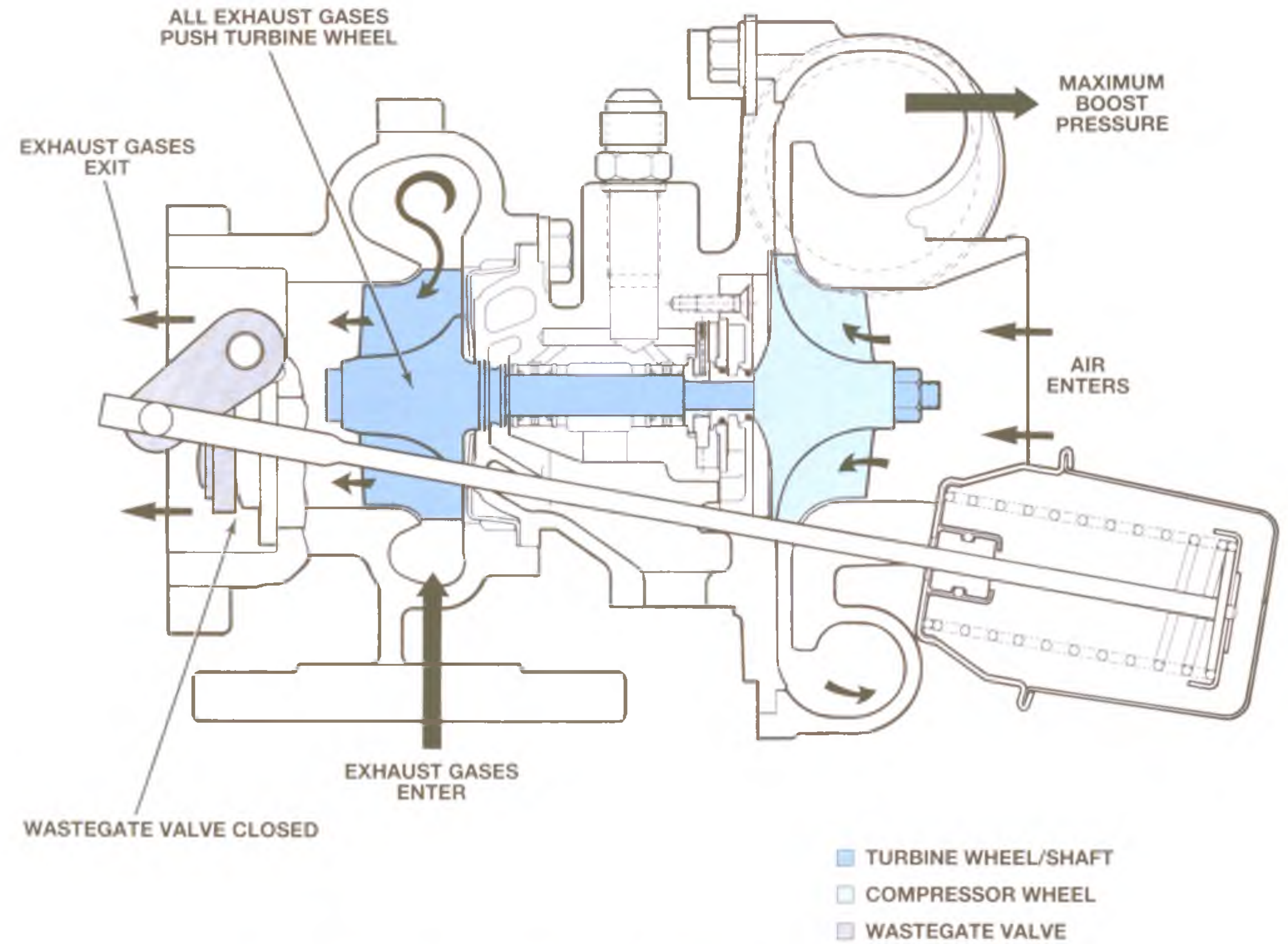


Figure 6-12, **Turbocharger Wastegate and Actuator (1)**

An actuator assembly provides a calibrated spring force to keep the wastegate valve closed, and the pressure of exhaust gases flowing in the turbine housing provides force to open the wastegate valve (see Figure 6-13). The position of the wastegate valve and length of the actuator rod are extremely critical for proper turbocharger operation.

During turbocharger manufacture, the turbine, bearing and compressor housings are aligned so that the positioning of the wastegate valve and actuator assembly provide the specified performance characteristics. Because of this feature, no realignment of the housings is permitted during service.

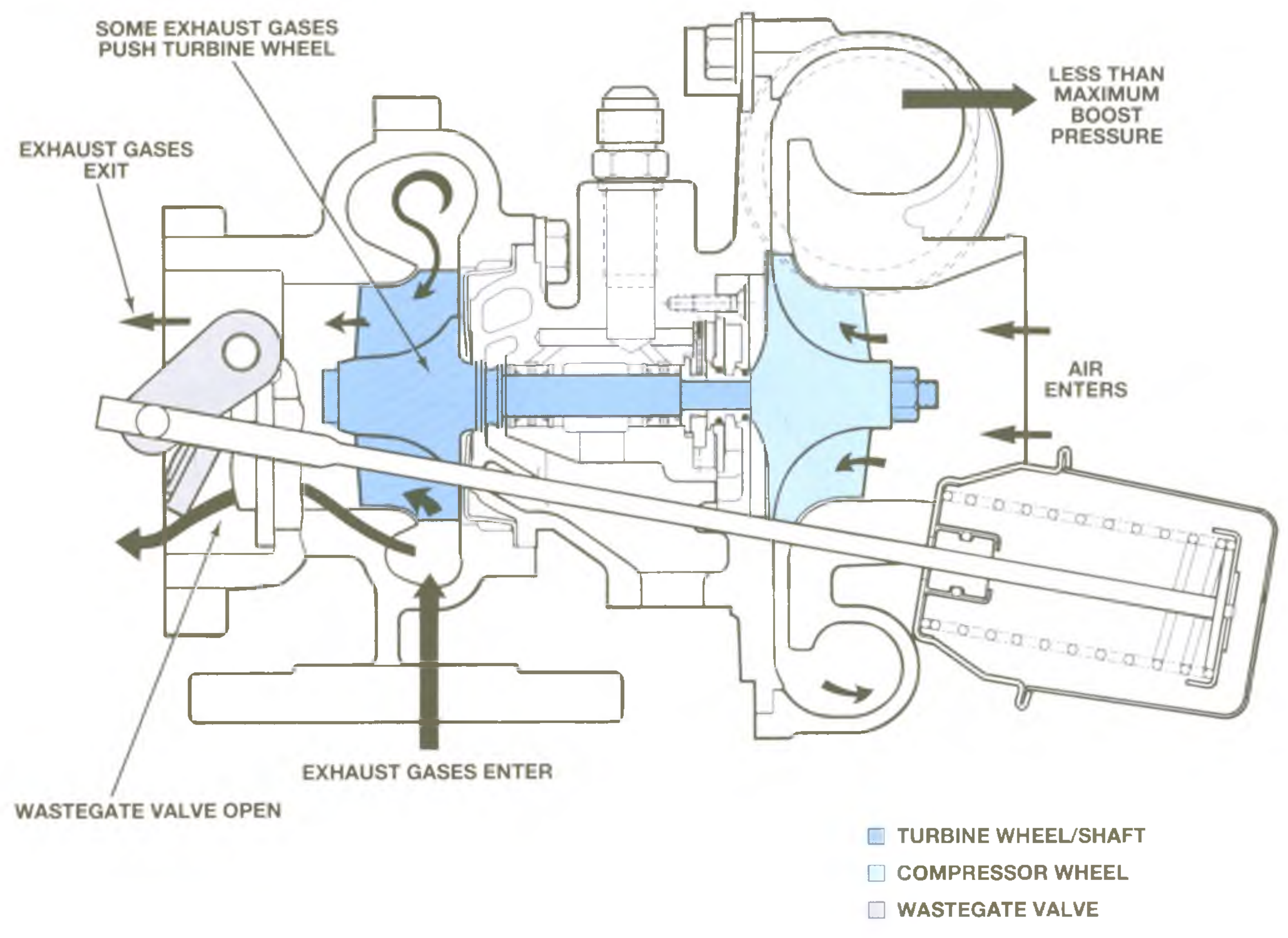


Figure 6-13, Turbocharger Wastegate and Actuator (2)

Engine/Turbocharger Performance

The 6.5L V8 diesel engine has a turbocharger for several reasons:

- To provide an increase in engine power without adding a substantial increase in weight
- To provide consistent power at all altitudes by compensating for changes in air density
- To increase combustion turbulence and air/fuel mixing efficiency, resulting in greater fuel economy
- To reduce exhaust emissions (especially smoke)

The 6.5L V8 turbo diesel engine provides quick power response at low engine speeds. Under full-load conditions, the engine is capable of steadily increasing its output torque as it accelerates up to approximately 1,700 rpm (refer to Figure 6-14). At this point, the intake manifold has a maximum boost pressure of 5 psi, and the turbocharger compressor wheel speed may reach 80,000 rpm.

Under less than full-load conditions, the turbocharger works with the engine to provide varying levels of power under a broader range of speeds. Intake manifold boost pressure will also vary, and turbocharger compressor wheel speeds can be as low as 15,000 rpm (at idle speed).

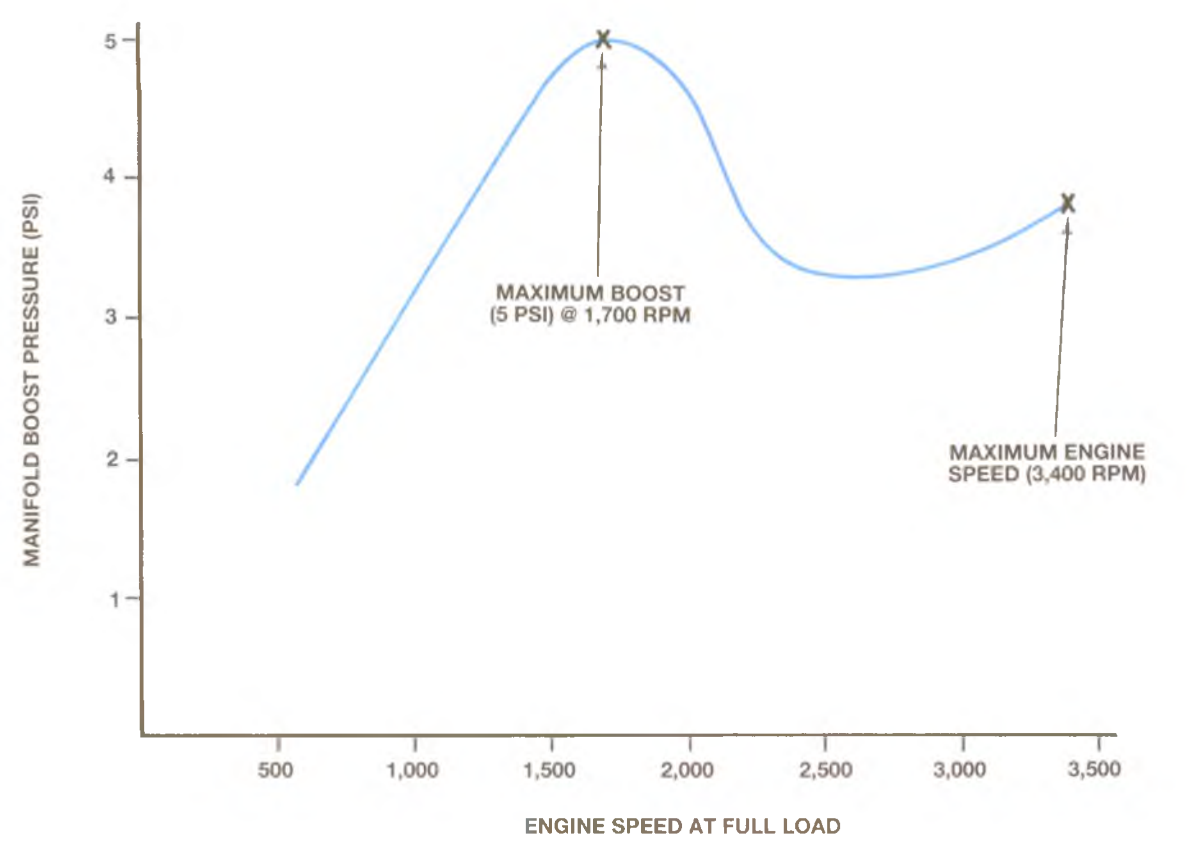


Figure 6-14, **Engine/Turbocharger Performance At Full Load**

As part of diagnosis, a technician may test intake manifold boost pressure in these steps:

1. Follow these safety precautions:
   - Use an assistant to stand on either side of the vehicle during the test.
   - Block the drive wheels of the vehicle and set the parking brake.
2. Remove the front center mounting bolt of the air inlet duct and replace it with the special boost gauge (see Figure 6-15).
3. Start the engine, place the transmission in OD range, and operate the engine at full-throttle for 10 seconds.
4. Have the assistant observe the boost gauge reading during the test.

Note: A boost test reading above 2 psi indicates that the turbocharger is working properly.

– Caution –

Do not conduct the manifold boost pressure test for longer than 10 seconds to prevent the possibility of transmission overheating. After the test, allow the engine to run at idle speed for transmission fluid cooling purposes.

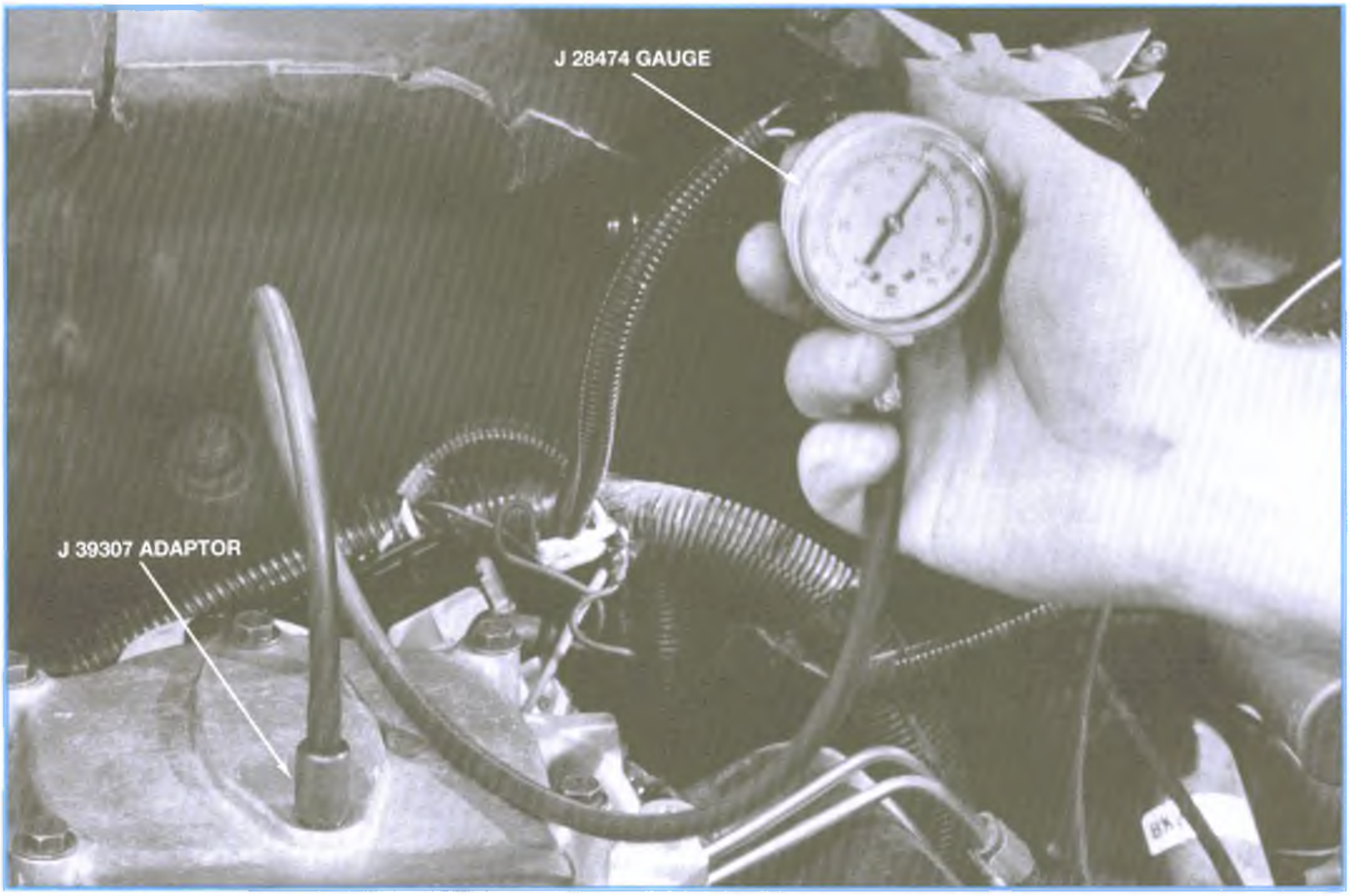


Figure 6-15, **Boost Gauge Installation**

Turbocharger Diagnosis

Turbocharger operation relates to the following diagnosis hints (refer to Figure 6-16 for component identification):

Condition #1: Engine lacks power

Cause:
- A. Restricted air filter
- B. Obstructed turbocharger inlet duct
- C. Air leak in turbocharger inlet or outlet ducts
- D. Obstructed intake manifold
- E. Air leak in intake manifold/gaskets
- F. Restricted exhaust system
- G. Exhaust gas leak in manifold
- H. Turbocharger turbine wheel/shaft binding due to coking
- I. Turbocharger turbine wheel/shaft or compressor wheel unbalanced
- J. Internal turbocharger damage

Correction:
- A. Replace air filter.
- B. Remove obstruction.
- C. Secure clamps or replace damaged duct(s).
- D. Remove obstruction.
- E. Tighten mounting bolts or replace manifold/gaskets.
- F. Check exhaust system and replace damaged part(s).
- G. Tighten manifold mounting bolts or replace damaged part(s).
- H. Replace turbocharger, check oil supply and drain for restrictions, and change engine oil/filter.
- I. Replace turbocharger.
- J. Replace turbocharger.

Condition #2: Turbocharger noise

Cause:
- A. Restriction or air leak in turbocharger inlet or outlet ducts
- B. Turbocharger turbine wheel/shaft or compressor wheel unbalanced
- C. Turbocharger turbine wheel/shaft or compressor wheel contacting housing

Correction:
- A. Secure clamps or replace damaged duct(s).
- B. Replace turbocharger.
- C. Locate cause of damage and replace turbocharger.

Condition #3: Black exhaust smoke

Cause: Lack of intake air, causing improper air/fuel ratio

Correction: Refer to corrections for condition #1.

Condition #4: Blue exhaust smoke and abnormal oil consumption

Cause:

A. Lack of intake air
B. Restricted oil drain tube
C. Oil leakage past turbine seal ring
D. Oil leakage past compressor seal rings

Correction:

A. Refer to corrections for condition #1.
B. Clean or replace oil drain tube.
C. Replace turbocharger.
D. Replace turbocharger.

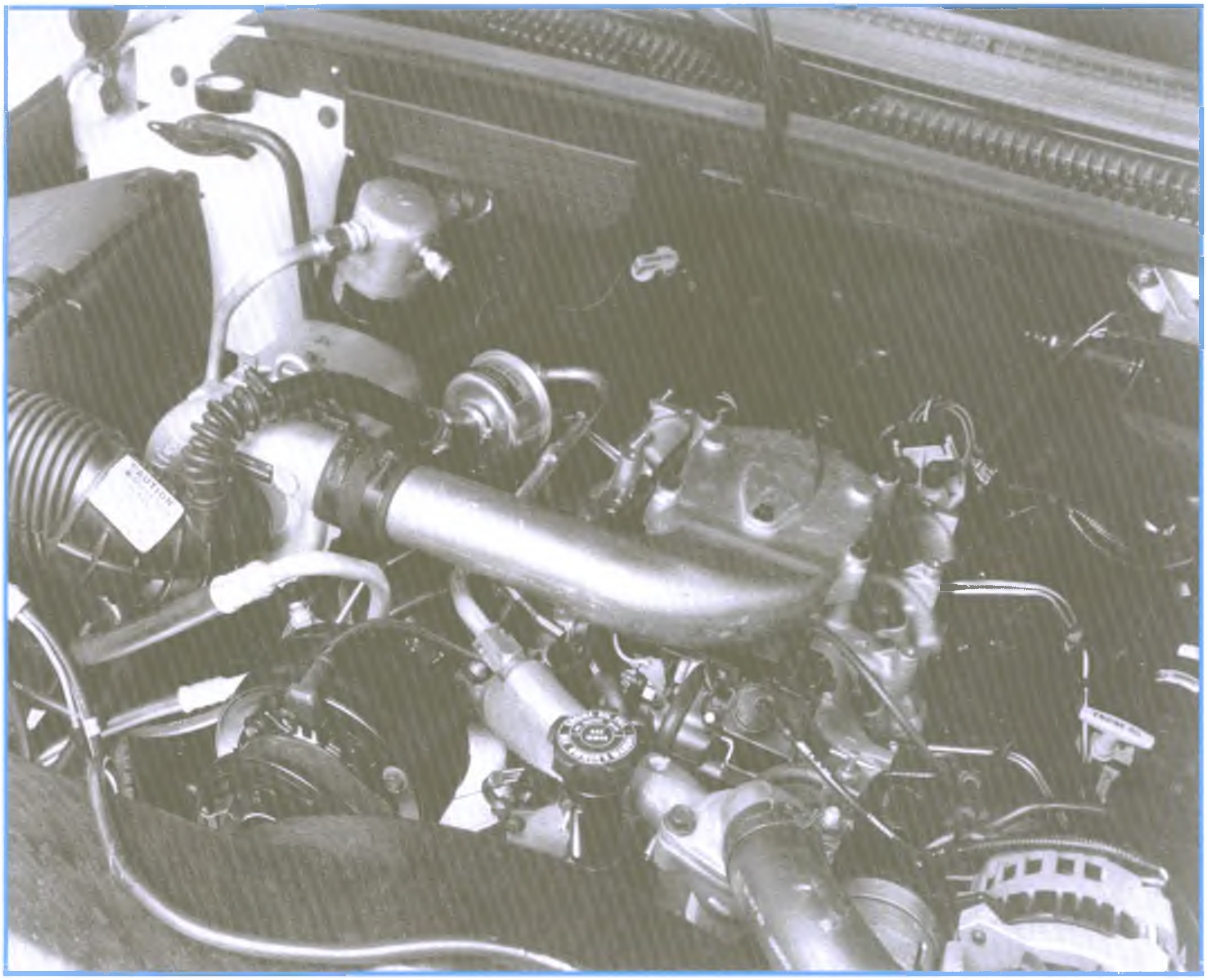


Figure 6-16, Turbocharger and Related Components

Turbocharger Inspection

As part of diagnosis of the turbocharger, perform the following steps:

1. Listen for the unusual sounds:
   - A high-pitched whine that may indicate an air induction or exhaust leak
   - A sound that is cycling in pitch that may indicate one of the following faults:
     - Blockage in the turbocharger inlet duct
     - Restriction in the air filter
     - Dirt accumulation on the turbocharger compressor wheel
   - A sharp, high-pitched scream that indicates turbocharger bearing wear or turbine/compressor wheel contact with a housing
2. Look at components:
   - The compressor wheel blades (inspect for bends, breaks, erosion, cracks or dirt accumulation) - refer to Figure 6-17
   - The compressor housing (inspect for signs of contact)
   - The bearing housing (inspect for signs of oil leakage)

Note: Oil on the compressor wheel blades may be seen, since the Crankcase Depression Regulator Valve (CDRV) outlet is on the inlet duct to the turbocharger compressor housing.

3. Check internal rotating parts in these steps:
   - Rotate the compressor wheel by spinning the nut on the end of the shaft in a clockwise direction (observe signs of binding or housing contact).
   - While rotating the compressor wheel, pull and push the shaft nut (observe signs of binding or housing contact).
   - While rotating the compressor wheel, raise and lower the shaft nut slightly (observe signs of binding or housing contact).

Note: If the turbocharger fails any of the above checks, replace it as an assembly. No specifications for runout or end-play are given, due to the design characteristics of the sleeve-type floating bearings.

4. Inspect the wastegate and actuator in the following steps:
   - Pull the actuator rod toward the rear of the engine, causing the wastegate valve to open (observe no signs of binding).
   - Release the actuator rod (observe that the valve closes under spring tension without binding).

Note: If the actuator does not snap back into a closed position, replace it.

5. Perform the boost pressure test (see page 6-15).

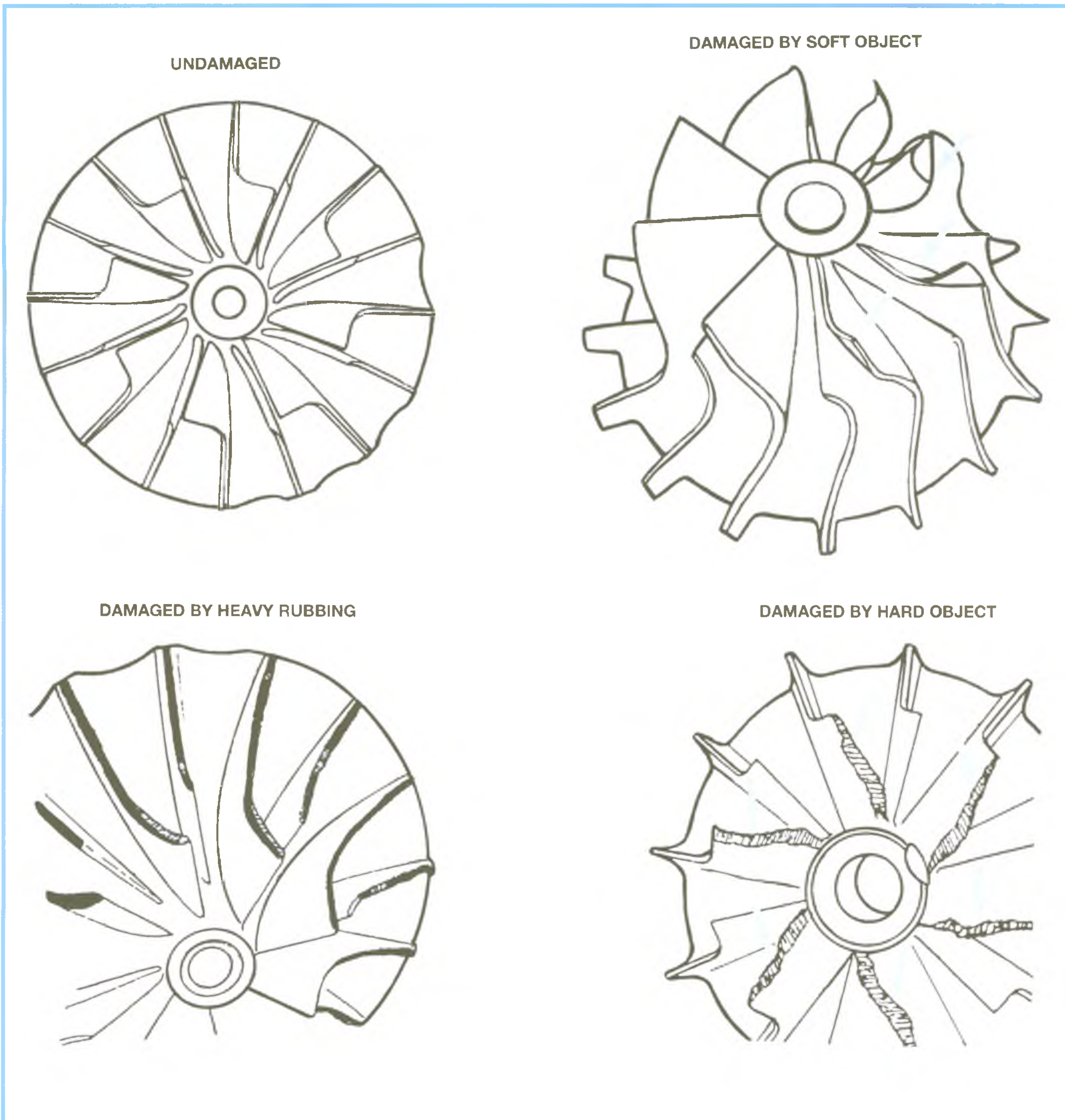


Figure 6-17, **Turbocharger Compressor Wheel Inspection**

Air Inlet Duct

Air travels from the turbocharger compressor housing to the engine intake manifold through the air inlet duct. A hose with two screw-type clamps forms the joint between the compressor housing and the air inlet duct.

The air inlet duct mounts on the intake manifold, using six bolts and a gasket (see Figure 6-18). A sound insulator covers the air inlet duct and mounts to the intake manifold with four bolts using grommets.

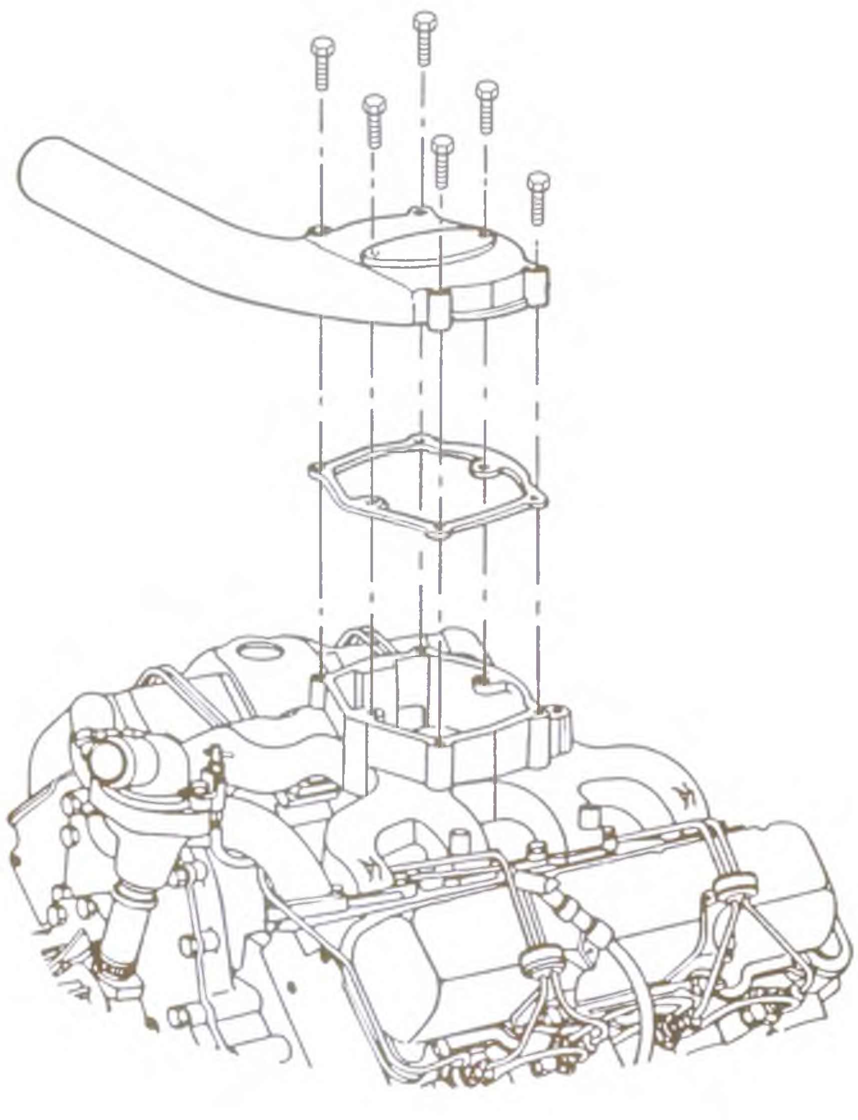


Figure 6-18, **Air Inlet Duct Mounting**

Crankcase Ventilation System

The crankcase ventilation system uses the open areas inside the engine cylinder case and right cylinder head to transfer the gases caused from combustion blow-by into the right rocker arm cover area. At that location, a Crankcase Depression Regulator Valve (CDRV) controls the entry of gases into the intake manifold.

The CDRV has an inlet fitting that connects to the right rocker cover, using a grommet (see Figure 6-19). It has an outlet fitting that attaches to a fitting on the turbocharger inlet duct with a combination of pipe, hoses and clamps.

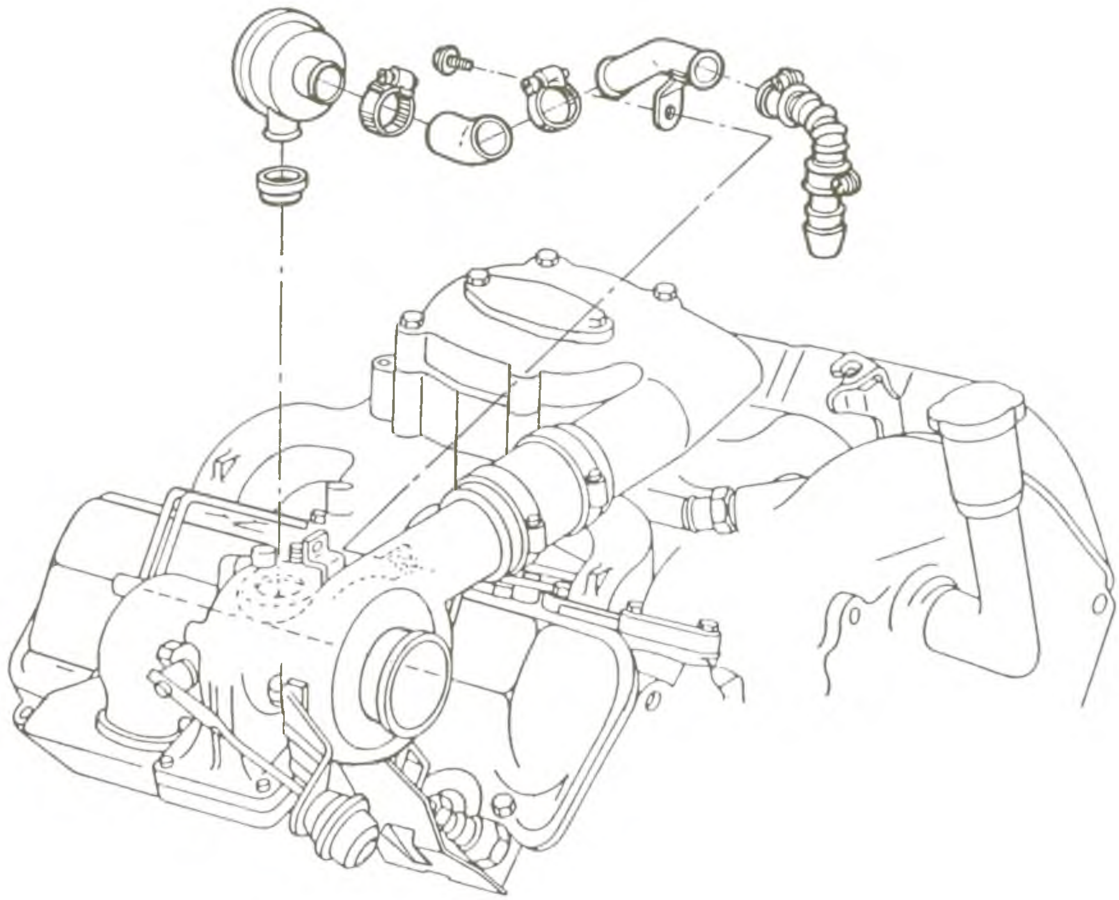


Figure 6-19, Crankcase Depression Regulator Valve Mounting

Inside the CDRV, a spring holds open a valve plate that connects to the CDRV body with a flexible diaphragm. The valve plate is capable of restricting the outlet passage to the turbocharger air inlet duct when airflow pulls it closed against the force of the spring.

When the engine is running at idle speed, the airflow past the CDRV outlet passage may not be great enough and crankcase pressure could be 1 inch H_2O (see Figure 6-20, view A).

At higher engine speeds, the valve closes to provide more restriction (see Figure 6-20, view B). This prevents the movement of oil vapors into the intake manifold by limiting the crankcase vacuum (measured at 2,000 rpm to be between 2 and 5 inches H_2O).

See page 6-24 for information about the crankcase pressure checking procedure.

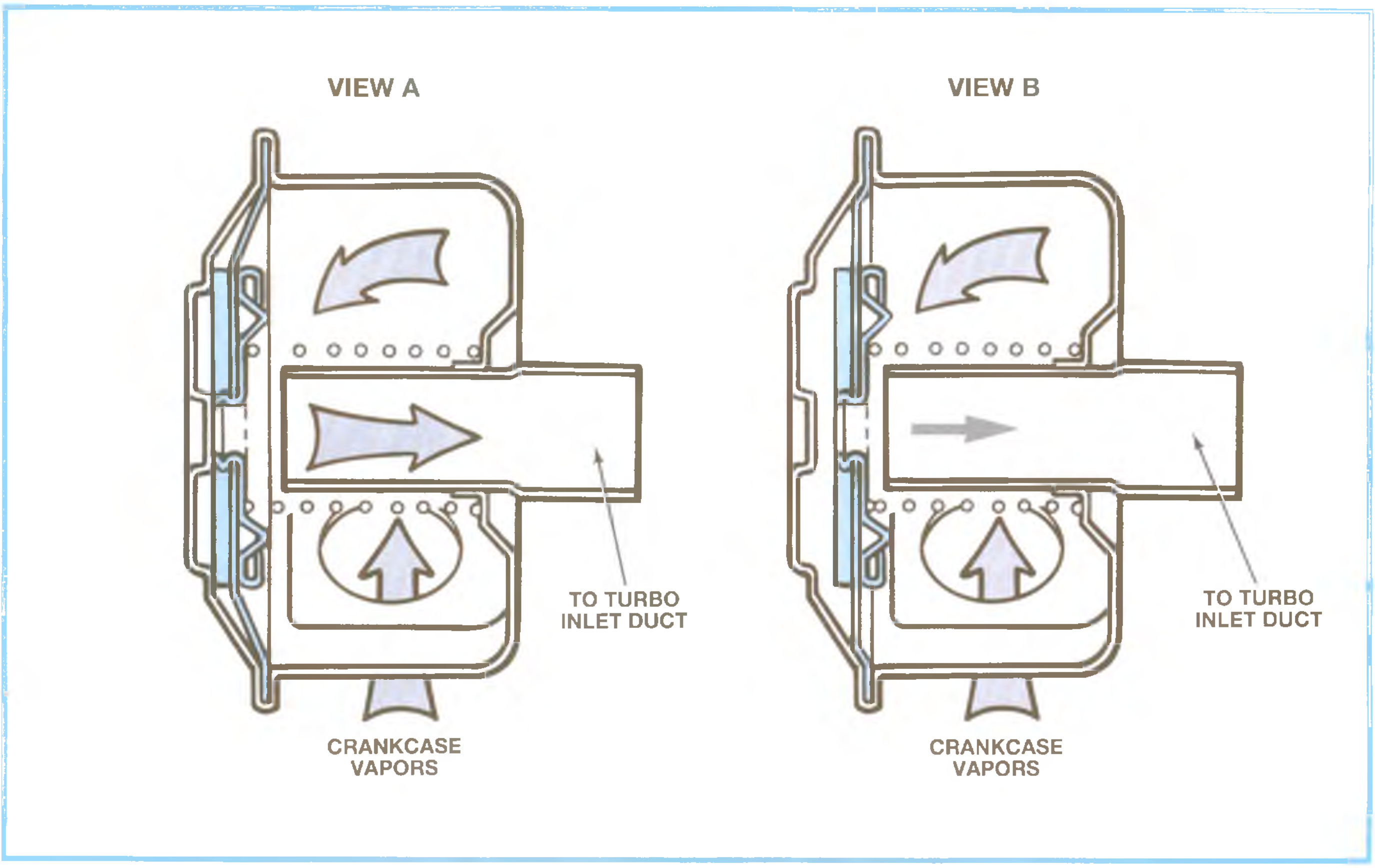


Figure 6-20, **Crankcase Depression Regulator Valve Operation**

Exhaust Pipes and Muffler

The exhaust gases from cylinders #1, #3, #5 and #7 travel through the left exhaust manifold and an exhaust crossover pipe to the right exhaust manifold, where they join the exhaust gases from cylinders #2, #4, #6 and #8 before entering the turbocharger. Flared flanges seal the joints between the exhaust manifolds and the crossover pipe.

Exhaust gases exiting the turbocharger travel through a single pipe to the muffler (see Figure 6-21). A pipe carries exhaust gases from the muffler to the outside air. Hangers positioned in several locations have isolators made of composite material to dampen the transmission of noise and vibration from the exhaust system to the vehicle body.

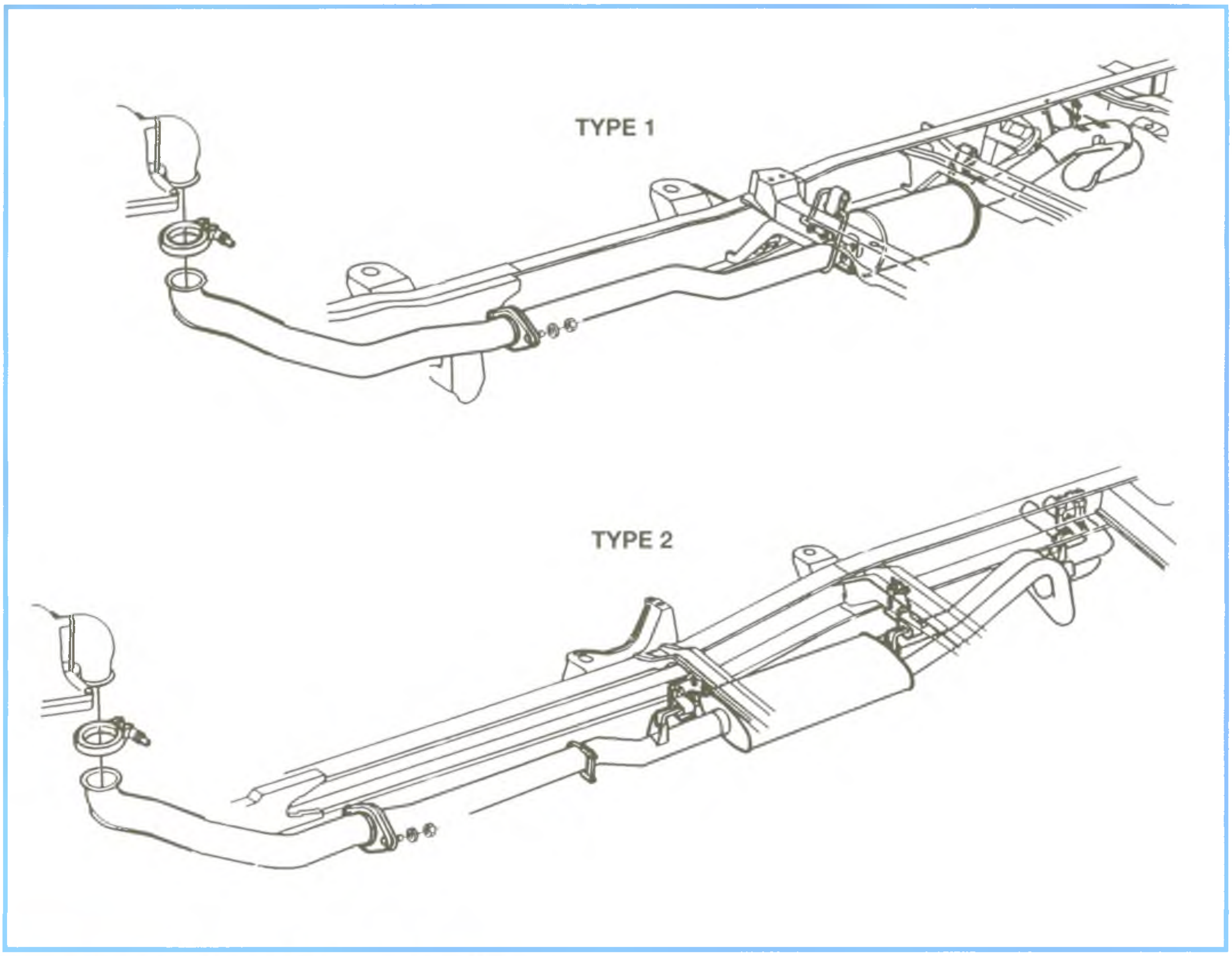


Figure 6-21, **Exhaust Pipe and Muffler**

Related Diagnosis/Service Procedures

Crankcase Pressure Check

1. Bring the engine to operating temperature with the air filter installed.
2. Obtain a water manometer (special tool J 23951).
3. Remove the engine oil dipstick and attach the hose of the water manometer to the oil disptick tube.
4. Start and run the engine at idle speed, observing the water manometer reading (see Figure 6-22):
   - If the reading indicates that crankcase pressure is approximately 1 inch of pressure or less, go to step 5.
   - If the reading indicates that crankcase pressure is higher than 1 inch of pressure, inspect the Crankcase Depression Regulator Valve (CDRV) and re-check crankcase pressure (if the CDRV checks good, perform a compression test).

Example: 4 inches of pressure is higher than 1 inch of pressure.

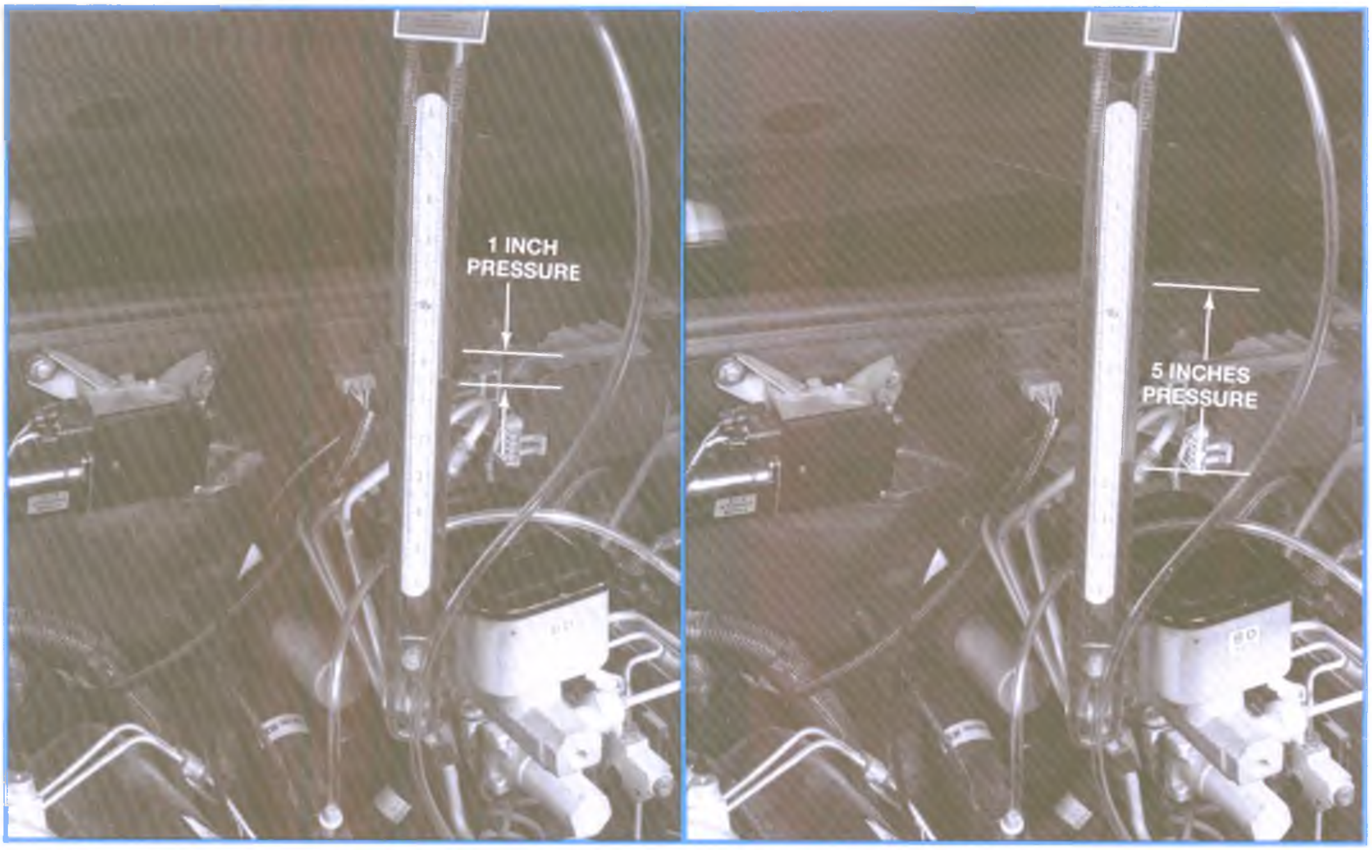


Figure 6-22, **Crankcase Pressure Check at Idle Speed**

5. Run the engine at 2,000 rpm, observing the water manometer reading (see Figure 6-23):
   - If the reading indicates that crankcase pressure is approximately 2 to 5 inches of vacuum, go to step 6.
   - If the reading indicates that crankcase pressure is lower than 2 inches of vacuum, inspect the CDRV and re-check crankcase pressure (if the CDRV checks good, check the air intake/exhaust systems).

Example: 8 inches of vacuum is lower than 2 inches of vacuum.

- If the reading indicates that crankcase pressure is higher than 5 inches of vacuum, inspect the CDRV and re-check crankcase pressure.

Example: 1 inch of pressure is higher than 5 inches of vacuum.

6. Separate the hose of the water manometer from the oil dipstick tube and install the engine oil dipstick.
7. Stop the engine.

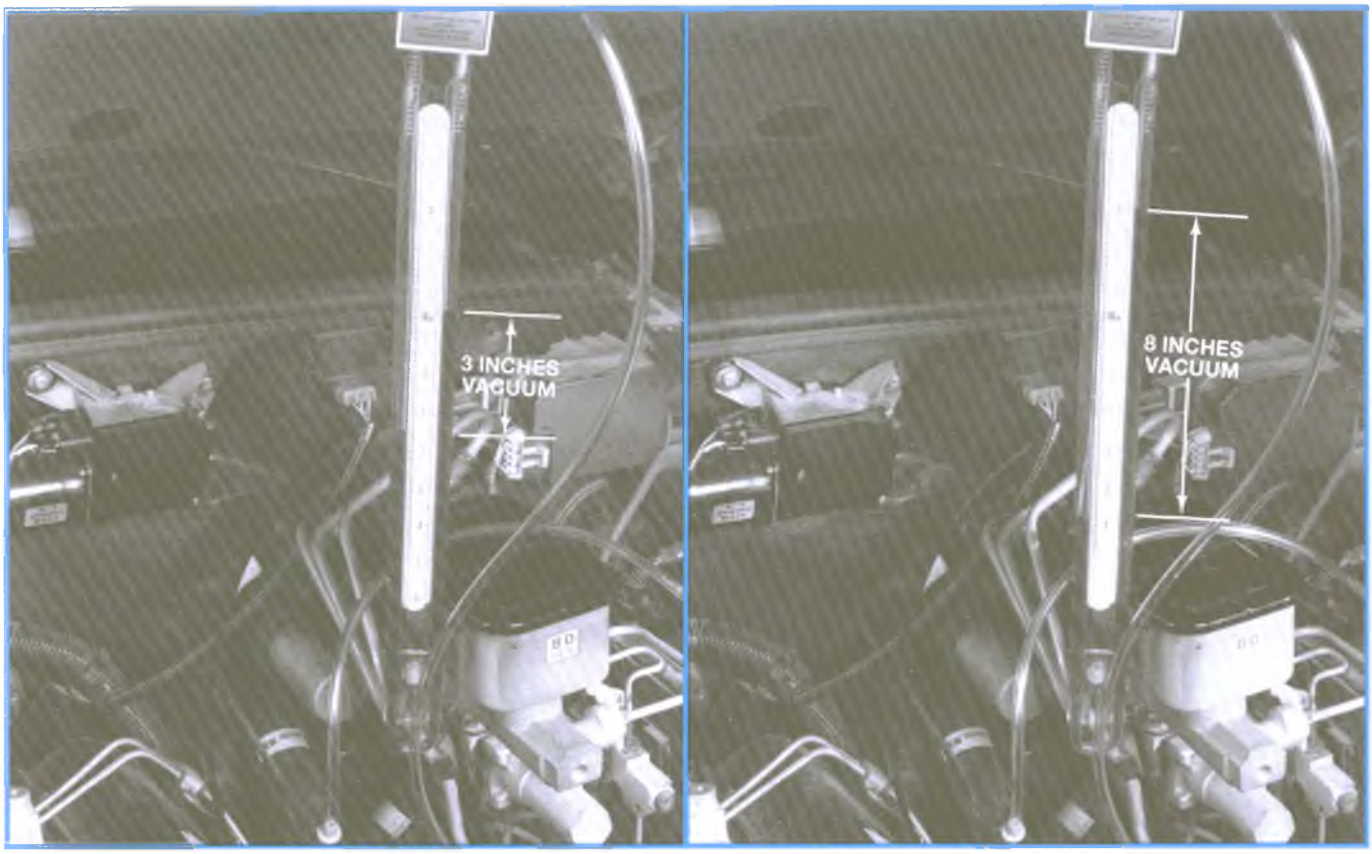


Figure 6-23, Crankcase Pressure Check at 2,000 rpm

NOTES

7. Fuel System

Overview

The fuel system of the 6.5L V8 turbo diesel engine includes the following parts (refer to Figure 7-1):

- Fuel tank assembly
- Lift pump assembly
- Fuel filter assembly
- Fuel injection pump assembly
- Fuel injection lines
- Fuel injection nozzles
- Fuel return system

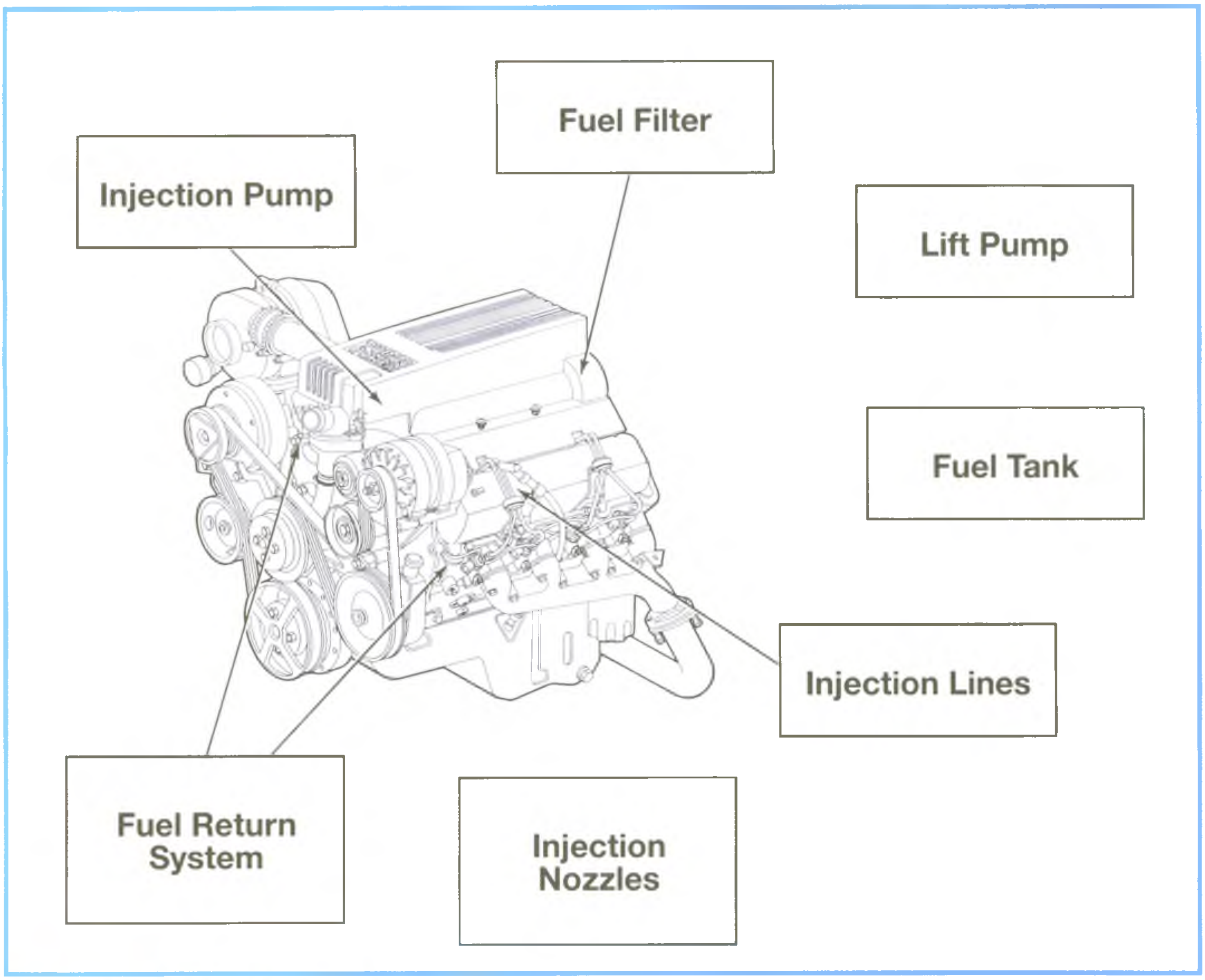


Figure 7-1, **Fuel System Parts**

Fuel Tank Assembly

On some vehicles, the fuel tank assembly mounts on the left framerail (see Figure 7-2, view A). Other vehicles have a fuel tank mounted behind the rear axle assembly that is supported between the left and right framerails (see Figure 7-2, view B). In either case, the fuel tank has a filler tube with a flexible coupling and screw-type clamps.

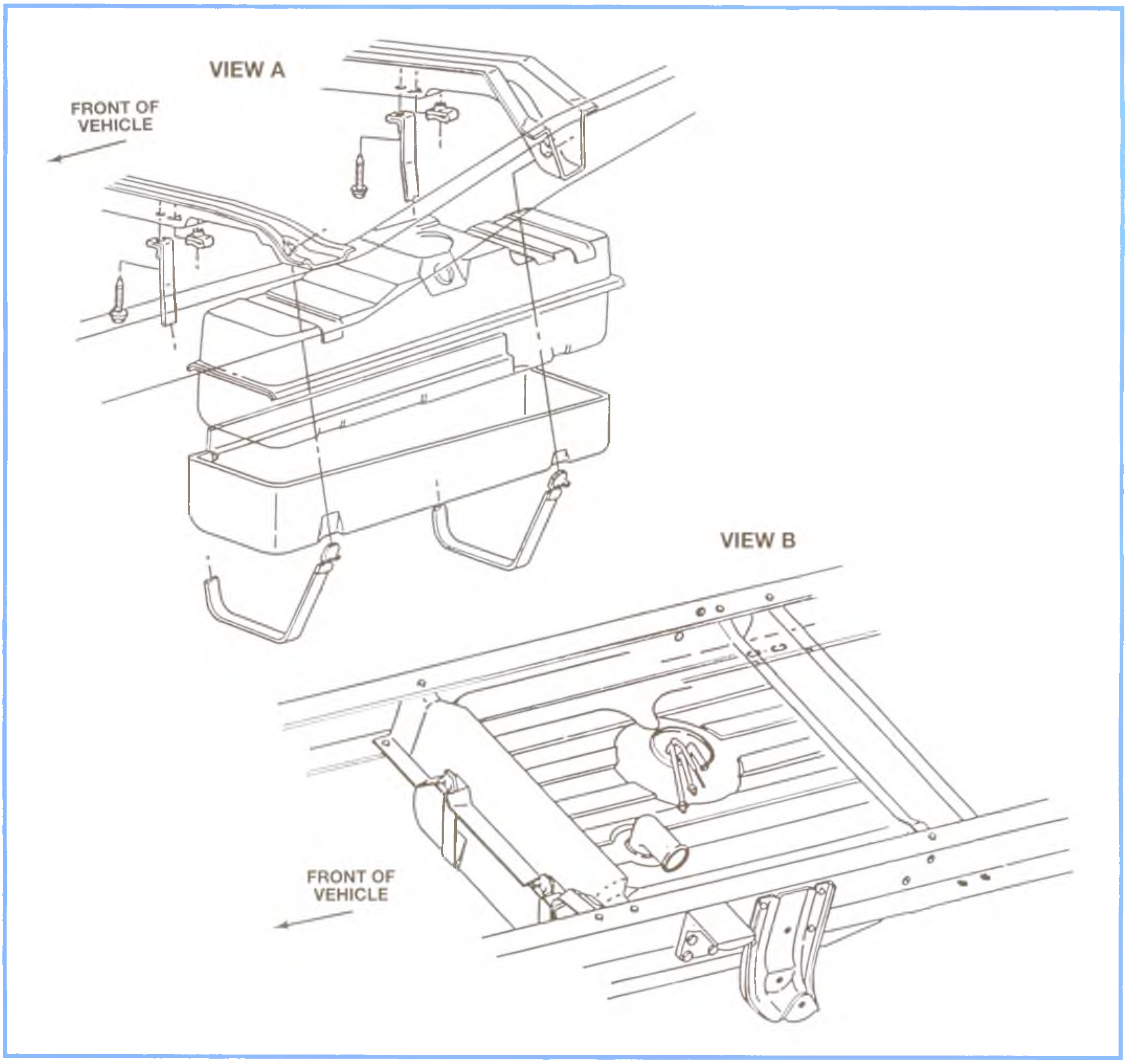


Figure 7-2, Fuel Tank Locations

The fuel tank has a removeable pick-up/sending unit (see Figure 7-3). The pick-up tube has a saran filter sock with a bypass valve that opens when the filter becomes excessively restricted. The sending unit is a variable resistor with a wiper contact moved by a float.

The pick-up/sending unit has threaded fittings with O-ring seals for the fuel supply and return hoses. The sealing of these fittings is critical to the correct operation of the fuel system. Loose parts can allow air to enter the fuel supply system, affecting the operation of the fuel injection pump.

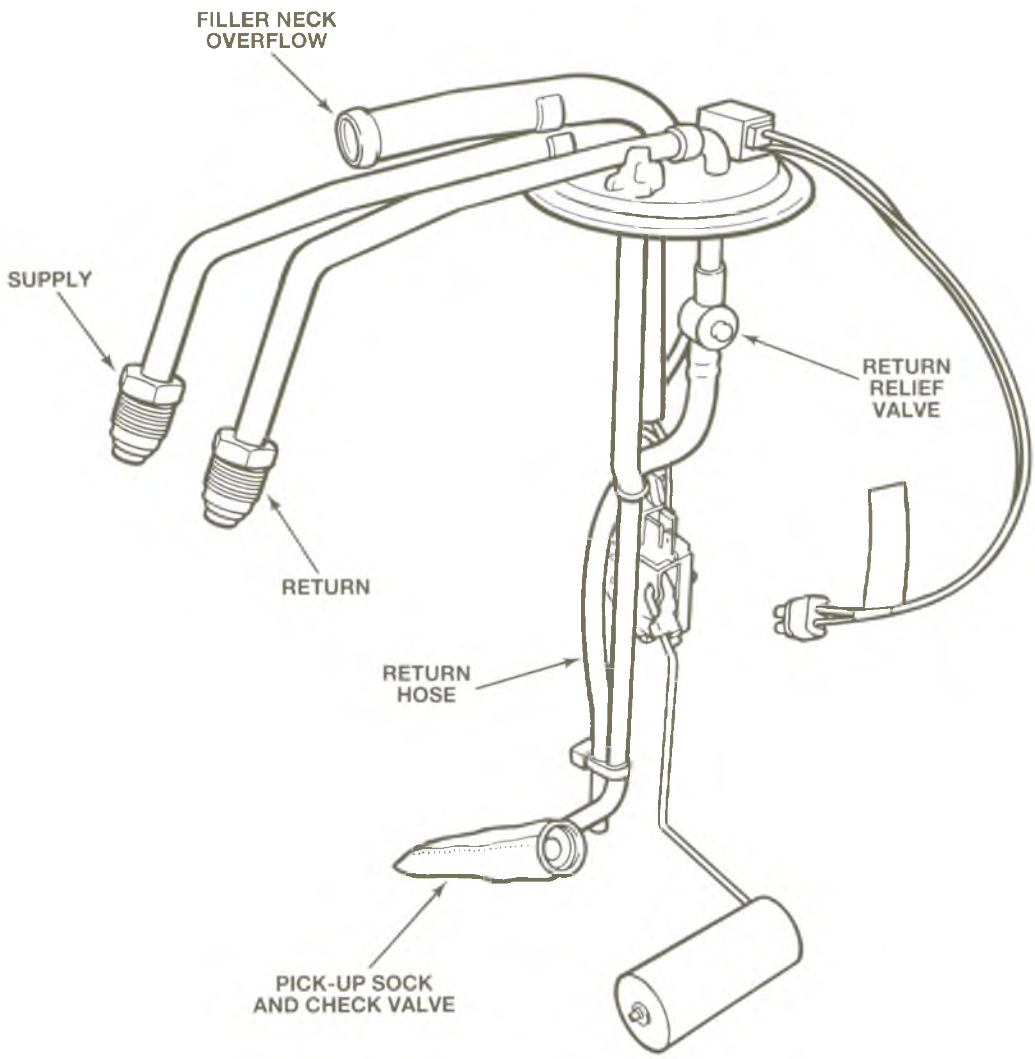


Figure 7-3, **Fuel Pick-Up/Sending Unit**

7. Fuel System

The fuel tank supplies the lift pump with fuel under a low (suction) pressure (see Figure 7-4). Fuel used to cool and lubricate the injection pump and eight nozzles returns to the fuel tank under a low pressure.

The filler cap of the fuel tank has a two-way check valve that limits fuel tank pressure to 2 psi and vacuum to 1 inch Hg. Correct fuel tank pressure is critical to the operation of the entire fuel system.

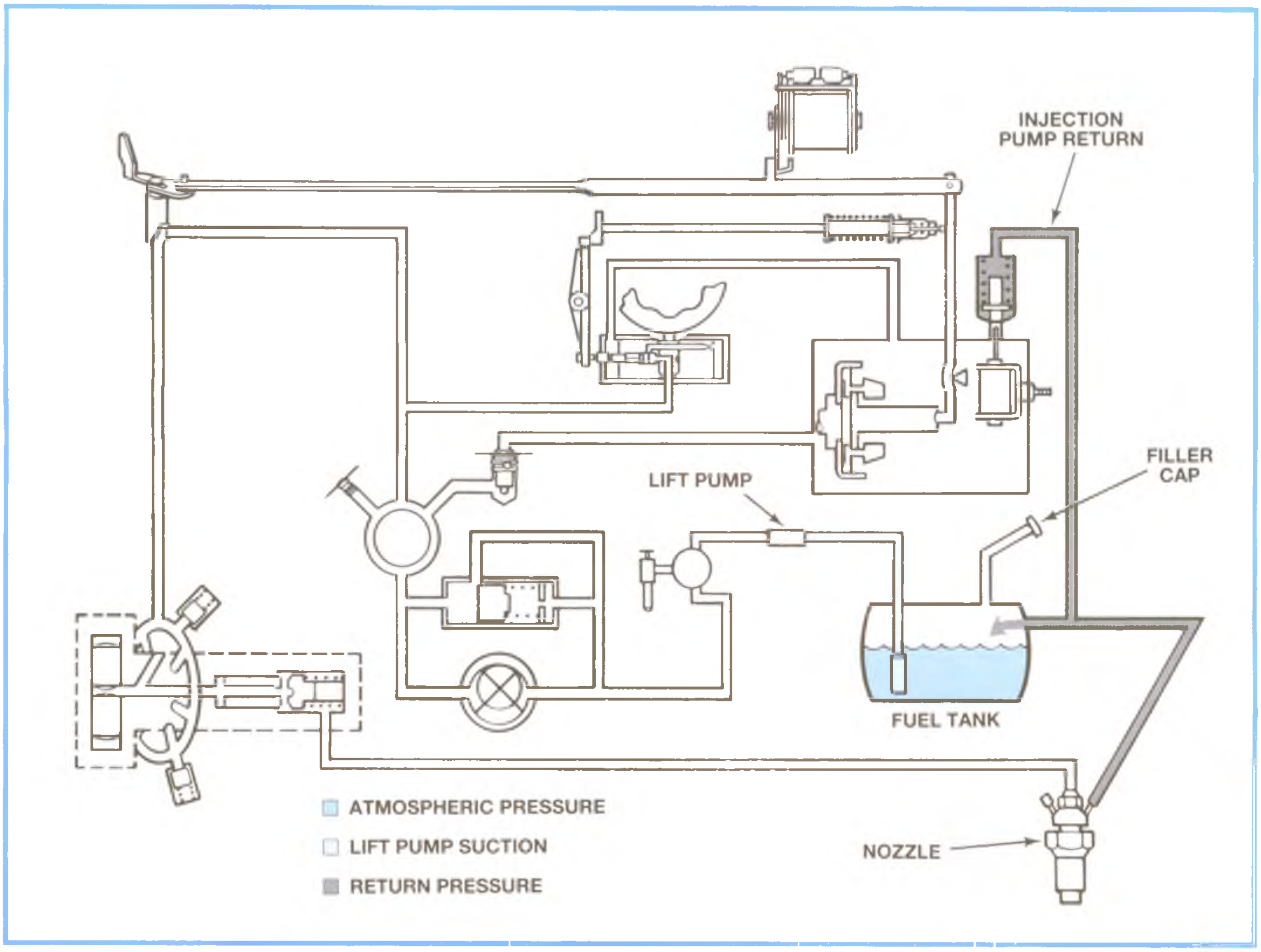


Figure 7-4, Fuel System Diagram – Fuel Tank Flow

Lift Pump Assembly

Location

An electric lift pump mounts on the inside of the left framerail, using a bracket (see Figure 7-5). The lift pump receives power from a circuit that includes the engine oil pressure switch, a relay and an in-line fuse (see page 8-30 for more information). Wiring from the fuse travels through a bulkhead connector and along the inside of the left framerail to the pump.

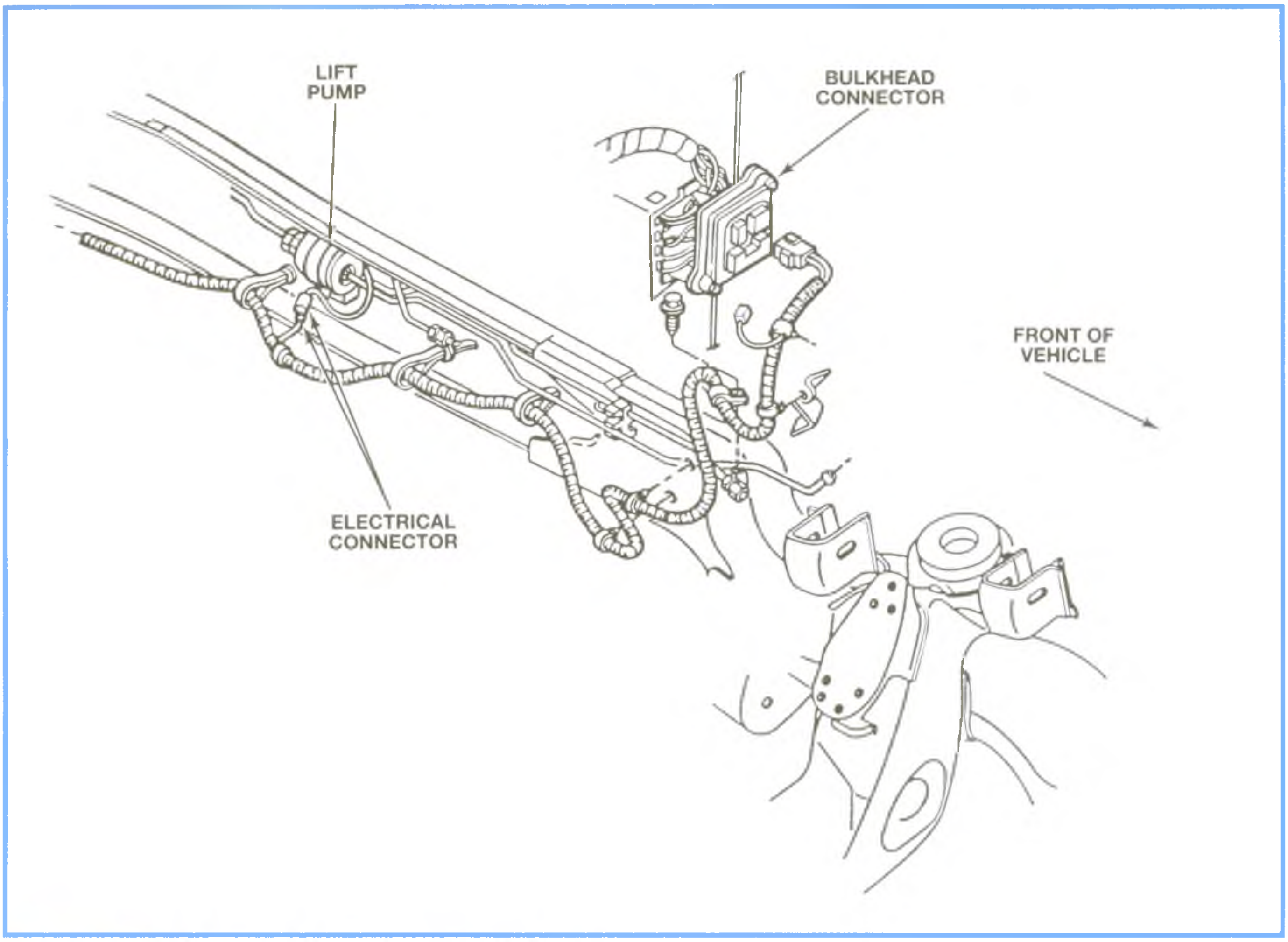


Figure 7-5, **Lift Pump Location and Wiring**

Construction

The inlet fitting of the lift pump connects to the fuel tank pick-up/sending unit fuel supply fitting, using a pipe/hose assembly with air-tight connections. The outlet fitting of the lift pump connects to the inlet fitting of the fuel filter assembly on the engine, using another pipe/hose assembly.

The electric lift pump has a hollow plunger that slides in a bore located in the center passage between the inlet and outlet ports (see Figure 7-6). An inlet valve is mounted on one end of the hollow plunger, and an outlet valve is positioned at the outlet end of the center passage. Both valves are closed by spring force.

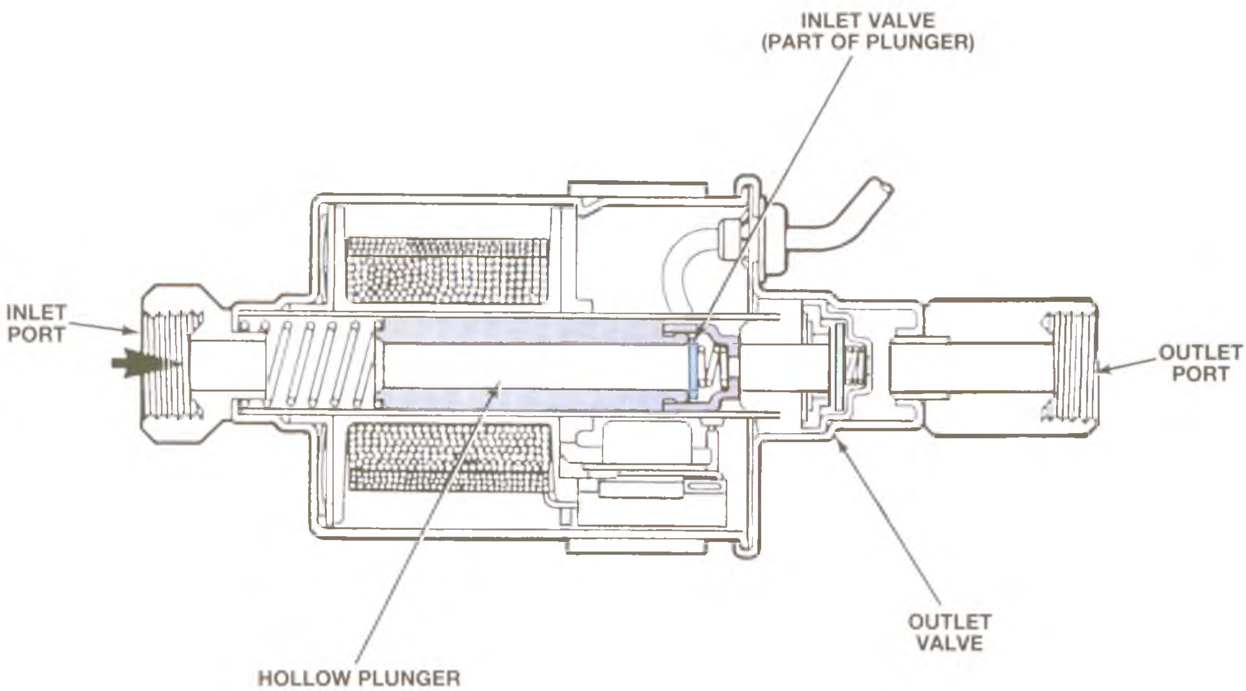


Figure 7-6, **Lift Pump Construction**

The lift pump is designed to move fuel under a low (suction) pressure from the fuel tank and deliver it through the filter to the transfer pump inside the fuel injection pump (see Figure 7-7). To operate correctly, the injection pump must have fuel with the correct pressure and no air bubbles.

The lift pump is checked as part of fuel supply system diagnosis (see page 7-68). The lift pump should deliver fuel with a minimum volume of 0.24 liter (1/2 pint) in 15 seconds at a pressure of 40 to 60 kPa (5.8 to 8.7 psi). The air-tightness of the lift pump suction line from the fuel tank is also important for correct operation of the injection pump.

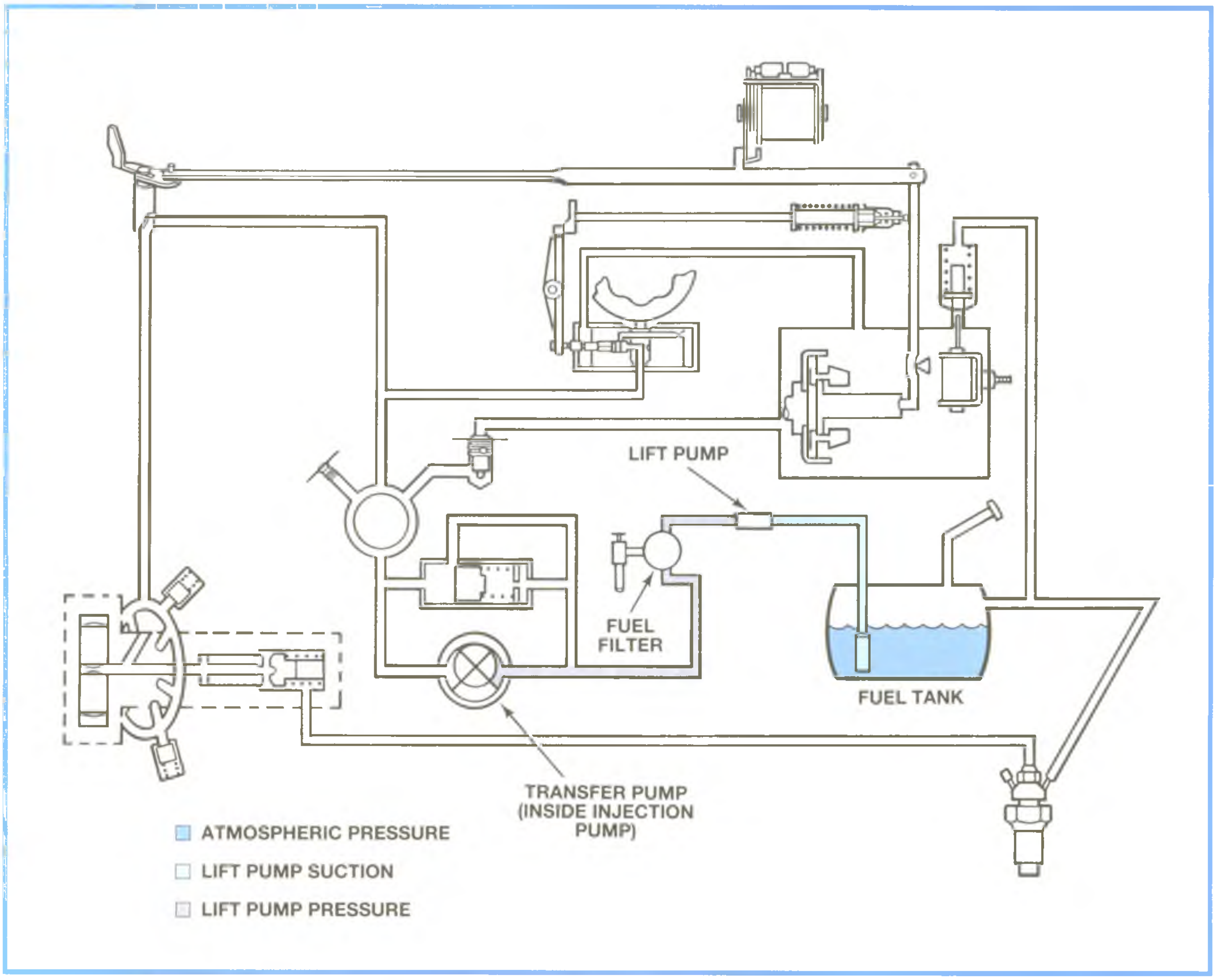


Figure 7-7, **Fuel System Diagram – Lift Pump Flow**

Operation

When the pump is at rest, a spring pushes the hollow plunger in the direction of the outlet (see Figure 7-8). Both the inlet and outlet valves are closed, keeping fuel in the supply line from draining back to the fuel tank.

When the pump has electrical power, a solenoid turns ON and pulls the hollow plunger toward the inlet port against spring force (see Figure 7-9, view A). This action causes the inlet valve to open, allowing fuel to enter the pumping chamber.

As the hollow plunger reaches full travel in the direction of the inlet port, the solenoid is turned OFF and spring force pushes the plunger toward the outlet port (see Figure 7-9, view B). This action closes the inlet valve (causing fuel to be drawn from the fuel tank into the pump) and pressurizes the fuel in the pumping chamber (opening the outlet valve to allow fuel to travel to the fuel filter).

As long as the fuel pump has electrical power, the solenoid ON/OFF cycle causes the movement of the hollow plunger and valves necessary to deliver a fuel supply to the filter and injection pump.

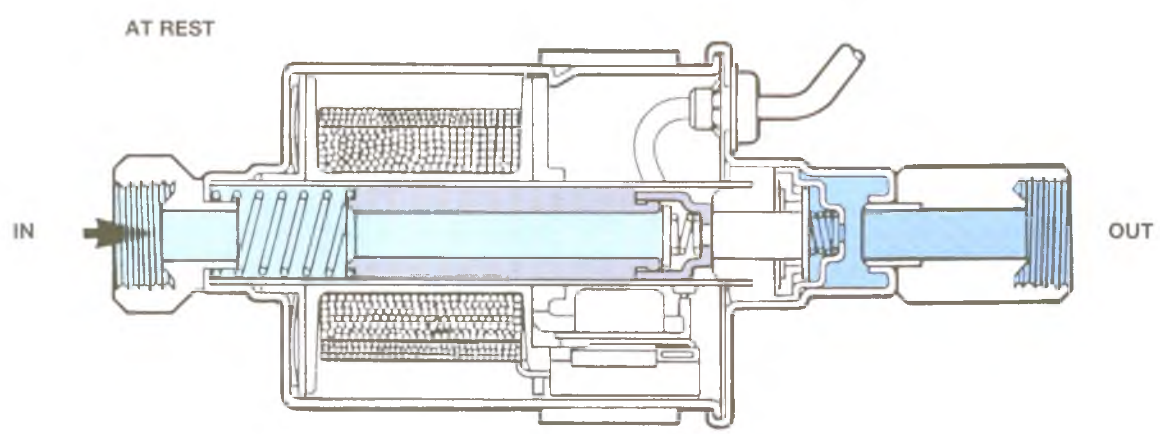


Figure 7-8, **Lift Pump Operation (1)**

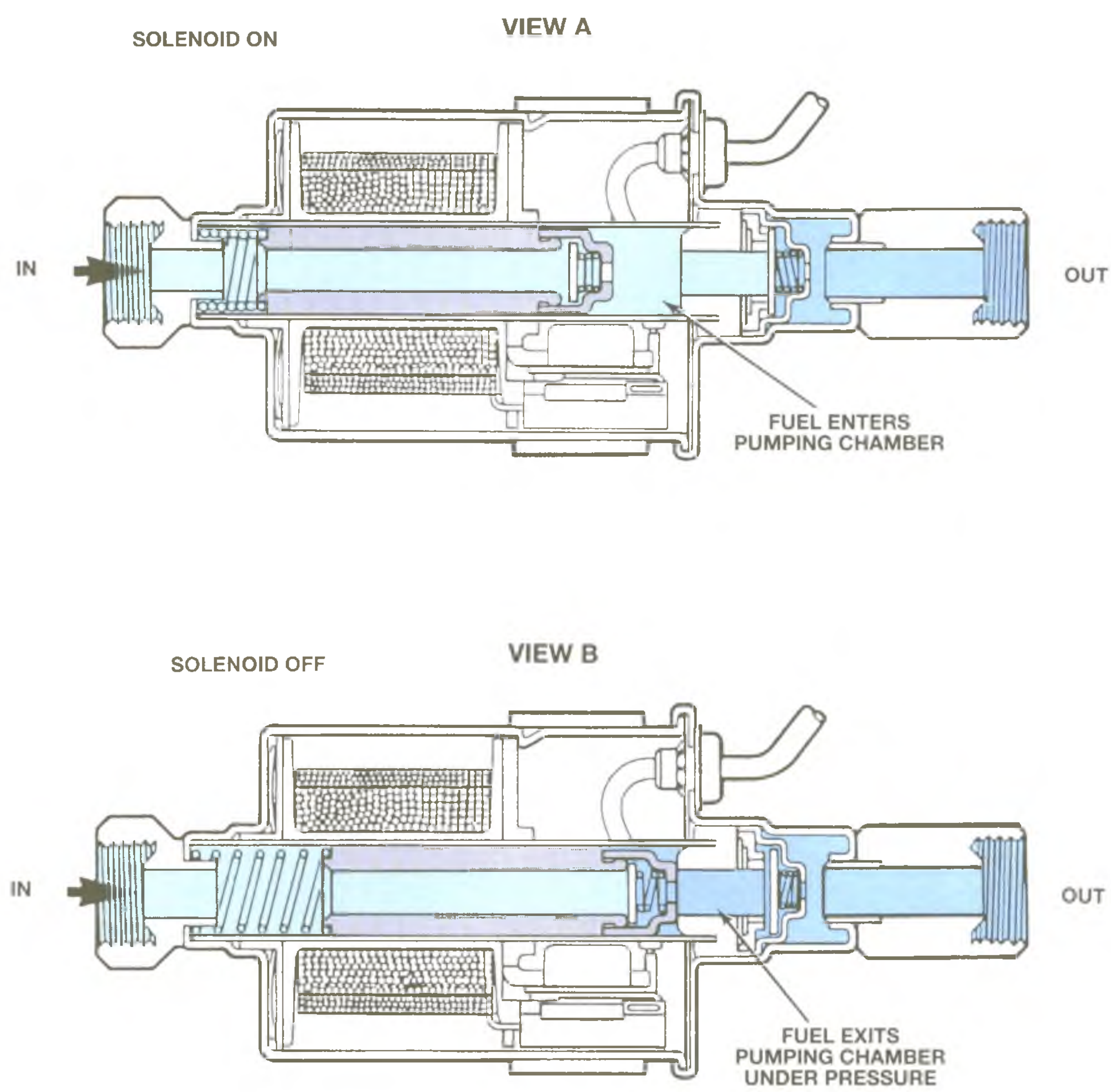


Figure 7-9, **Lift Pump Operation (2)**

Fuel Filter Assembly

Construction

The fuel filter assembly mounts on the rear of the intake manifold, using two bolts (see Figure 7-10, view A). The filter housing has an inlet fitting connecting to the pipe/hose from the lift pump and an outlet fitting connecting to the fuel injection pump with a hose. A third fitting connects through a hose to a drain valve mounted on the water crossover/thermostat (see Figure 7-10, view B).

The fuel filter assembly has a two-stage replaceable element with integral seals (refer to Figure 7-9). A threaded nut retains the element in the housing. The element has an air vent valve on its top surface that is used during a filter element replacement procedure.

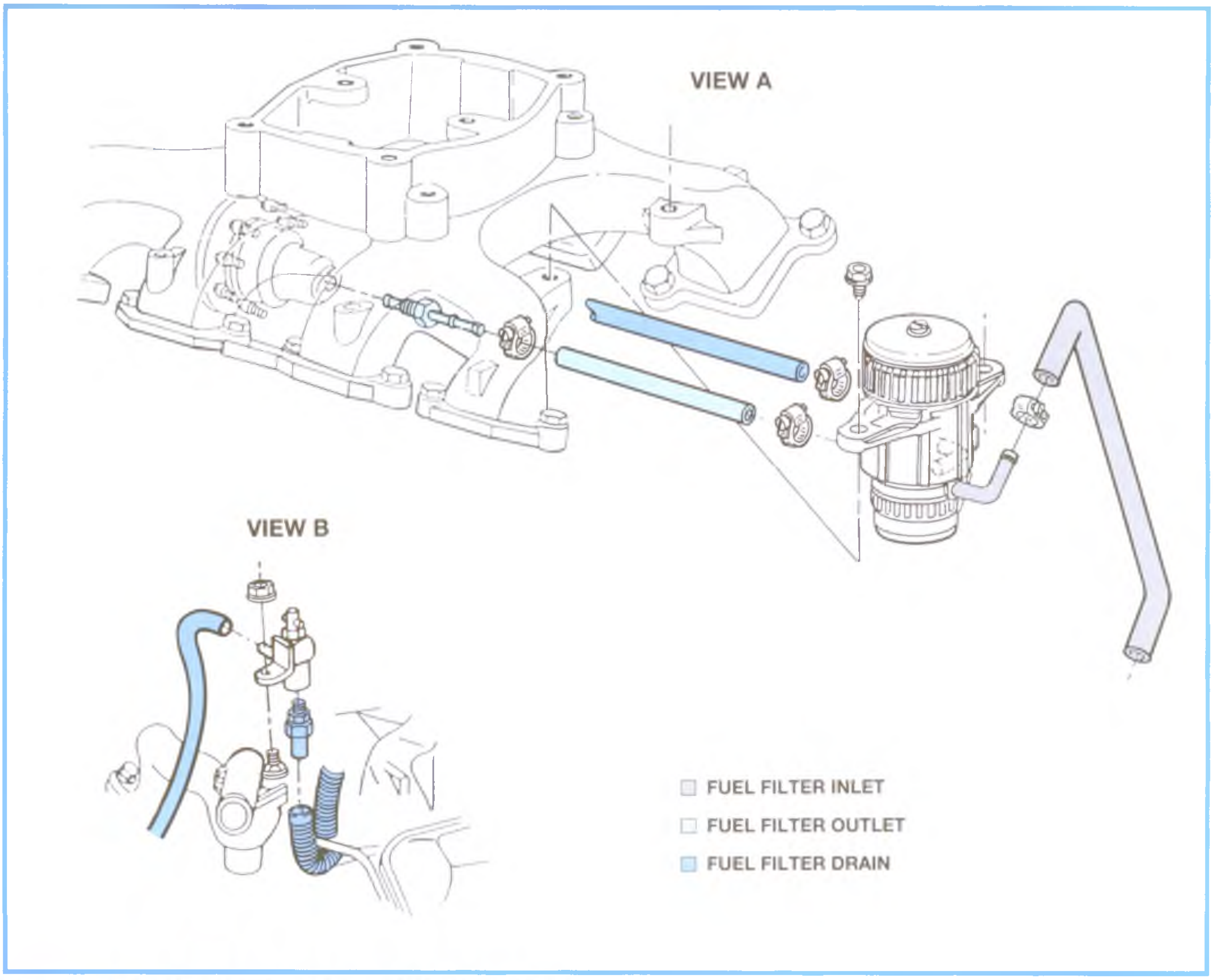


Figure 7-10, **Fuel Filter Assembly Mounting**

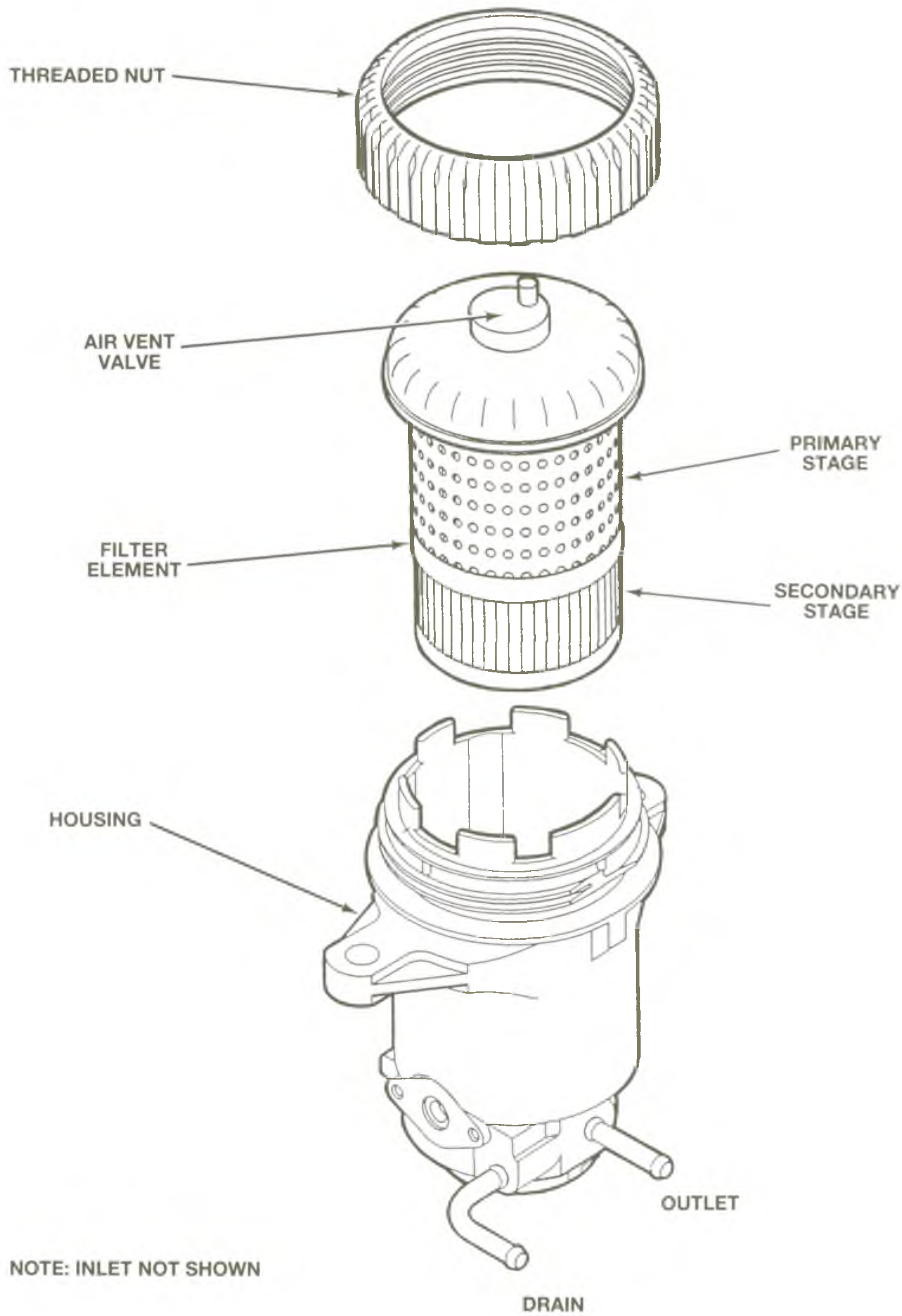


Figure 7-11, Fuel Filter Assembly Parts (1)

The fuel filter assembly has a fuel heater mounted to its bottom side that is retained with a threaded nut and seal ring (refer to Figure 7-12). Another part of the fuel filter assembly is a Water In Fuel (WIF) sensor. The WIF sensor has an O-ring seal and two mounting screws. Three wires connect the WIF sensor to a power supply circuit, as well as to an instrument cluster-mounted amber warning lamp.

Figure 7-13 shows a section view of the fuel filter assembly.

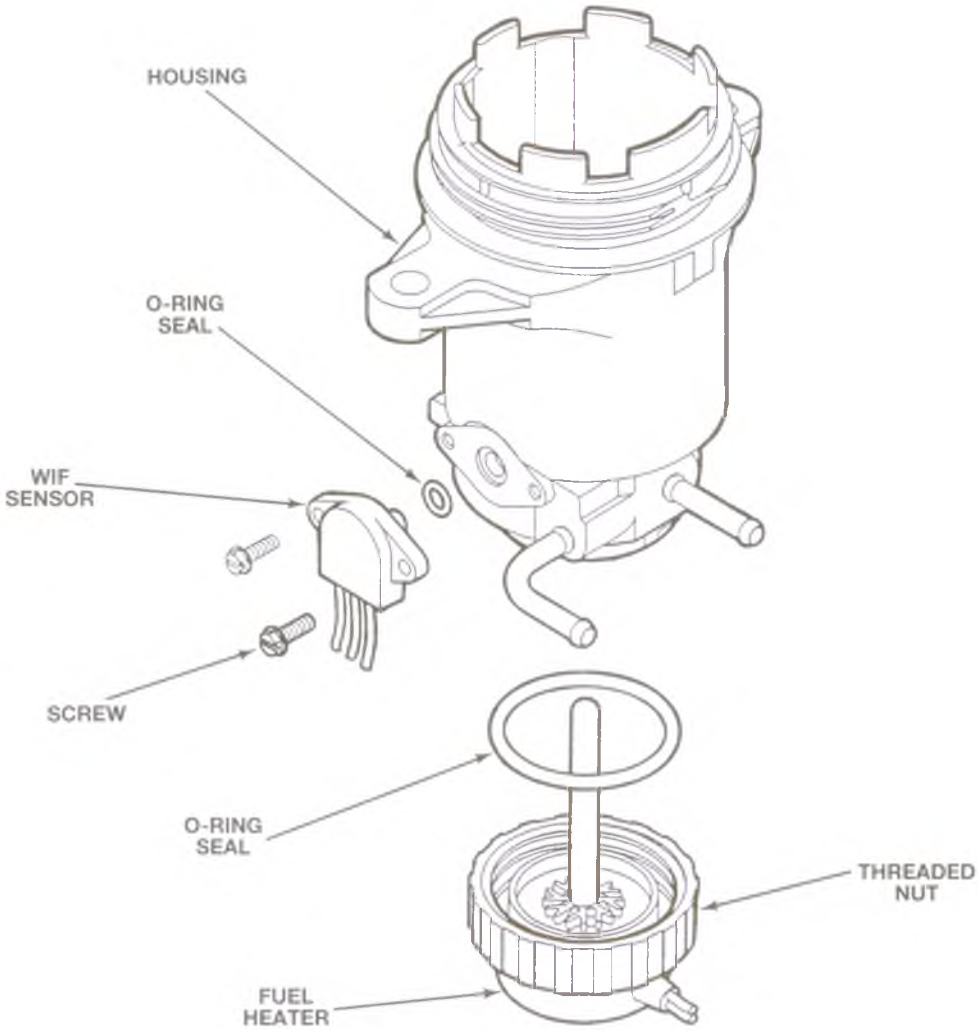


Figure 7-12, Fuel Filter Assembly Parts (2)

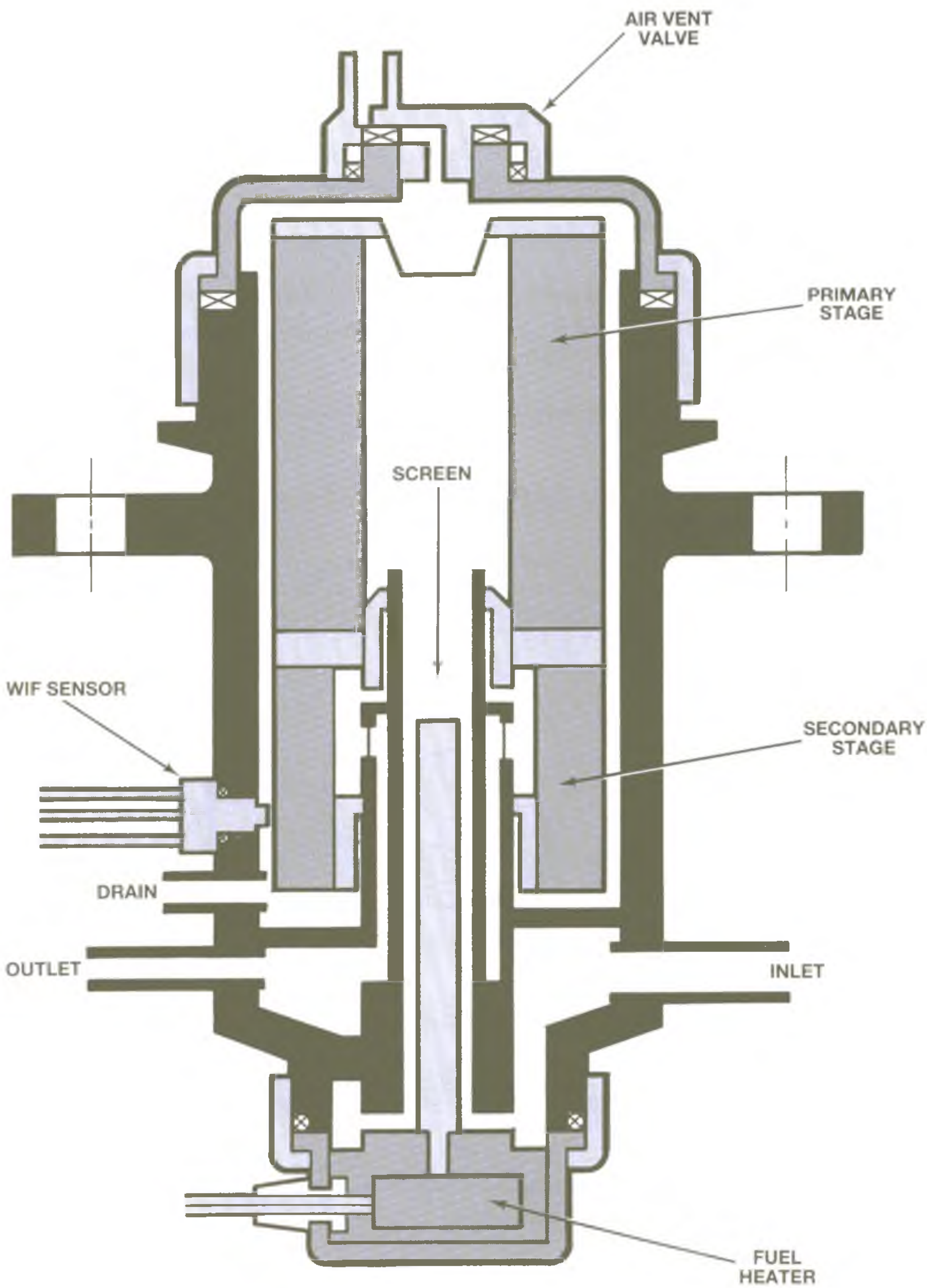


Figure 7-13, Fuel Filter Section View

Operation

The fuel filter element separates particles larger than 10 microns (0.00039-in.) from fuel moving through it under lift pump pressure (see Figure 7-14). Filter action is very critical to the operation of internal parts of the fuel injection pump, such as the transfer pump, rotor and automatic advance mechanism.

The path of fuel under lift pump pressure inside the fuel filter assembly is as follows (refer to Figure 7-15):

- From the inlet fitting into the bottom of the housing
- Past the fuel heater element to the primary stage of the filter element
- Through the primary filter element (from the inside to the outside) to the secondary filter element
- Through the secondary filter element (from the outside to the inside) to the screen
- Through the screen to the outlet fitting
- From the fuel filter outlet fitting to the transfer pump inside the fuel injection pump

The 6.5L V8 turbo diesel engine does not use a sensor to detect excessive filter element restriction, and no instrument cluster-mounted CHANGE FILTER lamp exists.

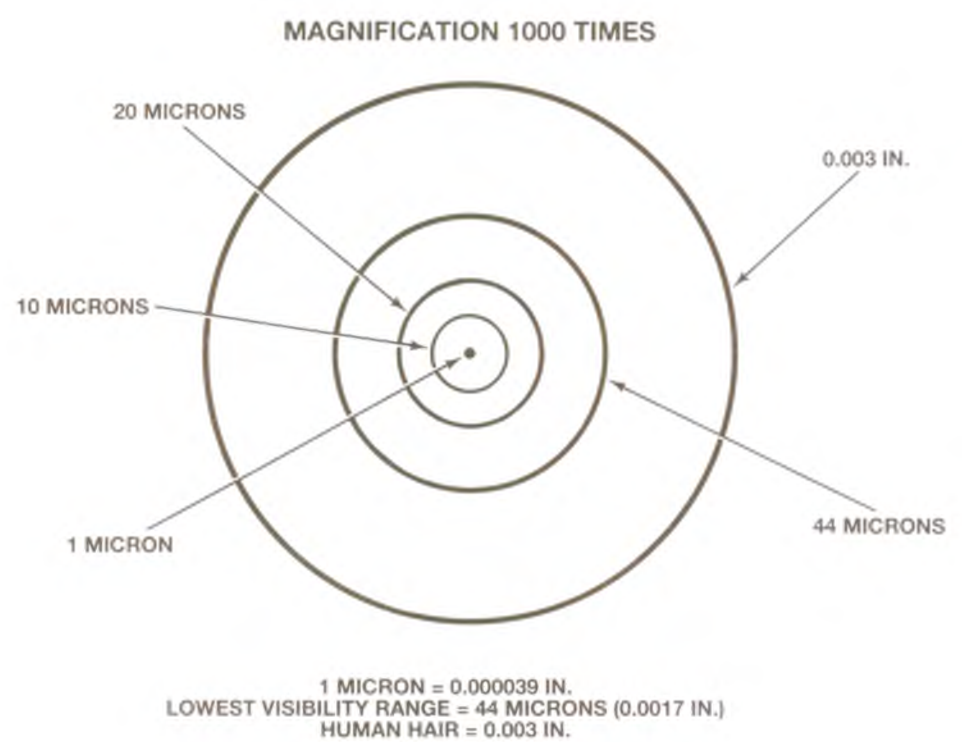


Figure 7-14, Relative Size of Micron Particles

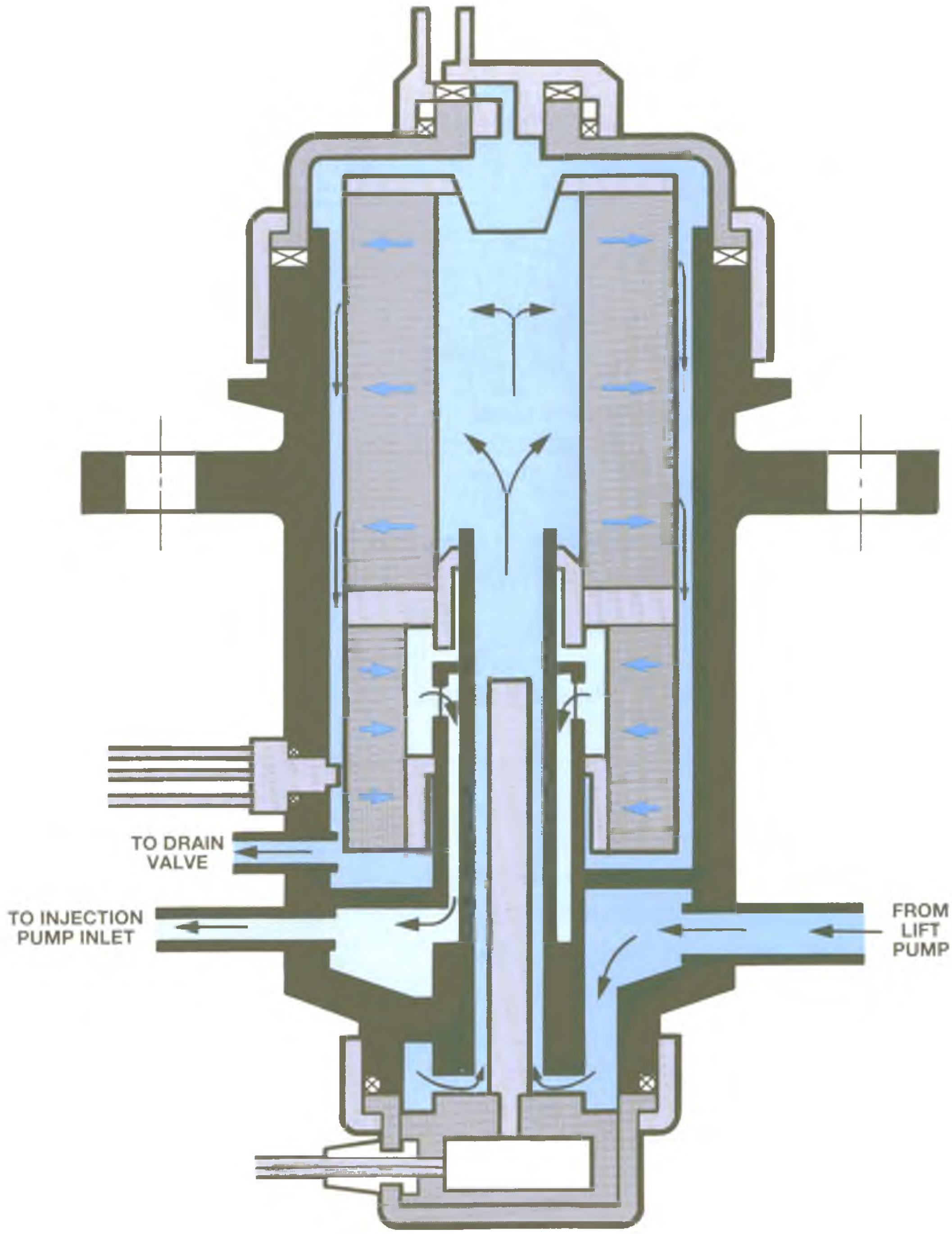


Figure 7-15, Fuel Flow Through Filter

Figure 7-16 shows the flow of fuel into and out of the fuel filter, as well as from the transfer pump inside the fuel injection pump to various components. The pressure, volume and quality of the fuel exiting the fuel filter has a major effect on the performance of the injection pump.

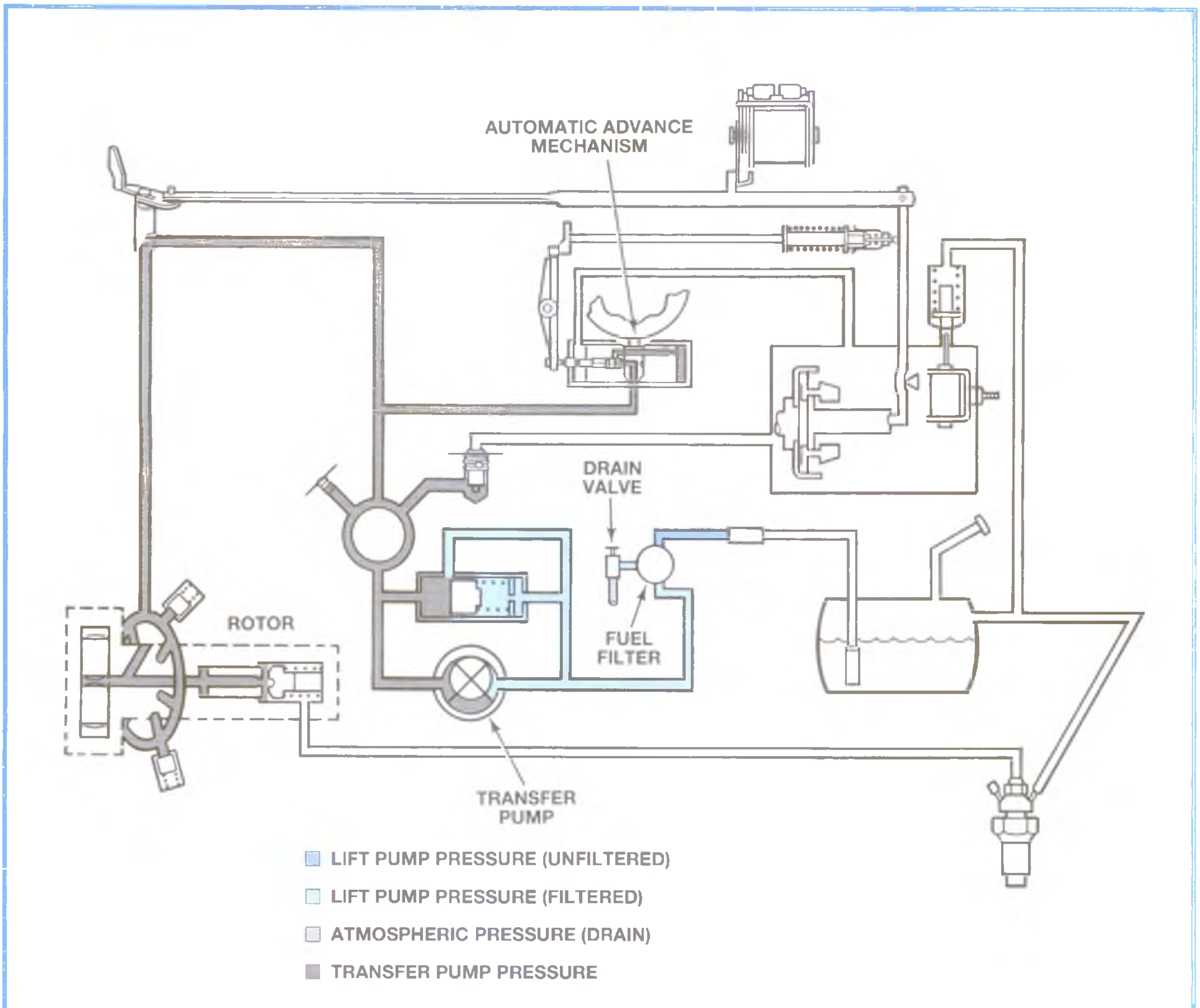


Figure 7-16, **Fuel System Diagram – Fuel Filter Flow**

The design of the filter element includes a coalescent area that allows water droplets (as small as one micron) to separate from the fuel and collect in a lower portion of the housing (see Figure 7-17). The WIF sensor has a capacitive probe controlled by an electronic ciruit inside the sensor that allows it to detect a certain amount of water in the fuel inside the filter housing and then complete the SERVICE FUEL FILTER warning lamp circuit in the instrument cluster to alert the driver. The vehicle owner's manual directs the driver to drain the filter when this condition occurs.

When the ignition switch is first turned to the RUN position, the WIF sensor will complete the SERVICE FUEL FILTER lamp circuit for 2 to 5 seconds. This action provides a bulb check for the vehicle driver.

See page 8-35 for information about the WIF sensor electrical circuit.

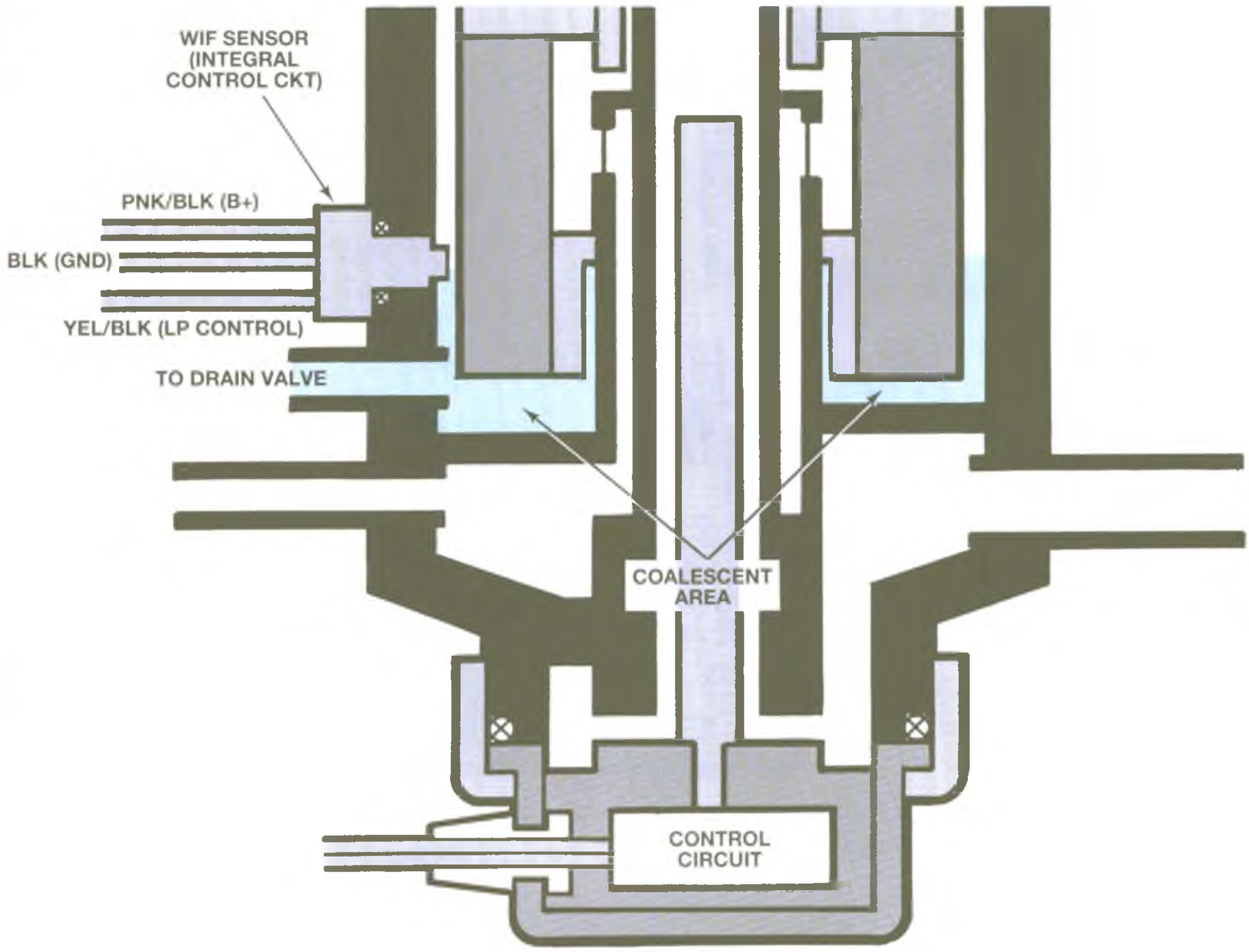


Figure 7-17, **Fuel Filter Operation – Water Separation**

The heater portion of the fuel filter assembly operates when the temperature of fuel at the inlet of the filter housing is cold enough to possibly cause waxing that could restrict flow to the injection pump (see Figure 7-18). A control circuit inside the fuel heater completes the circuit for the heater element when it senses a temperature below 46° F (8° C).

See page 8-34 for more information about the fuel heater circuit.

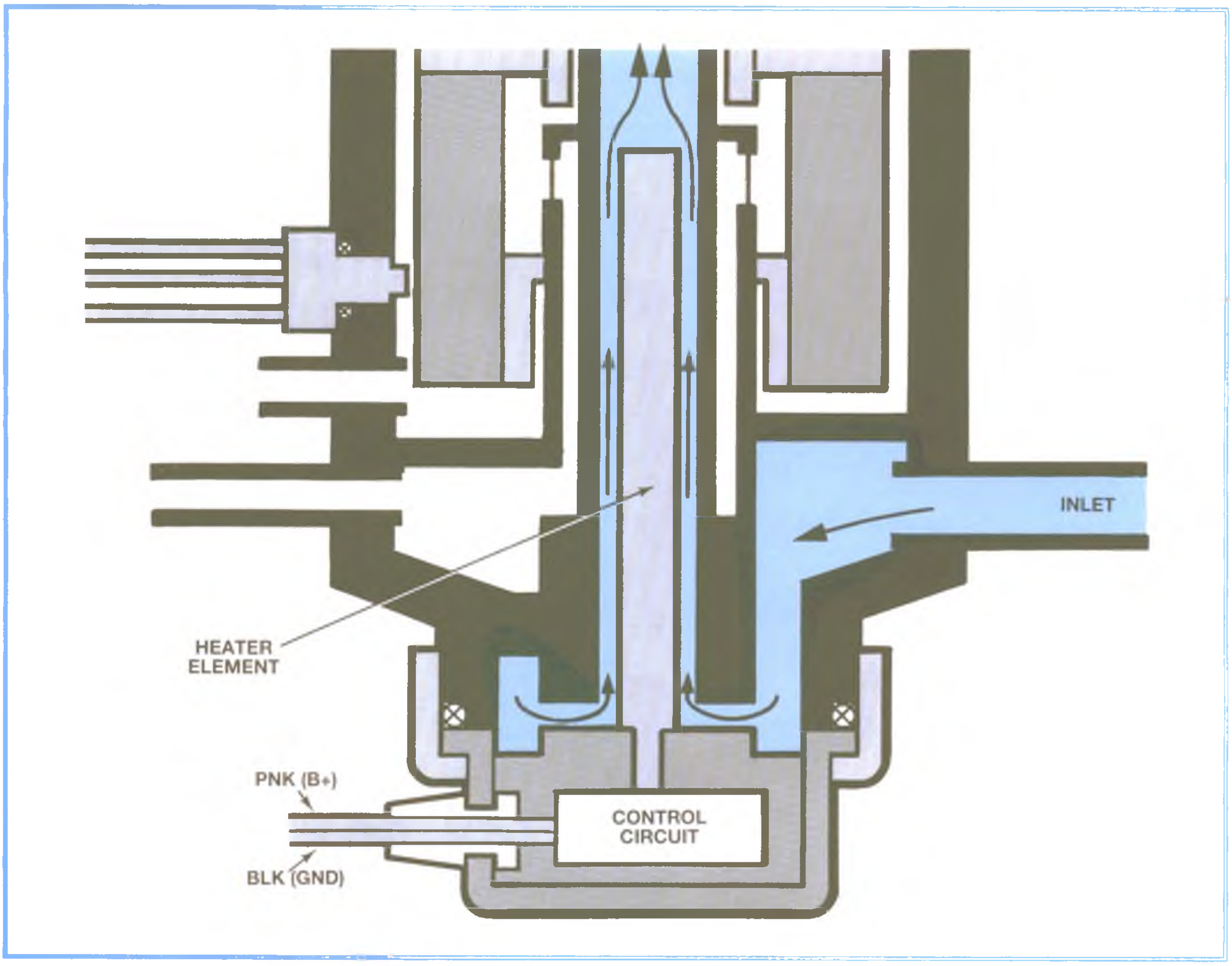


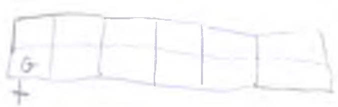
Figure 7-18, Fuel Filter Operation – Fuel Heater

Fuel Filter Assembly Service

FUEL FILTER ELEMENT REPLACEMENT

The fuel filter element has the following replacement steps:

1. Loosen the fuel tank filler cap to release pressure or vacuum.
2. Remove the threaded nut for the filter element from the filter housing, using hand pressure or a strap wrench.
3. Remove the filter element from the filter housing and clean the sealing surfaces.
4. Position and install the new filter element, using hand pressure to seat the sealing surfaces.
5. Install the threaded nut, tightening it with hand pressure.
6. Bleed air from the filter housing in these steps:
   - Open the air vent valve on the top of the filter element.
   - Position a shop towel under the filter housing.
   - Disconnect the fuel shut-off solenoid B+ wire (pink) from the injection pump.
   - Crank the engine for 10 to 15 seconds to fill the filter housing with fuel (if necessary, wait one minute and crank the engine again).
   - When clear fuel exits the air bleed valve, close it and wipe any spilled fuel from both the filter housing and the engine.
   - Connect the injection pump fuel shut-off solenoid B+ wire.
7. Start the engine, allow it to run for five minutes and check for fuel leaks.



WIF SENSOR DIAGNOSIS AND REPLACEMENT

The WIF sensor has a diagnosis procedure related to the WATER IN FUEL warning, alerting the vehicle driver. When this occurs, use the following procedure:

1. Drain the fuel filter housing by doing these things:
   - Stop the engine.
   - Place a container under the drain valve exit hose at the left front side of the engine.
   - Open the drain valve.
   - Start the engine and operate it at operating speed until clear fuel appears at the drain valve exit hose.
   - Close the drain valve.
2. Observe the WATER IN FUEL warning lamp:
   - If it is OFF, end the diagnosis.
   - If it is ON, do the following things:
     - Remove the fuel tank filler cap to release pressure or vacuum.
     - Remove the two fuel filter assembly mounting bolts.
     - Separate the electrical connector for the WIF sensor.
     - Remove the WIF sensor mounting screws, and pull the sensor from the filter housing.
     - Wipe the tip of the WIF sensor to remove water.
     - Install the WIF sensor (with a new O-ring seal) and mounting screws.
     - Attach the WIF sensor electrical connector.
     - Install the two fuel filter assembly mounting bolts.
     - Install the fuel tank filler cap.
     - Follow the filter housing air bleeding procedure (page 7-19, steps 6 and 7).
3. Once again, observe the WATER IN FUEL warning lamp:
   - If it is OFF, end the diagnosis.
   - If it is ON, follow the WIF sensor replacement procedure in Step 2.

FUEL HEATER DIAGNOSIS AND REPLACEMENT

The fuel heater has the following diagnosis and replacement procedure:

1. Remove the fuel tank filler cap to release pressure or vacuum.
2. Remove the two fuel filter assembly mounting bolts.
3. Separate the inlet, outlet and drain hoses from filter housing fittings and cap both the hose and fitting ends.
4. Separate the electrical connectors for the WIF sensor and fuel heater.
5. At a workbench, remove the fuel heater threaded nut, using hand pressure or a strap wrench.
6. Remove the fuel heater from the filter housing and clean the sealing surfaces.
7. With the fuel heater at 70° F (21° C), connect its B+ and ground wires to a 12-volt battery.
8. Observe the heating element (no heating should occur).
9. Cool the sensor part of the fuel heater, using ice.
10. With the fuel heater below 46° F (8° C), wet its heating element with fuel and connect its B+ and ground wires to a 12-volt battery for 30 seconds.
11. Observe the heating element (heating should occur).

Note: If heating does not occur, replace the fuel heater.

12. Install the fuel heater (with a new O-ring seal) in the filter housing.
13. Install the threaded nut for the fuel heater, using hand pressure.
14. Attach the WIF sensor and fuel heater electrical connectors.
15. Remove the fitting and hose end caps and install the inlet, outlet and drain hoses on the filter housing.
16. Install the two fuel filter assembly mounting bolts.
17. Install the fuel tank filler cap.
18. Follow the filter housing air bleeding procedure (page 7-19, steps 6 and 7).

Fuel Injection Pump Assembly

Injection Pump Mounting and Drive

The fuel injection pump assembly mounts on the rear of the front cover, using a pilot bore, three stud/nut fasteners and a gasket. The injection pump mounting flange has a timing mark that aligns with a timing mark on the front cover during the installation procedure (see Figure 7-19, view A).

The injection pump drive gear is held on the front of the camshaft with a bolt and alignment dowel, and rotates a driven gear with a 1:1 ratio. The drive and driven gears have alignment marks for installation to assure correct timing (see Figure 7-19, view B).

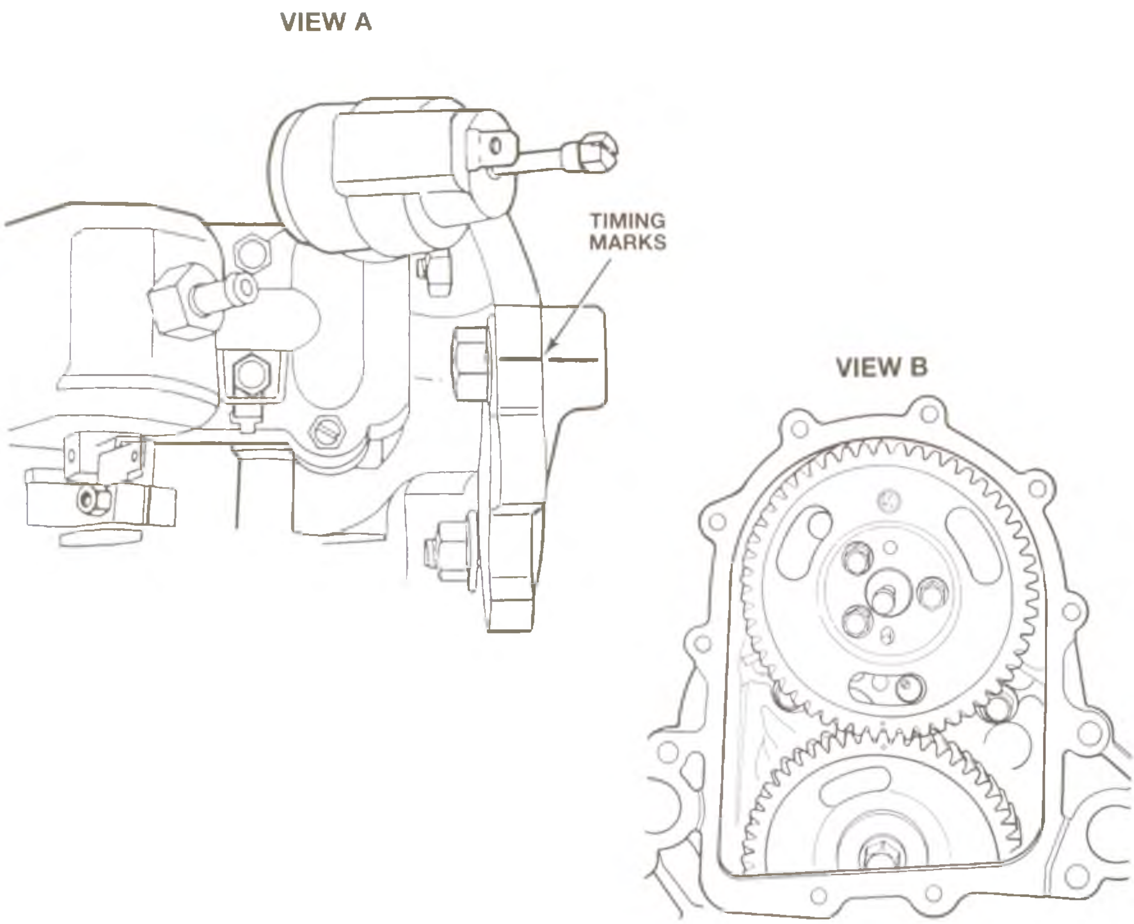


Figure 7-19, **Injection Pump Mounting and Drive (1)**

The fuel injection pump driven gear mounts on the injection pump drive shaft flange, using a pilot bore, an alignment dowel and three bolts coated with thread-locking compound. The injection pump drive shaft has a center bore that allows a spring-loaded plunger to contact a metal finger on the back side of the water pump plate (see Figure 7-20, view A).

Because the gears use teeth cut in a helical pattern, end-play causes changes in fuel injection timing. The spring-loaded plunger provides thrust force on the injection pump drive shaft to control the end-play of internal parts. It also keeps the timing between the drive and driven gears from changing as the result of driven gear endwise movement.

During injection pump replacement, access to the three driven gear mounting bolts is possible after the oil fill pipe and grommet are removed (see Figure 7-20, view B). The crankshaft must be rotated for access to each of the bolts.

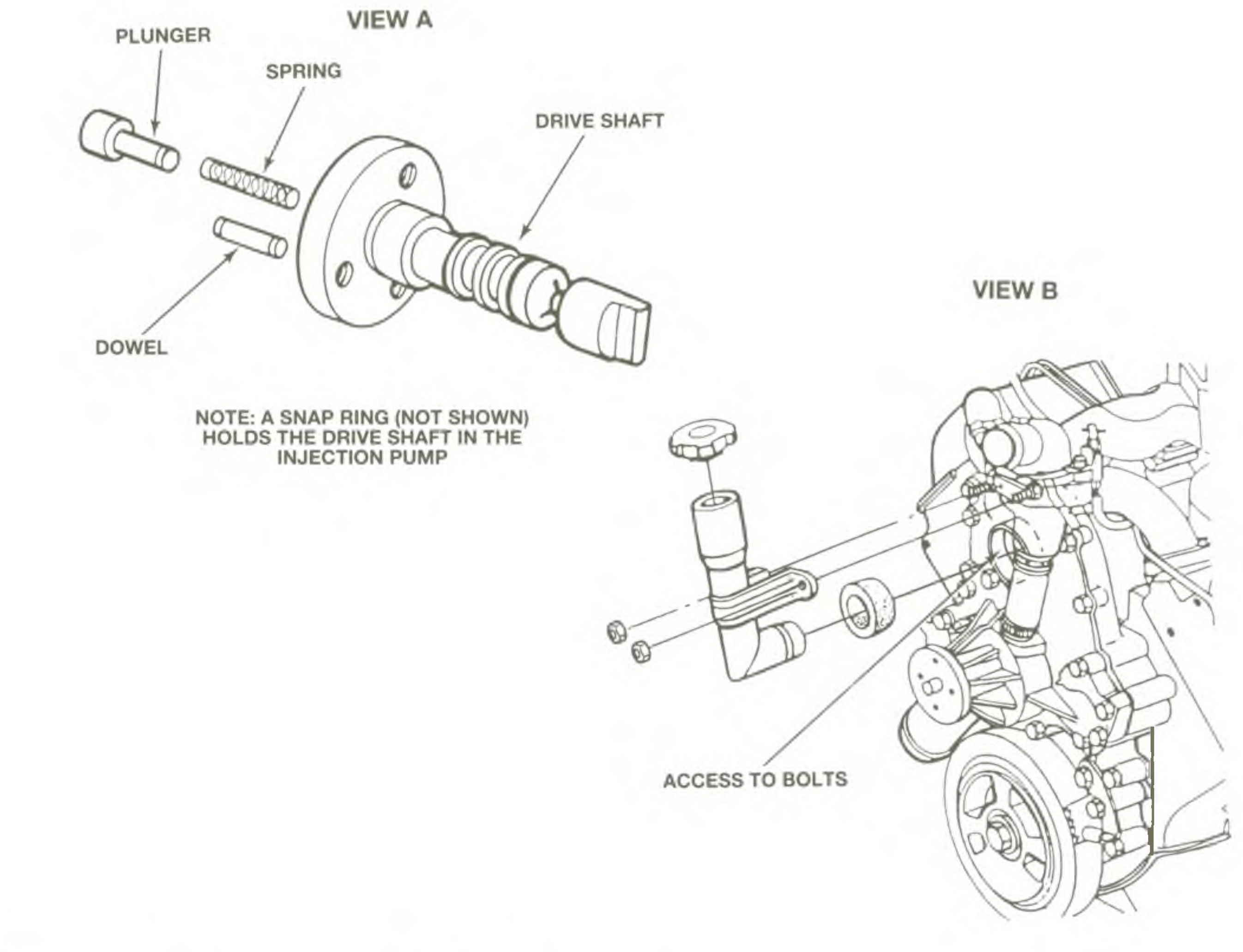


Figure 7-20, **Injection Pump Mounting and Drive (2)**

Injection Pump External Linkage

The fuel injection pump has an external bracket that supports the throttle cable assembly (see Figure 7-21, view A). The throttle cable attaches to the injection pump throttle shaft and connects with the accelerator pedal in the passenger compartment. Vehicles equipped with cruise control have a similar cable attachment to the injection pump.

The injection pump throttle shaft has a full-throttle stop screw that is pre-adjusted during calibration, as well as an idle speed screw that provides adjustment during service (see Figure 7-21, view B). A throttle return spring fastened between the bracket and injection pump keeps the throttle shaft in a closed position for engine idling.

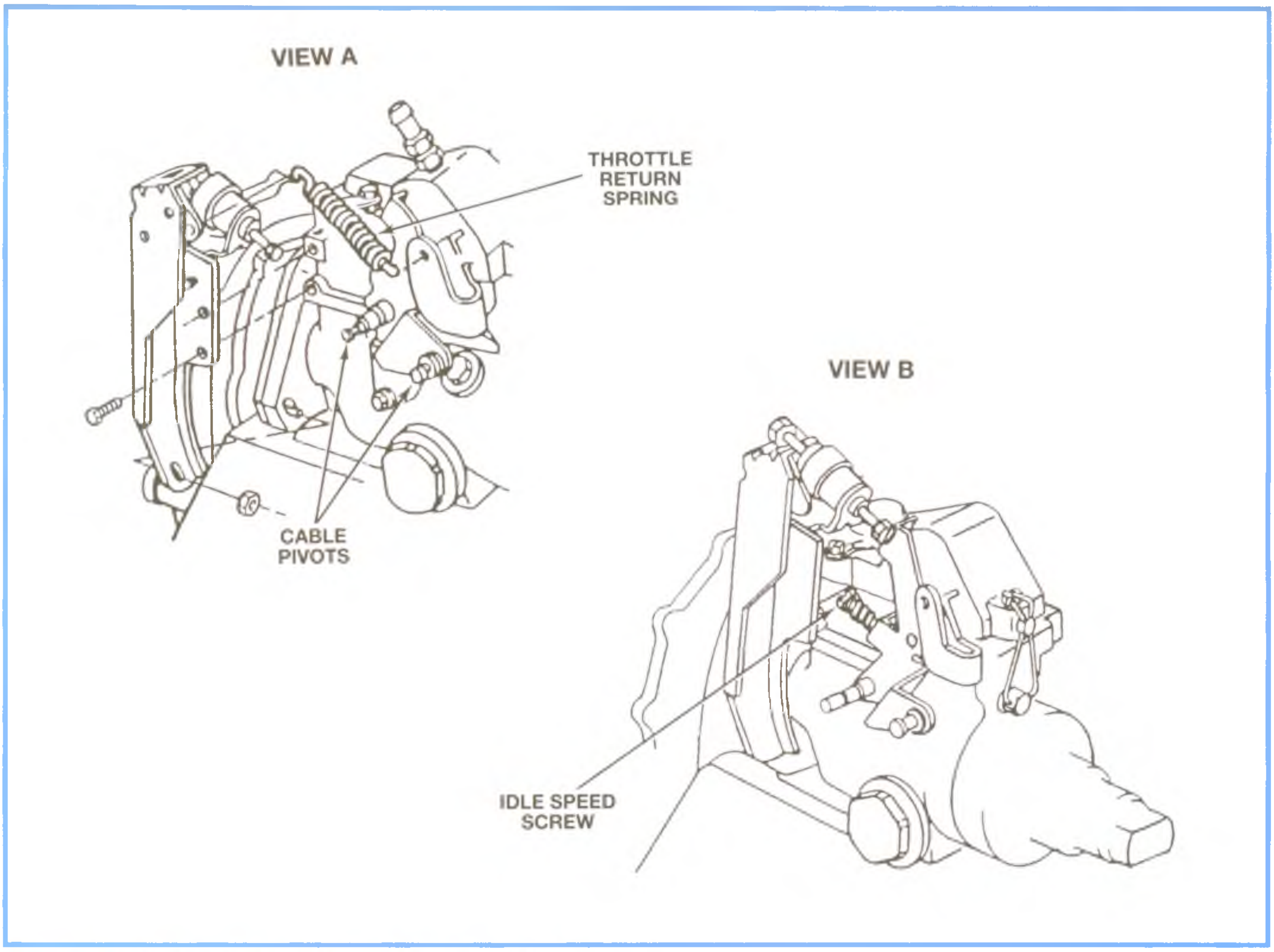


Figure 7-21, **Injection Pump External Linkage**

Injection Pump Electrical Connections

The fuel injection pump has electrical connectors for four devices. The top of the injection pump (called the governor cover) contains an internal fuel shut-off solenoid with a B+ terminal that receives power when the ignition switch is in either the START or RUN position (see Figure 7-22). The shut-off solenoid ground is provided through the injection pump housing mounting to the engine.

Another electrical control inside the injection pump governor cover is the Housing Pressure Cold Advance (HPCA) solenoid. Like the shut-off solenoid, it has a B+ terminal and ground connection through the housing.

A third control, the fast idle solenoid, mounts on the external bracket, aligns with the throttle shaft and has a single B+ terminal. The fourth electrical device is the Throttle Position Sensor (TPS), an input to the Transmission Control Module (TCM).

Refer to Section 8 for more information about these electrical circuits.

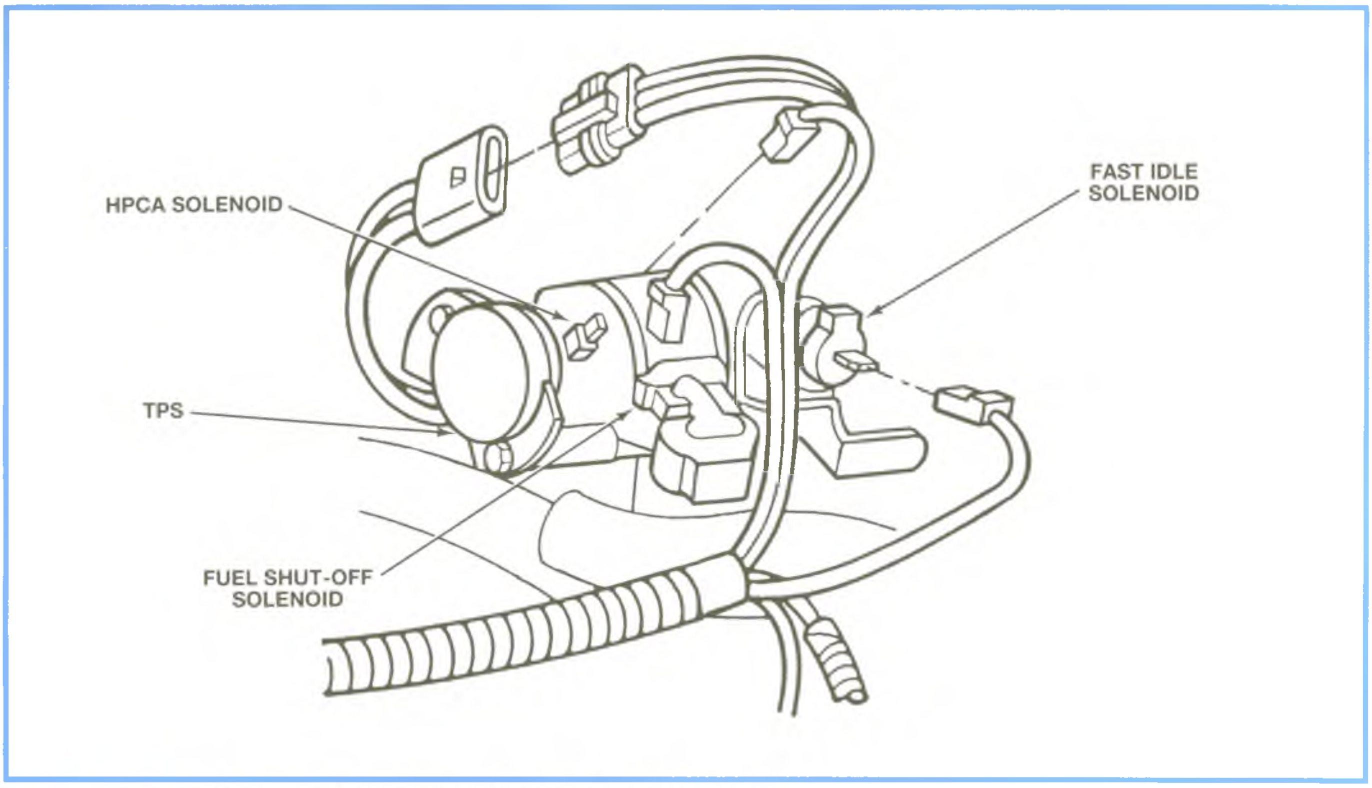


Figure 7-22, **Injection Pump Electrical Connections**

Injection Pump Fuel System Connections

The fuel injection pump has a fitting on its transfer pump end cap for the hose from the fuel filter assembly. Fuel under lift pump pressure enters the injection pump at this location.

The governor cover of the injection pump has a fitting at its housing pressure regulator for a hose connecting to the fuel return system (see Figure 7-23, view A). The return system sends fuel heated by internal part movement inside the injection pump and injection nozzles to the fuel tank.

The injection pump head assembly has eight high-pressure outlet fittings for the lines connecting to nozzles in the cylinders (see Figure 7-23, view B). Each fitting connects with a specific cylinder.

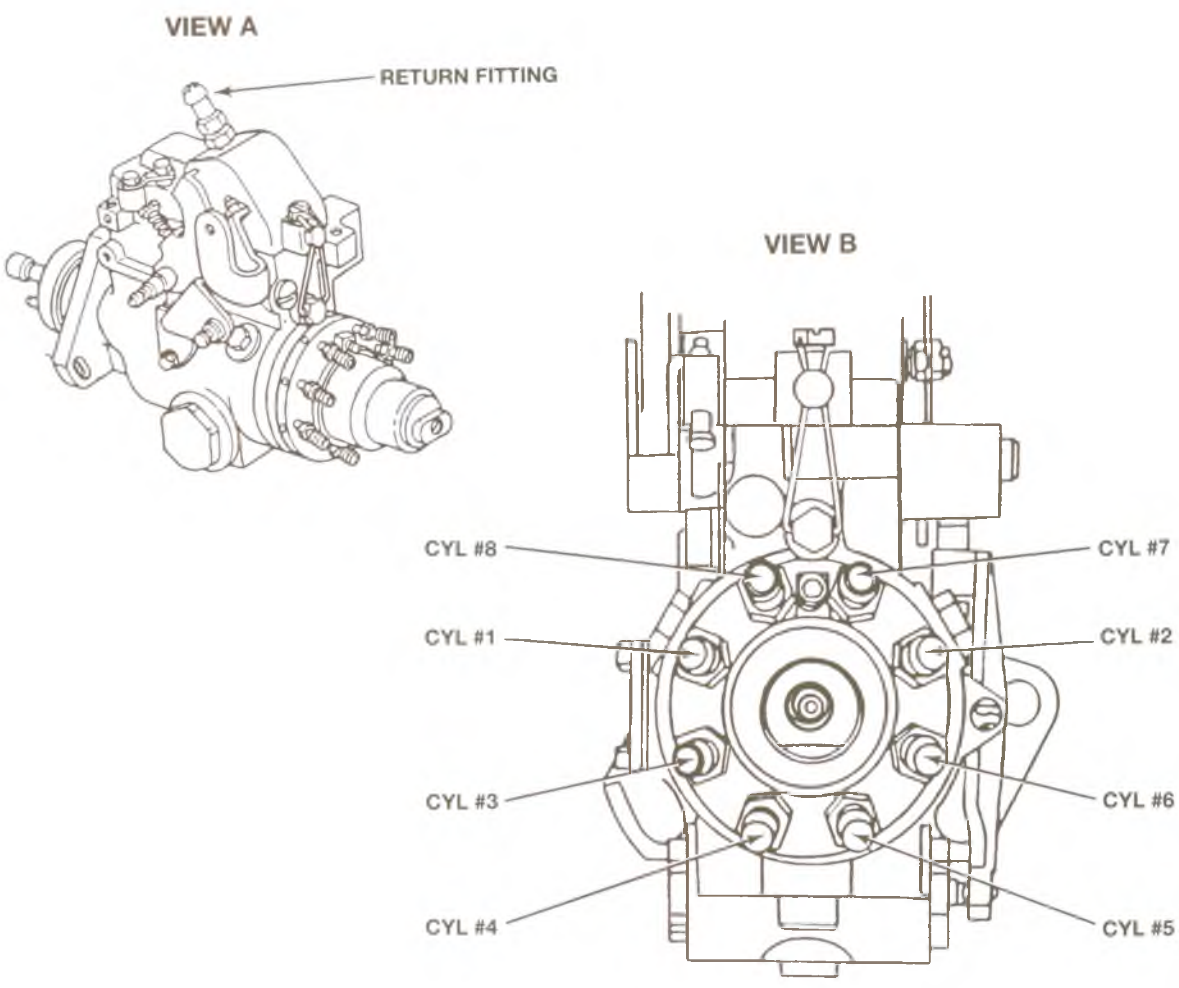


Figure 7-23, Injection Pump Fuel System Connections

Injection Pump Construction

The fuel injection pump pressurizes and distributes a metered amount of fuel to each cylinder nozzle at the proper time, based on the calibrated needs of the engine. The injection pump uses a variety of internal components that require lubrication from the very highly filtered fuel flowing around them (refer to Figure 7-24).

Some parts have surfaces with machining tolerances measured in microns (millionths of an inch) and require handling by skilled technicians operating in a "clean room" environment with a ventilation system using temperature, humidity and dust control. Other internal injection pump parts have adjustments that are made during a calibration procedure with a special test stand. **For these reasons, very few repairs are made by dealership service technicians.**

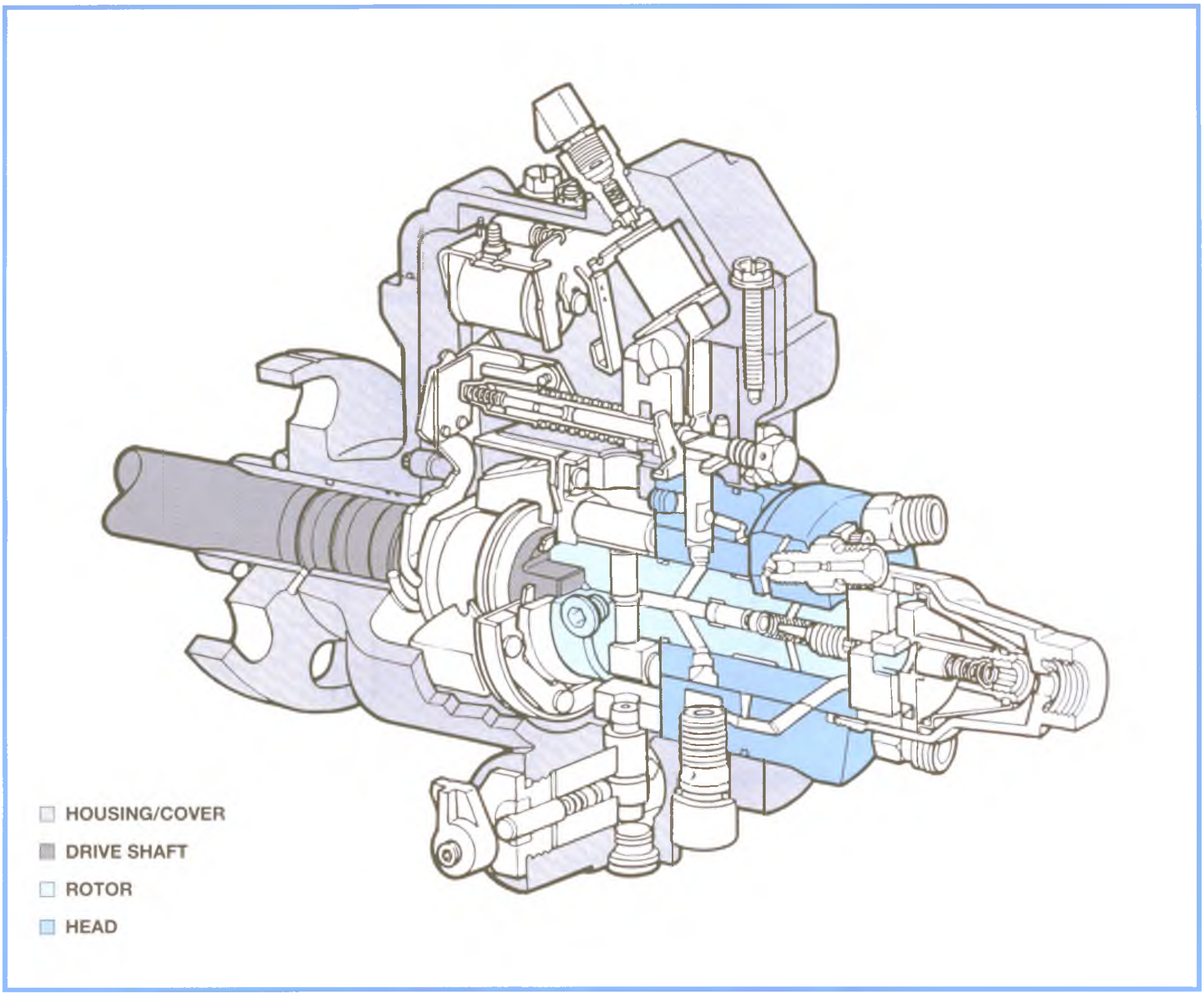


Figure 7-24, **Injection Pump Cutaway View – Major Parts**

Injection Pump Operation

The operation of the fuel injection pump has four functions related to the delivery of fuel to the injection lines and nozzles:

- Metering
- Pressurization and distribution
- Lubricating
- Timing

The injection pump accomplishes its functions using fuel as a hydraulic fluid (refer to Figures 7-25 and 7-26). Several different pressures exist in the injection pump as it operates. During service, test gauges may be installed to diagnose the fuel system.

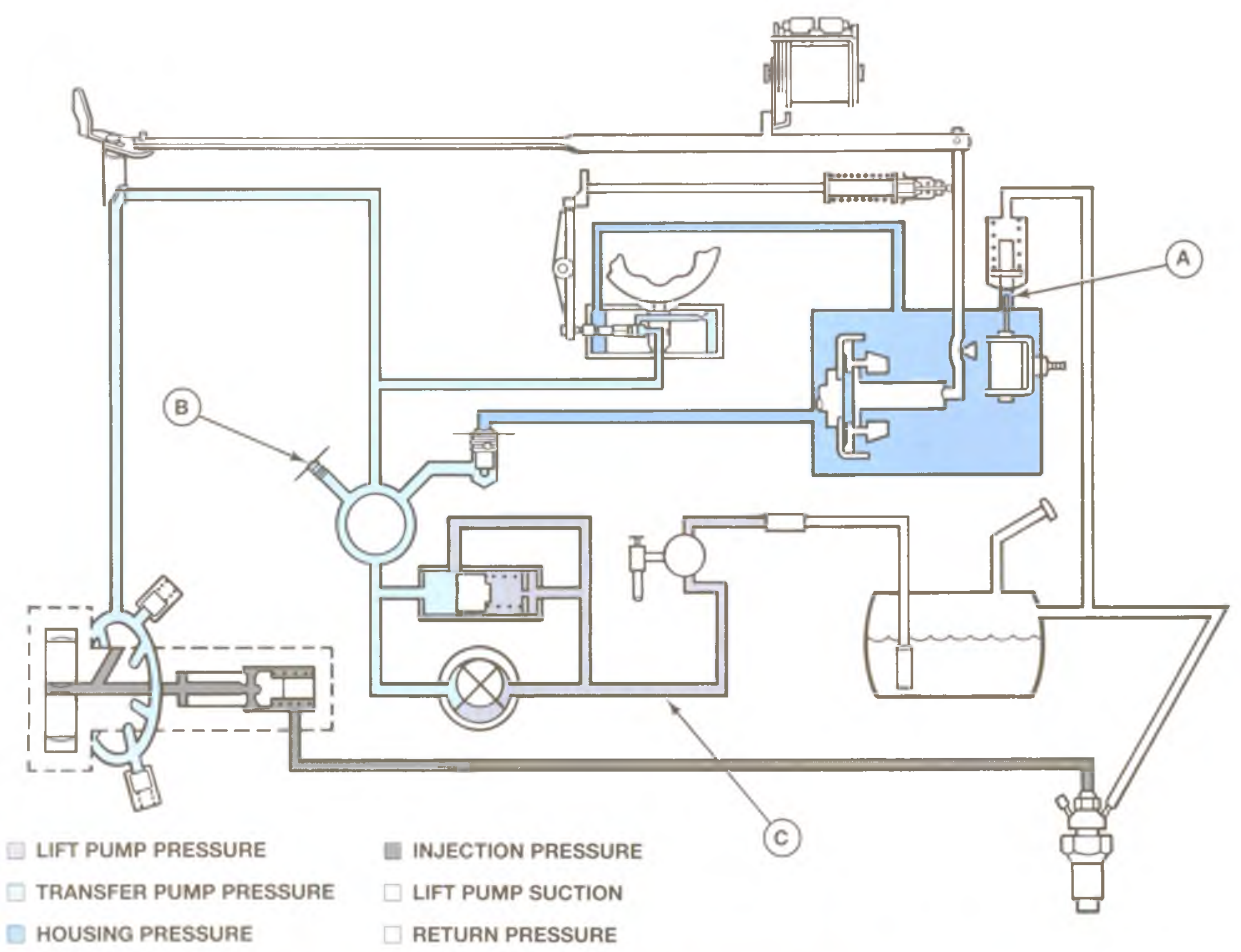


Figure 7-25, **Fuel System Diagram – Injection Pump Hydraulic Pressures**

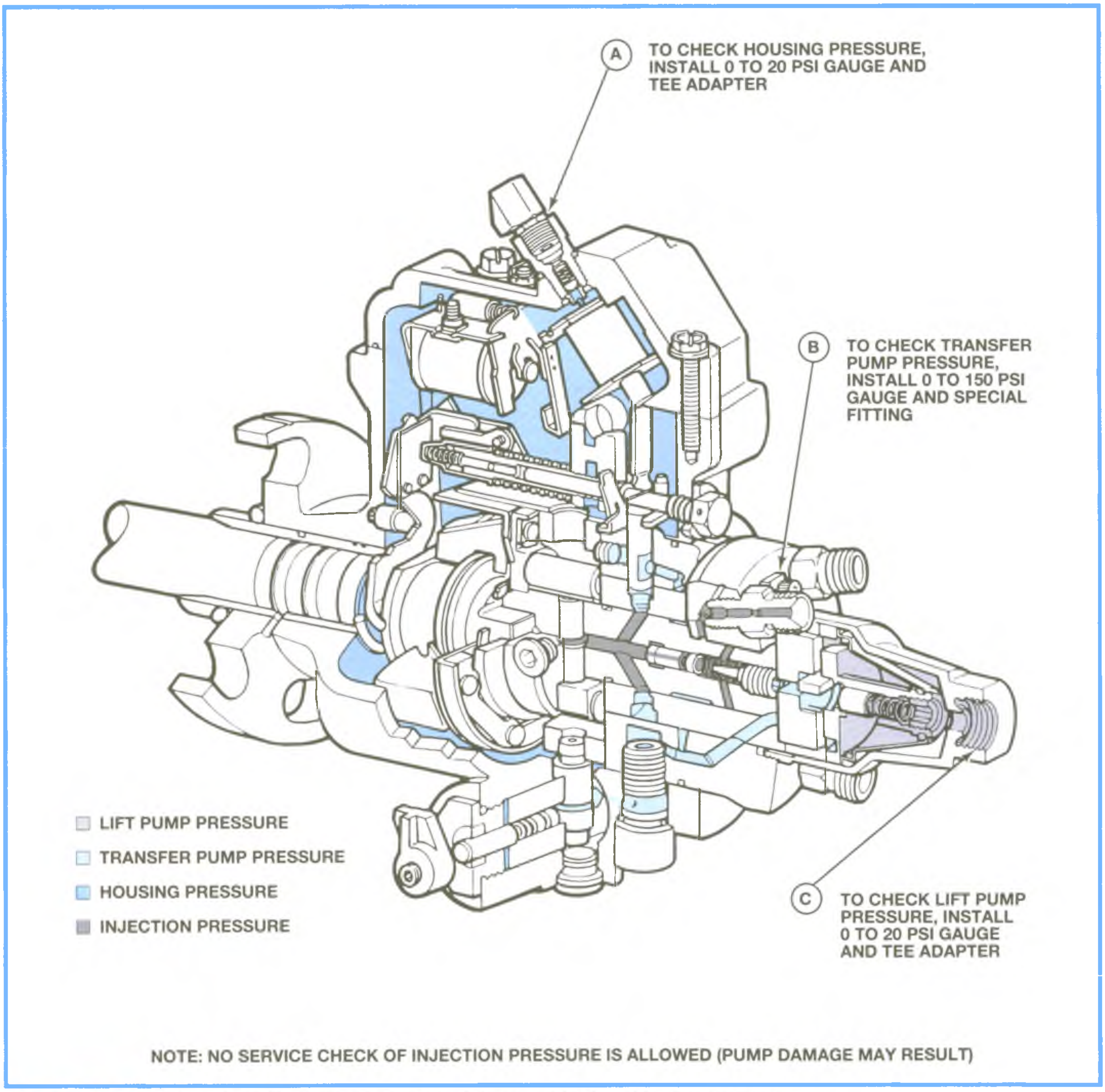


Figure 7-26, Injection Pump Cutaway View – Hydraulic Pressures

METERING

Fuel under lift pump pressure enters the inlet of the transfer pump (refer to Figures 7-27 and 7-28). The drive shaft rotates the rotor, which has slots in its end to operate the blades of the transfer pump inside a stationary cam ring.

The transfer pump varies the pressure of the fuel, depending on the speed of the engine. At idle, the transfer pump outlet pressure is approximately 20 to 30 psi. At full engine speed, the transfer pump outlet pressure may be over 100 psi.

A regulator valve controls the transfer pump outlet pressure and has an adjustment made during injection pump calibration.

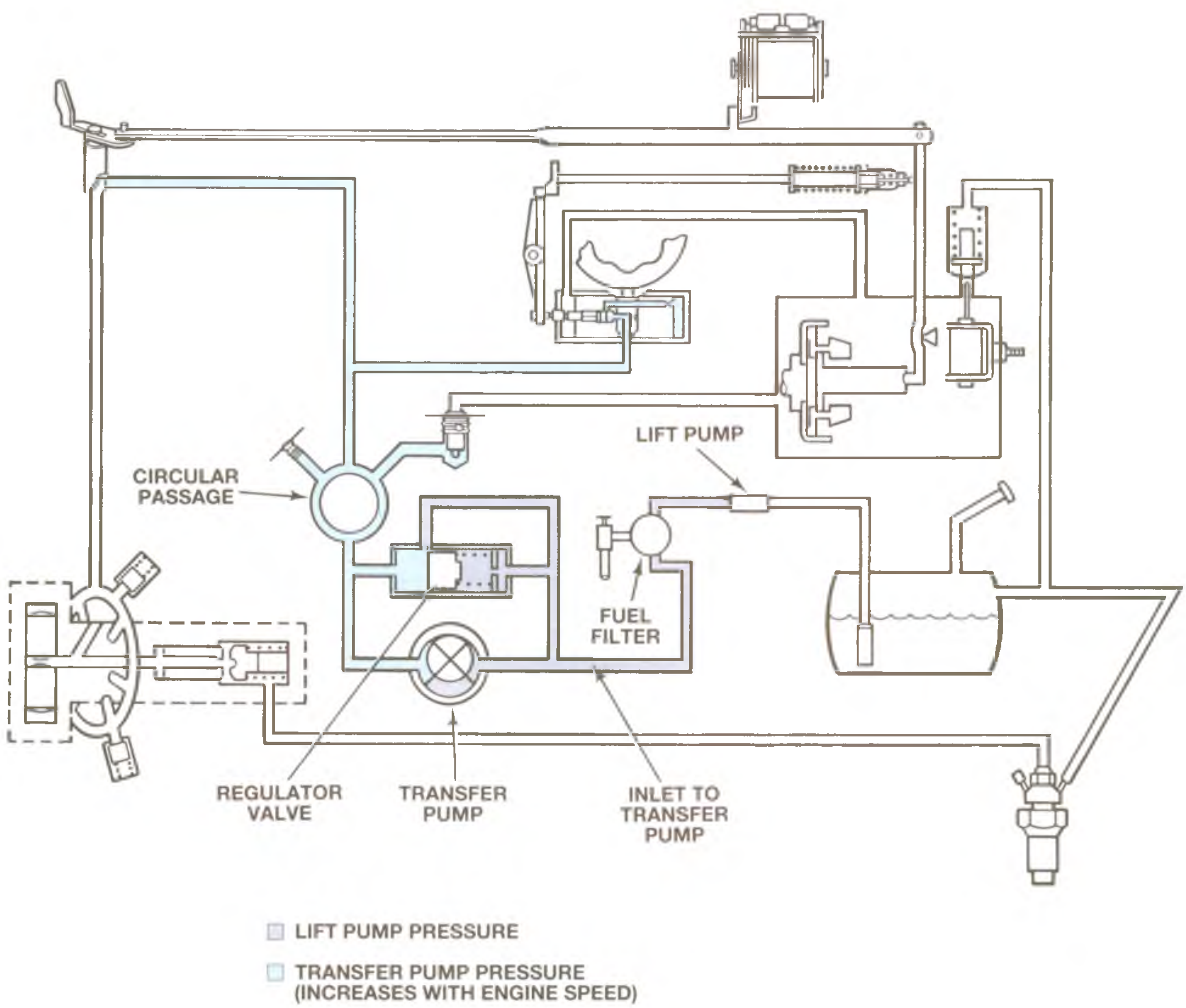


Figure 7-27, Fuel System Diagram – Transfer Pump Flow

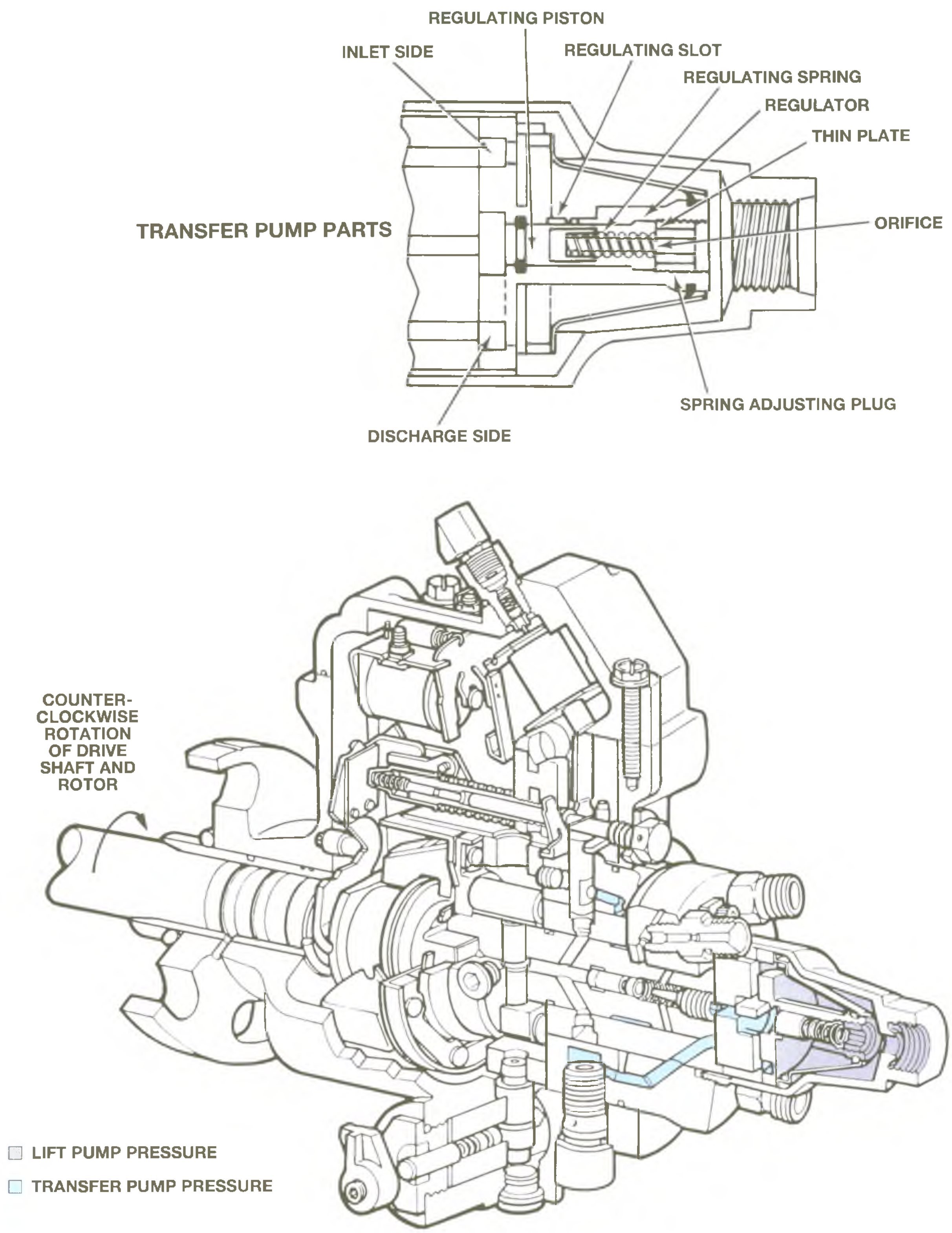


Figure 7-28, **Injection Pump Cutaway View – Transfer Pump Operation**

Fuel under transfer pump pressure travels through passages to several components, including a metering valve (refer to Figures 7-29 and 7-30). The metering valve directly affects the speed and power of the engine.

The metering valve controls how much fuel under transfer pump pressure enters a circular charging passage in the high-pressure part of the injection pump. When the valve rotates in a clockwise direction, less fuel enters the charging passage. As the valve rotates in a counterclockwise direction, more fuel enters the charging passage.

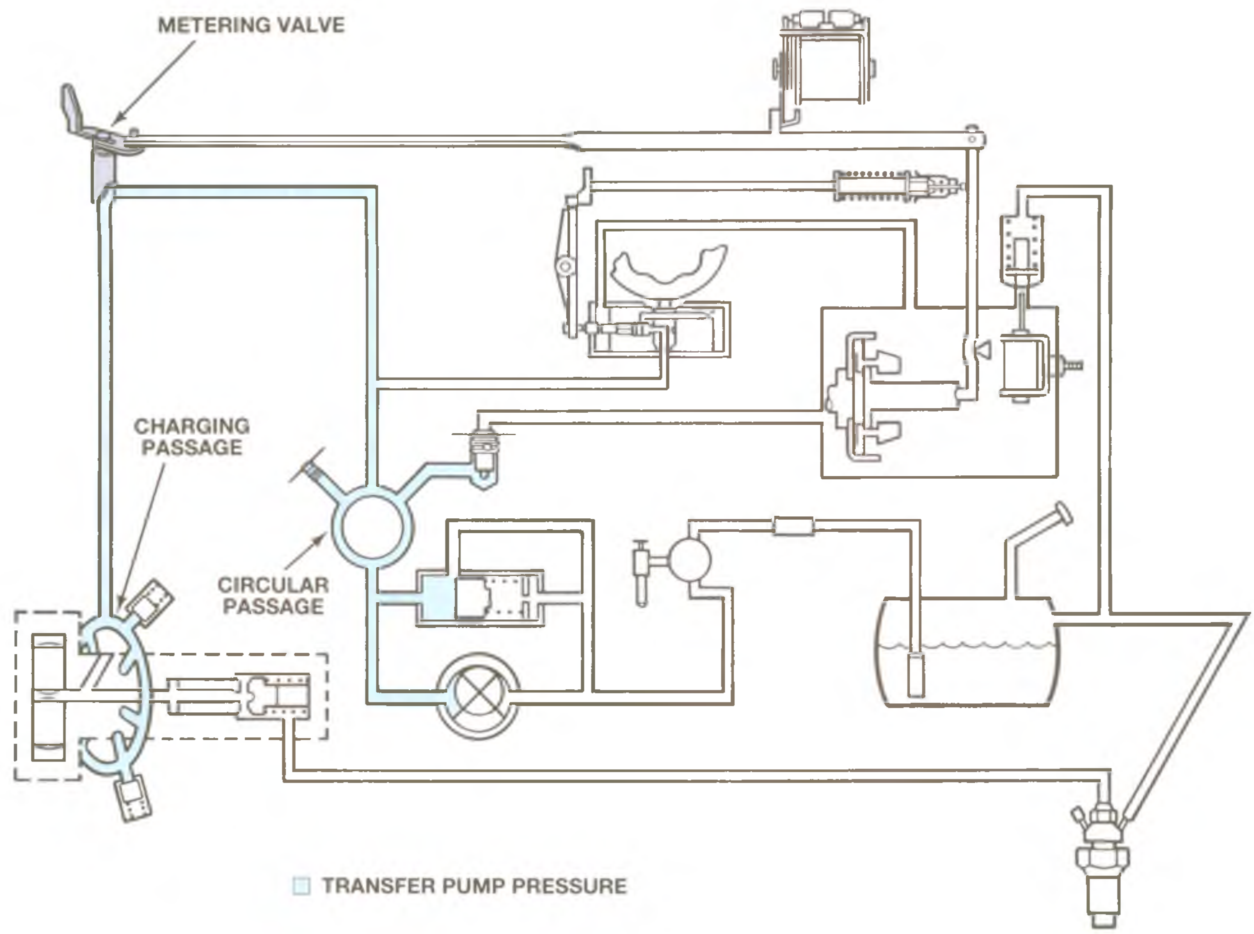


Figure 7-29, **Fuel System Diagram – Metering Valve Flow**

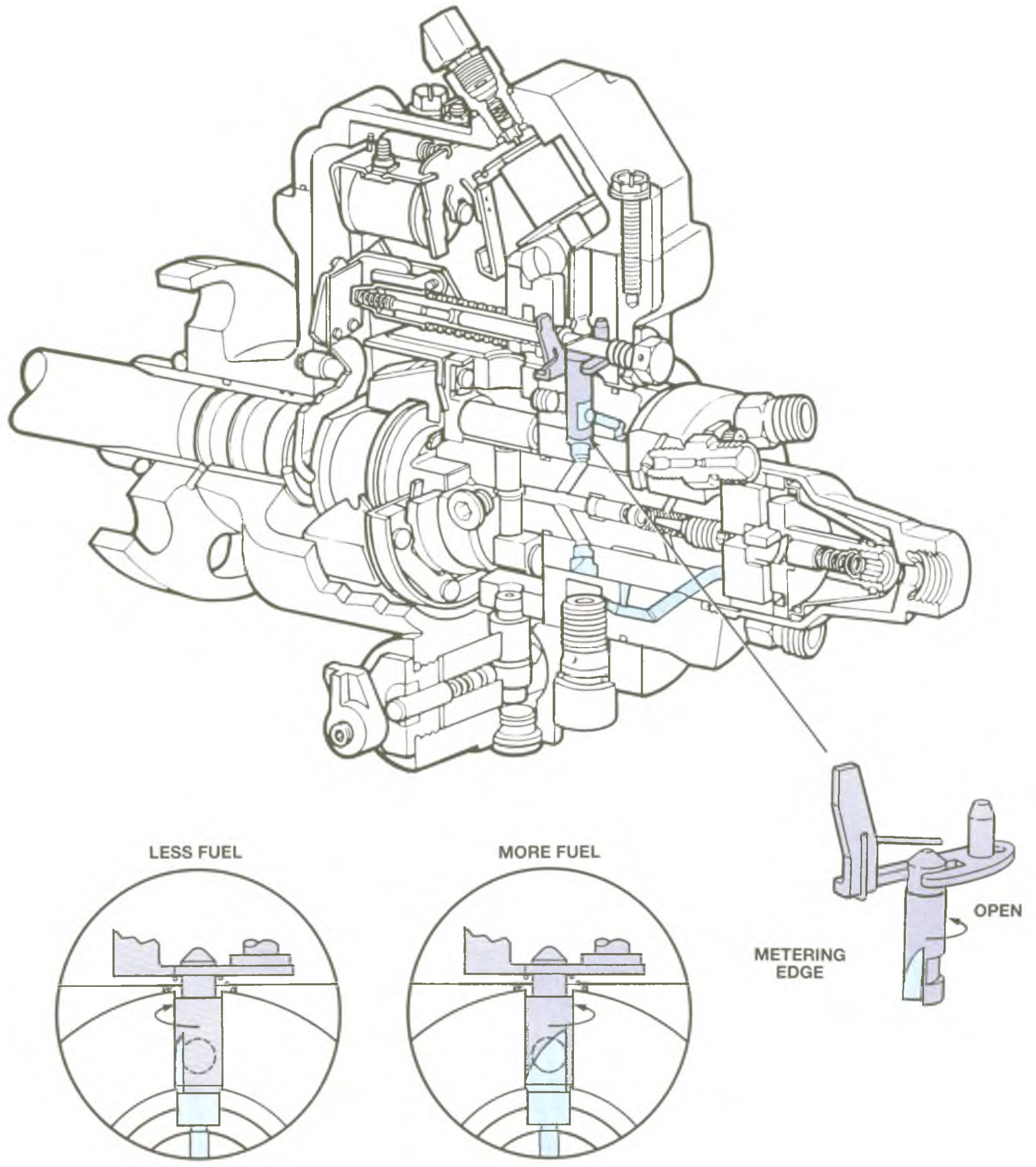


Figure 7-30, **Injection Pump Cutaway View – Metering Valve Operation**

A governor mechanism positions the metering valve by balancing the opposing forces of the throttle shaft position and the speed of the injection pump. The governor mechanism includes the following parts (refer to Figure 7-31):

- The metering valve
- Linkage connected to the metering valve (not shown)
- The governor arm, connected to the linkage and pivoting on a pin in the injection pump housing
- Two parts that contact the governor arm:
  - A governor weight assembly
  - A min-max governor assembly

The governor weight assembly has these parts:

- A weight retainer, mounted on the rotor and rotated by the drive shaft
- Six weights that pivot further outward as injection pump speed increases
- A governor sleeve that is moved by the action of the weights and in turn moves the bottom end of the governor arm

The min-max governor assembly has the parts shown in Figure 7-32, view A. It mounts in the injection pump housing by sliding on a guide stud and connects the throttle shaft to the upper end of the governor arm (see Figure 7-32, view B).

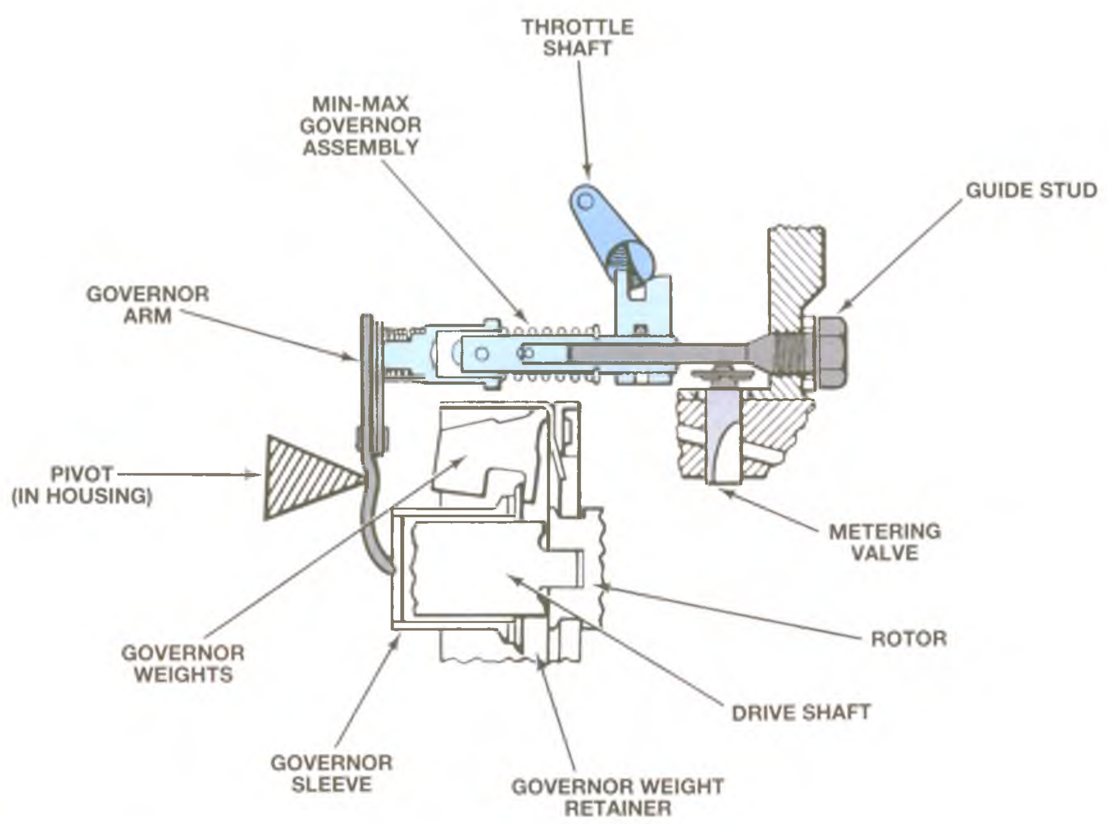


Figure 7-31, Governor Mechanism Parts

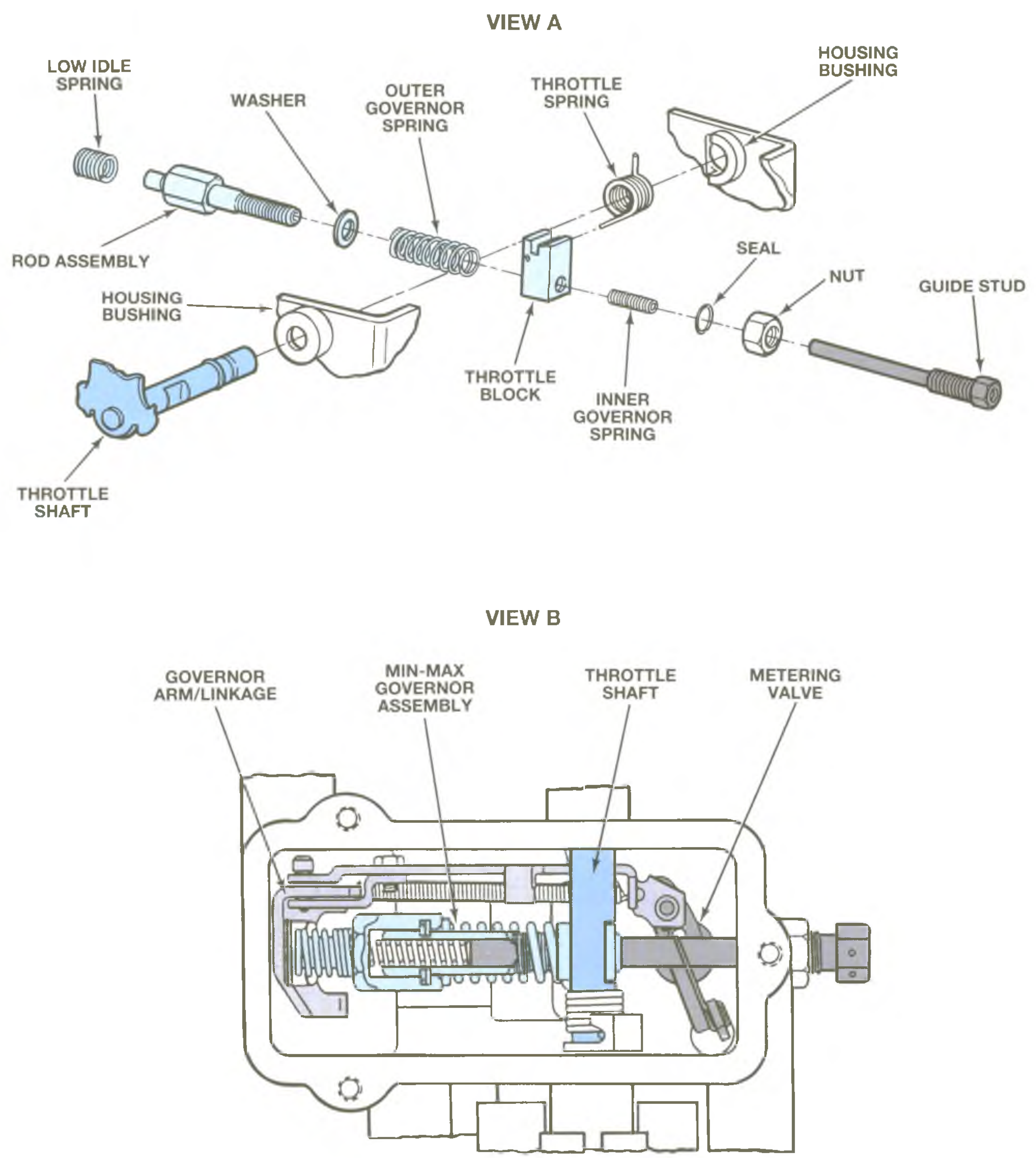


Figure 7-32, Min-Max Governor Assembly

The governor mechanism operates as follows (refer to Figures 7-33 and 7-34):

- A fuel shut-off solenoid contacts the metering valve linkage when it is OFF, blocking fuel from entering the charging passage and stopping engine operation.
- At any engine speed, the metering valve is positioned by opposing forces:
  - The throttle shaft position, acting on the governor arm/linkage with the min-max governor and the tension of its springs:
    - Low idle
    - Outer
    - Inner
  - The injection pump drive shaft speed, acting on the governor arm/linkage with force from the rotating weights and governor sleeve

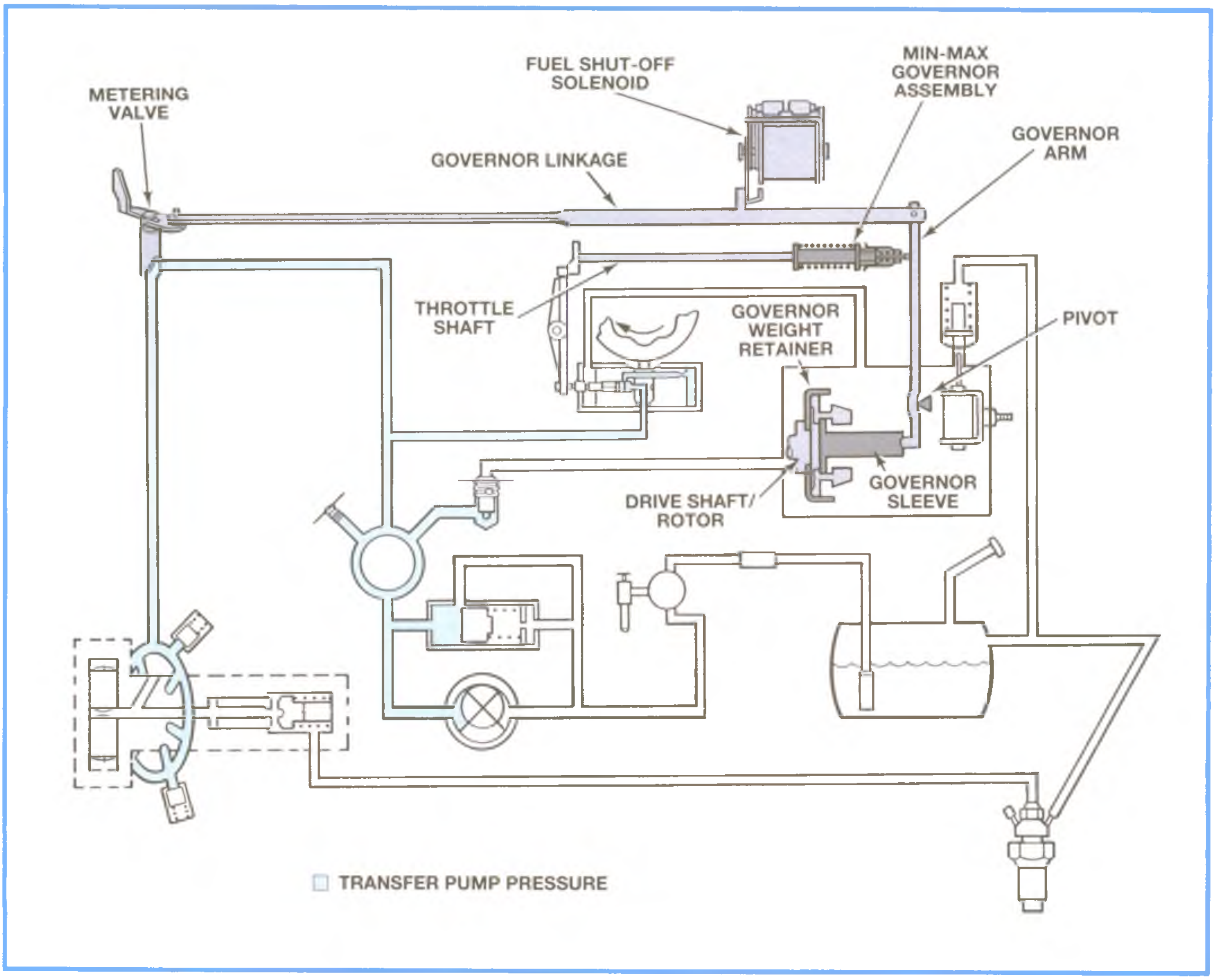


Figure 7-33, **Fuel System Diagram – Governor Mechanism Operation**

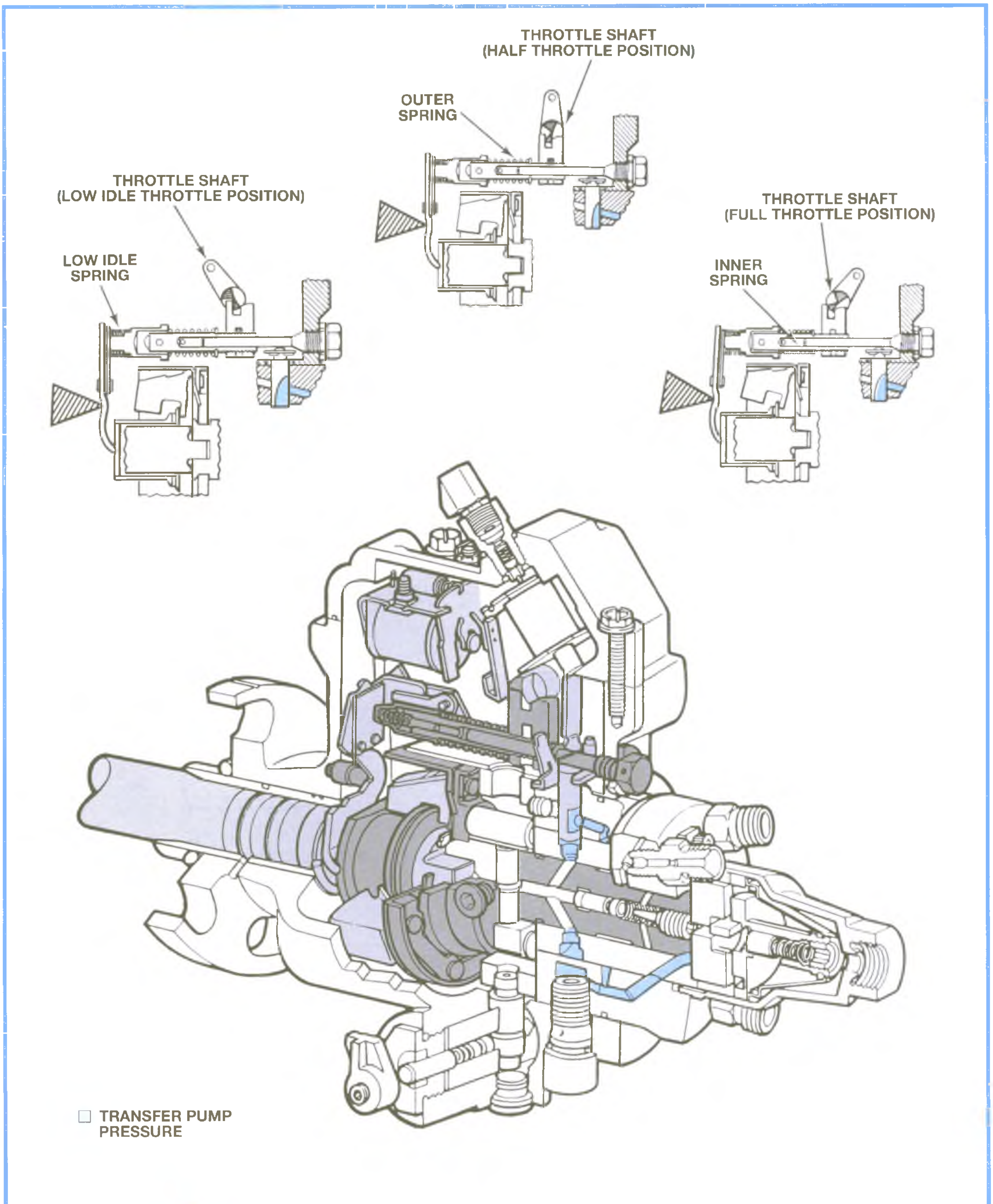


Figure 7-34, Injection Pump Cutaway View – Governor Mechanism Operation

PRESSURIZING AND DISTRIBUTING

The circular charging passage in the head of the injection pump has eight ports that align in pairs with the two ports of the rotor pumping chamber. Metered fuel under transfer pump pressure travels through the charging passage and enters the rotor, pushing two pumping plungers outward as it fills the chamber (refer to Figures 7-35 and 7-36). Two accumulators help maintain a consistent pressure in the charging passage.

Each pumping plunger contacts a shoe/roller assembly. The two shoe/roller assemblies contact the inner surface of a cam ring, which has eight lobes and valleys. During the charging of the pumping chamber, the valleys of the cam ring allow the pumping plungers and shoe/roller assemblies to move outward at a distance controlled by how much fuel fills the pumping chamber.

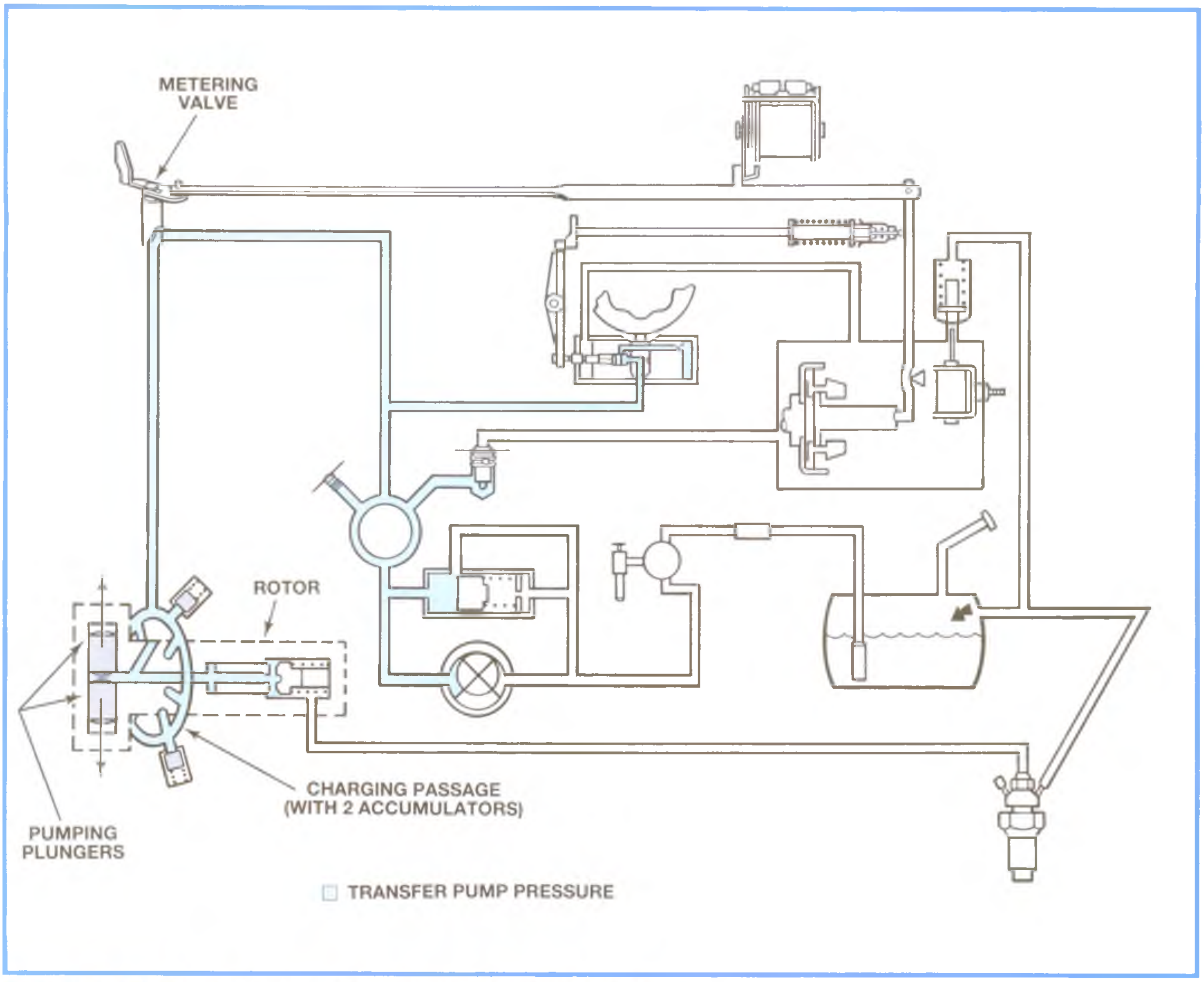


Figure 7-35, Fuel System Diagram – Charge Cycle

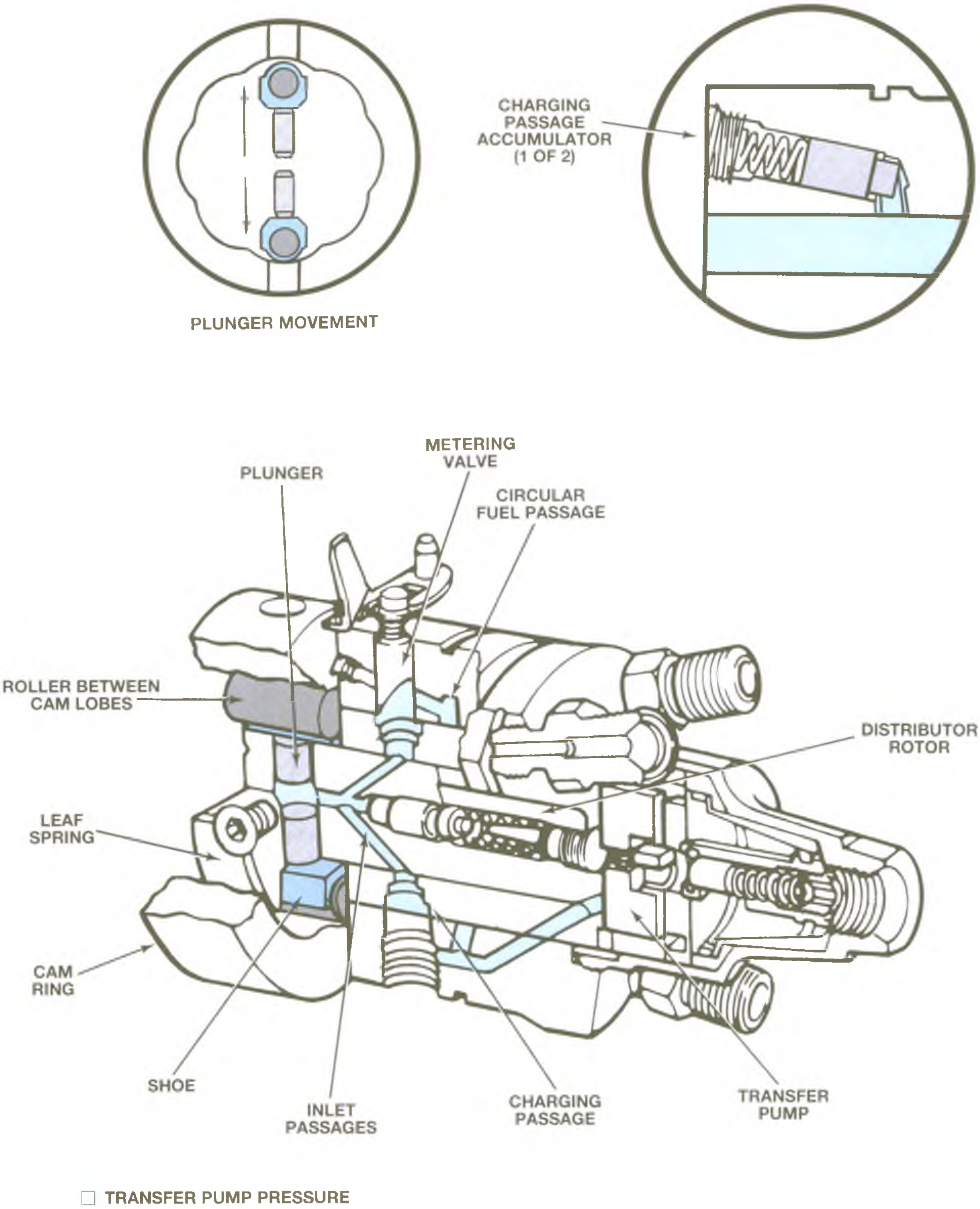


Figure 7-36, Injection Pump Cutaway View – Charge Cycle

As the injection pump rotor continues its rotation, the two ports of the pumping chamber are blocked from the charging passage (refer to Figures 7-37 and 7-38). At the same time, two of the cam ring lobes push the shoe/roller assemblies and pumping plungers inward, increasing fuel pressure in the pumping chamber to an amount approximately 100 times greater than the transfer pump pressure.

When the fuel pressure in the pumping chamber rises, a delivery valve is pushed against spring force. The fuel then moves past the delivery valve to a discharge port of the rotor. When a port in the head connecting to the injection line and nozzle for a particular cylinder aligns with the rotor discharge port, fuel under a pressure wave exits the injection pump.

The process of pressurizing and distributing fuel occurs eight times in one revolution of the injection pump drive shaft and rotor.

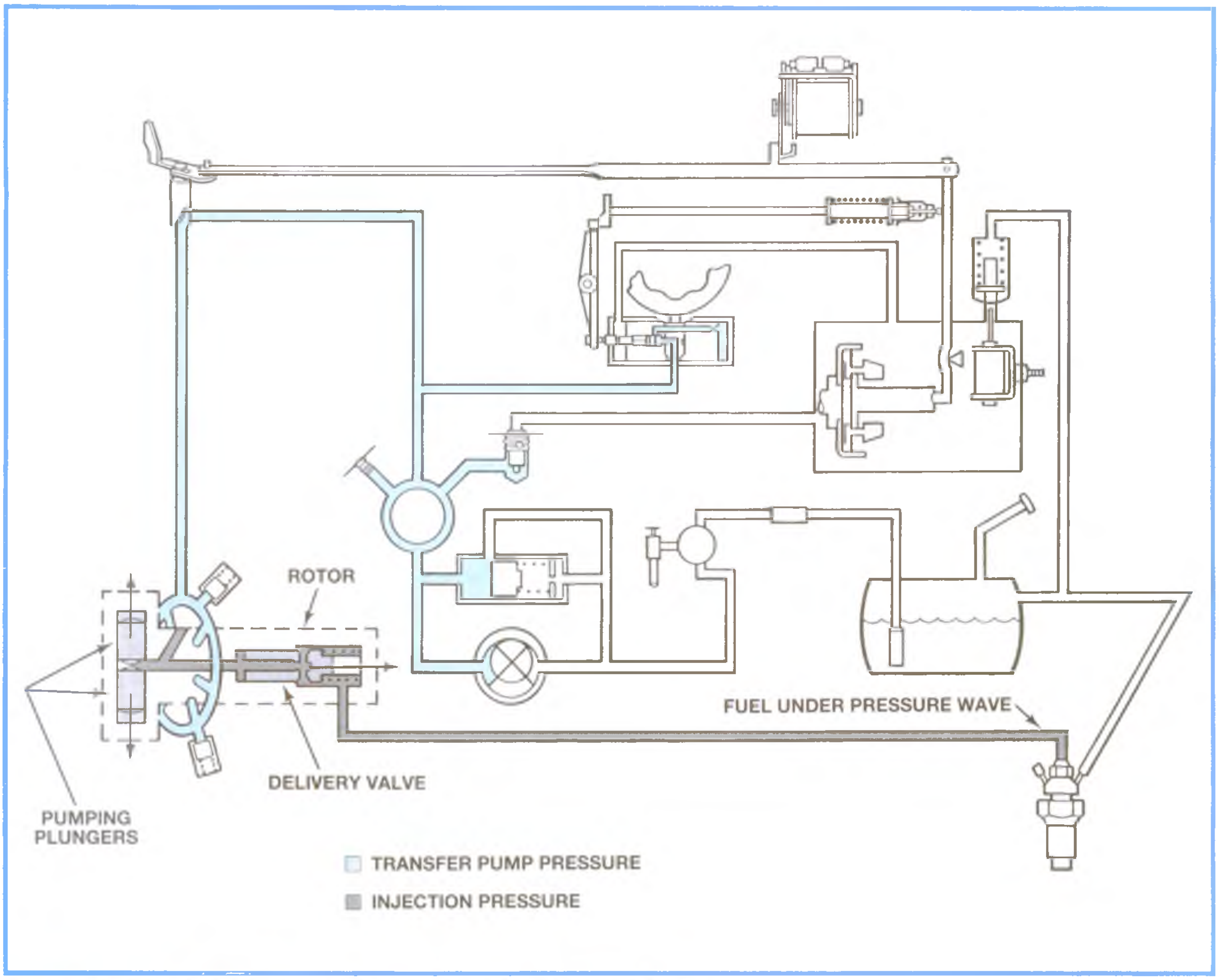


Figure 7-37, Fuel System Diagram – Discharge Cycle

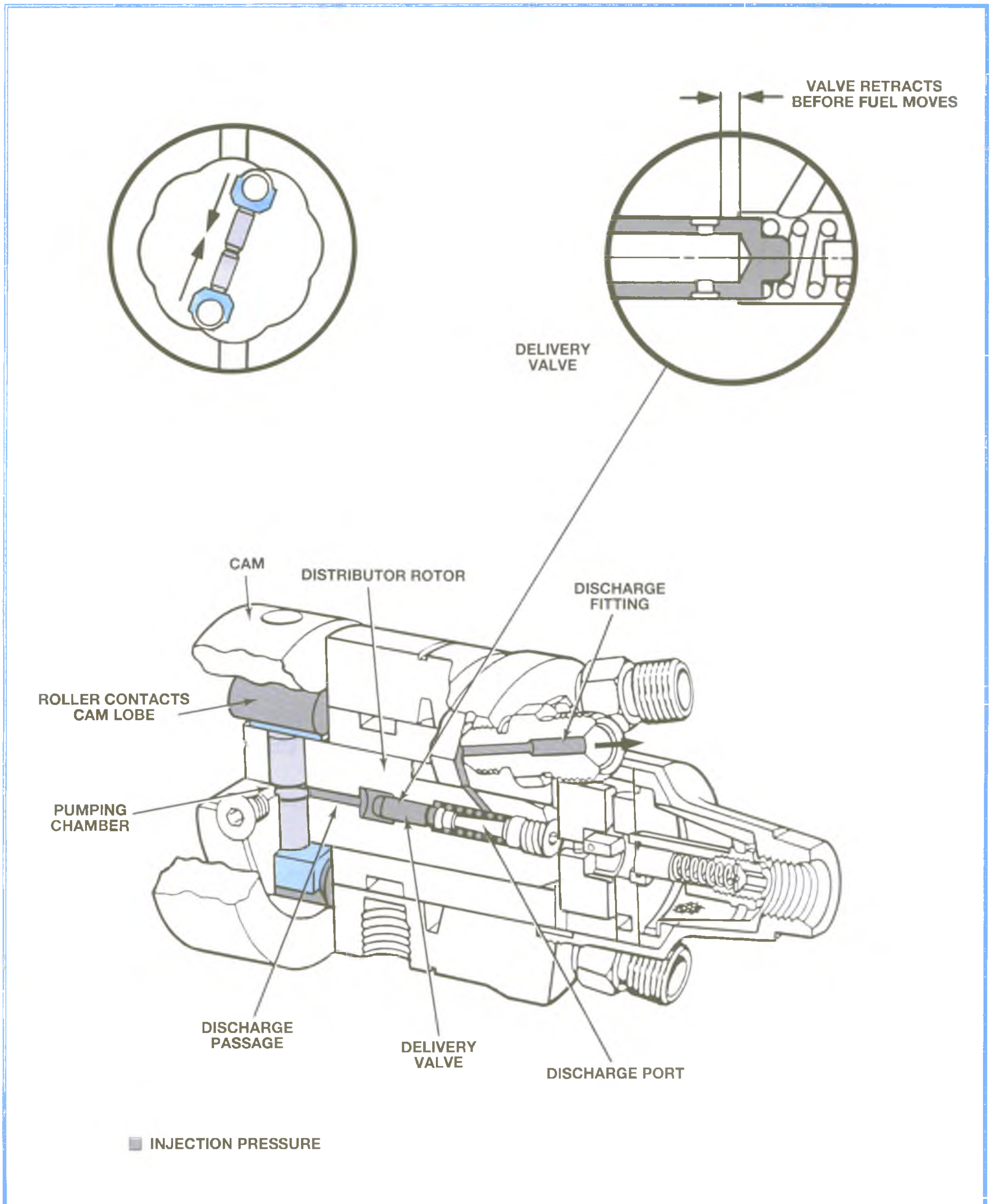


Figure 7-38, **Injection Pump Cutaway View – Discharge Cycle**

LUBRICATING

The outlet of the transfer pump connects to a threaded restrictor known as the vent wire assembly. This component causes fuel under transfer pump pressure to undergo a pressure decrease. It also vents the pump of air and uses a wire with hooked ends to assist in this task.

The fuel passing through the vent wire assembly flows inside the pump housing to cool and lubricate most of the injection pump internal parts (refer to Figures 7-39 and 7-40). An outlet port in the governor cover allows fuel to enter the return system and travel back to the fuel tank.

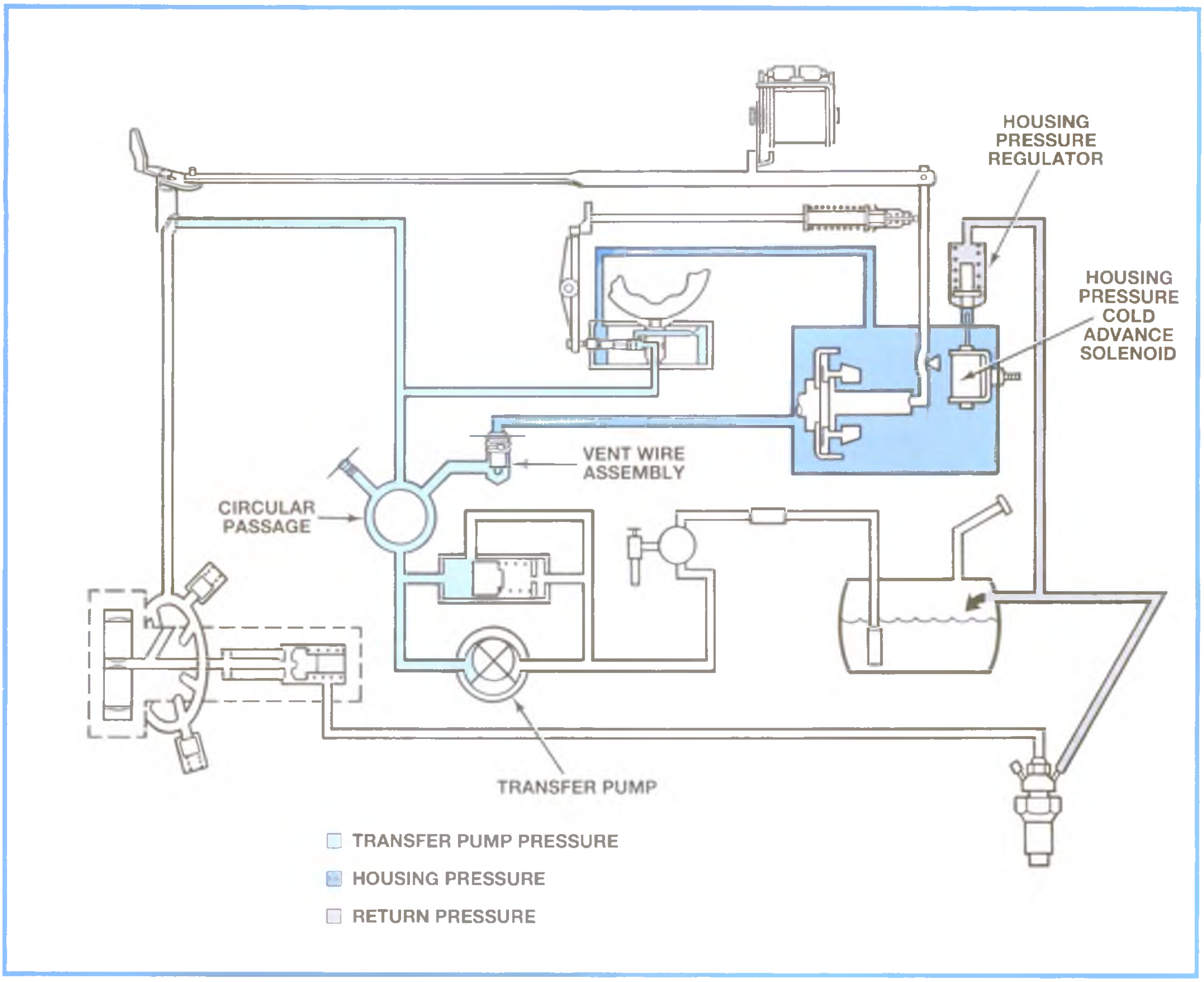


Figure 7-39, Fuel System Diagram – Lubrication Flow

The outlet port has a spring-loaded valve that regulates the flow of fuel from the injection pump housing into the return system. This valve, known as the housing pressure regulator, works with the vent wire assembly to provide a housing pressure of approximately 10 psi.

The vent wire assembly has several sizes, based on the amount of restriction required. The selection of this component is a part of the injection pump calibration procedure.

A solenoid in the governor cover uses a plunger to unseat the valve in the housing pressure regulator, causing housing pressure to drop to 0 psi. This component, known as the Housing Pressure Cold Advance (HPCA) solenoid, is ON during cold engine operation to cause a change in fuel injection timing. Refer to page 8-33 for information about the electrical circuit for the HPCA solenoid.

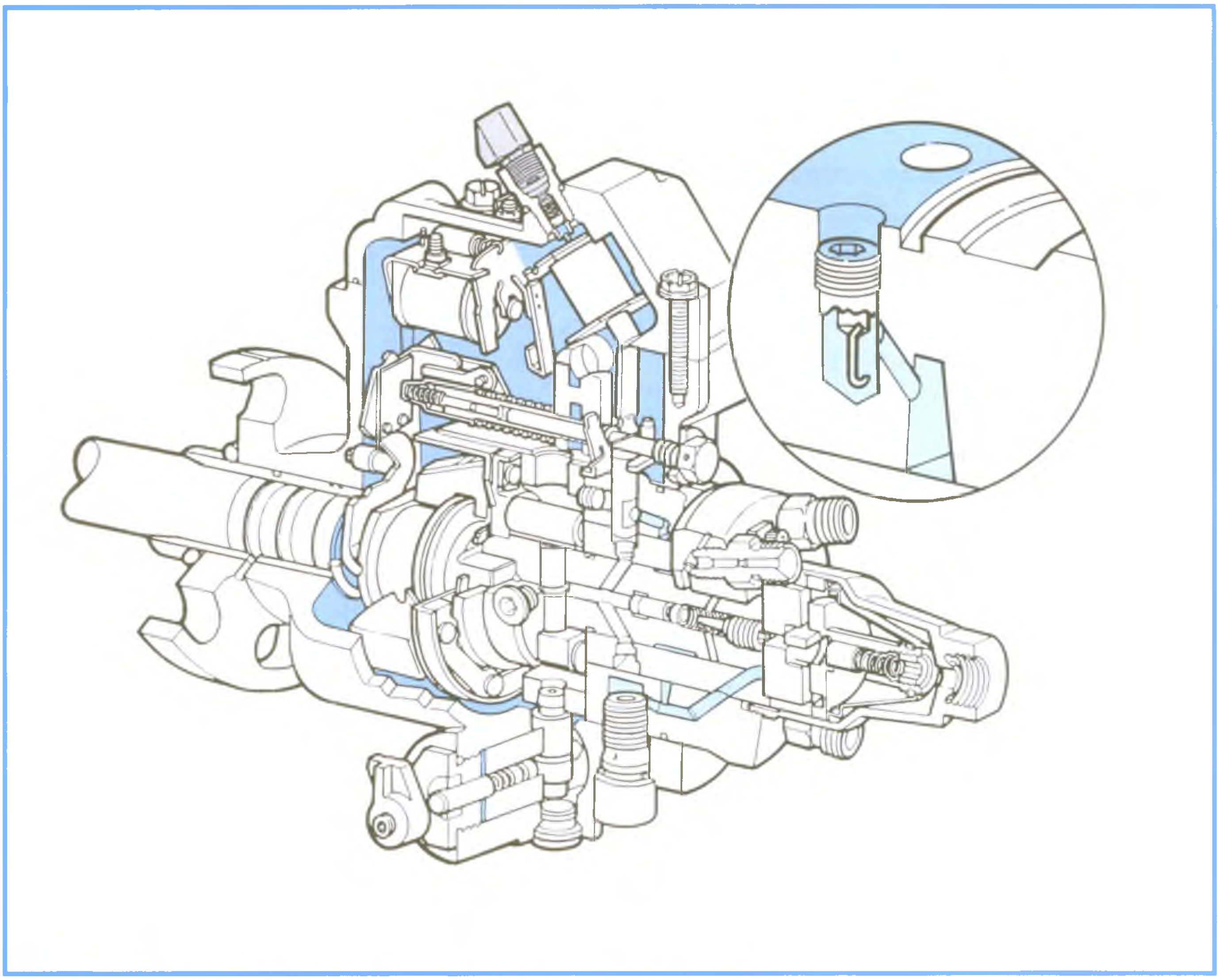


Figure 7-40, **Injection Pump Cutaway View – Lubrication**

TIMING

The cam ring that controls the pressurizing of fuel in the pumping chamber of the rotor can be rotated in the pump housing to change fuel injection timing. The automatic advance mechanism for the injection pump uses a sliding piston connected to the cam ring with a pin. As the piston slides in its housing bore, the cam ring rotates to change injection timing (refer to Figures 7-41 and 7-42).

One of the outlet passages of the transfer pump connects to the piston of the automatic advance mechanism, following a passage in the head of the injection pump, through a hollow head locating screw and into a housing passage. Fuel under transfer pump pressure pushes the piston, causing the injection timing to advance automatically in relation to engine speed.

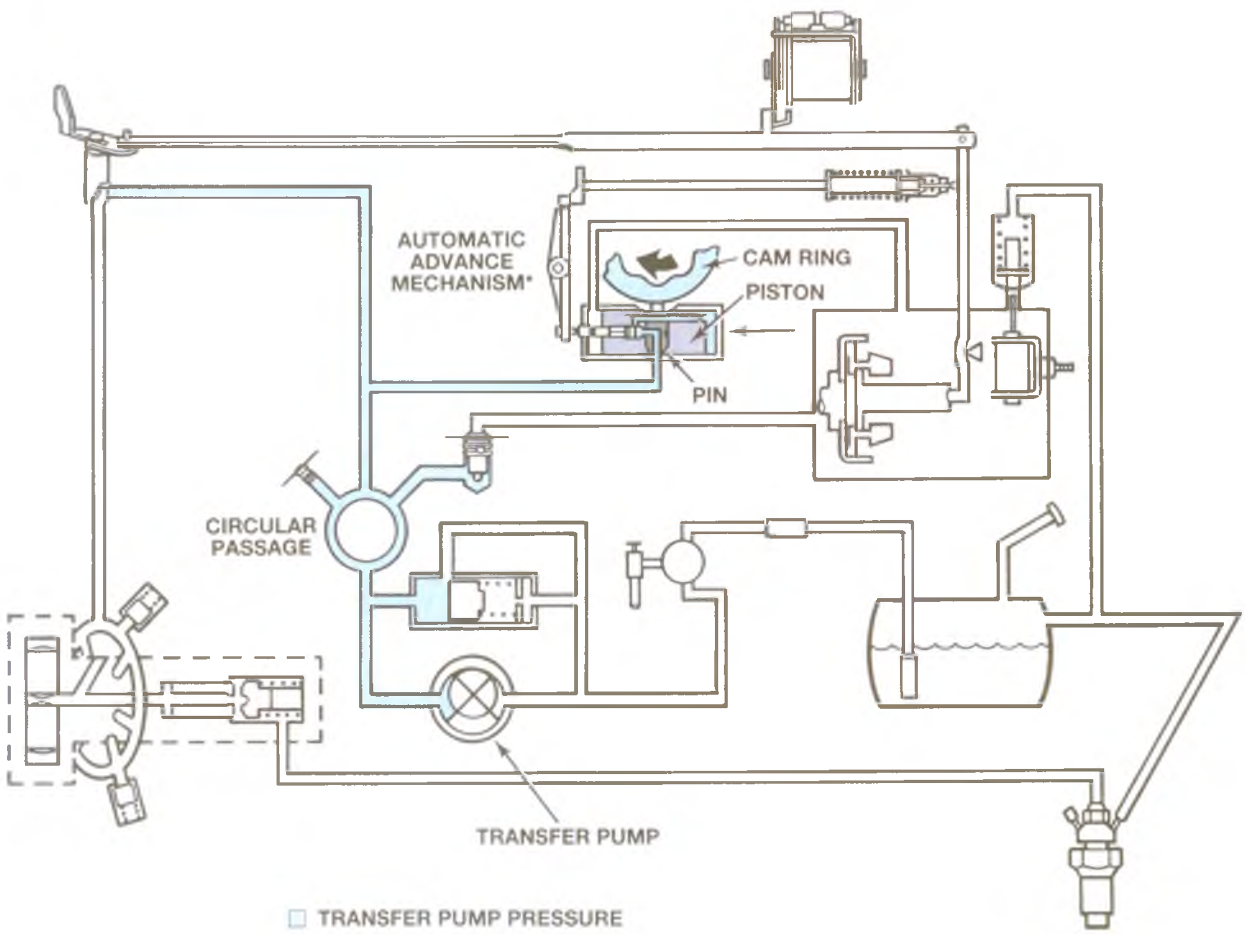


Figure 7-41, Fuel System Diagram – Basic Injection Timing

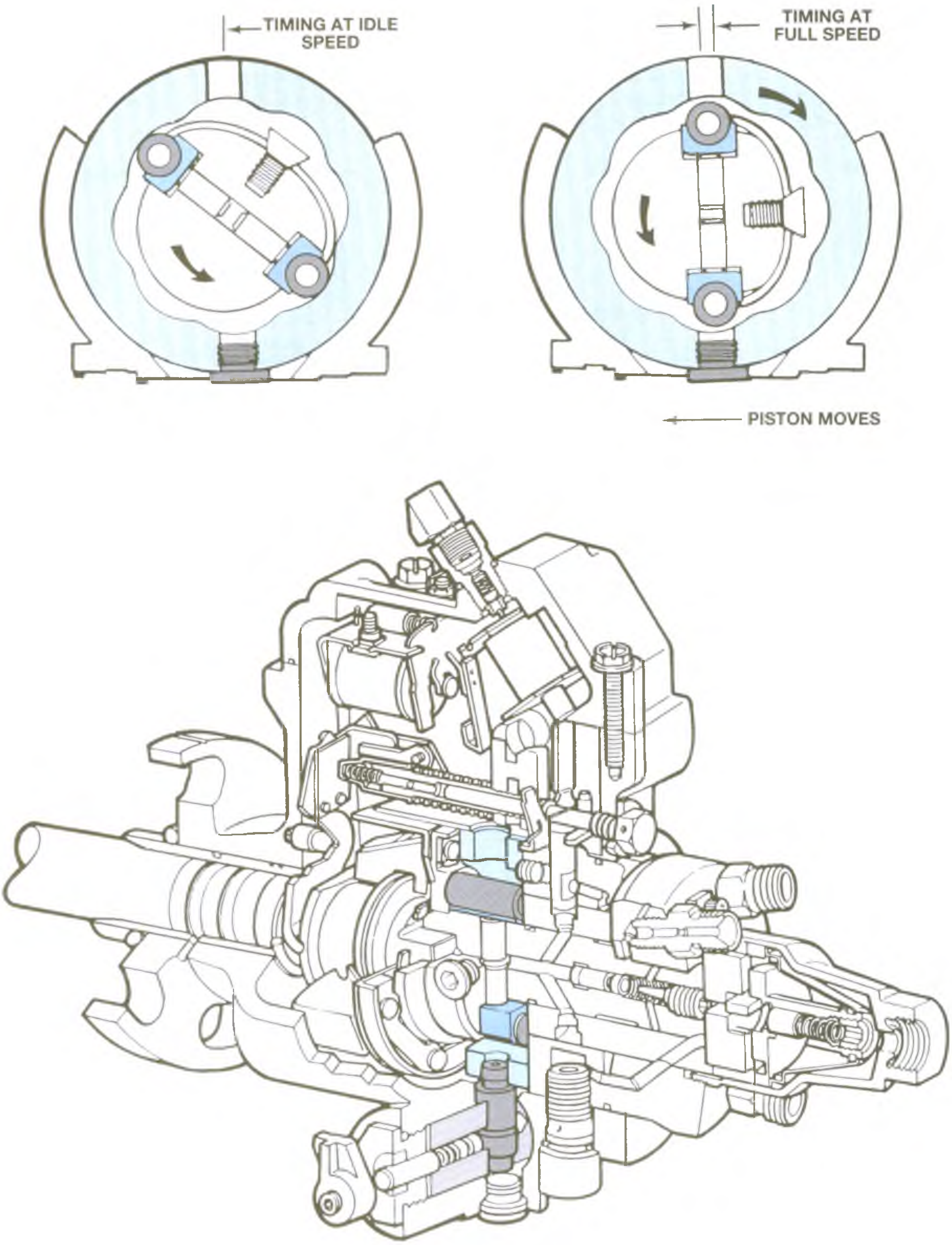


Figure 7-42, Injection Pump Cutaway View – Basic Injection Timing

The throttle shaft has a face cam mounted on the outside of the injection pump that operates a servo valve inside the bore of the advance piston (refer to Figures 7-43 and 7-44). The face cam contacts a lever arm, which changes the spring force acting on the valve by pushing a plunger in contact with the spring. In this way, the timing of fuel delivery can be varied to correspond to engine requirements.

The mechanical action of the throttle shaft, face cam and rocker lever allows a more rapid advance of injection timing under light loads by permitting an unrestricted flow of fuel under transfer pump pressure to the advance end of the piston. Under heavier loads, the throttle shaft, face cam and rocker lever increase the servo valve spring force, resulting in a restriction of fuel flow to the advance piston.

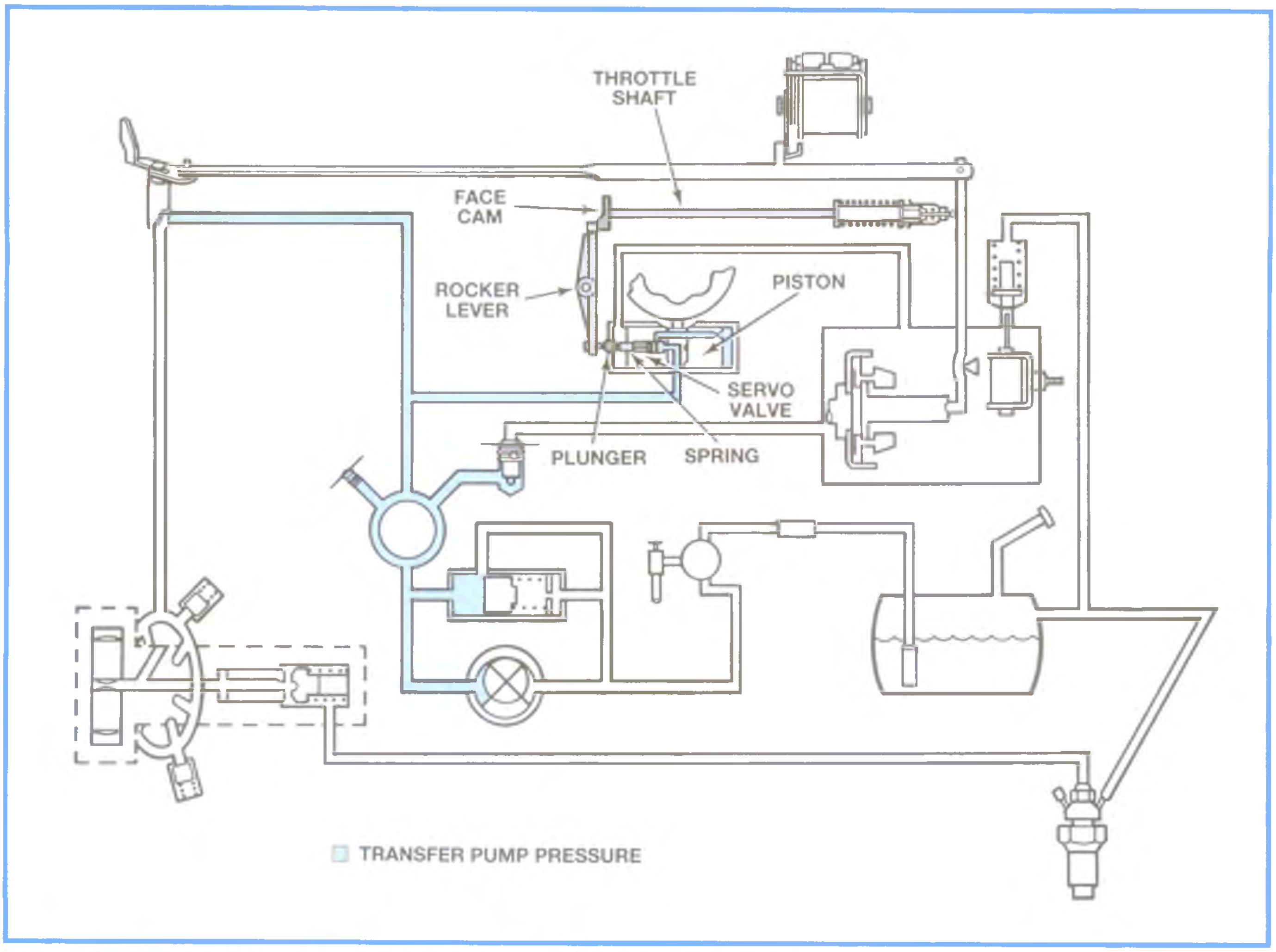


Figure 7-43, Fuel System Diagram – Light Load Advance

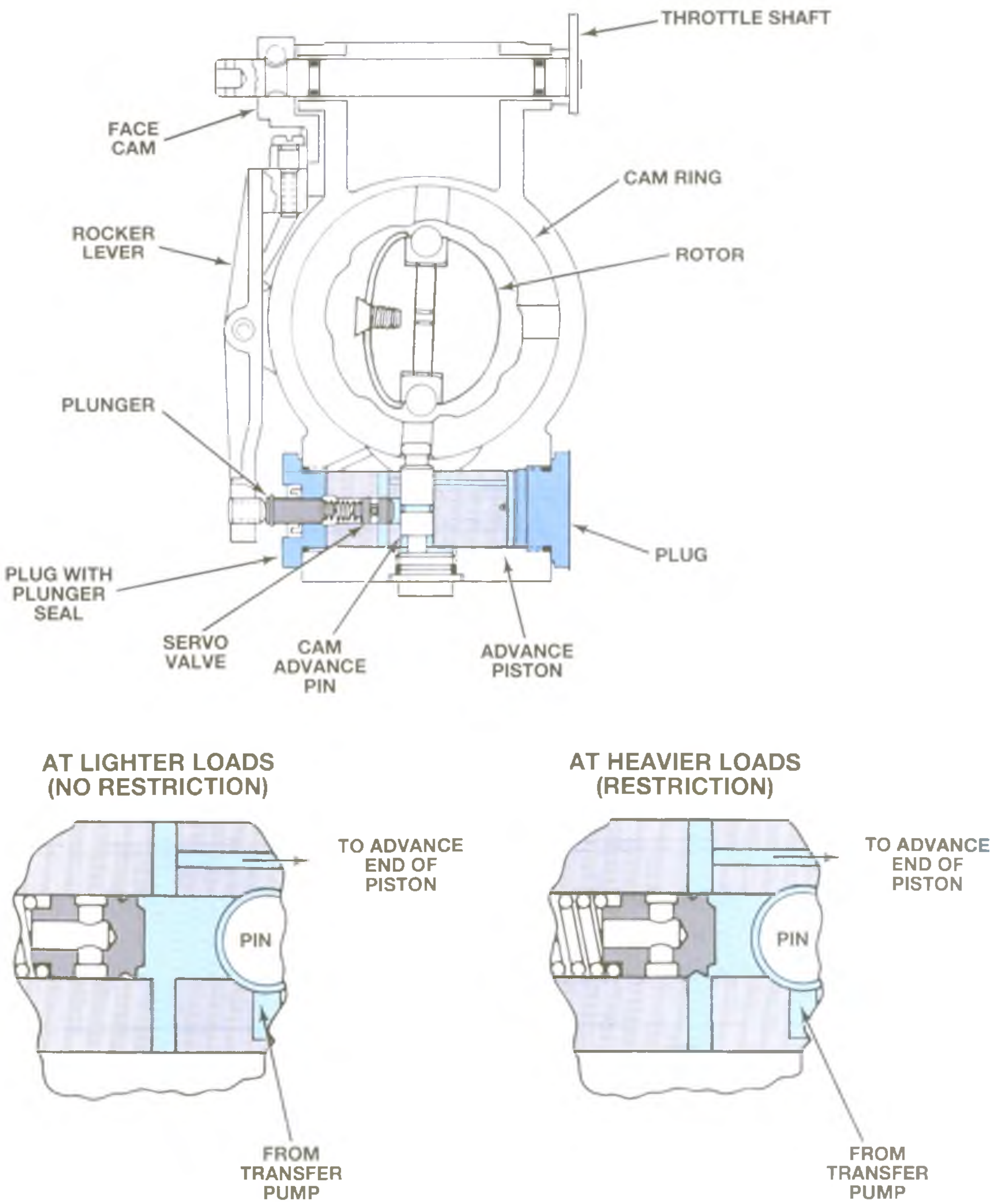


Figure 7-44, Injection Pump Cutaway View – Light Load Advance

During warm engine operation, fuel under housing pressure pushes on the retard end of the advance mechanism piston, providing lubrication and a fluid cushion (refer to Figure 7-45).

When the HPCA solenoid is ON (during cold engine operation), a drop in housing pressure causes transfer pump pressure to push the advance piston farther (refer to Figure 7-46). This results in smoother engine operation during warm-up and combines with the action of the fast idle solenoid to temporarily increase engine idle speed.

If the HPCA solenoid is OFF during starting in cold temperatures, white exhaust smoke may result. If the HPCA solenoid is ON during warm or hot engine operation, black exhaust during acceleration may result.

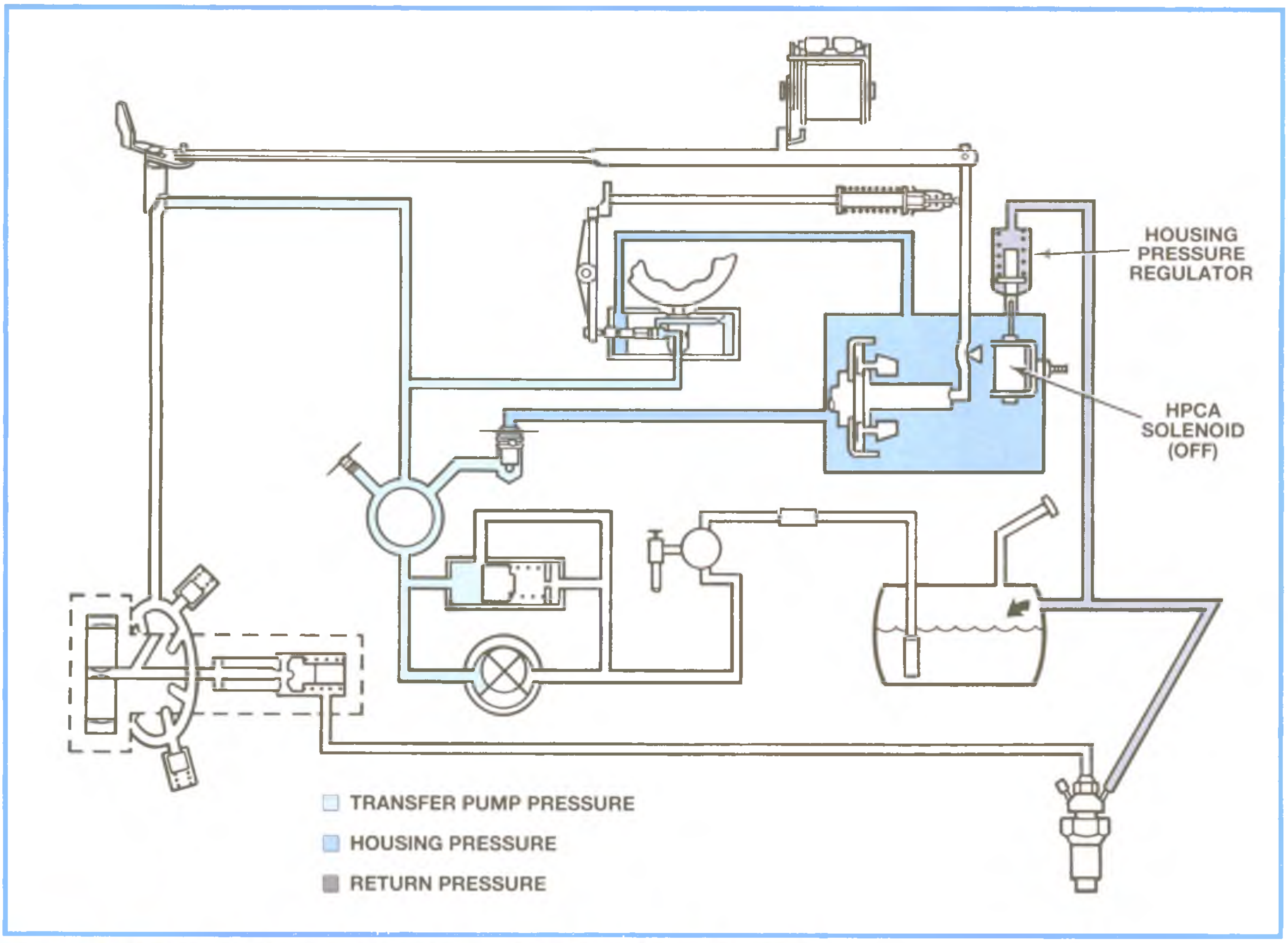


Figure 7-45, **Fuel System Diagram – HPCA (Warm Engine)**

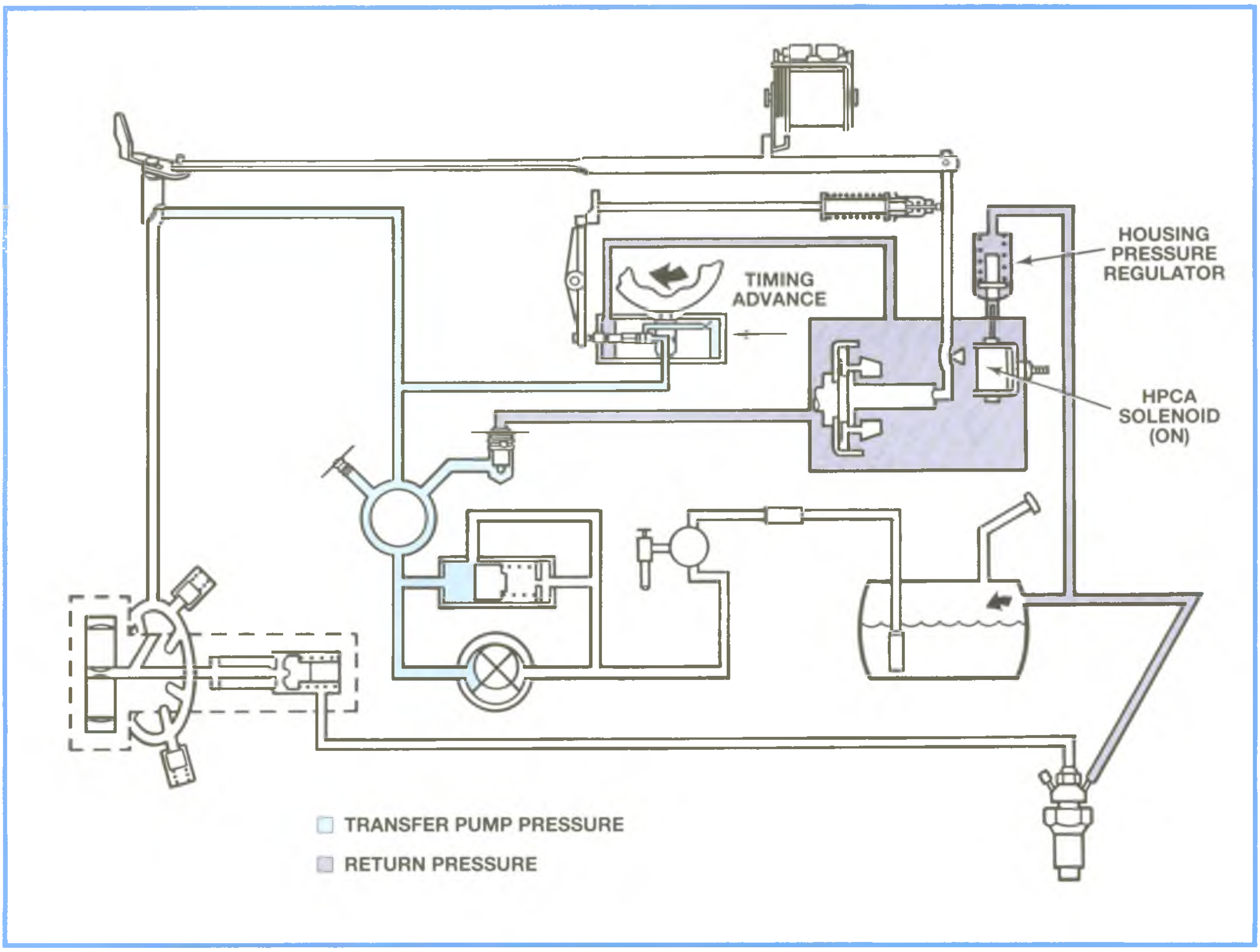


Figure 7-46, Fuel System Diagram – HPCA (Cold Engine)

Injection Pump Diagnosis

Diagnosis of the fuel injection pump includes the following diagnostic steps (more detail for these checks can be found at the end of this section):

1. Check the fuel supply to the injection pump (refer to Figure 7-47):
   - Check that the output of the lift pump is correct:
     - Volume of at least 0.24 liter (1/2 pint) in 15 seconds
     - Pressure of 40 to 60 kPa (5.8 to 8.7 psi)
   - Check that the restriction of the fuel filter is not excessive:
     - Lift pump volume and pressure should be present at the inlet of the injection pump.
   - Check the fuel entering the injection pump for the presence of air, using a transparent hose:
     - If air bubbles appear, check the lift pump suction line for air leakage under a vacuum.
   - Check the quality of the fuel:
     - If necessary, use a fuel with a known cetane rating.

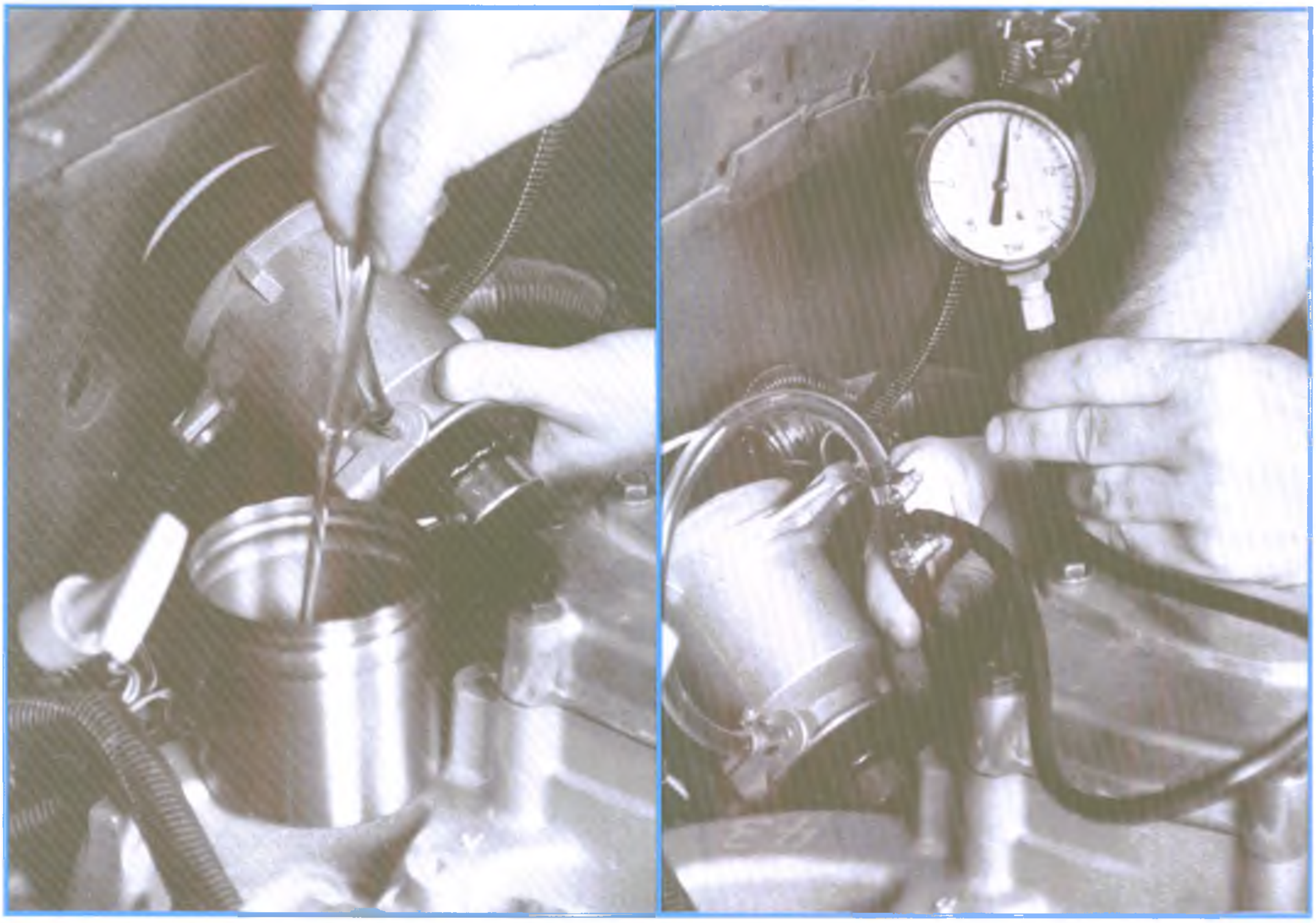


Figure 7-47, Injection Pump Fuel Supply Checks

2. Check the fuel return from the injection pump (refer to Figure 7-48):
   - Check the injection pump housing pressure:
     - If pressure is not within 55 to 83 kPa (8 to 12 psi), do one of these things:
       - Check the return line for a restriction.
       - Check the housing pressure regulator for a restriction.
   - Check the fuel exiting the injection pump for the presence of air, using a transparent hose:
     - If air bubbles appear, remove the injection pump for service.
3. Check the injection pump transfer pump pressure (refer to Figure 7-48):
   - Pressure while cranking should be at least 138 to 207 kPa (20 to 30 psi).
   - Pressure should increase as engine speed increases, and a maximum of over 690 kPa (100 psi) is possible.

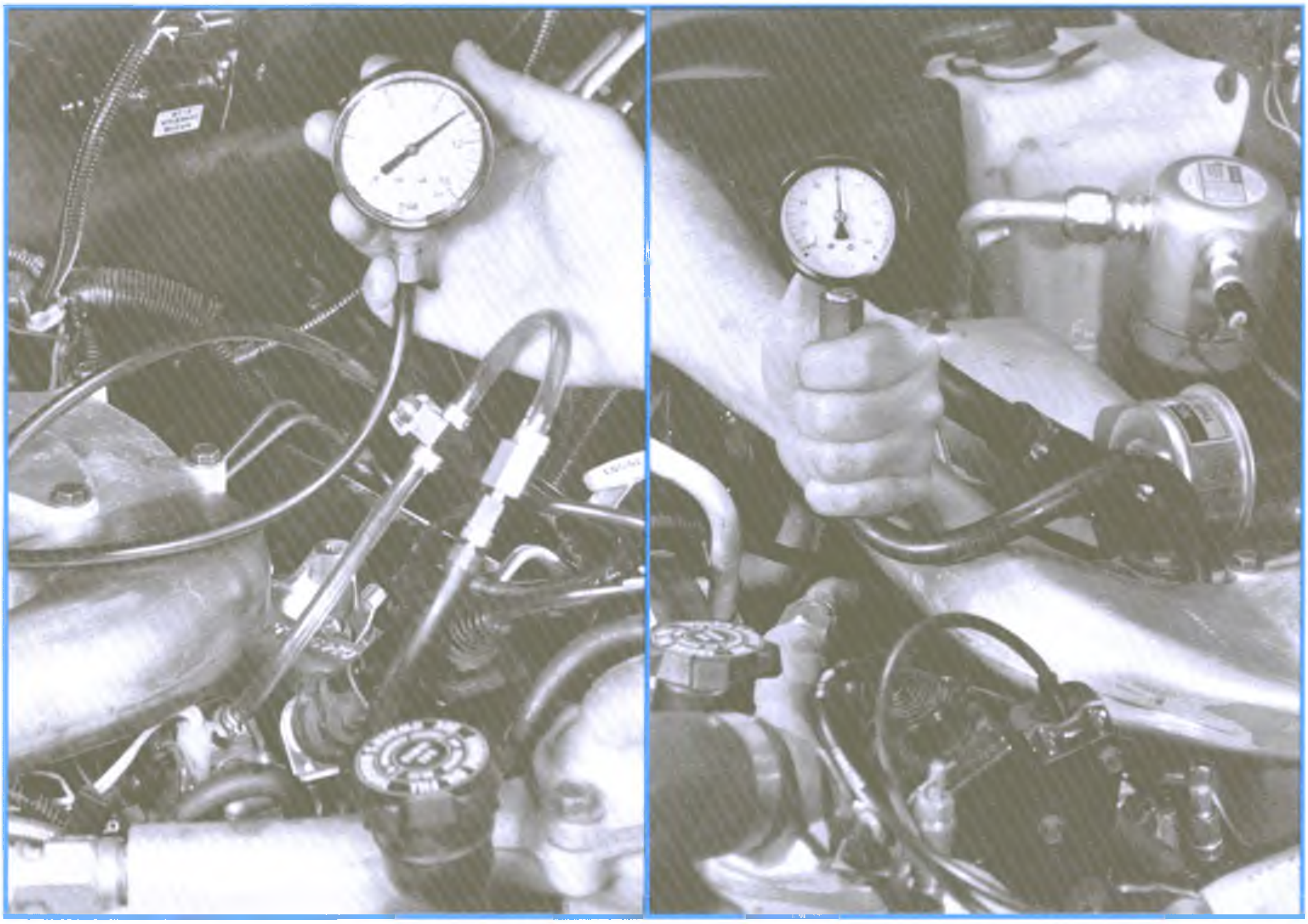


Figure 7-48, Injection System Fuel Return and Transfer Pump Checks

4. Check the Housing Pressure Cold Advance (HPCA) solenoid operation (refer to Figure 7-49):
   - With the engine at 2,000 rpm, jumper the fast idle/cold advance temperature switch to energize the HPCA solenoid circuit.
   - Observe that the engine speed increases, indicating an advance in injection timing.
   - If no change in engine speed occurs, diagnose the fast idle/cold advance circuit.
5. Check the injection pump automatic advance mechanism piston for movement (refer to Figure 7-49):
   - With the engine at 2,000 rpm, press the lower end of the mechanical light load advance rocker arm toward the injection pump.
   - Observe that the engine speed decreases, indicating a retard in injection timing.
   - If no change in engine speed occurs, remove the injection pump for service.

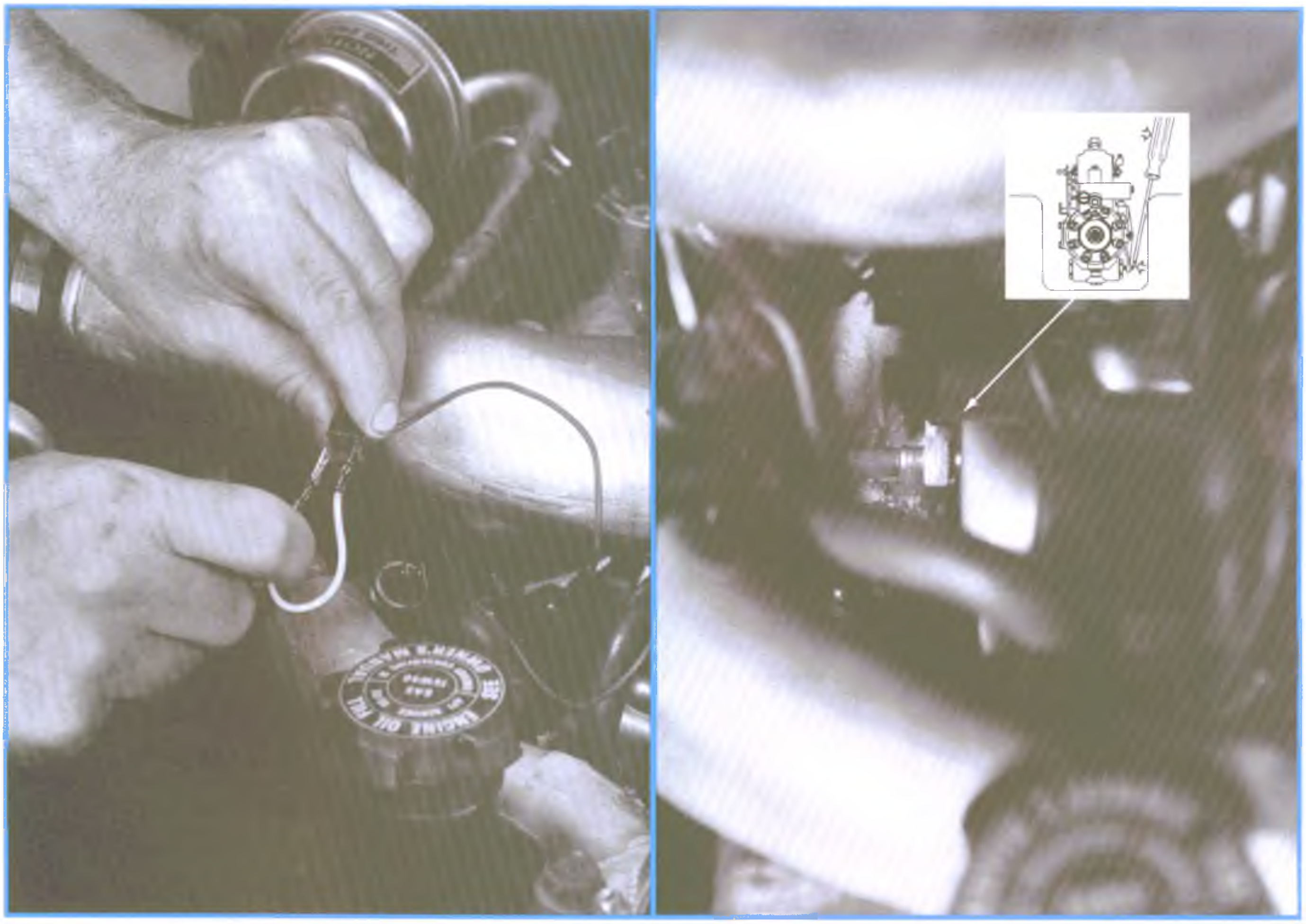


Figure 7-49, Injection System Advance Mechanism Checks

6. Check the operation of the injection lines and nozzles (refer to Figure 7-50):
   - Inspect the injection lines for external damage and evidence of fuel leakage.
   - Replace any damaged injection line.
   - Remove and test each injection nozzle for correct opening pressure, chatter, leakage and spray pattern (see page 7-60 for more information).
   - Replace any faulty nozzle and install the nozzles with new compression gaskets.
7. If a fuel system fault still exists, remove the injection pump and send it to an authorized diesel injection pump repair shop.

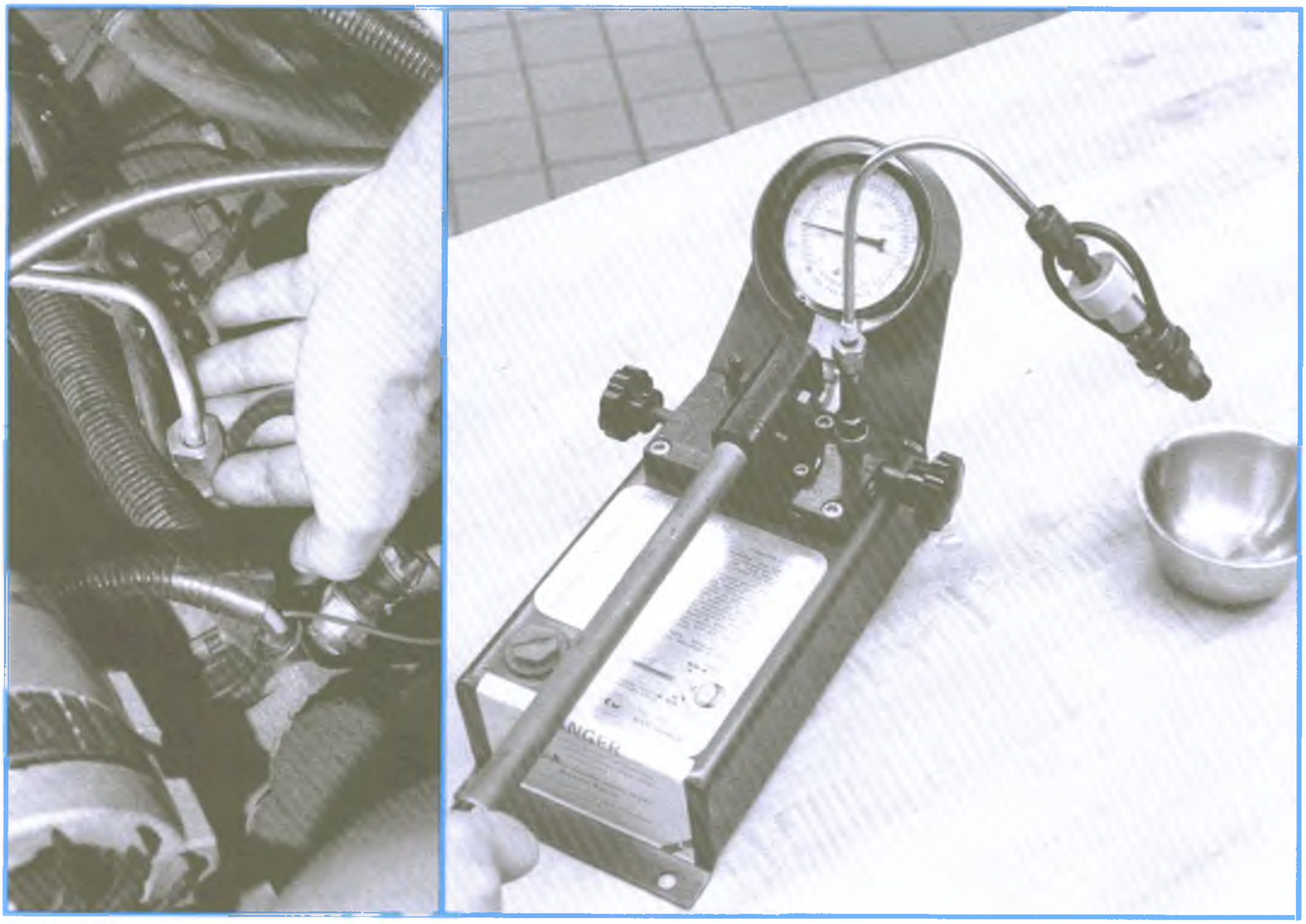


Figure 7-50, Injection Line and Nozzle Checks

Injection Pump Service

Since several calibration adjustments are disturbed during disassembly, most injection pump repairs are made by an authorized Stanadyne diesel injection repair service. Repairs to the injection pump that can be made by a dealership technician include replacement procedures for the following parts:

- Governor cover seal (in-vehicle)
- Fuel shut-off solenoid (in-vehicle)
- HPCA solenoid (in-vehicle)
- Timing window cover gasket (out-of-vehicle)

Replacement of the seal and two solenoids involves removal of the governor cover, as Figure 7-51 shows. Installation of the governor cover requires the use of a special tool to align the fuel shut-off solenoid with the governor linkage (refer to Figure 7-52). **Incorrect installation of the governor cover may cause damage to the engine by forcing the metering valve into an over-fueling position.**

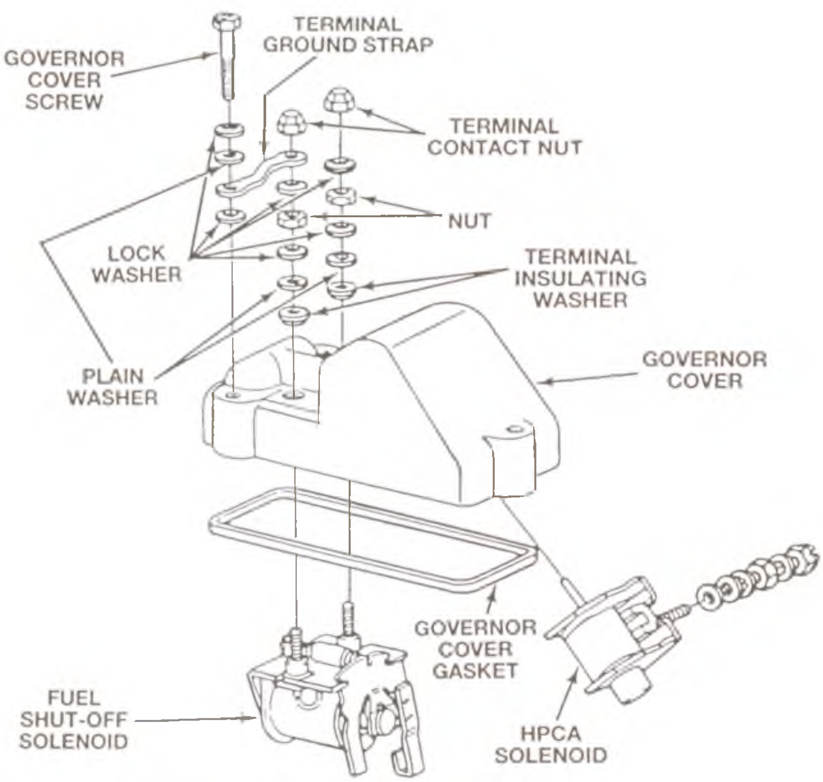
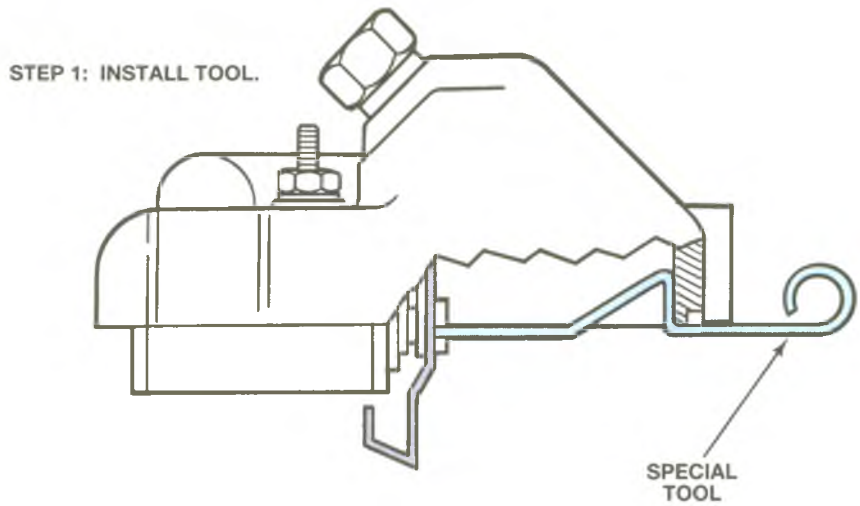


Figure 7-51, Injection Pump Governor Cover and Parts



STEP 2: LOWER COVER ON HOUSING (1/8-IN. CLEARANCE) AND PIVOT TOOL TO REMOVE.

STEP 3: LOWER COVER FULLY.

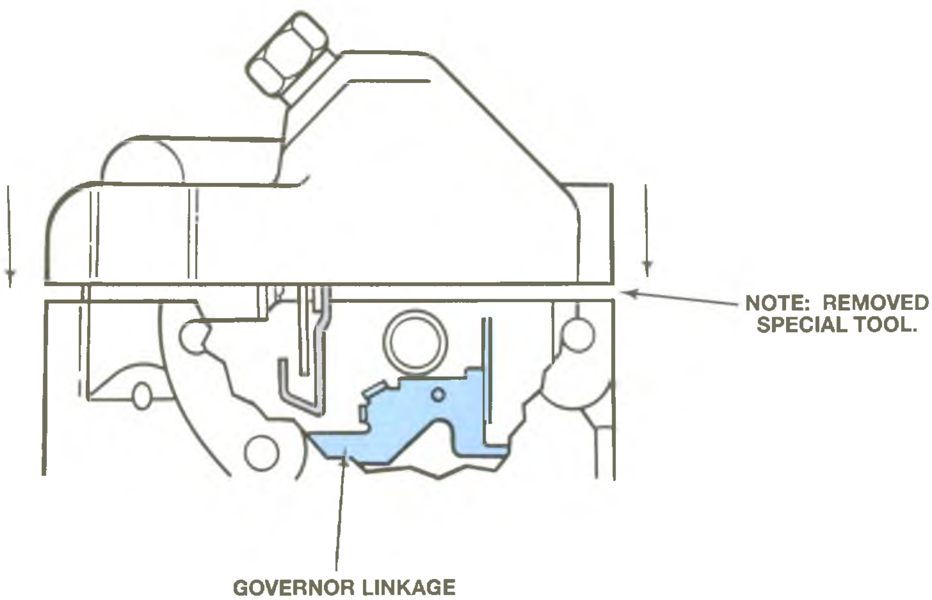


Figure 7-52, **Injection Pump Governor Cover Installation**

Injection Lines

The high-pressure discharge fittings on the head of the injection pump connect to the injection nozzles with steel lines of equal length and interior volume (see Figure 7-53). The ends of the injection lines have special fittings and nuts.

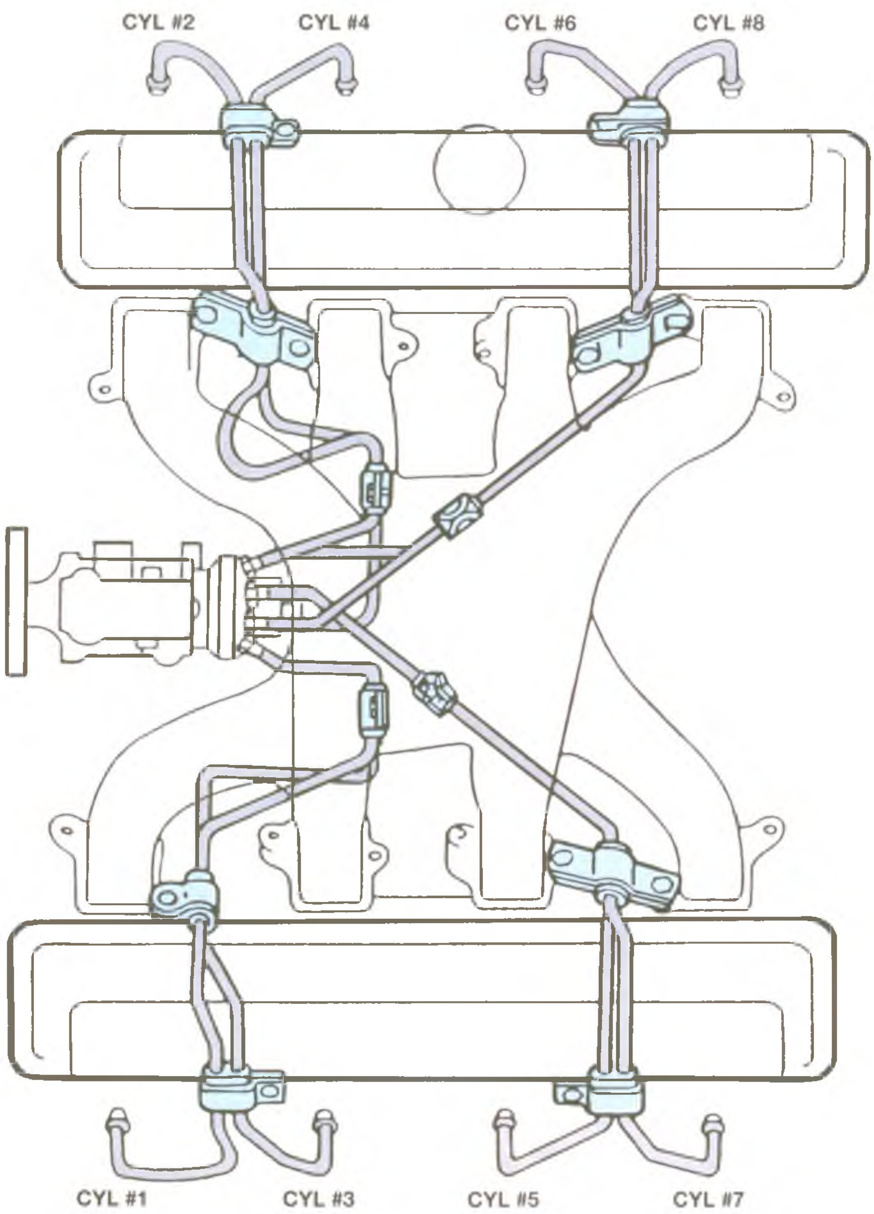


Figure 7-53, **Injection Lines (1)**

Intake manifold mounting bolts and studs secure the injection lines, using straps and soft isolators (see Figure 7-54). Each injection line is clamped in three locations to prevent breakage due to vibration from the engine and from injection pressure pulses.

When the engine is not running, fuel is contained in the injection lines. During engine operation, a residual pressure of approximately 500 psi is maintained in each injection line. As injection occurs in each line, a small amount of fuel enters the line, pushing a similar amount into the nozzle at the other end with a pressure wave.

During service, injection lines are serviced by replacement. Diagnosis includes an inspection for tubing and fitting end damage that causes restrictions or leakage.

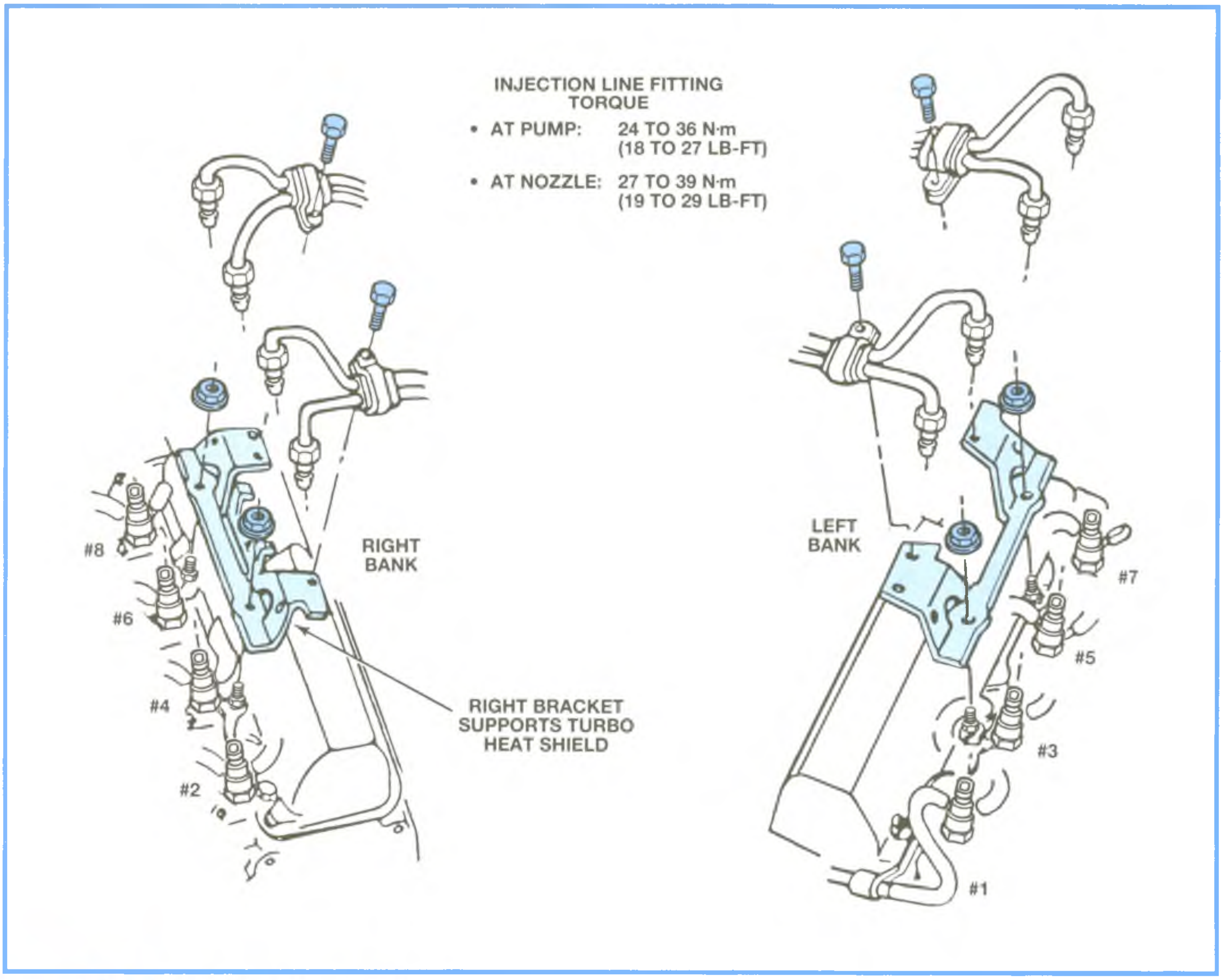


Figure 7-54, **Injection Lines (2)**

Injection Nozzles

Construction and Operation

Each cylinder has an identical fuel injection nozzle mounted in the pre-combustion chamber, using threads and a copper sealing gasket. A specific injection line connects to each nozzle, using a special fitting and nut.

Each nozzle is an assembly containing a two-piece body, a needle valve/pintle nozzle assembly, a pressure spring and other parts (see Figure 7-55). During the manufacturing process, a selective thickness shim is used to adjust the nozzle opening pressure .

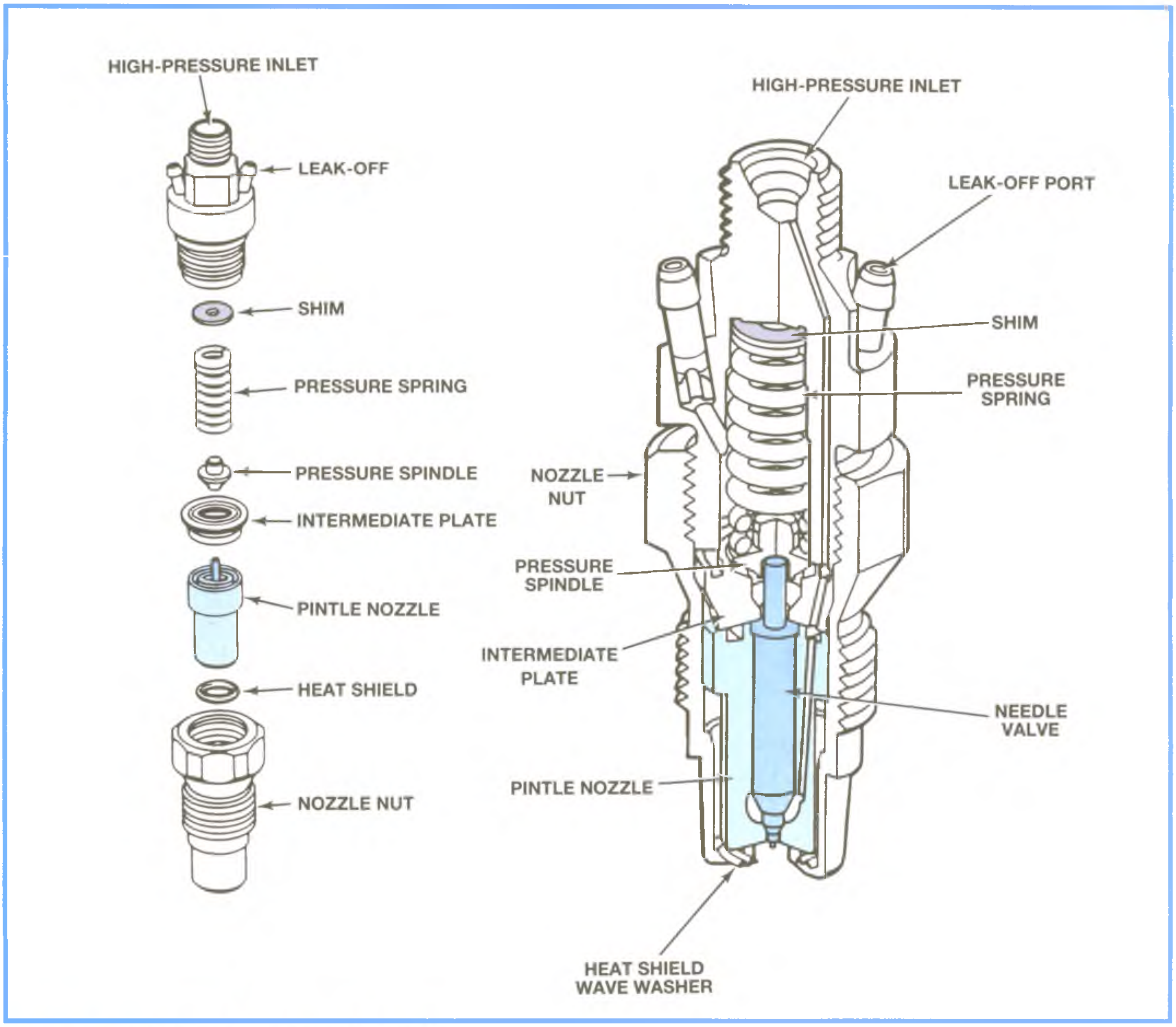


Figure 7-55, **Injection Nozzle Parts**

As the pressure wave of injection reaches a nozzle, the needle valve is lifted against spring force and fuel exits into the pre-combustion chamber of the cylinder as a highly atomized spray (refer to Figure 7-56). A small amount of fuel travels between the needle valve and pintle nozzle, providing lubrication.

Two passages inside the upper half of the nozzle body allow fuel that has lubricated the needle valve to exit into the fuel return system. Fittings on the nozzle connect with hoses and clamps to the return system pipes.

During service, nozzles are serviced by replacement. Installation involves the use of a new compression gasket, anti-seize compound (GM P/N 1052771) on the cylinder head threads and a tightening torque of 60 to 80 N·m (44 to 59 lb-ft), using a special socket.

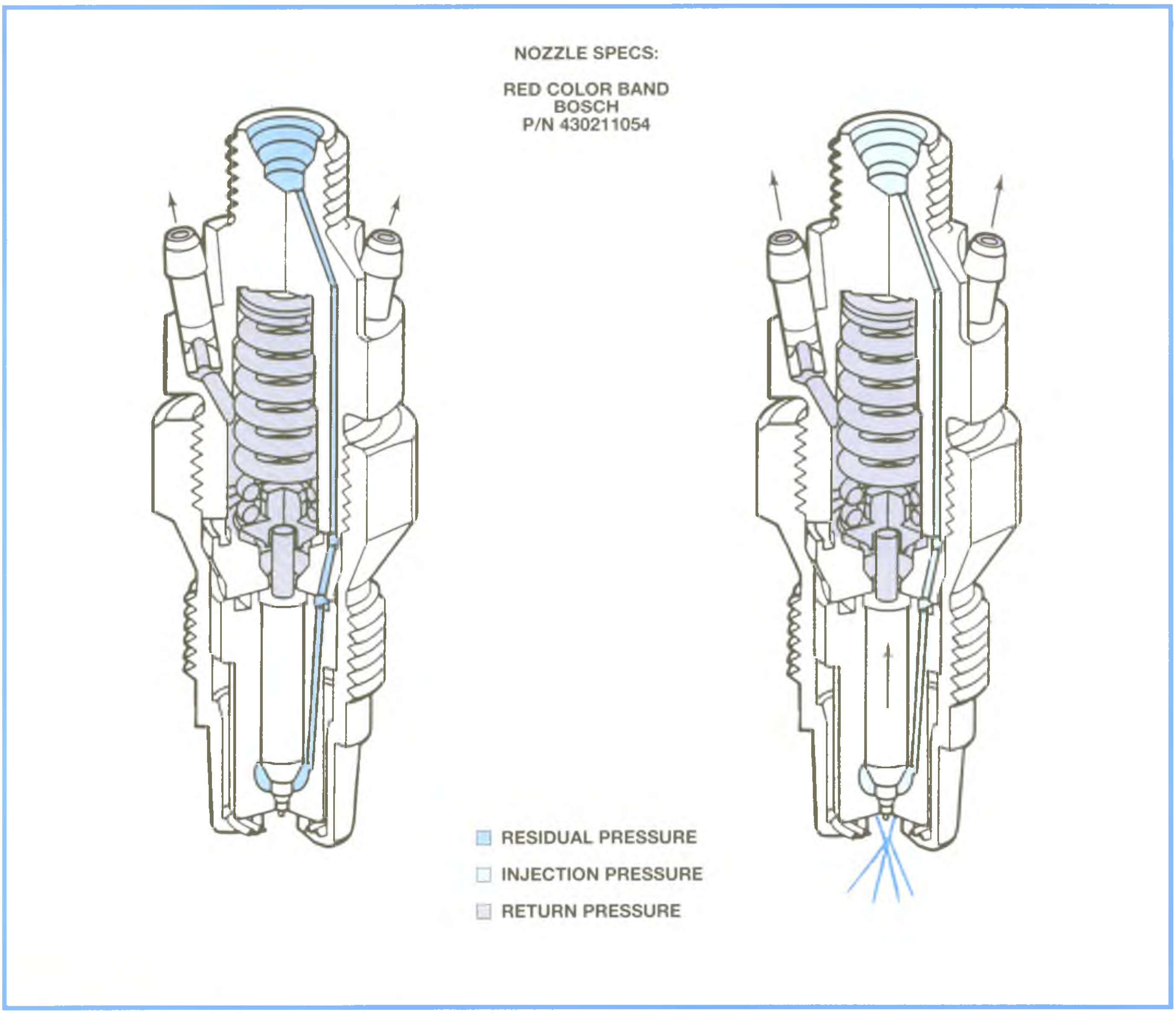


Figure 7-56, **Injection Nozzle Operation**

Injection Nozzle Testing

During diagnosis, each injection nozzle may be tested after it is removed from the engine (refer to page 7-53). Nozzle tests include the following checks:

1. Preparation
   - Position a nozzle tester on a workbench.
   - Install one nozzle on the tester fitting.
   - Place a container under the nozzle that will deflect the nozzle spray and absorb the test fluid.
   - Install two clear plastic hoses ($1^1/_2$ in. long) over the leak-off fittings.
   - Close the shut-off valve at the pressure gauge.
   - Operate the lever of the nozzle tester repeatedly and briskly to fill and flush the nozzle with test oil.

Note: Never allow the nozzle spray to contact your hands, since it can penetrate the skin and cause blood poisoning.

2. Opening pressure check: NORMAL 2100
   - Open the shut-off valve at the pressure gauge 1/4-turn.
   - Push the lever of the tester to increase pressure slowly.
   - Observe the pressure gauge at the point which the nozzle sprays, and note the reading as the opening pressure.

Note: Do not consider dripping at the nozzle during this check as a fault.

   - Compare the reading to the specification 120 bar (1750 psi), and replace the nozzle if the opening pressure is below this point.

3. Leakage check:
   - Open the shut-off valve at the pressure gauge 1/2 to $1^1/_2$ turns.
   - Dry the nozzle tip with air.
   - Push the lever of the tester to increase pressure to 95 bar (1400 psi). 1900
   - Observe the tip of the nozzle for drops of test oil.
   - If a drop falls from the nozzle tip within 10 seconds, replace the nozzle.

4. Chatter check:
   - Close the shut-off valve at the pressure gauge.
   - Push the lever at a speed that causes the nozzle to chatter as it sprays repeatedly.
   - If chatter is not heard, push the lever at a faster speed.
   - If no chatter is heard, replace the nozzle.

Note: New and used nozzles have different sound characteristics during the chatter check.

5. Spray pattern check:
   - Close the shut-off valve at the pressure gauge.
   - Push the lever of the tester abruptly and quickly.
   - Observe the spray pattern of the nozzle:
     - Do not be too critical of the spray pattern since it is not tested properly with this check.

Fuel Return System

The fuel return system has several different sizes and types of hoses and pipes connected to each other and sealed with compression-type clamps. The injection pump housing pressure regulator connects to the return system, using a hose and two clamps (see Figure 7-57, view A).

The nozzles for each cylinder head use a system of short lengths of small diameter hose to connect to a metal pipe at the front (see Figure 7-57, views B and C). The rear fittings of the nozzles for cylinders #7 or #8 have caps and clamps.

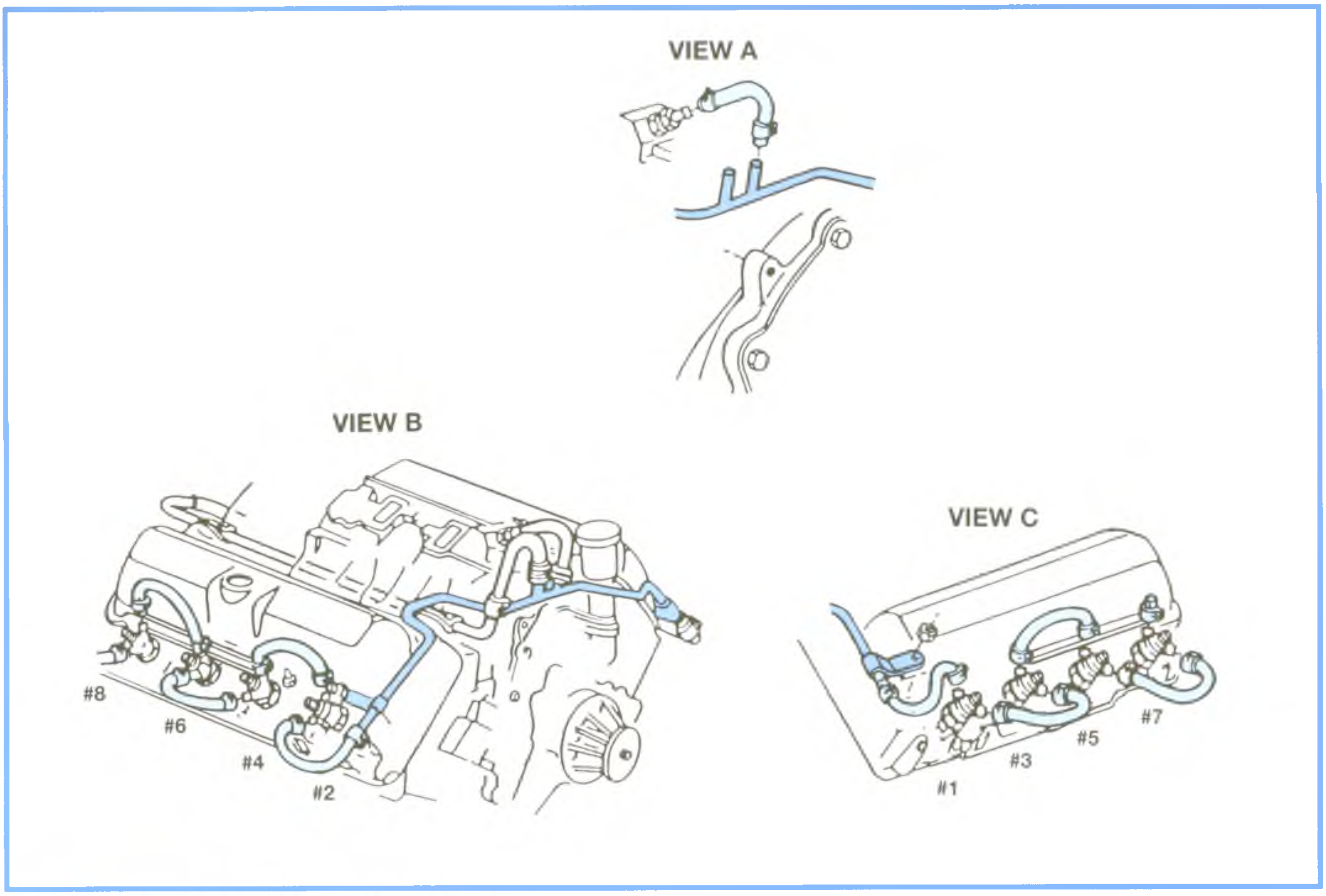


Figure 7-57, **Fuel Return System (1)**

The return hoses for cylinders #1 and #2 connect to a center pipe (see Figure 7-58, view A). The injection pump fuel return hose also connects to the center pipe, and it connects with a hose to a pipe mounted under the right underside of the intake manifold (see Figure 7-58, view B).

At the rear of the engine, the return system pipe under the intake manifold connects to a series of hoses and pipes that send fuel back to the fuel tank (see Figure 7-58, view C).

During diagnosis of the injection pump, the return system is checked for restrictions. Any blockage in the path of fuel leaving the injection pump will greatly affect the performance of the engine.

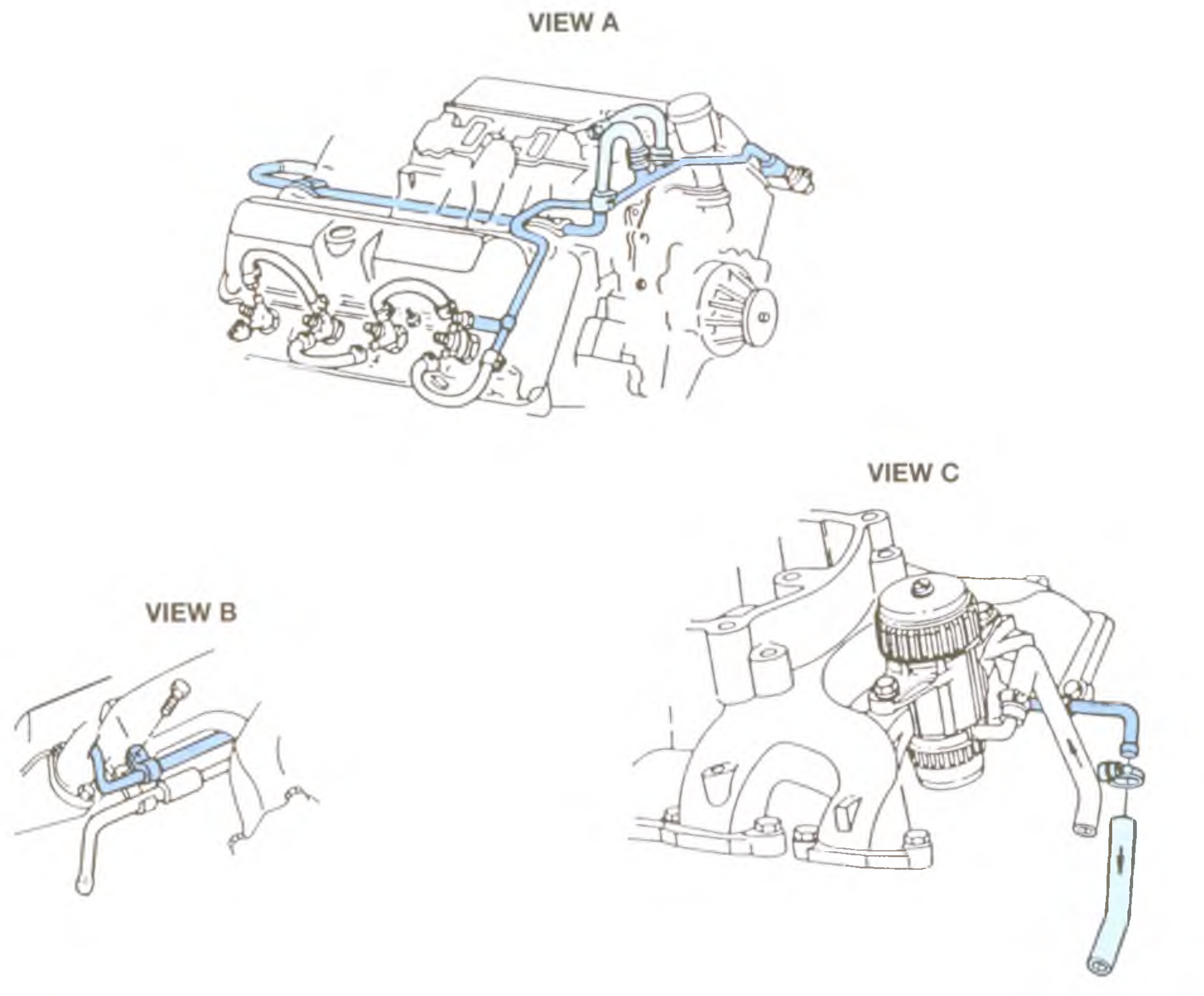


Figure 7-58, Fuel Return System (2)

Related Diagnosis/Service Procedures

Fuel Contamination Inspection and Cleaning

Note: This procedure checks for the presence of water and gasoline in diesel fuel that may cause injection pump and nozzle damage.

1. Remove the fuel filter element and inspect it:
   - If water, gasoline or fungi/bacteria are not present, end the inspection.
   - If water or fungi/bacteria are present, go to step 2.
   - If gasoline is present, go to step 3.
2. Clean water from the fuel system in these steps:
   A. Disconnect the batteries.

   B. Drain the fuel tank.

   C. Remove the fuel tank.

   D. Remove the fuel pick-up/sending unit.

   E. Inspect the fuel tank and fuel pick-up/sending unit for rust, fungi or bacteria:
   - If no rust is present, clean the inside of the fuel tank and fuel pick-up/sending unit with hot water, then dry them with compressed air.
   - If rust is present, replace the parts.

   F. Disconnect the ends of the following lines:
   - Lift pump suction
   - Lift pump pressure
   - Fuel filter outlet
   - Fuel filter drain
   - Fuel return

   G. Inspect each of the lines and replace any rusted pipes.

   H. Dry the inside of each line with low-pressure air.

   I. Clean the inside of the fuel filter housing and dry it with compressed air.

   J. Disconnect the electrical connector for the fuel shut-off solenoid in the injection pump.

   K. Install a new fuel filter element.

   L. Install the fuel pick-up/sending unit and fuel tank (add clean diesel fuel to 1/4 full).

M. Connect the following lines:
   - Lift pump suction (both ends)
   - Lift pump pressure (both ends)
   - Fuel filter drain
   - Fuel return (at injection pump)

N. Connect the fuel filter outlet and the fuel return line at the pick-up/sending unit to hoses that flow to metal containers.

O. Connect the batteries and crank the engine until clean fuel flows from the fuel filter outlet into a metal container (see Figure 7-59):
   - Allow a maximum of 15 seconds cranking time, followed by 1 minute of cranking motor cooling time.

P. Connect the hose from the fuel filter outlet to the injection pump inlet.

Q. Open each injection line at its nozzle end and crank the engine until clean fuel flows from it:
   - Use two wrenches when loosening the injection line fittings.
   - Allow a maximum of 15 seconds cranking time, followed by 1 minute of cranking motor cooling time.

R. Tighten each injection line fitting at its nozzle:
   - Use two wrenches when tightening the injection line fittings.

S. Remove the electrical connector for the fast idle/cold advance temperature switch and jumper its wiring harness terminals with an insulated wire.

Figure 7-59, Fuel System Cleaning (1)

T. Connect the electrical connector for the fuel shut-off solenoid in the injection pump.

U. Start and run the engine for 15 minutes while fuel flows from the fuel return line into a metal container (see Figure 7-60).

V. Stop the engine.

W. Connect the fuel return hose to the fuel pick-up/sending unit.

X. Remove the jumper wire and install the electrical connector for the fast idle/cold advance temperature switch.

Y. Clean the engine of fuel spillage.

Z. Fill the fuel tank and add a biocide, if needed.

3. Clean gasoline from the fuel system in these steps:

A. Determine a procedure:

- If the engine runs, follow steps B, C, J and K.
- If the engine does not run, begin at step C.

B. Drain the fuel tank.

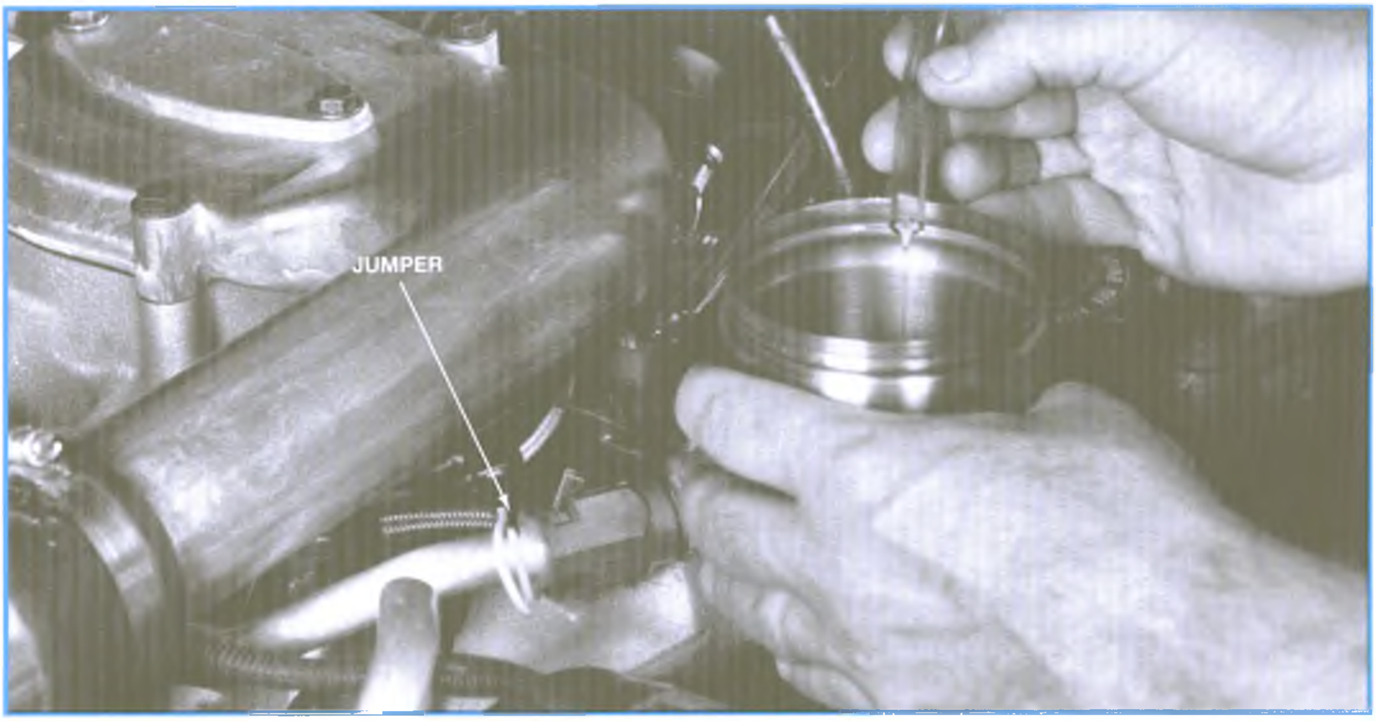


Figure 7-60, Fuel System Cleaning (2)

C. Fill the fuel tank.

D. Disconnect the electrical connector for the fuel shut-off solenoid in the injection pump.

E. Remove the fuel filter outlet and connect it to a hose that flows to a metal container.

F. Crank the engine until clean fuel flows from the fuel filter outlet into a metal container:
   - Allow a maximum of 15 seconds cranking time, followed by 1 minute of cranking motor cooling time

G. Connect the hose from the fuel filter outlet to the injection pump inlet.

H. Remove the electrical connector for the fast idle/cold advance temperature switch and jumper its terminals with an insulated wire.

I. Connect the electrical connector for the fuel shut-off solenoid in the injection pump.

J. Start and run the engine for 15 minutes.

K. Stop the engine.

L. Remove the jumper wire and install the electrical connector for the fast idle/cold advance temperature switch.

M. Clean the engine of fuel spillage.

Fuel-Specific Gravity Check

Note: The hydrometer fuel quality tester provides a general indication of fuel quality and should not be considered scientifically accurate.

1. Drain the fuel filter housing by doing these things:
   - Stop the engine.
   - Place a container under the drain valve exit hose at the left front side of the engine.
   - Open the drain valve.
   - Start the engine and operate it at operating speed until clear fuel appears at the drain valve exit hose.
   - Fill a 1-liter (0.946-quart) container with a sample of clean fuel.
   - Close the drain valve and stop the engine.
   - Bring the fuel sample to 60° F (16° C).

2. Obtain a fuel quality hydrometer (special tool J 34352).

3. Fill the hydrometer with the fuel sample by doing these things:
   - Squeeze the hydrometer bulb.
   - Submerse the hydrometer tip into the sample.
   - Release the bulb, allowing fuel to enter the glass tube until it floats the glass bulb inside the tube.
   - Gently spin the hydrometer to relieve the surface tension of the fuel sample.

4. Read the scale on the glass bulb at the point where the top of the fuel sample contacts it (see Figure 7-61):
   - If the top of the fuel sample is in the yellow part of the glass bulb scale (above the green part), suspect the presence of gasoline in the fuel.
   - If the top of the fuel sample is in the green part of the glass bulb scale, the fuel has high quality (approximate cetane rating of 46 to 50).
   - If the top of the fuel sample is in the yellow part of the glass bulb scale (below the green part), the fuel has moderate quality (approximate cetane rating of 41 to 45).
   - If the top of the fuel sample is in the red part of the glass bulb scale, the fuel has low quality (approximate cetane rating of 38 to 40).

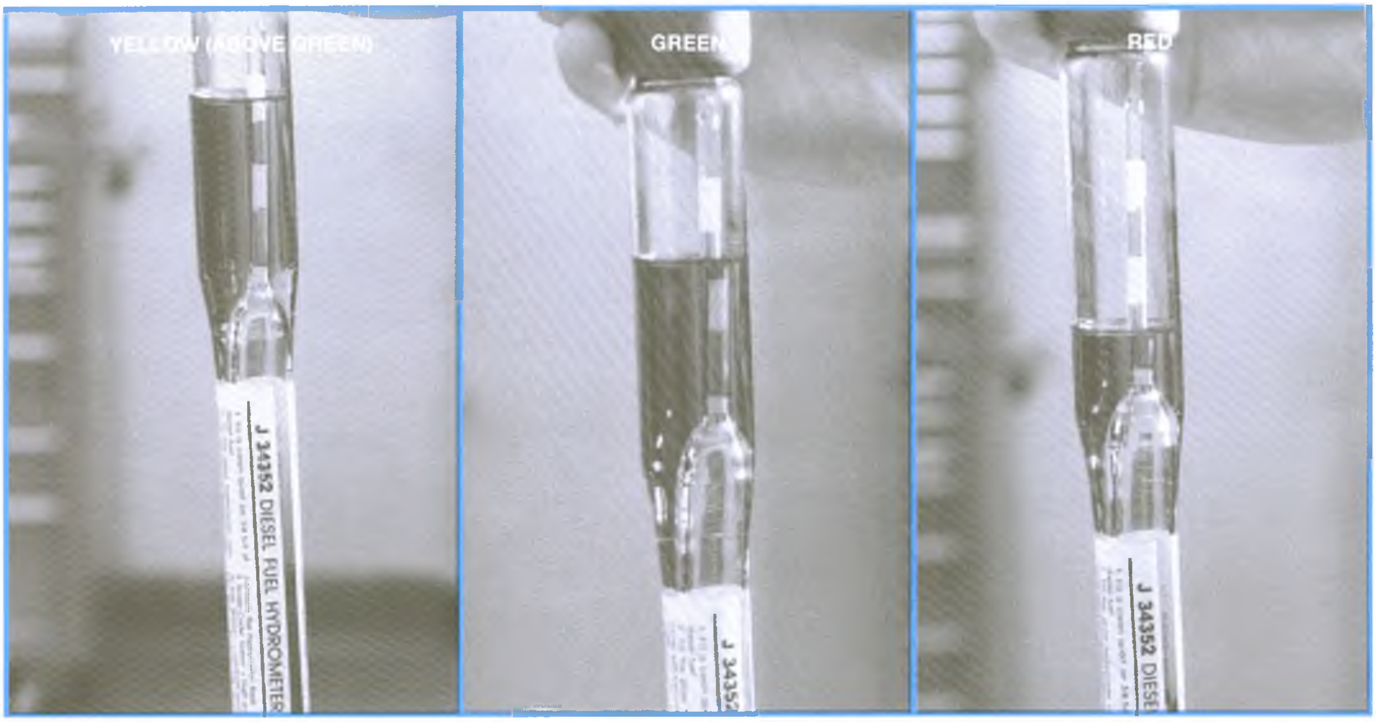


Figure 7-61, **Fuel Specific Gravity Check**

Fuel Supply System Checks

1. Check the output volume of the lift pump in the following steps:
   A. Remove the electrical connector for the fuel shut-off solenoid at the injection pump.
   B. Remove the pipe at the lift pump outlet fitting.
   C. Install a hose at the lift pump outlet fitting and place a 1-liter (0.946-quart) container at the hose to collect fuel.
   D. Crank the engine and measure the fuel volume (see Figure 7-62):
      - If the volume is more than 0.24 liter (1/2 pint) in 15 seconds, check lift pump output pressure (part 3).
      - If the volume is less than 0.24 liter (1/2 pint) in 15 seconds, check the lift pump suction line (part 2).
2. Check the suction line of the lift pump in the following steps:
   A. Remove the fuel tank cap and repeat the lift pump output volume check (step 1):
      - If the volume is more than 0.24 liter (1/2 pint) in 15 seconds, replace the defective fuel tank cap and go to part 3.
      - If the volume is less than 0.24 liter (1/2 pint) in 15 seconds, go to step B.

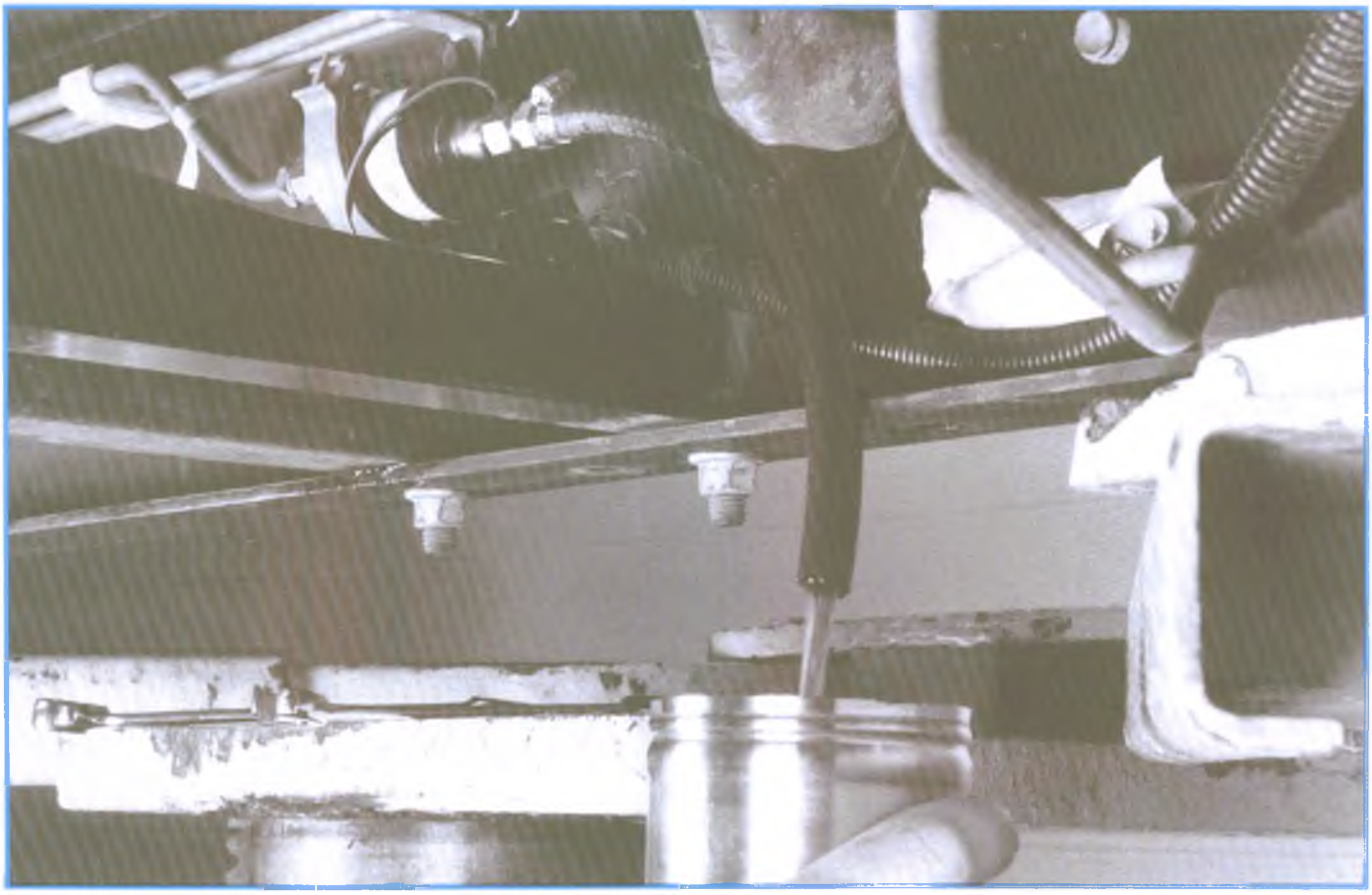


Figure 7-62, Volume Check at Lift Pump Outlet (1)

B. Separate the lift pump suction line from the fuel pick-up/sending unit.

C. Connect the suction line to a source of clean fuel, using an additional hose.

D. Repeat the lift pump output volume check (see Figure 7-63):

- If the volume is more than 0.24 liter (1/2 pint) in 15 seconds, remove the fuel pick-up/sending unit and check it for restriction.
- If the volume is less than 0.24 liter (1/2 pint) in 15 seconds, go to step E.

Note: If the fuel pick-up filter is restricted with waxed fuel, bring the fuel to operating temperature before performing further tests.

E. Check the lift pump suction line for restriction:

- If restriction exists, repair it and re-check lift pump output volume.
- If no restriction exists, replace the lift pump and re-check lift pump output volume.

F. Attach the lift pump suction line to the fuel pick-up/sending unit and check lift pump output pressure (part 4).

Figure 7-63, **Volume Check at Lift Pump Outlet (2)**

3. Check the output pressure of the lift pump in the following steps:
   A. Install a tee adaptor between the lift pump outlet fitting and pressure line.
   B. Connect a pressure gauge with a dial indication of 0 to 103 kPa (0 to 15 psi) to the tee adaptor.
   C. Run the engine and measure the fuel pressure (see Figure 7-64):
      - If the pressure is between 40 and 60 kPa (5.8 and 8.7 psi), go to step D.
      - If the pressure is less than 40 kPa (5.8 psi), replace the lift pump and re-check output pressure.
   D. Remove the pressure gauge and tee adaptor.
   E. Install the pressure line at the lift pump outlet fitting.
   F. Clean any fuel spillage.
   G. Run the engine to check for fuel leakage
   H. Check the lift pump pressure line (part 4).

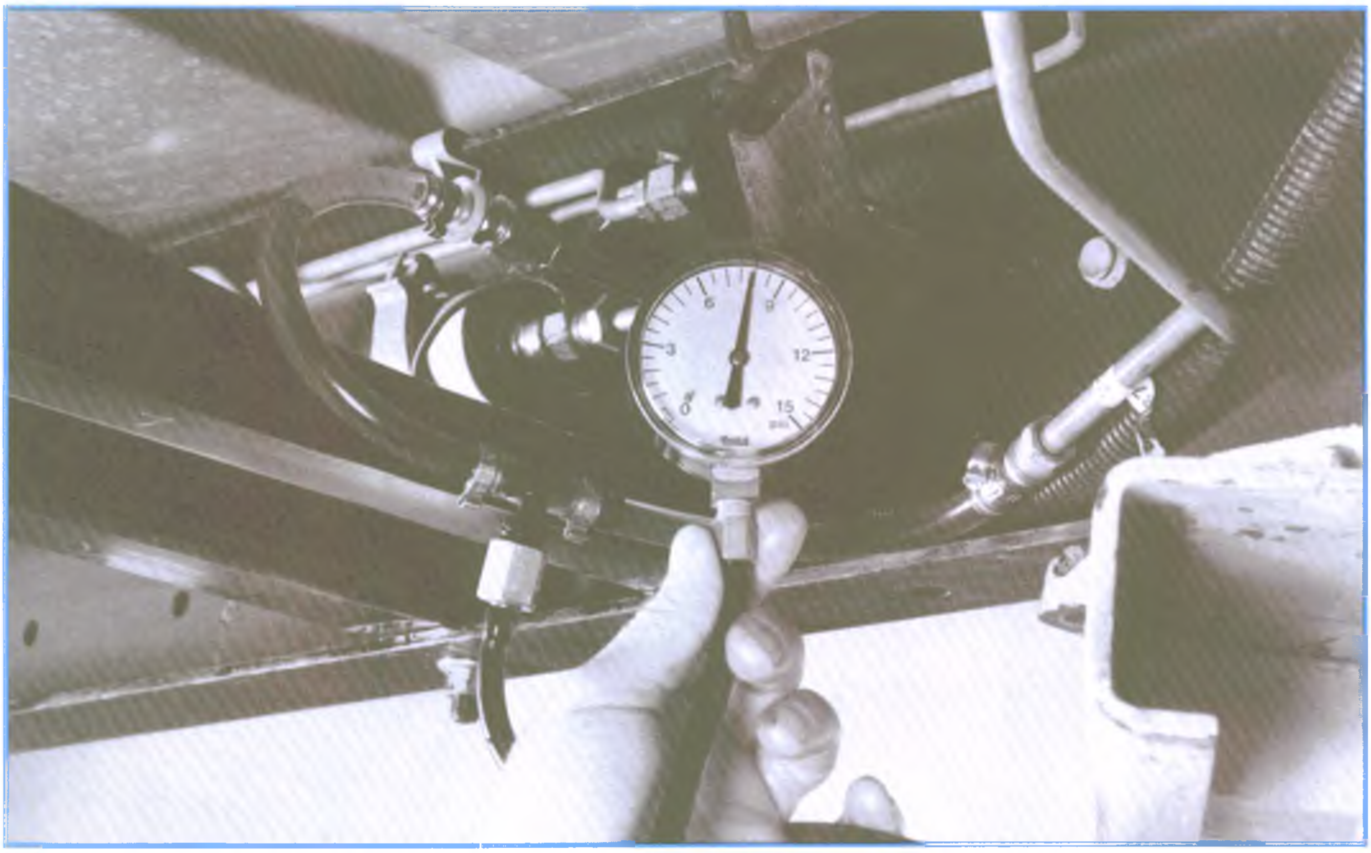


Figure 7-64, Pressure Check at Lift Pump Outlet

4. Check the lift pump pressure line in the following steps:
   A. Separate the hose of the lift pump pressure line from the fuel filter inlet fitting.
   B. Install an extension hose at the lift pump pressure line and place a 1-liter (0.946-quart) container at the hose to collect fuel.
   C. Repeat the lift pump output volume check (see Figure 7-65):
      - If the volume is more than 0.24 liter (1/2 pint) in 15 seconds, check the fuel filter.
      - If the volume is less than 0.24 liter (1/2 pint) in 15 seconds, go to step D.
   D. Check the lift pump pressure line for restriction:
      - If restriction exists, repair it and re-check lift pump output volume.
      - If no restriction exists, replace the lift pump and re-check lift pump output volume.
   E. Attach the hose of the lift pump pressure line to the fuel filter.
   F. Clean any fuel spillage.
   G. Run the engine to check for fuel leakage.
   H. Check the fuel filter (part 5).

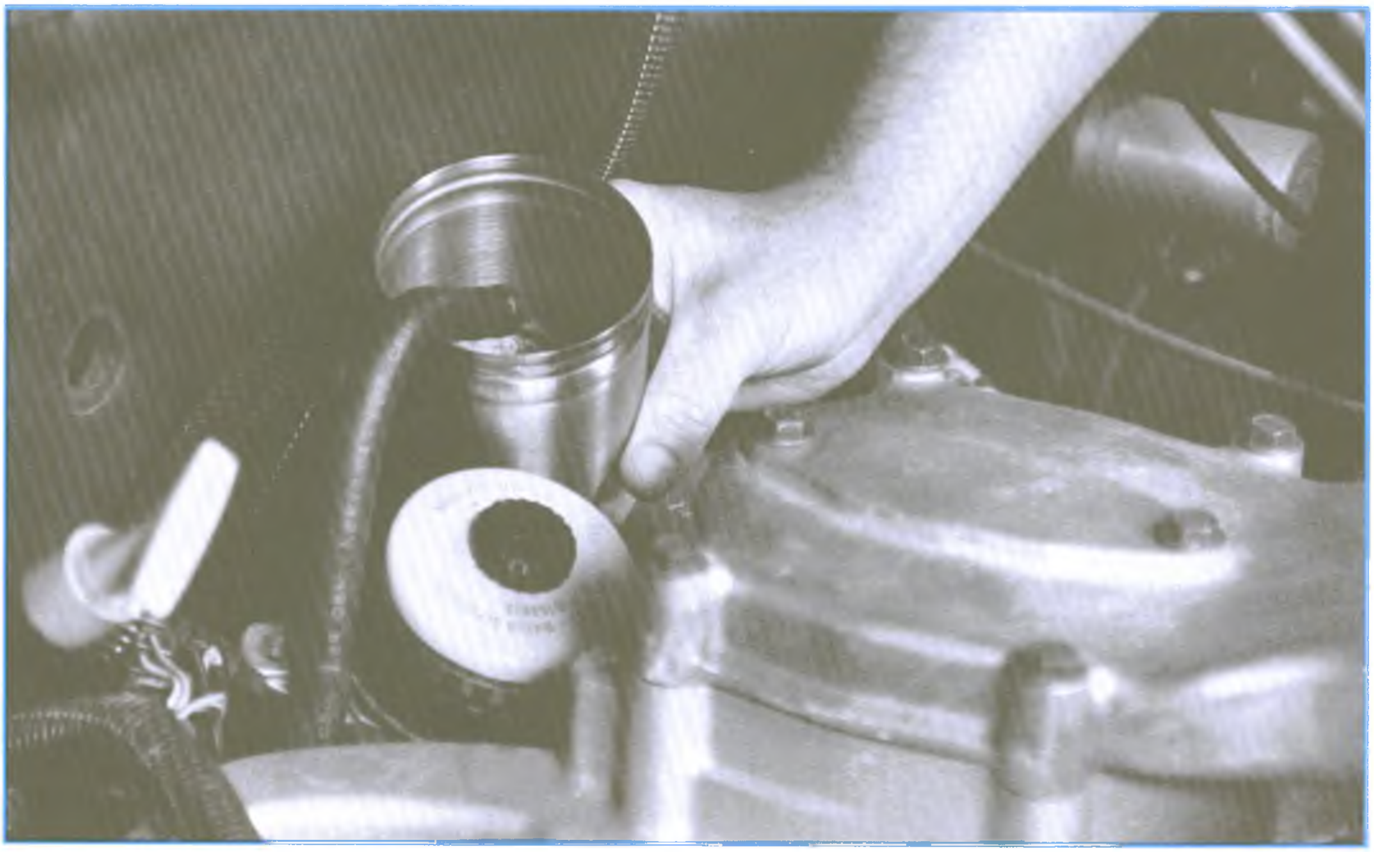


Figure 7-65, Volume Check at Lift Pump Pressure Line

5. Check the fuel filter in the following steps:
   A. Remove the electrical connector for the fuel shut-off solenoid at the injection pump.
   B. Separate the hose of the filter outlet to the injection pump inlet fitting.
   C. Install an extension hose at the filter outlet and place a 1-liter (0.946-quart) container at the hose to collect fuel.
   D. Repeat the lift pump output volume check (see Figure 7-66):
      - If the volume is more than 0.24 liter (1/2 pint) in 15 seconds, go to step E.
      - If the volume is less than 0.24 liter (1/2 pint) in 15 seconds, replace the fuel filter element and re-check lift pump output volume.

Note: If the fuel filter element is restricted with waxed fuel, bring the fuel to operating temperature before performing further tests. Also check the operation of the fuel heater (see page 7-21).

   E. Install a tee adaptor between the lift pump outlet fitting and pressure line.

Figure 7-66, **Volume Check at Fuel Filter Outlet**

F. Connect a pressure gauge with a dial indication of 0 to 103 kPa (0 to 15 psi) to the tee adaptor.

G. Install the electrical connector for the fuel shut-off solenoid at the injection pump, then start and run the engine.

H. Repeat the lift pump output pressure check (see Figure 7-67):
   - If the pressure is between 40 and 60 kPa (5.8 and 8.7 psi), go to step I.
   - If the pressure is less than 40 kPa (5.8 psi), replace the fuel filter element and re-check lift pump output pressure.

I. Remove the pressure gauge and tee adaptor.

J. Check the fuel supply for air leaks (part 6).

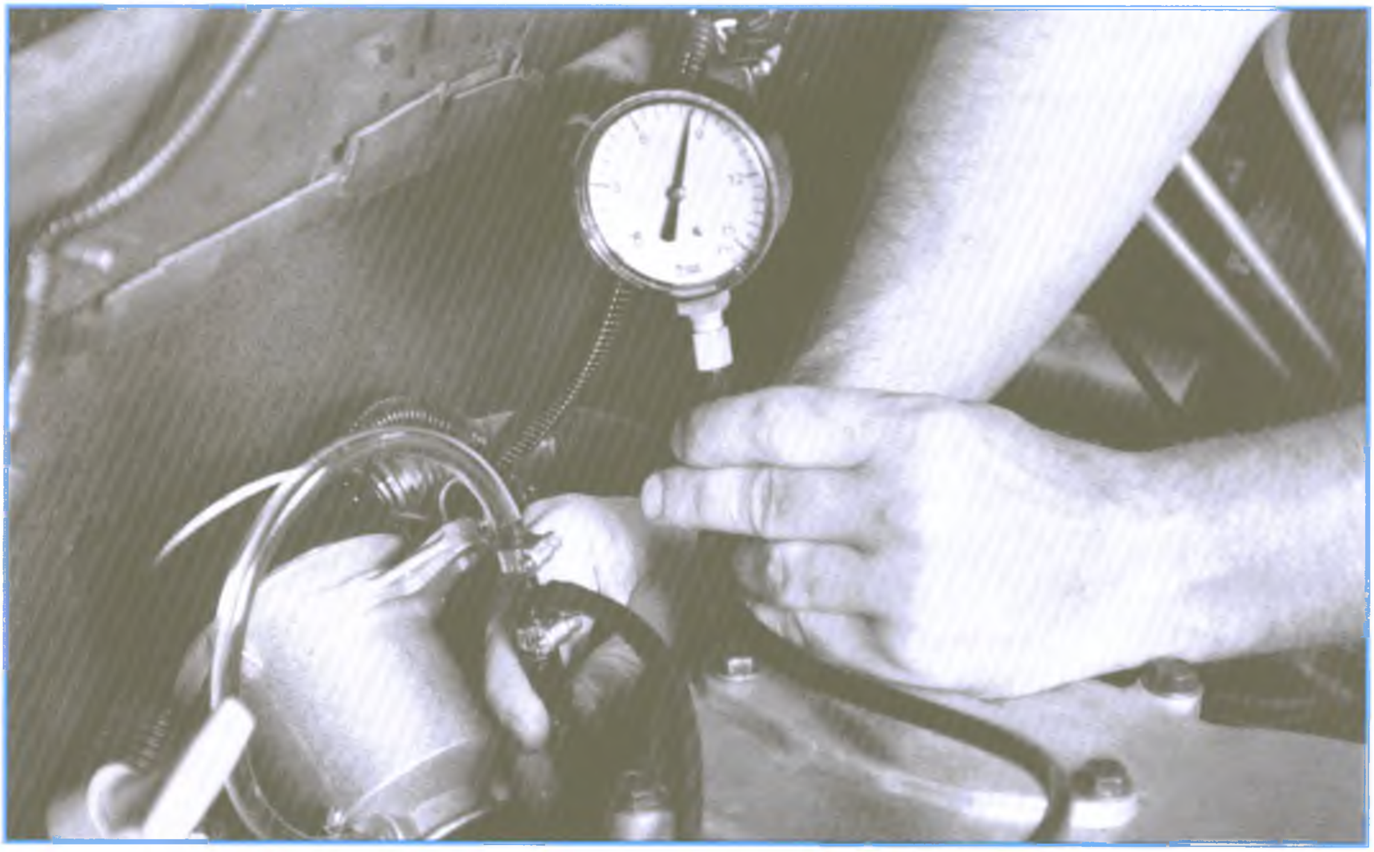


Figure 7-67, Pressure Checks at Fuel Filter Outlet

6. Check the fuel supply for air leaks, following these steps:
   A. Install a transparent hose between the filter outlet and injection pump inlet.
   B. Start and run the engine, observing the fuel for air bubbles (see Figure 7-68):
      - If air bubbles are not present, stop the engine and go to step F.
      - If air bubbles are present, stop the engine and go to step C.
   C. Check the lift pump suction line for air leakage:
      - Separate the suction line hose from the fuel pick-up/sending unit and plug it.
      - Separate the suction line pipe from the lift pump, and connect a vacuum pump/gauge to it.
      - Apply a vacuum to the suction line, and observe the gauge reading:
        - If vacuum does not drop, attach the suction line pipe and go to step D.
        - If vacuum drops, repair the air leak in the suction line and attach the suction line pipe and hose.

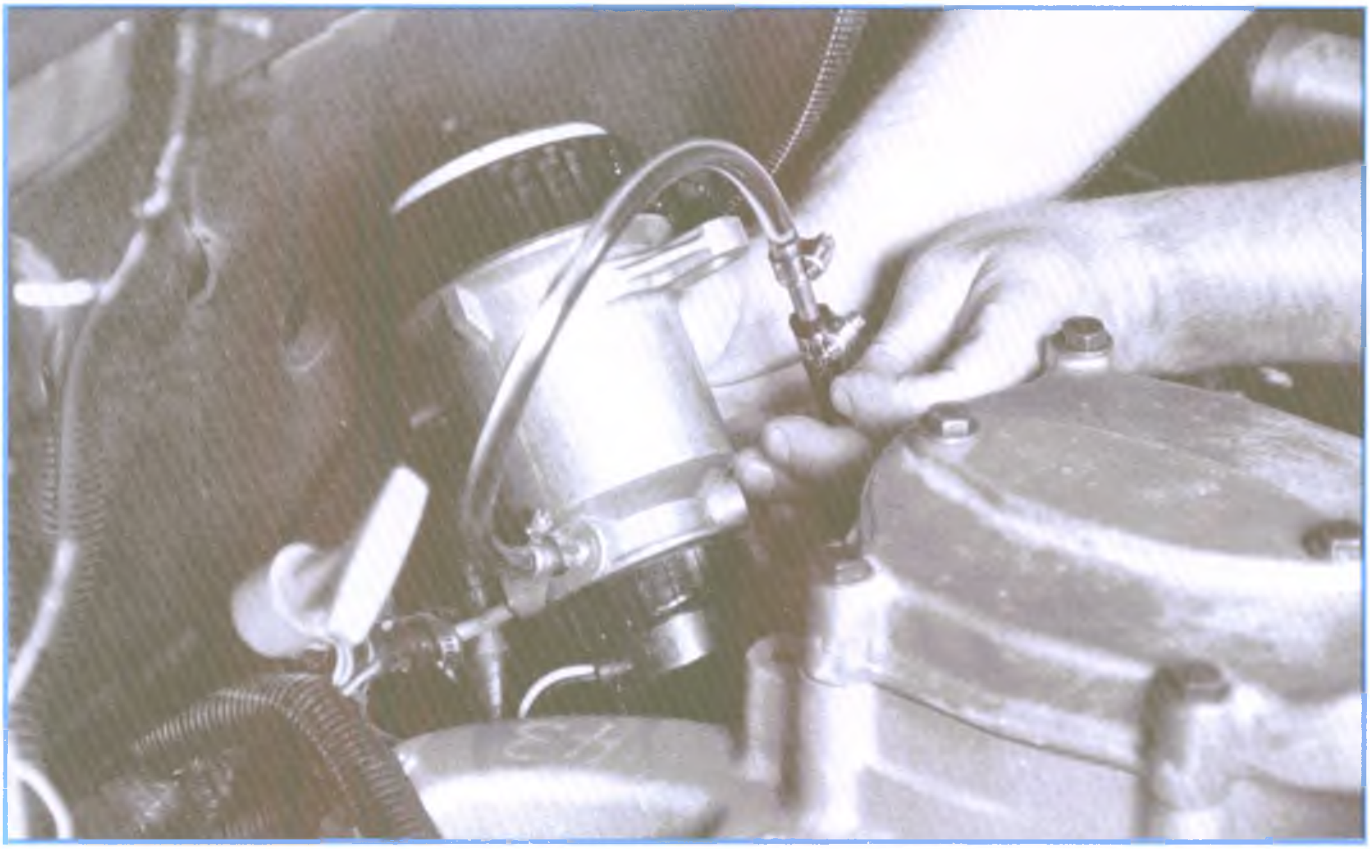


Figure 7-68, Check for Air in Fuel at Injection Pump Inlet

D. Check the fuel pick-up/sending unit for air leakage:
- Remove the fuel tank.
- Remove the fuel pick-up/sending unit from the fuel tank, remove the filter and plug the bottom end of the pick-up tube.
- Apply a vacuum to the upper end of the pick-up tube, and observe the gauge reading (see Figure 7-69):
  - If vacuum does not drop, install the fuel pick-up sending unit and fuel tank.
  - If vacuum drops, replace the fuel pick-up/sending unit, install the fuel tank, attach the suction line hose and go to step E.

E. Start and run the engine, observing the fuel for air bubbles:
- If air bubbles are present, stop the engine and re-check steps C and D.
- If air bubbles are not present, stop the engine and go to step F.

F. Remove the transparent hose and attach the hose of the filter outlet to the injection pump inlet fitting.

G. Clean any fuel spillage.

H. Run the engine to check for fuel leakage.

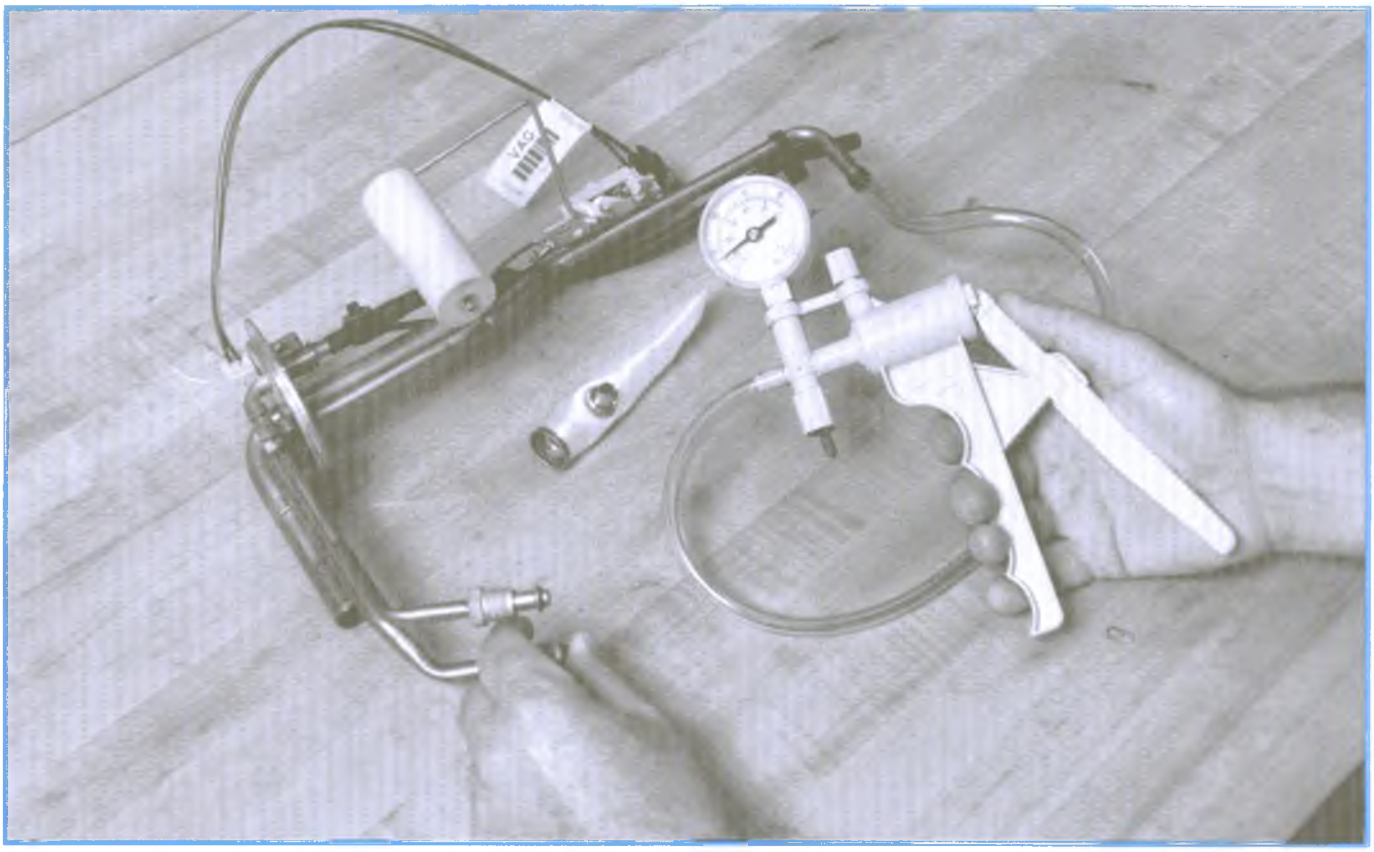


Figure 7-69, Fuel Pick-Up/Sending Unit Check

Fuel Return System Checks

1. Check injection pump housing pressure in the following steps:

   A. Remove the housing pressure regulator from the injection pump governor cover.

   B. Install a tee adaptor between the governor cover and the housing pressure regulator.

   C. Connect a pressure gauge with a dial indication of 0 to 103 kPa (0 to 15 psi) to the tee adaptor.

   D. Start and run the engine, observing the gauge reading (see Figure 7-70):
      - If the pressure is between 55 and 83 kPa (8 and 12 psi), go to step F.
      - If the pressure is more than 83 kPa (12 psi), go to step E.

   E. Replace the housing pressure regulator and re-check housing pressure:
      - If the pressure is between 55 and 83 kPa (8 and 12 psi), go to step F.
      - If the pressure is more than 83 kPa (12 psi), check the fuel return system.

   F. Remove the pressure gauge and tee adaptor.

   G. Clean any fuel spillage.

   H. Run the engine to check for fuel leakage.

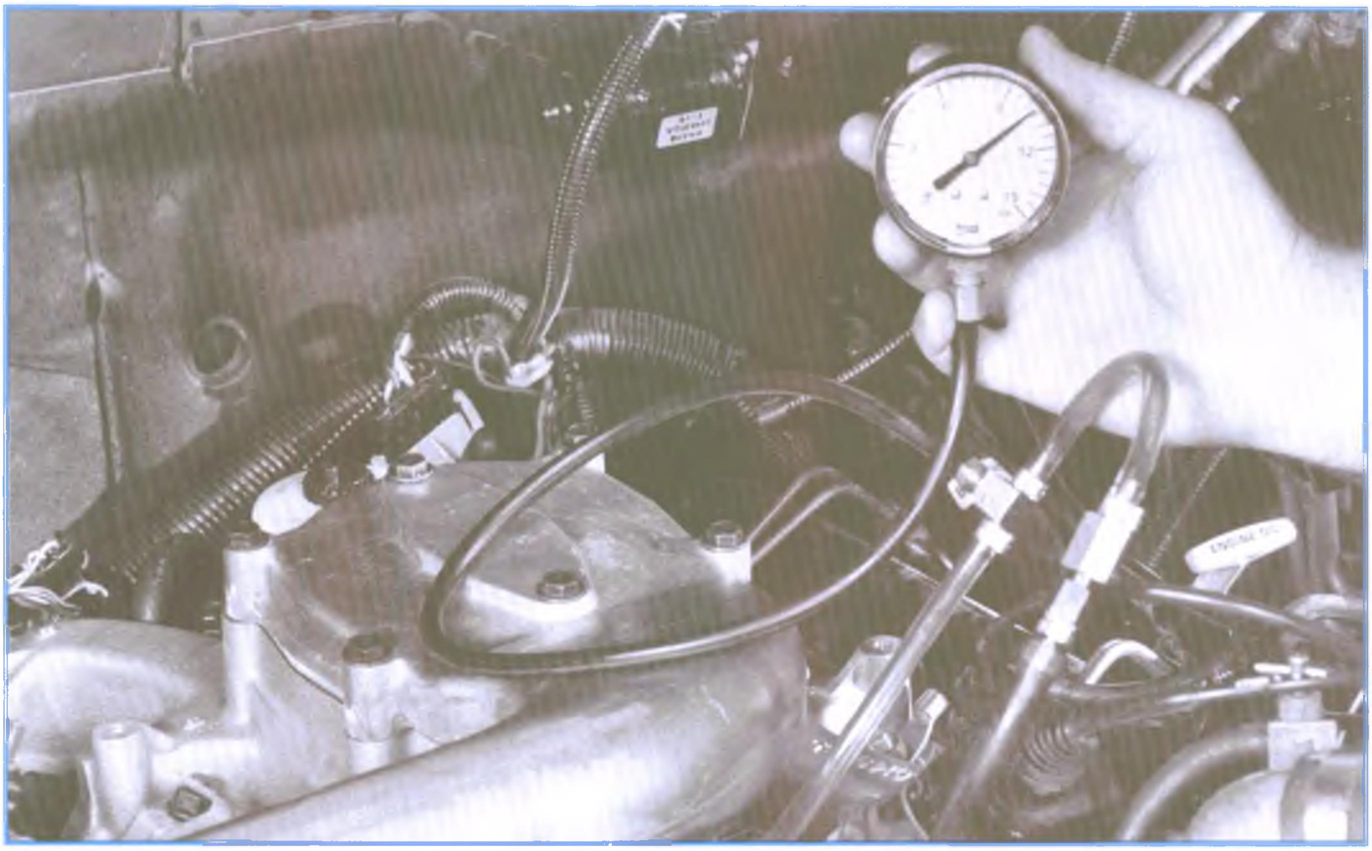


Figure 7-70, Housing Pressure Check

2. Check the fuel return system for restriction in the following steps:
   A. Separate the hose of the fuel return line at the fuel pick-up/sending unit.
   B. Separate the hose of the fuel return line at the housing pressure regulator on the injection pump, and connect a vacuum pump/gauge to the hose.
   C. Apply vacuum to the return line and observe the gauge reading (see Figure 7-71):
      - If vacuum does not build, go to step D.
      - If vacuum builds, repair the return line restriction and re-check housing pressure.
   D. Attach the hoses of the fuel return line at the injection pump and fuel pick-up/sending unit.
   E. Clean any fuel spillage.
   F. Run the engine to check for fuel leakage.

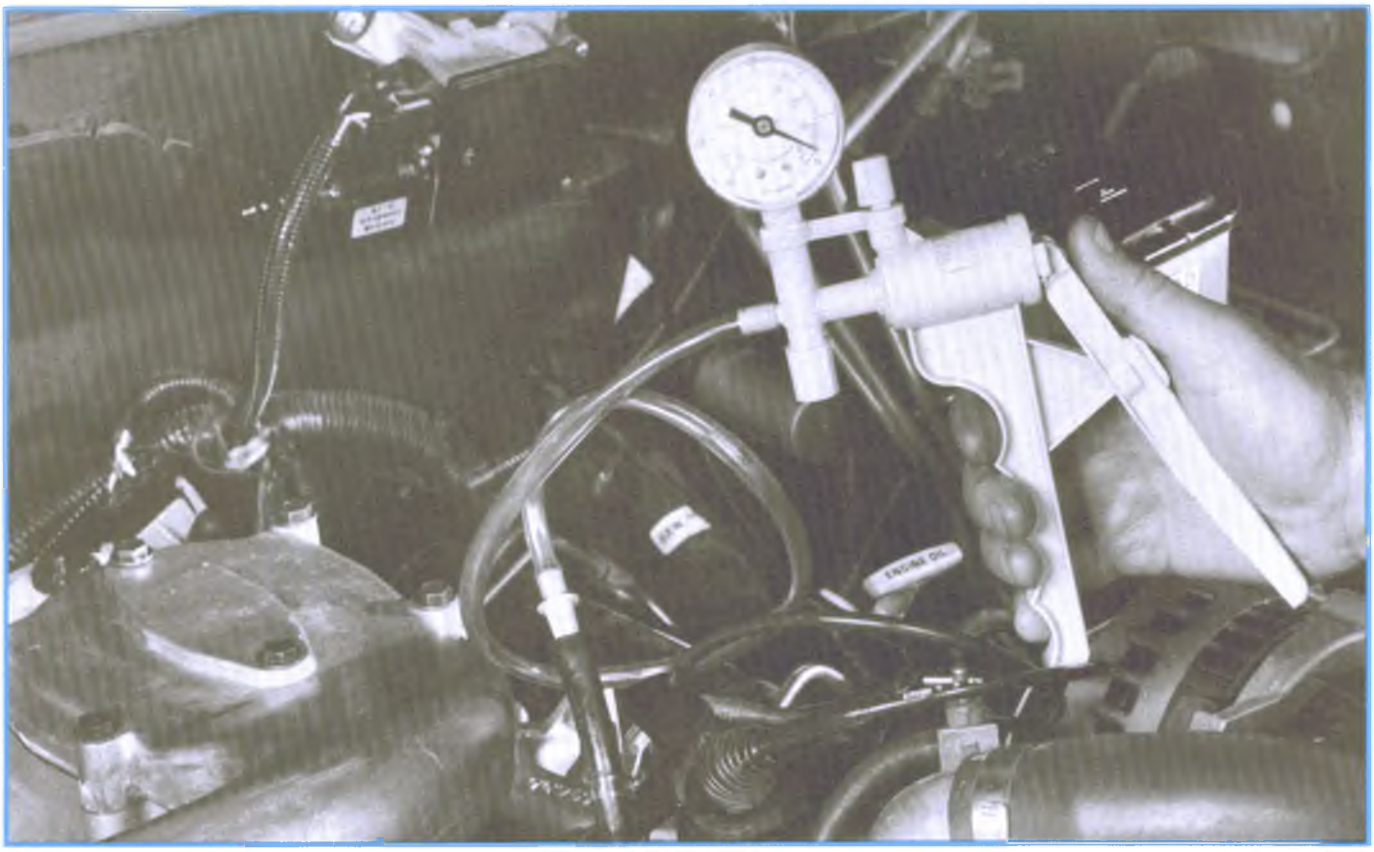


Figure 7-71, **Fuel Return Line Restriction Check**

3. Check the fuel return system for air leaks, following these steps:

   A. Separate the return hose at the injection pump housing pressure regulator.

   B. Install a transparent hose between the housing pressure regulator and the hose of the return line.

   C. Start and run the engine, observing the fuel for air bubbles (see Figure 7-72):

      - If air bubbles are not present, go to step D.
      - If air bubbles are present, check the fuel supply system for air leaks (if the fuel supply system checks good, replace the injection pump and re-check the fuel return system).

   D. Stop the engine.

   E. Remove the transparent hose and attach the fuel return hose at the injection pump.

   F. Clean any fuel spillage.

   G. Run the engine to check for fuel leakage.

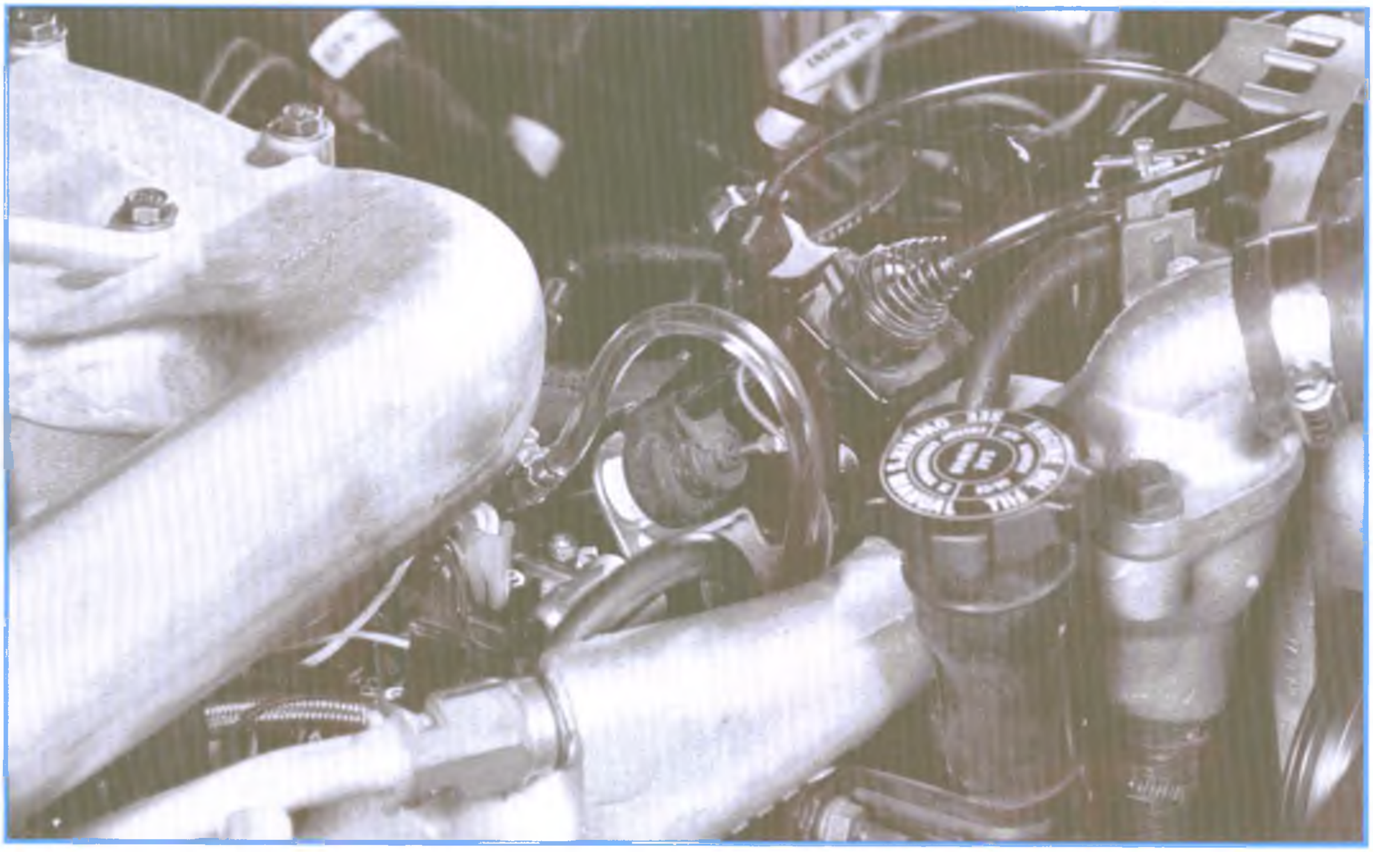


Figure 7-72, Check for Air in Fuel at Injection Pump Outlet

Fuel Injection Pump Transfer Pressure Check

1. Remove the locking plate, screw and O-ring seal from the head of the injection pump. (This procedure may require removing and installing the intake manifold.)
2. Install the transfer pump pressure test adaptor in the head of the injection pump (see Figure 7-73).
3. Connect a pressure gauge that reads from 0 to 1034 kPa (0 to 150 psi).
4. Remove the electrical connector for the fuel shut-off solenoid at the injection pump.
5. Crank the engine and observe the gauge reading:
   - If the gauge reading is more than 138 kPa (20 psi), go to step 6.
   - If the gauge reading is less than 138 kPa (20 psi), perform the fuel supply checks (if the fuel supply checks good, replace the injection pump and re-check transfer pump pressure).
6. Install the electrical connector for the fuel shut-off solenoid at the injection pump.
7. If available, install a diesel injection timing meter (J 33300).

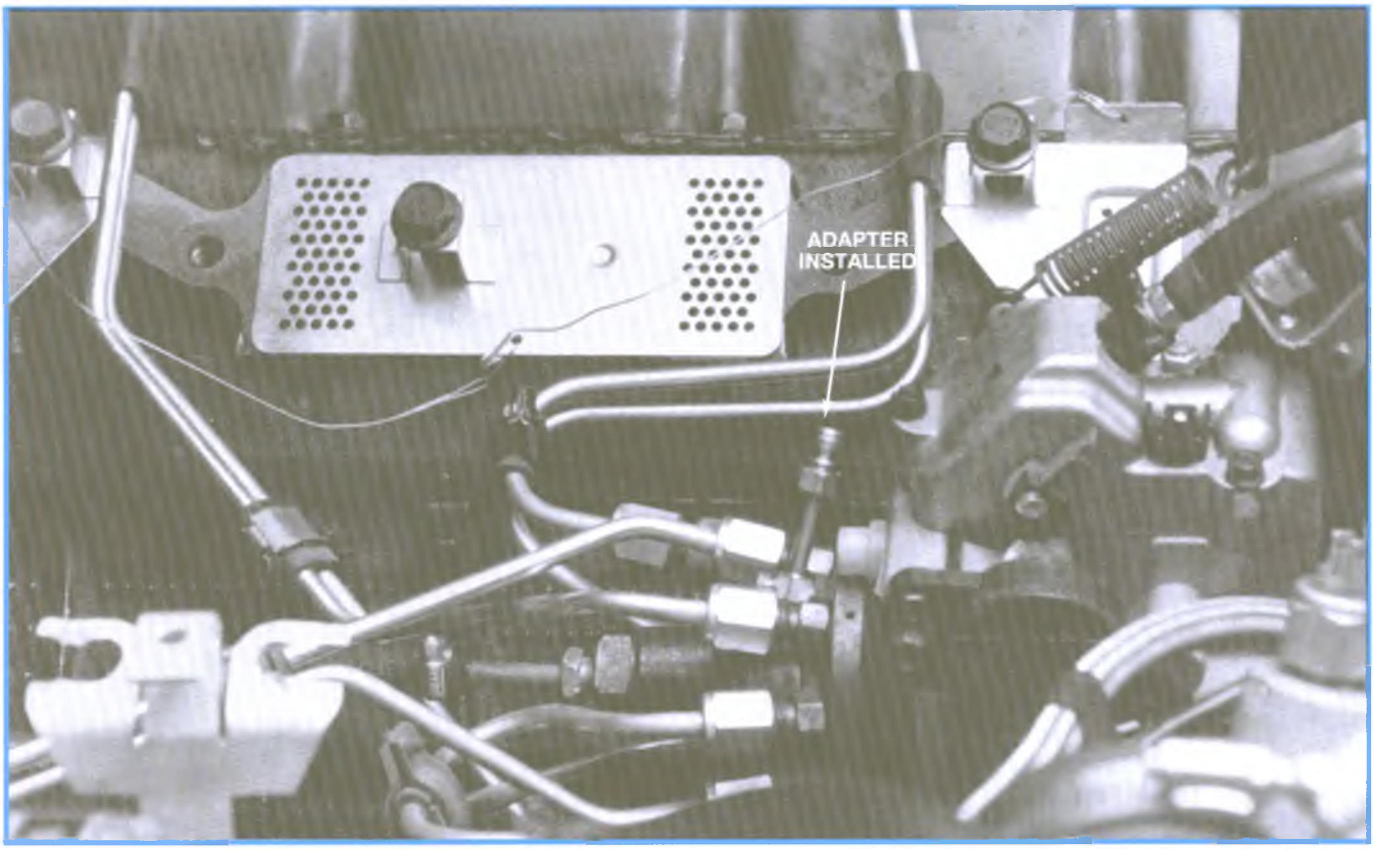


Figure 7-73, Transfer Pump Pressure Adaptor Installation

8. Start and run the engine, observing the gauge reading (see Figure 7-74):
   - At idle speed, the gauge reading should be approximately 138 to 276 kPa (20 to 40 psi).
   - As engine speed increases, the gauge reading should indicate a steady increase in pressure (injection timing should advance).
9. If transfer pump pressure does not increase steadily (and the fuel supply checks good), replace the injection pump and re-check transfer pump pressure).
10. Disconnect the pressure gauge and transfer pump pressure test adaptor.
11. Install the locking plate, screw and a new O-ring seal on the head of the injection pump. (This procedure may require removing and installing the intake manifold.)
12. Remove the diesel injection timing meter, if used.

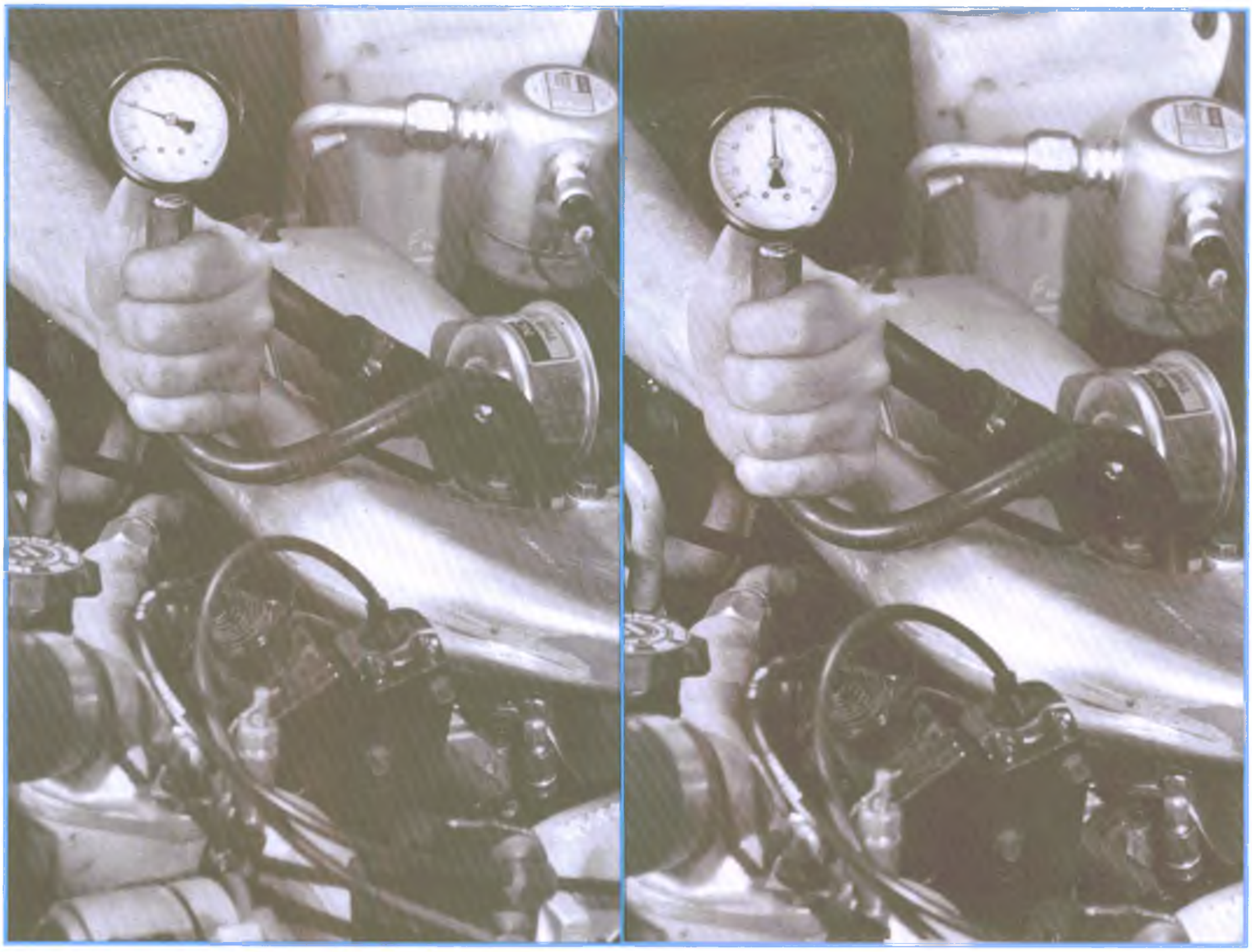


Figure 7-74, Transfer Pump Pressure Check

Fuel Injection Pump Advance Mechanism Check

1. Bring the engine to operating temperature.
2. If available, install a diesel injection timing meter (J 33300).
3. Remove the intake manifold upper cover (sound insulator).
4. Start and run the engine.
5. While the engine is running at 2,000 rpm, use a long screwdriver to press the bottom of the rocker lever for the injection pump light load advance mechanism inward (see Figure 7-75).
6. As the rocker lever is pressed inward, observe a change in engine speed:
   - If engine speed drops (injection timing retards), go to step 7.
   - If engine speed does not drop, replace the injection pump and re-check the advance piston operation.
7. Stop the engine.
8. Install the intake manifold upper cover (sound insulator).
9. Remove the diesel injection timing meter, if used.

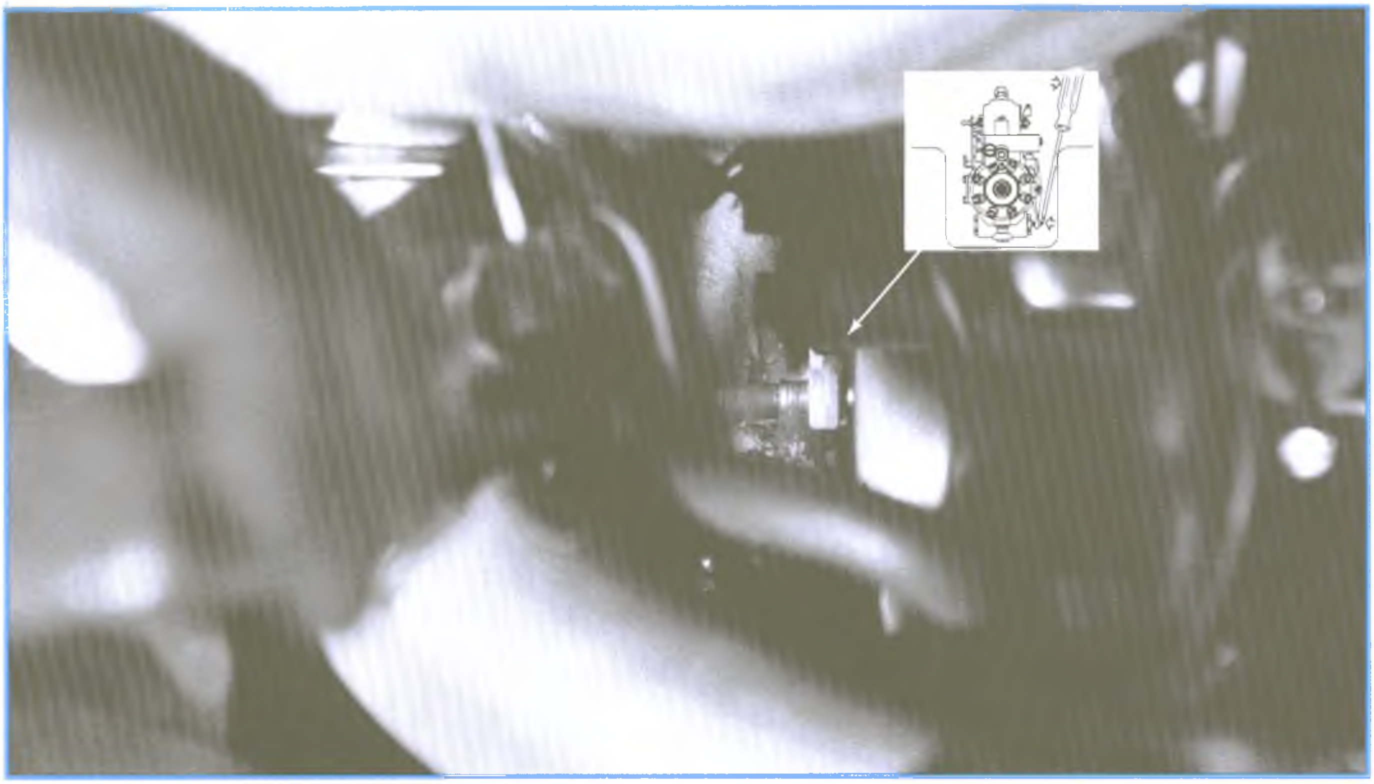


Figure 7-75, **Advance Mechanism Check**

Rough Idle Diagnosis Check

1. Check fuel injection pump static timing:
   - Align the front cover and injection pump marks.
2. Check low idle speed (refer to page 7-87 for the complete procedure steps):
   - Adjust to the vehicle emission label specification.
3. Inspect fuel injection lines and nozzles for fuel leakage:
   - Repair any leakage.
4. Check fuel supply to the injection pump (refer to page 7-68 for the complete procedure steps):
   - Minimum volume is 0.24 liter (1/2 pint) in 15 seconds.
   - Minimum pressure is 40 kPa (5.8 psi).
   - Fuel must be free of air bubbles.
   - Make repairs, if needed.
5. Check the fuel return from the injection pump (refer to page 7-76 for the complete procedure steps):
   - Fuel must be free of air bubbles.
   - Repair injection pump, if needed.
6. Check each nozzle during engine operation:
   - Loosen the injection line fitting nut at the nozzle to be tested.
   - Observe that solid fuel flows from the line (no air bubbles).
   - If air bubbles exist, go to step 7.
   - If air bubbles do not exist, go to step 8.
7. Check a nozzle during engine cranking:
   - Remove the B+ wire from the injection pump fuel shut-off solenoid.
   - Remove and relocate the injection line to observe the nozzle inlet.
   - Crank the engine and watch for air bubbles at the nozzle inlet fitting.
   - If bubbles exist, replace the nozzle and go to step 8.
   - Install all injection lines and remove all glow plugs.
   - Crank the engine while observing the fuel mist exiting each glow plug hole.
   - If no mist is present at any of the glow plug holes, remove and test the related injection nozzle.
8. Follow the steps of the glow plug resistance check (see next page).

Glow Plug Resistance Check

1. Bring the engine to operating temperature, with all glow plugs operating correctly.
2. With the engine running, do the following things:
   - Disconnect the wire from each glow plug.
   - Separate the electrical connector for the generator (at the regulator).
   - Install a magnetic probe tachometer.
   - Adjust the engine speed to the point of rough idle (do not exceed 900 rpm).
   - Allow the engine operation to stabilize for one minute.
3. As the engine continues to run, test each cylinder in the following steps:
   - Adjust a high-impedence digital multimeter to the 200-ohm scale.
   - Connect the meter negative lead to the injection pump bracket that supports the fast idle solenoid.
   - Connect the meter positive lead to the electrical terminal of the glow plug of the cylinder to be tested.
   - Observe the resistance reading of the glow plug.
   - Test each cylinder in the firing order, noting the resistance on a chart (see example in Figure 7-76).
   - Stop the engine.
   - Allow the engine to rest for several minutes.
   - Re-test each cylinder in the firing order, noting the resistance on a chart (see Figure 7-76).

	CYLINDER TESTED							
MEASUREMENT	**#1**	**#8**	**#7**	**#2**	**#6**	**#5**	**#4**	**#3**
Glow Plug Resistance (Engine ON) (Before Nozzle Substitution)	2.5	2.6	1.9	1.8	2.3	2.4	2.5	2.6
Glow Plug Resistance (Engine OFF) (Before Nozzle Substitution)	0.8	0.6	0.6	0.8	0.9	1.0	0.7	0.8
Nozzle Opening Pressure (Before Substitution)								
Nozzle Opening Pressure (After 1st Substitution)								
Glow Plug Resistance (Engine ON) (After 1st Nozzle Substitution)								
Nozzle Opening Pressure (After 2nd Substitution)								

Figure 7-76, Glow Plug Resistance Test Worksheet (1)

4. Analyze the glow plug resistance readings:
   - Readings during engine operation should be between 1.9 and 3.9 ohms, with a maximum variation of 0.4 ohm between cylinders.
     - For cylinders with readings that vary more than 0.4 ohm when compared to the other cylinders, go to step 5.
     - For cylinders with readings below 1.6 ohms, perform a compression test to confirm a mechanical fault.
     - For cylinders with varying readings and extremely erratic idle roughness, install a timing meter luminosity probe in each suspect cylinder (J 33300-1) to confirm erratic combustion.
   - Readings with the engine at rest should be between 0.5 and 1.6 ohms.
     - For cylinders with readings not within specifications, check meter operation and test lead connections.

5. Remove the nozzles from the cylinders with glow plug resistance readings that vary more than 0.4 ohm and do the following things:
   - Test each nozzle for opening pressure, leakage, chatter and spray pattern.
     - If a nozzle fails testing, substitute it with a new nozzle.
   - Note the opening pressure of each nozzle on a chart (see Figure 7-77), including any new nozzle.

	CYLINDER TESTED							
MEASUREMENT	**#1**	**#8**	**#7**	**#2**	**#6**	**#5**	**#4**	**#3**
Glow Plug Resistance (Engine ON) (Before Nozzle Substitution)	2.5	2.6	1.9	1.8	2.3	2.4	2.5	2.6
Glow Plug Resistance (Engine OFF) (Before Nozzle Substitution)	0.8	0.6	0.6	0.8	0.9	1.0	0.7	0.8
Nozzle Opening Pressure (Before Substitution)		1650	1950	1900				1600
Nozzle Opening Pressure (After 1st Substitution)								
Glow Plug Resistance (Engine ON) (After 1st Nozzle Substitution)								
Nozzle Opening Pressure (After 2nd Substitution)								

A: High glow plug resistance and low nozzle opening pressure

B: Low glow plug resistance and high nozzle opening pressure

Figure 7-77, **Glow Plug Resistance Test Worksheet (2)**

6. Analyze the opening pressure readings of the nozzles tested (see Figure 7-78):
   - To increase the glow plug resistance reading of a cylinder, switch to a nozzle with a lower opening pressure.
   - To decrease the glow plug resistance reading of a cylinder, switch to a nozzle with a higher opening pressure.
7. Install the switched nozzles into the appropriate cylinders, following this procedure:
   - Use a new compression gasket with each nozzle.
   - Apply anti-seize compound on the cylinder head threads.
   - Use a nozzle tightening torque of 60 to 80 N·m (44 to 55 lb-ft).
   - Tighten the injection line fitting nut to 27 to 39 N·m (19 to 29 lb-ft) torque.
8. Connect the generator and glow plug wiring, start the engine and bring it to operating temperature.
9. Evaluate idle quality at the same speed as previously checked:
   - If idle quality is acceptable, end the test.
   - If idle quality is still not acceptable, see step 10.

	CYLINDER TESTED							
MEASUREMENT	**#1**	**#8**	**#7**	**#2**	**#6**	**#5**	**#4**	**#3**
Glow Plug Resistance (Engine ON) (Before Nozzle Substitution)	2.5	2.6	1.9	1.8	2.3	2.4	2.5	2.6
Glow Plug Resistance (Engine OFF) (Before Nozzle Substitution)	0.8	0.6	0.6	0.8	0.9	1.0	0.7	0.8
Nozzle Opening Pressure (Before Substitution)		1650	1950	1900				1600
Nozzle Opening Pressure (After 1st Substitution)		1950	1650	1600				1900
	A	B	B				A	
Glow Plug Resistance (Engine ON) (After 1st Nozzle Substitution)								
Nozzle Opening Pressure (After 2nd Substitution)								

A: Higher nozzle opening pressure will lower glow plug resistance reading

B: Lower nozzle opening pressure will raise glow plug resistance reading

Figure 7-78, Glow Plug Resistance Test Worksheet (3)

10. With the engine running, repeat the glow plug resistance test, following steps 2 and 3.
11. Analyze the glow plug resistance readings (see Figure 7-79):
    - If cylinders with previously varying readings are still out of specification, repeat the process of nozzle testing and substitution (steps 5, 6 and 7).
    - If the readings for cylinders with varying readings do not change, replace the injection pump.
    - If different cylinders now have varying readings, replace the injection pump.
12. Connect the generator and glow plug wiring, start the engine and bring it to operating temperature.
13. Evaluate idle quality at the same speed as previously checked:
    - If idle quality is acceptable, end the test.
    - If idle quality is still not acceptable, proceed with other testing.

	CYLINDER TESTED							
MEASUREMENT	**#1**	**#8**	**#7**	**#2**	**#6**	**#5**	**#4**	**#3**
Glow Plug Resistance (Engine ON) (Before Nozzle Substitution)	2.5	2.6	1.9	1.8	2.3	2.4	2.5	2.6
Glow Plug Resistance (Engine OFF) (Before Nozzle Substitution)	0.8	0.6	0.6	0.8	0.9	1.0	0.7	0.8
Nozzle Opening Pressure (Before Substitution)		1650	1950	1900				1600
Nozzle Opening Pressure (After 1st Substitution)		1950	1650	1600				1900
Glow Plug Resistance (Engine ON) (After 1st Nozzle Substitution)	2.5	1.9	2.4	2.5	2.3	2.4	2.5	2.3
Nozzle Opening Pressure (After 2nd Substitution)		1700						

SUBSTITUTE NOZZLE:
- USE NEW NOZZLE FOR NEW ENGINE
- USE USED NOZZLE FOR OLDER ENGINE

Figure 7-79, **Glow Plug Resistance Test Worksheet (4)**

Idle Speed Adjustments

1. Bring the engine to operating temperature.

2. Set the parking brake and block the drive wheels.

3. Turn off all accessories.

4. Install a magnetic tachometer.

5. Adjust the low idle speed screw on the side of the injection pump according to the specifications on the vehicle emissions label (refer to Figure 7-80, view A).

6. Remove the electrical connector for the fast idle/cold advance temperature switch and jumper its wiring harness terminals with an insulated wire (see Figure 7-80, view B).

7. Open the throttle momentarily to allow the fast idle solenoid to extend fully.

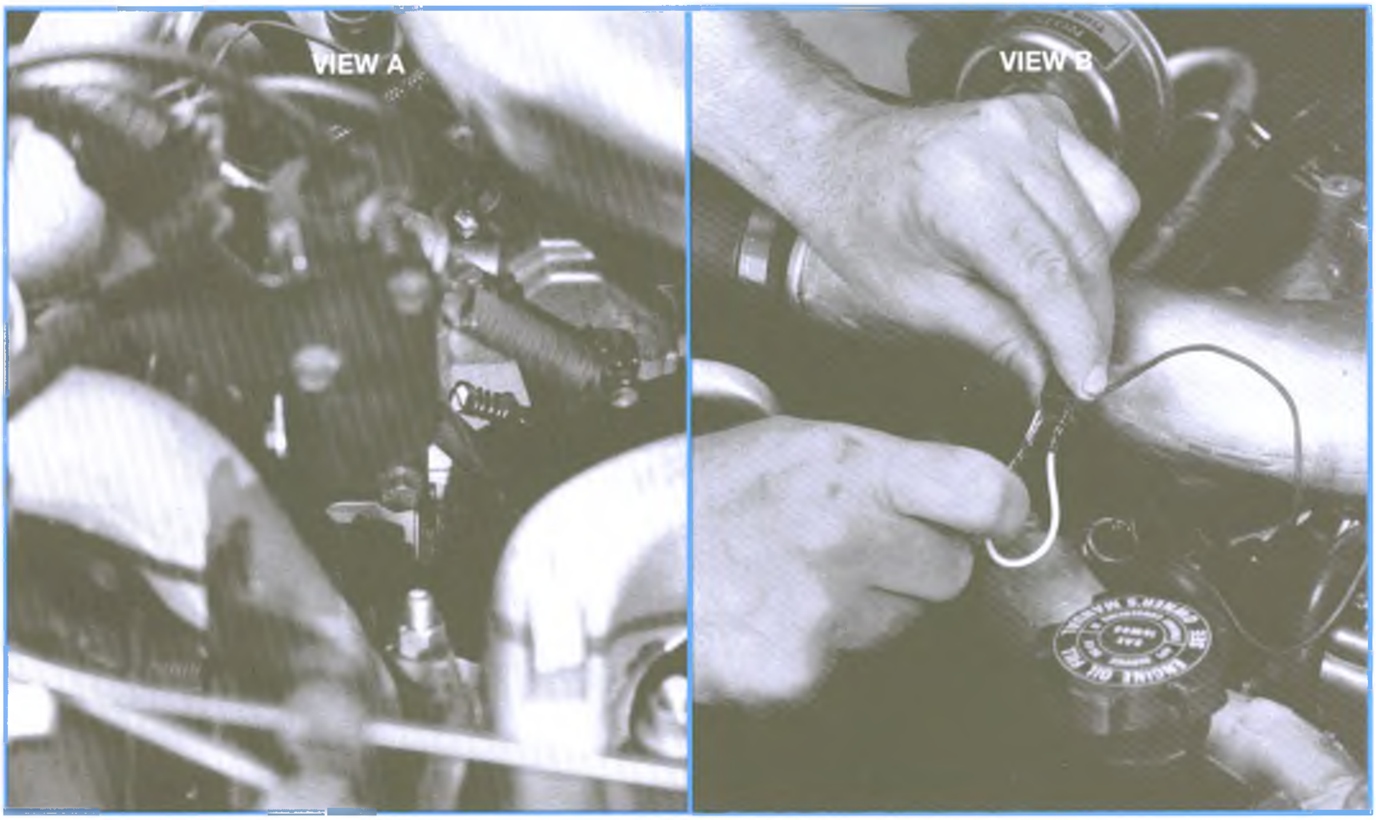


Figure 7-80, **Idle Speed Adjustment (1)**

8. Adjust the fast idle solenoid plunger/screw on the bracket of the injection pump according to the specifications on the vehicle emissions label (see Figure 7-81).
9. Stop the engine.
10. Remove the jumper wire and install the electrical connector for the fast idle/cold advance temperature switch.
11. Remove the magnetic tachometer and wheel blocks.

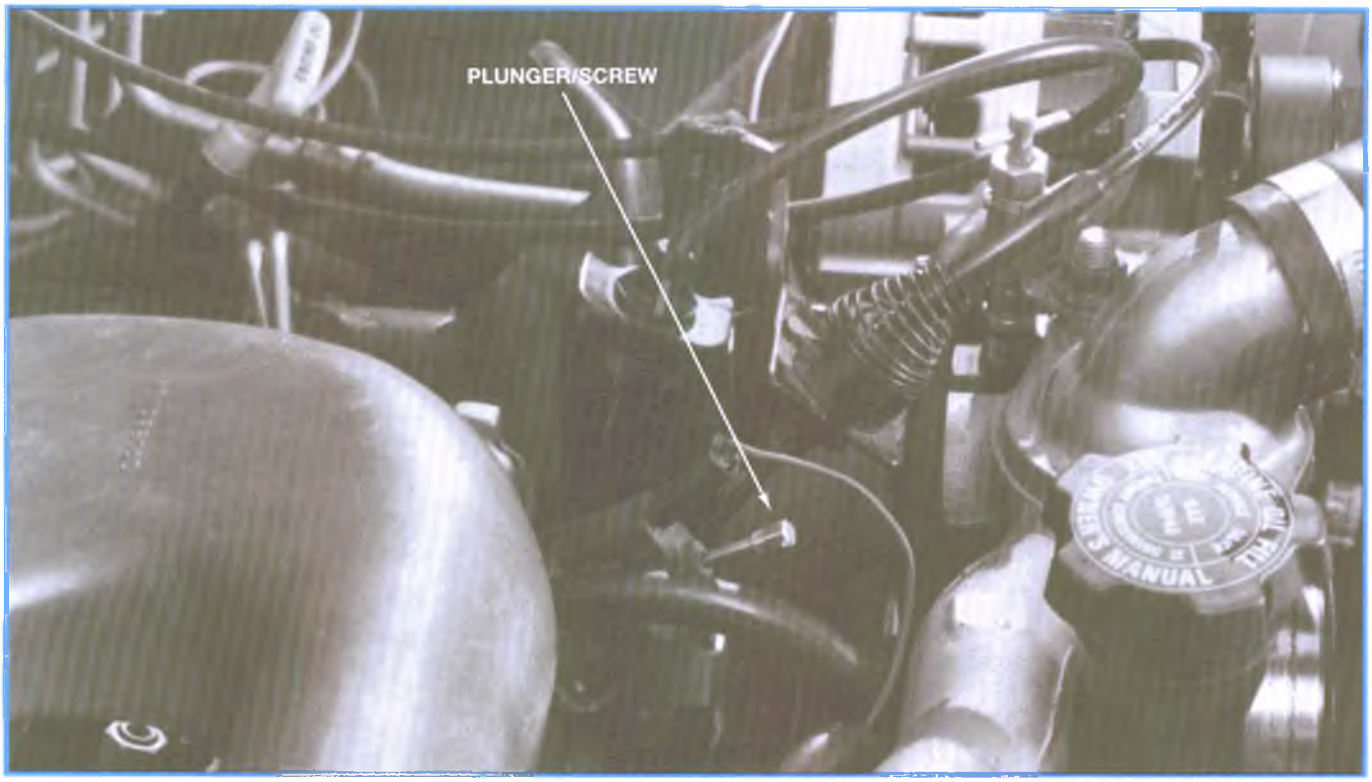


Figure 7-81, Idle Speed Adjustment (2)

Fuel Shut-Off Solenoid Check

1. Remove the electrical connector for the fuel shut-off solenoid from the injection pump.

2. Move the ignition switch to the RUN position.

3. Momentarily connect and disconnect the fuel shut-off solenoid connector and listen:
   - If a clicking sound is heard, the solenoid action is correct.
   - If a clicking sound is not heard, do the following things:

     A. Measure the voltage at the fuel shut-off solenoid connector:
        - If voltage measured is battery voltage, go to step B.
        - If voltage measured is zero, repair the circuit from the ignition switch to the solenoid and re-check the solenoid operation.

     B. Check the condition of the fuel shut-off solenoid ground terminal and strap at the injection pump governor cover:
        - If the ground connection is good, go to step C.
        - If the ground connection is poor, repair it and re-check solenoid operation.

     C. Remove the injection pump governor cover and do the following things:
        - Connect a jumper wire from the fuel shut-off solenoid to the vehicle battery negative terminal.
        - Momentarily connect and disconnect a jumper wire from the fuel shut-off solenoid to the vehicle battery positive terminal.
        - Observe the solenoid action:
          - If it operates, check the governor linkage inside the injection pump for binding.
          - If it does not operate, replace it, install the governor cover and re-check the solenoid operation (refer to Figure 7-51 on page 7-54).

4. Move the ignition switch to the OFF position.

5. Install the electrical connector for the fuel shut-off solenoid from the injection pump.

Housing Pressure Cold Advance (HPCA) Solenoid Check

1. Bring the engine to a temperature of 80° F (27° C).
2. If available, install a diesel injection timing meter (J 33300).
3. Start and operate the engine, noting its speed.
4. Remove the electrical connector for the HPCA solenoid and note the engine speed:
   - If engine speed decreases (and timing retards), the solenoid action is correct.
   - If engine speed does not decrease (no timing retard), do the following things:

     A. Measure the voltage at the HPCA solenoid connector:
        - If voltage measured is battery voltage, go to step B.
        - If voltage measured is zero, repair the circuit from the GAGES fuse to the solenoid and re-check the solenoid operation.

     B. Remove the injection pump governor cover and do the following things:
        - Connect a jumper wire from the HPCA solenoid to the vehicle battery negative terminal.
        - Momentarily connect and disconnect a jumper wire from the HPCA solenoid to the vehicle battery positive terminal.
        - Observe the solenoid action:
          - If it operates, check the housing pressure regulator and fuel return system for a restriction.
          - If it does not operate, go to step C.

     C. Measure the resistance between the HPCA solenoid frame and the injection pump governor cover:
        - If the resistance measured is less that 0.5 ohm, replace the solenoid, install the governor cover and re-check the solenoid operation.
        - If the resistance measured is more than 0.5 ohm, repair it, install the governor cover and re-check the solenoid operation (refer to Figure 7-51 on page 7-54).
5. Move the ignition switch to the OFF position.
6. Install the electrical connector for the HPCA solenoid from the injection pump.
7. Remove the diesel injection timing meter, if used.

8. Electrical Systems

Overview

The electrical systems of the 6.5L V8 turbo diesel engine include the following groups of parts (refer to Figure 8-1):

- Block heater system
- Cranking/charging systems
- Glow plug system
- Lift pump circuit
- Fuel shut-off solenoid circuit
- Fast idle/cold advance circuit
- Fuel filter circuits
- Instrument cluster circuits
- Automatic transmission control system

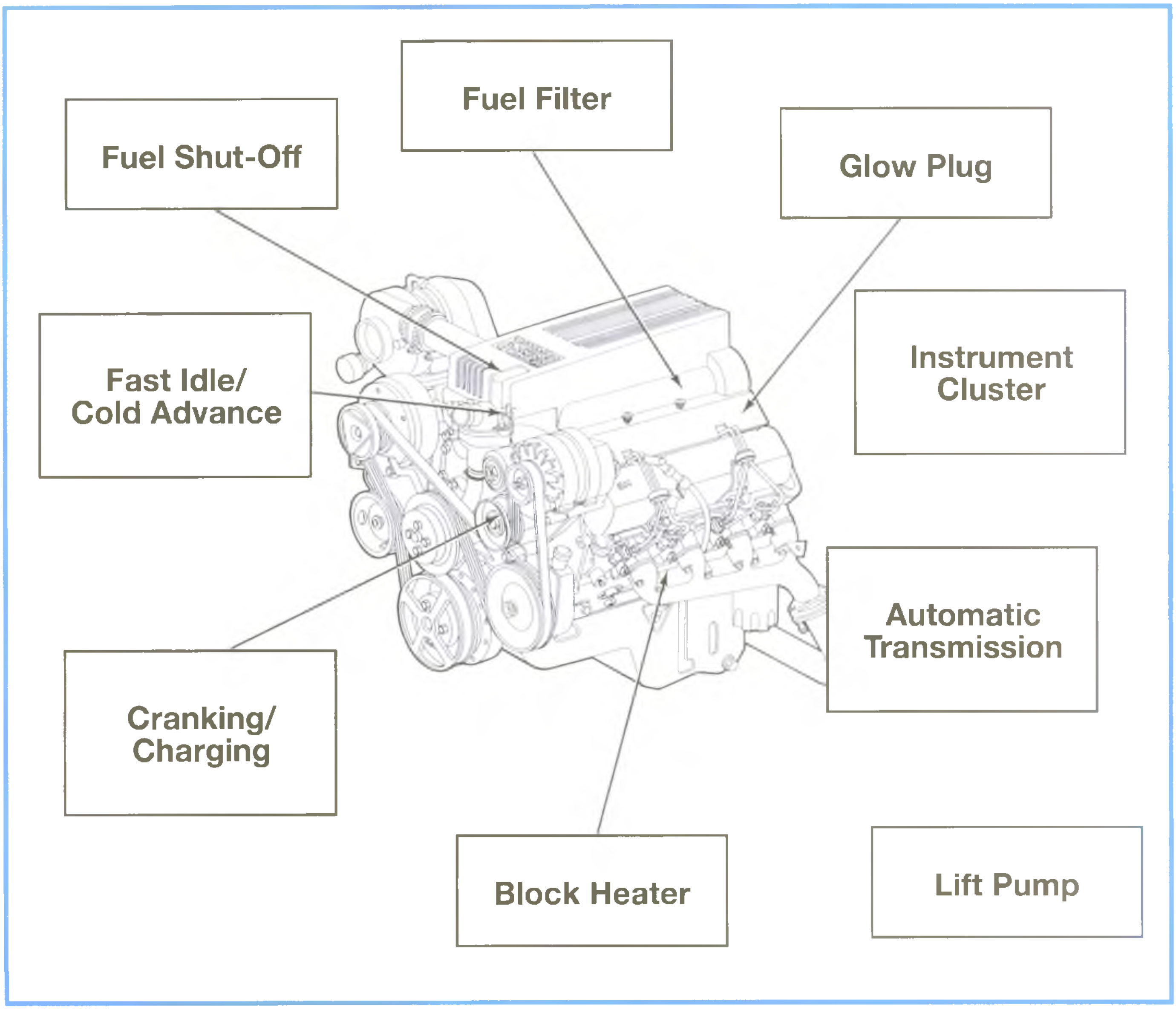


Figure 8-1, Electrical Systems

Block Heater System

The engine block heater mounts in the middle coolant passage bore of the left side of the cylinder case (see Figure 8-2, view A). It uses an expandable yoke mechanism that secures it to the cylinder case when a center screw is tightened (see Figure 8-2, views B and C).

The block heater seals the coolant passage with an O-ring seal mounted in a groove in its outer diameter. During installation, the O-ring seal is lubricated with petroleum jelly.

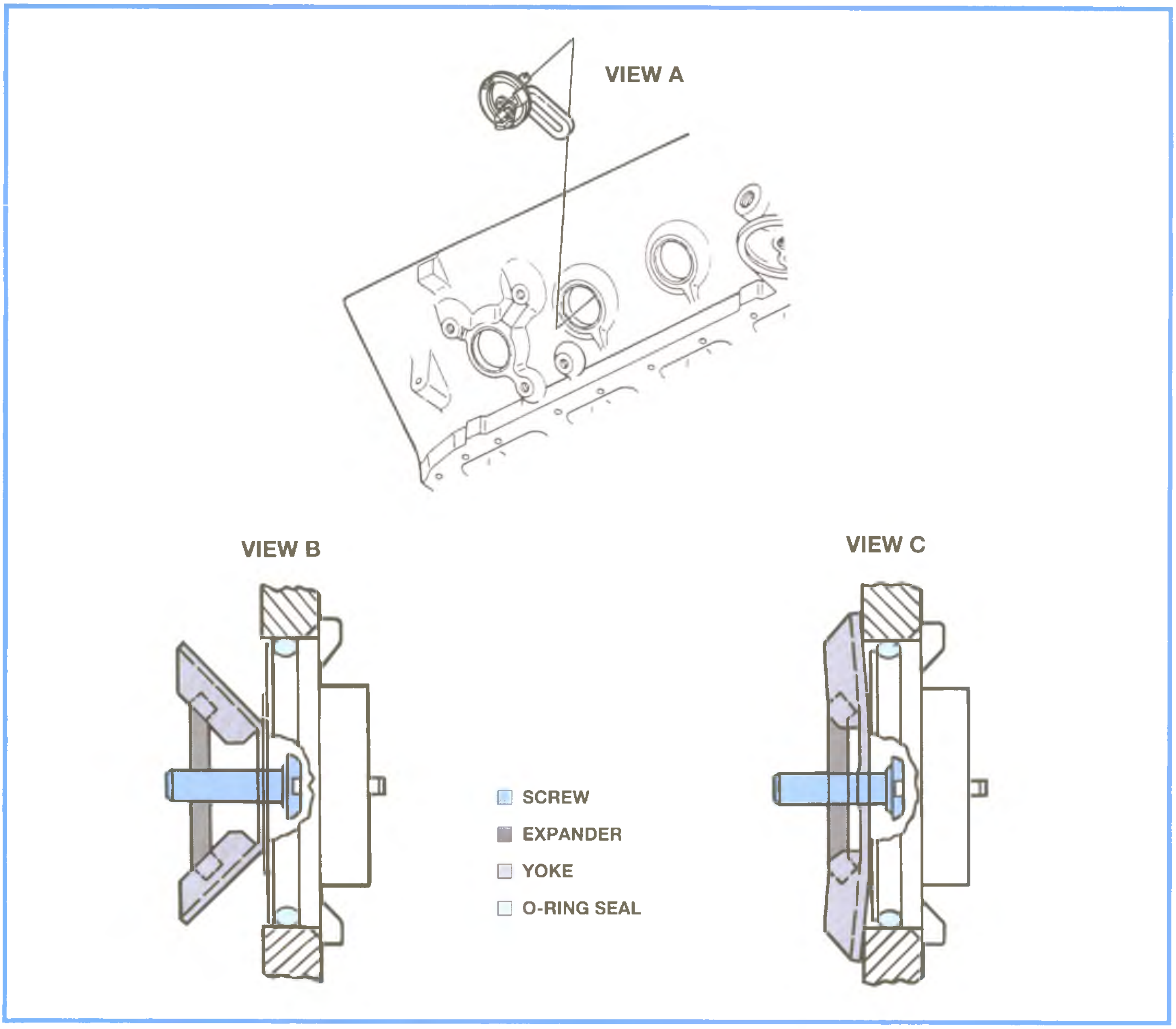


Figure 8-2, **Block Heater Features**

The block heater has a 600-watt heating element, using 5 amperes of electricity at 120 VAC. A three-conductor cord connected to the block heater is routed along the left framerail to the front of the engine compartment, where the remaining length is coiled with a plastic strap (see Figure 8-3).

Refer to the block heater usage chart on page 1-15 for details about preparing for cold weather starting. Since house current is required, care should be used in the selection of an extension cord for this purpose.

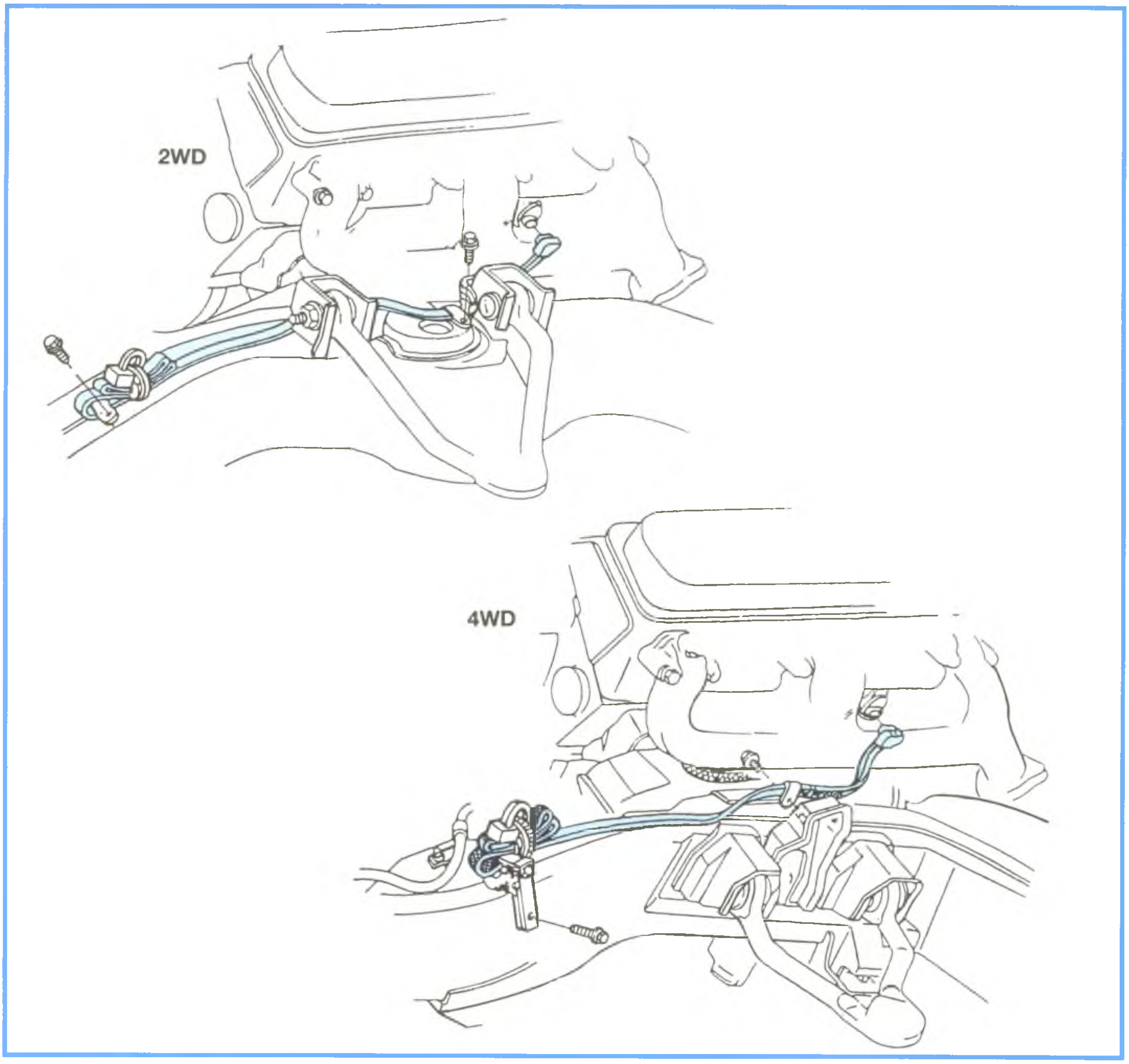


Figure 8-3, **Block Heater Electrical Cord Routing**

Cranking/Charging Systems

Batteries

The vehicle electrical systems use two 12-volt batteries connected in parallel to provide a cold cranking current of 1140 amperes at 0° F (-18° C).

Figures 8-4 and 8-5 show battery cable routing. The left battery connects with the right battery (+ terminal) and engine (- terminal). The right battery connects to the cranking motor (+ terminal), which also connects to the power distribution junction block on the vehicle cowl. The right battery also connects to the engine and vehicle sheet metal (- terminal). The engine and vehicle sheet metal connect with a strap-type ground cable.

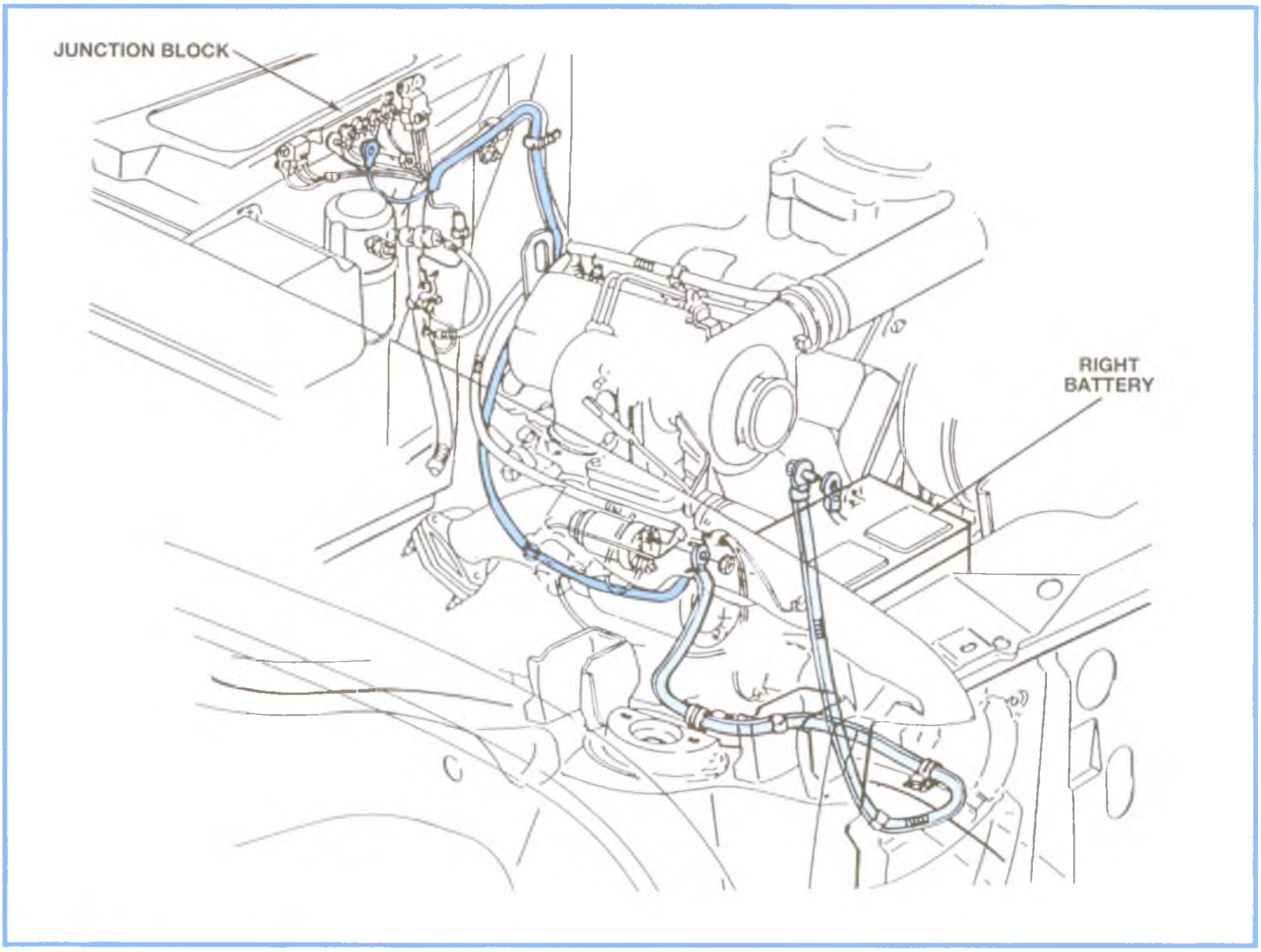


Figure 8-4, Battery Cable Routing (1)

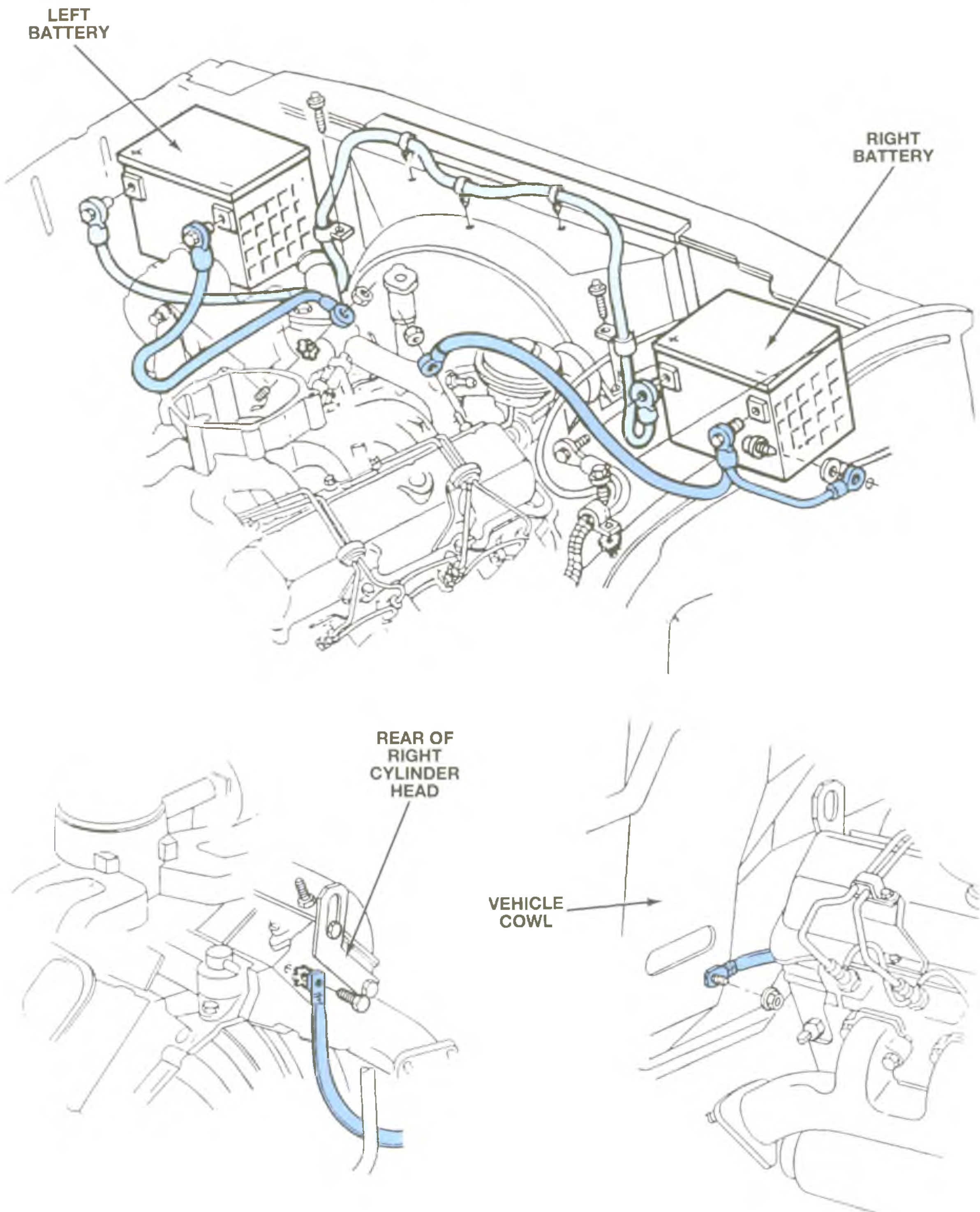


Figure 8-5, Battery Cable Routing (2)

Cranking System

The cranking system has the the following parts (refer to Figure 8-7):

- Connection to battery power
- The ignition switch and wiring
- A cranking motor assembly, with these parts:
  - A solenoid/switch
  - A motor
  - A gear reduction assembly
  - A drive mechanism

Operation of the cranking system is similar to that of gasoline-powered engines, using a 12-volt circuit. The cranking motor is specific to diesel engine use and provides a high amount of torque through the use of gear reduction (refer to Figure 8-6). Two versions of the cranking motor are used, depending on 2WD or 4WD applications.

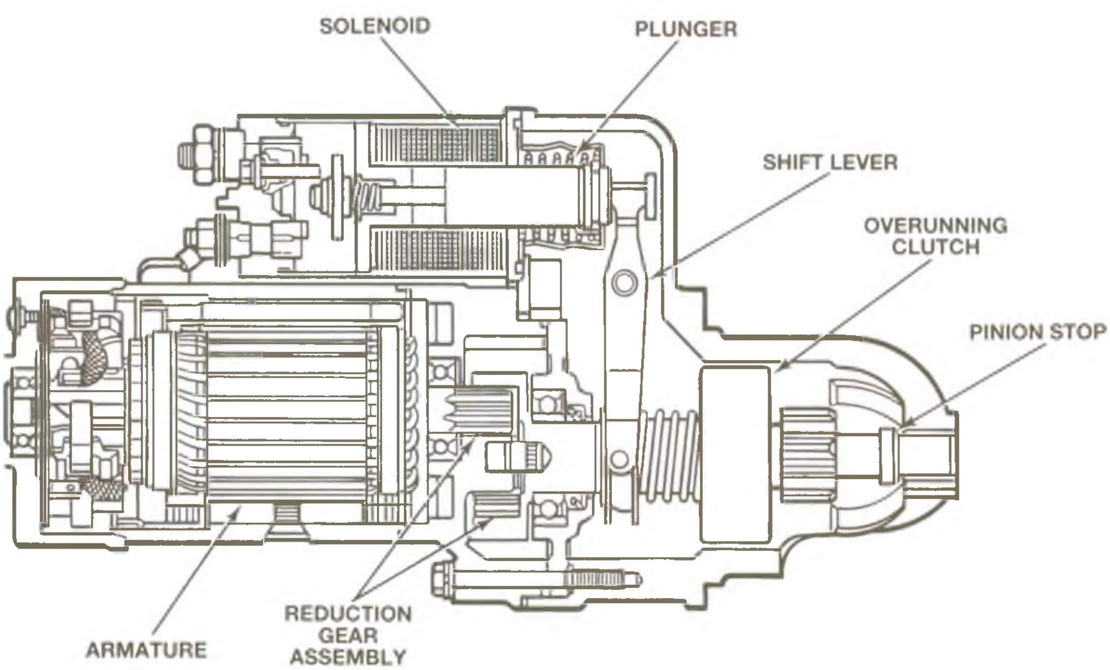


Figure 8-6, **Cranking Motor Mounting**

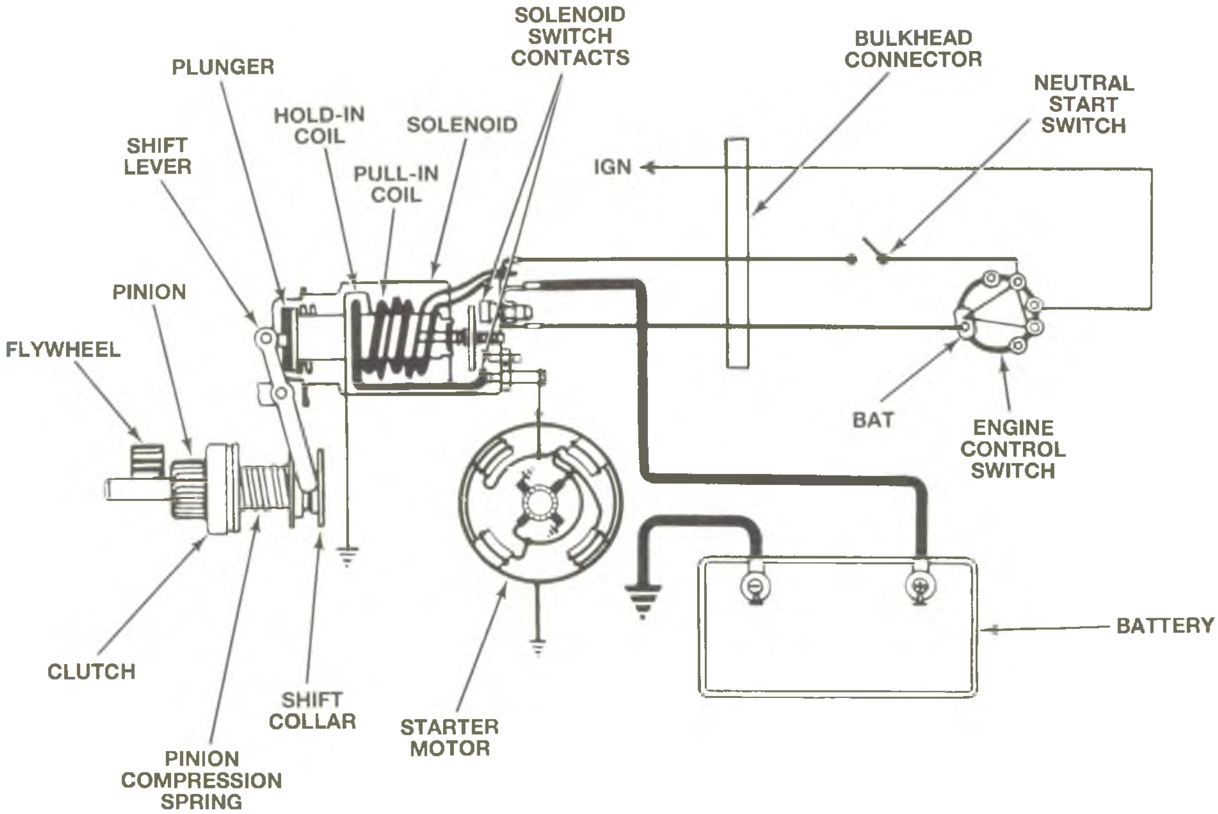


Figure 8-7, **Cranking System Electrical Diagram**

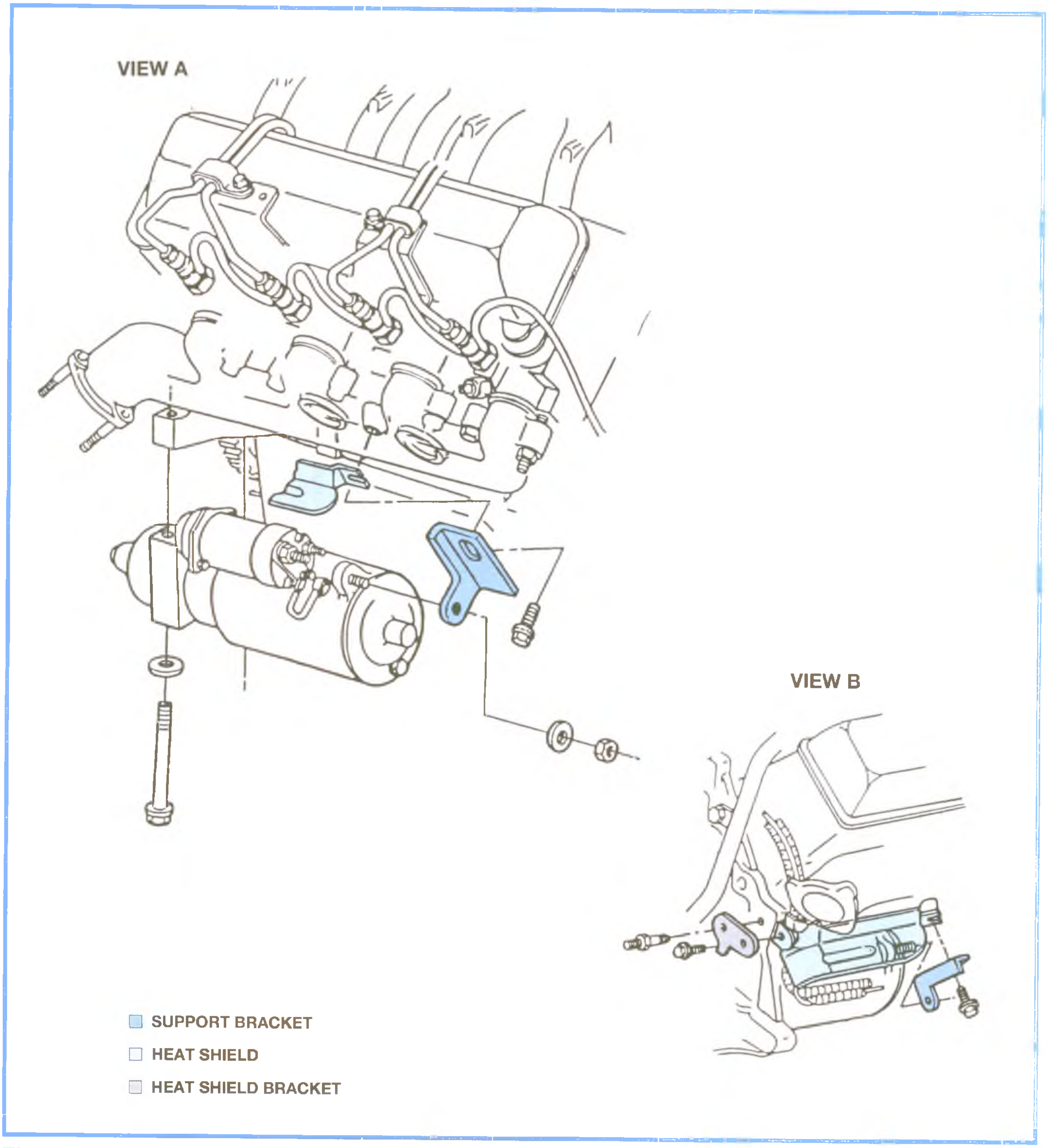


Figure 8-8, Cranking Motor Mounting

The cranking motor mounts to the cylinder case, using two bolts with washers (see Figure 8-8, view A). A bracket adds to the cylinder case support of the cranking motor, and a heat shield protects related wiring (see Figure 8-8, view B).

As a part of service, the cranking motor may have shims installed to obtain a clearance of 0.5 to 1.5 mm (0.020 to 0.060 in.) between the pinion and flexplate gear teeth (see Figure 8-9). A special procedure is used to make the clearance measurement as part of noise diagnosis (see page 8-41). Shims of two thicknesses (1.0 [0.039 in.] and 2.0 mm [0.079 in.]) may be used to obtain clearance, with a total shim pack thickness limit of 4.0 mm (0.158 in.).

During bench testing, the cranking motor has a no-load test specification of using 130 to 190 amperes at 10 volts, with a pinion speed of 2300 to 5600 rpm.

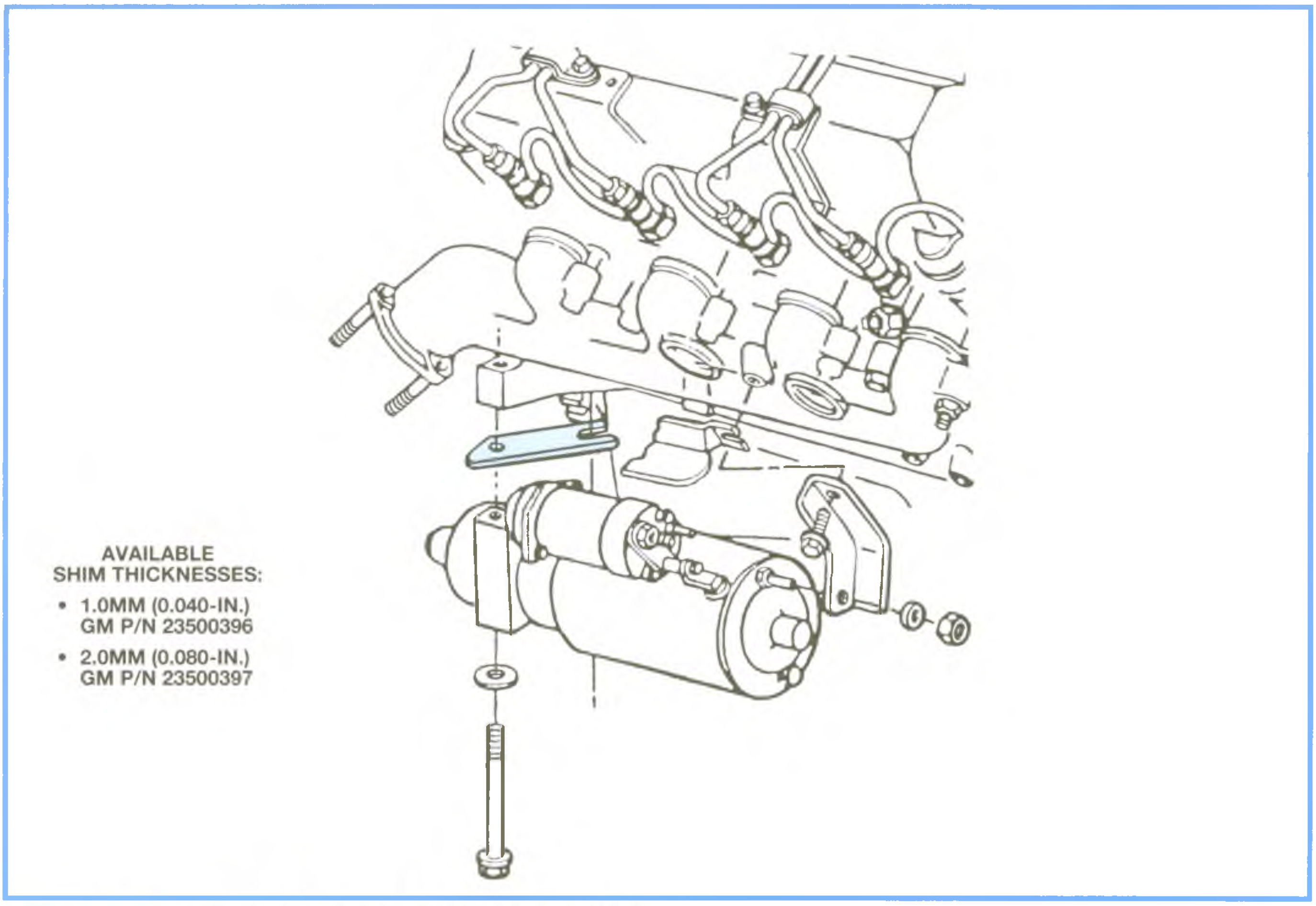


Figure 8-9, **Cranking Motor Shim Installation**

Charging System

The charging system has the the following parts (refer to Figures 8-10 and 8-11):

- The ignition switch and wiring
- A generator assembly, with these major parts:
  - A rotor (field winding)
  - A stator
  - A rectifier bridge
  - A regulator
- An indicator lamp
- Generator output connection to the electrical system

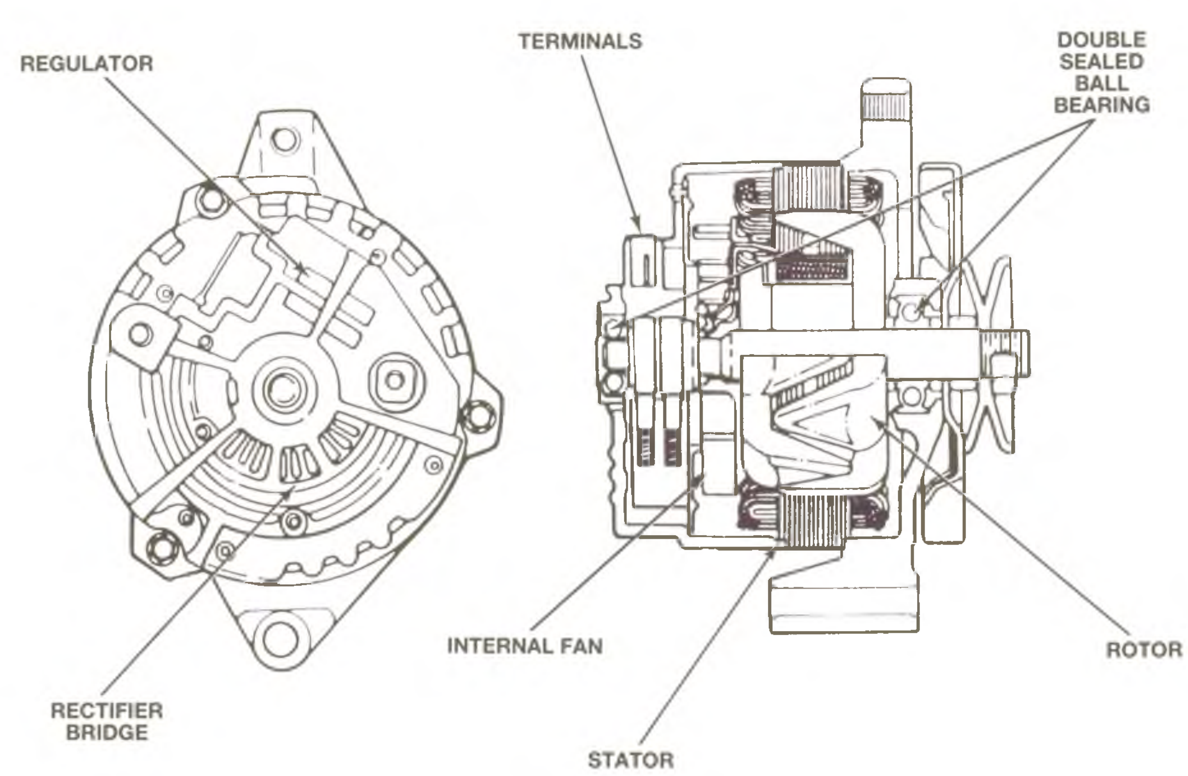


Figure 8-10, Generator Features

Operation of the charging system is similar to that of gasoline-powered engines, using a 12-volt circuit. The regulator connects to an instrument cluster-mounted GEN warning lamp, using one wire from terminal L. Vehicles with a tachometer have a wiring connection to regulator terminal P.

The generator output terminal connects to the battery and vehicle electrical system, using a wire and fusible link at the junction block.

The generator is specific to diesel engine use, due to its mounting configuration. Two versions of the generator are used, depending on non-A/C (85-ampere output) or A/C (100-ampere output) applications.

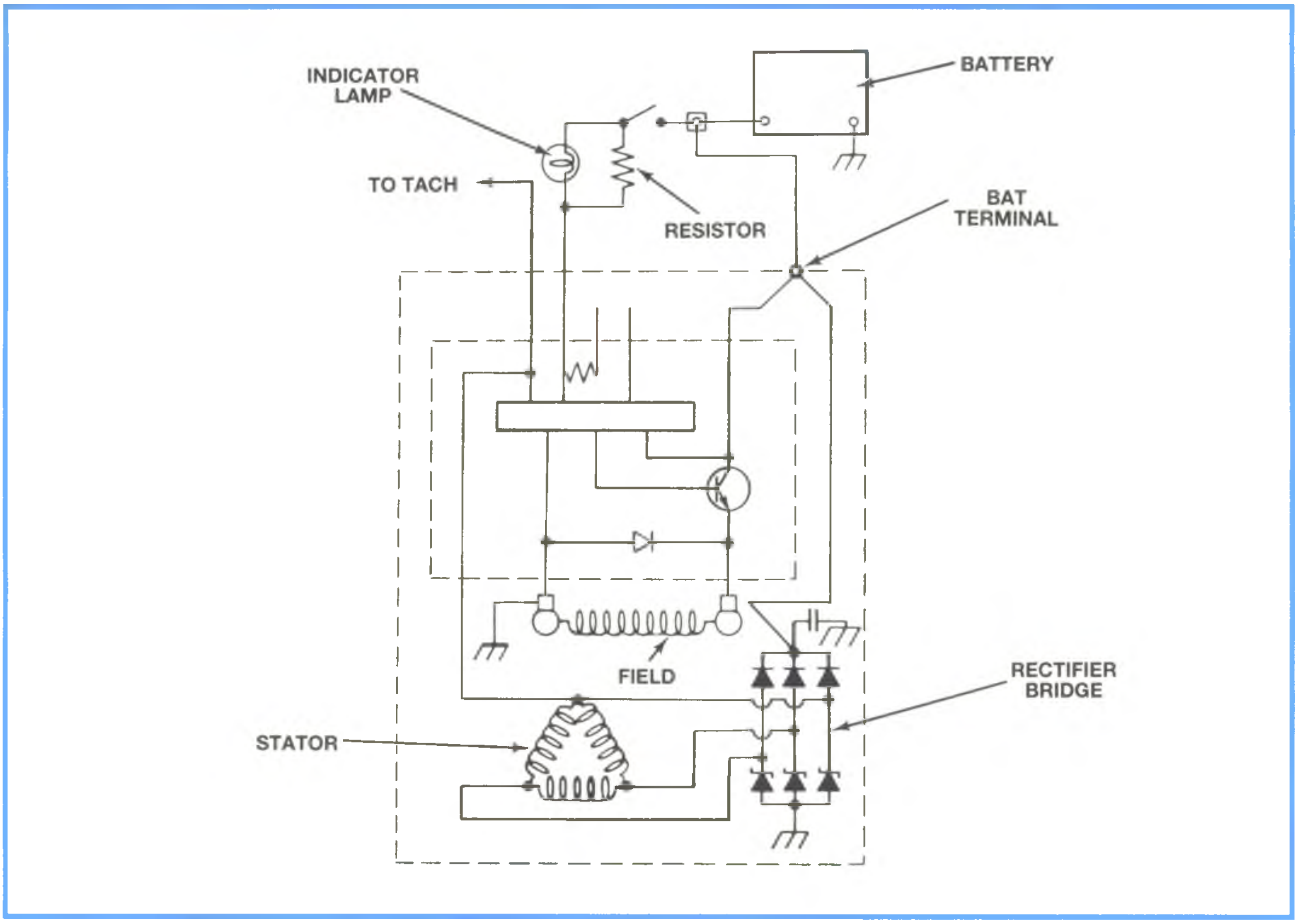


Figure 8-11, Charging System Electrical Diagram

Glow Plug System

Operation

The glow plug system has the following parts (refer to Figure 8-12):

- Eight glow plugs
- An electronic controller/relay assembly
- A GLOW PLUGS indicator lamp
- Related wiring

The glow plug system is used to assist in providing the heat required to begin combustion during engine starting at cold ambient temperatures. Electrical heating occurs before and during cranking, as well as during initial engine running.

Each glow plug threads into a cylinder head hole so that its tip is near the center of the pre-combustion chamber (see Figure 8-13, view A). The glow plug has an electrical heater coil element (rated at 6 volts) that is designed to provide very rapid heating when a 12-volt power circuit is completed for a few seconds (see 8-13, view B).

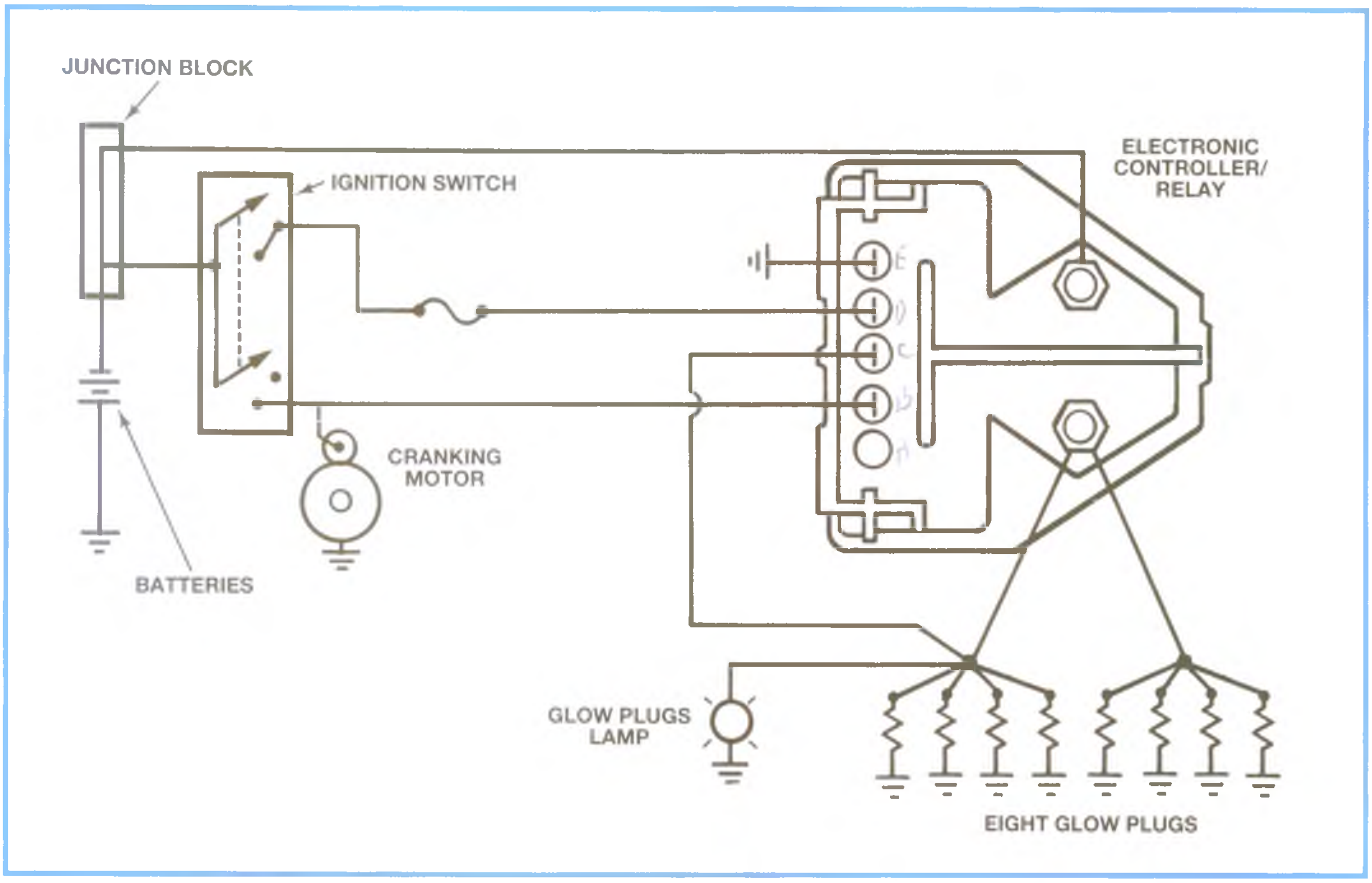


Figure 8-12, **Glow Plug System Electrical Diagram**

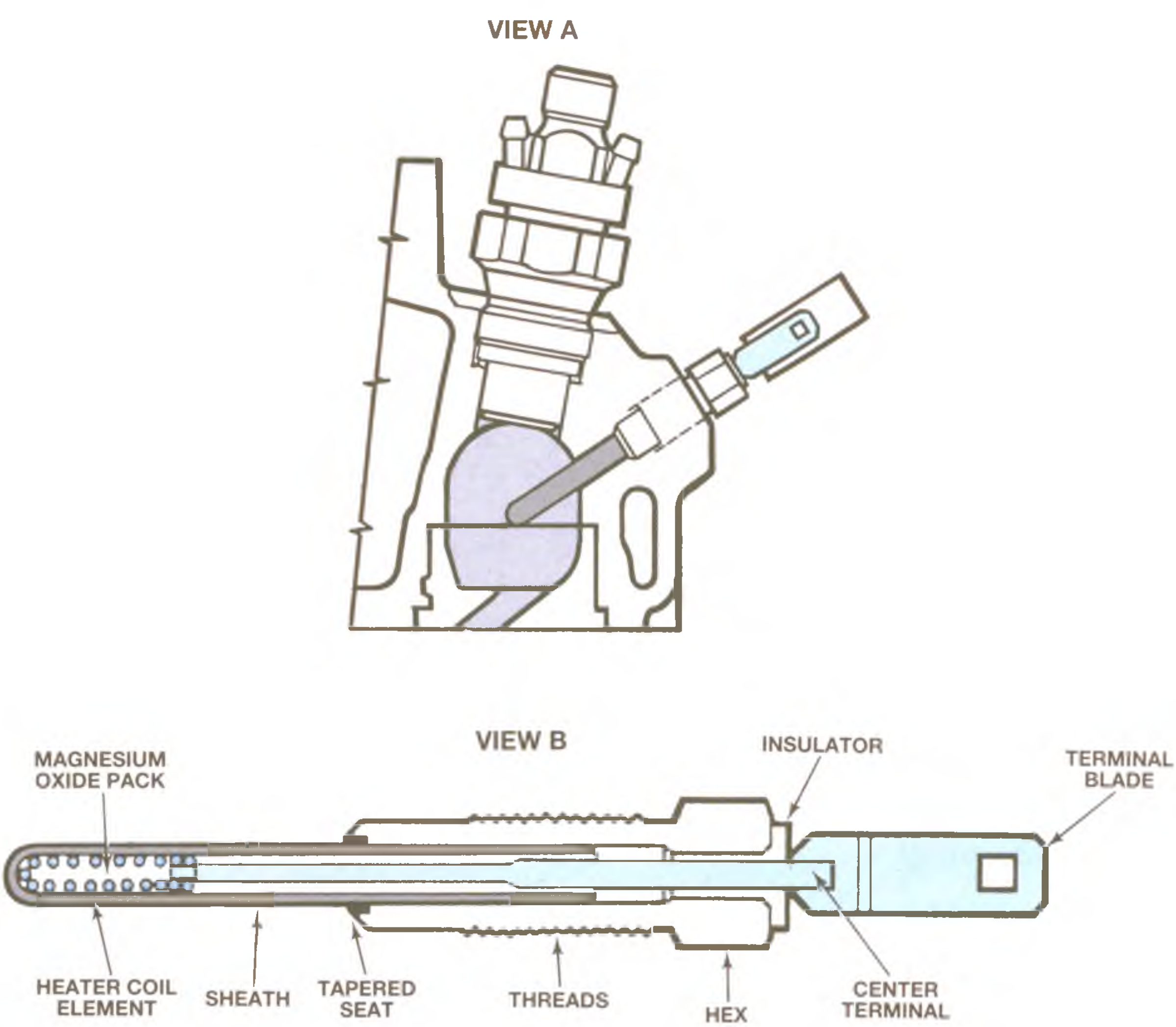


Figure 8-13, **Glow Plug Features**

Each glow plug connects to power from a terminal stud of the electronic controller/relay assembly, using a harness wired in parallel (refer to Figure 8-15). The other terminal stud of the electronic controller/relay connects to battery power, using fusible link protection at the vehicle junction block. Each glow plug is grounded through its cylinder head mounting.

The glow plug wiring for cylinders #4 and #6 is protected from exhaust manifold heat by shields (see Figure 8-14, view A). At each of these locations, an extension wire connects the glow plug terminal with its wiring harness terminal (see Figure 8-14, view B). During service, a special tool is used for removal and installation of the extension wires.

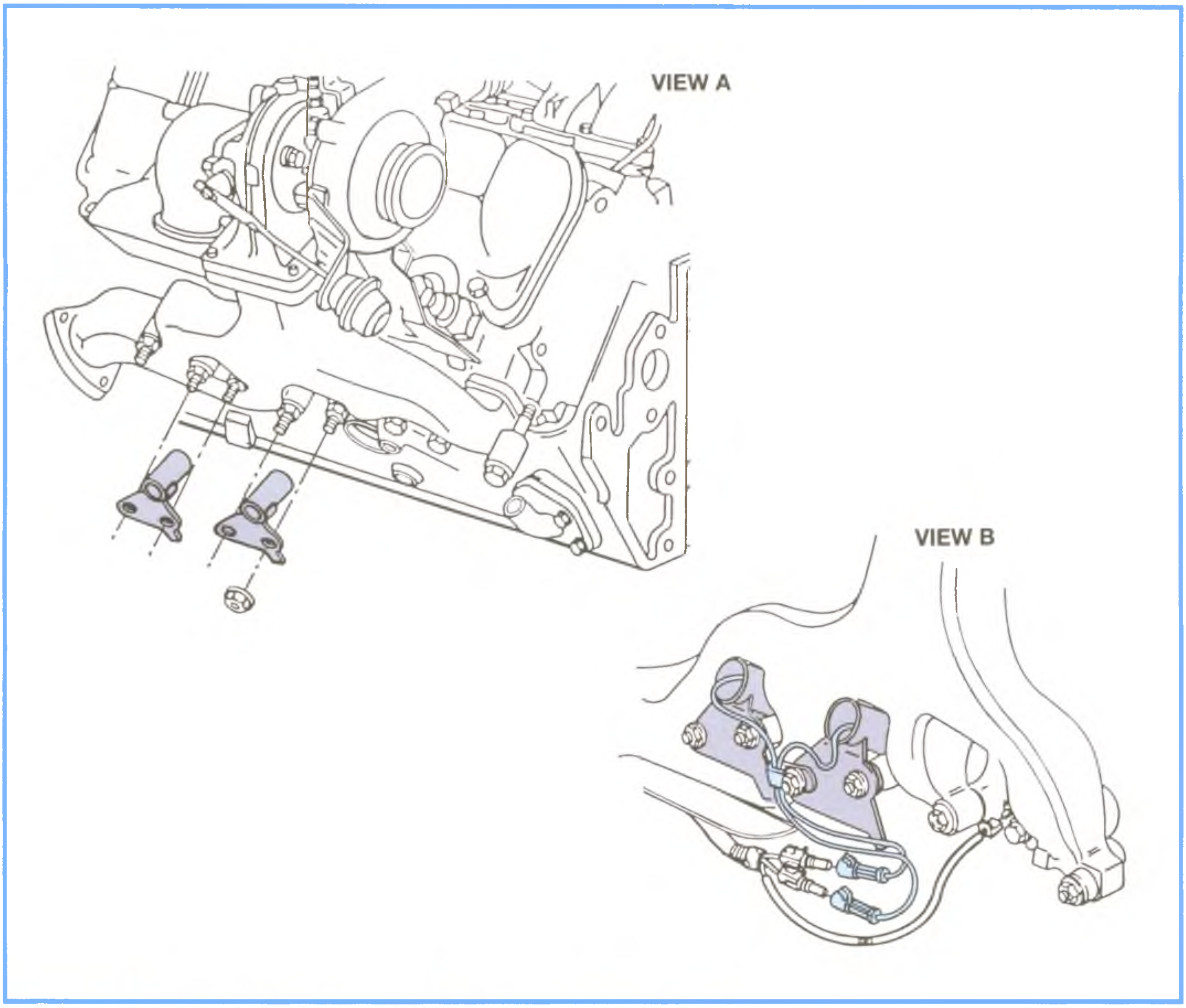


Figure 8-14, **Glow Plug Wiring Shields and Extension Wires**

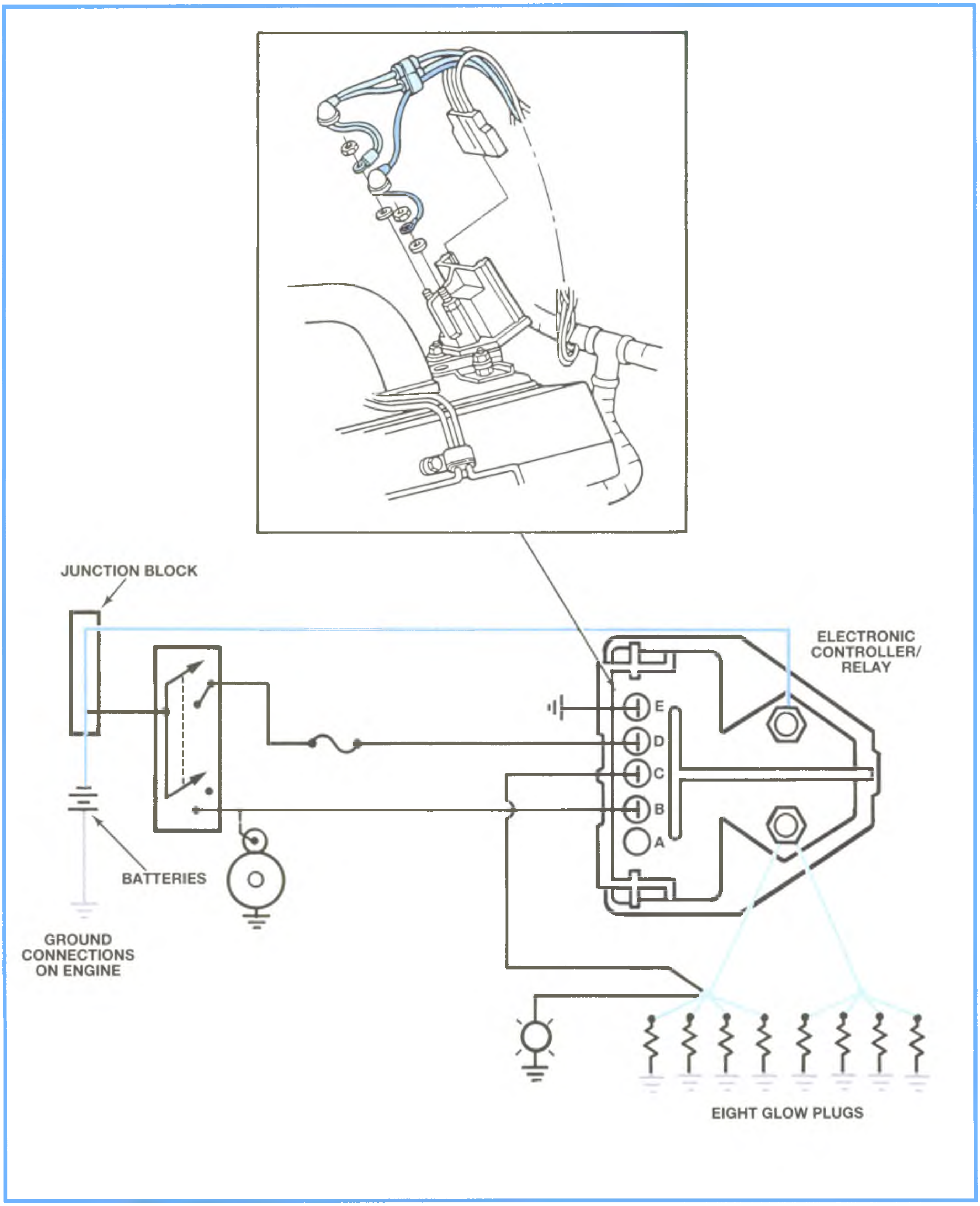


Figure 8-15, Glow Plug System – Relay Wiring

The electronic circuit inside the controller/relay receives power at terminal D that is controlled by the ignition switch and protected by the GAGES fuse (see Figure 8-16). The ground side of the electronic circuit inside the controller/relay connects to a wire at terminal E. The wire has a terminal that attaches to the vehicle sheet metal at a point near the junction block.

The electronic controller receives a feedback signal at terminal C from a wire in the glow harness (refer to Figure 8-17). The cranking motor solenoid circuit also provides an electrical input to the electronic controller/relay at terminal B.

The glow plug harness includes parallel wiring for the GLOW PLUGS indicator lamp mounted in the instrument cluster (refer to Figure 8-17). The lamp will illuminate whenever the electronic controller/relay provides power to the glow plugs.

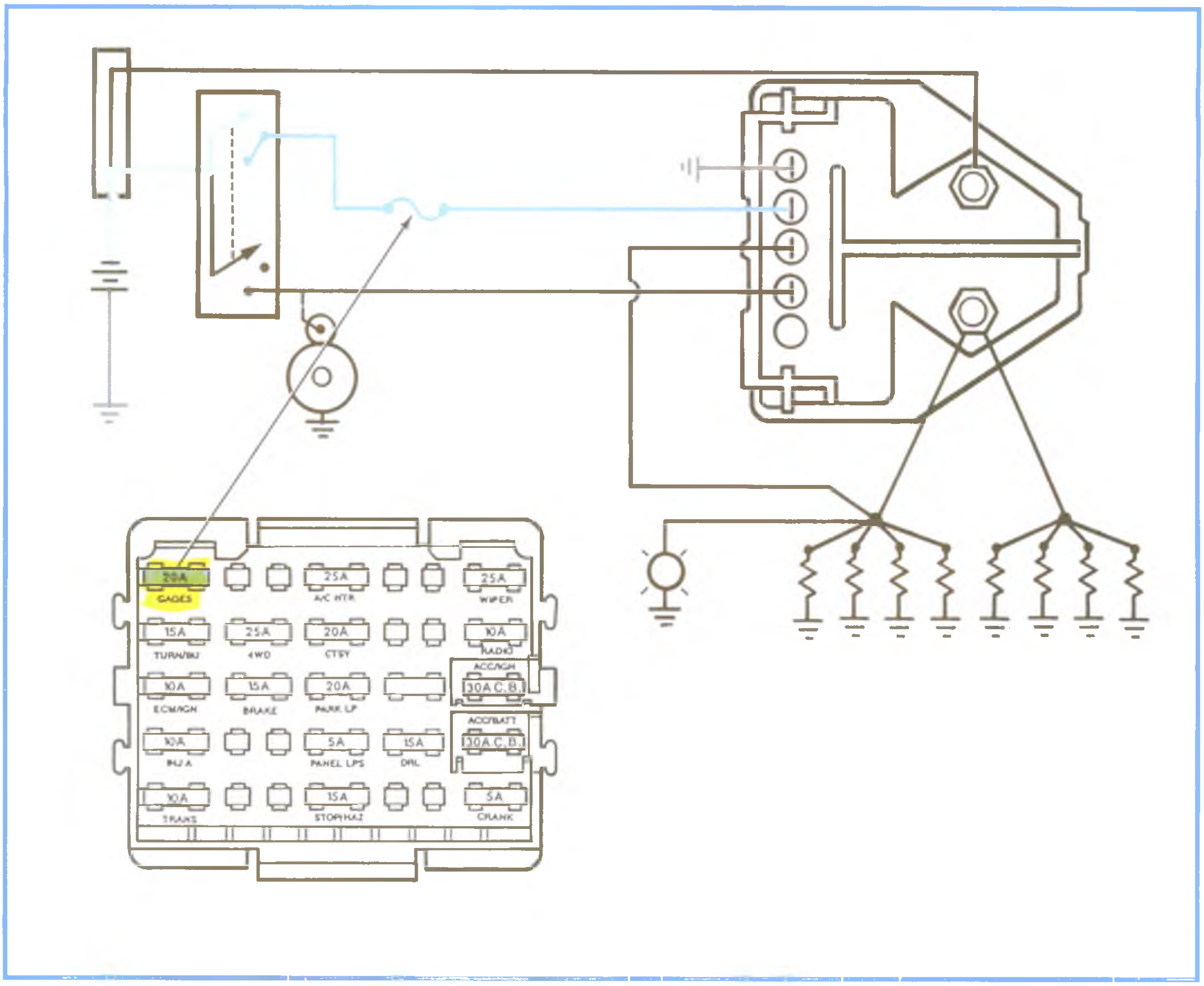


Figure 8-16, Glow Plug System – Controller Power

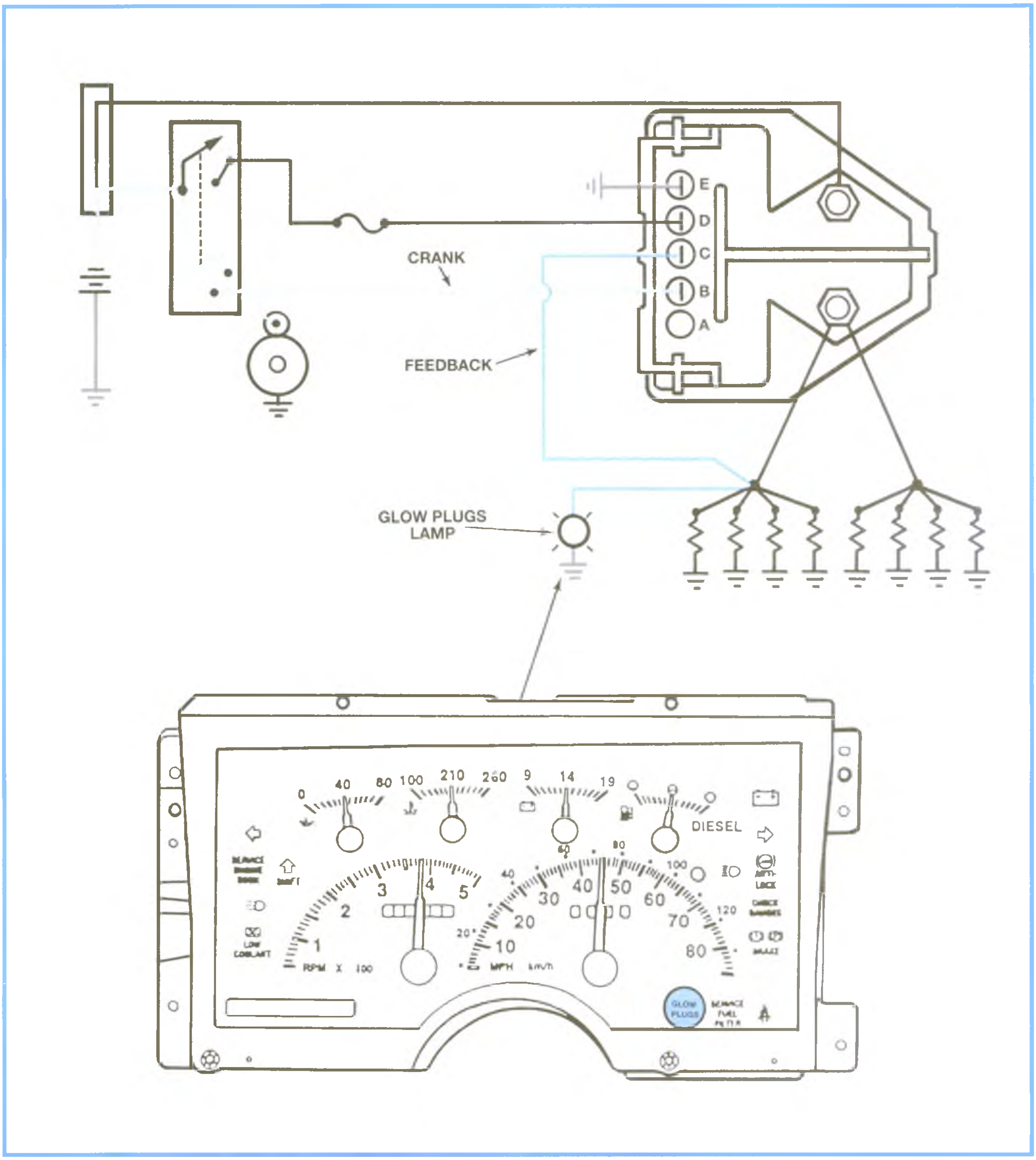


Figure 8-17, Glow Plug System – Input Wiring

The glow plug controller electronic circuit operates the relay with cycling action that varies in length, based on the underhood air temperature and engine temperature sensed at its mounting bracket.

At room temperature, the glow plug system operates as follows:

- When the vehicle driver rotates the ignition switch to the RUN position, the following things occur (refer to Figure 8-18):
  - The controller electronic circuit completes the relay coil circuit, causing glow plug and indicator lamp operation for 4 to 6 seconds.
  - Based on the temperature and feedback inputs, the controller electronic circuit opens the relay coil circuit for 4 to 5 seconds.

Note: At this time, the vehicle driver would normally rotate the ignition switch to the CRANK position to start the engine.

- If the vehicle driver keeps the ignition switch in the RUN position, the following things occur:
  - The controller electronic circuit completes the relay coil circuit again, causing glow plug and indicator lamp operation for 1 to 2 seconds.
  - Based on the temperature and feedback inputs, the controller electronic circuit opens the relay coil circuit for 4 to 5 seconds.
  - The ON/OFF cycling action will continue until a total cycling time of approximately 20 seconds has elapsed.

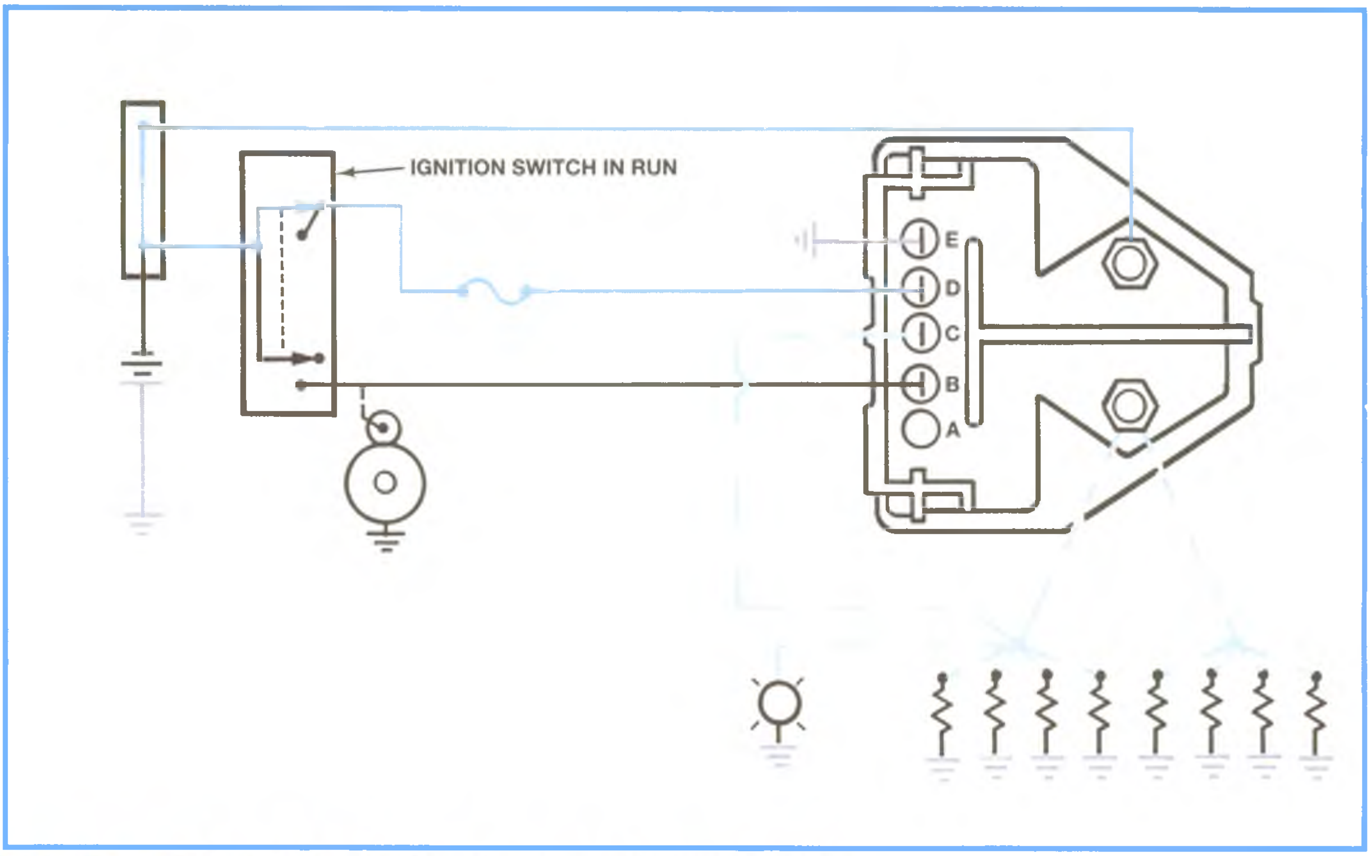


Figure 8-18, **Glow Plug System Cycling – Before Cranking**

- If the vehicle driver rotates the ignition switch to the CRANK position during or after the previous cycling sequence, the following things occur (refer to Figure 8-19):
  - The controller electronic circuit completes the relay coil circuit again, causing glow plug and indicator lamp operation for 1 to 2 seconds.
  - Based on the temperature and feedback inputs, the controller electronic circuit opens the relay coil circuit for 4 to 5 seconds.
  - The ON/OFF cycling action will continue until the total cycling time after the ignition switch has returned to the RUN position is approximately 20 seconds.

Note: The maximum length of glow plug cycling does not depend on whether or not the engine runs after cranking.

Glow plug system cycling times are approximate, because temperature and feedback voltage inputs vary. As a rule, colder ambient starting temperatures result in longer initial ON times and total duration of cycling.

A controller/relay that applies power to the glow plugs for longer than five seconds may cause damage to the glow plugs. If all eight glow plugs are replaced because of open circuit faults, the controller/relay should also be replaced.

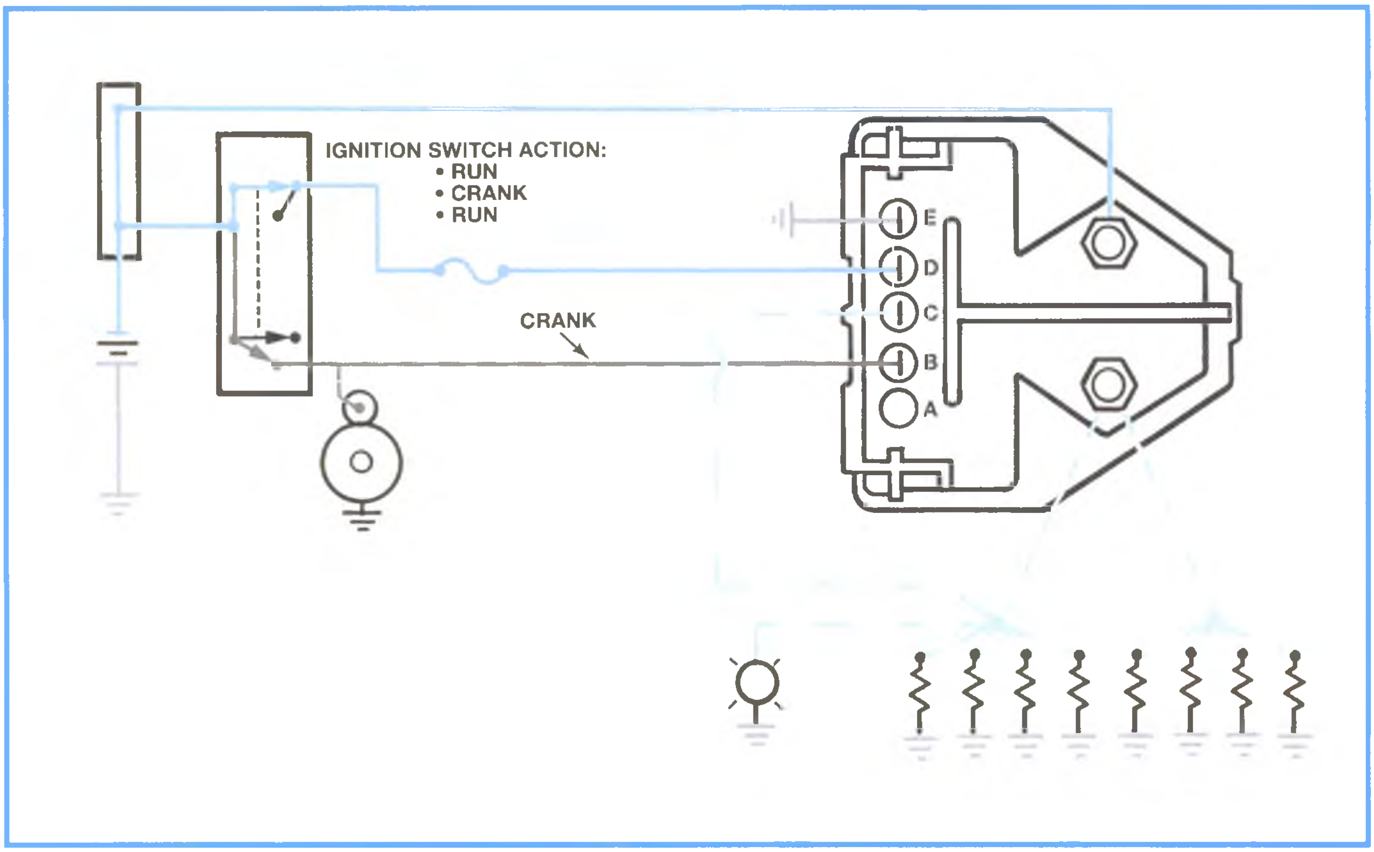


Figure 8-19, **Glow Plug System Cycling – After Cranking**

Diagnosis

Note: Never install a jumper wire between the terminal studs of the controller/relay, since immediate damage to all glow plugs may result.

PRIMARY CHECKS

1. Make sure that the engine is at a temperature below 95° F (35° C).
2. Install an ammeter at the controller/relay terminal stud (glow plug side), move the ignition switch to RUN and measure the amperage of each bank of the glow plugs (refer to Figure 20, view A):
   - If both banks have a minimum of 55 amperes current flow, the system is working normally.
   - If either bank has less than 55 amperes current flow, go to step 3.
   - If both banks have a zero ampere current flow, go to **SECONDARY CHECKS.**
3. Install an ammeter in series with one glow plug wire, move the ignition switch to RUN and measure the amperage of the glow plug (refer to Figure 8-20, view B):
   - If the glow plug has a current flow of 14 amperes, it is working normally.
   - If the glow plug has a current flow of less than 14 amperes, go to step 3.
4. Check the continuity of the glow plug wiring harness from the controller/relay terminal stud to the glow plug terminal (refer to Figure 8-20, view C):
   - If the wiring harness has continuity, go to step 4.
   - If the wiring harness has no continuity, repair it and check system operation.
5. Replace the glow plug and follow steps 2 and 3 for other glow plugs. Use an AC-type 9G glow plug.
6. When all glow plugs have 14 amperes of current flow, end the diagnosis.

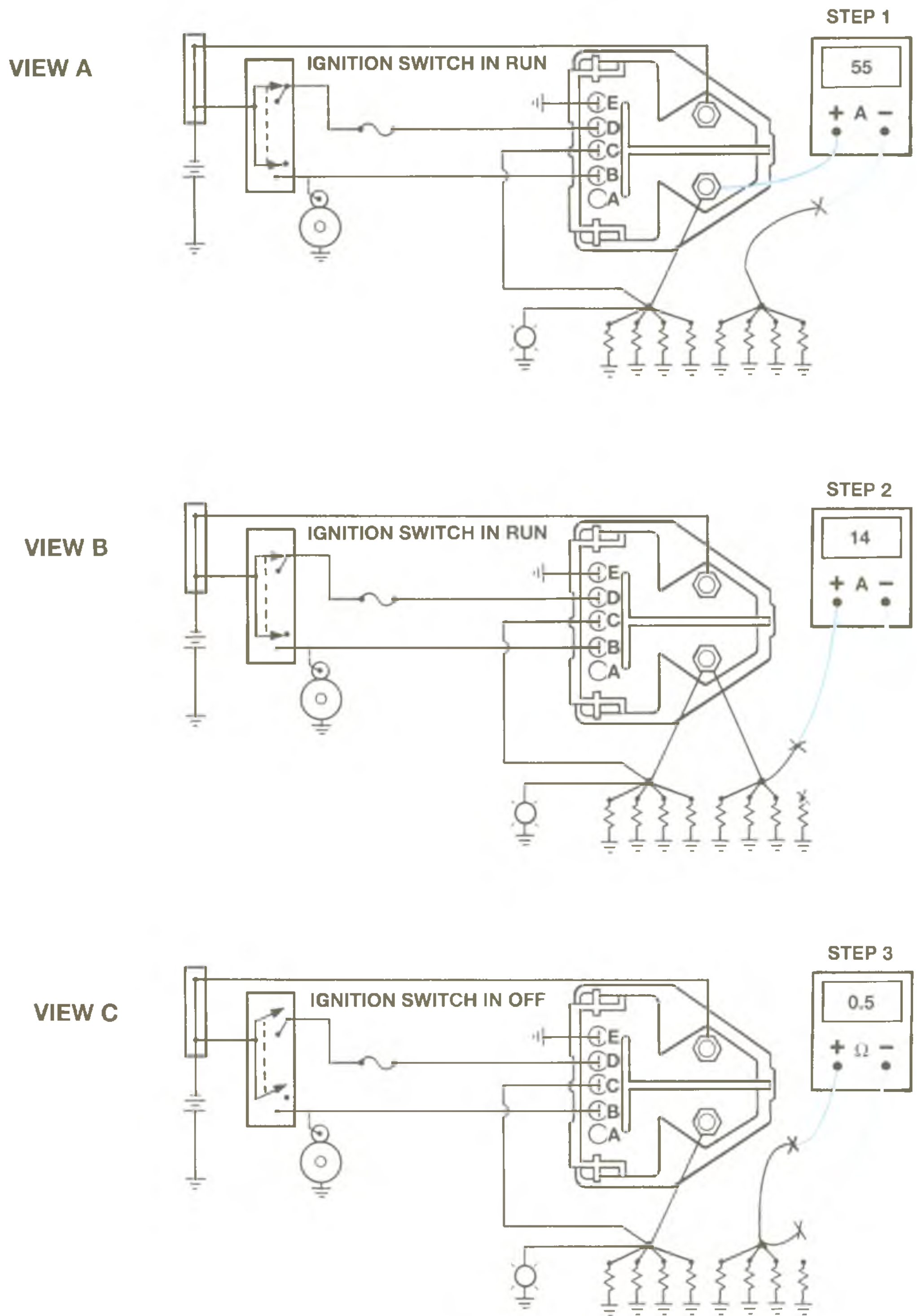


Figure 8-20, Glow Plug System Diagnosis – Primary Checks

SECONDARY CHECKS

Note: Follow this procedure if the engine does not start cold, with or without GLOW PLUGS lamp operation.

1. Check the following items:
   - Fuel system (must check OK)
   - Cranking/charging system (battery must have 12.4 volts minimum)
   - Cranking speed (100 rpm minimum)
2. Check voltage at the controller/relay terminal stud (battery side) (refer to Figure 8-21, view A):
   - If voltage measured is battery voltage, go to step 3.
   - If voltage measured is zero, repair the circuit from the battery to the relay terminal stud and check system operation.
3. Check voltage at the controller/relay terminal stud (glow plug side) (refer to Figure 8-21, view B):
   - If voltage measured is zero, go to step 4.
   - If voltage measured is battery voltage, replace the controller/relay (shorted relay contacts) and all glow plugs, then check system operation.
4. Disconnect all glow plug wires and measure glow plug resistance (refer to Figure 8-21, view C):
   - If each glow plug has a resistance less than 1 ohm, go to step 5.
   - If any glow plug has a resistance greater than 1 ohm, replace it and check system operation.

Note: After step 4, reconnect all glow plug wires.

Refer to the following reference chart, if necessary:

Terminal	Circuit	Electrical Check
A	None	
B	Crank input	Battery voltage while cranking
C	Feedback input	Continuity (less than 1 ohm)
D	Power supply	Battery voltage in RUN
E	Power ground	Continuity (less than 1 ohm)

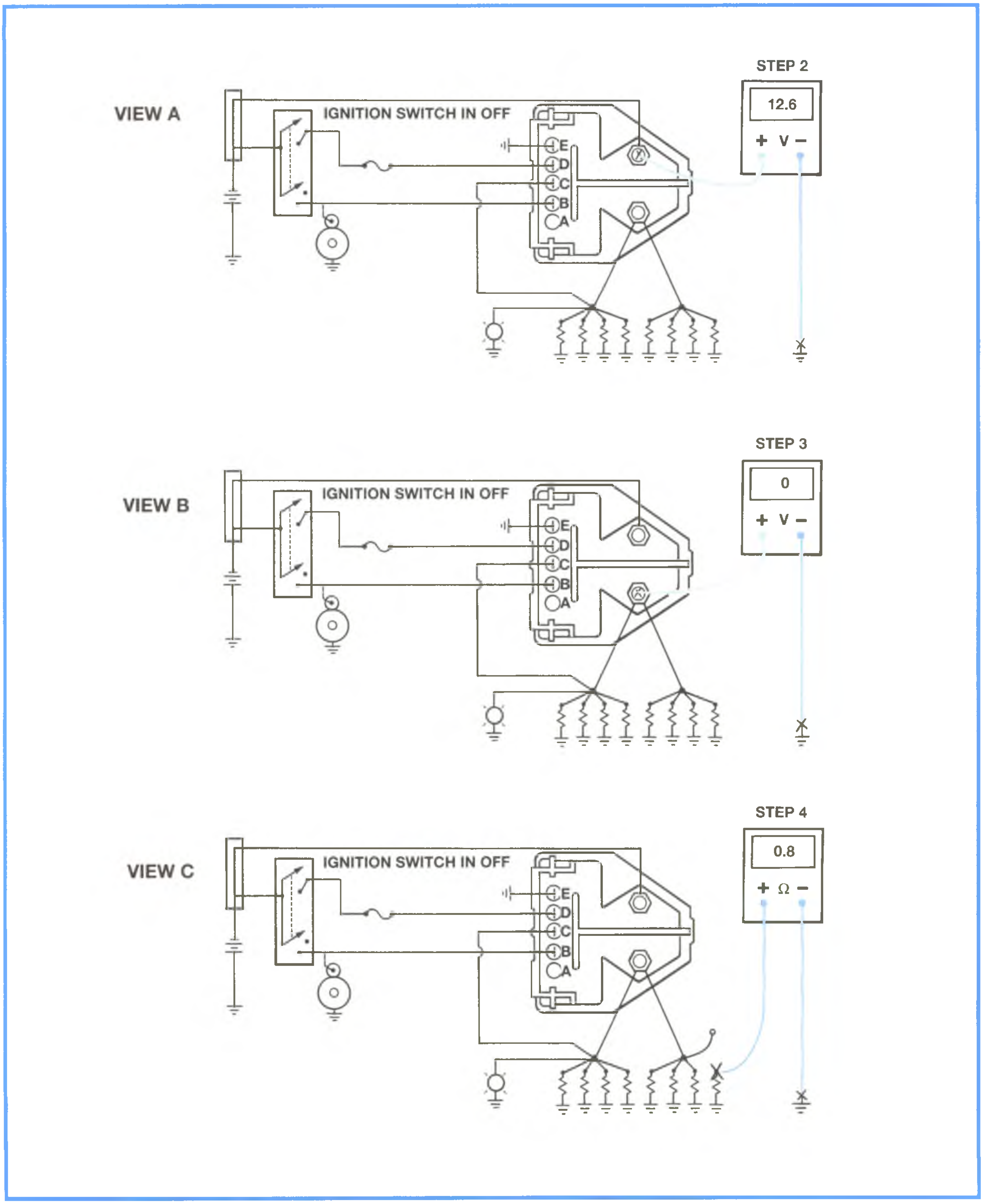


Figure 8-21, Glow Plug System Diagnosis – Secondary Checks (1)

5. Remove the controller circuit electrical connector, move the ignition switch to RUN and measure the voltage at terminal D (harness side) (refer to Figure 8-22, view A):
   - If voltage measured is battery voltage, go to step 6.
   - If voltage measured is zero, repair the circuit from the ignition switch to terminal D and check system operation.

Note: After step 5, move the ignition switch to OFF.

6. With the controller circuit electrical connector removed, measure the resistance between terminal E (harness side) and the cylinder case (refer to Figure 8-22, view B):
   - If resistance measured is less than 1 ohm, go to step 8.
   - If resistance measured is more than 1 ohm, repair the circuit from terminal E and the vehicle ground and check system operation.
7. With the controller circuit electrical connector removed, measure the resistance between terminals C and E (harness side) (refer to Figure 8-22, view C):
   - If resistance measured is less than 2 ohms, go to step 8.
   - If resistance measured is more than 2 ohms, repair the circuit from the glow plug wiring harness to terminal C and check system operation.

Note: After step 7, reconnect the controller circuit electrical connector.

Refer to the following reference chart, if necessary:

Terminal	Circuit	Electrical Check
A	None	
B	Crank input	Battery voltage while cranking
C	Feedback input	Continuity (less than 1 ohm)
D	Power supply	Battery voltage in RUN
E	Power ground	Continuity (less than 1 ohm)

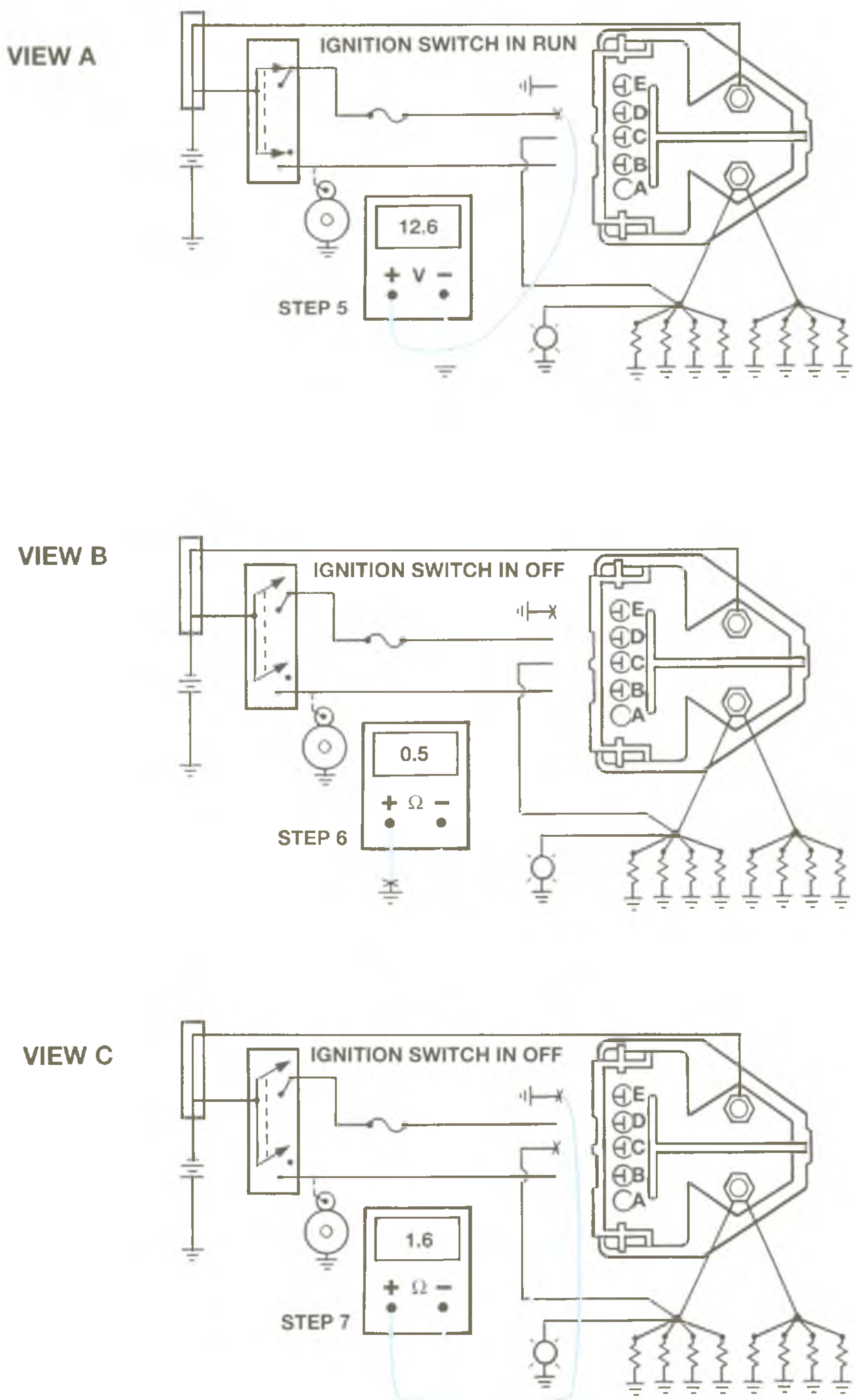


Figure 8-22, Glow Plug System Diagnosis – Secondary Checks (2)

8. Move the ignition switch to RUN while measuring the voltage at the controller/relay terminal stud (glow plug side) (refer to Figure 8-23, view A):
   - If voltage measured is battery voltage, go to step 9.
   - If voltage measured is zero, replace the glow plug controller/relay and check system operation.
9. Move the ignition switch to RUN while measuring the voltage at any glow plug on each cylinder bank (refer to Figure 8-23, view B):
   - If voltage measured is battery voltage, go to step 10.
   - If voltage measured is zero, repair the circuit between the controller/relay and glow plugs, then check system operation.
10. Note GLOW PLUGS lamp operation (refer to Figure 8-23, view C):
    - If the lamp does not cycle on and off when the controller/relay cycles, repair the lamp circuit and check system operation.
    - If the lamp cycles on and off, end the diagnosis.

Refer to the following reference chart, if necessary:

Terminal	Circuit	Electrical Check
A	None	
B	Crank input	Battery voltage while cranking
C	Feedback input	Continuity (less than 1 ohm)
D	Power supply	Battery voltage in RUN
E	Power ground	Continuity (less than 1 ohm)

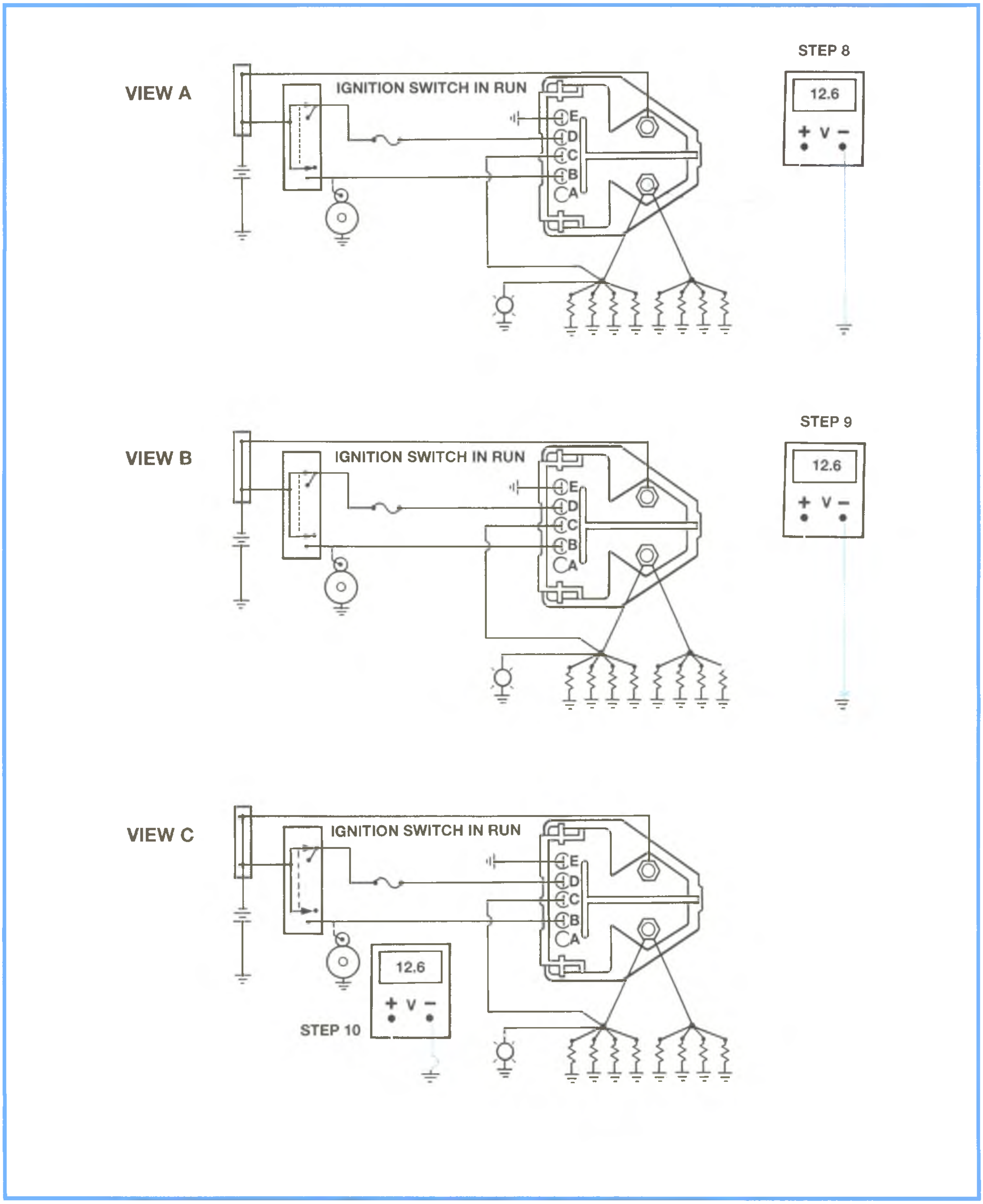


Figure 8-23, Glow Plug System Diagnosis – Secondary Checks (3)

GLOW PLUG AFTERSTART CHECK

Note: Follow this procedure to diagnose the conditions of excessive white smoke and/or poor idle quality after starting.

1. Begin the test with the engine at 80° F (27° C).
2. Rotate the ignition switch to the RUN position and allow the glow plug system to cycle for 2 minutes.
3. Crank the engine for 1 second and return the ignition switch to the RUN position.
4. Observe that the glow plug system continues to cycle at least once after cranking.
5. If the glow plug system does not cycle after cranking, remove the controller circuit electrical connector, move the ignition switch to RUN and measure the voltage at terminal B (harness side) (refer to Figure 8-24, view A):
   - If voltage measured is zero, go to step 6.
   - If voltage measured is battery voltage, repair the circuit from the cranking motor solenoid to terminal B and check system operation.
6. With the controller circuit electrical connector removed, move the ignition switch to crank for 1 second while measuring the voltage at terminal B (harness side) (refer to Figure 8-24, view B):
   - If voltage measured is battery voltage, replace the controller/relay and check system operation.
   - If voltage measured is zero, repair the circuit between the circuit from the cranking motor solenoid to terminal B and check system operation.

Note: Install the controller circuit electrical connector after step 6.

Refer to the following reference chart, if necessary:

Terminal	Circuit	Electrical Check
A	None	
B	Crank input	Battery voltage while cranking
C	Feedback input	Continuity (less than 1 ohm)
D	Power supply	Battery voltage in RUN
E	Power ground	Continuity (less than 1 ohm)

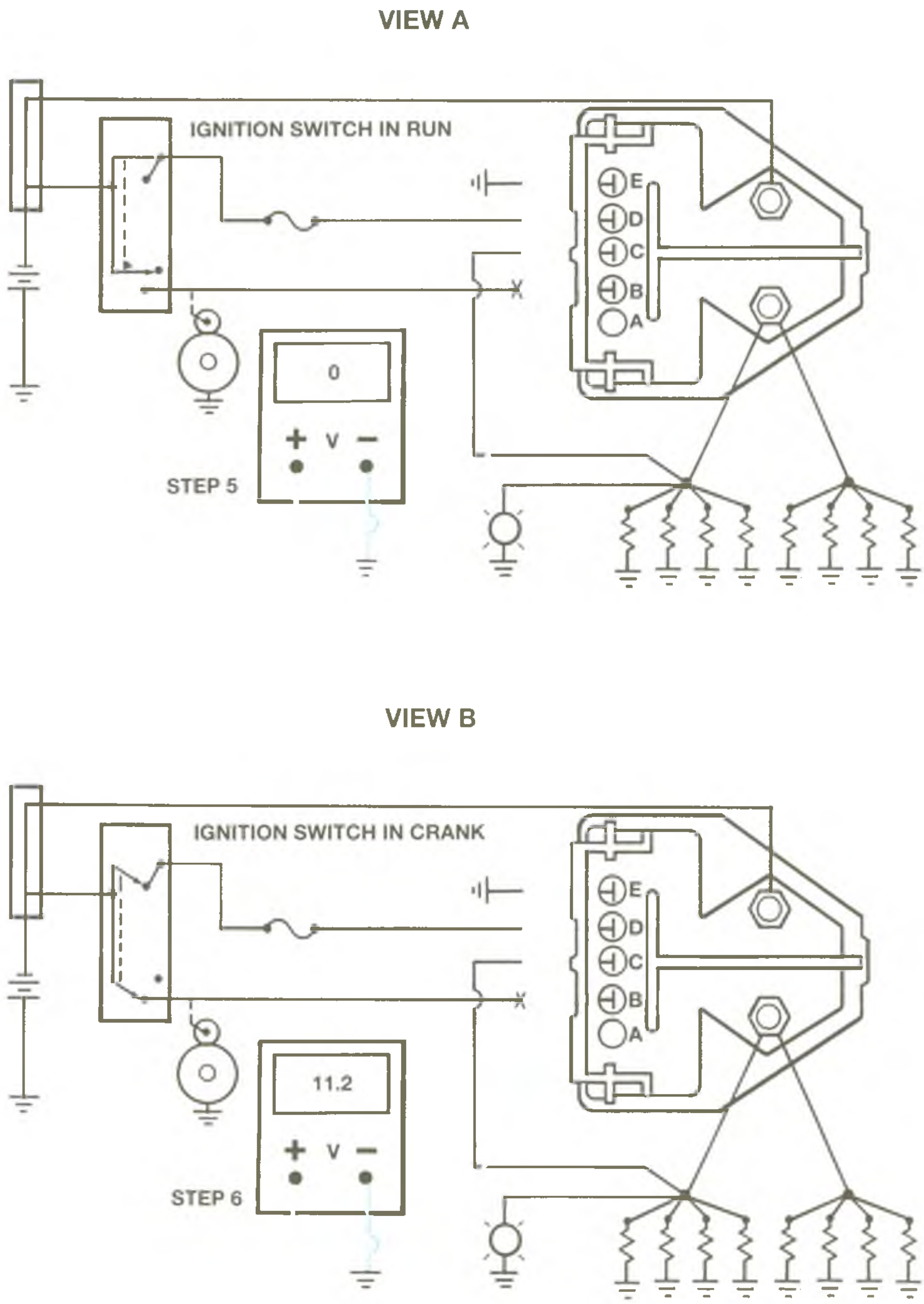


Figure 8-24, Glow Plug Diagnosis – Afterstart Check

Lift Pump Circuit

The electrical circuit for the lift pump involves several main components (refer to Figure 8-25):

- The oil pressure switch/sending unit (threaded into a lubrication system passage at the rear of the cylinder case)
- A relay (mounted near the junction block on the vehicle cowl)
- An in-line fuse (also mounted near the junction block)
- The lift pump itself (mounted under the vehicle on the inside of the left framerail)
- Terminal G of the Assembly Line Data Link (ALDL) connector (vehicles equipped with the 4L80-E Transmission Control Module [TCM])

When the vehicle driver moves the ignition switch to the CRANK position, the lift pump circuit is completed through the relay contacts (refer to Figure 8-26, view A). During this time, oil pressure is building to the point of closing the contacts of the pressure switch/sending unit. A minimum of 28 kPa (4 psi) is required to close the switch contacts.

When the ignition switch is returned to the RUN position, the oil pressure of the running engine maintains electrical power to the lift pump (refer to Figure 8-26, view B). If engine oil pressure drops below 28 kPa (4 psi), the engine will run poorly or stall when the lift pump circuit opens.

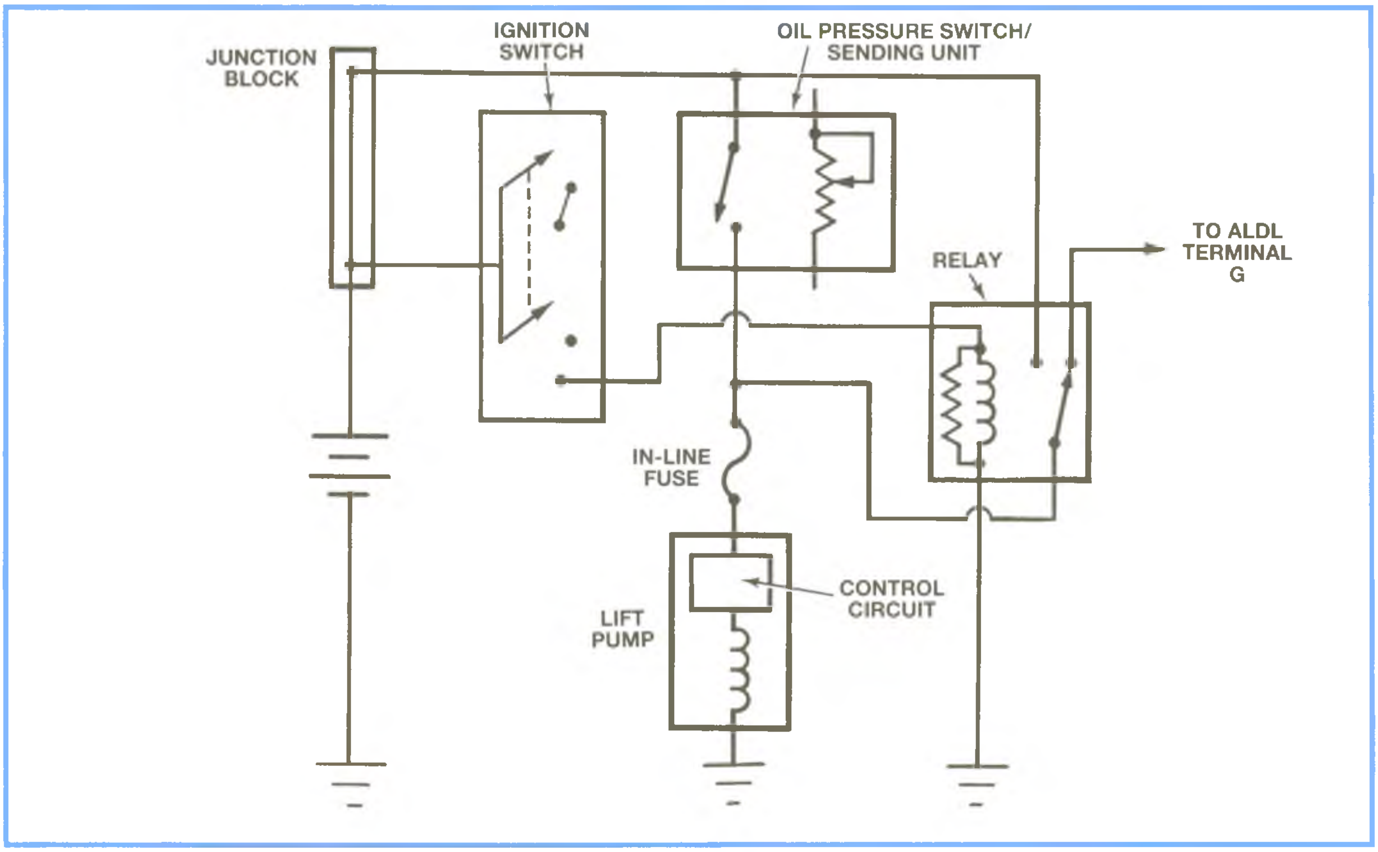


Figure 8-25, **Lift Pump Circuit Components**

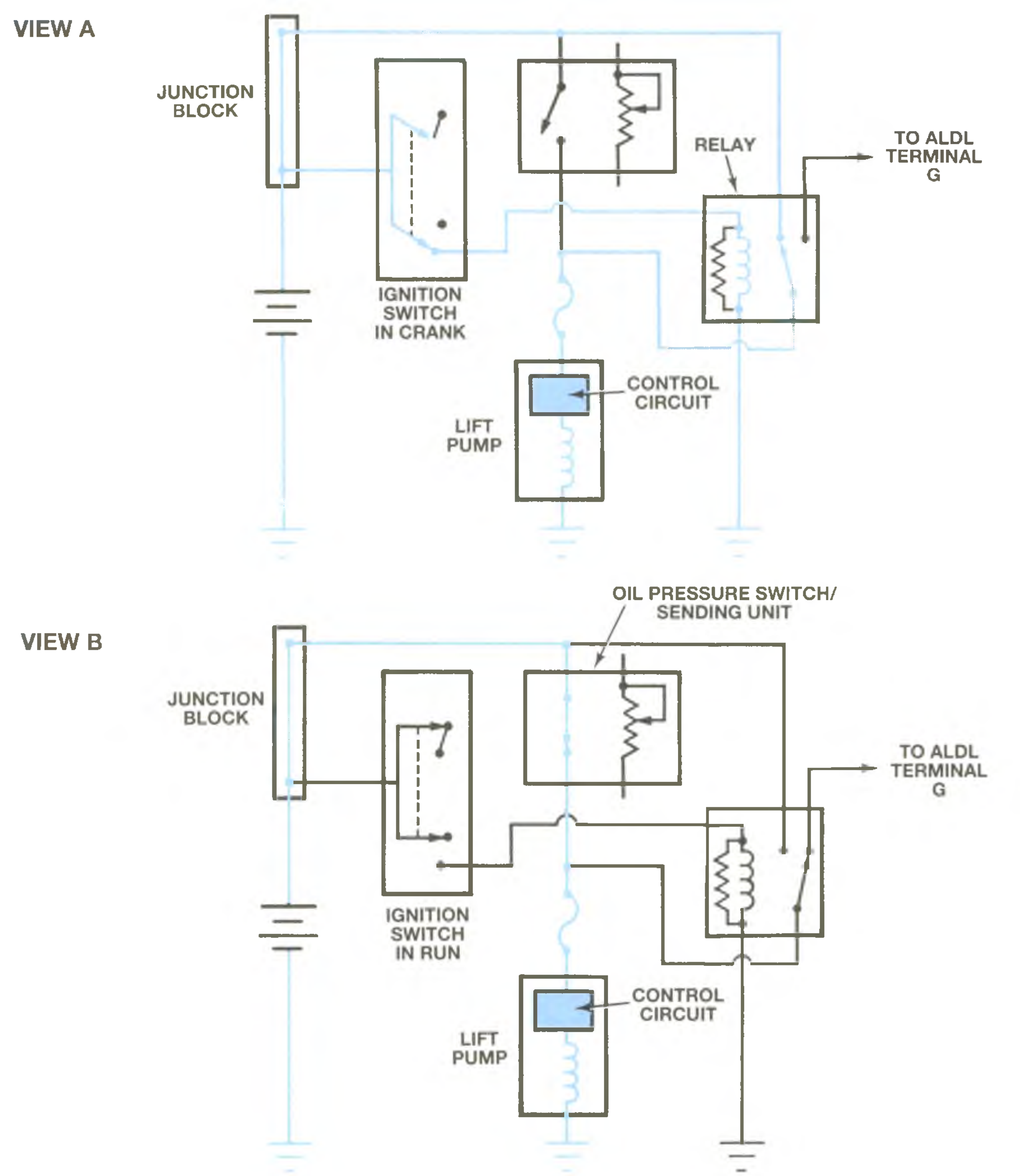


Figure 8-26, Lift Pump Circuit Operation

Fuel Shut-Off Solenoid Circuit

The electrical circuit for the fuel shut-off solenoid in the injection pump involves the ignition switch as the only control (refer to Figure 8-27). A fusible link at the junction block provides circuit protection.

When the ignition switch is in the OFF position, the fuel shut-off solenoid circuit is open. The spring tension of the fuel shut-off solenoid and governor linkage operate a lever that moves the metering valve inside the injection pump to the "no fuel" position (see page 7-32 for more information).

When the ignition switch is in either the CRANK or RUN position, the circuit for the fuel shut-off solenoid is complete. The action of the solenoid lever allows the governor linkage inside the injection pump to control the position of the metering valve.

The fuel shut-off solenoid is designed to operate with a minimum of 8 volts. The resistance of the solenoid coil is 3.5 to 4.5 ohms at room temperature. Diagnosis includes initial testing by listening for the clicking sound of solenoid operation as electrical power is momentarily connected and disconnected.

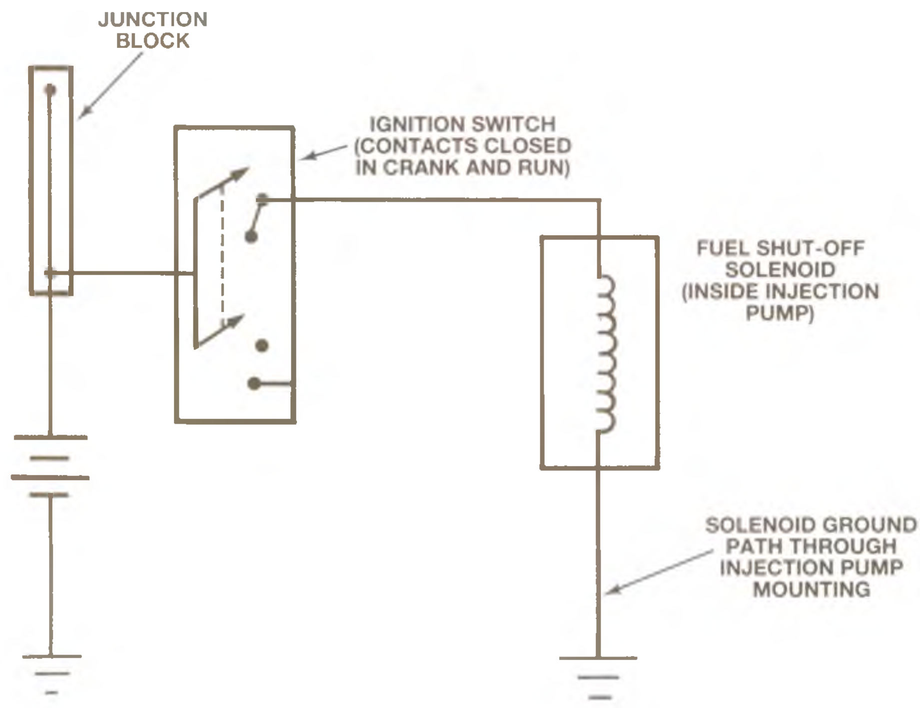


Figure 8-27, **Fuel Shut-Off Solenoid Circuit**

Fast Idle/Cold Advance Circuit

The fast idle/cold advance circuit has the components shown in Figure 8-28. When the ignition switch is in the CRANK or RUN position, power through the GAGES fuse is present at the contacts of the temperature switch.

At temperatures below approximately 85° F (29° C), the temperature switch contacts close, providing power to both the fast idle and HPCA solenoids. As part of the starting procedure, the vehicle driver must first press the accelerator pedal to allow the fast idle solenoid plunger to extend. When it is ON, the fast idle solenoid (mounted on an external injection pump bracket) holds the throttle shaft away from its low idle position slightly to increase engine idle speed.

At the same time, the HPCA solenoid (mounted inside the injection pump governor cover) unseats the valve of the housing pressure regulator to provide timing advance (see page 7-44 for more information). When engine coolant temperature exceeds 95° F (35° C), the temperature switch contacts open, disabling the system.

The fast idle solenoid has a resistance of 20 ohms, and the HPCA solenoid resistance is 24 ohms. Diagnosis of the HPCA solenoid is similar to the fuel shutoff solenoid, with initial checks involving a "click" test.

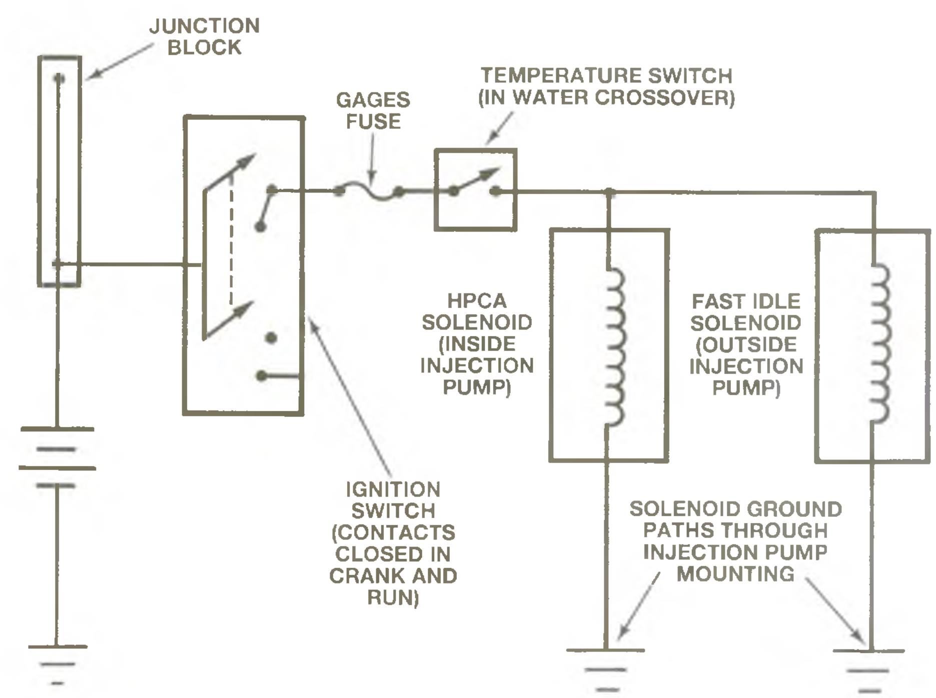


Figure 8-28, **Fast Idle/Cold Advance Circuit**

Fuel Filter Circuits

Fuel Heater Circuit

The fuel filter assembly has a fuel heater (refer to Figure 8-29). The fuel heater receives power through the GAGES fuse when the ignition switch is in the CRANK or RUN position. The fuel heater circuit is completed through the metal of the fuel filter housing to the engine intake manifold.

When the circuit of the fuel heater senses a temperature below 40° F (5° C) inside the fuel filter assembly, it completes the circuit for a heating element. As the temperature increases above 75° F (24° C), the circuit opens the heating element circuit. The resistance of the fuel heater element is 2 ohms at room temperature, providing a current flow of approximately 6 amperes.

See page 7-21 for details about diagnosing and servicing the fuel heater.

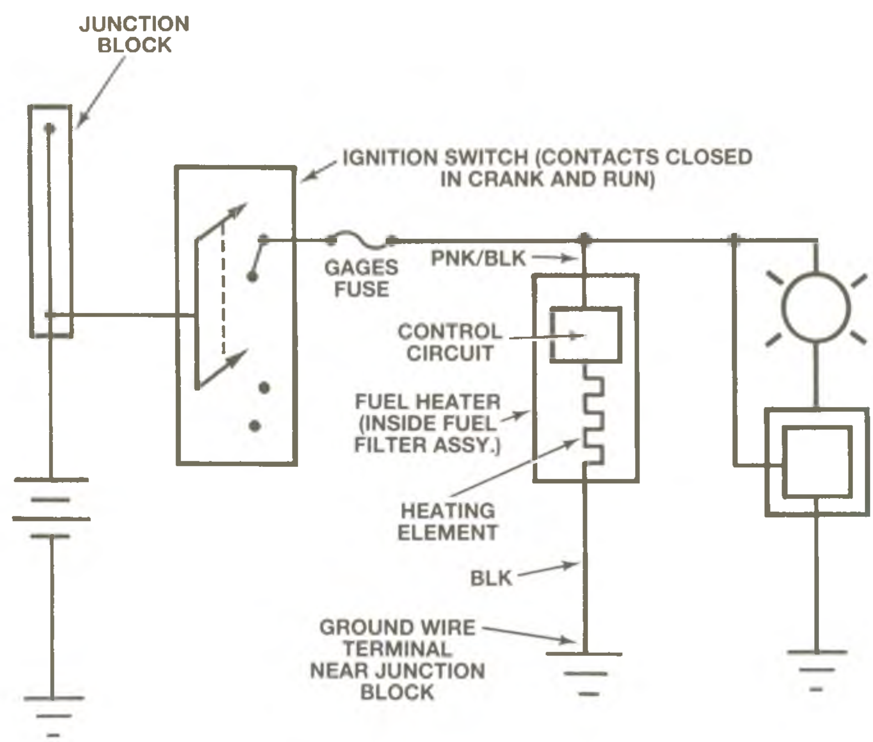


Figure 8-29, **Fuel Heater Circuit**

WIF Sensor Circuit

The fuel filter assembly has a Water In Fuel (WIF) sensor that controls the operation of a warning lamp in the instrument cluster (refer to Figure 8-30). Like the fuel heater, the WIF sensor receives power through the GAGES fuse when the ignition switch is in the CRANK or RUN position.

When the circuit of the WIF sensor detects that a specific amount of water has accumulated inside the filter assembly, it completes the circuit for the warning lamp by providing a ground path. After the filter is drained of the accumulated water, the WIF sensor opens the warning lamp circuit.

See page 7-20 for details about diagnosing and servicing the WIF sensor.

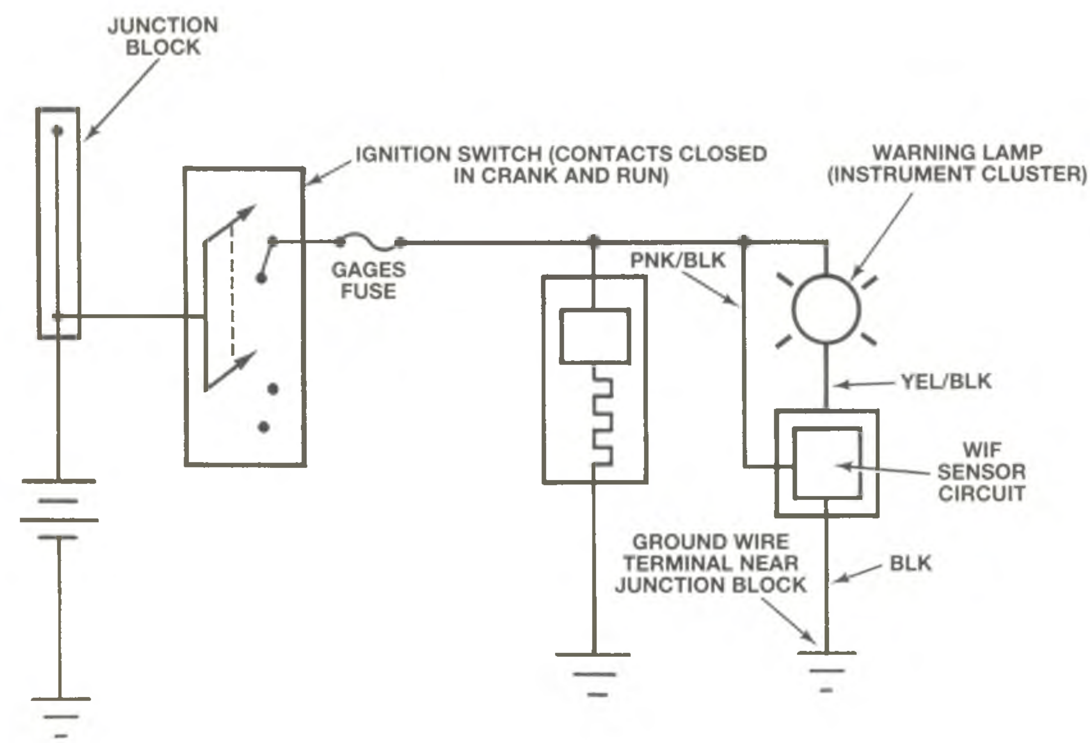


Figure 8-30, **WIF Sensor Circuit**

Instrument Cluster Circuits

The 6.5L V8 turbo diesel engine uses an oil pressure and coolant temperature gauge for vehicle driver information (refer to Figure 8-31). Power from the ignition switch in the CRANK and RUN position moves through the GAGES fuse to the gauges mounted in the instrument cluster. A CHECK GAUGES warning lamp and its control module are also in the cluster and alert the vehicle driver when low oil pressure and/or high coolant temperature conditions exist.

The position of the indicator needle for the oil pressure gauge is controlled by the varying resistance of the oil pressure switch/sending unit, located in a lubrication system passage at the rear of the cylinder case. The position of the coolant temperature gauge is controlled by a sending unit threaded into the coolant passage at the front of the left cylinder head.

The oil pressure switch/sending unit provides low resistance for low gauge indication and high resistance for high gauge readings, while the temperature sending unit acts in the opposite way. Diagnosis includes opening or grounding the sending unit wire while observing gauge indicator needle movement.

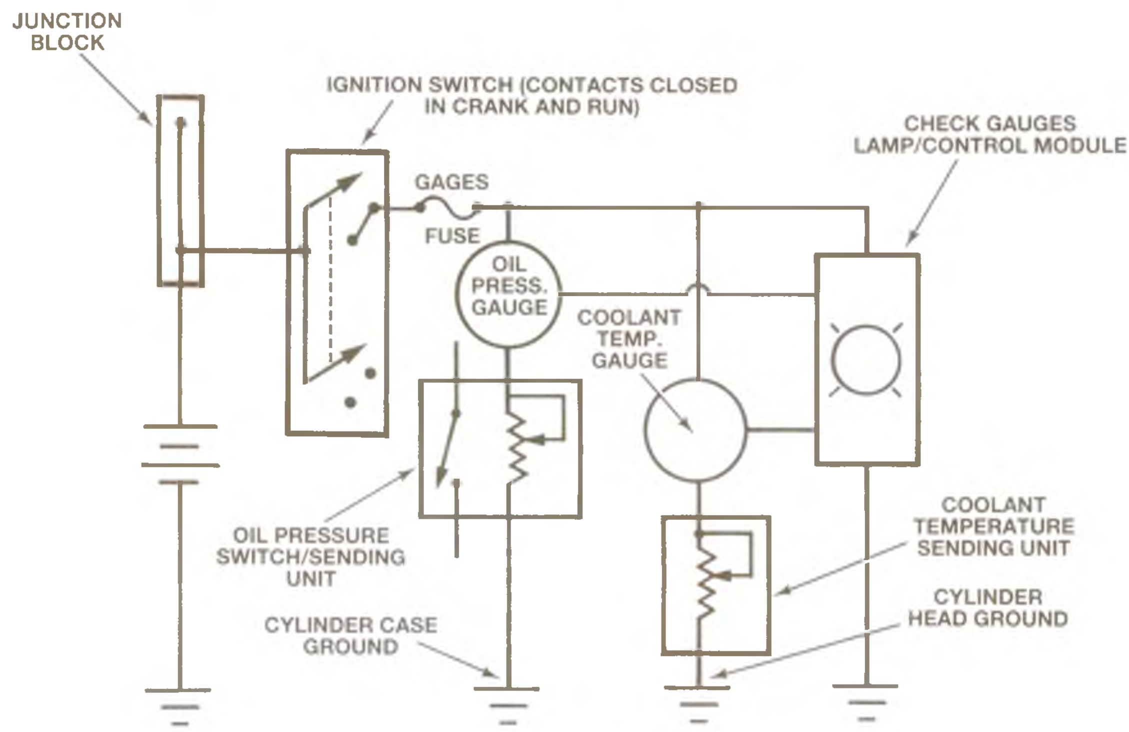


Figure 8-31, **Oil Pressure and Coolant Temperature Gauge Circuits**

The 6.5L V8 turbo diesel engine also uses an instrument cluster-mounted low coolant lamp to alert the vehicle driver (refer to Figure 8-32). Power from the ignition switch in the CRANK and RUN position moves through the GAGES fuse to the lamp mounted in the instrument cluster. A control module mounted behind the instrument panel above the ash tray also receives power through the GAGES fuse and has a circuit ground wire.

A probe for the low coolant lamp circuit threads into the right tank of the radiator and provides a varying path to ground as an input for the control module circuit. If the probe senses the absence of coolant (indicating a loss of fluid), the control module completes the circuit for the warning lamp. After repairs have been performed to correct the loss of coolant, the control module detects a changed probe circuit resistance and opens the warning lamp circuit.

The low coolant probe provides a low resistance that results in the warning lamp remaining OFF, and high probe circuit resistance causes the warning lamp to illuminate. Part of the steps of diagnosis includes opening or grounding the probe wire while observing the warning lamp status.

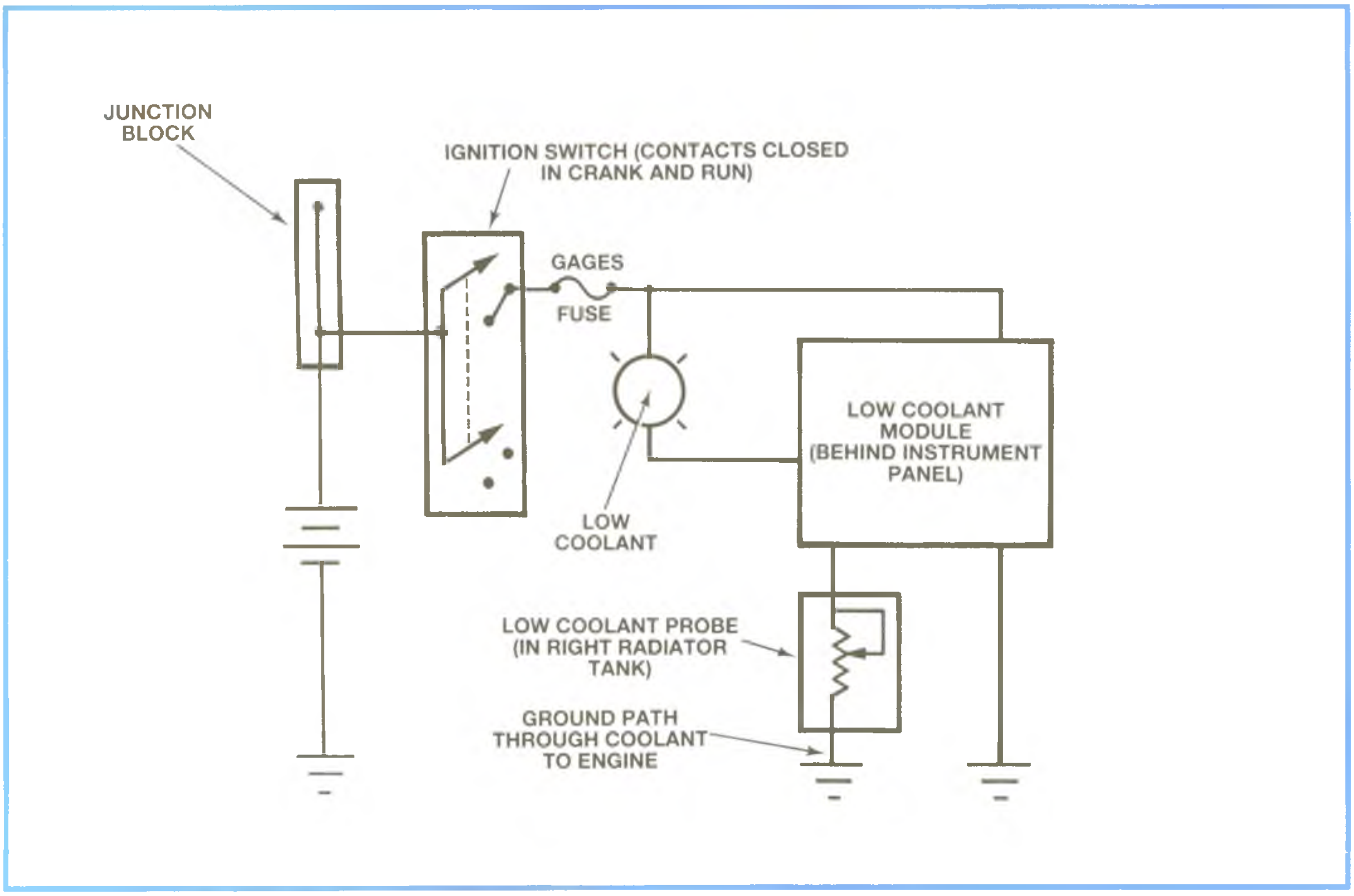


Figure 8-32, **Low Coolant Lamp Circuit**

Automatic Transmission Control System

Vehicles with the 6.5L V8 turbo diesel engine powertrain also have the Hydra-matic 4L80-E automatic transmission. The 4L80-E is a four-speed unit that uses a Transmission Control Module (TCM) to provide the following (refer to Figure 8-33):

- Control of shift timing (through solenoids A and B)
- Control of the TCC apply and release (through a PWM solenoid)
- Control of line pressure (through a variable force motor)

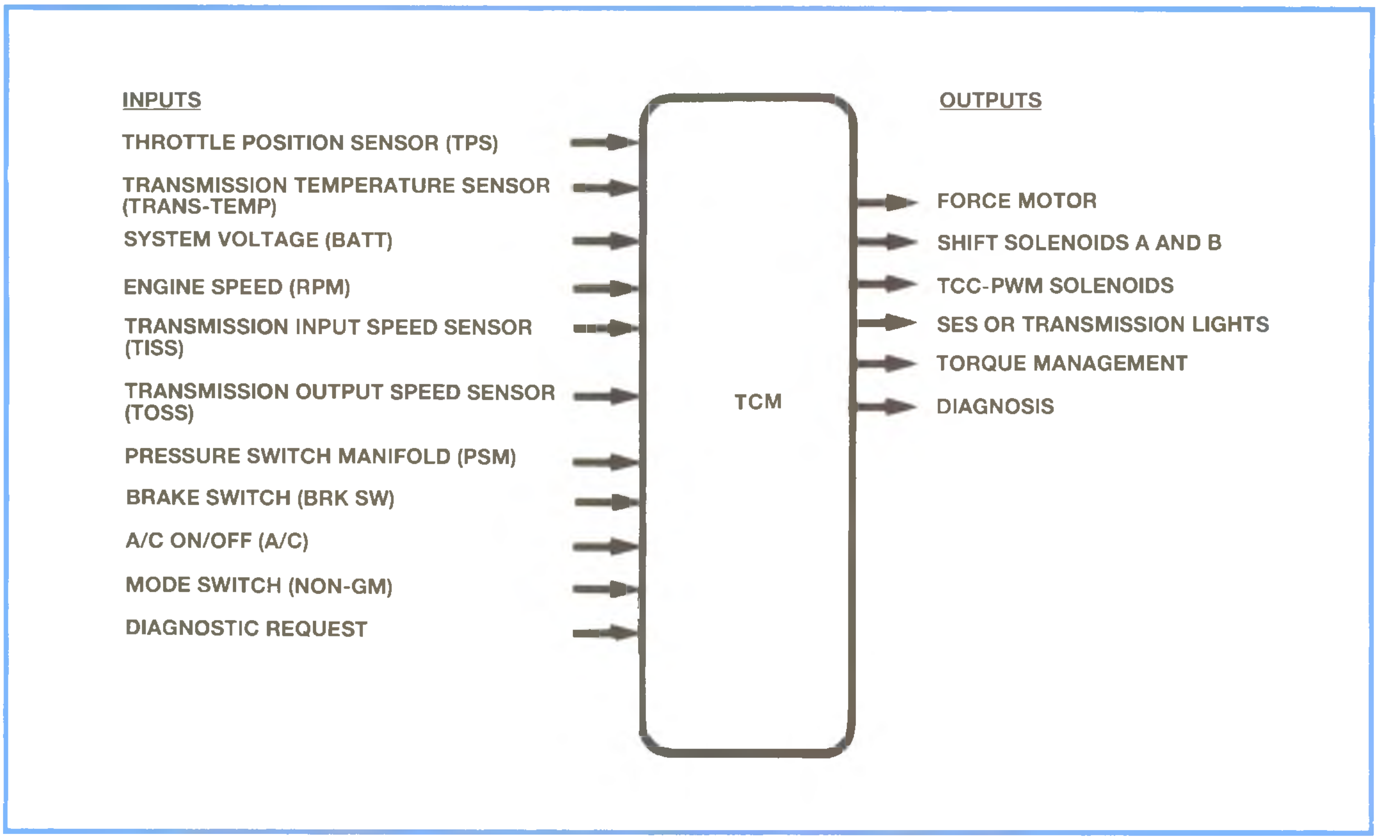


Figure 8-33, **Automatic Transmission Control System Flow Chart**

The automatic transmission control system uses two engine-mounted sensors to perform its functions. The first is the engine speed sensor, which is part of the oil pump drive mounted at the rear of the cylinder case (see Figure 8-34, view A). This sensor generates an alternating current signal with a frequency of four cycles per camshaft revolution.

The second input for automatic transmission control is the Throttle Position Sensor (TPS), mounted on the right side of the injection pump and operated by the rotation of the throttle shaft (see Figure 8-34, view B). This sensor has mounting slots, and an adjustment procedure must be performed during any service procedures that involve removal and installation of the TPS.

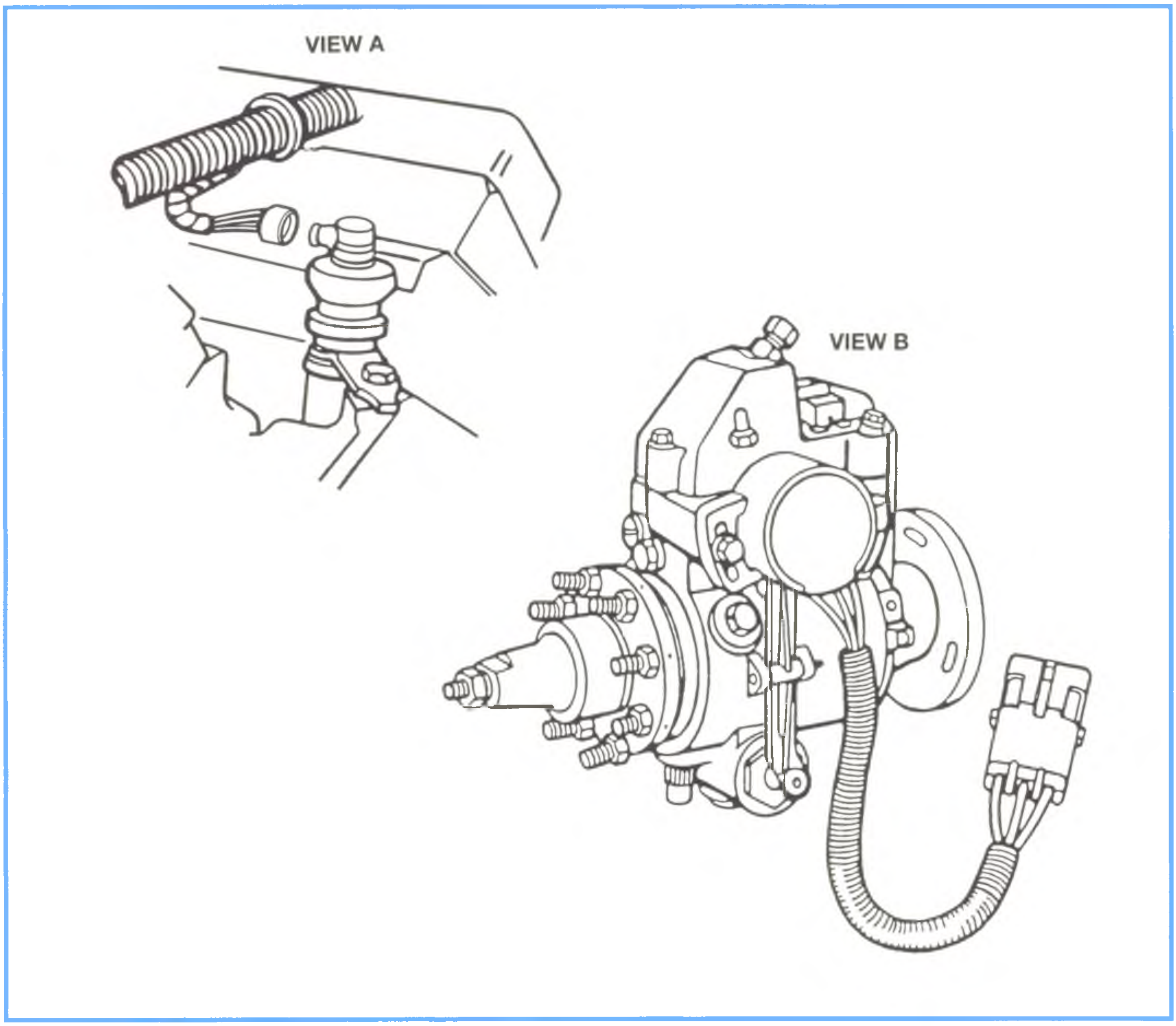


Figure 8-34, Engine-Mounted Sensors

The adjustment procedure for the TPS has the following steps:

- Remove the intake manifold sound insulator cover.
- Install jumper wires between the TPS and vehicle wiring harness (see Figure 8-35, view A).
- Rotate the ignition switch to the RUN position.
- Measure the voltage between terminals A and C of the TPS connector, and multiply the measurement by 0.33 to obtain the desired TPS voltage.

Example: 5.05 volts times 0.33 equals 1.66 (plus or minus 0.01 volt).

- Install a gauge block (16.5mm [0.646-in.] thickness) between the injection pump throttle lever and the casting boss on the injection pump housing (see Figure 8-35, view B).
- Rotate the injection pump throttle lever so that the maximum speed stop screw holds the gauge block against the housing boss.

Note: Keep the throttle lever in this position during the remainder of the adjustment steps.

- Measure the voltage between terminals B and C of the TPS connector:
  - If the measured voltage is within the calculated specification, reconnect the TPS and install the intake manifold sound insulator cover.
  - If the voltage is not within the calculated specification, go to the next step.
- Loosen the TPS mounting screws and rotate it toward the rear of the vehicle (counterclockwise direction).
- With the voltmeter connected to terminals B and C of the TPS connector, rotate the TPS slowly toward the front of the vehicle (clockwise direction) until the voltmeter indicates the correct voltage (1.65 to 1.67 volts, for example).
- Tighten the TPS mounting screws and confirm that the adjustment did not change.
- Reconnect the TPS and install the intake manifold sound insulator cover.

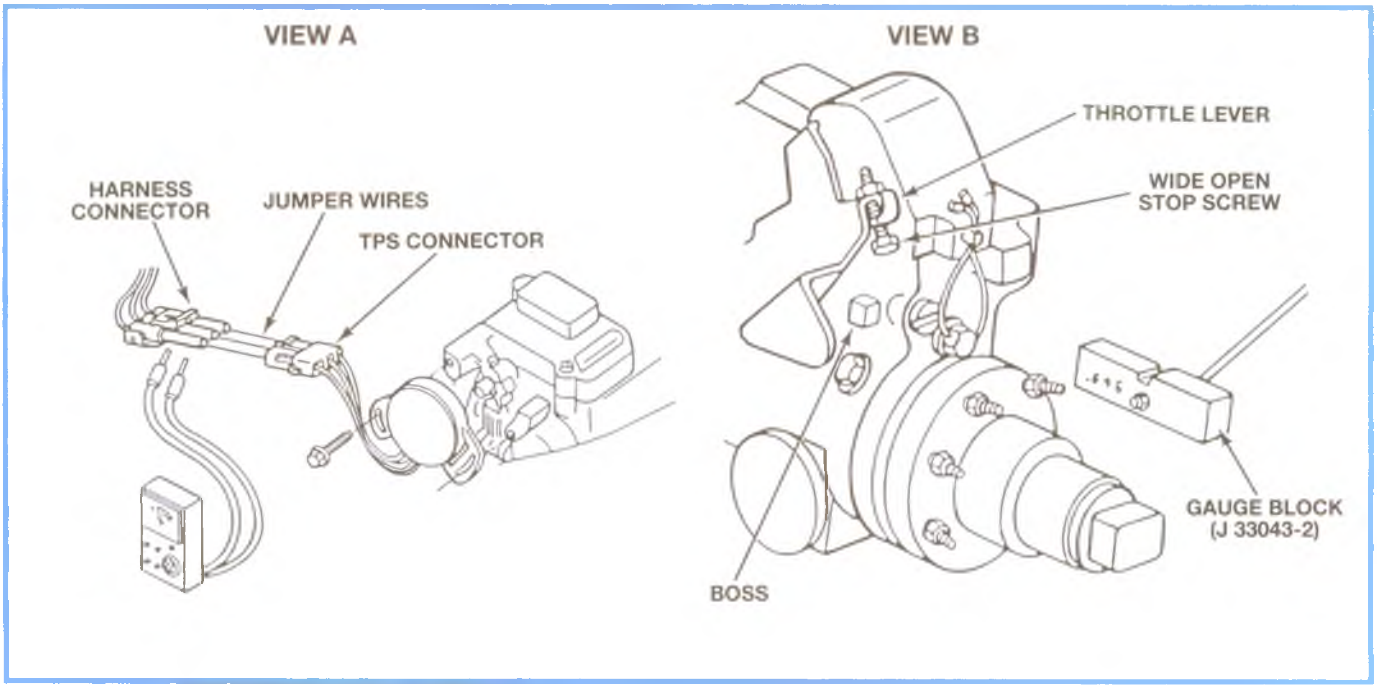


Figure 8-35, TPS Adjustment Steps

Related Diagnosis/Service Procedures

Cranking Motor Noise Diagnosis

1. Listen to the cranking system during cranking (**before the engine starts**):
   - If a high-pitched whining noise exists, decrease the distance between the pinion and flexplate gear teeth by subtracting shims.
   - If a high-pitched whining noise does not exist, go to step 2.
2. Listen to the cranking system during cranking (**after the engine starts**):
   - If a high-pitched whining noise exists, increase the distance between the pinion and flexplate gear teeth by adding shims.

Note: If the high-pitched whining noise is rhythmic, check the runout of the flexplate gear teeth.

   - If a loud "whoop" sound exists (and changes in pitch as engine speed changes), replace the cranking motor clutch.
   - If a rumbling, growling or knocking noise exists, inspect the cranking motor armature for imbalance or a bent shaft.
   - If none of the above noises exist, go to step 3.
3. Listen to the cranking system after cranking (**as the ignition switch moves from the CRANK to RUN position**):
   - If a rumbling, growling or knocking noise exists, inspect the cranking motor armature for imbalance or a bent shaft.

Cranking Speed Check

1. Remove the B+ wire from the fuel shut-off solenoid wire on the injection pump.
2. Remove the glow plug for one cylinder.
3. Install compression gauge adapter J 26999-10 into the glow plug hole of the cylinder.
4. Connect compression gauge J 26999-12 to the adapter, and press the gauge pressure relief valve.
5. Crank the engine in the following manner:
   - Allow initial cranking for three seconds.
   - Count the number of “puffs” that occur in the next 10 seconds of cranking.
   - Stop cranking.
6. Calculate the cranking speed by multiplying the number of “puffs” by 12.

   Example: 10 “puffs” times 12 is 120 cranking rpm.
7. Remove the gauge and install the glow plug (tighten to 11 to 16 N·m [8 to 12 lb-ft] torque).
8. Connect the B+ wire for the injection pump fuel shut-off solenoid.
9. Check the engine operation and charge the batteries.

Note: Minimum cranking speed is 100 rpm with a cold engine and 180 rpm with a warm or hot engine. Actual cranking speed needed will vary depending on the condition of the engine (compression) and nozzles.

9. Diagnosis

Diagnostic Strategy

The diagnosis of faults related to the 6.5L V8 turbo diesel engine involves the following steps (refer to Figure 9-1):

1. Verify that a condition related to a fault exists
2. Select the condition for the fault
3. Select a system or to check that relates to the condition
4. Perform checks of system components to find the fault
5. Make the necessary repair to correct the fault
6. Verify that the repair has eliminated the condition

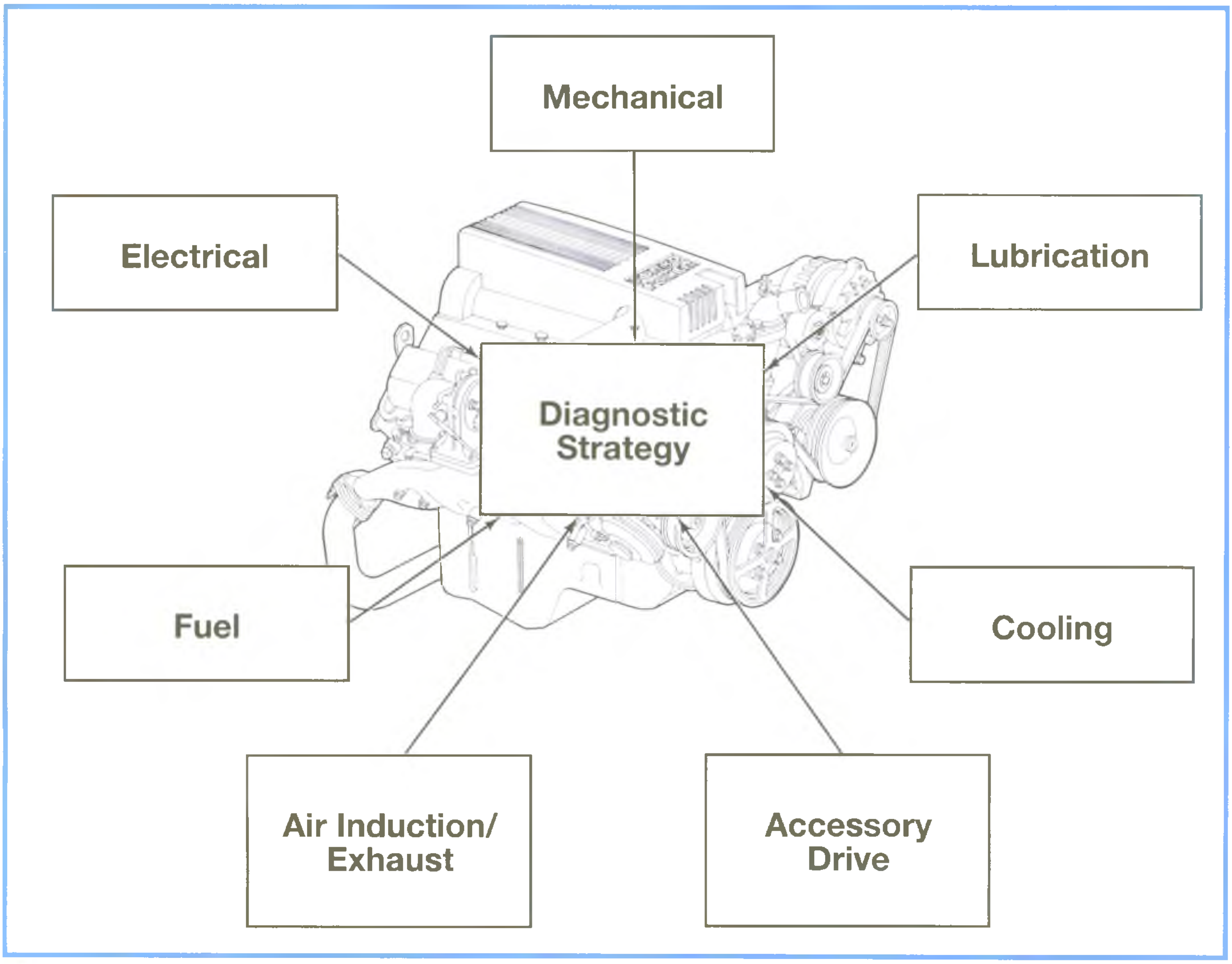


Figure 9-1, **Diagnostic Strategy**

Condition Verification

The process of verifying that a condition related to a component of the 6.5L V8 turbo diesel engine exists includes the following steps:

1. Inspect the level and condition of fluids, and observe any leakage from components:
   - Engine oil
   - Coolant
   - Fuel
2. Inspect the condition and tension of the accessory drive belt.
3. Inspect the condition of the outside air intake and air filter element.
4. Inspect electrical wiring and connectors:
   - Left battery
   - Right battery
   - Generator
   - Cranking motor
   - Fuel shut-off solenoid
   - Housing Pressure Cold Advance solenoid
   - Fast idle solenoid
   - Throttle Position Sensor
   - Engine speed sensor
   - Water In Fuel sensor
   - Fuel heater
   - Oil pressure switch/sending unit
   - Glow plug controller/relay
   - Glow plugs

5. Inspect electrical wiring and connectors (continued):
   - Block heater
   - Coolant temperature switch/sending unit
   - Low coolant probe
   - Fuel pump relay
   - Junction block and fusible links
   - Fuses
   - Fuel pump
6. Operate the engine (if possible) and observe the following:
   - Check the basic function of the glow plug, cranking, charging and fast idle/cold advance systems.
   - Listen for unusual noises.
   - Look for excessive exhaust smoke.
   - Observe the smoothness of engine operation at various speeds.
7. Operate the vehicle (if possible) and observe the following:
   - Listen for unusual noises.
   - Look for excessive exhaust smoke.
   - Observe the smoothness of engine, transmission and driveline operation at various vehicle speeds and loads.

Based on these initial checks, do one of three things:

- If a condition is not found, consult the service advisor, vehicle owner or operator for more diagnostic information.
- If both a condition and its cause are found, make a repair and verify it.
- If a condition (but no cause) is found, proceed to the next section, Identifying a Condition.

Condition Identification

Based on verifying that a condition exists, identify the condition(s) and proceed with further diagnosis. Each condition has a cause/correction chart, located on the pages indicated:

Diagnosis Charts

Low Power or Loss of Power

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy/purity)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Operation while overloaded or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Cooling System:	
Cooling fan clutch always applied	• Check cooling fan clutch operation. - Refer to page 4-15 for diagnostic hints.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Low Power or Loss of Power (continued)

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Restricted exhaust system	• Inspect exhaust system for collapsed pipes or muffler.
Fuel System:	
Binding injection pump throttle cable	• Check throttle controls.
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply checks (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system checks (see page 7-76).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).
Internal injection pump fault (sticking governor linkage)	• Check injection pump (see page 7-50 for diagnosis).
Electrical Systems:	
Faulty automatic transmission control system	• Perform TCM diagnostic check.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Hard To Start

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy/purity)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Improper starting procedures	• Inform customer of the following: - Correct use of glow plug system - Correct use of block heater - Correct use of accelerator pedal
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Hard To Start (continued)

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems (continued):	
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect fuel shut-off solenoid operation	• Perform fuel shut-off solenoid diagnosis (see page 7-89).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).
Internal injection pump fault (no high-pressure fuel delivery)	• Check injection pump (see page 7-50 for diagnosis).
Electrical Systems:	
Incorrect glow plug operation	• Perform glow plug system diagnosis (see page 8-20).
Slow cranking speed	• Perform cranking speed check (see page 8-42). • Check the following, if needed: - Battery state-of-charge - Cranking system operation - Charging system operation

[1]Items that are highlighted in blue are the most likely causes for the condition.

Will Not Start – Cold

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy/purity)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Improper starting procedures	• Inform customer of the following: - Correct use of glow plug system - Correct use of block heater - Correct use of accelerator pedal
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Fuel System:	
Incorrect low/fast idle speeds	• Perform adjustments (see page 7-87).
Incorrect fuel supply to injection pump	• Check fuel system for bleed-down. • Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect fuel shut-off solenoid operation	• Perform fuel shut-off solenoid diagnosis (see page 7-89).
Incorrect HPCA solenoid operation	• Perform HPCA solenoid diagnosis (see page 7-90).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Will Not Start – Cold (continued)

Cause[1]	Correction/Further Diagnosis
Fuel System (continued):	
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).
Internal injection pump fault (no high-pressure fuel delivery)	• Check injection pump (see page 7-50 for diagnosis).
Electrical Systems:	
Incorrect glow plug operation	• Perform glow plug system diagnosis (see page 8-20).
Slow cranking speed	• Perform cranking speed check (see page 8-42). • Check the following, if needed: - Battery state-of-charge - Cranking system operation - Charging system operation

[1]Items that are highlighted in blue are the most likely causes for the condition.

Will Not Start – Hot

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (low viscosity)	• Replace fuel.
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect fuel shut-off solenoid operation	• Perform fuel shut-off solenoid diagnosis (see page 7-89).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Internal injection pump fault (no high pressure fuel delivery)	• Check injection pump (see page 7-50 for diagnosis).
Electrical Systems:	
Slow cranking speed	• Perform cranking speed check (see page 8-42). • Check the following, if needed: - Battery state-of-charge - Cranking system operation - Charging system operation

[1]Items that are highlighted in blue are the most likely causes for the condition.

Engine Starts, Then Stalls

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel viscosity (hot/cold ambient temperature)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Restricted exhaust system	• Inspect exhaust system for collapsed pipes or muffler.
Fuel System:	
Incorrect low/fast idle speeds	• Perform adjustments (see page 7-87).
Incorrect fuel supply to injection pump (air in fuel)	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect fuel shut-off solenoid operation	• Perform fuel shut-off solenoid diagnosis (see page 7-89).
Incorrect HPCA solenoid operation	• Perform HPCA solenoid diagnosis (see page 7-90).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Internal injection pump fault (sticking governor linkage or no high-pressure fuel delivery)	• Check injection pump (see page 7-50 for diagnosis).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Rough/Erratic Idle

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Operation during extreme ambient temperatures (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Fuel System:	
Binding injection pump throttle cable	• Check throttle controls.
Incorrect low/fast idle speeds	• Perform adjustments (see page 7-87).
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump (air in fuel)	• Perform fuel supply check (see page 7-68).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Rough/Erratic Idle (continued)

Cause[1]	Correction/Further Diagnosis
Fuel System (continued):	
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect HPCA solenoid operation	• Perform HPCA solenoid diagnosis (see page 7-90).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).
Internal injection pump fault (sticking governor linkage)	• Check injection pump (see page 7-50 for diagnosis).
Electrical Systems:	
Incorrect glow plug operation (after start-up)	• Perform glow plug system diagnosis (see page 8-20).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Engine Will Not Shut Off

Cause	Correction/Further Diagnosis
Fuel System:	
Incorrect fuel shut-off solenoid operation	• Perform fuel shut-off solenoid diagnosis (see page 7-89).
Internal injection pump fault (sticking governor linkage)	• Check injection pump (see page 7-50 for diagnosis).

Engine Misfires or Backfires

Cause[1]	Correction/Further Diagnosis
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Damaged crankshaft bearings	• Inspect main and connecting rod bearings.
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Fuel System:	
Incorrect low/fast idle speeds	• Perform adjustments (see page 7-87).
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump (air in fuel)	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Engine Speed Fluctuates

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (water in fuel)	• Inspect and clean fuel tank, if needed (see page 7-63).
Mechanical System:	
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Fuel System:	
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Internal injection pump fault (sticking governor linkage)	• Check injection pump (see page 7-50 for diagnosis).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Poor Acceleration

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy/purity)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Operation while overloaded or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Poor Acceleration (continued)

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems (continued):	
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Restricted exhaust system	• Inspect exhaust system for collapsed pipes or muffler.
Fuel System:	
Binding injection pump throttle cable	• Check throttle controls.
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle test (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive White Smoke

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy/purity)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Operation with long periods of engine idling	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Fuel System:	
Incorrect low/fast idle speeds	• Perform adjustments (see page 7-87).
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump (air in fuel)	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect HPCA solenoid operation	• Perform HPCA solenoid diagnosis (see page 7-90).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive White Smoke (continued)

Cause	Correction/Further Diagnosis
Fuel System (continued):	
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).
Electrical Systems:	
Incorrect glow plug operation	• Perform glow plug system diagnosis (see page 8-20).

Black Smoke at Load – Hot

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Operation with long periods of engine idling	• Advise customer of correct vehicle usage.
Operation while overloaded or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Black Smoke at Load – Hot (continued)

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems (continued):	
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Black Smoke at Idle

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect HPCA solenoid operation	• Perform HPCA solenoid diagnosis (see page 7-90).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive Smoke During Acceleration

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Operation with long periods of engine idling	• Advise customer of correct vehicle usage.
Operation while overloaded or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Gray Smoke

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Operation with long periods of engine idling	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Restricted exhaust system	• Inspect exhaust system for collapsed pipes or muffler.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Gray Smoke (continued)

Cause[1]	Correction/Further Diagnosis
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Blue Smoke

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn valve guides	• Check valve stem oil seal condition. • Check valve-to-guide oil clearance. • Make repairs, if needed

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive Lube Oil Consumption

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Incorrect oil change interval	• Advise customer of correct vehicle maintenance.
Operation while overloaded or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn valve guides	• Check valve-to-guide oil clearance. • Make repairs, if needed.
Air Induction/Exhaust Systems:	
Faulty CDRV operation	• Check crankcase pressure (see page 6-24).
Leaking crankcase ventilation system (pipes/hoses)	• Inspect system for oil leakage. • Repair or replace damaged parts, if needed.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive Fuel Consumption

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy)	• Advise customer of correct fuel usage.
Operation with long periods of engine idling	• Advise customer of correct vehicle usage.
Operation while overloaded (add-on accessories) or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Cooling System:	
Cooling fan clutch always applied	• Check cooling fan clutch operation. - Refer to page 4-15 for diagnostic hints.
Low coolant temperature	• Check thermostat for low opening temperature (see page 4-20).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive Fuel Consumption (continued)

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (see page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.
Restricted exhaust system	• Inspect exhaust system for collapsed pipes or muffler.
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).
Internal injection pump fault (sticking governor linkage)	• Check injection pump (see page 7-50 for diagnosis).
Electrical Systems:	
Faulty automatic transmission control system	• Perform TCM diagnostic check.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive Coolant Consumption

Cause[1]	Correction/Further Diagnosis
Mechanical System:	
Faulty cylinder combustion area (leaking head gasket, cracked passages)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces and passages.
Cooling System:	
Faulty radiator pressure cap	• Check radiator cap for low opening pressure and replace it, if needed.
Leaking coolant reservoir/hose	• Check reservoir and hose for leakage and replace, if needed.
Leaking cylinder case/head coolant passages	• Pressure test cooling system. • Inspect cylinder case/head passages for cracks.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Fuel or Lube Oil Leaks

Cause	Correction/Further Diagnosis
Lubrication System:	
Component leakage	• Inspect sealing surfaces and areas for signs of oil leakage: - Rocker arm covers - Front cover - Oil fill pipe - Oil pump drive/engine speed sensor - Cylinder case passage plugs - Oil filter mounting - Oil cooler pipes/hoses - Oil pan - Oil dipstick tube - Crankshaft front and rear seals
Air Induction/Exhaust Systems:	
Leaking crankcase ventilation system (pipes/hoses)	• Inspect system for oil leakage. • Repair or replace damaged parts, if needed.
Fuel System:	

Component leakage	• Inspect sealing surfaces and areas for signs of fuel leakage:
	- Fuel tank
	- Fuel pick-up/sending unit
	- Lift pump suction pipe/hose
	- Lift pump
	- Lift pump pressure pipe/hose
	- Fuel filter assembly
	- Fuel filter outlet hose
	- Fuel injection pump:
	  • Governor cover
	  • Housing
	  • Head
	  • Drive shaft
	- Fuel injection lines
	- Fuel injection nozzles
	- Fuel return lines:
	  • From injection pump (hose)
	  • At nozzles (hoses and caps)
	  • From nozzles (hoses/pipes)
	  • From engine to fuel pick-up/sending unit

Lube Oil Contaminated

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation: Incorrect oil change interval	• Advise customer of correct vehicle maintenance.
Mechanical System: Faulty cylinder combustion area (leaking head gasket, cracked passages)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces and passages.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Lubrication System: Air/dirt ingestion at oil leakage areas	• Inspect sealing surfaces and areas for signs of oil leakage (see list on page 9-33).
Oil filter bypassed	• Remove filter and check bypass valve operation.
Air Induction/Exhaust Systems: Leaking crankcase ventilation system (pipes/hoses)	• Inspect system for oil leakage. • Repair or replace damaged parts, if needed.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Coolant Contaminated

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect coolant change interval	• Advise customer of correct vehicle maintenance.
Mechanical System:	
Faulty cylinder combustion area (leaking head gasket, cracked passages)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces and passages.
Lubrication System:	
Lube passage leak into coolant passage	• Check the cylinder case and head passages for cracks.
Oil cooler leak into radiator coolant	• Perform oil cooler pressure check (see page 3-18).

[1]Items that are highlighted in blue are the most likely causes for the condition.

High Coolant Temperature

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Operation while overloaded or at excessive speed	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Faulty cylinder combustion area (leaking head gasket, cracked passages)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces and passages.
Cooling System:	
Incorrect coolant quality/grade	• Check cooling system for overheating (see page 4-17).
Incorrect coolant level	• Check cooling system for overheating (see page 4-17).
Faulty radiator pressure cap	• Check cooling system for overheating (see page 4-17).
Restricted air flow through radiator	• Check cooling system for overheating (see page 4-17).
Faulty water pump	• Check cooling system for overheating (see page 4-17).
Cooling fan clutch never applied	• Check cooling system for overheating (see page 4-17). - Refer to page 4-15 for diagnostic hints.
Leaking coolant reservoir/hose	• Check reservoir and hose for leakage and replace, if needed.
Restricted coolant flow in hoses	• Check cooling system for overheating (see page 4-17).
Restricted coolant flow in cylinder case and cylinder head passages	• Check cooling system for overheating (see page 4-17).
Electrical Systems:	
Inaccurate coolant temperature gauge operation	• Check gauge circuit operation.

[1]Items that are highlighted in blue are the most likely causes for the condition.

High Oil Sump Temperature

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Lubrication System:	
Oil cooler restricted or bypassed	• Check oil flow through cooler system. • Remove filter and check oil cooler bypass valve operation.
Oil filter bypassed	• Remove filter and check oil filter bypass valve operation.
Sticking oil pump pressure regulator valve	• Check oil pressure (see page 3-17). • Remove, disassemble and inspect oil pump.
Cooling System:	
High coolant temperature	• Check cooling system for overheating (see page 4-17).

[1]Items that are highlighted in blue are the most likely causes for the condition.

No Heat From Heater

Cause[1]	Correction/Further Diagnosis
Mechanical System:	
Faulty cylinder combustion area (leaking head gasket, cracked passages)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces and passages.
Cooling System:	
Incorrect coolant level	• Follow step 1 of cooling system diagnosis for overheating (see page 4-17).
Low coolant temperature	• Check thermostat for low opening temperature (see page 4-20).
Faulty water pump	• Follow step 7 of cooling system diagnosis for overheating (see page 4-17).
Restricted coolant flow in hoses	• Follow step 3 of cooling system diagnosis for overheating (see page 4-17).
Restricted coolant flow in cylinder case and cylinder head passages	• Follow step 6 of cooling system diagnosis for overheating (see page 4-17).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Crankcase Sludge

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Incorrect oil change interval	• Advise customer of correct vehicle maintenance.
Operation with long periods of engine idling	• Advise customer of correct vehicle usage.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Lubrication System:	
Oil cooler restricted or bypassed	• Check oil flow through cooler system. • Remove filter and check oil cooler bypass valve operation.
Oil filter bypassed	• Remove filter and check oil filter bypass valve operation.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Low Oil Pressure

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Mechanical System:	
Excessive oil clearance for crankshaft bearings	• Inspect crankshaft main and connecting rod bearing oil clearance.
Damaged crankshaft bearings	• Inspect main and connecting rod bearings for wear.
Lubrication System:	
Worn or damaged oil pump (gears, pick-up tube/screen)	• Check oil pressure (see page 3-17). • Remove, disassemble and inspect oil pump.
Faulty oil pump drive or shaft	• Check oil pressure (see page 3-17). • Remove and inspect oil pump drive and shaft.
Sticking oil pump pressure regulator valve	• Check oil pressure (see page 3-17). • Remove, disassemble and inspect oil pump.
Oil cooler restricted or bypassed	• Check oil flow through cooler system. • Remove filter and check oil cooler bypass valve operation.
Oil filter bypassed	• Remove filter and check oil filter bypass valve operation.
Lube passage leak into crankcase	• Check the cylinder case passages for cracks.
Electrical Systems:	
Inaccurate oil pressure gauge operation	• Check gauge circuit operation.

[1]Items that are highlighted in blue are the most likely causes for the condition.

High Oil Pressure

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation: Operation during extreme ambient temperature (hot/cold)	• Inform customer of normal operating characteristics.
Lubrication System: Sticking oil pump pressure regulator valve	• Check oil pressure (see page 3-17). • Remove, disassemble and inspect oil pump.
Electrical Systems: Inaccurate oil pressure gauge operation	• Check gauge circuit operation.

[1]Items that are highlighted in blue are the most likely causes for the condition.

High Crankcase Pressure

Cause[1]	Correction/Further Diagnosis
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces.
Air Induction/Exhaust Systems:	
Faulty CDRV operation	• Check crankcase pressure (see page 6-24).
Restricted crankcase ventilation system (pipes/hoses)	• Inspect system for restriction. • Repair or replace damaged parts, if needed.
Restricted exhaust system	• Inspect exhaust system for collapsed pipes or muffler.

[1]Items that are highlighted in blue are the most likely causes for the condition.

High Inlet Restriction

Cause[1]	Correction/Further Diagnosis
Air Induction/Exhaust Systems:	
Outside air intake or air filter restricted	• Disassemble air filter to inspect element. • With air filter disassembled, check outside air intake.
Air leakage or restriction in turbocharger inlet duct	• See turbocharger diagnosis (page 6-16).
Worn or damaged turbocharger turbine wheel/ shaft or compressor wheel	• See turbocharger diagnosis (see page 6-16).
Air leakage or restriction in air inlet duct or intake manifold	• Check air inlet duct bolt and clamp tightness. • Check intake manifold bolt/stud tightness. • Disassemble and inspect air inlet duct. • With air inlet duct removed, check intake manifold runners.

[1]Items that are highlighted in blue are the most likely causes for the condition.

Mechanical Knocks

Cause	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect oil level (high/low) and quality (grade/viscosity/purity)	• Remove or add oil to correct level. • Drain and refill crankcase, if needed.
Mechanical System:	
Excessive oil clearance for crankshaft bearings	• Inspect crankshaft main and connecting rod bearing oil clearance.
Damaged crankshaft bearings	• Inspect main and connecting rod bearings for excessive wear.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Loose engine mounts	• Check tightness of mounting fasteners. • Check flexible parts for wear or damage.
Loose clamps or brackets	• Check tightness of clamp and bracket fasteners.
Fluid or debris in cylinder(s)	• Remove fluid and inspect the following: - Cooling system (cylinder head passages and gasket) - Fuel injection nozzle(s) • Remove debris and inspect the following: - Turbocharger compressor wheel - Glow plug(s)

Fuel Knocks (Combustion Noise)

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation:	
Incorrect fuel quality (heating energy/purity)	• Check specific gravity of fuel (see page 7-66). • Inspect and clean fuel tank, if needed (see page 7-63).
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Incorrect fuel return from injection pump	• Perform fuel return system check (see page 7-76).
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Excessive Engine Vibration

Cause[1]	Correction/Further Diagnosis
Mechanical System:	
Worn camshaft lobes	• Perform compression test (see page 2-39). • Perform camshaft lobe lift check (see page 2-41). • Inspect camshaft, if needed.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Incorrect camshaft or injection pump timing	• Perform compression test (see page 2-39). • Remove engine front cover and inspect sprockets, chain and gears, if needed (see page 2-42).
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.
Faulty torsional damper	• Inspect damper for misaligned inner hub and outer ring.
Incorrect flexplate/torque converter balance	• Inspect flexplate for missing balance weights.
Loose engine mounts	• Check tightness of mounting fasteners. • Check flexible parts for wear or damage.
Loose clamps or brackets	• Check tightness of clamp and bracket fasteners.
Fuel System:	
Incorrect fuel supply to injection pump	• Perform fuel supply check (see page 7-68).
Leaking fuel injection lines	• Repair or replace leaking lines.
Faulty fuel injection nozzles	• Perform nozzle tests (see page 7-60).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Seized Engine Component

Cause	Correction/Further Diagnosis
Mechanical System:	
Damaged crankshaft bearings	• Inspect main and connecting rod bearings for excessive wear.
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Faulty cylinder combustion area (leaking head gasket, cracked passages)	• Perform compression test (see page 2-39). • Remove cylinder head(s) and inspect sealing surfaces and passages.
Fluid or debris in cylinder(s)	• Remove fluid and inspect the following: - Cooling system (cylinder head passages and gasket) - Fuel injection nozzle(s) • Remove debris and inspect the following: - Turbocharger compressor wheel - Glow plug(s)

Low Cylinder Compression

Cause	Correction/Further Diagnosis
Mechanical System:	
Worn cylinder case bores, pistons or rings	• Perform compression test (see page 2-39). • Follow procedure for unsticking piston rings (see page 2-40). • Inspect cylinder case and pistons, if needed.
Worn or damaged valve train parts (lifters, push rods, rocker arms, valves)	• Perform compression test (see page 2-39). • Inspect valve train parts, if needed.
Faulty cylinder combustion area (leaking head gasket, missing pre-chamber)	• Perform compression test (see page 2-39). • Check for missing pre-chambers. • Remove cylinder head(s) and inspect sealing surfaces.

SERVICE FUEL FILTER Lamp Is On

Cause[1]	Correction/Further Diagnosis
Maintenance and Operation: Incorrect fuel quality (water in fuel)	• Inspect and clean fuel tank, if needed (see page 7-63).
Electrical Systems: Faulty WIF sensor operation	• Perform WIF sensor diagnosis (see page 7-20).

[1]Items that are highlighted in blue are the most likely causes for the condition.

9. Diagnosis

Glow Plug Failure (All 8)

Cause[1]	Correction/Further Diagnosis
Electrical Systems:	
Incorrect mounting for glow plug controller/relay	• Inspect controller/relay mounting for good heat transfer from left cylinder head.
Open feedback circuit between glow plug harness and controller/relay	• Perform glow plug system diagnosis (see page 8-20).
Faulty glow plug controller/relay	• Perform glow plug system diagnosis (see page 8-20).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Glow Plug Failure (Less Than 8)

Cause[1]	Correction/Further Diagnosis
Fuel System:	
Incorrect injection pump static timing	• Align static timing marks.
Incorrect HPCA solenoid operation	• Perform HPCA solenoid diagnosis (see page 7-90).
Incorrect automatic advance mechanism operation	• Perform automatic advance mechanism check (see page 7-81).

[1]Items that are highlighted in blue are the most likely causes for the condition.

Glow Plugs and Lamp Inoperative (Relay Cycles)

Cause	Correction/Further Diagnosis
Electrical Systems:	
Open circuit from junction block to glow plug controller/relay	• Perform glow plug system diagnosis (see page 8-20).
Open circuit from glow plug controller/relay to glow plugs and lamp	• Perform glow plug system diagnosis (see page 8-20).
Faulty glow plug controller/relay	• Perform glow plug system diagnosis (see page 8-20).

Glow Plug System and Lamp Do Not Work

Cause	Correction/Further Diagnosis
Electrical Systems:	
Open circuit from GAGES fuse to glow plug controller/relay	• Perform glow plug system diagnosis (see page 8-20).
Open ground circuit from glow plug controller/relay to vehicle cowl	• Perform glow plug system diagnosis (see page 8-20).
Faulty glow plug controller/relay	• Perform glow plug system diagnosis (see page 8-20).

NOTES

10. Reference

Common Service Parts

Item	Specification
FLUIDS	
Engine Oil	API SG/CE grade, SAE 10W-30, 15W-40 or 30 viscosity rating (see page 1-9 for more information)
Engine Coolant	50/50 mix of water and coolant meeting GM 1899 M specification (GM P/N 1052103 or equivalent)
FILTERS	
Engine oil filter	GM P/N 6438384 (AC P/N PF-35) or equivalent
Engine air filter	GM P/N 25042562 (AC P/N A917C) or equivalent
Fuel filter	GM P/N 10154635 or equivalent
REPLACEMENT PARTS	
Accessory Drive Belt	GM P/N 22518599, for applications without A/C
	GM P/N 14102104, for applications with A/C
Crankcase Depression Regulator Valve	GM P/N 25098666
Fuel Heater	GM P/N 12511964
WIF Sensor	GM P/N 12511965
Fuel Lift Pump	GM P/N 25115224
Lift Pump Relay	GM P/N 14089936
Fuel Injection Nozzle	GM P/N 10183974
Nozzle Return Hose	GM P/N 9438315
Nozzle Return Hose Clamp	GM P/N 12338007
Nozzle Return Fitting Cap	GM P/N 14066301
Glow Plug	GM P/N 5613738 (AC P/N 9G)
Glow Plug Controller/Relay	GM P/N 12088520
Thermostat	GM P/N 10154622
Engine Block Heater	GM P/N 10154624
Cylinder Head Gasket	GM P/N 14098623
Cylinder Head Bolt	GM P/N 14077193 (17 bolts per cylinder head)
Crankshaft Front Seal	GM P/N 23500286
Crankshaft Rear Seal	GM P/N 23503969
SEALANTS	
RTV Sealant	GM P/N 1052915 or equivalent
Anaerobic Sealant	GM P/N 1052942 or equivalent
Thread Sealant with TEFLON	GM P/N 1052080 or equivalent
Thread Locking Compound	GM P/N 12345382 (Loctite #242)

Engine Specifications

General Data

Type	90-degree V8 diesel with turbocharger	
Displacement	6.5L	396 in.^{3}
RPO	L65	
Bore	103 mm	4.055 in.
Stroke	97 mm	3.818 in.
Compression Ratio	21.0 to 1	
Firing Order	1-8-7-2-6-5-4-3	
Oil Pressure (at idle, hot)	69 kPa	10 psi
Oil Pressure (at 2,000 RPM)	276 to 310 kPa	40-45 psi

Cylinder Bore

Diameter	102.974 to 103.000 mm	4.0541 to 4.0552 in.
Out-of-Round Limit	0.02 mm	0.0008 in.
Taper Limit (Thrust Side)	0.02 mm	0.0008 in.

Piston

Clearance (Bores 1 to 6)	0.089 to 0.115 mm	0.0035 to 0.0045 in.
Clearance (Bores 7 and 8)	0.102 to 0.128 mm	0.004 to 0.005 in.

Piston Ring

Top Compression Ring:		
Ring Side Clearance	0.076 to 0.178 mm	0.003 to 0.007 in.
Ring End Gap	0.26 to 0.51 mm	0.010 to 0.020 in.
2nd Compression Ring:		
Ring Side Clearance	0.75 to 1.00 mm	0.030 to 0.039 in.
Ring End Gap	0.75 to 1.00 mm	0.030 to 0.039 in.
Oil Control Ring:		
Ring Side Clearance	0.040 to 0.096 mm	0.0016 to 0.0038 in.
Ring End Gap	0.25 to 0.60 mm	0.0098 to 0.0236 in.

Piston Pin

Diameter	30.9961 to 31.0039 mm	1.2203 to 1.2206 in.
Clearance	0.0081 to 0.0309 mm	0.0003 to 0.0012 in.
Fit in rod	0.0081 to 0.0309 mm	0.0003 to 0.0012 in.

Crankshaft

Main Journal:		
Diameter (#1 to #4)	74.917 to 74.941 mm	2.9494 to 2.9504 in.
Diameter (#5)	74.912 to 74.936 mm	2.9492 to 2.9502 in.
Taper Limit	0.005 mm	0.0002 in.
Out-of-Round Limit	0.005 mm	0.0002 in.
Main Bearing Clearance:		
#1 to #4	0.045 to 0.083 mm	0.0018 to 0.0033 in.
#5	0.055 to 0.093 mm	0.0022 to 0.0037 in.
Crankshaft End-Play	0.10 to 0.25 mm	0.0039 to 0.0098 in.

Crankshaft (continued)

Crankpin:		
Diameter	60.913 to 60.939 mm	2.3981 to 2.3992 in.
Taper Limit	0.005 mm	0.0002 in.
Out-of-Round Limit	0.005 mm	0.0002 in.
Rod Bearing Clearance	0.045 to 0.100 mm	0.0018 to 0.0039 in.
Rod Side Clearance	0.17 to 0.63 mm	0.0067 to 0.0248 in.

Camshaft

Lobe lift (± 0.05 mm):		
Intake	7.133 mm	0.281 in.
Exhaust	7.133 mm	0.281 in.
Journal Diameter:		
#1 to #4	54.975 to 55.025 mm	2.1643 to 2.1663 in.
#5	54.975 to 51.025 mm	2.1643 to 2.0089 in.
Journal Clearance	0.026 to 0.101 mm	0.0010 to 0.0040 in.
Camshaft End-Play	0.051 to 0.305 mm	0.0020 to 0.0120 in.

Valve System

Lifter Type	Hydraulic Roller	
Rocker Arm Ratio	1.5 to 1	
Valve Lash	Not Adjustable	
Face Angle	45 degrees	
Seat Angle	46 degrees	
Seat Runout Limit	0.05 mm	0.002 in.
Seat Width:		
Intake	0.89 to 1.53 mm	0.035 to 0.060 in.
Exhaust	1.57 to 2.36 mm	0.062 to 0.093 in.
Stem Clearance:		
Intake	0.026 to 0.069 mm	0.0010 to 0.0027 in.
Exhaust	0.026 to 0.069 mm	0.0010 to 0.0027 in.
Valve Spring:		
Pressure (Closed)	356 N at 46.0 mm	392 pounds at 1.81 in.
Pressure (Open)	1025 N at 35.3 mm	1130 pounds at 1.39 in.
Installed Height	46 mm	1.81 in.
Timing Chain Free-Play:		
New	12.7 mm	0.500 in.
Used	20.3 mm	0.800 in.
Hydraulic Lifter Diameter	23.39 to 23.41 mm	0.921 to 0.9217 in.
Lifter Bore Diameter	23.45 to 23.47 mm	0.923 to 0.924 in.
Lifter to Bore Clearance Limit	0.11 mm	0.0043 in.

Cylinder Head

Head/Case Deck Warpage Limits:		
Overall Length	0.15 mm	0.006 in.
Transverse Width	0.08 mm	0.003 in.
Pre-Combustion Chamber Fit Limits:		
Protrusion From Deck Surface	0.051 mm	0.002 in.
Recession Into Deck Surface	0 mm	0 in.

Torque Specifications

Fastener	Torque N·m	Lb-Ft
Converter housing	34-48	25-35
Camshaft sprocket bolt (pump drive gear)	75-90	55-66
Camshaft thrust plate	18-27	13-20
Connecting rod nuts	60-70	44-52
Crankshaft pulley bolts	34-48	25-35
Cylinder head bolts (torque angle method)	see page 2-20	
Cylinder head temperature switch	19-27	13-20
Cylinder head coolant passage plate bolts/studs	34-50	25-37
Exhaust manifold bolts/studs	25-35	18-26
Front cover to block bolts	34-50	25-37
Fuel filter mounting bolts	34-50	25-37
Fuel injection pump bracket bolts	18-27	13-20
Fuel injection driven gear bolts	18-27	13-20
Fuel injection pump mounting nuts	34-50	25-37
Fuel return line bracket nuts	18-27	13-20
Fuel injection line fitting nuts (at pump)	24-36	18-27
Fuel injection line fitting nuts (at nozzles)	27-39	19-29
Fuel supply line fittings at lift pump	24-26	17-19
Flexplate mounting bolts	80-95	60-70
Glow plugs	11-16	8-12
Glow plug controller/relay mounting nuts	18-27	13-20
Fast idle/cold advance temperature switch	10-12	7-9

Fastener	Torque N·m	Torque Lb-Ft
Intake manifold bolts/studs	34-50	25-37
Lifting bracket bolts/studs	45-60	33-44
Main bearing cap bolts (inner)	141-160	104-118
Main bearing cap bolts (outer)	126-145	93-107
Nozzles	60-80	44-60
Oil fill tube nuts	18-27	13-20
Oil pan bolts (except two at rear)	6-14	4-10
Oil pan rear bolts	18-27	13-20
Oil pump drive clamp bolt	34-50	25-37
Oil pump mounting bolt	80-100	60-74
Rocker arm cover bolts/studs	18-35	13-25
Rocker arm shaft bolts	50-60	37-44
Thermostat cover bolt/stud	34-50	25-37
Torsional damper bolt	270	200
TPS mounting bolts	5-7	4-5
Valve lifter guide clamp bolt	18-35	13-25
Water crossover mounting bolts/studs	34-50	25-37
Water pump to plate bolts	18-27	13-20
Water pump to front cover bolts/studs	18-27	13-20
Water pump/front cover to cylinder case bolts/studs	34-50	25-37
Turbocharger drain tube plate	6-10	4-7
Turbocharger mounting nuts	45-60	33-44

Special Tools

Tool Number[1]	Description
J 3936-03	Piston Ring Groove Cleaner
J 5345-4	Ring Gap Feeler Gauge
J 5347-B	Dial Bore Gauge (3 to 8 in.)
J 5830-02	Valve Guide Reamer Set
J 5902-01	Cylinder Hone
J 6098-01	Camshaft Bearing Remover and Installer
J 6098-10	Camshaft Bearing Remover/Installer Adapter Set
J 6125-1B	Slide Hammer
J 7049	Valve Guide Reamer Set
J 8037	Piston Ring Compressor
J 8056	Valve Spring Tester
J 8062	Valve Spring Compressor (Cylinder Head Removed)
J 8087	Cylinder Bore Checking Gauge
J 8089	Carbon Removing Brush
J 8101	Valve Guide Cleaner
J 8520	Valve Lobe Lift Indicator
J 22102	Front Cover Seal Installer
J 23059-01	Dial Bore Gauge Setting Master (3 to 8 in.)
J 23129	Front Cover Seal Remover
J 23523-E	Harmonic Balancer Remover and Installer
J 23738-A	Hand-Operated Vacuum Pump
J 24178	Fuel Tank Sending Unit Remover and Installer

[1]Special tools are available from Kent-Moore Tool Group, Sealed Power Corporation

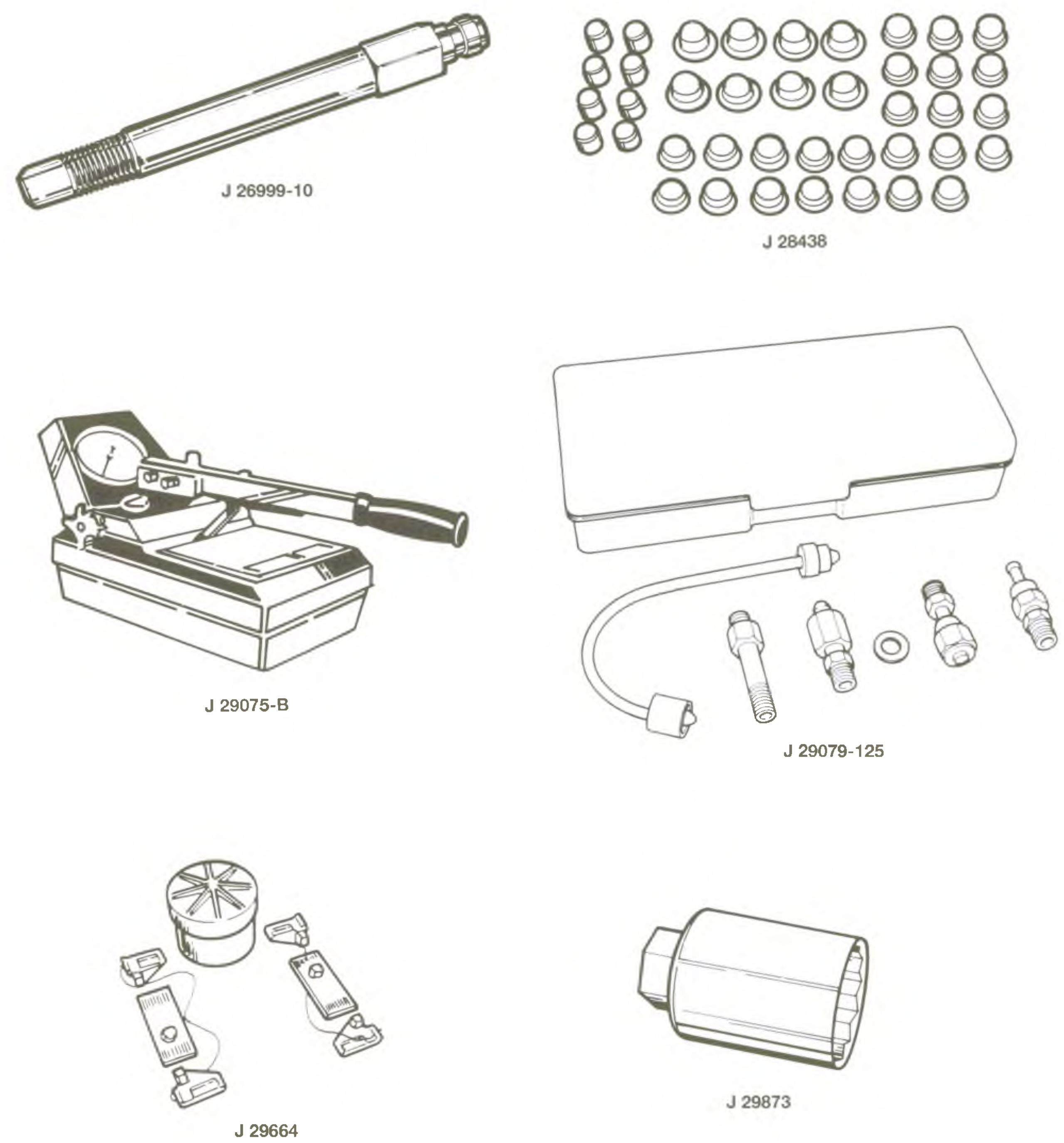
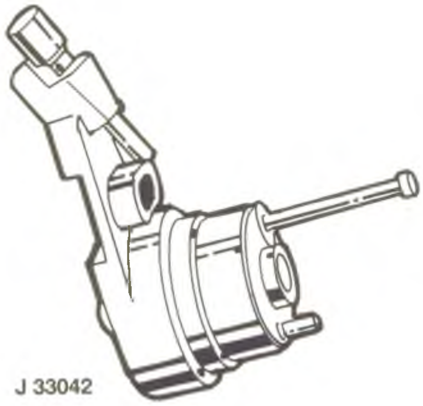


Figure 10-1, Special Tools (1)

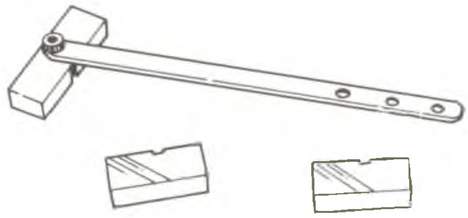
10. Reference

Tool Number[1]	Description
J 24270	Ridge Reamer (3 to 5 in.)
J 25087-C	Oil Pressure Tester and Pump Primer
J 25220	Piston Ring Expander
J 26400-1	Nozzle Test Oil
J 26513-A	Valve Spring Compressor (Cylinder Head Installed)
J 26925	Mag-Tac Engine Tachometer
J 26999-12	Compression Gauge
J 26999-10	Compression Gauge Adapter (see picture in Figure 10-1)
J 28428-B	High-Intensity Black Light
J 28438	Injection Pump Cap Plug Set (see picture in Figure 10-1)
J 28552	Pressure Gauge/Hose Assembly (0 to 15 psi)
J 29075-B	Nozzle Tester (see picture in Figure 10-1)
J 29079-125	Nozzle Tester Adapter Kit (see picture in Figure 10-1)
J 29134-A	Piston Pin Retaining Ring Installer
J 29664	Manifold Cover Set (see picture in Figure 10-1)
J 29666	Glow Plug Port Airline Adapter
J 29834	Hydraulic Valve Lifter Remover
J 29873	Nozzle Socket (see picture in Figure 10-1)
J 33042	Static Timing Gauge (see picture in Figure 10-2)
J 33043-2	TPS Gauge Block (0.646 and 0.668 thicknesses) – (see picture in Figure 10-2)
J 33300	Injection Timing Meter (see picture in Figure 10-2)
J 33333-B	Diesel Injection Pump Service Kit
J 33933	Diesel Mileage Tester (see picture in Figure 10-2)

[1]Special tools are available from Kent-Moore Tool Group, Sealed Power Corporation

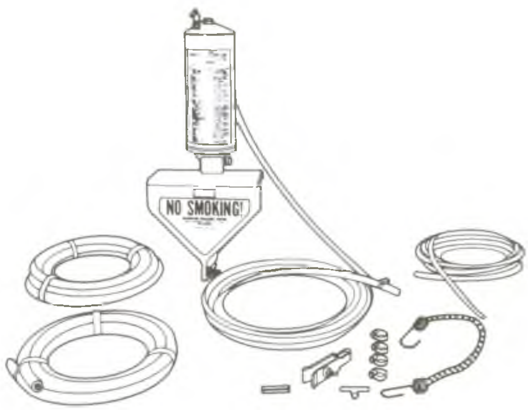


J 33042

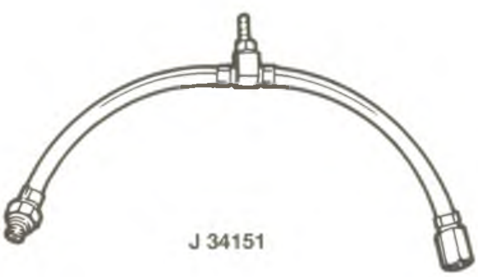


J 33043-2

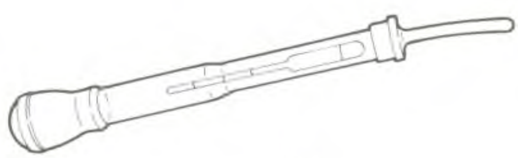
J 33300



J 33933



J 34151



J 34352

Figure 10-2, **Special Tools (2)**

10. Reference

Tool Number[1]	Description
J 34029-A	Digital Multimeter
J 34116	Cylinder Balance Tester
J 34151	Housing Pressure Adapter (see picture in Figure 10-2)
J 34352	Diesel Fuel Quality Tester (see picture in Figure 10-2)
J 39083	Glow Plug Connector Remover/Installer (see picture in Figure 10-3)
J 39084	Rear Main Seal Installer (see picture in Figure 10-3)
J 39307	Turbo Boost Gauge Adapter
MT 95	Timing Bracket Qualifier (Snap-On Tools Corp.)

[1]Special tools are available from Kent-Moore Tool Group, Sealed Power Corporation

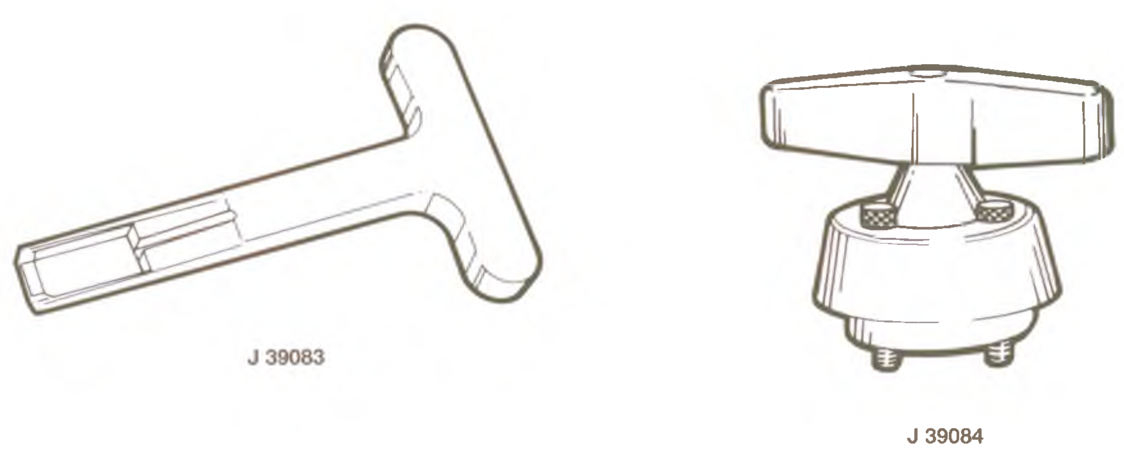


Figure 10-3, Special Tools (3)

External Engine Views

Figures 10-4 through 10-8 show reference views of the 6.5L V8 turbo diesel engine in complete assembly.

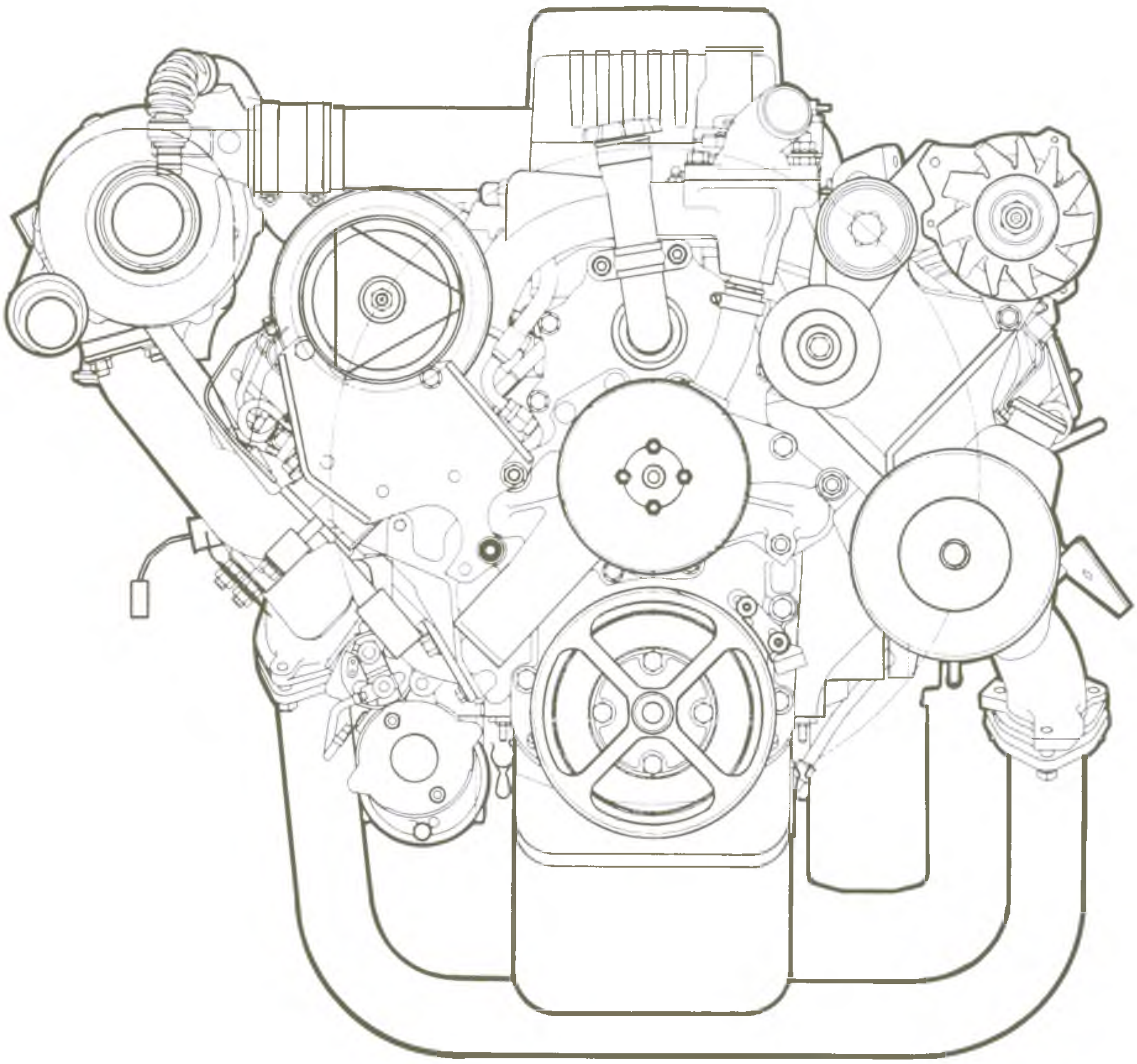


Figure 10-4, **6.5L V8 Turbo Diesel Engine – Front View**

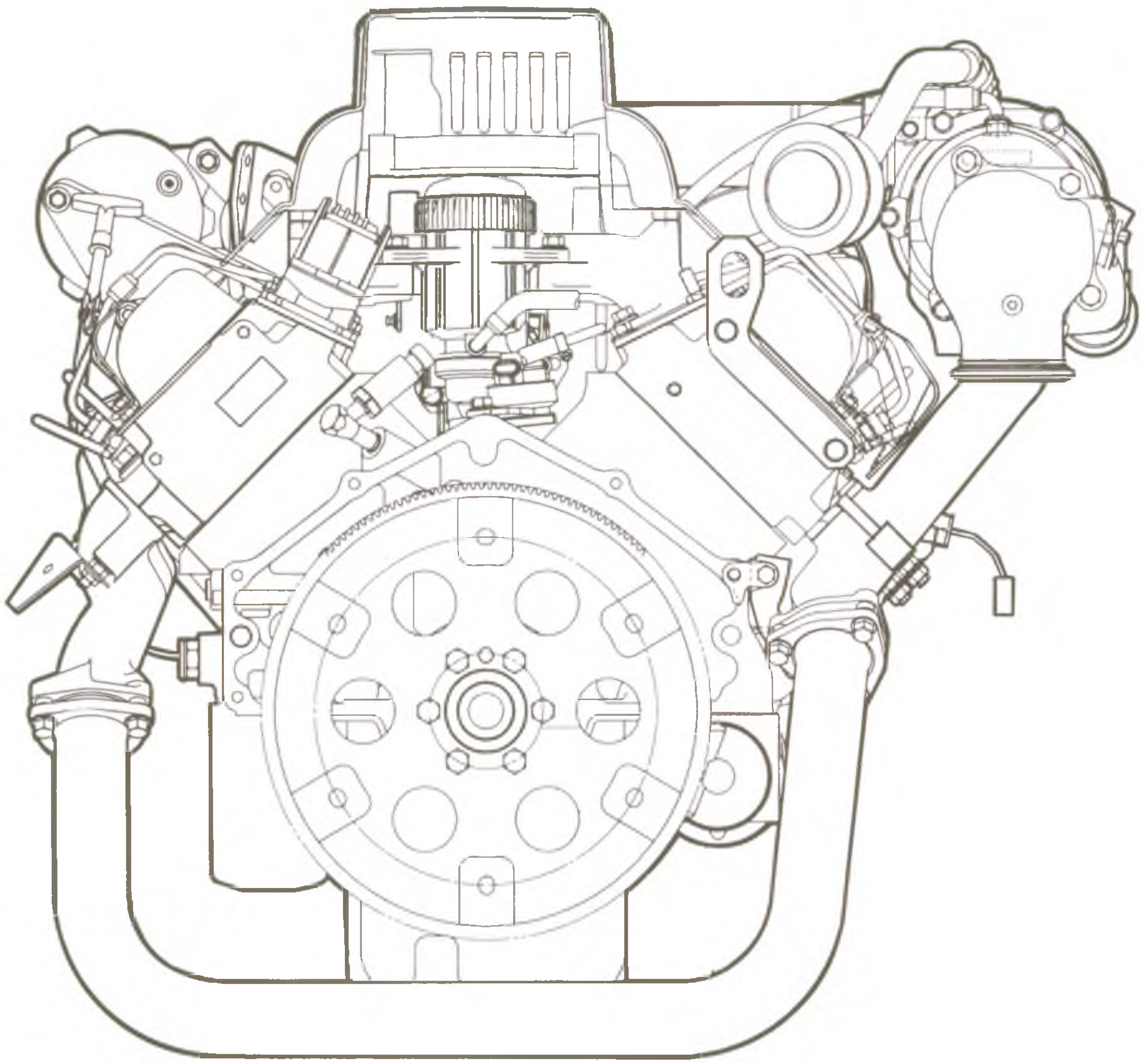


Figure 10-5, 6.5L V8 Turbo Diesel Engine – Rear View

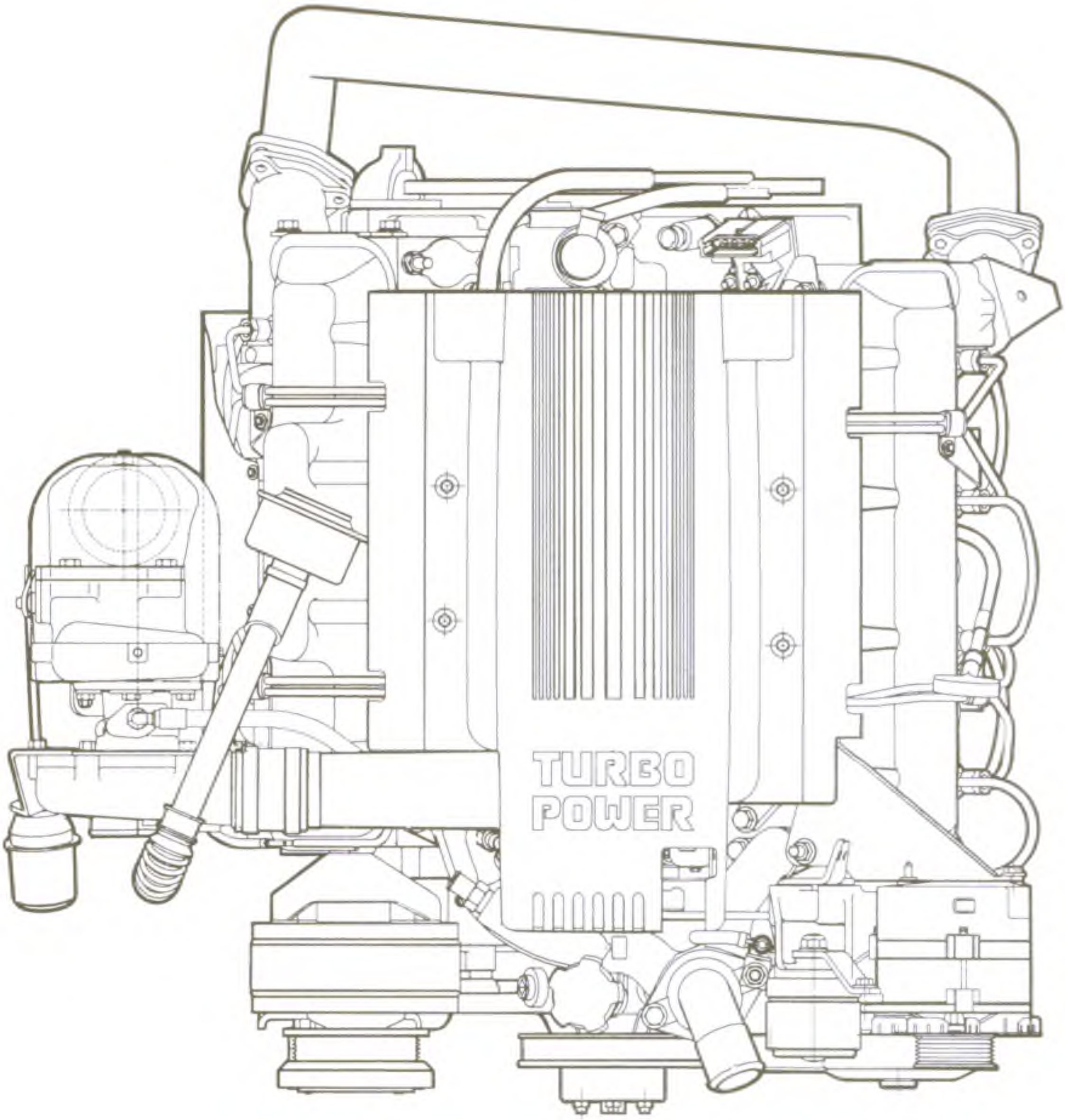


Figure 10-6, **6.5L V8 Turbo Diesel Engine – Top View**

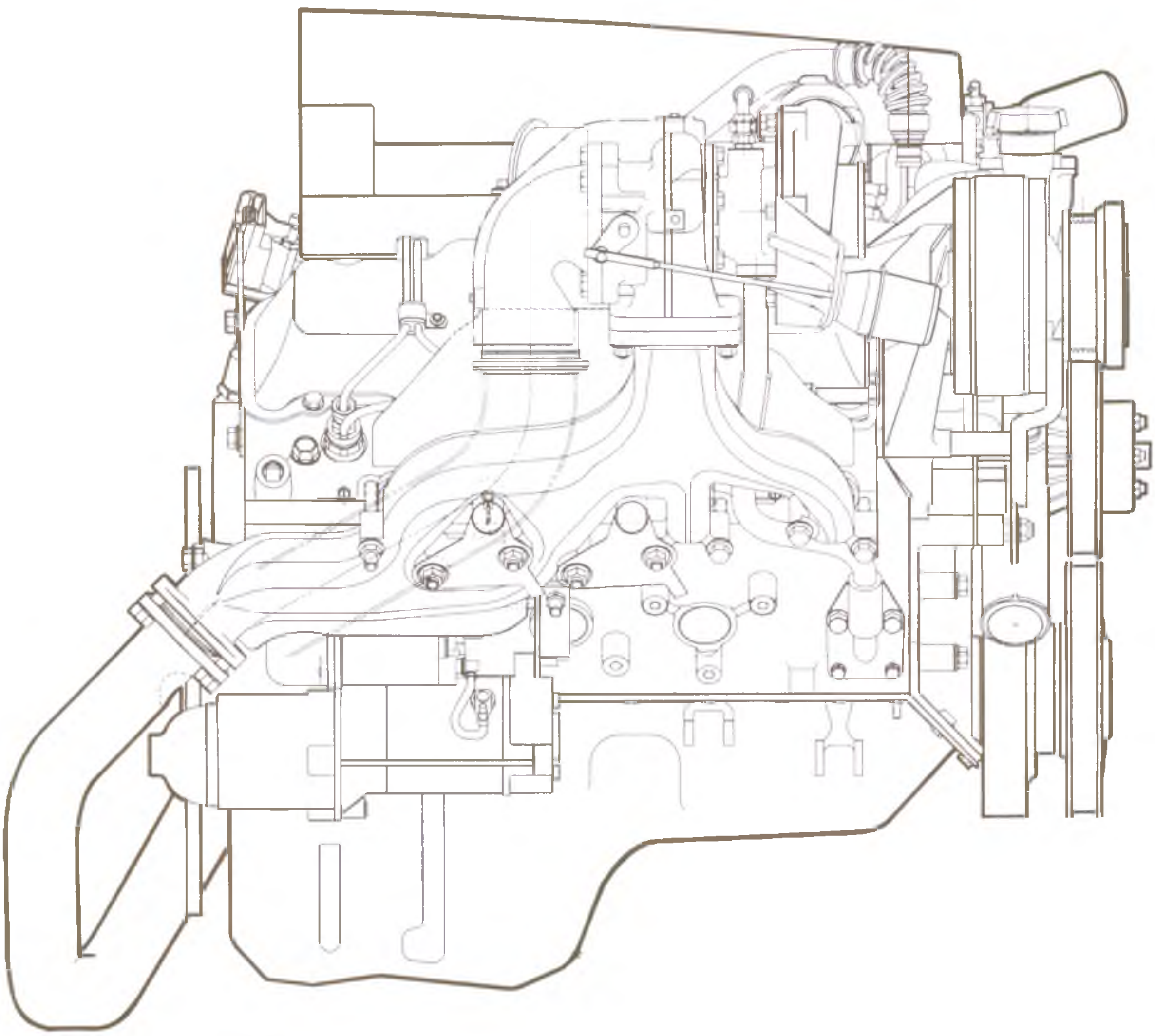


Figure 10-7, 6.5L V8 Turbo Diesel Engine – Right Side View

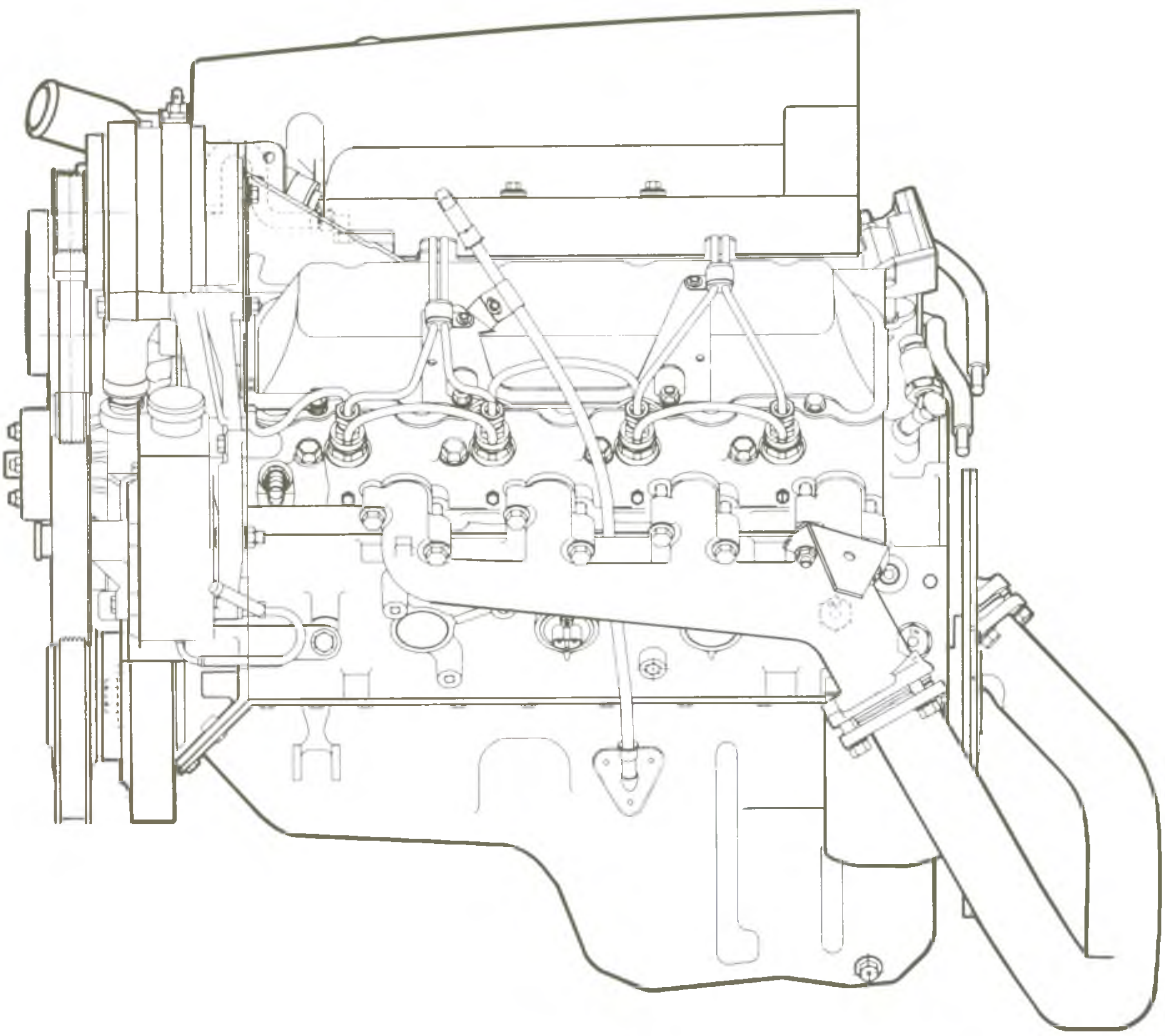
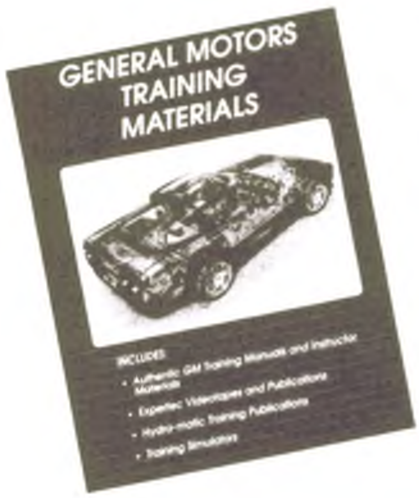


Figure 10-8, 6.5L V8 Turbo Diesel Engine – Left Side View

Bulletin History

Number	Date	Description

GENERAL MOTORS TRAINING MATERIALS



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