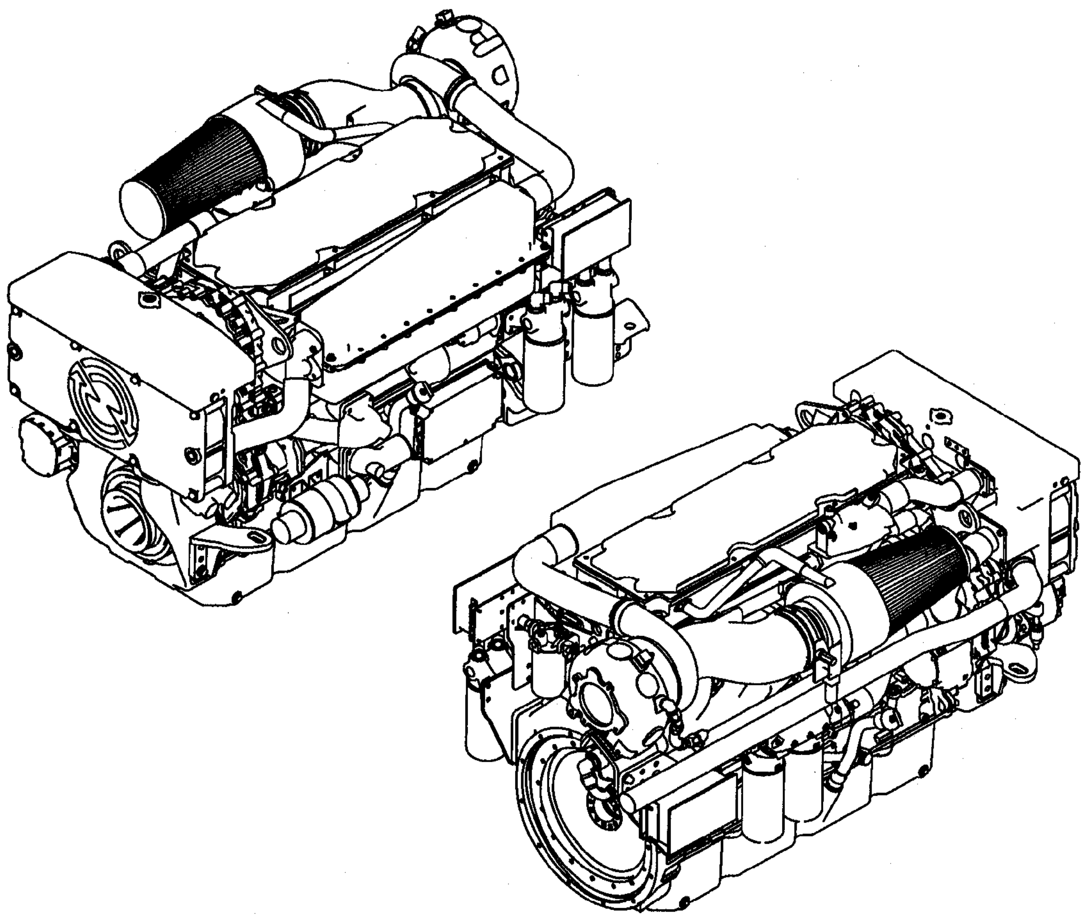
# TM 55-1945-222-14&P-2

TECHNICAL MANUAL

OPERATOR, UNIT, DIRECT SUPPORT AND
GENERAL SUPPORT MAINTENANCE MANUAL
FOR

## DIESEL ENGINE (DETROIT DIESEL)
## DDC MODEL 60 SERIES

NSN 2815-01-505-2025



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# IDENTIFYING TECHNICAL PUBLICATION SHEET
# FOR
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1. **PURPOSE**: This technical publication is issued to identify and authorize the following commercial manual for Army use.

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   PURCHASE ORDER OR CONTRACT NUMBER: DAAE 07-01-D-T026
   EQUIPMENT: Engine, Diesel, DDC Model 60 Series
   TITLE: Operator, Unit, Direct Support and General Support Maintenance Manual (Including Repair Parts and Special Tool List)
   DATE: 15 May 2004

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3. **FILE LOCATION**: The above described commercial manual is filed in ______________________________. (Each library will fill this in if this identifying technical publication sheet is filed separately from the commercial manual.)

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2. SUPPLEMENTARY INFORMATION. The information contained in the above identified commercial manual is supplemented as follows:
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   i. Maintenance Allocation Chart (MAC) Remarks.
   j. Maintenance Allocation Chart (MAC) Tools and Test Equipment.
   k. Repair Parts List.
   l. DA Form 2028.
   m. Metric Conversion Chart.

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 15 JUNE 2005

# TECHNICAL MANUAL

# OPERATOR, UNIT, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL FOR

# DIESEL ENGINE (DETROIT DIESEL) DDC MODEL 60 SERIES NSN 2815-01-505-2025

**REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS**

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TM 55-1945-222-14&P-3, consisting of: Table of Contents, Repair Parts and Special Tools Lists, Custom Parts Catalog, Drawings, and Supplemental Parts Data.

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**DELCO REMY CRANKING MOTORS 40-MT/400, 40-MT/450, AND 50-MT/400, VOL 2.**

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# MAINTENANCE MANUAL
# FOR
# DIESEL ENGINE (DETROIT DIESEL)

# 3 LUBRICATION SYSTEM

**Section** **Page**

## 3.1 OVERVIEW OF LUBRICATING SYSTEM

The lubrication system consists of the following components:

- ☐ Oil pump
- ☐ Pressure regulator valve
- ☐ Pressure relief valve
- ☐ Oil filters
- ☐ Oil filter adaptor
- ☐ Oil cooler
- ☐ Oil level dipstick
- ☐ Oil pan
- ☐ Ventilating system

A schematic of the lubricating system is shown in the following illustration. See Figure 3-1.

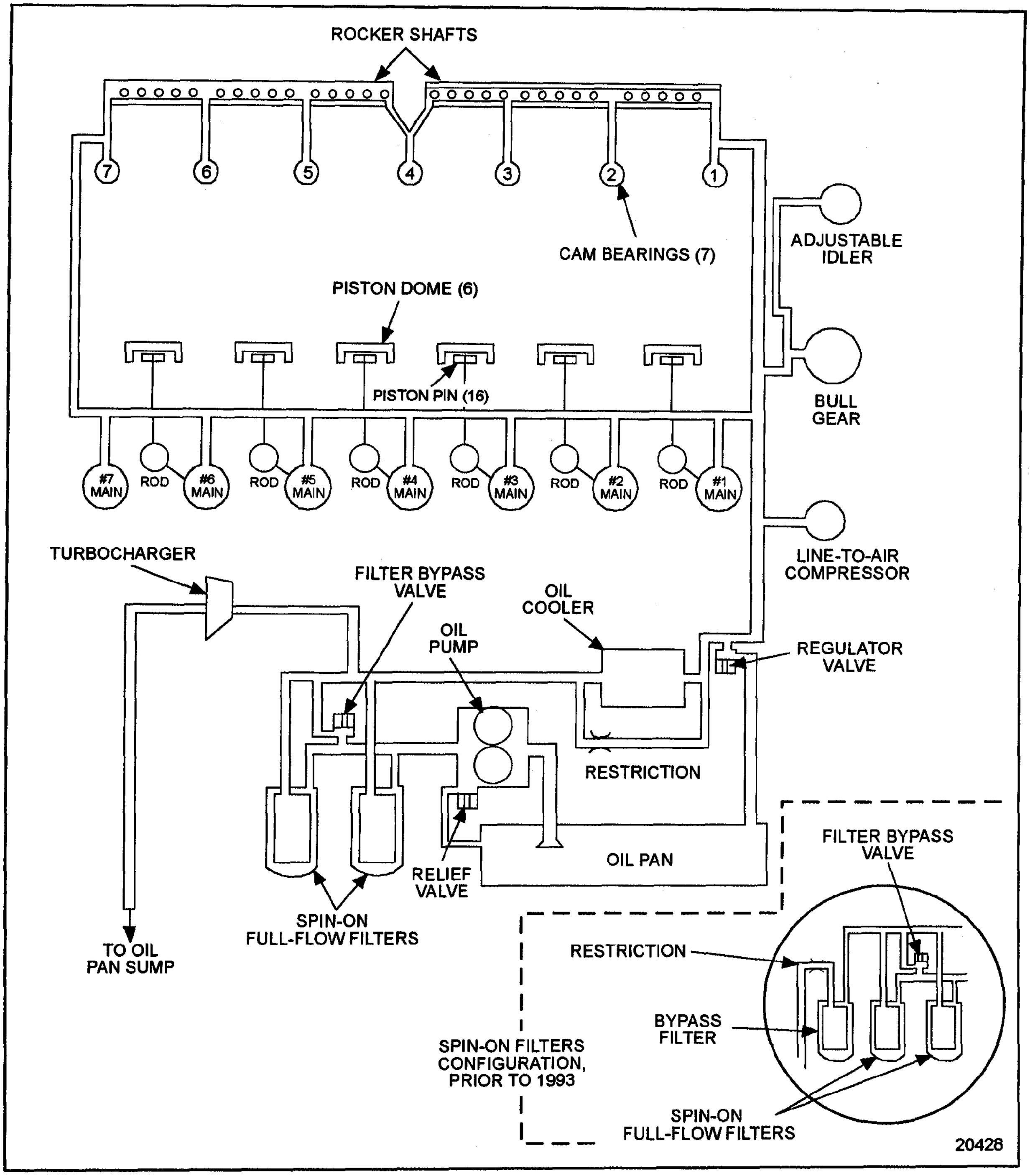



**Figure 3-1** **Schematic Diagram of Current Lubrication System**

Oil leaving the pump is forced through the full-flow filters to the oil cooler and bypass passage and then into the oil gallery in the cylinder block. From there the oil is distributed to the various engine bearings and moving parts. Prior to 1993, a bypass type, spin-on filter was used in addition to the two full-flow oil filters. A portion of the oil is continually fed through the bypass filter and returned to the engine oil pan. Drains from the cylinder head and other engine parts return oil back to the oil pan.

Oil from the cooler is directed to a longitudinal main oil gallery on the cooler side of the cylinder block. See Figure 3-1. This gallery distributes the pressurized oil to the main bearings and to a horizontal, transverse passage at each end of the cylinder block. From each of these two horizontal passages, oil flows into two vertical bores (one at each end of the cylinder block) to vertical passages in the cylinder head.

These passages in the cylinder head deliver oil from the cylinder block to the No. 1 and 7 lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 7 upper camshaft bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied goes to the rocker arm camshaft follower, roller pin and bushing.

The rocker is also drilled to supply oil to the valve adjusting screw, valve button, retainer clip, intake and exhaust valve stems and the fuel injector follower. The No. 4 camshaft cap is Y drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. The oil then drains through passages in the cylinder head and block, and back to the oil pan.

Oil for lubricating the connecting rod bearings, piston pins and for cooling the piston dome is provided through the drilled crankshaft from the adjacent forward main bearings.

Two holes in the bull gear recess area of the cylinder block are drilled into the cylinder block front-cross oil gallery, and supply oil to the bull gear bearings, bull gear and camshaft idler gear and hub. See Figure 3-2.

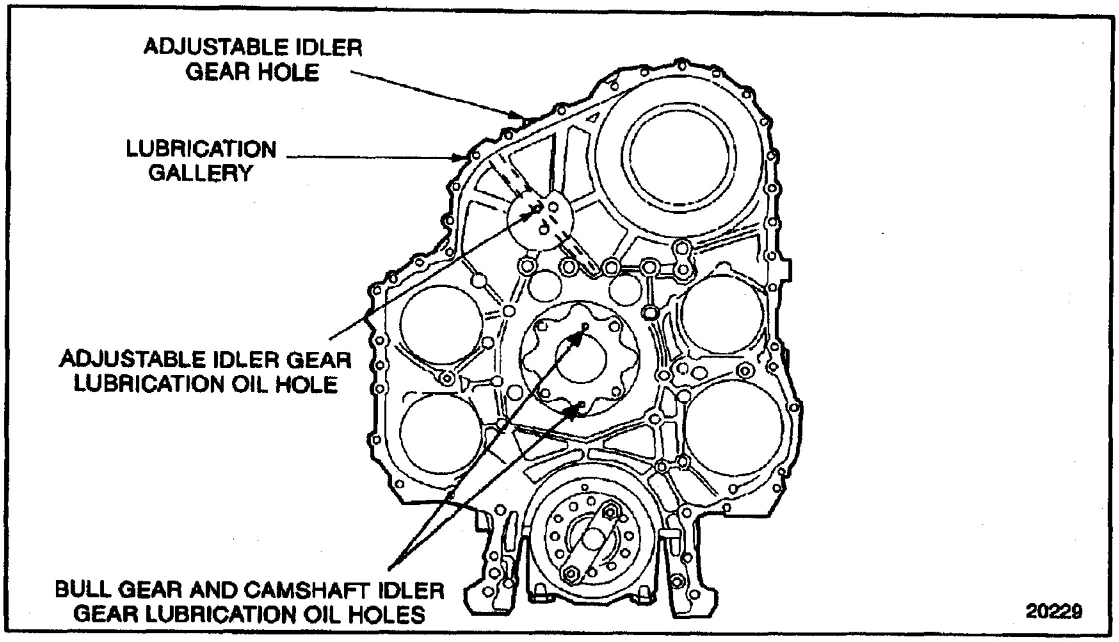



**Figure 3-2 Gear Train Oil Supply Holes**

Excess oil from the bull gear lubricates the crankshaft timing gear and oil pump drive gear. A hole at the top, front of the block, drilled into the block front-cross oil gallery, mates with an oil passage in the gear case that directs oil to the adjustable idler gear assembly. See Figure 3-2. Excess oil from the adjustable idler gear lubricates the accessory drive and water pump drive gears. The bearings and shafts of these two drive assemblies are splash-fed oil through holes in their housings.

A flexible, external oil line runs from a threaded hole at the top, front corner of the left side of the cylinder block, which is tapped into the main oil gallery. The flexible line runs to a fitting at the air compressor assembly.

Oil drains from the air compressor through a hole in the air compressor drive housing into the gear case.

**NOTE:**
On early Series 60 engines, there was a "T" fitting in the air compressor drive assembly. A flexible external oil line ran from the cylinder block to this "T" fitting and another line ran from the "T" fitting to the air compressor assembly.

A flexible, external oil line feeds oil from the oil filter adaptor housing pressure gallery to the turbocharger bearings and shaft. This oil is returned through an external line to the block near the block oil pan split line and then back to the oil pan.

Use the proper viscosity grade and type of heavy-duty oil. Refer to section 5.2.1.

Series 60 engines use red dye to detect lube oil system leaks during engine testing at the factory. Customers receiving new engines may notice some residual dye remaining in the lube oil systems. This dye should be quickly dispersed after the first few hours of engine operation, and will have no detrimental affect on the engine.

## 3.2 OIL PUMP

The gear-type oil pump is mounted to the cylinder block and is gear driven from the front end of the crankshaft. See Figure 3-3.

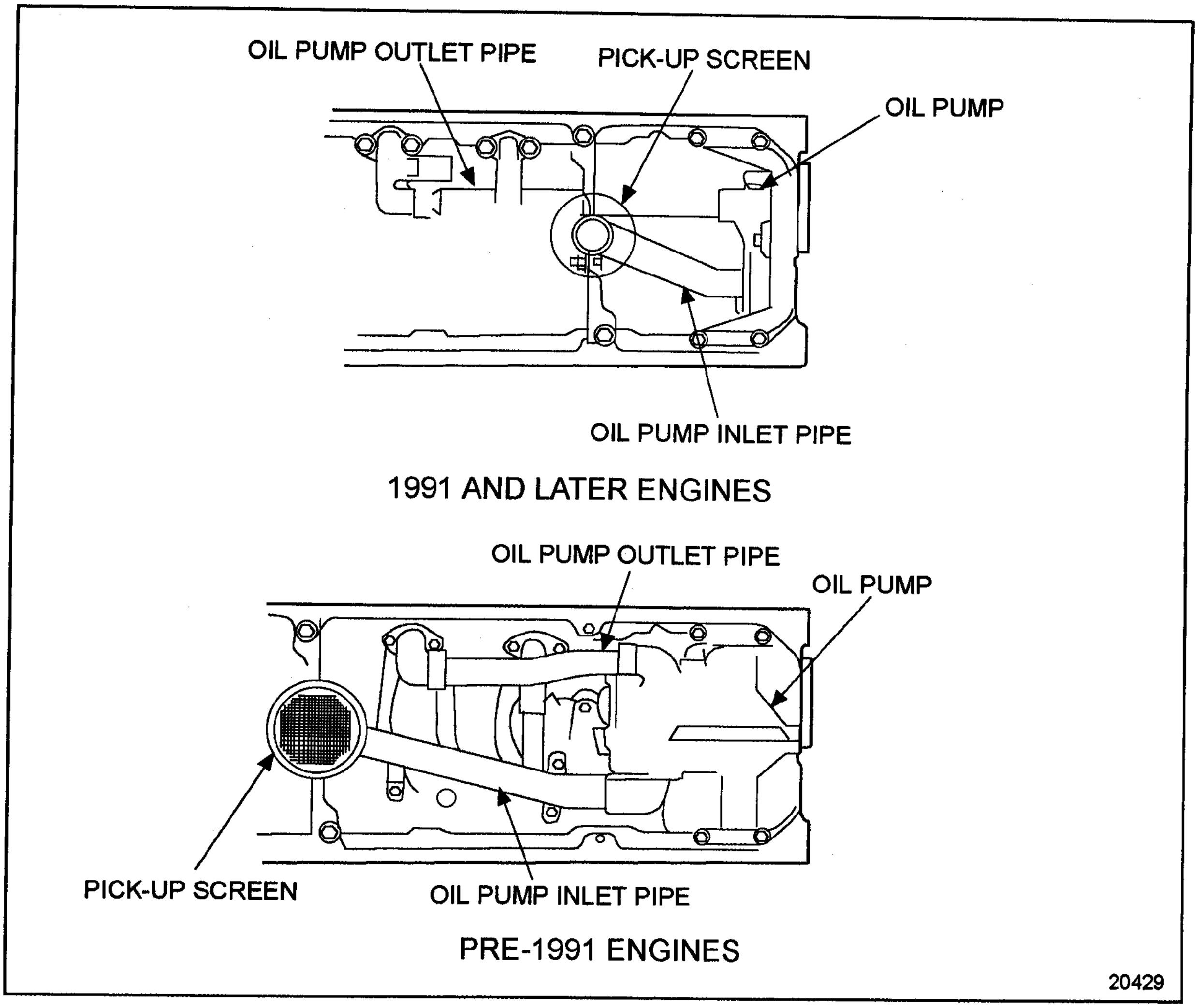
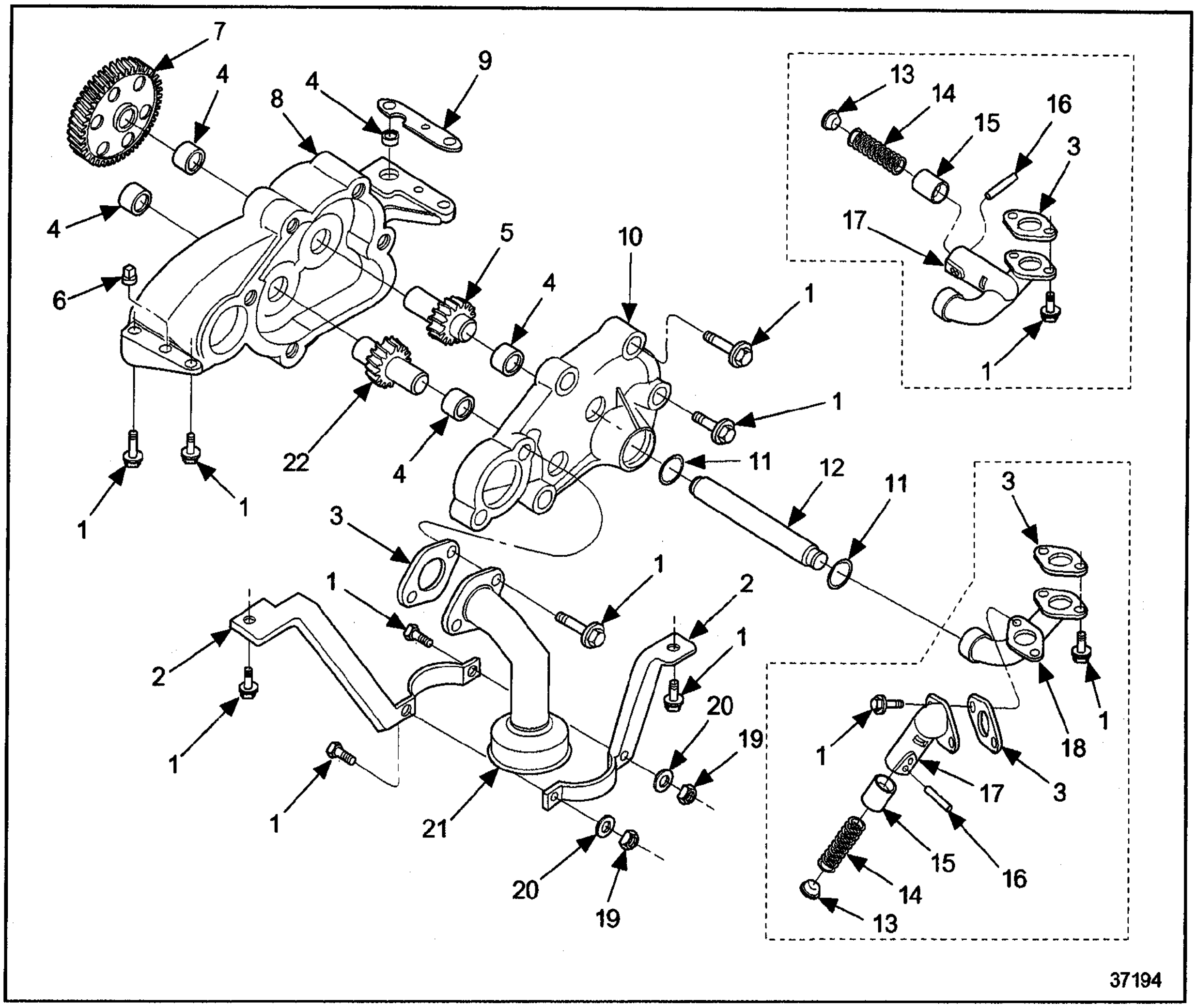



**Figure 3-3 Oil Pump Mounting**

Effective with 1991 model year engines, the design of the oil pump has been changed. The current oil pump is smaller, and contains a relief valve. See Figure 3-4. On both current and former design oil pumps, the helical gears rotate inside a housing. See Figure 3-5for the former oil pump.

The drive gear is pressed on the drive shaft, which is supported inside the housing on two bushings. The driven gear is pressed on the driven gear shaft, which is supported inside the housing on two bushings.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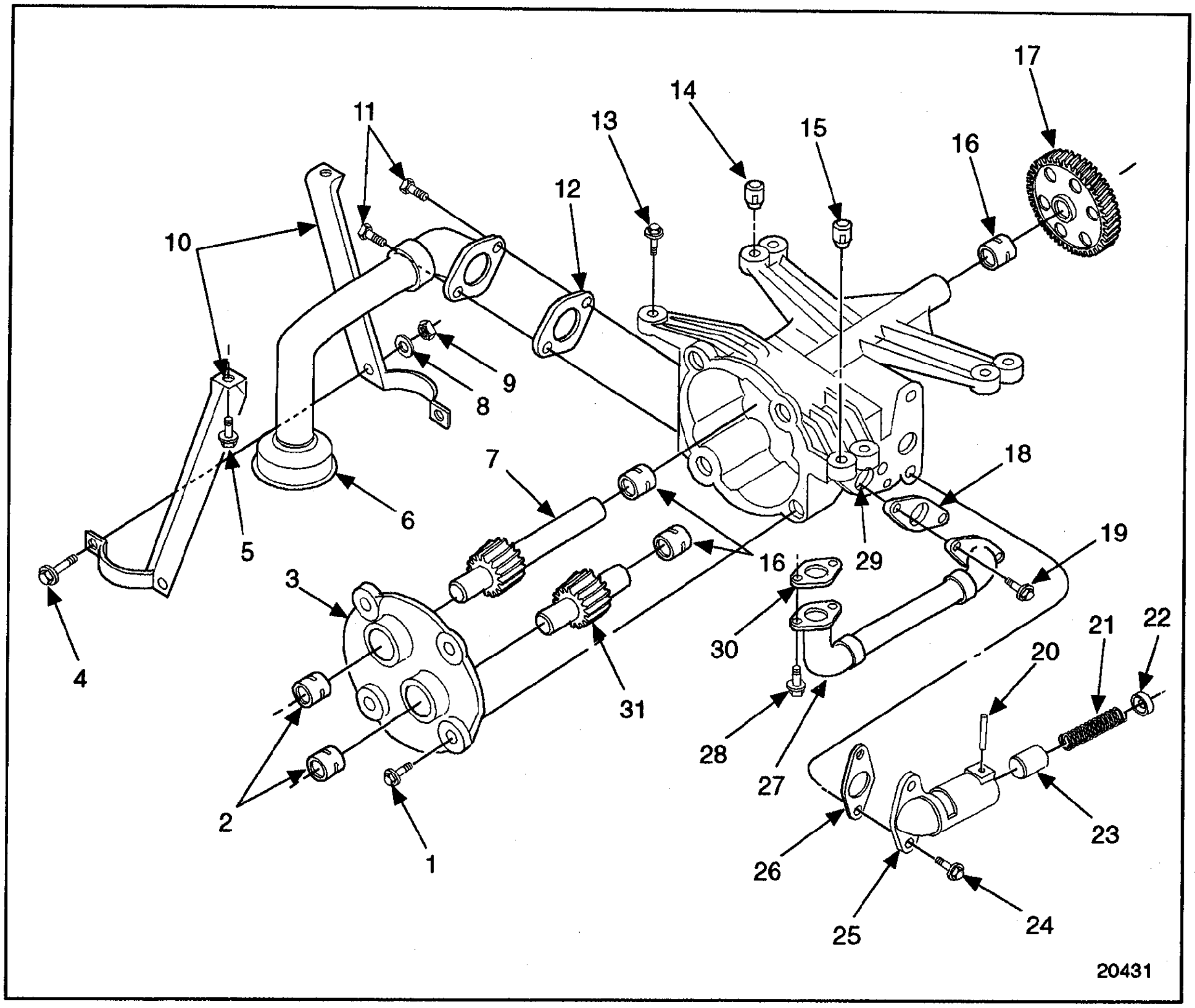
1. Bolt
2. Bracket
3. Gasket
4. Bushing
5. Drive Shaft and Gear Assembly
6. Dowel
7. Gear
8. Oil Pump Body
9. Shim
10. Oil Pump Housing Cover
11. Seal Ring
12. Oil Pump Outlet Tube
13. Spring Seat
14. Spring
15. Relief Valve
16. Pin
17. Relief Valve Housing
18. Oil Pump Outlet Elbow
19. Nut
20. Washer
21. Tube and Screen Assembly
22. Driven Shaft and Gear Assembly

**Figure 3-4 Lubricating Oil Pump and Parts - 1991 & Later Engines**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1. Bolt, Oil Pump Cover (4)
2. Bushing, Oil Pump Cover (2)
3. Cover, Oil Pump Housing
4. Bolt, Screen Bracket-to-Inlet Pipe (2)
5. Bolt, Inlet Pipe Bracket-to-Cylinder Block (2)
6. Pipe and Screen Assembly, Inlet
7. Drive Shaft and Gear Assembly
8. Washer, Screen Bracket-to-Inlet Pipe (2)
9. Nut, Screen Bracket-to-Inlet Pipe (2)
10. Bracket, Inlet Pipe (2)
11. Bolt, Inlet Pipe-to-Pump Body (2)
12. Gasket, Inlet Pipe-to-Pump
13. Bolt, Pump Body-to-Block
14. Dowel, Oil Pump Locating (Round)
15. Dowel, Oil Pump Locating (Diamond)
16. Bushing, Oil Pump Housing (3)
17. Gear, Oil Pump Drive
18. Gasket, Outlet Pipe-to-Oil Pump
19. Bolt, Outlet Pipe-to-Oil Pump Housing (2)
20. Pin, Retaining
21. Spring, Relief Valve
22. Spring, Seat
23. Valve, Relief
24. Bolt, Oil Relief Valve-to-Oil Pump Housing (2)
25. Body, Relief Valve
26. Gasket, Relief Valve-to-Oil Pump
27. Pipe, Outlet
28. Bolt, Outlet Pipe-to-Cylinder Block (2)
29. Body, Oil Pump
30. Gasket, Outlet Pipe-to-Cylinder Block
31. Driven Shaft and Gear Assembly

**Figure 3-5 Lubricating Oil Pump Parts (Pre-1991 Engines)**

An inlet pipe assembly, with screen, is attached to the inlet opening in the pump body. The screen end of the inlet pipe assembly is supported with brackets mounted to the cylinder block.

The inlet screen is located below the oil in the pan and serves to strain out any foreign material which might damage the pump.

### 3.2.1 Repair or Replacement of Oil Pump

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-6.

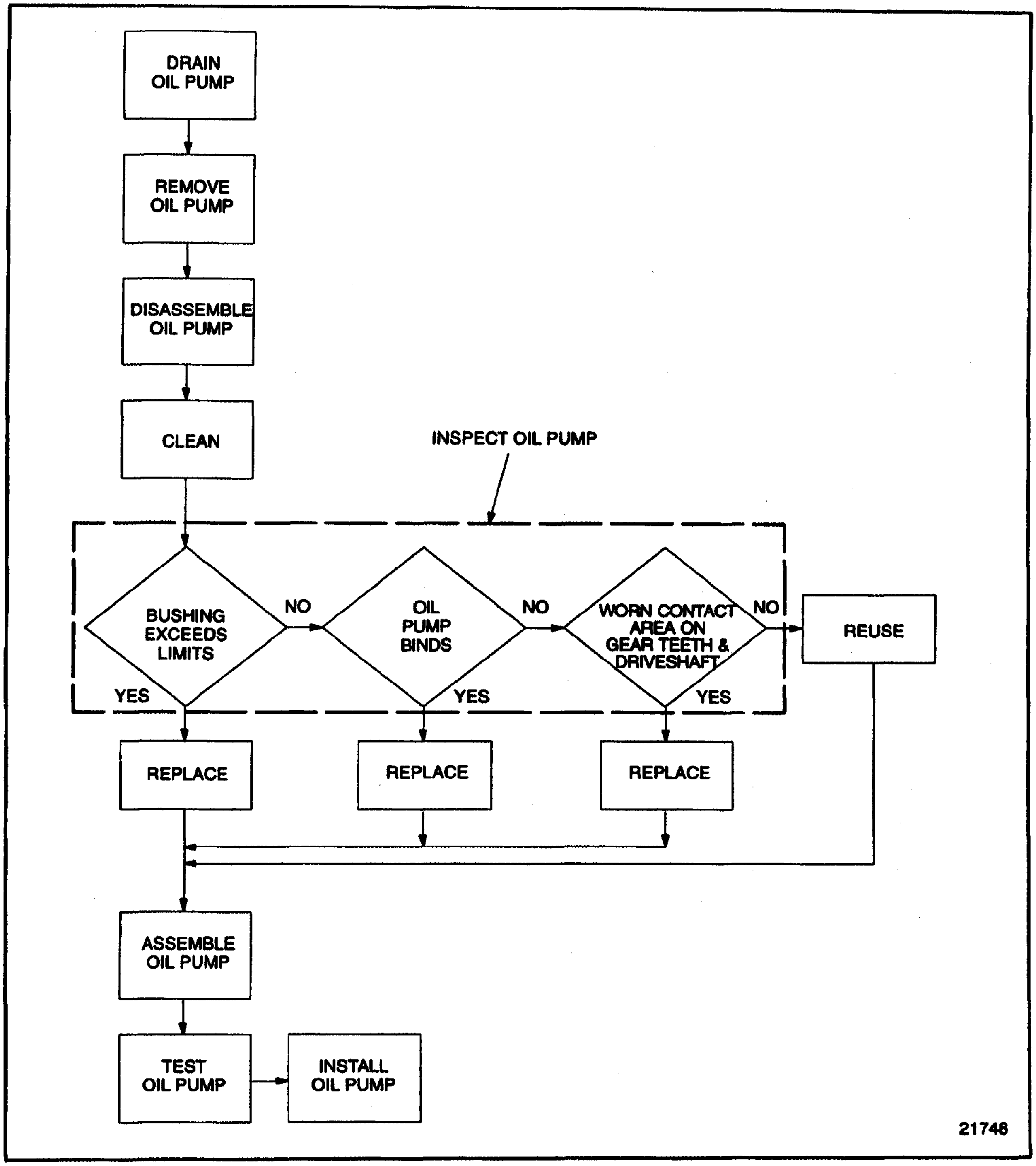



**Figure 3-6 Flowchart for Repair or Replacement of Oil Pump**

### 3.2.2 Removal of Oil Pump

Remove the oil pump as follows:

1. Remove the drain plug from the oil pan and drain the oil. Refer to section 13.13.1.
2. Remove the oil pan bolts, isolators, sleeves and washers, and oil pan. Refer to section 3.11.2.

| NOTICE: |
|---|
| The thru-bolts must be loosened first to prevent twisting the oil pick-up tube. Failure to do this could cause eventual stress-crack damage at the pick-up tube to flange joints. |

3. Loosen but do not remove the thru-bolts securing the oil pump bracket to the pick-up tube.
4. Remove the two bolts that secure the oil pump pick-up tube support bracket to the cylinder block.
5. Remove the two bolts securing the oil pump pick-up tube to the oil pump.
6. Tap the pick-up tube gently to loosen it from the gasket and remove the pipe.
7. Remove the two bolts securing the outlet pipe to the pump and cylinder block.
8. Tap the outlet pipe gently to loosen it from the gaskets and remove the pipe.

| NOTICE: |
|---|
| If removing the oil pump from the vehicle, loosen the bolts; but leave them in place to prevent the pump from falling, before the mechanic removes the oil pump. |

9. Remove the four bolts retaining the oil pump to the cylinder block.
10. If necessary, pry gently on the oil pump assembly to loosen it from the block.

**NOTE:**
Remove and save the shims, if used, between the oil pump mounting feet and the cylinder block. The shims are used to adjust the oil pump drive gear-to-crankshaft timing gear lash.

### 3.2.3 Disassembly of Oil Pump

Observe the position of all parts including the oil pick-up tube and outlet pipe during disassembly to facilitate reassembly of the pump.

Disassemble the oil pump as follows:

1. Remove the two bolts securing the oil pressure relief valve to the oil pump housing.
2. Tap the relief valve lightly to loosen it from the gasket and the oil pump housing (pre-1991 engines only).
3. Use a two-jaw puller to remove the oil pump drive gear from its shaft.
4. Remove the four oil pump cover bolts.
5. Remove the oil pump cover.
6. Remove the drive gear and shaft assembly, and the driven gear shaft and assembly from the oil pump housing.

#### 3.2.3.1 Inspection of Oil Pump

Inspect the oil pump as follows:

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

1. Wash all parts in clean fuel oil and dry them with compressed air.
2. Remove any gasket material from the oil pump housing at relief valve, inlet pipe and outlet pipe mating surfaces.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

3. Clean the outlet and inlet pipe and screen assembly in clean fuel oil and blow dry with compressed air.

4. Measure the bushing clearance in the pump body and cover.
   [a] If the shaft-to-pump cover bushing clearance exceeds 0.089 mm (0.0035 in.), replace bushing.
   [b] If the shaft-to-pump cover bushing clearance is within 0.089 mm (0.0035 in.), reuse the bushing.

| NOTICE: |
|---|
| The use of excessively worn gears will result in low engine oil pressure that, in turn, may lead to serious engine damage. |

5. Visually inspect the oil pump gear. Check to see if the gear turns freely in the pump housing.
   [a] If the gear binds, replace it with a new gear.
   [b] If the gear does not bind, reuse the gear.
6. Visually inspect gear teeth on drive shaft bushing contact areas. Check for worn contact areas on gear teeth and drive shaft.
   [a] If area is worn, replace gear and drive shaft with new parts.
   [b] If the area is not worn, reuse the parts.

### 3.2.4 Assembly of Oil Pump (1991 and Later Engines)

Assemble the oil pump as follows:

1. Lubricate the drive shaft bushing with clean engine oil.
2. Insert the drive shaft and gear assembly into the pump body. See Figure 3-4.
3. Position the oil pump assembly on a press, pump body down, supporting the drive shaft. The pump body should be free of the press bed supported by the pump gear contacting the bottom of the pump cavity.
4. Coat the bore of the drive gear with a light film of Lubriplate (or equivalent).
5. Position drive gear squarely on the end of the shaft.

6. Press the drive gear onto the shaft until a clearance of 1.00 mm (0.039 in.) is obtained between the inner face of the gear and the pump body. See Figure 3-7.

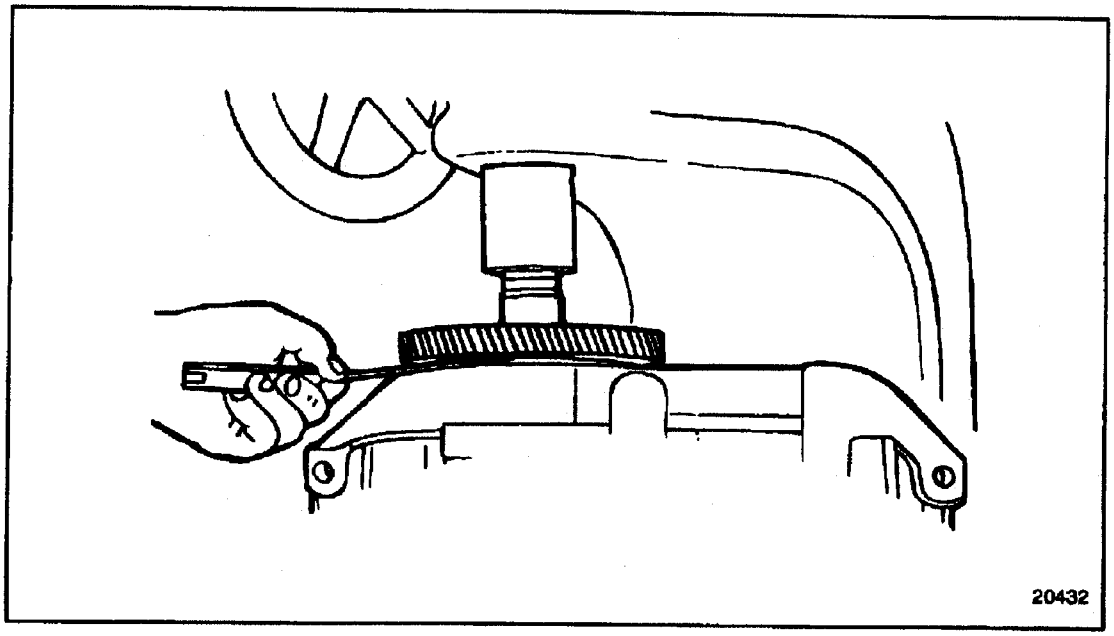



**Figure 3-7 Oil Pump Drive Gear Installation**

**NOTE:**
A minimum press load of 6.7 kN (1,515 lb) must be obtained when pressing the gear onto the shaft. When completed, an end play of 0.84-1.12 mm (0.033-0.044 in.) must be obtained.

7. Lightly coat the driven gear bushing with clean engine oil.
8. Insert the drive shaft and gear assembly into the pump body. See Figure 3-4.
9. Lightly coat both bushings in the pump cover with clean engine oil.
10. Index them with the shafts.
11. Install the four cover bolts and hand-tighten.
12. Rotate the oil pump by hand. The oil pump must turn freely without binding.

| NOTICE: |
|---|
| The cause of oil pump binding must be corrected before installation is complete or severe engine damage may result. |

13. If binding occurs, stop assembly and disassemble until the cause can be detected and corrected. Refer to section 3.2.3.
14. Torque the four cover bolts to 30-38 N·m (22-28 lb·ft).

## 3.2.5 Assembly of Oil Pump (Pre-1991 Engines)

Assemble the oil pump as follows:

1. Lightly coat the drive shaft bushings with clean engine oil. See Figure 3-7.
2. Insert the drive shaft and gear assembly into the pump body.
3. Position the oil pump assembly on a press, pump body down, supporting the drive shaft. The pump body should be free of the press bed supported by the pump gear contacting the bottom of the pump cavity.
4. Coat the bore of the drive gear with a light film of Lubriplate (or equivalent).
5. Position drive gear squarely on the end of the shaft.
6. Press the drive shaft until a clearance of 0.38 mm (0.015 in.) is obtained between the inner face of the gear and the pump body. See Figure 3-8.

**NOTE:**
**A minimum press load of 8.9 kN (2,000 lb) must be obtained when pressing the gear on the shaft. When completed, an end play of 0.25-0.51 mm (0.010-0.020 in.) must be obtained.**

7. Lightly coat the driven gear shaft bushing with clean engine oil.
8. Insert the driven shaft and gear assembly into the pump body. See Figure 3-5.

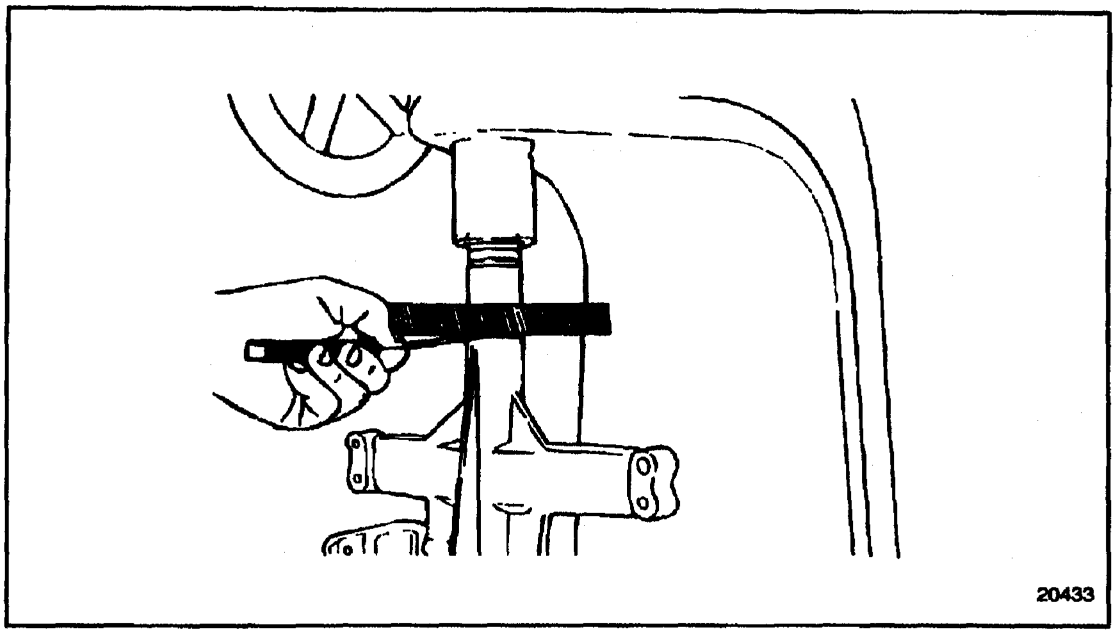



**Figure 3-8 Oil Pump Drive Gear Installation (Pre-1991 Engines)**

9. Lightly coat both bushings in the pump with clean engine oil.

10. Index them with the shafts.
11. Install the four cover bolts and hand-tighten.
12. Rotate the pump by hand. The oil pump must turn freely without binding.

| NOTICE: |
|---|
| The cause of oil pump binding must be corrected before installation is complete or severe engine damage may result. |

13. If binding occurs, stop assembly and disassemble until the cause can be detected and corrected. Refer to section 3.2.3.
14. Torque the four cover bolts 30-38 N·m (22-28 lb·ft).

### 3.2.5.1 Test Assembled Oil Pump

Test oil pump as follows:

1. Rotate the pump by hand. Check for binding.
   [a] If binding occurs, disassemble oil pump again, refer to section 3.2.3.
   [b] If no binding occurs, reuse the pump.
2. With a dial indicator mounted on the pump mounting surface, rotate the gear and check the gear run-out. The run-out specification is 0.08 mm (0.003 in.).
   [a] If run-out exceeds 0.08 mm (0.003 in.), disassemble oil pump. Refer to section 3.2.3.
   [b] If run-out is within specifications, reuse the pump.

### 3.2.6 Installation of Oil Pump

Install the oil pump to the cylinder block as follows:

| NOTICE: |
|---|
| If shims were used between the pump mounting feet and the engine block and a new drive gear was NOT installed, the same shims (cleaned) or the same number of new (identical) shims should be installed. If necessary, adjust shims to obtain the proper clearance between gear teeth. However, if a new drive gear has been installed, a different number of shims may be required under the mounting feet. In either case, the pump must be tightened to the cylinder block BEFORE the clearance between the gear teeth is measured. Gear lash measurements must be done with the engine in the upright position. |

1. Position the oil pump on the cylinder block so that the drive gear of the oil pump meshes with the crankshaft drive gear. The two dowels in the oil pump mounting feet should be positioned in the mating holes in the cylinder block.
2. Install the four bolts through the mounting feet of the pump into the cylinder block. Torque the bolts to 58-66 N·m (43-49 lb·ft) using the torque sequence shown. See Figure 3-9.

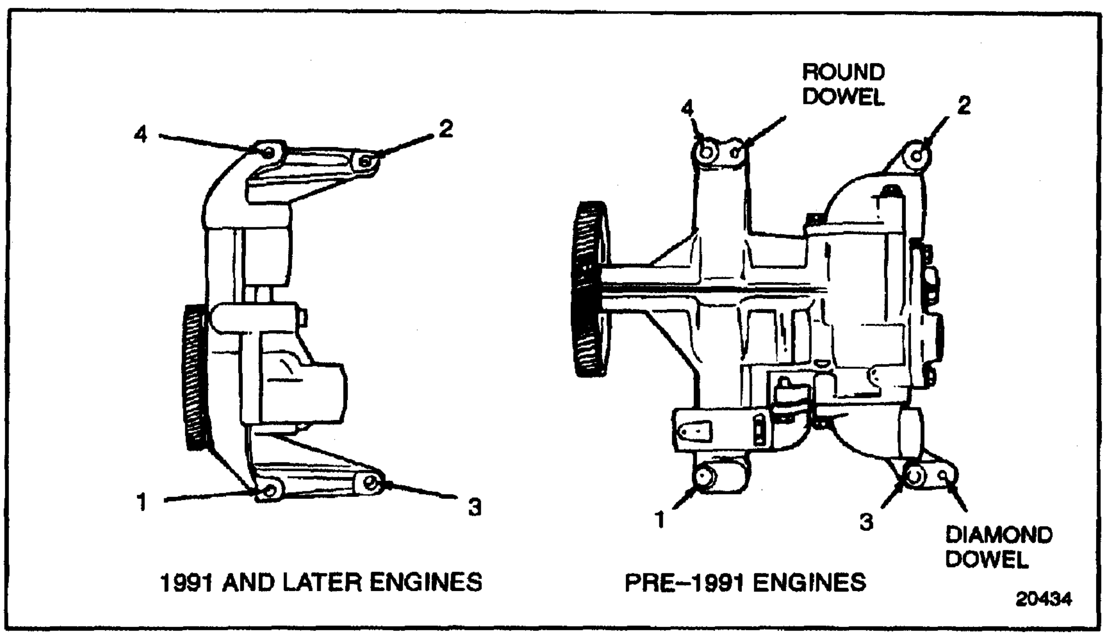



**Figure 3-9 Oil Pump Bolt Torque Sequence**

3. Fasten a dial indicator and magnetic base to the cylinder block so that the indicator tip rests on a tooth of the oil pump drive gear. See Figure 3-10.

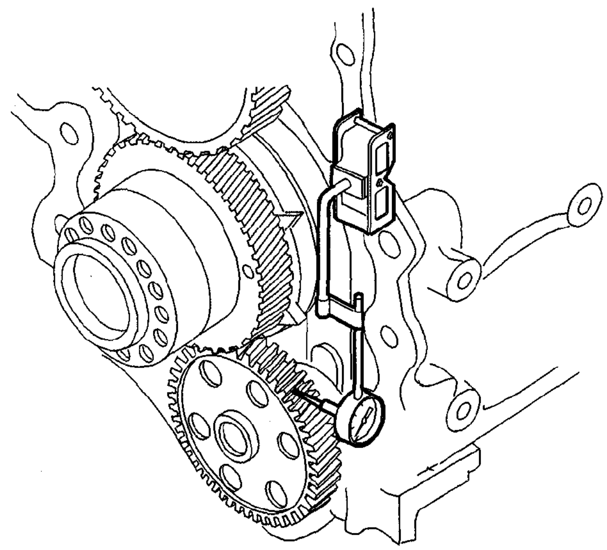



**Figure 3-10 Oil Pump Drive Gear-to-Crankshaft Gear Lash Measurement**

[a] Proper clearance between the crankshaft gear and the oil pump drive gear is 0.051-0.229 mm (0.002-0.009 in.).

**NOTE:**
This gear clearance measurement must be done with the engine in upright position. When adjusting for gear tooth clearance by installing or removing shims, the same number of shims must be changed under each foot so that the pump will always be level on the engine block.

[b] Remove or install shims as necessary to obtain proper gear lash. The insertion or removal of one 0.127 mm (0.005 in.) shim will change the gear tooth clearance by approximately 0.089 mm (0.0035 in.).

4. Install the oil pressure regulator valve to the block. Refer to section 3.3.5.
5. When attaching the pump outlet pipe to the oil pump housing and the cylinder block, none of the bolts should be tightened until all of the bolts have been started.
6. Install new gaskets and seals between the oil pump housing and outlet pipe and between the outlet pipe and cylinder block.
7. Torque the elbow-to-block bolts first then the elbow-to-pump bolts to 30-38 N·m (22-28 lb·ft).
8. Install a new gasket between the oil pump housing and pick-up tube.

9. Install and torque the two bolts, with washers attached, to 30-38 N·m (22-28 lb·ft).

| NOTICE: |
| --- |
| The thru-bolts must remain loose until last, to prevent twisting the oil pick-up tube. Failure to do this could cause eventual stress-crack damage at the pick-up tube to flange joints. |

10. Install and torque the two pick-up tube support bracket-to-engine block bolts to 58-73 N·m (43-54 lb·ft).
11. Torque the two thru-bolts at the inlet pipe to support bracket to 58-73 N·m (43-54 lb·ft).
12. Recheck all bolts for tightness to ensure there will be no leaks in the oil pump and pipe mounting connections.
13. Install the oil pan. Refer to section 3.11.4.
14. Fill the crankcase to the proper level with the recommended oil. Refer to section 5.2.1.
15. Refer to section 11.3 for verification of proper oil pump installation.

## 3.3 OIL PRESSURE REGULATOR VALVE

An oil pressure regulator valve maintains stable lubricating oil pressure within the engine, regardless of the oil temperature. Oil leaving the pump under pressure passes into the pressure relief valve body. The valve is installed in the end of a vertically drilled passage in the cylinder block, located on the oil cooler (right) side of the block, that connects with the main cylinder block oil gallery. See Figure 3-11.

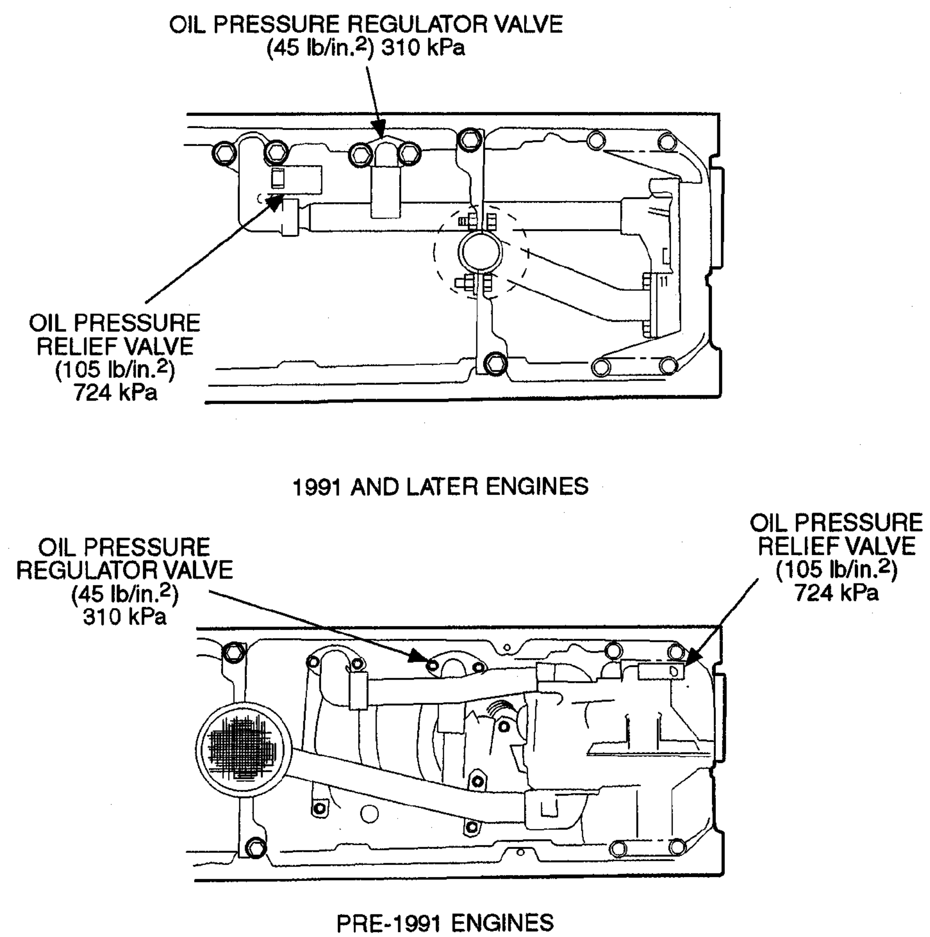
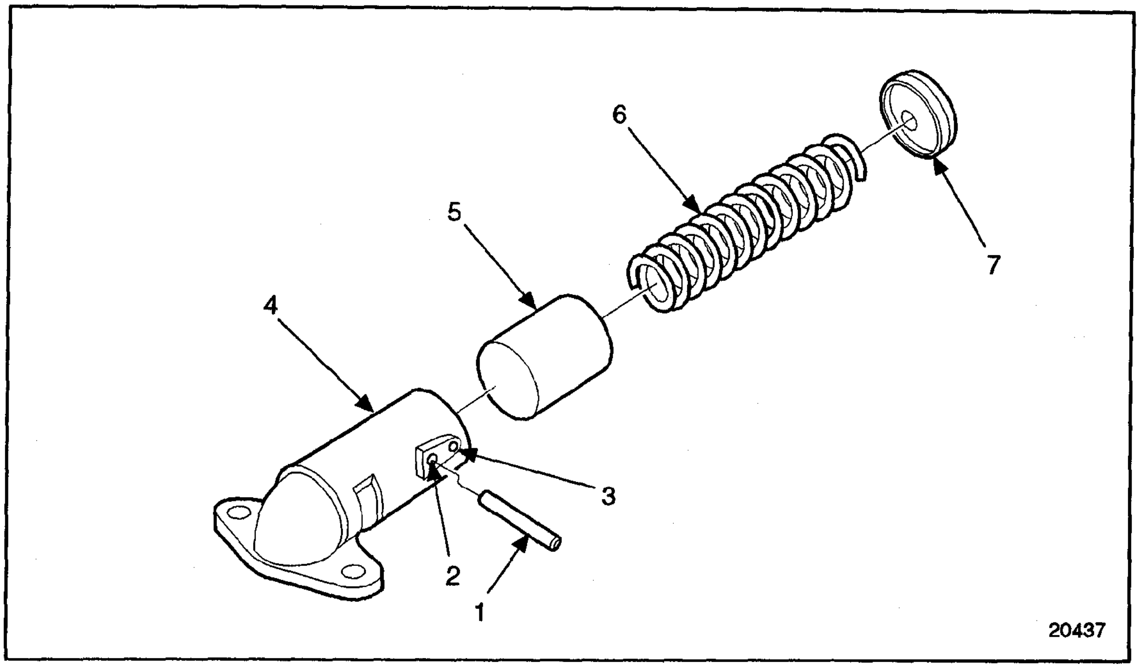



**Figure 3-11 Oil Pressure Regulator Valve Mounting**

The oil pressure regulator valve consists of a valve body, a hollow, piston-type valve, a spring, a spring seat and a pin to retain the valve assembly within the valve body. See Figure 3-12.




1. Pin
2. Pressure Relief Pin Location
3. Pressure Regulator Valve Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

**Figure 3-12 Oil Pressure Regulator Valve Parts and Relief Valve Details**

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the lower flange of the cylinder block and sealed against leaks by a gasket between the block and valve body. When conditions are such that the oil pressure at the valve exceeds 310 kPa (45 lb/in.$^2$), the valve begins to be forced from its seat and oil from the engine gallery is bypassed to the engine oil pan. Thus, stable lubricating oil pressure is maintained at all times.

### 3.3.1 Repair or Replacement of Oil Pressure Regulator Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-13.

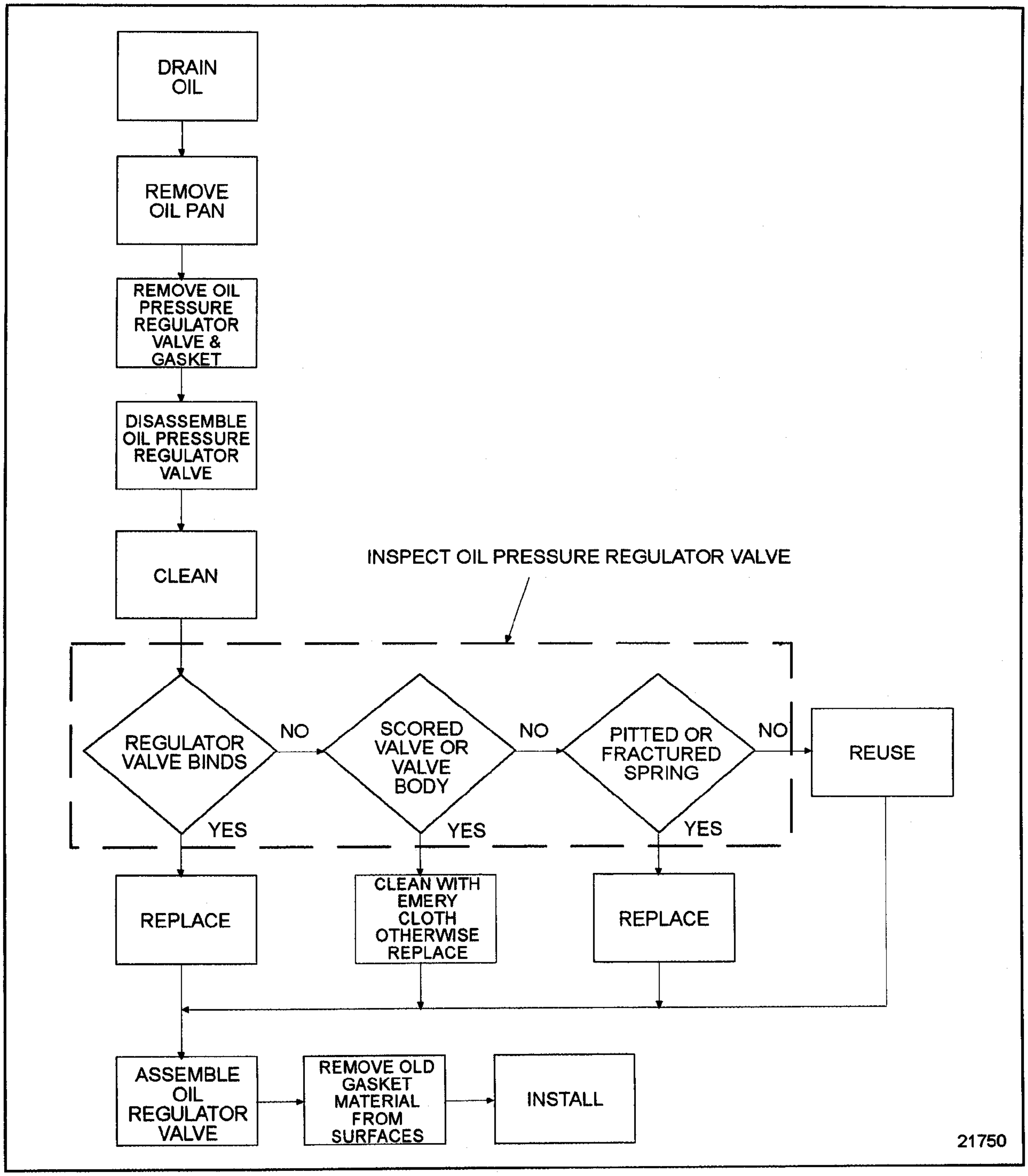



**Figure 3-13 Flowchart for Repair or Replacement of Oil Pressure Regulator Valve**

### 3.3.2 Removal of Oil Pressure Regulator Valve

Remove the oil pressure regulator valve as follows:

1. Drain the lubricating oil and remove the oil pan. Refer to section 3.11.2.
2. Remove the two regulator-to-cylinder block attaching bolts and washers.
3. Tap the regulator body lightly to loosen it from the gasket and cylinder block.
4. Remove the oil pressure regulator valve and gasket.

### 3.3.3 Disassembly of Oil Pressure Regulator Valve

Disassemble the oil pressure regulator valve as follows:

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

1. Clamp the regulator in the soft jaws of a bench vise and remove the spring seat retaining pin from the regulator body.
2. Remove the spring seat, spring and valve from the regulator body.

### 3.3.3.1 Inspection of Oil Pressure Regulator Valve

Inspect the oil pressure regulator valve as follows:

1. Clean all of the oil pressure regulator valve components in fuel oil.

> **CAUTION:**
>
> **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry the components with compressed air.
3. Inspect the oil pressure regulator valve for movement. Check to see if the oil pressure regulator valve moves freely in the valve body.
   [a] If oil pressure regulator valve binds, replace it with a new part.
   [b] If oil pressure regulator valve does not bind, reuse part.
4. Inspect the components for wear or damage. Check to see if valve or the valve body are scored.
   [a] If the valve or valve body parts cannot be cleaned up with a fine emery cloth, replace with new parts.
   [b] If the valve or valve body parts can be cleaned up with a fine emery cloth, reuse parts.
5. Inspect spring for pitting or fractures.
   [a] If spring is damaged, replace it.
   [b] If spring is not damaged, reuse the component.

### 3.3.4 Assembly of Oil Pressure Regulator Valve

Assemble the oil pressure regulator valve as follows:

1. Apply clean engine oil to the outer face of the valve. See Figure 3-14.
2. Slide valve into the regulator body, closed end first. See Figure 3-14.
3. Insert the spring in the valve and install the spring seat.
4. While compressing the spring, install the retaining pin behind the spring seat.
5. Press the pin flush to 0.254 mm (0.010 in.) below the surface of the valve body.

**NOTE:**
The valve body has two retaining pin holes. See Figure 3-14. Install the pin in the outermost hole for the regulator valve. The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3-14.

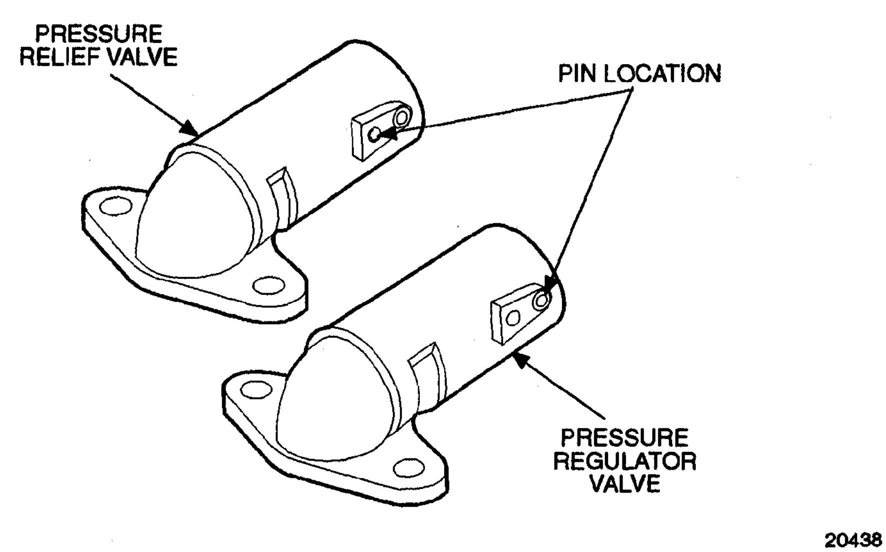



**Figure 3-14 Comparison of Pressure Regulator and Relief Valve Assemblies**

### 3.3.5 Installation of Oil Pressure Regulator Valve

Install the oil pressure regulator valve as follows:

1. Remove all traces of old gasket material from the mating surfaces of the regulator body and the cylinder block.
2. Secure the oil pressure regulator valve assembly to the cylinder block with two bolts. Torque the bolts to 30-38 N·m (22-28 lb·ft).
3. Refer to section 11.3 for verification of proper oil pressure regulator installation.

## 3.4 OIL PRESSURE RELIEF VALVE

Oil leaving the pump under pressure passes into the pressure relief valve body. The spring-loaded valve opens when the pressure exceeds 724 kPa (105 lb/in.$^2$) and directs the excess oil to the oil pan. The pressure relief valve is attached to the oil pump outlet tube (on 1991 and later engines), or the oil pump body (on pre-1991 engines). See Figure 3-11.

The pressure relief valve consists of a valve body, a hollow, piston-type valve, a spring, spring seat and a pin to retain the valve assembly within the valve body.

The relief valve assembly is composed of the same parts as the regulator valve assembly with the exception of the body. See Figure 3-12.

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the lower flange of the cylinder block and sealed against leaks by a gasket between the block and valve body. When conditions are such that the oil pressure at the valve exceeds 689 kPa (100 lb/in.$^2$), the valve begins to be forced from its seat and oil from the engine gallery is bypassed to the engine oil pan. Thus, stable lubricating oil pressure is maintained at all times.

### 3.4.1 Repair or Replacement of Oil Pressure Relief Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-15.

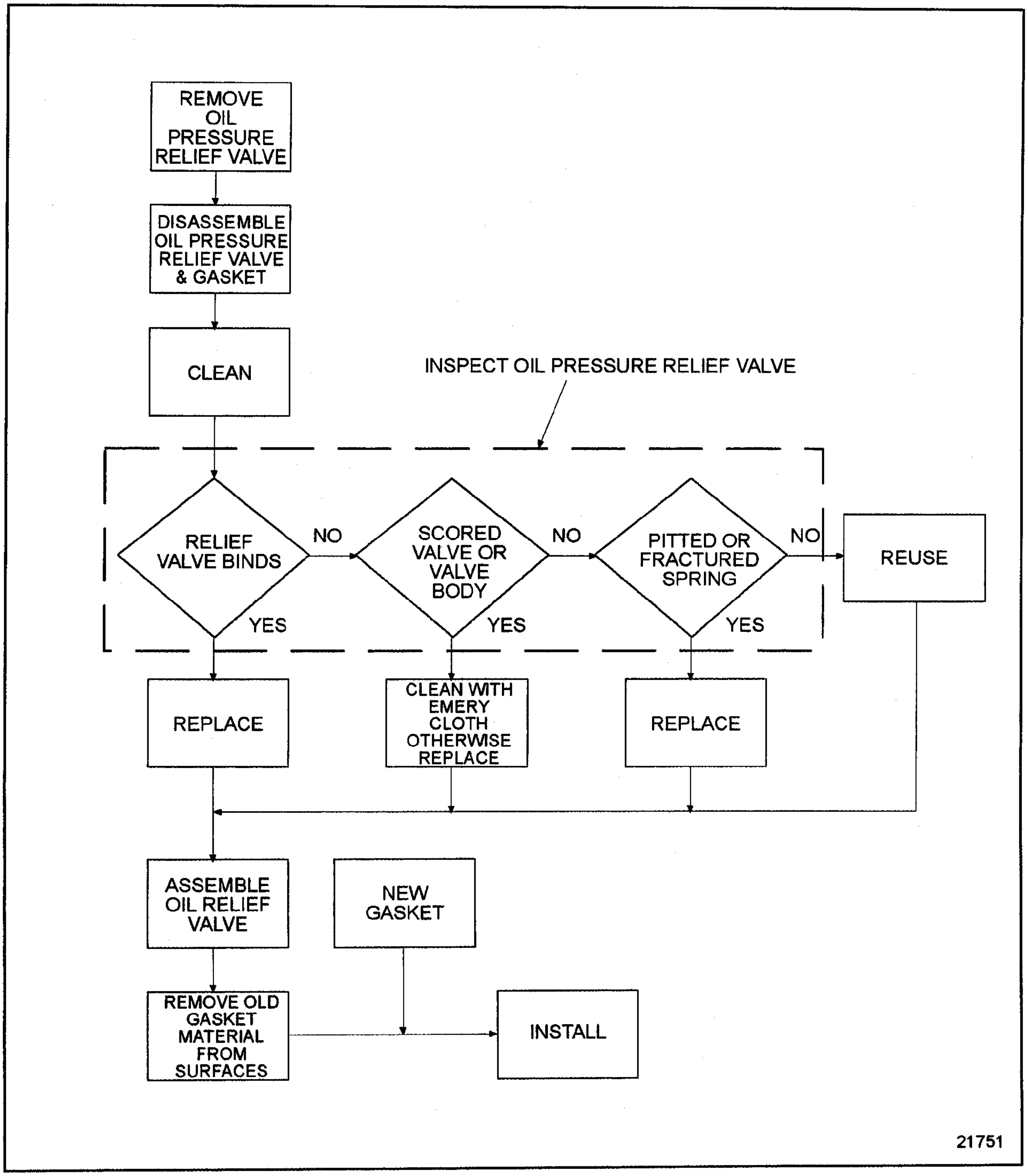



**Figure 3-15 Flowchart for Repair or Replacement of Oil Pressure Relief Valve**

### 3.4.2 Removal and Cleaning of Oil Pressure Relief Valve

Remove the oil pressure relief valve as follows:

1. Remove the two bolts and washers securing the relief valve to the cylinder block.
2. Tap the oil pressure relief valve body lightly to loosen it from the gasket and cylinder block.
3. Remove the oil pressure relief valve and gasket.

### 3.4.3 Disassembly of Oil Pressure Relief Valve

Disassemble the oil pressure relief valve as follows:

1. Clamp the oil pressure relief valve in the soft jaws of a bench vise.

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

2. Remove the spring seat retaining pin from the oil pressure relief valve body. See Figure 3-12.
3. Remove the spring seat, spring and valve from the oil pressure relief valve body. See Figure 3-12.

### 3.4.4 Cleaning the Oil Pressure Relief Valve

Perform the following steps to clean the oil pressure relief valve:

1. Clean all of the oil pressure relief valve components in fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry the components with compressed air.

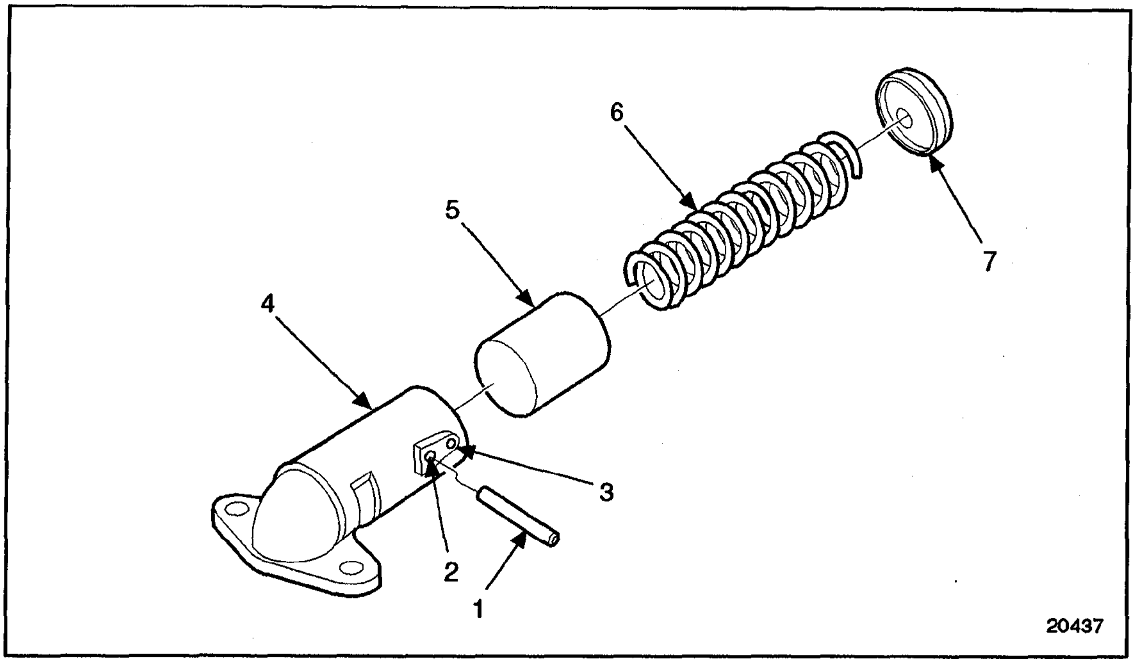
### 3.4.4.1 Inspection of Oil Pressure Relief Valve

Inspect the oil pressure relief valve as follows:

1. Inspect the oil pressure relief valve for movement. Check to see if the oil pressure relief valve moves freely in the valve body.
   [a] If relief valve binds, replace it with a new part.
   [b] If relief valve did not bind, reuse the component.
2. Inspect the components for wear or damage. Check to see if valve or the valve body are scored.
   [a] If the valve and valve body parts cannot be cleaned with a fine emery cloth, replace with new parts.
   [b] If the valve and valve body parts can be cleaned with a fine emery cloth, reuse the parts.
3. Inspect spring for pitting or fractures.
   [a] If spring is damaged, replace the component.
   [b] If spring is not damaged, reuse the component.

### 3.4.5 Assembly of Oil Pressure Relief Valve

The oil pressure relief valve body has two retaining pin holes. See Figure 3-16. Install the pin in the outermost hole for the regulator valve.




1. Pin
2. Pressure Relief Pin Location
3. Pressure Regulator Valve Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

**Figure 3-16 Location of Oil Pressure Regulator Valve and Relief Valve Pin**

Assemble the relief valve as follows:

1. Apply clean engine oil to the outer face of the valve.
2. Slide valve into the oil pressure regulator body, closed end first. See Figure 3-16.
3. Insert the spring in the valve and install the spring seat.

| NOTICE: |
|---|
| The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3-16. |

4. While compressing the spring, install the retaining pin behind the spring seat.
5. Press the pin flush to 0.254 mm (0.010 in.) below the surface of the valve body.

### 3.4.6 Installation of Oil Pressure Relief Valve

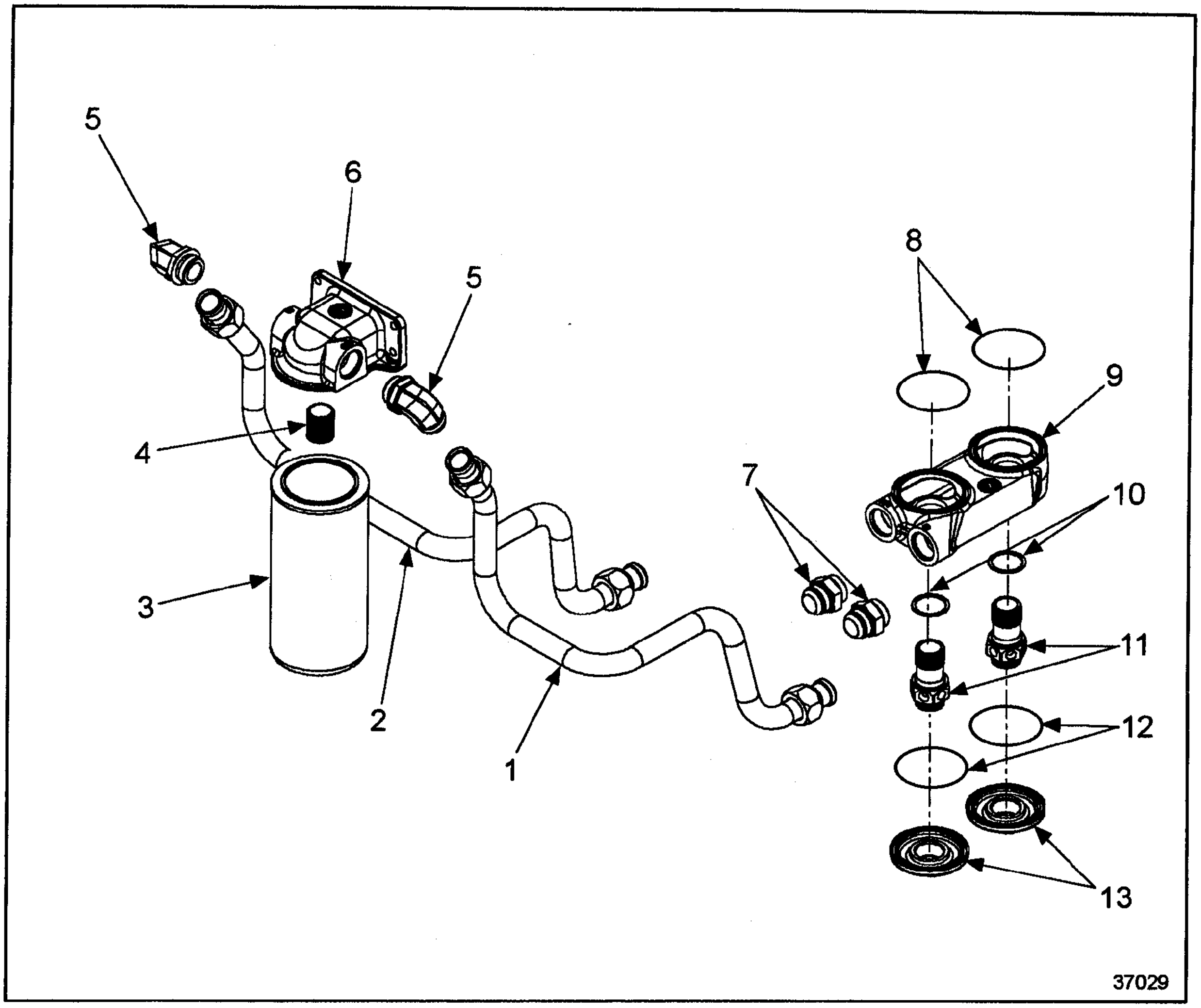
Install the oil pressure relief valve as follows:

1. Remove all traces of old gasket material from the mating surfaces of the oil pressure relief valve body and the cylinder block.
2. Place a new gasket onto the relief valve body.
3. Secure the oil pressure relief valve assembly to the cylinder block with two bolts. Torque the bolts to 30-38 N·m (22-28 lb·ft).
4. Refer to section 11.3 for verification of proper oil pressure relief valve installation.

## 3.5 OIL FILTER

Two full-flow type lubricating oil filters are used on current Series 60 engines. The oil filters are mounted in a downward position. The filters are throw away, spin-on type. Prior to 1993 the Series 60 engines also had a bypass filter. See Figure 3-18.

**NOTE:**
Certain pleasure craft marine engines use a single, high capacity, remote-mounted lubricating oil filter. When installed, adaptor plates drilled and tapped for hose connections are used to seal the spin-on filter openings in the engine-mounted oil filter adaptor. See Figure 3-17.




1. Lube Oil Return Tube
2. Lube Oil Supply Tube
3. Spin-on Lube Oil Filter
4. Filter Adaptor Insert
5. Elbow
6. Spin-on Lube Oil Filter Adaptor
7. Connector (2)
8. Adaptor-to-Oil Cooler Seal Ring (2)
9. Remote-mounted Filter Adaptor
10. Seal Washer (2)
11. Remote-mounted Adaptor Special Stud
12. Adaptor Cap Seal Ring (2)
13. Cap (2)

**Figure 3-17 Remote-mounted Lubricating Oil Filter**

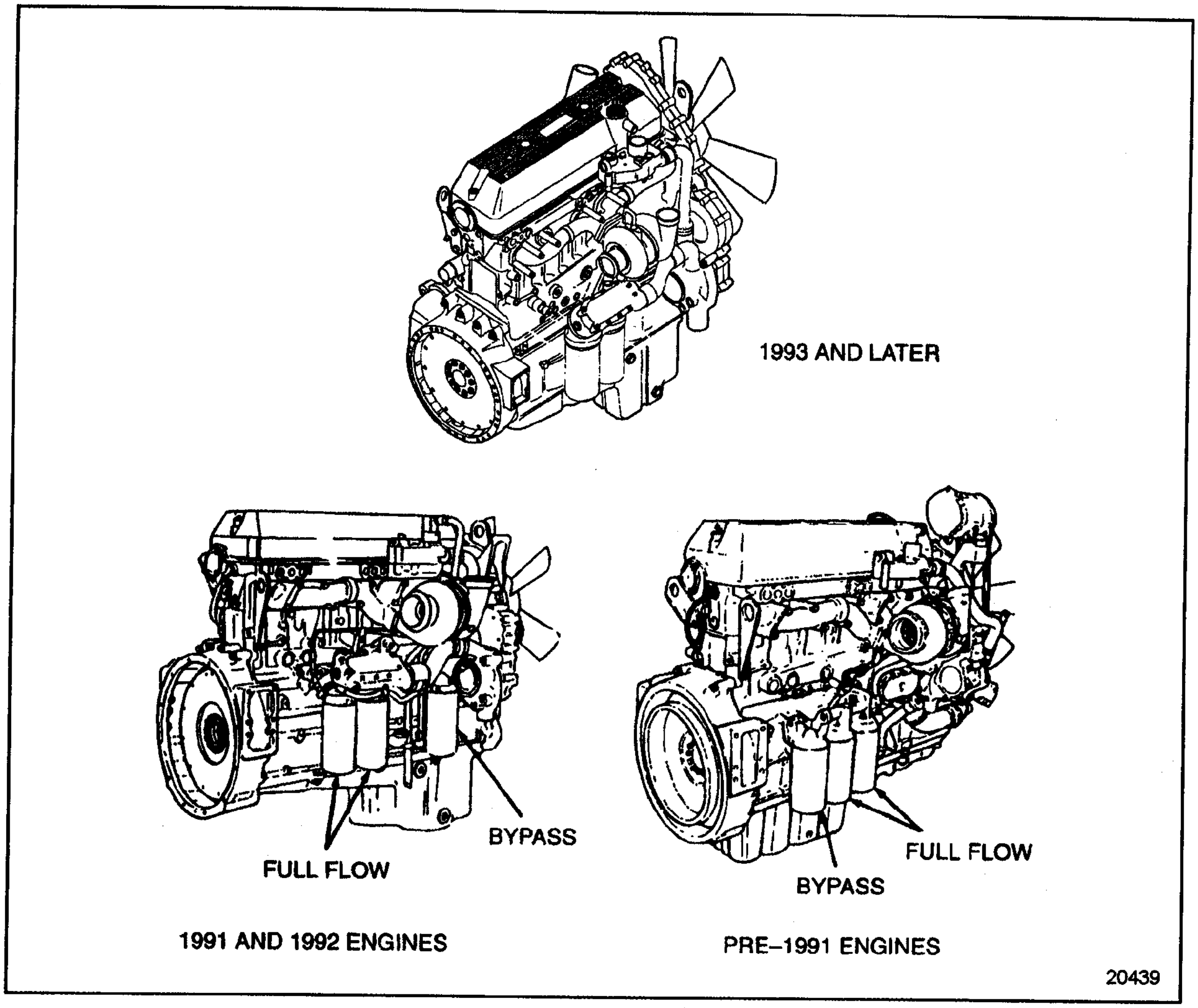



**Figure 3-18 Spin-on Oil Filters**

Oil supplied by the engine oil pump passes through the full-flow filters before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor and into the elements. Impurities are filtered out as the oil passes through the elements and out through another passage in the filter adaptor.

### 3.5.1 Replacement of Oil Filter

Install new, full-flow, spin-on oil filters at the following (maximum) intervals or each time the engine oil is changed, whichever comes first:

- ☐ Truck and Parlor Coach — 15,000 Miles (24,000 Km)
- ☐ Transit Coach — 6,000 Miles (9,600 Km)
- ☐ Industrial, Agricultural, Generator Set — 150 Hours or one year, whichever comes first
- ☐ Marine — 250 Hours, or one year, whichever comes first

### 3.5.2 Installation of Oil Filter

Install oil filter as follows:

1. Fill new oil filters with clean engine oil and lightly coat the filter seal.
2. Install new filters onto the adaptors, turning them until they contact the gasket fully with no side movement. Then turn an additional 2/3 turn by hand or as indicated on the filter.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

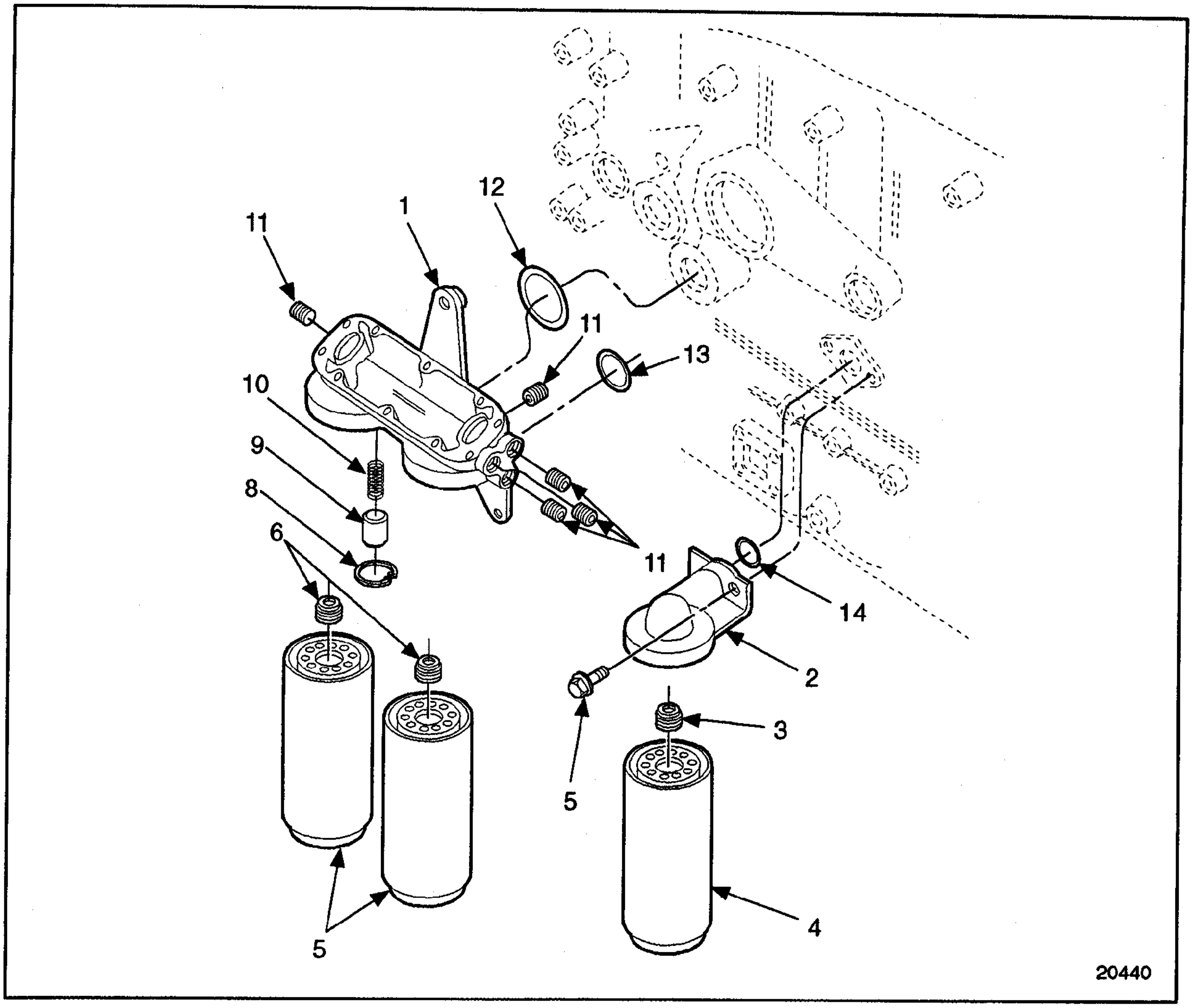
3. Start the engine and check for oil leaks.

Make a visual inspection of all lubricating oil lines for wear and/or chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

If the engine has not been operated for a prolonged period or the turbocharger has been removed or replaced, prelubricate the turbocharger. Refer to section 6.6.6.

## 3.6 OIL FILTER ADAPTOR

The oil filter adaptor is located on the right side of the engine and is attached to the oil cooler. The 1991 and later engines have a separate oil filter bypass adaptor. See Figure 3-19.




1. Oil Filter Adaptor
2. Bypass Oil Filter Adaptor*
3. Insert, Bypass Filter-to-Adaptor*
4. Oil Filter, Bypass*
5. Bolt, Adaptors-to-Block (6)*
6. Insert, Full-Flow Filter-to-Adaptor
7. Oil Filter, Full-Flow
8. Snap Ring
9. Valve, Bypass
10. Spring, Bypass
11. Pipe Plugs (5)
12. O-ring, Adaptor-to-Block
13. O-ring, Adaptor-to-Block
14. O-ring, Adaptor-to-Block*

*Not used after 1992.

**Figure 3-19 Oil Filter Adaptors, Bypass Valve and Related Parts (1992 & Later)**

A bypass valve in the filter adaptor opens at approximately 124-145 kPa (18-21 lb/in.$^2$) pressure differential, and will bypass the oil should the full-flow filters become plugged.

## 3.6.1 Repair or Replacement of Oil Filter Adaptor

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-20.

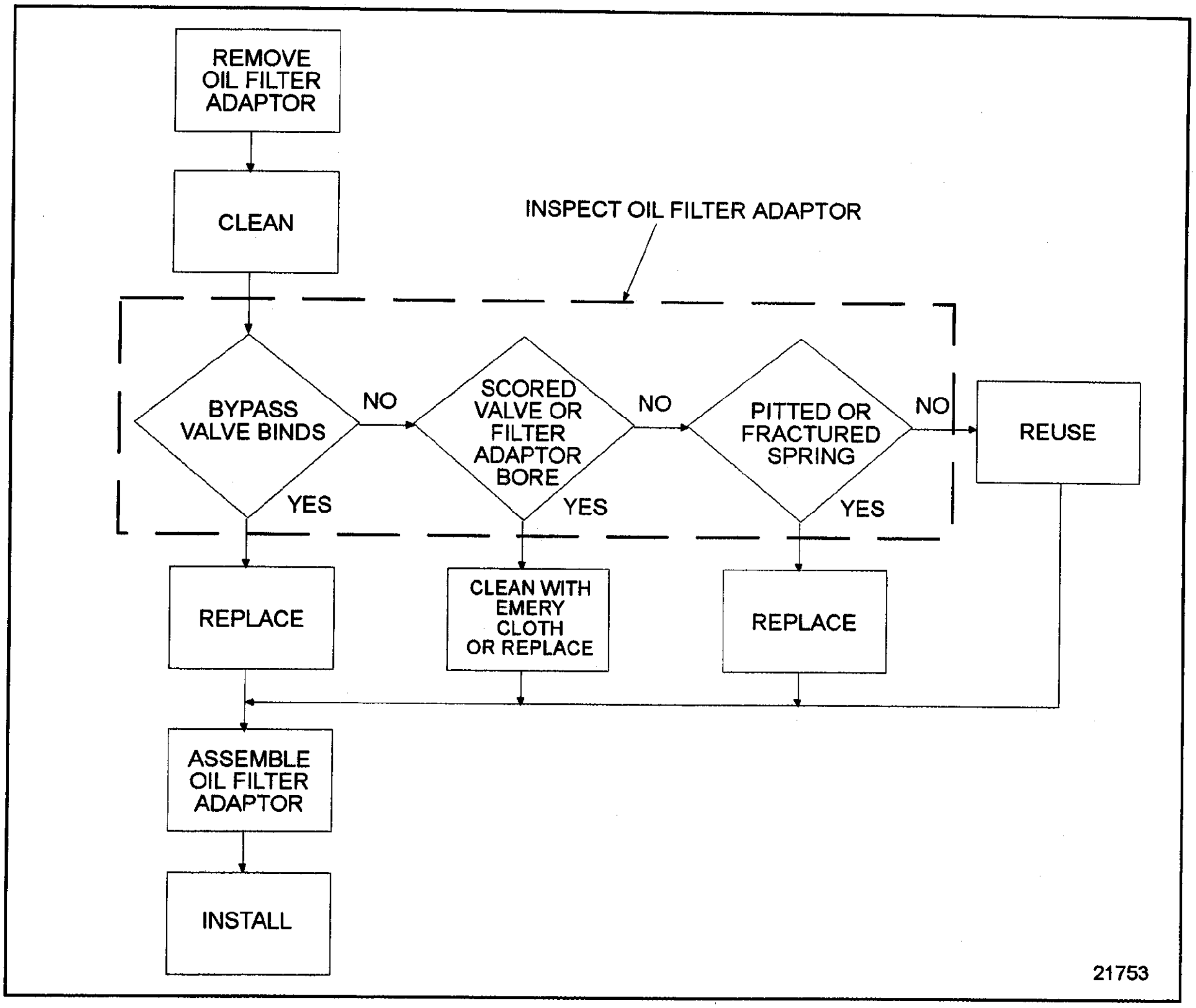



**Figure 3-20 Flowchart for Repair or Replacement of Oil Filter Adaptor**

### 3.6.2 Removal of Oil Filter Adaptor

Precleaning is not necessary.

Remove the oil filter adaptor as follows:

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

1. Remove the snap ring, using J 23432.
2. Withdraw the spring and bypass valve (engines built prior to 1993). See Figure 3-19.
3. Remove the pipe plugs.

### 3.6.3 Cleaning the Oil Filter Adaptor

Clean the oil filter adaptor as follows:

1. Clean all of the oil filter adaptor components in fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry the parts with compressed air.

#### 3.6.3.1 Inspection of Oil Filter Adaptor

Inspect the oil filter adaptor as follows:

1. Inspect the bypass valve for movement. Check to see if the bypass valve moves freely in the adaptor.
   [a] If the bypass valve binds, replace it with a new part.
   [b] If the bypass valve does not bind, reuse the part.
2. Inspect the components for wear or damage. Check to see if the valve or the filter adaptor bore are scored.
   [a] If the valve and the filter adaptor bore parts cannot be cleaned with a fine emery cloth, replace with new parts.
   [b] If the valve and the filter adaptor bore parts can be cleaned with a fine emery cloth, reuse the parts.
3. Inspect the spring for damage. Check for pitting or fractures.
   [a] If spring is damaged, replace the component.
   [b] If spring is not damaged, reuse the component.

### 3.6.4 Assembly of Oil Filter Adaptor

Assemble the oil filter adaptor as follows:

1. Install bypass spring and bypass valve into the oil filter adaptor.
2. Install snap ring using J 23432.
3. Install oil filter adaptor inserts, if removed.
4. Install the pipe plugs:
   [a] Apply a sealant such as, Loctite® 620, (or equivalent) to the threads that will engage the adaptor.
   [b] Wipe off any sealant remaining exposed on the threads.
   [c] Torque all three pipe plugs to 129-161 N·m (95-119 lb·ft).
5. Coat new O-rings with petroleum jelly.
6. Install the O-rings in the recesses in the oil filter adaptor.

### 3.6.5 Installation of Oil Filter Adaptor

Install oil filter adaptor as follows:

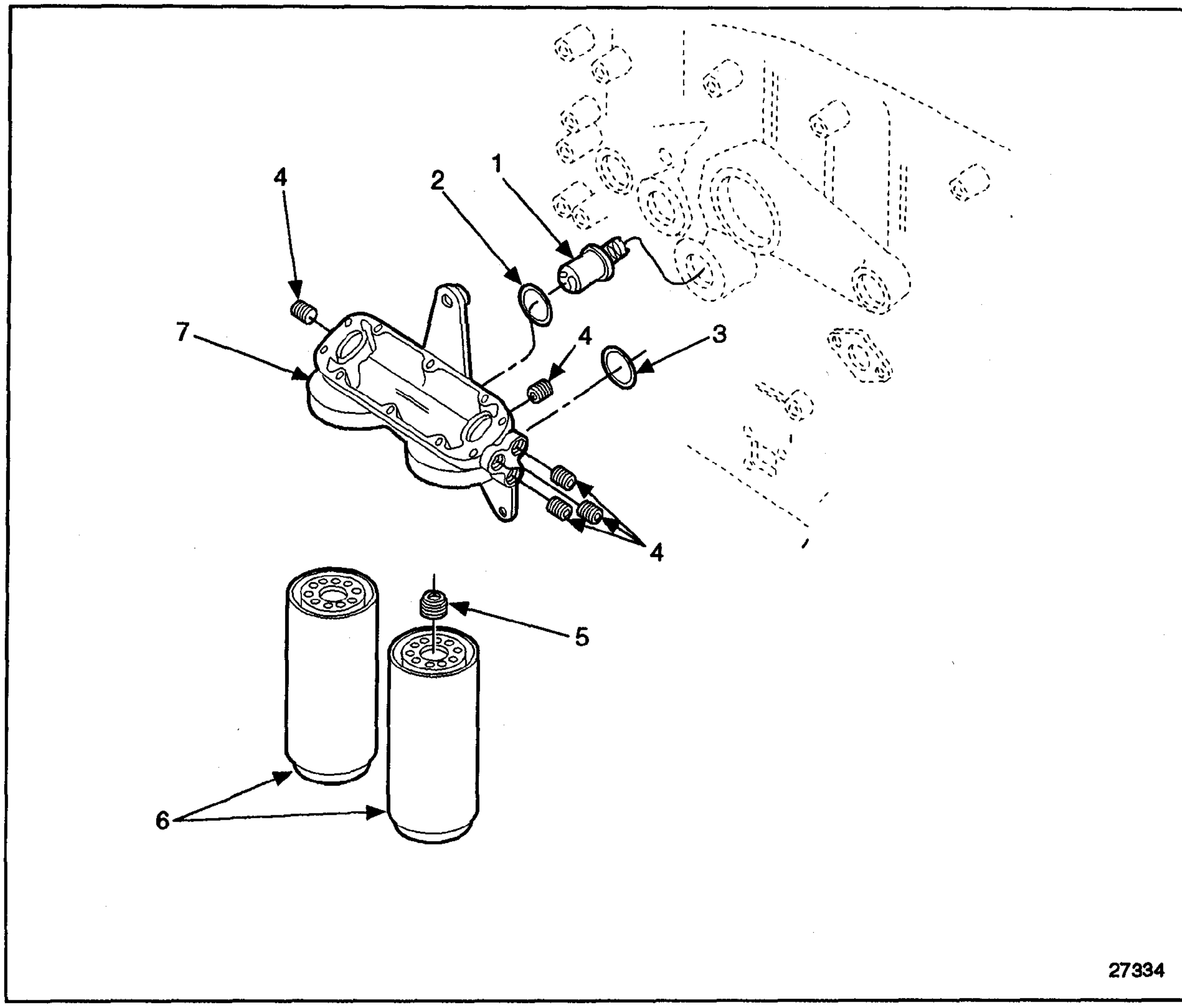
| NOTICE: |
| --- |
| Failure to tighten oil filter adaptor mounting bolts to the required torque may lead to a loss of lubricating oil during engine operation. Inadequate lubrication can result in severe engine damage. |

| CAUTION: |
| --- |
| **To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.** |

1. Install the oil filter adaptor to the cylinder block and fasten as follows:
   [a] Torque the four M10 mounting bolts on current two-element oil filter adaptor to 58-73 N·m (43-54 lb·ft).
   [b] Torque the six M8 mounting bolts on former three-element oil filter adaptor to 30-38 N·m (22-28 lb·ft).
2. Install full-flow oil filter(s). Refer to section 13.13.13.
3. Refer to section 11.3 for verification of proper oil filter adaptor installation.

## 3.7 THERMATIC OIL CONTROL VALVE

A dual spin-on lube oil filter adaptor assembly with a temperature-sensitive thermatic oil control valve is available on Series 60, 11.1L low compression (15:1) industrial and automotive engines and certain 12.7L engines. See Figure 3-21.




1. Thermatic Oil Control Valve
2. O-ring, Adaptor to Block
3. O-ring, Adaptor to Block
4. Pipe Plugs (5)
5. Insert, Full-Flow to Adaptor
6. Oil Filter, Full-Flow (2)
7. Oil Filter Adaptor

**Figure 3-21 Thermatic Oil Control Valve**

The thermatic oil control valve is installed in the oil filter adaptor assembly where it operates like a thermostat to control the flow of lube oil through the engine and oil cooler. The thermatic oil control valve operates in the following manner: See Figure 3-22.

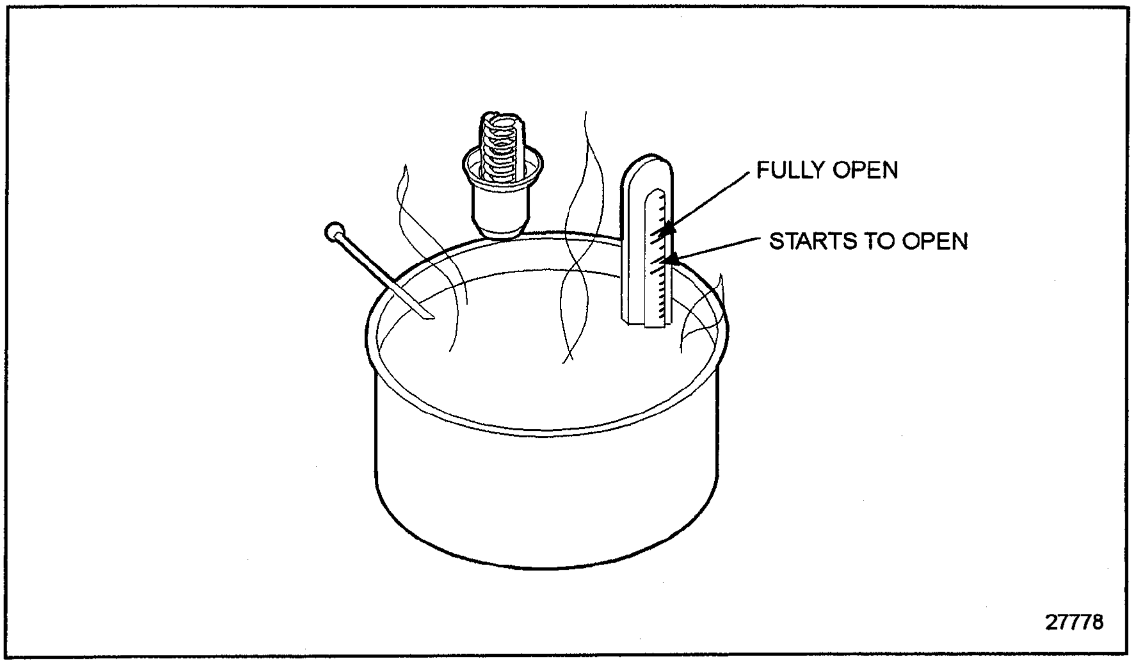



**Figure 3-22 Thermatic Oil Control Valve Operation**

At lube oil temperature below 104°C (220°F) the thermatic oil valve stays in the bypass mode. Filtered engine oil bypasses the oil cooler and flows directly to the main oil gallery. With no oil passing through the oil cooler, engine oil warms up rapidly. When oil temperature is between 104° -108°C (220° -227°F) the thermatic oil valve begins to open. The valve senses oil temperature and modulates oil both through and around the oil cooler. At oil temperatures of 114°C (237°F) the thermatic oil valve is fully open, and all oil flows through the oil cooler. To test the valve refer to section 3.7.2.2.

Use of the thermatic oil control valve allows the engine lube oil to reach its normal temperature range quickly, reducing the amount of time during which the engine operates on heavier cold engine lube oil. During light load engine operation, the thermatic valve keeps the oil within the proper temperature range for optimum lubrication. By maintaining the engine oil temperature within the 104° -114°C (220° -237°F) range, friction and pumping losses are minimized, resulting in more efficient engine operation.

## 3.7.1 Repair or Replacement of Thermatic Oil Control Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-23.

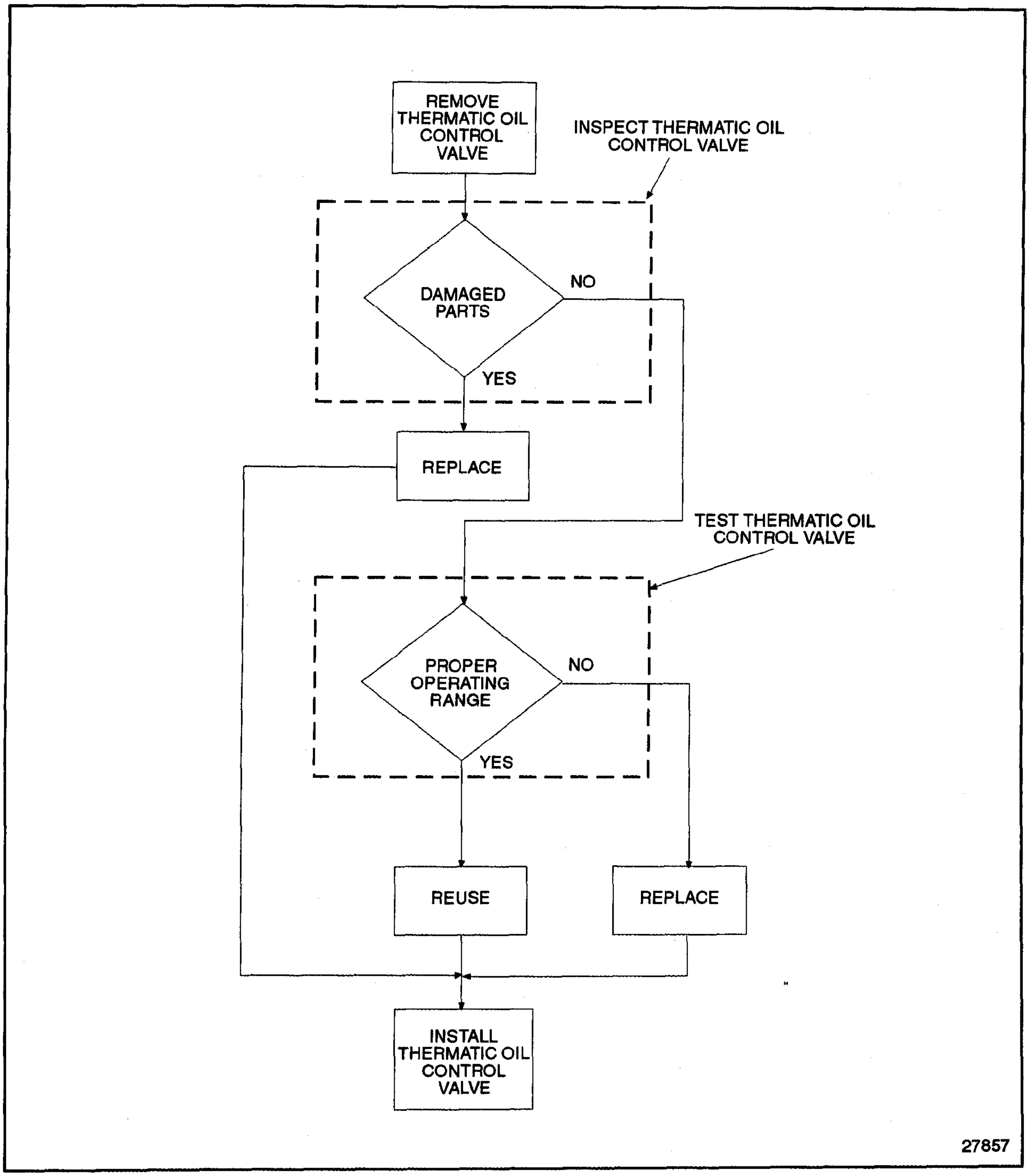



**Figure 3-23 Flowchart for Repair or Replacement of Thermatic Oil Control Valve**

### 3.7.2 Removal and Cleaning of Thermatic Oil Control Valve

Remove the thermatic oil control valve as follows:

| NOTICE: |
|---|
| Use care when removing oil filter adaptor assembly so as not to drop thermatic oil control valve from inside of oil filter adaptor assembly, if engine is so equipped. |

1. Remove the oil filter adaptor. Refer to section 3.6.2.
2. Remove the thermatic oil valve from oil filter adaptor.
3. Clean the thermatic oil control valve in clean fuel oil.

| CAUTION: |
|---|
| **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.** |

4. Dry thermatic oil control valve with compressed air.

#### 3.7.2.1 Inspection of Thermatic Oil Control Valve

Inspect the thermatic oil control valve as follows:

1. Inspect the thermatic oil control valve for wear or damage.
   [a] If damage is found, replace the thermatic oil control valve.
   [b] If no damage is found, reuse the thermatic oil control valve.

### 3.7.2.2 Testing Thermatic Oil Control Valve

Check the operation of the thermatic oil control valve as follows:

| NOTICE: |
|---|
| Ensure thermatic oil control valve is operational. If the thermatic oil control valve motion becomes impaired, engine overheating may result. An engine that has overheated may also cause the thermatic oil control valve to become inoperative. A thermatic oil control valve that does not fully open may cause overheating. A thermatic oil control valve stuck in the open position may cause poor fuel economy in cold starting conditions. |

1. Immerse a thermometer and the thermatic oil control valve in a container with clean engine oil. Do not allow thermometer or thermatic oil control valve to touch the sides of the container. See Figure 3-24.

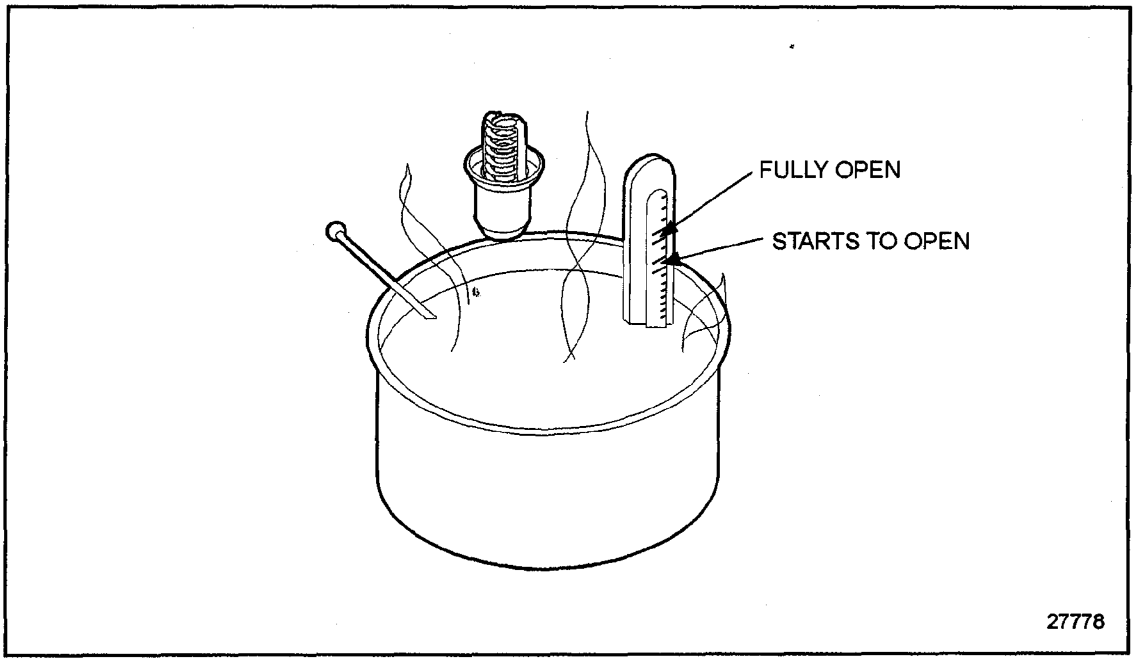



**Figure 3-24 Checking Thermatic Oil Control Valve Operation**

**CAUTION:**

**To avoid injury from fire caused by heated lubricating-oil vapors:**

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if an oil leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves, apron, etc.) to avoid burns.**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

**Lubricating oil is relatively harmless at ambient temperatures.**

**CAUTION:**

**To avoid injury from oil spray, wear adequate eye protection (face shield or safety goggles) when performing the oil test procedure.**

2. While slowly agitating the clean engine oil to maintain an even temperature, apply heat to the container. Allow at least 10 minutes for the thermatic oil control valve to react before determining if it is opening at the correct temperature range.

**CAUTION:**

**To avoid injury from scalding, use lifting tools and wear heat-resistant gloves when retrieving the thermostat from boiling water.**

3. As the mixture is heated, the thermatic oil control valve should begin to open. (The normal opening temperature is stamped on the thermostat.) The start-to-open temperature range is 104-107°C (220-225°F). The thermostat is fully opened to 8.13 mm (0.320 in.) at 114°C (237°F).
4. If the thermatic oil control valve does not operate properly, replace.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

5. If the thermatic oil control valve operates properly, dry with compressed air and apply a thin coat of lubricating oil to protect surfaces from corrosion.

### 3.7.3 Installation of Thermatic Oil Control Valve

Install the thermatic oil control valve as follows:

**NOTE:**
If the thermatic oil control valve dislodges from the oil filter adaptor during installation and falls to the ground, ensure valve is undamaged and is free of dirt and debris before continuing with installation.

1. Apply light coating of petroleum jelly on underside of thermatic oil control valve upper lip to aid in installation.
2. Insert beveled end of thermatic oil control valve into oil filter adaptor.
3. Install oil filter adaptor onto block. Be careful not to dislodge thermatic oil control valve from oil filter adaptor. Refer to section 3.6.4.
4. Refer to section 11.3 for verification of proper oil filter adaptor installation.

## 3.8 OIL COOLER (1991 AND LATER ENGINES)

To perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, and it cannot carry away enough heat. As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive.

While performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat, and this heat must be dissipated by an oil cooler.

The lubricating oil cooler is mounted on the right side of the cylinder block near the water pump. See Figure 3-25.

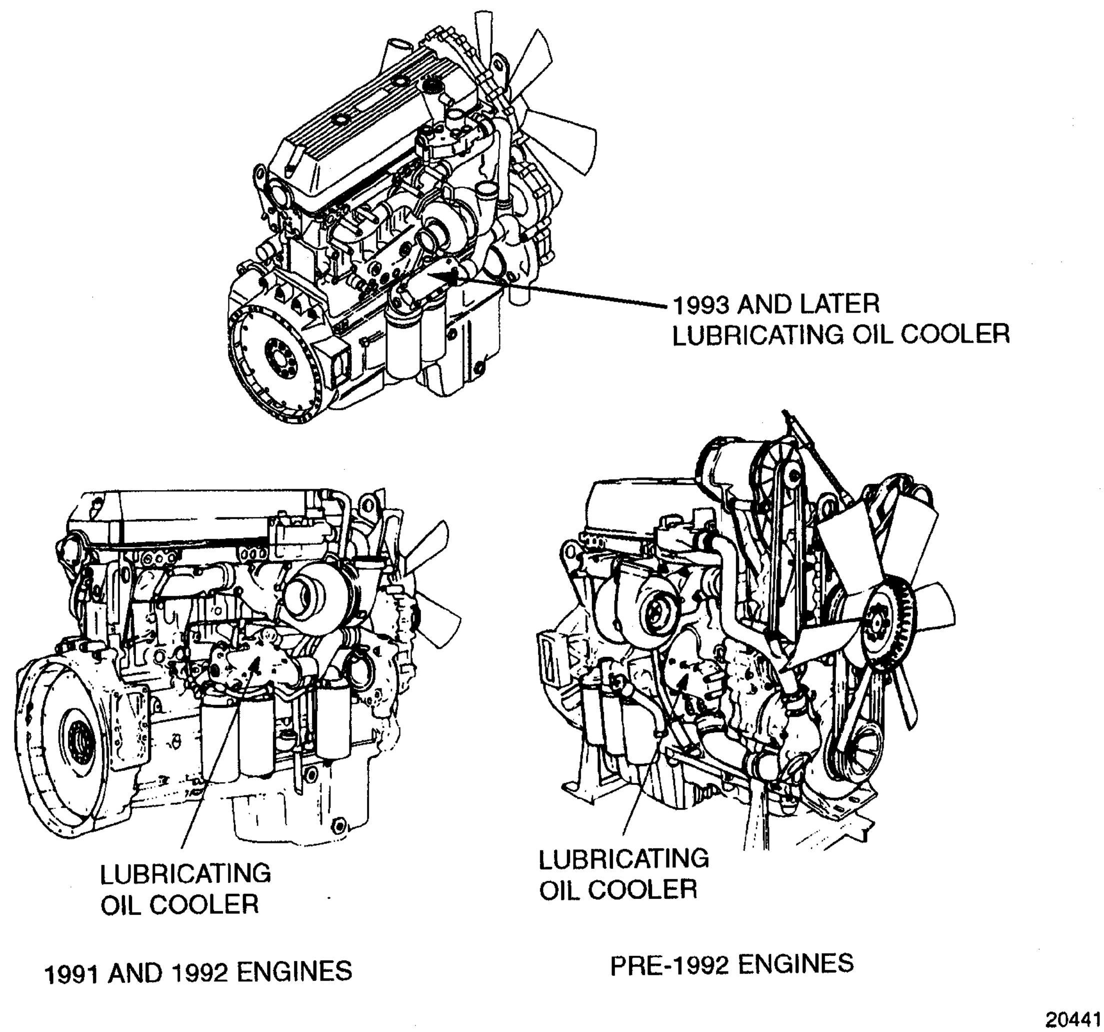


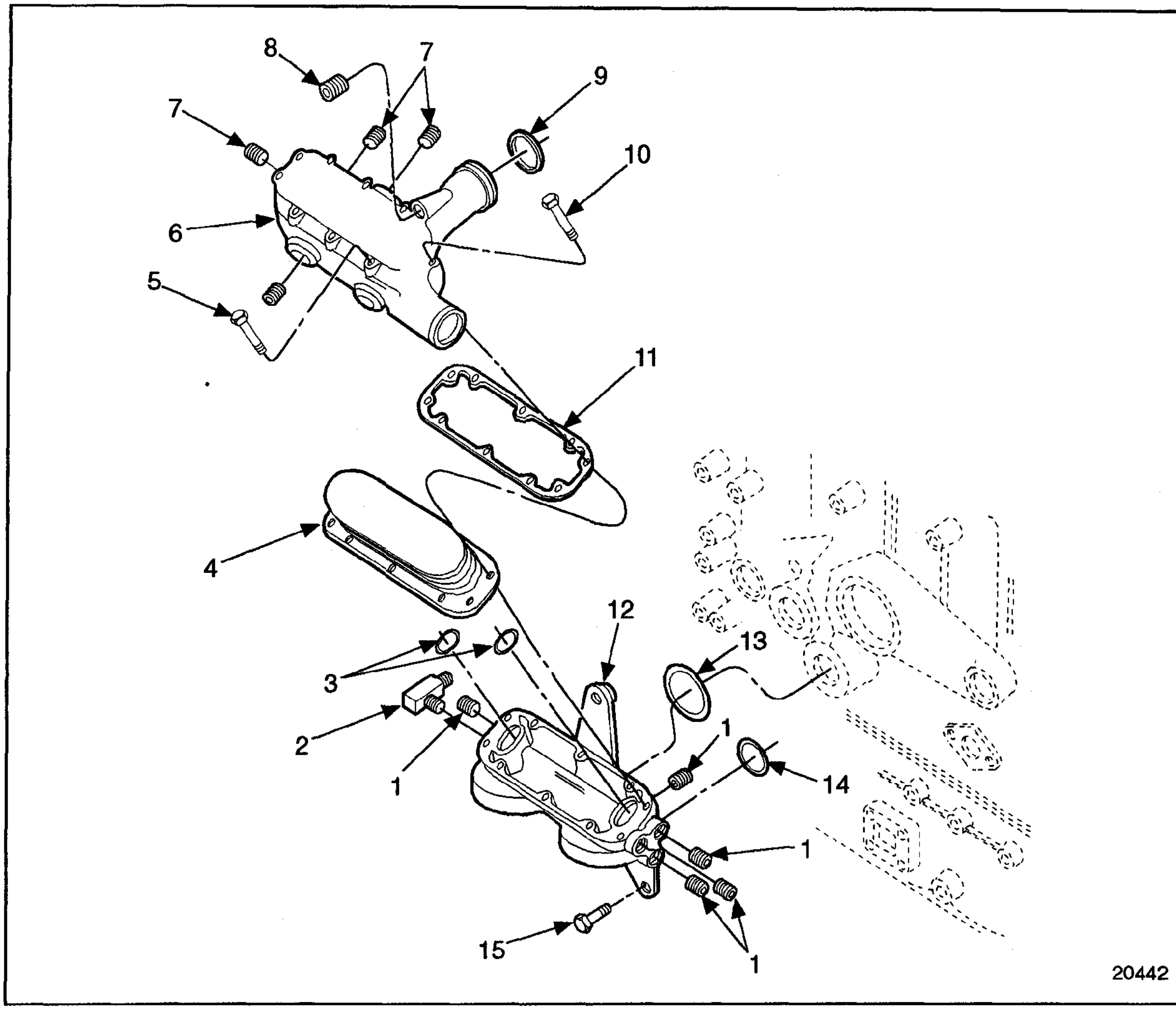

**Figure 3-25 Lubricating Oil Cooler (1991 and Later Engines)**

To ensure continued engine lubrication if the oil cooler becomes plugged, a bypass passage, located at the oil inlet to the cooler, allows oil to bypass the cooler and flow directly directly to the oil gallery in the cylinder block.

Cooling water is circulated through the oil cooler housing completely surrounding the oil cooler core. Therefore, whenever an oil cooler is assembled, care must be taken to have the proper gaskets in place and the retaining bolts tight to ensure good sealing.

A design change was made to the oil cooler housing and the mounting of Series 60 engines built after 6R37023. Because of this change, there are differences in the servicing of the two designs.

The oil cooler housing coolant outlet uses one large rubber O-ring seated in a groove in the outlet neck. See Figure 3-26.




1. Pipe Plugs (5)
2. Fitting
3. O-rings (2)
4. Oil Cooler
5. Bolt, Oil Cooler Housing-to-Adaptor (3)
6. Oil Cooler Housing
7. Pipe Plugs (4)
8. Pipe Plug
9. O-ring
10. Bolt, Oil Cooler Housing-to-Adaptor (7)
11. Gasket, Oil Cooler-to-Housing
12. Oil Filter Adaptor
13. O-ring
14. O-ring
15. Bolt, Oil Filter Adaptor-to-Block (5)

**Figure 3-26 Oil Cooler Housing and Related Parts (1991 and Later Engines)**

Two small O-rings are positioned in oil filter adaptor counterbores to seal the lubricating oil passages between the oil filter adaptor and the cooler core.

The oil cooler housing is attached to the oil filter adaptor. The flow of oil is from the oil pump, through a vertical passage in the cylinder block, through the full-flow oil filters and then through the oil cooler core and the cylinder block main oil galleries.

### 3.8.1 Repair or Replacement of Oil Cooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-27.

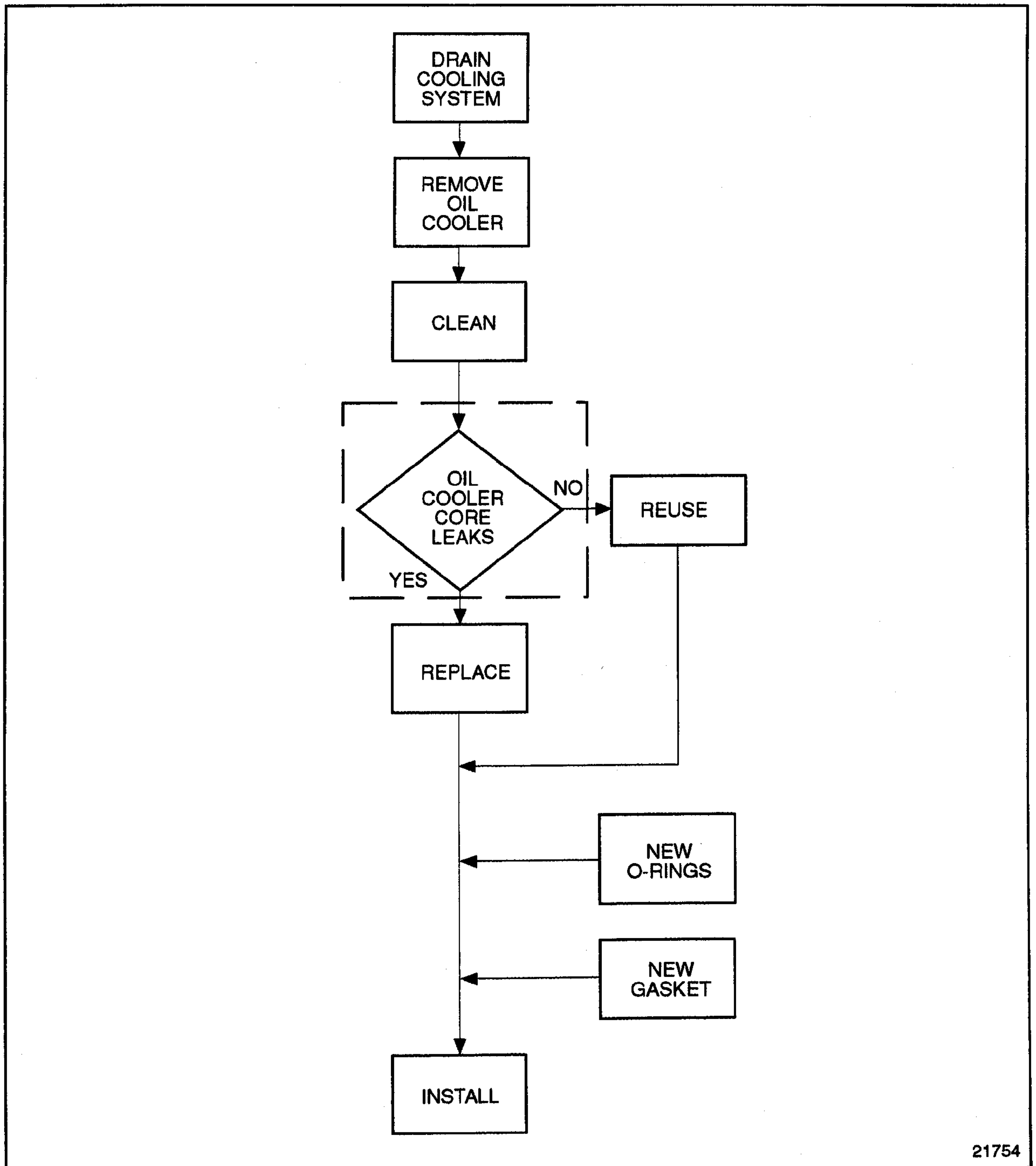



**Figure 3-27 Flowchart for Repair or Replacement of Oil Cooler**

### 3.8.2 Removal of Oil Cooler

Remove the oil cooler core and housing as follows:

1. Drain the cooling system by opening the drain cocks at the right rear of the cylinder block, and in the bottom of the water pump housing.
2. Disconnect the hose from the water pump at the lower neck of the oil cooler housing.
3. Match-mark the oil cooler core and housing to ensure correct reinstallation.
4. Remove the bolts that attach the oil cooler housing and core to the oil filter adaptor.
5. Place a pry bar between the oil cooler housing and cylinder block, just below the upper neck. Gently pry the oil cooler housing from the cylinder block and the oil filter adaptor.
6. Use a gasket scraper or chisel and a fiber mallet or plastic hammer to separate the oil cooler core and housing.
7. Remove all traces of gasket material from the oil cooler and housing.

### 3.8.3 Cleaning of Oil Cooler

Clean the oil cooler core prior to inspection as follows:

1. Remove the core from the oil cooler.

**CAUTION:**

**To avoid injury from chemical burns, wear a face shield and neoprene or PVC gloves when handling sensor hoses.**

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

**CAUTION:**

**To avoid injury when using chemical substances, it is essential to observe the manufacturer's instruction for use, safety, and waste disposal.**

**CAUTION:**

**To avoid injury when using caustic cleaning agents, follow the chemical manufacturers usage, disposal, and safety instructions.**

**NOTICE:**

Do not attempt to clean an oil cooler when an engine failure releases metal particles from worn or broken parts into the lubricating oil. The oil cooler core must be replaced. Otherwise, severe engine damage may result.

2. Circulate a solution of 1,1,1-trichloroethylene through the core passages with a force pump to remove the carbon and sludge.

3. Clean the core before the sludge hardens.
4. If the oil passages are badly clogged, circulate an alkaline solution through the core and flush thoroughly with clean, hot water.

Clean the outside of the core:

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

**CAUTION:**

**To avoid injury when using chemical substances, it is essential to observe the manufacturer's instruction for use, safety, and waste disposal.**

1. Mix the following solutions: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one third muriatic acid and two-thirds water.
2. Immerse the core in the solution.
3. Watch the process carefully. When bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution.
4. Thoroughly flush it with clean, hot water.
5. Dip the core in light oil.

### 3.8.3.1 Inspection of Oil Cooler

Inspect oil cooler as follows:

| NOTICE: |
|---|
| In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent corrosion to its internal components. Refer to section 13.13.4. |

1. Make a suitable plate and gasket using oil cooler as a template. Use a gasket made from rubber to insure a tight seal.
2. Drill and tap the plate prior to mounting to permit an air hose fitting to be attached at the inlet side of the core. See Figure 3-28.

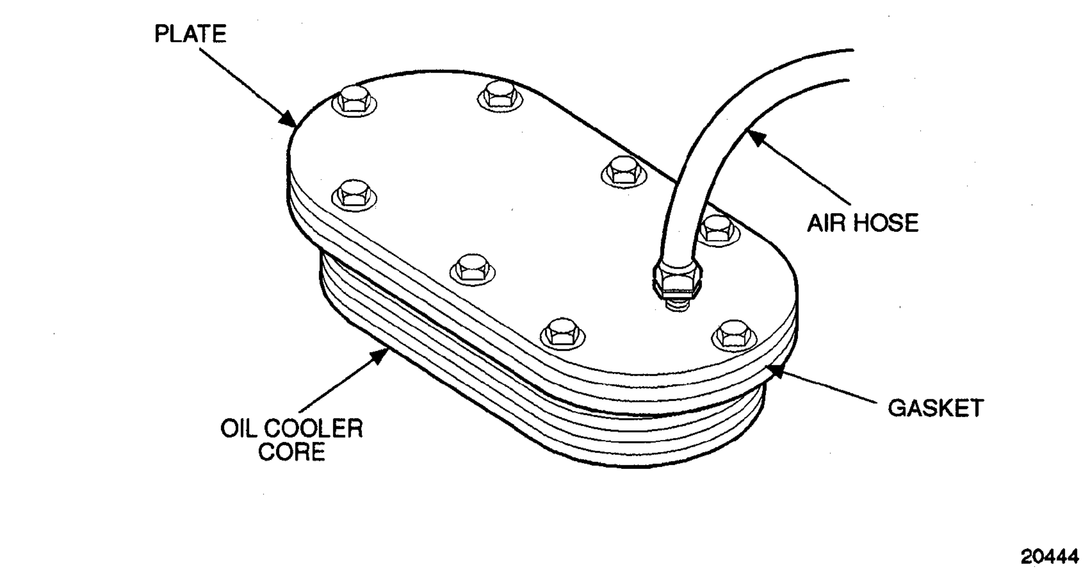



**Figure 3-28 Preparing Oil Cooler Core for Pressure Test**

3. Attach plate to flanged side of oil cooler core using suitable nuts, washers and bolts.

**CAUTION:**

**To avoid injury from failure of a fitting, hose, or oil cooler core, wear a face shield or goggles when conducting a pressure test.**

4. Attach an air hose to the air hose fitting.
5. Regulate air pressure to 517-690 kPa (75-100 lb/in.$^2$) and submerge the oil cooler and plate assembly in a container of water heated to 82°C (180°F).
   [a] Check for leaks as indicated by air bubbles in the water.
   [b] If leaks are indicated, replace the core.
6. After the pressure check is completed, remove the plate and air hose from the cooler core.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

7. Dry the core with compressed air.

### 3.8.4 Installation of Oil Cooler

Install the oil cooler core as follows:

1. Lubricate new O-rings with a light coat of petroleum jelly. See Figure 3-26.
2. Install the new O-rings in the counterbores in the oil filter adaptor.
3. Coat the O-ring with ethylene glycol (coolant).
4. Install a new O-ring in the groove on the oil cooler housing outlet neck.
5. Install a new gasket on the face of the core that will contact the housing.

| NOTICE: |
|---|
| Use care when installing the oil cooler housing to prevent damaging the outlet neck O-rings on the sharp edges of the opening in the cylinder block. Some cleaning of the block opening is usually needed. |

6. Install the core to the housing and install the assembly on the oil filter adaptor.
7. Align the oil cooler housing assembly to the oil filter adaptor. Install the ten oil cooler housing bolts and torque to 30-38 N·m (22-28 lb·ft) using the correct sequence. See Figure 3-29.

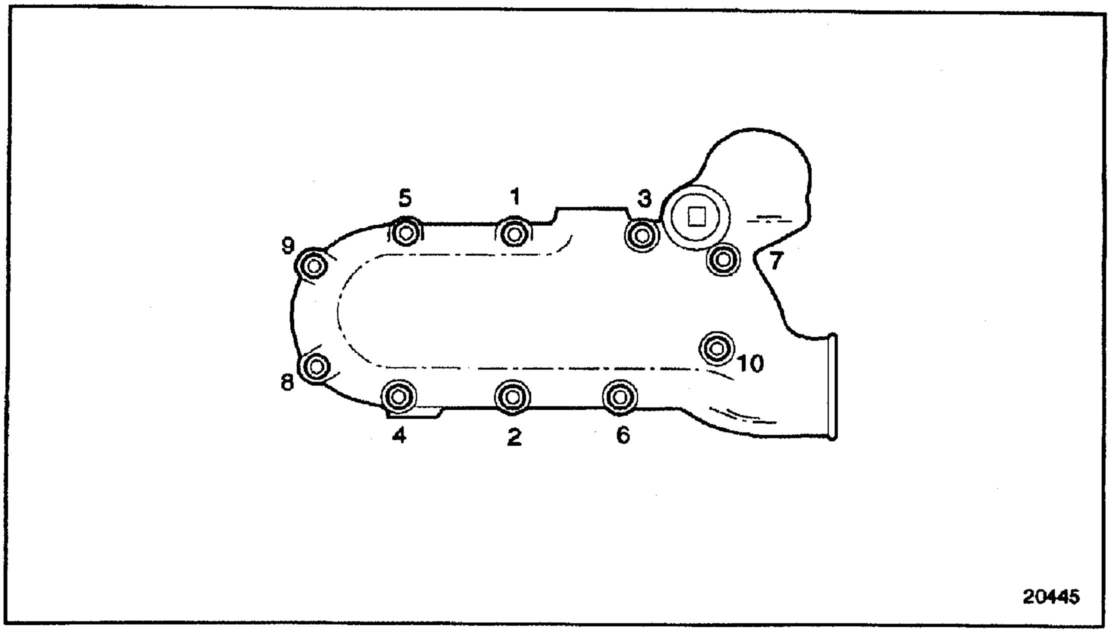



**Figure 3-29 Oil Cooler Housing Bolt Torque Sequence**

8. Position the hose and clamps in place at the lower neck of the oil cooler housing, ensure the clamps are positioned inside the lip on both the housing and tube. Tighten the clamps.
9. Close the draincocks in the cylinder block and water pump housing. Fill the cooling system. Refer to section 13.13.4.
10. Fill the lubricating system. Refer to section 13.13.1.
11. Refer to section 11.3 for verification of proper oil cooler installation.

# 3.9 OIL COOLER (PRE-1991 ENGINES)

To perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, and it cannot carry away enough heat. As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive.

While performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat, and this heat must be dissipated by an oil cooler.

Pre-1991 engines use 4, 6, 7, or 8 plate oil coolers, depending on the horsepower. Ensure that the correct oil cooler is used.

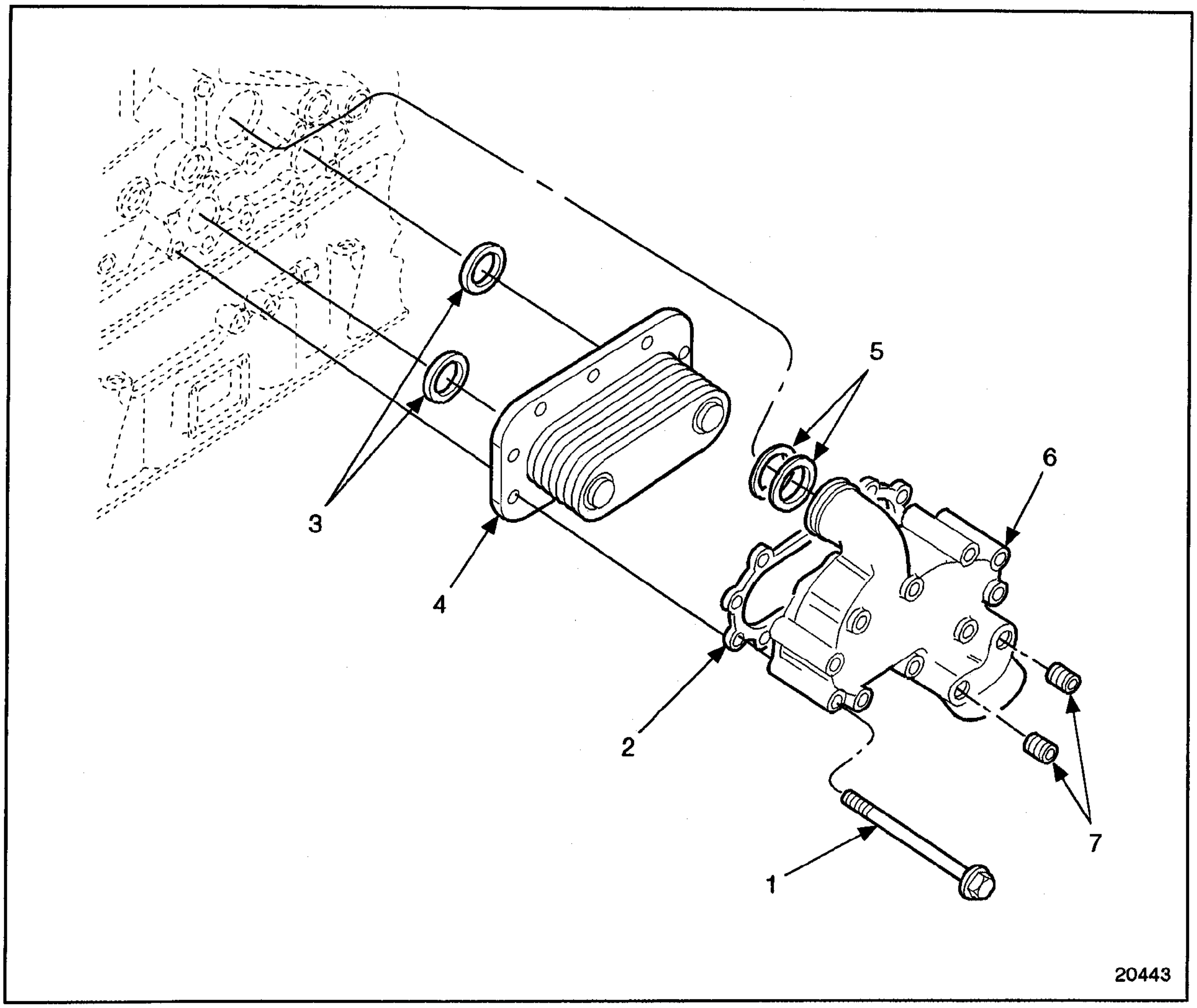
The lubricating oil cooler is mounted on the right side of the cylinder block near the water pump. See Figure 3-25.

To ensure continued engine lubrication if the oil cooler becomes plugged, a bypass passage located at the oil inlet to the cooler, allows oil to bypass the cooler and flow directly to the oil gallery in the cylinder block.

Cooling water is circulated through the oil cooler housing completely surrounding the oil cooler core. Therefore, whenever an oil cooler is assembled, care must be taken to have the proper gaskets in place and the retaining bolts tight to ensure good sealing.

A design change was made to the oil cooler housing and the mounting on Series 60 engines built after 6R37023. Because of this change, the two designs are serviced differently.

The coolant outlet oil cooler housing uses two large rubber O-rings seated in a groove in the outlet neck. See Figure 3-30.




1. Bolt, Oil Cooler Housing-to-Block (10)
2. Gasket, Oil Cooler-to-Housing
3. O-rings, Small (2)
4. Oil Cooler
5. O-rings, Large (2)
6. Oil Cooler Housing
7. Pipe Plugs (2)

**Figure 3-30 Oil Cooler Housing and Related Parts (Pre-1991 Engines)**

Two small O-rings are positioned in cylinder block counterbores to seal the lubricating oil passages between the block and the cooler core.

The oil cooler housing is attached to the cylinder block. The flow of oil is from the oil pump, through a vertical passage in the cylinder block, through the full-flow oil filters and then through the oil cooler core and the cylinder block main oil galleries.

### 3.9.1 Repair or Replacement of Oil Cooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-31.

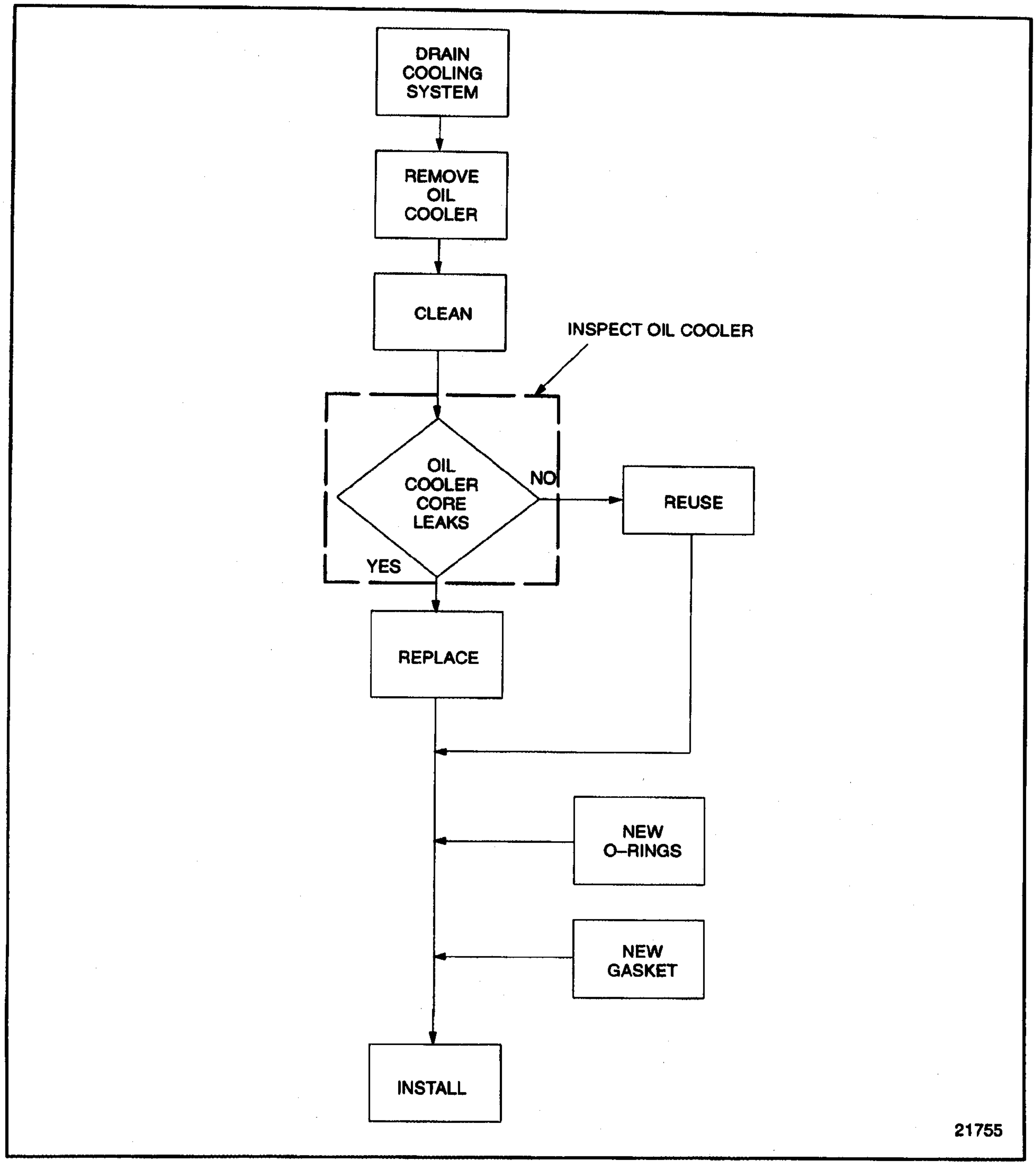



**Figure 3-31 Flowchart for Repair or Replacement of Oil Cooler**

### 3.9.2 Removal of Oil Cooler

Remove the oil cooler core and housing as follows:

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

**CAUTION:**

**To avoid injury when using chemical substances, it is essential to observe the manufacturer's instruction for use, safety, and waste disposal.**

**CAUTION:**

**To avoid injury when using caustic cleaning agents, follow the chemical manufacturers usage, disposal, and safety instructions.**

**NOTICE:**

Do not attempt to clean an oil cooler when an engine failure releases metal particles from worn or broken parts into the lubricating oil. The oil cooler core must be replaced. Otherwise, severe engine damage may result.

1. Drain the cooling system by opening the drain cocks at the right rear of the cylinder block, and in the bottom of the water pump housing.

2. Disconnect the hose from the water pump at the lower neck of the oil cooler housing.
3. Match-mark the oil cooler core and housing to ensure correct reinstallation.
4. Remove the bolts that attach the oil cooler housing and core to the cylinder block.
5. Place a pry bar between the oil cooler housing and cylinder block, just below the upper neck. Gently pry the oil cooler housing straight out from the cylinder block. Avoid bending the cooler housing neck that connects into the cylinder block.
6. Use a gasket scraper or chisel and a fiber mallet or plastic hammer to separate the oil cooler core and housing.
7. Remove all traces of gasket material from the oil cooler and housing.

### 3.9.3 Cleaning of Oil Cooler

Clean the oil cooler prior to inspection as follows:

1. Remove the core from the oil cooler.
2. Circulate a solution of 1,1,1-trichloroethylene through the core passages with a force pump to remove the carbon and sludge.
3. Clean the core before the sludge hardens.
4. If the oil passages are badly clogged, circulate an alkaline solution through the core and flush thoroughly with clean, hot water.

Clean the outside of the core:

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

**CAUTION:**

**To avoid injury when using chemical substances, it is essential to observe the manufacturer's instruction for use, safety, and waste disposal.**

**CAUTION:**

**To avoid injury when using caustic cleaning agents, follow the chemical manufacturers usage, disposal, and safety instructions.**

1. Mix the following solutions: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one third muriatic acid and two-thirds water.
2. Immerse the core in the solution.
3. Watch the process carefully. When bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution.
4. Thoroughly flush it with clean, hot water.
5. Dip the core in light oil.

### 3.9.3.1 Inspection of Oil Cooler

Inspect the oil cooler as follows:

| NOTICE: |
|---|
| In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent corrosion to its internal components. Refer to section 13.13.4. |

1. Make a suitable plate and gasket using the oil cooler as a template. Use a gasket made from rubber to ensure a tight seal.
2. Drill and tap the plate prior to mounting to permit an air hose fitting to be attached at the inlet side of the core. See Figure 3-32.

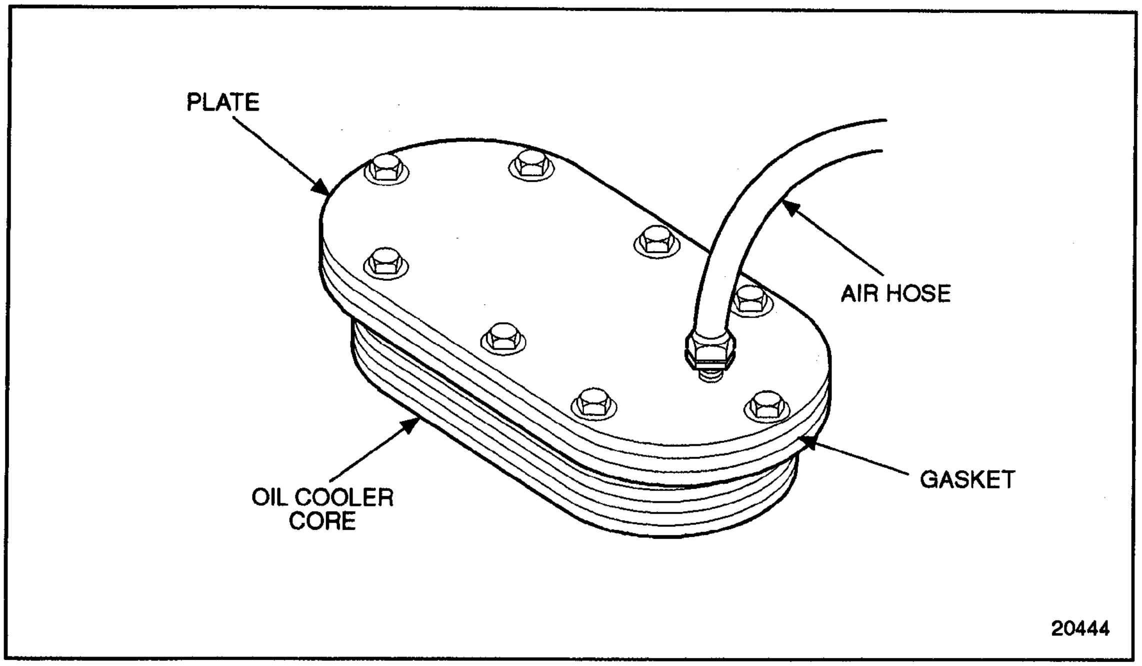



**Figure 3-32 Preparing Oil Cooler Core for Pressure Test**

3. Attach plate to flanged side of oil cooler core using suitable nuts, washers and bolts.

**CAUTION:**

**To avoid injury from failure of a fitting, hose, or oil cooler core, wear a face shield or goggles when conducting a pressure test.**

4. Attach an air hose to the air hose fitting.
5. Regulate air pressure to 517-690 kPa (75-100 lb/in.$^2$) and submerge the oil cooler and plate assembly in a container of water heated to 82°C (180°F).
   [a] Check for leaks as indicated by air bubbles in the water.
   [b] If leaks are indicated, replace the core.
6. After the pressure check is completed, remove the plate and air hose from the cooler core.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

7. Dry the core with compressed air.

### 3.9.4 Installation of Oil Cooler

Install the oil cooler core as follows:

1. Lubricate the new O-rings with a light coat of petroleum jelly.
2. Install the O-rings in the counterbores in the cylinder block.
3. Replace the O-rings on the oil cooler housing outlet neck.
4. Coat the O-ring with ethylene glycol (coolant).
5. Install the O-ring in the groove on the oil cooler housing outlet neck.
6. Install the guide studs, J 35786, into two threaded holes in the cylinder block. See Figure 3-33.

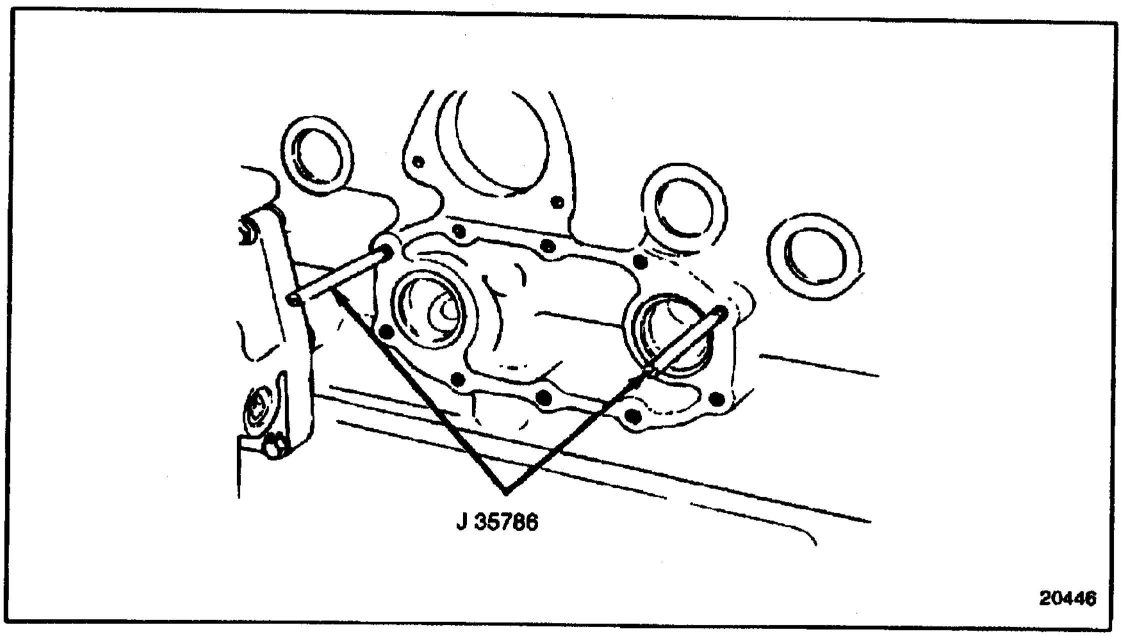



**Figure 3-33 Oil Cooler Guide Stud Installation**

| NOTICE: |
| --- |
| Use care when installing the oil cooler housing to prevent damaging the outlet neck O-rings on the sharp edges of the opening in the cylinder block. Some cleaning of the block opening is usually needed. |

7. Install a new gasket on the face of the core that will contact the housing.

8. Install the core to the housing and install the assembly on the guide studs.
9. Use a fiber mallet or plastic hammer to seat the oil cooler assembly by striking the snout and lower area with several sharp blows.
10. Install at least two oil cooler housing-to-cylinder block bolts and finger-tighten.
11. Remove the guide studs.
12. Install the remaining bolts. Torque the ten bolts to 30-38 N·m (22-28 lb·ft) using the proper sequence. See Figure 3-34.

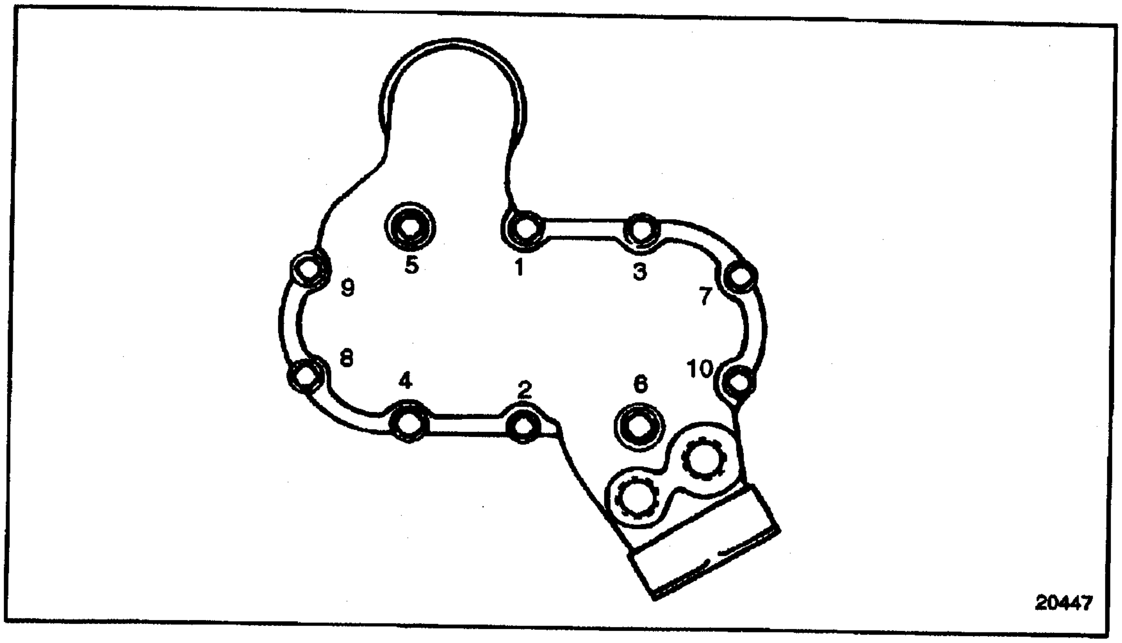
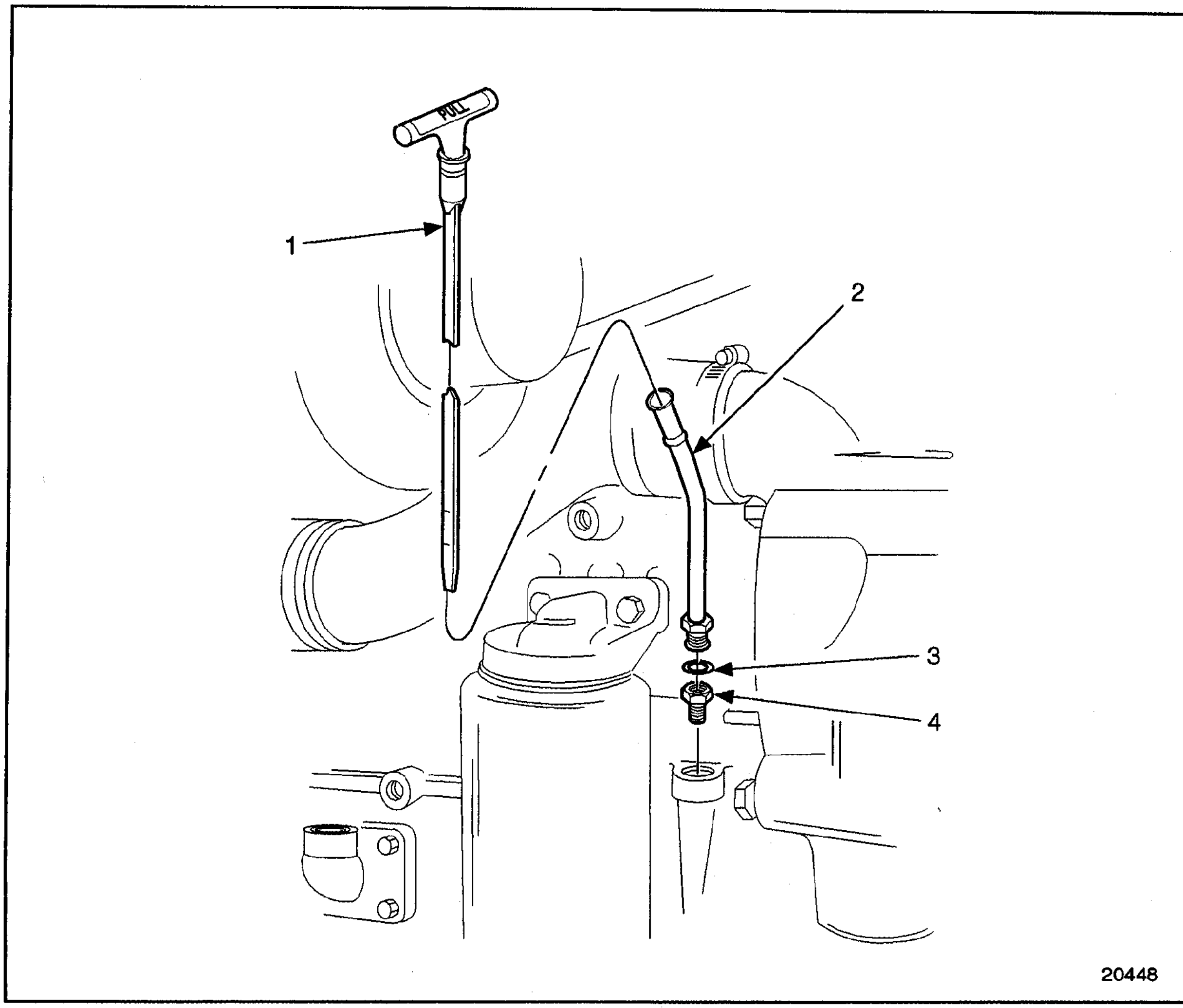



**Figure 3-34 Oil Cooler Housing Bolt Torque Sequence**

13. Coat the threads of the pipe plug with Loctite® Pipe Sealer with Teflon® PT-7260 (or equivalent) before installation.
14. Position the hose and clamps in place at the lower neck of the oil cooler housing, ensure the clamps are positioned inside the lip on both the housing and tube. Tighten the clamps.
15. Close the drain cocks in the cylinder block and water pump housing.
16. Fill the cooling system. Refer to section 13.13.4.
17. Fill the lubricating system. Refer to section 13.13.1.
18. Refer to section 11.3 for verification of proper oil cooler installation.

# 3.10 OIL LEVEL DIPSTICK ASSEMBLY

A steel ribbon-type oil level dipstick may be used to check the level of oil in the engine oil pan. The dipstick is located in a tube attached by a threaded adaptor to an opening in the oil pan. See Figure 3-35.




1. Dipstick Gage
2. Dipstick Tube Assembly
3. Copper Seal
4. Adaptor

**Figure 3-35 Oil Level Dipstick Location**

Snap action dipsticks have locking tangs and an O-ring seal in the tee-handle. A copper sealing ring between the adaptor and dipstick tube insures a tight seal.

**NOTICE:**

Maintain the oil level between the full and low marks on the dipstick. Never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling may cause the oil to be churned by the balance shafts and crankshaft throws, causing foaming or aeration of the oil. Operation below the low mark may expose the pump pickup, causing aeration, loss of pressure and engine damage.

Check the oil level after the engine has been stopped for a minimum of 20 minutes to permit oil in the various parts of the engine to drain back into the oil pan.

**NOTE:**
Engine oil capacity can vary, depending on the oil pan used and the engine application.

For total oil capacity refer to the engine application manual or contact an authorized Detroit Diesel distributor.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade, or if insufficient time is allowed for oil to drain back to the sump.

The current dipstick adaptor has a thicker wall than the former adaptor and requires a copper seal between the adaptor and the nut on the oil gage tube assembly. See Figure 3-35.

### 3.10.1 Repair or Replacement of Oil Dipstick Assembly

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-36.

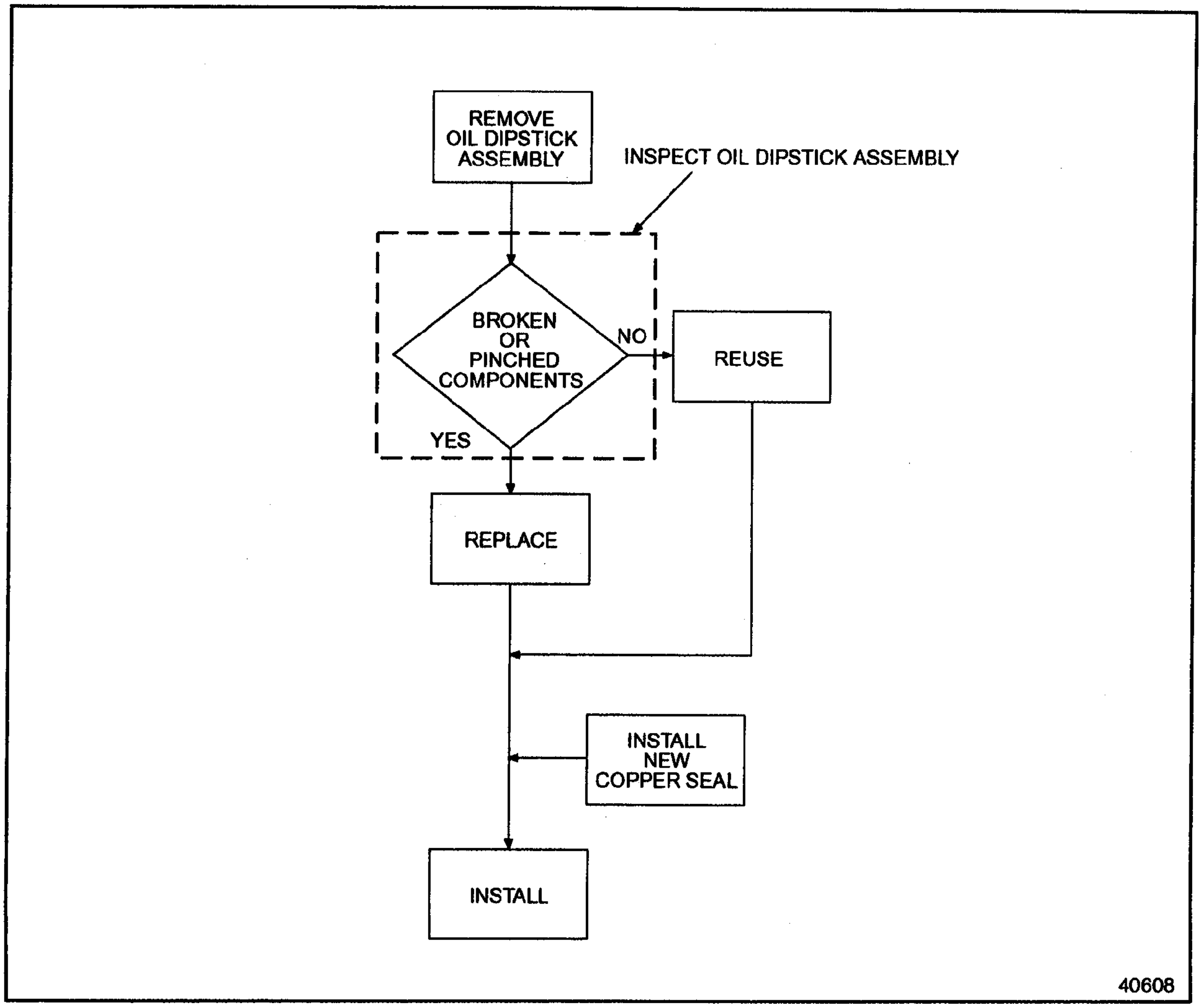



**Figure 3-36 Flowchart for Repair or Replacement of Oil Dipstick Assembly**

### 3.10.2 Removal of Oil Dipstick Assembly

Precleaning is not necessary.

Remove oil dipstick assembly as follows:

1. Remove dipstick from dipstick adaptor.
2. Remove oil tube assembly, copper seal, and dipstick adaptor from cylinder block. Discard copper seal.

#### 3.10.2.1 Inspection of Oil Dipstick Assembly

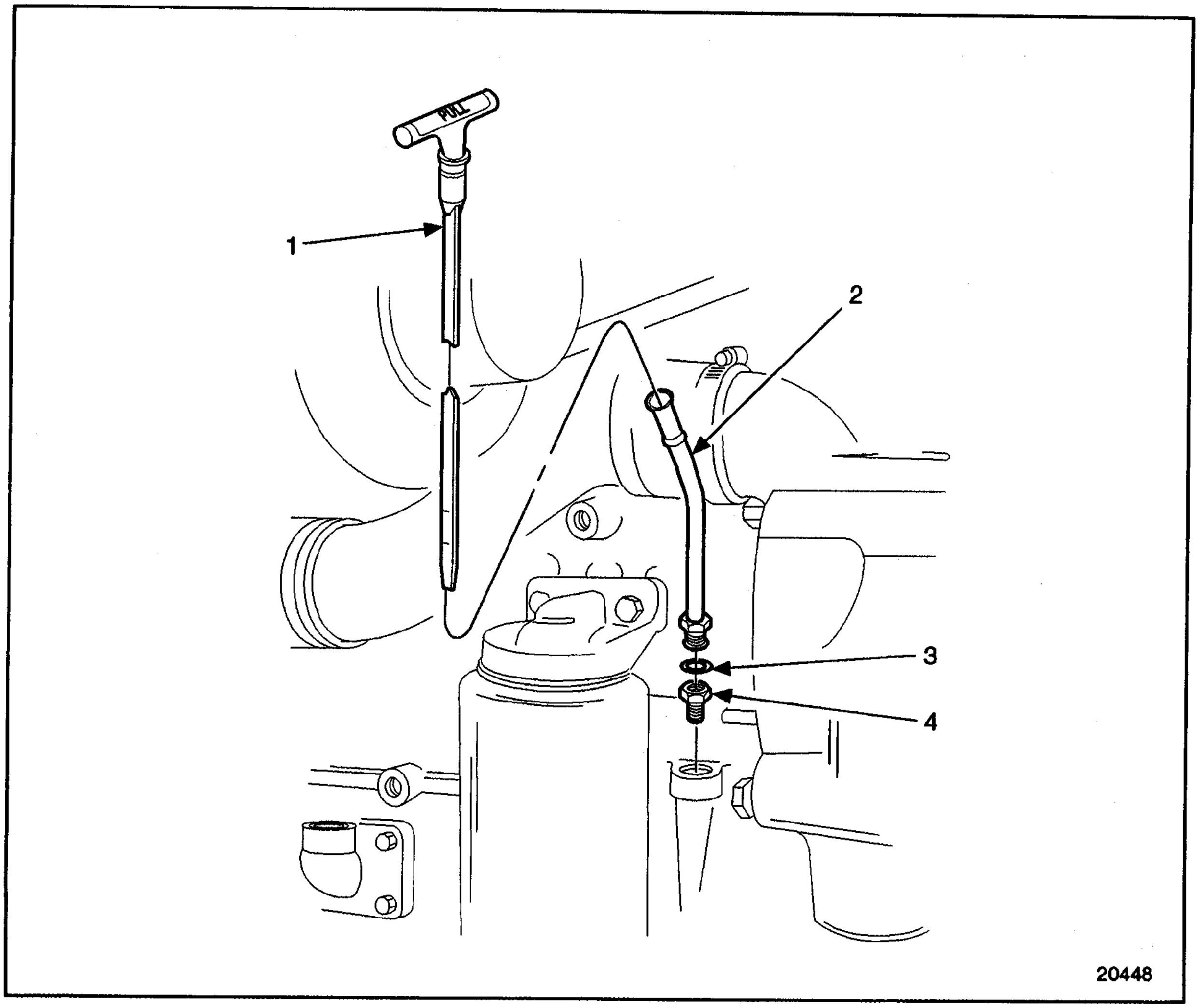
Inspect oil dipstick assembly as follows:

1. Inspect dipstick assembly for any damaged parts. Check components for any broken or pinched parts.
   [a] If any components are damaged, replace with new parts.
   [b] If components are not damaged, reuse the parts.

### 3.10.3 Installation of Oil Dipstick Assembly

Assemble oil dipstick assembly as follows:

1. Install dipstick adaptor into cylinder block. Torque to 22 N·m (16 lb·ft). See Figure 3-37.




1. Dipstick Gage
2. Dipstick Tube Assembly
3. Copper Seal
4. Adaptor

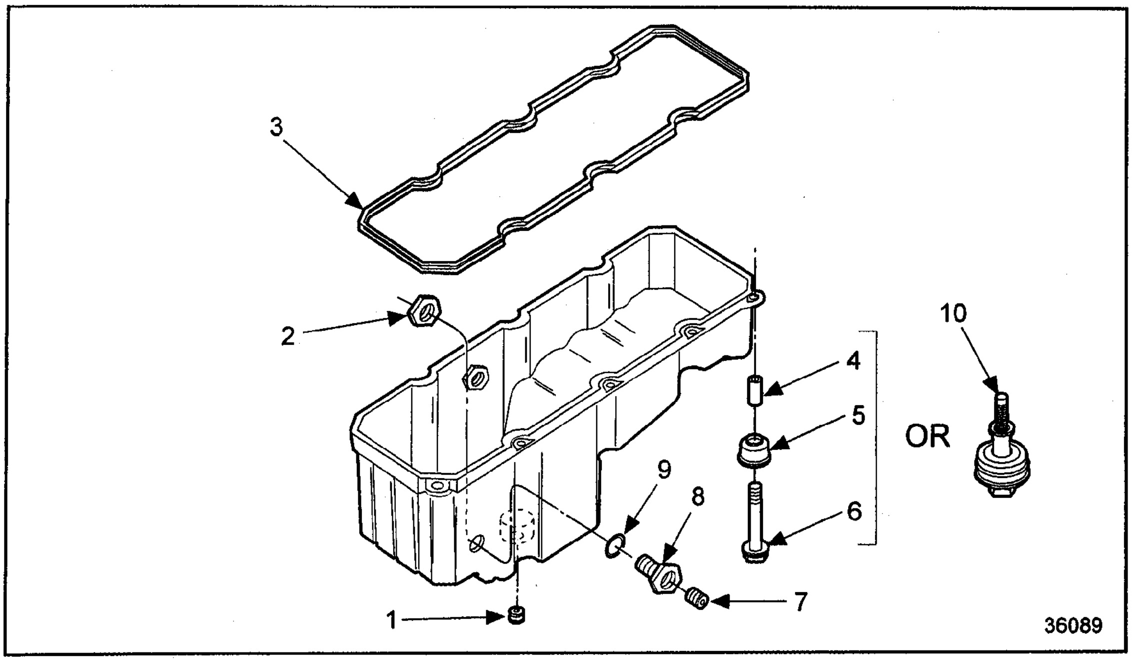
**Figure 3-37 Dipstick Adaptor with Seal**

2. Insert the new copper seal and thread the oil gage tube assembly nut into the adaptor.
3. While holding the adaptor with a wrench, properly align the oil gage tube assembly.
4. Tighten the nut on the tube securely.
5. Install dipstick.

## 3.11 OIL PAN

The oil pan used on the Series 60 engine is made of plastic (epoxy vinyl ester) or aluminum. For engines built after April 1999, a one-piece bolt assembly is used with the improved plastic front sump and rear sump oil pans and isolator seal. For engines built prior to April 1999, a reusable isolator seal is used between the oil pan and engine block. See Figure 3-38.

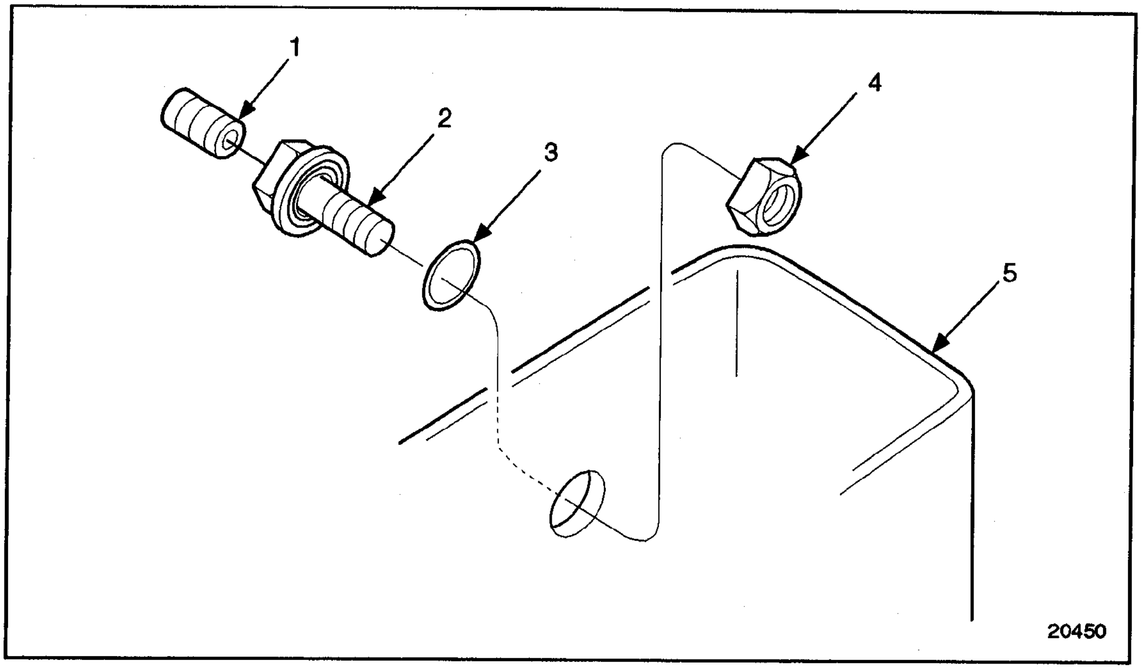
**NOTE:**
To expedite oil pan seal installation, use a soapy water solution to assist in installing the seal into the groove of the pan. When installing a new pan on an engine prior to serial number 6R490000 (built March 1, 1999), shift the pan toward the front of the engine before tightening the bolts. This will help eliminate the potential for any interference between the flywheel housing and the oil pan.




1. Drain Plug
2. Nut
3. Isolator Seal
4. Sleeve
5. Isolator and Washer
6. Bolt
7. Plug
8. Insert
9. Seal
10. Bolt ASM, Replaces 4, 5, 6

**Figure 3-38 Typical Oil Pan Assembly**

The plastic oil pan has side plugs that are threaded into a special stainless steel insert which is restrained by a nut inside the pan. Sealing is provided by a fluoroelastomer seal ring that fits into a groove machined on the flange of the insert. See Figure 3-39.




1. Plug
2. Insert
3. Seal
4. Nut
5. Oil Pan

**Figure 3-39 Side Plug Detail**

Rubber isolator-washer assemblies and sleeves are used for attaching the oil pan. The metal sleeve spacer is inserted through the isolator and limits the travel of the oil pan bolts to prevent over-tightening and damaging the oil pan and isolator.

Effective August 1995, isolators made of an improved vibration-absorbing material were released to reduce noise emissions. In addition, isolator bolt sleeve length was increased by 0.8 mm (0.032 in.) to accommodate the slightly longer isolators.

When installing a pipe plug, coat the threads with Loctite® PT 7271 sealant (or equivalent), hold the insert to keep it from turning, and torque the plug to 45-56 N·m (33-41 lb·ft).

### 3.11.1 Repair or Replacement of Oil Pan

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-40.

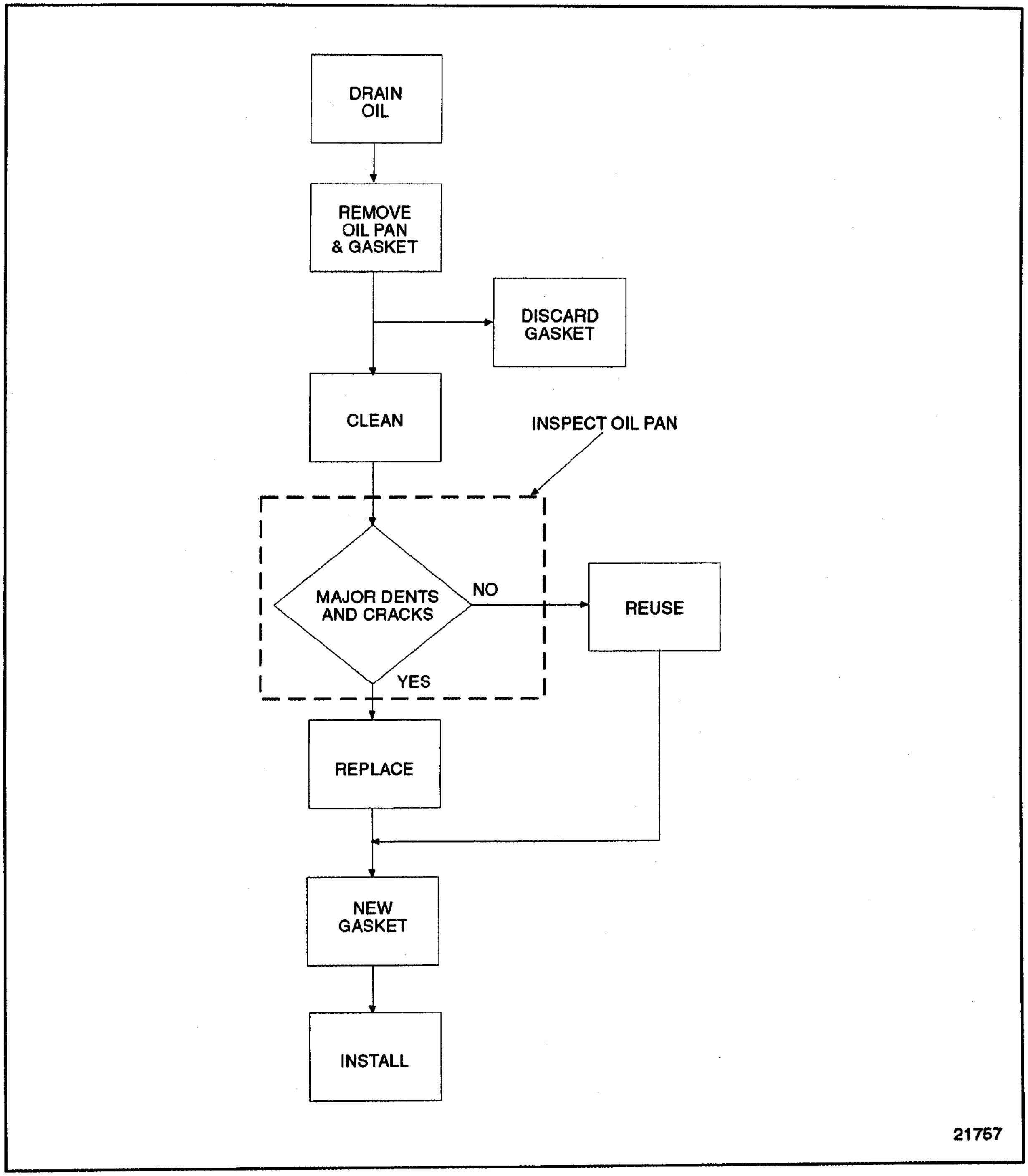



**Figure 3-40 Flowchart for Repair or Replacement of Oil Pan**

### 3.11.2 Removal of Oil Pan

Precleaning is not necessary.

| NOTICE: |
|---|
| Do not support the engine on the oil pan. Damage to the oil pan or engine could result. |

**NOTE:**
On almost all engine applications it is possible to remove the oil pan without removing the engine.

If the engine is to be removed from the vehicle, the oil pan should be left in place until the engine is removed.

The procedure for removing the oil pan will vary with each installation. However, the following procedures will generally apply.

| NOTICE: |
|---|
| When removing a side plug, hold the flats of the insert with a 2-1/8 in. open end or large adjustable wrench to keep it from turning. If the insert is loosened, it may be necessary to remove the oil pan and tighten the nut to prevent a possible oil leak. If required, torque the nut to 186-199 N·m (137-147 lb·ft). |

Remove the oil pan as follows:

1. Remove the drain plug and drain the engine oil.
2. Remove the ten oil pan bolts, washers, isolators and sleeves. Remove the counter bolts on each side last.
3. Remove the oil pan, taking care not to damage the oil pump inlet pipe and screen.
4. Remove the oil pan isolator seal and discard.

### 3.11.3 Cleaning of Oil Pan

Clean the oil pan prior to inspection as follows:

1. Clean the oil pan and attaching hardware with clean fuel oil.

| CAUTION: |
|---|
| **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.** |

2. Dry with compressed air.

| NOTICE: |
|---|
| Do not use solvents to clean isolators. Damage to the isolator will result. |

3. Clean the surfaces of the cylinder block, gear case and flywheel housing where they mate with the oil pan.

#### 3.11.3.1 Inspection of Oil Pan

Inspect the oil pan, inserts, oil and bolt isolators as follows:

1. Check for dryness, cracks or tears.
   [a] If isolator is damaged, replace with new part.
   [b] If isolator is not damaged, reuse the part.
2. Check oil pan inserts and nut assemblies for tightness.
   [a] If inserts and nut assemblies are loose, torque to 183-197 N·m (135-145 lb·ft).
3. Check oil pan for major dents, cracks and other damage.
   [a] If oil pan is damaged, replace with new part.
   [b] If oil pan is not damaged, reuse the part.

## 3.11.4 Installation of Oil Pan

Install the oil pan as follows:

1. Insert the raised lip portion of the isolator seal into the groove in the oil pan.
2. Press down on the isolator seal and insert it completely around the oil pan. Be careful not to stretch or bunch the seal. For best results, install the seal at each corner, then at points half way between the corners. Continue in this manner, halving the distance and seating the seal.
3. Insert a metal sleeve spacer into each isolator.
4. Install the ten oil pan bolts into isolator assemblies.
5. Ensure the joint surfaces of the gear case and the cylinder block, the gear case cover and gear case, and the flywheel housing and the cylinder block are cleaned and there is no damage to prevent sealing.
6. Apply a 3 mm (1/8 in.) bead of RTV across joints shown. See Figure 3-41.

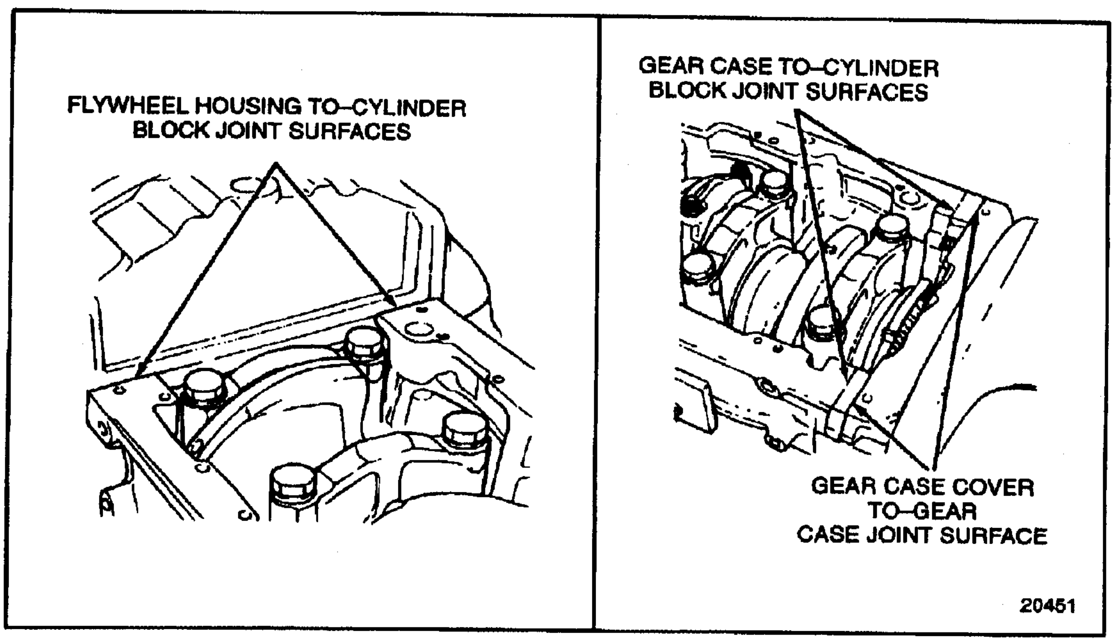



**Figure 3-41 RTV Application**

7. Install the oil pan assembly in position on the cylinder block.

8. Ensure that the isolator seal has not been disturbed. Torque the ten oil pan bolt assemblies to 24-30 N·m (18-22 lb·ft), using the proper sequence. See Figure 3-42.

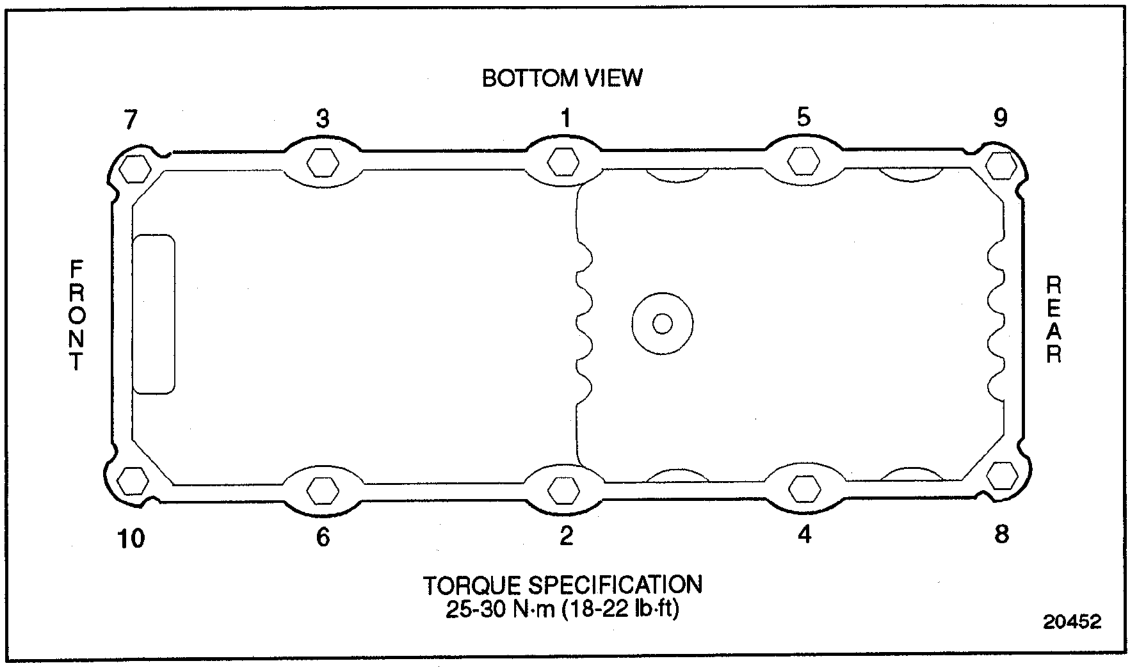



**Figure 3-42 Oil Pan Bolt Sequence**

9. Install and torque the 3/4 in.-14 square, magnetic, oil drain plug to 45-56 N·m (33-41 lb·ft).
10. Install and tighten any other plugs that were removed from the oil pan.

**NOTE:**
When installing a pipe plug, coat the threads with Loctite® PT 7271 sealant (or equivalent).

11. Refill the crankcase with lubricating oil. Refer to section 13.13.1.
12. Refer to section 11.3 for verification of proper oil pan installation.

# 3.12 VENTILATING SYSTEM

Vapors, formed within the engine, are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the normal seepage of a small amount of air and combustion gases past the piston rings. These gases are swept up through the engine and pass through a crankcase breather. On vehicle and industrial engines the gases are then vented to the atmosphere.

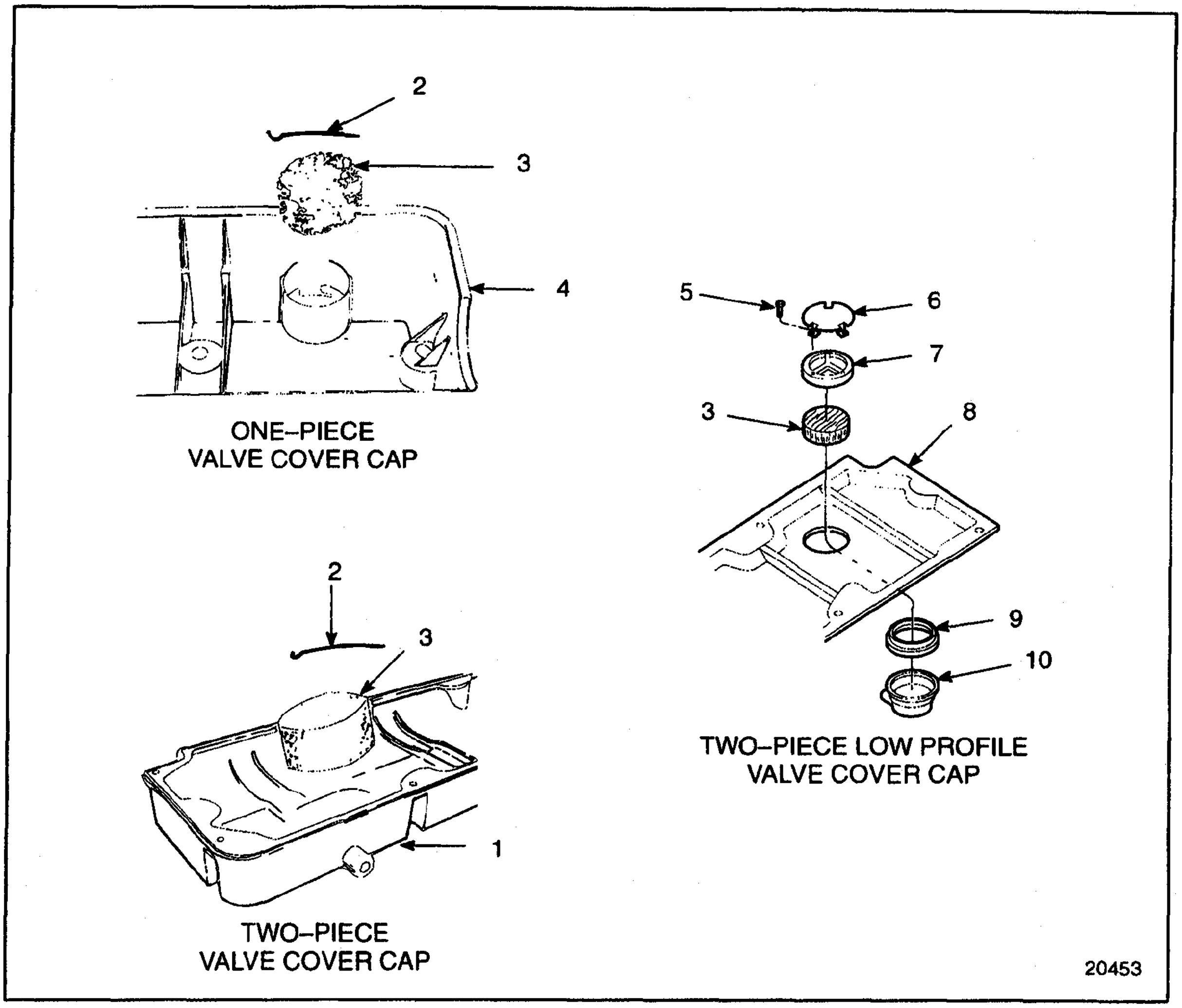
Breather extension hoses may be required on certain Series 60 engines used in on-highway vehicle applications. Under certain conditions, the vapors from an operating engine may be circulated through the battery charging alternator by the alternator cooling fan. Excessive ingestion of vapors may lead to alternator malfunction. This can occur if the internal components of the alternator become coated with oil-laden dust or road grit.

To minimize the potential for this condition, check the length of the engine breather tube and add an extension hose, if necessary. For proper dissipation of vapors, the end of the breather hose *must* extend at least 12 inches below the oil pan rail.

Series 60 pleasure craft marine engines and certain commercial marine engines use a closed crankcase ventilation system. In this system, engine vapors are piped from the valve rocker cover breather into the air separator/air silencer assembly, where they mix with incoming air for combustion. The vapors are not vented to the atmosphere, as on vehicle and industrial engines. Any oil droplets contained in the vapor are trapped within the air separator and drain back to the crankcase. Refer to section 6.3 for air seperator information.

A wire mesh element is located inside the valve cover, or in a separate housing on the valve cover cap or at the gear case cover. This element traps excess engine oil particles in the vapor and returns them to the crankcase. See Figure 3-43.

**NOTE:**
The Series 60G automotive engine uses a closed crankcase breather system. Refer to section 6.5 for more information.




1. Two-piece Valve Cover Cap
2. Retainer Clip
3. Wire Mesh Element
4. One-piece Valve Cover
5. Screws
6. Baffle
7. Retainer
8. Valve Cover Cap
9. Seal
10. Breather Housing

**Figure 3-43 Wire Mesh Elements**

The former baffle, installed on engines between 6R128446 and 6R134254, has been replaced with the current baffle to redirect oil splash from the rocker arms. This prevents oil from contaminating the breather element.

### 3.12.1 Repair or Replacement of Ventilating System

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-44.

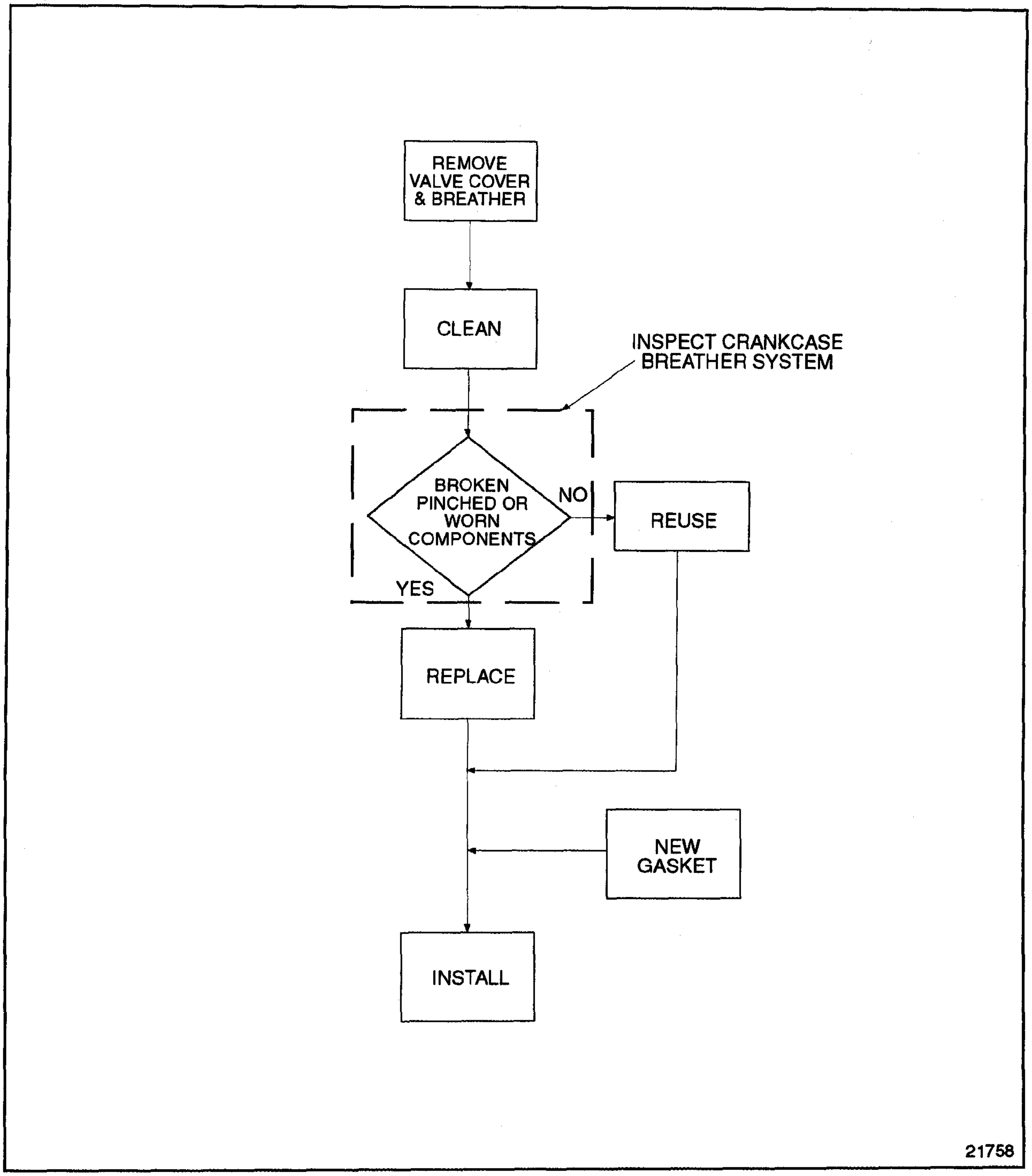



**Figure 3-44 Flowchart for Repair or Replacement of Ventilating System**

### 3.12.2 Removal of Ventilating System

Precleaning is not necessary.

Remove ventilating system as follows:

1. Remove the valve cover. Refer to section 1.6.2 for one-piece, refer to section 1.6.3 for two-piece, and refer to section 1.6.5 for three-piece rocker cover.
2. If the engine is equipped with a gear case cover breather, remove as follows:
   [a] Remove the five bolts that secure the breather-oil fill housing to the gear case cover. See Figure 3-45.

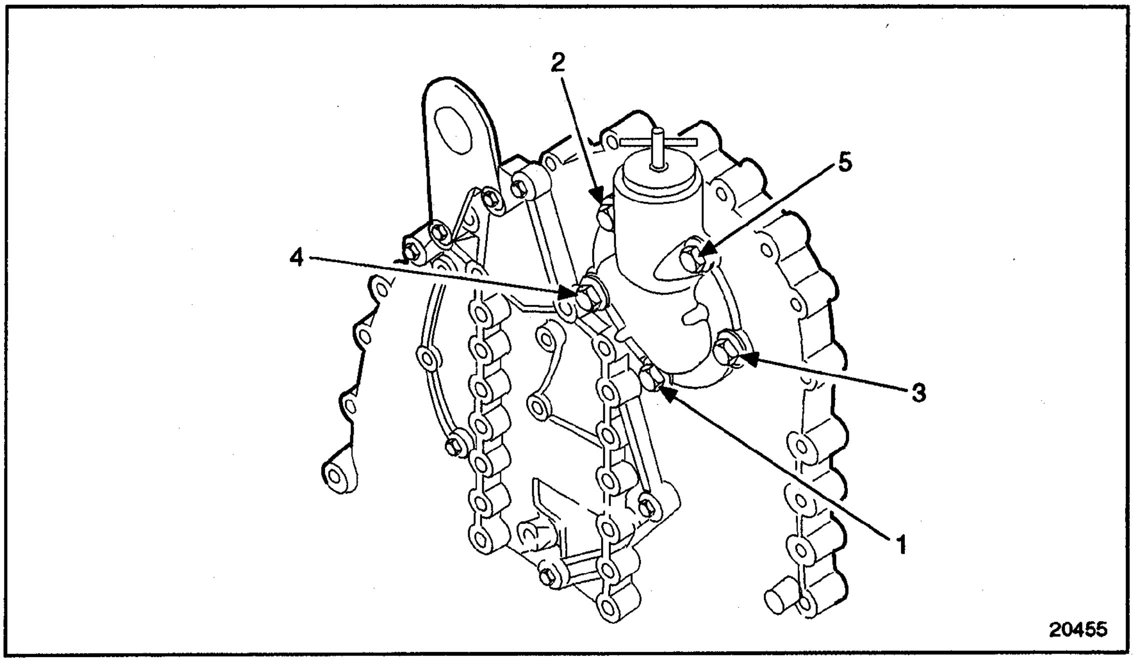
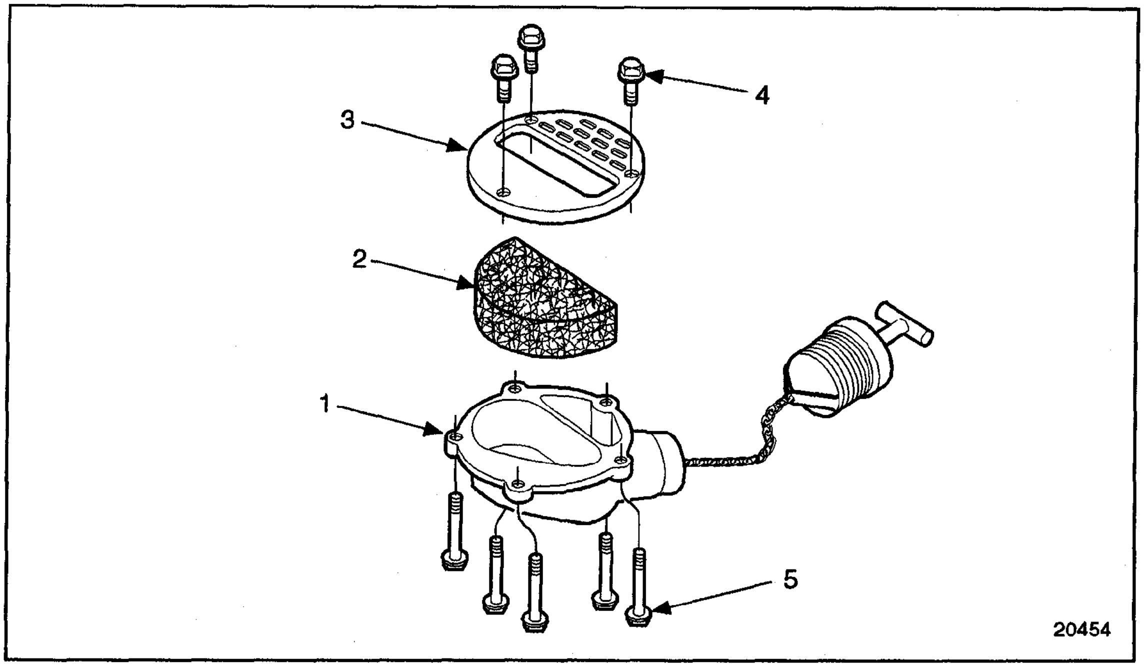



**Figure 3-45 Breather-Oil Fill Housing Bolt Location**

[b] Remove the three bolts that secure the retainer to the housing. See Figure 3-46.



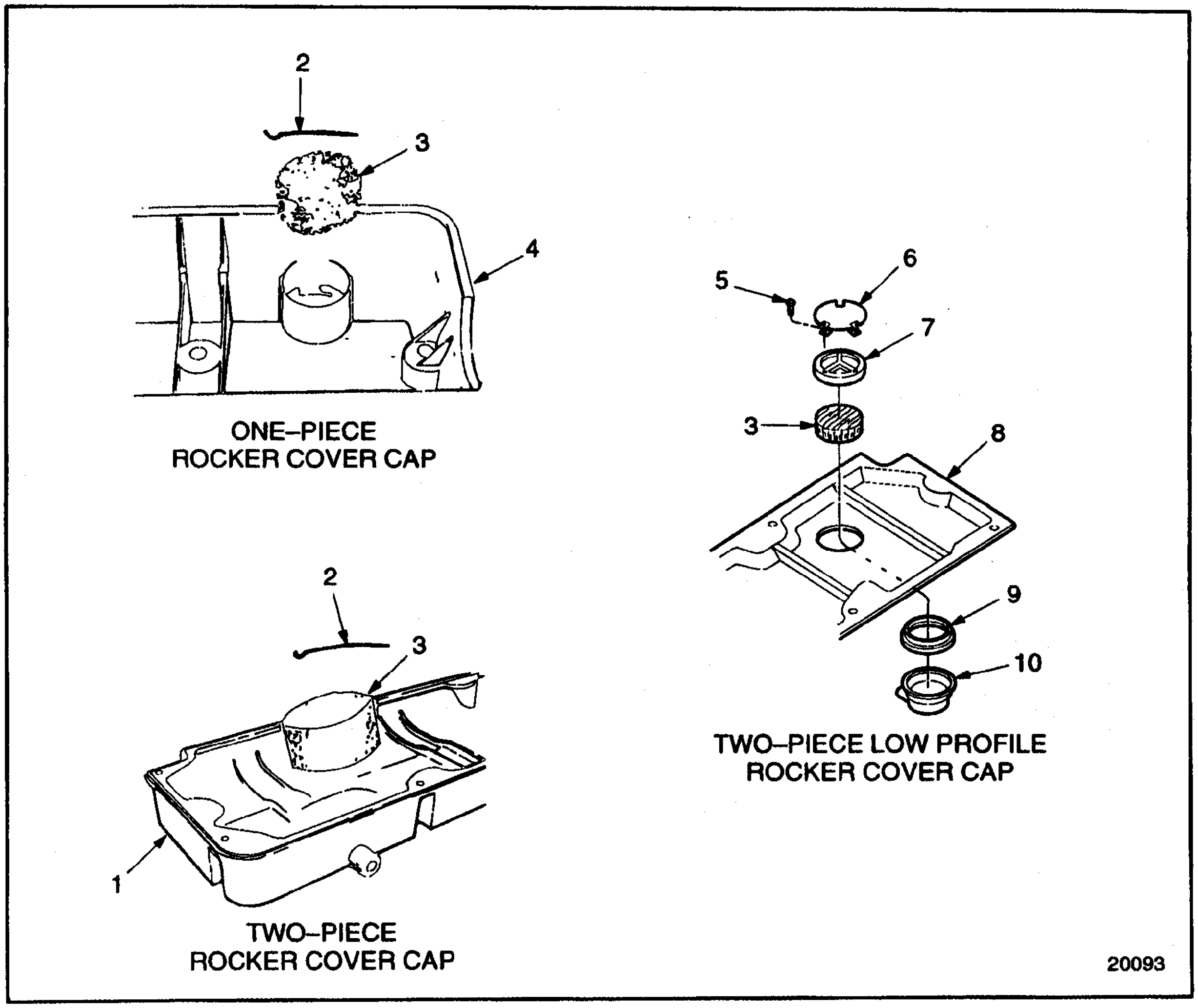

1. Breather Housing
2. Wire Mesh Element
3. Retainer
4. Bolts (3)
5. Bolts (5)

**Figure 3-46 Gear Case Cover-Mounted Breather Housing**

[c] Remove the retainer and wire mesh element from the breather housing.

3. If the engine is equipped with a breather mounted on the housing, remove as follows:

   [a] Remove the three screws, baffle, and end retainer on the breather housing. See Figure 3-47.




1. Two-piece Valve Rocker Cover
2. Retainer Clip
3. Wire Mesh Element
4. One-piece Rocker Cover
5. Screws
6. Baffle
7. Retainer
8. Rocker Cover Cap
9. Seal
10. Breather Housing

**Figure 3-47 Breather Housing-Mounted Breather**

   [b] Remove the breather housing seal and wire mesh element.

4. If the engine is equipped with a valve cover mounted breather, remove as follows:
   [a] Press the center of the spring steel retaining clip outward and disengage the straight end from the valve cover. Rotate the clip upward and remove clip.
   [b] Remove the wire mesh element from the valve cover.

#### 3.12.2.1 Inspection of Ventilating System

Inspect the ventilating system as follows:

1. Inspect the ventilating system for damaged parts. Check components for pinched, broken, worn, and unclean parts.
   [a] If any components are damaged, replace with new parts.
   [b] If components are not damaged, reuse the parts.

### 3.12.3 Cleaning the Ventilating System

Clean the wire mesh element components prior to inspection as follows:

1. Wash the components in clean fuel oil.

| **CAUTION:** |
|---|
| **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.** |

2. Blow dry with compressed air.

### 3.12.4 Installation of Ventilating System

Install the ventilating system as follows:

1. Install the gear case cover mounted breather as follows:
   [a] Install the wire mesh element in breather housing.
   [b] Install the three screws and retainer to breather housing. Torque the screws to 2.5 N·m (22 lb·in.).
   [c] Install new gasket, breather and oil fill housing and five bolts on gear case cover. Torque bolts to 30-38 N·m (22-28 lb·ft), using the proper torque sequence. See Figure 3-45.
2. Install the breather housing mounted breather as follows:
   [a] Install the wire mesh element in breather housing.
   [b] Install breather housing in valve cover.
   [c] Install retainer on valve cover.
   [d] Place the baffle on the retainer with three flat bolting flanges against the retainer.

**NOTE:**
**The baffle must be installed with bolting flanges against the retainer to permit proper engine breathing.**

   [e] Install the three screws into baffle and torque to 2.5 N·m (22 lb·in.).
3. Install the valve cover mounted breather as follows:
   [a] Install wire mesh element in valve cover.
   [b] Install retaining clip in valve cover by engaging curved end in valve cover and then engaging straight end.
4. Install valve covers. Refer to section 1.6.8for one-piece, refer to section 1.6.9 for two-piece or three-piece valve rocker cover.

# 3.A ADDITIONAL INFORMATION

**Description** **Page**

## SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

### Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 1-34 in the "General Information" section. The exceptions to standard fastener is listed in Table 3-1.

| FASTENER | SIZE | Torque, N·m (lb·ft) |
|---|---|---|
| Bolt, Oil Pan-to-Block | M10 x 1.5 | 24-30 (18-22) |

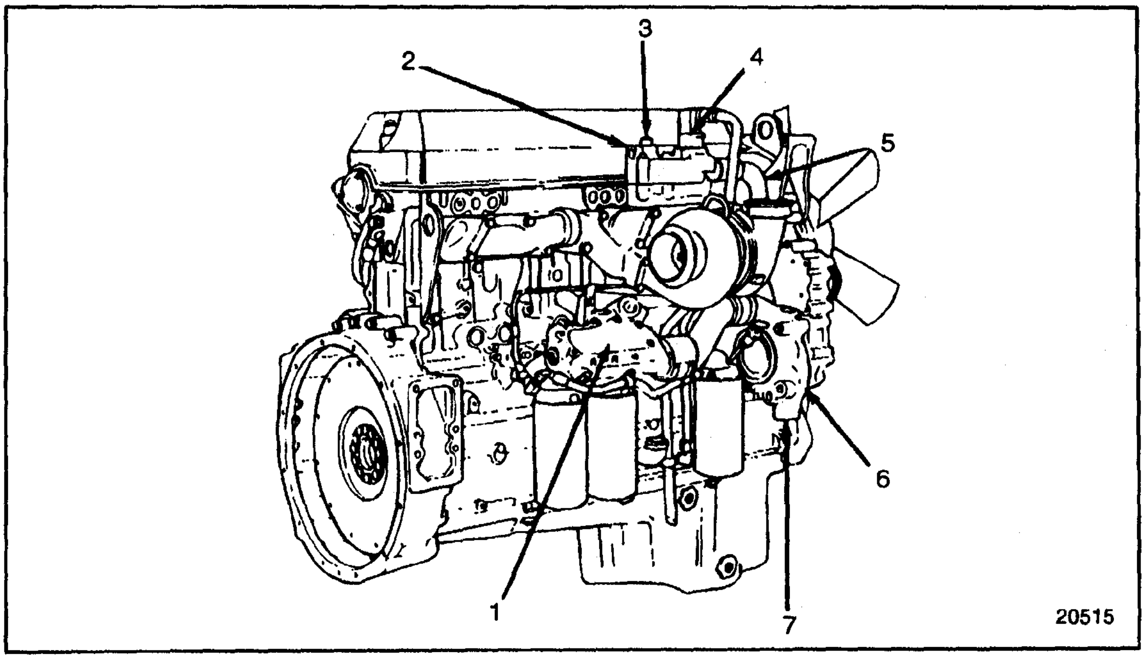
**Table 3-1 Exceptions To Standard Fastener Torque Specifications**

# 4 COOLING SYSTEM

## 4.1 COOLING SYSTEM OVERVIEW

The cooling system consists of the following components (see Figure 4-1):

- ☐ Water pump
- ☐ Pressure control cap
- ☐ Thermostat
- ☐ Engine cooling fan
- ☐ Coolant filter and conditioner
- ☐ Radiator or heat exchanger
- ☐ Charge air cooler raw water pump




1. Oil Cooler Housing
2. Thermostat Housing
3. Vent Line Outlet
4. Water Outlet (To Radiator)
5. Water Bypass Tube
6. Water Pump
7. Water Inlet

**Figure 4-1 Cooling System Components**

An OEM supplied radiator along with a factory installed and thermo-modulated fan are used to effectively dissipate the heat generated by the engine. A centrifugal-type water pump is used to circulate the engine coolant.

Two full blocking-type thermostats are used in the water outlet passage to control the flow of coolant, providing fast engine warm-up and regulating coolant temperature. Listed in Table 11-2 are the normal cooling system operational parameters.

The pressurized engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block. See Figure 4-2.

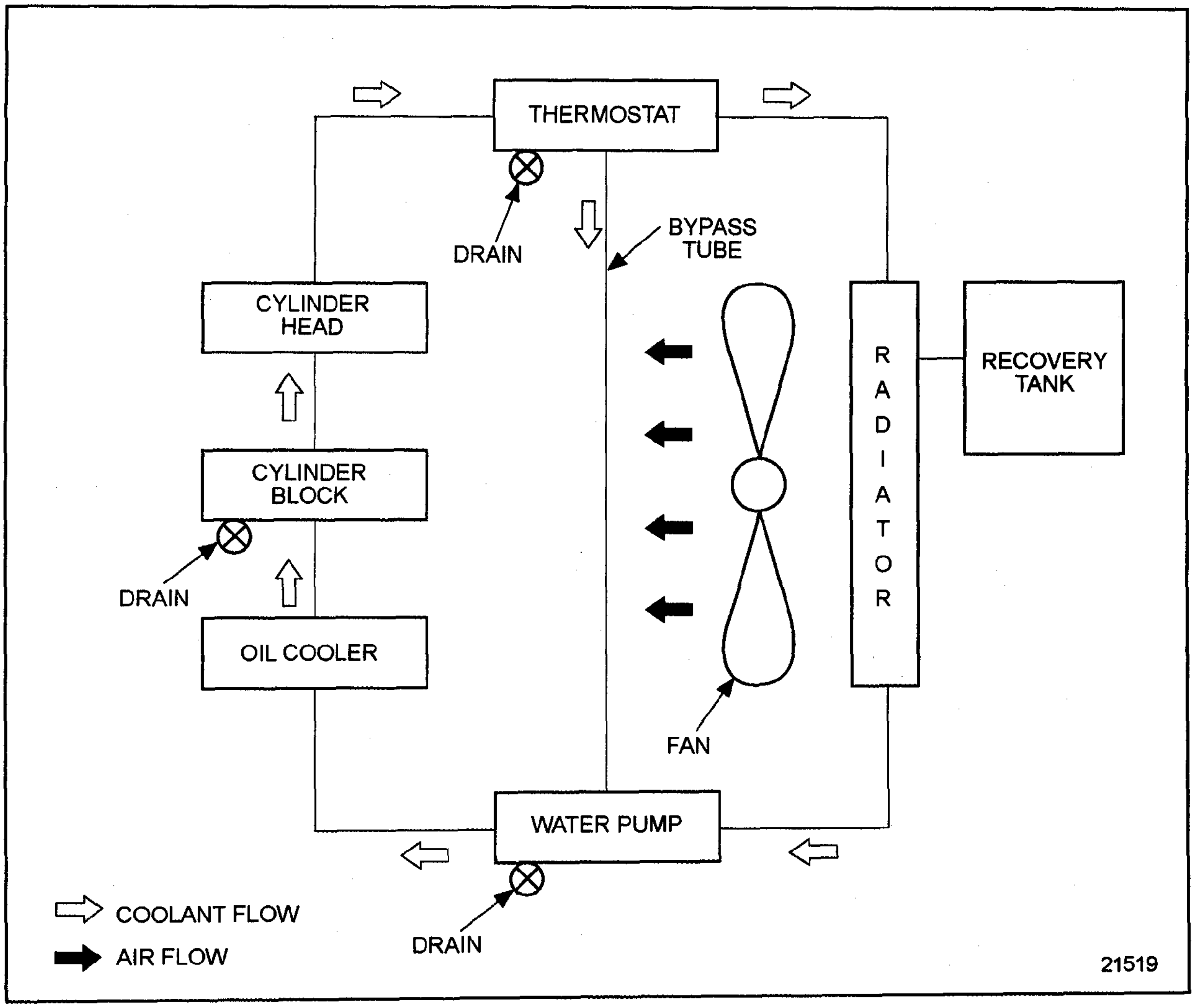



**Figure 4-2 Coolant Flow Schematic for Vehicle and Industrial Engines**

On marine engines, coolant from the fresh water pump flows through the engine in three circuits: Coolant flowing into the oil cooler passes through the cylinder block, the cylinder head, and the thermostat housing before moving on to the heat exchanger. See Figure 4-3 and see Figure 4-4. Coolant going to the water-cooled exhaust manifold flows directly back to the thermostat housing and then into the heat exchanger, where it is cooled. Coolant going to the water-cooled turbocharger flows into the bypass (rapid warm-up) cooling circuit and back to the pump.

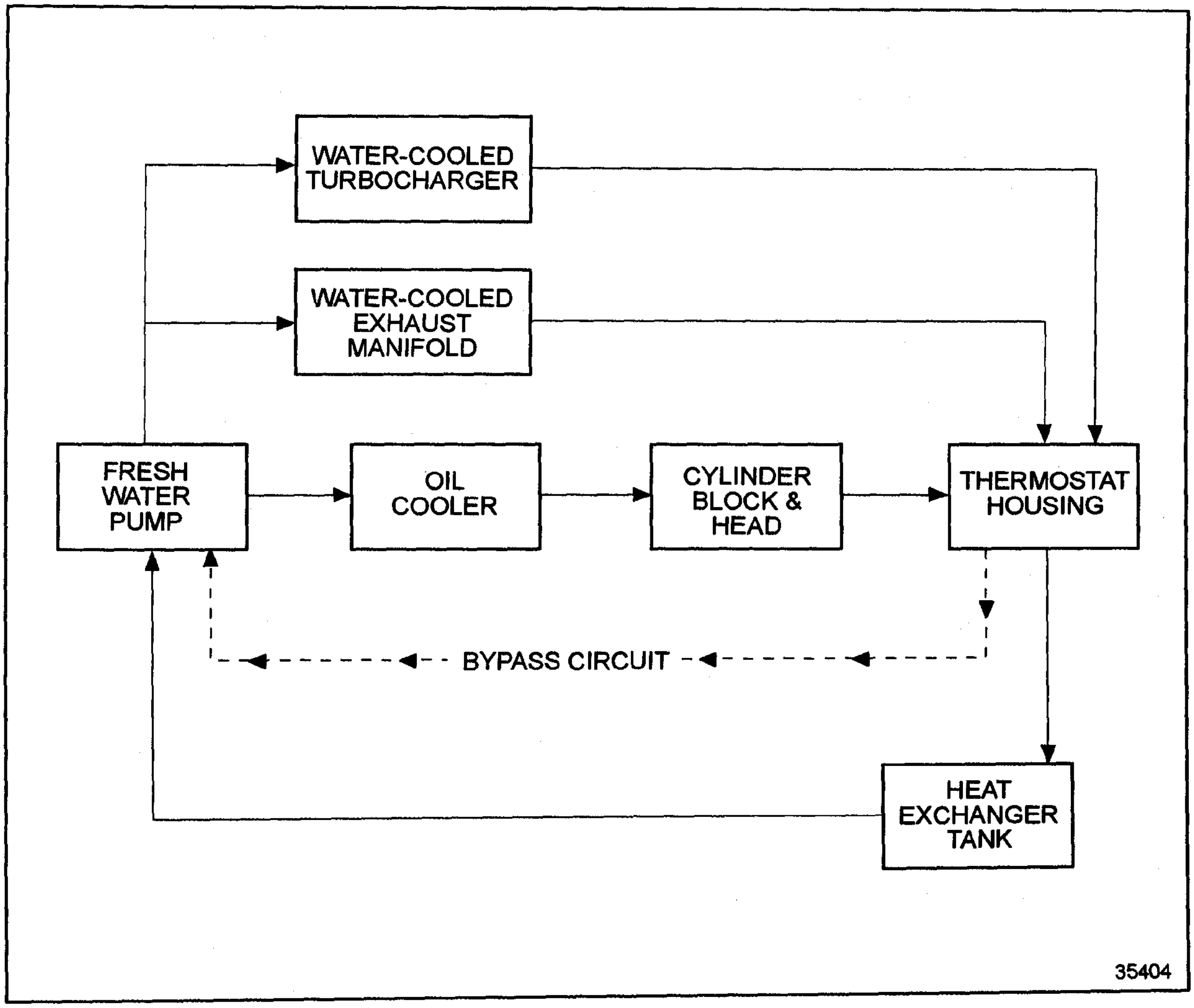



**Figure 4-3** **Coolant Flow Schematic for Heat Exchanger-Cooled Marine Engine**

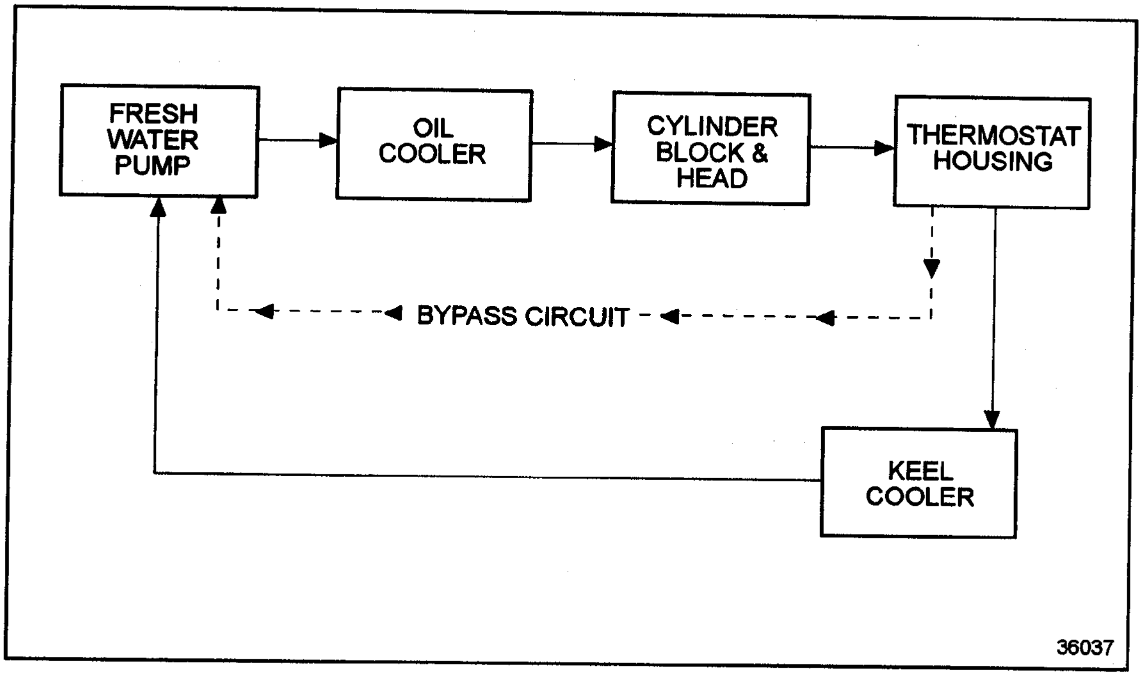



**Figure 4-4 Coolant Flow Schematic for Keel-Cooled Marine Engine**

On keel-cooled marine engines, fresh water coolant flow is similar to the flow on vehicle engines, except that it passes through a keel cooler instead of a radiator. See Figure 4-5and see Figure 4-6.

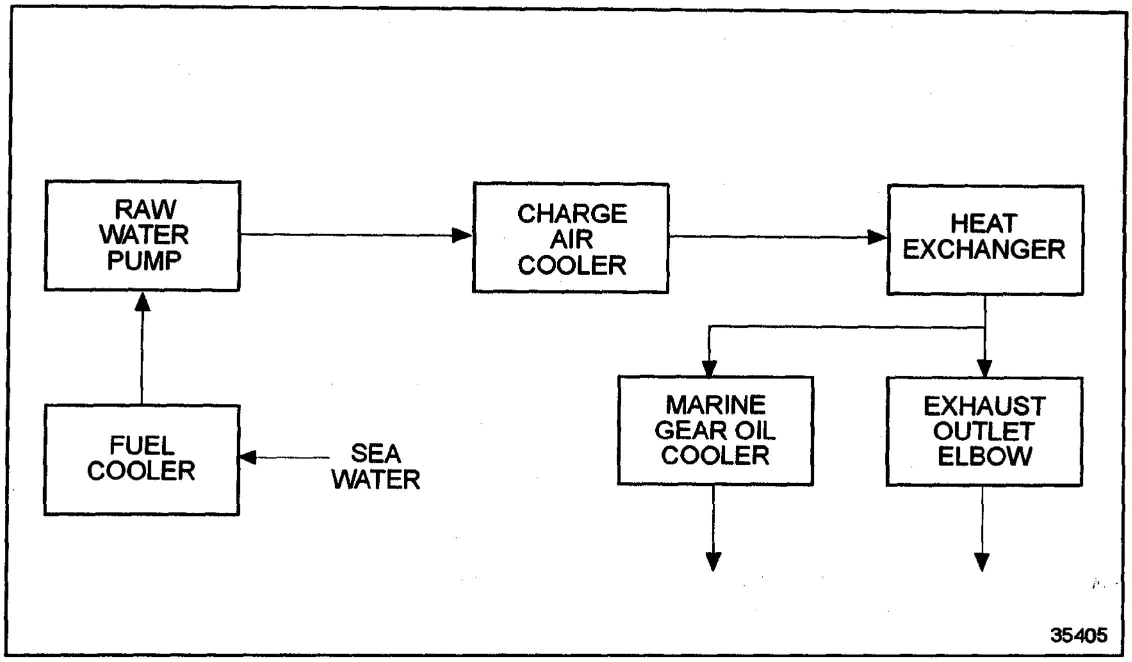



**Figure 4-5** **Raw Water Flow on Heat Exchanger-Cooled Marine Engine**

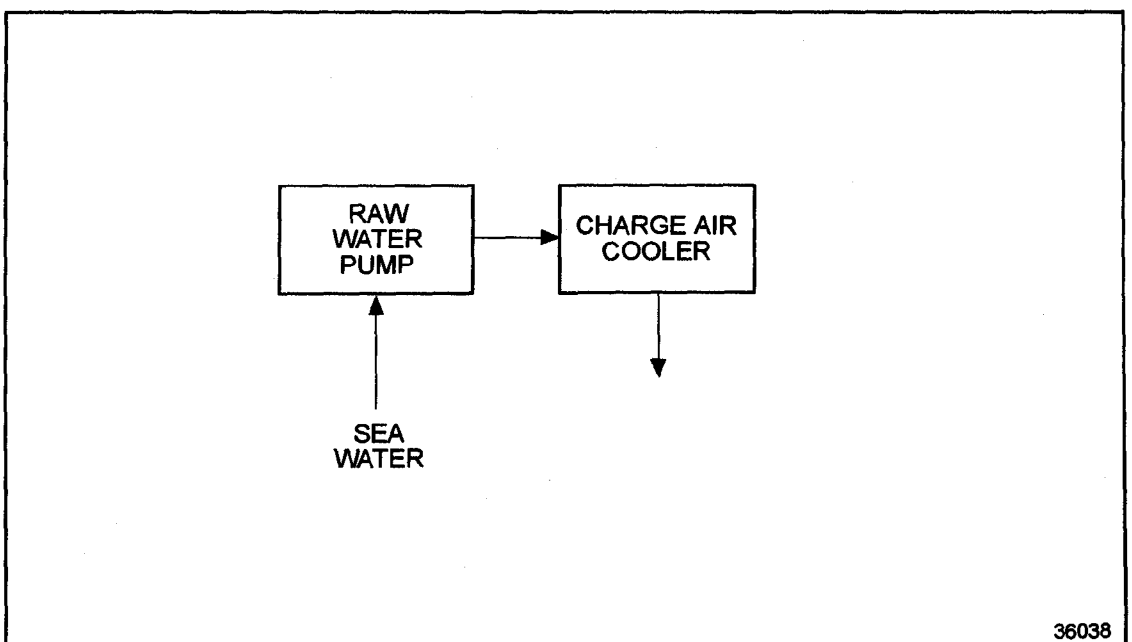



**Figure 4-6** **Raw Water Flow on Keel-Cooled Marine Engine**

When the engine is at normal operating temperature, the coolant passes from the cylinder block up through the cylinder head, through the thermostat housing and into the upper portion of the radiator. The coolant then passes through a series of tubes where the coolant temperature is lowered by the airflow created by the revolving fan and the motion of the vehicle.

Upon starting a cold engine or when the coolant is below operating temperature, the closed thermostats direct coolant flow from the thermostat housing through the bypass tube to the water pump. Coolant is recirculated through the engine to aid engine warm-up. When the thermostat opening temperature is reached, coolant flow is divided between the radiator inlet and the bypass tube. When the thermostats are completely open, all of the coolant flow is to the radiator inlet.

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as the valves and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water oil cooler. Coolant recommendations for the Series 60 engine are listed in Table 11-2.

A pressurized cooling system permits higher temperature operation than a non-pressurized system. It is essential that the cooling system is kept clean and leak-free, that the filler cap and pressure relief mechanisms are properly installed and operate correctly, and that the coolant level is properly maintained.

As the engine temperature increases, the coolant and air in the system starts to expand and build pressure. The valve in the radiator pressure cap unseats and allows the coolant to flow into the coolant recovery tank. See Figure 4-7.

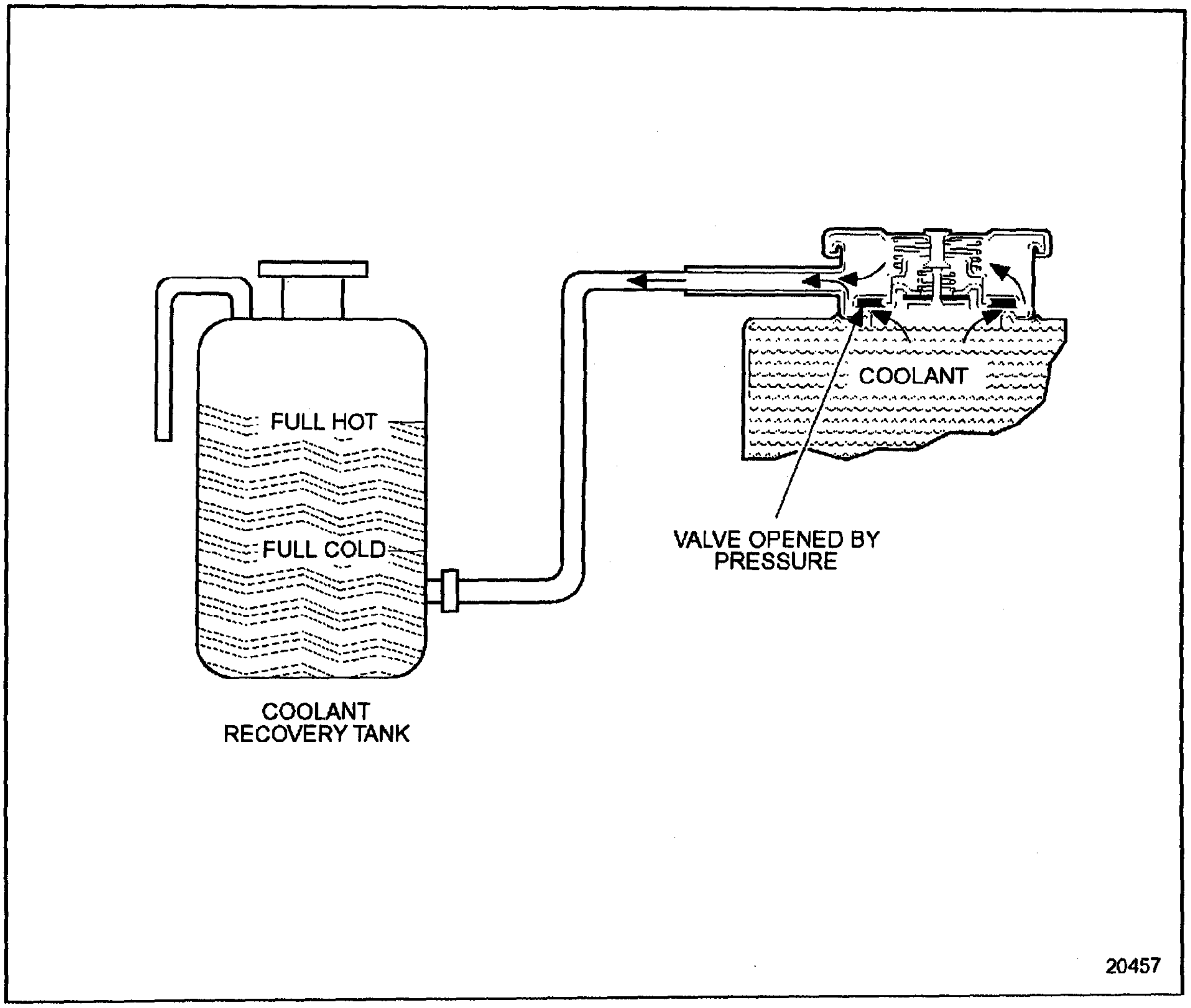



**Figure 4-7 Coolant Expansion**

When the engine starts to cool down, the air and coolant contract, causing a void and creating a vacuum in the system. The vacuum unseats another valve in the pressure cap, allowing the coolant to flow back into the expansion tank, radiator or heat exchanger tank. See Figure 4-8.

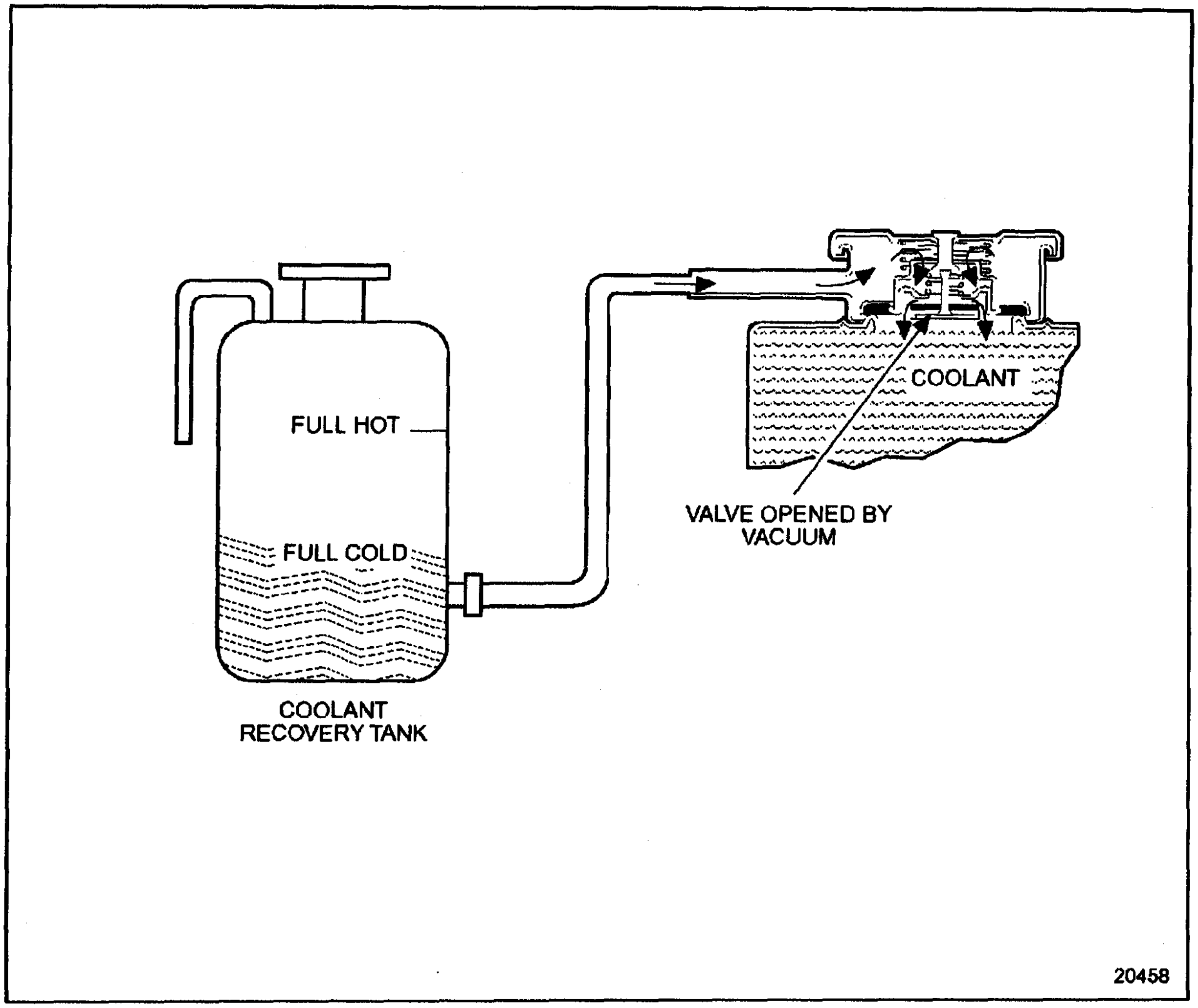



**Figure 4-8 Coolant Recovery**

## 4.2 WATER PUMP (GEAR CASE MOUNTED - 1991 AND LATER) (GCM)

The centrifugal-type water pump circulates the engine coolant through the cooling system.

The pump is mounted on the rear of the gear case on units built after 6R37023, engines and is driven by the water pump drive gear. See Figure 4-9. The water pump drive gear meshes with the bull gear. The pump was mounted on the front of the gear case cover on units built prior to and including 6R37023. See Figure 4-37 Refer to section 4.3

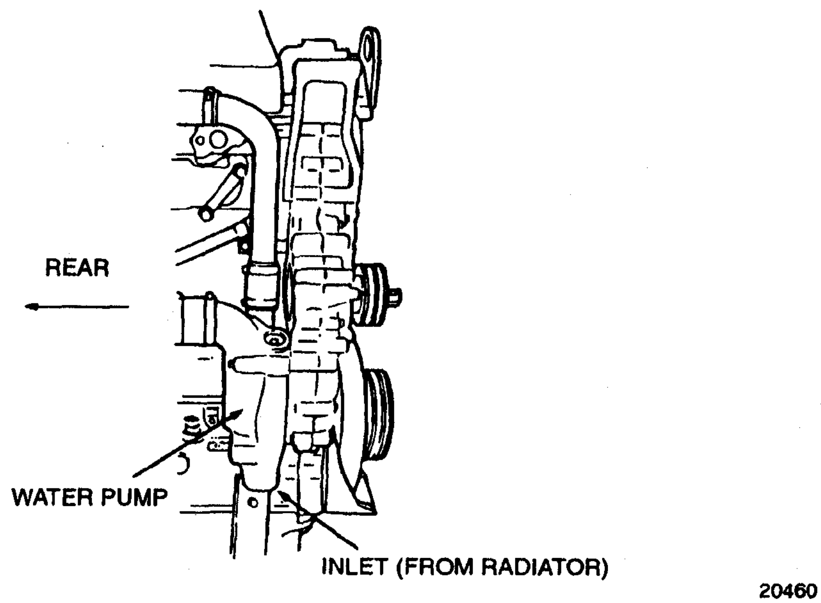
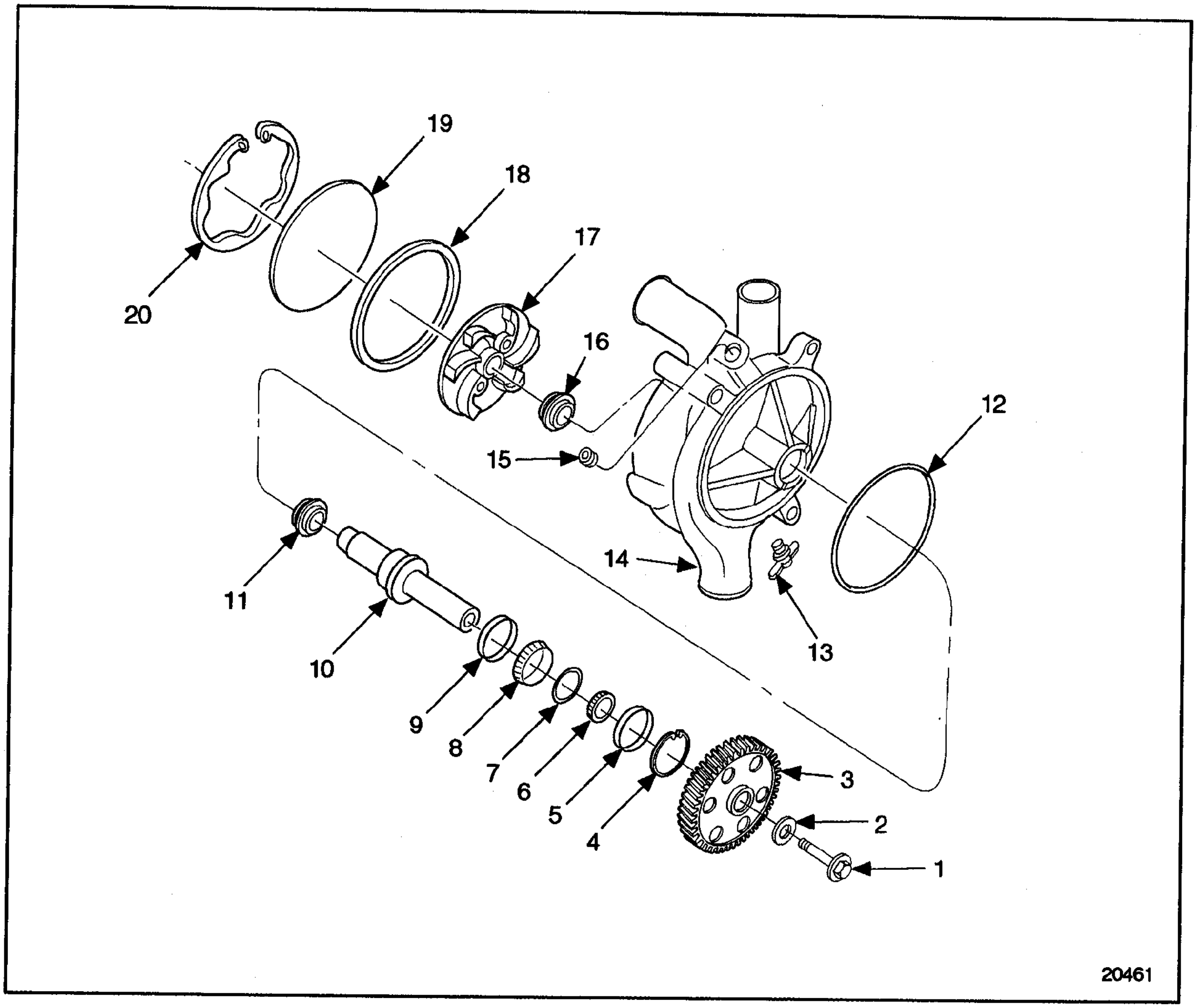



**Figure 4-9 Water Pump Mounting (1991 and Later Model)**

An impeller is pressed on one end of the stainless steel drive shaft. The other end of this shaft has internal threads, and a retaining bolt secures the water pump drive gear to the shaft. Two tappered roller bearing assemblies are used to support the shaft. See Figure 4-10.

An O-ring, located in a groove in the water pump housing, seals the water pump to the gear case. An O-ring, located under the water pump cover, seals the cover to the water pump housing. The water pump bearings are lubricated by splash oil through a passage from the front of the pump housing.

An oil seal is located behind the bearing assemblies, and a unitized, spring-loaded, face-type water seal is used behind the impeller. This seal prevents water from leaking down the shaft and into the gear case. It also prevents lubricating oil from entering the cooling system. The water and oil seals cannot be replaced without removing the water pump from the engine.




1. Retaining Bolt
2. Washer
3. Gear, Water Pump Drive
4. Snap Ring
5. Bearing Race
6. Roller Bearing, Small
7. Spacer Rings (2)
8. Roller Bearing, Large
9. Bearing Race
10. Drive Shaft
11. Oil Seal
12. O-ring Seal
13. Drain Cock
14. Housing, Water Pump
15. Pipe Plug, Water Pump Housing
16. Water Seal
17. Impeller
18. O-ring, Water Pump Cover
19. Water Pump Cover
20. Snap Ring, Water Pump Cover

**Figure 4-10 Water Pump Details and Relative Location of Parts (Gear Case Mounted (GCM)**

### 4.2.1 Repair or Replacement of Water Pump (GCM)

To determine if repair or replacement is necessary, perform the following procedure. See Figure 4-11.

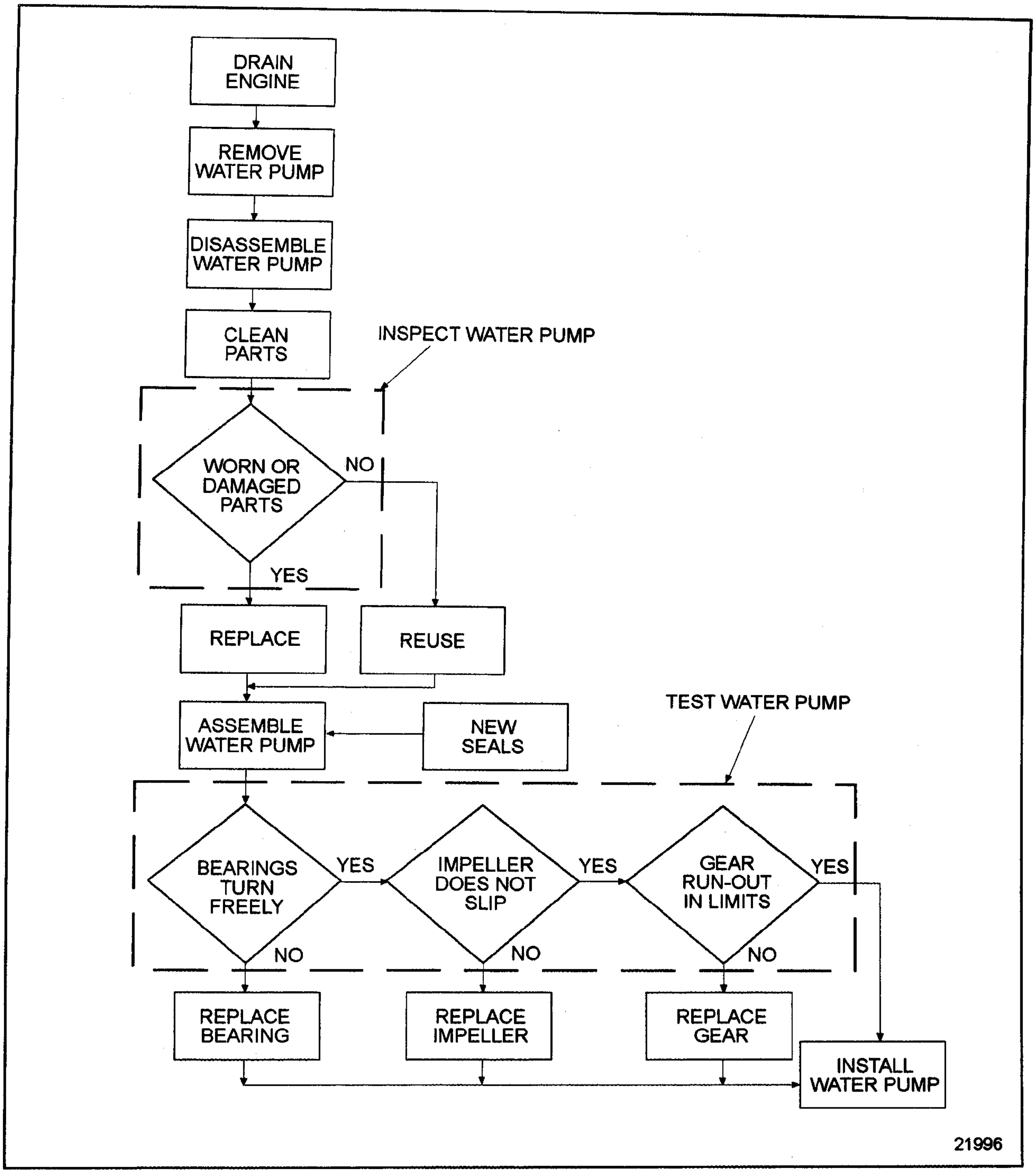



**Figure 4-11 Flowchart for Repair or Replacement of Water Pump (GCM)**

### 4.2.2 Draining and Removal of Water Pump (GCM)

Drain the cooling system as follows:

Open the drain cocks located at the right rear corner of the engine, at the bottom of the water pump and in the bottom of the thermostat housing.

Remove the water pump as follows:

1. Loosen the hose clamps and remove the coolant hoses from the water pump housing.
2. Loosen and remove the three water pump housing-to-gear case bolts. Remove the water pump from the engine by pulling it straight out of the gear case.

### 4.2.3 Disassembly of Water Pump (GCM)

Disassemble the water pump as follows:

| CAUTION: |
|---|
| **To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).** |

1. Remove water pump cover snap ring with snap ring pliers, J 22380 or equivalent. Remove water pump cover and seal ring.

| NOTICE: |
|---|
| When clamping gears, use soft jaws on vise to prevent damage to the gear teeth. |

2. Clamp the water pump drive gear in a vise, with the impeller facing up. Use a two-screw gear puller and remove the water pump impeller from the shaft, using the two threaded holes in the impeller.

3. Hold square end of water pump shaft and remove water pump drive gear retaining bolt and washer. See Figure 4-12.

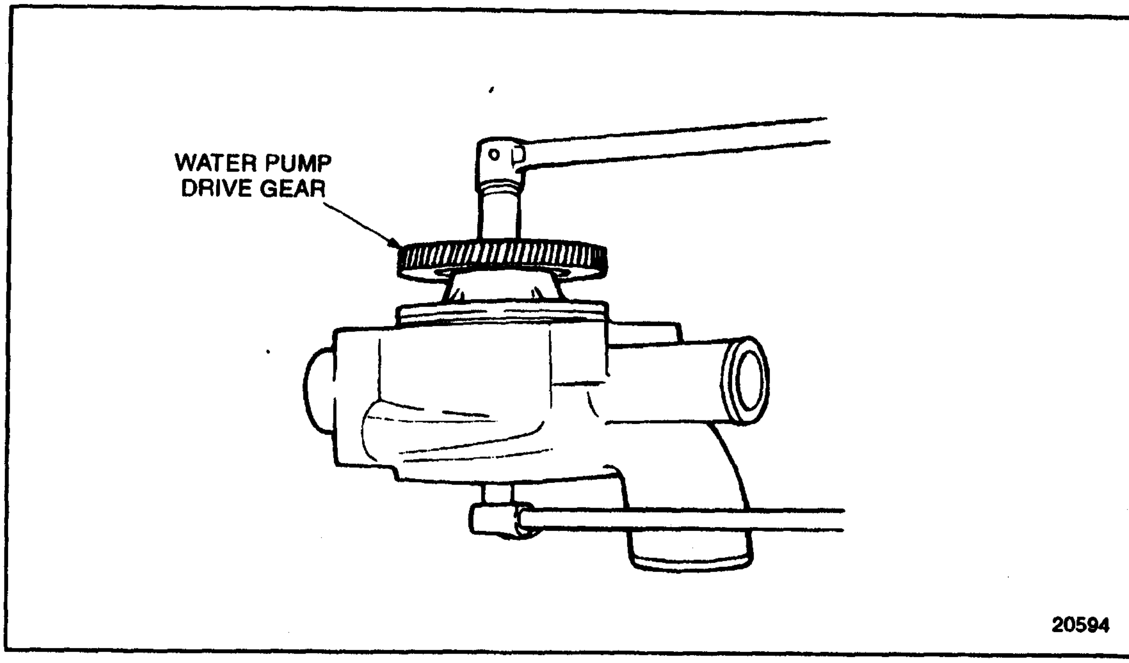



**Figure 4-12 Water Pump Drive Gear Retaining Bolt Removal (GCM)**

4. Use a two-jaw gear puller to remove the water pump drive gear from the drive shaft.

5. Remove the snap ring from the water pump housing. See Figure 4-13.

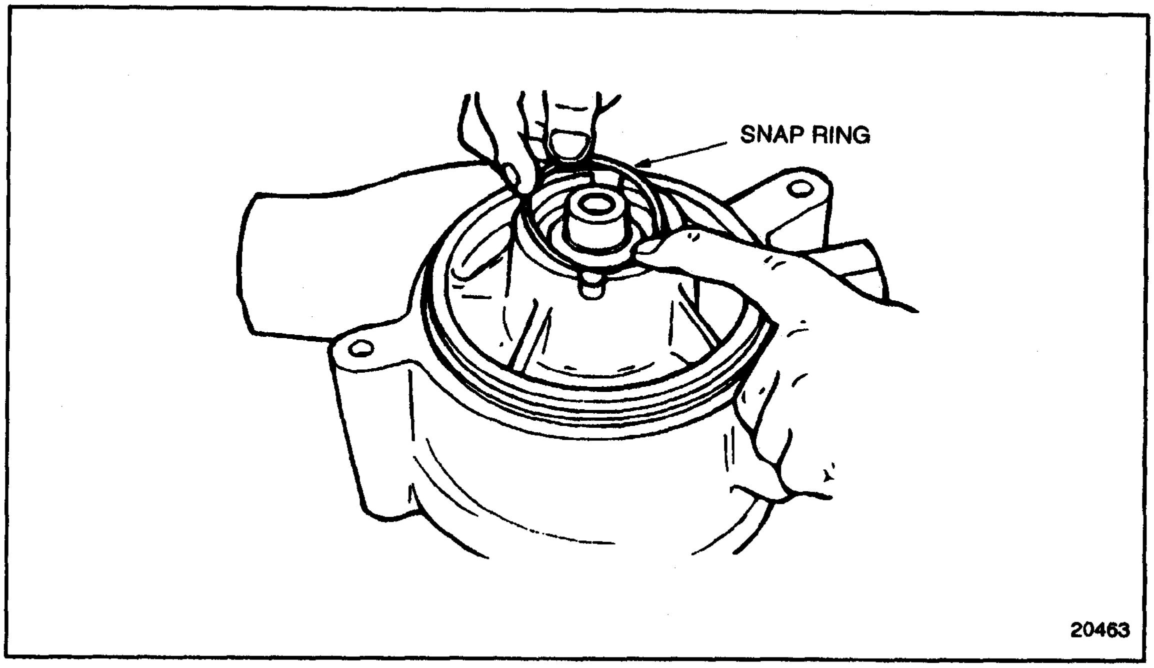



**Figure 4-13 Snap Ring Removal (GCM)**

6. Support the water pump housing, using steel blocks or plates, to allow at least 76 mm (3in.) of clearance between the pump housing and the press bed.
7. Press the drive shaft and bearings assembly out through the front (engine side) of the water pump housing, until both bearing races are clear of the housing.

**NOTE:**
Once the bearing assemblies are pressed out of the water pump housing, they must be replaced with new assemblies.

| NOTICE: |
| --- |
| Do not allow brass drift to score housing bore when tapping out seals. A scored bore will cause coolant leaks and can damage engine. |

| CAUTION: |
| --- |
| **To avoid injury from chemical burns, wear a face shield and neoprene or PVC gloves when handling fluoroelastomer O-rings or seals that have been degraded by excessive heat. Discard gloves after handling degraded fluoroelastomer parts.** |

8. Remove both the water and oil seals from the housing using a brass drift and hammer.
9. Support the drive shaft assembly on two steel blocks, at the bearing inner race.

10. Insert J 35988-3A , part of tool set J 35988-B, in end of drive shaft. See Figure 4-14.

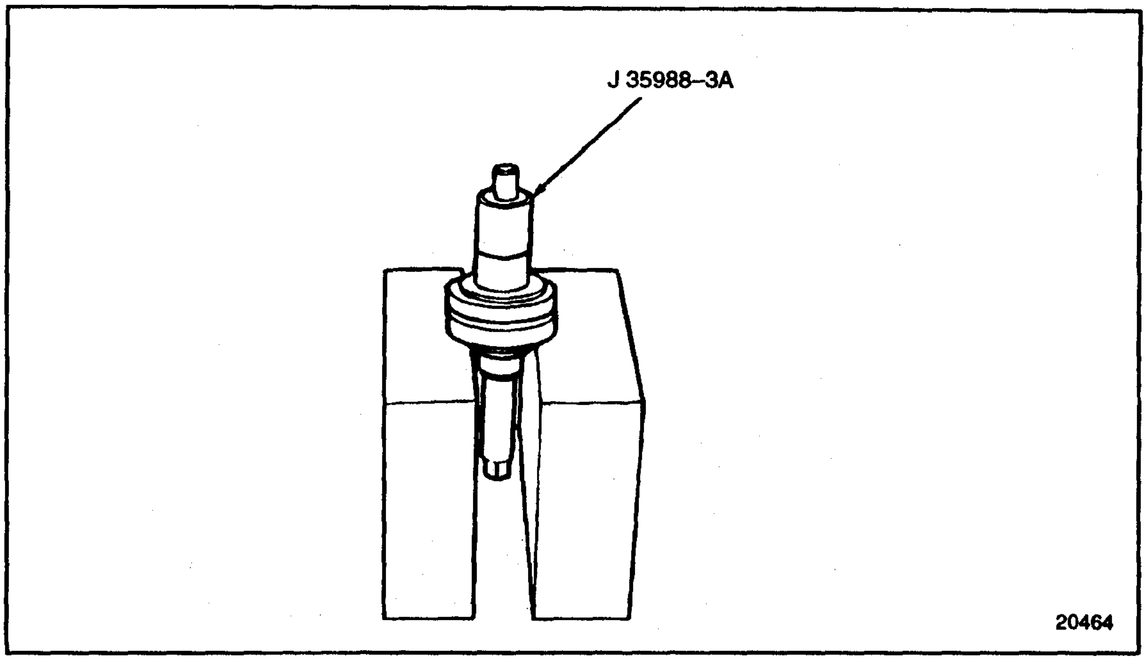



**Figure 4-14 Removing Bearing Assemblies**

11. Press the drive shaft out until it is clear of both bearing and race assemblies. Discard the used bearings, races and the two spacer rings located between the bearing packs.

### 4.2.3.1 Inspection of Water Pump (GCM)

Inspect the water pump parts as follows:

1. Visually inspect the parts for cracks, wear or other damage.
   [a] If parts are cracked, worn, or other damage is evident, replace damaged or worn parts.
   [b] If no damage is found, reuse remaining components.

## 4.2.4 Cleaning of Water Pump (GCM)

Clean the water pump as follows:

1. Wash all of the pump parts in clean fuel oil.

> **CAUTION:**
>
> **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry the parts with compressed air.

## 4.2.5 Assembly of Water Pump (GCM)

Assemble the water pump as follows:

1. Coat the bearing bores of the water pump housing and the drive shaft bearing surfaces with clean engine oil.

| NOTICE: |
|---|
| Although the bearings are identical, the bearings and races are matched parts, and should be installed as they are removed from the box. Parts that are not matched will cause damage to the water pump. |

2. Assemble the new bearing packs, as follows:

   [a] Place the small spacer ring on the inner bearing race. See Figure 4-15.

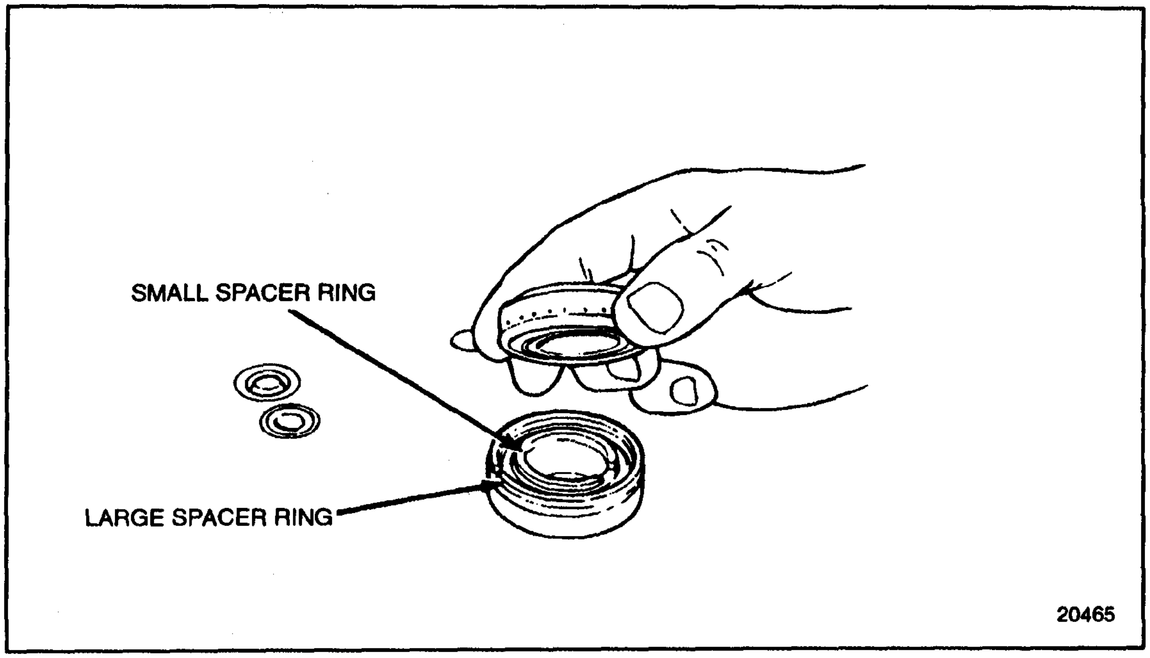



**Figure 4-15 Bearing Pack Assembly (GCM)**

   [b] Place the larger spacer ring on the outer bearing race.

3. Install J 35988-18 into the center of J 35988-2, parts of tool set J 35988-B. See Figure 4-16.

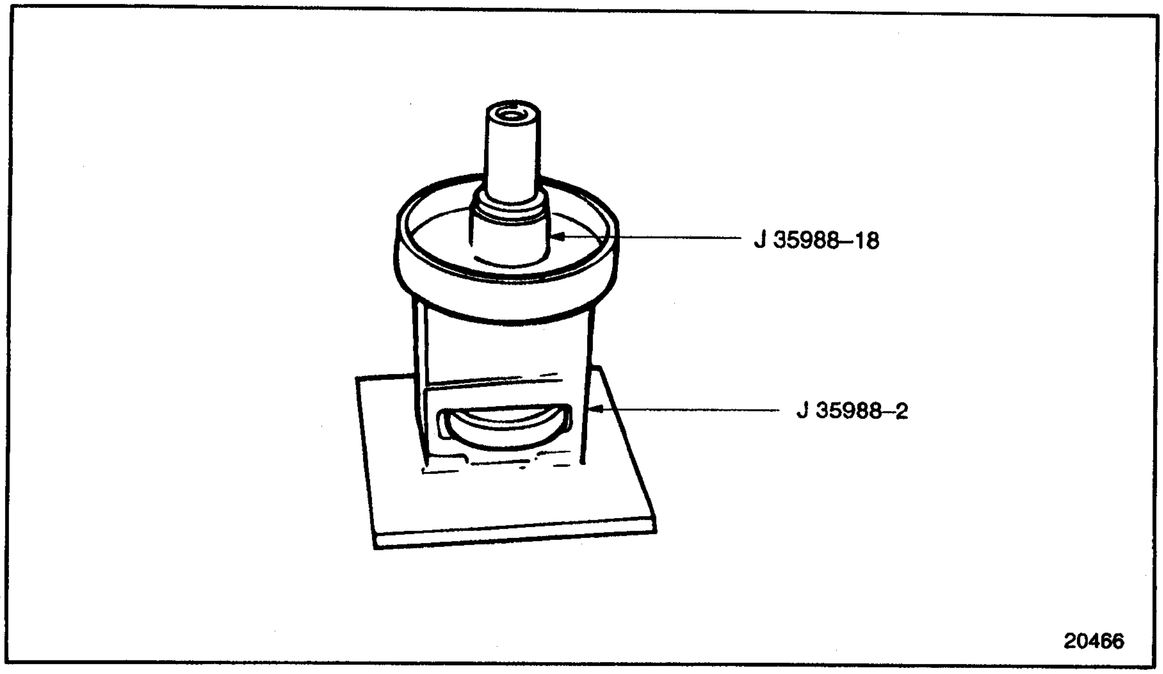



**Figure 4-16 Bearing Installation Set-up (GCM)**

4. Install J 35988-3A part of tool set J 35988-B, on the end of the water pump shaft. Install the assembled bearing packs to the drive shaft. See Figure 4-17.

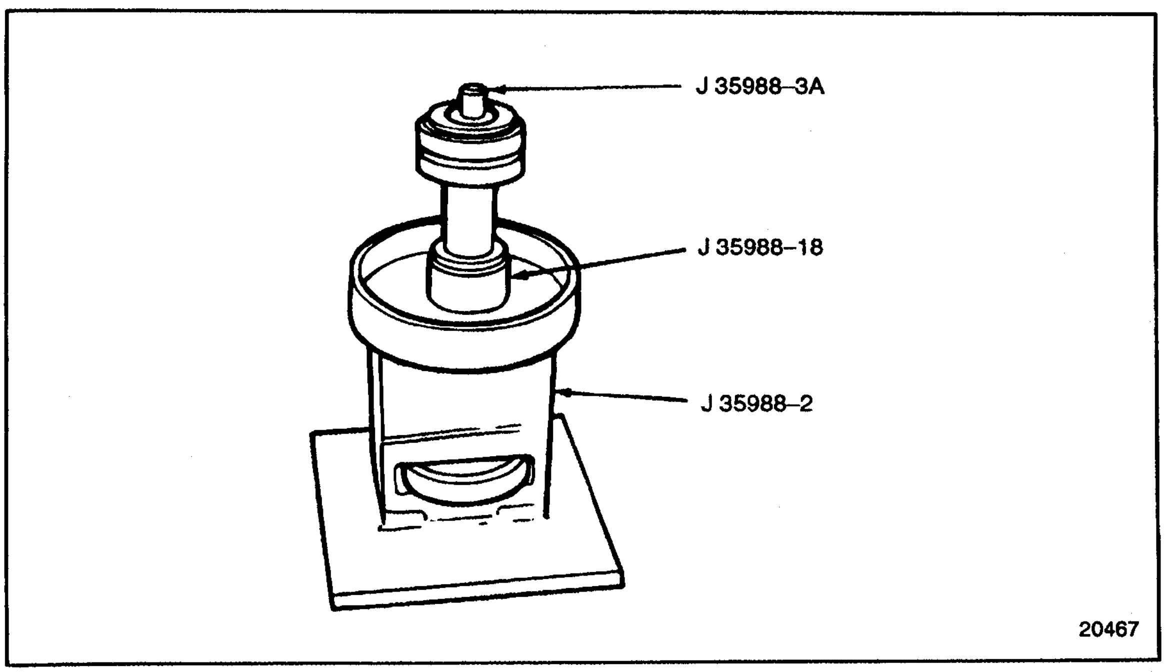



**Figure 4-17 Bearing Placement (GCM)**

5. Center the small end of J 35988-1A, part of tool set J 35988-B, on the bearing inner race. Press the bearing pack onto the shaft until it contacts the shoulder of the shaft. Remove the tool used to pilot the bearings. See Figure 4-18.

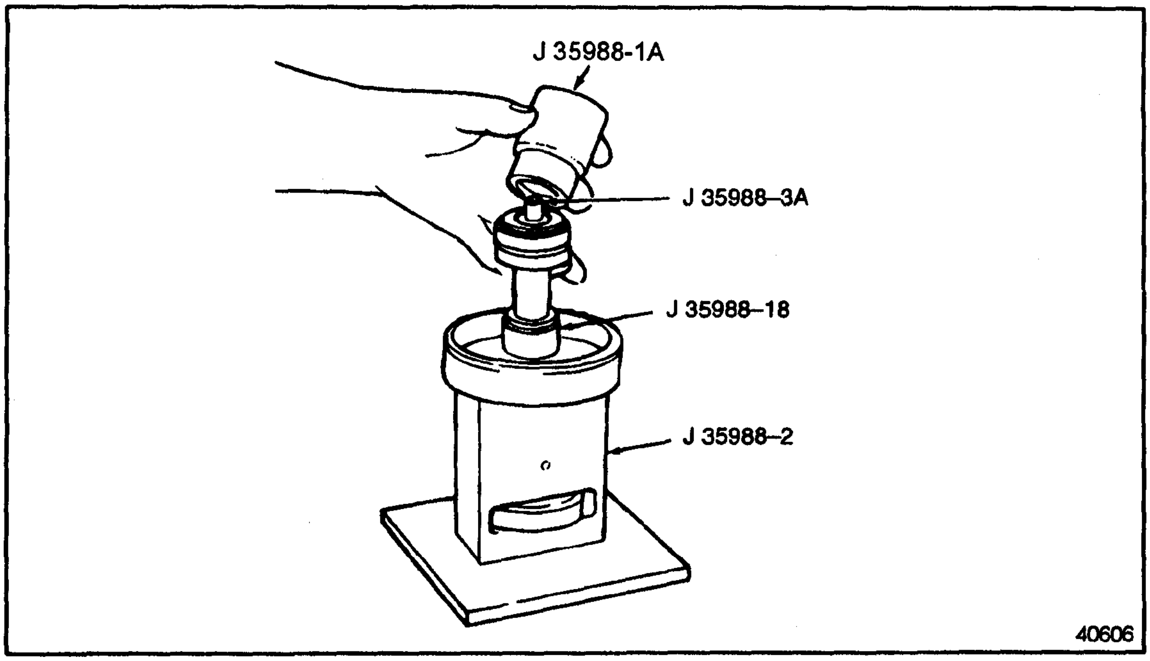



**Figure 4-18 Bearing Installation (GCM)**

6. Remove the shaft and bearing assembly from the press.

### 4.2.5.1 Test Bearing Assembly

Test bearing assembly as follows:

1. Turn bearings to ensure they turn freely.
2. If bearings bind, disassemble water pump and replace bearing assembly. Refer to section 4.2.3.

## 4.2.6 Assembly of Water Pump (GCM) - cont'd

Continue assembling the water pump, as follows:

1. Coat the oil seal contact area of the water pump housing with a thin film of clean engine oil. See Figure 4-19.

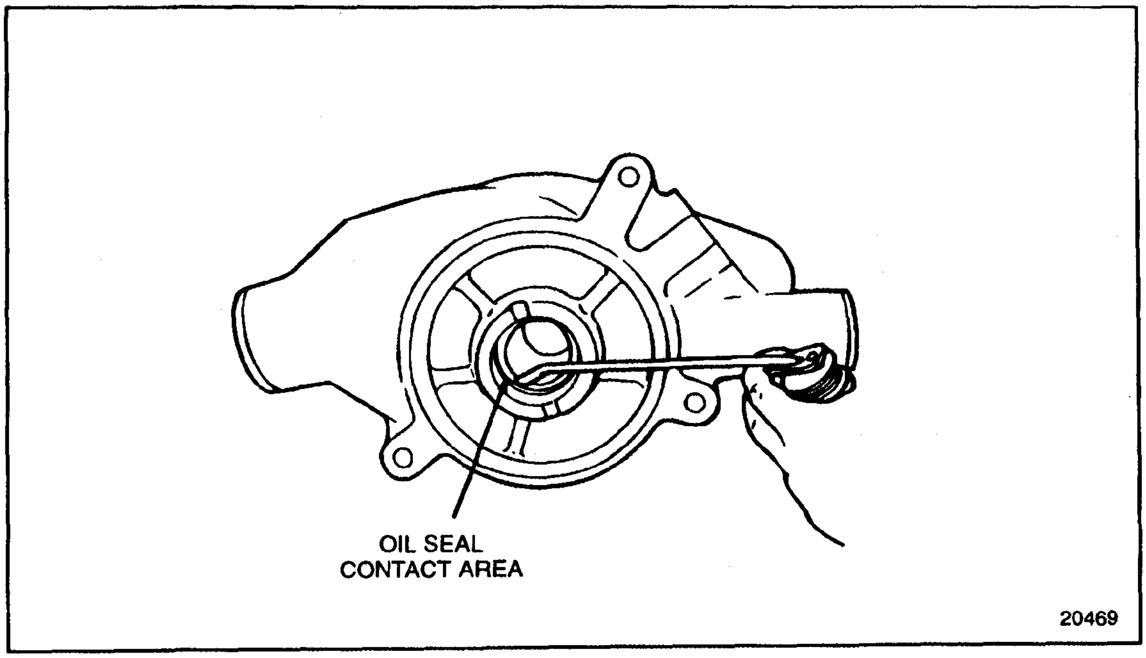



**Figure 4-19 Oil Seal Contact Area Lubrication (GCM)**

2. Install a new oil seal into the water pump housing from the front (gear side). See Figure 4-20.

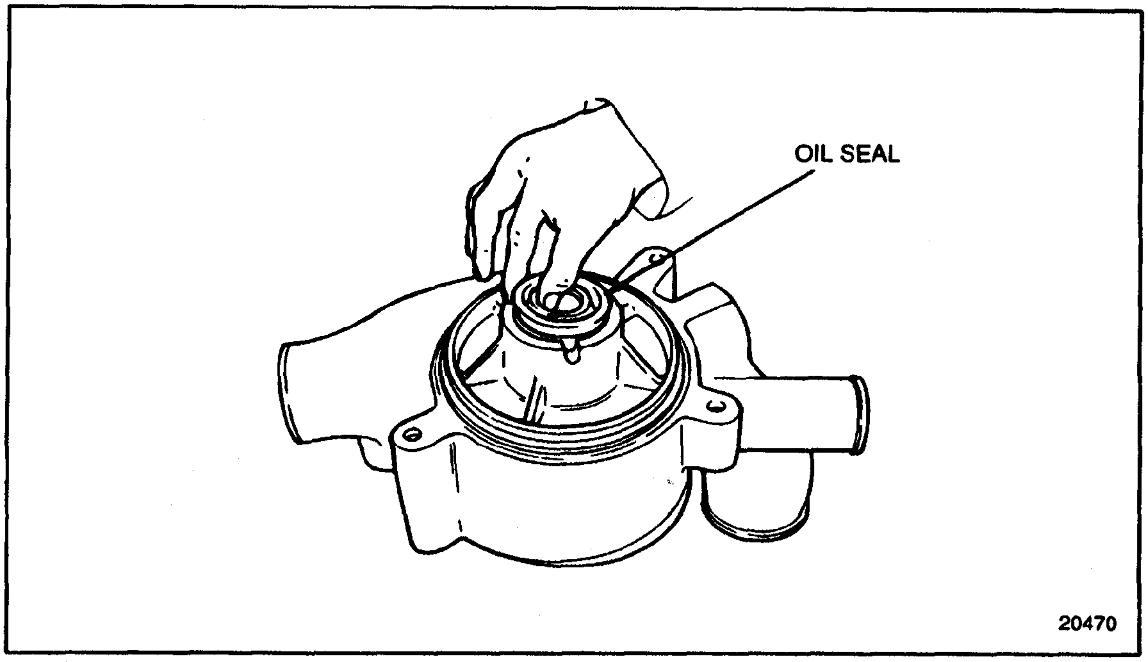



**Figure 4-20 Oil Seal Positioning (GCM)**

| NOTICE: |
| --- |
| The contact surface of the oil seal is coated with a special sealant. Do NOT remove this sealant before installing the oil seal. If sealant is removed, leakage can occur. |

3. Place the small end of tool J 35988-1A, part of tool set J 35988-B, into the water pump housing until it contacts the oil seal. See Figure 4-21.

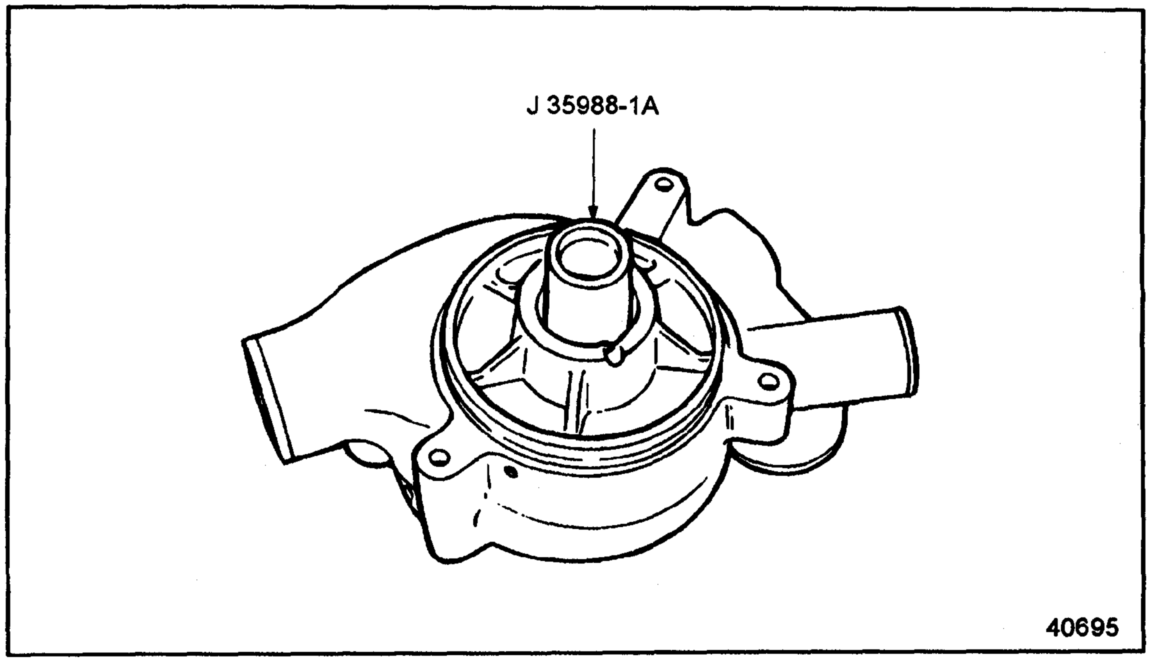



**Figure 4-21 Oil Seal Installation (GCM)**

4. Press the oil seal into the housing until the seal lip is bottomed in the pump housing. Remove the tool J 35988-1A, part of tool set J 35988-B.
5. Coat the bearings with clean engine oil.
6. Place the water pump housing, with the gear side up, on a press bed.
7. Install the drive shaft, with bearings installed, to the water pump housing. See Figure 4-22.

**NOTE:**
**During the bearing installation, the water pump housing must be parallel to the press bed or table surface.**

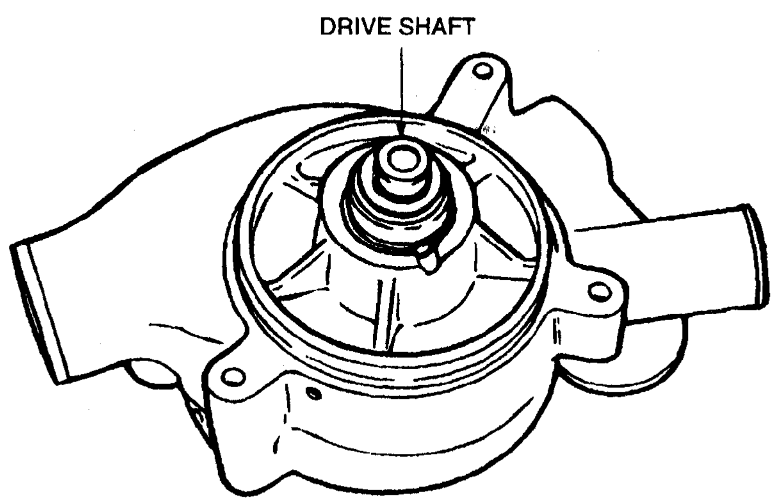



**Figure 4-22 Drive Shaft Insertion (GCM)**

8. Place the large end of tool J 35988-1A, part of tool set J 35988-B, over the drive shaft so that the lip of the tool rests squarely on the outer bearing race. See Figure 4-23.

**NOTICE:**

The drive shaft must be installed using the outer bearing race only. Any other attempt at installation may damage the bearings.

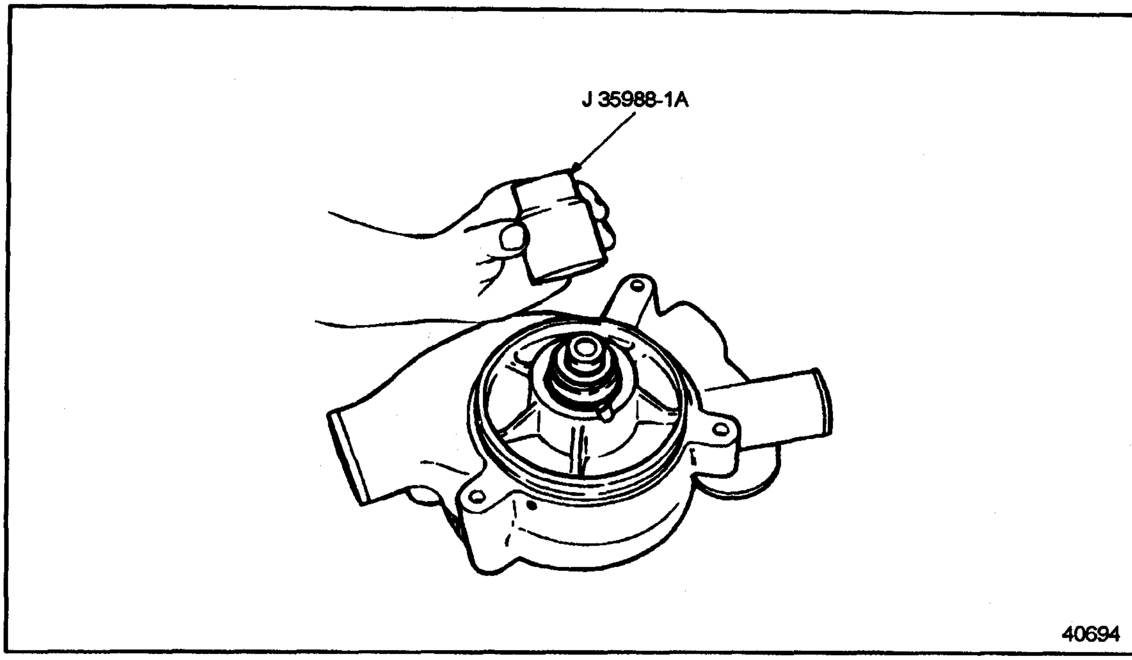



**Figure 4-23 Drive Shaft Installation (GCM)**

9. Press the drive shaft and bearing assembly into the water pump housing, using tool J 35988-1A , part of tool set J 35988-B, until it is seated firmly against the shoulder in the housing.

10. Install the snap ring to the water pump housing. See Figure 4-24.

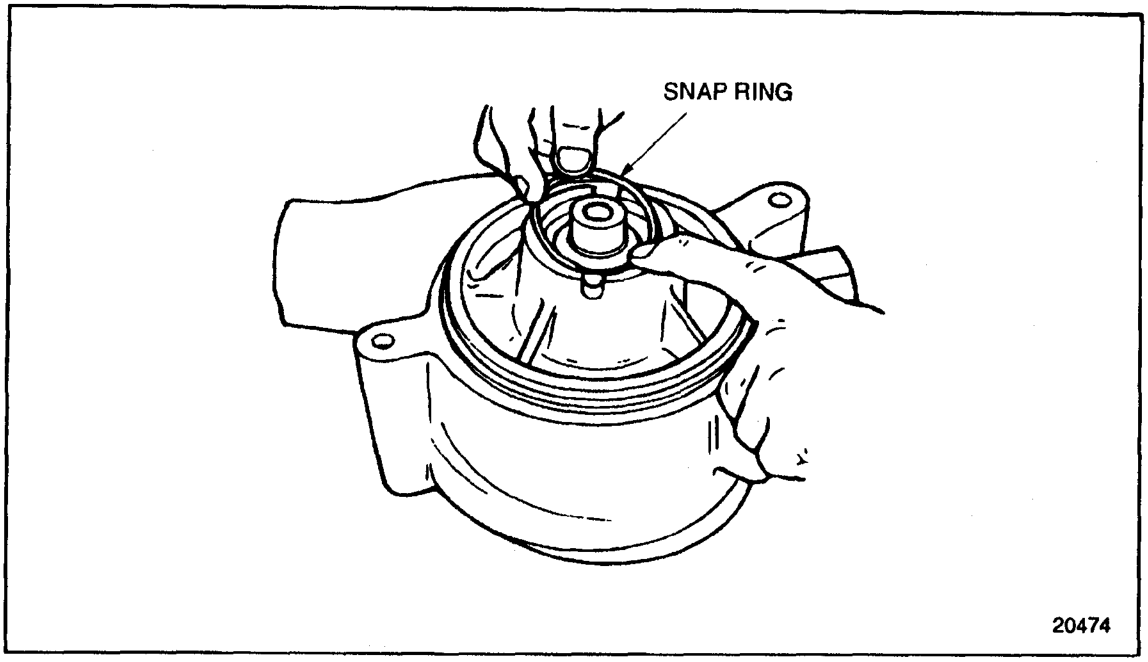
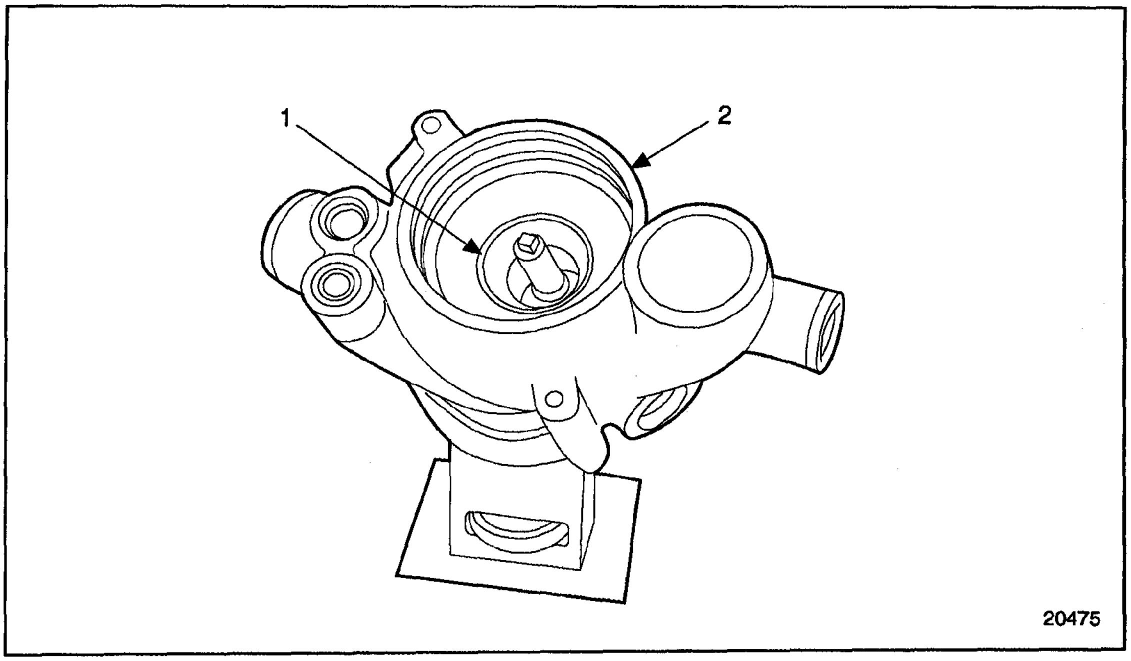



**Figure 4-24 Snap Ring Installation (GCM)**

**NOTICE:**

Apply sealant sparingly. Use of excess sealant may result in seal failure due to contamination of the sealing faces, which may cause pump leakage.

11. Turn the water pump housing over and check to make sure no residual sealant remains in the water seal bore or on the seal flange contact surface. Remove any residual sealant found in these areas. Working through the rear, apply a new coating of aviation Form-A-Gasket Number 3 or equivalent to the area where the water pump seal case contacts the pump body. See Figure 4-25.




1.Seal Bore  2.Water Pump Housing

**Figure 4-25 Water Pump Housing Seal Bore (GCM)**

12. Install J 35988-3A , part of tool set J 35988-B, to the fixture tool. See Figure 4-26.

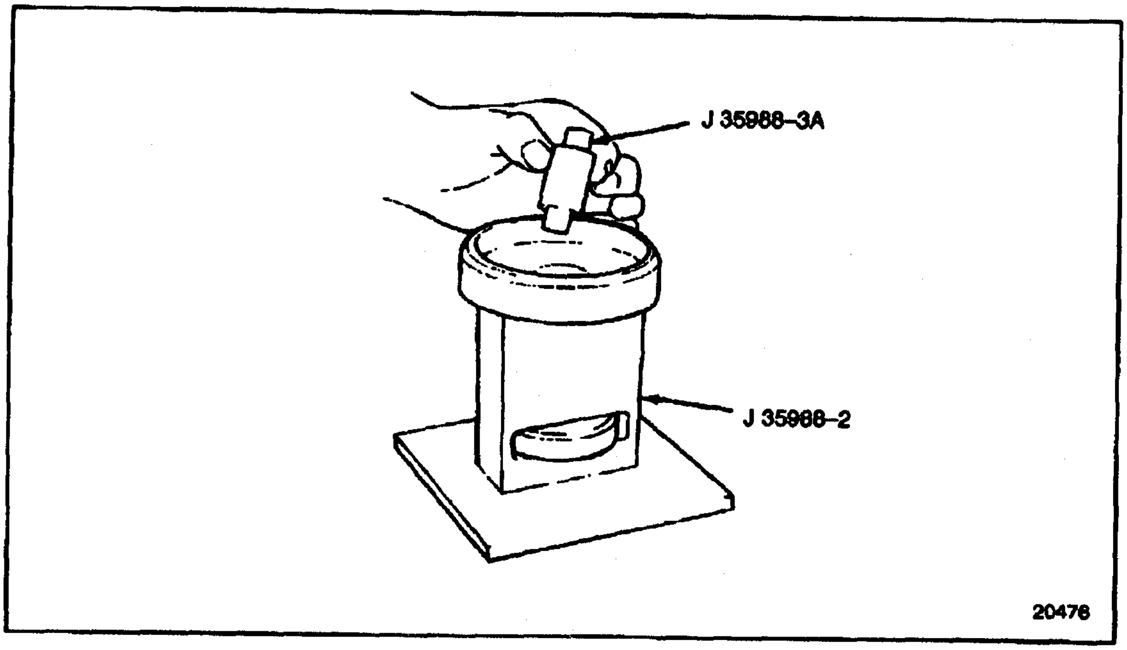



**Figure 4-26 Support Installation (GCM)**

**NOTICE:**

The extension must contact and support the shaft when installing the water seal and impeller to prevent damage to the bearings.

13. Install the water pump housing assembly to the fixture. See Figure 4-27.

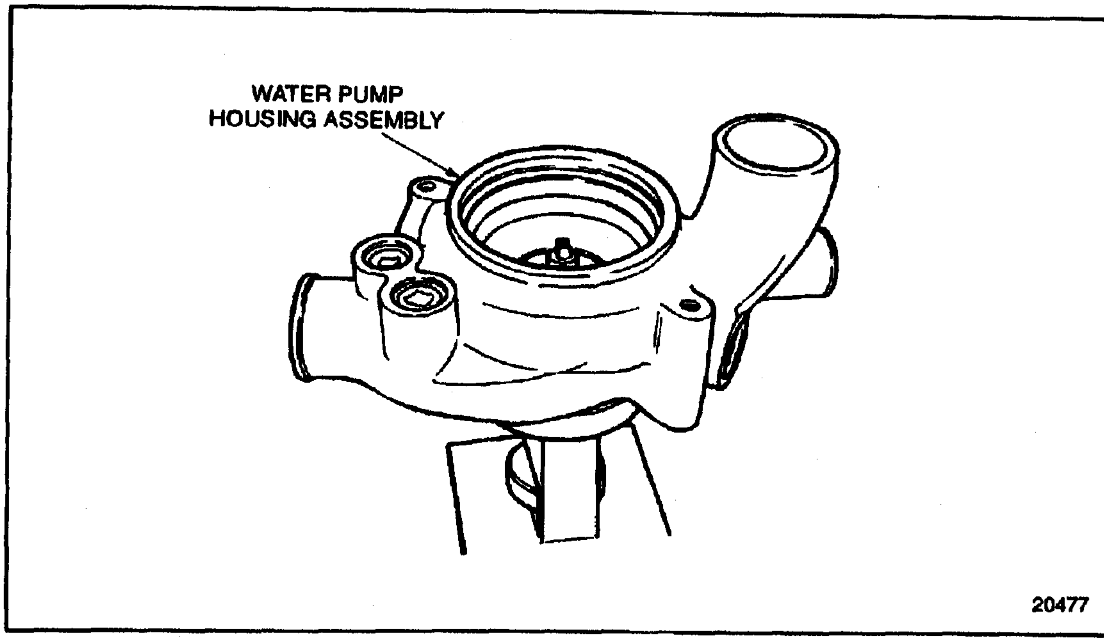



**Figure 4-27 Water Pump Impeller Installation Set-up (GCM)**

14. Turn the adjustor wheel to raise the extension until it contacts the drive shaft in the water pump housing.
15. Apply Loctite® primer (Locquic Primer N, Part No. 764) by swabbing onto the I.D. of the rotor of the seal.

16. Install a new water seal over the drive shaft and seat it in the water pump housing. See Figure 4-28.

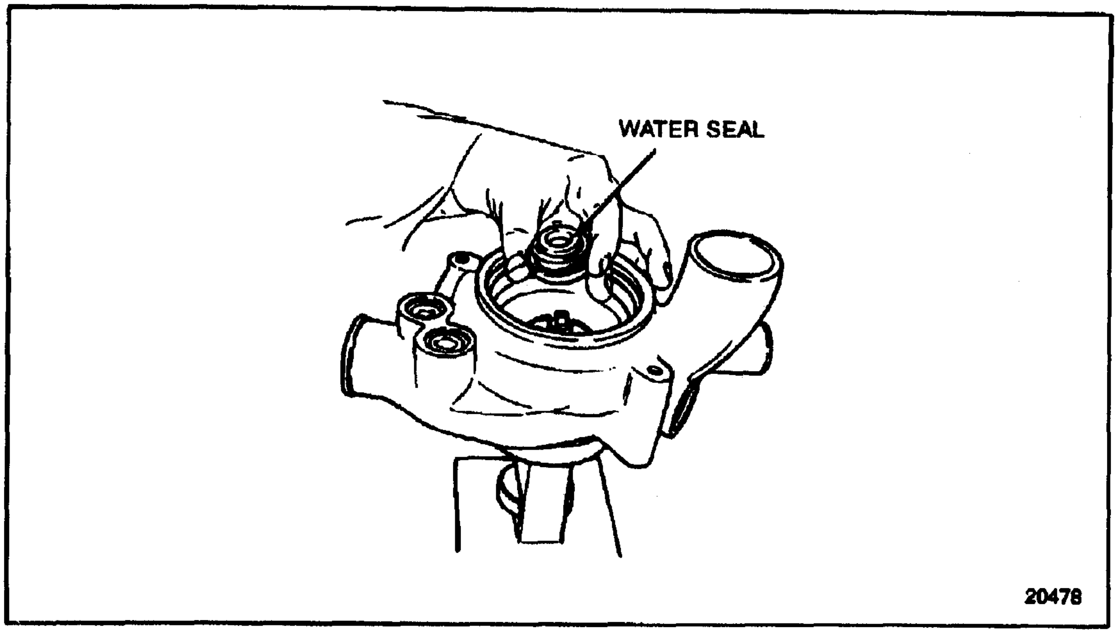



**Figure 4-28 Water Seal Insertion (GCM)**

17. Position J 35517-1 or J 35988–1A, part of tool set J 35988-B over the water seal. See Figure 4-29.

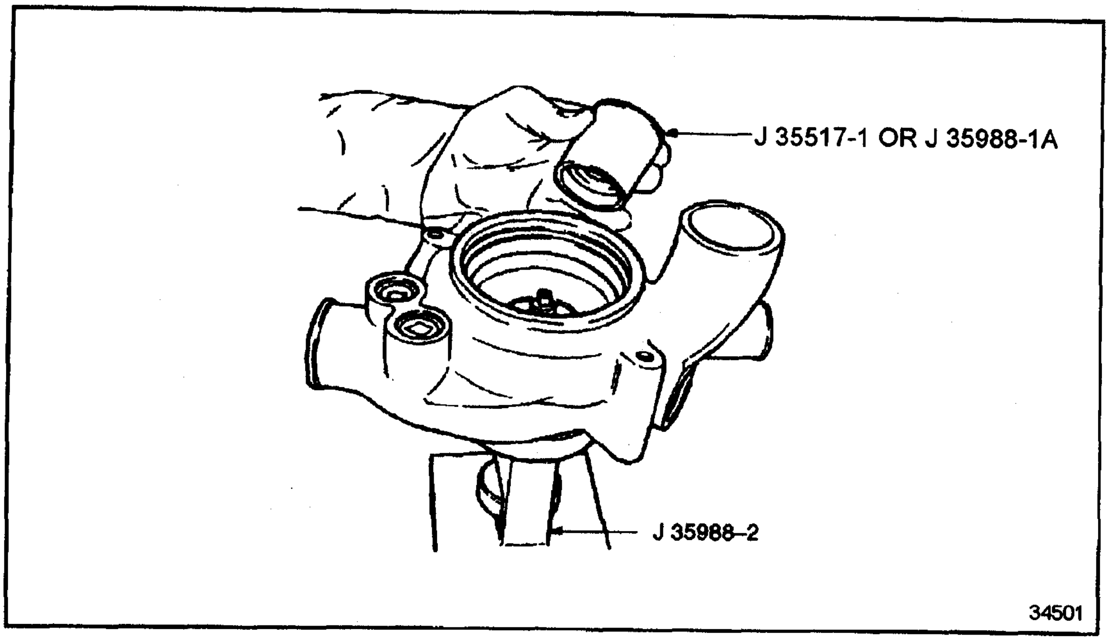



**Figure 4-29 Water Seal Installation (GCM)**

18. Press the water seal into the housing until the flange of the seal case contacts the water pump housing a full 360 degrees. Remove tool J 35517-1 or J 35988–1A , part of tool set J 35988-B.

**NOTICE:**

The shaft should not be turned, moved from vertical or the seal pressure tested for at least two hours. Do not exceed 172 kPa (25 lb/in.$^2$) when pressure testing. Sealant requires curing to prevent leaks and damage to engine.

**NOTICE:**

The Loctite® 290 sealant must not be allowed to spill over the side of the water pump seal. Damage to the seal may occur.

19. Apply only one drop of Loctite® 290 sealant to the drive shaft where it contacts the water seal. The sealant will wick around the shaft making a complete seal. Wipe off excess sealant. See Figure 4-30.

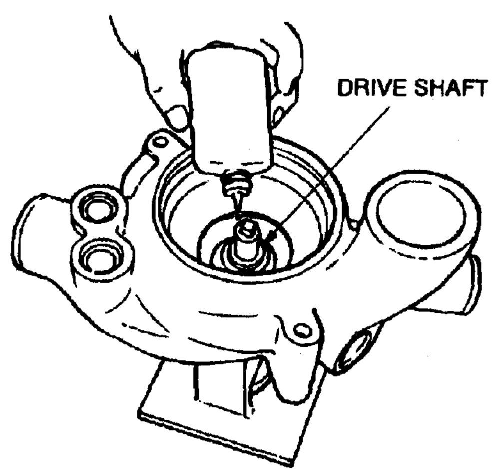



**Figure 4-30 Sealant Installation (GCM)**

20. With the shaft in the vertical, position apply Locquic Primer Non top of the Loctite® 290 by swabbing.

**NOTE:**
Due to time required for curing, DDC recommends keeping a pump built up in parts for immediate use when needed. A pump removed from an engine could be rebuilt and placed in storage for later use.

21. With the water pump housing still housed in tool J 35988-2, part of tool set J 35988-B, and located on a press bed, position the impeller over the square end of the drive shaft with the vanes of the impeller facing down. See Figure 4-31.

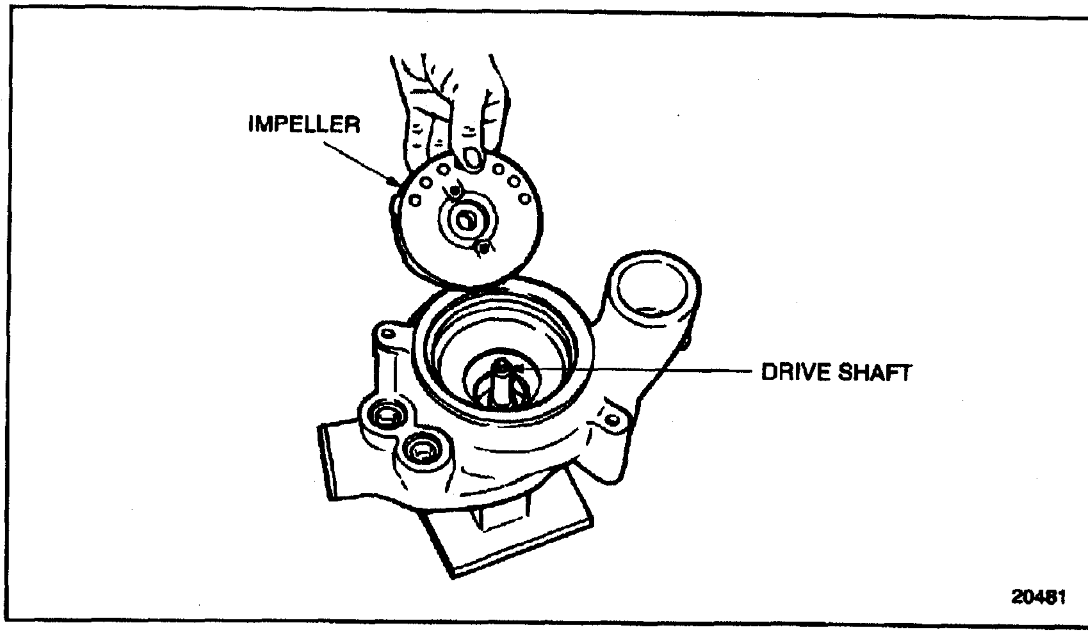



**Figure 4-31 Water Pump Impeller Installation (GCM)**

**NOTICE:**

During this procedure, the drive shaft must be supported by the extension tool J 35988-3A, part of tool set J 35988-B. Failure to support the drive shaft while installing the impeller may result in bearing damage.

22. Using the impeller installation tool J 35988-14, part of tool set J 35988-B, press the impeller on until the tool is flush against the water pump body. See Figure 4-32.

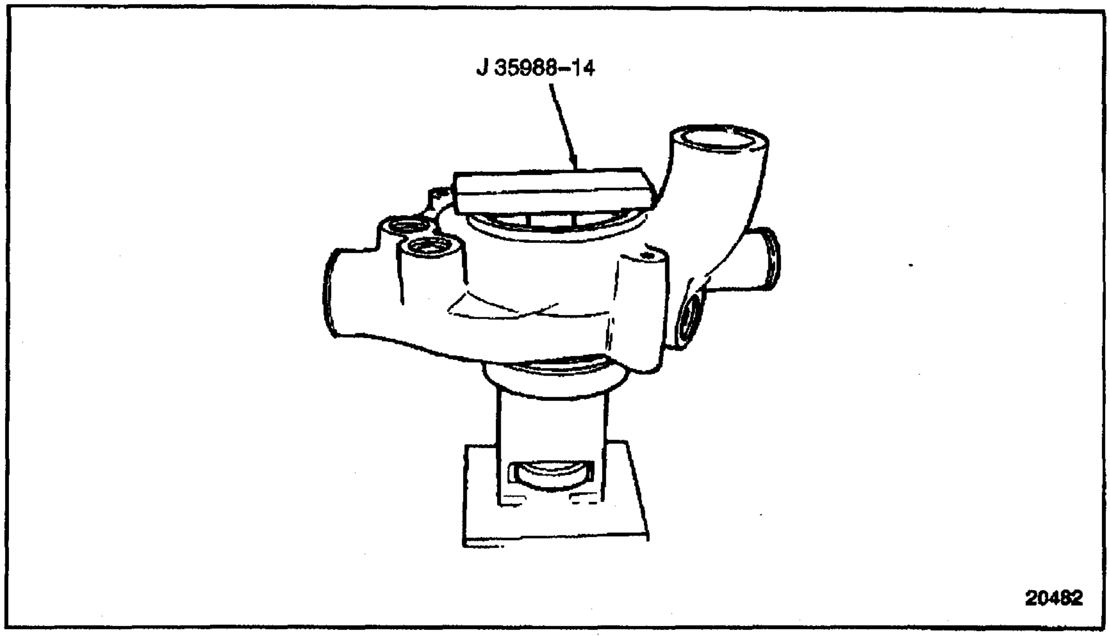



**Figure 4-32 Water Pump Impeller Location (GCM)**

23. Turn the housing over and place it face (impeller side) down on the fixture J 35988-2 , part of tool set J 35988-B. See Figure 4-33.

| NOTICE: |
|---|
| If the gear has a press fit, turn the adjustor wheel to raise the extension J 35988-3A, part of tool set J 35988-B, until it contacts and supports the shaft. This is necessary to prevent damage to the bearings when pressing the gear onto the shaft. |

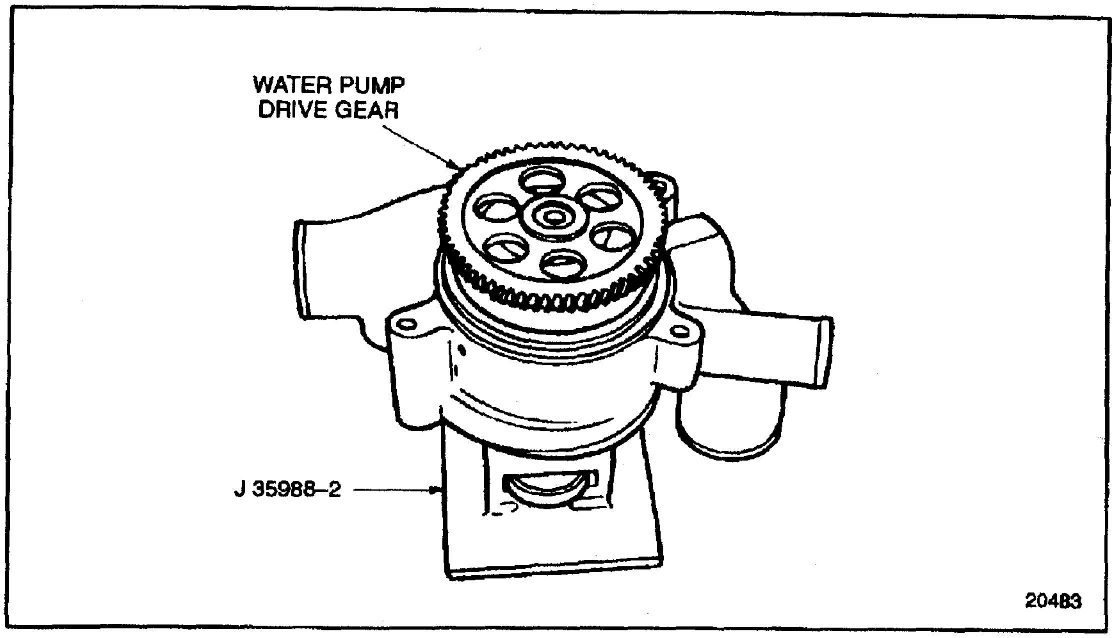



**Figure 4-33 Water Pump Drive Gear Installation (GCM)**

24. Install the water pump drive gear to the drive shaft.

**NOTE:**
The water pump drive gear may have a slip fit. This is due to manufacturing tolerances and is acceptable.

25. Using the small end of tool J 35988-1A, part of tool set J 35988-B, press the drive gear down onto the drive shaft until it touches the bearings. See Figure 4-34.

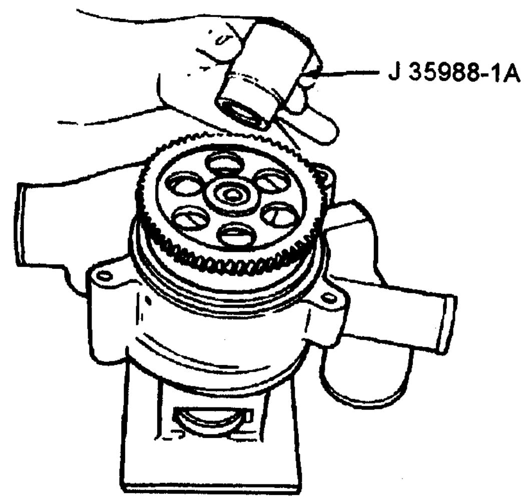



**Figure 4-34 Water Pump Drive Gear Installation (GCM)**

26. Install the retaining bolt and washer. Hold the square end of the drive shaft and torque the retaining bolt to 101-126 N·m (75- 93 lb·ft).

### 4.2.6.1 Assembly Integrity Test

Verify the assembly integrity as follows:

1. Turn the pump over and install the water pump impeller slip and lash tester, J 35687-1, into the tapped holes provided in the impeller.

| NOTICE: |
|---|
| When clamping gears, use soft jaws on vise to prevent damage to the gear teeth. |

2. Clamp the water pump drive gear in a vise, with the impeller facing up.
3. Using a 1/2 in. drive torque wrench in the hole provided in the center of the slip and lash tester J 35687-1, apply 68 N·m (50 lb·ft) torque in either direction. The impeller must withstand 68 N·m (50 lb·ft) torque without slipping.
   [a] If the torque specification is not satisfied, disassemble water pump and replace the impeller. Refer to section 4.2.3.
   [b] If the torque specification is satisfied, reuse the part.

4. Using a dial indicator with magnetic base, measure the total run-out of the water pump drive gear at four places, at 90° intervals. Maximum allowable run-out is 0.0635 mm (0.0025 in.). See Figure 4-35.

   [a] If this value is exceeded, disassemble the water pump and check for burrs or foreign particles. Refer to section 4.2.3.

   [b] If the valve is not exceeded, reuse the part.

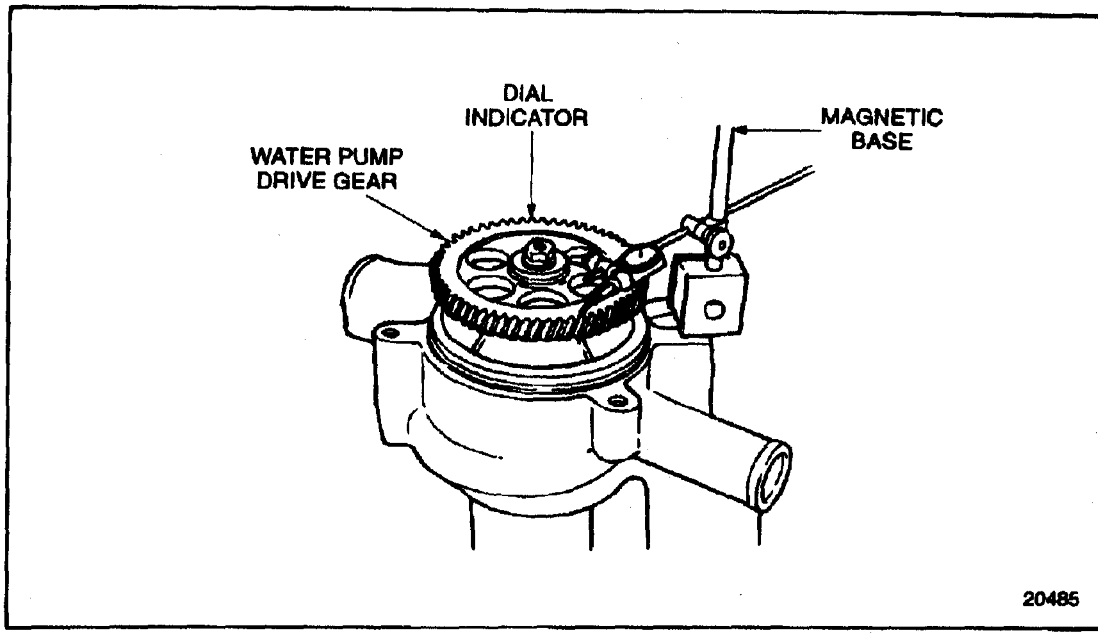



**Figure 4-35 Measuring Water Pump Drive Gear Runout (GCM)**

5. Remove dial indicator and magnetic base.

### 4.2.7 Assembly of Water Pump (GCM) - cont'd

Continue assembly of the water pump as follows:

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

1. Install seal ring, water pump cover, and snap ring with the beveled side of snap ring facing out. Tap around the inside rim of the snap ring with a brass drift and hammer to seat snap ring in groove fully.

### 4.2.8 Installation of Water Pump (GCM)

Install the water pump as follows:

1. Coat the water pump seal ring with clean engine oil.
2. Install the seal ring to the groove in the water pump housing.
3. Coat the water pump drive gear with clean engine oil.
4. Install the water pump to the engine, meshing the water pump drive gear with the bull gear.
5. Install the three water pump housing-to-gear case bolts. Tighten the bolts alternately and evenly to draw the water pump straight into the engine. Torque the bolts to 58-73 N·m (43-54 lb·ft).
6. Measure the gear backlash. Refer to section 1.21.2.1.
7. Install water bypass tube. If using a spring type hose clamps, refer to step 8. If using worm screw drive, liner type hose clamps, refer to step 9

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

8. If spring type hose clamps are used, fasten the bypass tube to the water pump bypass outlet and thermostat housing water inlet as follows:

   [a] Using hose clamp installer tool J 41454, install two hose clamps onto the water bypass tube; then push a connecting hose onto each end of the bypass tube. See Figure 4-36. Using hose clamp installer tool J 41454, open the clamps and slide them over the hoses to secure them in place on the tube.

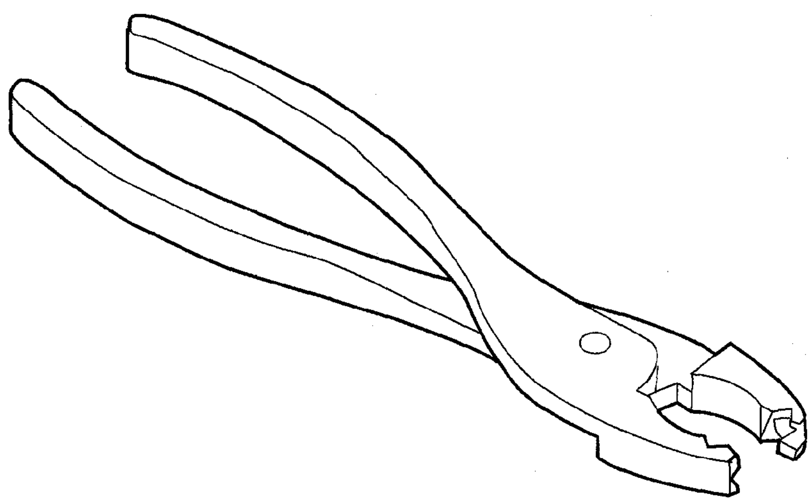



**Figure 4-36 Clamp Installer Tool**

**NOTE:**

Ensure the clamps are seated against the beads on the bypass tube neck and are at least one-half inch from the hose ends.

   [b] Using tool J 41454 (if required), install one clamp over the water bypass outlet on the water pump and one clamp over the thermostat housing water inlet.

[c] Push one end of the bypass tube and hose assembly onto the water pump bypass outlet and the other end onto the thermostat housing water inlet, ensuring the tube is properly oriented to avoid interference.

[d] Using installer tool J 41454, open the clamps and slide them over the hoses to secure them in place on the water pump bypass outlet and the thermostat housing inlet.

**NOTE:**
**Ensure the clamps are seated against the beads on the water pump bypass outlet and the thermostat housing water inlet and are at least one-half inch from the hose ends.**

[e] Proceed to step 10

9. If worm screw drive, liner type clamps are used, fasten the bypass tube to the water pump bypass outlet and the thermostat housing water inlet as follows:

   [a] Install two hose clamps onto the water bypass tube and push connecting hoses onto the ends of the tube.

   [b] Push the hoses on the ends of the bypass tube onto the thermostat housing water inlet and the water pump bypass outlet, ensuring the tube is properly oriented to avoid interference.

   [c] Secure the clamps onto the hoses and secure the hoses to the bypass tube, thermostat housing water inlet, and water pump bypass outlet by tightening the clamp screws.

**NOTE:**
**Ensure the clamps are seated against the beads on the bypass tube neck; the thermostat housing water inlet, and the water pump bypass outlet, are at least one-half inch from the hose ends.**

10. Fasten the water transfer tube to the water pump and oil cooler housing as follows:

    [a] Install four worm screw drive hose clamps onto the water transfer tube and push connecting hoses onto the ends of the tube.

    [b] Push the hoses on the ends of the transfer tube onto the oil cooler water inlet and the water pump outlet, ensuring the tube is properly oriented to avoid interference.

    [c] Secure the ends of the hoses to the transfer tube, oil cooler inlet, and water pump outlet by tightening the clamp screws.

11. Refer to section 11.3.5 for verification of proper water pump installation.

## 4.3 WATER PUMP (FRONT MOUNTED) (FM)

The centrifugal-type water pump circulates the engine coolant through the cylinder block, cylinder head, radiator and the oil cooler. See Figure 4-37.

The pump is mounted on the front of the engine gear case cover on units built prior to 6R037024 and is driven by the water pump drive gear. The water pump drive gear meshes with the bull gear.

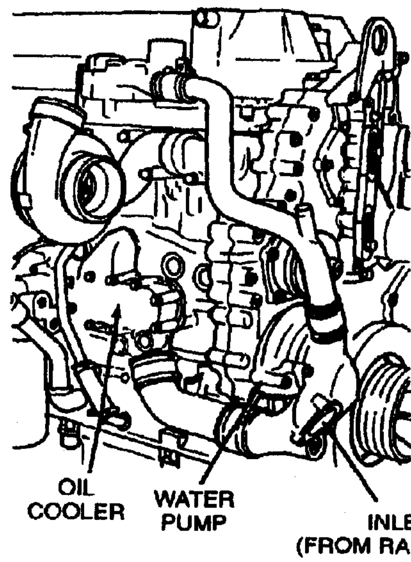
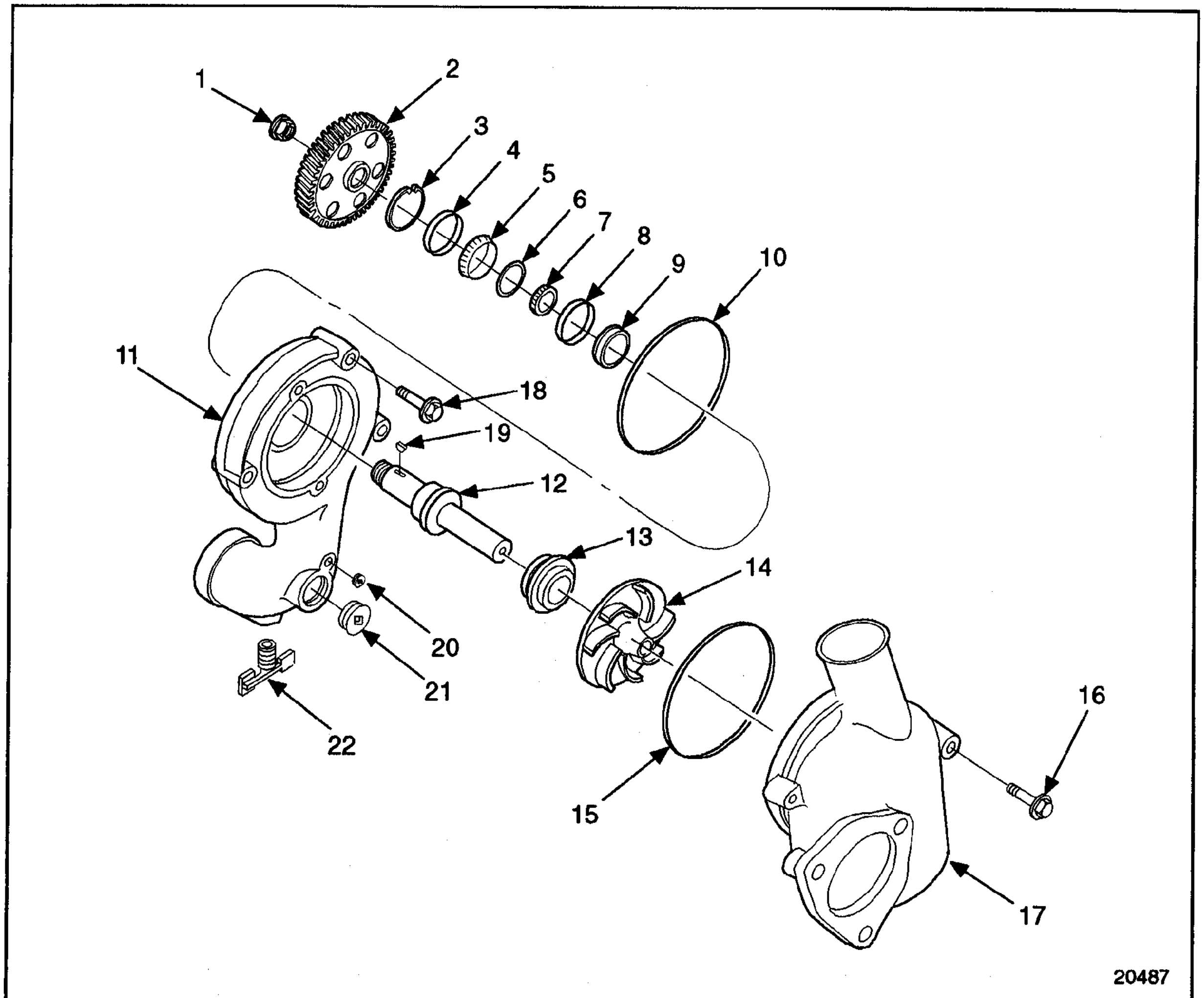



**Figure 4-37 Front Mounted Water Pump**

An impeller is pressed on one end of the stainless steel drive shaft. The other end of this shaft has internal threads, and a retaining bolt secures the water pump drive gear to the shaft. Two identical roller bearing assemblies are used to carry the shaft See Figure 4-38.




1. Locknut
2. Gear, Water Pump Drive
3. Snap Ring
4. Bearing Race
5. Roller Bearing, Larger
6. Spacer Rings (2)
7. Roller Bearing, Small
8. Bearing Race
9. Oil Seal
10. Seal Ring, Water Pump Housing
11. Housing, Water Pump
12. Drive Shaft
13. Water Seal
14. Impeller
15. Seal Ring, Water Pump Cover
16. Bolt, Cover-to-housing
17. Water Pump Cover
18. Bolt, Pump Housing to Gear Case Cover
19. Woodruff Key
20. Small Pipe Plug, Water Pump Housing
21. Large Pipe Plug, Water Pump Housing
22. Drain Cock

**Figure 4-38 Front Mounted Water Pump Details and Relative Location of Parts**

A rectangular rubber ring, located in a groove in the water pump housing, seals the water pump to the gear case cover. A smaller rectangular rubber ring, located in a groove in the water pump cover, seals the cover to the water pump housing. Engines built before October, 1989, are equipped with rubber O-ring seals on the water pump housing and cover. See Figure 4-38.

An oil seal is located behind the bearing assemblies, and a unitized, spring-loaded, face-type water seal is used behind the impeller. This seal prevents water from leaking down the shaft and into the gear case. It also prevents lubricating oil from entering the cooling system. The water and oil seals cannot be replaced without removing the water pump from the engine.

The pump bearings are lubricated by splash oil through a passage from the front of the pump housing.

## 4.3.1 Repair or Replacement of Water Pump (FM)

To determine if repair or replacement of the water pump is necessary, perform the following procedure. See Figure 4-39.

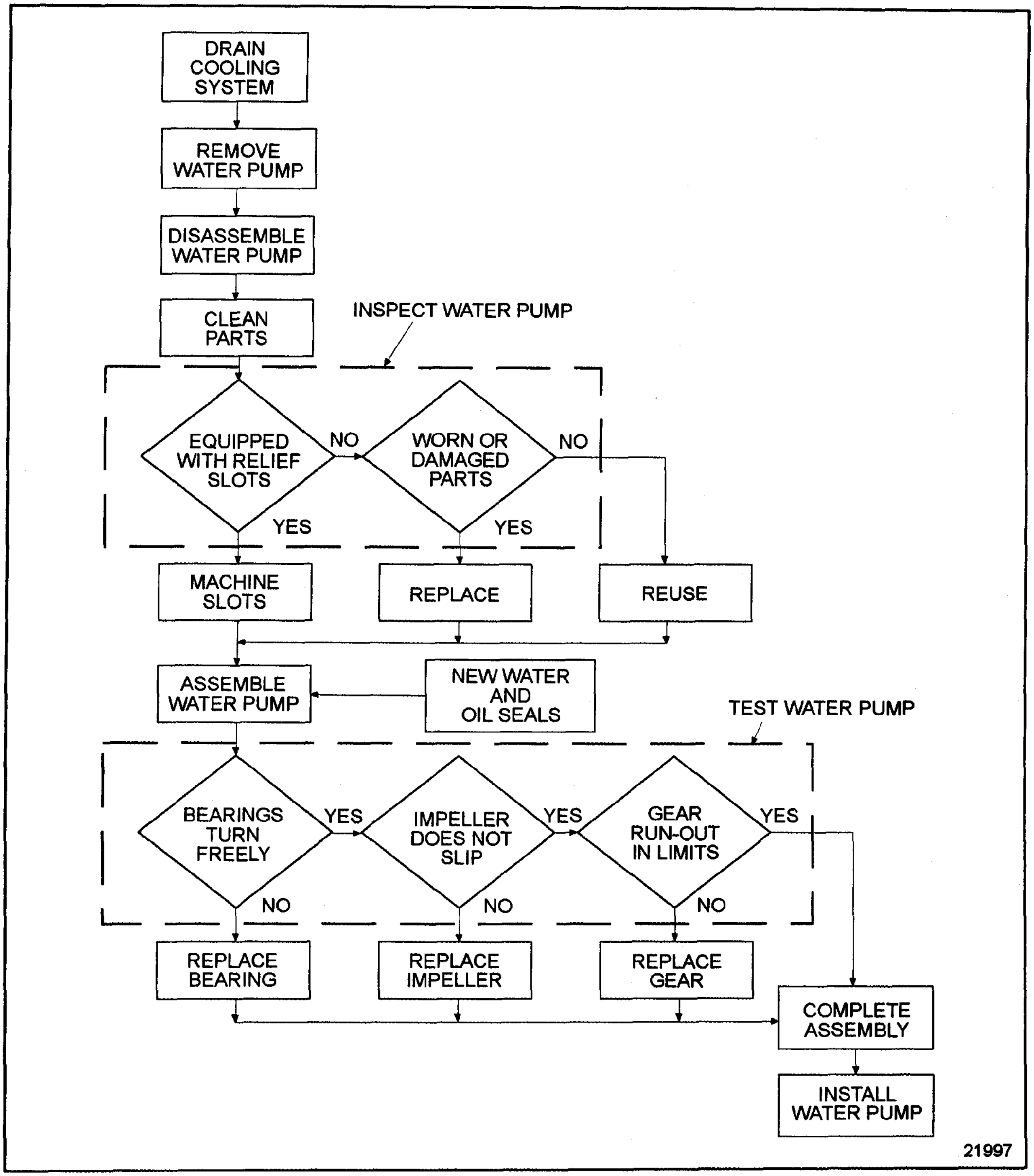



**Figure 4-39 Flowchart for Repair or Replacement of Water Pump (FM)**

### 4.3.2 Draining and Removal of Front Mounted Water Pump

Drain the cooling system as follows:

Open the drain cocks located at the right rear corner of the engine, at the bottom of the water pump and in the bottom of the thermostat housing.

Remove the water pump as follows:

1. Loosen the hose clamps and remove the coolant hoses from the water pump housing.
2. Loosen and remove the three water pump housing-to-gear case bolts. Remove the water pump from the engine by pulling it straight out of the gear case.

### 4.3.3 Disassembly of Front Mounted Water Pump

Disassemble the water pump as follows:

1. Loosen and remove the two water pump cover-to-pump housing bolts. Remove the water pump cover by pulling it straight out of the water pump housing, to prevent possible damage to the seal ring.

| NOTICE: |
| --- |
| If a vise is used to secure the water pump drive gear for locknut or impeller removal, use soft jaws on the vise and exercise extreme caution to prevent damage to the water pump drive gear teeth. |

2. Clamp the water pump drive gear in a vise, with the impeller facing up. Use a two-screw puller and remove the water pump impeller from the shaft, using the two threaded holes in the face of the impeller.

3. Place the water pump face down on a press bed. Using J 35988-5, part of tool set J 35988-B, and two breaker bars, loosen the locknut that secures the water pump drive gear to the shaft. Remove the locknut. See Figure 4-40.

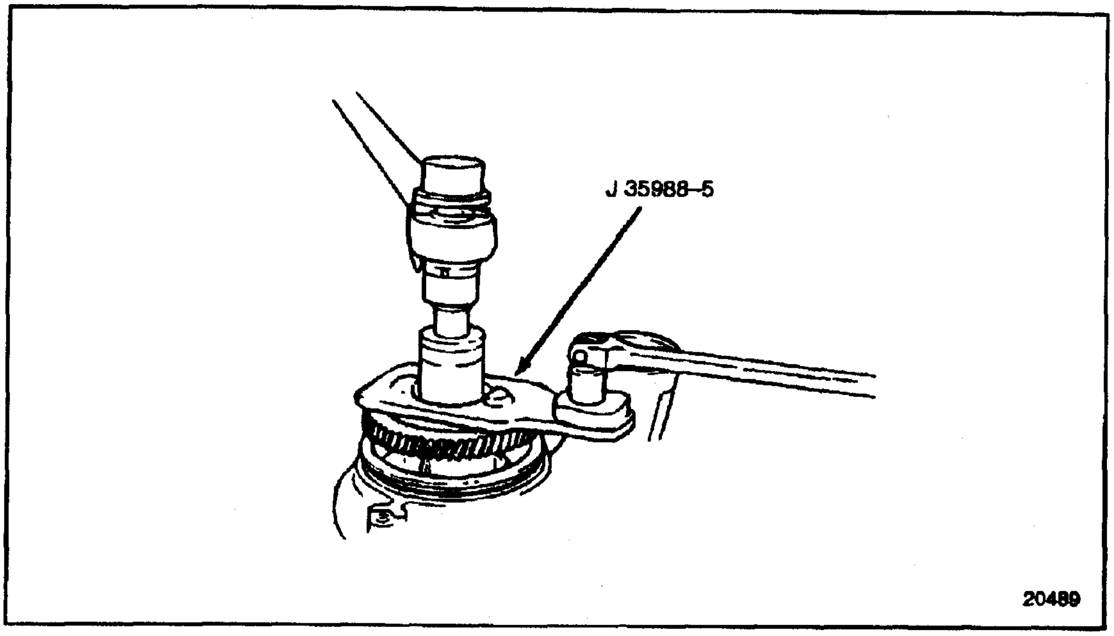



**Figure 4-40 Water Pump Drive Gear Locknut Removal (FM)**

4. Use a two-jaw puller to remove the water pump drive gear from the drive shaft.

**NOTE:**
Use care not to lose the Woodruff key.

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

5. Remove the snap ring from the water pump housing. See Figure 4-41.

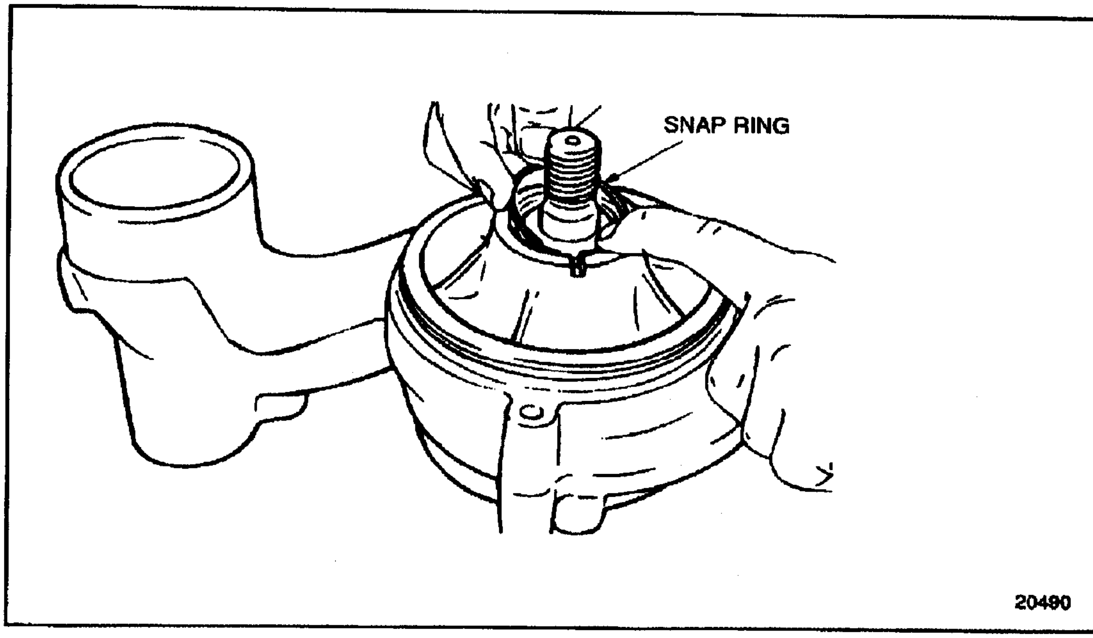



**Figure 4-41 Snap Ring Removal (FM)**

6. Support the water pump housing, engine side down, using steel blocks or plates, to allow at least 76 mm (3 in.) of clearance between the pump housing and the press bed.
7. Press the drive shaft and bearings assembly out through the back (engine side) of the water pump housing, until both bearing races are clear of the housing.

**NOTICE:**

Use care not to damage the housing. Damaged housing bore will cause coolant leaks and damage to the engine.

8. Remove both the water and oil seals from the housing using a brass drift and hammer.

9. Support the drive shaft assembly on two steel blocks, at the bearing inner race. See Figure 4-42.

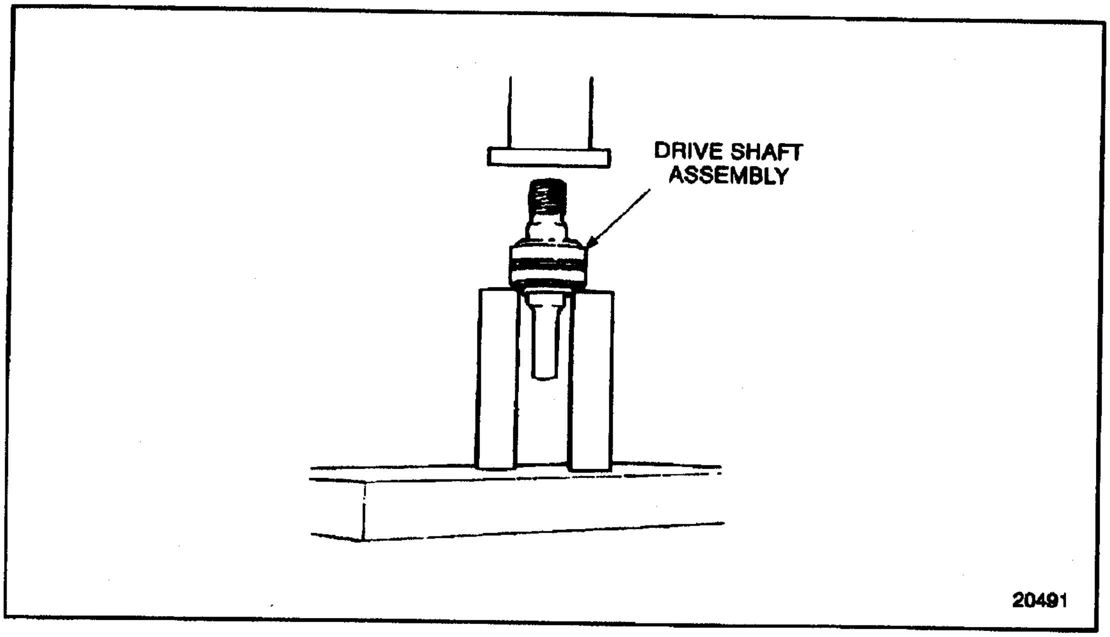



**Figure 4-42 Removing Bearing Assemblies (FM)**

10. Press the drive shaft out until it is clear of both bearing and race assemblies. Discard the used bearings, races and the two spacer rings located between the bearing packs.

### 4.3.3.1 Inspection of Front Mounted Water Pump

Inspect the water pump parts as follows:

1. Visually inspect the parts for cracks, wear or other damage.
   [a] If parts are cracked, worn or have other damage, replace damaged or worn parts. Refer to section 4.3.5.
   [b] If parts are not cracked, worn or damaged, reuse remaining components.
2. Inspect the water pump housing for relief slots in the water seal cavity. If pump is without the relief slots, modify the area in which the impeller rides to add the slots. See Figure 4-43.

**NOTE:**
The gear case cover mount water pumps have two cast slots in the water seal cavity. Effective with Engine Serial Number 6R2807 machined relief slots were added to the pump. The relief slots ensure coolant flow to the seal faces.

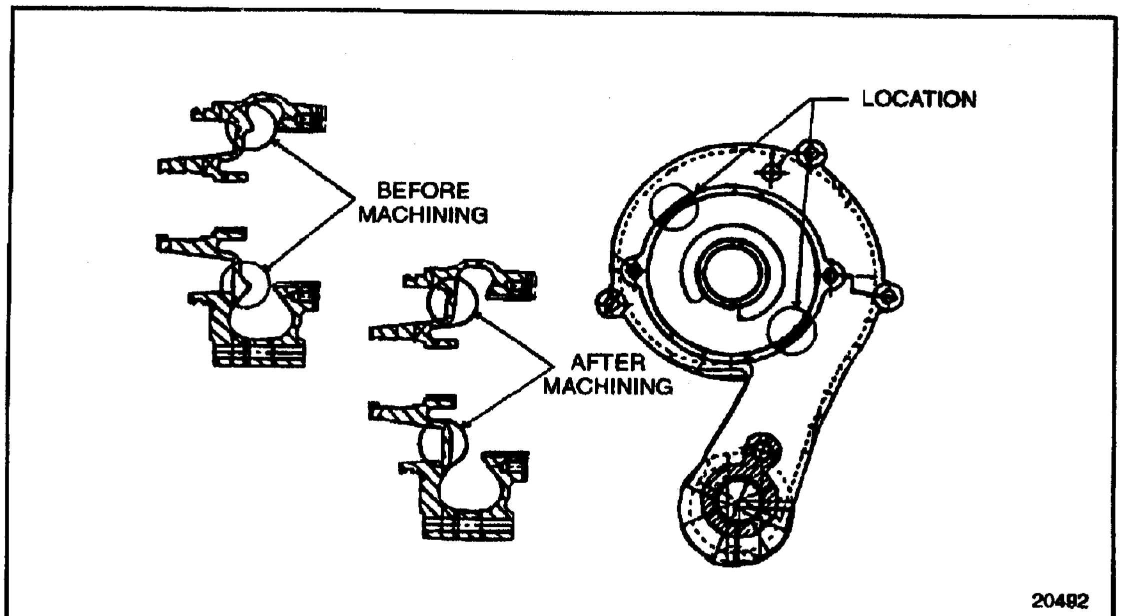



**Figure 4-43 Water Pump Body Modification (FM)**

**NOTICE:**

If a vise is used to secure the water pump drive gear for locknut or impeller removal, use soft jaws on the vise and exercise extreme caution to prevent damage to the water pump drive gear teeth.

[a] Lock the water pump body securely in the soft jaws of a bench vise.

[b] Using a die grinder (if possible, have professionally machined), remove 38.1 mm (1.5 in.) of material in the 10 o'clock and 4 o'clock positions of the raised belt that surrounds the water pump impeller. See Figure 4-43. Enough material should be removed so that, when machined, the slot is flush with the rest of the casting.

[c] After machining, wash the pump housing and all other pump parts in clean fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

[d] Dry with compressed air.

### 4.3.4 Cleaning of Front Mounted Water Pump

Clean the water pump parts as follows:

1. Wash all of the pump parts in clean fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry the parts with compressed air.

### 4.3.5 Assembly of Front Mounted Water Pump

Assemble the water pump as follows:

1. Coat the bearing bores of the water pump housing and the drive shaft bearing surfaces with clean engine oil.

| NOTICE: |
|---|
| Although the bearings are identical, the bearings and races are matched parts, and should be installed as they are removed from the box. Parts that are not matched will cause damage to the water pump. |

2. Assemble new bearing packs. See Figure 4-44.

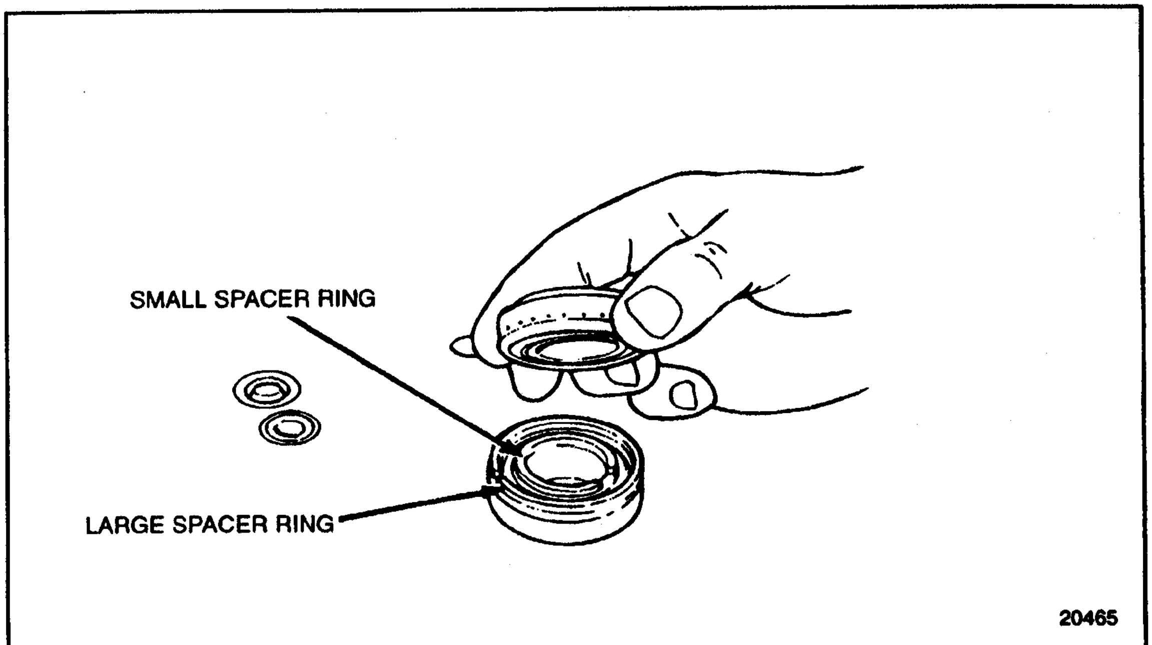



**Figure 4-44 Bearing Pack Assembly (FM)**

3. Install the drive shaft into the center of the fixture usingJ 35988-18 andJ 35988-2 , parts of tool set J 35988-B. See Figure 4-45.

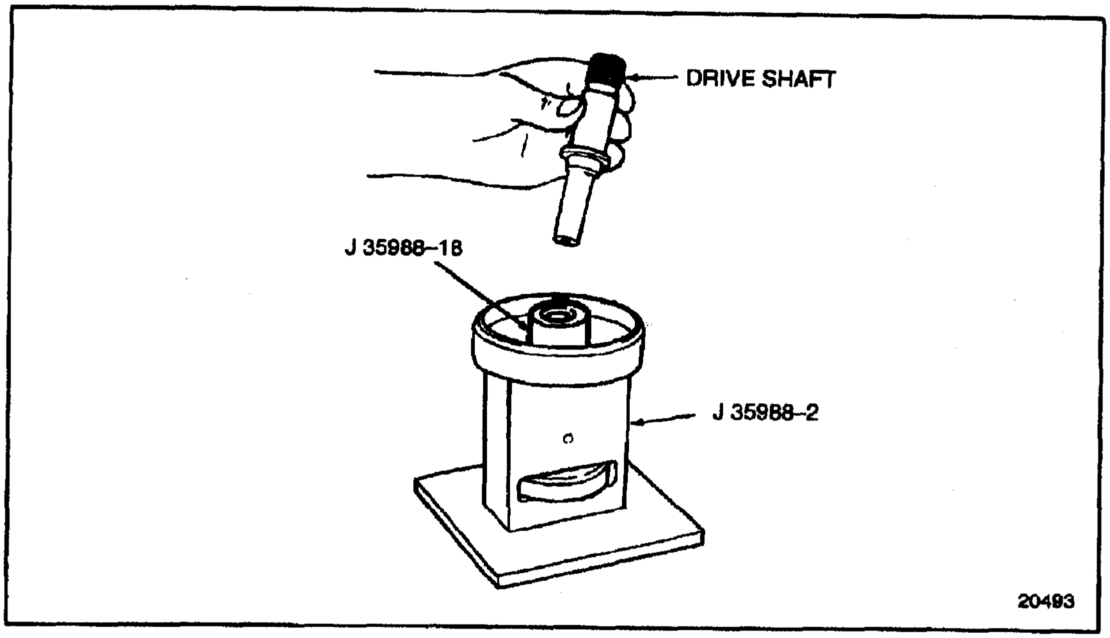



**Figure 4-45 Bearing Installation Set-Up (FM)**

4. Install the assembled bearing packs to the drive shaft. See Figure 4-46.

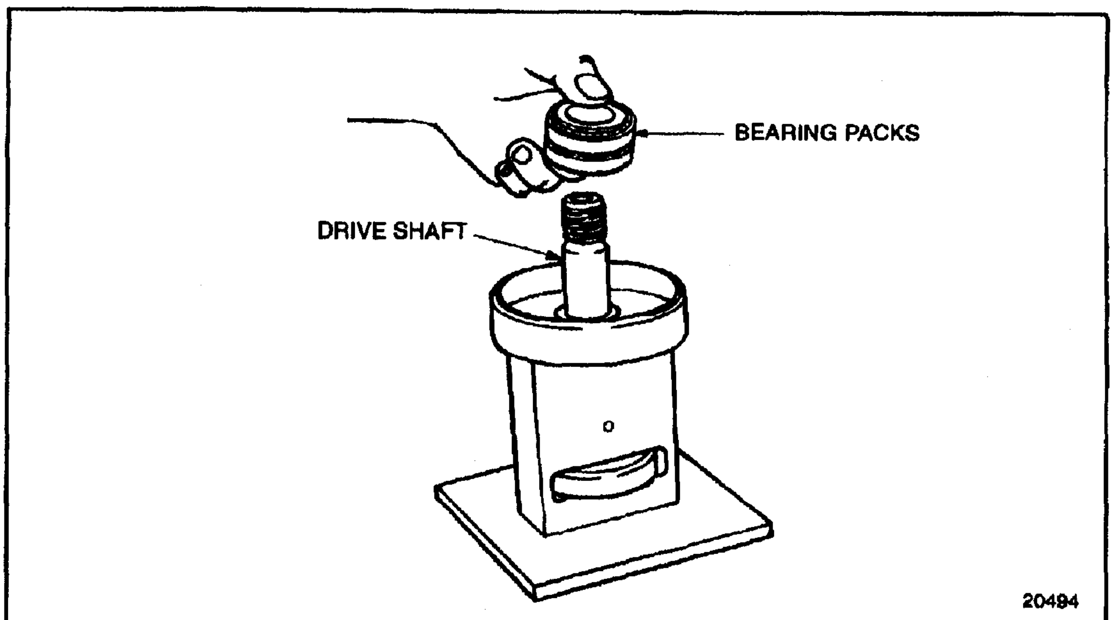



**Figure 4-46 Bearing Placement (FM)**

5. Press the bearing pack onto the shaft until it contacts the shoulder of the shaft using J 35988-1A, part of tool set J 35988-B. See Figure 4-47.

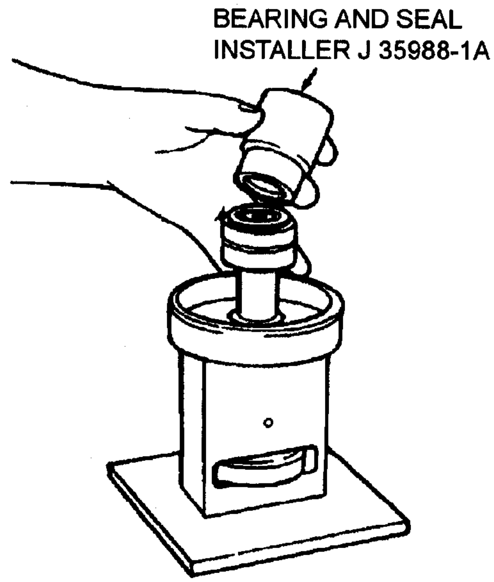



**Figure 4-47 Bearing Installation (FM)**

6. Remove the shaft and bearing assembly from the press.

### 4.3.5.1 Test Bearing Assembly (FM)

Check bearing assembly as follows:

1. Turn bearings to ensure they turn freely.
   [a] If bearings bind, disassemble water pump and replace bearing assembly. Refer to section 4.3.3.
   [b] If bearings do not bind, reuse the part.

## 4.3.6 Assembly of Water Pump (FM) - cont'd

Continue assembling the water pump, as follows:

1. Coat the new oil seal contact area of the water pump housing with a thin film of clean engine oil. See Figure 4-48.

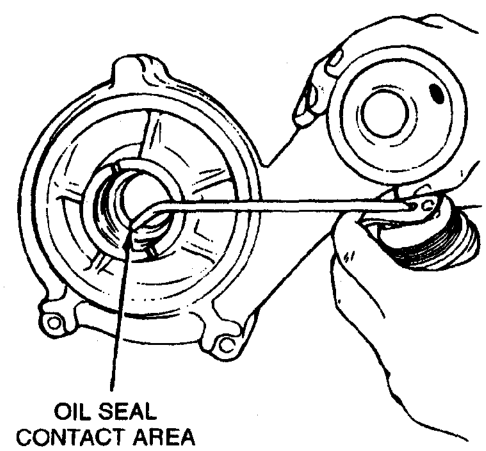



**Figure 4-48 Oil Seal Contact Area Lubrication (FM)**

2. Install the oil seal to the water pump housing from the rear (gear side). See Figure 4-49.

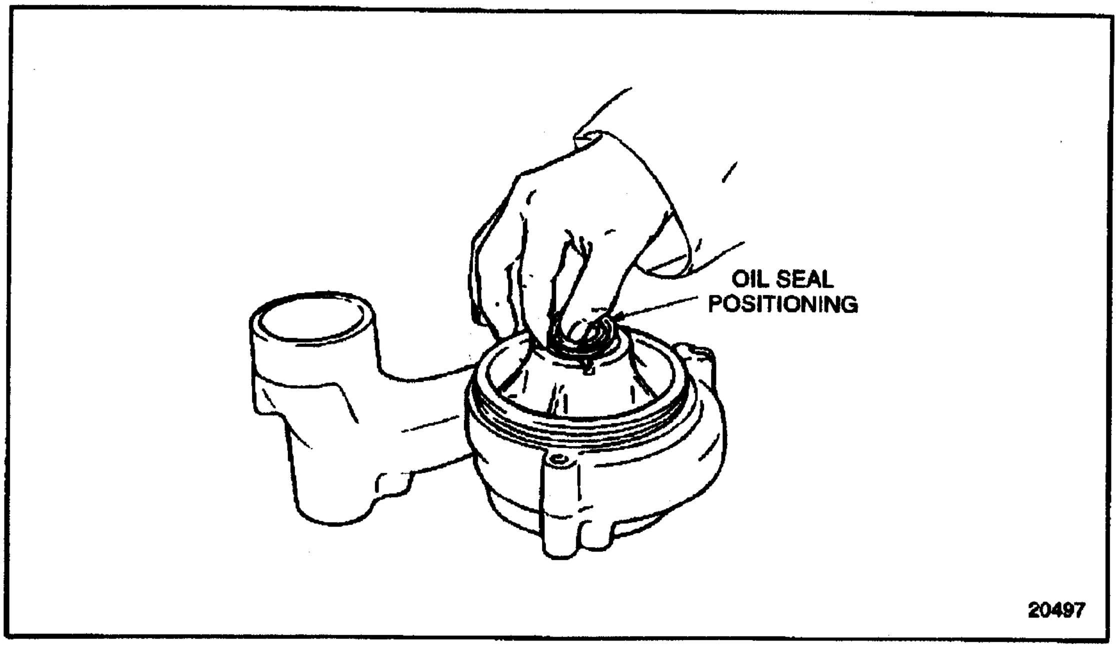



**Figure 4-49 Oil Seal Positioning (FM)**

3. Place the small end of tool J 35988-1A, part of tool set J 35988-B, into the water pump housing until it contacts the oil seal. See Figure 4-50.

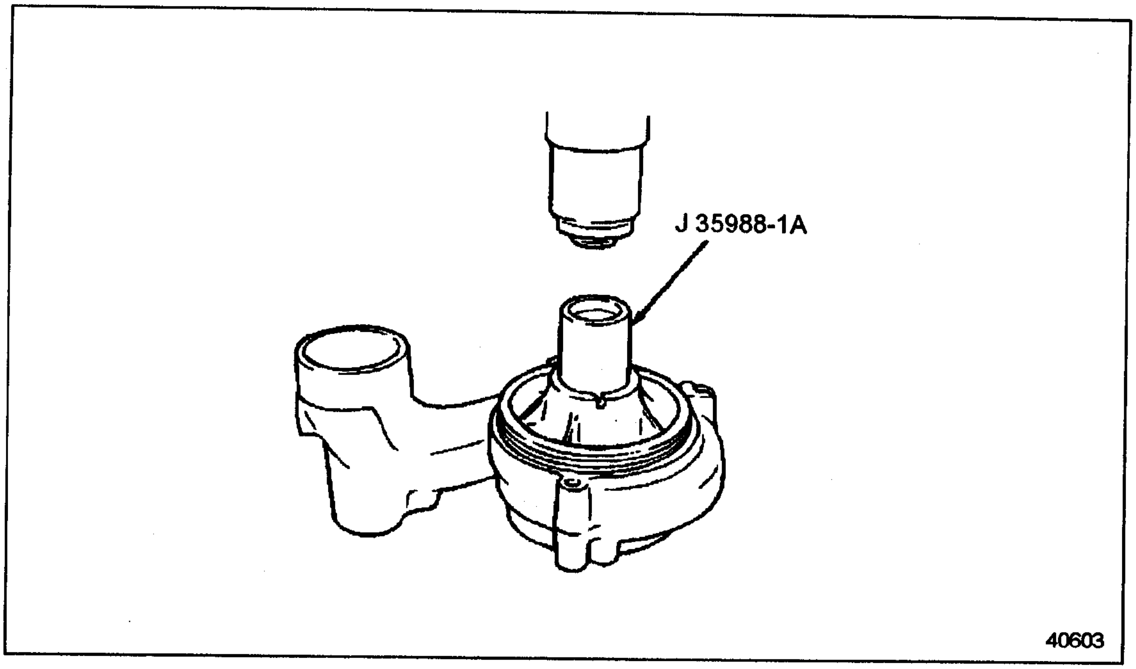



**Figure 4-50 Oil Seal Installation (FM)**

| NOTICE: |
|---|
| The contact surface of the oil seal is coated with a special sealant. Do NOT remove this sealant before installing the oil seal. If sealant is removed, leakage can occur. |

4. Press the oil seal into the housing until the seal lip is bottomed in the pump housing. Remove the toolJ 35988-1A, part of tool set J 35988-B.
5. Coat the bearings with clean engine oil.
6. Place the water pump housing, face down (gear side up), on a press bed.

7. Install the drive shaft, with bearings installed, to the rear of the water pump housing. See Figure 4-51.

**NOTE:**
During the bearing installation, the water pump housing must be parallel to the press bed or table surface.

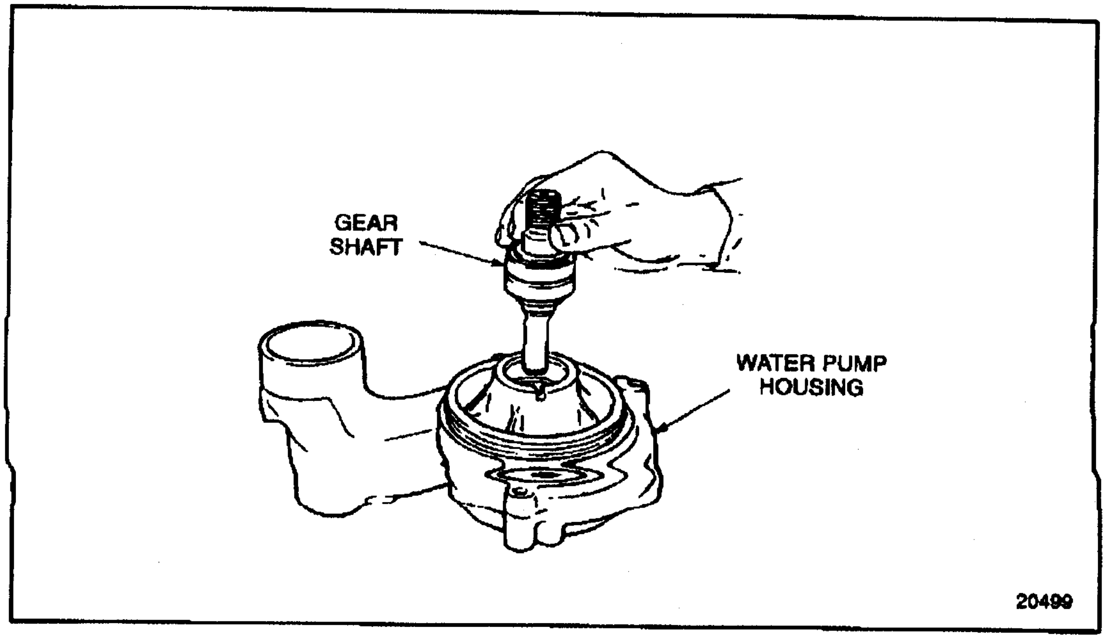



**Figure 4-51 Drive Shaft Insertion (FM)**

8. Place the large end of tool J 35988-1A, part of tool set J 35988-B, over the drive shaft so that the lip of the tool rests squarely on the outer bearing race. See Figure 4-52.

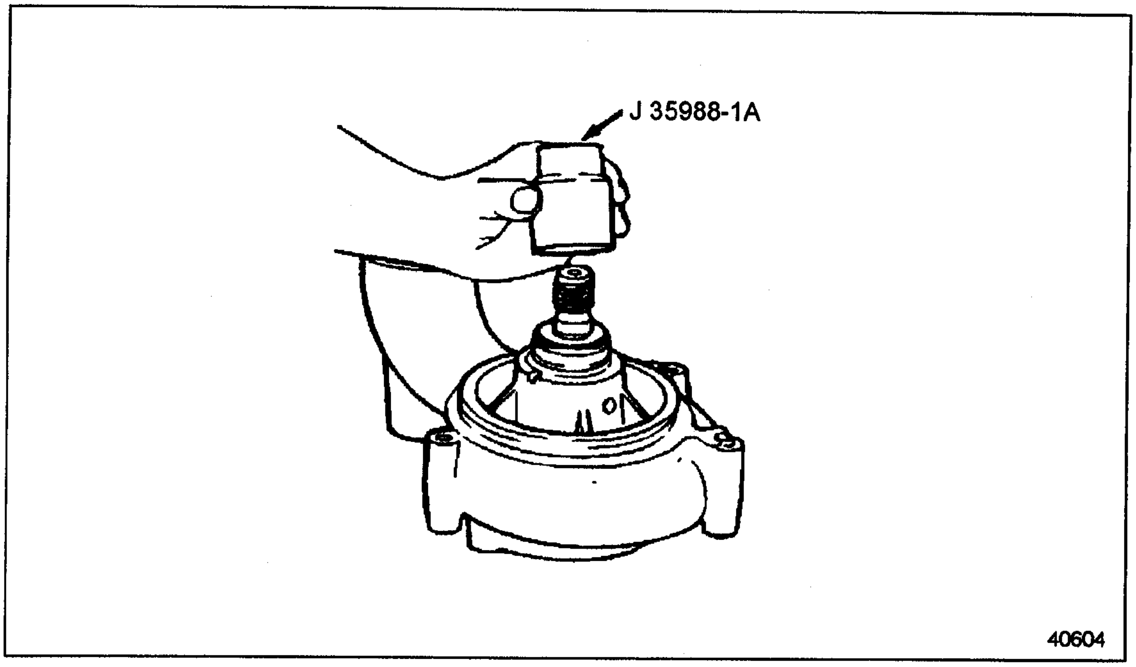



**Figure 4-52 Drive Shaft Installation (FM)**

| NOTICE: |
|---|
| The drive shaft must be installed pressing on the outer bearing race only. Any other attempt at installation may damage the bearings. |

9. Press the drive shaft and bearing assembly into the water pump housing, using the tool J 35988-1A, part of tool set J 35988-B, until it is seated firmly against the shoulder in the housing.

10. Install the snap ring to the water pump housing. See Figure 4-53.

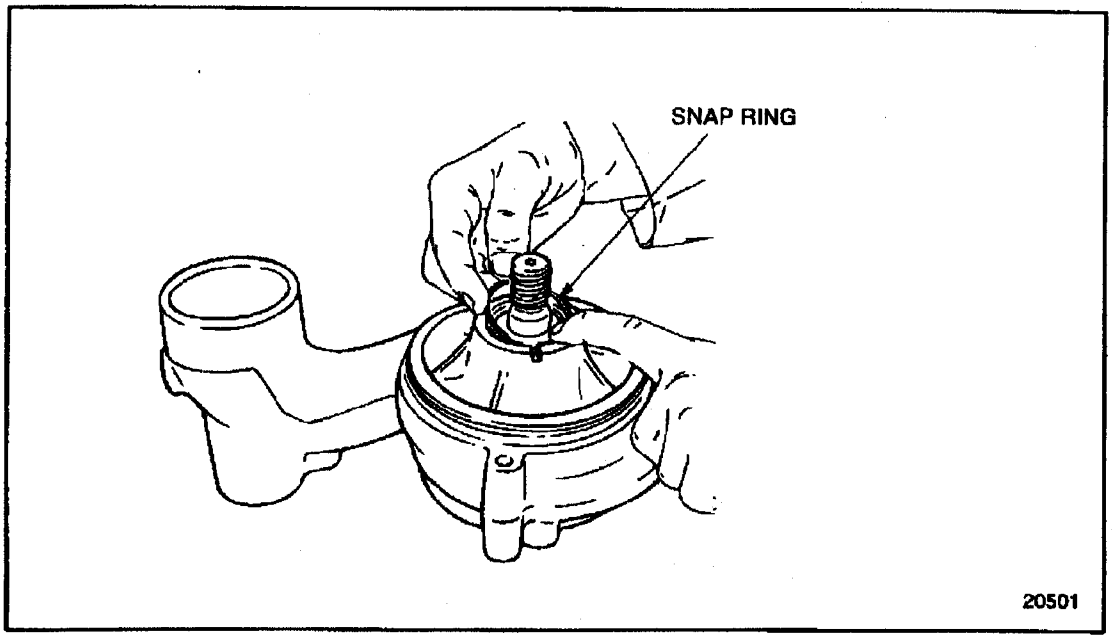



**Figure 4-53 Snap Ring Installation (FM)**

**NOTICE:**

Form-a-Gasket Sealer must be used sparingly, and kept from the shaft and bearing surfaces. Excessive amounts of Form-a-Gasket Sealer could cause plugging of radiator or cooler core.

11. Turn the water pump housing over. Working through the front, apply a coating of Aviation Form-a-Gasket, Form-a-Gasket No. 3 or equivalent to the area where the water pump seal case contacts the pump body. See Figure 4-54.

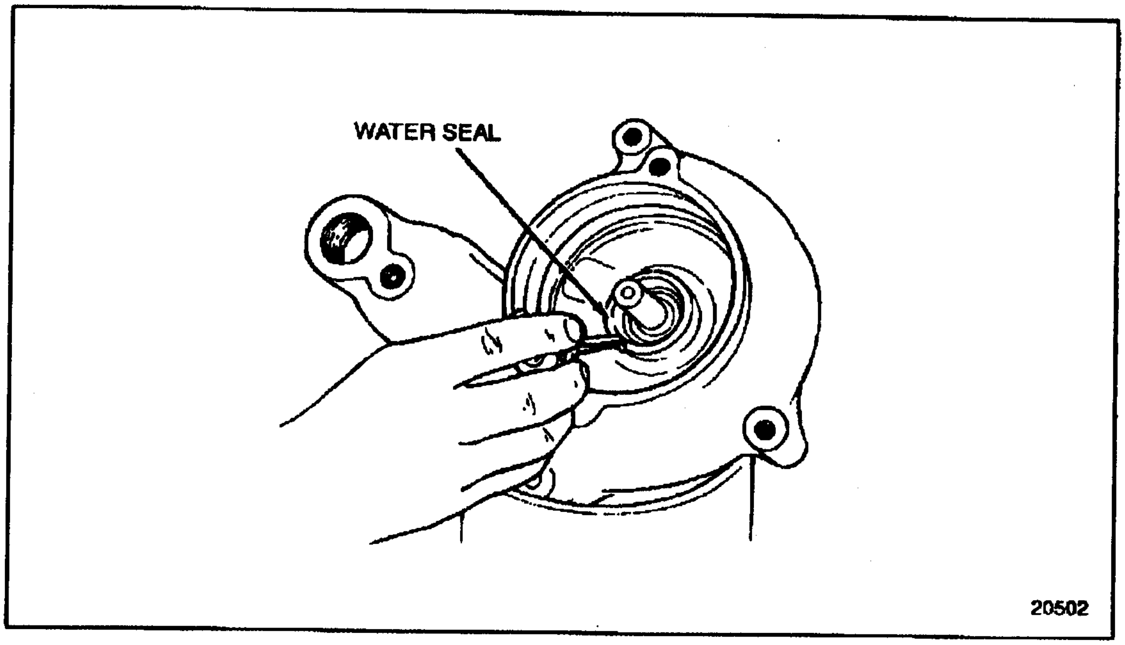



**Figure 4-54 Sealer Installation**

12. Install J 35988-3A , part of tool set J 35988-B, to the fixture tool. See Figure 4-55.

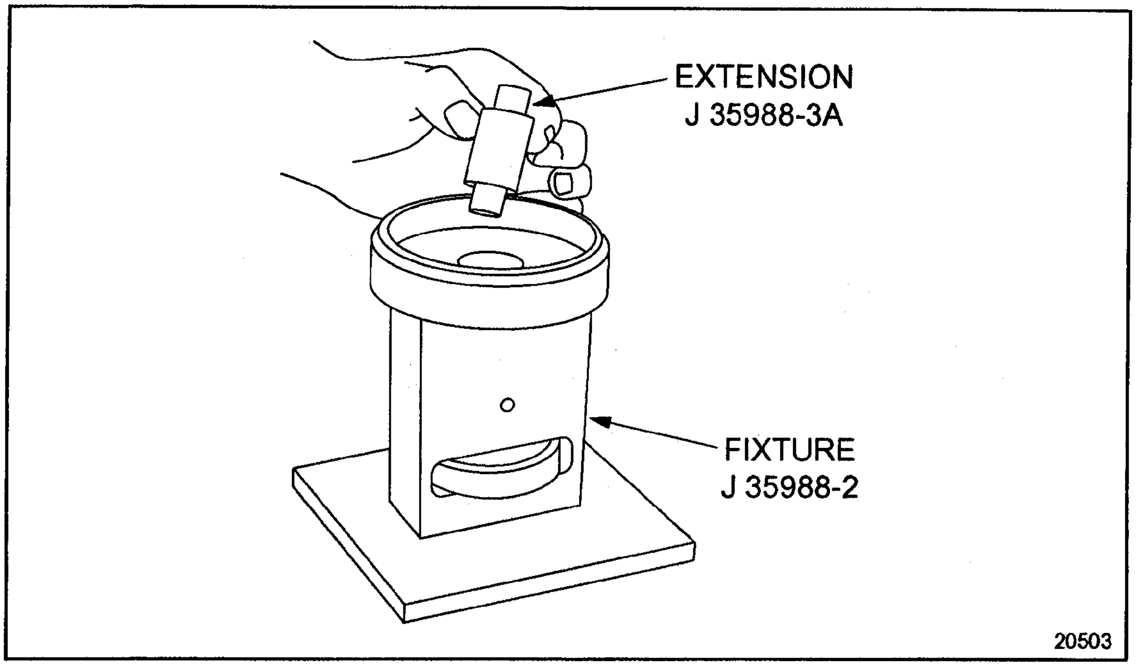



**Figure 4-55 Support Installation (FM)**

13. Install the water pump housing assembly to the fixture. See Figure 4-56.

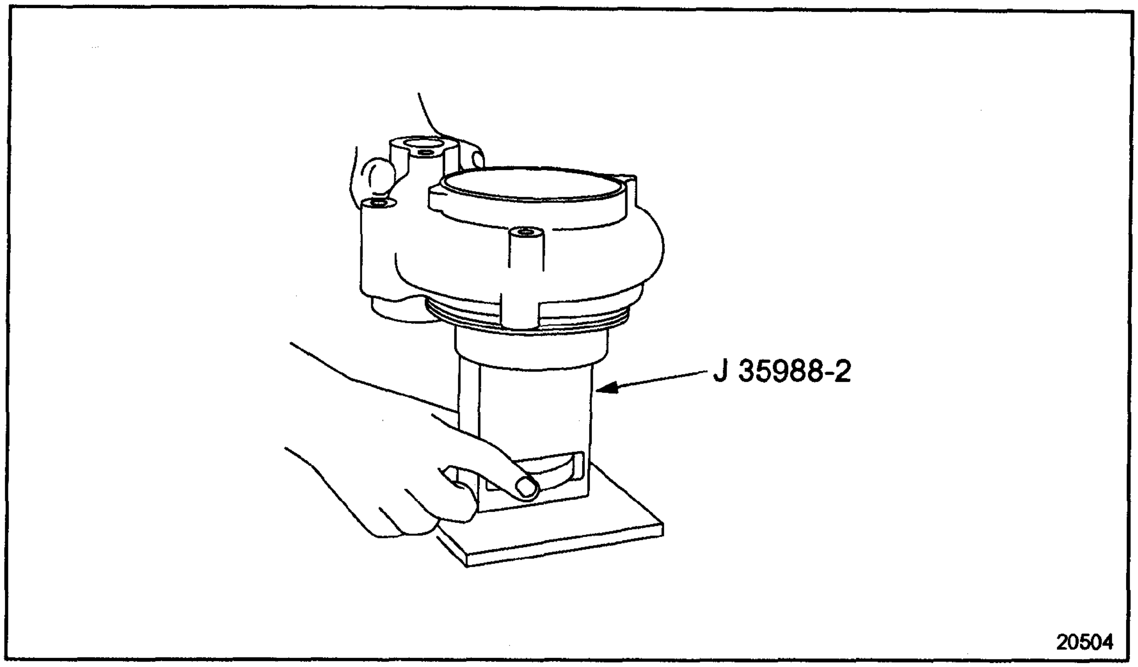



**Figure 4-56 Water Pump Impeller Installation Set-Up (FM)**

| NOTICE: |
|---|
| The extension must contact and support the shaft when installing the water seal and impeller to prevent damage to the bearings. |

14. Turn the adjustor wheel to raise the extension until it contacts the drive shaft in the water pump housing.
15. Apply Loctite® primer (Locquic Primer N, Part No. 764) by swabbing onto the I.D. of the rotor of the seal.

16. Install a new water seal over the drive shaft and seat it in the water pump housing. See Figure 4-57.

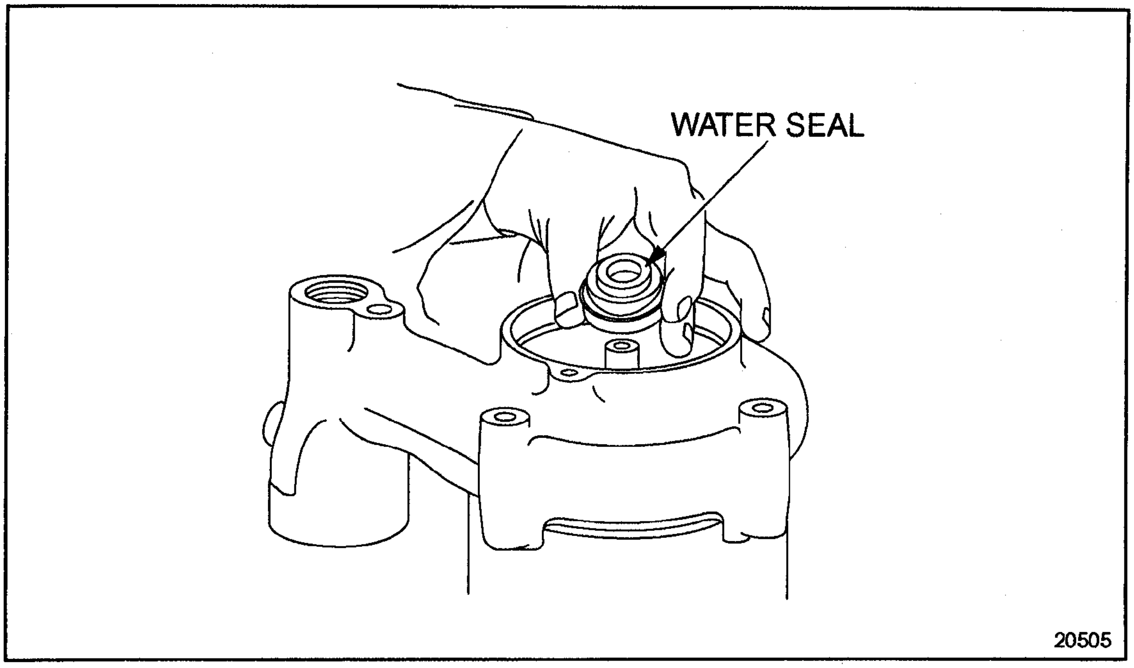



**Figure 4-57 Water Seal Insertion (FM)**

17. Position tool J 35517-1, part of tool set J 35988-B, over the water seal. See Figure 4-58.

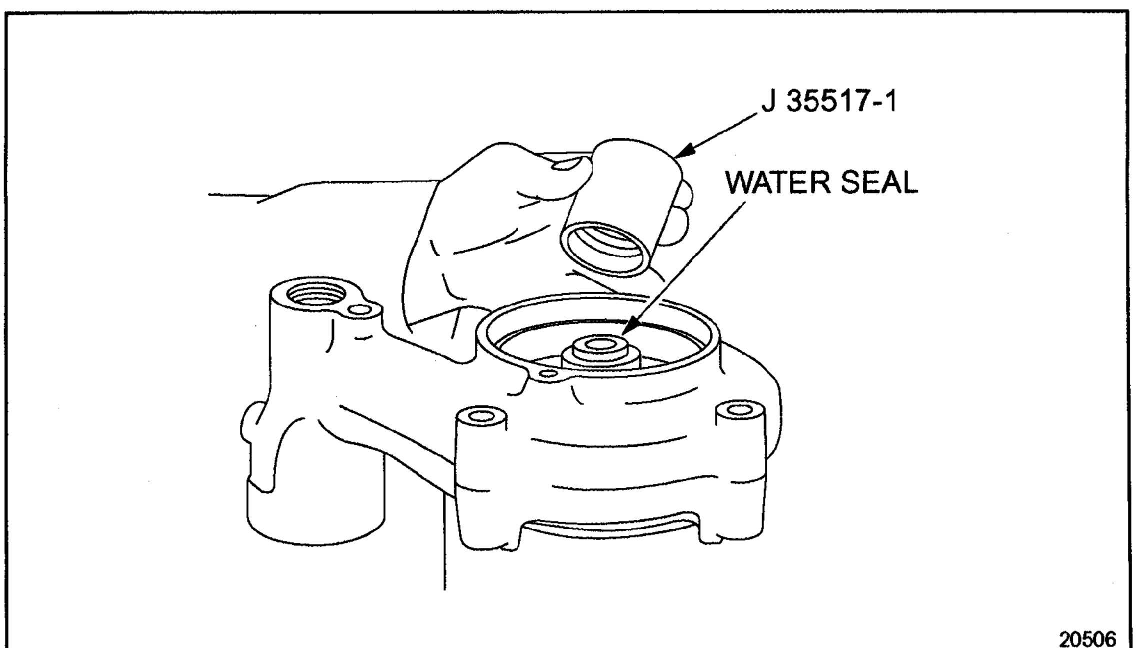



**Figure 4-58 Water Seal Installation (FM)**

18. Press the water seal into the housing until the flange of the seal case contacts the water pump housing a full 360°. Remove toolJ 35517-1, part of tool set J 35988-B.

| NOTICE: |
|---|
| The sealant must not be allowed to spill over the side of the water pump seal. Damage to the seal may occur. |

19. Apply only one drop of Loctite® 290 sealant to the drive shaft where it contacts the water seal. The sealant will wick around the shaft making a complete seal. See Figure 4-59. Wipe off excess sealant.

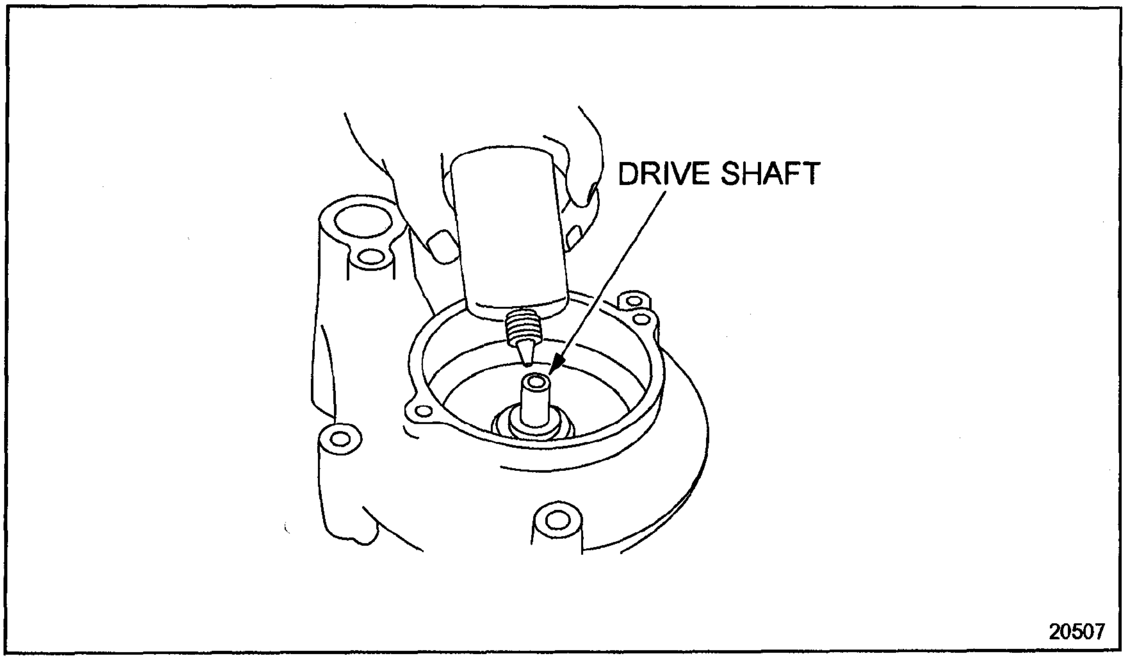



**Figure 4-59 Sealant Installation (FM)**

**NOTICE:**

The shaft should not be turned, moved from vertical or the seal pressure tested for at least two hours. Do not exceed 172 kPa (25 lb/in.$^2$) when pressure testing. Sealant requires time to cure to prevent coolant leaks and possible engine damage.

20. With the shaft in the vertical position apply Locquic Primer N on top of the Loctite® 290 by swabbing.

**NOTE:**
Due to time required for curing, DDC recommends keeping a pump built up in parts for immediate use when needed. A pump removed from an engine could be rebuilt and placed in storage for later use.

21. With the water pump housing still housed in toolJ 35988-2, part of tool set J 35988-B, and located on a press bed, install the water pump impeller to the end of the drive shaft. Position the impeller so that the machined end is parallel with the housing machined face. See Figure 4-60.

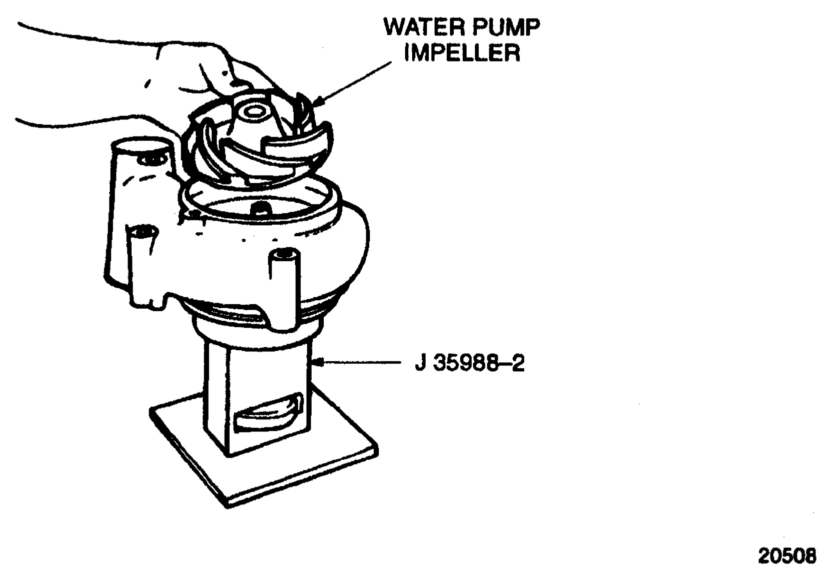



**Figure 4-60 Water Pump Impeller Installation (FM)**

22. Press the impeller on until it is flush with the end of the drive shaft. See Figure 4-61.

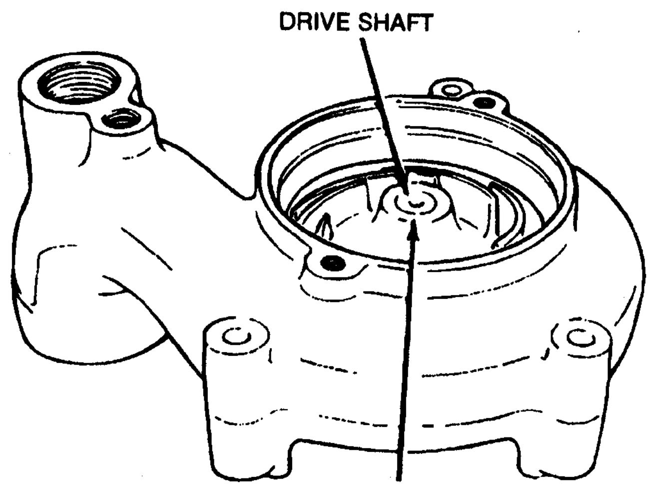



**Figure 4-61 Water Pump Impeller Location (FM)**

23. Turn the housing over and place it face (impeller side) down on fixtureJ 35988-2 , part of tool set J 35988-B.

24. Install the Woodruff key to its slot in the drive shaft. Tap the key with a brass hammer to seat it squarely in the slot. See Figure 4-62.

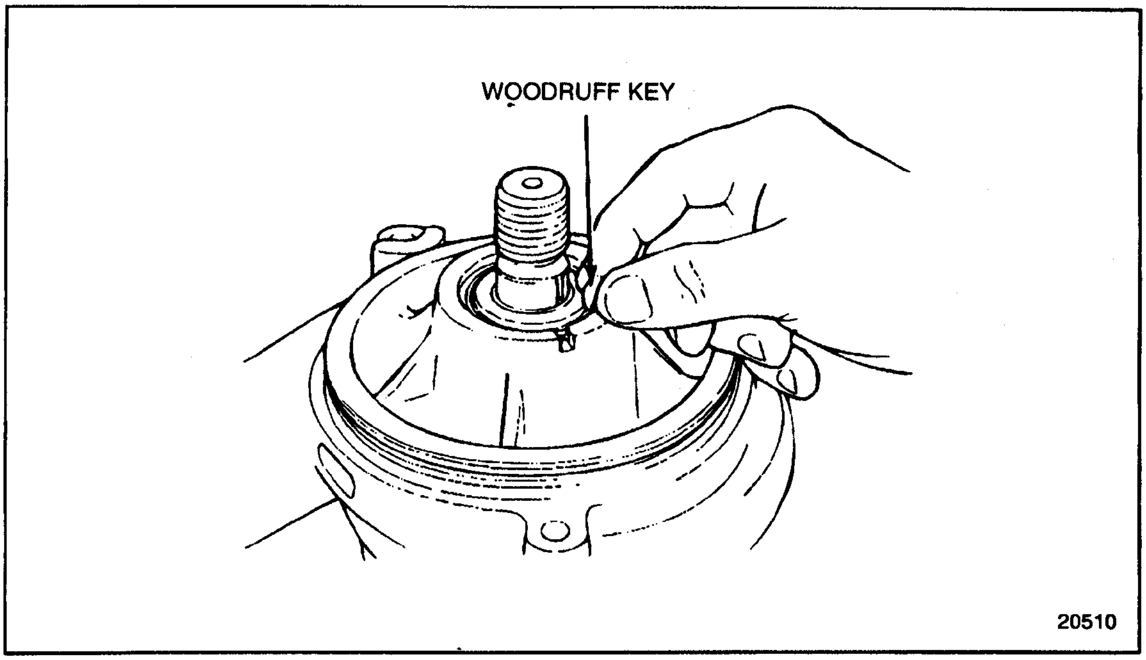



**Figure 4-62 Woodruff Key Installation (FM)**

25. Install the water pump drive gear to the drive shaft, indexing the slot in the gear with the Woodruff key.

| NOTICE: |
|---|
| Extension tool J 35988-3, part of tool set J 35988-B, must support the shaft. This is necessary to prevent damage to the bearings when pressing the gear onto the shaft. |

26. Turn the adjustor wheel to raise the extension toolJ 35988-3, part of tool set J 35988-B, until it contacts the shaft.

27. Using the small end of toolJ 35988-1A, part of tool set J 35988-B, press the drive gear down onto the drive shaft until it touches the bearings. See Figure 4-63.

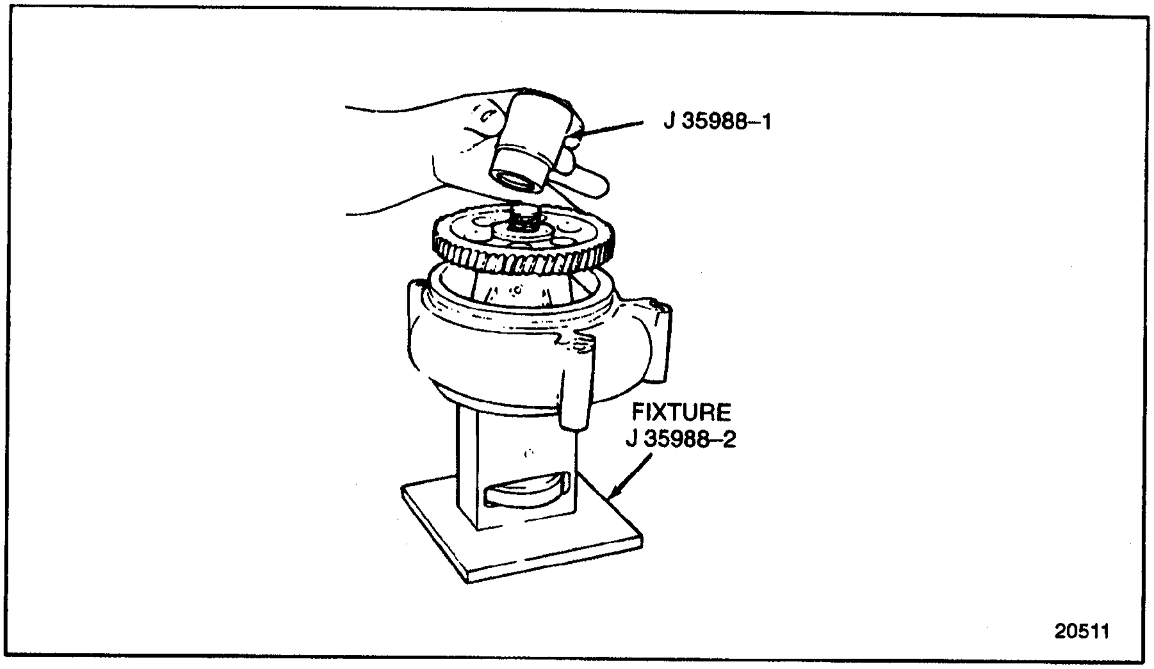



**Figure 4-63 Water Pump Drive Gear Installation (FM)**

28. Install locknut to the drive shaft threads. See Figure 4-64.

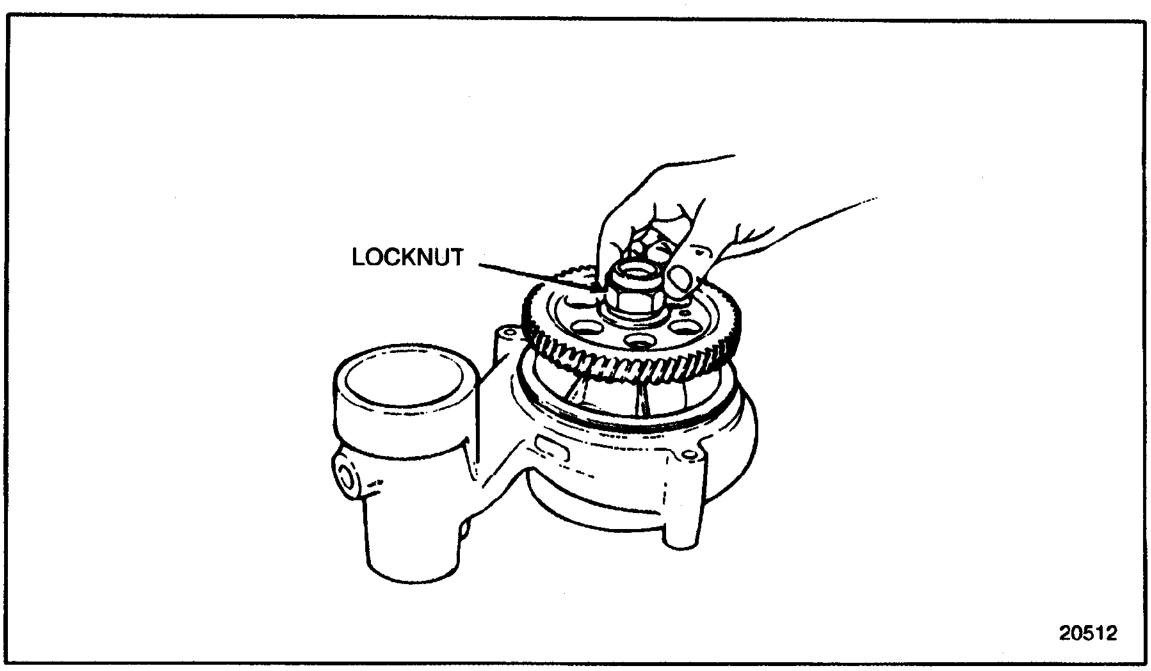



**Figure 4-64 Locknut Installation (FM)**

29. Using J 35988-5, part of tool set J 35988-B, with a breaker bar to hold the gear and shaft, tighten the locknut with a torque wrench to 203-230 N·m (150-170 lb·ft) torque.

### 4.3.6.1 Assembly Integrity Test

Verify the assembly integrity as follows:

1. Turn the pump over and install J 35687 into the tapped holes provided in the impeller.
2. Clamp J 35988-5 , part of tool set J 35988-B, (legs up) in a vise and position the lightening holes in the drive gear over the legs of the tool.
3. Using a 1/2 in.-drive torque wrench in the hole provided in the center of J 35687, apply 68 N·m (50 lb·ft) torque in either direction.
   [a] The gear and impeller must withstand 68 N·m (50 lb·ft) torque without slipping.
   [b] If the torque specification is not satisfied, disassemble water pump and replace the impeller. Refer to section 4.3.3.
4. Using a dial indicator with magnetic base, measure the total run-out of the water pump drive gear at four places, at 90 degree intervals. Maximum allowable run-out is 0.0635 mm (0.0025 in.). See Figure 4-65.

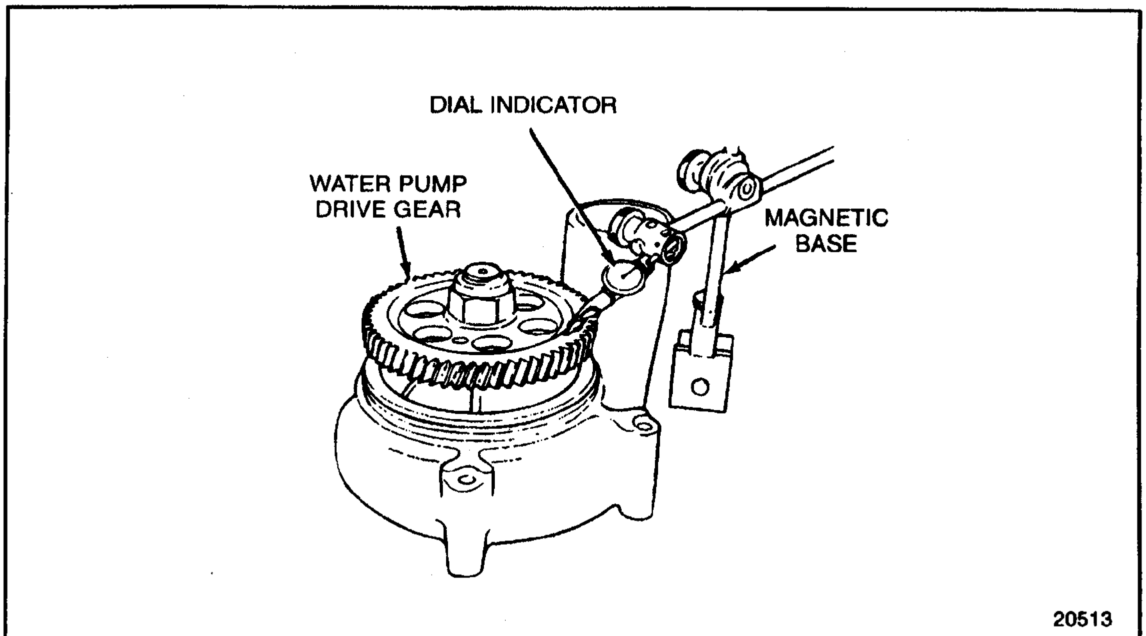



**Figure 4-65 Measuring Water Pump Drive Gear Runout (FM)**

   [a] If specifications are exceeded, disassemble the water pump and check for burrs or foreign particles. Refer to section 4.3.3.
   [b] If specifications are with limits, reuse part.

### 4.3.7 Installation of Front Mounted Water Pump

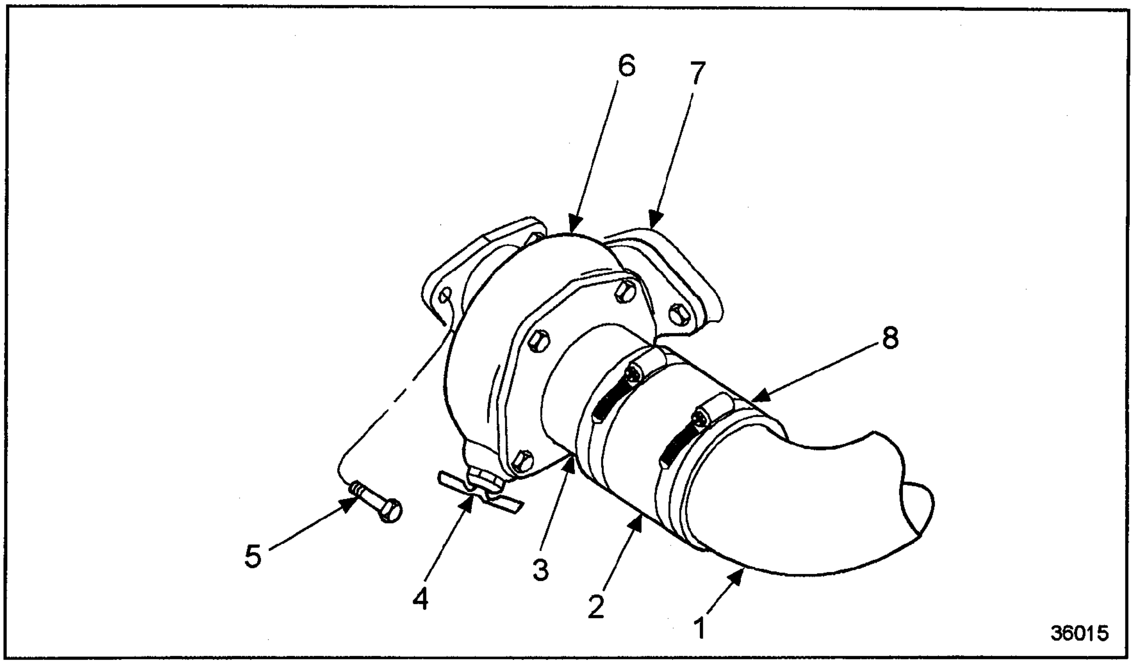
Install the water pump as follows:

1. Coat the two seal rings with clean engine oil. Install the larger seal ring to the groove in the water pump housing. Install the smaller seal ring to the groove in the water pump cover. Coat the water pump drive gear with clean engine oil.
2. Install the water pump to the engine, meshing the water pump drive gear with the bull gear.
3. Install the three water pump housing-to-gear case cover bolts. Tighten the bolts alternately and evenly to draw the water pump straight into the engine. Torque the bolts to 30-38 N·m (22-28 lb·ft).
4. Measure the gear backlash. Refer to section 1.21.2.1.
5. Install the water pump cover to the water pump with two bolts. Torque the bolts alternately and evenly to draw the cover straight into the water pump housing. Torque the bolts to 30-38 N·m (22-28 lb·ft).
6. Slide the coolant hoses into position and tighten the hose clamps.
7. Fill the cooling system. Refer to section 13.13.4 of engine maintenance.

## 4.4 CHARGE AIR COOLER RAW WATER PUMP (KEEL-COOLED COMMERCIAL MARINE)

The centrifugal-type water pump circulates raw water through the charge air cooler (CAC) on keel-cooled marine engines. The drive end of the pump shaft is supported by a sealed double-row combination radial and thrust ball bearing. The pump shaft serves as the inner race of the bearing.

The pump is mounted to the rear end of the gear case on the intake side of the engine. The drive coupling, pressed on the end of the pump shaft, has an integral oil thrower that shrouds the flange end of the pump body and deflects the oil away from the bearing. See Figure 4-66.




1. To Charge Cooler
2. Hose
3. Pump Cover
4. Drain Cock
5. Bolt
6. Water Pump
7. Inlet Flange
8. Clamp

**Figure 4-66 CAC Water Pump Mounting**

**NOTE:**
The high capacity water pump has a shaft bearing assembly, unitized seal assembly, drive coupling, and ceramic insert.

## 4.4.1 Replacement of CAC Water Pump

To determine if repair or replacement is necessary, perform the following procedure. See Figure 4-67.

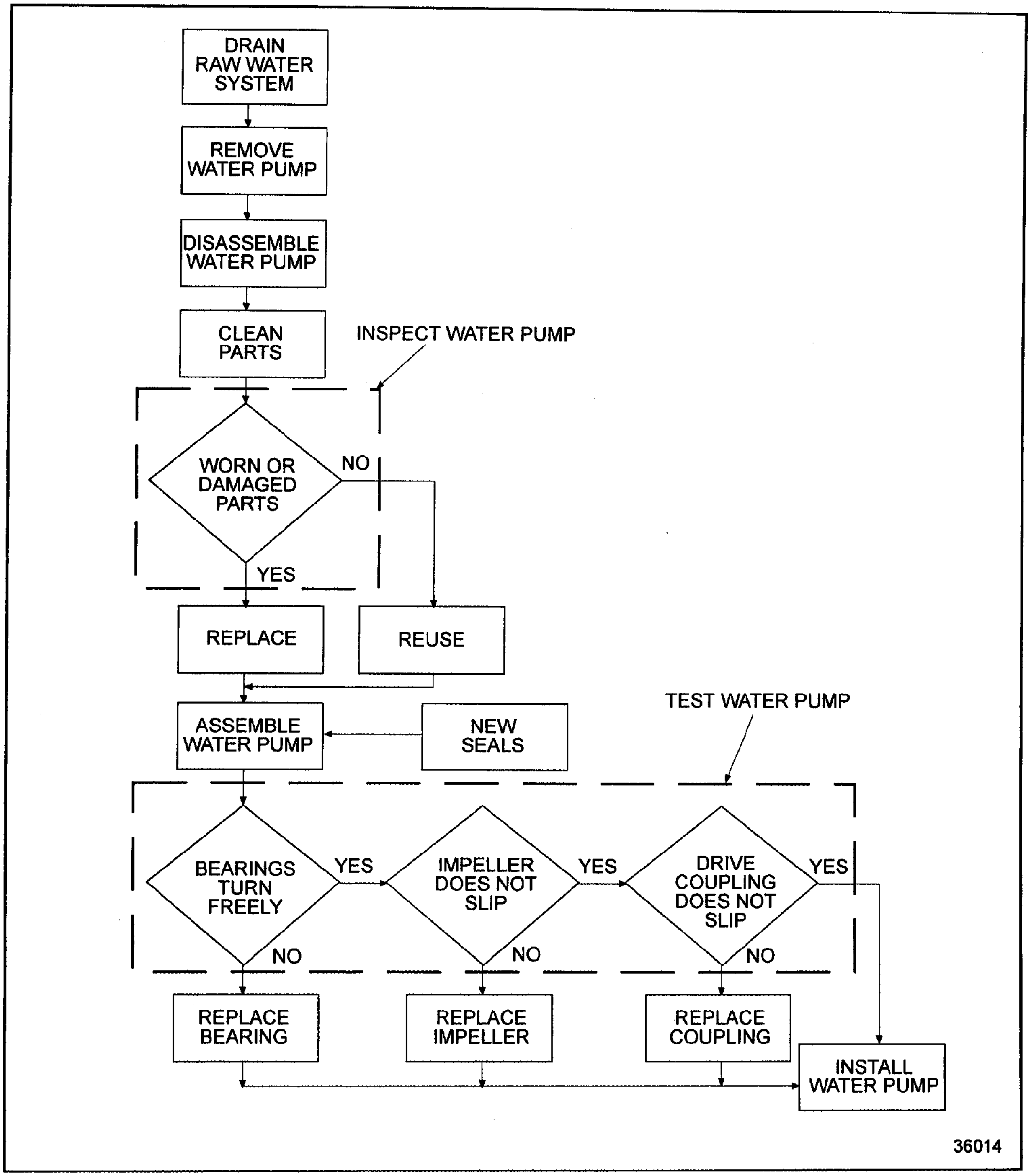



**Figure 4-67 Flowchart for Repair or Replacement of CAC Water Pump**

### 4.4.2 Removal of CAC Water Pump

Remove the water pump as follows:

1. Drain the raw water from the charge air cooler system and open the drain cock in the pump body.
2. Loosen the hose clamps and slide the water pump inlet hose back onto the charge cooler inlet pipe.
3. Remove the nuts and bolts that attach the pump to the raw water supply pipe.
4. Remove the bolts and lock washers that attach the pump mounting flange to the drive assembly.
5. Withdraw the pump and remove the gasket.

### 4.4.3 Disassembly of CAC Water Pump

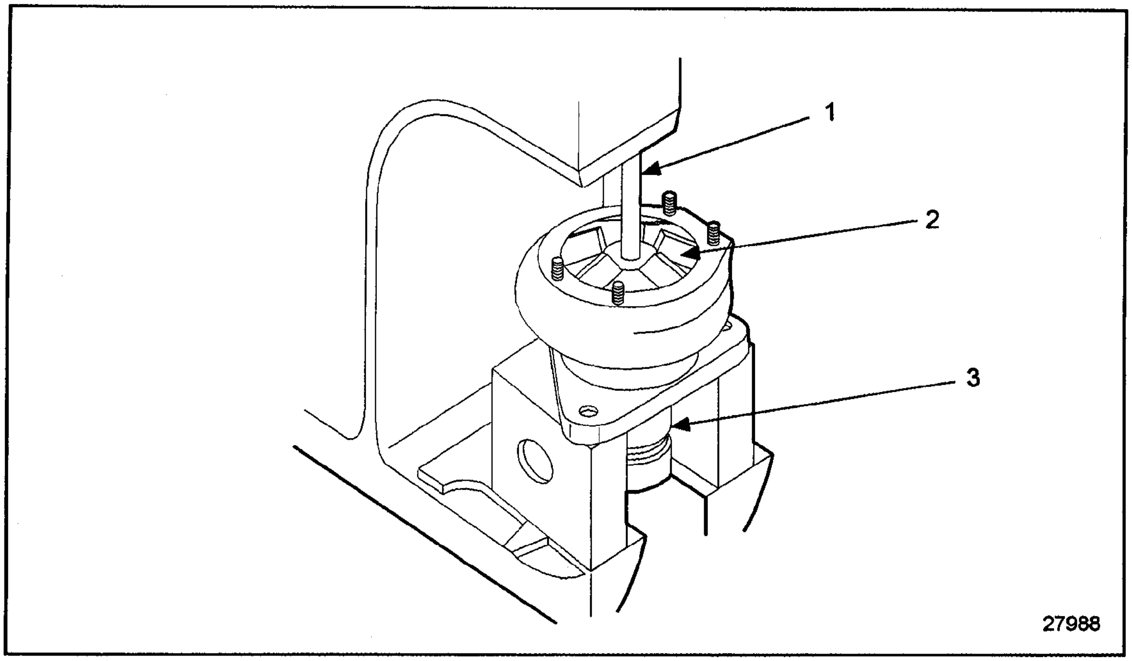
Disassemble the water pump as follows:

1. Remove the pump cover and gasket.

**NOTE:**
Clean any corrosion from around the impeller and shaft before separating the shaft and bearing assembly from the impeller, seal, and pump body.

| NOTICE |
|---|
| Shaft bearing damage may occur on the water pump if an excessive thrust load is applied to the bearing assembly during pump disassembly for seal replacement. For this reason DDC recommends replacing the shaft and bearing assembly of the water pump whenever the seal is replaced and /or at time of water pump overhaul. |

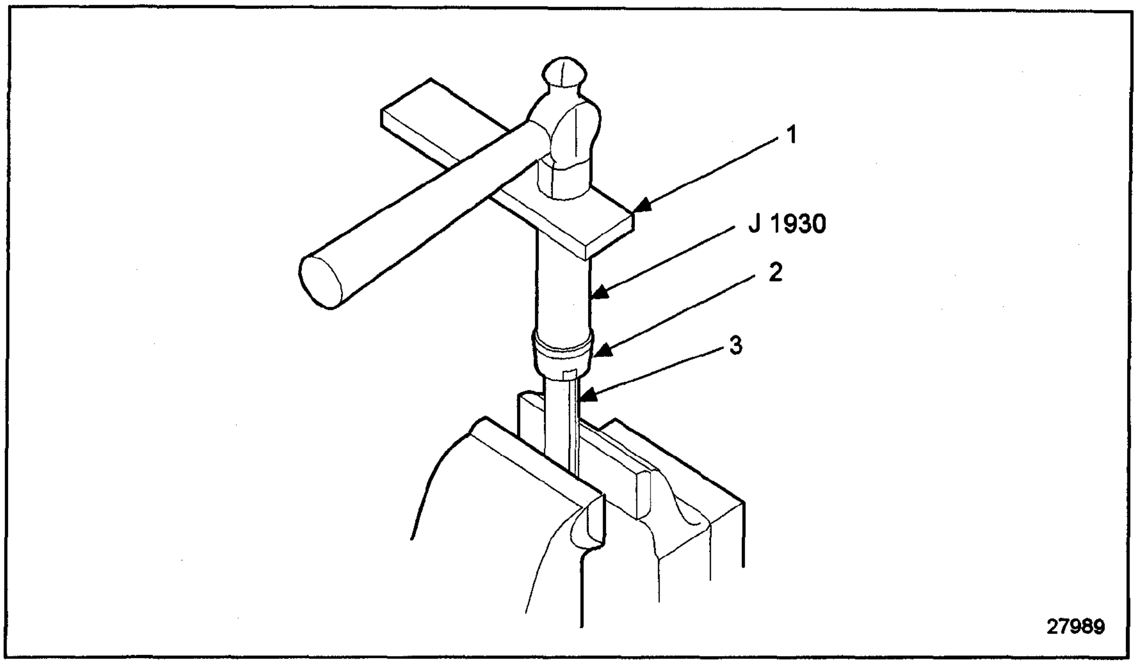
2. Support the pump on its mounting flange in an arbor press. See Figure 4-68. Place a short steel rod on the end of the shaft and press the shaft and bearing assembly from the impeller, seal, and pump body.




1. Steel Bar
2. Impeller
3. Shaft and Bearing Assembly

**Figure 4-68 Pressing Pump Shaft from Impeller**

3. Remove the impeller and seal assembly from the pump body.
4. Remove the pump drive coupling from the shaft with tool J 1930. See Figure 4-69.




1. Steel Bar
2. Drive Coupling
3. Steel Rod

**Figure 4-69 Removing Pump Drive Coupling from Shaft**

### 4.4.3.1 Inspection of CAC Water Pump

Inspect the water pump as follows:

1. Visually inspect the parts for cracks, wear, or other damage.
   [a] If parts are cracked, worn, or other damage is evident, replace damaged or worn parts.
   [b] If no damage is found, reuse remaining components.

### 4.4.4 Assembly of CAC Water Pump

Assemble the water pump as follows:

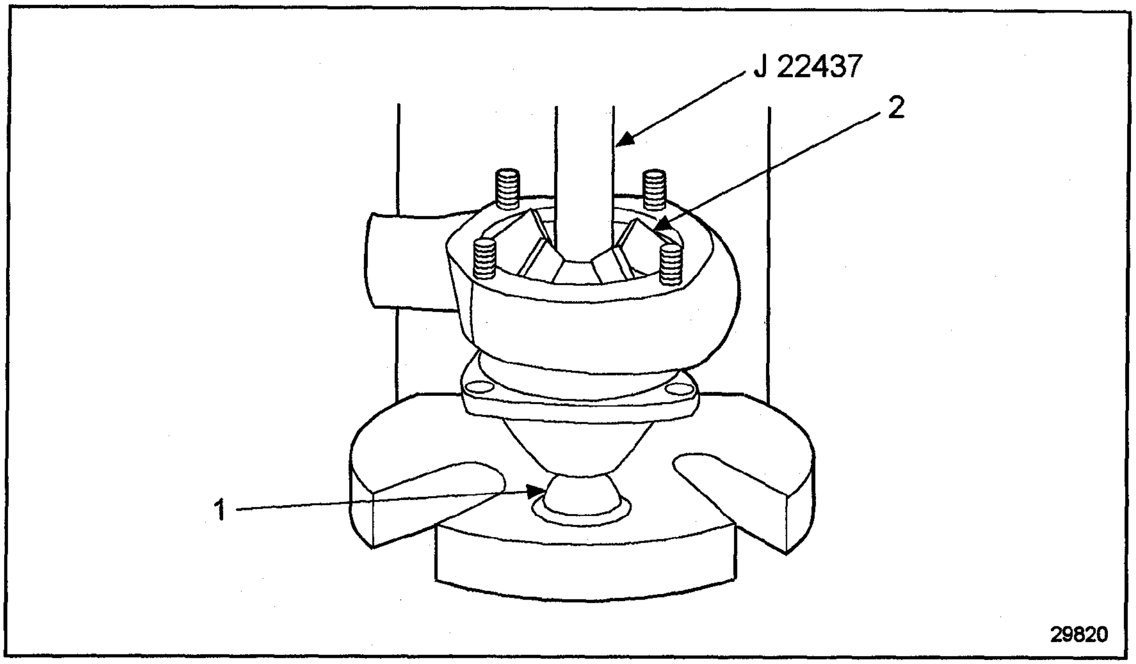
| NOTICE |
|---|
| To avoid possible engine damage, the sealed pump shaft bearing must not be immersed in a cleaning fluid, since dirt may be washed in and fluid cannot entirely be removed. |

1. Clean all of the parts, except the shaft and bearing assembly.
2. Replace the shaft and bearing assembly and the seal assembly.
3. Support the pump body on the bed of an arbor press, impeller end down. Insert the long (impeller) end of the shaft and bearing assembly into the body.

| NOTICE |
|---|
| The shaft and bearing assembly will be damaged if it is installed by applying pressure to the shaft or inner race. |

4. Press against the outer race of the bearing until the bearing is flush with the end of the pump body.
5. To eliminate possible coolant leakage, apply a light coat of Loctite® 290 sealant to the outside diameter of the new seal.

6. Invert the pump so that the impeller end faces up. See Figure 4-70.




1. Shaft Support
2. Impeller

**Figure 4-70 Installing Water Pump Impeller**

7. With the pump body and bearing shaft properly supported, place a fresh unitized seal over the shaft. Tool J 38858 *must* be used to set the seal to its proper installed height. Using tool J 38858, press the seal into place.
8. Ensure the mating surfaces of the water seal and impeller are free of dirt, metal particles, and oil film.

| NOTICE |
|---|
| The bearing shaft end must be supported during this operation. Do not press against the outer race of the bearing. This can damage the bearing. |

9. Support the bearing end of the shaft on the bed of an arbor press. Using tool J 22347, press the impeller onto the shaft. The distance between the end of the shaft and the face of the impeller hub is 0.0078 — 0.083 mm (0.031 - 0.033 in.).
10. Invert the pump. With the impeller end of the shaft properly supported on the arbor press, press the drive coupling onto the shaft until it is flush with the end of the shaft.

**NOTE:**
When installed, the drive coupling must hold 41 N·m (30 lb·ft) minimum torque.

11. Rotate the shaft by hand to ensure the rear faces of the impeller blades do not rub against the pump body.
12. If previously removed, install the drain cock in the pump body.

### 4.4.5 Installation of CAC Water Pump

Install the water pump as follows:

1. Ensure the intermediate shaft coupling is secure.
   [a] If it was previously removed, insert the splined end of the coupling into the mating splines in the drive assembly.
   [b] Install the bolts and lockwashers, then draw the coupling in place with the bolts.
   [c] Torque the bolts to 20 – 26 N·m (15 – 19 lb·ft).
2. Slide the charge cooler inlet hose in place and secure it with the hose clamps.
3. Close the pump drain cock.
4. Remove and check the condition of the raw water pump electrodes (zincs). Replace if required.
5. Fill the raw water cooling system.

**CAUTION:**

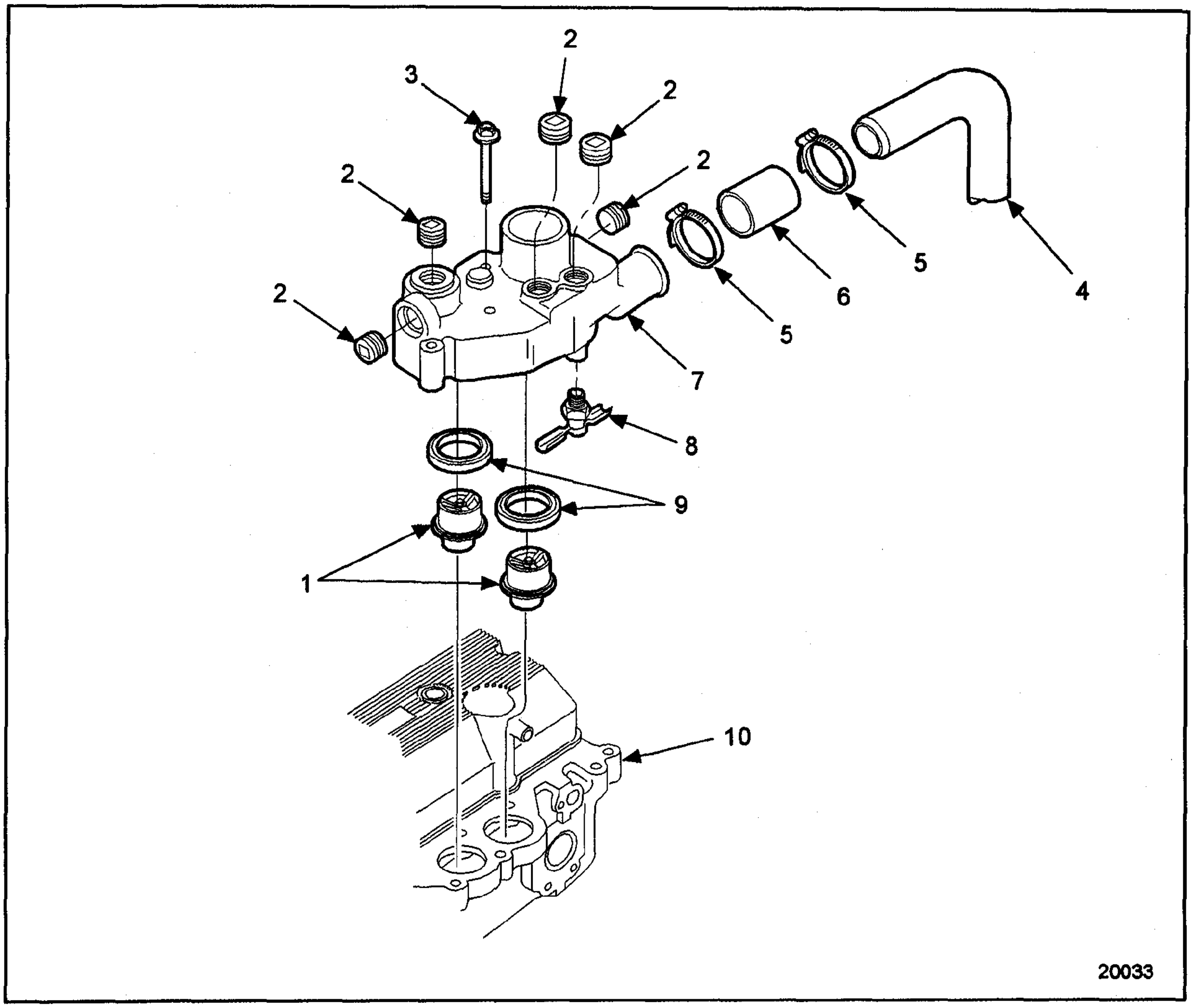
**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

6. Start the engine and check for leaks.

## 4.5 THERMOSTAT

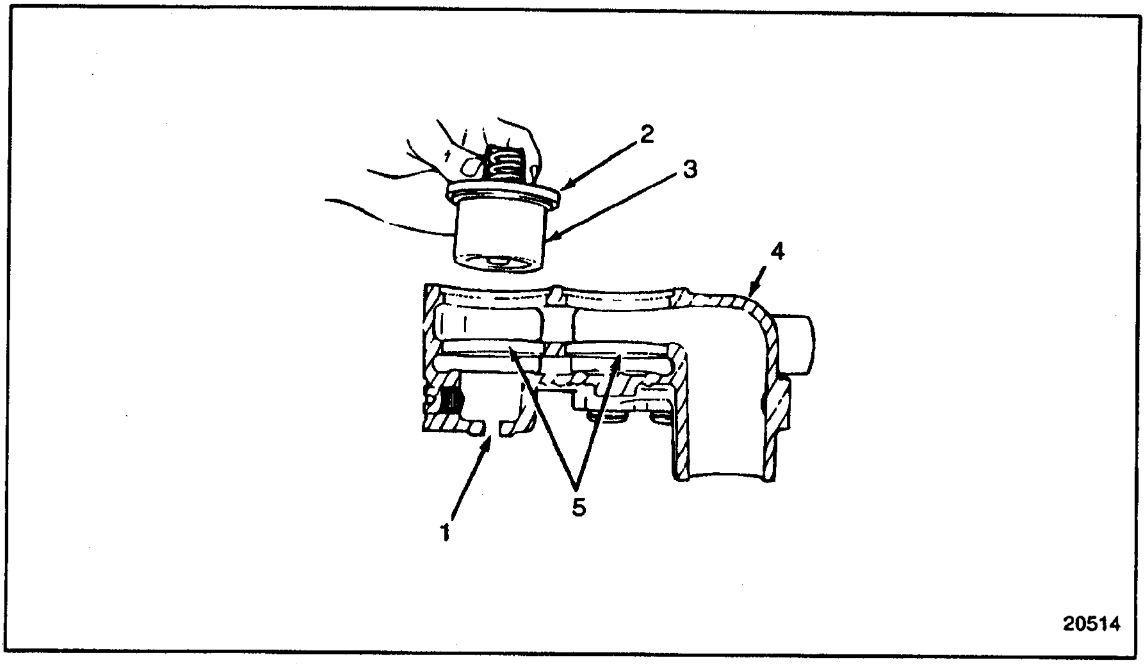
The temperature of the engine coolant is controlled by two blocking-type thermostats located in a housing attached to the right side of the cylinder head. See Figure 4-71.




1. Thermostat (2)
2. Pipe Plug
3. Bolt, Thermostat Housing-to-Cylinder Head (4)
4. Bypass Tube
5. Hose Clamp (2)
6. Hose, Coolant
7. Thermostat Housing
8. Drain Cock
9. Seal, Thermostat Housing (2)
10. Cylinder Head

**Figure 4-71 Thermostat and Related Parts**

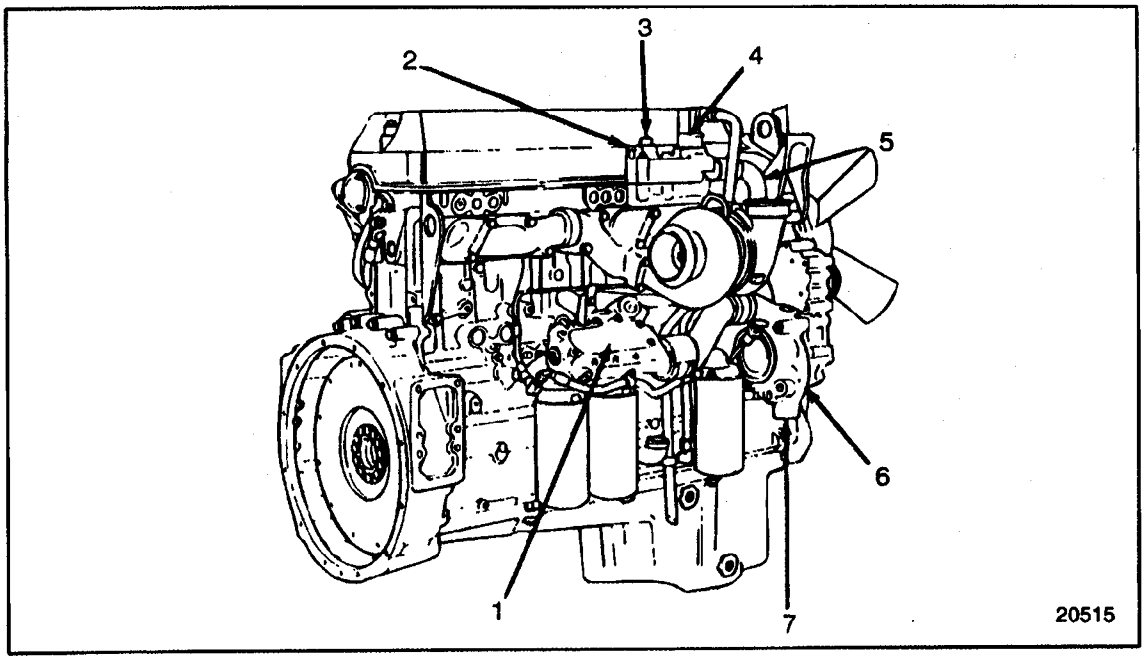
In addition to a rubber seal that is part of the thermostat, there is a lip-type seal for each thermostat that is installed in a bore in the thermostat housing. See Figure 4-72.




1. Connection Opening, Vent Line
2. Seal, Thermostat (2)
3. Thermostat (2)
4. Thermostat Housing
5. Seals, Thermostat Housing (2)

**Figure 4-72 Thermostat Seals**

At coolant temperatures below approximately 86 - 89°C (186 - 193°F) for vehicle, industrial, and keel-cooled marine engines or 69 – 73°C (156 – 163°F) for heat exchanger-cooled marine engines, the thermostat valves remain closed and block the flow of coolant from the engine to the radiator or heat exchanger. During this period, all of the coolant in the system is recirculated through the engine and is directed back to the suction side of the water pump via a bypass tube. As the coolant temperature rises above 86 - 89°C (186 - 193°F) for vehicle, industrial, and keel-cooled marine engines or 69 — 73°C (156 — 163°F) for heat exchanger-cooled marine engines, the thermostat valves start to open, restricting the bypass system, and allowing a portion of the coolant to circulate through the radiator or heat exchanger. When the coolant temperature reaches approximately 97°C (207°F) (or 82°C [179°F] for heat exchanger-cooled marine engines), the thermostat valves are fully open, the bypass system is blocked off, and the coolant is directed through the radiator or heat exchanger. See Figure 4-73.




1. Oil Cooler Housing
2. Thermostat Housing
3. Vent Line Outlet
4. Water Outlet (To Radiator)
5. Water Bypass Tube
6. Water Pump
7. Water Inlet

**Figure 4-73 Cooling System Operation**

Properly operating thermostats are essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 86 - 99°C (186-210°F) (or 69 – 82°C [156 — 179°F] for heat exchanger-cooled marine engines), inspect and replace the thermostats, if necessary.

## 4.5.1 Repair or Replacement of Thermostats

To determine if repair or replacement of the thermostat is necessary, perform the following procedure. See Figure 4-74.

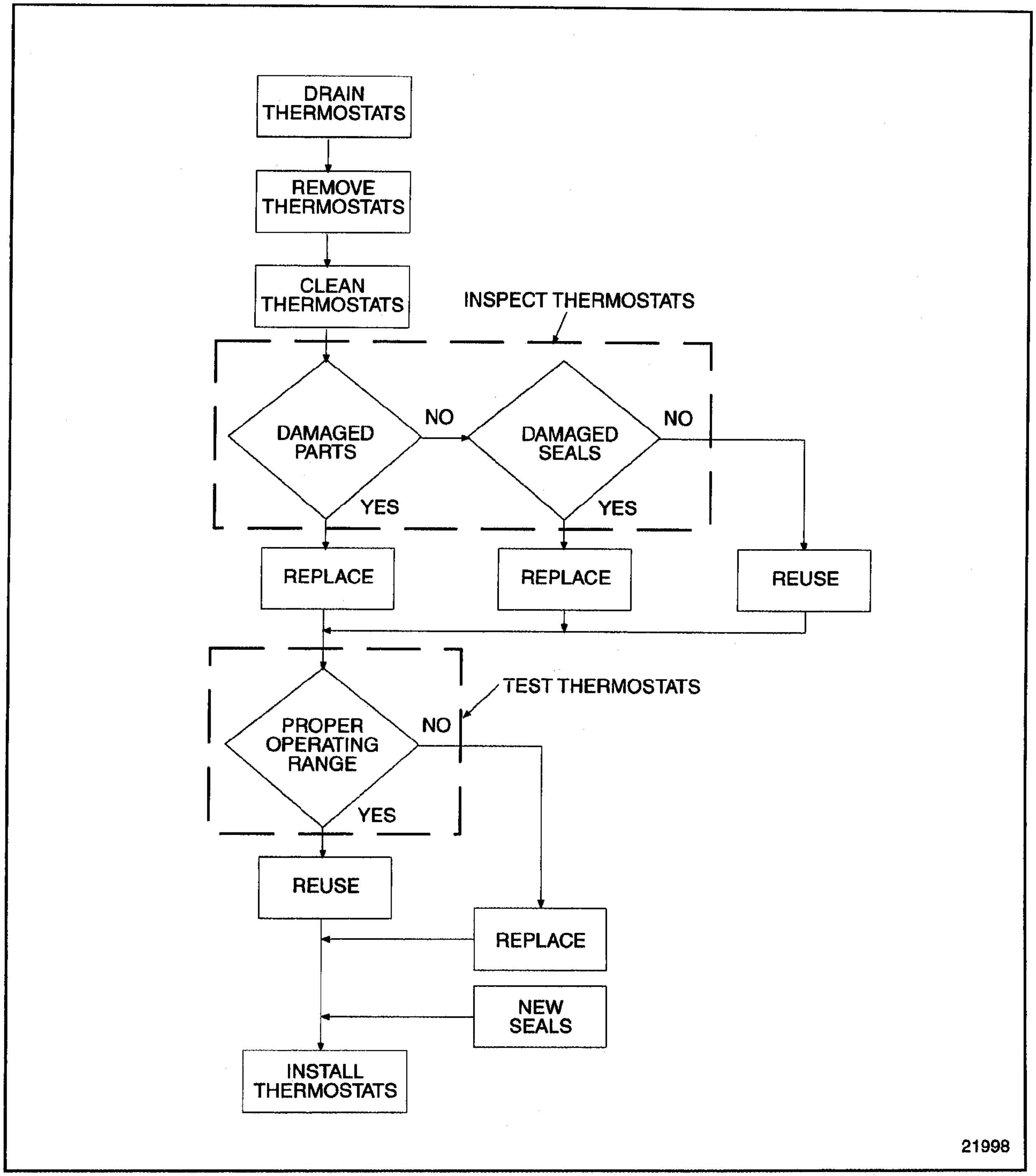



**Figure 4-74 Flowchart for Repair or Replacement of Thermostats**

### 4.5.2 Draining and Removal of Thermostats

Drain the thermostats as follows:

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

1. Slowly open the coolant pressure control (radiator) cap.
2. Open the drain cock located on the bottom of the thermostat housing.
3. Drain the cooling system so that the coolant is below the thermostat level.

Remove the thermostats as follows:

1. Loosen the hose clamps on the coolant hoses connected to the thermostat housing.
2. Slide the hoses off the housing.
3. Disconnect the vent line and any other lines which are connected to the thermostat housing.
4. Remove the four thermostat housing-to-cylinder head attaching bolts.
5. Remove the thermostat housing assembly from the engine.
6. Remove the thermostats from the thermostat housing.
7. Remove and discard the thermostat housing seals.

#### 4.5.2.1 Inspection of Thermostats

Inspect thermostats as follows:

1. Visually inspect all parts for wear or damage.
   [a] If wear or damage is found, replace parts.
   [b] If wear or damage is not found, reuse parts.
2. Visually inspect thermostat body seal for damage, cracks or nicks.
   [a] If any damage is noted, replace seal.
   [b] If no damage is found, reuse parts.

### 4.5.3 Cleaning of Thermostats

Clean the thermostats as follows:

1. Clean all of the parts in clean fuel oil.

| CAUTION: |
|---|
| **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.** |

2. Dry all parts with compressed air.

### 4.5.4 Testing Thermostat

Check the operation of a thermostat as follows:

| NOTICE: |
|---|
| Ensure thermostat is operational. If thermostat motion becomes impaired, overheating may result. An engine which has overheated may also cause the thermostats to become inoperative. A thermostat stuck in the open position may not allow the engine to reach normal operating temperature. The incomplete combustion of fuel due to cold operation will result in build-up of carbon deposits on the pistons, rings and valves. A thermostat that does not fully open may cause engine overheating. |

1. Immerse the thermostat in a metal container of water. See Figure 4-75.

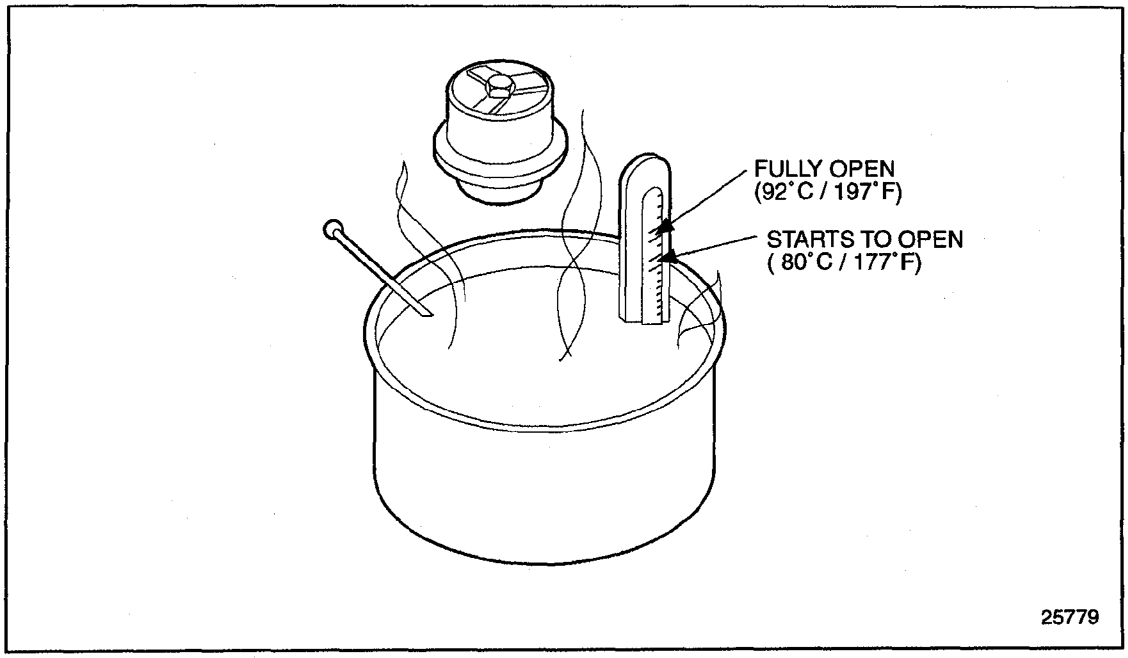



**Figure 4-75 Checking Thermostat Operation**

2. Place a thermometer in the container using care not to allow the thermometer to touch the bottom or sides of the container.
3. While slowly agitating the water to maintain an even temperature, apply heat to the container. Allow at least 10 minutes for the thermostats to react before determining if the thermostats are opening in the correct temperature range.

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

4. As the water is heated, the thermostat should begin to open. The nominal opening temperature (stamped on the thermostat), the start-to-open temperature range, and the full open temperature are listed in Table 4-1.

| Nominal Opening Temperature (Stamped on the Thermostat) | Thermostat Start-to-Open Temperature Range | Fully Open Temperature |
|---|---|---|
| 160°F (71°C) | 156-163°F (69-73°C) | 179°F (82°C) |
| 180°F (82°C) | 176-183°F (80-84°C) | 197°F (92°C) |
| 190°F (88°C) | 186-193° (86-89°) | 207°F (97°C) |

**Table 4-1 Thermostat Nominal, Start-to-Open, and Fully Open Temperatures**

5. If thermostat does not operate properly replace.

### 4.5.5 Installation of Thermostat and Seal

Install new thermostats as follows:

1. Position a new seal onto seal installer, J 8550, and handle, J 7079-2. See Figure 4-76.

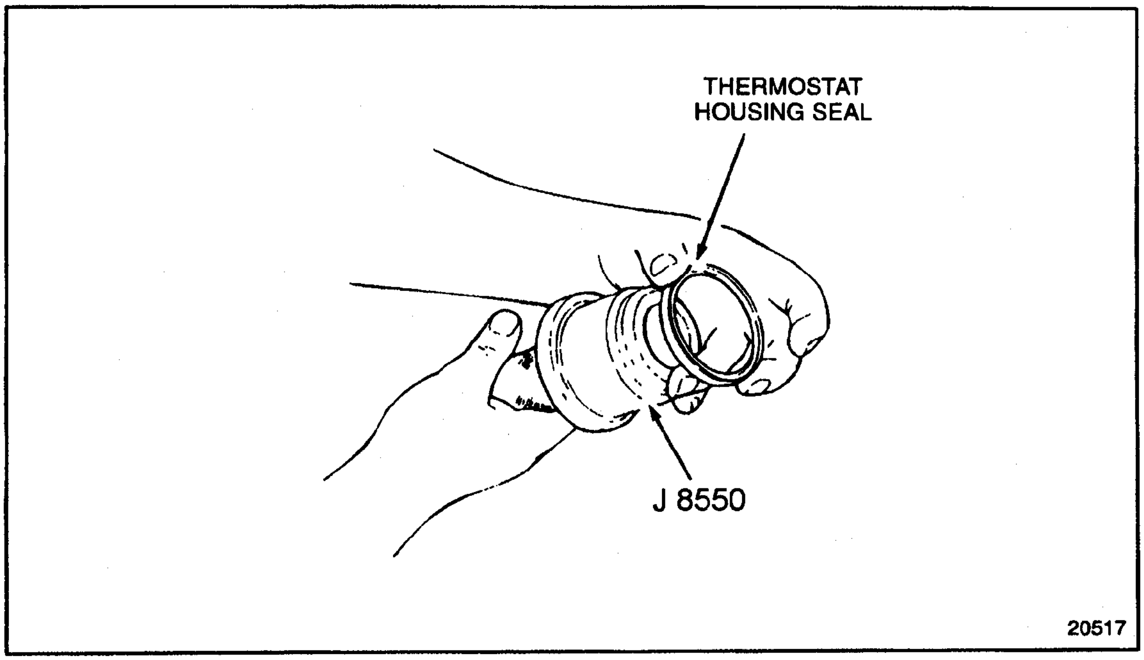



**Figure 4-76 Positioning the Seal onto Seal Installer**

2. Support the thermostat housing on a work bench so that it is level. See Figure 4-77.

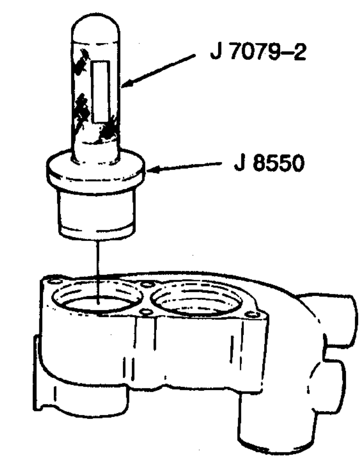



**Figure 4-77 Thermostat Housing Seal Insertion**

3. Insert the seal driver with seal installed, into the thermostat housing.

4. Drive the seal into the bore with a hammer, until the installation tool bottoms on the housing. Rotate the tool during installation to ensure the seal is installed straight. Remove tools J 7079-2 and J 8550. See Figure 4-78.

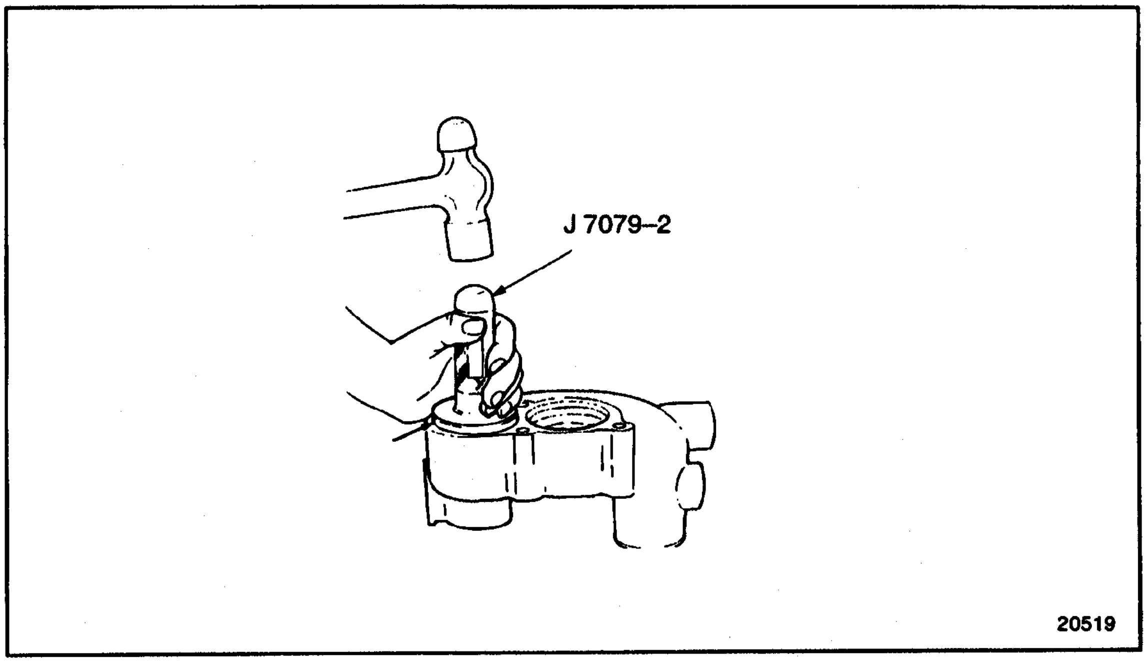



**Figure 4-78 Thermostat Housing Seal Installation**

5. Repeat step 1 through step 4 for the other seal.
6. Coat the lip of the seals with clean engine oil.
7. Place the thermostats, spring up, into the thermostat housing.

8. Press down on the thermostats to seat them. See Figure 4-79.

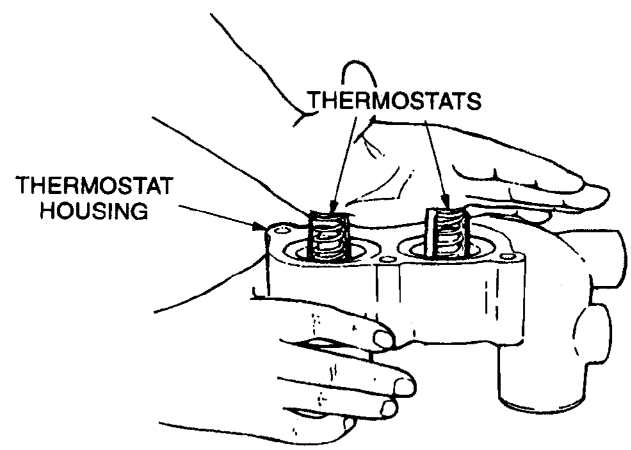



**Figure 4-79 Seating Thermostats**

9. Ensure the machined surface of the thermostat housing, where it contacts the cylinder head, is clean and dry.
10. Install the thermostat housing to the cylinder head with the four attaching bolts. Torque the bolts to 58-73 N·m (43-54 lb·ft).
11. Install the coolant hoses to the thermostat housing. Tighten the hose clamps.
12. Apply a coating of Loctite® Pipe Sealer with Teflon, PT-7260, or equivalent to the threads of the drain cock if it was removed from the bottom of the thermostat housing.
13. Install and tighten the drain cock.
14. Install any other components removed for this operation.
15. Close the drain cocks in the water pump housing and at the right rear of the cylinder block.
16. Install the thermostat housing vent line and any other lines that were removed from the housing.
17. Fill the cooling system. Refer to section 13.13.4.
18. Refer to section 11.3.5 for verification of thermostat installation. Listed in Table 11-2are the normal cooling system operational parameters.

## 4.6 COOLANT PRESSURE CONTROL CAP

The radiator or heat exchanger (or expansion tank) has a pressure control cap with a normally closed valve. The cap is designed to permit a pressure in the cooling system equal to the rating stamped on the top of the cap. A cap with a 9 on the top allows the cooling system to develop 62 kPa (9 lb/in.$^2$) before the valve opens. See Figure 4-80. This system pressure raises the boiling point of the coolant and reduces coolant loss. The maximum allowable coolant temperature, regardless of the pressure cap used, is 99°C (210°F).

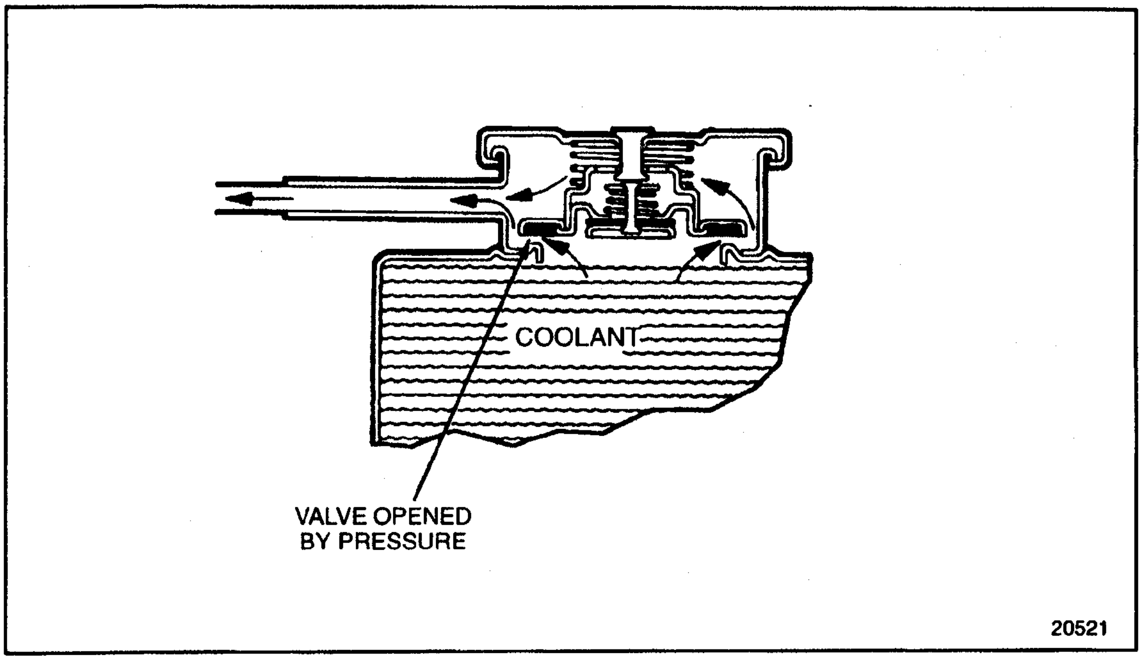



**Figure 4-80 Pressure Control Cap (Pressure Valve Open)**

To prevent collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools. See Figure 4-81. It also permits coolant to flow from coolant recovery bottle (when used) to the radiator tank.

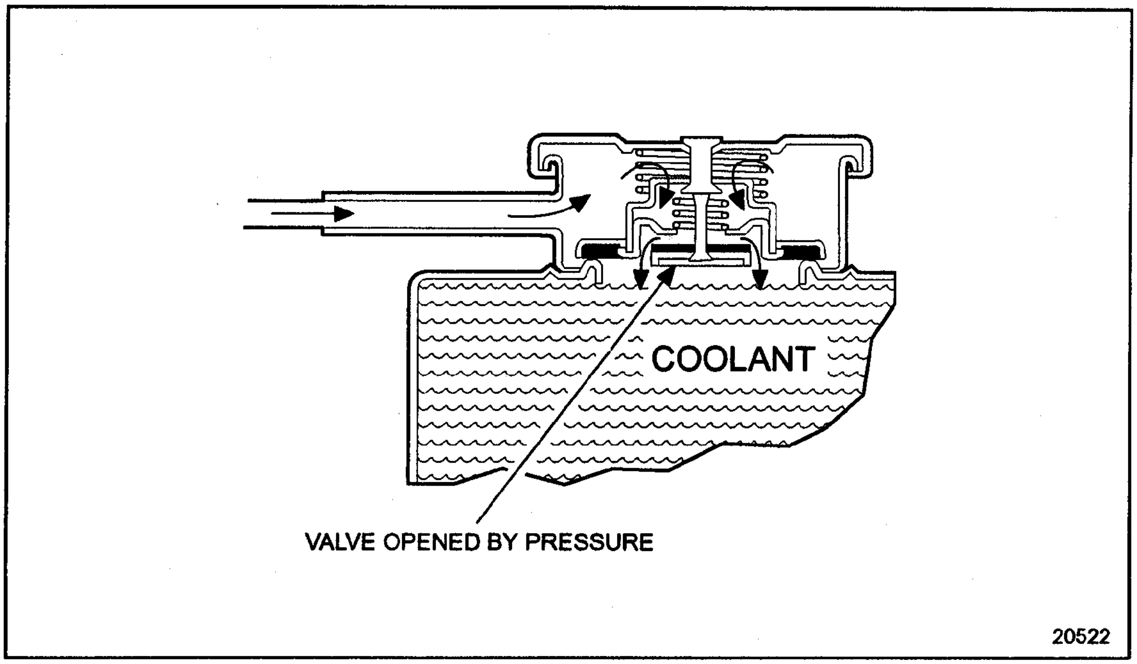



**Figure 4-81 Pressure Control Cap (Vacuum Valve Open)**

### 4.6.1 Repair or Replacement of Pressure Control Cap

Refer to the OEM guideline for pressure control cap service procedure.

### 4.6.2 Removal and Cleaning of Pressure Control Cap

Remove the pressure control cap as follows:

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

1. Wipe the outside area on the pressure control cap clean before removal.
2. Push down on pressure control cap while turning counterclockwise.

### 4.6.2.1 Inspection of Pressure Control Cap

Detroit Diesel does not offer pressure control (radiator) caps as original equipment on Series 60 engines, except on marine engines.

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

Clean and inspect cap periodically. Check operation of both valves using test kit J 24460-01 or equivalent. Replace if necessary. Inspect and clean filler neck. Replace if damaged.

It is recommended that all Series 60 on-highway vehicle and keel-cooled marine engines use a minimum 62 kPa (9 $lb/in.^2$) pressure control cap. If the pressure valve does not open between 55 kPa (8 $lb/in.^2$) and 69 kPa (10 $lb/in.^2$) or the vacuum valve does not open at 4.3 kPa (.625 $lb/in.^2$) (differential pressure), replace the pressure control cap.

Series 60 heat exchanger-cooled marine engines require a 48 kPa (7 $lb/in.^2$) pressure control cap. If the pressure valve does not open between 41 kPa (6 $lb/in.^2$) and 55 kPa (8 $lb/in.^2$), replace the pressure control cap.

### 4.6.3 Installation of Pressure Control Cap

Refer to vehicle or equipment manufacturer instructions for installation procedures.

Refer to section 11.3.5 for verification of proper pressure control cap installation.

## 4.7 ENGINE COOLING FAN

The engine cooling fan can be mounted at the front of the engine and is belt driven from the crankshaft pulley. See Figure 4-82.

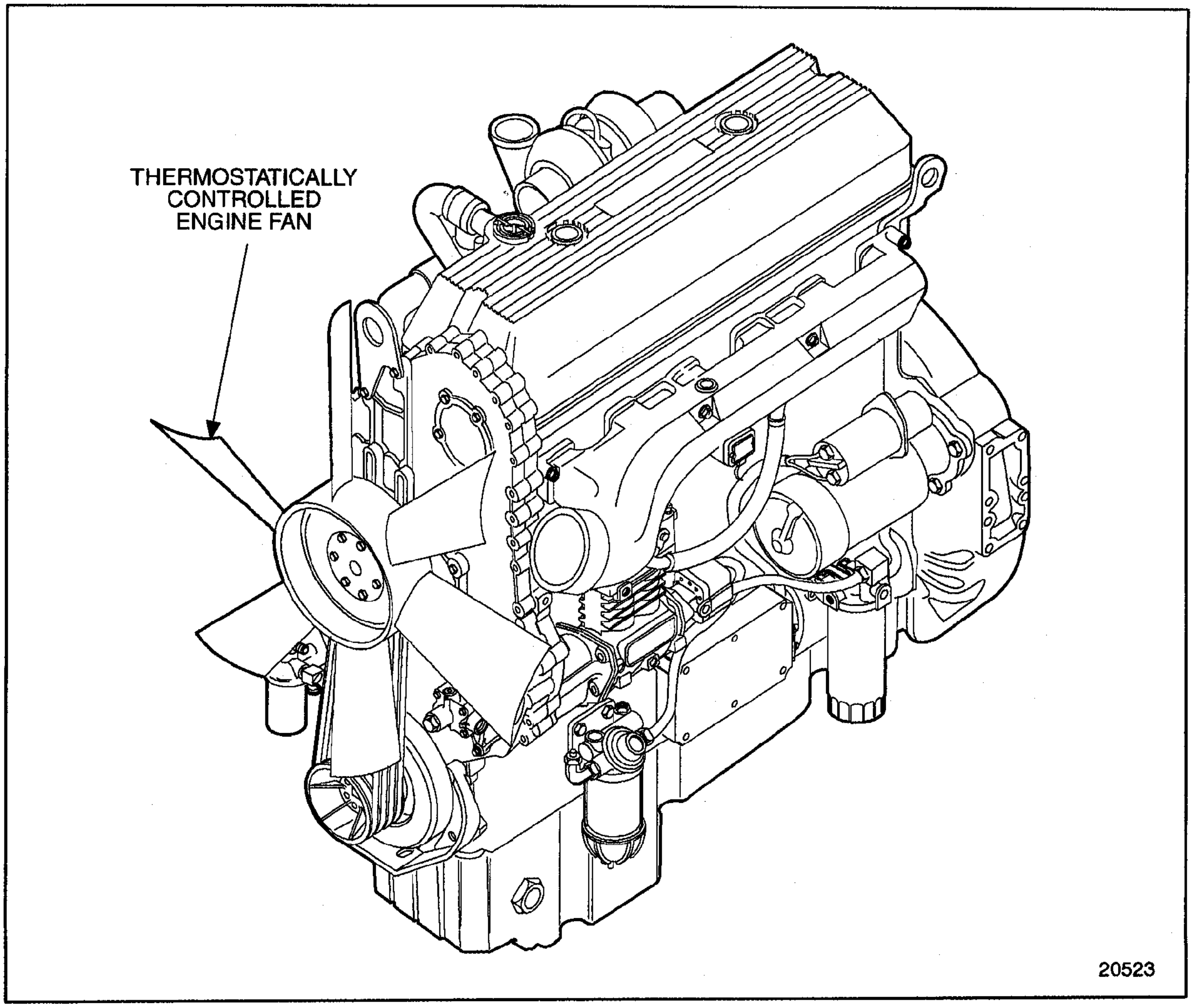
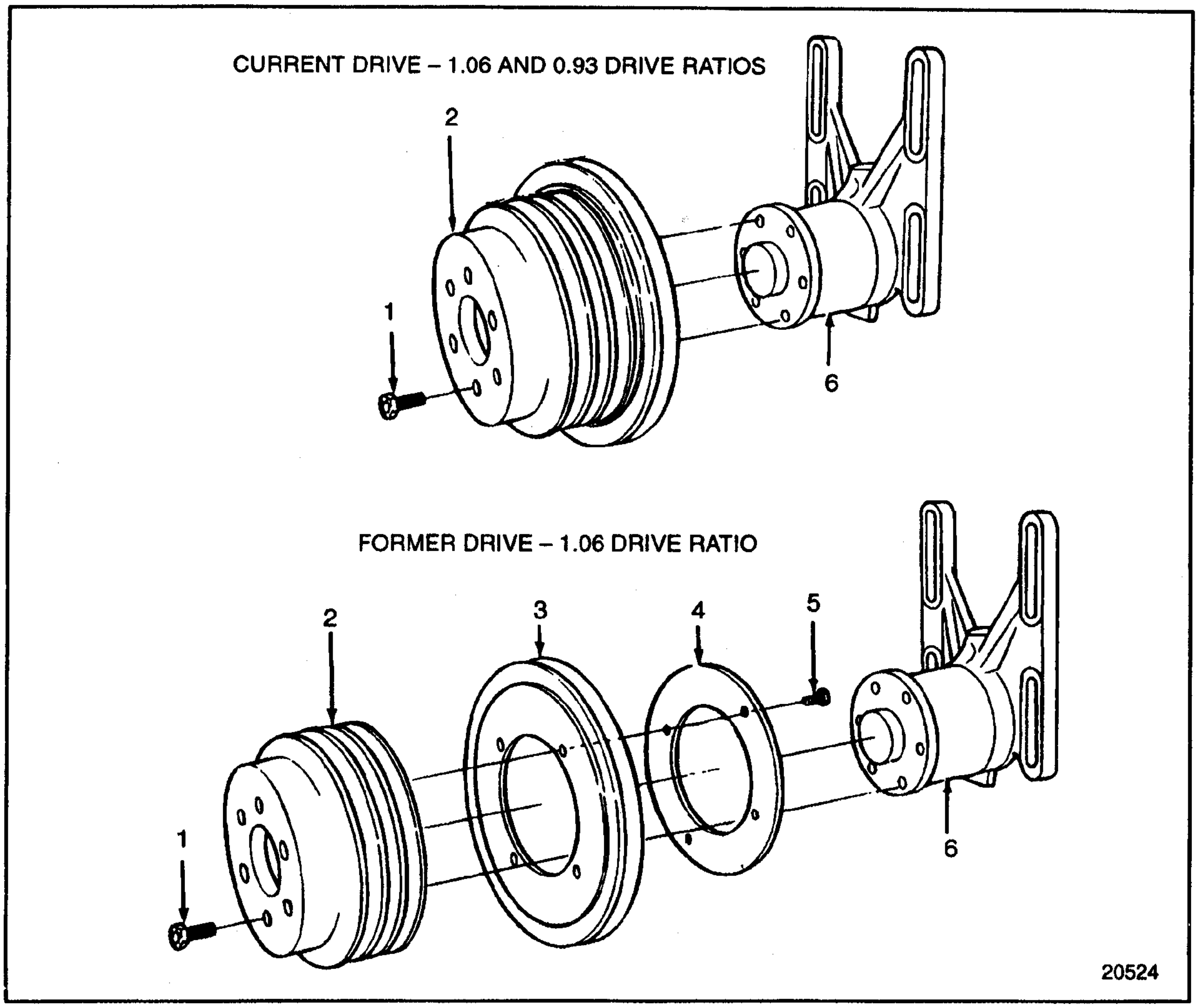



**Figure 4-82 Engine Cooling Fan Location**

On most applications, the fan is thermostatically controlled. This fan assembly is designed to regulate the fan speed and maintain an efficient engine coolant temperature regardless of the variations in the engine load or outside air temperature. No adjustment of the thermostatic control is necessary.

The three-groove pulley hub uses a matched set of three drive belts. On some units equipped with an air conditioning compressor, an additional pulley and retaining plate are attached to the three-groove pulley. See Figure 4-83.

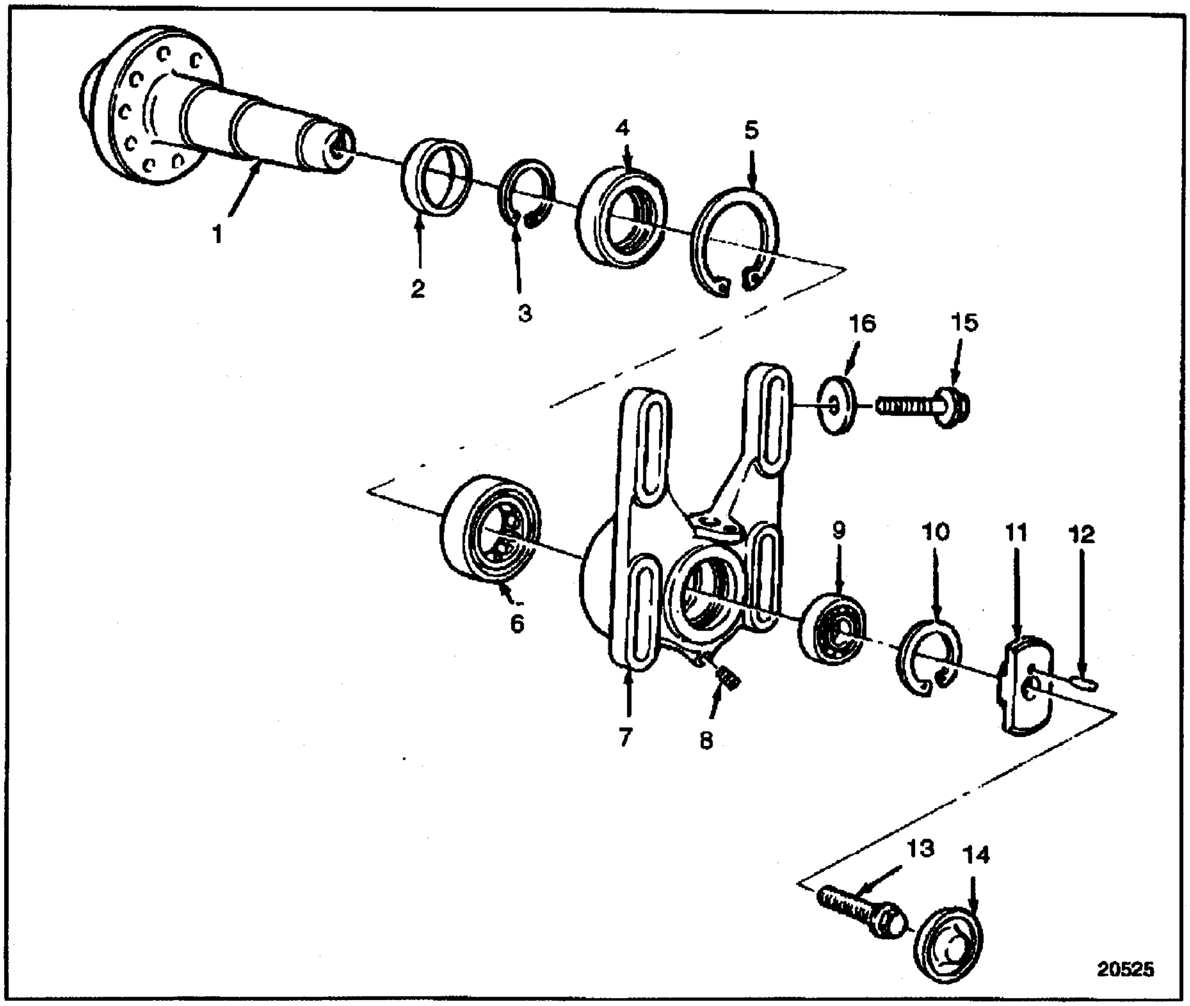



1. Bolt, Fan Retaining (6)
2. Fan Pulley
3. Drive Pulley, Air Conditioning Compressor
4. Retaining Plate
5. Bolt, Air Conditioning Retaining
6. Fan Hub Assembly

**Figure 4-83 Air Conditioning Compressor Drive Pulley and Related Parts**

Whenever it is necessary to replace one of the crankshaft pulley-to-fan hub drive belts, all three belts must be replaced as a matched set. Refer to section 13.13.10 for belt adjustment or replacement information.

The fan hub is supported by a front roller bearing and a rear ball bearing. Internal snap rings are used to retain the bearings in the housing and on the shaft. A single lip grease seal is mounted in the fan hub housing. A hub cap seals the bearing cavity at the rear of the housing. See Figure 4-84.




1. Drive Shaft, Fan
2. Race, Front Bearing Inner
3. Snap Ring, Inner Race Retaining
4. Grease Seal
5. Snap Ring, Front Bearing Retaining
6. Bearing, Front Roller
7. Housing, Fan Hub
8. Pipe Plug
9. Ball Bearing, Rear
10. Snap Ring, Rear Bearing Retaining
11. Spacer
12. Pin
13. Bolt, Spacer-to-drive
14. Hub Cap
15. Bolt, Fan Hub Mounting (4)
16. Hardened Washer (4)

**Figure 4-84 Fan Hub and Related Parts**

The fan hub utilizes four elongated mounting holes and a single threaded rod for adjustment. The fan hub is mounted to the fan support bracket with four bolts. See Figure 4-85.

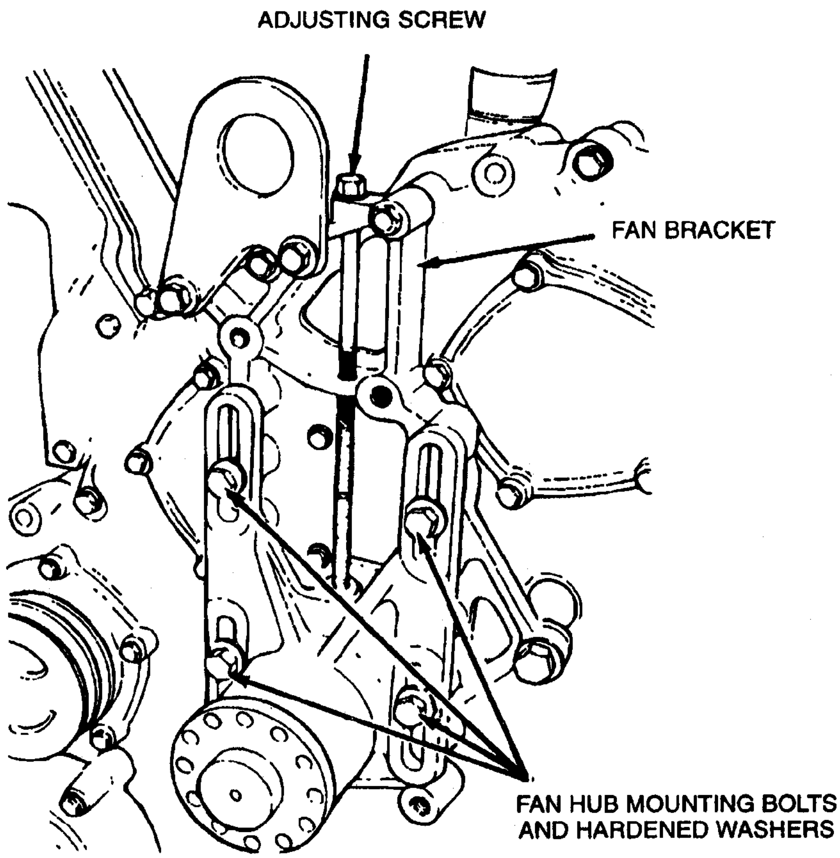



**Figure 4-85 Fan Hub Mounting**

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to section 13.5 for the maintenance schedule.

### 4.7.1 Repair and Replacement of Engine Cooling Fan

To determine if repair is possible or replacement of the engine cooling fan is necessary preform the following procedure. See Figure 4-86.

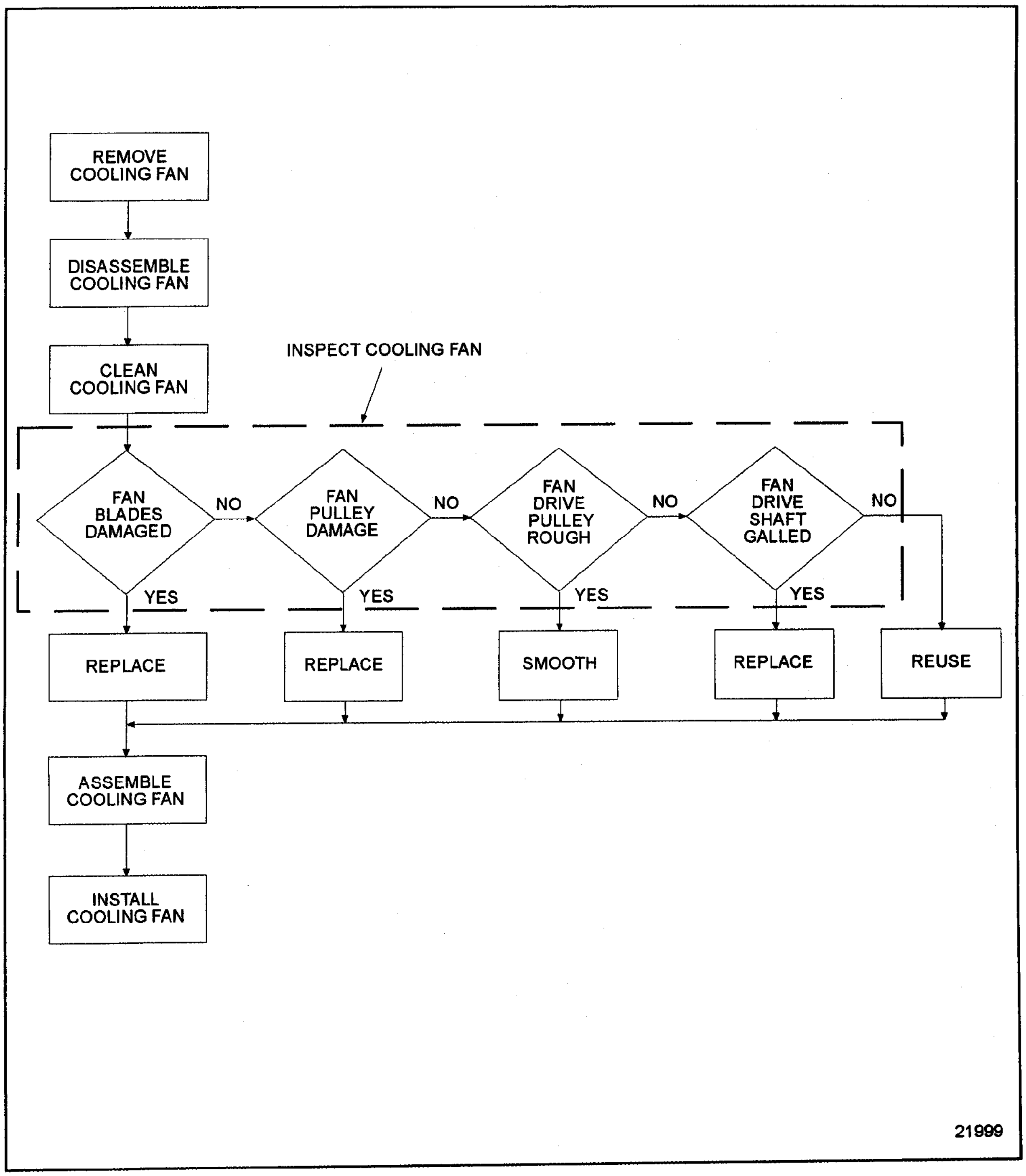



**Figure 4-86 Flowchart for Repair or Replacement of Engine Cooling Fan**

### 4.7.2 Removal of Engine Cooling Fan

Remove the engine cooling fan as follows:

| NOTICE: |
|---|
| Before removing the fan, check the blades for alignment or damage. Do not rotate the fan by pulling on the fan blades. Engine damage and radiator damage could result. |

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Cracked, deformed or otherwise damaged fan blades may reduce the efficiency of the cooling system, throw the fan out of balance, or damage the radiator cores.

1. If equipped with air conditioning, loosen the air conditioning compressor mounting bolts. Remove the compressor drive belt.
2. Loosen the four fan hub-mounting bolts. See Figure 4-85.
3. Turn the adjusting rod counterclockwise enough to allow slack in the drive belts.
4. Remove the fan attaching bolts and remove the fan, fan drive belts and fan pulley.
5. Remove the adjusting rod from the housing by unscrewing it.
6. Remove the four fan hub-mounting bolts. Remove the fan hub assembly.

### 4.7.3 Disassembly of Engine Cooling Fan

Disassemble the engine cooling fan as follows:

1. Remove the hub cap at the rear of the housing by piercing the cap with a punch and prying the cap out of the housing.

| NOTICE: |
|---|
| If a vise is used to secure the fan hub, use wood or leather between hub and vise. Exercise extreme caution to prevent damage to the fan hub. |

2. Secure the fan hub in a vise. Loosen and remove the bolt, securing the spacer to the shaft.
3. Remove the spacer.
4. Place the housing, fan mounting surface down, on a press bed on wood blocks high enough to allow the shaft to be removed. Press the shaft to remove it from the housing.

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

5. Remove the roller bearing inner race snap ring from the shaft using snap ring pliers.
6. Remove the roller bearing inner race using a two-jaw puller.

**NOTE:**
Any time the shaft is removed from the housing, the ball bearing assembly (rear bearing) must be replaced. Any time the roller bearing inner race is removed from the shaft or the roller bearing assembly is removed from the housing, the roller bearing assembly must be replaced.

7. Remove the grease seal from the housing and discard the seal.
8. Remove the bearings from the housing as follows:
   [a] Remove the rear ball bearing snap ring using snap ring pliers.
   [b] Support the housing, fan side up, on two wood blocks spaced far enough apart to permit removal of the rear bearing from the housing.
   [c] Remove the bearing from the housing by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.
   [d] Reverse the housing on the wood blocks. Remove the front bearing snap ring using snap ring pliers.
   [e] Remove the front bearing from the hub in the same manner as the rear bearing. Refer to step 8[a] through step 8[d].

### 4.7.3.1 Inspection of Engine Cooling Fan

Inspect the engine cooling fan as follows:

1. Visually examine the fan blades for cracks or other damage.
   [a] If the blades are cracked or deformed, replace the fan.
   [b] If the fan blades are not cracked or deformed, reuse parts.
2. Visually inspect fan pulley for wear or damage to grooves.
   [a] If fan pulley grooves are damaged or severely worn, replace the pulley.
   [b] If fan pulley grooves are not damaged or severely worn, reuse the pulley.
3. Inspect fan pulley for rust or rough spots.
4. Remove any rust or rough spots in the grooves of the fan pulley.

5. Visually inspect the fan drive shaft for galling, pitting, scoring or cracks.
   [a] If galling, pitting, scoring or cracks are found, replace parts as necessary.
   [b] If no galling, pitting, scoring or cracks are not found, reuse parts.

### 4.7.4 Cleaning of Engine Cooling Fan

Clean the engine cooling fan as follows:

1. Clean the fan, fan hub, and related parts with clean fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry the fan, fan hub, and related parts with compressed air.

### 4.7.5 Assembly of Engine Cooling Fan

Assemble the engine cooling fan as follows:

1. Install the roller bearing inner race to the fan hub shaft. Support the shaft (fan side down) on a press bed. Use tool, J 36310-A, part of tool set J 36310-A, to press the race on the shaft firmly against the shoulder.

**NOTE:**
The identification number side of the race should be against the tool.

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

2. Using snap ring pliers, install the inner race retaining snap ring on the shaft.

**NOTE:**
Be sure the snap ring is fully seated in the groove.

3. Using Mobilgrease® HP or equivalent lithium base multipurpose grease, pack the roller bearing.

4. With the fan drive housing on a press bed (fan side up) install the roller bearing into the housing. Using J 36310-2, part of tool set J 36310-A, press the bearing firmly against the shoulder in the housing.
5. Install the roller bearing retaining snap ring.

**NOTE:**
Be sure the snap ring is fully seated in the groove in the housing.

| NOTICE: |
|---|
| Care must be taken to only apply enough pressure to seat the seal against the snap ring. Excess pressure will deform the seal case. |

6. Using the opposite (smooth) side of tool J 36310-2, part of tool set J 36310-A, press the oil seal into the housing against the snap ring.
7. Using Mobilgrease® or equivalent lithium-base multipurpose grease, pack the ball bearing.
8. Using the wider end of toolJ 36310-1, part of tool set J 36310-A, to press on the outer race of the bearing; turn the fan hub housing over (fan side down) on the press bed and install the ball bearing assembly into the housing.
9. Press the bearing firmly against the shoulder in the housing.
10. Install the ball bearing retaining snap ring in the housing.

**NOTE:**
Be sure the snap ring is fully seated in the groove.

11. Pack the housing with Mobilgrease® HP or equivalent lithium base multipurpose grease. Do not overfill the housing.
*Mobilgrease® is a registered trademark of Mobil Oil Corporation.*

**NOTE:**
The housing should be between 1/2 to 2/3 full.

12. Coat the lip of the new oil seal with clean engine oil.
13. With the fan hub shaft (fan side down) supported on a press bed, carefully install the housing over the shaft.
14. Using the narrow end of toolJ 36310-1, part of tool set J 36310-A, press the inner race of the ball bearing onto the shaft until it is firmly seated against the shoulder on the shaft.
15. Secure the fan hub shaft in a vice with soft (brass) jaws.
16. Index the locating pin in the shaft with its mating hole in the spacer and install the spacer.
17. Install the spacer retaining bolt and torque to 58-73 N·m (43-54 lb·ft).
18. Coat the edge of the hub cap with a sealant such as Loctite® 620 or equivalent.
19. Install the cap into the end of the housing.

20. Using the flat side of tool J 36310-2, part of tool set J 36310-A, press the cap into the housing.

**NOTE:**
The raised center section of the cap should be flush with the surface of the housing.

### 4.7.6 Installation of the Engine Cooling Fan

Install the engine cooling fan as follows:

1. Install the fan hub assembly to the support bracket using the four bolts and hardened washers. Do not tighten the bolts.
2. Install the adjusting rod in the housing.
3. If removed, install the air conditioning compressor drive pulley and retaining plate to the fan drive pulley. Torque the retaining bolts to 30-38 N·m (22-28 lb·ft).
4. Install the fan drive pulley on the fan hub assembly.
5. Install the fan to the fan drive pulley. Align the holes in the fan, drive pulley and drive shaft.
6. Install the attaching bolts through the fan and pulley and thread them into the tapped holes in the fan hub. Torque the bolts in a crisscross pattern to 47-53 N·m (35-39 lb·ft).
7. Install the drive belts to the fan pulley and crankshaft pulley.
8. Adjust the drive belts to provide the proper tension. Refer to section 13.13.10.
9. Torque the fan hub-mounting bolts to 101-126 N·m (75-93 lb·ft).

## 4.8 COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a replaceable spin-on type element. See Figure 4-87. The factory-installed coolant filter is mounted on the gear case cover.

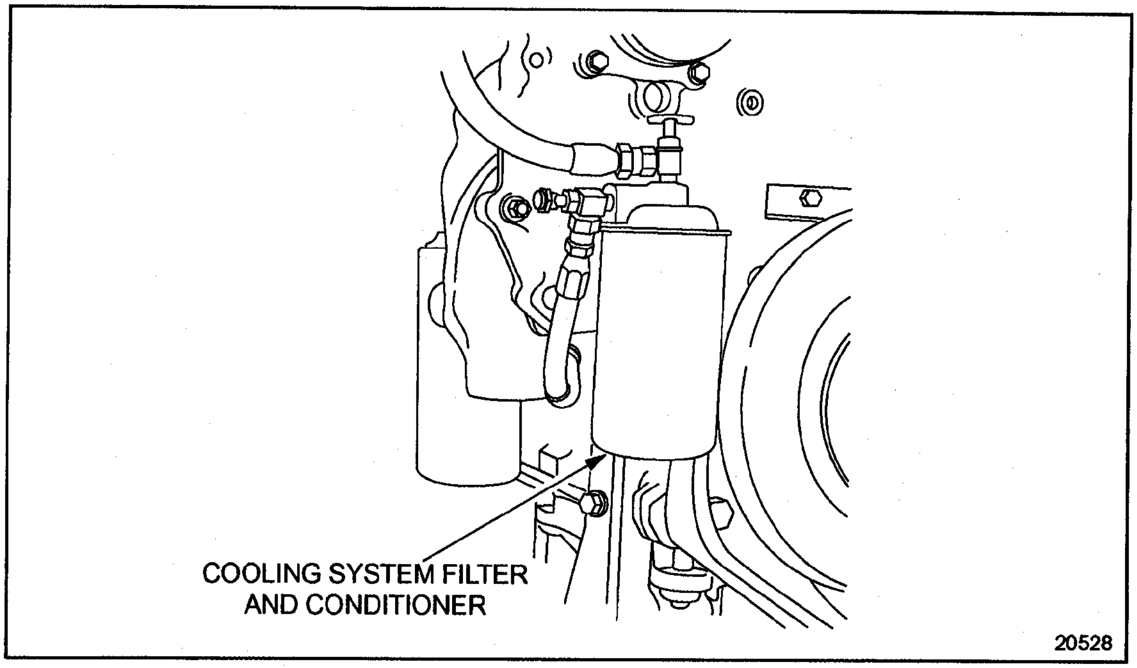



**Figure 4-87 Coolant Filter**

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system. Refer to section 5.4.3.

## 4.8.1 Repair or Replacement of Coolant Filter and Conditioner

Replace filters at regularly scheduled maintenance intervals. Refer to section 13.13.16.

### 4.8.1.1 Inspection of Coolant Filter and Conditioner

Detroit Diesel does not offer coolant filter and conditioners as original equipment on Series 60 engines.

## 4.8.2 Installation of Coolant Filter and Conditioner

Refer to OEM guidelines for coolant filter and conditioner installation procedure.

## 4.9 RADIATOR

The radiator is an OEM supplied component. Follow OEM guidelines.

### 4.9.1 Repair or Replacement of Radiator

If it is determined that your radiator is plugged, use the following procedure to reverse flush the radiator:

1. Remove scale in cooling system by using a descaling solvent. Follow OEM instructions.
2. Neutralize the system with a neutralizing agent. Follow OEM instructions.
3. Drain the cooling system. Refer to section 13.13.4.
4. Remove the radiator inlet and outlet hoses.
5. Remove the water pump inlet and outlet hoses.
6. Attach a hose to the top of the radiator to lead water away from the engine.
7. Attach a hose at the bottom of the radiator and insert a flushing gun in the hose.
8. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.

| NOTICE: |
|---|
| Apply air gradually. Do not exert more than 138 kPa (20 lb/in.$^2$) air pressure. Too great a pressure may rupture a radiator tube. |

9. Turn on the water and when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between blasts.
10. Continue flushing until only clean water is expelled from the radiator.
11. Remove flushing gun and hoses from radiator.
12. Attach the water pump inlet and outlet hoses.
13. Attach the radiator inlet and outlet hoses.
14. Fill cooling system. Refer to section 13.13.4.
15. Refer to section 11.3.5 for verification of installation.

## 4.10 KEEL COOLING SYSTEM (COMMERCIAL MARINE)

In the keel cooling system, the engine coolant is drawn by the engine water pump from the keel cooler mounted on the hull of the vessel and is forced through the engine oil cooler, cylinder block and head to the thermostat housing. Then it flows back to the keel cooler, completing its cooling circuit. A bypass from the thermostat housing to the inlet side of the water pump permits circulation of coolant through the engine when the thermostats are closed. When the thermostats open, the coolant flows into the surge tank and through the coils of the keel cooler to be cooled. See Figure 4-88.

The heat of the engine coolant is transferred through the keel cooler coils to the surrounding sea water.

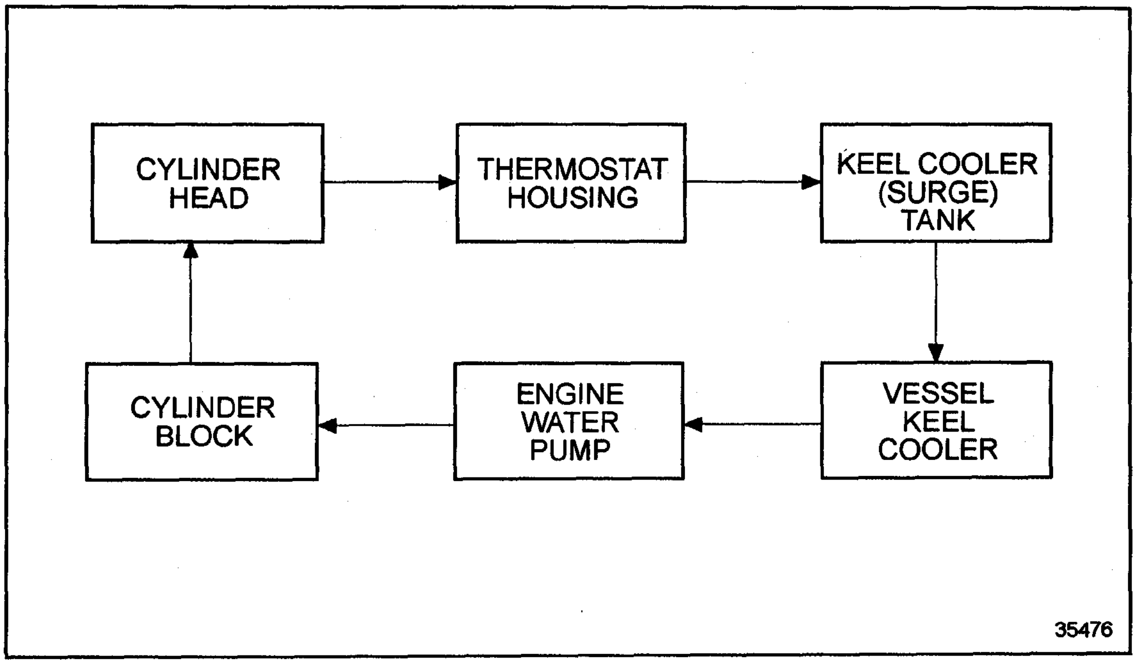



**Figure 4-88 Schematic of the Keel Cooling System (Raw Water Cooled)**

## 4.11 HEAT EXCHANGER COOLING SYSTEM (PLEASURE CRAFT MARINE)

In the heat exchanger cooling system, the coolant is drawn by the engine water pump from the heat exchanger and is forced through the engine oil cooler, cylinder block, cylinder heads and exhaust manifolds to the thermostat housings. A bypass from the thermostat housings to the inlet side of the water pump permits circulation of coolant through the engine when the thermostats are closed. See Figure 4-89 and see Figure 4-90.

When the thermostats are open, the coolant flows through the heat exchanger where it is cooled.

An engine driven raw water pump circulates raw water (sea water) through the heat exchanger to lower the temperature of the engine coolant.

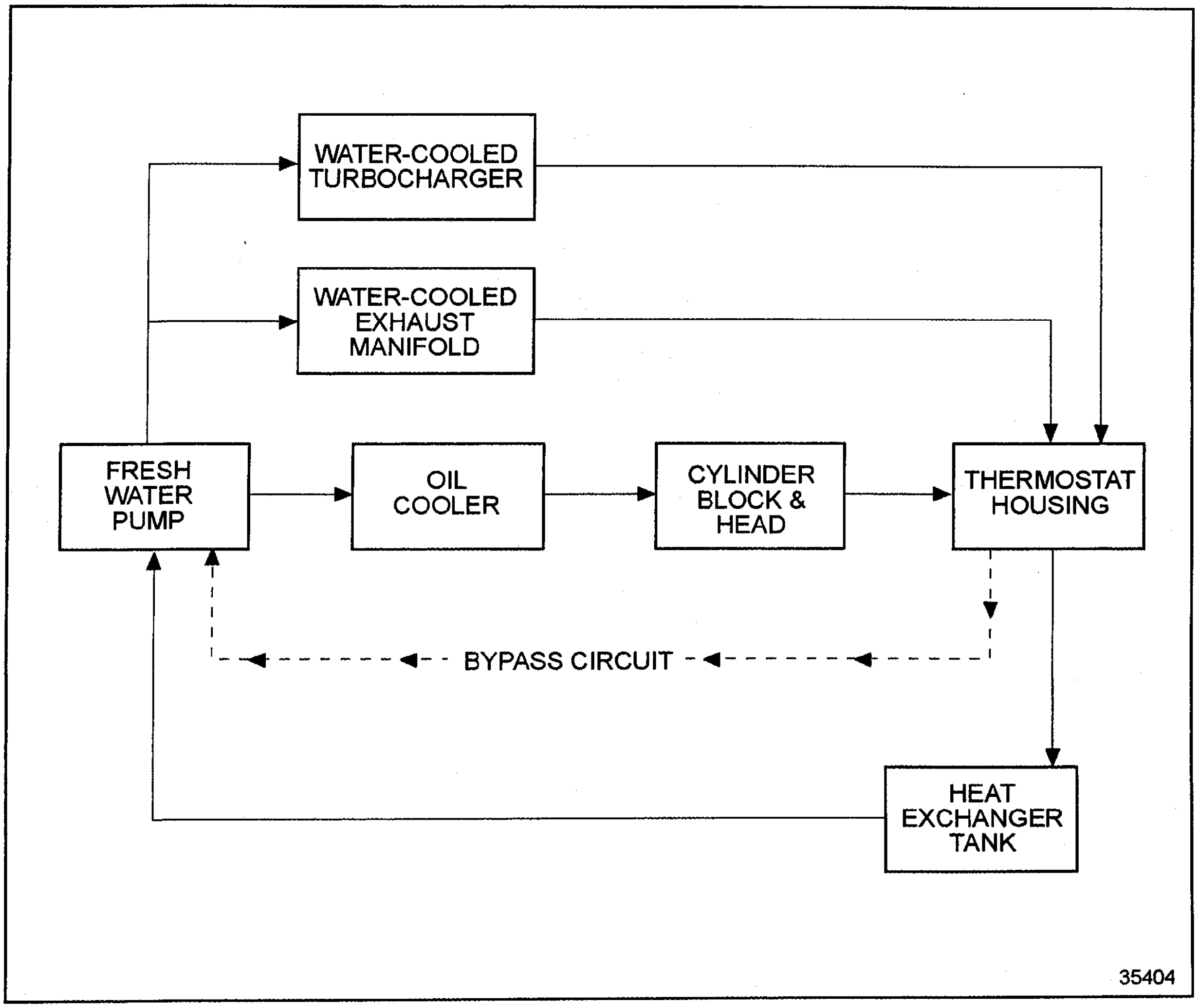



**Figure 4-89 Schematic of the Heat Exchanger-Cooled Pleasure Craft Marine Engine**

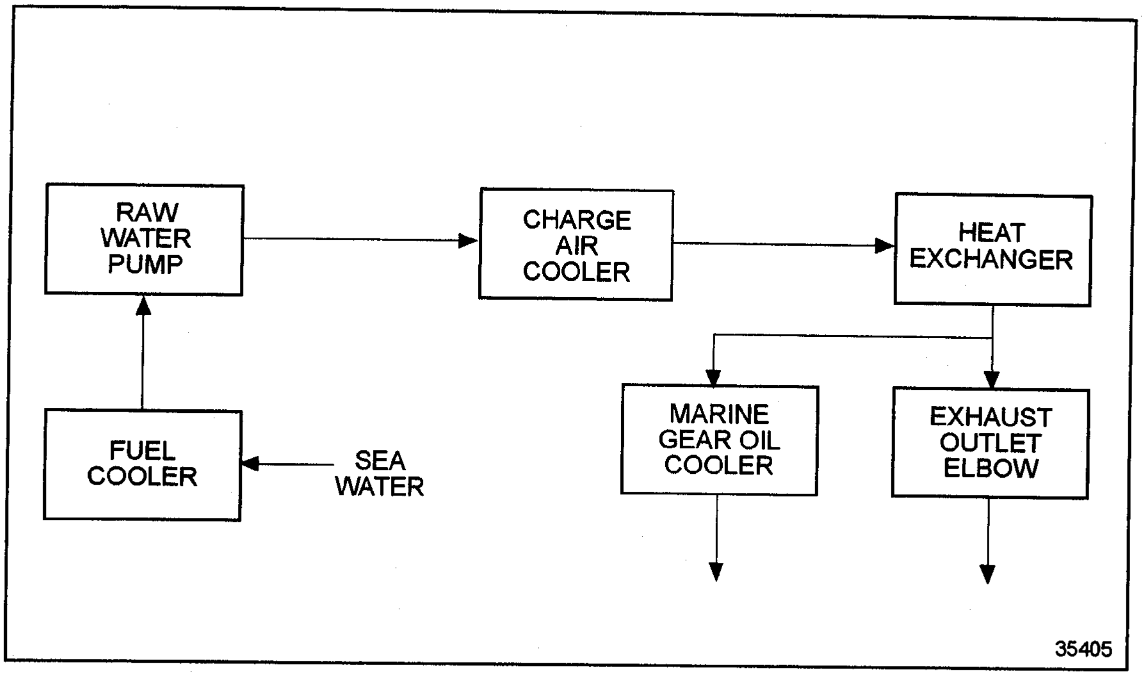



**Figure 4-90 Raw Water Flow on Heat Exhanger-Cooled Marine Engine**

## 4.12 HEAT EXCHANGER (PLEASURE CRAFT MARINE)

The heat exchanger used on the Series 60 marine engine is a stacked plate cooler design assembly. In this type of assembly, heat exchanger membranes or plates are stacked side-by-side with special gaskets between the plates. The plates and gaskets are then compressed in a bundle to provide sealing. The sides of the heat exchanger plates are exposed for enhanced heat rejection and to make it easier to detect coolant leaks, which could lead to a low coolant level and engine overheating. The system operates as follows:

Hot engine coolant from the thermostat housing flows into the heat exchanger tank and through the plate stack. See Figure 4-91. As this is taking place, sea water from the raw water pump flows into the charge air cooler and then into the plate stack. See Figure 4-92. Sea water flows through the plate stack on one side of the plates, while engine coolant flows through on the opposite side, reducing the temperature of the engine coolant inside. This lower temperature coolant then flows back to the fresh water pump and is disbursed again throughout the engine.

**NOTE:**
The heat exchanger tank is mounted onto six isolators to minimize the effects of normal engine vibration. These isolators *must* be replaced whenever the heat exchanger is removed.

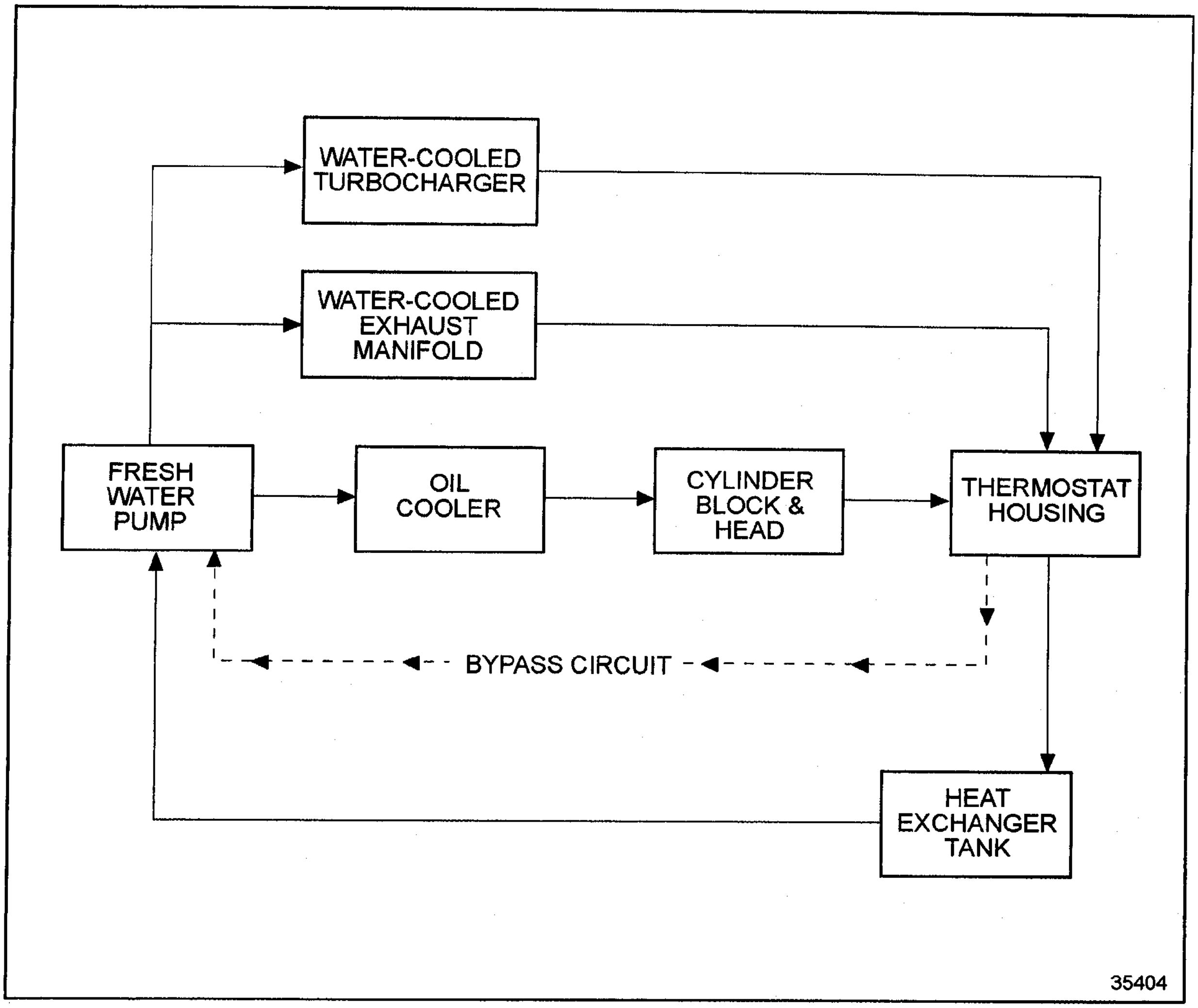



**Figure 4-91** **Fresh Water Flow on Heat Exchanger-Cooled Pleasure Craft Marine Engine**

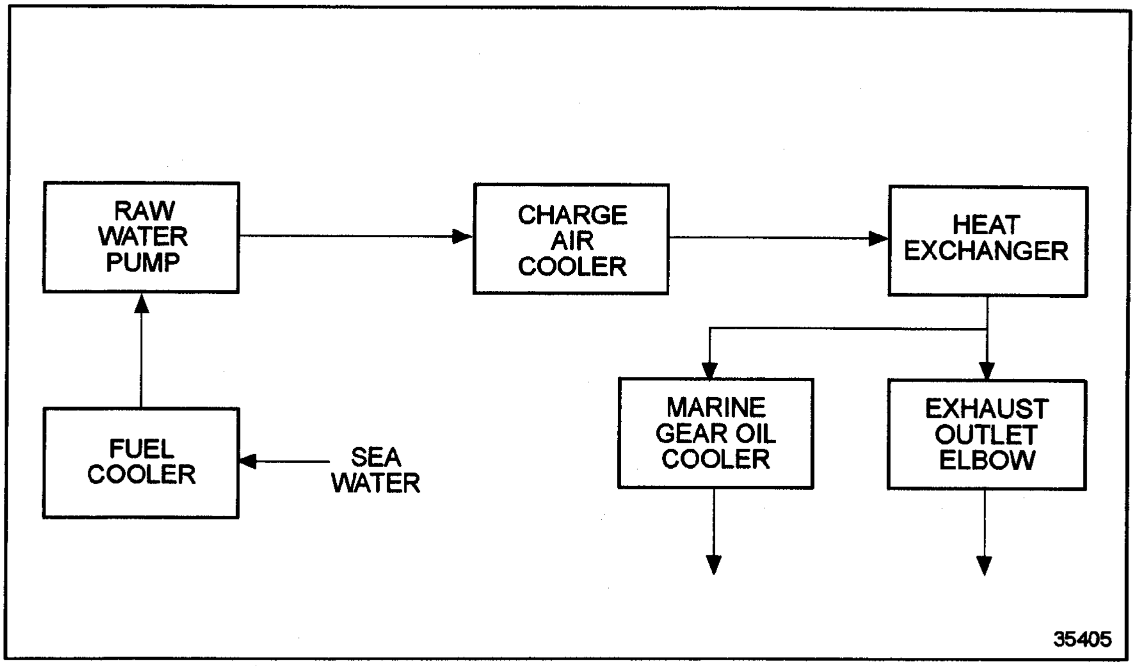



**Figure 4-92 Raw Water Flow on Heat Exchanger-Cooled Marine Engine**

### 4.12.1 Repair or Replacement of the Heat Exchanger

To determine if repair is possible or replacement of the heat exchanger is necessary, perform the following procedure. See Figure 4-93.

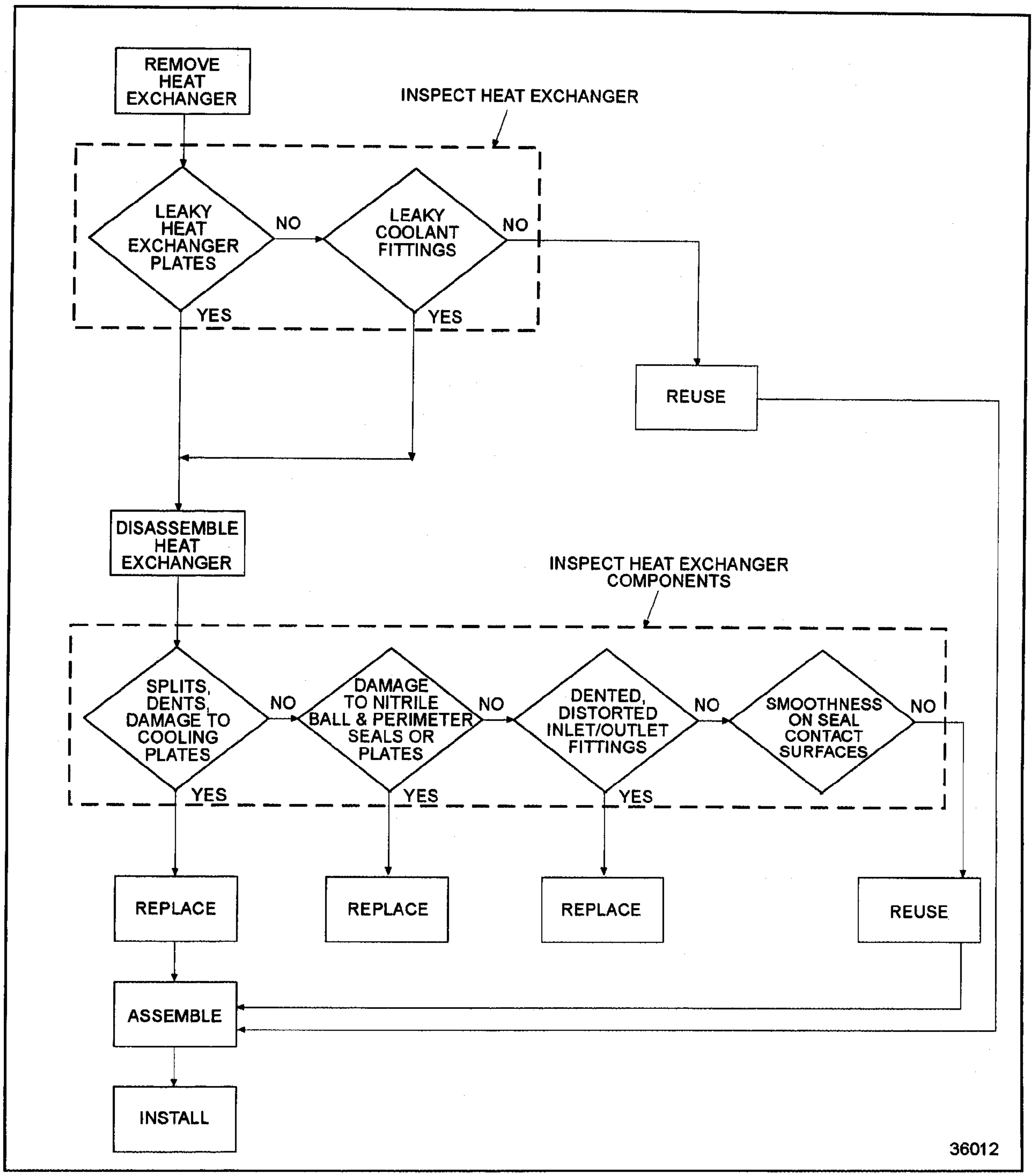



**Figure 4-93 Flowchart for Repair or Replacement of Heat Exchanger**

### 4.12.2 Removal of the Heat Exchanger

Remove the heat exchanger from the engine as follows:

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

1. With the engine at ambient temperature, place a suitable container beneath the heat exchanger. Open the fresh water drain cock and drain the engine coolant from the tank. Close the drain cock.

**NOTE:**
If the coolant is to be reused, cover the container and place in a protected area away from possible contaminants. If the coolant is not to be reused, dispose of it in an environmentally friendly manner according to state and/or federal (EPA) recommendations.

2. Place a suitable container beneath the heat exchanger. Open the sea water drain cock and drain the raw water from the tank. Close the drain cock and discard the raw water.

**NOTICE:**

The heat exchanger is fastened to the mounting bracket with six (6) M8 mounting bolts, four on the bottom and two on the back. When removing the heat exchanger, do not remove any of the bolts on the heat exchanger itself. These bolts are used to hold the components of the heat exchanger assembly together. Removing them will result in loosening of the core membrane plates and coolant leakage,which could lead to overheating and severe engine damage.

3. Loosen the hose clamps holding the raw water inlet and outlet tubes to the heat exchanger. Slide the hoses along the tubes and disconnect the tubes from the tank.
4. Loosen the hose clamps holding the engine coolant inlet and outlet tubes to the heat exchanger. Slide the hoses along the tubes and disconnect the tubes from the tank.
5. Remove two (2) mounting bolts holding the heat exchanger to the back isolator brackets.
6. Remove four (4) mounting bolts holding the heat exchanger to the isolators on the bottom bracket.
7. Using a suitable chain hoist and sling, lift the heat exchanger from the engine.

### 4.12.2.1 Inspection of the Heat Exchanger

Inspect the heat exchanger assembly as follows:

1. With the engine at ambient temperature and cool to the touch, inspect ends of the heat exchanger plates for any signs of fresh water coolant or raw water coolant leaks. Leaks can be detected by feeling beneath the core or by visually checking the floor beneath the heat exchanger.
2. Inspect raw water and fresh water coolant fittings on the back of the heat exchanger assembly. If fresh water or raw water is found leaking from the plate bundle, the heat exchanger must be disassembled, the plates and gaskets must be inspected for serviceability, and the heat exchanger must be reassembled with new gaskets or plates, as required.

## 4.12.3 Disassembly of the Heat Exchanger

Disassemble the heat exchanger assembly as follows:

**NOTE:**
It is not necessary to remove the heat exchanger assembly from the engine for disassembly and repair.

1. With the engine at ambient temperature, place a suitable container beneath the heat exchanger. Open the fresh water drain cock and drain the engine coolant from the tank. Close the drain cock.

**NOTE:**
If the coolant is to be reused, cover the container and place in a protected area away from possible contaminants. If the coolant is not to be reused, dispose of it in an environmentally friendly manner according to state and/or federal (EPA) recommendations.

2. Remove the M12 1.75 X 130 mm left-center and right-center bolts (bolt locations 9 and 10 see Figure 4-94) from the front cover plate of the heat exchanger. Install M12 1.75 X 180 mm bolts and spacers in their place. Tighten bolts securely.

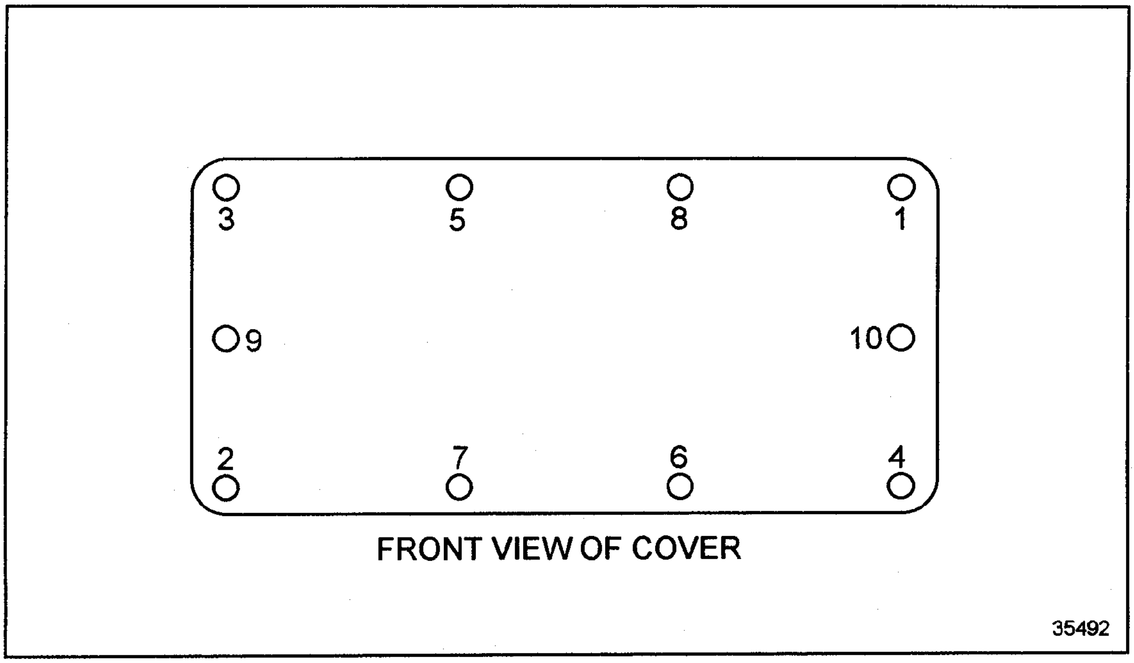
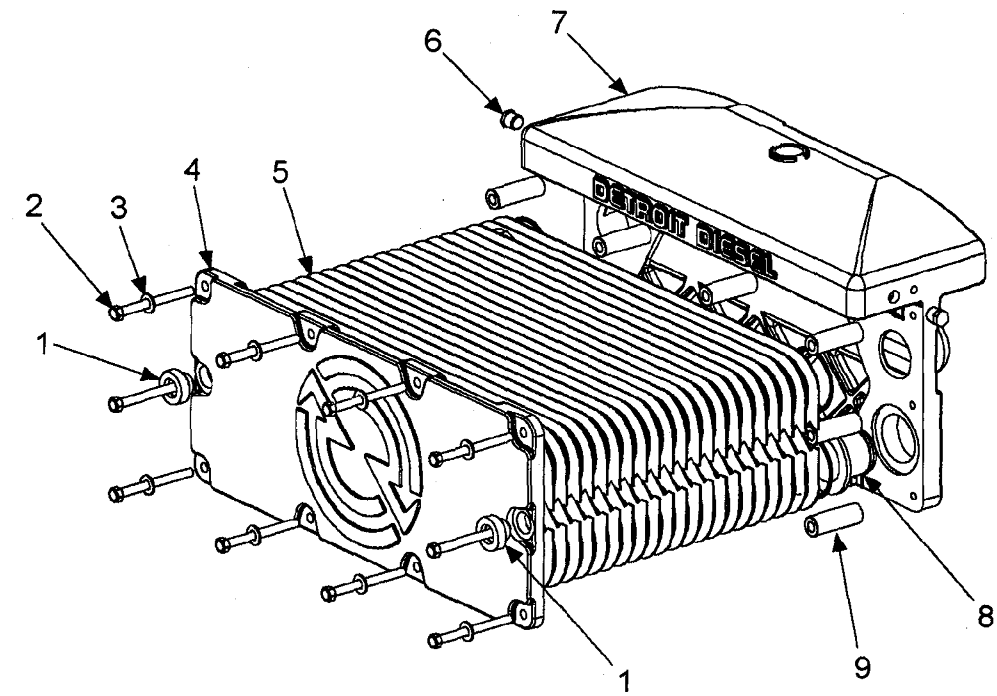



**Figure 4-94 Front Cover Plate Bolt Location and Torque Sequence**

3. Alternating from top to bottom, gradually loosen and then remove the M12 1.75 X 130 mm top and bottom bolts from the front cover plate. *Do not remove the M12 1.75 X 180 mm left-center and right-center bolts just installed.* As bolts are loosened, the plate bundle will expand forward.

4. With the expanded plate bundle resting only on the center bolt/spacers, support the plate bundle by hand and carefully remove the center bolts until the bundle can be pulled away from the tank/back plate. Remove the raw water inlet and outlet fittings. See Figure 4-95.




1. Bushing
2. Retaining Bolt
3. Washer
4. Front Plate
5. Plates
6. Sight Glass
7. Heat Exchanger Tank
8. Raw Water Inlet Fitting
9. Spacer

**Figure 4-95 Location of Heat Exchanger Components**

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

**CAUTION:**

**To avoid injury when using chemical substances, it is essential to observe the manufacturer's instruction for use, safety, and waste disposal.**

**CAUTION:**

**To avoid injury when using caustic cleaning agents, follow the chemical manufacturers usage, disposal, and safety instructions.**

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

5. Using pure mineral spirits or a mild commercial cleaning solvent, remove any residual sealing material from the tank/back plate and from the cast front cover plate. Blow-dry with compressed air.

### 4.12.3.1 Inspection of the Heat Exchanger Components

Inspect the heat exchanger assembly components as follows:

1. Inspect cooling plates carefully for pinholes, splits, dents, or distortion. Replace any plate showing obvious signs of damage.
2. Inspect gaskets on plates. Replace any gaskets showing signs of leakage, such as tears, cracks, or erosion.
3. Inspect for buildups of deposits on plates and remove, if found.

**NOTE:**
There are small balls welded into the gasket groove of each plate and corresponding holes in the gaskets. Gaskets are easily replaced, since they simply snap into place on the plates. A "4–corner" gasket is used on the sealing (first) plate and "standard" gaskets are used on the core plates and the closure (final) plate. Replacement plates and gaskets are available from authorized Detroit Diesel parts distributors.

4. Inspect raw water inlet and outlet fittings for dents, distortion, or damaged sealing areas on the flanges, and replace if required.
5. Inspect gasket contact surfaces on the tank/backplate for smoothness. If required, carefully smooth any rough areas that will come in contact with the gaskets on the plates.

### 4.12.4 Assembly of the Heat Exchanger

Assemble the heat exchanger assembly as follows:

1. Install two M12 1.75 X 180 mm long bolts, each with two spacers, into the center right and center left holes in the heat exchanger tank/backplate (locations 9 and 10 see Figure 4-96). The spacers will properly align the plates during assembly.

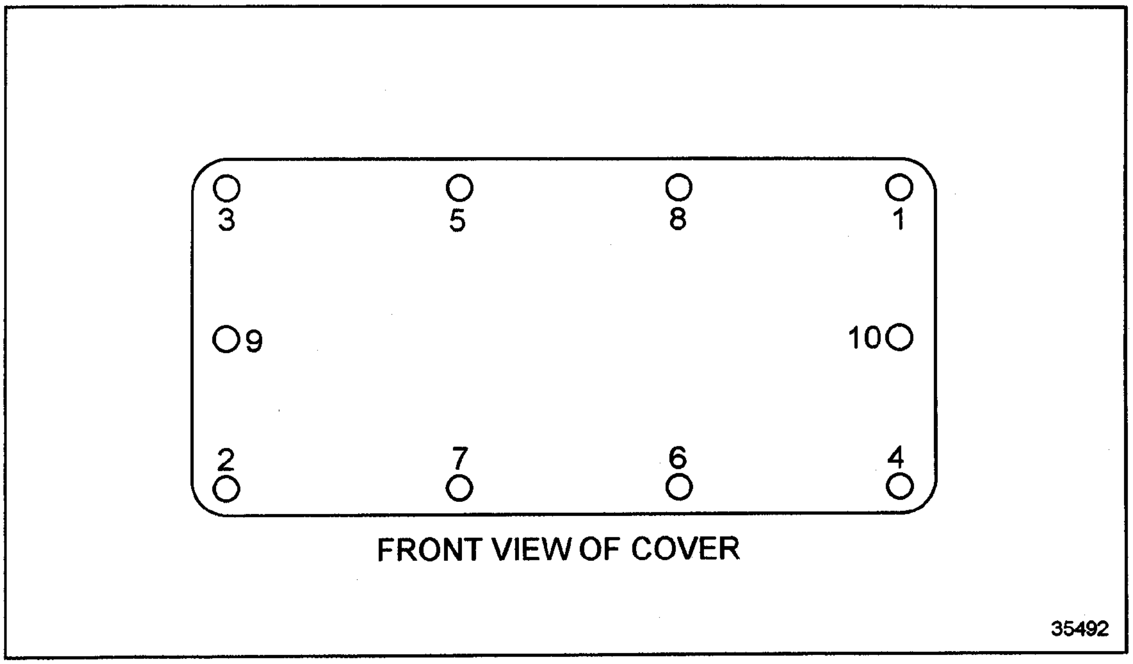



**Figure 4-96 Heat Exchanger Bolt Hole Location**

2. Install raw water inlet and outlet fittings. Install the curved fitting (elbow) on the right side (as viewed from the rear of the heat exchanger tank), and angle it 3 degrees down from horizontal (pointing right).

3. See Figure 4-97and install the first (sealing) plate, onto the center bolt/spacers. Install this plate with the gasketing side facing the tank and the letter "N" on the left-hand side as viewed from the rear of the heat exchanger tank.

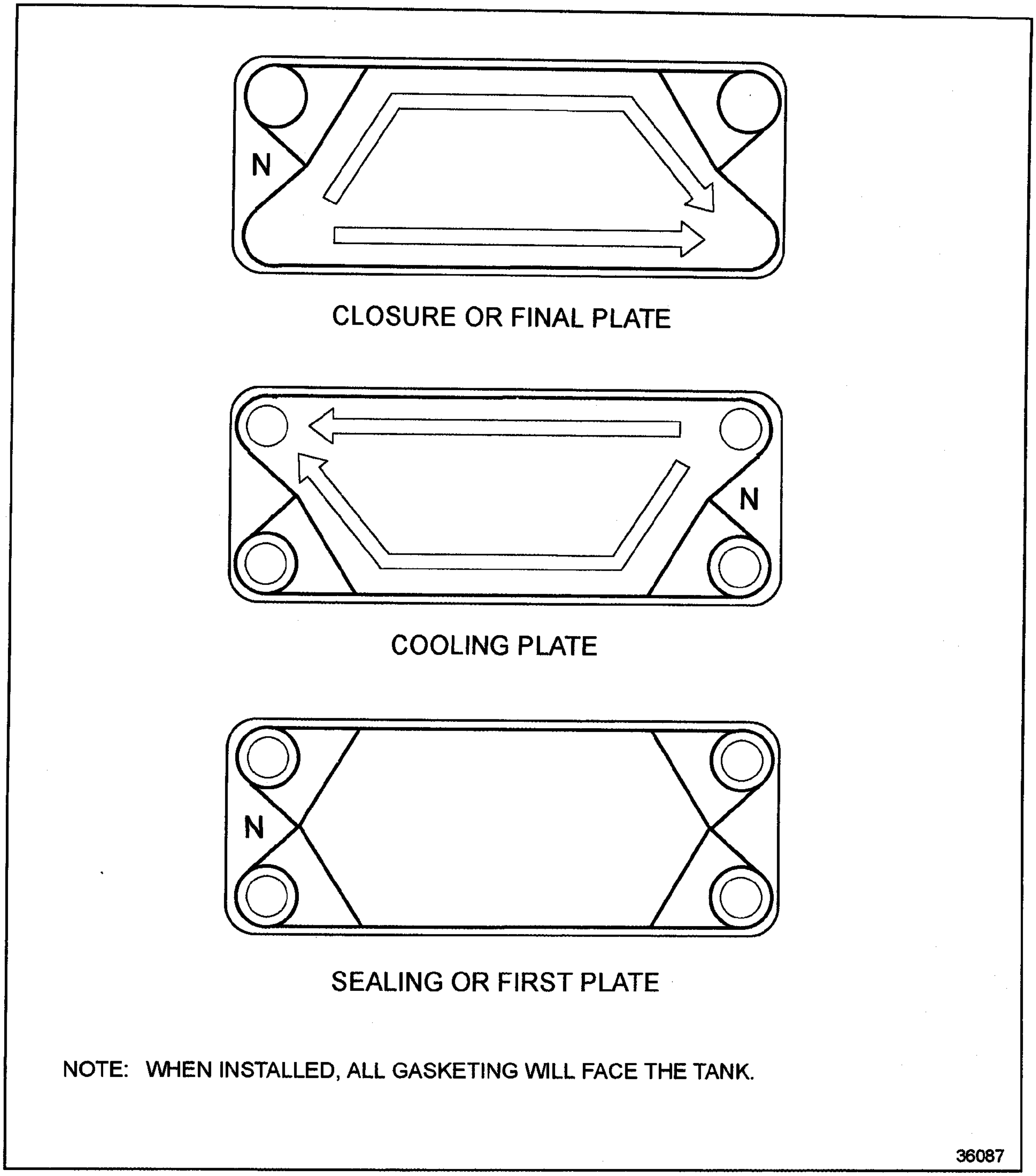



**Figure 4-97 Gasket Faces and Orientation of Heat Exchanger Plates**

4. Install a core plate onto the center bolt/spacers with gasketing side against the smooth back of the sealing plate and the letter "N" on the right-hand side.
5. Invert the next core plate and install with gasketing side against the smooth back of the previous core plate and the letter "N" on the left-hand side.
6. Continue inverting and installing the remaining core plates, alernating the "N" locations right and left side until all core plates are installed.

**NOTE:**
Plates are correctly installed if the bent fins on the sides and ends touch each other, forming a honeycomb pattern, and not running parallel to each other. See Figure 4-98.

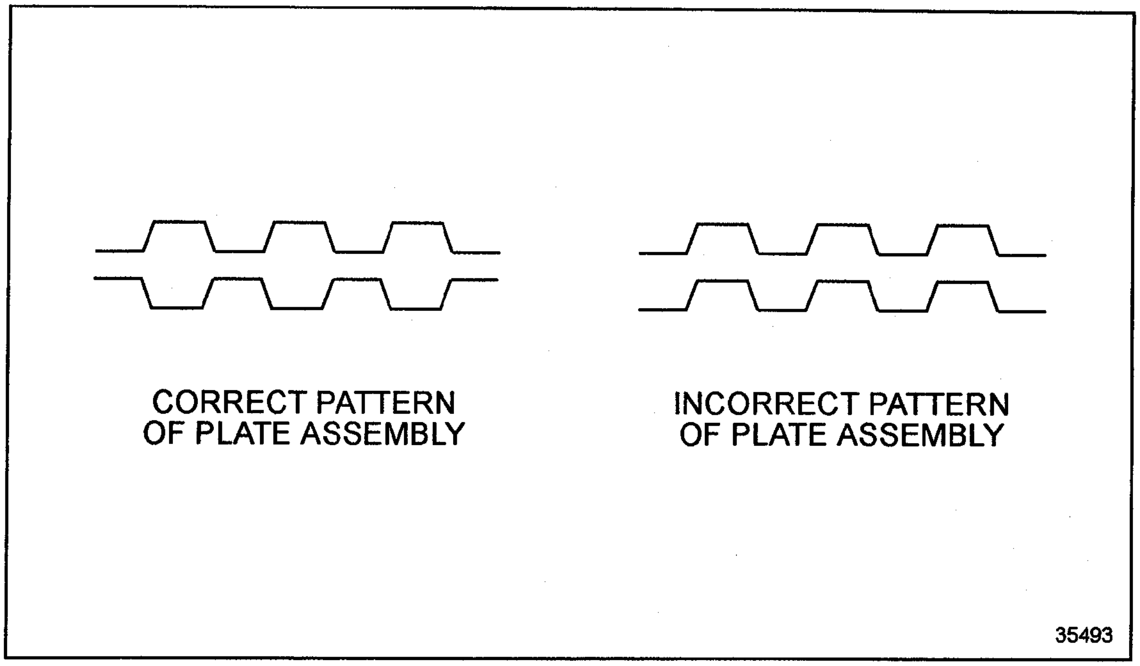



**Figure 4-98 Correct and Incorrect Pattern of Heat Exchanger Plate Assembly**

7. Install the closure plate (no openings) with gasketing against the smooth back of the last core plate.
8. When all cooler plates are stacked, install the cast aluminum front cover plate.

**NOTE:**
The wider web sections of the front cover plate are positioned toward the top (tank) side. Secure with four (4) long M12 1.75 X 180 bolts, spacers, and washers in positions 2, 5, 6 and 1. See Figure 4-95.

9. Position angled raw water outlet fitting three degrees below horizontal, facing outboard.

10. Use M12 1.75 X 180 mm bolts and spacers at locations 2, 5, 6 and 1 for initial tightening. Alternating from side to side, tighten 180 mm long bolts uniformly and evenly until shorter M12 1.75 X 130 mm bolts will reach the threads. When plates are compressed to allow use of 130 mm bolts, install the shorter bolts with washers and spacers in positions 3, 7, 8, and 4. Snug bolts, but do not tighten.
11. Remove 180 mm bolts from locations 2, 5, 6, and 1. Install 130 mm bolts with washers and spacers. See Figure 1-274. Snug bolts, but do not tighten.
12. Remove 180 mm bolts and one spacer from the center hole locations 9 and 10 and replace with 130 mm long bolts, spacers, and bushings.
13. See Figure 1-274for torque pattern and gradually snug up all bolts evenly so as not to warp or distort the plates. When bolts are bottomed against spacers, torque to 108 N·m (80 lb·ft) using the torque pattern shown.

## 4.12.5 Installation of the Heat Exchanger

Install the heat exchnager as follows:

1. If previously removed, install heat exchanger mounting bracket onto the gear case cover with four (4) M14 mounting bolts. Torque to 190 N·m (140 lb·ft). Install battery-charging alternator; refer to section 8.2.
2. Six synthetic rubber vibration isolators are used with the heat exchanger mounting bolts. Each isolator is installed with four No. 10– 24 X 0.5 in. L. slotted head screws. If previously removed, install four isolators onto the bracket base using four screws per isolator. Install the two remaining isolators onto the isolator mounting brackets attached to the gear case cover and the accessory drive cover plate.

| NOTICE: |
|---|
| Before assembling the heat exchanger tank to the bottom support and engine fromt cover, make sure the isolators are positioned with their high sides against the tank. Failure to observe this precaution may result in component misalignment and greatly degraded isolator performance. |

3. Using a suitable chain hoist and sling, carefully lower the heat exchanger onto the mounting bracket. Line up the holes in the isolators with the bolt holes in the bottom and back of the heat exchanger tank. Install six (6) M8 bolts through the isolators and torque to 35 N·m (26 lb·ft.).

4. Using required blue connector hoses and hose clamps, attach the raw water inlet and outlet tubes to the heat exchanger tank. See Figure 4-99.

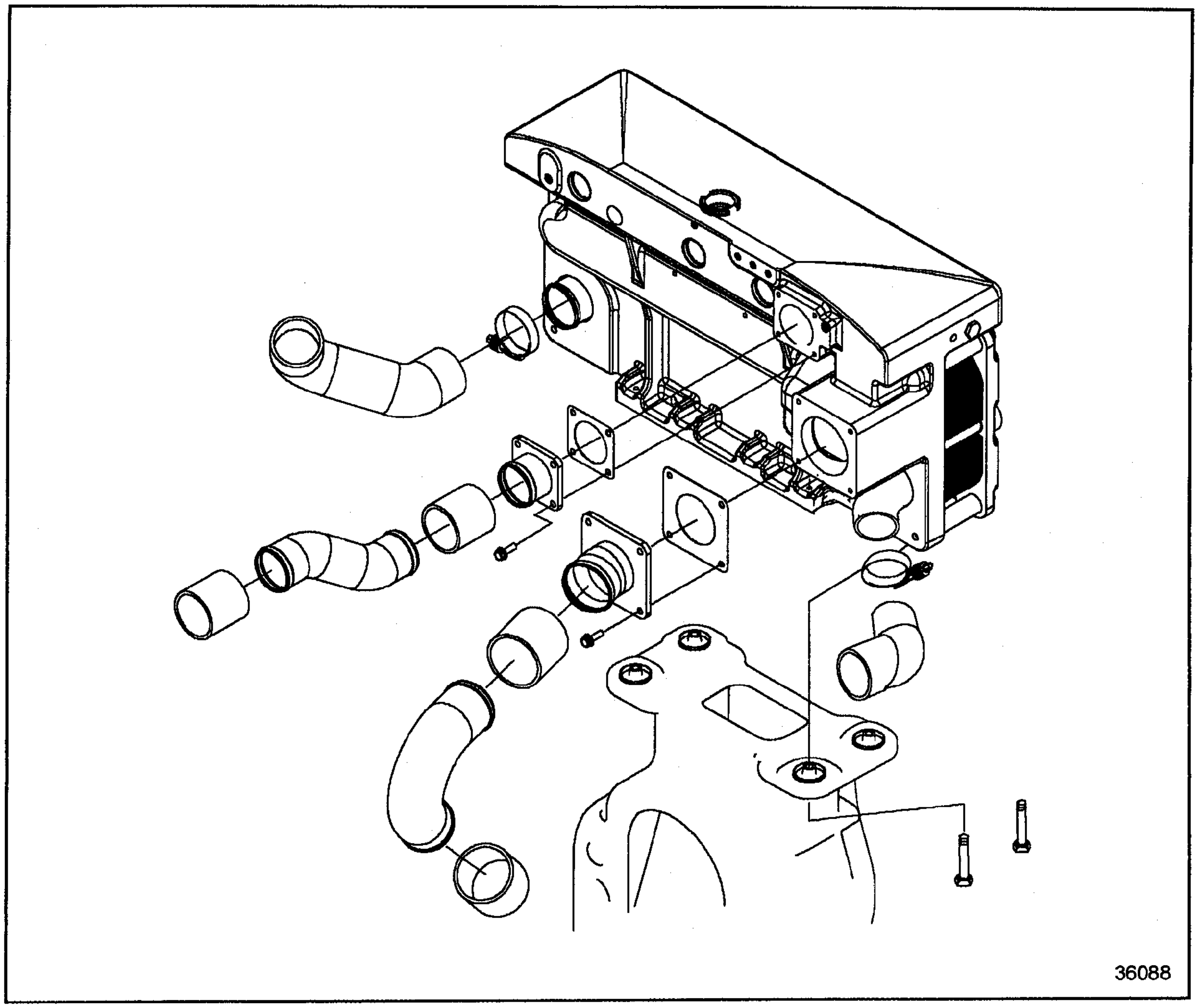



**Figure 4-99 Back of Heat Exchanger Showing Piping**

5. Using required blue connector hoses and hose clamps, attach the fresh water inlet and outlet tubes to the heat exchanger tank.
6. Fill the fresh water cooling system with the required coolant.
7. Prime the raw water pump, if required.

**CAUTION:**

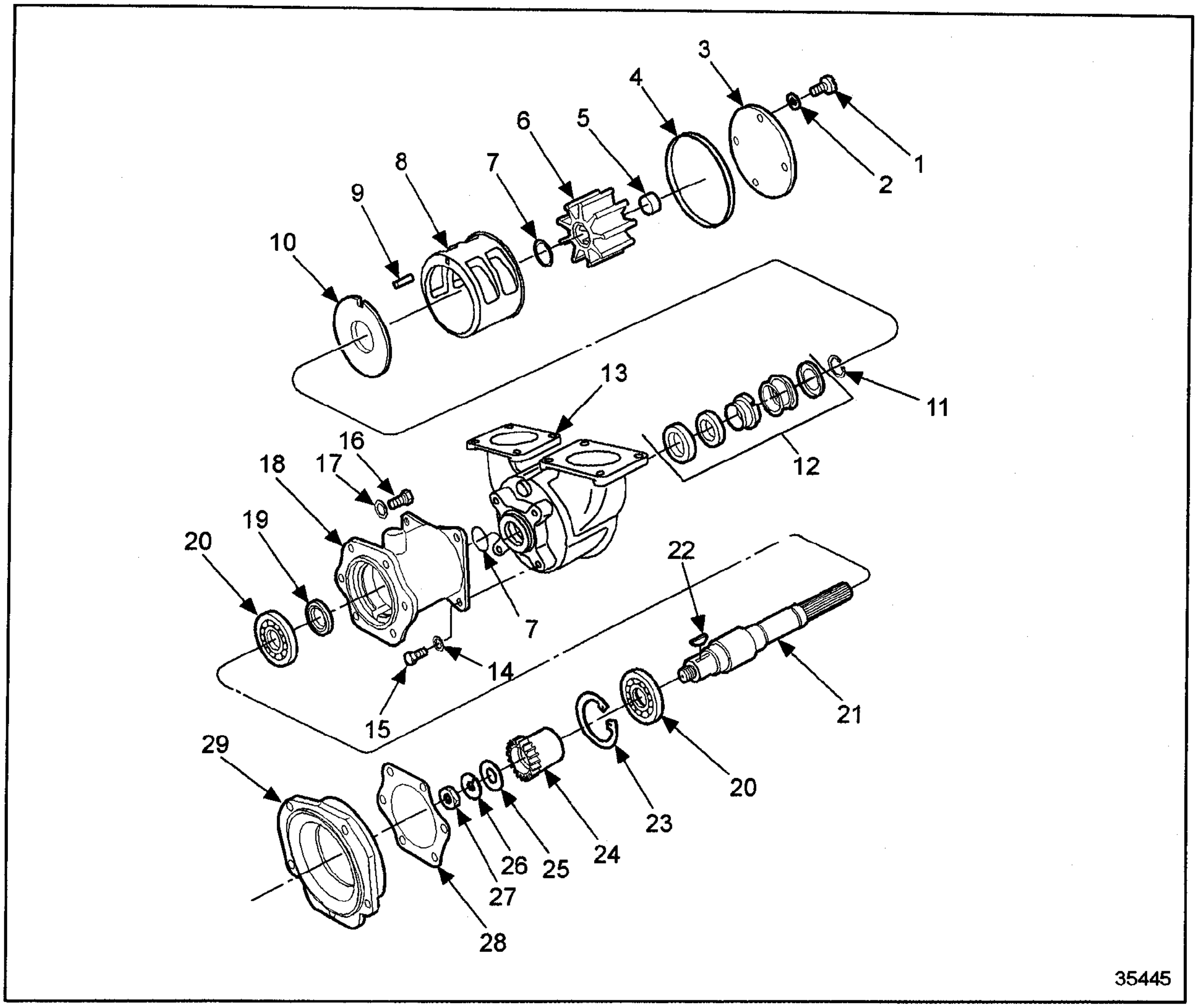
**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

8. Start the engine and check for leaks.

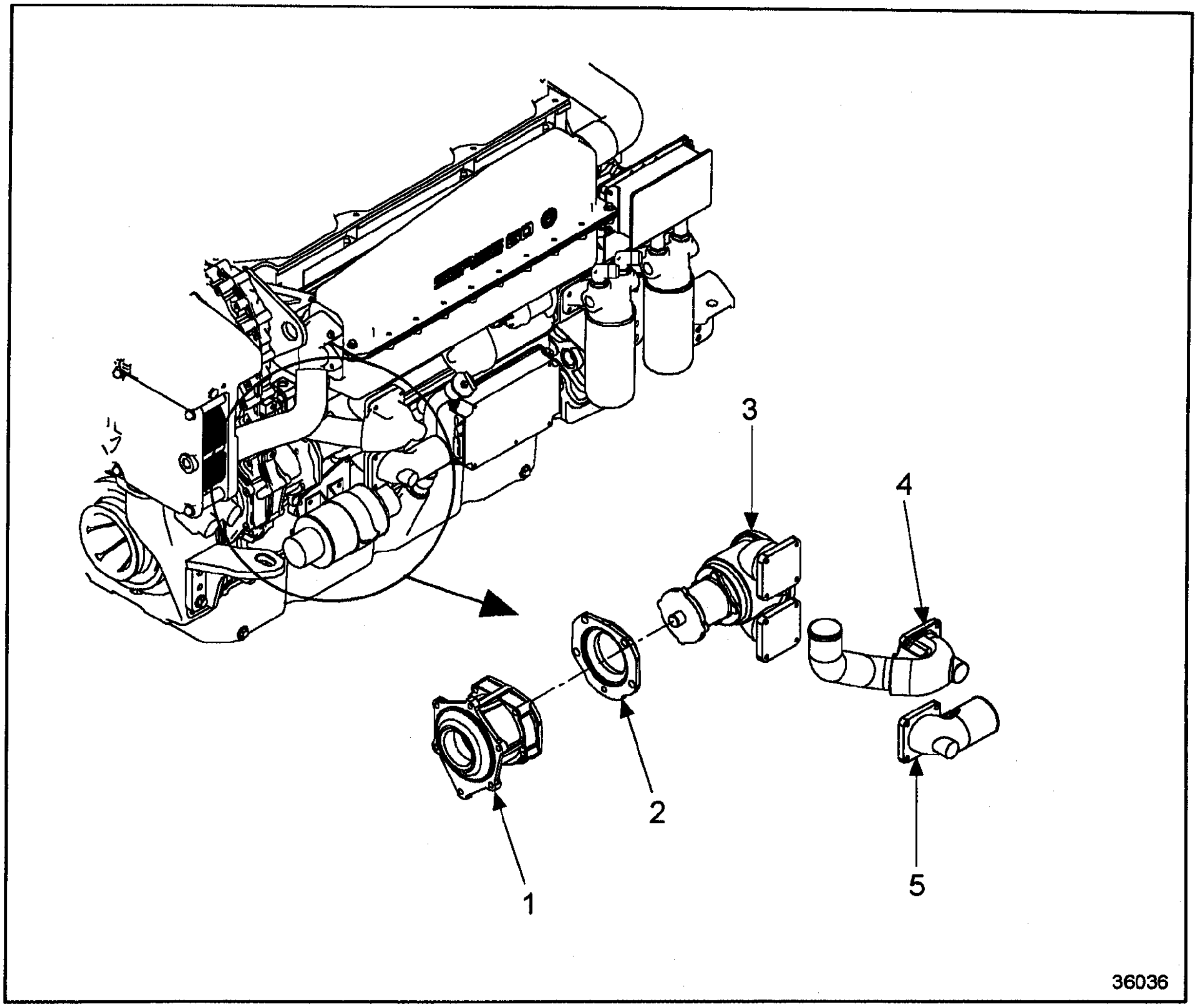
## 4.13 JABSCO® ENGINE COOLING RAW WATER PUMP (MARINE)

A positive displacement pump circulates raw water through the heat exchanger to lower the engine coolant temperature. See Figure 4-100. The pump is attached to a drive assembly bolted to the gear case on the left side of the engine and driven by the bull gear. A hub bolted to the opposite end of the drive assembly meshes with the gear on the pump drive shaft to drive the pump. See Figure 4-101.



1. Hex Bolt
2. Flat Washer, 1/2 (4)
3. End Cover
4. O-ring Seal
5. Seal Spling
6. Impeller
7. O-ring
8. Cam Liner
9. Dowel Pin
10. Wear Plate
11. Retaining Ring
12. Seal Mechanical
13. Body
14. Lock Washer, 5/16 (4)
15. Hex Head Screw, 5/16–18 x 3/4
16. Hex Head Screw, 3/8–16 x 1" (6)
17. Lock Washer, 3/8 (6)
18. Bearing Housing
19. Seal
20. Bearing
21. Shaft
22. Woodruff Key
23. Retaining Ring
24. Gear
25. Flat Washer (1)
26. Lock Washer, 5/8
27. Hex Nut, 5/8 — 18
28. Gasket
29. Adaptor

**Figure 4-100 Raw Water Pump Assembly**




1. Raw Water Pump Drive Assembly
2. Mounting Flange/Adaptor
3. Raw Water Pump Assembly
4. Raw Water Outlet Elbow
5. Raw Water Inlet Elbow

**Figure 4-101 Raw Water Pump Mounting**

The gear-driven pump drive shaft is carried on a double-row ball bearing located in the pump housing flange end.

| NOTICE: |
|---|
| The pumped water lubricates the impeller. To avoid possible impeller damage, do not run the impeller dry for longer than normally required for the pump to prime itself. |

The raw water pump has an impeller that rotates against a polyurethane cam and liner inside the pump body (housing). A wear plate, on the inboard end of the impeller, is used to prevent pump housing wear. Slots in the plate register with dowel pins in the pump housing, cam and liner, preventing the plate from rotating with the impeller.

The wear plate can be reversed if plate wear becomes excessive. A rotary-type seal assembly seals against leakage along the shaft. The shielded type double-row ball bearing is filled with lubricant when assembled. No further lubrication is required.

The pump can operate clockwise or counterclockwise. On the Series 60 marine engine, raw water is drawn into the pump through the opening at the bottom of the pump housing.

| NOTICE: |
|---|
| Always prime the raw water pump before starting the engine. Since water acts as a lubricant for the impeller, failure to prime the pump (or at least wet the impeller vanes to induce a self-priming suction) can result in severe impeller damage when the engine is started. Insufficient raw water flow into the heat exchanger can lead to overheating and engine damage. |

Prime a raw water pump as follows:

1. Remove the pipe plug or zinc electrode from the water inlet elbow. This is the elbow mounted on the lower pump opening.
2. Pour in at least a pint of water.
3. Replace the plug or electrode.

### 4.13.1 Repair or Replacement of the Jabsco Raw Water Pump

To determine if repair is possible or replacement of the Jabsco® raw water pump is necessary, perform the following procedure. See Figure 4-102.

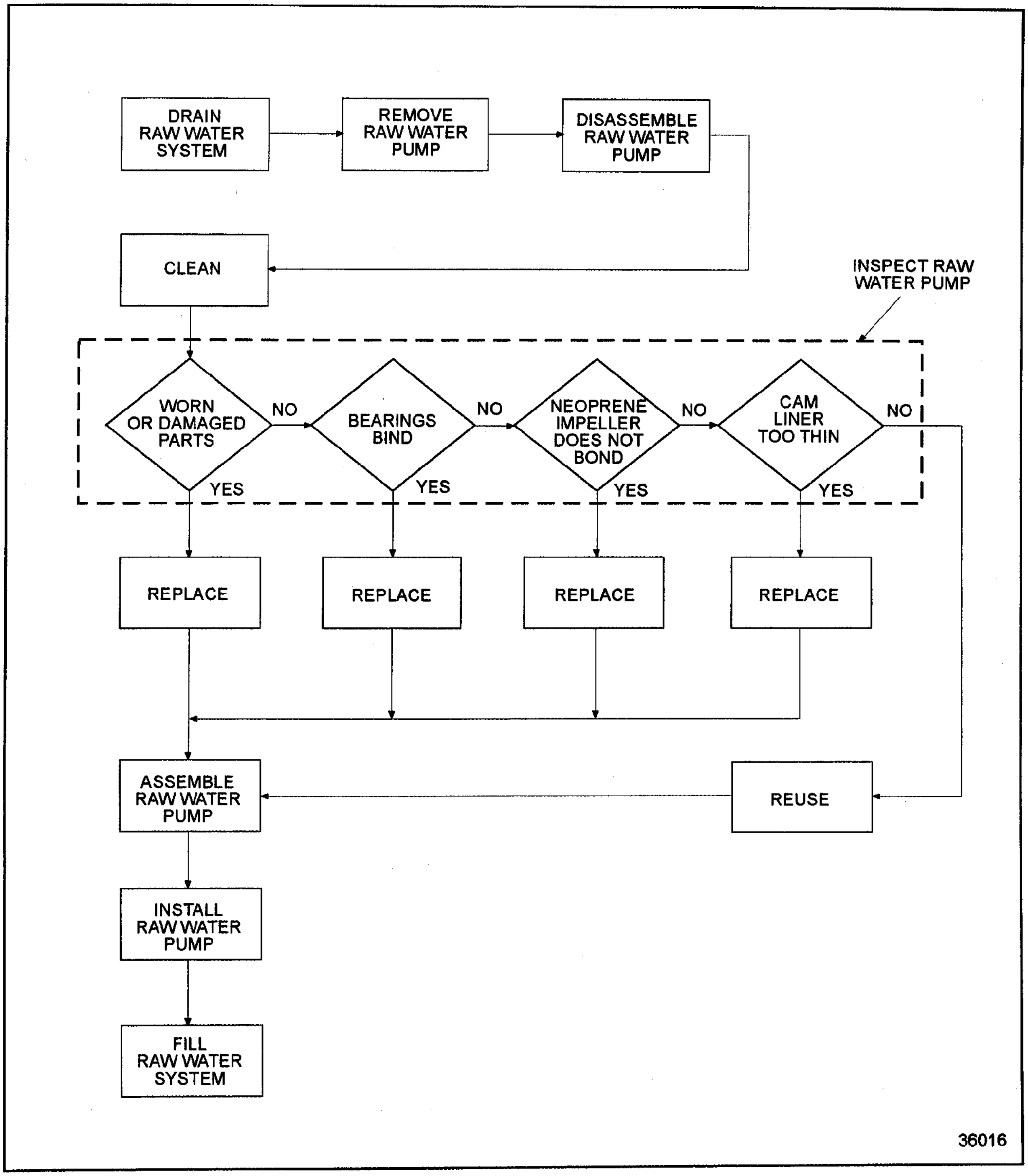



**Figure 4-102 Flowchart for Repair or Replacement of Raw Water Pump**

## 4.13.2 Removal of the Jabsco Raw Water Pump

Remove the raw water pump as follows:

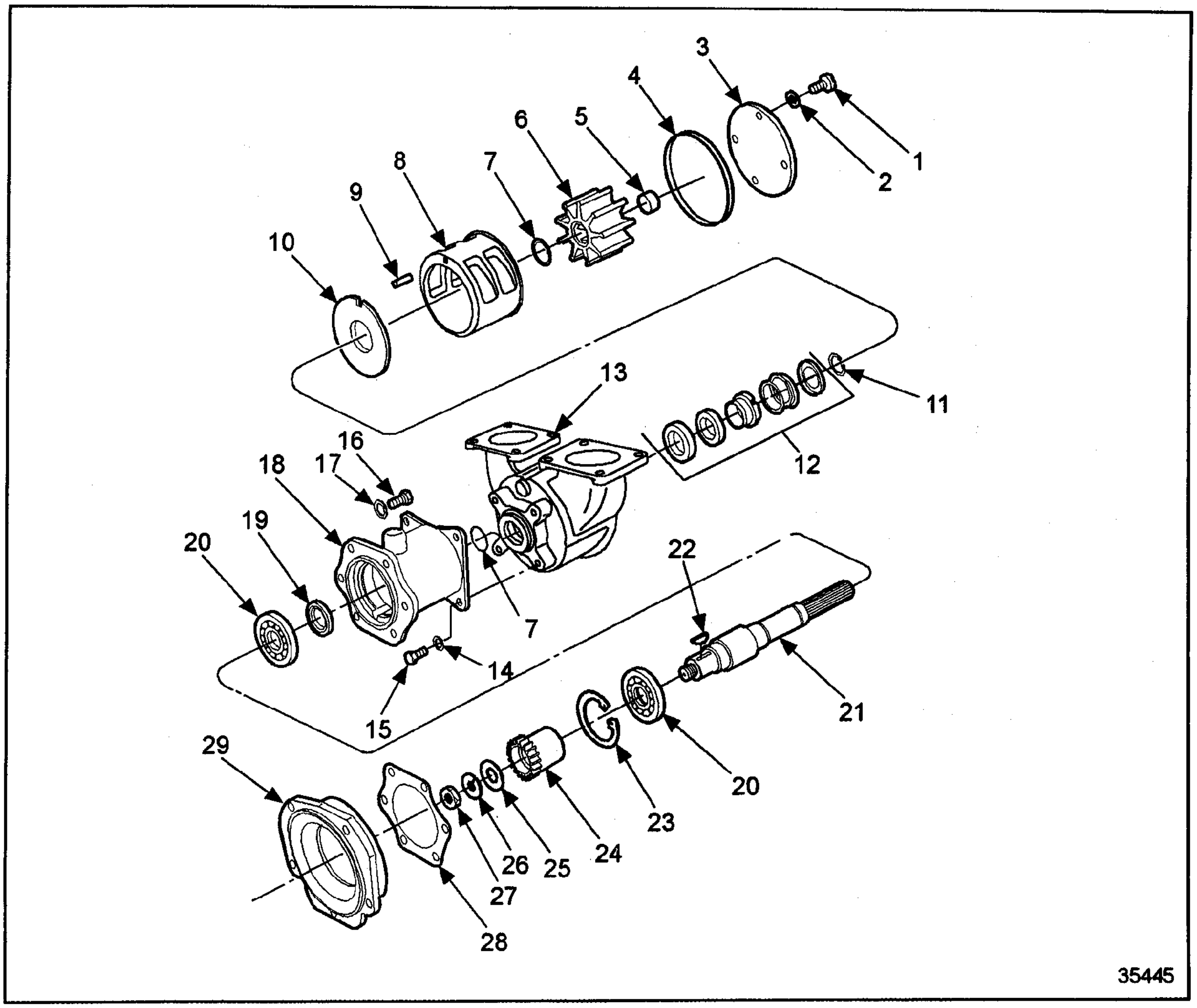
**NOTE:**
Seal parts can be removed and replaced without removing the pump from the engine. Refer to section 4.13.3 for seal removal procedures.

1. Drain the raw water system.
2. Loosen the hose clamps at the outlet elbow and slide the hose along the tube.
3. Loosen the hose clamps at the inlet elbow and slide the hose along the tube.
4. Remove the bolts and lock washers holding the inlet and outlet elbows to the pump, and lift the elbows from the pump.
5. Remove the gaskets.
6. Remove the five bolts holding the pump to the drive assembly.
7. Tap the pump body with a soft hammer to loosen the pump from the drive assembly.
8. Withdraw the pump straight out from the drive assembly while disengaging the drive gear from the coupling.
9. Cover the pump opening in the flywheel housing with a clean cloth to prevent foreign matter from entering.

### 4.13.3 Disassembly of the Jabsco Raw Water Pump

Disassemble a raw water pump with a polyurethane or phenolic cam and liner as follows:

1. Remove the end cover screws and end cover. See Figure 4-103.



1.Hex Bolt
2.Flat Washer, 1/2 (4)
3.End Cover
4.O-ring Seal
5.Seal Spling
6.Impeller
7.O-ring
8.Cam Liner
9.Dowel Pin
10.Wear Plate
11.Retaining Ring
12.Seal Mechanical
13.Body
14.Lock Washer, 5/16 (4)
15. Hex Head Screw, 5/16–18 x 3/4
16. Hex Head Screw, 3/8–16 x 1" (6)
17. Lock Washer, 3/8 (6)
18. Bearing Housing
19. Seal
20. Bearing
21.Shaft
22.Woodruff Key
23. Retaining Ring
24. Gear
25. Flat Washer (1)
26. Lock Washer, 5/8
27. Hex Nut, 5/8 — 18
28. Gasket
29. Adaptor

**Figure 4-103 Raw Water Pump Details (Synthetic Cam and Liner Design)**

2. Remove the end cover O-ring seal from the pump body.
3. Grasp hub of impeller with pliers, and remove it from the impeller bore.

**NOTE:**
The spline seal will come off with the impeller. If the impeller O-ring remains on the shaft, remove it.

4. Remove cam liner from pump body.
5. Remove inner wear plate.
6. Remove the seal retaining ring. Take care not to scratch the shaft.
7. Remove the carbon portion of the mechanical seal with tension spring attached.
8. Remove bolts securing adaptors elbows to pump inlet and outlet ports.
9. Hold the pump body securely, and remove the four 5/16 in. screws and lock washers holding the pump body to the bearing housing.
10. Remove pump body from the bearing housing and shaft subassembly.
11. Remove any residual gasket material from port adaptors.
12. Remove slinger O-ring from the shaft.
13. >From the drive end of the pump body, press out the remaining mechanical seal parts (boot and ceramic seat).

Remove and disassemble the pump bearing housing on raw water pumps with polyurethane or phenolic cam and liners as follows:

1. With housing held securely, remove the six 3/8 in. screws and lock washers in the housing flange.
2. Remove the bearing housing and shaft subassembly by pulling straight out from the adaptor. Place the bearing housing on a clean bench surface.
3. Prevent the shaft from rotating by holding it with a wrench on the shaft flats of the impeller end. Then, remove the drive gear retaining nut, lock washer, and retaining flat washer.
4. Remove drive gear from the shaft. A punch and small mallet may be used to gently tap the underside of the drive gear teeth to loosen the gear from the shaft.
5. Remove the Woodruff key.
6. Remove the retaining ring securing the bearing in the bearing housing.
7. Press against the impeller end of the shaft to remove the shaft and bearing subassembly from the bearing housing.

8. Support the inner race of the bearing, and press the shaft out of the bearing.
9. Remove the retaining ring securing the second bearing in the bearing housing.
10. Press against the impeller end of the shaft to remove the shaft and bearing subassembly from the bearing housing.
11. Support the inner race of the second bearing, and press the shaft out of the bearing.
12. >From the pump end of the bearing housing, push the oil seal out of the housing. Discard the seal.

Prior to inspection, clean all the raw water pump parts as follows:

**NOTICE:**

To avoid bearing damage, do not wash the shielded bearing. Dirt may be washed in and cleaning fluid may not wash out of the bearing.

1. Wipe the bearing clean with a dry cloth.
2. Wash parts in clean fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

3. Dry parts with compressed air.

### 4.13.3.1 Inspection of the Jabsco Raw Water Pump

Perform the following steps to inspect the Jabsco raw water pump:

1. Inspect the bearing as follows:
   [a] Hold the inner race, and revolve the outer race slowly.
   [b] Replace the bearing if it is worn or does not roll freely.
2. Inspect the seal assembly as follows:
   [a] Examine the seal assembly components.
   [b] Replace worn or damaged parts.
3. Inspect the oil seal contact shaft surfaces as follows:
   [a] Inspect the shaft surfaces that contact the oil seal for scratches and grooves.
   [b] If scratched, smooth the surface with a crocus cloth dampened in fuel oil.
   [c] If grooved, replace the shaft.
4. Inspect the impeller as follows:
   [a] Ensure the neoprene bonds to the metal.
   [b] Inspect the impeller blades.
   [c] If the blades have a permanent set, replace the impeller.
5. Inspect the wear plate as follows:
   [a] Examine the wear plate for burrs and excessive wear.
   [b] If burred, remove the burrs from the plate.
   [c] If slightly worn, reverse the plate.
   [d] If excessively worn, replace the plate.
6. Inspect a polyurethane or phenolic cam liner as follows:
   [a] Check the cam liner thickness.
   [b] If the thickness is 3/8 or less at its thickest section, replace the cam liner.

## 4.13.4 Assembly of the Jabsco Raw Water Pump

Replace the seal as follows:

1. If removed, place the gasket and seal seat over the shaft, and press them into position in the seal cavity.
2. Assemble the carbon seal, seal ring, and washer in their proper positions, and slide them over the shaft and against the seal seat.

**NOTE:**
Ensure the seal ring is contained snugly within the ferrule, gripping the shaft.

3. Install the Marcel washer next to the flat washer.
4. Compress the impeller blades to clear the offset cam, and press the impeller onto the splined shaft.
5. Install the spline.
6. Turn the impeller several turns in its normal operating direction to properly position the blade.
7. Use a new gasket; install the cover on the housing.

Assemble the raw water pump with polyurethane or phenolic cam and liners as follows:

1. Install new slinger O-ring on the shaft near the bearing housing.
2. Install mechanical seal components. Do not allow seal components to become soiled during assembly.
3. Lubricate ceramic seal seat boot with water only, and press into pump body seal bore.
4. Install ceramic seal seat. Exposed ceramic surface should face toward impeller bore.
5. Slide the pump body over the shaft, taking care not to dislodge seal seat as body is moved toward (and aligned with) bearing housing.
6. Attach the pump body to the bearing housing with four 5/16 in. screws and lock washers. Torque to 19-22 N·m (14-15 lb·ft).
7. Install the carbon portion of mechanical seal with tensioning spring and spring washer shaft, and position it in seal bore with carbon face against ceramic seal seat.
8. Slide seal retaining ring over shaft against seal thrust ring, and position it in retaining ring groove.
9. Install inner wear plate in pump body, aligning notch in wear plate with pin in body.
10. Lubricate body bore with water pump grease.
11. Align the hole in top of cam liner with pin in pump body, and push cam liner into body.
12. Liberally coat inside of cam liner with water pump grease.
13. Insert impeller O-ring in groove in impeller recess.

14. With O-ring end of impeller facing the pump housing, rotate the impeller in its operating direction to bend vanes under the cam, and push into bore until impeller insert flats align with shaft flats.
15. Push impeller completely into the impeller bore. The impeller end should be approximately even with cam liner.
16. Install the rubber spline plug into the impeller end.
17. Place new end cover seal ring into the groove in the pump body.
18. Install the end cover.
19. Install four 1/4 in. hex-head bolts in end plate cover. Torque to 9 N·m (80 lb· in). Do not over-torque.

Assemble the pump bearing housing as follows:

1. Lightly coat the outside diameter of a new oil seal with clean engine oil.
2. >From the drive end of the bearing housing, press new oil seal into seal bore. Seal lip must point to drive end of housing.
3. With pressure applied to inner race of bearings, press bearings onto shaft.
4. With pressure applied to outer race of outer bearing, install bearing and shaft subassembly into bearing housing.
5. Install bearing retaining ring in bearing housing, ensuring ring is securely seated in the ring groove.
6. Insert Woodruff key into groove on shaft end.
7. Gently tap drive gear onto shaft with a small plastic-face mallet.
8. Install flat washer, lock washer, and retaining nut onto shaft.
9. Hold shaft with a wrench on shaft flats at impeller end, and torque retaining nut to 33-41 N·m (24-30 lb·ft).
10. Install new adaptor flange gasket; secure pump assembly to adaptor with four mounting bolts. Torque to 24-31 N·m (18-23 lb·ft). Use wrench J 35948 to torque the upper inside bolt to 24-31 N·m (18-23 lb·ft).
11. Using new gaskets, attach raw water pump inlet and outlet adaptors.

## 4.13.5 Installation of the Jabsco Raw Water Pump

Install the raw water pump as follows:

**NOTE:**
Seal parts can be removed and replaced without removing the pump from the engine. Refer to section 4.13.3 for seal removal procedures.

1. Remove the clean cloth covering the pump opening.
2. Install the pump straight into the drive adaptor assembly while engaging the drive gear to the coupling.
3. Tap the edge of the bearing housing flange with a soft hammer to secure the pump into the adaptor.
4. Install the adaptor-to-adaptor bolts and lock washers.
5. Install new gaskets to the inlet and outlet elbows and install the elbows on the pump.
6. Secure the inlet and outlet elbows to the pump with bolts and lock washers.
7. Slide the hose onto the inlet tube, and tighten the hose clamps at the inlet elbow.
8. Slide the hose onto the outlet tube, and tighten the hose clamps at the outlet elbow.
9. Close drain cocks, and fill the raw water system. Prime the raw water pump by removing the pipe plug or zinc electrode from the water inlet elbow and powering at least a pint of water into the pump housing. Replace the plug or zinc electrode.

# 4.A ADDITIONAL INFORMATION

**Description** **Page**

## SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

### Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 1-34 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 4-2. Standard (nonmetric) nut and bolt torque specifications are listed in Table 1-36 in the "General Information" section at the beginning of this manual.

## EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS

| Bolt and Size, mm | Torque, N · m | Torque, lb · ft |
|---|---|---|
| M24 X 1.0 | 203-230 | 150-170 |

**Table 4-2 Exceptions - Metric Fastener Torque Specifications**

**NOTE:**
The water pump drive gear retaining nut is M24 X 1.0.

# 5 FUEL, LUBRICATING OIL, AND COOLANT

**Section** | **Page**

## 5.1 FUEL

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. The Series 60 engine was designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (Grades 1–D and 2–D) have provided satisfactory performance. The ASTM D 975 specification, however, does not in itself adequately define the fuel characteristics necessary to assure fuel quality. The properties listed in Table 5-1, Diesel Fuel Specification Table, provide optimum engine performance.

| General Fuel Classification | ASTM Test | No. 1-D | No. 2-D# |
|---|---|---|---|
| API Gravity, @ 60°F | D 287 | 40 - 44 | 34 - 38 |
| Specific Gravity, @ 60°F | D 1298 | 0.806 - 0.825 | 0.835 - 0.855 |
| Flash Point, °C, Minimum | D 93 | 38 | 52 |
| Viscosity, Kinematic - cSt @ 40°C | D 445 | 1.3 - 2.4 | 1.9 - 4.1 |
| Sulfur wt% Maximum for On-Road Use ‡ | D 2622 | 0.05 | 0.05 |
| Cloud Point °F (°C) † | D 2500 | See Note | See Note |
| Cetane No., Minimum † | D 613 | 45 | 45 |
| Cetane Index, Minimum † | D 4737 | 40 | 40 |
| Distillation % Vol. Recovery, °C (°F) | D86 | - | - |
| - IBP, Typical* | - | 350 (177) | 375 (191) |
| - 10% Typical* | - | 385 (196) | 430 (221) |
| - 50% Typical* | - | 425 (218) | 510 (256) |
| - 90% Maximum | - | 500 (260) | 625 (329) |
| - 95% Maximum* | - | 550 (288) | 671 (355) |
| - Recovery Volume, % Minimum* | - | 98 | 98 |
| Water & Sediment, % Maximum | D 2709 | 0.05 | 0.05 |
| Ash, % Maximum | D 482 | 0.01 | 0.01 |
| Carbon Residue on 10%, wt%, Maximum | D 524 | 0.15 | 0.35 |
| Copper Corrosion, Maximum 3h | D 130 | No. 3 | No. 3 |
| Accelerated Storage Stability, Maximum* | D 2274 | 15 mg/L | 15 mg/L |
| Dupont Pad Test, Rating Maximum* | TM-F21-61 \|\| | 7 | 7 |
| Lubricity, gm, Minimum* | SLWT § | 2800 | 2800 |

* Not specified in ASTM D 975

† Differs from ASTM D 975

‡ The sulfur content of diesel fuel for off road use is 0.5% maximum. This fuel is dyed red.

§ Scuffing load, ball on cylinder wear test, higher values indicate less wear and greater lubricity.

|| Alternate test method predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

# No. 2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

Note: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

**Table 5-1 Diesel Fuel Specifications**

### 5.1.1 Fuel Lubricity

Fuels such as those containing kerosene and jet fuel and some low sulfur fuels have characteristics which may cause operational concerns in some engine designs. The fuel injection systems used on VM and natural gas Detroit Diesel manufactured engines has demonstrated trouble-free operation on a wide variety of fuels without the need for supplemental additives.

### 5.1.2 Biodiesel Fuels

Biodiesel fuels may be produced from a wide variety of sources and may be used in all DDC engines provided (1) they are derived from soy methyl ester (SME) and/or rape methyl ester (RME) and (2) are blended to a maximum of 20% by volume in diesel fuel. The resulting blend must meet the properties listed in Table 5-1.

Although such blends purport to reduce exhaust emission particulates, they increase the nitrogen oxides in engine exhaust. They also tend to have poorer thermal stability and may deteriorate engine oil TBN more rapidly than wholly petroleum-based diesel fuels. These fuel blends have not been fully evaluated relative to diesel fuel system durability or engine oil effects.

## 5.1.3 Other Fuels

In addition to the diesel fuels listed in Table 5-1, customers have used other fuels successfully, including fuels marketed as premium diesel fuels, kerosene-based jet fuels, and other fuels listed in Table 5-2. These fuels have provided economic and availability advantages for some applications, particularly where 1-D type fuels are required, and may be used in all Detroit Diesel engines. These fuels should be accompanied by exhaust emission data demonstrating emission equivalency to 1-D for those engines requiring 1-D fuel. Fuel type specifications and applications are listed in Table 5-3.

| Property | Jet A/A-1 D 1655 | JP-5 | JP-8 | CONUS DF-1 | CONUS DF-2 | OCONUS DF-2 |
|---|---|---|---|---|---|---|
| API Gravity, @ 605F | 44.3 | 41.1 | 45.6 | 42.3 | 34.2 | 38.5 |
| Flash Point, 5C | 3 | 62 | 45 | 50 | 74 | 70 |
| Viscosity, Kin., cSt @ 405C | - | 1.5 | 1.2 | 1.6 | 2.8 | 3.0 |
| Cloud Point 5C | -40 | -46 | -47 | -41 | -12 | -19 |
| Sulfur, % mass | 0.3 Max. | 0.4 Max. | 0.4 Max. | 0.05 Max. | 0.05 Max. | 0.3 Max. |
| Cetane Number | - | 42 | 45 | 44 | 47 | 49 |
| Distillation % Vol. Recovery, 5C | - | - | - | - | - | - |
| IBP | - | 180 | 157 | 174 | 190 | 176 |
| 10% Typical | 205 | 191 | 175 | 196 | 222 | 219 |
| 50% Typical | Report | 215 | 200 | 219 | 265 | 365 |
| 90% Max. | Report | 242 | 236 | 246 | 313 | 311 |
| Final Boiling Point, Max. Temp. | 300 | - | - | - | - | - |
| Heat Content, Btu/gal., Net | 123,608 | 125,270 | 123,069 | 125,960 | 131,207 | 127,820 |

**Table 5-2 Selected Typical Fuel Properties**

| Type | NATO Spec. | Mil Spec. | Application |
|---|---|---|---|
| JP-4 | F-40 | Mil-T-5624 | Jet Fuel, Contains 50% Gasoline, *Not Recommended* |
| JP-5 | F-44 | Mil-T-5624 | Jet Fuel, Kerosene Based |
| JP-8 | F-34 | Mil-T83133 | Jet A-1 with De-icer and Corrosion Inhibitor |
| Jet A | None | None | Industry Standard Jet Fuel |
| Jet A-1 | F-35 | None | Jet Fuel, ASTM D 1655 |
| DF-1/DF-2 | F-54 | VVF-800 CONUS | Specified Military Use Inside Continental U.S. |
| DF-2 | F-54 | VVF-800 OCONUS | Specified Military Use Outside Continental U.S. |

**Table 5-3 Fuel Type Specifications and Applications**

Lower density fuels, such as those listed in Table 5-2 and "winter blended" diesel fuels, have a lower volumetric heat content than the standard 2-D fuel listed in Table 5-1. Operating with these fuels will result in reduced engine output and reduced fuel mileage, compared to standard 2-D fuel. Reductions of 5% are not unusual and may be as high as 10%. A good rule of thumb is: The engine power is proportional to the heating value of the fuel.

Lower density fuels also tend to have lower viscosity and poor lubrication characteristics.

## 5.1.4 Fuel Cleanliness

Fuel should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier. If fuel is stored on site, the following is recommended:

| NOTICE: |
|---|
| Do not use a fuel storage tank or lines made from galvanized steel. The fuel will react chemically with the galvanized coating to form powdery flakes that will quickly clog fuel filters and cause damage to the fuel pump and injectors. |

1. Keep the storage tank filler cap covered to prevent contamination by rain water.
2. Keep the tank clean, especially around the filler cap and tap areas.
3. Position the tank so that it tilts slightly toward the bottom drain. This will make it easier to drain accumulated water and sediment.
4. Minimize condensation by keeping the tank reasonably filled at all times.
5. After filling the fuel storage tank, wait a few hours before filling equipment tanks. This will allow contaminants to settle.

## 5.1.5 Cold Weather Operation

In cold weather, diesel fuel will form wax crystals that can restrict flow and clog filters. Fuel suppliers approach this problem several ways. Some provide a specially refined product, while others may use flow improving additives or winter blends. Winter blended fuel will likely contain kerosene or 1-D fuel, which provide good cloud point temperatures but will result in a lighter fuel with a lower heat content. The use of such fuels is acceptable but may result in reduced engine power and/or fuel mileage.

### 5.1.6 Prohibited Fuel Additives

Used Lubricating Oil: Detroit Diesel specifically prohibits the use of drained lubricating oil in diesel fuel. Used lubricating oil contains combustion acids and particulate materials which erode injector components, resulting in loss of power and increased exhaust emissions. In addition, the use of drained lubricating oil will increase maintenance requirements due to filter plugging and combustion deposits. Refer to the section 5.1.6for recommendations on proper used oil disposal.

**CAUTION:**

**To avoid injury from fire, keep all potential ignition sources away from diesel fuel, open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.**

**NOTE:**
Do not add gasoline to diesel fuel.

Besides creating a serious fire hazard, the presence of gasoline in diesel fuel will reduce fuel cetane number and increase combustion temperatures. Tanks which contain such mixtures should be drained and cleaned as soon as possible.

Gasoline: The addition of gasoline to diesel fuel will create a serious fire hazard. The presence of gasoline in diesel fuel will reduce fuel cetane number and increase combustion temperatures. Tanks which contain such mixtures should be drained and cleaned as soon as possible.

### 5.1.7 Waste Oil Disposal and Rerefined Oils

With over one billion gallons of waste oil generated annually in the U.S. alone, disposal of waste oil has become a serious environmental concern. Rerefining waste oils provides an environmentally viable way of handling this material. Detroit Diesel favors the recycling of waste oil and permits the use of rerefined oils in all engine product lines, provided the rerefined oil meets the SAE Viscosity and API specifications previously mentioned.

**CAUTION:**

**To avoid injury from fire caused by heated lubricating-oil vapors:**

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if an oil leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves, apron, etc.) to avoid burns.**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

**Lubricating oil is relatively harmless at ambient temperatures.**

Consideration for the disposal of waste oil should begin when negotiating the purchase of new oil. Oil supplier selection criteria should include a proposal for handling waste oil. It is important to know exactly how the oil will be disposed of since it is the generator, not the hauler, that is ultimately responsible for its proper disposal.

### 5.1.8 Specifications for Natural Gas Engine

Listed in Table 5-4 are the natural gas specifications for Detroit Diesel engines.

| Property | Limit | ASTM Test Method |
|---|---|---|
| **Hydrocarbon** MethaneEthane-PropaneC4 and Higher | mole percent88% Minimum6% max.1.7% max.0.3% max. | D 1945 |
| **Other Gaseous Species** HydrogenCarbon dioxide + Nitrogen + OxygenOxygenCarbon Monoxide **Other Species** MethanolSulfur, Total | mole percent0.1% max.5.0% max.0.5% max.0.1% max.0% mass max.1.0 grains / 100 SCF, max.(32 ppm mass, max., \|\|) | D 2650D1945D-1945D 2650No Test MethodASTM D 5504 |
| **Performance Related Properties** Motor Octane NumberWobbe Number | 115 Minimum1290-1380 BTU/SCF | *D 2623D 3588 |
| **Contaminates** | † | |
| **Pressure Water Dew PointTemperature, max.** | ‡ | D 1142 |
| **Pressure Hydrocarbon DewPoint Temperature, max.** | ‡ Below which will form1% condensate | D 1142 |
| **Odorant** | § | |

* Test Method D 2623 was obsoleted by ASTM in 1991. Wobbe Index (WI), also known as Wobbe Number, is a measure of fuel energy flow rate through a fixed orifice under given inlet conditions. Numerically, WI= (dry, higher heating value)/ (Specific gravity).

† The compressed natural gas shall not contain dust, sand, dirt, gums, oils, or other substances in an amount sufficient to be injurious to the fuel station equipment or the vehicle being fueled.

‡ The water and hydrocarbon dew point at fuel pressure shall be at least 10°F below the 99.0% winter design temperature listed in Chapter 24, Table 1, Climatic Conditions for the United States, in American Society of Heating, Refrigerating and Air Conditioning Engineer's (ASHRAE) Handbook, 1989 fundamentals volume. Testing for water and hydrocarbon vapor shall be in accordance with ASTM D 1142, utilizing the Bureau of Mines apparatus.

§ The natural gas at ambient conditions must have a distinctive odor potent enough for its presence to be detected down to a concentration in air of 1% by volume. || For Genset applications, when using fuel containing sulfur in excess of 16 ppm, the oil change interval must be reduced. Refer to Item 1 in the Lubrication and Preventive Maintenance Intervals sections.

**Table 5-4 Natural Gas Specifications for Detroit Diesel Natural Gas Engines**

## 5.2 LUBRICATING OIL (DIESEL)

The selection of the proper lubricating oil is important for achieving the long and trouble-free service Detroit Diesel Series 60 engines are designed to provide. Only oils displaying the American Petroleum Institute (API) Symbol shown below are recommended. This symbol assures that the lubricant meets the minimum performance levels necessary for proper engine performance and durability.

### 5.2.1 Lubricant Requirement — All Diesel, Except Pleasure Craft Marine

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules. For the API symbol for this, see Figure 5-1.

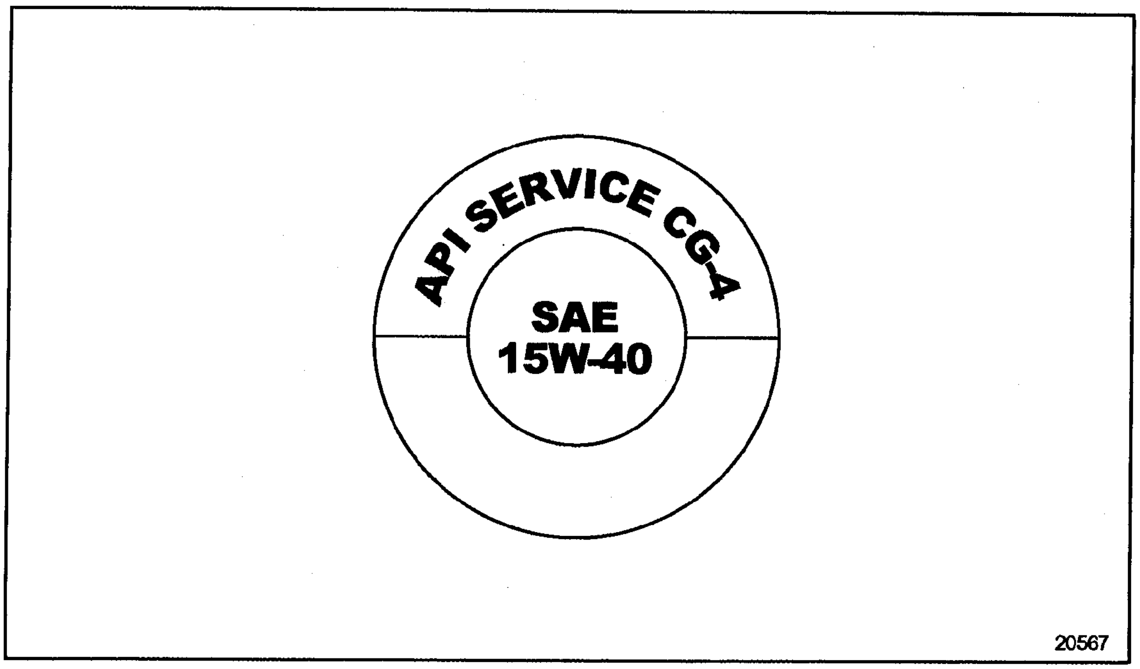



**Figure 5-1 API Symbol**

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with specified oil drain and filter maintenance schedules. Only oils licensed by API may be used in Detroit Diesel engines. Lubricants meeting API Service category CH-4 are intended for use primarily with low (0.05%) sulfur fuel and may be used in all Detroit Diesel Series 60 engines.

API CG-4 and CF-4 oils may be used when CH-4 oils are not available; however, their use may require a reduction in oil drain interval depending upon the application and the fuel sulfur level.

At ambient temperatures below -20°C (-4°F) when sufficient starter speed cannot be achieved with SAE 15W-40 oils, the use of 5W-XX and 10W-XX oils, where XX is 30 or 40, may be used to improve startability provided they are API CH-4 and have demonstrated field performance in DDC engines. These oils must possess a HT/HS of 3.7 minimum.

When the use of high sulfur fuel (greater than 0.5% mass sulfur) is unavoidable, higher alkalinity lubricants are recommended. High sulfur fuels require modification to oil drain intervals. For further information refer to the section titled "The Use of High Sulfur Fuels."

### 5.2.2 Lubricant Requirement — Heat Exchanger-Cooled Pleasure Craft Marine

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules. For the API symbol for this, see Figure 5-2.

| NOTICE: |
|---|
| Do not use 15W-40 lubricating oil in Series 60 pleasure craft marine engines. 15W-40 lubricating oil is not suitable for use in engines with closed crankcase ventilating systems. |

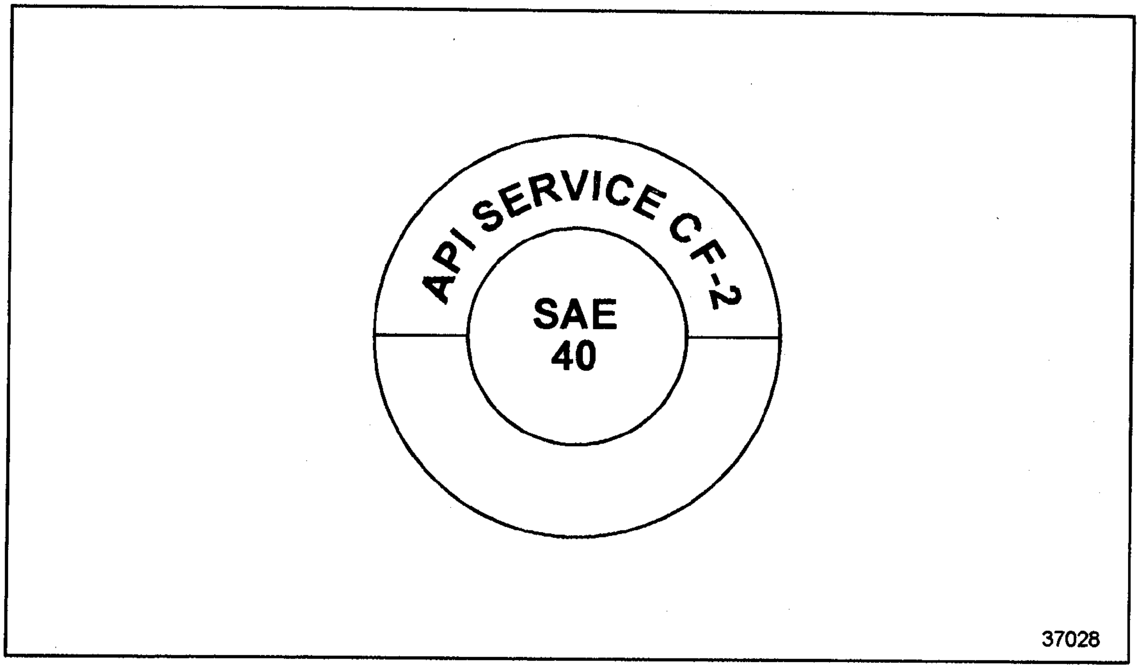



**Figure 5-2 API Symbol — Heat Exchanger-Cooled Pleasure Craft Marine**

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with specified oil drain and filter maintenance schedules. Only oils licensed by API may be used in Detroit Diesel engines. Lubricants meeting API Service category CF—2 are intended for use primarily with low (0.05%) sulfur fuel and should be used in Detroit Diesel Series 60 pleasure craft marine engines.

### 5.2.3 Oil Change Interval

The length of time an engine may operate before changing oil depends on the lubricant and fuel used, engine oil consumption, and operating cycle. The maximum interval the engine may operate before changing oil is listed in Table 5-5. Oil analysis may be used to determine whether this interval should be shorter, but should not be used to lengthen the interval.

| Application | Oil Drain Schedule |
|---|---|
| Highway Truck and Motor Coach† | 15,000 miles (24,000 km) |
| City Transit Coach, Pick-up and Delivery, Stop-and-Go, Short Trip† | 6,000 Miles (9,600 km) or 3 Months* |
| Fire Fighting, Crash/Rescue, and Emergency Vehicle | 6,000 Miles (9,600 km) or 300 Hours* |
| Industrial and Agricultural | 250 hours or 1 year* |
| Stationary Generator, Prine Power or Continuous | 300 hours or 1 year* |
| Stationary Generator, Standby | 150 hours or 1 year* |

Note: Change both full-flow filters when lube oil is changed.

*Whichever comes first.

†Drain intervals shown apply to pre-1998 model year engines. 1998 and newer engines

**Table 5-5 Maximum Oil Drain Intervals**

**NOTE:**

The use of fuels with sulfur content above 0.5% will require a shorter drain interval, and/or the use of a higher TBN oil. Refer to DDC Publication 7SE270, Lubricating Oil, Fuel, and Filter Recommendations, for details.

Extending Oil Drain Intervals: Some oil companies may promote engine lubricants with a claimed useful life that would allow customers following certain maintenance and operating parameters to elect to extend oil drain intervals beyond the recommended periods. The ability of such lubricants to maintain their protective qualities over a longer period and the acceptability of maintenance and operating parameters must be established by the oil company and the customer. Claims for engine failure attributable to the inadequacy of the lubricant are not covered under the terms of the engine's limited warranty.

### 5.2.4 Statement of Policy on Supplemental Fuel and Lubricant Additives

The Series 60 engine will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets.

Supplementary additives include all products marketed as fuel conditioner, smoke suppressants, masking agents, deodorants, tune-up compounds, top oils, break-in oils, graphitizers, and friction-reducing compounds. The regular and continued use of supplementary additives in fuels and lubricants is not recommended.

**NOTE:**
DDC is not responsible for the cost of maintenance or repairs due to lack of required maintenance services performed or the failure to use fuel, oil, lubricants and coolant meeting DDC-recommended specifications. Performance of required maintenance and use of proper fuel, oil, lubricants and coolant are the responsibility of the owner. See the OEM's guidelines for details.

### 5.2.5 Filter Selection and Change Intervals for Series 60 Engine

The engine oil and fuel filters recommended for use on the Series 60 engine are as follows:

- ☐ Engine Oil Filter:
  - ☐ Full Flow - DDC Part No. 23527033
  - ☐ Single full flow, large diameter, high capacity — DDC Part No. 5361840001
- ☐ Fuel Filters, Spin-on:
  - ☐ Primary- DDC Part No. 23518481
  - ☐ Primary w/Separator - DDC Part No. 23512317
  - ☐ Primary w/Separator - DDC Part No. 23514654*
  - ☐ Secondary- DDC Part No. 23518482
- ☐ Fuel Filters, Fuel Pro®:
  - ☐ Fuel Pro 321 - DDC Part No. 23518482
  - ☐ Fuel Pro 380, 380E - DDC Part No. 23521528
- ☐ Fuel Filters, Sea Pro®:
  - ☐ Sea Pro 150 or 300 - DDC Part No. 23518168 (30 micron)
  - ☐ Sea Pro 152 or 511 - DDC Part No. 23521528

*Requires installation of reusable plastic bowl.

*Fuel Pro® and Sea Pro® are registered trademarks of Davco Manufacturing, L.L.C.*

The change intervals for oil and fuel filters are listed in Table 5-6.

| Application | Replacement Intervals (Fuel Sulfur Content Less Than 0.5 wt.%) |
|---|---|
| Highway Truck and Motor Coach† | 15,000 Miles (24,000 Km) |
| City Transit Coach† | 6,000 Miles (9,600 Km), 300 hours or 3 months* |
| Fire Fighting Apparatus, Emergency Vehicles | 6,000 Miles (9,600 Km), 300 hours, or 1 year* |
| Industrial, Agricultural, and Marine | 250 hours or 1 year* |
| Stationary Electrical Generator Sets, Continuous | 250 hours or 3 months* |
| Stationary Electrical Generator Sets, Standby | 150 hours or 1 year* |

* Whichever comes first.

†Drain intervals shown apply to pre-1998 model year engines. 1998 and newer engines may require a modification to these intervals based on used oil analysis. Refer to publication "Lubricating Oil, Fuel, and Filters", form 7SE270 (9901), available from authorized Detroit Diesel distributors.

**Table 5-6 Maximum Lubricating Oil and Fuel Filter Replacement Intervals**

**NOTE:**
The spin-on fuel filter replacement intervals listed in Table 5-5 do not apply to Fuel Pro filter elements, which must be replaced when the fuel level in the see-through cover reaches the top of the element or after one year of service, whichever comes first.

## 5.2.6 Used Lubricating Oil Analysis Guidelines

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown. Characteristics relating to lubricating oil dilution should trigger corrective action to identify and find the source(s) of leaks, if the values listed in Table 5-7 are realized. Contact your DDC distributor or dealer regarding oil analysis services.

| Warning Limits | ASTM Designation | Condition Measured | Series 60 Limit |
|---|---|---|---|
| Viscosity at 40 °C cS<br>Maximum Increase-%<br>Maximum Decrease-% | D-445 | Engine & Oil | 40.0<br>15.0 |
| Carbon (Soot) Content, Maximum - Mass % | E-1131 or LEM$^{SM}$ * | Engine Combustion | 1.5 |
| Pentane Insolubles - Mass % | D-893 | Engine Combustion | 1.0 |
| Total Base Number (TBN) Minimum | D 4739D 2896 | OilOil | 1.0<br>2.0 |
| Water Content (Dilution), Maximum - Vol. % | D 1744 | Engine | 0.30 |
| Fuel Vol., % Maximum | D 3524 | Engine | 2.5 |
| Antifreeze Maximum | D2982 | Engine | Neg. |
| Iron Content, Maximum - ppm (Fe) | D 5185 | Engine Wear | 150 |
| Copper Content, Maximum - ppm (Cu) | D 5185 | Engine Wear | 30 |

* LEM$^{SM}$ is a patented soot measurement process by Analysts, Inc.

NOTE: These limits are intended to be used for guidance when a single oil sample is tested. Actual limits are dependent on engine, application, and oil type. Refer to DDC Publication 7SE398 to determine the warning limits specific to your application.

**Table 5-7 Used Lubricating Oil Analysis Guidelines for Immediate Oil Change**

## 5.2.7 Miscellaneous Fuel and Lubricant Information

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled *EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines*. The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

**ENGINE MANUFACTURERS ASSOCIATION**

**401 NORTH MICHIGAN AVE.**

**CHICAGO, ILLINOIS 60611-4267**

## 5.3 LUBRICATING OIL FOR THE SERIES 60G ENGINE

Lubricants formulated for use in natural gas fueled engines must provide adequate engine lubrication, minimal thermal degradation, and good deposit control. Currently there is not an API category for natural gas engine oils. Therefore, selection of the proper engine oil is limited to the two lubricants listed in Table 5-8. These oils have demonstrated adequate performance in these engines.

| Viscosity Grade, SAE | 15W40 |
|---|---|
| Sulfated Ash Content, % max. | 0.50% |
| Phosphorous, ppm max. | 800 ppm max. |

**Table 5-8 Series 60G Engine Lubricating Oil Specifications**

While Detroit Diesel does not maintain an approved list for these lubricants, other lubricants may be selected by the customer provided the oil supplier can demonstrate equivalent performance with the two oils identified. Detroit Diesel will not determine this equivalency.

### 5.3.1 Oil Change Intervals for Series 60 Natural Gas Engine

During engine operation, lubricating oil deteriorates due to combustion by-products and contamination. Oil change intervals may vary depending on engine operation, fuel quality, and lubricant quality. The oil drain intervals are listed in Table 5-9and listed in Table 5-10.

| Application | Oil Drain Interval |
|---|---|
| City Transit Coach | 6,000 miles (9,600 km) or 3 months* |
| Pick-up and Delivery Stop and Go | 6,000 miles (9,600 km) or 3 months* |

* Whichever comes first.

**Table 5-9 Maximum Recommended Oil Drain Intervals (Normal Operation) for Series 60 Diesel Engine**

| Application | Oil Drain Interval |
|---|---|
| Stand-by Continuous/Prime | 250 hours or 12 months* 250 hours or 3 months* |
| Stand-by † Continuous/Prime † | 200 hours or 6 months* 200 hours or 3 months* |
| Stand-by ‡ Continuous/Prime ‡ | 150 hours or 3 months* 150 hours or 3 months* |

† Fuel with total sulfur greater than 17 ppm, but less than 24 ppm.

‡ Fuel with total sulfur greater than 24 ppm, but less than 32 ppm.

* Whichever comes first.

**Table 5-10 Series 60 Natural Gas Generator Set Engine**

**NOTE:**

Operation with fuels having total sulfur greater than 32 ppm, on a mass basis, may result in engine damage, and is not recommended by Detroit Diesel Corporation.

### 5.3.2 Used Lubricating Oil Analysis for the Series 60G Engine

A used lubricating oil analysis, such as Detroit Diesel's "Power Trac," is recommended for monitoring crankcase oil in all engines. The application of used engine oil analysis to natural gas fueled engines can help to identify contamination from excessive wear metals and foreign substances and monitor oil degradation through oxidation. If any abnormal conditions are identified, the oil should be changed immediately. Warning limits are listed in Table 5-11.

| **Viscosity Increase, % from new, max. (ASTM D 445) Kinematic @ 100_C** | **10%** |
|---|---|
| Total Base Number decrease, max. (ASTD D 4739) | 3 |
| Total Acid Number increase, max. (ASTM D 664) | 2 |
| Iron Content, ppm | 150 max. |
| Oxidation/Nitration, Infrared Spectroscopy | 25 absorbance units |

**Table 5-11 Used Oil Analysis Warning Limits for Series 60G Engine**

## 5.4 COOLANT

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, some of the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. Therefore, coolant must be carefully selected and properly maintained.

The following terms are used throughout this section and must be understood.

- Coolant - The fluid mixture circulating in the engine cooling system.
- IEG - Full strength (non-diluted) Inhibited Ethylene Glycol meeting applicable heavy-duty formulation specifications.
- IPG - Full strength (non-diluted) Inhibited Propylene Glycol meeting applicable heavy-duty formulation specifications.
- SCA - Supplemental Coolant Additives. Used to prevent corrosion, cavitation, and the formation of deposits.
- Initial fill - Any time the cooling system is empty, then filled with new coolant.
- Precharged IEG - Also referred to as a fully formulated IEG. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IEG at initial fill.
- Precharged IPG - Also referred to as a fully formulated IPG. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IPG at initial fill.
- Dropout - Sludge or deposit formation in or on cooling system components.

Using a coolant with the appropriate concentrations of SCA is one of the most important aspects of quality engine maintenance. To achieve the chemical balance needed to protect a cooling system, certain coolant basics must be understood.

This section provides the directions and information required to ensure cooling system protection for Detroit Diesel Series 60 engines. These recommendations are general rules and reflect the current technology. Specific concerns not covered should be addressed to your local Detroit Diesel representative.

The coolant used in Detroit Diesel Series 60 engines must meet the following basic requirements:

- Provide an adequate heat transfer medium.
- Protect against cavitation damage.
- Provide a corrosion/erosion-resistant environment.
- Prevent formation of scale or sludge deposits.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze protection.

A properly maintained coolant can be used up to the intervals listed in Table 5-22. At this time the cooling system must be drained, thoroughly cleaned and filled with new coolant.

To achieve these requirements, coolants are mixtures of good quality water, SCA and often an IEG or IPG for freeze protection. The rest of this bulletin will describe the requirements and usage of the water, SCA, IEG, and IPG.

### 5.4.1 Water

Water is the best practical medium for heat transfer. However, water alone can cause corrosion and inherently contains minerals that can produce scale deposits on internal cooling system surfaces. Chlorides, sulfates, magnesium, and calcium dissolved in the water can cause scale deposits, sludge deposits and/or corrosion.

Distilled or deionized water is preferred to minimize the adverse effects of minerals in water. The maximum allowable limits for minerals in water are listed in Table 5-12. For the procedure for evaluating the quality of water, see Figure 5-3.

| Mineral | Limit - ppm | Limit - grains per gallon |
|---|---|---|
| Chlorides | 40 | 2.5 |
| Sulfates | 100 | 5.8 |
| Total dissolved solids | 340 | 20 |
| Total Hardness: Magnesium & Calcium | 170 | 10 |

**Table 5-12 Maximum Allowable Limits for Minerals in Water**

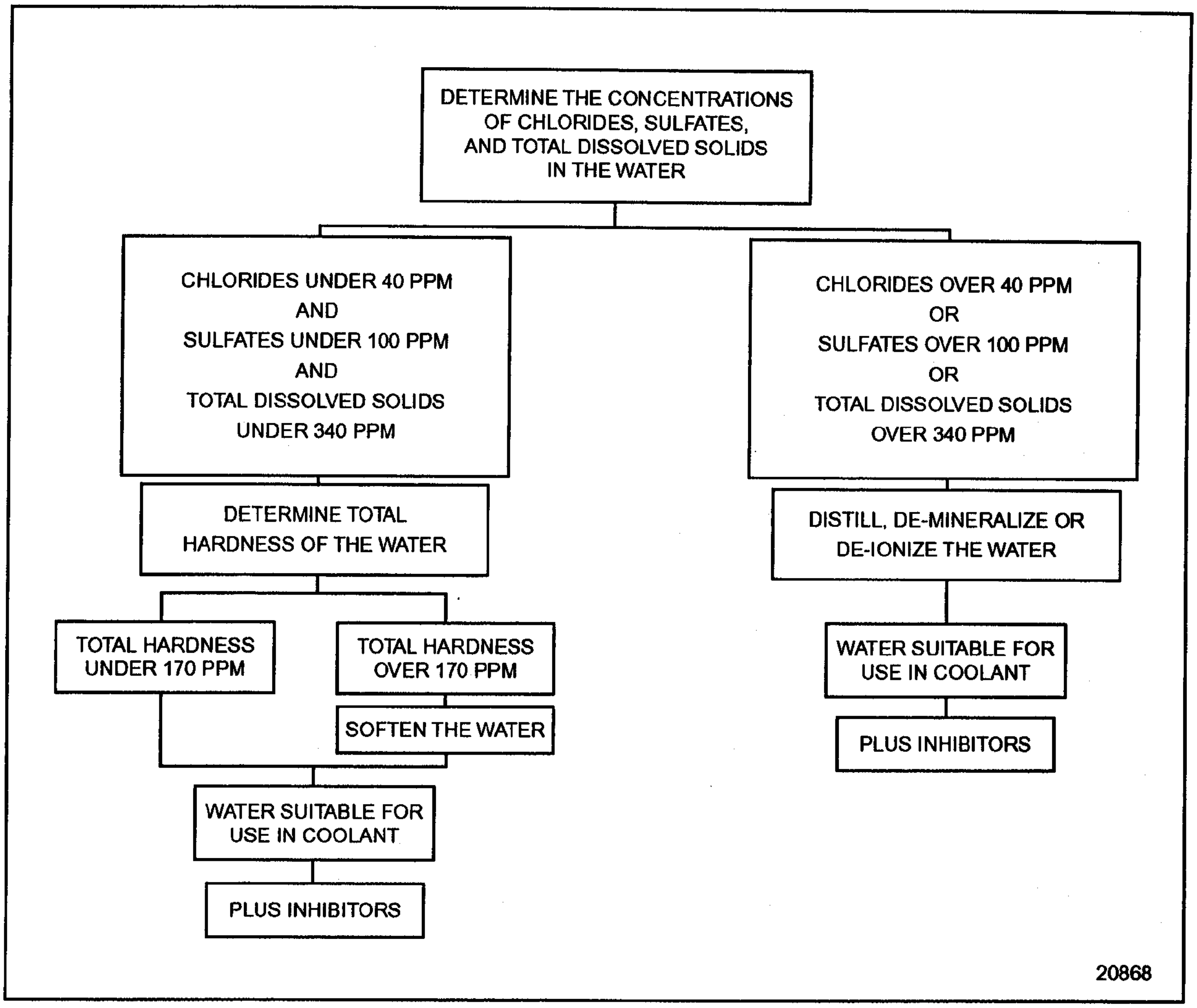



**Figure 5-3 Water Evaluation Procedure**

### 5.4.1.1 Antifreeze, Inhibited Ethylene Glycol

Ethylene glycol is used for freeze protection of the coolant. IEG, commonly referred to as antifreeze, also contains chemicals that provide a limited protection against corrosion. The use of an IEG product with a low silicate formulation that meets either the GM 6038-M formulation (GM1899-M performance) or ASTM D 4985 requirements is recommended.

### 5.4.1.2 Antifreeze, Inhibited Propylene Glycol

An IPG/water mixture provides freeze protection.

Propylene glycol must meet the performance requirements of ASTM D 4985 and the physical/chemical requirements of ASTM D5216. The maintenance procedures for propylene glycol are the same as for IEG. All references to IEG will also apply to IPG for the Series 60 engines.

For best overall performance, a 50% concentration of IEG (1/2 IEG, 1/2 water) is recommended. An IEG concentration over 67% (2/3 IEG, 1/3 water) is not recommended because of poor heat transfer, reduced freeze protection, and possible silicate dropout. An IEG concentration below 33% (1/3 IEG, 2/3 water) offers little freeze or corrosion protection and is not recommended (see Figure 5-4, see Figure 5-5, and see Figure 5-6).

IEG coolants require the addition of SCA to provide cooling system corrosion and deposit protection. The SCA added should match the chemistry of the additive package included in the coolant. If this precaution is not observed, coolant monitoring can become difficult, making over-inhibiting more likely. IEG formulations available in the market may contain from zero to the full amount of the required SCA. A basic IEG with no SCA must have additional SCA added at the time of initial fill. A Fully Formulated or Precharged IEG such as Detroit Diesel Power Cool® already contains the required SCA (listed in Table 5-13). Overconcentration will result if SCAs are added to a fully formulated IEG coolant at the time of initial fill. This can result in solids dropout and the formation of deposits.

| Power Cool - DDC Part Number | Size |
|---|---|
| 23512138 | 1 gallon |
| 23512139 | 55 gallons |
| 23512140 | bulk |

**Table 5-13 Power Cool Fully Formulated/Precharged IEG**

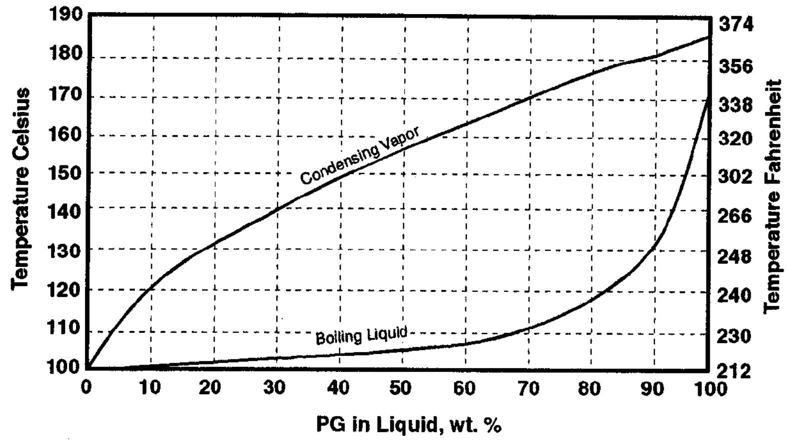



**Figure 5-4 IPG Boiling Point**

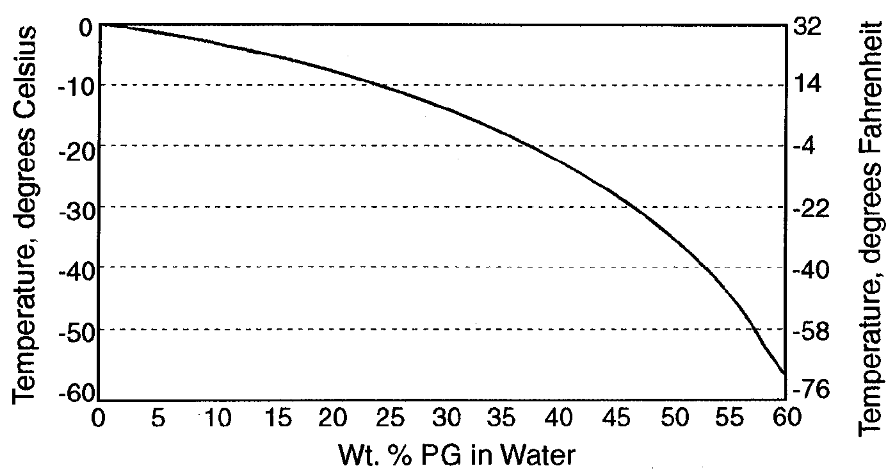



**Figure 5-5 IPG Freezing Point**

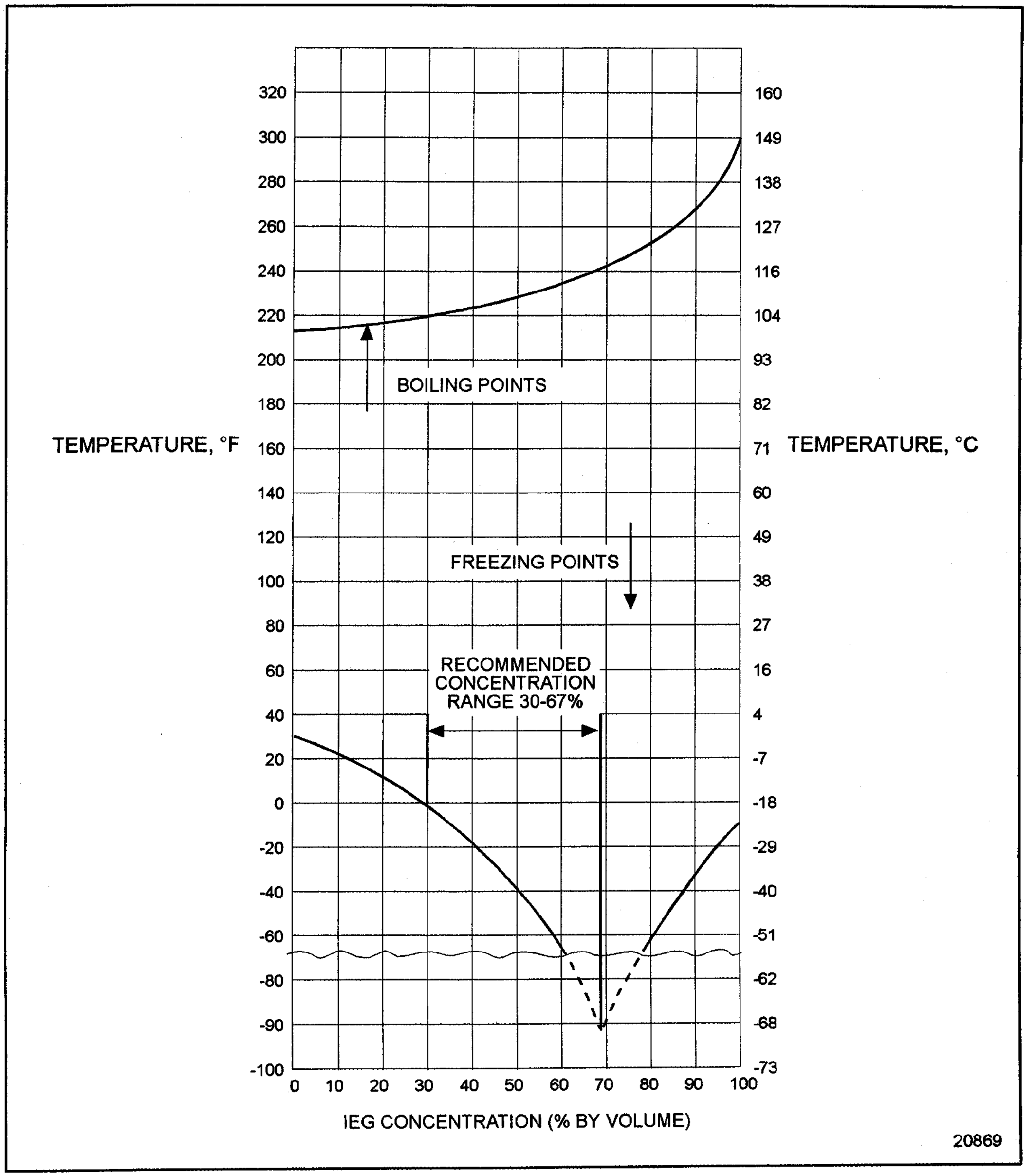



**Figure 5-6** **Coolant Freezing and Boiling Temperature vs. Inhibited Ethylene Glycol Concentration (Sea Level)**

### 5.4.2 Coolants Not Recommended

Methyl alcohol-based antifreeze should not be used in Detroit Diesel Series 60 engines because of its effect on the non-metallic components of the cooling system and its low boiling point. Similarly, methoxy propanol-based antifreeze should not be used in Detroit Diesel Series 60 engines because it is not compatible with fluoroelastomer seals found in the cooling system. Glycol-based coolants formulated for heating/ventilation/air conditioning (HVAC) should not be used in Detroit Diesel Series 60 engines. These coolants generally contain high levels of phosphates, that can deposit on hot internal engine surfaces and reduce heat transfer.

### 5.4.3 Supplemental Coolant Additive

SCAs provide protection for the cooling system components. The coolant must have the proper concentration of SCAs. Detroit Diesel Maintenance products are recommended for use in Detroit Diesel Series 60 engines.

| NOTICE: |
|---|
| Excessive amounts of chemicals in the engine coolant can cause a gel-type or crystalline deposit that reduces heat transfer and coolant flow. The deposit, called dropout takes the color of the coolant when wet, but appears as a white powder when dry. It can pick up solid particles in the coolant and become gritty, causing excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non-acid (alkali) type heavy-duty cleaner, Detroit Diesel Maintenance Product cleaner DD-2001 (sodium nitrite/sodium tetraborate). If the gel is allowed to dry, it is necessary to disassemble the engine and clean with a caustic solution or mechanically clean individual components. |

The proper application of SCA will provide:

- ☐ A pH control to prevent corrosion.
- ☐ Water-softening to deter formation of mineral deposits.
- ☐ Cavitation protection to reduce the effects of cavitation.

The proper dosage for initial cooling system fill is listed in Table 5-14. Maintenance cooling system fill is listed in Table 5-15, initial coolant inhibitor element size requirements for IPG and IEG plus water coolant mixtures are listed in Table 5-16. Coolant inhibitor element size requirements, initial dosage for water-only systems, are listed in Table 5-17. The proper maintenance dosages are listed in Table 5-18.

| Coolant | Coolant Element | Liquid * |
|---|---|---|
| Precharged IEG and Water | NONE | NONE |
| IEG and Water | Select Element listed in Table 5-16. | 3% by volume, or 1 pint per 4 gallons |
| Water only | Select Element listed in Table 5-17. | 6% by volume, or 1 quart per 4 gallons |

*1 gallon = 3.785 L; 2 pints = 1 quart; 4 quarts = 1 gallon

**Table 5-14 Initial Fill SCA Dosage**

| Coolant Element | Liquid * |
|---|---|
| Select element listed in Table 5-18. | 0.6% by volume or 1 pint per 20 gallons |

*1 gallon = 3.785 L; 8 pints = gallon

**Table 5-15 Maintenance Fill SCA Dosage**

| Cooling System Capacity, Gallons (L) | Quantity | DDC Part Number |
|---|---|---|
| 9-12 (34-45) | 1 | 23508426 |
| 13-16 (49-61) | 1 | 23507189 |

**Table 5-16 Coolant Inhibitor Element Size Requirements-Initial Fill Dosage for IEG or IPG plus Water Coolant Mixtures**

| Cooling System Capacity Gallons (L) | SCA Element Quantity | Detroit Diesel SCA Element Part Number | Additional SCA Liquid Required |
|---|---|---|---|
| 7 (26) | 1 | 23508426 | None |
| 10 (38) | 1 | 23507189 | None |
| 15 (57) | 2 | 23508426 | None |

**Table 5-17 Coolant Inhibitor Element Size Requirements-Initial Dosage for Water-Only System**

| Cooling System Capacity, Gallons (L) | Fiter Quantity | Filter Part Number | Liquid Only Number of Pints |
|---|---|---|---|
| 9-12 (34-45) | 1 | 23507545 | 1/2 - 3/4 |
| 13-16 (49-61) | 1 | 23507545 | 3/4 - 1 |

**Table 5-18 Coolant Inhibitor Element Size Requirements-Maintenance Dosage for IEG, IPG, Precharged, and Water-Only Coolant Mixture**

The concentration of SCA will gradually deplete during normal engine operation. Check the SCA concentration at the regular intervals listed in Table 5-19. Additional SCA must be added to the coolant when it becomes depleted below a specified level (listed in Table 5-20). Maintenance dosage of SCA must only be added if nitrite concentration is less than 800 ppm. If nitrite concentration is greater than 800 ppm, do not add additional SCA. Due to the elevated fire deck temperatures in the Series 60G engine, it is very important that the phosphorus (P) level remain below the maximum. Operation of the Series 60G engine with phosphorus levels above the maximum will lead to phosphorus dropout on the hot firedeck surfaces. This dropout will form an insulation layer between the fire deck and coolant, and lead to eventual engine damage.

| Service Application | Inhibitor Test Interval |
|---|---|
| On-highway Trucks and Motor Coaches | 205,000 miles (32,000 km) |
| City Transit Coaches, Pick-up and Delivery, Short Trip, and Emergency Vehicles | 6,000 miles (9,600 km) or three months, whichever comes first. |
| Industrial, Continuous Duty Generator Set, Marine and all other applications | 500 hours or yearly, whichever comes first. |
| Standby Generator Set | 200 hours or yearly, whichever comes first. |

**Table 5-19 Required Coolant Inhibitor Test Intervals**

| SCA | Minimum SCA ppm | Maximum SCA ppm |
|---|---|---|
| Boron (B) | 1,000 | 1,500 |
| Nitrite ($NO_2$) | 800 | 2,400 |
| Nitrates ($NO_3$) | 1,000 | 2,000 |
| Silicon (Si) | 50 | 250 |
| Phosphorus (P) | 0 | 500 |
| pH | 8.5 | 10.5 |

**Table 5-20 SCA Limits with GM6038-M or ASTM-D 4985 (50/50 Coolant/Water Mixture)**

### 5.4.4 Soluble Oils

Soluble oil additives are not approved for use in the Detroit Diesel Series 60 engine cooling systems. A small amount of oil adversely affects heat transfer. A 1.25% concentration of soluble oil increases the fire deck temperature 6%. A 2.50% concentration increases the fire deck temperature 15%.

### 5.4.5 Chromate

Chromate additives are not approved for use in the Detroit Diesel Series 60 engine cooling systems. Chromate additives can form chromium hydroxide, commonly called green slime. This, in turn, can result in engine damage due to poor heat transfer. Cooling systems operated with chromate-inhibited coolant must be chemically cleaned with Power Cool 2015 cooling system cleaner and conditioner (or equivalent sulfamic acid/sodium carbonate cleaner) and flushed.

Some coolant filter elements with magnesium internal support plates have caused engine damage. The coolant dissolves the magnesium and deposits it on the hot zones of the engine where heat transfer is most critical. The use of elements with these plates is not approved.

### 5.4.6 Detroit Diesel Cooling System Maintenance Products

Detroit Diesel Maintenance Products with SCA are water-soluble chemical compounds. These products are available in coolant filter elements, liquid packages, and a fully formulated IEG.

### 5.4.7 Coolant Inhibitor Elements

Replaceable coolant inhibitor elements (spin-on canisters) are available in various sizes suitable for cooling systems of varying capacity. If a fully formulated IEG or IPG coolant *is not* used, a pre-charge element *must* be installed. Selection of the proper element size is vital when precharging the coolant system at initial fill. If a coolant inhibitor element is used, it is important to make sure that the coolant inlet/outlet valves on the element adaptor head are fully opened prior to filling the cooling system with coolant.

**NOTE:**
A fully formulated IEG or IPG must NOT have SCA added at initial fill.

The need for maintenance elements is determined by the results of the SCA concentration test performed at each cooling system service interval.

### 5.4.8 Supplemental Coolant Additive Test Procedures

Nitrite concentration is an indication of the SCA concentration in the coolant. Nitrite test kits and test strips are commercially available. The coolant must be tested for required inhibitor levels at the intervals listed in Table 5-19. SCA levels must be within the ranges listed in Table 5-20.

### 5.4.8.1 Liquid Supplemental Coolant Additive

Detroit Diesel Cooling System Maintenance Procedures SCA and Cleaners are available in liquid form and are listed in Table 5-21.

| Product | Size * | DDC Part No. |
|---|---|---|
| Power Cool 2000 - Liquid SCA | 1 pint (12 per case) | 23507858 |
| Power Cool 2000 - Liquid SCA | half gallon (6 per case) | 23507859 |
| Power Cool 2000 - Liquid SCA | 5 gallons | 23507860 |
| Power Cool 2000 - Liquid SCA | 55 gallons | 23507861 |
| Power Cool 3000 † - Liquid SCA | 1 pint (12 per case) | 23507854 |
| Power Cool 3000 † - Liquid SCA | half gallon (6 per case) | 23507855 |
| Power Cool 3000 † - Liquid SCA | 5 gallons | 23507856 |
| Power Cool 3000 † - Liquid SCA | 55 gallons | 23507857 |
| Power Cool 2001 ON-LINE CLEANER | half gallon (6 per case) | 23507862 |
| Power Cool 2001 ON-LINE CLEANER | 5 gallons | 23507863 |
| Power Cool 2001 ON-LINE CLEANER | 55 gallons | 23507864 |
| Power Cool 2015, Twin Pac, Dry Chemical Cleaner/Conditioner | 2 per case | 23507867 |

* 1 gallon = 3.785 L; 8 pints = gallon

† Power Cool 3000 is more compatible with hard water than Power Cool 2000. Use Power Cool on-line cleaner for light deposits. Use Power Cool dry chemical cleaner conditioner for heavy deposits or scale.

**Table 5-21 Liquid SCA and Additional Coolant Treatment Products**

### 5.4.8.2 Test Kit Procedures

Use Detroit Diesel Powertrac® 2-Way Coolant Test Strips (part number 23515917) to measure nitrite and glycol concentrations. Cavitation/corrosion protection is indicated on the strip by the level of nitrite concentration.

| NOTICE: |
|---|
| Do not use Detroit Diesel **Power Cool™** test strips to determine the inhibitor levels of coolant with non-DDC approved additive packages. Incompatible chemicals and variance in inhibitor levels in the additive packages may cause inaccurate interpretation of test strip readings. This can lead to under-inhibiting the coolant, which may result in cavitation erosion. |

Freeze and boil over protection is determined by glycol concentration. Use the test strips as follows:

1. Dip the strip into coolant for one second. Remove and shake briskly to eliminate excess fluid.
2. Immediately compare end pad (% glycol) to the color chart.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad to the chart contained within the kit.

For best results make the tests while the coolant is between 50 and 140°F (10 - 60°C). Wait at least 60, but not longer than 75 seconds before reading the nitrite level. Promptly replace and tighten container cap after each use. Discard unused strips if they have turned light pink or tan.

A factory coolant analysis program is also available through authorized Detroit Diesel service outlets under part number 23508774.

## 5.4.9 Summary of Coolant Recommendations

Coolant recommendations may be summarized as follows:

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

**NOTE:**

Propylene glycol meeting ASTM D 4985, and ASTM D 5216, is approved for use in Series 60 engines.

1. Always maintain the engine coolant to meet Detroit Diesel specifications.
2. Only use water that meets Detroit Diesel specifications. Distilled or deionized water is preferred.
3. The proper dosage of SCA must be included in the coolant at initial fill for all Detroit Diesel Series 60 engines.This dosage can be either included in part or entirely in the IEG used, or it may need to be added. Dosage is also dependent on whether water or IEG is used. The user is urged to refer to the full text of this bulletin to determine the proper dosage. Mixing of different manufacturers' inhibitors (SCAs) could cause cooling system problems.
4. Maintain the SCA to the prescribed concentration. Test the nitrite concentration by using a titration kit or Detroit Diesel 2-Way Coolant Test Strips. Add SCA only if the nitrite concentration is below 800 ppm.Do not use another manufacturer's test kit to measure the SCA concentration of Detroit Diesel Maintenance Products.
5. Pre-mix coolant makeup solutions at the proper concentration before adding to the coolant system.
6. Where antifreeze/boilover protection is required, use only ethylene glycol coolant (low silicate formulation) meeting GM 6038-M, GM 1899-M, or ASTM D 4985. Propylene glycol meeting ASTM D 4985, and ASTM D 5216 is also approved for use in Series 60 engines.
7. Always maintain proper coolant level.
8. A properly maintained cooling system can be operated for up to intervals listed in Table 5-22, listed in Table 5-23 and listed in Table 5-24. The cooling system must be thoroughly cleaned and the coolant replaced at these intervals.

| Coolant | Interval - Whichever comes first | Action |
|---|---|---|
| Antifreeze/Water + SCA Inhibitor (DDC *Power Cool*) | **A** 20,000 miles (32,000 km) or 3 months<br>**B** 3 months or 500 hours | Test nitrite concentration with test strip. Add SCA or dilute coolant as needed. |
| | **A** 300,000 miles (480,000 km)<br>**B** 2 years or 4,000 hours | Drain and clean system. Replace with new coolant. |
| Ethylene Glycol Antifreeze/Water + SCA Inhibitor | **A** 20,000 miles (32,000 km) or 3 months<br>**B** 3 months or 500 hours | Test nitrite concentration with test strip. Add SCA or dilute coolant as needed. |
| | **A** 300,000 miles (480,000 km)<br>**B** 2 years or 4,000 hours | Drain and clean system. Replace with new coolant. |
| Propylene Glycol Antifreeze/Water + SCA Inhibitor | **A** 20,000 miles (32,000 km) or 3 months<br>**B** 3 months or 500 hours | Test nitrite concentration with test strip. Add SCA or dilute coolant as needed. |
| | **A** 300,000 miles (480,000 km)<br>**B** 2 years or 4,000 hours | Drain and clean system. Replace with new coolant. |
| Ethylene Glycol Antifreeze/Water + NOAT Inhibitor | **A** 300,000 miles (480,000 km) or 2 years<br>**B** 5,000 hours | Add *Power Cool* Plus Extender |
| | **A** 600,000 miles (960,000 km)<br>**B** 4 years or 10,000 hours | Drain and clean system. Replace with new coolant. |
| Propylene Glycol Antifreeze/Water + NOAT Inhibitor | **A** 300,000 miles (480,000 km) or 2 years<br>**B** 5,000 hours | Add *Power Cool* Plus Extender |
| | **A** 600,000 miles (960,000 km)<br>**B** 4 years or 10,000 hours | Drain and clean system. Replace with new coolant. |
| Water only+ SCA Inhibitor | **A** 20,000 miles (32,000 km) or 3 months<br>**B** 3 months or 500 hours | Test nitrite concentration with test strip. Add SCA or dilute coolant as needed. |
| | **A** 300,000 miles (480,000 km)<br>**B** 2 years or 4,000 hours | Drain and clean system. Replace with new coolant. |
| Water only+ NOAT Inhibitor | **A** 300,000 miles (480,000 km) or 2 years<br>**B** 2 years or 5,000 hours | Add *Power Cool* Plus Extender |
| | **A** 600,000 miles (960,000 km)<br>**B** 4 years or 10,000 hours | Drain and clean system. Replace with new coolant. |

**A** On Highway Trucks and Motor Coaches, City Transit Coaches, Pick up and Delivery, Short Trip, and Emergency Vehicles.

**B** Industrial, Generator Set, and other applications.

Note: Detailed marine engine coolant fill options and maintenance intervals are listed in Table 5-23 and listed in Table 5-24.

## Table 5-22 Cooling System Cleaning Intervals

| Item | Water Solution | Antifreeze Solution Premixed Coolant with Water |
|---|---|---|
| Products | *POWER COOL®* 3000 (P/N 23507855) | *POWER COOL®* (P/N 23518918) |
| Initial Fill | 3% by Volume *POWER COOL®* 3000 | 100% by Volume *POWER COOL®* |
| Maintenance | Check with PowerTrac test strip every 250 hours or 1 year, whichever comes first. Add *POWER COOL®* 3000 to maintain 3% by volume concentration. | Check with PowerTrac test strip every 250 hours or 1 year, whichever comes first. Add SCA or dilute coolant as needed. |
| Maintenance — Drain and Fill | Drain, clean system, and replace with new coolant every 2 years or 4,000 hours, whichever comes first. | Drain, clean system, and replace with new coolant every 2 years or 4,000 hours, whichever comes first. |

**Table 5-23 Coolant Initial Fill Options and Maintenace Intervals — Commercial Marine Engines**

| Item | Water Solution (See Notes) | Antifreeze Solution Premixed Coolant with Water |
|---|---|---|
| Products | *POWER COOL®* Plus 6000 | *POWER COOL®* Plus Marine |
| Initial Fill | 10% by Volume *POWER COOL®* Plus 6000 in water. | 100% by Volume *POWER COOL®* Plus Marine. |
| Maintenance | Check with PowerTrac test strip every 250 hours or 1 year, whichever comes first. Add 2% by volume *POWER COOL®* Plus 6000 (P/N 23522128) every 2 years. | Check with PowerTrac test strip every 250 hours or 1 year, whichever comes first. Add 0.6% by volume *POWER COOL®* Extender (P/N 23519400) every 2 years. |
| Maintenance — Drain and Fill | Drain, clean system, and replace with new coolant every 4 years or 10,000 hours, whichever comes first. | Drain, clean system, and replace with new coolant every 4 years or 10,000 hours, whichever comes first. |

**Table 5-24 Coolant Initial Fill Options and Maintenace Intervals — Pleasure Craft Marine Engines**

9. Do not use the following in Detroit Diesel engine cooling systems:
   - ☐ Soluble oil
   - ☐ Chromate SCA
   - ☐ Methoxy propanol-base coolant
   - ☐ Methyl alcohol-base coolant
   - ☐ Sealer additives or coolant containing sealer additives
   - ☐ HVAC coolant

# 6 AIR INTAKE SYSTEM

## 6.1 AIR INTAKE SYSTEM OVERVIEW

The air intake system consists of the following components:

- Air cleaner or air silencer
- Gas mixer (Series 60 gas engine)
- Turbocharger
- Charge air cooler
- Throttle actuator (Series 60 gas engine)
- Intake manifold
- Air dryer

The turbocharger supplies air under pressure to the CAC and then to the intake manifold. The air enters the turbocharger after passing through the air cleaner or air silencer. Power to drive the turbocharger is extracted from energy in the engine exhaust gas. The expanding exhaust gases turn a single stage turbocharger wheel, which drives an impeller, thus pressurizing intake air. This charge air is then cooled by an air-to-air or air-to-water (marine engine) intake manifold before flowing into the cylinders for improved combustion efficiency. See Figure 6-1.

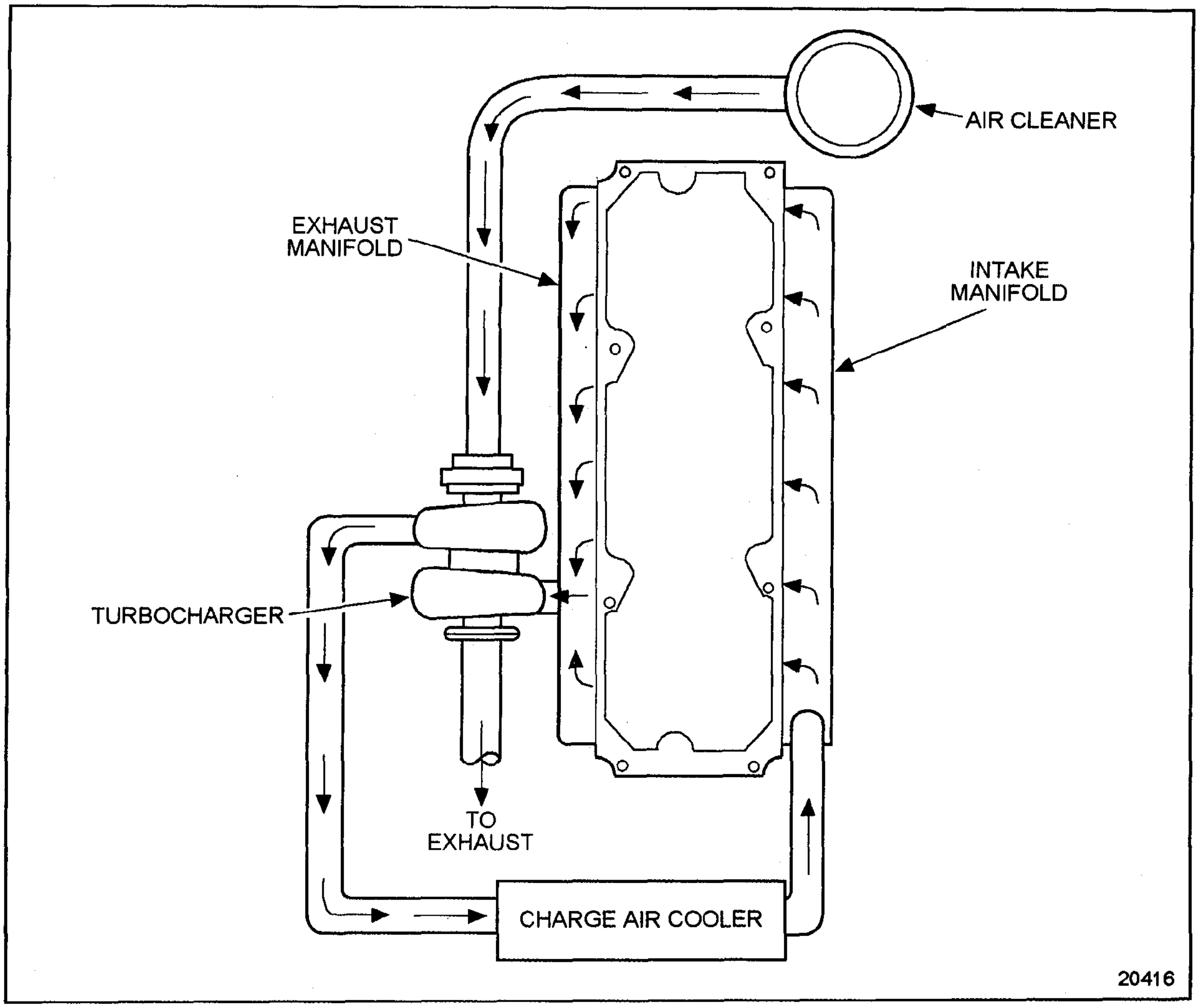



**Figure 6-1 Air Intake System Schematic (Series 60 Diesel Engine)**

On vehicle and industrial engines, charge air cooler (CAC) is mounted ahead of the engine coolant radiator. The pressurized intake charge is routed from the discharge side of the turbocharger, through the CAC to the intake manifold, which directs the air to ports in the cylinder head, through two intake valves per cylinder, and into the cylinder. At the beginning of the compression stroke, each cylinder is filled with clean air.

On heat exchanger-cooled pleasure craft marine engines, the raw water-cooled charge air cooler/air intake manifold is mounted on the intake side of the engine. The pressurized intake charge is routed from the discharge side of the turbocharger, through the CAC/intake manifold, which directs the air to the ports in the cylinder head. See Figure 6-2.

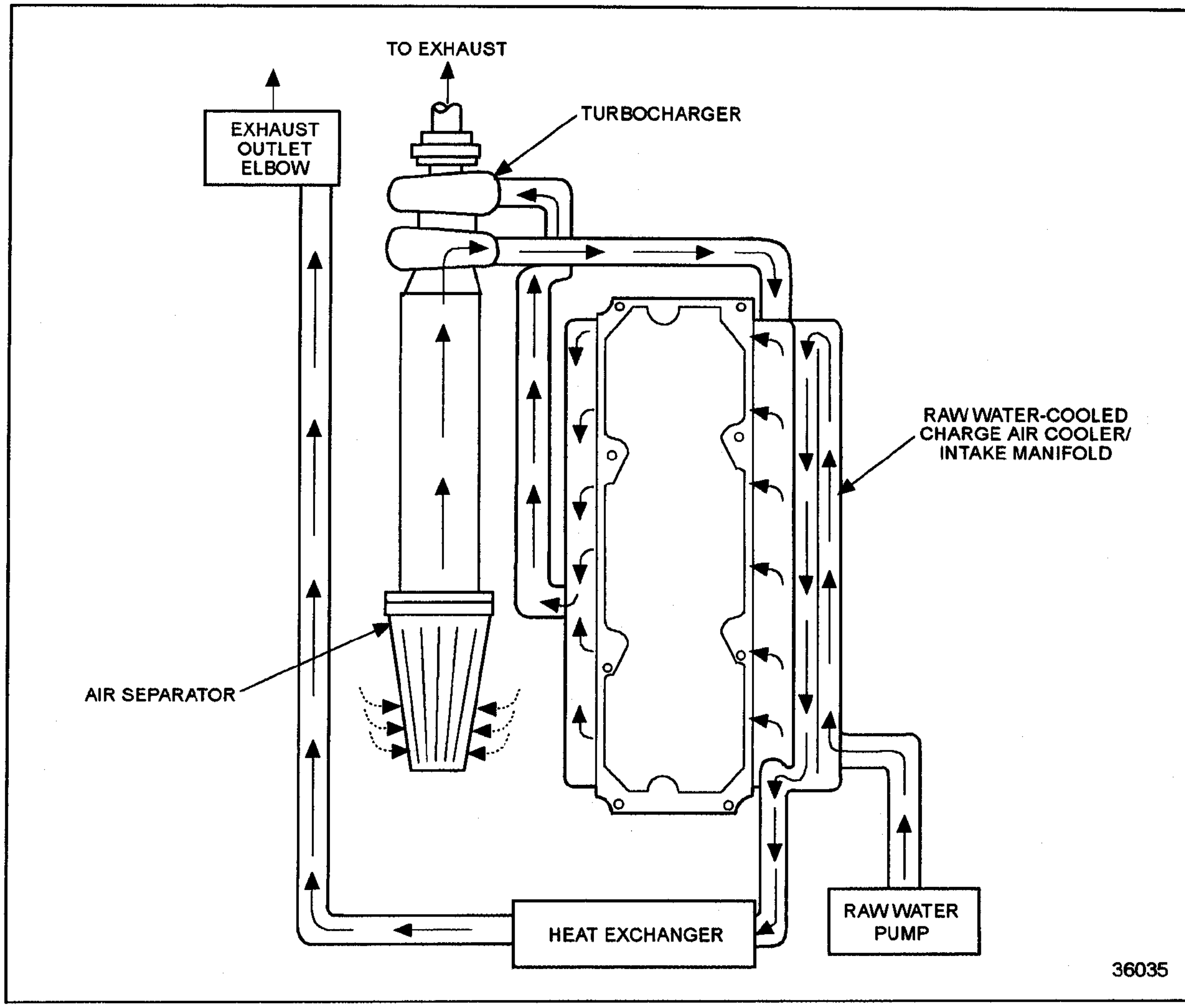



**Figure 6-2 Air Intake System Schematic — Heat Exchanger-Cooled Marine Engine**

On keel-cooled commercial marine engines, the charge air cooler (CAC) is mounted at the front of the engine. The pressurized intake charge is routed from the discharge side of the turbocharger, through the CAC to the intake manifold, which directs the air to ports in the cylinder head, through two intake valves per cylinder, and into the cylinder. At the beginning of the compression stroke, each cylinder is filled with clean air. See Figure 6-3.

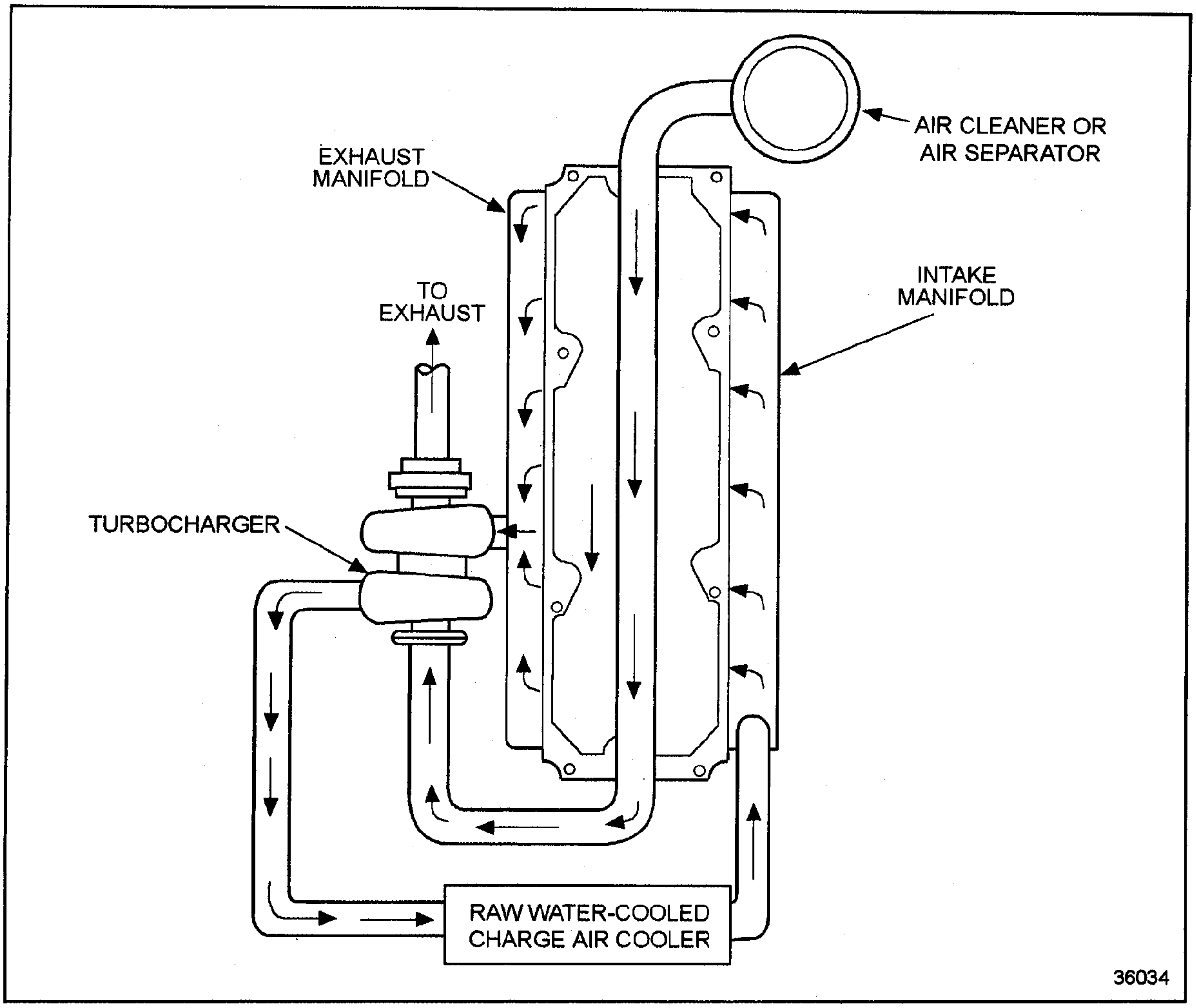



**Figure 6-3 Air Intake System Schematic — Keel-Cooled Marine Engine**

Repair and replacement procedures for the individual components of the air intake system are contained in this section.

### 6.1.1 Air System for Series 60G Engine (Low Pressure Natural Gas)

The air system components on the Series 60G engine with low pressure fuel system are similar to the diesel engine air system except for the addition of a gas mixer and throttle, see Figure 6-4. The turbocharger for this engine is similar to the diesel turbocharger. The features are described in more detail in the turbocharger section. Refer to section 6.7.

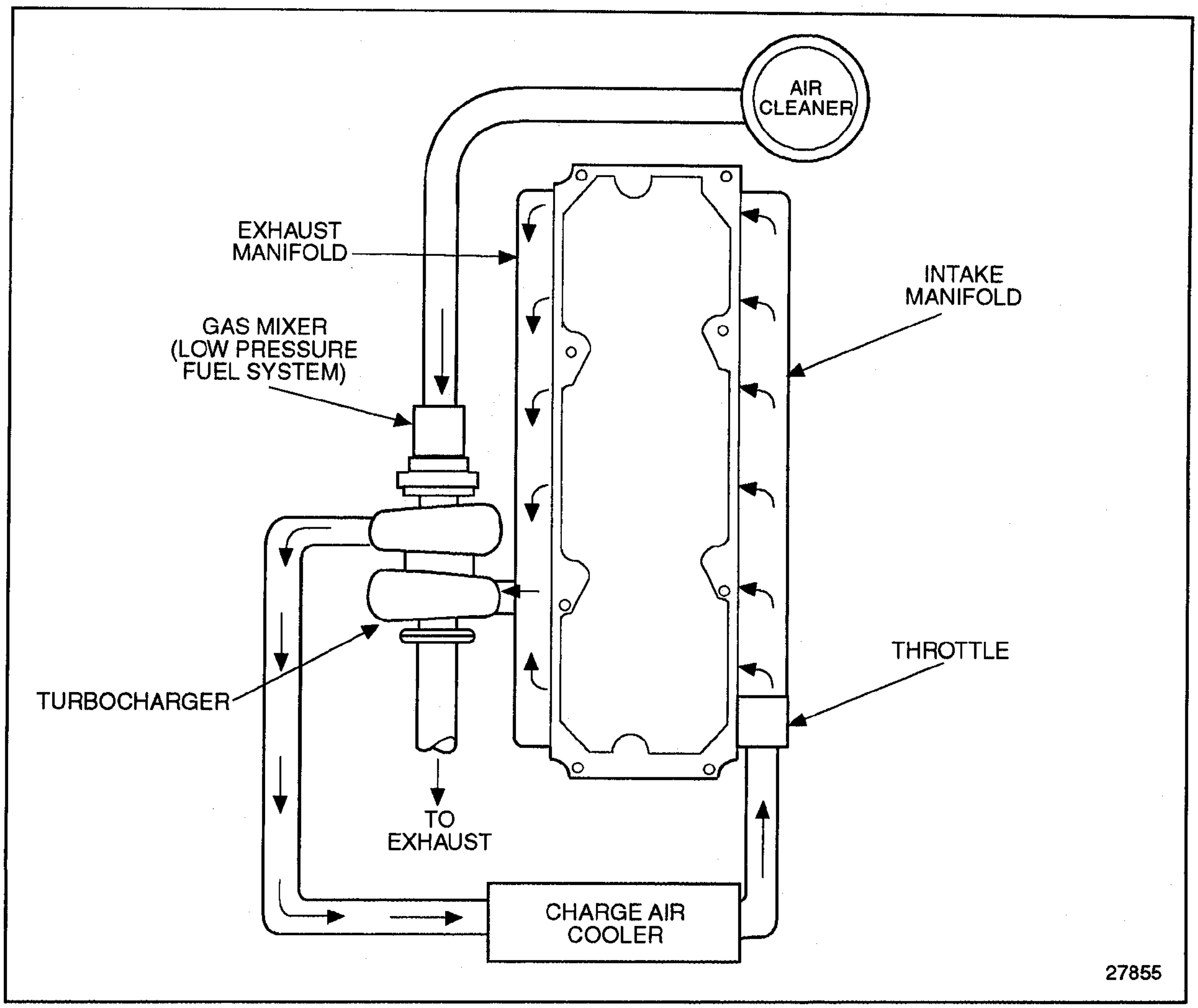



**Figure 6-4 Air Intake System Schematic Series 60G (Low Pressure)**

On genset engines, which have the low pressure fuel system, air is drawn into the gas mixer ahead of the turbocharger. A precisely controlled flow of natural gas is mixed with the air and flows into the turbocharger where it is compressed before flowing through the charge air cooler. This combustible air fuel mix then passes through the throttle and into the intake manifold. The throttle controls the flow of air-fuel mixture to the intake manifold there by providing control over the power output of the engine.

### 6.1.2 Air System for Series 60G (High Pressure)

The air system components on the Series 60G engine with high pressure fuel system are similar to the diesel engine air system except for the addition of a gas mixer and throttle, See Figure 6-5. The turbocharger for this engine is also different and features a turbine bypass (wastegate) and compressor recirculation valve. These features are described in more detail in the turbocharger section. Refer to section 6.5.

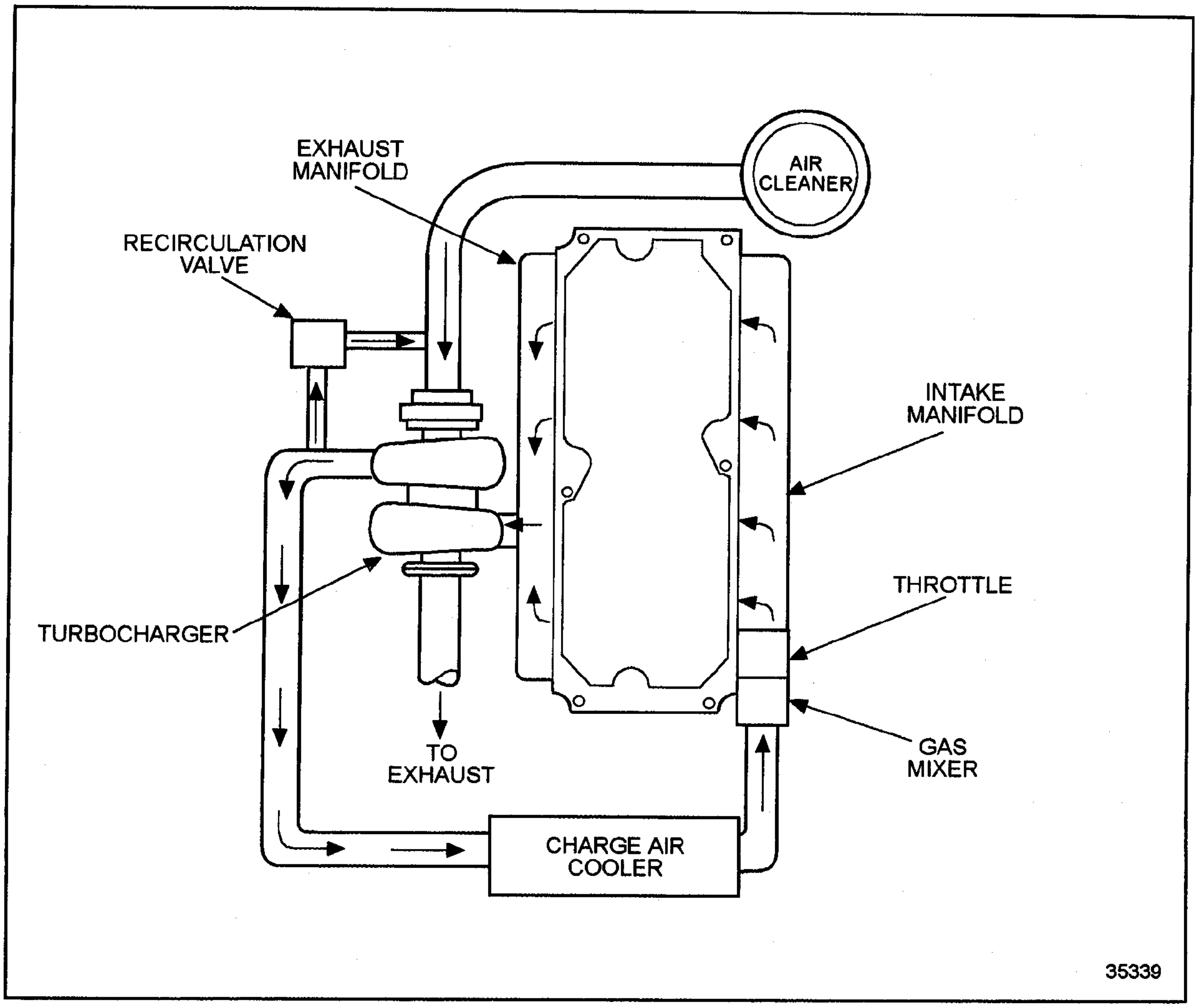



**Figure 6-5 Air Intake System Schematic 60G (High Pressure)**

In this system, air leaving the charge air cooler enters the mixer assembly and is mixed with a precisely controlled flow of natural gas. This combustible air fuel mixture then passes through the throttle and into the intake manifold. The throttle controls the flow of air-fuel mixture to the intake manifold there by providing control over the power output of the engine.

## 6.2 AIR CLEANER

Air cleaners are designed to remove foreign matter from the air and pass the required volume of air for proper combustion. Manufacturers guidelines should be consulted to maintain efficient operation for a reasonable period of time before requiring service.

The importance of keeping dust and grit-laden air out of the engine cannot be overemphasized, since clean air is essential to satisfactory engine operation and long engine life. Should dust in the air supply enter the engine, it would be carried into the cylinders and, due to its abrasive properties, cause premature wear of the moving parts. Dirt, which is allowed to build up in the air cleaner passages, will eventually restrict the air supply to the engine and result in heavy carbon deposits on the valves and pistons due to incomplete combustion. The air cleaner must have a capacity large enough to retain the material separated from the air to permit operation for a reasonable length of time before cleaning is required.

| NOTICE: |
| --- |
| Detroit Diesel is aware of attempts to use air cleaner elements made of foam or fabric batting material soaked with a sticky substance to improve dirt-holding capability. In some installations this substance has been found to transfer from the filter media, coating the inside surfaces of air ducts and engine air inlet systems, blowers, and air boxes. The result has been reduced engine performance and a change in engine operating conditions. |

Only oil bath type and dry paper element type air cleaners are recommended for use on all Detroit Diesel Series 60 engines. Alternate types of air filtration systems may be available in the after-market. Detroit Diesel does not recommend use or extend warranty to cover damage or malfunction of engine components as a result of usage on Detroit Diesel Series 60 engines.

If a foam or fabric air cleaner element soaked with a sticky, dirt-holding substance was previously installed, check for the presence of coated engine components. Remove and clean coated engine components as required. Refer to section 1.1.2.

### 6.2.1 Repair or Replacement of Air Cleaner

Refer to the OEM guidelines for air cleaner service procedures.

### 6.2.2 Removal and Cleaning of Air Cleaner

Detroit Diesel does not offer air cleaners as original equipment on Series 60 engines.

| NOTICE: |
|---|
| Always vacuum check air intake restriction indicators after cleaning to ensure proper operation. Failure to observe this step may result in faulty indicator readings, which may lead to inefficient engine operation and/or damage. |

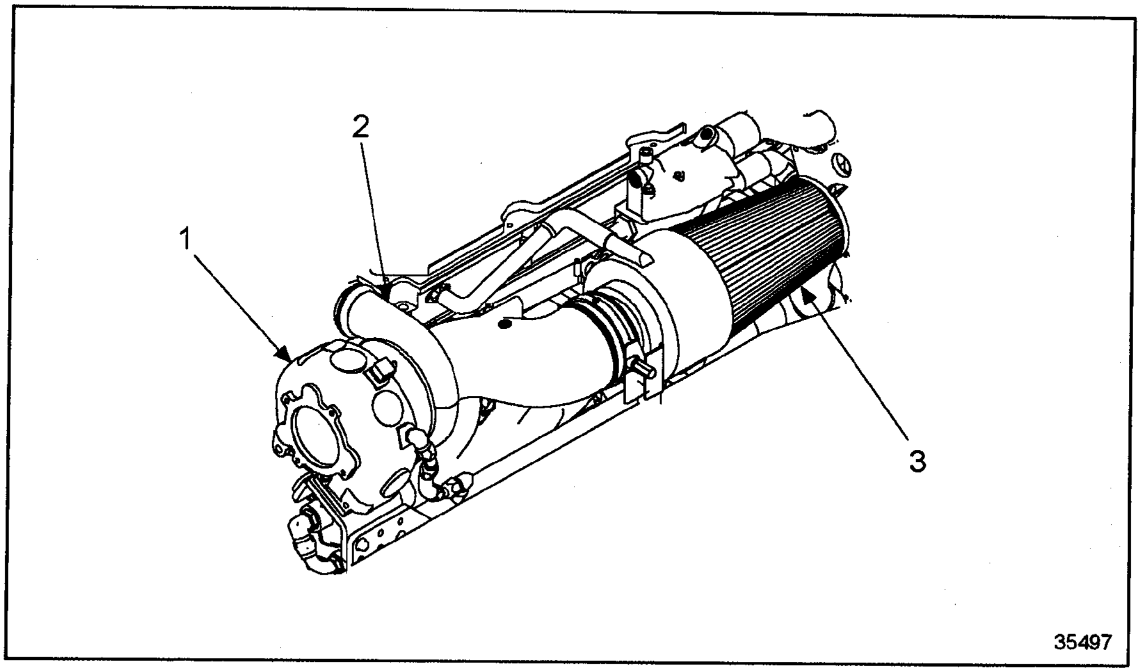
Refer to OEM guidelines for removal and cleaning procedures.

### 6.2.3 Air Cleaner Installation

Refer to OEM guidelines for installation and verification procedures.

## 6.3 AIR SEPARATOR

The breather system consists of an air separator assembly mounted to the inlet side of the turbocharger, along with an oil drain tube(s), check valve(s), required breather piping and mounting hardware.See Figure 6-6.




1. Turbine Housing
2. Compressor Housing
3. Air Separator Assembly

**Figure 6-6 Typical Air Separator System**

The system performs three functions:

- ☐ Collects the crankcase vapors normally emitted to atmosphere and separates particles of oil from the vapors. Any oil collected in this manner drains back to the crankcase, while the remaining fumes are mixed with the turbocharger air flow. This system virtually eliminates crankcase fumes from the engine room.
- ☐ Filters the outside air entering the turbocharger. The oil-coated filter element removes dirt and salt particles from the incoming air.
- ☐ Serves as an air silencer to reduce air induction noise.

### 6.3.1 Repair or Replacement of Air Separator Filter Element

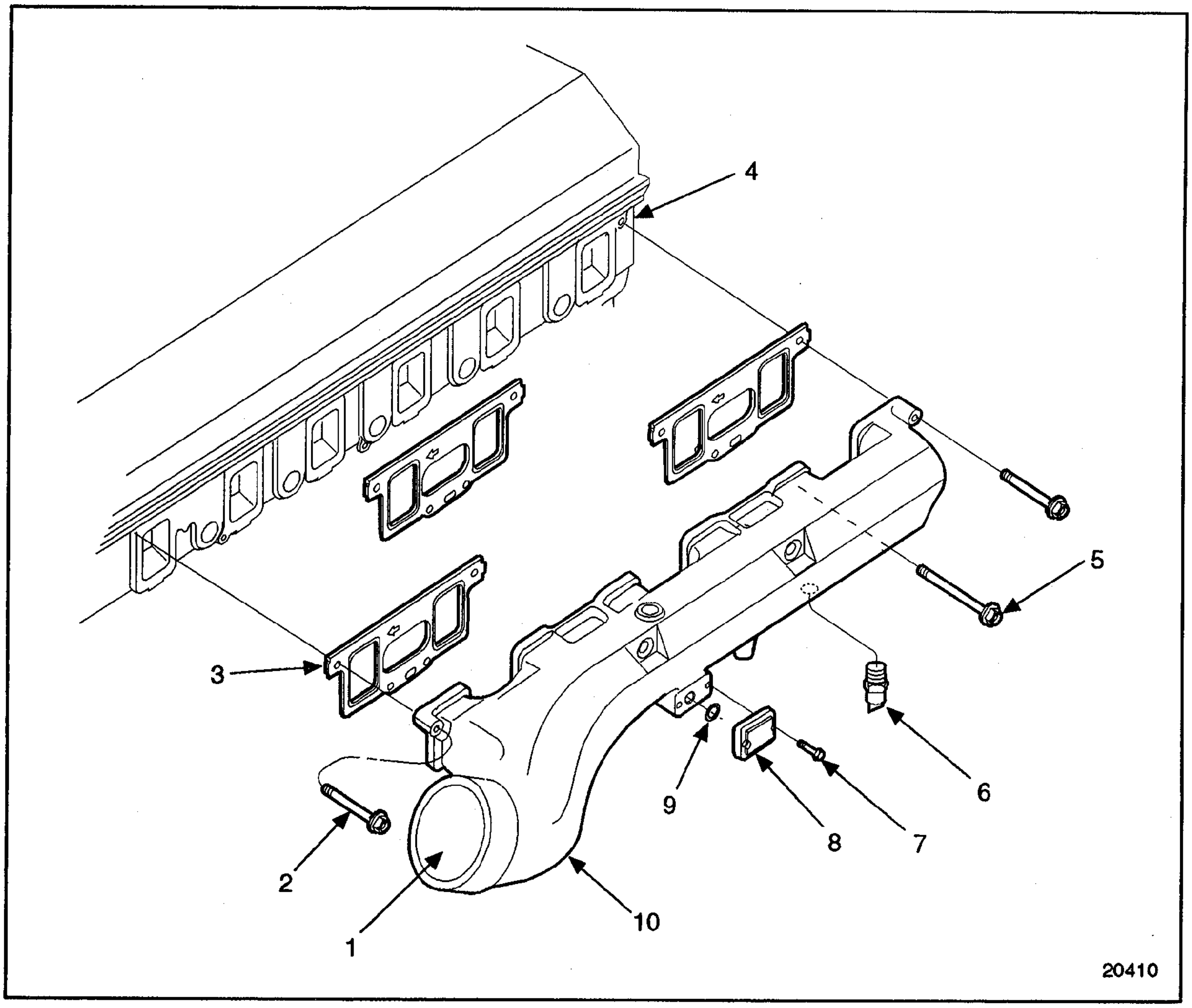
Refer to OEM for repair procedures.

| NOTICE: |
|---|
| Failure to clean the air separator filter and the vacuum regulator/limiter will affect the operation of the air separator and may cause reduced engine performance and/or engine damage caused by engine overheating. |

Refer to section 13.14, preventive maintenance for change intervals and cleaning and replacement procedures.

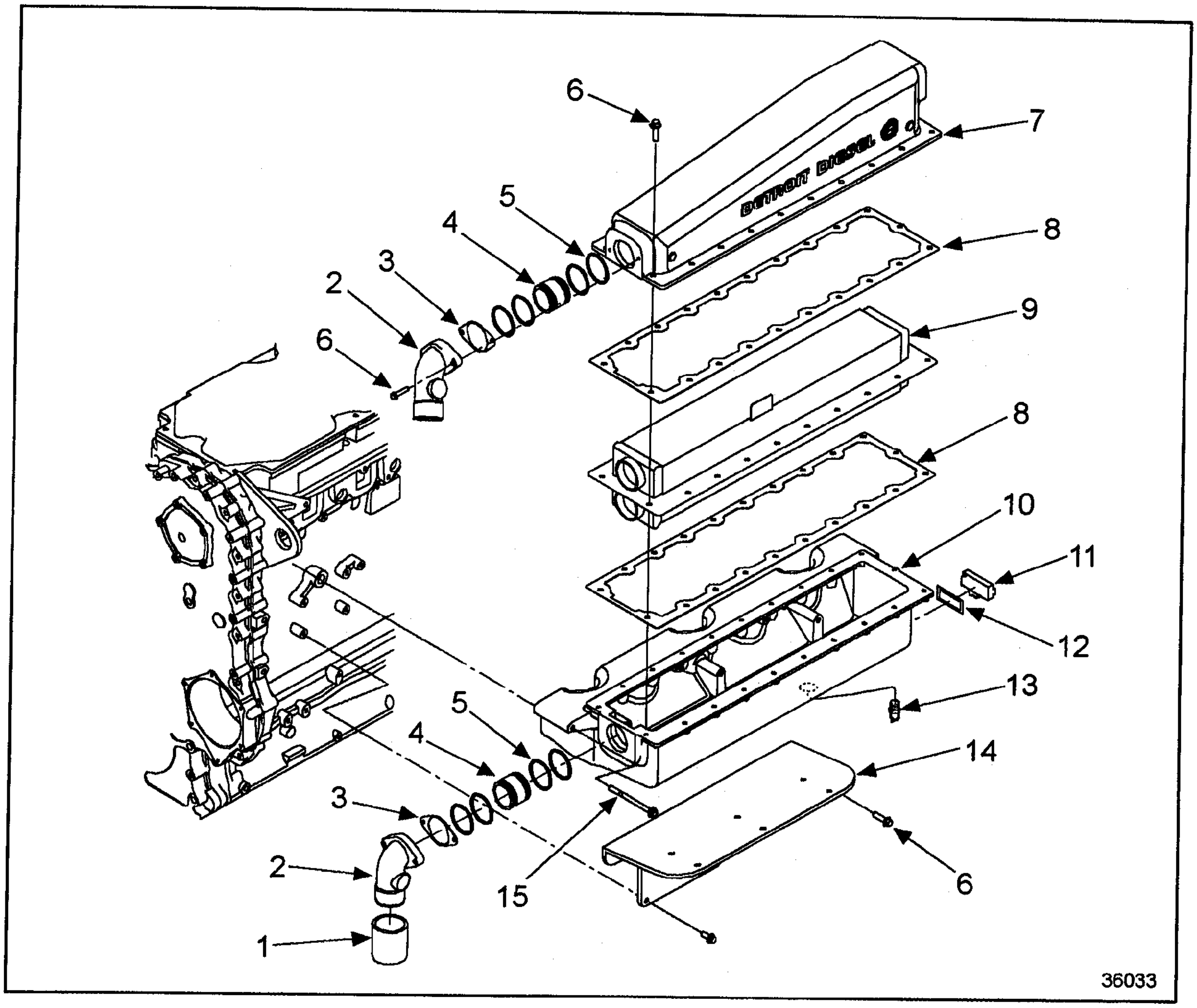
## 6.4 INTAKE MANIFOLD

On diesel engines, the intake charge air is routed to the individual cylinders by an intake manifold that is bolted to the cylinder head with seven bolts. The mating surface of the manifold and cylinder head is machined. The intake manifold is sealed to the cylinder head with three 2-port graphite coated gaskets. If the manifold is removed, new gaskets must be installed to maintain seal under higher boost pressure. A turbo-boost pressure sensor is mounted to the intake manifold with two bolts. An O-ring seals the boost sensor where it enters a hole in the manifold. On DDEC III/IV engines there is an air temperature sensor located on the bottom of the manifold. See Figure 6-7. and see Figure 6-8. The intake manifold air inlet is attached to the CAC ducting and the air compressor using flexible hose and clamps.




1. Intake Manifold Inlet
2. Bolt (2)
3. Intake Manifold Gasket
4. Cylinder Head
5. Bolt (5)
6. Air Temperature Sensor
7. Turbo Boost Sensor Bolt
8. Turbo Boost Sensor
9. O-ring
10. Intake Manifold

**Figure 6-7 Intake Manifold and Related Parts — All Diesel (Except Heat Exchanger-Cooled Pleasure Craft Marine) Engine**



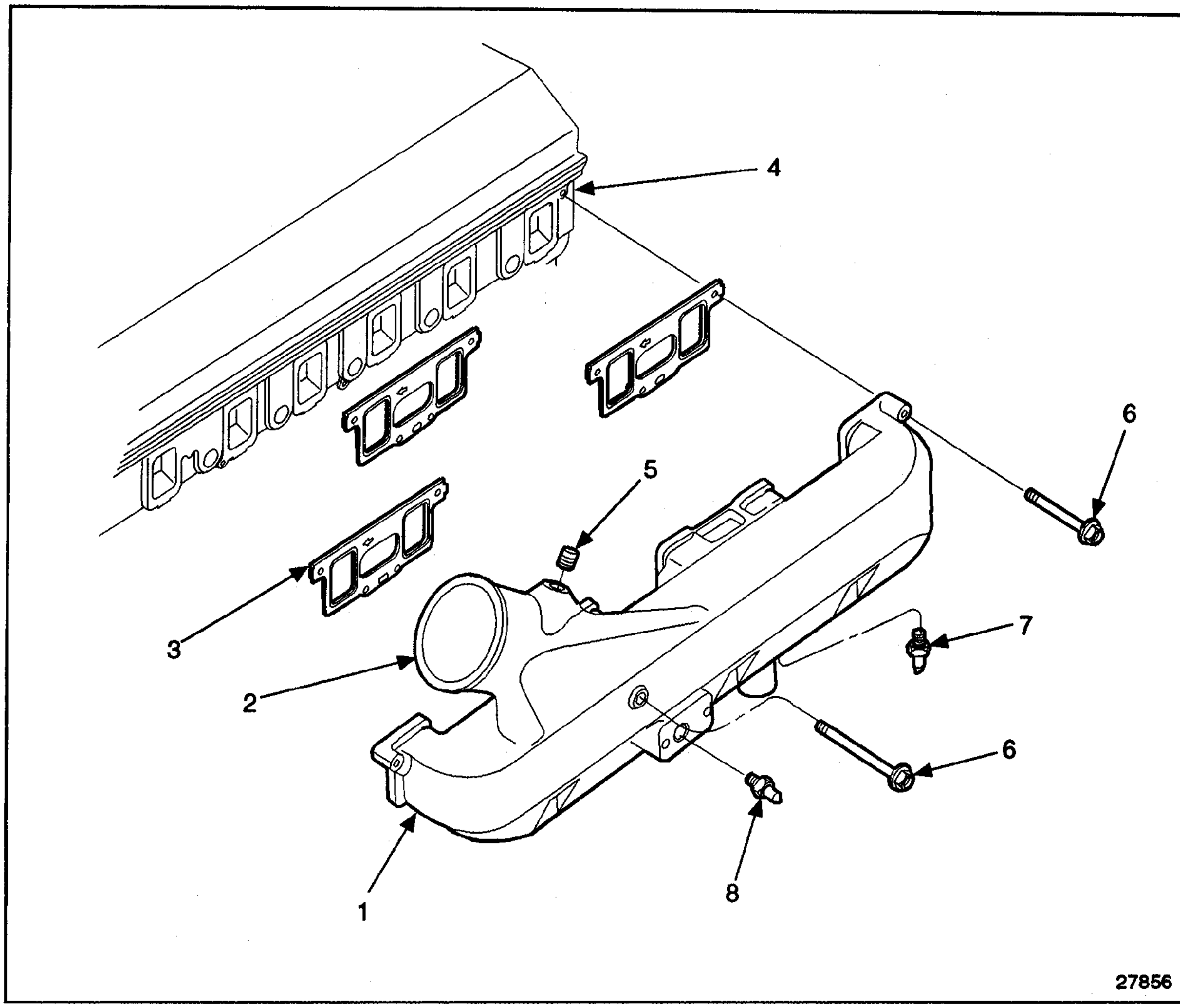

1. Hose
2. Elbow
3. Gasket
4. Sleeve
5. Seal Ring
6. Bolt
7. Housing Upper
8. Gasket
9. CAC Matrix
10. Housing Lower
11. Sensor
12. Seal Ring
13. Air Temperature Sensor
14. Bracket
15. Bolt

**Figure 6-8 Intake Manifold and Related Parts — Heat Exchanger-Cooled Pleasure Craft Marine Engine**

On Series 60 Gas engines a pipe thread hole is provided for mounting the air inlet pressure sensor. The Series 60G engines are throttled and therefore require a wide range boost sensor capable of measuring both negative and positive pressures in the intake manifold. In natural gas engines the intake manifold contains a combustible air-fuel mixture. See Figure 6-9.

**CAUTION:**

**The air inlet manifold contains combustible gas. To avoid injury from explosion, do not connect the air inlet manifold to any devices or lines external to the manifold.**




1. Intake Manifold
2. Air/Gas Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Pipe Plug
6. Manifold Bolt
7. Air Temperature Sensor (Low Pressure System Only)
8. Air Inlet Pressure Sensor

**Figure 6-9 Intake Manifold and Related Parts Series 60 Gas Engine**

### 6.4.1 Repair or Replacement of Intake Manifold

To determine if repair is possible or replacement of the intake manifold is necessary perform the following procedure. See Figure 6-10.

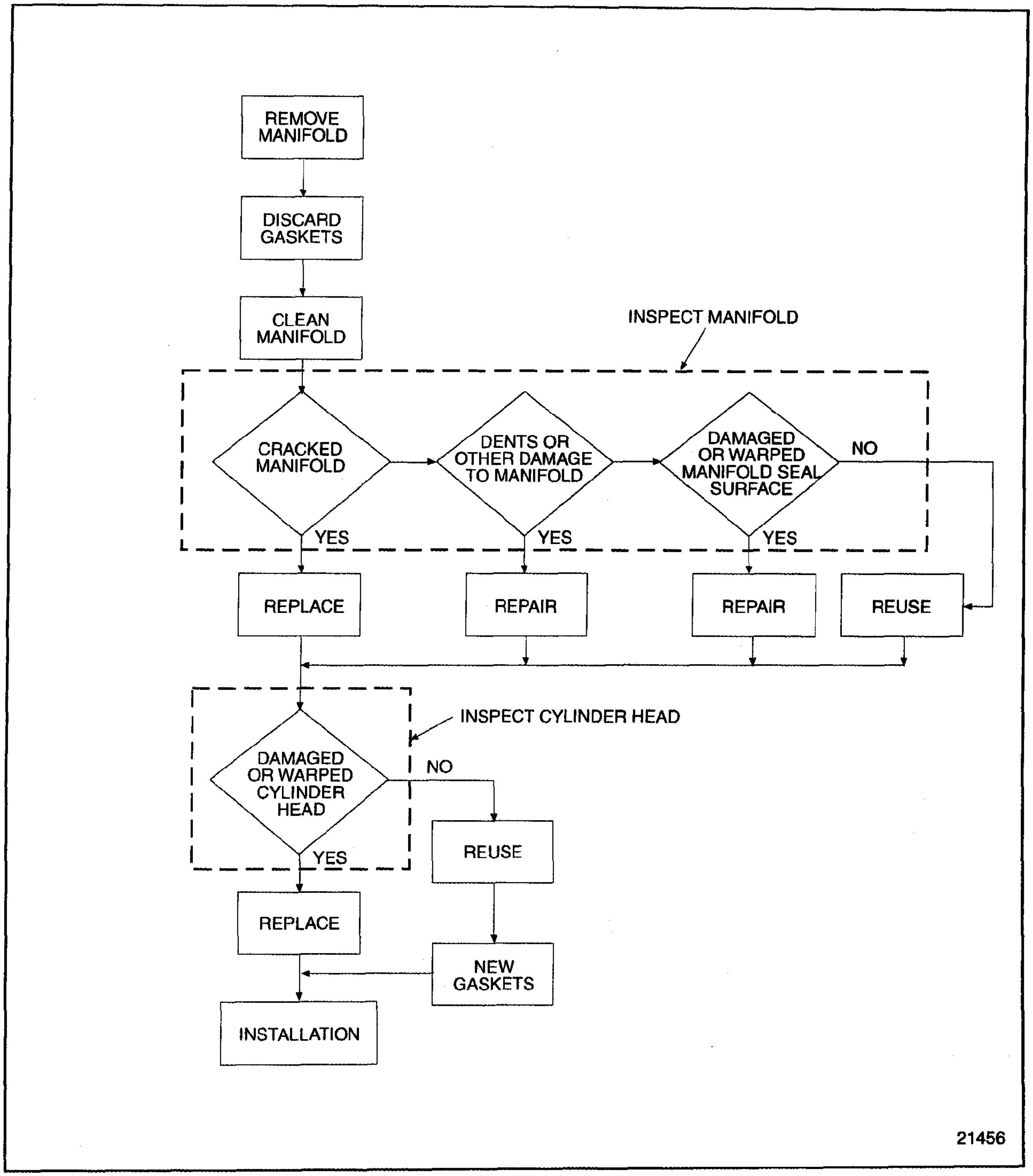



**Figure 6-10 Flowchart for Repair or Replacement of Intake Manifold**

### 6.4.2 Removal of Intake Manifold

Remove the intake manifold as follows:

1. Disengage the locking tang on the turbo-boost pressure sensor connector. Grasp the connector body and pull it straight out of the turbo-boost pressure sensor.
2. Remove the turbo boost sensor. Refer to section 2.22.2.
3. Remove air temperature sensor. Refer to section 2.26.2.
4. If servicing a DDEC III/IV engine, disengage the locking tang on the air temperature sensor connector. Grasp the connector body and pull it straight out of the air temperature sensor.
5. Loosen the hose clamps connecting the hose coupling between the intake manifold and the CAC ducting. Slide the clamps and hose away from the intake manifold (diesel), or the elbow from the throttle (natural gas).
6. Remove the air compressor intake air line from the bottom of the intake manifold if used. Refer to section 10.1.5.
7. Remove the seven bolts that retain the intake manifold to the cylinder head.
8. Tap the intake manifold lightly to separate the intake manifold from the cylinder head.
9. Remove and discard manifold seals.

**NOTE:**
Units built prior to 6R0135846 may not have gasket seals.

10. Remove the intake manifold.

### 6.4.3 Cleaning of Intake Manifold

Clean the intake manifold, prior to inspection as follows:

| NOTICE: |
|---|
| When removing and cleaning the intake manifold and cylinder head, J 36571 *must* be used. Failure to do so may damage the intake manifold, cylinder head or both. |

1. Remove loose gasket material from the cylinder head and intake manifold mating surfaces.
2. To clean the intake manifold mating surface and the head port area, use the surface conditioning set J 36571. See Figure 6-11.
   [a] To clean steel surfaces use a coarse grit disc (brown), part of the surface conditioning set, J 36571 with an electric or air powered hand drill operating at a speed of 15,000-18,000 r/min. The pads are easily interchangeable using the disc holder provided in the set.

   [b] To clean aluminum surfaces use a medium grit disc (maroon), part of the surface conditioning set, J 36571 with an electric or air powered hand drill operating at a speed of 15,000-18,000 r/min. The pads are easily interchangeable using the disc holder provided in the set.

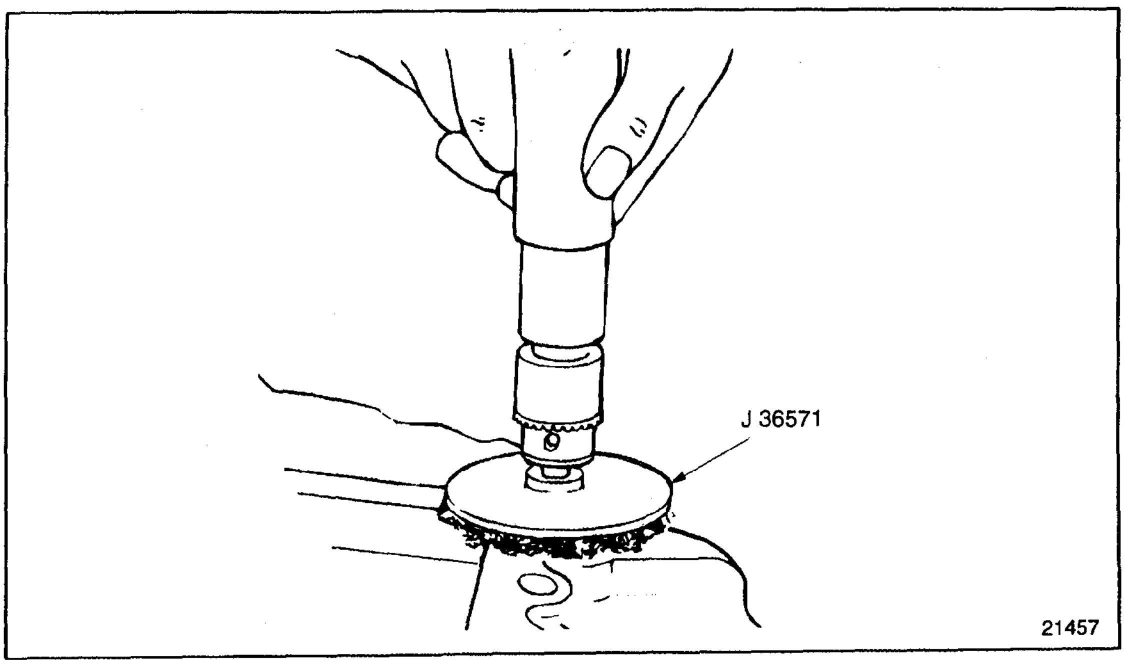



**Figure 6-11 Cleaning the Manifold**

3. Wash all of the parts in clean fuel oil.

| CAUTION: |
|---|
| **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.** |

4. Blow dry with compressed air.

### 6.4.3.1 Inspection of Intake Manifold

Inspect the intake manifold as follows:

1. Visually inspect the manifold for any cracks, dents or other damage. Pay particular attention to the bolt areas.
   [a] If a crack is found, replace the intake manifold. Refer to section 6.4.4.
   [b] If no cracks are found, reuse the intake manifold. Refer to section 6.4.4.
2. Inspect the manifold mating surface for imperfections that could affect its sealing to the cylinder head.
   [a] If the manifold mating surface has imperfections, replace the intake mainfold.
   [b] If the manifold mating surface is not damaged, reuse part. Refer to section 6.4.4.
3. Check the mating ports for warpage, using a 0.5 m (14 in.) long by 6 mm (1/4 in.) wide straight edge bar laying the bar across the manifold
   [a] If all port flange area measurements are less than 0.127 mm (0.005 in.), the manifold is reusable and can be reinstalled with new gaskets. Refer to section 6.4.4 for installation.
   [b] If the manifold does not meet this requirement the manifold *must* be resurfaced. Refer to section 6.4.4 for installation.

### 6.4.4 Installation of Intake Manifold

Install the intake manifold as follows:

| NOTICE: |
|---|
| It is necessary to completely seal the intake manifold to the cylinder head, due to the high pressure of the intake charge provided by the turbocharger. The arrow on the gasket must point to the front of the engine. Gasket eliminator can not be used with intake manifold seals. Failure to seal this interface will reduce engine performance. |

1. Install three new manifold gaskets to the mating surfaces of the intake manifold with the arrow on the gasket pointing to the front of the engine. See Figure 6-12.

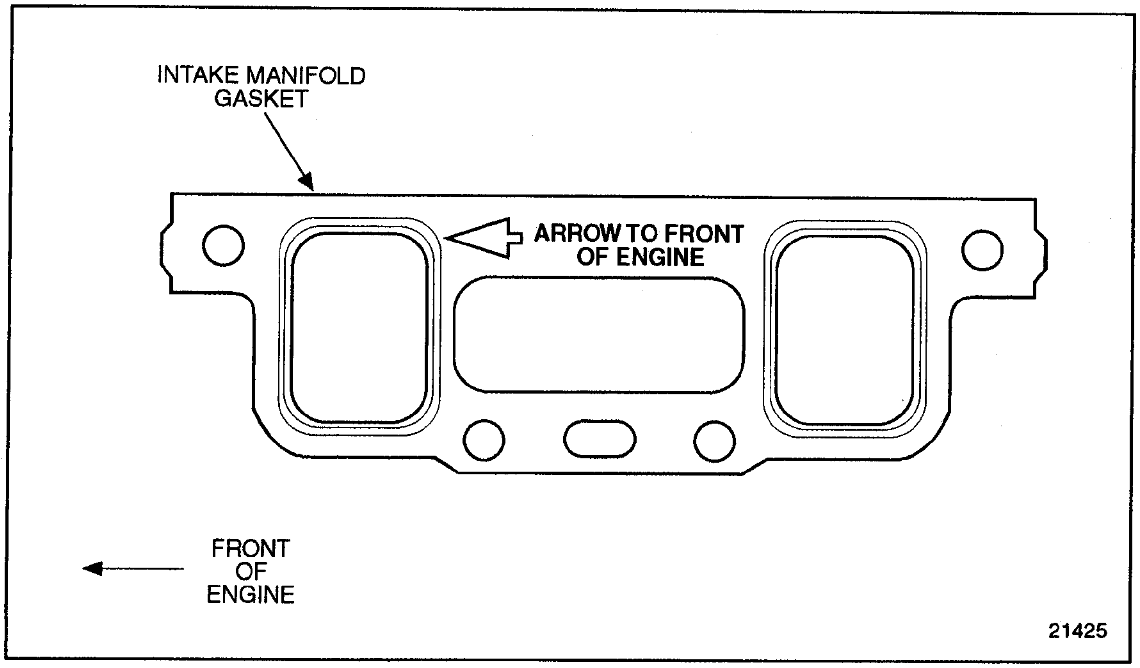



**Figure 6-12 Intake Manifold Gasket Orientation**

2. Install bolts six and seven through the intake manifold and into the cylinder head and hand-tighten. See Figure 6-13.

3. Install the five remaining bolts through the intake manifold and into the cylinder head. Torque all of the intake manifold retaining bolts to 58-73 N·m (43-54 lb·ft) in the proper torque sequence. See Figure 6-13.

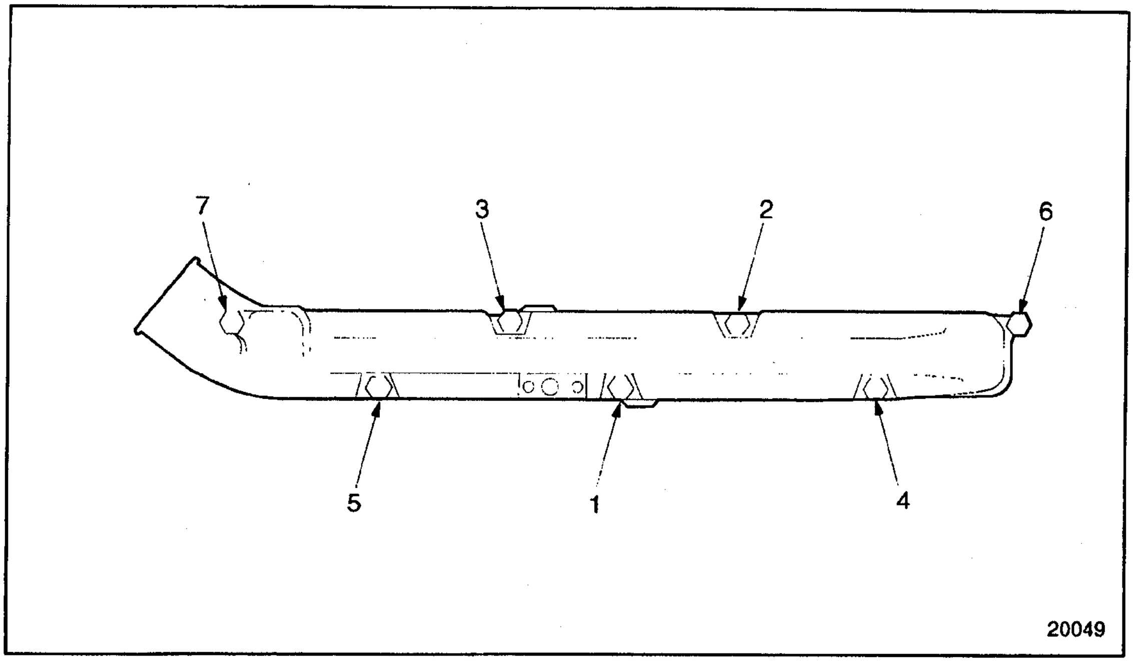



**Figure 6-13 Intake Manifold Bolt Position and Torque Sequence**

4. Plug in the turbo-boost pressure sensor wiring connector by pressing the connector into the body of the sensor until the locking tang snaps into place.
5. If servicing a DDEC III/IV engine, plug in the air temperature sensor wiring connector by pressing the connector into the body of the sensor until the locking tang snaps into place.

| NOTICE: |
| --- |
| Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC, CAC ducting or the intake manifold. Use of lubricant can cause the hose to blow off when the turbocharger builds boost pressure. |

6. Slide the hose over the intake manifold and position it to its original location.
7. Slide the hose clamps into place and tighten them alternately. Insure that hose clamps are installed away from the cast bead on the manifold inlet to prevent separation of the joint.

**CAUTION:**

**The air inlet manifold contains combustible gas. To avoid injury from explosion, do not connect the air inlet manifold to any devices or lines external to the manifold.**

8. Reattach air line to air compressor, if used, and tighten clamp. Refer to section 6.4.4.
9. Refer to section 11.8 for verification of proper intake manifold installation.

# 6.5 CLOSED CRANKCASE BREATHER FOR SERIES 60G AUTOMOTIVE ENGINES

Closed breathers are required for natural gas automotive engines in 1998. The Series 60G engine uses a remote mount Racor CV4500 Crankvent breather/filter. See Figure 6-14.

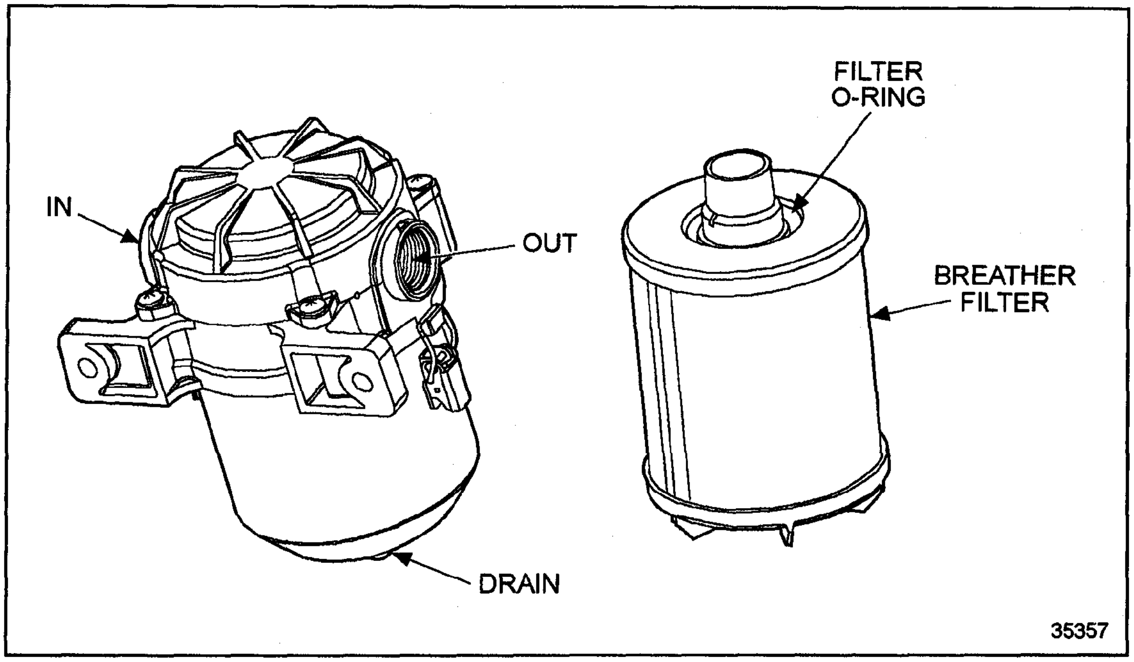



**Figure 6-14 Crankvent and Breather Filter**

The Crankvent contains a coalescing filter to remove liquid from the blowby gas. The liquid that is coalesced from the blowby is drained back to the ground. The blowby gas is routed out of the rocker cover, through the filter element and returns to the inlet side of the turbo.

### 6.5.1 Replacement of the Closed Crankcase Breather

The Crankvent coalescing filter is a nonservicable component but should be changed in conjunction with oil service intervals. Refer to section 13.10.3.

### 6.5.2 Removal of Closed Crankcase Breather

Remove the closed crankcase breather as follows:

1. Release latches on the side of the breather assembly and lower canister away from the assembly.
2. Remove the filter from the assembly.
3. Dispose of the used filter in an environmentally responsible manner.
4. Clean the filter canister with a clean lint-free cloth.

### 6.5.3 Installation of the Closed Crankcase Breather Filter

Install the closed crankcase breather filter as follows:

1. Insert new filter into the top of the assembly, ensuring the new filter contains the top O-ring. See Figure 6-14.
2. Replace the lower canister ensuring the larger O-ring is secure in the top half of the assembly.
3. Secure the latches on the side of the can.
4. There are two O-rings in the system. One on the filter element itself and one that seals between the lower canister and the upper body. Ensure both O-rings are secure before reassembling the crankvent.

# 6.6 TURBOCHARGER (DIESEL)

The turbocharger is designed to increase the overall power and efficiency of the engine. Power to drive the turbocharger is extracted from the energy in the engine exhaust gas.

A turbocharger can be broken down into three basic pieces; a compressor cover, a center housing rotating assembly (CHRA), and a turbine housing.

The compressor cover provides a hose connection for the compressor inlet, and a V-band connection for the compressor outlet. The compressor cover is secured to the compressor side of the CHRA, and encloses the compressor wheel.

The CHRA contains a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel, and wheel retaining nut. This rotating assembly is supported on two pressure-lubricated bearings that are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings, thrust washer, thrust collar, and thrust spacer.

The turbine housing is a heat-resistant steel alloy casting that encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing.

The Garrett (formerly Airesearch) family of turbochargers look similar. The model TV51 turbocharger is used on all Series 60 diesel engines through the 1989 models. The TV45 turbocharger is used on 1991 and later 11.1 liter displacement diesel engines. See Figure 6-15.

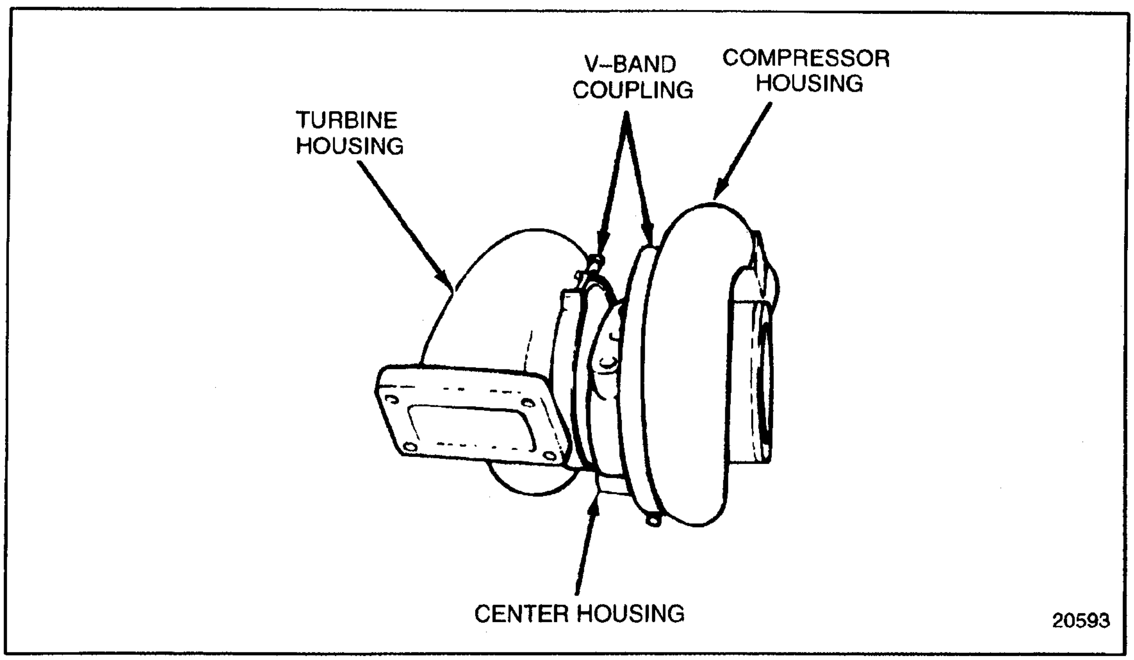



**Figure 6-15 TV45, TV51 Turbocharger Assembly**

A turbocharger with a water-cooled turbine housing is installed on all heat exchanger-cooled marine engines. This turbocharger is similar to "dry" turbochargers, except that it incorporates a water-jacketed turbine housing. The coolant supply line is located at the bottom of the turbine housing, and the return/bypass line is located at the top. The water-cooled turbocharger operates as follows:

Coolant from the fresh water pump flows through the supply line into the turbine housing. As it circulates through the housing, it picks up heat from the exhaust gasses used to drive the turbocharger. The heated coolant then passes into the thermostat housing and flows back to the heat exchanger, thus lowering its temperature. See Figure 6-16. Pressurized air from the turbocharger compressor outlet passes directly into the raw water-cooled charge air cooler/air intake manifold assembly, providing charge air for combustion. See Figure 6-17.

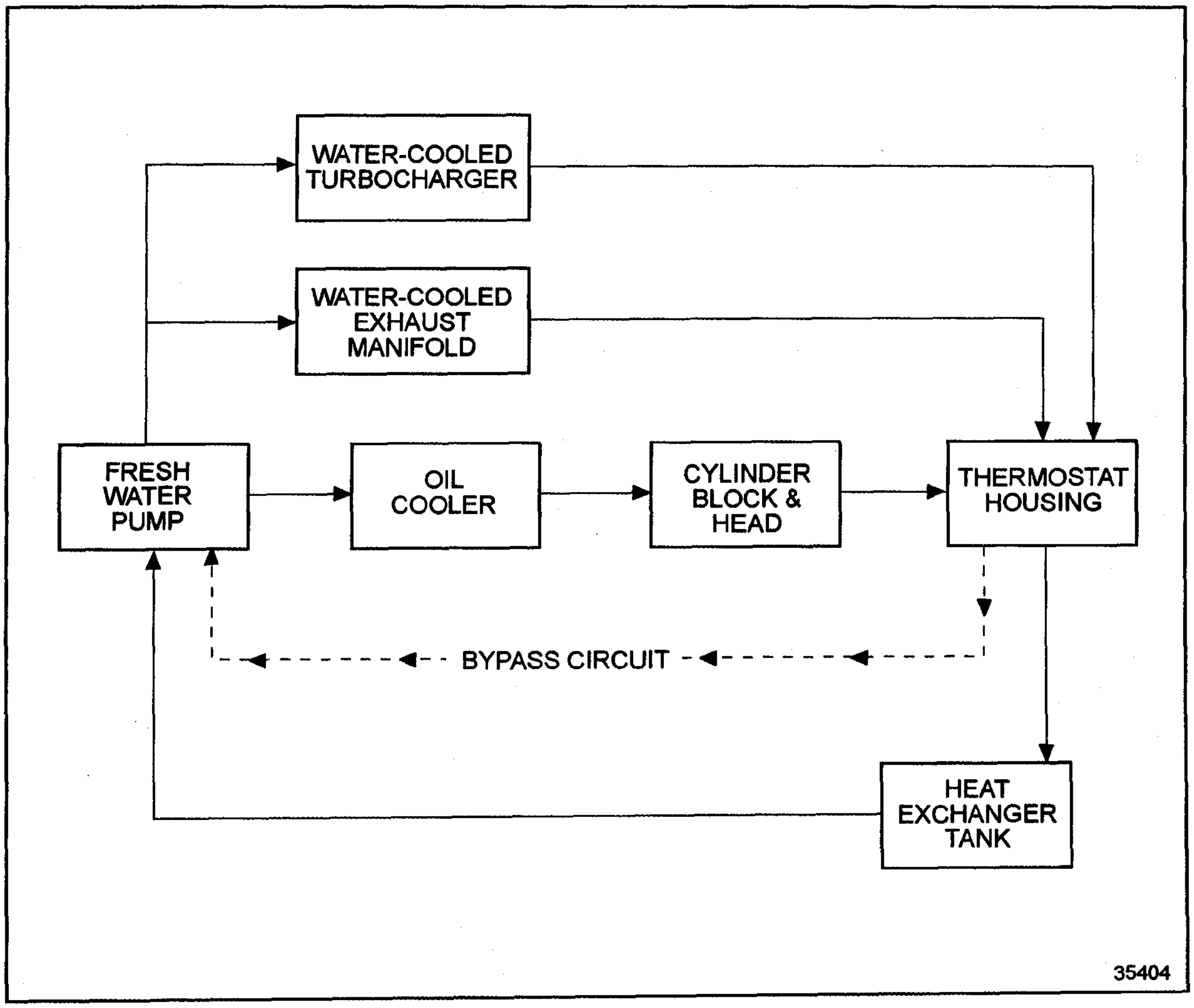
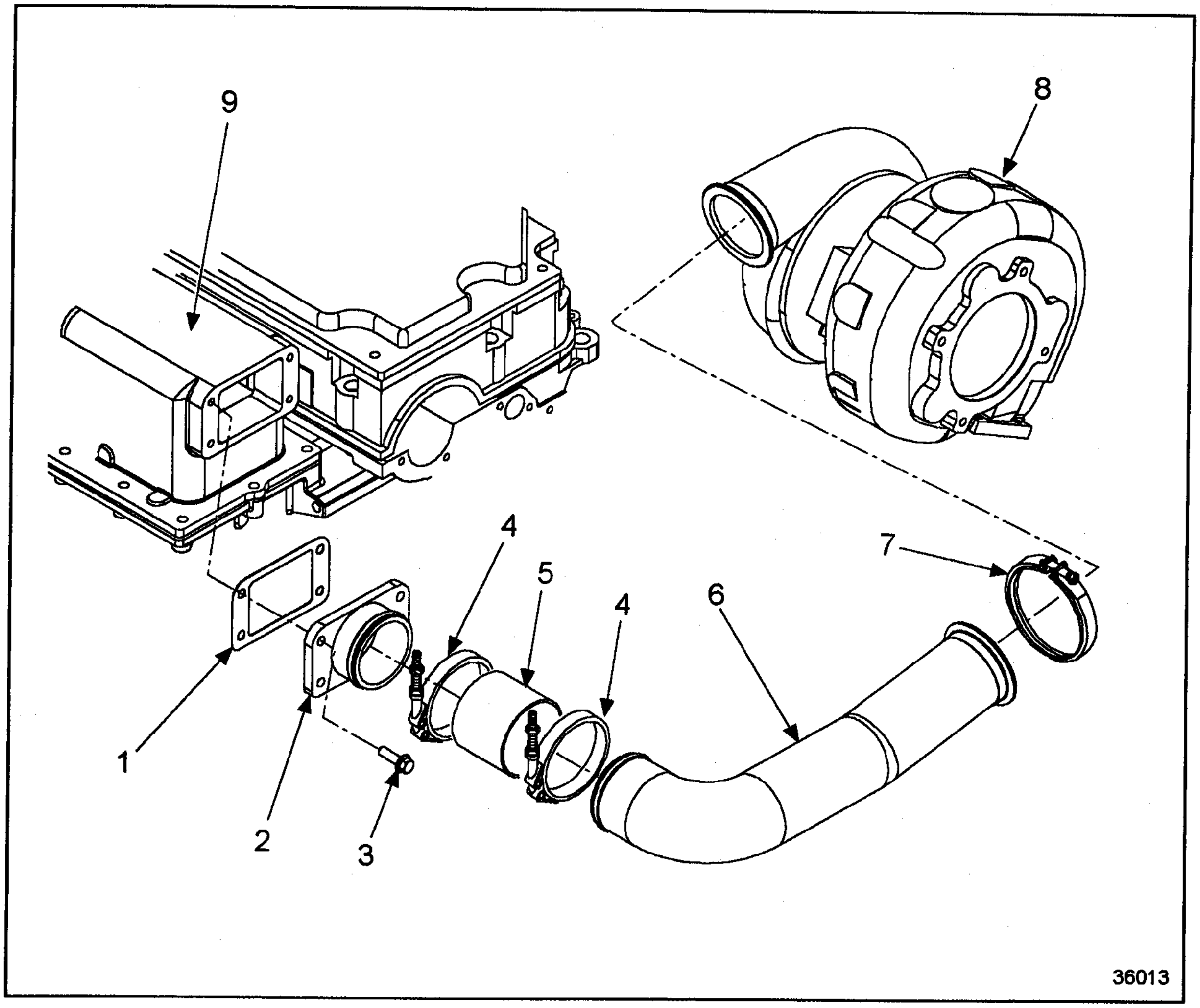



**Figure 6-16 Fresh Water Cooling Circuit**




1. Gasket
2. End Plate
3. Bolt
4. Clamps, Hose
5. Hose
6. Air Inlet Tube
7. Clamps, Marmon - Style
8. Water-Cooled Turbocharger
9. Charge Air Cooler/Air Intake Manifold Assembly

**Figure 6-17 Typical Heat Exchanger-Cooled Pleasure Craft Marine Turbocharger and Charge Air Cooler/Air Intake Manifold Installation**

The TMF turbocharger is used on 1990 and later 12.7 liter displacement engines, except heat exchanger-cooled pleasure craft marine engines. See Figure 6-18.

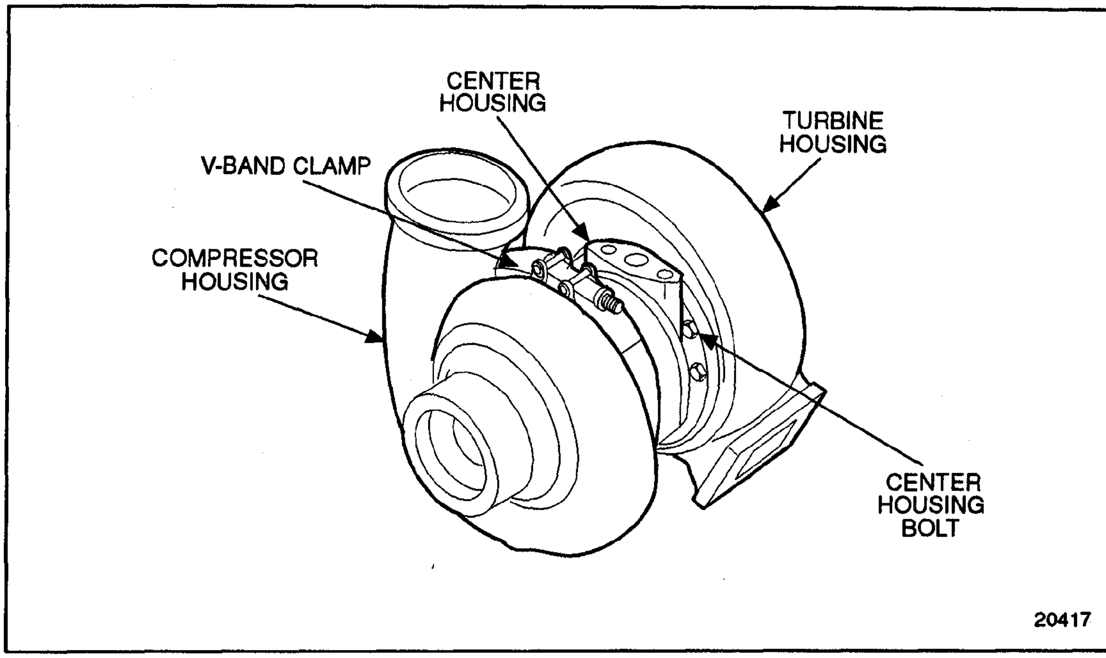



**Figure 6-18 TMF Turbocharger Assembly**

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flow from the engine and through the turbine housing causing the turbine wheel and shaft to rotate. See Figure 6-19.

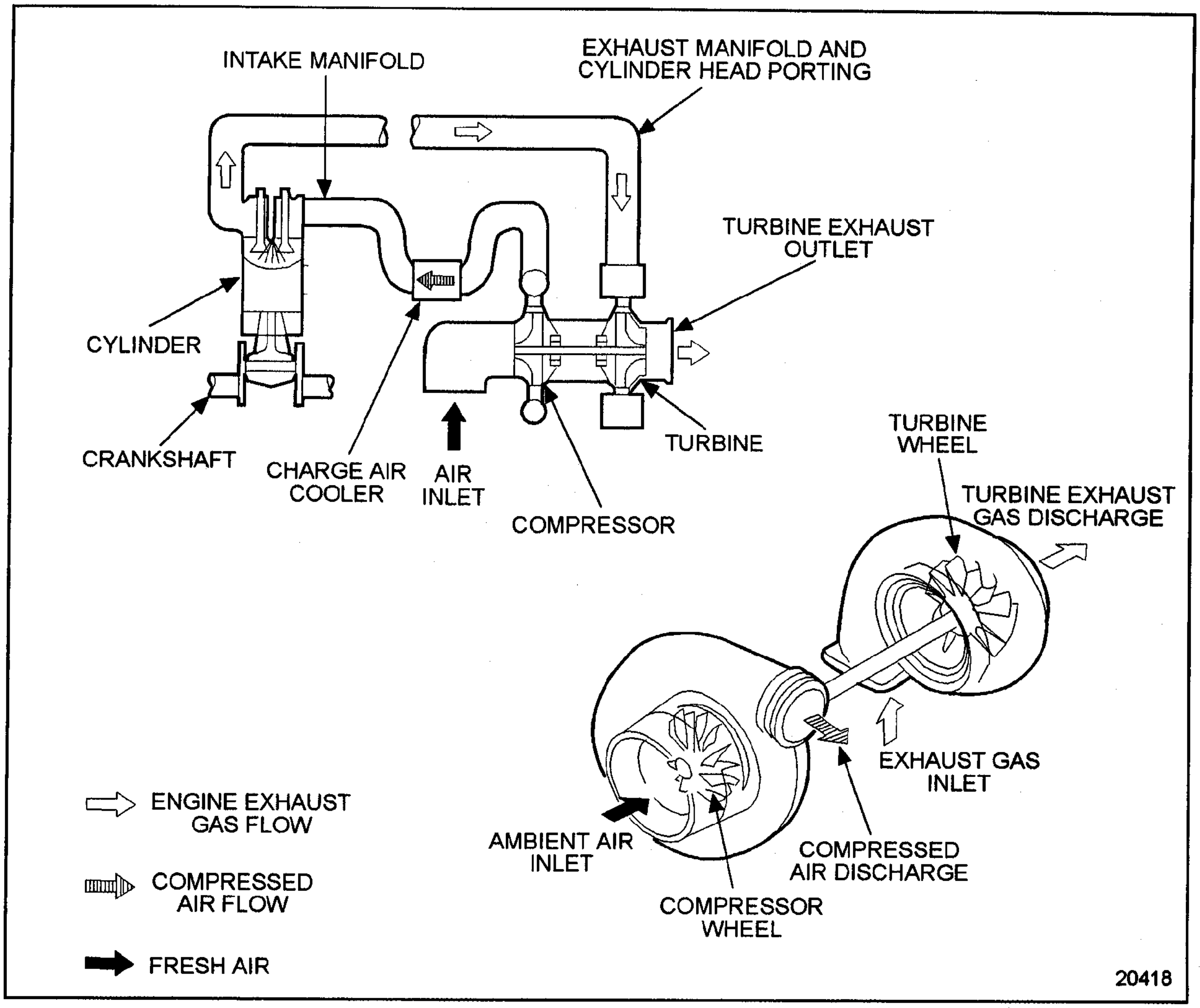


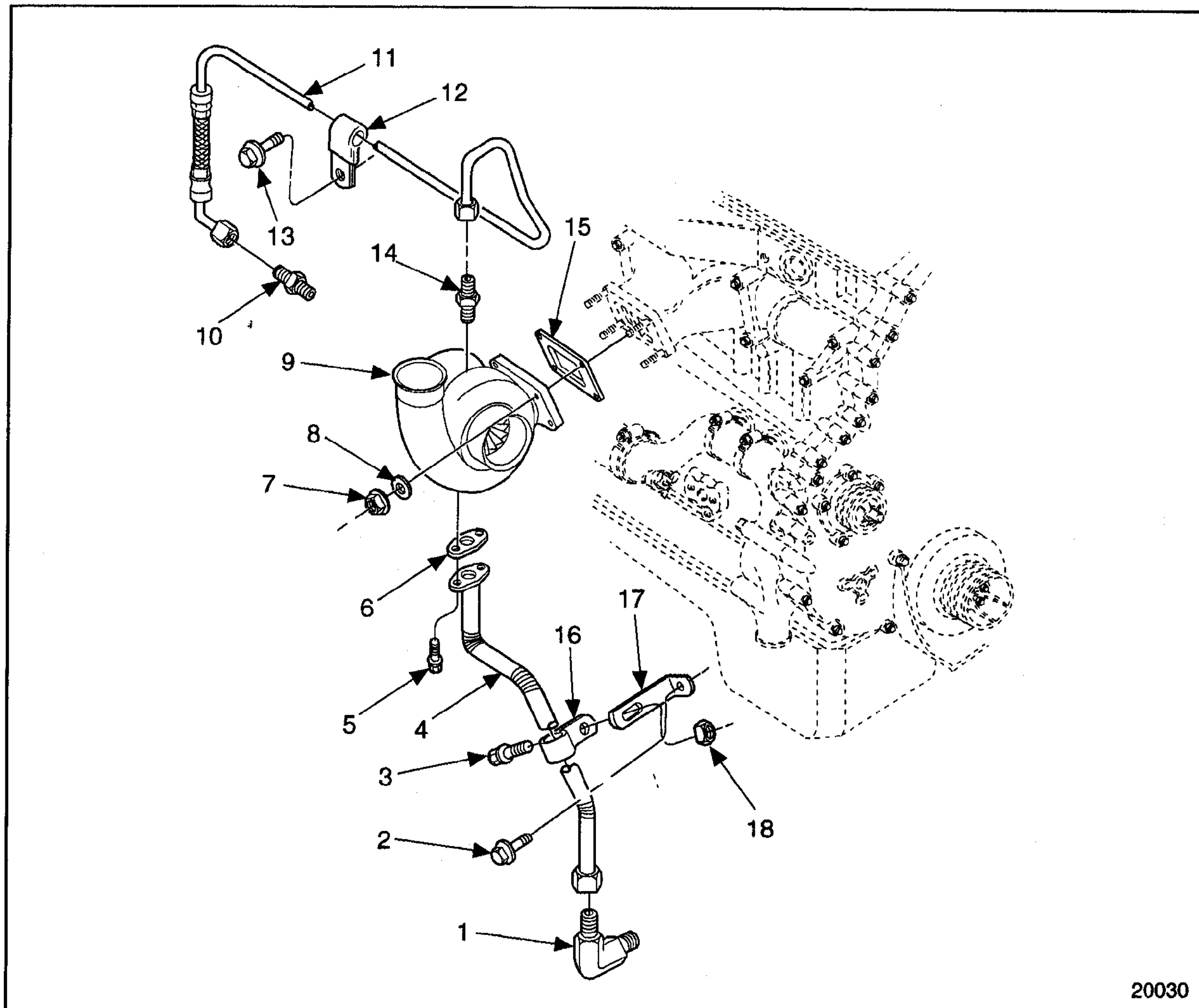

**Figure 6-19 Schematic Air Flow Diagram**

The gases are discharged into the exhaust system after passing through the turbine housing.

The compressor wheel, in the compressor housing, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in clean air, compresses it, and delivers high pressure air through the intake manifold to the engine cylinders.

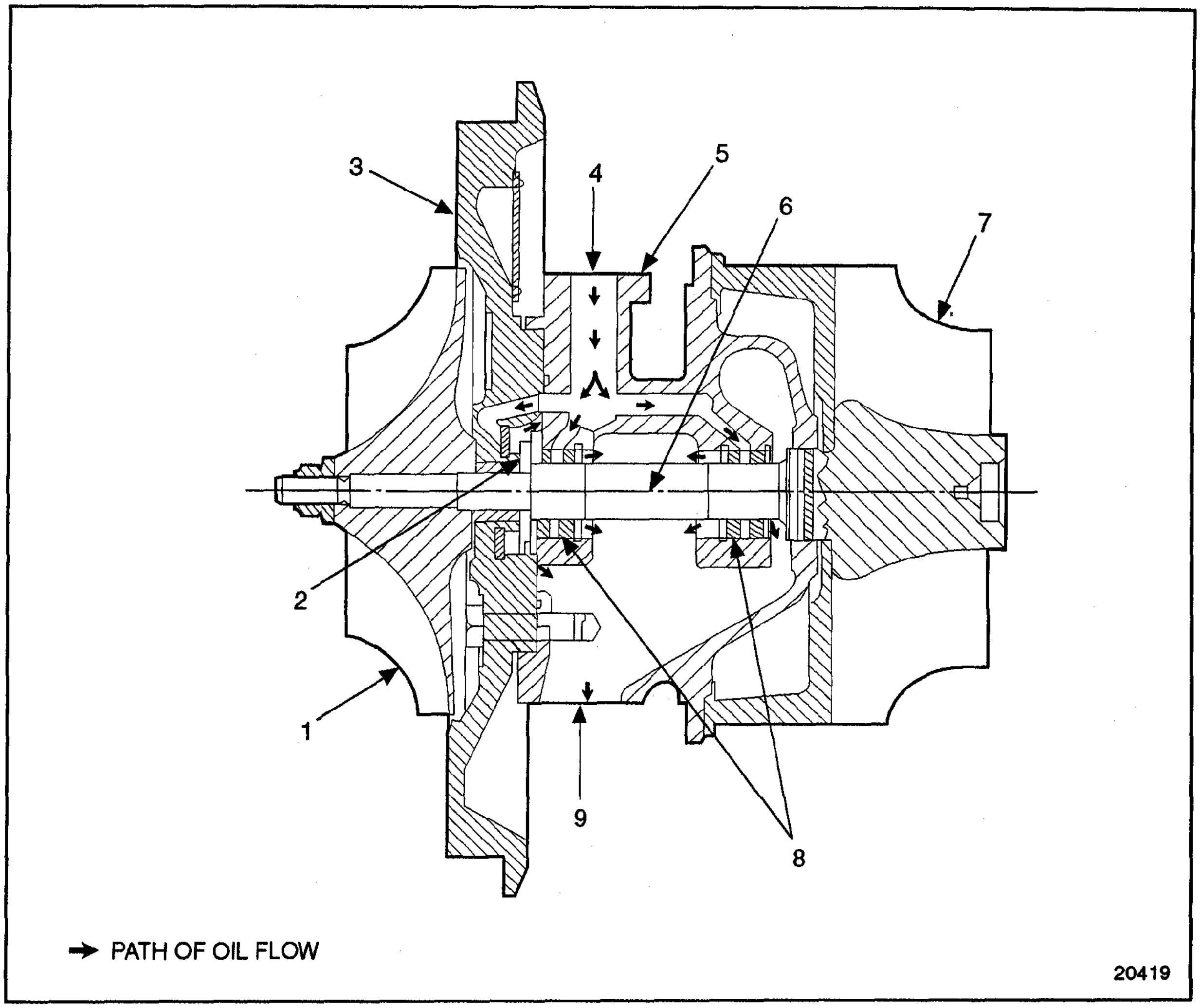
Oil for lubricating the turbocharger is supplied under pressure through an external oil line extending from the oil filter adaptor to the top of the center housing. See Figure 6-20.




1. Elbow, Oil Drain Tube
2. Bolt, Mounting Bracket
3. Bolt, Oil Drain Tube Clip
4. Tube, Turbo Oil Drain
5. Bolt, Oil Drain Tube Mounting
6. Gasket, Turbo Oil Drain Tube
7. Nut, Turbo Mounting
8. Washer, Turbo Mounting
9. Turbocharger Assembly
10. Connector, Oil Supply Tube
11. Tube Assembly, Turbo Oil Supply
12. Clip, Oil Supply Tube
13. Bolt, Oil Supply Tube Clip
14. Connector, Oil Supply Tube (to turbocharger)
15. Gasket, Turbo Exhaust Inlet
16. Clip, Oil Drain Tube
17. Bracket, Oil Drain Tube Clip Mounting
18. Nut, Oil Drain Tube Clip

**Figure 6-20 Turbocharger Oil Lines — All Engines (Except Heat Exchanger-Cooled Pleasure Craft Marine)**

From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing, and backplate or thrust plate. See Figure 6-21.




1. Compressor Wheel
2. Thrust Bearing
3. Backplate
4. Oil Inlet
5. Center Housing
6. Shaft
7. Turbine Wheel
8. Shaft Bearings
9. Oil Outlet

**Figure 6-21 Turbocharger Oil Flow Diagram**

The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block. See Figure 6-20.

If the turbocharger is water-cooled, the coolant supply line is connected to the bottom of the turbine housing, and the coolant return/bypass line is connected to the top. Coolant from the fresh water pump flows through the supply line into the turbine housing, passes into the thermostat housing then flows back to the heat exchanger, thus lowering its temperature.

## 6.6.1 Repair or Replacement of Turbocharger

To determine if repair is possible or replacement of the turbocharger is necessary perform the following procedure. See Figure 6-22.

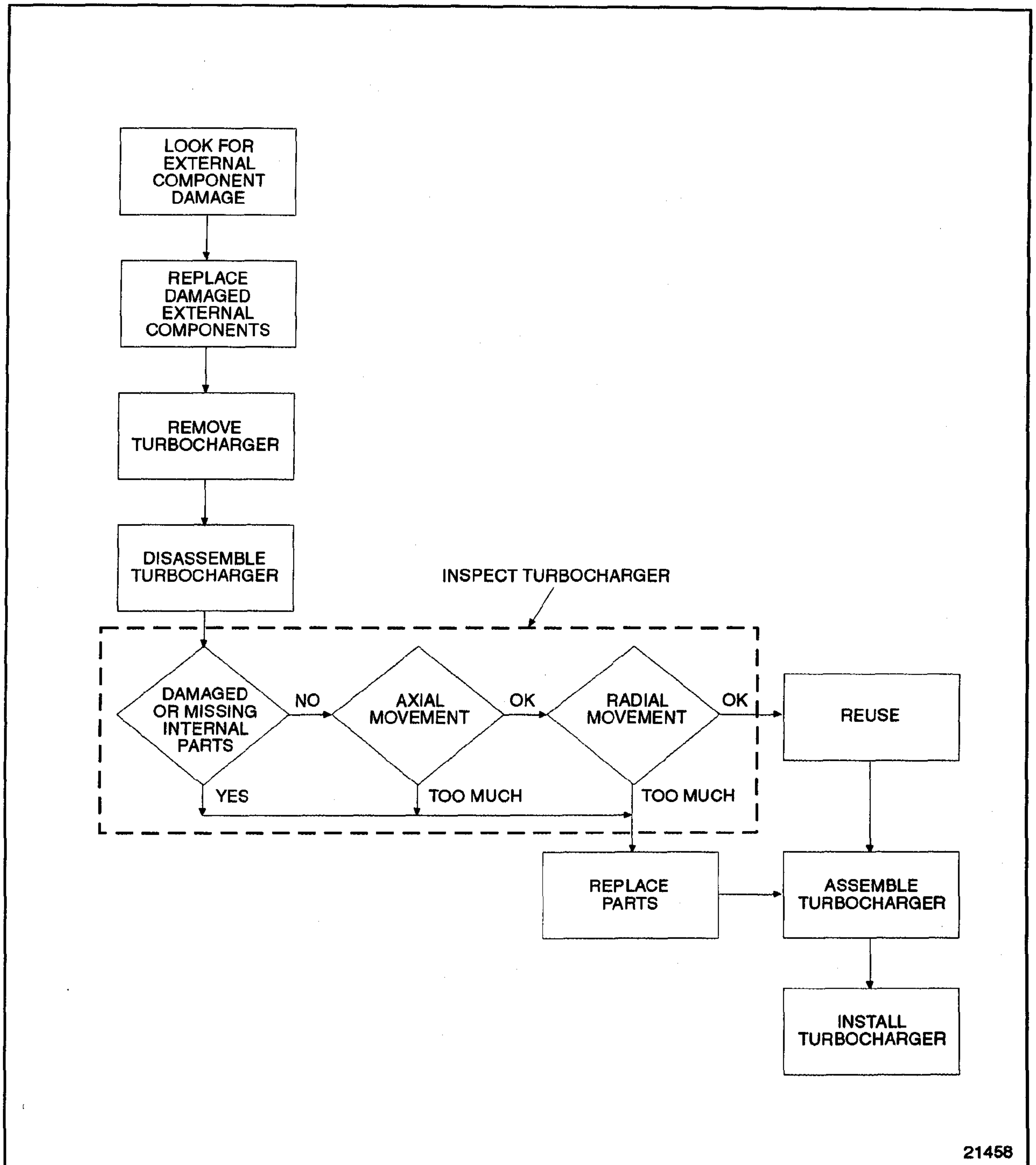



**Figure 6-22 Flowchart for Repair or Replacement of Turbocharger**

### 6.6.2 Removal and Cleaning of Turbocharger

Cleaning the turbocharger is not necessary before removal.

**CAUTION:**

**To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.**

**CAUTION:**

**To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.**

Many Series 60 engines use turbochargers with ceramic turbine (exhaust) wheels. To avoid ceramic wheel damage, care must be taken to remove debris after servicing the air intake and exhaust systems on these engines.

| NOTICE: |
|---|
| If the ceramic wheel becomes damaged or bursts, Detroit Diesel recommends replacing the exhaust system muffler if positioned in such a way that debris will fall back into the turbine housing. This precaution will prevent damage to the turbocharger at engine start-up. |

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil supply and drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage or coolant leakage, if water-cooled.
6. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

| NOTICE: |
|---|
| Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup. |

1. Disconnect and remove the CAC ducting at the compressor housing.
2. Disconnect and remove the air inlet hose attached to the compressor housing. Refer to section 6.10.2.
3. Disconnect the exhaust outlet pipe from the turbine housing of the turbocharger. For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.
4. Remove the inlet oil line from the top of the center housing.
5. Remove the oil drain line from the bottom of the center housing.
6. If turbocharger is water-cooled, drain coolant into a suitable container until engine coolant level is below the turbine inlet flange. Remove coolant inlet and outlet hoses from turbocharger.
7. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
8. Remove the nuts securing the turbocharger assembly to the exhaust manifold. Then, lift the turbocharger assembly away from the engine and place it on a bench.

9. Cover the end of the oil drain line, the oil outlet line, coolant inlet and outlet hoses (if water-cooled turbocharger), the air inlet and the exhaust outlet openings on the engine and turbocharger, to prevent the entry of foreign material.

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

10. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly.

### 6.6.3 Disassembly of Turbocharger

Prior to disassembly, the exterior of the turbocharger must be cleaned. Refer to section 6.6.2, step 10

Disassemble the turbocharger as follows:

1. Mark the related positions of the compressor housing, center housing and turbine house with a punch or scribe to assure reassembly in the same relative position.

**NOTICE:**

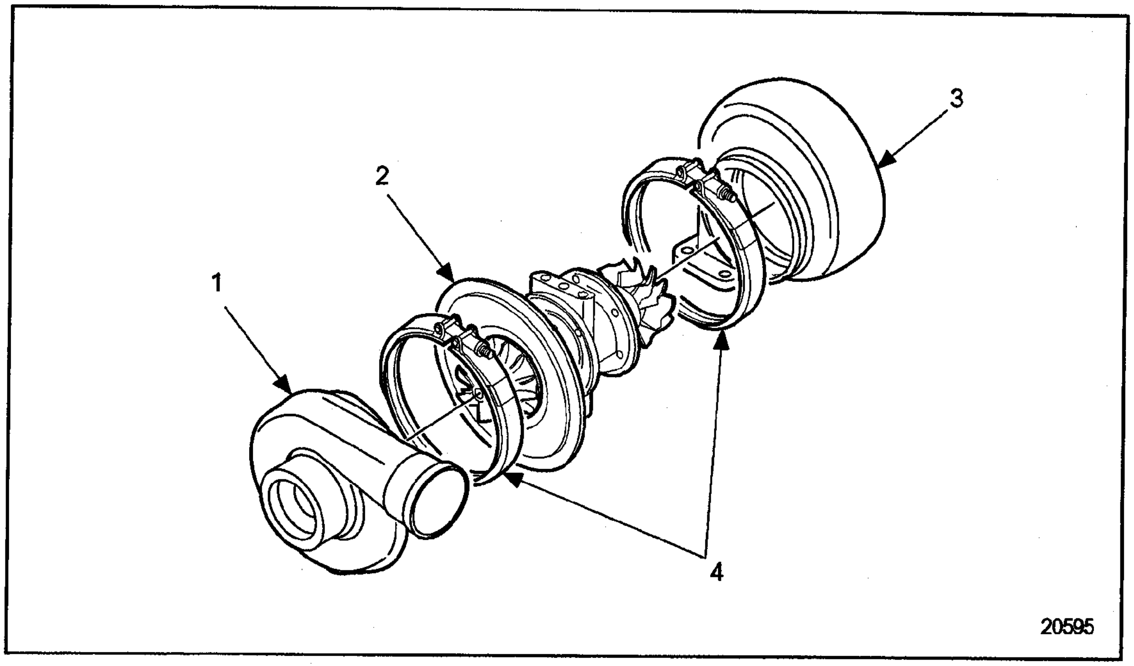
Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen the V-band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and V-band.

3. Perform the following steps to disassemble the TV45 or TV51 turbocharger: See Figure 6-23.

   [a] Loosen the V-band coupling securing the turbine housing to the center housing.

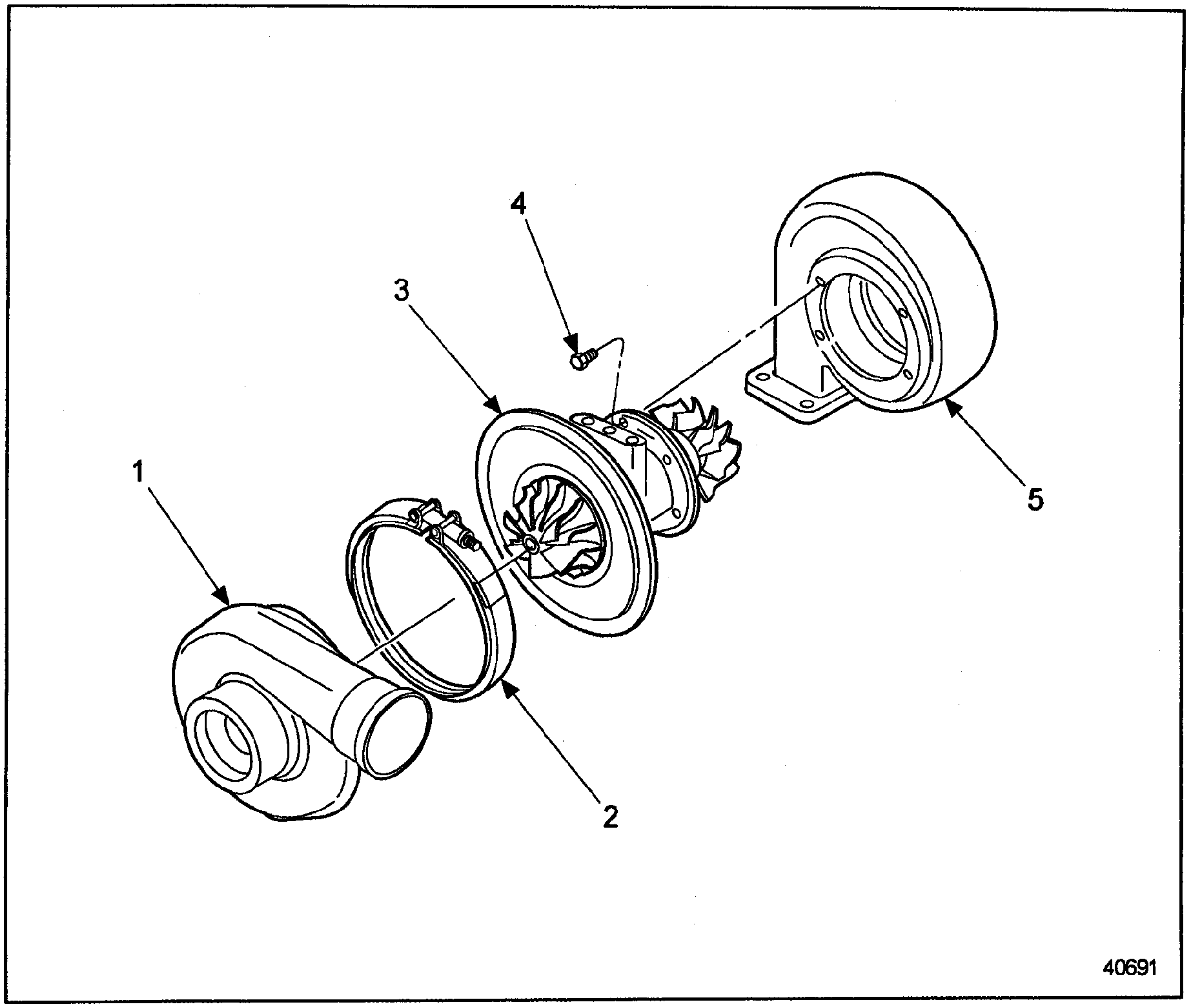
   [b] Remove the turbine housing from the center housing.




1. Compressor Housing
2. Compressor Housing and Rotating Assembly
3. Turbine Housing
4. V-band Couplings

**Figure 6-23 Typical Turbocharger**

4. Perform the following steps to disassemble the TMF turbocharger. See Figure 6-24.
   [a] Remove the four bolts securing the turbine housing to the center housing. If they are 3/8 in. hex-head bolts, discard them and replace with new 5/8 in. hex-head bolts.
   [b] Remove the turbine housing from the center housing.




1. Compressor Housing
2. V-band Coupling
3. Center Housing Rotating Assembly
4. Bolt
5. Turbine Housing

**Figure 6-24 Series TMF Turbocharger**

### 6.6.3.1 Inspection of Turbocharger

Inspect the disassembled turbocharger, discarding any damaged parts, in the following manner:

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.
3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.
4. Check the bearing axial end play:

   [a] Clamp the center housing assembly in a bench vise equipped with soft jaws. See Figure 6-25.

   [b] Fasten the dial indicator and magnetic clamp, part of magnetic base dial indicator set, J 7872, to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. See Figure 6-25.

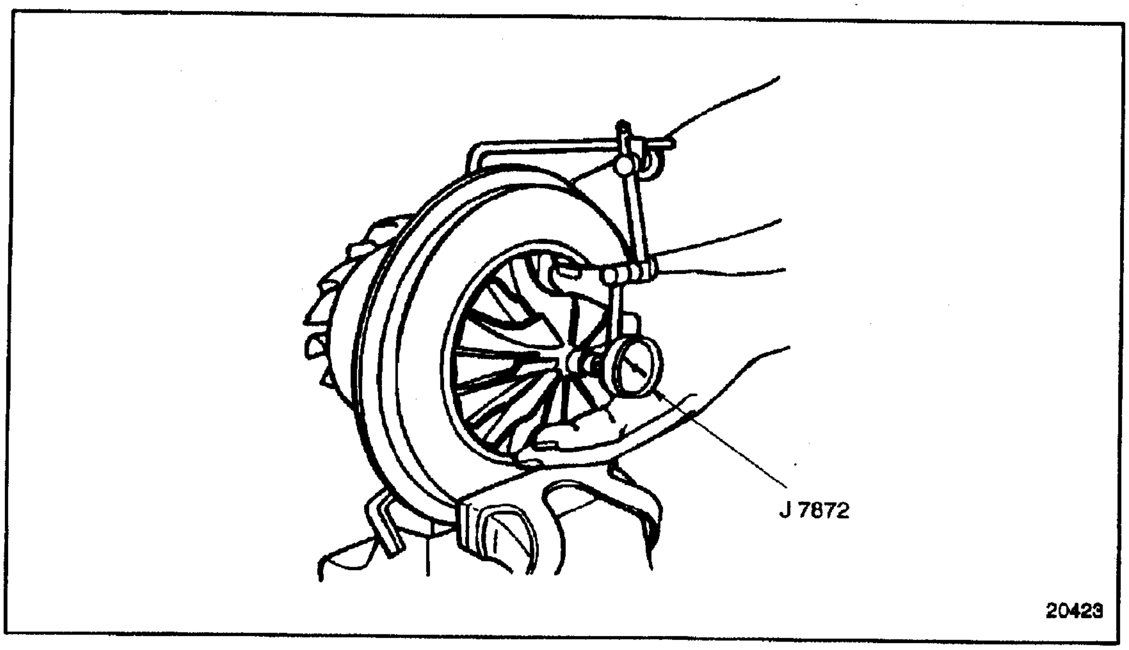



**Figure 6-25 Checking Bearing Axial End Play**

   [c] Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be 0.004-0.009 in. (0.1016-0.2286 mm) for TMF turbochargers. The total indicator reading should be 0.003 to 0.010 in. (0.0762-0.254 mm) for TV45 and TV51 turbochargers. If the total dial indicator readings do not fall within the specified limits, replace the rotating assembly.

5. Check the shaft radial movement as follows:

   [a] Install the turbo shaft checker, J 39164, to the oil drain opening of the center section. The special curved end of the tool must contact the wheel shaft through the oil outlet port and an internal opening in the center section casting. See Figure 6-26.

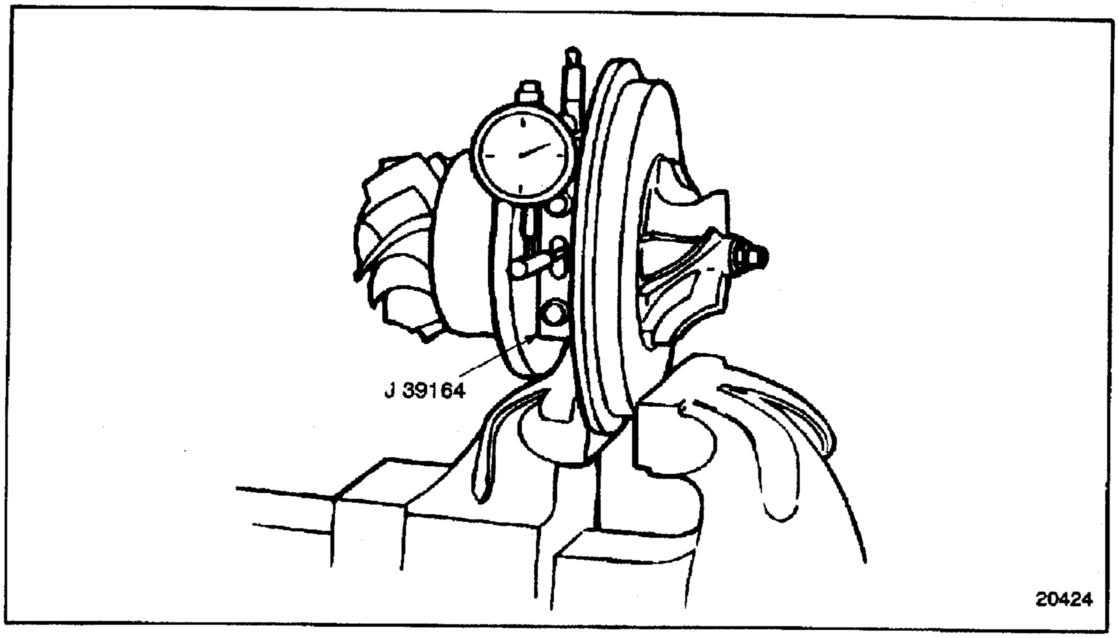



**Figure 6-26 Checking Shaft Radial Movement**

   [b] Install a dial indicator. See Figure 6-26.

   [c] Place the swivel adaptor, part of magnetic base dial indicator set, against the scribed line of the turbo shaft checker, J 39164.

   [d] Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The total indicator reading (radial movement) should be 0.005 -0.007 in. for TMF turbochargers. The total indicator reading should be 0.005 -0.0065 in. (0.127-0.165 mm) for TV45 and TV51 turbochargers. If the total indicator readings do not fall within the specified limits, replace the rotating assembly.

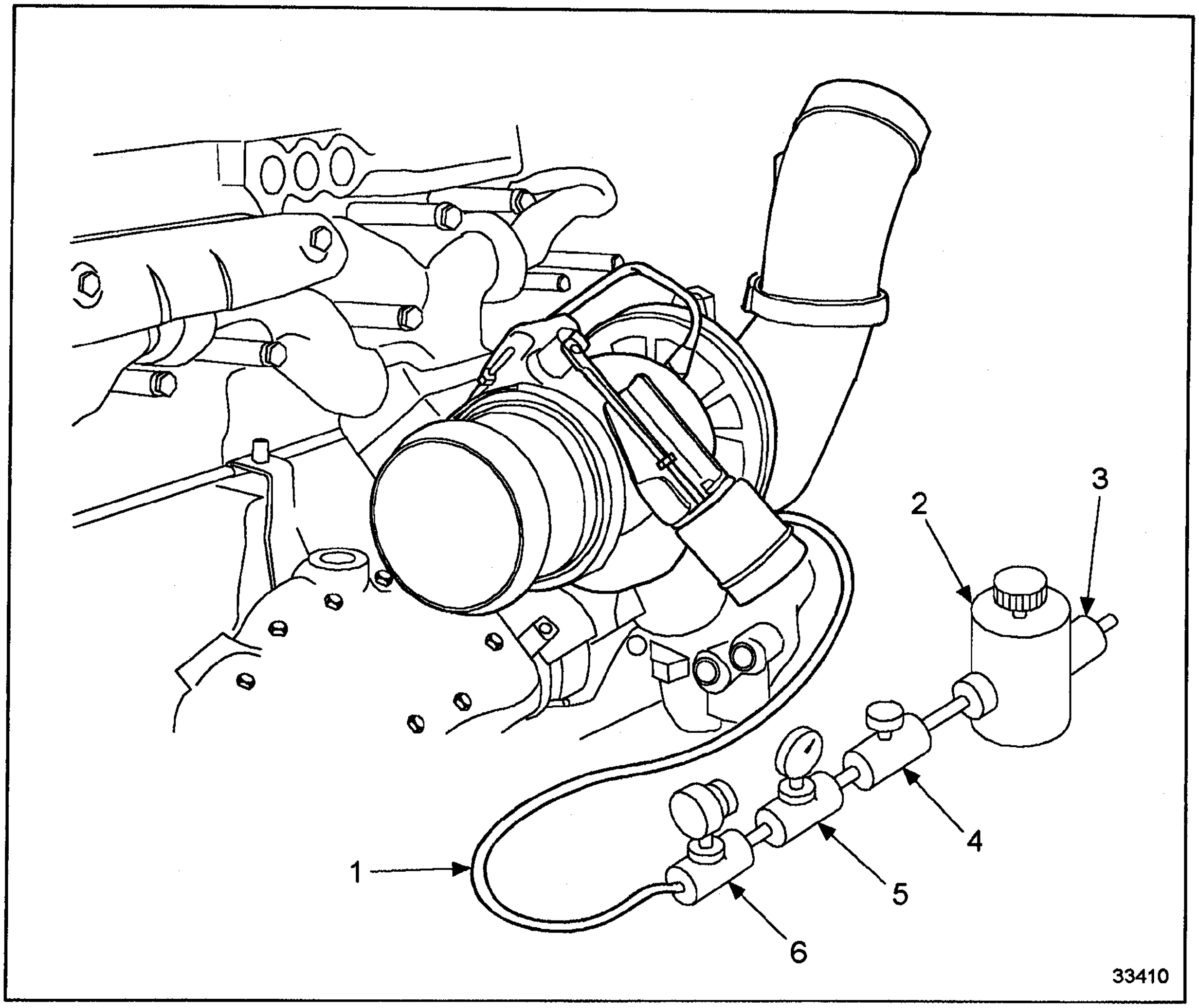
### 6.6.3.2 Checking Wastegate Calibration

Check the wastegate calibration as follows:

**NOTE:**
Turbochargers used on some engines do not have wastegates.

1. Remove hose from wastegate actuator.
2. Set up an indicator at the end of the wastegate actuator adjusting rod to measure actuator rod travel. The indicator should have a minimum travel of 0.100 in.

3. Connect regulator and pressure gage setup to wastegate actuator. See Figure 6-27.




1. Hose to Wastegate Actuator
2. Pressure Regulator
3. Shop Air Supply
4. Supply Air Shutoff Valve
5. Pressure Gage
6. Vent Valve

**Figure 6-27 Checking Wastegate Calibration**

4. Apply specified calibration pressure as listed in Table 6-1, to the wastegate actuator.

| Model | Rating | Set Pressure Travel at 0.04 in. Rod |
|---|---|---|
| 11.1 L | 330-350 Hp | 27 lb/in.$^2$ (186 kPa) |
| 12.7 L | 360-500 Hp | 31 lb/in.$^2$ (214 kPa) |

**Table 6-1 Wastegate Calibration Pressure at 0.04 Inch Rod Travel**

5. Close air supply shutoff valve. The pressure should hold at the specified pressure. If not, check air hose and fitting connections for leaks. If none are found, replace wastegate actuator. Refer to section 6.6.4.
6. Open vent to relieve pressure. Check gage for zero pressure reading. Adjust regulator to zero pressure and close vent valve.
7. Adjust dial indicator so it just contacts the actuator rod end and adjust to zero reading.
8. Open air supply shutoff valve and slowly adjust regulator until dial indicator reads 0.040 in. Switch pressure on and off, opening and closing supply air and vent valves, to ensure dial indicator travel is from 0.00 in. to 0.040 in. and that the pressure reading is consistent.
9. For currently calibrated wastegate actuator, a pressure within ± 0.50 lb/in.$^2$ (3.4 kPa) of the value listed in Table 6-1, will be required to obtain precisely 0.040 in. actuator travel. If the pressure required is outside this range, wastegate adjustment is necessary. Refer to section 6.6.5.1.

### 6.6.4 Removal of Wastegate Actuator

Remove the wastegate actuator as follows:

1. Remove actuator hose from top side of actuator can. See Figure 6-27. With the pressure gage setup, apply enough pressure to the actuator can until the rod begins to move. Lifting the wastegate valve off its seat.
2. Remove the retaining clip that holds the actuator rod end on the worm pin. Lift rod off the wastegate lever pin.

| NOTICE: |
| --- |
| Never remove the rod end from the wastegate lever pin without applying pressure to the top side actuator port, or damage to the actuator diaphragm may result. |

3. Remove the locknuts that secure the actuator can to the base of the actuator bracket and remove the can from the turbocharger assembly.

### 6.6.5 Installation of Wastegate Actuator

Further adjustment of the actuator will be necessary to achieve the correct pressure setting, listed in Table 6-1.

Install the wastegate actuator as follows:

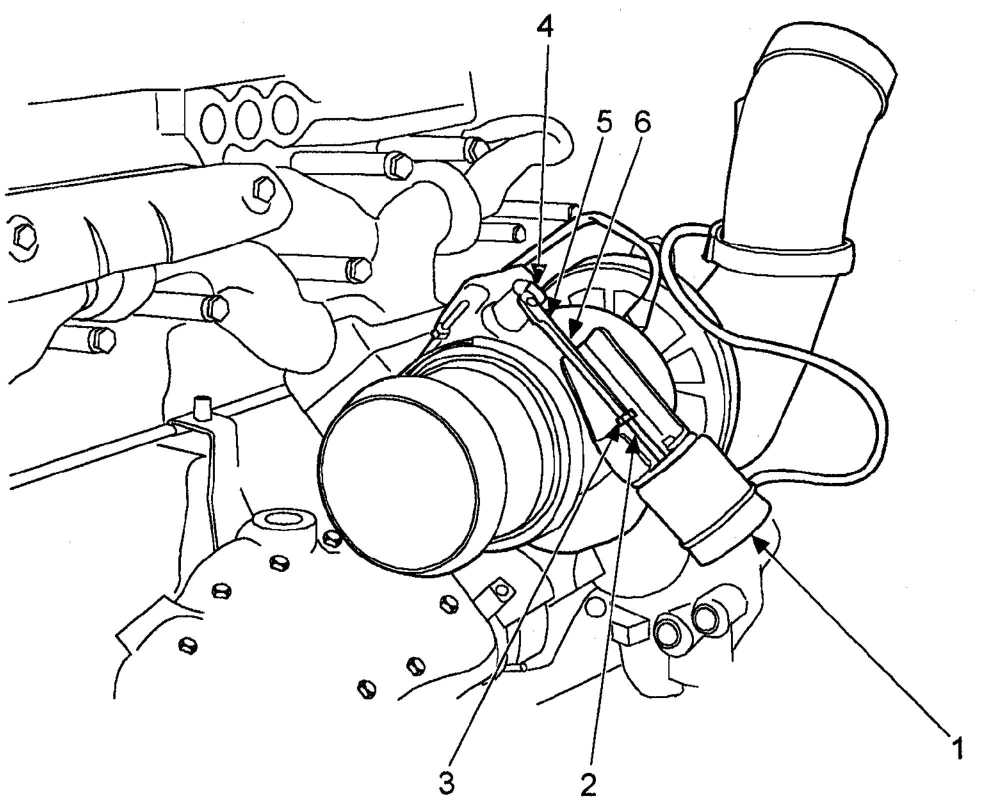
1. Install actuator can on bracket; tighten locknuts.
2. Using pressure gage setup, apply enough pressure to the new service actuator can until the rod begins to move.
3. Adjust actuator rod end by turning either clockwise or counterclockwise on rod so that the rod end hole lines up with the wastegate lever arm. While wastegate is held shut, slip rod over pin.
4. Before installing retaining clip, the rod end will need to be adjusted to the correct setting. Refer to section 6.6.5.1.

### 6.6.5.1 Setting the Wastegate

Before following this procedure, check the actuator set pressure to see if adjustment is needed. Refer to section 6.6.3.2.

Set pressure adjustment as follows:

1. Loosen the jam nut that secures the rod end on the actuator rod. If locking collar is present on the actuator rod, remove and discard collar. See Figure 6-28.




1. Wastegate Actuator Assembly
2. Locking Collar
3. Jam Nut
4. Adjusting Rod End
5. Retainer Clip
6. Wastegate Lever and Pin Assembly

**Figure 6-28 Wastegate Adjustment**

2. Remove the retaining clip that holds the actuator rod end on the wastegate lever arm pin.
3. Using pressure gage setup, apply enough pressure to the top side actuator can port until the rod begins to move, lifting the wastegate valve off its seat. See Figure 6-28.
4. Slip rod end off the wastegate lever arm pin.
5. Adjust rod as needed:
   [a] To INCREASE pressure setting at 0.04 in., turn rod end CLOCKWISE.
   [b] To DECREASE pressure setting at 0.04 in., turn rod end COUNTERCLOCKWISE.
6. With pressure still applied to actuator, replace rod end on wastegate lever arm.
7. Check actuator set pressure again. Refer to section 6.6.3.2.
   [a] If actuator is still out of adjuststment, repeat this procedure.
   [b] If actuator is within specified set pressure, install retaining clip on wastegate lever arm pin.
8. Tighten jam nut to secure rod end.

### 6.6.6 Assembly of Turbocharger

Use the following procedure to assemble the turbocharger:

| NOTICE: |
|---|
| As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material, which may cause component damage. |

1. Cover all openings.
2. Position the turbine housing as marked at disassembly against the center housing and secure it in place.
3. If a TMF turbocharger is to be assembled, proceed to step 7.

| NOTICE: |
|---|
| Failure to properly orient the Tee-bolt end of the clamp can result in an exhaust leak, turbine wheel damage or both. |

4. To assemble the TV45 and TV51 turbochargers, position the V-band coupling between the turbine housing and center housing so that the Tee-bolt end does not interfere with the turbine housing. Then tighten the V-band coupling nut, as follows:
   [a] Lubricate the toggle bolt threads with a high temperature anti-seize compound.
   [b] Tighten the nut on the V-band toggle bolt to approximately 18 N·m (160 lb· in.) torque.

**NOTE:**
Do not pull a misaligned turbine housing into alignment with the V-band coupling. The parts must be aligned and seated first.

   [c] Loosen the V-band coupling nut to approximately 6 N·m (50 lb· in.) torque, then torque the nut to 12-15 N·m (106-130 lb· in.).
5. Position the compressor housing as marked at disassembly against the backplate assembly and secure it in place with the V-band coupling.
6. Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 12-15 N·m (106-130 lb· in.) torque. This completes the assembly of TV45 and TV51 turbochargers.

**NOTICE:**

The 5/8 in. hex-head turbine housing bolts replaced 3/8 in. hex-head bolts. The 5/8 in. hex-head bolts are required to ensure sufficient clamp load.

7. Secure the TMF turbine housing with four 5/8 in. hex-head bolts.
8. Tighten the bolts to 34 N·m (300 lb· in.) torque.

### 6.6.7 Installation of Turbocharger

To install the turbocharger:

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
3. Remove any covers on the oil inlet and drain lines, and the oil inlet and drain openings on the turbocharger.
4. Place the turbocharger assembly into position on the exhaust manifold. Use a new gasket between the exhaust manifold and the turbine housing flange.
5. Secure the turbocharger to the exhaust flange. Tighten the nuts just enough to hold the turbocharger in place.
6. Slide the charge air cooler air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

**CAUTION:**

**To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.**

**NOTE:**
Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

7. Tighten the turbocharger to exhaust manifold locknuts to 58-73 N·m (43-54 lb·ft) torque.
8. Install the oil drain line, using a new gasket, between the opening in the bottom side of the turbocharger center housing and the drain hose that runs to the cylinder block. Tighten the bolts to 30-38 N·m (22-28 lb·ft) torque.
9. If turbocharger is water cooled, install the coolant supply and return hoses.
10. Refer to section 11.1.3 for verification of proper turbocharger installation.

## 6.7 TURBOCHARGER SERIES 60 GAS ENGINES (GENSET)

The turbocharger is designed to increase the overall power and efficiency of the engine. Power to drive the turbocharger is extracted from the energy in the engine exhaust gas.

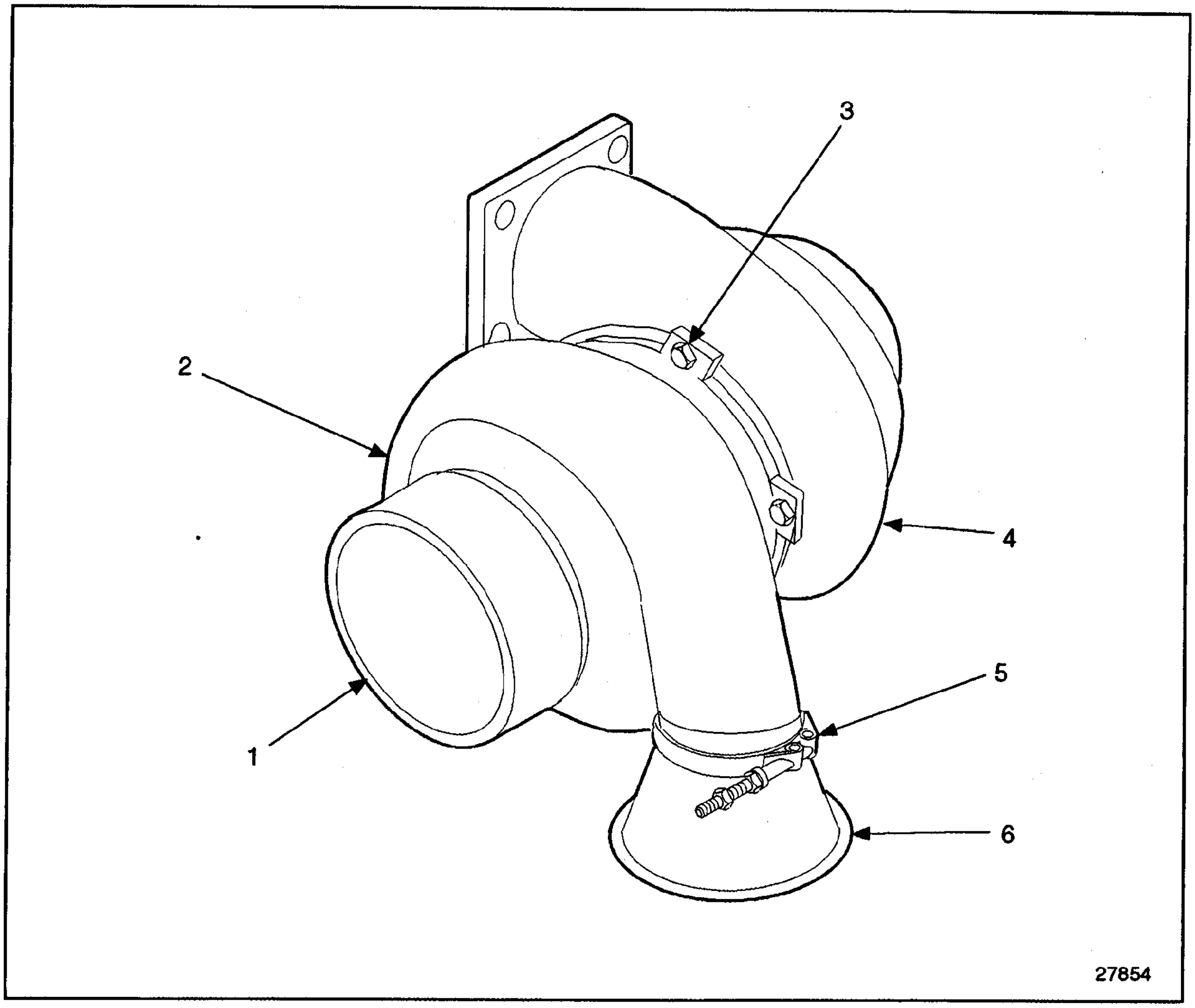
A turbocharger can be broken down into 3 basic pieces; a compressor cover, a center housing rotating assembly (CHRA), and a turbine housing.

The compressor cover is an aluminum alloy casting that encloses the compressor wheel and provides a V-band connection for the compressor outlet, and a hose connection for the compressor inlet. The compressor cover is secured to the compressor side of the CHRA.

The CHRA contains a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel, and wheel retaining nut. This rotating assembly is supported on two pressure-lubricated bearings that are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings, thrust washer, thrust collar, and thrust spacer.

The turbine housing is a heat-resistant steel alloy casting that encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing.

All Series 60G, 60 Hz Genset engines use a model K33 turbocharger, manufactured by 3K turbosystems. See Figure 6-29.

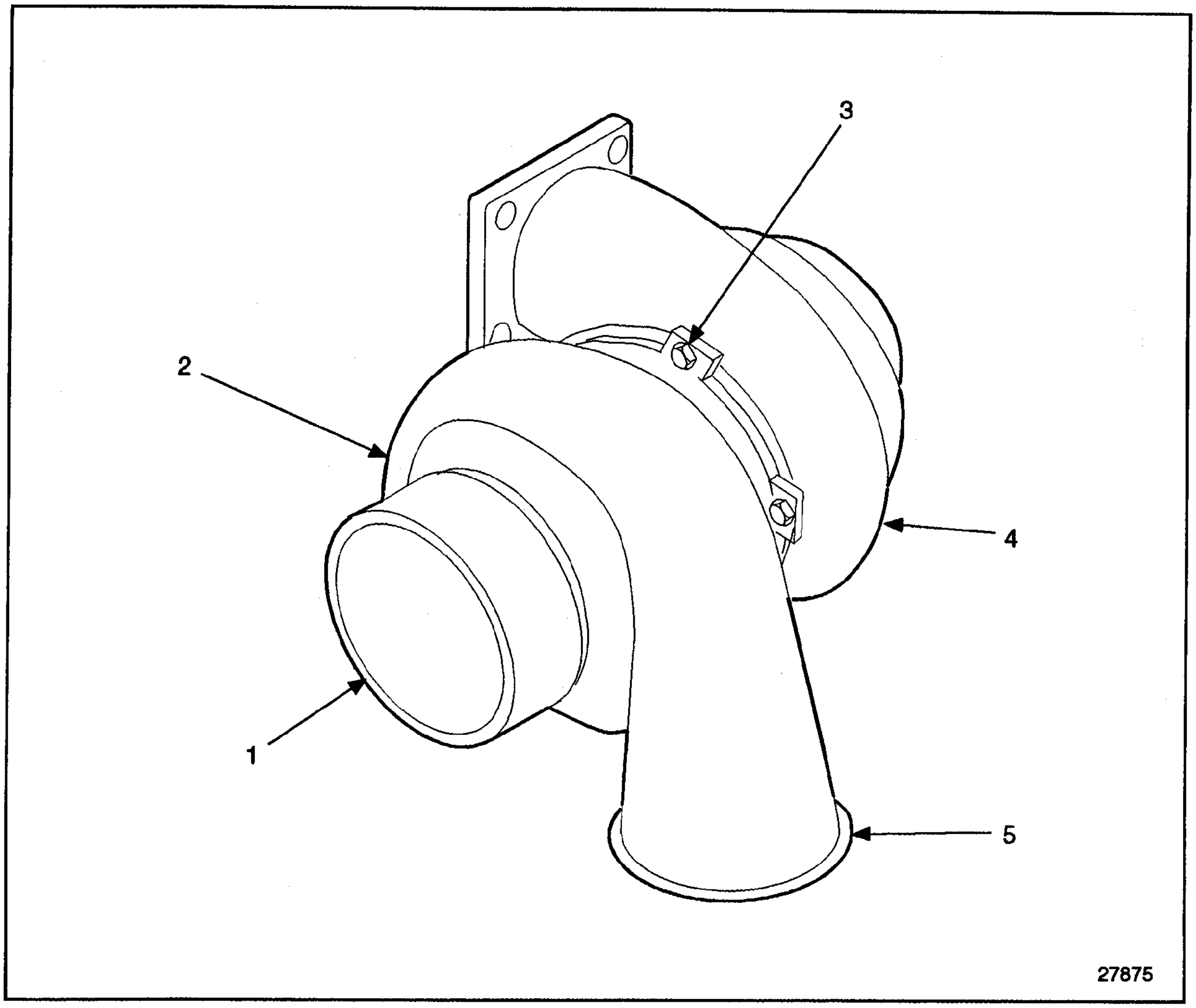



1. Compressor Inlet
2. Compressor Housing
3. Turbine Housing Bolt
4. Turbine Housing
5. V-Band Clamp
6. Compressor Outlet Adapter

**Figure 6-29 K33 Turbocharger Assembly (1996 Model)**

This turbocharger is similar in appearance to the diesel turbochargers.

For the 1996 model year, the compressor cover has an adaptor cone on the compressor outlets, attached with a V-clamp. This compressor cover is attached to the CHRA with a bolted joint. For the 1997 model, a new compressor cover with the correct compressor outlet dimensions will be introduced, eliminating the adapter cone. The new cover will be secured to the CHRA with a V-band clamp. These compressor covers will not be interchangeable. See Figure 6-30.




1. Compressor Inlet
2. Compressor Housing
3. Turbine Housing Bolt
4. Turbine Housing
5. Compressor Outlet

**Figure 6-30 K33 Turbocharger Assembly (1997 and later Model)**

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flow from the engine and through the turbine housing causing the turbine wheel and shaft to rotate. See Figure 6-31.

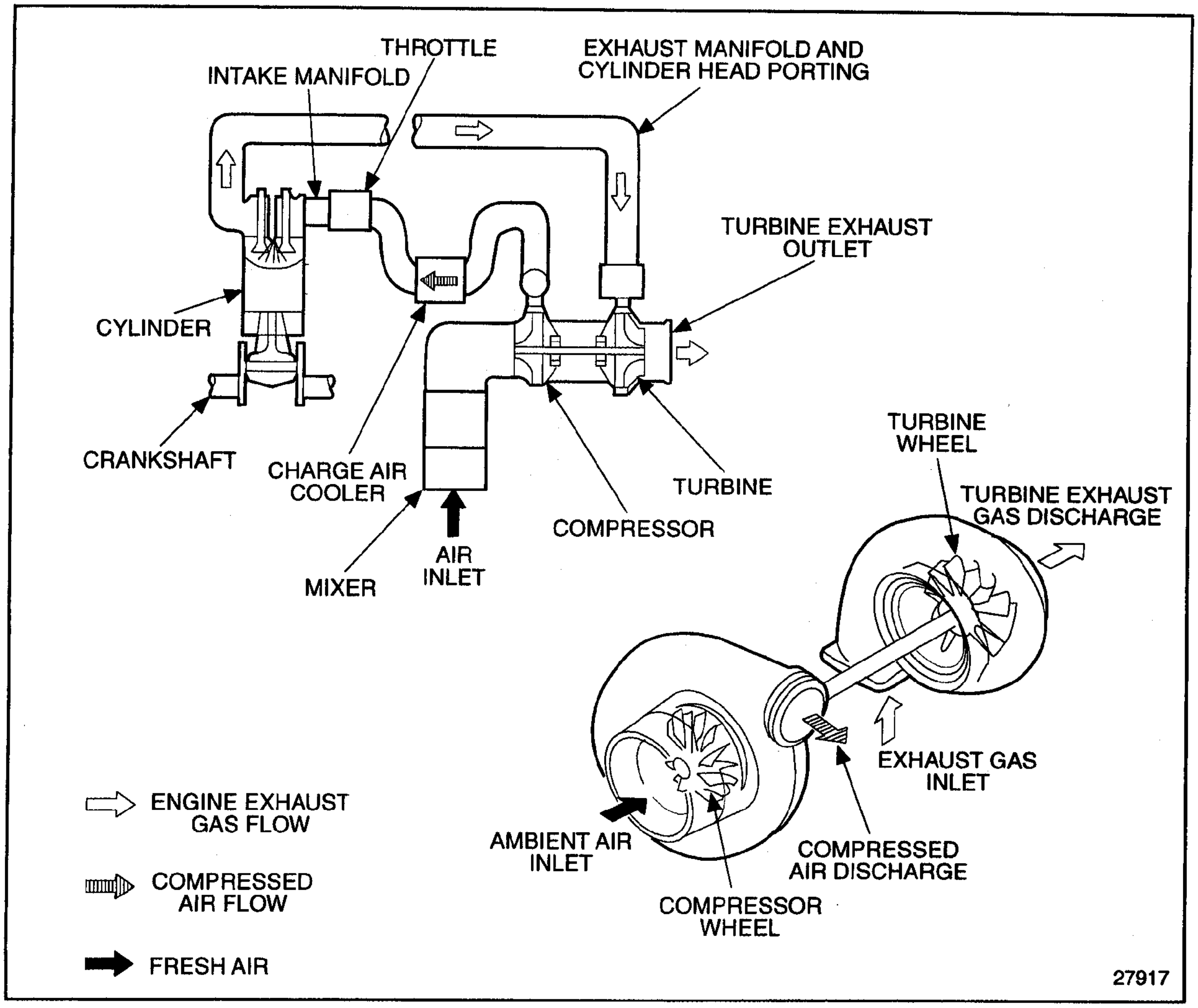
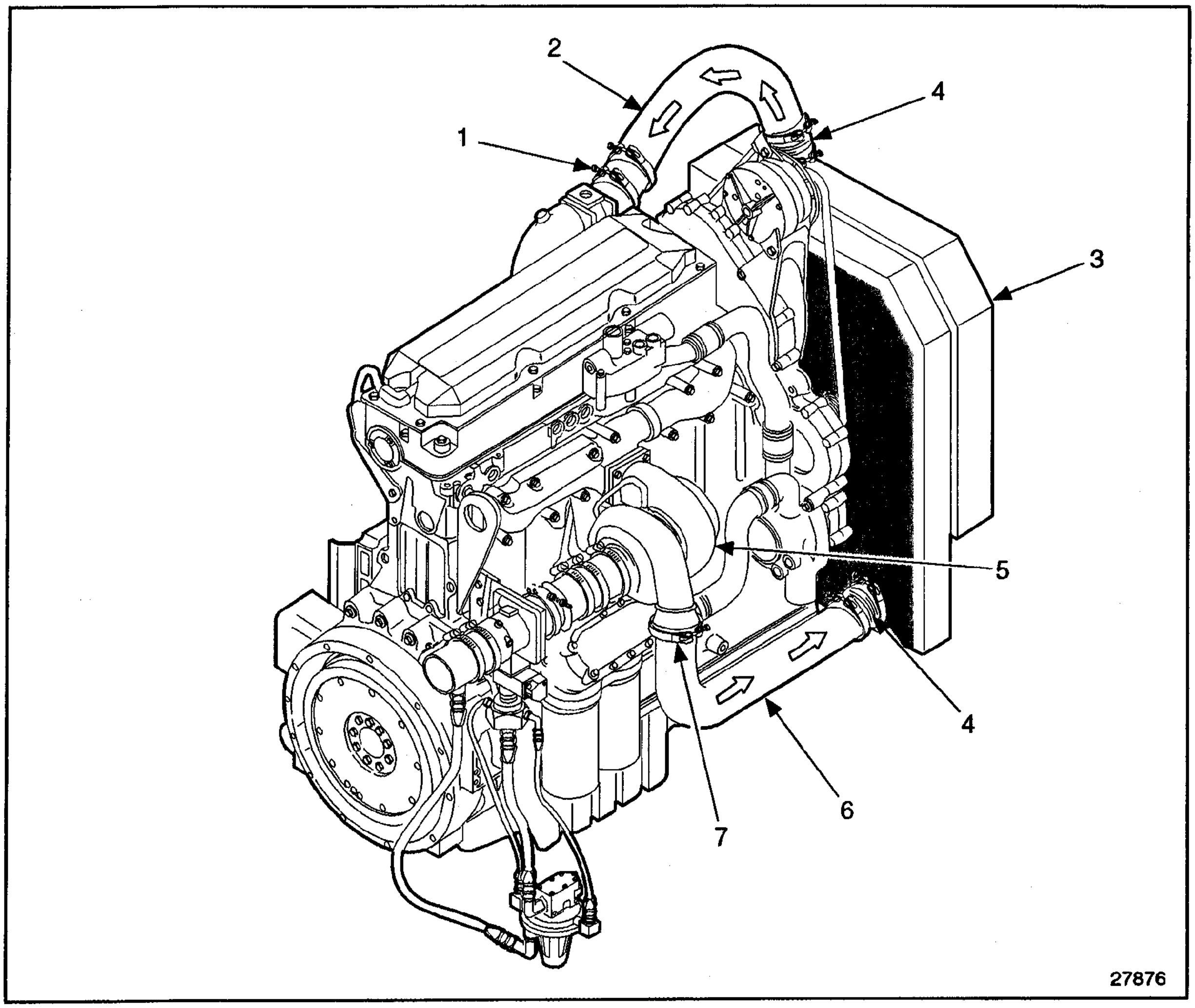



**Figure 6-31 Schematic Air Flow Diagram (Series 60G Engine, low pressure fuel system)**

The gases are discharged into the exhaust system after passing through the turbine housing.

The compressor wheel, in the compressor housing, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in clean gas and air, compresses it, and delivers high pressure air and gas through the throttle and intake manifold to the engine cylinders.

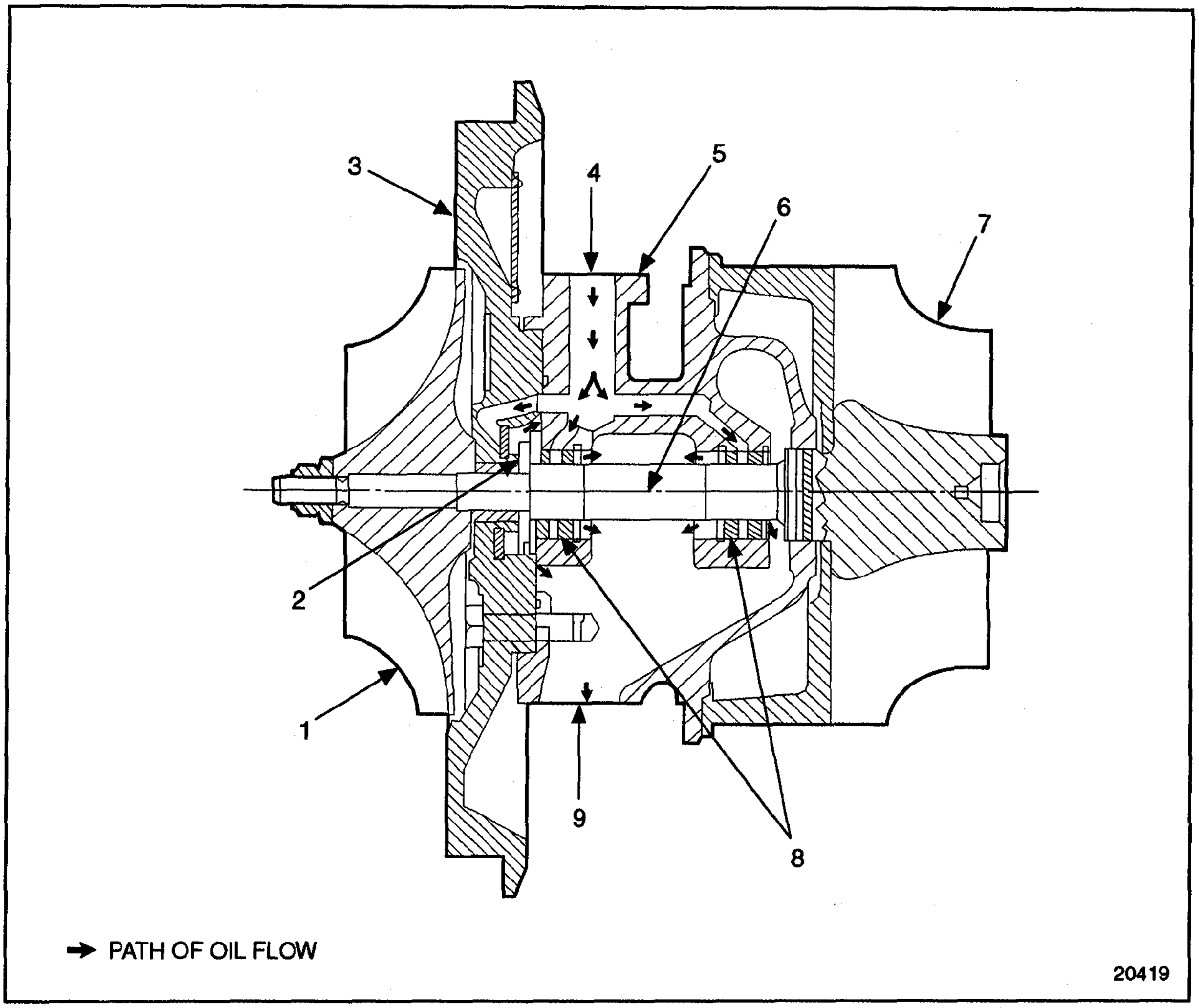
Oil for lubricating the turbocharger is supplied under pressure through an external oil line extending from the oil filter adaptor to the top of the center housing. See Figure 6-32.




1. Coupling Hose Clamp
2. Charge Air Cooler Outlet Duct
3. Charge Air Cooler
4. Flexible Coupling
5. Turbocharger
6. Charge Air Cooler Inlet Duct
7. V-Band Clamp

**Figure 6-32 Turbocharger Oil Lines Series 60 Gas Engine (Low Pressure System)**

From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing, and backplate or thrust plate. See Figure 6-33.




1. Compressor Wheel
2. Thrust Bearing
3. Backplate
4. Oil Inlet
5. Center Housing
6. Shaft
7. Turbine Wheel
8. Shaft Bearings
9. Oil Outlet

**Figure 6-33 Turbocharger Oil Flow Diagram (Series 60G Engine)**

The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

Listed in Table 6-2are the diagnostic codes.

**Parameter Identification Character (PID):** A PID is a single byte character used in J 1587 messages to identify the data byte(s) that follow. PIDs in the range 0-127 identify single byte data, 128-191 identify double byte data, and 192-253 identify data of varying length.

**Failure Mode Identifier (FMI):** The FMI describes the type of failure detected in the subsystem and identified by the PID. The FMI and the PID combine to form a given diagnostic code defined inJ 1587 within PID 194.

| DDR Description | Voltage | PID | FMI | Information |
|---|---|---|---|---|
| AIR INLET PRESSURE | HIGH | 106 | 0 | Indicates that the MAP has detected that engine intake manifold pressure has exceeded the recommended operating range. |
| AIR INLET PRESSURE | HIGH | 106 | 3 | Indicates that the MAP input to the ECM has exceeded 95% (normally >4.75 volts) of the sensor supply voltage. This diagnostic condition is typically detected when there is an open sensor return circuit or the sensor signal circuit is shorted to the sensor +5 volt supply. |
| AIR INLET PRESSURE | LOW | 106 | 4 | Indicated that the MAP input to the ECM has dropped below 5% (normally, 0.25 volts) of the sensor supply voltage. This diagnostic condition is typically detected when there is:- An open sensor signal circuit- An open sensor signal circuit opens sensor +5 volt supply circuit- The sensor signal is shorted to the sensor return circuit or ground- The sensors +5 volt supply is shorted to sensor return circuit or to ground. |

**Table 6-2 Air Inlet Pressure Diagnostic Codes for the Series 60G Engine**

### 6.7.1 Repair or Replacement of Turbocharger (Series 60 Gas Engine)

To determine if repair is possible or replacement of the turbocharger is necessary perform the following procedure. See Figure 6-34.

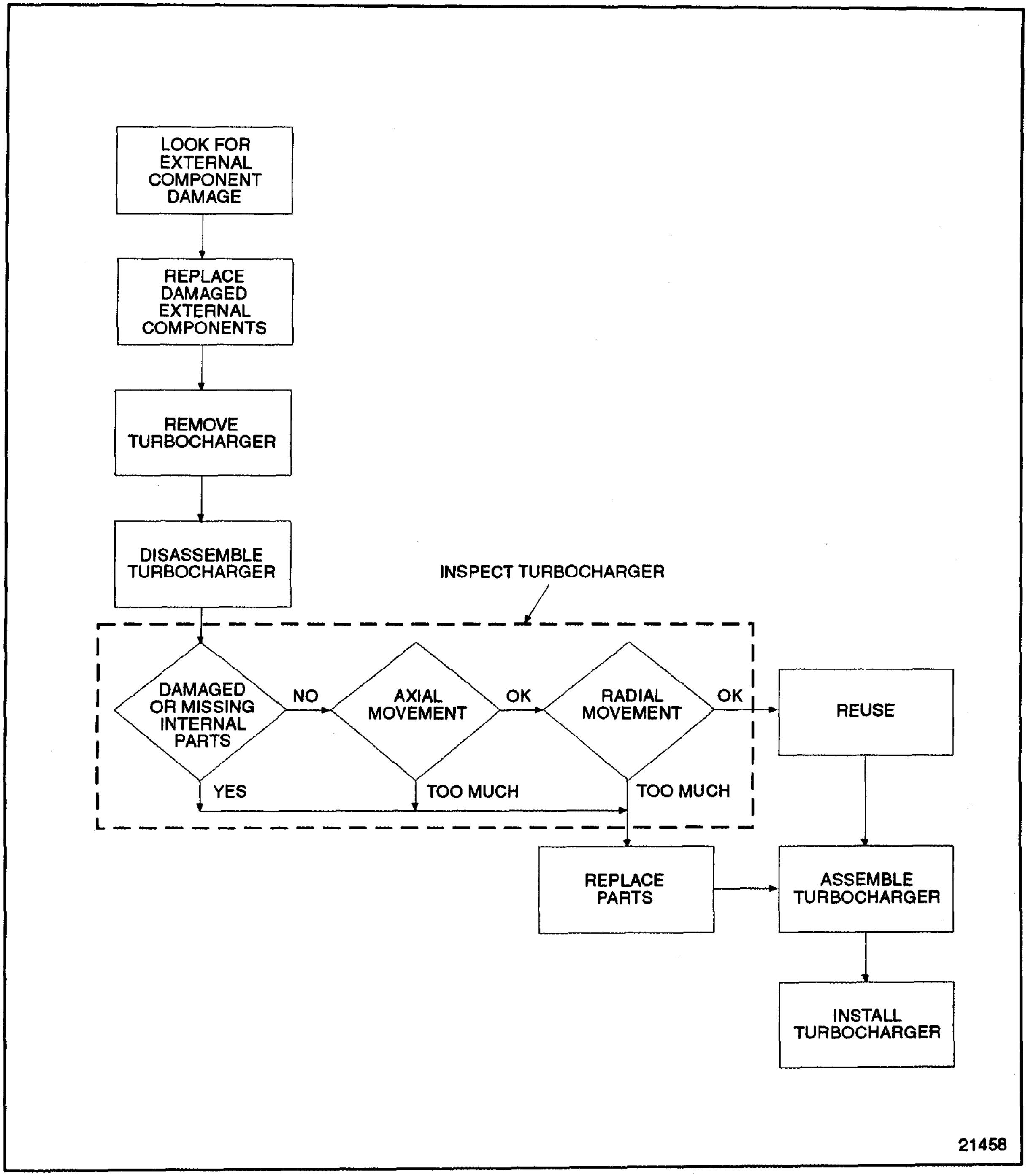



**Figure 6-34 Flowchart for Repair or Replacement of Turbocharger (Series 60 Gas Engine)**

### 6.7.2 Cleaning and Removal of Turbocharger (Series 60G Engine)

Cleaning the turbocharger is not necessary before removal.

| **CAUTION:** |
|---|
| **To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.** |

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil supply and drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage.
6. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

| **NOTICE:** |
|---|
| Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup. |

1. Disconnect and remove the elbow at the compressor housing outlet, by removing the V-band clamp.
2. Disconnect and remove the inlet hose attached to the compressor housing inlet. To do this, disconnect the gas mixer housing two-piece bracket by removing the two bolts connecting the brackets together. Remove the mixer, bracket, and inlet piping as an assembly; set aside until re-installation.
3. Disconnect the exhaust outlet pipe from the turbine housing of the turbocharger. For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.

4. Remove the inlet oil line from the top of the center housing.
5. Remove the oil drain line from the bottom of the center housing.
6. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
7. Remove the nuts securing the turbocharger assembly to the exhaust manifold. Then, lift the turbocharger assembly away from the engine and place it on a bench.
8. Cover the end of the oil drain line, the oil outlet line, water supply, water return, the air inlet and the exhaust outlet openings on the engine and turbocharger to prevent the entry of foreign material.

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

9. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly.

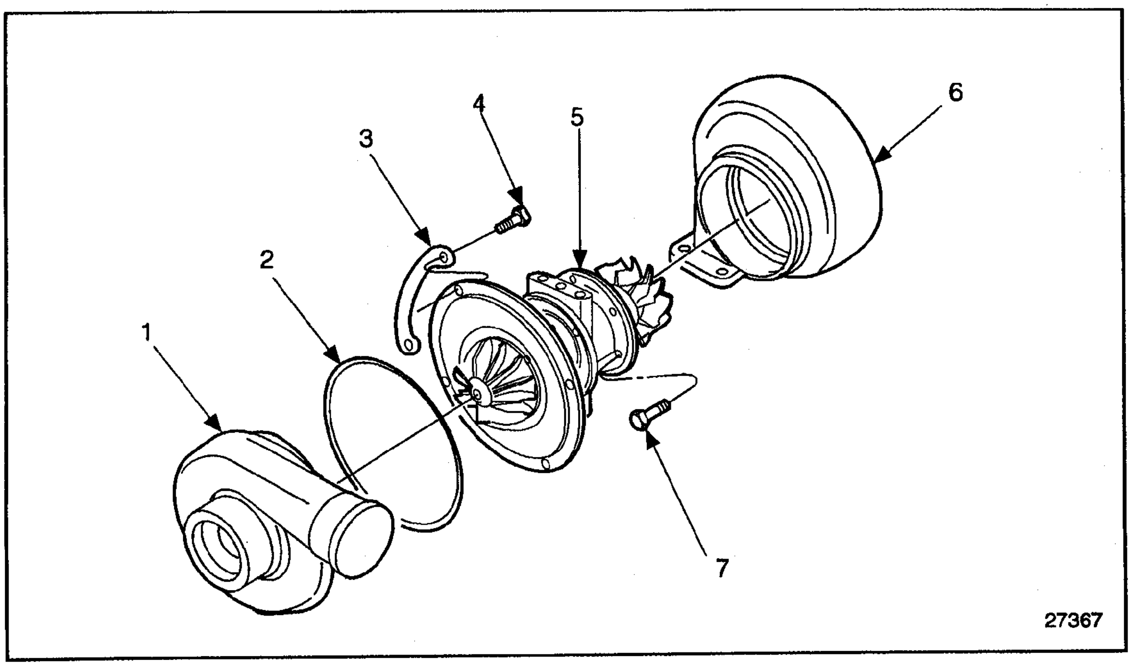
### 6.7.3 Disassembly of Turbochargers (Series 60G Engine)

Disassemble the turbocharger as follows:

1. Mark the related positions of the compressor housing, center housing and turbine house with a punch or scribe to assure reassembly in the same relative position.

| NOTICE: |
|---|
| Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels. |

2. Loosen and remove the bolts and retaining clamps securing the compressor housing to the backplate assembly and remove the compressor housing.
3. Loosen and remove the bolts securing the turbine housing to the center housing. See Figure 6-35.




1. Compressor Housing
2. O-ring
3. Retaining clamp (compressor housing)
4. Bolt (compressor housing)
5. Center Housing Rotating Assembly (CHRA)
6. Turbine housing
7. Bolt (turbine housing)

**Figure 6-35 Series K33 Turbocharger (Series 60G Genset, 1996 Model)**

4. Remove the turbine housing from the center housing.

### 6.7.3.1 Inspection and Cleaning of Turbocharger (Series 60G)

Inspect the disassembled turbocharger, discarding any damaged parts, in the following manner:

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.
3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.
4. Check the bearing axial end play:

   [a] Clamp the center housing assembly in a bench vise equipped with soft jaws. See Figure 6-36.

   [b] Fasten the dial indicator and magnetic clamp, part of magnetic base dial indicator set, J 7872-2, to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. See Figure 6-36.

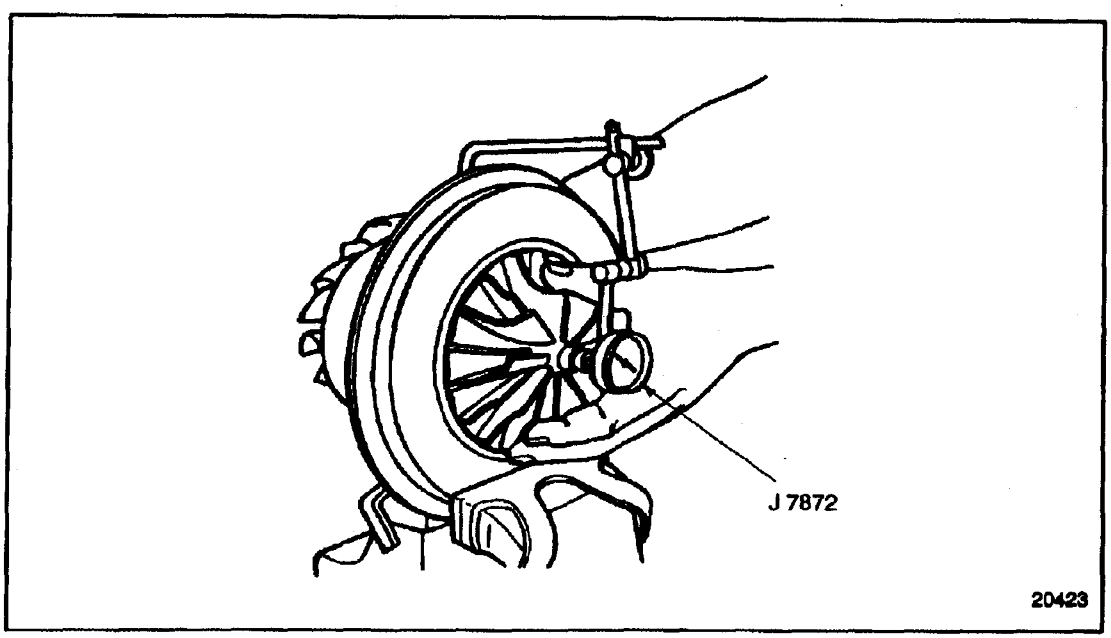



**Figure 6-36 Checking Bearing Axial End Play**

   [c] Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be 0.08-0.12 mm (0.003-0.005 in.) for K33 turbochargers. If the total dial indicator readings do not fall within the specified limits, replace the rotating assembly.

5. Check the shaft radial movement as follows:

[a] Install the turbo shaft checker, J 39164, to the oil drain opening of the center section. The special curved end of the tool must contact the wheel shaft through the oil outlet port and an internal opening in the center section casting. See Figure 6-37.

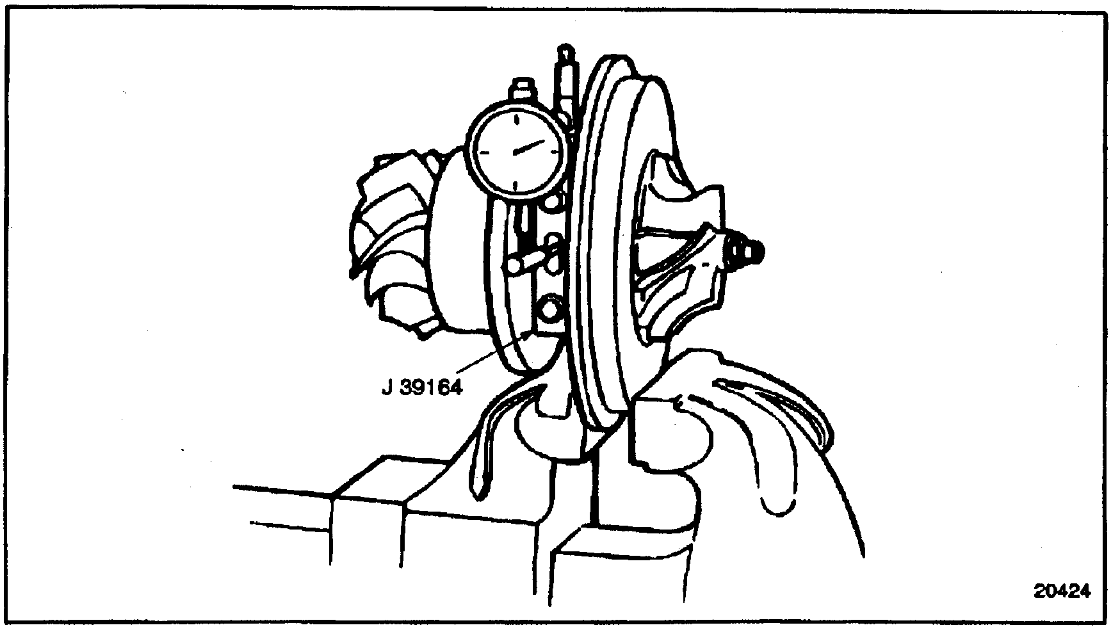



**Figure 6-37 Checking Shaft Radial Movement**

[b] Install a dial indicator. See Figure 6-37.

[c] Place the swivel adaptor, part of magnetic base dial indicator set, against the scribed line of the turbo shaft checker, J 39164.

[d] Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The total indicator reading (radial movement) should be 0.42-0.9 mm (0.016 -0.035 in.) for K33 turbochargers. If the total indicator readings do not fall within the specified limits, replace the rotating assembly.

### 6.7.4 Assembly of Turbocharger (Series 60G)

Use the following procedure to assemble the turbocharger:

| NOTICE: |
|---|
| As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material, which may cause component damage. |

1. Cover all openings.
2. Position the CHRA into the turbine housing as marked at disassembly, and line up bolt holes. Apply anti-seize compound to bolts, and torque to 20 N·m (177 lb· in.).

| NOTICE: |
|---|
| Always remove the compressor cover before positioning on the Center Housing Rotating Assembly (CHRA); otherwise, damage to the O-ring can result. |

3. Position the compressor housing as marked at disassembly against the Center Housing Rotating Assembly (CHRA) and secure it in place with the bolts and clamps.
4. Lightly lubricate the threads of the bolt with engine oil and torque the nut to 15 N·m (133 lb· in.).

### 6.7.5 Installation of Turbocharger (Series 60G)

To install the turbocharger:

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
3. Remove any covers on the oil inlet and drain lines, and the oil inlet and drain openings on the turbocharger.
4. Place the turbocharger assembly into position on the exhaust manifold. Use a new gasket between the exhaust manifold and the turbine housing flange.
5. Secure the turbocharger to the exhaust flange. Torque the turbocharger to exhaust manifold and locknuts to 58-73 N·m (43-54 lb·ft).

**CAUTION:**

**To avoid injury, wear a face shield or goggles.**

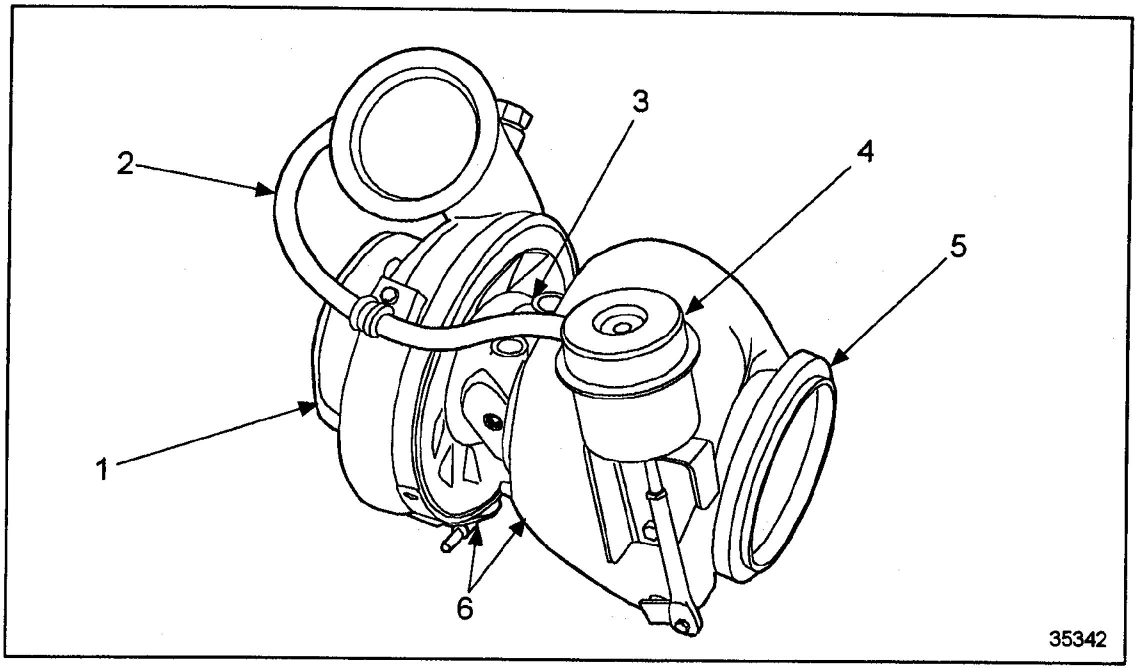
**NOTICE:**

Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

6. Install mixer and turbo inlet hose assembly onto the compressor inlet, and align the mixer bracket holes. Install bracket bolts and tighten.
7. Install elbow to compressor outlet and secure with V-band clamp.
8. Install the oil drain line, using a new gasket, between the opening in the bottom side of the turbocharger center housing and the drain hose that runs to the cylinder block. Torque the bolts to 30-38 N·m (22-28 lb·ft).
9. Refer to section 11.1.3 for verification of proper turbocharger installation.
10. Install water supply and return lines.

## 6.8 TURBOCHARGER SERIES 60 NATURAL GAS (AUTOMOTIVE) ENGINE

The Garrett GT 42 turbocharger is used on all Series 60G automotive engines. See Figure 6-38.




1. Compressor Housing
2. Actuator Hose
3. Water-cooled Center Housing
4. Wastegate Actuator
5. Turbine Housing
6. V-Band Joints

**Figure 6-38 GT 42 Turbocharger Assembly (Coach)**

The turbocharger is designed to increase the overall power and efficiency of the engine. Power to drive the turbocharger is extracted from the energy in the engine exhaust gas.

The CHRA consists of a turbine wheel and shaft, a compressor wheel, and a center housing that serves to support the rotating assembly, bearings, seals, a turbine housing, and a compressor housing. The center housing has connections for oil inlet, oil outlet, water inlet and water outlet fittings.

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel, and wheel retaining nut. The rotating assembly is supported on two pressure-lubricated bearings that are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings, thrust washer, thrust collar, and thrust spacer. Internal water passages provide cooling and subsequent protection against oil cooking in the housing.

The turbine housing is a heat-resistant alloy casting that encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing. An internal turbine bypass valve, commonly called a wastegate, allows exhaust gas to flow around the turbine wheel. This provides control over the maximum boost pressure.

The wastegate is controlled with a pneumatic actuator mounted on the side of the turbine housing. The Series 60G coach engine turbocharger has an actuator with a single hose port on the top side of the actuator can with a silicon hose that runs to a port on the compressor cover. See Figure 6-38. Air pressure from the compressor outlet is fed through the line to the top side of the actuator, which opens the wastegate valve at a specified pressure.

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flow from the engine and through the turbine housing causing the turbine wheel and shaft to rotate. See Figure 6-39.

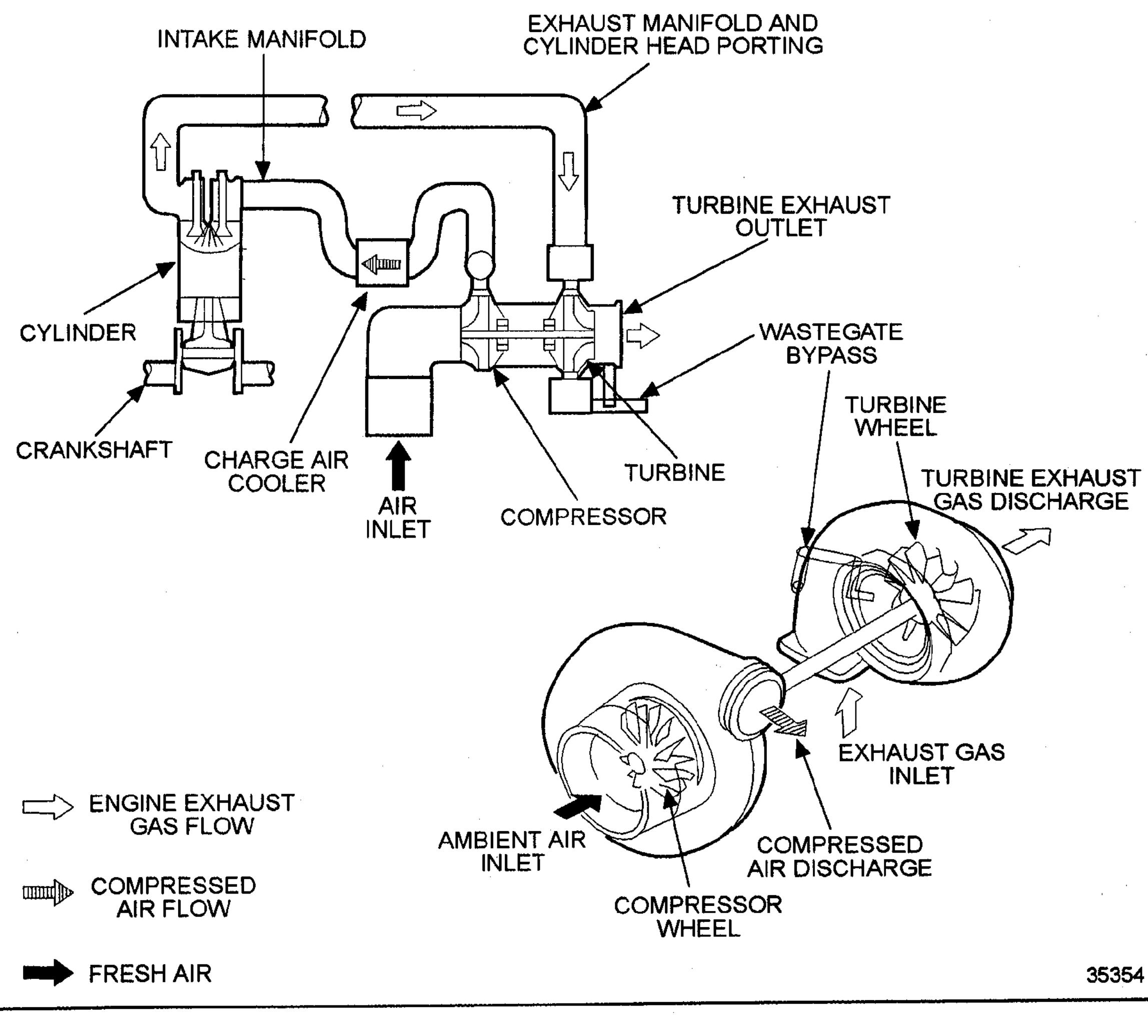
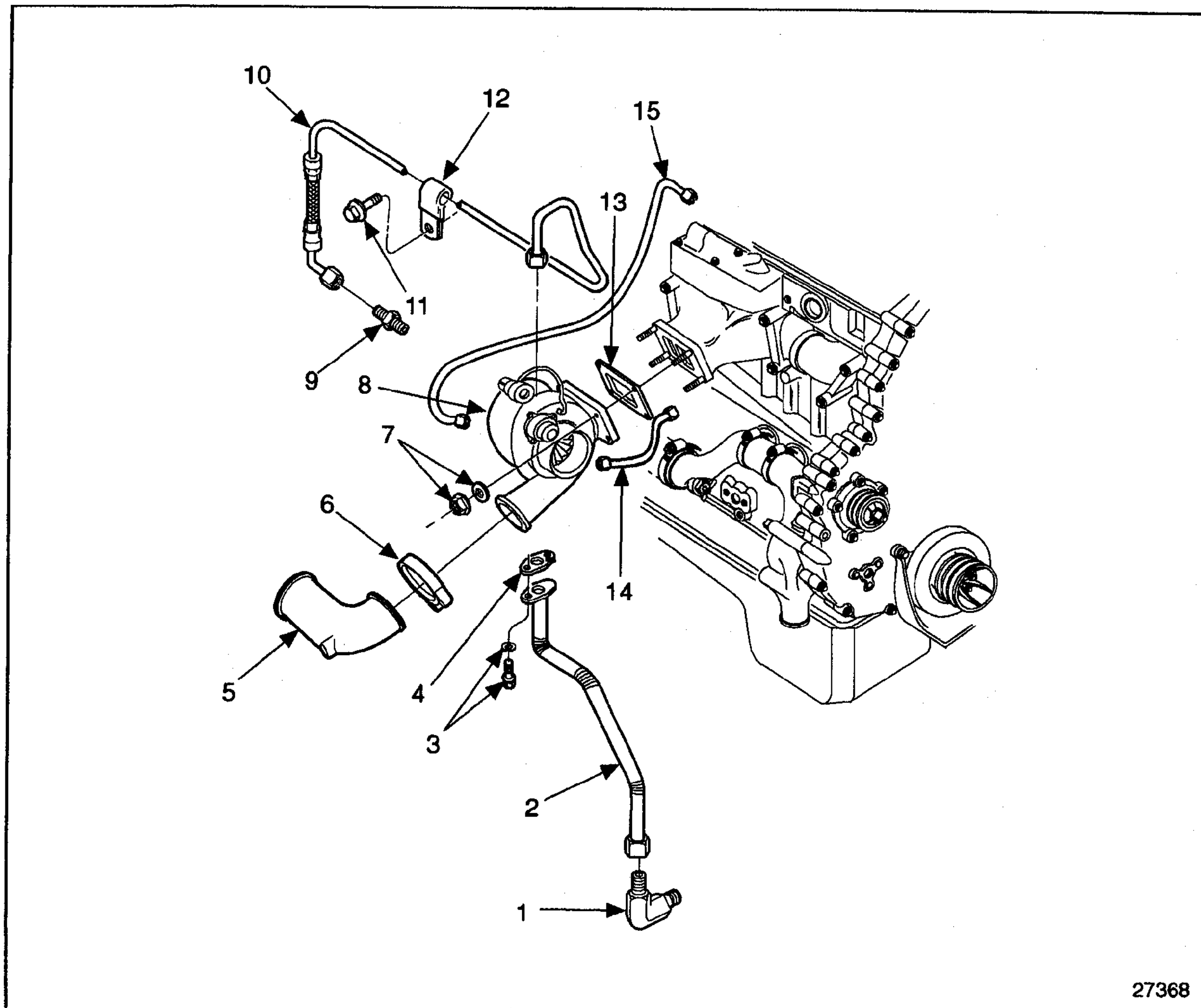



**Figure 6-39 Schematic Air Flow Diagram (Series 60G Automotive)**

The gases are discharged into the exhaust system after passing through the turbine housing. On automotive engines, an oxygen sensor and exhaust temperature sensor are installed within 12 inches of the turbocharger turbine outlet. A harness connects the sensors to the ECM.

The compressor wheel, in the compressor housing, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in clean air, compresses it, and delivers high pressure air through the intake manifold to the engine cylinders.

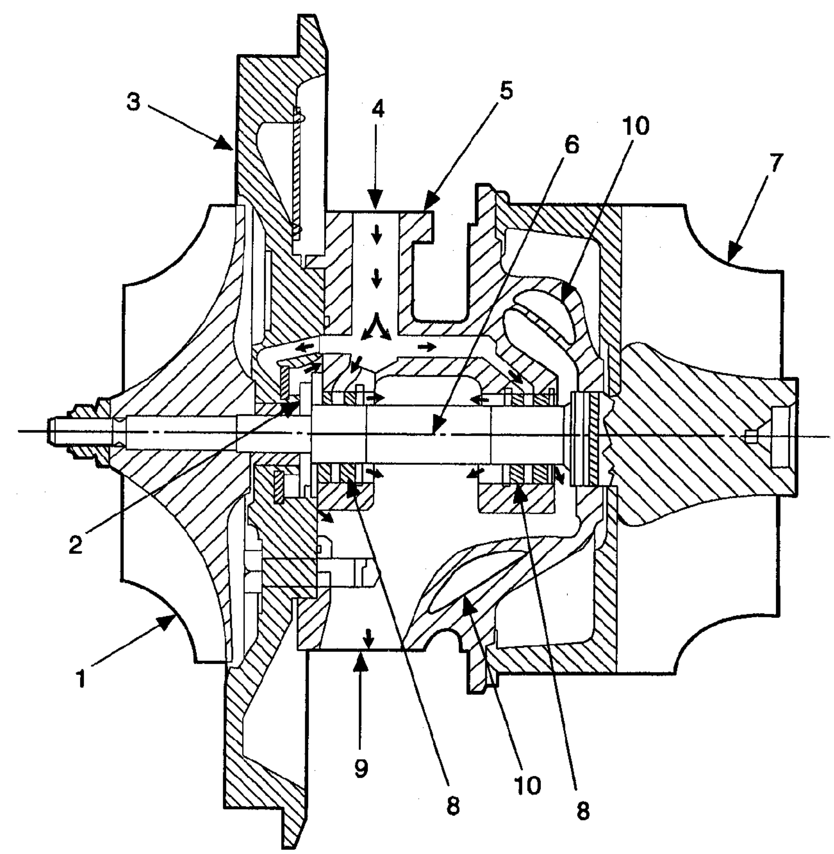
Oil for lubricating the turbocharger is supplied under pressure through an external oil line extending from the oil filter adaptor to the top of the center housing. Water for cooling the bearing housing is supplied from the oil cooler, and is returned to the top of the thermostat housing. See Figure 6-40.




1. Elbow, Oil Drain Tube
2. Tube, Turbo Oil Drain
3. Bolt, and Lockwashers, Oil Drain Tube Mounting
4. Gasket, Oil Drain Tube
5. Elbow
6. Clamp
7. Nut, and Washer Turbo Mounting
8. Turbocharger Assembly
9. Connector, Oil Supply Tube (from oil filter adaptor)
10. Tube Assembly, Turbo Oil Supply
11. Bolt, Oil Supply Tube Clip
12. Clip, Oil Supply Tube
13. Gasket, Turbo Exhaust Inlet
14. Water Supply Line
15. Water Return Line

**Figure 6-40 Turbocharger Oil/Water Lines Series 60 Gas (Automotive)**

From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing, and backplate or thrust plate. See Figure 6-41.




1. Compressor Wheel
2. Thrust Bearing
3. Backplate
4. Oil Inlet
5. Center Housing
6. Shaft
7. Turbine Wheel
8. Shaft Bearings
9. Oil Outlet
10. Water passages

**Figure 6-41 Turbocharger Oil Flow Diagram (Series 60G, Automotive)**

The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block. Water flows through the bearing housing in a U-shape flow path, removing heat generated by the hot exhaust gas in the turbine.

### 6.8.1 Repair or Replacement of Turbocharger (Series 60 Gas Automotive Engine)

To determine if repair is possible or replacement of the turbocharger is necessary perform the following procedure. See Figure 6-42.

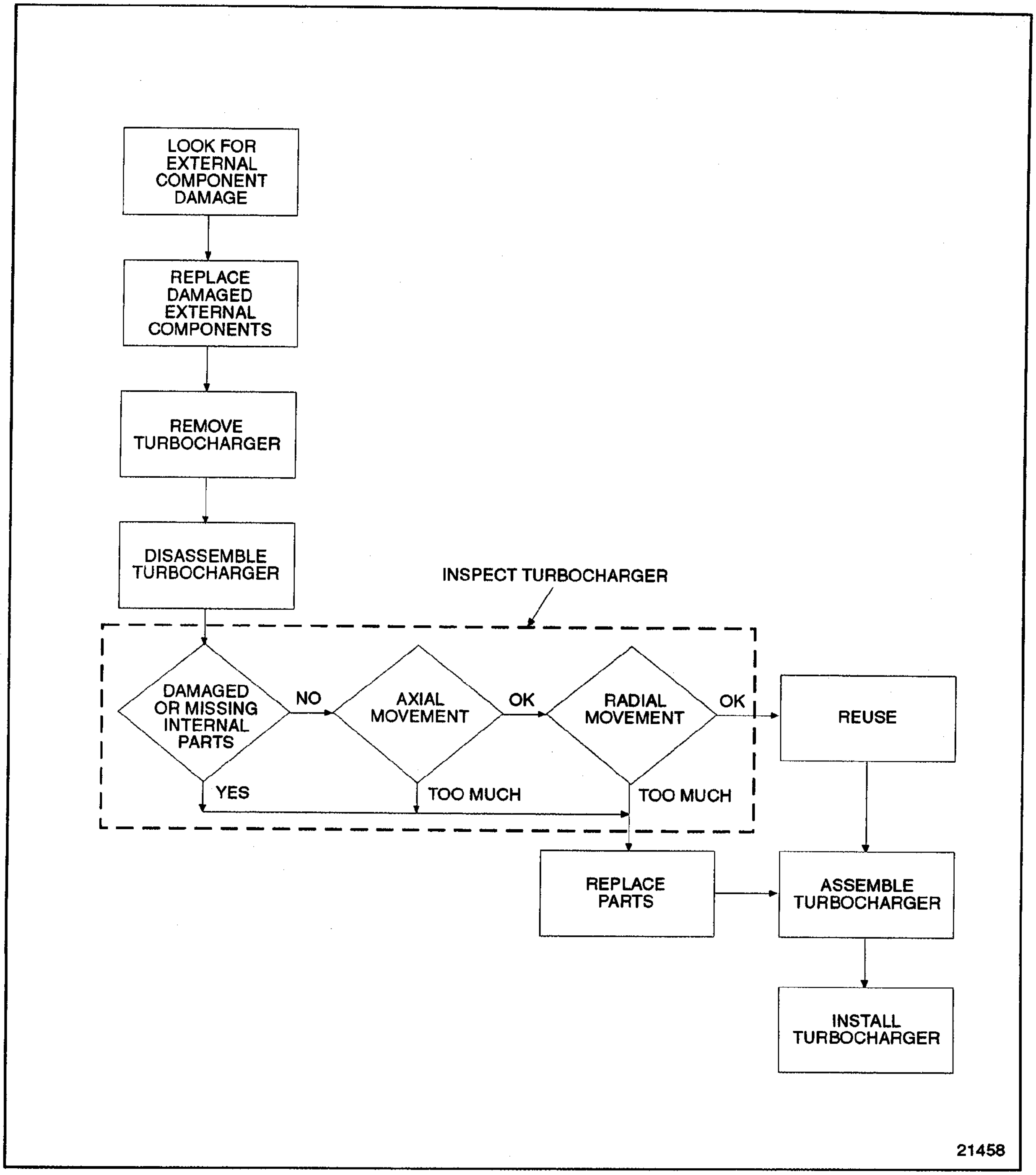



**Figure 6-42 Flowchart for Repair or Replacement of Turbocharger (Series 60 Gas, Automotive)**

## 6.8.2 Cleaning and Removal of Turbocharger (Series 60G Automotive Engine)

Cleaning the turbocharger is not necessary before removal.

| **CAUTION:** |
|---|
| **To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.** |

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil supply and drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage.
6. Damaged water supply and return lines.
7. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

| **NOTICE:** |
|---|
| Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup. |

1. Disconnect and remove the CAC ducting at the compressor housing.
2. Disconnect and remove the air inlet hose attached to the compressor housing.
3. Disconnect the exhaust outlet pipe from the turbine housing of the turbocharger. For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.
4. Remove the inlet oil line from the top of the center housing.
5. Remove the oil drain line from the bottom of the center housing.

**NOTE:**
Be sure to drain coolant before removing water lines from bearing housing.

6. Remove water lines from bearing housing.

7. Remove actuator return line on bottom port of actuator.
8. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
9. Remove the nuts securing the turbocharger assembly to the exhaust manifold. Then, lift the turbocharger assembly away from the engine and place it on a bench.
10. Cover the end of the oil drain line, the oil outlet line, water supply, water return, the air inlet and the exhaust outlet openings on the engine and turbocharger to prevent the entry of foreign material.

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

### 6.8.3 Disassembly of Turbochargers (Series 60G Automotive Engine)

Disassemble the turbocharger as follows:

**NOTE:**
Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly.

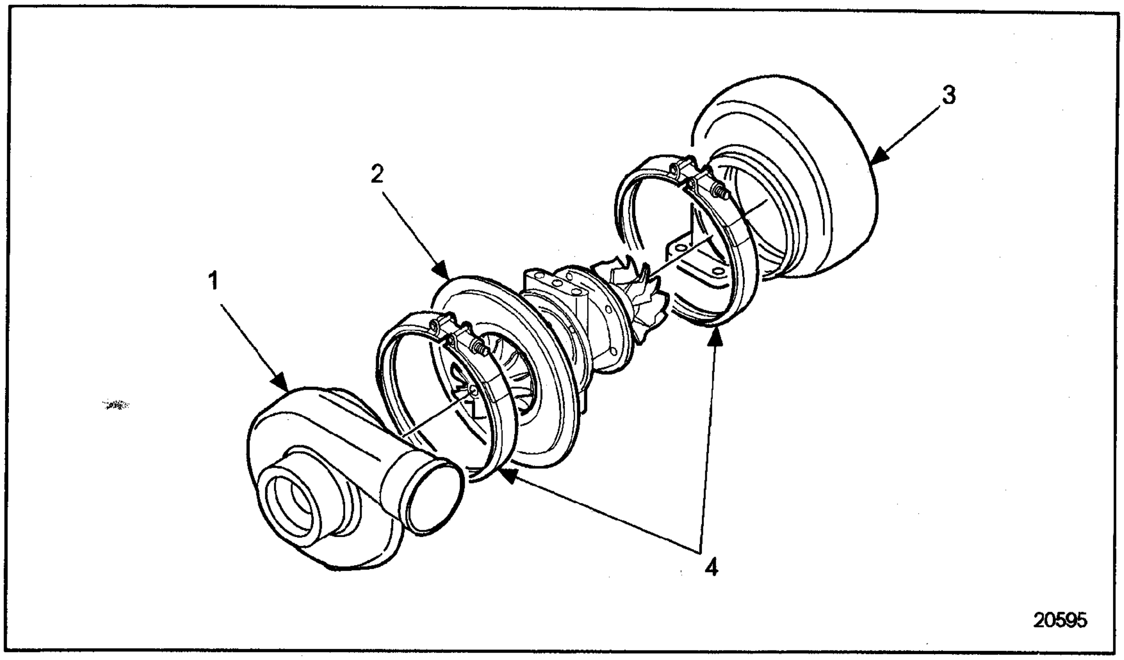
1. Mark the related positions of the compressor housing, center housing and turbine housing with a punch or scribe to assure reassembly in the same relative position.

**NOTICE:**

Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen the V-band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and V-band.

3. Perform the following steps to disassemble the GT42 turbocharger: See Figure 6-43.
   [a] Loosen the V-band coupling securing the turbine housing to the center housing.
   [b] Remove the turbine housing from the center housing.




1. Compressor Housing
2. Compressor Housing and Rotating Assembly
3. Turbine Housing
4. V-Band Couplings

**Figure 6-43 GT42 Turbocharger**

### 6.8.3.1 Inspection and Cleaning of Turbocharger (Series 60G Automotive Engine)

Damage can result from a contaminated exhaust system. Any debris left in the exhaust system after service work can fall back into the exhaust wheel. If large enough, these particles may cause turbine wheel damage at initial engine startup. The exhaust manifold and exhaust piping attached to the turbocharger should also be inspected for debris and cleaned, if necessary, before being installed.

Any time the charge air cooler is removed, all charge air cooling system components *must* be inspected to make sure they are clean and free of any casting slag, core sand, welding slag, or any other contaminants that could break free during engine operation and damage the turbine wheel.

Inspect the disassembled turbocharger, discarding any damaged parts, in the following manner:

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.
3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.
4. Check actuator can for external damage.
5. Check actuator pressure setting; refer to section 6.8.4.
6. Check compressor cover recirculation valve (coach only).
7. Visually check wastegate lever arm, valves, and ports. Ensure the ports are completely covered by the valves.

8. Check the bearing axial end play:

   [a] Clamp the center housing assembly in a bench vise equipped with soft jaws. See Figure 6-44.

   [b] Fasten the dial indicator and magnetic clamp, J 7872-2 , to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. See Figure 6-44.

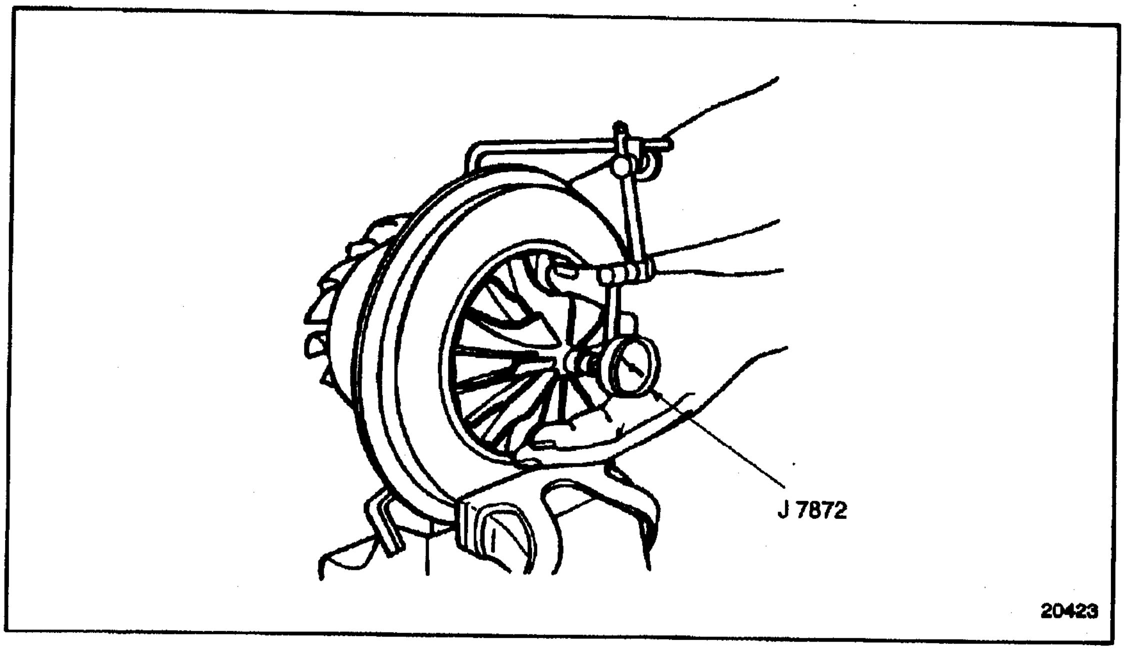



**Figure 6-44 Checking Bearing Axial End Play**

   [c] Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be 0.0127-0.0889 mm 0.0005-0.0035 in.). If the total dial indicator readings do not fall within the specified limits, replace the rotating assembly.

9. Check the shaft radial movement as follows:Due to the internal construction of the GT42 bearing housing, access to the shaft through the oil drain is not possible. Therefore, radial movement cannot be accurately measured to determine the condition of radial turbine bearings.

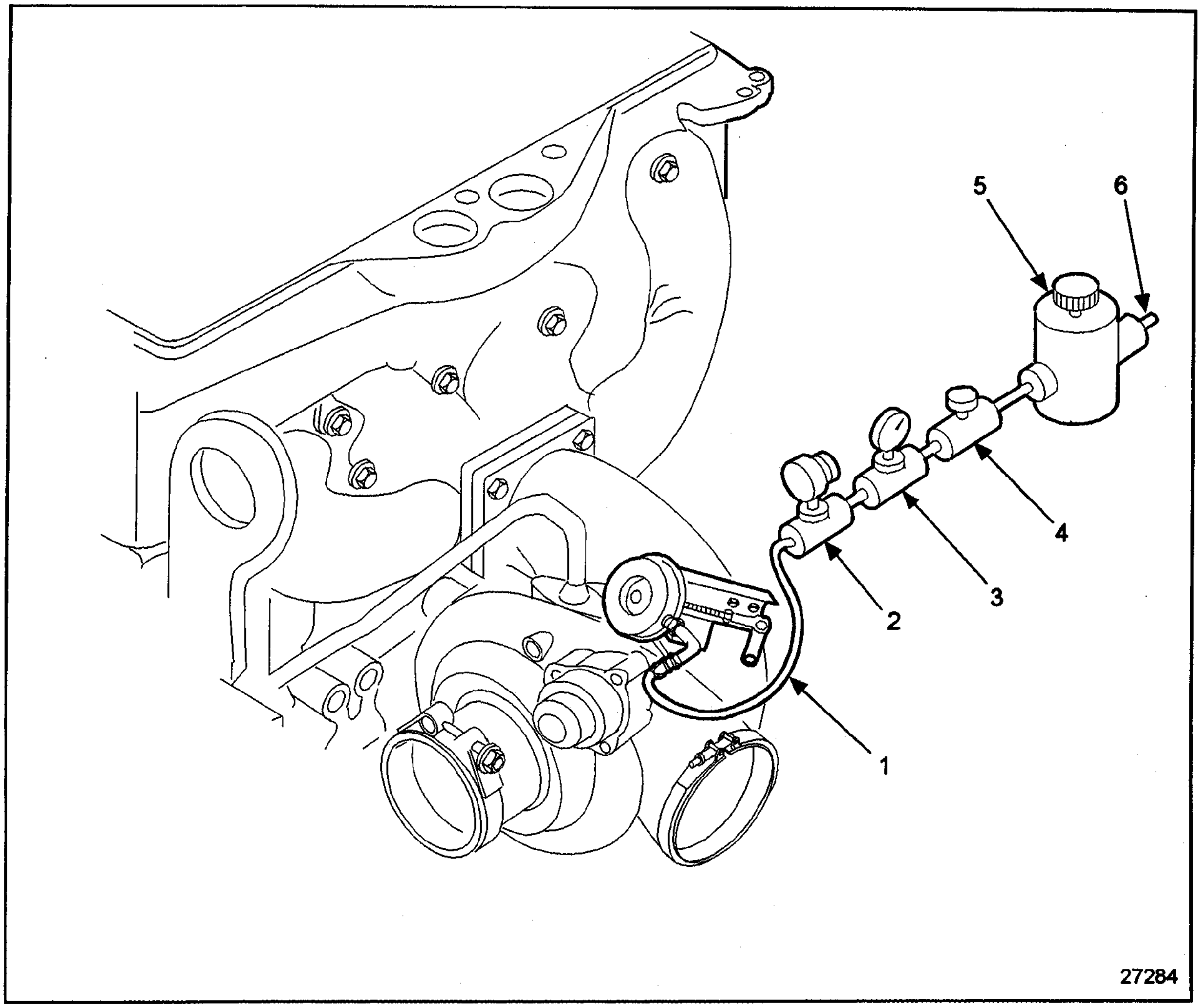
   To determine the general condition of the radial bearings, check radial end play after the turbocharger is cleaned and assembled. Push on the end of the shaft, towards the side of the compressor (or turbine) housing. If the wheel contacts either housing, the radial bearings may be worn out, and the CHRA should be replaced (be sure to check if the housing is seated and installed correctly also).

10. Service of the center housing rotating assembly (CHRA)The CHRA is serviced by replacement only. Do not attempt disassembly of the CHRA, as possible shaft imbalance and damage may result.

### 6.8.4 Checking Wastegate Calibration for the Series 60G Automotive Engine

This procedure provides a method for verifying proper wastegate calibration.

1. Remove hose from wastegate actuator (for gensets, remove line on top side of can).
2. Set-up an indicator at the end of the wastegate actuator adjusting rod to measure actuator rod travel. The indicator should have a minimum travel of 0.100 in.
3. Connect regulator and pressure gage set-up to wastegate actuator. See Figure 6-45.




1. Hose to Wastegate Actuator
2. Vent Valve
3. Pressure Gage
4. Supply Air Shutoff Valve
5. Pressure Regulator
6. Shop Air Supply

**Figure 6-45 Checking Wastegate Calibration for the Series 60G Automotive Engine**

4. Apply specified calibration pressure (listed in Table 6-3) to the wastegate actuator.

| Model | Rating | Set Pressure Travel at 0.04 in. Rod |
|---|---|---|
| Coach | 330 Hp | 24 lb/in.$^2$ |

**Table 6-3 Series 60G Wastegate Calibration Pressure at 0.04 in. Rod Travel**

| NOTICE: |
|---|
| For genset turbochargers, NEVER apply pressure to bottom part of actuator can. Damage to actuator may result. |

5. Close air supply shutoff valve. The pressure should hold at the specified pressure. If not, check air hose and fitting connections for leaks. If none are found, replace wastegate actuator assembly. Refer to section 6.8.5.
6. Open vent to relieve pressure. Check gage for zero pressure reading. Adjust regulator to zero pressure and close vent valve.
7. Adjust dial indicator so it just contacts the actuator rod end and adjust to zero reading.
8. Open air supply shutoff valve and slowly adjust regulator until dial indicator reads 0.040 in. Switch pressure on and off, opening and closing supply air and vent valves, to make certain dial indicator travel is from 0.00 in. to 0.040 in. and that the pressure reading is consistent.
9. For currently calibrated wastegate actuator, a pressure within ± 0.25 lb/in.$^2$ of the value listed in Table 6-3, will be required to obtain precisely 0.040 in. actuator travel. If the pressure required is outside this range, wastegate adjustment is necessary; refer to section 6.8.5.

### 6.8.5 Removal and Replacement of Series 60G Wastegate Actuator

This procedure describes the removal of a actuator currently mounted on a turbocharger, and the replacement with a new service actuator. Further adjustment of the actuator will be necessary to achieve the correct pressure setting, listed in Table 6-3.

1. Remove actuator hose from the top side of the actuator can. With the pressure gage set-up (see Figure 6-45), apply enough pressure to the actuator can until the rod begins to move; refer to section 6.8.6.
2. Remove the retaining clip that holds the actuator rod end on the wastegate lever pin. Lift rod off the wastegate lever pin.

| NOTICE: |
| --- |
| Never remove the rod end from the wastegate lever pin unless pressure is applied to the top side actuator port; otherwise, damage to the actuator diaphragm may result. |

3. Remove the lock nuts that secure the actuator can to the base of the actuator bracket, and remove the can from the turbocharger assembly.

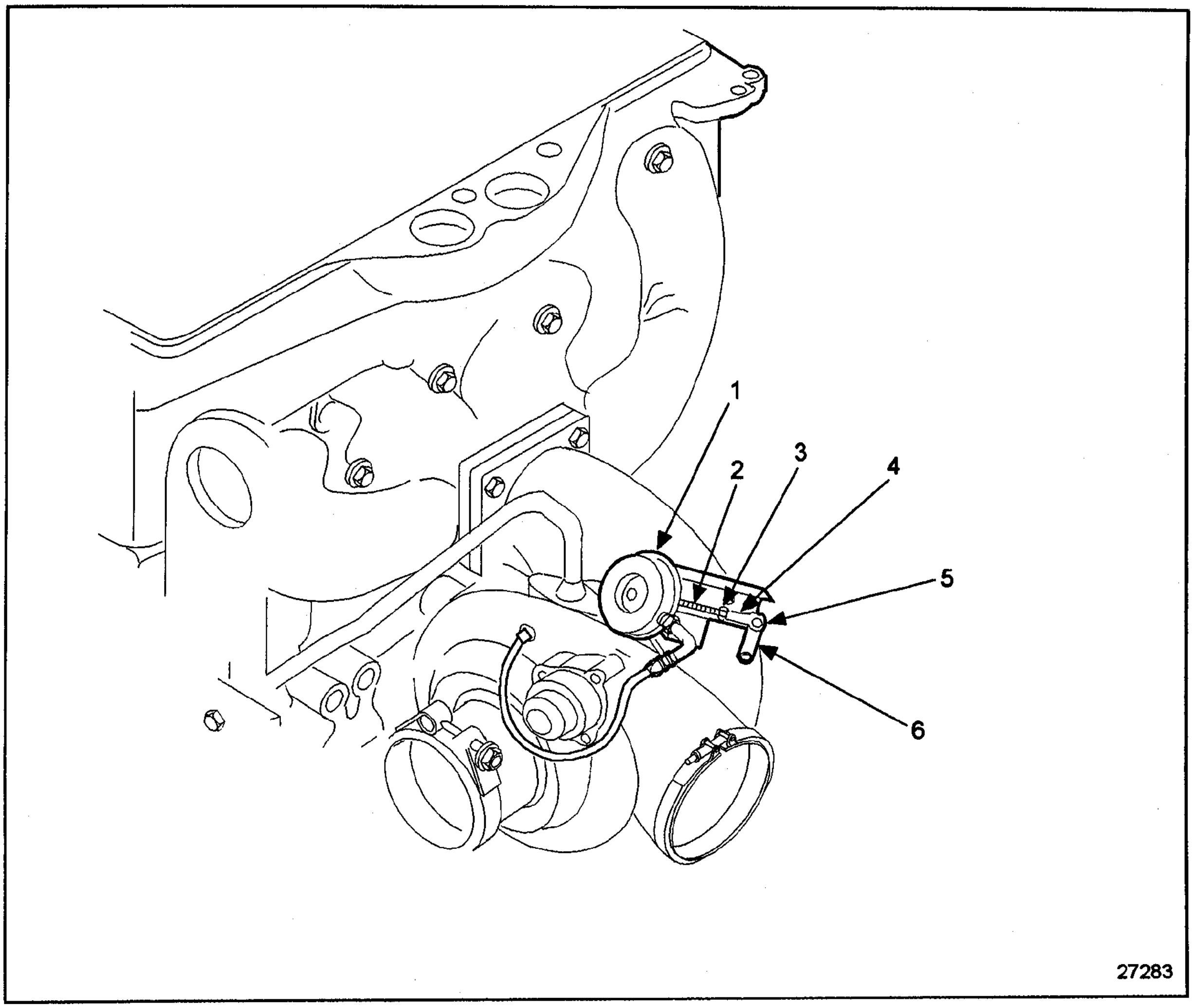
Replace wastegate actuator as follows:

1. Install actuator can on bracket; tighten lock nuts.
2. Using pressure gage set-up, apply enough pressure to the new service actuator can until the rod begins to move.
3. Adjust actuator rod end by turning either clockwise or counterclockwise on rod so that the rod end hole lines up with the wastegate lever arm, while wastegate is held shut pin, slip rod over pin.
4. Before installing the retaining clip again, the rod end will need to be adjusted to the correct setting. Refer to section 6.8.6.

### 6.8.6 Setting the Wastegate on the Series 60G Automotive Engine

This procedure describes the set pressure adjustment of an installed wastegate actuator. Before following this procedure, first check the actuator set pressure to see if adjustment is needed refer to section 6.8.4.

1. Loosen the jam nut that secures the rod end on the actuator rod. If locking collar is present on the actuator rod, remove and discard collar, see Figure 6-46.




1. Wastegate Actuator Assembly
2. Locking Collar
3. Jam Nut
4. Adjusting Rod End
5. Retainer Clip
6. Wastegate Lever and Pin Assembly

**Figure 6-46 Wastegate Adjustment**

2. Remove the retaining clip that holds the actuator rod end on the wastegate lever arm pin.

| NOTICE: |
|---|
| For genset actuator, never apply pressure to the bottom side of actuator port. Damage to the actuator may result. |

3. Using pressure gage setup (see Figure 6-46) apply enough pressure to the top side actuator can port until the rod begins to move, lifting the wastegate valve off of it's seal.
4. Slip rod end off the wastegate lever arm pin.
5. Adjust rod as needed
   - ☐ To INCREASE pressure setting at 0.04 in. turn rod end CLOCKWISE.
   - ☐ To DECREASE pressure setting at 0.04 in. turn rod end COUNTERCLOCKWISE.
6. With pressure still applied to actuator, replace rod end on wastegate lever arm
7. Check actuator set pressure again; refer to section 6.8.6.
8. If actuator is still out of adjustment, repeat this procedure again.
9. If actuator is within specified set pressure, re-install retaining clip on wastegate lever arm pin.
10. Tighten jam nut to secure rod end.

## 6.8.7 Assembly of Turbocharger Series 60G Automotive Engine

Use the following procedure to assemble the turbocharger:

| NOTICE: |
|---|
| As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material, which may cause component damage. |

1. Cover all openings.
2. Position the turbine housing as marked at disassembly against the center housing and secure it in place.

| NOTICE: |
|---|
| Failure to properly orient the Tee-bolt end of the clamp can result in an exhaust leak, turbine wheel damage or both. |

3. To assemble the GT42 turbochargers, position the V-band coupling between the turbine housing and center housing so that the Tee-bolt end does not interfere with the turbine housing. Then tighten the V-band coupling nut, as follows:

   [a] Lubricate the toggle bolt threads with a high temperature anti-seize compound.

   [b] Torque the nut on the V-band toggle bolt to approximately 18 N·m (160 lb· in.).

**NOTE:**
Do not pull a misaligned turbine housing into alignment with the V-band coupling. The parts must be aligned and seated first.

   [c] Loosen the V-band coupling nut to approximately 6 N·m (50 lb· in.) torque, then torque the nut to 12-15 N·m (106-130 lb· in.).

4. Position the compressor housing as marked at disassembly against the backplate assembly and secure it in place with the V-band coupling.
5. Lightly lubricate the threads of the toggle bolt with engine oil and torque the nut to 12-15 N·m (106-130 lb· in.). This completes the assembly of GT42 turbocharger.

| NOTICE: |
|---|
| The 5/8 in. hex-head turbine housing bolts replaced 3/8 in. hex-head bolts. The 5/8 in. hex-head bolts are required to ensure sufficient clamp load. |

6. Secure the TMF turbine housing with four 5/8 in. hex head bolts.
7. Torque the bolts to 34 N·m (300 lb· in.).

### 6.8.8 Installation of Turbocharger Series 60G Automotive Engine

To install the turbocharger:

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
3. Remove any covers on the oil inlet and drain lines, and the oil inlet and drain openings on the turbocharger.
4. Place the turbocharger assembly into position on the exhaust manifold. Use a new gasket between the exhaust manifold and the turbine housing flange.
5. Secure the turbocharger to the exhaust flange. Tighten the nuts just enough to hold the turbocharger in place.
6. Slide the charge air cooler air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

**CAUTION:**

**To avoid injury, wear a face shield or goggles.**

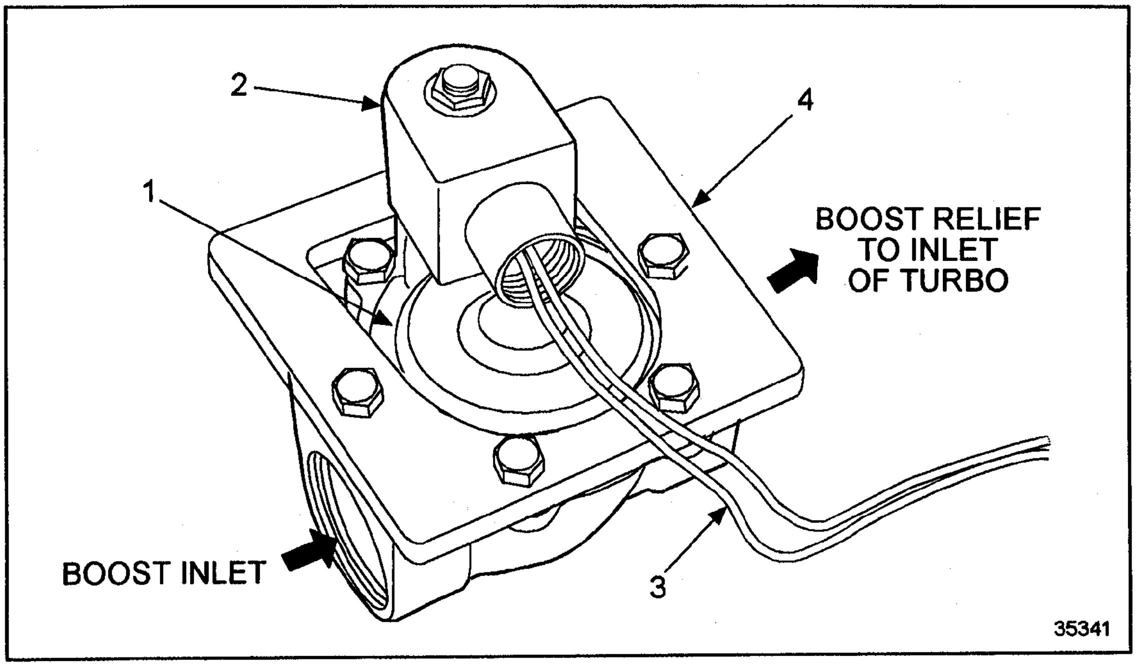
**NOTICE:**

Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

7. Torque the turbocharger to exhaust manifold locknuts to 58-73 N·m (43-54 lb·ft).
8. Install the oil drain line, using a new gasket, between the opening in the bottom side of the turbocharger center housing and the drain hose that runs to the cylinder block. Torque the bolts to 30-38 N·m (22-28 lb·ft).
9. Refer to section 11.1.3 for verification of proper turbocharger installation.
10. Install water supply and return lines.

## 6.9 RECIRCULATION VALVE FOR SERIES 60G AUTOMOTIVE ENGINE

The Series 60G automotive GT42 turbocharger requires a boost recirculation valve to reduce air system pressure pulsations and turbocharger surging during engine throttling operations. The recirculation valve is remote-mounted by the OEM and routes air from the high-pressure boost side back to the air inlet side during deceleration. The recirculation valve is a large solenoid valve that is triggered to open by DDEC through a digital output pin of the ECM. See Figure 6-47 for recirculation valve.




1. Recirculation Valve Body
2. 12V Coil
3. 2-pin Connector
4. Bracket

**Figure 6-47 Recirculation Valve**

### 6.9.1 Replacement of the Recirculation Valve for Series 60G Automotive Engine

The recirculation valve isa non-serviceable component and should be replaced as a unit. No adjustment is required.

### 6.9.2 Removal of the Recirculation Valve for Series 60G Automotive Engine

Remove the recurculation valve as follows:

1. Disconnect the inlet and outlet hoses from the valve.
2. Disconnect the two-pin electrical connector.
3. Remove the two bolts that attach the recirculation valve to the mounting surface.

**NOTE:**
The valve has a mounting bracket attached to its body. Do not remove the bolts in the valve body to gain access to the valve. Removal of these bolts can expose the valve diaphragm and cause permanent damage.

4. If replacing the unit, remove the inlet and outlet fittings from the valve.

### 6.9.3 Installation of the Recirculation Valve for Series 60G Automotive Engine

Install the recirculation valve as follows:

1. Position the valve on the mounting surface and secure it in place with the two mounting bolts.

**NOTE:**
Ensure the arrow on the base of the valve corresponds with the flow of air from the turbo outlet side to the turbo inlet side.

2. Connect the inlet and outlet hoses to the valve fittings.
3. Connect the two-pin electrical connector.
4. Check for any leaks in the system.

## 6.10 CHARGE AIR COOLER

On vehicle and industrial engines, a CAC (charge air cooler) is normally mounted ahead of the cooling system radiator. On keel-cooled marine engines the charge air cooler is incorporated into the keel cooler tank. On heat exchanger-cooled engines, the charge air cooler is part of the intake manifold. The compressed air leaving the turbocharger is directed through the CAC before it goes to the air inlet side of the intake manifold. See Figure 6-48. Refer to section 4.4 for CAC Water Pump.

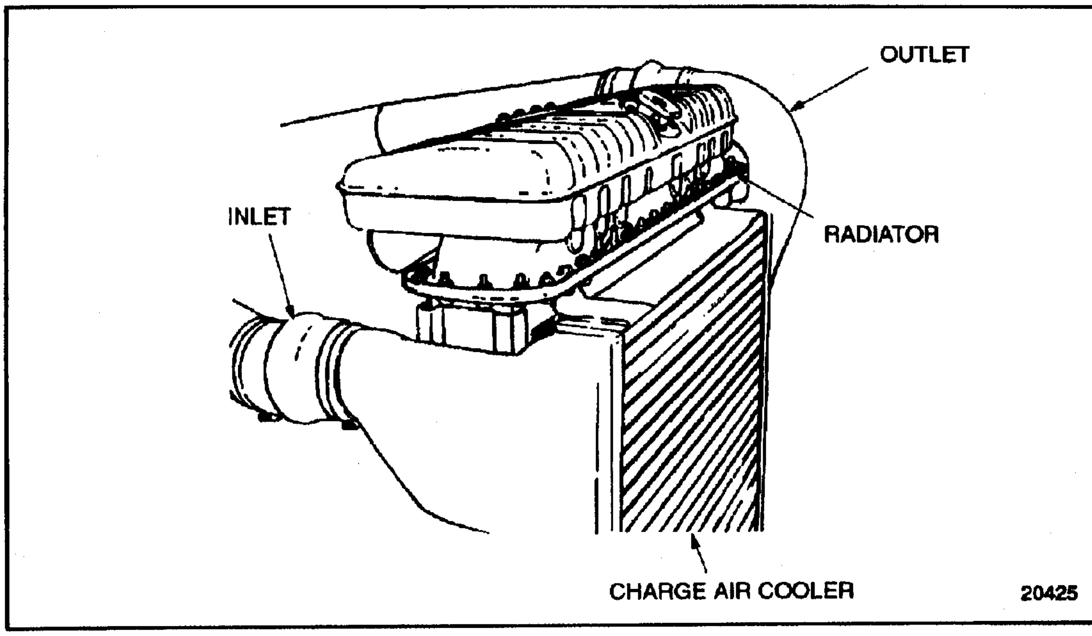



**Figure 6-48 Typical Charge Air Cooler**

The CAC is used to reduce the temperature of the compressed air leaving the turbocharger before it reaches the intake manifold. This permits a more dense charge of air to be delivered to the engine.

Cooling is accomplished by incoming air flowing past the tubes and fins of the charge air cooler. The compressed intake charge flowing inside the CAC core transfers the heat to the tubes and fins where it is picked up by the incoming outside air (vehicle and industrial engines) or raw water (marine engines). See Figure 6-49. See Figure 6-50and see Figure 6-51.

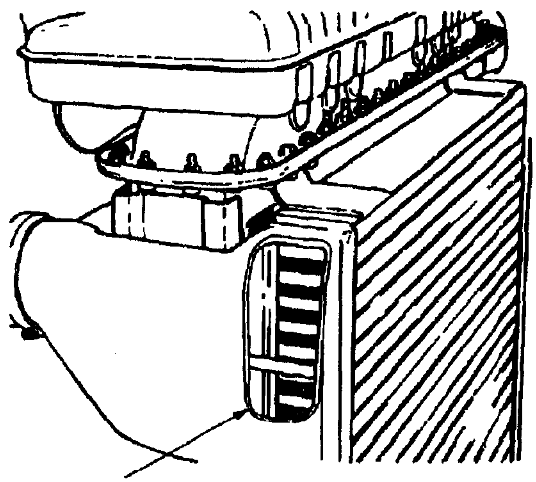
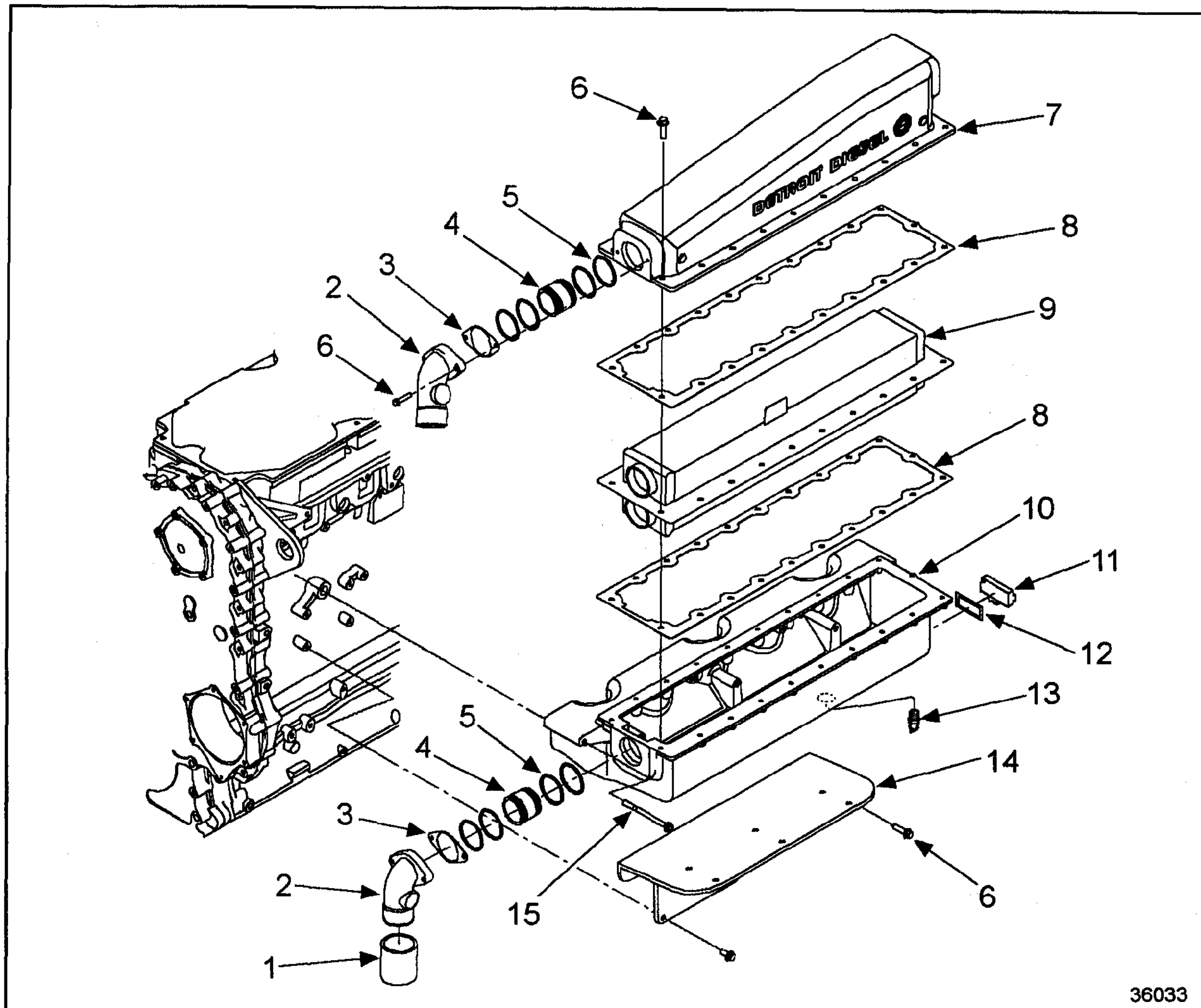
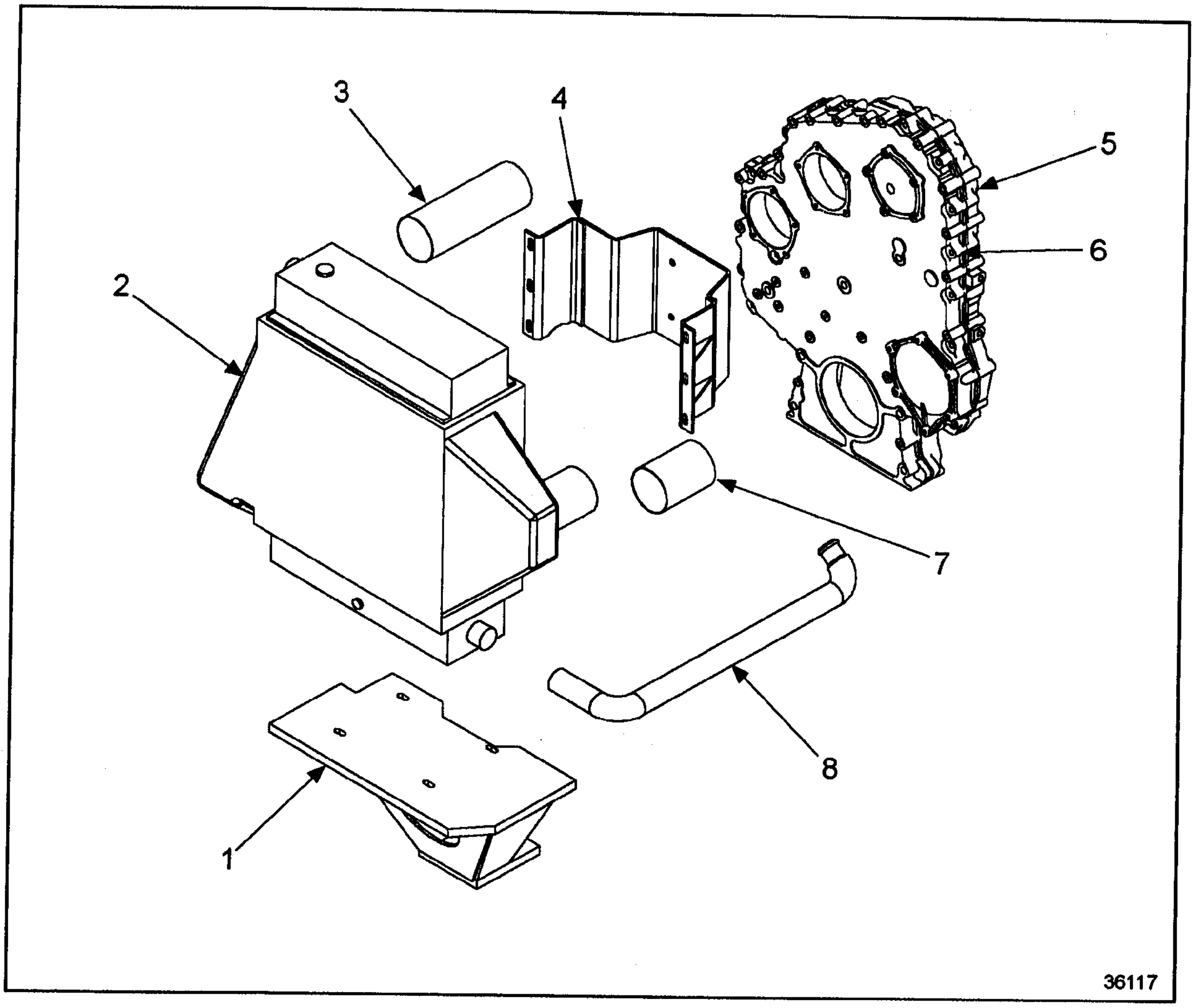



**Figure 6-49 Radiator—mounted Charge Air Cooler Cross-section**




| | |
|---|---|
| 1. Hose | 8. Gasket |
| 2. Elbow | 9. CAC Matrix |
| 3. Gasket | 10. Housing Lower |
| 4. Sleeve | 11. Sensor |
| 5. Seal Ring | 12. Seal Ring |
| 6. Bolt | 13. Air Temperature Sensor |
| 7. Housing Upper | 14. Bracket |
| | 15. Bolt |

**Figure 6-50 Charge Air Cooler Assembly — Heat Exchanger-Cooled Pleasure Craft Marine Engine**

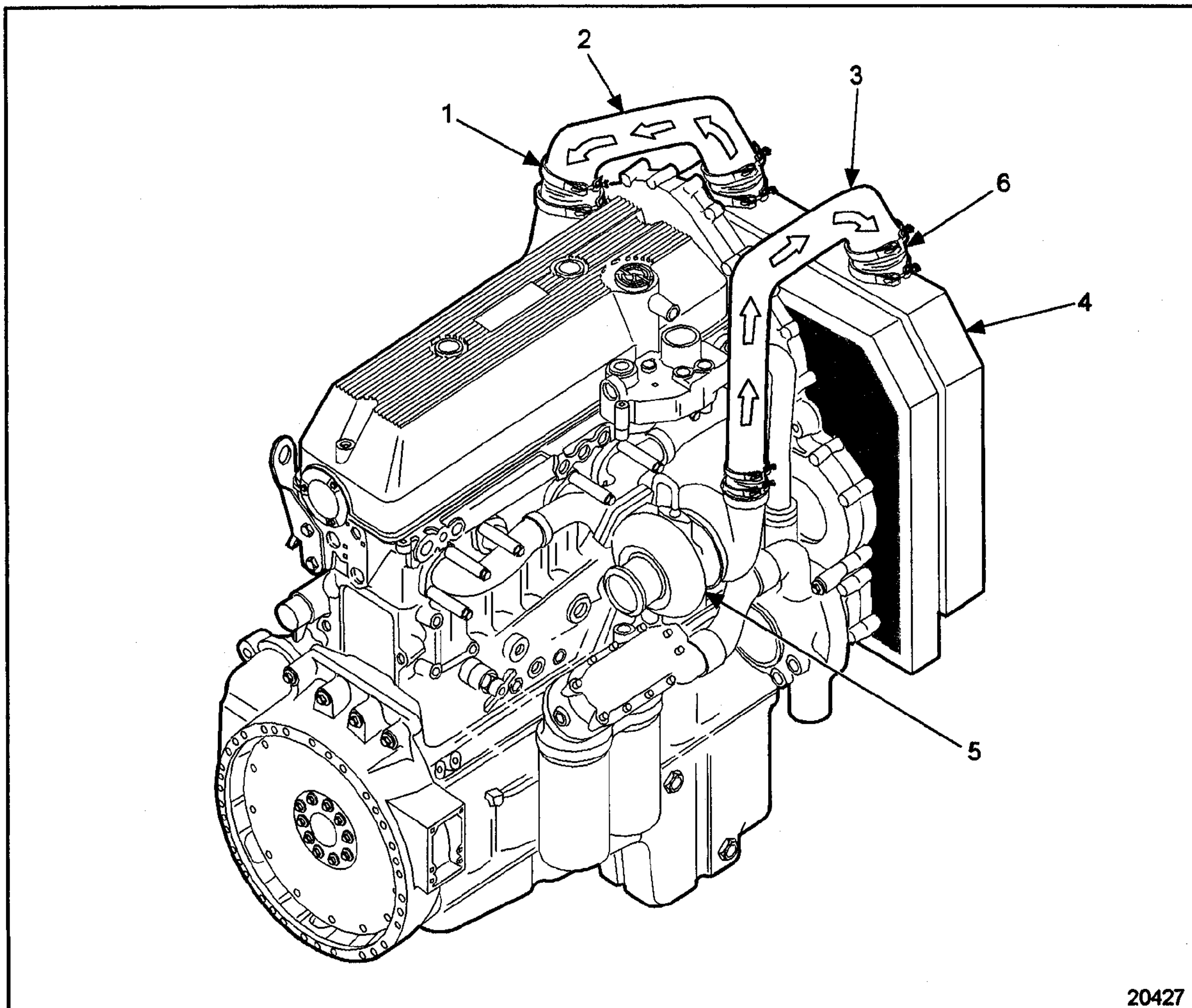



1. Bracket, Charge Air Cooler Mounting
2. Charge Air Cooler
3. Tube, Charge Air Cooler Air Inlet
4. Bracket, Charge Air Cooler Rear Mounting
5. Gear Case
6. Gear Case Cover
7. Tube, Charge Air Cooler Air Inlet
8. Inlet Tube, Raw Water

**Figure 6-51 Keel—Cooled Commercial Marine Charge Air Cooler**

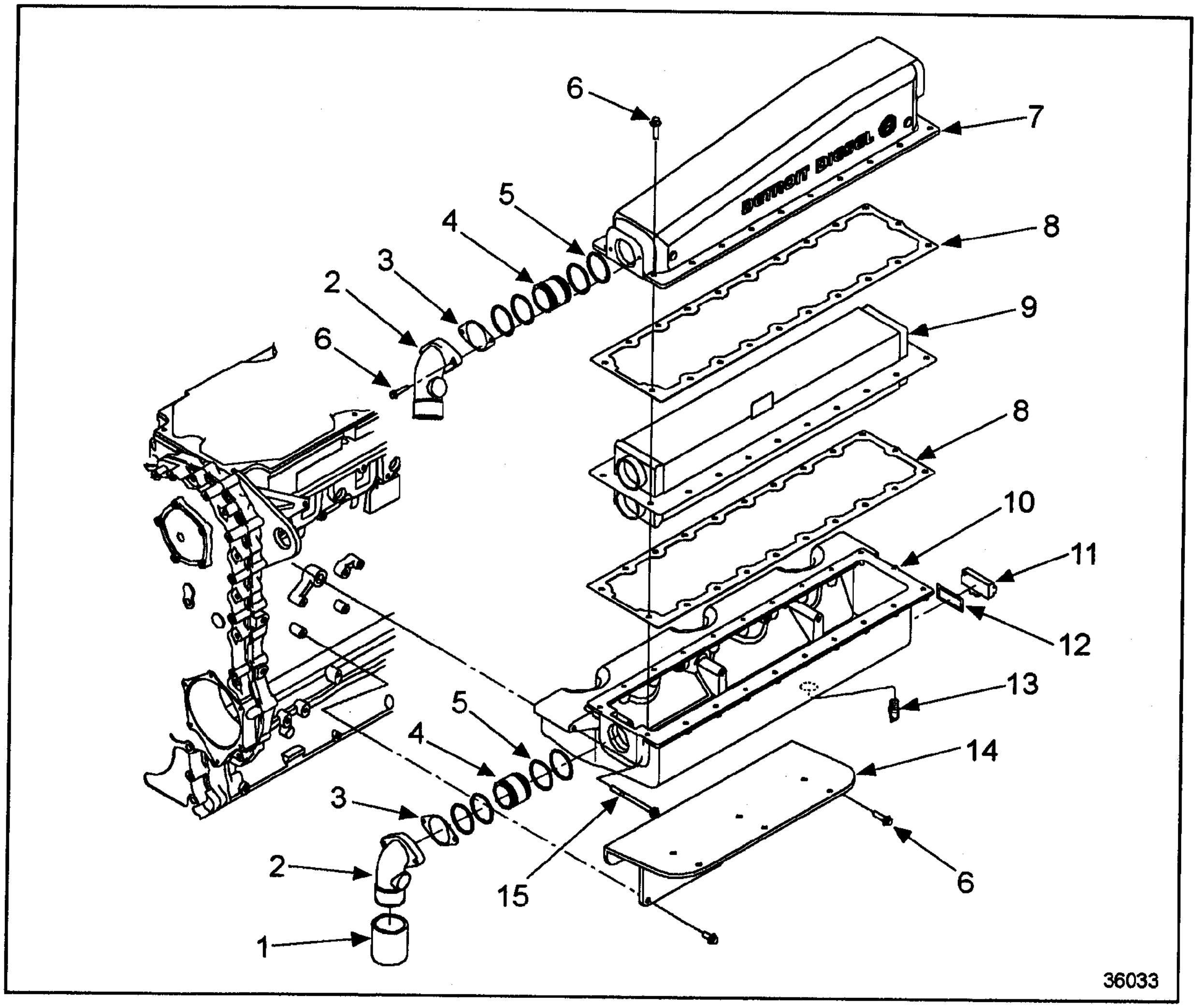
Metal ductwork is used to transfer the air from the turbocharger outlet to the CAC, and from there to the intake manifold. See Figure 6-52.

On diesel engines, flexible rubber couplings and hose clamps are used to secure the ductwork to the turbocharger, the CAC inlet and outlet, and the intake manifold.



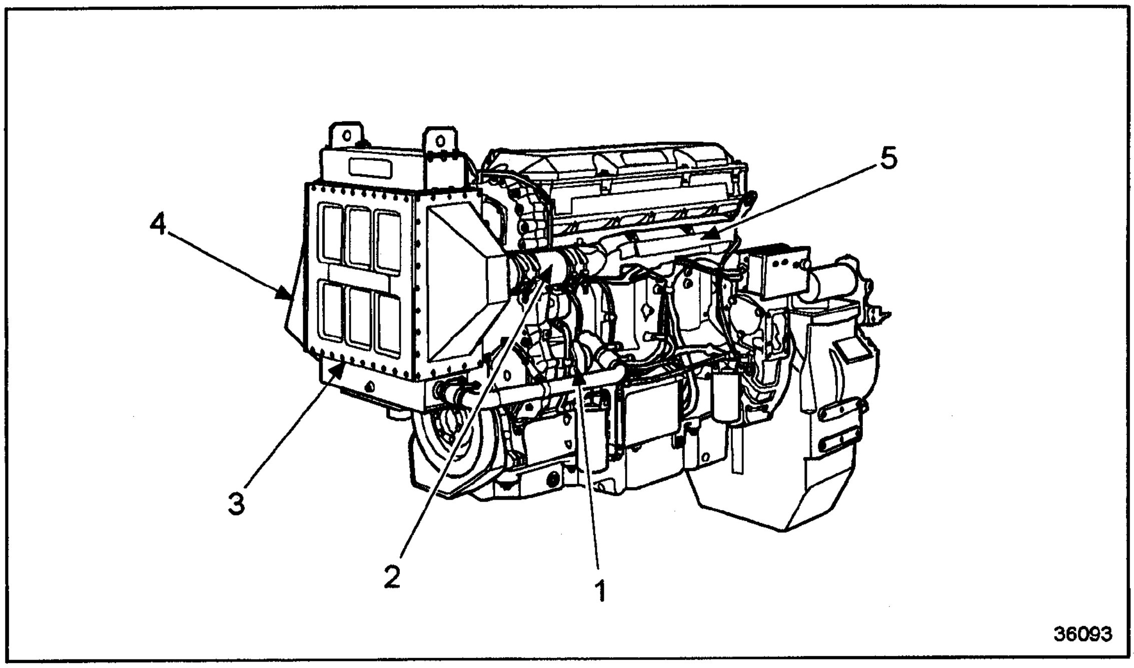

1. Coupling Hose Clamp
2. Charge Air Cooler Outlet Duct
3. Charge Air Cooler Inlet Duct
4. Charge Air Cooler
5. Turbocharger
6. Coupling Hose Clamp

**Figure 6-52 Radiator—mounted Charge Air Cooler and Related Parts (Series 60 Diesel Engine)**




1. Hose
2. Elbow
3. Gasket
4. Sleeve
5. Seal Ring
6. Bolt
7. Housing Upper
8. Gasket
9. CAC Matrix
10. Housing Lower
11. Sensor
12. Seal Ring
13. Air Temperature Sensor
14. Bracket
15. Bolt

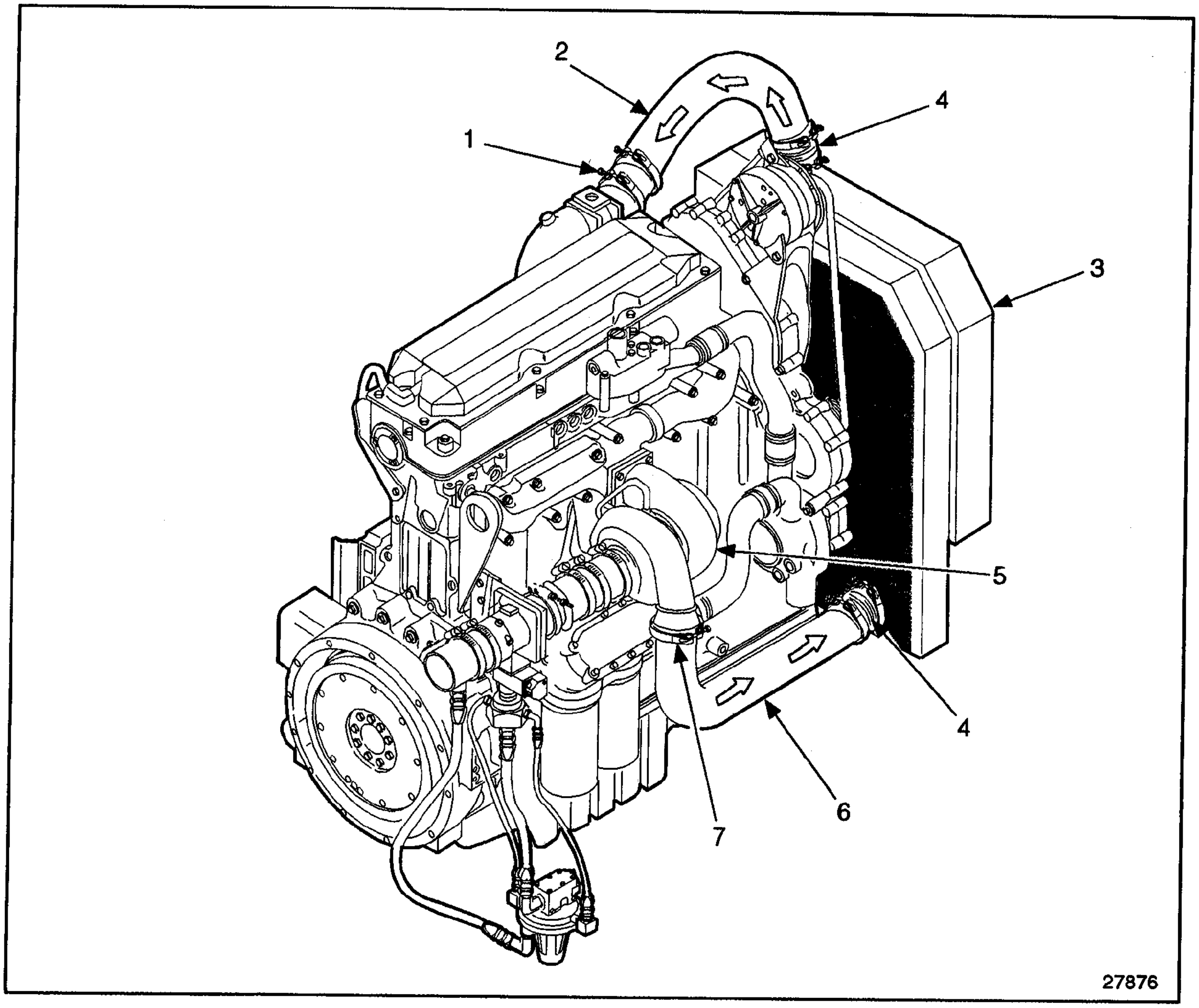
**Figure 6-53 Heat Exchanger Charge Air Cooler and Related Parts (Series 60 Diesel Engine)**




1. Raw Water Pump
2. Charge Air Cooler Outlet Pipe
3. Charge Air Cooler
4. Charge Air Cooler Inlet
5. Air Intake Manifold

**Figure 6-54 Keel—Cooled Charge Air Cooler and Related Parts (Series 60 Diesel Engine)**

For the Series 60G Genset engines, hoses connect steel piping from the turbo to the CAC, and from the CAC to the throttle. See Figure 6-55.




1. Coupling Hose Clamp
2. Charge Air Cooler Outlet Duct
3. Charge Air Cooler
4. Flexible Coupling
5. Turbocharger
6. Charge Air Cooler Inlet Duct
7. V-Band Clamp

**Figure 6-55 Charge Air Cooler and Related Parts (Series 60G Engine) Genset**

### 6.10.1 Repair or Replacement of Charge Air Cooler

Refer to the OEM guidelines for CAC repair and replacement procedures.

### 6.10.2 Removal and Cleaning of Charge Air Cooler

Refer to the OEM guidelines for CAC service procedures.

### 6.10.3 Installation of Charge Air Cooler

Refer to the OEM guidelines for CAC installation procedures.

When installation is completed, refer to section 11.8 for engine test.

## 6.11 THROTTLE ACTUATOR FOR THE SERIES 60G ENGINE

The throttle actuator is used to control the amount of air and fuel mixture to the engine. A butterfly valve within the body is positioned by an electric actuator that is controlled by DDEC III/IV. See Figure 6-56.

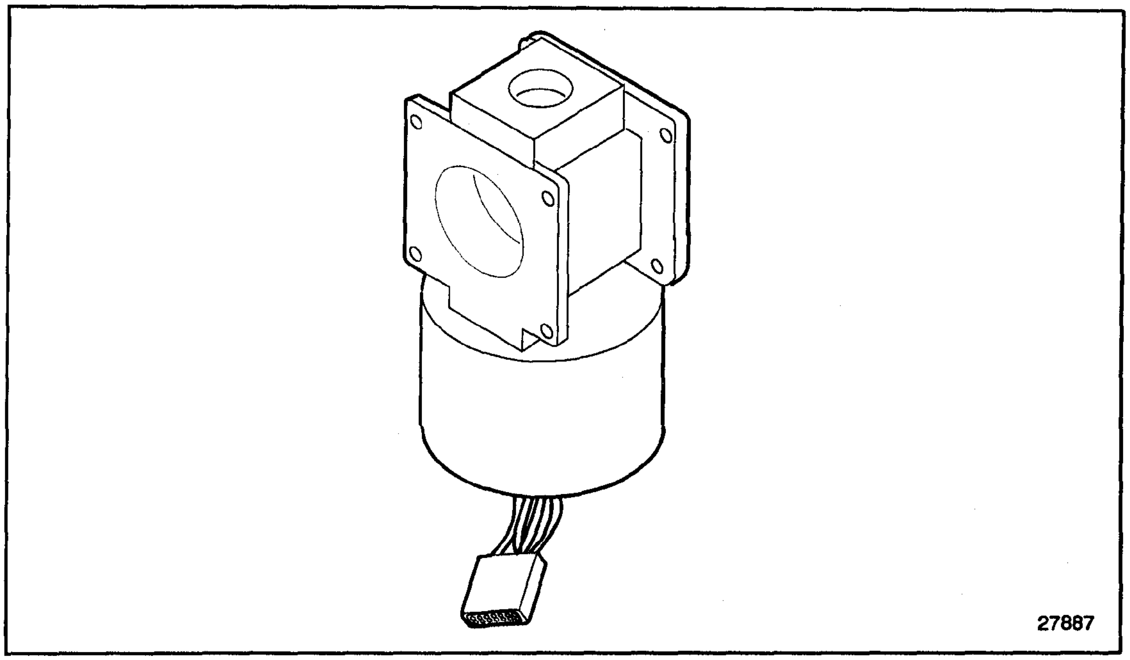



**Figure 6-56 Throttle Actuator for the Series 60G Engine**

Listed in Table 6-4are the throttle control diagnostic codes:

| Description | Condition | PID | FMI | Information |
|---|---|---|---|---|
| Throttle Plate Position | HIGH Voltage | P51 | 3 | Indicates that the Throttle Plate Position Sensor input to the ECM has exceeded 95% (normally >4.75 volts) of the sensor supply voltage. This diagnostic is typically an open sensor return circuit or sensor signal circuit is shorted to the sensor +5 volt supply. |
| Throttle Plate Position | LOW Voltage | P51 | 4 | Indicates that the Throttle Plate Position Sensor input to the ECM has dropped below 5% (normally < 0.25 volts) of the sensor supply voltage. This diagnostic condition is typically detected when there is:- An open sensor signal circuit- An open sensor +5 volt supply circuit- The sensor signal is shorted to the sensor return circuit or to ground. |
| Throttle Plate Position | HIGH Position | P51 | 0 | Indicates that the Throttle Plate Position Sensor input to the ECM has indicated that the throttle plate has exceeded the recommended operating range. |
| Throttle Plate Position | LOWPosition | P51 | 1 | Indicates that the Throttle Plate Position Sensor input to the ECM has indicated that the throttle plate has dropped below the recommended operating range. |

**Table 6-4 Throttle Control Diagnostic Codes for the Series 60G Engine**

### 6.11.1 Reuse or Replacement of Throttle Actuator for the Series 60G Engine

The throttle actuator is non-serviceable and should be replaced as a unit. No adjustment is required.

### 6.11.2 Removal of Throttle Actuator for the Series 60G Engine

Remove the throttle actuator as follows:

1. Vent fuel system; refer to section 2.49.1and refer to section 2.49.2.
2. Disconnect and remove the six-wire power harness connectors from the throttle actuator.
3. Remove the four bolts connecting the throttle actuator to the mounting bracket.
4. Remove 8 bolts and nuts attaching the throttle to the inlet and outlet tube assemblies.

### 6.11.3 Disassembly of Throttle Actuator for the Series 60G Engine

Disassembly of the throttle actuator is not required.

### 6.11.4 Cleaning of Throttle Actuator for the Series 60G Engine

Cleaning of the throttle actuator is not required.

#### 6.11.4.1 Inspection of Throttle Actuator for the Series 60G Engine

Inspection of the throttle actuator is not required.

#### 6.11.4.2 Test of Throttle Actuator for the Series 60G Engine

Test of the throttle actuator is not required.

### 6.11.5 Installation of Throttle Actuator for the Series 60G Engine

Install the throttle actuator as follows:

1. Secure the throttle actuator to the mounting bracket with the four bolts and washers and torque to 20 N·m (15 lb·ft).
2. Connect the six-wire power harness.
3. Install a new gasket and attach the outlet tube assembly using four bolts.
4. Install a new gasket and attach the inlet tube assembly using four bolts.

**CAUTION:**

**To avoid injury from an explosion of natural gas, the following precautions must be taken:**

- ☐ **Do not smoke when installing or servicing the engine or fuel system.**
- ☐ **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- ☐ **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- ☐ **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- ☐ **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- ☐ **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- ☐ **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- ☐ **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

**Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).**

5. Run engine and check for air or air and fuel mixture leaks at the throttle and connecting hoses. Refer to section 2.49.3.

## 6.12 AIR DRYER

Refer to OEM guidelines for air dryer repair and replacement procedures.

# 6.A ADDITIONAL INFORMATION

**Description** **Page**

## SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

### Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 1-34 in the "General Information" section. Standard (nonmetric) nut and bolt torque specifications are listed in Table 1-36 in the "General Information" section. The exception to this rule is listed in Table 6-5.

| Bolt and Size | Torque, N· m | Torque, lb · in. |
|---|---|---|
| M5 X 30.0 mm | 24-30 | 21-26 |

**Table 6-5 Exceptions - Metric Fastener Torque Specifications**

**NOTE:**
The diesel turbo-boost pressure sensor retaining bolts are M5 x 30.0 mm long.

# 7 EXHAUST SYSTEM

**Section** **Page**

## 7.1 OVERVIEW OF EXHAUST SYSTEM

The automotive and industrial engine exhaust system consists of a three-piece exhaust manifold. See Figure 7-1 for a typical configuration of the exhaust manifold and gaskets.

The outlet flange is centrally located and connects directly to the turbocharger turbine housing.

The three pieces of the exhaust manifold incorporate slip joints which slide together easily on initial assembly and seal when the manifold is heated by engine operation.

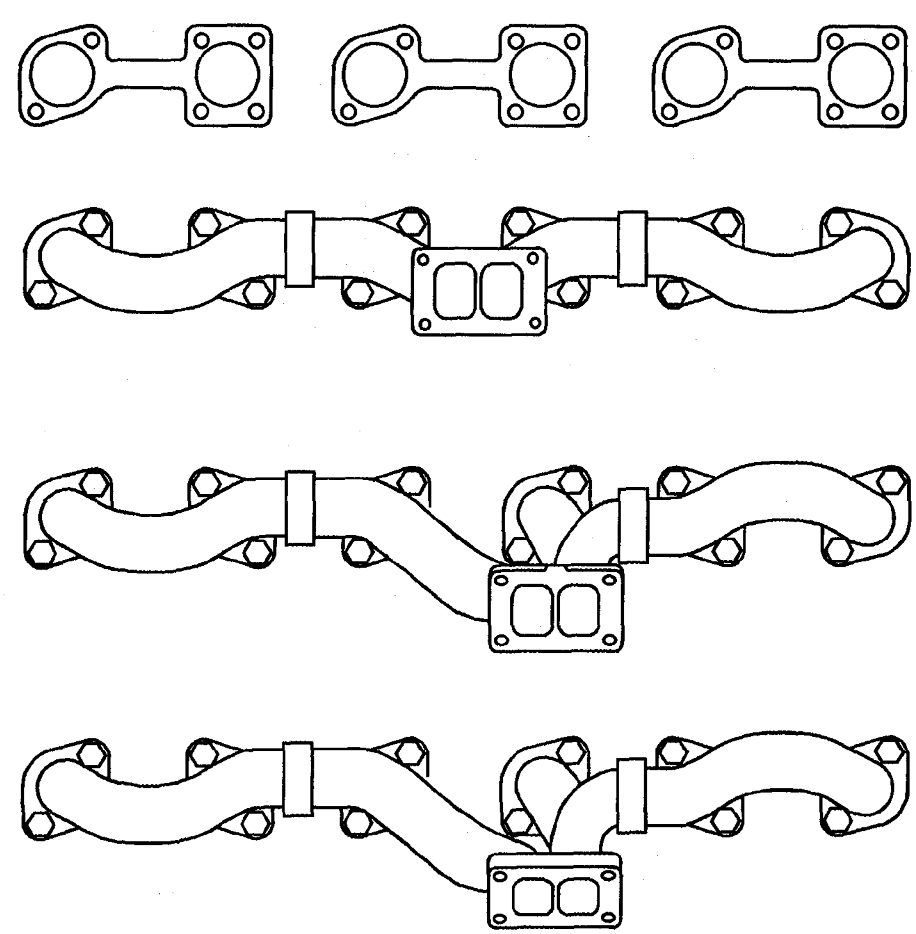


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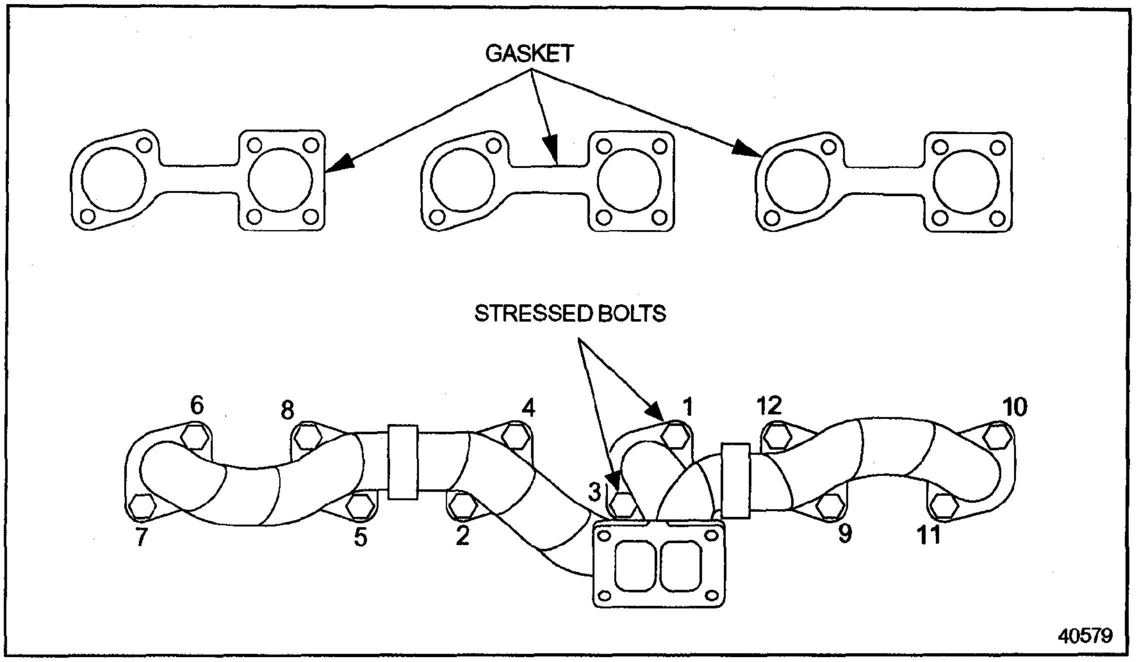
**Figure 7-1 Three-Piece Exhaust Manifold and Gasket Configurations**

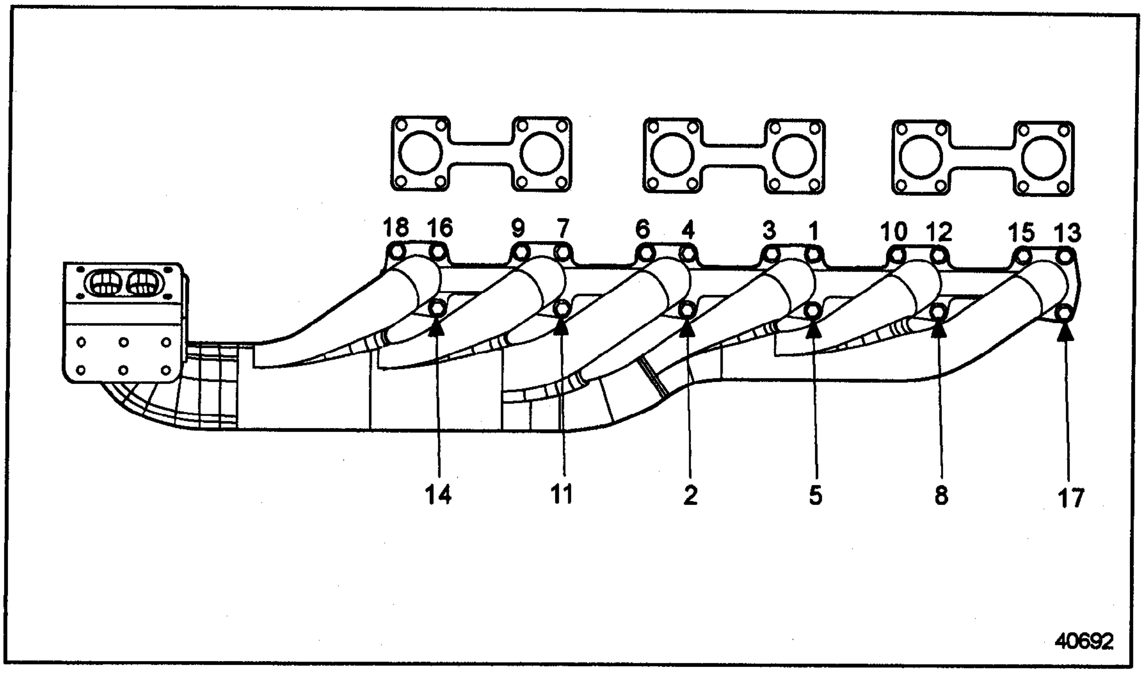
The keel-cooled marine engine exhaust system consists of a three-piece, thermal-wrapped exhaust manifold. See Figure 7-2for typical exhaust manifold and gasket configuration.

The heat exchanger-cooled marine engine exhaust system consists of a one-piece, water-cooled exhaust manifold. See Figure 7-3 for a typical exhaust manifold and gasket configuration.




Numbers indicate torque sequence..

**Figure 7-2 Typical Three-Piece Thermal-Wrapped Exhaust Manifold and Gasket Configuration**




Numbers indicate bolt sequence.

**Figure 7-3** **Typical One-Piece Water-Cooled Exhaust Manifold and Gasket Configuration**

## 7.2 EXHAUST MANIFOLD

**Three-Piece Exhaust Manifold:** A three-piece, cast-iron exhaust manifold is attached to the cylinder head with twelve special alloy hardened bolts. The manifold has a square outlet flange which is bolted directly to the turbocharger turbine housing. See Figure 7-4. Three identical exhaust manifold gaskets are used between the manifold and the cylinder head. See Figure 7-1.

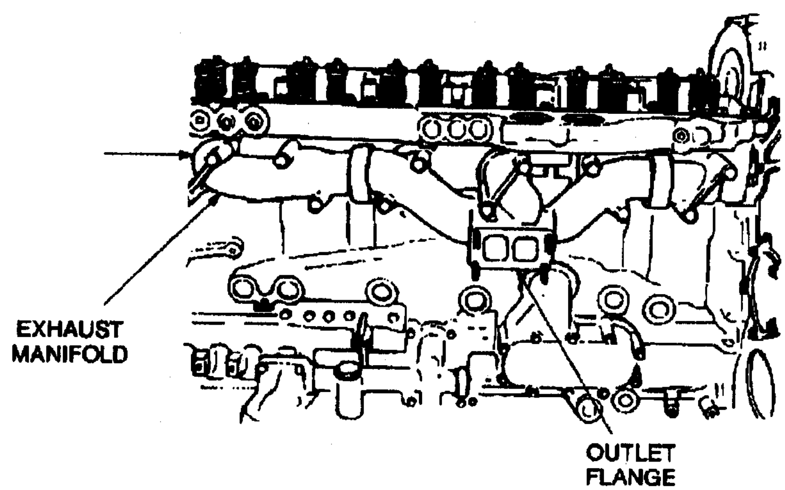
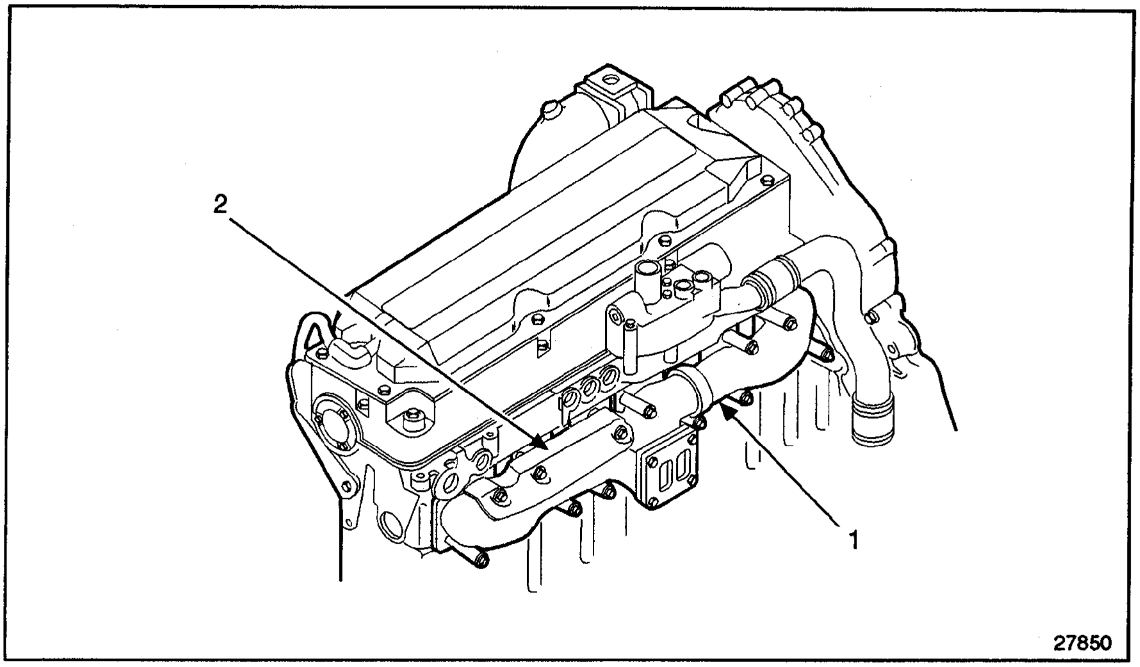



**Figure 7-4 Typical Exhaust Manifold Mounting**

**NOTE:**
Exhaust manifolds on Series 60G genset engines provide a heat shield for efficiency, see Figure 7-5.

**NOTE:**
Exhaust manifolds on Series 60G automotive engines and on Series 60 keeled-cooled marine engines have an insulation wrap to contain heat. One-piece exhaust manifolds on Series 60 heat exchanger-cooled marine engines are water-cooled. See Figure 7-6.




1. Exhaust Manifold
2. Heat Shield

**Figure 7-5 Typical Exhaust Manifold Mounting (Series 60G Genset Engine)**

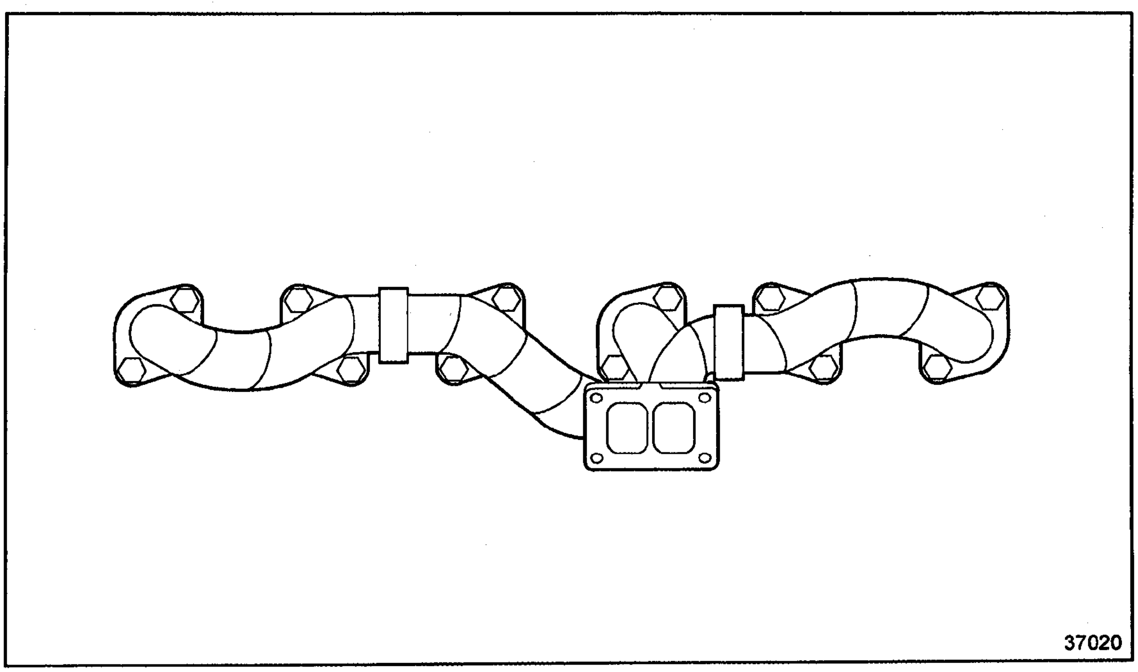



**Figure 7-6 Typical Exhaust Manifold of a Pleasure Craft Marine**

### 7.2.1 Repair or Replacement of the Exhaust Manifold

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 7-7.

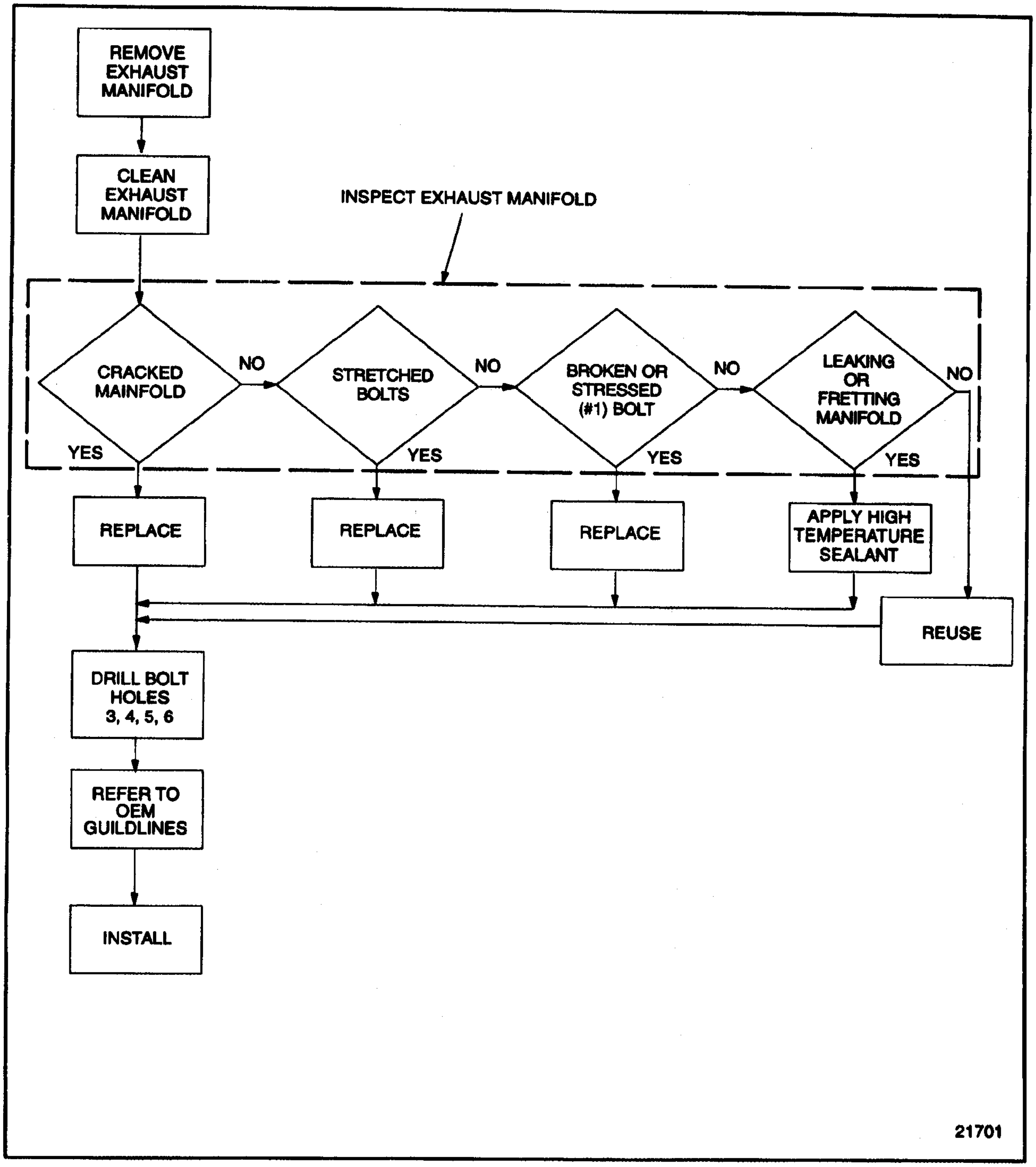



**Figure 7-7 Flowchart for Repair or Replacement of Exhaust System**

### 7.2.2 Removal and Cleaning of the Exhaust System

Remove the exhaust manifold as follows:

**NOTE:**
The exhaust manifold need not be clean prior to removal.

1. Remove the turbocharger assembly. Refer to section 6.6.2 (diesel) or refer to section 6.7.2 (natural gas).
2. Remove the bolts that secure the exhaust manifold to the cylinder head.
3. Remove the three-piece manifold as an assembly or remove the one-piece manifold. Discard the three gaskets.

### 7.2.3 Cleaning of Exhaust Manifold

Clean the exhaust manifold prior to inspection as follows:

1. Remove any loose scale and carbon that may have accumulated on the internal walls of the manifold.
2. Clean the manifold exterior with a wire brush.

#### 7.2.3.1 Inspection of the Exhaust Manifold

Inspect the exhaust manifold as follows:

1. Visually inspect the exhaust manifold for cracks, especially in the bolt clamp areas.
   [a] If exhaust manifold is cracked, replace with a new manifold. If it is necessary to replace individual sections of the three-piece exhaust manifold, clamp the manifold in a vise equipped with soft jaws. Use a brass drift and hammer to separate the pieces. Refer to section 7.2.4.
   [b] If exhaust manifold is not damaged, reuse the component. Refer to section 7.2.4.

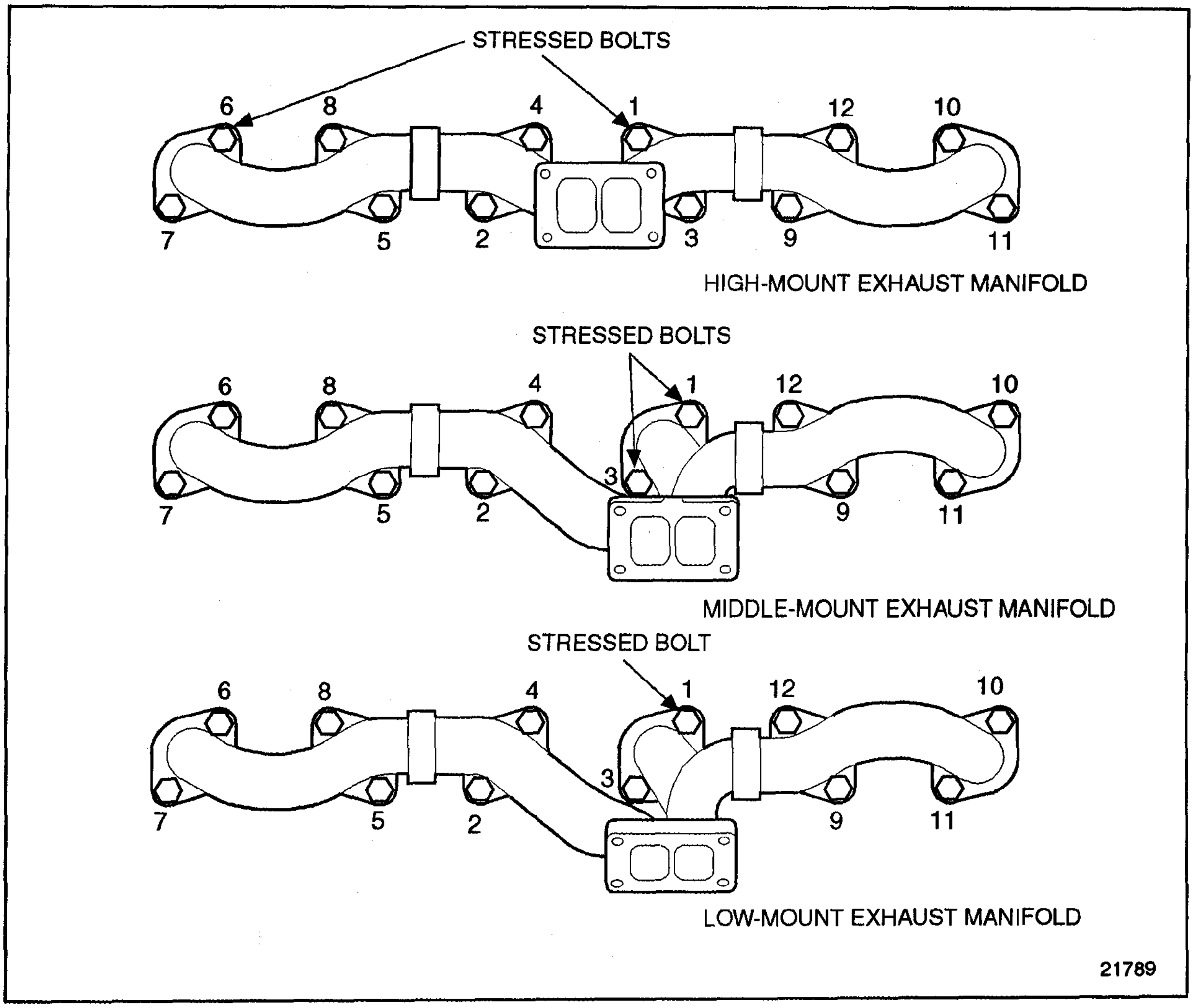
2. Visually inspect manifold mounting bolts for damage.

   [a] If bolts are excessively stretched, or if threads are excessively damaged, replace with new bolts. Refer to section 7.2.4.

   [b] If bolts are not stretched or damaged, refer to section 7.2.4.

**NOTE:**

**If bolt holes 3, 4, 5, and 6 are 12.6-13.7 mm (0.496 - 0.539 in.) diameter, they should be drilled out to 14.7-15.7 mm (0.577-0.618 in.) before the manifold is reinstalled on the engine. This provides an extra margin of safety for thermal expansion of the manifold. See Figure 7-8.**




Numbers indicate bolt locations.

**Figure 7-8 Exhaust Manifold Torque Sequence**

3. Inspect manifold for leakage.
   [a] Check the three-piece manifold for fretting near the slip joints.
   [b] Joint leakage can be minimized by applying a high temperature, anti-seize sealant compound, DDC/Loctite® P/N 23509545 (or equivalent), to the inner and outer diameters of the joint surfaces before installation. See Figure 7-9.

   *Loctite® is a registered trademark of the Loctite Corporation.*

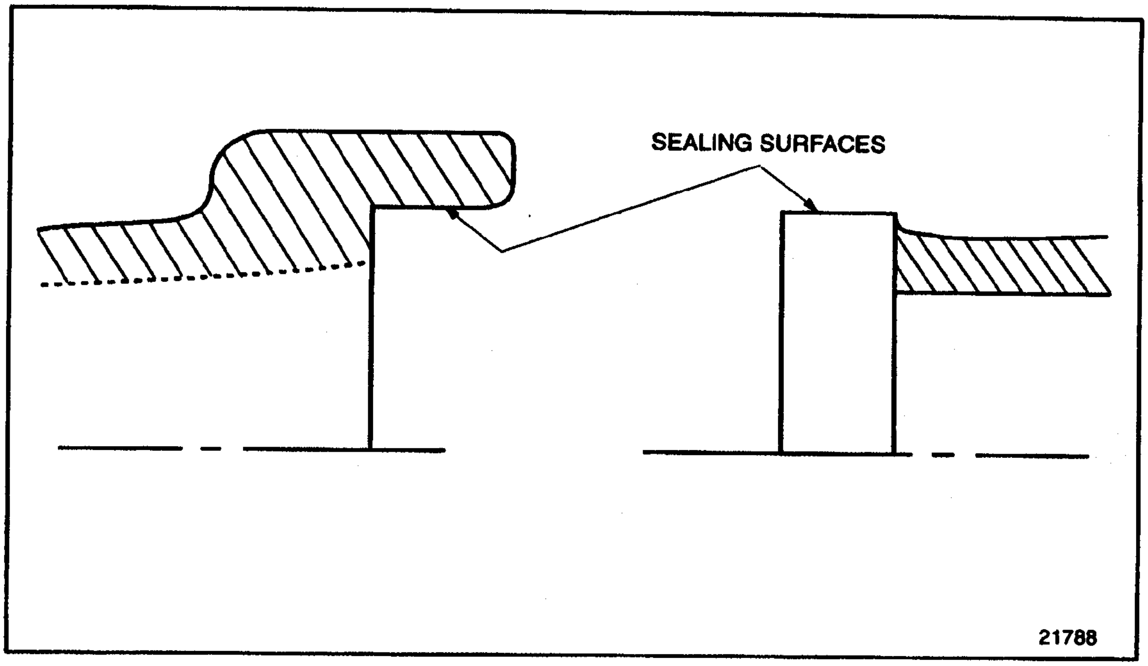
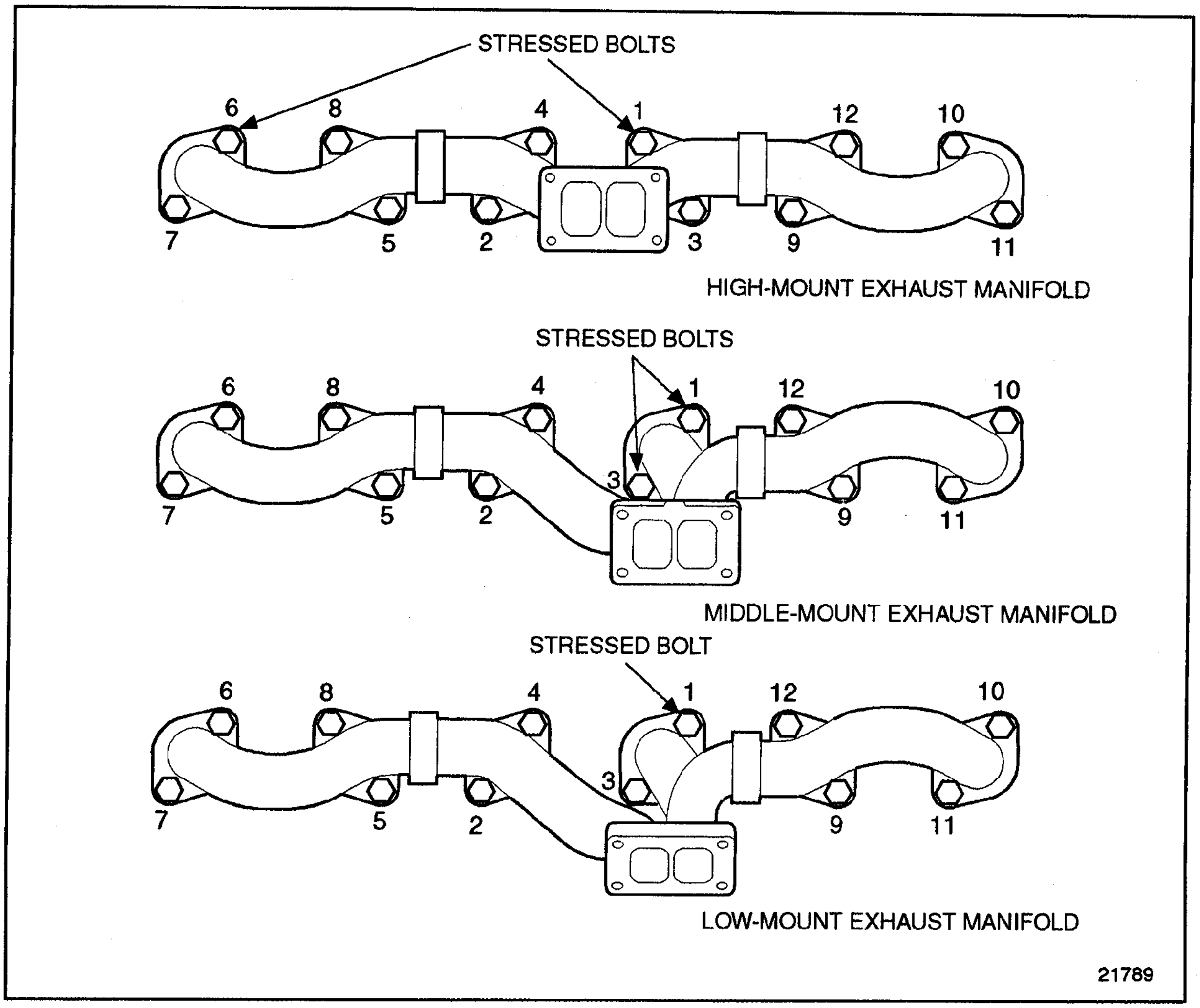



**Figure 7-9 Exhaust Manifold Sealing Surfaces**

4. Inspect #1 location manifold mounting bolt for damage. See Figure 7-10.
   [a] Check for broken or stressed bolt.
   [b] If bolt is excessively stretched, or if threads are excessively damaged, and complete manifold assembly replacement is required, three new exhaust manifold kits having center sections with reduced bolt hole boss at the #1 location, see Figure 7-10, are available. The new kits (23512896 - high mount, 23512897 middle mount, and 23513470 - low mount) also include bolts, studs, spacers, and special graphite-composition gaskets required for complete manifold replacement.

[c] If bolt is excessively stretched, or if threads are excessively damaged, and if the exhaust manifold assembly is reusable, rework the center section reducing the height of the cast-in bolt hole boss, #1 location, on the center section, see Figure 7-10, by grinding it down to 22 mm (0.87 in.). An isolating washer will be installed in this location. Glass bead inner and outer diameters of the slip joints.




Numbers indicate bolt locations.

**Figure 7-10 Exhaust Manifolds Showing Location of Stressed Bolt and Bolt Torque Sequence**

5. Check one-piece, water-cooled exhaust manifold for cracks or obvious signs of coolant leakage and replace, if necessary.
6. Inspect exhaust pipe hangers for cracks. Replace as required. Refer to OEM guidelines for proper replacement procedure.
7. Inspect the flexible exhaust connection to ensure there is adequate flexibility to permit engine movement without stressing the turbocharger and exhaust manifold. Refer to OEM guidelines for proper flexibility specifications.
8. Ensure the exhaust pipe is adequately supported. Refer to OEM guidelines to verify that the exhaust pipe is adequately supported.

### 7.2.4 Installation of Three-Piece Exhaust Manifold

Install the exhaust manifold as follows:

1. If disassembled, reassemble the three pieces of the exhaust manifold.
2. Install four exhaust manifold guide studs, J 36107, into the cylinder head to hold the three exhaust manifold gaskets in the correct position, and facilitate manifold installation. For the modified bolt boss on the reusable center section, include one P.N. 23511667 exhaust manifold spacer under the bolts.

**NOTE:**
The bolt tightening pattern on cylinders 1, 2, and 3 reverses between middle-mount and high-mount exhaust manifolds. The exhaust gasket can be positioned either way. Ensure the guide studs and gaskets are positioned correctly for the manifold being installed.

3. Install the exhaust gaskets to the guide studs.
4. Install the assembled manifold to the guide studs.
5. Install eight of the bolts and spacers to the vacant holes. Finger-tighten the bolts.
6. Remove the four guide studs.
7. Install the remaining four manifold bolts and spacers to the holes from which the studs were removed.

8. Torque the bolts to 58-73 N·m (43-54 lb·ft) using the tightening sequence. See Figure 7-10. For a wrapped exhaust manifold see Figure 7-11.

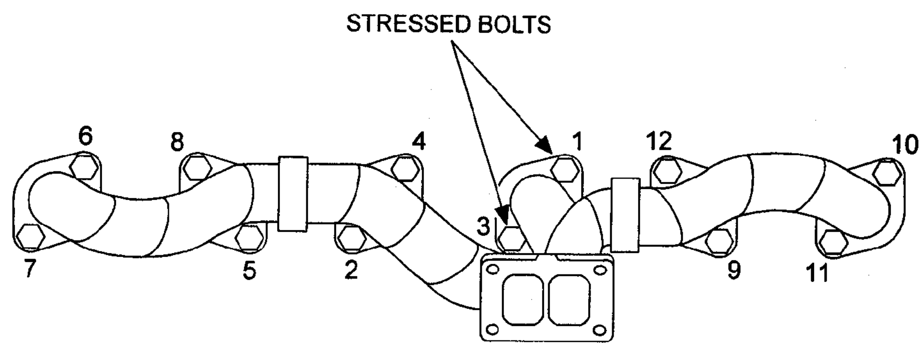



**Figure 7-11 Wrapped Manifold Bolt Torque Sequence**

9. Install the turbocharger assembly. Refer to section 6.6.7(diesel) or refer to section 6.7.5 (gas).
10. Install any other equipment that was removed for this procedure.

**CAUTION:**

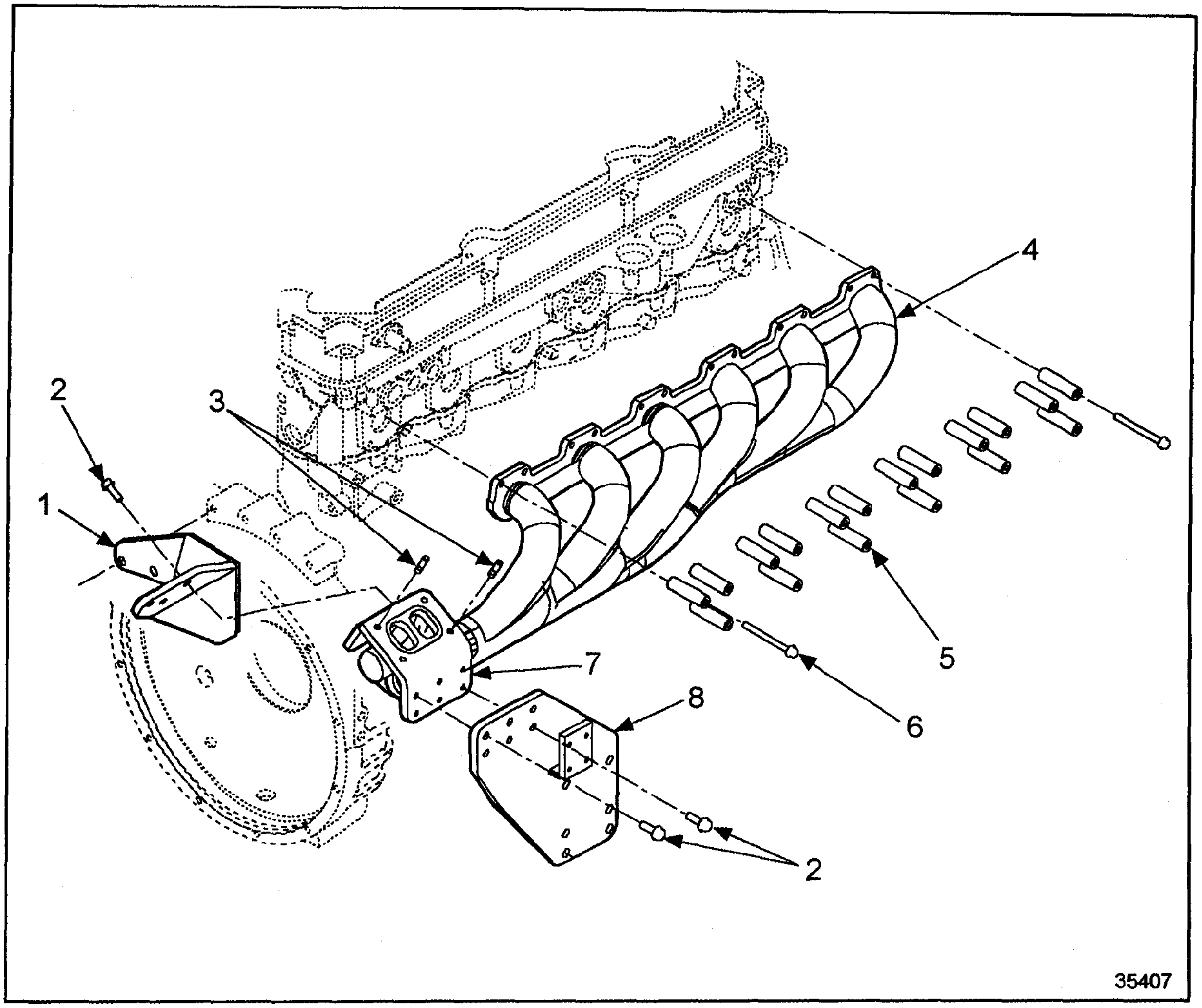
**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

11. Start the engine and check for exhaust leaks.
12. Refer to section 11.3.6 for verification of proper exhaust manifold installation.

### 7.2.5 Installation of One-Piece Water-Cooled Exhaust Manifold

Install the one-piece water-cooled exhaust manifold as follows: (See Figure 7-12).




1. Bracket, Upper Manifold Support
2. Bolt
3. Stud
4. Exhaust Manifold
5. Spacer
6. Bolt
7. Turbo Mounting Flange (part of exhaust manifold)
8. Bracket, Turbo Mounting

**Figure 7-12 One-Piece Water-Cooled Exhaust Manifold and Related Parts**

1. Install six exhaust manifold guide studs, J 36107, into the cylinder head to hold the six exhaust manifold gaskets in the correct position and facilitate manifold installation.
2. Install the exhaust gaskets (3) to the guide studs.
3. Install the manifold to the guide studs.

4. Install twelve of the bolts and spacers to the vacant holes. Finger-tighten the bolts.
5. Remove the six guide studs.
6. Install the remaining manifold bolts to the holes from which the studs were removed.
7. Torque the bolts to 58-73 N·m (43-54 lb·ft) using the tightening sequence. See Figure 7-13.

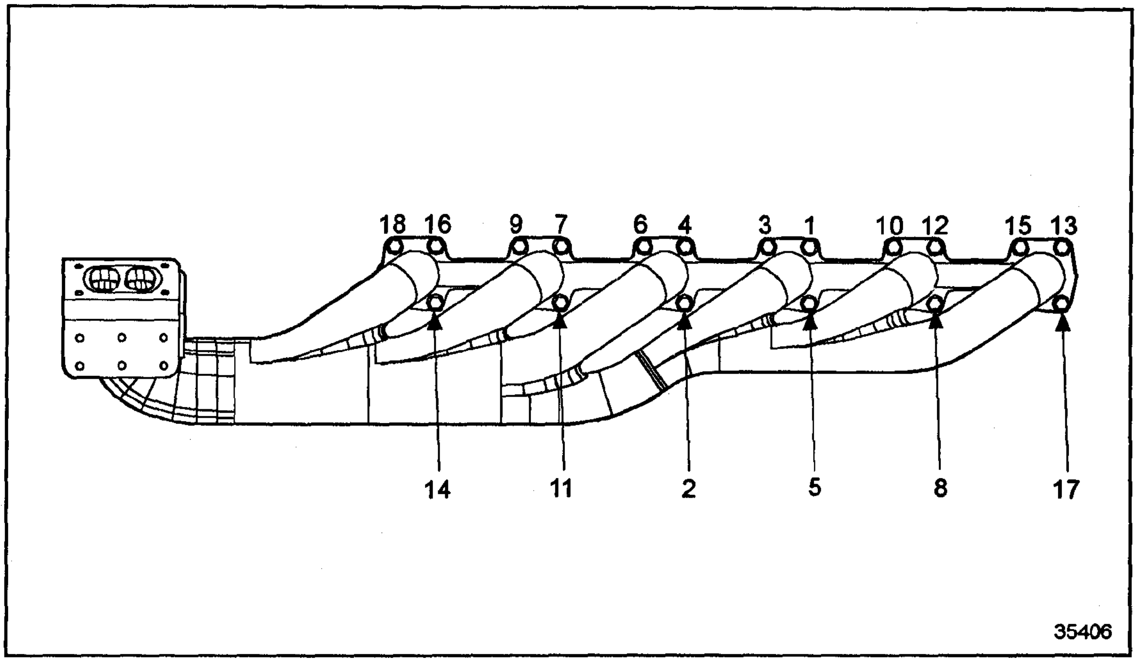



**Figure 7-13 One-Piece Water-Cooled Exhaust Manifold Bolt Torque Sequence**

8. Install coolant inlet and outlet elbows to the exhaust manifold and attach coolant lines.
9. Install the turbocharger assembly. Refer to section 6.6.7(diesel) or refer to section 6.7.5 (gas).
10. Install any other equipment that was removed for this procedure.
11. Refer to section 7.2.4 for the exhaust caution before preceeding. Start the engine and check for exhaust or coolant leaks.
12. Refer to section 11.3.6 for verification of proper exhaust manifold installation.

# 8 ELECTRICAL EQUIPMENT

## 8.1 OVERVIEW OF ELECTRICAL SYSTEM

The electrical system consists of the following components:

- Starting motor
- Battery-charging generator (alternator)
- Transistorized voltage regulator (normally integral to the alternator)
- Storage battery(s)
- Ignition switch
- Starting motor relay

**CAUTION:**

**To avoid injury from electrical shock, follow OEM furnished operating instructions prior to usage.**

Detailed information on the maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from an AC-Delco service outlet, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

Information regarding equipment manufactured by the Robert Bosch Company N.A. may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from an authorized Bosch® automotive equipment service outlet.

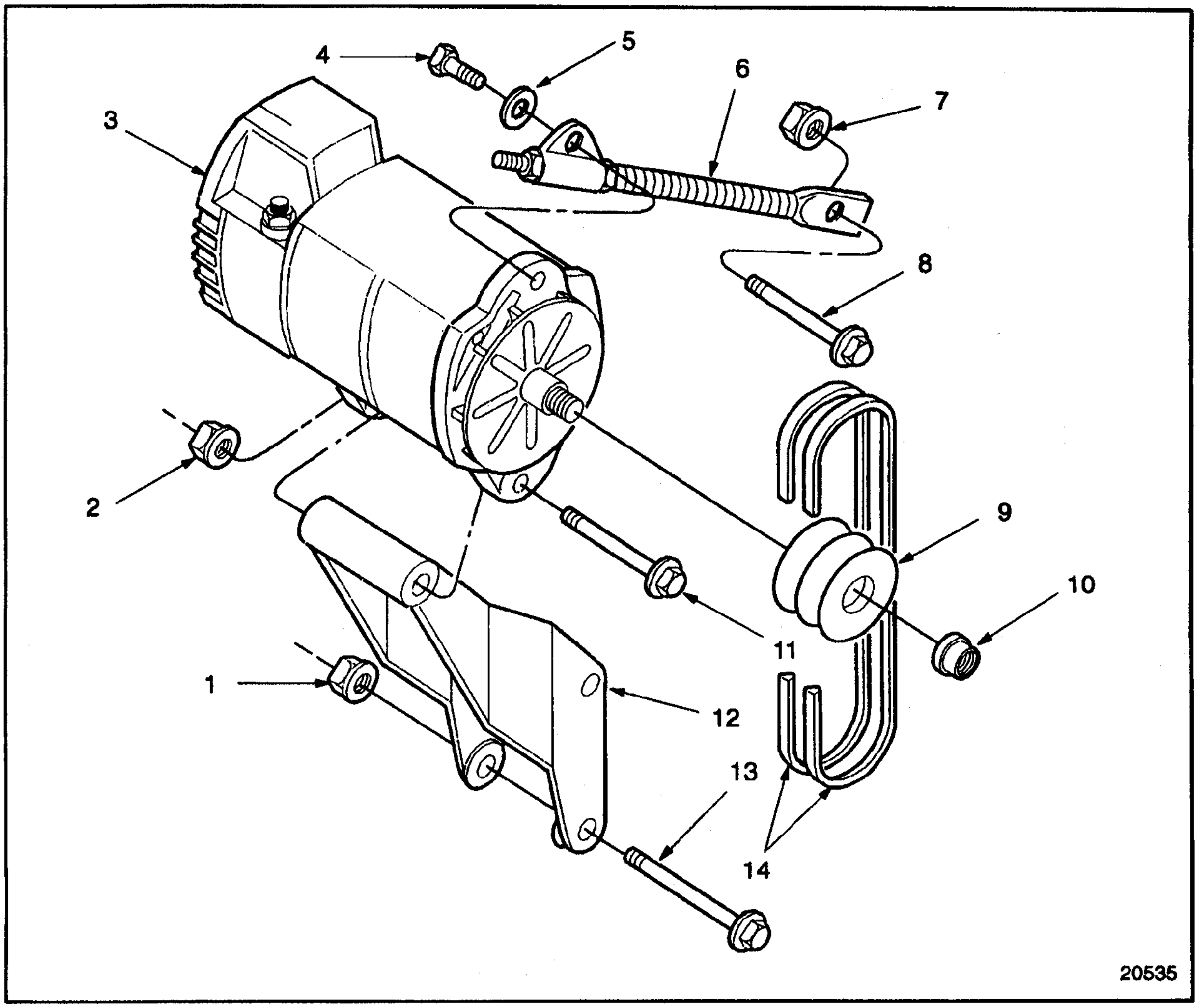
In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the equipment manufacturer. With the exception of DDEC components, replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally supplied with the engine. For electrical equipment manufactured by Delco-Remy Division, service and parts are available through AC-Delco branches and repair stations. For electrical equipment manufactured by Robert Bosch N.A., service and parts are available through Bosch automotive equipment service outlets.

*Bosch® is a registered trademark of Robert Bosch N.A.*

## 8.2 BATTERY CHARGING ALTERNATOR

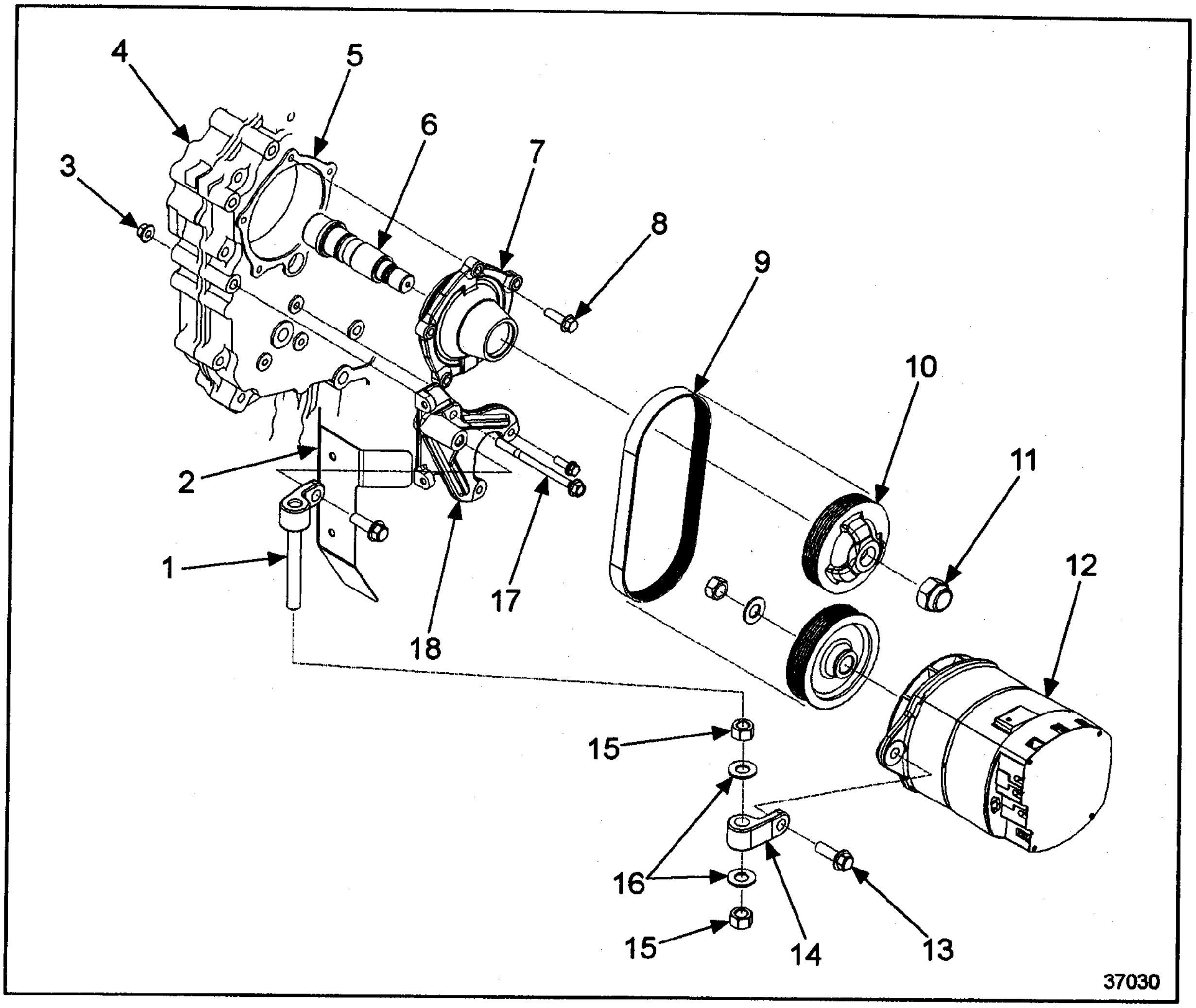
The battery charging alternator provides a source of electrical current for maintaining the storage battery in a charged condition and supplies sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

The battery charging circuit consists of an alternator, with an integral voltage regulator, a battery(s) and the connecting wiring. See Figure 8-1 and see Figure 8-2, for parts of the battery charging alternator system.




1. Nut (2)
2. Nut
3. Alternator
4. Bolt, Alternator-to-Adjusting Rod
5. Washer
6. Alternator Adjusting Rod
7. Nut
8. Bolt, Adjusting Rod-to-Engine
9. Pulley, Alternator Drive
10. Locknut
11. Bolt, Alternator-to-Mounting Bracket
12. Mounting Bracket
13. Bolt, Mounting Bracket-to-Engine (2)
14. Drive Belts

**Figure 8-1 Typical Alternator and Related Parts — Trucks and Industrial**




1. Belt Guard Support
2. Belt Guard
3. Nut
4. Gear Case Front Cover
5. Alternator Drive Gasket
6. Alternator Drive Shaft
7. Alternator Drive Bearing Housing
8. Alternator Drive Mounting Bolt
9. Drive Belt
10. Alternator Drive Pulley
11. Alternator Drive Pulley Nut
12. Alternator
13. Belt Guard Support Bracket Bolt
14. Belt Guard Support Bracket
15. Belt Guard Support Nut
16. Belt Guard SupportWasher
17. Alternator Support Bolt
18. Alternator Support

**Figure 8-2 Typical Alternator and Related Parts — Heat Exchanger-Cooled Pleasure Craft Marine**

The hinge mounted 25 - SI and 33 – SI alternators and the bracket mounted 50 DN alternator are alternating current (AC), self-rectifying units. See Figure 8-3.

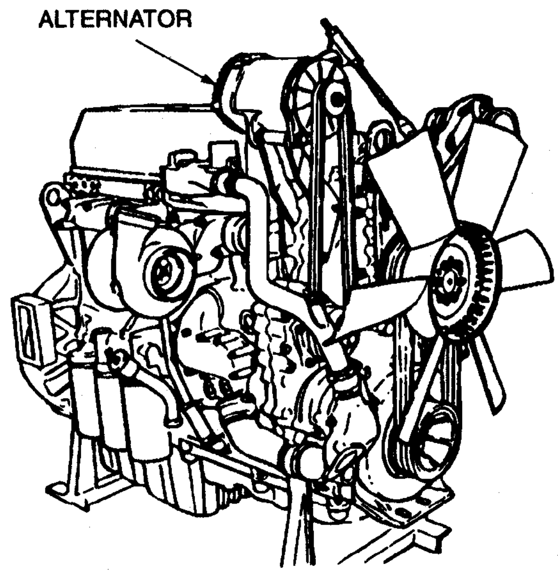



**Figure 8-3 Alternator Mounting**

On engines equipped with the SI series Delco-Remy alternators, the voltage regulator is typically electronic and is located inside the alternator. Refer to the appropriate manufacturer's service instructions for complete regulator and alternator servicing information.

The alternator is front mounted and belt driven using the accessory drive pulley. The accessory drive pulley is gear driven by the bull gear. Refer to section 1.28 for accessory drive information.

In 1995, the former 50 DN alternator drive system replaced the early 50 DN alternator drive system previously used on coach engines. The changes to the drive system took effect with the engine serial numbers listed in Table 8-1.

| Change | Engine Serial Number | Build Date |
|---|---|---|
| Alternator Pulley | 6R-274215 | Nov. 27, 1995 |
| Accessory Drive Asm. | 6R-276579 | Dec. 16, 1995 |
| Tensioner/Support Plate/Adjusting Bolt | 6R-277807 | Dec. 20, 1996 |

**Table 8-1 Effectivity of Improved 50 DN Alternator Drive System Changes**

The former 50 DN alternator drive system included a new tensioner assembly, support plate, tensioner adjusting bolt, alternator assembly and accessory drive assembly. The top pulley of the tensioner assembly is the same size as the bottom pulley (127 mm), and all pulleys in the system had front and back flanges to insure proper belt positioning during installation and improved belt tracking during engine operation.

The early and former tensioner assembly, support plate, and tensioner adjusting bolt are not separately interchangeable on a part-for-part basis and should not be used on an engine.

To simplify installation of the DN alternator drive belt and ensure proper running tension throughout drive belt life, an auto belt tensioner assembly replaced the former tensioner/support plate assembly on December 15, 1997, effective with engine serial number 6R392714.
See Figure 8-4. Use of the auto tensioner eliminates the need for periodic belt tension inspection. Only the auto belt tensioner assembly is used on engines with 50 DN alternators.

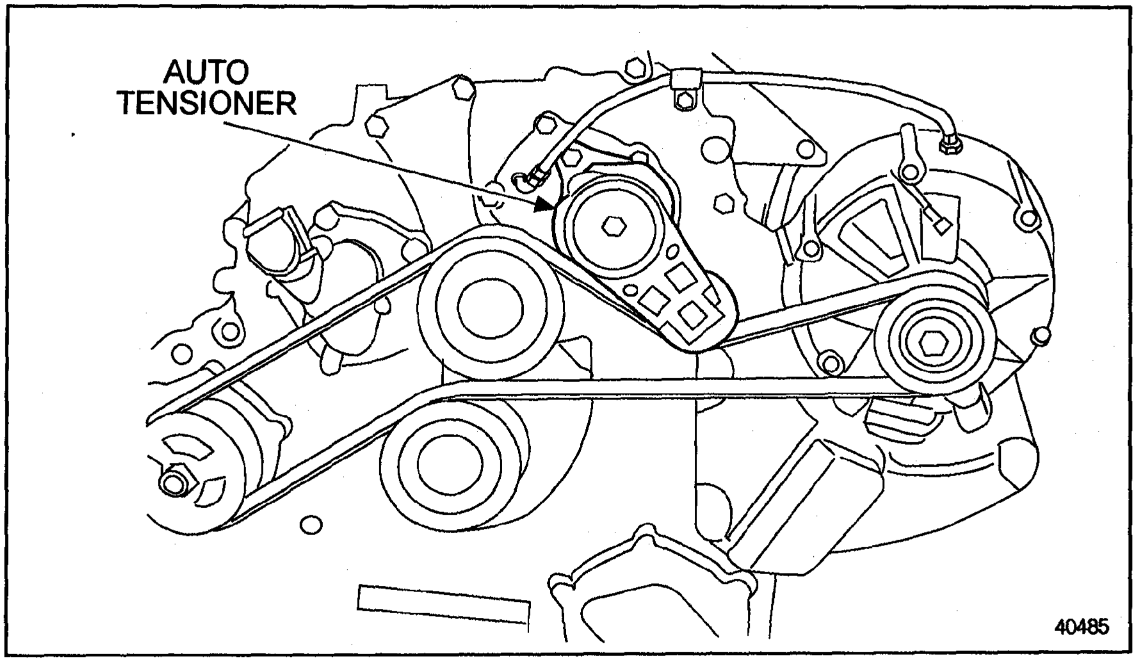



**Figure 8-4 Auto Belt Tensioner Assembly with 50 DN Alternator**

Effective June 2000, the No. 4 size vent hose on the 50DN alternator was replaced by a No. 6 braided hose to improve venting of the alternator and extend alternator life. In addition, the vent line connection point on the engine was moved from a tapped hole in the gear case to a tapped hole in the auto belt tensioner mounting plate.

### 8.2.1 Repair of Alternator

Refer to the OEM guidelines for alternator repair procedures.

### 8.2.2 Removal of Alternator

Precleaning is not necessary.

Remove the alternator as follows:

**CAUTION:**

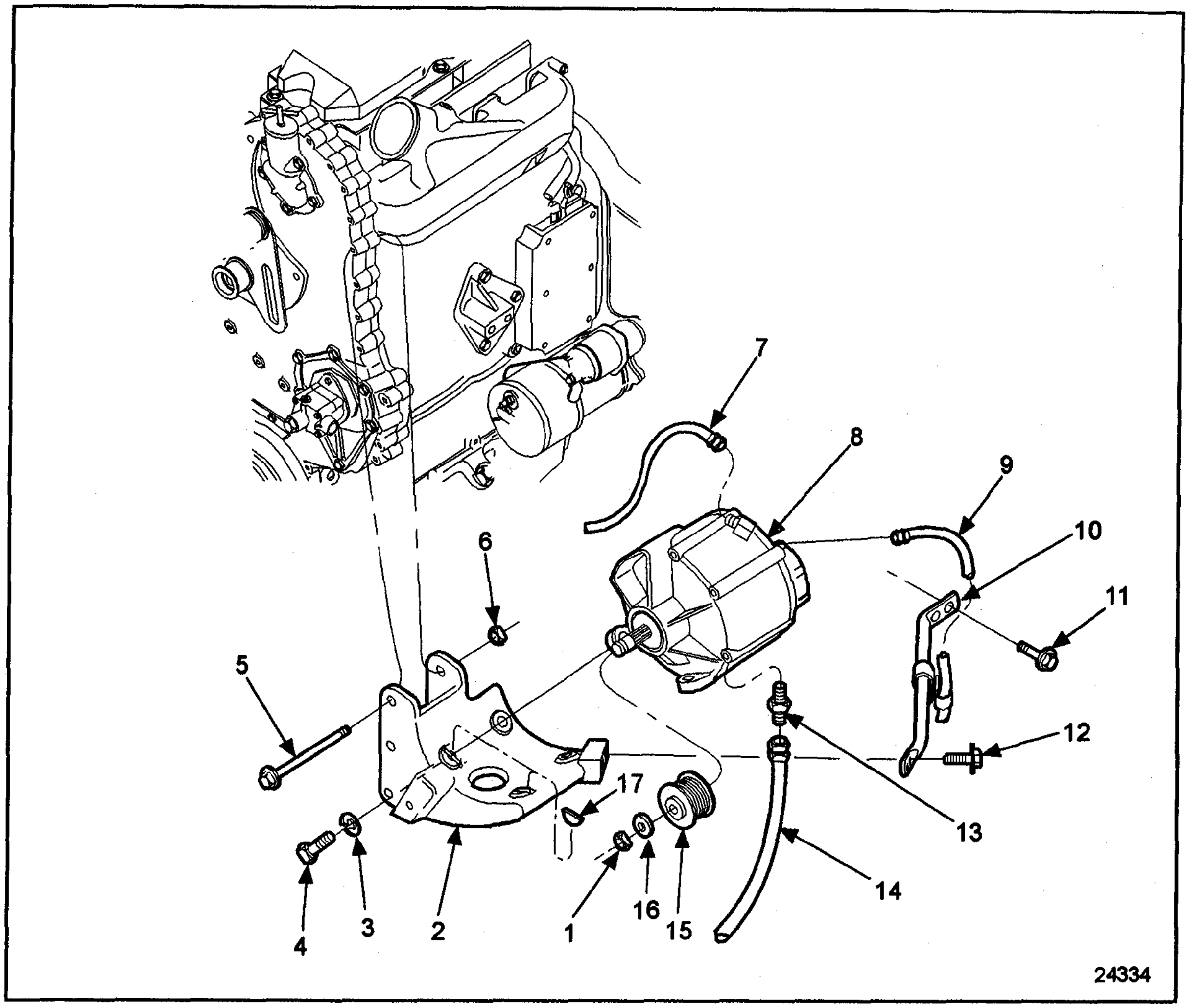
**To avoid injury from electrical shock, follow OEM furnished operating instructions prior to usage.**

1. Disconnect the cables at the batteries. Tag each lead to ensure correct connection when the alternator is reinstalled.
2. If the alternator has more than the output cable lead, disconnect all other leads from the alternator, and tag each one to ensure correct installation.
3. Remove the alternator output cable.
4. Remove the drive belts. See Figure 8-1.
5. If an auto belt tensioner assembly is installed, use a breaker bar with a 3/4 inch drive to rotate the tensioner pulley upward to relieve belt tension.

**CAUTION:**

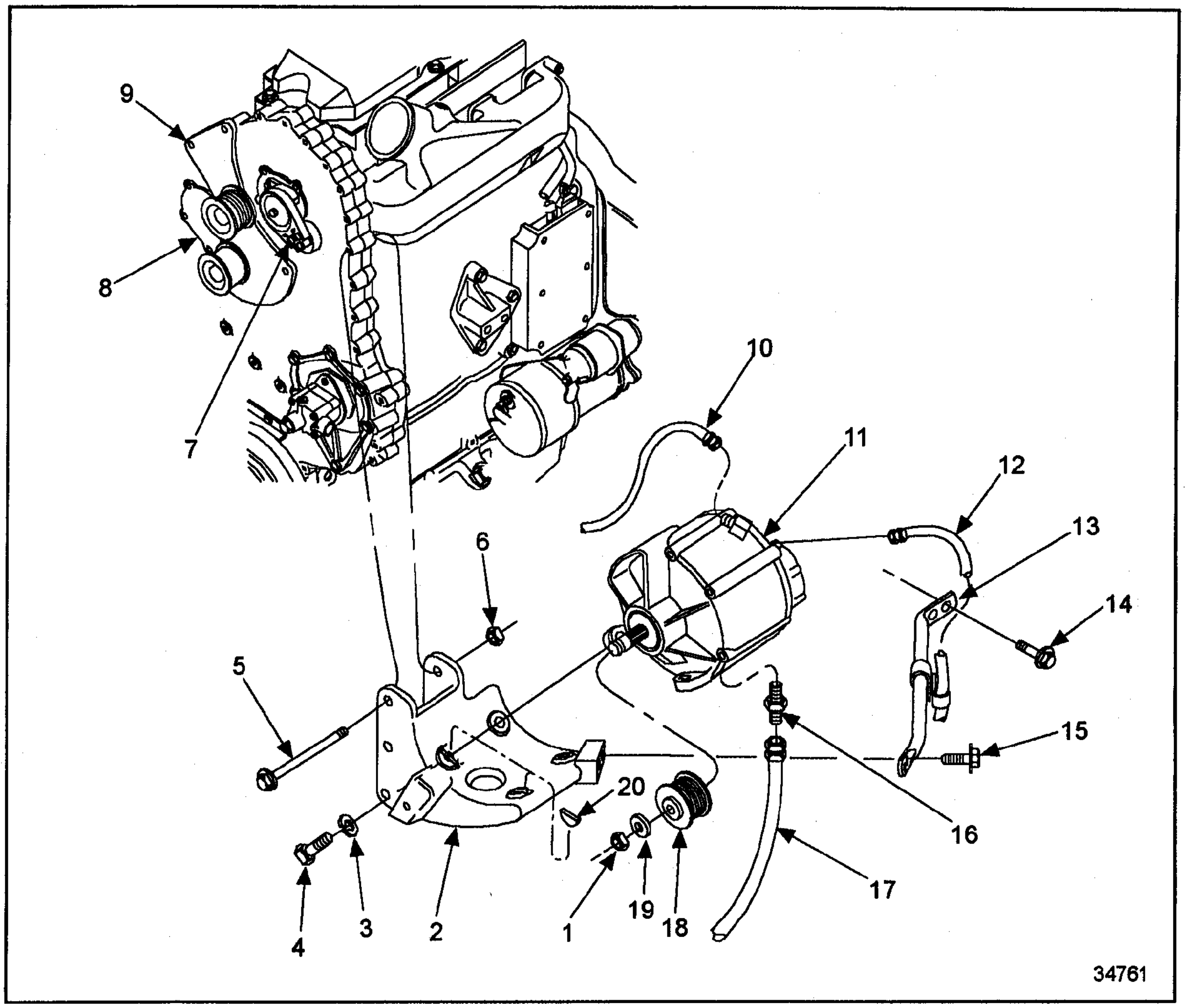
**To avoid injury to hands and fingers from the spring-loaded auto belt tensioner violently snapping back, do not cut the belt to remove it.**

6. If an auto belt tensioner assembly is not installed, loosen the alternator mounting bolts and adjusting rod nut to allow slack in the drive belts.
7. If an oil-cooled alternator is installed, disconnect the oil supply, return, and vent lines. Plug the ends of the oil lines and the oil inlet and outlet on the alternator to prevent the entrance of dirt. See Figure 8-5 for former or see Figure 8-6 for current.




1. Pulley Nut
2. Alternator Mounting Bracket
3. Washer (4)
4. Bolt, Bracket to Alternator (4)
5. Bolt, Bracket to Front Cover (3)
6. Nut (3)
7. Alternator Vent Hose
8. Alternator
9. Oil Supply Tube
10. Alternator Bracket Support
11. Bolt, Support to Block (2)
12. Bolt, Bracket Support (2)
13. Oil Drain Tube Connector
14. Oil Drain Tube
15. Alternator Pulley
16. Washer
17. Woodruff Key (2)

**Figure 8-5 Former Coach Alternator and Related Parts**




1. Pulley Nut
2. Alternator Mounting Bracket
3. Washer (4)
4. Bolt, Bracket to Alternator (4)
5. Bolt, Bracket to Front Cover (3)
6. Nut (3)
7. Auto Tensioner
8. Idler Assembly
9. Auto Tensioner Mount
10. Alternator Vent Hose
11. Alternator
12. Oil Supply Tube
12. Alternator Brace Bracket
14. Bolt, Support to Block (2)
15. Bolt, Bracket Support (2)
16. Oil Drain Tube Connector
17. Oil Drain Tube
18. Alternator Pulley
19. Washer
20. Woodruff Key (2)

**Figure 8-6 Current Coach Alternator and Related Parts**

8. While supporting the alternator, remove the adjusting rod bolt and hardened washer. See Figure 8-1.
9. Remove the nut and washer at the rear alternator mounting flange.
10. While supporting the alternator, remove the alternator-to-bracket bolt to prevent it from falling. See Figure 8-1.
11. Remove the two woodruff keys, if equipped.
12. Remove and retain the alternator pulley locknut, alternator pulley, and fan from the unit. See Figure 8-1.

#### 8.2.2.1 Inspection of Alternator

Refer to OEM guidelines for alternator inspection procedures.

### 8.2.3 Installation of Alternator

Install alternator as follows:

1. Install alternator mounting bracket to the gearcase, if it was removed. Torque the mounting bolts to 58–73 N·m (43–54 lb·ft). See Figure 8-1.
2. If a 50 DN alternator is used, install the pulley and locknut to the alternator (if removed). See Figure 8-6 for former or see Figure 8-5 for current. If an air cooled alternator is used, install the fan, drive pulley and locknut to the alternator (if removed). Torque the pulley retaining nut to 305 N·m (225 lb·ft).
3. If the pulley was not removed, check the retaining nut for proper torque. Torque the retaining nut to 305 N·m (225 lb·ft), as necessary.
4. If the pulley was removed during disassembly, install two woodruff keys in the mounting bracket.
5. Position the alternator on the mounting bracket, and align the holes in the alternator mounting flanges with the tube in the bracket support.

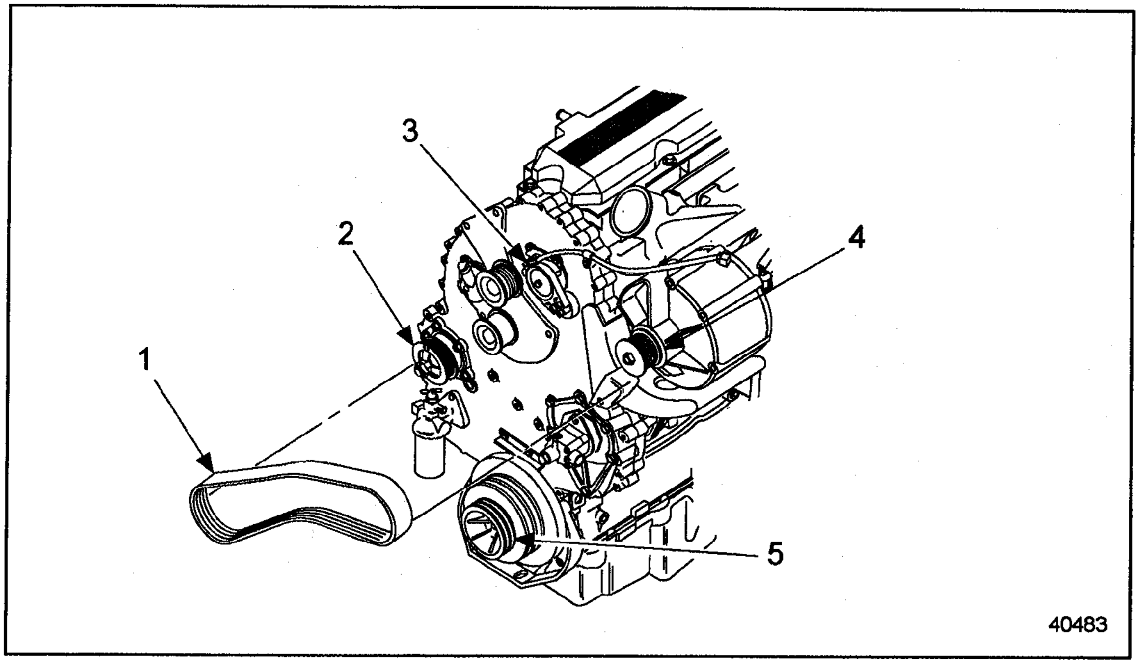
**NOTE:**
There are two holes in the front alternator end frame mounting flanges. One is threaded and one is not threaded. The threaded hole is positioned up and is used to secure the alternator to the adjusting rod.

6. Install the alternator-to-bracket bolt and locknut. Insert the adjusting rod bolt, with washer installed, through the adjusting rod bracket and into the threaded hole in the alternator end frame. Finger-tighten both bolts. See Figure 8-1.
7. If the alternator is oil-cooled, replace the oil supply, return, and vent lines and tighten fittings securely.

**NOTICE:**

Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup.

8. Depending on the application, install the belt(s) carefully over the pulleys on the crankshaft or alternator drive and the drive belt tensioner. If an auto belt tensioner is installed, use a breaker bar with a 3/4 inch drive to rotate the tensioner pulley upward for belt installation. Ensure the grooved and smooth faces of the belt are properly positioned on the pulleys before taking up slack. See Figure 8-7.




1. Poly-Vee Belt
2. Accesory Drive Pulley
3. Belt Adjusting Bracket
4. Alternator Pulley
5. Crankshaft Pulley

**Figure 8-7 Coach Poly-Vee Belt Installation**

9. If an auto belt tensioner assembly is not installed, adjust the alternator belt tension. For twin belt-driven alternator refer to section 8.2.3.1. For twin-vee belt-driven 50 DN alternator refer to section 8.2.3.1. For poly-vee belt-driven 50 DN alternator refer to section 8.2.3.2.
10. Torque the alternator-to-mounting bracket bolt and nut and the alternator-to-adjusting rod bracket bolt to 81-95 N·m (60-70 lb·ft).
11. Attach the wires and cables to the alternator. Ensure that each one is correctly installed in the location from which it was removed. Keep all connections clean and tight.

### 8.2.3.1 Checking Twin-Vee Belt Driven Alternator Belt Tension

The recommended tension for new belts is 556 N (125 lb). However, because new belts lose tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 10 to 15 minutes. To check belt tension, use the following procedure:

| NOTICE: |
| --- |
| Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup. |

| CAUTION: |
| --- |
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

1. Tension the new drive belts to 556 N (125 lb) using a belt tension tool, J 41251-B or equivalent.

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine from 10 to 15 minutes to allow the belts to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 10 to 15 minutes.
4. Measure belt tension:
   [a] If tension is 445 N (100 lb) or more, no tensioning is required.
   [b] If tension is less than 445 N (100 lb), retension the belt to 445 N (100 lb).
5. Check belt tension every 100 hours or 7,500 miles (12,000 km). Refer to section 13.13.10 and retension if necessary.

### 8.2.3.2 Checking 12-Rib Poly-Vee Belt-Driven 50 DN Alternator Belt Tension

If an auto belt tensioner assembly is installed, no further action is required as long as the belt has been properly positioned in the grooves of the pulleys. If a belt tensioner/support plate assembly is installed, the belt must be tightened to the required value as outline in the following.

The recommended tension for new poly-vee belt is 1558 N (350 lb). However, because a new belt loses tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 10 to 15 minutes. To check belt tension, use the following procedure:

| NOTICE: |
| --- |
| Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup. |

1. Tension the new drive belt to 1558 N (350 lb) using belt tension gage J 41251-B or equivalent.
2. Refer to section 8.2.3.1 for the exhaust caution before preceding. Start and run the engine for 10 to 15 minutes to allow the belt to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 10 to 15 minutes.
4. Measure belt tension:
   [a] If tension is 1112 N (250 lb) or more, no further tension is required.
   [b] If tension is less than 1112 N (250 lb), adjust belt tension to 1112 N (250 lb).
5. Check belt tension every month, every 100 hours, or every 7,500 miles (12,000 km). Refer to section 13.13.10and re-tension to 1112 N (250 lb), if necessary.

### 8.2.3.3 Checking Belt Tension on a Two-Groove Powerband® Alternator Drive Belt

The recommended tension for a new belt is 890 N (200 lb). However, because a new belt loses tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 10 to 15 minutes. To check belt tension, use the following procedure:

| NOTICE: |
| --- |
| Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup. |

1. Tension the new drive belts to 890 N (200 lb) using tension gage, BT-3386–WE-75–225–2N-1.1.3–31–R-P .
2. Refer to section 8.2.3.1 for exhaust caution before preceding. Start and run the engine for 10 to 15 minutes to allow the belts to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 10 to 15 minutes.

4. Measure belt tension:

   [a] If tension is 667 N (150 lb) or more, no tensioning is required.

   [b] If tension is less than 667 N (150 lb), adjust the belt tension to 667 N (150 lb).

5. Check belt tension every 100 hours or every 12,000 km (7,500 miles). Refer to section 13.13.10 and re-tension 667 N (150 lb), if necessary.

*Powerband® is a registered trademark of the Gates Rubber Company.*

### 8.2.3.4 Checking Belt Tension on a 6 – Rib Poly-vee Alternator Drive Belt

The recommended tension for a new belt is 978 N (220 lb). However, because a new belt loses tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 10 to 15 minutes. To check belt tension use the following procedure:

| NOTICE: |
|---|
| Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup. |

1. Tension the new drive belts to 978 N (220 lb) using tension gage, BT-3386–WE-75–225–2N-1.1.3–31–R-P, or equivalent.
2. Refer to section 8.2.3.1 for exhaust caution before preceding. Start and run the engine for 10 to 15 minutes to allow the belts to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 10 to 15 minutes.
4. Measure belt tension:

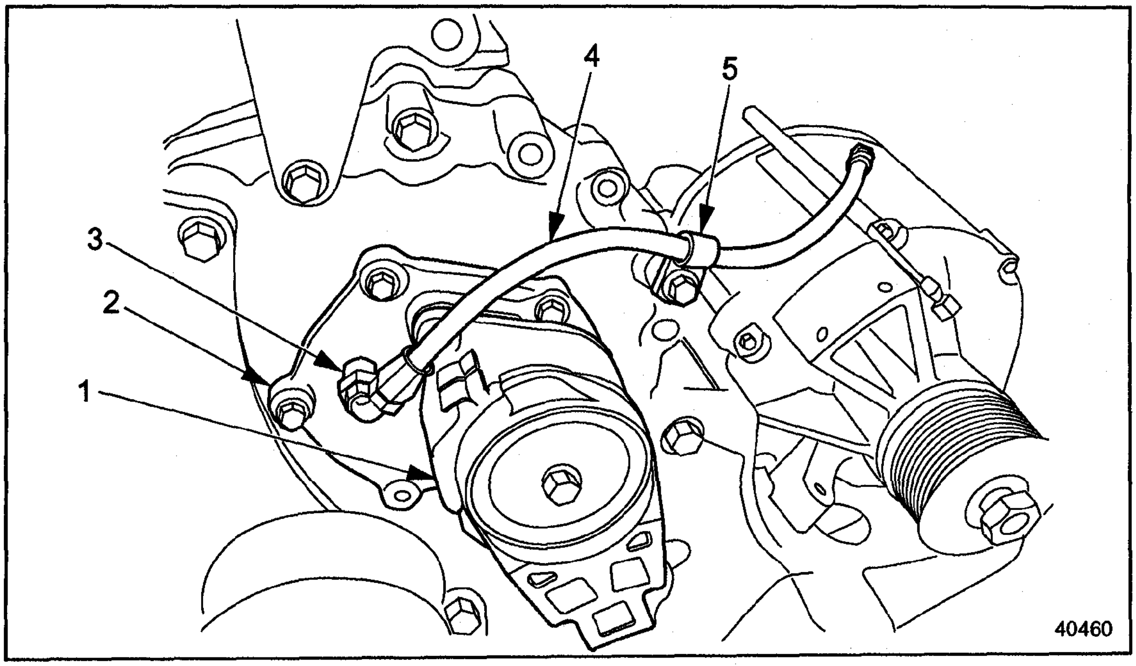
   [a] If tension is 800 N (180 lb) or more, no tensioning is required.

   [b] If tension is less than 800 N (180 lb), adjust the belt tension to 800 N (180 lb).

5. Check belt tension every 100 hours or every 12, 000 km (7,500 miles). Refer to section 13.13.10 and re-tension to 800 N (180 lb), if necessary.

## 8.2.3.5 50 DN Alternator Vent Line

Delco 50DN alternators are oil cooled and require an oil supply line from a port on the side of the engine block, an oil drain line from the bottom of the alternator to the oil pan or block, and a vent line to keep the oil within the alternator at an acceptable level and avoid overheating. The original vent line was a No. 4 hose connected between the top of the alternator and a tapped hole in the back of the gear case. Effective June 2000, the former vent line was replaced by a No. 6 braided hose connected between the orifice on top of the alternator and a tapped hole in the mounting plate for the auto belt tensioner assembly. See Figure 8-8. The larger diameter hose provides improved venting and helps eliminate the potential for vent line plugging, which could lead to insufficient cooling of alternator components and shortened alternator life.




1. Auto Tensioner Assembly
2. Mounting Plate, Auto Tensioner Assembly
3. Connector, 3/8 in. flared to 1/4 in. NPTF, straight
4. Vent Line, Alternator
5. Clip, Hose

**Figure 8-8 Vent Line Installed in Auto Tensioner Mounting Plate**

## INSTALLATION OF THE IMPROVED VENT LINE

The improved vent line is installed between the alternator case and the drive belt auto-tensioner mounting plate on the gear case cover. Existing Series 60 engines with auto tensioner assemblies and engines with former manual drive belt tensioner assemblies may be modified to accept the improved vent line. Use the following procedures:

| CAUTION: |
|---|
| **To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.** |

| CAUTION: |
|---|
| **To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.** |

### *Installation of Vent Line in Drive Belt Auto Tensioner Assembly Mounting Plate*

On engines with current drive belt auto tensioner assemblies, install the improved vent line between the alternator and the tensioner mounting plate as follows:

1. With the engine at ambient temperature and cool to the touch, remove and discard the former alternator vent line. Plug the vent line hole at the back of the gear case with a 1/4 in. NPTF square socket head pipe plug.
2. Remove the former vent fitting from the top of the alternator case.
3. Install the 3/8 in. flared to 1/4 in. NPTF, 90 degree elbow into the top of the alternator case.
4. Remove the alternator drive belt. Refer to section 8.2.2.
5. Remove the drive belt auto tensioner assembly from the mounting plate on the gear case cover.
6. Remove the mounting plate from the gear case cover.

7. Drill a 0.425 in. diameter hole on the left side of the mounting plate and thread with a 1/4 in. NPTF - 4FF tap. See Figure 8-9for hole location.

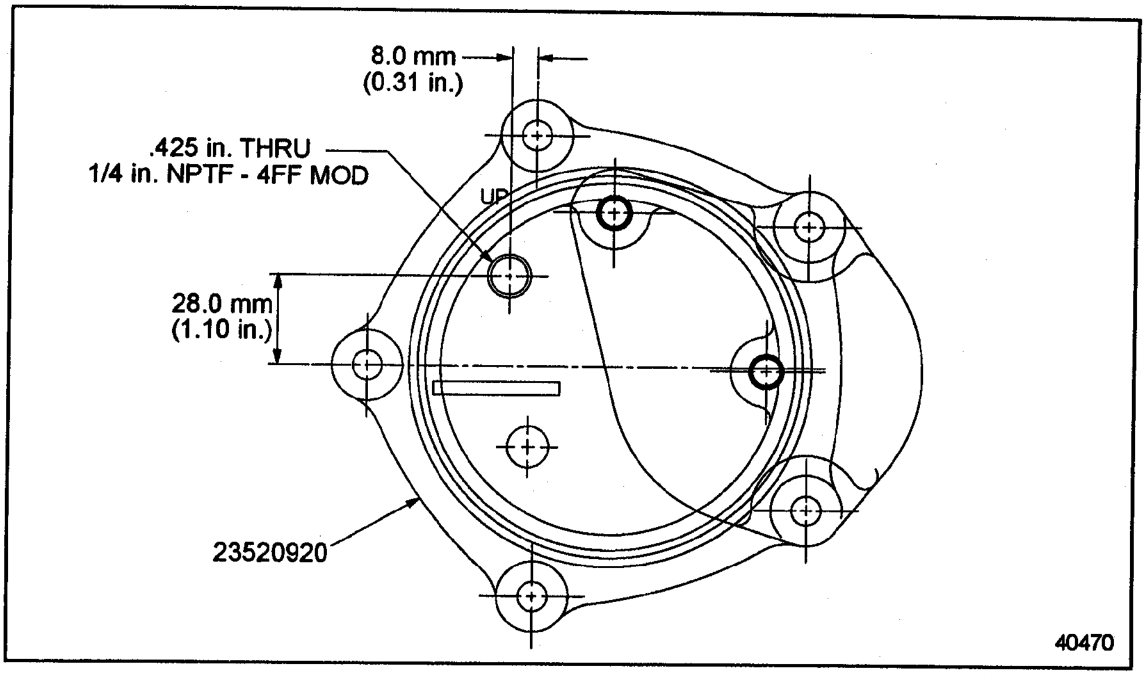



**Figure 8-9 Location of Drilled and Tapped Vent Line Hole in Auto Tensioner Mounting Plate**

8. Clean the plate carefully to remove all drill chaff.
9. Using a new gasket, install the plate onto the gear case cover.
10. Install the auto tensioner assembly onto the mounting plate.
11. Apply DDC®/Loctite® pipe sealant with Teflon® P/N 23509542, or equivalent, to the 3/8 in. flared to 1/4 in. NPTF straight fitting and install into the mounting plate. Attach the improved vent line and tighten securely.

| NOTICE: |
|---|
| Do not drill the engine lifter bracket to install a hose clip, since this will weaken the bracket. |

| NOTICE: |
|---|
| Do not fasten the hose clip to either of the engine lifter bracket mounting bolts. The hose clip **must** be attached to the bolt on the right side of the lifter bracket to ensure unrestricted air flow through the vent line. |

12. To prevent sags and low points, secure the vent line with the hose clip. Remove the gear case cover mounting bolt on the right side of the lifter bracket (bolt No. 12 – see Figure 8-10). Attach the hose clip to the bolt, reinstall, and torque the bolt to 58–73 N·m (43–54 lb·ft).

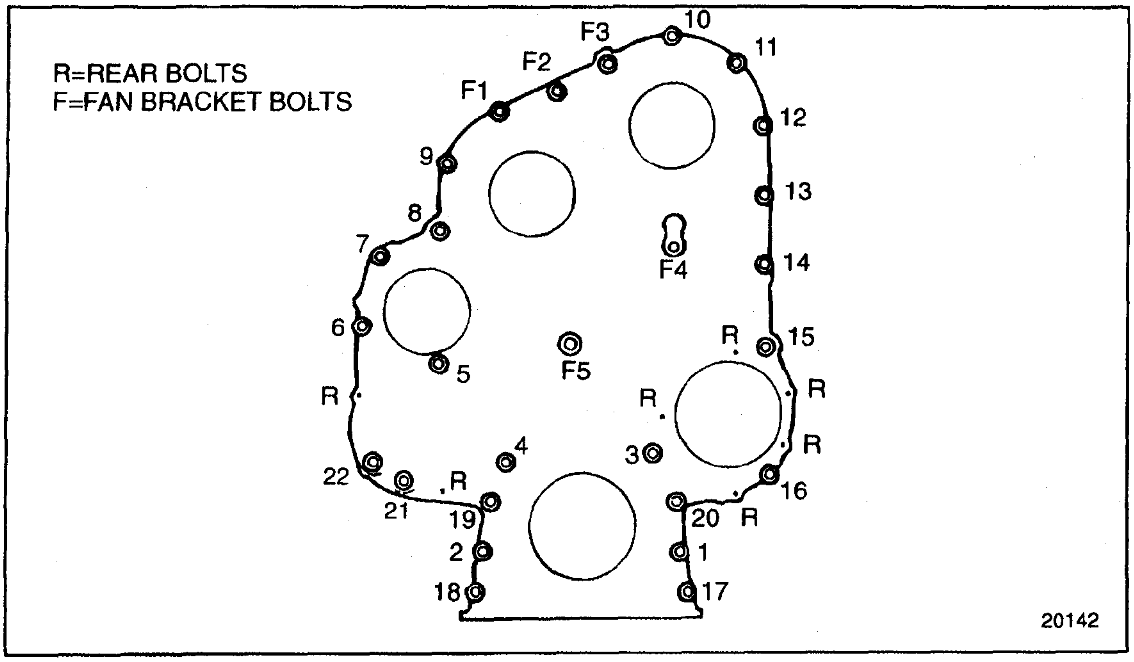



**Figure 8-10 Gear Case Cover Mounting Bolt Locations**

13. Install the alternator drive belt. Refer to section 8.2.3.
14. Refer to section 8.2.3.1 for the exhaust caution before preceeding. Reconnect starting power, start the engine, and check for proper vent line operation.

***Installation of Vent Line in Front Camshaft Cover on Engines with Former Manual Belt Tensioner Assembly***

On engines equipped with the former manual belt tensioner assembly, the front camshaft cover is situated behind the tensioner assembly, requiring its removal. Install the improved vent line on these engines as follows:

**CAUTION:**

**To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.**

**CAUTION:**

**To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.**

1. With the engine at ambient temperature and cool to the touch, remove and discard the former alternator vent line. Plug the vent line hole at the back of the gear case with a 1/4 in. NPTF square socket head pipe plug.
2. Remove the former vent fitting from the top of the alternator case.
3. Install the 3/8 in. flared to 1/4 in. NPTF, 90 degree elbow into the top of the alternator case.
4. Remove the alternator drive belt. Refer to section 8.2.2.
5. Remove the manual belt tensioner assembly from the gear case cover.
6. Remove the front camshaft cover from the gear case cover.

7. The center hole in the cover has a 1/8 in. NPTF thread which must be enlarged. Using a 0.425 in. drill bit, carefully drill out the tapped hole. Thread the hole with a 1/4 in. NPTF - 4FF tap. See Figure 8-11.

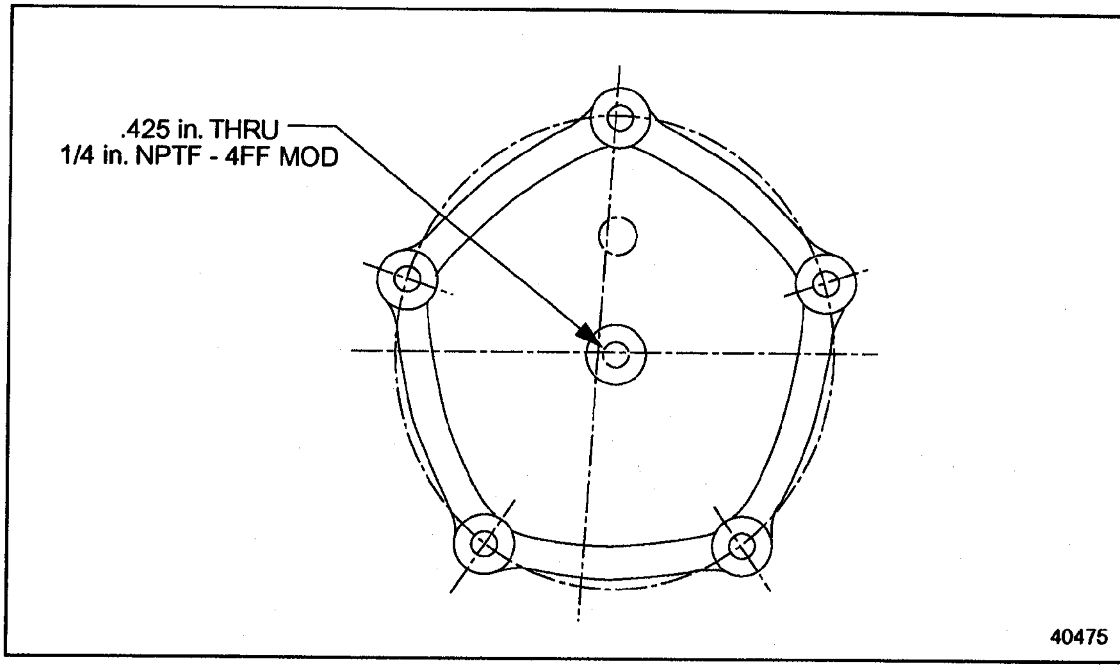



**Figure 8-11 Drilled and Tapped Vent Line Hole in Front Camshaft Cover**

8. Clean the cover carefully to remove all drill chaff.
9. Using a new gasket, install the front camshaft cover onto the gear case cover.
10. Apply DDC/Loctite® pipe sealant with Teflon P/N 23509542, or equivalent, to the 3/8 in. flared to 1/4 in. NPTF straight fitting and install into the cover. Attach the improved vent line and tighten securely.
11. Install the manual belt tensioner assembly.

| NOTICE: |
|---|
| Do not drill the engine lifter bracket to install a hose clip, since this will weaken the bracket. |

| NOTICE: |
|---|
| Do not fasten the hose clip to either of the engine lifter bracket mounting bolts. The hose clip **must** be attached to the bolt on the right side of the lifter bracket to ensure unrestricted air flow through the vent line. |

12. To prevent sags and low points, secure the vent line with the hose clip. Remove the gear case cover mounting bolt on the right side of the lifter bracket (bolt No. 12 – see Figure 8-10). Attach the hose clip to the bolt, reinstall, and torque the bolt to 58 –73 N·m (43–54 lb·ft).
13. Install the alternator drive belt. Refer to section 8.2.3.
14. Refer to section 8.2.3.1 for the exhaust caution before preceeding. Reconnect starting power, start the engine, and check for proper vent line operation.

## 8.3 STORAGE BATTERY

The lead-acid storage battery is an electro-chemical device for storing energy and converting chemical energy into electrical energy.

The battery has three major functions:

- It provides a source of current for starting the engine.
- It acts as a stabilizer to the voltage in the electrical system.
- It can, for a limited time, furnish current when the electrical demands exceed the output of the alternator.

**CAUTION:**

**To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:**

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

If you come in contact with battery electrolyte:

1. Flush your skin with water.
2. Apply baking soda or lime to help neutralize the acid.
3. Flush your eyes with water for 10-15 minutes.
4. Get medical attention immediately.

In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer. This information is listed in Table 8-2.

| Series 60 Engine Family | System Voltage | Minimum Battery Rating [SAE Cold Cranking AMPS (CCA) at -17.8°C (0°F)] |
|---|---|---|
| 11.1 Liter | 12V | 1875 CCA* |
| 12.7 Liter | 12V | 1875 CCA* |
| 12.7 Liter† | 24V | 950 CCA* |

*Recommendation based on the use of Delco-Remy 42MT (or equivalent) cranking motor.

†Heat exchanger-cooled pleasure craft marine.

**Table 8-2 Electrical Size of Engine Replacement Battery**

## 8.3.1 Replacement of Storage Battery

Refer to the OEM for replacement procedure.

## 8.3.2 Removal and Cleaning of Storage Battery

Precleaning of the battery carrier may be necessary. Refer to OEM guidelines.

Remove storage battery as follows:

1. Disconnect grounded terminal of the battery.
2. Remove the cable clamps and felt washer.
3. Remove the battery.

### 8.3.2.1 Inspection of Storage Battery

Refer to OEM guidelines, for storage battery inspection procedure.

### 8.3.3 Installation of Storage Battery

Install the battery as follows:

1. Seat the battery level in its carrier.

| NOTICE: |
|---|
| Do not draw the hold-down clamps down too tightly or the battery case will become distorted or crack. |

2. Tighten the hold-down clamps evenly until snug.
3. Attach the cable clamps after ensuring the cables and terminal clamps are clean and in good condition.
4. Place a new felt washer at the base of each terminal beneath the cable clamps, to make the cable connections as corrosion resistant as possible.
5. Coat the entire connection with a heavy general-purpose grease.

**NOTE:**
Ensure the ground cable is clean and tight at the engine block or frame.

| NOTICE: |
|---|
| Connect the **grounded** terminal of the battery **last** to avoid short circuits, which will damage the battery. |

6. Check the polarity to ensure the battery is not reversed with respect to the generating system.
7. Refer to section 11.1.8 for verification of proper storage battery installation.

## 8.4 CRANKING MOTOR

The cranking motor is bolted to the flywheel housing. See Figure 8-12.

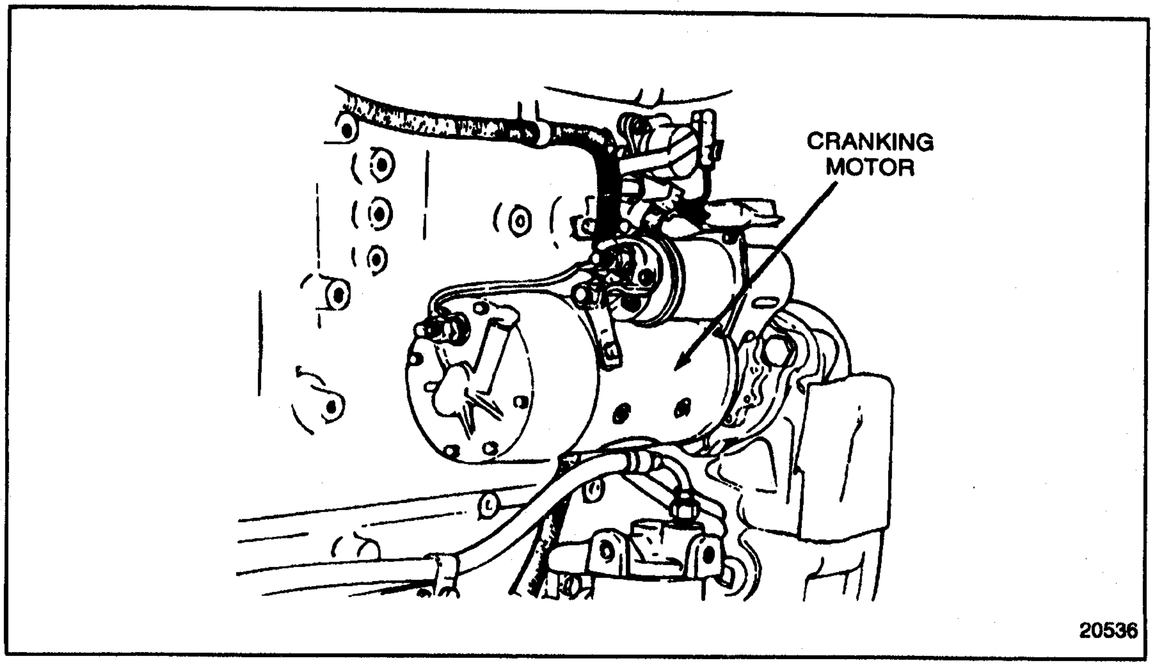



**Figure 8-12 Cranking Motor Mounting**

**NOTICE:**

To prevent excessive overrun and damage to the drive and armature windings, the switch should be opened immediately when the engine starts. A cranking period should not exceed 15 seconds without stopping to allow the motor to cool for at least 15 seconds.

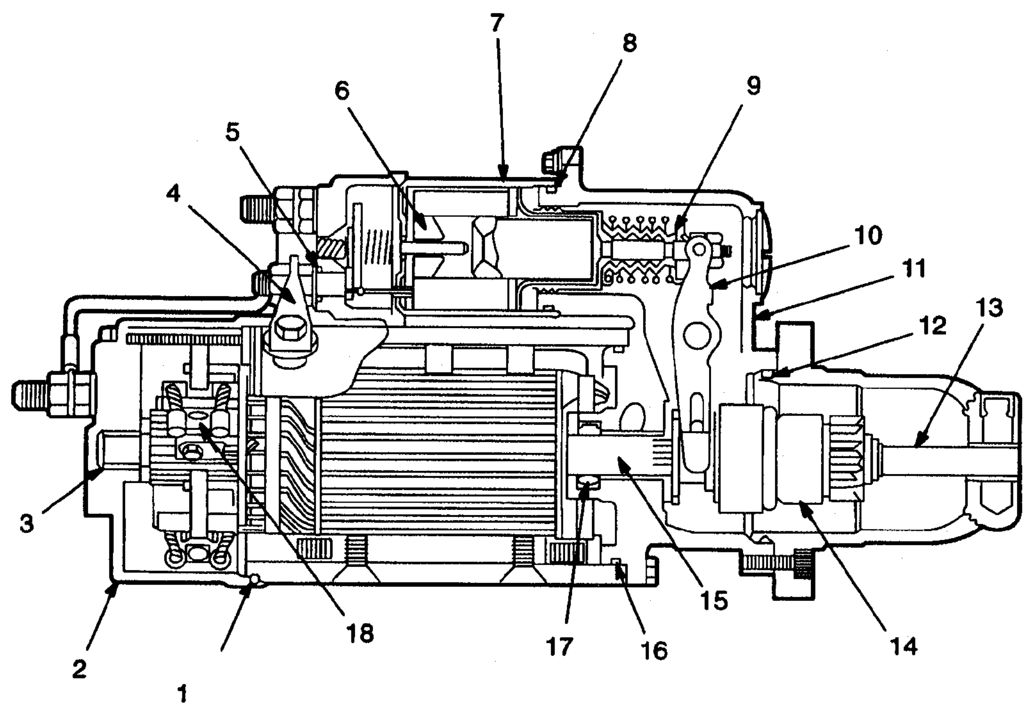
When the cranking circuit is closed, a drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the cranking motor. To accomplish this, the cranking motor is equipped with an over-running clutch within the drive pinion. The cranking motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

**NOTE:**
Some engines may be equipped with air starters. Contact starter manufacturer for operating characteristics and rebuilding procedures.

The 42 MT cranking motor typically used on the engine has a nose housing that can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. The commutator end cap can be removed to inspect the brushes, in most cases, without removing the cranking motor from the vehicle.

**NOTE:**
The 50 MT cranking motor is used on heat exchanger-cooled pleasure craft marine engines.

The cranking motor armature is supported by three sintered bronze bearings located, one each, in the nose and intermediate housings, with one in the commutator end cap. See Figure 8-13.




1. O-ring
2. End Cap (Removal for Inspection)
3. Bronze Bearing
4. Connector Strap
5. Gasket
6. Low Friction Bushing
7. Seamless, One-piece Solenoid Case
8. O-ring
9. Sealing Boot
10. Shift Mechanism (Totally Enclosed)
11. Two-piece Housing
12. O-ring
13. Shaft
14. Heavy-duty Drive Overrunning Clutch
15. Shaft
16. O-ring
17. Shaft Seal
18. One-piece Brush

**Figure 8-13 Typical Cranking Motor Cross-section**

Sintered bronze bearings used in the current cranking motors have a dull finish, compared to the former machined, cast bronze bearings, which had a shiny finish.

The cranking circuit may contain a key start switch or push switch (or both), a relay, magnetic switches, solenoids, oil pressure switch, fuel pressure switch, and other protective devices. For the complete cranking circuit, refer to the vehicle manufacturer's wiring diagram.

For basic cranking circuit, see Figure 8-14.

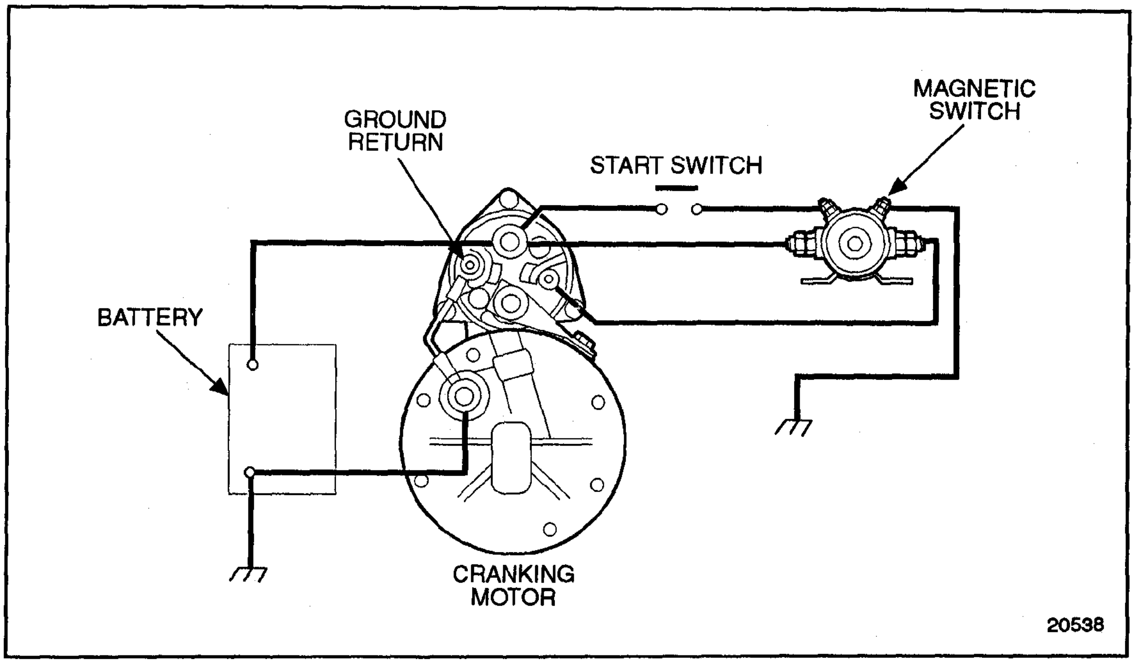



**Figure 8-14 Basic Cranking Circuit**

A solenoid, mounted on the cranking motor housing, operates the over-running clutch drive by linkage and a shift lever. When the start switch is closed, the magnetic switch contacts close, and the solenoid windings are connected to the battery. The resulting plunger and shift lever movement causes the pinion to engage the engine flywheel ring gear and the solenoid main contacts to close, and the cranking takes place.

### 8.4.1 Repair of Cranking Motor

Refer to the OEM guidelines for cranking motor repair procedures.

### 8.4.2 Removal of Cranking Motor

Precleaning is not necessary.

Remove the cranking motor as follows:

| CAUTION: |
|---|
| **To avoid injury from electrical shock, follow OEM furnished operating instructions prior to usage.** |

1. Remove the ground strap or negative cable(s) from the battery(s).
2. Tag each lead to ensure correct connections when the cranking motor is reinstalled.
3. Disconnect the cranking motor cables and solenoid wiring.
4. Support the motor, and remove the three bolts which secure it to the flywheel housing.
5. Pull the motor out to remove it from the flywheel housing.

If the nose housing requires relocation, perform the following steps:

| NOTICE: |
|---|
| The solenoid should not be located below the centerline of the cranking motor. Dust, oil, moisture and foreign material can collect and cause solenoid failure. |

1. Remove the six socket-head screws (one short and five long) and six neoprene plugs from the unused holes if a twelve-hole mounting flange is used.
2. Turn the nose housing to the required position.
3. Install the six socket-head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole mounting flange is used.
4. Torque the screws to 18-23 N·m (13-17 lb·ft).

### 8.4.3 Installation of Cranking Motor

Install the cranking motor as follows:

**CAUTION:**

**To avoid injury from electrical shock, follow OEM furnished operating instructions prior to usage.**

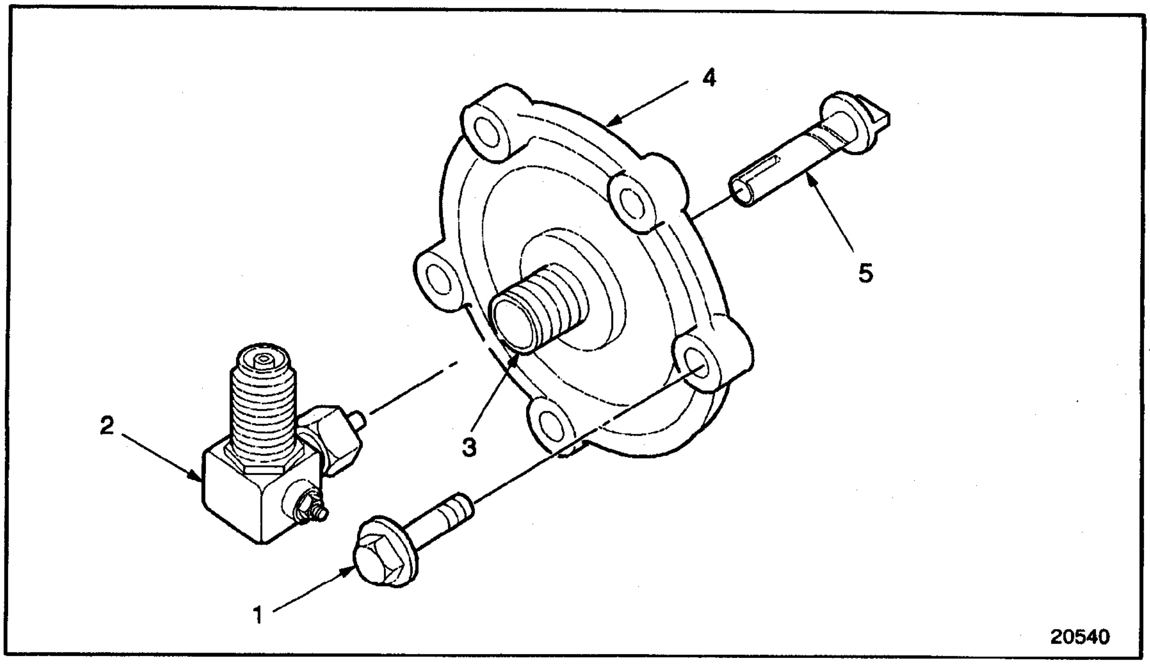
1. Support the cranking motor, and install the three bolts that secure it to the flywheel housing.
2. Connect the cranking motor cables and the solenoid wiring.
3. Install the ground strap or negative cable(s) to the battery(s).
4. If an aluminum flywheel housing is used, torque the cranking motor attaching bolts to 187-209 N·m (138-154 lb·ft). If a cast iron flywheel housing is used, torque the cranking motor attaching bolts to 245-306 N·m (181-226 lb·ft).
5. If equipped with a 42 MT or 50 MT starting motor, install wiring terminal leads to the cranking motor and the solenoid switch.
6. Torque the smaller connections to 1.8-3.4 N·m (16-30 lb· in.). Torque the larger connections to 27-34 N·m (20-25 lb·ft).

**NOTE:**
Keep all of the electrical connections clean and tight.

7. Refer to section 11.2 for verification of proper cranking motor installation.

## 8.5 TACHOMETER DRIVE

The Series 60 engine can be configured with or without a mechanical tachometer drive. A camshaft drive gear access cover mounted to the gear case cover and a slotted head camshaft bolt must be used with the mechanical tachometer drive option. See Figure 8-15.




1. Attaching Bolts
2. Tachometer Drive Adaptor
3. Tachometer Drive Unit
4. Camshaft Drive Gear Access Cover
5. Tachometer Drive Shaft

**Figure 8-15 Tachometer Drive and Related Parts**

The tachometer drive is driven off the head of the camshaft drive gear retaining bolt, which must be of the slotted configuration, and mates with the blade of the tachometer drive unit. The tachometer drive unit is driven at half crankshaft speed. A tachometer drive adaptor is attached to the drive. See Figure 8-16.

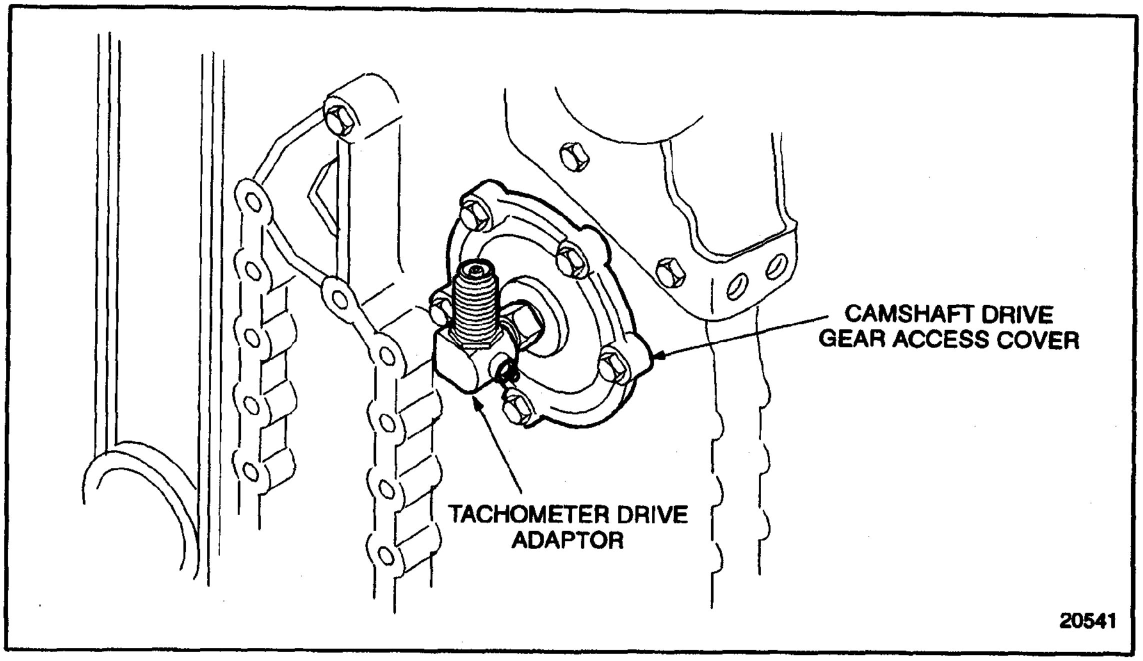



**Figure 8-16 Tachometer Drive Adaptor**

A grease fitting on the tachometer drive adaptor is supplied for lubrication. The tachometer drive adaptor should be greased any time the vehicle chassis is lubricated.

### 8.5.1 Repair or Replacement of Tachometer Drive

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 8-17.

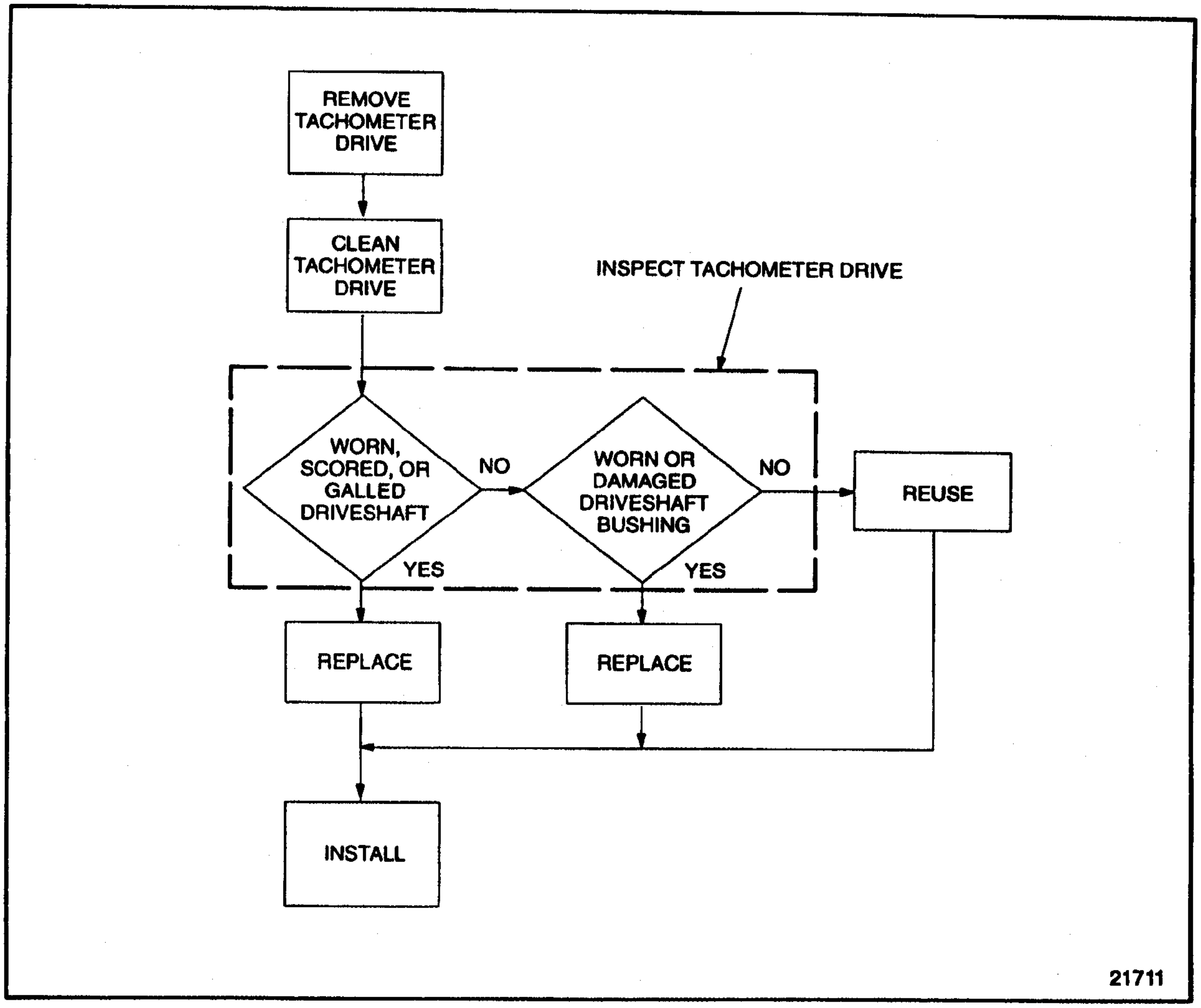



**Figure 8-17 Flowchart for Repair or Replacement of Tachometer Drive**

### 8.5.2 Removal of Tachometer Drive Adaptor

Remove the tachometer drive adaptor as follows:

1. Disconnect the tachometer drive cable from the tachometer drive adaptor by unscrewing the bezel nut and pulling the cable straight out of the unit.
2. Unscrew the nut that retains the tachometer drive adaptor to the tachometer drive in the camshaft drive gear access cover.
3. Remove the tachometer drive adaptor.
4. Loosen and remove the five bolts that secure the camshaft drive gear access cover to the gear case cover.
5. Tap the cover with a rubber mallet or plastic hammer to break the gasket loose.
6. Remove the camshaft drive gear access cover/tachometer drive unit from the gear case.
7. Remove the tachometer drive shaft from the access cover.

### 8.5.3 Cleaning of Tachometer Drive Adaptor

Clean the tachometer drive prior to inspection.

Clean all of the gasket material from the mating surfaces of the camshaft drive gear access cover and the gear case.

#### 8.5.3.1 Inspection of Tachometer Drive

Inspect the tachometer drive as follows:

1. Visually inspect the drive shaft for galling, scoring, or wear.
   [a] If the drive shaft is damaged or excessively worn, replace with new part. Refer to section 8.5.4.
   [b] If the drive shaft is not damaged, reuse part. Refer to section 8.5.4.
2. Inspect the tachometer drive shaft bushing for wear or damage.
   [a] If bushing is excessively worn or damaged, replace tachometer drive gear access cover assembly as a unit. Refer to section 8.5.4.
   [b] If bushing is not worn or damaged, reuse part. Refer to section 8.5.4.

### 8.5.4 Installation of Tachometer Drive

Install tachometer drive as follows:

1. Lubricate the drive shaft with clean engine lubricating oil.
2. Install the drive shaft into the bushing in the access cover.
3. Using a new gasket, install the camshaft drive gear access cover tachometer drive unit to the engine by indexing the tachometer drive blade with the slotted camshaft drive gear retaining bolt. See Figure 8-18.

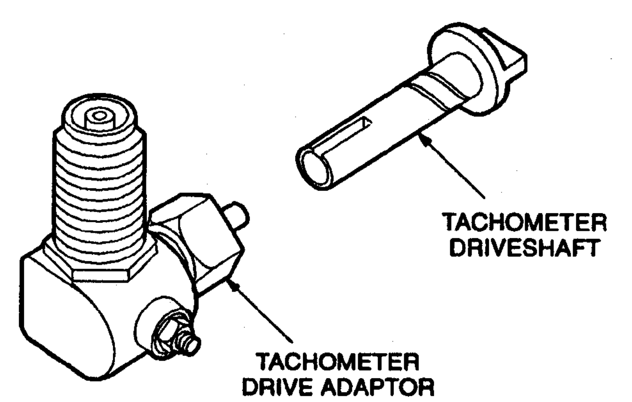



**Figure 8-18 Tachometer Drive Unit Installation**

4. Install the camshaft drive gear access cover retaining bolts, and torque the bolts to 30-38 N·m (22-28 lb·ft) using the pattern as shown in the illustration. See Figure 8-19.

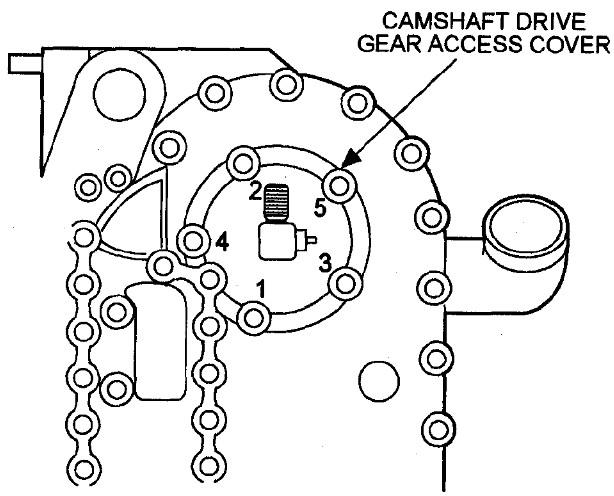



**Figure 8-19 Camshaft Drive Gear Access Cover Bolt Tightening Sequence**

5. Index the tachometer drive adaptor shaft with the drive shaft.
6. Install the tachometer drive adaptor to the drive. Torque the nut to 12-15 N·m (9-11 lb·ft).
7. Index the tachometer drive cable to the adaptor, and install the cable. Finger-tighten the bezel nut.

| NOTICE: |
|---|
| Do not use a power grease gun when lubricating the tachometer drive. Over-lubrication can damage the drive. One shot of grease with a hand operated grease gun is sufficient. |

8. Lubricate the tachometer drive unit at the grease fitting using chassis lube.
9. Refer to section 11.8 for verification of proper tachometer drive installation.

## 8.6 DDEC III/IV ENGINE SENSOR HARNESS

The DDEC III/IV engine sensor harness for vehicle engines was originally equipped with five metal retaining clips and was secured to the engine cylinder block with bolts. Effective with engines built in May of 1995, three of the metal clips were replaced by three plastic push-in clips. See Figure 8-20.

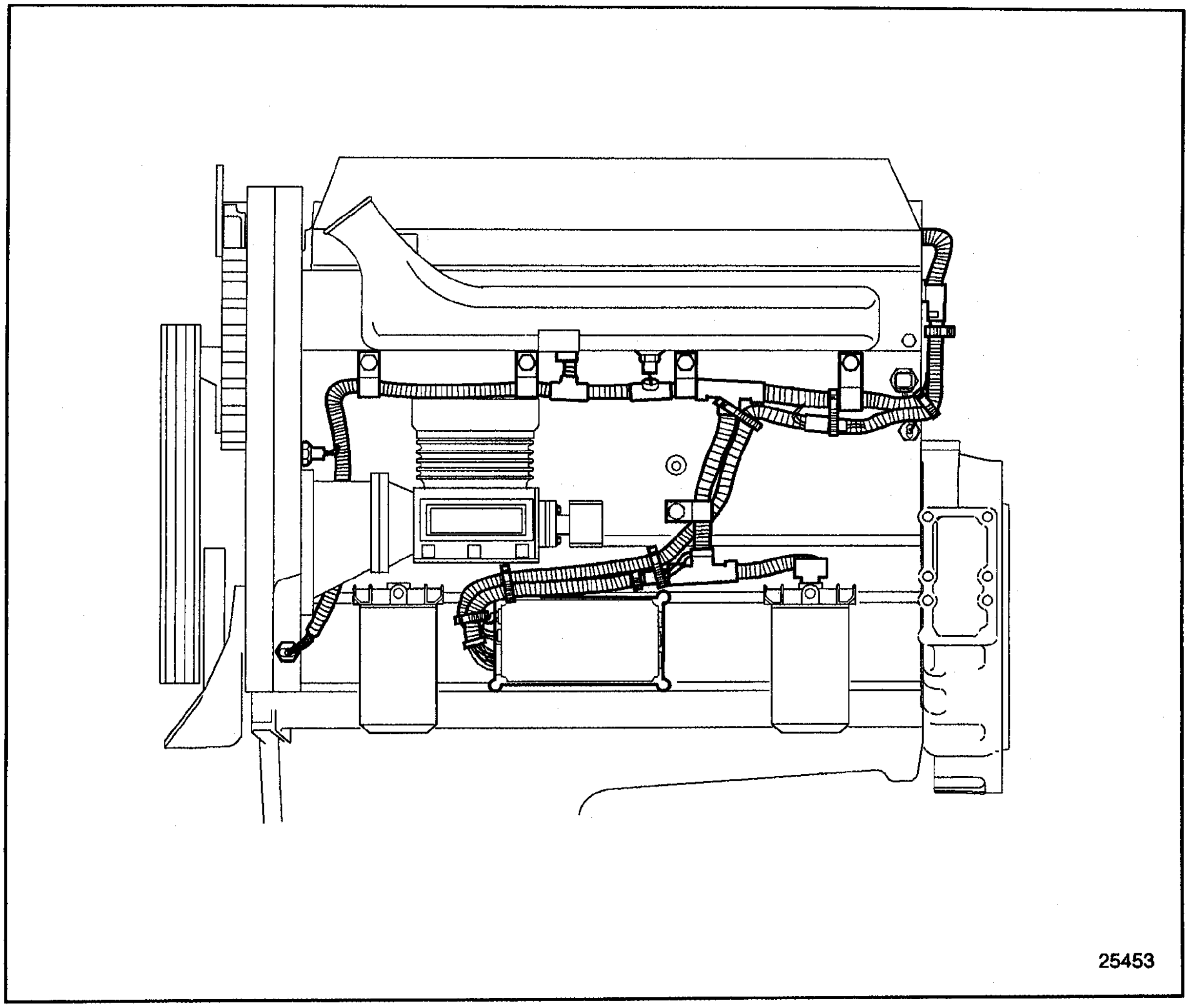



**Figure 8-20 Typical DDEC III/IV Engine Sensor Harness**

Due to a hardware change made in October of 1995 to the DDEC® III ECM, a path to ground can arise during ECM powerdown which may allow unintended engine cranking.

Unintended engine cranking can occur if *all* of the following conditions exist:

- ☐ The engine has an ECM manufactured between October of 1995 and September of 1996.
- ☐ The engine is equipped with the Optimized Idle™ feature.
- ☐ The ignition remains turned on while battery power is removed from the ECM during servicing.

**NOTE:**
This condition will not occur on engines manufactured after September of 1996.

To address this concern and eliminate the potential for unintended engine cranking under the conditions listed above, an Optimized Idle Starter Relay Harness Overlay Service Kit was released for engines with ECM's manufactured between October of 1995 and September of 1996.

### 8.6.1 Diagnostic Procedures

Basic mechanical checks should be made beforehand to verify that the problem is definitely related to the electrical portion of the system. If the basic mechanical checks fail to locate the problem, refer to the *Detroit Diesel Single ECM Troubleshooting Manual,* (6SE497). Start by reading the "Basic Knowledge Required" section before attempting to diagnosis electrical faults.

### 8.6.2 Repair and Replacement of DDEC III/IV Engine Sensor Harnesses

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 8-21.

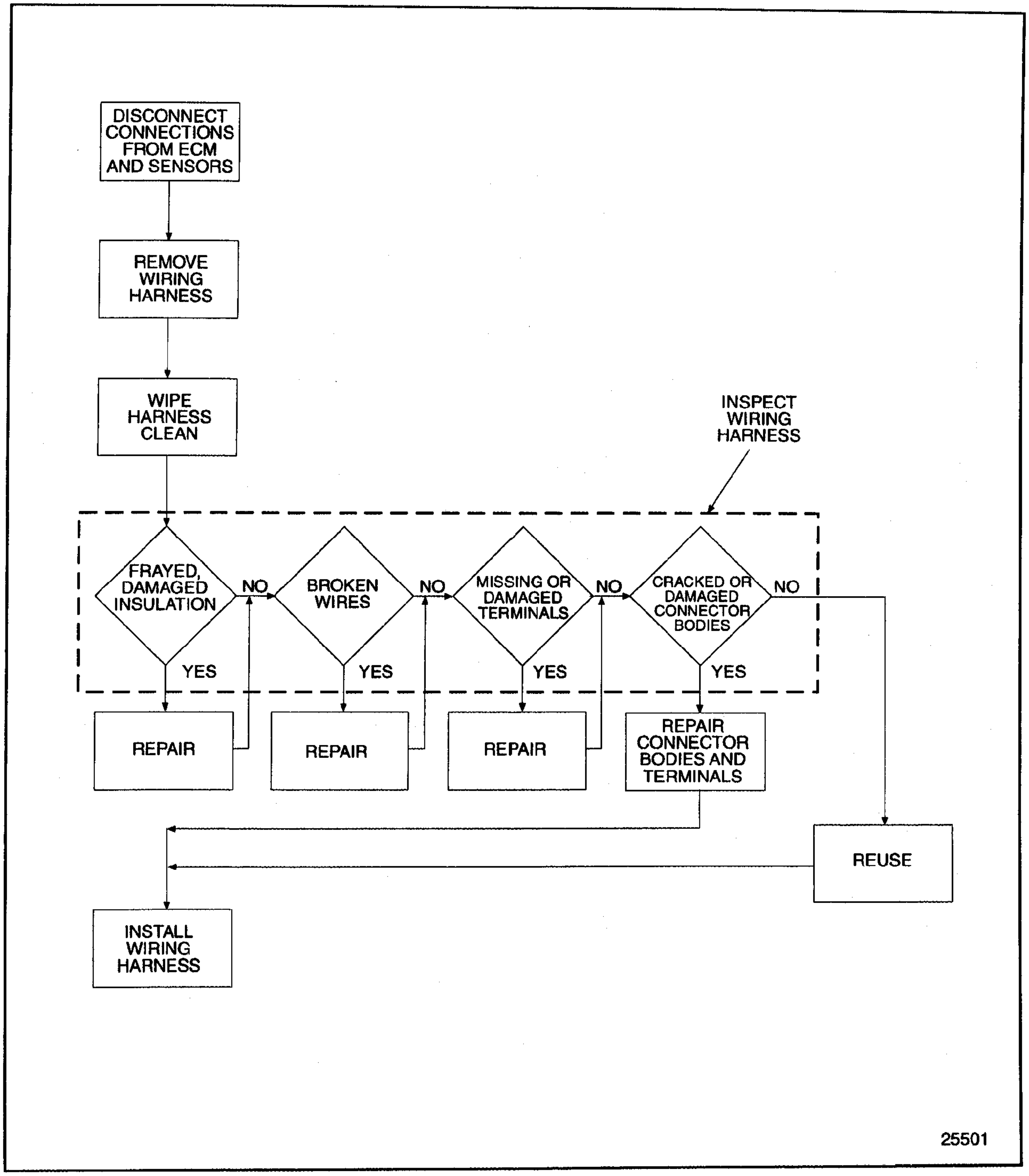
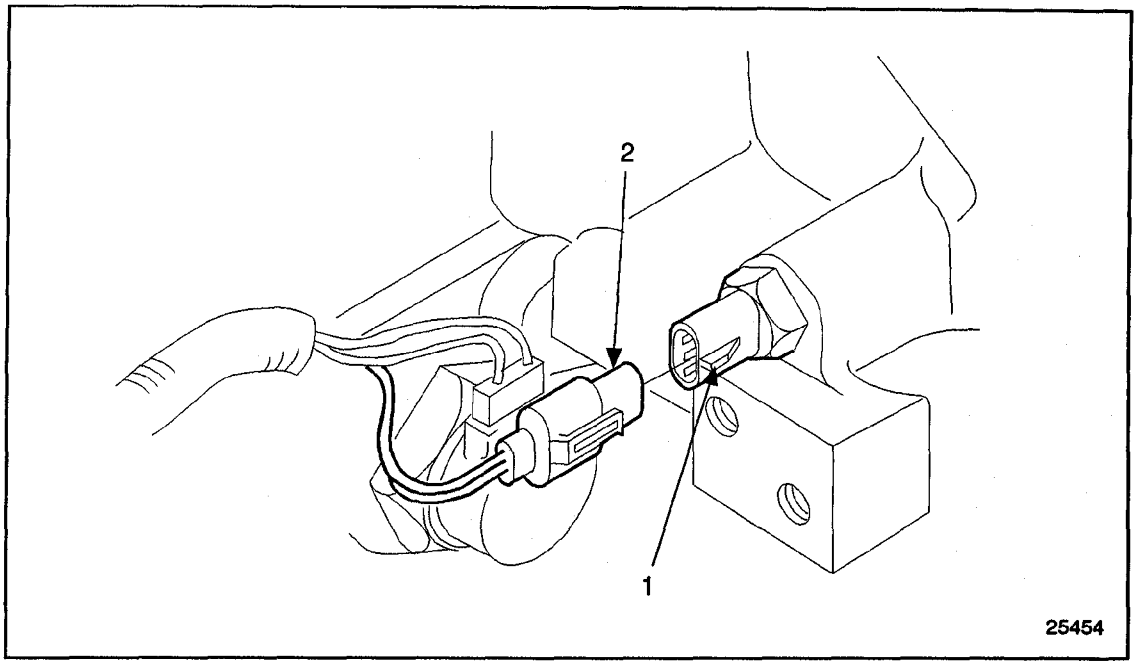



**Figure 8-21 Flowchart for Repair or Replacement of Engine Sensor Harness**

### 8.6.3 Removal of DDEC III/IV Engine Sensor Harnesses

Remove the DDEC III/IV engine sensor harness as follows:

1. Disengage the locking tang on each individual sensor connector body. See Figure 8-22.




1. Locking Tang 2. Connecting Body

**Figure 8-22 Typical Sensor Connector Locking Tang**

2. Grasp the connector body and gently pull it from the sensor.
3. Install the harness clips:
   [a] Remove the bolts securing the metal harness clips to the engine.
   [b] Proceed to step 6
4. If the engine has metal and plastic harness clips:
   [a] Remove the bolts securing the metal harness clips to the engine.
   [b] The plastic harness clips do not require removal from the engine. Open the clips by inserting a tool such as a flat blade screwdriver into the slot on the side and twist to unhook the clip.

| NOTICE: |
| --- |
| Do not attempt to remove the plastic harness clips from the engine by pulling or forcing them out with a flat tool. This will damage the clip threads, which may make them unusable. |

5. If removal of the plastic harness attaching clips from the engine is required, unscrew them from the block by rotating them in a counterclockwise direction.
6. Remove the 30-pin connector from the ECM by loosening the connector attaching bolt. Carefully pull the connector from the ECM and remove the harness from the engine.

### 8.6.4 Installation of DDEC III/IV Engine Sensor Harness

Install the DDEC III/IV engine sensor harness as follows:

1. Install the 30-pin connector to the ECM, and torque the connector body attaching bolt to 0.79-1.47 N·m (7-13 lb· in.).
2. If removal of the plastic harness attaching clips from the engine is required, unscrew them from the bolt holes in the block by rotating in a counterclockwise direction.
3. If the engine has five metal harness clips:
   [a] Install the five bolts securing the metal harness clips to the engine. Torque bolts to 30-38 N·m (22-28 lb·ft).
   [b] Proceed to step 5
4. If the engine has two metal and three plastic harness clips:
   [a] Install the two bolts securing the metal harness clips to the engine. Torque bolts to 30-38 N·m (22-28 lb·ft).
   [b] Install new clips by pressing the threaded clip base into the appropriate block bolt hole, as required.
   [c] Place the harness into the open plastic clips and snap the clips shut to retain the harness.

**NOTE:**
To ensure proper engine sensor harness support, all missing and damaged plastic harness clips must be replaced.

5. Carefully plug the two-pin and three-pin harness connectors into the appropriate sensors.
6. If the engine ECM is programmed with the Optimized Idle option, a starter relay harness overlay kit may be installed. Refer to section 8.6.4 and refer to section 8.6.5.

### 8.6.5 Installation of Starter Relay Harness Overlay Service Kit

Install starter relay harness overlay service kit on an Optimized Idle option-equipped vehicle engine as follows:

**NOTE:**
Optimized idle is not available on industrial or marine engines.

#### 8.6.5.1 Qualifying the ECM for Use with the Starter Relay Harness Overlay Kit

Before installing the starter relay harness overlay service kit, the ECM *must* be qualified for use with the kit and replaced, if necessary. Qualify the ECM for use as follows:

Refer to the DDEC III/IV ECM serial number/model number label located on top of the ECM.

If the second letter of the ECM *serial number* is "D," "E," or "F" and the last three characters of the *model number* are "A01", "A02", "A03", or "A04", the ECM *must* be replaced before the kit can be installed. Following is an example of an ECM that must be replaced:

***ECM Serial Number*** S E 600KZM / ***ECM Model Number*** 6DD2368 A03

If the second letter of the ECM *serial number* is "A" through "C" or any letter from "G" onward *and* the last three characters of the *model number* are "C01" through "C03" or "A05" and later alpha-numeric designations, the ECM *does not* require replacement before the kit can be installed. Following are examples of ECMs that do not require replacement:

***ECM Serial Numbers*** SC 6005QM / ***ECM Model Number*** 6DD2296CO3 or 6DD2296AO5.

A summary of this procedure is listed in Table 8-3.

| If Second Letter of ECM Serial Number Is: | And Last 3 Characters of ECM Model Number Are: | Disposition of ECM |
|---|---|---|
| "D", "E", or "F" | A02, A03, or A04 | Replace ECM |
| "A-C", "G" and later letters | C01-C03, A05 and later alpha-numeric designations | Use ECM |

**Table 8-3 Qualifying ECM for Use with Optimized Idle Overlay Kit**

### 8.6.6 Preparation of Engine for Installation of Optimized Idle Starter Relay Harness Overlay Kit

Prepare engine for installation of optimized idle starter relay harness overlay kit as follows:

1. Place the transmission in neutral, set the parking brake, stop the engine, block the vehicle wheels, and close the hood/cab.
2. Turn ignition to the *On* position, but do not start the engine.

3. Locate Optimized Idle starter relay. See Figure 8-23.

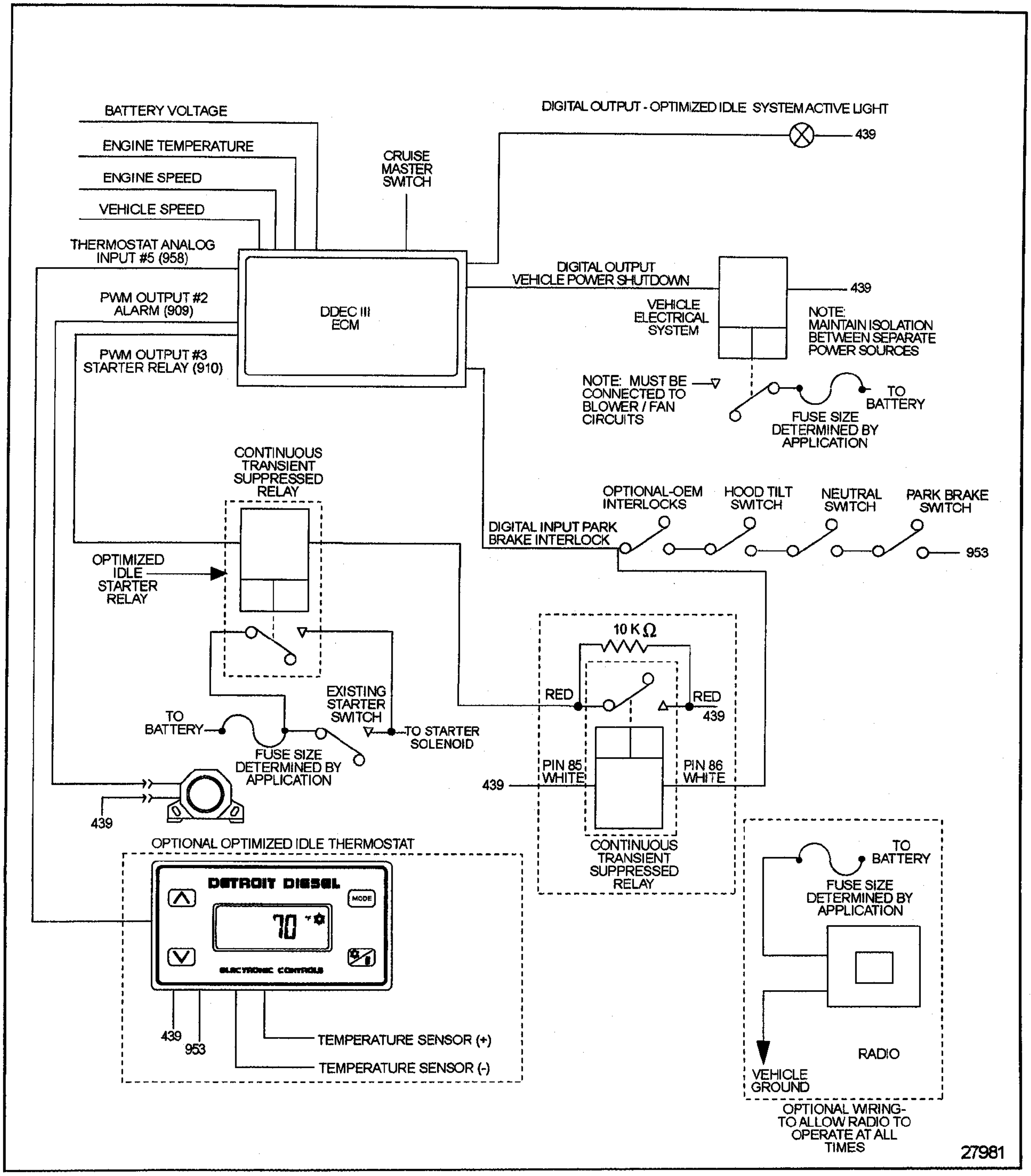



**Figure 8-23 Optimized Idle System Overview**

4. Remove starter relay from relay block (Note: The *Check Engine Light* will illuminate once the relay is removed from the relay block, and a code 63 [PWM driver #3 Open Circuit] will be logged).
5. Measure the voltage between pin 85 of the relay block and a good ground and note the voltage.
   [a] If the voltage is *less than* 4 VDC, pin 85 is PWM # 3. Mark the wire as "PWM # 3" and mark the wire attached to pin 86 of the relay coil as "power".
   [b] If the voltage is *greater than* 4 VDC, pin 85 is the power side of the relay. Mark the wire as "power" and mark the wire attached to pin 86 of the relay coil as "PWM # 3".
6. Open the hood/cab.
7. Using the DDR (diagnostic data reader) select "Calibration Configuration," then select ECM inputs and outputs.
8. Arrow through the selections to find the pin position configured for "Park Brake Interlock."
9. Locate the appropriate wire in the 30-pin connector and label it "Park Brake Interlock."
10. Turn off the ignition.

**CAUTION:**

**To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. If you come in contact with battery acid:**

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

11. Remove negative (-) battery cables.

### 8.6.7 Installation of Optimized Idle Starter Relay Harness Overlay Kit Components

Install optimized idle starter relay harness overlay kit components as follows:

1. Mount relay supplied in kit near Optimized Idle starter relay. See Figure 8-23.
2. Cut the wire labeled "power" from the previous section, refer to step 5.
3. Route both of the red wires from the overlay harness to the cut wire.
4. Cut off any excess wire and strip the insulation.
5. Splice one of the red wires to the one side of the cut wire.
6. Splice the other red wire to the other side of the cut wire.
7. Splice the pink wire (439) to DDEC wire 439.
8. Route the white wire from the overlay harness through the fire wall to the Optimized Idle park brake interlock input wire located in previous section, refer to step 9
9. Cut off any excess wire and strip the insulation from the white overlay harness wire.
10. Splice the white wire into the wire labeled "Digital Input" from the previous section, refer to step 9, approximately 6 inches from the ECM 30-pin connector.
11. Install conduit on the section of the white wire in the engine compartment.
12. Secure conduit.
13. Close hood/cab.
14. Replace the starter relay into the relay block.

### 8.6.8 Verify Installation of Service Kit

Verify installation of service kit as follows:

**CAUTION:**

**To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. If you come in contact with battery acid:**

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

1. Reconnect the battery negative (-) cables.
2. Turn ignition to ON position and wait through bulb check. If "Check Engine" light remains on, check the codes. If a code 63 (PWM driver #3 Open Circuit) is logged, refer to the troubleshooting procedure included below. Otherwise, refer to the *Detroit Diesel Single ECM Troubleshooting Manual* (6SE497).

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Toggle the "Cruise" on/off switch from *off* to *on*. The "Optimized Idle" light should flash.
5. After the engine shuts down, turn the thermostat on by pressing any button. Press *up* or *down* arrow until the heat or cool symbol begins to flash.

   [a] If the engine starts, repairs are complete.

   [b] If the engine does not start, refer to the *Detroit Diesel Single ECM Troubleshooting Manual,* (6SE497).

## 8.7 DDEC II ENGINE SENSOR HARNESS

An improved vehicle engine sensor harness which virtually eliminates the potential for wire chafing damage has replaced the former harness on all Detroit Diesel Series 60 DDEC II engines. This change took effect approximately October 30, 1992. See Figure 8-24.

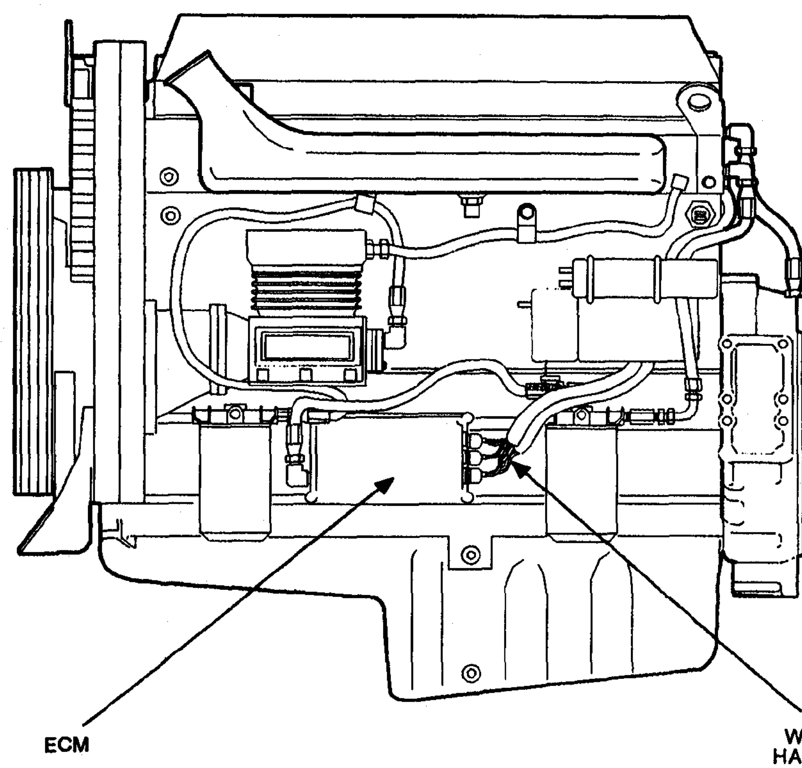



**Figure 8-24 Typical DDEC II Engine Sensor Harness**

Detroit Diesel has found instances of chafing on the sensor connector harness (part number 8929468) used on DDEC II engines. The chafing can occur at the end of the plastic tee-coupling where the wires from the 30-way connector enter the coupling. See Figure 8-25. The chafing results from the absence of abrasion-resistant, convoluted tubing around the wires. Installing convoluted tubing is impractical due to the shortness of the wires at this point. With no abrasion-resistant material surrounding the wires, the rough plastic ridges inside the leg of the tee-coupling can cut through the wire coatings, exposing the wires to moisture and potential shorting. Shorting can result in the logging of false DDEC trouble codes.

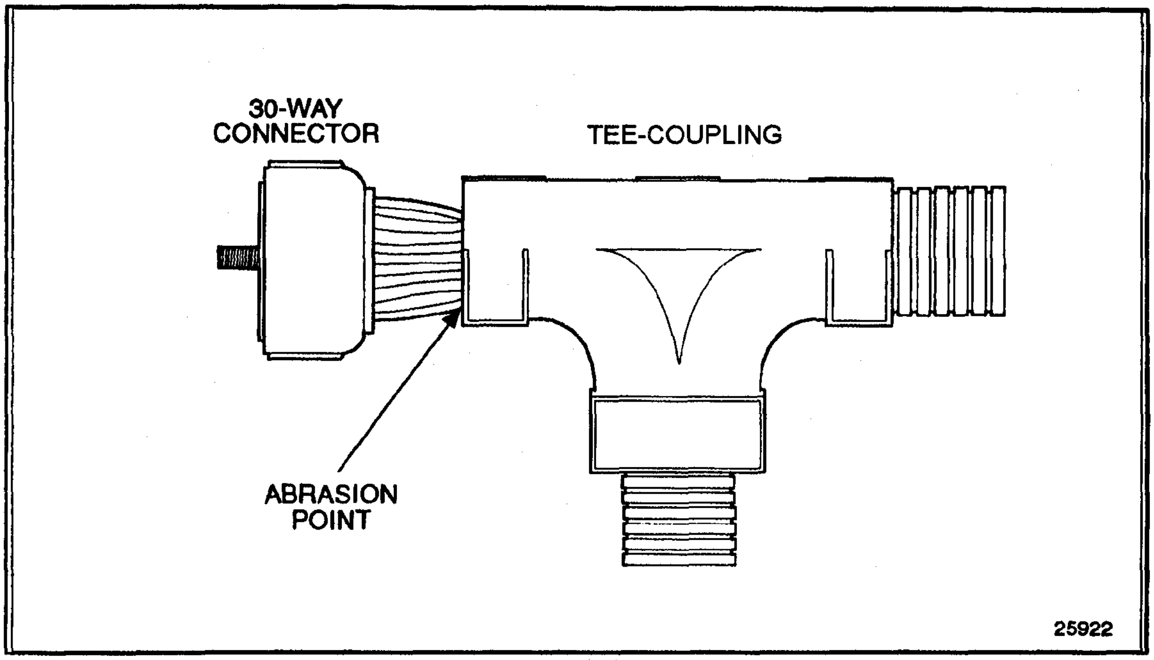



**Figure 8-25 Former Engine Sensor Harness Showing Abrasion Point**

To eliminate this concern, engine sensor harness 8929468 has been improved. The improved harness is identical to the former harness, except that abrasion-resistant tape is now wrapped around the short length of 30-way connector wires where they enter the tee-coupling. See Figure 8-26. This reduces the potential for wire damage caused by abrasion.

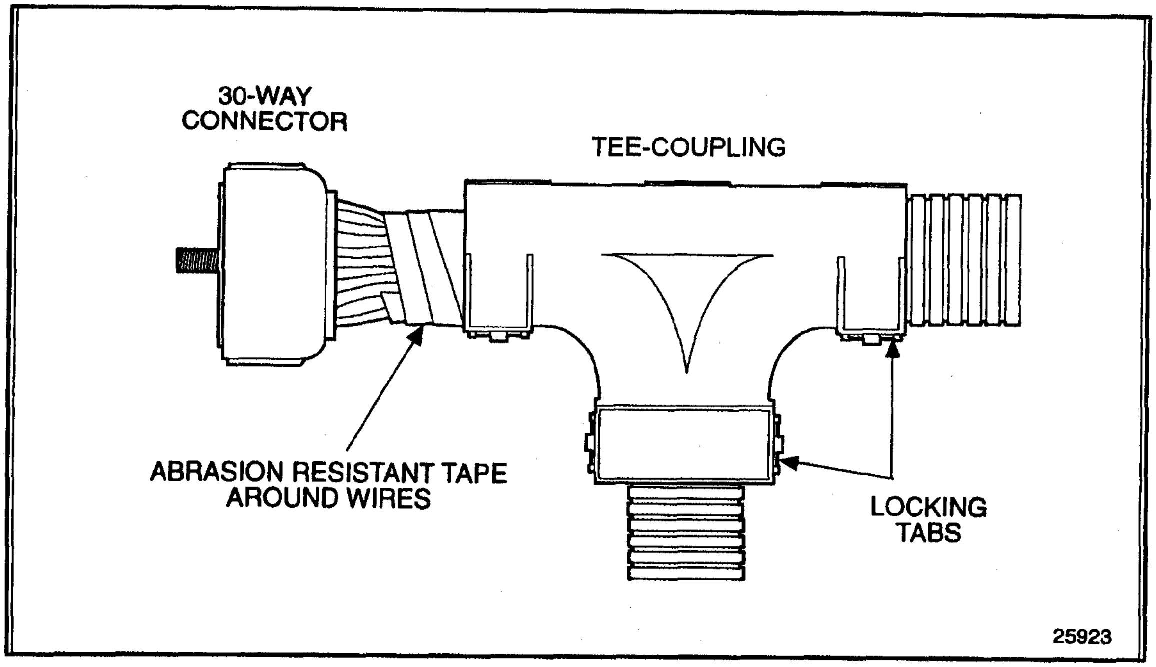



**Figure 8-26 Improved Engine Sensor Harness with Abrasion-resistant Tape**

### 8.7.1 Diagnostic Procedures

Basic mechanical checks should be made beforehand to verify that the problem is definitely related to the electrical portion of the system. If the basic mechanical checks fail to locate the problem, refer to the *Detroit Diesel Single ECM Troubleshooting Manual,* (6SE497). Start by reading the "Basic Knowledge Required" section before attempting to diagnosis electrical faults.

The DDEC II ECM provides the following electrical connections:

- ☐ One 6-way connection at the ECM for battery power and ground.
- ☐ Two 5-way connections at the ECM for the injectors.
- ☐ A 30-way connection at the ECM for all engine electrical connections. (Engine Sensor Harness)
- ☐ A 30-way connection at the ECM for all cab electrical connections. (Vehicle Interface Harness)

## 8.7.2 Repair and Replacement of DDEC II Engine Sensor Harnesses

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 8-27.

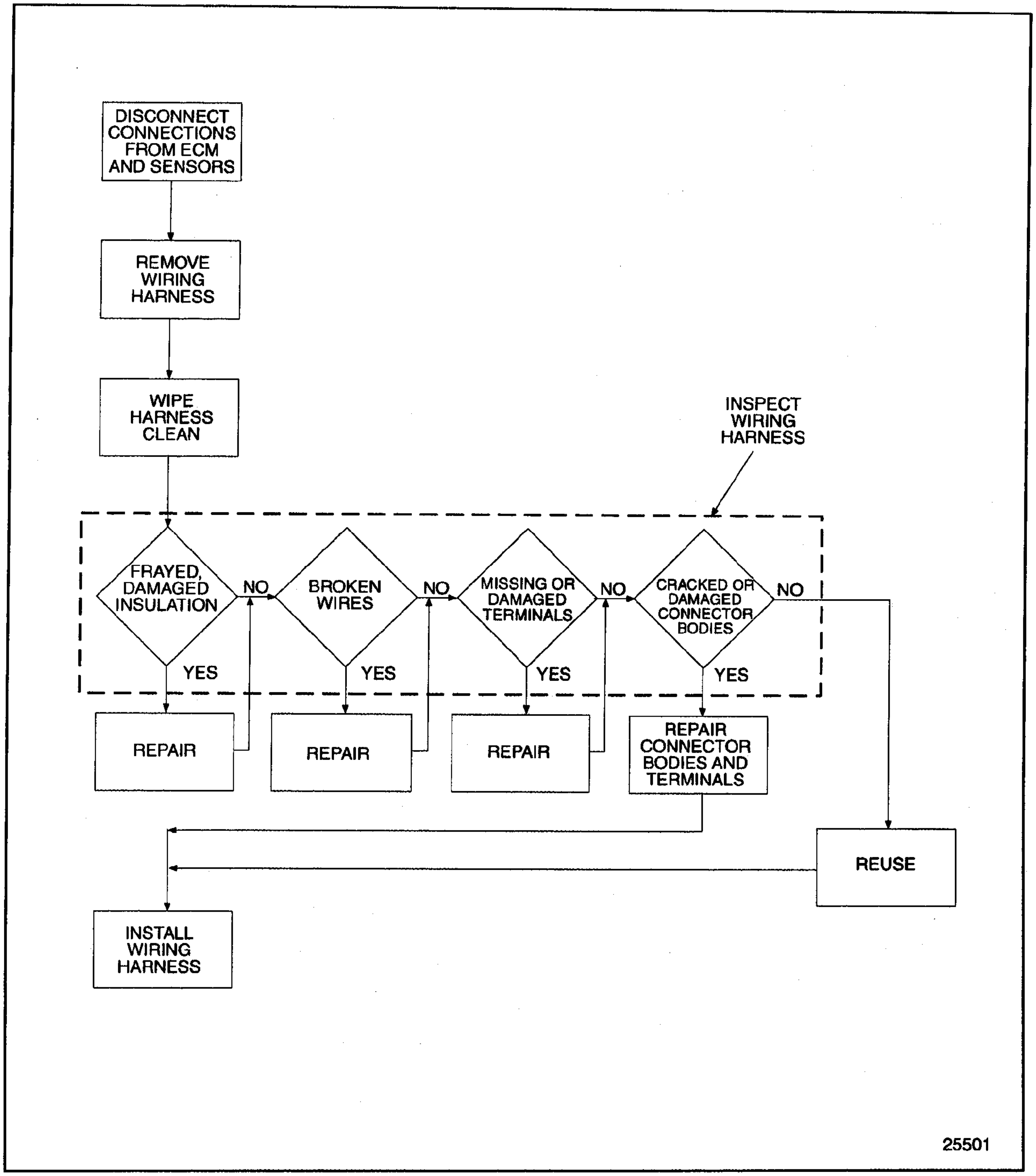
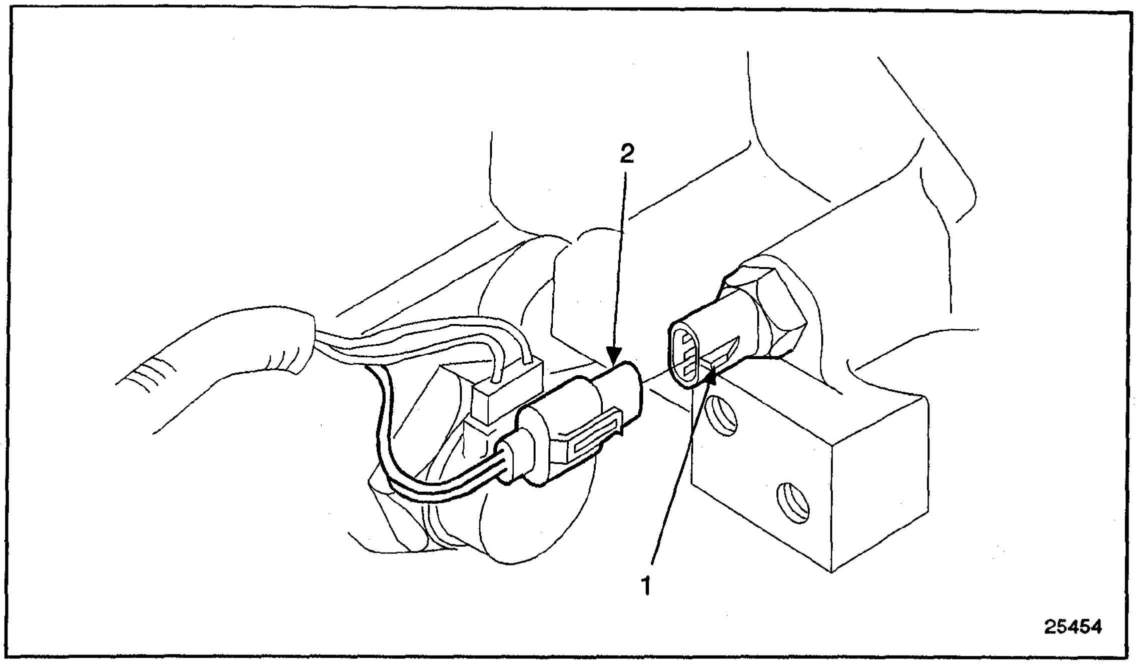



**Figure 8-27 Flowchart for Repair or Replacement of Engine Sensor Harness**

### 8.7.3 Removal of DDEC II Engine Sensor Harnesses

Remove the DDEC II engine sensor harness as follows:

1. Disengage the locking tang on each individual sensor connector body. See Figure 8-28.




1. Locking Tang 2. Connecting Body

**Figure 8-28 Typical Sensor Connector Locking Tang**

2. Grasp the connector body and gently pull it from the sensor.
3. Remove the five bolts securing the metal harness clips to the engine.
4. Remove the 30-pin connector from the ECM by loosening the connector attaching bolt. Carefully pull the connector from the ECM and remove the harness from the engine.

### 8.7.3.1 Inspection of DDEC II Engine Sensor Harness

Inspect the engine sensor harness for the following damage:

- ☐ Frayed or damaged insulation, repair as necessary. Refer to section 8.12.2.
- ☐ Broken wires, repair as necessary. Refer to section 8.12.5.
- ☐ Missing or damaged terminals, repair as necessary. Refer to section 8.9.2.
- ☐ Cracked or damaged connector bodies require removal and replacement. Refer to section 8.9.2 and refer to section 8.9.3.

If the 30-way connector wires do not have a protective covering at the tee, Detroit Diesel recommends wrapping abrasion-resistant tape around the 30-way connector wires where the tee-coupling end clamps onto them, using the following procedure:

1. With the harness on or off the engine, open the plastic tee-coupling by disengaging the locking tabs (two on each side). See Figure 8-26. Remove the coupling.
2. Apply two or three wraps of abrasion-resistant tape such as Polyken 266 Black Tape*, or equivalent, around the 30-way connector wires where the tee-coupling clamps onto them. See Figure 8-26. This reduces the potential for wire damage caused by abrasion.
3. Reinstall the tee-coupling on the harness and check to make sure the tape extends a minimum of 1/2 inch outside the arm of the tee. Add an additional wrap of tape, if necessary.
4. Secure the tee-coupling in place by engaging the locking tabs.

**NOTE:**
* Polyken 267 Black Tape is available from the following supplier in a 1 in. (25.4 mm) wide, 100 foot (30.5 m) long roll: Eliot Tape, 1902 Rochester Industrial Highway, Rochester Hills, MI 48309 Phone: (248) 652-4010 Fax: (248) 652-6591

## 8.7.4 Installation of DDEC II Engine Sensor Harness

Install the DDEC II engine sensor harness as follows:

1. Install the 30-pin connector to the ECM, and torque the connector body attaching bolt to 0.79-1.47 N·m (7-13 lb·in.) torque.
2. If removal of the harness attaching clips from the engine is required, unscrew and remove them from the cylinder block by rotating in a counterclockwise direction.
3. Install the bolts securing the harness clips to the engine. Torque to 30-38 N·m (22-28 lb·ft).

**NOTE:**
To ensure proper engine sensor harness support, all missing and damaged harness clips must be replaced.

4. Carefully plug the two-pin and three-pin harness connectors into the appropriate sensors.

## 8.8 METRI-PACK 150 SERIES CONNECTORS

Metri-Pack 150 series connectors are "pull-to-seat" connectors. Each wire must be pushed through the connector prior to crimping the terminal. Cable seals are inserted into the shell of the connector and hold many wires.

### 8.8.1 Repair and Replacement of Metri-Pack 150 Series Connectors

Repairs to Metri-Pack 150 series connectors are not possible. Remove the defective or damaged connector and replace. Refer to section 8.8.2.

### 8.8.2 Removal of Metri-Pack 150 Series Connectors

A tang on the terminal locks into a tab molded into the plastic connector to retain the cable assembly. Remove and repair Metri-Pack 150 terminals using the following instructions.

1. Insert the removal tool into the cavity of the connector, placing the tip of the tool between the locking tang of the terminal and the wall of the cavity. See Figure 8-29.

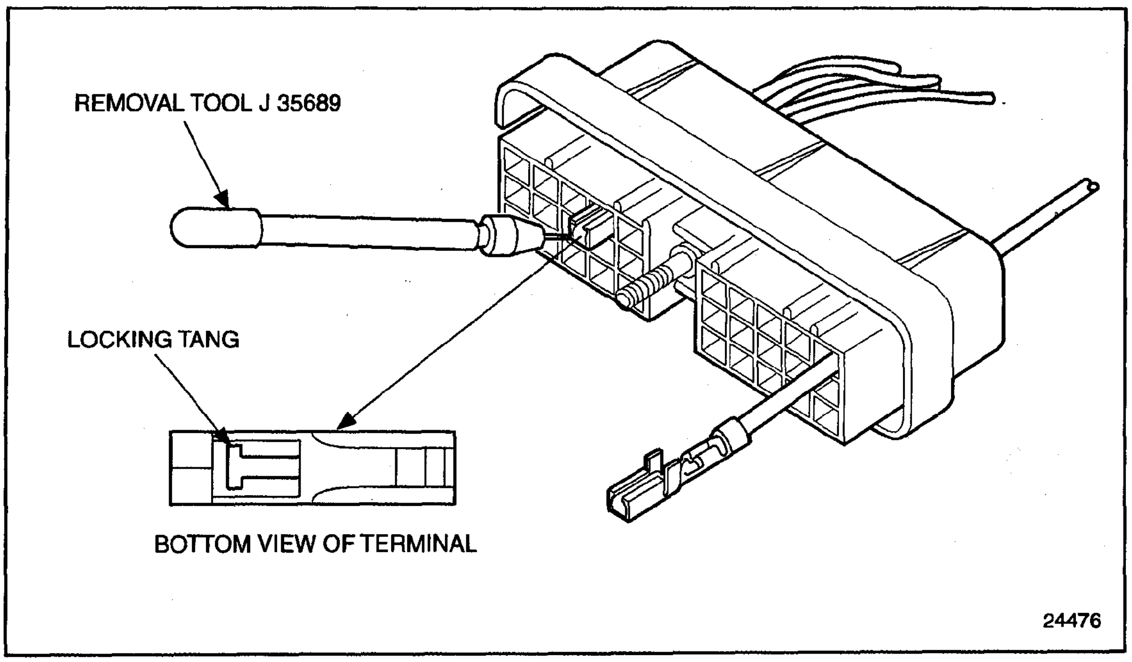



**Figure 8-29 Terminal Removal**

2. Depress the tang of the terminal to release it from the connector.
3. Push the cable forward through the terminal until the complete crimp is exposed.
4. Cut the cable immediately behind the damaged terminal to repair it.
5. Follow the installation instructions for crimping the terminal and inserting it into the connector.

### 8.8.3 Installation of Metri-Pack 150 Series Connectors

Metri-Pack 150 connectors are of the "pull-to-seat" type. Each cable must be pushed through the seal and connector prior to crimping the terminal. Cable seals are inserted into the shell of the connector and hold many wires. Use the following instructions for terminal installation:

1. Push the cable through the correct cavity of the seal and connector. See Figure 8-30.

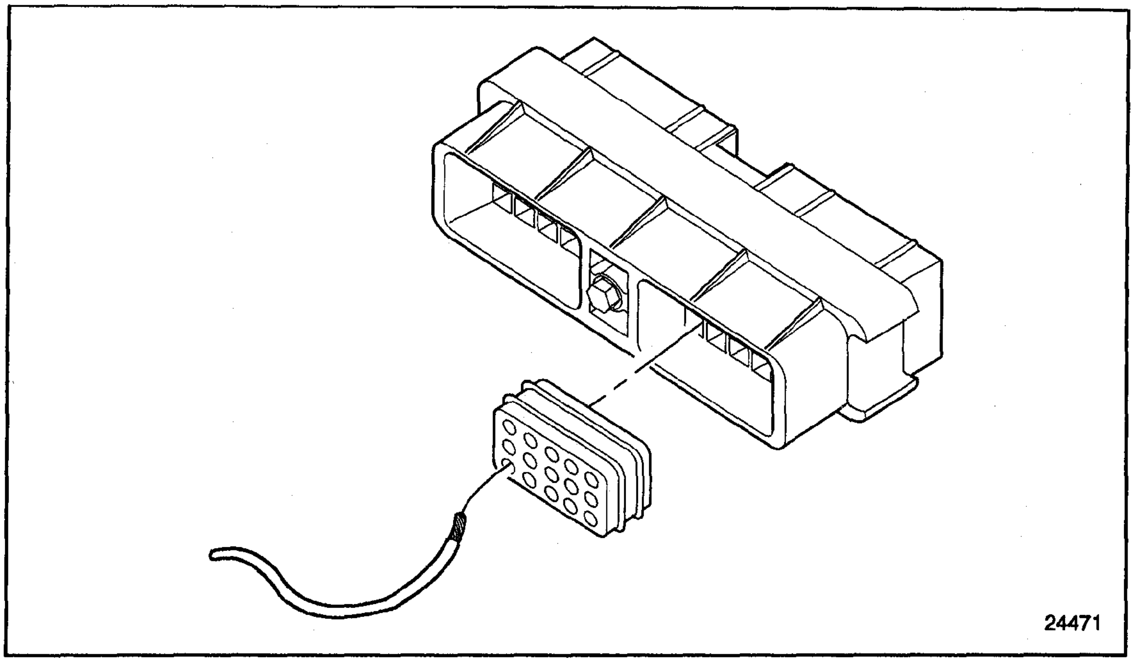



**Figure 8-30 Inserting Wire Connector**

2. Strip the end of the cable using wire strippers to leave 5.0 mm (0.20 in.) (± 0.5 mm ± 0.02 in.) of bare conductor.
3. Squeeze the handles of the crimping tool together firmly to cause the jaws to automatically open.
4. Hold the "wire side" facing you.

5. Insert the terminal until the wire attaching portion of the terminal rests on the 20-22 anvil. Ensure the wire core wings and the insulation wings of the terminal are pointing toward the upper jaw of the crimping tool. See Figure 8-31.

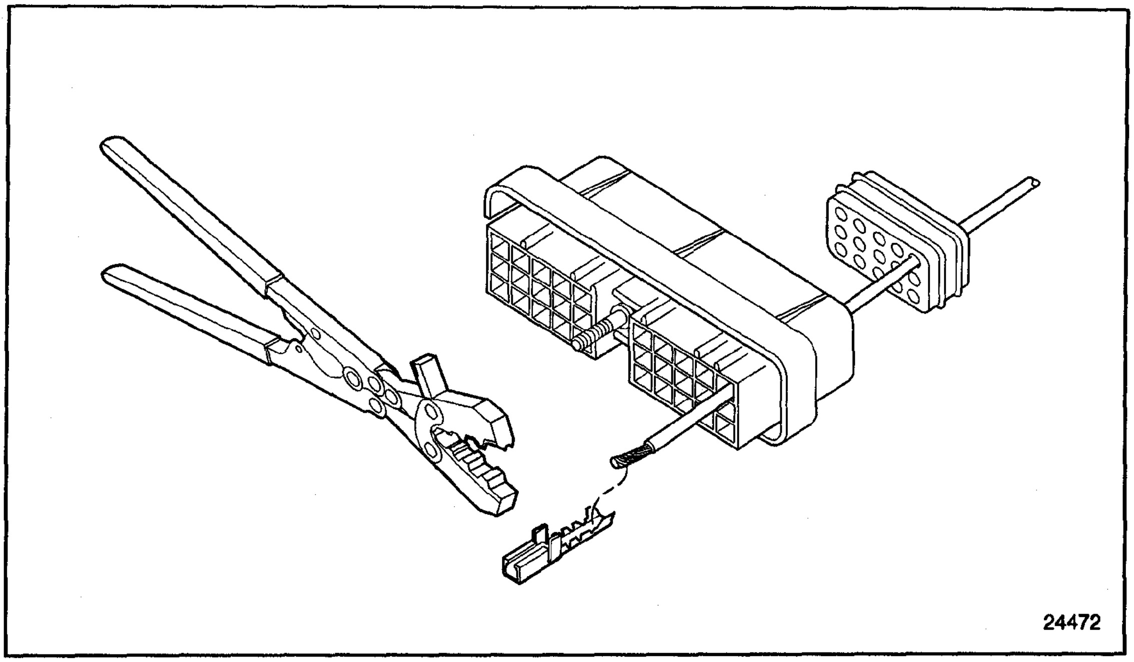



**Figure 8-31 Terminal and Crimping Tool Position**

6. Insert the cable into the terminal until the stripped portion is positioned in the wire core wings, and the insulation portion ends just forward of the insulation wings. See Figure 8-32.

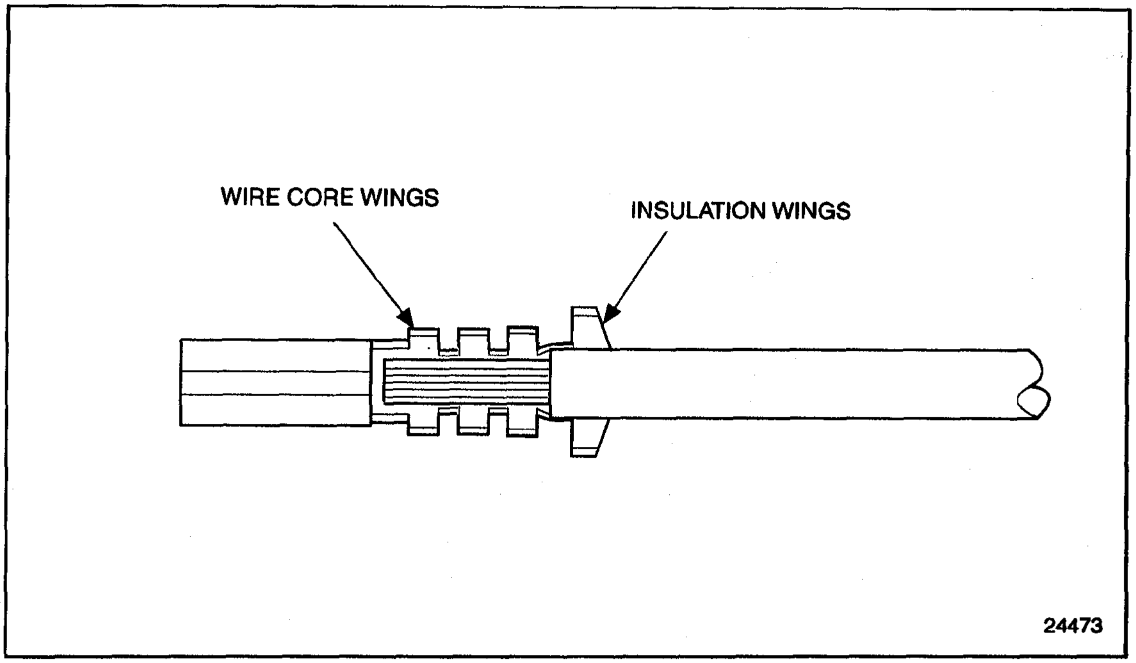



**Figure 8-32 Cable to Terminal Alignment**

7. Compress the handles of the crimping tool until the ratchet automatically releases and the crimp is complete.

**NOTE:**
For faster, more efficient crimping operation, a bracket or bench rest may be used to cradle one handle of the tool. The operator can apply the terminals by grasping and actuating only one handle of the tool. See Figure 8-33.

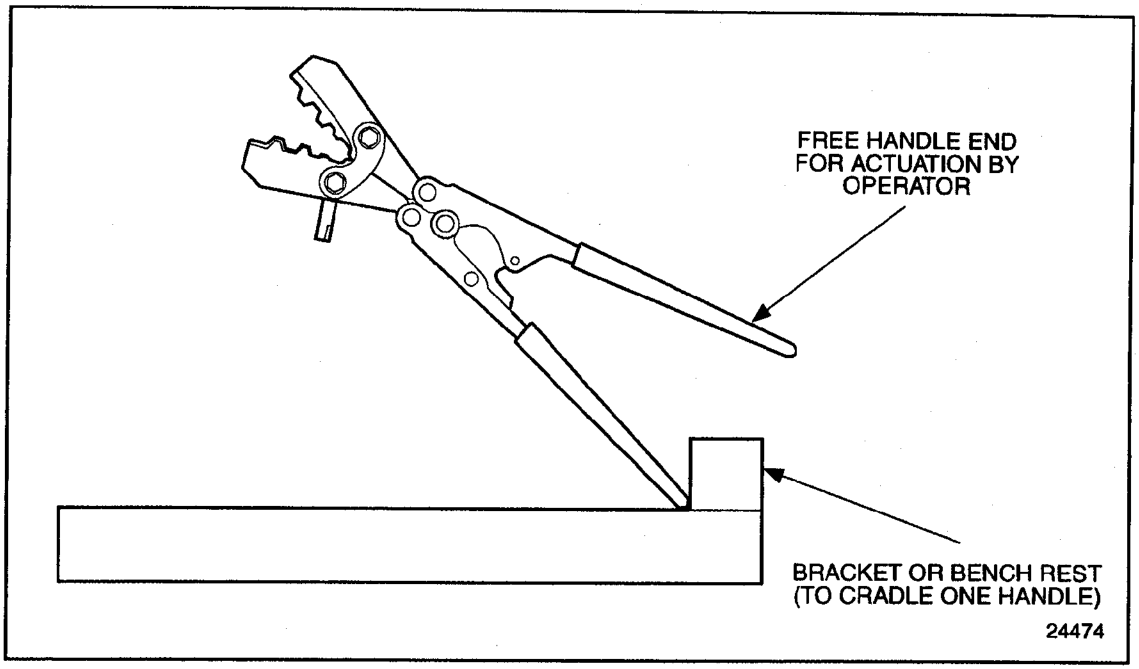



**Figure 8-33 Crimping Operation**

8. Release the crimping tool with the lock lever located between the handles, in case of jamming.
9. Align the locking tang of the terminal with the lettered side of the connector.

10. Pull the cable back through the connector until a click is heard. See Figure 8-34. Position the seal into the connector.

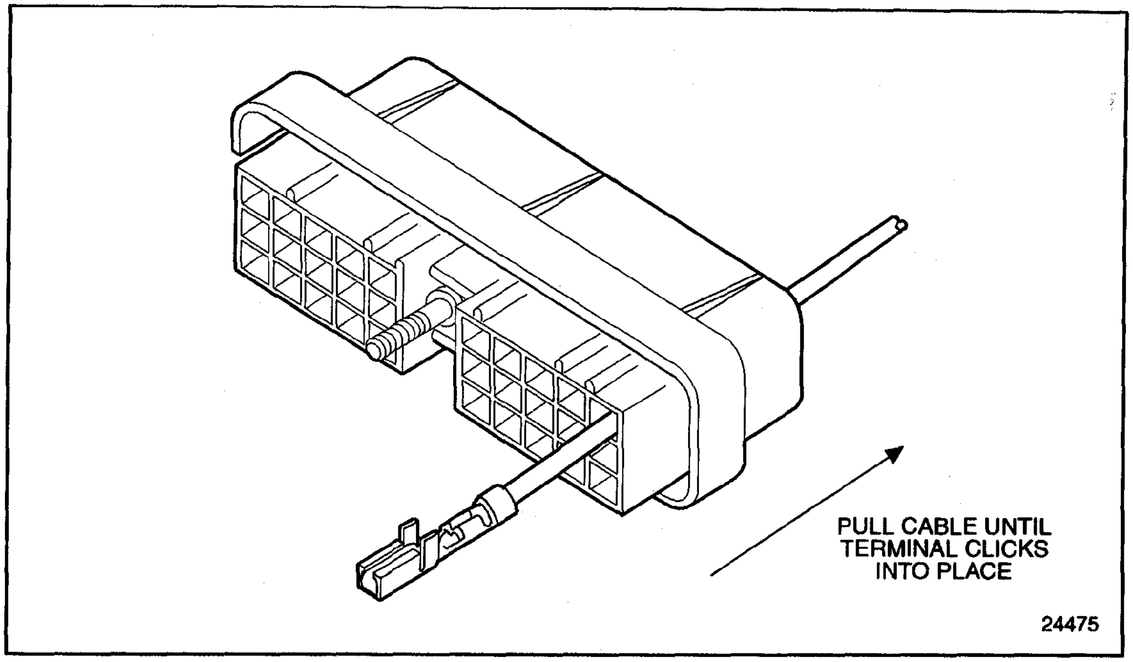



**Figure 8-34 Pulling the Terminal to Seat**

**NOTE:**
For ECM 30-pin connectors, put locking tang opposite lettered side.

## 8.9 MICRO-PACK SERIES CONNECTORS

Micro-Pack series connectors are push-to-seat connectors. Each wire must be crimped into the terminal before it is inserted into the connector. All terminals require 18 gage GXL wire.

### 8.9.1 Repair and Replacement of Micro-Pack Connectors

Repairs to Micro-Pack connectors are not possible. Remove the defective or damaged connector and replace. Refer to section 8.9.2.

### 8.9.2 Removal of Micro-Pack Connectors

To remove the connector:

1. Cut the cable immediately behind the damaged terminal.
2. Install a fresh connector. Refer to section 8.9.3.

### 8.9.3 Installation of Micro-Pack Connectors

Micro-Pack series connectors are of the push-to-seat design. The terminal is crimped on the wire before it is inserted into the connector.

Use the following instructions for terminal installation:

| NOTICE: |
| --- |
| The cable should be stripped of insulation *before* it is inserted through the connector body. |

1. Strip the end of the cable using wire strippers to leave 5.0 mm (0.20 in.) (± 0.5 mm ± 0.02 in.) of bare conductor.
2. Insert the terminal into the locating hole of the crimping tool. Check the gage of the cable to locate the proper hole.

3. Insert the cable into the terminal until the stripped portion is positioned in the cable core wings, and the insulated portion of the cable is in the insulation wings. See Figure 8-35.

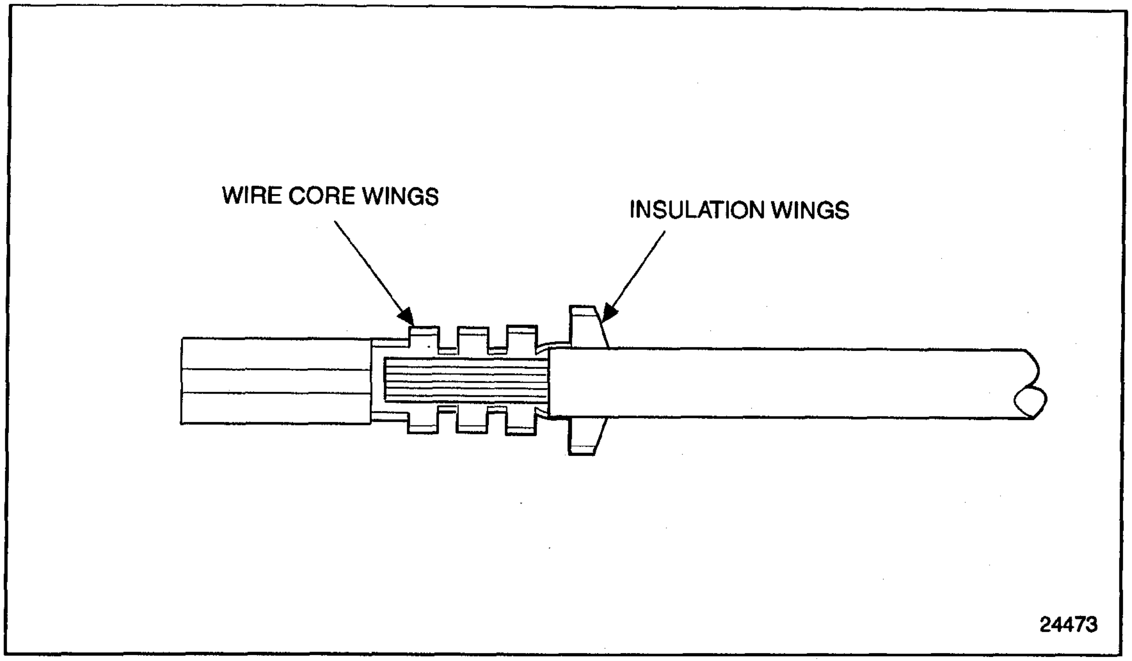



**Figure 8-35 Cable to Terminal Alignment**

4. Compress the handles of the crimping tool until the crimp is complete.

**NOTE:**
For faster, more efficient crimping operation, a bracket or bench rest may be used to cradle one handle of the tool. The operator can then apply the terminals by grasping and actuating only one handle of the tool.

5. Release the crimping tool with the lock lever located between the handles, in case of jamming.
6. Push the crimped terminal into the connector until it clicks into place. Gently tug on the cable to make sure it is secure.

## 8.10 WEATHER PACK AND METRI-PACK 280 SERIES CONNECTORS

Weather Pack and Metri-Pack 280 series connectors are push-to-seat. The terminal is crimped onto each wire before it is inserted into the connector. A cable seal is crimped on each wire at the same time the terminal is crimped onto the wire. Weather Pack connectors use a secondary lock on both male and female connector bodies and the lock snaps into place over the cable seals after installation. Some Metri-Pack connectors have secondary locks as well.

### 8.10.1 Repair and Replacement of Weather Pack and Metri-Pack 280 Series Connectors

Repairs to Weather Pack and Metri-Pack 280 series connectors are not possible. Remove the defective or damaged connector and replace. Refer to section 8.10.2.

### 8.10.2 Removal of Weather Pack and Metri-Pack 280 Series Connectors

Two locking tangs are used on the terminals to secure them to the connector body. Use the following instructions for removing terminals from the connector body.

1. Grasp the cable to be removed and push the terminal to the forward position.
2. Insert the removal tool straight into the front of the connector cavity until it rests on the cavity shoulder. See Figure 8-36.

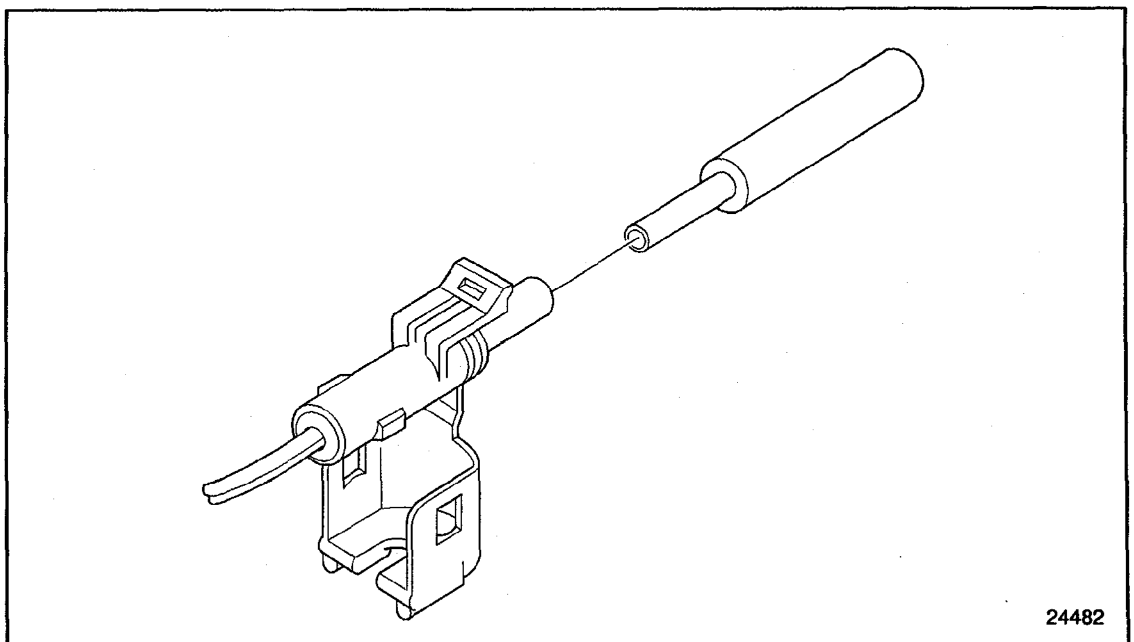



**Figure 8-36 Removal Tool Procedure**

3. Grasp the cable and push it forward through the connector cavity into the tool while holding the tool securely in place. The tool will depress the locking tangs of the terminal.

4. Pull the cable rearward (back through the connector).
5. Remove the tool from the connector cavity.
6. Cut the wire immediately behind the cable seal.
7. Follow the installation instructions for crimping the terminal and inserting it into the connector.

### 8.10.3 Installation of Weather Pack and Metri-Pack 280 Series Connectors

Use the following instructions for terminal installation:

1. Slip the cable seal onto the wire.
2. Strip the end of the cable using strippers to leave 5.0 mm 0.20 in. (± 0.5 ± 0.02 in.) of bare connector.
3. See Figure 8-37 to position the cable seal.

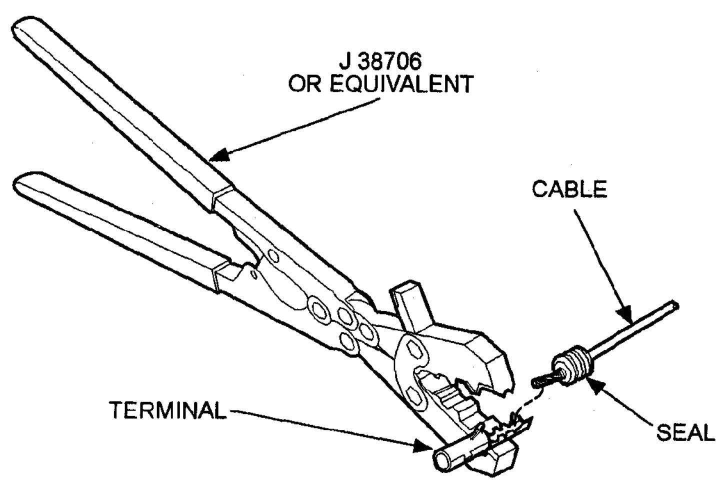



**Figure 8-37 Terminal Position**

4. Insert the terminal into the locating hole of the crimping tool using the proper hole according to the gauge of the cable to be used. See Figure 8-38.
5. Insert the cable into the terminal until the stripped portion is positioned in the cable core wings, and the seal and insulated portion of the cable are in the insulation wings. See Figure 8-38.

6. Compress the handles of the crimping tool until the ratchet automatically releases and the crimp is complete. See Figure 8-38 for a properly crimped terminal.

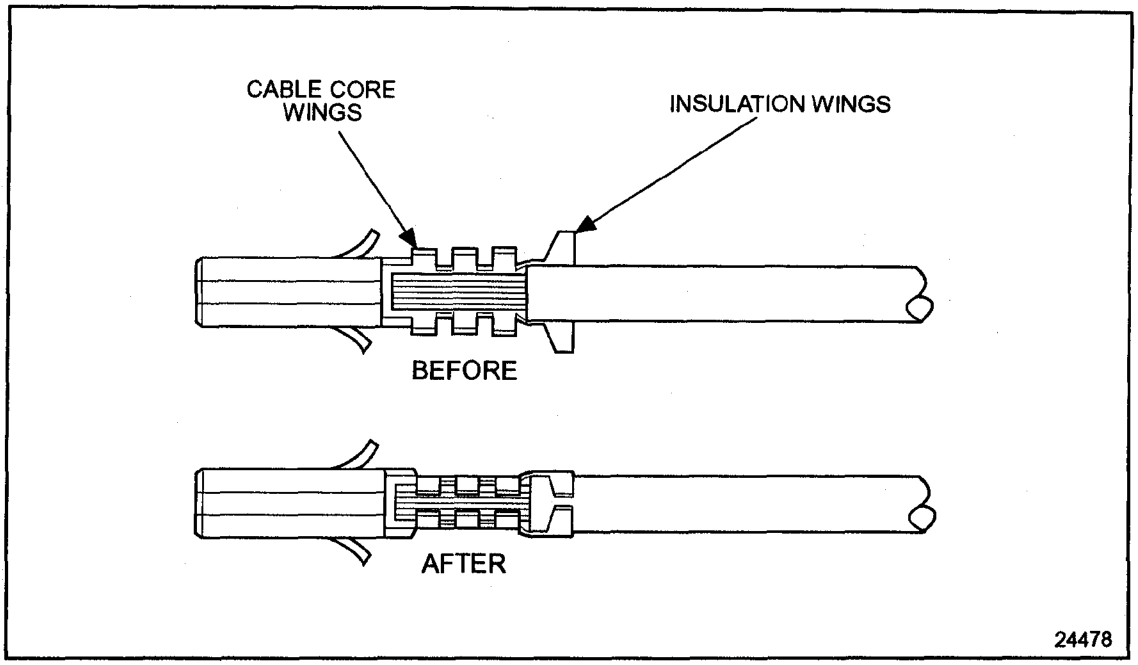



**Figure 8-38 Cable and Terminal Position Before and After Crimping**

7. Release the crimping tool with the lock lever located between the handles, in case of jamming.

8. Push the crimped terminal into the connector until it clicks into place. Gently tug on the cable to make sure it is secure. See Figure 8-39.

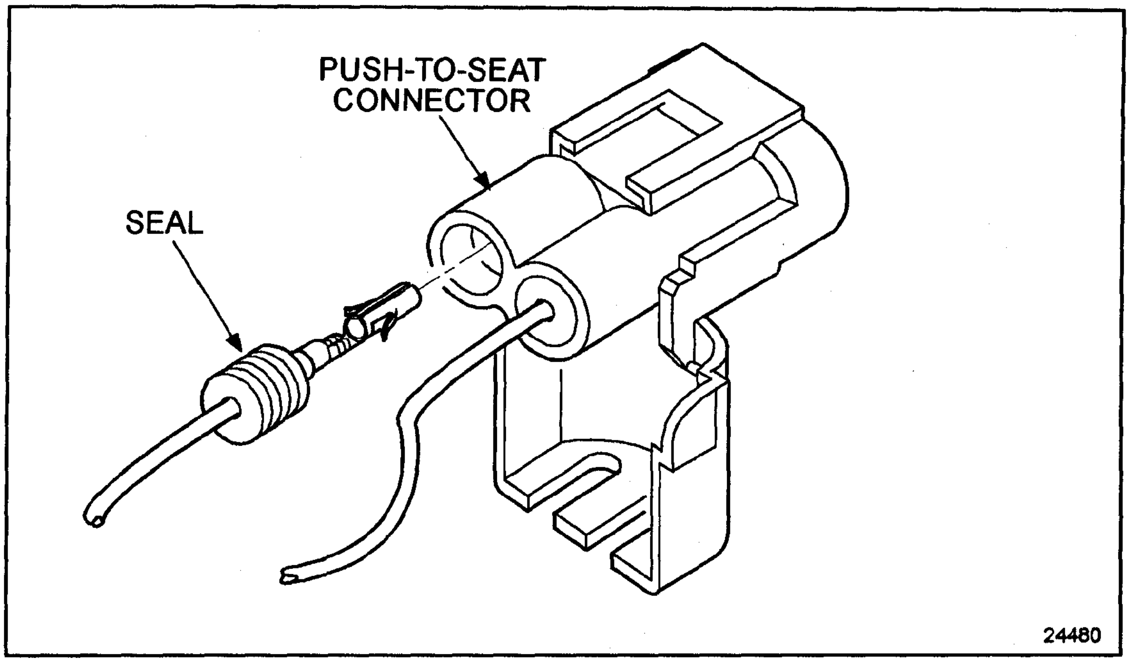



**Figure 8-39 Inserting Terminal in Connector**

## 8.11 CONNECTOR TOOLS

Crimp tools and connector removing tools can be purchased from Kent-Moore:

The tools listed in Table 8-4 are used with the connectors associated with the DDEC III/IV Systems.

| Connector | Tool | Kent-Moore Part No. |
|---|---|---|
| Micro-Pack | Crimp Tool | J 38125-6 |
| Micro-Pack | Removal Tool | J 38125-12 |
| Weather-Pack | Removal Tool | J 36400-5 |
| Metri-Pack 150 Series | Crimp Tool | J 35123 |
| Metri-Pack 150 Series | Removal Tool | J 35689 |
| Metri-Pack 280 Series | Crimp Tool | J 38125-6 |
| Metri-Pack 280 Series | Removal Tool | J 33095 |

**Table 8-4 Terminal Replacement Tools**

# 8.12 SPLICING GUIDELINES

The following are guidelines which may be used for splices. The methods described are not the only acceptable methods. Any method should produce a high quality, tight splice with durable insulation which can be expected to last the life of the vehicle.

The selection of crimpers and splice connectors is optional. Select a high quality crimper equivalent to Kent-Moore tool J 38706 and commercially available splice clips.

## 8.12.1 Splicing Tools

The following is a list of tools required for splicing wires:

- ☐ Soldering iron
- ☐ Rosin core solder
- ☐ Wire strippers
- ☐ Heat shrink tubing
- ☐ Splice clips
- ☐ Crimp pliers

## 8.12.2 Straight Leads

To splice straight leads:

1. Locate broken wire
2. Remove insulation as required; ensure exposed wire is clean and not corroded.
3. Slide a sleeve of shrink wrap on the wire long enough to cover the splice and overlap the wire insulation, about 1/4 inch on both sides.
4. Insert one wire into splice clip (P/N: 0597428 or equivalent) and crimp.

5. Insert the other wire into splice clip and crimp. See Figure 8-40.

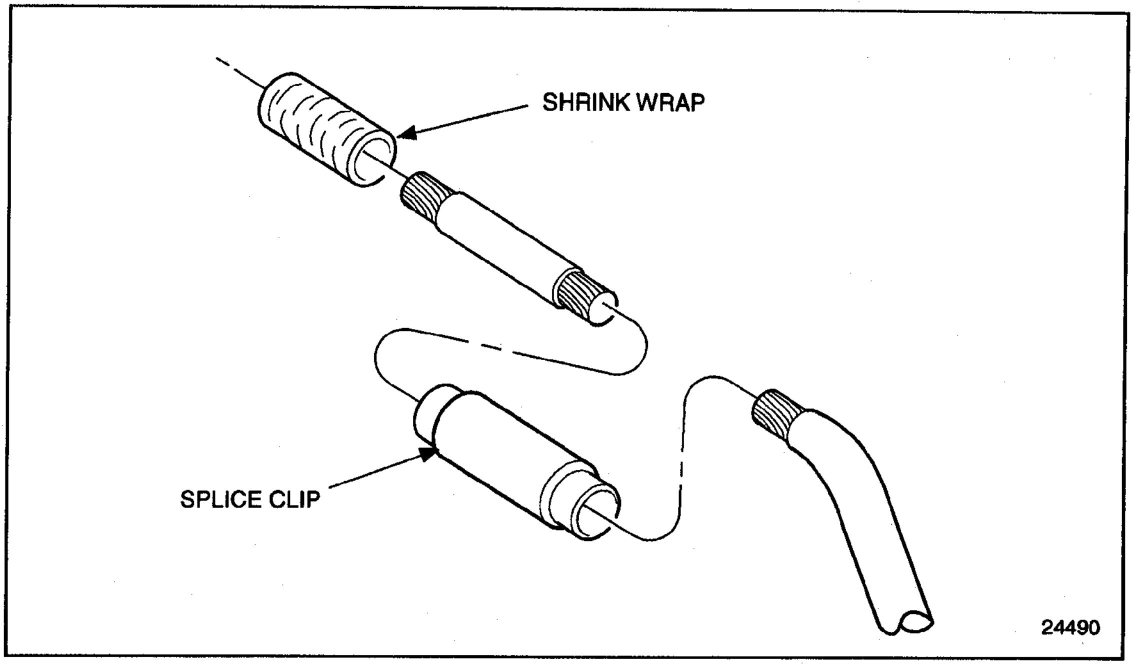



**Figure 8-40 Spliced Wire**

### 8.12.3 Solder

Soldering splice connectors is optional. To solder splice connectors:

1. You *must* use rosin core solder.
2. Check the exposed wire before the splice is crimped in its connector. The exposed wire *must* be clean before the splice is crimped.
3. Use a suitable electronic soldering iron to heat the wires. Apply the solder to the heated wire (not to the soldering iron), allowing sufficient solder flow into the splice joint.
4. Pull on connection to assure crimping and soldering integrity.

## 8.12.4 Shrink Wrap

Shrink wrap is required. Alpha FIT-300, Raychem TAT-125 or any equivalent heat shrink, dual wall, epoxy encapsulating adhesive polyolefin is required. For information on this product contact the companies listed in Table 8-5.

| Alpha Wire Corporation | Raychem Corporation, Thermofit Division |
|---|---|
| 711 Lidgerwood Ave. | 300 Constitution Drive |
| P.O. Box 711 | Building B |
| Elizabeth, New Jersey 07207-0711 | Menlo Park, CA 94025 |
| 1-800-522-5742 | 415-361-3860 |

**Table 8-5 Addresses**

To heat shrink wrap a splice:

1. Select the correct diameter to allow a tight wrap when heated. The heat shrink wrap *must* be long enough to overlap the wire insulation about 6.35 mm (0.25 in.) on both sides of the splice.
2. Heat the shrink wrap with a heat gun; do not concentrate the heat in one location, but play the heat over the entire length of shrink wrap until the joint is complete.

### 8.12.5 Multiple Broken Wires

To splice multiple broken wires:

1. Stagger the position of each splice. See Figure 8-41.
2. You *must* stagger positions to prevent a large bulge in the harness and to prevent the wires from chafing against each other.

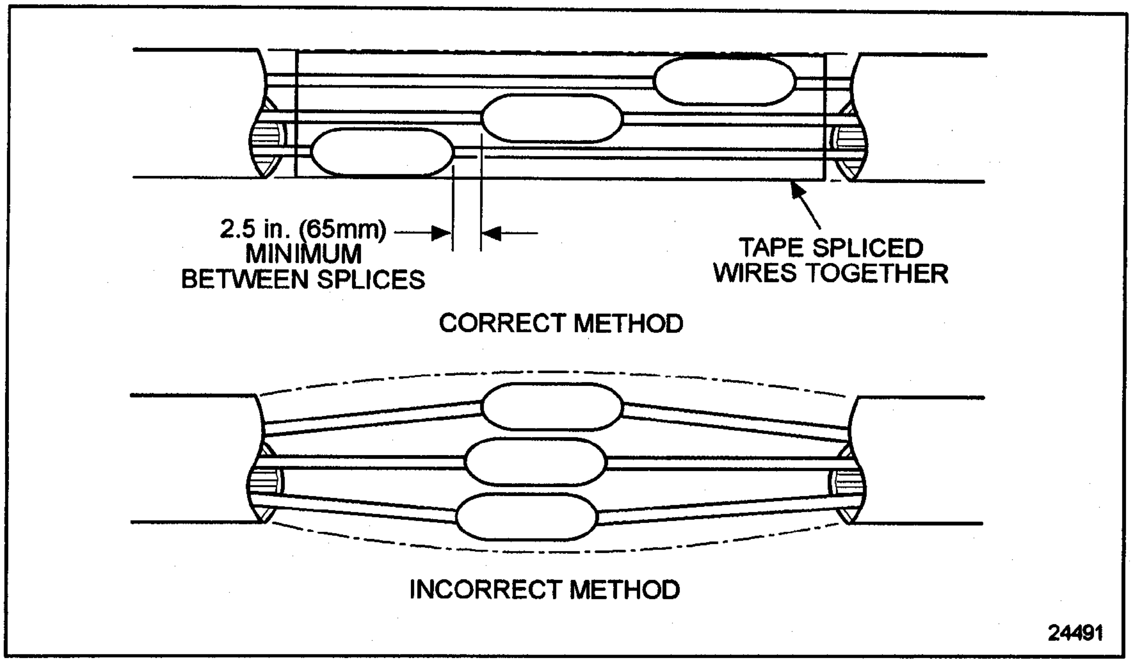



**Figure 8-41 Multiple Splices**

### 8.12.6 Three-Wire Splice

Three-way splice connectors are commercially available to accommodate three-wire splices. The technique is the same as a single butt splice connector. See Figure 8-42.

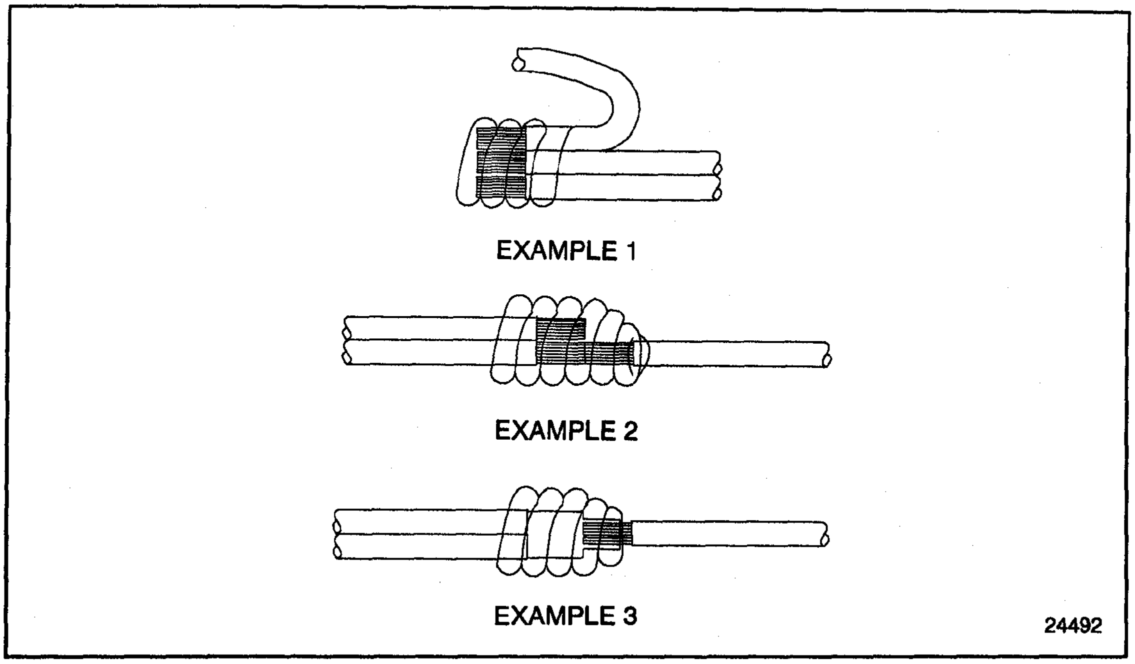



**Figure 8-42 Three-Way Splice**

# 8.A ADDITIONAL INFORMATION

**Description** **Page**

## SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

### Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 8 in the "General Information". Standard (nonmetric) nut and bolt torque specifications are listed in Table 7 in the "General Information" section. The exceptions to this rule are listed in Table 8-6.

| Fastener | Torque, N · m | Torque, lb · ft |
|---|---|---|
| Bolt, Alternator Mounting Bracket | 58-73 | 43-54 |
| Nut, Drive Pulley | 95-108 | 70-80 |
| Bolt, Alternator-to-Mounting Bracket | 81-95 | 60-70 |

**Table 8-6 Exceptions - Metric Fastener Torque Specifications**

# 9 POWER TAKE-OFF

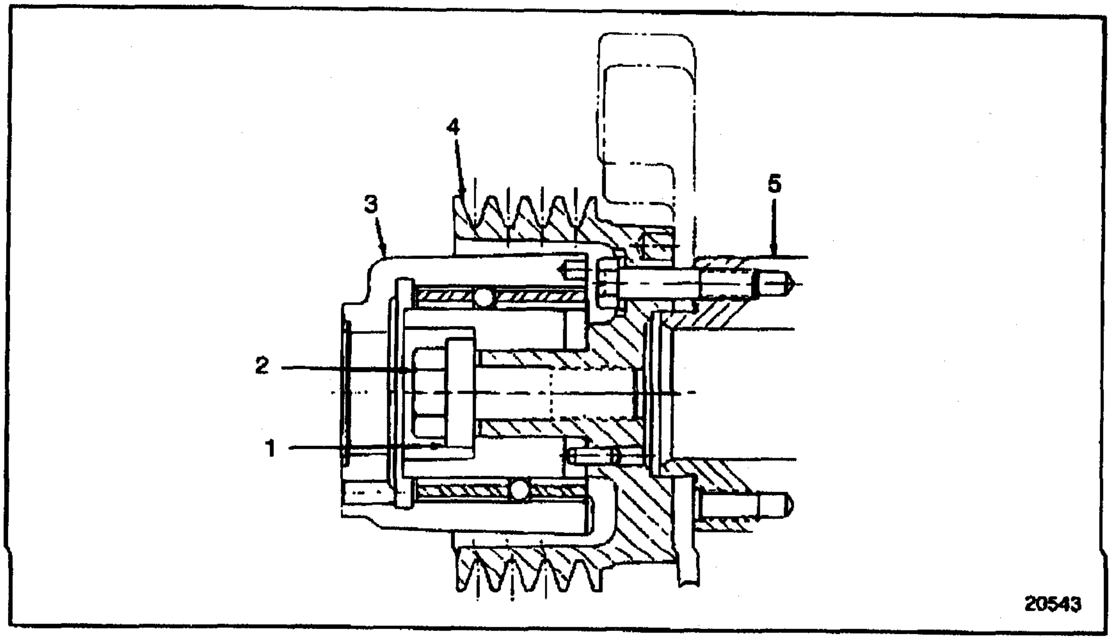
Section | Page

## 9.1 REAR MOUNTED POWER TAKE-OFF

There is no rear mounted power take-off (PTO) available for use on the Series 60 engines.

## 9.2 FRONT MOUNTED POWER TAKE-OFF

Detroit Diesel Corporation (DDC) has a front mounted PTO, for use on the Series 60 vehicle engines. See Figure 9-1.




1. Retainer
2. Bolt
3. Hub Assembly
4. Pulley Assembly
5. Crankshaft

**Figure 9-1 Front Mounted Power Take-off Components**

This PTO is available in two different models, adaptable to Spicer 1310 and Spicer 1350 drive shafts depending on the torque and horsepower requirements. Maximum torque and horsepower for the two PTO assemblies are listed in Table 9-1.

| Power Take-off Models | Engine Speed | Torque | Horsepower |
|---|---|---|---|
| Spicer 1310 | 1800 r/min | 162.7 N·m (120 lb·ft) | 30.6 kW (41 hp) |
| Spicer 1310 | 2100 r/min | 158.7 N·m (117 lb·ft) | 29.8 kW (40 hp) |
| Spicer 1350 | 1800 r/min | 261.7 N·m (193 lb·ft) | 57.4 kW (77 hp) |
| Spicer 1350 | 2100 r/min | 253.6 N·m (187 lb·ft) | 56.0 kW (75 hp) |

**Table 9-1 Torque and Horsepower for the Front Mounted Power Take-off Assemblies**

**NOTE:**

These torque and horsepower values are the maximum available taken at three degrees shaft angle. Any increase in the shaft angle has a direct negative effect on the amount of available torque and horsepower, as well as shaft life.

Also, any new application must have a "Torsional Analysis" performed by the DDC Engineering Department.

The PTO drive shaft must be purchased through Spicer Universal Joint Division, Dana Corporation.

If a PTO adaptor kit is to be installed on an engine that has been in service, it will be necessary to remove the standard pulley configuration and replace it with one of the PTO adaptor kits.

Perform the following steps to install the new PTO assembly:

1. Remove the six bolts that retain the standard crankshaft pulley: refer to section 1.13.2.
2. Install the new PTO pulley; refer to section 1.13.3. Use the new bolts and washer provided with the PTO adaptor kit.
3. Install the new hub insulator assembly inside the new pulley assembly ensuring that the slot on the backside of the hub fits over the dowel in the pulley.
4. Install the new 1 in. - 14 x 3.50 in. long bolt and retainer after coating the bolt threads and underside of the bolt head with International Compound #2®. Torque the bolt to 610 N·m (450 lb·ft).

### 9.2.1 Repair and Replacement for the Front Mounted Power Take-off Assembly

The front mounted power take-off assembly is a nonserviceable component; tag for remanufacture.

### 9.2.2 Removal of Front Mounted Power Take-off

Perform the following steps to remove the PTO assembly:

1. Remove the inspection plug in the bottom of the flywheel housing and install the J 36375–A ; see Figure 9-2.

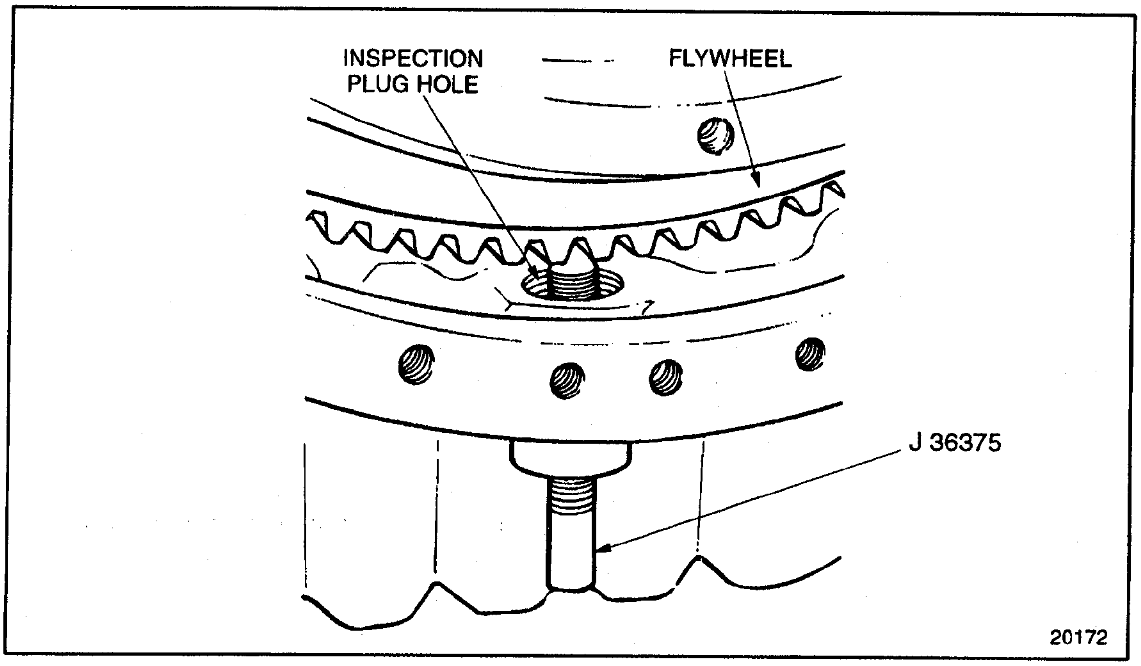



**Figure 9-2 Flywheel Lock**

2. Thread the center screw of the J 36375–A into the flywheel housing until the tip of the tool rests between two teeth of the flywheel ring gear. Finger-tighten the knurled knob; see Figure 9-3.

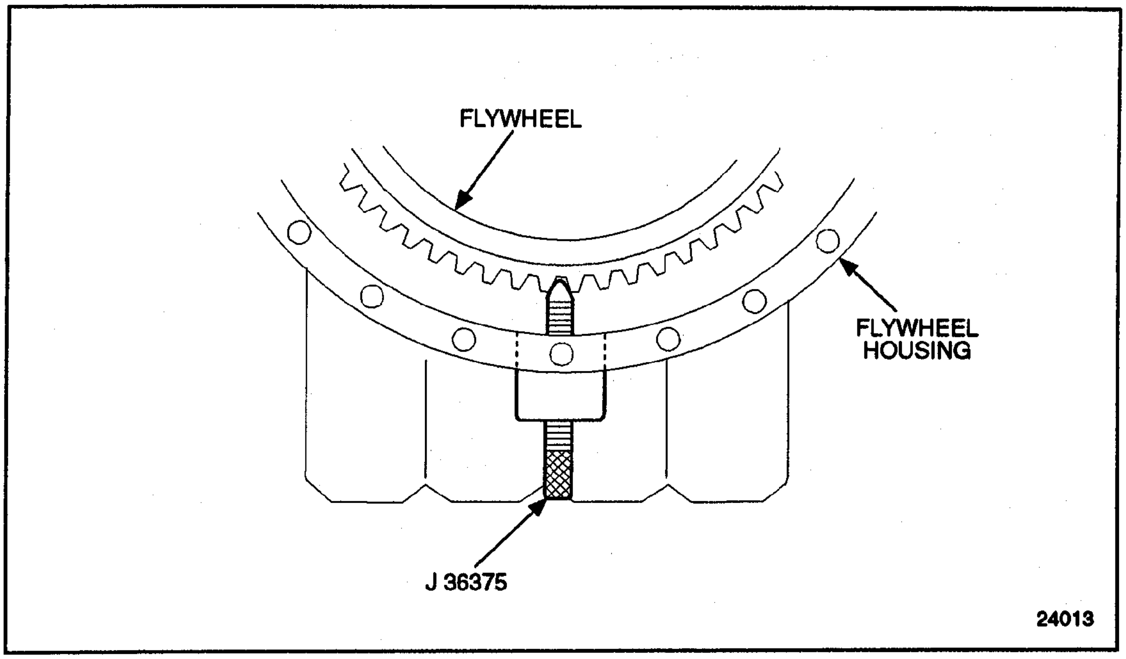



**Figure 9-3 Flywheel Lock Location**

**NOTE:**
It may be necessary to bar the engine over so that the tool center screw is exactly between two teeth.

3. Remove the PTO hub assembly attaching bolt and retainer.
4. Remove the PTO hub assembly.
5. Remove the PTO/crankshaft pulley; refer to section 1.13.2.

#### 9.2.2.1 Inspection of Front Mounted Power Take-off

Visually inspect the PTO hub contact surfaces for galling or burrs. To correct surfaces that have damage, smooth these surfaces with emery cloth or a stone.

### 9.2.3 Installation of Front Mounted Power Take-off

Perform the following steps to install the PTO assembly:

1. If removed, install J 36375–A, to the inspection plug hole in the bottom of the flywheel housing; see Figure 9-2.
2. Install the PTO/crankshaft pulley; refer to section 1.13.3.
3. Install the PTO hub assembly inside of the PTO/crankshaft pulley ensuring the slot on the backside of the hub fits over the dowel in the pulley.
4. Install the PTO hub assembly attaching bolt and retainer after coating the bolts threads and underside of the bolt head with International Compound #2® or equivalent. Torque the bolt to 610 N·m (450 lb·ft).

# 10 SPECIAL EQUIPMENT

## 10.1 AIR COMPRESSOR (VEHICLE APPLICATIONS ONLY)

The original Series 60 air compressor is mounted to the rear of the gear case on the left side of the engine. See Figure 10-1.

**NOTE:**
Genset and marine engines do not have air compressors.

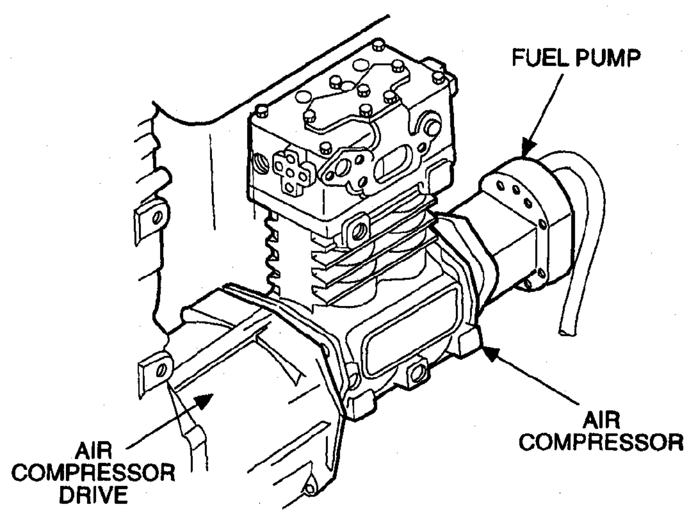



**Figure 10-1 Original Air Compressor Mounting**

The original air compressor drives the engine fuel pump which is bolted to the rear end of the compressor. The air compressor is designed to accept a drive coupling placed between the air compressor and fuel pump.

Certain applications, and all Series 60 engines built before 1990, do not use the air compressor to drive the engine fuel pump. The air compressor is mounted in the same place on these units, but the engine fuel pump is mounted to the fuel pump drive assembly. The fuel pump drive assembly is bolted to the gear case above the air compressor and is driven by the bull gear. See Figure 10-2.

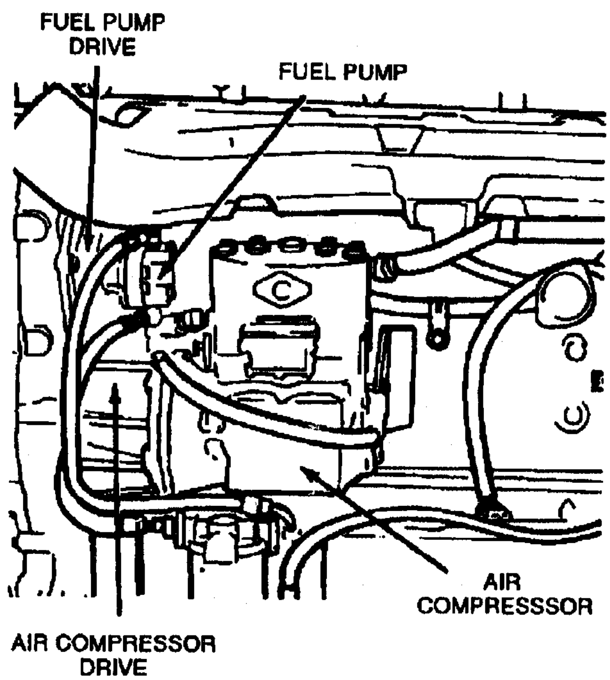



**Figure 10-2 Original Air Compressor with Flange Mounted Fuel Pump**

The original air compressor is driven by the bull gear and water cooled. Engine coolant is fed to the compressor through a flexible hose tapped into the engine block water jacket and connected to the front of the compressor. Coolant returns from the rear of the compressor through a flexible hose to the engine cylinder head. Lubricating oil is supplied to the compressor by a line from the cylinder block oil gallery that connects to the air compressor. Lubricating oil returns to the engine crankcase through the air compressor drive assembly.

**NOTE:**
An air compressor oil test card (DD5524) is available to test engine-mounted air compressors for excessive oil leakage. Contact an authorized Detroit Diesel service outlet for details.

The current adaptorless air compressors have replaced the original air compressors and adaptors on the majority of Series 60 on-highway engines. This change took effect with unit serial number 6R210293, built November 30, 1994. The original compressor and adaptor are available on certain on-highway and industrial models due to customer preference.

An optional 28 cfm, twin-cylinder air compressor has replaced the former optional 31 cfm, four-cylinder air compressor, starting with model year 1999. The 28 cfm, high output air compressor is a naturally aspirated design that requires the intake air to be plumbed from the clean air side of the air filter.

Both high-output air compressors require the engine-driven fuel pump to be mounted to the gear case above the air compressor.

Current adaptorless air compressors are similar to the original compressors, except that their mounting flanges have been redesigned to permit direct installation of the compressor onto the gear case. The drive gear stackup on this compressor has been modified to eliminate the need for a drive adaptor. See Figure 10-3.

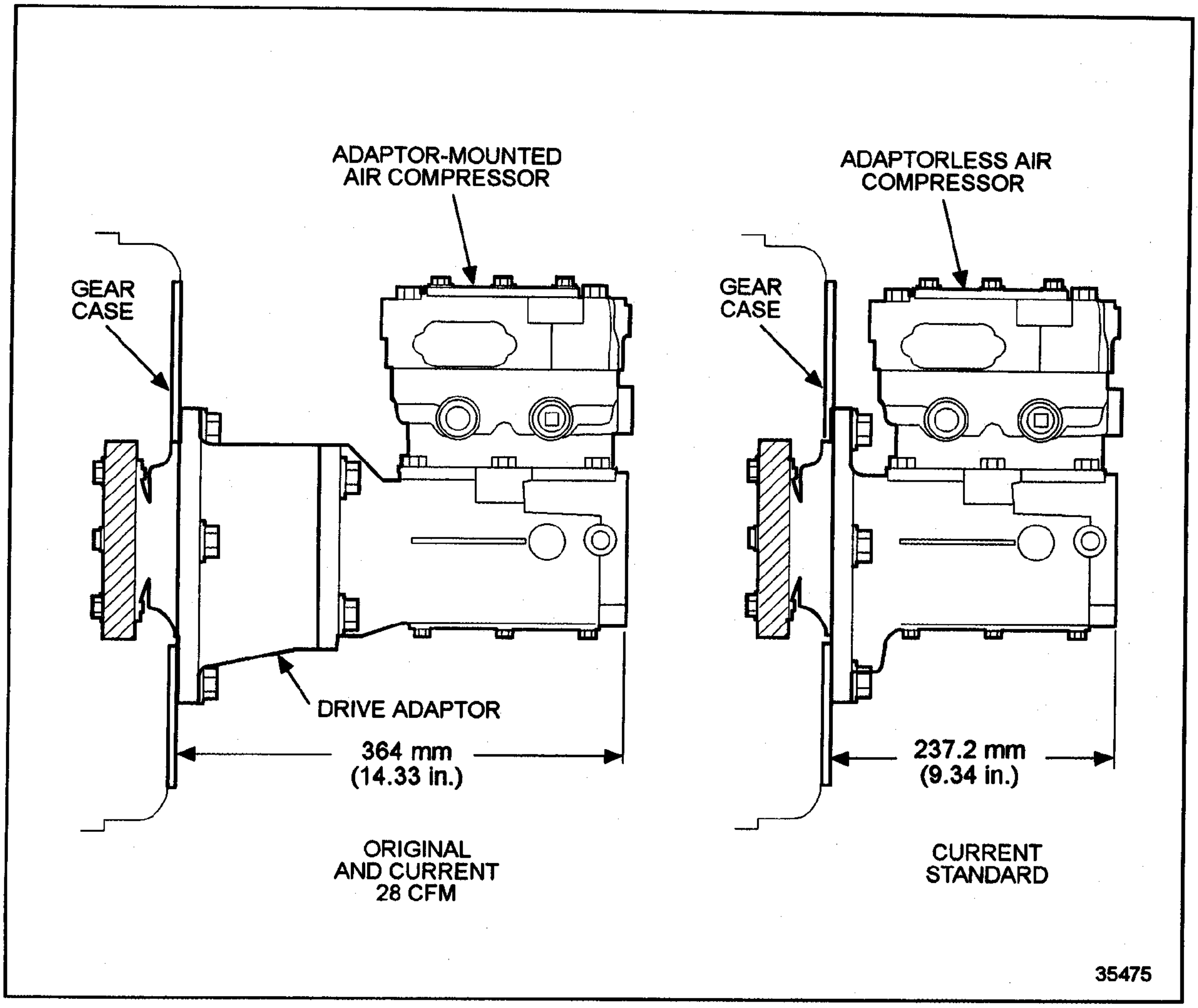



**Figure 10-3 Original Adaptor, Current 28 CFM-mounted, and Current Adaptorless Air Compressor**

**NOTE:**
If information is required to service an original air compressor, refer to section 10.1.8.

The current Series 60 adaptorless air compressor is flange-mounted to the rear of the gear case, located on the left side of the engine. See Figure 10-4.

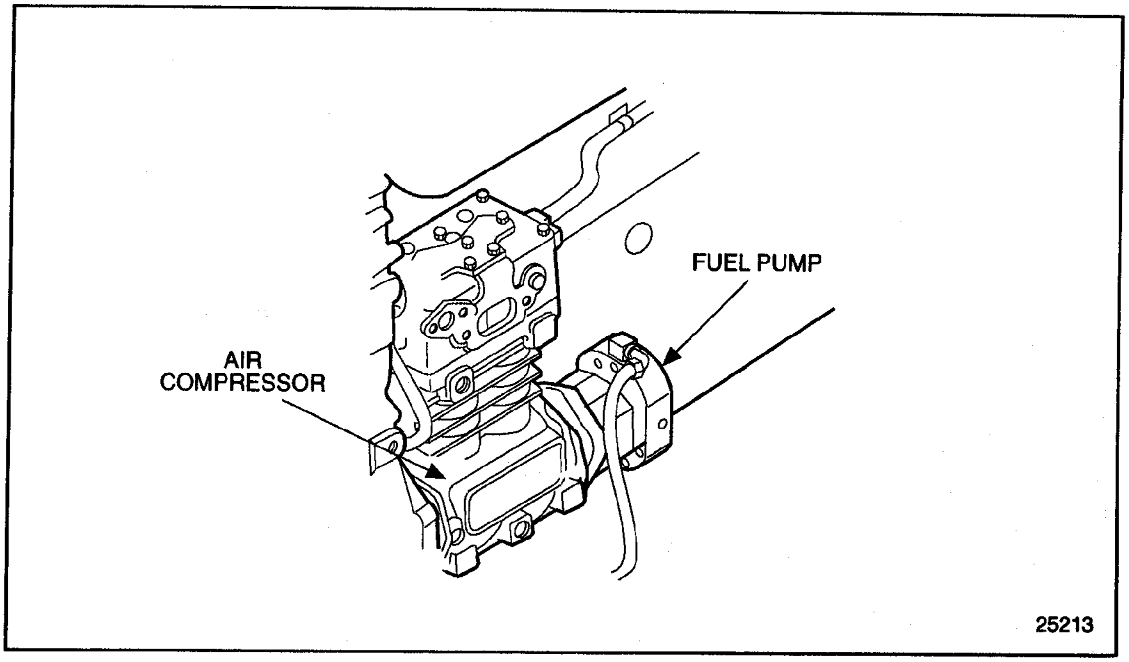



**Figure 10-4 Adaptorless Air Compressor Mounting**

Current adaptorless air compressors also drive the engine fuel pump which is bolted to the rear end of the compressor. The compressor crankshaft is designed to accept a drive coupling placed between the compressor and fuel pump.

### 10.1.1 Replacement of Adaptorless Air Compressor

Detroit Diesel does not service the adaptorless air compressor. Service of an adaptorless air compressor should be referred to an authorized service center of the original equipment manufacturer.

To replace the adaptorless air compressor, perform the following procedure. See Figure 10-5.

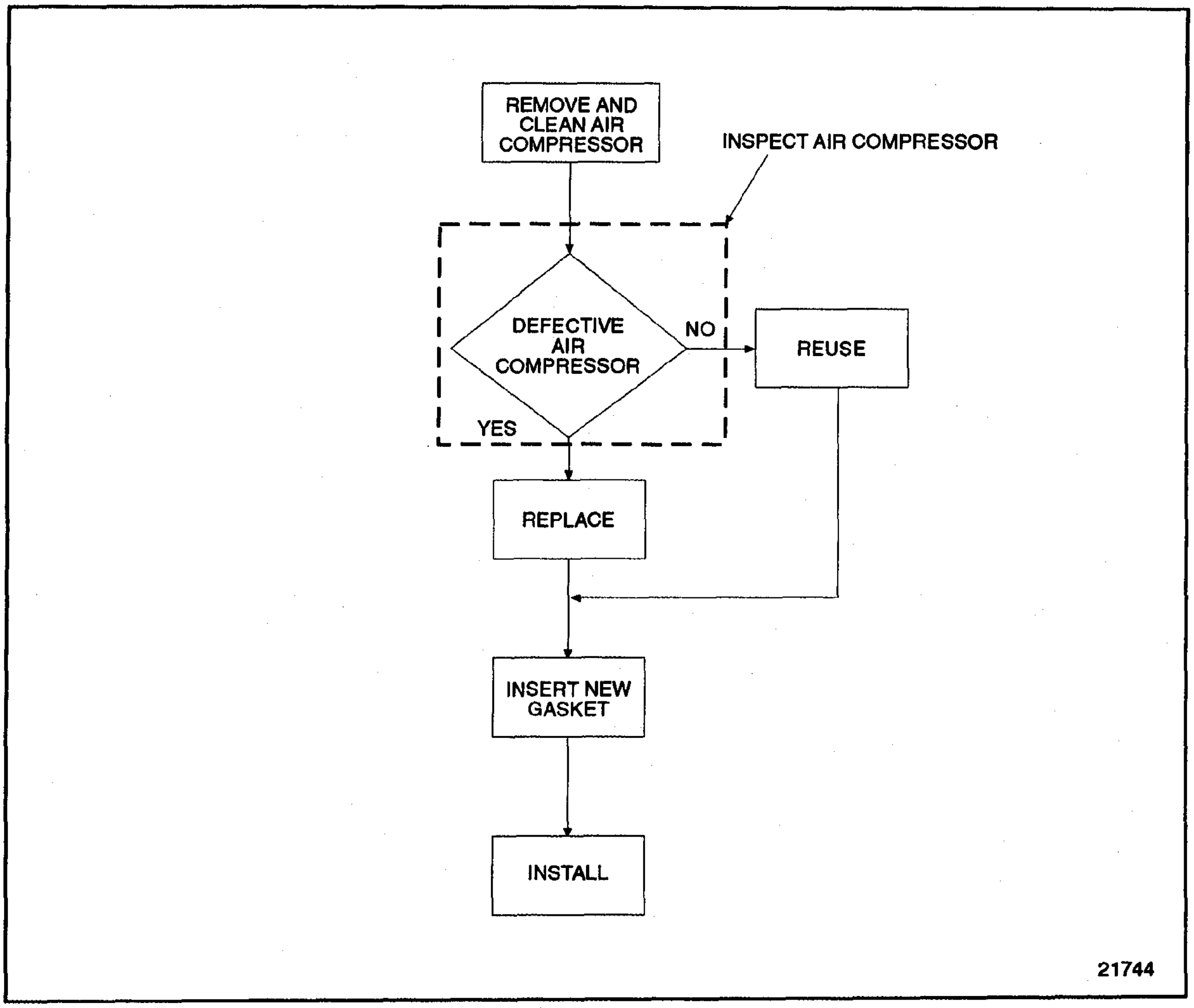



**Figure 10-5 Flowchart for Replacement of Adaptorless Air Compressor**

### 10.1.2 Cleaning and Removal of Adaptorless Air Compressor

Precleaning is not necessary.

Remove the adaptorless air compressor as follows:

1. Disconnect the air lines to and from the compressor.
2. Disconnect the fuel pump lines.
3. Remove the fuel pump and drive coupling. Refer to section 2.6.2.
4. Drain the cooling system. Refer to section 13.13.4.
5. Disconnect and drain the coolant supply and return lines at the air compressor.
6. Disconnect the lubricating oil supply line from the compressor.
7. Remove the bolts securing the air compressor support bracket to the cylinder block and air compressor.
8. Remove the support bracket.

**NOTE:**
**Due to the cylinder block and compressor configuration, the upper inside air compressor-to-air compressor drive bolt is difficult to reach with standard tools. Compressor Wrench J 35948 will facilitate removal and installation of this bolt.**

9. Remove the five bolts and one nut that secure the air compressor to the gear case.
10. Slide the air compressor rearward to disengage the hub from the coupling.

#### 10.1.2.1 Inspection of Adaptorless Air Compressor

Refer to OEM guidelines to determine if the air compressor needs to be repaired or replaced.

### 10.1.3 Installation of Adaptorless Air Compressor

Install the adaptorless air compressor as follows:

1. Clean all gasket material from the mating surfaces of the air compressor and the gear case.
2. Align the reference mark on the fuel pump drive coupling to the nine o'clock position. This will set the air compressor piston at top dead center and will help to ease the process of checking gear lash.
3. Using a new gasket and bolts and nut previously removed, install the air compressor to its original location on the gear case.

**NOTE:**
**The shorter bolt is installed in the two o'clock position and the nut is installed in the twelve o'clock position.**

4. For torquing sequence, see Figure 10-6. Use compressor wrench J 35948 to torque the upper inside bolt. Using the bolt and nut torquing sequence, torque five bolts and one nut to 58–73 N·m (43–54 lb·ft).

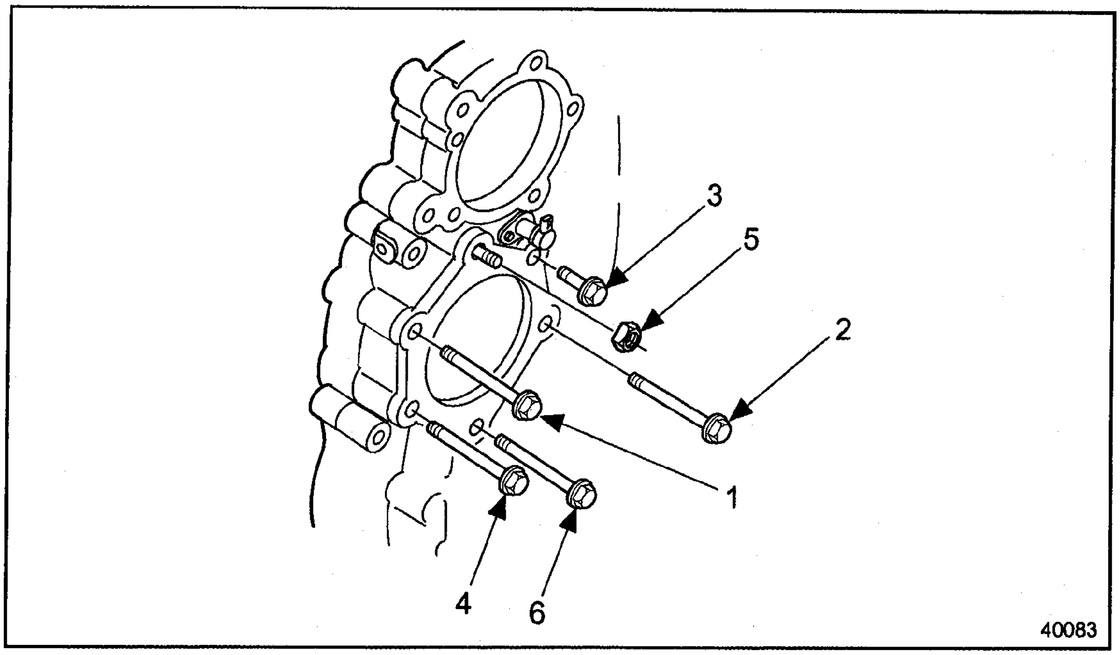



**Figure 10-6 Bolt Torque Sequence**

5. Refer to section 1.21.2.1 step 14 and check the bull gear-to-air compressor drive gear lash measurement.
6. Refer to section 1.21.2.1 step 14 and install the power steering pump drive coupling, power steering pump, and cover assembly to the gear case cover.

7. Install the improved air compressor support bracket to the compressor and cylinder block as follows:

   [a] Tighten the support bracket-to-air compressor bolts. For 25 mm long bolts, use a torque of 41 - 52 N·m (30 - 38 lb·ft). For 20 mm long bolts, use a torque of 30–38 N·m (22–28 lb·ft).

   [b] Torque the support bracket-to-cylinder block bolts to 58 - 73 N·m (43 - 54 lb·ft).

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

8. Install the hose clamps onto the hoses. Install the coolant supply and return lines and connect them to the air compressor.
9. Install the lubricating oil supply line to the air compressor.
10. Install the air lines to and from the compressor.
11. Refer to section 2.6.6 and install the air compressor-driven fuel pump.
12. Refer to section 13.13.4 and fill the cooling system.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

13. Start the engine and check for leaks.

## 10.1.4 Replacement of the Original-type Air Compressor

Detroit Diesel does not service the original-type air compressor. Service of the original-type air compressors should be referred to an authorized service center of the original equipment manufacturer.

To replace the original-type air compressor, perform the following procedure. See Figure 10-7.

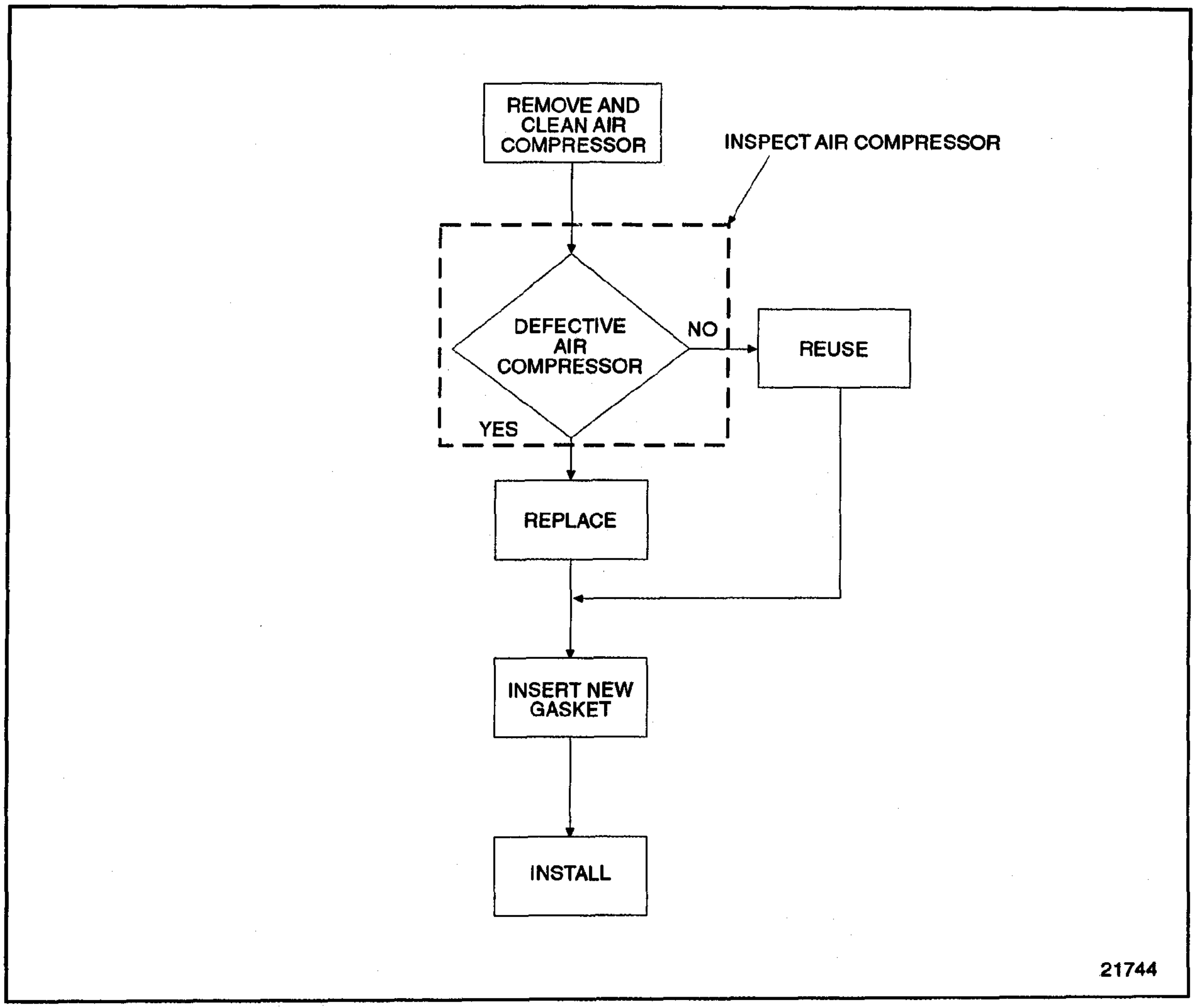



**Figure 10-7 Flowchart for Replacement of the Original-type Air Compressor**

### 10.1.5 Cleaning and Removal of the Original-type Air Compressor

Precleaning is not necessary.

Remove the air compressor as follow:

1. Disconnect the air lines to and from the compressor.
2. Disconnect the fuel pump lines.
3. Remove the fuel pump and drive coupling. Refer to section 2.6.2.
4. Drain the cooling system. Refer to section 13.13.4.
5. Disconnect and drain the coolant supply and return lines at the air compressor.
6. Disconnect the lubricating oil supply line from the compressor.
7. Remove the bolts securing the air compressor support bracket to the cylinder block and air compressor.
8. Remove the support bracket.

**NOTE:**
Due to the cylinder block and compressor configuration, the upper inside air compressor-to-air compressor drive bolt is difficult to reach with standard tools. Compressor Wrench,J 35948, will facilitate removal and installation of this bolt.

9. Remove the five bolts that secure the air compressor to the air compressor drive assembly.
10. Slide the air compressor rearward to disengage the hub from the coupling.

### 10.1.6 Inspection of Former Air Compressor

Refer to OEM guidelines to determine if the air compressor needs to be repaired or replaced.

### 10.1.7 Pressure Relief Installation

Use the following procedure to install the air compressor pressure relief valve:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

1. Disconnect the battery terminals to prevent accidental engine start-up.
2. Carefully relieve air compressor system pressure by slowly opening the air storage tank drain valve or by loosening an air line. Allow all pressure to drain from the system.
3. Remove an unused compressor discharge port plug on the top or side of the compressor head. See Figure 10-8.

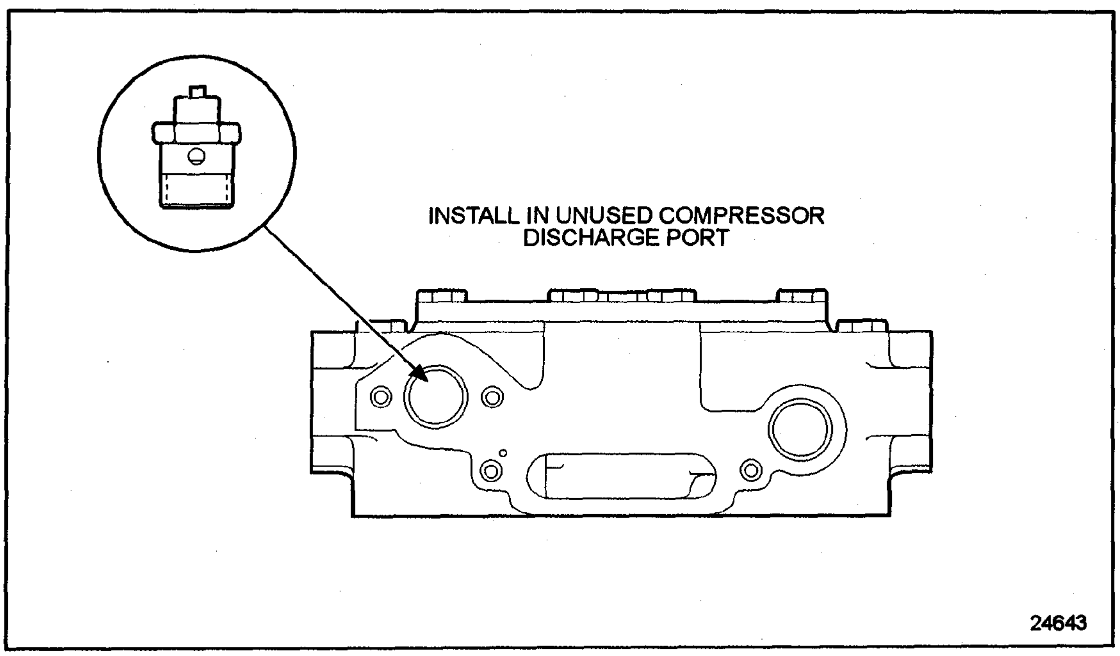



**Figure 10-8 Location of Bendix Air Compressor Pressure Relief Valve**

| NOTICE: |
|---|
| To prevent possible damage to the valve, do not install with a crescent wrench or locking pliers and do not exceed required torque. |

4. Threads on the pressure relief valve are precoated with sealant; so no additional sealant is required. Install the valve into the compressor port and, using a 7/8 in. (No. 14 metric) deep socket, carefully torque the valve to 23-31 N·m (17-23 lb·ft).
5. Close the air tank drain valve or retighten the air supply line, if previously loosened.
6. Refer to section 10.1.3 for the exhaust caution before preceeding. Reconnect the battery terminals, start the engine, and check for leaks.

### 10.1.8 Installation of Former Air Compressor

Install the air compressor as follows:

1. Clean all gasket material from the mating surfaces of the air compressor and air compressor drive.
2. Using a new gasket, install the air compressor to the air compressor drive. Refer to section 10.3.1 for air compressor drive assembly replacement procedure. Mate the internal teeth of the drive hub with the external teeth of the coupling.
3. Align the bolt holes of the two components and install the air compressor-to-air compressor drive bolts. Torque the bolts to 101-126 N·m (75-93 lb·ft). Use compressor wrench J 35948 to tighten the upper-inside bolt.
4. Install the air compressor support bracket to the compressor and cylinder block. Torque the support bracket-to-air compressor bolts to 18-23 N·m (13-17 lb·ft).
5. Torque the support bracket-to-cylinder block bolts to 58-73 N·m (43-54 lb·ft).

**CAUTION:**

**To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).**

6. Install the coolant supply and return lines from the cylinder block and connect to the air compressor using four spring type hose clamps.
7. Install the lubricating oil supply line to the compressor.

**CAUTION:**

**The air inlet manifold contains combustible gas. To avoid injury from explosion, do not connect the air inlet manifold to any devices or lines external to the manifold.**

8. Install the air lines to and from the compressor.
9. If the unit has a compressor-driven fuel pump, install the fuel pump. Refer to section 2.6.6.
10. Refer to section 13.13.4 to fill the cooling system.

## 10.2 AIR COMPRESSOR DRIVE HUB

The air compressor crankshaft will turn while removing or tightening the drive hub retaining nut unless some provision is made to hold it. One method is to weld a modified drive coupling to a support or base which can be anchored to the mounting flange of the compressor.

A Series 71 or 92 flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. When positioned, the exterior splines of the coupling mesh with the internal splines of the drive hub and the assembly is secured to the compressor housing. The shaft is then kept from rotating when the nut is loosened or tightened, by the hub and key.

### 10.2.1 Replacement of Air Compressor Drive Hub

To replace the air compressor drive hub, perform the following procedure. See Figure 10-9.

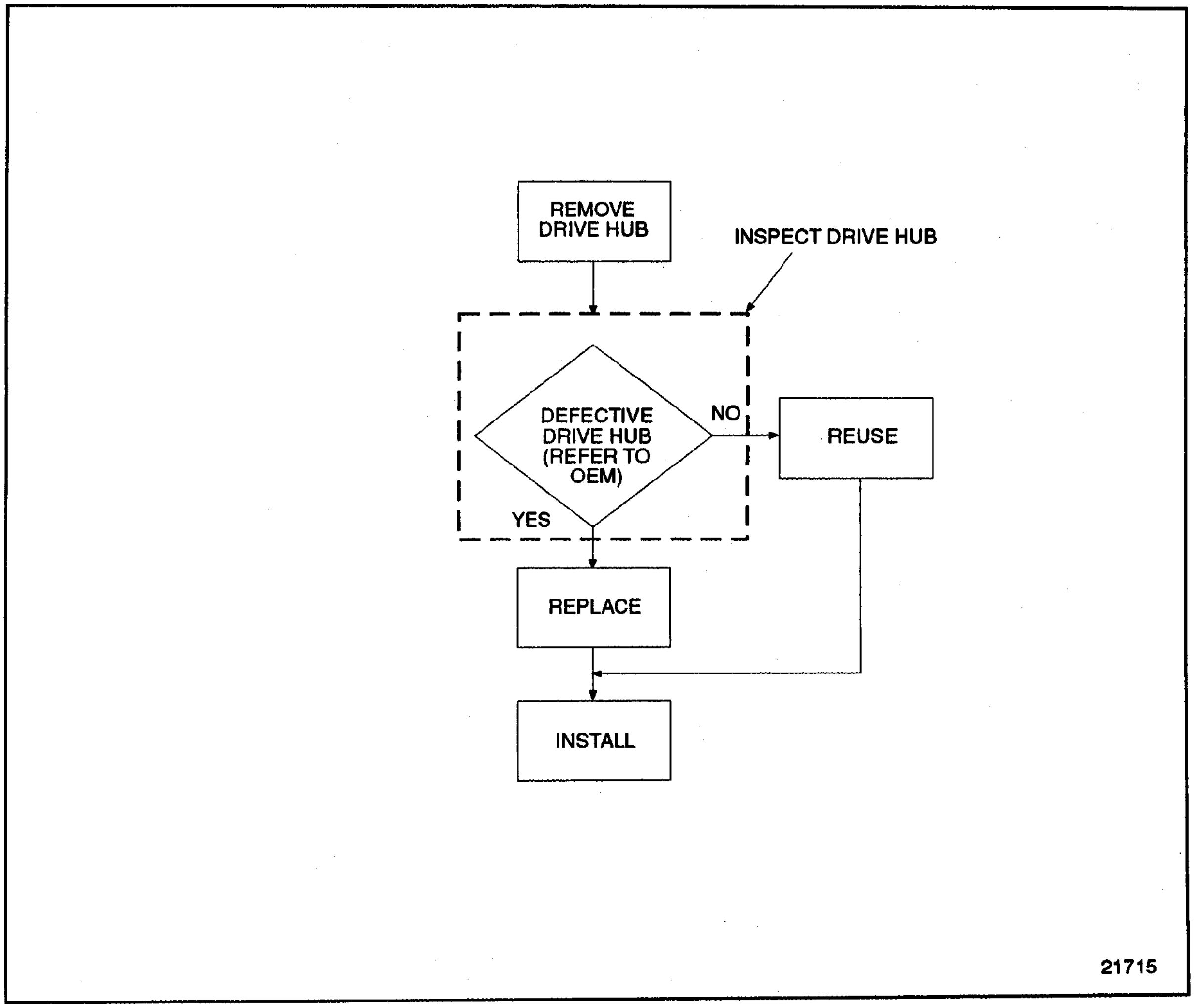



**Figure 10-9 Flowchart for Replacement of Air Compressor Drive Hub**

### 10.2.2 Removal of Air Compressor Drive Hub

To keep the shaft from rotating, perform the following:

To properly position the cover and coupling with the drive hub, four collars, 19 mm O.D. and 12.7 mm I.D., 19 mm long (3/4 in. O.D. and 1/2 in. I.D., 3/4 in. long), and two pieces of bar stock 19 mm x 19 mm x 102 mm (3/4 in. x 3/4 in. x 4 in.) must be fabricated and welded to the flywheel housing cover at the positions shown in the next illustration. See Figure 10-10.

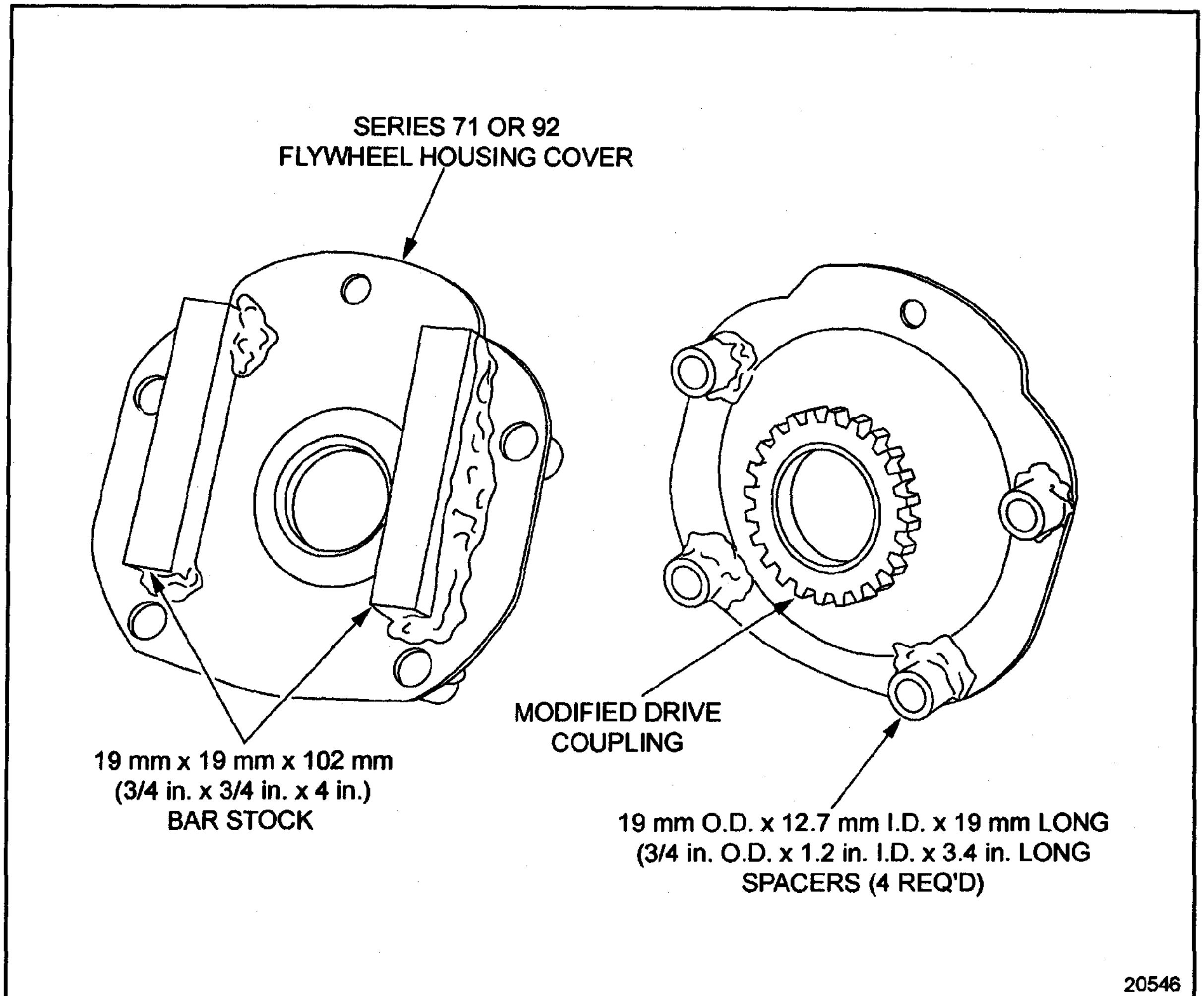



**Figure 10-10 Holding Fixture**

Position the coupling into the drive hub. Lay the flywheel housing cover over the coupling, center the collars over the compressor housing bolt holes, and tack weld the cover to the coupling.

The diameter of the cover hole must be opened up to the same diameter as the coupling inside diameter to permit access to the drive hub retaining nut. Two bolts will secure the base to the compressor during the operation.

Remove the air compressor drive hub as follows:

1. Install the holding fixture to the flange of the air compressor, engaging the coupling with the internal teeth of the drive hub. Install two bolts to secure the fixture to the compressor. See Figure 10-11.

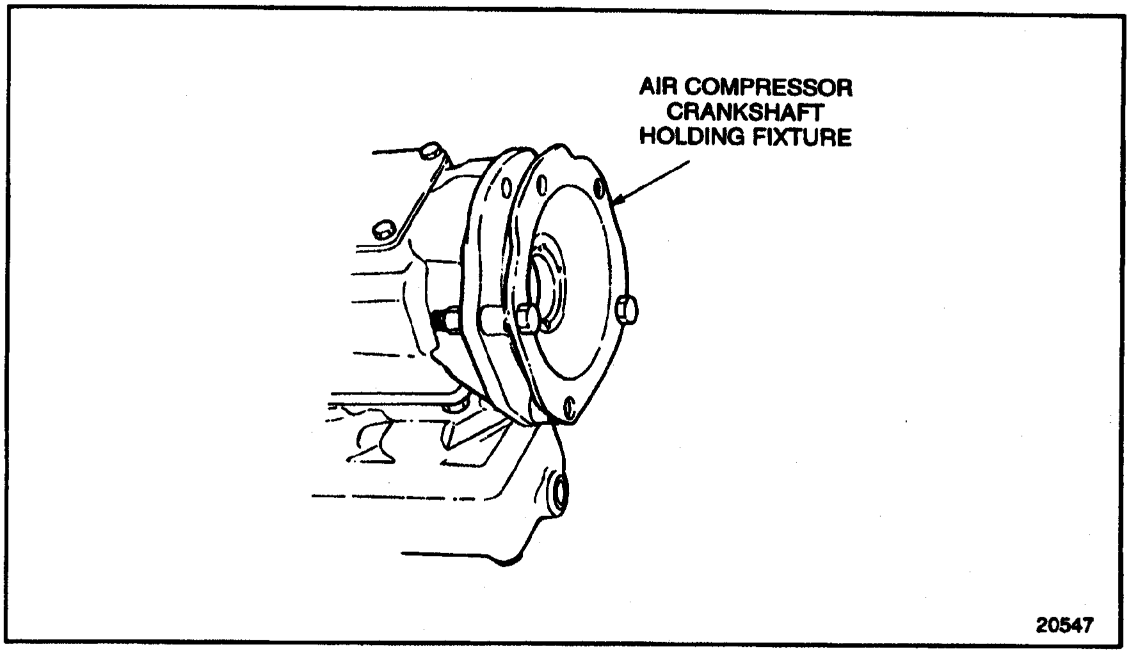



**Figure 10-11 Air Compressor Crankshaft Holding Fixture Installation**

2. Loosen and remove the drive hub retaining nut.
3. Remove the drive hub from the air compressor by lifting the hub off the shaft.

### 10.2.3 Inspection of Air Compressor Drive Hub

Refer to OEM guidelines to determine if the air compressor drive hub needs to be repaired or replaced.

### 10.2.4 Installation of Air Compressor Drive Hub

Install the air compressor drive hub as follows:

| NOTICE: |
|---|
| The drive hub and nut on the Series 60 engine have a unique configuration. Only the correct part numbers should be used. |

1. Install the hub to the shaft as far as it will go by hand. Do not cock or jam the hub. See Figure 10-12.

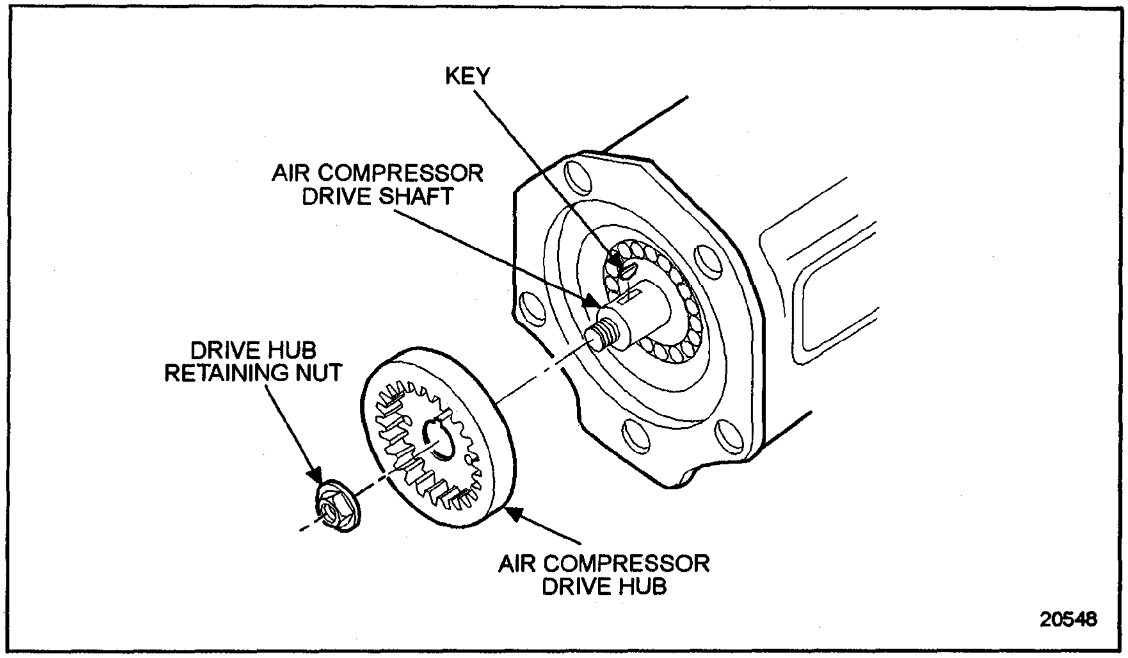



**Figure 10-12 Air Compressor Drive Hub Assembly**

2. Install the drive holding fixture to the flange of the air compressor, engaging the coupling with the internal teeth of the drive hub. Install two bolts to secure the fixture to the compressor. See Figure 10-11.

3. Torque the air compressor drive hub retaining nut to 300-345 N·m (220-255 lb·ft). See Figure 10-13.

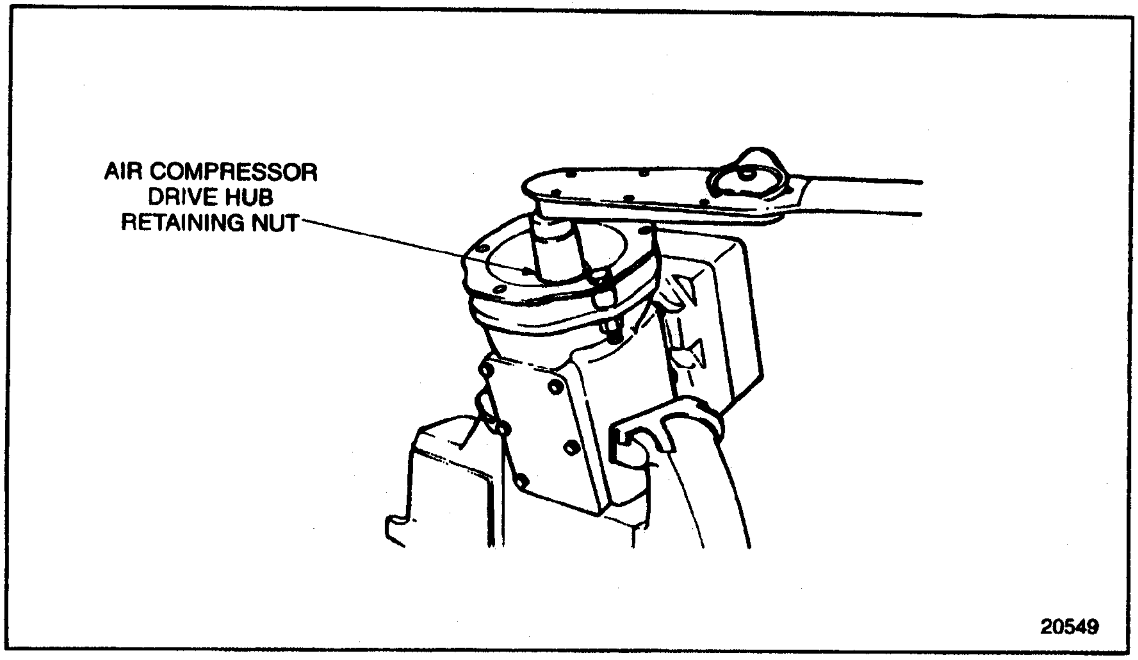
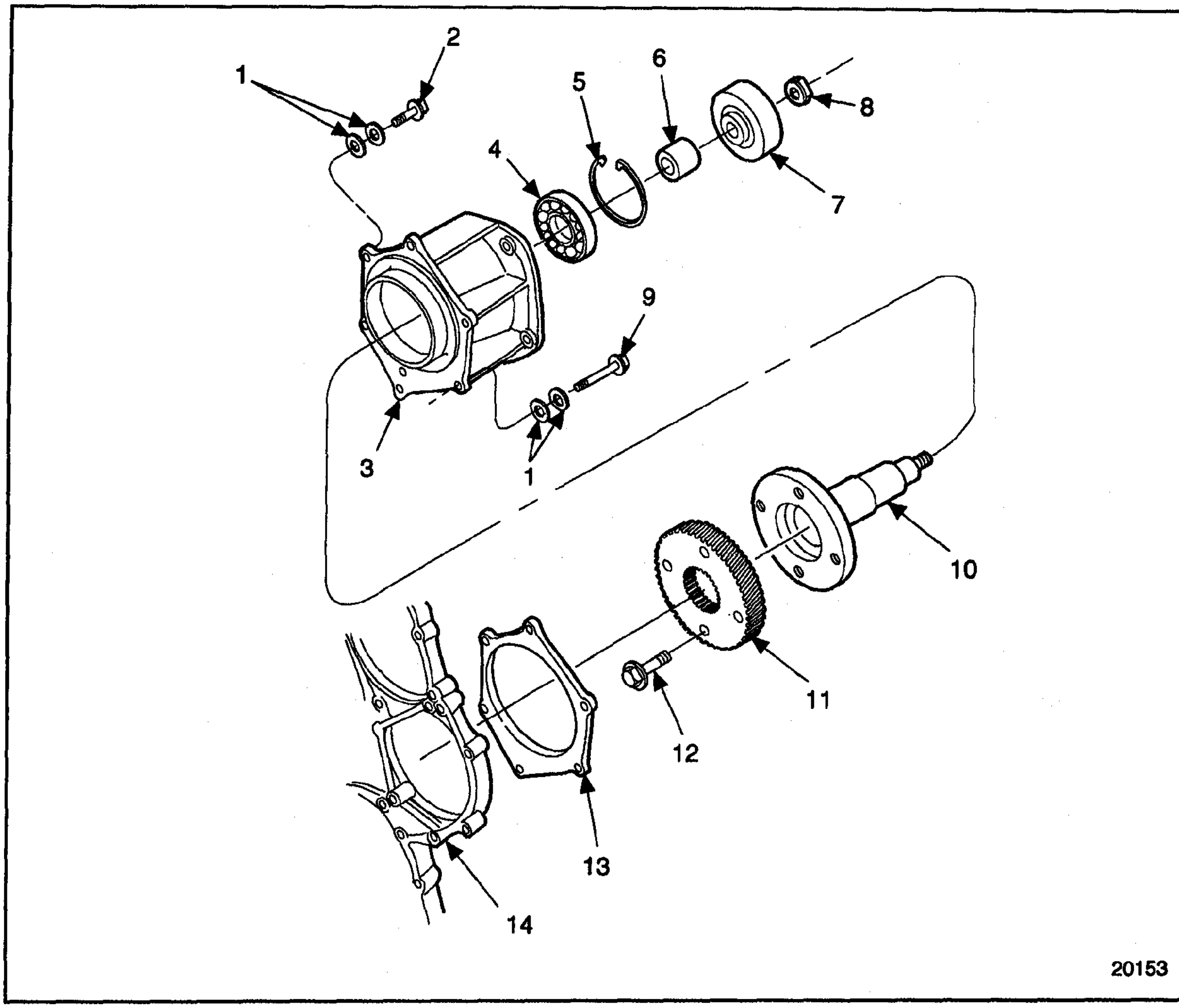



**Figure 10-13 Torquing Drive Hub Retaining Nut**

4. Loosen the two bolts that retain the holding fixture to the compressor flange, and remove the holding fixture.

# 10.3 AIR COMPRESSOR/RAW WATER PUMP DRIVE ASSEMBLY

The air compressor/marine engine raw water pump drive assembly mounts to the rear of the gear case on the intake side of the engine. See Figure 10-14.




| | |
|---|---|
| 1. Plain Washers (Shims) | 8. Flange Nut, Drive Hub |
| 2. Short Bolt (1) | 9. Long Bolt, Drive Housing |
| 3. Housing, Drive | 10. Shaft, Drive |
| 4. Ball Bearing, Air Compressor Drive | 11. Gear, Drive |
| 5. Snap Ring | 12. Bolt, Drive Gear |
| 6. Spacer | 13. Gasket |
| 7. Hub, Drive | 14. Gear Case |

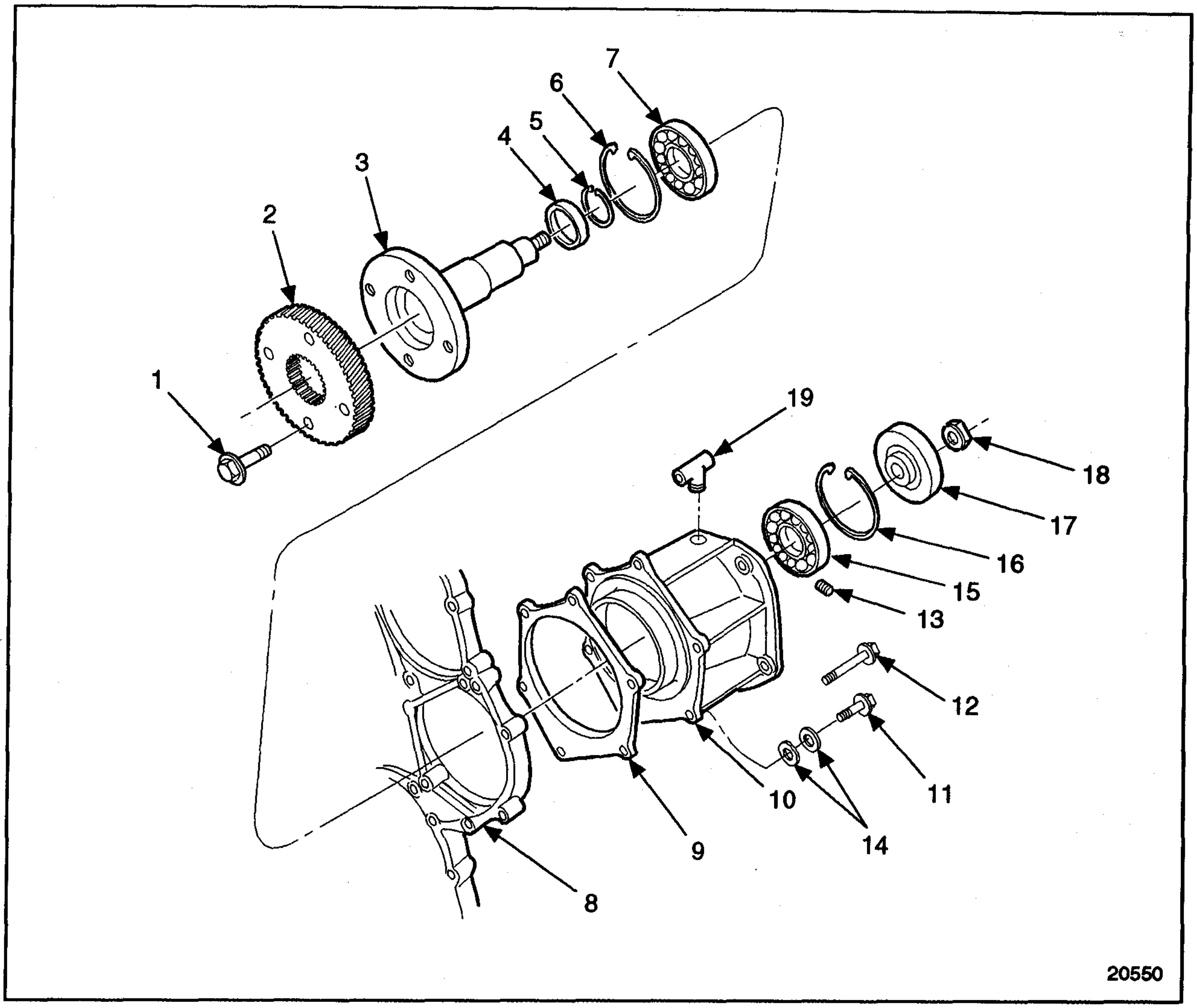
**Figure 10-14 Air Compressor/Raw Water Pump Drive Detail and Location of Parts**

A drive gear meshes with the bull gear and is driven at a ratio of 1.19:1.

The drive gear is bolted to the air compressor /raw water pump drive shaft. A drive hub is installed onto the opposite end of the air compressor drive shaft, and is used to drive the air compressor or raw water pump. On vehicles with power steering, a short splined coupling connects the drive gear to the power steering pump. The coupling is inserted in the splined center of the air compressor drive gear.

Two composition gaskets are used, one to seal the air compressor drive housing to the gear case, and one to seal the air compressor or raw water pump to the drive housing.

Two air compressor drives have been used on Series 60 engines. The current drive assembly, see Figure 10-14, differs from the former, see Figure 10-15, in that it does not have an external oil supply, and only one bearing assembly is used to support the drive shaft.




1. Bolt, Air Compressor Drive Gear
2. Gear, Air Compressor Drive
3. Shaft, Air Compressor Drive
4. Inner Race Bearing
5. Small Snap Ring
6. Large Snap Ring
7. Front Roller Bearing
8. Gear Case
9. Gasket
10. Housing, Air Compressor Drive
11. Short Bolt (1)
12. Long Bolt, Air Compressor Drive Housing
13. Plug, Air Compressor Housing
14. Plain Washers (Shims)
15. Rear Roller Bearing
16. Large Snap Ring
17. Hub, Air Compressor Drive
18. Flange Nut, Air Compressor Drive Hub
19. "T" Fitting

**Figure 10-15 Former Air Compressor Drive Detail and Location of Parts**

Disassembly and assembly of the two drives are similar. Differences in the disassembly and assembly procedures are detailed in this section.

### 10.3.1 Replacement of Air Compressor/Raw Water Pump Drive Assembly

To replace the air compressor/raw water pump drive assembly, perform the following procedure. See Figure 10-16.

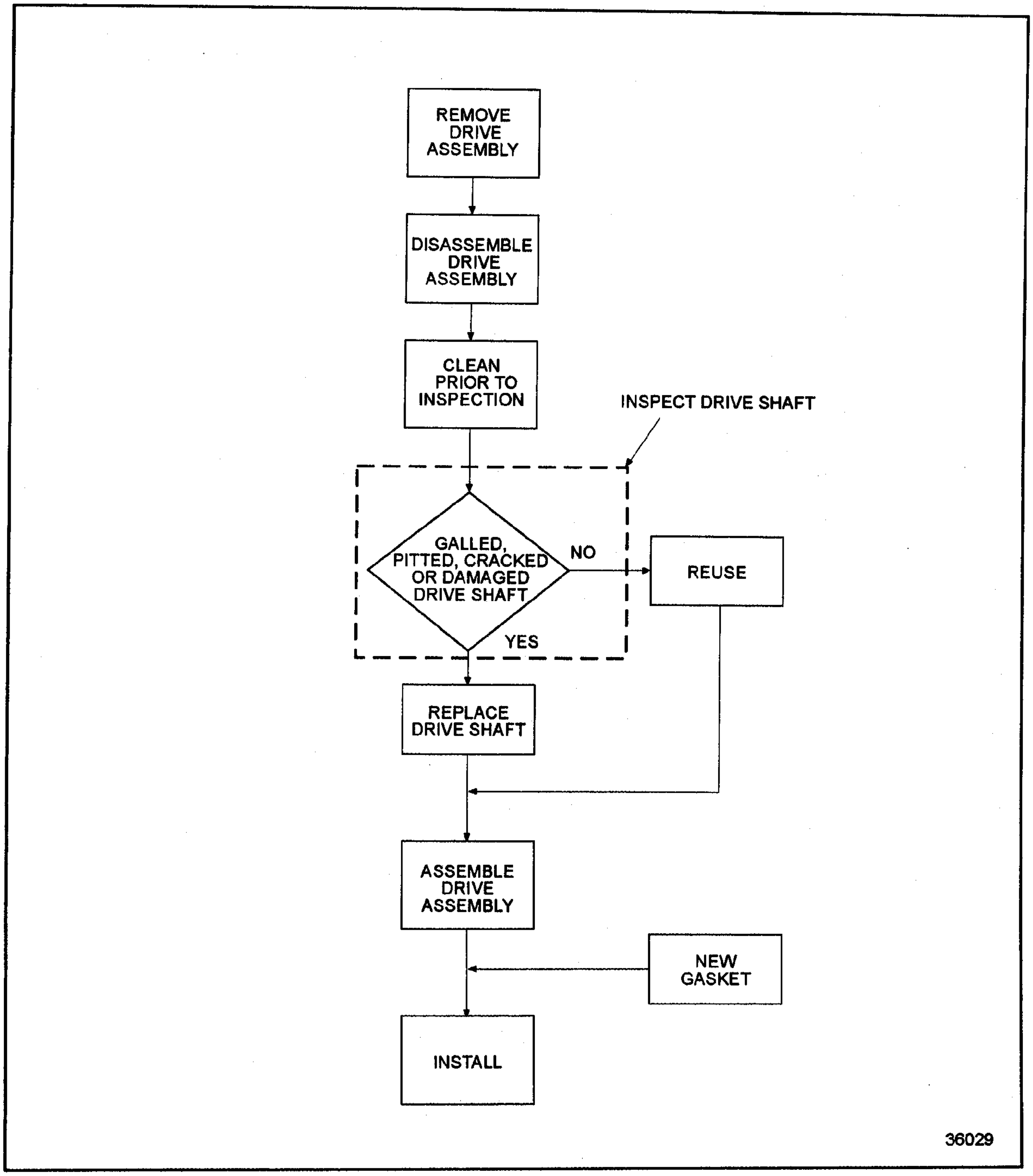



**Figure 10-16 Flowchart for Replacement of Air Compressor/Raw Water Pump Drive Assembly**

### 10.3.2 Removal of Air Compressor/Raw Water Pump Drive Assembly

Remove the drive assembly as follows:

1. If equipped, remove the air compressor or raw water pump. Refer to section 10.1.5 and refer to section 4.4.
2. If equipped with power steering, loosen and remove the five bolts securing the power steering pump and cover assembly to the gear case cover.
3. Remove the pump and cover assembly.
4. Remove the power steering drive coupling from the air compressor /raw water pump drive gear.
5. Disconnect the oil supply lines from the "T" fitting, if applicable, at the top of the air compressor /raw water pump drive housing. See Figure 10-15.
6. Remove the six bolts that secure the drive assembly to the gear case.
7. Remove the assembly by pulling it straight out of the gear case.

### 10.3.3 Disassembly of Air Compressor/Raw Water Pump Drive Assembly

Disassemble the drive assembly as follows:

1. Secure the holding fixture, see Figure 10-10, in a suitable vise with the drive coupling facing up. See Figure 10-17.

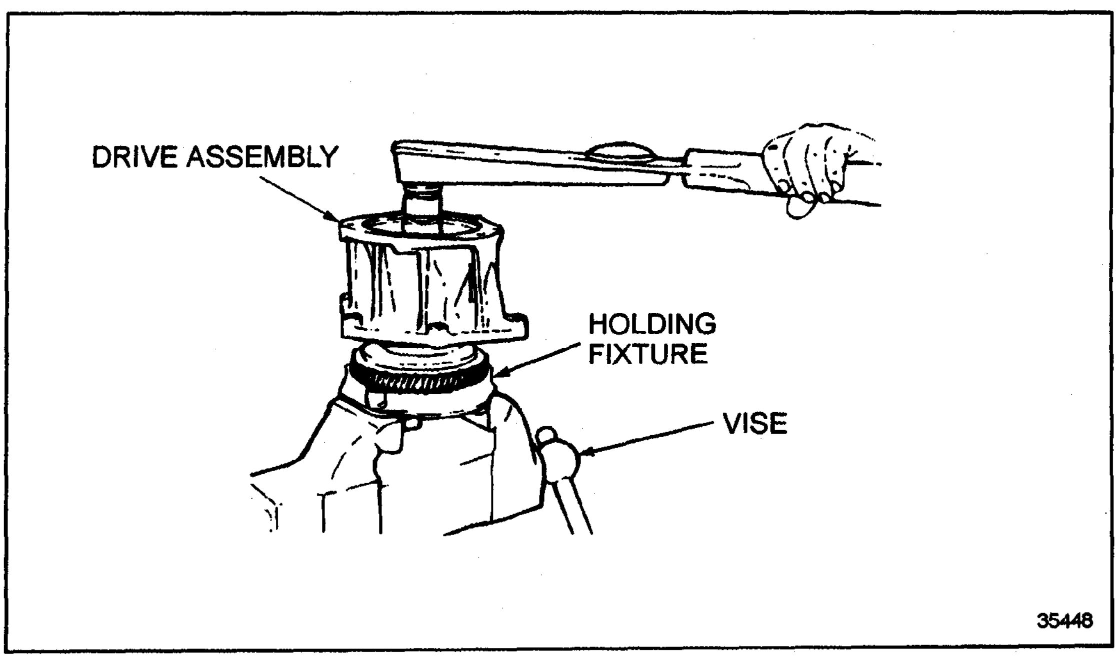



**Figure 10-17 Air Compressor/Raw Water Pump Drive Hub Disassembly**

2. Position the drive assembly onto the holding fixture, engaging the internal teeth of the drive gear with the coupling on the holding fixture.
3. Loosen and remove the flanged nut retaining the drive hub to the drive shaft.
4. Remove the drive hub from the drive assembly.
5. Remove the spacer from the drive shaft (current air compressor/raw water pump drive only).
6. Remove the drive assembly from the holding fixture and place on bench.
7. Remove the four bolts that secure the drive gear to the drive shaft flange and remove gear.
8. Use the air compressor and fan drive service tool set, J 36310-A, for disassembly. See Figure 10-18.

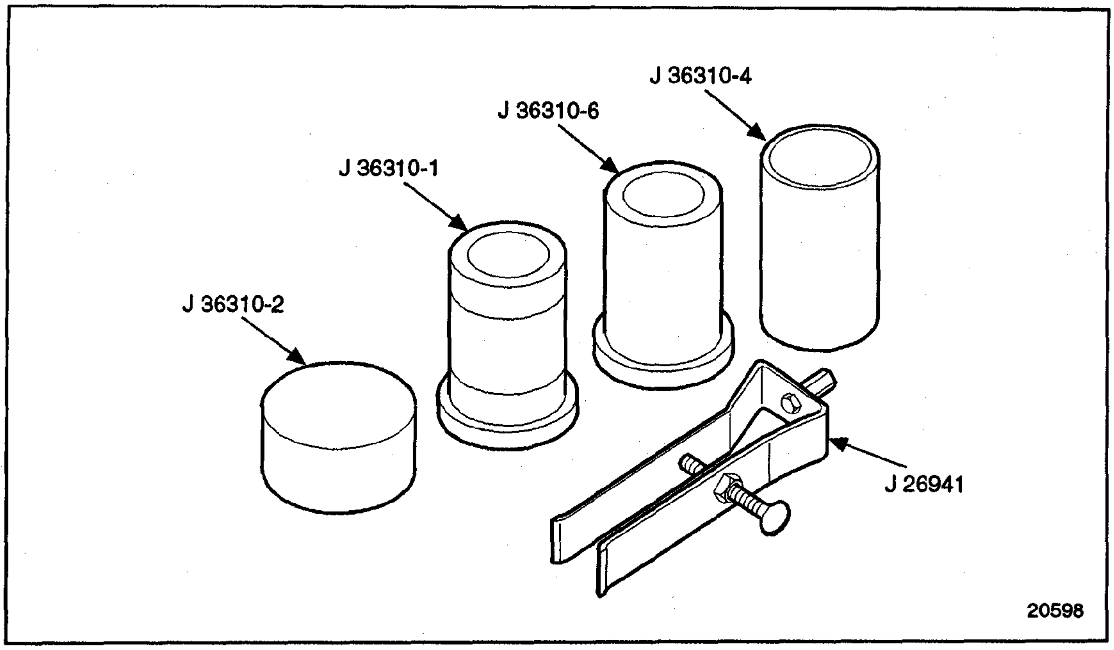



**Figure 10-18 Air Compressor and Fan Drive Service Tool Set**

9. Support the air compressor/raw water pump drive housing on press plates with the drive hub side facing up.
10. Press the drive shaft out of the drive housing.

**NOTE:**
Whenever the drive shaft is removed from the housing, the ball bearing assembly must be replaced.

11. Remove the large snap ring retaining the ball bearing in the drive hub housing using snap ring pliers. See Figure 10-19.

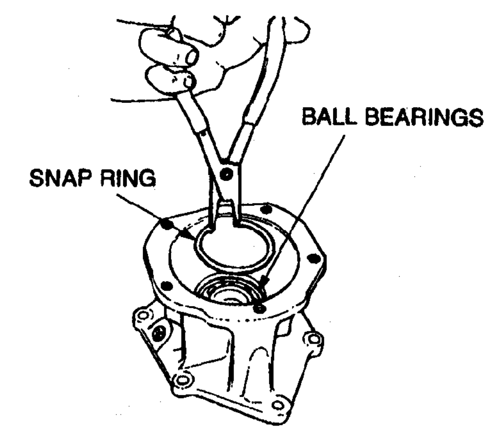



**Figure 10-19 Roller Bearing Snap Ring Removal**

12. On current design drive only, turn the drive housing over and support it on the press bed.
13. Using the narrow end of J 36310-6 part of J 36310–A, against the bearing, press the bearing from the housing.
14. Discard the bearing.

**NOTE:**
The next seven steps apply only to the former design air compressor drive.

15. Using the snap ring pliers, turn the drive assembly over, and remove the large snap ring retaining the roller bearing in the air compressor drive housing. See Figure 10-20.

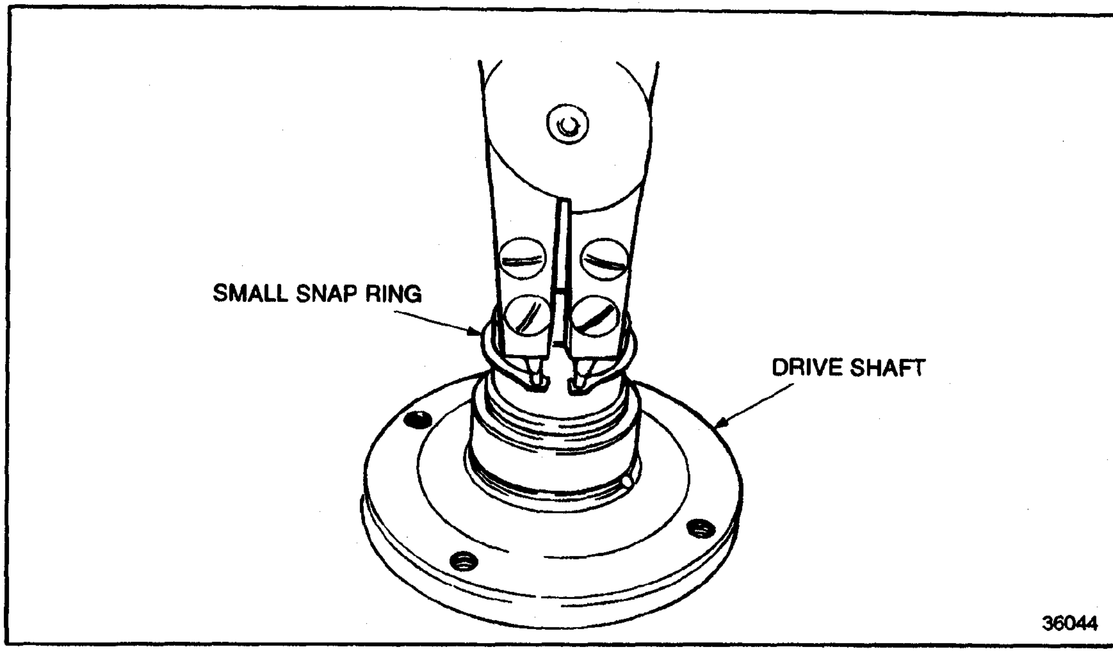



**Figure 10-20 Ball Bearing Snap Ring Removal**

**NOTE:**
Whenever the bearings are removed from the housing, the bearing assemblies must be replaced.

16. Install J 26941, under the bearing. See Figure 10-21.

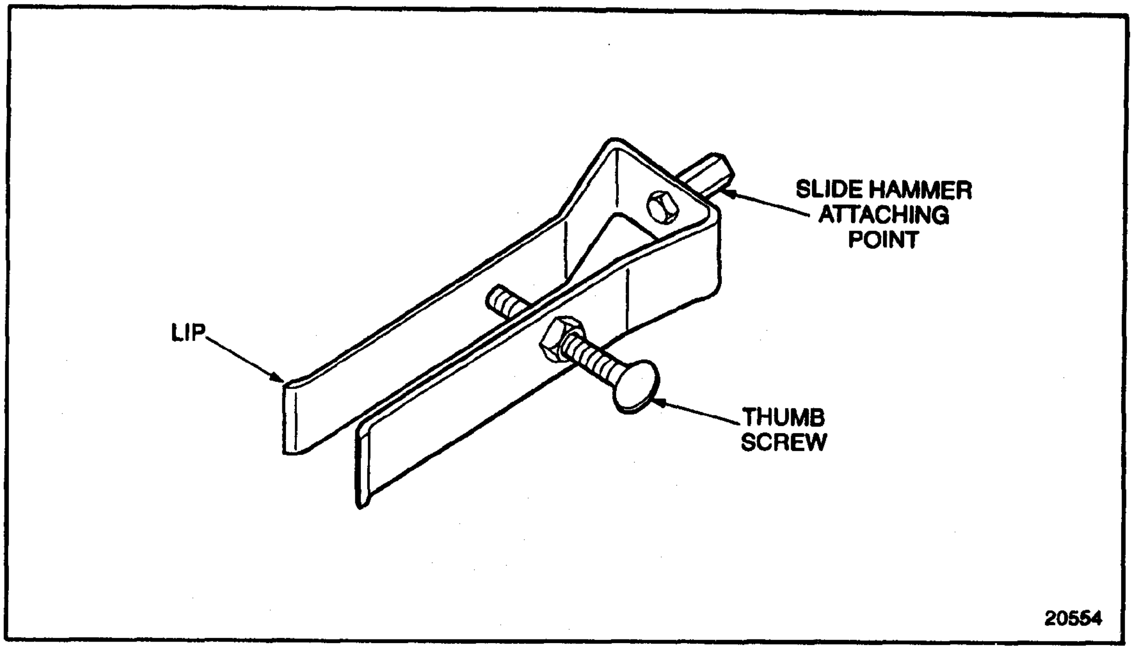



**Figure 10-21 Bearing Remover**

17. Tighten the thumb screw on the bearing remover until it is snug against the bearing.
18. Install a suitable slide hammer to the top of the bearing remover. Remove the bearing.
19. Repeat this procedure to remove the other bearing from the housing.

20. Using snap ring pliers, remove the small snap ring retaining the roller bearing inner race on the air compressor drive shaft. See Figure 10-22.

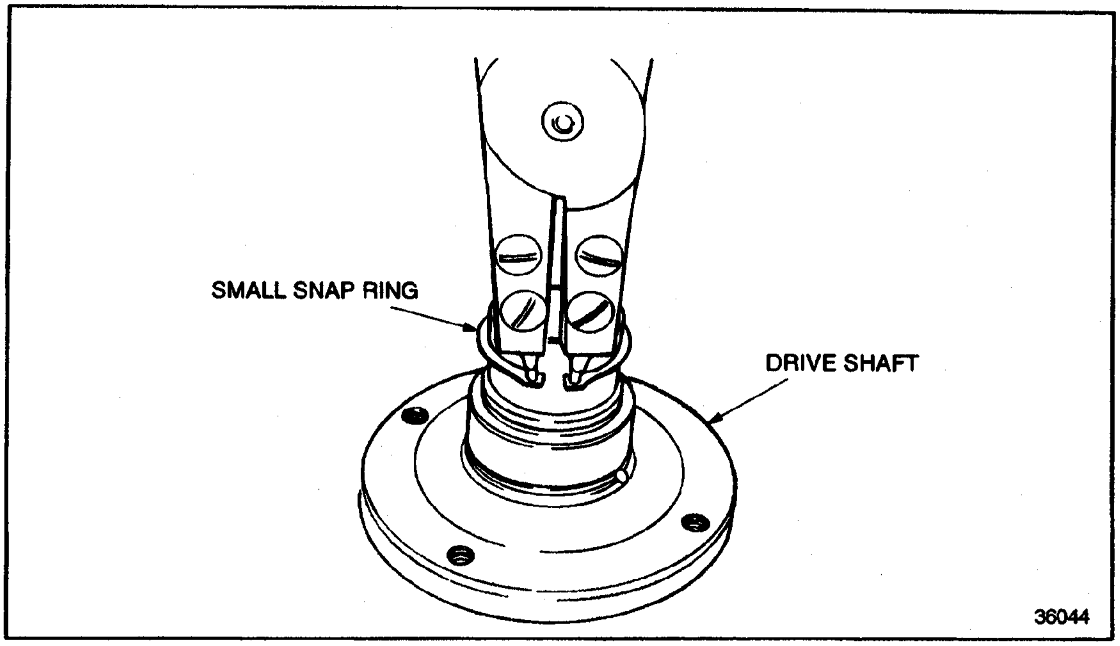



**Figure 10-22 Roller Bearing Inner Race Snap Ring Removal**

21. Using a punch and hammer, work through the two access holes to drive the roller bearing inner race from the air compressor drive shaft. See Figure 10-23.

**NOTE:**
Whenever the roller bearing inner race is removed from the shaft, the roller bearing assembly must be replaced.

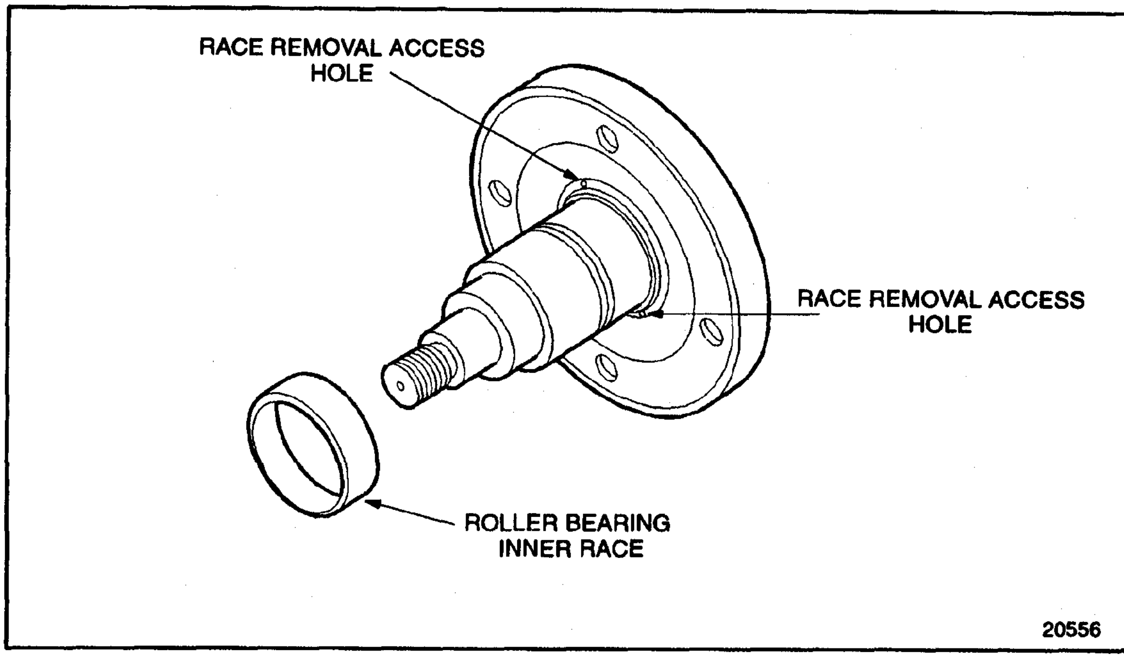



**Figure 10-23 Bearing Inner Race Removal**

### 10.3.4 Cleaning of Air Compressor/Raw Water Pump Drive Assembly

Clean the air compressor/raw water pump drive assembly prior to inspection as follows:

1. Clean all of the parts with clean fuel oil.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry with compressed air.

#### 10.3.4.1 Inspection of the Air Compressor Drive Assembly

Inspect the air compressor drive assembly as follows:

1. Visually inspect the drive shaft for galling, pitting, cracks, or other damage.
   [a] If drive shaft has galling, pitting, cracks, or other damage, replace with new part.
   [b] If drive shaft has no damage, reuse part.

### 10.3.5 Assembly of Air Compressor/Raw Water Pump Drive Assembly

Assemble the air compressor/raw water pump drive assembly as follows:

**NOTE:**
The first four steps apply to the former air compressor drive assembly only. If rebuilding a current design air compressor/raw water pump drive assembly, begin with step 5.

1. Install the roller bearing inner race to the air compressor drive shaft using a press and J 36310-4, part of J 36310–A. See Figure 10-24.

**NOTE:**
The identification numbers on the race must face the installer. Be sure the race is firmly seated against the shoulder on the drive shaft.

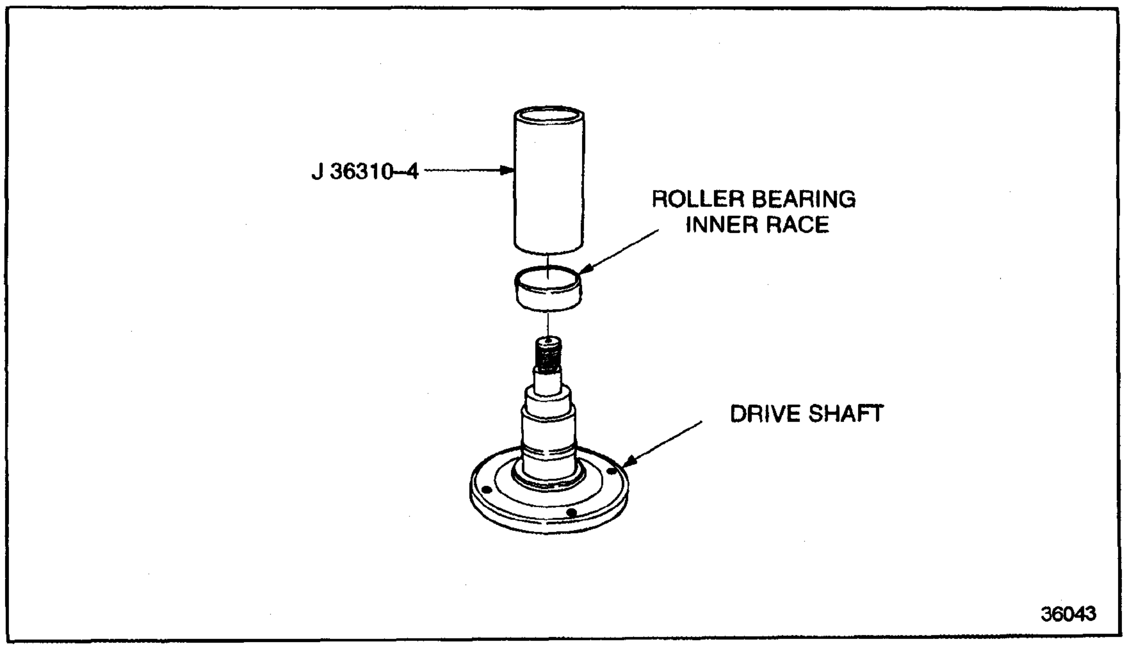



**Figure 10-24 Bearing Inner Race Installer**

2. Install the small snap ring to the drive shaft using snap ring pliers.

**NOTE:**
Ensure the snap ring is fully seated in its groove on the drive shaft. See Figure 10-25.

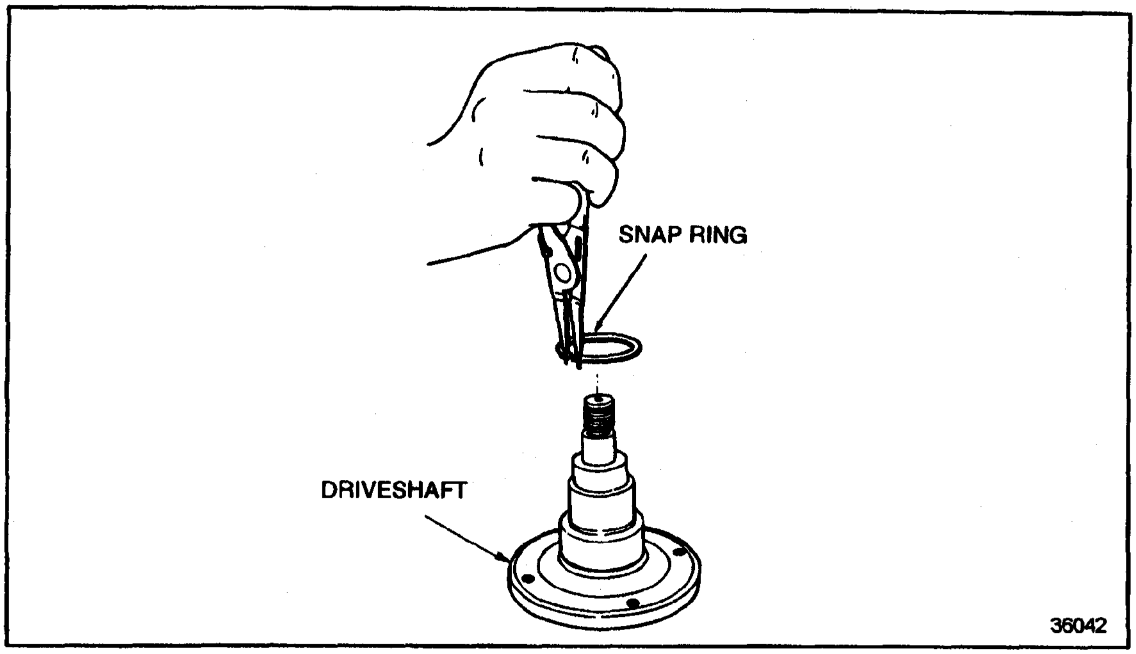



**Figure 10-25 Bearing Inner Race Snap Ring Installation**

3. Install the roller bearing in the air compressor drive housing using J 36310-2, part of J 36310–A . Ensure that the bearing is fully seated in the housing far enough for the snap ring to be installed. See Figure 10-26.

**NOTE:**
The bearing identification numbers must face the installer.

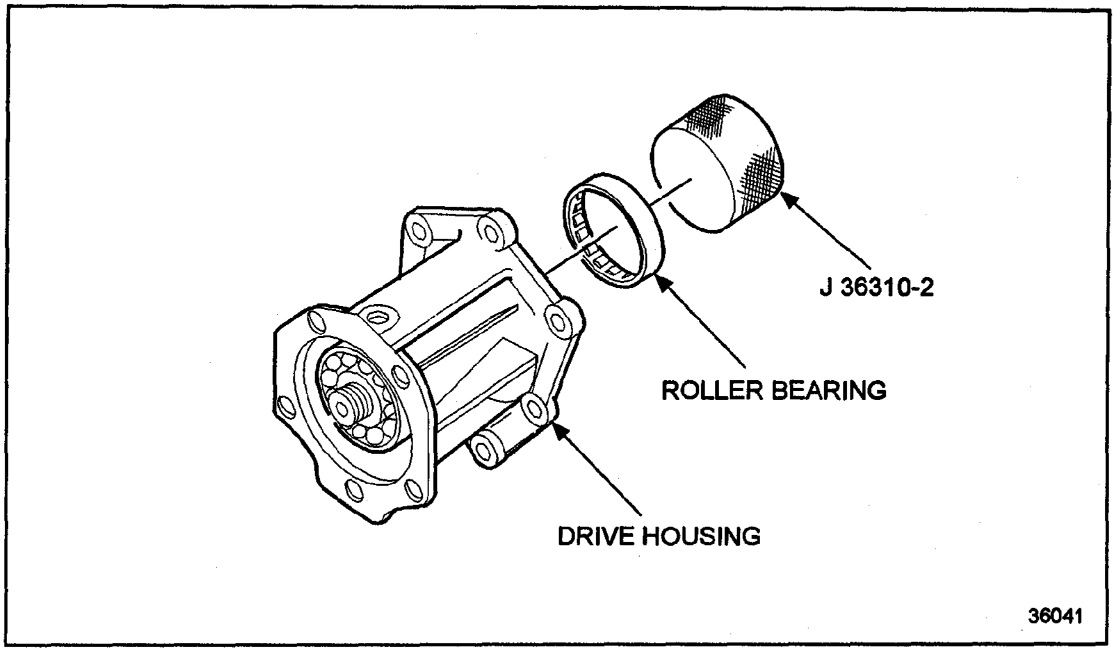



**Figure 10-26 Roller Bearing Installation**

4. Install the snap ring retaining the roller bearing in the drive housing using snap ring pliers. See Figure 10-27.

**NOTE:**
Ensure the snap ring is fully seated in its groove in the housing.

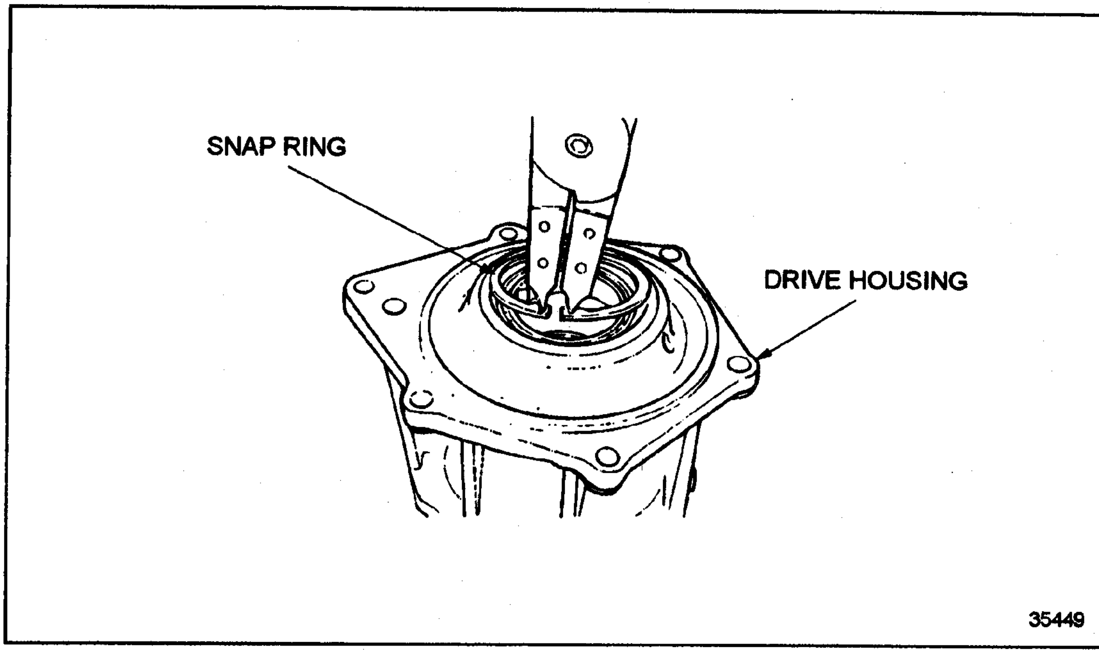



**Figure 10-27 Snap Ring Installation**

**NOTE:**
The first four steps apply to the former air compressor drive assembly only. If rebuilding a current design air compressor/raw water pump drive assembly, begin with the following step.

5. Turn the housing over.
6. Install the ball bearing in the drive housing using a press and the large end of the ball bearing installer, pressing only on the outer race of the bearing. See Figure 10-28.

**NOTE:**
There is a plastic sleeve in the current design ball bearing which must not be removed when installing the bearing. The sleeve will be pushed out when the drive shaft is installed.

7. Be sure the bearing is fully seated against the shoulder in the housing for the snap ring to be installed. See Figure 10-28.

**NOTE:**
The bearing identification numbers must face the installer when installing the bearing.

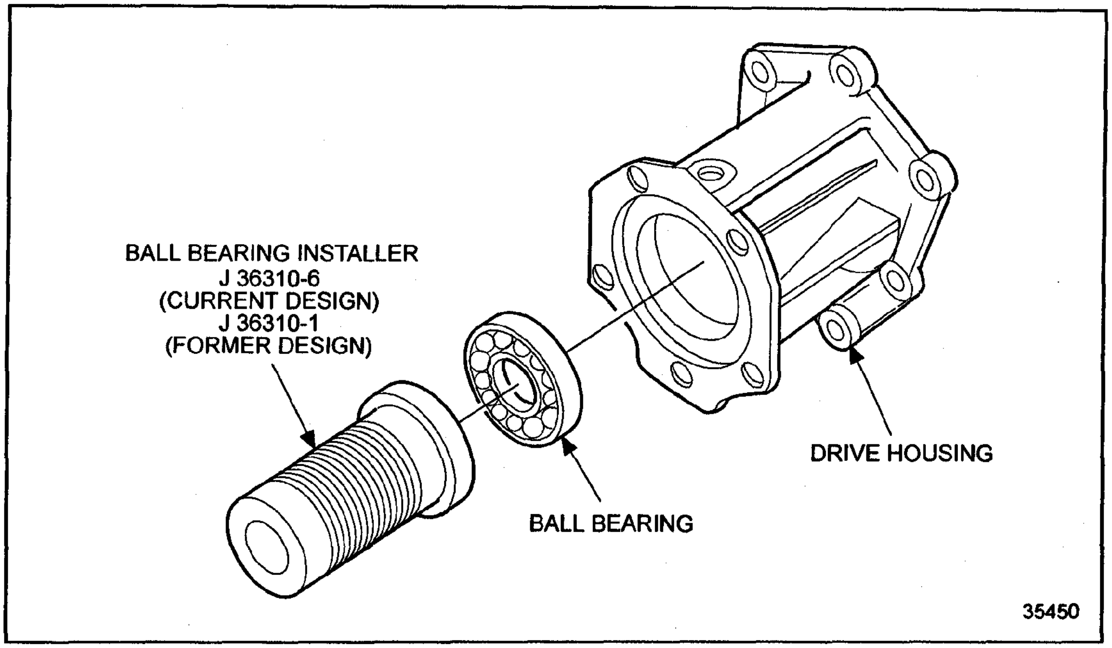



**Figure 10-28 Ball Bearing Installation**

8. Install the snap ring retaining the ball bearing in the housing using snap ring pliers. See Figure 10-29.

**NOTE:**
Ensure the snap ring is fully seated in its groove in the housing.

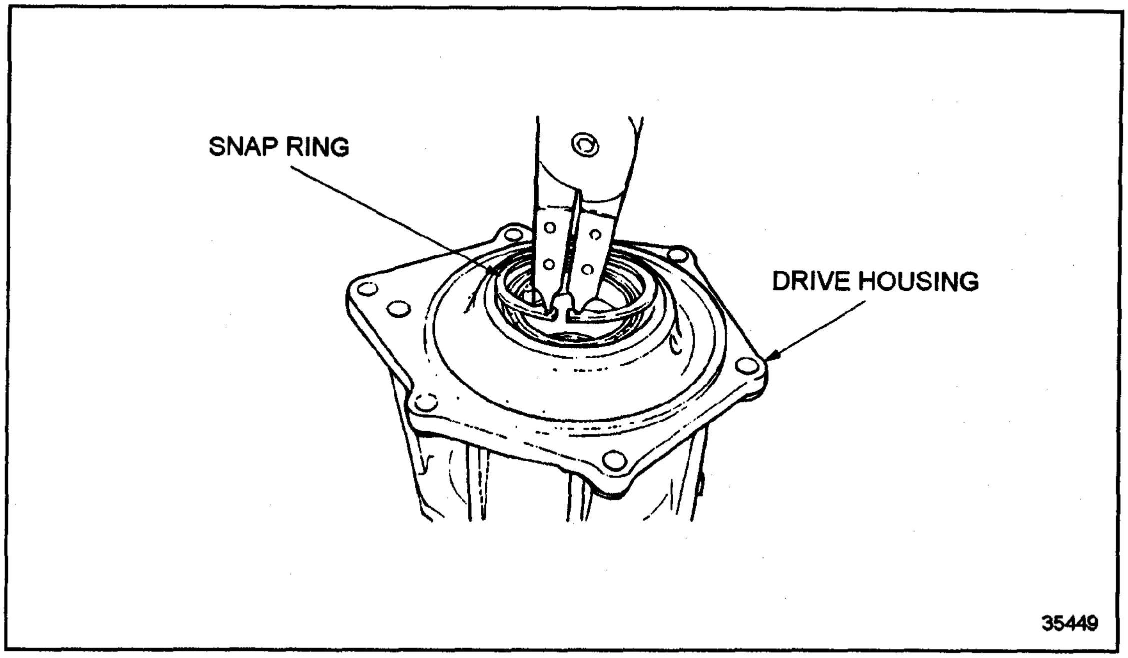



**Figure 10-29 Snap Ring Installation**

9. Lubricate the roller bearing inner race with clean engine oil. See Figure 10-30.

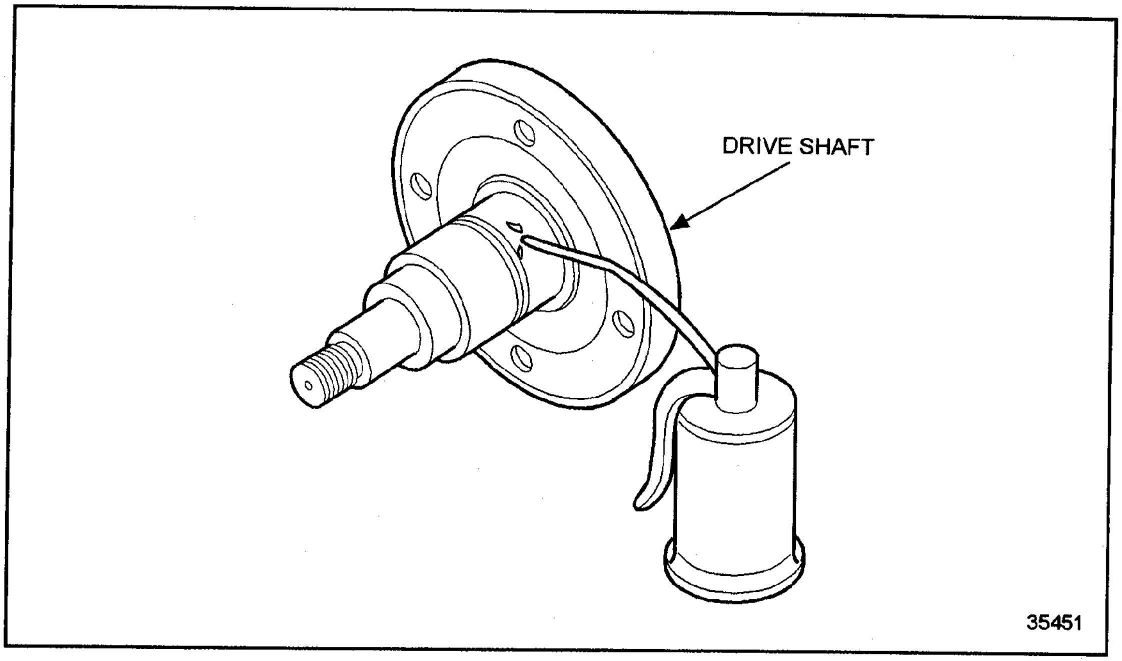



**Figure 10-30 Bearing Inner Race Lubrication**

10. Place the drive shaft, flange side down, on a press bed.
11. Carefully position the drive housing over the shaft, and lower the housing down as far as it will go without forcing it.

12. Place the small end of the ball bearing installer, J 36310-1 part of J 36310–A, against the ball bearing inner race. Press the ball bearing and housing down onto the drive shaft until the ball bearing inner race is firmly seated against the shoulder of the drive shaft. See Figure 10-31.

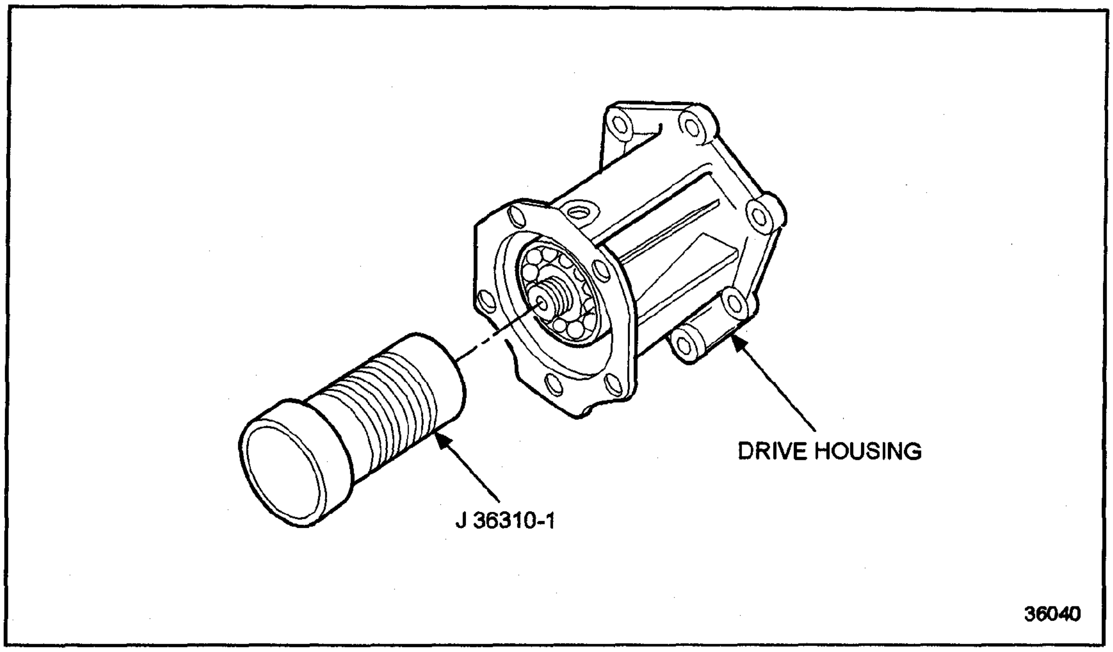



**Figure 10-31 Air Compressor Drive Shaft Installation (Former Design)**

**NOTE:**
The previous four steps apply to the former design air compressor drive only. If assembling a current design air compressor/raw water pump drive, go to the next step.

13. Place wide end of ball bearing installer, J 36310-6, part of J 36310–A, on press bed. See Figure 10-32.

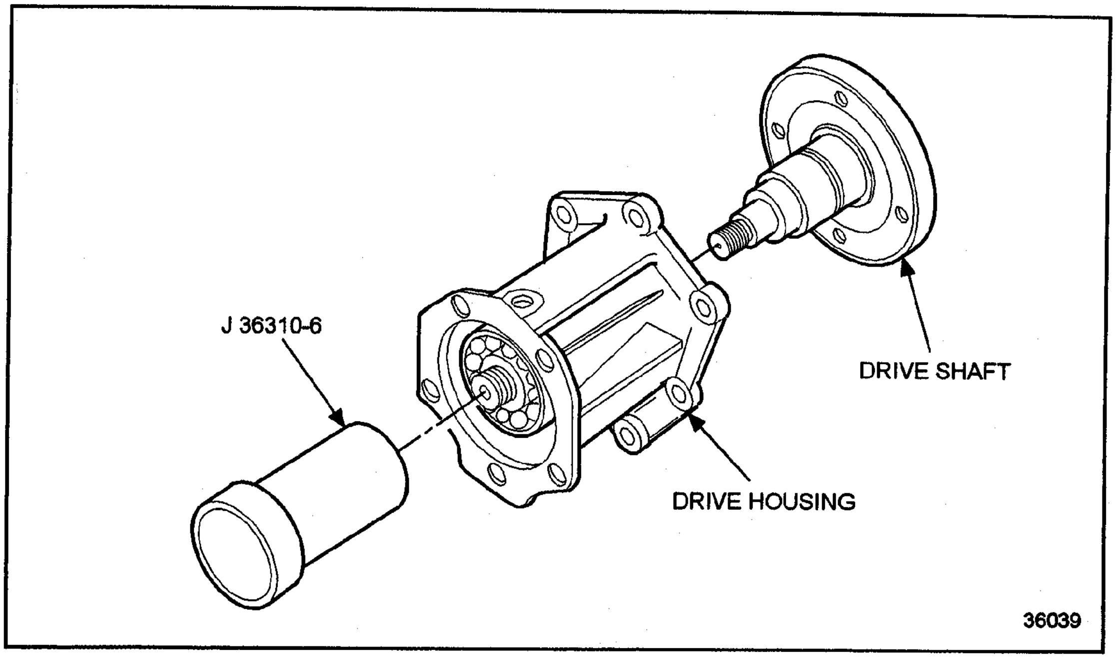



**Figure 10-32 Air Compressor/Raw Water Pump Drive Shaft Installation (Current Design)**

14. Place the drive housing on the bearing installer, ensuring that the installer is centered on the bearing inner race.
15. Position the drive shaft in the bearing inner race.
16. Press the drive shaft into the bearing and housing assembly until the shaft shoulder is seated against the bearing inner race.
17. Remove the drive assembly from the tool, and remove the plastic sleeve from inside the tool.
18. Discard the plastic sleeve.

19. Install the drive gear to the shaft. See Figure 10-33.

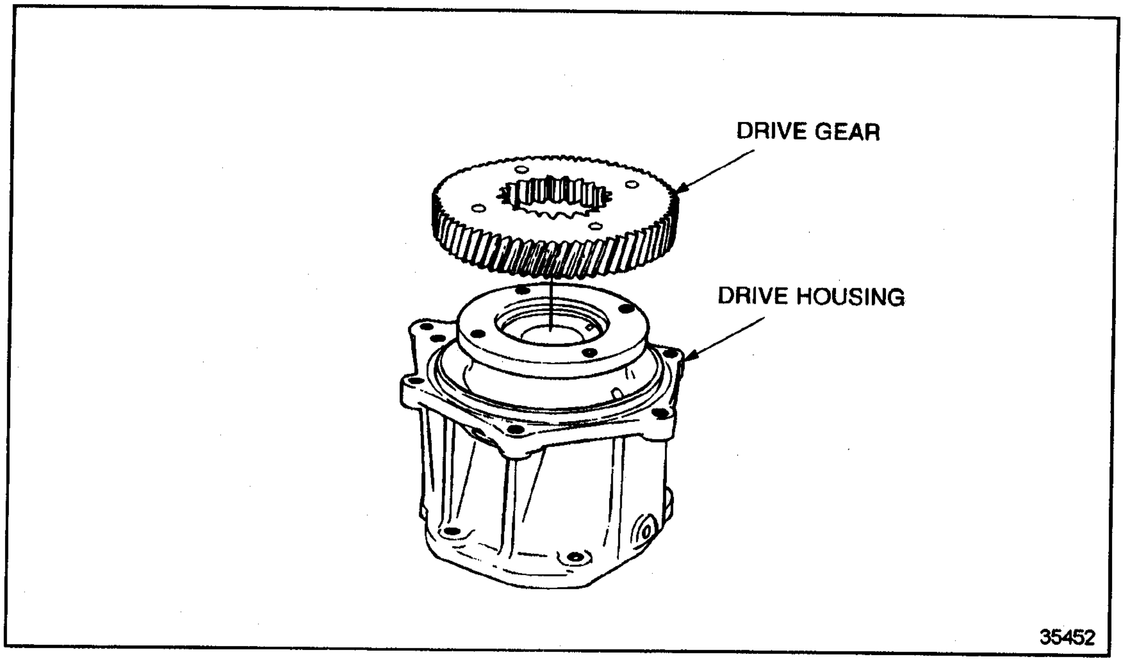



**Figure 10-33 Air Compressor Drive Shaft Installation (Former Design)**

20. Install the four drive gear-to-drive shaft bolts and torque to 58-73 N·m (43-54 lb·ft).

21. Secure the holding fixture, see Figure 10-10, in a suitable vise with the drive coupling positioned up. See Figure 10-34.

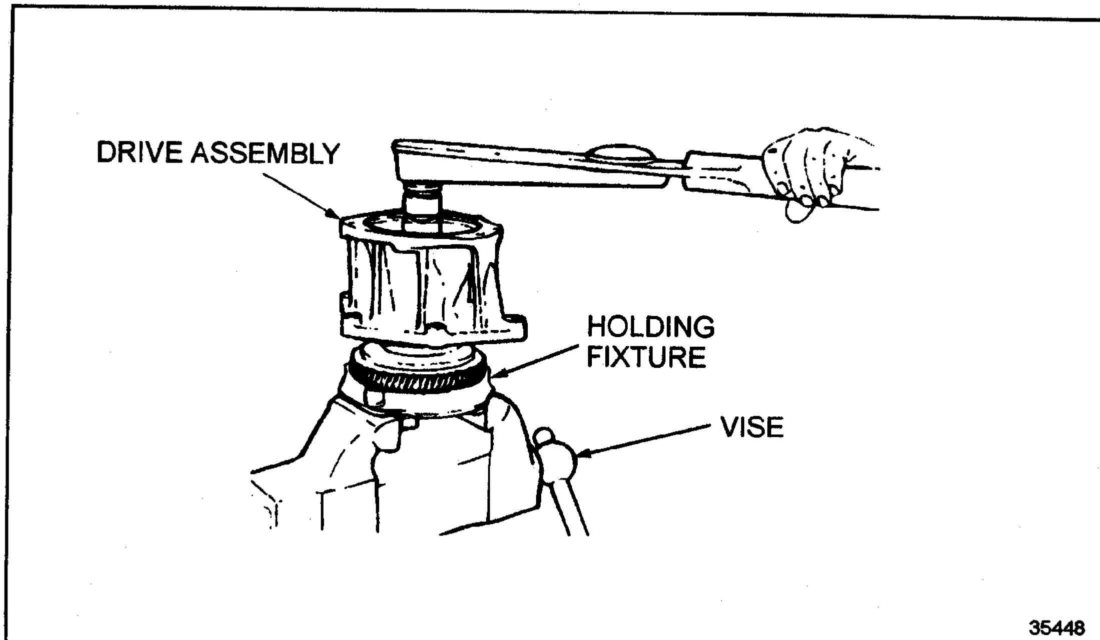



**Figure 10-34 Air Compressor Drive Shaft Installation (Former Design)**

22. Position the drive assembly on the holding fixture, engaging the internal teeth of the drive gear with the coupling on the fixture.
23. Lubricate the ball bearing with clean engine oil.
24. Place the spacer on the drive shaft (current design only), seating it against bearing inner race. Install the drive hub on the drive shaft. See Figure 10-35.

25. Torque flanged nut to 298-346 N·m (220-255 lb·ft).

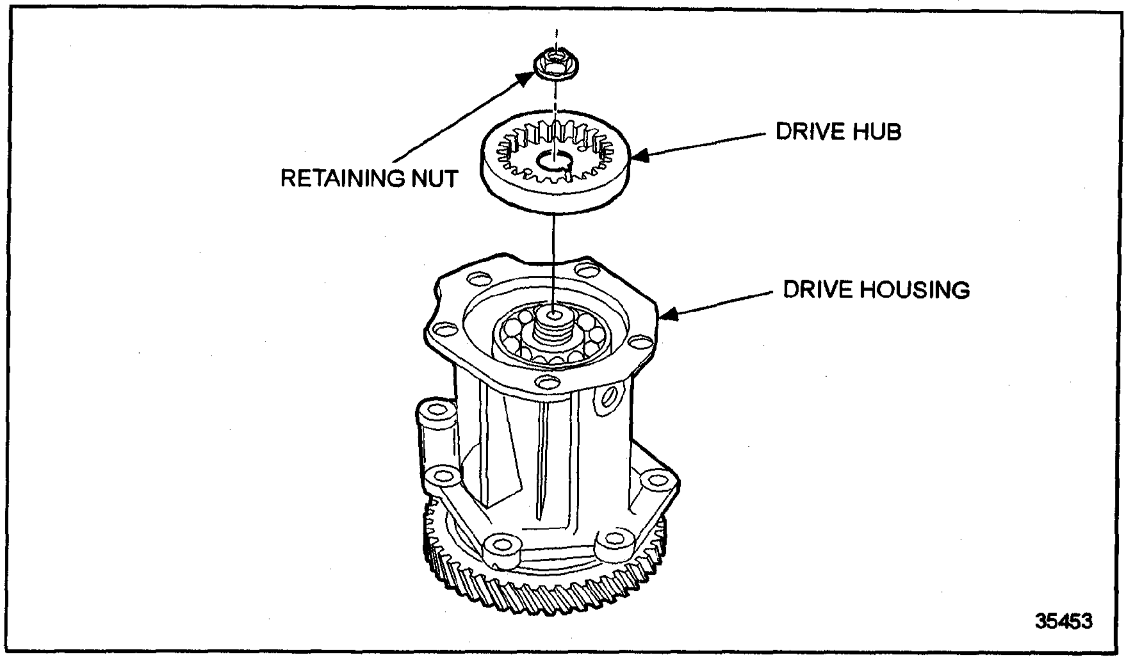



**Figure 10-35 Air Compressor/Raw Water Pump Drive Hub Installation**

26. Remove the drive assembly from the holding fixture and position it on a suitable flat surface with the drive gear facing up.

27. Assemble a dial indicator and magnetic base so that the indicator stem rests on the face of the drive gear just inboard of the drive gear teeth. See Figure 10-36.

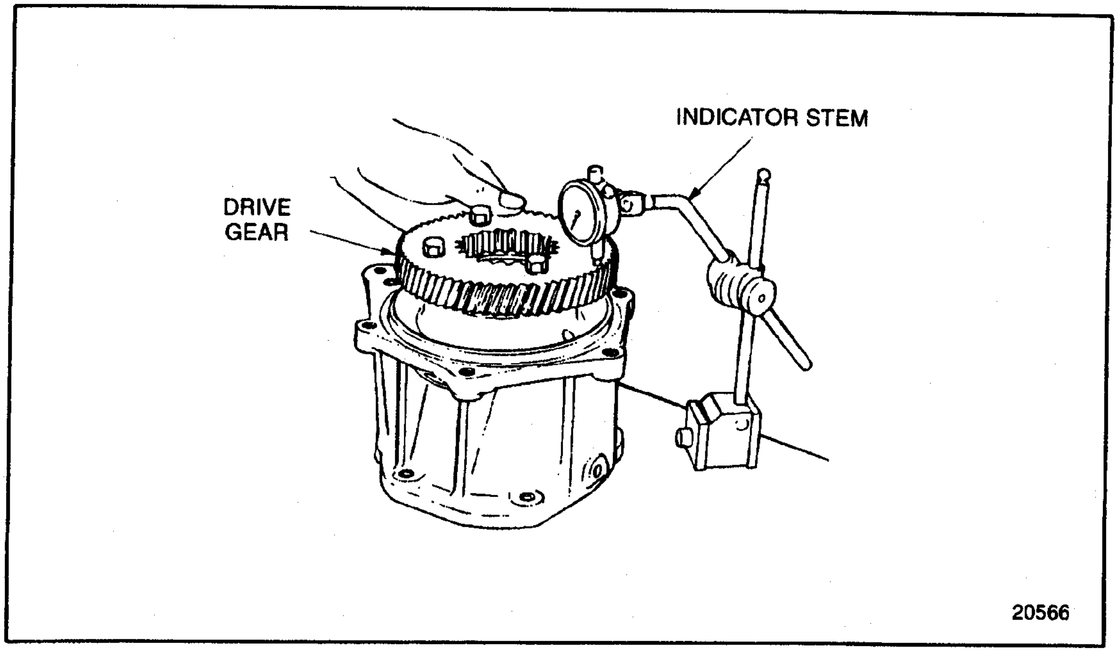



**Figure 10-36 Air Compressor Drive Shaft Installation (Former Design)**

28. Zero the dial indicator.
29. Rotate the drive gear two full revolutions. As the gear is rotated, the dial indicator may register both to the left and right of zero. The total amount the indicator needle moves to the left and right of zero, added together, gives the total indicated run-out (TIR).
30. If maximum TIR exceeds 0.08 mm (0.003 in.), it may be necessary to repeat the assembly procedure until the cause can be detected and eliminated.

### 10.3.6 Installation of Air Compressor/Raw Water Pump Drive Assembly

Install the air compressor/raw water pump drive assembly as follows:

1. On engines manufactured through unit serial no. 06R175824, install two 1.5 mm x 10.0 mm (0.375 in. x 0.060 in.) flat washers under each of the six air compressor drive mounting bolts. Engines built after serial no. 06R175825 do not require the addition of washers to mounting bolts.
2. Install the drive assembly to its original position in the gear case, using a new gasket between the housing and gear case. Install the bolts (and washers, if required) that secure the drive assembly to the gear case.

**NOTE:**
The shorter bolt is installed in the two o'clock position.

3. Torque the five bolts and one nut to 58 - 73 N·m (43 - 54 lb·ft), using the required torque pattern. See Figure 10-37.

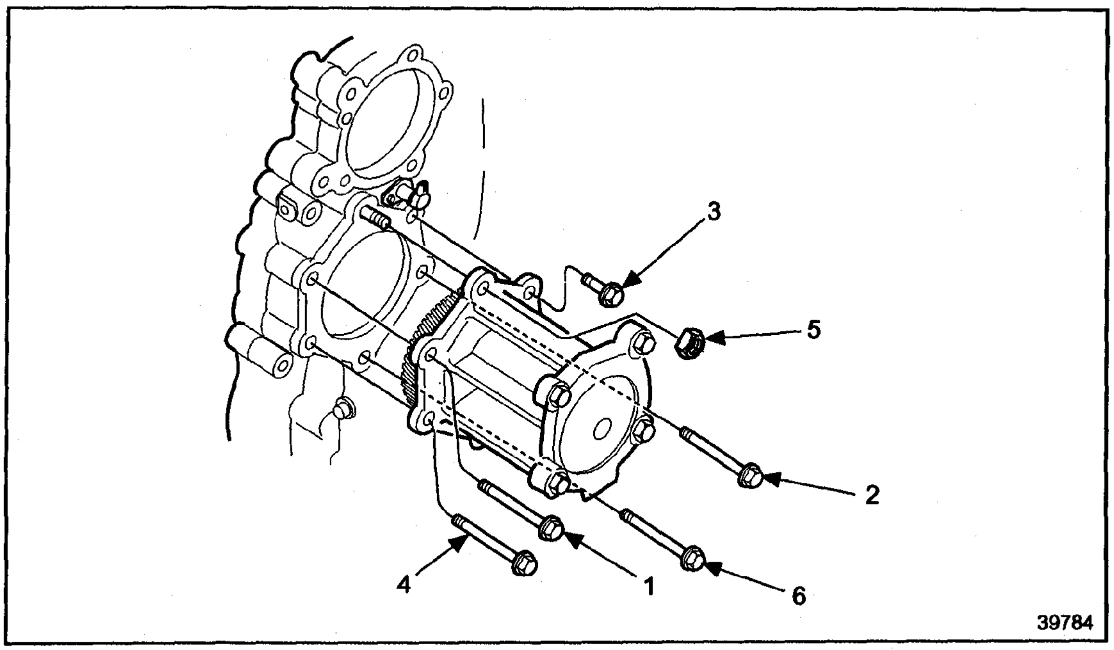



**Figure 10-37 Bolt Torque Sequence**

4. Measure the bull gear-to-drive gear lash. Refer to section 1.21.2.1
5. Install the access cover. Use a new gasket between the access cover and the gear case cover, and torque the five bolts to 30-38 N·m (22-28 lb·ft) in a star-shaped tightening pattern.
6. If the engine is equipped with a power steering pump, install the proper steering drive coupling and power steering pump and cover assembly to the gear case cover. Install a new gasket between the cover and the gear case cover, and torque the 5 bolts to 30-38 N·m (22-28 lb·ft) in a star-shaped tightening pattern.

7. Connect the oil supply line at the Tee fitting, if applicable, at the top of the air compressor/raw water pump drive housing.
8. Install the air compressor. Refer to section 10.1.8.

**NOTE:**
For engines used in coach applications, a high strength air compressor supply hose *must* be installed between the intake manifold and the air compressor inlet. This hose can be identified by the light blue color on the inside of the hose. Flat band spring type hose clamps must be used.

| **CAUTION:** |
|---|
| **To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).** |

9. Install any other components that were removed for this procedure.

## 10.4 KIM HOT START STARTING AID SYSTEM (MARINE)

A Kim Hot Start® starting aid system is installed in certain heat exchanger-cooled marine engines. This system consists of a 1000 watt heater element installed in a boss in the oil cooler housing where the coolant flows into the cylinder block. A thermostat located in the thermostat housing spacer is used to turn the heater element on and off. The heater element and thermostat are wired to a harness connected to a bracket-mounted control box on the right-rear of the cylinder block. The Kim Hot Start system provides a coolant temperature of between 38 — 49°C (100 – 120°F) for rapid engine start-up.

| NOTICE: |
| --- |
| Always disconnect the electrical harness to the block heater system before draining the engine coolant. Failure to observe this precaution may result in damage to the block heater system should the thermostat energize the element after coolant is drained from the engine. |

The Kim Hot Start heater element and thermostat do not require periodic maintenance. As long as they are operating properly, no further maintenance is needed.

The wiring harness should be inspected periodically for loose or damaged connections and frayed insulation. Tighten connections or repair or replace the harness, as required.

*Kim Hot Start® is a registered trademark of the Kim Corporation.*

# 10.A ADDITIONAL INFORMATION

**Description** **Page**

## INSTALLATION GUIDELINES FOR ALLIED SIGNAL®-BENDIX® AIR COMPRESSOR TF-550 AND TF-750

Installation guidelines for Allied Signal®-Bendix® air compressor are as follows:

### Compressor Discharge Line

Avoid installing valves (pressure regulator valves, etc.) in the compressor discharge line between the compressor, and reservoir or air dryer. The valves can trap water and lead to discharge line freeze-up during cold temperature conditions. The longer the discharge line length, the greater the potential for a frozen discharge line to occur. Compressor discharge line lengths are listed in Table 10-1.

| LENGTH | I.D. MIN. |
|---|---|
| 6.0-9.5 ft. | 9.5-12 ft.* |
| 9.5-12 ft.* | 1/2in† |
| 12-16 ft.* | 5/8in. |

* Last three feet including reservoir or air dryer supply port fitting must be insulated with 1/2 in. thick closed cell polyethylene pipe insulation.

† Use of larger I.D. discharge line will further reduce the chances of freeze-up in extreme cold weather conditions and should be considered for "cold weather package" applications.

**Table 10-1 Discharge Line Length and Diameter (Low Duty Cycle Applications)**

**NOTE:**
High duty cycle application with lengths of 10 to 16 feet should use a 1/2 in. I.D. discharge line.

**NOTE:**
If the actual application requires the discharge line length to fall outside the specified ranges given, it is recommended that Allied Signal® TBS Engineering department be contacted.

### Discharge Line Material

If a copper discharge line is used, a flexible connection to the first reservoir or air dryer should be added to prevent fatigue of the copper line. Wire-braided Teflon® hose must have a minimum operating temperature of 232°C (450°F) and a working pressure of 150 psig (10.0 bar) if connected directly to the compressor discharge fitting.

### Discharge Line Slope

The discharge line should slope continuously downward from the air compressor discharge port, with no sharp bends, water traps, risers or elbow fittings, to the first reservoir or air drying device. If there are any upward or downward deviations, the line can trap water, which can freeze during cold weather, causing a blockage. Compressor damage can occur as a result of a blocked discharge line.

## Carbon Restricted Discharge Line

If the discharge line becomes restricted with carbon, the compressor must work harder to deliver compressed air, thus reducing compressor durability. Make sure the discharge line does not have a carbon restriction.

## Discharge Line Accessories

The application of a downstream device such as an air dryer, discharge line unloader, or turbocharger cut-off valve, needs to be installed properly to avoid premature compressor durability problems. Refer to the manufacturer's instructions for these products.

**NOTE:**
Alcohol injectors which restrict the flow of air in the discharge line should be avoided. Restrictions in the discharge line increase the time required to build up system pressure.

## Compressor Inlet

The following summarizes the three compressor inlet connections and the associated pitfalls:

- ☐ Turbocharger: Must be consistent with pressure and speed limits determined by the manufacturer.
- ☐ Inlet side of the turbocharger: Engine air cleaner must be serviced at regular intervals. (See manufacturer's instructions)
- ☐ Local air filter: Local air filter must be serviced at regular intervals. (See manufacturer's instructions)

## Inlet Connection Recommendations

Inlet connection recommendations are as follows:

- ☐ Line size: The preferred inlet size is 19 mm (3/4 in.) I.D. The minimum line size for the inlet connection is 15.9 mm (5/8 in.) I.D., for either naturally aspirated or turbocharger applications.
- ☐ Depression of inlet pressure: A compressor inlet connected to the engine induction system must not depress the intake pressure to more than 635 mm (25 in.) of water.
- ☐ Separate inlet filters: Separate inlet filters must not depress the intake pressure to more than 635 mm (25 in.) of water. The polyurethane sponge strainer should be serviced every 8050 km (5000 miles) or 150 operating hours. The paper element type should be replaced every 32,190 km (20,000 miles) or 800 operating hours.

## Alcohol Evaporator

The alcohol evaporator can be used to reduce the potential for an air system freeze-up; however, it does not remove any moisture from the air system, but only lowers its freezing point. The preferred method of protecting the air system against cold weather freeze-up is with an air dryer. The moisture generated by the compression of air is removed, thus minimizing the possibility of contaminating the air system.

## Unloader Pressure

In a turbocharged application a minimum pressure of 85 psi (5.9 bar) is required to insure proper unloader operation. The cut in pressure of the governor used must be at least 95 psi (6.6 bar).

## Governor

Governor guidelines are as follows:

- ☐ Governor/Reservoir line routing: The governor/reservoir line should slope downward toward the first reservoir to eliminate a potential water trap or ice restriction. The governor may operate erratically if the governor/reservoir line becomes restricted. Compressor unloader or inlet valve damage may result. The governor/reservoir line should be plumbed into the top of the reservoir. The governor/reservoir line should never be plumbed into the bottom of the reservoir, because water and contamination may cause the governor to malfunction.
- ☐ Governor/reservoir line size: The governor/reservoir line size is 6.4 mm (1/4 in.) I.D. tubing; however, 4.8 mm (3/16 in.) I.D. is acceptable.
- ☐ Governor mounting: The governor mounting is on the compressor unloader pad. The governor may be remote mounted; however, the line from the governor to the unloader pad should be as short as possible (not to exceed 1.2 mm [4 ft.]). The governor should be mounted with the exhaust port toward the road surface, to reduce the possibility of moisture contamination.
- ☐ Waterproof governor: In situations where the exhaust port of the governor must be pointed upward, a special waterproof governor should be used.
- ☐ High temperature governor: A high temperature governor should be used when the under-hood ambient temperature exceeds 93°C (200°F).

## Compressor Orientation

The maximum side-to-side roll is degrees beyond the nominally designated orientation. Some models are designed with an orientation other than zero degrees.

## Power Angle

The maximum fore-aft tilt (power angle) the compressor may be subjected to is eight degreesfor the TF550 and six degrees for the TF750. These values may be increased by five degrees if the compressor is turbocharged or if the flange-mounted compressor is bottom drained.

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# 11 OPERATION AND VERIFICATION

## 11.1 PREPARATION FOR A FIRST TIME START

Before starting an engine for the first time, carefully read and follow the instructions in this section:

| NOTICE: |
|---|
| Attempting to run the engine before studying these instructions may result in serious damage to the engine. |

| NOTICE: |
|---|
| When preparing to start a new or overhauled engine or an engine that has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see Daily Operations in the Lubrication and Preventive Maintenance Chart. Refer to section 13.1. Failure to perform required prestart operations may result in engine damage. |

### 11.1.1 Cooling System

Install all the drain cocks and plugs in the cooling system as instructed below:

1. Open the cooling system vents.
2. Remove the filler cap and fill the cooling system with the coolant specified. Refer to section 5.4. The coolant level should be within 2 in. (50 mm) of the filler neck to allow for fluid expansion.
3. Close the vents, if used, after filling the cooling system.

| NOTICE: |
|---|
| Failure to prime the raw water pump may result in damage to the pump impeller. |

4. On marine engines, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet elbow and pour water into the pump.

### 11.1.2 Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 172 kPa (25 lb/in.$^2$) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use lubricating oil as specified. Refer to section 5.2.1. Then, remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the *full* mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with lubricating oil. Refer to section 13.13.1. Then, prelubricate the upper engine parts by removing the valve rocker cover and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms, rocker arm shafts, camshaft lobes and camshaft follower rollers.

### 11.1.3 Turbocharger

When a turbocharger is replaced, or if the engine has been in storage, the turbocharger must be prelubricated by pouring oil into the oil supply inlet before the engine is started. Rotate the shaft to coat the bearings with oil.

| NOTICE: |
|---|
| The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure before the turbocharger reaches its maximum operating speed which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure have reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger. |

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

Start and run the engine at idle until oil supply pressure has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers 138 kPa (20 lb/in.$^2$) pressure at idle speed.

### 11.1.4 Air Cleaner

Refer to OEM instructions for the air cleaner, and service accordingly.

### 11.1.5 Transmission

Check the oil level and, if necessary, fill the transmission, marine gear, or torque converter to the proper level with the lubricant specified by the manufacturer.

### 11.1.6 Diesel Fuel System

Fill the fuel tank with the fuel specified. Refer to section 5.1.

If the unit is equipped with a fuel valve, it must be opened. To ensure prompt starting, the fuel system between the pump and fuel return line must be full of fuel.

If the engine has been out of service for a considerable length of time, prime the fuel system between the fuel pump and the fuel return manifold. Before priming the fuel system, remove and fill both fuel filters with clean fuel oil and reinstall them. Refer to section 11.1.3 for the exhaust caution before preceeding.

**NOTE:**
The engine fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

### 11.1.7 Drive Belts

Adjust all drive belts as recommended. Refer to section 13.13.10.

### 11.1.8 Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of silicone spray or petroleum jelly and the electrolyte must be at the proper level.

A hydrometer reading (corrected for the temperature of the electrolyte) should be 1.265 or higher. If necessary, charge the battery.

### 11.1.9 Clutch

Disengage the clutch, if the unit is so equipped.

## 11.2 STARTING

Before starting the engine for the first time, perform the operations listed under "Preparation For Starting Engine First Time." Refer to section 11.1.

Before a routine start, see "Daily Maintenance - All Applications." Refer to section 13.2.

Start an engine equipped with an electric starting motor as follows:

1. Turn the ignition switch to the ON position. The yellow check engine and red stop engine lights should both light up. After 6-10 seconds both lights should go out. If both lights fail to go out, refer to section 2.15for instructions on monitoring the DDEC system.

| NOTICE: |
|---|
| To prevent serious damage to the cranking motor, if the engine does not start, do not press the starting switch again while the cranking motor is spinning. |

2. If the check engine and stop engine lights both go out, press the starting motor switch firmly. If the engine fails to start within 15 seconds, release the starting switch and allow the starting motor to cool for 15 seconds before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

# 11.3 RUNNING

The following sections cover normal operations.

## 11.3.1 Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, or the stop engine light (red) comes on, stop the engine and check the lubricating oil system.

## 11.3.2 Warm-up

Make sure area is well-ventilated before starting the engine.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

Run the engine at idle with no-load for approximately five minutes, allowing it to warm-up before applying a load. The engine will idle at a higher speed if the oil is cold when started.

As the engine reaches operating temperature, the electronic control system of the engine will lower the idle speed if not equipped with an automatic transmission.

If the unit is operating in a closed room, start the room ventilating fan or open the windows and doors, as weather conditions permit, so ample air is available for the engine.

### 11.3.2.1 Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

While the engine is idling, check the transmission or marine gear for proper level and add oil as required. On marine engines check that water is flowing out the exhaust pipe or raw water discharge pipe. Look for coolant, fuel, or lubricating oil leaks at this time. If any are found, shut down the engine immediately and have leaks repaired after the engine has cooled.

### 11.3.3 Engine Temperature

Refer to section 11.5 for normal operating temperature.

### 11.3.4 Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 20 minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the lubricating oil specified. Refer to section 5.2.1.

### 11.3.5 Cooling System

Several types of cooling systems are used by vehicle, vessel, off-road machinery, and generator set manufacturers. Refer to OEM guidelines.

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

Remove the radiator or heat exchanger pressure cap slowly and check the engine coolant level. The coolant level should be within two inches of the top of the opening. If necessary, add properly inhibited coolant.

Entrapped air must be purged after the cooling system is filled. To do this allow the engine to warm up without the pressure cap installed. With the transmission or marine gear in neutral, increase engine rpm above 1000 rpm and add coolant as required. On marine engines, vent the drain cock on the water return line at the water-jacket turbocharger (if used) until coolant (no air) comes out. Install the pressure cap after the coolant level has stabilized at the bottom of the radiator or heat exchanger and check to make sure the coolant level is at the bottom of the filler neck. Add coolant as required, replace the pressure cap, and fill the recovery bottle to the "Full Cold" level, or no more than one-quarter of its volume.

## 11.3.6 Turbocharger

Make a visual inspection of the turbocharger for oil leaks, coolant leaks, marine engine exhaust leaks, excessive noise and vibration.

**CAUTION:**

**To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.**

Stop the engine immediately if a leak or unusual noise or vibration is noted. Do not restart the engine until the cause of the concern has been investigated and corrected. Authorized Detroit Diesel service outlets are properly equipped to perform this service.

## 11.3.7 Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

**NOTE:**
When prolonged engine idling is necessary, maintain at least 850 r/min spring/summer and 1200 rpm fall/winter.

## 11.4 STOPPING

The following should be performed for NORMAL stopping:

1. Release the load and decrease the "engine speed" in the NEUTRAL position.

| NOTICE: |
|---|
| Stopping a turbocharged engine immediately after high speed operation may cause damage to the turbocharger, as it will continue to turn without an oil supply to the bearings. |

2. Allow the engine to run at idle with no-load for four or five minutes. This allows the turbocharger to cool and slow down. Then turn the key switch to the OFF position.

### 11.4.1 Emergency Stopping

To stop the engine, turn the key to the OFF position. On certain marine engines, the emergency shutdown system may be activated to stop the engine.

| NOTICE: |
|---|
| Never use the emergency shutdown system, except in an emergency. Use of the emergency shutdown can cause turbocharger damage. |

| NOTICE: |
|---|
| If the emergency air shutdown is used to stop the engine in an emergency situation, always have the shutdown checked for damage and for proper operation before the vessel is returned to service. This is especially important if shutdown is made at high engine rpm. To ensure positive valve closure should another emergency shutdown be required, the shutdown must be checked and required repairs or adjustments made at this time. Failure to observe this precaution may permit engine run-on when the emergency shutdown is activated. |

The emergency shutdown should be used only when the engine does not respond to the normal stop engine procedure.

To shut down the engine, simply activate the emergency shutdown control. This is an electrical switch which is normally identified as such on the control panel.

The air shutdown must be reset by hand. If an "emergency stop" knob connected to a bowden wire is also installed on the shutdown, this should be pushed in before the engine is ready to start again.

## 11.5 OPERATING CONDITIONS

The operating limits for the Series 60 diesel engine are listed in Table 11-1, listed in Table 11-2 and listed in Table 11-3. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Be sure that the readings represent true values and the instruments are accurate before attempting to make corrections to the engine. This data represents rated conditions. Actual data may be influenced by environmental conditions.

| Parameter Limits | Operating Limits at 2100 r/min | Operating Limits at 1800 r/min |
|---|---|---|
| Lubrication System Rated | 345 (50) | 345 (50) |
| Lubricating oil pressure (at idle speed) - kPa (lb/in.$^2$) | 290 (42) | 255 (37) |
| In gallery oil temperature, maximum - °C (°F) | 110 (230) | 110 (230) |
| In pan oil temperature - °C (°F) | 113 (235) | 113 (235) |
| In pan oil temperature - 11.1 liter with thermatic oil control valve - °C (°F) | 114 (237) | 114 (237) |
| Oil flow - liters/minute (gallons/minute) | 136 (36) | 136 (36) |
| Oil pan capacity: | | |
| High - liters (quarts) | 30 (32) | 30 (32) |
| Low - liters (quarts) | 25 (26) | 25 (26) |
| Total engine oil capacity (with 2 filters) - liters (quarts) | 36 (38) | 36 (38) |
| Total engine oil capacity (with 3 filters) - liters (quarts) | 39 (41) | 39 (41) |

**Table 11-1 Series 60 Engine Lubrication System Parameters**

| Air, Fuel, and Cooling System Parameter Limits | Operating Limits at 2100 r/min | Operating Limits at 1800 r/min |
|---|---|---|
| **Air System** | | |
| Air Inlet restriction full load, maximum - kPa (in. $H_2O$): | | |
| Dirty air cleaner | 5.0 (20) | 5.0 (20) |
| Clean air cleaner | 3.0 (12) | 3.0 (12) |
| Crankcase pressure full load, maximum - kPa (in. $H_2O$) | 0.75 (3) | 0.75 (3) |
| Exhaust back pressure, maximum kPa (in. Hg): | | |
| Full load | 10.1 (3.0) | 10.1 (3.0) |
| Maximum allowable temperature rise (ambient air to engine inlet) - °C (°F) | 16.7 (30) | 16.7 (30) |
| Maximum allowable charge air cooler pressure drop - kPa (in. Hg) | 10.1 (3.0) | 10.1 (3.0) |
| **Fuel System** | | |
| Fuel pressure at secondary filter outlet - kPa (lb/in.$^2$) | | |
| Normal with.03 mm (0.080 in.) restriction | 577 (75) | 577 (75) |
| Minimum | 345 (50) | 345 (50) |
| Fuel spill minimum at no-load - L/min (gal/min): | | |
| Normal with 2.03 mm (0.080 in.) restriction | 4.9 (1.3) | 4.1 (1.0) |
| Fuel pump suction at pump inlet, maximum - kPa (in. Hg): | | |
| Clean system | 20 (6) | 20 (6) |
| Dirty system | 41 (12) | 41 (12) |
| **Cooling System** | | |
| Coolant temperature normal - °C (°F) | 88 (190) | 88 (190) |
| Coolant inlet restriction, maximum - kPa (in. Hg) | 0.0 (0.0) | 0.0 (0.0) |
| Coolant flow at full load speed-L/min (gal/min) | 341 (90) | 276 (73) |
| Engine coolant capacity - liters (quarts) | 23 (24) | 23 (24) |
| Minimum pressure cap - kPa (lb/in.$^2$): | 69 (10) | 69 (10) |
| Maximum top tank temperature - °C (°F) | 99 (210) | 99 (210) |
| Minimum top tank temperature - °C (°F) | 71 (160) | 71 (160) |
| Thermostats: | | |
| Start to open - °C (°F) | 88 (190) | 88 (190) |
| Fully open - °C (°F) | 96 (205) | 96 (205) |

**Table 11-2 Series 60 Engine Air System, Fuel System, and Cooling System Parameters**

| Air, Fuel, and Cooling System Parameter Limits | Operating Limits at 2300 r/min |
|---|---|
| **Air System** | |
| Air Inlet restriction full load, maximum - kPa (in. $H_2O$): | |
| Dirty air cleaner | 5.0 (20) |
| Clean air cleaner | 2.5 (10) |
| Crankcase pressure full load, maximum - kPa (in. $H_2O$) | 0.75 (3) |
| Exhaust back pressure, maximum kPa (in. Hg): | |
| Full load | 7.4 (2.2) |
| Maximum allowable temperature rise (ambient air to engine inlet) - °C (°F) | 13.9 (25) |
| Maximum allowable charge air cooler pressure drop - kPa (in. Hg) | 10 (2.5) |
| **Fuel System** | |
| Fuel pressure at secondary filter outlet - kPa (lb/in.$^2$) | 577 (75) |
| Normal with.03 mm (0.080 in.) restriction | 345 (50) |
| Minimum | |
| Fuel spill minimum at no-load - L/min (gal/min): | |
| Normal with 2.03 mm (0.080 in.) restriction | |
| Fuel pump suction at pump inlet, maximum - kPa (in. Hg): | |
| Clean system | 20 (6) |
| Dirty system | 41 (12) |
| Fuel Inlet Temperature, Maximum °F (°C) | 140 (60) |
| **Cooling System** | |
| Coolant temperature normal - °C (°F) | 71 (160) |
| Coolant inlet restriction, maximum - kPa (in. Hg) | 0.0 (0.0) |
| Raw Water Inlet Restriction, Maximum, L/min (galmin) | 10 (3.0) |
| Coolant flow at full load speed-L/min (gal/min) | 632 (167) |
| Raw Water Flow - L/min (gal/min) | 443 (117) |
| Charge Air Cooler Water Flow - L/min (gal/min) | 443 (117) |
| Engine coolant capacity - liters (quarts) | 56 (60) |
| Minimum pressure cap - kPa (lb/in.$^2$): | 5.2 (7.5) |
| Maximum top tank temperature - °C (°F) | 99 (210) |
| Minimum top tank temperature - °C (°F) | 71 (160) |
| Thermostats: | |
| Start to open - °C (°F) | 71 (160) |
| Fully open - °C (°F) | 82 (180) |
| **Exhaust System** | |

| Air, Fuel, and Cooling System Parameter Limits | Operating Limits at 2300 r/min |
|---|---|
| Exhaust Temperature - °C (°F) | 645 (341) |
| Maximum Back Pressure - in. Hg (kPa) | 2.2 (7.4) |

**Table 11-3 Heat Exchanger-Cooled Pleasure Craft Marine Air System, Fuel System, and Cooling System Parameters**

## 11.6 SERIES 60G GENSET ENGINE OPERATING CONDITIONS

Listed in Table 11-4are the engine operating conditions specifications.

| SYSTEM | SPEC |
|---|---|
| **Fuel System** | |
| Maximum Fuel Inlet Temperature - °F (°C) | 140 (60) |
| Minimum Fuel Inlet Temperature - °F (°C) | 32 (0) |
| Maximum Fuel Inlet Pressure to Regulator @ Idle - in. $H_2O$ (kPa) | 20 (5) |
| Minimum Fuel Inlet Pressure to Regulator @ full load - in. $H_2O$ (kPa) | 5 (1) |
| Fuel Filter, Primary | - |
| Fuel Filter, Secondary | - |
| **Lubrication System** | |
| Oil Pressure at Rated Speed - lb/in$^2$ (kPa) | 50 (345) |
| Oil Pressure at Low Idle - lb/in$^2$ (kPa) | 12 (83) |
| In Pan Oil Temperature - °F (°C) | 235 (113) |
| Oil Pan Capacity, High Limit - qt (L) | 32 (30) |
| Oil Pan Capacity, Low Limit - qt (L) | 26 (25) |
| Total Engine Oil Capacity with Filters - qt (L) | 38 (36) |
| Oil Filter, Two Full Flow - microns | 28 |
| **Cooling System** | |
| Thermostat: | |
| Start to Open - °F (°C) | 186 (86) |
| Fully Open - °F (°C) | 207 (97) |
| Maximum Water Pump Inlet Restriction - in. Hg (kPa) | 0 (0) |
| Engine Coolant Capacity - qt (L) | 24 (23) |
| Minimum Pressure Cap - lb/in$^2$ (kPa) | 7 (48) |
| Maximum Coolant Pressure (Exclusive of Pressure Cap) - lb/in$^2$ (kPa) | 10 (69) |
| Maximum Top Tank Temperature - °F (°C) | 210 (99) |
| Minimum Top Tank Temperature - °F (°C) | 160 (71) |
| **Air System** | |
| Maximum Ambient to Turbo Compressor Inlet Temperature Rise - °F (°C) | 30 (16.7) |
| Maximum Air Intake Restriction: | |
| Dirty Air Cleaner - in. $H_2O$ (kPa) | 20 (5) |
| Clean Air Cleaner - in. $H_2O$ (kPa) | 12 (3) |
| Engine Manifold Pressure - in. Hg (kPa) | 43 (146) |
| Maximum Charge Air Cooler System Total Pressure Drop - in. $H_2O$ (kPa) | 41 (10.2) |
| Maximum Ambient to Intake Manifold Temp. - °F (°C) | 30.0 (16.7) |

| SYSTEM | SPEC |
|---|---|
| Maximum Crankcase Pressure - in. $H_2O$ (kPa) | 2 (0.5) |
| **Exhaust System** | |
| Exhaust Flow: | |
| Rated Speed - $ft^3$ /min ($m^3$ /min) | 2325 (65.8) |
| Peak Torque Speed - $ft^3$ /min ($m^3$ /min) | - |
| Exhaust Temperature: | |
| Rated Speed - °F (°C) | 1020 (549) |
| Peak Torque Speed - °F (°C) | - |
| Maximum Back Pressure - in. Hg (kPa) | 3.0 (10.1) |

**Table 11-4 Engine Operating Conditions for the Series 60G Genset Engine**

## 11.7 SERIES 60G AUTOMOTIVE ENGINE OPERATING CONDITIONS

Listed in Table 11-5 are the engine operating conditions specifications.

| SYSTEM | SPEC |
|---|---|
| **Fuel System** | |
| Maximum Fuel Inlet Temperature - °F (°C) | 158 (70) |
| Minimum Fuel Inlet Temperature - °F (°C) | -40 (-40) |
| Maximum Fuel Inlet Pressure to Regulator @ Idle - lb·in. $_2$ (kPa) | 210 (1448) |
| Minimum Fuel Inlet Pressure to Regulator @ full load - lb·in. $_2$ (kPa) | 70 (482) |
| Fuel Filter, Primary | Coalescing 1 micron |
| Fuel Filter, Secondary | Coalescing 1 micron |
| **Lubrication System** | |
| Oil Pressure at Rated Speed - lb/in$^2$ (kPa) | 50 (345) |
| Oil Pressure at Low Idle - lb/in$^2$ (kPa) | 12 (83) |
| In Pan Oil Temperature - °F (°C) | 235 (113) |
| Oil Pan Capacity, High Limit - qt (L) | 32 (30) |
| Oil Pan Capacity, Low Limit - qt (L) | 26 (25) |
| Total Engine Oil Capacity with Filters - qt (L) | 38 (36) |
| Oil Filter, Two Full Flow - microns | 28 |
| **Cooling System** | |
| Thermostat: | |
| Start to Open - °F (°C) | 186 (86) |
| Fully Open - °F (°C) | 207 (97) |
| Maximum Water Pump Inlet Restriction - in. Hg (kPa) | 0 (0) |
| Engine Coolant Capacity - qt (L) | 24 (23) |
| Minimum Pressure Cap - lb/in$^2$ (kPa) | 7 (48) |
| Maximum Coolant Pressure (Exclusive of Pressure Cap) - lb/in$^2$ (kPa) | 10 (69) |
| Maximum Top Tank Temperature - °F (°C) | 210 (99) |
| Minimum Top Tank Temperature - °F (°C) | 160 (71) |
| **Air System** | |
| Maximum Ambient to Turbo Compressor Inlet Temperature Rise - °F (°C) | 30 (16.7) |
| Maximum Air Intake Restriction: | |
| Dirty Air Cleaner - in. $H_2O$ (kPa) | 20 (5) |
| Clean Air Cleaner - in. $H_2O$ (kPa) | 12 (3) |
| Engine Manifold Pressure - in. Hg (kPa) | 43 (146) |
| Maximum Charge Air Cooler System Total Pressure Drop - in. $H_2O$ (kPa) | 41 (10.2) |
| Maximum Ambient to Intake Manifold Temp. - °F (°C) | 30.0 (16.7) |

| SYSTEM | SPEC |
|---|---|
| Maximum Crankcase Pressure - in. $H_2O$ (kPa) | 2 (0.5) |
| **Exhaust System** | |
| Exhaust Flow: | |
| Rated Speed - $ft^3$ /min ($m^3$ /min) | 1961 (55) |
| Peak Torque Speed - $ft^3$ /min ($m^3$ /min) | 1250 (35) |
| Exhaust Temperature: | |
| Rated Speed - °F (°C) | 1110 (600) |
| Peak Torque Speed - °F (°C) | 1065 (575) |
| Maximum Back Pressure - in. Hg (kPa) | 2.4 (8.1) |

**Table 11-5 Engine Operating Conditions for the Series 60G Automotive Engine**

# 11.8 ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair that uses replacement piston rings, pistons, or bearings, for example, the engine should be run-in on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine to determine if the engine will perform to published specifications and to permit a physical inspection for leaks of any kind. It is an excellent method for detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear.

| NOTICE: |
| --- |
| Thermostats are required to control the coolant flow and to help maintain a constant engine temperature. Therefore, be sure that they are in place and fully operative or the engine may overheat during the run-in. Furthermore, a deaeration line must be installed in the uppermost portion of the engine to prevent any overheat problems during run-in. |

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 5.6°C (10°F) higher than the water inlet temperature. A 5.6°C (10°F) rise across an engine is recommended; however, an 8.3°C (15°F) temperature rise maximum is permitted.

## 11.8.1 The Basic Engine

A basic engine includes only those components actually necessary to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the Engine Run-In Check. The fan and battery-charging alternator typify accessories not considered on the basic engine.

Since the DDEC system requires a source of electrical power to operate the Electronic Unit Injectors, all DDEC equipment should be connected and operating properly. In addition, a fully charged battery must be connected to the system. Refer to OEM guidelines.

In situations where other than basic engine equipment is used during the test, a proper record of this fact should be made on the Engine Test Report. The effects of additional equipment on engine performance should then be considered when evaluating test results.

### 11.8.2 Chassis Dynamometer Room Ventilation Recommendations

For accurate dynamometer readings during a Series 60 engine run-in, the chassis dynamometer room *must* be properly ventilated. See Figure 11-1.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

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**Figure 11-1 California Proposition 65 Warning**

If an engine is tested on a dynamometer located in an area without proper ventilation, the engine will be subject to high ambient air temperatures. High air inlet temperatures can result in false low power readings on the dynamometer.

To help ensure accurate dynamometer readings, the dynamometer room should have a ceiling-mounted fan with a 850 to 1133 $m^3$ /min (30,000 to 40,000 $ft^3$ /min) capacity. This will provide proper ventilation of exhaust gases and heat radiated by the operating engine.

In situations where air circulation and proper room cooling are questionable, Detroit Diesel recommends the use of an additional 368 $m^3$ /min (13,000 $ft^3$ /min) or greater capacity barrel-type ram air fan. This should be portable so that it can be conveniently placed three to five feet (approximately one to two meters) in front of the truck and aimed directly at the charge air cooler.

### 11.8.3 Dynamometer Test and Run-in Procedure

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, provisions for engine mounting, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb·ft) or Non a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula, see Figure 11-2.

$$BHP = \frac{T_1 \times RPM}{5250} \qquad kW = \frac{T_2 \times RPM}{9429}$$

WHERE;

| | | |
|---|---|---|
| BHP | = | BRAKE HORSEPOWER, hp |
| kW | = | POWER, kW |
| $T_1$ | = | TORQUE, ft·lb |
| $T_2$ | = | TORQUE, N·m |
| RPM | = | ENGINE SPEED, r/min |
| 5250 | = | DYNAMOMETER CONSTANT |
| 9429 | = | DYNAMOMETER CONSTANT |

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**Figure 11-2 Formulas for Brake Power Developed in the Engine**

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an Engine Test Report, see Figure 11-3.

### 11.8.3.1 Instrumentation

Certain instrumentation is necessary so that data required to complete the Engine Test Report may be obtained. The following list contains the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

- ☐ Oil pressure gage installed in one of the engine main oil galleries (DDEC data can also be used)
- ☐ Water temperature gage installed in the thermostat housing or water outlet manifold
- ☐ Adaptor for connecting a pressure gage or water manometer to the crankcase
- ☐ Fuel pressure gage at the rear of the cylinder head

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in lb/in.$^2$, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

| NOTICE: |
|---|
| Before starting the run-in or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions; see "Preparation for a First Time Start:" refer to section 11.1. Failure to follow instructions could result in engine damage. |

Gage reading = (lb/in.$^2$) x 27.7 = inches of water

Gage reading = (lb/in.$^2$) x 2.04 = inches of mercury

### 11.8.3.2 Run-in Procedure

Use the following procedure for preparation of engine run-in. See Figure 11-3, part A.

1. Fill the lubrication system as outlined under Lubrication System , "Preparation for a First Time Start." Refer to section 11.1.
2. Prime the fuel system as outlined under Fuel System, "Preparation for a First Time Start." Refer to section 11.1.
3. Make a preliminary valve clearance adjustment before the engine is started. Refer to section 12.2.
4. Make a preliminary injector timing check before starting the engine. Refer to section 12.2.
5. Ensure that the turbocharger has been prelubricated by adding oil to the turbocharger oil inlet or by pressurizing the lubrication system.
6. Check to be sure all test stand water valves, fuel valves, etc. are open.
7. Inspect the exhaust system, checking that it is properly connected to the engine.

Use the following procedures for engine run-in:

1. See Figure 11-1 for exhaust caution before preceeding. Start the engine with minimum dynamometer resistance.

| NOTICE: |
| --- |
| All Series 60 engines should be operated at idle for at least one minute after starting to ensure oil supply and pressure to the turbocharger bearings. Inadequate lubrication will result in bearing damage. |

2. Set the engine throttle at idle speed; idle for 30 seconds. Record oil pressure and water temperature values on the engine Test Report; see Figure 11-3, Part B. Check all connections to be sure there are no leaks.
3. The Engine Test Report sample, see Figure 11-3, establishes the sequence of events and specifications for the test and run-in. Also, refer to section 11.5, *"Operating Conditions"* which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation.or lack of power. After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the Warm-Up - 5 minutes; see Figure 11-3, Part C. Complete leak information.

## SERIES 60 ENGINE TEST REPORT

Date: ____________________ Unit Number: ____________________
Repair Order Number: ____________________ Model Number: ____________________
PROM I.D.: ____________________ Max. N/L RPM: ____________________
Rated F/L RPM: ____________________
Idle RPM: ____________________

**A. PRESTART**

| 1. PRIME LUBE OIL SYSTEM | 2. PRIME FUEL OIL SYSTEM | 3. FILL COOLING SYSTEM |
|---|---|---|
| | | |

**B. START-UP AND IDLE FOR 30 SECONDS**

START__________ STOP __________ OIL PRESSURE __________ WATER TEMPERATURE __________

**C. WARM-UP — 5 MINUTES** **START** __________ **STOP** __________

| RPM MAX. SPEED | LOAD 50% | OIL PRESSURE | WATER TEMPERATURE |
|---|---|---|---|
| | | | |
| 1. LUBE OIL LEAKS | 2. FUEL OIL LEAKS | 3. COOLANT LEAKS | 4. LOOSE BOLTS |
| | | | |

**D. RUN-IN — 5 MINUTES** **START** __________ **STOP** __________

| RPM MAX. SPEED | LOAD 75% | OIL PRESSURE | WATER TEMPERATURE |
|---|---|---|---|
| | | | |

**E. FINAL RUN-IN — 20 MINUTES** **START** __________ **STOP** __________

| RPM MAX. SPEED | LOAD 100% | CRANKCASE PRESSURE AT F/L | EXHAUST BACK PRESSURE AT F/L |
|---|---|---|---|
| | | | |
| LUBE OIL PRESS. AT F/L | LUBE OIL TEMP. AT F/L | FUEL OIL TEMP. AT F/L | FUEL OIL PRESSURE AT F/L |
| | | | |
| WATER TEMP. AT F/L | TURBO BOOST PRESS. AT F/L | LUBE OIL PRESSURE AT IDLE | IDLE RPM |
| | | | |

**REMARKS:**

OK __________ Reject __________ Dynamometer Operator __________ Date __________

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**Figure 11-3 Series 60 Engine Test Report Form**

4. See Figure 11-1 for exhaust caution before preceeding. Run the engine at this speed and load for 5 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length start and stop times, speed, brake horsepower, coolant temperature and lubricating oil pressure on the Engine Test Report; see Figure 11-3, Part D.
5. See Figure 11-1 for exhaust caution before preceeding. Run the engine at each speed and rating for the length of time indicated in the Engine Run-In Schedule. During this time, engine performance will improve as new parts begin to seat in.
6. Inspect the engine for fuel oil, lubricating oil and water leaks.
7. Upon completion of the run-in and inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.
8. Record all data requested; see Figure 11-3, Part E.

**NOTE:**
Allow the engine to idle with no load for 4 or 5 minutes in order for the turbocharger to cool and reduce speed before shutdown.

After all the tests have been made and the Engine Test Report is completed, see Figure 11-3, Part D., the engine is ready for final test, see Figure 11-3, Part E. This portion of the test and run-in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm up period of five minutes at the same speed and load used for warm-up. If piston rings or bearings have been replaced as a result of problems during the warm-up, the entire run-in must be repeated as though the test and run-in procedure were started anew.

All readings observed during the final run-in should fall within the range specified in the "Operating Conditions", refer to 11.5, and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

- ☐ The engine water temperature should be taken during the last portion of the run-in at full load. It should be recorded and should be within the specified range.
- ☐ The lubricating oil pressure should be recorded in kPa or lb/in.$^2$ after being taken at engine speeds indicated in the "Operating Conditions," refer to section 11.5.
- ☐ Check the crankcase pressure while the engine is operating at maximum run-in speed. Attach a manometer to the oil dipstick opening to measure crankcase pressure.

The following steps are necessary to complete the final Engine Repair Schedule.

1. Determine the maximum rated brake horsepower and the full-load speed to be used during the final run-in.
2. Apply this load to the dynamometer.
3. The engine should be run at this speed and load for five minutes.

**NOTE:**
While making the final run-in, the engine should develop the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

4. All information, see Figure 11-3, Part E, should be recorded.
5. After the prescribed time for the final run-in has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine.
6. A final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system, (refer to section 13.13.2) and adding a rust inhibitor to the cooling system, (refer to section 13.13.4).
7. Change the lubricating oil filters.

# 12 ENGINE TUNE-UP

**Section** **Page**

## 12.1 ENGINE TUNE-UP PROCEDURES

The Series 60 engine is equipped with Detroit Diesel Electronic Control system (DDEC). Since DDEC replaces any mechanical governing devices, and the fuel injectors are electronically controlled, it is unnecessary to perform engine speed adjustments.

**CAUTION:**

**To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.**

**CAUTION:**

**To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.**

**NOTICE:**

To prevent possible damage, do not perform engine tune-up procedures or engine repair without first disconnecting the engine cranking motor and/or batteries.

The turbocharger compressor inlet shield, J 26554-A, must be used anytime the engine is operated with the air inlet piping removed. See Figure 12-1.

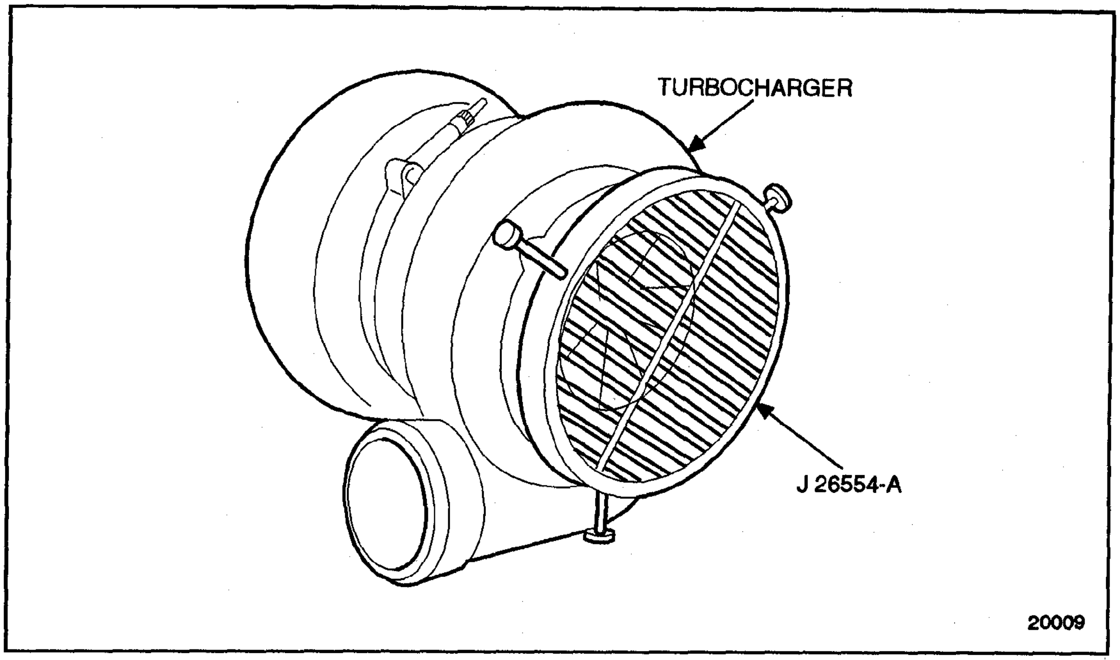



**Figure 12-1 Turbocharger Compressor Inlet Shield**

The shield helps prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the impeller.

The tune-up procedure for the Series 60 engine consists of intake and exhaust valve clearance adjustments, fuel injector height adjustments, and Jake Brake® lash adjustments. These adjustments should be made with the engine cold. Refer to section 12.2 and refer to section 12.2.1.

## 12.2 VALVE LASH, INJECTOR HEIGHT (TIMING) AND JAKE BRAKE® LASH ADJUSTMENTS

Accurate adjustment of clearance between valve buttons, intake and exhaust valves is important if maximum performance and economy are to be obtained.

Likewise, injector height should be properly maintained.

To ensure efficient engine performance and extended valve and injector service life, an initial valve lash and injector height measurement/adjustment requirement has been established.

Effective immediately, the valve lash and injector heights on all Series 60 engines must be measured and, if necessary, adjusted at the initial period listed in Table 12-1.

| NOTICE: |
|---|
| Failure to measure valve clearances and injector heights at the required initial period and make necessary adjustments may result in gradual degrading of engine performance and reduced fuel combustion efficiency. |

| Engine Application | Initial Valve Lash and Injector Height Measurement/Adjustment Period |
|---|---|
| Vehicle Engines | 60,000 miles (96,000 km) or 24 months (Whichever comes first) |
| Stationary or Industrial Engines | 45,000 miles (72,000 km) or 1,500 hours (Whichever comes first) |
| Marine Engines | 1,500 hours |

**Table 12-1 Measurement/Adjustment Period**

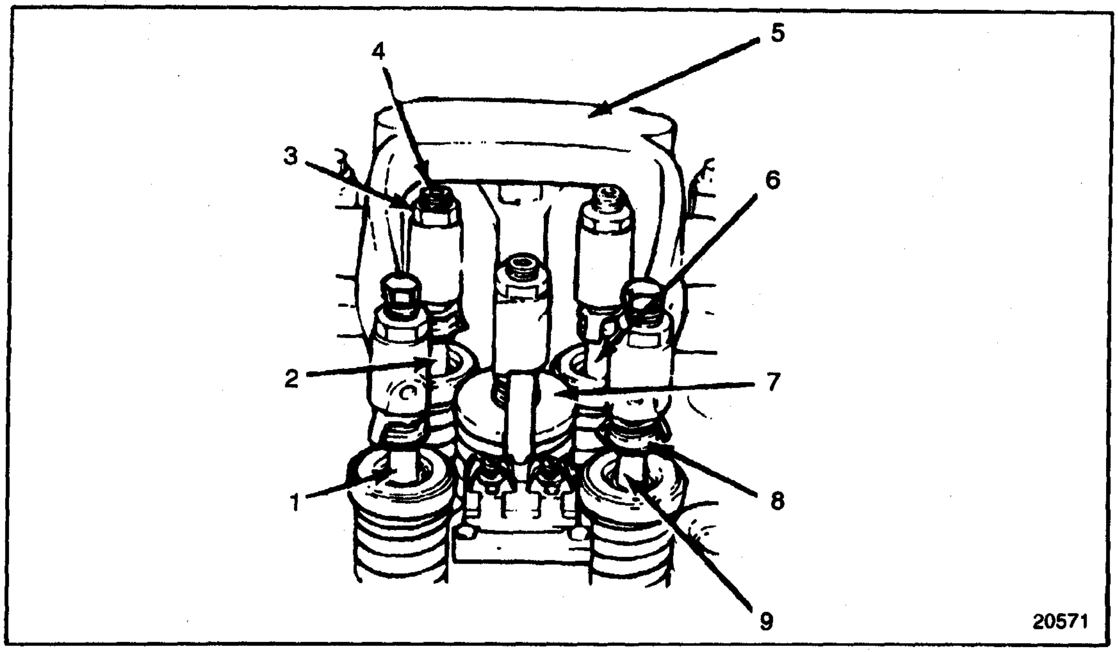
Once the initial measurements and adjustments have been made, any adjustments beyond this point should be made only as required to maintain satisfactory engine performance.

**NOTE:**
This is a change from the original recommendation, which required checking and (if necessary) adjusting valve lash and injector heights at 120,000 miles (190,000 km) for vehicle engines or at 2,500 hours for non-vehicle engines.

**NOTE:**
On engines equipped with a Jake Brake®, measure valve lash and injector height before removing any brake housings. Only remove the brake housings necessary to provide access for adjustment.

Intake and exhaust valve clearance and fuel injector height are adjusted by means of an adjusting set screw and locknut located at the valve end of the rocker arm. See Figure 12-2.




1. Exhaust Valve
2. Intake Valve
3. Locknut
4. Adjusting Set Screw
5. Exhaust Rocker Arm Assembly
6. Intake Valve
7. Fuel Injector Follower
8. Valve Button
9. Exhaust Valve

**Figure 12-2 Valve and Fuel Injector Rocker Arm Assembly Components**

**NOTE:**
Ensure the height gage seats on the machined surface with the tip in the pilot hole. Foreign material in the pilot hole or on the machined surface may prevent accurate setting of the injector height.

The fuel injector height is measured using the required Injector Height Gage as listed in Table 12-2. On engines equipped with a Jake Brake®, move the handle on the injector height gage to the alternate position, 90 degrees to the shank. A height gage locating hole is provided in the injector body on the machined surface contacted by the injector clamp near the solenoid. See Figure 12-3.

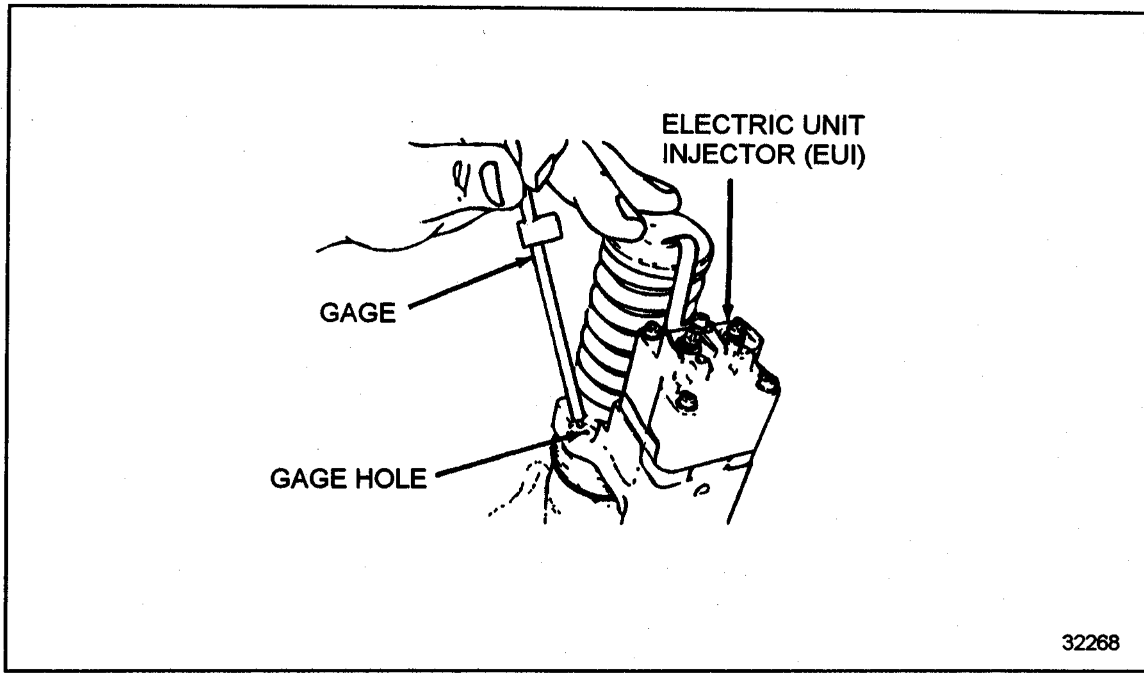



**Figure 12-3 Using Timing Gage on DDEC II, DDEC III, and DDEC IV**

| Components ‡ | Setting Dimensions | Tolerance † |
|---|---|---|
| FUEL INJECTOR HEIGHTS Models: 6067GT40, 6067WT40, 6067WU40,6067GU40, 6063WU00, 6063GU00,6067WU60, 6067GU60, 6067GU91 (All DDEC I and DDEC II / 1986 - 1993) | 78.2 mm (3.078 in.) Use tool J 35637-A | 77.95 - 78.45 mm (3.068 - 3.088 in.) |
| FUEL INJECTOR HEIGHTS Models: 6064TKXX, 6063TKXX, 6063EKXX, 606XGKXX, 606XWKXX, 606XSKXX (All DDEC III 1994-1997) | 78.8 mm (3.102 in.) Use tool J 39697 | 77.55 - 79.05 mm (3.092 - 3.112 in.) |
| FUEL INJECTOR HEIGHTS Models: 6067TKXX, 606XPKXX, 606XGKXX (1997-98 DDEC IV and later 1997 DDEC III) | 80.3 mm (3.161 in.) Use tool J 42665 | 80.05 - 80.55 mm (3.151 - 3.171 in.) |
| FUEL INJECTOR HEIGHTS Models: 6067EKXX, 606XBKXX, 606XMKXX, 606XLKXX, 606XHKXX, 606XFKXX (1998 & 1999 DDEC IV) | 81.0 mm (3.189 in.) Use tool J 42749 | 80.75 - 81.25 mm (3.179 - 3.199 in.) |
| INTAKE VALVE CLEARANCE | 0.203 mm (0.008 in.) | 0.127 - 0.280 mm (0.005 - 0.011 in.) |
| EXHAUST VALVE CLEARANCE - * "U" Models: 6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063XX00, (1986 - 1990 All DDEC I & Early DDEC II) | 0.508 mm (0.020 in.) | 0.432 - 0.584 mm (0.017 - 0.023 in.) |
| EXHAUST VALVE CLEARANCE - * "H" Models: 606XWUXX, 606XGUXX, 606XXKXX, (1991 - 1999 All DDEC IV, III and later DDEC II) | 0.660 mm (0.026 in.) | 0.584 - 0.736 mm (0.023 - 0.029 in.) |

*"H" valves have a machined identification ring above the valve lock groove. "U" valves do not. Refer to section 1.4 for valve identification.

† When setting injector heights or valve clearances, the component should be set to the "Setting Dimension" shown.

‡ XX Any character in these positions, set to the adjacent column.

**Table 12-2 Checking Tolerance Chart**

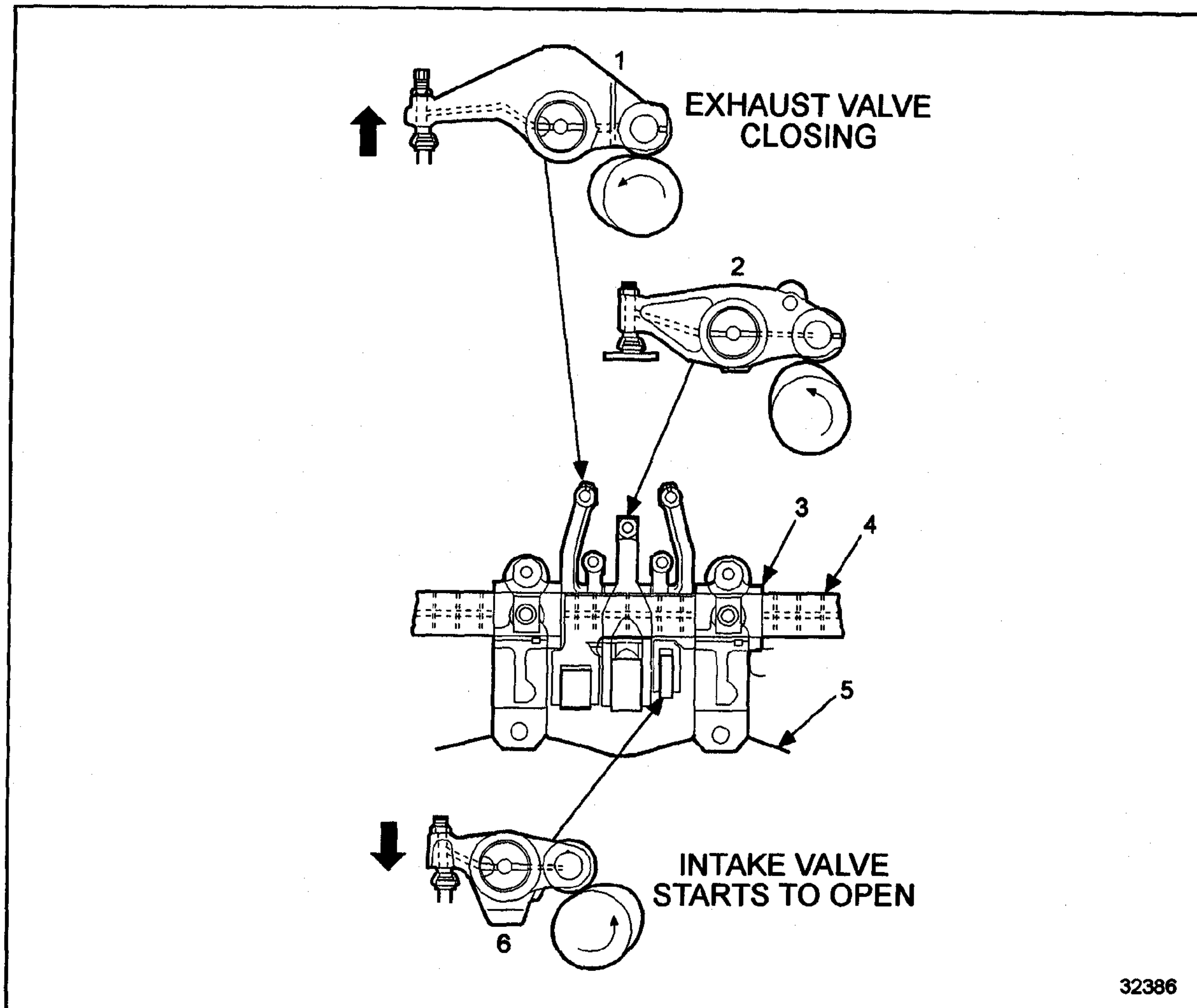
**NOTE:**

When setting valve lash clearance or injector height, always set them to the dimension listed in Table 12-2.

Adjust the valves and set the fuel injector heights as follows:

1. Disconnect starting power for engine.
2. Remove the engine valve rocker cover as outlined. Refer to section 1.6.2for one-piece, refer to section 1.6.3 for two-piece rocker cover, and refer to section 1.6.5for three-piece rocker cover.
3. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley.
4. Bar the engine in the direction of rotation and observe the intake and exhaust valve rollers at any cylinder that is close to TDC (top dead center). See Figure 12-4. Choose a cylinder that has the exhaust valves almost completely closed. Just as the exhaust valves are closing, the intake valves will start to open. This is the valve overlap period.




1. Exhaust Valve Rocker Arm Assembly
2. Fuel Injector Rocker Arm Assembly
3. Camshaft
4. Rocker Arm Shaft
5. Cylinder Head
6. Intake Rocker Arm Assembly

**Figure 12-4 Valve Overlap Period**

5. Stop engine rotation at the time of valve overlap. Note which cylinder this is, and follow the sequence listed in Table 12-3 to correctly set valves and injector heights. The timing can be started with any cylinder in valve overlap.

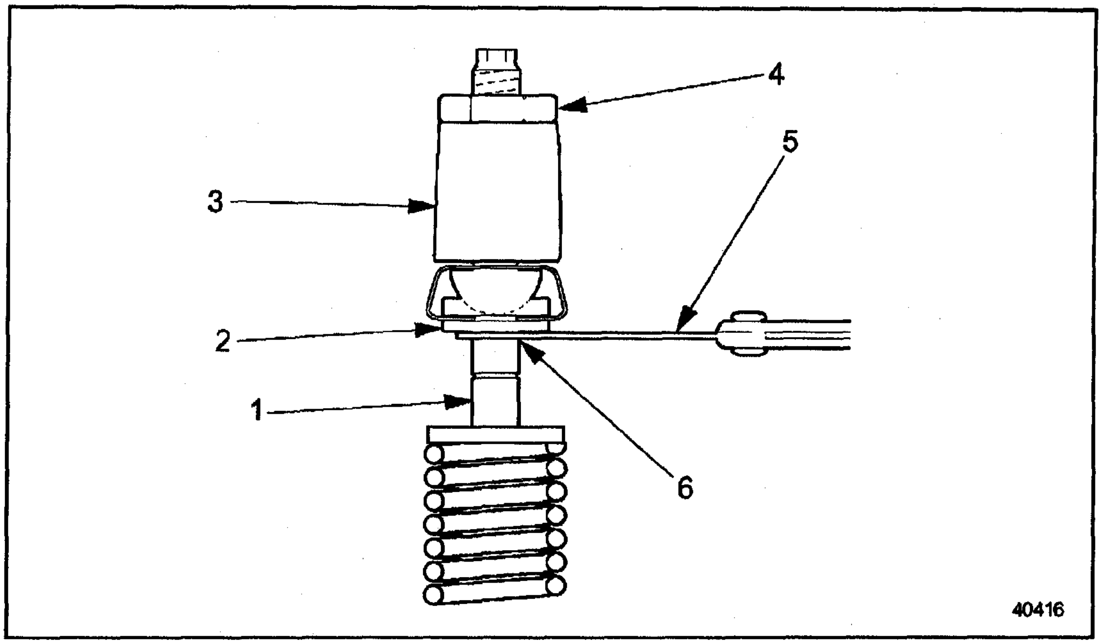
| Cylinder with Valve Overlap | Set Valves on Cylinder No. | Set Injector Height on Cylinder No. |
|---|---|---|
| 6 | 1 | 5 |
| 2 | 5 | 3 |
| 4 | 3 | 6 |
| 1 | 6 | 2 |
| 5 | 2 | 4 |
| 3 | 4 | 1 |

**Table 12-3 Valve Lash and Injector Height Adjustment Sequence**

**NOTICE:**

Never set the valves and injector of the same cylinder at the same time. Doing this will result in engine damage.

6. To adjust the intake valves, insert a 0.203 mm (0.008 in.) feeler gage between the tip of the valve stem and the valve button at the end of the rocker arm. See Figure 12-5.

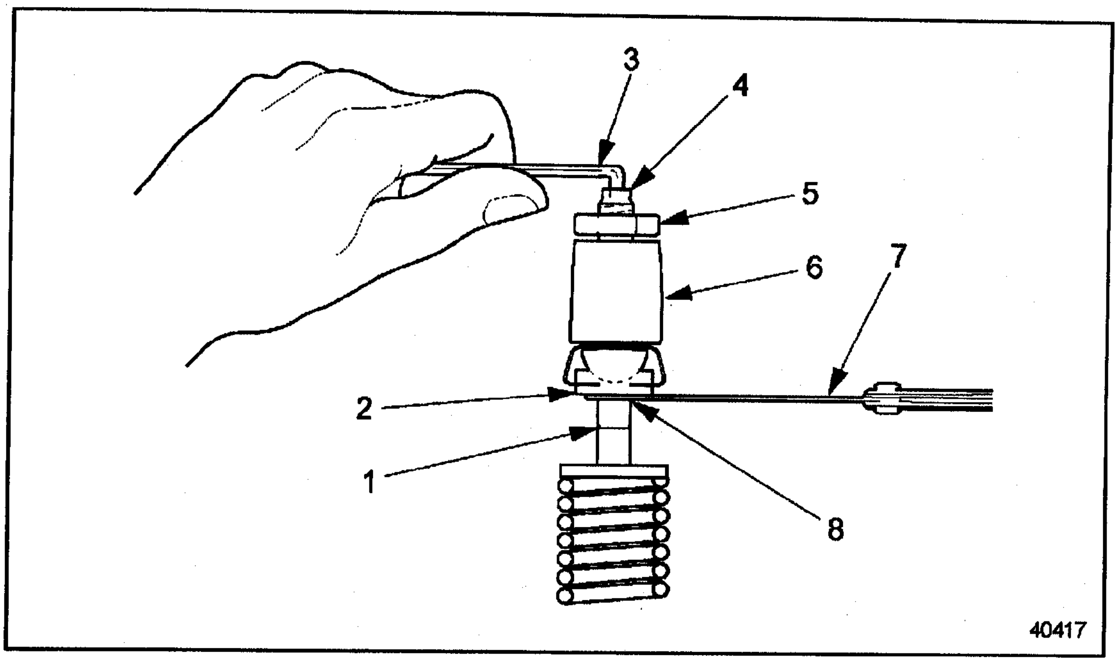



1. Intake Valve
2. Valve Button
3. Intake Rocker Arm Assembly
4. Locknut
5. Feeler Gage
6. Tip of Intake Valve

**Figure 12-5 Intake Valve Adjustment**

7. Loosen the locknut, and turn the adjusting set screw until the feeler gage produces an even smooth pull between the valve stem and valve button.
8. Torque the locknut to 41 - 47 N·m (30 - 35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.

9. The exhaust valves are adjusted the same way as the intake valves, except use a 0.660 mm (0.026 in.) feeler gage (1991 and later models only). Early models (pre-1991 models) use 0.508 mm (0.020 in.) feeler gage as listed in Table 12-2. See Figure 12-6.




1. Location of Identification Groove
2. Valve Button
3. Allen Wrench
4. Adjusting Screw
5. Locknut
6. Exhaust Rocker Arm Assembly
7. Feeler Gage
8. Tip of Exhaust Valve

**Figure 12-6 Exhaust Valve Adjustment**

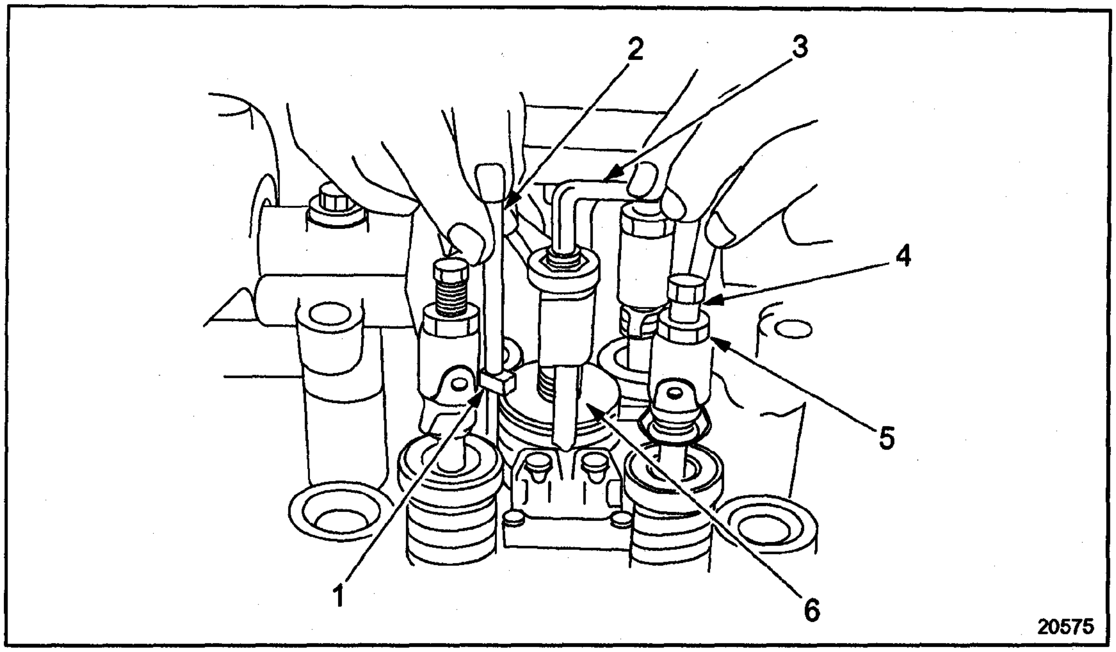
**NOTE:**
Effective with all 1991 model year engines, a change was made to the exhaust valve material which requires a different exhaust valve lash setting. Refer to section 1.4 for exhaust valve identification.

10. After each set of intake and exhaust valves is adjusted, adjust the corresponding injector listed in Table 12-3. Injector height settings and tools are listed in Table 12-2.

11. For natural gas applications the valves are adjusted the same way as on the diesel engine, except that a 0.036 in. (0.914 mm) feeler gage is used for exhaust valves and a 0.011 in. (0.279 mm) feeler gage is used for intake valves.

12. Adjust the fuel injector height for the engine models in parentheses by placing the small end of the height gage in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger. See Figure 12-3. The injector height settings for Series 60 engines are listed in Table 12-2.

13. Loosen the fuel injector rocker arm locknut and turn the adjusting set screw until the extended part (flag) of the gage will just pass over the top of the injector follower. An accurate "feel" will be developed. The objective is to adjust all six injectors to the same feel.
14. Torque the locknut to 41 - 47 N·m (30 - 35 lb·ft). Check the adjustment with the height gage and, if necessary, readjust the set screw. Remove the height gage. See Figure 12-7.




1. Height Gage Flag
2. Height Gage
3. Allen Wrench (3/16")
4. Set Screw
5. Locknut
6. Fuel Injector Follower

**Figure 12-7 Fuel Injector Height Adjustment**

15. Refer to the adjusting sequence listed in Table 12-3 and proceed to the next cylinder in the adjustment sequence.
16. Bar the engine over in the direction of normal rotation until the next cylinder in the adjustment sequence is in its valve overlap period.
17. Repeat the valve adjustment and fuel injector height adjustments procedures until all the valves and fuel injectors have been adjusted.
18. Replace the engine rocker cover.
19. Reconnect starting power to the engine.

### 12.2.1 Slave Piston Adjustment (Jake Brake® Lash)

Refer to information listed in Table 12-4 for the correct slave piston adjustment specification.

| NOTICE: |
| --- |
| The slave piston adjustment procedure must be strictly followed. Failure to use the proper adjustment procedure will result in poor engine brake performance, serious engine damage, or both. |

**NOTE:**
Slave piston clearance settings for the different engine models are not the same.

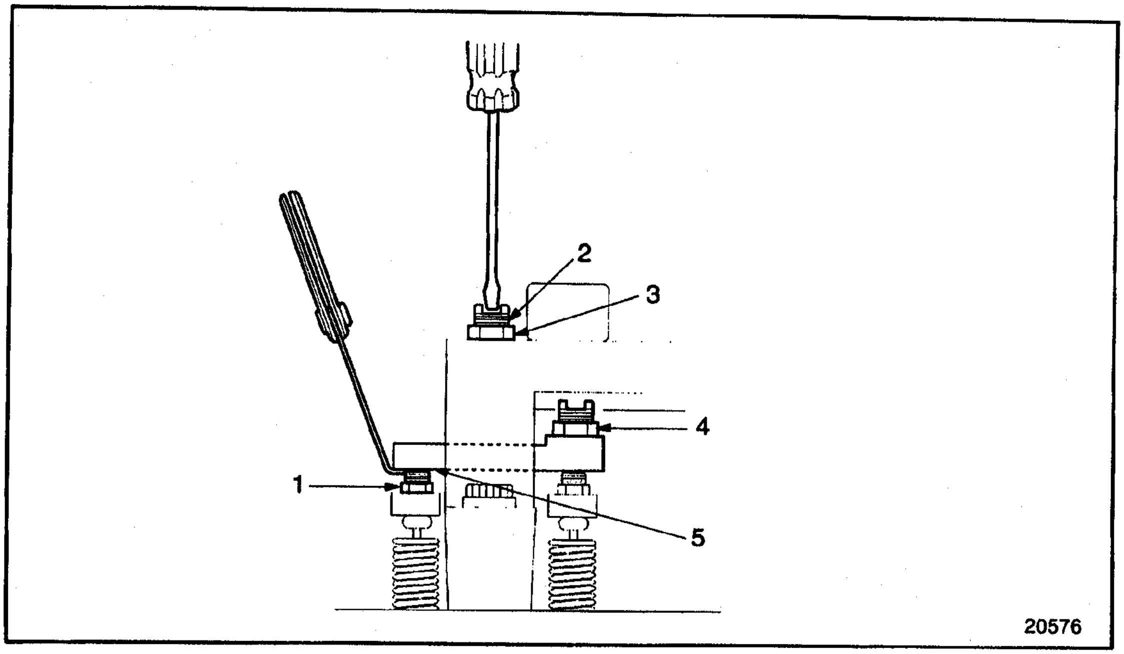
| MODEL NUMBER/DISPLACE-MENT/MODEL YEAR | ENGINE BRAKE | SLAVE PISTON ADJUSTMENT |
|---|---|---|
| 6067WU40 11.1L PRE - 1991 | 760/760A | 0.660 mm (0.026 in.) |
| 6067GU40 12.7L PRE - 1991 | 760/760A | 0.508 mm (0.020 in.) |
| 6067WU60 11.1L 1991 - 93 | 760A | 0.660 mm (0.026 in.) |
| 6067GU60 12.7L 1991 - 93 | 765 | 0.660 mm (0.026 in.) |
| 6067WK60 11.1L 1994 - 97 | 760A | 0.660 mm (0.026 in.) |
| 6067GK60 12.7L 1994 - 97 | 765 | 0.660 mm (0.026 in.) |
| 6067WK28 11.1L 1994 - 97 | 760A | 0.660 mm (0.026 in.) |
| 6067GK28 12.7L 1994 - 97 | 765 | 0.660 mm (0.026 in.) |
| 6067EK60 11.1L 1998 DDEC IV | 760B | 0.6584 mm (0.023 in.) |
| 6067PK60 12.7L 1998 DDEC IV | 765A | 0.6584 mm (0.023 in.) |
| 6067TK60 12.7L 1998 DDEC IV | 765A | 0.6584 mm (0.023 in.) |
| 6067FK6X, 6067BK6X, 6067HK6X 14L 1999 DDEC IV | 770 | 0.6584 mm (0.023 in.) |
| 6067MK6X 12.7L 1999 DDEC IV | 770 | 0.6584 mm (0.023 in.) |
| 6067LK6X 11.1L 1999 DDEC IV | 760B | 0.6584 mm (0.023 in.) |
| 6067MK28, 6067MK45, 6067MK57, 6067MK60 — 12.7L Standard — 2000 | 790 | 0.660 mm (0.026 in.) |
| 6067BK28, 6067BK45, 6067BK57, 6067BK60 — 12.7L Premium – 2000 | 790 | 0.660 mm (0.026 in.) |
| 6067HK45, 6067HK60 — 14L U.S. — 2000 | 790A | 0.660 mm (0.026 in.) |
| 6067WK28, 6067WK60 — 11.1L — 2000 | 790B | 0.660 mm (0.026 in.) |
| 6067LK28, 6067LK45, 6067LK60 — 11.1L — 2000 | 790B | 0.660 mm (0.026 in.) |
| 6063GK60, 6067GK28, 6067GK45, 6067GK91, 6067PK62, 6067TK28, 6067TK60, 6067TK62 — 12.7L — 2000 | 790B | 0.660 mm (0.026 in.) |
| 6067HK62 — 14L Australian — 2000 | 790C | 0.660 mm (0.026 in.) |

X= Any digit.

**Table 12-4 Jake Brake® Models and Slave Piston Settings**

**NOTE:**
Make the following adjustment with the engine stopped and cold with oil temperature 140°F (60°C) or below. The exhaust valves on the cylinder to be adjusted must be in the closed position (rocker arm loose).

1. Back out the bridge leveling screw in the slave piston assembly until the end of the screw is beneath the surface of the bridge in the slave piston assembly. See Figure 12-8.




1. Rocker Arm Adjusting Screw and Locknut
2. Slave Piston Adjusting Screw
3. Locknut
4. Bridge Leveling Screw Locknut
5. Bridge

**Figure 12-8 Adjusting Slave Piston Screw**

2. Place the required feeler gage listed in Table 12-4 between the solid side of the bridge (the side without the leveling screw) and the exhaust rocker arm adjusting screw.

**NOTE:**

**The slave piston adjusting screws used in the Series 60 engine brake prior to August 1994 were reset screws. Reset screws are not to be dissembled in the field. Effective with August 1994 engines, reset screw assemblies were replaced with Power-Lash® assemblies.**

*Power-Lash® is a registered trademark of Jacobs Vehicle Systems™.*

3. Turn the slave piston adjusting screw clockwise until a light drag is felt on the feeler gage.
4. Hold the screw in this position and torque the locknut to 34 N·m (25 lb·ft). Remove the feeler gage.

5. Place the feeler gage from step 4 between the leveling screw and the rocker arm adjusting screw. Turn the leveling screw clockwise until a light drag is felt on the feeler gage. See Figure 12-9.

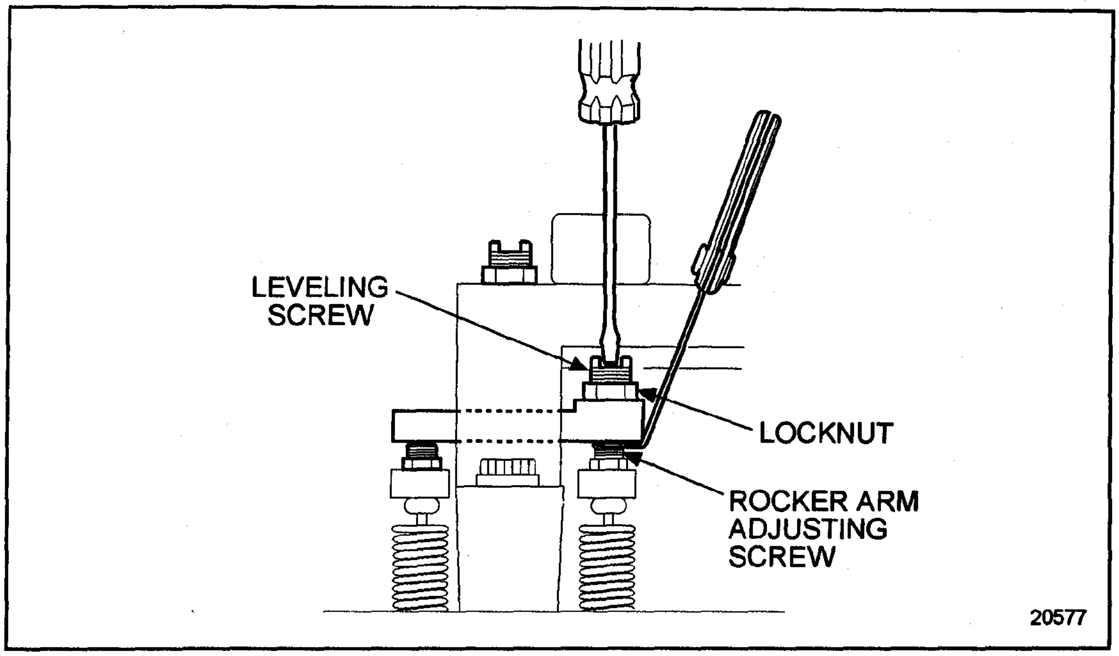



**Figure 12-9 Adjusting Leveling Screw**

6. Hold the leveling screw in this position and torque the locknut to 47 N·m (35 lb·ft).
7. Repeat the adjustment procedures in steps 1 through 6 for the remaining cylinders. Rotate the engine when necessary to put the exhaust valves in the closed position for slave piston adjustment.

## 12.3 ENGINE TUNE-UP PROCEDURES FOR THE SERIES 60G ENGINE

The Series 60G engine is equipped with Detroit Diesel Electronic Controls (DDEC III/IV).

The tune-up procedure for the Series 60G engine consists of intake and exhaust valve clearance adjustments and spark plug replacement. These procedures should be performed with the engine cold. See Figure 12-10 for the gas turbocharger compressor inlet shield.

**CAUTION:**

**To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.**

**CAUTION:**

**To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.**

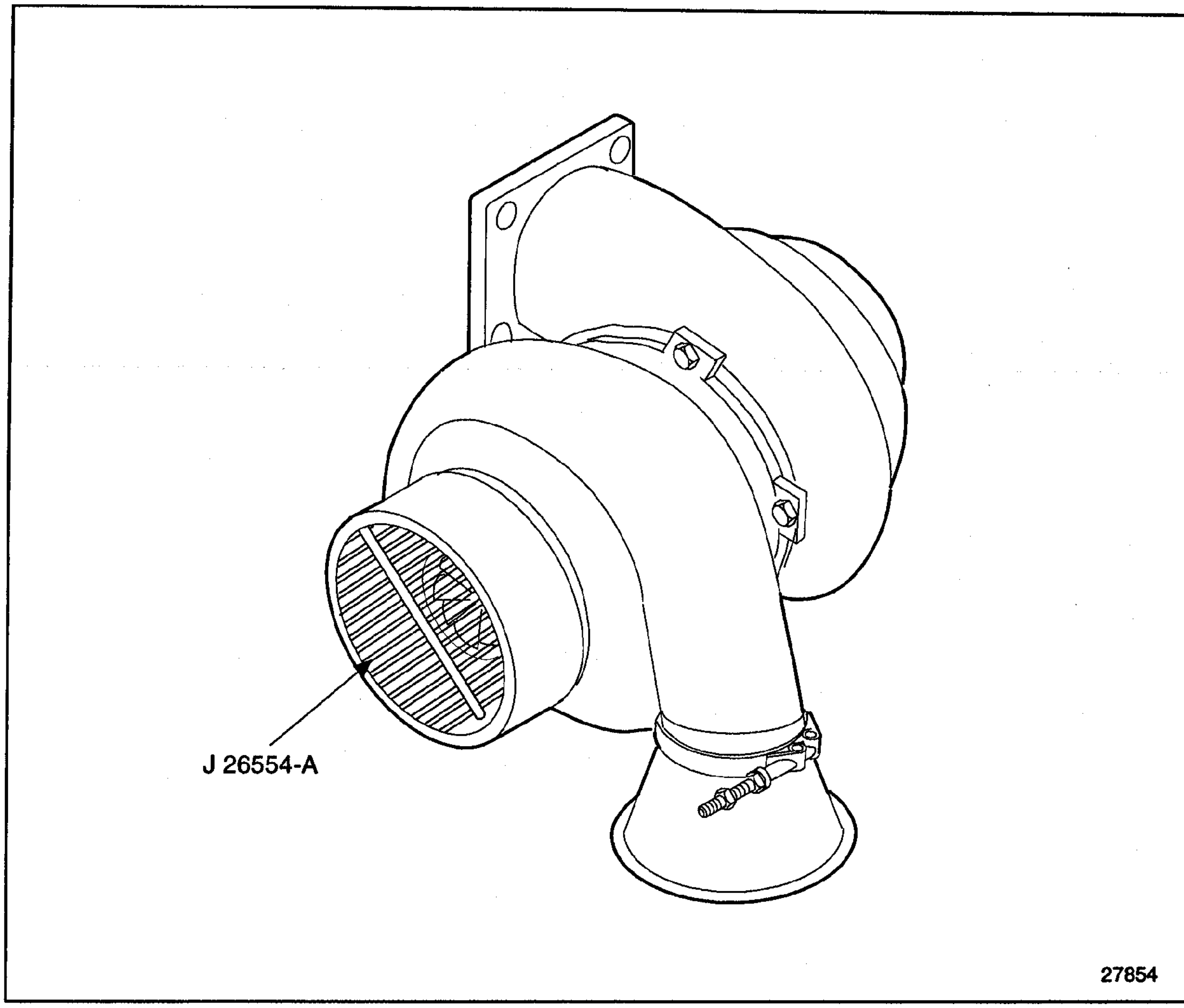



**Figure 12-10 Turbocharger Compressor Inlet Shield (Series 60G Engine)**

## 12.4 VALVE LASH FOR THE SERIES 60G ENGINE

Accurate adjustment of the clearance between the valve buttons and the intake and exhaust valves is important if maximum performance and economy are to be obtained.

Intake and exhaust valve clearance are adjusted by an adjusting set screw and locknut located at the valve end of the rocker arm. See Figure 12-11.

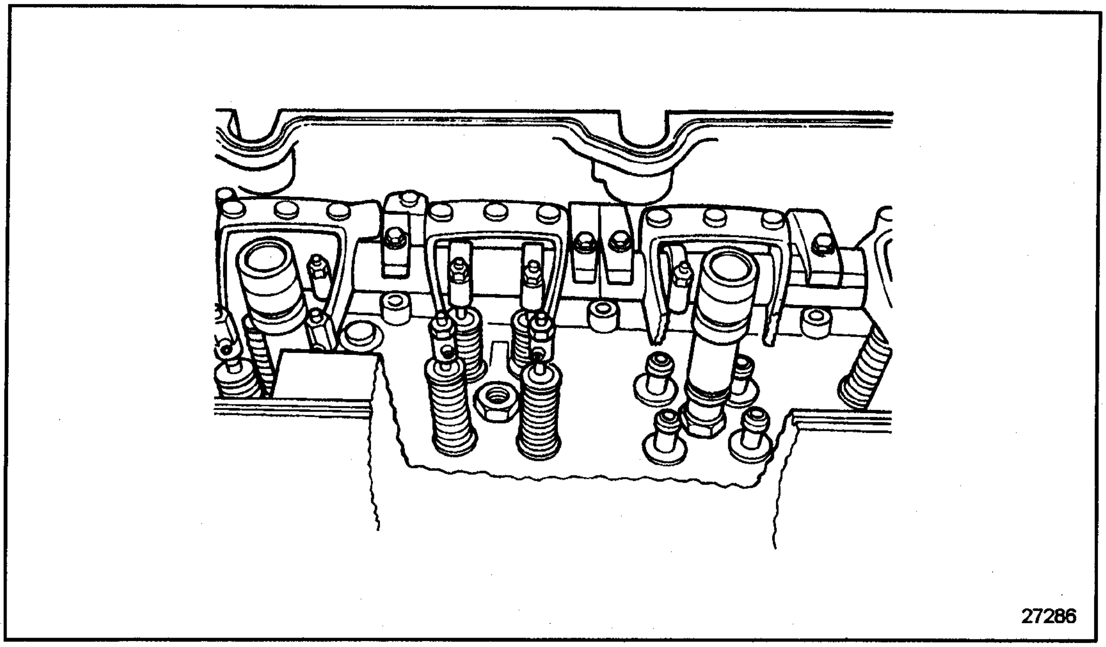



**Figure 12-11 Valve Height Adjustment Components for the Series 60G Engine**

Bar the engine over clockwise until one of the cylinders has the intake and exhaust cam follower rollers on the base circle of the camshaft. Adjust all four valves at this position. Continue barring the engine over until the next cylinder is in position. Follow the timing valve circle chart until all of the valves have been adjusted. See Figure 12-12.

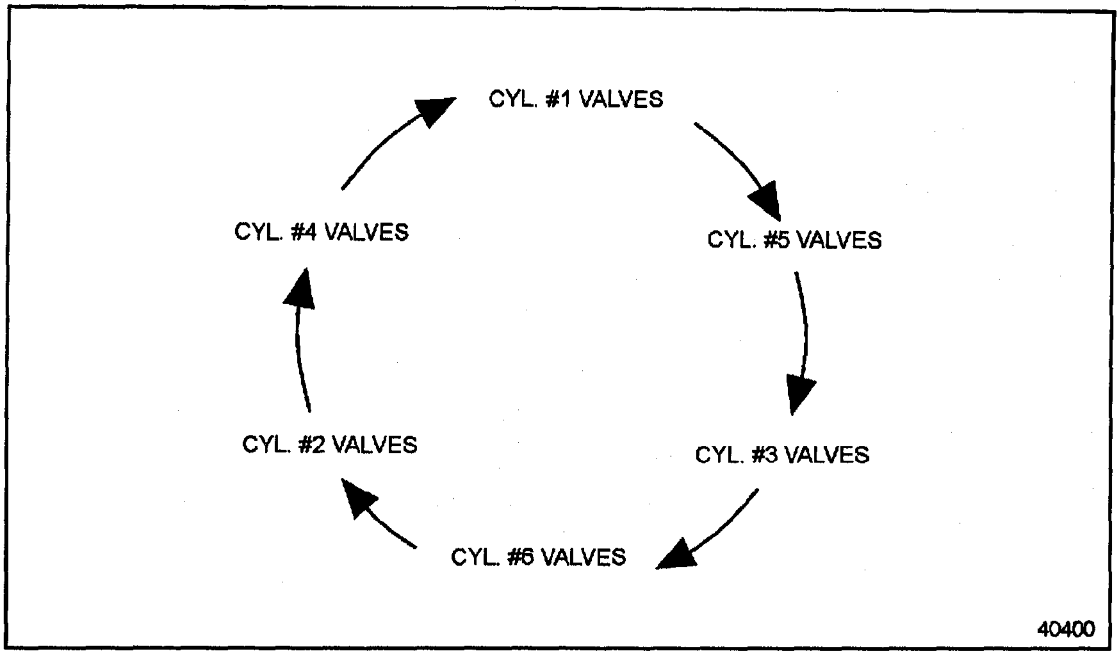


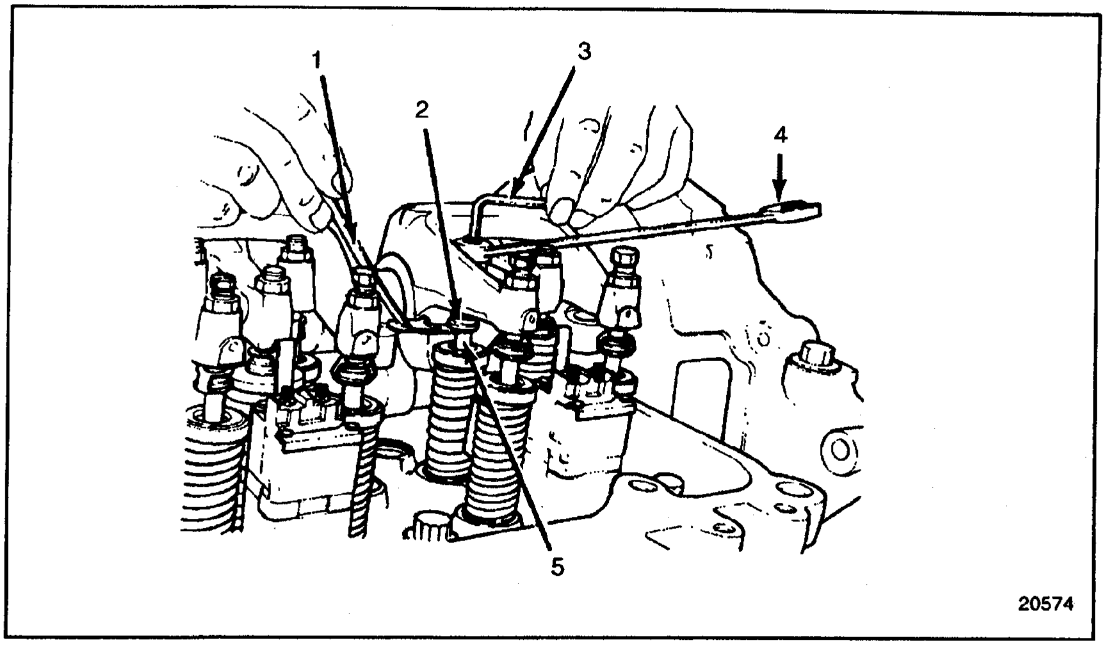

**Figure 12-12 Timing Circle Chart for the Series 60G Engine**

1. Disconnect starting power for the engine.
2. Remove the spark plug boots from the connection on the rocker cover.
3. Remove the engine valve rocker cover; refer to section 1.6.
4. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley. Bar the engine over until both the intake and exhaust cam rollers are on the base circle of the camshaft. Stop engine rotation.

**NOTE:**
The cylinder number.

5. See Figure 12-12 and locate the cylinder. The timing circle can be started with any cylinder. Ensure the circle is completed to set all valves.

6. To adjust the intake valves, insert a 0.279 mm (0.011 in.) feeler gage between the tip of the valve stem and the valve button at the end of the rocker arm. See Figure 12-13.




1. Feeler Gage
2. Valve Button
3. Allen Wrench (3/16 in.)
4. Wrench (9/16 in.)
5. Intake Valve Stem

**Figure 12-13 Valve Clearance Adjustment Series 60G Engines**

7. Loosen the locknut, and turn the adjusting set screw until the feeler gage produces an even or smooth pull between the valve stem and the valve button.
8. Torque the locknut to 41-47 N·m (30-35 lb·ft), and remove the feeler gage. Insert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.
9. The exhaust valves are adjusted the same way as the intake valves, except that a 0.914 mm (0.036 inch.) feeler gage is used.
10. Complete the adjustment of all four valves (two intake, two exhaust) for that cylinder before proceeding to the next step.
11. See Figure 12-12 and note the cylinder number, in parentheses, directly under the cylinder that just received the valve adjustment.

# 13 PREVENTIVE MAINTENANCE

**Section** **Page**

## 13.1 MAINTENANCE OVERVIEW

The lubrication and preventive maintenance schedule is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from the Series 60 engine. The intervals indicated are time or miles of actual operation.

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under "Preparation for a First Time Start." Refer to section 11.1.

The daily maintenance of Series 60 engines is the same for all applications. Refer to section 13.2. Periodic maintenance of Series 60 engines is dependent on the application. For engines installed in stationary and industrial applications, refer to section 13.6. For engines installed in vehicles, refer to section 13.5.

## 13.2 DAILY MAINTENANCE - ALL APPLICATIONS

The following items need to be inspected, serviced, corrected or replaced on a daily basis, as necessary:

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Fuel tank, refer to section 13.13.2
- ☐ Fuel lines and flexible hoses, refer to section 13.13.3
- ☐ Cooling system, refer to section 13.13.4
- ☐ Turbocharger, refer to section 13.13.8

## 13.3 DAILY MAINTENANCE - MARINE APPLICATIONS

The following items need to be inspected, serviced, corrected or replaced on a daily basis, as necessary:

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Fuel tank, refer to section 13.13.2
- ☐ Fuel lines and flexible hoses, refer to section 13.13.3
- ☐ Cooling system, refer to section 13.13.4
- ☐ Turbocharger, refer to section 13.13.8
- ☐ Marine gear oil level, refer to section 13.13.31

## 13.4 MAINTENANCE OF MARINE ENGINES

Marine engine components must be maintained at various intervals.

### 13.4.1 Fuel Cooler

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.36.

- ☐ Every 400 hours — Remove, clean, inspect.
- ☐ Every 4 years — Replace.

### 13.4.2 Fuel Injectors

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.37.

- ☐ Every 1,000 hours — Replace on pleasure craft marine engine.
- ☐ Every 5,000 hours — Replace on commercial marine engine.

### 13.4.3 Vibration Damper

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.38.

- ☐ Replace at time of engine overhaul.

### 13.4.4 Heat Exchanger

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.35.

- ☐ Every 400 hours or 2 years (whichever comes first) — Clean and flush.
- ☐ Every year— Check low coolant level sensor operation.

### 13.4.5 Charge Air Cooler — Keel-Cooled Engine

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.34.

- ☐ Every 5000 hours or 1 year (whichever comes first) — Clean and flush.

### 13.4.6 Raw Water System Zincs

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.32.

- ☐ After the first 60 hours — Inspect for cavitation.
- ☐ Every 200 hours or 1 year (whichever comes first) — Inspect and replace on pleasure craft marine engine.
- ☐ Every 5000 hours or 1 year (whichever comes first) — Inspect and replace commercial marine engine.

### 13.4.7 Marine Gear

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.31.

- ☐ Every 1000 hours — Replace gear oil and filter.
- ☐ Every 1000 hours — Check mounting bolts and pads and retighten or replace.
- ☐ Every 800 hours or 4 years (whichever comes first) — Replace gear oil cooler on pleasure craft marine.
- ☐ Every 10,000 hours or 4 years (whichever comes first) — Replace gear oil cooler on commercial marine engine.

### 13.4.8 Valve Lash and Injector Height

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 1.3.

- ☐ After the first 1500 hours — Check and reset, if required.

### 13.4.9 Crankcase Breather (in valve rocker cover)

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.29.

- ☐ Every 1000 hours — Remove, clean.

### 13.4.10 Thermostats and Seals

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.27.

- ☐ Every 400 hours or 2 years (whichever comes first) — Replace on pleasure craft marine engine.
- ☐ Every 10,000 hours or 2 years (whichever comes first) — Replace on commercial marine engine.

### 13.4.11 Engine Mounts

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.24.

- ☐ Every 1000 hours — Check and retighten.

### 13.4.12 Air Separator Filter Element and Vacuum Limiter

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.14.

- ☐ Every 250 hours — Clean and re-oil.
- ☐ Every 10,000 hours — Replace.

### 13.4.13 Water Pump

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.5.

- ☐ Every 100 hours or 6 months (whichever comes first) — Inspect drain hole for plugging.

### 13.4.14 Fuel Filters

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.14.

- ☐ Every 250 hours — Replace Spin-on primary and secondary fuel filters on heat exchanger-cooled pleasure craft marine engine.
- ☐ Every 250 hours — Replace Sea Pro 150 or 300 primary fuel filters and secondary spin-on filter on heat exchanger-cooled pleasure craft marine engine.
- ☐ When fuel level reaches top of element in see-thru cover — Replace element in Sea Pro 152 primary filter.
- ☐ Every 150 hours — Replace spin-on primary and secondary filter on keel-cooled commercial marine engines.
- ☐ Every 150 hours — Replace Sea Pro 150 or 300 primary fuel filters on keel-cooled commercial marine engines.

### 13.4.15 Lube Oil Filters

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.13.

- ☐ Every 250 hours — Replace Spin-on lube oil filters on heat exchanger-cooled marine engine.

### 13.4.16 Air Cleaner

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.12.

- ☐ Every 150 hours — Inspect element and clean or replace, as required.

### 13.4.17 Battery

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.9.

- ☐ Every month — Inspect for charge.

### 13.4.18 Engine Coolant

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.16.

- ☐ Every 250 hours or 3 months — Test nitrite concentration and add supplemental coolant additives or dilute, as required.
- ☐ Every 4000 hours or 2 years — If installed, replace the required mix of Power Cool 3000 and water, or a 50/50 mix of Power Cool fully formulated ethylene glycol antifreeze and water, or a 50/50 mix of fully formulated propylene glycol and water. Drain, clean, and flush system before refill.
- ☐ Every 10,000 hours or 4 years — If installed, replace required mix of Power Cool Plus 6000 and water, or replace Power Cool Plus Marine antifreeze/water premix solution. Drain, clean, and flush system before refill.
- ☐ At engine overhaul — If installed, replace a 50/50 mix of phosphate-free TMC RP — 329 "Type A" (IEG) or TMC RP — 330 "Type A" (IPG) antifreeze and water. Drain, clean, and flush system before refill.
- ☐ Every 8000 hours or 6 years — If installed, replace 50/50 mix of NOAT coolant and water. Drain, clean, and flush system before refill.

### 13.4.19 Cooling System

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.4.

- ☐ Every 500 hours — Inspect hoses. Replace, if required.

### 13.4.20 Fuel System

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 2.

- ☐ Every 500 hours — Inspect hoses, except fire-resistant. Replace, if required.
- ☐ Every 1000 hours — Inspect fire-resistant hoses. Replace, if required.

### 13.4.21 Hoses

The component must be inspected, serviced, corrected or replaced as necessary at the given interval. Refer to section 13.13.3.

- ☐ Every 5 years — Replace.

## 13.5 MAINTENANCE OF VEHICLE ENGINES

Vehicle engine components must be maintained at various intervals.

### 13.5.1 7,500 Miles (12,000 km) Interval Maintenance

Every 7,500 miles (12,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to section 13.13.9
- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11

### 13.5.2 15,000 Miles (24,000 km) or 6 Month Interval Maintenance

Every 15,000 miles (24,000 km) or 6 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air cleaner, refer to section 13.13.12

Likewise, the following components must be replaced every 15,000 miles (24,000 km) or 6 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.3 30,000 Miles (48,000 km) or 12 month Interval Maintenance

Every 30,000 miles (48,000 km) or 12 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Battery charging alternator, refer to section 13.13.23

Likewise, the following components must be replaced every 30,000 miles (48,000 km) or 12 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.4 45,000 Miles (72,000 km) or 18 Month Interval Maintenance

Every 45,000 miles (72,000 km) or 18 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 45,000 miles (72,000 km) or 18 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.5 60,000 Miles (97,000 km) or 24 Month Interval Maintenance

Every 60,000 miles (97,000 km) or 24 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Cooling system, refer to section 13.13.4
- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Oil pressure, refer to section 13.13.22
- ☐ Engine tune-up, refer to section 13.13.30.
- ☐ Battery charging alternator, refer to section 13.13.23
- ☐ Engine and transmission mounts, refer to section 13.13.24
- ☐ Crankcase pressure, refer to section 13.13.25
- ☐ Thermostats and seals, refer to section 13.13.27
- ☐ Crankcase breather, refer to section 13.13.29

Likewise, the following components must be replaced every 60,000 miles (97,000 km) or 24 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.6 75,000 Miles (121,000 km) or 30 Month Interval Maintenance

Every 75,000 miles (121,000 km) or 30 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 75,000 miles (121,000 km) or 30 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.7 90,000 Miles (145,000 km) or 36 Month Interval Maintenance

Every 90,000 miles (145,000 km) or 36 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Battery charging alternator, refer to section 13.13.23

Likewise, the following components must be replaced every 90,000 miles (145,000 km) or 36 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.8 105,000 Miles (169,000 km) or 42 Month Interval Maintenance

Every 105,000 miles (169,000 km) or 42 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 105,000 miles (169,000 km) or 42 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.9 120,000 Miles (193,000 km) or 48 Month Interval Maintenance

Every 120,000 miles (193,000 km) or 48 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Cooling system, refer to section 13.13.4
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Oil pressure, refer to section 13.13.22
- ☐ Battery charging alternator, refer to section 13.13.23
- ☐ Engine and transmission mounts, refer to section 13.13.24
- ☐ Crankcase pressure, refer to section 13.13.25
- ☐ Fan Hub, refer to section 13.13.26
- ☐ Thermostats and seals, refer to section 13.13.27
- ☐ Crankcase breather, refer to section 13.13.29
- ☐ Engine Tune-up, refer to section 13.13.30

Likewise, the following components must be replaced every 120,000 miles (193,000 km) or 48 months.

- ☐ Drive belts, refer to section 13.13.10
- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.10 135,000 Miles (217,000 km) or 54 Month Interval Maintenance

Every 135,000 miles (217,000 km) or 54 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 135,000 miles (217,000 km) or 54 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.11 150,000 Miles (241,000 km) or 60 Month Interval Maintenance

Every 150,000 miles (241,000 km) or 60 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Drive belts, refer to section 13.13.10
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Battery charging alternator, refer to section 13.13.23

Likewise, the following components must be replaced every 150,000 miles (241,000 km) or 60 months.

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.5.12 200,00 Miles (321,000 km) or 4000 Hours Interval Maintenance

Every 200,000 miles (321,000 km) or 4000 hours, the following component must be replaced:

- ☐ Rocker cover-mounted breather assembly and seal for closed crankcase breather system, refer to section 13.13.29.

## 13.6 MAINTENANCE OF ENGINES USED IN STATIONARY AND INDUSTRIAL APPLICATIONS

Diesel engine components used in stationary and industrial applications must be maintained at various intervals.

### 13.6.1 100 Hours (3,000 Miles - 4,800 km) Maintenance

Every 100 hours (3,000 miles - 4,800 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to section 13.13.9
- ☐ Drive belts, refer to section 13.13.10

### 13.6.2 150 Hours (4,500 Miles - 7,200 km) Maintenance

Every 150 hours (4,500 miles - 7,200 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to section 13.13.11
- ☐ Air cleaner, refer to section 13.13.12

Likewise, the following components must be replaced every 150 hours (4,500 miles - 7,200 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.3 300 Hours (9,000 Miles - 14,500 km) Maintenance

Every 300 hours (9,000 miles - 14,500 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Battery charging alternator, refer to section 13.13.23

Likewise, the following components must be replaced every 300 hours (9,000 miles - 14,500 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.4 450 Hours (13,500 Miles - 21,700 km) Maintenance

Every 450 hours (13,500 miles - 21,700 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 450 hours (13,500 miles - 21,700 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.5 600 Hours (18,000 Miles - 29,000 km) Maintenance

Every 600 hours (18,000 miles - 29,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Oil pressure, refer to section 13.13.22
- ☐ Battery charging alternator, refer to section 13.13.23
- ☐ Engine and transmission mounts, refer to section 13.13.24
- ☐ Crankcase pressure, refer to section 13.13.25
- ☐ Thermostats and seals, refer to section 13.13.27
- ☐ Crankcase breather, refer to section 13.13.29

Likewise, the following components must be replaced every 600 hours (18,000 miles - 29,000 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.6 750 Hours (22,500 Miles - 36,000 km) Maintenance

Every 750 hours (22,500 miles - 36,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Cooling system, refer to section 13.13.4
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 750 hours (22,500 miles - 36,000 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.7 900 Hours (27,000 Miles - 43,500 km) Maintenance

Every 900 hours (27,000 miles - 43,500 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Battery charging alternator, refer to section 13.13.23

Likewise, the following components must be replaced every 900 hours (27,000 miles - 43,500 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.8 1,050 Hours (31,500 Miles - 50,700 km) Maintenance

Every 1,050 hours (31,500 miles - 50,700 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Fan Hub, refer to section 13.13.26

Likewise, the following components must be replaced every 1,050 hours (31,500 miles - 50,700 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.9 1,200 Hours (36,000 Miles - 58,000 km) Maintenance

Every 1,200 hours (36,000 miles - 58,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Oil pressure, refer to section 13.13.22
- ☐ Battery charging alternator, refer to section 13.13.23
- ☐ Engine and transmission mounts, refer to section 13.13.24
- ☐ Crankcase pressure, refer to section 13.13.25
- ☐ Thermostats and seals, refer to section 13.13.27
- ☐ Crankcase breather, refer to section 13.13.29

Likewise, the following components must be replaced every 1,200 hours (36,000 miles - 58,000 km).

- ☐ Lubricating oil, refer to section 13.13.1.
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

### 13.6.10 1,350 Hours (40,500 Miles - 65,000 km) Maintenance

Every 1,350 hours (40,500 miles - 65,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19

Likewise, the following components must be replaced every 1,350 hours (40,500 miles - 65,000 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

## 13.6.11 1,500 Hours (45,000 Miles - 72,000 km) Maintenance

Every 1,500 hours (45,000 miles - 72,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Cooling system, refer to section 13.13.4
- ☐ Air compressor, refer to section 13.13.11
- ☐ Air system, refer to section 13.13.18
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Engine (steam clean), refer to section 13.13.20
- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21
- ☐ Battery charging alternator, refer to section 13.13.23
- ☐ Engine tune-up, refer to section 13.13.30

Likewise, the following components must be replaced every 1500 hours (45,000 miles - 72,000 km).

- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Lubricating oil filter, refer to section 13.13.13
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Coolant filter and inhibitor, refer to section 13.13.16

## 13.6.12 4000 Hours

Every 4000 operating hours, the following component must be replaced:

- ☐ Rocker cover-mounted breather assembly and seal for closed crankcase breather system, refer to section 13.13.29.

## 13.7 MAINTENANCE OF SERIES 60 DIESEL ENGINES FOR GENERATOR SET

60 diesel genset components must be maintained at various intervals.

### 13.7.1 Daily Maintenance for Prime Diesel Genset

The following Prime genset components must be inspected daily: (Replace every 250 hours or three months, whichever comes first.)

**NOTE:**
Cranking motor, follow OEM recommendations.

- ☐ Battery, refer to section 13.13.9
- ☐ Drive belts, refer to section 13.13.10
- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Fuel tank, refer to section 13.13.2
- ☐ Cooling system, refer to section 13.13.4
- ☐ Air cleaner, refer to section 13.13.12
- ☐ Air system, refer to section 13.13.18
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Oil pressure, refer to 11.5

### 13.7.2 Monthly Maintenance for Standby Diesel Genset

The following Standby genset components must be inspected monthly: (Replace every 150 hours or one year, whichever comes first.)

- ☐ Battery, refer to section 13.13.9
- ☐ Lubricating oil, refer to section 13.13.1
- ☐ Fuel tank, refer to section 13.13.2
- ☐ Cooling system, refer to section 13.13.4
- ☐ Air cleaner, refer to section 13.13.12
- ☐ Air system, refer to section 13.13.18
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Oil pressure, refer to 11.5

Perform maintenance of lubricating oil, cooling system, fuel filters, water separator, and oil pressure at the time of Load Test. Load Test should be at least 35% of the unit's full rated output. Refer to generator set manufacturer's instructions.

### 13.7.3 150 hrs (or 2 months) Interval Maintenance for Genset

Every 150 hrs (or 2 months) the following components must be inspected:

- ☐ Battery, refer to section 13.13.9
- ☐ Drive belts, refer to section 13.13.10
- ☐ Air cleaner, refer to section 13.13.12
- ☐ Air system, refer to section 13.13.18
- ☐ Tachometer Drive, refer to section 8.5.3.1

### 13.7.4 300 hrs (or 4 months) Interval Maintenance for Genset

Every300 hrs (or 4 months) the following components must be inspected:

- ☐ Radiator and air-to-air charge cooler, refer to section 13.13.21

### 13.7.5 600 hrs (or 8 months) Interval Maintenance for Genset

Every 600 hrs (or 83 months) the following components must be inspected:

- ☐ Fuel tank, refer to section 13.13.2
- ☐ Fuel filter, refer to section 13.13.14
- ☐ Exhaust system, refer to section 13.13.19
- ☐ Battery charging alternator, refer to section 13.13.23
- ☐ Fuel lines and flexible hoses, refer to section 13.13.3
- ☐ Engine and transmission mounts, refer to section 13.13.24
- ☐ Crankcase pressure, refer to section 13.13.25
- ☐ Oil pressure, refer to 11.5

### 13.7.6 1000 hrs (or 13 months) Interval Maintenance for Genset

Every 1000 hrs (or 13 months) the following components must be inspected:

- ☐ Crankcase breather, refer to section 13.13.29
- ☐ Fan Hub, refer to section 13.13.26

### 13.7.7 1500 hrs (or 20 months) Interval Maintenance for Genset

Every 1500 hrs (or 20 months) the following components must be inspected:

- ☐ Engine tune-up, refer to section 13.13.30

### 13.7.8 2000 hrs (or 26 months) Interval Maintenance for Genset

Every 2000 hrs (or 26 months) the following components must be replaced:

- ☐ Fuel lines and flexible hoses, refer to section 13.13.3

Every 2000 hrs (or 26 months) the following components must be inspected:

- ☐ Engine (steam clean), refer to section 13.13.20

### 13.7.9 3000 hrs (or 39 months) Interval Maintenance for Genset

Every 3000 hrs (or 39 months) the following components must be inspected:

- ☐ Water pump, refer to section 13.13.5.

### 13.7.10 4000 hrs (or 52 months) Interval Maintenance for Genset

Every 4000 hrs (or 52 months) the following components must be replaced:

- ☐ Cooling system, refer to section 13.13.4
- ☐ Crankcase breather, refer to section 13.13.29
- ☐ Thermostats and seals, refer to section 13.13.27

## 13.8 MAINTENANCE OF SERIES 60G ENGINES FOR GENERATOR SET

60G genset components must be maintained at various intervals.

### 13.8.1 Daily Maintenance for Genset

The following components must be maintained daily:

- ☐ Lubricating oil, refer to 11.5
- ☐ Oil pressure, refer to 11.5
- ☐ Turbocharger, refer to 13.13.8
- ☐ Drive belts, refer to 13.13.10
- ☐ Fuel lines and hoses, refer to 13.13.3
- ☐ Intake system from air cleaner to intake manifold, refer to 13.13.28

### 13.8.2 250 hrs (or 3 months) Interval Maintenance for Genset

Every 250 hrs (or 3 months) the following components must be replaced:

- ☐ Lubricating oil, refer to 11.5
- ☐ Lube oil filter, refer to 13.13.13

Every 250 hrs (or 3 months), the following components must be maintained:

- ☐ Crankcase breather, refer to 13.13.29
- ☐ Drive belts, refer to 13.13.10
- ☐ Air cleaner, refer to 13.13.12
- ☐ Battery, refer to 13.13.9

### 13.8.3 500 hrs (or 6 months) Interval Maintenance for Genset

Every 500 hrs (or 6 months), the following components must be maintained:

- ☐ Crankcase pressure, refer to 13.13.25
- ☐ Coolant filter/inhibitor, refer to 13.13.16
- ☐ Charge air cooler, refer to 6.10
- ☐ Fan hub, refer to 13.13.26

### 13.8.4 1,000 hrs (or 12 months) Interval Maintenance for Genset

Every 1,000 hrs (or 12 months) the following components must be replaced:

- ☐ Air cleaner, refer to 13.13.12

Every 1,000 hrs (or 12 months), the following components must be maintained:

- ☐ Thermostat, refer to 13.13.27
- ☐ PSV valve, refer to 2.42
- ☐ Fuel lines and hoses, refer to 13.13.3
- ☐ Battery charging alternator, refer to 13.13.23
- ☐ Engine and generator mounts, refer to 13.13.24
- ☐ Radiator, refer to 13.13.21
- ☐ Exhaust system, refer to 13.13.19

### 13.8.5 1,500 hrs (or 12 months) Interval Maintenance for Genset

Every 1,500 hrs (or 12 months) the following components must be replaced:

- ☐ Spark plugs, refer to 15.7

Every 1,500 hrs (or 12 months) the following components must be maintained:

- ☐ Spark plug boots; inspect, refer to 13.8.3
- ☐ Valve lash; inspect/adjust, refer to 12.4

### 13.8.6 3,800 hrs (or 24 months) Interval Maintenance for Genset

Every 3,800 hrs (or 24 months) the following must be replaced:

- ☐ Coolant, refer to 13.13.4

Every 3,800 hrs (or 24 months), the following components must be maintained:

- ☐ Fuel mixer, refer to 2.46
- ☐ Vibration damper, refer to 1.12

## 13.9 LUBRICATING OIL AND FILTER CHANGE INTERVALS FOR GENSET

The following must be maintained at various intervals.

### 13.9.1 250 hrs (or 12 months) Interval Maintenance (Standby Duty)

Every 250 hrs (or 12 months), the following must be replaced for an engine on standby:

- ☐ Lubricating oil, refer to 11.5

### 13.9.2 250 hrs (or 3 months) Continuous Duty Interval Maintenance (Continuous/Prime Duty)

Every 250 hrs (or 3 months), the following must be replaced for a continuous/prime running engine:

- ☐ Lubricating oil, refer to 11.5

# 13.10 PREVENTIVE MAINTENANCE FOR THE SERIES 60G AUTOMOTIVE ENGINE (CITY TRANSIT COACH)

The following is a list of items that are unique to the Series 60G engine for preventive maintenance (city transit coach):

## 13.10.1 Coalescing Fuel Filters

Drain coalescing fuel filters daily. Replace natural gas fuel filter and seal every 6,000 miles (9,600 km). More frequent replacement required if large quantities of contaminants are present in the fuel.

## 13.10.2 Valve Lash

Check valve lash. Valve lash should be inspected and adjusted every 36,000 miles (58,000 km) as specified.

## 13.10.3 Closed Crankcase Breather System

The closed crankcase breather filter must be replaced every 6000 miles (9,600 km). The filter is located in the remote mounted crank vent assembly.

## 13.10.4 Dry-Type Air Cleaner

Under no operating condition should the intake restriction exceed 20 inches of water at full load and rated speed. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine. For equivalent restriction limits for lower speed, refer to Detroit Diesel Corporation Engineering Bulletin No. 39, "Air Cleaner Systems for Detroit Diesel Engines".

Inspect the air cleaner element every 12,000 miles (19,000 km) for coaches. Inspect the air cleaner more often if the engine is operated under severe dust conditions. Replace the element if necessary. Check the gaskets for deterioration and replace, if necessary. If the dry-type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean and repair as necessary.

## 13.10.5 Engine Lubricating Oil

Change the lubricating oil every 6,000 miles (9,600 km) for city transit coaches. (Refer to Engine Requirements - Lubricating Oil, Fuel and Filters - 7SE272).

## 13.10.6 Engine Lubricating Oil Filters

Change the lubricating oil filters at each oil change 6,000 miles (9,600 km) for city transit coaches).

## 13.10.7 Coolant

Check the coolant level daily before starting the engine. Ensure coolant is up to the proper level. Add coolant as necessary. DO NOT OVERFILL. Check all cooling system lines and hoses for damage, leaks or loose connections. Tighten or replace as necessary. (Refer to Coolant Selections for Detroit Diesel Engines 7SE298). Check for proper inhibitor level at each oil change (15,000 miles or 24,000 km) and add as required; or 6,000 miles (9,600 km) for coaches.

## 13.10.8 Turbocharger and Wastegate Assembly

Inspect turbocharger mountings, air intake and exhaust ducts, recirculation valve assembly, and wastegate valve assembly, including hoses, for leaks. Check the oil and water inlet and outlet lines and connections for leaks and restrictions to flow. Check for unusual vibrations or noises. If excessive, remove unit from service and have cause corrected.

### 13.10.9 Thermostat

Check thermostats and seals every 108,000 miles (173,800 km) for coach. Replace the seals and/or thermostat, if necessary.

### 13.10.10 Spark Plugs

Replace the spark plugs and boot spring assembly every 24,000 miles (38,600 km) for coach; see service manual for plug information, refer to section 15.7 and refer to section 15.3.

## 13.11 MAINTENANCE OF SERIES 60G AUTOMOTIVE ENGINES

Series 60G transit coach components must be maintained at various intervals.

### 13.11.1 6,000 Miles (10,000 km) Interval Maintenance for Transit Coach

Every 6,000 miles (10,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.2 12,000 Miles (19,000 km) Interval Maintenance for Transit Coach

Every 12,000 miles (19,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.3 18,000 Miles (29,000 km) Interval Maintenance for Transit Coach

Every 18,000 miles (29,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.4 24,000 Miles (39,000 km) Interval Maintenance for Transit Coach

Every 24,000 miles (39,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.
- ☐ Change spark plugs, inspect spring and boot assembly, refer to section 15.7.

### 13.11.5 30,000 Miles (48,000 km) Interval Maintenance for Transit Coach

Every 30,000 miles (48,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.6 36,000 Miles (58,000 km) Interval Maintenance for Transit Coach

Every 36,000 miles (58,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.
- ☐ Valve lash, refer to section 13.10.2.

### 13.11.7 42,000 Miles (68,000 km) Interval Maintenance for Transit Coach

Every 42,000 miles (68,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.8 48,000 Miles (77,000 km) Interval Maintenance for Transit Coach

Every 48,000 miles (77,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Change spark plugs, inspect spring and boot assembly, refer to section 15.7.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.9 54,000 Miles (87,000 km) Interval Maintenance for Transit Coach

Every 54,000 miles (87,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.10 60,000 Miles (97,000 km) Interval Maintenance for Transit Coach

Every 60,000 miles (97,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.11 66,000 Miles (106,000 km) Interval Maintenance for Transit Coach

Every 66,000 miles (106,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.12 72,000 Miles (116,000 km) Interval Maintenance for Transit Coach

Every 72,000 miles (116,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Valve lash, refer to section 13.10.2.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Change spark plugs, inspect boot and spring assembly, refer to section 13.10.10.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.13 78,000 Miles (126,000 km) Interval Maintenance for Transit Coach

Every 78,000 miles (126,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.14 84,000 Miles (135,000 km) Interval Maintenance for Transit Coach

Every 84,000 miles (135,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.15 90,000 Miles (145,000 km) Interval Maintenance for Transit Coach

Every 90,000 miles (145,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.16 96,000 Miles (154,000 km) Interval Maintenance for Transit Coach

Every 96,000 miles (154,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Change spark plugs, inspect boot and spring assembly, refer to section 13.10.10.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.17 102,000 Miles (164,000 km) Interval Maintenance for Transit Coach

Every 102,000 miles (164,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.18 108,000 Miles (174,000 km) Interval Maintenance for Transit Coach

Every 108,000 miles (174,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Valve lash, refer to section 13.10.2.
- ☐ Crankcase breather element, refer to section 13.10.3.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Thermostat, refer to section 13.10.9.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.19 114,000 Miles (183,000 km) Interval Maintenance for Transit Coach

Every 114,000 miles (183,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

### 13.11.20 120,000 Miles (193,000 km) Interval Maintenance for Transit Coach

Every 120,000 miles (193,000 km), the following components must be maintained:

- ☐ Primary and secondary coalescing filters and seals, refer to section 13.10.1.
- ☐ Engine lubricating oil, refer to section 13.10.5.
- ☐ Engine lubricating oil filter, refer to section 13.10.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to section 13.10.8.
- ☐ Dry-type air cleaner, refer to section 13.10.4.
- ☐ Coolant, refer to section 13.10.7.
- ☐ Change spark plugs, inspect boot and spring assembly, refer to section 13.10.10.
- ☐ Crank vent breather filter replaced, refer to section 13.10.3.

## 13.11.21 4,000 Hours Interval Maintenance

Every 4000 operating hours, the following component must be replaced:

- ☐ Rocker cover-mounted breather assembly and seal ring for closed crankcase breather system, refer to section 13.13.29.

## 13.12 LUBRICATING OIL AND FILTER CHANGE INTERVALS FOR GENSET (WITH HIGH SULFUR FUELS)

The following must be maintained at various intervals.

| NOTICE: |
|---|
| Operation with fuels having total sulfur greater than 32 ppm, on a mass basis, may result in engine damage, and is not recommended by Detroit Diesel Corporation. |

### 13.12.1 150 hrs (or 3 months) Interval Maintenance (Standby Duty)

Every 150 hrs (or 3 months), the following must be replaced for a engine on standby:

Fuel with total sulfur greater than 24 ppm, but less than 32 ppm.

- ☐ Lubricating oil, refer to 11.5

### 13.12.2 150 hrs (or 3 months) Interval Maintenance (Continuous/Prime Duty)

Every 150 hrs (or 3 months), the following must be replaced for a engine on continuous/prime:

Fuel with total sulfur greater than 24 ppm, but less than 32 ppm.

- ☐ Lubricating oil, refer to 11.5

### 13.12.3 200 hrs (or 6 months) Interval Maintenance (Standby Duty)

Every 200 hrs (or 6 months), the following must be replaced for an engine on standby:

Fuel with total sulfur greater than 17 ppm, but less than 24 ppm.

- ☐ Lubricating oil, refer to 11.5

### 13.12.4 200 hrs (or 3 months) Interval Maintenance (Continuous/Prime Duty)

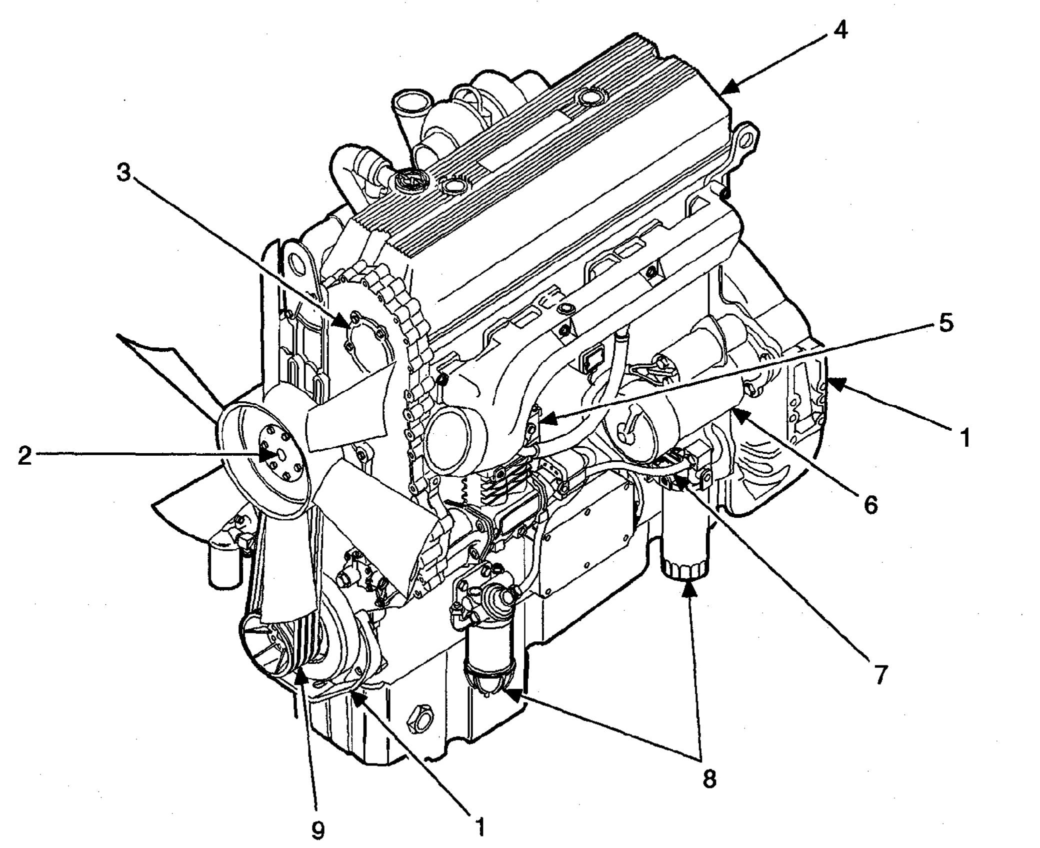
Every 200 hrs (or 3 months), the following must be replaced for a continuous/prime running engine:

Fuel with total sulfur greater than 17 ppm, but less than 24 ppm.

- ☐ Lubricating oil, refer to 11.5

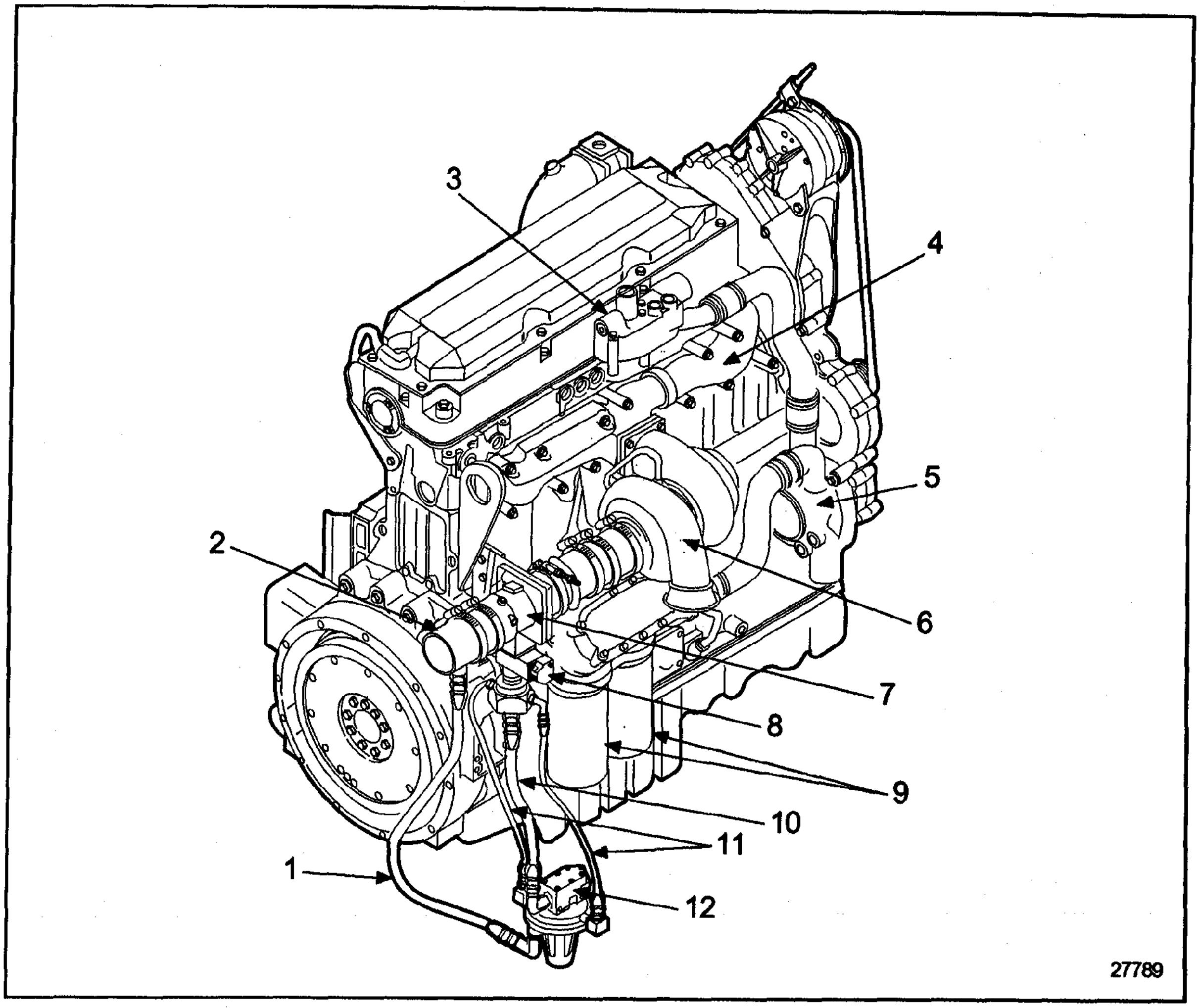
## 13.13 DESCRIPTION OF MAINTENANCE ITEMS

For locations of components and systems to be maintained, see Figure 13-1, see Figure 13-2and see Figure 13-3.



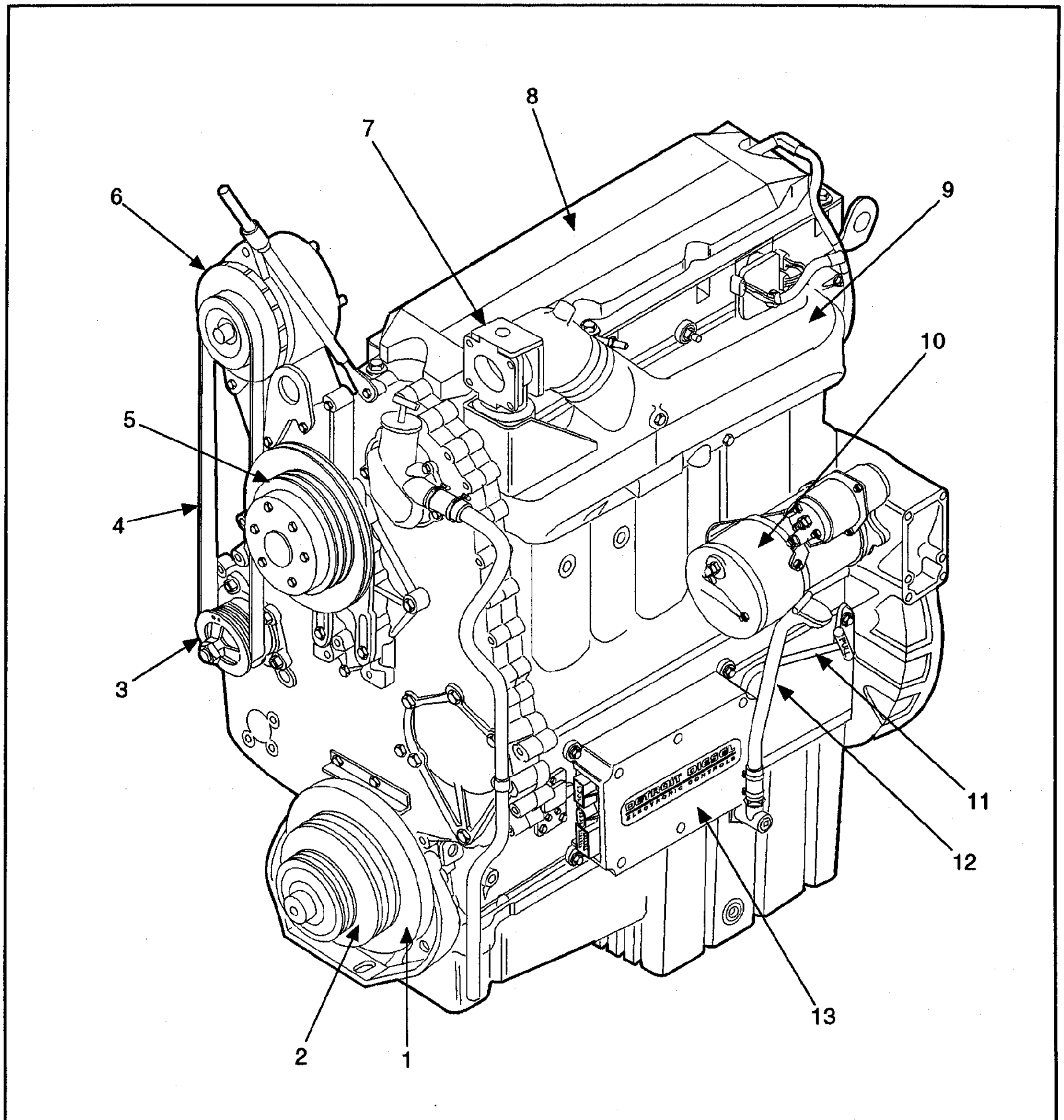

1. Engine Transmission Mounts
2. Fan Hub
3. Tachometer Drive
4. Rocker Cover
5. Air Compressor
6. Cranking Motor
7. Fuel Lines and Flexible Hoses
8. Fuel Filters
9. Drive Belts

**Figure 13-1 Preventive Maintenance Service Items (Diesel)**




1. Air Balance Hose
2. Air Inlet Tube
3. Thermostat Housing
4. Exhaust Manifold
5. Fresh Water Pump
6. Turbocharger
7. Fuel Mixer Assembly
8. Pulse Width Modulated Stepper Motor Valve (PSV)
9. Lube Oil Filters
10. Fuel Supply Hose
11. Fuel Balance Hoses
12. Low Pressure Regulator

**Figure 13-2 Preventive Maintenance Service Items (Natural Gas)**


8
7
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27790

1. Vibration Damper
2. Crankshaft Pulley
3. Accessory Drive Assembly
4. Alternator Drive Belt
5. Fan Pulley
6. Alternator
7. Throttle
8. Rocker Cover
9. Intake Manifold
10. Electric Starting Motor
11. Dipstick
12. Oil Filler
13. Electronic Control Module (ECM)

**Figure 13-3 Preventive Maintenance Service Items**

### 13.13.1 Lubricating Oil

Check the lubricating oil level with the engine stopped and the vehicle on level ground. If the engine has just been stopped and is warm, wait approximately ten minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as recommended to maintain the correct oil level on the dipstick. Refer to section 5.2.1.

**NOTE:**
Do not overfill. Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

Change the lubricating oil as follows:

1. Position the vehicle or equipment on level ground.
2. If the engine is cold, run it until it is warm.

| NOTICE: |
|---|
| When removing or installing a side plug, hold the flats of the insert with a 2 1/8 in., or larger, open end adjustable wrench to keep it from turning. If the insert is loosened, it may be necessary to remove the oil pan and retighten the nut to prevent a possible oil leak. |

3. Remove drain plug on the bottom of oil pan. Drain lube oil into a suitable container. *Always dispose of used lubricating oil in an environmentally responsible manner, according to state and/or federal (EPA) recommendations.*

**NOTE:**
If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily.

4. Coat drain plug(s) with Loctite® PT 7271 sealant (or equivalent). Install and torque to 45-56 N·m (33-41 lb·ft).

To replace the lube oil filters, perform the following procedure:

1. Remove the spin-on filter cartridges using J 29917, (or equivalent) and a 1/2 in. drive socket wrench and extension.
2. Dispose of the used oil and filters. *Always dispose of used oil and filters in an environmentally responsible manner, according to state and/or federal (EPA) recommendations.*
3. Clean the filter adaptor with a clean, lint-free cloth.
4. Lightly coat the filter gaskets (seals) with clean engine oil.
5. Start the new filters on the adaptor, and tighten by hand until the gaskets touch the mounting adaptor head.

**NOTE:**
Tighten full-flow filters an additional two-thirds turn by hand or refer to instructions on the replacement filter.

Add oil as required to bring the level to the FULL mark on the dipstick.

**NOTE:**
Engine oil capacity can vary, depending on the oil pan used and the engine application. For total oil capacity refer to the engine application manual or contact an authorized Detroit Diesel distributor.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

Start and run the engine for a short period, and check for leaks. After leaks have been corrected, stop the engine long enough for oil to drain back to the crankcase (approximately 20 minutes). Add oil as required to bring the level to the proper mark on the dipstick.

**NOTE:**

Do not overfill. Oil may be blown out through the crankcase breather if the crankcase is overfilled.

### 13.13.2 Fuel Tanks

Keep the fuel tank(s) filled to reduce the condensation to a minimum. Select the proper grade of fuel. Refer to section 5.1 for the fuel specifications that are **listed in Table** 5-1.

Open the drain at the bottom of the fuel tank every 30,000 miles - 48,000 km (300 hours for non-vehicle applications), to drain off any water and/or sediment.

Every 12 months or 60,000 miles - 96,000 km (600 hours for non-vehicle applications), whichever comes first, tighten all fuel tank mountings and brackets (refer to OEM maintenance guidelines). At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the flexible fuel lines. Repair or replace the parts as necessary (refer to OEM maintenance guidelines).

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organizations (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Condensation is particularly prevalent on units that stand idle for extended periods of time. Ambient temperature changes cause condensation in partially filled fuel tanks.

Units in storage are particularly susceptible to microbe growth. The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commercially available biocides. There are two basic types on the market:

- ☐ The water-soluble type treats only the tank where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.
- ☐ The diesel fuel-soluble type, such as Biobor® JF or equivalent, treats the fuel itself, and therefore, the entire fuel system.

*Biobor® is a registered trademark of United States Borax and Chemical Corporation.*

Any units that will sit idle for extended periods, or any units being stored, should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. The use of isopropyl alcohol (dry gas) is no longer recommended due to it's negative effect on fuel lubricity.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

### 13.13.3 Fuel Lines and Flexible Hoses

Make a visual check for fuel leaks at all engine-mounted fuel lines and connections, and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant, natural gas and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre-start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Ensure that hoses are not resting on or touching shafts, couplings, heated surfaces, including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary (refer to OEM maintenance guidelines).

Investigate leaks immediately to determine if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

**CAUTION:**

**To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.**

A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures and amount of flexing and vibration to which it is subjected. With this in mind, all hoses should be thoroughly inspected annually. Look for cover damage or indications of damaged, twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

**NOTICE:**

It is especially important that identical DDC replacement hoses be used on the Series 60G engine. The fuel line from the regulator to the PSV and air/fuel balance lines are precisely specified in terms of material, diameter and length. Incorrect substitution of these hoses can lead to poor performance and possible engine damage.

All hoses in or out of machinery should be replaced during major overhaul or after a maximum of five years service.

The final fuel regulator on the Series 60G engine does not require any adjustment or maintenance and is replaced as a complete assembly.

### 13.13.4 Cooling System

Check the coolant level daily. Ensure it is within 2 in. (50 mm) of the filler neck on the radiator or heat exchange filler bottle r or per the recommendation of the equipment manufacturer. Add recommended coolant, as necessary. Refer to section 5.4. **Do not overfill.**

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the engine during periods when the engine is running and when the engine is stopped.

**NOTE:**
In order to ensure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system (103-138 kPa, 15-20 $lb/in.^2$) using radiator cap and J 24460-01. Do not exceed 138 kPa (20 $lb/in.^2$). Any measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any internal coolant system leaks.

**CAUTION:**

**To avoid injury when using caustic cleaning agents, follow the chemical manufacturers usage, disposal, and safety instructions.**

Clean the cooling system every 24 months using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then fill the system with the proper anti-freeze/water mixture and pre-charge of inhibitors. When a thorough cleaning of the cooling system is required, it should be flushed.

Inspect all of the cooling system hoses at least once every 30,000 miles (48,000 km) (300 hours for industrial and marine applications) to ensure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses, if necessary. Refer to OEM maintenance guidelines.

Drain the engine coolant as follows:

1. Allow engine to cool.

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

2. Remove drain plugs from the bottom of water pump, at the right rear of the engine, and at the bottom of the thermostat housing.
3. Remove radiator or heat exchanger tank pressure cap.
4. Open drain valve at bottom of radiator or charge air cooler.
5. Collect used antifreeze in a suitable container, and dispose of the solution in an environmentally responsible manner, according to state and federal (EPA) recommendations.
6. Replace all drain plugs, and close any drain valves.
7. Refill the system with proper antifreeze and clean soft water mixture.
8. Purge entrapped air by allowing the engine to warm-up without the pressure cap installed. With the transmission or marine gear in neutral, increase engine speed above 1000 r/min. Add coolant as required.
9. Allow engine to cool.
10. Install the pressure cap after filling the coolant level to the bottom of the radiator or heat exchanger filler bottle neck.

If the cooling system is contaminated, flush the cooling system as follows:

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

1. Drain the coolant from the engine.

**NOTICE:**

If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

2. Refill with soft clean water.
3. Refer to section 13.13.1 for the exhaust caution before preceeding. Start the engine and operate it for 15 minutes after the thermostats have opened to thoroughly circulate the water.
4. Stop the engine and drain the unit completely.
5. If the engine is hot, refill slowly with clean water and operate for 15 minutes after the thermostats have opened.
6. Drain the unit completely.
7. If the engine is hot, fill slowly with 50/50 antifreeze water and pre-charge of inhibitor or required coolant and inhibtor. Refer to section 5.4.
8. Purge entrapped air by allowing the engine to warm-up without the pressure cap installed. With the transmission or marine gear in neutral, increase engine speed above 1000 r/min. Add coolant as required.
9. Allow engine to cool.
10. Install the pressure cap after filling the coolant level to the bottom of the radiator or heat exchanger filler neck.

### 13.13.5 Guidelines for Water Pump Replacement

The investigation of engine water pumps returned to the factory has, in many cases, revealed normal weepage from the water pump weep hole. This condition is often misdiagnosed as a water pump seal failure. The diagnostic procedure that follows is used to determine if the engine water pump seal has failed or is functioning normally. Guidelines are also presented for the steps that should be taken prior to water pump replacement.

#### 13.13.5.1 Source of Premature Failure of Water Pump Seals

Water pump seal failures may result from debris or deposits at the seal surface, low coolant levels, improper coolant chemicals or fabrication defects. Fabrication defects are quickly evident at low mileage/engine hours, while failures caused by debris or deposits at the seal surface appear over the service life of the pump. Premature failure of the water pump seal is typically an indication of poor coolant and lubricating oil maintenance.

Improper coolant maintenance can lead to excess supplemental coolant additives (SCA) in the coolant. This can cause excess phosphorus and silicates to precipitate within the cooling system. Deposits can build up between the shaft and the seal, causing a leak path or an abrasive effect on the seal face. Coolant formulated with hard water can also result in excess magnesium and calcium precipitation, with the same effect on the water seal. For additional information on the effects of inadequate cooling system maintenance, see DDC publication, 7SE390, *Cooling System Technician's Guide,* "available from authorized Detroit Diesel distributors.

On gear-driven water pumps, oil from the weep hole indicates a failure of the oil seal within the water pump. The normal causes for premature failure of the oil seal are excessive wear, debris, and soot in the engine oil, thatcan result from extended oil change intervals. These contaminants act abrasively on the seal-to-shaft interface.

### 13.13.5.2 Water Pump Seal Assessment

The following steps should be followed to verify leakage prior to removal and replacement of the water pump:

1. When accessible, clean any debris or obstruction from the weep hole, being careful not to disturb the seal. This will help address the nature of the leakage. See Figure 13-4.

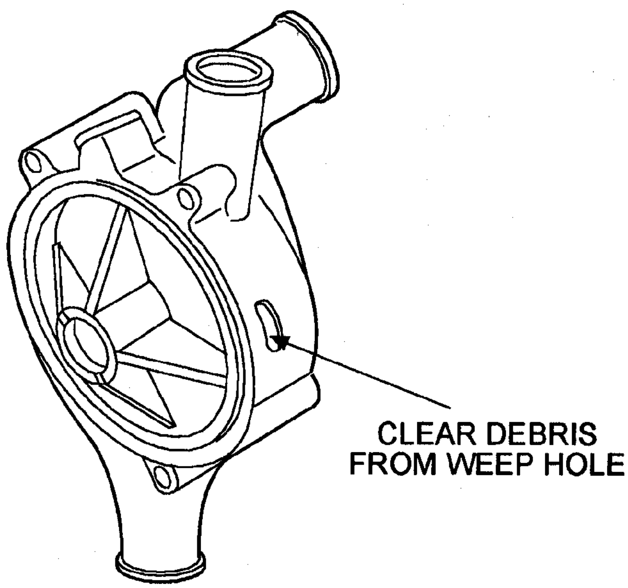



**Figure 13-4 Water Pump Weep Hole**

2. If no leakage of coolant is observed under operating conditions, the water pump should not be replaced.

**NOTE:**
Chemical streak trails and seepage are normal, but continuous drip leaks are not.

**NOTE:**
Weeping is described as a passing of liquid across a sealed surface of about 1-5 drops per day's usage. See Figure 13-5. Seeping describes a greater amount of liquid equal to more than 5 drops per day's usage. Leaking describes a near-constant dripping of liquid. See Figure 13-6.

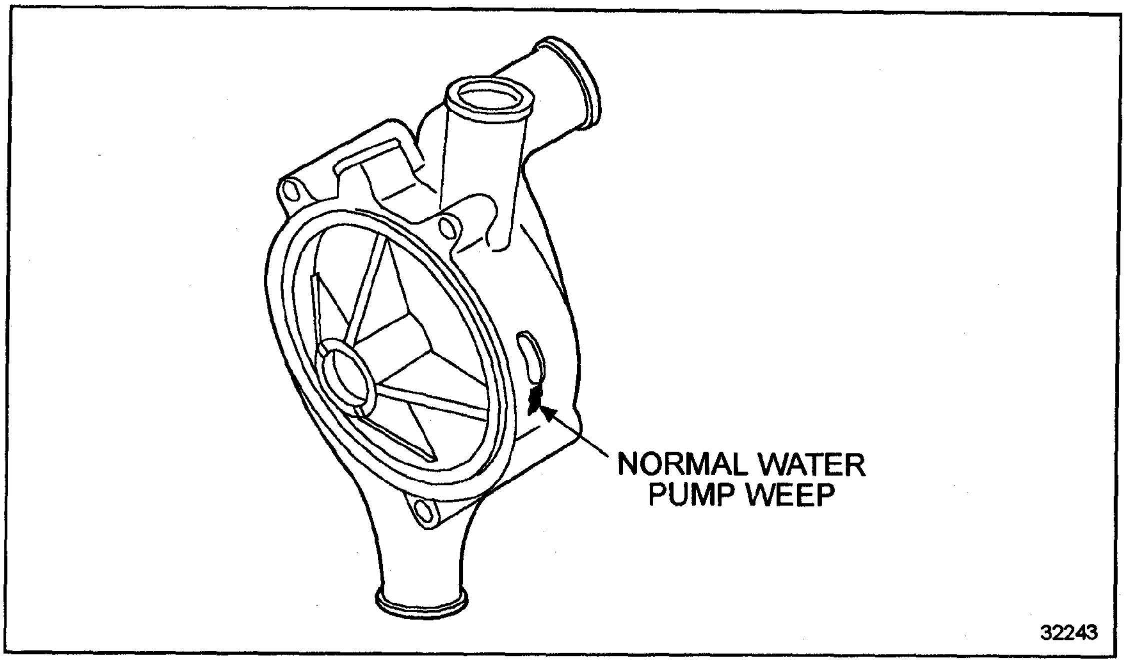



**Figure 13-5** **Water Pump Showing Normal Weeping**

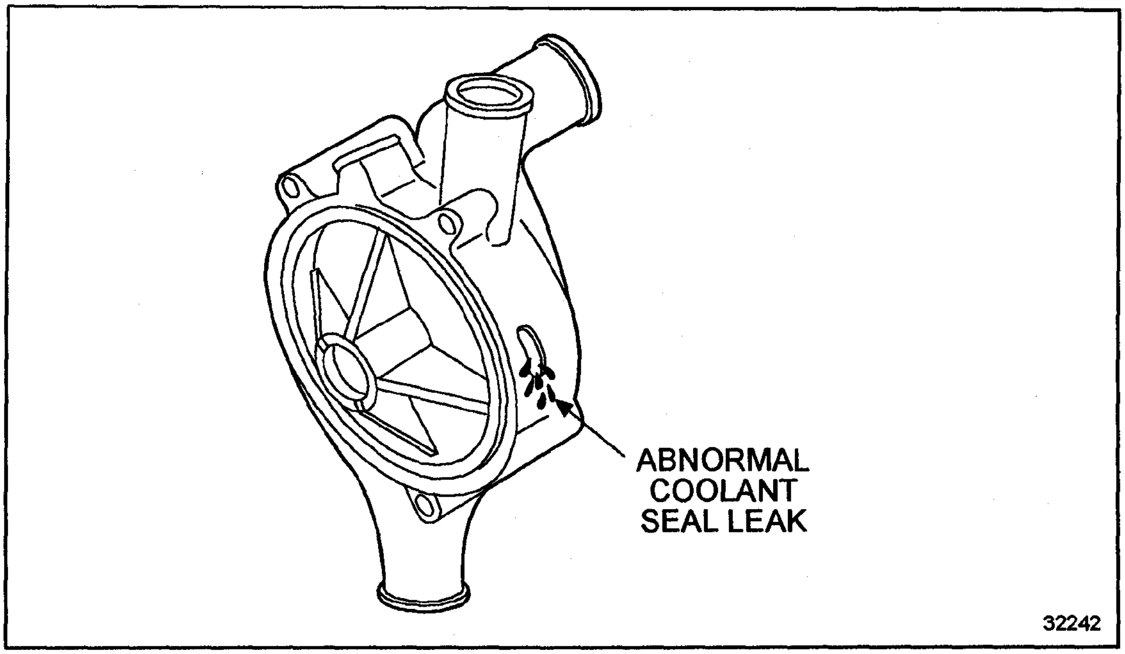



**Figure 13-6** **Water Pump Showing Abnormal Leaking**

**NOTE:**
A water pump thatexhibits a chemical build-up in the weep hole does not necessarily require replacement. See Figure 13-7. Some weeping is expected as a result of the coolant lubrication of the seal surface.

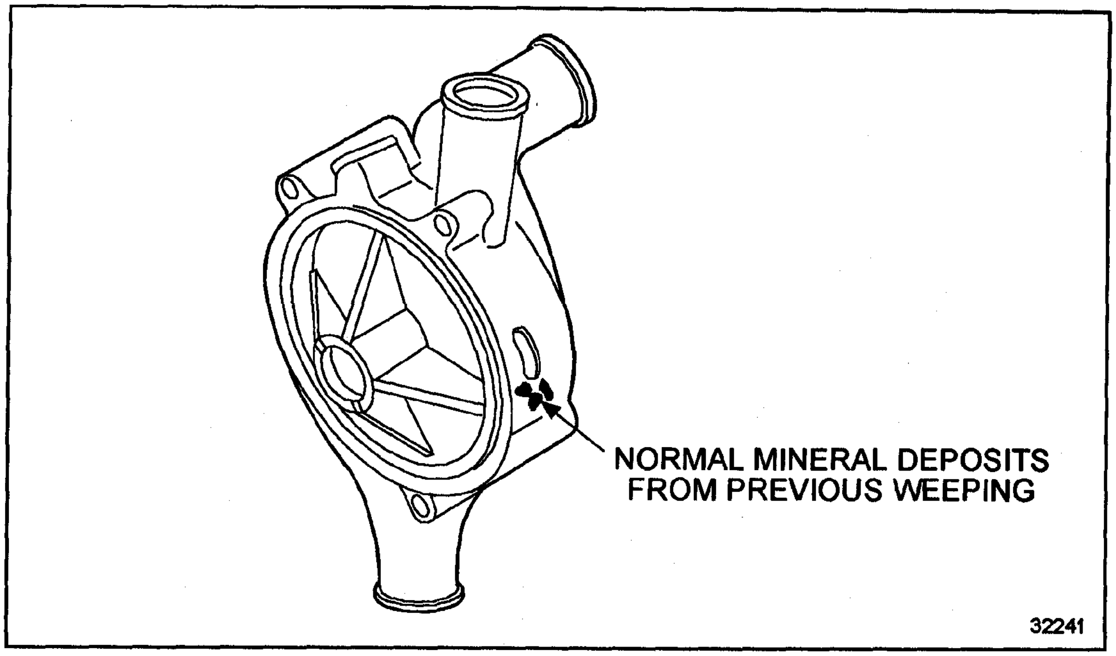



**Figure 13-7 Water Pump Showing Normal Mineral Deposits Caused By Weeping**

Replace water pump if oil is found coming from the weep hole on gear-driven water pumps. The engine oil must then be tested for excess debris, and replaced if not conforming to specifications.

The SCA inhibitors and glycol concentration must be checked according to the recommended maintenance schedule as described in the Detroit Diesel *Series 60 Service Manual* and Operators Guide for that specific engine or DDC publication 7SE298, available from authorized Detroit Diesel distributors.

### 13.13.5.3 Water Pump Leak Test Summary

Test water pump for leaks as follows:

1. Ensure weep hole is clear.
2. Refer to section 13.13.1 for the exhaust caution before preceeding. Run engine and look for coolant leaking from weep hole.
   [a] Do not replace water pump due to chemical streaks.
   [b] Replace the water pump if coolant is leaking or dripping.

## 13.13.10 Drive Belts

New standard vee-belts will stretch after the first few hours of operation. Refer to section 13.13.1 for the exhaust caution before preceeding. Run the engine for 10 to 15 minutes at 1200 r/min to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, battery charging alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 250 miles (402 km) of operation. Thereafter, check the tension of the drive belts every 100 hours or 7,500 miles (12,000 km) and adjust, if necessary. Belts should be neither too tight nor too loose. Belts that are too tight impose excess loads on the crankshaft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. A loose belt will slip and may cause damage to accessory components.

**Replace ALL belts in a set when one is worn.** Single belts of similar size should not be used as a substitute for a matched belt set. Premature belt wear can result because of belt length variation. All belts in a matched belt set are within 0.032 in. (0.81 mm) of their specified center distances.

When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

Adjust the belt tension as listed in Table 13-1 and listed in Table 13-2, using J 41251-B.

| Fan Drive Single Belt | Fan Drive 2 or 3 Belts |
|---|---|
| 80-100 lb(355 - 455 N) | 60-80 lb(266 - 355 N) |

**Table 13-1 Fan Drive Belt Tensioning**

| BELT | NEW | USED |
|---|---|---|
| Two 1/2 in. Vee-Groove | 125 lbs. | 100 lbs. |
| 2-Groove Powerband® | 200 lbs.<br>890 N | 150 lbs.<br>667 N |
| 12-Rib Poly-Vee<br>50 DN Alternator | 350 lbs.<br>1,557 N | 250 lbs.<br>1,112 N |
| 6-Rib Poly-Vee | 220 lbs.<br>979 N | 180 lbs.<br>801 N |

**Table 13-2 Alternator Drive Belt Tensioning**

If a belt tension gage is not available, adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 12.70-19.05 mm (0.500 -0.750 in.).

**NOTE:**
When installing or adjusting an accessory drive belt, ensure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

**NOTE:**
Drive belts (vee and poly-vee) should be replaced every 2,000 hours or 100,000 miles (161,000 km).

A single poly-vee belt is used with the 50 DN Alternator. The 50 DN alternator drive belt tension is set at 1558 N (350 lb) during engine assembly and belt replacement. A new belt loses tension rapidly during the first few minutes of operation. Therefore, it is important to check the tension after 30 minutes of operation. Allow the belt to cool with the engine off for 30 minutes before measuring tension.

- ☐ If the tension on the belt is greater than or equal to 1115 N (250 lb), no further tensioning is required.
- ☐ If the tension on the belt is less than 1115 N (250 lb), tension the belt to 1115 N (250 lb).

Periodic tensioning of the belt is required to maximize belt life. The belt tension should be measured once per month or every 7,500 miles (12,000 km), whichever comes first.

A belt tensioning tool is available from Detroit Diesel, J 41251-B. The gage is calibrated from 779 to 1558 N (175 to 350 pounds). The following procedure will describe proper use of the belt tensioning tool:

| NOTICE: |
|---|
| Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup. |

1. Poly-vee belts are very sensitive to undertension. Without a gage and proper tension measurement, the belt tension will probably be too low. Undertension wears belts rapidly and will lead to premature belt failure.
2. Measure the belt tension between the alternator drive pulley and the upper idler pulley, or between the upper idler pulley and the alternator pulley.

| NOTICE: |
|---|
| Do not let gage handle snap back after pressing handle when not installed on belt under tension. Broken gear will result. |

3. Fully press the plunger on the belt gage. The belt must pass between the hook and the leg pads. The entire belt width must be supported by the hook and leg pads.
4. Use quick release on the gage handle. Read tension on the face of the gage. Repeat the measurement 2 or 3 times to ensure accuracy.
5. The support legs on the gage should not contact pulleys or any other engine hardware.
6. Keep gage clean. Dirt will wear out the leg pads.

3. Run engine and check for oil leaks from weep hole.
   [a] If oil leak is observed, replace the water pump and conduct an oil analysis per publication, 7SE390, available from authorized Detroit Diesel distributors. Then replace water pump as needed.
4. Test and reformulate the coolant to proper glycol and SCA concentrations per the Service Manual Maintenance schedule as indicated in the engine operators guide or DDC publication, 7SE298, available from authorized Detroit Diesel distributors.

### 13.13.6 Test Procedure for DDEC Engines Equipped with Low Coolant Level Sensor (CLS)

The following test procedure is for engine cooling systems that are equipped with a low coolant level sensor mounted in the top tank of the radiator or the heat exchanger. This sensor must be tested annually or every 100,000 miles (161,000 km), whichever comes first.

**CAUTION:**

**To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).**

1. Allow the engine to cool to ambient temperature.
2. Turn ignition switch on and verify no coolant level sensor codes. (DO NOT START ENGINE.)
3. Reduce coolant level below CLS level.
4. Check "stop engine light". It should illuminate within 10 seconds, indicating low coolant level.
   [a] If light illuminates, system is working properly.
   [b] If light does not illuminate, refer to section 13.13.6.1.
5. Fill coolant to proper level. Refer to section 13.13.4.

#### 13.13.6.1 Stop Engine Light Did Not Illuminate

If "stop engine light" did not illuminate, use the following procedure:

1. Check wiring harness and mating connector for damaged wires or pins.
2. Remove and clean sensor. Wash with mild detergent and rinse with clean water.
3. Submerge sensor in container of water up to connector with wiring harness connected.
4. Turn ignition switch on. (DO NOT START ENGINE.)
5. Slowly remove sensor from water.
6. The light should illuminate, indicating low coolant level.
7. If light does illuminate, system is working properly.
8. If light still does not illuminate, replace sensor and return it to DDC.

### 13.13.7 Transmission or Marine Gear

Check the marine gear oil pressure. The operating oil pressure range at operating speed is 621 – 1034 kPa (90 – 150 lb·in.) The operating oil pressure varies with the different DDC/Twin Disc gears. Check and, if necessary, replenish the oil supply in the transmission.

### 13.13.8 Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks and/or restrictions to oil flow. Inspect water-cooled turbochargers for coolant leaks. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause. Refer to section 6.6.2.

### 13.13.9 Battery

On batteries equipped with charge indicator eyes, periodically check for adequate charge. If batteries are the filler-cap type, check the level of the electrolyte every 100 hours or every 7,500 miles (12,000 km). Inspect marine engine batteries for charge every month. In warm weather, however, check more frequently due to a more rapid loss of water from the electrolyte. Electrolyte should be maintained in accordance with the recommendations of the battery manufacturer. Periodically remove, check and clean battery post terminals and connections. Replace corroded or damaged parts. Refer to section 8.3.2.

### 13.13.10.1 Inspect for Rib Cracking

As a poly-vee belt goes through its natural life, it passes through several phases:

- ☐ After an extended time in service, minor rib cracks may appear, usually one or two cracks per inch of belt. See Figure 13-8. This condition is considered normal.

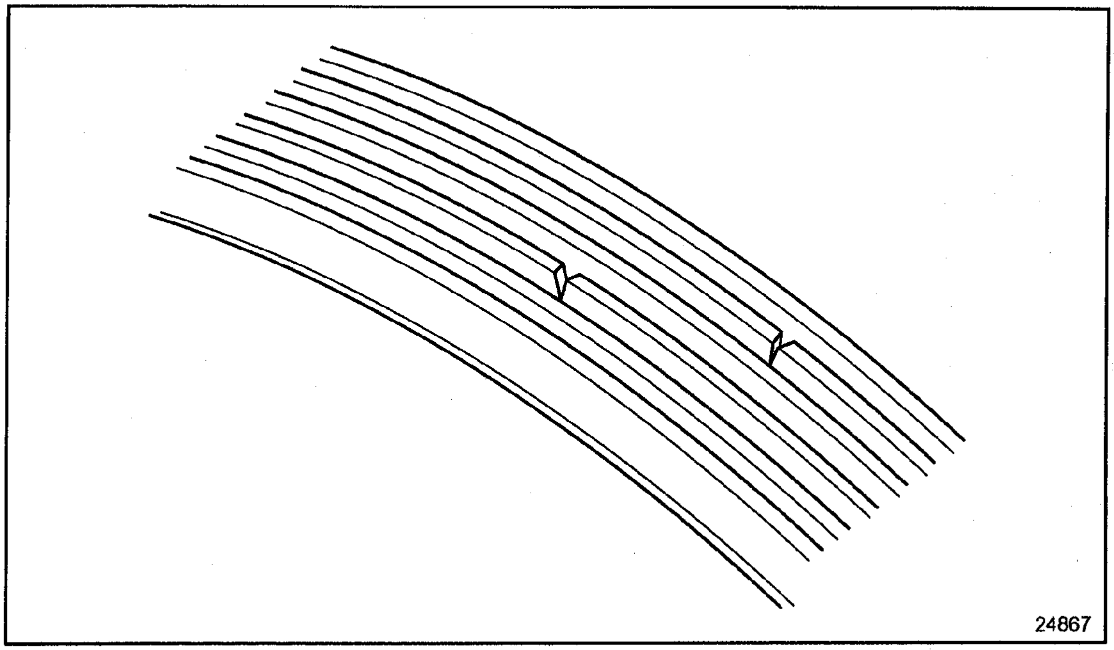



**Figure 13-8 Minor Rib Cracking**

- ☐ A replacement concern occurs when the belt ribs exhibit severe multiple cracking (see Figure 13-9). This leads to "chunking" (breaking away of rib material). See Figure 13-10.

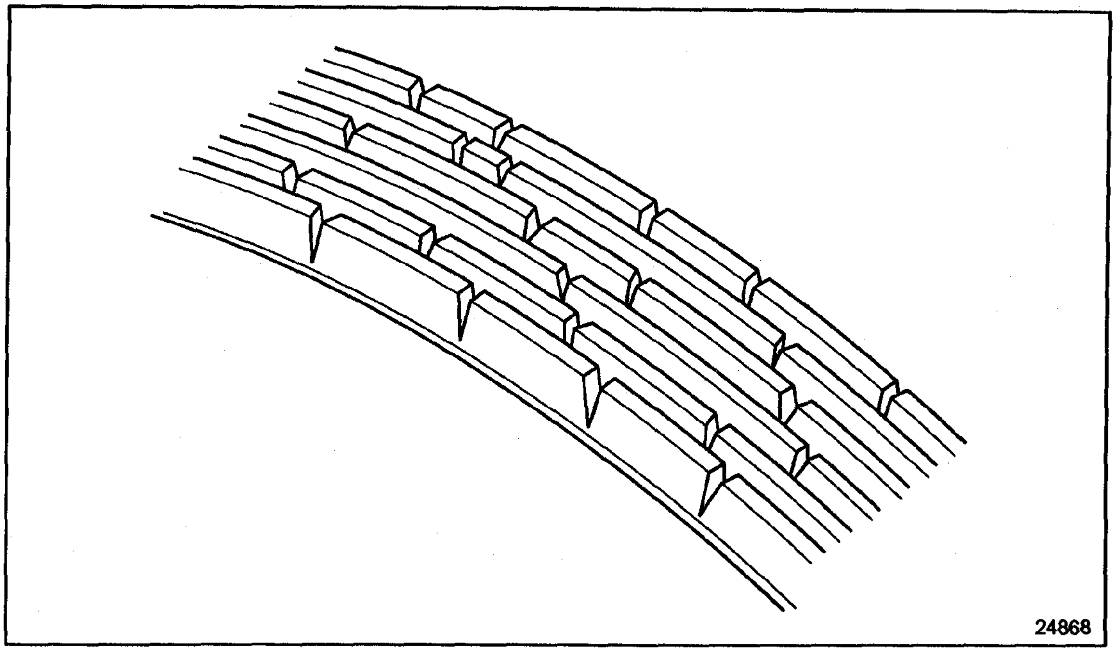



**Figure 13-9 Severe Rib Cracking**

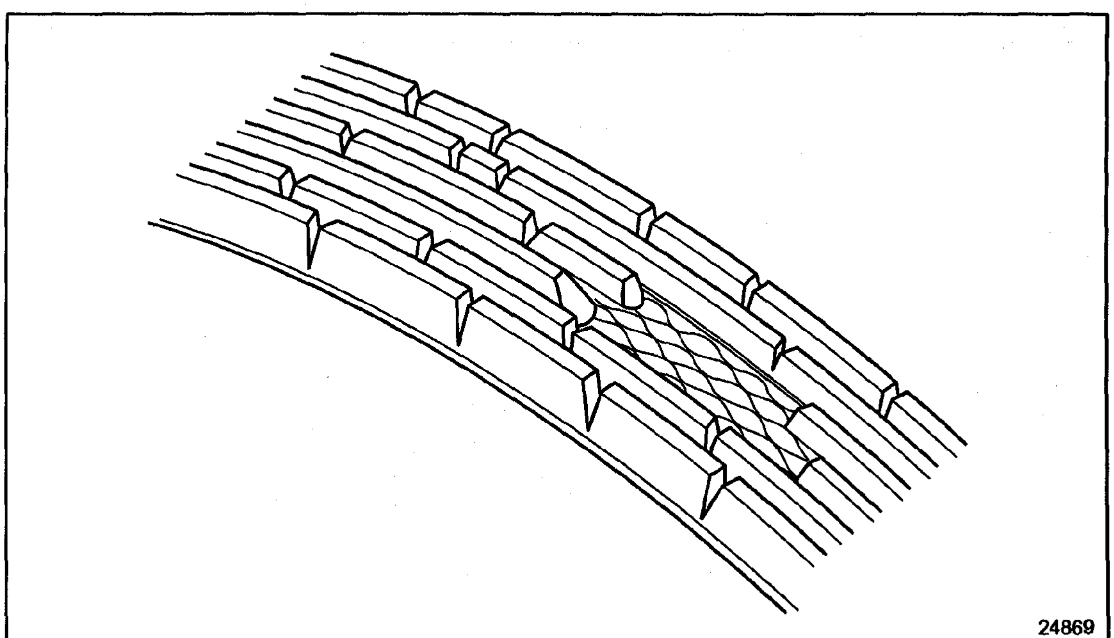



**Figure 13-10 Rib Chunking**

- When severe cracking or rib "chunking" appears, belt replacement is required.

### 13.13.10.2 Inspect for Rib Sidewall Glazing

When the ribs appear to have a shiny surface that is hard and brittle, it is usually a symptom of belt slippage. This results from inadequate tension, extreme temperature, or both. Both characteristics will lead to severe cracking and failure, often with little advance warning. If this happens, locate the cause and correct before installing a new belt.

### 13.13.10.3 Inspect for Belt Wear

Accelerated wear on any part of the belt fabric backing, tensile cord, or rib rubber is a concern and should be investigated. The causes of accelerated wear are:

- Drive misalignment - Misalignment must not exceed 1.59 mm (1/16 in.) for each 305 mm (12.0 in.) of belt span
- Incorrect belt length
- Environmental conditions - Temperature, excessive exposure to engine fluids, etc.
- Abrasive material - Stones, sand, metal shavings, etc.

### 13.13.10.4 Inspect for Foreign Objects

Premature failure may be caused by the belt coming in contact with a foreign object.

| NOTICE: |
|---|
| Any object protruding into the path of the belt drive that contacts the belt will cause damage and failure of the belt. |

Prior to installing a new belt, verify removal of any foreign objects protruding into the belt path.

### 13.13.10.5 Inspect for Noise Vibration

Much effort has gone into the design of each poly-vee belt drive in order to prevent noise vibration. However, field problems occasionally occur. Some causes of noise vibration are:

- Misalignment - This may cause a chirping noise, especially at or near idle speed.
- Mounting - Rigid bracketing of accessories is a must for acceptable free belt span vibration.

**NOTE:**
Some span vibration is to be expected during the range of engine speed and accessory loading.

- Belt tension - Insufficient belt tension may cause a high - pitched howl (squeal) or rasping sound during engine acceleration or deceleration.

### 13.13.11 Air Compressor

Remove and clean all air compressor air intake parts every 150 hours or 15,000 miles (24,000 km). Refer to section 10.1.5. To clean either the hair-type or polyurethane-type compressor air strainer element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until it is dirt-free. Then, dip the element in lubricating oil and squeeze it dry before placing it back in the air strainer.

For replacement of the air strainer element, contact the nearest servicing dealer; replace with the polyurethane element, if available.

Every 12 months or 30,000 miles (48,000 km) [300 hours for non-vehicle applications] tighten the air compressor mounting bolts.

### 13.13.12 Air Cleaner

Inspect the air cleaner element every 15,000 miles (24,000 km) for vehicle engines, 150 hours for non-vehicle engines, or more often if the engine is operated under severe dust conditions. Replace the element if necessary. Check the gaskets for deterioration and replace, if necessary. If the dry-type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean and repair as necessary.

Under no engine operating conditions should the air inlet restriction exceed 20 inches of water (5.0 kPa). A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Dry-type air cleaner elements used in on-highway applications should be discarded and replaced with new elements when the maximum allowable air inlet restriction has been reached. No attempt should be made to clean or reuse on-highway elements after these intervals.

Dry-type elements used in industrial applications should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached, whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations, if any.Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations, if any.

***Air Separator:*** Clean and oil marine engine air separator filter element and vacuum limiter every 250 hours. Replace the filter element after three cleanings. Replace the vacuum limiter every 1000 hours or every two years, whichever comes first.

### 13.13.13 Lubricating Oil Filter

Refer to section 3.5.1.

### 13.13.14 Fuel Filters (Diesel)

Refer to section 2.8.2.

### 13.13.15 Fuel Filters (Natural Gas)

The precision fuel metering systems of the Series 60G engine require that a fuel filter be used to screen the fuel of liquids and debris that may be carried along with the fuel in the pipeline.

The filter should not allow infiltration of particles larger than 0.05mm, and should have a replaceable element with a high capacity for accumulated dust.

The restriction offered by the filter should not exceed 12 inches of water (30 mbar).

The fuel system pressure requirements as stated in the performance curves must be maintained AFTER any pressure losses caused by the filter.

A suggested fuel filter manufacturer is: MAXITROL Model: GF80-1-1616; MAXITROL Co., 23555 Telegraph Road, PO Box 2230, Southfield, MI 48037; Phone: 248-356-1400, FAX: 248-356-0829

Install the filter properly with gas flowing as indicated by the arrow on the casting. It is also important to leave sufficient space above the cover to allow for removal of the filter insert. Frequency of filter insert maintenance is dependent upon the associated pressure drop at the filter. If the inlet fuel pressure to the engine regulator falls below the specified minimum, engine performance will be degraded.

Before changing the fuel filter, turn off the manual control fuel lever. Start and run the engine until the engine stops. This will eliminate most of the residual gas pressure when removing the filter or draining.

Check carefully for gas leaks immediately after the filter has been installed and the gas turned on. Do this before attempting to operate the engine. Use a rich liquid soap solution or other accepted leak tester on the area between the cover and housing, and at the pipe connections. Never operate the engine if leakage is detected.

### 13.13.16 Coolant Filter and Water Pump

Inspect the water pump drain hole every 6 months, ensuring it is open. A small chemical build up or streaking at the drain hole may occur, but this is not an indication of a defective water pump or seal. If coolant does not leak from the drain hole under normal operating conditions, do not replace the water pump. If the cooling system is protected by a coolant filter and conditioner, the element should be changed every 15,000 miles (24,000 km) or 150 hours (non-vehicle applications). Use the proper coolant filter element in accordance with instructions given under coolant specifications. Refer to section 5.4.7.

### 13.13.17 Cranking Motor

Refer to OEM maintenance guidelines.

### 13.13.18 Air System

It is important with turbocharged engines that all the connections in the air system be checked to ensure they are tight. Check all hoses and ducting for punctures, deterioration or other damage and replace, if necessary.

Every 250 hours or one year, whichever comes first, remove the square head recess plugs (2) from the bottom of the charge air cooler and drain. reinstall plugs and tighten securely.

Refer to OEM maintenance guidelines.

### 13.13.19 Exhaust System

Check the exhaust manifold retaining bolts and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if so equipped.

Refer to OEM maintenance guidelines.

### 13.13.20 Engine (Steam Clean)

Refer to OEM maintenance guidelines.

| NOTICE: |
|---|
| Do not apply steam or solvent directly on the battery charging alternator, starting motor, DDEC components, sensors, or other electrical components, as damage to electrical equipment may result. |

Steam clean the engine and engine compartment.

### 13.13.21 Radiator

Inspect the exterior of the radiator core every 12 months, 30,000 miles (48,000 km), or 300 hours for non-vehicle applications. If necessary, clean it with a quality grease solvent, such as mineral spirits, and dry it with compressed air. **Do NOT use fuel oil, kerosene or gasoline.** It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Refer to OEM maintenance guidelines.

### 13.13.22 Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. If equipment has warning lights instead of rather than pressure indicators, the pressure should be checked and recorded every 60,000 miles (96,000 km) for vehicle engines or 600 hours for stationary, industrial, or marine engines.

Refer to OEM maintenance guidelines.

### 13.13.23 Battery Charging Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

Refer to OEM maintenance guidelines.

### 13.13.24 Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 600 hours or 60,000 miles (96,500 km). Tighten and repair as necessary.

Refer to OEM maintenance guidelines.

### 13.13.25 Crankcase Pressure

Check and record the crankcase pressure every 600 hours - 96,000 km (60,000 miles). Refer to section 16.7.

### 13.13.26 Fan Hub

If the fan bearing hub assembly has a grease fitting, use a hand grease gun and lubricate the bearings with one shot of Mobilgrease® Hp, or an equivalent lithium-base multi-purpose grease every 100,000 miles (160,000 km) for vehicle engines or 1,050 hours for non-vehicle engines. Care should be taken not to overfill the housing.

Refer to OEM maintenance guidelines.

*Mobilgrease® is a registered trademark of the Mobil Corporation.*

### 13.13.27 Thermostats and Seals

Inspect the thermostats and seals every 24 months. Refer to section 4.5.2.1. The thermostats and seals should be replaced every 200,000 miles (322,000 km) for vehicle engines or 4,000 hours for non-vehicle engines, except marine. Replace at the following intervals on marine engines: Heat exchanger-cooled pleasure craft, every 400 hours or 2 years (whichever comes first); keel-cooled commercial craft, every 10,000 hours or 2 years (whichever comes first).

### 13.13.28 Intake System

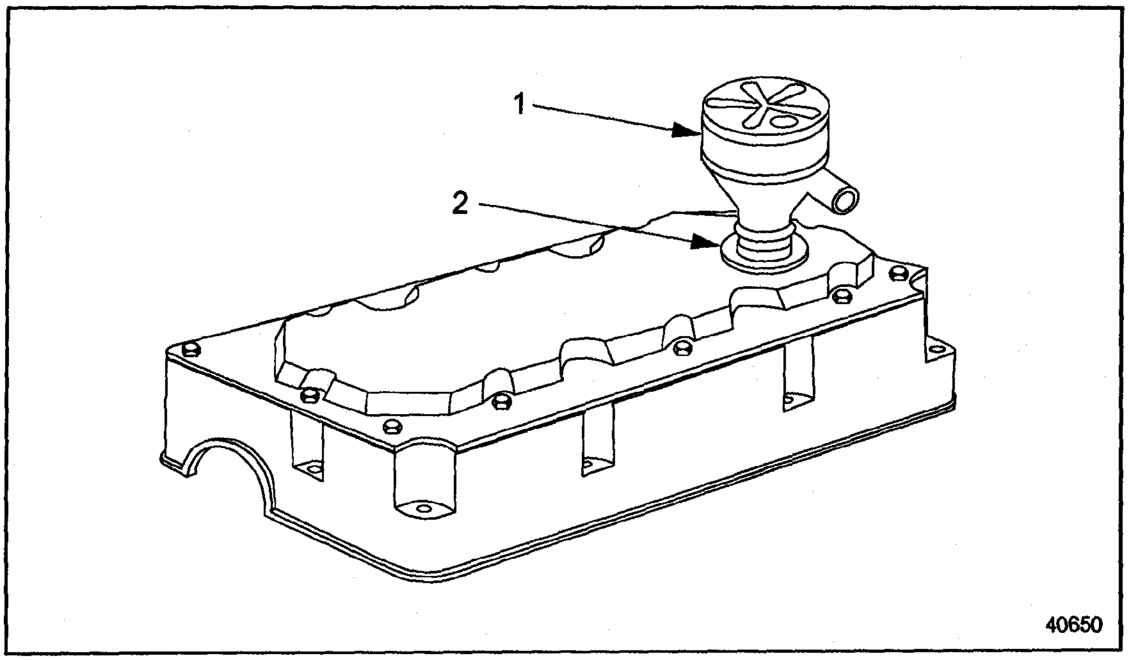
Because natural gas is mixed with the air before the turbocharger on the Series 60G engine, special precautions and inspections are required. Inspect the fuel system components (regulator, PSV, and mixer), intake ducting, turbocharger compressor connections, charge air cooler connections, throttle connections, and intake manifold connections for leaks. Any leak in the intake system downstream of the mixer will result in reduced engine performance and the possible release of a combustible mixture of fuel/air into the atmosphere. The charge air cooler should be tested for leaks as recommended by the manufacturer.

The throttle used on the Series 60G engine is fully enclosed, automatically calibrated at engine start up and requires no adjustment or maintenance. The throttle is serviced as a complete unit.

### 13.13.29 Crankcase Breather

Remove the internally mounted (in the engine rocker cover for diesel engines and on front gear case cover for natural gas engines) crankcase breather assembly annually (vehicle engines) or every 1,050 hours (non-vehicle engines) and wash the steel mesh pad in clean fuel oil. Refer to section 1.6.6. This cleaning period may be reduced or lengthened according to the severity of service.

The rocker cover-mounted breather assembly (part number 23512984) and seal ring (part number 23515211) used in the closed crankcase breather system should be *replaced* every 4000 engine operating hours. These parts are not reusable and no attempt should be made to clean or reuse them. See Figure 13-11.




1. Breather
2. Seal

**Figure 13-11 Rocker Cover-Mounted Breather Location**

## 13.13.30 Engine Tune-up

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed.

The valve lash and injector heights on Series 60 diesel-fueled engines must be measured and, if necessary, adjusted after the first 60,000 miles (96,000 km) or 24 month period, whichever comes first, or after the first 1500 hours for marine engines. Once the initial measurements and adjustments have been made, any changes beyond this point should be made only as required to maintain satisfactory engine performance.

Refer to section 12.2 of this service manual for valve lash and injector height adjustment procedures.

| NOTICE: |
|---|
| Failure to measure valve clearances and injector heights at the required initial period and make necessary adjustments may result in gradual degradation of engine performance and reduced fuel combustion efficiency. |

The valve lash on Series 60G natural gas-fueled engines should be checked and adjusted as follows:

- ☐ Truck and Motor Coach Engines - Check every 36,000 miles (58,000 hm) or 12 months, whichever comes first, and adjust if necessary.
- ☐ Generator Set Engines - Check every 1,500 hours of operation or 12 months, whichever comes first, and adjust if necessary.

Refer to section 12.4 of this service manual for valve lash adjustment procedures.

| NOTICE: |
|---|
| Failure to measure valve lash at the required intervals and make necessary adjustments may result in gradual degradation of engine performance and reduced fuel combustion efficiency. |

## 13.13.31 Marine Gear

Check the marine gear oil level daily and fill to the proper level with the required lubricant. The oil and filter maintenance requirements for Detroit Diesel (Twin Disc) marine gears are listed in Table 13-3.

<table>
<tr><td colspan="3">Oil Service Class<br>Use API service classification CD, CD-II, CF-2, or CE, CF or CG-4 engine oil which is certified to pass TO2 or TO4 and C-4 specifications or meet the requirements of MIL-L-2104E. Engine oil may be used, provided it meets these requirements.</td></tr>
<tr><td colspan="3">Oil Viscosity</td></tr>
<tr><td colspan="2">Sump Temperature, also Oil Temperature into Heat Exchanger</td><td rowspan="2">Recommended Oil Viscosity</td></tr>
<tr><td>During Start-Up</td><td>Steady Operating Conditions</td></tr>
<tr><td>-</td><td>Below 150°F (66°C)</td><td>This operating condition is not approved.</td></tr>
<tr><td>32°F (0°C) Min.</td><td>150-185°F (66-85°C)</td><td>SAE viscosity number 40 engine oil 1.12:1-2.54:1</td></tr>
<tr><td>32°F (0°C) Min.</td><td>150-185°F (66-85°C)</td><td>SAE viscosity number 40 engine oil 3.10:1-4.95:1</td></tr>
<tr><td>32°F (0°C) Min.</td><td>175-210°F (80-99°C)</td><td>SAE viscosity number 40 engine oil 3.10:1-4.95:1</td></tr>
<tr><td>-</td><td>Above 210°F (99°C)</td><td>This operating condition is not approved.</td></tr>
<tr><td colspan="3">Oil and Filter Change Interval<br>First oil and filter change should take place after 10 hours and thereafter every 1000 hours of operation for both filter element and oil, or 6 months, whichever occurs first.</td></tr>
<tr><td colspan="3">Filter Screen<br>Remove and clean after first 10 hours and thereafter every 1000 hours of operation, or 6 months, whichever comes first.</td></tr>
</table>

**Table 13-3 DDC (Twin Disc) Marine Gear Lube Oil and Filter Change Requirements**

Check marine gear mounting bolts and the condition of the mounting pads every 1,000 hours and tighten or repair, as required.

Replace marine gear oil coolers onn pleasure craft marine engines every 4 years or 8000 hours, whichever comes first. Replace marine gear oil coolers on commercial marine engines every 4 years or 10,000 hours, whichever comes first.

### 13.13.32 Raw Water System Zincs

Heat exchanger zincs should be checked initially after the first 60 hours. Thereafter, inspect and clean or replace on pleasure craft marine engines every 200 hours or one year, whichever comes first. Inspect and clean or replace on commercial marine engines every 5000 hours or one year, whichever comes first.Clean with a wire brush if serviceable. Replace if badly deteriorated. Zinc anodes are generally found in the heat exchanger assembly, the raw water pump elbows, the fuel cooler, and the engine/marine gear auxiliary coolers. See Figure 13-12.

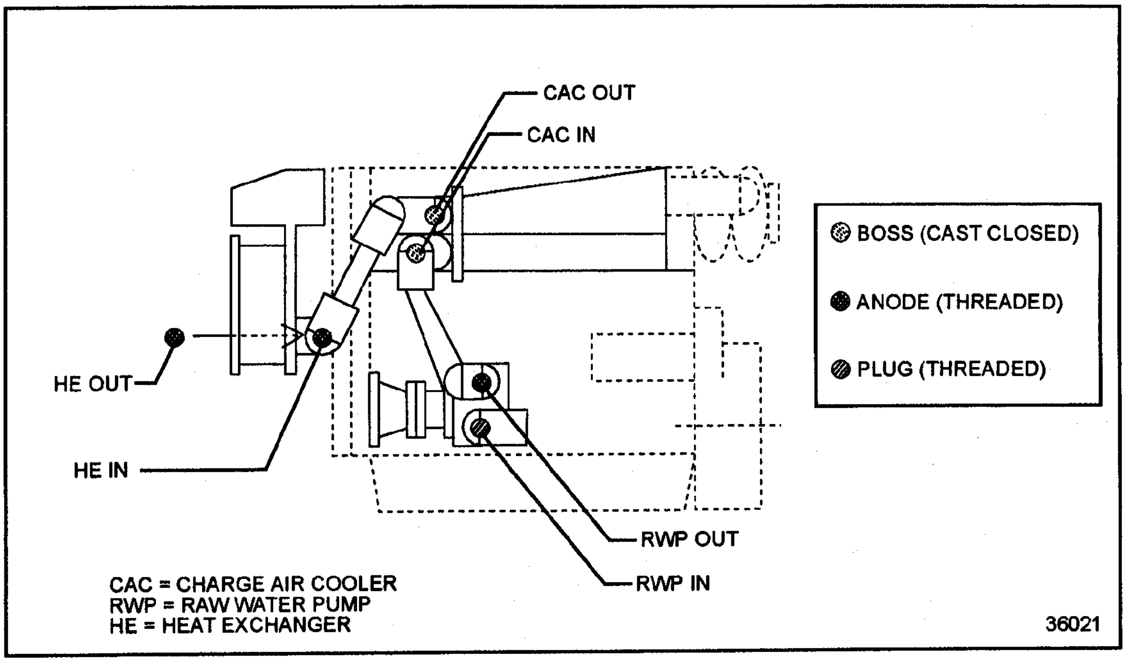



**Figure 13-12 Zinc Anode Locations — Heat Exchanger-Cooled Marine Engine**

### 13.13.33 Raw Water Pump

A raw water pump seal malfunction is indicated by leakage of water from the openings in the pump housing. These openings, located between the pump mounting flange and the inlet and outlet ports, must remain open at all times.

Leaky seals require replacement. Worn or brittle flexible impellers should be replaced. The raw water pump body or liner should also be checked for cracks or wear and replaced, if necessary. Authorized Detroit Diesel service outlets are properly equipped to perform these services.

### 13.13.34 Charge Air Cooler/Auxiliary Pump

Every 5000 hours or one year, whichever comes first, the charge air cooler on keel-cooled engines should be flushed with a mild solvent and rinsed with clean, fresh water. The engine-mounted auxiliary raw water pump used to circulate coolant through the charge air cooler should be examined periodically to make sure the weep hole is open and unblocked. A plugged weep hole may lead to water pump seal and bearing damage, which could cause pump malfunction. The charge air cooler/air intake manifold assembly on heat exchanger-cooled engines does not require periodic maintenance. See Figure 13-13.

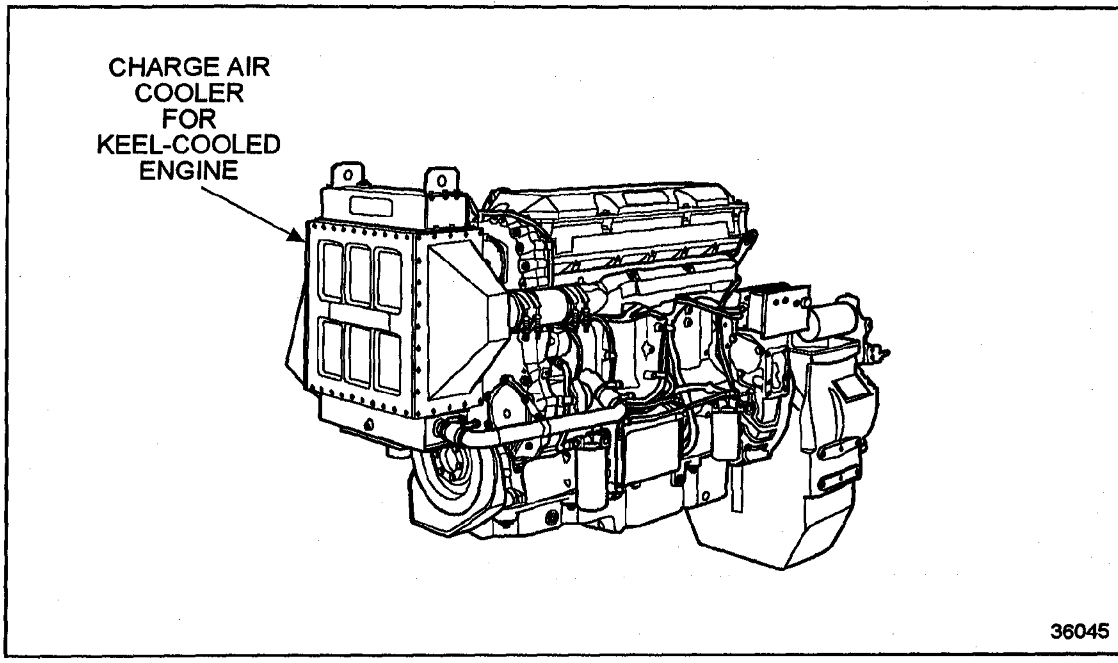



**Figure 13-13 Typical Charge Air Cooler for Keel-Cooled Engine**

### 13.13.35 Heat Exchanger

Every 400 hours or 2 years, whichever comes first, the heat exchanger core should be flushed with a mild solvent and rinsed with clean, fresh water to remove dust, dirt, or other contamination from the element. See Figure 13-14. Authorized Detroit Diesel service outlets are properly equipped and have the trained personnel to perform this service.

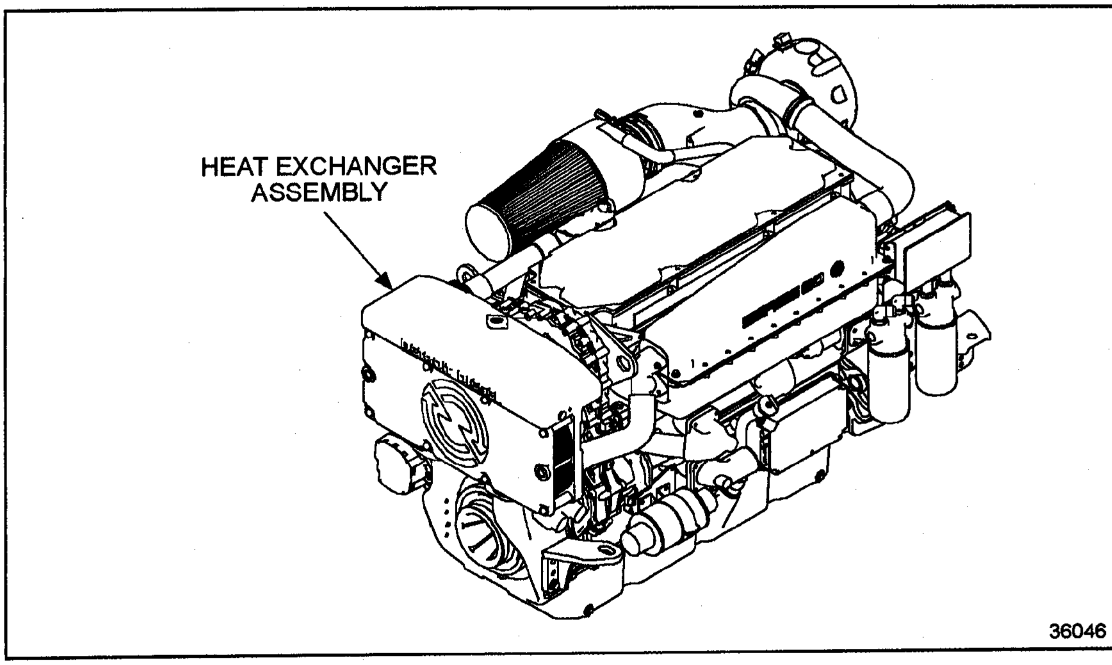



**Figure 13-14 Typical Heat Exchanger Assembly**

### 13.13.36 Fuel Cooler

Every 400 hours or two years, whichever comes first, the fuel cooler should be removed, back flushed with clean, fresh water to remove any contaminants, and inspected before being reinstalled. Refer to section 2.13.

Fuel coolers should be replaced every 4 years or every 4,000 operating hours, whichever comes first.

### 13.13.37 Fuel Injectors

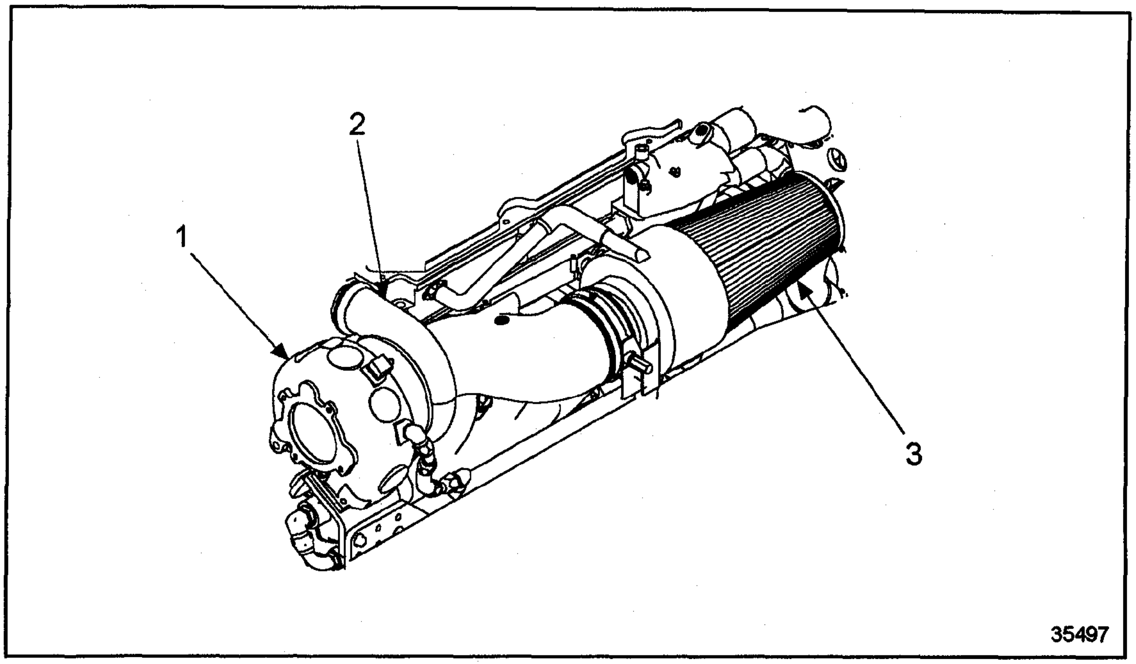
Replace fuel injectors on pleasure craft marine engines every 1,000 hours of operation. Replace injectors on commercial marine engines every 5,000 hours of operation.

### 13.13.38 Vibration Damper

The viscous vibration damper should be inspected periodically and replaced if dented or leaking. Heat from normal engine operation may, over a period of time, cause the fluid within the viscous vibration damper to break down and lose its dampering properties. For this reason, the viscous vibration damper must be replaced at time of normal major engine overhaul, regardless of apparent condition.

## 13.14 AIR SEPARATOR FILTER ELEMENT (MARINE)

The closed breather system consists of an air separator assembly mounted to the inlet side of the turbocharger. See Figure 13-15.




1. Turbine Housing
2. Compressor Housing
3. Air Separator Assembly

**Figure 13-15 Typical Air Separator System**

To operate efficiently, air separator filter and vacuum limiter must be properly maintained.

- ☐ Clean and oil the filter element and vacuum limiter every 250 hours of engine operation or once a year, whichever comes first. Refer to section 13.14.1, refer to section 13.14.2, and refer to section 13.14.4.

**NOTE:**
Filter element and vacuum limiter must also be cleaned and oiled any time the restriction gage shows red.

- ☐ Filter element must be replaced after three cleanings.
- ☐ Replace vacuum regulator/limiter every 1000 hours of engine operation or every two years, whichever comes first.

| NOTICE |
|---|
| Failure to properly clean the engine room may allow loose debris to plug air separator elements. Plugging can lead to high air inlet restriction, causing reduced engine performance and/or engine damage caused by engine overheating. |

**NOTE:**
For best cleaning results, and to avoid damaging filter elements, Walker Cleaning and Re-oiling Kit must be used. This kit is available from Walker Engineering supply distributors or directly from manufacturer:

Walker Engineering Enterprises

8321 De Celis Place

North Hills, CA 91343

### 13.14.1 Pre-Clean Air Separator Filter Element

Perform the following procedures to clean and re-oil the air separator filter element:

| NOTICE |
|---|
| Failure to clean the air separator filter element and the vacuum regulator/limiter will affect the operation of the air separator and may cause reduced engine performance and/or engine damage caused by engine overheating. |

**NOTE:**
A filter that is damaged or clogged with soot due to an exhaust leak may not be able to be cleaned to maximum air flow condition. Replacement of element may be necessary.

1. Remove filter element from air separator by detaching the end cap. On some installations this is accomplished by removing the end cap bolt. Other installations require removal of the end cap attaching springs.

**NOTE:**
Filter elements and vacuum limiters must also be cleaned and oiled when the air inlet restrictions turns *red.* This indicates the maximum allowable system restriction has been reached.

2. Tap element to dislodge any large, imbedded particles of dirt.

3. Gently brush outside of element with soft bristle brush, such as a paint brush, to remove smaller particles of dirt.
   - [a] If complete cleaning is impractical at this time, re-oil and install element. Refer to section 13.14.2 for oiling procedure.
   - [b] If complete cleaning is practical at this time, refer to section 13.14.2 and follow cleaning and oiling procedure.

## 13.14.2 Cleaning of Air Separator Filter Element

Perform the following procedures to clean air separator:

1. Spray Walker cleaning solution onto element and let soak 10 minutes.

| NOTICE |
|---|
| To avoid filter damage, do not clean with gasoline, steam, high pressure water or air, caustic solutions, strong detergents, or parts cleaning solvents. |

2. Rinse element with clean, low pressure, fresh (not salt) water. Rinse from clean side (inside) to dirty side.

| NOTICE |
|---|
| To avoid filter damage, do not use compressed air, open flame, ovens, or heat dryers. Excess heat will shrink the filter element, and compressed air will blow holes through it. |

3. Shake off excess water and allow element to dry naturally.

| NOTICE |
|---|
| To avoid filter damage, do not use transmission fluid, motor oil, diesel fuel, WD-40® or other lightweight oil. |

4. Squeeze Walker air filter fluid out of the bottle and across the top of each pleat. Make one pass per pleat.

**NOTE:**
Filter effectiveness is reduced if the element is used without re-oiling.

5. Allow oil to work into element for 20 minutes.
6. Re-oil any white spots on the element.
7. Install air separator filter element.

### 13.14.3 Clean Vacuum Regulator Filter Element

The vacuum regulator filter can be cleaned without removing the regulator from the system.

1. Detach filter using a standard blade screwdriver.
2. Refer to section 13.14.1, and follow same pre-clean procedure.
3. Refer to section 13.14.2, and follow same cleaning procedure.

### 13.14.4 Clean Vacuum Limiter Filter Element

Clean vacuum limiter filter element as follows:

1. Remove entire vacuum limiter assembly. Do not detach filter element.
2. Refer to section 13.14.1, and follow same pre-clean procedure.
3. Refer to section 13.14.2, and follow same cleaning procedure.

## 13.15 CLEANING CONTAMINATED LUBRICATION OIL SYSTEM

If coolant should leak into the lubrication system, the lube system *must* be thoroughly flushed to avoid or limit damage using the flushing procedures outlined below.

### 13.15.1 Before Flushing Lubrication System

The following steps must be followed before flushing the contaminated lubrication system:

1. Determine the cause of the internal coolant leak and correct the problem.
2. Thoroughly drain the lubricating oil. Take and label a representative 6-8 ounce sample for chemical analysis.
3. Examine the drained oil:
   [a] Refer to section 13.15.2 if the oil is still reasonably fluid and is typical of the used oil at regular drain intervals.
   [b] Refer to section 13.15.3 if the oil shows a gelling texture.
4. Inspect main bearing shells:
   [a] If damaged, the engine must be disassembled and checked for any additional damage.
   [b] If not damaged, proceed as follows:
   - ☐ Refer to section 13.15.2 if the oil on the bearing shell(s) is viscous with normal flowing texture
   - ☐ Refer to section 13.15.3 if the oil on the bearing shell(s) has gelled up, requiring scraping to remove.

## 13.15.2 Flushing a Non-Gelled Oil System

Use this procedure if the contaminated lubricating oil is still freely flowing without gelling. This requires the lubricating oil recommended for normal operation.

**CAUTION:**

**To avoid injury from fire caused by heated lubricating-oil vapors:**

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if an oil leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves, apron, etc.) to avoid burns.**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

**Lubricating oil is relatively harmless at ambient temperatures.**

1. Remove and discard the oil filter and replace with new filters.
2. Pressure fill the lubricating system to 25 psi (172 kPa) with the lubricating oil recommended for normal operation, making sure the crankcase is filled to the proper operating level. Refer to section 5.2 of the engine service manual.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start and run the engine at fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check engine running conditions frequently, especially the oil pressure, and stop immediately if a reading is out of range.

4. Stop the engine and immediately drain the crankcase. Allow enough time to drain all the fluid. Take and label a second oil sample.
5. Repeat steps 1 through step 4.
6. Remove and discard all oil filters and replace with new filters.
7. Replace oil drain plugs and pressure fill the engine to the proper level with the lubricating oil recommended for normal operation.
8. Have oil samples analyzed for coolant contamination and condition of the engine.

### 13.15.3 Flushing an Oil System that Exhibits Gelling

Use this procedure if the contaminated oil exhibits gelling. This requires the lubricating oil recommended for normal operation and the addition of a solvent.

**CAUTION:**

**To avoid injury from fire caused by heated lubricating-oil vapors:**

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if an oil leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves, apron, etc.) to avoid burns.**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

**Lubricating oil is relatively harmless at ambient temperatures.**

1. Remove and discard all oil filters and replace with new filters.

**CAUTION:**

**To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.**

2. Mix two parts of the lubricating oil recommended for normal operation with one part of butyl cellosolve. Refer to section 5.2 of the service manual for recommended oil. Pressure fill the engine with this mixture to 25 psi (172 kPa) until the crankcase is filled to the proper operating level.

3. Refer to section 13.15.2 for exhaust caution before preceeding. Start and run the engine at fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check engine running conditions frequently, especially oil pressure, and stop immediately if a reading is out of range.
4. Stop the engine and immediately drain the crankcase. Allow enough time to drain all the fluid. Take and label a second oil sample.
5. Remove and discard all oil filters and replace with new filters.
6. Using a fresh charge of the lubricating oil recommended for normal operation, pressure fill the engine via the oil gallery to 25 psi (172 kPa) until the crankcase is filled to the proper operating level.
7. Refer to section 13.15.2 for the exhaust caution before preceeding. Start and run the engine at fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check engine running conditions frequently, especially oil pressure, and stop immediately if a reading is out of range.
8. Stop the engine and immediately drain the crankcase. Allow enough time to drain all the fluid. Take and label a third oil sample.
9. Remove and discard all oil filters and replace with new filters.
10. Replace oil drain plugs and pressure fill the engine to the proper level with the lubricating oil recommended for normal operation.
11. Have oil samples analyzed for coolant contamination and condition of the engine.

This procedure should flush all coolant contamination from the lubrication system. However, a thin coating from the coolant may still be evident on certain moving engine parts. This coating should disappear within one or two oil changes due to the detergent and dispersant additives in the engine oil.

**NOTE:**
The next oil change should be at one-half the normal oil change interval. Make sure that new filters are installed and that an oil sample is analyzed for coolant contamination and condition of the engine.

# 14 STORAGE

**Section** **Page**

## 14.1 PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below:

- ☐ It will be necessary to remove all rust or corrosion completely from any exposed part before applying rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.
- ☐ The engine should be stored in a building that is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

### 14.1.1 Temporary Storage (30 Days or Less)

To protect an engine for a temporary period of 30 days or less, proceed as follows:

1. Drain the engine crankcase. Refer to section 13.13.1.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil, listed in Table 14-2.
3. Fill the fuel tank with the recommended grade of fuel oil, listed in Table 14-3. Operate the engine for two minutes at 1200 r/min and no load.

**NOTE:**
Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary. Refer to OEM guidelines.
5. If freezing weather is expected during the temporary storage period, add an ethylene glycol base antifreeze solution to the cooling system in accordance with the manufacturer's recommendations. Otherwise, the coolant system should be flushed and filled with a good rust inhibitor to prevent rusting of the outside diameter of the cylinder liners. Refer to section 13.13.4.
6. Remove electrical components. Refer to section 8.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

7. Clean the engine exterior with fuel oil and dry the engine with compressed air.
8. Seal all of the engine openings with a material used for this purpose. The material used for sealing must be waterproof, vapor proof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

### 14.1.2 Restoring a Temporarily Stored Engine

An engine that was stored in accordance with DDC guidelines can be returned to service in a short time by removing the seals at the engine openings and by checking the engine coolant, fuel oil, lubricating oil and transmission oil levels. Refer to section 14.1.1.

### 14.1.3 Extended Storage (More Than 30 Days)

To prepare an engine for extended storage (more than 30 days), follow this procedure:

1. Drain the cooling system. Refer to section 13.13.4.
2. Flush with clean, soft water. Refer to section 13.13.4.
3. Refill with clean, soft water and add a rust inhibitor to the cooling system. Refer to section 5.4.
4. Circulate the coolant by operating the engine until normal operating temperature is reached, listed in Table 14-1.

| Cooling System Parameters | Normal Range for2100 r/min Operation | Normal Range for1800 r/min Operation |
|---|---|---|
| Coolant temperature normal - °C (°F) | 88 (190) | 88 (190) |
| Coolant inlet restriction, maximum - kPa (in. Hg) | 0.0 (0.0) | 0.0 (0.0) |
| Engine coolant capacity - liters (quarts) | 23 (24) | 23 (24) |
| Minimum pressure cap - kPa (lb/in.$^2$) | 48.3 (7) | 48.3 (7) |
| Maximum top tank temperature - °C (°F) | 99 (210) | 99 (210) |
| Minimum top tank temperature - °C (°F) | 71 (160) | 71 (160) |
| Thermostats start to open - °C (°F) | 88 (190) | 88 (190) |
| Thermostats are fully open - °C (°F) | 96 (205) | 96 (205) |

**Table 14-1 Series 60 Operating Conditions**

5. Stop the engine.
6. Remove the drain plug to drain the engine crankcase. Refer to section 13.13.1.
7. Install and torque the 3/4 in.-14 square, magnetic oil drain plug to 45-56 N·m (33-41 lb·ft).
8. Install new lubricating oil filters. Refer to section 13.13.1.
9. Fill the crankcase to the proper level with Tectyl® 390A preservative lubricating oil or an equivalent 30-weight preservative lubricating oil meeting MIL-L-21260C, Grade 2 specification.
10. Drain the fuel tank. Refer to section 13.13.2.

11. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it is not convenient to refill the fuel tank, use a separate, portable supply of recommended fuel.

**NOTE:**
If engines in vehicles are stored where condensation of water in the fuel tank may be a problem, supplemental additives containing methyl carbitol or butyl cellusolve are effective. Follow the manufacturer's instructions for their use. The use of isopropyl alcohol is no longer recommended due to its negative effect on fuel lubricity.

**NOTE:**
In environments where microbe growth is a problem, a fungicide such as Biobor® JF (or equivalent) may be used. Biobor® is a registered trademark of United States Borax and Chemical Corp. Microbial activity may be confirmed with commercially available test kits. Follow the manufacturer's instructions for treatment. Avoid the use of fungicides containing halogenated compounds, since these may cause fuel system corrosion.

12. Drain the fuel system. Refer to section 13.13.2.
13. Remove the fuel filters. Refer to section 13.13.14.
14. Install new filters with No. 1 diesel fuel or pure kerosene. Refer to section 13.13.14.
15. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine. Ensure the engine fuel system is full.
16. Disconnect the fuel return line and the inlet line at the primary filter and securely plug both to retain the fuel in the engine.
17. Service the air cleaner. Refer to section 13.13.12.
18. To prepare the transmission, power take-off and turbocharger:
    [a] Follow OEM recommendations for prolonged storage to store the transmission.
    [b] Follow OEM recommendations for prolonged storage to store the power take-off.
    [c] Since turbocharger bearings are pressure lubricated through the external oil line leading from the oil filter adaptor while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

| NOTICE: |
|---|
| Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances, which can sweat out during operation and cause the clutch to slip. |

19. Apply a non-friction rust preventive compound to all exposed engine parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

**NOTICE:**

Incomplete draining of the water pump may result in rusting of the impeller to the pump body during extended engine storage, especially if inadequate inhibitor was used in the remaining coolant. Damage from freezing temperatures may occur if the coolant remaining in the engine has insufficient antifreeze to prevent it from freezing and expanding. To ensure complete pump drainage, always remove the drain plug from the bottom of the pump before extended storage. If a coolant filter/inhibitor system hose is attached to the bottom of the pump, disconnect the hose and allow the pump to drain completely. Open the drain cock at the bottom of the filter. Do not reinstall the pump drain plug or filter hose or retighten the filter drain plug until the engine is put back into service.

20. Drain the engine cooling system. Refer to section 13.13.4.
21. Drain the preservative oil from the engine crankcase. Reinstall and torque the 3/4 in.-14 square, magnetic drain plug to 45-56 N·m (33-41 lb·ft).
22. Remove and clean the battery and battery cables with a baking soda-water solution and rinse with fresh water. Do not allow the soda solution to enter the battery.
23. Add distilled water to the electrolyte (if necessary) and fully charge the battery.

**NOTICE:**

To avoid possible battery damage caused by freezing, never store a battery in a place below 0°C (32°F).

24. Store the battery in a cool, dry place. Keep the battery fully charged and check the level and specific gravity of the electrolyte regularly.
25. Insert heavy paper strips between the pulleys and drive belts to prevent sticking.
26. Seal all engine openings including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.
27. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.
28. Protect the engine with a good weather-resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

**NOTE:**

Plastic may be used for indoor storage.

### 14.1.4 Marine Gear Storage (More than 30 Days)

Prepare marine gear for extended storage as follows:

1. Drain the oil completely, and refill with clean oil of the recommended grade and viscosity.
2. Remove and clean or replace the strainer and filter elements.

| **CAUTION:** |
|---|
| **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**<br>☐ **Always start and operate an engine in a well ventilated area.**<br>☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**<br>☐ **Do not modify or tamper with the exhaust system or emission control system.** |

3. Start and run the engine at 600 r/min. for 10 minutes to coat all internal parts of the marine gear with clean oil.
4. Engage the clutches alternately to circulate clean oil through all moving parts.

### 14.1.5 Outdoor Storage (30 Days or Less)

In some cases outdoor storage may be unavoidable.

**NOTE:**
Outdoor storage of engines is not recommended.

| **NOTICE:** |
|---|
| Do NOT use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result. |

If units must be kept out-of-doors, protect these units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts.

### 14.1.6 Outdoor Storage (More Than 30 Days)

In some cases outdoor storage may be unavoidable.

**NOTE:**
Outdoor storage of engines is not recommended.

If units must be kept out-of-doors. Refer to section 14.1.5.

| NOTICE: |
|---|
| Do NOT use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result. |

Protect these units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

## 14.2 RESTORING AN EXTENDED STORAGE ENGINE

Use the following procedure to restore an engine that has been in extended storage.

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. Do not overlook the exhaust outlet.
2. Remove the plugs from the inlet and outlet fuel lines and connect the lines to their proper position.
3. Wash the exterior of the engine with fuel oil to remove the rust preventive. (Do NOT wash electrical components.)
4. Remove the rust preventive from the flywheel.
5. Remove the paper strips from between the pulleys and drive belts.
6. Fill the crankcase to the proper level, with the recommended grade of lubricating oil listed in Table 14-2. Use a pressure lubricator to insure all bearings and rocker shafts are oiled.

| Specification | Recommendation |
|---|---|
| SAE Viscosity Grade | 15W-40 |
| API Classification | CH - 4 |
| Military Specification | MIL-L-2104E |
| HT/HS Viscosity | 3.7 cP (minimum) |

**Table 14-2 Recommended Engine Oil**

7. Fill the fuel tank to specifications listed in Table 14-3.

| General Fuel Classification | ASTM Test | No. 1 ASTM 1-D | No. 2 ASTM 2-D |
|---|---|---|---|
| Gravity, ° API (Not Specified in ASTM D 975) | D 287 | 40 - 44 | 33 - 37 |
| Flash Point, Minimum - °F (°C) | D 93 | 100 (38) | 125 (52) |
| Viscosity, Kinematic - cSt @ 100°F (40°C) | D 445 | 1.3 - 2.4 | 1.9 - 4.1 |
| Cloud Point (Not Specified in ASTM D 975) | D 2500 | ‡ | ‡ |
| Sulfur Content, Maximum - wt% | D 129 | 0.05* (0.5 †) | 0.05* (0.5 †) |
| Carbon Residue on 10%, Maximum - wt%, | D 524 | 0.15 | 0.35 |
| Accelerated Stability, Total Insolubles, Maximum - mg/100 mL | D 2274 | 1.5 | 1.5 |
| Ash, Maximum - wt % | D 482 | 0.01 | 0.01 |
| Cetane Number, Minimum(Differs from ASTM D 975) | D 613 | 45 | 45 |
| Distillation Temperature, °F (°C) | ASTM Test | No. 1 ASTM 1-D | No. 2 ASTM 2-D |
| IBP, Typical (Not Specified in ASTM D 975) | D 86 | 350 (177) | 375 (191) |
| 10% Typical (Not Specified in ASTM D 975) | D 86 | 385 (196) | 430 (221) |
| 50% Typical (Not Specified in ASTM D 975) | D 86 | 425 (218) | 510 (256) |
| 90% Maximum (Differs from ASTM D 975) | D 86 | 500 (260) | 625 (329) |
| End Point, Maximum (Not Specified in ASTM D 975) | D 86 | 550 (288) | 675 (357) |
| Water & Sediment, Maximum wt% | D 1796 | 0.05 | 0.05 |

* U.S. on-highway requirement.

† Non-domestic and off-highway applications only.

‡ The cloud point should be 10°F (-12°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by crystals.

**Table 14-3 Fuel Oil Selection Chart**

8. Close all of the drain cocks and fill the engine cooling system with clean soft water and proper inhibitors. Refer to section 5.4. If the engine is to be exposed to freezing temperatures, fill the cooling system with an ethylene glycol base antifreeze solution. Refer to section 13.13.4.
9. Install and connect the battery. Ensure that the average specific gravity of the battery is 1.265 or higher. Charge the battery if necessary.
10. Perform the following steps for proper air cleaner restoration:
    [a] Keep the air cleaner housing tight on the air intake pipe.
    [b] Ensure the correct filter replacement is used.
    [c] Keep the air cleaner properly assembled so the joints are strictly airtight.
    [d] Repair any damage to the air cleaner or related parts immediately.
    [e] Inspect and clean or replace the air cleaner elements as operating conditions warrant.
    [f] Carefully inspect the entire system periodically. Enough dust-laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

    [g] If a foam or fabric air cleaner element soaked with sticky dirt-holding substance was previously installed, check for the presence of coated engine components. Remove and clean them with a suitable solvent, as required, and blow dry with compressed air.
11. Follow OEM recommendations covering the return of the transmission to service.
12. Follow OEM recommendations covering the return of the power take-off to service.
13. Remove the covers from the turbocharger air inlet and turbine outlet connections. Pre-lube the turbocharger.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

14. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause smoky exhaust for a few minutes.

**NOTE:**

Before subjecting the engine to a load or high speed, it is advisable to allow the engine to reach normal operating temperature. Then, monitor the DDEC Diagnostic Data Link for trouble codes. Refer to the *Detroit Diesel Single ECM Troubleshooting Manual,* (6SE497).

### 14.2.1 Restore Marine Gear (More than 30 Days)

Restore marine gear from extended storage as follows:

1. Inspect the marine gear oil cooler and coolant hoses, ensure that they are secure.
2. Refill gear case to the proper level, as necessary, with the correct grade of lubricating oil.

## 14.3 WINTER STORAGE FOR MARINE ENGINE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, marine gear, and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building that is dry and can be heated during the winter months. Where this is not practical, moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

### 14.3.1 Store Marine Engine for Winter

Store the marine engine for winter as follows:

1. Prepare marine cooling system for winter storage as follows:
   [a] Check the protection of the antifreeze. The solution of ethylene glycol-base permanent antifreeze should be sufficient to protect your engine from freeze-up during the coldest part of winter. The maximum ratio of antifreeze compared to water, used in high performance engines, should not exceed 50% antifreeze and 50% water.

**NOTE:**
An excessive amount of antifreeze adversely affects freeze protection and heat transfer rates.

   [b] A non-chromate inhibitor is recommended for additional corrosion protection. Inhibitor level should be checked in accordance with manufacturer's procedures every 150 hours.

   [c] Check all hoses and hose clamps. Worn hoses should be replaced.

   [d] It is recommended that the cooling system be cleaned every 1,000 hours or four years.

   [e] A good radiator cleaning compound should be used according to the instructions on the container.

   [f] After the cleaning operation, rinse the cooling system thoroughly with fresh water.

   [g] Fill the system with soft water, adding Detroit Diesel Power Cool or equivalent fully formulated, inhibited ethylene glycol-base antifreeze in the required concentration.

   [h] Drain the raw water system.

**NOTE:**
Ensure that the raw water is drained from the lowest position in the system.

[i] If a Jabsco® water pump is installed, remove the raw water pump cover and impeller.

**NOTE:**
The blade of the impeller bent against the cam may take a set (lose flexibility) during long storage time.

*Jabsco® is a registered trademark of ITT International.*

2. Prepare marine lube oil system for winter storage as follows:

[a] Drain the engine crankcase.

[b] Install and tighten the crankcase drain plugs.

[c] Install new lubricating oil filter elements and gaskets.

[d] Fill the crankcase to the proper level with Tectyl® 930A preservative lubricating oil or an equivalent 30-weight preservative lubricating oil meeting Mil-L-21260C, Grade 2 specification.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

[a] Start the engine and allow to idle approximately 10 minutes or more to ensure complete lubrication of all the moving parts.

[b] Shut down the engine.

*Tectyl® is a registered trademark of Ashland Oil, Inc.*

3. Prepare marine fuel system for winter storage as follows:

   [a] Top off fuel tanks to prevent water from entering the system from condensation.

**NOTE:**
**If the boat is stored where water in the fuel tanks may be a problem, additives containing methyl carbitol or butyl cellusolve may be used.**

   [b] Follow additive manufacturer's usage and handling recommendations, and observe all precautions. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF, or equivalent, to the fuel.

**NOTE:**
**When using a biocide, follow the manufacturer's usage and handling recommendations, and observe all precautions.**

**NOTE:**
**Isopropyl alcohol is no longer recommended due to its negative effect on fuel lubricity.**

   [c] Drain and replace fuel filters.

   [d] Fill the fuel filters with #1 diesel fuel or pure kerosene.

   [e] Start and operate the engine for approximately five minutes to circulate the clean fuel throughout the system.

   [f] Shut down the engine.

   *Biobor® is a registered trademark of United States Borax and Chemical Corporation.*

4. Prepare marine gears for winter storage as follows:

   [a] Drain the oil completely and refill with clean oil of the recommended grade and viscosity.

   [b] Remove and clean or replace the strainer and filter element.

   [c] Refer to section 14.3 for the exhaust caution before preceeding. Start and run the engine at 600 rpm for ten minutes to coat all the internal parts of the marine gear with clean oil.

   [d] Engage the clutch, alternating from forward to reverse, to circulate clean oil throughout all of the moving parts.

   [e] Shut down the engine.

5. Prepare marine electrical system for winter storage as follows:
   - [a] Remove and clean the batteries and battery cables with a baking soda-water solution and rinse with fresh water.

**NOTE:**
Do not allow the solution to enter the battery.

   - [b] Add distilled water to the electrolyte, if necessary, and fully charge the battery.
   - [c] Store the battery in a cool dry place (never below 32°F or 0°C).
   - [d] Keep the battery fully charged and check the level and specific gravity of the electrolyte periodically.
   - [e] Loosen alternator and accessory drive belts.

**NOTE:**
Loosening of the belts will prevent sticking between the belt and pulley.

6. Prepare marine air intake and exhaust system for winter storage as follows:
   - [a] Seal all engine openings, including the exhaust outlet, with a moisture-resistant tape. Use cardboard, plywood or metal covers where practical.
7. Completely clean the exterior of the engine.
8. Check for areas that show corrosion and touch up with spray paint.

### 14.3.2 Restore Marine Engine from Winter Storage

Restore the marine engine from winter storage as follows:

1. Restore the air intake, exhaust system, air box drains and crankcase vent tubes from winter storage as follows:
   - [a] Remove all the covers and tape from the openings of the engine.
   - [b] Check that the fuel tank vents are open, along with the openings that may have been closed off in the engine room during winter storage.
2. Restore the lube oil system from winter storage as follows:
   - [a] Remove the drain plug and drain the preservative oil from the crankcase.
   - [b] Install the drain plug and tighten.
   - [c] Fill the crankcase to the proper level with the recommended grade of oil. Refer to section 5.2.

**NOTE:**
You may wish to change the lube oil filters, especially if they were not changed before winter storage.

   - [d] Remove the air silencers or air cleaners in order to rotate the turbocharger.

[e] Disconnect the oil pressure line to the turbocharger.

[f] Using an oil can, pre-lube the turbocharger bearings.

[g] While pre-lubing the bearings, turn the turbocharger by hand. Fill the turbo bearing housing cavity with approximately one pint of the recommended grade of engine oil.

[h] Reconnect the oil pressure line.

[i] Install the air cleaner or air silencer.

**NOTE:**
**Where available, a pressure prelubricator may be used to charge the lube oil system prior to starting the engine.**

[j] Remove the pipe plug from the engine main oil gallery and attach the prelubricator hose.

[k] Using a positive displacement pump set at 25-35 psi, pump in the recommended grade of engine lubricating oil.

[l] Disconnect the prelubricator hose, plug the main oil gallery hole and replace all components previously removed.

[m] After approximately 20 minutes, check the crankcase oil level.

[n] Add enough oil to bring the level to the full mark on the dipstick.

3. Restore the electrical system from winter storage as follows:

   [a] Charge the storage batteries and install.

   [b] Securely fasten the cables in place.

   [c] Tighten alternator belt to the proper tension.

4. Restore the cooling system from winter storage as follows:

   [a] Close all drains that were open on the raw water system.

   [b] If previously removed, install the raw water pump impeller, ensuring the vane of the impeller is turned in the correct direction.

   [c] Install the raw water pump cover using a new gasket.

   [d] Remove the plug or zinc electrode on the suction side of the raw water pump.

   [e] Prime the raw water pump to prevent the pump running dry. Pour in at least one pint of water.

   [f] Install plug or zinc electrode and tighten.

   [g] Check the level of the antifreeze and coolant inhibitors in the fresh water system.

   [h] Check tightness on all hoses.

   [i] Insure that the raw water inlet sea cocks are operable and are open.

5. Restore the fuel system from winter storage as follows:
   [a] Prime the system with clean diesel fuel.
   [b] Rotate the engine 180 degrees.
   [c] Prime the system a second time to ensure fuel has passed through the injectors.
6. Restore the marine gear from winter storage as follows:
   [a] Check the oil level in the marine gear.
   [b] Marine gear oil filters may be changed if they were not changed before winter storage.
7. On non-DDEC engines, ensure that the stop lever is working freely.
8. Check the emergency shut-down system to ensure that the engine can be stopped under emergency conditions.
9. While holding the stop button in, crank the engine, release the stop button allowing the engine to start.
10. To prevent serious damage to the starter, do not crank the engine over 15 seconds at a time.
11. After the engine has started, observe the oil pressure gage immediately.
12. If there is no oil pressure indicated within 10 to 15 seconds, stop the engine and check the lube oil system.
13. Increase the RPM to part throttle and no load for approximately five minutes, allowing the engine to warm up before applying a load.
14. While the engine is running, check for coolant, fuel or lubricating oil leaks.
15. Tighten and align connections where necessary to stop leaks.
16. Operate the engine at idle, engaging the marine gear forward and reverse to ensure complete circulation of oil.
17. Monitor the marine gear oil pressure.
18. Shut down the engine, then check the oil level in the engine and marine gear.
19. Check the level of coolant in the expansion tank.
20. Fire off the engines for sea trial.
21. Once the engines have reached operating temperature, again check for water, lube oil and fuel leaks.
22. Check that the pressure line to the turbocharger is tight and that there are no leaks.
23. Monitor the operating conditions of the engine at 1200, 1400, 1600, 1800, 2000 and full load RPM.
24. Inspect the engines for corrosion. Where necessary, clean and apply spray paint.

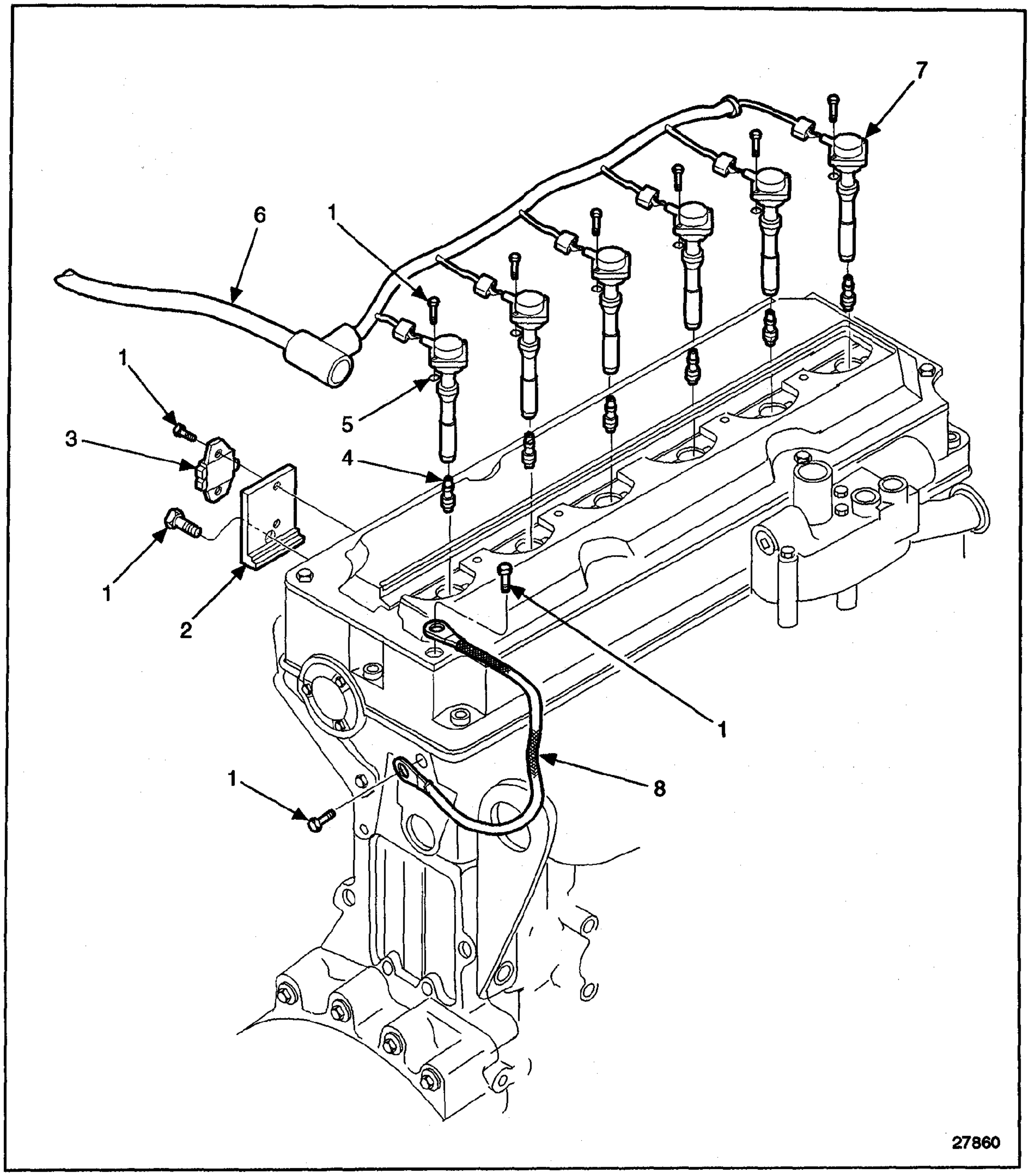
# 15 IGNITION SYSTEM

## 15.1 OVERVIEW OF IGNITION SYSTEM

The Series 60G engine uses a distributorless ignition system (DIS) to initiate combustion and to control combustion timing. The ECM controls dwell time as a function of supply voltage and ignition timing for all speeds and load conditions. The spark event is controlled based on a magnetic pick-up on the crankshaft so it is not necessary to adjust ignition timing.

## 15.2 COIL OVER PLUG IGNITION SYSTEM

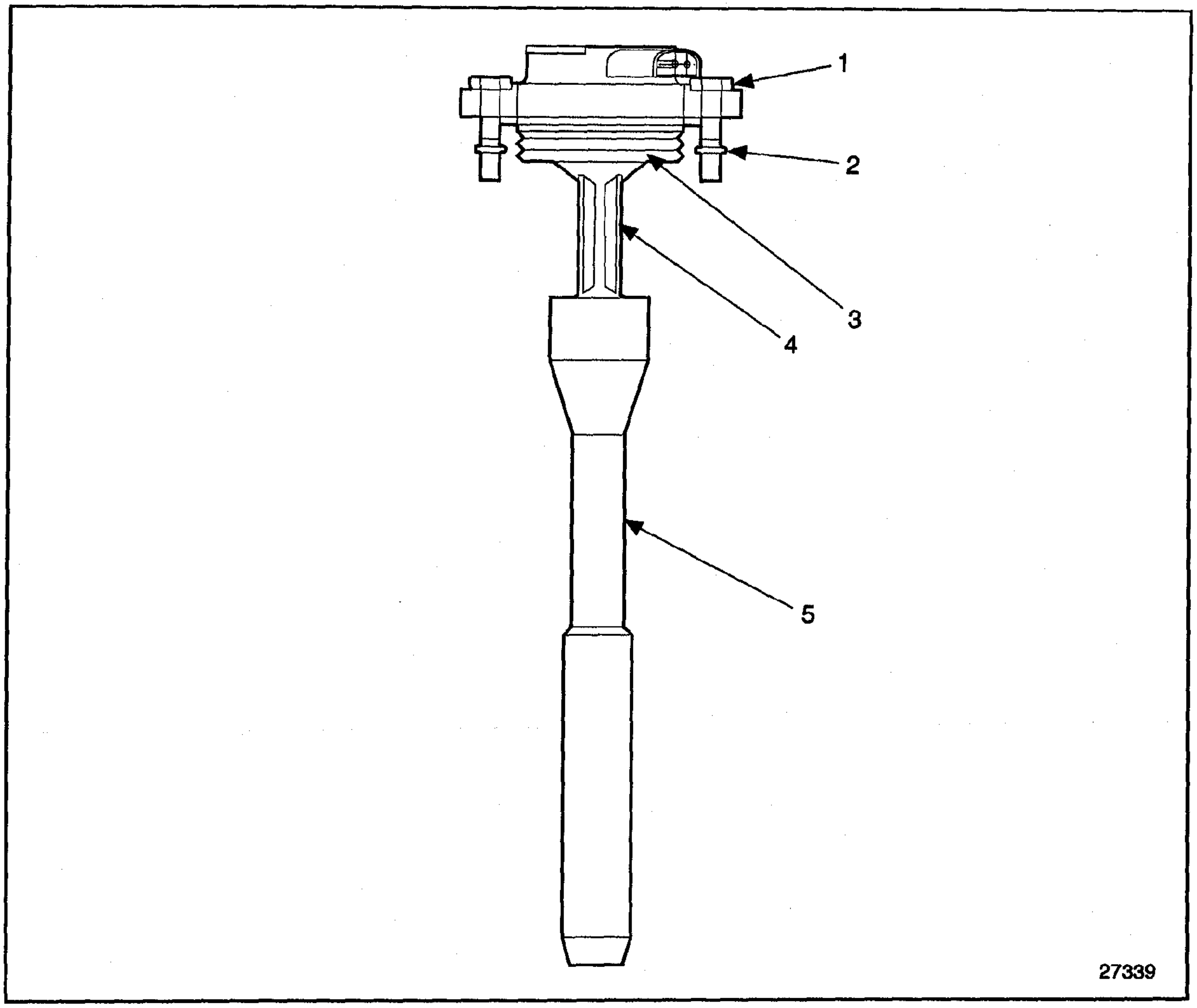
Series 60G genset engines use the coil over plug ignition system. This system consists of six coils, six ignition boots, mounting screws and seals, an igniter module, an igniter module bracket, an ignition coil harness, a ground strap, and six spark plugs. The coils mount in the rocker cover directly above the spark plugs. A coil cover mounts in the rocker cover which protects the coils and shields electromagnetic radiation (EMR) from the environment. See Figure 15-1.




1. Bolt
2. Igniter Module Bracket
3. Igniter Module
4. Spark Plug
5. O-ring
6. Igniter Coil Harness
7. Coil and Igniter Boot Assembly
8. Ground Strap

**Figure 15-1 Coil Over Plug Ignition System**

The ignition coil assembly consists of the ignition coil and integral seal. This is serviced as an assembly, or the seal can be serviced separately. Before the coil can be installed into the engine, it is necessary to attach the boot, mounting screws, and O-rings onto the ignition coil assembly. See Figure 15-2.




1. Bolt, M6 x 1.0 in. (2)
2. O-ring (2)
3. Ignition Coil Seal
4. Ignition Coil Assembly
5. Boot and Spring Assembly

**Figure 15-2 Ignition Coil Assembly**

### 15.2.1 Removal of Ignition Coil

Remove the ignition coil as follows:

1. Remove the two Phillips screws holding the coil cover in the rocker cover.
2. Remove the low voltage wire harness connectors at each coil to be removed.
3. Unscrew the two M6 x 1.0 bolts that attach the coil to the rocker cover. Pull the coil assembly with the boot, mounting screws, and O-rings out of the spark plug well.
4. Inspect the ignition coil. Refer to section 15.2.1.1.

#### 15.2.1.1 Inspection of Ignition Coil

Inspect the ignition coil as follows:

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

1. Visually check the ignition coil for dirt and debris.
   [a] If dirt and debris are present, clean as necessary and apply a light coat of dielectric grease on the inside of the ignition boot. Reuse ignition coil. Refer to section 15.2.2.
   [b] If no dirt and debris are present, reuse ignition coil. Apply a light coat of dielectric grease on the inside of the ignition boot. Refer to section 15.2.2.
2. Visually check the interface between the boot and spark plug for oil.
   [a] If oil is present, clean as necessary. Apply a light coat of dielectric grease on the inside of the ignition boot. Refer to section 15.2.2.
   [b] If no oil is present, reuse ignition coil. Apply a light coat of dielectric grease on the inside of the ignition boot. Refer to section 15.2.2.

### 15.2.2 Installation of Ignition Coil

Install the ignition coil as follows:

1. Install the ignition coil assembly with the boot, mounting screws, and O-rings into the spark plug well.
2. Guide the mounting bolts through the holes in the rocker cover and screw them into the extension tube. Torque the bolts to 13-16 N·m (10-12 lb·ft).
3. Push the connectors of the low voltage wire harness onto the ignition coils.
4. Put antisieze compound on the two coil cover mounting screws to aid removal in the future.
5. Install the coil cover on the rocker cover with two Phillips mounting screws.

## 15.3 IGNITION BOOT ASSEMBLY

The boot assembly consists of the boot and spring and is serviced as an assembly.

### 15.3.1 Removal of Ignition Boot

Remove the ignition boot as follows:

1. Peel the end back from the coil and pull the two components apart.

### 15.3.2 Installation of Ignition Boot

Install the ignition boot as follows:

1. Secure the boot over the end of the coil.

**NOTE:**
Ensure that the boot is all the way on the coil.

# 15.4 IGNITER MODULE

The igniter module creates a ground path for the ignition coil primary circuit and limits the current to 7.5 amps. A 12-volt power source is supplied to the igniter module along with the command signals from the ECM.

## 15.4.1 Removal of Igniter Module

Remove the igniter module as follows:

1. Disconnect the ignitor coil harness from the igniter module.
2. Unscrew the two M6 x 1.0 attachment bolts.
3. Inspect the igniter. Refer to section 15.4.1.1.

### 15.4.1.1 Inspection of Igniter Module

Inspect the igniter module as follows:

1. Visually check the back surface of the igniter module, igniter module bracket, and connectors for dirt and debris.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

[a] If dirt and debris are present, clean as necessary with compressed air and reuse. Refer to section 15.4.2.

[b] If no dirt or debris are present, reuse the igniter module. Refer to section 15.4.2.

## 15.4.2 Installation of Igniter Module

Install the igniter module as follows:

1. Install the two M6 x 1.0 mounting screws. Torque to 13 - 16 N·m (10-12 lb·ft).
2. Press the connectors into the igniter module.

## 15.5 IGNITER MODULE BRACKET

The igniter module gives off heat and must be mounted on the bracket to keep the internal temperature within acceptable limits. The igniter module bracket is made of aluminum to conduct heat from the igniter module.

### 15.5.1 Removal of Igniter Module Bracket

Remove the igniter module bracket as follows:

1. Disconnect the ignition coil harness from the igniter module.
2. Remove the igniter module. Refer to section 15.4.1.
3. Remove the M10 x 1.5 x 30 mounting bolt.
4. Inspect the igniter module bracket.

#### 15.5.1.1 Inspection of Igniter Module Bracket

Inspect the igniter module bracket as follows:

1. Visually check the igniter module bracket for cracks and distortion.
   [a] If damage is found, replace the igniter module bracket.
   [b] If no damage is found, reuse the igniter module bracket.

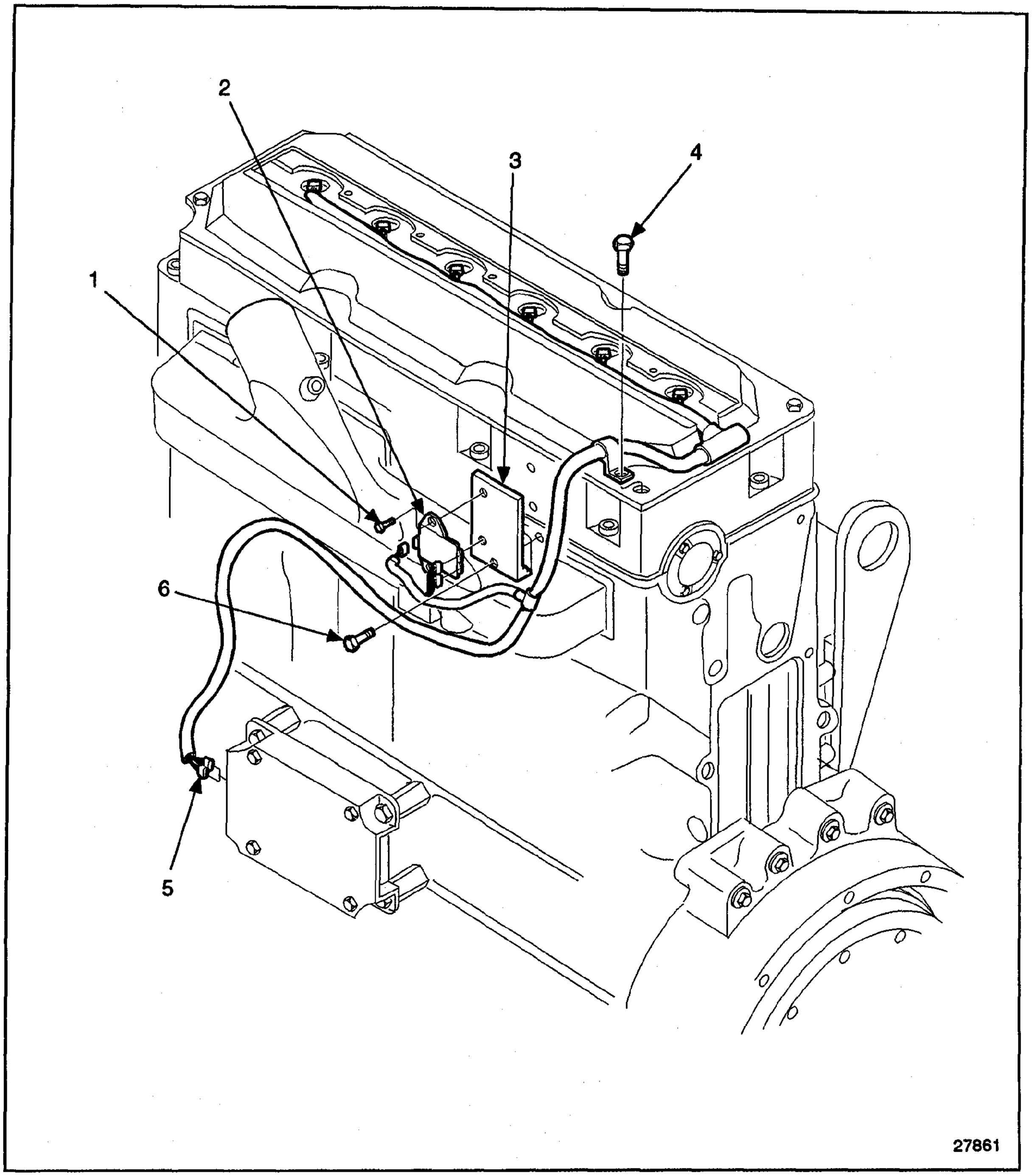
### 15.5.2 Installation of Igniter Module Bracket

Install the igniter module bracket as follows:

1. Install the bracket to the cylinder head using M10 x 1.5 x 30 mounting bolt. Torque bolt to 58 - 73 N·m (43-54 lb·ft).
2. Press the connectors of the ignition coil harness on the igniter module.

## 15.6 IGNITION COIL HARNESS

The ignition coil harness provides the 12-volt power to the ignition coils and igniter module, transmits the command signals from the ECM to the igniter module, and the ground circuit from the coils to the igniter module. See Figure 15-3.




1. Bolt
2. Module
3. Bracket
4. Bolt
5. Harness Connector
6. Bolt

**Figure 15-3 Ignition Coil Harness**

## 15.6.1 Removal of Ignition Coil Harness

Remove the ignition coil harness as follows:

1. Remove the two Phillips screws holding the coil cover in the rocker cover. Remove the coil cover.
2. Pull the connectors of the ignition coil harness from the four ignition coils.
3. Pull the connectors from the igniter module.
4. Disconnect the ignition coil harness from the 12-volt power supply.
5. Disconnect the ignition coil harness from the ECM.
6. Unscrew the harness clips from the rocker cover and the cylinder block.
7. Inspect the ignition coil harness. Refer to section 15.6.1.1.

### 15.6.1.1 Cleaning of Ignition Coil Harness

Clean the ignition coil harness as follows:

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

1. Remove dirt and debris form the connectors on the ignition coil harness, coils, igniter module, 12-volt power supply, and the ECM with compressed air.

## 15.6.2 Inspection of Ignition Coil Harness

Inspect the ignition coil harness as follows:

1. Visually check the harness for damage.
   [a] If damage is found, replace the ignition coil harness. Refer to section 15.6.3.
   [b] If no damage is found, reuse the ignition coil harness. Refer to section 15.6.3.

### 15.6.3 Installation Ignition Coil Harness

Install the ignition coil harness as follows:

1. Press the connectors of the ignition coil harness onto the four ignition coils.
2. Connect the ignition coil harness to the igniter module.
3. Connect the ignition coil harness to the 12-volt power supply.
4. Connect the ignition coil harness to the ECM.
5. Attach the harness clips to the rocker cover and cylinder block.
6. Add antisieze compound to the two coil cover mounting screws to aid removal in the future.
7. Install the coil cover on the rocker cover with the two Phillips mounting screws.

# 15.7 SPARK PLUGS

The condition of the spark plug determines the high voltage level and is the single most important component in the ignition system. The size of the electrode gap, condition of the electrodes, and the amount of deposits on the electrodes all affect the life of the spark plug. The electrodes of the spark plug are made from platinum which will minimize electrode wear.

Replace the spark plug with a new one if the electrode wear and amount of deposits are excessive. Otherwise the spark plug can be regapped to 0.015 in.

## 15.7.1 Removal of Spark Plug

Remove the spark plug from the cylinder head as follows:

1. Remove the ignition coils. Refer to section 15.2.1.
2. Remove the plug using a 5/8 in. thin wall spark plug socket and appropriate extensions.

### 15.7.1.1 Cleaning of Spark Plug Terminal, Ceramic Insulation, and Socket Area

Clean the spark plug terminal, ceramic insulation, and spark plug socket as follows:

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

1. Remove dirt and debris with compressed air.
2. Remove oil and grease deposits.
3. Inspect the spark plug.

### 15.7.1.2 Inspection of Spark Plug

Inspect the spark plug as follows:

1. Measure the spark plug gap using a 0.015 in. feeler gage.
   - [a] If the spark plug gap measured is not to specifications, regap the plug and reuse. Refer to section 15.7.2.
   - [b] If the spark plug gap is within specifications, reuse the spark plug. Refer to section 15.7.2.
2. Visually check the spark plugs for excessive deposits and condition of the electrode.
   - [a] If the spark plug has excessive deposits and electrode wear, replace the spark plug. Refer to section 15.7.2.
   - [b] If the spark plug has no deposits nor excessive electrode wear, reuse the spark plug. Refer to section 15.7.2.

## 15.7.2 Installation of Spark Plug

Install the spark plug as follows:

1. Install the spark plug using a 5/8 in. thin wall socket and appropriate extensions. Torque the spark plug to 35 - 40 N·m (26-30 lb·ft).
2. Install the ignition boot.
3. Install the ignition harness. Refer to section 15.6.3.

# 16 MISFIRING CYLINDER

## 16.1 POOR VEHICLE GROUND

To determine if poor vehicle ground is causing the cylinder to misfire, perform the following steps:

1. Remove alternator belt.

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

2. Start the engine.
3. Run the engine through operating range.
4. Listen for engine misfiring.
   [a] If the engine is not misfiring, refer to section 16.1.1. Shut down the engine.
   [b] If the engine is still misfiring, check for aerated fuel; refer to section 16.2.

### 16.1.1 Negative Lead Repair

Perform the following steps for negative lead repair:

1. Shut down the engine.
2. Remove negative lead(s) at frame ground stud near battery box.
3. Clean ground stud; refer to OEM guidelines.
4. Clean negative lead(s) terminal lugs with low grit sandpaper.
5. Repair any loose or damaged lead(s), using the splice method or rosin core solder.
6. Install negative lead(s) to frame ground stud; refer to OEM guidelines.

7. Install alternator belt. Tighten belt to:
   [a] If installing a new belt, tighten to 170 N·m (125 lb).
   [b] If installing a used belt, tigthen to 135 N·m (100 lb).
   [c] If a belt tension gage is not available, adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 12.70 - 19.05 mm (0.500 -0.750 in.).

**NOTE:**
**When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.**

**NOTE:**
**Drive belts (Vee and poly-vee) should be replaced every 2,000 hours or 100,000 miles (160,000 km).**

8. Verify negative lead repair; refer to section 16.1.1.1.

### 16.1.1.1 Verification of Repair for Negative Lead

Perform the following steps to determine if negative lead repair resolved the misfiring cylinder condition:

1. Refer to section 16.1 for exhaust caution before preceeding. Start engine.
2. Run engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is misfiring, check for aerated fuel. Shut down the engine; refer to section 16.2.

## 16.2 AERATED FUEL

To determine if aerated fuel is causing the cylinder to misfire, perform the following steps:

1. Disconnect the fuel line return hose from the fitting located at the fuel tank.
2. Place the opened end of fuel line into a suitable container.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine at 1000 r/min.
5. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are present, refer to section 16.2.1.
   [b] If air bubbles are not present, check for improper calibration setting; refer to section 16.3. Shut down the engine.

### 16.2.1 Aerated Fuel Repair

Perform the following steps for air in fuel repair:

1. Shut down engine.
2. Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
3. Visually inspect all fuel lines between fuel tank and fuel pump for leaks.
4. Replace any damaged components; refer to section 2.
5. Verify repair of fuel lines:
   [a] If no air in the fuel return, refer to section 16.2.1.1.
   [b] If air in the ruel return, locate and repair. Then refer to section 16.2.1.1.

#### 16.2.1.1 Test the Engine with Repair for Aerated Fuel

Perform the following steps to determine if the aerated fuel repair resolved the misfiring cylinder condition:

1. Refer to section 16.2 for exhaust caution before preceeding. Start engine.
2. Run engine at 1000 r/min.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is misfiring, check for improper injector setting. Shut down the engine; refer to section 16.3.

## 16.3 IMPROPER INJECTOR CALIBRATION SETTING (DDEC III/IV ENGINES ONLY)

For troubleshooting DDEC I and DDEC II engines, refer to section 16.4.

To determine if an improper injector calibration setting is causing the cylinder to misfire, perform the following steps:

1. Remove the valve rocker cover(s); for one-piece refer to section 1.6.2, for two-piece refer to section 1.6.3, for three-piece refer to section 1.6.5.
2. Record the injector calibration code of each injector noting the cylinder number; see Figure 16-1.

**NOTE:**
Injector calibration and bar codes may be absent from the load plates on first-run production DDEC III/IV injectors 5235575, 5235580, and 5235550. The correct calibration code for these units is "01". Load plates on current DDEC III/IV injectors include the required calibration or bar code information.

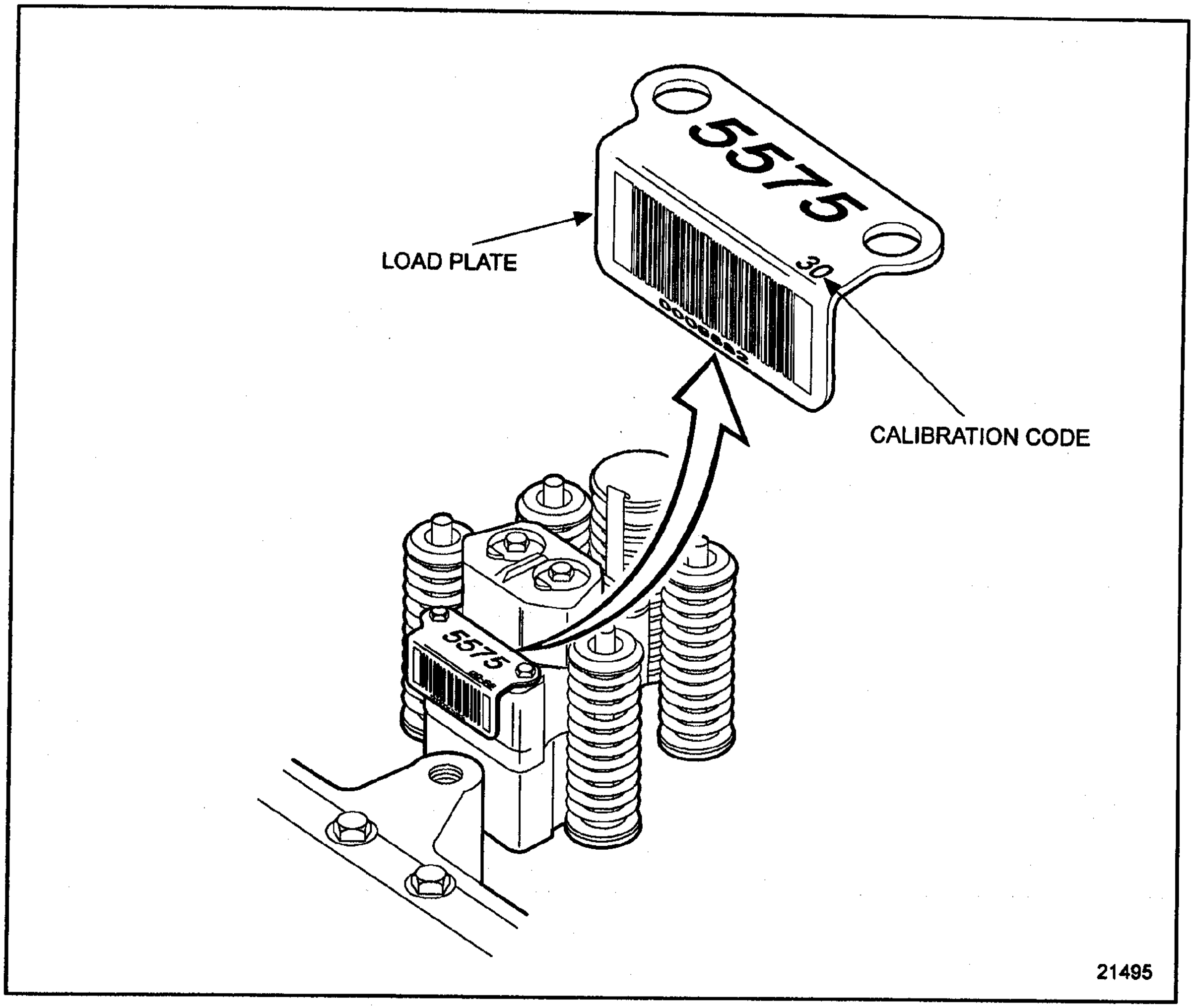



**Figure 16-1 Injector Calibration Code Location**

3. Turn vehicle ignition to the *on position*, but do not run engine.
4. Install Display Data Line (DDL) adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.
5. >From the Diagnostic Data Reader (DDR) DDEC III/IV Select Menu, scroll to select ENGINE and press the ENTER key.
6. Scroll to select FUEL INJECTOR INFO and press the ENTER key.
7. Scroll to select FUEL INJECTOR CAL and press the ENTER key.
8. Scroll to select FUEL INJECTOR CAL. Select VIEW and press the ENTER key.
9. Compare the calibration code(s) shown on the display with the two digit calibration code(s) on the injector(s).
   [a] If the calibration code on the display is different then the calibration code on the suspect injector for that cylinder, the injector setting must be repaired, see Figure 16-1; refer to section 16.3.1.
   [b] If test codes match; refer to section 16.4.

### 16.3.1 Improper Injector Setting Repair

Perform the following steps to recalibrate improper injector setting:

| NOTICE: |
| --- |
| Whenever a DDEC III injector is removed from the engine, it should be reinstalled in its original location to maintain proper cylinder balance. If reinstalled in a different cylinder head location, injector calibration ***must*** be rechecked with the DDR and updated. Failure to observe these steps may result in reduced engine performance. |

**NOTE:**
Injector calibration and bar codes may be absent from the load plates on first-run production DDEC III/IV injectors 5235575, 5235580, and 5235550. The correct calibration code for these units is "01". Load plates on current DDEC III/IV injectors include the required calibration or bar code information. See Figure 16-1.

1. Scroll to select FUNCTION to return to the FUEL INJECTOR CAL menu on the DDR.
2. Scroll to select FUEL INJECTOR CAL. Select UPDATE and press the ENTER key.
3. Type the four-digit "Update Injector Calibration" password for the DDR and press the ENTER key. If this feature is not password protected, type "0000" and press the ENTER key.

4. A message will appear telling you to use the scroll keys to select the cylinder (requiring changes) or select TYPE # (enter the numerical keys to change the CAL (calibration value).

**NOTE:**
An asterisk (*) will highlight the first cylinder number on the list.

5. Scroll to the cylinder requiring change and type in the required two-digit injector calibration code number. Press the ENTER key.

**NOTE:**
The ENTER key must be pressed before the DDR will allow selection of another cylinder number.

6. Repeat step 5, until all changes have been made.
7. Scroll to select FUNCTION and press the ENTER key.
8. Scroll to select YES and press the ENTER key to reprogram the ECM with the revised injector calibration codes.

**NOTE:**
Turning the ignition to the *off position* and waiting five seconds before starting the engine is not required.

9. Disconnect the DDR; refer to OEM guidelines.

### 16.3.1.1 Verification of Repair for Improper Injector Setting

Perform the following steps to determine if the proper injector setting adjustment resolved the misfiring cylinder condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

1. Install the valve rocker cover(s); for one-piece refer to section 1.6.8, for two-piece and three-piece refer to section 1.6.9.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

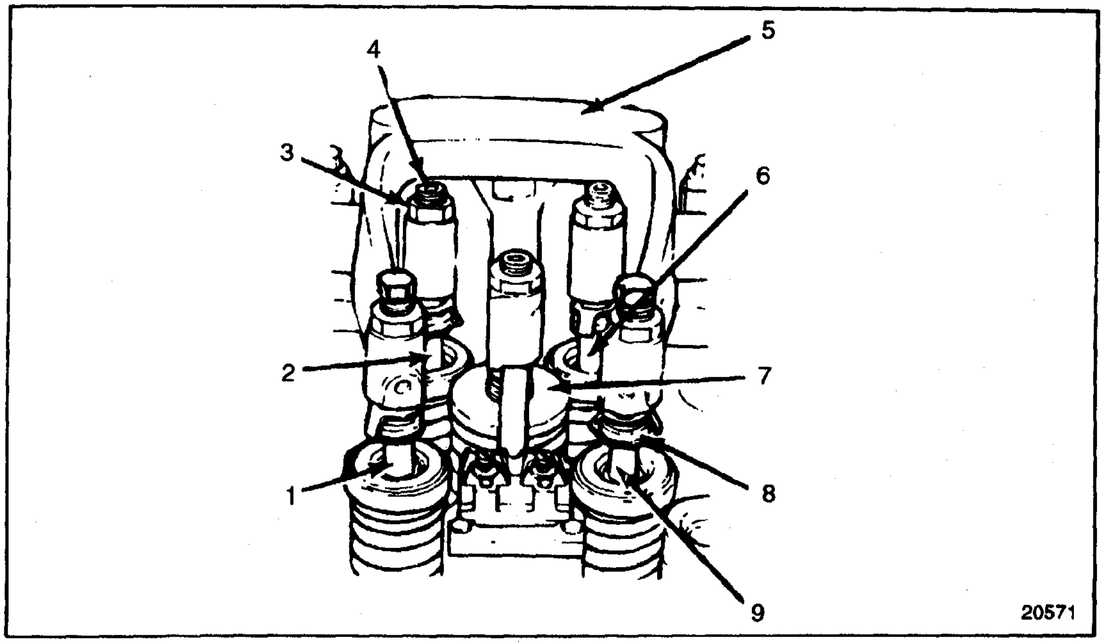
2. Start the engine.
3. Run the engine at 1000 r/min.
4. Listen for misfiring cylinder.

   [a] If the engine is not misfiring, no further troubleshooting is required. Shut down the engine.

   [b] If the engine is misfiring, shut down the engine. Check for improper valve clearance and injector height and damaged or worn camshaft lobes and rollers; refer to section 16.4.

## 16.4 IMPROPER VALVE CLEARANCE OR INJECTOR HEIGHT, WORN OR DAMAGED CAMSHAFT LOBES AND ROLLERS

Intake valve clearance and injector height are adjusted by means of an adjusting set screw and locknut located at the valve (or injector) end of the rocker arm; see Figure 16-2.




1. Exhaust Valve
2. Intake Valve
3. Locknut
4. Adjusting Set Screw
5. Exhaust Rocker Arm Assembly
6. Intake Valve
7. Fuel Injector Follower
8. Valve Button
9. Exhaust Valve

**Figure 16-2 Valve and Fuel Injector Height Adjustment Components**

**NOTE:**

On engines equipped with a Jake Brake®, measure valve lash and injector height before removing any brake housings. Only remove the brake housings necessary to provide access for adjustment.

The injector height is adjusted using the injector height gage, J 39697 (DDEC III/IV) or J 35637-A (DDEC II and I). On engines equipped with a Jake Brake®, move the handle on the injector height gage to the alternate position, 90 degrees to the shank. A height gage pilot hole is provided in the fuel injector body on the machined surface contacted by the injector clamp near the solenoid; see Figure 16-3.

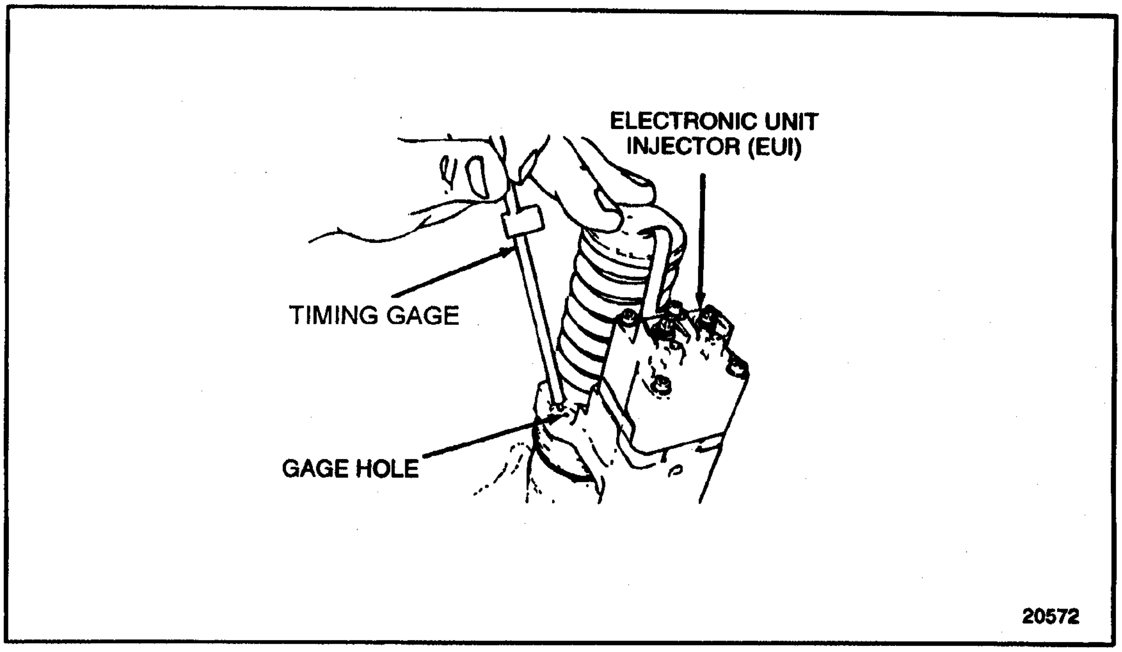


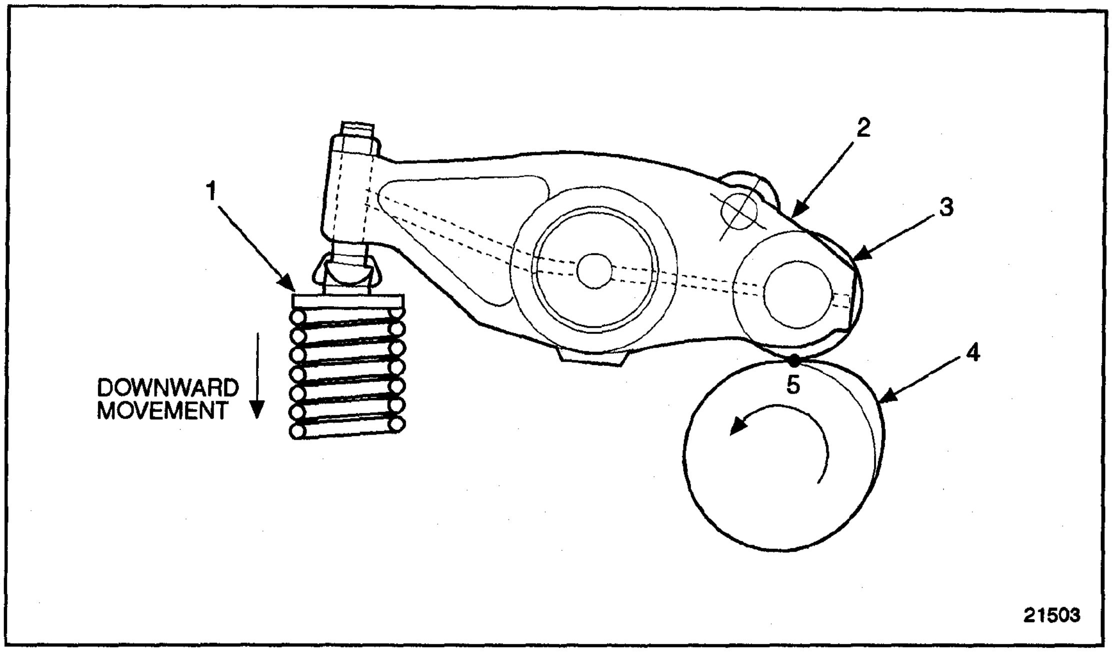

**Figure 16-3 Timing Gauge**

**NOTE:**
Be sure the height gage seats on the machined surface with the tip in the pilot hole. Foreign material in the pilot hole or on the machined surface may prevent accurate setting of the injector height.

To determine if improper valve clearance, injector height or both are causing the cylinder to misfire, perform the following preliminary step 1through step 3 and repeat step 4 through step 9 for each cylinder to determine if worn or damaged lobes or rollers are causing the engine to misfire:

1. Disconnect starting power for engine.
2. Remove the valve rocker cover(s); for one-piece refer to section 1.6.2, for two-piece refer to section 1.6.3, for three-piece refer to section 1.6.5.
3. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley.

4. Bar the engine over and inspect camshaft and rollers for wear or damage. Stop engine rotation when any one of the injector followers has just begun its downward stroke; see Figure 16-4.




1. Injector Follower
2. Injector Rocker Arm Assembly
3. Injector Roller
4. Injector Cam Lobe
5. Point on the Camshaft Lobe that First Produces Downward Motion of the Injector Follower

**Figure 16-4 Injector Followers Downward Stroke**

[a] If damage is found on the camshaft lobes or rollers, stop this procedure and replace damaged components as necessary; refer to section 1.23.2. Once complete, refer to section 16.4.1.1.

[b] If no damage was found to camshaft or rollers, continue with task.

5. Using timing chart, see Figure 16-5, determine if the intake valve clearances are acceptable (listed in Table 16-1), by inserting a feeler gage between the tip of the intake valve stem and the button; see Figure 16-6.

   [a] If the intake valve stem clearance is between 0.127 - 0.280 mm (0.005 -0.011 in.), step 6.

   [b] If the intake valve stem clearance is not between 0.127 - 0.280 mm (0.005 -0.011 in.), reset the intake valve(s) to 0.203 mm (0.008 in.); refer to section 16.4.1, step 1.

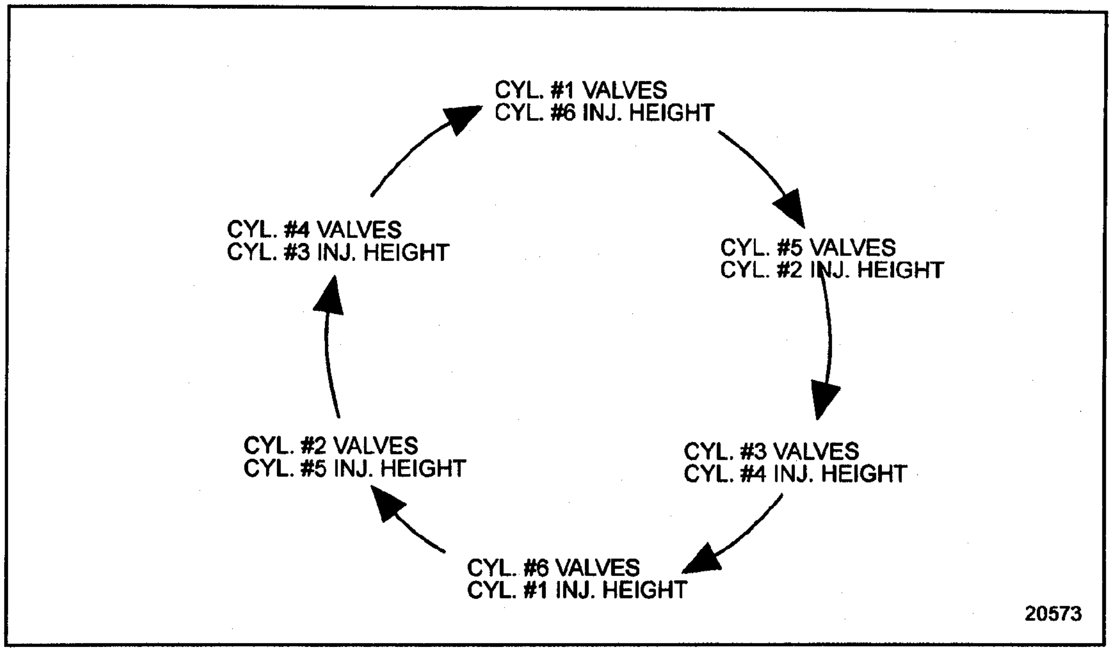
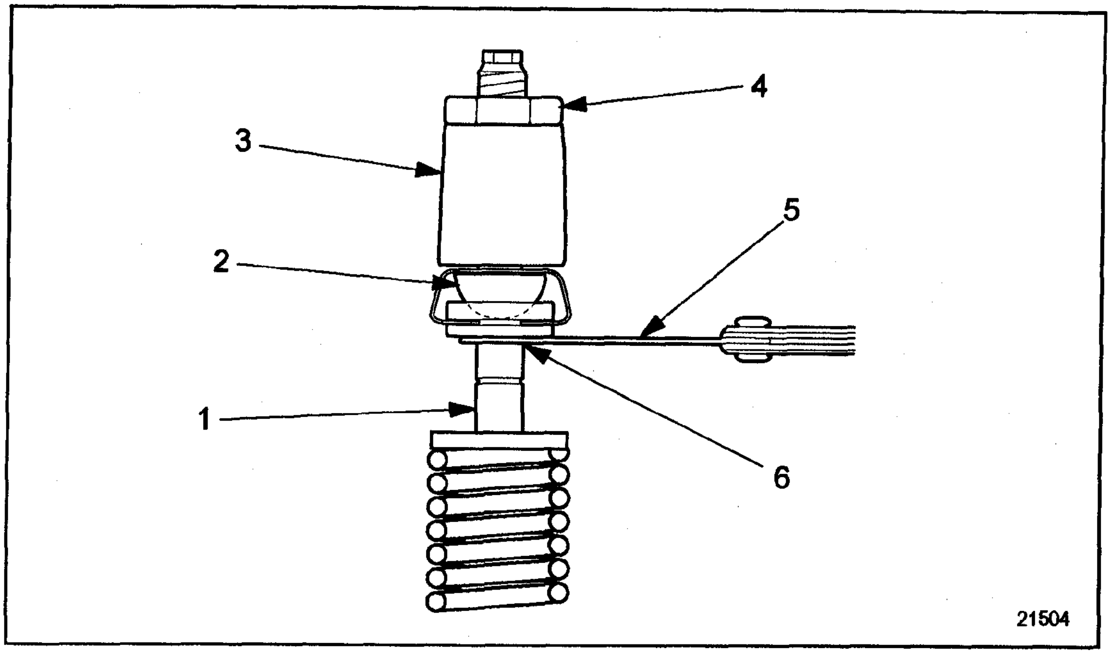



**Figure 16-5 Timing Circle Chart**




1. Intake Valve
2. Valve Button
3. Intake Rocker Arm Assembly
4. Locknut
5. Feeler Gage
6. Tip of Intake Valve

**Figure 16-6 Intake Valve Clearance**

| Settings and Models | Acceptable Range | Recommended Setting |
|---|---|---|
| Injector HeightsDDEC I and II (6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063WU00, 6063GU00, 6067WU60, 6067GU60, and 6067GU91) | 77.9–78.4 mm (3.068–3.088 in.) | 78.2 mm (3.078 in.) |
| Injector HeightsDDEC III (6067WK60, 6067WK28, 6067GK60, 6067GK28, 6063WK60, 6063WK28, 6063GK05 6063GK60, and 6063GK28) | 2.992–3.112 mm (2.992–3.112 in.) | 78.8 mm (3.102 in.) |
| Intake Valve Clearance | 0.127 - 0.280 mm (0.005. - 0.011 in.) | 0.203 mm (0.008 in.) |
| Exhaust Valve Clearance "U" (6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063WU00, 6063GU00) | 0.432 - 0.054 mm (0.017 - 0.023 in.) | 0.508 mm (0.020 in.) |
| Exhaust Valve Clearance "H"(6067WU60, 6067GU60, 6067WK60, 6067GK60, 6067GK28, 6067WK28 6067GU91, 6063WU60, 6063GK05, 6063GK32, 6063GK60, 6063GU41, 6063GU60, 6063WK32, 6063WK60, 6063WU00, 6063WU41, 6063GU00) | 0.584 - 0.736 mm (0.023 - 0.029 in.) | 0.660 mm (0.026 in.) |

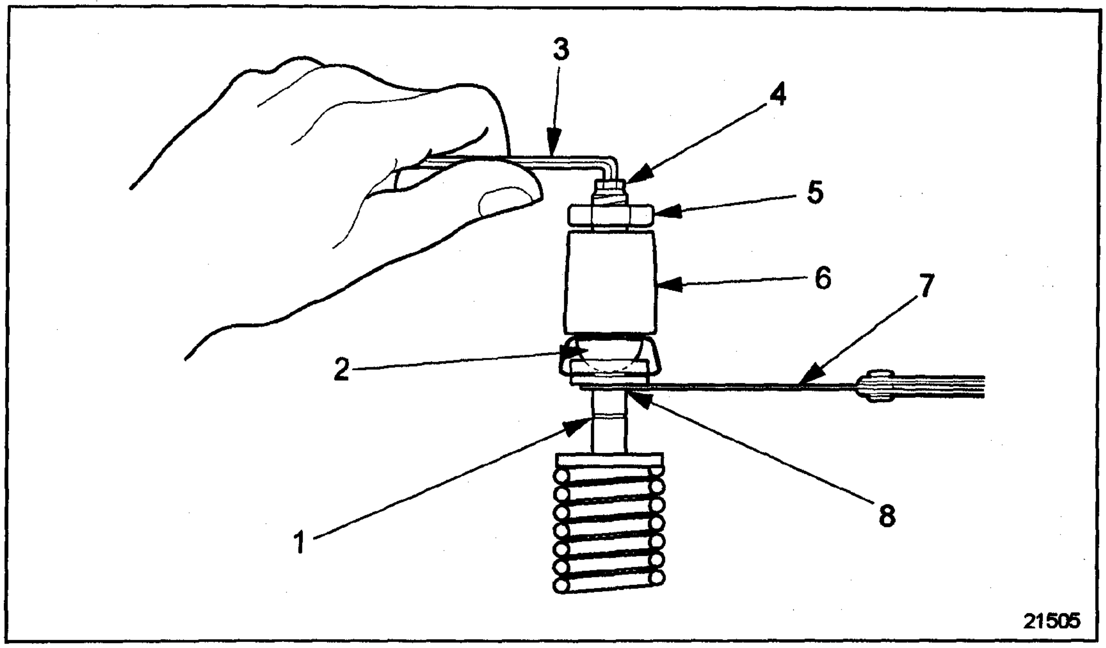
**Table 16-1 Valve Clearance and Injector Height Settings**

6. Using timing chart, see Figure 16-5, determine if the exhaust valve clearances are acceptable, (listed in Table 16-1) by inserting a feeler gage between the tip of the exhaust valve stem and the button; see Figure 16-7.

   [a] For exhaust valves with a machined groove between the rotator and tip, the exhaust valve stem clearance should be between 0.584 - 0.736 mm (0.023 -0.029 in.). If the exhaust valve stem clearance is between 0.584 - 0.736 mm (0.023 -0.029 in.), proceed to step 7For exhaust valves without a machined groove between the rotator and tip, the exhaust valve stem clearance should be between 0.432 - 0.584 mm (0.017 -0.023 in.). If the exhaust valve stem clearance is between 0.432 - 0.584 mm (0.017 -0.023 in.), perform to step 7or step 8.

   [b] If the exhaust valve stem clearance is not between 0.584 - 0.736 mm (0.023 -0.029 in.) for exhaust valves with a machined groove between the rotator and tip, reset the valve(s) to 0.660 mm (0.026 in.); refer to step 7 or step 8.

[c] If the exhaust valve stem clearance is not between 0.432 - 0.584 mm (0.017 -0.023 in.) for exhaust valves without a machined groove between the rotator and tip, reset the valve(s) to 0.508 mm 0.020 in.); refer to section 16.4.1, step 2



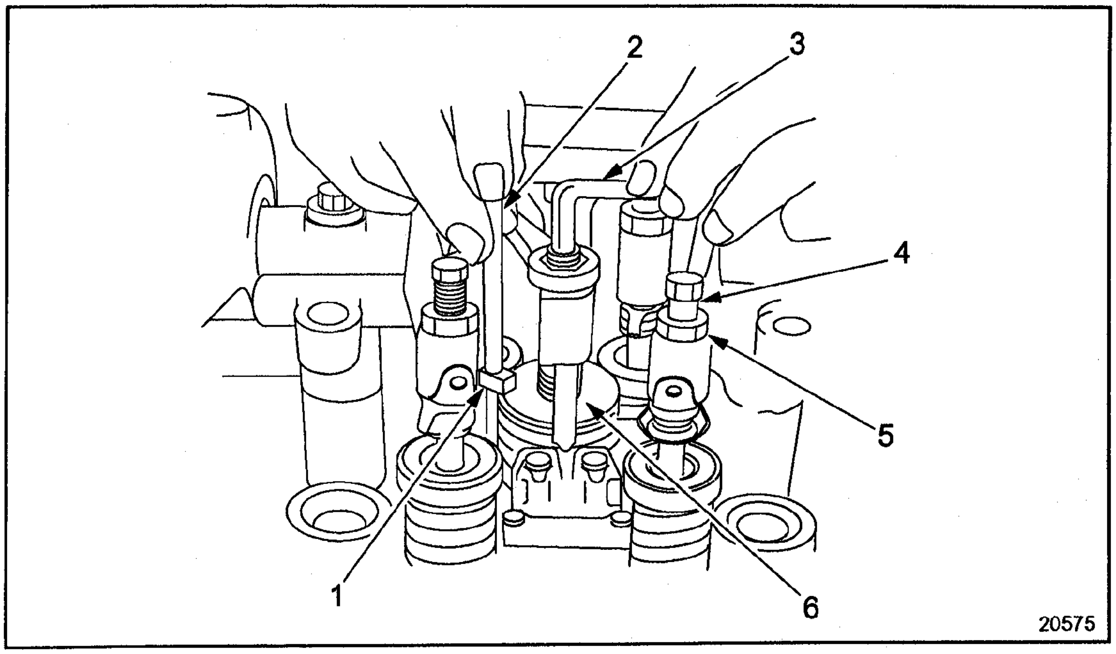

1. Location of Identification Groove
2. Valve Button
3. Allen Wrench
4. Adjusting Screw
5. Locknut
6. Exhaust Rocker Arm Assembly
7. Feeler Gage
8. Tip of Exhaust Valve

**Figure 16-7 Exhaust Valve Clearance**

7. If troubleshooting a DDEC III/IV engine, place the small end of J 39697 in the hole provided in the injector body, with the flat of the gage toward the fuel injector plunger; see Figure 16-8.

   [a] If the tool is flush against the follower, the injector height is acceptable; refer to step 9.

   [b] If the tool is not flush, adjust injector height; refer to section 16.4.1, step 3




1. Height Gage Flag
2. Height Gage
3. 3/16 in. Allen Wrench
4. Adjusting Screw
5. Locknut
6. Fuel Injector Follower

**Figure 16-8 Fuel Injector Adjustment**

8. If troubleshooting a DDEC I or II engine, place the small end of J 35637-A in the hole provided in the injector body, with the flat of the gage toward the fuel injector plunger; see Figure 16-8.

   [a] If the tool is flush against the follower, the injector height is acceptable; refer to step 9

   [b] If the tool is not flush, adjust injector height; refer to section 16.4.1, step 3

9. Bar the engine over, clockwise, until the fuel injector for the next cylinder begins its downward stroke; see Figure 16-4. Repeat steps 5 through step 8 and repeat until all six fuel injectors and sets of valves have been checked and reset as necessary. When all cylinders have been checked, refer to section 16.4.1, step 4

### 16.4.1 Improper Valve Clearance or Injector Height Repair

Perform the following steps to repair improper fuel injector height, intake valve clearance, and exhaust valve clearance.

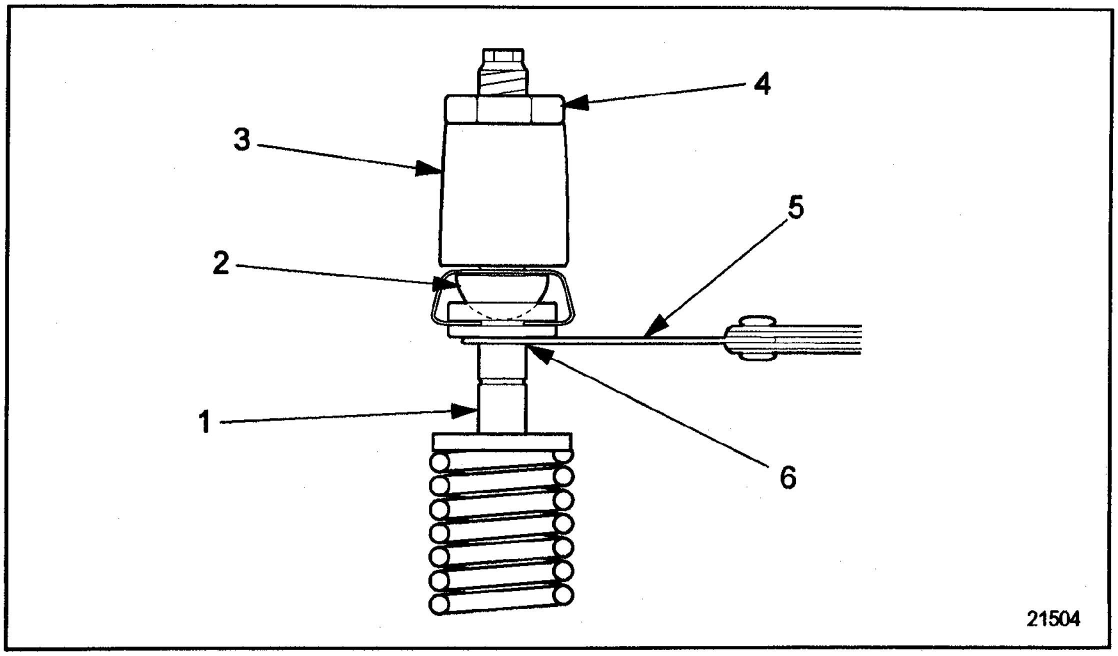
**NOTE:**
Using the steps below, it will be necessary to bar the engine over only two complete revolutions. Three cylinders will be adjusted for valves, and three cylinders will be adjusted for injectors on each revolution.

If required, remove Jake Brake® housing necessary to provide access for repair; refer to section 1.29.2.

| NOTICE: |
|---|
| Never set the valves and injector of the same cylinder at the same time. Doing this will result in engine damage. |

1. Adjust the intake valve clearances as follows:
   [a] Insert a 0.203 mm (0.008 in.) feeler gage between the tip of one valve stem and the valve button; see Figure 16-9.
   [b] Loosen the locknut, and turn the adjusting set screw until the feeler gage produces a snug, smooth pull between the intake valve stem and valve button; see Figure 16-9.

[c] Torque the locknut to 41 - 47 N·m (30 - 35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.




1. Intake Valve
2. Valve Button
3. Intake Rocker Arm Assembly
4. Locknut
5. Feeler Gauge
6. Tip of Intake Valve

**Figure 16-9 Measurement of Intake Valve Clearance**

2. Perform the following steps to adjust the exhaust valve clearances:

   [a] Insert a 0.660 mm (0.026 in.) feeler gage for valves with a machined groove between the tip of the valve stem and the valve button. Insert a 0.508 mm (0.020 in.) feeler gage for valves without machined groove; see Figure 16-7.

   [b] Loosen the locknut, and turn the adjusting set screw until the feeler gage produces a snug, smooth pull between the exhaust valve stem and the valve button.

   [c] Torque the locknut to 41 - 47 N·m (30 - 35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.

3. Perform the following steps to adjust fuel injector heights.
   [a] For DDEC III/IV engines, place the small end of the height gage, J 39697, in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger; see Figure 16-3 and proceed to step 3[c].
   [b] For DDEC I or II engines place the small end of the height gage, J 35637–A, in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger.
   [c] Loosen the locknut and turn the adjusting set screw until the extended part (flag) of the gage will just pass over the top of the injector follower. A snug feel is recommended. The objective is to adjust all six injectors to the same feel; see Figure 16-9.
   [d] Torque the locknut to 41 - 47 N·m (30 - 35 lb·ft).
   [e] Check the adjustment with the height gage, J 39697 (DDEC III/IV engines) J 35637-A (DDEC I or II engines), and if necessary, readjust the set screw.
4. Install the valve rocker cover(s); refer to section 1.6.7.
5. Install the Jake Brakes® if removed for repair, refer to section 1.29.5.
6. Reconnect starting power to the engine.
7. Verify repair of valve clearance or injector height setting. Refer to section 16.4.1.1.

### 16.4.1.1 Verification of Repair for Improper Valve Clearance or Injector Height Setting

Perform the following steps to determine if valve clearance or injector height adjustment resolved the misfiring cylinder condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine at 1000 r/min.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, shut down the engine. No further troubleshooting is required.
   [b] If the engine is misfiring, shut down the engine and check for faulty fuel injector; refer to section 16.5.

## 16.5 FAULTY FUEL INJECTOR

To determine if a faulty fuel injector is causing the cylinder to misfire, perform the following steps:

1. Install DDL adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start the engine.
3. >From the DDEC III/IV Select Menu, scroll to select ENGINE and press the ENTER key.
4. Scroll to FUEL INJECTOR INFO (CUTOUT) and press the ENTER key.
5. Scroll to select NEW TEST and press the ENTER key.
6. Scroll to select RPM SETTING FOR CCO TEST NORMAL and scroll to select 1000 and press the ENTER key.
7. Scroll to select AUTO and press the ENTER key. Wait for END OF TEST.

**NOTE:**
If an injector cannot be cutout, you will see an ERROR message. Press FUNC to exit the cylinder cutout function, press the FUNC key.

8. Scroll the list to review the results of the cylinder cutout test. To find suspect injectors, look for a cylinder with a value that is within 0.2 degrees of the NO CUTOUT PULSE WIDTH, by comparing the CUTOUT PULSE WIDTH values to the NO CUTOUT PULSE WIDTH values.
   [a] If any CUTOUT PULSE WIDTH values are within 0.2 degrees of the NO CUTOUT PULSE WIDTH, shut down the engine and refer to section 16.5.1.
   [b] If any CUTOUT PULSE WIDTH values are not within 0.2 degrees of the NO CUTOUT PULSE WIDTH, shut down the engine and refer to section 16.6.

### 16.5.1 Faulty Fuel Injector Repair

Perform the following steps for faulty fuel injector assembly(s):

1. Remove and replace injector assembly(s) whose values are within 0.2 degrees of the NO CUTOUT PULSE WIDTH; refer to section 2.3.2.
2. Verify replaced injector assembly(s), refer to section 16.5.1.1.

#### 16.5.1.1 Verification of Repair for Faulty Fuel Injector

Perform the following steps to determine if the replaced fuel injector(s) resolved the misfiring cylinder condition:

1. Refer to section 16.5 for the exhaust caution before preceeding. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, shut down the engine. No further troubleshooting is required.
   [b] If the engine is misfiring, shut down the engine and check for a faulty electronic control module (ECM); refer to section 16.6.

## 16.6 FAULTY ELECTRONIC CONTROL MODULE

To determine if a faulty electronic control module (ECM) is causing the cylinder to misfire, perform the following:

**NOTE:**
Carefully disengage the lock tab on the power harness and injector harness connectors when removing.

1. Remove the thru-bolts holding the ECM to the engine; refer to section 2.16.2.
2. Remove the ECM from the engine and tag the ECM for core return.
3. Obtain a new reprogrammed ECM for the engine you are troubleshooting.
4. Inspect the ECM isolators for any damage. Replace if necessary, refer to section 2.16.3.
5. Install the ECM to the engine using thru-bolts; refer to section 2.16.3.
6. Torque the ECM thru-bolts to 23 - 27 N·m (17 - 20 lb·ft).
7. Torque the ECM connector hold-down screws to 24 - 30 N·m (21 - 26 lb·in.).

### 16.6.1 Faulty ECM Repair

No repair authorized for ECM.

### 16.6.1.1 Verification of Repair for Faulty ECM

Perform the following steps to determine if the new ECM resolved the misfiring cylinder condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, shut down the engine. No further troubleshooting is required.
   [b] If the engine is misfiring, shut down the engine and check for worn or damaged valves and cylinder kits; refer to section 16.7.

## 16.7 WORN OR DAMAGED VALVE OR CYLINDER KIT

Loss of compression in Series 60 engines may result from a variety of sources, including worn or broken fire or compression rings, holes in pistons, leaky valves, scored or worn cylinder walls, leaky or broken gaskets and cracked cylinder heads or cylinder liners. The detection and elimination of the cause or causes of cylinder pressure losses is vital to engine life and efficient operation. To assist the mechanic in effectively measuring the loss of cylinder pressure, and locating the source of abnormal leaks in individual cylinders, the following test procedure has been developed.

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to section 10.1.5.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run vehicle to full load and rated speed.
6. Attach a manometer calibrated to read in. $H_2O$, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down engine.
9. Remove the vehicle from the chassis dynamometer.

10. Review the crankcase pressure test results.
    [a] If the crankcase pressure was greater than 3 in. $H_2O$ (.75 kPa); refer to section 16.7.1.
    [b] If the crankcase pressure was less than 3 in. $H_2O$ (.75 kPa); perform a cylinder compression test.
11. Compare the cylinder compression test results to specifications.
    [a] If cylinder pressure is below specifications, refer to section 16.7.1.
    [b] If cylinder pressure is within specification, call Detroit Diesel Technical Service Group.

### 16.7.1 Worn or Damaged Valve or Cylinder Kit Repair

Perform the following steps for worn or damaged valve or cylinder kit:

1. Remove cylinder head; refer to section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to section 1.2.3.1. For repair and replacement procedures refer to section 1.4.1.
3. Inspect the cylinder kit components for worn or damaged liners, refer to section 1.20.2.2; pistons or piston rings; refer to section 1.17.3.1.
4. Verification of repairs made to cylinder valve(s) or cylinder kit components is required; refer to section 16.7.1.1.

#### 16.7.1.1 Verification of Repair for Worn or Damaged Valve or Cylinder Kit

Perform the following steps to determine if the repaired valve or cylinder kit resolved the misfiring cylinder condition:

1. Refer to section 16.7 for the exhaust caution before preceeding. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.
    [a] If the engine is not misfiring, no further troubleshooting is required.
    [b] If the engine is misfiring, call Detroit Diesel Technical Service Group.

# 17 STARTING DIFFICULTY (ENGINE ROTATES)

**Section** **Page**

## 17.1 ELECTRONIC CONTROL MODULE WIRING HARNESS

To determine if the electronic control module (ECM) wire harness is causing starting difficulty, perform the following steps:

1. Turn the ignition switch to the on position.
2. Install the Diagnostic Data Link (DDL) adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.
3. Determine if ECM data is being received by the DDR; refer to OEM guidelines.
   [a] If no data is being received by the DDR, check for intermittent code or a fault and no codes in the Detroit Diesel DDEC Single ECM, *Troubleshooting Guide*, (6SE497).
   [b] If data is being received by the DDR, check vehicle circuit breakers or fuses; refer to section 17.1.1.

### 17.1.1 Vehicle Circuit Breakers or Fuses Check

To determine if the vehicle circuit breakers are causing starting difficulty, perform the following steps:

1. Visually check ECM circuit breakers or fuses and determine if circuit breaker(s) or fuse(s) are tripped or blown; refer to OEM guidelines.
   [a] If circuit breakers tripped, determine cause and repair or replace as necessary; refer to OEM guidelines. Perform validation; refer to section 17.1.3.1.
   [b] If circuit breakers are not tripped, measure the voltage at the ECM power harness; refer to section 17.1.2.

### 17.1.2 ECM Power Harness Voltage Test

To determine if the electronic control module power harness is causing circuit breakers to be tripped or blown, perform the following steps:

1. Turn ignition off, if required.
2. Disconnect the 5-way power harness connector; see Figure 17-1.

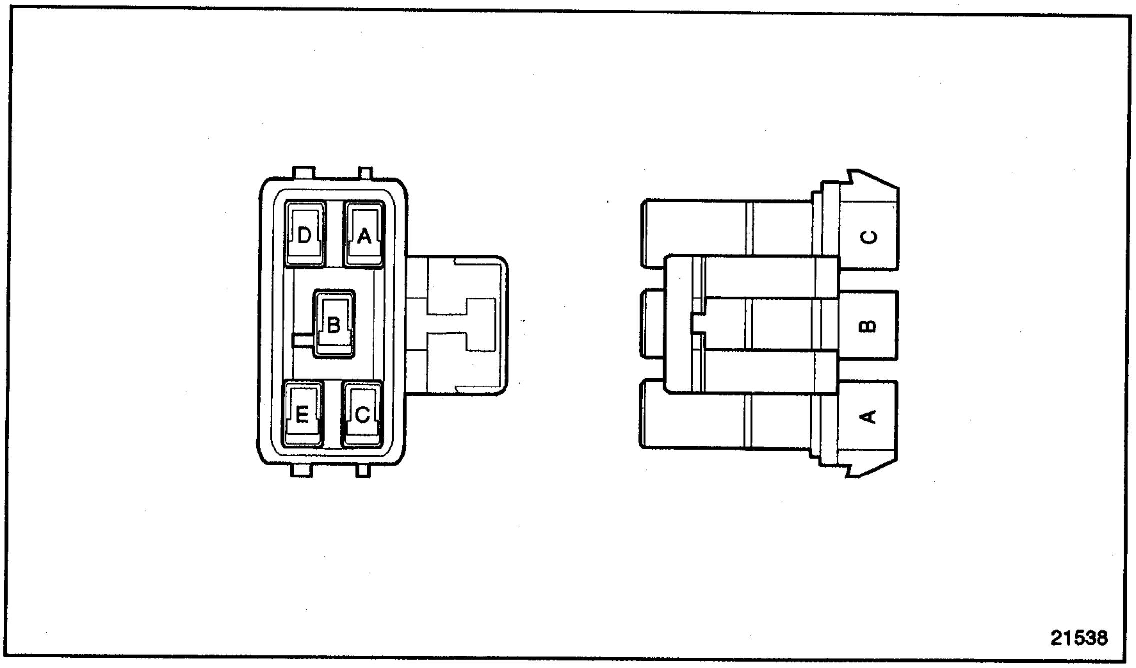



**Figure 17-1 5-Way ECM Power Harness Connector**

3. Measure and record voltage from socket "A" (red lead) of 5-way power harness connector to a good ground (black lead).
4. Measure and record voltage from socket socket "C" (red lead) to a good ground (black lead).
5. Review the measured voltage readings.
   [a] If the voltage measured is less than 10 volts, inspect and repair power harness; refer to section 17.1.3.
   [b] If the voltage measured is greater than 10 volts, check for low battery voltage; refer to section 17.3.

### 17.1.3 Power Harness Repair

Perform the following steps to repair power harness:

1. Repair damage to the power harness.
2. Verify repair of the power harness; refer to section 17.1.3.1.

#### 17.1.3.1 Test Engine with Repaired Power Harness

Perform the following steps to determine if the repair resolved starter difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check for empty fuel tank; refer to section 17.2.

## 17.2 EMPTY FUEL TANK

To determine if an empty fuel tank is causing starting difficulty, perform the following steps:

1. Determine the amount of fuel in fuel tank; refer to OEM guidelines.
   [a] If fuel is at recommended level, check for a weak battery; refer to section 17.3.
   [b] If fuel is below recommended level, refer to section 17.2.1.

### 17.2.1 Low Fuel Level Resolution

Perform the following steps to resolve low fuel level:

1. Fill fuel tank to full; refer to OEM guidelines.
2. Verify fuel tank refill; refer to section 17.2.1.1.

#### 17.2.1.1 Test Engine with Filled Tank

Perform the following steps to determine if a filled fuel tank resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the battery; refer to section 17.3.

## 17.3 LOW BATTERY VOLTAGE

To determine if a weak battery is causing starting difficulty, perform the following steps:

**CAUTION:**

**To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:**

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

1. Measure the battery voltage; refer to OEM guidelines.
   [a] If voltage is between 10.5 - 14 volts (21 - 26 volts for a 24 volt system), check the terminals; refer to section 17.4.
   [b] If voltage is less than 10.5 volts (21 volts for a 24 volt system), replacement is necessary; refer to section 17.3.1.

### 17.3.1 Battery Replacement

Perform the following steps for battery repair:

1. Remove and replace the battery; refer to OEM guidelines.
2. Verify battery replacement; refer to section 17.3.1.1.

#### 17.3.1.1 Test Engine with Replaced Battery

Perform the following steps to determine if the battery replacement resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the terminals; refer to section 17.4.

## 17.4 CORRODED OR DAMAGED BATTERY TERMINALS

To determine if corroded or damaged terminals is causing starting difficulty:

1. Visually inspect terminals for corrosion or damage.
   [a] If corrosion or damage are not found, check the magnetic switch; refer to section 17.5.
   [b] If corrosion or damage are found, repair is necessary; refer to section 17.4.1.

### 17.4.1 Corroded or Damaged Battery Terminal Repair

Perform the following steps to repair corroded or damaged battery terminals:

1. Repair or replace any corroded or damaged terminals; refer to OEM guidelines.
2. Verify repair of corroded or damaged terminals; refer to section 17.4.1.1.

#### 17.4.1.1 Test with Repaired Battery Terminals

Perform the following steps to determine if the repair resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the magnetic switch; refer to section 17.5.

## 17.5 DEFECTIVE MAGNETIC SWITCH

To determine if a defective magnetic switch is causing starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start engine.

**CAUTION:**

**To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.**

2. Clamp a heavy gauge battery jumper cable between the two large studs of the magnetic switch. See Figure 17-2.

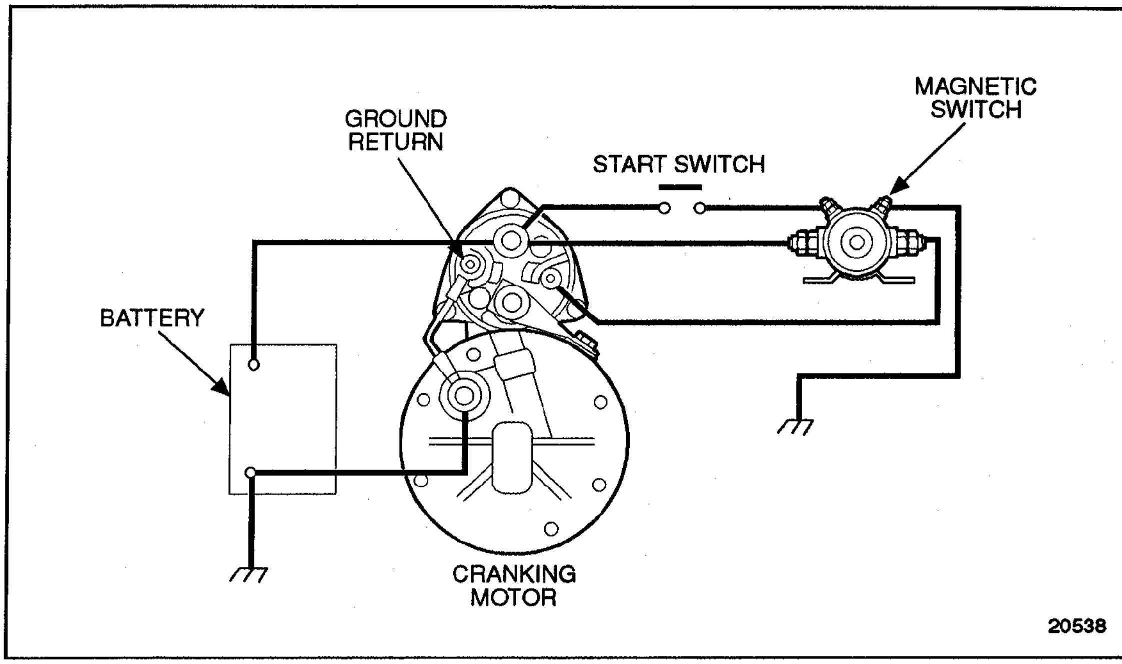



**Figure 17-2 Basic Cranking Circuit**

[a] If the engine cranked with the jumper cable in place, the magnetic switch must be replaced; refer to section 17.5.1.

[b] If the engine did not crank with the jumper cable in place, check the starter; refer to section 17.6.

### 17.5.1 Magnetic Switch Replacement

Perform the following steps for magnetic switch replacement:

1. Replace the magnetic switch; refer to OEM guidelines.
2. Verify magnetic switch replacement; refer to section 17.5.1.1.

#### 17.5.1.1 Test Engine with Replaced Magnetic Switch

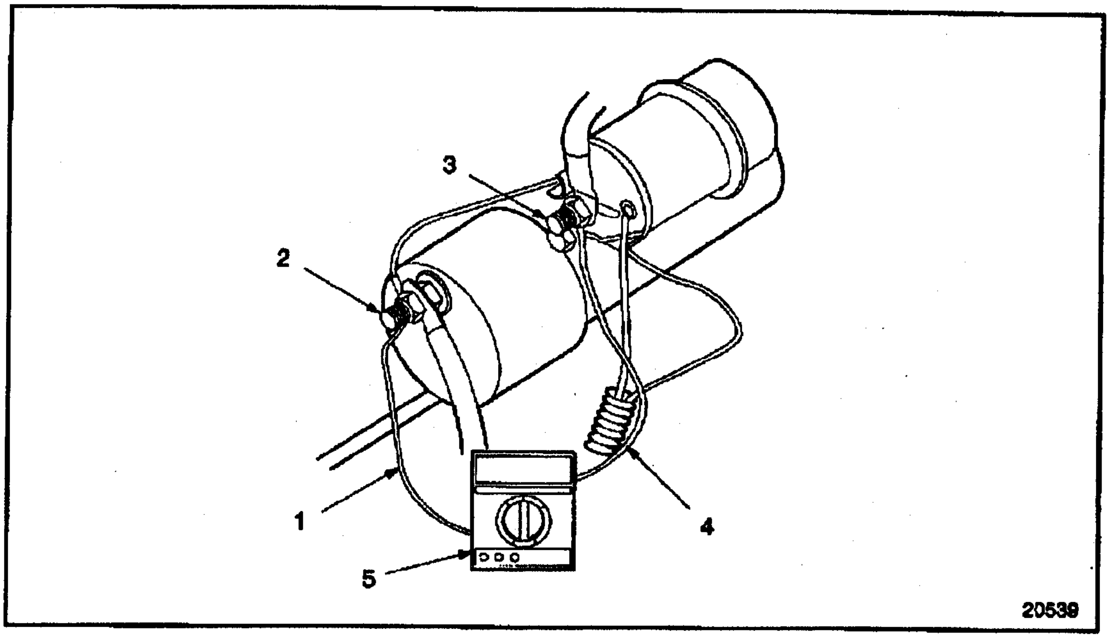
Perform the following steps to determine if the magnetic switch replacement resolved starting difficulty:

1. Refer to section 17.5 for the exhaust catuion before preceeding. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the starter; refer to section 17.6.

## 17.6 DEFECTIVE STARTER

To determine if a defective starter is causing starting difficulty, perform the following steps:

1. Place the red lead of a voltmeter to the solenoid "BAT" terminal, see Figure 17-3.




1. Black Voltmeter Lead
2. Starter Ground Terminal Lug
3. Red Voltmeter Lead
4. Harness Tube
5. Volt Ohm Meter

**Figure 17-3 Cranking Motor Available Voltage Test**

2. Place the black voltmeter lead to the starter ground terminal, see Figure 17-2.
3. Engage the starter switch.
4. View the voltage reading on the meter.
   [a] If the voltage is less than specification while cranking the engine, replacement is necessary; refer to section 17.6.1.
   [b] If the voltage is to specification while cranking the engine, check the cranking speed; refer to section 17.7.

### 17.6.1 Starter Replacement

Perform the following steps for starter replacement:

1. Replace the starter; refer to section 8.4.2.
2. Verify replacement of starter; refer to section 17.6.1.1.

### 17.6.1.1 Test Engine with Replaced Starter

Perform the following steps to determine if the replaced starter resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the cranking speed; refer to section 17.7.

## 17.7 LOW CRANKING SPEED

To determine if low cranking speed is causing starting difficulty, perform the following steps:

1. Install a tachometer to the engine and record engine revolution while cranking the engine; refer to OEM for guidelines.
   [a] If the cranking speed is greater than 100 r/min, check the fuel supply valve; refer to section 17.8.
   [b] If the cranking speed is less than 100 r/min; refer to section 17.7.1.

### 17.7.1 Low Cranking Speed Repair

Perform the following steps for low cranking speed repair:

1. Drain the engine oil. Refer to section 13.13.1.
2. Remove oil filter(s). Refer to section 13.13.4.
3. Install new oil filter(s). Refer to section 13.13.14.
4. Refill the lubrication system with new oil. Refer to section 13.13.1.
5. Verify low cranking speed repair; refer to section 17.7.1.1.

#### 17.7.1.1 Test Engine with Replaced Oil

Perform the following steps to determine if the replaced oil resolved starting difficulty:

| CAUTION: |
|---|
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

| CAUTION: |
|---|
| **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**<br>□ **Always start and operate an engine in a well ventilated area.**<br>□ **If operating an engine in an enclosed area, vent the exhaust to the outside.**<br>□ **Do not modify or tamper with the exhaust system or emission control system.** |

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the fuel supply valve; refer to section 17.8.

## 17.8 FUEL SUPPLY VALVE

To determine if the fuel supply valve is causing starting difficulty, perform the following steps:

1. Check that fuel supply valve is open; refer to OEM guidelines.
   [a] If the fuel supply valve is open, check the fuel filters; refer to section 17.9.
   [b] If the fuel supply valve is closed, repair is necessary; refer to section 17.8.1.

### 17.8.1 Fuel Supply Valve Repair

Perform the following steps for fuel supply valve repair:

1. Open the closed valve; refer to section 2.14.2.
2. Prime the fuel system; refer to section 11.1.6.
3. Verify fuel supply valve repair; refer to section 17.8.1.1.

#### 17.8.1.1 Test Engine with Fuel Supply Valve Open

Perform the following steps to determine if opening the fuel supply valve resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the fuel filters; refer to section 17.9.

## 17.9 PLUGGED FUEL FILTER(S)

To determine if a plugged fuel filters is causing starting difficulty, perform the following steps:

1. Disconnect the fuel line return hose from the fitting located at the fuel tank.
2. Place the opened end of fuel line into a five gallon container.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine at 1000 r/min.
5. Clock fuel rate for one minute.
6. Measure the amount of fuel flowed into the container.

   [a] If the fuel flow is greater than 1 gal/min (3.8 L/min), check for air in fuel; refer to section 17.11.

   [b] If the fuel flow is less than 1 gal/min (3.8 L/min), replace the fuel filters; refer to section 17.9.1.

### 17.9.1 Plugged Fuel Filter(s) Replacement

Perform the following steps to replace fuel filter(s):

1. Replace the fuel filter; refer to section 13.13.14.
2. Test the engine to determine if starting has been improved; refer to section 17.9.1.1.

#### 17.9.1.1 Test Engine with Replaced Fuel Filters

Perform the following steps to determine if the replaced fuel filters resolved starting difficulty:

1. Refer to section 17.9 for the exhaust caution before preceeding. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check the fuel pump; refer to section 17.10.

## 17.10 FUEL PUMP

To determine if the fuel pump is causing starting difficulty, perform the following steps:

1. Insert a piece of wire through the pump flange drain hole, see Figure 17-4.

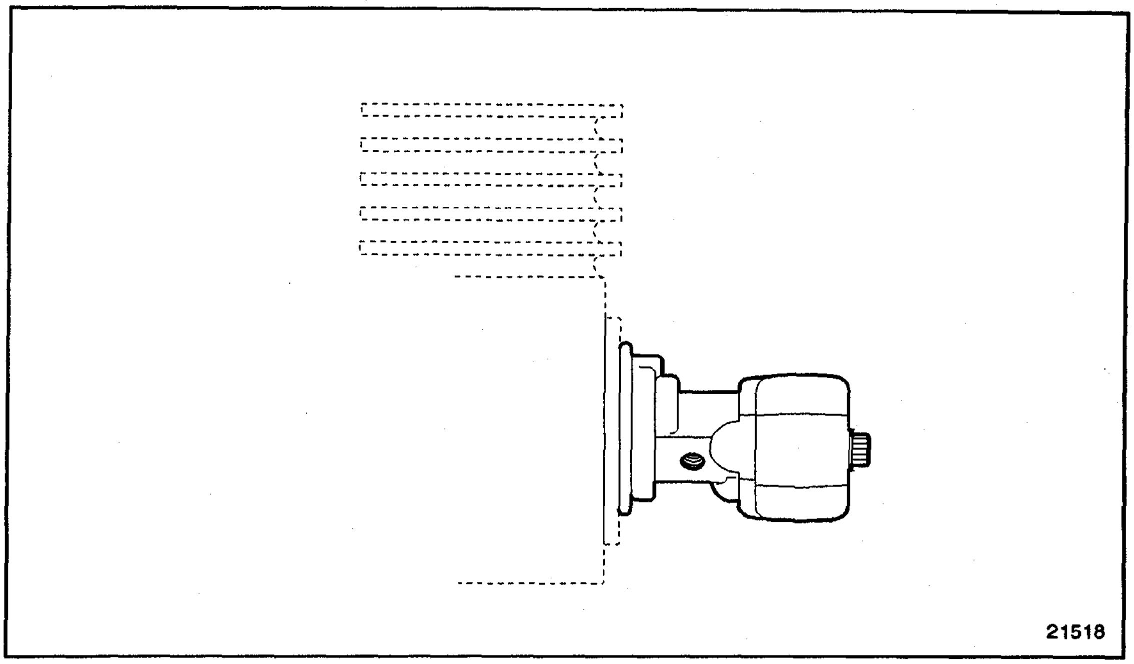



**Figure 17-4 Fuel Pump Flange Drain Hole Location**

2. Crank the engine momentarily and feel for wire vibration.
   [a] If the wire did not vibrate, determine if the drive hub or coupling should be replaced; refer to section 17.10.1.
   [b] If the wire did vibrate, check for aerated fuel. Refer to section 17.11.

### 17.10.1 Drive Hubs and Coupling Replacement

Perform the following steps for drive hub or coupling replacement:

1. Replace the drive hub or coupling; refer to section 2.7.
2. Test the engine to determine if starting has been improved; refer to section 17.10.1.1.

#### 17.10.1.1 Engine Test with Replaced Drive Hubs or Replaced Coupling

Perform the following steps to determine if replaced drive hubs or coupling resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.

   [b] If the engine fails to start and run, check for aerated fuel; refer to section 17.11.

## 17.11 AERATED FUEL

To determine if aerated fuel is causing starting difficulty, perform the following steps:

1. Disconnect the fuel line return hose from the fitting located at the fuel tank; refer to OEM guidelines.
2. Place the opened end of the fuel line into a suitable container.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine at 1000 r/min.
5. Visually check to see if air bubbles are rising to the surface of the fuel within the container.

   [a] If air bubbles are present, repair is necessary; refer to section 17.11.1.

   [b] If air bubbles are not present, check for a restrictive air filter. Shut down the engine; refer to section 17.12.

## 17.11.1 Aerated Fuel Resolution

Perform the following steps for aerated fuel resolution:

1. Shut down engine.
2. Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
3. Visually inspect all fuel lines between fuel tank and fuel pump for leaks.
4. Replace damaged components as required; refer to OEM guidelines.
5. Verify aerated fuel resolution; refer to section 17.11.1.1.

### 17.11.1.1 Test Engine with Aerated Fuel Resolution

Perform the following steps to determine if aerated fuel resolution resolved starting difficulty:

1. Refer to section 17.11 for exhaust caution before preceeding. Attempt to start and run the engine.
   - [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   - [b] If the engine fails to start and run, check for a restrictive air filter; refer to section 17.12.

## 17.12 RESTRICTIVE AIR FILTER

To determine if a restrictive air filter is causing starting difficulty, perform the following steps:

1. Remove the air filter element; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, refer to section 17.12.1.

### 17.12.1 Air Filter Replacement

Perform the following steps for air filter replacement:

1. Visually inspect the air filter for clogging and replace as necessary; refer to OEM guidelines.
2. Visually inspect gaskets for deterioration and replace as necessary; refer to OEM guidelines.
3. Visually inspect air inlets for restrictions and clean as necessary; refer to OEM guidelines.
4. Verify air filter replacement; refer to section 17.12.1.1.

#### 17.12.1.1 Test Engine with Replaced Air Filter

Perform the following steps to determine if the replaced air filter resolved starting difficulty:

1. Refer to section 17.12 for the exhaust before preceeding. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, check compression; refer to section 17.13.

## 17.13 LOW COMPRESSION

To determine if low compression is causing starting difficulty, perform the following steps:

1. Perform a cylinder compression test.
2. Compare cylinder compression test results to specifications.
   [a] If cylinder pressure is below specifications; refer to section 17.13.1.
   [b] If cylinder pressure is within specifications, call Detroit Diesel Technical Service Group.

### 17.13.1 Low Compression Repair

Perform the following steps for low compression repair:

1. Remove cylinder head; refer to section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to section 1.2.3.1.
3. Replace damaged valves; refer to section 1.4.1.
4. Inspect the cylinder kit components for worn or damaged liners, refer to section 1.20.2.2; pistons or piston rings; refer to section 1.17.3.1.
5. Verify repairs made to cylinder head valve(s) or cylinder kit components; refer to section 17.13.1.1.

#### 17.13.1.1 Test Engine with Repaired Cylinder Head Valve(s), and Cylinder Kit

Perform the following steps to determine if the cylinder head, valve and cylinder kit repair resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start and run, call the Detroit Diesel Technical Service.

# 18 NO START (ENGINE WILL NOT ROTATE)

## 18.1 DISCHARGED BATTERY

To determine if a discharged battery is causing the engine not to start, perform the following steps:

1. Measure and record the voltage at the battery terminals; refer to OEM guidelines.
   [a] If the voltage recorded is below OEM specifications and the engine failed to start, replacement is necessary; refer to section 18.1.1.
   [b] If the voltage recorded is at recommended OEM specifications and the engine failed to start, check the magnetic switch; refer to section 18.2.

### 18.1.1 Discharged Battery Resolution

Perform the following steps for battery replacement:

1. Replace the battery; refer to OEM guidelines.
2. Verify replacement of the battery; refer to section 18.1.1.1.

#### 18.1.1.1 Test Engine with New Battery

Perform the following steps to determine if the new battery resolved the no start condition:

| CAUTION: |
|---|
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

| CAUTION: |
|---|
| **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**<br>☐ **Always start and operate an engine in a well ventilated area.**<br>☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**<br>☐ **Do not modify or tamper with the exhaust system or emission control system.** |

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.

   [b] If the engine fails to start or run, check the magnetic switch; refer to section 18.2.

## 18.2 DEFECTIVE MAGNETIC SWITCH

To determine if a defective magnetic switch is causing no start:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start engine.

**CAUTION:**

**To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.**

2. Clamp a heavy gage battery jumper cable between the two large studs of the magnetic switch; see Figure 18-1.

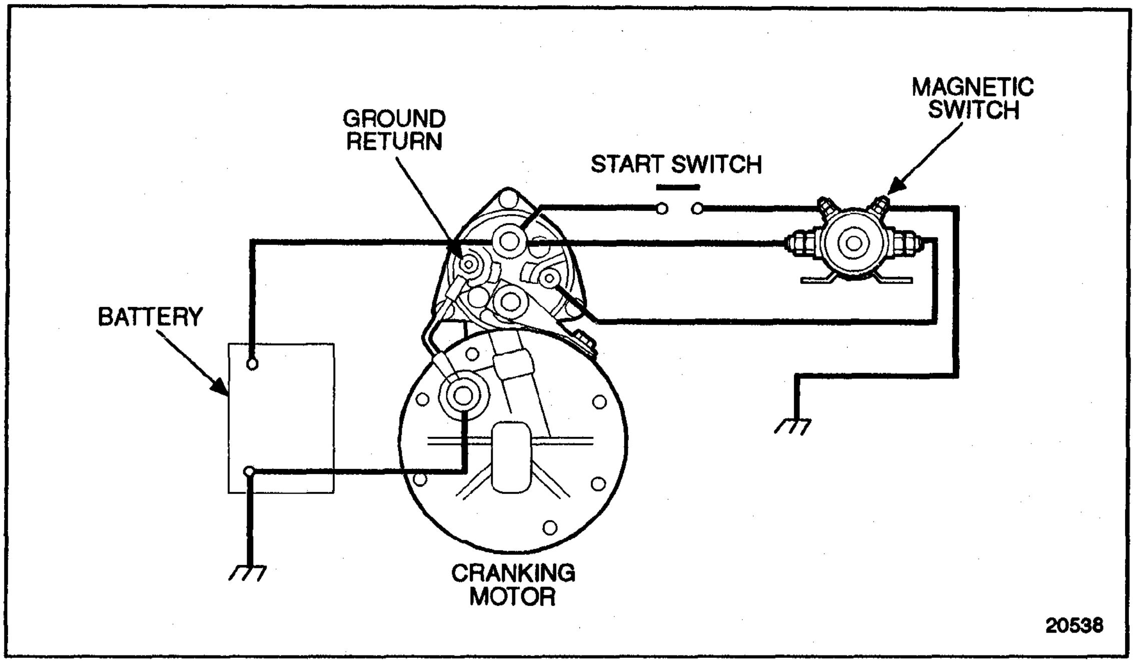



**Figure 18-1 Basic Cranking Circuit**

[a] If the engine cranked with the jumper cable in place, the magnetic switch must be replaced; refer to section 18.2.1.

[b] If the engine did not crank with the jumper cable in place, check the starter; refer to section 18.3.

### 18.2.1 Magnetic Switch Replacement

Perform the following steps for magnetic switch replacement:

1. Replace the magnetic switch. Refer to OEM guidelines.
2. Perform verification of magnetic switch replacement; refer to section 18.2.1.1.

#### 18.2.1.1 Test Engine with New Magnetic Switch

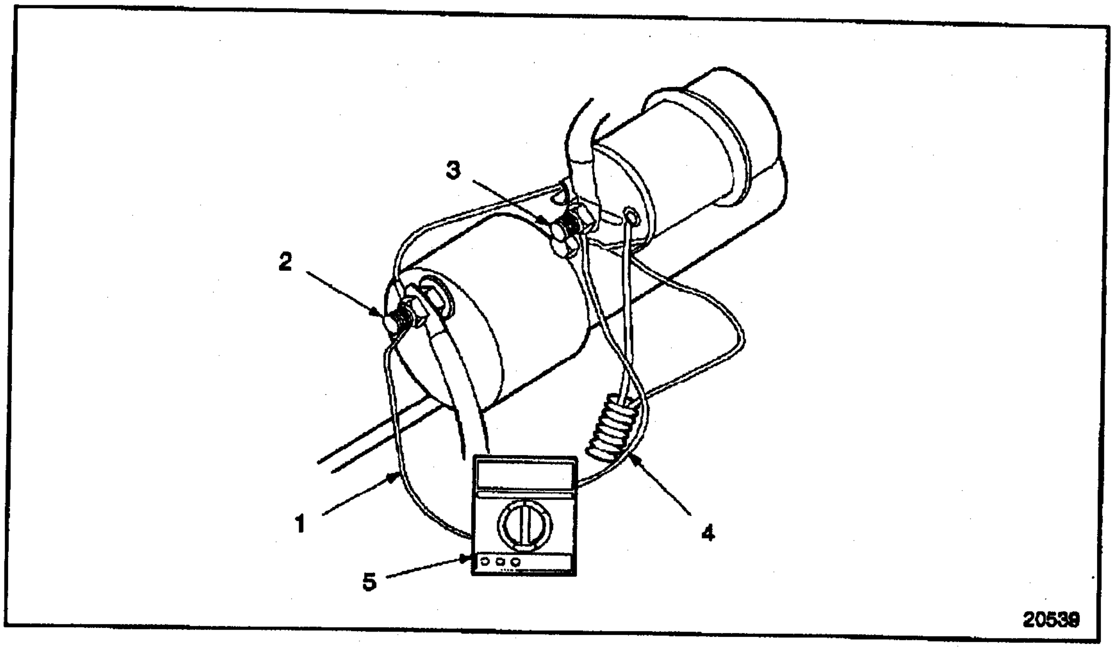
Perform the following steps to determine if the magnetic switch replacement resolved the no start condition:

1. Refer to section 18.2 for exhuast caution before preceeding. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start or run, check the starter; refer to section 18.3.

## 18.3 DEFECTIVE STARTER

To determine if a defective starter is causing no start, perform the following steps:

1. Place the red lead of a voltmeter to the solenoid "BAT" or terminal; see Figure 18-2.




1. Red Lead
2. Starter Ground
3. Solenoid Terminal
4. Black Lead
5. Voltmeter

**Figure 18-2 Cranking Motor Available Voltage Test**

2. Place the black voltmeter lead to the starter ground terminal; see Figure 18-2.
3. Engage the starter switch.
4. View the voltage reading on the meter.
   [a] If the voltage is less than specification (refer to OEM guidelines) while cranking the engine, starter replacement is necessary; refer to section 18.3.1.
   [b] If the voltage is to specification (refer to OEM guidelines) while attempting to crank the engine, check for internal damage; refer to section 18.4.

### 18.3.1 Starter Replacement

Perform the following steps for starter replacement:

1. Replace the starter; refer to section 8.4.1.
2. Verify replacement of starter; refer to section 18.3.1.1.

#### 18.3.1.1 Test Engine with New Starter

Perform the following steps to determine if the new starter resolved no start condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.
   [b] If the engine fails to start or run, check for internal engine damage. Refer to section 18.4.

## 18.4 INTERNAL ENGINE DAMAGE

To determine if internal engine damage is causing no start condition, perform the following steps:

1. Install a 3/4 in. breaker bar or ratchet and attempt to bar the engine over by hand.
2. Determine severity of internal engine damage.
   [a] If the engine rotates freely, check the electronic control module wiring harness; refer to section 17.1.
   [b] If the engine binds and will not rotate freely, replace crankshaft bearings; refer to section 1.9.1 and cylinder liners; refer to section 1.9.3.

### 18.4.1 Internal Engine Damage Replacement

Perform the following steps for crankshaft bearings, and cylinder liners replacement:

1. Replace the crankshaft bearings; refer to section 1.9.2.
2. Replace the cylinder liners; refer to section 1.20.1.
3. Verify replacement of components; refer to section 18.4.1.1.

### 18.4.1.1 Test Engine with Replaced Components

Perform the following steps to determine if the new components resolved no start condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut down the engine.

   [b] If the engine fails to start or run, call Detroit Diesel Technical Service.

# 19 EXCESSIVE OIL CONSUMPTION

## 19.1 MISCALIBRATED DIPSTICK

To determine if an overfilled crankcase is causing excessive oil consumption, perform the following:

1. Ensure vehicle is parked on level ground.
2. Perform a universal dipstick calibration check; refer to SIB 12-60-94R (May 1995).
   [a] If the calibration check indicates that the oil level is off by more than 2 mm (0.078 in.), contact your Detroit Diesel regional support office.
   [b] Check for oil leaks; refer to section 19.2.

## 19.2 EXTERNAL OIL LEAKS

To determine if oil leaks are causing excessive oil consumption, perform the following:

1. Steam clean the engine.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine to operating temperature 88°C (190°F).
3. Check for leaks at oil lines, connections, mating joints, seals, and gaskets.

   [a] If no oil leaks are found, shut down the engine and check for a leaking oil cooler core; refer to section 19.3.

   [b] If oil leaks are found, shut down the engine; refer to section 19.2.1.

### 19.2.1 Engine Oil Leak Repair

Perform the following steps, as necessary, to resolve engine oil leaks:

1. Repair or replace components leaking oil; refer to section 3.2.
2. Verify repairs made to correct oil leaks; refer to section 19.2.1.1.

#### 19.2.1.1 Test Engine with Repairs Made to Correct Oil Leaks

Perform the following steps to determine if the repairs resolved the oil leaks:

1. Refer to section 19.2 for exhaust caution before preceeding. Start and run the engine to operating temperature 88°C (190°F).
2. Shut down the engine.
3. Check the engine for oil leaks.
   [a] If no oil leaks are observed, check for a leaking oil cooler core; refer to section 19.3.
   [b] If external oil leaks are still present, repeat section 19.2.1.

## 19.3 LEAKING OIL COOLER CORE

To determine if a leaking oil cooler core is causing excessive oil consumption, perform the following:

1. Check for oil in the engine coolant or radiator.
   [a] If oil is present in either the engine coolant or radiator; perform step 2
   [b] If no oil is present in either the engine coolant or radiator, check for a defective air compressor; refer to section 19.4.
2. Remove the oil cooler core and housing; refer to section 3.8.2or refer to section 3.9.2 for pre-1991 oil coolers.
3. Clean both the oil side and water side of oil cooler core; refer to section 3.8.2 or refer to section 3.9.2 for pre-1991 oil coolers.
4. Perform an oil cooler core pressure test; refer to section 3.8.3.1or refer to section 3.9.3.1 for pre-1991 oil coolers.
5. Visually check to see if air bubbles are rising to the surface of the water within the container.
   [a] If air bubbles are present, refer to section 19.3.1.
   [b] If no air bubbles are present, complete a lube oil consumption report, call the Detroit Diesel Technical Service Group for a form.

### 19.3.1 Oil Cooler Core Replacement

Perform the following for oil cooler core replacement:

1. Remove and install a new oil cooler core refer to section 3.8.4 and refer to section 3.9.4.
2. Verify replacement of oil cooler core; refer to section 19.3.1.1.

### 19.3.1.1 Test Engine with New Oil Cooler Core

Perform the following steps to determine if the replaced oil cooler core reduced oil consumption:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine to operating temperature 88°C (190°F).
2. Shut down the engine.
3. Check the engine coolant for the presence of oil.

   [a] If no oil is present in the coolant, perform an lube oil consumption test report; refer to section 19.3.1.2.

   [b] If oil is present in the coolant, repeat section 19.3.1.

### 19.3.1.2 Test Engine for Reduced Oil Consumption

Perform a lube oil consumption report, call the Detroit Diesel Technical Service Group for a form.

1. Review the oil consumption report.

   [a] If the oil consumption report data is within specifications, check for defective air compressor. Refer to section 19.4.

   [b] If the oil consumption report data is not within specifications, call Detroit Diesel Technical Service Group.

## 19.4 DEFECTIVE AIR COMPRESSOR

To determine if a defective air compressor is causing excessive oil consumption, perform the following:

1. Perform a crankcase pressure test and record the test results.
2. Disconnect the air outlet line from the air compressor; see Figure 19-1; refer to section 10.1.5.

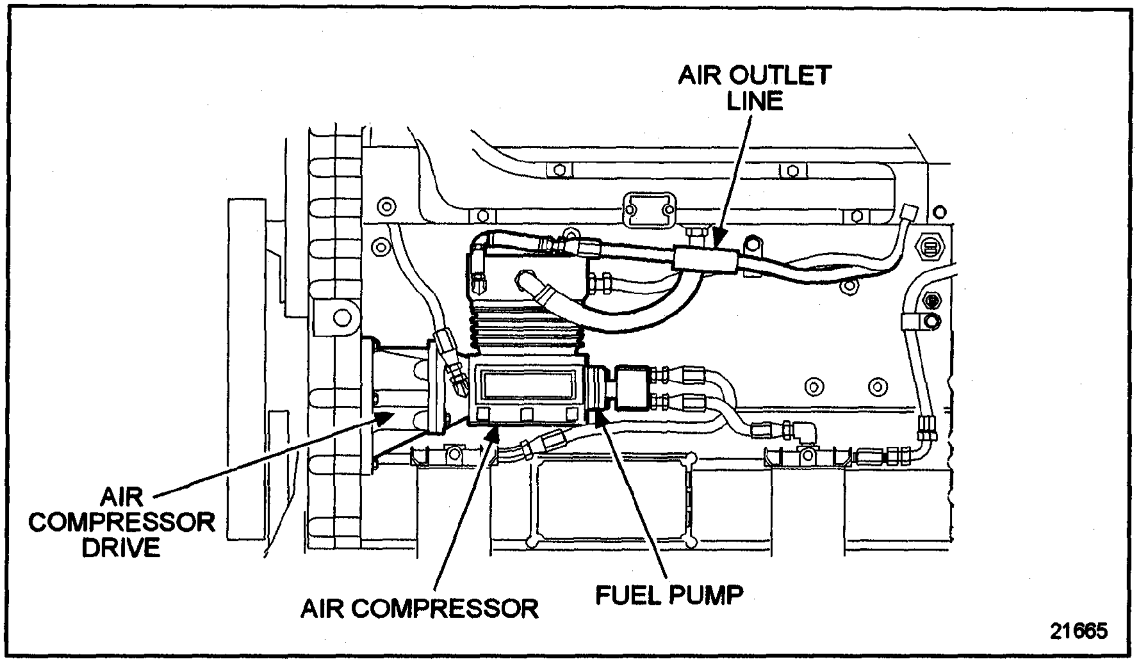



**Figure 19-1 Air Compressor Air Outlet Line**

3. Repeat step 1 and record the test results.
4. Compare the results of test one with test two.
   [a] If the engine crankcase pressure remained the same, check the turbocharger; refer to section 19.5.
   [b] If the engine crankcase pressure decreased, replace the air compressor; refer to section 19.4.1.

### 19.4.1 Air Compressor Removal

Perform the following steps to remove the defective air compressor:

1. Remove the air compressor from the engine; refer to section 10.1.5.
2. Disassemble and repair the air compressor; refer to OEM guidelines.
3. Install the repaired air compressor to the engine; refer to section 10.1.8.
4. Verify repair of the air compressor; refer to section 19.4.1.1.

#### 19.4.1.1 Test Engine with Repaired Air Compressor

Perform the following steps to determine if the repaired air compressor resolved the excessive crankcase pressure:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Perform a crankcase pressure test.

   [a] If the engine crankcase pressure exceeds 3 in. $H_2O$ (0.75 kPa), refer to section 19.5. Shut down the engine.

   [b] If the engine crankcase pressure is within 3 in. $H_2O$ (0.75 kPa), shut down the engine; no further troubleshooting is required.

# 19.5 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive oil consumption, perform the following:

1. Remove the turbocharger drain line connected to the crankcase and place the drain line into a suitable container.
2. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is more than 3 in. $H_2O$ (0.75 kPa), replace the turbocharger; refer to section 6.6.1.
   [b] If the engine crankcase pressure is 3 in. $H_2O$ (0.75 kPa) or more, check for worn or damaged valve and cylinder kit; refer to section 19.6.

## 19.5.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove the defective turbocharger from the engine; refer to section 6.6.2.
2. Tag removed turbocharger for remanufacture.
3. Install a new turbocharger to the engine; refer to section 6.6.7.
4. Verify replacement of new turbocharger; refer to section 19.5.1.1.

### 19.5.1.1 Test Engine with New Turbocharger

Perform the following steps to determine if a new turbocharger resolved the excessive crankcase pressure:

1. Remove the turbocharger drain line connected to the crankcase and place the drain line into a suitable container.
2. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is greater than 3 in. $H_2O$ (0.75 kPa), check for worn or damaged valve or cylinder kit; refer to section 19.6.
   [b] If the engine crankcase pressure is 3 in. $H_2O$ (0.75 kPa) or less, no further troubleshooting is required.

## 19.6 WORN OR DAMAGED VALVE OR CYLINDER KIT

A loss of cylinder pressure can cause increased oil consumption. The detection and elimination of cylinder pressure losses is vital to engine life and efficient operation. To assist the mechanic in effectively measuring the loss of cylinder pressure, and locating the source of abnormal leaks in individual cylinders, the following test procedure has been developed.

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor, refer to section 10.1.5.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run vehicle to full load and rated speed.
6. Attach a manometer calibrated to read in inches of water, to the oil dipstick opening. Measure and record the crankcase pressure.
7. Shut down engine.
8. Remove the vehicle from the chassis dynamometer.
9. Review the crankcase pressure test results.
   [a] If the crankcase pressure exceeds 3 in. $H_2O$ (0.75 kPa), repair worn or damaged valve(s) or cylinder kit; refer to section 19.6.1.
   [b] If the crankcase pressure was less than or equal to 3 in. $H_2O$ (0.75 kPa), perform cylinder compression test.

10. Compare the cylinder compression test results to specifications.
    [a] If the cylinder compression is below specifications, repair worn or damaged valve(s) or cylinder kit; refer to section 19.6.1.
    [b] If the cylinder compression is within specification, call Detroit Diesel Technical Service Group.

### 19.6.1 Worn or Damaged Valve(s) or Cylinder Kit(s) Repair

Perform the following steps to repair worn or damaged valve(s) and cylinder kit(s):

1. Remove cylinder head; refer to section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to section 1.2.3.1.
3. Inspect the cylinder kit components for worn or damaged liners; refer to section 1.20.2.2; pistons or piston rings, refer to section 1.17.3.1.
4. Replace damaged cylinder kit components; refer to section 1.18.4.
5. Verify repairs made to cylinder head valve(s) or cylinder kit components; refer to section 19.6.1.1.

#### 19.6.1.1 Test Engine with Repaired Cylinder Head Valve(s), and Cylinder Kit

Perform the following steps to determine if the cylinder head valve and cylinder kit repair resolved starting difficulty:

1. Refer to section 19.6 for exhaust caution before preceeding. Attempt to start and run the engine.
    [a] If the engine starts and runs, no further troubleshooting is required.
    [b] If the engine fails to start and run, call the Detroit Diesel Technical Service Group.

# 20 EXCESSIVE CRANKCASE PRESSURE

## 20.1 OBSTRUCTION OR DAMAGE TO ROCKER COVER BREATHER

To determine if an obstructed or damaged breather is causing excessive crankcase pressure, perform the following:

1. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is less than 3 in. $H_2O$ (0.75 kPa), check the air compressor. Refer to section 20.2.
   [b] If the engine crankcase pressure is greater than 3 in. $H_2O$ (0.75 kPa), replace wire mesh element. Refer to section 20.1.1.

### 20.1.1 Rocker Cover Breather Resolution

Perform the following steps to replace wire mesh element replacement:

1. Remove the valve rocker cover(s); for one-piece refer to section 1.6.2, for two-piece refer to section 1.6.3, for three-piece refer to section 1.6.5.
2. Remove the wire mesh form the rocker cover; refer to section 1.6.6.
3. Install a new wire mesh element to the rocker cover; refer to section 1.6.7.
4. Install the rocker cover to the engine; for one-piece refer to section 1.6.2, for two-piece or three-piece refer to section 1.6.9.
5. Verify replacement of wire mesh element; refer to section 20.1.1.1.

### 20.1.1.1 Test Engine with New Wire Mesh Element

Perform the following steps to determine if the new wire mesh element resolved the excessive crankcase pressure:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Perform a crankcase pressure test.

   [a] If the engine crankcase pressure is less than 3 in. $H_2O$ (0.75 kPa), no further troubleshooting is required. Shut down the engine.

   [b] If the engine crankcase pressure is greater than 3 in. $H_2O$ (0.75 kPa), check the air compressor; refer to section 20.2. Shut down the engine.

## 20.2 DEFECTIVE AIR COMPRESSOR

To determine if a defective air compressor is causing excessive crankcase pressure, perform the following:

1. Perform a crankcase pressure test and record the test results.
2. Disconnect the air outlet line from the air compressor; see Figure 20-1; refer to section 10.1.5.

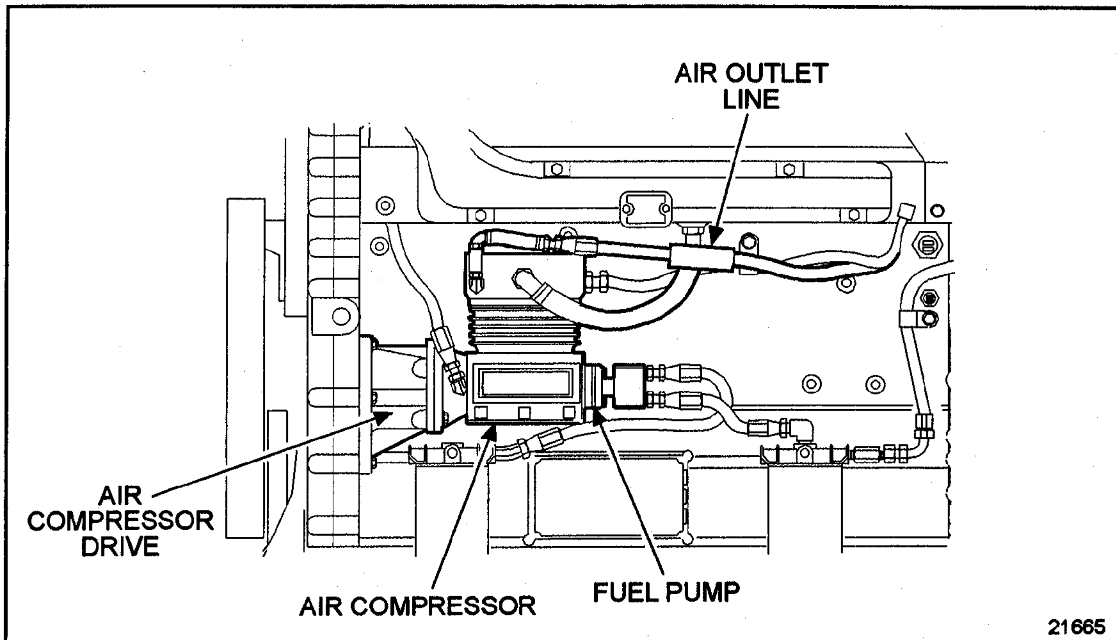



**Figure 20-1 Air Compressor Air Outlet Line**

3. Repeat step 1 and record the test results.
4. Compare the results of test one with test two.
   [a] If the engine crankcase pressure remained the same, check the turbocharger; refer to section 20.3.
   [b] If the engine crankcase pressure decreased, repair the air compressor; refer to section 20.2.1.

### 20.2.1 Air Compressor Repair

Perform the following steps to repair the defective air compressor:

1. Remove the air compressor from the engine; refer to section 10.1.5.
2. Install the repaired air compressor to the engine; refer to section 10.1.8.
3. Verify repair of the air compressor; refer to section 20.2.1.1.

### 20.2.1.1 Test Engine with Repaired Air Compressor

Perform the following steps to determine if a repaired air compressor resolved the excessive crankcase pressure:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is within 3 in. $H_2O$ (0.75 kPa), no further troubleshooting is required. Shut down the engine.
   [b] If the engine crankcase pressure is not within 3 in. $H_2O$ (0.75 kPa), check the turbocharger, refer to section 20.3. Shut down the engine.

## 20.3 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive crankcase pressure, perform the following:

| NOTICE: |
|---|
| Ensure that the engine is not allowed to operate longer than necessary to perform the crankcase pressure test. A complete loss of crankcase oil will severely damage the engine. |

1. Remove the turbocharger drain line connected to the crankcase and place the drain line into a suitable container; refer to section 6.6.2.
2. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is less than 3 in. $H_2O$, replace the turbocharger; refer to section 20.3.1. Shut down the engine.
   [b] If the engine crankcase pressure indicates no change, check for a worn or damaged valve or cylinder kit; refer to section 20.4. Shut down the engine.

### 20.3.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove defective turbocharger from the engine; refer to section 6.6.2.
2. Tag removed turbocharger for remanufacture.
3. Install a replacement turbocharger to the engine; refer to section 6.6.7.
4. Verify replacement of new turbocharger; refer to section 20.3.1.1.

#### 20.3.1.1 Test Engine with New Turbocharger

Perform the following steps to determine if a new turbocharger resolved the excessive crankcase pressure:

1. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is 3 in. $H_2O$ (0.75 kPa) or less, no further troubleshooting is required.
   [b] If the engine crankcase pressure is greater than 3 in. $H_2O$ (0.75 kPa), check for a worn or damaged valve or cylinder kit; refer to section 20.4.

## 20.4 WORN OR DAMAGED VALVE OR CYLINDER KIT

To determine if a worn or damaged cylinder kit is causing excessive crankcase pressure, perform the following:

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to section 10.1.5.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run the vehicle to full load and rated speed.
6. Attach a manometer calibrated to read in inches of water, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down the engine.
9. Remove the vehicle from the chassis dynamometer.
10. Review the crankcase pressure test.
    [a] If the crankcase pressure is greater than 3 in. $H_2O$ (0.75 kPa), refer to step 11.
    [b] If the crankcase pressure is less than 3 in. $H_2O$ (0.75 kPa); no further troubleshooting required.

11. Perform the cylinder compression test.
    [a] If cylinder pressure is below specifications, refer to section 20.4.1.
    [b] If cylinder pressure is within specifications, call Detroit Diesel Technical Service Group.

### 20.4.1 Worn or Damaged Valve or Cylinder Kit Repair

Perform the following steps for worn or damaged valve or cylinder kit:

1. Remove the cylinder head; refer to section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to section 1.2.3.1.
3. Inspect the cylinder kit components for worn or damaged liners; refer to section 1.20.2.2; pistons or piston rings, refer to section 1.17.3.1.
4. Verify repair to cylinder valve(s) or cylinder kit components; refer to section 20.4.1.1.

#### 20.4.1.1 Test Engine with Repairs Made to Correct Worn or Damaged Valve or Cylinder Kit

Perform the following to determine if the repaired valve or cylinder kit resolved the excessive crankcase pressure:

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to section 10.1.5.
3. Refer to section 20.4 for exhsut caution before preceeding. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run the vehicle to full load and rated speed.
6. Attach a manometer calibrated to read in inches of water, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down the engine.
9. Remove the vehicle from the chassis dynamometer.
10. Compare the cylinder pressure test results to specifications.
    [a] If cylinder pressure is within specifications, no further troubleshooting is required.
    [b] If cylinder pressure is not within specifications, call Detroit Diesel Technical Service Group.

# 21 EXCESSIVE EXHAUST SMOKE (BLACK OR GRAY)

## 21.1 IMPROPER GRADE OF FUEL OIL

To determine if an improper grade of fuel oil is causing excessive black or gray smoke, perform the following:

1. Acquire a fuel oil sample from the vehicle fuel tank(s).
2. Submit fuel oil sample for an ASTM test analysis.
   [a] If the fuel oil meets specifications, check for a restrictive air cleaner; refer to section 21.2.
   [b] If the fuel oil did not meet specifications, resolve improper grade of fuel; refer to section 21.1.1.

### 21.1.1 Improper Grade of Fuel Resolution

Perform the following steps to resolve the improper grade of fuel oil:

1. Drain the fuel oil tanks, refer to OEM guidelines, and dispose of properly.
2. Refill the fuel oil tanks with new fuel oil having a cetane number greater than 40.
3. Verify fuel oil resolution; refer to section 21.1.1.1.

### 21.1.1.1 Test the Engine with New Fuel Oil

Perform the following steps to determine if the fuel oil refill resolved the excessive exhaust smoke condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust smoke is excessively black or gray, shut down the engine. Check the air filter; refer to section 21.2.

## 21.2 RESTRICTED AIR CLEANER ELEMENT

To determine if a restrictive air cleaner is causing excessive black or gray smoke, perform the following:

1. Remove the air filter element from the air cleaner container; refer to OEM guidelines.
2. Visually inspect the air cleaner element for damage or clogging.
   [a] If no damage or clogging is found, check the charge air cooler; refer to section 21.3.
   [b] If damage or clogging is found, refer to section 21.2.1.

### 21.2.1 Air Filter Element Replacement

Perform the following to replace the air filter element:

1. Remove and replace the damaged or clogged air filter element; refer to OEM guidelines.
2. Verify air filter element replacement; refer to section 21.2.1.1.

### 21.2.1.1 Test the Engine with Replaced Air Filter Element

Perform the following to determine if the new filter element resolved excessive exhaust smoke:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.
   - [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   - [b] If the engine exhaust emission is excessively black or gray, shut down the engine. Check the charge air cooler; refer to section 21.3.

## 21.3 RESTRICTED OR CRACKED CHARGE AIR COOLER

To determine if a charge air cooler is causing excessive exhaust smoke, perform the following:

| NOTICE: |
|---|
| To avoid engine damage, follow the installation instructions provided with the air-to-air charge air cooler test kit. |

1. Attach a WK93 air-to-air charge air cooler test kit; refer to OEM guidelines.
2. Disconnect the air inlet hose from the outlet side of the turbocharger compressor housing; refer to section 6.6.2.
3. Attach the air-to-air cooler test kit adaptor plug to fit into the hose at the compressor connector; refer to OEM guidelines.
4. Attach an air pressure hose to the air chuck at the regulator and gradually pressurize the air inlet system to a pressure of 25 · $lb{\cdot}in.^2$ (177 kPa).
5. Apply a water and soap solution to each hose connection, across the face of the charge air cooler.
6. Apply a water and soap solution to the air intake manifold and cylinder head mating surface area.
7. Visually inspect all joints for air leaks and all charge air cooler welded surfaces for stress cracks.
   [a] If air leaks are present around the joints, replace the charge air cooler; refer to section 21.3.1.
   [b] If any leaks are present around the air intake manifold, repair the air intake manifold; refer to section 21.3.2.
   [c] If no leaks are present, check for faulty exhaust system; refer to section 21.4.

### 21.3.1 Charge Air Cooler Replacement

Perform the following steps to replace the charge air cooler:

1. Replace the charge air cooler, refer to OEM guidelines.
2. Verify replacement of the charge air cooler; refer to section 21.3.2.1.

### 21.3.2 Air Intake Manifold Repair

Perform the following steps to repair the air intake manifold:

1. Remove the air intake manifold; refer to section 6.4.2.
2. Inspect the air intake manifold; refer to section 6.4.3.1.
3. Install the air intake manifold; refer to section 6.4.4.
4. Verify repair of the air intake manifold; refer to section 21.3.2.1.

#### 21.3.2.1 Test the Engine with Replaced Charge Air Cooler and Air Intake Manifold

To determine if the replaced charge air cooler and air intake manifold resolved the excessive exhaust smoke condition, perform the following:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively black or gray, shut down the engine. Check the faulty exhaust system; refer to section 21.4.

## 21.4 FAULTY EXHAUST SYSTEM

To determine if a faulty exhaust system is causing excessive exhaust smoke, perform the following:

1. Drill an 11/32 in. hole in the exhaust pipe, 5 to 12 in. (127 - 305 mm) from the turbocharger exhaust outlet.

**NOTE:**
The tapped hole must be in a comparatively straight area of the turbocharger exhaust outlet.

2. Tap the hole to accommodate an 1/8 in. pipe plug.
3. Connect a manometer to the tapped hole.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Start and run the engine.
5. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
6. Run the engine speed to full load.
   [a] If the exhaust back pressure at full load is less than 3.0 in. Hg (10.1 kPa), check the fuel injectors, refer to section 21.5. Shut down the engine.
   [b] If the exhaust back pressure at full load is 3.0 in. Hg (10.1 kPa) or greater, refer to section 21.4.1. Shut down the engine.

## 21.4.1 Engine Exhaust System Resolution

Perform the following steps to resolve the engine exhaust system:

1. Visually inspect the engine exhaust system; refer to OEM guidelines.
2. Repair and replace defective exhaust system components; refer to OEM guidelines.
3. Verify exhaust system resolution; refer to section 21.4.1.1.

### 21.4.1.1 Test the Engine with Replaced Exhaust System

Perform the following steps to determine if replaced engine exhaust system components resolved excessive exhaust smoke condition:

1. Refer to section 21.4 for exhaust caution before preceeding. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively black or gray, shut down the engine. Check the fuel injectors; refer to section 21.5.

## 21.5 FAULTY FUEL INJECTOR

To determine if a faulty fuel injector is causing the cylinder to misfire, perform the following steps:

1. Install DDL adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine at no-load.
3. >From the DDEC III/IV Select Menu, scroll to select ENGINE and press the ENTER key.
4. Scroll to FUEL INJECTOR INFO (CUTOUT) and press the ENTER key.
5. Scroll to select NEW TEST and press the ENTER key.
6. Scroll to select RPM SETTING FOR CCO TEST NORMAL and scroll to select 1000 and press the ENTER key.
7. Scroll to select AUTO and press the ENTER key. Wait for END OF TEST.

**NOTE:**
If an injector cannot be cutout, an ERROR message will appear. Press FUNC to exit the cylinder cutout function, press the FUNC key.

8. Scroll the list to review the results of the cylinder cutout test. To find suspect injectors, look for a cylinder with a value that is within 0.2° of the NO CUTOUT PULSE WIDTH, by comparing the CUTOUT PULSE WIDTH values to the NO CUTOUT PULSE WIDTH values.
   [a] If any CUTOUT PULSE WIDTH values are within 0.2° of the NO CUTOUT PULSE WIDTH, shut down the engine; refer to section 21.5.1.
   [b] If any CUTOUT PULSE WIDTH values are not within 0.2° of the NO CUTOUT PULSE WIDTH, shut down the engine; refer to section 21.6.

### 21.5.1 Faulty Fuel Injector Repair

Perform the following steps for faulty fuel injector assembly(s):

1. Remove and replace injector assembly(s) whose values are within 0.2° of the NO CUTOUT PULSE WIDTH; refer to section 2.3.2.
2. Verify replaced injector assembly(s); refer to section 21.5.1.1.

#### 21.5.1.1 Verification of Repair for Faulty Fuel Injector

Perform the following to determine if the replaced fuel injector(s) resolved the excessive exhaust smoke condition:

1. Refer to section 21.5 for exhaust caution before preceeding. Start the engine.
2. Run the engine speed to full load.
3. Visually inspect the exhaust for excessive smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessive, check for defective turbocharger; refer to section 21.6. Shut down the engine.

## 21.6 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive exhaust smoke, perform the following:

1. Remove the turbocharger outlet line connected to the crankcase and place the drain line into a suitable container; refer to section 6.6.2.
2. Perform a crankcase pressure test.
   [a] If the engine crankcase pressure is greater than 3 in. $H_2O$ (0.75 kPa), replace the turbocharger; refer to section 21.6.1.
   [b] If the engine crankcase pressure is 3 in. $H_2O$ (0.75 kPa), call the Detroit Diesel Technical Service Group.

### 21.6.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove defective turbocharger from the engine; refer to section 6.6.2.
2. Tag removed turbocharger for remanufacture.
3. Install a new turbocharger to the engine; refer to section 6.6.7.
4. Verify replacement of new turbocharger; refer to section 21.6.1.1.

### 21.6.1.1 Test Engine with Replaced Turbocharger

Perform the following steps to determine if a replaced turbocharger resolved the excessive exhaust smoke condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed to full load.
3. Visually inspect the exhaust for excessive smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessive, shut down the engine. Call Detroit Diesel Technical Service Group.

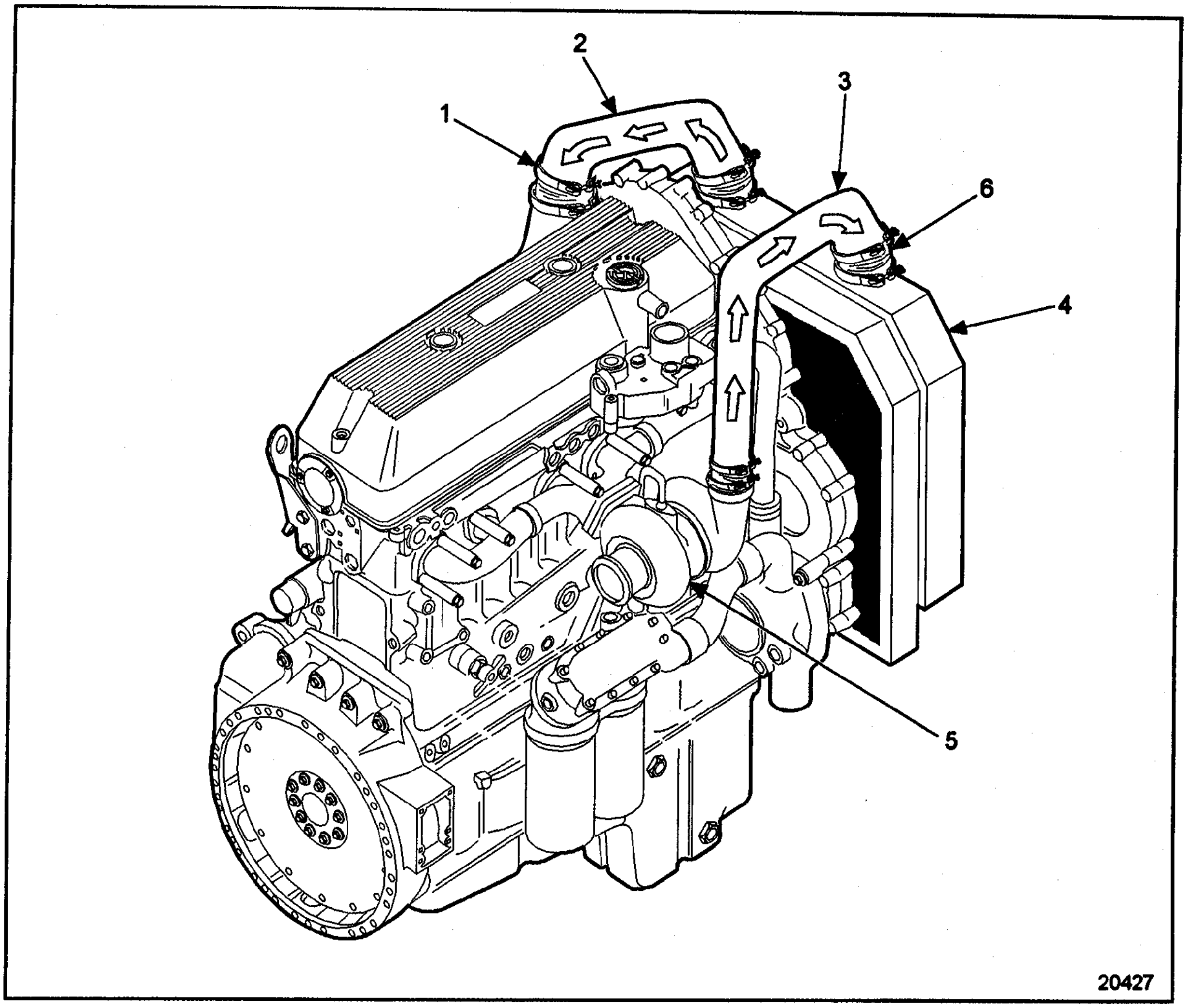
# 22 EXCESSIVE BLUE SMOKE

**Section** **Page**

## 22.1 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive exhaust smoke, perform the following:

1. Remove the charge air cooler inlet duct connected between the turbocharger and charge air cooler; see Figure 22-1.




1. Flexible Coupling
2. Charge Air Cooler Outlet Duct
3. Charge Air Cooler Inlet Duct
4. Charge Air Cooler
5. Turbocharger
6. Coupling Hose Clamp

**Figure 22-1 Charge Air Cooler and Related Parts**

2. Visually inspect the charge air cooler outlet duct.
   [a] If excessive engine lube oil is present, refer to section 22.1.1.
   [b] If no engine lube oil is present, check for worn or damaged valve or cylinder kit, refer to section 22.2.

### 22.1.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove defective turbocharger from the engine; refer to section 6.6.2.
2. Tag removed turbocharger for remanufacture.
3. Install a replacement turbocharger to the engine; refer to section 6.6.7.
4. Verify replacement of new turbocharger; refer to section 22.1.1.1.

### 22.1.1.1 Test Engine with Replaced Turbocharger

Perform the following steps to determine if a replaced turbocharger resolved the excessive exhaust smoke condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
3. Visually inspect exhaust for excessive smoke.

   [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut down the engine.

   [b] If the engine exhaust smoke is excessively black or gray, shut down the engine. Check for worn or damaged valve or cylinder kit; refer to section 22.2.

## 22.2 WORN OR DAMAGED VALVE OR CYLINDER KIT

To determine if a worn or damaged cylinder kit is causing excessive crankcase pressure, perform the following:

1. Move the vehicle requiring testing to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to section 10.1.5.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run the vehicle to full load and rated speed.
6. Attach a manometer calibrated to read in inches of water, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down the engine.
9. Remove the vehicle form the chassis dynamometer.

10. Review the crankcase pressure test.

    [a] If the crankcase pressure was greater than 3 in. $H_2O$ (0.75 kPa), refer to section 22.2.1.

    [b] If the crankcase pressure was less than 3 in. $H_2O$ (0.75 kPa), perform a cylinder compression test.

11. Compare the cylinder compression test results to specifications.

    [a] If cylinder pressure is below specifications, refer to section 22.2.1.

    [b] If cylinder pressure is within specifications, call Detroit Diesel Technical Service Group.

### 22.2.1 Worn or Damaged Valve or Cylinder Kit Repair

Perform the following steps for worn or damaged valve or cylinder kit:

1. Remove the cylinder head; refer to section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to section 1.2.3.1.
3. Inspect the cylinder kit components for worn or damaged liners; refer to section 1.20.2.2; pistons or piston rings, refer to section 1.17.3.1.
4. Verify repair to cylinder valve(s) or cylinder kit components; refer to section 22.2.1.1.

#### 22.2.1.1 Test Engine with Repairs Made to Correct Worn or Damaged Valve or Cylinder Kit

Perform the following to determine if the repaired valve or cylinder kit resolved the excessive crankcase pressure:

1. Refer to section 22.2 for exhaust catuion before preceeding. Start the engine.
2. Run the engine and bring the engine coolant temperature to normal operating range, 88-96°C (190-210°F).
3. Run the vehicle to full load and rated speed.
4. Visually inspect exhaust for excessive smoke.

    [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut down the engine.

    [b] If the engine exhaust smoke is excessively black or gray, call the Detroit Diesel Technical Service Group. Shut down the engine.

# 23 EXCESSIVE WHITE SMOKE

**Section** **Page**

## 23.1 IMPROPER GRADE OF FUEL

To determine if an improper grade of fuel oil is causing excessive white smoke, perform the following:

1. Acquire a fuel oil sample from the vehicle fuel tank(s).
2. Submit fuel oil sample for an ASTM test analysis.
   [a] If the fuel oil meets specifications, check the fuel pump; refer to section 23.2.
   [b] If the fuel oil did not meet specifications, resolve improper grade of fuel; refer to section 23.1.1.

### 23.1.1 Improper Grade of Fuel Resolution

Perform the following steps to resolve the improper grade of fuel oil:

1. Drain the fuel oil tank(s), refer to OEM guidelines, and dispose of properly.
2. Refill the fuel oil tanks with new fuel oil having a cetane number greater than 40.
3. Verify fuel oil resolution; refer to section 23.1.1.1.

### 23.1.1.1 Test the Engine with New Fuel Oil

Perform the following steps to determine if the new fuel oil refill resolved the excessive white smoke condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust smoke is excessively white, shut down the engine. Check the fuel pump; refer to section 23.2.

## 23.2 DEFECTIVE FUEL PUMP

To determine if the fuel pump is causing excessive white smoke, perform the following steps:

1. Insert a piece of wire through the fuel pump flange drain hole; see Figure 23-1.

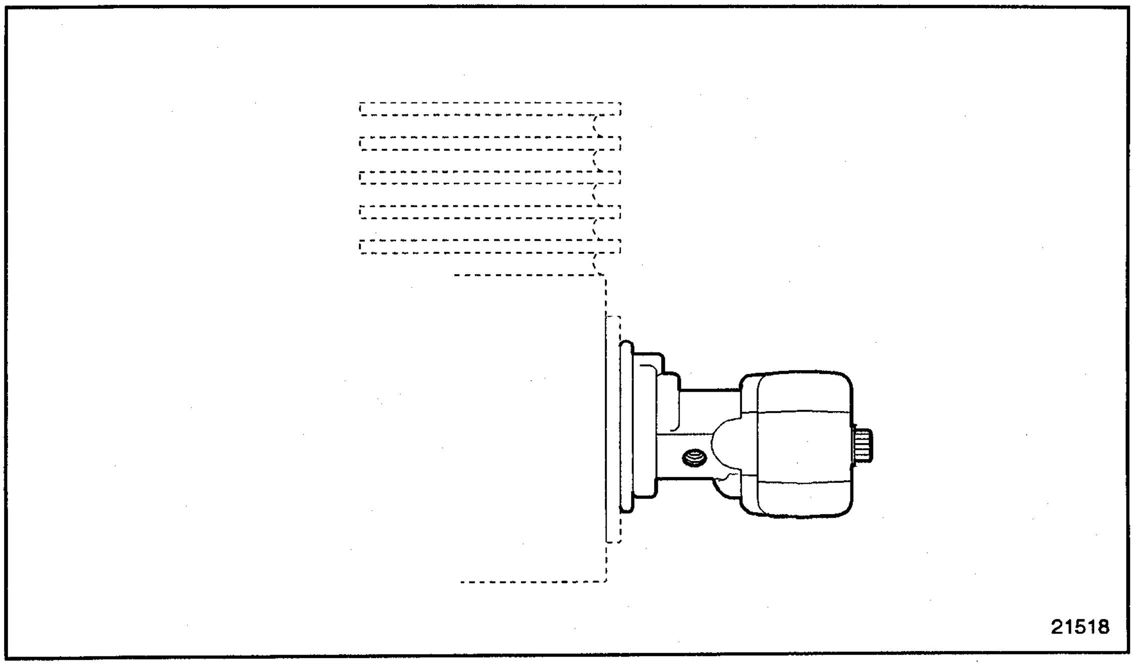



**Figure 23-1 Fuel Pump Flange Drain Hole Location**

2. Crank the engine momentarily and feel for wire vibration.
   [a] If the wire did not vibrate; refer to section 23.2.1.
   [b] If the wire did vibrate, check for aerated fuel; refer to section 23.3.

### 23.2.1 Drive Hubs and Coupling Replacement

Perform the following for drive hubs or coupling replacement:

1. Replace the drive hubs or coupling; refer to section 2.7.
2. Verify the drive hubs and coupling replacement; refer to section 23.2.1.1.

#### 23.2.1.1 Engine Test with Replaced Drive Hubs or Replaced Coupling

Perform the following to determine if replaced drive hubs and coupling resolved excessive white smoke:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive white smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively white, shut down the engine. Check for aerated fuel; refer to section 23.3.

## 23.3 AERATED FUEL

To determine if aerated fuel is causing excessive white smoke, perform the following steps:

1. Disconnect the fuel line return hose from the fitting located at the fuel tank; refer to OEM guidelines.
2. Place the open end of the fuel line into a suitable container.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start and run the engine.
4. Operate the engine at 1000 r/min.
5. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are present, shut down engine; refer to section 23.3.1.
   [b] If air bubbles are not present, shut down engine, check for improper injector calibration setting; refer to section 23.4.

## 23.3.1 Aerated Fuel Resolution

Perform the following to resolve aerated fuel:

1. Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
2. Visually inspect all fuel lines between fuel tank and fuel pump for leaks.
3. Repair damaged components as required; refer to OEM guidelines.
4. Verify aerated fuel resolution; refer to section 23.3.1.1.

### 23.3.1.1 Test the Engine with Aerated Fuel Resolution

Perform the following to determine if aerated fuel resolution resolved excessive white smoke condition:

1. Refer to section 23.3 for the exhaust caution before preceeding. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive white smoke.
   - [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   - [b] If the engine exhaust emission is excessively white, shut down the engine. Check for improper injector calibration setting; refer to section 23.4.

## 23.4 IMPROPER INJECTOR CALIBRATION SETTING (DDEC III/IV ENGINES ONLY)

To determine if an improper injector calibration setting is causing excessive white smoke, perform the following:

1. Check for improper injector calibration setting (DDEC III/IV engine only); refer to section 16.3.
2. Check for improper injector setting repair; refer to section 16.3.1.
3. Verify injector setting repair; refer to section 23.4.1.

### 23.4.1 Test Engine with Corrected Injector Setting

Perform the following to determine if injector setting repair resolved excessive white smoke:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.

2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive white smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively white, shut down the engine. Check for improper valve clearance or injector height, worn or damaged camshaft lobes and rollers; refer to section 23.5.

## 23.5 IMPROPER VALVE CLEARANCE OR INJECTOR HEIGHT, WORN OR DAMAGED CAMSHAFT LOBES AND ROLLERS

To determine if an improper valve clearance or injector height, worn or damaged camshaft lobes and rollers is causing excessive white smoke, perform the following:

1. Check for improper valve clearance or injector height, worn or damaged camshaft lobes and rollers; refer to section 16.4.
2. Check for improper valve clearance or injector height repair; refer to section 16.4.1.
3. Verify valve clearance or injector height, worn or damaged camshaft lobes and rollers repair; refer to section 23.5.1.

## 23.5.1 Test Engine with Corrected Valve Clearance or Injector Height, Worn or Damaged Camshaft Lobes and Rollers

Perform the following to determine if the valve clearance or injector height, worn or damaged camshaft lobes and rollers repair resolved excessive white smoke:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive white smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively white, shut down the engine. Check for faulty fuel injector; refer to section 23.6.

## 23.6 FAULTY FUEL INJECTOR

To determine if a faulty fuel injector is causing excessive white smoke, perform the following:

1. Check for faulty fuel injector; refer to section 16.5.
2. Check for faulty fuel injector repair; refer to section 16.5.1.
3. Verify fuel injector repair; refer to section 23.6.1.

### 23.6.1 Test the Engine with Repaired Fuel Injector

Perform the following to determine if the fuel injector repair resolved excessive white smoke:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive white smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively white, shut down the engine. Check for faulty electronic control module; refer to section 23.7.

## 23.7 FAULTY ELECTRONIC CONTROL MODULE

To determine if a faulty electronic control module is causing excessive white smoke, perform the following:

1. Check for faulty electronic control module; refer to section 16.6.
2. Check for faulty ECM repair; refer to section 16.6.1.
3. Verify ECM repair; refer to section 23.7.1.

### 23.7.1 Test Engine with Repair to the Electronic Control Unit

Perform the following to determine if the ECM repair resolved excessive white smoke:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive white smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut down the engine.
   [b] If the engine exhaust emission is excessively white, shut down the engine. Call Detroit Diesel Technical Service Group.

# 24 ROUGH RUNNING OR STALLING

**Section** **Page**

## 24.1 LOW BATTERY VOLTAGE

To determine if a weak battery is causing rough running or stalling, perform the following steps:

**CAUTION:**

**To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:**

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.

2. Measure the battery voltage; refer to OEM guidelines.
   [a] If the battery voltage is greater than or equal to 10.5 volts, check for aerated fuel oil; refer to section 24.2.
   [b] If the battery voltage is less than 10.5 volts, replace the battery; refer to section 24.1.1.

### 24.1.1 Battery Replacement

Perform the following steps for battery replacement:

1. Remove and replace the battery; refer to OEM guidelines.
2. Verify battery replacement; refer to section 24.1.1.1.

#### 24.1.1.1 Test Engine with Replaced Battery

Perform the following steps to determine if the battery replacement resolved difficulty:

1. Refer to section 24 for exhaust caution before preceeding. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is running rough or stalling shut down the engine. Check for aerated fuel oil; refer to section 24.2.

## 24.2 AERATED FUEL OIL

To determine if aerated fuel is causing rough running or stalling, perform the following steps:

1. Test for aerated fuel; refer to section 23.3.
2. Aerated fuel resolution, refer to section 23.3.1.
3. Verify aerated fuel resolution; refer to section 24.2.1.

### 24.2.1 Test Engine with Aerated Fuel Resolution

Perform the following steps to determine if the aerated fuel resolution resolved rough running or stalling condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).

   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.

   [b] If the engine is running rough or stalling, shut down the engine. Check for insufficient fuel oil flow; refer to section 24.3.

## 24.3 INSUFFICIENT FUEL OIL FLOW

To determine if insufficient fuel oil flow is causing rough running or stalling, do the following steps:

1. Perform a fuel oil flow test.
2. Analyze the fuel oil flow test results.
   [a] If the fuel oil rate is 246 L/hr (65 gal/hr) or more, no further troubleshooting is required; refer to section 24.4.

   [b] If the fuel oil rate is less than 246 L/hr (65 gal/hr), resolve the insufficient fuel oil flow; refer to section 24.3.1.

### 24.3.1 Insufficient Fuel Oil Flow Resolution

Perform the following steps to resolve the insufficient fuel oil flow:

1. Replace the fuel filter(s); refer to section 2.8.1.

**NOTE:**
**Always fill the filter(s) with clean fuel oil before installing. Turn the filter(s) until they contact the gasket fully. Then, turn them an additional two-thirds by hand.**

2. Inspect the fuel lines for restrictions due to pinching, kinking or other damage. If damage is found, repair as necessary; refer to OEM guidelines.
3. Inspect the cylinder head for a correct restricted fitting. If an incorrect fitting is found, replace with a new fitting; refer to section 1.2.3.1.
4. Inspect the fuel return check valve for restrictive movement; refer to section 2.14.3.1.
5. Inspect the fuel pump drive assembly. If damage is found, repair as necessary; refer to section 2.6.3.1.
6. Verify repairs done to correct insufficient fuel oil flow; refer to section 24.3.1.1.

### 24.3.1.1 Test the Engine with Resolved Fuel Oil Flow

Perform the following steps to determine if the fuel oil flow resolution resolved rough running or stalling:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is running rough or stalling, shut down the engine. Check for high fuel oil temperature return; refer to section 24.4.

## 24.4 HIGH FUEL OIL TEMPERATURE RETURN

To determine if high fuel oil temperature return is causing rough running or stalling, perform the following steps:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 24-1; refer to OEM guidelines.

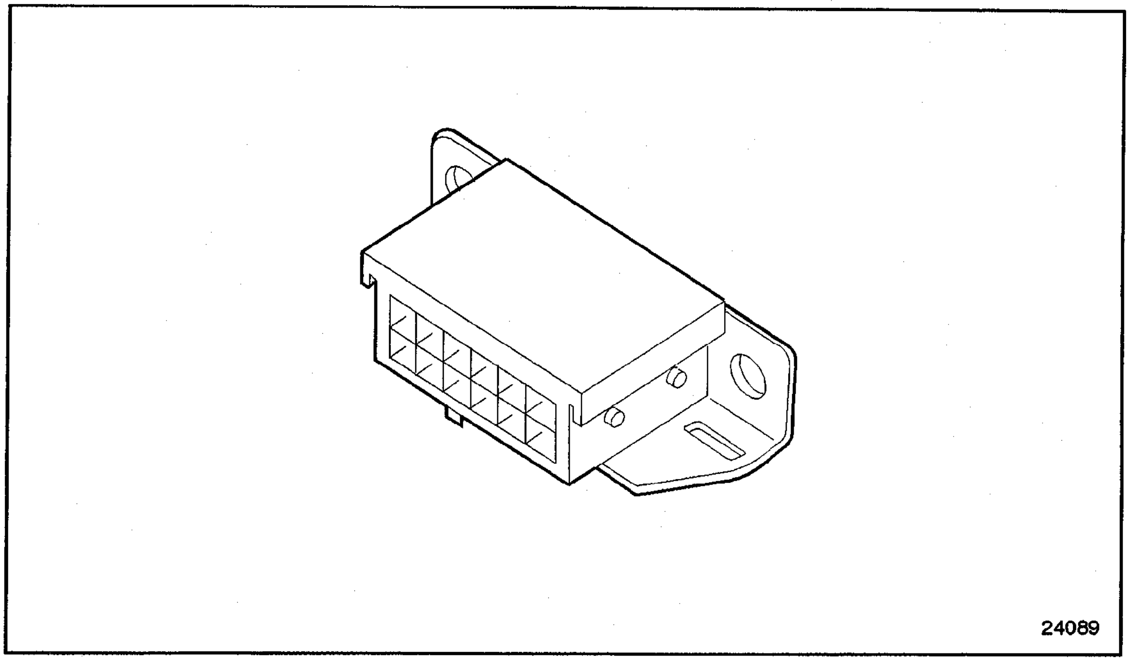



**Figure 24-1 Typical Display Data Line Adaptor**

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine.
3. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the return fuel oil temperature is less than or equal to 60°C (140°F), check for improper injector calibration setting; refer to section 24.5.
   [b] If the return fuel oil temperature is greater than 60°C (140°F), resolve the high fuel oil temperature; refer to section 24.4.1.

## 24.4.1 High Fuel Oil Temperature Resolution

Perform the following steps to resolve high fuel oil temperature:

1. Remove and replace fuel oil filter(s); refer to section 2.8.1.
2. Inspect check valve for any restricted fitting; refer to section 2.14.2.
3. Replace both the restrictive fitting or check valve; refer to section 2.14.2.
4. Verify fuel oil filter(s) replacement; refer to section 24.4.1.1.

### 24.4.1.1 Test the Engine with Replaced Oil Filters

Perform the following steps to determine if the replaced oil filter(s) resolved the rough running or stalling condition:

1. Refer to section 24.4 for exhaust caution before preceeding. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is running rough or stalling, shut down the engine. Check for improper injector calibration setting; refer to section 24.5.

## 24.5 IMPROPER INJECTOR CALIBRATION SETTING (DDEC III/IV ENGINES ONLY)

To determine if improper injector calibration setting (DDEC III/IV engines only) is causing rough running or stalling, perform the following steps:

1. Test for improper injector setting; refer to section 16.3.
2. Compare the calibration code(s) shown on the Diagnostic Data Reader display with the two digit calibration code(s) on the injector(s). See Figure 24-2.

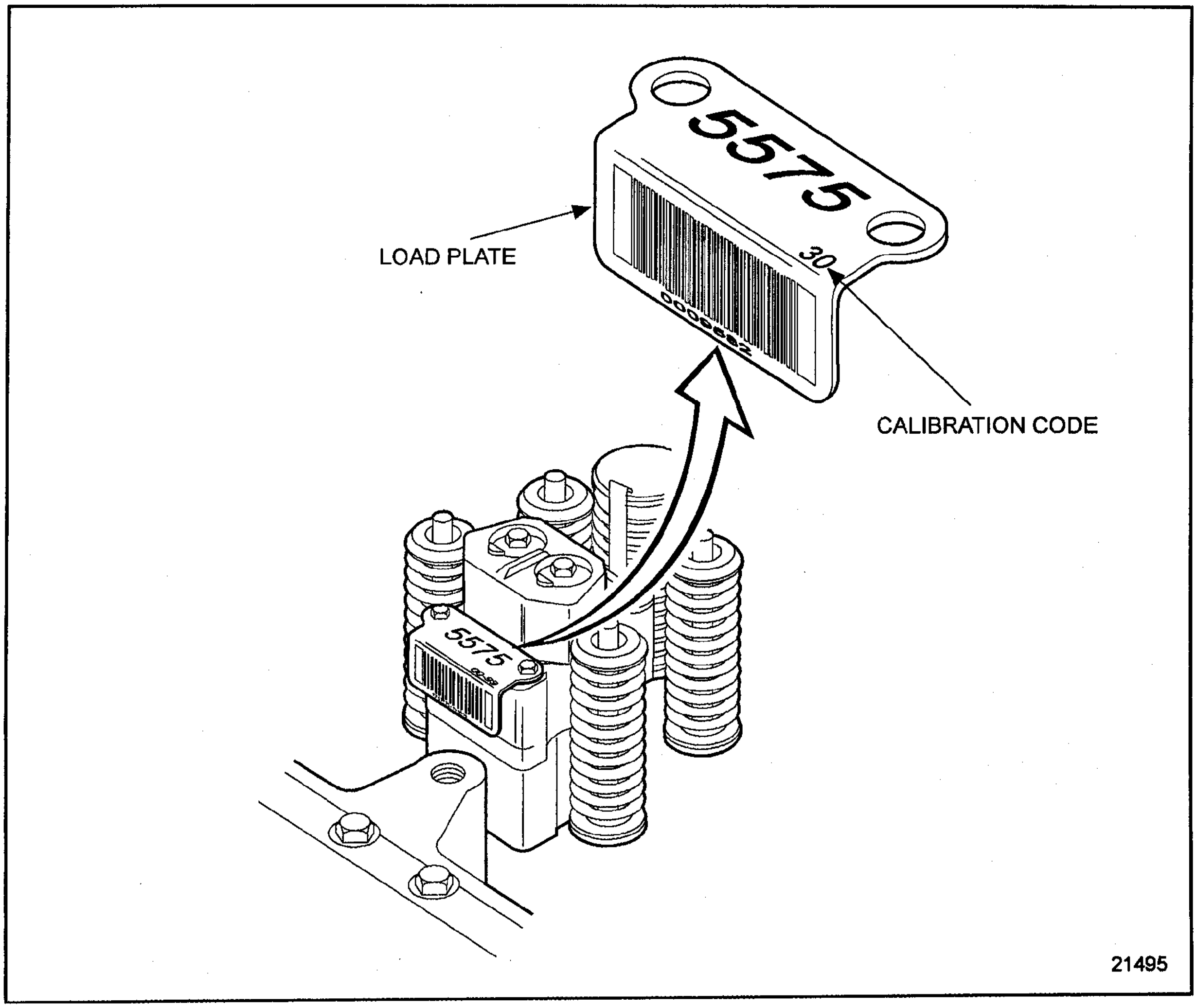



**Figure 24-2 Injector Calibration Code**

[a] If the calibration codes match, check compression pressure; refer to section 24.6.

[b] If the calibration code on the display is different then the calibration code on the suspect injector for that cylinder, the injector setting must be reset, see Figure 24-2; refer to section 24.5.1.

### 24.5.1 Improper Injector Setting Repair

Perform the following steps to recalibrate improper injector setting:

1. Reset incorrect injector setting; refer to section 16.3.1.
2. Verify injector setting repair; refer to section 24.5.1.1.

#### 24.5.1.1 Test the Engine with Corrected Injector Setting

Perform the following steps to determine if the corrected injector setting resolved rough running or stalling:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).

   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.

   [b] If the engine is running rough or stalling, shut down the engine. Check for low compression pressure; refer to section 24.6.

## 24.6 LOW COMPRESSION PRESSURE

To determine if low compression pressure is causing rough running or stalling, perform the following steps:

1. Perform a cylinder compression test.
2. Compare cylinder compression test results to specifications.
   [a] If cylinder pressure is within specifications, call Detroit Diesel Technical Service.
   [b] If cylinder pressure is below specifications, refer to section 24.6.1.

### 24.6.1 Low Compression Repair

Perform the following steps for low compression repair:

1. Perform low compression repair; refer to section 17.13.1.
2. Verify repairs to cylinder head valve or cylinder kit components; refer to section 24.6.1.1.

#### 24.6.1.1 Test Engine with Repaired Cylinder Head Valve(s) and Cylinder Kit

Perform the following steps to determine if the cylinder head valve and cylinder kit repair resolved starting difficulty:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is running rough or stalling, shut down the engine. Call Detroit Diesel Technical Service.

# 25 LACK OF POWER

## 25.1 AERATED FUEL

To determine if aerated fuel is causing lack of power, perform the following steps:

1. Test for aerated fuel; refer to section 23.3.
2. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are not present, shut down engine, check for high fuel pressure; refer to section 25.2.
   [b] If air bubbles are present, shut down engine; refer to section 25.1.1.

### 25.1.1 Aerated Fuel Resolution

Perform the following steps to resolve aerated fuel:

1. Perform aerated fuel repair; refer to section 23.3.1.
2. Verify aerated fuel resolution; refer to section 25.1.1.1.

### 25.1.1.1 Test the Engine with Aerated Fuel Resolution

Perform the following steps to determine if aerated fuel resolution resolved lack of power condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Test drive the vehicle to ensure lack of power has been resolved.

   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut down the engine.

   [b] If lack of power occurred during the test drive, shut down the engine. Check for high fuel pressure; refer to section 25.2.

## 25.2 HIGH FUEL PRESSURE

To determine if high fuel pressure is causing lack of power, perform the following steps:

1. Remove either the fuel pressure sensor (FPS) or fuel temperature sensor (FTS) fitting from the secondary filter, if equipped; see Figure 25-1 for FPS and see Figure 25-2 for FTS.

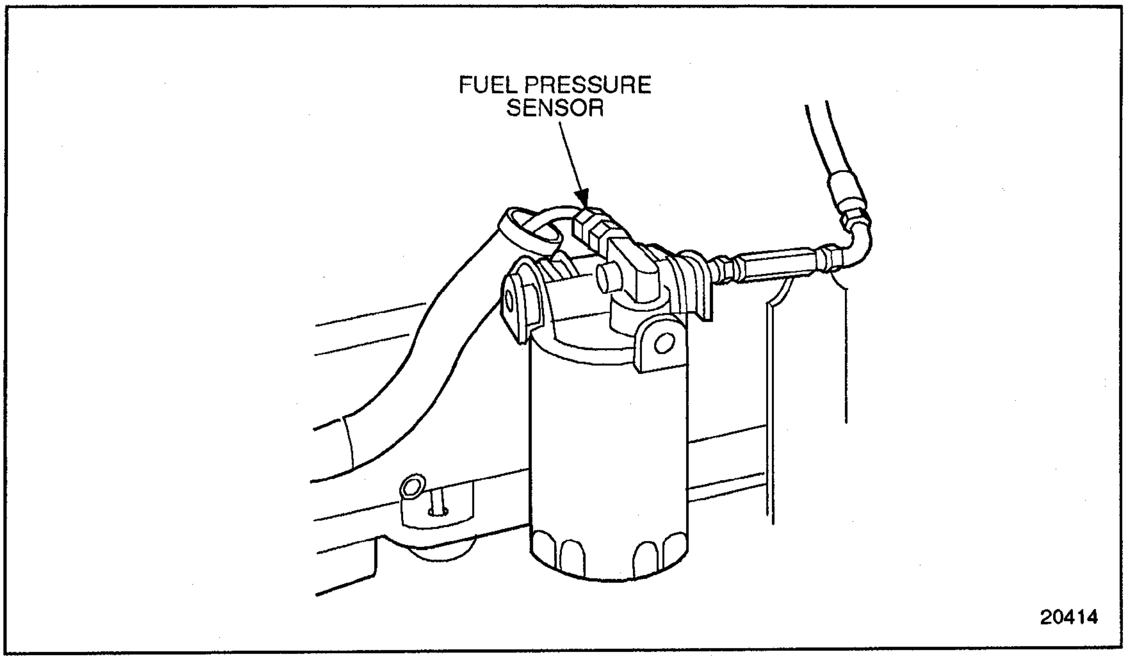



**Figure 25-1 Engine Fuel Pressure Sensor**

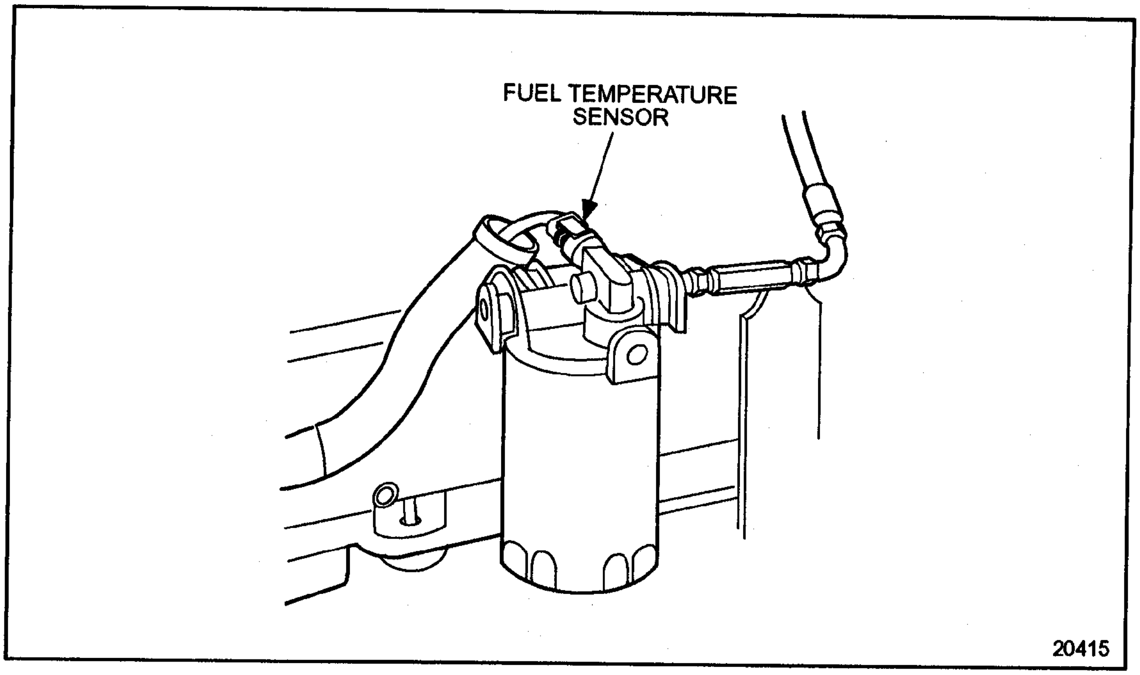



**Figure 25-2 Engine Fuel Temperature Sensor**

2. Install a tee fitting between the secondary filter and fuel outlet line.
3. Attach a calibrated gauge capable of reading 0 - 100 lb·in.$^2$ to the tee fitting.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

4. Start and run the engine to the speeds listed in Table 25-1 and record the fuel pressure:

**NOTE:**
When checking fuel pressure, start the engine, run at the speeds listed in Table 25-1, and record fuel pressure. Shut down the engine.

| Engine Speed, r/min | Fuel Pressure, psi (kPa) |
|---|---|
| 600 | 15 - 22 psi (103-152) |
| 1200 - 1300 | 30 - 45 psi (207-310) |
| 1800 - 2100 | 65 - 80 psi (448 - 552) |

**Table 25-1 Fuel Pressure at Various Speeds**

5. Shut down the engine.
6. Remove the tee fitting and calibrated gauge from the secondary filter.
7. Reinstall the FTS (refer to section 2.33.3) or FPS (refer to section 2.32.3) sensors, whichever was removed.

8. Analyze the measured fuel pressure readings.
   [a] If the fuel oil pressure is within specification listed in Table 25-1, check for high fuel oil temperature return; refer to section 25.3.
   [b] If the fuel oil pressure is greater than specifications listed in Table 25-1, refer to section 25.2.1.

### 25.2.1 Restricted Fitting and Check Valve Replacement

Perform the following steps to replace the restricted fitting and check valve.

1. Remove the restricted fitting; refer to section 2.14.2.
2. Install a new restricted fitting; refer to section 2.14.4.
3. Remove the check valve; refer to OEM guidelines.
4. Install a new check valve; refer to OEM guidelines
5. Verify check valve and restricted fitting replacement; refer to section 25.2.1.1.

| NOTICE: |
|---|
| Do not increase the size of the orifice in restricted fittings. Increasing restricted fittling hole size can cause injector caviation, resulting in reduced durability of injectors and other engine components, and increased engine emissions. |

#### 25.2.1.1 Test the Engine with Replaced Check Valve and Restricted Fitting

Perform the following steps to determine if the replaced check valve and restricted fitting resolved lack of power condition:

1. Refer to section 25.2 for exhaust caution before preceeding. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Check for high fuel oil temperature return; refer to section 25.3.

## 25.3 HIGH FUEL OIL TEMPERATURE RETURN

To determine if high fuel oil temperature return is causing lack of power, perform the following steps:

1. Test for high fuel oil temperature return; refer to section 24.4.
2. Analyze the high fuel oil temperature test results.
   [a] If the return fuel oil temperature is less than or equal to 60°C (140°F), check for air cleaner restriction; refer to section 25.4.
   [b] If the return fuel oil temperature is greater than 60°C (140°F), resolve the high fuel oil temperature return condition; refer to section 25.3.1.

### 25.3.1 High Fuel Oil Temperature Resolution

Perform the following steps to resolve high fuel oil temperature return:

1. Remove and replace fuel oil filter(s); refer to section 2.8.1.
2. Inspect the check valve for a restricted fitting, replace if necessary; refer to section 2.14.2.
3. Verify high fuel oil temperature repair; refer to section 25.3.1.1.

#### 25.3.1.1 Test the Engine with Resolved High Fuel Oil Temperature

Perform the following steps to determine if high fuel oil temperature repairs resolved lack of power condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If lack of power did not occur during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Check for a restricted air cleaner element; refer to section 25.4.

## 25.4 RESTRICTED AIR CLEANER ELEMENT

To determine if a restricted air cleaner element is causing lack of power, perform the following steps:

1. Remove the air filter element from the air cleaner container; refer to OEM guidelines.
2. Visually inspect the air cleaner element for damage or clogging.
   [a] If no damage or clogging is found, check the charge air cooler; refer to section 25.5.
   [b] If damage or clogging is found; refer to section 25.4.1.

### 25.4.1 Air Filter Element Replacement

Perform the following steps to replace the air filter element:

1. Remove and replace the damaged or clogged air filter element; refer to OEM guidelines.
2. Verify air filter element replacement; refer to section 25.4.1.1.

### 25.4.1.1 Test the Engine with Replaced Air Filter Element

Perform the following steps to determine if the new filter element resolved lack of power:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If lack of power did not occur during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Check the charge air cooler; refer to section 25.5.

## 25.5 RESTRICTED OR CRACKED CHARGE AIR COOLER OR LEAKING INTAKE MANIFOLD

To determine if a restricted or cracked charge air cooler or leaking manifold is causing lack of power, perform the following steps:

1. Test the charge air cooler; refer to section 21.3.
2. Visually inspect all joints for air leaks and all charge air cooler welded surfaces for stress cracks.
   - [a] If charge air cooler leaks are present around the joints, replace the charge air cooler; refer to section 25.5.1.
   - [b] If the intake manifold leaks, repair intake manifold; refer to section 25.5.2.
   - [c] If neither charge air cooler nor intake manifold leaked, check the exhaust system; refer to section 25.6.

### 25.5.1 Charge Air Cooler Replacement

Perform the following steps to replace the charge air cooler:

1. Remove and replace the charge air cooler; refer to OEM guidelines.
2. If the intake manifold doesn't leak, verify replacement of the charge air cooler; refer to section 25.5.2.1.
3. If the intake manifold leaks, repair intake manifold; refer to section 25.5.2.

### 25.5.2 Air Intake Manifold Repair

Perform the following steps to repair the air intake manifold:

1. Remove the air intake manifold; refer to section 6.4.2.
2. Inspect the air intake manifold; refer to section 6.4.3.1.
3. Install the air intake manifold; refer to section 6.4.4.
4. Verify repair of the intake manifold; refer to section 25.5.2.1.

#### 25.5.2.1 Test the Engine with Replaced Charge Air Cooler and Air Intake Manifold

To determine if the repairs resolved the lack of power condition, perform the following steps:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Check the exhaust system; refer to section 25.6.

## 25.6 FAULTY EXHAUST SYSTEM

To determine if a faulty exhaust system is causing lack of power, perform the following steps:

1. Test the exhaust system; refer to section 21.4.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- □ **Always start and operate an engine in a well ventilated area.**
- □ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- □ **Do not modify or tamper with the exhaust system or emission control system.**

2. Run the engine speed to full load.
   [a] If the exhaust back pressure at full load is less than 3.0 in.Hg (10.1 kPa), check for high inlet air temperature; refer to section 25.7.
   [b] If the exhaust back pressure at full load is 3.0 in.Hg (10.1 kPa) or greater, refer to section 25.6.1.

### 25.6.1 Engine Exhaust System Resolution

Perform the following steps to resolve the engine exhaust system:

1. Visually inspect the engine exhaust system; refer to OEM guidelines.
2. Repair or replace defective exhaust system components; refer to OEM guidelines.
3. Verify exhaust system resolution; refer to section 25.6.1.1.

#### 25.6.1.1 Test the Engine with Replaced Exhaust System

Perform the following steps to determine if replaced engine exhaust system components resolved lack of power condition:

1. Refer to section 25.6 for the exhaust caution before preceeding. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Check for high inlet air temperature; refer to section 25.7.

## 25.7 HIGH INLET AIR TEMPERATURE

To determine if high inlet air temperature is causing lack of power, perform the following steps:

1. Test the radiator fan, fan drive, or fan shroud for proper operation or configuration; refer to OEM guidelines.
   [a] If the radiator fan, fan drive, or fan shroud pass OEM test, check high altitude operation; refer to section 25.8.
   [b] If the radiator fan, drive or shroud did not operate correctly; refer to section 25.7.1.

### 25.7.1 Radiator Fan, Drive and Shroud Replacement

Perform the following steps to replace the radiator fan, drive and or shroud:

1. Remove and replace the radiator fan, drive and/or shroud; refer to OEM guidelines.
2. Verify replacement; refer to section 25.7.1.1.

### 25.7.1.1 Test the Engine with Radiator Fan, Fan Drive, or Fan Shroud Replacement

Perform the following steps to determine if replaced radiator fan, fan drive, or fan shroud resolved lack of power condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Check high altitude operation; refer to section 25.8.

## 25.8 HIGH ALTITUDE OPERATION

To determine if high altitude operation is causing lack of power, see Figure 25-3:

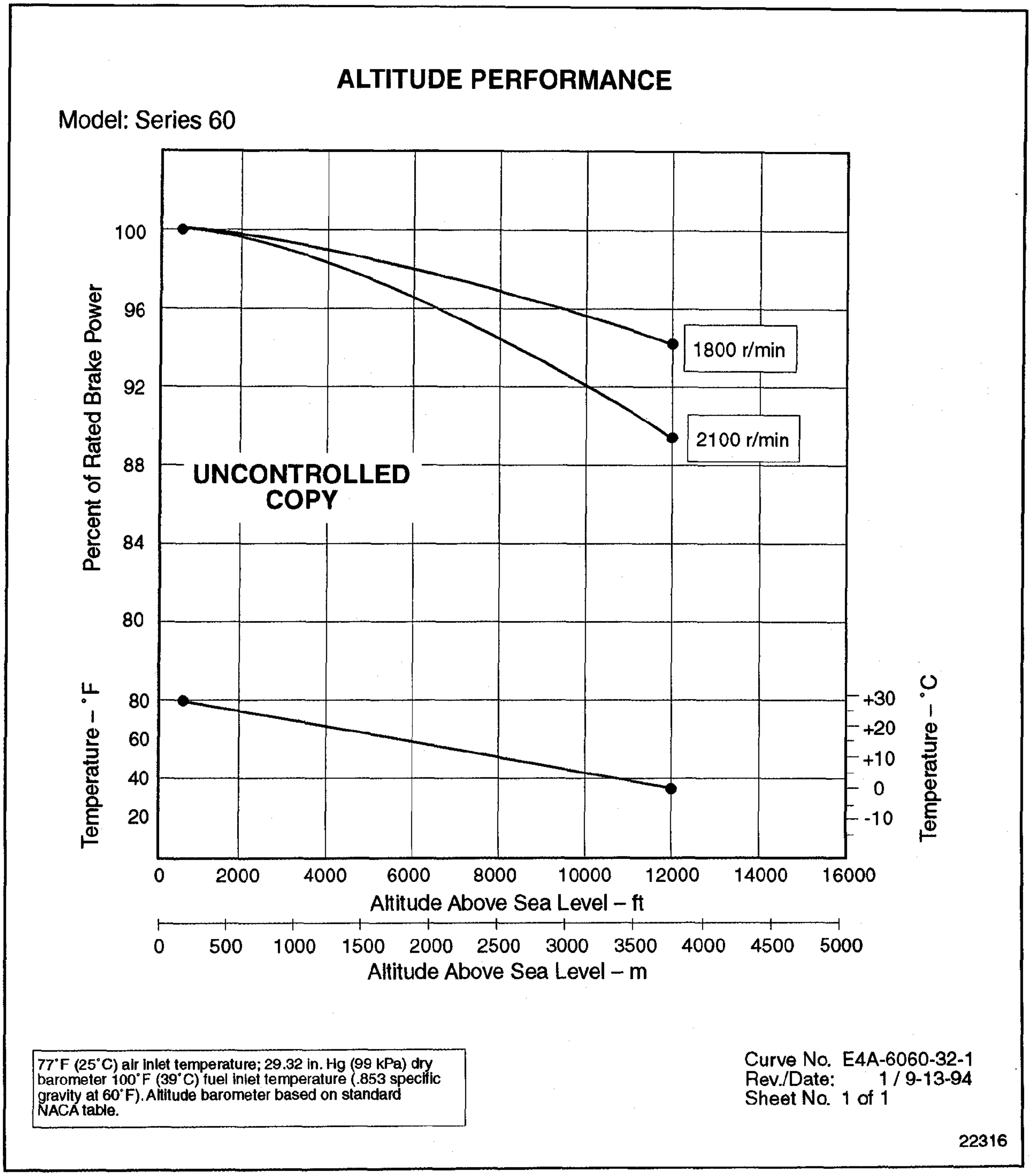



**Figure 25-3 Altitude Performance Curves**

1. Based on the altitude curve data, see Figure 25-3, decide if high altitude is causing the lack of power.
   [a] If your vehicle is operating above sea level, a loss of power will be encountered, no further troubleshooting is required.
   [b] If your vehicle is operating at or below sea level and there is a lack of power, refer to section 25.9.

## 25.9 INCORRECT CAMSHAFT TIMING

To determine if incorrect camshaft timing is causing lack of power, perform the following steps:

1. Check the camshaft timing; refer to section 1.23.6.1.
   [a] If the dial indicator reading is within 0.173 -0.215 in. (4.39 - 5.46 mm), no further troubleshooting is required.
   [b] If the dial indicator reading is not within 0.173 -0.215 in. (4.39 - 5.46 mm), check engine timing; refer to section 25.9.1.

### 25.9.1 Engine Timing Resolution

Perform the following steps to resolve incorrect engine timing:

1. Perform an engine gear train timing check; refer to section 1.21.2.1.
2. Verify engine timing resolution; refer to section 25.9.1.1.

#### 25.9.1.1 Test Engine with Correct Timing

Perform the following steps to determine if corrected engine timing resolved lack of power condition:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut down the engine.
   [b] If lack of power occurred during the test drive, shut down the engine. Call the Detroit Diesel Technical Service.

# 26 LOW OIL PRESSURE

## 26.1 IMPROPER ENGINE OIL LEVEL

To determine if improper engine oil level is causing low oil pressure, perform the following steps:

1. Ensure that the vehicle is parked on level ground.
2. Check the engine oil level; refer to section 13.13.1.
   [a] If the engine oil level is correct, check lubricating oil viscosity; refer to section 26.2.
   [b] If the engine oil level is incorrect, refer to section 26.1.1.

### 26.1.1 Low Engine Oil Level Resolution

Perform the following steps for low engine oil level:

1. Fill engine oil pan to correct level; refer to section 13.13.1.
2. Verify low engine oil resolution; refer to section 26.1.1.1.

#### 26.1.1.1 Test for Proper Engine Oil Level

Perform the following steps to determine if properly filled oil pan resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

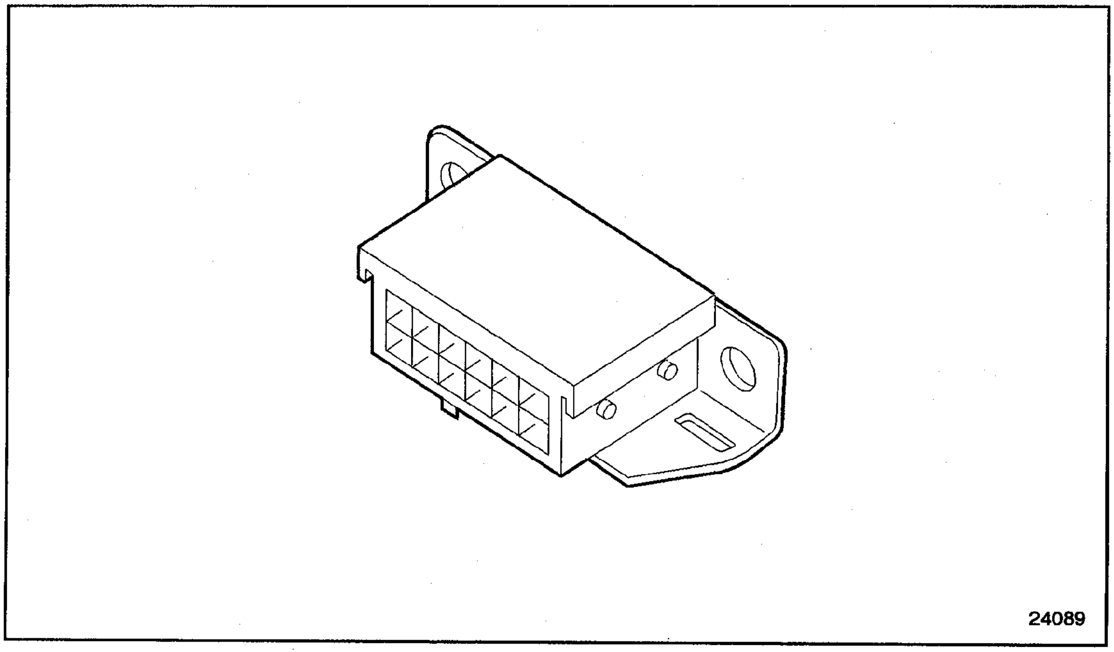



**Figure 26-1 Typical Display Data Line Adaptor**

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

2. Start and vary engine speed between 1800 - 2100 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than or equal 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.$^2$), at 1800 r/min, shut down the engine and disconnect the DDR. Check lubricating oil viscosity; refer to section 26.2.

## 26.2 IMPROPER LUBRICATING OIL VISCOSITY

To determine if improper lubricating oil viscosity is causing low oil pressure, perform the following steps:

1. Acquire a lubricating oil sample from the engine oil pan.
2. Submit oil sample for an ASTM test analysis.
   [a] If engine oil sample meets ASTM specifications, check to determine if lubricating oil is diluted with fuel or coolant; refer to section 26.3.
   [b] If engine oil sample did not meet ASTM specifications, refer to section 26.2.1.

### 26.2.1 Lubricating Oil Replacement

Perform the following steps to replace engine oil:

1. Drain and refill engine with new lubricating oil; refer to section 13.13.1.
2. Verify lubricating oil replacement, refer to section 26.2.1.1.

### 26.2.1.1 Test Engine with Replaced Lubricating Oil

Perform the following steps to determine if replaced lubricating oil resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

| CAUTION: |
|---|
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

| CAUTION: |
|---|
| **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**<br>☐ **Always start and operate an engine in a well ventilated area.**<br>☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**<br>☐ **Do not modify or tamper with the exhaust system or emission control system.** |

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than or equal 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. Check the lubricating oil for fuel and water dilution; refer to section 26.3.

## 26.3 LUBRICATING OIL DILUTED WITH FUEL OIL OR ENGINE COOLANT

To determine if lubricating oil is diluted with fuel oil or engine coolant is causing low oil pressure, perform the following steps:

1. Acquire a lubricating oil sample from the engine oil pan.
2. Visually examine lubricating oil sample for presence of engine coolant or fuel oil.
   [a] If coolant or fuel oil are not present, check for a faulty oil pressure gage, refer to section 26.4.
   [b] If water or fuel oil are present, refer to section 26.3.1.

### 26.3.1 Contaminated Lubricating Oil Resolution

Perform the following steps to resolve contaminated lubricating oil:

1. Drain engine oil pan, refer to section 13.13.1.
2. Refill engine crankcase with new oil; refer to section 13.13.1.
3. Verify lubricating oil replacement; refer to section 26.3.1.1.

### 26.3.1.1 Test Replaced Lubricating Oil

Perform the following steps to determine if replaced lubricating oil resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than or equal 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. Check for faulty oil pressure gage; refer to section 26.4.

## 26.4 FAULTY OIL PRESSURE GAUGE SENSOR

To determine if a faulty oil pressure gage sensor is causing low oil pressure, perform the following steps:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

| CAUTION: |
|---|
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

2. Start and vary the engine speed between 1800 - 2100 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than or equal 241 kPa (35 $lb/in.^2$) at 1800 r/min, shut down the engine and disconnect the DDR, check oil pressure gage sensor line for obstruction; refer to section 26.5.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 $lb/in.^2$) at 1800 r/min, shut down the engine; refer to section 26.4.1.

### 26.4.1 Oil Pressure Gage Sensor Replacement

Perform the following steps to replace the oil pressure gage sensor:

1. Remove and replace the oil pressure gage sensor; refer to OEM guidelines.
2. Verify replaced oil pressure gage sensor; refer to section 26.4.1.1.

### 26.4.1.1 Test the Engine with Replaced Oil Pressure Gage Sensor

Perform the following steps to determine if replaced oil pressure gage sensor resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

    [a] If the DDR indicates oil pressure greater than or equal 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

    [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. Check oil pressure gage sensor line for obstruction; refer to section 26.5.

## 26.5 OIL PRESSURE GAUGE LINE OBSTRUCTED

To determine if an oil pressure gage line obstruction is causing low oil pressure, perform the following steps:

1. Disconnect oil gage line from oil pressure gage; refer to OEM guidelines.
2. Visually inspect oil gage line for obstructions.
   [a] If no obstructions are found; check to determine if rocker arm shaft plugs are missing; refer to section 26.6.
   [b] If obstructions are found; refer to section 26.5.1.

### 26.5.1 Obstructed Oil Pressure Gage Line Repair

Perform the following steps to resolve oil pressure gage line obstructions:

1. Remove oil pressure gage line; refer to OEM guidelines.
2. Clean oil gage line by soaking in cleaning solution for 5 minutes.

**CAUTION:**

**To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

3. Blow out oil gage line of residue contamination with compressed air.
4. Install cleaned oil gage line; refer to OEM guidelines.
5. Verify oil gage line repair; refer to section 26.5.1.1.

### 26.5.1.1 Test the Engine with Repaired Oil Gage Line

Perform the following steps to determine if replaced oil pressure gage resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. Check for missing or damaged rocker arm shaft plugs; refer to section 26.5.

## 26.6 ROCKER ARM SHAFT PLUGS MISSING (NEW OR REBUILT ENGINES ONLY)

If engine is not new or has not been rebuilt, refer to section 26.7.

To determine if a missing rocker arm shaft plugs are causing low oil pressure, perform the following steps:

1. Remove the rocker arm cover; for one-piece refer to section 1.6.2, for two-piece refer to section 1.6.3, for three-piece refer to section 1.6.5.
2. Visually inspect the rocker arm shaft for missing or leaking shaft plugs.
   - [a] If the shaft plugs are present and are not leaking, check the oil cooler for restriction; refer to section 26.7.
   - [b] If the shaft plugs are missing, refer to section 26.6.2.
   - [c] If the shaft plugs are leaking, refer to section 26.6.1.

### 26.6.1 Leaking Rocker Arm Shaft Plug Repair

Perform the following steps to repair leaking rocker arm shaft plugs:

1. Remove damaged shaft plugs; refer to section 1.3.2.
2. Inspect rocker arm shaft for damage; refer to section 1.3.2.2. If damage is found, replace the rocker arm shaft; refer to section 1.3.2.2.
3. Install new shaft plugs; refer to section 1.3.3.

**NOTE:**
Shaft plug **must** be installed 1.0 - 1.3 mm (0.040 -0.050 in.) below surface using J 36236.

4. Install rocker arm cover; refer to section 1.6.7.
5. Verify repair made to the rocker shaft plugs; refer to section 26.6.2.1.

### 26.6.2 Missing Rocker Arm Shaft Plug Repair

Perform the following steps to repair missing rocker arm shaft plugs:

1. Inspect rocker arm shaft for damage; refer to section 1.3.2.2. If damage is found, replace the rocker arm shaft; refer to section 1.3.3.
2. Install new shaft plugs; refer to section 1.3.3.

**NOTE:**
Shaft plug **must** be installed 1.0 - 1.3 mm (0.040 -0.050 in.) below surface using J 36236.

3. Install rocker arm cover; refer to section 1.6.7.
4. Verify repair made to the rocker shaft plugs; refer to section 26.6.2.1.

### 26.6.2.1 Test Engine with Repaired Rocker Shaft Plugs

Perform the following steps to determine if repaired rocker shaft plugs resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$) or more at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. Check the oil cooler for restriction; refer to section 26.7.

## 26.7 RESTRICTED OIL COOLER

To determine if a restricted oil cooler is causing low oil pressure, perform the following steps:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

| **CAUTION:** |
|---|
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

| **CAUTION:** |
|---|
| **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**<br>☐ **Always start and operate an engine in a well ventilated area.**<br>☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**<br>☐ **Do not modify or tamper with the exhaust system or emission control system.** |

2. Start and run the engine at 1800 r/min.
3. Run the engine at 1800 r/min with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88 - 96°C (190 - 210°F).

   [a] If the DDR is indicating a lubricating oil temperature less than or equal to 110°C (230°F). Shut down the engine, disconnect the DDR, and check pressure regulator valve; refer to section 26.8.

   [b] If the DDR is indicating a lubricating oil temperature greater than 110°C (230°F). Shut down the engine and repair oil cooler; refer to section 26.7.1.

### 26.7.1 Oil Cooler Repair

Perform the following steps to repair the oil cooler:

1. Remove and repair oil cooler, refer to section 3.8.2. Refer to section 3.9.2for pre-1991 oil coolers.
2. Clean the oil cooler; refer to section 3.8.3or refer to section 3.9.3 for pre-1991 oil coolers.
3. Inspect the oil cooler for damage; refer to section 3.8.3.1or refer to section 3.9.3.1 for pre-1991 oil coolers.
4. Install repaired oil cooler; refer to section 3.8.4 or refer to section 3.9.4for pre-1991 oil coolers.
5. Verify repair of oil cooler; refer to section 26.7.1.1.

#### 26.7.1.1 Test Engine with Repaired Oil Cooler

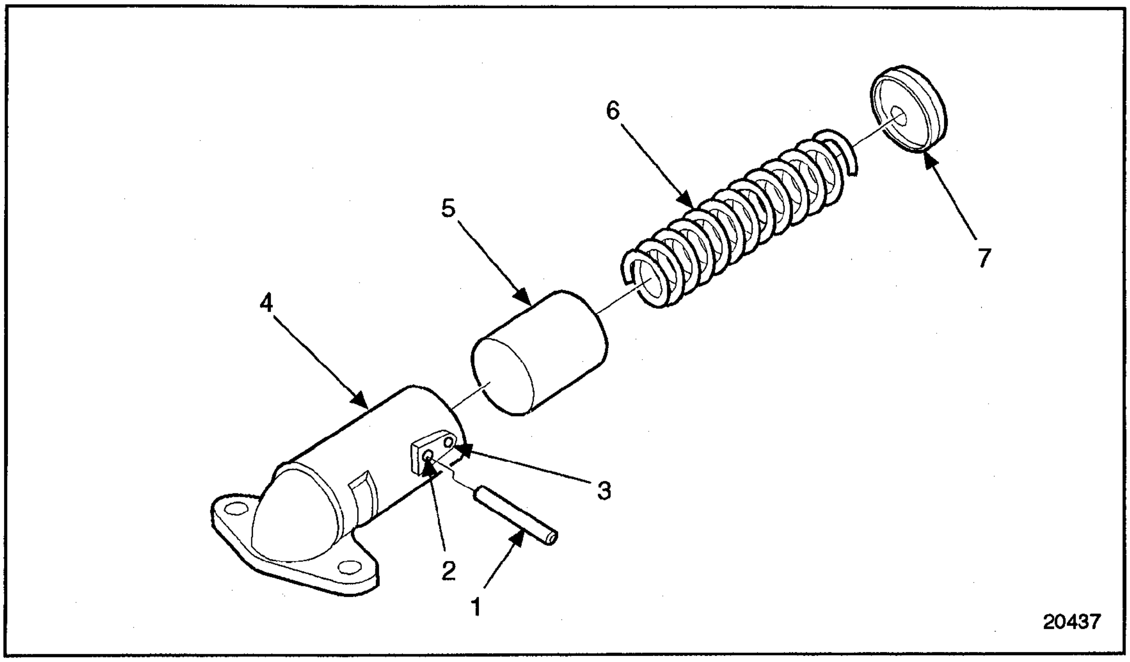
Perform the following steps to determine if oil cooler repair resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.
2. Refer to section 26.7 for the exhaust caution before preceeding. Start and run the engine at 1800 r/min.
3. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88 - 96°C (190 - 210°F).
   - [a] If the DDR is indicating a lubricating oil temperature less than or equal to 110°C (230°F) at 1800 r/min, disconnect the DDR and shut down the engine. No further troubleshooting is required.
   - [b] If the DDR is indicating a lubricating oil temperature greater than 110°C (230°F) at 1800 r/min, shut down the engine and disconnect the DDR. Check pressure regulator valve; refer to section 26.8.

## 26.8 NONFUNCTIONAL OR STICKING OIL PRESSURE REGULATOR VALVE

To determine if a nonfunctional or sticking regulator valve is causing low oil pressure, perform the following steps:

1. Remove the oil pressure regulator; refer to section 3.3.2.
2. Inspect the oil pressure regulator; refer to section 3.3.3.1.
   [a] If the regulator valve moves freely in the valve body; see Figure 26-2. Reinstall the oil pressure regulator assembly, refer to section 3.3.5. Check the bypass valve, refer to section 26.9.
   [b] If the regulator valve will not move freely in the valve body, refer to section 26.8.1.




1. Pin
2. Pressure Relief Valve Pin Location
3. Pressure Regulator Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

**Figure 26-2 Oil Pressure Regulator**

### 26.8.1 Oil Pressure Regulator Valve Repair

Perform the following steps to repair the oil pressure regulator valve:

1. Disassemble the pressure regulator valve and replace damaged components; refer to section 3.3.3.
2. Assemble the pressure regulator valve; refer to section 3.3.4.
3. Verify repair of the regulator valve; refer to section 26.8.1.1.

#### 26.8.1.1 Test Engine with Repaired Oil Pressure Regulator Valve

Perform the following steps to determine if repaired oil pressure regulator valve resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$) or more at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR; check bypass valve; refer to section 26.9.

## 26.9 DEFECTIVE BYPASS VALVE

To determine if a defective bypass valve is causing low oil pressure, perform the following steps:

1. Remove the oil filter adaptor; refer to section 3.6.2.
2. Inspect the oil filter adaptor; refer to section 3.6.3.1.
   [a] If no damage is found with the oil filter adaptor components, reinstall the oil filter adaptor; refer to section 3.6.5. Check pressure relief valve, refer to section 26.10.

   [b] If damage is found with the oil filter adaptor components; refer to section 26.9.1.

### 26.9.1 Oil Filter Adaptor Repair

Perform the following steps to repair the oil filter adaptor:

1. Disassemble the oil filter adaptor; refer to section 3.6.2.
2. Assemble the oil filter adaptor; refer to section 3.6.4.

**NOTE:**
Always replace the copper washer whenever the adaptor plug is removed.

3. Install repaired oil filter adaptor; refer to section 3.6.5.
4. Verify repairs made to the oil filter adaptor; refer to section 26.9.1.1.

#### 26.9.1.1 Test Engine with Repaired Oil Filter Adaptor

Perform the following steps to determine if repaired oil pressure regulator valve resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

2. Start and vary the engine speed between 1800 -2100 r/min.
3. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$), shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$), shut down the engine and disconnect the DDR, check pressure relief valve; refer to section 26.10.

## 26.10 DEFECTIVE PRESSURE RELIEF VALVE

To determine if a defective pressure relief valve is causing low oil pressure, perform the following steps:

1. Remove the pressure relief valve; refer to section 3.4.2.
2. Inspect the oil pressure relief valve; refer to section 3.4.4.1.
   - [a] If the relief valve moves freely in the valve body, reinstall the oil pressure relief valve; refer to section 3.4.6. Check the pickup tube and screen assembly for defects, refer to section 26.11.
   - [b] If the relief valve will not move freely in the valve body, refer to section 26.10.1.

### 26.10.1 Pressure Relief Valve Repair

Perform the following steps to repair the pressure relief valve:

1. Disassemble the pressure relief valve and replace damaged components; refer to section 3.4.3.
2. Assemble and install the pressure regulator valve; refer to section 3.3.4.
3. Verify repair of the regulator valve; refer to section 26.10.1.1.

#### 26.10.1.1 Test Engine with Repaired Relief Valve

Perform the following steps to determine if repaired relief valve resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$), or more at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$), at 1800 r/min, shut down the engine and disconnect the DDR, check pickup tube and screen assembly; refer to section 26.11.

## 26.11 DEFECTIVE PICKUP SCREEN TUBE AND SCREEN ASSEMBLY

To determine if a defective pickup screen tube or screen assembly is causing low oil pressure, perform the following steps:

1. Remove pickup screen tube and screen assembly; refer to section 3.2.2.
2. Visually inspect pickup screen tube and screen assembly; refer to section 3.2.3.1.
   [a] If no stress cracks, twisted screen tube, or cracked flange gaskets are found, check crankshaft main bearings; refer to section 26.12.
   [b] If stress cracks, twisted screen tube, or cracked flange gaskets are found, refer to section 26.11.1.

### 26.11.1 Pickup Screen Tube and Screen Assembly Repair

Perform the following steps to repair the pickup screen tube and screen assembly:

1. Replace all damaged components identified during inspection and install; refer to section 3.2.6.
2. Verify repairs to pickup screen tube and screen assembly; refer to section 26.11.1.1.

### 26.11.1.1 Test Engine with Repaired Pickup Screen Tube and Screen Assembly

Perform the following steps to determine if repaired relief valve resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$), or more at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR, check crankshaft main bearings; refer to section 26.12.

## 26.12 DEFECTIVE CRANKSHAFT MAIN BEARING SHELLS

To determine if defective crankshaft main bearing shells are causing low oil pressure, perform the following steps:

1. Check main bearing to crankshaft journal clearances; refer to section 1.7.2.1.
   - [a] If main bearing shell-to-journal clearance is within 0.040 - 0.151 mm (0.0016 -0.006 in.), check oil pump assembly; refer to section 26.13.
   - [b] If main bearing shell-to-journal clearance is not within 0.040 - 0.151 mm 0(.0016 -0.006 in.), refer to section 26.12.1.

### 26.12.1 Crankshaft Main Bearing Shell Repair

Perform the following steps to repair crankshaft main bearing shells:

1. Remove and replace defective crankshaft main bearing shells; refer to section 1.9.2.
2. Verify crankshaft main bearing shells repair: refer to section 26.12.1.1.

### 26.12.1.1 Test Engine with New Crankshaft Main Bearing Shells

Perform the following steps to determine if repaired relief valve resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine between 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. Check the oil pump assembly; refer to section 26.12.

## 26.13 DEFECTIVE OIL PUMP ASSEMBLY

To determine if a defective oil pump is causing low oil pressure, perform the following steps:

1. Remove the oil pump assembly; refer to section 3.2.2.
2. Manually rotate the oil pump drive gear.
   [a] If the drive gear rotates freely in the pump housing, call Detroit Diesel Technical Service Group.
   [b] If the drive gear did not rotate freely; refer to section 26.13.1.

### 26.13.1 Oil Pump Assembly Repair

Perform the following steps to repair the oil pump assembly:

1. Disassemble the oil pump assembly and replace worn or damaged components as required; refer to section 3.2.3.
2. Reassemble the oil pump; refer to section 3.2.4 or refer to section 3.2.5for pre-1991 oil pump.
3. Verify oil pump repair; refer to section 26.13.1.1.

### 26.13.1.1 Test Engine with Repaired Oil Pump Assembly

Perform the following steps to determine if repaired relief valve resolved low oil pressure:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.$^2$) at 1800 r/min, shut down the engine and disconnect the DDR; call Detroit Diesel Technical Service Group.

# 27 HIGH ENGINE COOLANT TEMPERATURE

## 27.1 IMPROPER ENGINE COOLANT LEVEL

To determine if improper engine coolant level is causing high engine coolant temperature, perform the following:

1. Visually inspect the radiator coolant level; refer to OEM guidelines.
   [a] If the radiator coolant level is within 2.0 in. (approximately 50 mm) of the radiator filler neck, check insufficient radiator air circulation; refer to section 27.2.
   [b] If the radiator coolant level is not within 2 in. (approximately 50 mm) of the radiator filler neck, refer to section 27.1.1.

### 27.1.1 Improper Coolant Level Resolution

Perform the following steps to resolve improper coolant level:

1. Fill coolant system to correct level; refer to section 13.13.4.
2. Verify coolant level resolution; refer to section 27.1.1.1.

#### 27.1.1.1 Test Engine with Proper Coolant Level

Perform the following to determine if proper coolant level resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check for insufficient radiator air circulation; refer to section 27.2.

## 27.2 INSUFFICIENT RADIATOR AIR CIRCULATION

To determine if insufficient radiator air circulation is causing high engine coolant temperature, perform the following:

1. Visually examine the radiator and radiator shrouding.
   [a] If the radiator is absent of clogging, debris, and dirt, check the pressure control cap; refer to section 27.3.
   [b] If the radiator has excessive clogging, debris, or dirt; refer to section 27.2.1.
   [c] If the radiator shrouding is not damaged, incorrectly positioned, or inadequate, check the pressure control cap; refer to section 27.3.
   [d] If the radiator shrouding is damaged, incorrectly positioned, or inadequate, refer to section 27.2.2.

### 27.2.1 Exterior Radiator Repair

Perform the following for exterior radiator repair:

1. Clean the exterior radiator of all clogging, debris, or excessive dirt; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to section 27.2.2.1.

### 27.2.2 Radiator Shroud Repair

Perform the following for radiator shroud repair:

1. Repair or replace damaged radiator shrouding; refer to OEM guidelines
2. Verify exterior radiator repair; refer to section 27.2.2.1.

### 27.2.2.1 Test Engine with Repaired Exterior Radiator and Shrouding

Perform the following to determine if exterior radiator and shrouding repair resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.

   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check the pressure control cap; refer to section 27.3.

## 27.3 FAULTY PRESSURE CONTROL CAP

To determine if a faulty pressure control cap is causing high engine coolant temperature, perform the following:

1. Perform coolant pressure control cap tests; refer to section 4.6.2.1.
   [a] If the cooling system pressure is less than or equal to 48.3 kPa (7 lb/in.$^2$), check the coolant hoses; refer to section 27.4.
   [b] If the cooling system pressure is greater than 48.3 kPa (7 lb/in.$^2$), refer to section 27.3.1.

### 27.3.1 Pressure Control Cap Resolution

Perform the following steps to resolve faulty pressure control cap:

1. Remove and replace pressure control cap; refer to OEM guidelines.
2. Install a new pressure control cap; refer to OEM guidelines.
3. Verify pressure control repair; refer to section 27.3.1.1.

### 27.3.1.1 Test Engine with Replaced Pressure Control Cap

Perform the following to determine if exterior radiator repair resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

   [a] If the engine coolant temperature is normal, no further troubleshooting is required. Shut down the engine.

   [b] If the engine coolant temperature is not normal, shut down the engine. Check coolant hoses; refer to section 27.4.

## 27.4 DEFECTIVE COOLANT HOSES

To determine if defective coolant hoses is causing high engine coolant temperature, perform the following:

1. Visually examine cooling system hoses; refer to OEM guidelines.
   [a] If cooling system hoses are not soft, deteriorated, or collapsed, check the fan belts; refer to section 27.5.
   [b] If cooling system hoses are soft, deteriorated, or collapsed, refer to section 27.4.1.

### 27.4.1 Coolant System Hoses Replacement

Perform the following steps to resolve worn or damaged coolant system hoses:

1. Remove and replace damaged or worn coolant hoses as necessary; refer to OEM guidelines.
2. Install new coolant hoses as necessary; refer to OEM guidelines.
3. Verify replaced coolant system hoses; refer to section 27.4.1.1.

### 27.4.1.1 Test Engine with Replaced Coolant Hoses

Perform the following to determine if the new coolant hoses resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, and visually examine replaced hoses for any leaks.

   [a] If the engine coolant temperature is 88-96°C (190-210°F) and no leaks are found, no further troubleshooting is required.

   [b] If the engine coolant temperature is 88-96°C (190-210°F) and leaks are found, repair leaks; refer to section 27.4.1. Shut down the engine.

   [c] If the engine coolant temperature is not 88-96°C (190-210°F) and no leaks are found, shut down the engine. Check fan belts; refer to section 27.5.

## 27.5 FAN BELTS ARE INCORRECTLY ADJUSTED

To determine if misadjusted fan belts are causing high engine coolant temperature, perform the following:

1. Test fan belt(s) tension; refer to section 13.13.10.
2. Compare tension to belt specifications listed in Table 27-1.
   [a] If the belt(s) tension is within specification, check the thermo-modulated fan; refer to section 27.6.
   [b] If the belt(s) tension is not within specification,refer to section 27.5.1.

| Single Belt, lb (N) | 2 or 3 Belts, lb (N) |
|---|---|
| 80 - 100 (335 - 345) | 60 - 80 (266 - 355) |

**Table 27-1 Fan Belt Tension**

### 27.5.1 Belt Tension Resolution

Perform the following steps to resolve incorrect belt tension:

1. Readjust belt(s) tension as necessary; refer to section 13.13.10.
2. Verify belt tension resolution; refer to section 27.5.1.1.

### 27.5.1.1 Test Engine with Correct Belt Tension

Perform the following to determine if exterior radiator repair resolved high engine coolant temperature:

| CAUTION: |
|---|
| **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.** |

| CAUTION: |
|---|
| **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**<br>☐ **Always start and operate an engine in a well ventilated area.**<br>☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**<br>☐ **Do not modify or tamper with the exhaust system or emission control system.** |

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check thermo-modulated fan; refer to section 27.6.

## 27.6 INOPERATIVE THERMO-MODULATED FAN

To determine if an inoperative thermo-modulated fan is causing high engine coolant temperature, perform the following:

1. Test the thermo-modulated fan; refer to OEM guidelines.
   [a] If the thermo-modulated fan is functioning correctly, check thermostats; refer to section 27.7.
   [b] If the thermo-modulated fan is not functioning correctly, refer to section 27.6.1.

### 27.6.1 Thermo-modulated Fan Replacement

Perform the following steps to replace inoperative thermo-modulated fan:

1. Replace inoperative thermo-modulated fan; refer to OEM guidelines.
2. Verify thermo-modulated fan replacement; refer to section 27.6.1.1.

### 27.6.1.1 Test Engine with Replaced Thermo-modulated Fan

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check thermostats; refer to section 27.7.

## 27.7 FAULTY THERMOSTATS

To determine if faulty thermostats are causing high engine coolant temperature, perform the following:

1. Remove thermostat from the thermostat housing; refer to section 4.5.2.
2. Inspect thermostat for correct operation; refer to section 4.5.2.1.
   [a] If thermostat opened at 97°C (207°F), check water pump; refer to section 27.8.
   [b] If thermostat did not open at 97°C (207°F), refer to section 27.7.1.

### 27.7.1 Thermostat Replacement

Perform the following steps to replace thermostats:

1. Install new thermostat; refer to section 4.5.5.
2. Verify replaced thermostat; refer to section 27.7.1.1.

### 27.7.1.1 Test Engine with New Thermostat

Perform the following to determine if thermostat replacement resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check water pump; refer to section 27.8.

## 27.8 FAULTY WATER PUMP

To determine if a faulty water pump is causing high engine coolant temperature, perform the following:

1. Remove the water pump; refer to section 4.2.2 (gear case mounted) or refer to section 4.3.2 (gear case cover mounted).
2. Turn the water pump over and install J 35687, water pump impeller slip and lash tester, into the tapped holes provided in the impeller; see Figure 27-1.

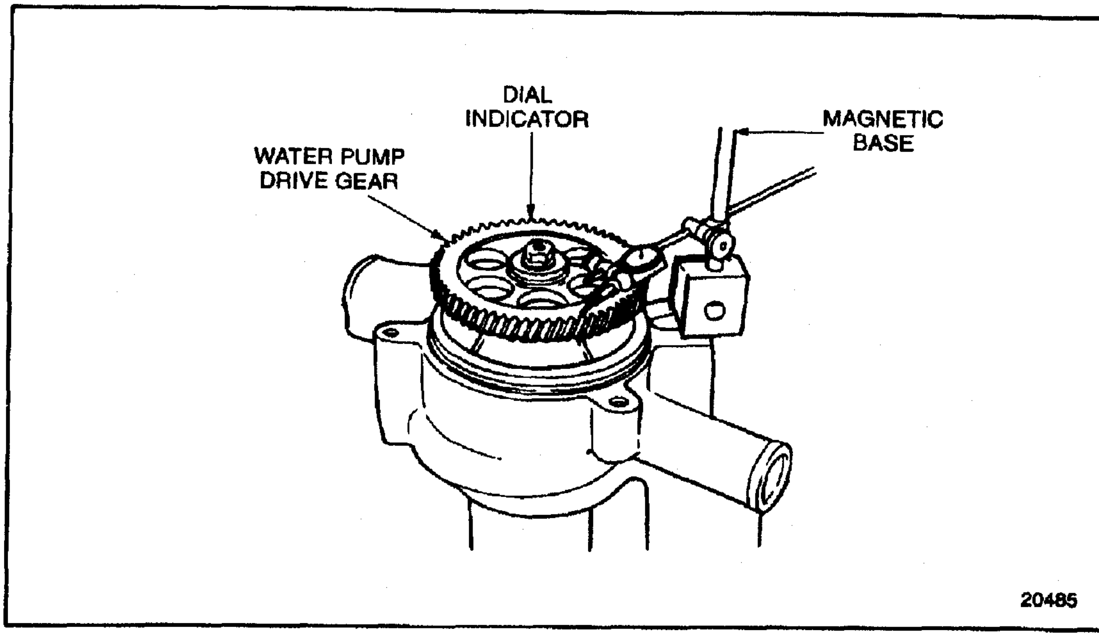



**Figure 27-1 Measuring Water Pump Drive Gear Run-out**

3. Clamp the water pump drive gear in a vise, with the impeller facing up. Use soft jaws to prevent damage to the gear teeth.
4. Using a 1/2 in. drive torque wrench in the hole provided in the center of the slip-lash tester, apply 68 N·m (50 lb·ft) torque in either direction. The impeller must withstand 68 N·m (50 lb·ft) torque without slipping.
   [a] If the torque 68 N·m (50 lb·ft) is satisfied without the impeller slipping, check combustion gases in coolant; refer to section 27.9.
   [b] If the torque 68 N·m (50 lb·ft) is not satisfied and the impeller is slipping, refer to section 27.8.1.

## 27.8.1 Water Pump Impeller Replacement

Perform the following steps to replace water pump impeller:

1. Disassemble the water pump and replace worn or damaged impeller; refer to section 4.2.3 for (gear case mounted) or refer to section 4.3.3(gear case cover mounted).
2. Reassemble the water pump with new components as necessary; refer to section 4.2.5 for (gear case mounted) or refer to section 4.3.5 (gear case cover mounted).

### 27.8.1.1 Test Engine with Repaired Water Pump

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.

   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check combustion gases in coolant; refer to section 27.9.

## 27.9 COMBUSTION GASES IN COOLANT

To determine if combustion gases in coolant is causing high engine coolant temperature, perform the following:

1. Perform a cylinder compression test.
   [a] If test results are to specifications; check radiator coolant flow, refer to section 27.10.
   [b] If test results are not to specifications; refer to section 27.9.1.

### 27.9.1 Cylinder Head Gasket Replacement

Perform the following steps to replace cylinder head gasket:

1. Remove and replace cylinder head gasket; refer to section 1.2.2.
2. Verify new cylinder head gasket replacement; refer to section 27.9.1.1.

### 27.9.1.1 Test Engine with Replaced Cylinder Head Gasket

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check radiator coolant flow; refer to section 27.10.

## 27.10 ABNORMAL RADIATOR COOLANT FLOW

To determine if abnormal radiator coolant flow is causing high engine coolant temperature, perform the following:

1. Install a sight glass with string (both ends) to the radiator outlet hose near radiator and before fill and heater return lines; see Figure 27-2.

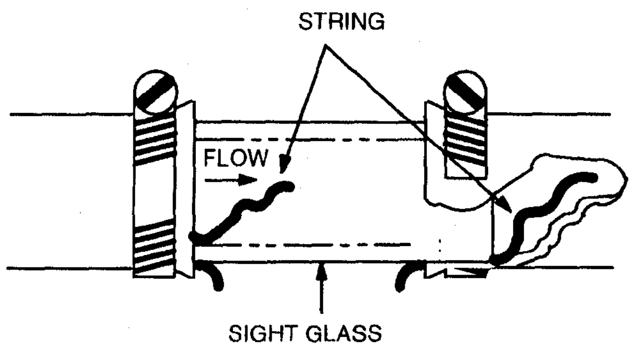



**Figure 27-2 Radiator Flow Check**

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine at full load.
3. Observe the string for flow and direction as well as the fill and bleed lines. Continue observation while varying the engine speed between 1800 - 2100 r/min.
   [a] If a balanced coolant flow is observed in the sight, call Detroit Diesel Technical Service Group. Shut down the engine.
   [b] If a balanced coolant flow is not observed in the sight glass, refer to section 27.10.1. Shut down the engine.

### 27.10.1 Abnormal Radiator Coolant Flow Resolution

Perform the following steps, as necessary, to resolve abnormal radiator coolant flow:

1. Correct bleed line size; refer to OEM guidelines.
2. Correct fill line size or connector fitting size; refer to OEM guidelines.
3. Correct restrictive top tank opening; refer to OEM guidelines.
4. Correct location of standpipe; refer to OEM guidelines.
5. Verify repairs made to correct abnormal radiator coolant flow; refer to section 27.10.1.1.

### 27.10.1.1 Test Engine with Resolved Radiator Coolant Flow

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

1. Refer to section 27.10 for the exhaust catuion before preceeding. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Call the Detroit Diesel Technical Service Group.

# 28 LOW COOLANT TEMPERATURE

**Section** **Page**

## 28.1 FAULTY THERMOSTATS

To determine if faulty thermostats are causing low engine coolant temperature, perform the following:

1. Remove thermostat from the thermostat housing; refer to section 4.5.2.
2. Inspect thermostat for correct operation; refer to section 4.5.2.1.
   [a] If thermostat opened at 97°C (207°F), check insufficient radiator air circulation; refer to section 28.2.
   [b] If thermostat did not open at 97°C (207°F), refer to section 28.1.1.

### 28.1.1 Thermostat Replacement

Perform the following steps to replace thermostats:

1. Install new thermostat; refer to section 4.5.5.
2. Verify replaced thermostat; refer to section 28.1.1.1.

#### 28.1.1.1 Test Engine with New Thermostat

Perform the following to determine if thermostat replacement resolved low engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.

   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Check insufficient radiator air circulation; refer to section 28.2.

## 28.2 INSUFFICIENT RADIATOR AIR CIRCULATION

To determine if insufficient radiator air circulation is causing high engine coolant temperature, perform the following:

1. Visually examine the radiator and radiator shrouding.
   [a] If the radiator has excessive clogging, debris, or dirt, refer to section 28.2.1.
   [b] If the radiator shrouding is not damaged, incorrectly positioned, or inadequate, and if the radiator is absent of clogging, debris, and dirt, call Detroit Diesel Technical Service Group.
   [c] If the radiator shrouding is damaged, incorrectly positioned, or inadequate, refer to section 28.2.2.

### 28.2.1 Exterior Radiator Repair

Perform the following for exterior radiator repair:

1. Clean the exterior radiator of all clogging, debris, or excessive dirt; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to section 27.2.2.1.

### 28.2.2 Radiator Shroud Repair

Perform the following for radiator shroud repair:

1. Repair or replace damaged radiator shrouding; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to section 27.2.2.1.

### 28.2.2.1 Test Engine with Repaired Exterior Radiator and Shrouding

Perform the following to determine if exterior radiator and shrouding repair resolved high engine coolant temperature:

**CAUTION:**

**To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

**CAUTION:**

**Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut down the engine.

   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut down the engine. Call Detroit Diesel Technical Service Group.

# 29 POOR FUEL ECONOMY

**Section** **Page**

## 29.1 PROBABLE CAUSE #1

NOT AVAILABLE

# INDEX

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## D

## E

## G



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# R

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# CHAPTER 2

## SUPPLEMENTAL MAINTENANCE INSTRUCTIONS
## FOR
## DIESEL ENGINE (DETROIT DIESEL)

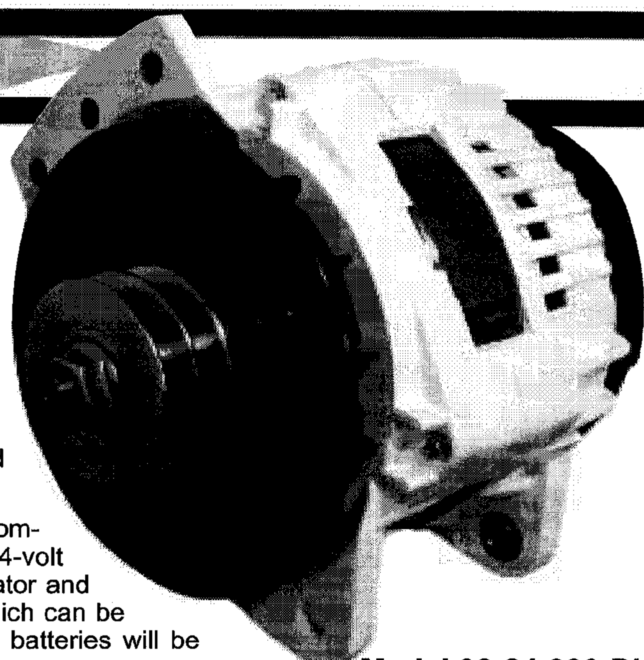
# SECTION 30

# MAINTENANCE MANUAL
# FOR
# BALMAR 24 VOLT ALTERNATOR

# Military 24-Volt DC Charging System Operations and Maintenance Manual

BALMAR®

## I. ALTERNATOR OVERVIEW



Your high-output BALMAR® Marine Alternator is uniquely designed and engineered to provide the finest performance and durability for your vessel. Unlike most automotive-type alternators found standard on the majority of pleasure craft, our marine alternators are designed to provide exceptional output at lower engine r.p.m.'s typical of marine diesel engines, so you can enjoy less noise and fumes, increased economy and shorter charge cycles.

This alternator requires external voltage regulation. We recommend our Max Charge MC-624 regulator for use with our 24-volt alternators. When combined, the Balmar high-output alternator and smart, Max Charge regulator deliver charging amperage which can be tailored to your specific battery technology -- ensuring that batteries will be charged safely and efficiently.

**Model 98-24-220-BL**

## II. SAFETY CONSIDERATIONS

Before installing your alternator, please take a moment to consider the following guidelines for safe alternator installation. Failure to follow these guidelines could result in injury or damage to your electrical system.

1. Always disconnect your batteries prior and turn your battery switch to its OFF position prior to installing your alternator.
2. Remove any loose-fitting clothing or jewelry, which could become entangled in your motor or other machinery.
3. Wear ANSI-approved safety glasses.
4. Ensure the engine has cooled sufficiently before initiating installation.
5. DO NOT install a high-output alternator without ensuring that system wiring is sufficient to handle increased amperage loads.
6. Be sure that your work area is well ventilated, and that no fuels or solvents are present in and around your work area.
7. DO NOT attempt to operate your charging system until proper fusing or circuit breakers are installed. Proper fusing, where indicated, provides protection against fire and resulting system damage. Missing or improperly-sized fusing can result in severe injury, death, or damage or destruction of your vessel.
8. Drugs and alcohol do not mix with safe installation procedures. Do not attempt installation while using alcohol or medication which could impair your judgment or reaction time.
9. Always use the right tool for the job. In addition to causing damage to the alternator or your boat, the use of incorrect or improperly-sized tools can result in personal injury.
10. Do not attempt installation if tired or fatigued.
11. Take time to read the manual. Equipment damage and possible injuries may result from an incomplete understanding of the installation and operation of the alternator.

***CAUTION:*** *The following instructions are intended for use by experienced marine electrical installers. If you are not experienced at installing electrical system components, we recommend a qualified marine electrician be used to install this alternator.*

## Contents

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1/6/02

# III. GENERAL INFORMATION

BALMAR 24-volt alternators are available in a wide range of sizes, mounting configurations and amperage outputs to match the needs of most marine engines. Alternators are "P" type (positive on the field wire), with max. field current of 4 amps and have 4.8 ohm rotors.

### *Amperage Ratings*

Alternators are rated in relation to their outputs at our test bench at specific pulley r.p.m. Circuit breakers and wire gauges must be scaled to meet indicated alternator amperage. See **Figure 1** for wire sizes based on amperage ratings. Actual amperages produced by the alternators after installation may vary due to factors such as battery capacity, battery type, wiring capacity, engine room temperature, and other variables. In most cases, maximum output is determined by your batteries' absorption rates at their voltage set point.

| 3% Voltage Drop Chart -- Distance reflects "round trip" | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length | 10 Ft. | 15 Ft. | 20 Ft. | 25 Ft. | 50 Ft. | 75 Ft. | 100 Ft. |
| Amps | | | | | | | |
| 25 | 10 | 8 | 8 | 6 | 4 | 2 | 1 |
| 50 | 8 | 6 | 4 | 4 | 1 | 2/0 | 3/0 |
| 75 | 6 | 4 | 2 | 2 | 2/0 | 3/0 | 4/0 |
| 100 | 4 | 2 | 2 | 1 | 3/0 | 4/0 | |
| 125 | 4 | 2 | 1 | 1/0 | 3/0 | 4/0 | |
| 150 | 2 | 1 | 1/0 | 2/0 | 4/0 | | |
| 175 | 2 | 1/0 | 2/0 | 3/0 | | | |
| 200 | 2 | 1/0 | 2/0 | 3/0 | | | |
| 225 | 1 | 2/0 | 3/0 | 4/0 | | | |
| 250 | 1 | 2/0 | 3/0 | 4/0 | | | |
| 275 | 1/0 | 2/0 | 4/0 | | | | |

**Figure 1 -** *Wire size must be upgraded to reflect the introduction of a high-output BALMAR alternator. Keep in mind that wiring must be measured in terms of the round trip distance between the alternator and your batteries -- and back to your batteries. Wire sizes are based on high-quality marine (AWG) wire.*

### *Grounding*

Most BALMAR marine alternators are case ground. In order to ensure proper grounding, we strongly recommend you supplement your case ground with a ground cable (the same size as your output cable) connected to your engine's preferred ground or a main ground buss. If your alternator is a dual post, isolated ground (IG) model, the negative ground must be established independent of the alternator case. The regulator's grounding wires must be attached to the alternator's negative terminal.

### *Mechanical and Electrical Noise*

As part of normal operation, your BALMAR marine alternator will make a slight whining noise while under load. This whining noise provides an indicator that the alternator is charging. In addition to a mechanical whine, you may experience a small amount of sticking or drag when the alternator is new. This is caused by the wood separators in the stator. With use, the separators will wear and the sticking will be eliminated.

By nature, electricity producing instruments like alternators will create electrical noise or interference that can be transmitted to radios, radars and other voltage-sensitive electronics. Your BALMAR alternator has been designed to minimize electrical interference. If interference persists, we recommend adding noise reduction filters to your system. One provider of quality noise reducing filters is Marine Tech, Inc., at (800)772-0796.

### *Pulleys and Belts*

Belts are not created equally, and in most instances you get what you pay for. Premium quality belts such as Gates' "Tri-Power" or green stripe, Dayco's "TopCog", or similar industrial-quality belts will provide a better value over lesser quality belts in both dependability and durability. If your battery banks or your load capacity are extremely large, or if your engine cannot accommodate the proper size belts to adequately drive a high-output alternator, a second alternator with an engine power takeoff (PTO) with dual dedicated belts or one of our DC Gensets or DC Genset/Watermaker combinations may provide an alternative solution for your charging needs.

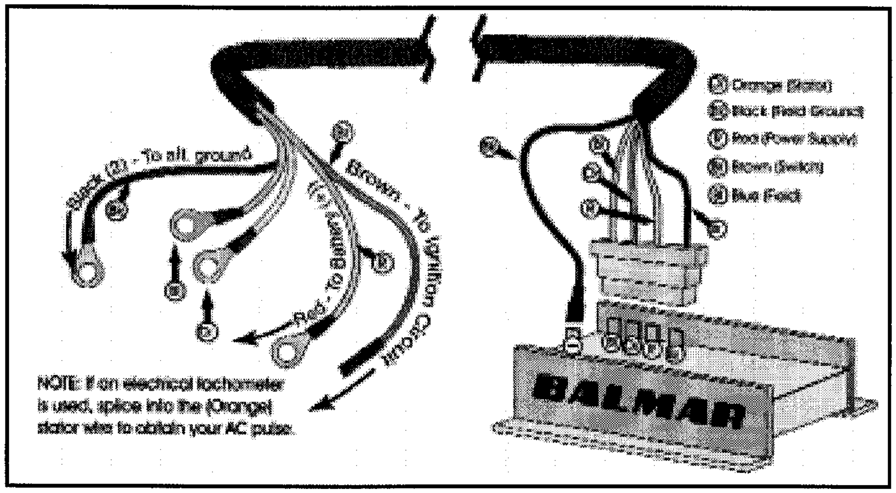
# IV. BASIC INSTALLATION

**CAUTION:** Alternator installation requires substantial mechanical and electrical understanding. If you are not experienced with alternator installations we strongly recommend you enlist the services of a qualified marine electrician. If you are unsure of your boat's batteries or wiring, have them inspected by a qualified electrician before proceeding with the alternator installation.

To install:

1. Disconnect the wiring from the existing alternator.
2. Loosen the mounting bolt and remove the existing alternator.
3. Once the alternator is disconnected from the engine, compare its mounting points to those on your new BALMAR alternator. In most applications, the new alternator will replace the old alternator with minimal shimming or similar modification. In some cases, a simple bracket can be fabricated by a local machine shop. BALMAR offers a universal mounting arm (UAA). Others can be obtained through your local auto or marine supply.
4. Attach the mounting foot of the new alternator to its engine mount. Some shimming may be required to ensure a solid fit. If your alternator is a dual foot style, use care when tightening the alternator in place that the two mounting ears are not compressed. The rear bushing is designed to support the mount.
5. Once in place, inspect to ensure that the alternator pulley is properly aligned with the engine pulley. If your belt configuration includes the pulley for the water pump, make sure that all three pulleys are properly aligned.
6. Connect the output cable(s), ground, field wire, stator (tach) wire if needed and other necessary wiring.
7. If a new regulator is being installed along with the alternator, complete its wiring installation according to its instructions.

After the alternator is installed and the wiring connections are attached, inspect the pulley for proper tension. When changing pulleys or when using the factory-installed pulley, torque the shaft nut to 50-60 foot-pounds. The shaft nut measures 15/16". To install the belt:




*Standard wiring harness configuration for 24-volt alternator/regulator installation. Wiring and connectors may vary based on alternator and/or regulator model. In applications requiring a pulse to drive an electric tachometer, splice into the stator wire and run splice to tach wire.*

When installation is complete, run the engine. Visually inspect the engine, while running, for evidence of poorly aligned pulleys and belts. Use caution to avoid hot or moving parts. Turn off the engine after approximately 15 minutes and re-inspect the belt tension as described above.

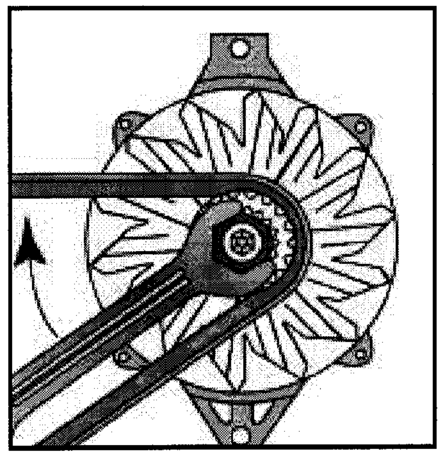


**Figure 9** - *Illustrates test for proper belt tension adjustment. Always use top-quality belts such as Gates Green Stripe or Tri-Power.*

## V. ADDITIONAL INSTALLATION INFORMATION

### *Battery Isolators*

Battery isolators may be used. Its capacity must equal the maximum alternator output. If isolators are used in conjunction with a dual-output alternator, both alternator outputs must have isolators installed to compensate for voltage loss. When sensing battery voltage with solators installed, sense wires must be connected on the battery side of the isolator. Sensing should be at the largest battery bank. If isolation is used for three battery banks, bridge a dual-output alternator and run a single positive output to a three-bank isolator.

### *Meters*

Most standard in-line Amp meters are UNDER-RATED for our alternators and, along with idiot lights, should be removed from the system. You may replace your existing amp meter with a standard volt meter. Should you wish to read output Amps, a high capacity 0-100 or 0-200 amp external shunt-type meter should be installed. Digital meters like the Link 10 or Link 20 by Heart Interface are excellent tools for charging system monitoring.

### *Output Connections*

The most efficient output connection is a direct wire between the alternator and the battery. DO NOT turn the battery switch off when the engine is running. Severe damage to the diodes and the regulator could result. If your battery switch is closer to the alternator than the batteries, you may connect the output cable to the common output terminal. On dual-output alternators, remove the bridge for isolated outputs and connect the cables directly to the batteries or the input terminals on the battery side of the battery switch.

### *Tachometers*

The alternator tachometer is energized by the pulse frequency generated by the alternator, which in turn is dependent on the alternator's rotor speed. Large case BALMAR alternators (94,95,96, series) have 12 poles and the small case (90/91/912 series) have 14 poles. Most standard tachometers are engineered for engines with alternator pulley to crankshaft ratios of 1.8 to 2.8 to 1 on alternators with 12 poles.

The WHITE wire or stator terminal may be used for electric tachometers not having their own sending unit. Tachometers will have to be adjusted and calibrated as necessary. We suggest running the engine up to a cruise RPM (2000), marking the throttle position BEFORE the original alternator is disconnected. After the installation is complete, run throttle up to mark and set the tachometer to its appropriate RPM. If you cannot set your existing tachometer, a programmable tach like the Teleflex Model 82430P should be considered as a replacement. Should bouncing of the tachometer be observed when the batteries are fully charged, turning on some DC loads or adding a 25-watt/25-ohm resistor between the field (blue) and ignition (brown) wires will often cure the problem.

### *Fusing*

BALMAR recommends that the alternator outputs be protected by a fuse or manual reset circuit breaker. If the alternator is connected directly to the battery, the breaker should be located at the battery terminal.

### *Wire Size*

Proper wire size is essential for safe and effective alternator operation. Refer to the wire chart (**Figure 2**) to determine the proper wire gauge for your installation. Contact the ABYC, BIA or your marine electrician for additional information.

| Length Amps | 10 Ft. | 15 Ft. | 20 Ft. | 25 Ft. | 50 Ft | 75 Ft. | 100 Ft. |
|---|---|---|---|---|---|---|---|
| 25 | 10 | 8 | 8 | 6 | 4 | 2 | 1 |
| 50 | 8 | 6 | 4 | 4 | 1 | 2/0 | 3/0 |
| 75 | 6 | 4 | 2 | 2 | 2/0 | 3/0 | 4/0 |
| 100 | 4 | 2 | 2 | 1 | 3/0 | 4/0 | |
| 125 | 4 | 2 | 1 | 1/0 | 3/0 | 4/0 | |
| 150 | 2 | 1 | 1/0 | 2/0 | 4/0 | | |
| 175 | 2 | 1/0 | 2/0 | 3/0 | | | |
| 200 | 2 | 1/0 | 2/0 | 3/0 | | | |
| 225 | 1 | 2/0 | 3/0 | 4/0 | | | |
| 250 | 1 | 2/0 | 3/0 | 4/0 | | | |
| 275 | 1/0 | 2/0 | 4/0 | | | | |
| 300 | 1/0 | 3/0 | 4/0 | | | | |
| 325 | 1/0 | 3/0 | 4/0 | | | | |
| 350 | 2/0 | 3/0 | | | | | |
| 375 | 2/0 | 4/0 | | | | | |

**Figure 2 -** *Wire size chart. Represents 3% voltage drop. Lengths should be measured in round trip.*

## VI. ROUTINE ALTERNATOR MAINTENANCE

Optimal alternator performance requires periodic inspection and maintenance. The following procedures should be included as part of regular engine room inspection.

### *Belts*

Belts should be inspected for proper tension after each hour of operation. A simple visual inspection while the engine is running will indicate excessive vibration or belt slap -- a good indication that belt tensioning is required.

A closer inspection of the belts at the beginning of each crew shift should be performed to ensure proper belt tension and identify any damage or wear. Frayed, worn, or damaged belts should be replaced immediately.

### *Wiring Connections*

Cable and wiring connections at the alternator should be inspected at the beginning of every crew shift. Wires and connections should be inspected for signs of rust or corrosion which could hinder current transfer. Connections should be clean and secure. Wiring should be clean and undamaged.

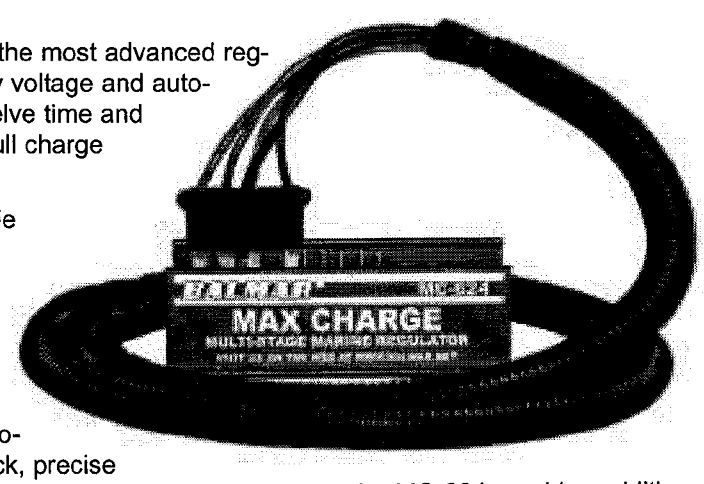
### *Mounting Connections*

Mounting and tensioning nuts and bolts must be securely tightened during operation. Inspect at beginning of crew shift to ensure proper tension/tightness.

### *Alternator Case*

Ensure that case is free of dirt, grime and accumulations of belt dust. Ensure that ventilation openings are clear of obstructions.

## VII. 24-VOLT REGULATOR




The microprocessor-controlled Max Charge MC-624 is the most advanced regulator available. Designed to continually monitor battery voltage and automatically optimize charging, the MC-624 uses up to twelve time and voltage increments to ensure your batteries receive a full charge quickly and safely.

The MC-624 lets you choose from a variety of selectable preset programs to best suit your charging needs. **Its Universal Factory Program allows you to connect the MC-624 to your alternator right out of the box.** Six additional preset programs support most popular battery types, including standard and deep-cycle flooded batteries, AGM, gel, and Optima (spiral wound) technologies. An easy-to-use magnetic reed switch delivers quick, precise regulator adjustment. Should your charging system require individualized adjustment, the MC-624 provides additional user-defined advanced program options.

When used with optional alternator and battery temperature sensors, the MC-624 automatically monitors ambient temperatures and compensates for over-temperature conditions by reducing field output. Alarm outputs connect to audible or visual alarms to warn of dangerous system conditions.

## To install the regulator:

1. Mount the regulator in a dry, well-ventilated location, well away from hoses and exhaust manifolds which may cause damage to the regulator or wiring. Avoid areas of heat and/or excessive vibration.

The Ford-style plug which connects the regulator to the alternator and on-board electrical system. See **Figure 3** at right for specific wire locations.

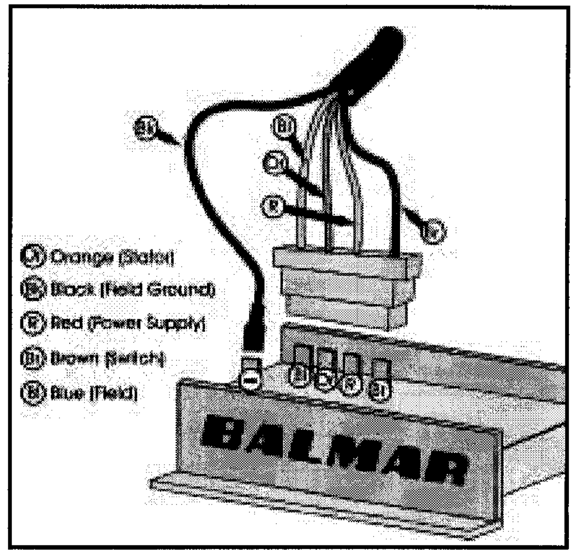



**Figure 3** - *Regulator wiring attachment.*

2. The **RED** wire (in the harness) powers the regulator, as well as sensing battery voltage. Attach at the positive output terminal at 1) the back of the alternator, 2) at the battery being charged (if used with a single-bank system or a combiner, or at 3) the common side of your battery switch. If an isolator is used, this wire must be located on the battery side of the isolator. On a 24V system, this wire can carry 8 amps and must be protected by a 10-amp fuse. A fuse is included with the wiring harness.
3. The **BROWN** (ignition) wire to a switched source of voltage. The auxiliary side of the ignition switch, or an independent (ungrounded) oil pressure switch are both acceptable connection points. A toggle switch may be added to this circuit to shut down the alternator load in cases where maximum propulsion is needed.
4. The **BLACK** (ground) wire attaches to the field ground terminal on the regulator, and to the preferred ground terminal on the alternator. A (user supplied) ground cable between the alternator and the preferred ground at the engine is also strongly recommended.

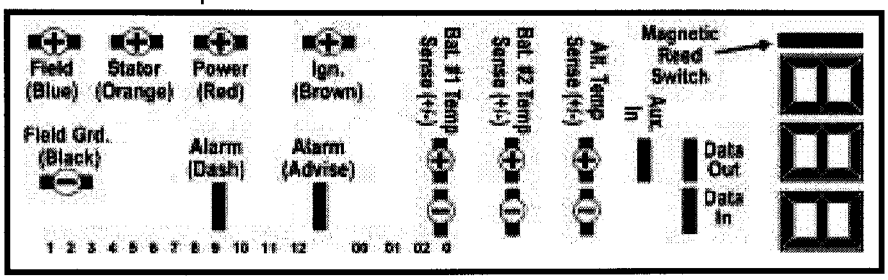



**Figure 4** - *Regulator terminal layout.*

5. Plug duplex plug with **BLUE** (field) and **ORANGE** (stator) wires into Field/Stator terminals at the alternator. The orange wire can be spliced into to provide an AC pulse to drive an electrical tachometer.

## VIII.ALARM AND SENSOR INSTALLATION

***Alternator Temperature Sensor (MC-TS-A) - Optional***

The Alternator Temperature Sensor enables the regulator to sense when the alternator temperature exceeds safe working limits. The MC-624 responds by reducing the field current to the alternator and activating the alarm output circuit. To install the Alternator Temperature Sensor:

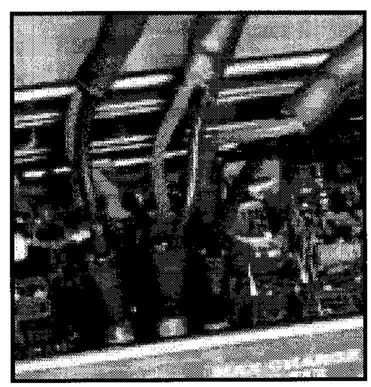


**Figure 4** - *Proper attachment of optional battery and alternator temp sensors at the regulator.*

1. Attach the positive and negative wires to the Alternator Temperature Sensor terminals on the MC-624 (See **Figure 4**). Observe proper polarity at the terminals.
2. Attach the heavy lug terminal to a location described below on your alternator. Flat washers are included with the temperature sensors to ensure solid mounting connections. The following are typical installation locations:

   **MID CASE MOUNT** - Large Case Alternator - Remove (1) of (4) 3/16" Allen bolts, install probe, re-secure bolt. See **Figure 5** on following page.

**Caution**: The alternator temperature sensor is not meant to be used as a method to maintain alternator temperature. Optional temperature sensors are not a guarantee of protection against damage from overheat conditions. Inspect your system as quickly as possible if the sensor alarm is activated. Have your system inspected if overheating occurs.

***Battery Temperature Sensor (MC-TS-B) - Optional***

When equipped with the optional Battery Temperature Sensor, the MC-624 will automatically compensate for variation above and below normal ambient temperatures, or shut down the field entirely if over-temp conditions are detected. The

MC-624 is equipped with dual battery sensors to enable sensing at two separate batteries. To ensure proper operation, be sure the battery terminals are completely clean and free of corrosion prior to installation. To install the Battery Temperature Sensor:

1. Secure the 3/8" copper probe to a clean negative (-) battery terminal (see **Figure 6**). The 20' leads may be shortened or extended, if needed. Note: An improperly installed or corroded battery terminal may generate heat and severely diminish charging and impede accurate temperature sensing.
2. While observing polarity, connect the battery temperature pins to the positive and negative terminals as shown on **Figure 4**.

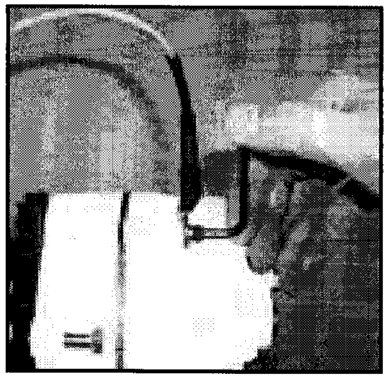


**Figure 5** - *Mounting temperature sensor mid-case on small case alternator.*


**Figure 6** - *Mounting temperature sensor on battery.*

**Note:** Battery #1 terminal is capable of temperature compensation and activating warning alarm. Battery #2 terminal activates the warning alarm only.

***Lamp / Alarm Outputs***

The MC-624 includes two output terminals, one for system alarms (dash lamp) and and another for advisory information (Aux. #1). These terminals output battery negative (0.5-amp max) when in alarm condition. Refer to **Figure 7** for common system conditions that may initiate an alarm. When in the alarm mode, the 3-digit numeric display will indicate the exact cause for the alarm. Specific advisory codes are shown in **Figure 17** on Page 6.

## Alarm Output Functions

**Alarm Output (Dash Lamp)**

*(-) 0.5 amp - when in alarm mode*
- **Low battery voltage (030)**
- **High battery voltage (040)**
- **High temperature at battery #1 (020)**
- **High temperature at battery #2 (021)**
- **High temperature at alternator (022)**

**Aux. #1 (Advisory) Output**

*(-) 0.5 amp - when in alarm mode*
- **Alt. output at full capacity**
- **Small engine option activated (051)**
- **Equalization mode activated**

**Figure 7** - *Alarm output functions.*

***Small Engine Mode***

The MC-624 can be modified for provide a half-power setting by installing a toggle switch between the positive and negative terminals of the alternator temperature sensor circuit. When activated by closing the switch, the regulator reduces the alternator output by approximately 50%. This mode is ideal for smaller engines that are not capable of providing suitable horsepower to drive both the alternator and propeller at full output. When in Small Engine Mode, the regulator will send a signal to the Auxiliary #1 Status Output.

## IX. SHORT DISPLAY

The Model MC-624 provides a wide range of operational, programming and diagnostic data through its 3-digit numeric LED readout. After an initial start-up period, the numeric LED will cycle through the **Short Display,** shown in **Figure 8** on the following page. The short display includes manufacturer, model, battery type, charging cycle, actual voltage and target voltage. This display cycles continuously during regulator operation.

**'ACTIVATE-RELEASE'** Refers to the activation and immediate deactivation of the switch by lowering a magnetic tool (such as a pocket screwdriver with a magnetic tip -- see **Figure 9 on following page**) onto the upper corner of the switch, and immediately deactivating the switch by removing the magnet from the switch. An LED dot, described in Figure 9 will indicate switch activation.

**'ACTIVATE-HOLD ... RELEASE'** Typically used during programming, this action requires holding the magnet to the switch until desired values are shown on the display. Once the desired setting is reached, the magnet is removed to deactivate the switch.

**Note: Program function will alternately cycle up or down each time the PrA Mode is activated. If you miss your desired program value, release the switch and re-activate, the cycling direction will automatically change. Any advanced programming values will be retained within the regulator's memory until the preset battery programming is reset.**

**SD Mode 1** - Manufacturer name. Readout displays "BAL".

**SD Mode 2** - Regulator model. Readout displays "624".

**SD Mode 3** - Battery type. Readout displays program currently in memory.

**SD Mode 4** - Battery type. Readout displays abbreviated battery type.

**SD Mode 5** - Charging stage. Shows current stage of charging cycle. See **Figure 12** on Page 5.

**SD Mode 6** - Battery voltage. Displays current battery voltage state.

**SD Mode 7** - Calculated voltage. Readout displays **voltage target** based on charging stage.

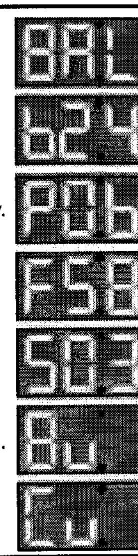


**Figure 8** - *Short display (SD).*

## X. PRESET BATTERY PROGRAMMING

In addition to its Universal (default) factory program, which can be used safely with most battery types, the MC-624 features programs for: gel, standard lead acid, deep-cycle lead acid, AGM (absorbed glass mat), Optima (spiral), as well as voltage-sensitive (halogen) applications.

The MC-624 is equipped with a magnetic reed switch, embedded in the epoxy potting, which activates the regulator's programming. The switch works in two specific actions, described in the shaded box below on the previous page:

To set the regulator for your desired battery program:

1. 'ACTIVATE-HOLD' the switch. The display will show the **"Pro"** mode, indicating that the Program mode has been activated.
2. 'HOLD' while the display scrolls, until the numeric equivalent to your battery type is displayed on the LED screen. See **Figure 10** to determine which selectable preset program is most desirable for your battery technology. **Figure 11** provides detailed information regarding preset programs.
3. 'RELEASE' when the desired value is attained.
4. Once a value has been chosen, the display will return to the **"Pro"** mode. At this point, you can adjust, up or down, by repeating Steps 1 through 3 until the numeric display reflects your desired preset program.

   If no changes are made, the program you have selected will be locked into permanent memory until modified. The **"SAV"** code will be displayed, indicating the program has been locked into memory.

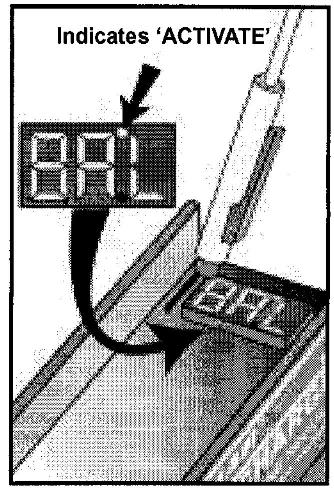



**Figure 9** - *Operation of magnetic reed switch.*

1 **Universal Factory Program (UFP)**. For multiple battery types. UFP

2 **Flooded Deep Cycle (Fdc)**. For deep-cell lead acid batteries. Fdc

3 **Sealed Gel Cell (GEL)**. For sealed gel batteries. GEL

4 **Absorbed Glass Mat (AGL)**. For AGM batteries. AGL

5 **Optima (OPS)**. For Optima spiral wound batteries. OPS

6 **Flooded Standard (FSB)**. For standard lead acid batteries. FSB

7 **Halogen (HAL)**. For voltage sensitive applications. HAL

**Figure 10** - *Selectable battery presets.*

| Primary Program Settings<br>Mode | PRG-1 Universal Factory Program | PRG-2 Deep Cycle Flooded Lead Acid | PRG-3 Gel Cell | PRG-4 Absorbed Glass Mat (AGM) | PRG-5 Optima Spiral Wound | PRG-6 Standard Flooded Lead Acid | PRG-7 Halogen Voltage Sensitive |
|---|---|---|---|---|---|---|---|
| Start Delay (Seconds) | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Ramp Up (Seconds) | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| Bulk Voltage (Max) | 28.40 | 29.20 | 28.20 | 28.76 | 29.20 | 28.80 | 28.00 |
| Bulk Time (Minimum) | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. |
| Absorption Voltage | 27.80 | 28.80 | 27.80 | 28.36 | 28.80 | 28.40 | 27.6 |
| Absorption Time (Minimum) | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. |
| Float Voltage | 27.00 | 26.70 | 27.40 | 26.76 | 26.80 | 26.80 | 27.00 |
| Float Time (Maximum) | 6 hr. | 6 hr. | 6 hr. | 6 hr. | 6 hr. | 6 hr. | 6 hr. |
| High Voltage Alarm | 30.40 | 31.20 | 30.20 | 30.76 | 31.20 | 30.80 | 30.00 |
| Low Voltage Alarm | 25.60 | 25.60 | 25.60 | 25.60 | 25.60 | 25.60 | 25.60 |
| Max Battery Temperature | 125F/52C | 125F/52C | 125F/52C | 125F/52C | 125F/52C | 125F/52C | 125F/52C |
| Max Alternator Temperature | 225F/107C | 225F/107C | 225F/107C | 225F/107C | 225F/107C | 225F/107C | 225F/107C |
| Equalization (User Prog.) | Yes | Yes | No | No | No | Yes | No |

**Figure 11** - *Preset program values. Voltages shown may vary by +/- 3% from values shown.*

# Advanced Programming and Diagnostics

## XI. ADDITIONAL DISPLAYS

### *Charging Stages*

The MC-624 uses up to 12 charging stages. Each stage contains a specific voltage or time value, or a combination of values. Stages are displayed in both Short and Long Display modes, and are described in **Figure 12**.

### *Long Display*

To access the Long Display, 'ACTIVATE-RELEASE' the reed switch while the Short Display is cycling. The numeric LED will immediately return to the **"BAL"** code and start cycling through the Long Display. See **Figure 13** for code definitions.

Once the Long Display has cycled through all of its information modes, the display will revert to the Short Display.

| | |
|---|---|
| **Stage 1** - Start Delay. Provides a 45-second delay before load is placed on engine and belts. Adjust time in PrA*. | **Stage 7** - Calculated Absorption. Time varies by state of charge at end of Stage 6. Adjust in PrA*. |
| **Stage 2** - Soft Ramp. One minute voltage ramp minimizes belt slippage. Non-adjustable. | **Stage 8** - Ramp Down. Transition from Absorption to Float stage. Non-adjustable. |
| **Stage 3** - Bulk. 30-minute set period. Program determines charging voltage. Time/voltage-adjustable in PrA*. | **Stage 9** - Float. 30-minute time period. Program sets charging voltage. Time/volts adjust in PrA*. |
| **Stage 4** - Calculated Bulk. Time varies by state of charge at end of Stage 3. Adjustable in PrA*. | **Stage 10** - Calculated Float. Time & voltage based on state of charge at end of Stage 9. Adjust in PrA*. |
| **Stage 5** - Ramp Down. Transition from Bulk to Absorption stage. Non-adjustable. | **Stage 11** - Ramp to Equalize. Batteries should be at full charge before initiating equalization. |
| **Stage 6** - Absorption. 30-min. set time. Preset program sets charging voltage. Time/voltage adjusts in PrA*. | **Stage 12** - Equalization. Time and Voltage adjustable in PrA*. See battery mfg. limits for time and voltage values. **User set.** |

PrA* - *Time and/or voltage adjustments can be made in the Advanced Program mode.*

**Figure 12** - *Charge stage codes as seen in Short and Long displays.*

| | |
|---|---|
| **LD Mode 1** - Readout displays **"BAL" (Short for Balmar.)** | **LD Mode 8** - Revision number. Displays software version. |
| **LD Mode 2** - Regulator model. Readout displays **"624"**. | **LD Mode 9** - Battery #1 temp. Followed by the sensor reading in degrees(Celsius). |
| **LD Mode 3** - Program level. **(P)** Shows program stored in memory. | **LD Mode 10** - Battery #2 temp. Followed by the sensor reading in degrees(Celsius). |
| **LD Mode 4** - Battery type. Readout displays abbreviated battery type.See **Figure 10** for descriptions. | **LD Mode 11** - Factory use only. |
| **LD Mode 5** - Charging stage Displays stage of charging cycle. See **Figure 13** for descriptions. | **LD Mode 12** - Factory use only. |
| **LD Mode 6** - Battery voltage. Shows current system voltage. | **LD Mode 13** - Run time. **"Hr "** code is followed by a numeric readout in 1/10-hr increments. |
| **LD Mode 7** - Calculated **(Target)** voltage based on program mode. | **LD Mode 14** - Advisory mode. See **Figure 17** for individual diagnostic/advisory codes. |

**Figure 13** - *Long Display (LD) attributes as displayed on digital numeric readout.*

## XII. ADVANCED PROGRAMMING

Advanced programming levels can be accessed in Long Display mode. To access:

1. With regulator in Long Display mode, ACTIVATE-HOLD until the **"Pro"** display code appears. RELEASE. The **"PrA"** display code will appear.

   **(CAUTION: If the switch is held too long, the regulator will return to the preset program adjustment mode).** Once in advanced program mode, the display will cycle through the individual advanced programming selections (see **Figure 14**). Changes to time and voltage values can be made in bulk, absorption and float modes.
2. When the desired advanced program mode is reached, ACTIVATE-HOLD. The display will scroll through the available time or voltage value selections. Time adjustments in the various stages are set in 1/10-hr. increments.
3. RELEASE when desired values are reached. Inversely, the values can be decreased, if desired. ACTIVATE-HOLD while values decrease. RELEASE when desired value is attained.
4. The PrA mode will cycle 3 times. Any changes made during those cycles will be saved.

| | |
|---|---|
| **PrA Mode 1** - Advanced program mode indicator. | **PrA Mode 8** - Float time control. **"Fc"** code is followed by time reading. Adjust up or down. |
| **PrA Mode 2** - Start delay **"DL"**. Adjusts seconds before ramp up. | **PrA Mode 9** - **Amp Manager** control. See details for Amp Manager on following page. |
| **PrA Mode 3** - Bulk voltage control. **"Bv"** code is followed by volt reading. Adjust up or down. | **PrA Mode 10** - **Equalization Voltage** control. See details for Equalization on following page. |
| **PrA Mode 4** - Bulk time control. **"Bc"** code is followed by time reading. Adjust up or down. | **PrA Mode 11** - **Equalization Time** control. See details for Equalization on following page. |
| **PrA Mode 5** - Absorption voltage control. **"Av"** code is followed by volt reading. Adjust up or down. | **PrA Mode 12** - **Alternator Constant**. Emulates tachometer. |
| **PrA Mode 6** - Absorption time control. **"Ac"** code is followed by time reading. Adjust up or down. | **PrA Mode 13** - **Compensation Limit**. Controls upper limits of voltage compensation when temp sensing at battery |
| **PrA Mode 7** - Float voltage control **"Fv"**. Followed by time reading. Adjust up or down. | |

**Figure 14** - *Advanced Programming (PrA) as displayed on digital numeric readout.*

### *Amp Manager (AP)*

Reduces the alternator output by controlling the voltage at the field wire. This feature can be used to minimize alternator overheating in warmer climates, as well as minimizing difficulties with chronic belt slippage. To adjust Amp Manager values:

1. 'ACTIVATE-RELEASE' when display cycles to **"AP"** (PrA Mode 09) See **Figure 15**. **"AP"** will be followed by **"OFF"** code.
2. 'ACTIVATE-HOLD' **"OFF"** display cycles to **"235"**. The value "235" represents full field output. The numeric value on the display will decrease until you RELEASE.

**Note:** Each scrolling value represents a 2% reduction or increase in field voltage.

### *Equalization Mode (EQ)*

Increases in charging voltage to minimize battery sulfation. **(ONLY suggested for batteries noted as "equalization friendly" in Figure 11 on Page 4).** Consult your battery manufacturer for time and voltage recommendations. Equalization must be initiated through the advanced programming. It is NOT a standard mode of operation. Once equalization **voltage** and **time** values are saved into the regulator's programming, the equalization process will start immediately. Once equalization has occurred, the regulator will revert to its preset program status.

**To adjust equalization voltage (PrA Mode 10):**

1. 'ACTIVATE-RELEASE' **"PrA"** display cycles to **"Ev"** followed by **"OFF"** code.
2. 'ACTIVATE-HOLD'. **"OFF"** display cycles to numeric voltage values. When the manufacturer-recommended voltage is reached, RELEASE.

**To adjust equalization time (PrA Mode 11):**

1. 'ACTIVATE-RELEASE' **"PrA".** Display cycles to **"Ec"** followed by **"OFF"** code.
2. 'ACTIVATE-HOLD'. **"OFF"** display cycles to numeric equalization time values. When the manufacturer-recommended time value is reached, 'RELEASE'.

### *Alternator Constant Mode* (ALC)

Emulates tachometer readings on regulator display. Must be activated in Advanced Programming. To determine proper calibration value, divide 384 by the number of poles in your alternator. (A 12-pole alternator has a calibration value of 32.)

**To enable ALC (PrA Mode 12):**

1. 'ACTIVATE-RELEASE' **"PrA"** display cycles to **"ALC"** followed by **"OFF"** code.
2. 'ACTIVATE-HOLD'. **"OFF"** display cycles to numeric calibration values. When the proper calibration value is reached, RELEASE.

### *Compensation Limit* (CL)

When equipped with optional Battery Temperature Sensor, the MC-624 will automatically adjust charging voltage to compensate for ambient battery temperature. In default mode, the regulator is limited to maximum compensated voltage of 29.6 volts (to minimize the likelihood of over-voltage shutdown by inverters and combiners). Compensation Limit allows the user to advance or decrease maximum compensated voltage to suit specific charging system needs.

**To enable CL (PrA Mode 13):**

1. 'ACTIVATE-RELEASE' **"PrA"** display cycles to **"CL"**.
2. 'ACTIVATE-HOLD'. **Default voltage value of 29.6** cycles to increasing voltage values. To decrease voltage values, RELEASE, wait for the voltage value to disappear. Re-activate and hold. When the proper voltage value is reached, RELEASE.

### *Explanatory / Advisory Codes*

Descriptions for these codes can be found in **Figure 17**. For additional technical information, see our Technical Support pages at the Balmar website (http://www.balmar.net). **To reset advisory/diagnostic codes, access the Advanced Programming mode as described at the beginning of Section VIII. Codes will automatically reset after the regulator scrolls through advanced programming (three cycles).**

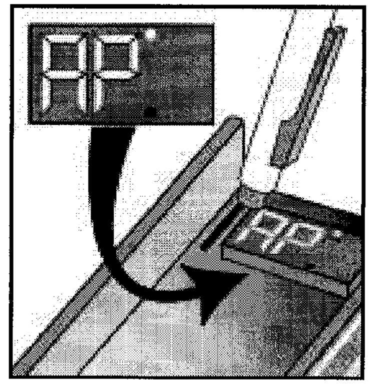


**Figure 15 -** *Indicates Amp Manager Mode.*

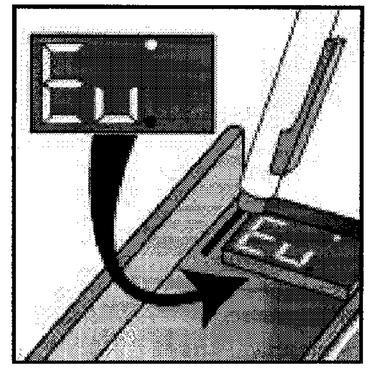


**Figure 16 -** *Equalization Voltage mode is activated.*

| | |
|---|---|
| CODE 001 - | Factory use only. |
| CODE 002 - | Factory use only. |
| CODE 010 - | Wire short at battery #1 temperature sensing terminal. |
| CODE 011 - | Sensor wire not found at battery #1 temperature sensing terminal. |
| CODE 012 - | Wire short at battery #2 temperature sensing terminal. |
| CODE 013 - | Sensor wire not found at battery #2 temperature sensing terminal. |
| CODE 014 - | Wire short at alternator temperature sensor terminal. |
| CODE 015 - | Sensor wire not found at alternator temperature sensor terminal. |
| CODE 020 - | Battery #1 exceeding recommended temperature limits. |
| CODE 021 - | Battery #2 exceeding recommended temperature limits. |
| CODE 022 - | Alternator exceeding recommended temperature limits. |
| CODE 024 - | Factory use only. |
| CODE 030 - | Voltage too low at battery. |
| CODE 031 - | Factory use only. |
| CODE 032 - | Factory use only. |
| CODE 040 - | Voltage too high at battery. |
| CODE 041 - | Factory use only. |
| CODE 042 - | Factory use only. |
| CODE 050 - | Open field. |
| CODE 051* - | Small Engine Mode activated. |
| CODE 052* - | Amp manager is in operation. |

*Underlined codes represent those pertaining to Alarm Output (dash lamp) operation.*

*Codes highlighted by an asterisk (*) pertain to Aux. #1 advisory output.*

**Figure 17 -** *Advisory/diagnostic codes.*

# XIII. Military Alternator and Regulator Troubleshooting

Determining the causes of failures in an electrical system is a "step by step" process. We recommend that you inspect and clean all system electrical connections before you begin your search to determine if the failure can be attributed to one of the two main components of your charging system: the alternator, and/or the voltage regulator.

## Most charging system problems will be corrected by performing the following steps.

1. Remove and clean all charging system electrical connections from the alternator through the batteries (this includes the ground side). Also, check the voltage regulator's harness for resistance. Wires and terminals can and will become corroded and need to be cleaned or replaced.
2. Charge all batteries to their proper fully charged state and determine if they are serviceable. If your batteries are flooded-type, use your hydrometer to determine their condition.
3. Check and tighten alternator belt. If the belt shows signs of wear or damage, now is an ideal time for replacement. Always replace existing belts with the finest quality replacements available.

After determining that your batteries and wiring are in suitable condition, use the following tests to determine if charging problems are a result of a faulty alternator or regulator. The following tests provide an opportunity to isolate the alternator, regulator and wiring harness in order to determine which component may be malfunctioning. In order to preform these tests, you will need an independent multimeter (preferably a digital type). In an emergency, a 24V light bulb can be used to help determine if power or working grounds exist. An amp meter and a battery hydrometer with a thermometer are also helpful diagnostic tools.

***Alternator /Regulator Field Tests***

**Test A** - The alternator and regulator can be tested for function by determining if a magnetic field exists at the alternator's pulley shaft or rear bearing. To test:

1. With the ignition in the OFF position, place the head of a steel screwdriver near the nut on the pulley shaft or near the rear bearing of the alternator. There should be no evidence of a magnetic field pulling the screwdriver toward the alternator.
2. Engage the ignition, without starting the engine, to activate the voltage regulator. If an oil pressure switch is used, a jumper across the switch will activate the regulator.
3. After allowing time for the regulator's start-up delay, place the head of a steel screwdriver near the nut on the pulley shaft or near the rear bearing of the alternator. There should be evidence of a magnetic field pulling the screwdriver toward the alternator. If a magnetic field is present, the voltage regulator, alternator brushes and rotor are likely to be working properly. If the system is not charging, remove the alternator and have it inspected by a qualified alternator shop.

**Test B** - If there is little or no magnetic pull at the pulley shaft or at the rear bearing, initiate the following test:

1. With the key off and the engine off, remove the large harness plug from the regulator.
2. Insert the end of a short length of electrical wire to the RED connector slot of the regulator harness and the other end of the wire to the BLUE connector slot. (See **Figure at right**.) This bypasses the regulator and tests the alternator and the harness.
3. Using your steel screwdriver, inspect for a magnetic field as described above.
4. With your voltmeter, check for voltage on the blue wire at the alternator. If voltage does not exist, the harness may be at fault. If voltage does exist at the harness, but charging is not occurring, the alternator is likely to be malfunctioning.

If a magnetic field is present. Both harness and alternator brushes and rotor appear to be working properly. If no magnetic field is present, proceed with the next test.

**Test C** - Testing the actual output of the alternator is known as "Full Field Testing". This can be accomplished by jumping a positive 24VDC current to the field terminal at the rear of the alternator. This test eliminates both the regulator and the harness, making it easier to isolate your investigation to the alternator. **CAUTION: Ensure that all voltage sensitive equipment is turned off prior to starting the engine. Voltage is unregulated during this test and could damage sensitive electronics. DO NOT let the engine run any longer than necessary to detect charging.**

To test the alternator:

1. Clip a jumper wire to the positive post of the alternator, or on the battery side of the isolator, if an isolator is in use. Use a SHIELDED alligator clip for post attachment. Unintentional contact between the alligator clip and the alternator case could result in damage to your electrical system.
2. Disconnect the field/stator plug from the rear of the alternator and attach the other end of the jumper wire to the alternator's Field terminal (F). Attach a female spade connector to the field end of the wire for a solid connection. **CAUTION:** Do not allow the wire to contact the case while it is attached to the positive post. The case is grounded and severe damage could occur.
3. The regulator is now bypassed. When the ignition is engaged and the motor is started, the voltage should rise and charging current should be present.
4. The motor should be run long enough to determine that charging voltage is present. Unregulated voltage can rise quickly. Do not allow extended unregulated charging to occur without carefully monitoring voltage levels.

If the alternator fails to generate voltage during field testing, a malfunction of the alternator is likely. Contact your local alternator repair shop or Balmar's technical service staff for recommendations.

***Voltage Regulator Test***

When you have inspected and repaired any wires and connections, inspected belts and replace as needed, and after you have determined that your batteries are properly charged, set your voltmeter to 24V and connect the voltmeter's negative lead to the BLACK ground wire at the regulator. Normally, connection is accomplished by inserting the negative lead alongside the ground wire in the regulator harness plug (see **Figure above**) and the positive lead alongside the wire referred to in each specific test. With the voltmeter securely connected to the regulator's ground, test for voltage at the points listed below.

1. With the ignition in the OFF position and your voltmeter's ground wire connected to the regulator's ground, check for voltage on the RED (sensing), BLUE (field) and BROWN (ignition) wires in the regulator plug by inserting the positive lead of the voltmeter alongside each wire in the regulator harness plug. The voltmeter should read:

| | Red Wire | Brown Wire | Blue Wire |
|---|---|---|---|
| **Expected Reading** | 24 V * | 0 V | 0 V |
| **Your Reading** | | | |

2. With the ignition in the ON position (engine not running) and your voltmeter's ground wire connected to the regulator's ground, check for voltage on the RED (sensing), BLUE (field) and BROWN (ignition) wires in the regulator plug. The voltmeter should read:

| | **Red Wire** | **Brown Wire** | **Blue Wire** |
|---|---|---|---|
| **Expected Reading** | **24 V*** | **24 V** | **<24 V** |
| **Your Reading** | | | |

3. With the ignition in the ON position (with engine running at 1,400 rpm fast idle) and your voltmeter's ground wire connected to the regulator's BLACK wire, check for voltage on the RED (sensing), BLUE (field) and BROWN (ignition) wires in the regulator plug. The voltmeter should read:

| | **Red Wire** | **Brown Wire** | **Blue Wire** |
|---|---|---|---|
| **Expected Reading** | **24 - 28V**** | **24 V** | **<25 V** |
| **Your Reading** | | | |

** 23-24.5 VDC battery voltage at rest (no charging occurring). If your batteries are isolated and your RED (sensing) wire shows voltages other than those shown above, make sure that the wire is connected on the "battery" side of the isolator. The RED wire must "see" the battery directly.*

*** 27 - 28 VDC battery voltage when charging.*

If your readings differ substantially from the "Expected Readings" listed in the charts above, the regulator may be malfunctioning, or there may be a continuity problem. Contact our technical support staff at (360) 435-6100. Keep your recorded readings in the spaces provided below the "Expected Readings" so you can share them with the technical support person. If your readings match those listed in the charts, your regulator should be working correctly. Continue with tests below to determine if your alternator may be the source of charging difficulties.If the preceding tests do not prove the existence of a failure within the regulator or alternator, we recommend you contact a licensed marine electrician who can test your system for wiring and circuit damage or other system failures that could be responsible for charging difficulties. If you determine that repair service is necessary for either your alternator or regulator, please gather the following information before contacting our service technicians.

1. Model of alternator.
2. Model of voltage regulator.
3. Voltage readings on red, brown and blue wire at regulator with engine off, key on.
4. Voltage readings on red, brown and blue wire at regulator with engine running at a fast ideal 1400 rpm.

# XIV. LIMITED PRODUCT WARRANTY

BALMAR warrants to the original consumer/purchaser the product is free from any defects in material or workmanship for a period of one year from the date of purchase. If any such defect is discovered within the warranty period, BALMAR will replace the regulator free of charge, subject to verification of the defect or malfunction upon delivery or shipping prepaid to BALMAR.

This warranty DOES NOT apply to defects or physical damage resulting from abuse, neglect, accident, improper repair, alteration, modification, or unreasonable use of the products resulting in breakdown, cracked or broken cases nor are parts damaged by fire, water, freezing, collision, theft, explosion, rust, corrosion or items damaged in shipment in route to BALMAR for repair. BALMAR assumes no responsibility for consequential damage or loss or expense arising from these products or any labor required for service or repair.

BALMAR WILL NOT repair or be held responsible for any product sent without proper identification and return address or RA number clearly marked on the package. You must include proof of date and place of purchase (photocopy of purchase invoice) or we cannot be responsible for repairs or replacement. In order to expedite warranty claims more efficiently, BALMAR asks that prior to returning a defective product for repair, you call their customer service department for a warranty return authorization number .

If factory service is required, you can contact our BALMAR Customer Service Department Monday through Thursday, 7:30 AM to 5:30 PM, (PST)1-360 435-6100 ext "3". Once contacted, Balmar will arrange for factory warranty repair. Based on alternator model, customer will be provided with a service order reference number and instructions for shipping to our factory service facilities. DO NOT return damaged or defective alternator to BALMAR before making arrangements with BALMAR's Customer Service Department.

Customer is responsible for all return transportation charges and any air or rush delivery expense. BALMAR reserves the right to determine whether to repair or replace defective components.

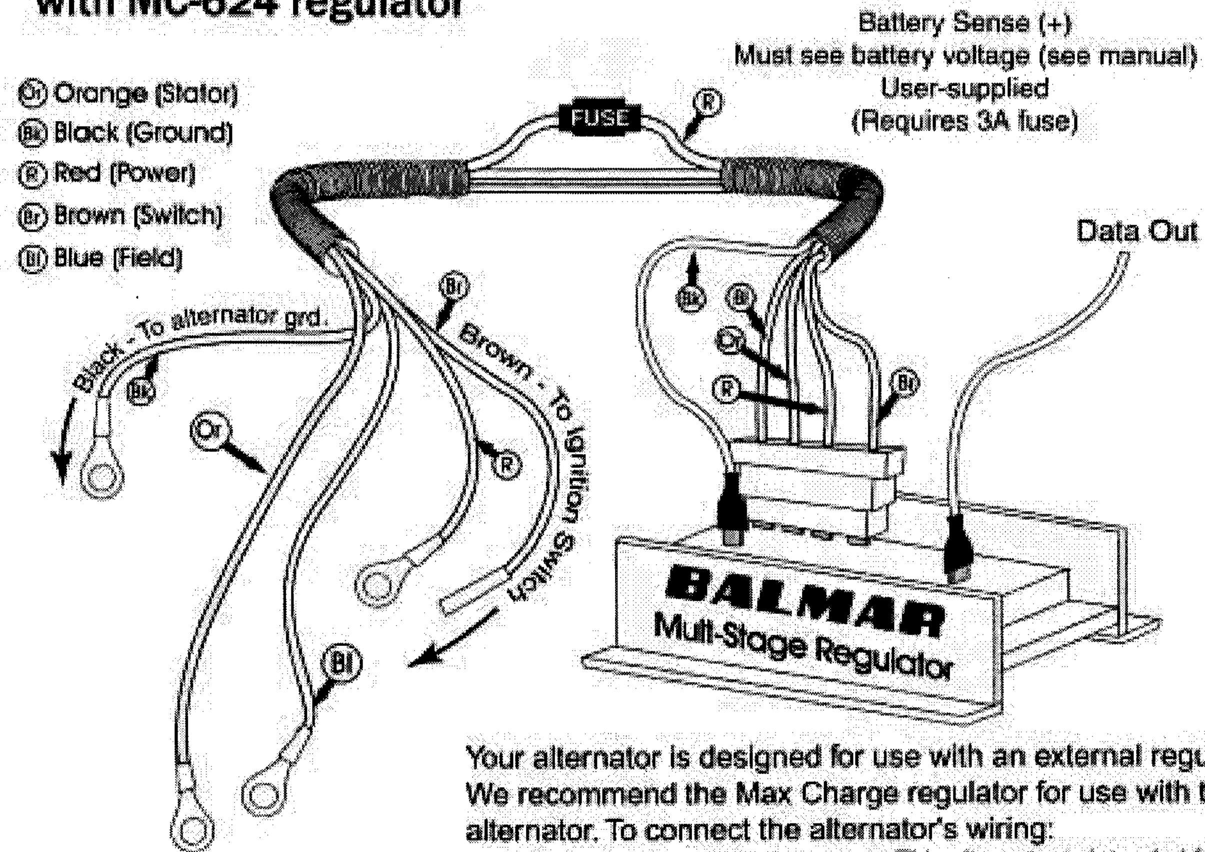
THE ABOVE LIMITATIONS MAY NOT APPLY TO YOU. SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS. NO PERSON, AGENT, DEALER IS AUTHORIZED TO GIVE ANY WARRANTY

**BALMAR 19009 61st Ave. NE, Arlington, WA 98223 Ph: (360) 435-6100, Fx; (360) 435-3210**

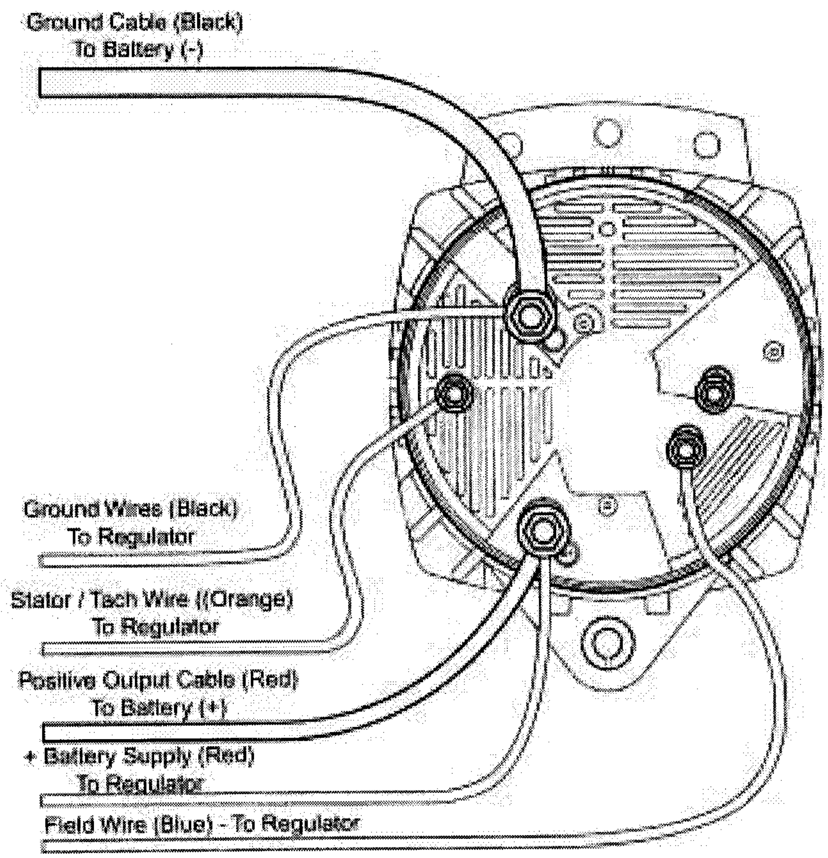
**E-mail: balmar@balmar.net, Web: www.balmar.net**

## Notes:

# 98-24-220 Alternator Wiring
## with MC-624 regulator



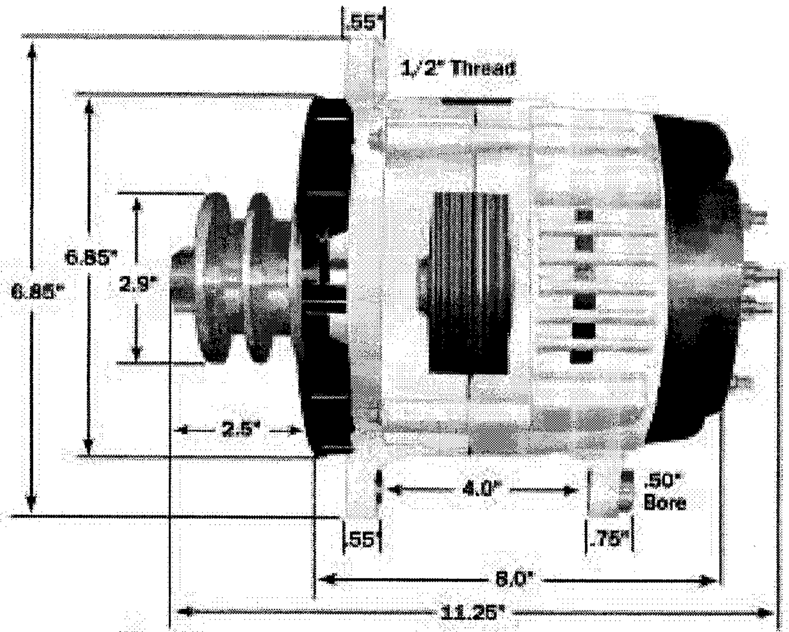

Your alternator is designed for use with an external regulator. We recommend the Max Charge regulator for use with this alternator. To connect the alternator's wiring:

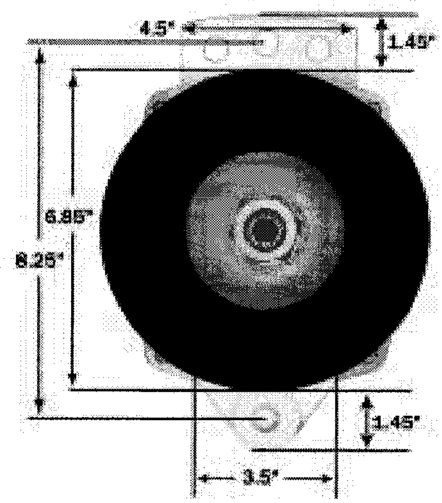


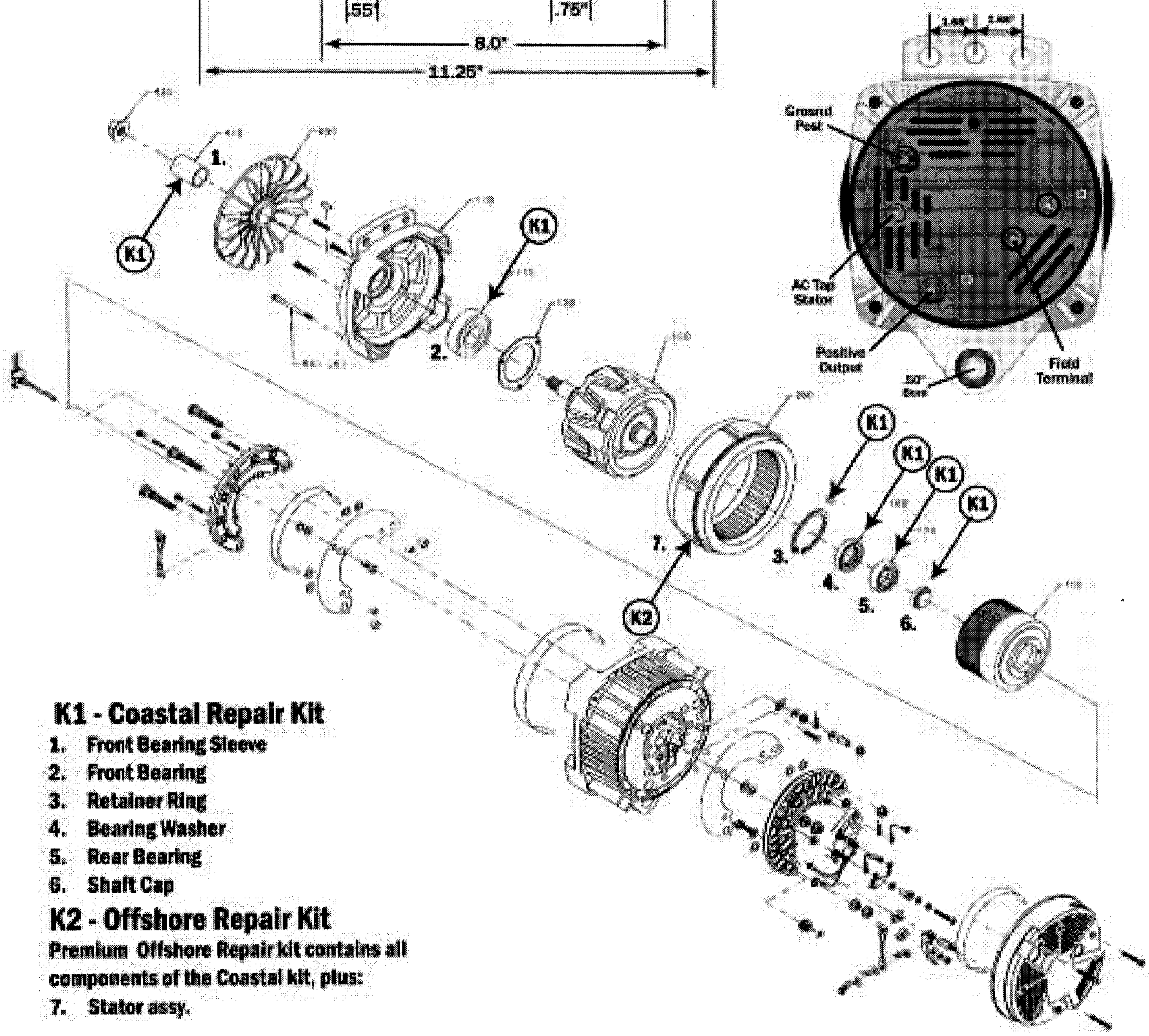

CAUTION: This alternator is intended for installation by a professional marine electrician. If you are not experienced with marine charging systems, we strongly recommend using a qualified marine electrician to install this alternator. The addition of fuses or circuit breakers may be required as part of this installation. Consult with ABYC regulations regarding charging system fusing.

1. Disconnect the ground cable from your battery. Turn the battery switch to its OFF position.
2. Attach the wires from your regulator harness as shown above and to left.
3. Attach the positive and negative output cables to the terminals shown below.
4. Attach battery end of positive cable to positive battery terminal or other appropriate (+) connection.
5. Attach battery end of negative cable to negative battery terminal or other appropriate (-) connection.

# Alternator Dimensions and Exploded Views




## K1 - Coastal Repair Kit

1. Front Bearing Sleeve
2. Front Bearing
3. Retainer Ring
4. Bearing Washer
5. Rear Bearing
6. Shaft Cap

## K2 - Offshore Repair Kit

Premium Offshore Repair kit contains all components of the Coastal kit, plus:

7. Stator assy.

UNIT LEVEL MAINTENANCE
WARPING TUG
POWERED SECTION DIESEL ENGINE ALTERNATOR BELTS
REPLACEMENT

**INITIAL SETUP:**

**Tools**
Tool Kit, General Mechanics (Rail and Marine) (TM 55-1945-225-24, Item 1 WP 0424 00)

**Materials/Parts**
Gloves, Men's and Women's (leather Palm) (55-1945-225-24, Item 10, WP 0425 00)

**Personnel Required**
Engineer 88L

**References**
TM55-1945-225-24

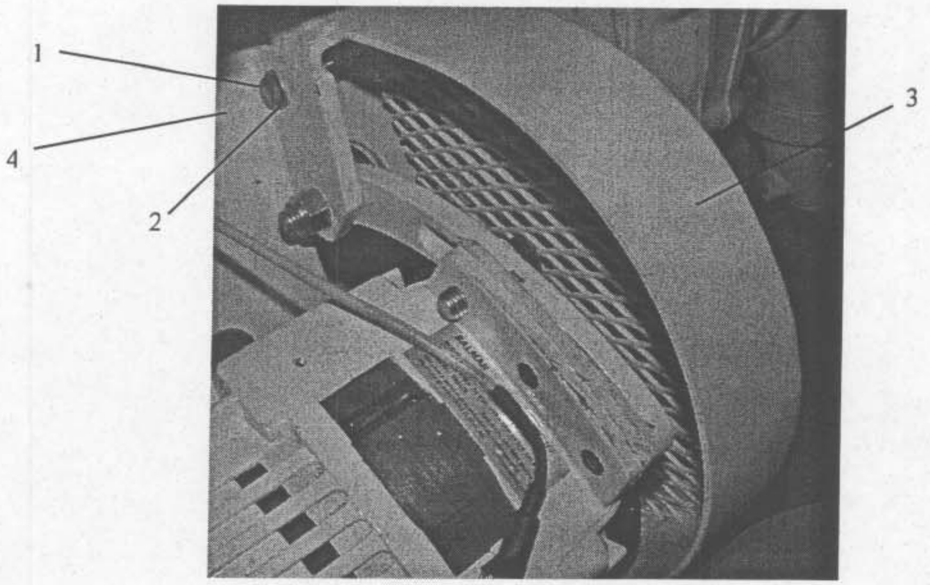
**Equipment Condition**
Engine Cooled Down
Engine Power Isolated (WP 0075 00)

REPLACE ALTERNATOR BELTS

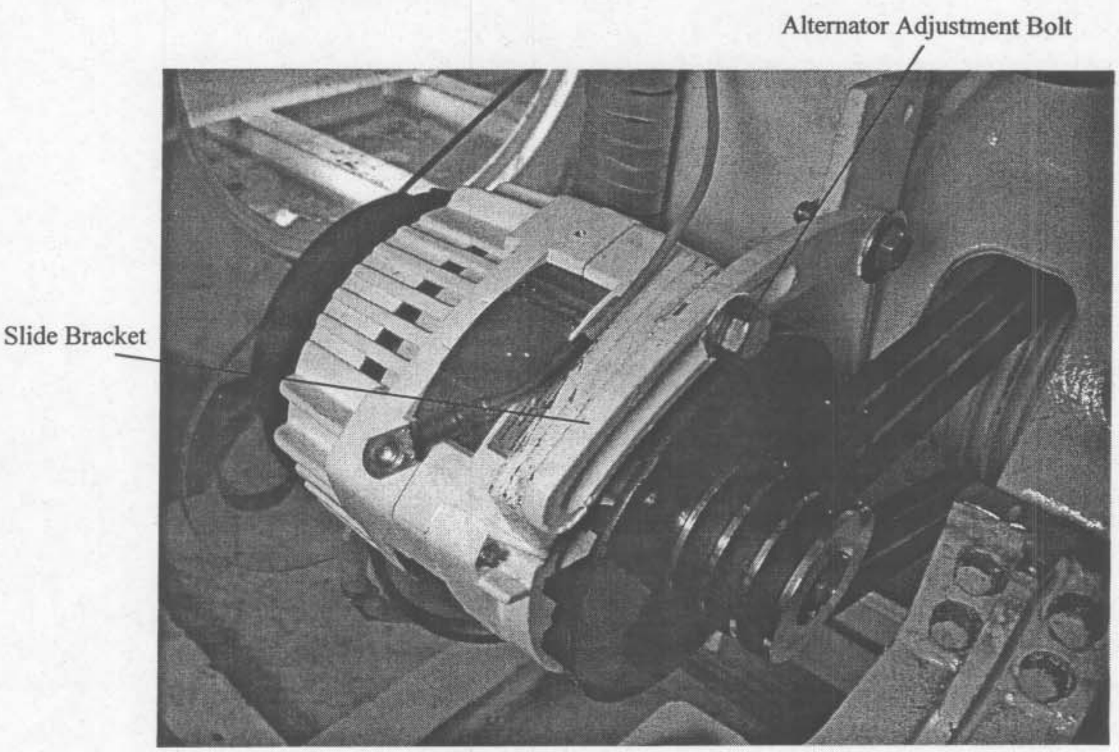
1. Remove alternator belt guard.

   a. Remove top and bottom bolt (1) and washer (2) holding alternator belt guard (3) to housing (4) covering the engine crankshaft pulley.

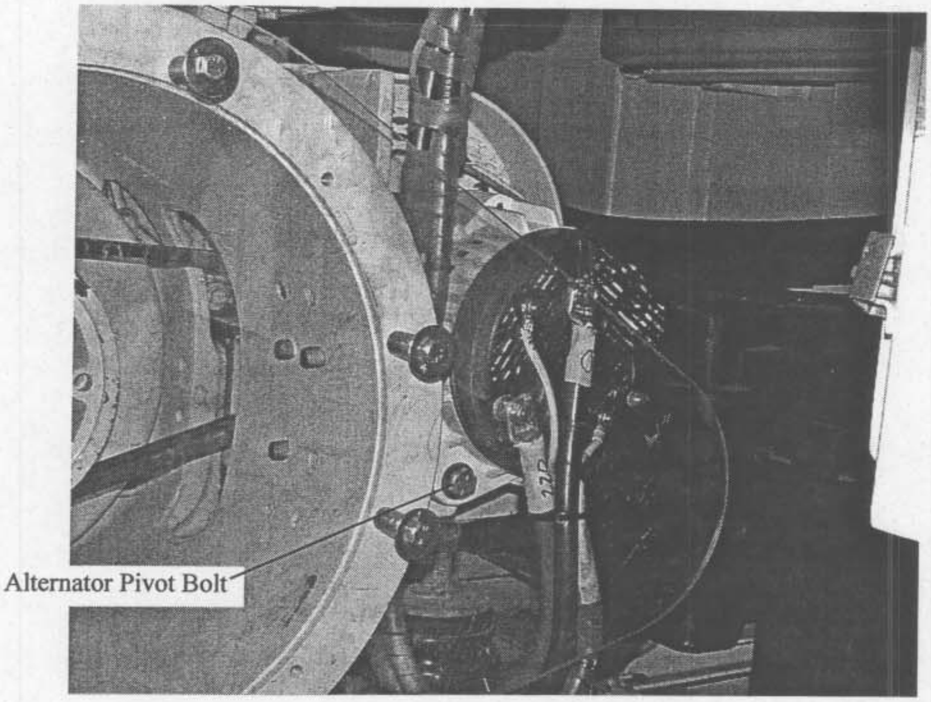
   b. Remove alternator belt guard (3) from housing (4).



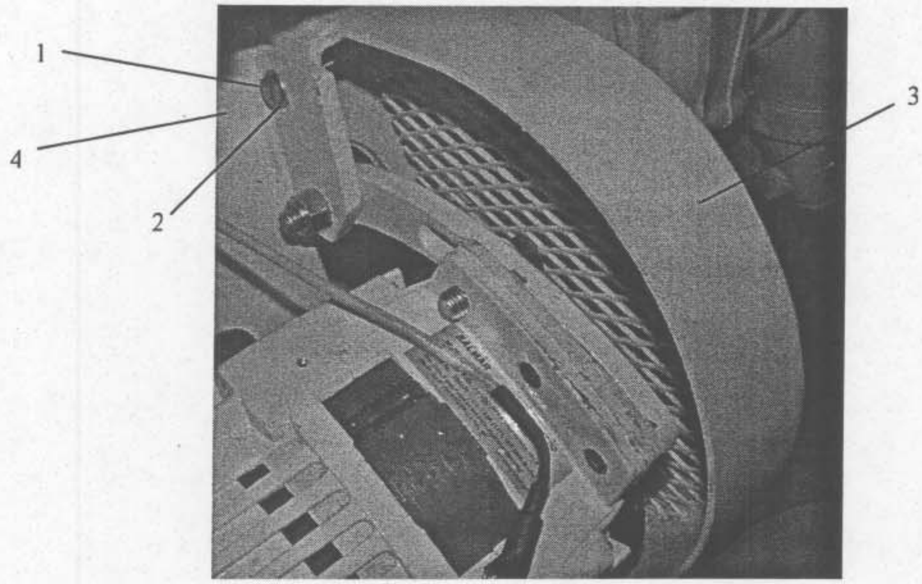

2. Loosen alternator adjustment bolt.




3. Loosen alternator pivot bolt.




4. Rotate alternator inward along the slide bracket, loosening the tension on the belts.
5. Remove belts.
6. Install new belts.
7. Adjust belt tension (Pg. 30-19).
8. Install alternator belt guard.
    a. Place alternator guard (3) on housing (4).
    b. Install top and bottom bolt (1) and washer (2) to alternator belt guard (3) and housing (4).


1
2
3
4

# UNIT LEVEL MAINTENANCE
# WARPING TUG
# POWERED SECTION DIESEL ENGINE ALTERNATOR BELTS
# TENSION INSPECTION AND ADJUSTMENT

**INITIAL SETUP**:

**Tools**

Tool Kit, General Mechanics (Rail and Marine) (TM 55-1945-225-24, Item 1 WP 0424 00)
Tester, Tension (Gates Part Number 7401-0076)

**Materials/Parts**

Gloves, Men's and Women's (leather Palm) (55-1945-225-24, Item 10, WP 0425 00)

**Personnel Required**

Engineer 88L

**References**

TM55-1945-225-24

**Equipment Condition**

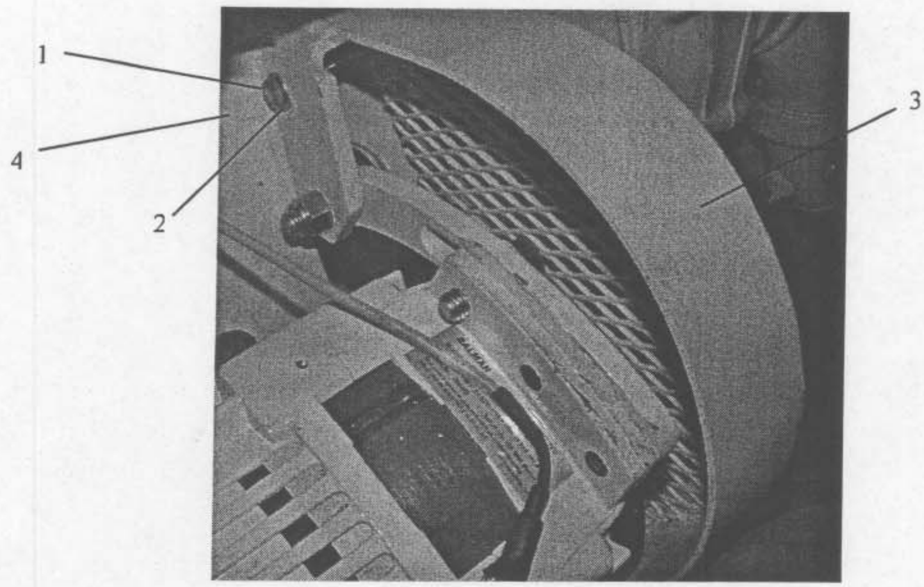
Engine Cooled Down
Engine Power Isolated (WP 0075 00)

## INSPECT ALTERNATOR BELT TENSION

1. Remove alternator belt guard.

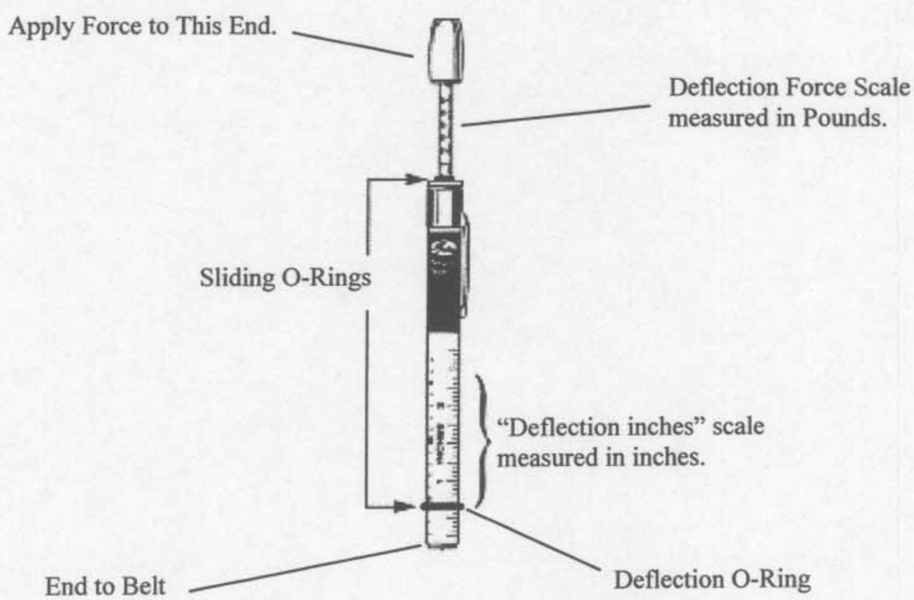
   a. Remove top and bottom bolt (1) and washer (2) holding alternator belt guard (3) to housing (4) covering the engine crankshaft pulley.

   b. Remove alternator belt guard (3) from housing (4).

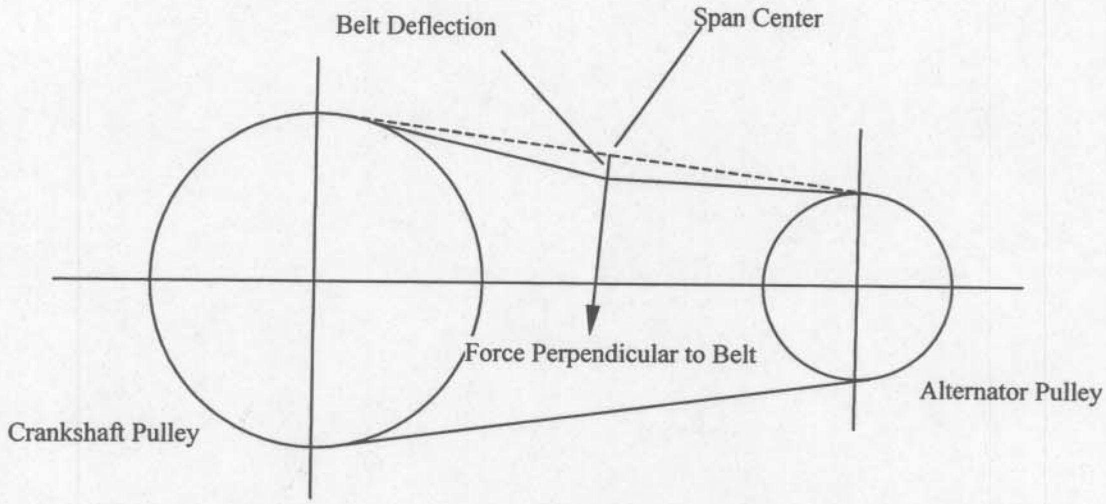



2. Deflect belt.

    a. On the tension tester scale reading “Deflection inches”, set the Deflection O-Ring to show a deflection of ¼ in.




Gates’ Tension Tester




b. Place the end of the Tension Tester's "Deflection inches" scale in the middle of one of the three belts at the center of the span between the engine crankshaft pulley and the alternator pulley.

c. Ensure the Tension Tester is perpendicular to the belt.

d. Apply a force at the top of the Tension Tester sufficient to deflect the belt until the bottom edge of the O-Ring on the "Deflection inches" scale is even with the tops of the remaining belts.

3. Observe force.

a. To find the amount of force that was required to deflect the belt ¼ in., refer to the upper Deflection Force scale of the tension tester. As the tool compresses, the sliding O-Ring slides up the tool and remains in its final position for accurate reading of pounds force. Read the value at the bottom edge of the ring.

b. The deflection force required to deflect the belt should be five pounds for newly installed belts that have not yet been used to drive the alternator, and between four and five pounds for belts that have seen use. If the force is less than five pounds for new belts or less than four pounds for used belts, the belt needs to be tightened. If the force is more than five pounds for new or used belts the belt needs to be loosened.

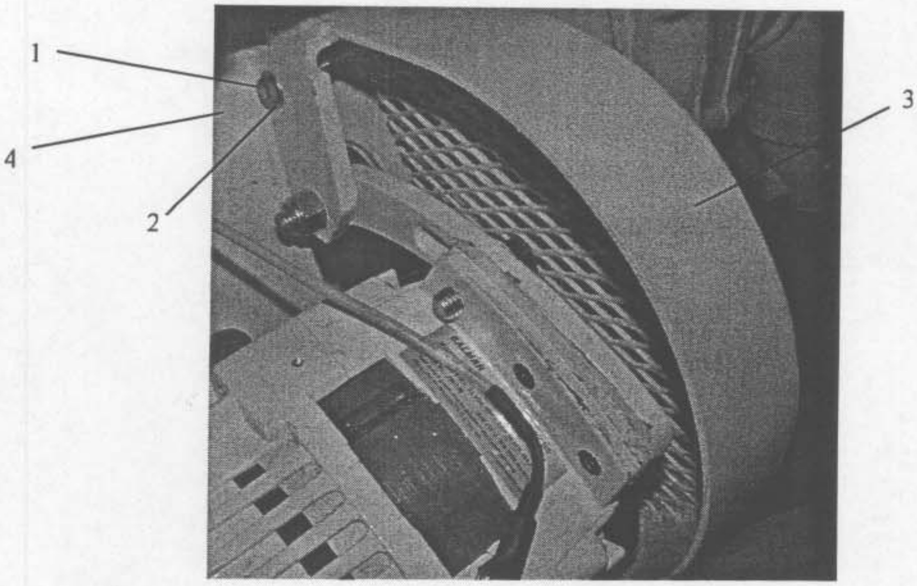
4. Make adjustment to belt tension if required and repeat steps 2 and 3.

5. Repeat steps 2 and 3 for each of the other two belts. The deflection force should be nearly identical for each belt. If one belt needs tightening while the other two do not, it should be replaced.

6. Install alternator belt guard.

a. Place alternator guard (3) on housing (4).

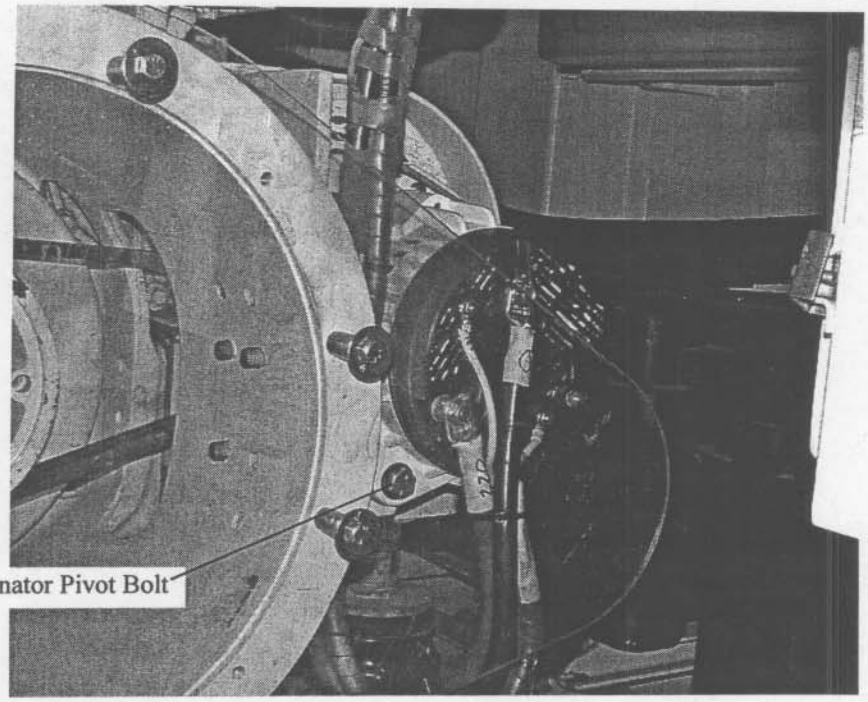
b. Install top and bottom bolt (1) and washer (2) to alternator belt guard (3) and housing (4).




ADJUST ALTERNATOR BELT TENSION

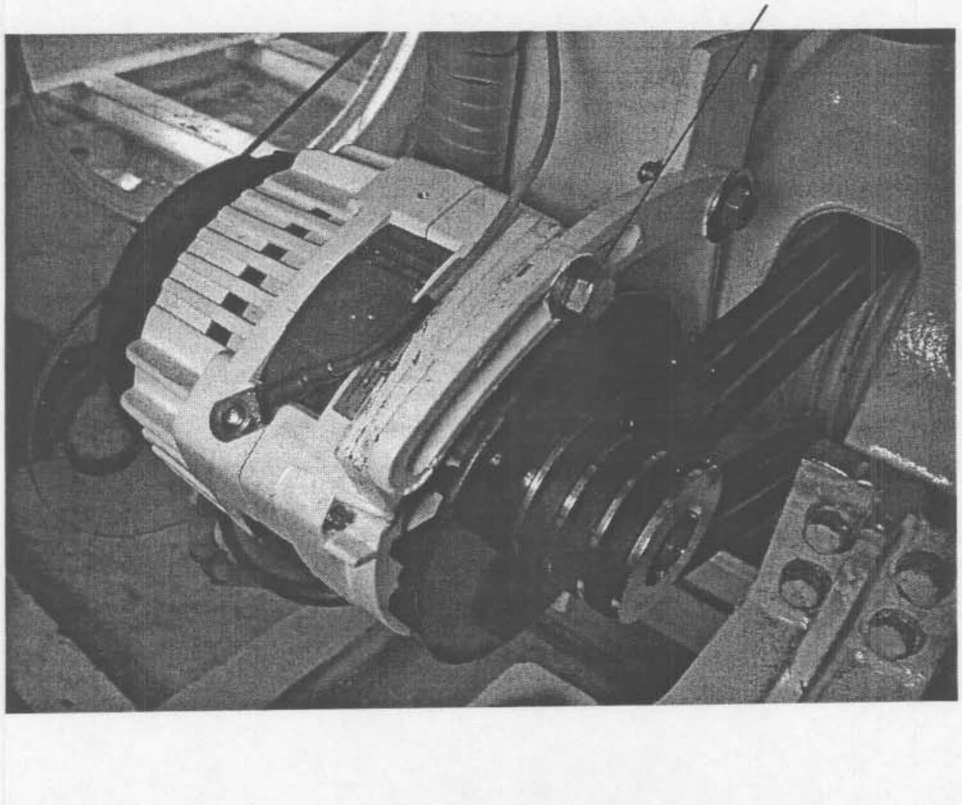
1. Remove alternator belt guard (see previous step).

2. Loosen the alternator pivot bolt.




3. Loosen the alternator adjustment bolt.

Alternator Adjustment Bolt



4. Using a bar, pry between the alternator and the crankshaft pulley housing, increasing or decreasing tension as necessary.

5. Retighten the alternator adjustment bolt first, then the alternator pivot bolt.

6. Re-inspect the alternator belt tension.

7. Repeat the alternator belt tension adjustment procedure as required until the correct deflection force of 5 pounds is observed for each of the three belts.

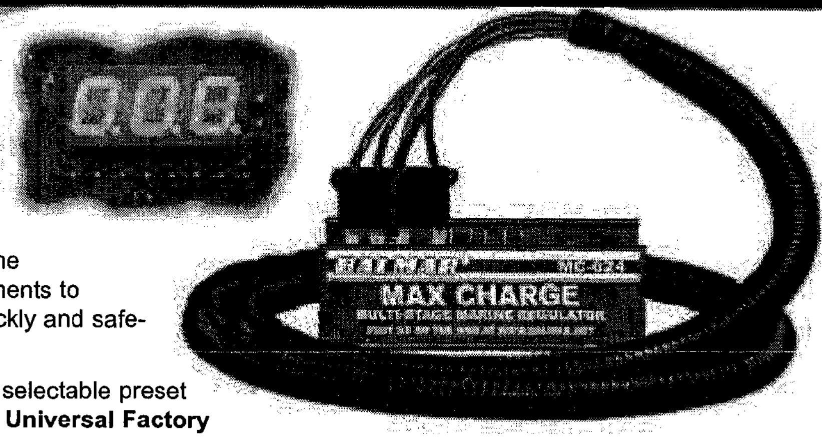
8. Reinstall alternator belt guard (pg. 30-17).

# SECTION 31

# INSTALLATION AND OPERATORS MANUAL
# FOR
# BALMAR MAX CHARGE MC-624

# Max Charge MC-624
# Installation and Operator's Manual

## I. INTRODUCTION




The microprocessor-controlled Max Charge MC-624 is the most advanced regulator available. Designed to continually monitor battery voltage and automatically optimize charging, the MC-624 uses up to 12 time and voltage increments to ensure your batteries receive a full charge quickly and safely.

The MC-624 lets you choose from a variety of selectable preset programs to best suit your charging needs. **Its Universal Factory Program allows you to connect the MC-624 to your alternator right out of the box.** Six additional preset programs support most popular battery types, including standard and deep-cycle flooded batteries, AGM, gel, and Optima (spiral wound) technologies. An easy-to-use magnetic reed switch delivers quick, precise regulator adjustment. Should your charging system require individualized adjustment, the MC-624 provides additional user-defined programming options.

When used with optional alternator and battery temperature sensors, the MC-624 automatically monitors ambient temperatures and compensates for over-temperature conditions by reducing field output. Alarm outputs connect to audible or visual alarms to warn of dangerous system conditions.

## II. SAFETY CONSIDERATIONS

Before installing your MC-624 marine regulator, please take a moment to consider these guidelines for safe regulator installation. Failure to work safely could result in personal injury or damage to your electrical system.

1. Always disconnect your battery banks and ensure that switches are "OFF" prior to installing your regulator.
2. Remove loose-fitting clothing or jewelry, which could become entangled in your motor or other machinery.
3. Wear ANSI-approved safety glasses.
4. DO NOT attempt to modify the regulator. Alterations could result in damage to your charging system, and will void your warranty.
5. Do not attempt installation if tired or fatigued.
6. Ensure the engine has cooled before initiating installation.
7. Do not attempt installation while using alcohol or any medication that could impair your judgment or reaction time.
8. Always use the right tool for the job. Improper tool use may damage the regulator or your boat, and could result in personal injury.
9. Take time to read the manual. Equipment damage and possible injuries may result from an incomplete understanding of the installation and operation of the MC-624 regulator. If you are unfamiliar with marine electrical systems, consult with a licensed marine electrician.

### CAUTION

***The following instructions are intended for use by experienced marine electrical installers. If you are not experienced at installing electrical system components, we recommend the use of a qualified marine electrical technician.***

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## III. BASIC INSTALLATION

The MC-624 is shipped with either a Port or Starboard harness. If the wiring needs to be extended beyond the length of the harness, marine grade 12AWG (American Wire Gauge) wire should be used.

To install the regulator:

1. Mount the regulator in a dry, well-ventilated location, well away from hoses and exhaust manifolds which may cause damage to the regulator or wiring. Avoid areas of heat and/or high vibration.
2. Attach the Ford-type harness plug to the regulator (see **Figure 1**).
3. The **RED** wire (in the harness) powers the regulator. Attach at the positive output terminal at the alternator. If an isolator is used, this wire must be located on the battery side of the isolator. On a 24V system, this wire can carry 8 amps and must be protected by a 10-amp fuse. A fuse is included with the wiring harness.
3. The **BROWN** (ignition) wire activates the regulator when +24VDC is applied to the system. Attach the BROWN wire to a switched +24VDC source. The auxiliary side of the ignition switch, or an independent (ungrounded) oil pressure switch are both acceptable connection points. A toggle switch may be added to this circuit to shut down the alternator load in cases where maximum propulsion is needed.
5. The **BLACK** (ground) wire in the harness attaches to the System Ground Terminal. The BLACK wire attaches to preferred ground terminal on the alternator. A (user supplied) ground strap between the alternator and the preferred ground at the engine is also strongly recommended.
6. Plug duplex connector with **BLUE** (field) and **ORANGE** (stator) wires into rear of alternator.
7. An AC tap wire for the tachometer can be utilized by splicing into the ORANGE stator wire with a wire connecting to the AC tap terminal at the tachometer.

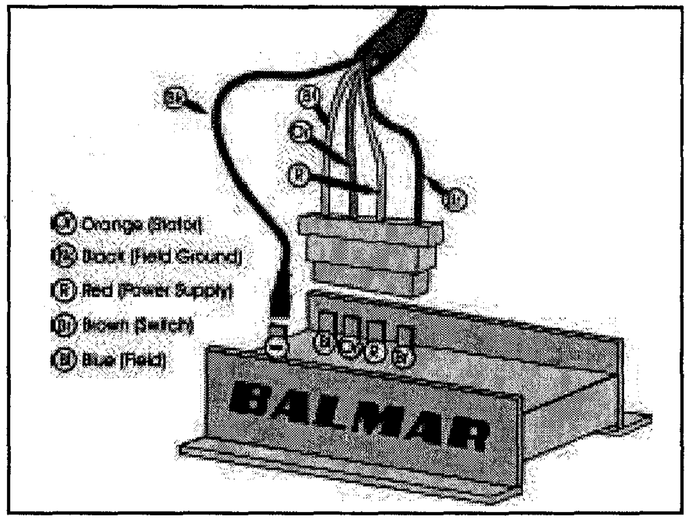


**Figure 1** - *Regulator wiring attachment.*

| Length Amps | 10 Ft. | 15 Ft. | 20 Ft. | 25 Ft. | 50 Ft | 75 Ft. | 100 Ft. |
|---|---|---|---|---|---|---|---|
| 25 | 10 | 8 | 8 | 6 | 4 | 2 | 1 |
| 50 | 8 | 6 | 4 | 4 | 1 | 2/0 | 3/0 |
| 75 | 6 | 4 | 2 | 2 | 2/0 | 3/0 | 4/0 |
| 100 | 4 | 2 | 2 | 1 | 3/0 | 4/0 | |
| 125 | 4 | 2 | 1 | 1/0 | 3/0 | 4/0 | |
| 150 | 2 | 1 | 1/0 | 2/0 | 4/0 | | |
| 175 | 2 | 1/0 | 2/0 | 3/0 | | | |
| 200 | 2 | 1/0 | 2/0 | 3/0 | | | |
| 225 | 1 | 2/0 | 3/0 | 4/0 | | | |
| 250 | 1 | 2/0 | 3/0 | 4/0 | | | |
| 275 | 1/0 | 2/0 | 4/0 | | | | |
| 300 | 1/0 | 3/0 | 4/0 | | | | |
| 325 | 1/0 | 3/0 | 4/0 | | | | |
| 350 | 2/0 | 3/0 | | | | | |
| 375 | 2/0 | 4/0 | | | | | |

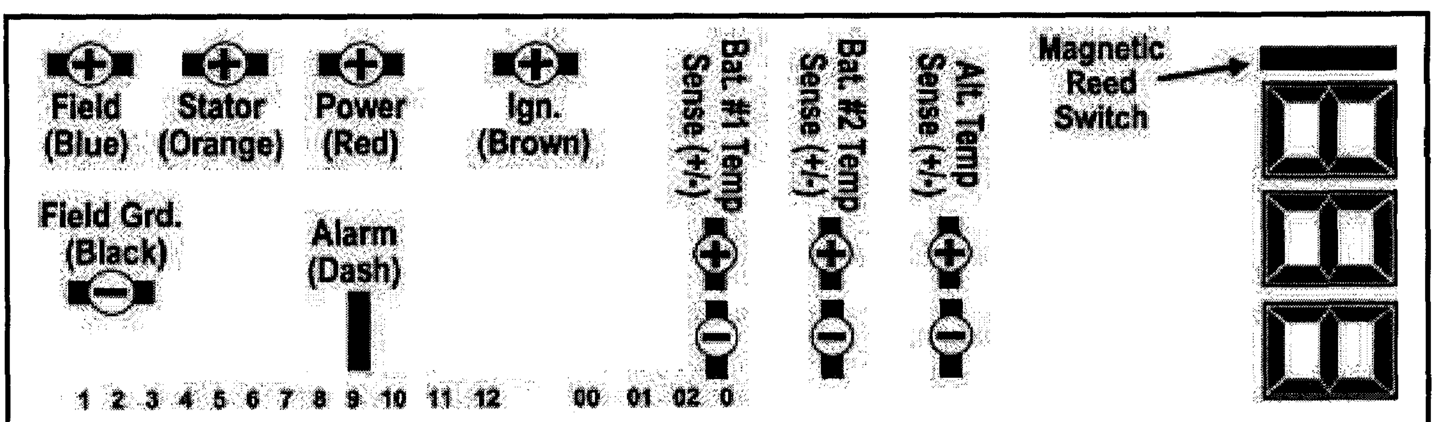


**Figure 3** - *Regulator terminal layout and function description.*

## IV. ALARM AND SENSOR INSTALLATION

### *Alternator Temperature Sensor (MC-TS-A) - Optional*

The Alternator Temperature Sensor enables the regulator to sense when the alternator temperature exceeds safe working limits. The MC-624 responds by reducing the field current at the alternator and activating the alarm output. To install the Alternator Temperature Sensor:

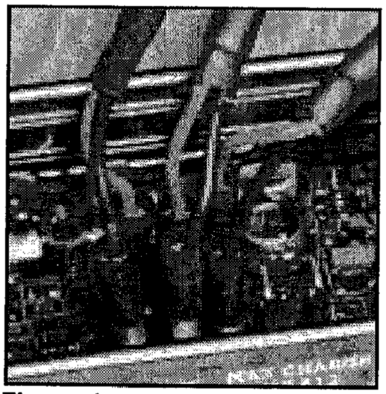


**Figure 4** - *Proper attachment of optional battery and alternator temp sensors at the regulator.*

1. Attach the positive and negative wires to the Alternator Temperature Sensor terminals on the MC-624 (See **Figure 4**). See **Figure 3** on previous page for pin locations. Observe proper polarity at the terminals.
2. Attach the heavy lug terminal to a location described below on your alternator. Flat washers are included with the temperature sensors to ensure solid mounting connections. The following are typical installation locations:

   **MID CASE MOUNT** - Small Case Alternator - Remove (1) of (4) 5/32" Allen bolts, install probe, re-secure bolt. (See **Figure 5**.)

   **MID CASE MOUNT** - Large Case Alternator - Remove (1) of (4) 3/16" Allen bolts, install probe, re-secure bolt.

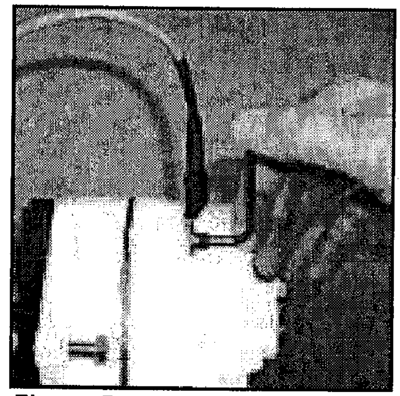


**Figure 5** - *Mounting temperature sensor mid-case on small case alternator.*

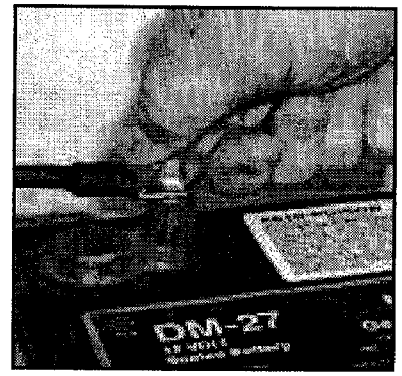



**Figure 6** - *Mounting temperature sensor on battery.*

**Caution:** The alternator temperature sensor is not meant to be used as a method to maintain alternator temperature. Optional temperature sensors are not a guarantee of protection against damage from overheat conditions. Inspect your system as quickly as possible if the sensor alarm is activated. Have your system inspected if overheating occurs.

### *Battery Temperature Sensor (MC-TS-B) - Optional*

When equipped with the optional Battery Temperature Sensor, the MC-624 will automatically compensate for variation above and below normal ambient temperatures. The MC-624 is equipped with dual battery sensors to enable sensing at two separate batteries. To ensure proper operation, be sure the battery terminals are completely clean and free of corrosion prior to installation. To install:

1. Secure the 3/8" copper probe to a clean negative (-) battery terminal (see **Figure 6**). The 20' leads may be shortened or extended, if needed. Note: An improperly installed or corroded battery terminal may generate heat and severely diminish charging and impede accurate temperature sensing.
2. While observing polarity, connect the battery temperature pins to the positive and negative terminals as shown on **Figure 4**.

**Alarm Output Functions**

**Alarm Output (Dash Lamp)**

*(-) 0.5 amp - when in alarm mode*

- **Low battery voltage (030)**
- **High battery voltage (040)**
- **High temperature at battery #1 (020)**
- **High temperature at battery #2 (021)**
- **High temperature at alternator (022)**

**Figure 7** - *Alarm output functions.*

**Note:** Battery #1 terminal temperature compensates andactivates alarm. Battery #2 terminal activates the warning alarm only.

### *Lamp / Alarm Outputs*

The MC-624 includes an output terminal for system alarms (dash lamp). This terminal outputs battery negative (0.5-amp max) when in alarm condition. Refer to **Figure 7** for common system conditions that may initiate an alarm.

### *Small Engine Mode*

The MC-624 can be modified for provide a half-power setting by installing a toggle switch between the positive and negative terminals of the alternator temperature sensor circuit. When activated by closing the switch, the regulator reduces the alternator output by approximately 50%. This mode is ideal for smaller engines that are not capable of providing suitable horsepower to drive both the alternator and propeller at full output. When in Small Engine Mode, the regulator will send a signal to the Auxiliary #1 Status Output.

## V. SHORT DISPLAY

The Model MC-624 provides a wide range of operational, programming and diagnostic data through its 3-digit numeric LED readout. After an initial start-up period, the numeric LED will cycle through the **Short Display,** shown in **Figure 8** on the following page. The short display includes manufacturer, model, battery type, charging cycle, actual voltage and target voltage. This display cycles continuously during regulator operation.

## VI. PRESET BATTERY PROGRAMMING

In addition to its Universal (default) factory program, which can be used safely with most battery types, the MC-624 features programs for: gel, standard lead acid, deep-cycle lead acid, AGM (absorbed glass mat), Optima (spiral), as well as voltage-sensitive (halogen) applications.

**'ACTIVATE-RELEASE'** Refers to the activation and immediate deactivation of the switch by lowering a magnetic tool (such as a pocket screwdriver with a magnetic tip -- see **Figure 9**) onto the upper corner of the switch, and immediately deactivating the switch by removing the magnet from the switch. An LED dot, described in Figure 9 will indicate switch activation.

**'ACTIVATE-HOLD ... RELEASE'** Typically used during programming, this action requires holding the magnet to the switch until desired values are shown on the display. Once the desired setting is reached, the magnet is removed to deactivate the switch.

**Note: Program function will alternately cycle up or down each time the PrA Mode is activated. If you miss your desired program value, release the switch and re-activate, the cycling direction will automatically change. Any advanced programming values will be retained within the regulator's memory until the preset battery programming is reset.**

The MC-624 is equipped with a magnetic reed switch, embedded in the epoxy potting, which activates the regulator's programming. The switch works in two specific actions, described in the shaded box below:

To set the regulator for your desired battery program:

1. 'ACTIVATE-HOLD' the switch. The display will show the **"Pro"** mode, indicating that the Program mode has been activated.
2. 'HOLD' while the display scrolls, until the numeric equivalent to your battery type is displayed on the LED screen. See **Figure 10** to determine which selectable preset program is most desirable for your battery technology. **Figure 11** provides detailed information regarding preset programs.
3. 'RELEASE' when the desired value is attained.

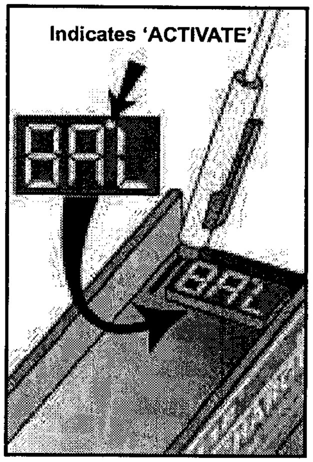
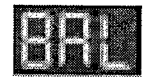



**Figure 9** - *Operation of magnetic reed switch.*

**Figure 8** - *Short display (SD).*

**SD Mode 1** - Manufacturer name. Readout displays "BAL".



**SD Mode 2** - Regulator model. Readout displays "624".

**SD Mode 3** - Battery type. Readout displays program currently in memory.

**SD Mode 4** - Battery type. Readout displays abbreviated battery type.

**SD Mode 5** - Charging stage. Shows current stage of charging cycle. See **Figure 12** on Page 5.

**SD Mode 6** - Battery voltage. Displays current battery voltage state.

**SD Mode 7** - Calculated voltage. Readout displays **voltage target** based on charging stage.

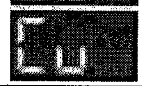


**Figure 10** - *Selectable battery presets.*

1 **Universal Factory Program (UFP)**. For multiple battery types.

2 **Flooded Deep Cycle (Fdc)**. For deep-cell lead acid batteries.

3 **Sealed Gel Cell (GEL)**. For sealed gel batteries.

4 **Absorbed Glass Mat (AGL)**. For AGM batteries.

5 **Optima (OPS)**. For Optima spiral wound batteries.

6 **Flooded Standard (FSB)**. For standard lead acid batteries.

7 **Halogen (HAL)**. For voltage sensitive applications.

4. Once a value has been chosen, the display will return to the **"Pro"** mode. At this point, you can adjust, up or down, by repeating Steps 1 through 3 until the numeric display reflects your desired preset program.

   If no changes are made, the program you have selected will be locked into permanent memory until modified. The **"SAV"** code will be displayed, indicating the program has been locked into memory.

**Figure 11** - *Preset program values. Voltages shown may vary by +/- 3% from values shown.*

| Primary Program Settings<br>Mode | PRG-1 Universal Factory Program | PRG-2 Deep Cycle Flooded Lead Acid | PRG-3 Gel Cell | PRG-4 Absorbed Glass Mat (AGM) | PRG-5 Optima Spiral Wound | PRG-6 Standard Flooded Lead Acid | PRG-7 Halogen Voltage Sensitive |
|---|---|---|---|---|---|---|---|
| Start Delay (Seconds) | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Ramp Up (Seconds) | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| Bulk Voltage (Max) | 28.40 | 29.20 | 28.20 | 28.76 | 29.20 | 28.80 | 28.00 |
| Bulk Time (Minimum) | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. |
| Absorption Voltage | 27.80 | 28.80 | 27.80 | 28.36 | 28.80 | 28.40 | 27.60 |
| Absorption Time (Minimum) | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. | 36 min. |
| Float Voltage | 27.00 | 26.70 | 27.40 | 26.76 | 26.80 | 28.40 | 27.00 |
| Float Time (Maximum) | 6 hr. | 6 hr. | 6 hr. | 6 hr. | 6 hr. | 6 hr. | 6 hr. |
| High Voltage Alarm | 30.40 | 31.20 | 30.20 | 30.76 | 31.20 | 30.80 | 30.00 |
| Low Voltage Alarm | 25.60 | 25.60 | 25.60 | 25.60 | 25.60 | 25.60 | 25.60 |
| Max Battery Temperature | 125F/52C | 125F/52C | 125F/52C | 125F/52C | 125F/52C | 125F/52C | 125F/52C |
| Max Alternator Temperature | 225F/107C | 225F/107C | 225F/107C | 225F/107C | 225F/107C | 225F/107C | 225F/107C |
| Equalization (User Prog.) | Yes | Yes | No | No | No | Yes | No |

## VII. Additional Displays

### *Charging Stages*

The MC-624 utilizes up to 12 individual stages to ensure proper charging. Each stage may contain a specific voltage or time value, or a combination of values which may be implemented by the regulator's microprocessor as it monitors your battery's state of charge. These stages are displayed in both Short and Long Display modes, and are described in **Figure 12**.

### *Long Display*

At any time during the Short Display's continuous cycle, additional data for various operations and diagnostic information can be monitored by accessing the numeric readout's **Long Display** mode.

To access the Long Display, 'ACTIVATE-RELEASE' the reed switch while the Short Display is cycling. The numeric LED will immediately return to the **"BAL"** code and start cycling through the Long Display. See **Figure 13** for code definitions.

Once the Long Display has cycled through all of its information modes, the display will automatically revert to the Short Display.

## VIII. Advanced Programming

Advanced programming levels can be accessed when the MC-624 is in Long Display mode. To access:

1. With regulator in Long Display mode, ACTIVATE-HOLD until the **"Pro"** display code appears. RELEASE. The **"PrA"** display code will appear. **(CAUTION: If the switch is held too long, the regulator will return to the preset program adjustment mode)**. Once in advanced program mode, the display will cycle through the individual time and voltage values (see **Figure 14**).
2. Each value will be followed by a numeric reading based on either time or voltage. ACTIVATE-HOLD to raise or lower the time or voltage value.

**Figure 12** - *Charge stage codes as seen in Short and Long displays.*

| | | | |
|---|---|---|---|
| **Stage 1** - Start Delay. Provides a 45-second delay before load is placed on engine and belts. Adjust time in PrA*. | S0 1 | **Stage 7** - Calculated Absorption. Time varies by state of charge at end of Stage 6. Adjust in PrA*. | S0 7 |
| **Stage 2** - Soft Ramp. One minute voltage ramp minimizes belt slippage. Non-adjustable. | S02 | **Stage 8** - Ramp Down. Transition from Absorption to Float stage. Non-adjustable. | S08 |
| **Stage 3** - Bulk. 30-minute set period. Program determines charging voltage. Time/voltageadjustable in PrA*. | S03 | **Stage 9** - Float. 30-minute time period. Program sets charging voltage. Time/volts adjust in PrA*. | S09 |
| **Stage 4** - Calculated Bulk. Time varies by state of charge at end of Stage 3. Adjustable in PrA*. | S04 | **Stage 10** - Calculated Float. Time & voltage based on state of charge at end of Stage 9. Adjust in PrA*. | S 10 |
| **Stage 5** - Ramp Down. Transition from Bulk to Absorption stage. Non-adjustable. | S05 | **Stage 11** - Ramp to Equalize. Batteries should be at full charge before initiating eqalization. | S 11 |
| **Stage 6** - Absorption. 30-min. set time. Preset program sets charging voltage. Time/voltage adjusts in PrA*. | S0b | **Stage 12** - Equalization. Time and Voltage adjustable in PrA*. See battery mfg. limits for time and voltage values. **User set.** | S 12 |

PrA* - *Time and/or voltage adjustments can be made in the Advanced Program mode.*

**Figure 13** - *Long Display (LD) attributes as displayed on digital numeric readout.*

| | | | |
|---|---|---|---|
| **LD Mode 1** - Readout displays **"BAL" (Short for Balmar.)** | BAL | **LD Mode 8** - Revision number. Displays software version. | r3.0 |
| **LD Mode 2** - Regulator model. Readout displays **"624"**. | b24 | **LD Mode 9** - Battery #1 temp. Followed by the sensor reading in degrees(Celcius). | B 1 |
| **LD Mode 3** - Program level. **(P)** Displays program currently in memory. | P0b | **LD Mode 10** - Battery #2 temp. Followed by the sensor reading in degrees(Celcius). | B2 |
| **LD Mode 4** - Battery type. Readout displays abbreviated battery type.See **Figure 10** for descriptions. | FS8 | **LD Mode 11** - Factory use only. | A45 |
| **LD Mode 5** - Charging stage Displays the specific stage of the charging cycle. See **Figure 13** for descriptions. | S03 | **LD Mode 12** - Factory use only. | F3 1 |
| **LD Mode 6** - Battery voltage. Shows current system voltage. | Bu | **LD Mode 13** - Run time. **"Hr "** code is followed by a numeric readout in 1/10-hr increments. | Hr |
| **LD Mode 7** - Calculated **(Target)** voltage based on program mode. | Cu | **LD Mode 14** - Explanatory mode. May be followed by one or more diagnostic codes. See **Figure 17** for details. | E30 |

**Figure 14** - *Advanced Programming (PrA) as displayed on digital numeric readout.*

| | | | |
|---|---|---|---|
| **PrA Mode 1** - Advanced program mode indicator. | PrA | **PrA Mode 7** - Float voltage control **"Fv"**. Followed by time reading. Adjust up or down. | Fu |
| **PrA Mode 2** - Start delay **"DL"**. Adjusts seconds before ramp up. | DLc | **PrA Mode 8** - Float time control. **"Fc"** code is followed by time reading. Adjust up or down. | F 1c |
| **PrA Mode 3** - Bulk voltage control. **"Bv"** code is followed by volt reading. Adjust up or down. | Bu | **PrA Mode 9 - Amp Manager** control. See details for Amp Manager on following page. | AP |
| **PrA Mode 4** - Bulk time control. **"Bc"** code is followed by time reading. Adjust up or down. | B 1c | **PrA Mode 10 - Equalization Voltage** control. See details for Equalization on following page. | Eu |
| **PrA Mode 5** - Absorption voltage control. **"Av"** code is followed by volt reading. Adjust up or down. | Au | **PrA Mode 11 - Equalization Time** control. See details for Equalization on following page. | E 1c |
| **PrA Mode 6** - Absorption time control. **"Ac"** code is followed by time reading. Adjust up or down. | A 1c | | |

3. RELEASE when desired values are reached. Inversely, the values can be decreased, if desired. ACTIVATE-HOLD while values decrese. RELEASE when desired value is attained.
4. The PrA mode will cycle 3 times. Any changes made during those cycles will be saved.

***Amp Manager***

The Amp Manager function enables you to reduce the alternator output by controlling the voltage at the field wire. This feature can be used as a method to minimize alternator overheating in warmer climates, as well as minimizing difficulties with chronic belt slippage. To adjust Amp Manager values:

1. 'ACTIVATE-RELEASE' when display cycles to **"AP"** (PrA Mode 09). **"AP"** will be followed by **"OFF"** code.
2. 'ACTIVATE-HOLD' **"OFF"** display cycles to **"249"**. The value "249" represents full field output. The numeric value on the display will decrease until you RELEASE.

**Note:** The value "200" represents approximately 75% field output, "150" represents approximately 50% field output, and "75" represents approximately 25% field output.

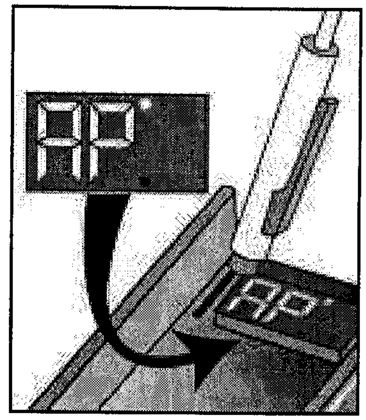


**Figure 15 -** *Indicates Amp Manager Mode.*

***Equalization Mode***

Equalization mode allows owners of some battery types to increase charging voltage for the purpose of minimizing battery sulfation. **(Equalization is only suggested for batteries noted as "equalization friendly" in Figure 11 on Page 4).** Consult your battery manufacturer to determine what equalization time and voltage is best for your specific battery. Equalization must be initiated through the advanced programming mode. It is NOT a standard mode of operation. This feature should **ONLY** be used periodically on batteries requiring equalization. Once equalization voltage AND time values are chosen and saved into the regulator's programming, the equalization process will start immediately. Once equalization has occurred, the regulator will revert to its preset program status. When equalization is once again warranted, the user will need to re-activate the equalization mode. Equalization voltage is limited to 31.2 volts.

**To adjust equalization voltage (PrA Mode 10):**

1. 'ACTIVATE-RELEASE' **"PrA"** display cycles to **"Ev"** followed by **"OFF"** code.
2. 'ACTIVATE-HOLD'. **"OFF"** display cycles to numeric voltage values. When the manufacturer-recommended voltage is reached, RELEASE.

**To adjust equalization time (PrA Mode 11):**

1. 'ACTIVATE-RELEASE' **"PrA".** Display cycles to **"Ec"** followed by **"OFF"** code.
2. 'ACTIVATE-HOLD'. **"OFF"** display cycles to numeric equalization time values. When the manufacturer-recommended time value is reached, 'RELEASE'.

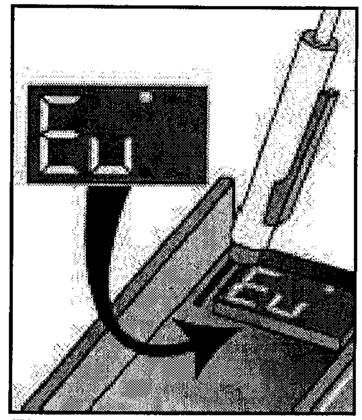


**Figure 16 -** *Equalization Voltage mode is activated.*

***Explanatory / Advisory Codes***

The codes in the final mode of the Long Display (LD Mode 14) provide a wide range of advisories regarding regular operations and possible technical difficulties. The descriptions for these codes can be found in **Figure 17**. For additional technical information regarding Explanatory and Advisory codes, see our Technical Support pages at the Balmar website (http://www.balmar.net). **To reset advisory/diagnostic codes, access the Advanced Programming mode as described at the beginning of Section VIII. Codes will automatically reset.**

| | | |
|---|---|---|
| **CODE 001** - Factory use only. | **CODE 015** - Sensor wire not found at alternator temperature sensor terminal. | **<u>CODE 040</u>** - Voltage too high at battery. |
| **CODE 002** - Factory use only. | **<u>CODE 020</u>** - Factory use only. | **CODE 041** - Factory use only. |
| **CODE 010** - Wire short at battery #1 temperature sensing terminal. | **<u>CODE 021</u>** - Battery #2 exceeding recommended temperature limits. | **CODE 042** - Factory use only. |
| **CODE 011** - Factory use only. | **<u>CODE 022</u>** - Factory use only. | **CODE 050** - Open field. |
| **CODE 012** - Wire short at battery #2 temperature sensing terminal. | **CODE 024** - Factory use only. | **CODE 051*** - Small Engine Mode activated. |
| **CODE 013** - Factory use only. | **<u>CODE 030</u>** - Voltage too low at battery. | **CODE 052*** - Amp manager is in operation. |
| **CODE 014** - Wire short at alternator temperature sensor terminal. | **CODE 031** - Factory use only. | *Underlined codes represent those pertaining to Alarm Output (dash lamp) operation.* |
| | **CODE 032** - Factory use only. | *Codes highlighted by an asterisk (*) pertain to Aux. #1 advisory output.* |

**Figure 17 -** *Advisory/diagnostic codes as displayed in LD Mode 14 on the digital numeric readout.*

**NOTES:**

# IX. SYSTEM TROUBLESHOOTING

Determining the causes of failures in an electrical system is a "step by step" process. We recommend that you inspect and clean all system electrical connections before you begin your search to determine if the failure can be attributed to one of the two main components of your charging system: the alternator, and/or the voltage regulator.

**Most charging system problems will be corrected by performing the following steps.**

1. Remove and clean all charging system electrical connections from the alternator through the batteries (this includes the ground side). Also, check the voltage regulator's harness for resistance. Wires and terminals can and will become corroded and need to be cleaned or replaced.
2. Charge all batteries to their proper fully charged state and determine if they are serviceable. If your batteries are flooded-type, use your hydrometer to determine their condition.
3. Check and tighten alternator belt. If the belt shows signs of wear or damage, now is an ideal time for replacement. Always replace existing belts with the finest quality replacements available.

After determining that your batteries and wiring are in suitable condition, use the following tests to determine if charging problems are a result of a faulty alternator or regulator. The following tests provide an opportunity to isolate the alternator, regulator and wiring harness in order to determine which component may be malfunctioning. In order to preform these tests, you will need an independent multimeter (preferably a digital type). In an emergency, a 24V light bulb can be used to help determine if power or working grounds exist. An amp meter and a battery hydrometer with a thermometer are also helpful diagnostic tools.

***Alternator /Regulator Field Tests***

**Test A** - The alternator and regulator can be tested for function by determining if a magnetic field exists at the alternator's pulley shaft or rear bearing. To test:

1. With the ignition in the OFF position, place the head of a steel screwdriver near the nut on the pulley shaft or near the rear bearing of the alternator. There should be no evidence of a magnetic field pulling the screwdriver toward the alternator.
2. Engage the ignition, without starting the engine, to activate the voltage regulator. If an oil pressure switch is used, a jumper across the switch will activate the regulator.
3. After allowing time for the regulator's start-up delay, place the head of a steel screwdriver near the nut on the pulley shaft or near the rear bearing of the alternator. There should be evidence of a magnetic field pulling the screwdriver toward the alternator. If a magnetic field is present, the voltage regulator, alternator brushes and rotor are likely to be working properly. If the system is not charging, remove the alternator and have it inspected by a qualified alternator shop.

**Test B** - If there is little or no magnetic pull at the pulley shaft or at the rear bearing, initiate the following test:

1. With the key off and the engine off, remove the large harness plug from the regulator.
2. Insert the end of a short length of electrical wire to the RED connector slot of the regulator harness and the other end of the wire to the BLUE connector slot. (See **Figure 18**.) This bypasses the regulator and tests the alternator and the harness.
3. Using your steel screwdriver, inspect for a magnetic field as described above.
4. With your voltmeter, check for voltage on the blue wire at the alternator. If voltage does not exist, the harness may be at fault. If voltage does exist at the harness, but charging is not occurring, the alternator is likely to be malfunctioning.

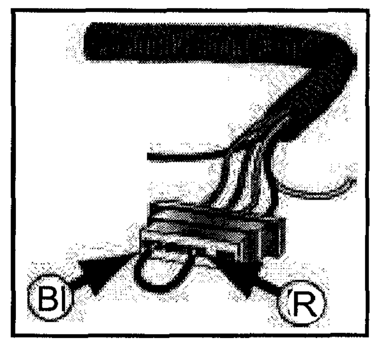



**Figure 18** - *Jumping power wire to field.*

If a magnetic field is present. Both harness and alternator brushes and rotor appear to be working properly. If no magnetic field is present, proceed with the next test.

**Test C** - Testing the actual output of the alternator is known as "Full Field Testing". This can be accomplished by jumping a positive 24VDC current to the field terminal at the rear of the alternator. This test eliminates both the regulator and the harness, making it easier to isolate your investigation to the alternator. **CAUTION: Ensure that all voltage sensitive equipment is turned off prior to starting the engine. Voltage is unregulated during this test and could damage sensitive electronics. DO NOT let the engine run any longer than necessary to detect charging.**

To test the alternator:

1. Clip a jumper wire to the positive post of the alternator, or on the battery side of the isolator, if an isolator is in use. Use a SHIELDED alligator clip for post attachment. Unintentional contact between the alligator clip and the alternator case could result in damage to your electrical system.
2. Disconnect the field/stator plug from the rear of the alternator and attach the other end of the jumper wire to the alternator's Field terminal (F). Attach a female spade connector to the field end of the wire for a solid connection. **CAUTION:** Do not allow the wire to contact the case while it is attached to the positive post. The case is grounded and severe damage could occur.
3. The regulator is now bypassed. When the ignition is engaged and the motor is started, the voltage should rise and charging current should be present.
4. The motor should be run long enough to determine that charging voltage is present. Unregulated voltage can rise quickly. Do not allow extended unregulated charging to occur without carefully monitoring voltage levels.

If the alternator fails to generate voltage during field testing, a malfunction of the alternator is likely. Contact your local alternator repair shop or Balmar's technical service staff for recommendations.

***Voltage Regulator Test***

When you have inspected and repaired any wires and connections, inspected belts and replace as needed, and after you have determined that your batteries are properly charged, set your voltmeter to 24V and connect the voltmeter's negative lead to the BLACK ground wire at the regulator. Normally, connection is accomplished by inserting the negative lead alongside the ground wire in the regulator harness plug (see **Figure 19**) and the positive lead alongside the wire referred to in each specific test. With the voltmeter securely connected to the regulator's ground, test for voltage at the points listed below.

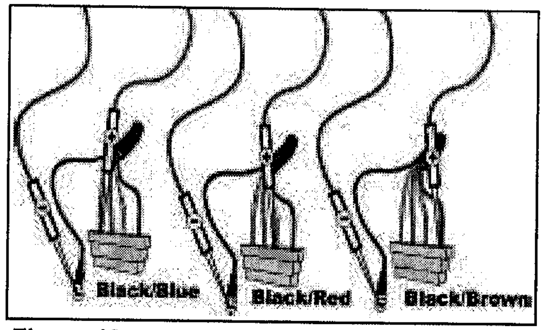


**Figure 19** - *Inserting voltmeter probes.*

1. With the ignition in the OFF position and your voltmeter's ground wire connected to the regulator's ground, check for voltage on the RED (sensing), BLUE (field) and BROWN (ignition) wires in the regulator plug by inserting the positive lead of the voltmeter alongside each wire in the regulator harness plug. The voltmeter should read:

| | Red Wire | Brown Wire | Blue Wire |
|---|---|---|---|
| **Expected Reading** | 24 V * | 0 V | 0 V |
| **Your Reading** | | | |

2. With the ignition in the ON position (engine not running) and your voltmeter's ground wire connected to the regulator's ground, check for voltage on the RED (sensing), BLUE (field) and BROWN (ignition) wires in the regulator plug. The voltmeter should read:

| | Red Wire | Brown Wire | Blue Wire |
|---|---|---|---|
| **Expected Reading** | 24 V* | 24 V | >24 V |
| **Your Reading** | | | |
| | | | |

3. With the ignition in the ON position (with engine running at 1,400 rpm fast idle) and your voltmeter's ground wire connected to the regulator's BLACK wire, check for voltage on the RED (sensing), BLUE (field) and BROWN (ignition) wires in the regulator plug. The voltmeter should read:

| | Red Wire | Brown Wire | Blue Wire |
|---|---|---|---|
| **Expected Reading** | 24 - 28V** | 24 V | >25 V |
| **Your Reading** | | | |

** 23-24.5 VDC battery voltage at rest (no charging occurring). If your batteries are isolated and your RED (sensing) wire shows voltages other than those shown above, make sure that the wire is connected on the "battery" side of the isolator. The RED wire must "see" the battery directly.*

*** 27 - 28 VDC battery voltage when charging.*

If your readings differ substantially from the "Expected Readings" listed in the charts above, the regulator may be malfunctioning, or there may be a continuity problem. Contact our technical support staff at (360) 435-6100. Keep your recorded readings in the spaces provided below the "Expected Readings" so you can share them with the technical support person. If your readings match those listed in the charts, your regulator should be working correctly. Continue with tests below to determine if your alternator may be the source of charging difficulties.If the preceding tests do not prove the existence of a failure within the regulator or alternator, we recommend you contact a licensed marine electrician who can test your system for wiring and circuit damage or other system failures that could be responsible for charging difficulties. If you determine that repair service is necessary for either your alternator or regulator, please gather the following information before contacting our service technicians.

1. Model of alternator.
2. Model of voltage regulator.
3. Voltage readings on red, brown and blue wire at regulator with engine off, key on.
4. Voltage readings on red, brown and blue wire at regulator with engine running at a fast ideal 1400 rpm.

## XII. LIMITED PRODUCT WARRANTY

BALMAR warrants to the original consumer/purchaser the product is free from any defects in material or workmanship for a period of one year from the date of purchase. If any such defect is discovered within the warranty period, BALMAR will replace the regulator free of charge, subject to verification of the defect or malfunction upon delivery or shipping prepaid to BALMAR.

This warranty DOES NOT apply to defects or physical damage resulting from abuse, neglect, accident, improper repair, alteration, modification, or unreasonable use of the products resulting in breakdown, cracked or broken cases nor are parts damaged by fire, water, freezing, collision, theft, explosion, rust, corrosion or items damaged in shipment in route to BALMAR for repair. BALMAR assumes no responsibility for consequential damage or loss or expense arising from these products or any labor required for service or repair.

BALMAR WILL NOT repair or be held responsible for any product sent without proper identification and return address or RA number clearly marked on the package. You must include proof of date and place of purchase (photocopy of purchase invoice) or we cannot be responsible for repairs or replacement. In order to expedite warranty claims more efficiently, BALMAR asks that prior to returning a defective product for repair, you call their customer service department for a warranty return authorization number .

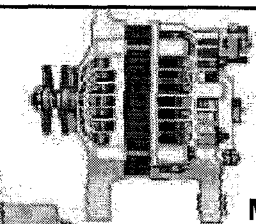
If factory service is required, you can contact our BALMAR Customer Service Department Monday through Thursday, 7:30 AM to 5:30 PM, (PST)1-360 435-6100 ext "3".

Material required for the repair or replacement for the defective part or product is to be supplied free of charge upon delivery of the defective regulator to BALMAR, 19009 61st Ave. NE, Arlington, WA 98223. Customer is responsible for all return transportation charges and any air or rush delivery expense. BALMAR reserves the right to determine whether to repair or replace defective components.

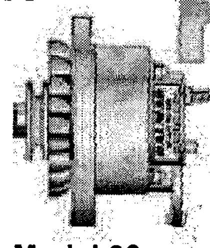
THE ABOVE LIMITATIONS MAY NOT APPLY TO YOU. SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS. NO PERSON, AGENT, DEALER IS AUTHORIZED TO GIVE ANY WARRANTY.

**BALMAR** **19009 61st Ave. NE, Arlington, WA 98223 Phone: (360) 435-6100, Fax: (360) 435-3210**
**E-mail: balmar@balmar.net, Web: www.balmar.net**

# TIPS TO SELECTING A HIGH OUTPUT ALTERNATOR REPLACEMENT FOR YOUR ENGINE

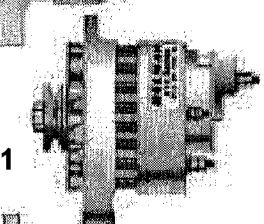


Model 70

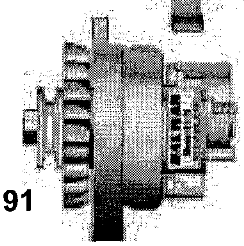


Model 90

Model 71



Model 81



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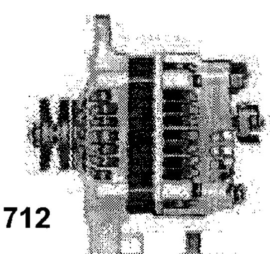
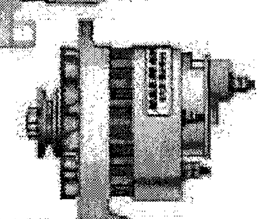
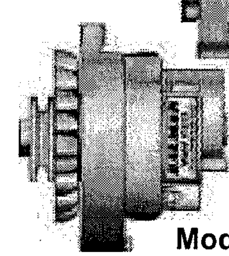


Model 712



Model 812



Model 912

*I want to replace my existing OEM position alternator. How do I know which Balmar Alternator to order?*

**Consider your engine fuel type:**
1. Diesel - All of our models are appropiate
2. Gasoline - (see below for more information)

**Determine your mounting style:**
1. Dual Foot (Imports) - 70-Series, 90 Series, 901 Series
2. Single 1" Foot - 71-Series, 81 Series, 91 Series
3. Single 2" Foot - 712-Series, 812 Series, 912 Series
4. Aids to Selection:
   a. See: Engine Mounting Guide (pg. 2)

**Determine your belt configuration:**
1. Single belt, approximately 3/8" - choose no more than 75 amps 12v or 65 amp 24v
2. Single belt, approximately ½" - choose up to 100 amps 12v or 65 amps 24v
3. Dual / Dedicated / Serpentine belts - choose up to 150 amps 12v or 80 amp 24v
4. Need more info on sizing to belt?
   a. See: Alternator Output / Belt Configuration (pg.3)
   b. See: RPM Chart (pg. 4)

**Consider your options:**
1. Dual Output - Charge two banks -
   a. See: Dual Output Option (pg. 6)
   b. See: Dual Output Wiring Diagram (pg 7)
2. Isolated Ground - Negative terminal, as well as positive, isolated from case
3. Reverse Rotation - Bi-directional fan

**Consider Your Batteries:**
1. Total Amp Hour Capacity
   a. See: Alternator Rating / Battery Capacity Formula (pg. 4)
   b. See: RPM Chart (pg 4)
2. Type of Batteries
   a. See: Batteries and Resistance

**Choose Your Regulator:**
1. Regulator Comparison Chart (pg. 8)

# ALTERNATORS & GASOLINE ENGINES

All Balmar alternators are Marine Certified and comply with Coast Guard and B.I.A. standards, which includes ignition protection certification.

Balmar offers a line of alternators that meet a higher standard of ignition protection, certified through J-1171 testing. The Balmar models that meet this higher standard, and are suggested for gasoline engines, include the 70, 71 and 712-Series; 81 & 812 Series, as well as the extra-large case 98-Series brushless alternators.

# Alternator Mounting Guide

The following guide provides a basic reference for matching High-Output Balmar alternators to your specific engine type. Keep in mind that "real world" factors, including engine age, engine model, engine marinizer, distributor and/or installer, can all have a dramatic effect on the actual mounting configuration you'll find on your specific engine.
In addition to your alternator's mounting style, it is essential to ensure that your alternator's amperage capacity is matched to the size of your drive belt. If your engine uses a 3/8" drive belt, we recommend our 75-amp alternator. If your existing drive belt measures 1/2", we recommend our 100-amp alternator. If your engine is equipped with a dual 1/2"-belt system, our 150-amp alternator would be the recommended choice for your system. Large case, high-output alternators should be driven by a minimum of two 1/2" belts. We strongly recommend you examine your engine to determine both mounting style and drive belt size before you order a replacement or upgrade alternator.

| Engine /Alt. Make | Series (Case size or type) | Mounting Foot Size ( M.F.) |
|---|---|---|
| Bukh | 71, 91 series | 1" M.F. |
| Caterpillar | Not Standard, usually isolated ground, 91 or large case | Varies by model |
| Chrysler | 70, 90 series with spacers | Varies by model |
| Crusader | 71, 81 or 91 series | 1" M.F. |
| Cummins | 92/94 TCU series( dual foot), 95 series or 912 | Varies by model |
| Delco 55 Alt. | (W/2" M.F.) 912 series 2" (Delco style) M.F. (or 91 w/ 1" M.F. & 1" spacer) | 2" M.F. |
| Detroit Diesel | 92/94 series (specify dual foot), some 912 series | Varies by model |
| Flagship | 71, 91 series | 1" M.F. |
| GMC | 71, 91 series for most (can use 92/94 series ) | Varies by model |
| Greymarine | 71, 91 series | 1" M.F. |
| Hawk Marine Power | 71, 91 series | 1" M.F. |
| Hitachi Alternator | 70, 90 series | (dual foot 3.15" separation) |
| Indmar | 71, 91 series | 1" M.F. |
| Isuzu | 70, 71, 91 series | 1" M.F., drill hole to 1/2" |
| John Deere | 71, 91 series | 1" M.F. |
| Lehman(Ford) | 71, 91 series | 1" M.F. Call American Diesel |
| Lehman(Sabre) | 901-75 or 901-100 series | (dual foot 3.15" separation) |
| Lugger 6125 | Lugger mounting kit for the 6125 465 hp engine | |
| Lucas Alt. | 901-75 or 901-100 series (all isolated ground) | (dual foot 3.15" separation) |
| Mann | No standard. (Can use 92/94 series ) | |
| Mercedes | 90 series | (dual foot 3.15" separation), with spacers common |
| Mercrusier | 71, 81 or 91 series | 1" M.F. |
| Mitsubishi | 70, 90 series case | (dual foot 3.15" separation) 1" spacer 3/8 bolt |
| Motorola Alternator | 71, 91 series | 1" M.F. |
| MTU | No standard (Can use 92/94 series ) | |
| Namni | 70, 90 series | (dual foot 3.15" separation) |
| Nippondenso Alt. | 70, 90 series | (dual foot 3.15" separation), Modify engine mount. |
| OMC | 71, 91 series | 1" M.F. |
| Pathfinder* | 912 series | 2" (Delco style) M.F. |
| Perkins 4-107,108 | 912 series | 2" (Delco style) M.F |
| Perkins (other) | 71, 91 series | 1" M.F. |
| Perkins-Volvo M series | 901-75 or 901-100 series | (dual foot 3.15" separation), isolated grounds |
| Pleasurecraft | 71, 91 series | 1" M.F. |
| Prestolite Alt. | 71, 91 series | 1" M.F. |
| Universal Atomic 4 | 712, 812, 91 or 912 series | 1" M.F. with 1" spacer |
| Universal 30, 50 -1982 | 71, 91 series | 1" M.F. |
| Vetus-Denouden | 70, 90 series | (dual foot 3.15" separation) |
| Volvo - 2001 -2003 | 712, 912 series | 2" ( Delco style) M.F. (turbo - swing arm mod.) |
| Volvo - Driven off Flywheel | | Alternator must have a special 3/8" x 4" pulley |
| Westerbeke 46 4107, 4108 (1979) 1" M.F. | | 91series |
| Westerbeke 46 (1986) | 70, 90 series | (dual foot 3.15" separation) |
| Yamaha (IO) | 71, 91 series | 1" M.F. |
| Yanmar ** | 70, 90 series | (dual foot 3.15" separation) |

*Remove original pulley and mount on BALMAR ® alternator; or move U bracket forward
**Yanmar Mounting: 35 amp uses 6 mm Mt. bolt, 55 amp 8 mm Mt. bolt, 80 amp special 10 mm bushing.

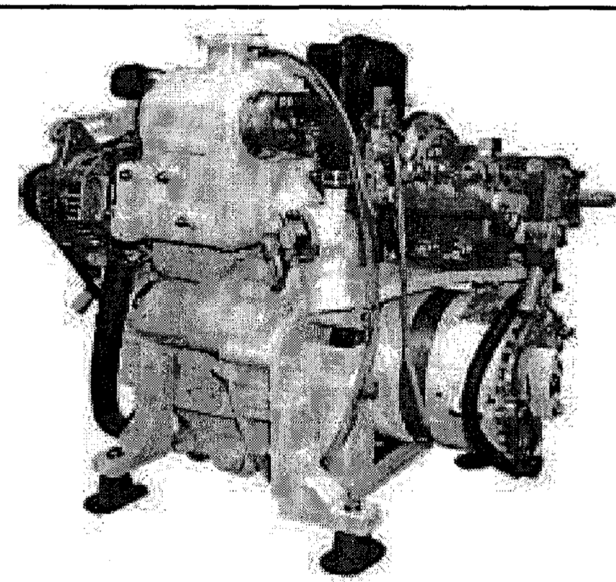
# Alternator Output / Belt Configuration

When replacing an alternator in the stock engine position, you're really facing the issue of physical limitation on the belt and side load on the water circulation pump. We don't drive more than a 75 amp high output Balmar marine alternator on a single 3/8" undedicated belt, or a 100 amp on a 7/16"-1/2" undedicated belt. Even though the numbers might not seem much higher than say a 55 amp stock automotive type alternator, most people see a huge improvement in performance between the two. That is because the alternators are designed to perform two very different jobs: the stock alternator is designed for handling light constant loads (such as lights, fans, radios, etc.) and the high output marine alternator is designed to charge banks of batteries. To move up to our 150 amp alternator, a dual dedicated belt is required.

As to the question of 'can't I just change pulleys?', consider this: Yes, you can get a variety of pulleys for the alternator. Yes, you can probably get a suitable pulley for the shaft from the engine manufacturer or in the worst case have one fabricated. But what about the water circulation pump? Even if you were to come up with a pulley for that, you must consider side load. The physical design limitations of what can be done in the stock alternator position on a single belt can't be ignored. The output of the alternator you select is simply limited by the original belt configuration.

When you need more output than a single belt can handle, the correct thing to do is come up with a PTO (power take-off) for the shaft. This is usually available through the engine manufacturer, or you can have it fabricated. Now you've got some major sheaves to work with. Next job is to come up with some bracketing to hang a second alternator, that will have dedicated dual belts and be dedicated to the job of charging the house bank. The most popular models for this application are the large case models 9400 series, with 160 amp output and a 2" single mounting foot, and the 9500 or 9800 series, with 160-300 amp (12v) output and a J-180 mount (dual foot, 4" between feet).

When you need more amperage than can be provided by a second alternator, your next option is the DC genset, for example the PC-750. This is a 2-cylinder Yanmar engine direct coupled with our largest brushless alternator. Available in a variety of voltages. Please see our website or contact Balmar for more information on these stand-alone chargers with the 40 gph watermaker option.



**APC 750 3.5Kw DC Genset with 40 g.p.h. watermaker**

## *Need a custom pulley or bracket for your large case or auxiliary alternator?*

The following manufacturers provide a wide variety of pulleys and bracketry designed to convert your engine to accept BALMAR high-output alternators.

**HS Marine Parts**
**Issaquah, WA**
**(425) 557-7820**
**(888) 946-3929**
**hms@aa.net**

**ZRD**
**P.O. Box 968**
**Titusville, FL 32781-0968**
**(321) 264-3243**
**http://www.zrd.com**

# RPM Chart

Alternator RPM Table - Not all models are listed here. Further information is available upon request. Please note that all outputs are given in alternator RPM. Engine RPM is typically about 1/2 (50%) or less because of the pulley ratio. Example alt. pulley 2.5", engine crank pulley of 5" equals a 2 to 1 ratio, 2500 alt. rpm = 1250 engine rpm.

Note:Table reflects outputs at 122° F using 14 or 28 volts with 2.5" pulley O.D.. Output at 12 or 24 volts could be 5 to 10 % lower or higher. Actual output on your boat will vary with wire size and condition, voltage sense point, battery age and condition, operating temperatures, and other installation criteria.

| **Alternator rotor rpm** | **1250** | **1500** | **1750** | **2000** | **2500** | **3000** | **3500** | **4000** | **4500** | **5000** | **6000** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine rpm (5" crank) | 625 | 750 | 875 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 3000 |
| Engine rpm (6" crank) | 520 | 625 | 730 | 833 | 1040 | 1250 | 1460 | 1665 | 1875 | 2080 | 2500 |
| **12-Volt Models** | | | | | | | | | | | |
| 70, 71, or 712-80 | 15 | 25 | 40 | 56 | 63 | 74 | 80 | 82 | 83 | 85 | |
| 70, 71, or 712-110 | 14 | 22 | 38 | 60 | 80 | 86 | 95 | 100 | 108 | 114 | |
| 81, or 812-50 | 15 | 25 | 36 | 40 | 42 | 45 | 48 | 49 | 50 | 51 | 52 |
| 81, or 812-65 | 12 | 18 | 35 | 45 | 55 | 60 | 61 | 63 | 64 | 65 | 66 |
| 81, or 812-100 | 10 | 18 | 28 | 35 | 60 | 80 | 90 | 95 | 98 | 100 | 110 |
| 90, 91, or 912-75 | 15 | 25 | 37 | 55 | 70 | 80 | 84 | 87 | 89 | 91 | 93 |
| 90, 91, or 912-100 | 15 | 25 | 38 | 51 | 77 | 93 | 101 | 107 | 109 | 112 | 115 |
| 90, 91, or 912-150 | 10 | 18 | 32 | 44 | 82 | 106 | 122 | 133 | 139 | 145 | 155 |
| 94-100 (9400) | 30 | 52 | 66 | 79 | 88 | 92 | 96 | 99 | 101 | 102 | 104 |
| 94-160 (9435) | | | 70 | 90 | 120 | 135 | 145 | 152 | 157 | 160 | 162 |
| 94-165 | 20 | 50 | 70 | 90 | 110 | 121 | 128 | 152 | 156 | 158 | 165 |
| 94-190 (9465) | | | 25 | 65 | 110 | 135 | 154 | 165 | 174 | 179 | 180 |
| 94-200 | | 10 | 38 | 71 | 128 | 152 | 180 | 190 | 197 | 203 | 210 |
| 95-165 | 20 | 50 | 70 | 90 | 110 | 121 | 128 | 152 | 156 | 158 | 165 |
| 95-200 | | 40 | 62 | 78 | 125 | 135 | 160 | 185 | 195 | 205 | 215 |
| 96-185 | 50 | 80 | 115 | 120 | 155 | 170 | 180 | 182 | 185 | 187 | 190 |
| 96-275 | | 40 | 90 | 121 | 168 | 205 | 235 | 250 | 270 | 275 | 290 |
| 9812-300-BL | | 83 | 125 | 168 | 212 | 242 | 258 | 275 | 282 | 291 | 303 |
| **24-Volt Models** | | | | | | | | | | | |
| 90, 91, or 912-24-65 | | | | 10 | 35 | 40 | 50 | 55 | 60 | 65 | 70 |
| 90, 91, or 912-24-80 | | | | 15 | 40 | 55 | 70 | 75 | 80 | 85 | 95 |
| 94-24-120-D (9200) | | | | 20 | 30 | 60 | 75 | 90 | 110 | 125 | 130 |
| 94-24-135-MHD | | | | | 45 | 82 | 90 | 130 | 135 | 148 | 156 |
| 94-24-MSL | | | 20 | 45 | 85 | 110 | 115 | 120 | 130 | 132 | 135 |
| 9624-140 | | | | 20 | 65 | 100 | 118 | 128 | 138 | 144 | 160 |
| 9824-220-BL | | | 60 | 110 | 170 | 205 | 225 | 250 | 260 | 270 | 272 |

# Alternator Rating / Battery Capacity Formula

Rule of thumb is that the alternator output equal 25% of the battery capacity, so for a 400 amp hour bank, our 100 amp alternator would be a wise choice. You can figure 1 hp draw per 25 amps (12 volt) at maximum output.

Be sure to read the information about batteries and resistance, on the following page. There are many factors that play into the correct sizing of the alternator to the battery bank.

# BATTERIES & RESISTANCE

Automotive type alternators that come standard on engines are typically designed for light load handling and are not up to the task of charging large banks of batteries. It is simply not what they are designed to do. Rule of thumb is that most people see at least a 50% increase in performance due to replacing an automotive type alternator with a similarly rated high output marine alternator.

Our rpm table rates the output at 122 degrees F and at 14 or 28 volts. The highest rated alternator that we recommend on a single belt in the factory alternator position is 100 amps. That is if the belt is ½". If the belt is 3/8", we would recommend the 75 amp model be used. The Balmar 100 amp alternator can actually put out about 120 amps. HOWEVER, the alternator will only put out as much current as the batteries can accept. There are many factors that determine how much current the batteries will accept.

Often it is not the output of the alternator, or even its regulation that causes the disappointing recharge scenario. This can many times be attributed to the rate of charge the batteries can accept. Typically, batteries absorb current at a rate of about 20-30% of their capacity. Your battery manufacturer can answer questions that you may have in this regard.

With the new AGM type batteries, we see a very substantial increase in this percentage. (Note: when using AGM batteries, we highly recommend using our Max Charge regulator with battery and alternator temperature sensing.) The larger the battery bank, the more current the batteries will accept and the harder the alternator has to work.

You can picture a 200-amp alternator charging one small car battery, you will never see that battery accepting more than 30 or 40 amps. Yet a 1000 amp hr battery bank, when deeply discharged can make that 200 amp alternator work at it maximum output. If the alternator has a 100 amp capacity, and the batteries can absorb 60 amps, and you have an additional 40 amp load, there would be a 100 amp output. There are, however, many factors that will affect this and some of them are somewhat abstract.

The first, and probably most important, is to realize that the absorption rate of the particular type of batteries sets the charge rate. In other words, if we were to set the voltage at 14.1, the batteries, would absorb current at a certain rate. If you raise the voltage the batteries will absorb more current but you may damage them. Different types of batteries made by different manufacturers have a wide span of absorption rates.

One other small factor to consider is that a 100 amp alternator is rated at 100 amps when it has adequate voltage to create the magnetic flux. In other words, if your battery was down to 10 volts, the alternator would not have the energy (10 volts) required to come to its full potential. In a way, it has to earn its way up to its full potential.

So you see there are many abstracts. It is often disappointing to try to achieve that last 10 or 15% back into your batteries. We find that adding more batteries, in other words a larger resistive target for the alternator, increases the current flow and shortens the length of time that the engine must operate to replenish yesterdays use of energy.

## Notes:

# Dual Output Option / Charging Multiple Battery Banks

There are four ways to accomplish the charging of multiple battery systems:

1) Dual Output Alternator
2) Battery Isolator
3) Battery Combiner
4) A/B Switch

Everyone has their own preference and opinion about which is best. The old 'A/B Switch' is extremely reliable, but some people don't like to have to try to remember to use it. Any of the methods listed above will work. We prefer the dual output alternator method, where the output simply goes from the alternator to the two individual battery banks requiring charging - there is nothing to be remembered and there is no additional equipment to fail.

There are several ways to charge two groups of batteries with one alternator. Using a dual output alternator is probably one of the simplest, as the outputs can go directly to each battery terminal. Therefore, whenever the alternator is in operation, both sets of batteries are being topped out, without having to remember where the switch setting is set.

The dual output alternator is rather simplistic in its design. It offers two complete sets of isolated diodes and cooling plates . Whichever terminal sees a load will receive the current flow. Either terminal on the alternator can put out 100% of the alternator's capacity. Some people that use extremely heavy loads on the alternator choose to use it as a single output model, leaving the bonding strap on the two terminals, thus doubling the cooling capacity of the alternator.

A very standard scenario is that the cranking battery is fully charged, or nearly fully charged, and the house bank is brought down from regular daily activity. What occurs is that the house battery will consume all of the alternator output until it is brought up to the same voltage level as the cranking battery. At that point, the alternator will bring both banks up and top them off together. As you can imagine, the cranking battery takes very little of the current, therefore the full capacity of the alternator is directed to the house load.

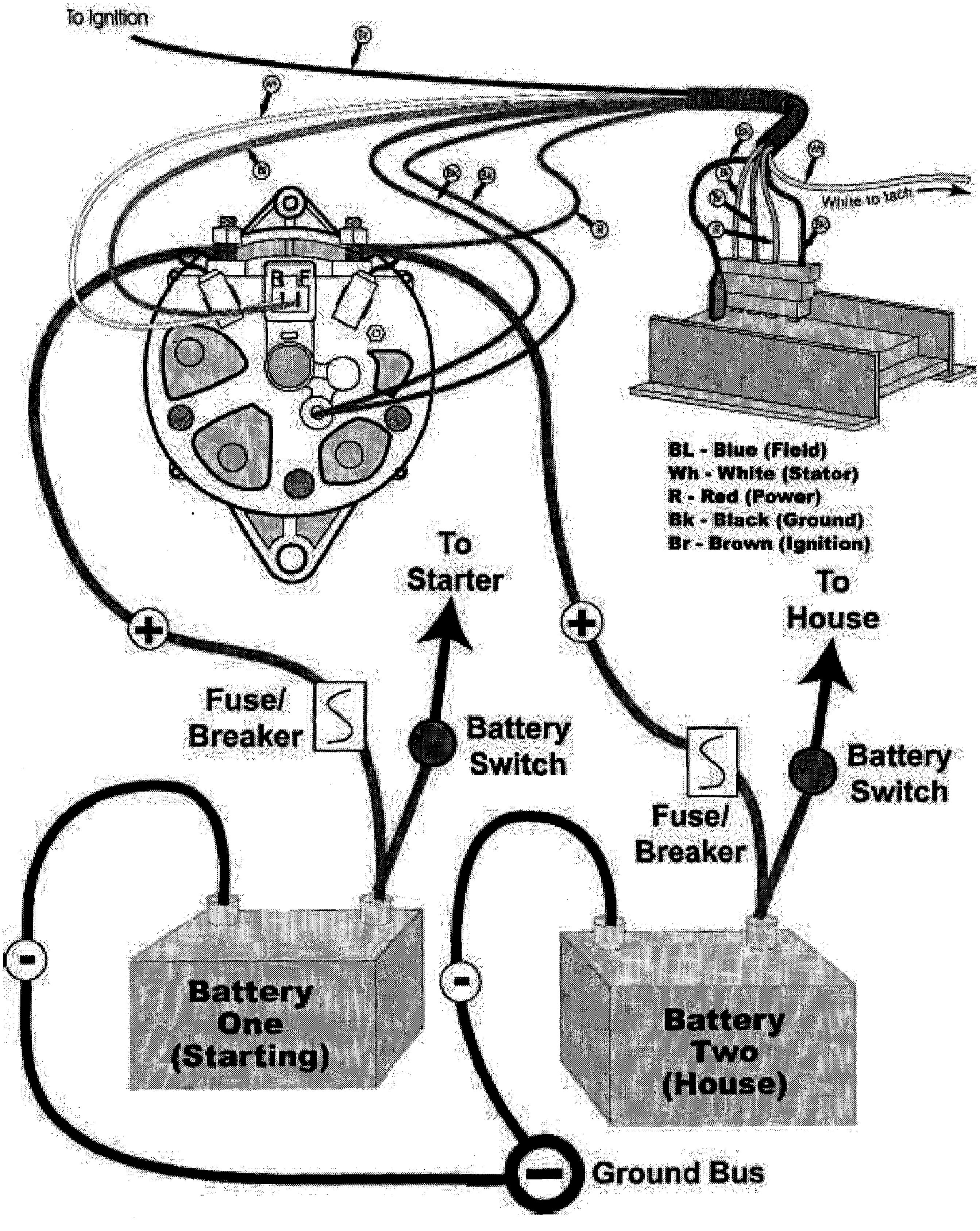
You do not need a separate regulator for each output. The regulator provides instructions to the alternator, and the alternator can only act upon one set of instructions. We usually regulate the heavy load, the house bank, and the regulator assures that the voltage on the system does not exceed the values set on the regulator. Again, with a dual output alternator, the red sense wire is used to sense the most heavily used (usually the house) bank. Connection may be may at the alternator output terminal, if the wiring is correctly sized. If the wiring is not correctly sized, there may be line loss to the battery. An alternative is to connect the red wire to battery positive.

The voltage level from the alternator is determined by the regulator. If the regulator is set at 14.2, both outputs will charge at 14.2 volts. The batteries acceptance rate of current is determined by the voltage setting. In other words, if the voltage setting of the regulator is 14.2 volts, a battery at 14.2 volts will accept very little current. On the other hand, if the battery is quite low, let's say at 12.2, it will accept 'X' amount of current, depending on the type and size of battery, an at a diminishing rate as it comes up to the set voltage. The higher the voltage is set, the more the battery will absorb. That is the fundamental philosophy of the 3 stage regulator. The batteries will simply come up to the given voltage. If they are both fully charged, very little current will flow. If one bank is low, the current will flow to that battery first. It doesn't matter if it is the house or the start battery.

Different types of batteries are a different story. Battery manufacturers and Balmar both suggest that all batteries in a system be of the same type. Different types of batteries often have different program parameters suggested for proper voltages and absorption rates.

***For more information about small and large case dual-output alternators, see our website at: www.balmar.net***

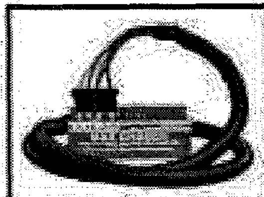
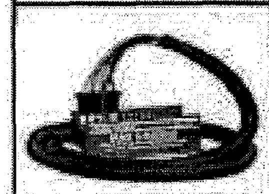
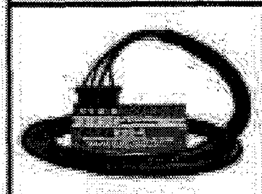
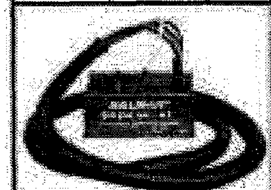
## Suggested Wiring for 12V Dual-Output Alternator / Two Batteries




NOTE: Typical installations are most efficient when battery sensing takes place at larger (house) bank. If smaller (starting) battery indicates overcharging, move sense wire to smaller battery.

# BALMAR

## Year 2000 Regulator Comparison Chart

| | Model # | Charge Volts | Charging Cycle | Battery Presets | Display Type | Temperature Sensing | Alarm Circuits | Advanced Programming |
|---|---|---|---|---|---|---|---|---|
|  | MC-612<br>MC-624 | 12-V<br>24-V | **Multi-Stage**<br>1. 45-Sec. Delay<br>2. Soft Ramp<br>3. Bulk Charge<br>4. Absorption<br>5. Float | 1. Universal Factory*<br>2. Deep-Cycle Flooded<br>3. Gel Cell<br>4. Glass Mat (AGM)<br>5. Optima<br>6. Standard Flooded<br>7. Halogen (Voltage sensitive) | **3-Digit Numeric**<br>Display provides up to 43 informational readouts including data regarding programming, operation, system and regulator diagnostics. | **Temp Sensing***<br>1. Alternator<br>2. Battery Bank #1<br>3. Battery Bank #2<br>Requires optional Alternator and Battery Temperature Sensors | **Dash Lamp**<br>Low bat. voltage, High bat. voltage, High field voltage, High stator voltage, High bat. temp, High alt. temp.<br>**Advisory**<br>Full alt. output, Small engine mode, Equalization mode | 1. Bulk Voltage<br>2. Bulk Time<br>3. Absorb Voltage<br>4. Absorb Time<br>5. Float Voltage<br>6. Float Time<br>7. Amp Manager<br>8. Equalization Time/Voltage |
|  | MC-412<br>MC-424 | 12-V<br>24-V | **Multi-Stage**<br>1. 45-Sec. Delay<br>2. Soft Ramp<br>3. Bulk Charge<br>4. Absorption<br>5. Float | 1. Universal Factory*<br>2. Deep-Cycle Flooded<br>3. Gel Cell<br>4. Glass Mat (AGM)<br>5. Optima<br>*for standard flooded and no-maintenance batteries | **8-LED Light Display**<br>Color coded LED lamps display programming, operational and diagnostic data. | **Temp Sensing***<br>1. Alternator<br>2. Battery Bank #1<br>Requires optional Alternator and Battery Temperature Sensors | **Dash Lamp**<br>High voltage, Low voltage.<br>**Advisory**<br>Small engine mode, Full field, Equalization mode | 1. System Voltage*<br>2. System Time*<br>3. Amp Manager<br>4. Equalization Time/Voltage<br>* System time and voltage adjustments alter values equally in all charging stages |
|  | ARS-4 | 12-V | **Multi-Stage**<br>1. 45-Sec. Delay<br>2. Soft Ramp<br>3. Bulk Charge<br>4. Absorption<br>5. Float | 1. Universal Factory*<br>2. Deep-Cycle Flooded<br>3. Gel Cell<br>4. Glass Mat (AGM)<br>5. Optima<br>*for standard flooded and no-maintenance batteries | **8-LED Light Display**<br>Color coded LED lights display programming, operational and diagnostic data. | **Temp Sensing***<br>1. Alternator<br>Requires optional Alternator Temperature Sensor | **Dash Lamp**<br>High voltage, Low voltage. | 1. System Voltage*<br>2. System Time*<br>3. Equalization Time/Voltage<br>* System time and voltage adjustments alter values equally in all charging stages |
|  | BRS-2<br>BRS-2-24 | 12-V<br>24-V | **Single-Stage**<br>Voltage adjustable approx. 13.7V-14.6V<br>**Single-Stage**<br>Voltage adjustable approx. 25.7V-28.6V | None | **3 LED Display**<br>Indicates power on, voltage at field and voltage at stator connections | None | None | None |
|  | ERS | 12-V | **Single-Stage**<br>Fixed Voltage 14.1V | None | None | None | None | None |

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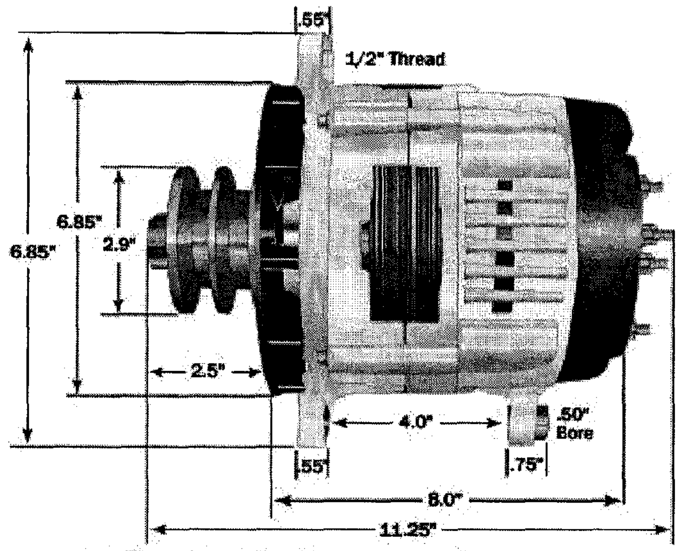
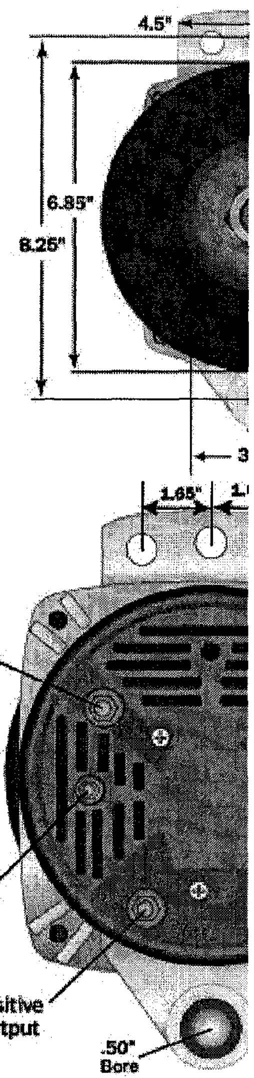
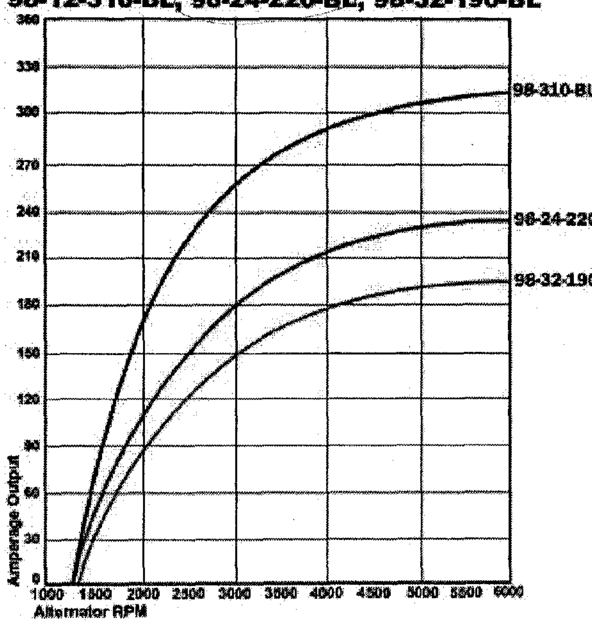
## 98-Series Extra-Large Case Alternato
Dimensional Drawings and Power Curves




**BALMAR** Curve Comparison
**98-12-310-BL, 98-24-220-BL, 98-32-190-BL**




## Alternator Specifications

CONTACT US

| | |
|---|---|
| Amperage output: | 80A/110A |
| Operating range: | 0-9,000 RPM (Rotor) |
| Alternator polarity: | P-type (Positive) |
| Mounting configuration: | Dual foot mount (4"ID) |
| Standard pulley type/size: | Dual 1/2" Vee, 2.9" diameter |
| Minimum Belt Width: | 1/2" Dual Belt |
| Outputs: | Single |
| Regulation: | External (Single or multi-stage) |
| Finish: | White Powdercoat |
| Ship weight: | 39 lbs. |

Back

NOTE: All of the information on this page is believed to be correct at the time of its creation. In order to maintai quality, Balmar reserves the right to make changes to its products without prior notice. Balmar accepts no liabil errors, omissions, or inconsistencies regarding product information on this website.

# SECTION 32

# SERVICE BULLETIN 1M-156
# FOR
# DELCO REMY CRANKING MOTOR

Service Bulletin 1M-156

Pages: 8 Dated 11-1-80

Reference: 1B-115, 1B-116
1M-188, 1S-188

# Delco Remy

## CRANKING MOTORS

### 40-MT/400 and 40-MT/450
### 50-MT/400

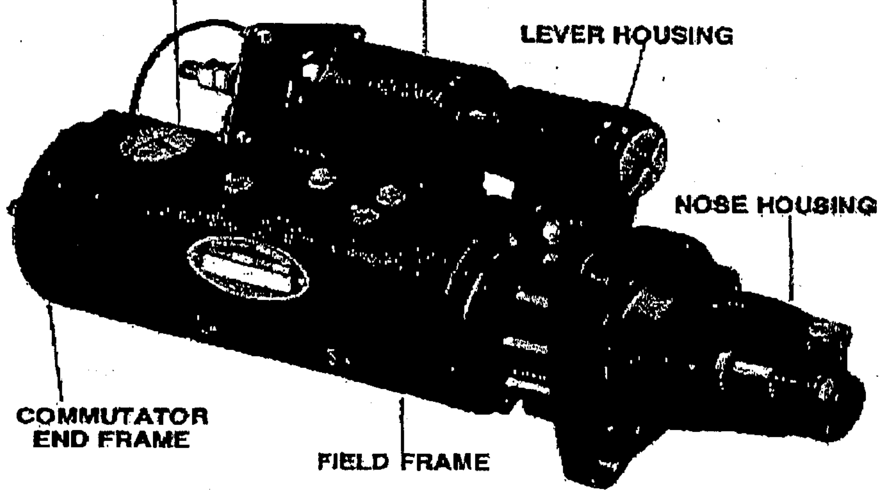



Figure 1—Typical 40-MT/400 motor

Heavy duty cranking motors have a shift lever and solenoid plunger that are totally enclosed to protect them from exposure to dirt, icing conditions and splash. The nose housing can be rotated to obtain a number of different solenoid positions will respect to the mounting flange.

Lubrication is provided to the sintered bronze bushings by an oil saturated wick. Oil can be added to each wick by removing an oil reservoir cup which is accessible on the outside of the motor. Additional information on lubrication is provided on page 7.

The pinion is moved into mesh with the ring gear by the action of the solenoid. The pinion remains engaged until the solenoid circuit is interrupted. In case of a butt engagement the motor will not be energized to prevent damage to the pinion and gear teeth.

### MAINTENANCE

Under normal operating conditions, no maintenance will be required between engine overhaul periods. At time of engine overhaul, motors should be disassembled, inspected, cleaned, and tested as described in succeeding paragraphs.

### ADJUSTABLE NOSE HOUSING

As shown in the cross-sectional view of Figure 2, the nose housing is attached to the lever housing by means of bolts located around the outside of the housing. to relocate the housing, it is only necessary to remove the bolts, rotate the housing to the desired position, and reinstall the bolts. the bolts should be torqued to 13-17 lb. ft. during reassembly. In this type of assembly, the lever housing and the commutator and frame are attached to the field frame independently by bolts entering threaded holes in the field frame.

# CRANKING MOTORS

## 1M-156 Service Bulletin

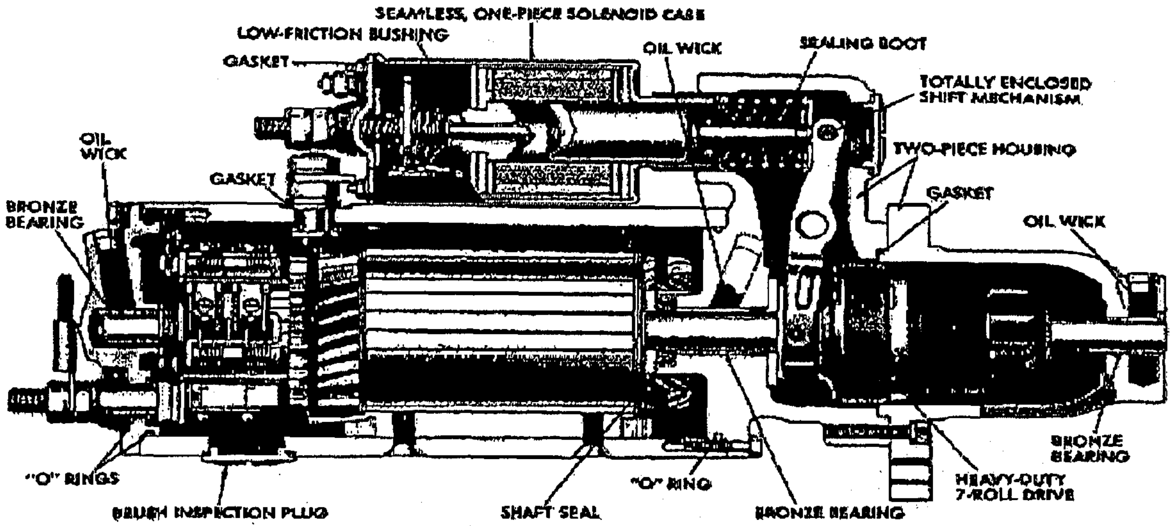



Figure 2—Cross-sectional view

### OPERATION

There are many different cranking motor circuits used on various applications. The cranking circuit may contain a key start switch or push switch, or both, a relay magnetic switches, solenoids, oil pressure switch, fuel pressure switch and other protective devices, such as an "ADLO" relay.

Reference should be made to the vehicle manufacture's wiring diagram for the complete cranking circuit.

A typical circuit is shown in Figure 3. The motor shown has a built-in thermostat to protect against damage due to over-cranking for excessively long periods of time. Thermostat components separated from the field coils and motor frame are shown in Figure 4. Also a motor with harness disconnected from the thermostat is shown in Figure 5.

When the start switch is closed, battery current flows through the magnetic switch winding and the thermostat to ground, as shown in Figure 3. The magnetic switch closes, connecting the motor solenoid "S" terminal to the battery.

The solenoid windings are energized and the resulting plunger and shift lever movement causes the pinion to engage the engine flywheel ring gear close, and

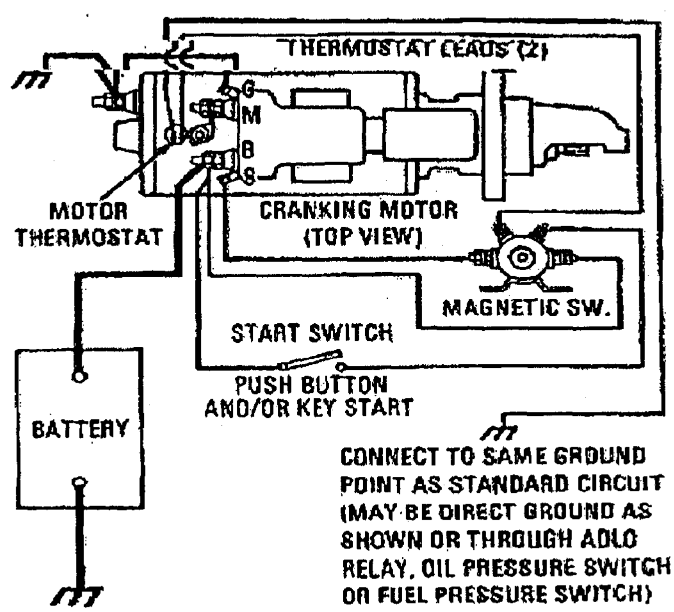



Figure 3—Typical wiring circuit

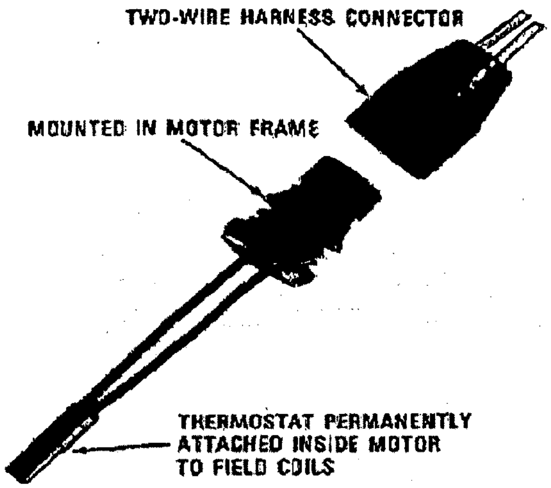



Figure 4—Typical thermostat

cranking takes place. Where the engine starts, pinion overrun protects the armature from excessive speed until the switch is opened, at which time the return spring causes the pinion to disengage. To prevent excessive overrun and damage to the drive and armature windings, the switch must be opened immediately when the engine starts.

A cranking period for all types of motors should never exceed 30 seconds without stopping to allow the motor to cool. If over-cranking should occur, the thermostat will open and the cranking cycle will stop to protect the motor. After the cranking motor cools, usually 1-6 minutes, the thermostat will close and then a new starting attempt can be made.

A circuit without the motor thermostat would be the same as Figure 3, except the magnetic switch winding terminal would be grounded directly to the point noted in Figure 3, without passing through a thermostat.

## TROUBLESHOOTING THE CRANKING CIRCUIT

If the cranking system is not performing properly, make the following checks to help determine which part of the circuit is at fault.

**Battery:** To determine the condition of the battery, follow the testing procedure outlined in Service Bulletin 1B-115 or 1B-116. Insure that the battery is fully charged. The wiring, switches, and cranking motor cannot be checked if the battery is defective or discharged.

**Wiring:** Inspect the wiring for damage. Inspect all connections to the cranking motor, solenoid, magnetic switch, ignition switch or any other control switch, and battery, including all ground connections. Clean and tighten all connections as required. The cranking system cannot operate properly with excessive resistance in the circuit.

**Magnetic Switch, Solenoid and Control Switches:** Inspect all switches to determine their condition. From the vehicle wiring diagram, determine which circuits should be energized with the starting switches closed. Use a voltmeter to detect any open circuits.

**Thermostat, or Overcrank Protection:** To check the thermostat for continuity, detach wiring harness connector and connection an ohmmeter to the two thermostat terminals on the motor (Fig. 5). The ohmmeter should read zero. If not, thermostat is open circuit. DO NOT check thermostat when hot, since it is supposed to be open-circuit above certain temporatures.

**Motor:** If the battery, wiring, and switches are in satisfactory condition, and the engine is known to be functioning properly, remove the motor and follow the test procedures out lined below.

A cranking motor is designed for intermittent duty only, and should never be operated for more than 30 seconds at a time. After 30 seconds, the cranking must be stopped for at least two minutes to allow the motor to cool. The same rule applies to a motor with a thermostat. The thermostat is an added protection against damage form overcraking.

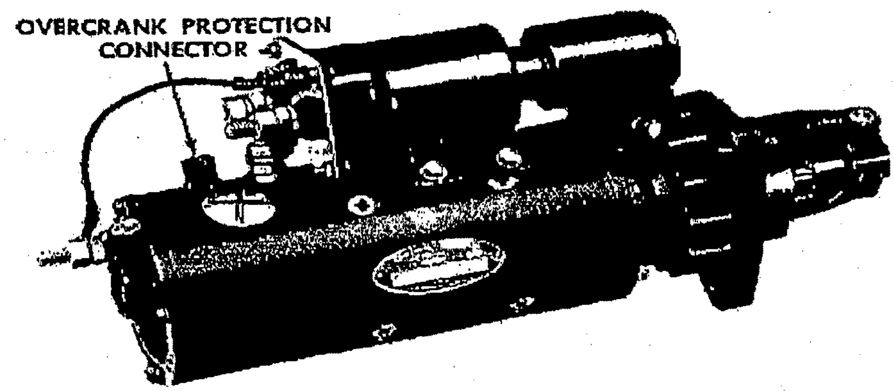



Figure 5—Typical motor showing thermostat connector (Overcrank Protection Connector)

# CRANKING MOTORS

## 1M-156 Service Bulletin

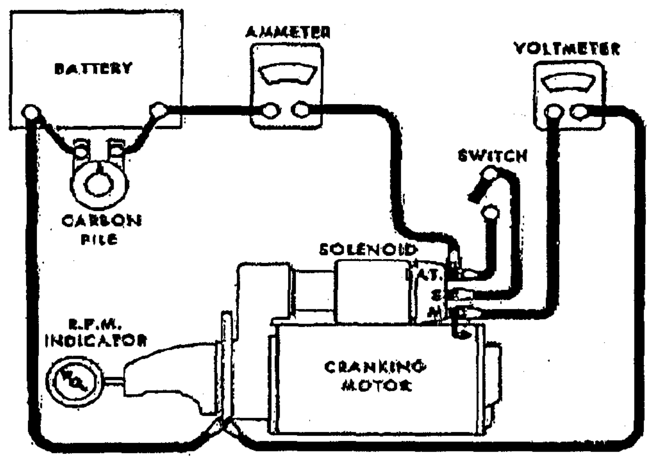



Figure 6—No-load test circuit

With the cranking motor removed from the engine, the armature should be checked for freedom of rotation by prying the pinion with a screwdriver. Tight bearings, a bent armature shaft, or a loose pole shoe screw will cause the armature to not turn freely. If the armature does not turn freely the motor should be disassembled immediately. However, if the armature does rotate freely, the motor should be given a no-load test before disassembly.

**No-Load Test (Fig. 6)**

Connect a voltmeter from the motor terminal to the motor frame, and use an r.p.m. indicator to measure armature speed. Connect the motor and an armature in series with a fully charged battery of the specified voltage, and a switch in the open position from the solenoid battery terminal to the solenoid switch terminal. Close the switch and compare the r.p.m., current, and voltage reading with the specifications in Service Bulletins 1M-188. It is not necessary to obtain the exact voltage specified in these bulletins, as an accurate interpretation can be made by recognizing that if the voltage is slightly higher the r.p.m. will be proportionately higher, with the current remaining essentially unchanged. However, if the exact voltage is desired, a carbon pile connected across the battery can be used to reduce the voltage to the specified value. If more than 12-volt battery is used, connect the carbon pile to only one of the 12-volt batteries. If the specified current draw does not include the solenoid, deduct from the ammeter reading the specified current draw of the solenoid "hold-in" winding, make disconnections only with the switch open. Interpret the test results as follows.

**Interpreting Results of Tests**

1. Rated current draw and no-load speed indicates normal condition of the cranking motor.
2. Low free speed and high current draw indicate:
   a. Too much friction-tight, dirty, or worn bearings, bent armature shaft or loose pole shoes allowing armature to drag.
   b. Shorted armature. This can be further checked on a growler after disassembly.
   c. Grounded armature or fields. Check further after disassembly.
3. Failure to operate with high current draw indicates:
   a. A direct ground in the terminal or fields.
   b. "Frozen" bearings (this should have been determined by turning the armature by hand).
4. Failure to operate with no current draw indicates:
   a. Open field circuit. This can be checked after disassembly by inspecting internal connections and tracing circuit with a test lamp.
   b. Open armature coils. Inspect the commutator for badly burned bars after disassembly.
   c. Broken brush springs, worn brushes, high insulation between the commutator bars or other causes which would prevent good contact between the brushes and commutator.
5. Low no-load speed and low current draw indicates:
   a. High internal resistance due to poor connections, defective leads, dirty commutator and cause listed under Number 4.
6. High free speed and high current draw indicate shorted fields. If shorted fields are suspected, replace the field coil assembly and check for improved performance.

**DISASSEMBLY**

Normally the cranking motor should be disassembled only so far as is necessary to make repair or replacement of the defective parts. As a precaution, it is suggested that safety glasses be worn when disassembling or assembling the cranking motor.

1. Note the relative position of the solenoid, leer housing, and nose housing so the motor can be reassembled in the same manner.
2. Disconnect field coil connector from solenoid motor terminal, and lead from solenoid ground terminal.
3. On motors which have brush inspection plates, remove the plates and

then remove the brush lead screws. This will disconnect the field leads from the bush holders.

4. Remove the attaching bolts and separate the commutator end frame from the field frame.
5. Separate the nose housing and field frame from lever housing by removing attaching bolts.
6. Remove armature and clutch assembly from lever housing.
7. Separate solenoid from lever housing by pulling apart.

**CLEANING**

The drive, armature and fields should not be cleaned in any degreasing tank, or with grease dissolving solvents, since these would dissolve the lubricant in the drive and damages the insulation in the armature and field coils. All parts except the drive should be cleaned with mineral spirits and a brush. The drive can be wiped with a clean cloth.

If the commutator is dirty it may be cleaned with No. 00 sandpaper. NEVER USE EMERY CLOTH TO CLEAN COMMUTATOR.

**Brushes and Holders**

Inspect the brushes for wear. If they are worn excessively when compared with a new brush, they should be replaced. Make sure the brush holders are clean and the brushes are not binding in the holders. The full brush surface should ride on the commutator to give proper performance. Check by hand to insure that the brush springs are giving firm contact between the brushes and commutator. If the springs are distorted or discolored, they should be replaced.

**ARMATURE SERVICING**

If the armature commutator is worn, dirty, out of round, or has high insulation, the armature should be put in a lathe so the commutator can be turned down. The insulation should then be undercut 1/32 of an inch wide and 1/32 of an inch deep, and the slots cleaned out to remove any trace of dirt or copper dust. As a final step in this procedure, the commutator should be sanded lightly with No. 00 sandpaper to remove any burrs left as a result of the undercutting procedure. NOTE: The undercut operation must be omitted on cranking motors having Test Specifications 2412, 2415, 3501, 3564, 3574 and 3599 as listed in Delco Remy Service Bulletin 1M-188. Do not undercut commutators on motors having these specifications.

The armature should be checked for opens, short circuits and grounds as follows:

1. Opens - Opens are usually caused by excessively long cranking periods. The most likely place for an open to occur is at the commutator riser bars. Inspect the points where the conductors are joined to the commutator bars for loose connections. Poor connections cause arcing and burning of the commutator bars as the cranking motor is used. If the bars are not too badly burned, repair can often be effected by resoldering or welding the leads in the riser bars (using rosin flux), and turning down the commutator in a lathe to remove the burned material. The insulation should then be undercut except as noted above.
2. Short Circuits - Short circuits in the armature are located by using a growler. When the armature is revolved in the growler with a steel

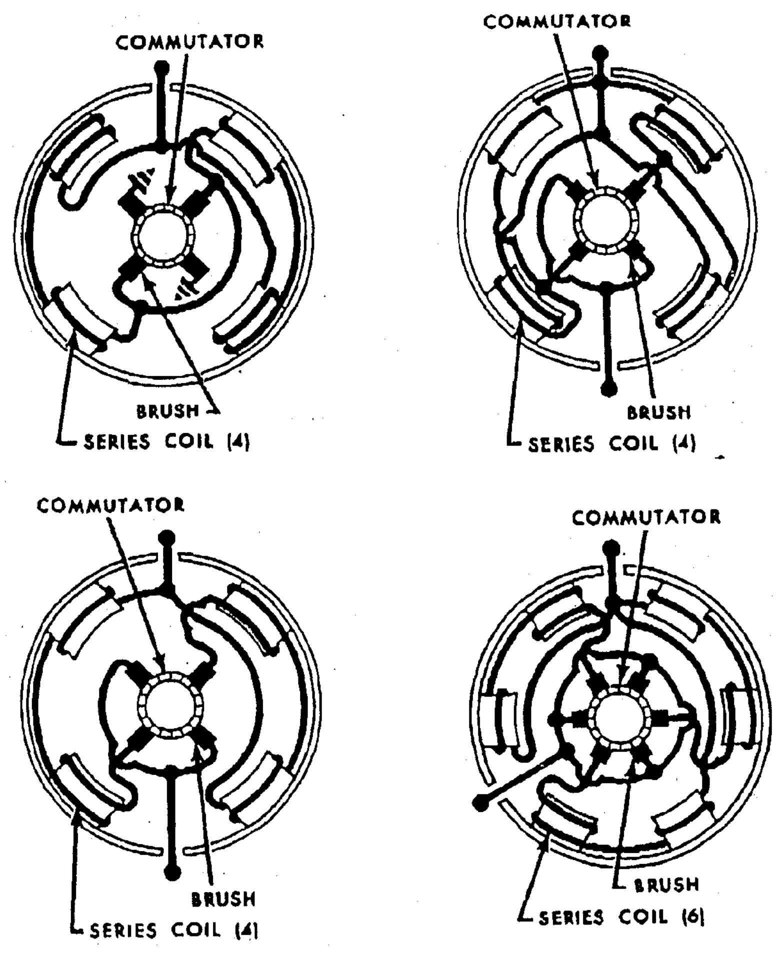



Figure 7—Internal motor circuits

# 1M-156 Service Bulletin

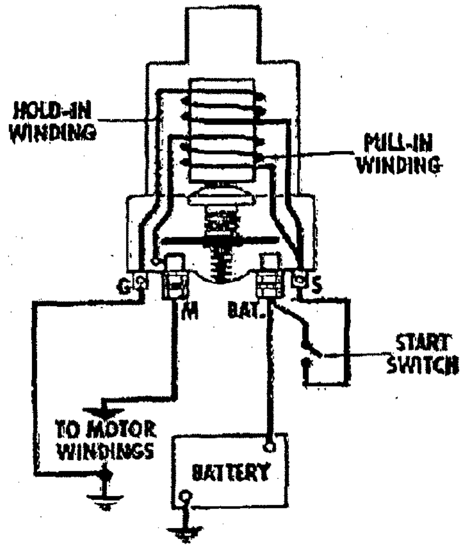



Figure 8—Internal solenoid circuit. ("G" and "S" terminals moved to clarify illustration.)

strip such as a hacksaw blade held above it, the blade will vibrate above the area of the armature core in which the short circuit is located. Shorts between bars are sometimes produced by brush dust or copper between the bars. These shorts can be eliminated by cleaning out the slots.

3. Grounds - Grounds in the armature can be detected by the use of a 110-volt test lamp and test points. If the lamp lights when one test point is placed on the commutator with the other point on the core or shaft, the armature is grounded. Grounds occur as a result of insulation failure which is often brought about by overheating of the cranking motor produced by excessively long cranking periods or by accumulation of brush dust between the commutator bars and the steel commutator ring.

## FIELD COIL CHECKS

The various types of circuits used are shown in the wiring diagrams of Figure 7. The field coils can be checked for grounds and opens by using a test lamp

**Grounds** - If the motor has one or more coils normally connected to ground, the ground connections must be disconnected to ground, the ground connections must be disconnected during this check. Connect one lead of the 110-volt test lamp to the field frame and the other lead to the field connector. If the lamp lights, at least one field coil is grounded which must be repaired or replaced. This check cannot be made if the ground connection cannot be disconnected.

**Opens** - Connect test lamp leads to ends of field coils. If lamp does not light, the field coils are open.

## FIELD COIL REMOVAL

Field coils can be removed from the field frame assembly by using a pole shoe screwdriver. A pole shoe spreader should also be used to prevent distortion of the field frame. Careful installation of the field coils is necessary to prevent shorting or grounding of the field coils as the pole shoes are tightened into place. Where the pole shoe has a long lip on one side and a short lip on the other, the long lip should be assembled in the direction of armature rotation so it becomes the trailing (not leading) edge of the pole shoe.

## SOLENOID CHECKS

A basic solenoid circuit is shown in Figure 8. Solenoids may differ in appearance but can be checked electrically by connecting a battery of the specified voltage, a switch, and an ammeter to the two solenoid windings. With all leads disconnected from the solenoid, make test connections as shown to the solenoid switch terminal and to the second switch terminal, (G), to check the hold-in winding (Fig. 9). Use the carbon pile to decrease the battery voltage to the value specified in Service Bulletin 1S-188 and compare the ammeter reading with specifications. A high reading indicates a shorted hold-in winding, and a low reading excessive resistance. To check the pull-in winding connect from the solenoid switch terminal (S) to the solenoid motor (M or MTR) terminal (Fig. 10).

To check for grounds, mo e battery lead from "G" (Fig. 9) and from "MTR" (Fig. 10) to solenoid case, (not shown). Ammeter should read zero. If not, winding is grounded.

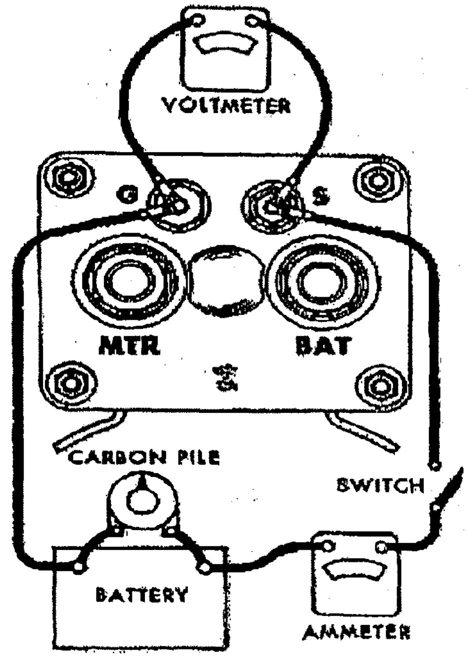



Figure 9—Checking solenoid hold-in winding

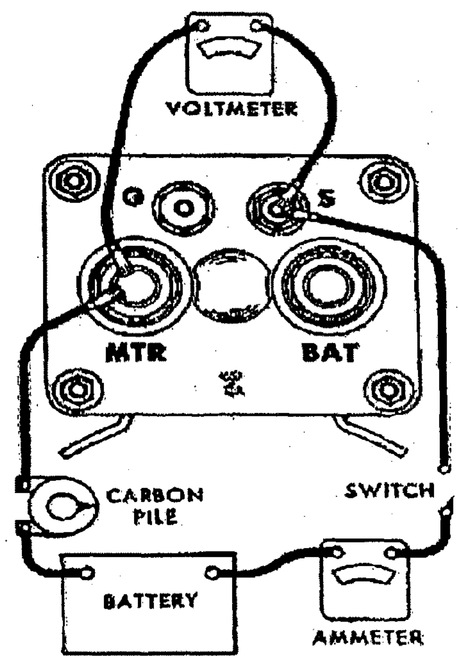



Figure 10—Checking solenoid pull-in winding

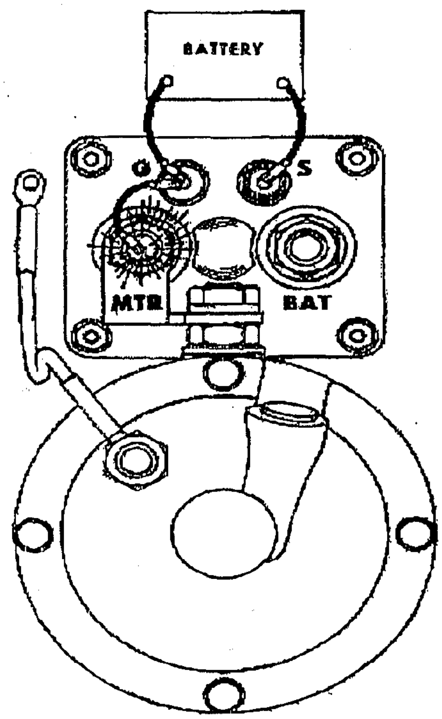



Figure 11—Checking pinion clearance circuit

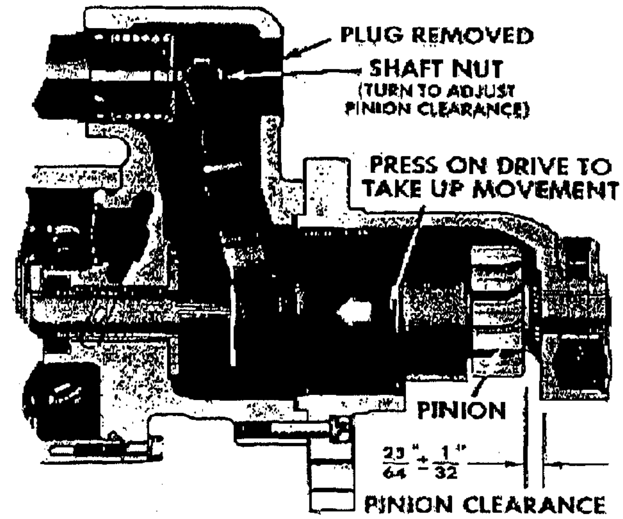



Figure 12—Measuring pinion clearance

NOTE: If needed to reduce the voltage to the specified value, connect the carbon pile between the battery and the "MTR" terminal as shown. If the carbon pile is not needed, connect a jumper directly from the battery to the "MTR" terminal.

CAUTION: To prevent overheating, do not leave the pull-in winding energized more than 15 seconds. The current draw will decrease as the winding temperature increases.

A magnetic switch can be checked in the same manner by connecting across its winding.

**REASSEMBLY**

To reassemble the end frame with brushes onto the field frame, pull the armature out of the field frame just far enough to permit the brushes to be placed over the commutator. Then push the commutator end frame and the armature back against the field frame.

**LUBRICATION**

All bearings, wicks and oil reservoirs should be saturated with SAE No. 20 oil. Place a light coat of lubricant Delco Remy No. 1960954 on the washer located on the shaft between the armature and shift lever housing.

Sintered bronze bearings used in these motors have a dull finish.

Before pressing the bearing into place, dip it in SAE No. 20 oil. Also, tangent wicks (if present) should be soaked with SAE No. 20 oil. Insert the wick into place first, and then press in the bearing.

DO NOT DRILL, REAM, OR MACHINE sintered bearings in any way. These bearings are supplied to size. If drilled or reamed, the I.D., (inside diameter) will be too large, also the bearing pores will be sealed over.

It is not necessary to cross-drill a sintered bearing when used with a tangent wick. Because the bearing is so highly porous, oil from the wick touching the outside bearing surface will bleed through and lubricate the shaft.

Middle bearings are support bearings and prevent armature deflection during cranking. As compared to end frame bearings, the clearance between middle bearing and shaft is large and the clearance provides a loose fit when assembled.

**PINION CLEARANCE**

To check pinion or drive Clarence follow the steps listed below.

1. Make connections as shown in Figure 11.
2. Momentarily flash a jumper lead from terminal G to turmoil MTR (Fig. 11). The drive will now shift into cranking position and remain so until the battery is disconnected.
3. Push the pinion or drive back towards the commutator end to eliminate slack movement.
4. Measure the distance between drive and housing (Fig. 12).
5. Adjust clearance by removing plug and turning shaft nut (Fig. 12). Although typical specifications are shown, always refer to 1Mj-188 for specifications applying to specific models.

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The following format must be used if submitting an electronic 2028. The subject line must be exactly the same and all fields must be included; however, only the following fields are mandatory: 1, 3, 4, 5, 6, 7, 8, 9, 10, 13, 15, 16, 17 and 27.

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**To:** whomever@avma27.army.mil
**To:** TACOM-TECH-PUBS@ria.army.mil

Subject:DA Form 2028

1. ***From:*** Joe Smith
2. ***Unit:*** home
3. ***Address:*** 4300 Park
4. ***City:*** Hometown
5. ***St:*** MO
6. ***Zip:*** 77777
7. ***Date Sent:*** 19-OCT-93
8. ***Pub no:*** 55-1915-200-10
9. ***Pub Title:*** TM
10. ***Publication Date:*** 11-APR-88
11. ***Change Number:*** 12
12. ***Submitter Rank:*** MSG
13. ***Submitter Fname:*** Joe
14. ***Submitter Mname:*** T
15. ***Submitter Lname:*** Smith
16. ***Submitter Phone:*** 123-123-1234
17. ***Problem:*** 1
18. ***Page:*** 1
19. ***Paragraph:*** 3
20. ***Line:*** 4
21. ***NSN:*** 5
22. ***Reference:*** 6
23. ***Figure:*** 7
24. ***Table:*** 8
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26. ***Total:*** 123
27. ***Text:***

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| | 0019 00 1 | 3 | 1 | 1 | | Step No. 2 says to secure doors open with locking bar or hooks from where to what? The bars or hooks are not identified. |
| | 0019 00 4 | 4 | 1 | 1 | | Step No. 19 states to remove locking bars, pins or hooks from where to what? The bars, pins or hooks are not identified. Where are they stored? |

SAMPLE

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**PART III - REMARKS** *(Any general remarks or recommendations, or suggestions for improvement of publications and blank forms. Additional blank sheets may be used if more space is needed.)*

* Reference to line numbers within the paragraph or subparagraph.

| TYPED NAME, GRADE OR TITLE | TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION | SIGNATURE |
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# The Metric System and Equivalents

### Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

### Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 dekagram = 10 grams = .35 ounce
1 hectogram = 10 dekagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

### Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

### Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

### Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

# Approximate Conversion Factors

| *To change* | *To* | *Multiply by* |
|---|---|---|
| inches | centimeters | 2.540 |
| feet | meters | .305 |
| yards | meters | .914 |
| miles | kilometers | 1.609 |
| square inches | square centimeters | 6.451 |
| square feet | square meters | .093 |
| square yards | square meters | .836 |
| square miles | square kilometers | 2.590 |
| acres | square hectometers | .405 |
| cubic feet | cubic meters | .028 |
| cubic yards | cubic meters | .765 |
| fluid ounces | milliliters | 29,573 |
| pints | liters | .473 |
| quarts | liters | .946 |
| gallons | liters | 3.785 |
| ounces | grams | 28.349 |
| pounds | kilograms | .454 |
| short tons | metric tons | .907 |
| pound-feet | newton-meters | 1.356 |
| pound-inches | newton-meters | .11296 |

| *To change* | *To* | *Multiply by* |
|---|---|---|
| ounce-inches | newton-meters | .007062 |
| centimeters | inches | .394 |
| meters | feet | 3.280 |
| meters | yards | 1.094 |
| kilometers | miles | .621 |
| square centimeters | square inches | .155 |
| square meters | square feet | 10.764 |
| square meters | square yards | 1.196 |
| square kilometers | square miles | .386 |
| square hectometers | acres | 2.471 |
| cubic meters | cubic feet | 35.315 |
| cubic meters | cubic yards | 1.308 |
| milliliters | fluid ounces | .034 |
| liters | pints | 2.113 |
| liters | quarts | 1.057 |
| liters | gallons | .264 |
| grams | ounces | .035 |
| kilograms | pounds | 2.205 |
| metric tons | short tons | 1.102 |

# Temperature (Exact)

| | | | | |
|---|---|---|---|---|
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

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